Nutrients, Suspended Sediment, and Pesticides in Streams and Irrigation Systems in the Central Columbia Plateau in Washington and Idaho, 1959-1991

By Karen E. Greene, James C. Ebbert, and Mark D. Munn

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FOREWORD

The mission of the U.S. Geological Survey (USGS) is to assess the quantity and quality of the earth resources of the Nation and to provide information that will assist resource managers and policymakers at Federal, State, and local levels in making sound decisions. Assessment of water-quality conditions and trends is an important part of this overall mission.

One of the greatest challenges faced by water-resources scientists is acquiring reliable information that will guide the use and protection of the Nation's water resources. That challenge is being addressed by Federal, State, interstate, and local water-resource agencies and by many academic institutions. These organizations are collecting water-quality data for a host of purposes that include: compliance with permits and water-supply standards; development of remediation plans for a specific contamination problem; operational decisions on industrial, wastewater, or water-supply facilities; and research on factors that affect water quality. An additional need for water-quality information is to provide a basis on which regional and national-level policy decisions can be based. Wise decisions must be based on sound information. As a society we need to know whether certain types of water-quality problems are isolated or ubiquitous, whether there are significant differences in conditions among regions, whether the conditions are changing over time, and why these conditions change from place to place and over time. The information can be used to help determine the efficacy of existing water-quality policies and to help analysts determine the need for and likely consequences of new policies.

To address these needs, the Congress appropriated funds in 1986 for the USGS to begin a pilot program in seven project areas to develop and refine the National Water-Quality Assessment (NAWQA) Program. In 1991, the USGS began full implementation of the program. The NAWQA Program builds upon an existing base of water-quality studies of the USGS, as well as those of other Federal, State, and local agencies. The objectives of the NAWQA Program are to:

- Describe current water-quality conditions for a large part of the Nation's freshwater streams, rivers, and aquifers.

- Describe how water quality is changing over time.

- Improve understanding of the primary natural and human factors that affect water-quality conditions.

This information will help support the development and evaluation of management, regulatory, and monitoring decisions by other Federal, State, and local agencies to protect, use, and enhance water resources.

The goals of the NAWQA Program are being achieved through ongoing and proposed investigations of 60 of the Nation's most important river basins and aquifer systems, which are referred to as study units. These study units are distributed throughout the Nation and cover a diversity of hydrogeologic settings. More than two-thirds of the Nation's freshwater use occurs within the 60 study units and more than two-thirds of the people served by public water-supply systems live within their boundaries.

National synthesis of data analysis, based on aggregation of comparable information obtained from the study units, is a major component of the program. This effort focuses on selected water-quality topics using nationally consistent information. Comparative studies will explain differences and similarities in observed water-quality conditions among study areas and will identify changes and trends and their causes. The first topics addressed by the national synthesis are pesticides, nutrients, volatile organic compounds, and aquatic biology. Discussions on these and other water-quality topics will be published in periodic summaries of the quality of the Nation's ground and surface water as the information becomes available.

This report is an element of the comprehensive body of information developed as part of the NAWQA Program. The program depends heavily on the advice, cooperation, and information from many Federal, State, interstate, Tribal, and local agencies and the public. The assistance and suggestions of all are greatly appreciated.

Robert M. Hirsch
Chief Hydrologist

CONTENTS

FIGURES

FIGURES--Continued

TABLES

TABLES--Continued

CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
inch (in.)	25.4	millimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
acre	4,047	square meter
square mile (mi^2)	2.590	square kilometer
gallon (gal)	3.785	liter
million gallons (Mgal)	3,785	cubic meter
cubic foot (ft^3)	0.02832	cubic meter
acre-foot (acre-ft)	1,233	cubic meter
cubic foot per second (ft^3/s)	0.028317	cubic meter per second
gallon per day (gal/d)	0.003785	cubic meter per day
million gallons per day (Mgal/d)	0.04381	cubic meter per second
pound	0.4536	kilogram
ton	0.9072	megagram
degree Fahrenheit (^oF)	$^oC = 5/9 \times (^oF-32)$	degree Celsius (^oC)

CONVERSION FACTORS AND VERTICAL DATUM--Continued

Additional Conversions

1 mg/L = 8.34 lbs/Mgal (pounds per million gallons)

1 mg/L = 1 g/m^3 (gram per cubic meter)

1 mg/L = 1 ppm (parts per million)

1 µg/L = 1 ppb (parts per billion)

0.2259 mg/L as N = 1 mg/L as NO_3

0.3045 mg/L as N = 1 mg/L as NO_2

0.7778 mg/L as N = 1 mg/L as NH_4

0.3261 mg/L as P = 1 mg/L as PO_4

1 Mgal/d = 1.5472 ft^3/s

1 acre = 43,560 ft^2

1 acre-ft/y = 0.001381 ft^3/s

1 ft^3 = 7.48 gal

1 lb = 453.6 grams

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

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ABSTRACT

Water-quality conditions in the Central Columbia Plateau were evaluated as part of the National Water Quality Assessment Program on the basis of analysis of nutrient, suspended-sediment, and pesticide data collected from 1959 to 1991 at 105 surface-water sampling locations. Three subunits were delineated based on differences in surface-water hydrology and water-quality conditions in the study unit. The movement of surface water through the Quincy-Pasco subunit in the southwestern part of the study unit is artificially controlled by the Columbia Basin Irrigation Project. The highly variable streamflows in the Palouse subunit in the eastern part of the study unit are more naturally influenced by storm runoff and snowmelt. The North-Central subunit in the central and northern parts of the study unit has few perennial streams and an extensive network of ephemeral streams.

Non-point sources account for at least 97 percent of the estimated inputs of nitrogen and phosphorus to the study unit. Locally, however, point sources may dominate: most of the nutrient loading to the South Fork Palouse River during low streamflows comes from the Moscow and Pullman sewage treatment plants (STPs). The Quincy-Pasco subunit receives the highest rates of fertilizer and pesticide applications (approximately 132 pounds of nitrogen, 17 pounds of phosphorus, and 2.3 pounds of pesticides per acre per year) in the study unit. The combined annual loads of total nitrogen and phosphorus from four large drainages from the Quincy-Pasco subunit (which together represent approximately 0.8 percent of the drainage area of the Columbia River below Priest Rapids Dam) are about 3.4 percent and 0.7 percent, respectively, of the corresponding annual loads in the Columbia River below Priest Rapids Dam.

Nutrient concentrations in the Quincy-Pasco subunit vary seasonally and spatially as a result of the operations of the irrigation project and of changing proportions of irrigation return flows, unused irrigation water, and ground-water seepage in the surface drains and wasteways. Higher phosphorus concentrations occur during the irrigation season, when suspended-sediment concentrations also are highest. Detections of pesticide compounds throughout the year in the Quincy-Pasco subunit indicate that pesticides may be transported to surface waters by agricultural and storm runoff and influx from the ground-water system. Variations in nitrogen-species concentrations in the Quincy-Pasco subunit during and after the irrigation season indicate interactions between ground and surface waters: constituents are carried to the ground-water table by artificial recharge, shallow ground water then discharges to surface drains and wasteways, and concentrations are diluted by unused excess water during the irrigation season. Concentrations generally increase downstream as a result of contributions from agricultural runoff and ground-water seepage, except when mitigated by dilution and (or) biological assimilation of nutrients.

Variations in water quality in the Palouse subunit relate to runoff from agricultural lands during storms and to dilution of STP discharges. There is more precipitation in this part of the study unit, and the loess soils are particularly subject to erosion during storms. Runoff transports nutrients, sediment, and possibly pesticides to the streams.

Nutrient and suspended-sediment concentrations are highest from November through April in most of this subunit. Several STPs operate in the Palouse subunit, and nutrient concentrations in tributaries affected by these STPs are highest during low streamflows.

The chronic water-quality criterion for the protection of aquatic life was exceeded at 9 of the 10 sites in the study unit where water samples collected during the 1970's were analyzed for DDT and its metabolites; the overall frequency of detection was low, however. DDT was detected in 97 percent of the whole-fish samples collected in the irrigation project. U.S. Environmental Protection Agency and Washington State surface-water-quality chronic standards for dieldrin were exceeded at four of nine sites; dieldrin was detected in 43 percent of the whole-fish samples collected in the irrigation project, and the human health criterion for edible fish fillets was exceeded in four fish.

Better information is needed about the timing, amounts, and new types of pesticides applied in the study unit. Many of the pesticides investigated in previous studies currently are not used, or are not used as much as other compounds. Some of the compounds currently in use are less stable and more soluble than pesticides used in the past and may result in a larger flux of pesticides to surface waters from the shallow ground-water system.

More data are needed to further improve understanding of water quality in the Central Columbia Plateau. Little is known about surface-water quality outside of the irrigation project and the Palouse River Basin or about water-quality conditions in barren and range lands and ground-water-irrigated farm lands. Because streamflows in the irrigation project are relatively uniform from year to year, it is possible to estimate constituent loads in this part of the study unit with fewer samples than are required for the rest of the study unit.

INTRODUCTION

The Central Columbia Plateau is 1 of 60 study units targeted for study by the National Water Quality Assessment Program (NAWQA), which is designed to describe the status and trends in the quality of the Nation's ground- and surface-water resources and to link the status and trends with an understanding of the natural and human factors that affect the quality of these resources. The program integrates information about water quality at a wide range of spatial scales from local to national, and focuses on water-quality conditions that affect large geographic areas of the Nation or that occur frequently within numerous smaller areas.

The building blocks of NAWQA are the study unit investigations, which will be conducted in 60 of the major hydrologic basins in the United States. The main components of the study unit investigations are (1) analysis of existing data to aid in the study design, (2) occurrence and distribution assessment to characterize the broad-scale geographic and seasonal distributions of water-quality conditions in relation to major contaminant sources and background conditions, (3) long-term monitoring to assess long-term changes in selected aspects of water-quality conditions, and (4) source, transport, and effect studies to address specific questions about the characteristics and causes of water-quality degradation in individual areas.

Information about the relations between water quality and upstream or upgradient characteristics is an integral part of all four components of NAWQA activity. The information from each study unit will form the basis for later synthesis at regional and national scales. NAWQA's national synthesis involves comparisons of water quality on a national basis and, where a given condition exists in only a few study units or where there are insufficient sites to discuss across a gradient, side-by-side discussions of study unit findings. The national synthesis also will include regional survey results. These comparisons are intended to highlight consistent national patterns in concentrations and frequencies of exceedance of water-quality standards as a function of land-use groups, population density, amounts of chemical applications, season of the year, time (trends), streamflow, soil type, and other factors. Comparisons of water quality across the Nation will aid in recognizing the effects of human activity on water quality and will show how widespread are violations of water-quality standards for drinking water and for the protection of aquatic life.

One of the first activities in the NAWQA study units is the analysis of existing data in order to (1) develop a conceptual model of the water-quality conditions within each basin, (2) provide an historical perspective on the water quality of the Central Columbia Plateau study unit, and (3) summarize the current understanding of various aspects of the water-quality conditions in the study unit and of the natural and human factors that affect those aspects of water quality within the study unit. The review of existing water-quality data describes the strengths and weaknesses of available information and the implications for understanding water-quality issues, and is then used to

guide new data collection activities of the NAWQA program. The analysis of existing data continues throughout the study period, and findings will be published along with the results from newly collected data (Hirsch and others, 1988). This report, one of the first products of NAWQA, is the analysis of existing water-quality data for nutrients, suspended sediment, and pesticides in surface waters of the Central Columbia Plateau study unit. A similar analysis of existing water-quality data for ground water was completed by Jones and Wagner (1995).

Purpose and Scope

This report provides an initial analysis of nutrient, suspended-sediment, and pesticide concentration data collected from 1959-1991 in the Central Columbia Plateau study unit. The purposes of this report are to (1) identify the spatial and temporal patterns of concentrations and loads of nutrients, suspended sediment, and pesticides within the Central Columbia Plateau study unit, (2) use existing water-quality data to guide additional data collection in the study unit, (3) contribute to a synthesized description of the status and trends in the quality of the Nation's water resources, (4) document findings for future NAWQA activities in the Central Columbia Plateau study unit, and (5) present a preliminary conceptual model of the spatial and temporal patterns of concentrations and loads of suspended sediment, nutrients, and pesticides within the study area, based on the available data and the time frame allotted for analyses.

The first activity necessary to achieve these purposes was the compilation of water-quality data collected in the Central Columbia Plateau study unit by many different agencies for a variety of purposes. Data for sampling locations in lakes and reservoirs, which are not the primary focus of the NAWQA program, are not included in this report. Data for water discharged at springs or from subsurface agricultural tile drains also are not included in this report. Sites on the main channels of the Columbia and Snake Rivers are considered to be outside of the study unit boundaries and therefore are not included in this report. Water-quality data for industrial and sewage treatment plant (STP) effluents are not included in this report, although some of the data were used to estimate loading to reaches of streams in the study unit.

Water-quality and discharge data analyzed in this study were obtained from the U.S. Geological Survey's National Water Data Storage and Retrieval System (WATSTORE) data base and in the U.S. Environmental Protection Agency's Storage and Retrieval Computer System (STORET) data base. Selected paper records with land-use information, discharge data, and water-quality data also are included in the study. Spatial, temporal, and flow-regime gaps in these data are identified in this report.

The nutrients included in this report are total nitrogen, dissolved nitrate, dissolved or total ammonia, total phosphorus, and dissolved orthophosphate. Both suspended-sediment and suspended-solids data are included. All available pesticide data are included.

Acknowledgments

The authors would like to thank the following people for their invaluable contributions to this report: Erika E. McPhee of the Washington District of the U.S. Geological Survey for compilation and interpretation of point-source load data; Michael Mansfield, Keith Franklin, and Hugh McEachon of the East, Quincy, and South Columbia Basin Irrigation Districts and Alan Hattrup and Wesley O. Green of the Bureau of Reclamation for sharing their knowledge of the Columbia Basin Irrigation Project area; John Holmes and Mark Neilson of the Franklin Conservation District for providing data and for consultation; and all of the members of the NAWQA Central Columbia Plateau study unit's liaison committee for providing information and guidance in setting our study unit priorities.

DESCRIPTION OF THE CENTRAL COLUMBIA PLATEAU STUDY UNIT

The Central Columbia Plateau study unit is located in east-central Washington and northwestern Idaho (fig. 1). The approximately 13,000-square-mile area is bordered on the north by the Columbia River and by the topographic divide that separates the headwaters of Crab Creek and the lower Spokane River drainage system; the lower Snake River is the southern boundary and the Columbia River is the western boundary; and the eastern boundary is the topographic divide that separates the headwaters of the Palouse River Basin in Washington and Idaho from headwaters of Hangman Creek in Washington and Idaho and St. Maries River and Potlatch River in Idaho (fig. 1). The study unit includes all of Adams, Douglas, Franklin, and Grant Counties, nearly all of Lincoln and Whitman Counties, and approximately the southeast third of Spokane County in Washington, and approximately the northwest half of Latah County in Idaho. The Columbia and Snake Rivers are not considered to be part of the study unit.

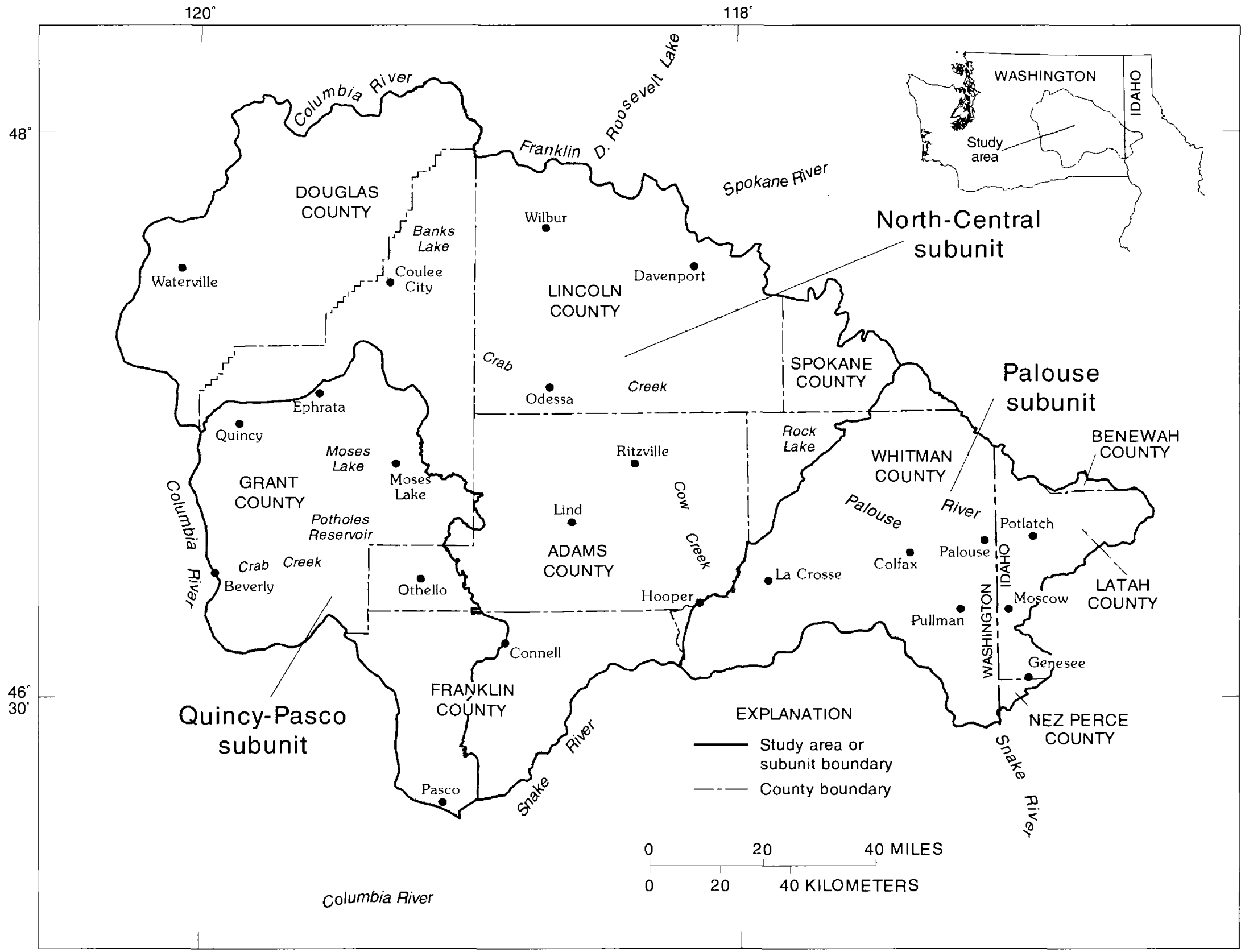


Figure 1.--Location of the Central Columbia Plateau study unit in Washington and Idaho.

Physiography, Geology, and Topography

The Central Columbia Plateau study unit has numerous land forms, including low-elevation mountains and rolling loess hills on the eastern side and a wide range of high-desert land forms throughout the western part of the study unit. The altitude of the land surface ranges from less than 300 feet above sea level near Pasco to nearly 5,000 feet above sea level in the Moscow Mountains of the Palouse Range, about 8 miles northeast of Moscow.

The study unit is part of the extensive Columbia Plateau, which covers parts of the States of Washington, Oregon, and Idaho. The Columbia Plateau was formed by the extrusion of basaltic lava (Walters and Grolier, 1960) from 6 to 17.5 million years ago (Drost and Whiteman, 1986). The area is underlain by massive basalt flows that have a composite thickness of about 16,000 feet at their lowest point near Pasco. Unconsolidated sedimentary deposits overlie the basalt over large areas (fig. 2). After the basalt was extruded, the Plateau region was warped into a broad basin. Several subbasins were formed locally by steep folding and faulting. Deposits of clay, silt, sand, and gravel accumulated in these subbasins by glacial action during the Pleistocene Epoch.

The cataclysmic Lake Missoula Flood that occurred during the Pleistocene Epoch about 18,000 to 20,000 years ago (U.S. Geological Survey, 1974) had a major influence on the topography of the region. This flood covered all of the study unit except for the headwaters of the Palouse River in the Moscow Mountains. This flood, plus additional smaller floods, created the scablands, a 15,000-square-mile area where the floods washed off all of the overlying deposits of loess, leaving exposed basalt (Weis and Newman, 1989). The silt and sand deposits have been extensively reworked and continue to be reworked and shifted by wind action, especially in the western part of the study unit (Walters and Grolier, 1960). Erosion is now considered to be the dominant geologic process affecting the area.

Three overlying unconsolidated units are exposed in the study unit. The Ringold Formation and the glaciofluvial deposits make up the unconsolidated sediments in the western and central parts of the study unit (fig. 2). Loess, a wind-blown deposit of generally unstratified silt-sized particles, was deposited by prevailing southwest winds over the study unit to depths ranging from about 20 inches to several hundred feet (Bain, 1985). These deposits are most prominent in the east-central part of the study unit, but also occur in several other places in the study unit (Bain, 1985; and Tanaka and others, 1974).

Delineation of the Central Columbia Plateau Study Unit into Subunits

The Central Columbia Plateau study unit is somewhat unusual within the NAWQA program because it consists of several distinct surface-water systems (fig. 1). These systems include two dominant perennial streams (the Palouse River and Crab Creek), small perennial streams that discharge directly into either the Columbia or Snake Rivers, numerous intermittent streams of varying flow durations, lakes and wetlands, and the Columbia Basin Irrigation Project (fig. 3), which consists of 5,000 miles of irrigation canals and drainage ditches.

In order to more easily identify the causes for observed water-quality conditions, the Central Columbia Plateau study unit was divided into three major areas: the Quincy-Pasco, North-Central, and Palouse subunits (fig. 4). These subunits were identified by geology, hydrology, and land-use patterns that can be compared on a nationwide scale. These factors, singly or in combination, are believed to produce characteristically different water-quality conditions within the study unit and will therefore permit the development and testing of hypotheses about the factors associated with changes in water quality at the subunit level. Some of the defining characteristics of each of the three subunits are shown in table 1.

The Quincy-Pasco Subunit

The Quincy-Pasco subunit lies in the arid southwestern part of the study unit in Grant County and western Franklin and Adams Counties. There are few natural perennial streams in this subunit; the hydrology of the Quincy-Pasco subunit is dominated by the importation of surface water from the Columbia River for the irrigation project and the movement of this water through a controlled system of canals, drainage ditches, and wasteways. This part of the study unit has nearly flat terrain and an overburden of unconsolidated deposits that range in thickness from a few tens of feet to several hundred feet. The area is amenable to agriculture; growing seasons are long and a variety of crops are produced, usually on rotations. Most of the land in this subunit is irrigated by the surface water diverted from the Columbia River, although there are barren and range lands and some areas in the subunit that are irrigated using ground water (fig. 4). The current depth to ground water is less than 50 feet in most of this subunit. Artificial recharge from irrigation has caused ground-water levels in this part of the study unit to rise as much as hundreds of feet (Drost and others, 1993).

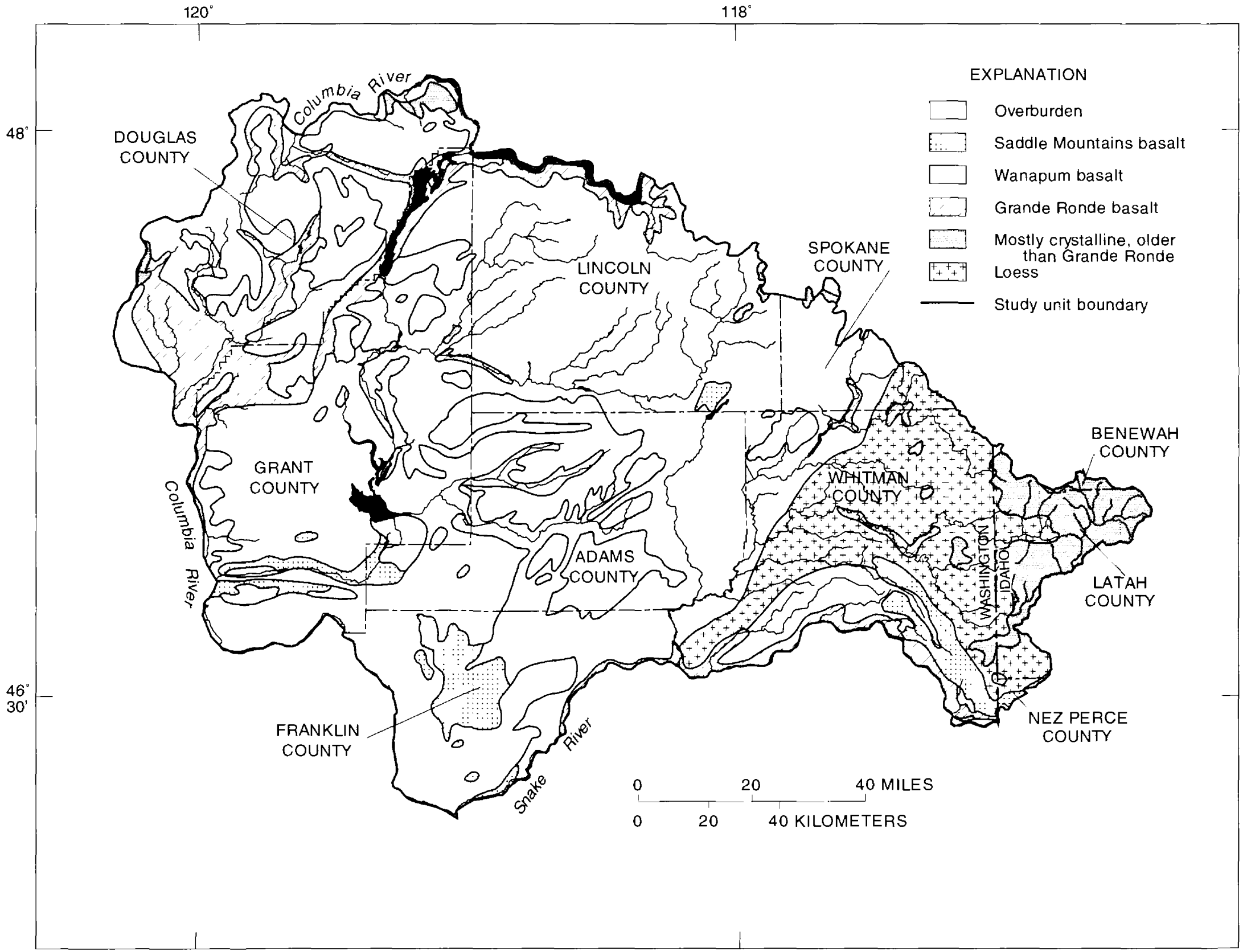


Figure 2.--Surficial geology of the Central Columbia Plateau study unit. (Modified from Drost and Whiteman, 1986.)

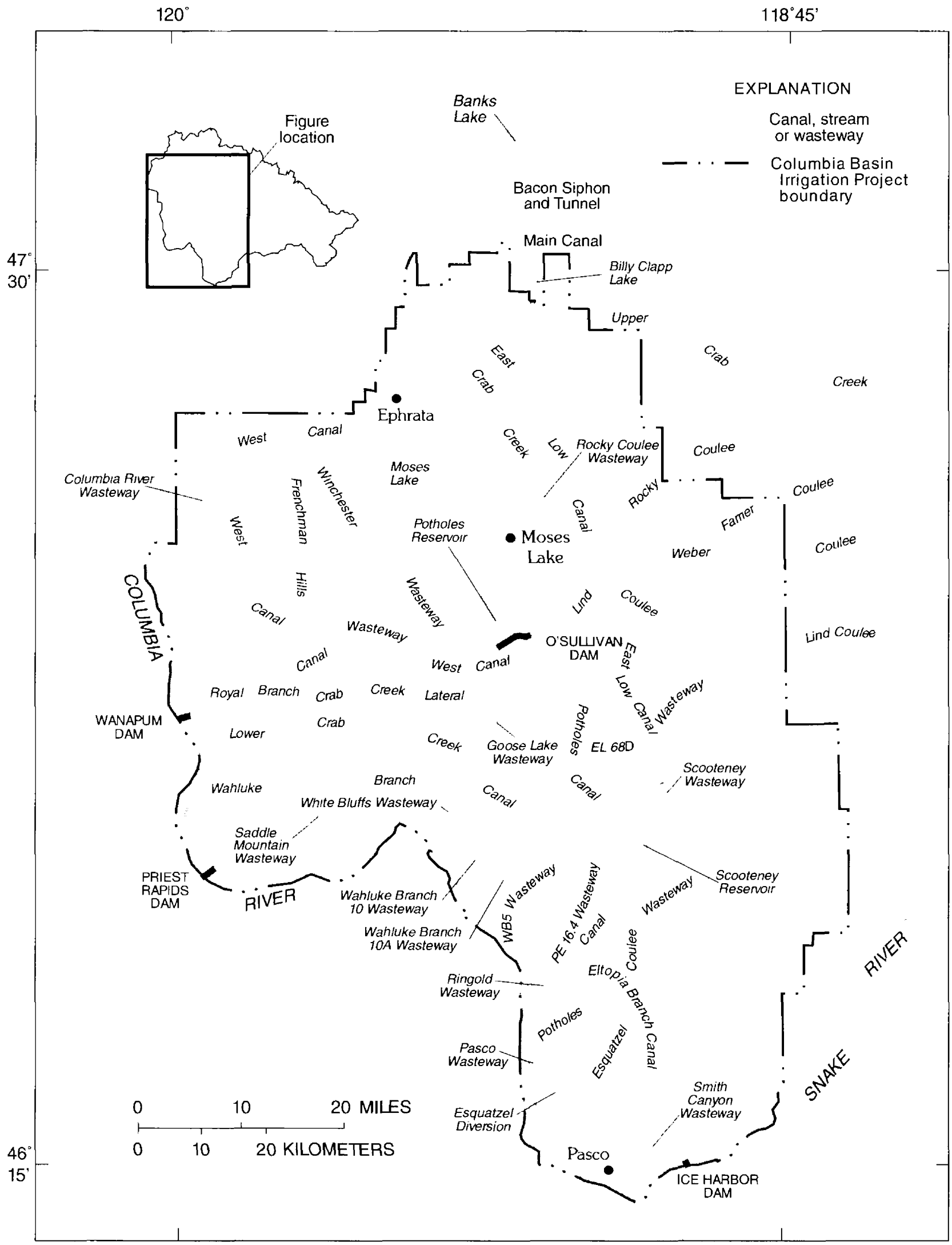


Figure 3.--Location of the Columbia Basin Irrigation Project area in the Quincy-Pasco subunit. Base modified from the Bureau of Reclamation, 1982.

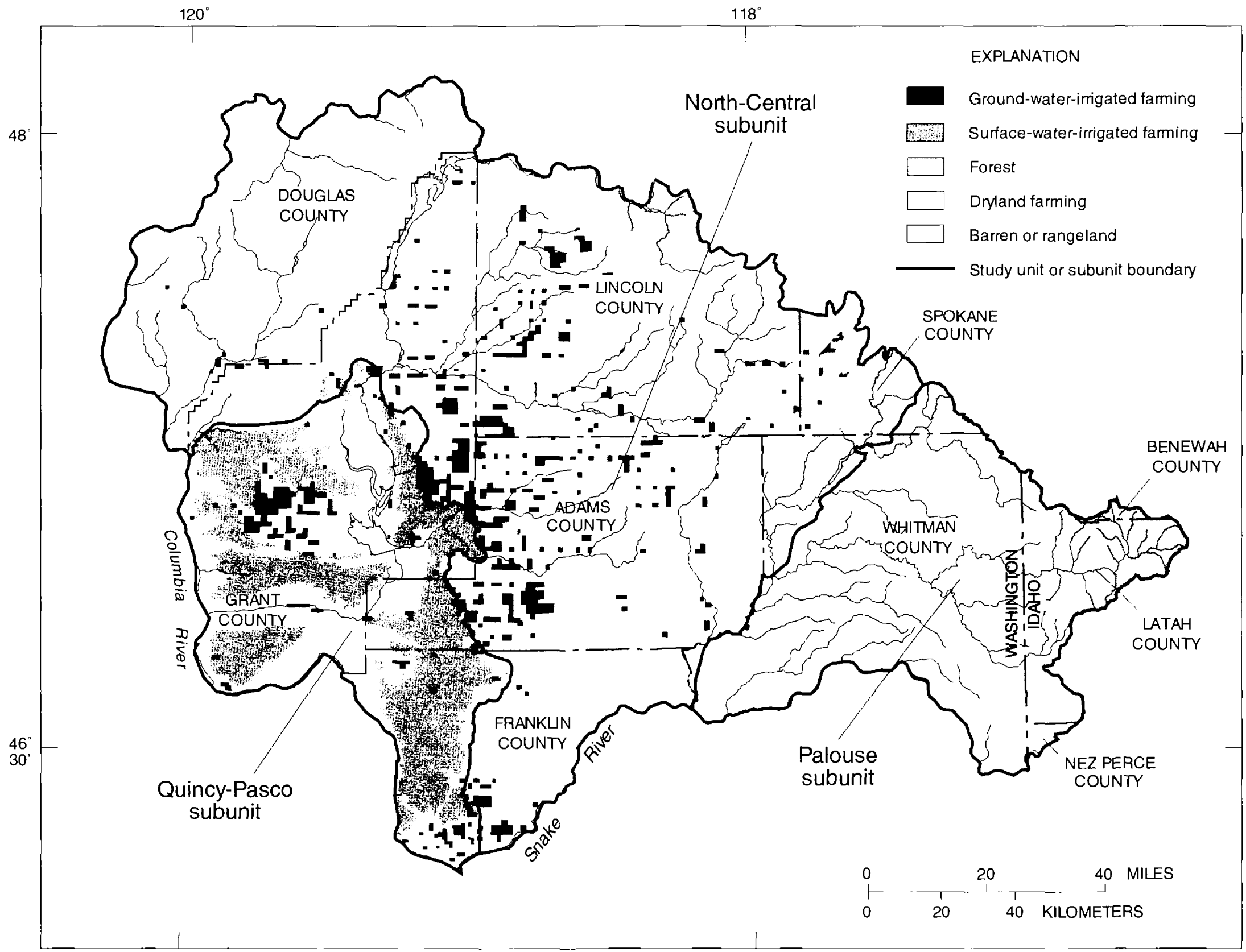


Figure 4.--Land use and the delineation of subunits in the Central Columbia Plateau study unit.

Table 1.--*Characteristics of the three subunits in the Central Columbia Plateau study unit*

	Quincy-Pasco subunit	North-Central subunit	Palouse subunit
Area, in square miles	2,500	8,100	2,500
Annual precipitation, in inches	6 to 8	8 to 13	13 to 25
Surficial geology	alluvial basin fill	basalt near surface	5 to 100 feet of loess over basalt
Hydrology	controlled during irrigation season nearly all canals & wasteways	natural climatic variation few and disconnected perennial streams	natural climatic variation perennial streams in larger basins
Topography	nearly flat basins between bluffs	channelled scablands	rolling hills
Major land uses	surface-water irrigated farming ground-water irrigated farming range land grazing dryland farming	dryland farming range land grazing ground-water irrigated farming	dryland farming range land grazing forested land
Water-quality issues related to stream ecology	channel modifications nutrient loading / eutrophication pesticides dissolved oxygen / temperature	riparian degradation instream flow sedimentation pesticides dissolved oxygen / temperature	soil erosion and sedimentation nutrient loading / eutrophication dissolved oxygen / temperature pesticides riparian degradation
Major point- and localized nonpoint-sources of nutrients	feed lots food-processing effluent wastewater-treatment effluent	feed lots	wastewater-treatment effluent

The North-Central Subunit

The North-Central subunit is located in the central and northern parts of the study unit in most of Douglas and Lincoln Counties, in eastern Franklin and Adams Counties, and in southwestern Spokane County. This subunit is the largest and most diverse of the three subunits, and is best described by its lack of a characteristic surficial geologic unit overlying the basalts found throughout the study unit. Most of the scablands areas created by the ancient floods discussed in the preceding section of this report are in the North-Central subunit. The major physiographic features of the subunit include the scablands areas of barren and range lands along Cow Creek and upper Crab Creek, the surficial basalt areas in the south-central part of the study unit, and the high-desert area in Douglas County (figs. 2 and 4). There is dryland and ground-water-irrigated farming (fig. 4) and extensive cattle grazing in this subunit.

The upper Crab Creek drainage area is nearly all basalt outcrop (fig. 2) and has a relatively shallow water table. There are numerous lakes in the north-central part of the subunit, many of which have surface-water outflows only during extremely wet years. The Cow Creek drainage area is a typical scablands stream system with few defined channels, although some perennial streams and lakes are supported where there is slightly more precipitation. The water table is generally within 150 feet of the land surface. Unique in the study unit, the surficial basalt area in central Adams County has no perennial streams or lakes, but has an extensive network of dry channels (fig. 5). The ground-water table in this part of the subunit generally is deep, and the basalt generally is exposed or is near the land surface in this part of the study unit.

The Douglas County area can be characterized as high desert with a deep water table. It has few perennial streams, and several of those have intermittent reaches. The northern part of the subunit includes the southern extent of glaciation where few stream channels exist and there are large erratics (boulders dropped by the ice sheet) strewn across the landscape, somewhat limiting agricultural development. The basalt generally is exposed, or is near the land surface where there is a thin overburden of unconsolidated deposits.

The Palouse Subunit

The Palouse subunit is in the eastern part of the study unit and includes most of the Palouse River Basin except for the drainage basin of Cow Creek, a tributary of the Palouse River (because there is little loess overburden in the Cow Creek drainage basin (fig. 4), the area is considered to be part of the North-Central subunit). The Palouse subunit includes a small forested mountainous region along the eastern border of the study unit (fig. 4); the rest of the subunit is rolling hills, typically 100 to 200 feet in relief, that are almost entirely basalt overlain by loess (windblown fine) deposits (fig. 2) that thicken heading eastward. The loess develops into rich soils, ideally suited to dryland farming of grains. The major streams generally are cut down into the basalt rocks, leaving rolling hills above the incised stream valleys. There are many perennial streams in this area, as well as a network of ephemeral streams. The water-table level is about 50 to 100 feet beneath the crests of the hills. Soil erosion during storms is a major issue in this subunit.

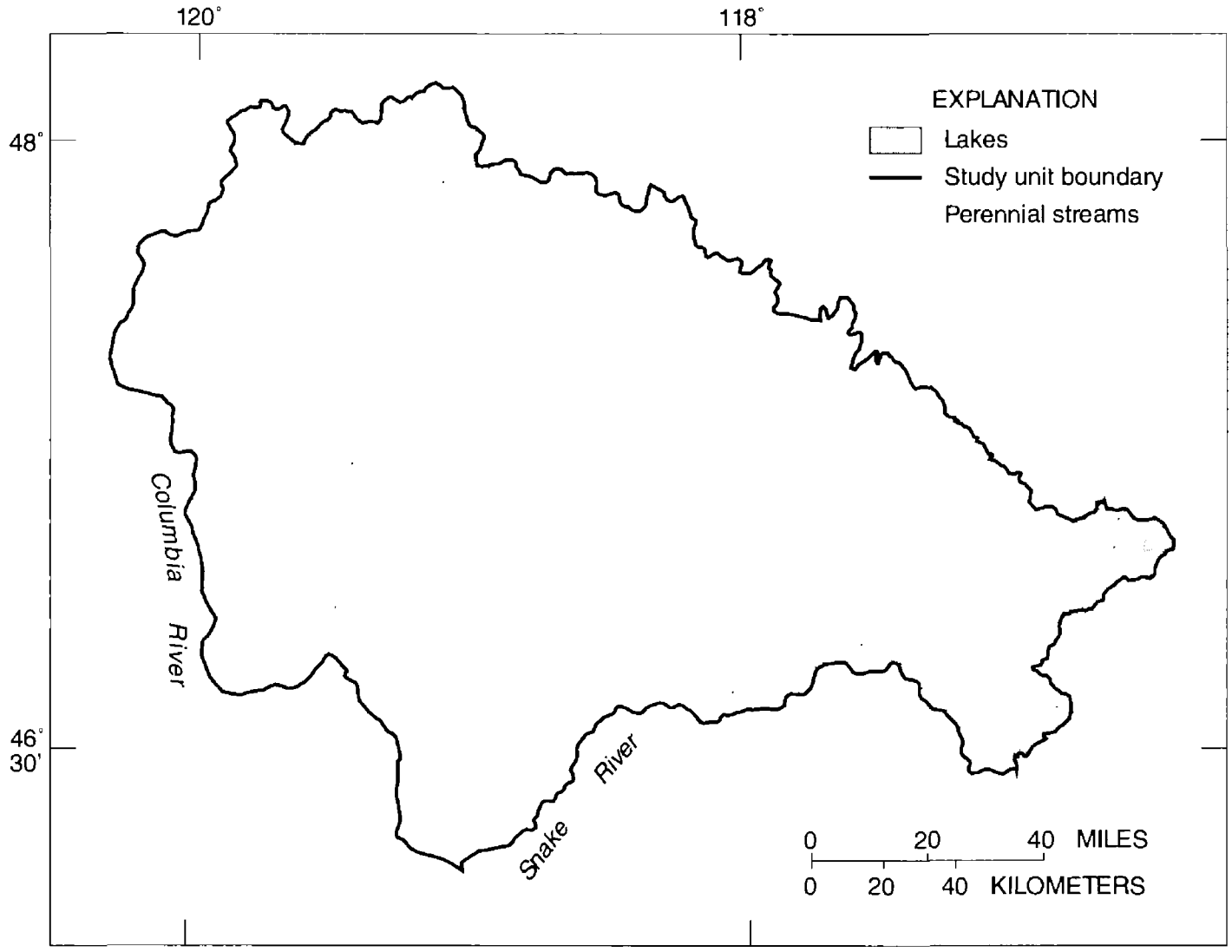
Climate

Most of the study unit is semiarid with seasonally variable temperature ranges. The climate in the study unit is strongly influenced by the mountains: the Cascade Range to the west serves as a precipitation barrier by capturing most of the maritime precipitation that moves into Washington from the west, northwest, and southwest (Turney, 1986). Precipitation generally increases heading eastward. There is less than 8 inches of precipitation per year in most of the Quincy-Pasco subunit, which includes the southwestern quarter of the study unit; about 13 to 22 inches of precipitation fall in Whitman County, in the east-central part of the study unit; and precipitation continues to increase eastward to more than 25 inches in the upper headwaters of the Palouse River Basin in the mountainous eastern part of the study unit in Idaho (fig. 6). About 85 percent of the total annual precipitation occurs from October through May and nearly 40 percent occurs from November through January (Tanaka and others, 1974; and Nelson, 1988).

Temperatures in the study unit range from well below 0°F during winter to more than 100°F in the summer (Turney, 1986). Mean air temperature data during the period from 1956 to 1977 at selected stations in the study unit ranged from 47°F in Pullman, Wash., to 55°F near Pasco, Wash. (Bauer and Vaccaro, 1990).

Surface-Water Hydrology

Major surface-water systems in the Central Columbia Plateau study unit are the Palouse River system, which is mostly in the Palouse subunit; Crab Creek, which is in



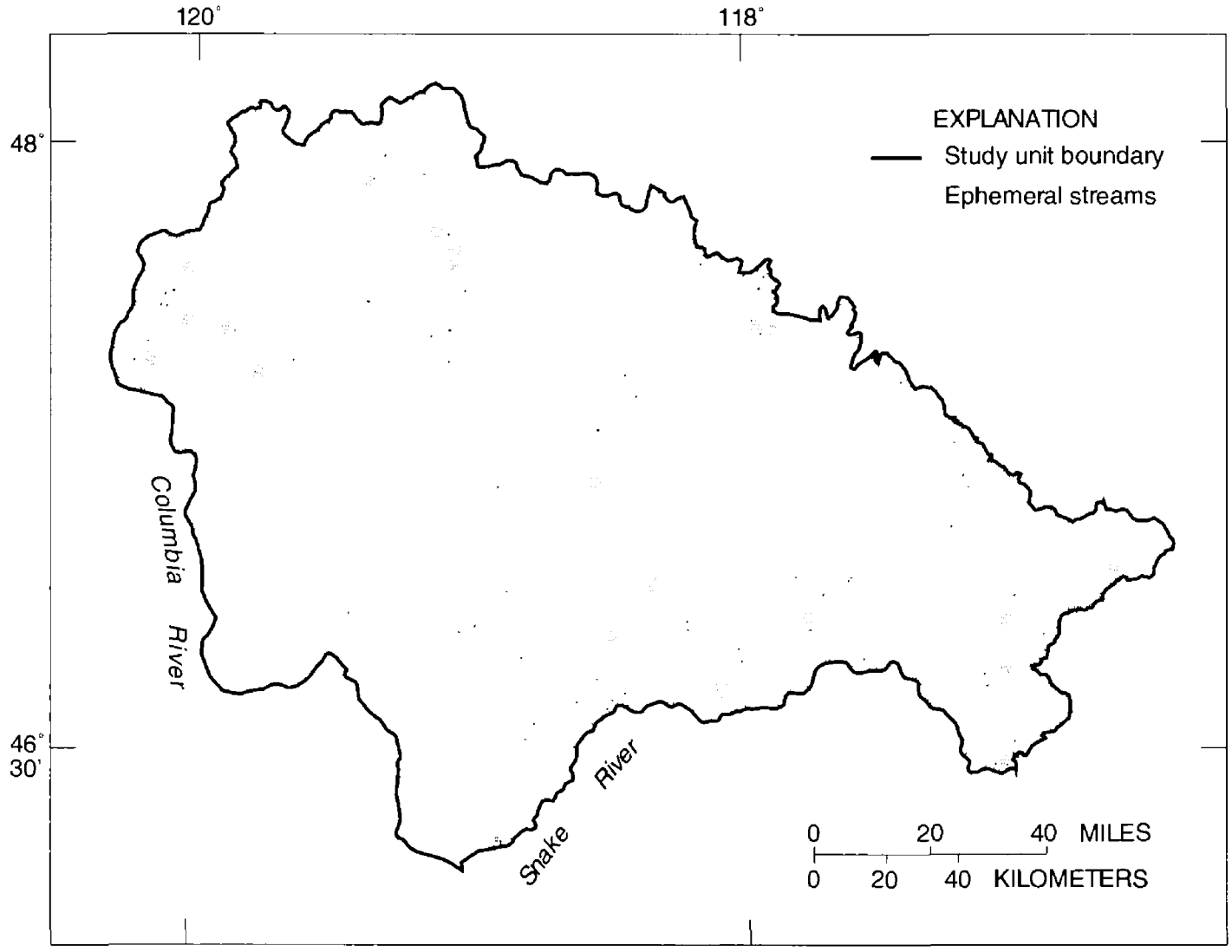


Figure 5.--Lakes, perennial streams, and ephemeral streams in the Central Columbia Plateau study unit.

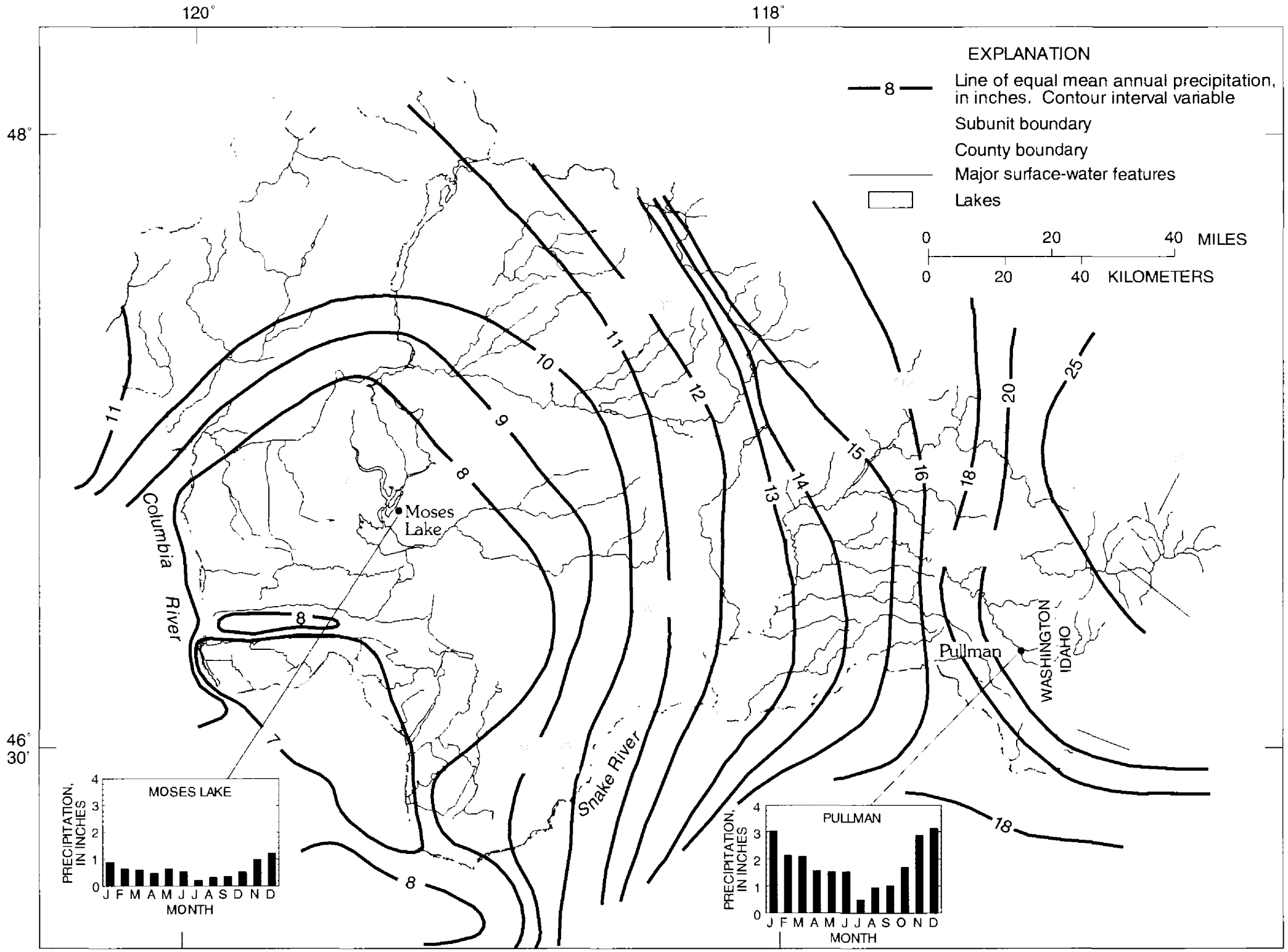


Figure 6.--Mean annual precipitation in the Central Columbia Plateau study unit and mean monthly precipitation at Moses Lake and Pullman, Washington (modified from Nelson, 1991).

both the North-Central and Quincy-Pasco subunits; and the numerous irrigation canals and drainage ditches in the Quincy-Pasco subunit (figs. 1, 3). In addition to the perennial streams, the Central Columbia Plateau study unit contains a large number of intermittent, ephemeral streams (fig. 5). Many of the streams in the Quincy-Pasco subunit that were historically intermittent are presently perennial because of augmented flows from the irrigation project.

The Palouse River originates near Beals Butte in the Clearwater Mountains and in the Moscow Mountains of the Palouse Range (fig. 1). The principal tributaries of the Palouse River are the South Fork Palouse River, which enters the main channel at Colfax, Wash.; Rock Creek, which enters the main channel about 6 miles northwest of La Crosse, Wash.; and Cow Creek, which enters the Palouse River 0.3 mile downstream from Hooper, Wash. The Palouse River is free flowing and is not used significantly for irrigation. The river flows only a short distance through forested lands before emerging into rolling loess-covered hills, where it remains a moderate-gradient stream, averaging 13 feet per mile from Colfax to Hooper, through an area dominated by dryland farming until it flows through open range and eventually discharges to the Snake River.

Crab Creek originates in the highlands of east central Lincoln County (fig. 1). It is informally divided into two sections: upper Crab Creek above Moses Lake and lower Crab Creek below Potholes Reservoir. Flow in the reaches of upper Crab Creek that are east of Billy Clapp Lake (fig. 1) is derived mostly from natural runoff and ground-water seepage. Several of these reaches are intermittent, depending on local and seasonal hydrologic conditions. Upper Crab Creek receives some irrigation return flows southwest of Billy Clapp Lake before it enters Moses Lake. Lower Crab Creek originates below Potholes Reservoir; however, there is no perennial outlet from Potholes Reservoir into lower Crab Creek. Most of the water in this reach of lower Crab Creek comes from the West Canal through Goose Lake Wasteway (fig. 3). Lower Crab Creek receives additional excess irrigation water and irrigation return flows between Potholes Reservoir and the mouth, and becomes an irrigation wasteway.

Surface-water hydrology in the Quincy-Pasco subunit is dominated by the large quantities of surface water imported into the area by the Columbia Basin Irrigation Project. Irrigation water for this project is pumped from Franklin D. Roosevelt Lake on the Columbia River into Banks Lake, a large storage reservoir (fig. 1). From Banks Lake, water is diverted into the Main Canal for distribution by way of the West Canal, East Low Canal, and numerous smaller canals and laterals. Prior to irrigation, many natural drainages were intermittent. Now, most are perennial because of higher ground-water levels caused by recharge from imported surface water. The rising ground-water levels also have created many acres of wetlands. Most of the reservoirs, lakes, ponds, and wetlands either did not exist or were much smaller prior to the construction of the irrigation project.

Numerous drains and wasteways collect irrigation return flows from the Quincy-Pasco subunit. Wasteways, which were designed to drain excess irrigation water dumped from the delivery system of canals and laterals, drain both internally to Moses Lake and Potholes Reservoir and externally to the Columbia and Snake Rivers (fig. 3). In addition to excess delivery water, wasteways carry ground-water seepage and irrigation return flows routed from drains. Although some drains connect to canals, most discharge to wasteways.

Shallow ground water collected by subsurface field drains also is routed to drainage ditches; such drains have been installed in many parts of the Quincy-Pasco subunit (fig. 7) to intercept rising ground-water levels and to maintain the water table at an acceptable depth below the land surface.

Large quantities of irrigation water delivered to the Quincy-Pasco subunit regulate flows in surface-water systems draining the subunit. Although some storms produce runoff, the subunit receives only 6 to 8 inches of annual precipitation. Because the quantities of water delivered are relatively uniform, there is little year-to-year variation in annual mean flows in the subunit. High flows usually occur during the irrigation season, which is from mid-March to mid-October. Lower Crab Creek has peak flows toward the end of the irrigation season, when more excess irrigation water is being discharged to wasteways (fig. 8). From 1960 to 1970, mean annual streamflow at Crab Creek near Beverly was increasing (fig. 9).

In contrast to the Quincy-Pasco subunit, most of upper Crab Creek and all of the Palouse River do not carry excess imported irrigation water and irrigation return flows. The hydrograph of the Palouse River reflects a natural river system with a seasonal runoff pattern where high flows occur from January to April during the rainy season and low flows occur from July to October (figs. 8, 9). There is high variability both within an annual cycle and between years (fig. 9).

