Distribution and Sources of Nitrate, and Presence of Fluoride and Pesticides, in Parts of the Pasco Basin, Washington, 1986-88

By J.C. Ebbert, S.E. Cox, B.W. Drost, and K.M. Schurr

U.S. Geological Survey
Water-Resources Investigations Report 93-4197

Prepared in cooperation with the
WASHINGTON STATE DEPARTMENT OF ECOLOGY

Tacoma, Washington
1995

U.S. DEPARTMENT OF THE INTERIOR

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CONTENTS

FIGURES

FIGURES--CONTINUED

TABLES

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
foot per day (ft/d)	0.3048	meter per day
cubic foot (ft^3)	0.02832	cubic meter
gallon (gal)	3.785	liter
pounds per cubic foot (lb/ft^3)	0.01602	grams per cubic centimeter
ounce, avoirdupois (oz)	28.35	gram
pound, avoirdupois (lb)	453.6	gram

Temperature: To correct temperature given in this report in degrees Fahrenheit (°F) to degrees Celsius (°C), use the following equation: $°C = 5/9(°F-32)$

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

Altitude: In this report "altitude" is measured in feet above or below sea level.

DISTRIBUTION AND SOURCES OF NITRATES, AND PRESENCE OF FLUORIDE AND PESTICIDES, IN PARTS OF THE PASCO BASIN, WASHINGTON, 1986-88

By J.C. Ebbert, S.E. Cox, B.W. Drost, and K.M. Schurr

ABSTRACT

Ground water was sampled in a 900-square-mile agricultural area in the Pasco Basin, which includes parts of eastern Benton County and western Franklin County, Washington, to determine distributions of nitrate and fluoride. Additional data were obtained to determine if fertilizers, irrigation water, septic systems, and naturally occurring nitrate are sources of nitrate in ground water. Limited sampling also was done to determine if pesticides were present in the ground water.

Nitrate concentrations in ground water ranged from less than 0.1 to 100 milligrams per liter as nitrogen, and median concentrations of nitrate nitrogen in ground water were 3.2 and 6.7 milligrams per liter for Benton and Franklin Counties, respectively. In Franklin County, where a large percentage of the land is used for irrigated agriculture, nitrate nitrogen concentrations in water from 31 percent of sampled wells were equal to or greater than the maximum contaminant level for drinking water of 10 milligrams per liter. In Benton County, nitrate concentrations in water from about 10 percent of the sampled wells exceeded the maximum contaminant level.

Nitrate concentrations in ground water at some locations in Franklin County have increased by as much as two orders of magnitude since the early 1950's. Historical data generally were not available to evaluate changes of nitrate concentrations in ground water in Benton County, except for the area around the town of Finley. A comparison of data collected during this study with data collected during 1976-77 indicate that nitrate concentrations in ground water of the Finley area probably have not changed over the intervening period.

Applied nitrogen fertilizers are a major source of nitrate in ground water at many locations in the study area. Surface water used for irrigation does not contain sufficient nitrate to cause elevated concentrations in ground water. Instead, canal seepage, which makes up about 50 percent of the ground-water recharge in the study area, tends to dilute the nitrate present in ground water.

Septic systems in the Finley area of Benton County are a source of nitrate in ground water, but analyses of data and results of a numerical model analysis of nitrate concentrations in the unconfined ground-water system indicate that they are not the primary source of nitrate in ground water in this area.

Naturally occurring nitrate may be a source of nitrate in ground water underlying Badger Coulee in Benton County. Average masses of natural nitrate per unit volume of sediment in two boreholes in Badger Coulee were equivalent to 2,590 and 964 pounds of nitrogen, respectively, in a block of sediments 50 feet thick underlying an acre of land. At most other locations in the study area, the amount of natural nitrate in ground water is probably small compared with nitrate from anthropogenic sources.

Fluoride concentrations in ground water in the study area ranged from less than 0.1 to 4.7 milligrams per liter; the median concentration was 0.5 milligram per liter. The concentration of fluoride in water from only two of 143 wells equalled or exceeded 2.0 milligrams per liter, which is the secondary maximum contaminant level for drinking water. Both are deep wells open to the Saddle Mountains Basalt in Franklin County. Large concentrations of fluoride in deep ground waters of the Pasco Basin are apparently the result of natural conditions in the deeper basalt aquifers.

One or more pesticide compounds were detected in 10 of 29 ground-water samples, which were analyzed for selected chlorophenoxy acid herbicides, triazine herbicides, carbamate insecticides, organophosphorus insecticides, and a few other types of pesticides. The sampling locations did not represent a random distribution, but instead, most were wells open to unconfined, shallow ground water in irrigated areas. The pesticides found include the herbicides atrazine, dicamba, metribuzin, picloram, and 2,4,5-T. Also present were aldicarb sulfone and aldicarb sulfoxide, which are degradation products of the insecticide aldicarb. Except for metribuzin, pesticide concentrations were at or near the analytical reporting limits. In all instances, the concentrations of pesticides detected were below the health advisory levels that are issued by the U.S. Environmental Protection Agency.

INTRODUCTION

Increases in surface- and ground-water irrigation over the last 40 years have transformed the Pasco Basin in eastern Washington (fig. 1) from an area of primarily rangeland and dryland farming into a major agricultural area. The extensive application of irrigation water in the basin has caused a variety of problems, however. The use of surface water for irrigation has been linked to rises in ground-water levels at many locations. Conversely, pumping of ground water has lowered water levels in other areas, resulting in increased pumping costs. Other problems relate to water quality. Large concentrations of nitrate in water from some wells tentatively have been linked to the application of nitrogen fertilizers. There also is concern that pesticides, which have been applied for many years, may have entered the ground water. Fluoride, naturally present in ground water in the Pasco Basin, is found at concentrations above recommended levels for drinking water in some of the deeper wells.

To address many of these water-related concerns, the U.S. Geological Survey (USGS), in cooperation with the Washington State Department of Ecology (Ecology),[1] began a hydrologic study in parts of the Pasco Basin (fig. 1). Data were collected from 1986 into 1989. This report describes the results of that part of the overall study that focused on the quality of ground water. The primary emphasis of the water-quality study was to determine the distribution of nitrate in the ground-water system and to determine the sources of the nitrate. Secondary goals were to determine the distribution of fluoride in the ground water and to test for the presence of pesticides in selected ground-water samples. A companion report (Drost and others, 1996) from this study addresses the causes of ground-water level changes and identifies the geohydrologic factors to be considered for managing the ground-water system.

[1] The Ecology part of the study included a cooperative agreement with the following local agencies: Benton County, Franklin County, City of Kennewick, City of Pasco, City of Richland, City of West Richland, Columbia Irrigation District, and South Columbia Basin Irrigation District.

Purpose and Scope

This report describes (1) the distribution and movement of nitrate in ground water in the study area; (2) how various sources of nitrogen affect nitrate concentrations in ground water; and (3) the distribution of fluoride in ground water. An evaluation of the results of a reconnaissance sampling for analysis of pesticides in ground water is also included.

The distribution of nitrate in ground water was determined by collecting 784 ground-water samples from 436 wells and one spring and analyzing them for nitrate concentration. Samples were collected from September 1986 through November 1989, most in the years 1986 and 1988.

Methods used to determine how sources of nitrogen affect nitrate concentrations in ground water included:

- The sampling and analysis of water samples from surface irrigation canals to determine if imported surface irrigation water is a source of nitrate in ground water;
- The analysis of water from shallow piezometers installed in irrigated fields and from subsurface field drains to determine concentrations of nitrate in shallow ground water beneath cropland;
- The interpretation of long-term changes of nitrate concentrations in ground water;
- An assessment of the spatial relation between nitrate concentrations in ground water and estimates of nitrate loading from various sources;
- The use of major-ion geochemistry to confirm the conceptual understanding of the ground-water flow system that is based on physical and hydrologic factors;
- Selective use of nitrogen-isotope ratios to assess contributions of nitrate from septic systems to the ground water;
- The application of a simplified solute transport model to assess the effects of nitrate loading from septic systems on nitrate concentrations in ground water; and
- The collection and analysis of soil and sediment samples to determine concentrations of natural nitrate.

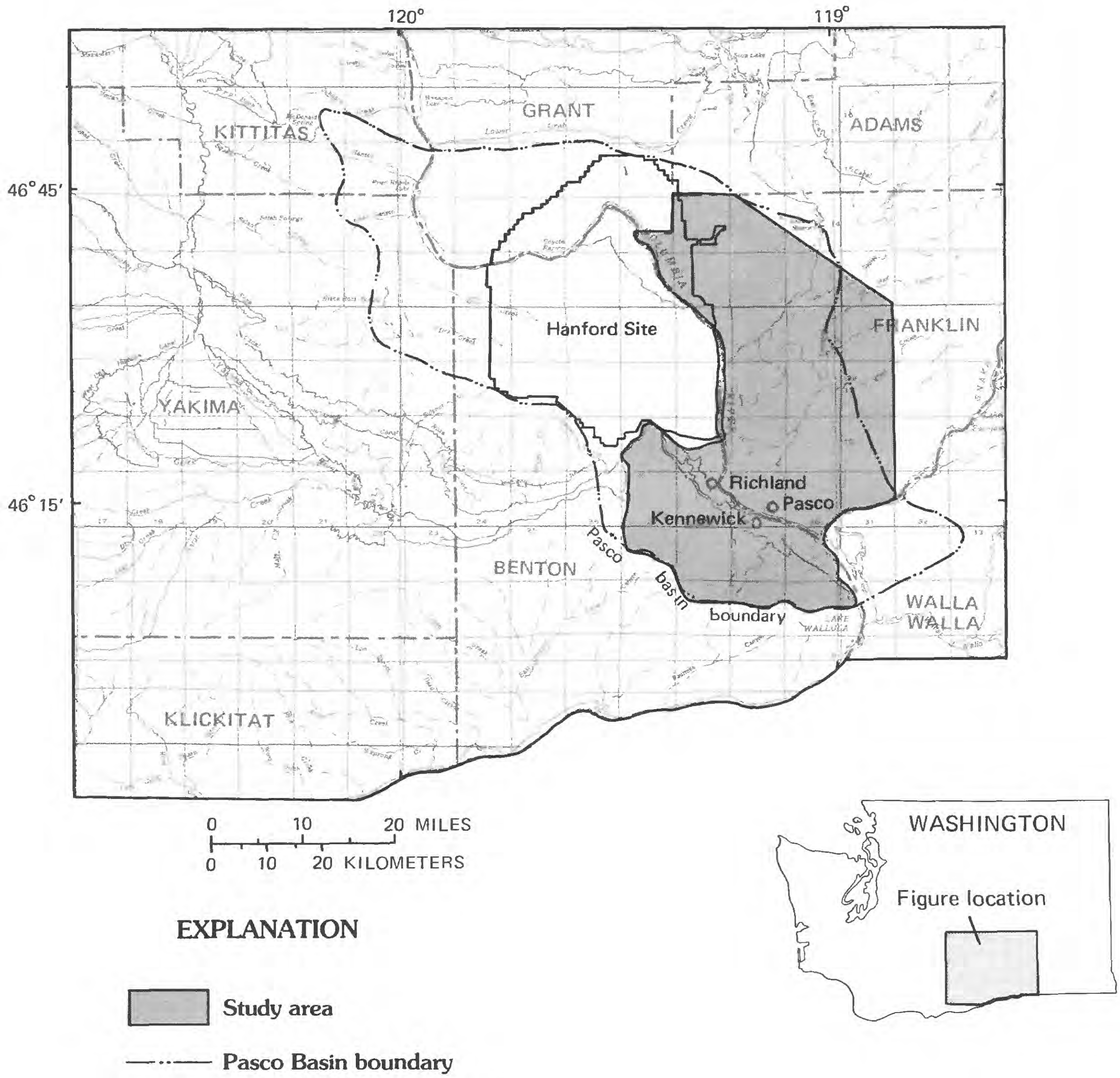


Figure 1.--Location of Pasco Basin and the study area.

Data used to describe the distribution of fluoride in ground water were obtained from the analyses of 152 water samples collected at 143 sites. A total of 29 ground-water samples collected from 24 wells and 4 subsurface field drains were analyzed for pesticides.

A supplemental information section contains explanatory and background information. Tables 13-21 in the supplemental information section list ground-water quality data collected during this study, historical ground-water-quality data collected by the USGS, and surface-water-quality data collected during 1988. Additional data pertaining to ground-water levels, surface-water discharges, and surface-water-quality data collected in 1986 were reported by Drost and others (1989).

Well- and Spring-Identification System

The well numbers give the location of wells and springs according to the official rectangular public-land survey. For example, in well number 09N/27E-12F02, the part preceding the hyphen indicates successively the township (T.09 N.) north and the range (R.27 E.) east of the Willamette base line and meridian. The number following the hyphen indicates the section (sec. 12), and the letter (F) indicates the 40-acre subdivision of the section as shown on figure 2. Last is a sequence number (02) used to distinguish wells in the same 40-acre tract. Thus, well 09N/27E-12F02 is in the SE 1/4 of the NW 1/4 of sec. 12, T.09 N., R.27 E. A "D" following the sequence number indicates a well that has undergone changes in construction (generally deepening). The number following the "D" is a sequence number to distinguish multiple construction changes in the same well. An "S" following the sequence number indicates that the site is a spring. On some plates and figures the well number is shortened by not including the township and range designation because they are shown on the basemap (for example, 12F02).

Acknowledgments

John Holmes and Mark Nielson of the Franklin Conservation District provided data and information that were relevant to this investigation. They also were willing to share their technical knowledge and understanding of the study area. Bruce Perkins of the Benton-Franklin District Health Department provided data and insight pertaining to sources of nitrate in the Finley area of Benton County. Gary Weatherly of the Kennewick Irrigation District provided historical nitrate data for samples collected from the main canal of the district.

Dan Hubbs of the Bureau of Reclamation (BOR) supplied information on BOR observation wells that were sampled during this study. The BOR also provided some of the soil and sediment samples that were analyzed for nitrate concentrations and helped with the installation of additional observation wells for this study.

The assistance and cooperation of many well owners who provided information and access to their wells for sampling is appreciated.

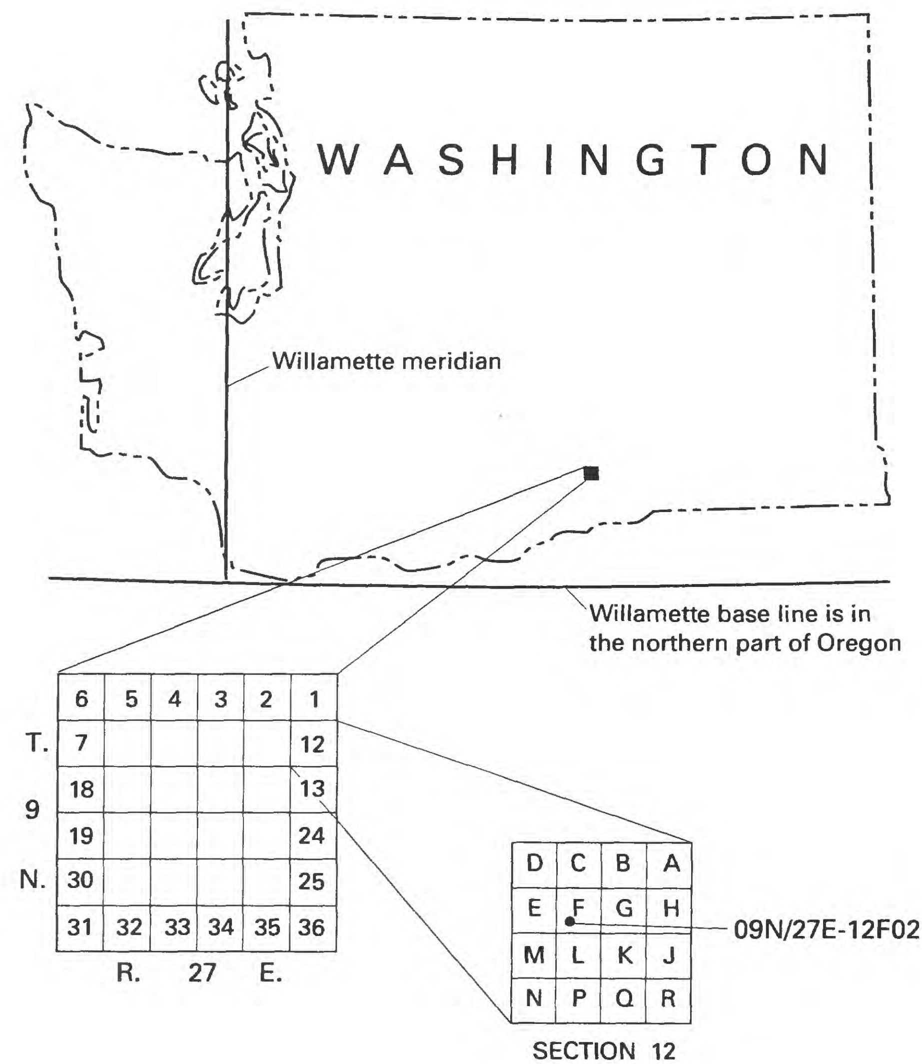


Figure 2.--Well- and spring-identification system.

DESCRIPTION OF THE STUDY AREA

The study area (fig. 1) consists of nearly 900 mi^2 in eastern Benton County and western Franklin County that have been or may be affected by changing ground-water levels and (or) elevated nitrate concentrations in ground water. It lies almost entirely within the Pasco Basin, one of several basins in the Columbia Plateau physiographic province that are separated by anticlinal ridges. The study area is transected by many canyons, coulees, and scab lands that are features resulting from glacial meltwater flooding during the Pleistocene Epoch. Altitudes range from about 340 to 2,200 ft, but most of the land area lies below 1,000 ft. Three major rivers, the Columbia, Snake, and Yakima, flow through or along the boundaries of the study area.

The climate is arid to semiarid. Average annual precipitation over the study area ranges from 6 to 10 inches and occurs primarily in winter. Spring and summer precipitation occurs mainly as a result of thunderstorms, whereas winter precipitation generally falls as light rain or snow. The mean annual temperature for the period 1951-80 at the Kennewick weather station was about 54°F. During the same period, the mean monthly temperatures for the warmest month, July, and the coldest month, January, were about 75°F and 33°F, respectively (U.S. National Oceanic and Atmospheric Administration, 1982).

Population and Land Use

The population of the study area as of 1986 was about 125,000, about three-quarters of which resided in the four largest cities of Kennewick, Pasco, Richland, and West Richland (fig. 1). The principal economic activities in the study area are food processing, agriculture, and the manufacture of chemical, metal, and nuclear products.

Most (59 percent) of the land in the study area is used for agricultural purposes or is classified as rangeland (34 percent). The remaining 7 percent comprises residential-urban and commercial-industrial areas and surface-water bodies. A land-use map based on standard land-use categories (Fegeas and others, 1983) is shown on figure 3.

In 1986, about 70 percent of the agricultural land in the study area was irrigated. Alfalfa, wheat, potatoes, and corn were the major crops, which in 1986 covered about 70 percent of the irrigated area. Asparagus, fruits (apples, grapes, and cherries), pasture, and barley covered about 25 percent of the irrigated areas. The remaining 5 percent supported grass seed, carrots, peas, onions, oats, sorghum, cauliflower, and melons.

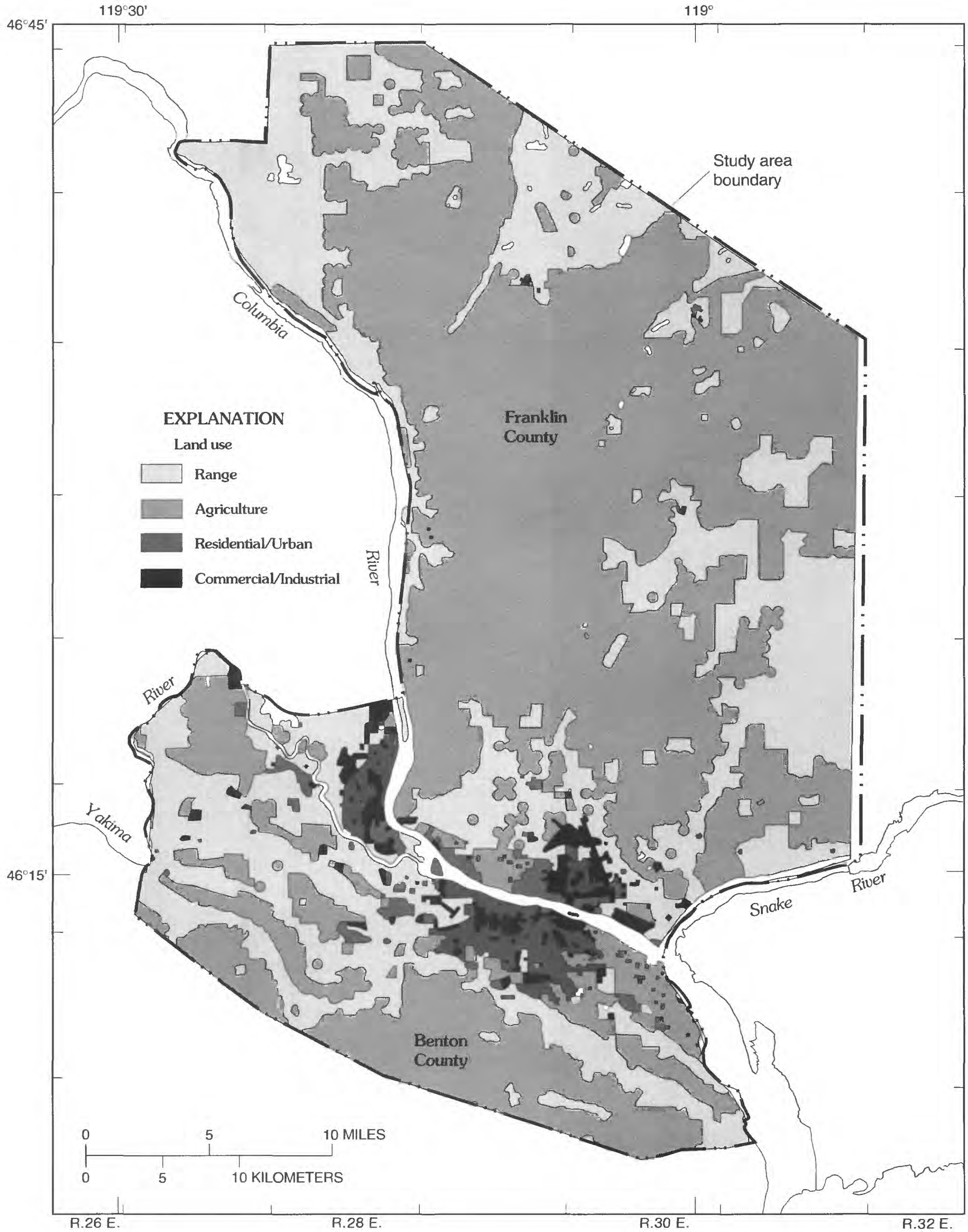


Figure 3.--Generalized land use in the study area, based on standard land-use categories (from Fegas and others, 1983).

Geohydrologic Setting

A summary of the geohydrologic setting in the study area is presented here and certain aspects of the geohydrology that are particularly relevant to understanding the movement of solutes in ground water are emphasized. A detailed description of the geohydrologic setting is presented in a companion report (Drost and others, 1996).

The Pasco Basin is underlain by three major stratigraphic units in which nearly all ground water occurs (fig. 4). These units are from top to bottom, (1) the informally named "Hanford formation of Brown and Isaacson (1977)", hereafter referred to as the Hanford formation; (2) the Ringold Formation; and (3) the Yakima Basalt Subroup. The surficial distribution of these units is shown on figure 5. Several minor stratigraphic units of Pleistocene and Holocene age also crop out in areas too small to be shown on small-scale maps. These units are generally less than 20 ft thick and include loess, sand dunes, landslide debris, and alluvium. All of the stratigraphic units shown on figure 4 function either as aquifers or as confining layers in at least some parts of the study area.

The two sedimentary formations above the basalt (fig. 4) are further separated into units, largely on the basis of texture. The Hanford formation has two textural facies—the Touchet Beds, composed of silt and sand, and the Pasco gravels, composed of sand or sand and gravel. The sediments of the Hanford formation were deposited during the late Pleistocene Epoch from repeated inundations of the Pasco Basin by glacial flood waters. The Ringold Formation was deposited during the Miocene and Pliocene Epochs as fluvial sediments carried by ancestral rivers flowing into and through the basin, and consists of four textural facies as classified by Brown (1979). The facies are from top to bottom, (1) the upper Ringold Formation composed of silt and sand; (2) the middle Ringold Formation composed of sand, gravel, and silt; (3) the lower Ringold Formation composed of silt and clay; and (4) the basal Ringold Formation composed of sand and gravel. The coarse-grained units (Pasco gravels, middle Ringold, and basal Ringold Formations) are generally very productive aquifers wherever they occur in the study area. The fine-grained units (Touchet Beds, upper Ringold, and lower Ringold Formations) generally can produce small amounts of water in some locations, but primarily are confining layers.

The formations of the Yakima Basalt Subgroup that are of geohydrologic interest in the study area are the Saddle Mountains, Wanapum, and Grande Ronde Basalts (fig. 4). Almost all ground-water samples from basalt aquifers were collected from the Saddle Mountains and Wanapum units, the most widely used aquifers of the basalt group in the study area.

Ground water in basalt occurs in joints, vesicles, fractures, and in other localized features that result in permeable zones. The tops of basalt flows are the most permeable, and therefore serve as aquifers. The centers of most basalt flows are dense and have very low permeabilities. They generally are confining layers, but differ from most confining layers in that they usually have vertical jointing which leads to vertical flow of ground water that is greater than horizontal flow.

Between basalt flows, particularly the youngest flows, minor amounts of sediment, generally referred to as the Ellensburg Formation, were interbedded with the basalts. Some of the interbeds are areally extensive and can serve as stratigraphic divisions between individual basalt formations; for example, the Mabton Member of the Ellensburg Formation (fig. 4) at various locations in the study area lies between the Saddle Mountains and Wanapum Basalts. Interbedded sediments in the basalts are aquifers where they are coarse grained and are confining layers where there are fine grained. The fine-grained sediments consist of volcanic ash and fluvial, lacustrine, or eolian deposits. Locally, the sediments may affect the concentrations of major ions in ground water but these chemical effects are poorly understood because variations in the composition of the sediments are not generally known.

The previously described stratigraphic units are designated geohydrologic units, except that the sedimentary interbeds are included with the basalt units. For example, the Mabton Member of the Ellensburg Formation is included with the Saddle Mountains Basalt and the Vantage Member of the Ellensburg Formation is included with the Wanapum Basalt. The geohydrologic units are described in detail by Drost and others, 1996).

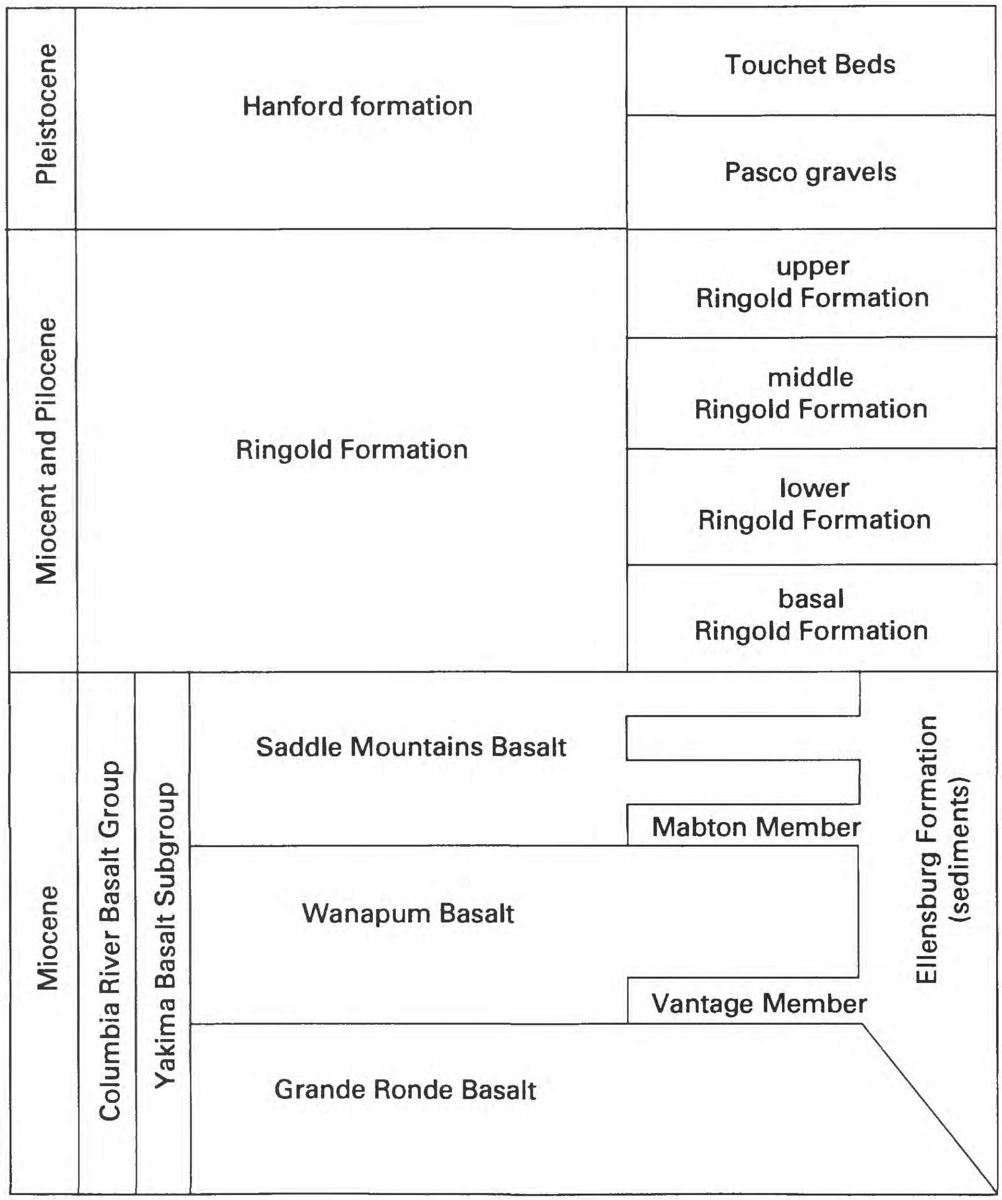


Figure 4.--Major stratigraphic units in the Pasco Basin (from Myers and Price, 1979).

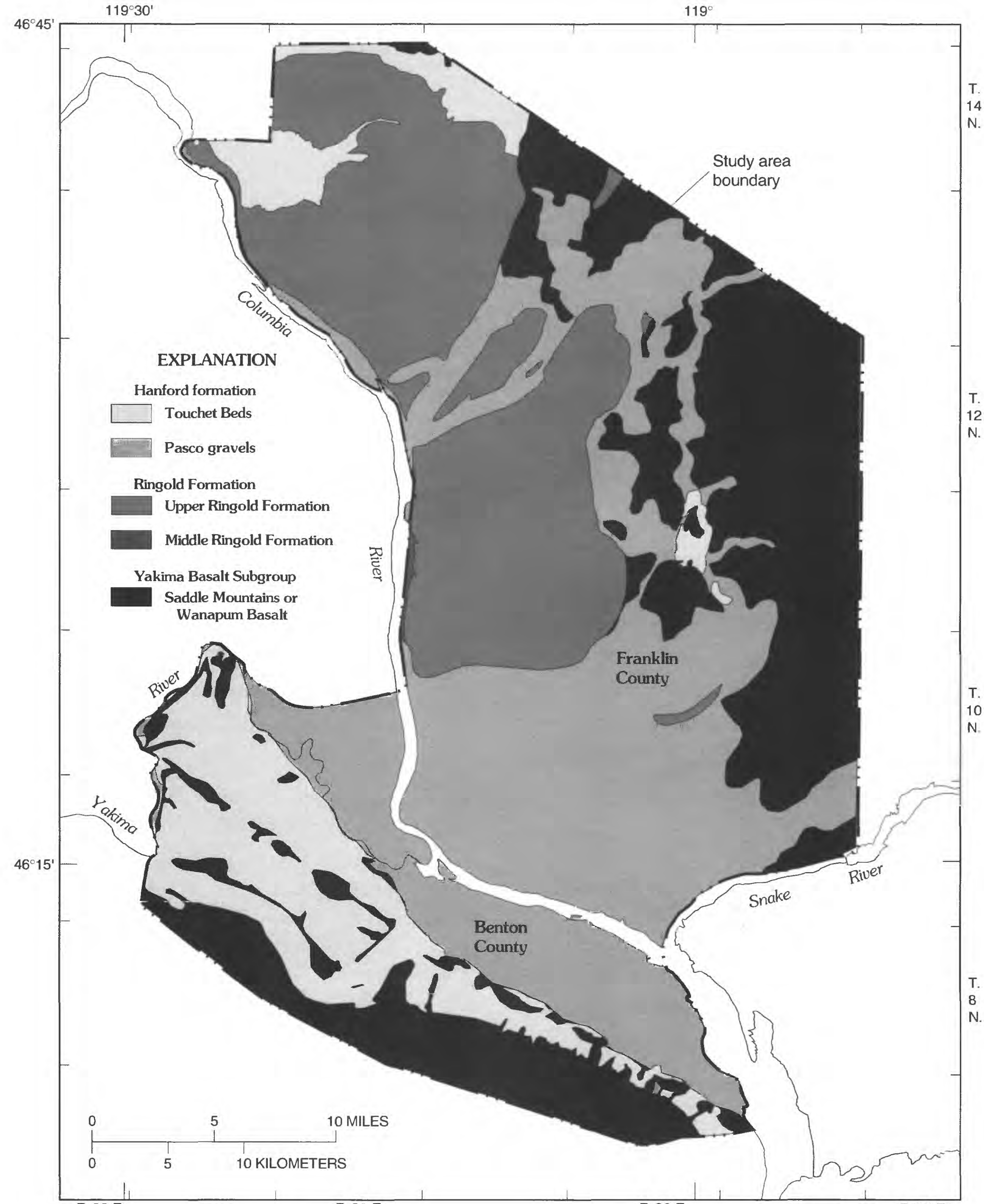


Figure 5.--Surficial geology of the study area.

Most of the ground-water flow at the water table in the study area is directed toward the Columbia, Snake, and Yakima Rivers—the major areas of ground-water discharge in the study area. However, some flow at the water table is toward internal drains such as Esquatzel and Ringold Coulees. On a local scale (tens of acres), flow at the water table is frequently toward subsurface field drains, which have been installed to prevent waterlogging of agricultural fields. Although the altitude of the water table changes seasonally, the general pattern of flow remains fairly constant. The general direction of ground-water flow can be inferred from plates 1 and 2, which show the configuration of the water table for March 1986. Ground-water movement is generally perpendicular to the water-table contours shown. The water-table contours were drawn using an aggregate of water levels in wells open to all unconsolidated units (Pasco gravels and Ringold Formations) and do not show possible head differences between these units.

With increasing depth in the ground-water system, flow is more toward the rivers and less influenced by the internal drains. Flow in the Saddle Mountains Basalt (pls. 1 and 2) is generally toward the rivers, but shows the influence of Esquatzel Coulee. Flow in the Wanapum Basalt (pls. 1 and 2) shows little or no effects of internal drains.

Vertical flow in the ground-water system occurs within aquifers and between aquifers through the confining beds. In most of the study area, vertical flow is downward. This can be seen by comparing the water table shown for the unconsolidated units with water levels in the Saddle Mountain Basalt or Wanapum Basalt, which are deeper units (pls. 1 and 2). Vertical flow is upward in discharge areas along rivers and drains. In areas with buried field drains, localized vertical flow within the water-table aquifer is toward the drains (fig. 26).

Natural sources of ground-water recharge in the study area are percolation from precipitation and infiltration from rivers. Anthropogenic sources of ground-water recharge are percolation from applied irrigation waters, seepage from irrigation canals, and infiltration from artificial-recharge basins. Seepage from irrigation canals and percolation from applied irrigation water were determined to account for about 85 percent of the total recharge in the study area (Drost and others, 1996). Excessive recharge from irrigation water has required the installation of subsurface field drains in many locations to prevent waterlogging of fields.

Irrigation Systems

Surface and ground water are used extensively for commercial agricultural irrigation in the study area and, to a lesser extent, domestic irrigation of lawns and gardens. Most of the irrigation water used, however, is surface water from the Columbia, Yakima, and Snake Rivers (fig. 6). About 6 percent of the irrigated cropland in the study area is irrigated by ground water, most of it in the southern part of Franklin County (fig. 6).

More than 1,300 mi of open channel or pipe make up the conveyance network of surface-water irrigation delivery and wastewater collection systems. The major surface-water irrigation systems in Benton County are the Badger Mountain Irrigation District (BMID), the Columbia Irrigation District (CID), the Kennewick Irrigation District (KID), and the McWhorter Canal System (fig. 7). They all obtain water from the Yakima River. Major surface-water irrigation systems in Franklin County, the South Columbia Basin Irrigation District (SCBID) and the Franklin County Irrigation District (FCID) (fig. 7), obtain water from the Columbia River. Detailed descriptions and histories of these irrigation systems are given by Drost and others, 1996).

Many of the irrigation systems rely on gravity to move water; consequently, canals and laterals that deliver the water commonly are located along upland areas. For the most part, they are open-channel, unlined waterways in which water can infiltrate through the bed. However, numerous waterway sections have been lined in an attempt to retard the loss of water. Seepage from delivery systems is the largest source (about 50 percent) of ground-water recharge within the study area (Drost and others, 1996).

Wasteways and drains collect and remove excess irrigation water. In general, wasteways follow natural drainage channels and can collect ground-water seepage in the same manner as natural streams. Ground water derived from the seepage and percolation of irrigation water is discharged by springs found along several of the major wasteways. Wasteways also serve as an outlet to dump excess water from the delivery system. Most of the wasteways, and particularly the larger wasteways, empty into the Columbia River. There also are several wasteways that empty into infiltration ponds or back into another part of the delivery system.

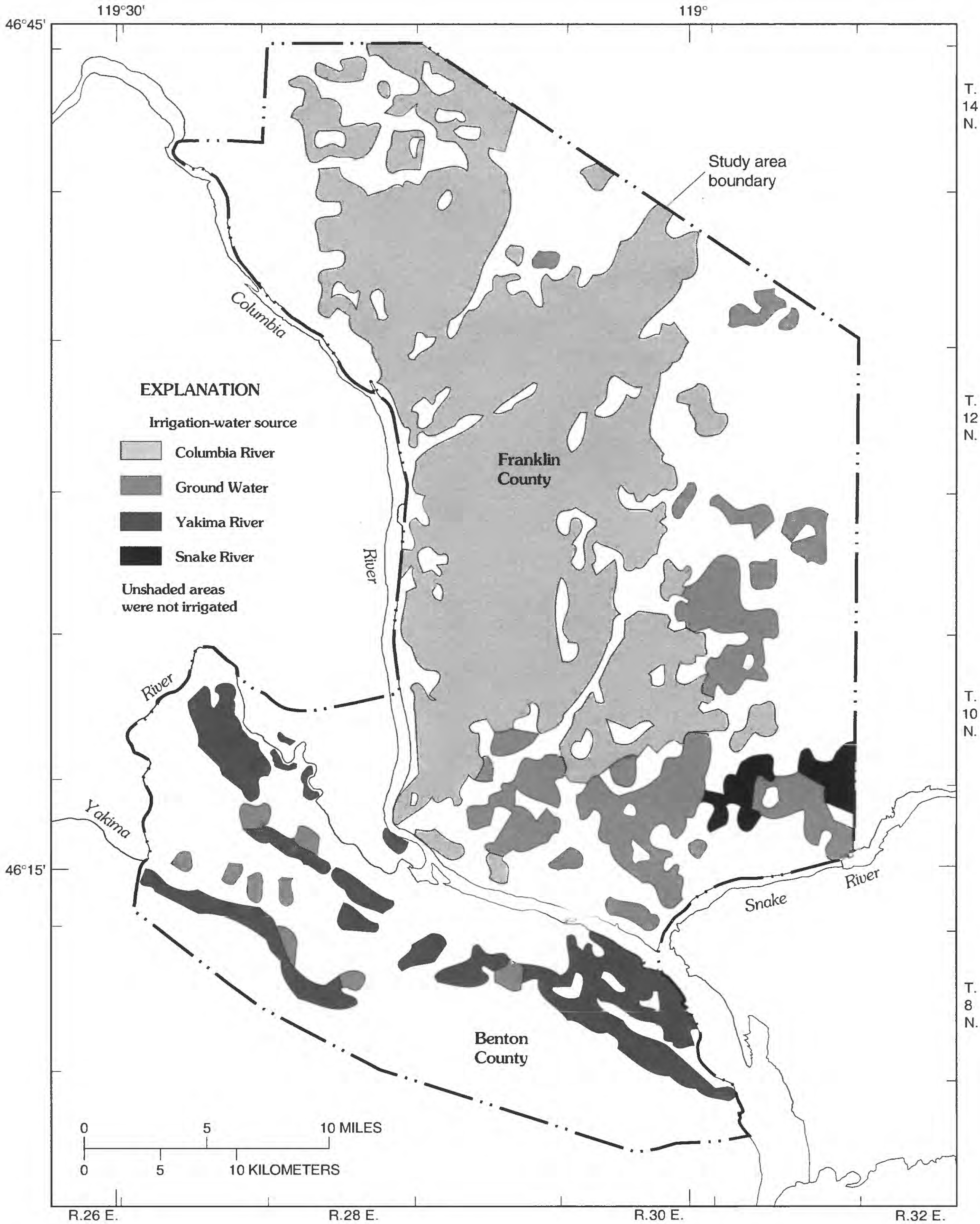


Figure 6.--Areas irrigated by surface water from the Columbia, Yakima, and Snake Rivers and by ground water.

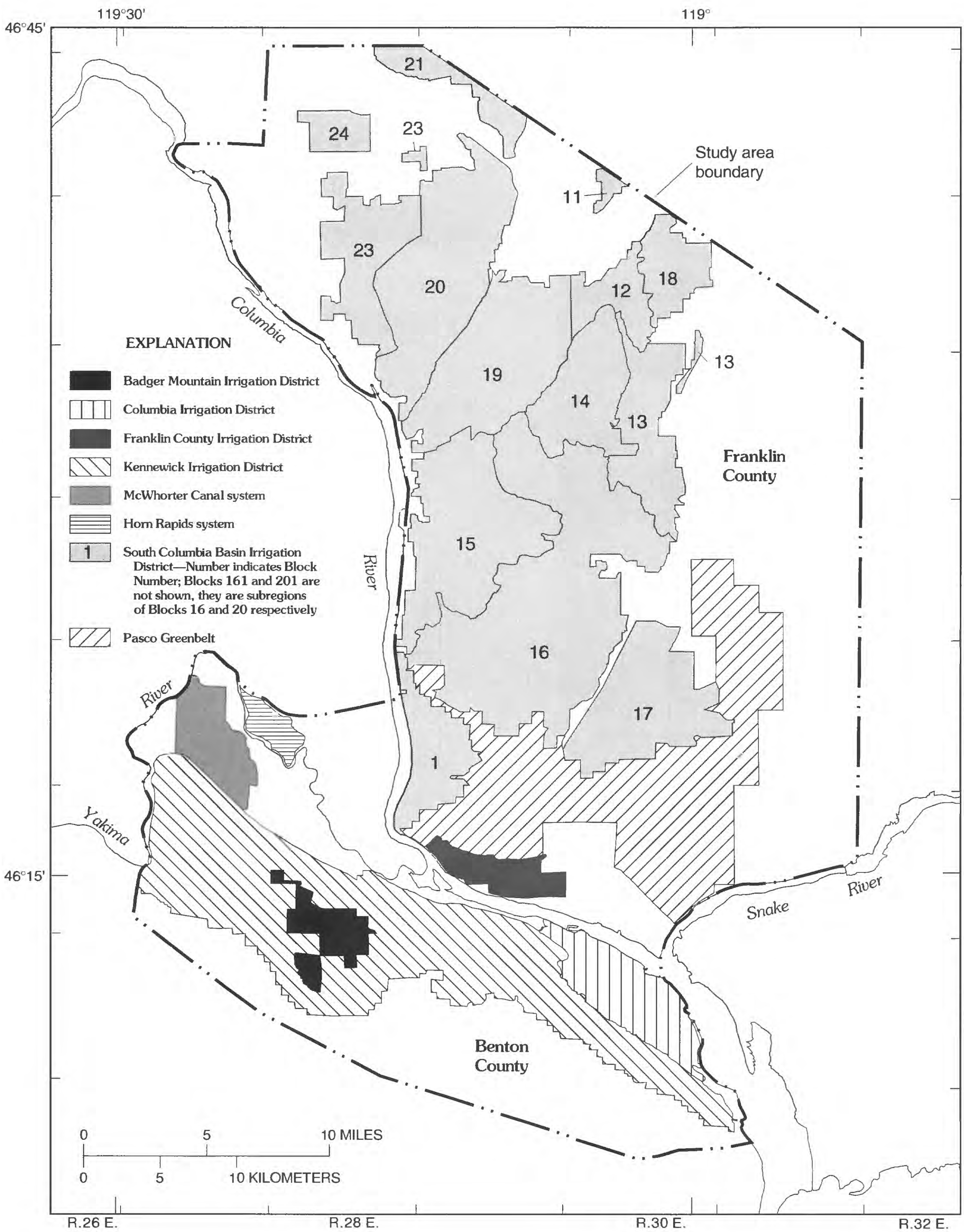


Figure 7.--Areas served by the major surface-water irrigation systems.