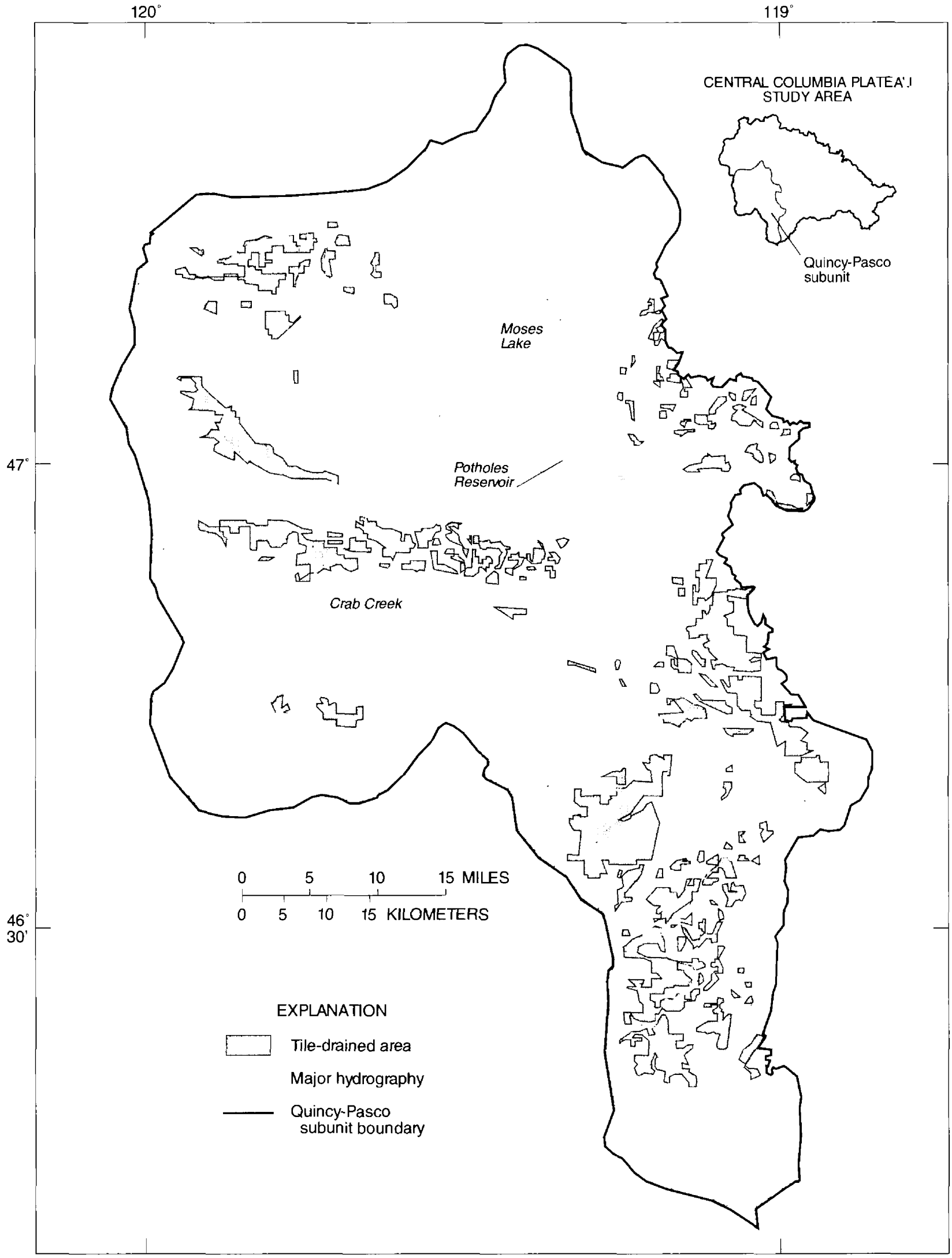


Figure 7.--Tile-drained areas of the Columbia Basin Irrigation Project area in the Quincy-Pasco subunit. Data are from the Bureau of Reclamation.

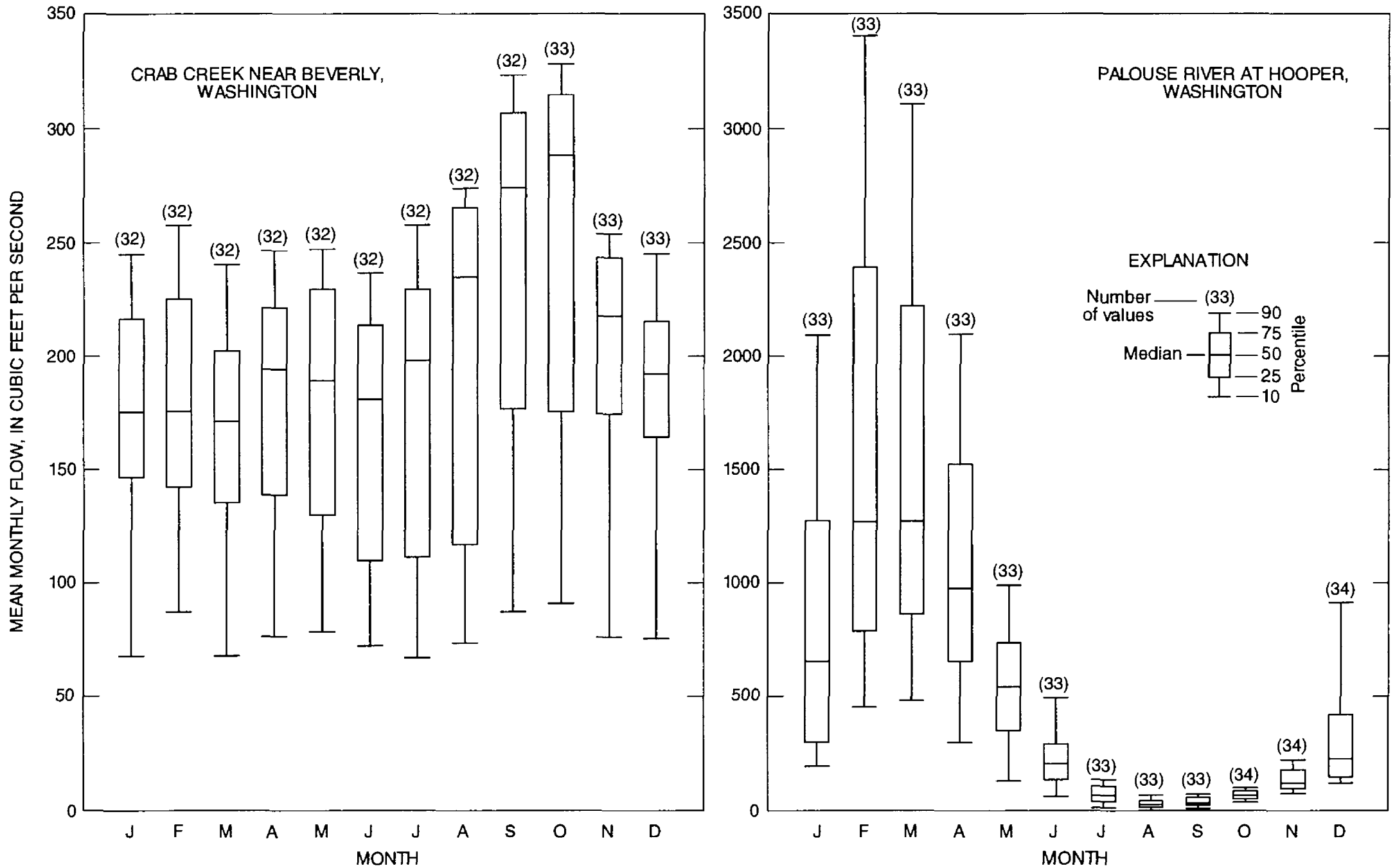


Figure 8.--Mean monthly streamflow at Crab Creek near Beverly, Washington (site 5, figure 17) and Palouse River at Hooper, Washington (site 90, figure 17).

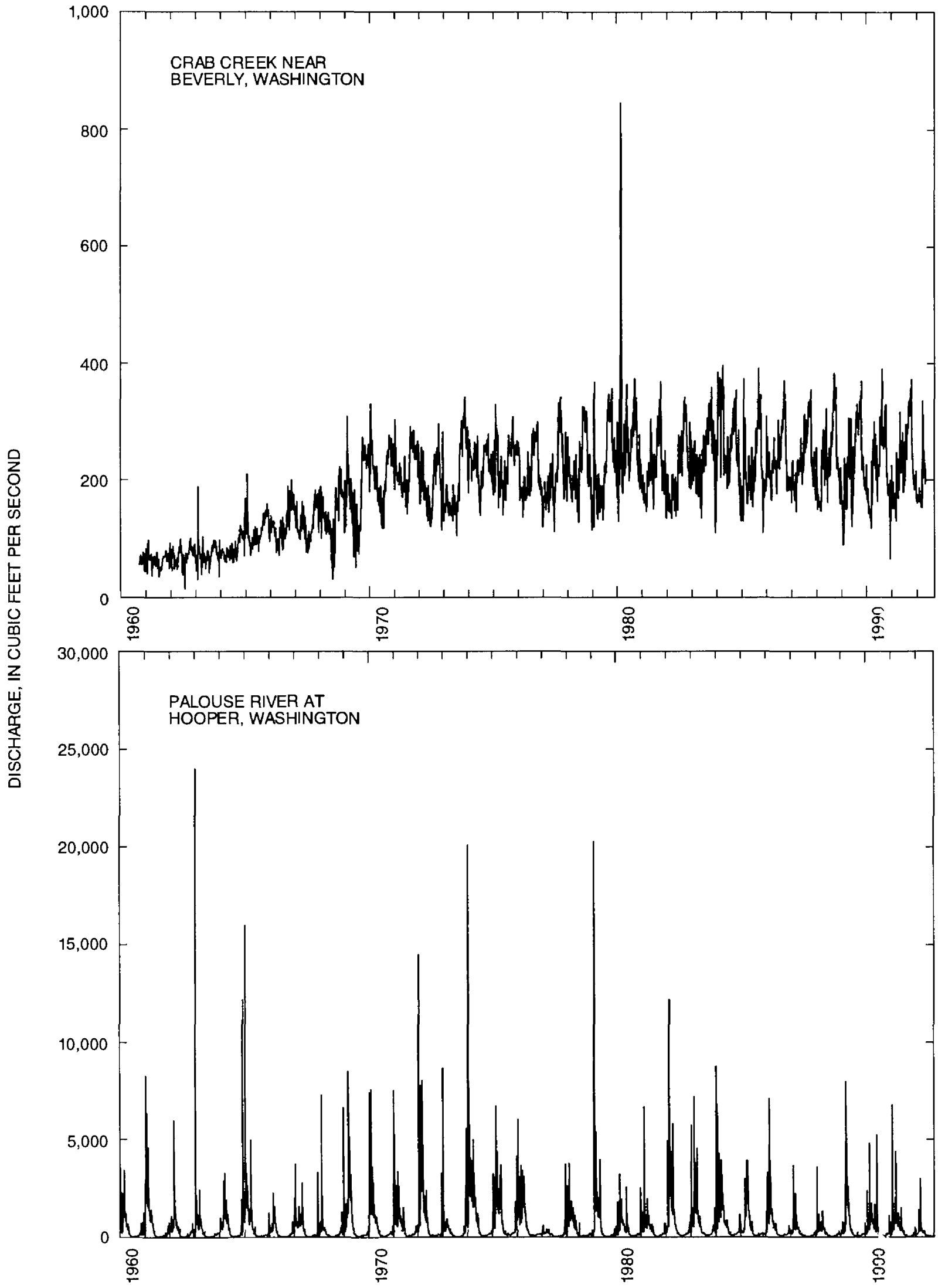


Figure 9.--Daily mean streamflow at Crab Creek near Beverly, Washington (site 5, figure 17) and Palouse River at Hooper, Washington (site 90, figure 17).

Flow characteristics at Crab Creek near Moses Lake, on upper Crab Creek, represent a combination of irrigated and non-irrigated areas. Storm runoff from the upper Crab Creek Basin produces peak flows at the site during winter months, but median flows are larger during the irrigation season because irrigation return flows enter the part of the creek that is within the irrigation project.

Population and Land Use

The population of the Central Columbia Plateau study unit has increased from several thousand native Americans before the 1800's to nearly 200,000 people in 1990 (Bortleson, 1991). Early explorers in the region (Lewis and Clark in 1805 and David Thompson and Gabriel Frachere during the following decade) estimated the population to be about 14,000. In the late nineteenth century, large areas of land were granted to railroad companies to attract settlers, encourage crop export, and promote investment in irrigation and other agriculture-related enterprises. Economic improvement followed, and numerous towns sprang up while lumber and agricultural industries grew steadily until about 1910; population increased during this period of economic growth and then rose more slowly during the period from 1910 to 1940 due to an economic slowdown (Whiteman and others, 1994).

The expansion of agricultural irrigation during the 1940's and 1950's resulted in a rapid increase in population in the area. During the 1940's, the construction of the Hanford Nuclear Reservation, now known as the U.S. Department of Energy Hanford Site and located just across the Columbia River from southern Franklin County (fig. 1), increased job opportunities and added to the influx of people to the Pasco area. The larger towns in the study unit such as Moscow, Idaho, and Pullman, Pasco, and Moses Lake, Wash., make up a large part of the population (approximately 85,000 people), but there are numerous small agricultural towns spread throughout the study unit; about 60 percent of the population lives in these small towns. The population in the study unit is presently stable at approximately 200,000 people (fig. 10).

Land-use coverages were defined on the basis of the Anderson classification system (Anderson and others, 1976). Most of the land in the study unit is used as pasture and range land for grazing, dryland farming, and ground- and surface-water-irrigated farming (see fig. 4, table 1), but land use within the Central Columbia Plateau study unit includes a small percentage of urban and forest lands.

There are approximately 100 square miles of urban land in the Central Columbia Plateau study unit (less than 1 percent). Most of the urban land is scattered throughout the study unit in small farming communities. The effects of urbanization on water quality in the study unit are considered to be small overall, but do have significant local impacts.

Forested lands cover about 600 square miles (5 percent) of the study unit. Most of this land is located at the eastern perimeter of the Palouse subunit. There has been significant logging in the upper Palouse River Basin, but most of this activity has decreased in recent years. Any current activity is localized and timber harvesting is not expected to play a large role in water-quality issues in the Central Columbia Plateau study unit.

Barren and range lands cover approximately 4,200 square miles (32 percent) of the study unit. All three of the subunits contain tracts of range lands. Range lands have been used extensively in the study unit for intensive grazing since the early arrival of settlers. Grazing has decreased over recent years, but there are still areas throughout the study unit where range land grazing is common, and this could play a significant role in water quality in these parts of the study unit.

Crop-production agriculture is the dominant land use in the study unit, comprising a total area of about 8,000 square miles (62 percent) of the area. These lands can be further categorized as dryland farming, ground-water-irrigated farming, or surface-water-irrigated farming (fig. 4). The Quincy-Pasco subunit has all three types of farming, but surface-water-irrigated farming is the most prevalent; the North-Central subunit has a combination of dryland and ground-water-irrigated farming; and the Palouse subunit is almost entirely dryland farming.

Crop statistics presented in this report are from the Census of Agriculture (1987), Van Metre and Seevers (1991), and unpublished data for 1991 from the East, South, and Quincy Irrigation Districts that make up the Columbia Basin Irrigation Project area. The Census of Agriculture data are county-level and are presented as such. The six counties each do not necessarily fall into a single subunit; and Latah County in Idaho was not included because only a small fraction of that county is inside the study unit and much of that area is forested lands. There are some differences among data sources due to variation in methods of calculation and year(s) of study.

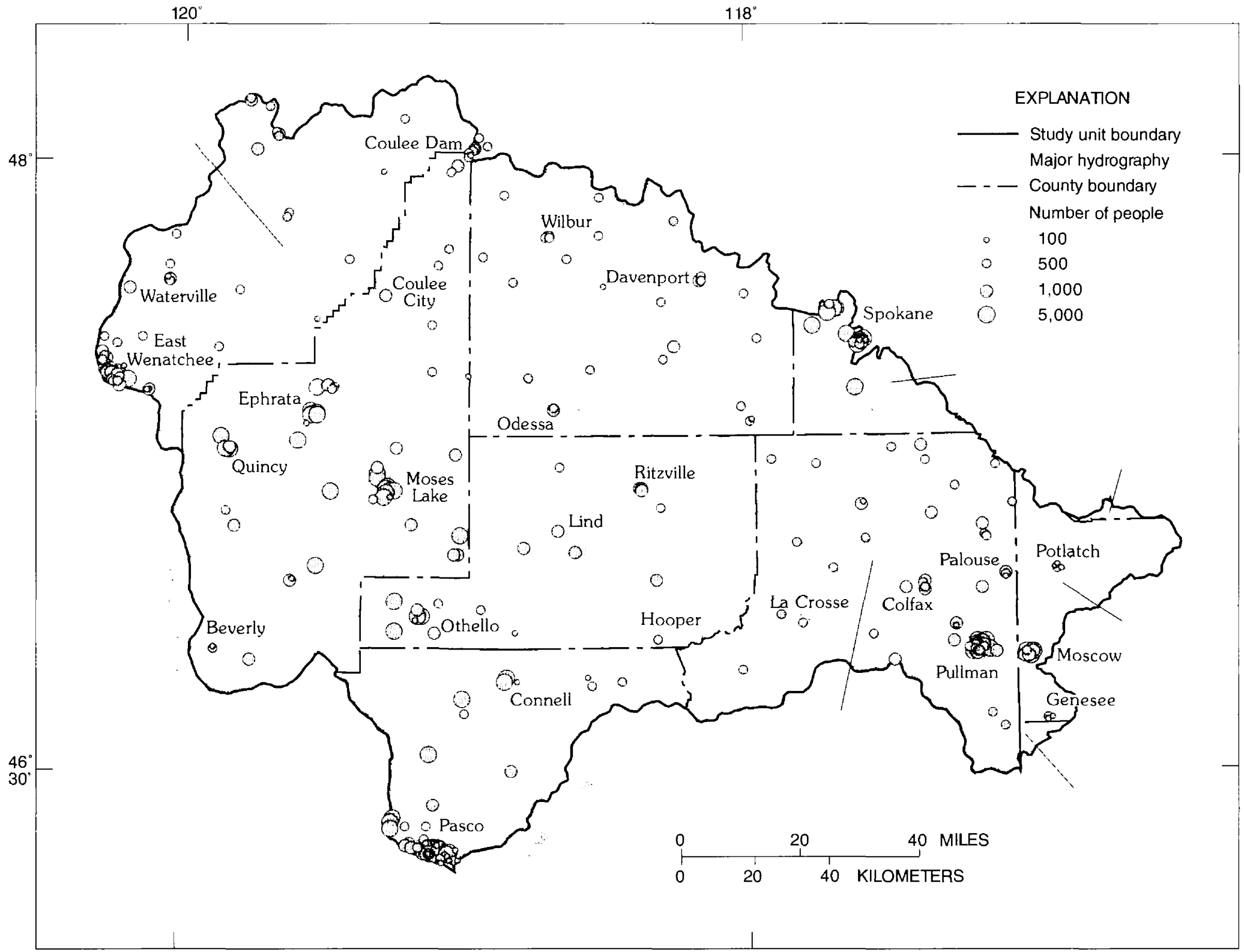


Figure 10.--Population in the Central Columbia Plateau study unit. Data are from the 1990 Census (U.S. Department of Commerce, 1990).

The Central Columbia Plateau study unit produces more than 22 crops in 8 major crop groups (table 2) on about 2.6 million acres of land. The dominant crops, in decreasing acreage, include wheat, alfalfa, other field crops, potatoes, vegetables, orchards, and corn (fig. 11). The crop category "other field crops" refers to dry beans (including lentils), dry peas, mint, and seed crops. Different agricultural practices are used and different crops are grown in the three subunits and in the counties within the subunits. A greater variety of crops is grown when more water is available for irrigation; therefore the Quincy-Pasco subunit grows the greatest diversity of crops. Table 3 shows the distribution of crops grown according to the water source used for growing crops. Ground-water-irrigated crop land covers about 12 percent of the crop land in the study unit, surface-water-irrigated crop land about 22 percent, and non-irrigated crop land about 66 percent (Alan Hattrup, Bureau of Reclamation, written commun., 1992).

The Quincy-Pasco subunit (Franklin and Grant Counties) has both surface- and ground-water-irrigated crop land and contains 29 percent of all the crop land in the study unit. The North-Central subunit (Adams, Douglas, and Lincoln Counties) has both dryland and ground-water-irrigated farming and 42 percent of the total crop land in the study unit. The Palouse subunit (Whitman County) contains 29 percent of the crop acreage in the study unit. Almost all of the crop land in this subunit is dryland farming. Approximately 97 percent of the crop land acreage, or about 44 percent of the total acreage in this subunit, is planted in wheat, barley, dry beans (lentils), and dry peas (see table 2, fig. 11).

Water Use

The primary uses of water in the Central Columbia Plateau study unit are for irrigation, public water supply, and maintenance of fish, wildlife, and recreational activities. The total quantity of water used for domestic and irrigation purposes during 1985 was about 3 billion gallons per day (Bortleson, 1991).

Water Supplies for Irrigated Agriculture

About 80 percent of all of the water (from both surface- and ground-water sources) used in the study unit in 1985 was surface water used for irrigation; about 99 percent of the consumptive use of water during that year was for irrigation. Ground-water irrigation accounted for about 14 percent of the total water use in 1985 (Bortleson, 1991). Dryland, or non-irrigated, farming is practiced in most of the Palouse subunit in the eastern part of the study unit.

Surface water imported from the Columbia River through Franklin D. Roosevelt Lake, Banks Lake, Billy Clapp Lake, and the Main Canal (figs. 1, 3) is used in the Quincy-Pasco subunit in the southwestern third of the study unit by the Bureau of Reclamation's Columbia Basin Irrigation Project, where most of the surface-water irrigation in the study unit is practiced. The irrigation project began in about 1950 and encompasses about 330 miles of main canals, 1,990 miles of laterals, and 3,160 miles of drains and wasteways (fig. 3). More than 575,000 acres are currently irrigated by this system. The project facilities are designed for irrigating up to 1.1 million acres using water delivered from Franklin D. Roosevelt Lake. About 2.2 million acre-feet of water per year are pumped from Franklin D. Roosevelt Lake into Banks Lake. The quantity of water delivered by the irrigation project and the area of irrigated land have increased steadily since 1950 (fig. 12).

The primary delivery canals for the upper project area are the West and East Low Canals. West Canal discharges into lower Crab Creek; East Low Canal discharges into Scooteney Wasteway and Potholes Canal (fig. 3). West Canal is 88 miles long and carries about 1,400,000 acre-feet of water per year from the Main Canal. About a third of this water is diverted to reservoirs, lost to leakage, or discharged as excess; about 3.9 acre-feet per acre is supplied to about 230,000 acres of farm land in the northwestern part of the irrigation project (Francis Jensen, Bureau of Reclamation, written commun., 1992). East Low Canal is 87 miles long and carries about 1,300,000 acre-feet of water per year from the Main Canal. About one-half of this water is diverted to reservoirs, lost to leakage, or discharged as excess; about 3.3 acre-feet per acre is supplied to about 150,000 acres along the eastern upper two-thirds of the irrigation project (Francis Jensen, Bureau of Reclamation, written commun., 1992). Potholes Reservoir covers 27,000 acres, has a 332,000-acre-feet water storage capacity, and separates the natural drainages of upper and lower Crab Creek. The reservoir collects and stores unused delivery water from several wasteways that drain return flows from the upper irrigation project and releases this water to the southern part of the irrigation project through the Potholes Canal to irrigate about 234,000 acres. Some of the water is discharged into lower Crab Creek.

Table 2.--*Area of crops grown by county, grouped by subunit, in the Central Columbia Plateau study unit (Census of Agriculture, 1987)*

[Values are in acres. Part of Adams County is in the Quincy-Pasco subunit. Dry beans include lentils. Crop distribution changes each year. Pasture and range land are not included in the total crop land acreage]

		Quincy-Pasco		North-Central			Palouse	
Crop category	Individual crop	Franklin	Grant	Adams	Douglas	Lincoln	Whitman	Totals
Alfalfa		57,200	102,200	20,800	2,800	14,300	7,100	204,400
Other hay		3,000	7,500	2,600	2,900	11,200	5,900	33,100
Field corn		16,500	27,900	4,900	0	0	0	49,300
Potatoes		36,100	33,000	10,700	0	0	0	79,800
Vegetables	Sweet corn	5,600	15,400	0	0	0	0	21,000
	Asparagus	10,200	2,000	300	0	0	0	12,500
	Peas	200	1,500	300	0	0	6,700	8,700
	Onions	100	2,400	600	0	0	0	3,100
	Green beans	2,900	100	0	0	0	0	3,000
	Carrots	1,600	1,200	0	0	0	0	2,800
Total for vegetables		20,600	22,600	1,200	0	0	6,700	51,100
Wheat and other grains	Wheat	112,300	175,800	303,400	185,300	316,400	389,300	1,482,500
	Barley	11,100	23,300	37,900	12,100	129,700	182,100	396,200
	Oats	300	2,400	1,900	3,900	1,600	1,000	11,100
Total for grains		123,700	201,500	343,200	201,300	447,700	572,400	1,889,800
Other field crops	Dry beans	0	19,900	4,400	0	500	62,900	87,700
	Dry peas	2,000	7,200	5,300	0	1,100	71,700	87,300
	Seed crops	4,900	7,900	5,200	0	2,400	3,400	23,800
	Mint	0	12,300	0	0	0	0	12,300
Total for other field crops		6,900	47,300	15,000	0	4,000	140,000	213,200
Orchards	Apples	5,800	18,300	1,700	12,600	0	100	38,500
	Grapes	3,700	1,000	0	0	0	0	4,700
	Cherries	1,400	1,300	0	1,100	0	0	3,800
	Pears	200	700	0	900	0	0	1,800
	Peaches	200	300	0	200	0	0	700
	Plums	100	100	0	0	0	0	200
Total for orchards		11,400	21,700	1,700	14,800	0	100	49,700
Total for all crop categories		275,400	463,700	400,100	221,800	477,200	732,200	2,570,400
Pasture and range land		211,000	562,000	340,000	427,000	448,000	268,000	1,483,000

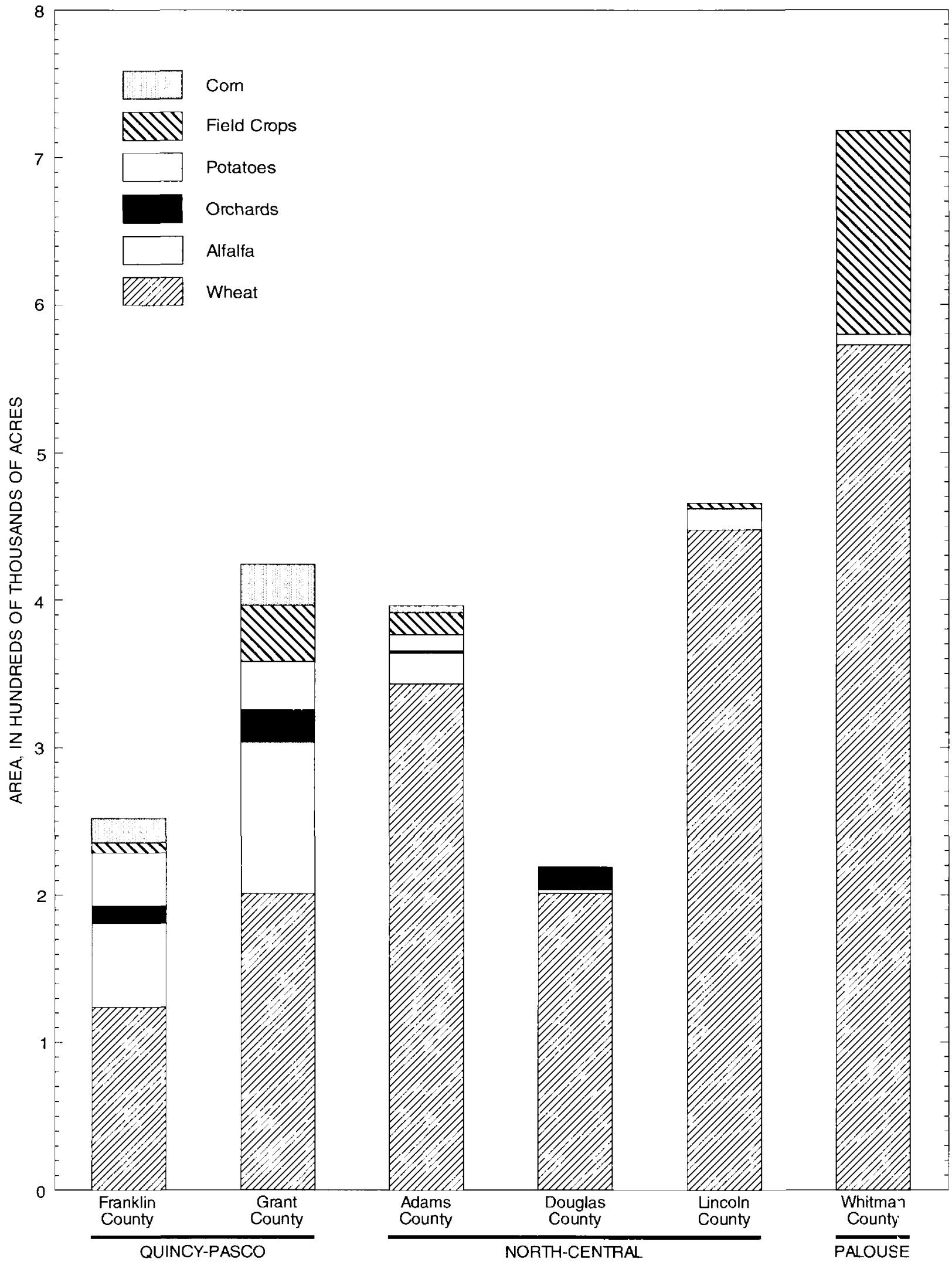


Figure 11.--Acres of major crops grown, by county, in the Central Columbia Plateau study unit (Census of Agriculture, 1987). The crop distribution changes each year. Part of Adams County is in the Quincy-Pasco subunit.

Table 3.--*Percentage of farm land, by crop type, in the Central Columbia Plateau study unit (Census of Agriculture, 1987; Van Metre and Seevers, 1991; Alan Hattrup, U.S. Bureau of Reclamation, written commun., 1991)*

[Data are from different periods; crop distribution changes each year. Approximately 16,000 acres of pasture are known to be irrigated using surface water. The type of irrigation for 14,000 acres of orchards in Douglas County, in the North-Central subunit, was not known]

Crop	Surface-water irrigated	Ground-water irrigated	Dryland or non-irrigated
Wheat and other grains	21	63	92
Alfalfa	32	8	0
Field and sweet corn	12	18	0
Potatoes	11	8	0
Dry beans and lentils	5	0	4
Dry peas	2	2	4
Orchards and vineyards	7	0	0
Asparagus	2	0	0
Mint	2	0	0
Other	6	1	0

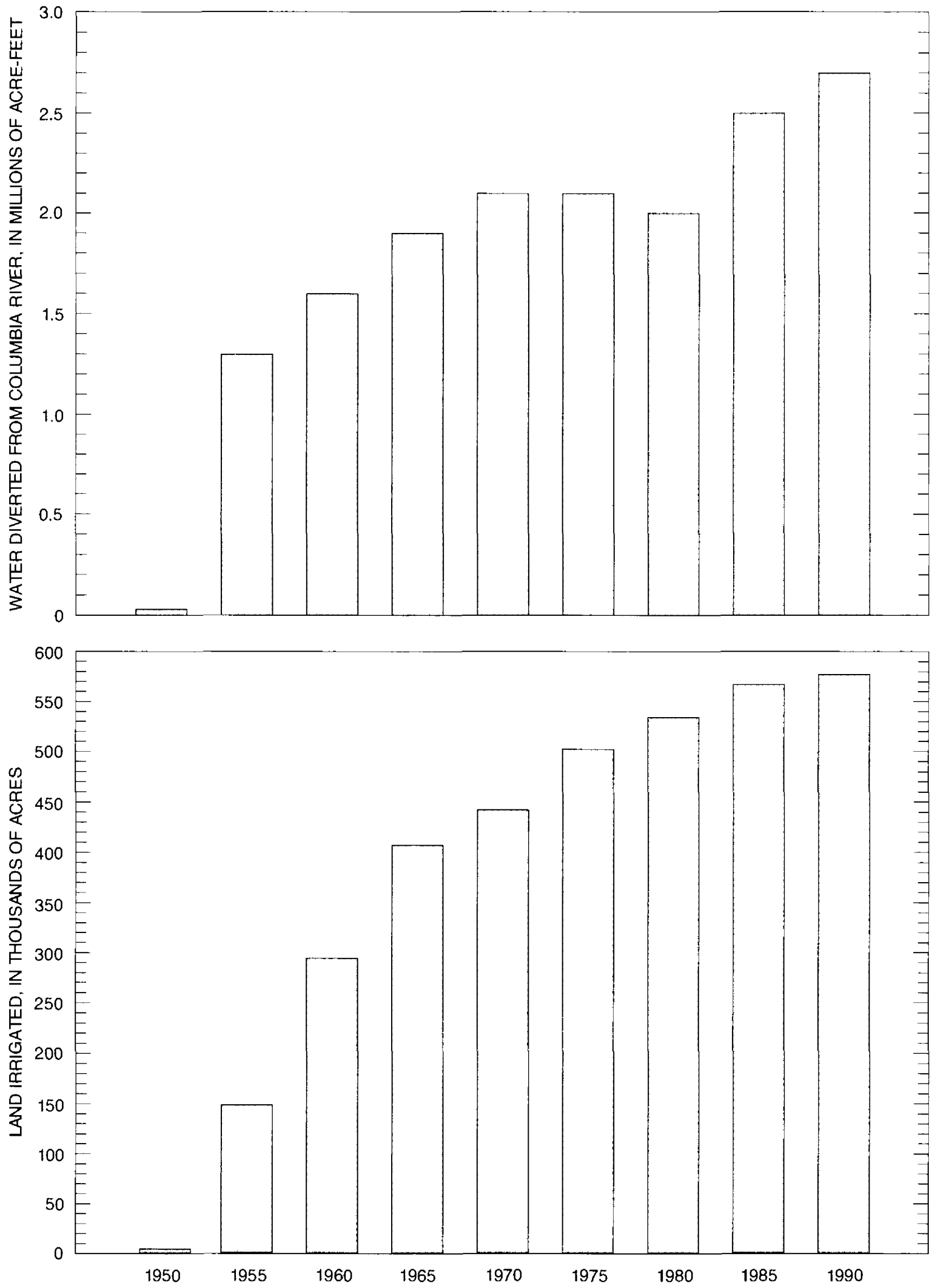


Figure 12.--Surface-water withdrawals and acres irrigated in the Columbia Basin Irrigation Project, 1950-90. Data are from the Bureau of Reclamation (Alan Hattrup, written communication, 1991).

Domestic Water Supply

All domestic water supplies, including those furnished through public supply and distribution systems, are from ground-water wells. Basalt aquifers, particularly the interflow zones, are the major sources of ground water used in the study unit for agriculture, domestic supplies, and municipal uses. Most domestic supplies are from shallow wells in the unconsolidated units or in the shallowest basalt unit, and are likely to be more vulnerable to contamination. Most of the public-supply wells and some local domestic wells are finished in deeper basalt aquifers.

Water Supplies for Fish, Wildlife, and Recreation

Non-consumptive uses of surface water in the study unit include the support of fisheries, wildlife habitat, and water-based recreational activities. Prior to development of the irrigation project, there were 35 lakes in the Columbia Basin Irrigation Project area; there are now more than 140 lakes, ponds, and reservoirs. There are State parks at Banks Lake, Billy Clapp Lake, and Potholes Reservoir, and a Bureau of Reclamation park is located at Scooteney Reservoir.

The irrigation project is on a major waterfowl migration route, and the many acres of wetlands in the Quincy-Pasco subunit are used by numerous species of waterfowl, shorebirds, and other birds for migration stopover, wintering, and nesting. Pheasant are found throughout this popular hunting area. Large tracts in the Quincy-Pasco subunit are managed for the protection of wildlife. There are extensive Federal lands and State-managed wildlife areas.

The Bureau of Reclamation and the Washington State Department of Wildlife have cooperated in stocking most sizeable bodies of surface water in the Quincy-Pasco subunit with a variety of fish, including salmonid and warm-water species, to provide year-round sport fishing. Surface waters in the Palouse subunit are used only minimally for recreation. There is some fishing in the Palouse River by local citizens.

SOURCES OF NUTRIENTS, SUSPENDED SEDIMENT, AND PESTICIDES

Many surface-water-quality issues in the Central Columbia Plateau study unit are associated with nutrients, suspended sediment, and pesticides. The following sections present background information on how different sources of nutrients, suspended sediment, and pesticides may affect water-quality conditions within the study unit.

Nutrients

Nitrogen, especially in the form of nitrate and ammonia, and phosphorus, usually in the form of orthophosphate, are required for aquatic plant growth. In excessive concentrations, however, these nutrients contribute to eutrophication and diminished water quality. Nitrogen can be toxic to aquatic life depending on its chemical form and ambient conditions in the stream. Additionally, nitrate is a human health concern, and the U.S. Environmental Protection Agency has established a criterion of 10 mg/L as N (milligrams per liter, reported as nitrogen) as the maximum allowable concentration of nitrate in drinking water supplies. Nitrate can be reduced to nitrite in the human gastrointestinal tract; nitrite is transported to the bloodstream and reacts directly with hemoglobin to produce methemoglobin, which impairs oxygen transport in the human body (U.S. Environmental Protection Agency, 1987). Elevated concentrations of ammonia also are toxic to aquatic life.

The three main sources of nutrients within the study unit are agricultural fertilizers, livestock both in feedlots and grazing on range lands, and discharges from sewage treatment plants (STPs). The dominant source of nutrients is fertilizers, because of the large areal coverage of crops and the need for fertilizer augmentation in the irrigated regions. Estimated nutrient loadings from fertilizers, atmospheric deposition, and some STPs are included in this report (see subsections in the "Loads of Nutrients and Suspended Sediment" section in this report). There are insufficient data to quantify land application of food-processing wastewater, a common practice in the study unit, as a source of nutrients in surface waters.

Non-Point Sources

Fertilizers

The main nutrients found in the fertilizers used for crop production are nitrogen and phosphorus. Nitrogen is used in greater quantities. Some county-level data on nitrogen and phosphorous applications in the Central Columbia Plateau study unit are available and are based

on county-level fertilizer expense estimates from the 1987 Census of Agriculture (Jerald Fletcher, West Virginia University, written commun., 1991).

In 1991, approximately 98,000 tons of nitrogen and 13,000 tons of phosphorus were purchased in the study unit. Estimated application rates by county, grouped by subunit, are available for comparison (table 4). Because the county lines and subunit boundaries are not the same, and because chemicals that are purchased in one county may be applied in another, these values are only approximations. The Quincy-Pasco subunit received the most nitrogen and phosphorus in terms of both total quantity purchased (48,600 tons of nitrogen and 6,400 tons of phosphorus) and estimated quantity applied per acre of crop land (132 pounds of nitrogen per acre and 17 pounds of phosphorus per acre). This subunit has nutrient-poor soils, intensive crop production, and poor retention of applied nutrients in the soil; applied irrigation water flushes nutrients below the root zone. Less nitrogen (30,300 tons, 55 pounds per acre) and phosphorus (4,000 tons, 7 pounds per acre) were estimated to be used in the North-Central subunit. The smallest estimated quantities of nitrogen (19,600 tons, 54 pounds per acre) and phosphorus (2,600 tons, 7 pounds per acre) were used in the Palouse subunit (table 4), which is dominated by dryland farming.

Feedlots and Range Land Grazing

Little information is available about the loading of nutrients and other water-quality effects related to feedlots and range land grazing. There are approximately 350,000 cattle in the study unit, and 190,000 (about 55 percent) of these cattle are in feedlots and dairy farms (Washington Agricultural Statistics Service, 1991; Randy Baldree and others, Washington State University Agricultural Extension Service, oral commun., 1992). Approximately 90 percent of the cattle in feedlots are in Adams, Franklin, and Grant Counties. Feedlots are highly localized sources and may contribute substantially to nutrient loading, particularly during low streamflow conditions.

Table 4.--*Total nitrogen and phosphorus purchased in the Central Columbia Plateau study unit, and estimated applications as fertilizer (Jerald Fletcher, West Virginia University, written commun., 1991)*

[N, nitrogen; P, phosphorus; lbs/acre, pounds per acre]

Subunit	County [1]	Crop land acreage	Total nitrogen (tons as N)	Applied nitrogen (lbs/acre) [2]	Total phosphorus (tons as P)	Applied phosphorus (lbs/acre) [2]
Quincy-Pasco subunit	Franklin	275,000	20,700	151	2,700	20
	Grant	464,000	27,900	120	3,700	16
(subunit totals)		739,000	48,600	132	6,400	17
North-Central subunit	Adams	400,000	13,600	68	1,800	9
	Douglas	222,000	5,400	49	700	6
	Lincoln	477,000	11,300	47	1,500	6
(subunit totals)		1,099,000	30,300	55	4,000	7
Palouse subunit	Whitman	732,000	19,600	54	2,600	7
(subunit totals)		732,000	19,600	54	2,600	7
Study unit totals		2,570,000	98,500	77	13,000	10

[1] Part of Adams County is in the Quincy-Pasco subunit.
[2] Fertilizers purchased in any county might be applied outside of that county.

Nutrient loading from range land cattle is even more difficult to assess than that from feedlots because it occurs throughout the study unit and the cattle are moved to various locations for grazing. There are approximately 160,000 range land cattle in the study unit. Between 19,000 and 33,000 range land cattle are in each county in the study unit (Washington Agricultural Statistics Service, 1991; Randy Baldree and others, Washington State University Agricultural Extension Service, oral commun., 1992). Stock watering sources commonly are unavailable, and range land cattle are commonly found grazing along stream corridors. This practice may contribute substantially to nutrient loading. Intensive grazing along stream corridors also may have a significant additional effect on riparian and in-stream habitats.

Point Sources

A point-source loading refers to the mass of a constituent in the water discharged through a pipe or outfall by either a municipality or an industry. Effluent standards for many point-source dischargers are regulated through the National Pollutant Discharge Elimination System (NPDES) permit program. These standards establish maximum effluent quantities for a range of water-quality constituents.

There are 22 permitted facilities that discharge effluent to surface waters within the Central Columbia Plateau study unit (fig. 13). These facilities do not include those that discharge directly to the Spokane, Columbia, or Snake Rivers. Of the 22 dischargers, 16 are STPs, 2 are industrial dischargers, and 4 are hatcheries. The permitted effluent flow limits range from 0.04 to 7.5 Mgal/d (million gallons per day). The facilities that discharge more than 1.0 Mgal/d are Quincy Industrial (2.1 Mgal/d), Moscow STP (3.0 Mgal/d), Pullman STP (4.3 Mgal/d), and Othello STP (7.5 Mgal/d).

Most studies on effects of STPs on surface-water quality in the Central Columbia Plateau study unit have been done in the Palouse subunit. These studies have found that effluent discharges from wastewater treatment plants in the Palouse River Basin contribute large quantities of nutrients to receiving waters. The effects are most pronounced during low streamflow in the South Fork Palouse River, where elevated nutrient concentrations have resulted in the proliferation of dense mats of aquatic vegetation along most of the river (Joy, 1987).

Suspended Sediment

Suspended-sediment concentrations affect in-stream habitat conditions and the transport and fate of water-quality constituents. Phosphorus, metals, and some organic compounds commonly are associated with suspended sediment in the water column and also with streambed sediments. Sediment that settles out on the stream bottom can reduce the diversity of the biological community in the stream, the total abundance of benthic invertebrates, and the spawning habitat of fish (Marshall, 1984, and Bell, 1986).

The major anthropogenic causes of erosion and sediment-related water-quality problems throughout the Central Columbia Plateau study unit include agricultural practices and range land grazing. The steep topography, the low permeability of the loess soils and farming practices in the Palouse subunit naturally lend themselves to erosion and rapid storm-driven transport of sediment and attached constituents to streams (Palouse Cooperative River Basin Study, 1978). In the Quincy-Pasco subunit, sediment transport from agricultural lands commonly occurs where ridge and furrow (as opposed to sprinkler) irrigation dominates. Additional soil erosion in this subunit is attributed to wind transport. There is more exposed basalt in the North-Central subunit (figs. 2, 4), where most of the range land grazing in the study unit is practiced. Range land grazing increases sediment erosion in several ways. Livestock alter the upland areas and cause increased sediment transport to streams. In areas along streams where range land grazing is permitted, riparian communities often are impacted, and stream banks erode into streambeds.

Pesticides

Pesticides include herbicides, fungicides, and insecticides. In the Central Columbia Plateau study unit, pesticides are applied to crops and also are used for aquatic plant management by the irrigation districts, roadside weed control by the Washington State Department of Transportation and local agencies, mosquito control, and urban applications.

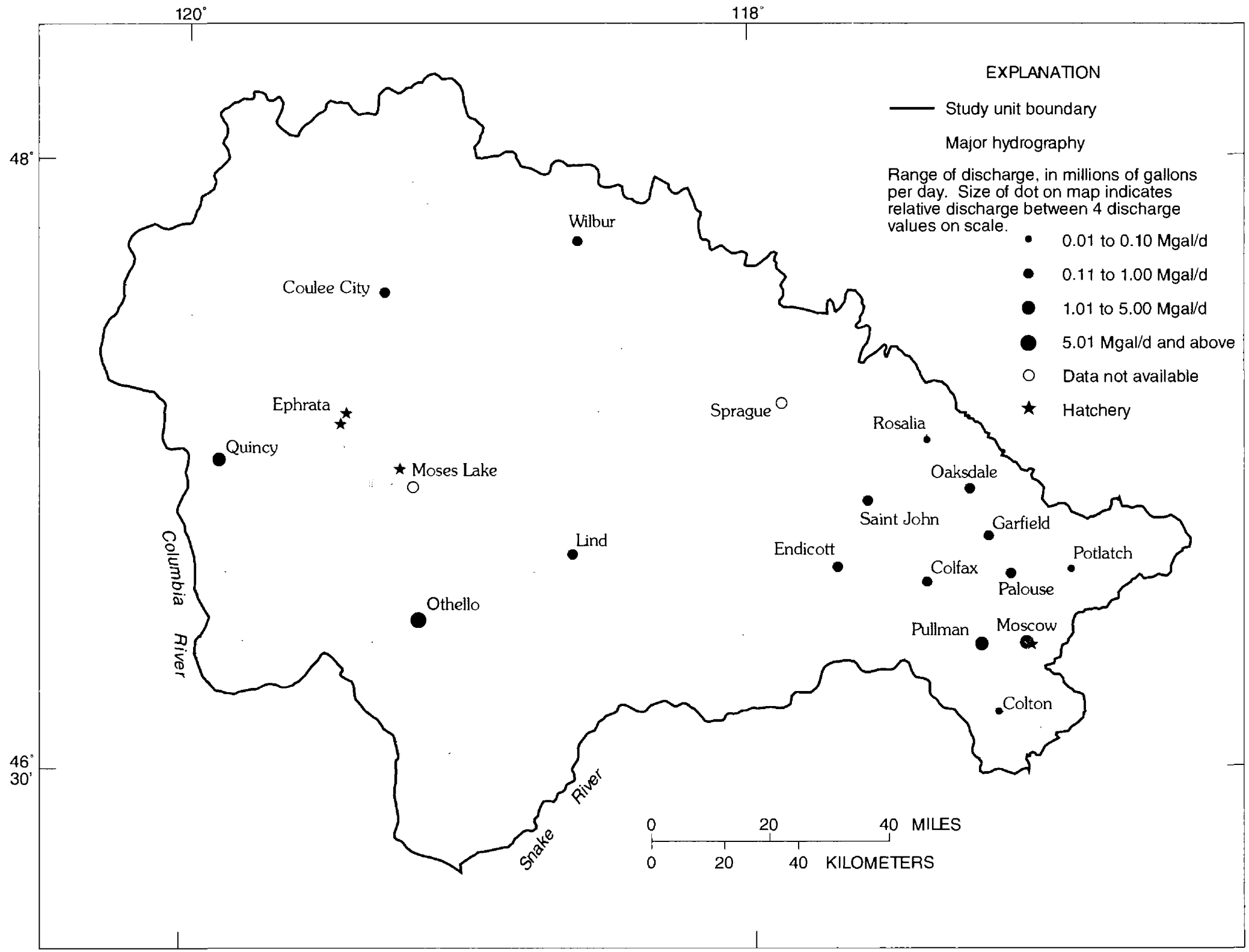


Figure 13.--Point-source dischargers in the Central Columbia Plateau study unit and National Pollutant Discharge Elimination System (NPDES) permitted discharges in millions of gallons per day (Mgal/d) (Pat Hallinan, Washington State Department of Ecology, and Jerry Schaffer, Idaho Department of Environmental Quality, written communication, 1992). Hatcheries are exempt from effluent discharge limits.

Agricultural Applications

Agricultural pesticides are a potential human health and environmental issue in the Central Columbia Plateau study unit. Application data are presented in this report for Adams, Douglas, Franklin, Grant, Lincoln, and Whitman Counties. Herbicide data were obtained from a Resources for the Future data base (Gianessi and Puffer, 1991) in which herbicide application data for 1987 were reported by county. The 1987 fungicide and insecticide data also were obtained from Resources for the Future (Gianessi and Puffer, 1992a and 1992b); however, these data were reported as quantities of pesticides applied for the entire State of Washington. County-level data were estimated on the basis of the acreages of individual crops grown in each county.

Of these three pesticide groups, the largest in terms of quantity applied is herbicides: approximately 1.8 million pounds per year of 42 herbicides are used in the study unit (fig. 14, table 5). Insecticides are next: an estimated 900,000 pounds per year of 36 different insecticides are used. The smallest amount of pesticides applied are fungicides: 500,000 pounds per year of 24 compounds are estimated to be applied in the study unit. The largest total quantities of pesticides, approximately 2.3 pounds per acre per year, are used in the two counties of the Quincy-Pasco subunit (fig. 14). Whitman County, which makes up most of the Palouse subunit, has the next largest pesticide usage (mostly herbicides). Smaller estimated quantities of pesticides are applied in the three counties of the North-Central subunit.

The approximate pesticide use for each of the major crop groups grown in the study unit also varies (table 6). The major crops grown in the study unit include wheat, potatoes, orchards, field crops, alfalfa, and corn; these groups are ranked from the largest total pesticide use down to the smallest (fig. 15; see table 2). Herbicides are more commonly used on wheat, field crops, and alfalfa, and insecticides are used more on orchards and potatoes. Orchards receive the most intensive pesticide application per acre of crop, followed by potatoes, vegetables, and field corn (table 6). Table 19 (end of report) lists pesticide compounds used on individual crop categories.

Control of Roadside Weeds and Algae and Aquatic Plants

The maintenance of the canals in the Quincy-Pasco subunit includes the control of weeds along the irrigation right-of-ways and of aquatic vegetation that grows in the canal system itself. Although the amount of pesticides applied for this type of weed control is about an order of magnitude less than the amount applied for agricultural purposes, pesticide compounds are applied directly into or alongside the streams for this purpose. The irrigation districts use a variety of herbicides to prevent and (or) remove unwanted plants. These herbicides can be divided into pre- and post-emergent terrestrial herbicides and aquatic herbicides. The information on pesticide usage is unpublished data supplied by the Quincy Irrigation District (Keith Franklin, written commun., 1992), the East Irrigation District (Mike Mansfield, written commun., 1992), and the South Irrigation District (Hugh McEachon, written commun., 1992) of the Columbia Basin Irrigation Project.

Pre-emergent terrestrial herbicides, also referred to as soil sterilants, are used to make soil incapable of supporting plant growth and are commonly applied by the irrigation districts to control the growth of weeds along the irrigation roads and waterways. The districts use several formulations of pre-emergent herbicides, and the most commonly used active ingredients are the organic herbicides diuron and atrazine. These herbicides are applied in the fall or early winter in order to permit the winter-spring rains to activate and leach the herbicides into the soil. In 1991, the three irrigation districts used approximately 5,900 pounds of diuron and 3,600 pounds of atrazine.

The post-emergent terrestrial herbicides are used to remove specific weeds that are already present. The irrigation districts rely mainly on herbicides with the active ingredients 2,4-D and glyphosate. The herbicide 2,4-D is selective for broad-leaf weeds and is applied either one or two times a year depending on local needs. Glyphosate is applied in the same manner as 2,4-D. Both of these herbicides are used to control weeds that grow along the waterline and therefore are sprayed directly along the banks of the canals. In 1991, the irrigation districts used approximately 55,600 pounds of 2,4-D and 2,700 pounds of glyphosate.

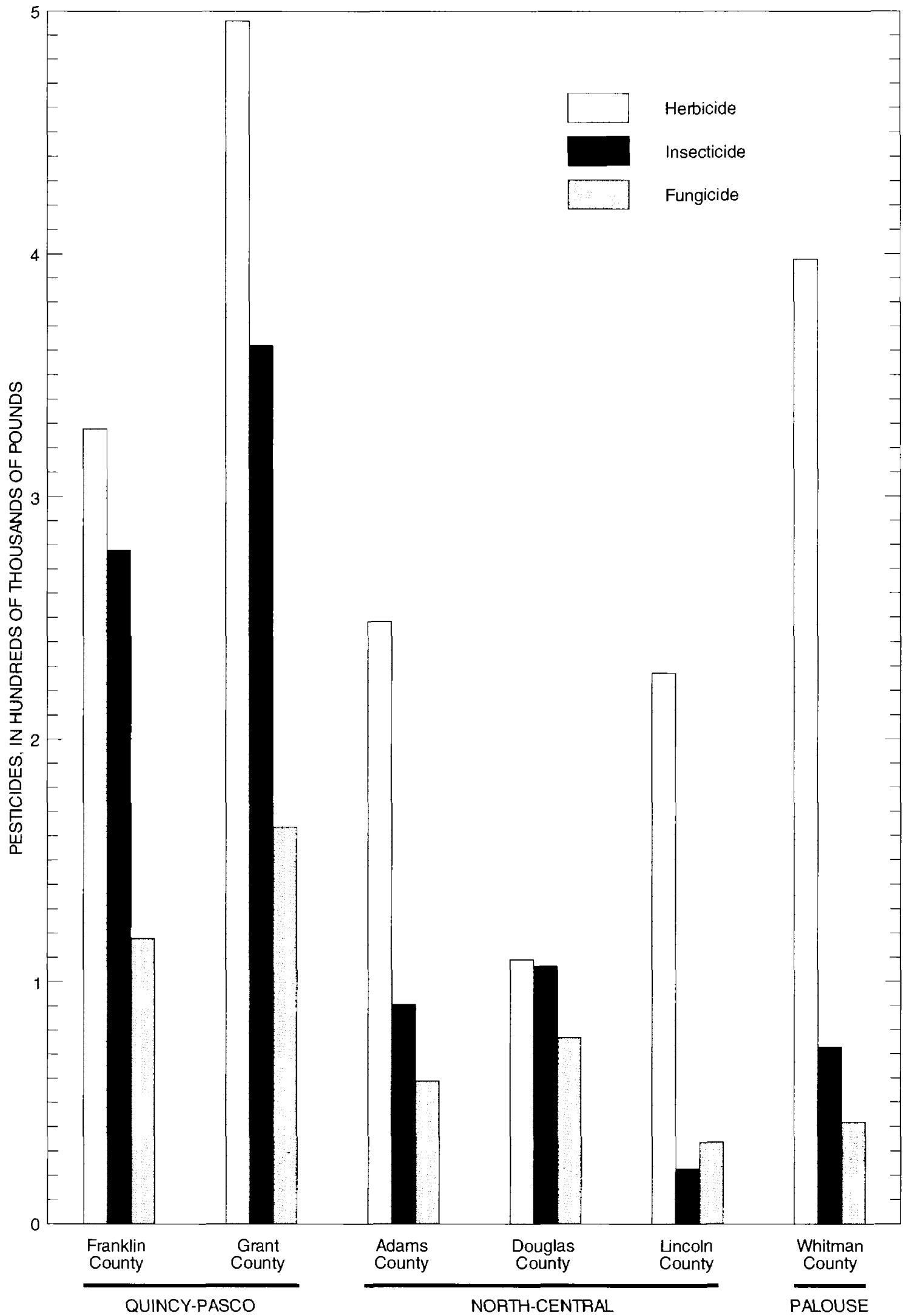


Figure 14.--Estimated quantities of pesticides applied in the Central Columbia Plateau study unit (Gianessi and Puffer, 1991, 1992a, and 1992b). Part of Adams County is in the Quincy-Pasco Subunit.

Table 5.--*Pesticides applied on crops in the Central Columbia Plateau study unit (Gianessi and Puffer, 1991, 1992a, and 1992b)*

[lbs/yr, estimated pounds per year]

Fungicides	Quantity (lbs/yr)	Herbicides	Quantity (lbs/yr)	Insecticides	Quantity (lbs/yr)
Benomyl	67,300	2,4-D	318,200	Abamectin	100
Captan	8,200	2,4-DB	148,100	Acephate	1,400
Chlorothalonil	18,200	Alachlor	45,100	Aldicarb	17,100
Copper	19,100	Atrazine	30,600	Amitraz	500
Dcna	1,200	Benefin	11,400	Azinphos-methyl	92,400
Dinocap	500	Bentazon	3,900	Carbaryl	43,000
Dodine	4,700	Bromoxynil	82,200	Carbofuran	3,700
Fenarimol	1,200	Chlorpropham	40,900	Chlorpyrifos	91,700
Iprodione	28,000	Chlorsulfuron	4,400	Cyfluthrin	100
Mancozeb	60,700	Cyanazine	1,500	Diazinon	24,000
Maneb	15,300	Dcpa	59,200	Dicofol	3,600
Metalaxyl	2,100	Dicamba	40,600	Dimethoate	20,000
Metiram	14,800	Dichlobenil	2,200	Disulfoton	150,500
Myclobutanil	2,300	Diclofop_methyl	14,900	Endosulfan	33,200
Oxytetracycline	400	Dinoseb	11,200	Esfenvalerate	200
Sulfur	110,000	Diquat	8,900	Ethion	3,800
Thiabendazole	73,400	Diuron	64,500	Ethoprop	82,900
Thiophanate Methyl	17,800	Endothall	1,200	Ethyl Parathion	17,900
Triadimefon	1,900	Eptc	324,900	Fenbutatin Oxide	500
Triforine	500	Ethalfluralin	4,600	Fonofos	13,200
Triphenyltin Hyd	200	Glyphosate	53,200	Formetanate HCL	2,000
Vinclozolin	100	Hexazinone	4,100	Malathion	23,900
Ziram	44,700	Linuron	3,700	Methamidophos	77,400
		Mcpa	22,800	Methidathion	1,100
		Metachlor	36,500	Methomyl	3,400
		Metribuzin	72,300	Methyl Parathion	35,800
		Metsulfuron	2,400	Mevinphos	1,300
		Napropamide	3,800	Naled	1,000
		Norflurazon	6,400	Oxamyl	7,800
		Oryzalin	29,400	Oxydemeton-methyl	6,000
		Oxyfluorfen	200	Oxythioquinox	3,500
		Paraquat	800	Permethrin	4,900
		Pendimethalin	19,400	Phorate	76,500
		Pronamide	7,700	Phosmet	26,400
		Propham	69,500	Propargite	61,000
		Sethoxydim	1,100	Trichlorfon	600
		Simazine	10,100		
		Terbacil	13,500		
		Terbutryn	88,900		
		Triallate	82,200		
		Trifluralin	29,400		
		Vernolate	31,000		

Table 6.--*Quantities of fungicides, herbicides, and insecticides applied on crops in the Central Columbia Plateau study unit (Gianessi and Puffer, 1991, 1992a, and 1992b)*

[lbs/acre/yr, pounds per acre per year; lbs/yr, pounds per year]

Crop category	Acres of crop land	Fungicides		Herbicides		Insecticides		Sum [1]	
		(lbs/acre/yr)	(lbs/yr)	(lbs/acre/yr)	(lbs/yr)	(lbs/acre/yr)	(lbs/yr)	(lbs/acre/yr)	(lbs/yr)
Orchards	50,000	3.7	186,900	1.1	53,800	6.0	299,500	11	540,200
Potatoes	80,000	1.7	138,100	2.2	178,700	4.7	374,000	8.6	690,800
Vegetables	51,000	0.2	9,700	2.0	103,000	1.2	62,300	3.4	175,000
Field corn	49,000	0	0	2.6	127,400	0.1	4,600	2.7	132,000
Other field crops	213,000	0.0005	100	1.3	278,000	0.3	68,600	1.6	346,700
Alfalfa	204,000	0	0	1.1	221,500	0.2	36,300	1.3	257,800
Wheat and grains	1,890,000	0.1	157,900	0.4	787,100	0.05	87,200	0.5	1,032,200

[1] Sum for pesticides listed in table 5. Fumigants and soil sterilants are not included.

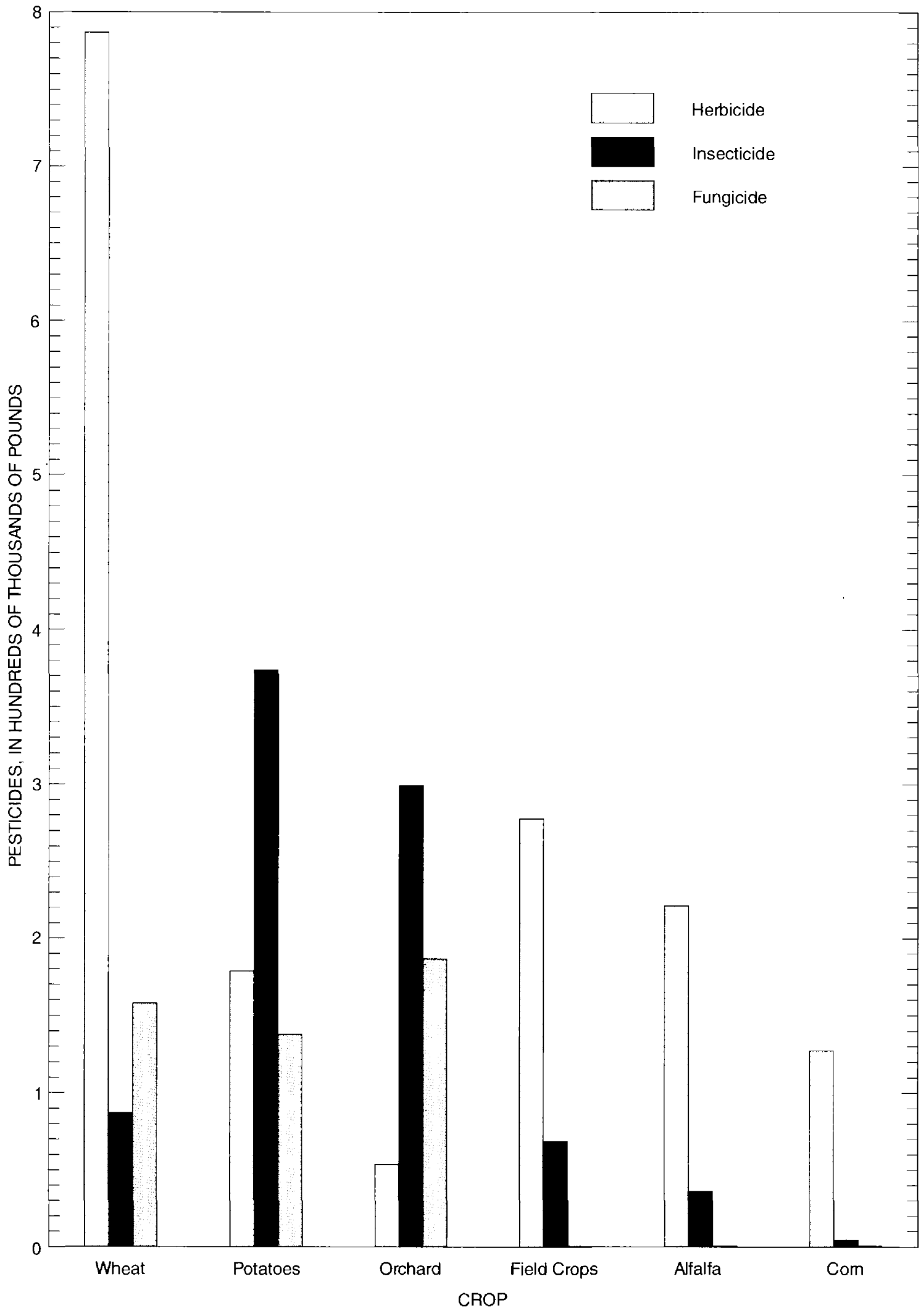


Figure 15.--Estimated quantities of pesticides applied on major crops in the Central Columbia Plateau study unit (Gianessi and Puffer, 1991, 1992a, and 1992b).

Aquatic plants are a major management issue for the irrigation districts because of their interference with flows within the canals. Herbicides used to control aquatic plants are released directly into the canals, and the exact method and timing depends on the herbicide itself. Copper sulfate is an inorganic herbicide used to control algal growth in the canals. This herbicide is applied every 2 to 3 weeks during the irrigation season. Copper sulfate is released in a large quantity at a discrete location; the high concentration of the chemical then moves downstream. In 1991, the irrigation districts used approximately 81,700 pounds of copper sulfate.

Xylene is used for controlling both algae and aquatic macrophytes. This herbicide is used as needed, and is injected below the waterline with the dosage dependent on flows in the canal. Approximately 12,300 gallons of xylene were used in 1991. Another aquatic plant herbicide used in the study unit is acrolein, a highly volatile organic chemical that is toxic to fish, algae, and aquatic macrophytes. This herbicide is applied at 14- to 21-day rotations from May to October. The three irrigation districts used a total of approximately 211,700 pounds of acrolein in 1991.

DESCRIPTION AND QUALIFICATION OF DATA

Most of the surface-water-quality sampling sites included in this report are located in the Quincy-Pasco subunit or in the Palouse subunit; only five sites are located in the North-Central subunit. Surface-water-quality and streamflow data for the Central Columbia Plateau study unit were retrieved from the U.S. Geological Survey's National Water Data Storage and Retrieval System (WATSTORE) data base and from the U.S. Environmental Protection Agency's STORET data base. These data were combined and converted to a new data base, where the data were screened and the initial data review was performed. There is good distribution of water-quality data throughout time and flow regime for many of the sampling locations included in this report; however, most of the water-quality data for the Quincy-Pasco subunit were collected from April through October, during the irrigation season.

This report includes all surface-water sampling locations in the WATSTORE and STORET data bases with at least 10 observations for nutrient or suspended-sediment concentrations or any observation for pesticide concentrations in the Central Columbia Plateau study unit. Data for 105 of the 136 surface-water-quality sampling locations in the study unit initially considered for analysis were included in this report. The other sites were not included for the following reasons. Twelve sites had limited or biased seasonal coverage of the samples collected. Eight sites in the Palouse River Basin had only suspended-sediment concentration data for samples that were collected during 1964-65 (the results of that study (Boucher, 1970) are discussed, but those data are not included in this report). On Deep Creek, a tributary to the Palouse River, four sites had data for water-quality samples collected only during the spring and early summer months in 1987 and 1988. Nineteen sites represented drainage areas of less than 1 square mile. (Those data were collected for field studies of nutrient and suspended-sediment fluxes by the U.S. Geological Survey (USGS) in a block of the irrigation project near Royal City in 1977-81). Two of the 105 sites were included because one or more samples were analyzed for pesticide concentrations at those sites; fewer than 10 samples for nutrient or suspended-sediment concentrations were collected at these two sites and those nutrient and suspended-sediment concentration data were not included in this report. The date of sampling was not known for 23 observations, and those data were not included in this report.

Several of the 105 sites in the Central Columbia Plateau study unit were sampled by more than one agency for different purposes. Data from different agencies were combined if samples were collected at the same location or at nearby locations with no significant inflows in between. These sites and their periods of record are listed in table 7.

Data Sources and Methods of Collection and Analysis

Samples for water-quality analysis are collected for many different purposes, including monitoring of ambient conditions, assessment of point- and nonpoint-source pollution effects, estimation of constituent loading, and detection of spatial and temporal status and trends. Sampling methods are chosen on the basis of the accuracy of sampling that is necessary to achieve the purposes of a study, as well as the costs of alternative sampling methods.

The two principal sampling methods used for determining water quality in streams and rivers are commonly called grab sampling and depth- and width-integrated sampling. When grab sampling techniques are employed, samples usually are collected in an open or closed container at or near the stream surface. Sample collection at a representative point is considered to be sufficient for characterizing water quality in most studies of dissolved

Table 7.--*Surface-water sites in the Central Columbia Plateau study unit that were combined for analyses in this report (water-quality data collected for different monitoring programs were collected at the same location or at nearby locations with no significant inflow in between)*

[USGS, U.S. Geological Survey; BR, Bureau of Reclamation; Ecology, Washington Department of Ecology; EPA, U.S. Environmental Protection Agency; IDEQ, Idaho Department of Health and Welfare, Division of Environmental Quality]

Reference number on figure 17	Station name	Agency	Station number	Period of record	Frequency of sampling
5	Crab Creek	USGS	12472600	8/9/59-1/15/74, 11/21/91, 3/5/92	weekly, monthly
	near Beverly, Washington	BR	CBP072	5/13/74-2/1/91	quarterly
		Ecology	41A070	8/9/59-9/25/72, 10/21/74-9/12/90	monthly, bimonthly
		EPA	543121	11/15/71	one sample only
6	Crab Creek	BR	CBP061	10/18/67-1/29/91	quarterly
	near Moses Lake, Washington	EPA	CCM0N03	9/22/74-8/13/75	monthly, bimonthly
		Ecology	41A110	10/24/61-9/12/62, 7/24/80-9/15/83	monthly
		EPA	5309A2	3/20/77-9/29/77	weekly
21	EL 68D Wasteway	USGS	12473740	3/6-3/7/70, 3/1/78-10/22/79, 11/19/91, 3/4/92	daily
	near Othello, Washington	BR	CBP065	5/13/74-1/16/78, 1/15/80-1/29/90	quarterly
67	Rocky Coulee Wasteway	EPA	5309B1	9/22/74-8/13/75	monthly, bimonthly
	near Moses Lake, Washington	EPA	RCMON02	3/20/77-9/2977	weekly
90	Palouse River	USGS	13351000	6/27/61-9/20/77	annually
	at Hooper, Washington	Ecology	34A070	7/30/59-9/20/71, 10/16/73-9/4/90	monthly, bimonthly
98	Palouse River	USGS	13345000	10/16/72-3/8/82, 7/10/89-5/23/91	quarterly
	near Potlatch, Idaho	IDEQ	2020042	3/6/68-5/12/75, 3/15/78-9/21/83, 10/26/88-9/19/89	monthly
102	South Fork Palouse River	USGS	13348000	11/25/64-1/30/65	weekly
	at Pullman, Washington	Ecology	34B110	12/9/70-9/17/74, 10/26/77-9/4/90	monthly, bimonthly
104	South Fork Palouse River	USGS	13349200	10/21/64-5/26/65	bimonthly
	near Colfax, Washington	Ecology	34B070	12/9/70-9/25/75	bimonthly

constituents (Martin and others, 1992). Depth- and width-integrated samples are composited from cross-sectionally integrated and flow-weighted samples that are collected using depth-integrating nozzled samplers. The collection of depth- and width-integrated samples requires a greater investment in time and equipment than the collection of grab samples; however depth- and width-integrated samples are more representative of the horizontal and vertical variations, particularly for suspended-sediment concentrations and total-constituent concentrations, which are of interest in many water-quality studies. Sediment-related constituents such as total phosphorus may be under-represented in grab samples. With few exceptions, the USGS employs depth- and width-integrated sampling techniques and most other agencies use grab sampling techniques. Much of the water-quality data available for analysis in this report was collected using grab techniques, and data were not available to compare grab sampling with depth- and width-integrated sampling at any of the sites. A summary of the water-quality data available for analysis, and the number of samples collected by each agency, is shown in table 8.

Table 8.--*Determinations of nutrient, suspended-sediment, and pesticide concentrations, by collecting agency*

[BR, Bureau of Reclamation; USGS, U.S. Geological Survey; Ecology, Washington State Department of Ecology; IDEQ, Idaho Department of Health and Welfare, Division of Environmental Quality; EPA, U. S. Environmental Protection Agency; TN, total nitrogen; NO_3, nitrate; NH_4, ammonia; TP, total phosphorus; PO_4, orthophosphate; $\%Q_i$, percentage of determinations with instantaneous discharge measurements; $\%Q_m$, percentage of determinations with mean daily flow measurements (both Q_i and Q_m may have been observed for the same sample); --, no data. Some sites were sampled by more than one agency and several sites were cooperatively sampled by more than one agency. Some Ecology data were collected and analyzed by USGS or EPA]

		Number of determinations								
Agency	Number of sites	TN	NO_3	NH_4	TP	PO_4	Suspended solids	Suspended sediment	Pesticides in water	Pesticides in bed sediment
BR	73	1,432	3,577	3,527	3,575	3,578	3,056	--	6,642	2,363
($\%Q_i$)		16	33	33	33	33	27	--	0	0
($\%Q_m$)		14	13	13	13	13	12	--	0	0
USGS	32	4,896	5,064	247	5,245	322	2	5,844	--	--
($\%Q_i$)		26	26	79	26	72	100	29	--	--
($\%Q_m$)		54	54	31	54	38	100	45	--	--
Ecology	9	232	1,256	898	894	1,118	459	9	--	3
($\%Q_i$)		78	53	73	73	56	65	100	--	0
($\%Q_m$)		74	59	47	46	57	65	100	--	0
IDEQ	9	100	184	171	102	11	72	28	37	--
($\%Q_i$)		42	23	25	41	55	26	79	0	--
($\%Q_m$)		64	54	55	63	10	88	4	0	--
EPA	6	119	196	122	196	70	--	--	--	--
($\%Q_i$)		1	1	1	1	1	--	--	--	--
($\%Q_m$)		1	18	11	19	19	--	--	--	--

Most surface-water-quality data in the Central Columbia Plateau study unit is for the Bureau of Reclamation (BR) sites. The BR has collected and analyzed water-quality data at 73 of the sites in this report beginning as early as 1956 and continuing to the present (1993). Data collected before 1967 have not been entered into the STORET data base and were not included in this review. Samples for analysis of nutrients and suspended solids were routinely collected using grab techniques and analyzed at the BR laboratory in Boise, Idaho. These nutrient samples were preserved with sulfuric acid and chilled on ice prior to analysis, as recommended by U.S. Environmental Protection Agency (EPA) standard procedures. Samples for all analyses that required filtering were filtered in the laboratory (Bill Stroud, Bureau of Reclamation, oral commun., 1992). Streamflow data were available for 13 of these sites (streamflow data from BR paper records were included for 4 of these sites). The BR collected samples at 12 of these sites between 1974 and 1978 for the analysis of pesticides in one to three media, including the water column, fish tissues, and streambed sediments.

The USGS has collected water-quality data for 32 surface-water sites in the study unit from as early as 1961 to the present (1993). Samples were collected using depth- and width-integration techniques (Guy and Norman, 1970) and analyzed at USGS District laboratories or at the USGS National Water Quality Laboratory (NWQL) in Arvada, Colo. Samples were analyzed for nutrient concentrations at the USGS District laboratory in Portland, Oreg., prior to 1971. From 1971 until September 30, 1978, nutrient samples were analyzed at the USGS District laboratory in Tacoma, Wash. Samples collected after October 1, 1978, were analyzed for nutrient concentration at the USGS NWQL. Samples that required filtration generally were filtered in the field and samples for nutrients were chilled prior to analysis. Beginning October 1, 1980, mercuric chloride was added to nutrient samples as a preservative in addition to chilling (USGS Office of Water Quality Technical Memorandum 80.26, September 19, 1980). Streamflow data were available for 27 of these sites.

The Washington State Department of Ecology (Ecology) has collected surface-water-quality samples at nine sites in the study unit from as early as 1959 to the present (1993). Samples were collected using grab techniques. These samples were analyzed for nutrient concentrations by USGS laboratories until 1980, and at Ecology's Southwest Regional Office Laboratory from June 1, 1980, until 1985. Beginning in 1985, analyses for nutrient concentrations generally were performed at Ecology's Manchester Laboratory, although samples were analyzed by a contract laboratory during the periods from January to July 1987; September 17 to October 12, 1990; and February through March 1991 (Dave Hallock, Washington Department of Ecology, oral and written commun., 1992). Streamflow data were available for four of these sites.

The Division of Environmental Quality of the Idaho Department of Health and Welfare (IDEQ) has collected samples at nine sites in the study unit from as early as 1968 to 1990. Samples were analyzed for nutrient concentrations at the Idaho Department of Health and Welfare Laboratory in Boise, Idaho. Samples were collected by grab-sample techniques, preserved by adding sulfuric acid, and chilled on ice prior to analysis. Samples were filtered in the field after February 1987 (Ranae Hardy, IDEQ, oral commun., 1992). Streamflow data were available for five of these sites.

The EPA collected surface-water-quality samples at six of the sites in the study unit from as early as 1968 to 1977. Samples were collected as part of the EPA National Eutrophication Study (NES), the USEPA Clean Lakes Program, or Federal-State Cooperative Studies. Samples collected as a part of the NES were analyzed using standard EPA methodology at the EPA Laboratory in Las Vegas, Nevada. Nutrient samples were filtered, preserved with sulfuric acid, and chilled on ice at a field laboratory before being flown to the Las Vegas laboratory. A quality-assurance program consisted of replicate field samples as well as laboratory quality-assurance procedures that used blanks and replicates (Victor Lambou, University of Florida, oral commun., 1992). Streamflow generally was not measured at these sites when samples were collected.

Construction of the Data Base

In order to meet NAWQA objectives, a data base was needed from which water-quality constituents could be compared at all sites in the study unit. The constituents of interest and the steps necessary to create this data base are discussed in this section. Some conversions and substitutions of data were necessary to construct this data base. The detection limit, or the smallest measurable concentration that may reliably be determined for a particular constituent, also varies for many water-quality constituents, and before analysis, concentrations reported as less than a given detection limit may be assigned values between 0 and the detection limit. The water-quality constituents of interest to the first NAWQA national synthesis are total nitrogen (TN), dissolved nitrate (NO_3), dissolved or total

ammonia (NH_4), total phosphorus (TP), dissolved orthophosphate (PO_4), any pesticides, and suspended sediment (for which both suspended-sediment and suspended-solids data are included). A list of the pesticides (herbicides and insecticides) for which concentrations at sampling locations in the study unit were determined is included in the "Concentrations of Pesticides" section.

Suspended sediment and suspended solids are differentiated because of the techniques used to collect samples and the analytical methods used to determine concentrations. A suspended-sediment determination usually gives a higher concentration than a suspended-solids determination. "Suspended-sediment" samples are collected using depth- and width-integrated techniques, which usually capture higher density (sand) material than a grab sample. The entire suspended-sediment sample is filtered, evaporated, and weighed to determine sediment concentration. The method for determining "suspended-solids" concentrations was developed for evaluating wastewater treatment operations, where suspended sediments have a lower density than in many natural waters. Suspended-solids samples are usually collected using grab (dip sampling) techniques. A subsample is pipetted out, filtered, evaporated, and weighed to determine suspended-solids concentration. The heavier material captured in the original sample may settle rapidly and therefore not be captured in the subsample. The lower concentration of heavier particles in the initial sample and this settling of the heavy material result in lower reported sediment concentrations (Robert F. Middleburg, Jr., U.S. Geological Survey, written commun., 1992).

The detection limit may change with the technology or with the analytical method used. Detection limits for pesticide compounds are discussed in the "Concentrations of Pesticides" section. The available nutrient and suspended-sediment data for this report include relatively few concentrations below analytical detection limits. All nutrient and suspended-sediment determinations reported below detection limits, and determinations reported as zero values, are indicated by "less-than" values (for example, <0.01 mg/L or <1 mg/L), and for interpretive purposes were usually assigned concentrations of half of the detection limit (for example, 0.005 mg/L or 0.5 mg/L, respectively) for each observation. Zero values also were assigned concentrations of half of the detection limit.

For nitrate, 266 of 10,277 concentrations were reported as less than detection limits, which ranged from less than 0.01 mg/L to 0.10 mg/L. There were 193 observations for nitrate at 18 sites in the data set that had concentrations reported as less than 0.10 mg/L; these observations were assigned values of 0.05 mg/L. All nitrate observations that were reported as zero values or as less than 0.01 mg/L were assigned values of 0.005 mg/L. The 50 nitrate observations that were reported as less than other concentrations were left as those numbers if they were less than 0.01 mg/L or assigned concentrations of half of that value if they were greater than 0.01 mg/L but less than 0.10 mg/L.

There were no reported total-nitrogen concentrations below the analytical detection limit. For dissolved ammonia, 13 of 3,689 analyses were reported as less than 0.01 mg/L; these observations and an additional 665 zero values were assigned values of 0.005 mg/L (1 dissolved ammonia analysis was reported as less than 0.06 mg/L and was left as that number). Three of 1,431 total ammonia analyses had reported values of less than 0.01 mg/L (these observations were assigned values of 0.005 mg/L); 41 additional observations were zero values and also were assigned values of 0.005 mg/L. For orthophosphate, 55 of 5,099 observations were reported as less than 0.01 mg/L and 17 observations were reported as less than 0.001 mg/L. All orthophosphate observations that were reported as zero values or as less than 0.01 mg/L were assigned values of 0.005 mg/L; observations reported as actual values that were less than 0.01 mg/L were left as those numbers. For total phosphorus, 12 of 10,193 observations had reported values as less than 0.01 mg/L and 3 observations had reported values of less than 0.05 mg/L; these cases were assigned values of 0.005 mg/L and 0.025 mg/L, respectively. The detection limit for the 5,881 suspended-sediment and 3,589 suspended-solids observations in the data set was 1 mg/L. No non-zero suspended-sediment observations were reported as below the detection limit; the 31 suspended-solids observations reported as below the detection limit and the 51 suspended-sediment and 6 suspended-solids observations with zero values all were assigned values of 0.5 mg/L.

Historically, changes in laboratory and field procedures have resulted in changes in the ways concentrations of nutrients and suspended sediment were reported. Equivalent determinations with different reporting units were combined to produce a smaller set of constituents for analysis in this report. Some constituents determined by different agencies, and reported as different constituents, were found to be equivalent. Others could be calculated from a combination of different constituents measured for a given sample. Some agencies and laboratories used different reporting units for the same analyses and only a conversion factor was needed to calculate the value of one constituent from the other. The possible combinations and substitutions of nutrient and suspended-sediment

constituents that were made during the compilation of data for this report are listed in table 9. These combinations and conversions were made in order to compile a data set that includes the maximum available information on surface-water quality in the study unit. Determinations of equivalency were based on visual inspection of scatterplots and statistical tests for sites where data for the constituents in question were available. All nutrient concentrations listed in the text of this report are in milligrams per liter as nitrogen or as phosphorus (mg/L as N or as P).

No combinations or substitutions of constituents were made for total phosphorus, orthophosphate, or ammonia. A simple sign test was performed to compare data for dissolved and total ammonia at sites where both were available. This test indicated that at probability level (p-value) less than 0.001 dissolved values are likely to be lower than total values; therefore summary statistics for dissolved and total ammonia are listed separately. References to ammonia in the text of this report may be to either total- or dissolved-ammonia concentrations.

Combinations and substitutions of reported constituents were made in many cases for total nitrogen, nitrate, and suspended solids (table 9). Concentrations of suspended solids were analytically determined by evaporating samples at two different temperatures; this difference in methodology was considered to be negligible for the purposes of this report. Dissolved and total nitrate concentrations in surface waters generally were the same within the range of analytical accuracy; therefore a value for total nitrate was substituted if a dissolved nitrate concentration was not determined for a particular sample. Measurements of nitrate-plus-nitrite concentrations were substituted for nitrate concentrations in some cases where nitrite concentrations generally are negligible (at sites that are not influenced by STP discharges). The 90th-percentile concentration of total nitrite in the data set was 0.05 mg/L.

Information such as the collecting agency, date, time, and streamflow at the time the sample was collected also were included in the combined data set. Drainage areas and upstream land uses were determined for selected sites (table 20, end of report). About a third of the existing nutrient and suspended-sediment data for the Central Columbia Plateau study unit do not have streamflow at time of sampling (instantaneous or daily-mean discharge). Knowledge of the streamflows when samples were collected improves assessment of water-quality trends and is needed to estimate constituent loads.

Classification of Sites

For the purposes of this report, each of the 105 sites in the study unit was assigned a site classification based on the predominant water source and land use upstream of the sampling location (table 20, end of report). In the Quincy-Pasco subunit, the predominant water sources and land uses for most of the sites fell into one of three categories. Sixteen sites were classified as "irrigation delivery water (canals)," which generally is water diverted from one of the reservoirs in the irrigation project; 52 sites were classified as "irrigation wasteways," which, depending on the wasteway and the season, carry substantial quantities of excess delivery water and lesser quantities of irrigation return flows and ground-water seepage; and 17 sites were classified as "surface irrigation drains," which carry surface runoff, subsurface drainage, ground-water seepage, and smaller quantities of unused delivery water. Surface irrigation drains usually discharge into irrigation wasteways. Most of the sites in the Quincy-Pasco subunit are classified as irrigation wasteways. The sites among these three classifications include both natural and artificial channels, some of which are concrete-lined. One site in the Quincy-Pasco subunit and two sites in the North-Central subunit are in natural channels that are not affected by irrigation practices; these three sites were classified as "natural flow."

Sampling locations in the Palouse subunit, all of which are in natural channels, were classified according to somewhat different criteria. The uppermost site in the forested region of this subunit was classified as the "headwaters" of the Palouse River. Seven sites on Paradise Creek and the South Fork Palouse River that are known to be affected by point-source discharges (see "Sources of Nutrients, Suspended Sediment, and Pesticides" and "Loads of Nutrients and Suspended Sediment" sections) were classified as "STP-affected tributaries" of the Palouse River. The other nine sites in this subunit were classified as "main channel" of the Palouse River.

The site classifications used for the analyses in this report reflect the effects of most of the major water- and land-use classifications in the study unit (fig. 4, table 20, end of report). The headwaters site of the Palouse River drains forested land. All of the remaining sites in the Palouse subunit drain dry-farmed areas, and the STP-affected tributaries are additionally affected by urban activities. The natural flow sites generally drain barren and range lands and dry-farmed lands. The artificially controlled hydrology of the irrigation system makes the

Table 9.--*Water-quality constituents used to represent nutrients and suspended sediment in this report*

[N, nitrogen; NO_3, nitrate; NO_2, nitrite; NH_4, ammonia; P, phosphorus; PO_4, phosphate. Kjeldahl is total ammonia plus total organic nitrogen. All nutrient parameters are converted to as N or as P before calculations. All parameters are reported as milligrams per liter (mg/L)]

	Reported, calculated, or substituted water-quality constituents, in order of preference for comparative analysis in this report
Nitrate	Dissolved nitrate as N or as NO_3 converted to N
	(Dissolved nitrate plus nitrite as N) - (Dissolved nitrite as N or as NO_2 converted to N)
	Dissolved nitrate plus nitrite as N
	Total nitrate as N
	(Total nitrate plus nitrite as N) - (Total nitrite as N)
	Total nitrate plus nitrite as N
Total nitrogen	Total nitrogen as N or as NO_3 converted to N
	(Total nitrate plus nitrite as N) + (Total Kjeldahl as N)
	(Dissolved nitrate plus nitrite as N) + (Total Kjeldahl as N)
	(Total nitrate as N) + (Total Kjeldahl as N)
	(Dissolved nitrate as N) + (Total Kjeldahl as N)
Ammonia	Dissolved ammonia as N or as NH_4 converted to N
	Total ammonia as N or as NH_4 converted to N
Total phosphorus	Total phosphorus as P or as PO_4 converted to P
Orthophosphate	Dissolved orthophosphate as P or as PO_4 converted to P
Suspended sediment	Suspended sediment
Suspended solids	Suspended solids at 105 degrees centigrade
	Suspended solids at 110 degrees centigrade

effects of individual water and land uses in the Quincy-Pasco subunit more difficult to identify clearly. The sites classified as irrigation delivery water (canals) serve as reference sites for water quality in this part of the study unit. Both irrigation wasteways and surface irrigation drains indicate water quality in irrigated farm lands. Because irrigation wasteways generally are diluted with larger quantities of unused irrigation water, the surface irrigation drains probably provide the best indication of the land-use effects of surface-water-irrigated farming on water quality.

Distribution of the Available Data

The collation and screening of available water-quality data resulted in a combined data file consisting of more than 56,000 determinations of nutrient, suspended-sediment, and pesticide concentrations for 105 sites in the Central Columbia Plateau study unit. A summary of the numbers of samples and determinations of constituents is shown in table 21 at the end of the report. These data were collected mostly during the years from 1959 through 1991. Nutrient data for a few samples collected in 1992 are included because determinations for pesticides were made for those samples (the pesticide concentration data for these sites were still in review and subject to revisions; therefore they were not included in this report). Additional data collected during this period but not yet available in the WATSTORE and STORET data bases, along with data collected in the future, will continue to be added to the data bases as part of the NAWQA.

The number of determinations of constituents and the number of samples collected by subunit, by month, and by site classification are shown in figure 16. Most of the data in the study unit were collected during the months from April through October, and at sites classified as surface irrigation drains. Most of the water-quality data for the study unit are for sampling locations in the Quincy-Pasco subunit, and most of the additional data are for the Palouse subunit.

Concentration data for nitrate, orthophosphate, total phosphorus, and to a lesser degree, total nitrogen are available for most sites in the study unit. Data for dissolved ammonia concentrations are available for most sampling locations in the Quincy-Pasco subunit; total ammonia concentration data are available for most of the sites in the Palouse subunit and a few sites in the Quincy-Pasco subunit. With some exceptions, most of the available suspended-solids data are for sites in the Quincy-Pasco subunit, and most of the suspended-sediment data are for sites in the Palouse subunit. The suspended-sediment data and locations for several sites in the Palouse subunit are not included in this report except as discussed in the "Loads of Nutrients and Suspended Sediment" section in this report (these data were collected mostly during storms, for a study in the 1960's; no nutrient concentrations were determined). Figure 17 shows the locations of the sampling sites for nutrients, suspended sediment, pesticides, and streamflow that were included in this report. Table 21 (end of report) lists the total number of samples collected and the number of determinations of the nutrient, suspended-sediment, pesticide, and streamflow constituents at each of these sites. Most of the sites with 100 or more observations are located in the Quincy-Pasco subunit. Only one sampling location in the Palouse subunit (the Palouse River at Hooper, site 90, fig. 17c) has 100 or more observations. Most of the pesticide data are for sampling locations in the Quincy-Pasco subunit; there are no pesticide data available for the North-Central subunit.

Most of the water-quality data for the Central Columbia Plateau study unit were collected during the 1970's in the Quincy-Pasco subunit. Only six sites have long-term data for many of the constituents (see "Trends..." in the "Concentrations of Nutrients and Suspended Sediment" section). The data included in this report were collected at frequencies ranging from daily to biannual sampling. Data for all of the sites included determinations made for samples collected during more than one season of the year. Most of the nutrient and sediment samples collected in the Quincy-Pasco subunit were collected during irrigation season; a few samples have been collected at many sites during only 1 or 2 months outside of the irrigation season. The relative lack of information outside of the irrigation season is the most obvious seasonal gap in the existing data. Sample collection for pesticide determinations in the Quincy-Pasco subunit has been distributed throughout the year; in the Palouse subunit, only 12 pesticide samples have been collected, during only a few months of the year. (See table 21, end of report, for a list of the periods of records and frequencies of sampling for each of the sites included in the analyses.)

The number of samples collected for determinations of nutrient and sediment concentrations throughout the flow regime, based on the periods of record at six long-term sampling locations in the study unit, is shown in figure 18. These are the sites in the study unit with at least 10 years of streamflow data available for determination of deciles of daily mean discharge. Deciles of daily mean discharge describe the observed frequency of the range of streamflow measured at a site. The first decile of flow includes the lowest streamflows, which are exceeded 90 percent of the time, and the last decile represents the

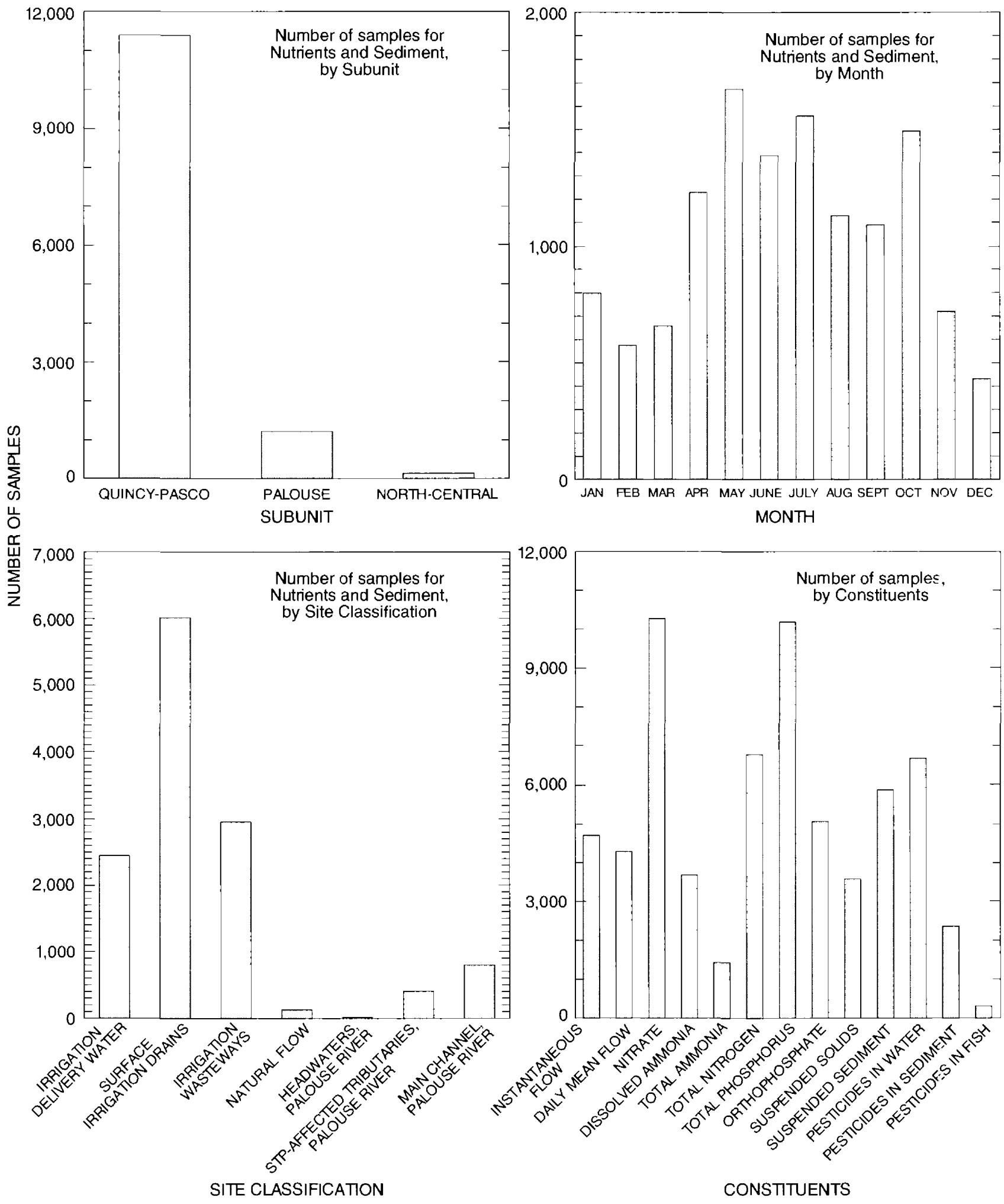
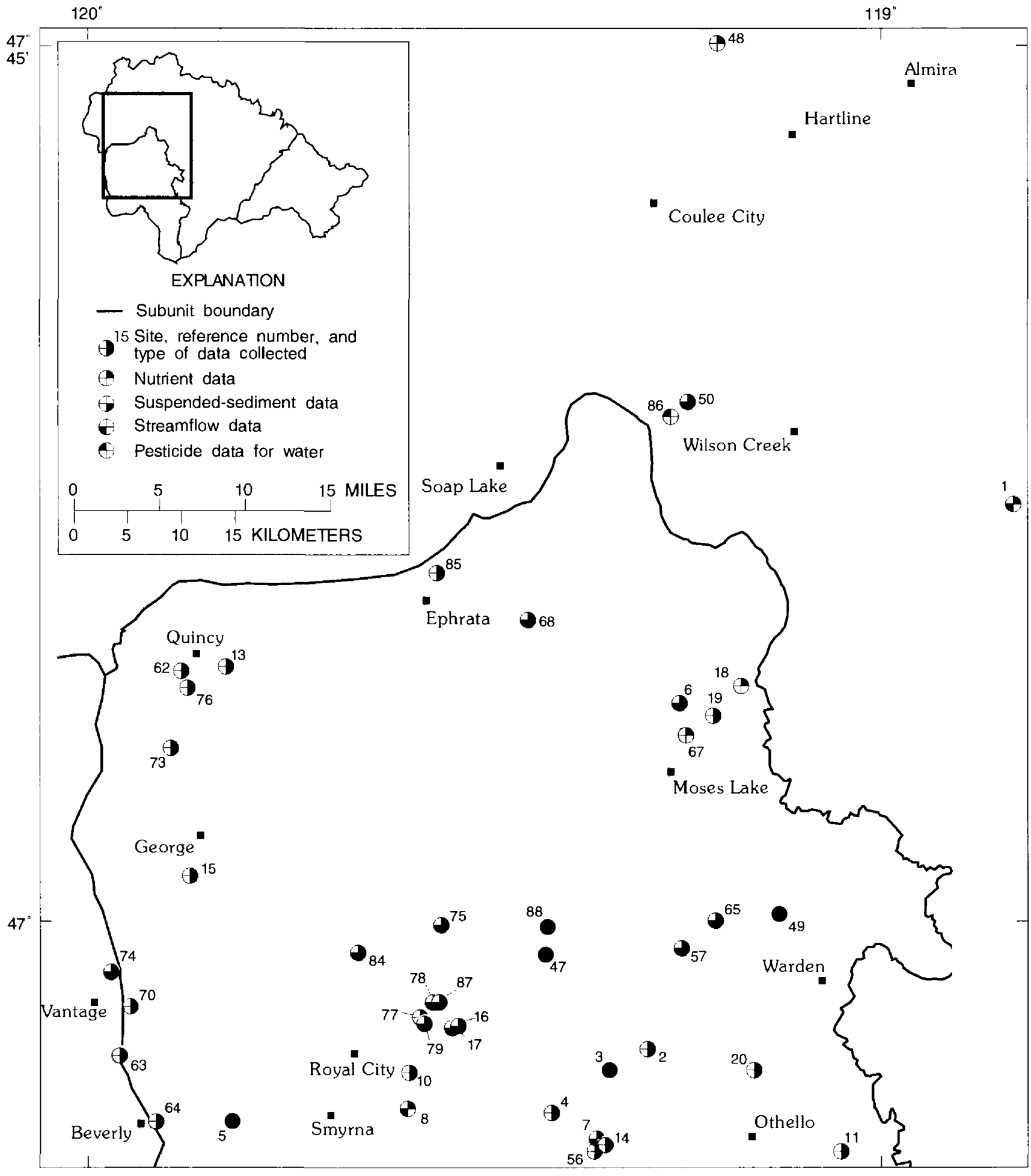
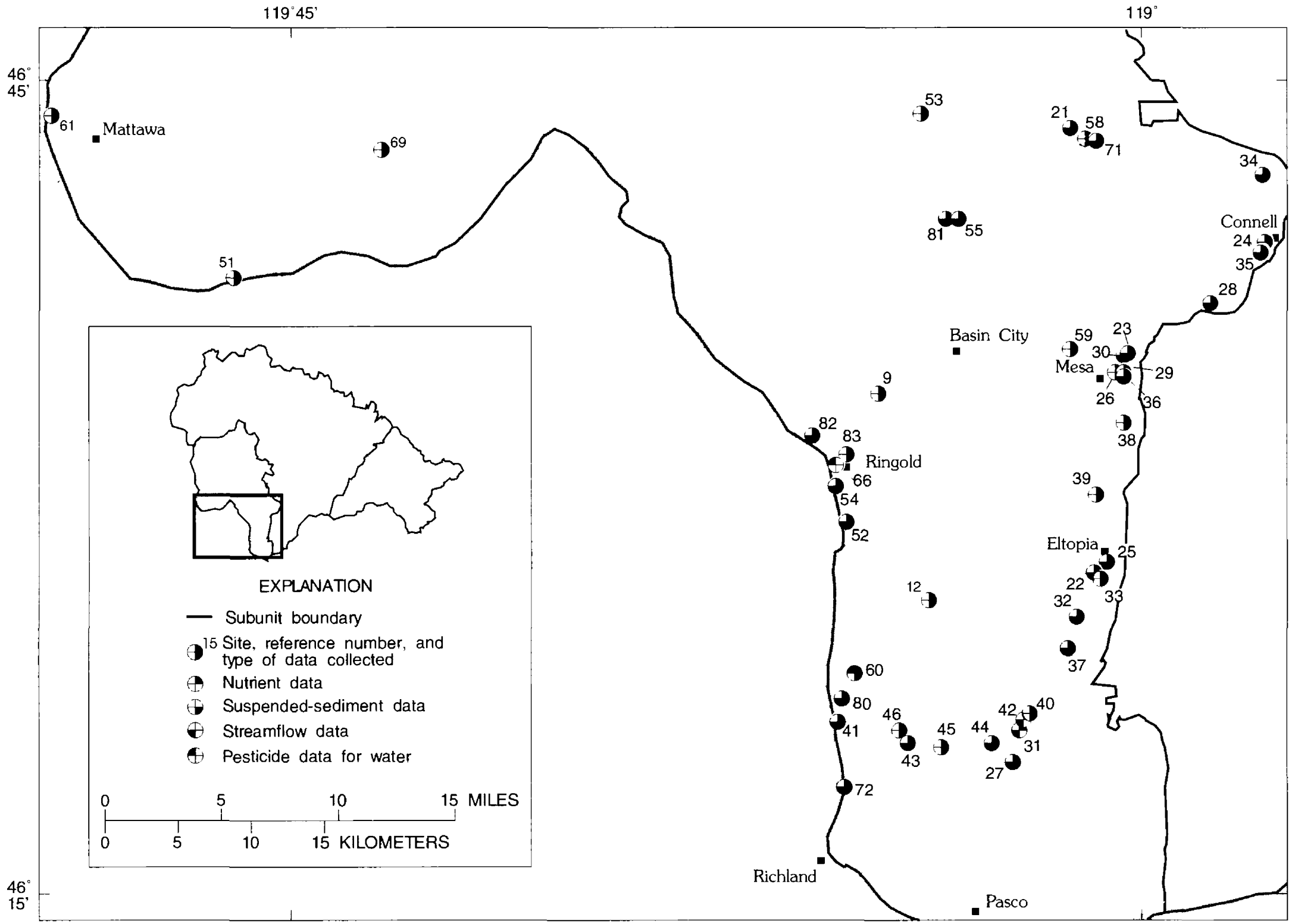


Figure 16.--Number of samples collected for measurements of nutrient and suspended-sediment concentrations by subunit, by month, and by site classification; and the number of measurements of flow and determinations of nutrient, suspended-sediment, and pesticide concentrations for all sites in the study unit.



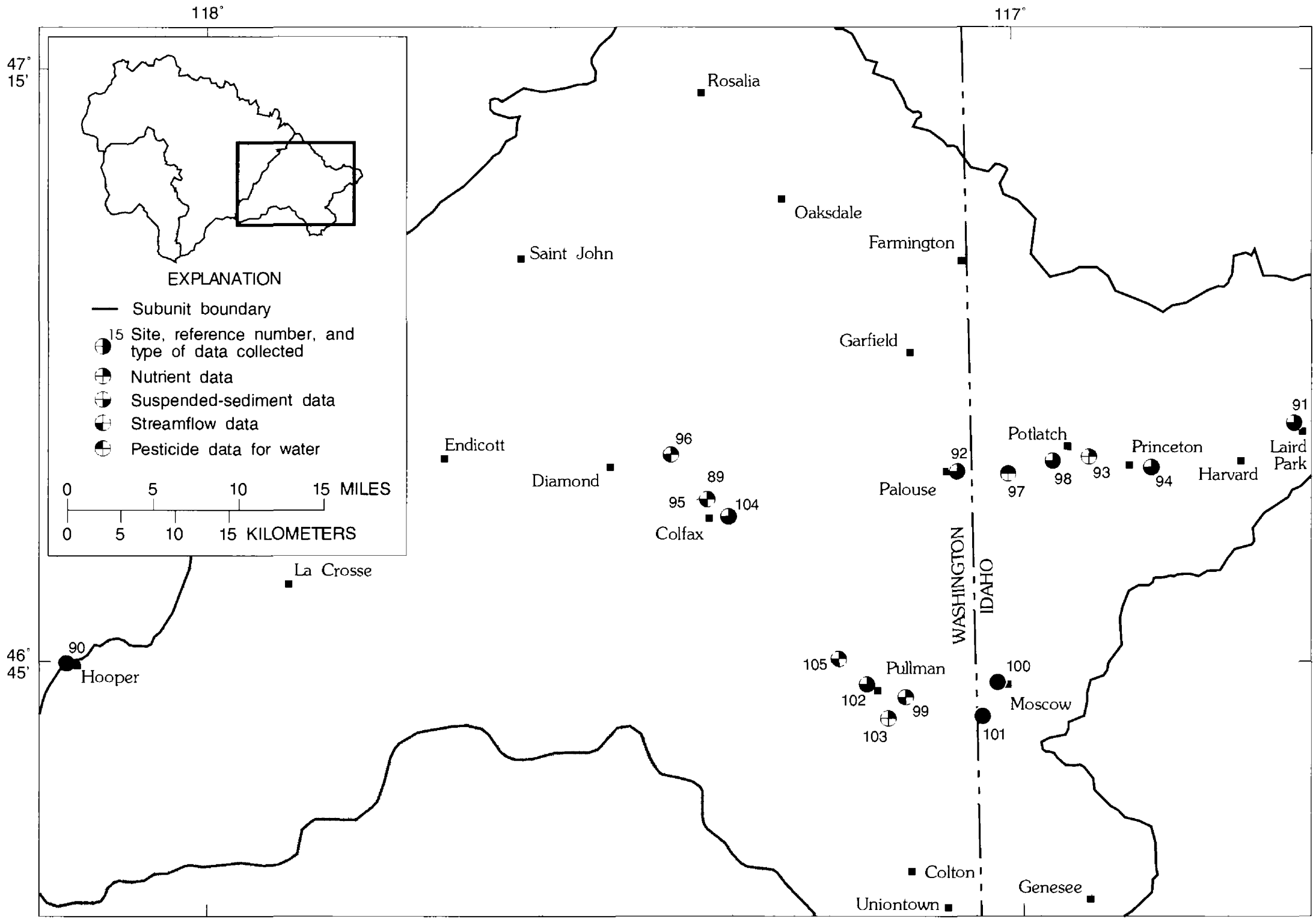
(a) Sites in the North-Central and northern Quincy-Pasco subunits

Figure 17.--Surface-water sites with suspended-sediment, nutrient, streamflow, and pesticide data in (a) the North-Central and northern Quincy-Pasco subunits; (b) the southern Quincy-Pasco subunit: and (c) the Palouse subunit.



(b) Sites in the southern Quincy-Pasco subunit

Figure 17.--Continued



(c) Sites in the Palouse subunit

Figure 17.--Continued

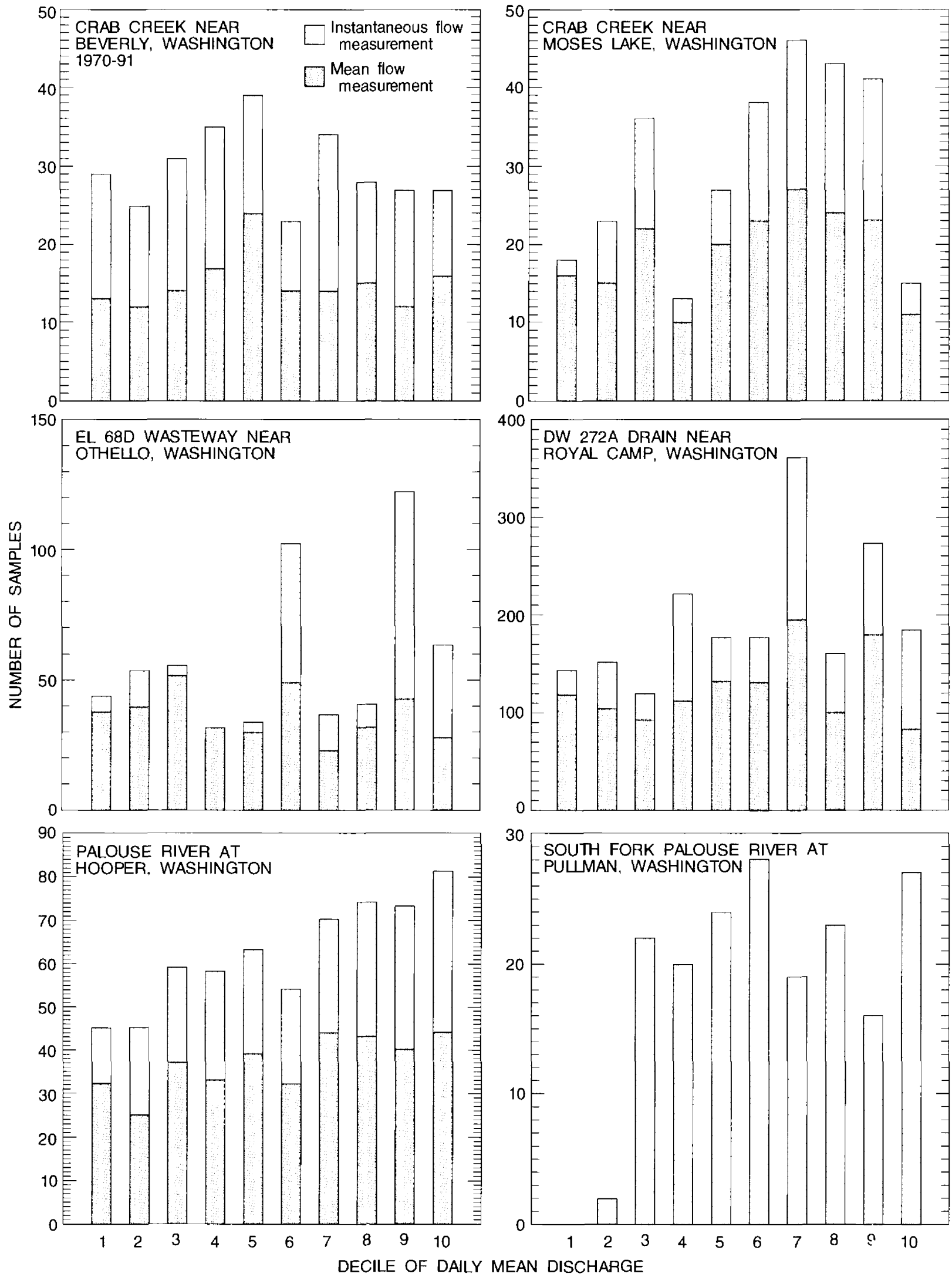


Figure 18.--Number of samples collected for determination of nutrient and sediment concentrations at six sites in the Central Columbia Plateau study unit, by decile of flow.

highest (unexceeded) 10 percent of streamflows at the site. The sampling distribution for Crab Creek near Beverly (fig. 18) reflects only those samples collected from 1970 on, because streamflow at this site was increasing until about 1970 (see fig. 9 and "Surface-Water Hydrology" in the "Description of the Central Columbia Plateau Study Unit" section) and many of the samples collected during this period would be considered to have been collected during the low end of the flow regime. Overall, there appears to be a good distribution of water-quality sampling throughout the flow regime at these sites, with the exception of the South Fork Palouse River at Pullman, Wash. (fig. 18), a perennial stream, where no nutrient or sediment data are available for the lowest 10 percent of streamflows known to occur at that site.

CONCENTRATIONS OF NUTRIENTS AND SUSPENDED SEDIMENT

The basis for a conceptual model of water quality in the Central Columbia Plateau study unit depends largely on information about spatial and temporal (especially seasonal) variability in concentrations of constituents in the study unit, and about the natural and human factors that might affect concentrations. For the purposes of these analyses, each of the 105 sites was assigned to 1 of 7 site classifications (table 20, end of report), as discussed in "Classification of Sites" in the "Description and Qualification of Data" section. This section presents the spatial ranges in concentrations of nutrients and suspended sediment found in the study unit and discusses some explanation for the variations identified among sites or groups of sites. Much of the data presented in this section is for samples collected using grab techniques (see "Data Sources and Methods of Collection and Analysis" in the "Description and Qualification of Data" section). Also presented and discussed are seasonal variations in constituent concentrations across the study unit, some concentration-streamflow relations, and temporal trends at several sites.