Drains can be of either the surface or subsurface type. Surface drains are drainage ditches that intercept ground-water seepage, return flows of applied irrigation water, and discharges from subsurface drains. Surface drains connect to wasteways, and many of the wasteways also act as surface drains. Subsurface drains are perforated pipes buried horizontally below the land surface, and are used to intercept a rising water table and maintain it at a level below the root zone of plants or at some other desired level. Like some of the smaller wasteways, some surface and subsurface drains discharge to canals or laterals of the delivery system. This recycling of water generally degrades the quality of water in the delivery system by adding nitrate and other constituents.

DISTRIBUTION OF NITRATE IN GROUND WATER

Nitrate concentrations in ground water in the study area vary greatly. Observed concentrations ranged from less than 0.1 to 100 mg/L NO_3-N (milligrams per liter, nitrate as nitrogen). In Benton County, nitrate concentrations in water from about 10 percent of the wells sampled were equal to or greater than the U.S. Environmental Protection Agency Primary Drinking Water Regulation maximum contaminant level of 10 mg/L NO_3-N (U.S. Environmental Protection Agency, 1986b). The median observed concentration in Benton County was 3.2 mg/L NO_3-N. In Franklin County, nitrate concentrations in water from 31 percent of the wells sampled were equal to or greater than 10 mg/L NO_3-N, and the median concentration was 6.7 mg/L NO_3-N. Tables 13-21 listing nitrate and other data are found in the supplemental information section.

The distribution of nitrate in the ground water of the study area, (pls. 1 and 2) represents concentrations in samples collected from September 1986 through November 1989, most in the years 1986 and 1988. Seven hundred and eighty-four ground-water samples, which were collected from 436 wells and 1 spring, were analyzed for nitrate. Five other springs were sampled for nitrate, but these are discussed in a subsequent section along with the surface-water sites because the spring discharges were sampled after flowing overland for various distances. Nitrate concentrations in ground water represent either the concentration in a single water sample or, if two or more samples were collected on different days from a well or spring, the arithmetic mean of the concentrations in the individual samples.

Short-term and long-term temporal variations of nitrate concentrations in ground water are described where data are available. Short-term variations are defined as differences that were observed during this study (1986-89). Short-term variations may be caused by factors that change seasonally, such as rates of ground-water recharge, or they may be caused by other factors, such as changes in well-pumping schedules. Long-term variations, defined as differences between nitrate concentrations in ground water determined during this study and those determined previously, are useful in relating concentration trends to changes in land use or other factors that may affect nitrate concentrations in ground water. Nitrate-concentration data for ground-water samples collected as far back as the early 1940's at various locations in Franklin County were available to assess long-term variations. Also, some of the previously sampled wells were located and resampled. In Benton County, historical water-quality data were few, except for samples collected during the late 1970's in the Finley area (Wood, 1977).

Ground-water samples that were analyzed for nitrate were collected more than once from 182 of the 437 sites sampled (table 14). Not included in table 14 are duplicate samples that were collected for quality control purposes (table 20). Nitrate concentrations in samples from 13 of the 182 wells, which were sampled 6 to 11 times each to observe seasonal changes, also are shown graphically on plates 1 and 2. The remainder of the 182 wells were sampled two to four times each.

Benton County

In Benton County, concentrations of nitrate in ground-water samples ranged from less than 0.1 to 52 mg/L NO_3-N (table 13). Nitrate concentrations greater than or equal to 10 mg/L NO_3-N, the maximum contaminant level for drinking water, were found in ground water sampled in Richland, northeast of Candy and Badger Mountains near Richland, in Badger Coulee, and in the Finley area (pl. 1). Ground water containing less than 0.1 mg/L NO_3-N was found throughout the county (pl. 1), indicating that areal variations of nitrate concentrations are large.

The largest concentrations of nitrate, as well as the largest range in concentrations, were found in water from the Pasco gravels, the middle Ringold Formation, and the Saddle Mountains Basalt (pl. 1). In Benton County, water in the Pasco gravels and middle Ringold Formation generally is unconfined, and therefore may be vulnerable to nitrate loading at locations where surface or near-surface sources of nitrogen are present. Although ground water in the Saddle Mountains Basalt generally is confined, it is vulnerable to nitrate loading where it is unconfined or where it is recharged from the overlying water-table aquifer.

Water samples from the lower Ringold Formation and the Wanapum Basalt unit generally contained less than 1 mg/L NO_3-N (pl. 1). The Wanapum Basalt is mostly confined, and near the Columbia River, the vertical component of ground-water flow is generally upward in this unit. The lower Ringold Formation is a confining layer and wells completed in this mostly clay unit are open to coarse lenses within it (B.W. Drost, U.S. Geological Survey, oral commun., 1990).

Nitrate concentrations in water from wells located along section AA' (shown on plate 1) in and near Richland illustrate differences between nitrate concentrations in unconfined ground water and concentrations in the underlying lower Ringold Formation confining layer and Saddle Mountains Basalt. Nitrate concentrations in ground water in the lower Ringold Formation were typically less than the minimum reporting level of 0.1 mg/L NO_3-N, (table 13), whereas nitrate concentrations in water from most wells open to the overlying Pasco gravels and middle Ringold Formation, which are unconfined over much of this area, were greater than 5 mg/L NO_3-N (pl. 1).

Water from two wells located along section A-A' that are open to the Saddle Mountains Basalt also contained less than 0.1 mg/L NO_3-N (pl. 1, table 13). A comparison of the major-ion composition of the ground water in the Saddle Mountains Basalt with that of the water in the overlying lower Ringold Formation indicates that the waters do not travel along similar flow paths (fig. 8). Ground water sampled from well 09N/28E-04G01, open to the Saddle Mountains Basalt, contained a much larger percentage of sodium than ground water in the lower Ringold Formation, as represented by a sample collected from well 09N/28E-03P01. Bicarbonate-type water that is enriched in sodium is typical of water that has chemically evolved after long contact time with basalt (Hearn and others, 1985). The major-ion composition of ground water sampled from the lower Ringold Formation is similar to that of water from the Yakima River (fig. 8), an indication that the river may recharge this unit.

Although similar in major-ion composition, nitrate concentrations in most of the ground-water samples from the lower Ringold Formation were less than the median concentration of 0.89 mg/L NO_3-N in samples collected from the Yakima River at Kiona over the period from 1974 through 1981 (Joseph Rinella, U.S. Geological Survey, written commun., 1989). Ground-water samples from the lower Ringold near Richland contained no oxygen (table 13), and on the basis of the strong odor of sulfide in water from most wells sampled, the ground water is highly reducing. Therefore, any nitrate introduced with the recharge to the lower Ringold Formation would have been removed by denitrification or reduction.

According to Drost and others, 1996), the Yakima River recharges the unconfined ground-water system in the Pasco gravels and middle Ringold Formation in the area between the Yakima and Columbia Rivers in townships 9 and 10 N., R.28 E. (pl. 1). Water moves from the Yakima River through these units and discharges to the Columbia River. Although not shown, the major-ion composition of water from wells open to the Pasco gravels and middle Ringold Formation is similar to the composition of water from the Yakima River, an indication that the river is indeed recharging these units. Nitrate concentrations in water from most of these wells (pl. 1) are larger than the median concentration of nitrate in water from the Yakima River at Kiona, indicating that nitrate is added to the unconfined ground water from various sources. An exception is well 10N/28E-17B01 (Pasco gravels, pl. 1), which is located on the Hanford Site near its southern boundary. The percentages of major ions and the concentration of nitrate (0.85 mg/L NO_3-N) in water from this well are similar to those of water from the Yakima River. This well is located south of a plume of nitrate in the unconfined ground water beneath the Hanford Site (Evans and others, 1988), and there are no known nitrate sources in the immediate vicinity of this well.

In contrast to section A-A', a location where nitrate is present in ground water in the Saddle Mountains Basalt is along the northeastern flanks of Candy and Badger Mountains (T.9 N., R.28 E; section B-B' on pl. 1). Although the basalt at this location is recharged largely by water containing about 1 mg/L NO_3-N that seeps from the Badger East Lateral Canal, nitrate concentrations larger than 10 mg/L NO_3-N were found in ground water sampled from this unit. Because the population density is low and there are no crops grown in this area that require large amounts of nitrogen fertilizers, it is difficult to account for the elevated concentrations of nitrate found in the ground water. A potential source, which was not investigated at this location, is natural nitrate present within sediments of the Ellensburg Formation, which occurs as interbeds in and underlying the Saddle Mountains Basalt. Additional information on naturally occurring nitrate in the study area is presented in the section "Natural Nitrate" in this report

Nitrate concentrations of 10 mg/L NO_3-N or greater were found in unconfined ground water sampled from the Pasco gravels in Badger Coulee, which extends from Kiona through parts of townships T.9 N. R.27 E. and T.8 N. R.28 E. to near the West Highlands area of Kennewick (pl. 1). Much smaller concentrations of nitrate (less than 1 to about 2 mg/L NO_3-N) were found in ground water in the underlying Saddle Mountains and Wanapum Basalt units in this area. Nitrate concentrations shown at wells on section C-C' (pl. 1) are typical of the vertical variations of concentrations found in ground water throughout Badger Coulee. Although the uppermost unit, the Touchet Beds, is saturated at some locations in Badger Coulee, few wells are open to this unit. The nitrate concentration in the only ground-water sample obtained from the Touchet Beds in Badger Coulee (piezometer 08N/28E-17P01) was 25 mg/L NO_3-N (table 13).

Large concentrations of nitrate in the uppermost geohydrologic units in Badger Coulee indicate a near-surface source of nitrate. Nitrate that is derived from applied nitrogen fertilizers and transported to the water table in recharge from applied irrigation water is probably one source of the nitrate. Another source may be the dissolution of natural nitrate in the Touchet Beds by recharge or rising ground-water levels. The presence of natural nitrate in the Touchet Beds was confirmed by the analysis of samples collected during this study.

At some locations in Badger Coulee, recharge to the ground-water system by seepage from the Kennewick Main Canal appears to govern the major-ion and nitrate composition of the shallow ground water. The chemical similarity of water from well 08N/28E-21H01, which is open to the Pasco gravels, and water from the nearby Kennewick Main Canal (fig. 9) suggests that seepage of water from the canal is a primary source of recharge to the Pasco gravels near this well. The major-ion composition of water from the Kennewick Main Canal is represented by samples from the Yakima River, which is the source of water to the canal. Farther from the canal, toward the center of the coulee, ground water in the Pasco gravels generally contains more nitrate (fig. 9 and pl. 1), and its major-ion composition, as represented by water from well 08N/28E-15P01, differs from that of canal water. Nitrate concentrations in water from wells 08N/28E-15P01, 08N/28E-16R01, 08N/28E-21A01, and 08N/28E-22D01 range from 8 to 25 mg/L NO_3-N (fig. 9).

The composition of water from some wells open to the Saddle Mountains Basalt underlying Badger Coulee also is similar to that of water from the Kennewick Main Canal. Because of the shallower depth to basalt near the canal, it is likely that water seeping from the canal enters the basalt aquifer.

The concentrations of nitrate in water in the Pasco gravels underlying the Finley area (T. 8 N., R. 30 E.) were generally greater than 1 mg/L, but less than 10 mg/L NO_3-N (pl. 1). Water in the Pasco gravels is unconfined, and for much of the Finley area the water table is within 20 ft of the land surface. Concentrations less than 1 mg/L NO_3-N were found in samples from wells 08N/30E-10M03 and 08N/30E-14C01 (Pasco gravels, pl. 1). These low concentrations probably can be attributed to recharge from the Columbia River to the Pasco gravels adjacent to the river. The major-ion composition of water from well 10M03 (fig. 10) is similar to water in the Columbia River.

Most wells in the Finley area open to water containing less than 1 mg/L NO_3-N are finished in the Saddle Mountains Basalt (pl. 1). Some of these wells tap the deeper water-bearing zones within the basalt, as illustrated by well 08N/30E-20R01 on section D-D' (pl. 1). Others, although open near the top of the Saddle Mountains Basalt, are located where the vertical component of flow is upward from the basalt to the overlying Pasco gravels (Drost and others, 1996). Examples are well 08N/30E-23E03 (located on section D-D', pl. 1) and well 08N/30E-05J01 (fig. 10), both of which yield bicarbonate-type water with a relatively large percentage of sodium (fig. 10). This type of water is indicative of water that has had a relatively long contact time with basalt.

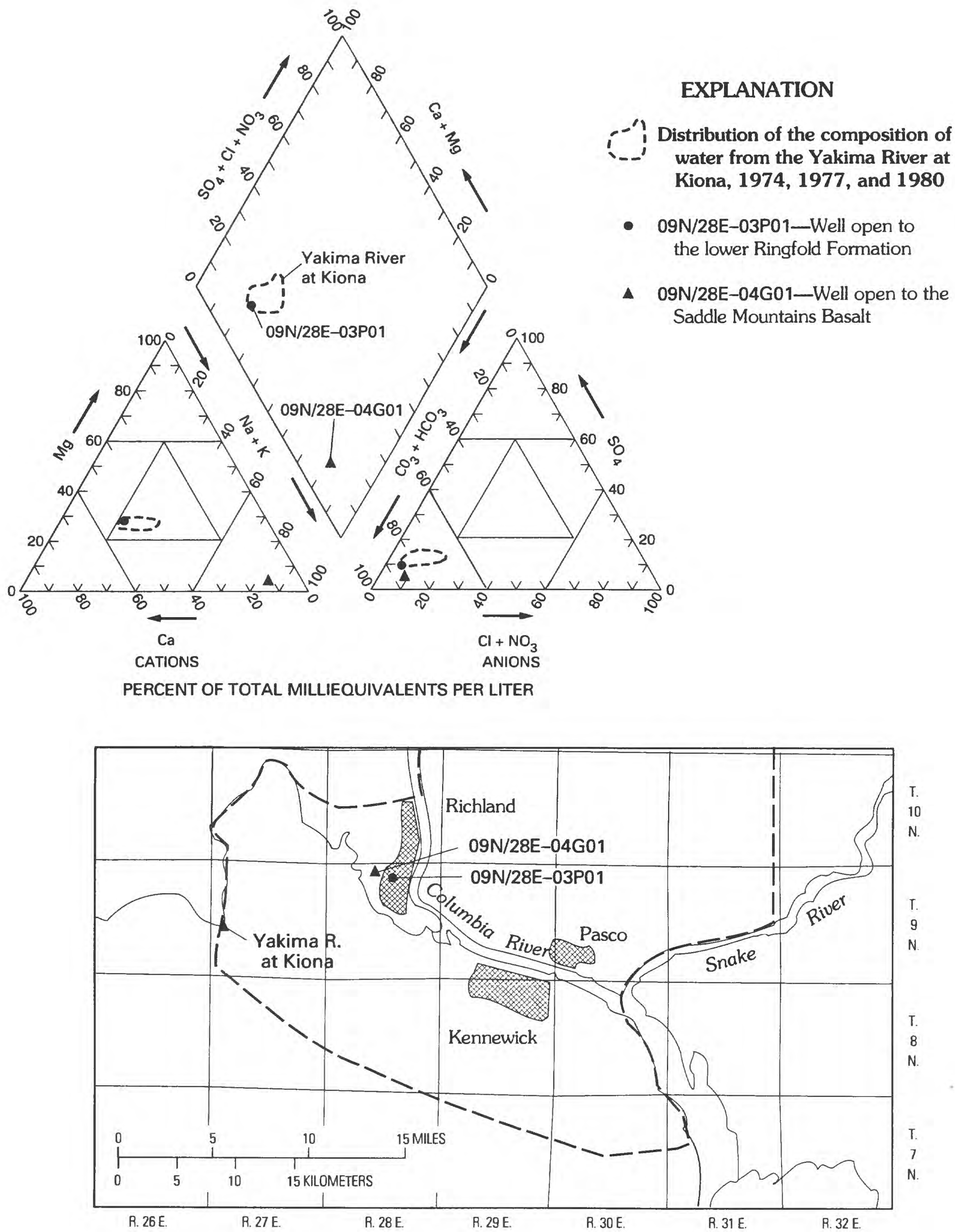


Figure 8.--Major-ion composition of ground water from the lower Ringold Formation and Saddle Mountains Basalt underlying the Richland area, and of water from the Yakima River at Kiona.

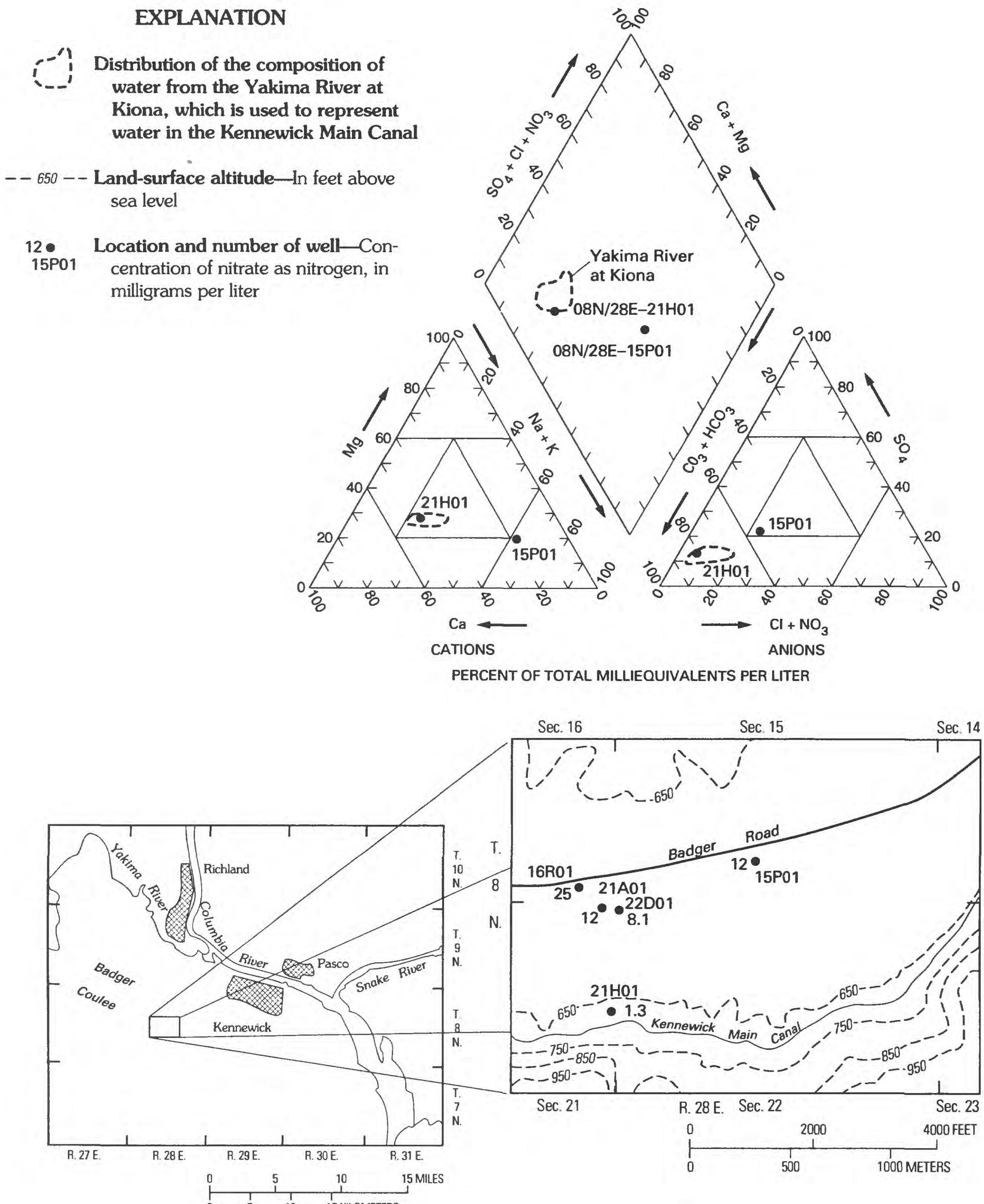
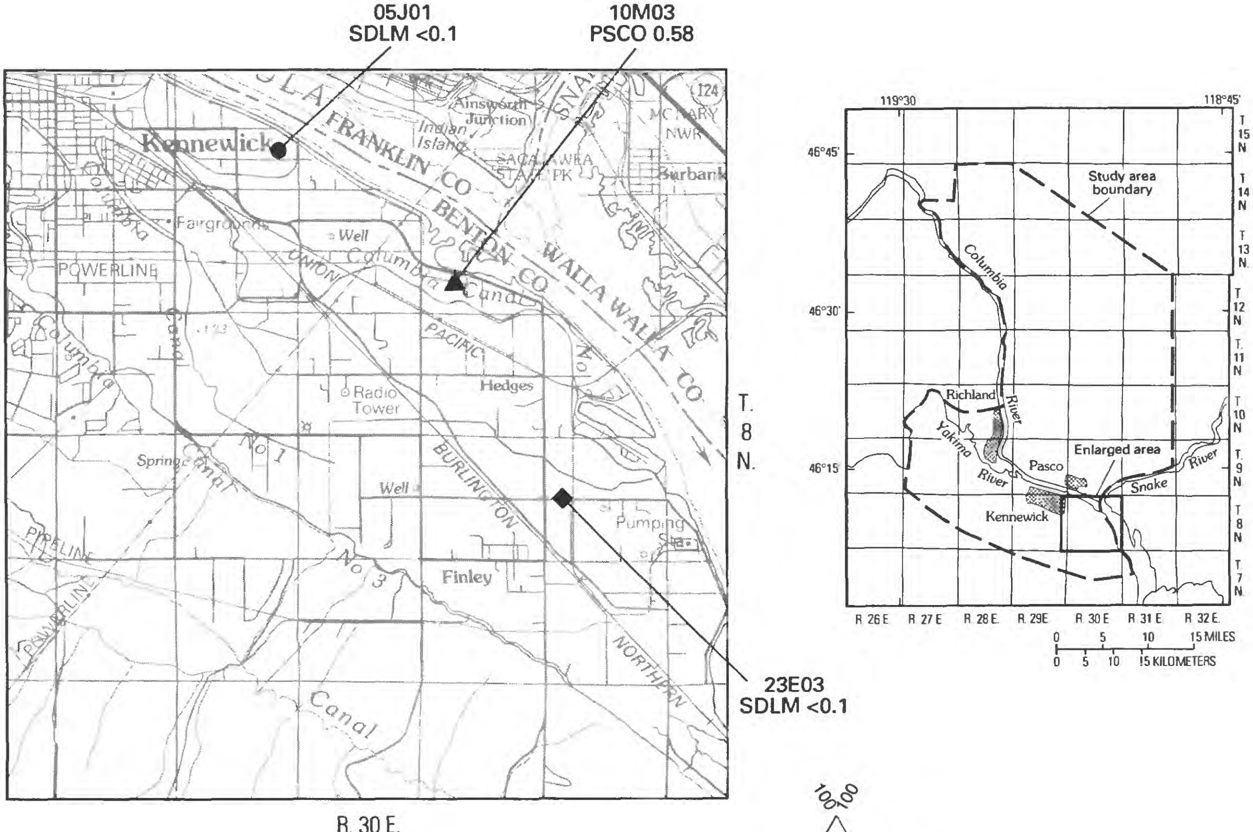


Figure 9.--Chemical composition of unconfined ground water of Badger Coulee and surface water in the Kennewick Main Canal.



EXPLANATION

05J01; SDLM; <0.1	**Quarter-quarter section and sequence-number designation for well; geohydrologic unit; nitrate concentration, in milligrams per liter as nitrogen, (< = less than)**
PSCO	**Pasco gravels**
SDLM	**Saddle Mountains Basalt**

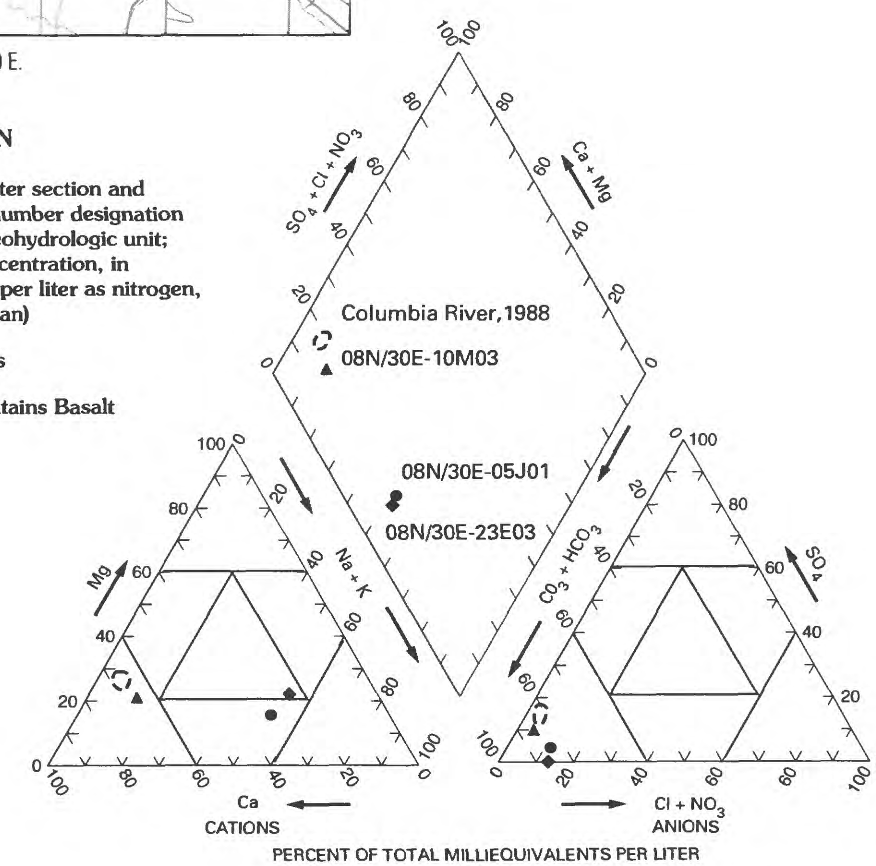


Figure 10.--Chemical composition of ground water containing less than 1 milligram per liter nitrate from three wells in the Finley area, and of water from the Columbia River.

Short-Term Temporal Variations of Nitrate Concentrations

Six wells in Benton County were sampled quarterly or more frequently to observe short-term variations of nitrate concentrations in ground water (Pasco gravels, Saddle Mountains Basalt, pl. 1). The largest variations, from about 7.5 to 17 mg/L NO_3-N, were found in samples from wells 08N/28E-15P01 and 08N/28E-21A01, which are open to the Pasco gravels in Badger Coulee. For both wells, concentrations were largest during the summer months. Large concentrations during summer months may relate to increased amounts of recharge containing nitrate from the percolation of applied irrigation water. Nitrate concentrations in ground water from the other four wells either did not change or their variations do not appear to be related to seasonal factors.

Insufficient samples were collected from most other wells sampled more than one time (table 14) to relate observed variations of nitrate concentrations with changes in season. A possible exception is the area around the town of Finley (T.8N, R.30E) because it was sampled more extensively. There, it was noted that nitrate concentrations in unconfined water sampled from the Pasco gravels during September and October tended to be larger than concentrations in samples collected during February and April.

Seasonal differences between nitrate concentrations in paired samples of unconfined ground water (wells less than 100 ft deep) from the Finley area are shown in table 1. For 11 of 14 pairs, nitrate concentrations were larger in samples collected in September and October than in samples collected in February and April. The median difference between paired concentrations was 1.05 mg/L NO_3N. Members of all sample pairs were collected within a period of 1 year.

Table 1.--*Seasonal differences between nitrate concentrations in water from wells less than 100 feet deep in the Finley area, Benton County, Washington*

[Members of all sample pairs were collected within a period of 1 year; PSCO, Pasco gravels; SDLM, Saddle Mountains Basalt; mg/L, milligrams per liter]

Well number	Geohydro-logic unit	Depth of well (feet)	Milligrams per liter; month and year of sample collection: Summer-Autumn	Winter-Spring	Summer-autumn minus winter-spring nitrate as nitrogen (mg/L)
08N/30E-05K01	PSCO	36	7.6; 9/88	5.8; 2/88	1.8
08N/30E-07J02	PSCO	45	3.8; 9/88	6.8; 4/88	-3.0
08N/30E-07Q04	PSCO	38	10 ; 9/88	9.2; 4/88	0.80
08N/30E-09L02	PSCO	43	2.2; 9/88	3.4; 2/88	-1.2
08N/30E-16F01	PSCO	50	5.3; 9/86	4.2; 2/87	1.1
08N/30E-16F01	PSCO	50	3.9; 9/88	3.4; 2/88	.5
08N/30E-17R01	PSCO	40.5	8.4; 9/88	5.5; 4/88	2.9
08N/30E-21C03	PSCO	35	11 ; 9/86	7.6; 2/87	3.4
08N/30E-21C03	PSCO	35	3.7; 9/88	1.4; 2/88	2.3
08N/30E-21C04	PSCO	28	4.5; 9/88	2.4; 2/88	2.1
08N/30E-22J02	PSCO	30	4.6; 9/86	4.1; 2/87	.5
08N/30E-22M02	PSCO	29.5	3.2; 10/88	3.5; 2/88	-.3
08N/30E-34B02	SDLM	56	11 ; 9/88	7.5; 2/88	3.5
08N/30E-35E02	PSCO	50	19 ; 9/88	18 ; 2/88	1.0
				median difference =	1.05
				mean difference =	1.1

Long-Term Temporal Variations of Nitrate Concentrations

Available nitrate data for the part of the study area in Benton County include nitrate concentrations in miscellaneous ground-water samples collected by the USGS and data generated by a previous study of ground water in the Finley area (Wood, 1977). Some of the samples (table 13) were collected by the USGS prior to 1980, and attempts to resample these wells were unsuccessful. Some of the wells that were sampled by the USGS after 1980 were resampled during this study. Time-concentration plots for ground waters sampled by the USGS and containing detectable amounts of nitrate are shown on figure 11. These wells are too widely distributed areally to indicate any general trends within the study area.

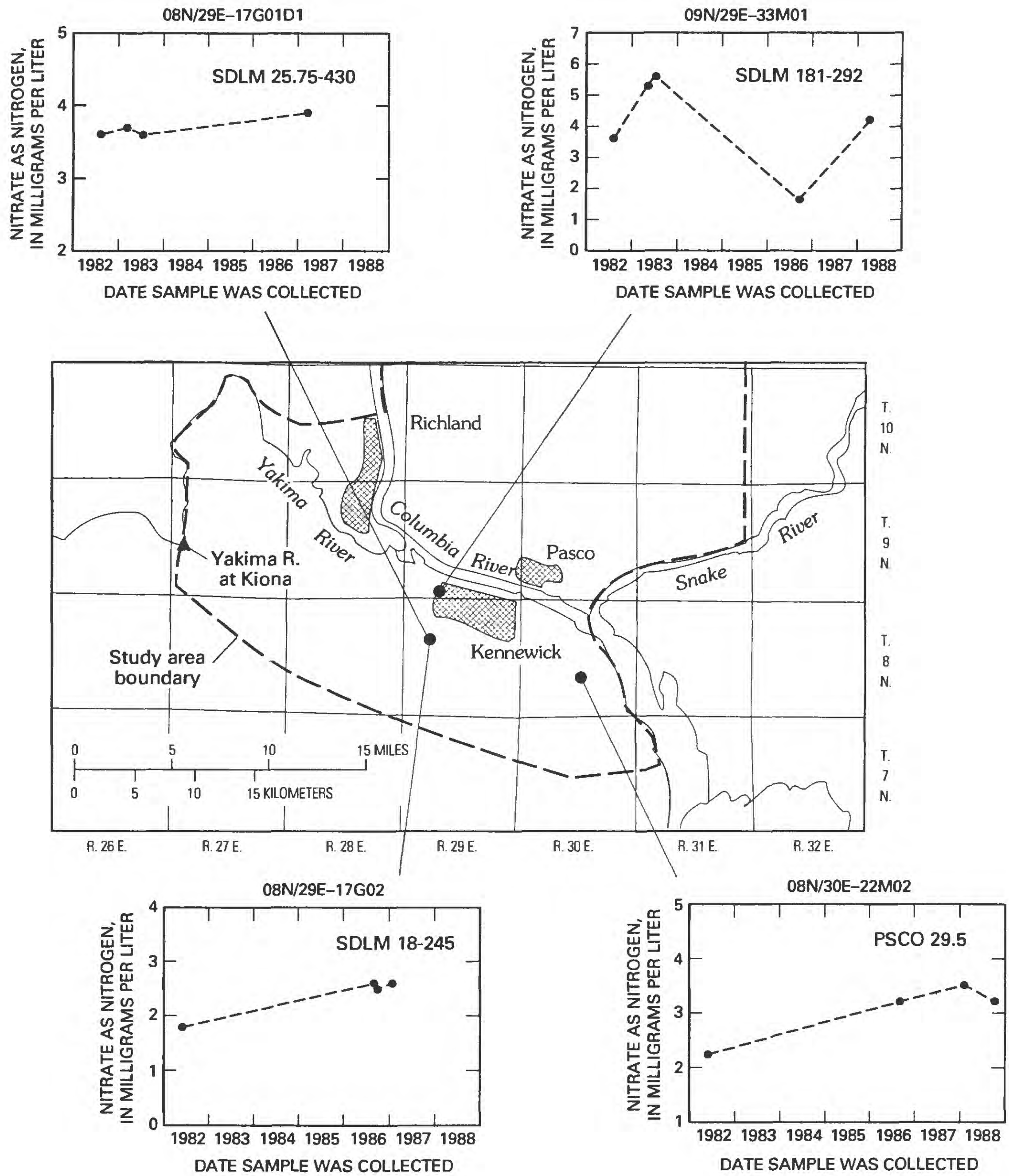
During the study conducted by Wood (1977) in the Finley area (T.8 N., R.30 E., pl. 1), 100 ground-water samples collected during 1976-77 were analyzed for nitrate and other constituents. Comparisons of Wood's data with the data collected in 1986-88 during this study indicate that nitrate concentrations in Finley-area ground water have not changed over the 10-year period between the two studies.

Three factors complicated the use of data collected by the two studies to determine if a temporal change occurred. First, a systematic error that was detected in the reporting of the nitrate data collected by Wood (1977) had to be verified and corrected. Nitrate concentrations reported as nitrate as nitrate (NO_3-NO_3) should have been reported as nitrate as nitrogen (NO_3-N). Wood was unable to locate the analytical records, therefore verification of this error was required and is provided in the supplemental information section.

The second complicating factor was that the two data sets do not represent the same vertical distribution of wells in the Finley area. To the extent that they could be identified, only four of the 100 wells sampled by Wood (1977) were resampled during this study. Although wells sampled during both studies were distributed throughout the Finley area, a larger percentage of deeper wells was sampled during this study. The median depth of wells sampled during this study was 56 ft, compared with a median depth of 35.5 ft for wells sampled by Wood. About 43 percent of the wells sampled during this study were more than 100 ft deep, compared with only 6 percent of the wells sampled by Wood. This problem was resolved by using nitrate data only from the analyses of samples collected from wells less than 100 ft deep. In this data set, the median depth of wells sampled by the USGS was 39 ft, compared with 33 ft for wells sampled by Wood (fig. 12). Selection of another cutoff depth, 50 ft for example, does little to make the two distributions of well depths more comparable (fig. 12). Also, for each study, the distribution of nitrate concentrations in samples from wells less than 50 ft deep is similar to the distribution in samples from wells less than 100 ft deep (fig. 12).

The third complicating factor was the need to account for seasonal variations in nitrate concentrations before the data could be used to determine the presence of a trend. All of Wood's samples were collected during December and January. During the USGS study, most samples were collected in September and October. As previously discussed, the few data available indicate that nitrate concentrations in unconfined ground water of the Finley area are larger in September and October than in December and January. However, these data are inadequate to rigorously evaluate seasonal changes in nitrate concentrations. For this reason, Wood's data are compared with three sets of data (fig. 13) from samples collected during this study: nitrate concentrations in all samples; concentrations in samples collected during February only; and concentrations in all samples, but with a factor of 1.05 subtracted from concentrations in samples collected during September and October. The factor of 1.05 is the median seasonal difference between nitrate concentrations in 14 pairs of water samples collected from Finley-area wells that are less than 100 ft deep (table 1).

Of the three concentration distributions, two of them—the February data and the seasonally adjusted data—are most similar to distributions in samples collected by Wood (fig. 13). If typical seasonal variations are of the magnitude of those observed during this study, then the comparisons indicate that nitrate concentrations have not changed much in the time period between the Wood and USGS studies. Additionally, nitrate concentrations in water from four wells sampled by Wood (1977) and again during this study (fig. 14) also support the conclusion that nitrate concentrations in Finley-area ground water have not changed during the period between the two studies. Nitrate concentrations in water from two of the wells show no general trend. For the other two wells, Wood reported a concentration of 1 mg/L, which was the value he used for all concentrations less than or equal to 1 mg/L. In both cases, the concentrations determined by the USGS also were less than 1 mg/L.



EXPLANATION

PSCO	**Pasco gravels**
SDLM	**Saddle Mountains Basalt**
18-245	**Open interval or depth of well, in feet below land surface**

Figure 11.--Nitrate concentrations in water from selected wells in Benton County that were sampled both in the early 1980's and during this study.

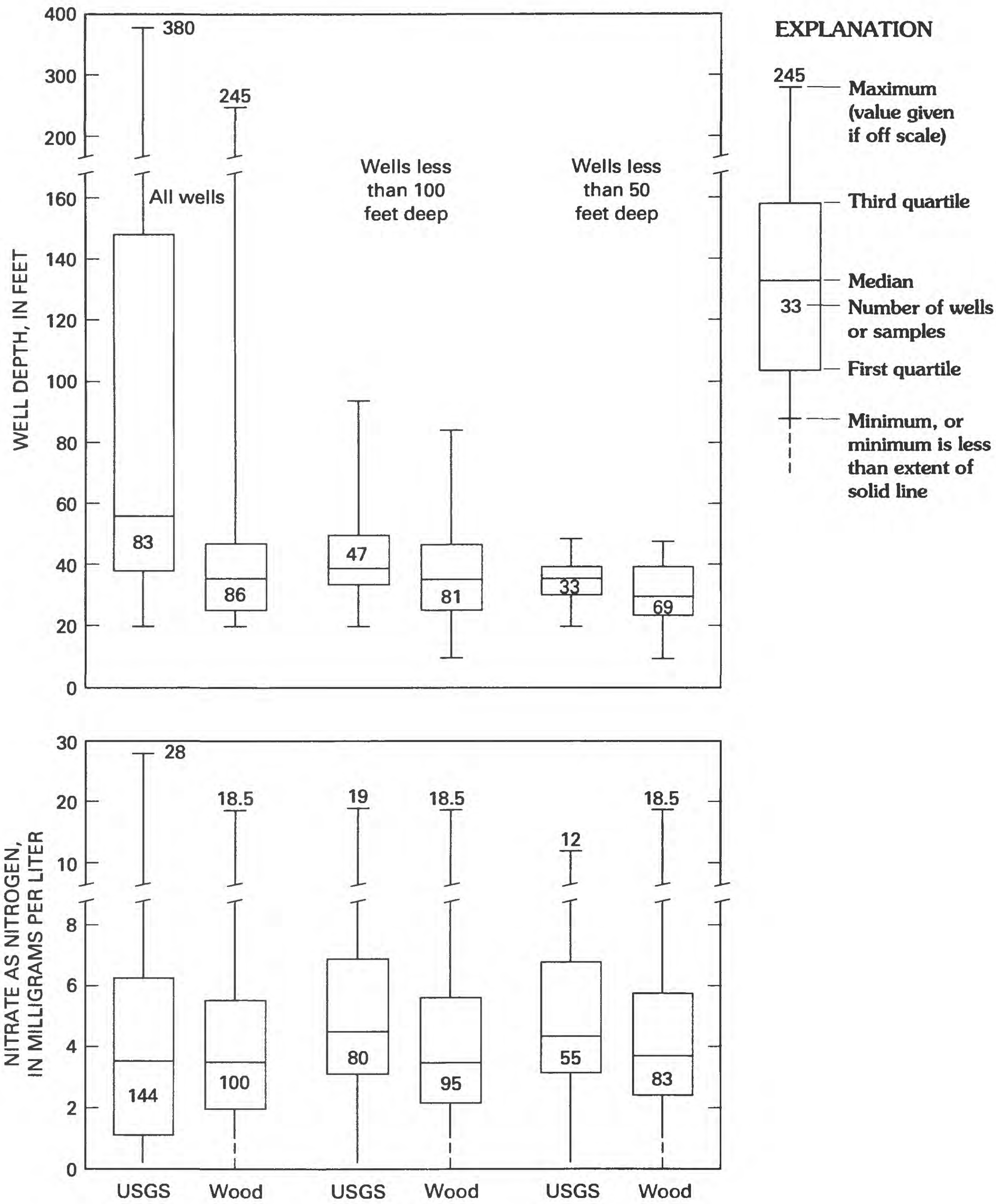


Figure 12.--Well depths and corresponding nitrate concentrations in ground water in Finley area. Wells designated "USGS" were sampled during this study; other wells were sampled by R.F. Wood (1977).

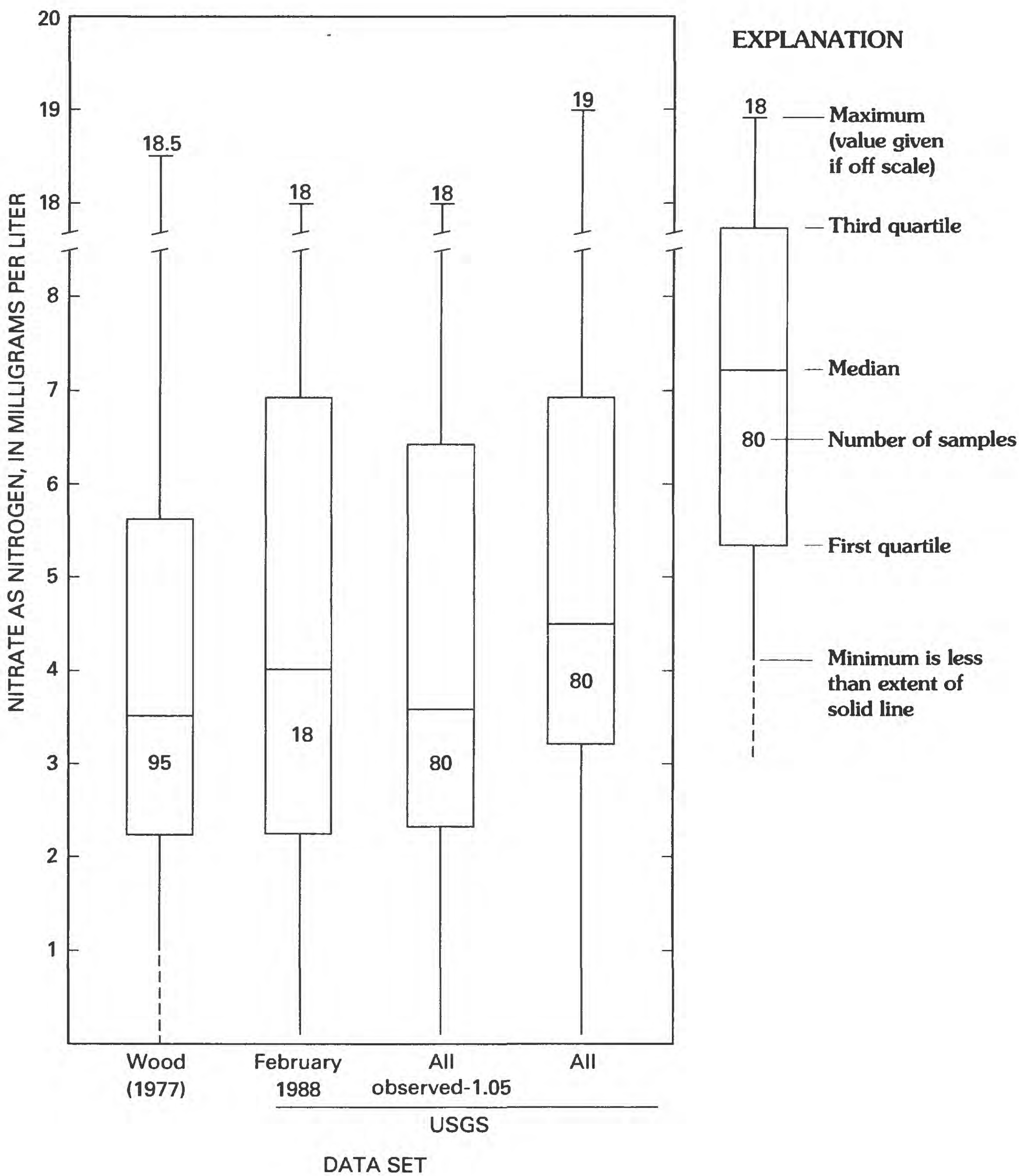


Figure 13.--Nitrate concentrations in water from wells less than 100 feet deep in the Finley area.