Sites With Elevated Concentrations

The ranges of concentrations observed for nutrient and suspended-sediment constituents are shown in table 10. The minimum, median, and maximum concentrations of these constituents for all sampling locations in the study unit are shown in table 22 at the end of the report. The U.S. Environmental Protection Agency's maximum contaminant level (MCL) of 10 mg/L as N for nitrate concentrations in drinking water was exceeded at 15 sites in the study unit. These sites include six of the seven sampling locations on the South Fork Palouse River and Paradise Creek in the Palouse subunit; the other nine are

Table 10.--*Ranges of concentrations of nutrients and suspended sediment for all observations in the Central Columbia Plateau study unit*

[All nitrogen constituents are as nitrogen and all phosphorus constituents are as phosphorus. <, less than. One percent of the data are concentrations higher than the 99th percentile]

Constituent	Number of observations	Number of sites	Concentration, in milligrams per liter				Number of sites exceeding 99th percentile
			Minimum	Median	99th percentile	Maximum	
Nitrate	10,277	103	<0.01	1.98	9.7	21.2	15
Total nitrogen	6,779	59	0.07	2.90	11.5	33.3	10
Total phosphorus	10,192	100	<0.01	0.09	3.5	26.0	11
Orthophosphate	5,099	97	<0.01	0.04	4.6	24.4	7
Ammonia, total	1,434	26	<0.01	0.09	2.7	14.0	4
Ammonia, dissolved	3,689	79	<0.01	0.03	4.2	21.8	2
Suspended solids	3,589	77	<1	19	790	13,100	16
Suspended sediment	5,881	15	<1	49	2,650	17,200	8

agricultural surface drains and irrigation wasteways in the Quincy-Pasco subunit. No sites in the study unit had median nitrate concentrations exceeding the MCL for drinking water. Crab Creek Lateral Wasteway in Unit 88 of Block 88 near Othello, Wash., (site 4, fig. 17a) had the highest median concentration of nitrate in the study unit, at 9.6 mg/L. Paradise Creek at Pullman, Wash., (site 99, fig. 17c) and DE 14-179 drain near Othello (site 11, fig. 17a) had a median nitrate concentration of 8.0 mg/L.

The highest concentrations of ammonia in the study unit (21.8 mg/L and 19.4 mg/L) occurred in the Quincy-Pasco subunit at W 645W at R-NW Road near Quincy, Wash. (site 76, fig. 17a), which is affected by effluent from a food processing plant, and at Esquatzel Coulee Wasteway at bridge west of Connell, Wash. (site 24, fig. 17b), which is downstream from livestock feedlots. Median concentrations of ammonia at these two sites were 3.6 mg/L and 0.09 mg/L, respectively. In the Palouse subunit, the highest maximum and median concentrations of ammonia (14.0 mg/L and 1.2 mg/L) were at the South Fork Palouse River near Pullman, Wash. (site 105, fig. 17c), a site affected by discharges from STPs. Only four of the sites in the Palouse subunit had median ammonia concentrations less than 0.10 mg/L; these four sites are in the headwaters of the Palouse River. The USEPA's ambient water-quality criteria for ammonia are based on the pH and temperature of the surface water at the time of sampling. These relations were investigated for two sites in the study unit, Crab Creek near Beverly, Wash. (site 5, fig. 17a) and Palouse River at Hooper, Wash. (site 90, fig. 17c), and the criteria were not exceeded at either site.

Water-quality criteria for total nitrogen and total phosphorus have not been set by the USEPA; however, elevated concentrations of these nutrients can be indicators of eutrophication in surface waters. The highest concentrations of total nitrogen in the study unit (33.3 mg/L, 29 mg/L, and 22 mg/L) were detected at W 645W at R-NW Road near Quincy (site 76, fig. 17a) and DW 272 A1 and A drains from block 86 near Royal Camp (sites 17 and 16, fig. 17a) in the Quincy-Pasco subunit. The highest total-nitrogen concentrations in the Palouse subunit (20.0 mg/L and 19.0 mg/L) were detected at South Fork Palouse River at the Idaho-Washington State line (site 101, fig. 17c) and at Paradise Creek at the USGS gaging station near Moscow (site 100, fig. 17c). The highest concentrations of total phosphorus in the Quincy-Pasco subunit (26.0 mg/L and 11.3 mg/L) were detected at W 645W at R-NW Road near Quincy (site 76, fig. 17a) and Esquatzel Coulee Wasteway at bridge west of Connell (site 24, fig. 17b), which are the same two sites with the highest concentrations of ammonia. The highest concentrations of total phosphorus in the Palouse subunit (5.3 mg/L to 10.0 mg/L) occurred at five sites on the South Fork Palouse River and on Paradise Creek, all known to be affected by discharges from STPs.

Water-quality criteria for suspended sediment in natural waters have not been established, but many studies have shown that elevated suspended-sediment concentrations affect fish habitat (U.S. Environmental Protection Agency, 1987). Suspended-sediment concentrations of 17,200 mg/L, 15,300 mg/L, and 12,200 mg/L were detected in the Palouse subunit at South Fork Palouse River near Colfax (site 104, fig. 17c), Palouse River at Hooper (site 90, fig. 17c), and South Fork Palouse River at Pullman (site 102, fig. 17c); even higher concentrations of suspended sediment were observed during a study of sediment transport in the Palouse River Basin during the 1960's (Boucher, 1970); these data were not entered into the computer data base and are discussed only in the "Loads of Nutrients and Suspended Sediment" section of this report. Suspended-sediment concentrations of 10,500 mg/L and 5,980 mg/L were detected in the Quincy-Pasco subunit in the DW 272 A and A1 drains from block 86 near Royal Camp (sites 16 and 17, fig. 17a). Suspended-solids concentrations of 13,100 mg/L, 12,490 mg/L, and 6,880 mg/L were detected in the Palouse River at Hooper, Old PE 64 Wasteway at the Columbia River near Ringold, and Esquatzel Coulee below PE 38 Wasteway at Mesa (sites 90, 52, and 36, fig. 17).

Spatial Variations in Concentrations

Most irrigation delivery water in the Quincy-Pasco subunit comes from the Columbia River and has dilute concentrations of nutrients and suspended sediment; the median concentrations of total nitrogen and total phosphorus for all sites classified as irrigation delivery water were 0.35 mg/L and 0.04 mg/L, respectively, and the median concentration of suspended solids was 11 mg/L. The Main Canal at Pinto Dam near Wilson Creek, (site 50, fig. 17a) provides the best probable background concentrations for this part of the study unit: median concentrations at this site were 0.03 mg/L for nitrate, 0.04 mg/L for total phosphorus, and 3 mg/L for suspended solids (table 22, end of report). Water in other canals in the system is affected to varying degrees by return flows from wasteways and fields. Potholes East Canal delivers irrigation water that comes from Potholes Reservoir, which receives irrigation delivery water and return flows; median concentrations at the Potholes Canal headworks (site 57, fig. 17a) were 0.8 mg/L for nitrate, 0.05 mg/L for total phosphorus,

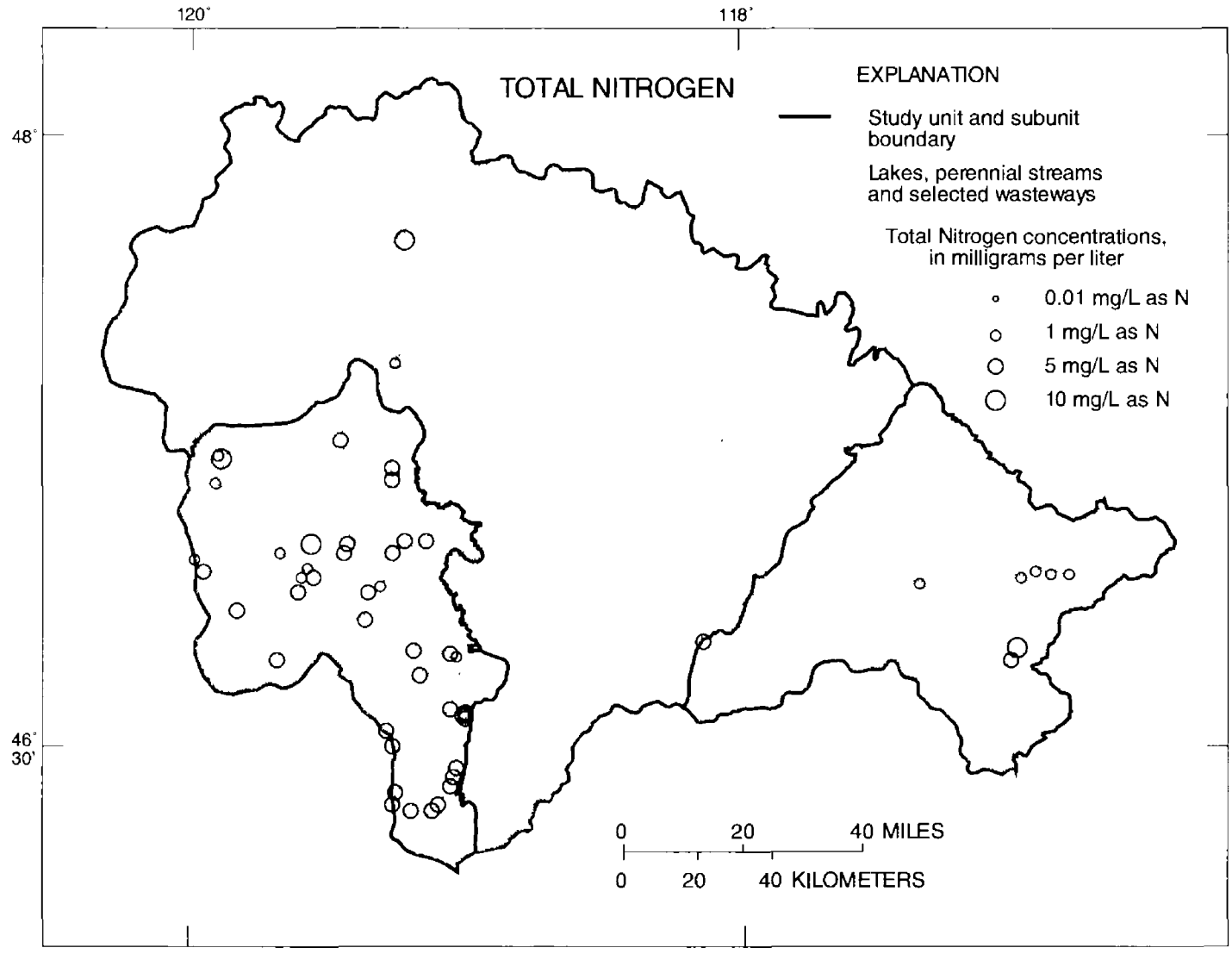
and 8 mg/L for suspended solids (table 22, end of report). The median nitrate concentration in the headwaters of the Palouse River at Laird Park near Harvard, Idaho (site 91, fig. 17c), a forested site in the mountains northeast of Moscow, Idaho, was 0.02 mg/L (table 22, end of report).

Suspended-sediment concentrations in the study unit ranged from less than 1 mg/L to 17,200 mg/L (table 10); higher concentrations of suspended sediment were observed during a study of sediment transport in the Palouse River Basin during the 1960's (Boucher, 1970), but these data were not entered into the computer data base and are discussed only in the "Loads of Nutrients and Suspended Sediment" section of this report (no nutrient data were collected during that study). Concentrations of suspended solids ranged from less than 1 mg/L to 13,100 mg/L. The lowest concentrations of suspended sediment in the Central Columbia Plateau study unit occurred in irrigation delivery waters in the Quincy-Pasco subunit. The lowest concentrations of suspended solids occurred at sampling locations in the upper reaches of the Palouse River and at many different sites in the Quincy-Pasco subunit (table 22, end of report). The highest concentrations of suspended sediment occurred in the Palouse subunit. The highest concentrations of suspended solids in the study unit occurred in the Palouse subunit and in irrigation wasteways in the Quincy-Pasco subunit.

Median concentrations of nitrate and ammonia generally vary little throughout the study unit (fig. 19); however median nitrate concentrations increase moving downstream in the irrigation system and along the main channel of the Palouse River (fig. 20). One site in the northwest of the Quincy-Pasco subunit, W 645W at R-NW Road near Quincy, Wash. (site 76, fig. 17a), had among the highest median concentrations of ammonia, total nitrogen, total phosphorus, and orthophosphate in the entire study unit. This site is affected by effluent from a food-processing plant. The median total phosphorus concentration at this site was 4.1 mg/L of phosphorus. Median concentrations of total phosphorus and orthophosphate in the Palouse subunit also were higher along the STP-affected South Fork Palouse River and Paradise Creek than in the rest of the subunit; the median total- phosphorus concentration at Paradise Creek at Pullman was 3.1 mg/L. The highest median concentrations of suspended sediment in the study unit occurred in the Palouse subunit.

In both the Quincy-Pasco and Palouse subunits, nutrient concentrations generally increase in the downstream direction as a result of increasing contributions from agricultural runoff and ground-water seepage. Concentrations of nitrate by month for the periods of record at four sites in the Columbia Basin Irrigation Project and four sites along the Palouse River are shown in figure 20. Nitrate concentrations are dilute in the Main Canal (site 50, fig. 17a), which provides the water supply for the irrigation project. This water passes through agricultural lands, in channels that are continually receiving runoff from agricultural lands as well as excess irrigation delivery water. As shown in figure 20, nitrate concentrations in Frenchman Hills Wasteway (site 47, fig. 17a) above Potholes Reservoir are higher than nitrate concentrations in the Main Canal. Nitrate concentrations at the headworks of Potholes Canal (site 57, fig. 17a) below the reservoir are lower than concentrations above the reservoir, probably due to both dilution and retention of nutrients in the reservoir. Nitrate concentrations are higher again where PE 16.4 Wasteway enters the Columbia River (site 54, fig. 17b). This sequence of water-quality evolution reflects the way that concentrations fluctuate throughout the irrigation project as drains and wasteways alternately receive agricultural runoff and excess delivery water, and also pass through reservoirs. Nitrate concentrations alternately increase and decrease along Esquatzel Coulee Wasteway (fig. 17; table 22, end of report) as varying proportions of agricultural runoff and unused delivery water are intermittently discharged to the wasteway.

Concentrations of nitrate along the main channel of the Palouse River are not subject to similar mitigating effects of dilution and retention in reservoirs, nor are they affected by irrigation practices. Concentrations at sampling locations along the main channel of the Palouse River would be expected to increase downstream because of agricultural activities. Increased streamflow and biological assimilation would be expected to reduce the concentrations of nutrients contributed by the STPs in the basin (some effects of STP nutrient loading are discussed in the "Loads of Nutrients and Suspended Sediment" section). As shown in figure 20, concentrations of nitrate are dilute in the forested headwaters of the Palouse River at Laird Park near Harvard, Idaho (site 91, fig. 17c). Nitrate concentrations are higher downstream, especially during higher winter streamflows at Palouse, Wash. (site 92, fig. 17c), where storms may flush accumulated nutrients from agricultural lands. Nitrate concentrations continue to increase further downstream at Colfax, Wash. (site 89, fig. 17c) and again at Hooper, Wash. (site 90, fig. 17c), where the Palouse River drains a greater percentage of farm lands and also is affected by STP effluent.



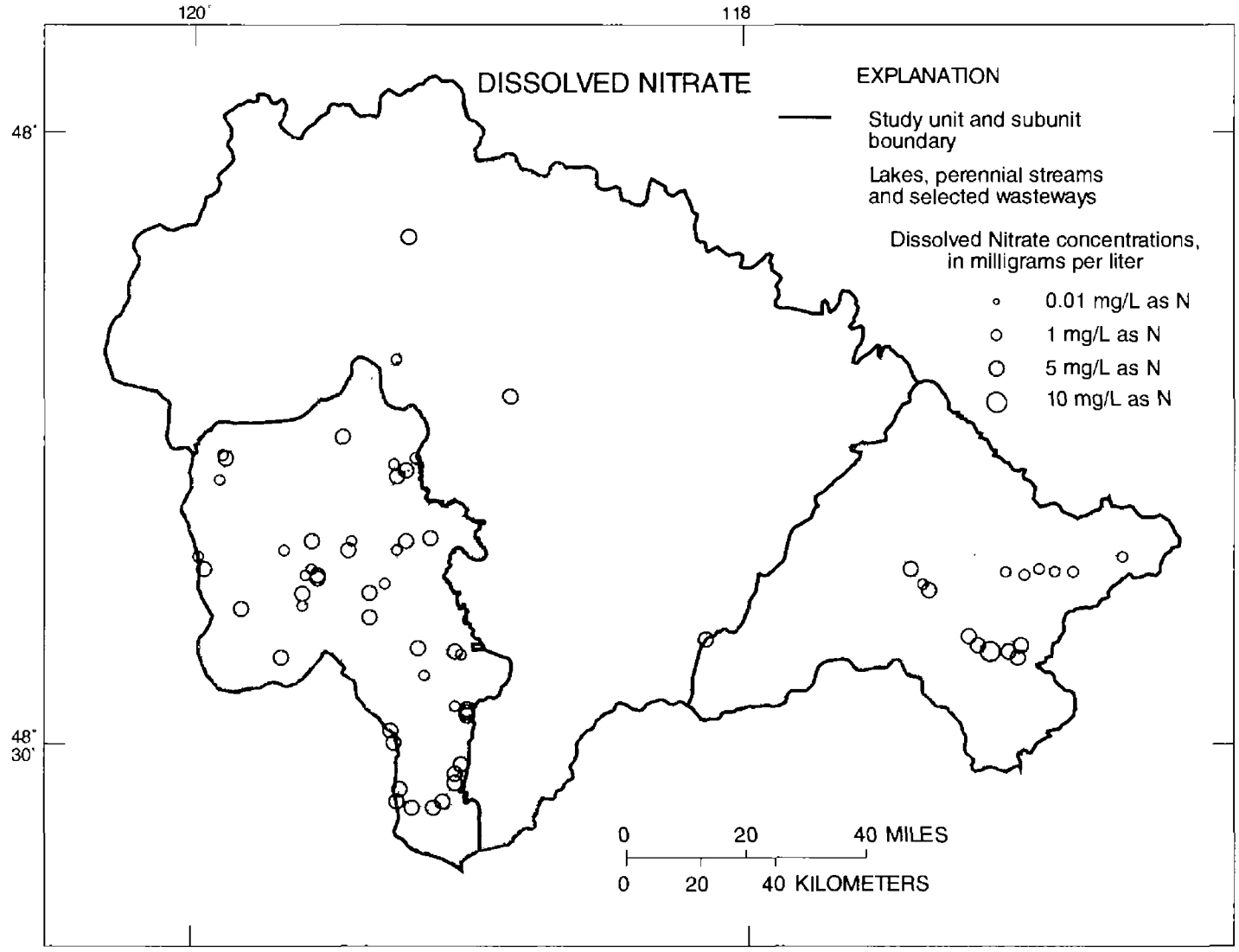
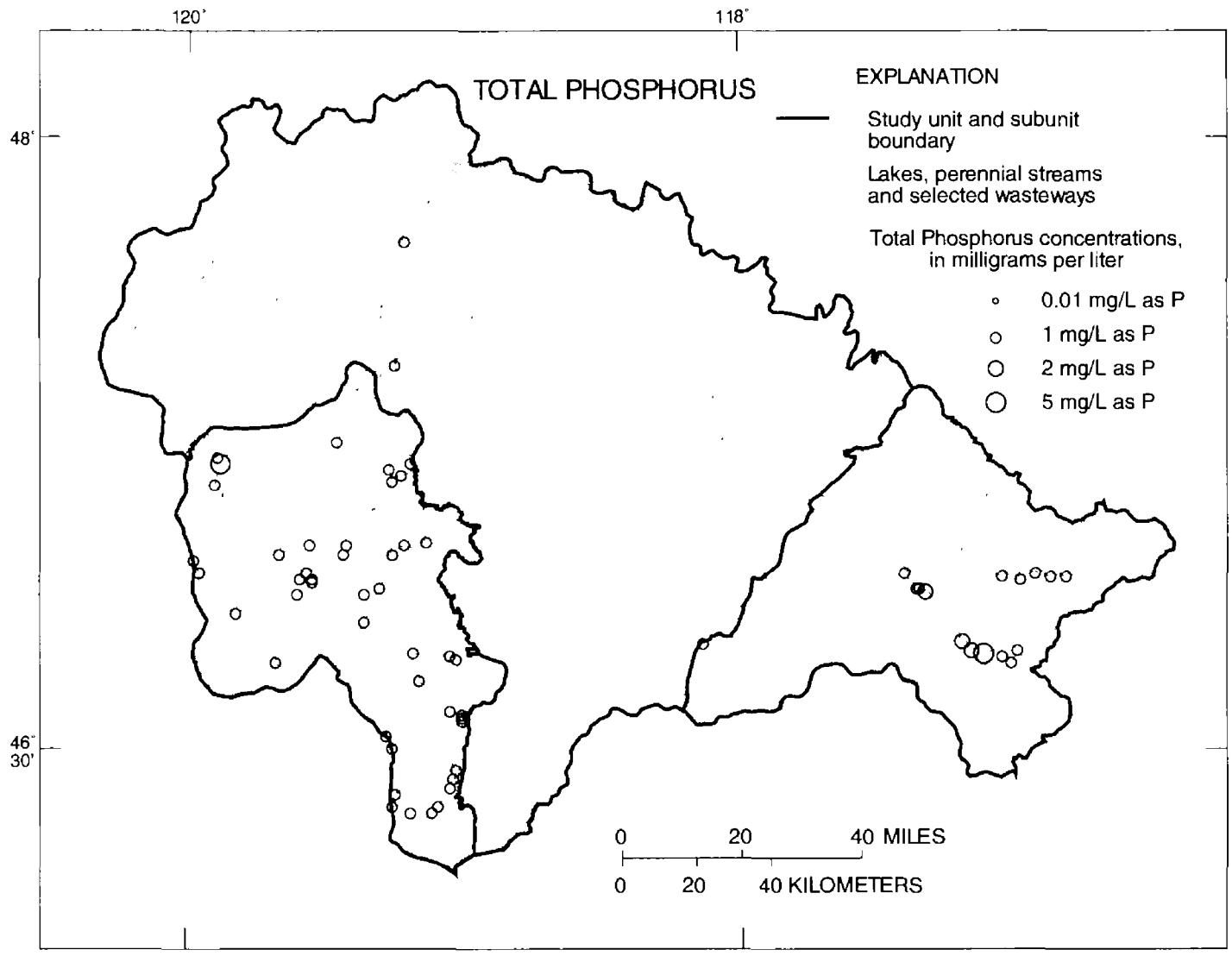


Figure 19.–Median concentrations of nutrients and suspended sediment in the Central Columbia Plateau study unit.



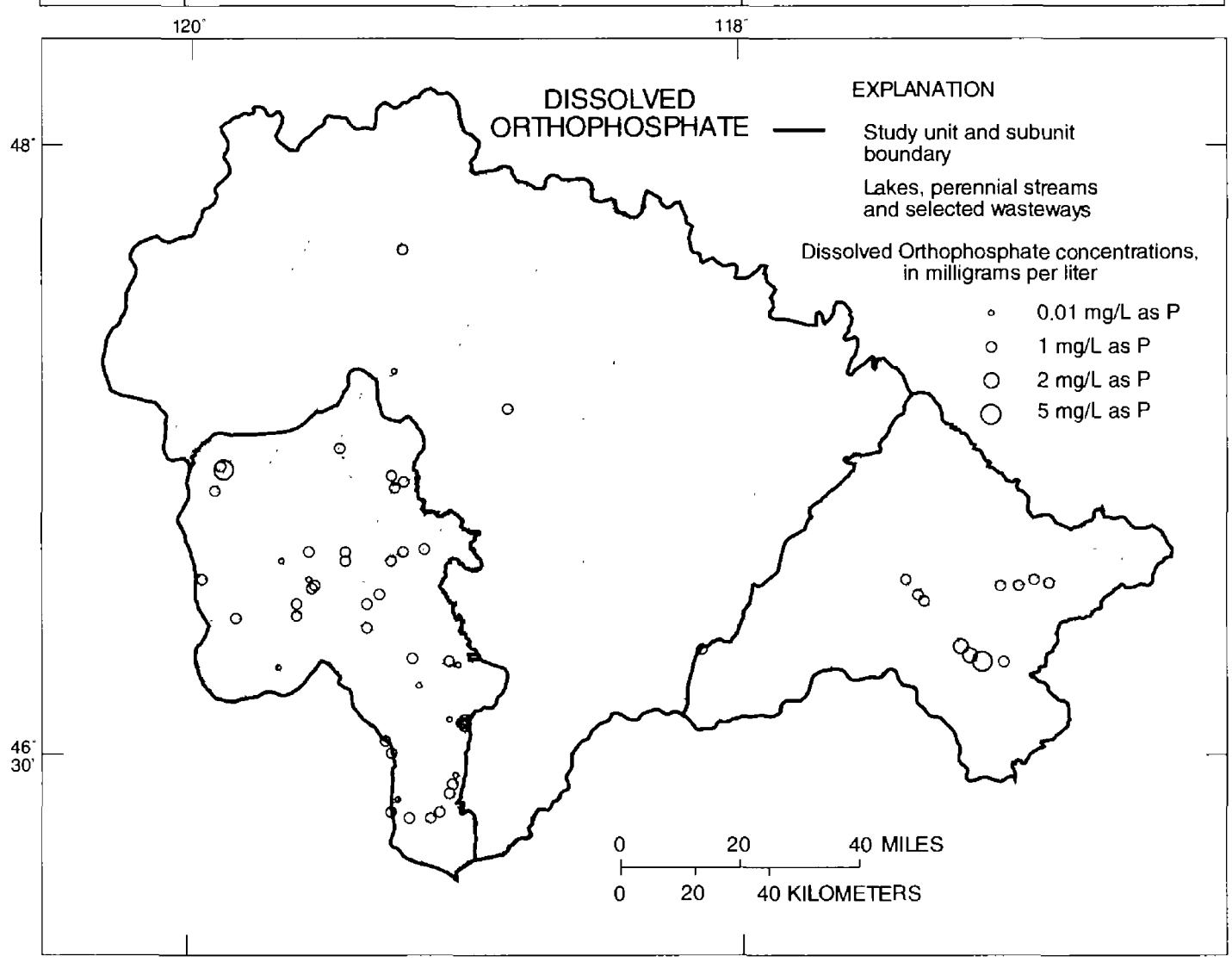
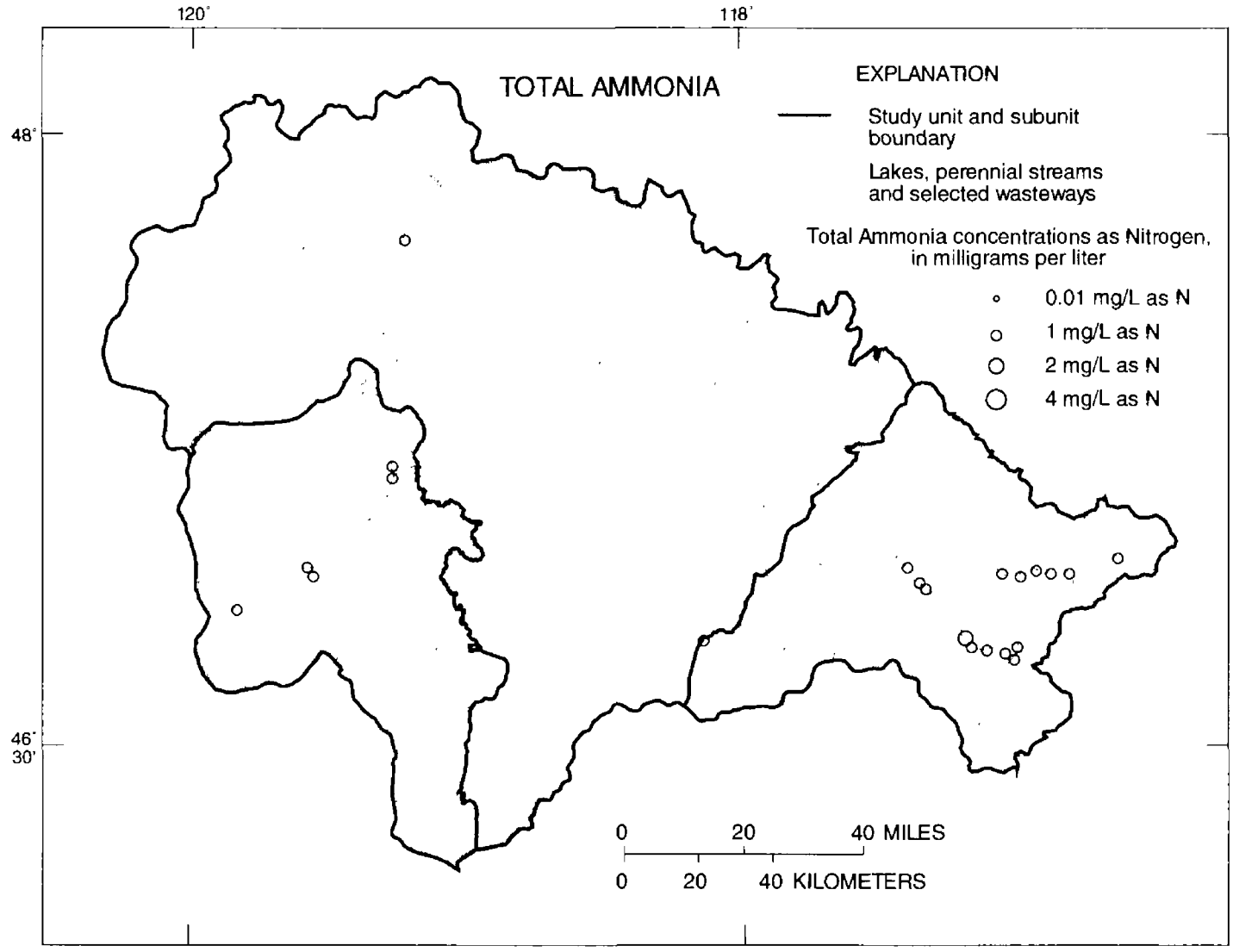


Figure 19.--Continued



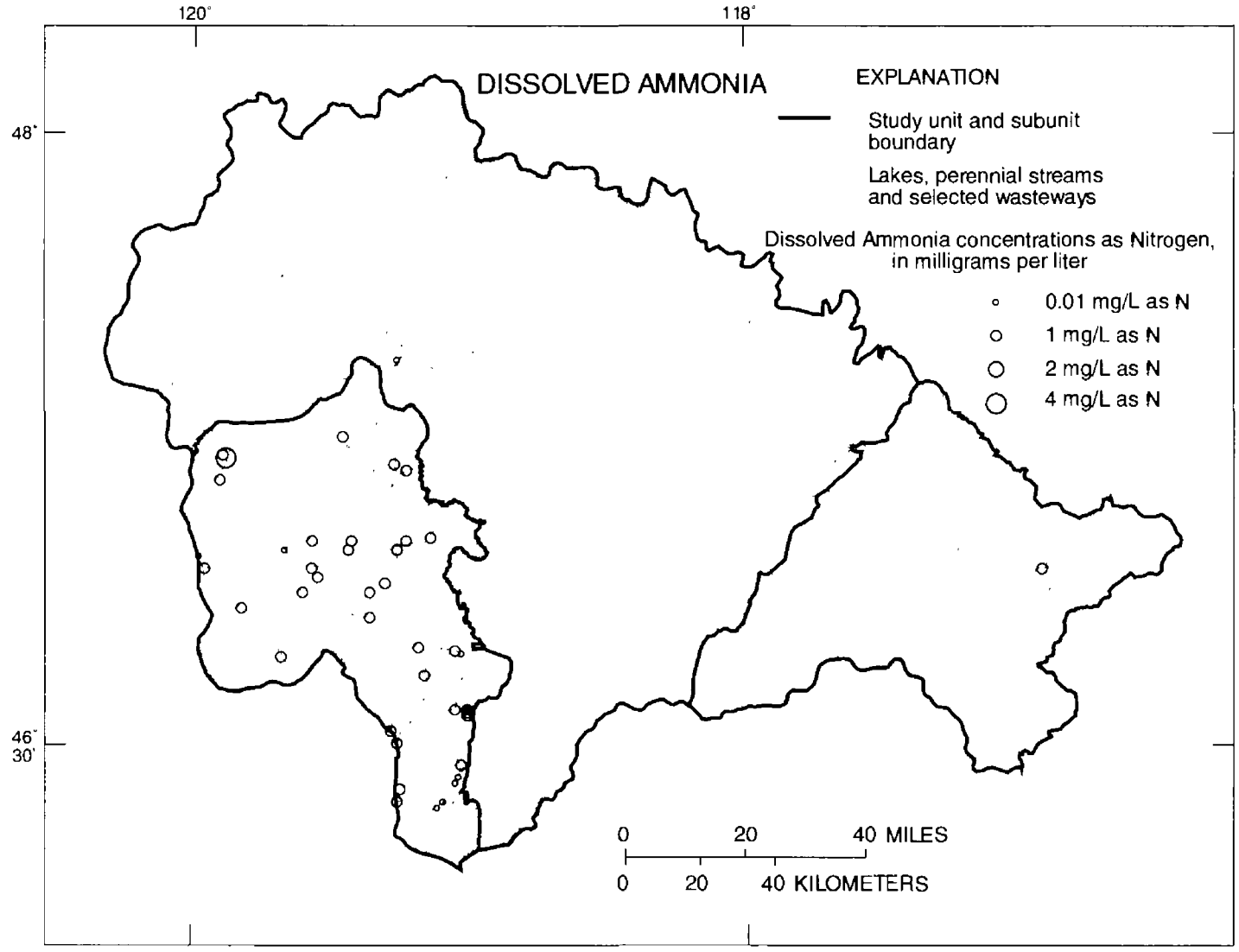
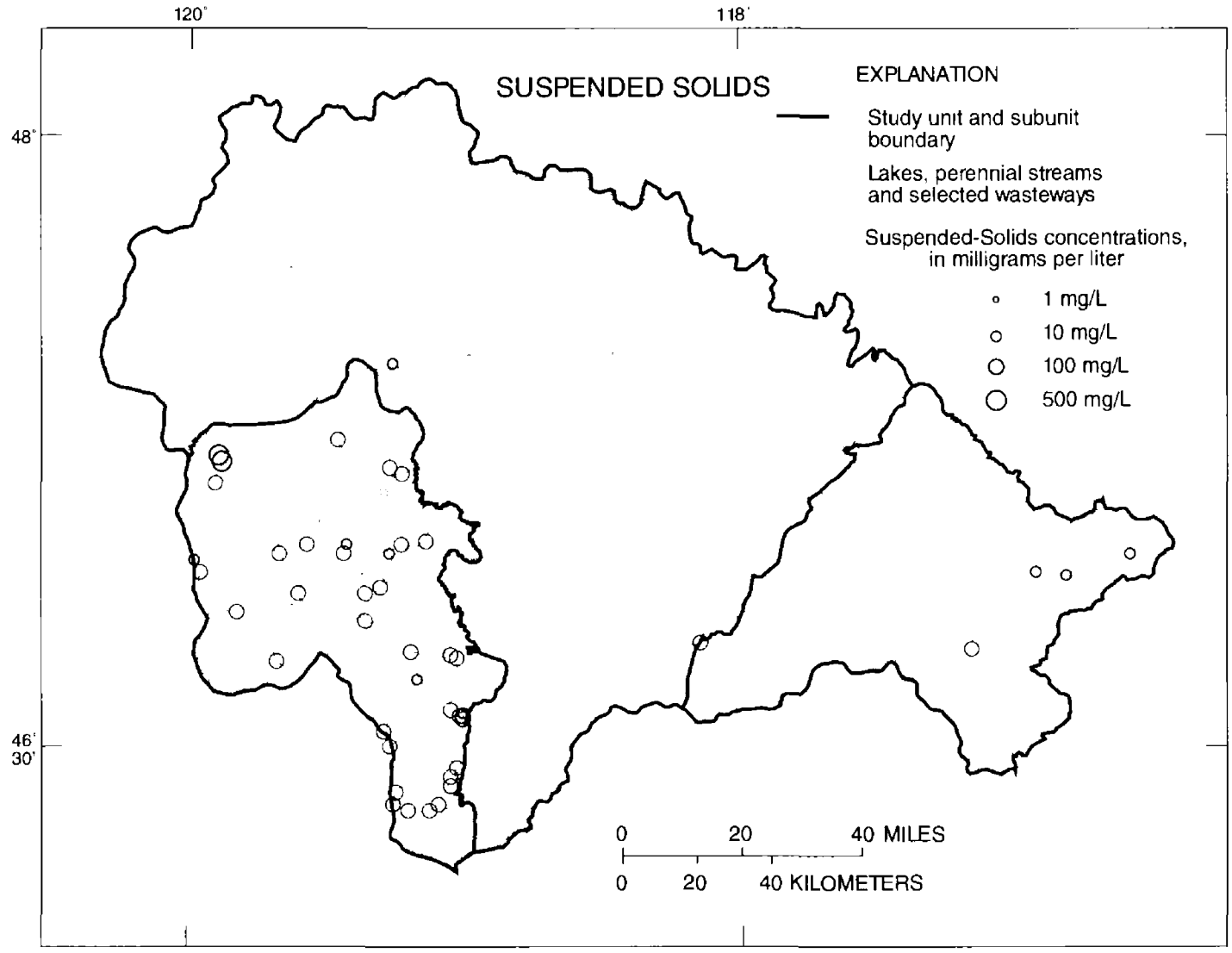
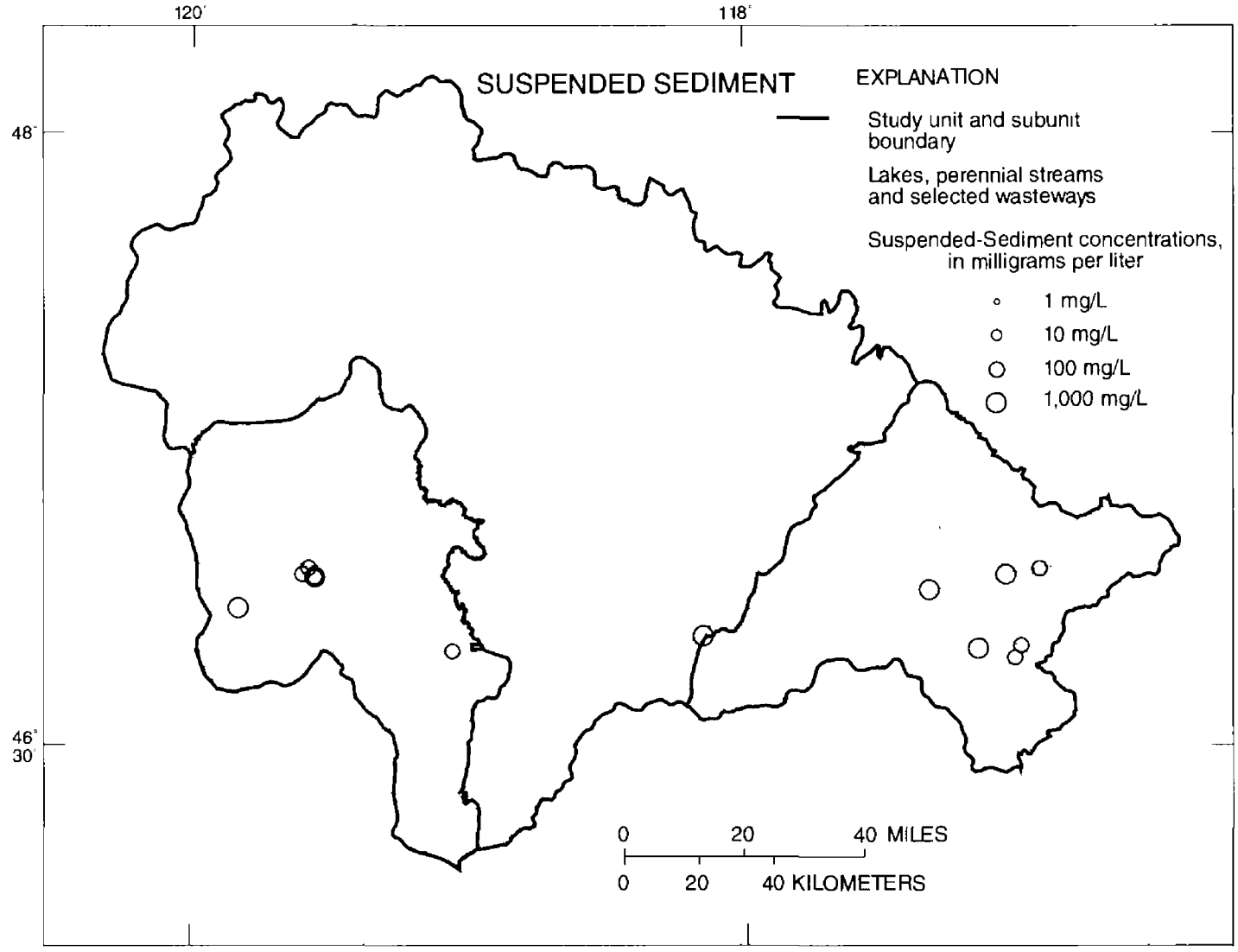


Figure 19.--Continued





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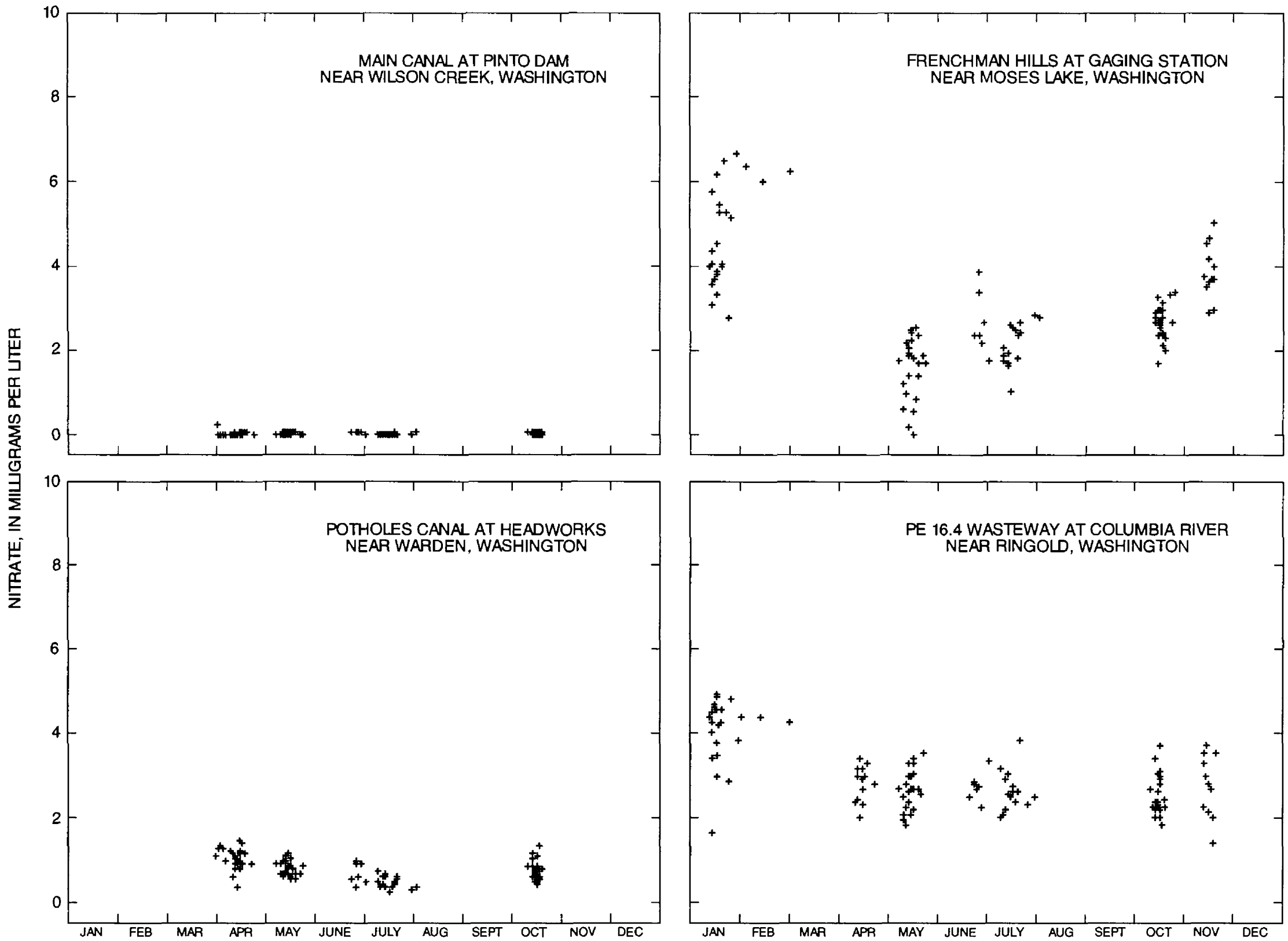


Figure 20.--Concentrations of nitrate at (a) two locations above and two locations below Potholes Reservoir in the Columbia Basin Irrigation Project; and (b) four locations along the Palouse River, in downstream order.

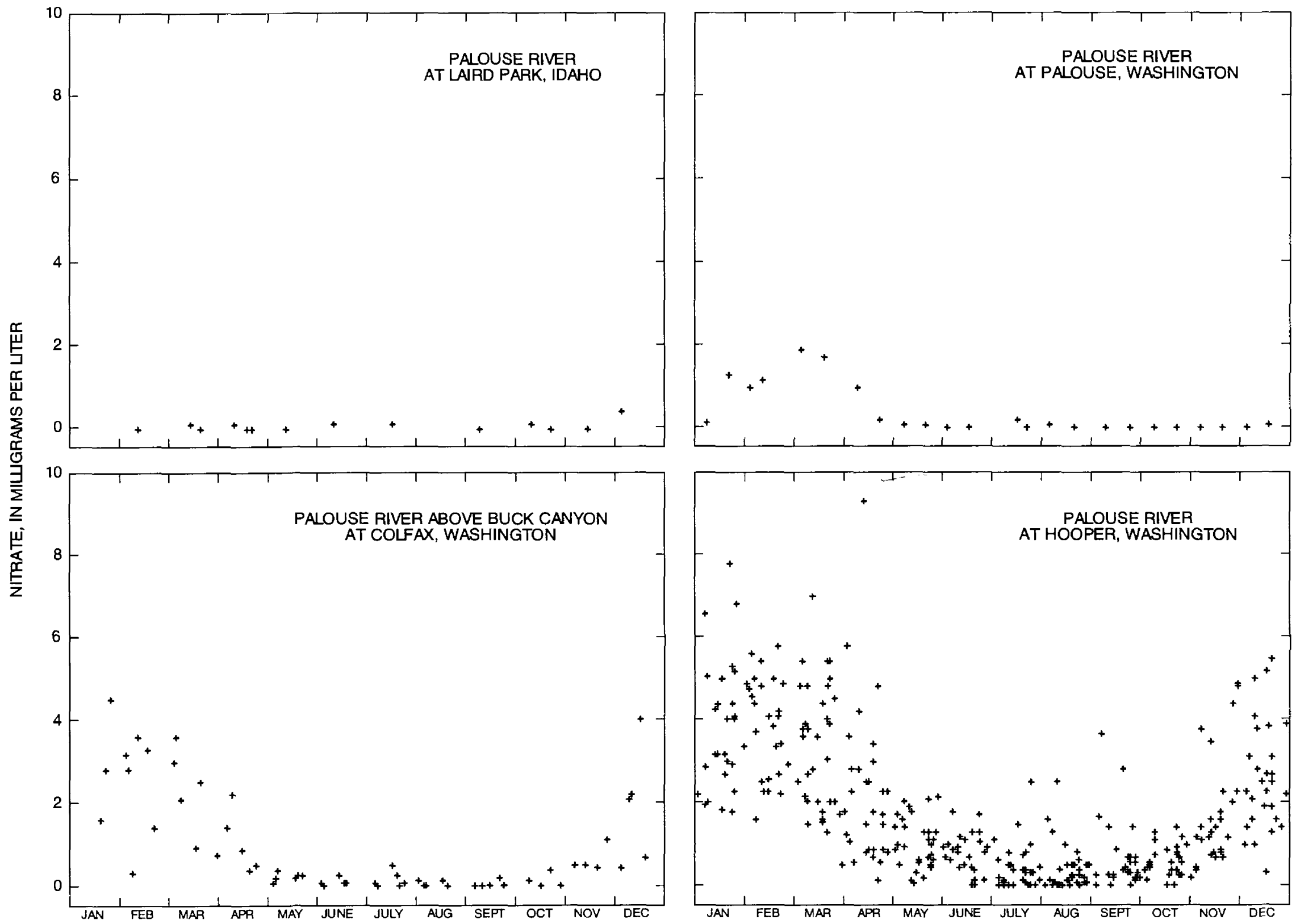


Figure 20.--Continued

Seasonal Variations and Relation of Concentrations to Streamflow

Nutrient and suspended-sediment concentrations in the surface waters of the Central Columbia Plateau study unit vary seasonally as well as spatially. The highest concentrations of nitrate, total nitrogen, total phosphorus, and orthophosphate occurred in agricultural surface drains in the Quincy-Pasco subunit during the winter (low streamflow) months and in STP-affected tributaries in the Palouse subunit during the summer (low streamflow) months. The lowest concentrations of nutrients and suspended sediment were in the irrigation delivery waters, which only flow from March to October, and throughout the year in the headwaters of the Palouse River at Laird Park near Harvard, Idaho, (site 91, fig. 17c). The highest concentrations of suspended sediment and suspended solids occurred during high streamflows in the main channel and tributaries of the Palouse River and in surface irrigation drains in the Quincy-Pasco subunit.

Seasonal variations in streamflow are different in the Palouse and Quincy-Pasco subunits. During the irrigation season in the Quincy-Pasco subunit, streamflows at most of the sampling locations included in this report are controlled by the operation of the irrigation project by the Bureau of Reclamation: high mean-monthly flows generally occur during the irrigation season from April through October and there is little variation in streamflow from May through September at most of the sites. High flows in the Palouse subunit generally are caused by winter storms, and the streamflow conditions in this subunit represent natural hydrologic variability (see "Surface-Water Hydrology" in the "Description of the Central Columbia Plateau Study Unit" section). Less is known about seasonal patterns in streamflow in the North-Central subunit, where few streamflow measurements have been made, but streamflows in this subunit probably are similarly affected by climatic variability.

Some seasonal variations in streamflow and in nutrient and suspended-sediment concentrations were identified at four sites in the Quincy-Pasco subunit and two sites in the Palouse subunit. Figure 21 shows boxplots of mean monthly streamflow and concentrations of nitrate, total phosphorus, and suspended sediment or suspended solids by month for each of these sites.

Seasonal variations in total-phosphorus and suspended-sediment concentrations correspond to seasonal variations in streamflow at DW 272A drain from Block 86 near Royal Camp, Wash., and at EL 68D Wasteway near Othello, Wash. (fig. 21). Increased irrigation returns probably cause increases in both of these constituents. The February peak in concentrations of total phosphorus and suspended sediment at EL 68D Wasteway is associated with annual dredging upstream from the site during this month. Seasonal variations in nitrate concentrations and streamflow vary inversely at both of these sites, classified as a surface irrigation drain and an irrigation wasteway, respectively. Irrigation return flows may dilute nitrate concentrations at both sites.

Seasonal variations at the sites on Crab Creek near Moses Lake and near Beverly in the Quincy-Pasco subunit are similar to the variations in the irrigation wasteways. Although these two sites are part of a natural flow system, they are affected by irrigation practices and were classified as irrigation wasteways. Streamflows at Crab Creek near Moses Lake peak during storms in January through April, but streamflows at Crab Creek near Beverly peak in September and October, probably due to discharges of unused irrigation delivery water toward the end of the irrigation season. Suspended-solids concentrations at both of these sites peak during the irrigation season. Nitrate concentrations at both of these sites peak during the winter months, after the irrigation season. Concentrations of total phosphorus are lower during the fall months at both of these sites.

Seasonal variations in nitrate and suspended sediment correspond with seasonal variations in streamflows at both the Palouse River at Hooper, a main channel site, and the South Fork Palouse River at Pullman, an STP-affected tributary to the Palouse River (fig. 21). Seasonal variations in total-phosphorus concentrations do not appear to correspond with seasonal variations in streamflows at the Palouse River at Hooper, and vary inversely with seasonal variations in streamflows at the South Fork Palouse River at Pullman. Total phosphorus at the Pullman site probably is dominated by orthophosphate from the STP; therefore total phosphorus would be diluted during high streamflows. At the Hooper site, (dissolved) orthophosphate from the STPs may dominate total phosphorus during low flows, and erosion-derived (suspended) phosphorus may dominate during high flows; therefore there is no apparent relation between total phosphorus concentrations and streamflow for the Palouse River at Hooper. An increase in concentrations with streamflow would be due to contributions of suspended material during periods of runoff, and an inverse relation with flow would be due to dilution of the dissolved phase.