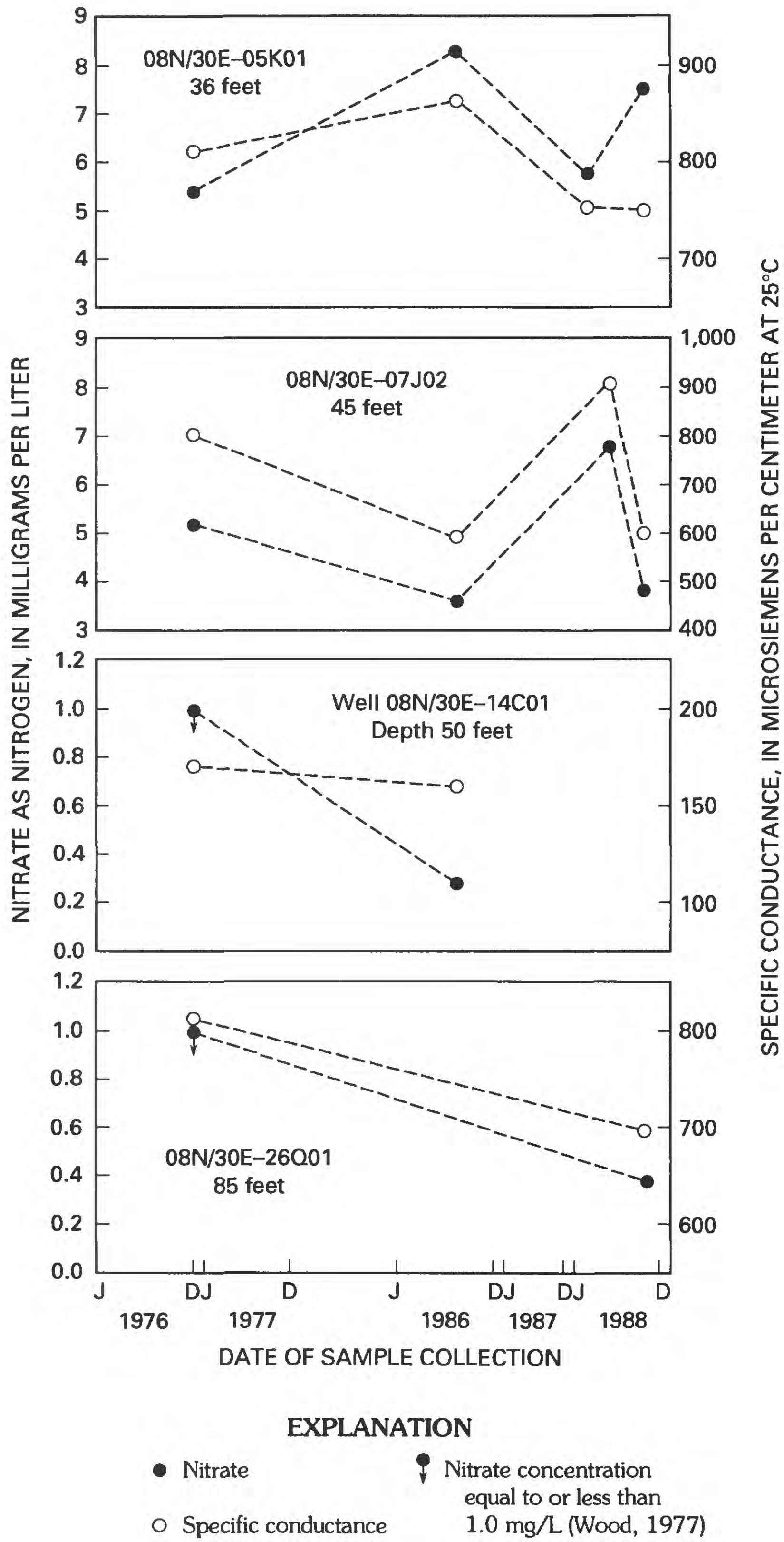


Figure 14.--Long-term variations in nitrate concentrations and specific conductance values in water from four wells in the Finley area. Data for 1976-77 from Wood (1977).

Franklin County

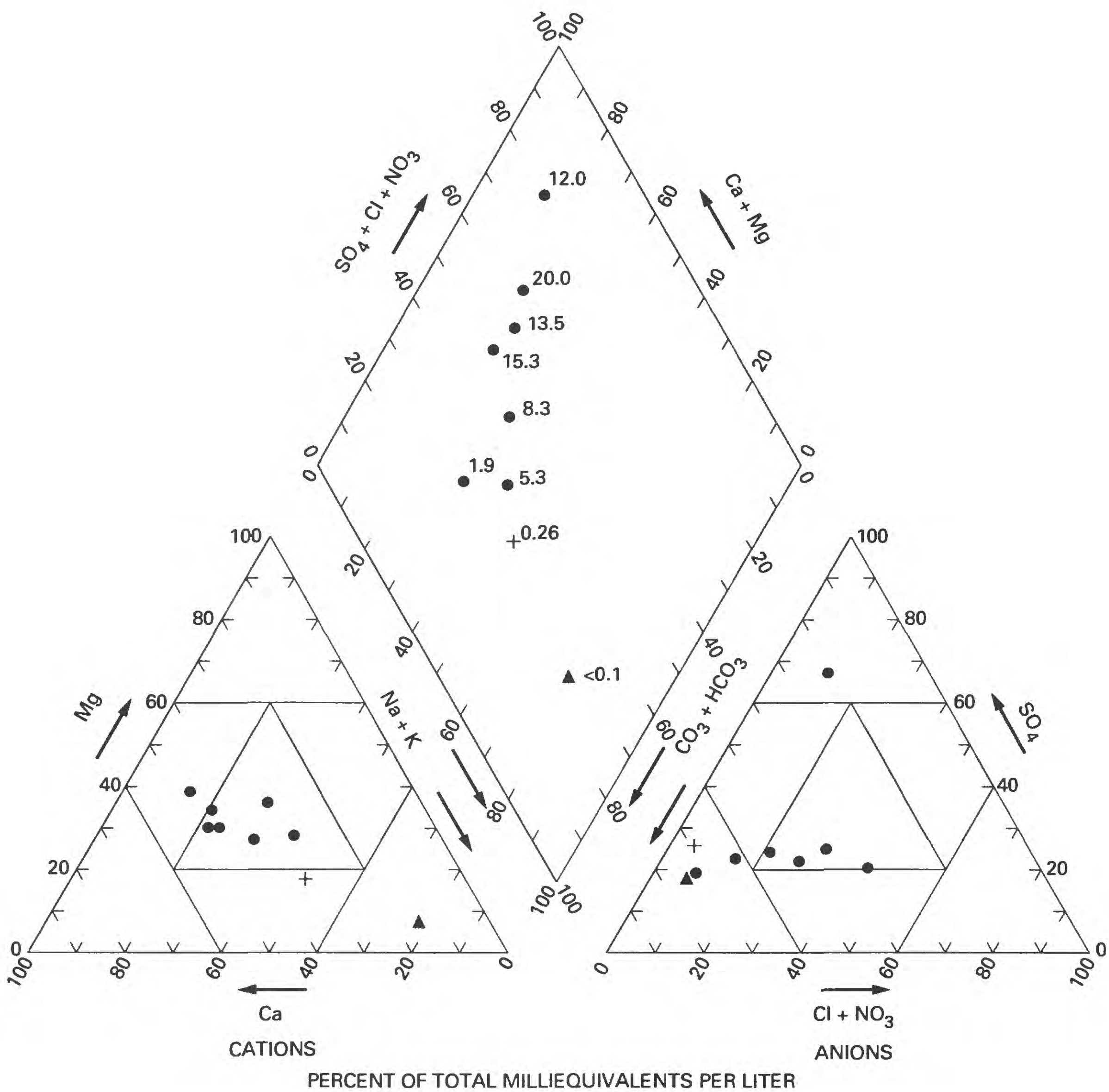
Observed concentrations of nitrate in ground water in Franklin County ranged from less than 0.1 to 100 mg/L NO_3-N (table 13). Ground water containing more than 10 mg/L NO_3-N, the maximum contaminant level for drinking water, was found throughout the county and in all major geohydrologic units (pl. 2). Most ground water containing less than 1 mg/L NO_3-N, the smallest concentration range represented on plate 2, was found in the deeper water-bearing zones of the Saddle Mountains and Wanapum Basalts, where the ground water is relatively far downgradient from sources of recharge. Shallow ground water containing about 1 mg/L NO_3-N or less was also found at locations near irrigation canals, where seepage of water from the canal is the primary source of recharge to the shallow ground-water system, and at locations where no significant nitrate sources are present.

Nitrate concentrations in unconfined ground water sampled from the two major uppermost sedimentary geohydrologic units, the Pasco gravels and the upper Ringold Formation, were typically between 5 and 20 mg/L NO_3-N (pl. 2). Only four wells open to these units yielded ground water containing less than 1 mg/L NO_3-N (upper Ringold Formation, pl. 2). Small nitrate concentrations in water from three of the four wells are related to locations of the wells. Wells 10N/29E-3P01 and 10N/29E-14D01 are located near canals, where the composition of the shallow ground water is believed to be controlled by seepage of water from the canals. Canal water typically contained about 1 mg/L NO_3-N (see discussion, p. 36). There are no major sources of nitrate near well 14N/28E-16A01.

Water in the middle Ringold Formation, which underlies the upper Ringold Formation and Pasco gravels, also typically contained between 5 and 20 mg/L NO_3-N (pl. 2). This is to be expected because at most locations the vertical component of ground-water flow is generally downward from the Pasco gravels and upper Ringold Formation to the middle Ringold Formation. Some exceptions were found, however. Water from wells 10N/28E-12J01, 11N/29E-07M01, and 12N/28E-25M01, which are located near the Columbia River (see sections J-J', I-I', and G-G', respectively, on pl. 2), contained less than 1 mg/L NO_3-N. Because these wells are located near the Columbia River where the vertical component of ground-water flow is upward, they may intercept ground water that is moving from the underlying Saddle Mountains Basalt into the middle Ringold Formation. Major-ion data for water from well 12N/28E-25M01 support this hypothesis because the water contained a larger percentage of sodium than other ground water in the middle Ringold Formation (fig. 15). Water from well 12N/28E-25M01 may be a composite of sodium-bicarbonate type water from the Saddle Mountains Basalt and water of a more mixed composition (fig. 15) from the upgradient unconfined ground-water system.

In the Saddle Mountains Basalt, the largest nitrate concentrations (commonly greater than 10 mg/L NO_3-N) in water were generally found in the eastern and northern parts of the study area, where the basalt is at or near land surface. Nitrate concentrations greater than 10 mg/L NO_3-N also were found at locations where wells are open to the upper parts of the basalt underlying the sedimentary units. Water containing less than 1 mg/L NO_3-N was found in the deeper water-bearing zones of the Saddle Mountains Basalt and in upper zones located upgradient of irrigated areas or where seepage of canal water is the primary source of recharge to the top of the basalt aquifer. An example is well 13N/30E-12N01 (see section G-G' on pl. 2), in which the major-ion composition of water is similar to the composition of water (fig. 16) delivered by the East Low 85 Lateral Canal to the northeast part of the study area where the well is located.

In contrast, the mean concentration of nitrate in water samples from nearby well 13N/30E-13M01D1 (section G-G', pl. 2) was 13.2 mg/L NO_3-N. This concentration is more typical of that found in water in the upper part of the Saddle Mountains Basalt, where it is recharged by percolation of applied irrigation water containing nitrate derived from nitrogen fertilizers. Water from well 13N/30E-13M01D1 also contains larger percentages of sulfate and chloride than water from well 13N/30E-12N01 (fig. 16), which is a common characteristic of the composition of ground water that includes recharge percolated through fertilized fields.



EXPLANATION

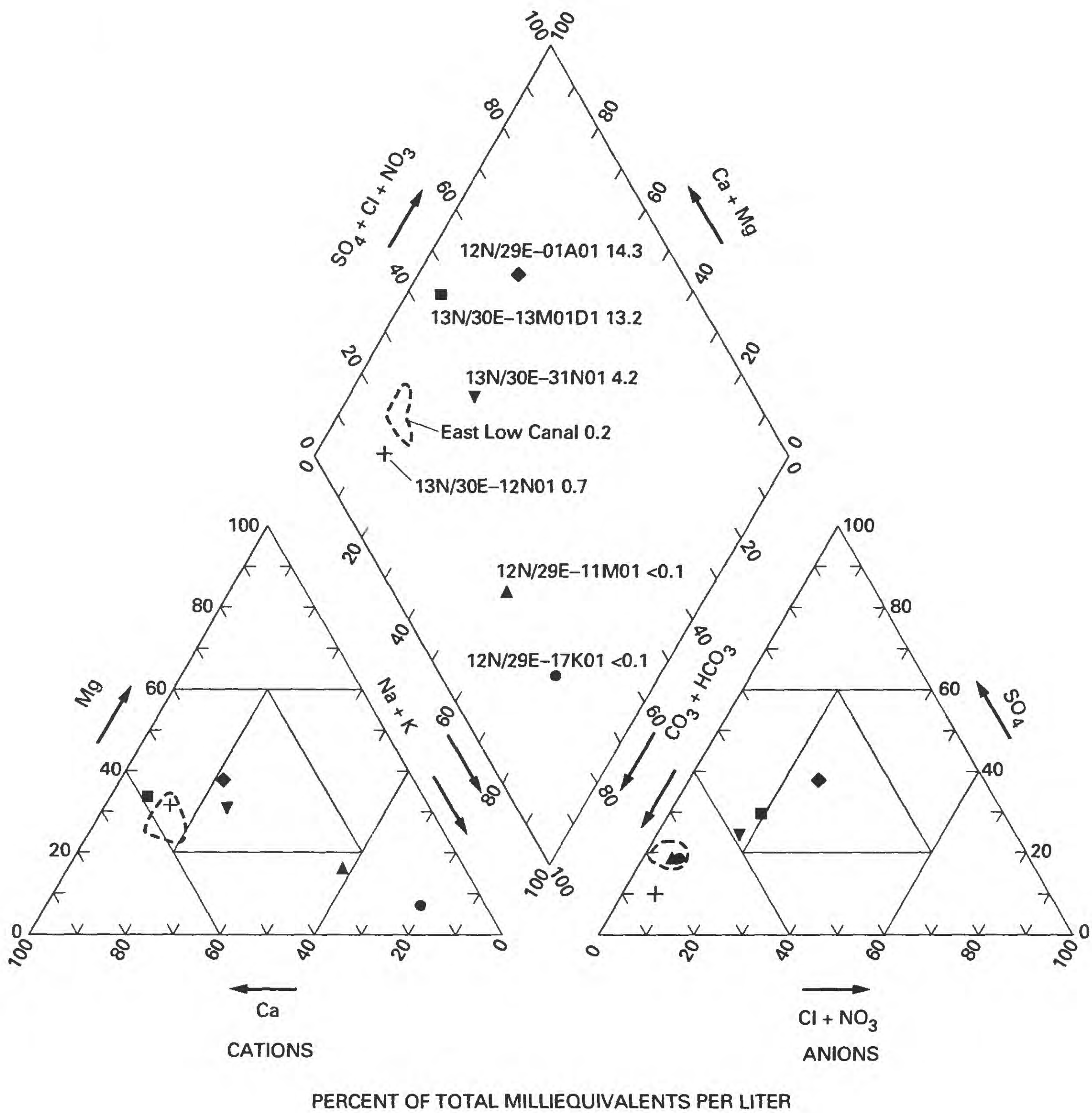
+ **Well 12N/28E-25M01**—Open to the middle Ringold Formation (section G-G', Plate 2)

● **Other wells**—Open to middle Ringold Formation

▲ **Water from well 12N/29E-17K01**—(Section G-G', Plate 2) used to represent the composition of ground water in the Saddle Mountains Basalt underlying well 12N/28E-25M01

<0.1 Number next to symbol is the mean of nitrate concentrations, in milligrams per liter as nitrogen, in water samples from the well, (< = less than)

Figure 15.--Composition of ground water in the middle Ringold Formation and in the Saddle Mountains Basalt underlying well 12N/28E-25M01.



EXPLANATION

12N/29E-01A01 14.3 **Local well number and concentration of nitrate in milligrams per liter as nitrogen. Wells are along section G-G' (Plate 2), (< = less than)**

Figure 16.--Composition of water from selected wells open to the Saddle Mountains Basalt, and of water from the East Low 85 Lateral Canal. Canal-water samples were collected and analyzed in 1983-84 by the Bureau of Reclamation.

The horizontal component of ground-water flow in the Saddle Mountains Basalt along most of section G-G' (pl. 2) is toward the Columbia River. Nitrate, which is present in water in the Saddle Mountains Basalt at and upgradient from well 12N/29E-01A01, was not detected in water from downgradient wells 12N/29E-11M01 and 12N/29E-17K01. Possible reasons for this are (1) the two downgradient wells are open to old ground water, which does not contain nitrate; or (2) biological or chemical reactions have removed nitrate that would ordinarily be present if nitrate were a nonreactive constituent. Water from wells 11M01 and 17K01 was analyzed for tritium, which can be used for recent-age dating because it is radioactive and decays naturally. The water from both wells contained less than 0.3 tritium unit (table 2), indicating that it is older than 50 years (Tyler Coplen, U.S. Geological Survey, written commun., 1983). Therefore, the age of this water predates the beginning of surface-water irrigation in this part of Franklin County. Water from both wells was also of sodium-enriched bicarbonate-type (fig. 16), which is typical of ground water that has had long contact time with basalt and is another indication that the waters are not of recent origin.

Water sampled from the Wanapum Basalt generally contained between 1 and 10 mg/L NO_3-N (pl. 2). Exceptions were wells 13N/28E-13N01 and 13N/29E-23P01, where the ground water, which is relatively deep, contained less than 1 mg/L NO_3-N. The largest nitrate concentrations in water in the Wanapum Basalt were found along the eastern and northern edges of the study area. Because these locations correspond to those where water in the Saddle Mountains Basalt commonly contains large concentrations of nitrate, it is likely that nitrate-bearing ground water is introduced into the Wanapum Basalt from the overlying Saddle Mountains Basalt.

Table 2.--*Tritium and nitrate concentrations in water from selected wells open to the Saddle Mountains Basalt, Franklin County, Washington*

[<, less than; mg/L, milligrams per liter]

Well number	Open interval of well (feet below land surface)		Sampling date	Tritium (units)	Nitrate as nitrogen (mg/L)
	Top	Bottom			
12N/29E-11M01	188	212	09-12-88	<0.30	<0.10
12N/29E-17K01	416	478	09-12-88	<0.30	<0.10
13N/29E-35Q01	191	330	09-13-88	<0.30	.21

Short-Term Temporal Variations of Nitrate Concentrations

Nitrate concentrations in water from seven wells sampled quarterly or more frequently are shown graphically on plate 2. The ranges, means, standard deviations, and coefficients of variation of nitrate concentrations in water from all wells sampled more than one time are given in table 14.

Nitrate concentrations in water from well 13N/30E-16G01D2, which is open to the Saddle Mountains Basalt, ranged from 4.5 to 11 mg/L NO_3-N and showed a distinct seasonal periodicity (pl. 2). Concentrations were smallest during the summer months, probably as a result of seepage from the nearby Potholes Canal during the irrigation season. Nitrate concentrations in water from well 10N/30E-33N04, which is open to the middle Ringold Formation, and well 12N/29E-01A01, which is open to the Saddle Mountains Basalt, were larger during the summer months. Larger concentrations during the summer months may relate to variations in amounts of recharge from crop irrigation, as well as variations in amounts of nitrate contained in recharge. Nitrate concentrations in water from the other four wells appear to vary more randomly or were constant.

Long-Term Temporal Variations of Nitrate Concentrations

Nitrate concentrations in ground water at some locations in Franklin County have increased by as much as two orders of magnitude since the early 1950's (figs. 17-21). In many instances, nitrate concentrations in ground water increased in just a few years after an area was opened to irrigation. In the more populated part of Franklin County in and near the city of Pasco, including the Riverview area, nitrate sources characteristic of urban areas probably account for some of the observed increases of nitrate concentrations in ground water.

The limited available data indicate that nitrate concentrations in water in the Pasco gravels underlying the Riverview area have increased since 1942 (fig. 17). The nitrate concentration in water from well 09N/29E-23P01 was 0.9 mg/L NO_3-N in 1942. In 1961, the nitrate concentrations in samples from two nearby wells 09N/29E-23P02 and 09N/29E-23J02 were 2.5 and 1.4 mg/L NO_3-N, respectively (fig. 17). During this study, nitrate concentrations in water samples from four wells open to the Pasco gravels ranged from 7.5 to 14 mg/L NO_3-N (fig. 17). Depths to ground water in the Riverview area range from about 10 to 50 ft below the land surface, and therefore the shallow ground-water system is vulnerable to loading from nitrate sources at the land surface. Because land use in this area ranges from rural to medium-density residential, potential nitrate sources include septic tanks as well as sources related to agricultural activities. The transport of nitrate into the Riverview area in ground water from upgradient locations also is possible.

Nitrate concentrations in ground water increased after the onset of irrigation (figs. 18-21). Nitrate concentrations in water from some wells increased rapidly after areas were opened to irrigation, and then dropped back from the maximum observed values to concentrations that were usually above the pre-irrigation levels. Examples are well 11N/30E-11C01 (fig. 19) and wells 14N/30E-08G01, 14N/30E-10P01, and 14N/30E-20A01 (fig. 21). In an earlier report on the quality of water in the Columbia River Basalt Group, Newcomb (1972) speculated that some of the initial increase of nitrate concentrations in ground water may have been caused by the flushing of accumulated salts containing nitrate from soils and sediments into the ground water by percolation of water applied in the early phases of irrigation.

Nitrate concentrations in waters from other wells have increased after the onset of irrigation and have remained elevated. Examples are well 10N/29E-10D01 (fig. 19) and well 12N/30E-05B01 (fig. 20).

Two wells, 12N/28E-12H01 and 13N/28E-13N01 (fig. 20), are open to zones in the Saddle Mountains Basalt where water contains little or no detectable nitrate (pl. 2). This observation is consistent with tritium data showing that the age of deep water in the Saddle Mountains Basalt near the Columbia River in Franklin County predates the onset of irrigation.

It is difficult to determine if nitrate concentrations in ground water in Franklin County are continuing to increase. Data collected at various times during the 1980's (figs. 18-21) indicate that recent trends in nitrate concentrations are location dependent.

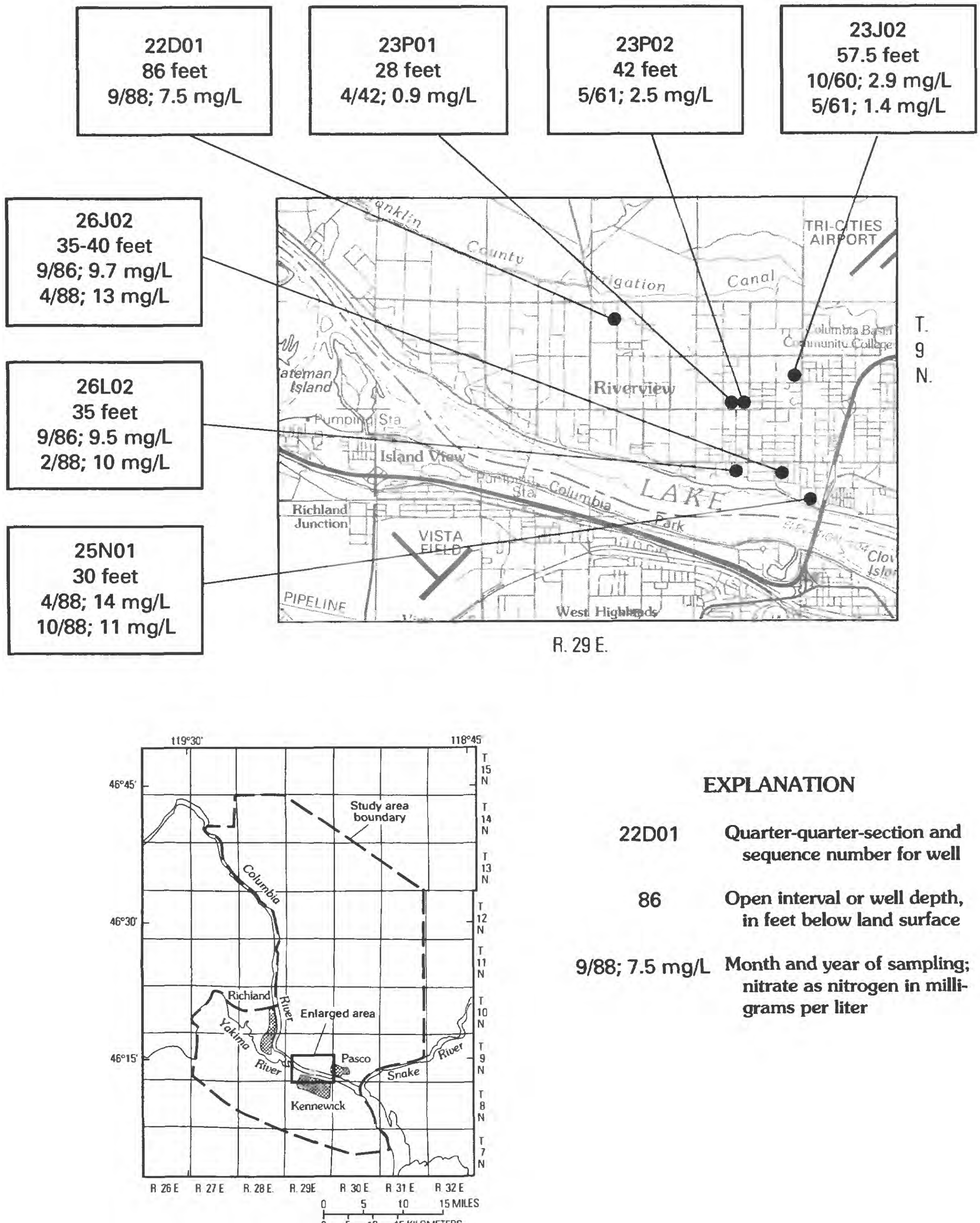


Figure 17.--Historical (pre-1962) and recent (1986-88) nitrate concentrations in ground water in the Pasco gravels of the Riverview area.

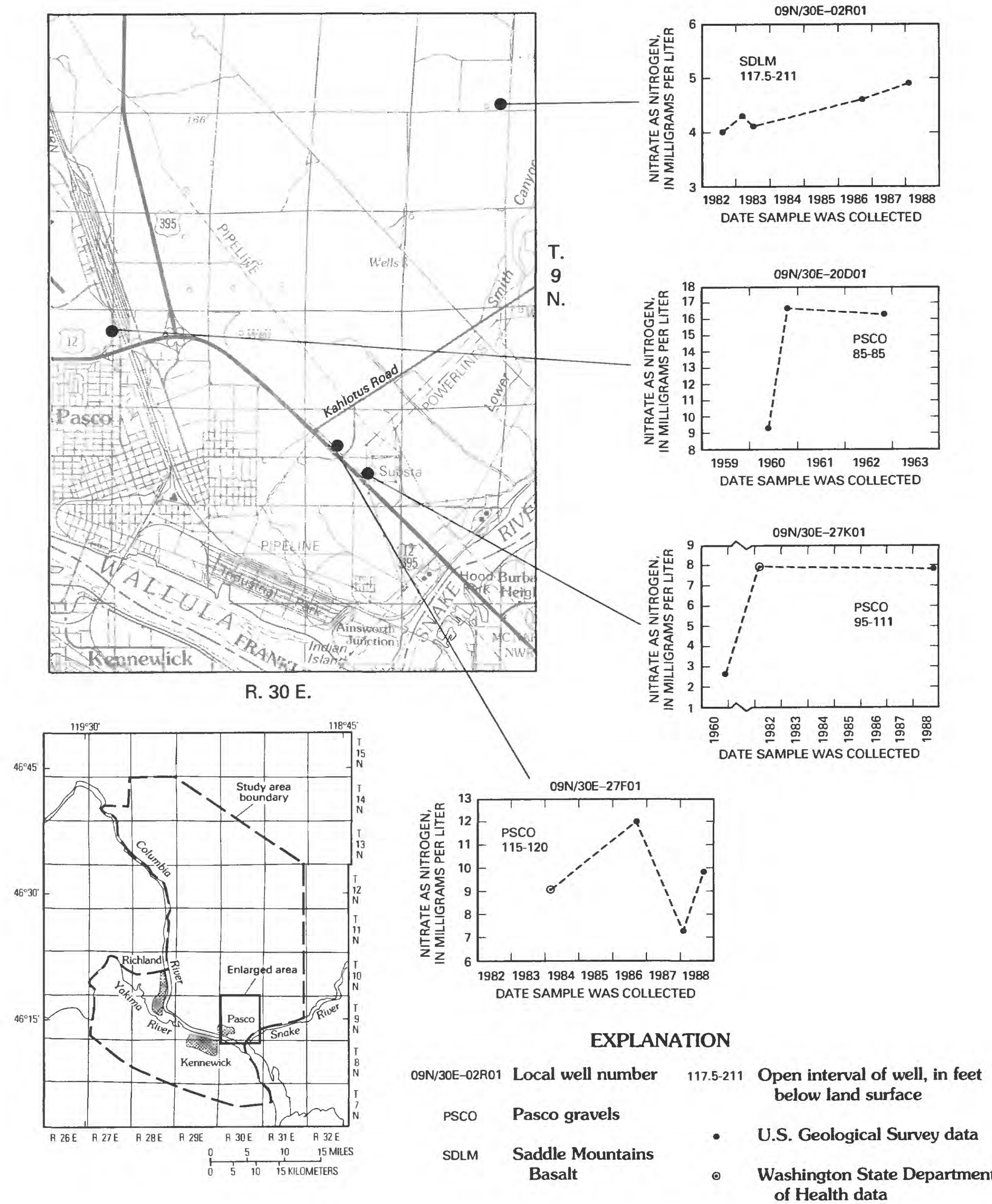


Figure 18.--Long-term variations of nitrate concentrations in water from wells near Pasco.

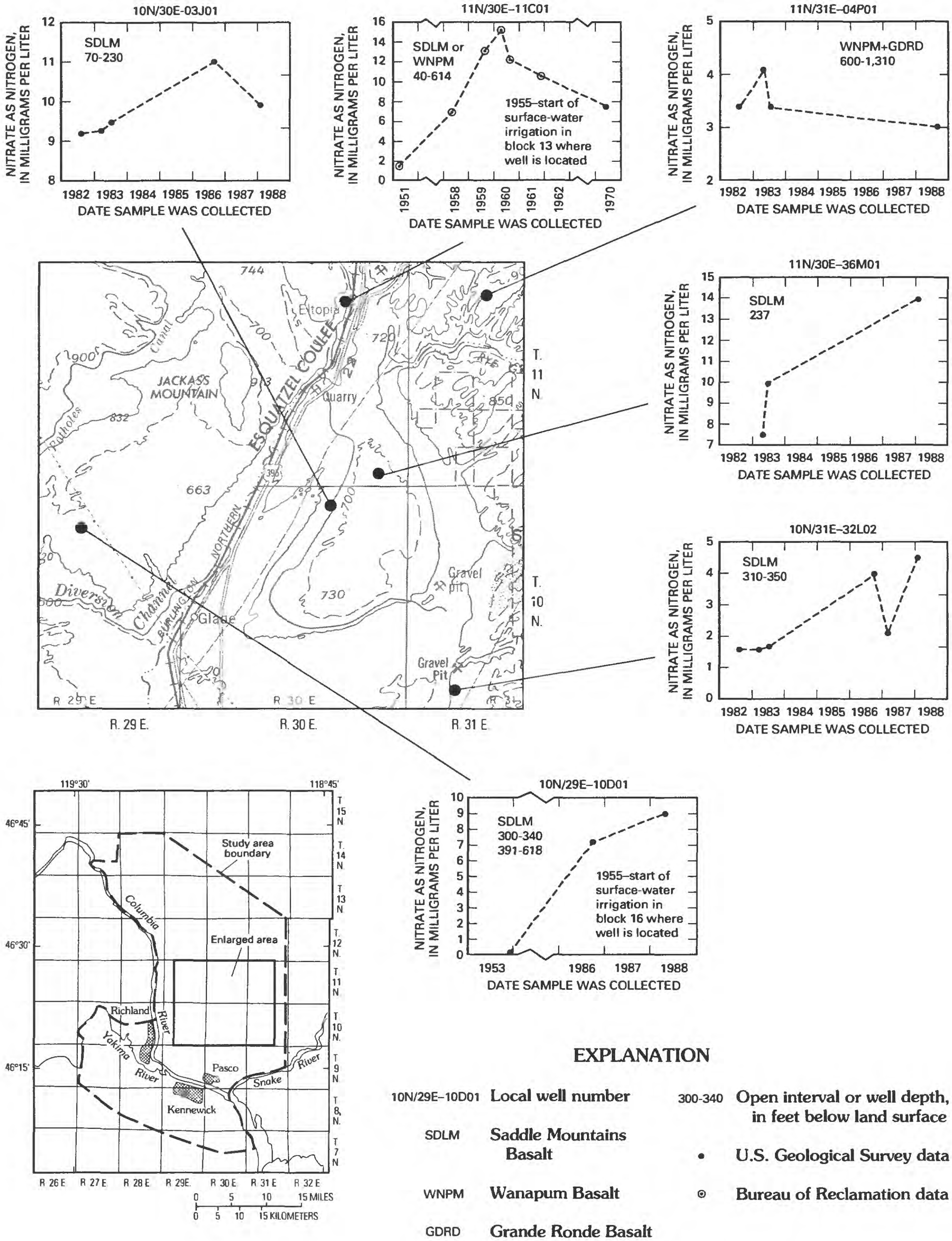


Figure 19.--Long-term variations of nitrate concentrations in water from wells in townships 10 and 11 north in Franklin County.

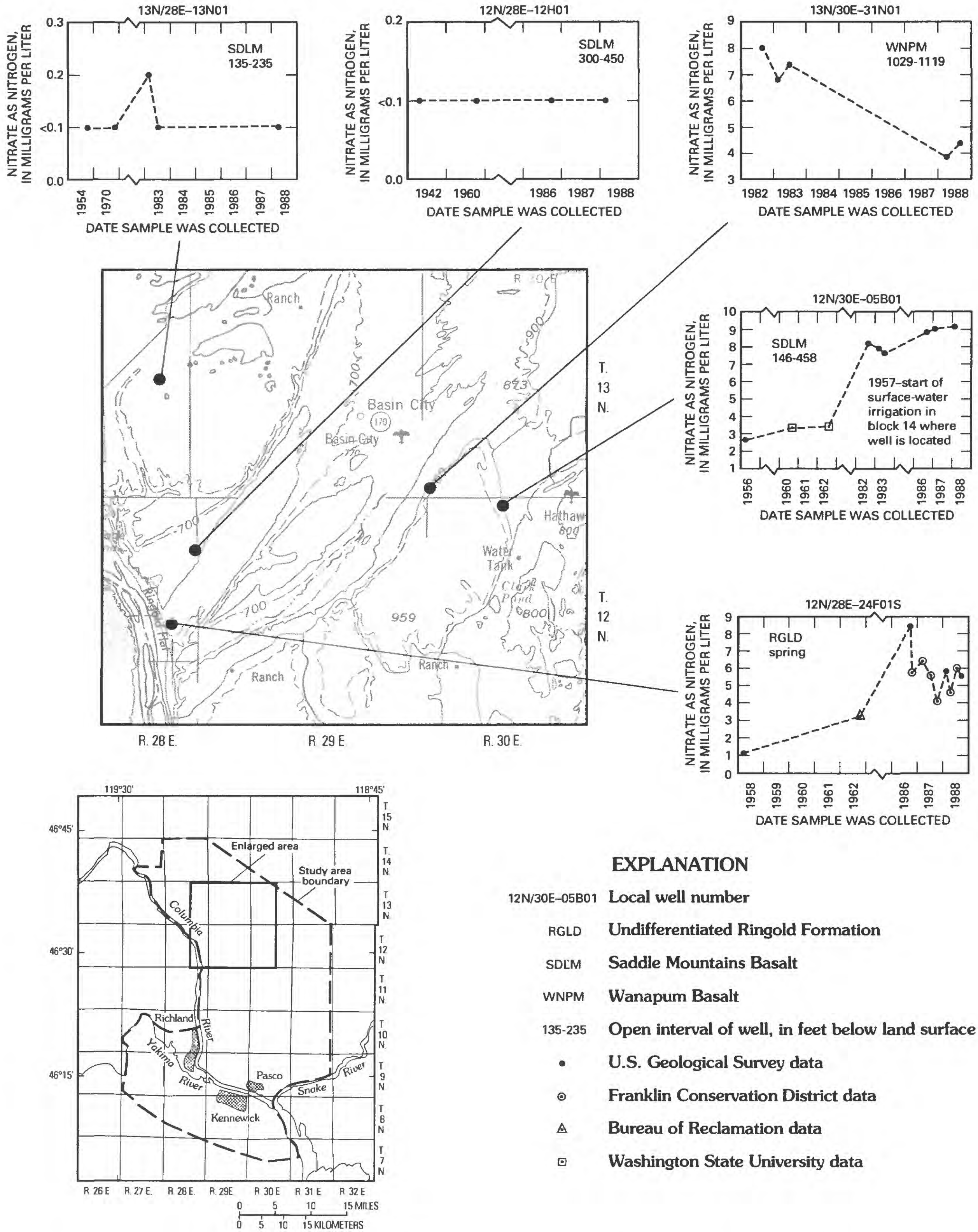


Figure 20.--Long-term variations of nitrate concentrations in water from wells and one spring in townships 12 and 13 north in Franklin County.

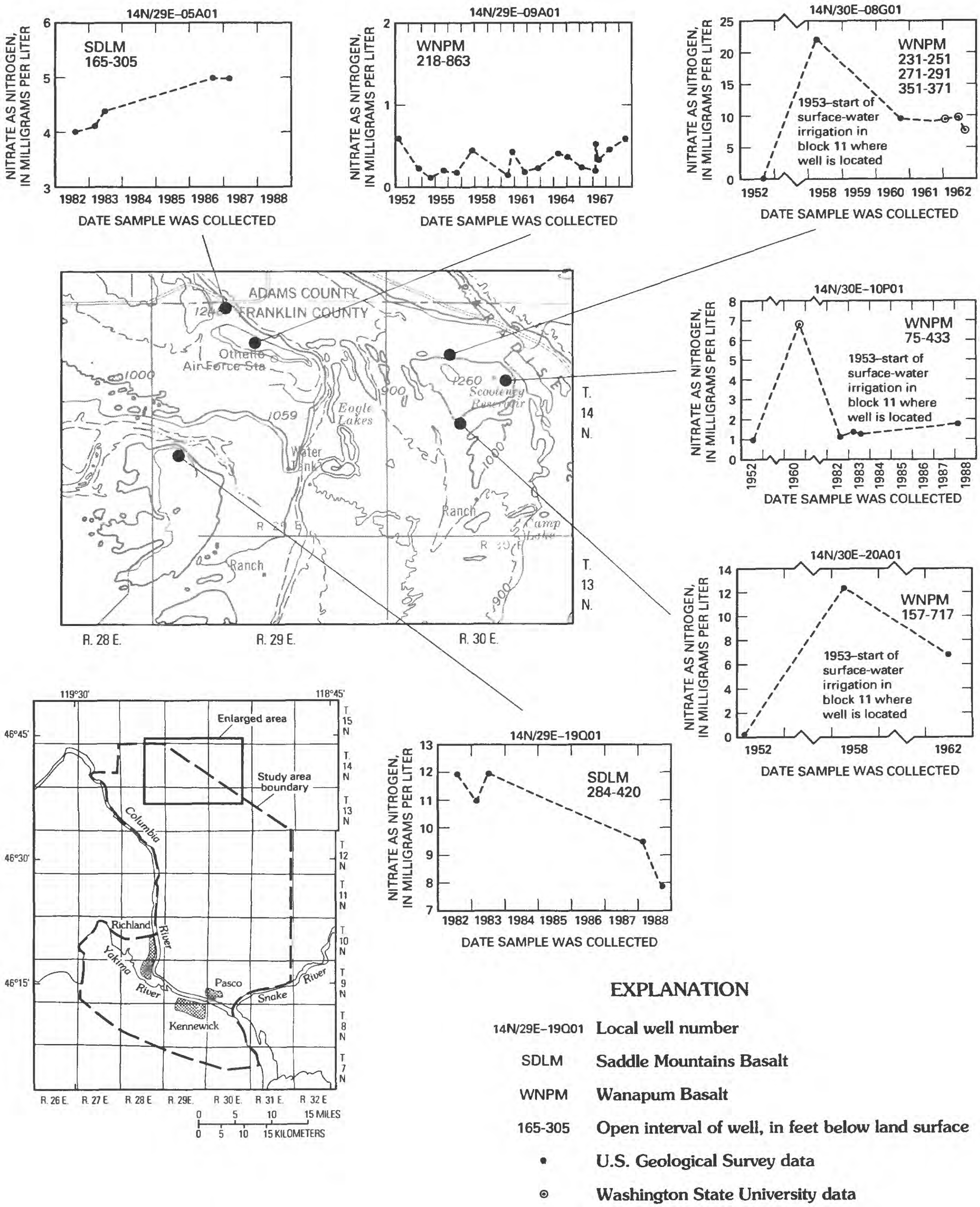


Figure 21.--Long-term variations of nitrate concentrations in water from wells in township 14 north in Franklin County.

POTENTIAL SOURCES OF NITRATE

Four potential sources of nitrate in ground water were assessed: (1) surface water used for irrigation; (2) applied nitrogen fertilizers; (3) septic systems; and (4) naturally occurring nitrate. Livestock manure, a potential source of nitrate in ground water, is not included because feedlots and dairies in the study area are widely distributed and their effects on nitrate concentrations in ground water are probably localized. The collection of enough data to characterize these localized sources was beyond the scope of this study.

Surface Water Used for Irrigation

Prior to this study, it was suggested that nitrate in the surface water used for irrigation is a potential source of the nitrate in ground water. To resolve this question, various parts of the surface-water irrigation systems were sampled. Although surface water used for irrigation is the major source of recharge to ground water, analysis of the samples showed that nitrate concentrations in irrigation water are small (median concentration of 0.88 mg/L NO_3-N). Therefore, the water itself is not the source of elevated concentrations of nitrate in ground water. In fact, seepage from irrigation canals and laterals dilutes the concentration of nitrate already present in the ground water. Previously described examples of this diluting effect include water from well 08N/28E-21H01, which is chemically similar to water from the Kennewick Main Canal (fig. 9), and water from well 13N/30E-12N01, which is similar to water from the East Low 85 Lateral Canal (fig. 16). This relation was explored further by Ebbert and others (1991), who showed that the lining of canals to reduce seepage could result in an increase in concentrations of nitrate in ground water.

In contrast to the irrigation water delivered to fields, higher nitrate concentrations are found in parts of the surface-water irrigation network that convey more drain water (irrigation return flows and discharges from subsurface drains) and ground-water seepage. Surface-water sites sampled during this study (pl. 3) were divided into four general categories, shown in the table below, according to rough estimates of source water.

Category of waterway	Estimated quantity of drain water plus ground water
(1) Delivery canals or laterals	Little or none (0 to 10 percent)
(2) Delivery wasteways (wasteways that cease operation when irrigation water is turned off at the end of the irrigation season)	Small fraction (0 to 20 percent)
(3) Natural drainage wasteways (wasteways that also act as surface drains and may flow year round due to ground-water seepage)	20 to 100 percent
(4) Surface water derived primarily from spring flow	Usually 100 percent

The last category, surface water derived primarily from spring flow, is not strictly part of the surface-water irrigation systems, but was sampled to determine nitrate concentrations in ground-water seepage. The reason the springs were included with other surface-water sites is because they were sampled downstream from their sources at locations where surface runoff may contribute to the flow.

Surface-water samples collected as many as four times at 54 sites (pl. 3) were analyzed for nitrate for this study. In 1988, samples were collected at 50 of the 54 sites and were analyzed for nitrate, ammonia, and chloride (table 15). Most sites were sampled three times in 1988, and nitrate concentrations shown on plate 3 are the arithmetic means of the concentrations in these samples. Nitrate concentrations for sites 15, 22, 26, and 47 (pl. 3) are from a single sample collected in 1986 (Drost and others, 1989).

The surface-water irrigation systems in Benton County obtain water from the Yakima River. Analyses of water samples collected from the Yakima River at Kiona (U.S. Geological Survey, 1972-88) provide an excellent long-term record of nitrate concentrations in water similar to that entering the irrigation systems. Nitrate concentrations in samples collected from the Yakima River at Kiona for the period 1972 through 1988 ranged from less than 0.1 to 1.9 mg/L NO_3-N (pl. 3). The largest concentrations of nitrate were generally observed in late summer and autumn, because irrigation return flows from outside the study area are routed to the river upstream from Kiona. The median nitrate concentration in samples collected from 1974 through 1981 was 0.89 mg/L NO_3-N (Joseph Rinella, U.S. Geological Survey, written commun., 1989).

In Franklin County, the two major surface-water systems obtain water from the Columbia River: the FCID from the Columbia River within the study area and the SCBID from Scooteney Reservoir, the Wahluke Branch Canal, and the East Low (EL) 85 Lateral (fig. 7, pl. 3). For these delivery systems, the original source of the irrigation water is Columbia River water diverted at Grand Coulee Dam, approximately 50 mi north of the SCBID service area.

The pathways by which the water reaches SCBID affect the quality of the water. The Scooteney Reservoir and the Wahluke Branch Canal are fed from the Potholes Reservoir, which is located north of the study area. In addition to Columbia River water, flow into the Potholes Reservoir includes irrigation return flows and ground-water seepage from the northern two-thirds of the Columbia Basin Irrigation Project. Additionally, about 20 percent of the flow into the Potholes Reservoir is natural runoff and drainage from Crab Creek and Lind Coulee, which drain the north-east portion of the Columbia Plateau. Because proportions of Columbia River water, irrigation return flows, ground-water seepage and natural runoff vary throughout the irrigation season, nitrate concentrations in water delivered from Potholes Reservoir vary seasonally. Long-term data available for the Potholes East Canal at mile 38 (pl. 3) indicate that from 1967 through 1988, nitrate concentrations in canal water ranged from 0.54 to 1.4 mg/L NO_3-N. The median concentration was 0.9 mg/L NO_3-N.

In contrast to water delivered from the Potholes Reservoir, the EL 85 Lateral is fed by the East Low Canal. Because there are few significant irrigation return flows that empty into the East Low Canal (U.S. Department of the Interior, 1976), water in the EL 85 lateral more closely resembles unaltered Columbia River water than water delivered from Potholes Reservoir. As a result, the average nitrate concentration in the EL 85 JJ Lateral (site 25, pl. 3) was less than 0.1 mg/L NO_3-N.

Within the study area, nitrate concentrations in the surface-water irrigation systems generally increase during the irrigation season as return flows, drain water, and ground-water seepage are added to the delivery water. Where these additions do not occur, nitrate concentrations in canal water remain relatively constant. In the case of the main part of the KID delivery system (sites 1-5, pl. 3), nitrate concentrations actually decrease in a downstream direction. During the irrigation season, the main KID delivery system receives no irrigation return flows and little or no ground-water seepage. Because chloride concentrations in the KID delivery water remain relatively constant (table 15), the decrease in nitrate concentrations is probably caused by nitrate utilization by aquatic plants and algae.

Ranges of nitrate concentrations (fig. 22) in the four categories of waterways illustrate how concentrations increase as the waterways carry larger percentages of irrigation return flows, drain water, and ground-water seepage. Median nitrate concentrations in delivery canals and laterals and delivery wasteways, which carry mostly delivery water, were 0.88 and 0.83 mg/L NO_3-N, respectively. Median nitrate concentrations in natural drainage wasteways and surface water derived primarily from springflow were 1.7 and 4.5 mg/L NO_3-N, respectively. Although waters in wasteways contain larger concentrations of nitrate than waters in canals, ground water generally discharges to the wasteways (Drost and others, 1996), and they are generally not a source of nitrate to the shallow ground- water system.

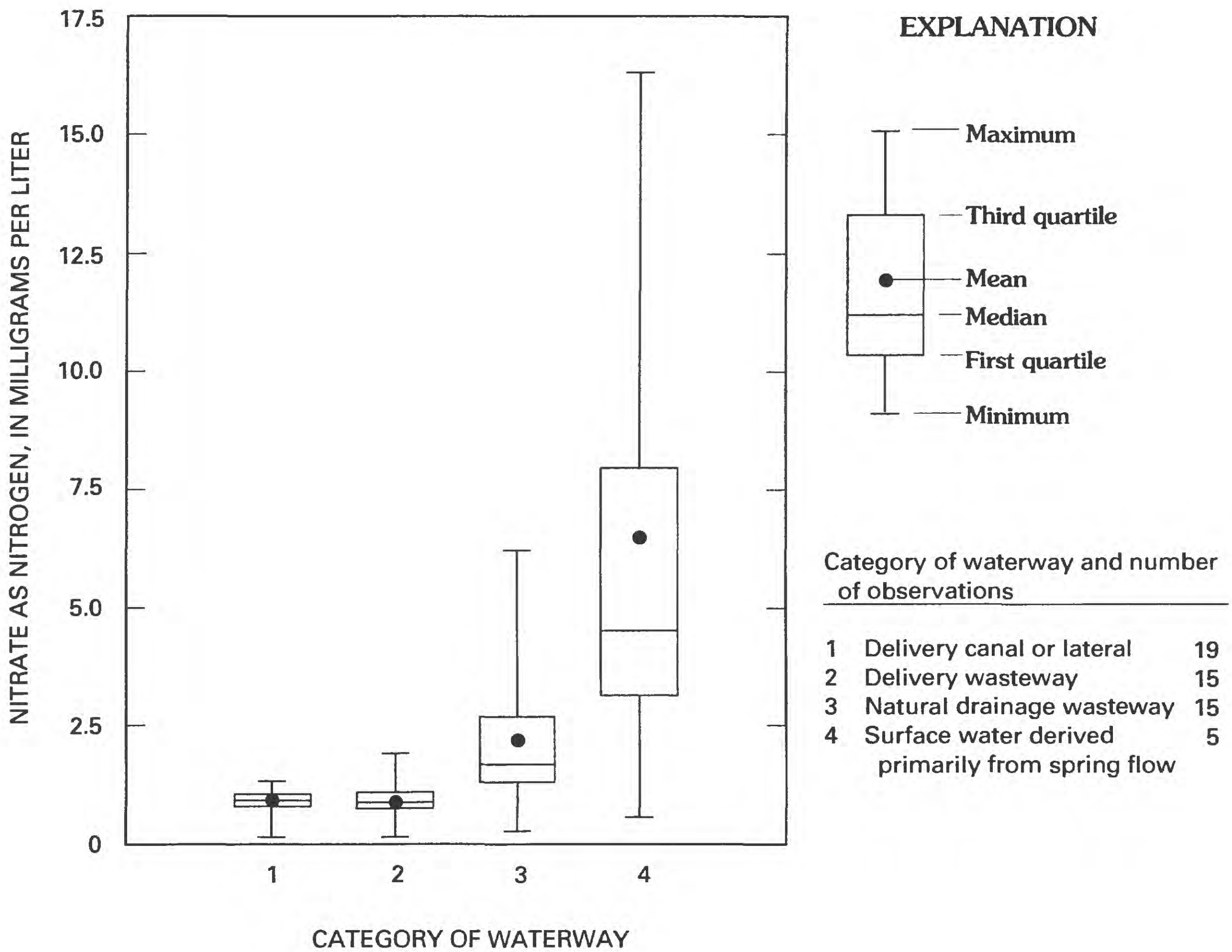


Figure 22.--Nitrate concentrations in surface-water samples from the study area.

Applied Nitrogen Fertilizers

The spatial correlation between irrigated cropland and the occurrence of nitrate in ground water at concentrations greater than or equal to 10 mg/L NO_3-N (fig. 23) suggests that agricultural activities are a major source of nitrate in ground water in the study area. The association between agricultural activities and nitrate in ground water is well known. Elsewhere in the United States, agricultural activities, including livestock operations and crop production, are the largest nonpoint sources of elevated nitrate concentrations in ground water (U.S. Geological Survey, 1984). Numerous studies have shown that the leaching of applied nitrogen fertilizers has resulted in elevated concentrations of nitrate in underlying ground waters (Schmidt and Sherman, 1987; Hallberg, 1986; National Academy of Sciences, 1978).

Studies that addressed the leaching of applied nitrogen fertilizers to ground water were included in a review conducted by Legg and Meisinger (1982) of research examining soil nitrogen budgets. The results of studies reviewed showed that the amounts of nitrogen leached as a percentage of nitrogen applied were quite variable, ranging from 0 to 102 percent. However, the typical range was from 25 to 50 percent. Factors that appear to govern the leaching of nitrogen fertilizers to ground water are the amount of inorganic nitrogen present in the soil zone, the amount of water percolating through the soil zone, the soil texture, the depth of the root zone, and the depth of the water table.

Many of the conditions conducive to the leaching of nitrogen fertilizers to ground water are present in the study area. The predominant land use is irrigated agriculture, and many of the irrigated crops require large quantities of nitrogen fertilizers (table 3). Recharge from applied irrigation water (sometimes referred to as deep percolation) is estimated to be about 35 percent of the ground-water recharge within the study area, and in many locations the depth to ground water is 20 ft or less (Drost and others, 1993). In Franklin County, soils are typically coarse textured (U.S. Department of Agriculture, 1917).

Previously collected data indicate that nitrogen fertilizers are a source of nitrate in ground water in the study area. Historical data indicate that nitrate concentrations in ground water underlying irrigated cropland commonly increased after the onset of irrigation (see p. 30). In a separate investigation conducted during 1986-87, nitrate concentrations in soil water sampled at depths of 4 and 6 ft beneath irrigated fields in Franklin County ranged from 0.3 to 496 mg/L NO_3-N, with a median value of 35 mg/L NO_3-N (John Holmes, Franklin Conservation District, written commun., 1990).

This study investigated fertilizers as a source of nitrate in ground water by conducting a field study to determine nitrate concentrations in shallow ground water beneath irrigated fields at locations remote from other sources of nitrate, and by comparing concentrations of nitrate in ground water with concentrations that were computed using estimates of nitrate loading and recharge to ground water. The results of both approaches indicate that fertilizers are a source of enough nitrogen to account for the nitrate found in the shallow ground water underlying irrigated areas. Data collected during the field study also helped to explain variations of nitrate concentrations in the shallow ground-water system.

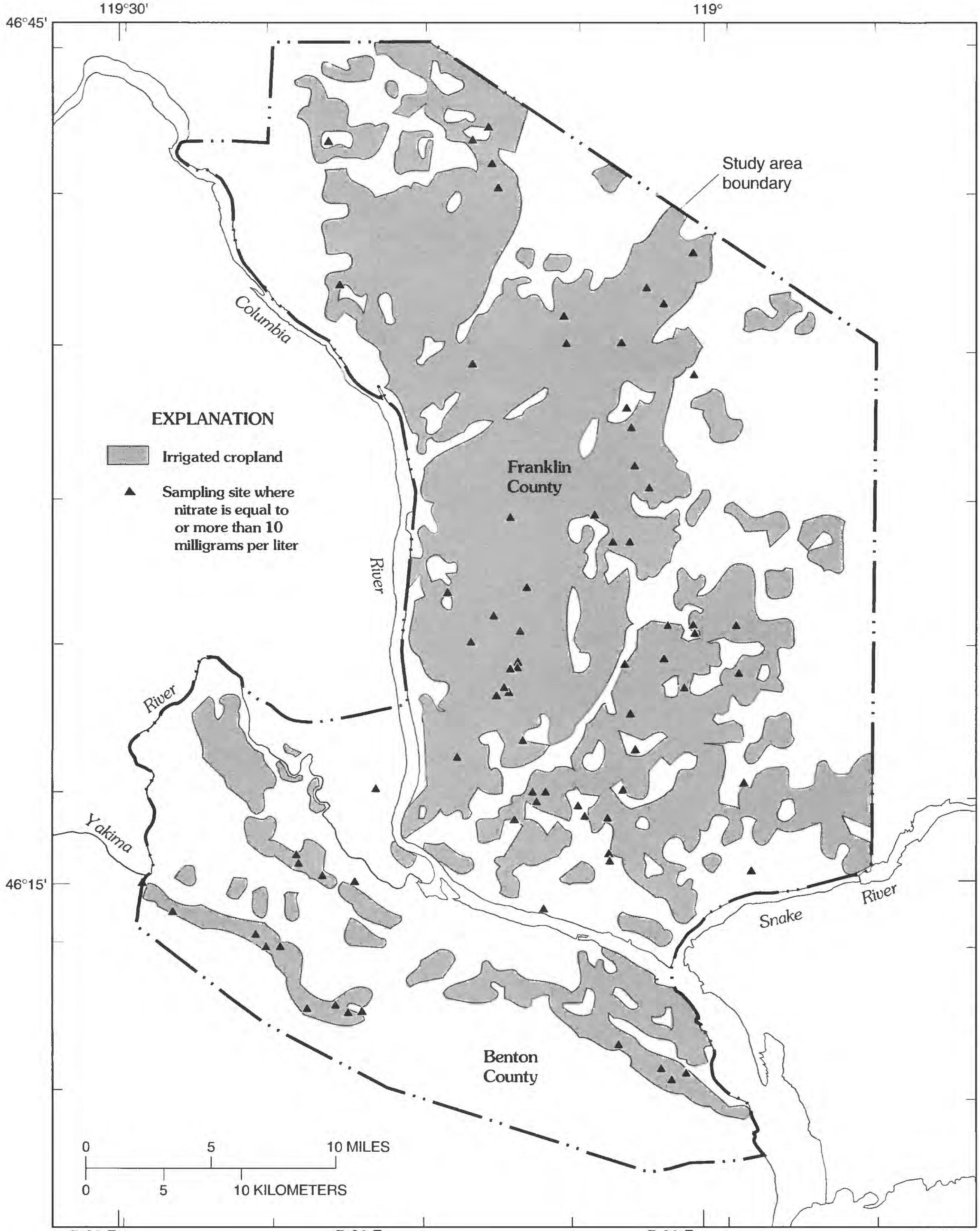


Figure 23.--Locations underlying irrigated croplands where nitrate concentrations in ground water were 10 milligrams per liter or more.

Table 3.--*Estimates of annual applications of nitrogen for major crops grown in areas serviced by the Kennewick and South Columbia Basin Irrigation Districts, Benton and Franklin Counties, Washington*

[Acreage data supplied by the Bureau of Reclamation are for 1986. The application estimates were derived from information in fertilizer guides published by the Washington State University Cooperative Extension Service; KID, Kennewick Irrigation District; SCBID, South Columbia Basin Irrigation District]

Crop	Acres KID	Acres SCBID	Fertilizer guide number	Estimated application in pounds of nitrogen per acre: Low	High	Typical
Alfalfa	3,583	42,343	FG-3	0	40	10
Wheat	743	17,803	EB-1487	0	240	160
Feed corn	0	13,839	FG-6	0	280	240
Sweet corn	0	1,592	FG-35	0	280	240
Asparagus	126	12,094	FG-12	40	100	70
Early potatoes	0	5,708	FG-7	80	350	300
Late potatoes	0	12,636	FG-7	120	375	350
Fruit trees	2,085	7,131	FG-28a	80	80	80
Pasture	1,259	4,128	FG-4	0	200	100
Dry beans	95	3,740	FG-0005	0	120	40
Fresh beans	0	3,280	FG-42	0	180	100
Grapes	47	1,828	FG-13	40	120	80

Field Study

The field study was conducted in parts of the SCBID area of Franklin County where existing subsurface field drains provided a way to collect samples of shallow ground water underlying irrigated fields. Piezometers also were installed in irrigated fields and they, as well as shallow domestic wells and piezometers installed previously by the Bureau of Reclamation, were sampled.

Ground-water samples from subsurface drains represent a larger contributing area than samples from domestic wells and piezometers. Subsurface drain water is ground water intercepted at the water table by horizontal drain laterals, which are perforated pipes packed in gravel envelopes and buried horizontally 8 to 10 ft below the land surface. Therefore, a drain sample represents ground water collected over an extended area defined by the distribution of drain laterals upstream from the location where the sample is collected.

Drain-water samples were collected from 46 subsurface drain laterals within the SCBID (fig. 24). Laterals within the three areas referred to as field sites 1, 2, and 3 (fig. 24) were sampled more intensively than those outside these areas. Field sites 1-3 are where piezometer clusters, with openings placed at various intervals extending from about 8 to 50 ft below land surface (table 13), were installed. Drain laterals were sampled one to six times each, and most samples were collected during and after the irrigation season in 1988. Some laterals were sampled in 1989 either during, or before and during, the irrigation season. Most of the piezometers were sampled three times during and after the irrigation season in 1988.

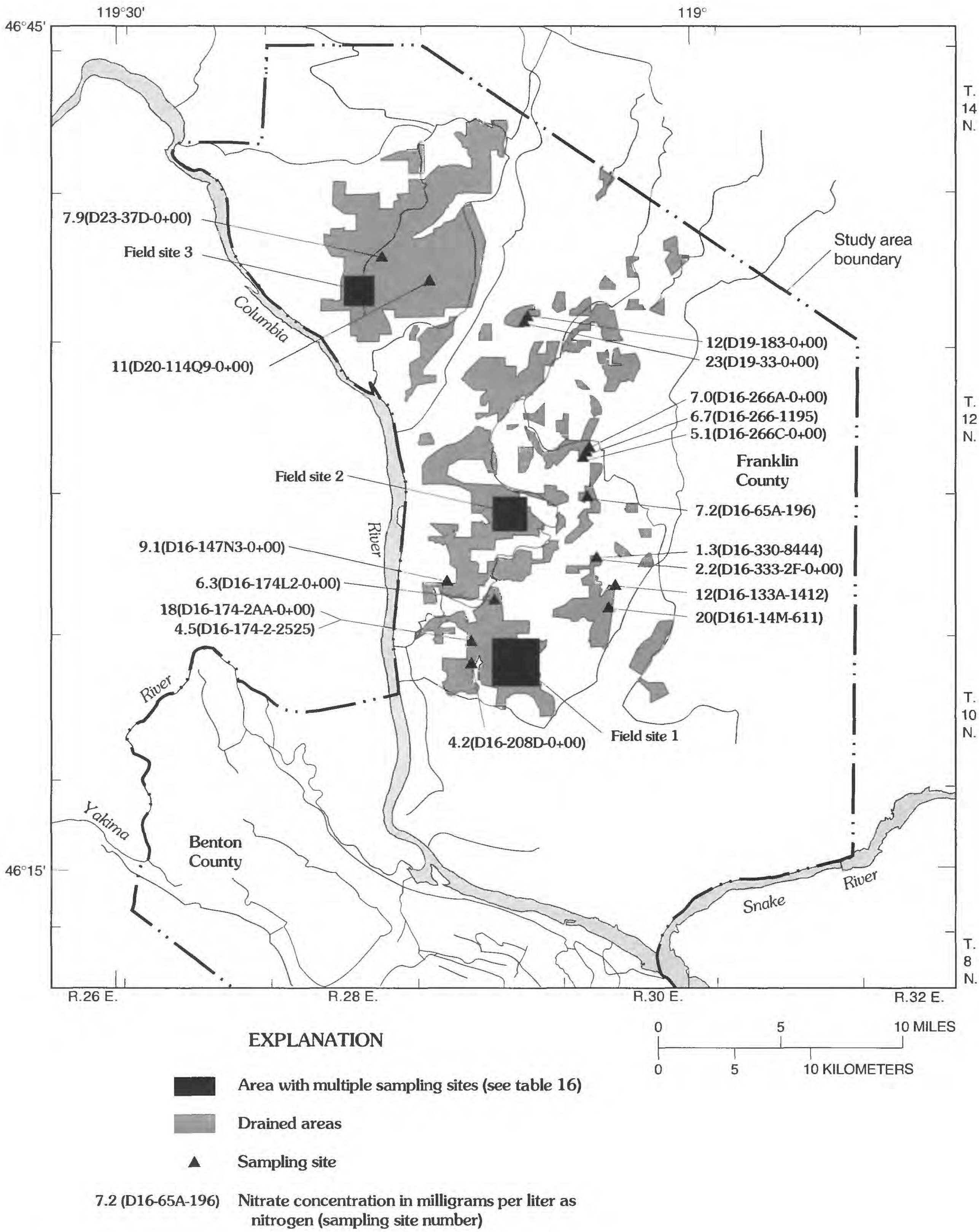


Figure 24.--Locations where subsurface field drains were sampled.

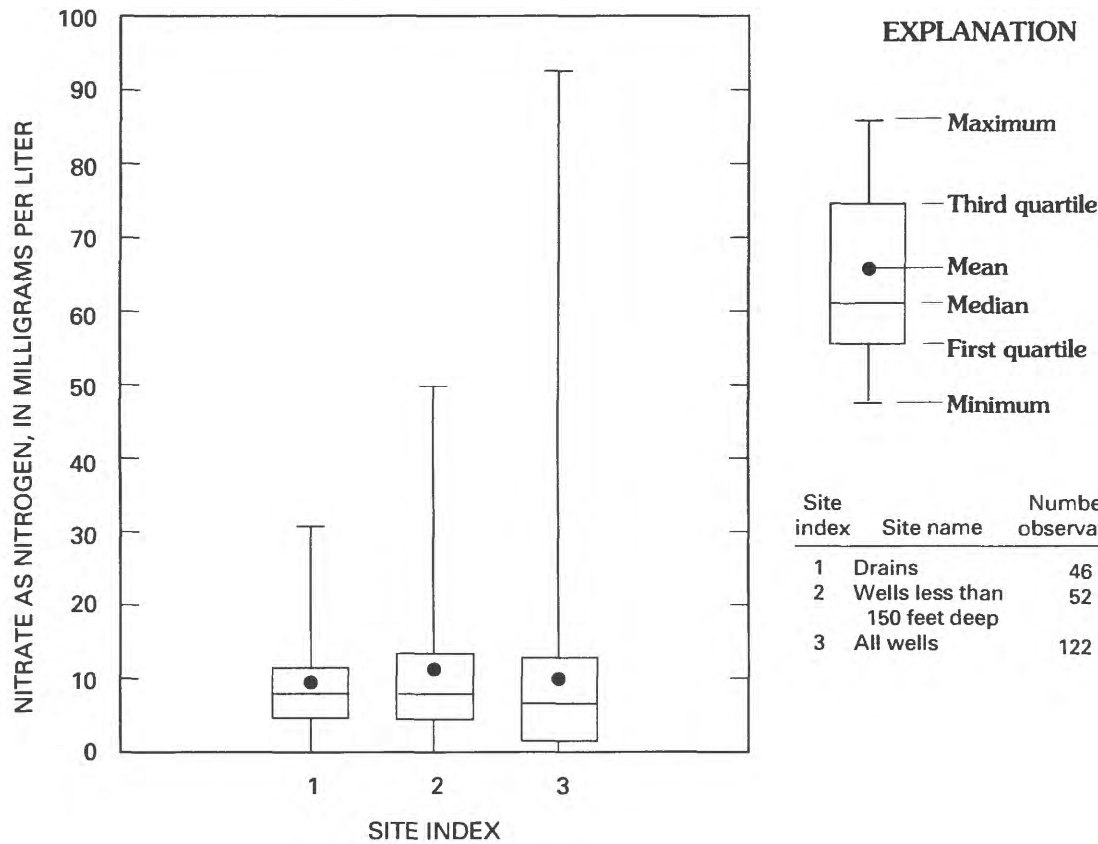
Although the field study focused on nitrate, other constituents were analyzed to help interpret the nitrate data. Most samples were analyzed to determine specific conductance values and concentrations of dissolved chloride, and about 50 percent of the samples were analyzed for ammonia (tables 13 and 16). About 15 percent of the drain-water samples, and at least one sample from each piezometer, were analyzed for major ions (tables 17 and 18, respectively). Four drains and one piezometer were sampled for pesticides (table 12) to augment other data collected as part of the pesticide reconnaissance. Samples for the determination of concentrations of the stable isotopes of oxygen and hydrogen were collected at 10 locations in the vicinity of field sites 1 and 3 to help identify sources of recharge to the shallow ground-water system.

Because the drain-water samples were collected at locations where applied nitrogen fertilizers are the only significant sources of nitrate, nitrate concentrations in the drain samples were used to indicate how the leaching of fertilizers affects nitrate concentrations in shallow ground water beneath irrigated fields. Nitrate concentrations in drain-water samples were similar to those in water sampled from all wells open at depths of 150 ft or less and located within the SCBID in Franklin County (fig. 25), indicating that although some of the wells may be in locations where other sources of nitrate are present, fertilizers are a source of sufficient magnitude to account for the range of concentrations observed in samples from these wells. The data also indicate that there is vertical transport of nitrate to depths of at least 150 ft. In most of the SCBID, the depth to the water table is less than 20 ft, and wells open at depths of 150 ft or less were arbitrarily selected to represent the shallow ground-water system. For comparison, the distribution of nitrate concentrations in all samples of ground water underlying the SCBID in Franklin County is also shown on figure 25.

Data collected during the field study also helped explain some of the variations of nitrate concentrations observed in shallow ground water beneath irrigated cropland. Detailed studies of the flow of ground water in the vicinity of drains in agricultural fields (Fio and Deveral, 1991; Deveral and Fujii, 1988; and Jury 1975a,b) indicate that some of the variations in nitrate concentrations observed in this study probably relate to the complex nature of the ground-water flow system. It is likely that some of the recharge from canal seepage moves laterally and mixes with ground water and recharge from applied irrigation water as illustrated on figure 26. Because canal water contains less nitrate than percolation from applied irrigation water, smaller concentrations of nitrate in ground water should be found at locations where canal water is the dominant source of recharge. This was observed at field site 1 (fig. 27), where smaller concentrations of nitrate in drain water and ground water were found near irrigation lateral PE 59.4.

Inferences about sources of recharge to the shallow ground water beneath cropland can be made by examining the distribution of the stable isotopes of oxygen and hydrogen in the ground water. For information about stable isotopes, the reader is referred to the supplemental information section of the report. On figure 28, the isotopic composition of these samples is compared with the isotopic composition of samples collected from the Columbia River at Vernita Bridge (Carol Kendall, U.S. Geological Survey, written commun., 1990). The Columbia River waters plot along the North American meteoric water line (Gat, 1980), whereas the shallow ground-water samples and irrigation water plot below the meteoric water line, which is indicative of some degree of evaporative concentration. The slope of the regression line calculated for the shallow ground water samples is 4.4, which is within the typical range of 3 to 6 for slopes of regression lines for evaporated surface waters (Tyler Coplen, written commun., 1990).

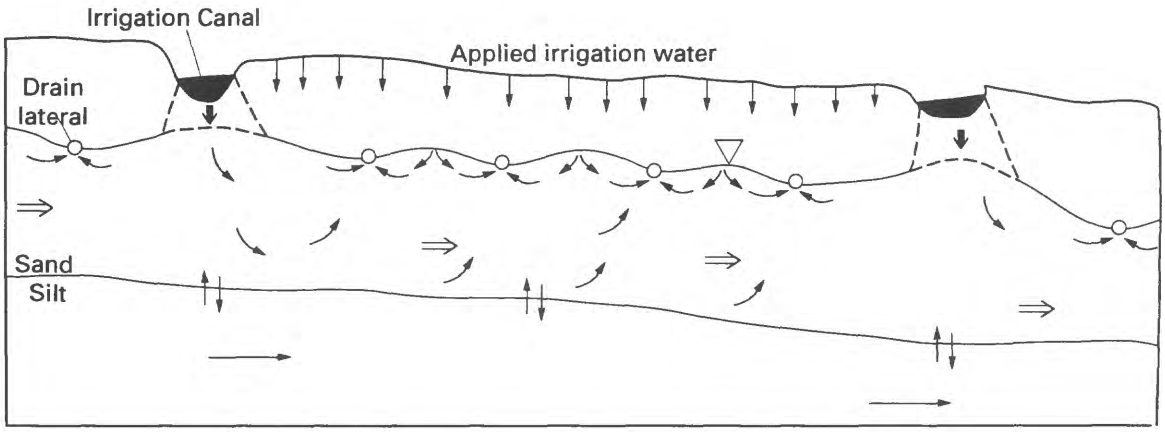
The similarity between the isotopic composition (fig. 28) of water from well 10N/29E-03P01 and water from irrigation lateral PE 54.9 is another indication that water in the lateral is the dominant source of recharge to the ground water at this location (fig. 27). Little or no evaporation would occur as seepage from the lateral moves to the shallow ground water. In contrast, irrigation water is subject to evaporative losses after application, as indicated by the isotopic composition of water samples (fig. 28) from wells in township 10N/29E that are located farther from lateral PE 54.9 (fig. 27), where applied irrigation water is a larger percentage of total recharge.



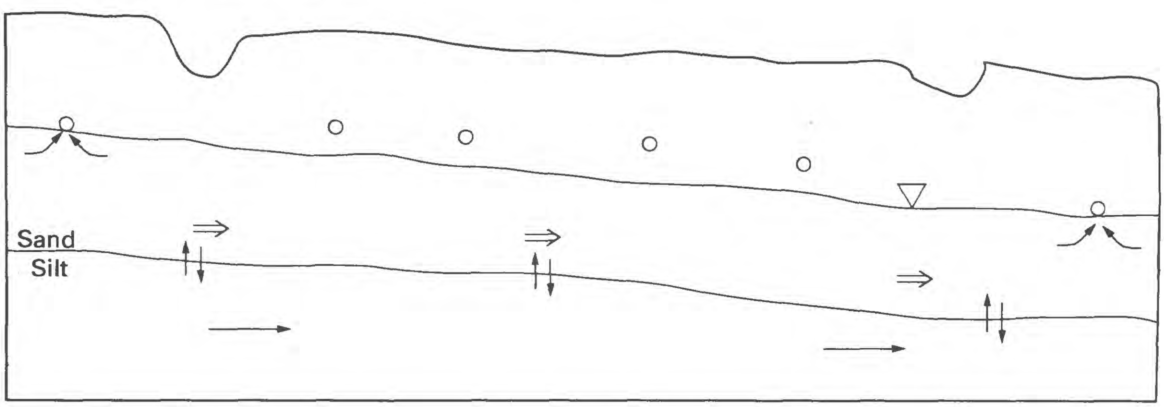
Site index	Site name	Number of observations
1	Drains	46
2	Wells less than 150 feet deep	52
3	All wells	122

Figure 25.--Nitrate concentrations in drain water and ground water collected within the South Columbia Basin Irrigation District, Franklin County, Washington.

A. Irrigation season



B. Non-irrigation season



EXPLANATION

⇒ **Arrows indicate direction of flow**—Width of arrow indicates amount of flow. Flow across sand-silt boundary is generally small and can be in either direction depending on position of boundary and (or) time of year

▽ **Water table**

Figure 26.--Schematic representation of a local ground-water flow system beneath drained agricultural fields with "leaky" irrigation canals.

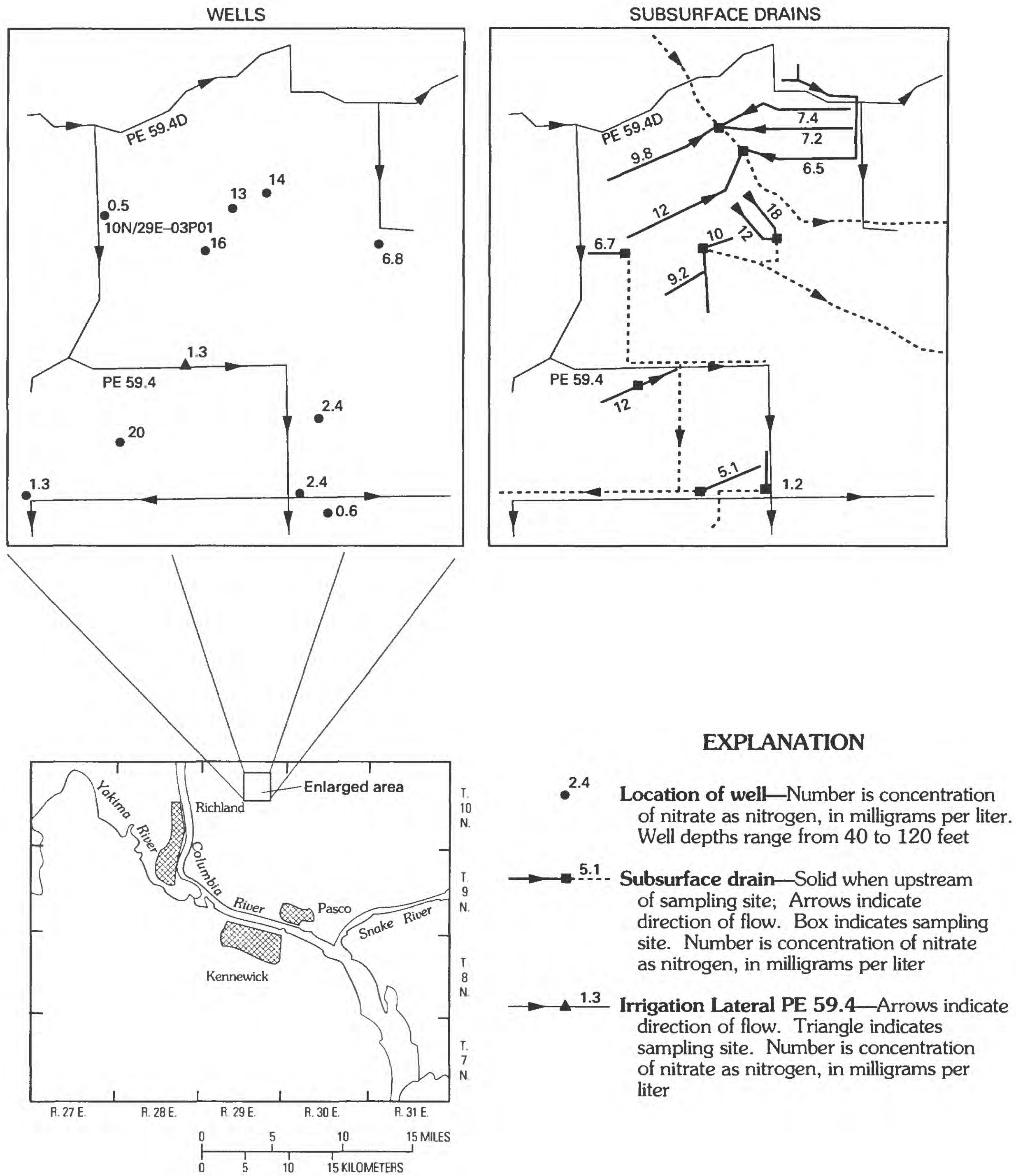


Figure 27.--Nitrate concentrations in drain water, ground water, and irrigation water at field site 1, South Columbia Basin Irrigation District.

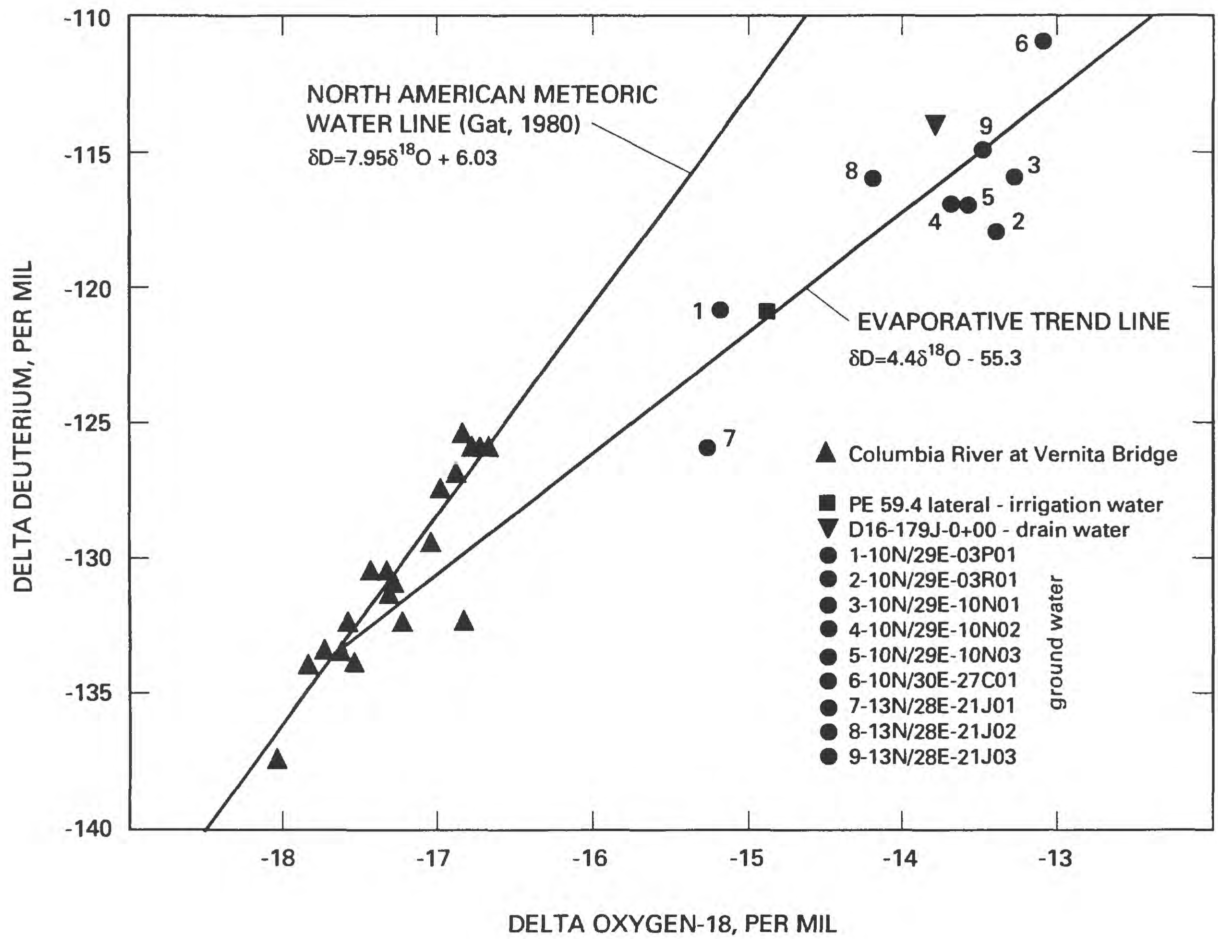


Figure 28.--Isotopic composition of ground water, drain water, irrigation water, and water from the Columbia River, Pasco Basin, Washington.

Nitrogen-Loading Computations

Estimated values of nitrogen loading to ground water and recharge were used to compute average concentrations of nitrate in shallow ground water underlying the SCBID. Computations were performed for nitrogen loads ranging from 5 to 50 percent of the estimated amounts of applied and deposited nitrogen. Sources of applied and deposited nitrogen included fertilizers, applied irrigation water, and precipitation. Nitrate loading from canal seepage was also included; however, other sources of nitrate, such as possible contributions from animal waste, were not included because data were not available to estimate nitrate loading from these sources.

Results of the loading computations indicate that leaching of about 22 percent of the estimated amount of the applied and deposited nitrogen could account for the nitrate found in the shallow ground water underlying the SCBID. Twenty-two percent is near the low end of the typical reported range of 25 to 50 percent of applied nitrogen fertilizers lost to ground water beneath irrigated cropland (Legg and Meisinger, 1982). Because fertilizers account for an estimated 94 percent of total amount of applied and deposited nitrogen in the SCBID, the results of the loading computations are therefore consistent with interpretations of other data indicating that fertilizers are the primary source of nitrate found in ground water underlying the SCBID in the study area.

The nitrogen-loading equation used to compute the average concentration of nitrate in ground water can be expressed as:

$$\textit{Concentration of nitrate} = \frac{\textit{Annual load of nitrogen}}{\textit{Annual volume of recharge}} \quad (1)$$

The simple relation between concentration, load, and recharge shown in equation 1 represents a ground-water system where (1) the flux of water into the system is entirely recharge, as opposed to inflow from adjacent or deeper ground water; (2) annual average concentrations of nitrate in ground water do not change with time (this implies that the system is at steady state); and (3) all applied or deposited inorganic nitrogen is in the form of nitrate or is converted to nitrate, which is itself nonreactive. Although none of these conditions strictly applies to the shallow ground-water system in the SCBID, the mass-loading computations are useful to indicate the approximate magnitude of the effects of nitrate loading on concentrations in ground water.

The annual amounts of precipitation, applied irrigation water, and recharge listed in table 4 pertain to the area within the SCBID in the study area and were provided by B.W. Drost (U.S. Geological Survey, written commun., 1990). Although only recharge is used directly in equation 1, amounts of precipitation and applied irrigation water were needed to estimate amounts of nitrogen contributed from these sources. The methodologies used to determine amounts of precipitation and applied irrigation water are described by Drost and others, 1993).

A range of nitrate concentrations in ground water was computed (table 5) by equating loading from nitrogen deposited in precipitation, nitrate in applied irrigation water, and nitrogen applied as fertilizer equal to a percentage, ranging from 5 to 50, in increments of 5, of the total amount of deposited and applied nitrogen. Fertilizers account for 94 percent of the total estimated amount of nitrogen deposited and applied. The contribution of nitrogen to ground water from canal seepage, another source of nitrogen loading, was assumed to be constant and equal to the product of the annual volume of recharge from canal seepage times the median concentration of nitrate in canal-water samples (table 5).

Precipitation-weighted mean concentrations of ammonia and nitrate in samples collected during 1986-88 at Pullman, Wash., about 100 mi east of the study area, were used to compute the annual amount of nitrogen deposited by precipitation (table 4). Ammonia was included because of the possibility that it will oxidize to nitrate after deposition. The amount of nitrate in applied irrigation water (table 4) was determined by multiplying the median concentration of nitrate in canal water by the volume of irrigation water applied annually. Fertilizer application rates used to compute amounts of nitrogen applied to individual crops (table 4) represent the typical rates previously listed in table 3. Acreages for major crops grown in this area (table 4) were obtained from 1986 crop reports supplied by the Bureau of Reclamation. These data were used to determine acreages of individual crops as a percentage of the total reported irrigated acreage. These percentages were then multiplied by the total number of irrigated acres within the SCBID, as determined from aerial photographs, to compute the number of acres for individual crops that are reported in table 4. Some minor crops are not included in the tabulation.

Table 4.--*Estimates of annual amounts of precipitation, applied irrigation water, recharge, and application and deposition of nitrogen in the South Columbia Basin Irrigation District, Franklin County, Washington*

[SCBID, South Columbia Basin Irrigation District; NO_3-N, nitrate as nitrogen; Areas listed are for the part of the SCBID within the study area; estimates of applied irrigation water and recharge are from Drost and others (1994); 1986 data unless otherwise indicated; fertilizer applications are based on typical application amounts listed in table 3]

Areas

Total area in SCBID:	176,000 acres
Irrigated areas in SCBID:	164,000 acres

Precipitation and applied irrigation water

Precipitation:	10 inches over 176,000 acres = 147,000 acre-feet
Applied irrigation water:	29.4 inches over 164,000 acres = 401,000 acre-feet

Recharge

	Acre-Feet	Percent of total
Precipitation	12,000	6
Applied irrigation water	63,000	29
Canal seepage	140,000	65
Total	215,000	100

Application of nitrogen fertilizers

Crop	Acreage	Percent total acreages	Pounds nitrogen
Alfalfa	55,100	33.6	551,000
Wheat	23,100	14.1	3,700,000
Corn	20,000	12.2	4,800,000
Asparagus	15,700	9.6	1,100,000
Early potatoes	7,400	4.5	2,220,000
Late potatoes	16,400	10.0	5,740,000
Fruit trees	9,300	5.7	744,000
Pasture	5,400	3.3	540,000
Dry beans	4,900	3.0	196,000
Fresh beans	4,300	2.6	430,000
Grapes	2,300	1.4	184,000
Total	164,000	100.0	20,200,000

Nitrogen deposition in precipitation

The concentration of nitrogen in precipitation is the sum of the precipitation-weighted mean concentration of nitrate and ammonia in samples collected 1986-88 at Pullman, Washington (National Atmospheric Deposition Program, 1987-89).