Graphs of total-nitrogen and total-phosphorus concentrations compared to the log of instantaneous streamflow confirm some constituent-streamflow relations

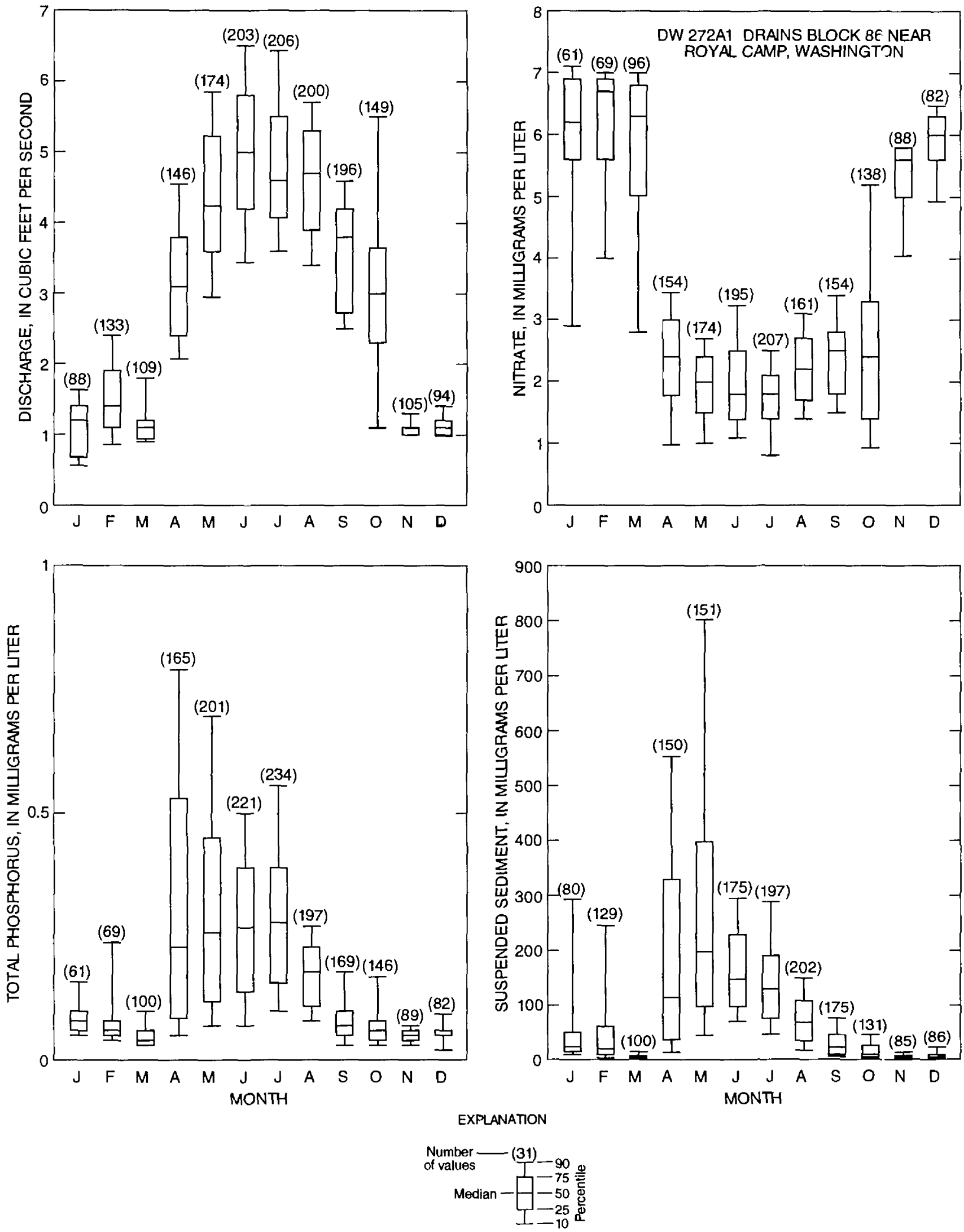
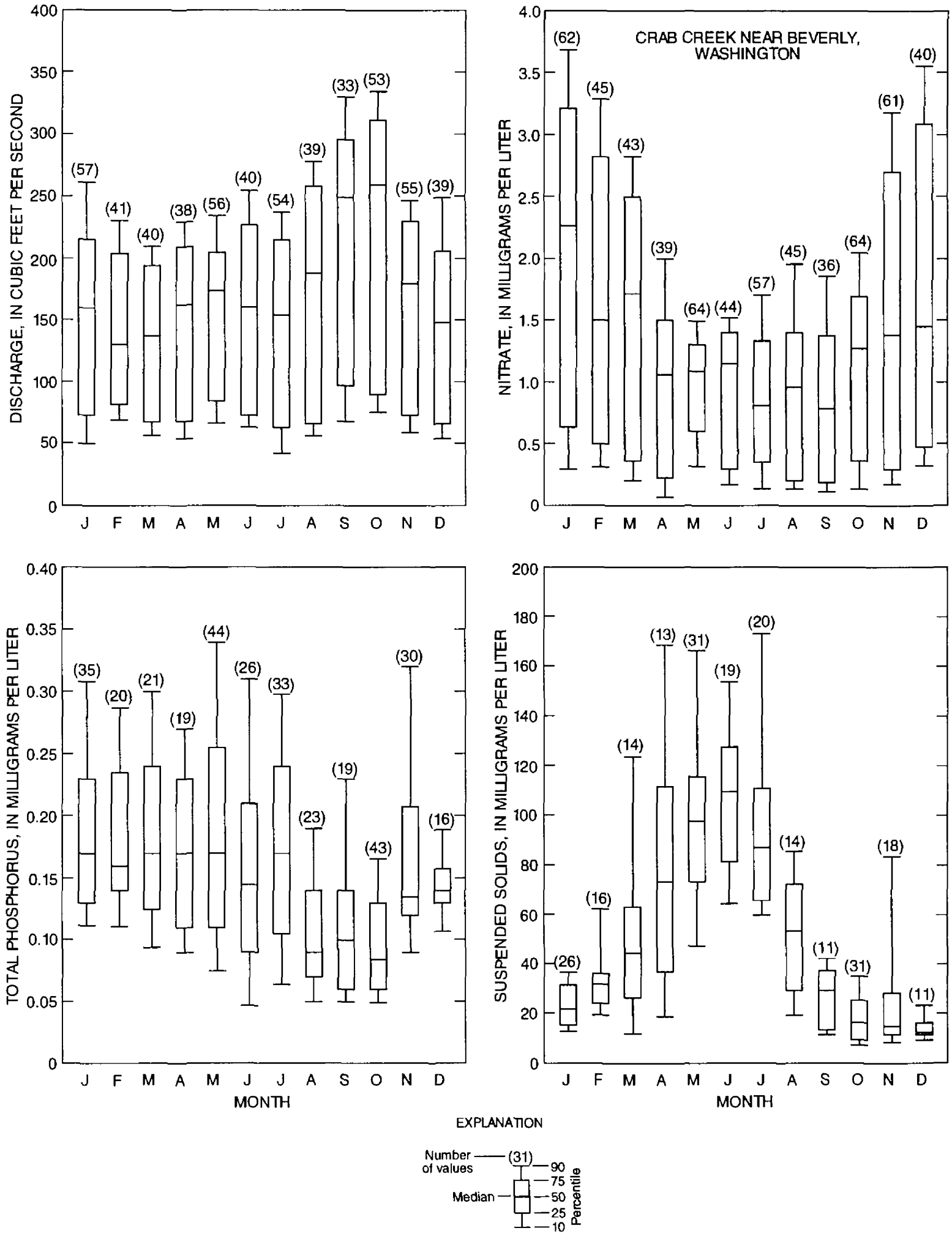


Figure 21.--Streamflow and concentrations of nitrate, total phosphorus, and suspended sediment or suspended solids at six sites in the Central Columbia Plateau study unit, by month. Concentrations are plotted at different scales for each site.



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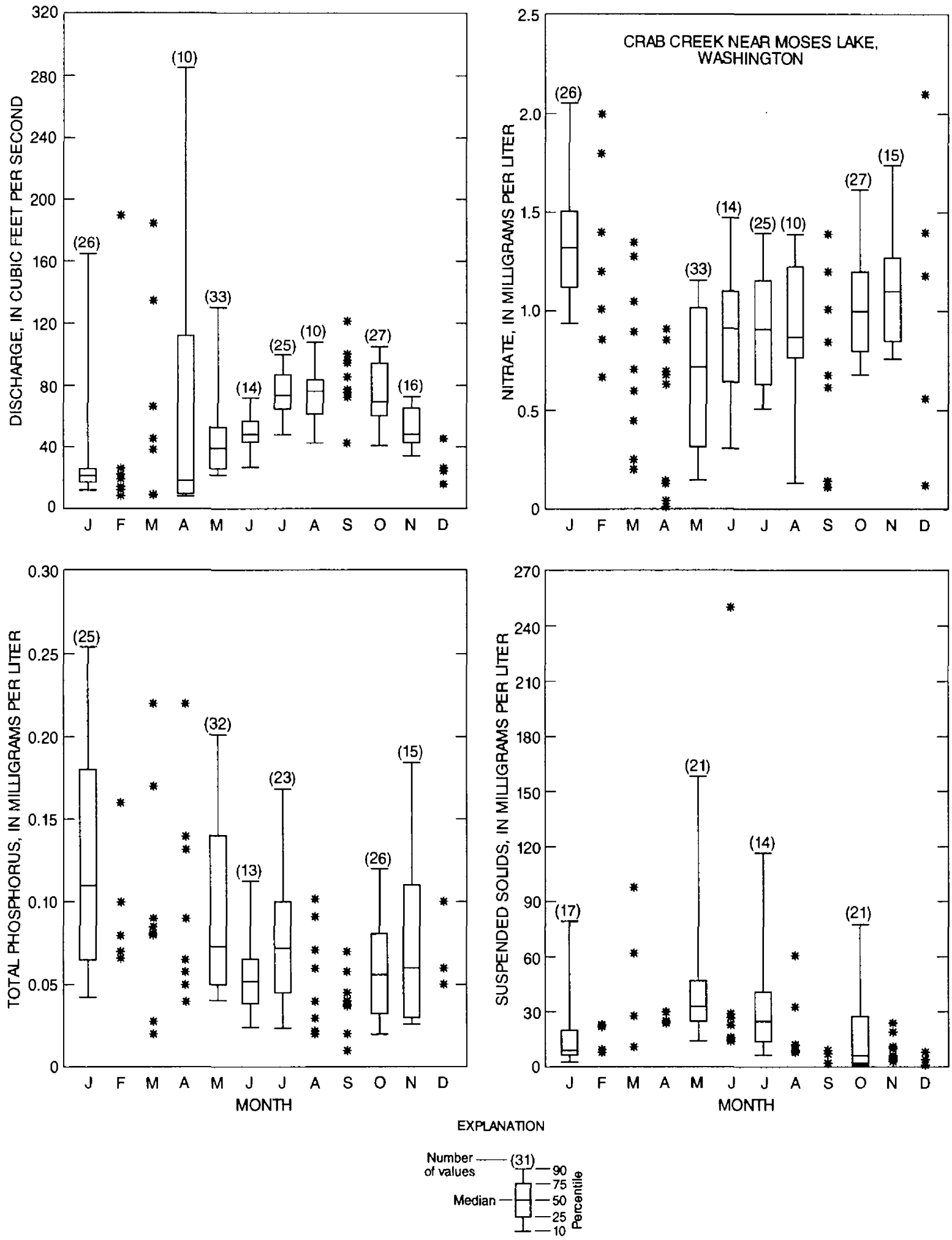

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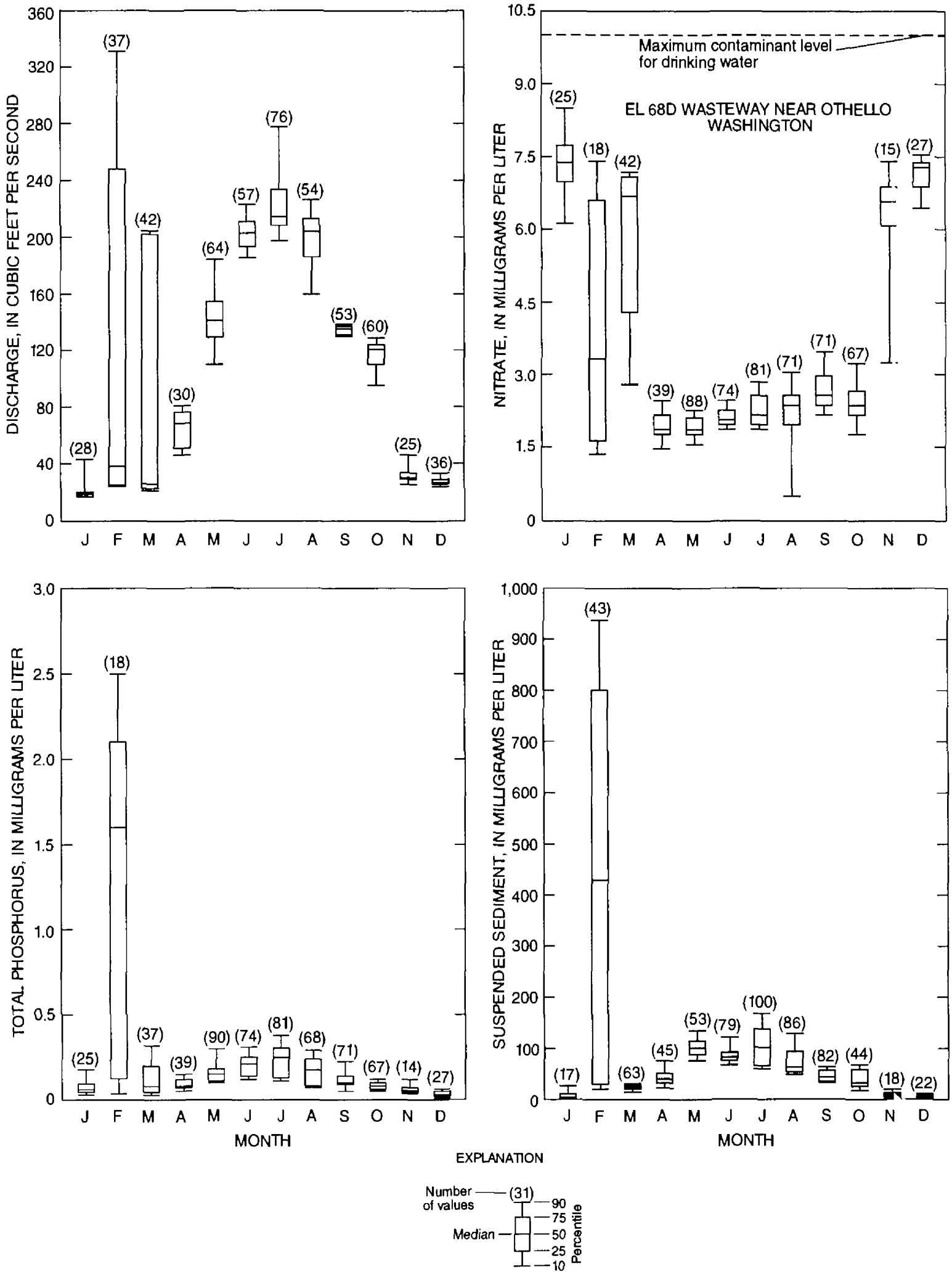

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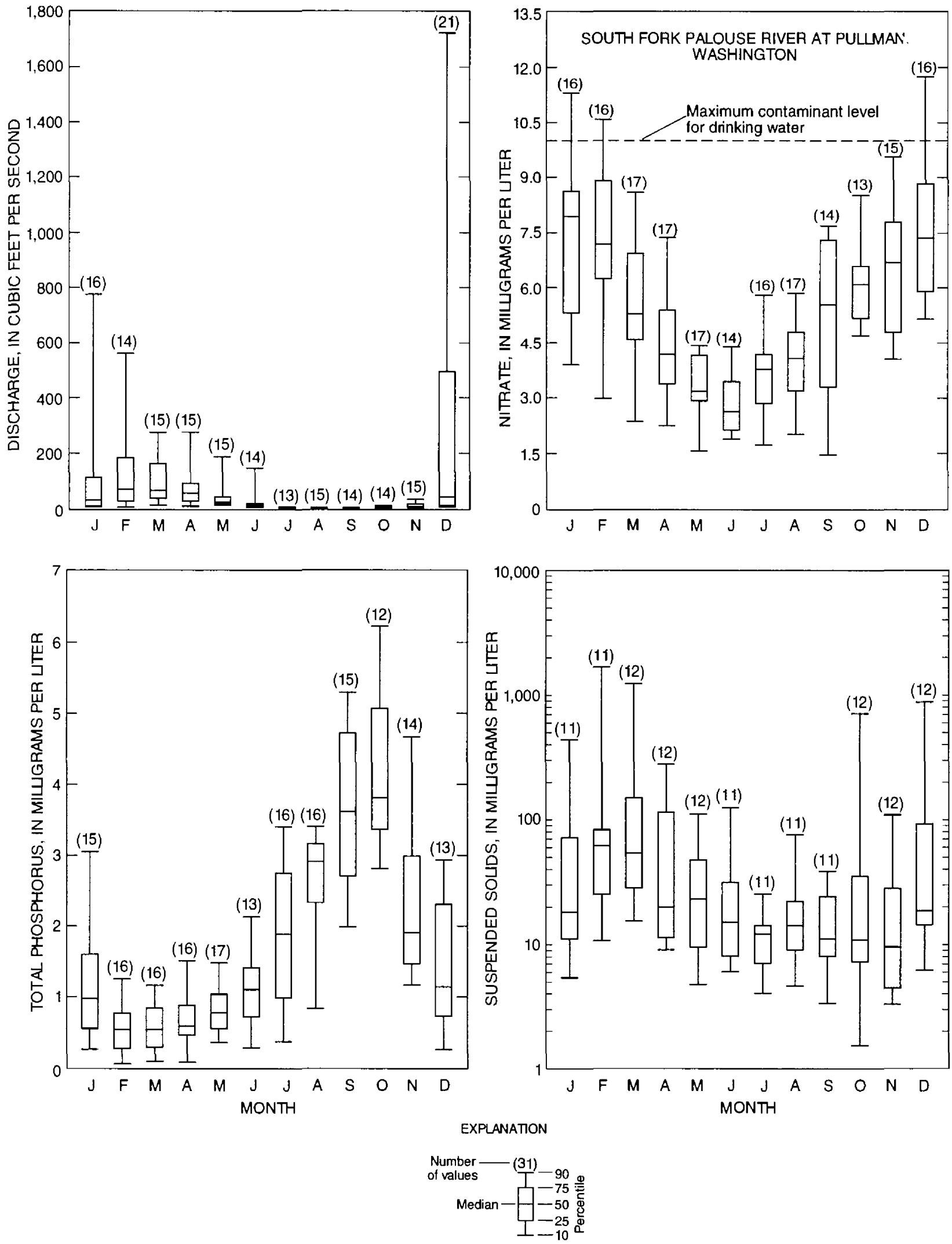

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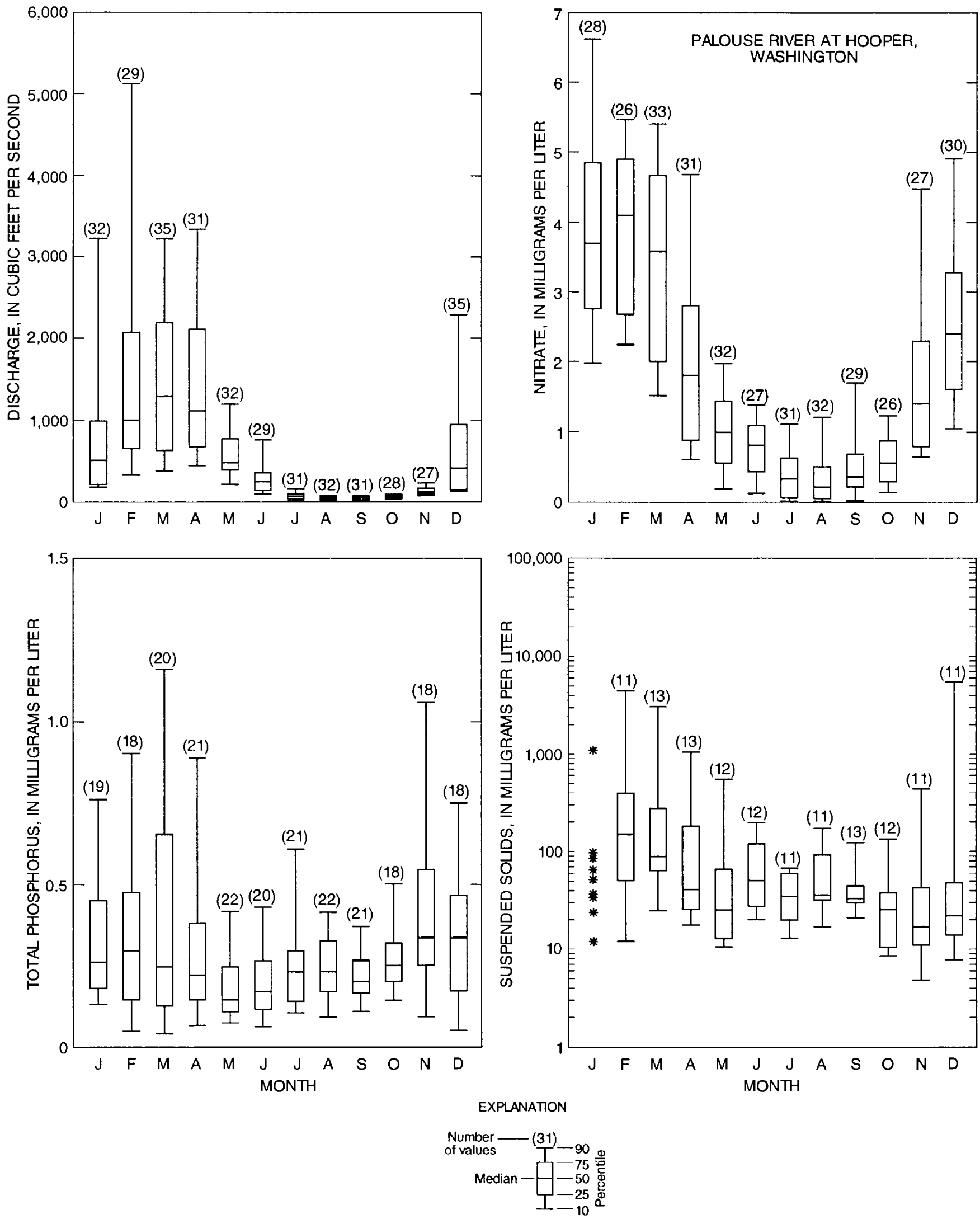

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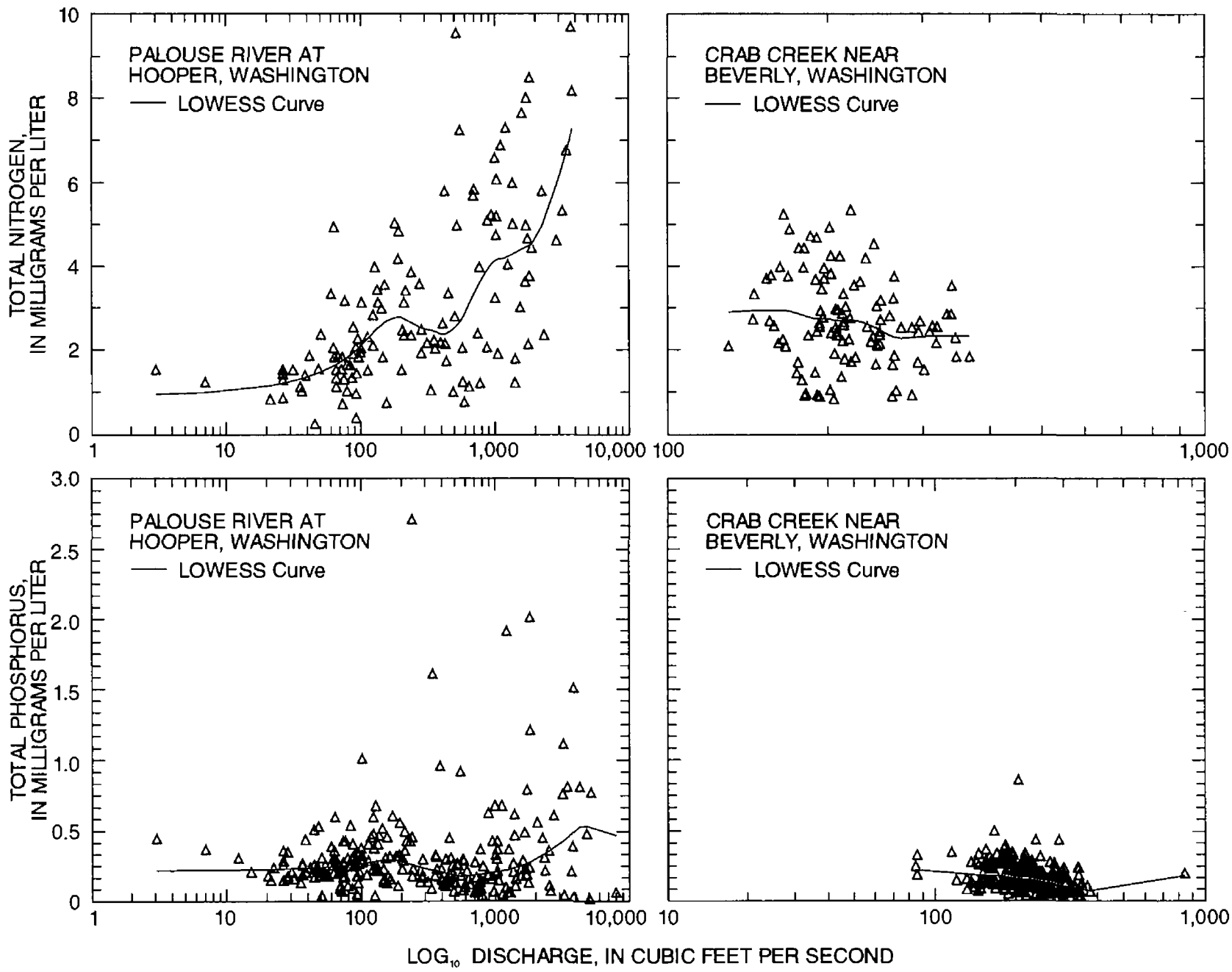


Figure 22.--Relation of concentrations of total nitrogen and total phosphorus to streamflow for the Palouse River at Hooper, Washington, (site 90, figure 17) and Crab Creek near Beverly, Washington, (site 5, figure 17). A locally weighted scatterplot smoothing (LOWESS) curve was added to help identify changes in concentration caused by streamflow.

inferred from figure 21 and are shown in figure 22 for the Palouse River at Hooper, Wash. (site 90, fig. 17c) and Crab Creek near Beverly, Wash. (site 5, fig. 17a). Water-quality data are well-distributed throughout the year (fig. 21) and flow regimes (fig. 18) at both of the sites. The locally weighted scatterplot smoothing (LOWESS) technique (Cleveland, 1979) fits a smooth curve to a scatterplot and was used in this figure to help identify changes in concentrations caused by streamflow. No direct relation between either total-nitrogen or total-phosphorus concentrations and streamflow is apparent at Crab Creek near Beverly (fig. 22). Total-nitrogen concentrations at the Palouse River at Hooper increase with streamflow, but there is no apparent relation between total-phosphorus concentrations and streamflow for this site (fig. 22).

The seasonal variations identified at the six sites in figure 21 are similar to those identified when sites were grouped by subunit and by site classification. The seasonal distributions of the median nutrient and suspended-sediment concentrations for each site in the Quincy-Pasco, North-Central, and Palouse subunits and for four of the site classifications are shown in figures 23 and 24. There are not sufficient data to identify seasonal

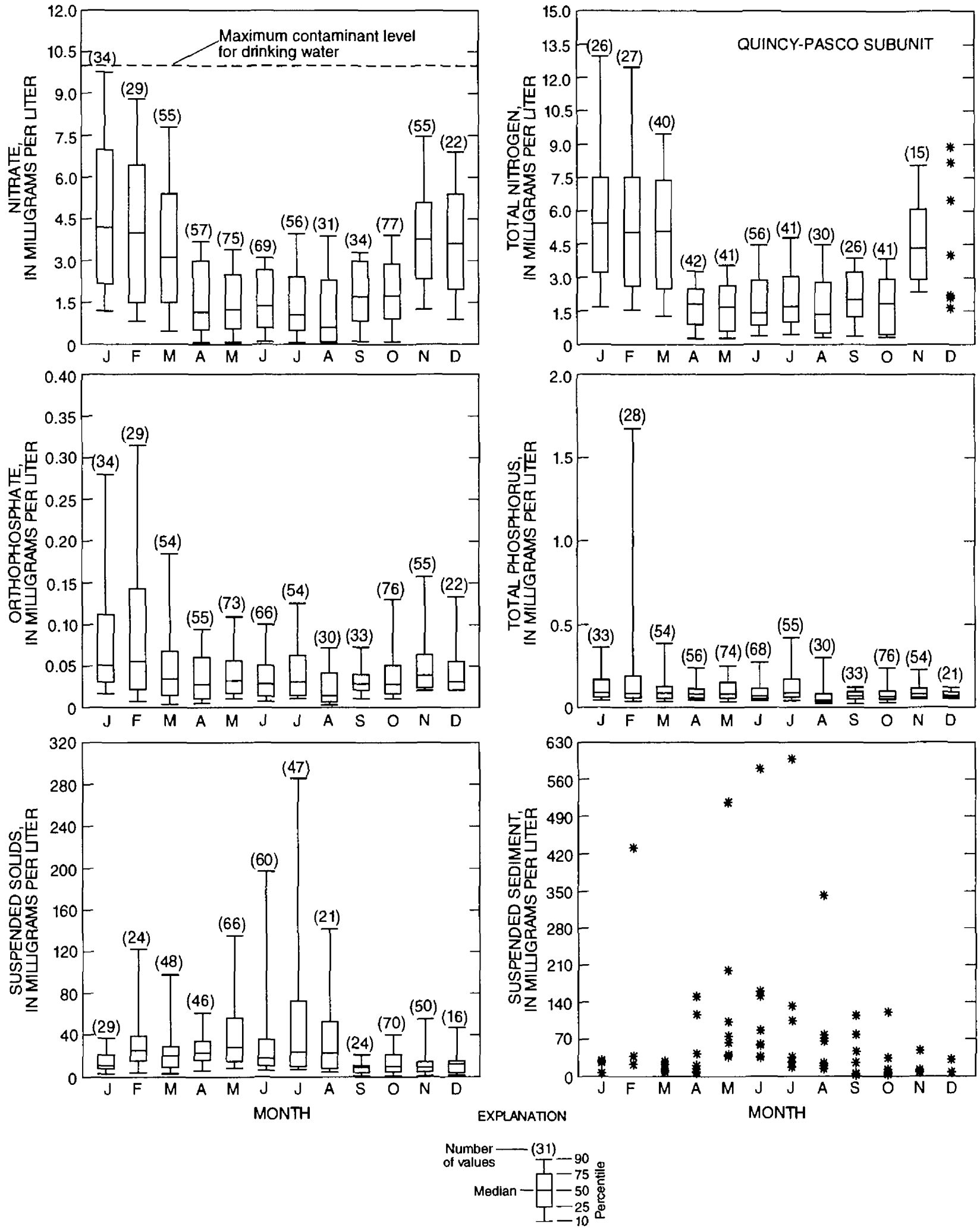
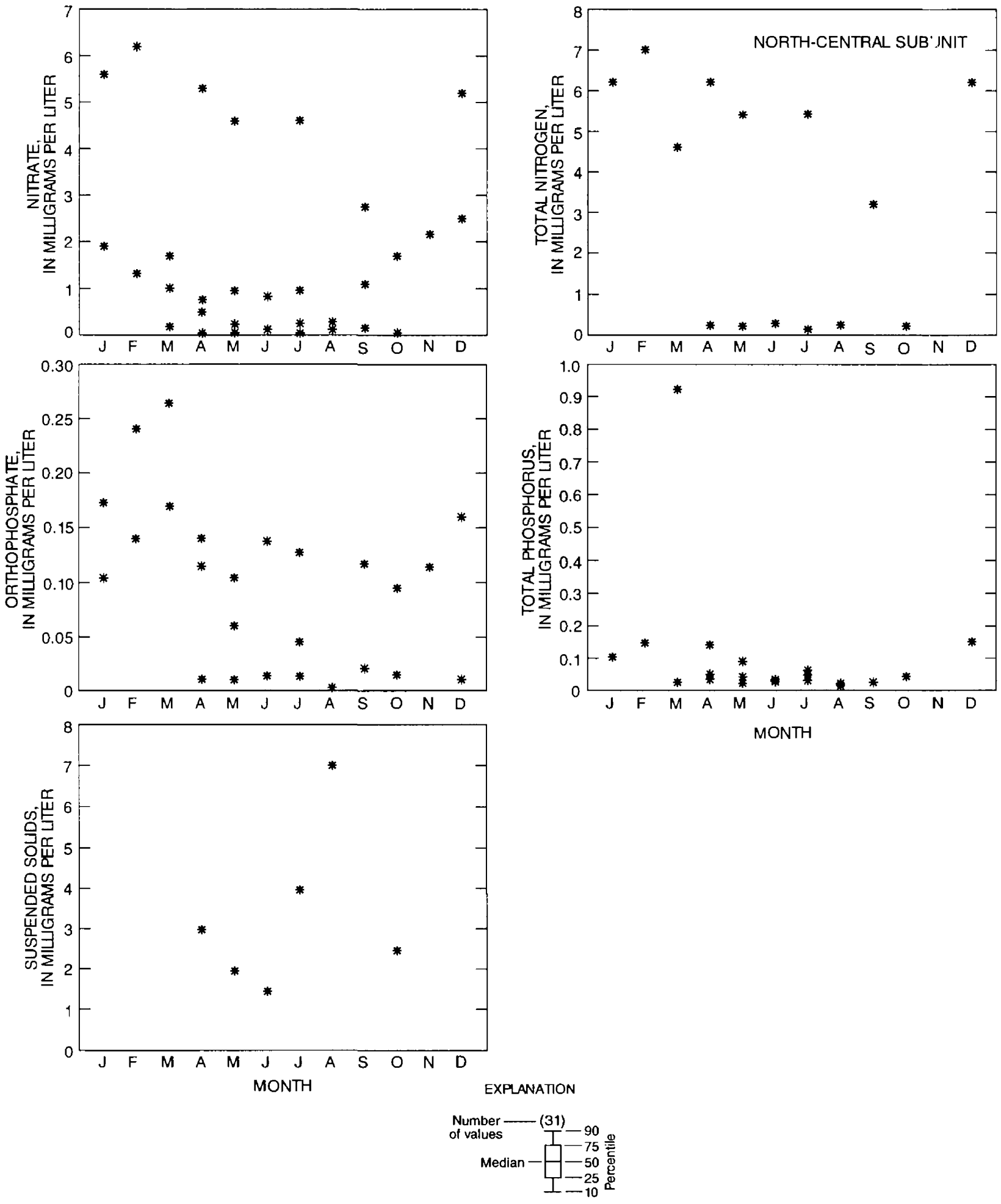


Figure 23.--Concentrations by month for nitrate, total nitrogen, orthophosphate, total phosphorus, suspended solids, and suspended sediment in the Quincy-Pasco, North-Central, and Palouse subunits. No suspended-sediment data were available for the North-Central subunit. Concentrations are plot'ed at different scales for each subunit.



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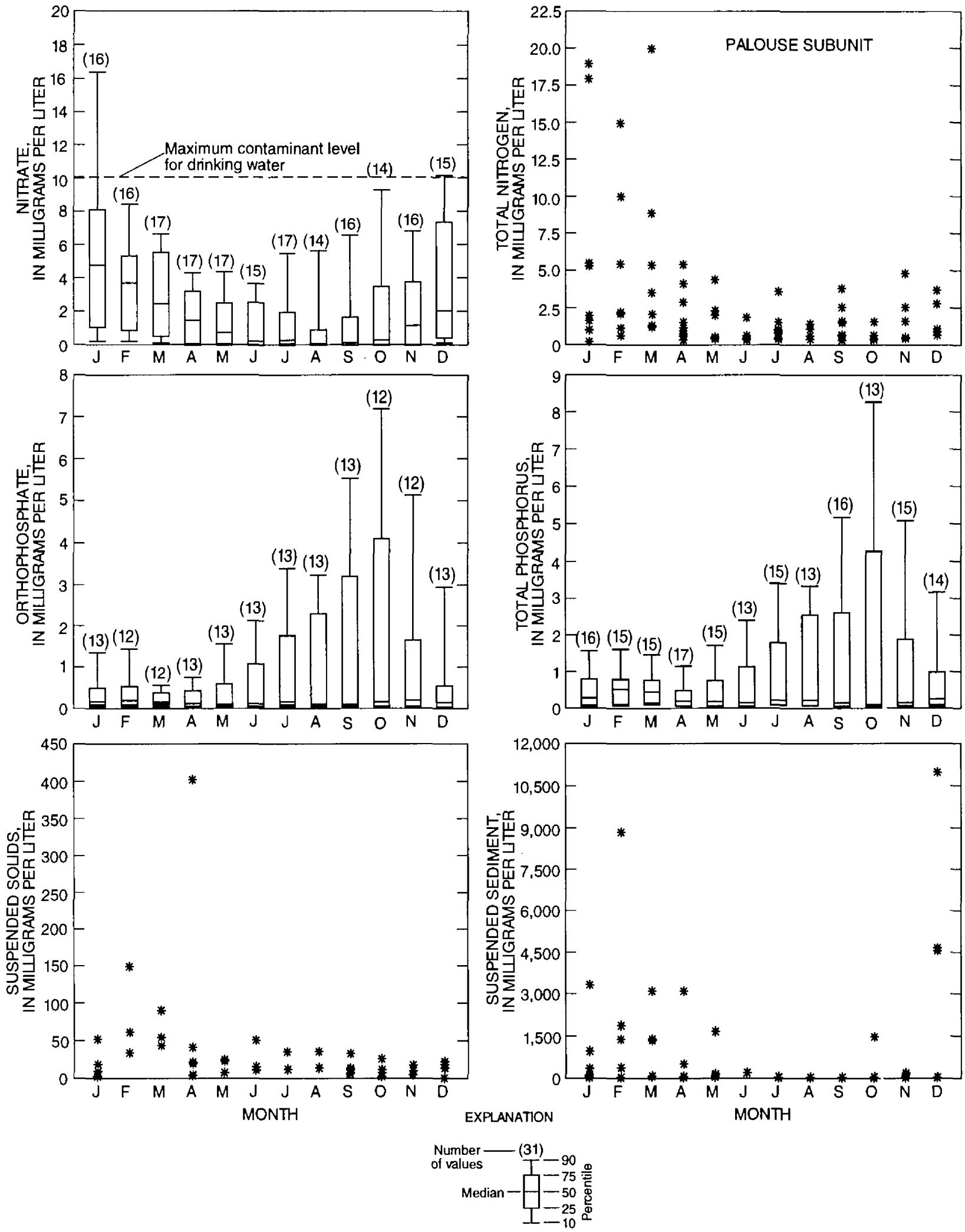

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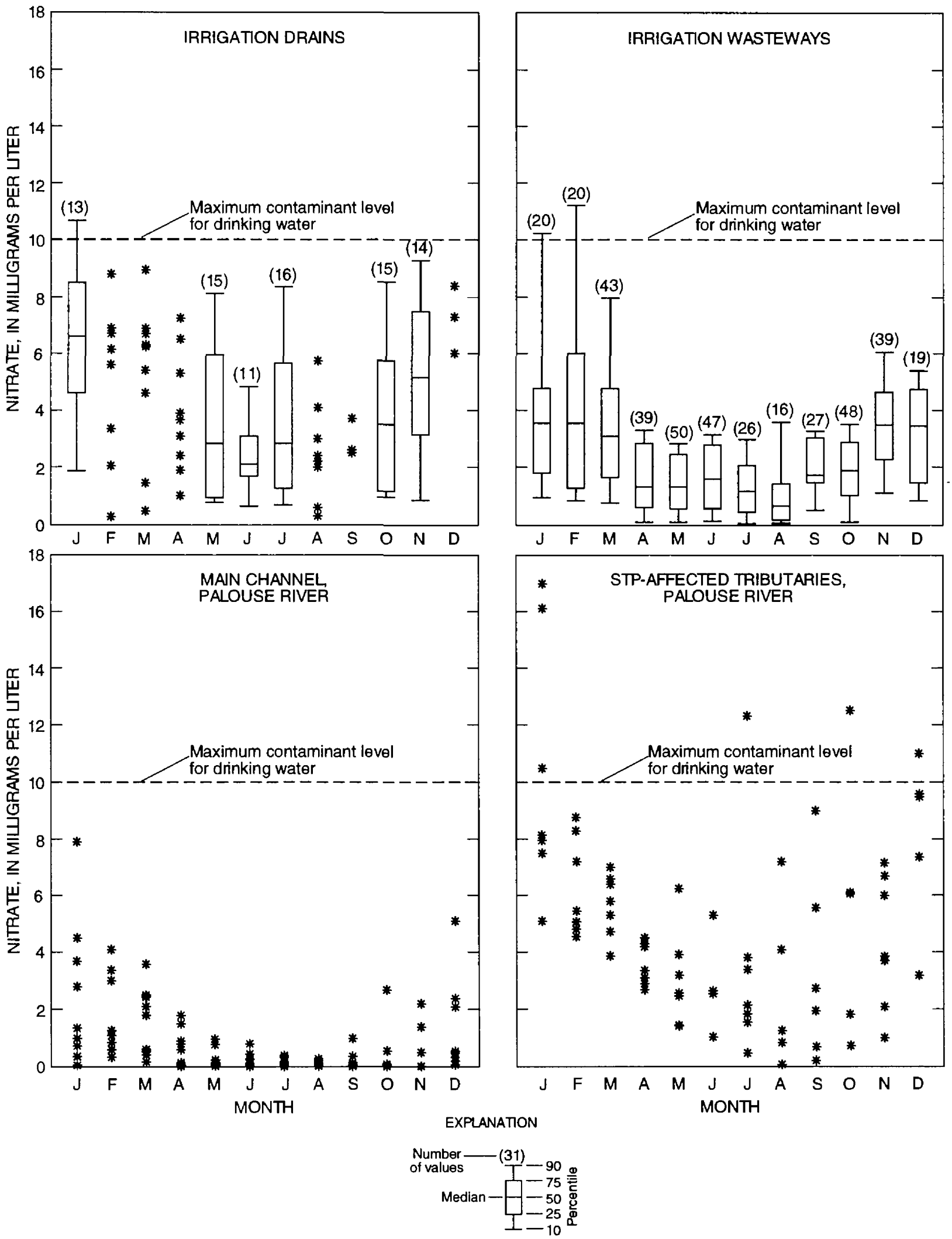

Figure 24.--Concentrations of nitrate and total phosphorus by month for four site classifications.

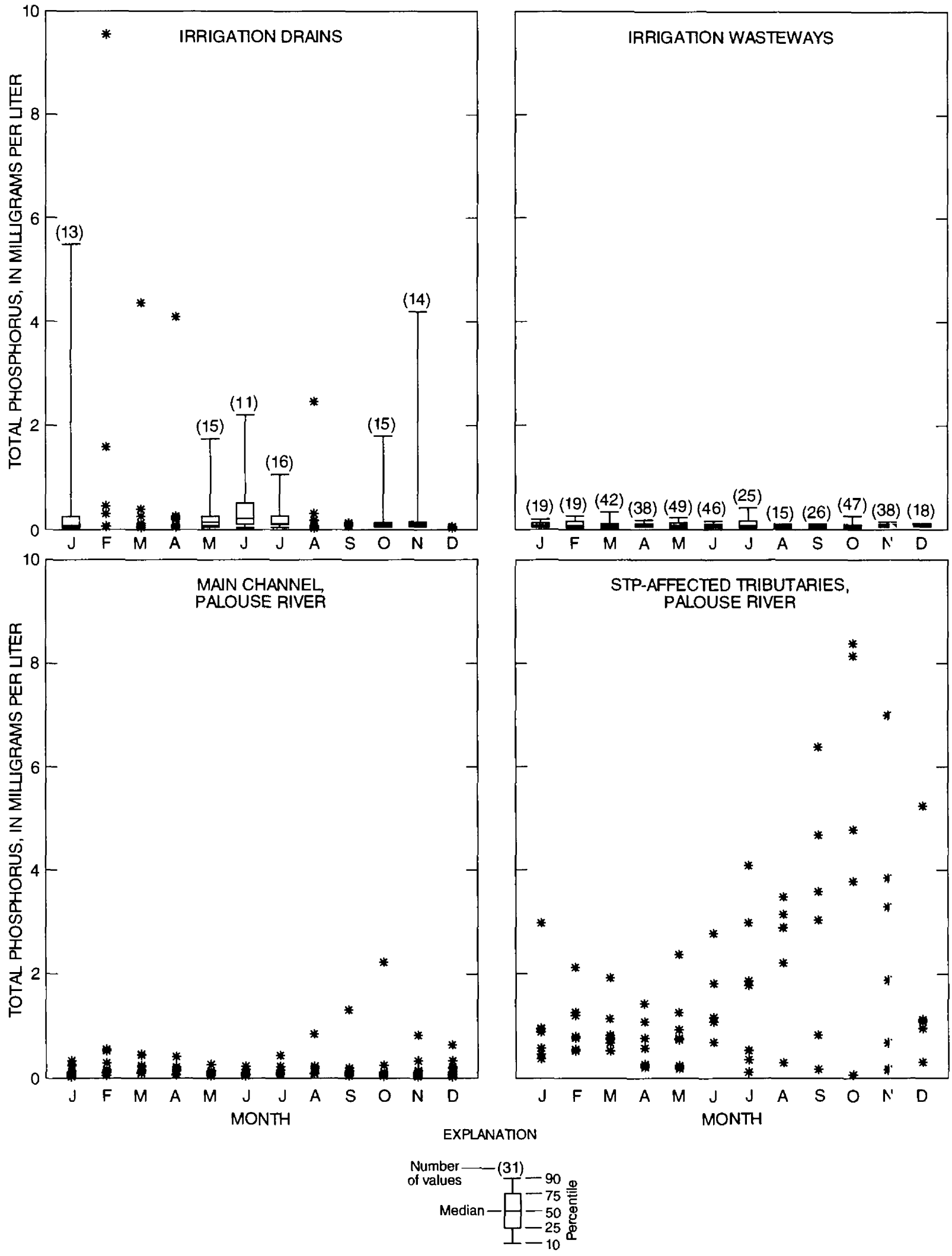

Figure 24.--*Continued*

variations in concentrations in the North-Central subunit. There were insufficient data for producing boxplots of monthly concentrations for the natural flow sites and for the Palouse River headwaters site. For irrigation delivery sites, data were available only for boxplots of concentrations from March through October; concentrations varied little from month to month for this site classification.

Total-nitrogen and nitrate concentrations in the Quincy-Pasco subunit are higher from November through March than from April through October, probably due to dilution by excess irrigation water during the irrigation season (fig. 23). Total-nitrogen and nitrate concentrations in the Palouse subunit are higher during the winter months and probably are associated with runoff from agricultural lands (fig. 23). Concentrations of total phosphorus and orthophosphate peak during the fall months in the Palouse subunit, probably because STP discharges are not as diluted during low-flow conditions: average monthly flows from STPs are more than 80 percent of the streamflow in the South Fork Palouse River during August and September (Pelletier, 1993). Orthophosphate and total-phosphorus concentrations vary throughout the year in the Quincy-Pasco subunit. Suspended-solids and suspended-sediment concentrations peak during the irrigation season, or the months of higher streamflow, in the Quincy-Pasco subunit. The highest concentrations of suspended sediment and suspended solids in the Palouse subunit occurred from December through April, also the months of higher streamflow in the subunit.

Seasonal variations in nitrate concentrations are similar for all four site classifications, and peak during the winter months (fig. 24). Low streamflow conditions occur in the Quincy-Pasco subunit from November to April (outside the irrigation season) and high streamflows generally occur from December to May in the Palouse subunit. Total-phosphorus concentrations peak during high-flow months in surface irrigation drains and probably are associated with suspended sediment. Total-phosphorus concentrations peak during low-flow months in STP-affected tributaries of the Palouse River, and probably are associated with elevated proportions of STP effluent in the streams. Total-phosphorus concentrations for sites classified as irrigation wasteways or on the main channel of the Palouse River do not appear to vary seasonally: variations in total phosphorus concentrations for these site classifications probably are due to a combination of factors such as dilution and changes in the suspended and dissolved components of total phosphorus.

The seasonal variations and relations of nutrient and suspended-sediment concentrations to streamflow varies between the Quincy-Pasco and Palouse subunits. In the Quincy-Pasco subunit, nutrient concentrations generally decrease as mean streamflows increase, probably due to dilution by irrigation supply waters. In the Palouse subunit, except at the sites most affected by STP effluent, nutrient concentrations generally increase as mean streamflows increase, probably due to increased erosion and subsequent transport of sediment and nutrients during storms. Suspended-sediment concentrations generally increase with increasing streamflow due to runoff from agricultural lands at sampling locations throughout the study unit.

Trends in Concentrations of Nutrients and Suspended Solids

The seasonal Kendall test (Crawford and others, 1983) was used to determine time trends in concentrations of nutrients and suspended solids at five sites in the study unit (table 11). These sites were selected because both flow and concentration data were available for the 10-year period from 1980 to 1990; for four of the sites, data were available from 1970 to 1990 for most of the constituents.

The seasonal Kendall test is a distribution-free test that compares relative values, or ranks, of the data and not the actual concentrations. It is a seasonal test because data collected in the same month or season of different years are compared. This seasonal adjustment minimizes erroneous conclusions that could result from comparing data collected during the summer of one year with data collected during the winter of another year. The seasonal Kendall test compares all possible pairs of data values within given months or seasons over the period of the trend test. If a later value in time is higher, a plus is scored; if a later value is lower, a minus is scored. If there is no trend in the data, the odds are the same that a value is higher or lower than one of its predecessors. In the absence of a trend, the number of pluses should be about equal to the number of minuses. If there are many more pluses, then an upward trend is likely.

Changes in water quality are associated not only with seasonal changes but also with changes in streamflow; changes occur because of dilution and wash-off. Dilution affects concentrations when water entering a stream contains smaller concentrations of dissolved constituents than

Table 11.--*Summary of significant (probability level less than or equal to 0.1) trends for nutrients and suspended solids at surface-water sites in the Central Columbia Plateau study unit*

[nt; no trend; --, insufficient data to perform trend test; ↓, decreasing concentrations; ↑, increasing concentrations; items in bold and doubled arrows indicate concentration data were flow adjusted before performing trend test]

Reference number on figure 17	Site name	Water years	Nitrate	Total nitrogen	Total phosphorus	Orthophosphate	Suspended solids
6	Crab Creek near Moses Lake, Washington	1980-90	**nt**	--	**nt**	**nt**	**nt**
		1970-90	**nt**	--	**nt**	**nt**	--
5	Crab Creek near Beverly, Washington	1980-90	**⇓**	**↓**	**nt**	**nt**	**⇓**
		1970-90	⇑	--	⇓	⇓	--
3	Crab Creek Lateral above Royal Lake near Othello, Washington	1980-90	nt	nt	nt	nt	nt
		1970-90	↓	--	↓	↓	--
90	Palouse River at Hooper, Washington	1980-90	**nt**	--	**nt**	**nt**	**nt**
		1970-90	↓	--	⇓	⇓	--
102	South Fork Palouse River at Pullman, Washington	1980-90	**nt**	--	**nt**	**nt**	**nt**
		1970-90	--	--	--	--	--

those already present in the stream water. The opposite effect occurs when wash-off carries constituents of higher concentration into a stream, and concentrations increase with increasing streamflow. If changes in concentrations caused by changes in streamflow are removed from the data, it becomes easier to identify causative factors, other than streamflow, that affect temporal trends.

The locally weighted scatterplot smoothing (LOWESS) technique (Cleveland, 1979) was used to help remove changes in concentrations caused by streamflow. The LOWESS procedure was used to fit a smooth curve to scatterplots of constituent concentrations and the streamflow measured at the time samples were collected. The residuals from this relation, or differences between the observed values and values on the curve fitted to the data, are then added to the mean constituent concentration for the period of interest to compute flow-adjusted concentrations. Because flow-adjusted concentrations are the sum of a mean concentration and a regression residual, they can be negative numbers. When possible, flow-adjusted concentrations were used to test for trends (table 11).

The presence of a statistically significant trend is indicated in table 11 if the probability level (p-value) from the seasonal Kendall test was less than or equal to 0.10. The p-value is the probability of identifying a trend when, in fact one does not exist. For example, if the p-value is equal to 0.10, there is a 10 percent chance of saying a trend is present when there is no trend. Scatterplots of unadjusted and flow-adjusted concentrations of nitrate, total phosphorus, and suspended solids are shown for sites where trends were indicated by the seasonal Kendall test (figs. 25-27). The LOWESS procedure was used to fit a concentration trend line to the data in the scatterplots as a visual aid in identification of trends.

Definitive information to explain the presence, or absence, of indicated trends (table 11) are not available, but for one site, Crab Creek Lateral (fig. 26), downward trends from 1970 to 1990 in concentrations of phosphorus and nitrate are consistent with changes in farming practices. Decreasing concentrations of phosphorus may relate to less soil erosion because of the increased use of sprinklers, instead of ridge and furrow irrigation methods, for

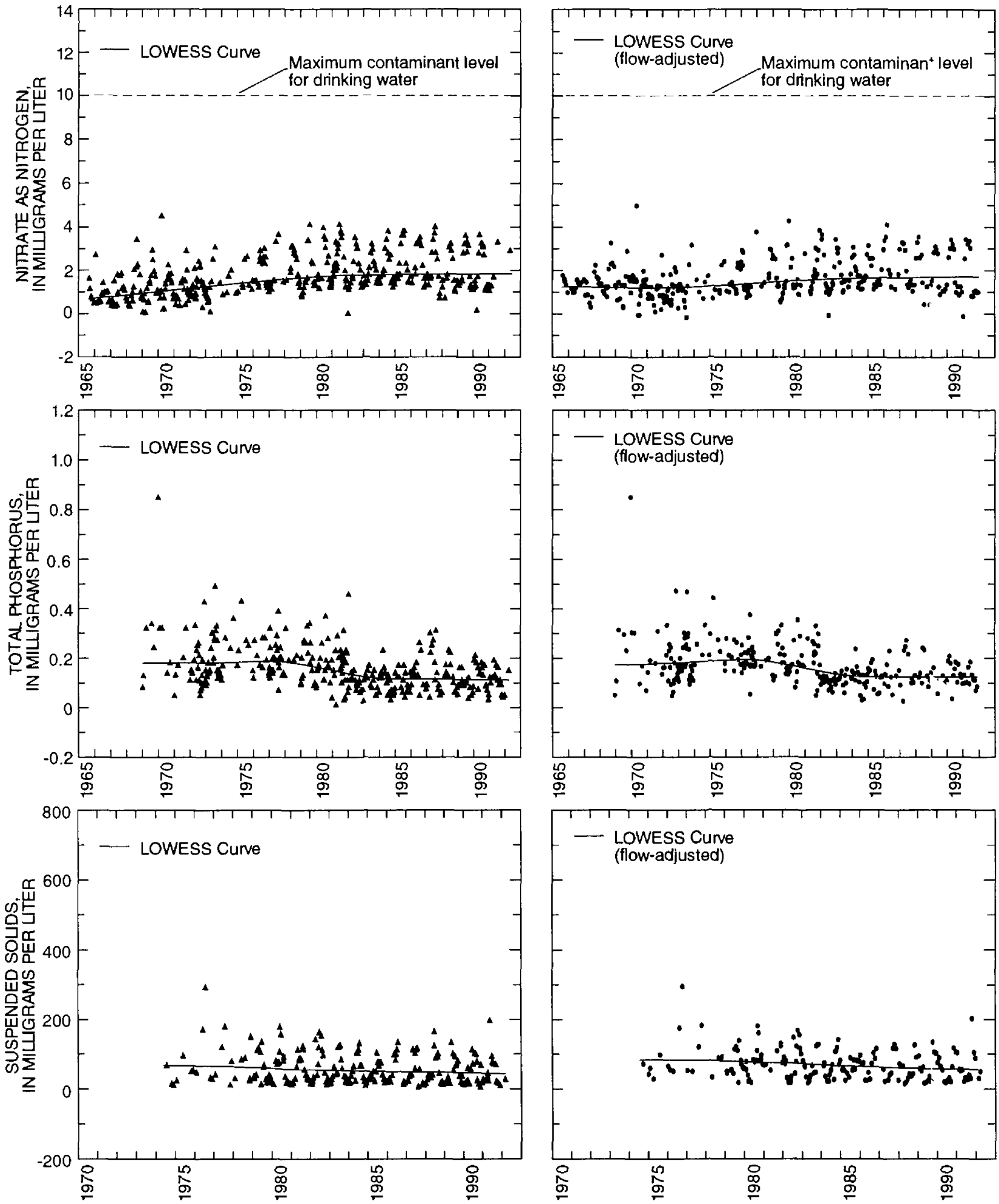

Figure 25.--Temporal variations in concentrations of nitrate, total phosphorus, and suspended solids at Crab Creek near Beverly, Washington, (site 5, figure 17a). Some outlying data points are not shown. Flow-adjusted concentrations can be less than zero; see text page 69 for explanation. A locally weighted scatterplot smoothing (LOWESS) curve was added to help identify changes in concentrations caused by streamflow.

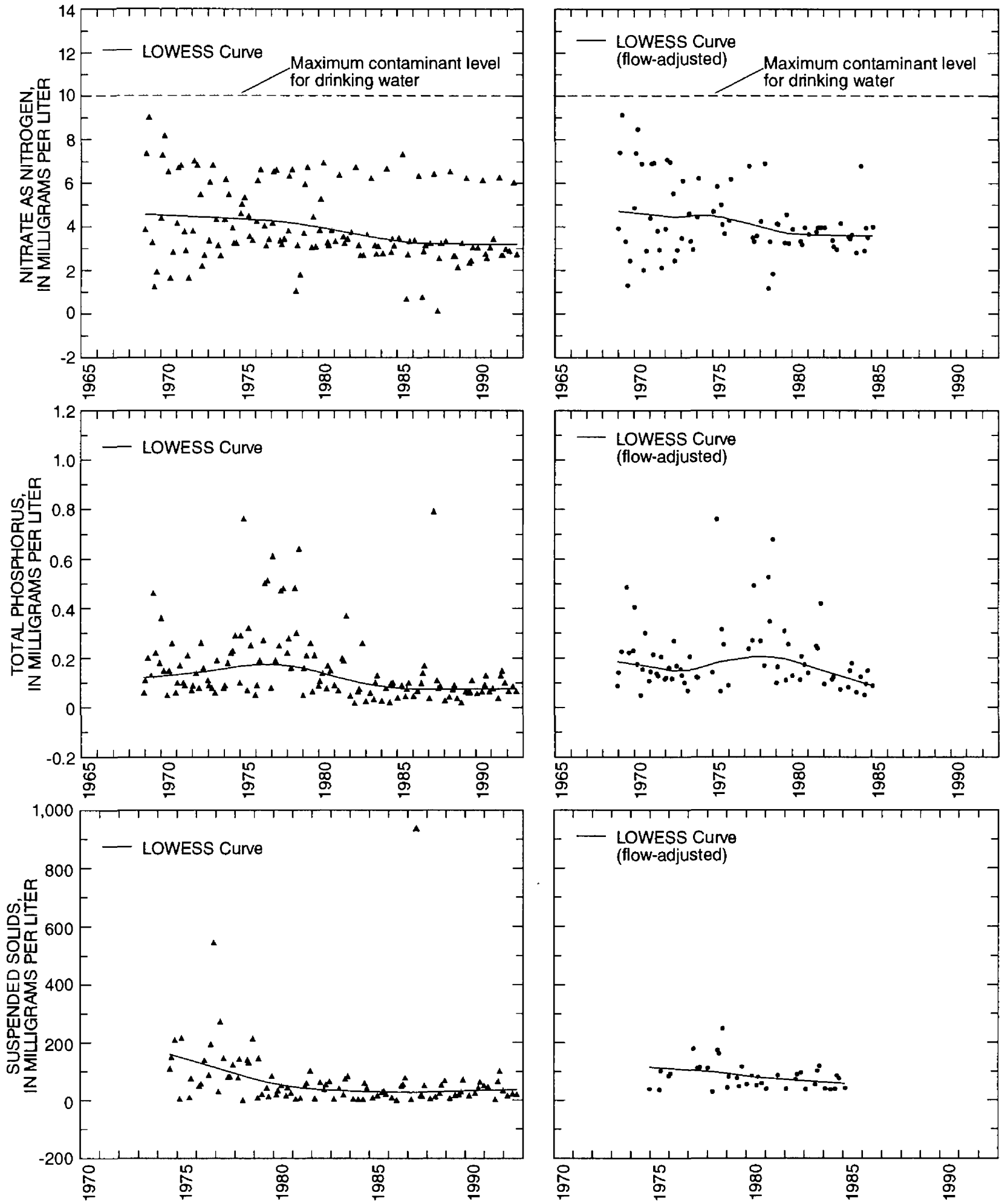

Figure 26.--Temporal variations in concentrations of nitrate, total phosphorus, and suspended solids at Crab Creek Lateral above Royal Lake near Othello, Washington, (site 3, figure 17a). Some outlying data points are not shown. Flow-adjusted concentrations can be less than zero; see text page 69 for explanation. A locally weighted scatterplot smoothing (LOWESS) curve was added to help identify changes in concentrations caused by streamflow.