(147,000 acre-feet) (0.54 mg/L nitrogen) = 216,000 pounds

Nitrate in applied irrigation water

The concentration of nitrate in irrigation water is the median concentration in canal-water samples collected during this study.

(401,000 acre-feet) (0.88 mg/L NO_3-N) = 960,000 pounds

Total amount of nitrogen applied or deposited

Source	Pounds
Fertilizers	20,200,000
Precipitation	216,000
Irrigation water	960,000
Total	21,400,000

For losses of nitrogen to ground water ranging from 5 to 50 percent of the estimated amounts of applied and deposited nitrogen, computed concentrations in ground water range from 2.4 to 19 mg/L NO_3-N (table 5). A computed concentration of 8.5 mg/L NO_3-N, which is similar to the median concentration of 8.4 mg/L observed in the shallow ground water underlying the SCBID, corresponds to a loss to ground water of about 22 percent of the applied and deposited nitrogen. At this level, nitrate loading to ground water from canal seepage is only 5 percent of the total.

Because a loss of 22 percent of applied nitrogen is near the low end of the range of expected losses, the results of the nitrogen-loading computations indicate that it is reasonable to attribute most of the nitrate in ground water underlying the SCBID in the study area to the leaching of fertilizers, which are estimated to account for 94 percent of deposited and applied nitrogen.

Table 5.--*Computed concentrations of nitrate in shallow ground water underlying the South Columbia Basin Irrigation District, Franklin County, Washington*

Annual loading from applied and deposited nitrogen			Annual[2] loading from canal seepage (pounds)	Annual recharge (acre-feet)	Nitrate, (milligrams per liter as N)
Nitrogen[1] applied or deposited (pounds)	Percentage lost to ground water	Nitrogen loading (pounds)			
21,400,000	5	1,060,000	335,000	215,000	2.4
21,400,000	10	2,120,000	335,000	215,000	4.2
21,400,000	15	3,180,000	335,000	215,000	6.0
21,400,000	20	4,240,000	335,000	215,000	7.8
21,400,000	25	5,300,000	335,000	215,000	9.7
21,400,000	30	6,360,000	335,000	215,000	11
21,400,000	35	7,420,000	335,000	215,000	13
21,400,000	40	8,480,000	335,000	215,000	15
21,400,000	45	9,540,000	335,000	215,000	17
21,400,000	50	9,890,000	335,000	215,000	19

[1]From table 4.

[2]Loading from canal seepage is computed as the product of recharge from canal seepage (140,000 acre-feet) times the median concentration of nitrate (0.88 mg/L nitrate as nitrogen) in canal water.

Septic Systems

Two locations where officials have expressed concern that septic systems may contribute nitrate to ground water are the Finley area in Benton County (fig. 29) and the Riverview area in Franklin County (fig. 17). Data collected in the Finley area were used to examine the effects of discharges from septic systems on nitrate concentrations in ground water. The Finley area was selected because land use over much of the area is rural residential with variable housing densities, most of the dwellings have septic systems, the distance between the land surface and the water table typically is less than 20 ft, and numerous ground-water samples were collected in this area.

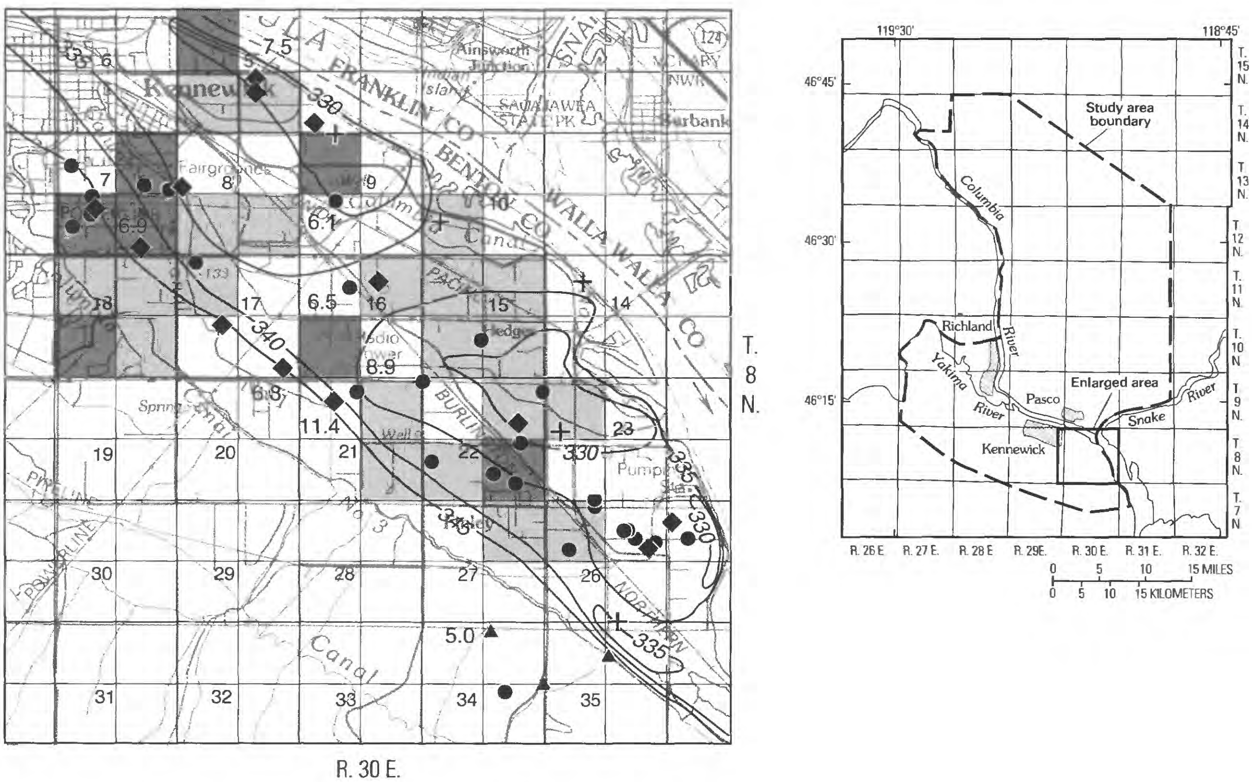
Nitrate concentrations in the unconfined ground-water system of the Finley area do not appear to be related to the numbers of upgradient septic systems. This suggests that septic systems are not the major source of nitrate in the ground water of the Finley area. However, variations in the isotopic composition of nitrate nitrogen in ground water in the Finley area indicate that septic systems are a source of at least some of the nitrate. Using available data, it was not possible to determine how much of this nitrate was contributed from septic systems. To provide an estimate of the effects of septic-system discharges on nitrate concentrations in the unconfined ground-water system of the Finley area, a solute transport model was used to simulate the distribution of nitrate in ground water downgradient from a source area consisting of two land-grid sections (2 mi^2) with septic-system densities of 0.4, 0.8, and 1.6 systems per acre. These densities correspond to lot sizes of 2.5, 1.25, and 0.625 acres, respectively.

Relation Between Nitrate Concentrations in Finley-Area Ground Water and Density of Septic Systems

No relation is evident between the density of septic systems in the Finley area and nitrate concentrations in underlying or downgradient ground water (fig. 29). Nitrate concentrations in water shown on figure 29 are from wells less than 100 ft deep, most of which are open to the unconfined ground-water system. Isotope ratios of nitrate nitrogen, the altitude of the water table, and the density of septic systems in each quarter section (0.25 mi^2) of the Finley area are shown on figure 29. The direction of ground-water flow is approximately perpendicular to the lines of equal altitude of the water table and in the direction from higher to lower altitudes. A correlation between density and nitrate concentrations would be expected if septic systems were the predominant source of nitrate in the ground water of the Finley area.

The number of septic systems per quarter section (fig. 29) was determined by counting structures on a high-resolution aerial photograph. Individual residences and small business or commercial structures were assumed to have one system. Barns, sheds, and other unoccupied structures were assumed to have none. For the Finley Grade School and the Riverview High School, located in section 22, an equivalent number of individual septic systems was computed using the count of students and staff divided by the average number of persons per individual residence in the Finley area times the fractions of time of the day and year the schools are occupied. The industrial complexes along the Columbia River in sections 14, 23, and 24 were not counted because few wells were sampled in these locations. Sewered areas near Kennewick were identified from information provided by the City of Kennewick and the Benton-Franklin District Health Department.

Although not shown, nitrate and chloride concentrations in ground water also were plotted as a function of the number of septic systems in a 0.25 mi^2 area centered on, and just upgradient from, a sampled well. There was no apparent correlation between the concentrations of either constituent and the numbers of upgradient septic systems.



EXPLANATION

Average number of septic systems per acre in quarter section:

- Less than 0.2
- 0.2 to less than 0.4
- 0.4 to less than 0.8

—*330*— Altitude of water table, in feet above sea level

Nitrate concentration, in milligrams per liter. Number is isotope ratio (^{15}N), parts per thousand

- + Less than 1.0
- ● 1.0 to less than 5.0
- ◆ 5.0 to less than 10
- ▲ Equal to or more than 10

Figure 29.--Density of septic systems in the Finley area and nitrate concentrations and isotopic ratios of nitrate nitrogen in shallow ground water.

Isotope Ratios of Nitrate Nitrogen in Finley-Area Ground Water

Variations in the isotopic composition of nitrate nitrogen have been used by several investigators (Kreitler and Jones, 1975; Spalding and others, 1982) to identify sources of nitrate in ground water. In general, the nitrogen from septic systems and animal waste is isotopically heavier than the nitrogen from inorganic fertilizers and natural soils. For information about nitrogen-isotope chemistry, the reader is referred to the supplemental information section. Variations in the isotopic composition of the nitrate nitrogen in selected ground-water samples from the Finley area indicate that some of the nitrate in the ground water in the more populated part of the Finley area probably is derived from septic systems.

The isotope ratios ($\delta^{15}N$) of nitrate nitrogen in seven water samples collected from wells located northeast of Columbia Canal no. 3, in sections 5, 7, 9, 16, 17, and 21 (fig. 29), ranged from 6.1 to 11.4 parts per thousand (table 6); the median value was 6.9 parts per thousand. These wells are located in the more populated part of the Finley area. The $\delta^{15}N$ values in water samples collected from two wells located southwest of Columbia Canal no. 3, in sections 29 and 34, were 5.1 and 5.0 parts per thousand, respectively (table 6). Well 08N/30E-29A01 is not shown on figure 29 because it is more than 100 ft deep, but it, and the well in section 34, are located in the part of the Finley area where land use is primarily irrigated agriculture (fig. 3).

The isotope ratios described above are consistent with land-use patterns in that the isotopically heavier nitrate nitrogen was observed in samples collected where septic systems are present. However, the $\delta^{15}N$ values of nitrate nitrogen in most water samples from wells located in the more populated part of the Finley area are less than those typical of nitrogen from septic systems. This fact, and the lack of correlation between septic system density and nitrate concentrations in ground water, suggest that other significant sources of nitrate are present. Because it is not known how much of the nitrate is contributed from septic systems, a solute transport model was used to simulate the effects of different densities of septic systems on nitrate concentrations in an idealized ground-water system with physical and hydraulic properties similar to the unconfined ground-water system in part of the Finley area where land use is primarily irrigated agriculture (fig. 3).

Table 6.--*Isotope ratios ($\delta^{15}N$) and concentrations of nitrate nitrogen in selected samples of Finley-area ground water, Benton County, Washington*

Well number	Depth of well (feet)	Date of collection	$\delta^{15}N$ (parts per thousand)	Nitrate as nitrogen (milligrams per liter)
08N/30E-05K01	36	09-07-88	7.5	7.6
08N/30E-07Q04	38	09-07-88	6.9	10
08N/30E-09L02	43	09-09-88	6.1	2.2
08N/30E-16F01	50	09-07-88	6.5	3.9
08N/30E-17R01	40	09-08-88	6.8	8.4
08N/30E-21C03	35	09-08-88	11.4	3.7
08N/30E-21C04	28	09-08-88	8.9	4.5
08N/30E-29A01	215	09-08-88	5.1	27
08N/30E-34B01	56	09-09-88	5.0	11

Simulation of Nitrate Concentrations in Ground Water Downgradient from Septic Systems

Concentrations of nitrate in ground water were simulated beneath and downgradient from a 2-mi^2 source area composed of two adjoining land-grid sections of land. The direction of ground-water flow is parallel to the longer side of the rectangle formed by the two adjoining sections (figs. 30-32), so that septic systems are distributed over approximately 2 mi parallel to the direction of flow and 1 mi perpendicular to the direction of flow. Two miles is the approximate distance of the maximum horizontal flow path in the unconfined ground-water system in the Finley area (fig. 29).

The effects of septic systems on nitrate concentrations in ground water were simulated using three distributions of septic systems in the 2-mi^2 source area. These distributions were obtained by placing one septic system at the centers of 2.5, 1.25, and 0.625 acre lots, for totals of 512, 1,024, and 2,048 septic systems, respectively, in the source area (figs. 30-32). These distributions correspond to densities of 0.4, 0.8, and 1.6 systems per acre, respectively.

A description of the simulation model is provided in the supplemental information section. The values of the input variables for the model are given in table 7. The width of each individual source (w_i) was set at 10 ft, which is the approximate width of a septic system drainfield. The loading rate of 21.84 pounds of NO_3-N per year for each septic system was determined by multiplying a value for annual septic-system loading of 7 pounds NO_3-N per person (Alhajjar, 1985) times the average number of 3.12 persons per individual residence in the Finley area (U.S. Department of Commerce, 1983). The assumptions used in the determination of this loading rate, along with the tabulation of loading rates published in two other reports, are given in table 8. An annual loading of 7 pounds NO_3-N per person agrees with the value used by Frimpter and others (1988), but is somewhat higher than the rate of 4.6 pounds NO_3-N per year used by Porter (1980) (table 8).

The specific discharge (q) of 3.1 ft/day (table 7) was computed by multiplying a hydraulic conductivity of 1,100 ft/d for Pasco gravels by a hydraulic gradient of 15 ft/mi. The hydraulic conductivity of 1,100 ft/d is the median value for the Pasco gravels in sections 7, 8, and 17 of the Finley area (Brian Drost, U.S. Geological Survey, written commun., 1990). The hydraulic gradient corresponds to the slope of the water table at section 08N/30E-07 (fig. 29) as determined from water-level measurements made during August 1986. The value used for specific discharge in the simulations is believed to be generally representative of the entire unconfined aquifer (mostly Pasco gravels) in the Finley area.

The values of lateral and vertical dispersivity are a function of the properties of the porous medium that constitute an aquifer and must be determined experimentally. Because dispersivities were not determined during this study, the values used for input variables (table 7) were selected from a tabulation of values published by other investigators (Electric Power Research Institute, 1985). Values for lateral and vertical dispersivity of 3.28 and 0.0328 ft, respectively, which are considered to be characteristic of the Pasco gravels in the Finley area, were used in the simulations.

Simulated nitrate concentrations are shown at sections drawn perpendicular to flow lines at distances of 1, 2, and 2.25 mi downgradient from the upgradient end of the source area where x, the longitudinal coordinate, is equal to zero (figs. 30-32). The repetitive patterns formed by lines of equal nitrate concentrations result from dispersion of nitrate downgradient from linear arrays of septic systems parallel to the direction of ground-water flow. Of the three sections shown, the largest concentrations are at $x = 2$ mi, because nitrate derived from the cumulative contributions of all septic systems in the source area is not widely dispersed.

Simulated concentrations of nitrate in ground water resulting from loading by 512 septic systems (0.4 systems per acre) are shown on figure 30. A density of 0.4 septic systems per acre is approximately equivalent to the density of septic systems in the unsewered part of section 7, T.8 N., R.30 E., of the Finley area (fig. 29), where the estimated density of septic systems is 0.44 systems per acre, or one system for every 2.27 acres. The maximum simulated nitrate concentration at the 2-mi section (section 2-2') is 2.0 mg/L NO_3-N at the water table, and the 0.5 mg/L NO_3-N contour is at a depth of about 23 ft below the water table. Dispersion of nitrate results in smaller concentrations at the 2.25-mi section (section 2.25-2.25') compared with concentrations at the upgradient section. At the 2.25-mi section, the maximum concentration is 1.4 mg/L NO_3-N, and the 0.5 mg/L contour extends to approximately 25 ft below the water table (fig. 30). Because nitrate concentrations in the shallow ground water of the Finley area are generally larger than 2 mg/L (fig. 29), this simulation is consistent with previous data showing that septic systems are not the major source of nitrate in the ground water.

Nitrate concentrations resulting from uniform distributions of 0.8 and 1.6 septic systems per acre are shown on figures 31 and 32, respectively. With 0.8 septic systems per acre, simulated concentrations are larger by about a factor of 2 than those simulated with 0.4 septic systems per acre. With 1.6 septic systems per acre, simulated concentrations exceed 6 mg/L NO_3-N at the water table at the 2-mi cross section (section 2-2', fig. 32), and the 0.5 mg/L contour extends to approximately 45 ft below the water table.

The simulated concentrations are a function of the variables input to the model, and of these, the dispersivity values are probably the most uncertain. Larger dispersivity values will result in more dispersion and smaller simulated nitrate concentrations. Smaller dispersivity values will result in less dispersion and larger concentrations near the water table.

Table 7.--*Values of input variables used to simulate the distribution of nitrate in ground water downgradient from septic systems*

[Variables are defined in the supplemental information section; values listed are considered characteristic of the unconfined ground-water system in the Finley area]

Variable	Value	
Annual loading rate per septic system, S_i	21.84	pounds of nitrogen
Source width, w_i, (width of drainfield)	10.0	feet
Specific discharge, q	3.1	feet per day
Lateral dispersivity, α_y	3.28	feet
Vertical dispersivity, α_z	0.0328	feet

Table 8.--*Estimates of nitrate loading to ground water from septic systems*

[NO_3-N, nitrate as nitrogen; NO_3, nitrate; NH_3, ammonia; mg/L, milligrams per liter]

Reference	Annual NO_3-N loading, in pounds per person	Assumptions
Alhajjar (1985)	7.0	56 mg/L (NO_3-N) in effluent, complete conversion of NH_3 to NO_3, no loss of NO_3 in drainfield, mean flow rate of 41 gallons per person per day
Frimpter and others (1988)	7.3	40 mg/L NO_3-N from effluent reaching the water table, mean flow rate of 60 gallons per person per day (authors used data from other studies for estimates)
Porter (1980)	4.6	50 percent of the 75 mg/L total N in effluent reaches the ground water as NO_3-N, mean flow rate of 40 gallons per person per day (author used data from other studies for estimates)

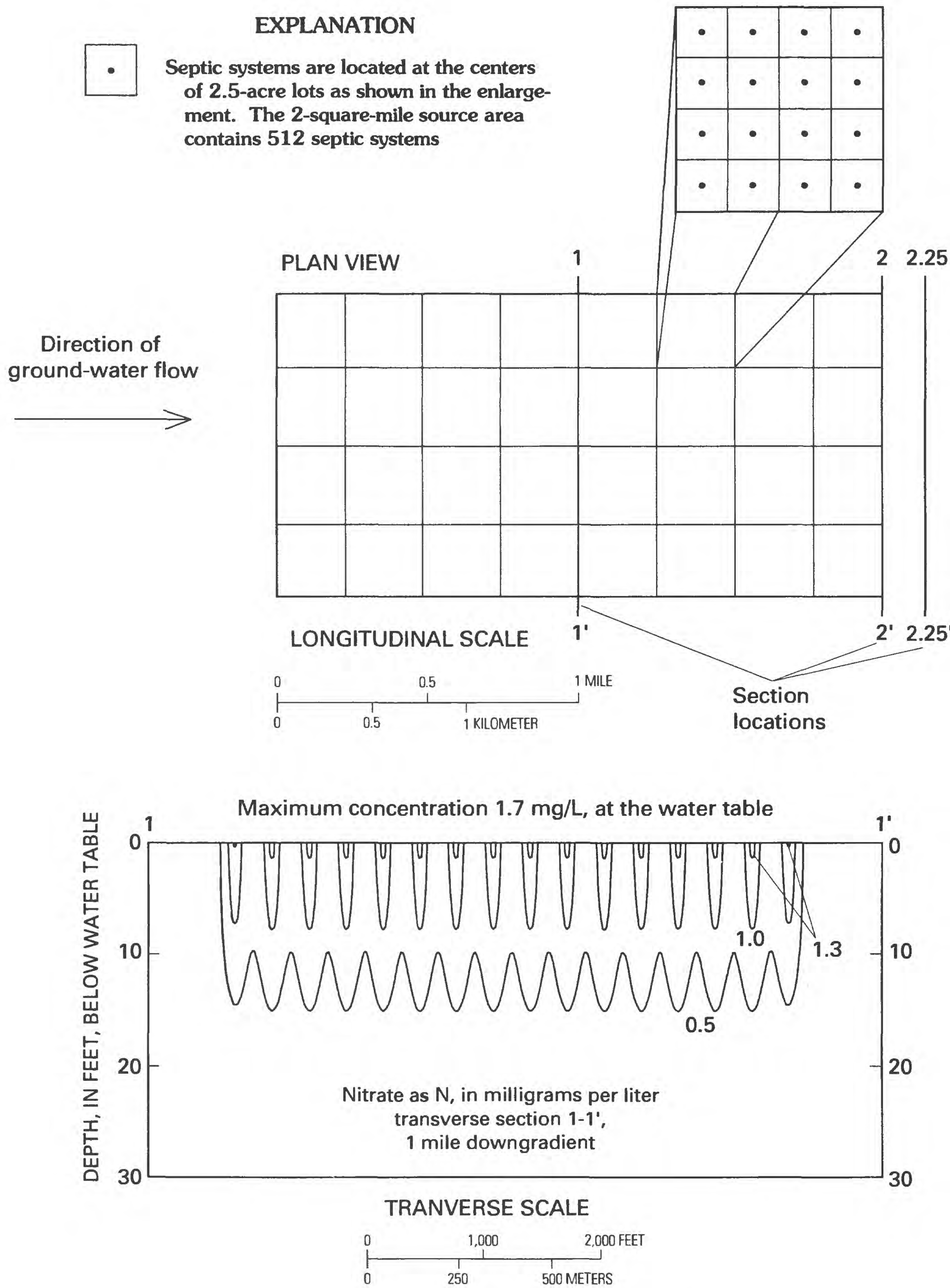


Figure 30.--Simulated distributions of nitrate concentration in ground water at three transverse sections underlying and downgradient from a 2-square-mile source area with 512 septic systems in a uniform distribution of 0.4 septic systems per acre.

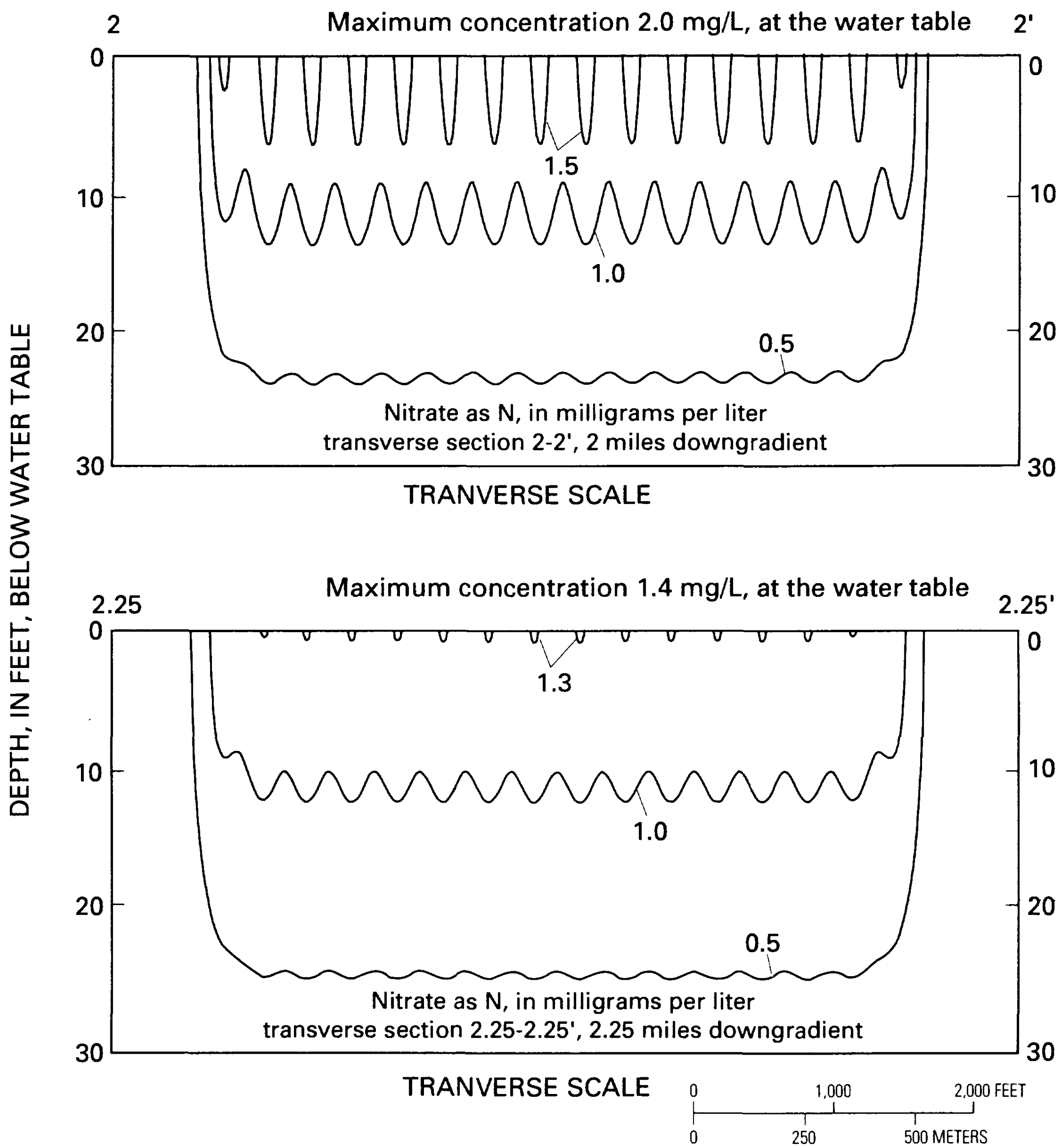


Figure 30.--Continued.

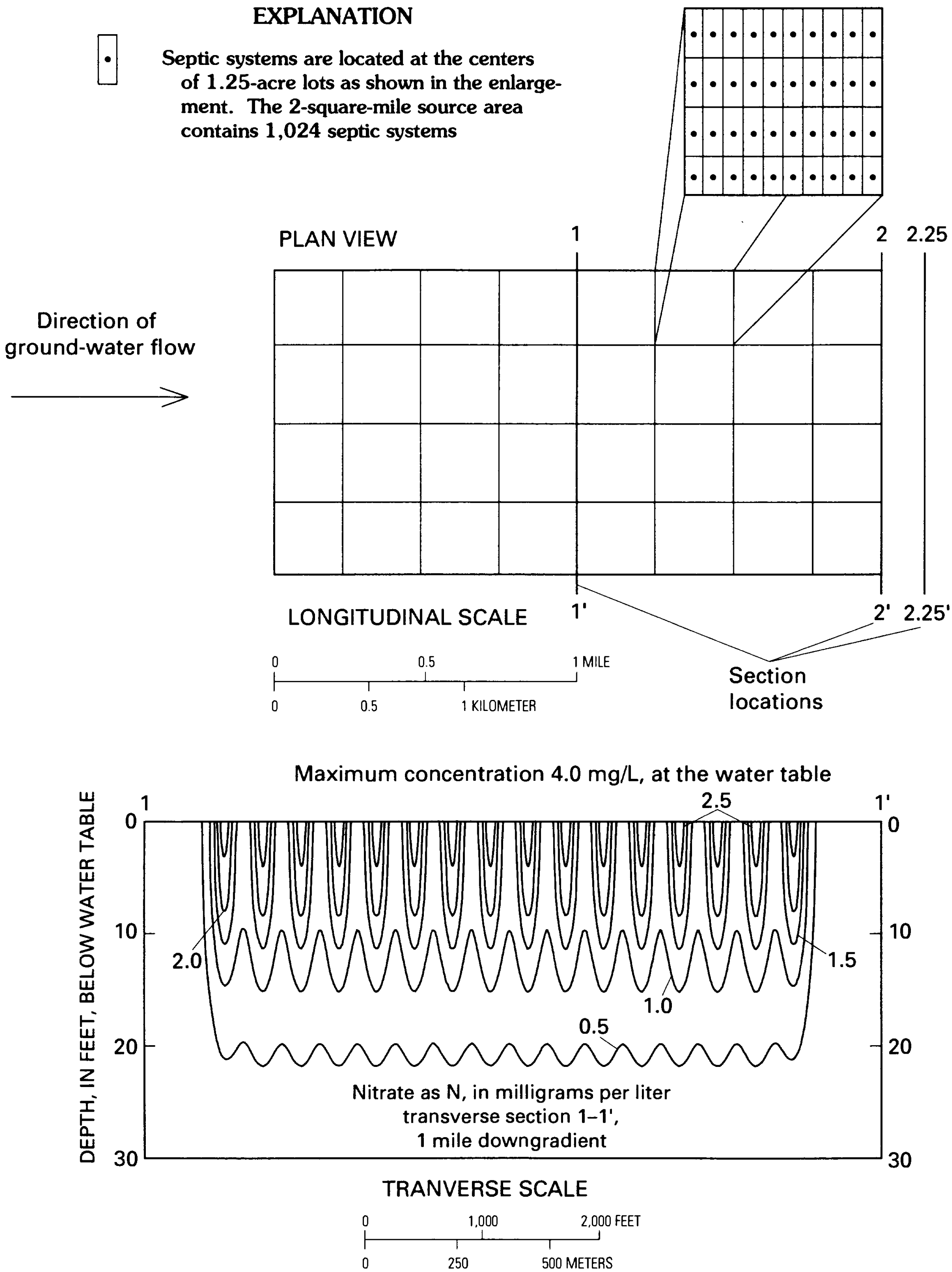


Figure 31.--Simulated distributions of nitrate concentration in ground water at three transverse sections underlying and downgradient from a 2-square-mile source area with 1,024 septic systems in a uniform distribution of 0.8 septic systems per acre.

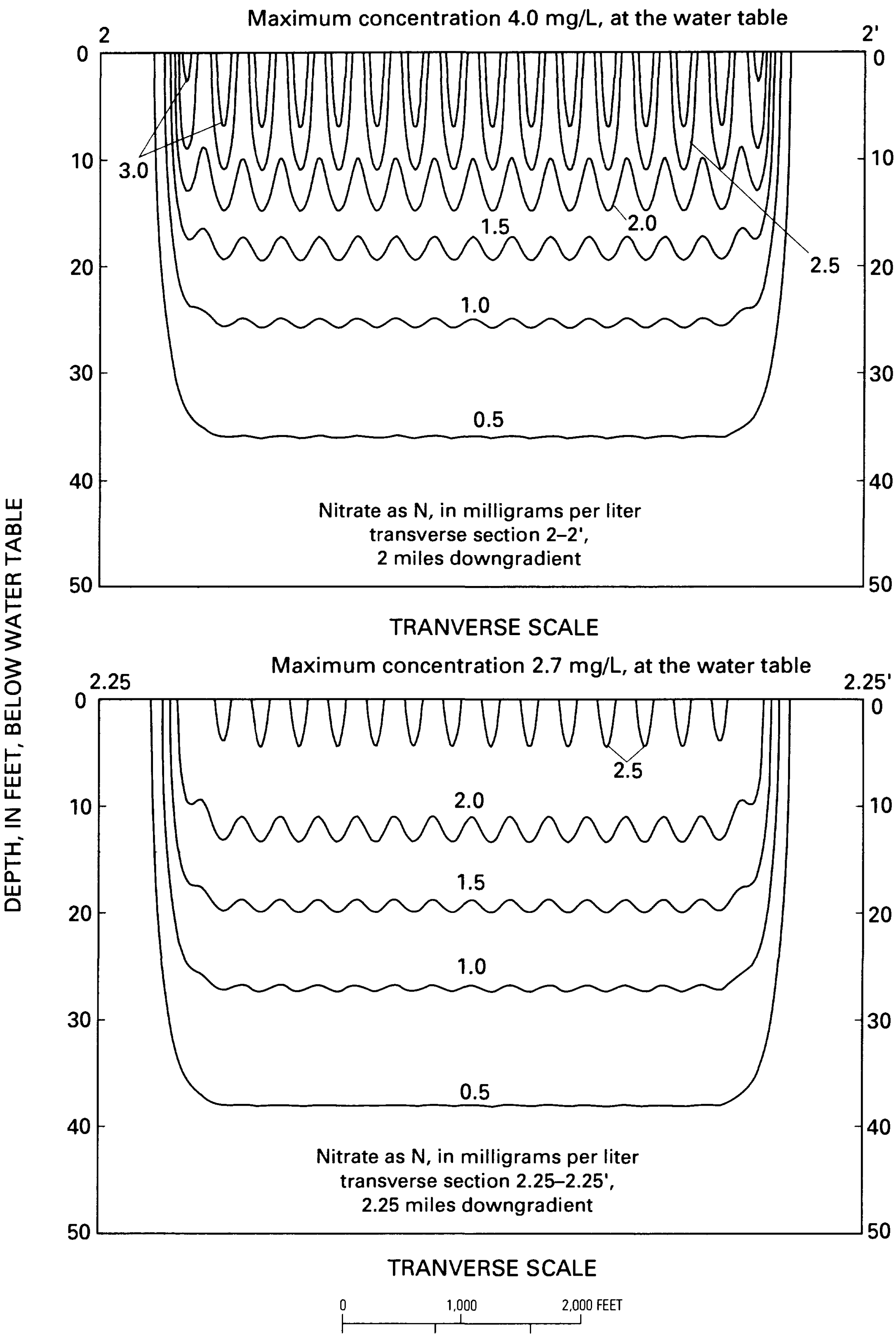


Figure 31.--Continued.

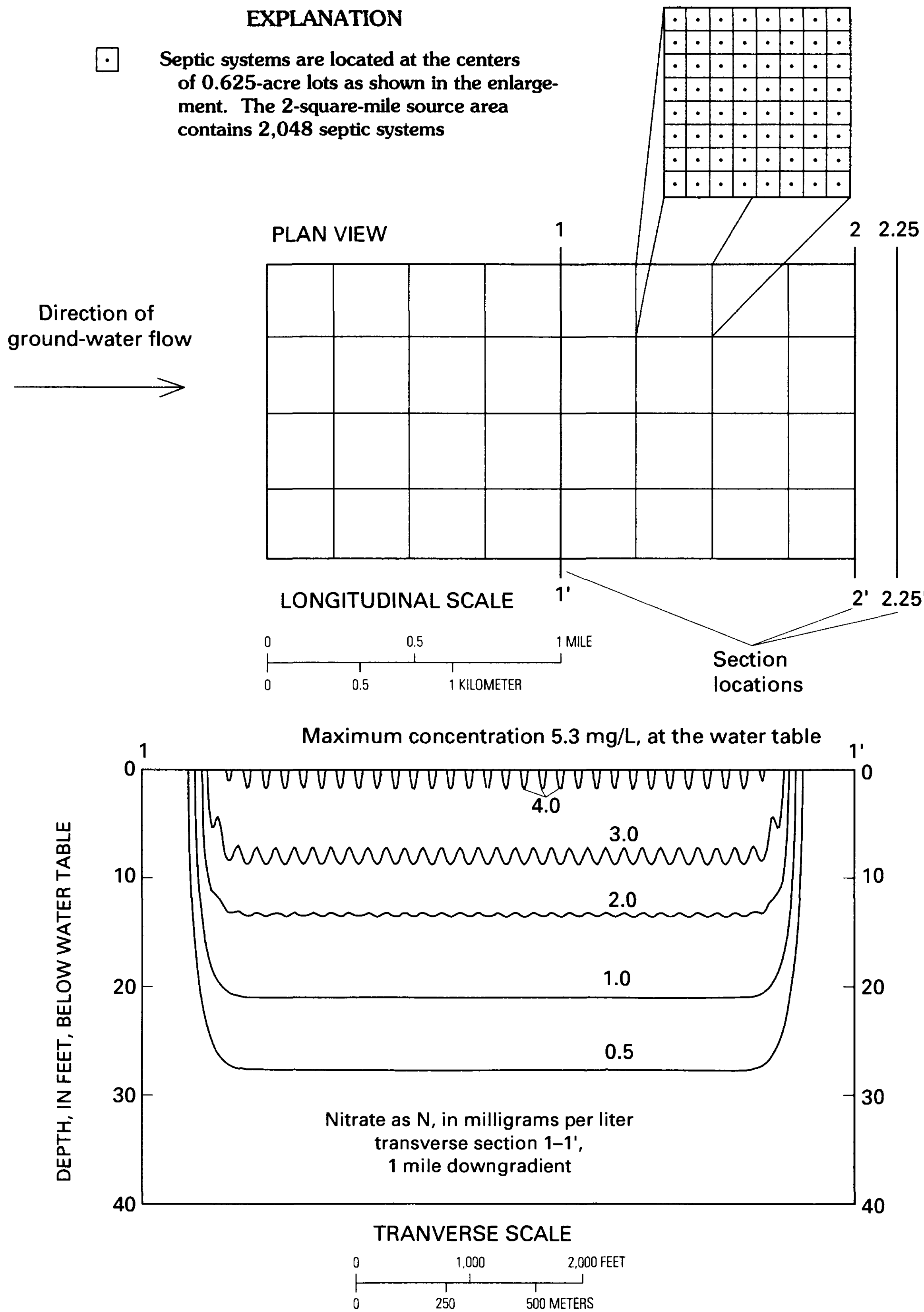


Figure 32.--Simulated distributions of nitrate concentrations in ground water at three transferse sections underlying and downgradient from a 2-square-mile source area with 2,048 septic systems in a uniform distribution of 1.6 septic systems per acre.

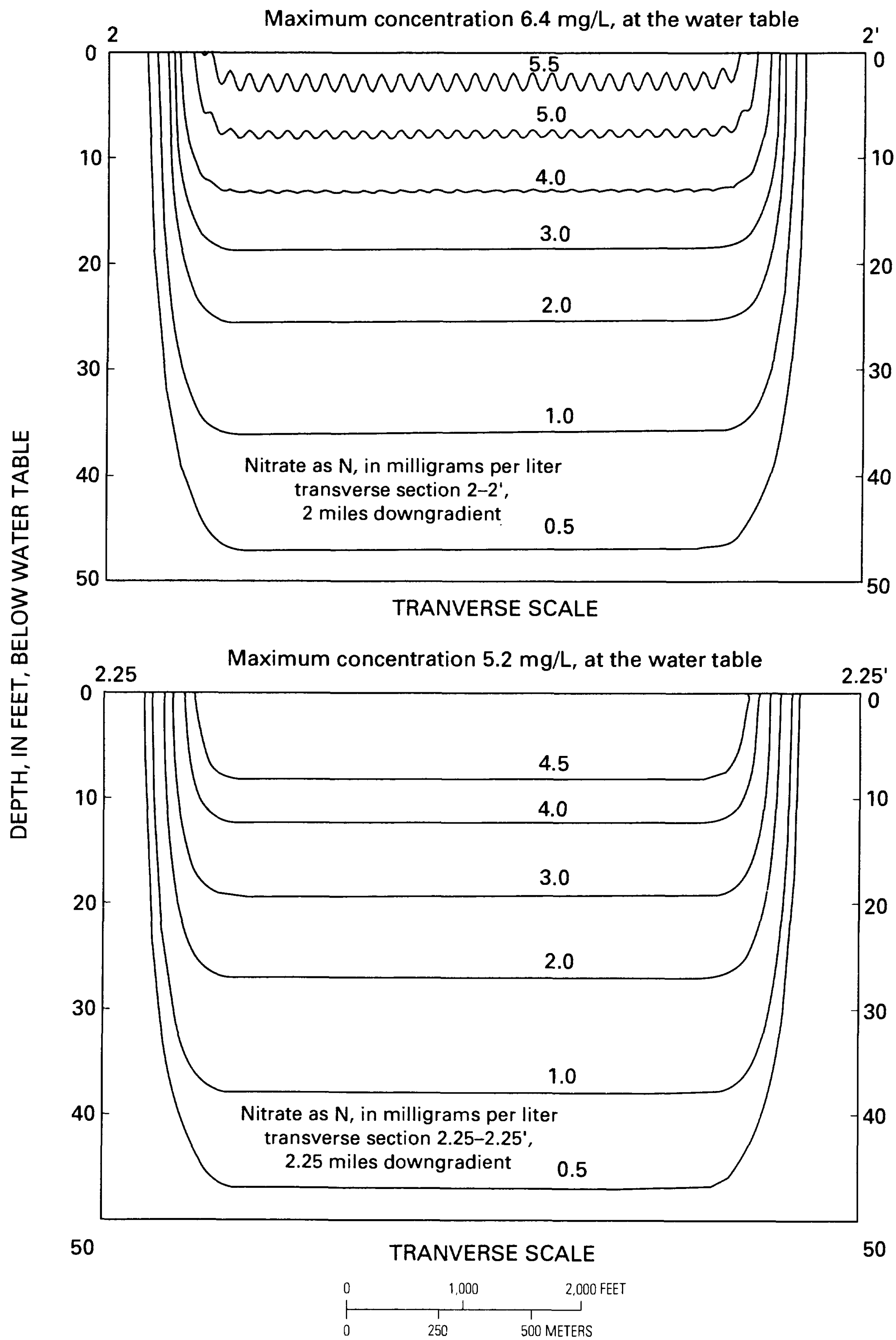


Figure 32.--Continued.

Natural Nitrate

After the initial round of sample collection in 1986, it was noted that the elevated concentrations of nitrate found in ground water generally corresponded to locations where it was estimated that nitrogen sources of sufficient magnitude to account for the observed concentrations were present. A possible exception was ground water sampled from wells open to the Saddle Mountains Basalt along the northeast flanks of Badger and Candy Mountains in Benton County (T.9 N., R.28 E., pl. 1). Here, it was difficult to attribute nitrate concentrations as large as 52 mg/L NO_3-N to the observed land use, which was scattered houses surrounded by undeveloped land, pasture land, and orchards. This observation, along with information documenting the presence of natural nitrate at locations elsewhere in the United States (Mansfield and Boardman, 1932), and possibly in the State of Washington (Fretwell, 1979), indicated the need to collect soil and sediment samples to determine concentrations of natural nitrate. Additional background information about the occurrence of natural nitrate is given in the supplemental information section.

Although some sediments collected in the study area contained large concentrations of natural nitrate, three conditions make it virtually impossible to verify the occurrence of natural nitrate in ground water. Only a limited number of soil and sediment samples were collected and analyzed. Secondly, we have a limited understanding of the manner in which natural nitrate, if present in soils and sediments, is leached into ground water. Thirdly, nitrogen fertilizers have been applied in many parts of the study area, thereby preventing a simple comparison between concentrations of natural nitrate in soils and sediments and nitrate concentrations in underlying ground water.

Nitrate in Soils and Sediments

Soil and sediment samples were collected at 11 sites in Benton, Franklin, and Grant Counties (fig. 33) and analyzed for nitrate and moisture content. In Benton County, the samples were collected from fine-grained sediments of the Touchet Beds in Badger Coulee. Two of the five sampling sites were on undeveloped land (table 9) where known anthropogenic activities that may have contributed nitrate to the subsurface are limited to the grazing of sheep on natural vegetation and to atmospheric deposition. The other three sites were on cropland and were selected to provide comparative data. In Franklin and Grant Counties, all sampling sites were on undeveloped land, where samples were of the soils and underlying Touchet Beds or Ringold Formation (table 9). Although the sampling sites in Grant County are located north of the study area, conditions are similar to those in the study area.

Corehole and outcrop samples were collected by hand using either an auger or a shovel. In contrast to corehole samples, borehole samples were collected with a coring device attached to a hollow-stem auger drilling rig. The borehole samples from Grant County were provided by the Bureau of Reclamation. The samples, which were sealed in plastic bags or in plastic core-barrel inserts, were stored at 4°C until analyzed.

A 5-gram subsample was weighed, dried at 105°C for 24 hours, cooled, and reweighed to determine water content by weight. Nitrate was extracted by mixing 20 grams of an undried subsample with 100 milliliters of deionized water and shaking the mixture for 1 hour on a wrist-action shaker. The aqueous phase, which was separated from the solids by centrifugation, was then analyzed for nitrate. Concentrations are reported as milligrams of NO_3-N per kilogram of dry soil or sediment (table 9). These units are equivalent to parts per million.

The precision of the sampling and analytical procedures was determined by analyzing 23 duplicate samples (table 21). The median difference between nitrate concentrations in sample pairs was 16 percent.

Nitrate concentrations in 59 soil and sediment samples collected at eight sites located on undeveloped land ranged from 0.3 to 24.3 mg/kg NO_3-N (table 9). The median concentration in samples collected at these sites was 1.5 mg/kg NO_3-N. Concentrations of 16.8 to 20.2 mg/kg NO_3-N found in samples collected from borehole no. 2 on undeveloped land in Badger Coulee are of the same order of magnitude as the overall maximum concentration of 27.4 mg/kg NO_3-N, which was found in a soil sample collected from corehole no. 3 in a wheat field in Badger Coulee (table 9). It is not known if 27.4 mg/kg NO_3-N represents a typical maximum nitrate concentration in soils beneath fertilized cropland in the study area. It is, however, similar to the maximum concentration of 23.1 mg/kg NO_3-N found by Spalding and Kitchen (1988) in soil samples collected beneath a test plot receiving annual treatments of 400 lb of nitrogen fertilizer per acre. This application rate is large and exceeds the recommended maximum annual application for irrigated potatoes of 320 lb of nitrogen fertilizer per acre (Washington State University, 1974).

Table 9.--*Nitrate and moisture content of soil and sediment samples*

[Depth, below land surface or from top of outcrop; <, less than; --, no data]

Sampling location	Depth (feet)	Description of material	Nitrate as N, in milligrams per kilogram dry weight	Water content by weight (percent)
		Soils and underlying Touchet Beds in Badger Coulee, Benton County, Wash.		
Borehole No. 1,	2-2.5	silt, fine sand	1.3	5.5
09N/27E-26N,	7.9-8.3	silt, fine sand	4.0	4.4
undeveloped land,	9-10.5	silt	5.4	6.7
slight incline	14-15.5	silt	13.4	5.3
near bottom of	19-20.5	silt, sand	4.7	6.0
ravine, sample	24-25.5	silt	2.9	6.3
collected	29-30.5	sand	2.3	5.8
10-11-88	34-35.5	sand, silt	2.9	14.9
	39-40.5	sand, silt	5.4	16.9
	49-50.5	sand, silt	2.0	26.9
	53	cobbles, no sample		
Borehole No.2,	4-5.5	silt	0.8	4.8
09N/27E-26M,	9-10.5	silt	4.7	5.0
undeveloped land,	14-15.5	silt, very compact	16.8	5.4
hilltop, sample	19-20.5	silt	18.4	7.1
collected	24-25.5	silt	20.2	4.9
10-12-88	29	rock, no sample		
Corehole No. 1,	1-1.4	fine sand, silt	4.5	6.8
09N/27E-35D,	2-2.4	fine sand, silt	2.4	4.8
cropland idle	4-4.2	fine sand, silt	9.4	4.0
since about 1980,	8-8.4	fine sand, silt	0.70	5.0
grass cover, slight				
incline near bottom of				
hill, sample collected				
06-22-88				
Corehole No.2,	1-1.4	fine sand, silt	9.8	14.6
09N/27E-35D,	2-2.4	fine sand, silt	0.8	9.8
cropland	4-4.2	fine sand, silt	<0.50	7.9
(1988, alfalfa,	7.8-8.2	fine sand, silt	<0.50	9.3
1987 oats, 1981-86,				
idle), slight incline				
near bottom of hill,				
sample collected				
06-22-88				

Table 9.--*Nitrate and moisture content of soil and sediment samples--Continued*

Sampling location	Depth (feet)	Description of material	Nitrate as N, in milligrams per kilogram dry weight	Water content by weight (percent)
Soils and underlying Touchet beds in Badger Coulee, Benton County, Wash.--Continued				
Corehole, No. 3, 09N/27E-35H, cropland (1988 wheat, 1987 potatoes, 1984-86 alfalfa), slight incline near bottom of hill, sample collected 06-22-88	1-1.4	fine sand, silt	27.4	21.4
	2-2.4	fine sand, silt	23.1	17.6
	4-4.4	fine sand, silt	2.9	14.5
	7.8-8.2	fine sand, silt	1.2	13.8
Soils and underlying sediments in Franklin County, Wash.				
Jackass Mountain corehole, 11N/30E-17P, undeveloped land, hillside, sample collected 11-16-88	surface	medium-fine sand	2.5	10.2
	1	medium-fine sand	1.0	8.5
	2	sand with caliche fragments	0.50	6.7
White Bluffs, outcrop 13N/27E-11, undeveloped land, exposed face of upper Ringold sediments, collected 11-21-88	3	fine sand	0.30	2.3
	6	caliche, sand	1.5	4.8
	20	clayey fine silt	1.5	2.8
	50	clayey fine silt	24.3	3.0
	100	silt, clay	4.3	4.6
Soils and underlying Touchet Beds or upper Ringold Formation in Grant County, Wash.				
White Bluffs, outcrop 14N/27E-16L undeveloped land, sample collected 11-20-88	20	fine sand	1.3	1.5
	71	sand	0.30	7.7
	73	sand, silt	4.3	2.4
	75	hard sand	0.30	5.2

Table 9.--*Nitrate and moisture content of soil and sediment samples--Continued*

Sampling location	Depth (feet)	Description of material	Nitrate as N, in milligrams per kilogram dry weight	Water content by weight (percent)
Soils and underlying Touchet beds or upper Ringold Formation in Grant County, Wash.--Continued				
Borehole No. 88-9, 14N/27E-22Q, undeveloped land, level ground, sample collected 08-00-88	28-30	fine silt, clay	1.5	--
	58-60	fine silt, clay	2.5	--
Borehole No. AH18, 14N/27E-23M, undeveloped land, level ground, sample collected 07-06-89	0-2	medium-fine sand	1.8	1.6
	2-4	medium sand basaltic	2.0	1.7
	4-6	medium sand basaltic	0.80	2.0
	6-8	medium sand basaltic	0.80	1.7
	8-10	medium sand basaltic	0.80	4.6
	10-12	medium sand basaltic	1.0	3.0
	12-14	tan silt	1.5	12.2
	14-16	tan silt	2.5	13.4
	16-18	tan silt	3.0	13.7
	18-20	tan silt	2.8	10.8
	25	silt, some clay	3.0	21.6
	30	silt, fine sand	1.3	9.8
	35	silt	1.0	11.0
	40	silt, fine sand	0.50	4.7
	45	silt, clay	1.0	12.2
	50	silt, clay	2.0	14.8
Borehole No. AH20, 14N/27E-24C, undeveloped land, top of ridge, sample collected 07-06-89	0-1.5	fine-medium sand	2.0	5.9
	1.5-4	caliche and sand	1.5	13.7
	4-6	sand and caliche	0.80	10.0
	6-8	sand, silt, caliche	1.0	8.1
	8-10	sand, silt, caliche	1.0	8.8
	10-12	sand, silt, caliche	2.8	15.2
	12-14	sand, silt, caliche	1.3	14.0
	14-16	sand, silt, caliche	1.5	11.8
	16-18	silt, sand, hard	1.0	12.0
	18-20	silt, sand, hard	0.80	11.3
	25	silt, fine sand	1.0	9.1
	30	silt, fine sand, clay	0.80	6.9
	35	silt, fine sand, clay	0.5	9.2
	41	silt, fine sand, clay	1.8	6.5

Volume-weighted average concentrations of 4.4 and 11.9 mg/kg NO_3-N in vertical sample sequences from borehole nos. 1 and 2, respectively, in Badger Coulee (fig. 33) were the largest average concentrations found at sampling sites on undeveloped land. The larger average of concentrations in samples from borehole no. 2 is a result of the abrupt increase in nitrate concentrations in samples collected below a depth of 14 ft (fig. 34). An extremely compact layer of sediment was present at a depth of approximately 15 ft at this site. It is probable that by reducing the downward percolation of recharge water, this compact layer retards the leaching of nitrate present in the deeper sediments. It is not known if this compact layer was deposited with the sediments or is the lower extent of a wetting front where the evaporation of soil water has deposited a layer of salt.

Differences in amounts of recharge at the locations of borehole nos. 1 and 2 also may affect nitrate concentrations in soil profiles. Borehole no. 1 was located in a depression at the bottom of a ravine, where erosional features indicate that surface runoff from upslope locations during intense rainfall may contribute to subsurface recharge. In contrast, borehole no. 2 was located at the top of a small hill, where recharge is limited to some percentage of the amount of precipitation falling on the overlying land surface. Larger amounts of recharge at borehole no. 1 may have leached nitrate from the underlying soils and sediments.

For comparison, it is helpful to convert nitrate concentrations in samples from individual boreholes to a hypothetical mass of nitrate contained in a given thickness of sediments underlying an area larger than the cross-sectional area of the borehole. This is done by multiplying the volume-weighted average concentration of nitrate in samples from a borehole by the average density of the sediments, to compute the average mass of nitrate per unit volume of sediment. Based on the work of Klein and Bradford (1979), the average density of sediments is assumed to be 1.6 g/cm^3. The average mass of nitrate per unit volume of sediment is then multiplied by the depth of the borehole, or an arbitrary depth, to obtain the mass of nitrate per unit area of land surface. An assumption implicit in this computation is that the average mass of nitrate per unit volume of sediment in the borehole represents the average in the sediments underlying the unit area of land surface represented. If that area is an acre, then the result is expressed in pounds of nitrate per acre.

The average mass of nitrate per unit volume of sediment in borehole no. 2 in Badger Coulee is equivalent to 2,590 lb of NO_3-N in a block of sediments 50-ft thick underlying an acre of land. The equivalent amount for borehole no. 1 in Badger Coulee is 964 lb NO_3-N per acre. In contrast, the amount of nitrate in borehole AH18 in Grant County is equivalent to only 341 lb per acre for 50-ft thickness of sediments.

Although the presence of natural nitrate in soils and sediments at selected locations in the study area has been demonstrated, these data, along with other available data, are insufficient to determine directly if any of the nitrate in ground water is derived from natural sources. Even with additional soil and sediment analyses, this determination would be very uncertain because (1) the available sampling locations are too widely distributed to accurately estimate the mass of natural nitrate present before the introduction of agriculture; (2) it is difficult to estimate the rate at which natural nitrate salts may be, or may have been, leached into the ground water and to quantify the effects of subsequent dilution of the nitrate by ground water; and (3) fertilizers have been applied in most locations, where the percolation of irrigation water may have leached natural nitrate salts into the ground water.

Although the presence of natural nitrate in ground water was not directly confirmed, historical data collected at various locations in Franklin County permit limited inferences about the occurrence of natural nitrate in parts of the ground-water system.

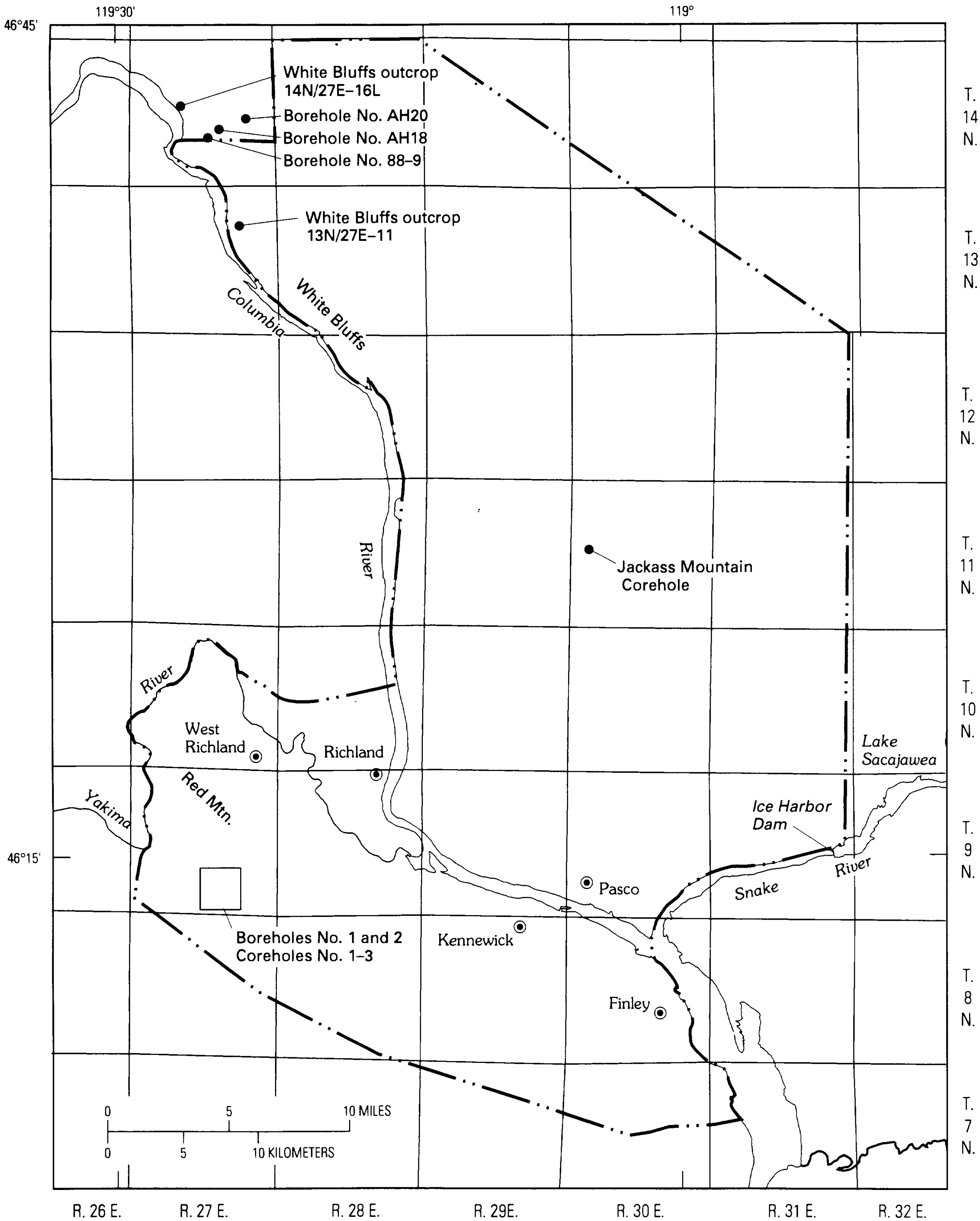


Figure 33.--Soil and sediment sampling locations in the study area.

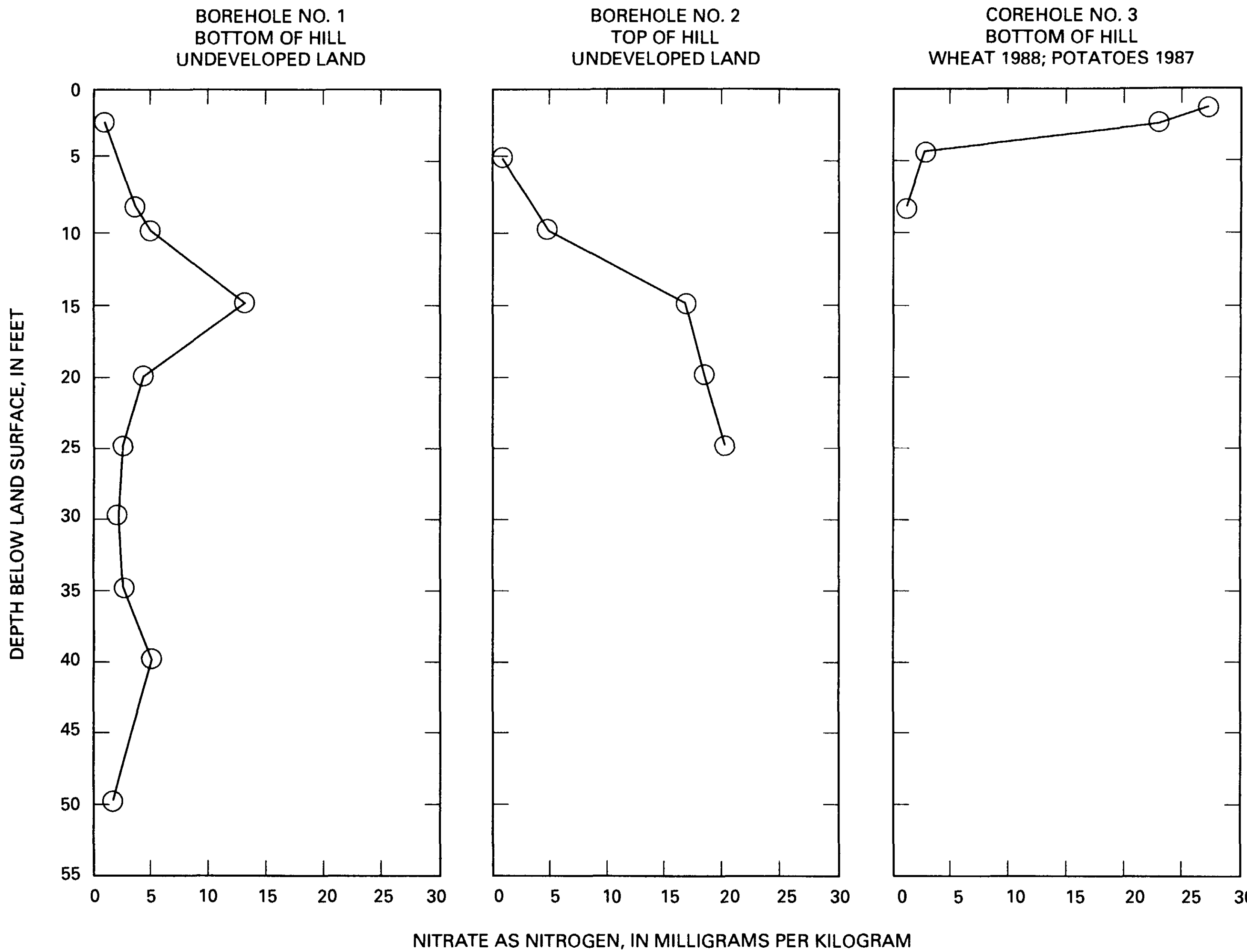


Figure 34.--Nitrate concentrations in soils and sediments as a function of depth at three sites in Badger Coulee, Benton County, Washington.

Inferences From Historical Data

Ringold Springs, 12N/28E-24F01S (fig. 20), started flowing in October 1957 as a result of rising ground-water levels caused by increased recharge from surface-irrigation water (Walters and Grolier, 1960). The concentration of nitrate in water from Ringold Springs has increased from 1.2 mg/L NO_3-N when it was first sampled in March 1958 to the present (1988) level, which typically varies between 4 and 7 mg/L NO_3-N (fig. 35). During the same time interval, bicarbonate concentrations in Ringold Springs water have increased, sulfate and chloride concentrations have decreased, and dissolved-solids concentrations (represented as total milliequivalents per liter) have decreased slightly (fig. 35, and tables 13 and 18). The initially large concentrations of sulfate and chloride in Ringold Springs water are consistent with the observation by Newcomb (1972) that with the introduction of irrigation water into the Columbia Basin, salts containing sulfate and lesser amounts of chloride were flushed from soils and sediments into the ground water. The relatively small concentration of nitrate in the initial sample of Ringold Springs water indicates that the amount of natural nitrate in soils and sediments within the contributing recharge area was not large, relative to the amount that is now contributed from agricultural practices. Additional support for this conclusion is provided by data collected during this study showing that concentrations of natural nitrate in soils and sediments sampled in Franklin and Grant Counties were relatively small (table 9).

The leaching of natural nitrate salts by percolation of irrigation water may have caused some of the initial increase in nitrate concentrations in water from wells 14N/30E-8G01, 10P01, and 20A01 (figs. 35 and 36). These wells are located near Scooteney Reservoir in northern Franklin County (fig. 21). Nitrate concentrations in water from these wells were less than 1 mg/L NO_3-N prior to the start of the filling of Scooteney Reservoir in January 1953. When next sampled, either in 1958 or 1960, nitrate concentrations in water from these wells ranged from 6.8 to 22 mg/L NO_3-N (figs. 35 and 36). In subsequent samples, nitrate concentrations had decreased from the maximum observed values.

Well 14N/30E-10P01, which was sampled during this study, was the only one of the three wells resampled after the early 1960's. Nitrate concentrations in recent water samples from this well are only slightly larger than the concentration of 0.97 mg/L NO_3-N in the sample collected in 1952 prior to the filling of Scooteney Reservoir. This well is located within 0.1 mi of Scooteney Reservoir, and the similarity between the major-ion composition of the well water and that of the reservoir water (fig. 36) suggests that seepage from the reservoir is the principal source of recharge to the basalt in the vicinity of the well.

Recent data for the other two wells are not available. One might speculate that the leveling off of nitrate concentrations at about 10 mg/L NO_3-N in water from well 14N/30E-08G01 during the early 1960's (fig. 35) indicates the presence of a more sustained source of nitrate after the initial flushing of natural nitrate salts into the ground water. Because crops were grown in the vicinity of this well as early as 1958 (Onzel Capps, retired farmer, oral commun., 1989), nitrogen fertilizers may be a source of nitrate in water from this well.

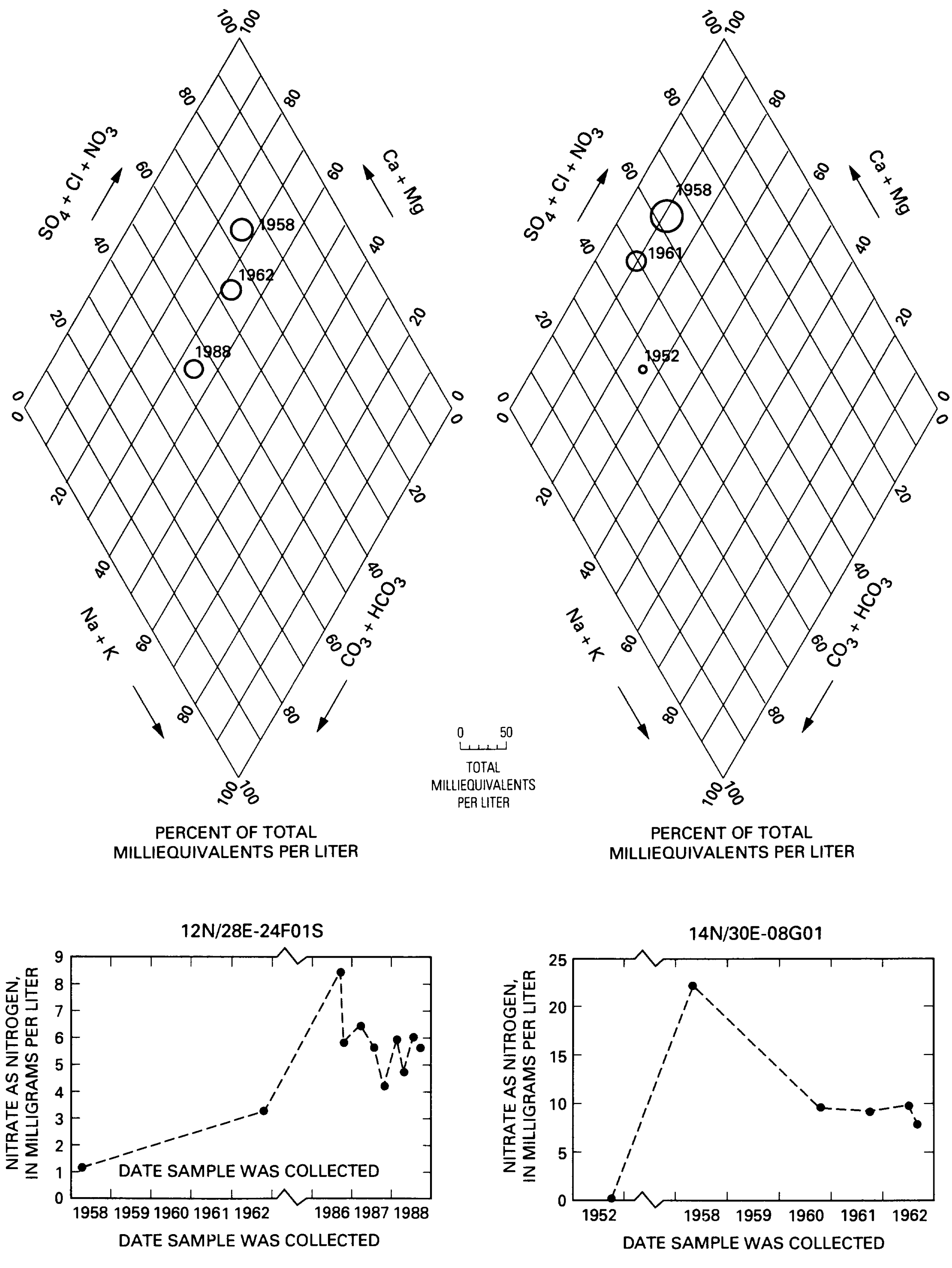


Figure 35.--Temporal changes in the composition of water from spring 12N/28E-24F01S and well 14N/30E-08G01, in Franklin County, Washington.

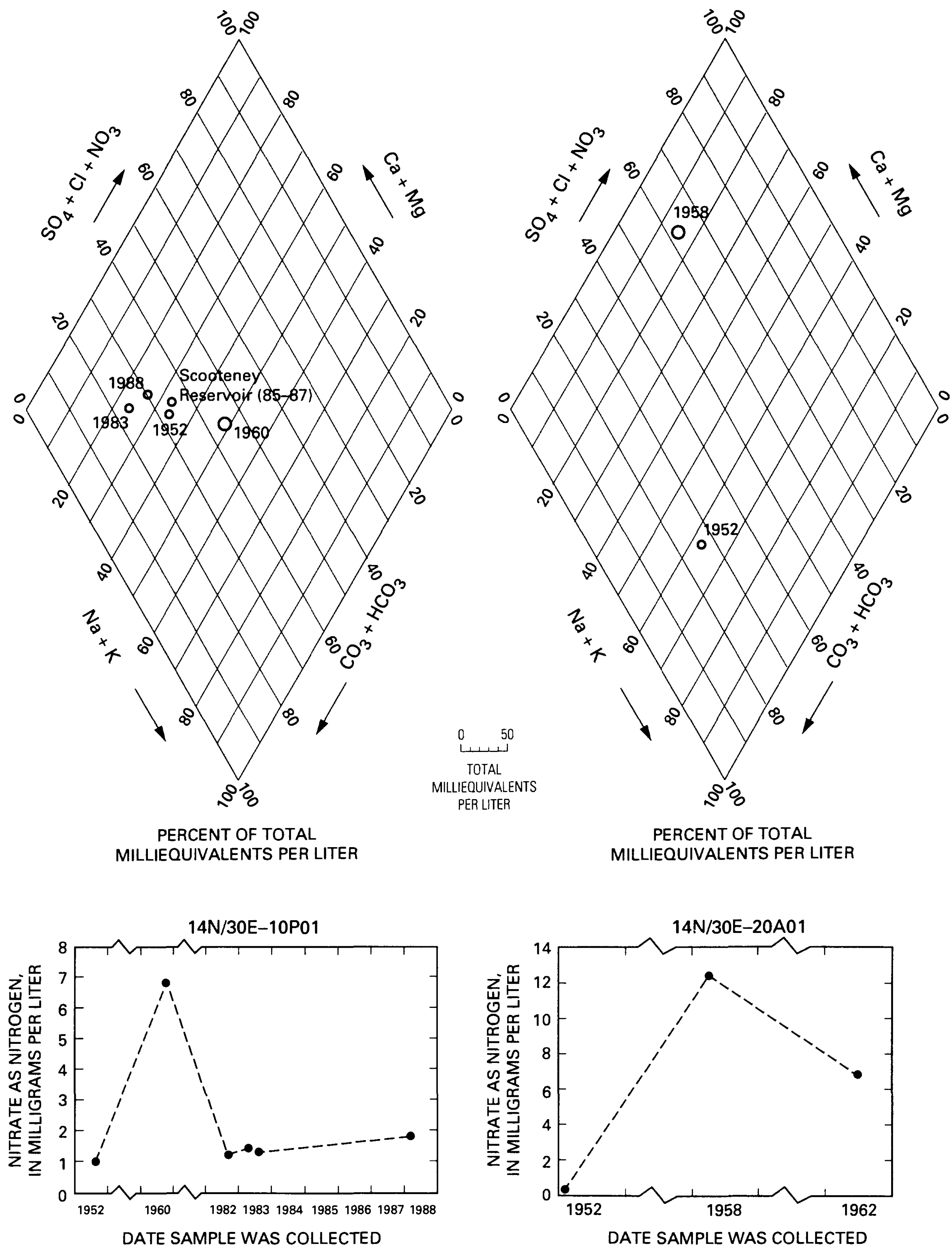


Figure 36.--Temporal changes in the composition of water from wells 14N/30E-10P01 and 14N/30E-20A01, in Franklin County, Washington.

Preliminary Conclusions and Unresolved Questions

Conclusions regarding natural nitrate as a source of nitrate in ground water are tentative and location specific. In the northwestern part of Franklin County, small concentrations of natural nitrate in soils and sediments, and the small initial concentration of nitrate in water from Ringold Springs, suggest that amounts of natural nitrate presently in ground water are small, compared with nitrate derived from farming practices.

The leaching of natural nitrate salts by recharge from irrigation water may have caused temporary increases in nitrate concentrations in water from three wells in northern Franklin County. The temporary nature of the concentration increases suggests that if natural nitrate salts were present, they have been flushed into the ground water and diluted, and do not represent an ongoing source of nitrate.

In Benton County, it is probable that some of the nitrate in the unconfined ground water underlying Badger Coulee is derived from natural nitrate leached from the Touchet Beds. It is not known how much of the nitrate presently in ground water is from natural deposits, because with the introduction of irrigated agriculture, nitrogen fertilizers were applied. After the start of irrigation in the late 1950's, it is likely that large amounts of nitrogen fertilizers were applied in parts of Badger Coulee, because potatoes, which require large applications of fertilizers, were grown over several large areas (Charles Foster, retired farmer, oral commun., 1988).

It is not known if the Touchet Beds (fig. 5) have been a source, or are a potential source, of nitrate to ground water at locations outside of Badger Coulee in Benton County where samples from the Touchet Beds were not collected and analyzed. A comparison of nitrate concentrations in Touchet Beds collected in Badger Coulee with those collected in Grant County (table 9) indicates that spatial variations of nitrate concentrations in Touchet Beds may be large. Also, it should be noted that at locations outside of Badger Coulee the thickness of the Touchet Beds is generally less than 50 ft (Drost and others, 1996). In contrast, the maximum thickness of Touchet Beds in Badger Coulee exceeds 150 ft.

The question as to whether the Ellensburg interbeds are a source of nitrate in ground water in the Saddle Mountains Basalt along the northeast slopes of Badger and Candy Mountains (pl. 1) remains unresolved. As previously mentioned, seepage from Badger East Lateral Canal is a source of dilute recharge to the Saddle Mountains Basalt, and the surrounding land-use pattern does not indicate that large amounts of nitrogen fertilizers have been applied in this area. Similarly, the Touchet Beds are not a likely nitrate source because they are extremely thin where they appear along the flanks of Badger and Candy Mountains.

FLUORIDE IN GROUND WATER

Water samples from 142 wells and one spring were analyzed for fluoride and other major ions (table 18). Fluoride concentrations equal to or more than 2.0 mg/L, the current secondary maximum contaminant level for drinking water (U.S. Environmental Protection Agency, 1986a), were found in two samples. The fluoride concentration in one of the two samples was 4.7 mg/L, a value that exceeds the primary maximum contaminant level for drinking water of 4.0 mg/L (U.S. Environmental Protection Agency, 1986b). Both of these samples were taken from wells open to the Saddle Mountains Basalt in Franklin County.

Local residents were interested in information about the presence of fluoride in ground water because in a compilation of available ground-water-quality data for Washington, Lum and Turney (1982) reported fluoride concentrations in excess of maximum contaminant levels in ground water of the Pasco Basin. At that time, the primary maximum contaminant level for fluoride in drinking water was a function of average daily air temperatures, and was computed by Lum and Turney (1982) to be 1.8 mg/L for eastern Washington. Their data showed that the largest fluoride concentrations were in ground water in the deeper basalt aquifers.

Newcomb (1972) also found that the larger fluoride concentrations in the Columbia River Basalt Group were in ground water from deeper zones in the basalt. He considered 0.2 to 0.8 mg/L to be the typical concentration range for fluoride in ground water in the Columbia River Basalts in general, and 0.7 to 2.0 mg/L to represent the upper end of the total range of concentrations. The upper range of concentrations was found in ground water in deeper basalt aquifers.

Fluoride concentrations in ground waters sampled during this study ranged from less than 0.1 to 4.7 mg/L, and the median concentration was 0.5 mg/L (fig. 37). Fluoride concentrations in ground water from 12 of 143 sampling sites were equal to or more than 1.0 mg/L (table 10). One milligram per liter is an arbitrary value chosen to illustrate the upper range of concentrations; it corresponds to about the upper 8 percent. The two fluoride concentrations equal to or more than 2.0 mg/L, the secondary maximum contaminant level, were in water from deep wells open to the Saddle Mountains Basalt. Large concentrations of fluoride in ground water in basalt aquifers are apparently the result of natural conditions. Fluoride is present as a minor constituent in basalt, primarily occurring in basaltic glass. It is believed to be selectively leached into ground water along interflow contacts. Fluoride concentrations as high as 23 mg/L (Rockwell International, 1982) have been observed in ground water sampled from the Grande Ronde Basalt, which is the deepest basalt unit in the study area.

Table 10.--*Ground-water samples from the study area containing 1.0 milligrams per liter fluoride or more*

[The value of 1.0 milligram per liter was selected arbitrarily to represent the upper range (equivalent to about the upper 8 percent) of observed concentrations. The secondary maximum contaminant level is 2.0 milligrams per liter (U.S. Environmental Protection Agency, 1986a); WNPM, Wanapum Basalt; SDLM, Saddle Mountains Basalt; URPG, upper unit of the Ringold Formation; --, no data]

Well number	Primary geohydro-logic unit	Open interval of well (feet below land surface)		Sampling date	Fluoride (milligrams per liter)
		Top	Bottom		
		Benton County, Wash.			
08N/27E-01G01	WNPM	352	600	02-20-88	1.4
08N/28E-07M01	WNPM	224	440	09-15-88	1.4
09N/27E-08N01	WNPM	618	638	04-19-88	1.0
		Franklin County, Wash.			
09N/29E-02G02D1	SDLM	460	493	04-15-88	1.6
10N/29E-10N01	UPRG	42	45	11-17-88	1.4
10N/29E-10Q02	UPRG	--	168	09-13-88	1.4
11N/29E-05R01	SDLM	575	1,000	09-09-88	4.7
11N/29E-20N01	SDLM	612	667	04-12-88	2.0
		669	936		
11N/29E-23C01	SDLM	330	519	09-10-88	1.0
11N/31E-04P01	WNPM	600	1,310	09-13-88	1.0
14N/28E-15E01	unknown	1.0	9.6	11-06-89	1.0
14N/29E-28A01	UPRG	1.0	43	11-04-89	1.0

PESTICIDES IN GROUND WATER

Some ground-water samples were analyzed for pesticides because of concern that, if nitrate is present in ground water underlying cropland, pesticides also may be present. A total of 29 ground-water samples collected from 24 wells and 4 subsurface field drains (fig. 38) were analyzed for chlorophenoxy acid herbicides, triazine herbicides, carbamate insecticides, organophosphorus insecticides, and a few other types of pesticides (table 11). Many of these pesticides are known to be used in the study area (Sacha and others, 1987), and one or more of the compounds were found in 10 of the 29 samples (table 12).

The pesticide sampling was strictly a reconnaissance effort, and wells where water samples were found to contain pesticides were generally not resampled. Analytical methods are given in Wershaw and others (1987).

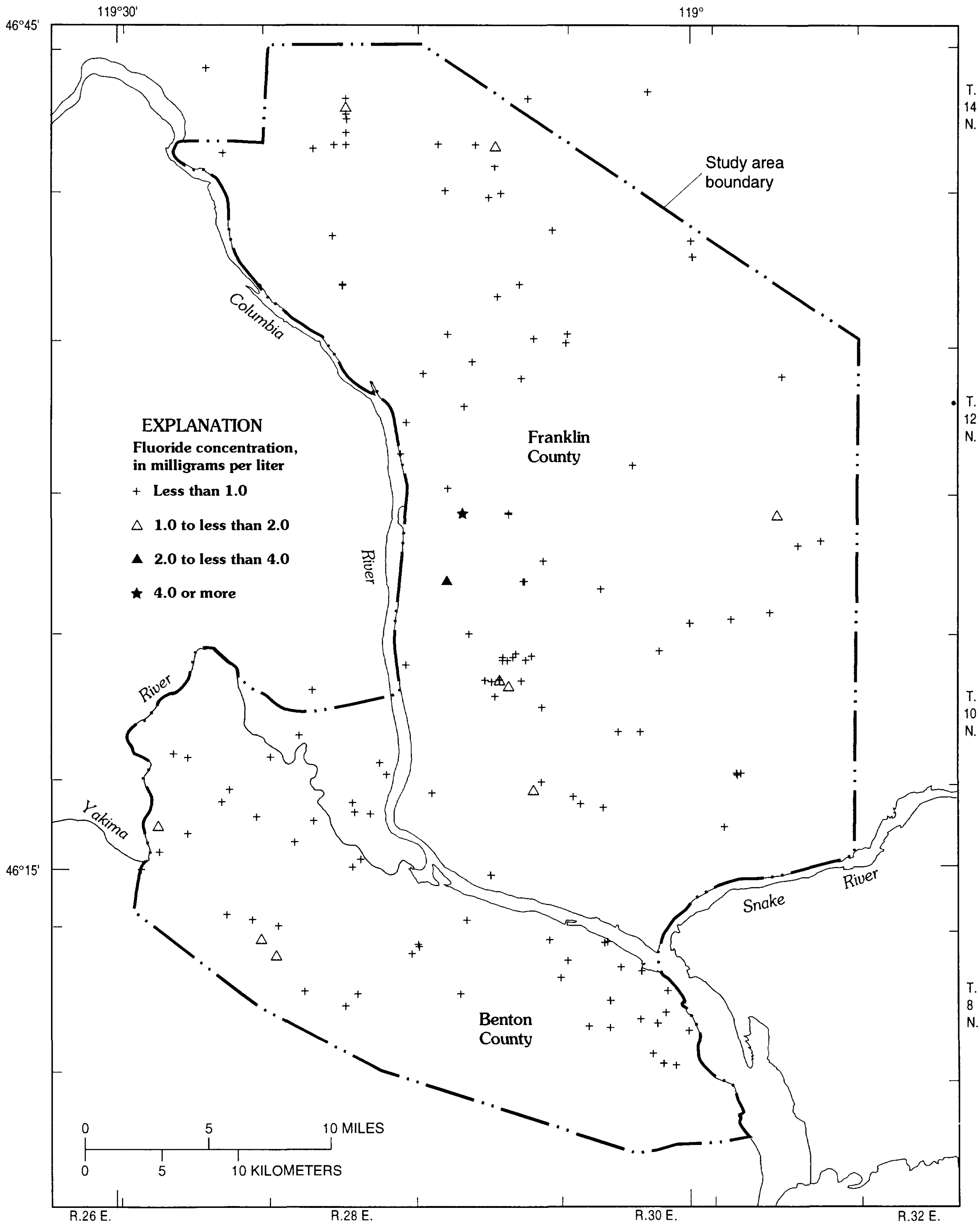


Figure 37.--Fluoride concentrations in ground water.

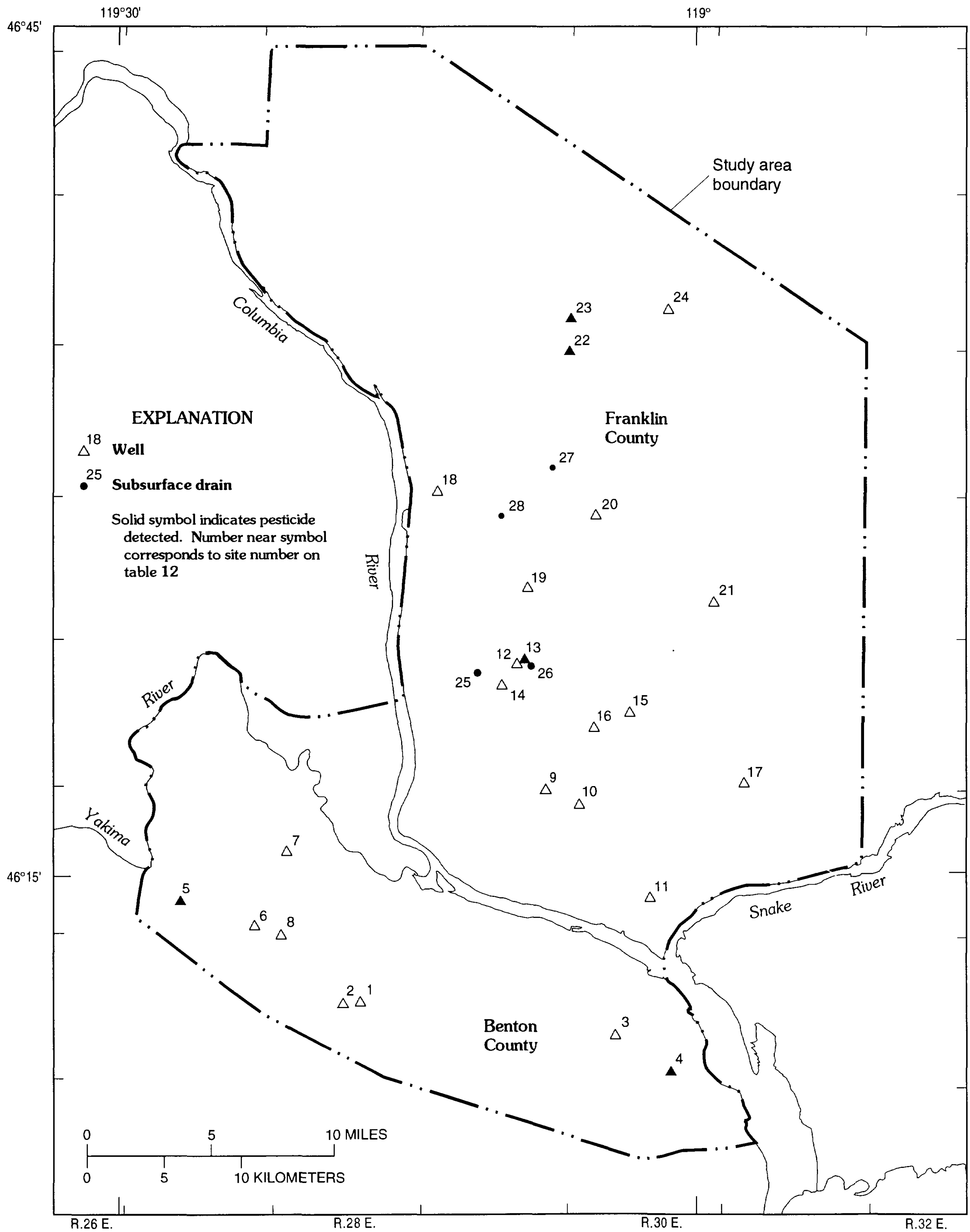


Figure 38.--Ground-water sample sites and sites at which pesticides were detected in ground water.