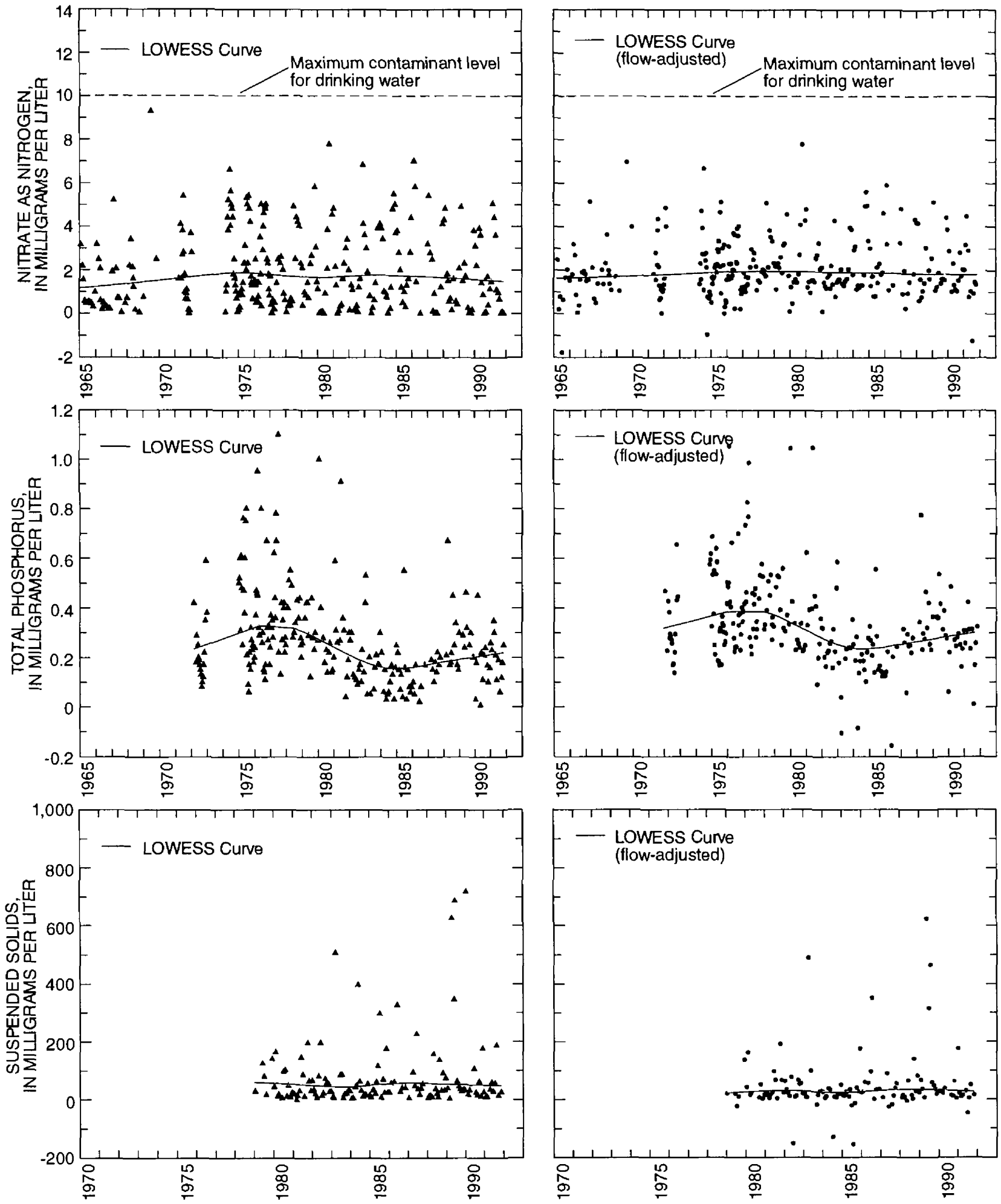

Figure 27.--Temporal variations in concentrations of nitrate, total phosphorus, and suspended solids at Palouse River at Hooper Washington, (site 90, figure 17c). Some outlying data points are not shown. Flow-adjusted concentrations can be less than zero; see text page 69 for explanation. A locally weighted scatterplot smoothing (LOWESS) curve was added to help identify changes in concentrations caused by streamflow.

irrigation. Although the total amount of irrigated crop land draining to Crab Creek Lateral has remained relatively constant at about 30,000 acres from 1974 to 1990, the proportion of crop land irrigated by sprinklers has increased from 27 to 56 percent (Alan Hattrup, Bureau of Reclamation, written commun., 1993). Because phosphorus sorbs to sediment particles, the downward trend in concentrations of total phosphorus in Crab Creek Lateral is consistent with the apparent decrease in concentrations of suspended solids from 1975 to the mid-1980's (fig. 26).

The reason for a significant decrease in concentrations of nitrate in Crab Creek Lateral from 1970 to 1990 (table 11 and fig. 26) is not known, but may relate to an increase in the amount of orchards as a percent of total crop land. Except for alfalfa, most irrigated crops require more applied nitrogen than orchards. From 1974 to 1990, the period in which the total amount of crop land draining to Crab Creek Lateral has remained relatively constant, the proportion of orchards has increased from 9 to 29 percent of the total crop land.

LOADS OF NUTRIENTS AND SUSPENDED SEDIMENT

A load is defined as the mass of a constituent that is transported past a point in a stream over a specified time interval. Most of the load estimates in this report are given for a period of 1 year; however, estimates of daily loads were used to assess nutrient loading from STPs to parts of the Palouse River Basin during low streamflows. Some annual loads obtained from previous studies are reported.

Annual Loads of Nutrients

A statistical model was used to estimate annual loads of total nitrogen and phosphorus for sites with continuous streamflow and long-term water-quality records. The model uses multiple regression analyses to relate logarithms of constituent concentrations to logarithms of daily-mean streamflows and other explanatory variables that are measured or are available on a continuous basis (such as time, for example). The regression relation is used to estimate constituent concentrations at times when no samples were collected. Constituent loads are then computed on a daily basis by multiplying estimated concentrations by streamflow; these daily loads are summed to determine monthly and annual loads. Details of the model are described by Cohn and others (1992).

The statistical model was used to compute annual loads of total nitrogen and phosphorus in Palouse River at Hooper and Crab Creek near Beverly (fig. 28), two sites with sufficient streamflow and water-quality data to develop the regression relation. Palouse River at Hooper (site 90, fig. 17c) represents the combined drainage from the Palouse subunit and almost all of the drainage from the Palouse River Basin. Crab Creek near Beverly (site 5, fig. 17a) is a major drainage from the Quincy-Pasco subunit. The two sites also are characteristic of other sites in their respective subunits, because the variations in annual mean streamflows are large at sites in the Palouse subunit and relatively small at most sites in the Quincy-Pasco subunit (see fig. 9). Because streamflows in the Palouse subunit are not regulated, runoff is a function of annual climatic variations. In contrast, the scheduled delivery of large quantities of irrigation water to the Quincy-Pasco subunit regulates most of the surface-water drainage from this subunit. Annual mean streamflows at sites in the Quincy-Pasco subunit are relatively uniform because there is little variation in the quantities of irrigation water delivered from year to year.

Loads of total nitrogen and total phosphorus were computed using the statistical model for years representing low (about the 10th percentile), median, and high (about the 90th percentile) annual mean streamflows in Palouse River at Hooper and Crab Creek near Beverly (fig. 28). The estimated loads of total nitrogen and total phosphorus for median annual streamflow were 580 and 24 tons per year, respectively, at Crab Creek near Beverly, and 1,400 and 120 tons per year, respectively, at Palouse River near Hooper. The large differences between low and high annual streamflows and loads at Palouse River at Hooper relate to large year-to-year variations in storm flows during the winter and spring months (fig. 21). During years with high annual streamflows, much of the constituent transport in the Palouse subunit is carried by storm runoff. In contrast, the relatively small variations between annual loads of nitrogen and phosphorus at Crab Creek near Beverly relate to the small variations in annual mean streamflows at this site (fig. 28).

For comparison, simplified estimates of the annual loads of total nitrogen and phosphorus in Palouse River at Hooper and Crab Creek near Beverly were computed as the product of the mean nitrogen or phosphorus concentration for all years of record and the annual mean streamflow for each year being considered (table 12). The comparison between the two methods is shown because the simpler product method is used to compute loads for sites in the Quincy-Pasco subunit that do not have enough streamflow data to use the statistical model.

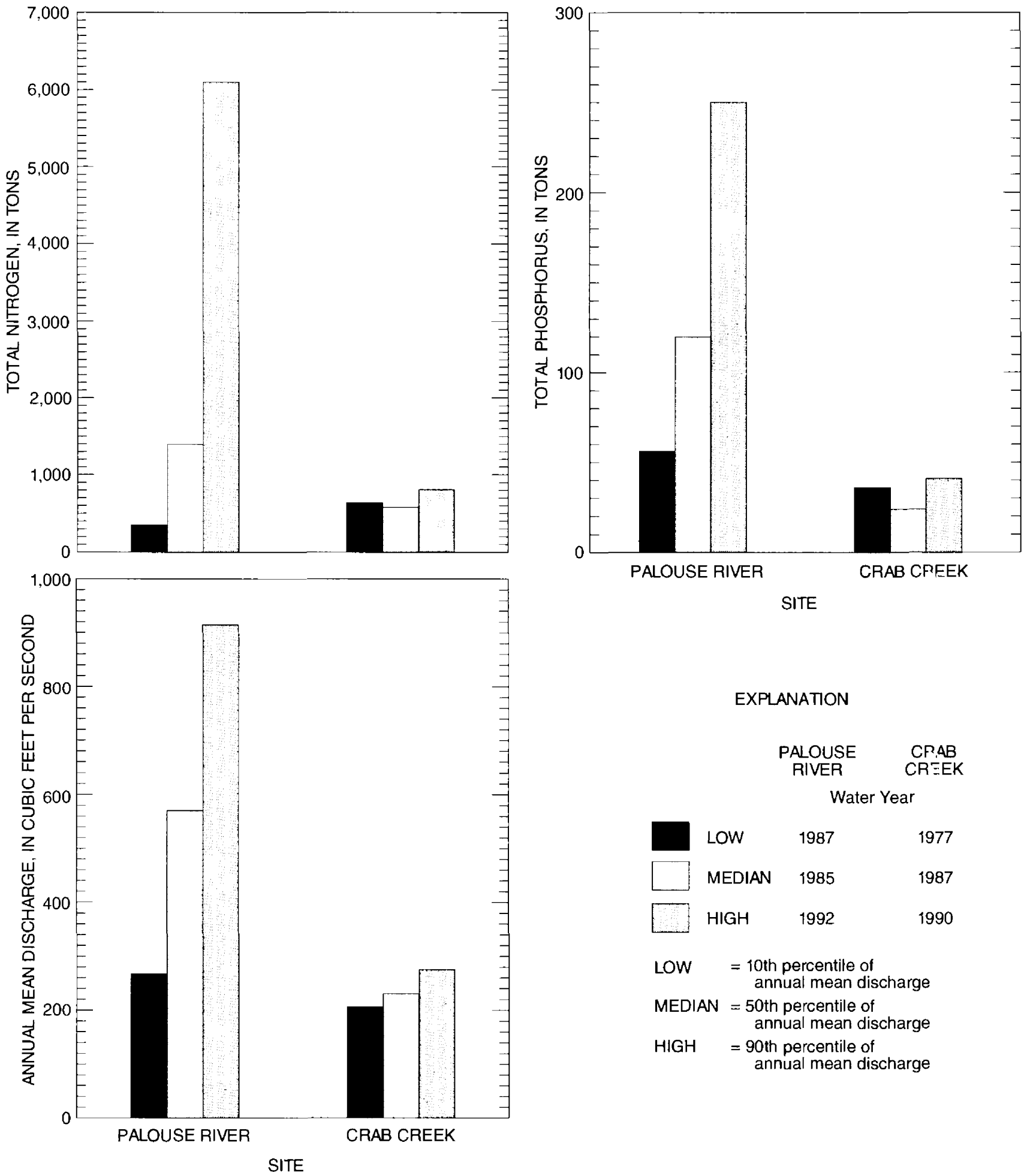

Figure 28.--Annual loads of total nitrogen and total phosphorus and annual mean discharges associated with low, median, and high annual flows in Palouse River at Hooper and in Crab Creek near Beverly, Washington, (sites 90 and 5, figure 17).

Table 12.--*Results of two methods used to compute annual loads of total nitrogen and total phosphorus in Palouse River at Hooper, Wash., and Crab Creek near Beverly, Wash.*

[Model, annual load computed using a statistical model; Product, annual load computed as the product of annual mean discharge and the mean constituent concentration. Precision listed for model results is the approximate 95 percent confidence interval; low flow and high flow years are about the 10th and 90th percentiles, respectively, of annual mean discharges for the period of record]

Site	Water year	Hydro-logic condition	Annual mean discharge (cubic feet per second)	Nitrogen (tons per year)		Phosphorus (tons per year)	
				Model	Product	Model	Product
Palouse River	1987	low flow year	268	350±280	800	56±16	84
at Hooper,	1985	median flow year	571	1,400±750	1,700	120±30	180
Washington	1982	high flow year	915	6,100±2,300	2,700	250±87	290
Crab Creek	1977	low flow year	206	640±55	560	36±4	32
near Beverly,	1987	median flow year	231	580±83	620	24±3	36
Washington	1980	high flow year	276	810±89	740	41±6	43

For sites and constituents where there is some correlation between flow and concentration, the product method over-estimates the annual load for a low-flow year and under-estimates the annual load for a high-flow year (table 12). This is because the mean concentration, which was computed using concentration data for the period of record, overestimates concentrations for a low-flow year and underestimates concentrations during storms when much of the constituent transport occurs during a high-flow year. An example of this is shown in figure 22 for total nitrogen in Palouse River at Hooper.

If there is little correlation between flow and concentration, then differences between loads computed using the two methods are not as large as when there is a good correlation (table 12). For example, there was little correlation between flow and total phosphorus in both the Palouse River at Hooper and Crab Creek near Beverly and between flow and total nitrogen in Crab Creek near Beverly (fig. 22).

Loads of total nitrogen and phosphorus for surface-water sites in the Quincy-Pasco subunit were estimated for the period from March 1986 to February 1987, (a 1-year interval that includes the 1986 irrigation season) using the product method (fig. 29). For many of the sites, continuous flow data were available only for that period. The product method should produce the most accurate load estimates for canals (sites 50, 57, and 59, fig. 29), where there is little variation in concentrations of nitrogen and phosphorus. For Crab Creek near Beverly (site 5, fig. 29), comparisons between the product and statistical methods, as well as errors associated with the statistical method, are listed in table 12. Most of the other sites on figure 29 are wasteways where concentrations of nitrogen and phosphorus are typically lower during the irrigation season because irrigation return flows and ground-water seepage are diluted with unused irrigation water. For these sites, the product method will likely overestimate the actual load because (1) the mean concentrations of nitrogen and phosphorus in wasteways are usually higher than actual concentrations during the irrigation season, and (2) most of the flow is during the irrigation season when concentrations are lowest.

Estimates of annual loads of nitrogen and phosphorus in the Columbia River below Priest Rapids Dam (a USGS monitoring site) also were made using the product method. The combined loads of total nitrogen and phosphorus from Crab Creek near Beverly and the WB 5, PE 16.4, and Esquatzel Wasteways are about 3.4 percent and 0.7 percent, respectively, of the corresponding annual loads of total nitrogen and phosphorus in the Columbia River below Priest Rapids Dam (fig. 29). These four drainage areas, combined, represent about 0.8 percent of the drainage area of the Columbia River below Priest Rapids dam. The largest amount of nitrogen applied as fertilizer in the study unit (about 48,600 tons per year or 132 pounds per acre in 1991) is in the Quincy-Pasco subunit (see table 4). This fertilizer application amount is

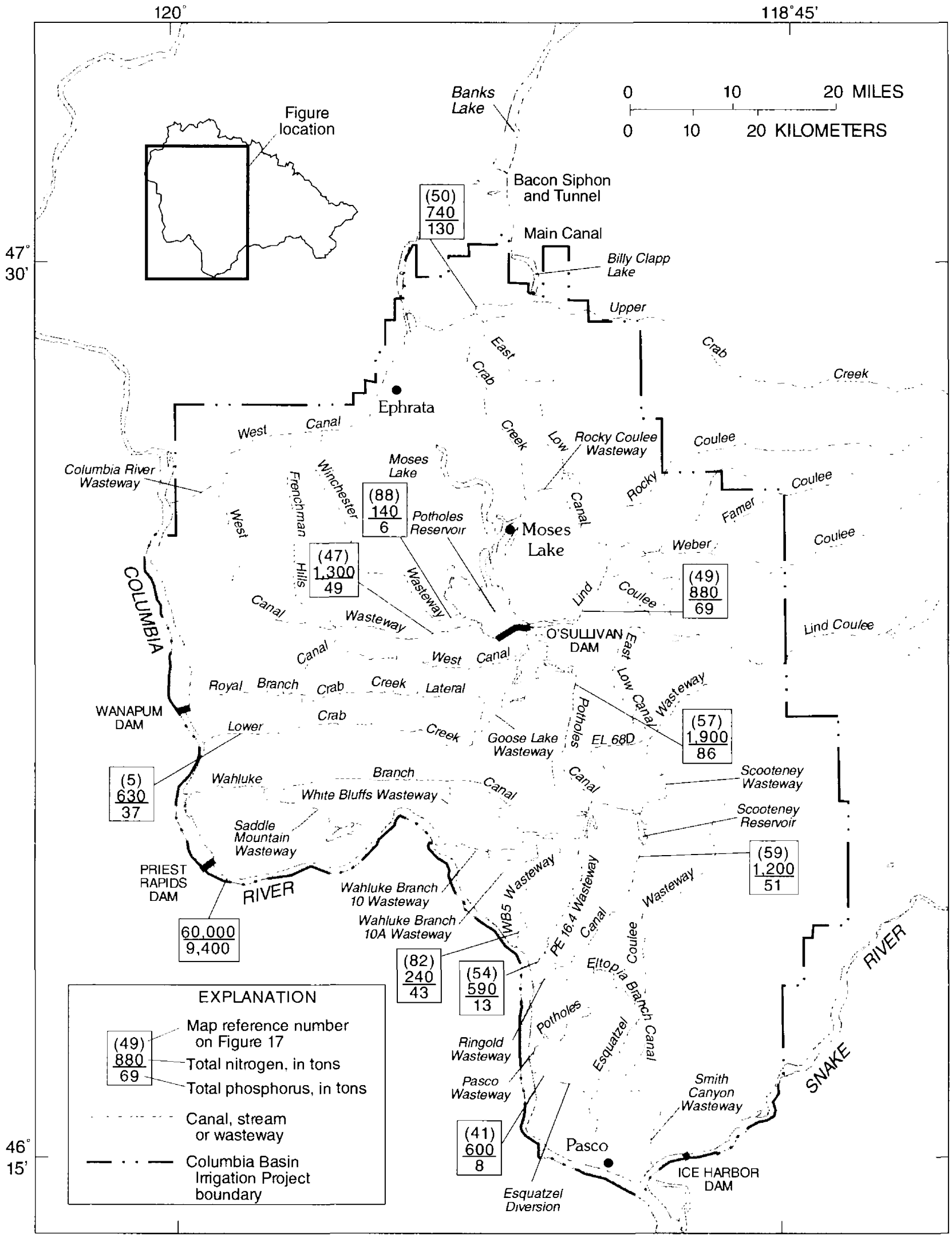

Figure 29.--Annual loads of total nitrogen and total phosphorus at sites in the Quincy-Pasco subunit and in the Columbia River below Priest Rapids Dam for March 1986 to February 1987. Base modified from the Bureau of Reclamation, 1982.

many times more than the estimated load of approximately 2,000 tons per year of nitrogen leaving the subunit in the four wasteways that drain to the Columbia River (fig. 29).

Estimates of Point and Non-point Sources of Nutrients

Non-point sources make up at least 97 percent of the estimated sources of nitrogen and phosphorus to the Quincy-Pasco and Palouse subunits (table 13). Applied nitrogen fertilizers account for about 82 and 87 percent of the non-point inputs of nitrogen to the Quincy-Pasco and Palouse subunits, respectively. In both subunits, nitrogen inputs from atmospheric deposition, computed as the product of the precipitation-weighted mean concentration of nitrogen in rainfall times the annual volume of rainfall, are less than 10 percent. Inputs of nitrogen from livestock are about 13 percent in the Quincy-Pasco subunit and about 6 percent in the Palouse subunit (table 13).

Compared with non-point sources of nitrogen, a larger percentage of phosphorus is derived from livestock: 28.6 percent in the Quincy-Pasco subunit and 18.4 percent in the Palouse subunit (table 13). Data were not available to estimate inputs of phosphorus from atmospheric deposition.

Although non-point sources account for most of the total inputs of nitrogen and phosphorus to the Palouse subunit, discharges from four of the sewage treatment plants in the study unit (fig. 13) account for most of the nitrogen and phosphorus loading to parts of the Palouse River Basin during low flow. The Pullman STP discharges to the South Fork of the Palouse River about 2 miles downstream from the city of Pullman and has the largest discharge of the four STPs. The Moscow STP is located along Paradise Creek, which is a tributary of the South Fork of the Palouse River. The Palouse STP discharges to the main channel of the Palouse River near the State line, and the Colfax STP discharges to the main channel of the Palouse River downstream from the confluence with the South Fork of the Palouse River (fig. 30).

The effects of discharges from STPs were assessed in three studies conducted by the Washington State Department of Ecology during low flow conditions from August to October. Discharge from the STPs and reaches of the streams above and below the STPs were sampled at Pullman in 1978 and 1986 (Joy, 1987); at Palouse during 1986 and 1987 (Kendra, 1988); and at Colfax in 1982 (Bill Yake, Washington State Department of Ecology, written commun., 1983). Data were collected for standard physical properties (streamflow, water temperature, conductivity, biochemical oxygen demand, turbidity, pH, and dissolved oxygen), concentrations of chlorine and nutrients, and some information about the relative abundances of benthic invertebrates and fish.

In the three studies, concentrations of phosphorous were reported as either total phosphorus or total phosphate, and concentrations of nitrogen species were reported as some combination of nitrate, nitrite, and ammonia. For this report, phosphorus concentrations were converted to common units (as phosphorus), but no distinction was made between possible differences in analytical methods. Nitrogen is considered to be the sum of nitrate, nitrite, and ammonia for the Pullman (Joy, 1987) and Palouse (Kendra, 1988) studies, and the sum of nitrate and ammonia for the Colfax study (Bill Yake, Washington State Department of Ecology, written commun., 1983). None of the studies determined concentrations of organic nitrogen, so the data represent only the amount of inorganic nitrogen in the STP discharges and streams. Although these studies did not determine concentrations of organic nitrogen, samples of effluent from the Moscow STP collected monthly from October 1988 through September 1989 indicate that about 80 percent of the nitrogen in the effluent was inorganic (J. M. Bellatty, Idaho Department of Health and Welfare, written commun., 1994).

The Moscow STP discharges to Paradise Creek, and during low flow most of the streamflow in Paradise Creek is STP effluent (Joy, 1987). The Moscow STP, through Paradise Creek, contributes more than 90 percent of the daily load of inorganic nitrogen and phosphorus entering the South Fork Palouse River at the confluence (fig. 30). The inorganic nitrogen load and the total phosphorus load from the Pullman STP are about 63 percent and 73 percent, respectively, of the combined loads from the STP and the river upstream from the STP.

Effluent from the Palouse STP contributes about 80 to 90 percent of the inorganic nitrogen and phosphorus loading to the main channel of the Palouse River immediately downstream, but the total amount of nutrients discharged by the Palouse STP is far smaller than the amount discharged by the Pullman STP (fig. 30). These relatively small nutrient loads from the Palouse STP contribute a large percentage of the total load in that reach of the Palouse River because nitrogen and phosphorus concentrations in the upper reaches of the Palouse River are much lower than nutrient concentrations in the South Fork Palouse River. The South Fork Palouse River contributes 93 percent of the daily load of inorganic nitrogen and 96 percent of the daily load of phosphorus entering the main

Table 13.--*Estimated annual inputs of nitrogen and phosphorus to parts of the Central Columbia Plateau study unit*
[--, no data; mi^2, square mile]

	Point sources			Non-point sources					
	Sewage treatment plants[1]	Industrial[2]	Total point sources	Imported irrigation water[3]	Fertilizer[4]	Livestock[5]	Atmospheric deposition[6]	Total non-point sources	Total
				Quincy-Pasco subunit					
Nitrogen									
Tons	173	352	525	740	31,900	5,080	909	38,700	39,200
Percent of total	0.4	0.9	1.3	1.9	81.5	13.0	2.3	98.7	100
Pounds per mi^2	118	239	357	503	21,700	3,450	618	26,300	26,600
Phosphorus									
Tons	148	--	148	128	3,210	1,400	--	4,740	4,890
Percent of total	3.0	--	3.0	2.6	65.8	28.6	--	97.0	100
Pounds per mi^2	101	--	101	87	2,190	950	--	3,220	3,320
				Palouse subunit					
Nitrogen									
Tons	131	0	131	0	26,300	1,900	1,970	30,200	30,300
Percent of total	0.4	0	0.4	0	86.8	6.3	6.5	99.6	100
Pounds per mi^2	104	0	104	0	20,800	1,500	1,550	23,900	24,000
Phosphorus									
Tons	81.5	0	81.5	0	2,650	616	--	3,270	3,350
Percent of total	2.4	0	2.4	0	79.2	18.4	--	97.6	100
Pounds per mi^2	64	0	64	0	2,100	487	--	2,580	2,650

[1] Flow data (Washington State Department of Ecology, written commun., 1992); concentration data (National Oceanic and Atmospheric Administration, 1993).

[2] Data are for surface water discharges from a single food processing plant in Quincy, Washington. Flow data (Washington State Department of Ecology, written commun., 1992); concentration data (table 3.1, p. 41, Bean and Runsten, 1993). There are six food processing plants located in the Quincy-Pasco subunit; nutrient inputs by land application of wastewater from these plants are not included in this report.

[3] Input computed as the product of the mean concentration of total nitrogen in samples collected from the Main Canal at Pinto Dam near Wilson Creek and amount of irrigation water delivered during 1986 (U.S. Bureau of Reclamation data).

[4] Estimates of fertilizer applications (J. Fletcher, West Virginia University, written commun., 1991) were prepared from county-level fertilizer sales data. Differences between application data in this table and those listed in table 4 are because (1) 1987 data were used in this table to be consistent with the reporting period for other sources, and (2) average annual applications per acre of crop land were estimated for each subunit using county-level data. The average rates were then multiplied by the total acres of crop land in a subunit to obtain the total amount of fertilizer applied in that subunit.

[5] Estimates based on 1987 animal population data (R. B. Alexander, U.S. Geological Survey, written commun., 1992).

[6] Computed as the product of the concentration of nitrogen in rainfall times the annual volume of rainfall in the subunit. The concentration of nitrogen in precipitation is the sum of the precipitation-weighted mean concentration of nitrate and ammonia in samples collected 1985-91 at Pullman, Washington (National Atmospheric Deposition Program, 1985-91).

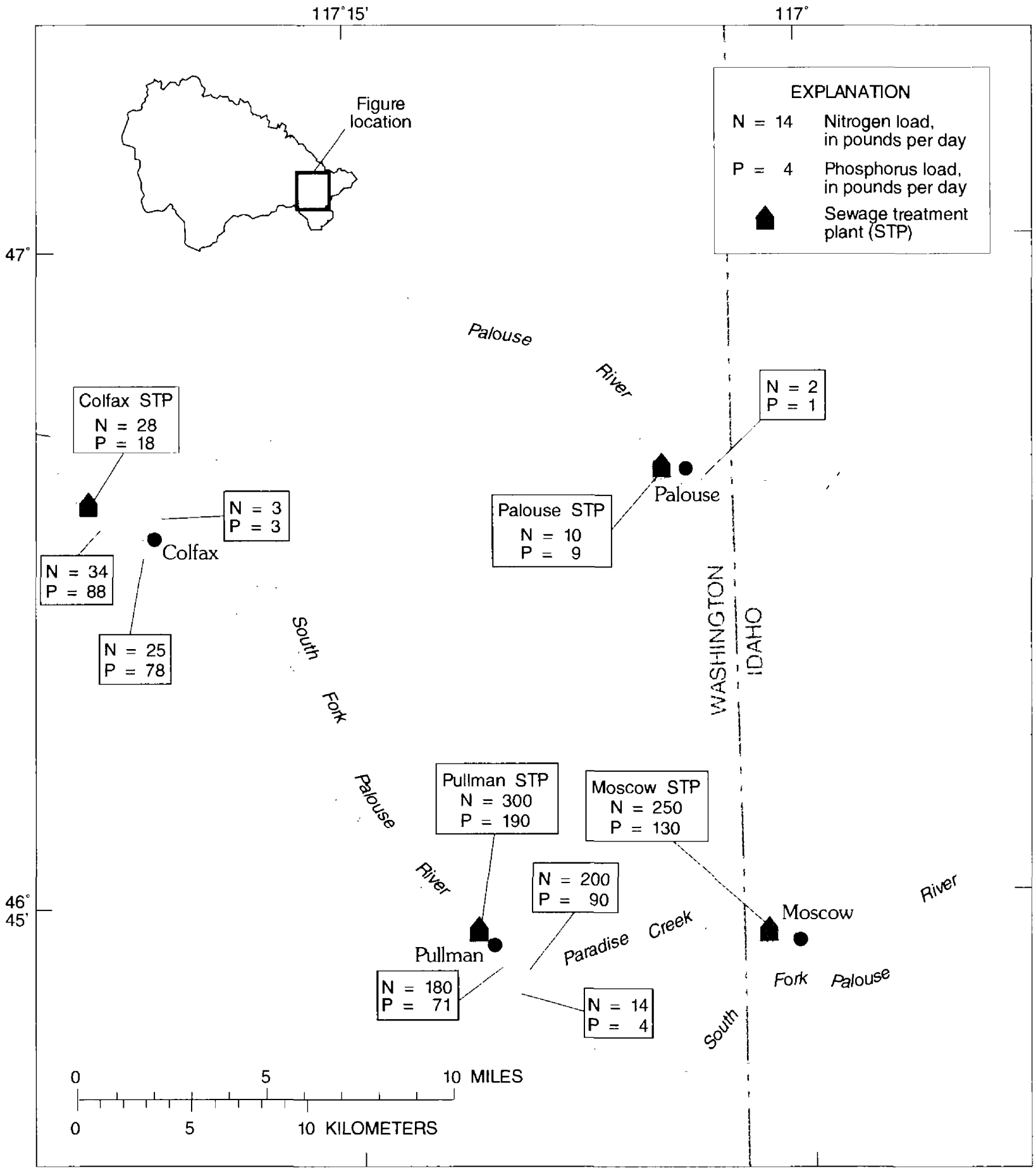

Figure 30.--Estimated daily loads of inorganic nitrogen and phosphorus from sewage treatment plants and in parts of the Palouse River system. The data were collected during low streamflow conditions; therefore only daily loads were calculated.

channel of the Palouse River at the confluence. The combined loads from the Colfax STP, 2 miles downstream from the confluence, and the loads in the river just upstream from the STP indicate that 45 percent of the inorganic nitrogen and 17 percent of the phosphorus just downstream from the STP are contributed by the STP.

Annual Loads of Suspended Sediment

Loads and yields of suspended sediment were computed for sites in the Palouse River Basin by Boucher (1970) using data collected from July 1961 through June 1965 (fig. 31, table 14). Constituent yield, defined as mass transported over a specified time interval per unit drainage area, is useful for comparing the amount of sediment lost per unit area at different sites.

Boucher determined that most of the sediment transport from the Palouse River Basin and the highest suspended-sediment concentrations occurred during winter storms. Three storms that occurred during the 4-year study period accounted for about 81 percent of the total 4-year suspended-sediment load from the basin. During these storms, suspended-sediment concentrations reached high levels. For example, 85,000 mg/L was measured in the South Fork of the Palouse River at Colfax (site 3492, fig. 31) during one of the storms. The maximum concentration measured at the Palouse River at Hooper near the mouth of the basin (site 3510, fig. 31) was 69,100 mg/L (Boucher, 1970). The maximum instantaneous suspended-sediment concentration of 69,100 mg/L at Palouse River at Hooper is larger than the maximum concentration of 15,300 mg/L listed in table 22 at the end of the report because the only suspended-sediment concentration data collected during the Boucher study that were entered into the computer data base were for samples that also were analyzed for nutrient concentrations.

During the Boucher study, the average annual suspended-sediment load at the Palouse River at Hooper was 1,572,000 tons and the yield was 630 tons per square mile (table 14). In the Palouse River Basin, the average annual yield ranged from 5 tons per square mile for the Cow Creek drainage in the western part of the basin to 2,200 tons per square mile in the central part. Although Cow Creek is in the Palouse River Basin, it is not in the Palouse subunit because there is little loess overlying the basalt in the Cow Creek Basin.

It was not possible to report or compute suspended-sediment loads at sites elsewhere in the study unit because little or no suspended-sediment concentration data were available. Suspended-solids data are available for many of the surface-water sites in the Quincy-Pasco subunit, but loads were not estimated because suspended-solids concentrations underestimate actual sediment transport and an analysis of how to compare results of the two different determinations is beyond the scope of this report.

CONCENTRATIONS OF PESTICIDES

Current knowledge of the distribution of pesticides in surface-water systems in the study unit is based on the analyses of water, bed sediment, and fish-tissue samples (table 15). Most samples analyzed for pesticides were collected in the Quincy-Pasco subunit. Some samples collected in the Palouse subunit have been analyzed for pesticides, but both the number of sites represented and the number of determinations are few. No pesticide data are available for samples collected in the North-Central subunit.

Most of the water and bed sediment samples from the Quincy-Pasco subunit were collected during 1974-76 by the Bureau of Reclamation and analyzed by the Washington State Division of Health Laboratory in Wenatchee. Fish-tissue samples from the Quincy-Pasco subunit were collected by the Bureau of Reclamation during 1975, 1977, 1978, and 1982, and by the U.S. Fish and Wildlife Service in 1982 and 1985. The numbers of fish-tissue samples collected are shown in table 15; the complete results of the analyses, some of which are summarized in this report, are presented in a separate report (Block, 1993).

In the Palouse subunit, all water samples except one were collected during 1979-80 by the Idaho Department of Health and Welfare and were analyzed by that agency. The exception, a sample from the Palouse River near Palouse was collected and analyzed by the U.S. Environmental Protection Agency in 1971. The only bed sediment sample from this subunit was collected in 1984 by the Washington State Department of Ecology at the Palouse River at Hooper.

Most water samples were analyzed to determine concentrations of one or more of the organochlorine insecticide compounds, the group of chemicals that includes DDT and its metabolites DDD and DDE (table 16). Analyses of water samples collected in the Quincy-Pasco subunit included more determinations for insecticides than for herbicides. As a result, these samples were not analyzed for some of the commonly used herbicides such as 2,4-D and related compounds. Some water samples collected in

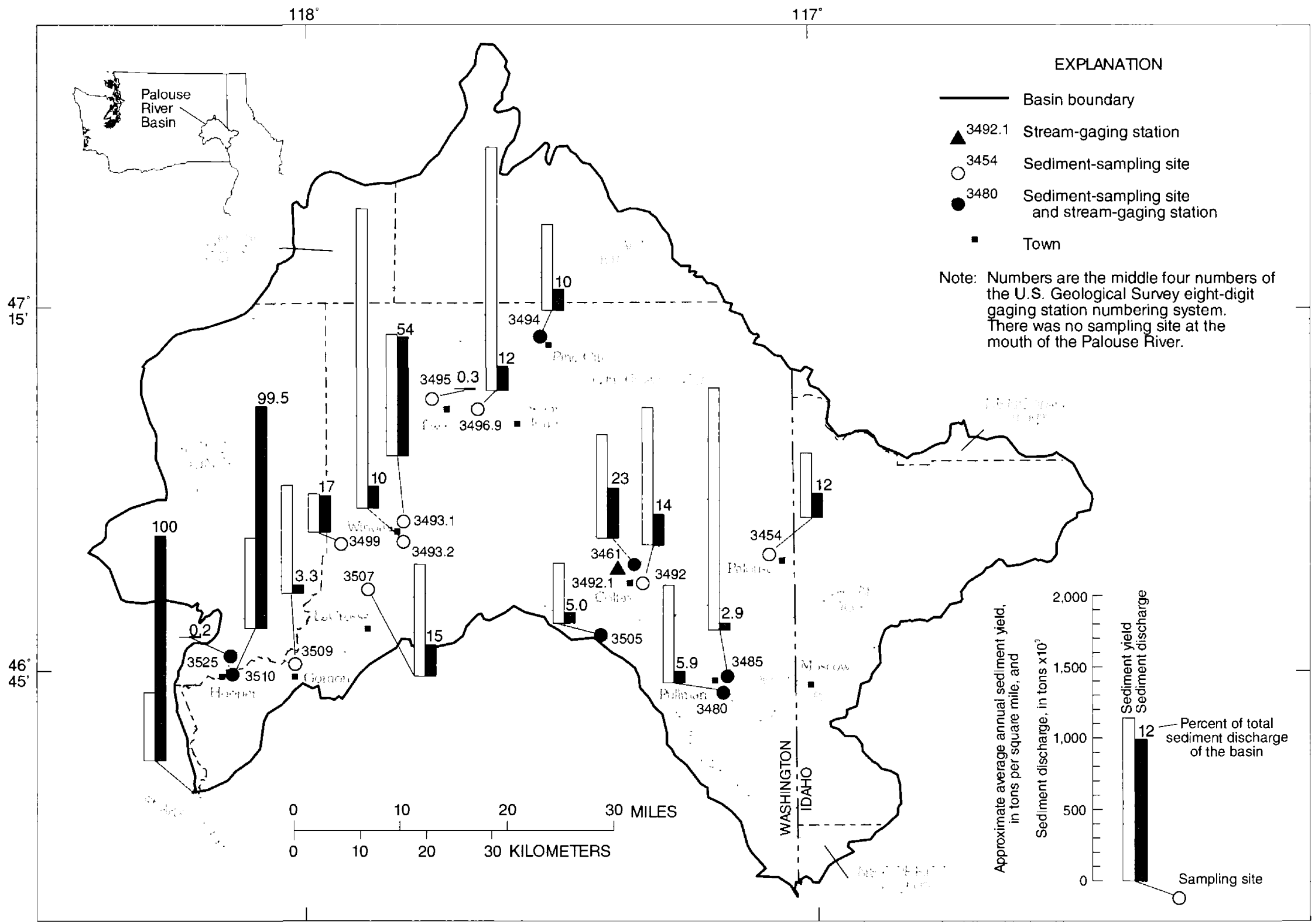

Figure 31.--Approximate average annual sediment loads and yields, and the percentage of the total sediment discharge of the Palouse River Basin, for the period from July 1, 1961 to June 30, 1965. Modified from Boucher, 1970.

Table 14.--*Average annual sediment loads and yields for the period July 1, 1961-June 30, 1965, at selected sites in the Palouse River Basin*

[USGS, U.S. Geological Survey; --, no map reference number. Data are from Boucher, 1970]

Reference number on figure 17	USGS gaging station number	Site	Drainage area (square miles)	Average annual load (tons)	Average annual yield (tons per square mile)
92	13345400	Palouse River at Palouse, Washington	398	180,000	460
--	13346100	Palouse River at Colfax, Washington	497	360,000	730
102	13348000	South Fork Palouse at Pullman, Washington	132	93,000	700
--	13348500	Missouri Flat Creek at Pullman, Washington	27.1	46,000	1,700
--	13349200	South Fork Palouse River at Colfax, Washington	228	220,000	980
--	13349310	Palouse River at Winona, Washington	986	850,000	860
--	13349320	Rebel Flat Creek at Winona, Washington	73.2	160,000	2,100
--	13349400	Pine Creek at Pine City, Washington	302	160,000	600
--	13349500	Rock Creek at Ewan, Washington	526	4,700	9
--	13349690	Cottonwood Creek below Pleasant Valley Creek near Ewan, Washington	110	187,000	1,700
--	13349900	Rock Creek near Winona, Washington	954	260,000	280
--	13350500	Union Flat Creek near Colfax, Washington	189	80,000	420
--	13350700	Union Flat Creek near La Crosse, Washington	294	230,000	800
--	13350900	Willow Creek at Gordon, Washington	67.4	52,000	770
90	13351000	Palouse River at Hooper, Washington	2,500	1,572,000	630
--	13352500	Cow Creek at Hooper, Washington	697	3,200	5

Table 15.--*Numbers of samples collected and determinations made for pesticide compounds in water, bed sediment, and fish tissue at locations in the Central Columbia Plateau study unit*

[Number of samples/number of determinations; W/W, wasteway; USGS, U.S. Geological Survey. Samples were analyzed for varying numbers of pesticide compounds. Data are from U.S. Environmental Protection Agency's Storage and Retrieval System (STORET)]

Reference number on figure 17	Site name	Water	Bed sediment	Fish tissue
Quincy-Pasco subunit				
5	Crab Creek near Beverly, Wash.	42/994	28/476	14/ 58
3	Crab Creek Lateral above Royal Lake, near Othello, Wash.	36/900	28/476	0/ 0
47	Frenchman Hills W/W at gaging station near Moses Lake, Wash.	34/850	27/459	27/111
49	Lind Coulee at Route 17 near Warden, Wash.	38/951	27/459	30/123
57	Potholes Canal at headworks near Warden, Wash.	24/600	0/ 0	0/ 0
66	Ringold W/W at Columbia River near Ringold, Wash.	36/900	29/493	0/ 0
86	West Canal 1 mile east of B-NE Road near Soap Lake, Wash.	22/550	0/ 0	0/ 0
88	Winchester Wasteway at gaging station near Moses Lake, Wash.	36/900	0/ 0	6/ 25
Palouse subunit				
97	Palouse River near Palouse, Wash.	1/ 9	0/ 0	0/ 0
101	South Fork Palouse River at Idaho-Washington State line	5/ 14	0/ 0	0/ 0
100	Paradise Creek at USGS gage near Moscow, Idaho	5/ 14	0/ 0	0/ 0
90	Palouse River at Hooper, Wash.	0/ 0	1/ 3	0/ 0

Table 16.--*Pesticides in surface-water samples in the Central Columbia Plateau study unit*

[Number of detections/number of determinations (median concentration); W/W, wasteway; USGS, U.S. Geological Survey; µg/L, micrograms per liter; epox., epoxide; --, no value. For sites where only one determination was above the published minimum reporting level, that concentration is reported instead of the median concentration. Some reported concentrations are below the published minimum reporting level. Samples were not filtered for any analyses]

Pesticide	Minimum reporting level (µg/L)	Crab Creek near Beverly, Wash. (µg/L)	Crab Creek Lateral near Othello, Wash. (µg/L)	Frenchman Hills W/W at gaging station near Moses Lake, Wash. (µg/L)	Lind Coulee W/W at Route 17 near Warden, Wash. (µg/L)	Potholes Canal at headworks near Warden, Wash. (µg/L)
HERBICIDES						
2,4-D	0.10	0/ 0(--)	0/ 0(--)	0/ 0(--)	0/ 0(--)	0/ 0(--)
2,4,5-T	0.05	0/ 0(--)	0/ 0(--)	0/ 0(--)	0/ 0(--)	0/ 0(--)
2,4,5-TP	0.05	0/ 0(--)	0/ 0(--)	0/ 0(--)	0/ 0(--)	0/ 0(--)
Cycloate	0.15	0/37(--)	0/36(--)	0/34(--)	0/38(--)	0/24(--)
Dicamba	1.0	0/ 0(--)	0/ 0(--)	0/ 0(--)	0/ 0(--)	0/ 0(--)
EPTC	0.15	0/37(--)	0/36(--)	0/34(--)	0/38(--)	0/24(--)
Perthane	0.10	0/37(--)	0/36(--)	0/34(--)	0/38(--)	0/24(--)
Trifluralin	0.03	0/37(--)	0/36(--)	0/34(--)	0/38(--)	0/24(--)
INSECTICIDES						
Aldicarb	0.07	0/37(--)	0/36(--)	0/34(--)	0/38(--)	0/24(--)
Aldrin	0.01	0/42(--)	0/36(--)	0/34(--)	0/38(--)	0/24(--)
Azodrin	0.25	0/37(--)	0/36(--)	0/34(--)	0/38(--)	0/24(--)
Alpha BHC	0.06	0/ 5(--)	0/ 0(--)	0/ 0(--)	0/ 0(--)	0/ 0(--)
Chlordane	0.005	1/ 5(1.3)	0/ 0(--)	0/ 0(--)	0/ 0(--)	0/ 0(--)
DDD	0.001	0/ 5(--)	0/ 0(--)	0/ 0(--)	0/ 0(--)	0/ 0(--)
p,p'-DDD	0.01	0/37(--)	0/36(--)	0/34(--)	0/38(--)	0/24(--)
DDE	0.001	1/ 5(0.002)	0/ 0(--)	0/ 0(--)	0/ 0(--)	0/ 0(--)
p,p'-DDE	0.01	2/37(0.042)	5/36(0.023)	2/34(0.019)	2/38(0.04)	2/24(0.029)
DDT	0.003	2/ 5(0.012)	0/ 0(--)	0/ 0(--)	0/ 0(--)	0/ 0(--)
o,p'-DDT	0.01	0/ 0(--)	0/ 0(--)	0/ 0(--)	1/ 1(0.050)	0/ 0(--)
p,p'-DDT	0.01	0/37(--)	0/36(--)	0/34(--)	1/38(0.029)	0/24(--)
Diazinon	0.05	0/37(--)	0/36(--)	0/34(--)	0/38(--)	0/24(--)
Dieldrin	0.01	3/42(0.001)	2/36(0.013)	0/34(--)	13/38(0.029)	0/24(--)
Disulfoton	0.05	0/37(--)	0/36(--)	0/34(--)	0/38(--)	0/24(--)
Endosulfan alpha	0.005	0/37(--)	2/36(0.021)	1/34(0.012)	1/38(0.01)	0/24(--)
Endosulfan beta	0.01	0/37(--)	1/36(0.026)	0/34(--)	0/38(--)	0/24(--)
Endrin	0.01	0/42(--)	0/36(--)	0/34(--)	0/38(--)	0/24(--)
Ethion	0.05	0/37(--)	0/36(--)	0/34(--)	0/38(--)	0/24(--)
Parathion	0.05	0/37(--)	0/36(--)	0/34(--)	0/38(--)	0/24(--)
Ethyl trithion	0.05	0/37(--)	0/36(--)	0/34(--)	0/38(--)	0/24(--)
Heptachlor	0.01	0/42(--)	0/36(--)	0/34(--)	0/38(--)	0/24(--)
Heptachlor epox.	0.001	0/ 4(--)	0/ 0(--)	0/ 0(--)	0/ 0(--)	0/ 0(--)
Lindane	0.01	4/42(0.002)	0/36(--)	0/34(--)	0/38(--)	0/24(--)
Malathion	0.05	0/37(--)	0/36(--)	0/34(--)	0/38(--)	0/24(--)
Methyl parathion	0.05	0/37(--)	0/36(--)	0/34(--)	0/38(--)	0/24(--)
Ronnel	0.05	0/37(--)	0/36(--)	0/34(--)	0/38(--)	0/24(--)
Toxaphene	0.25	0/42(--)	0/36(--)	0/34(--)	0/38(--)	0/24(--)

Table 16.--*Pesticides in surface-water samples in the Central Columbia Plateau study unit--continued*

Ringold W/W at Columbia River near Ringold, Wash. (µg/L)	West Canal 1 mile east of B-NE Road near Soap Lake, Wash. (µg/L)	Winchester W/W at gaging station near Moses Lake, Wash. (µg/L)	Paradise Creek at USGS gage at Moscow, Idaho (µg/L)	Palouse River near Palouse Wash. (µg/L)	South Fork Palouse River at Idaho-Wash. State line (µg/L)
0/ 0(--)	0/ 0(--)	0/ 0(--)	0/2(--)	0/0(--)	0/1(--)
0/ 0(--)	0/ 0(--)	0/ 0(--)	0/2(--)	0/0(--)	0/1(--)
0/ 0(--)	0/ 0(--)	0/ 0(--)	1/4(0.023)	0/0(--)	1/3(0.013)
0/36(--)	0/22(--)	0/36(--)	0/0(--)	0/0(--)	0/0(--)
0/ 0(--)	0/ 0(--)	0/ 0(--)	0/5(--)	0/0(--)	0/5(--)
0/36(--)	0/22(--)	0/36(--)	0/0(--)	0/0(--)	0/0(--)
0/36(--)	0/22(--)	0/36(--)	0/0(--)	0/0(--)	0/0(--)
0/36(--)	0/22(--)	0/36(--)	0/0(--)	0/0(--)	0/0(--)
0/36(--)	0/22(--)	0/36(--)	0/0(--)	0/0(--)	0/0(--)
0/36(--)	0/22(--)	0/36(--)	0/0(--)	1/1(0.001)	0/0(--)
0/36(--)	0/22(--)	0/36(--)	0/0(--)	0/0(--)	0/0(--)
0/ 0(--)	0/ 0(--)	0/ 0(--)	0/0(--)	0/0(--)	0/0(--)
0/ 0(--)	0/ 0(--)	0/ 0(--)	0/0(--)	0/0(--)	0/0(--)
0/ 0(--)	0/ 0(--)	0/ 0(--)	0/0(--)	1/1(0.001)	0/1(--)
0/36(--)	0/22(--)	0/36(--)	0/0(--)	0/0(--)	0/0(--)
0/ 0(--)	0/ 0(--)	0/ 0(--)	0/0(--)	1/1(0.001)	1/1(0.024)
0/36(--)	2/22(0.052)	2/36(0.021)	0/0(--)	0/0(--)	0/0(--)
0/ 0(--)	0/ 0(--)	0/ 0(--)	0/0(--)	1/1(0.003)	1/1(0.056)
0/ 0(--)	0/ 0(--)	0/ 0(--)	0/0(--)	0/0(--)	0/0(--)
0/36(--)	0/22(--)	0/36(--)	0/0(--)	0/0(--)	0/0(--)
0/36(--)	0/22(--)	0/36(--)	0/0(--)	0/0(--)	0/0(--)
0/36(--)	0/22(--)	0/36(--)	0/0(--)	1/1(0.01)	0/0(--)
0/36(--)	0/22(--)	0/36(--)	0/0(--)	0/0(--)	0/0(--)
0/36(--)	0/22(--)	0/36(--)	0/0(--)	0/0(--)	0/0(--)
0/36(--)	0/22(--)	0/36(--)	0/0(--)	0/0(--)	0/0(--)
0/36(--)	0/22(--)	0/36(--)	0/0(--)	1/1(0.003)	0/0(--)
0/36(--)	0/22(--)	0/36(--)	0/0(--)	0/0(--)	0/0(--)
0/36(--)	0/22(--)	0/36(--)	0/0(--)	0/0(--)	0/0(--)
0/36(--)	0/22(--)	0/36(--)	0/0(--)	0/0(--)	0/0(--)
0/36(--)	0/22(--)	0/36(--)	0/0(--)	1/1(0.001)	0/0(--)
0/ 0(--)	0/ 0(--)	0/ 0(--)	0/0(--)	1/1(0.001)	0/0(--)
0/36(--)	0/22(--)	0/36(--)	1/1(0.33)	1/1(0.001)	1/1(0.004)
0/36(--)	0/22(--)	0/36(--)	0/0(--)	0/0(--)	0/0(--)
0/36(--)	0/22(--)	0/36(--)	0/0(--)	0/0(--)	0/0(--)
0/36(--)	0/22(--)	0/36(--)	0/0(--)	0/0(--)	0/0(--)
0/36(--)	0/22(--)	0/36(--)	0/0(--)	0/0(--)	0/0(--)

the Palouse subunit were analyzed for 2,4-D (table 16). All bed sediment samples were analyzed for concentrations of one or more organochlorine insecticide compounds, and some determinations included commonly used organophosphorus insecticides, such as parathion and malathion (table 17). The bed sediment samples were not analyzed for herbicides. Fish tissue samples were analyzed for organochlorine insecticides.

Acute toxicity criteria were not exceeded for any of the pesticides analyzed. The organochlorine insecticide DDT and its metabolites were detected at concentrations above the chronic water-quality criterion for the protection of aquatic life (U.S. Environmental Protection Agency, 1991 and Washington State Administrative Code, 1992) at 9 of the 10 sites where water samples were analyzed for these compounds (DDT+DDE+DDD and p,p'-DDT in table 18); the overall frequency of detection was low, however (table 16). These compounds also were detected at five of six sites at which bed sediment samples were collected in the study unit (table 17).

In samples of whole fish, DDT and its metabolites were found in about 97 percent of samples collected in the Quincy-Pasco subunit (Block, 1993). Block compared concentrations found with U.S. Food and Drug Administration criteria for edible fish fillets and with National Academy of Sciences and National Academy of Engineers criteria for whole fish and found that most concentrations were not above criteria levels. The maximum observed concentration of DDT and its metabolites in a whole fish sample was 6.8 ppm (parts per million) in a yellow perch collected from Lind Coulee in 1978. This concentration exceeded the U.S. Food and Drug Administration (FDA) criterion of 5.0 ppm.

Dieldrin, a degradation product of the organochlorine insecticide aldrin, was found in water at concentrations above chronic standards at three of the nine sites sampled (table 18). Dieldrin was detected in about 43 percent of whole fish samples collected in the Quincy-Pasco subunit. Compared with DDT, there were fewer detections of dieldrin in whole fish, but concentrations were of somewhat greater concern (Block, 1993): the FDA criterion of 0.3 ppm was exceeded in four whole fish samples collected at Lind Coulee and Frenchman Hills Wasteway. The maximum observed concentration of dieldrin was 0.44 ppm.

Pesticides generally not detected in water samples include the organophosphorus insecticides, such as diazinon, malathion, methyl parathion, and parathion (table 16). Although these compounds are known to be used in the study unit (see table 6), the reason that none of these compounds was detected is not known. Many of the bed sediment samples also were analyzed for organophosphorus insecticides, but these compounds are generally not found in bed sediments and were not detected in those samples.

Because samples were collected monthly during 1974-76 by the Bureau of Reclamation, some information about seasonal variations in the occurrence of pesticide compounds in surface waters of the Quincy-Pasco subunit can be inferred by comparing numbers of detections with numbers of determinations. Numbers of determinations ranged from 425 in December to 675 in September, and pesticide compounds were detected 2 to 9 times in all months except October and November (fig. 32). The most detections occurred in April, which is at the beginning of the irrigation season when many pre-emergent herbicides are applied. Pesticide compounds were detected in surface waters during almost all months of the irrigation season, which ends about the middle of October. Pesticide compounds also were detected during winter months before March, which is at the start of irrigation season.