Table 11.--*Analytical reporting limits, maximum contaminant levels, and health advisory levels for pesticides analyzed for in selected ground-water samples from the study area*

[--, no data]

Pesticide class	Common name	Trade name(s)	Analytical reporting limit (micrograms per liter)	Maximum[1] contaminant level (micrograms per liter)	Health[2] advisory level (micrograms per liter)
Chlorophenoxy acid herbicides	2,4-D	many	0.01	70	70
	2,4-DP	Dichlorprop	.01	--	--
	2,4,5-T	many	.01	--	70
	2,4,5-TP	Silvex	.01	50	50
Triazine herbicides	Ametryne	Evik, Ametrex	.1	--	60
	Atrazine	AAtrex	.1	3	3
	Cyanazine	Bladex	.1	--	10
	Metribuzin	Lexone, Sencor	.1	--	200
	Prometon	Pramitol	.1	--	100
	Prometryne	Caparol	.1	--	--
	Propazine	Milogard	.1	--	10
	Simazine	Princep, Simadex	.1	--	1
	Simetryne	Simetryn	.1	--	--
Other herbicides	Alachlor	Lasso	.1	2	--
	Dicamba	Banvel	.01	--	200
	Metolachlor	Dual	.1	--	100
	Picloram	Tordon	.01	--	500
	Trifluralin	Treflan	.1	--	5
Carbamate insecticides	Aldicarb	Temik	.05	--	1
	Aldicarb sulfone	Standak	.05	--	2
	Aldicarb sulfoxide		.05	--	1
	Carbaryl	Sevin	.05	--	700
	Carbofuran	Furadan	.05	40	40
	3-Hydroxycarbofuran		.05	--	--
	Methomyl	Lannate, Nudrin	.05	--	200
	Oxamyl	Vydate	.05	--	200
	Propham	Chem-Hoe	.05	--	100

Table 11.--*Analytical reporting limits, maximum contaminant levels, and health advisory levels for pesticides analyzed for in selected ground-water samples from the study area--Continued*

Pesticide class	Common name	Trade name(s)	Analytical reporting limit (micrograms per liter)	Maximum[1] contaminant level (micrograms per liter)	Health[2] advisory level (micrograms per liter)
Organophosphorus insecticides	Chlorpyrifos	Dursban, Lorsban	0.01	--	20
	Diazinon	Spectracide	.01	--	0.6
	Disulfoton	Di-Syston	.01	--	.3
	Ethion	Nialate	.01	--	--
	Fonofos	Dyfonate	.01	--	10
	Malathion	Cythion	.01	--	200
	Methylparathion		.01	--	2
	Methyltrithion		.01	--	--
	Parathion	Niran	.01	--	--
	Phorate	Thimet	.01	--	--
	Trithion	Trithion	.01	--	--
Other pesticides	DEF	De-green	.01	--	--
	1-Naphthol		.05	--	--

[1]The maximum contaminant level (U.S. Environmental Protection Agency, written commun., 1991) is the maximum permissible level of a contaminant in water that is delivered to any user of a public water system.

[2]The health advisory level (U.S. Environmental Protection Agency, written commun., 1991) is the suggested maximum concentration in drinking water that produces no adverse health effect with lifetime consumption of the water. It is calculated assuming the average human weighs 155 pounds and consumes 2 quarts of water daily and allowing that 20 percent of the acceptable daily intake is consumed in water. For known or suspected carcinogens, the health advisory level is based on intake rate that increases the risk of cancer by no more than 1 in 1,000,000 with lifetime consumption. Some of the advisories are preliminary.

Table 12.--*Pesticide concentrations in ground-water samples from the study area*

[All wells and subsurface drains from which ground-water samples were collected and analyzed for pesticides are listed. Compounds and their respective concentrations appear only if the compound was found at a concentration above the analytical reporting limit. Site numbers correspond to site numbers on figure 38; S, sediment; B, basalt; --, no concentrations above analytical reporting limits]

Site number	Well number	Type of primary water-bearing unit	Depth of well (feet)	Date of collection	Pesticides detected	Concentration (micrograms per liter)
			Benton County, Wash.			
1	08/28E-15P01	S	108	09-13-88	none	--
2	08/28E-16R01	S	114	05-25-88	none	--
3	08/30E-29A01	B	215	05-25-88	none	--
4	08/30E-35E02	S	50	02-18-88	Atrazine	0.2
				09-09-88	Atrazine	.1
5	09/27E-29J01	S	67	05-25-88	2,4,5-T	.01
6	09/27E-36M01	S	150	09-12-88	none	--
7	09/28E-18L01	B	100	09-10-88	none	--
8	09/28E-31P01D1	S	217	09-13-88	none	--
			Franklin County, Wash.			
			Wells			
9	09/29E-02A01	S	128	05-24-88	none	--
10	09/30E-06L01	S	93	09-07-88	Dicamba	.01
					Picloram	.03
11	09/30E-27F01	S	120	09-07-88	none	--
12	10/29E-03R01	S	95	02-22-88	none	--
13	10/29E-03R02	S	110	09-14-88	Dicamba	.01
14	10/29E-10N03	S	29	09-10-88	none	--
15	10/30E-16P01D1	S	111	09-08-88	none	--
16	10/30E-19J01	S	122	05-24-88	none	--
17	10/31E-32N03	B	295	09-10-88	none	--
18	11/29E-06C01	S	66	09-09-88	none	--
19	11/29E-23N02	S	98	09-09-88	none	--
20	11/30E-05N02	B	80	02-18-88	none	--
21	11/30E-25H01	S	133	09-10-88	none	--
22	12/29E-01A01	B	313	09-12-88	Atrazine	.1
23	13/29E-36A01D1	B	340	05-24-88	Atrazine	.1
					Aldicarb sulfone	.09
24	13/30E-27J01	B	56	02-25-88	none	--
			Subsurface Drains			
25	D16-208D-0+00	S	--	08-25-88	Aldicarb sulfone	.23
					Aldicarb sulfoxide	.21
26	D16-198P1-West	S	--	09-16-88	Dicamba	.01
27	D16-266A-0+00	S	--	08-26-88	Dicamba	.01
28	D15-112P-3471	S	--	09-16-88	Atrazine	.10
					Dicamba	.01
					Metribuzin	1.2

Selection of Sampling Sites

Wells from which water samples were collected for pesticides analysis were located in and downgradient of areas where pesticides are applied. Water from most sampled wells contained nitrate believed to be derived primarily from applied nitrogen fertilizers. Because the nitrate ion is relatively mobile in soil and ground water, its presence was used to indicate where ground water may be vulnerable to the downward leaching of other agricultural chemicals. However, the presence of nitrate in ground water, even at large concentrations, is not necessarily a reliable indicator that pesticides also are present. This is partly because nitrogen fertilizers are typically applied in much larger amounts than pesticides. In addition, many pesticide compounds degrade rapidly, and although the nitrate ion is mobile, many pesticides are not.

Because the wells were not randomly selected, it must not be assumed that the results of this reconnaissance sampling represent the typical domestic ground-water supply in the study area. For example, no wells yielding water containing less than 1 mg/L NO_3-N were sampled for pesticides.

Concentrations of Pesticides in Ground Water

One or more pesticide compounds were found in 10 of the 29 samples (table 12). Four of the 10 sites are subsurface drains, which are 8 to 10 ft below ground surface. All wells (fig. 38) were sampled one time only except site 4, which was sampled twice because the herbicide atrazine was detected in water collected from this well during the first round of pesticide sampling. Atrazine also was found in water from this well when it was resampled.

The pesticides found in ground-water samples (table 12) include the herbicides atrazine, dicamba, metribuzin, picloram, and 2,4,5-T, and aldicarb sulfone and aldicarb sulfoxide, which are degradation products of the insecticide aldicarb. Except for metribuzin, pesticide concentrations, which were at or near the analytical reporting limits, were small. In all instances, the concentrations of pesticides detected were below the health advisory levels (table 11) that are issued by the U.S. Environmental Protection Agency. The health advisory level is the suggested maximum concentration of a compound in drinking water that will produce no adverse health effects with a lifetime consumption of the water (U.S. Environmental Protection Agency, written commun., 1991).

In September 1988, Ecology collected water samples for pesticide and nitrate determinations from 27 wells in Franklin County (Erickson, 1989). The wells were located in a 34-mi^2 area in townships 10 and 11 north, range 29 east. All sampled wells were open to sedimentary units, either the Pasco gravels or the upper Ringold Formation. Five of the sampled wells were shallow observation wells installed by the Bureau of Reclamation. Pesticides were found in water from 10 of the 27 sampled wells. Dacthal (DCPA) was found at concentrations ranging from 0.26 to 1.08 micrograms per liter (μg/L) in water from seven wells; 1,2-dichloropropane was found at concentrations ranging from 0.40 to 0.8 μg/L in water from two wells; and bromacil was found at a concentration of 14.9 μg/L in water from one well. None of these compounds was included in the analyses done during this study.

Water samples from only one well, 10N/29E-03R02 (site 13, table 12), were analyzed for pesticides both by this and the Ecology study. Dicamba was found in the sample collected during this study. No pesticides were found in the Ecology sample, but their reporting limit for dicamba was 0.2 μg/L, compared with 0.01 μg/L for this study.

In evaluating the results of the pesticide sampling, it is helpful to compare them to the results of similar studies conducted elsewhere in the Nation. For example, two of the pesticides detected in ground water have been found, commonly at much larger concentrations, elsewhere. Atrazine, which is a widely used and relatively soluble herbicide, has been found in ground water in several Midwestern States (Cohen and others, 1984); typical concentrations were 0.8 μg/L. However, even larger concentrations have been found. In a study conducted by the U.S. Geological Survey in Kansas (Perry and others, 1988), a concentration of 46 μg/L atrazine was found in ground water sampled from an agricultural area. Aldicarb and its degradation products, aldicarb sulfoxide and aldicarb sulfone, have been found in ground water in numerous locations (Cohen and others, 1984). Concentrations of aldicarb as large as 515 μg/L were found in ground-water samples collected on Long Island, New York (Soren and Stelz, 1984).

MANAGEMENT CONSIDERATIONS

The greatest problems that confront water managers in the study area are shallow ground water that causes water-logged soils and large concentrations of nitrate in the ground water, which is commonly used for domestic water supplies (Drost and others, 1993). The primary causes of shallow ground water are excessive recharge from canal seepage and applied irrigation water. The primary source of nitrates in the ground water is applied nitrogen fertilizers.

Measures have been taken in much of the study area to address the problem of shallow ground water. More than 900 mi of buried drain systems have been installed to maintain the water table below the root zone of crops, and many more miles of drains might be needed to lower water tables in other parts of the study area. However, the installation of drains deals only with the effects and not the causes. Reducing recharge would reduce the area affected by shallow ground water and would reduce the need for drain systems.

The proper timing and amount of irrigation water applied can be modified to effect a significant decrease in recharge to the ground-water system with no loss in agricultural productivity (Franklin Conservation District, 1989). This approach also leads to a decrease in the nitrate load to the ground water.

Recharge from canal seepage can be reduced by lining canals. Most of the irrigation canals in the study area are unlined, and seepage from unlined canals in the study area generally occurs at rates of at least twice (and up to about 60 times) the rate from lined canals.

Some undesirable effects of reducing recharge and lowering water levels include increased pumping lifts and decreased ground-water availability. Throughout much of the study area, domestic water supplies are obtained from shallow wells and in some locations significant amounts of irrigation and industrial water supplies are obtained from the shallow ground-water system. A large reduction in ground-water recharge could lower water levels and therefore adversely affect these water uses.

A very significant undesirable consequence is likely if canal seepage is reduced. The recharge from canal seepage dilutes ground-water nitrate concentrations. Therefore, decreasing canal seepage would result in an increase in nitrate concentrations in the ground water (Ebbert and others, 1991).

A qualitative summary of the effects of various management alternatives on the ground-water system is shown on figure 39.

Expected effects

Management alternative	Water-table altitude		Pumping lifts and drilling depths	Nitrate in ground water	
	Regional (1)	Local (2)		Load (4)	Concentration
Lining all canals	▼	▼	▲	▼	▲
Lining key canals (3)	▼	▼	▲	▼	▲
Increasing irrigation efficiency	▼	▼	▲	▼	▼
Increasing fertilizing efficiency	--	--	--	▼	▼

(1) Regional refers to the entire study area.
(2) Local refers to areas immediately adjacent to where the management practice is applied.
(3) Refers to canals with greatest seepage rates and (or) canals closest to particular areas of concern.
(4) Load is tha total amount of nitrate going into the ground-water system (the quantity of recharge times the concentration).

NOTE: Size of arrow indicates general magnitude of effect, direction indicates decrease (down) or increase (up), Symbol (- -) indicates no effect.

Figure 39.--Expected effects on the ground-water system of selected management alternatives.

SUMMARY

Ground water in a 900-square-mile agricultural area in the Pasco Basin, which includes parts of eastern Benton County and western Franklin County, Washington, was sampled from 1986-89 to determine distributions of nitrate and fluoride. Additional data, including the sampling and analysis of surface water, were obtained to determine sources of nitrate in ground water. Limited sampling was done to determine if pesticides were present in the ground water. The study was conducted in cooperation with the Washington State Department of Ecology, which in turn cooperated with several local agencies.

Nitrate concentrations in ground water in the study area ranged from less than 0.1 to 100 milligrams per liter (mg/L) NO_3-N. In Benton County, the median concentration was 3.2 mg/L NO_3-N, and concentrations in water from about 10 percent of the wells sampled were equal to or greater than the U.S. Environmental Protection Agency Primary Drinking Water Regulation maximum contaminant level of 10 mg/L NO_3-N. In Franklin County, the median concentration was 6.7 mg/L, and concentrations in water from 31 percent of the wells sampled were equal to or greater than 10 mg/L.

In Benton County, nitrate concentrations of 10 mg/L NO_3-N or more were found in the Richland area, the area northeast of Candy and Badger Mountains near Richland, Badger Coulee, and the Finley area, generally in ground water sampled from the uppermost unconsolidated geohydrologic units, which include the Touchet Beds, the Pasco gravels, and the middle Ringold Formation. Concentrations of nitrate in excess of 10 mg/L also were found locally in ground water in the Saddle Mountains Basalt.

Ground water containing more than 10 mg/L NO_3-N was found throughout Franklin County, particularly in the uppermost geohydrologic units. In the deeper water-bearing zones of the Saddle Mountains and Wanapum Basalts nitrate concentrations were generally less than 1 mg/L NO_3-N. Shallow ground water containing less than 1 mg/L nitrate was found at some locations where no nitrate sources were present.

Except for the Finley area, data were not available to evaluate long-term trends of nitrate concentrations in ground water in Benton County. A comparison of data collected during this study with data collected by another investigator during 1976-77 indicated that there has been little, if any, change in concentrations of nitrate in Finley-area ground water.

In Franklin County, nitrate concentrations in ground water at some locations have increased by as much as two orders of magnitude since the early 1950's. In many instances, concentrations of nitrate in ground water underlying cropland increased after the onset of irrigated agriculture. Limited data indicate that nitrate concentrations in the unconfined ground water in the Riverview area, a more populated part of Franklin County located near the city of Pasco, have consistently increased from about 1 mg/L in 1942 to present (1986-88) concentrations, which ranged between 7.5 and 14 mg/L.

The seepage of surface water from irrigation canals and laterals is not a cause of elevated concentrations of nitrate in ground water in the study area. Instead, canal seepage, which contributes about 50 percent of the ground-water recharge in the study area, tends to dilute the nitrate present in ground water. The median concentration of nitrate in samples of canal water was 0.88 mg/L NO_3-N.

Applied nitrogen fertilizers are a major source of nitrate in ground water at many locations in the study area. Nitrate from fertilizers is transported to ground water in recharge from applied irrigation water. Two approaches were used to evaluate the effects of fertilizers as a source of nitrate in ground water underlying irrigated areas. A field study was conducted in Franklin County to determine nitrate concentrations in shallow ground water at locations isolated from other sources of nitrate. These concentrations were then compared with concentrations of nitrate in shallow ground water underlying the entire South Columbia Basin Irrigation District in the Franklin County area. Because the concentration distributions were similar in both sets of samples, fertilizers are likely a source of enough nitrate to account for concentrations found in ground waters of the South Columbia Basin Irrigation District area.

For the second approach, estimated values of nitrogen loading and recharge to the shallow ground water underlying the South Columbia Basin Irrigation District were used to compute nitrate concentrations in ground water as a function of loading. The computations indicate that leaching of about 22 percent of the estimated amount of nitrogen applied and deposited by precipitation could account for the nitrate in the shallow ground water underlying this area. Fertilizers account for 94 percent of the total amount of applied and deposited nitrogen.

In the Finley area of Benton County (a rural residential area), nitrate concentrations in the unconfined ground-water system do not appear to correlate with the numbers of upgradient septic systems. This suggests that septic systems may not be the major source of nitrate in the ground water of this area. However, variations in the isotopic composition of nitrate nitrogen in ground water in the Finley area indicate that septic systems are a probable source of at least some of the nitrate in parts of the unconfined ground-water system.

A simple solute transport model was used to simulate the distribution of nitrate downgradient from septic systems in an idealized ground-water system similar to the unconfined system of the Finley area. Simulation results support observations that indicate septic systems are not the primary source of nitrate in ground water of the area.

In Benton County, it is probable that some of the nitrate in the unconfined ground water underlying Badger Coulee is derived from natural nitrate leached from the fine-grained Touchet Beds. The presence of natural nitrate was established by sampling the Touchet Beds at two undisturbed locations in Badger Coulee and analyzing the sediments for nitrate. The average masses of nitrate nitrogen per unit volume of sediment in the two boreholes in Badger Coulee were equivalent to 2,590 and 964 pounds, respectively, in a block of sediments 50-ft thick underlying an acre of land. The maximum thickness of Touchet Beds in Badger Coulee exceeds 150 ft. It is not known how much of the nitrate presently in ground water underlying Badger Coulee is from natural deposits, because with the introduction of irrigated agriculture, nitrogen fertilizers were applied in this area.

At most other locations in the study area, the amount of natural nitrate presently in ground water is probably small compared with nitrate from anthropogenic sources. This conclusion is based on the results of analyses of undisturbed soils and sediments collected in Franklin and Grant Counties, the evaluation of long-term trends of nitrate concentrations in ground water, and the evaluation of the effects of other nitrate sources. A possible exception is ground water in the Saddle Mountains Basalt along the northeastern slopes of Badger and Candy Mountains in Benton County. Here, observed nitrate concentrations in ground water are large (as much as 52 mg/L NO_3-N) in relation to known anthropogenic sources; however, no data are available to verify the presence of natural nitrate in this location.

Fluoride concentrations in ground water in the study area ranged from less than 0.1 to 4.7 mg/L; the median concentration was 0.5 mg/L. The concentration of fluoride in water from only 2 of 143 wells sampled equalled or exceeded 2.0 mg/L, which is the secondary maximum contaminant level for drinking water. The concentration of 4.7 mg/L in water from one of the two wells exceeded the primary maximum contaminant level for drinking water. Both are deep wells and are open to the Saddle Mountains Basalt in Franklin County. Large concentrations of fluoride in deep ground waters of the Pasco Basin are apparently the result of natural conditions in the deeper basalt aquifers.

One or more pesticide compounds were found in 10 of 29 ground-water samples, which were analyzed for selected chlorophenoxy acid herbicides, triazine herbicides, carbamate insecticides, organophosphorus insecticides, and a few other types of pesticides. The sampling locations did not represent a random distribution, but instead, most were wells open to unconfined, shallow ground water in irrigated areas. The pesticides found include the herbicides atrazine, dicamba, metribuzin, picloram, and 2,4,5-T, and aldicarb sulfone and aldicarb sulfoxide, which are degradation products of the insecticide aldicarb. Except for metribuzin, pesticide concentrations were at or near the analytical reporting limits. In all instances, the concentrations of pesticides detected were below the health advisory levels that are issued by the U.S. Environmental Protection Agency.

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SUPPLEMENTAL INFORMATION

Explanation of Trilinear Diagrams

Trilinear diagrams are used in this report to show the major-ion composition of water. Composition data are useful to help determine sources of recharge to ground water. In basalt aquifers, composition data commonly indicate the length of time the water has been in contact with the basalt. Trilinear diagrams (Hem, 1985) show relative amounts of major ions in water, represented as percentages of total milliequivalents per liter. Percentages usually are shown separately for cations, anions, and a combination of both anions and cations. Zones of the diagrams where various ions, or combinations of ions, are dominant are shown on figure 40. In most natural waters, nitrate is only a small percentage of the total milliequivalents of anions.

Information About Sampling for Nitrate and Characteristics of Nitrate in Hydrologic Systems

All nitrate concentrations are reported in units of milligrams per liter as nitrate nitrogen (NO_3-N). For samples collected during this study, concentrations should properly be reported as nitrite-plus-nitrate because the analytical method used (Fishman and Friedman, 1989) included both species. In most natural waters, nitrite is a short-lived intermediate species produced during the oxidation of ammonia to nitrate, and as such is not usually present in significant quantities. To verify this, 31 ground-water samples, which were collected throughout the study area, were analyzed for nitrite. Nitrite concentrations in all samples were less than the analytical reporting limit of 0.01 mg/L as nitrogen (table 19).

In reporting all nitrate concentrations as NO_3-N, the operational definition of whether the concentration is "total" or "dissolved" is ignored. This designation depends on whether or not a sample was filtered at the time of collection through a membrane filter with pore sizes equivalent to or less than 0.45 micrometer. Filtering, which may have a significant effect on the concentrations of constituents that sorb to sediments, has little or no effect on the concentration of nitrate because it is very soluble in water.

Ground-water samples collected for nitrate analysis prior to January 1, 1988, were unfiltered; after that time, all ground-water samples were filtered immediately after collection. All surface-water samples were filtered immediately after collection. All nitrate samples, both filtered and unfiltered, were treated with mercuric chloride and chilled to inhibit biologically mediated reactions that could alter the concentration of nitrate.

Nitrogen compounds may undergo several transformations during the process of infiltration and percolation to ground water. Nitrogen sources commonly are compounds containing nitrogen in a low-oxidation state. These compounds, referred to as reduced nitrogen species, include organic nitrogen compounds and ammonia. Oxidation of these reduced species to nitrate occurs in the presence of oxygen and the required bacteria, which utilize the energy released during the reactions (fig. 41). The oxidation (or nitrification) of ammonia in water percolating through the unsaturated zone is generally complete if oxygen is present. Alhajjar (1985) found that ammonia was rapidly and almost completely converted to nitrate in the unsaturated zone beneath septic tank drainfields. He also found that much of the organic nitrogen present in septage was converted to ammonia, which in turn was oxidized to nitrate. An exception was observed in a waterlogged drainfield where lack of oxygen prevented the nitrification of ammonia.

Under anaerobic conditions (the lack of oxygen), nitrate may undergo denitrification to nitrogen gas or nitrous oxide, or it may be reduced to ammonia. Denitrification is believed to occur more readily than reduction except in organic-rich soils (Reddy and others, 1980). In denitrification, the bacteria usually responsible for the biological reduction are heterotrophic and require organic carbon as an energy source. It is entirely possible that nitrate introduced or formed in the upper soil zones may undergo denitrification in deeper zones where oxygen is not present and organic carbon is available.

Once infiltrating water has reached the water table, some of the same transformations that occur in the unsaturated zone may occur. Small concentrations of ammonia in ground water in the study area indicate that inorganic nitrogen is present primarily as nitrate. The median concentration of ammonia in 294 ground-water samples was less than the minimum reporting level of 0.01 mg/L, NH_3-N (ammonia as nitrogen), and the largest observed concentration was 0.3 mg/L NH_3-N (see table 13). Nitrate in ground water is relatively stable in the presence of oxygen.

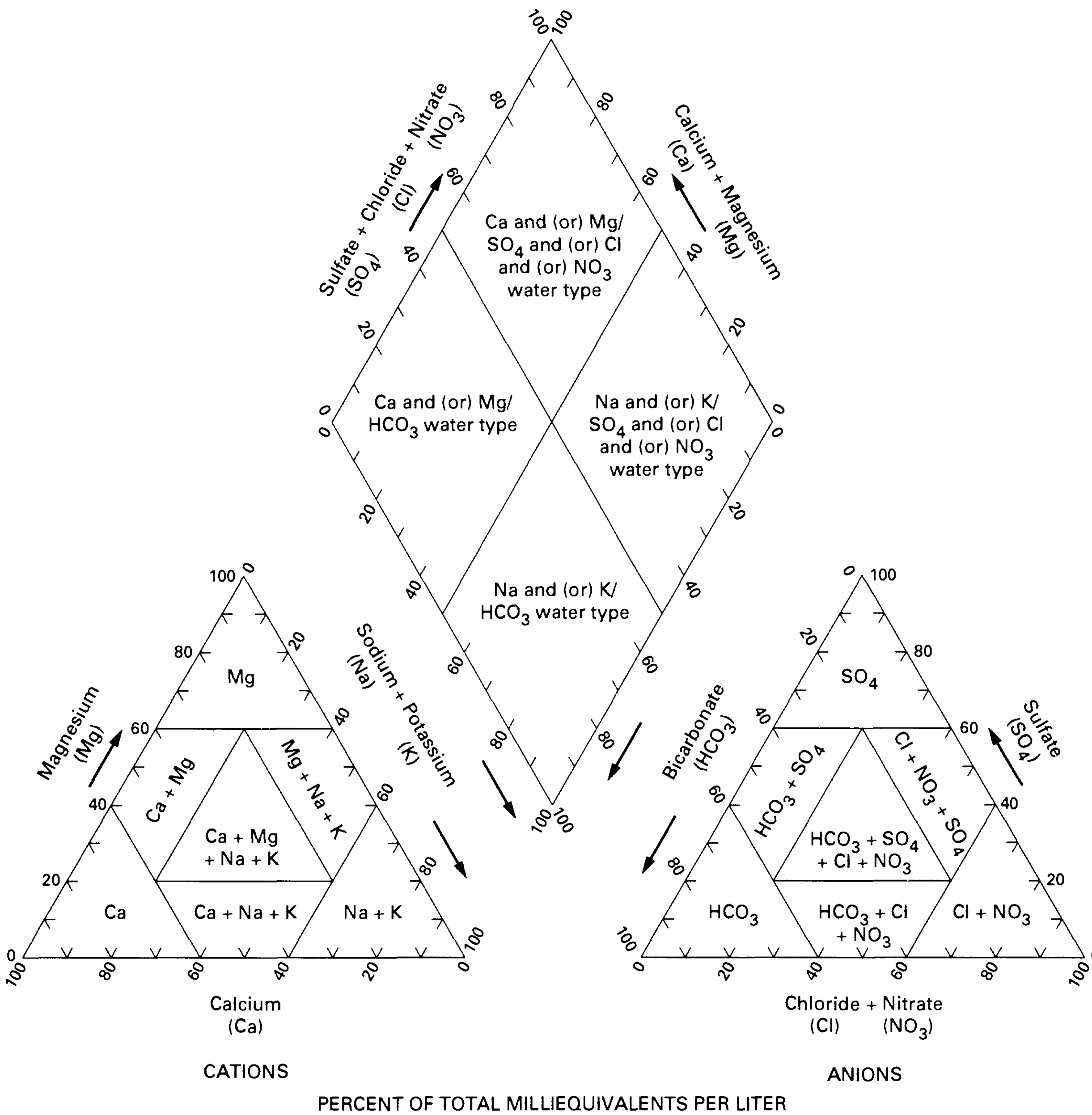

Figure 40.--Zones of different water types on trilinear diagrams (modified from Hem, 1985).

I. MINERALIZATION

A. AMMONIFICATION

$$\text{ORGANIC NITROGEN} \longrightarrow \underset{NH_4^+}{\text{AMMONIUM}}$$

B. NITRIFICATION

$$\underset{NH_4^+ + \,^3/_2\, O_2}{\text{AMMONIUM}} \xrightarrow[\text{bacteria}]{\text{Nitrosomonas}} \underset{2H^+ + H_2O + NO_2^-}{\text{NITRITE}}$$

$$\underset{NO_2^- + \,^1/_2\, O_2}{\text{NITRITE}} \xrightarrow[\text{bacteria}]{\text{Nitrobacter}} \underset{NO_3^-}{\text{NITRATE}}$$

II. DENITRIFICATION

$$\underset{NO_3^- + \,^5/_4\, (HCHO)}{\text{NITRATE CARBOHYDRATE}} \xrightarrow[\text{conditions}]{\text{Anaerobic}} \underset{^1/_2\, N_2 + \,^3/_4\, H_2O + \,^5/_4\, CO_2 + OH^-}{\text{NITROGEN GAS}}$$

OR

$$\underset{NO_3^- + HCHO}{\text{NITRATE CARBOHYDRATE}} \xrightarrow[\text{conditions}]{\text{Anaerobic}} \underset{^1/_2\, N_2O + \,^1/_2\, H_2O + CO_2 + OH^-}{\text{NITROUS OXIDE GAS}}$$

Figure 41.--Transformation reactions that can alter the concentration of nitrate in hydrologic systems (from Edelmann and Cain, 1985).

Justification of a Correction Applied to Nitrate Data Reported in a Previous Study of Finley-Area Ground Water

Nitrate concentrations in 100 samples of ground water in the Finley area that were collected by Wood (1977) and reported in units of nitrate as nitrate (NO_3-NO_3) are actually in units of nitrate as nitrogen (NO_3-N). This error was first suspected when it was noted that the median nitrate concentration in samples collected during this study was larger than the median nitrate concentration in Wood's samples by a factor of about 4.2. This is approximately equal to the factor of 4.43, which is obtained by dividing a nitrate concentration expressed in units of nitrate (NO_3-NO_3) by the concentration expressed as elemental nitrogen (NO_3-N).

Had the median nitrate concentration increased by a factor of 4.2 over the period between the two studies, then specific conductance values also should have increased, because there is some correlation (r-square of 0.33) between the two variables. Although this degree of correlation is small, the confidence at which one can reject the hypothesis that the variables are uncorrelated exceeds 99 percent. Specific conductance values did not, in fact, increase over the period between the two studies. This is shown on figure 42, where deciles of nitrate concentrations are plotted as a function of deciles of specific conductance values for data collected during this study; Wood's data as reported (NO_3-NO_3), but converted to NO_3-N; and for Wood's data assuming the correct reporting unit is NO_3-N. It is reasonable to assume that the relation between specific conductance values and nitrate concentrations in Finley-area ground water did not change significantly over time between the two studies. If Wood's nitrate concentrations were correctly reported, then a major change in this relation has occurred. However, if it is assumed that the correct reporting unit for his nitrate concentrations is really NO_3-N, the relation between specific conductance values and nitrate concentrations for the 1977 data is similar to that obtained during this study. It is therefore assumed that the nitrate concentrations reported by Wood are in units of NO_3-N.

Stable Isotopes

Stable-isotope concentrations of oxygen, hydrogen, and nitrogen are generally expressed in delta units (δ) given in per mil (0/00) or parts per thousand (Gat, 1980). These units represent relative deviations in the heavy isotope fraction in water and are defined as

$$\delta = \frac{R_{sample} - R_{standard}}{R_{standard}} \times 1,000 \quad , \qquad (1)$$

where:

R_{sample} = ratio of isotopic concentration $\left({}^{18}O/{}^{16}O,\ D/H,\ {}^{15}N/{}^{14}N\right)$ of the sample, and

$R_{standard}$ = ratio of isotopic concentration of the standard SMOW (standard mean ocean water) for oxygen and hydrogen, and the standard of atmospheric nitrogen for nitrogen.

The ratios of the stable-isotope concentrations of oxygen and hydrogen in vapor derived from seawater, the source of most precipitation, are constant. As this vapor condenses, the heavier isotopes are removed in a greater proportion than the lighter isotopes. This process, known as isotopic fractionation, results in isotopically enriched precipitation and a depleted vapor mass. Isotope fractionation is also temperature dependent, and the combination of the two effects causes areal distributions in the isotopic composition of precipitation that are related to topography as well as proximity to the ocean. Oxygen-18 and deuterium in precipitation are linearly correlated, and local linear relations, referred to as local meteoric water lines, vary little in slope from the local average or the global meteoric water line. Biological processes, evaporation, freezing, and melting also contribute to isotopic fractionation. In particular, the partial evaporation of water causes the ratio of deuterium to oxygen-18 to be lower than for precipitation, resulting in departure from the meteoric water line along an evaporative trend line.

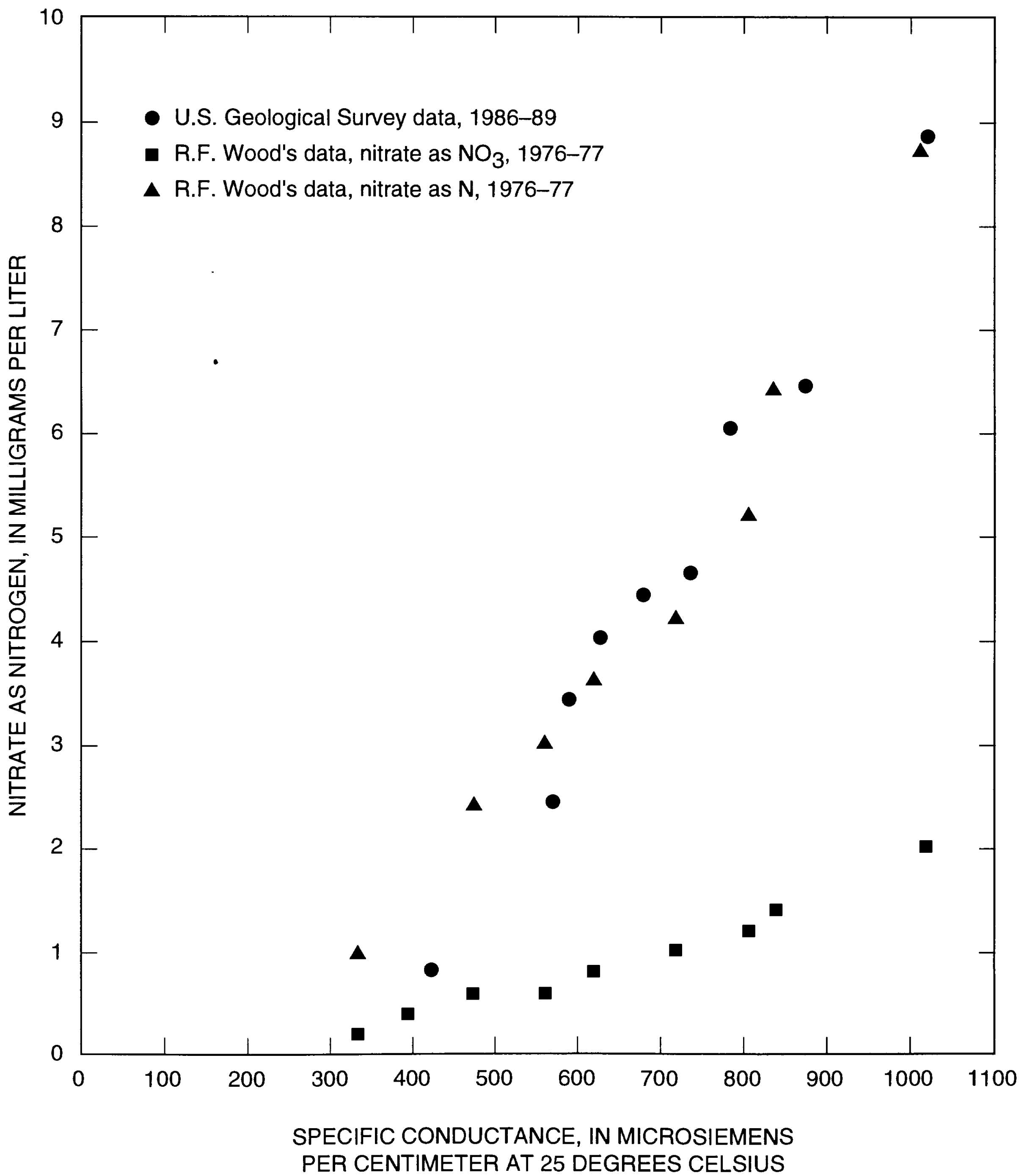

Figure 42.--Quantile-quantile plot of nitrate concentrations as a function of specific conductance values for ground water in the Finley area, Benton County, Washington.

Two naturally occurring stable isotopes of nitrogen are known: ^{14}N and ^{15}N. The ^{15}N atom, which is the heavier of the two isotopes, makes up only about 0.4 percent of the nitrogen in the earth's atmosphere. Although the isotopic composition of the nitrogen in the earth's atmosphere is relatively constant, the isotopic composition of nitrogen in other compounds is variable and is often different from that of the atmosphere. The variability in the isotopic composition of the nitrogen in the nitrate sometimes makes it possible to infer the source of nitrate in ground water.

The isotopic composition of nitrogen in ground water is governed by the isotopic composition of the source material(s) and the effects of chemical, biological, and physical processes that may alter the isotopic composition of the source material. The effects of many of the individual processes that alter the isotopic composition of source materials are known, but net effects are difficult to quantify in a field setting where multiple processes are likely to occur. For this reason, the use of nitrogen isotope ratios to infer sources of nitrate in ground water is most suitable in settings where few, if any, chemical, physical, or biological processes occur to alter the isotopic composition of the source material. Most suitable are locations like much of the Finley area where the unsaturated zone is relatively permeable and the water table is near land surface.

The approximate $\delta^{15}N$ values for nitrogen from various sources (Kreitler and Jones, 1975; Spalding and others, 1982) are:

Source	$\delta^{15}N$, in parts per thousand
Septic system effluent	$\geq$10 or greater
Farm animal waste	10 to 20
Inorganic fertilizers	-8 to 6
Natural soils	2 to 8

In general, the nitrogen from septic systems and animal waste is isotopically heavier than the nitrogen from inorganic fertilizers and natural soils. In the Finley area, where there are not large populations of farm animals, one would expect to find the isotopically heavier nitrate nitrogen in ground-water samples collected downgradient from septic systems. If the nitrate were derived predominately from septic systems, the $\delta^{15}N$ values should be equal to or greater than 10 parts per thousand, assuming that the nitrogen is not isotopically fractionated after being discharged from the septic systems.

Description of the Transport Model Used to Simulate Nitrate Concentrations in Ground Water Downgradient From Septic Systems

The distribution of nitrate in ground water downgradient from a septic system that is the only source of the nitrate is governed by (1) the rate at which nitrate, or nitrogenous compounds that are later converted to nitrate, enter the ground water; (2) the ground-water flow velocity (advection); (3) the vertical and lateral mixing of nitrate in ground water by molecular diffusion, hydrodynamic dispersion, and other mechanisms such as fluctuations in the elevation of the water table; (4) dilution of the nitrate by recharge with water containing little or no nitrate; and (5) chemical or biological processes that may remove nitrate from the ground water. Combined, these processes affect the distribution of nitrate in ways that are difficult to predict or simulate; however, concentrations of nitrate in ground water downgradient from septic systems can be approximated using a simple transport model if the following assumptions are made:

1. Nitrate from a septic system enters the ground water at the water table at a uniform rate along a line source that is perpendicular to the ground-water flow direction;

2. Ground water flow is in the horizontal direction and is uniform and steady (does not vary in space and time);

3. The aquifer material is homogenous;

4. Mixing is due only to hydrodynamic dispersion resulting from velocity differences caused by microscopic and macroscopic variations in the porous media;

5. Transport by mixing in the longitudinal direction is small compared with transport by advection in this direction;

6. The distribution of nitrate in ground water is steady (does not change with time); and

7. Nitrate is conservative (does not react) once it has entered the ground water.

In summary, these conditions describe a system where nitrate from a septic-system drainfield enters the ground water at a uniform rate at the water table and is transported downgradient in an unchanging flow field moving through homogeneous porous media. The dispersion of the nitrate is due to hydrodynamic dispersion, the amount of which is a function of the velocity of flow and the properties of the porous media; and the configuration of the nitrate plume does not change with time.

Incorporating the above conditions, the concentration of nitrate (or any conservative solute) downgradient from a given source, as depicted schematically on figure 43, can be approximated by the Gaussian distribution

$$C_i = \frac{S_i}{q\pi\sigma_y\,\sigma_z} \exp\left(\frac{-(y-y_1)^2}{2\sigma_y^2} - \frac{z^2}{2\sigma_z^2}\right) , \qquad (2)$$

where the variances of the concentration distributions in the y- and z- directions are

$$\sigma_y^2 = \frac{w_i^2}{12} + 2\,(x-x_i)\,\alpha_y , \qquad (3)$$

and

$$\sigma_z^2 = 2\,(x-x_i)\,\alpha_z , \qquad (4)$$

respectively. In equations 3 through 5,

C_i = the concentration $\left(M/L^3\right)$ of nitrate in ground water at coordinates x, y, and z due to input from the ith source;

S_i = the nitrate loading rate (M/T) of the ith source;

w_i = the width (L) of the ith source;

q = the ground-water discharge per unit cross-sectional area, which is called the specific discharge or the Darcian velocity L/T;

x = the longitudinal coordinate (L) where C_i is determined; x is paralled to the flow velocity;

x_i = the x coordinate (L) of the ith source;

y = the lateral coordinate (L) where C_i is determined; y is horizontal and perpendicular to x;

y_i = the y coordinate (L) of the ith source;

z = the vertical coordinate (L) , where C_i is determined, z is positive in the downward direction and is zero at the water table;

α_y = the lateral dispersivity (L) of the porous media, which is defined as the lateral dispersion coefficient divided by the specific discharge, and

a_z = the vertical dispersivity (L) of the porous media, which is defined as the vertical dispersion coefficient divided by the specific discharge.

If more than one source (septic system) is present, then the nitrate concentration (C) in ground water at a downgradient location is the sum of concentrations contributed from the individual source, or

$$C = \sum_{i=i}^{n} C_i , \qquad (5)$$

where n is equal to the number of individual sources.

Equations 3 through 5 can be derived from the fundamental solution to the advection-diffusion equation and properties of the concentration distributions (see, for example, Fischer and others, 1979, p. 38-54). Implicit in equation 2 is the assumption that the concentration distributions are Gaussian regardless of the distribution near the source.

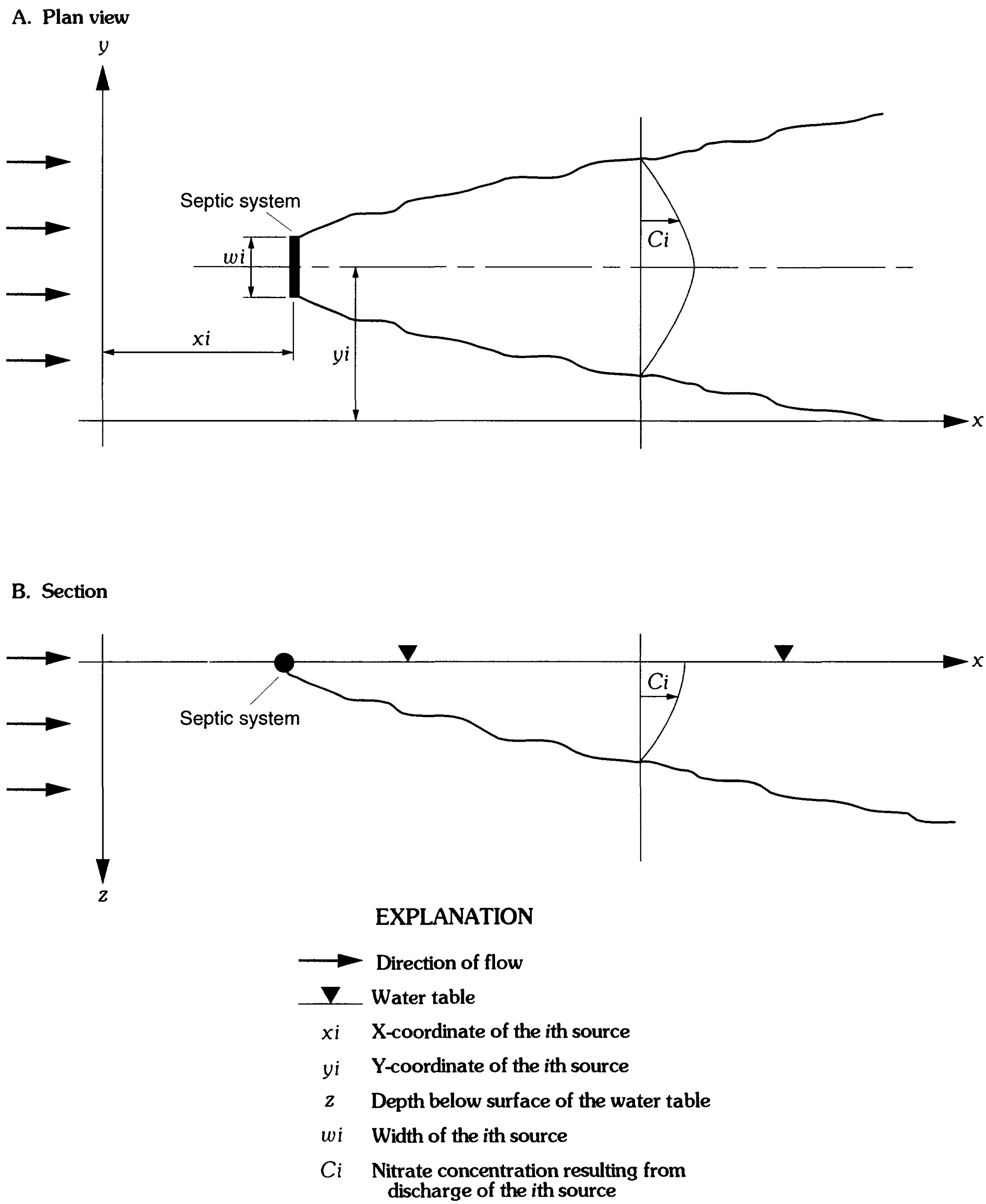

Figure 43.--Schematic representation of the simulated dispersion of nitrate in ground water downgradient from a septic system.