Detections of pesticide compounds throughout most of the year indicate that pesticide transport in the Quincy-Pasco subunit is not caused solely by irrigation return flows. Storm runoff and flux from the ground-water system are two other possible mechanisms that drive pesticide transport in surface waters. Many of the pesticide compounds analyzed for in the previous studies currently are not used, or are not used as much as other compounds (see table 5). Some of the compounds currently in use are less stable, but more soluble, than pesticides used in the past. These changes are likely to affect transport pathways: for example, the use of more soluble compounds may result in a larger flux of pesticides to surface waters from the shallow ground-water system and the flushing of soils during irrigation season.

EVALUATION OF THE DATA AND APPLICATION TO CONTINUING STUDY

This analysis of available data improves the scientific understanding of water quality in the Central Columbia Plateau and of some of the factors that affect water quality in the study unit. The information provided will be used to help design future sampling and enables better decisions about where and when to sample. Examination of the available data also has indicated areas in which more information is needed.

Table 17.--*Insecticides in bed sediment samples in the Central Columbia Plateau study unit*

[Number of detections/number of determinations (median concentration); W/W, wasteway; µg/kg, micrograms per kilogram; --, no value. For sites where only one determination was above the published minimum reporting level, that concentration is reported instead of the median concentration]

Insecticide (minimum reporting level, in µg/kg)	Frenchman Hills W/W at gaging station near Moses Lake, Wash. (µg/kg)	Lind Coulee W/W at Route 17 near Warden, Wash. (µg/kg)	Crab Creek Lateral near Othello, Wash. (µg/kg)	Crab Creek near Beverly, Wash. (µg/kg)	Ringold Wasteway at Columbia River near Ringold, Wash. (µg/kg)	Palouse River at Hooper, Wash. (µg/kg)
Aldrin (10)	0/27 (--)	0/27 (--)	0/28 (--)	0/28 (--)	0/29 (--)	0/0 (--)
Diazinon (50)	0/27 (--)	0/27 (--)	0/28 (--)	0/28 (--)	0/29 (--)	0/0 (--)
Dieldrin (10)	2/27 (6)	4/27 (8)	2/28 (7)	3/28 (3)	4/29 (2)	0/0 (--)
p,p'-DDD (10)	0/27 (--)	2/27 (3)	2/28 (6)	0/28 (--)	0/29 (--)	1/1 (2)
p,p'-DDE (10)	0/27 (--)	3/27 (7)	3/28 (11)	0/28 (--)	0/29 (--)	1/1 (3)
p,p'-DDT (10)	1/27 (1)	6/27 (10)	7/28 (11)	1/28 (1)	0/29 (--)	1/1 (3)
Endosulfan alpha (5)	0/27 (--)	0/27 (--)	0/28 (--)	0/28 (--)	0/29 (--)	0/0 (--)
Endosulfan beta (10)	0/27 (--)	0/27 (--)	0/28 (--)	0/28 (--)	0/29 (--)	0/0 (--)
Endrin (10)	0/27 (--)	0/27 (--)	0/28 (--)	0/28 (--)	0/29 (--)	0/0 (--)
Ethion (50)	0/27 (--)	0/27 (--)	0/28 (--)	0/28 (--)	0/29 (--)	0/0 (--)
Parathion (50)	0/27 (--)	0/27 (--)	0/28 (--)	0/28 (--)	0/29 (--)	0/0 (--)
Ethyl trithion (50)	0/27 (--)	0/27 (--)	0/28 (--)	0/28 (--)	0/29 (--)	0/0 (--)
Heptachlor (10)	0/27 (--)	0/27 (--)	0/28 (--)	0/28 (--)	0/29 (--)	0/0 (--)
Lindane (10)	0/27 (--)	0/27 (--)	0/28 (--)	0/28 (--)	0/29 (--)	0/0 (--)
Malathion (50)	0/27 (--)	0/27 (--)	0/28 (--)	0/28 (--)	0/29 (--)	0/0 (--)
Methyl parathion (50)	0/27 (--)	0/27 (--)	0/28 (--)	0/28 (--)	0/29 (--)	0/0 (--)
Toxaphene (250)	0/27 (--)	0/27 (--)	0/28 (--)	0/28 (--)	0/29 (--)	0/0 (--)

Table 18.--*Sites where concentrations of pesticide compounds exceeded water-quality criteria for the protection of aquatic life*

[--, criterion not determined; all criteria, except one, are from U.S. Environmental Protection Agency (1991). No acute toxicity criteria were exceeded]

Compound	Freshwater aquatic-life criteria, in micrograms per liter		Number of sites where compound was analyzed for	Site where criteria for chronic toxicity were exceeded	Map reference number
	Acute	Chronic			
Aldrin	3.0	--	9	None	
Chlordane	2.4	0.0043	1	Crab Creek near Beverly, Wash.	5
DDT+DDE+DDD[1]	1.1	0.001	9	Crab Creek near Beverly, Wash.	5
				Crab Creek Lateral at Crab Creek Wasteway near Othello, Wash.	3
				Frenchman Hills Wasteway at gaging station near Moses Lake, Wash.	47
				Lind Coulee at Route 17 near Warden, Wash.	49
				Potholes Canal at headworks near Warden, Wash.	57
				West Canal 1 mile east of B-NE Road near Soap Lake, Wash.	86
				Winchester Wasteway at gaging station near Moses Lake, Wash.	88
				Palouse River near Palouse, Wash.	97
				South Fork Palouse River at Idaho-Washington State line	101
p,p'-DDT	1.1	0.001	8	Lind Coulee at Route 17 near Warden, Wash.	49
Dieldrin	2.5	0.0019	9	Crab Creek Lateral at Crab Creek Wasteway near Othello, Wash.	3
				Lind Coulee at Route 17 near Warden, Wash.	49
				Palouse River near Palouse, Wash.	97
α Endosulfan	0.22	0.056	8	None	
β Endosulfan	0.22	0.056	8	None	
Endrin	0.18	0.0023	9	Palouse River near Palouse, Wash.	97
Heptachlor	0.52	0.0038	9	None	
Heptachlor epoxide	0.52	0.0038	2	None	
Lindane	2.0	0.08	11	Paradise Creek near Moscow, Idaho	100
Malathion	--	0.1	8	None	
Parathion	0.065	0.013	8	None	
Toxaphene	0.73	0.0002	8	None	

[1] Washington State criteria (Washington State Administrative Code, 1992).

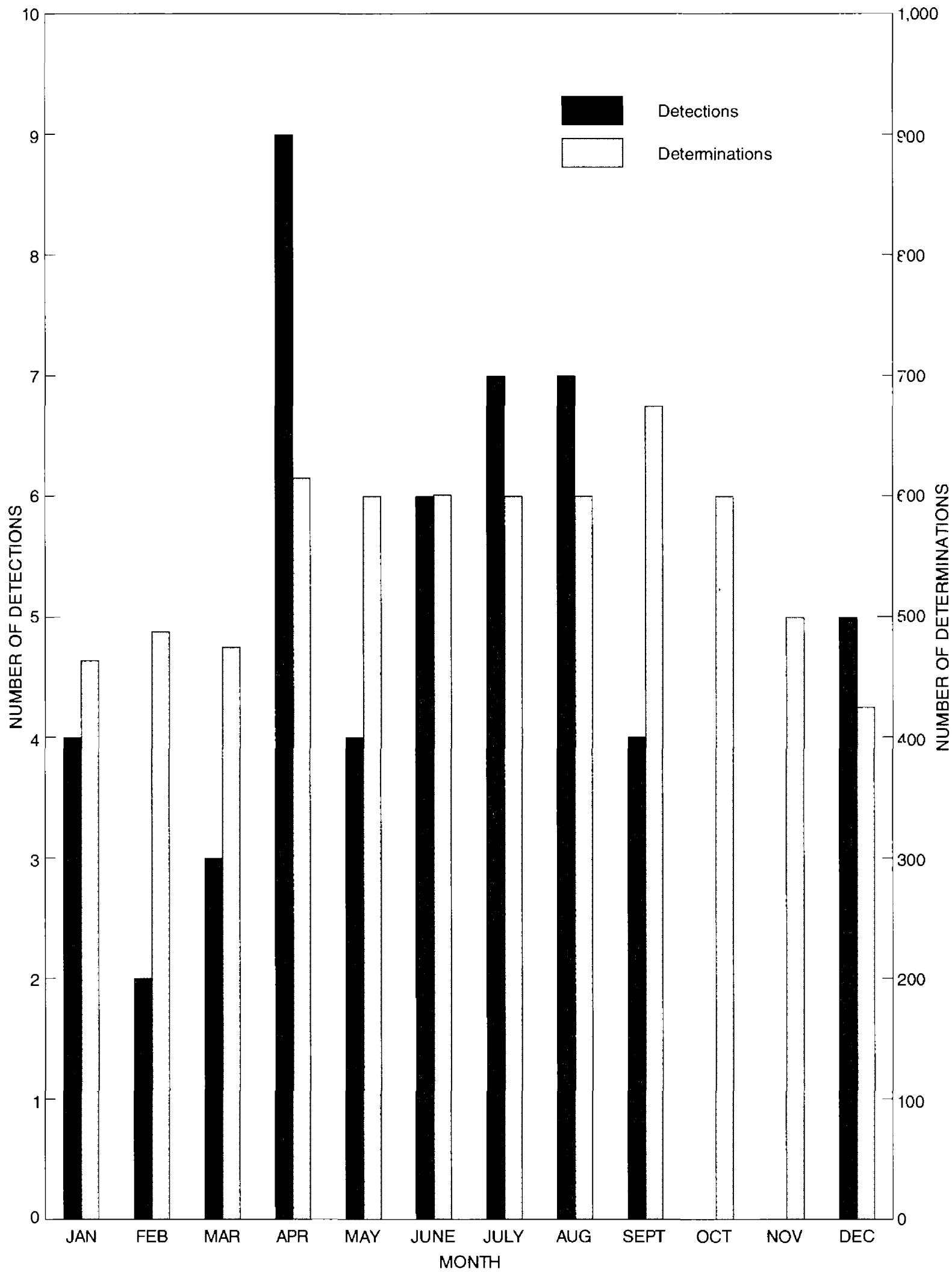

Figure 32.--Number of determinations for and detections of pesticide compounds in water by month at eight sites in the Quincy-Pasco subunit.

Limitations of the Available Data for Describing Water-Quality Conditions

For the purposes of this report, there were enough data available to aid in the development of a general understanding of the timing and spatial distribution of nutrient and suspended-sediment concentrations across much of the study unit. Streamflow data were not available for determining loads at most of the sites, and long-term data were available to determine trends at only six sites in the study unit. Pesticide data were available for 12 sites, and most of the determinations were for sites in the Quincy-Pasco subunit.

In order to achieve a better understanding of the water-quality conditions in the Central Columbia Plateau study unit, more data are needed in several places and times. Little is known about surface-water quality in the North-Central subunit, and more specifically about water-quality conditions in barren and range lands and in ground-water-irrigated farm land areas. The interaction between ground and surface waters in the study unit can be better understood by collecting more surface-water samples during low streamflow conditions throughout the study unit and by collecting more data outside the irrigation season, when concentrations of nutrients are higher in most of the irrigation drains and wasteways in the Quincy-Pasco subunit than during the irrigation season. Additional data will help to quantify the extent to which these waters are being diluted by unused irrigation delivery water and return flows during the irrigation season. More information is needed about the timing and amounts of pesticides applied in the study unit, including better information about those used for roadside weed control and those used for aquatic plant control. More consistent lab and reporting methods for these data will increase the amount of information available for evaluating and comparing water-quality conditions.

Preliminary Conceptual Model of Surface-Water Quality in the Study Unit

Understanding where and when the highest and lowest concentrations and loads occur throughout the study unit, and the probable explanations or hypotheses for these occurrences, provides the basis for a preliminary conceptual model of the source, cause, transport, fate, and effect of nutrients, suspended sediment, and pesticides in the study unit. Many of the water-quality conditions observed in the surface waters of the Central Columbia Plateau study unit relate to seasonal conditions and (or) upstream characteristics. There are many natural factors, such as climate and soil erodibility, and human factors such as agricultural practices and STPs, affecting water quality in the study unit. Fertilizer and pesticide application rates and timing also affect the occurrence and distribution of constituent concentrations throughout the study unit.

The Quincy-Pasco subunit receives the highest rates of nutrient and pesticide application in the Central Columbia Plateau study unit. This subunit also receives the smallest quantity of precipitation; however, the high rate and regularity of application of irrigation water to the land probably controls the transport of solutes in this subunit. Seasonal variations in concentrations of nutrients in the Quincy-Pasco subunit indicate interactions between surface and ground waters. It is likely that artificial recharge to the ground water, due to irrigation applications, carries nutrients and possibly pesticides to the water table. Shallow ground water is transported to surface drains and wasteways and is diluted by fresh delivery water or by runoff during the irrigation season. This explains the regular pattern of higher nutrient concentrations during the winter months in the Quincy-Pasco subunit.

There are not sufficient data available for identifying spatial or temporal variations in concentrations of nutrients, suspended sediment, or pesticides in the North-Central subunit. There is little precipitation over most of this part of the study unit, and less artificial recharge to the ground water from irrigation practices than in the Quincy-Pasco subunit. The interaction between surface and ground waters might play a major role in determining water-quality conditions in the intermittent streams of this subunit. Adjacent land uses, rather than dominant upstream land uses, also might have a greater effect on water quality.

Seasonal variations in concentrations of nutrients in the Palouse subunit relate to storms. Nutrients suspended sediment, and pesticides probably are transported to the surface waters of this subunit primarily by washoff from agricultural lands. There is more precipitation in the eastern part of the study unit, and the loess soils of this subunit are particularly subject to erosion during periods of runoff. Additionally, many of the STPs operating in the study unit are located along the major tributaries to the Palouse River: the STP effluent discharged to these tributaries contributes a substantial portion of the nutrient loading in this part of the study unit. Increasing streamflow dilutes the nutrient concentrations discharged from the STPs in the main channel of the Palouse River, but sampling locations along the main channel of the Palouse River are increasingly affected by agricultural activities.

Implications for Sampling Design

The surface-water systems in the Quincy-Pasco subunit are the most complicated in the study unit, especially in terms of the complexity of the interconnected canals, drains, and wasteways. Although the concentrations of nutrients may be larger when irrigation water is not delivered, the flux of nutrients is larger during the irrigation season when surface drains and wasteways carry more water. Delivery of large quantities of irrigation water to the Quincy-Pasco subunit regulates the surface-water drainage from the subunit. Because there is little year-to-year variation in the timing and quantities of irrigation water delivered to the subunit, flow characteristics in most waterways draining the subunit are predictable and relatively uniform from year to year. This characteristic makes it possible to estimate annual loads with fewer samples collected over a shorter period compared with waterways that transport a large percentage of constituents during storm runoff.

Available data indicate that pesticides are transported in surface drains and wasteways of the Quincy-Pasco subunit throughout most of the year. Intensive sampling for pesticides throughout the irrigation season, especially at the beginning of irrigation after pesticides are applied and when suspended-sediment loads are highest, would improve understanding of pesticide loading and factors affecting transport. Pesticides were detected most frequently during peak irrigation; however, because pesticides also were detected in surface drain and wasteway waters in winter, it is likely that storm runoff and ground-water seepage also transport pesticides.

In the Palouse subunit, storm runoff and runoff from snowmelt carry large amounts of nutrients and suspended sediment into rivers and streams. Sampling during periods of runoff is important to determine maximum concentrations and to obtain data for load estimates. Pesticides are likely to be transported to streams with storm runoff, but data were not available to confirm this hypothesis. During low-flow periods, parts of the South Fork Palouse River system receive most of their streamflow from STP discharges. In these parts of the river system, maximum concentrations of nutrients are found during low flow. For parts of the Palouse River system, there were no available nutrient data, and future sampling should include some of these locations.

Few data were available to evaluate surface-water quality in the North-Central subunit. Conditions at perennial stream sites in this subunit are similar to those in the Palouse subunit. This suggests that sampling strategies in these two subunits should be similar. Sampling during storm runoff will be essential for streams and wasteways with drainages that originate in the North-Central subunit but flow into the Quincy-Pasco subunit.

SUMMARY

The Central Columbia Plateau is 1 of 60 study units selected for investigation by the National Water Quality Assessment (NAWQA) Program. NAWQA is designed to describe the status of and trends in the quality of the Nation's water resources and to identify natural and human factors that affect water quality throughout the United States. This report reviews existing data and identifies spatial and temporal patterns in concentrations of nutrients and suspended sediment, loads of nutrients and suspended sediment, and the occurrence of pesticide compounds in the surface waters of the Central Columbia Plateau study unit.

The 13,000-square-mile study unit is part of the Columbia Plateau defined by massive basalt flows that cover parts of the states of Washington, Idaho, and Oregon, and is bordered by the Columbia and Snake Rivers and the drainage divides for upper Crab Creek and the Palouse River. Glacial deposits and windblown loess overlie the basalts; much of the loess was stripped away in ancient floods, leaving exposed basalt in parts of the study unit. There are some perennial streams and an extensive network of ephemeral streams in the study unit. The major surface-water systems in the study unit are the Columbia Basin Irrigation Project in the southwest and the Palouse River in the east. Precipitation ranges from less than 8 inches per year in the southwestern part of the study unit to more than 25 inches per year in the eastern part.

Differences in hydrology, geology, and land use distinguish the three subunits of the Central Columbia Plateau study unit. The importation of surface water for the Columbia Basin Irrigation Project and the controlled movement of this water through a system of canals and ditches dominate the hydrology of the Quincy-Pasco subunit in the arid southwestern part of the study unit. Most of the pasture, range lands, and ground-water-irrigated farm lands in the study unit are in the North-Central subunit, which includes the scablands areas of the upper Crab and Cow Creek Basins, the high-desert area of Douglas County, and the surficial basalt area of central Adams County. Most of the rolling loess hills of the eastern Palouse subunit are covered by dryland farming.

The major sources of nutrients in the study unit are agricultural fertilizers, livestock in feedlots and grazing on pasture or range lands, atmospheric deposition, and discharges from sewage treatment plants (STPs). Sediment erosion is associated with agricultural practices and range land grazing throughout the study unit; soils are eroded naturally by wind in the Quincy-Pasco subunit and by water during storms in the Palouse subunit. Pesticides are applied to crop lands and along roadsides throughout the study unit; in the Quincy-Pasco subunit, herbicides are released directly into canals and drainage ditches to control the growth of aquatic plants.

Water-quality data collected from 1959 to 1991 at 105 sites are summarized in this report. Most of the sites are located in the Quincy-Pasco and Palouse subunits; only five sites are located in the North-Central subunit, and few water-quality data were collected at these sites. Concentrations of nitrate, total nitrogen, ammonia, orthophosphate, total phosphorus, suspended sediment, suspended solids, 8 herbicides, and 29 insecticides are included in the analyses. Streamflow data are available for about two-thirds of the nutrient and suspended-sediment samples and for none of the pesticide samples.

The highest concentrations of nutrients occurred at sites in the study unit that are located downstream from STPs, food processing plants, or feedlots. The highest median concentrations of nutrients in the Quincy-Pasco subunit (9.6 mg/L of nitrate as nitrogen at Crab Creek Lateral near Othello and 4.1 mg/L of phosphorus at W 645W near Quincy) were in surface irrigation drains, and the lowest concentrations were in irrigation delivery waters (canals). The highest median concentrations of nutrients (8.0 mg/L of nitrate as nitrogen and 3.1 mg/L of phosphorus, both at Paradise Creek at Pullman) in the Palouse subunit were in the STP-affected tributaries, and the lowest concentrations were in the headwaters of the Palouse River. The highest suspended-sediment concentrations in the study unit were in the main channel of the Palouse River, and the lowest concentrations were in the irrigation delivery waters (canals) and in the headwaters of the Palouse River.

In both the Quincy-Pasco and Palouse subunits, nitrate concentrations increase downstream as a result of increasing contributions from agricultural runoff, return flows, and ground-water seepage, except as mitigated by dilution and biological uptake. As water in the irrigation project moves downstream, nitrate concentrations in large wasteways such as Esquatzel Coulee increase and decrease as agricultural runoff and unused delivery water are alternately discharged to the wasteways. Biological uptake reduces nitrate concentrations as water in the irrigation project passes through Potholes Reservoir and other lakes or impoundments.

There is a regular pattern of higher nitrate and total nitrogen concentrations during the winter months, the period of low streamflows in the Quincy-Pasco subunit and high streamflows in the Palouse subunit. This probably is the result of undiluted shallow ground-water contributions in the Quincy-Pasco subunit outside of the irrigation season, and to storm runoff in the Palouse subunit. Concentrations of phosphorus in the STP-affected tributaries of the Palouse River are highest during low streamflows from August through October. Higher concentrations of phosphorus for the other site classifications occur during high streamflows, when suspended-sediment concentrations also are highest throughout the study unit.

A seasonal Kendall test was used to determine whether significant trends in concentrations of nutrients and suspended solids exist at the five sites in the study unit that had sufficient data to perform these analyses. Where possible, tests were performed for two periods: 1980-90 and 1970-90. Results were mixed and no definite trends were noted, except possibly at Crab Creek Lateral, a surface irrigation drain, where decreasing concentrations of nitrogen and phosphorus from 1970 to 1990 may relate to a change in practices from gravity to sprinkler irrigation methods and to the planting of more orchards in the basin. Although sufficient data were not available to use the Kendall test, inspection of the time-concentration plot of the data for this site indicated an apparent downward trend in concentrations of suspended solids during the mid-1970's. This may be a result of decreased soil erosion from farm lands irrigated using sprinklers. The decrease in total phosphorus concentrations at this site is consistent with the decrease in concentrations of suspended solids.

The estimated loads of total nitrogen and total phosphorus for median annual streamflow at Crab Creek near Beverly, a major drainage of the Quincy-Pasco subunit, are 580 tons per year and 24 tons per year, respectively. The estimated annual loads of total nitrogen and phosphorus for median annual streamflow at the Palouse River at Hooper, which includes nearly all of the Palouse subunit, are 1,400 tons per year and 120 tons per year, respectively.

Non-point sources make up at least 97 percent of the estimated annual inputs of nitrogen and phosphorus to the Quincy-Pasco and Palouse subunits. In some locations, point sources may dominate water-quality conditions: discharges from the Moscow and Pullman STPs contribute most of the nutrient loading to the South Fork Palouse

River during low streamflows. Four of the main drainages from the Quincy-Pasco subunit (Crab Creek and the WB 5, PE 16.4, and Esquatzel Coulee Wasteways, which together represent approximately 0.8 percent of the drainage area of the Columbia River below Priest Rapids Dam) contribute about 3.4 percent and 0.7 percent, respectively, of the annual loads of total nitrogen and total phosphorus in the Columbia River below Priest Rapids Dam.

Streamflow characteristics in most of the Quincy-Pasco subunit are predictable and relatively uniform from year to year. In the Palouse subunit, storms and snowmelt that erode soil from farm lands carry large amounts of nutrients and suspended sediment into rivers and streams. During the 1960's, the average annual suspended-sediment load in the Palouse River at Hooper was 1,572,000 tons and the yield was 630 tons per square mile. Three storms that occurred during this 4-year study accounted for about 81 percent of the total 4-year suspended-sediment load from the basin.

In the Palouse subunit, pesticides are likely to be transported to streams with storm runoff. In the Quincy-Pasco subunit, detections of pesticide compounds throughout most of the year indicate that pesticide transport is not caused solely by irrigation return flows: storm runoff and influx from the ground-water system may transport pesticides to surface waters.

The organochlorine insecticide DDT and its metabolites were detected at concentrations above the chronic water-quality criterion for the protection of aquatic life at 9 of the 10 sites where water samples were collected during the 1970's and analyzed for these compounds; the overall frequency of detection was low, however. These compounds also were detected at five of six sites in the study unit at which bed sediment samples were collected in the study unit. Although DDT and its metabolites were found in about 97 percent of whole-fish samples collected in the Quincy-Pasco subunit, most concentrations were below criteria set by the U.S. Food and Drug Administration for edible fish fillets. The maximum observed concentration of DDT and its metabolites was 6.8 parts per million (ppm) for a yellow perch collected at Lind Coulee in 1978; this concentration exceeds the U.S. Food and Drug Administration (FDA) criterion of 5.0 ppm.

Dieldrin was detected in water at concentrations above chronic standards at four of the nine sites sampled, and was detected in about 43 percent of whole-fish samples collected in the Quincy-Pasco subunit. Compared with DDT, there were fewer detections of dieldrin in whole fish; however, the FDA criterion of 0.3 ppm for dieldrin was exceeded in four fish collected at Lind Coulee and Frenchman Hills Wasteway. The maximum observed concentration was 0.44 ppm.

More spatial, seasonal, and long-term data are needed to further improve understanding of water-quality conditions in the Central Columbia Plateau study unit. Better information is needed about the timing and amounts of pesticides applied in the study unit, and more samples need to be collected during periods of peak application and high streamflows. Additional water-quality samples collected during low streamflow conditions will improve the understanding of the interactions between ground and surface waters. Little is known about surface-water quality in the North-Central subunit or about water-quality conditions in range lands and in ground-water-irrigated farm lands. Conditions at perennial stream sites in the North-Central subunit are similar to those in the Palouse subunit, and sampling strategies in these two subunits should be similar. Little is known about water-quality conditions resulting from storm runoff in streams and wasteways that originate in the North-Central subunit but flow into the Quincy-Pasco subunit. More consistent field, laboratory, and reporting methods for all data will increase the amount of information available for evaluating and comparing water-quality conditions in the study unit.

SELECTED REFERENCES

Anderson, James R., Hardy, Ernest E., Roach. John T., and Witmer, Richard E., 1976, A land use and land cover classification system for use with remote sensor data: U.S. Geological Survey Professional Paper 964, 28 p.

Bain, R.C., 1985, Moses Lake clean lake project, stage: prepared for Moses Lake Irrigation and Rehabilitation District, March 1985, misc. pagination.

Bauer, H.H., and Vaccaro, J.J., 1990, Estimates of ground-water recharge to the Columbia Plateau regional aquifer system, Washington, Oregon, and Idaho, for predevelopment and current land-use conditions: U.S. Geological Survey Water-Resources Investigations Report 88-4108, 37 p., 2 pl.

Bean, William, and Runsten, David, 1993, Value added and subtracted--the processed potato industry in the Mid-Columbia Basin: Columbia Basin Institute, 112 p.

Bell, M.C., 1986, Fisheries handbook of engineering requirements and biological criteria: Fish passage development and evaluation program: U.S. Army Corps of Engineers, North Pacific Division, Portland, Oregon, 290 p.

Block, E., 1993, Aquatic biota within the Central Columbia Plateau NAWQA study unit, a review of existing information: U.S. Fish and Wildlife Service, Moses Lake, Washington, 92 p.

Bortleson, G.C., 1991, National water-quality assessment program mid-Columbia River basin, Washington and Idaho: U.S. Geological Survey Open-File Report 91-164 (Water Fact Sheet), 1 sheet.

Boucher, P.R., 1970, Sediment transport by streams in the Palouse River basin, Washington and Idaho, July 1961-June 1965: U.S. Geological Survey Water-Supply Paper 1899-C, 37 p.

Bureau of Reclamation, 1982, Columbia Basin Project water quality: U.S. Bureau of Reclamation, Pacific Northwest Region, Boise, Idaho, 53 p.

Census of Agriculture, 1987, Geographic area series, Washington state and county data, v. 1, part 47: U.S. Department of Commerce AC87-A-47, 292 p.

Cleveland, W.S., 1979, Robust locally weighted regression and smoothing scatterplots: Journal of the American Statistical Association, v. 74, n. 368, p. 829-836.

Cohn, T.A., Caulder, D.L., Gilroy, E.J., Zynjuk, L.D., and Summers, R.M., 1992, The validity of a simple statistical model for estimating fluvial constituent loads: an empirical study involving nutrient loads entering Chesapeake Bay: Water Resources Research, v. 28, n. 9, p. 2,353-2,363.

Crawford, G.C., Slack, J.R., and Hirsch, R.M., 1983, Nonparametric tests for trends in water-quality data using the statistical analysis system: U.S. Geological Survey Open-File Report 83-0550, 106 p.

Drost, B.W., Ebbert, James C., and Cox, Stephen E., 1993, Long-term effects of irrigation with imported water on water levels and water quality: U.S. Geological Survey Water-Resources Investigations Report 93-4060, 19 p.

Drost, B.W., and Whiteman, K.J., 1986, Surficial geology, structure, and thickness of selected geohydrologic units in the Columbia Plateau, Washington: U.S. Geological Survey Water Resources Investigations Report 84-4326, 11 pl.

Gianessi, L.P., and Puffer, C.A., 1991, Herbicide use in the United States: Quality of the Environment Division, Resources for the Future, Washington, D.C., 128 p.

_____1992a, Fungicide use in U.S. crop production: Resources for the Future, Washington, D.C., misc. pagination.

_____1992b, Insecticide use in U.S. crop production: Resources for the Future, Washington, D.C., misc. pagination.

Guy, H., and Norman, V., 1970, Field methods for measurement of fluvial sediment: U.S. Geological Survey, Techniques of Water-Resources Investigations, Book 3, C2, 59 p.

Hirsch, R.M., Alley, W.M., and Wilber, W.G., 1988, Concepts for a National Water-Quality Assessment Program: U.S. Geological Survey Circular 1021, 42 p.

Jones, Joseph L., and Wagner, Richard J., 1995, Water-quality assessment of the Central Columbia Plateau in Washington and Idaho--analysis of available nutrient and pesticide data for ground water, 1942-92: U.S. Geological Survey Water-Resources Investigations Report 94-4258, 119 p.

Joy, J., 1987, A water quality assessment and receiving water survey of the South Fork of the Palouse River at Pullman, September 1986: Washington State Department of Ecology, Water Quality Investigations Section, seg. 16-34-02, 40 p.

Kendra, Will, 1988, Quality of Palouse wastewater treatment plant effluent and impact of discharge to the North Fork of the Palouse River: Washington State Department of Ecology, Water Quality Investigations Section, seg. 16-34-01, 36 p.

Marshall, G.W., 1984, Aquatic insect-substratum relationships. Chapter 12, *in*, Resh, V.H., and Rosenbers, D.M., eds., The ecology of aquatic insects: New York, Pareger Publishers, p. 358-400.

Martin, Gary R., Smoot, James L., and White, Kevin D., 1992, A comparison of surface-grab and cross sectionally integrated stream-water-quality sampling methods: Water Environment Research, v. 64, no. 7, p. 866-876.

National Atmospheric Deposition Program, 1985-91, NADP/NTN annual data summary, precipitation chemistry in the United States 1986-88: National Resource Ecology Laboratory, Colorado State University, Fort Collins, Colorado, annual summary for years indicated, various pagination.

National Oceanic and Atmospheric Administration, 1993, Point source methods document: The National Coastal Pollutant Discharge Inventory, 19 p., 9 appendices.

Nelson, L.M., 1988, Surface-water resources for the Columbia Plateau, Washington, Oregon, and Idaho: U.S. Geological Survey Water-Resources Investigations Report 88-4105, 4 pl.

Palouse Cooperative River Basin Study, 1978: U.S. Government Printing Office 1979-797-658, 182 p.

Pelletier, Gregory J., 1993, South Fork Palouse River total maximum daily load of ammonia: Washington State Department of Ecology, Watershed Assessments Section, June 1993, WA-34-1020 and WA-34-1025, 49 p.

Tanaka, H.H., Hansen, A.J., Jr., and Skrivan, J.A., 1974, Digital model study of ground-water hydrology, Columbia River Basin Irrigation Project area, Washington: Washington State Department of Ecology Water-Supply Bulletin 40, 60 p.

Turney, G.L., 1986, Quality of ground water in the Columbia Basin, Washington, 1983: U.S. Geological Survey Water-Resources Investigations Report 85-4320, 172 p., 5 pls.

U.S. Department of Commerce, 1990, 1990 Census: U.S. Department of Commerce, Bureau of Census, 1990 Census of Population and Housing Public Law 94-171, digital data set.

U.S. Environmental Protection Agency, 1987, Quality criteria for water 1986: U.S. Environmental Protection Agency, Office of Water Regulations and Standards, Criteria and Standards Division, Washington, D.C., 440/5-86-001, 407 p.

_____1991, Quality criteria for water 1991: U.S. Environmental Protection Agency, Office of Water Regulations and Standards, Criteria and Standards Division, Washington, D.C., __ p.

U.S. Geological Survey, 1974, Channeled scablands of eastern Washington: U.S. Geological Survey Information Circular 72-2, 23 p.

Van Metre, P., and Seevers, P., 1991, Use of landsat imagery to estimate ground-water pumpage for irrigation on the Columbia Plateau in eastern Washington, 1985: U.S. Geological Survey Water-Resources Investigations Report 89-4157, 38 p.

Walters, K.L., and Grolier, M.J., 1960, Geology and ground-water resources of the Columbia Basin Project area, Washington: Washington Division of Water Resources Water-Supply Bulletin 8, v. 1, 542 p.

Washington Agricultural Statistics Service, 1991, Washington Agricultural Statistics 1990-1991 annual report: Washington Agricultural Statistics, Tumwater, Washington, 140 p.

Washington State Administrative Code, 1992, Water quality standards for surface waters of the State of Washington: Washington State Administrative Code, November 25, 1992, chapters 173-201A, 14 p.

Weis, Paul L., and Newman, William L., 1989, The channeled scablands of eastern Washington--the geologic story of the Spokane Flood: Eastern Washington University Press, Cheney, Washington, 0-910055-11-4, 24 p.

Whiteman, K.J., Vaccaro, J.J., Gonthier, J.B., and Bauer, H.H., 1994, The hydrogeologic framework and geochemistry of the Columbia Plateau aquifer system, Washington, Oregon, and Idaho: U.S. Geological Survey Professional Paper 1413-B, 73 p.

APPENDIX TABLES

Table 19.--*Pesticides applied on crops in the Central Columbia Plateau study unit (Gianessi and Puffer, 1991, 1992a, and 1992b)--Continued*

[lbs/yr, estimated pounds per year]

Crop	Fungicide	Quantity (lbs/yr)	Herbicide	Quantity (lbs/yr)	Insecticide	Quantity (lbs/yr)
Wheat	Thiabendazole	73,400	2,4-d	242,000	Disulfoton	53,700
	Benomyl	66,700	2,4-db	144,900	Ethyl Parathion	14,800
	Thiophanate Methyl	17,800	Terbutryn	88,900	Dimethoate	11,300
			Bromoxynil	79,800	Methyl Parathion	7,400
			Triallate	71,300		
			Diuron	45,200		
			Glyphosate	39,300		
			Dicamba	35,600		
			Metribuzin	18,500		
			Diclofop-methyl	14,900		
			Chlorsulfuron	4,400		
			Metsulfuron	2,400		
Potatoes	Mancozeb	46,200	Eptc	113,700	Ethoprop	82,900
	Iprodione	22,400	Metribuzin	27,000	Disulfoton	81,100
	Sulfur	21,200	Pendimethalin	17,100	Methamidophos	77,200
	Maneb	15,300	Metachlor	12,000	Phorate	76,500
	Chlorothalonil	13,600	Diquat	4,700	Diazinon	17,000
	Metiram	9,400	Trifluralin	4,300	Propargite	12,300
	Copper	8,000			Fonofos	10,000
	Metalaxyl	1,700			Endosulfan	5,000
	Triphenyltin Hyd	200			Oxamyl	4,200
					Azinphos-methyl	3,200
					Carbofuran	2,400
					Permethrin	2,200
					Esfenvalerate	200
Orchards	Sulfur	88,800	Oryzalin	29,400	Azinphos-methyl	88,700
	Ziram	44,700	Glyphosate	6,600	Chlorpyrifos	59,300
	Copper	11,100	Norflurazon	6,400	Carbaryl	36,200
	Mancozeb	9,300	Napropamide	3,200	Endosulfan	28,300
	Captan	8,200	2,4-d	2,200	Methyl Parathion	25,800
	Metiram	5,400	Dichlobenil	2,200	Phosmet	20,700
	Dodine	4,700	Simazine	1,500	Malathion	13,300
	Iprodione	4,000	Diuron	1,200	Propargite	6,400
	Chlorothalonil	2,600	Paraquat	700	Oxamyl	3,600
	Myclobutanil	2,300	Trifluralin	400	Oxythioquinox	3,500
	Triadimefon	1,900			Diazinon	3,100
	Fenarimol	1,200			Dimethoate	2,700
	Benomyl	600			Formetanate HCL	2,000
	Dcna	600			Methomyl	1,500
	Dinocap	500			Ethion	1,200
	Triforine	500			Methidathion	1,100
	Oxytetracycline	400			Amitraz	500
					Fenbutatin Oxide	500
					Disulfoton	400
					Carbofuran	300

Table 19.--*Pesticides applied on crops in the Central Columbia Plateau study unit (Gianessi and Puffer, 1991, 1992a, and 1992b)--Continued*

[lbs/yr, estimated pounds per year]

Crop	Fungicide	Quantity (lbs/yr)	Herbicide	Quantity (lbs/yr)	Insecticide	Quantity (lbs/yr)
					Methamidophos	200
					Cyfluthrin	100
					Abamectin	100
Other field crops	Metalaxyl	100	Eptc	79,000	Propargite	32,300
			Dcpa	47,800	Aldicarb	17,100
			Propham	28,600	Phosmet	4,700
			Alachlor	21,900	Dicofol	3,600
			Trifluralin	19,900	Chlorpyrifos	2,900
			Diuron	14,300	Disulfoton	2,700
			Metachlor	13,200	Malathion	2,000
			Triallate	10,900	Carbaryl	1,700
			Terbacil	5,300	Acephate	1,400
			Ethalfluralin	4,600	Oxydemeton-methyl	200
			Diquat	4,200		
			2,4-d	4,200		
			Dicamba	4,200		
			Bentazon	3,700		
			Simazine	3,600		
			2,4-db	2,800		
			Mcpa	2,400		
			Pendimethalin	2,200		
			Glyphosate	1,800		
			Metribuzin	1,500		
			Endothall	1,200		
			Napropamide	600		
			Paraquat	100		
			Oxyfluorfen	100		
Vegetables	Mancozeb	5,100	Eptc	20,600	Chlorpyrifos	19,300
	Chlorothalonil	2,000	Vernolate	14,300	Disulfoton	12,600
	Iprodione	1,600	Dcpa	11,500	Malathion	6,600
	Dcna	600	Dinoseb	11,200	Carbaryl	5,000
	Metalaxyl	300	Alachlor	8,400	Diazinon	4,000
	Vinclozolin	100	Simazine	5,000	Fonofos	3,200
			Metribuzin	4,900	Permethrin	2,700
			Trifluralin	4,800	Ethion	2,500
			2,4-d	4,300	Methyl Parathion	2,100
			Glyphosate	4,100	Methomyl	1,900
			Metachlor	4,000	Phosmet	1,000
			Diuron	3,700	Mevinphos	500
			Linuron	3,700	Azinphos-methyl	500
			Atrazine	1,000	Dimethoate	200
			2,4-db	400		
			Bromoxynil	300		
			Sethoxydim	200		
			Dicamba	200		
			Pendimethalin	200		

Table 19.--*Pesticides applied on crops in the Central Columbia Plateau study unit (Gianessi and Puffer, 1991, 1992a, and 1992b)--Continued*

[lbs/yr, estimated pounds per year]

Crop	Fungicide	Quantity (lbs/yr)	Herbicide	Quantity (lbs/yr)	Insecticide	Quantity (lbs/yr)
			Bentazon	100		
			Oxyfluorfen	100		
Corn			Eptc	50,300	Chlorpyrifos	4,100
			Atrazine	29,600	Methyl Parathion	500
			Vernolate	16,800		
			Alachlor	14,800		
			Metachlor	7,400		
			2,4-d	5,900		
			Cyanazine	1,500		
			Dicamba	600		
			Glyphosate	600		

Table 20.--*Characteristics of water-quality sampling locations in the Central Columbia Plateau study unit with at least 10 samples for nutrients or suspended sediment, or any sample for pesticides*

[W/W, wasteway; N-C, North-Central; Q-P, Quincy-Pasco; PL, Palouse; canal, irrigation delivery water; drain, surface irrigation drain; natural, natural flow; wasteway, irrigation wasteway; main channel, main channel of the Palouse River; headwaters, headwaters of the Palouse River; STP-affected, sewage-treatment plant affected tributaries of the Palouse River; mi^2, square miles; --, not determined; SW-irrigated farming, surface-water irrigated farming; GW-irrigated farming, ground-water irrigated farming; USGS, U.S. Geological Survey]

Reference number on figure 17	Station name	Drainage area (mi^2)	Subunit	Site classification	Major land uses in basin: 50 percent or more of basin	Major land uses in basin: 10-50 percent of basin
1	Crab Creek at Irby, Wash.	--	N-C	natural	dryland farming	barren and range
2	Crab Creek at McManamon Road near Othello, Wash.	--	Q-P	wasteway	--	--
3	Crab Creek Lateral above Royal Lake near Othello, Wash.	56	Q-P	drain	SW-irrigated farming	--
4	Crab Creek Lateral W/W, unit 88 block 88, near Othello, Wash.	--	Q-P	drain	SW-irrigated farming	--
5	Crab Creek near Beverly, Wash.	386	Q-P	wasteway	barren and range	SW-irrigated farming
6	Crab Creek near Moses Lake, Wash.	--	Q-P	wasteway	dryland farming	barren and range; SW-irrigated farming
7	Crab Creek near Othello, Wash.	--	Q-P	wasteway	barren and range	SW-irrigated farming; dryland farming
8	Crab Creek near Smyma, Wash.	--	Q-P	wasteway	barren and range	SW-irrigated farming; dryland farming
9	D 20-131 surface drain outlet to PE 16.4 near Basin City, Wash.	--	Q-P	drain	SW-irrigated farming	--
10	DCC 1 at Red Rocky Coulee Road near Royal City, Wash.	--	Q-P	drain	barren and range	--
11	DE 14-179 drain near Othello, Wash.	--	Q-P	drain	SW-irrigated farming	--
12	DE 15-146 drain at Bellview Drive Road near Richland, Wash.	--	Q-P	drain	SW-irrigated farming	--
13	DE 72-141 drain at 9-NW Road near Quincy, Wash.	--	Q-P	drain	SW-irrigated farming	--
14	DPE 215 at Route 26 near Othello, Wash.	--	Q-P	drain	--	--
15	DW 239B drain at West Canal near George, Wash.	--	Q-P	drain	SW-irrigated farming	--
16	DW 272A drains block 86 near Royal Camp, Wash.	--	Q-P	drain	SW-irrigated farming	--
17	DW 272A1 drains block 86 near Royal Camp, Wash.	--	Q-P	drain	SW-irrigated farming	--
18	East Low Canal at Moses Lake, Wash.	--	N-C	canal	--	--
19	EL 25A W/W at pumping plant near Moses Lake, Wash.	--	Q-P	wasteway	SW-irrigated farming	--
20	EL 68.3 W/W 1 at end in Lind Coulee W/W near Warden, Wash.	--	Q-P	wasteway	SW-irrigated farming	--
21	EL 68D wasteway near Othello, Wash.	146	Q-P	drain	--	dryland farming; SW-irrigated farming; GW-irrigated farming

Table 20.--*Characteristics of water-quality sampling locations in the Central Columbia Plateau study unit with at least 10 samples for nutrients or suspended sediment, or any sample for pesticides--Continued*

[W/W, wasteway; N-C, North-Central; Q-P, Quincy-Pasco; PL, Palouse; canal, irrigation delivery water; drain, surface irrigation drain; natural, natural flow; wasteway, irrigation wasteway; main channel, main channel of the Palouse River; headwaters, headwaters of the Palouse River; STP-affected, sewage-treatment plant affected tributaries of the Palouse River; mi^2, square miles; --, not determined; SW-irrigated farming, surface-water irrigated farming; GW-irrigated farming, ground-water irrigated farming; USGS, U.S. Geological Survey]

Reference number on figure 17	Station name	Drainage area (mi^2)	Subunit	Site classification	Major land uses in basin: 50 percent or more of basin	Major land uses in basin: 10-50 percent of basin
22	Eltopia Branch Canal at EB W/W near Eltopia, Wash.	--	Q-P	canal	SW-irrigated farming	dryland farming
23	Esquatzel Coulee at east side State Road 17 at Mesa, Wash.	--	Q-P	wasteway	SW-irrigated farming	dryland farming
24	Esquatzel Coulee W/W at bridge west of Connell, Wash.	--	Q-P	wasteway	dryland farming	--
25	Esquatzel Coulee W/W at gaging station at Eltopia, Wash.	--	Q-P	wasteway	dryland farming	SW-irrigated farming
26	Esquatzel Coulee W/W at Sheffield Road at Mesa, Wash.	--	Q-P	wasteway	dryland farming	barren and range; SW-irrigated farming
27	Esquatzel Coulee W/W below 59.4 wasteway near Richland, Wash.	--	Q-P	wasteway	SW-irrigated farming	--
28	Esquatzel Coulee W/W below D18-97 drain near Connell, Wash.	--	Q-P	wasteway	SW-irrigated farming	barren and range
29	Esquatzel Coulee W/W below DPE 38 at Mesa, Wash.	--	Q-P	wasteway	SW-irrigated farming	dryland farming
30	Esquatzel Coulee W/W below DPE 38B drain at Mesa, Wash.	--	Q-P	wasteway	SW-irrigated farming	dryland farming
31	Esquatzel Coulee W/W below EB 15 W/W near Pasco, Wash.	--	Q-P	wasteway	SW-irrigated farming	--
32	Esquatzel Coulee W/W below EB 8 W/W near Eltopia, Wash.	--	Q-P	wasteway	SW-irrigated farming	dryland farming
33	Esquatzel Coulee W/W below EB Canal W/W near Eltopia, Wash.	--	Q-P	wasteway	SW-irrigated farming dryland farming	dryland farming
34	Esquatzel Coulee W/W below EL 85M W/W near Connell, Wash.	--	Q-P	wasteway	dryland farming	--
35	Esquatzel Coulee W/W below EL 85Z W/W near Connell, Wash.	--	Q-P	wasteway	dryland farming	--
36	Esquatzel Coulee W/W below PE 38 W/W at Mesa, Wash.	--	Q-P	wasteway	SW-irrigated farming	--
37	Esquatzel Coulee W/W below PE 38.9B5 W/W near Mesa, Wash.	--	Q-P	wasteway	SW-irrigated farming	--
38	Esquatzel Coulee W/W below PE 38.9E W/W near Mesa, Wash.	--	Q-P	wasteway	SW-irrigated farming	dryland farming

Table 20.--*Characteristics of water-quality sampling locations in the Central Columbia Plateau study unit with at least 10 samples for nutrients or suspended sediment, or any sample for pesticides--Continued*

[W/W, wasteway; N-C, North-Central; Q-P, Quincy-Pasco; PL, Palouse; canal, irrigation delivery water; drain, surface irrigation drain; natural, natural flow; wasteway, irrigation wasteway; main channel, main channel of the Palouse River; headwaters, headwaters of the Palouse River; STP-affected, sewage-treatment plant affected tributaries of the Palouse River; mi^2, square miles; --, not determined; SW-irrigated farming, surface-water irrigated farming; GW-irrigated farming, ground-water irrigated farming; USGS, U.S. Geological Survey]

Reference number on figure 17	Station name	Drainage area (mi^2)	Subunit	Site classification	Major land uses in basin: 50 percent or more of basin	Major land uses in basin: 10-50 percent of basin
39	Esquatzel Coulee W/W Below PE 38.9P2 W/W near Eltopia, Wash.	--	Q-P	wasteway	SW-irrigated farming	dryland farming
40	Esquatzel Coulee W/W below PE 59 W/W near Eltopia, Wash.	--	Q-P	wasteway	SW-irrigated farming	--
41	Esquatzel Diversion Canal at Columbia River near Richland, Wash.	--	Q-P	wasteway	--	SW-irrigated farming; dryland farming; barren and range
42	Esquatzel Diversion Canal below headworks near Pasco, Wash.	798	Q-P	wasteway	SW-irrigated farming	dryland farming
43	Esquatzel Diversion Canal below PE 59.4 W/W near Richland, Wash.	--	Q-P	wasteway	SW-irrigated farming	--
44	Esquatzel Diversion Canal below PE 59.4D W/W near Pasco, Wash.	--	Q-P	wasteway	SW-irrigated farming	--
45	Equatzel Diversion Canal below PE 59.4K W/W near Richland, Wash.	--	Q-P	wasteway	SW-irrigated farming	--
46	Esquatzel Diversion Canal below PE 66M W/W near Richland, Wash.	--	Q-P	wasteway	SW-irrigated farming	--
47	Frenchman Hills W/W at gaging station near Moses Lake, Wash.	202	Q-P	wasteway	--	SW-irrigated farming; GW-irrigated farming; dryland farming
48	Lewis Creek at Highway 155 near Coulee City, Wash.	--	N-C	natural	dryland farming	barren and range
49	Lind Coulee at Route 17 near Warden, Wash.	703	N-C	wasteway	dryland farming	GW-irrigated farming
50	Main Canal at Pinto Dam near Wilson Creek, Wash.	--	N-C	canal	barren and range	GW-irrigated farming
51	Mattawa Drain, Sec 3 T13N R24E near Mattawa, Wash.	18	Q-P	drain	SW-irrigated farming	dryland farming; barren and range
52	Old PE 64 W/W at Columbia River near Ringold, Wash.	--	Q-P	wasteway	SW-irrigated farming	--
53	PE 16.4 W/W at Adams-Franklin county line near Othello, Wash.	--	Q-P	wasteway	SW-irrigated farming	barren and range
54	PE 16.4 W/W at Columbia River near Ringold, Wash.	118	Q-P	wasteway	SW-irrigated farming	barren and range
55	PE 16.4 W/W at Hendricks Road near Basin City, Wash.	--	Q-P	wasteway	barren and range	--
56	PE 16.4M12 W/W at DPE 215 near Othello, Wash.	--	Q-P	wasteway	SW-irrigated farming	barren and range
57	Potholes Canal at headworks near Warden, Wash.	--	Q-P	canal	barren and range	SW-irrigated farming

Table 20.--*Characteristics of water-quality sampling locations in the Central Columbia Plateau study unit with at least 10 samples for nutrients or suspended sediment, or any sample for pesticides--Continued*

[W/W, wasteway; N-C, North-Central; Q-P, Quincy-Pasco; PL, Palouse; canal, irrigation delivery water; drain, surface irrigation drain; natural, natural flow; wasteway, irrigation wasteway; main channel, main channel of the Palouse River; headwaters, headwaters of the Palouse River; STP-affected, sewage-treatment plant affected tributaries of the Palouse River; mi^2, square miles; --, not determined; SW-irrigated farming, surface-water irrigated farming; GW-irrigated farming, ground-water irrigated farming; USGS, U.S. Geological Survey]

Reference number on figure 17	Station name	Drainage area (mi^2)	Subunit	Site classification	Major land uses in basin: 50 percent or more of basin	Major land uses in basin: 10-50 percent of basin
58	Potholes East Canal at mile 26.6 near Othello, Wash.	--	Q-P	canal	--	--
59	Potholes East Canal at mile 38.0 near Mesa, Wash.	--	Q-P	canal	SW-irrigated farming	--
60	Potholes East Canal at mile 65.8 near Richland, Wash.	--	Q-P	canal	--	--
61	Priest Rapids W/W, Sec 33 T15N near Mattawa, Wash.	--	Q-P	wasteway	SW-irrigated farming	barren and range; dryland farming
62	Quincy District W/W at West Canal near Quincy, Wash.	--	Q-P	wasteway	SW-irrigated farming	--
63	RB 5J W/W at Columbia River near Beverly, Wash.	--	Q-P	wasteway	--	--
64	RBC W/W at Lower Crab Creek Road at Beverly, Wash.	--	Q-P	wasteway	--	--
65	RCD W/W at O'Sullivan Road crossing near Moses Lake, Wash.	--	Q-P	wasteway	SW-irrigated farming	--
66	Ringold W/W at Columbia River near Ringold, Wash.	--	Q-P	wasteway	--	--
67	Rocky Coulee W/W near Moses Lake, Wash.	--	Q-P	wasteway	--	--
68	Rocky Ford Creek at Route 17 near Ephrata, Wash.	--	Q-P	natural	barren and range	dryland farming
69	Saddle Mountain W/W at Highway 24 near Mattawa, Wash.	28	Q-P	wasteway	SW-irrigated farming	barren and range; dryland farming
70	Sand Hollow, RB 4C W/W, Sec 28 T17N R23E near Beverly, Wash.	47	Q-P	wasteway	SW-irrigated farming	barren and range
71	Scooteney W/W at Scooteney Resevoir near Othello, Wash.	--	Q-P	wasteway	--	--
72	Surface runoff from irrigation block one near Richland, Wash.	12	Q-P	drain	SW-irrigated farming	dryland farming
73	W 35.9B W/W at end near Quincy, Wash.	--	Q-P	wasteway	SW-irrigated farming	--
74	W 61C W/W at Highway I-90 near Vantage, Wash.	--	Q-P	wasteway	--	--
75	W 645 Drain at I-SW Road, Sec34 T13N R25E near George, Wash.	--	Q-P	drain	barren and range	--
76	W 645W at R-NW Road near Quincy, Wash.	--	Q-P	drain	barren and range	food processing
77	W 69 Lateral near Royal City, Wash.	--	Q-P	canal	SW-irrigated farming	--
78	W 69.7 Lateral near Royal City, Wash.	--	Q-P	canal	SW-irrigated farming	--
79	W 69D Lateral near Royal City, Wash.	--	Q-P	canal	SW-irrigated farming	--

Table 20.--*Characteristics of water-quality sampling locations in the Central Columbia Plateau study unit with at least 10 samples for nutrients or suspended sediment, or any sample for pesticides--Continued*

[W/W, wasteway; N-C, North-Central; Q-P, Quincy-Pasco; PL, Palouse; canal, irrigation delivery water; drain, surface irrigation drain; natural, natural flow; wasteway, irrigation wasteway; main channel, main channel of the Palouse River; headwaters, headwaters of the Palouse River; STP-affected, sewage-treatment plant affected tributaries of the Palouse River; mi^2, square miles; --, not determined; SW-irrigated farming, surface-water irrigated farming; GW-irrigated farming, ground-water irrigated farming; USGS, U.S. Geological Survey]

Reference number on figure 17	Station name	Drainage area (mi^2)	Subunit	Site classification	Major land uses in basin: 50 percent or more of basin	Major land uses in basin: 10-50 percent of basin
80	W/W Ditch no.1, abandoned PE 65 W/W near Richland, Wash.	--	Q-P	canal	SW-irrigated farming	--
81	WB 5 Lateral at WB Canal, State Road 260 near Othello, Wash.	--	Q-P	canal	--	--
82	WB 5 W/W at Columbia River near Ringold, Wash.	51	Q-P	wasteway	SW-irrigated farming	--
83	WB5 G Lateral at WB5 G W/W near Ringold, Wash.	--	Q-P	canal	SW-irrigated farming	--
84	West Canal at Frenchman Hills W/W near Royal City, Wash.	--	Q-P	canal	barren and range	SW-irrigated farming
85	West Canal at mile 18.0 near Ephrata, Wash.	--	Q-P	canal	barren and range	--
86	West Canal 1 mile east of B-NE Road near Soap Lake, Wash.	--	Q-P	canal	SW-irrigated farming	--
87	West Canal near Royal City, Wash.	--	Q-P	canal	--	--
88	Winchester W/W at gaging station near Moses Lake, Wash.	188	Q-P	wasteway	--	barren and range; SW-irrigated farming; GW-irrigated farming; dryland farming
89	Palouse River above Buck Canyon at Colfax, Wash.	491	PL	main channel	dryland farming	--
90	Palouse River at Hooper, Wash.	2,463	PL	main channel	dryland farming	--
91	Palouse River at Laird Park near Harvard, Idaho	67	PL	headwaters	forest	--
92	Palouse River at Palouse, Wash.	--	PL	main channel	forest	dryland farming
93	Palouse River at Potlatch, Idaho	--	PL	main channel	forest	dryland farming
94	Palouse River at Princeton, Idaho	--	PL	main channel	forest	--
95	Palouse River below South Fork at Colfax, Wash.	--	PL	main channel	dryland farming	--
96	Palouse River near Diamond, Wash.	--	PL	main channel	dryland farming	forest
97	Palouse River near Palouse, Wash.	--	PL	main channel	forest	dryland farming
98	Palouse River near Potlatch, Idaho	--	PL	main channel	forest	--
99	Paradise Creek at Pullman, Wash.	34	PL	STP-affected	dryland farming	urban
100	Paradise Creek at USGS gage near Moscow, Idaho	--	PL	STP-affected	dryland farming	urban
101	South Fork Palouse River at Idaho-Washington State line.	--	PL	STP-affected	dryland farming	urban
102	South Fork Palouse River at Pullman, Wash.	--	PL	STP-affected	dryland farming	urban

Table 20.--*Characteristics of water-quality sampling locations in the Central Columbia Plateau study unit with at least 10 samples for nutrients or suspended sediment, or any sample for pesticides--Continued*

[W/W, wasteway; N-C, North-Central; Q-P, Quincy-Pasco; PL, Palouse; canal, irrigation delivery water; drain, surface irrigation drain; natural, natural flow; wasteway, irrigation wasteway; main channel, main channel of the Palouse River; headwaters, headwaters of the Palouse River; STP-affected, sewage-treatment plant affected tributaries of the Palouse River; mi^2, square miles; --, not determined; SW-irrigated farming, surface-water irrigated farming; GW-irrigated farming, ground-water irrigated farming; USGS, U.S. Geological Survey]

Reference number on figure 17	Station name	Drainage area (mi^2)	Subunit	Site classification	Major land uses in basin: 50 percent or more of basin	Major land uses in basin: 10-50 percent of basin
103	South Fork Palouse River below Sunshine Creek at Pullman, Wash.	--	PL	STP-affected	dryland farming	urban
104	South Fork Palouse River near Colfax, Wash.	274	PL	STP-affected	dryland farming	urban
105	South Fork Palouse River near Pullman, Wash.	--	PL	STP-affected	dryland farming	urban

Table 21.--*Number of suspended-sediment, nutrient, and pesticide determinations at locations in the Central Columbia Plateau study unit*

[W/W, wasteway; Ecology, Washington Department of Ecology; BR, Bureau of Reclamation; USGS, U.S. Geological Survey; EPA, U.S Environmental Protection Agency; IDEQ, Idaho Department of Health and Welfare, Division of Environmental Quality; Q_i, instantaneous discharge; Q_μ, daily-mean discharge; NO_3, nitrate; DNH_4, dissolved ammonia; TNH_4, total ammonia; TN, total nitrogen; TP, total phosphorus; PO_4, orthophosphate; solids, suspended solids; sed, suspended sediment; bed, bed sediments; --, no data]

Reference number on figure 17	Station name	Agency	Station number[1]	Period of record	Frequency of sampling[2]
1	Crab Creek at Irby, Wash.	Ecology	43A070	10/61-9/62	monthly
2	Crab Creek at McManamon road near Othello, Wash.	BR*	CBP079	5/72-1/91	quarterly*
3	Crab Creek Lateral above Royal Lake near Othello, Wash.	BR*	CBP030	10/67-4/91	quarterly*
4	Crab Creek Lateral W/W, unit 88 block 88, near Othello, Wash.	BR	CBP081	5/72-1/74	quarterly
5	Crab Creek near Beverly, Wash.	Ecology*	41A070	8/59-1/74,5/74-9/90, 11/91,3/92	varied*
6	Crab Creek near Moses Lake, Wash.	BR	CBP061	10/61-9/62, 10/67-1/91	varied
7	Crab Creek near Othello, Wash.	USGS	12472200	12/70-9/71	bimonthly
8	Crab Creek near Smyrna, Wash.	Ecology	41A075	10/62-9/65	monthly
9	D 20-131 surface drain outlet to PE 16.4 near Basin City, Wash.	BR	CBP067	5/74-11/78	quarterly
10	DCC 1 at Red Rocky Coulee Road near Royal City, Wash.	BR*	CBP080	5/72-2/91	quarterly*
11	DE 14-179 drain near Othello, Wash.	BR	CBP091	4/75-11/78	quarterly
12	DE 15-146 drain at Bellview Drive Road near Richland, Wash.	BR	CBP089	4/75-10/78	quarterly
13	DE 72-141 drain at 9-NW Road near Quincy, Wash.	BR	CBP092	4/75-11/78	quarterly
14	DPE 215 at Route 26 near Othello, Wash.	BR*	CBP078	5/72-1/91	quarterly*
15	DW 239B drain at West Canal near George, Wash.	BR	CBP066	Jul. & Nov. 7/74-11/78	biannually
16	DW 272A drains block 86 near Royal Camp, Wash.	USGS	12472350	12/70, 3/77-11/81	daily
17	DW 272A1 drains block 86 near Royal Camp, Wash.	USGS	12472300	3/77-11/81	daily
18	East Low Canal at Moses Lake, Wash.	EPA	EIM0N01	7/76, 3/77-9/77	weekly
19	EL 25A W/W at pumping plant near Moses Lake, Wash.	BR	CBP082	5/73-11/78	quarterly
20	EL 68.3 W/W 1 at end in Lind Coulee W/W near Warden, Wash.	BR	CBP027	Jul. & Nov. 7/74-11/78	biannually
21	EL 68D wasteway near Othello, Wash.	BR*	CBP065	3/70, 5/74-1/90, 11/91, 3/92	varied*
22	Eltopia Branch Canal at EB W/W near Eltopia, Wash.	BR*	CBP051	Jul. & Oct. 7/74-10/90	biannually*
23	Esquatzel Coulee at east side State Road 17 at Mesa, Wash.	BR	CBP505	12/75-11/81	quarterly
24	Esquatzel Coulee W/W at bridge west of Connell, Wash.	BR	CBP502	4/76-9/81	quarterly

Table 21.--*Number of suspended-sediment, nutrient, and pesticide determinations at locations in the Central Columbia Plateau study unit--Continued*

Total number of samples	Flow		Nutrients						Suspended sediment		Pesticides		
	Q_i	Q_m	NO_3	DNH_4	TNH_4	TN	TP	PO_4	solids	sed	water	bed	fish
11	--	11	11	--	--	--	--	11	--	--	--	--	--
83	--	--	83	82	--	41	83	83	77	--	--	--	--
194	75	--	130	129	--	52	129	130	96	--	900	476	--
10	--	--	10	10	--	--	10	10	5	--	--	--	--
688	159	398	600	118	229	144	329	469	224	7	994	476	58
191	109	191	189	104	50	53	178	166	114	--	--	--	--
18	4	--	18	--	18	17	16	15	--	--	--	--	--
32	--	20	32	--	--	--	--	32	--	--	--	--	--
24	--	--	24	23	--	--	24	24	23	--	--	--	--
83	--	--	83	82	--	41	83	83	76	--	--	--	--
23	--	--	23	22	--	--	23	23	23	--	--	--	--
17	--	--	17	16	--	--	17	17	17	--	--	--	--
23	--	--	23	22	--	--	23	23	22	--	--	--	--
83	--	--	83	82	--	41	83	83	77	--	--	--	--
10	--	--	10	9	--	--	10	10	9	--	--	--	--
2,266	725	1,252	1,582	56	56	1,581	1,739	70	--	1,694	--	--	--
2,237	695	1,241	1,579	57	57	1,578	1,734	73	--	1,661	--	--	--
26	--	--	26	--	--	--	24	--	--	--	--	--	--
29	--	--	29	28	--	--	29	29	28	--	--	--	--
10	--	--	10	9	--	--	10	10	9	--	--	--	--
951	221	367	618	77	--	580	611	90	72	652	--	--	--
34	18	--	34	33	--	20	34	34	33	--	--	--	--
31	1	--	31	31	--	5	31	31	30	--	--	--	--
25	10	--	25	25	--	--	25	25	24	--	--	--	--

Table 21.--*Number of suspended-sediment, nutrient, and pesticide determinations at locations in the Central Columbia Plateau study unit--Continued*

Reference number on figure 17	Station name	Agency	State number[1]	Period of record	Frequency of sampling[2]
25	Esquatzel Coulee W/W at gaging station at Eltopia, Wash.	BR	CBP511	3/76-11/81	quarterly
26	Esquatzel Coulee W/W at Sheffield Road at Mesa, Wash.	BR*	CBP088	5/74-1/91	quarterly*
27	Esquatzel Coulee W/W below 59.4 wasteway near Richland, Wash.	BR	CBP523	4/76-11/81	quarterly
28	Esquatzel Coulee W/W below D18-97 drain near Connell, Wash.	BR	CBP504	4/76-4/81	quarterly
29	Esquatzel Coulee W/W below DPE 38 at Mesa, Wash.	BR	CBP507	12/75-11/81	quarterly
30	Esquatzel Coulee W/W below DPE 38B drain at Mesa, Wash.	BR	CBP506	12/75-11/81	quarterly
31	Esquatzel Coulee W/W below EB 15 W/W near Pasco, Wash.	BR	CBP517	4/76-11/81	quarterly
32	Esquatzel Coulee W/W below EB 8 W/W near Eltopia, Wash.	BR	CBP513	12/75-11/81	quarterly
33	Esquatzel Coulee W/W below EB Canal W/W near Eltopia, Wash.	BR	CBP512	12/75-11/81	quarterly
34	Esquatzel Coulee W/W below EL 85M W/W near Connell, Wash.	BR	CBP501	3/76-9/81	quarterly
35	Esquatzel Coulee W/W below EL 85Z W/W near Connell, Wash.	BR	CBP503	4/76-9/81	quarterly
36	Esquatzel Coulee W/W below PE 38 W/W at Mesa, Wash.	BR	CBP508	12/75-11/81	quarterly
37	Esquatzel Coulee W/W below PE 38.9B5 W/W near Mesa, Wash.	BR	CBP514	12/75-11/81	quarterly
38	Esquatzel Coulee W/W below PE 38.9E W/W near Mesa, Wash.	BR	CBP509	12/75-11/78	quarterly
39	Esquatzel Coulee W/W Below PE 38.9P2 W/W near Eltopia, Wash.	BR	CBP510	12/75-11/78	quarterly
40	Esquatzel Coulee W/W below PE 59 W/W near Eltopia, Wash.	BR	CBP515	12/75-11/78	quarterly
41	Esquatzel Diversion Canal at Columbia River near Richland, Wash.	BR*	CBP052	5/74-1/91	quarterly*
42	Esquatzel Diversion Canal below headworks near Pasco, Wash.	BR	CBP516	12/75-11/81	quarterly
43	Esquatzel Diversion Canal below PE 59.4 W/W near Richland, Wash.	BR	CBP520	12/75-11/81	quarterly
44	Esquatzel Diversion Canal below PE 59.4D W/W near Pasco, Wash.	BR	CBP518	12/75-11/81	quarterly
45	Esquatzel Diversion Canal below PE 59.4K W/W near Richland, Wash.	BR	CBP519	12/75-11/78	quarterly
46	Esquatzel Diversion Canal below PE 66M W/W near Richland, Wash.	BR	CBP521	3/76-11/78	quarterly
47	Frenchman Hills W/W at gaging station near Moses Lake, Wash.	BR*	CBP062	10/67-1/91	quarterly*

Table 21.--*Number of suspended-sediment, nutrient, and pesticide determinations at locations in the Central Columbia Plateau study unit--Continued*

Total number of samples	Flow		Nutrients						Suspended sediment		Pesticides		
	Q_i	Q_m	NO_3	DNH_4	TNH_4	TN	TP	PO_4	solids	sed	water	bed	fish
27	19	--	27	27	--	--	27	--	26	--	--	--	--
73	--	--	73	72	--	41	73	73	72	--	--	--	--
29	22	--	28	28	--	--	29	29	28	--	--	--	--
25	11	--	25	25	--	--	25	25	24	--	--	--	--
31	15	--	31	31	--	5	31	31	30	--	--	--	--
31	15	--	31	31	--	5	31	31	30	--	--	--	--
23	11	--	23	22	--	--	23	23	22	--	--	--	--
31	10	--	31	30	--	5	31	31	30	--	--	--	--
16	--	--	16	16	--	--	16	16	15	--	--	--	--
18	9	--	18	18	--	--	18	18	17	--	--	--	--
22	9	--	22	22	--	--	22	22	21	--	--	--	--
31	24	--	31	31	--	5	31	31	30	--	--	--	--
31	15	--	31	30	--	5	31	31	30	--	--	--	--
16	--	--	16	16	--	--	16	16	15	--	--	--	--
15	--	--	15	15	--	--	15	15	14	--	--	--	--
16	--	--	16	15	--	--	16	16	15	--	--	--	--
74	12	4	74	73	--	41	74	74	73	--	--	--	--
31	24	--	31	30	--	5	31	31	30	--	--	--	--
31	9	--	31	30	--	5	31	31	30	--	--	--	--
31	15	--	31	30	--	5	31	31	30	--	--	--	--
15	--	--	15	14	--	--	15	15	14	--	--	--	--
15	--	--	15	14	--	--	15	15	14	--	--	--	--
193	67	103	105	104	--	41	105	105	76	--	850	459	111

Table 21.--*Number of suspended-sediment, nutrient, and pesticide determinations at locations in the Central Columbia Plateau study unit--Continued*

Reference number on figure 17	Station name	Agency	Station number[1]	Period of record	Frequency of sampling[2]
48	Lewis Creek at Highway 155 near Coulee City, Wash.	EPA	530281	9/74, 12/74-7/75	varied
49	Lind Coulee at Route 17 near Warden, Wash.	BR	CBP011	10/67-1/91	quarterly
50	Main Canal at Pinto Dam near Wilson Creek, Wash.	BR*	CBP033	10/67-4/91	quarterly*
51	Mattawa drain, Sec 3 T13N R24E near Mattawa, Wash.	BR*	CBP098	4/86-4/91	quarterly*
52	Old PE 64 W/W at Columbia River near Ringold, Wash.	BR	CBP551	3/75-10/79	quarterly
53	PE 16.4 W/W at Adams-Franklin County line near Othello, Wash.	BR*	CBP090	4/75-4/91	quarterly*
54	PE 16.4 W/W at Columbia River near Ringold, Wash.	BR*	CBP029	10/67-4/91	quarterly*
55	PE 16.4 W/W at Hendricks Road near Basin City, Wash.	BR*	CBP017	4/77-4/91	quarterly*
56	PE 16.4M12 W/W at DPE 215 near Othello, Wash.	BR	CBP085	5/74-11/78	quarterly
57	Potholes Canal at headworks near Warden, Wash.	BR*	CBP010	10/67-4/91	quarterly*
58	Potholes East Canal at mile 26.6 near Othello, Wash.	BR	CBP013	7/74-11/78	quarterly
59	Potholes East Canal at mile 38.0 near Mesa, Wash.	BR*	CBP014	10/67-10/90	quarterly*
60	Potholes East Canal at mile 65.8 near Richland, Wash.	BR*	CBP015	10/67-4/91	quarterly*
61	Priest Rapids W/W, Sec 33 T15N near Mattawa, Wash.	BR*	CBP099	4/86-4/91	quarterly*
62	Quincy District W/W at West Canal near Quincy, Wash.	BR*	CBP083	10/77-4/91	quarterly*
63	RB 5J W/W at Columbia River near Beverly, Wash.	BR*	CBP108	5/88-4/91	quarterly*
64	RBC W/W at Lower Crab Creek Road at Beverly, Wash.	BR*	CBP109	2/89-4/91	quarterly*
65	RCD W/W at O'Sullivan Road crossing near Moses Lake, Wash.	BR*	CBP008	10/67-1/91	quarterly*
66	Ringold W/W at Columbia River near Ringold, Wash.	BR	USBR029	1/74-11/76	monthly
67	Rocky Coulee W/W near Moses Lake, Wash.	EPA	5309B1	9/74-8/75, 3/77-9/77	varied
68	Rocky Ford Creek at Route 17 near Ephrata, Wash.	BR*	CBP060	10/67-1/91	quarterly*
69	Saddle Mountain W/W at Highway 24 near Mattawa, Wash.	BR*	CBP096	1/79-4/91	quarterly*
70	Sand Hollow, RB 4C W/W, Sec 28 T17N R23E near Beverly, Wash.	BR*	CBP075	10/67-2/91	quarterly*
71	Scooteney W/W at Scooteney Resevoir near Othello, Wash.	BR*	CBP012	10/67-10/90	quarterly*
72	Surface runoff from irrigation block one near Richland, Wash.	BR	CBP301	11/75-10/79	quarterly

Table 21.--*Number of suspended-sediment, nutrient, and pesticide determinations at locations in the Central Columbia Plateau study unit--Continued*

Total number of samples	Flow		Nutrients						Suspended sediment		Pesticides		
	Q_i	Q_m	NO_3	DNH_4	TNH_4	TN	TP	PO_4	solids	sed	water	bed	fish
11	--	--	10	--	11	10	11	10	--	--	--	--	--
201	76	105	106	104	--	41	106	106	76	--	951	459	123
94	57	--	94	93	--	41	94	94	70	--	--	--	--
21	--	--	21	21	--	21	21	21	21	--	--	--	--
15	2	--	15	15	--	--	15	15	13	--	--	--	--
81	--	--	81	80	--	52	81	81	81	--	--	--	--
119	--	6	119	118	--	52	119	119	90	--	--	--	--
73	31	--	73	73	--	52	73	73	73	--	--	--	--
23	--	--	22	22	--	--	23	23	22	--	--	--	--
118	65	--	94	93	--	41	94	94	71	--	600	--	--
15	--	--	15	14	--	--	15	15	14	--	--	--	--
81	--	--	81	79	--	30	81	81	58	--	--	--	--
93	--	--	93	92	--	41	93	93	70	--	--	--	--
21	--	--	21	21	--	21	21	21	21	--	--	--	--
53	--	--	53	53	--	40	53	53	53	--	--	--	--
12	--	--	12	12	--	12	12	12	12	--	--	--	--
12	--	--	12	12	--	12	12	12	12	--	--	--	--
106	68	--	106	105	--	41	105	106	77	--	--	--	--
65	--	--	--	--	--	--	--	--	--	--	900	493	--
37	--	--	37	--	13	13	37	13	--	--	--	--	--
106	75	15	106	105	--	41	106	106	77	--	--	--	--
62	--	--	62	62	--	51	62	62	62	--	--	--	--
105	--	--	105	104	--	41	105	105	77	--	--	--	--
81	60	--	81	79	--	30	81	81	58	--	--	--	--
11	1	--	11	11	--	--	11	11	10	--	--	--	--

Table 21.--*Number of suspended-sediment, nutrient, and pesticide determinations at locations in the Central Columbia Plateau study unit--Continued*

Reference number on figure 17	Station name	Agency	Station number[1]	Period of record	Frequency of sampling[2]
73	W 35.9B W/W at end near Quincy, Wash.	BR*	CBP086	4/74-4/91	quarterly*
74	W 61C W/W at Highway I-90 near Vantage, Wash.	BR*	CBP554	7/75-4/91	quarterly*
75	W 645 drain at I-SW Road, Sec34 T13N R25E near George, Wash.	BR*	CBP016	7/74-2/91	biannually*
76	W 645W at R-NW Road near Quincy, Wash.	BR*	CBP084	5/74-2/91	quarterly*
77	W 69 Lateral near Royal City, Wash.	USGS	465514119345801	8/77-10/78, Mar.-Oct. 3/79-8/81	varied
78	W 69.7 Lateral near Royal City, Wash.	USGS	465604119335901	Apr.-Oct. 6/77-8/81	varied
79	W 69D Lateral near Royal City, Wash.	USGS	465503119345701	6/77-8/81	varied
80	W/W ditch no. 1, abandoned PE 65 W/W near Richland, Wash.	BR	CBP553	7/75-10/79	quarterly
81	WB5 Lateral at WB Canal, State Road 260 near Othello, Wash.	BR*	CBP046	Jul. & Oct. 7/74-10/90	biannually*
82	WB5 W/W at Columbia River near Ringold, Wash.	BR*	CBP087	5/74-1/91	quarterly*
83	WB5 G Lateral at WB5 G W/W near Ringold, Wash.	BR	CBP047	Jul. & Oct. 7/74-10/78	biannually
84	West Canal at Frenchman Hills W/W near Royal City, Wash.	BR	CBP032	10/67-10/90	quarterly
85	West Canal at mile 18.0 near Ephrata, Wash.	BR	CBP022	10/67-10/73	quarterly
86	West Canal 1 mile east of B-NE Road near Soap Lake, Wash.	BR	USBR033	1/74-11/76	monthly
87	West Canal near Royal City, Wash.	USGS	12466100	April-October 1977-1981	daily
88	Winchester W/W at gaging station near Moses Lake, Wash.	BR*	CBP028	10/67-1/91	quarterly*
89	Palouse River above Buck Canyon at Colfax, Wash.	Ecology	34A110	12/70-9/71, 10/73-9/75	bimonthly
90	Palouse River at Hooper, Wash.	Ecology*	34A070	7/59-9/90	varied*
91	Palouse River at Laird Park near Harvard, Idaho	IDEQ	2020038	11/72-4/76	varied
92	Palouse River at Palouse, Wash.	USGS*	13345300	10/64, 4/65, 7/65, 10/74-9/75	varied *
93	Palouse River at Potlatch, Idaho	EPA	153006	3/68-1/70	varied
94	Palouse River at Princeton, Idaho	IDEQ	2020041	3/68-4/76, 10/78-2/79	monthly
95	Palouse River below South Fork at Colfax, Wash.	USGS	13349210	12/70-9/71	bimonthly
96	Palouse River near Diamond, Wash.	Ecology	34A090	12/70-9/71, 10/73-9/74	bimonthly
97	Palouse River near Palouse, Wash.	EPA	153010	3/68-6/71	monthly
98	Palouse River near Potlatch, Idaho	IDEQ	151011	3/68-9/83, 10/88-5/91	varied
99	Paradise Creek at Pullman, Wash.	USGS	13346990	10/74-9/75	bimonthly
100	Paradise Creek at USGS gage near Moscow, Idaho	IDEQ	2020206	11/79-2/81	monthly
101	South Fork Palouse River at Idaho-Washington State line	IDEQ	2020068	9/75, 4/76, 11/79-2/81	monthly

Table 21.--*Number of suspended-sediment, nutrient, and pesticide determinations at locations in the Central Columbia Plateau study unit--Continued*

Total number of samples	Flow		Nutrients						Suspended sediment		Pesticides		
	Q_i	Q_m	NO_3	DNH_4	TNH_4	TN	TP	PO_4	solids	sed	water	bed	fish
69	--	--	69	68	--	41	69	69	67	--	--	--	--
44	2	--	44	44	--	30	44	44	43	--	--	--	--
35	18	--	35	34	--	20	35	35	34	--	--	--	--
75	--	--	75	73	--	41	73	74	73	--	--	--	--
430	--	--	208	--	--	207	209	5	--	413	--	--	--
41	41	1	33	5	5	32	36	11	--	41	--	--	--
30	30	--	25	--	--	25	29	--	--	30	--	--	--
10	2	--	10	10	--	--	9	9	10	--	--	--	--
34	18	--	34	33	--	20	34	34	33	--	--	--	--
71	--	4	71	70	--	40	71	71	70	--	--	--	--
10	--	--	10	9	--	--	10	10	9	--	--	--	--
81	60	--	80	80	--	30	81	81	58	--	--	--	--
25	--	--	25	25	--	--	25	25	--	--	--	--	--
22	--	--	--	--	--	--	--	--	--	--	550	--	--
1,358	959	--	883	20	20	880	1,020	28	--	1,279	--	--	--
148	77	99	106	105	--	41	106	106	77	--	900	--	25
62	50	1	60	--	58	14	61	58	--	--	--	--	--
373	253	369	352	--	242	129	238	303	139	13	--	3	--
15	2	--	15	--	14	--	--	--	--	--	--	--	--
34	34	1	24	--	24	--	24	24	--	10	--	--	--
29	--	--	27	--	27	26	26	11	--	--	--	--	--
40	2	--	40	--	34	5	7	--	6	--	--	--	--
18	18	--	16	--	14	15	17	14	--	--	--	--	--
42	30	--	42	--	37	--	41	40	--	--	--	--	--
62	--	--	59	--	57	57	60	22	--	--	9	--	--
142	48	102	136	6	113	83	100	19	63	25	--	--	--
24	21	--	24	--	24	--	24	24	--	--	--	--	--
14	9	--	9	--	9	9	9	--	--	9	14	--	--
15	9	--	10	--	10	10	10	--	--	8	14	--	--

Table 21.--*Number of suspended-sediment, nutrient, and pesticide determinations at locations in the Central Columbia Plateau study unit--Continued*

Reference number on figure 17	Station name	Agency	Station number[1]	Period of record	Frequency of sampling[2]
102	South Fork Palouse River at Pullman, Wash.	Ecology	34B110	11/64-1/65,12/70-9/74, 10/77-9/90	varied
103	South Fork Palouse River below Sunshine Creek at Pullman, Wash.	Ecology	34B130	10/74-9/75	bimonthly
104	South Fork Palouse River near Colfax, Wash.	Ecology	34B070	10/64-5/65, 12/70-9/75	bimonthly
105	South Fork Palouse River near Pullman, Wash.	Ecology	34B090	12/70-9/74	bimonthly
				TOTALS:	

[1] Sites with an asterisk represent a sampling location for more than one monitoring program. The station number and agency listed represent the longest period of record or the most samples for that location. See table 8 for a list of combined sampling locations.
[2] Sites with an asterisk are active sites, currently being sampled by the agency listed.

Table 21.--*Number of suspended-sediment, nutrient, and pesticide determinations at locations in the Central Columbia Plateau study unit--Continued*

Total number of samples	Flow		Nutrients						Suspended sediment		Pesticides		
	Q_i	Q_m	NO_3	DNH_4	TNH_4	TN	TP	PO_4	solids	sed	water	bed	fish
203	181	--	188	--	184	--	179	168	138	9	--	--	--
24	--	--	24	--	24	--	23	24	--	--	--	--	--
95	81	5	65	--	62	--	65	64	--	30	--	--	--
42	30	--	42	--	39	--	42	41	--	--	--	--	--
13,174	4,714	4,295	10,277	3,689	1,431	6,754	10,190	5,072	3,583	5,881	6,682	2,356	317

Table 22.--*Minimum, median, and maximum nutrient and suspended-sediment concentrations at sites in the Central Columbia Plateau study unit*

[mg/L, milligrams per liter; N, nitrogen; P, phosphorus; min, minimum; max, maximum; W/W, wasteway; <, less than; --, fewer than 10 observations]

Reference number on figure 17	Station name	Nitrate (mg/L as N)			Ammonia, dissolved (mg/L as N)			Ammonia, total (mg/L as N)		
		min	median	max	min	median	max	min	median	max
1	Crab Creek at Irby, Wash.	0.75	1.1	2.5	--	--	--	--	--	--
2	Crab Creek at McManamon Road near Othello, Wash.	<0.01	0.10	1.6	<0.01	0.03	0.16	--	--	--
3	Crab Creek Lateral above Royal Lake near Othello, Wash.	0.05	3.4	9.0	<0.01	0.02	0.42	--	--	--
4	Crab Creek Lateral W/W, unit 88 block 88, near Othello, Wash.	4.4	9.6	12.9	<0.01	<0.01	0.03	--	--	--
5	Crab Creek near Beverly, Wash.	0.01	1.1	4.5	<0.01	0.04	0.39	<0.01	0.05	0.65
6	Crab Creek near Moses Lake, Wash.	0.04	0.94	3.4	<0.01	0.03	0.62	<0.01	0.04	0.30
7	Crab Creek near Othello, Wash.	0.72	1.0	1.9	--	--	--	<0.01	0.08	0.26
8	Crab Creek near Smyma, Wash.	0.09	0.60	1.6	--	--	--	--	--	--
9	D 20-131 surface drain outlet to PE 16.4 near Basin City, Wash.	4.8	6.8	9.6	<0.01	0.01	0.76	--	--	--
10	DCC 1 at Red Rocky Coulee Road near Royal City, Wash.	0.30	2.8	6.3	<0.01	0.03	0.12	--	--	--
11	DE 14-179 drain near Othello, Wash.	2.3	8.0	12.8	<0.01	0.01	0.17	--	--	--
12	DE 15-146 drain at Bellview Drive Road near Richland, Wash.	4.8	6.4	8.3	<0.01	<0.01	0.02	--	--	--
13	DE 72-141 drain at 9-NW Road near Quincy, Wash.	1.7	3.7	5.8	<0.01	<0.01	0.42	--	--	--
14	DPE 215 at Route 26 near Othello, Wash.	0.05	1.1	4.0	<0.01	0.16	3.4	--	--	--
15	DW 239B drain at West Canal near George, Wash.	2.5	2.9	4.1	<0.01	0.03	0.08	--	--	--
16	DW 272A drains block 86 near Royal Camp, Wash.	0.07	3.6	14.0	<0.01	0.03	2.3	<0.01	0.04	1.9
17	DW 272A1 drains block 86 near Royal Camp, Wash.	0.01	2.4	21.2	<0.01	0.03	1.6	<0.01	0.04	1.7
18	East Low Canal at Moses Lake, Wash.	<0.01	0.24	1.0	--	--	--	--	--	--
19	EL 25A W/W at pumping plant near Moses Lake, Wash.	0.57	1.7	2.9	<0.01	0.08	0.41	--	--	--
20	EL 68.3 W/W 1 at end in Lind Coulee W/W near Warden, Wash.	0.41	1.7	2.5	0.02	0.18	1.7	--	--	--
21	EL 68D wasteway near Othello, Wash.	0.17	2.4	11.3	<0.01	0.04	0.46	--	--	--
22	Eltopia Branch Canal at EB W/W near Eltopia, Wash.	0.73	1.1	1.5	<0.01	0.03	0.08	--	--	--
23	Esquatzel Coulee at east side State Road 17 at Mesa, Wash.	0.05	2.3	2.9	<0.01	0.01	0.06	--	--	--
24	Esquatzel Coulee W/W at bridge west of Connell, Wash.	0.01	0.98	7.5	<0.01	0.09	19.4	--	--	--
25	Esquatzel Coulee W/W at gaging station at Eltopia, Wash.	0.41	1.9	3.4	<0.01	0.01	0.11	--	--	--

Table 22.--*Minimum, median, and maximum nutrient and suspended-sediment concentrations at sites in the Central Columbia Plateau study unit--Continued*

Total nitrogen (mg/L as N)			Total phosphorus (mg/L as P)			Orthophosphate (mg/L as P)			Suspended solids (mg/L)			Suspended sediment (mg/L.)		
min	median	max	min	median	max	min	median	max	min	median	max	min	median	max
--	--	--	--	--	--	0.09	0.14	0.24	--	--	--	--	--	--
0.33	0.52	1.2	0.01	0.07	0.27	<0.01	0.03	0.09	<1	12	60	--	--	--
0.58	3.5	8.9	0.02	0.10	0.79	<0.01	0.04	0.23	1	46	1,300	--	--	--
--	--	--	0.05	0.08	0.12	0.03	0.04	0.06	1	8	55	--	--	--
0.80	2.5	5.3	0.01	0.14	0.85	<0.01	0.07	0.33	3	37	2,600	74	128	2,770
0.92	1.5	3.8	0.01	0.07	0.77	<0.01	0.03	0.22	<1	16	480	--	--	--
0.80	1.3	3.2	0.04	0.09	0.21	<0.01	0.03	0.09	--	--	--	--	--	--
--	--	--	--	--	--	0.05	0.10	0.18	--	--	--	--	--	--
--	--	--	0.02	0.12	0.46	0.01	0.02	0.32	4	31	456	--	--	--
0.85	2.9	6.8	<0.01	0.06	0.44	<0.01	0.02	0.11	7	27	855	--	--	--
--	--	--	0.03	0.05	0.79	0.02	0.04	0.47	<1	5	67	--	--	--
--	--	--	0.03	0.04	0.08	<0.01	0.04	0.05	<1	4	18	--	--	--
--	--	--	0.08	0.12	5.5	0.06	0.10	1.0	<1	2	544	--	--	--
1.3	2.1	10.6	0.17	0.60	2.4	0.05	0.47	1.4	2	39	186	--	--	--
--	--	--	0.05	0.08	0.18	0.02	0.04	0.08	5	13	72	--	--	--
0.09	4.7	22.0	<0.01	0.23	3.3	<0.01	0.02	0.09	--	--	--	1	175	10,500
0.08	3.2	29.0	<0.01	0.12	2.6	<0.01	0.02	0.17	--	--	--	<1	49	5,980
--	--	--	<0.01	0.02	0.10	--	--	--	--	--	--	--	--	--
--	--	--	0.14	0.27	0.62	0.11	0.22	0.33	2	40	171	--	--	--
--	--	--	0.05	0.13	1.4	0.02	0.06	0.97	6	48	1,220	--	--	--
0.69	3.0	13.0	<0.01	0.12	2.5	<0.01	0.04	0.87	4	67	1,200	2	61	1,000
1.3	1.6	2.1	0.02	0.05	0.19	<0.01	0.01	0.07	3	15	73	--	--	--
0.61	2.2	3.0	0.05	0.07	0.19	<0.01	0.06	0.13	<1	4	22	--	--	--
--	--	--	0.30	0.72	11.3	0.26	0.63	10.0	1	7	105	--	--	--
--	--	--	0.01	0.06	0.19	<0.01	0.03	0.09	2	13	173	--	--	--

Table 22.--*Minimum, median, and maximum nutrient and suspended-sediment concentrations at sites in the Central Columbia Plateau study unit--Continued*

Reference number on figure 17	Station name	Nitrate (mg/L as N)			Ammonia, dissolved (mg/L as N)			Ammonia total (mg/L as N)		
		min	median	max	min	median	max	min	median	max
26	Esquatzel Coulee W/W at Sheffield Road at Mesa, Wash.	0.9	2.5	4.5	<0.01	0.03	0.29	--	--	--
27	Esquatzel Coulee W/W below 59.4 wasteway near Richland, Wash.	2.4	3.3	6.7	<0.01	0.01	0.06	--	--	--
28	Esquatzel Coulee W/W below D18-97 drain near Connell, Wash.	<0.01	0.31	1.4	<0.01	0.02	0.05	--	--	--
29	Esquatzel Coulee W/W below DPE 38 at Mesa, Wash.	0.97	2.8	5.1	<0.01	0.02	0.10	--	--	--
30	Esquatzel Coulee W/W below DPE 38B drain at Mesa, Wash.	0.49	2.4	3.3	<0.01	0.02	0.11	--	--	--
31	Esquatzel Coulee W/W below EB 15 W/W near Pasco, Wash.	0.42	1.1	4.1	<0.01	0.03	0.09	--	--	--
32	Esquatzel Coulee W/W below EB 8 W/W near Eltopia, Wash.	0.57	1.5	6.8	<0.01	0.01	2.9	--	--	--
33	Esquatzel Coulee W/W below EB Canal W/W near Eltopia, Wash.	0.13	1.6	4.5	<0.01	0.02	0.52	--	--	--
34	Esquatzel Coulee W/W below EL 85M W/W near Connell, Wash.	0.70	1.8	5.7	<0.01	0.01	0.04	--	--	--
35	Esquatzel Coulee W/W below EL 85Z W/W near Connell, Wash.	<0.01	0.58	11.4	<0.01	0.02	0.97	--	--	--
36	Esquatzel Coulee W/W below PE 38 W/W at Mesa, Wash.	0.30	2.6	4.0	<0.01	0.03	0.10	--	--	--
37	Esquatzel Coulee W/W below PE 38.9B5 W/W near Mesa, Wash.	1.3	4.2	7.9	<0.01	0.01	0.09	--	--	--
38	Esquatzel Coulee W/W below PE 38.9E W/W near Mesa, Wash.	1.1	2.2	3.6	<0.01	0.02	0.13	--	--	--
39	Esquatzel Coulee W/W Below PE 38.9P2 W/W near Eltopia, Wash.	0.55	1.6	3.6	<0.01	0.01	0.09	--	--	--
40	Esquatzel Coulee W/W below PE 59 W/W near Eltopia, Wash.	1.7	2.7	5.4	<0.01	0.02	0.06	--	--	--
41	Esquatzel Diversion Canal at Columbia River near Richland, Wash.	1.9	3.3	7.5	<0.01	0.02	0.10	--	--	--
42	Esquatzel Diversion Canal below headworks near Pasco, Wash.	1.7	3.2	6.7	<0.01	0.01	0.11	--	--	--
43	Esquatzel Diversion Canal below PE 59.4 W/W near Richland, Wash.	1.9	3.3	6.9	<0.01	<0.01	0.10	--	--	--
44	Esquatzel Diversion Canal below PE 59.4D W/W near Pasco, Wash.	1.8	3.1	6.8	<0.01	0.01	0.12	--	--	--
45	Equatzel Diversion Canal below PE 59.4K W/W near Richland, Wash.	2.6	3.1	5.5	<0.01	0.01	0.09	--	--	--
46	Esquatzel Diversion Canal below PE 66M W/W near Richland, Wash.	2.5	3.1	5.7	<0.01	0.01	0.06	--	--	--
47	Frenchman Hills W/W at gaging station near Moses Lake, Wash.	0.06	2.7	6.7	<0.01	0.02	0.35	--	--	--
48	Lewis Creek at Highway 155 near Coulee City, Wash.	1.7	4.9	6.9	--	--	--	<0.01	0.06	0.14

Table 22.--*Minimum, median, and maximum nutrient and suspended-sediment concentrations at sites in the Central Columbia Plateau study unit--Continued*

Total nitrogen (mg/L as N)			Total phosphorus (mg/L as P)			Orthophosphate (mg/L as P)			Suspended solids (mg/L)			Suspended sediment (mg/L)		
min	median	max	min	median	max	min	median	max	min	median	max	min	median	max
1.4	2.4	5.1	0.02	0.08	0.69	<0.01	0.04	0.6	3	22	788	--	--	--
--	--	--	<0.01	0.06	0.14	<0.01	0.02	0.06	2	12	45	--	--	--
--	--	--	0.03	0.09	0.24	<0.01	0.05	0.11	<1	10	621	--	--	--
1.2	3.4	5.6	0.03	0.10	1.8	<0.01	0.07	1.5	3	18	4,400	--	--	--
0.79	2.1	2.5	0.05	0.10	0.30	<0.01	0.07	0.19	1	8	224	--	--	--
--	--	--	0.02	0.09	0.58	<0.01	0.04	0.25	<1	14	157	--	--	--
1.1	1.8	7.8	0.02	0.07	0.16	<0.01	0.03	0.10	3	17	64	--	--	--
--	--	--	0.04	0.11	0.51	0.01	0.03	0.40	3	19	214	--	--	--
--	--	--	0.02	0.08	0.39	<0.01	0.04	0.17	<1	10	157	--	--	--
--	--	--	<0.01	0.04	0.16	<0.01	0.02	0.08	1	7	26	--	--	--
1.2	2.7	4.1	0.05	0.10	4.2	<0.01	0.06	3.4	5	25	6,880	--	--	--
3.4	4.9	8.5	0.02	0.06	0.24	<0.01	0.02	0.10	3	11	28	--	--	--
--	--	--	0.05	0.08	0.49	0.02	0.04	0.31	6	18	362	--	--	--
--	--	--	0.03	0.07	0.77	0.01	0.03	0.32	6	17	374	--	--	--
--	--	--	0.04	0.08	0.15	0.01	0.02	0.09	2	11	36	--	--	--
3.0	4.0	8.0	0.02	0.06	0.25	<0.01	0.02	0.09	2	16	52	--	--	--
2.2	3.3	7.4	0.01	0.07	0.17	<0.01	0.03	0.09	3	15	47	--	--	--
2.1	3.4	7.4	<0.01	0.07	0.15	<0.01	0.03	0.06	<1	13	78	--	--	--
2.2	3.3	7.2	0.01	0.08	0.15	<0.01	0.03	0.07	2	14	128	--	--	--
--	--	--	0.05	0.07	0.12	0.01	0.03	0.06	3	14	50	--	--	--
--	--	--	0.04	0.08	0.15	0.01	0.02	0.07	2	12	54	--	--	--
0.97	3.3	7.7	0.02	0.12	0.53	<0.01	0.06	0.47	<1	22	96	--	--	--
3.2	5.8	7.6	0.03	0.14	0.94	0.01	0.10	0.26	--	--	--	--	--	--

Table 22.--*Minimum, median, and maximum nutrient and suspended-sediment concentrations at sites in the Central Columbia Plateau study unit--Continued*

Reference number on figure 17	Station name	Nitrate (mg/L as N)			Ammonia, dissolved (mg/L as N)			Ammonia, total (mg/L as N)		
		min	median	max	min	median	max	min	median	max
49	Lind Coulee at Route 17 near Warden, Wash.	0.59	2.7	5.8	<0.01	0.05	0.70	--	--	--
50	Main Canal at Pinto Dam near Wilson Creek, Wash.	<0.01	0.03	0.29	<0.01	0.01	0.08	--	--	--
51	Mattawa Drain, Sec 3 T13N R24E near Mattawa, Wash.	0.30	0.80	1.3	0.02	0.04	0.10	--	--	--
52	Old PE 64 W/W at Columbia River near Ringold, Wash.	1.9	4.2	8.7	<0.01	0.01	0.13	--	--	--
53	PE 16.4 W/W at Adams-Franklin County line near Othello, Wash.	0.49	2.7	5.0	<0.01	0.05	0.39	--	--	--
54	PE 16.4 W/W at Columbia River near Ringold, Wash.	1.4	2.8	4.9	<0.01	0.03	0.20	--	--	--
55	PE 16.4 W/W at Hendricks Road near Basin City, Wash.	0.65	1.9	3.3	<0.01	0.05	0.37	--	--	--
56	PE 16.4M12 W/W at DPE 215 near Othello, Wash.	1.0	2.1	5.6	<0.01	0.04	0.22	--	--	--
57	Potholes Canal at headworks near Warden, Wash.	0.28	0.80	1.5	<0.01	0.05	0.50	--	--	--
58	Potholes East Canal at mile 26.6 near Othello, Wash.	0.21	1.1	6.8	<0.01	0.04	0.10	--	--	--
59	Potholes East Canal at mile 38.0 near Mesa, Wash.	0.54	0.93	1.4	<0.01	0.02	0.40	--	--	--
60	Potholes East Canal at mile 65.8 near Richland, Wash.	0.62	1.1	3.3	<0.01	0.02	0.25	--	--	--
61	Priest Rapids W/W, Sec 33 T15N near Mattawa, Wash.	0.09	0.70	1.4	0.01	0.05	0.13	--	--	--
62	Quincy District W/W at West Canal near Quincy, Wash.	<0.01	0.09	3.6	<0.01	0.03	0.75	--	--	--
63	RB 5J W/W at Columbia River near Beverly, Wash.	0.05	0.05	0.10	0.01	0.02	0.06	--	--	--
64	RBC W/W at Lower Crab Creek Road at Beverly, Wash.	0.05	0.43	1.3	0.02	0.06	0.10	--	--	--
65	RCD W/W at O'Sullivan Road crossing near Moses Lake, Wash.	0.12	1.5	5.1	<0.01	0.04	1.6	--	--	--
66	Ringold W/W at Columbia River near Ringold, Wash.	--	--	--	--	--	--	--	--	--
67	Rocky Coulee W/W near Moses Lake, Wash.	0.03	1.0	2.8	--	--	--	0.02	0.04	0.18
68	Rocky Ford Creek at Route 17 near Ephrata, Wash.	0.05	1.4	3.3	<0.01	0.07	0.32	--	--	--
69	Saddle Mountain W/W at Highway 24 near Mattawa, Wash.	0.30	1.6	16.9	<0.01	0.04	0.26	--	--	--
70	Sand Hollow, RB 4C W/W, Sec 28 T17N R23E near Beverly, Wash.	0.75	3.1	8.9	<0.01	0.02	1.6	--	--	--
71	Scooteney W/W at Scooteney Reservoir near Othello, Wash.	0.03	0.20	2.0	<0.01	0.01	0.09	--	--	--

Table 22.--*Minimum, median, and maximum nutrient and suspended-sediment concentrations at sites in the Central Columbia Plateau study unit--Continued*

Total nitrogen (mg/L as N)			Total phosphorus (mg/L as P)			Orthophosphate (mg/L as P)			Suspended solids (mg/L)			Suspended sediment (mg/L)		
min	median	max	min	median	max	min	median	max	min	median	max	min	median	max
1.2	3.2	6.7	0.02	0.19	1.7	0.01	0.08	0.59	3	77	815	--	--	--
0.12	0.24	0.36	<0.01	0.04	0.17	<0.01	0.01	0.06	<1	3	35	--	--	--
1.1	1.5	2.7	0.02	0.04	0.10	<0.01	<0.01	0.06	4	43	124	--	--	--
--	--	--	0.17	0.27	7.5	0.02	0.13	6.8	9	275	12,490	--	--	--
1.4	3.3	5.9	0.01	0.08	0.30	<0.01	0.02	0.10	4	34	141	--	--	--
2.6	3.3	5.9	<0.01	0.06	0.55	<0.01	0.02	0.23	5	20	192	--	--	--
1.3	2.6	3.9	0.02	0.04	0.16	<0.01	0.01	0.07	2	10	68	--	--	--
--	--	--	0.05	0.09	1.0	0.01	0.03	0.77	2	25	366	--	--	--
0.96	1.6	2.3	<0.01	0.05	0.78	<0.01	0.02	0.05	2	8	41	--	--	--
--	--	--	0.03	0.09	0.17	<0.01	0.03	0.11	3	25	162	--	--	--
1.2	1.6	2.0	0.01	0.07	0.18	<0.01	0.01	0.07	4	15	168	--	--	--
1.4	1.9	4.1	0.02	0.07	0.24	<0.01	0.01	0.15	1	30	278	--	--	--
0.68	1.5	2.4	0.02	0.04	0.14	<0.01	<0.01	0.01	4	15	47	--	--	--
0.23	0.63	8.0	0.03	0.15	0.96	<0.01	0.04	0.33	2	136	904	--	--	--
0.17	0.33	0.43	0.02	0.03	0.38	<0.01	0.01	0.01	2	35	398	--	--	--
0.45	0.88	2.6	0.01	0.02	0.08	<0.01	<0.01	0.01	1	3	34	--	--	--
0.50	1.6	5.4	0.01	0.09	0.61	<0.01	0.04	0.26	1	37	863	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
1.3	1.8	2.5	0.01	0.08	0.22	0.04	0.08	0.15	--	--	--	--	--	--
0.74	2.0	2.7	0.09	0.19	0.50	0.02	0.14	0.33	1	15	46	--	--	--
1.4	2.4	18.0	0.01	0.05	0.35	<0.01	0.01	0.28	2	22	200	--	--	--
2.6	5.0	9.5	0.01	0.10	0.96	<0.01	0.03	0.46	4	72	1,700	--	--	--
0.19	0.41	1.3	<0.01	0.05	0.25	<0.01	0.01	0.09	1	15	158	--	--	--

Table 22.--*Minimum, median, and maximum nutrient and suspended-sediment concentrations at sites in the Central Columbia Plateau study unit--Continued*

Reference number on figure 17	Station name	Nitrate (mg/L as N)			Ammonia, dissolved (mg/L as N)			Ammonia total (mg/L as N)		
		min	median	max	min	median	max	min	median	max
72	Surface runoff from irrigation block one near Richland, Wash.	0.18	1.3	2.1	<0.01	0.02	0.05	--	--	--
73	W 35.9B W/W at end near Quincy, Wash.	<0.01	0.05	0.90	<0.01	0.03	0.47	--	--	--
74	W 61C W/W at Highway I-90 near Vantage, Wash.	<0.01	0.05	0.16	<0.01	0.01	0.14	--	--	--
75	W 645 drain at I-SW Road, Sec34 T13N R25E near George, Wash.	0.04	4.5	7.2	<0.01	0.09	0.33	--	--	--
76	W 645W at R-NW Road near Quincy, Wash.	0.05	3.4	13.7	<0.01	3.6	21.8	--	--	--
77	W 69 Lateral near Royal City, Wash.	<0.01	0.06	1.1	--	--	--	--	--	--
78	W 69.7 Lateral near Royal City, Wash.	<0.01	0.06	0.31	<0.01	<0.01	0.15	<0.01	0.01	0.04
79	W 69D Lateral near Royal City, Wash.	<0.01	0.05	0.19	--	--	--	--	--	--
80	W/W ditch no.1, abandoned PE 65 W/W near Richland, Wash.	0.78	1.2	2.3	<0.01	0.01	0.17	--	--	--
81	WB 5 Lateral at WB Canal, State Road 260 near Othello, Wash.	0.45	0.73	1.4	<0.01	0.07	0.36	--	--	--
82	WB 5 W/W at Columbia River near Ringold, Wash.	2.4	4.4	11.8	<0.01	0.04	0.33	--	--	--
83	WB5 G Lateral at WB5 G W/W near Ringold, Wash.	1.9	2.5	3.4	<0.01	0.02	0.05	--	--	--
84	West Canal at Frenchman Hills W/W near Royal City, Wash.	<0.01	0.06	0.50	<0.01	0.01	0.19	--	--	--
85	West Canal at mile 18.0 near Ephrata, Wash.	<0.01	0.02	0.10	<0.01	<0.01	0.11	--	--	--
86	West Canal 1 mile east of B-NE Road near Soap Lake, Wash.	--	--	--	--	--	--	--	--	--
87	West Canal near Royal City, Wash.	<0.01	0.07	2.3	<0.01	0.02	0.10	<0.01	0.03	0.26
88	Winchester W/W at gaging station near Moses Lake, Wash.	<0.01	1.0	5.3	<0.01	0.02	0.16	--	--	--
89	Palouse River above Buck Canyon at Colfax, Wash.	0.01	0.40	4.5	--	--	--	0.02	0.16	2.7
90	Palouse River at Hooper, Wash.	<0.01	1.3	9.3	--	--	--	<0.01	0.11	2.0
91	Palouse River at Laird Park near Harvard, Idaho	<0.01	0.02	0.45	--	--	--	<0.01	0.08	0.19
92	Palouse River at Palouse, Wash.	0.01	0.09	1.9	--	--	--	0.04	0.11	0.42
93	Palouse River at Potlatch, Idaho	<0.01	0.02	1.5	--	--	--	<0.01	0.04	0.11
94	Palouse River at Princeton, Idaho	<0.01	0.10	1.8	--	--	--	<0.01	0.14	1.0
95	Palouse River below South Fork at Colfax, Wash.	0.06	0.26	4.5	--	--	--	0.02	0.13	0.37
96	Palouse River near Diamond, Wash.	0.03	1.2	8.9	--	--	--	<0.01	0.13	1.5
97	Palouse River near Palouse, Wash.	<0.01	0.90	3.1	--	--	--	0.01	0.05	0.24
98	Palouse River near Potlatch, Idaho	<0.01	0.07	3.2	0.01	0.04	0.13	<0.01	0.07	1.3

Table 22.--*Minimum, median, and maximum nutrient and suspended-sediment concentrations at sites in the Central Columbia Plateau study unit--Continued*

Total nitrogen (mg/L as N)			Total phosphorus (mg/L as P)			Orthophosphate (mg/L as P)			Suspended solids (mg/L)			Suspended sediment (mg/L)		
min	median	max	min	median	max	min	median	max	min	median	max	min	median	max
--	--	--	0.06	0.12	0.40	0.01	0.03	0.07	4	25	57	--	--	--
0.21	0.41	2.2	0.02	0.07	0.40	<0.01	0.02	0.12	5	28	272	--	--	--
0.18	0.32	0.91	<0.01	0.03	0.68	<0.01	<0.01	0.36	1	10	492	--	--	--
0.77	6.1	8.0	0.02	0.24	0.56	<0.01	0.16	0.56	3	67	202	--	--	--
2.2	12.8	33.3	0.06	4.1	26.0	0.04	3.2	24.4	7	176	1,560	--	--	--
0.10	0.31	1.5	<0.01	0.03	0.25	<0.01	0.01	0.01	--	--	--	<1	14	310
0.11	0.31	1.6	0.01	0.03	0.16	<0.01	0.01	0.05	--	--	--	<1	16	292
0.14	0.28	1.5	0.01	0.03	0.17	--	--	--	--	--	--	1	19	92
--	--	--	0.07	0.13	0.54	0.01	0.05	0.35	5	17	951	--	--	--
1	1.5	2.2	0.01	0.07	0.13	<0.01	0.01	0.07	2	10	41	--	--	--
3.3	4.9	12.0	<0.01	0.08	0.82	<0.01	0.02	0.16	1	38	561	--	--	--
--	--	--	0.03	0.06	0.09	<0.01	0.01	0.04	<1	5	23	--	--	--
0.27	0.39	0.75	<0.01	0.05	0.44	<0.01	0.01	0.08	1	13	67	--	--	--
--	--	--	0.02	0.04	0.14	<0.01	0.02	0.08	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
0.07	0.34	14.0	<0.01	0.03	0.41	<0.01	0.01	0.05	--	--	--	<1	21	276
0.46	1.3	3.8	0.01	0.05	0.43	<0.01	0.02	0.31	<1	10	86	--	--	--
0.20	0.49	5.3	0.02	0.12	1.4	<0.01	0.06	0.28	--	--	--	--	--	--
0.22	2.3	15.0	<0.01	0.23	2.7	<0.01	0.13	0.79	4	39	13,100	807	2,640	15,300
--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	0.04	0.09	0.54	0.01	0.04	0.12	--	--	--	7	307	2,670
0.20	0.70	2.8	0.04	0.07	0.15	0.01	0.02	0.05	--	--	--	--	--	--
0.19	0.85	2.2	0.03	0.04	0.12	--	--	--	<1	3	19	--	--	--
0.20	0.53	5.3	0.06	0.09	0.22	0.02	0.08	0.13	--	--	--	--	--	--
--	--	--	0.12	0.47	3.7	<0.01	0.19	3.3	--	--	--	--	--	--
0.16	1.7	4.5	0.05	0.11	1.3	0.02	0.04	1.7	--	--	--	--	--	--
0.10	0.60	4.8	<0.01	0.09	0.55	<0.01	0.02	0.15	<1	10	181	2	16	326

Table 22.--*Minimum, median, and maximum nutrient and suspended-sediment concentrations at sites in the Central Columbia Plateau study unit--Continued*

Reference number on figure 17	Station name	Nitrate (mg/L as N)			Ammonia, dissolved (mg/L as N)			Ammonia, total (mg/L as N)		
		min	median	max	min	median	max	min	median	max
99	Paradise Creek at Pullman, Wash.	1.3	8.0	16.0	--	--	--	0.10	0.32	5.6
100	Paradise Creek at USGS gage near Moscow, Idaho	0.80	4.7	17.0	--	--	--	0.04	0.21	1.5
101	South Fork Palouse River at Idaho-Washington State line	0.47	2.6	16.0	--	--	--	0.04	0.17	1.8
102	South Fork Palouse River at Pullman, Wash.	0.28	5.0	13.0	--	--	--	<0.01	0.17	8.0
103	South Fork Palouse River below Sunshine Creek at Pullman, Wash.	0.04	1.9	7.5	--	--	--	0.07	0.20	1.7
104	South Fork Palouse River near Colfax, Wash.	0.07	3.5	11.0	--	--	--	<0.01	0.25	3.3
105	South Fork Palouse River near Pullman, Wash.	0.59	2.7	13.0	--	--	--	0.11	1.2	14.0

Table 22.--*Minimum, median, and maximum nutrient and suspended-sediment concentrations at sites in the Central Columbia Plateau study unit--Continued*

Total nitrogen (mg/L as N)			Total phosphorus (mg/L as P)			Orthophosphate (mg/L as P)			Suspended solids (mg/L)			Suspended sediment (mg/L)		
min	median	max	min	median	max	min	median	max	min	median	max	min	median	max
--	--	--	0.68	3.1	9.2	0.32	2.7	7.2	--	--	--	--	--	--
2.2	6.1	19.0	0.20	0.69	1.7	--	--	--	--	--	--	2	48	2,290
0.77	4.5	20.0	0.12	0.41	2.0	--	--	--	--	--	--	2	43	3,110
--	--	--	<0.01	1.2	6.5	<0.01	1.2	6.4	1	16	2,900	152	3,530	12,200
--	--	--	0.05	0.24	10.0	0.04	0.16	1.1	--	--	--	--	--	--
--	--	--	0.41	1.2	5.3	0.08	0.77	5.2	--	--	--	54	513	17,200
--	--	--	0.55	1.8	8.5	0.10	1.2	7.5	--	--	--	--	--	--

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