Background Information About Natural Nitrate

After World War I, the Ordnance Department of the U.S. Army called upon the U.S. Geological Survey to investigate the occurrence of domestic nitrate deposits. Nitrate was essential for the production of munitions, and shipments of saltpeter (potassium or sodium nitrate) from Chile had been greatly reduced during the war. For the Army, the results of the investigation (Mansfield and Boardman, 1932) were disappointing, because deposits large enough for commercial exploitation had not been located. The report did, however, serve to document the presence of nitrate salts associated with cave, caliche, and playa deposits at various locations in the United States. Caliche deposits are common in soils and sediments of semiarid areas like the Pasco Basin. Subsequently, other investigators also have found natural nitrate salts in soils, sediments, and rocks, and some studies have reportedly linked nitrate in ground water to the leaching of these salts.

Boyce and others (1976) found natural nitrate in Pleistocene loess covering an area of about 9,600 mi^2 in southwestern and central Nebraska. Loess samples collected from 65 boreholes drilled in that area were analyzed for nitrate, and large concentrations were found between 20 and 100 ft below land surface. Within this zone, nitrate concentrations were typically 25 to 45 mg/kg; the largest concentration observed was 87 mg/kg NO_3-N. Using nitrate concentrations in samples collected from the two deepest boreholes (about 100 ft deep), the investigators calculated that masses of NO_3-N per acre were 5,500 and 11,300 lb.

Large nitrate concentrations in extracts of soil samples (Dyer 1965) and in water samples from tile-drain systems (Letey and others, 1977) collected on the west side of the San Joaquin Valley, Calif., were attributed to natural nitrate salts. The presence of nitrate, at concentrations as large as 4,800 mg/kg NO_3-N in sedimentary rocks in this area, was confirmed by Strathouse and others (1980). They concluded that sedimentary rocks were a source of nitrate to the alluvial soils sampled by Dyer (1965) and in the waters sampled by Letey and others (1977).

Although there are no reported deposits of nitrate in Washington State, it was suggested by Fretwell (1979) that large concentrations of nitrate in ground water underlying the Toppenish and Satus Creek basins may be partly a result of the leaching of natural nitrate salts. In both basins, large nitrate concentrations in ground water occur predominantly where the overlying soils and sediments are composed of silt and clay-like deposits. These deposits are known locally as the Touchet Beds. In the Satus Creek basin where the Touchet Beds are several tens of feet thick, observed concentrations of nitrate in ground water were as large as 170 mg/L NO_3-N. Fretwell (1979) speculated that the presence of fine-grained material may have attenuated the downward percolation of precipitation, allowing salts containing nitrate to accumulate over time. With the introduction of irrigation, recharge increased and the salts were flushed from the soils and sediments into the ground water.

Numerous mechanisms have been proposed to explain the formation and distribution of natural nitrate salts. An element that is common to most theories is the oxidation, or nitrification, of reduced nitrogen compounds to nitrate. Sources of reduced nitrogen compounds are thought to include plant and animal matter, subsurface nitrogen gases expelled during volcanic eruptions, volcanic ash, and nitrogen and ammonia in the atmosphere. The nitrification of reduced nitrogen compounds derived from plant and animal matter is probably the source of most natural nitrate salts (Mansfield and Boardman, 1932).

Because nitrate compounds are soluble in water, their distribution in soils and sediments is affected by climate and exposure. Nitrate salts are commonly associated with caliche deposits, which are the rock-like deposits formed by the accumulation of various salts, principally calcium carbonate, deposited by the evaporation of soil water or shallow ground water. Caliche deposits commonly overlie clays, which by retarding the downward seepage of moisture, serve to localize the deposits above the clay layer. Nitrate formed near the land surface by the nitrification of plant or animal material eventually is leached downward and deposited with caliche. These deposits will continue to accumulate until something causes an increase in the quantity of deep percolation water. Accumulated salts then may be dissolved and transported to the ground water.

Table 13.--*Concentrations of nitrate, ammonia, chloride, and dissolved oxygen and values of specific conductance, pH, and temperature in ground water in the eastern part of Pasco Basin, Washington*

[If no geohydrologic unit is designated, the primary contributing unit is unknown; if top and bottom of the open interval are equal, the well is open ended; mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; SDLM, Saddle Mountains Basalt; PSCO, Pasco gravels of the Hanford formation; WNPM, Wanapum Basalt; ELBG, Ellensburg Formation; TCHT, Touchet Beds of the Hanford formation; MBTN, Mabton Member of Ellensburg Formation; CRBG, Columbia River Basalt Group; ALVM, Alluvium of Pleistocene and Holocene age; MDRG, middle unit of the Ringold Formation; LRRG, lower unit of the Ringold Formation; RGLD, undifferentiated Ringold Formation; UPRG, upper unit of the Ringold Formation; DUNE, dunes of Pleistocene and Holocene age; GDRD, Grande Ronde Basalt; --, no data; <, less than]

Table 13.--*Concentrations of nitrate, ammonia, chloride, and dissolved oxygen and values of specific conductance, pH, and temperature in ground water in the eastern part of Pasco Basin, Washington--Continued*

Well number	Latitude	Longitude	Primary geohydrologic unit	Well depth (feet)	Open intervals of well (feet below land surface) Top	Open intervals of well (feet below land surface) Bottom	Sampling date	Specific conductance (µS/cm)	pH (units)	Temperature (degrees Celsius)	Dissolved oxygen (mg/L)	Nitrate as nitrogen (mg/L)	Ammonia as nitrogen (mg/L)	Chloride (mg/L)
							Benton County, Wash.							
07N/30E-01Q02	460637	1185956	SDLM	175	175	175	09-08-86	620	--	--	--	3.0	--	--
							02-19-88	580	8.0	14.5	2.0	2.1	0.01	29
07N/31E-06N01	460641	1185920	SDLM	250	25	250	09-08-86	575	--	--	--	2.3	--	--
							02-26-87	781	--	--	--	4.7	--	--
07N/31E-07D01	460628	1185922	SDLM	220	122	220	09-11-86	550	--	--	--	1.7	--	--
08N/27E-01A01D1	461245	1192215	SDLM	155	143	155	08-27-82	574	7.9	22.5	7.0	11	--	22
							03-08-83	550	7.8	10.5	--	7.9	--	21
							07-22-83	595	7.8	18.0	10	11	--	22
08N/27E-01A03	461243	1192212	PSCO	140	140	140	09-02-86	960	--	--	--	9.5	--	--
08N/27E-01B01	461244	1192235	PSCO	160	160	160	09-02-86	762	--	--	--	12	--	--
							02-25-87	715	--	--	--	16	--	--
							02-17-88	690	7.8	15.5	7.8	14	<.01	23
08N/27E-01G01	461227	1192238	WNPM	600	352	600	02-20-88	382	8.5	18.5	--	<.10	<.01	13
08N/27E-01K01	461216	1192235	WNPM	510	360	510	08-27-82	464	7.9	19.0	8.1	.33	--	7.0
							09-03-86	373	--	--	--	<.10	--	--
08N/27E-01R02	461209	1192214	WNPM	--	--	--	09-03-86	805	--	--	--	<.10	--	--
08N/28E-01R01	461213	1191433	PSCO	74	74	74	09-05-86	570	--	--	--	5.3	--	--
							02-19-88	591	7.9	15.0	8.3	5.1	<.01	28
08N/28E-01R03	461208	1191430	SDLM	180	140	180	09-05-86	1,410	--	--	--	.10	--	--
							02-17-88	1,220	7.5	15.5	0.4	<.10	.03	29
08N/28E-03P01	461211	1191750	WNPM	633	206	415	09-05-86	460	--	--	--	<.10	--	--
					626	633								

Table 13.--*Concentrations of nitrate, ammonia, chloride, and dissolved oxygen and values of specific conductance, pH, and temperature in ground water in the eastern part of Pasco Basin, Washington--Continued*

Well number	Latitude	Longitude	Primary geohydrologic unit	Well depth (feet)	Open intervals of well (feet below land surface) Top	Bottom	Sampling date	Specific conductance (µS/cm)	pH (units)	Temperature (degrees Celsius)	Dissolved oxygen (mg/L)	Nitrate as nitrogen (mg/L)	Ammonia as nitrogen (mg/L)	Chloride (mg/L)
							Benton County, Wash.--Continued							
08N/28E-06D01	461244	1192150	PSCO	193	193	193	09-03-86	701	--	--	--	16	--	--
08N/28E-06G01	461230	1192110	ELBG	332	282	322	09-23-71	487	7.6	18.0	--	8.6	--	15
08N/28E-07B01D2	461205	1192125	PSCO	220	--	--	09-03-86	564	--	--	--	3.6	--	--
08N/28E-07D01	461156	1192148	SDLM	260	70	260	09-03-86	403	--	--	--	2.8	--	--
08N/28E-07M01	461138	1192148	WNPM	440	224	440	09-15-88	393	8.1	20.5	0.4	<.10	<0.01	13
08N/28E-07P01	461127	1192137	WNPM	435	200	435	08-27-82	579	8.1	20.5	--	<.10	--	15
08N/28E-11Q01	461114	1191618	SDLM	120	109	115	09-16-86	357	--	--	--	1.6	--	--
					120	120								
08N/28E-11R01	461118	1191603	SDLM	320	28	320	09-04-86	408	--	--	--	.30	--	--
							02-17-88	425	8.2	14.0	0.4	<.10	.01	9.9
							09-12-88	402	7.8	17.5	0.4	<.10	.02	9.6
08N/28E-12B02	461153	1191452	SDLM	105	105	105	09-04-86	441	--	--	--	1.5	--	--
							09-12-88	452	7.8	16.5	6.1	1.5	<.01	11
08N/28E-12C03	461155	1191523	PSCO	118	118	118	09-04-86	680	--	--	--	5.0	--	--
08N/28E-14C02	461102	1191626	PSCO	140	131	140	09-04-86	510	--	--	--	3.0	--	--
							03-04-87	509	--	--	--	3.0	--	--
							02-20-88	502	7.7	16.0	10.2	2.8	<.01	13
08N/28E-14L01	461037	1191641	SDLM	190	190	190	09-05-86	505	--	--	--	2.5	--	--

Table 13.--*Concentrations of nitrate, ammonia, chloride, and dissolved oxygen and values of specific conductance, pH, and temperature in ground water in the eastern part of Pasco Basin, Washington--Continued*

Well number	Lati-tude	Longi-tude	Primary geo-hydro-logic unit	Well depth (feet)	Open intervals of well (feet below land surface) Top	Bottom	Sampling date	Spe-cific con-duc-(µS/cm)	pH (units)	Tempe-rature (degrees Celsius)	Dis-solved oxy-gen (mg/L)	Nitrate as nitrogen (mg/L)	Am-monia as nitrogen (mg/L)	Chlo-ride (mg/L)
						Benton County, Wash.--Continued								
08N/28E-15P01	461027	1191741	PSCO	108	103	108	09-16-86	860	--	--	--	17	--	--
							11-21-86	--	--	--	--	10	--	--
							12-10-86	--	--	--	--	9.4	--	--
							01-13-87	--	--	--	--	9.0	--	--
							02-03-87	--	--	--	--	9.2	--	--
							02-24-87	815	--	--	--	9.4	--	--
							05-06-87	--	--	--	--	13	--	--
							07-01-87	--	--	--	--	16	--	--
							09-15-87	--	--	--	--	14	--	--
							02-19-88	1,030	7.8	14.0	6.0	7.6	<0.01	67
							09-13-88	996	7.8	16.5	7.7	10	<.01	67
08N/28E-16L01	461035	1191858	PSCO	60	60	60	09-04-86	724	--	--	--	11	--	--
08N/28E-16R01	461022	1191827	PSCO	114	104	114	09-04-86	965	--	--	--	29	--	--
							02-24-87	824	--	--	--	20	--	--
							02-17-88	932	8.3	14.5	8.3	26	<.01	71
08N/28E-17D01	461108	1192035		200	--	--	09-15-88	340	7.9	19.5	5.9	1.5	<.01	6.8
08N/28E-17P01	461034	1192024	TCHT	67	--	--	09-11-88	1,190	7.5	15.0	--	25	<.01	8.8
08N/28E-21A01	461019	1191819	PSCO	120	120	120	09-04-86	895	--	--	--	15	--	--
							11-21-86	--	--	--	--	8.8	--	--
							12-1-986	--	--	--	--	8.1	--	--
							01-13-87	--	--	--	--	7.4	--	--
							02-03-87	--	--	--	--	7.9	--	--
							05-06-87	--	--	--	--	17	--	--
							07-01-87	--	--	--	--	16	--	--
							09-15-87	--	--	--	--	14	--	--
08N/28E-21H01	461002	1191818	PSCO	125	125	125	09-04-86	349	--	--	--	1.4	--	--
							02-24-87	402	--	--	--	1.4	--	--
							02-17-88	380	8.0	14.5	6.4	1.2	<.01	7.0

Table 13.--*Concentrations of nitrate, ammonia, chloride, and dissolved oxygen and values of specific conductance, pH, and temperature in ground water in the eastern part of Pasco Basin, Washington--Continued*

Well number	Lati-tude	Longi-tude	Primary geo-hydro-logic unit	Well depth (feet)	Open intervals of well (feet below land surface): Top	Open intervals of well (feet below land surface): Bottom	Sampling date	Spe-cific con-duc-(µS/cm)	pH (units)	Tempe-rature (degrees Celsius)	Dis-solved oxy-gen (mg/L)	Nitrate as nitrogen (mg/L)	Am-monia as nitrogen (mg/L)	Chlo-ride (mg/L)
							Benton County, Wash.--Continued							
08N/28E-22D01	461018	1191817	PSCO	126	126	126	09-04-86	815	--	--	--	8.1	--	--
08N/28E-23C01	461009	1191625	MBTN	820	740	820	09-05-86	482	--	--	--	1.0	--	--
08N/29E-01F02	461221	1190745	PSCO	93	76	88	09-03-86	755	--	--	--	5.9	--	--
					93	93	04-11-88	770	7.5	21.0	6.4	5.9	<0.01	32
08N/29E-05D01	461235	1191301	PSCO	90	85	90	09-04-86	795	--	--	--	7.7	--	--
08N/29E-07B01	461152	1191349	PSCO	154	154	154	09-02-86	570	--	--	--	8.2	--	--
							02-25-87	519	--	--	--	5.6	--	--
							02-17-88	532	8.0	16.0	6.8	5.0	.02	21
08N/29E-10C01	461150	1191012	PSCO	90	85	90	09-03-86	703	--	--	--	5.8	--	--
							02-26-87	618	--	--	--	4.8	--	--
							09-12-88	634	7.6	15.5	6.6	4.5	<.01	17
08N/29E-12B01	461142	1190732	SDLM	64	52.6	64	09-03-86	838	--	--	--	7.9	--	--
							04-11-88	820	7.4	16.0	6.4	7.6	<.01	30
08N/29E-12G01	461135	1190720	PSCO	61	61	61	09-03-86	855	--	--	--	5.0	--	--
08N/29E-12H01	461139	1190704	SDLM	125	58	62	09-04-86	625	--	--	--	1.7	--	--
					62	125	04-13-88	600	7.7	16.5	0.8	.62	.03	23
08N/29E-13A01	461101	1190711	SDLM	160	75	160	09-11-86	345	--	--	--	<.10	--	--
							12-16-86	--	--	--	--	<.10	--	--
							01-15-87	--	--	--	--	<.10	--	--
							02-05-87	--	--	--	--	<.10	--	--
							02-26-87	342	--	--	--	<.10	--	--
							05-07-87	--	--	--	--	<.10	--	--
							07-01-87	--	--	--	--	<.10	--	--
							02-17-88	338	8.4	16.0	<0.2	<.10	.03	8.9

Table 13.--*Concentrations of nitrate, ammonia, chloride, and dissolved oxygen and values of specific conductance, pH, and temperature in ground water in the eastern part of Pasco Basin, Washington--Continued*

Well number	Latitude	Longitude	Primary geohydrologic unit	Well depth (feet)	Open intervals of well (feet below land surface) Top	Bottom	Sampling date	Specific conductance (µS/cm)	pH (units)	Temperature (degrees Celsius)	Dissolved oxygen (mg/L)	Nitrate as nitrogen (mg/L)	Ammonia as nitrogen (mg/L)	Chloride (mg/L)
							Benton County, Wash.--Continued							
08N/29E-17G01D1	461043	1191237	SDLM	430	25.75	430	08-28-82	570	7.5	19.5	--	3.6	--	27
							03-09-83	495	7.7	19.0	5.8	3.7	--	29
							07-25-83	525	7.7	18.5	5.1	3.6	--	30
							03-05-87	546	--	--	--	3.9	--	--
08N/29E-17G02	461040	1191230	SDLM	245	18	245	06-25-82	820	7.9	18.5	--	1.8	--	19
							09-02-86	752	--	--	--	2.6	--	--
							09-16-86	752	--	--	--	2.5	--	--
							02-25-87	729	--	--	--	2.6	--	--
08N/29E-17K01D1	461027	1191221		1,000	20	710	02-18-88	471	8.3	7.5	0.7	.17	<0.01	11
					730	810								
					810	1,000								
08N/29E-17L01	461037	1191242	SDLM	352	112	132	09-02-86	466	--	--	--	3.2	--	--
					332	352								
08N/29E-22A01	461004	1190930	CBRV	802	--	--	11-17-70	1,240	7.3	23.0	--	<.10	--	16
08N/29E-24D01	461003	1190803	CBRV	300	--	--	09-27-86	310	--	--	--	.80	--	--
08N/30E-04N02	461156	1190418	PSCO	25	25	25	09-06-86	805	--	--	--	6.5	--	--
08N/30E-05J01	461217	1190446	SDLM	125	99	125	09-06-86	305	--	--	--	<.10	--	--
							02-18-88	252	8.4	16.0	0.2	<.10	.03	10
08N/30E-05K01	461215	1190455	PSCO	36	36	36	09-05-86	861	--	--	--	8.3	--	--
							02-22-88	755	7.3	13.5	3.3	5.8	.02	28
							09-07-88	751	7.3	15.0	4.3	7.6	.01	29
08N/30E-05K02	461208	1190455	PSCO	32	32	32	09-05-86	769	--	--	--	6.0	--	--
08N/30E-07E02	461137	1190649	PSCO	55	55	55	09-03-86	675	--	--	--	5.0	--	--
							02-18-88	675	7.5	14.5	6.0	4.5	.02	19

Table 13.--*Concentrations of nitrate, ammonia, chloride, and dissolved oxygen and values of specific conductance, pH, and temperature in ground water in the eastern part of Pasco Basin, Washington--Continued*

Well number	Latitude	Longitude	Primary geohydrologic unit	Well depth (feet)	Open intervals of well (feet below land surface) Top	Bottom	Sampling date	Specific conductance (µS/cm)	pH (units)	Temperature (degrees Celsius)	Dissolved oxygen (mg/L)	Nitrate as nitrogen (mg/L)	Ammonia as nitrogen (mg/L)	Chloride (mg/L)
							Benton County, Wash.--Continued							
08N/30E-07G03	461129	1190604	PSCO	39	39	39	09-03-86	396	--	--	--	1.6	--	--
08N/30E-07G04	461130	1190607	PSCO	66	53	55.5	06-24-82	730	7.5	17.5	--	4.8	--	29
					57	63								
08N/30E-07L01	461119	1190635	PSCO	39	34	39	09-04-86	739	--	--	--	6.4	--	--
08N/30E-07L02	461124	1190636	PSCO	48.6	43.6	48.6	09-03-86	579	--	--	--	3.9	--	--
08N/30E-07L03	461116	1190637	PSCO	48	48	48	09-04-86	610	--	--	--	4.0	--	--
08N/30E-07N02	461111	1190648	PSCO	55	45	55	09-04-86	685	--	--	--	4.6	--	--
08N/30E-07Q04	461102	1190606	PSCO	38	38	38	09-04-86	928	--	--	--	9.2	--	--
							02-18-88	1,030	7.3	15.5	5.0	9.2	0.04	56
							09-07-88	1,180	7.3	15.5	4.1	10	.02	59
08N/30E-08E01	461128	1190541	PSCO	74	74	74	09-11-86	726	--	--	--	5.5	--	--
08N/30E-09C01	461141	1190404	SDLM	182	85	182	09-05-86	402	--	--	--	<.10	--	--
							02-18-88	392	8.9	16.0	0.3	<.10	.02	4.9
08N/30E-09C02	461151	1190406	SDLM	94	74.5	94	09-05-86	737	--	--	--	1.9	--	--
							02-18-88	313	8.3	15.0	0.4	<.10	.03	12
08N/30E-09C02D1	461151	1190406	SDLM	102	74.5	102	09-07-88	352	8.1	15.5	0.4	<.10	.02	12
08N/30E-09L02	461123	1190405	PSCO	43	38	43	09-05-86	815	--	--	--	6.9	--	--
							02-20-88	535	7.4	15.5	4.2	3.4	<.01	15
							09-09-88	467	7.6	16.0	3.9	2.2	<.01	11
08N/30E-10M03	461114	1190301	PSCO	49	44	49	09-05-86	250	--	--	--	.70	--	--
							02-19-88	260	7.6	13.5	1.4	.47	.01	2.8

Table 13.--*Concentrations of nitrate, ammonia, chloride, and dissolved oxygen and values of specific conductance, pH, and temperature in ground water in the eastern part of Pasco Basin, Washington--Continued*

Well number	Latitude	Longitude	Primary geohydrologic unit	Well depth (feet)	Open intervals of well (feet below land surface) Top	Bottom	Sampling date	Specific conductance (µS/cm)	pH (units)	Temperature (degrees Celsius)	Dissolved oxygen (mg/L)	Nitrate as nitrogen (mg/L)	Ammonia as nitrogen (mg/L)	Chloride (mg/L)
							Benton County, Wash.--Continued							
08N/30E-14C01	461049	1190131	PSCO	50	45	50	09-05-86	161	--	--	--	0.30	--	--
08N/30E-14M01	461032	1190141	SDLM	160	49	160	09-06-86	1,010	--	--	--	.30	--	--
							04-27-88	1,120	4.2	14.5	0.7	.26	0.03	1.5
08N/30E-15K01	461023	1190234	PSCO	34	29	34	09-06-86	416	--	--	--	1.7	--	--
08N/30E-15N01	461010	1190310	SDLM	245	60	245	09-07-88	453	8.4	13.0	--	<.10	.02	15
08N/30E-16B03	461048	1190338	PSCO	34	29	34	09-05-86	620	--	--	--	5.8	--	--
08N/30E-16F01	461045	1190356	PSCO	50	45	50	09-06-86	660	--	--	--	5.3	--	--
							02-26-87	641	--	--	--	4.2	--	--
							02-19-88	680	7.4	16.5	4.0	3.4	.03	19
							09-07-88	645	7.4	17.0	5.0	3.9	<.01	17
08N/30E-17C01	461100	1190513	PSCO	107	100	107	09-04-86	835	--	--	--	4.5	--	--
08N/30E-17D02	461056	1190532	PSCO	61.5	56.5	61.5	06-25-82	605	7.4	18.5	--	2.8	--	15
							09-08-88	750	7.3	16.5	--	4.5	.02	22
08N/30E-17F05	461043	1190517	PSCO	100	90	100	09-04-86	910	--	--	--	5.8	--	--
08N/30E-17F06	461045	1190523	SDLM	155	83	155	09-04-86	527	--	--	--	<.10	--	--
08N/30E-17L01	461029	1190516	PSCO	51	--	--	09-06-86	1,110	--	--	--	8.5	--	--
08N/30E-17R01	461011	1190438	PSCO	40.5	40.5	40.5	09-04-86	931	--	--	--	12	--	--
							04-11-88	885	7.4	16.5	3.6	5.5	.02	32
							09-08-88	855	7.4	17.5	7.2	8.4	.03	34
08N/30E-19M01	460932	1190642		330	84	330	06-24-82	550	7.6	18.0	--	5.0	--	21

Table 13.--*Concentrations of nitrate, ammonia, chloride, and dissolved oxygen and values of specific conductance, pH, and temperature in ground water in the eastern part of Pasco Basin, Washington--Continued*

Well number	Latitude	Longitude	Primary geohydrologic unit	Well depth (feet)	Open intervals of well (feet below land surface) Top	Bottom	Sampling date	Specific conductance (µS/cm)	pH (units)	Temperature (degrees Celsius)	Dissolved oxygen (mg/L)	Nitrate as nitrogen (mg/L)	Ammonia as nitrogen (mg/L)	Chloride (mg/L)
							Benton County, Wash.--Continued							
08N/30E-20A01	460956	1190444	SDLM	155	139	155	09-03-86	821	--	--	--	<0.10	--	--
							02-19-88	359	8.6	16.0	0.4	<.10	0.01	4.9
							10-13-88	800	8.2	15.5	--	<.10	<.01	18
08N/30E-20G01	460944	1190505	SDLM	325	109	325	09-03-86	510	--	--	--	3.1	--	--
08N/30E-20R01	460918	1190446	SDLM	350	170	350	09-04-86	600	--	--	--	<.10	--	--
							04-12-88	600	8.0	19.0	1.4	<.10	<.01	20
08N/30E-21C03	460957	1190406	PSCO	35	35	35	09-03-86	1,320	--	--	--	11	--	--
							02-24-87	1,250	--	--	--	7.6	--	--
							02-19-88	1,540	6.0	15.5	6.0	1.4	.05	120
							09-08-88	1,260	7.5	16.0	7.2	3.7	.03	75
08N/30E-21C04	461001	1190352	PSCO	28	28	28	09-03-86	740	--	--	--	5.9	--	--
							02-19-88	840	7.3	16.5	6.5	2.4	.03	41
							09-08-88	985	7.4	15.5	4.6	4.5	.04	51
08N/30E-21H01D1	460943	1190323	SDLM	248	190	248	09-04-86	649	--	--	--	2.3	--	--
08N/30E-21J01	460935	1190317	SDLM	250	29.5	250	09-03-86	614	--	--	--	<.10	--	--
08N/30E-21Q02	460923	1190350	SDLM	125	20	125	09-04-86	396	--	--	--	<.10	--	--
08N/30E-21Q03D1	460921	1190336	SDLM	140	20	140	09-03-86	420	--	--	--	.30	--	--
08N/30E-21R01	460928	1190329	SDLM	122	19	22	09-04-86	2,170	--	--	--	4.9	--	--
					82	87								
					102	107								
					122	122								
08N/30E-22D04	461005	1190310	PSCO	26	26	26	09-04-86	905	--	--	--	4.8	--	--
							02-19-88	1,080	7.1	14.0	2.2	4.4	.03	61

Table 13.--*Concentrations of nitrate, ammonia, chloride, and dissolved oxygen and values of specific conductance, pH, and temperature in ground water in the eastern part of Pasco Basin, Washington--Continued*

Well number	Latitude	Longitude	Primary geohydrologic unit	Well depth (feet)	Open intervals of well (feet below land surface) Top	Bottom	Sampling date	Specific conductance (µS/cm)	pH (units)	Temperature (degrees Celsius)	Dissolved oxygen (mg/L)	Nitrate as nitrogen (mg/L)	Ammonia as nitrogen (mg/L)	Chloride (mg/L)
							Benton County, Wash.--Continued							
08N/30E-22G02D1	460946	1190225	SDLM	250	--	--	09-10-86	535	--	--	--	<0.10	--	--
							04-11-88	575	8.2	19.0	<0.2	<.10	0.02	12
08N/30E-22H02	460948	1190211	PSCO	28	23	28	09-08-86	755	--	--	--	5.9	--	--
08N/30E-22J02	460939	1190210	PSCO	30	30	30	09-04-86	691	--	--	--	4.6	--	--
							02-24-87	586	--	--	--	4.1	--	--
08N/30E-22M01	460938	1190312	SDLM	225	24	225	09-04-86	719	--	--	--	.20	--	--
08N/30E-22M02	460931	1190305	PSCO	29.5	26.5	29.5	06-24-82	570	7.5	--	--	2.2	--	19
							09-04-86	559	--	--	--	3.2	--	--
							02-22-88	1,220	7.4	15.0	4.0	3.5	.04	67
							10-13-88	598	7.6	17.5	--	3.2	<.01	17
08N/30E-22Q02	460926	1190227	SDLM	52	31	52	09-04-86	985	--	--	--	4.5	--	--
08N/30E-22R04	460922	1190212	SDLM	52	23	25	09-04-86	--	--	--	--	3.5	--	--
				--	26	52	02-20-88	590	7.4	17.0	5.0	2.5	<.01	18
08N/30E-23D01	461002	1190154	SDLM	105	27	105	09-09-86	415	--	--	--	1.4	--	--
08N/30E-23D02	461001	1190156		20.5	20	20.5	09-04-86	431	--	--	--	1.8	--	--
08N/30E-23E03	460945	1190146	SDLM	47	33	47	09-04-86	445	--	--	--	<.10	--	--
							02-22-88	398	8.2	16.5	0.2	<.10	.01	18
08N/30E-23P01	460915	1190123	PSCO	32	32	32	09-08-86	690	--	--	--	4.4	--	--
08N/30E-24N02	460921	1190032		41	--	--	10-30-59	238	7.9	12.0	--	<.10	--	1.2
08N/30E-25D01	460905	1190036	SDLM	40	35	40	09-08-86	880	--	--	--	7.7	--	--
							02-18-88	840	7.4	14.5	0.6	7.2	.01	27

Table 13.--*Concentrations of nitrate, ammonia, chloride, and dissolved oxygen and values of specific conductance, pH, and temperature in ground water in the eastern part of Pasco Basin, Washington--Continued*

Well number	Latitude	Longitude	Primary geohydrologic unit	Well depth (feet)	Open intervals of well (feet below land surface) Top	Bottom	Sampling date	Specific conductance (µS/cm)	pH (units)	Temperature (degrees Celsius)	Dissolved oxygen (mg/L)	Nitrate as nitrogen (mg/L)	Ammonia as nitrogen (mg/L)	Chloride (mg/L)
							Benton County, Wash.--Continued							
08N/30E-25E02	460858	1190026	PSCO	34	34	34	09-08-1986	--	--	--	--	1.3	--	--
08N/30E-26B01	460901	1190105	PSCO	37	32	37	09-08-86	646	--	--	--	4.0	--	--
08N/30E-26B02	460901	1190103	PSCO	36.5	31.5	36.5	09-08-86	594	--	--	--	3.3	--	--
08N/30E-26C01	460912	1190123	PSCO	34	34	34	09-08-86	573	--	--	--	3.1	--	--
08N/30E-26E01	460853	1190139	SDLM	45	25	45	09-09-86	962	--	--	--	2.7	--	--
08N/30E-26H01	460858	1190059	PSCO	37	37	37	09-08-86	591	--	--	--	3.3	--	--
08N/30E-26H02	460856	1190046	PSCO	35	30	35	09-08-86	571	--	--	--	3.7	--	--
08N/30E-26H03	460857	1190050	SDLM	298	100	298	09-0886	505	--	--	--	3.2	--	--
08N/30E-26H04	460854	1190050	PSCO	38	33	38	09-10-86	580	--	--	--	6.3	--	--
08N/30E-26L03	460843	1190124	SDLM	165	21	165	09-09-86	442	--	--	--	.30	--	--
08N/30E-26Q01	460822	1190110	SDLM	85	18.5	85	10-13-88	690	7.3	17.0	--	.38	<0.01	11
08N/30E-26Q02	460827	1190112	SDLM	100	18.5	100	09-10-86	915	--	--	--	1.3	--	--
08N/30E-27B01	460903	1190222	SDLM	125	23	125	09-09-86	791	--	--	--	2.1	--	--
08N/30E-27B02	460911	1190219	SDLM	124	27	124	09-10-86	400	--	--	--	.10	--	--
							02-18-88	395	8.4	15.0	<0.2	<.10	.03	11
08N/30E-27B03	460912	1190227	SDLM	141	141	141	09-09-86	541	--	--	--	1.1	--	--
08N/30E-27D02	460914	1190312	SDLM	181	16.5	181	09-10-86	1,230	--	--	--	5.5	--	--
08N/30E-27F01	460857	1190247	SDLM	125	20	125	09-09-86	495	--	--	--	<.10	--	--

Table 13.--*Concentrations of nitrate, ammonia, chloride, and dissolved oxygen and values of specific conductance, pH, and temperature in ground water in the eastern part of Pasco Basin, Washington--Continued*

Well number	Lati-tude	Longi-tude	Primary geo-hydro-logic unit	Well depth (feet)	Open intervals of well (feet below land surface) Top	Bottom	Sampling date	Spe-cific con-duc-(μS/cm)	pH (units)	Tempe-rature (degrees Celsius)	Dis-solved oxy-gen (mg/L)	Nitrate as nitrogen (mg/L)	Am-monia as nitrogen (mg/L)	Chlo-ride (mg/L)
							Benton County, Wash.--Continued							
08N/30E-27H01	460855	1190158	SDLM	215	18	215	09-09-86	388	--	--	--	<0.10	--	--
08N/30E-29A01	460913	1190439	SDLM	215	77	215	09-11-86	1,920	--	--	--	26	--	--
							12-16-86	--	--	--	--	25	--	--
							01-15-87	--	--	--	--	26	--	--
							02-05-87	--	--	--	--	26	--	--
							02-26-87	2,180	--	--	--	26	--	--
							05-07-87	--	--	--	--	28	--	--
							07-01-87	--	--	--	--	26	--	--
							09-15-87	--	--	--	--	28	--	--
							02-18-88	2,040	7.7	12.5	6.6	27	0.04	170
							09-08-88	1,930	7.4	18.5	4.7	27	.07	160
08N/30E-29D01	460916	1190544	PSCO	120	120	120	09-11-86	512	--	--	--	3.7	--	--
							12-16-86	--	--	--	--	3.6	--	--
							01-15-87	--	--	--	--	3.3	--	--
							02-05-87	--	--	--	--	3.4	--	--
							02-27-87	491	--	--	--	3.5	--	--
							05-07-87	--	--	--	--	3.6	--	--
							07-01-87	--	--	--	--	3.8	--	--
							09-15-87	--	--	--	--	3.4	--	--
							02-20-88	549	7.8	18.0	7.4	3.9	<.01	41
08N/30E-29R01	460830	1190446	WNPM	380	158	380	09-10-86	472	--	--	--	4.3	--	--
							02-22-88	545	8.0	16.0	7.2	8.5	<.01	30
							09-09-88	575	7.9	17.0	6.6	9.4	<.01	35
08N/30E-34B02	460818	1190229	SDLM	56	56	56	09-09-86	1,390	--	--	--	12	--	--
							02-18-88	1,130	7.5	13.5	7.2	7.5	.01	79
							09-09-88	1,170	7.5	15.0	7.0	11	.04	66
08N/30E-34G01	460756	1190233	SDLM	105	87	105	09-09-86	427	--	--	--	2.4	--	--
08N/30E-34J01	460747	1190200	SDLM	260	76	260	09-10-86	380	--	--	--	<.10	--	--

Table 13.--*Concentrations of nitrate, ammonia, chloride, and dissolved oxygen and values of specific conductance, pH, and temperature in ground water in the eastern part of Pasco Basin, Washington--Continued*

Well number	Lati-tude	Longi-tude	Primary geo-hydro-logic unit	Well depth (feet)	Open intervals of well (feet below land surface) Top	Bottom	Sampling date	Spe-cific con-duc-(µS/cm)	pH (units)	Tempe-rature (degrees Celsius)	Dis-solved oxy-gen (mg/L)	Nitrate as nitrogen (mg/L)	Am-monia as nitrogen (mg/L)	Chlo-ride (mg/L)
							Benton County, Wash.--Continued							
08N/30E-34K01	460752	1190219	PSCO	60	50	60	09-09-86	572	--	--	--	5.1	--	--
							02-26-87	505	--	--	--	4.0	--	--
08N/30E-34Q02	460736	1190228	PSCO	148	145	147	09-09-86	492	--	--	--	3.9	--	--
					148	148								
08N/30E-35E02	460756	1190156	PSCO	50	38	49	09-10-86	1,100	--	--	--	11	--	--
					50	50	02-18-88	935	7.6	13.5	7.8	18	0.01	35
							09-09-88	958	7.6	16.0	6.5	19	<.01	34
08N/30E-35G02	460807	1190116	PSCO	20	20	20	09-10-86	850	--	--	--	12	--	--
08N/30E-35K01	460752	1190117	SDLM	177	50	177	09-10-86	405	--	--	--	<.10	--	--
							09-09-88	410	7.9	18.0	2.0	<.10	<.01	10
09N/27E-02D03D1	461802	1192413		375	327	367	09-06-86	578	--	--	--	6.0	--	--
					369	375	--	--	--	--	--	--	--	--
09N/27E-02E01	461746	1192415	SDLM	273	234	273	09-08-86	610	--	--	--	6.9	--	--
							02-20-88	523	7.9	16.5	6.8	5.3	<.01	27
09N/27E-02L01	461724	1192357	SDLM	120	86	120	09-18-86	552	--	--	--	5.7	--	--
							02-26-88	589	7.7	17.0	7.9	5.9	<.01	33
09N/27E-03B01	461801	1192506	SDLM	275	121	275	09-08-86	572	--	--	--	2.3	--	--
09N/27E-03R02	461719	1192438	SDLM	280	260	280	09-06-86	470	--	--	--	<.10	--	--
							02-20-88	489	7.9	19.0	0.2	<.10	.07	13
09N/27E-05D01D1	461752	1192806	SDLM	150	--	--	09-05-86	442	--	--	--	<.10	--	--
09N/27E-05E01	461741	1192808	ALVM	38	33	38	09-05-86	437	--	--	--	<.10	--	--
							02-19-88	436	8.2	15.0	0.4	<.10	.03	86

Table 13.--*Concentrations of nitrate, ammonia, chloride, and dissolved oxygen and values of specific conductance, pH, and temperature in ground water in the eastern part of Pasco Basin, Washington--Continued*

Well number	Latitude	Longitude	Primary geohydrologic unit	Well depth (feet)	Open intervals of well (feet below land surface) Top	Bottom	Sampling date	Specific conductance (µS/cm)	pH (units)	Temperature (degrees Celsius)	Dissolved oxygen (mg/L)	Nitrate as nitrogen (mg/L)	Ammonia as nitrogen (mg/L)	Chloride (mg/L)
							Benton County, Wash.--Continued							
09N/27E-06A01	461755	1192821	SDLM	104	65.5	104	09-05-86	377	--	--	--	<0.10	--	--
09N/27E-08J02	461637	1192701	SDLM	560	300	560	09-16-86	348	--	--	--	<.10	--	--
09N/27E-08N01	461631	1192809	WNPM	638	618	638	09-05-86	367	--	--	--	.10	--	--
							04-19-88	352	8.1	20.5	<0.2	<.10	0.07	5.4
09N/27E-09J01	461635	1192551	SDLM	446	365	446	09-06-86	386	--	--	--	.10	--	--
09N/27E-11H01	461653	1192333	SDLM	104	70	104	09-06-86	641	--	--	--	8.2	--	--
09N/27E-12F02	461647	1192252	SDLM	180	90	180	09-06-86	534	--	--	--	6.7	--	--.
							04-11-88	508	7.9	18.0	5.3	4.9	<.01	22
							04-19-88	510	7.9	17.0	6.2	5.2	<.01	23
09N/27E-16B01	461611	1192624	SDLM	290	285	290	09-16-86	319	--	--	--	<.10	--	--
							02-19-88	320	8.1	17.5	1.2	<.10	<.01	2.7
							09-13-88	336	8.1	18.5	0.8	<.10	.03	2.2
09N/27E-17P01	461532	1192751	SDLM	252	152	252	09-05-86	560	--	--	--	5.7	--	--
							09-13-88	608	8.1	18.0	6.9	6.2	.01	28
09N/27E-17P02	461534	1192746	SDLM	324	162	324	09-06-86	541	--	--	--	6.0	--	--
09N/27E-18A01	461613	1192822	SDLM	115	18	115	09-05-86	256	--	--	--	<.10	--	--
09N/27E-19J01	461453	1192830	PSCO	113	111.5	113	09-02-86	615	--	--	--	2.9	--	--
							09-16-86	615	--	--	--	2.8	--	--
							02-17-88	690	7.9	15.0	2.5	2.7	<.01	33
09N/27E-19K02	461454	1192846	PSCO	100	100	100	09-05-86	759	--	--	--	9.5	--	--
							02-26-87	817	--	--	--	11	--	--
							02-19-88	820	7.8	15.5	5.5	11	<.01	39

Table 13.--*Concentrations of nitrate, ammonia, chloride, and dissolved oxygen and values of specific conductance, pH, and temperature in ground water in the eastern part of Pasco Basin, Washington--Continued*

Well number	Latitude	Longitude	Primary geohydrologic unit	Well depth (feet)	Open intervals of well (feet below land surface) Top	Bottom	Sampling date	Specific conductance (µS/cm)	pH (units)	Temperature (degrees Celsius)	Dissolved oxygen (mg/L)	Nitrate as nitrogen (mg/L)	Ammonia as nitrogen (mg/L)	Chloride (mg/L)
							Benton County, Wash.--Continued							
09N/27E-19P01	461440	1192910	SDLM	438	181	438	09-16-86	350	--	--	--	0.70	--	--
							02-03-87	--	--	--	--	.70	--	--
							02-26-87	369	--	--	--	.70	--	--
							05-06-87	--	--	--	--	.70	--	--
							07-01-87	--	--	--	--	.70	--	--
							02-17-88	370	8.0	17.0	8.3	.62	<0.01	5.6
09N/27E-21C01	461524	1192644	SDLM	405	370	405	09-06-86	425	--	--	--	4.2	--	--
09N/27E-21D01	461522	1192654	WNPM	825	607	825	08-28-82	400	8.0	22.5	--	.93	--	4.4
09N/27E-28L01	461359	1192645	PSCO	125			09-15-88	820	7.6	17.0	7.9	4.5	<.01	68
09N/27E-29J01	461405	1192711	PSCO	67	67	67	09-02-86	732	--	--	--	5.4	--	--
							05-25-88	760	7.7	16.0	--	5.9	.02	42
09N/27E-29J03	461358	1192712	PSCO	98	96	98	09-02-86	1,140	--	--	--	13	--	--
09N/27E-34C01	461340	1192519		160			09-15-88	668	7.6	17.5	7.7	7.7	<.01	42
09N/27E-35E01	461319	1192424	SDLM	160	160	160	09-02-86	401	--	--	--	1.7	--	--
							02-17-88	410	7.8	16.5	5.0	2.1	<.01	7.4
							09-15-88	398	7.8	17.5	5.1	1.1	<.01	6.7
09N/27E-36M01	461308	1192305	PSCO	150	150	150	09-12-88	532	7.6	17.0	8.2	14	<.01	23
09N/28E-02G01	461741	1191619	MDRG	31	31	31	09-05-86	830	--	--	--	7.8	--	--
09N/28E-02N01D1	461710	1191646	LRRG	148	148	148	09-05-86	152	--	--	--	<.10	--	--
09N/28E-03G01	461747	1191723	MDRG	65.3	65.3	65.3	09-05-86	660	--	--	--	8.6	--	--
09N/28E-03P01	461716	1191756	LRRG	115	115	115	09-05-86	223	--	--	--	<.10	--	--
							09-10-88	215	8.1	17.5	0.6	<.10	<.01	2.3

Table 13.--*Concentrations of nitrate, ammonia, chloride, and dissolved oxygen and values of specific conductance, pH, and temperature in ground water in the eastern part of Pasco Basin, Washington--Continued*

Well number	Latitude	Longitude	Primary geohydrologic unit	Well depth (feet)	Open intervals of well (feet below land surface) Top	Open intervals of well (feet below land surface) Bottom	Sampling date	Specific conductance (µS/cm)	pH (units)	Temperature (degrees Celsius)	Dissolved oxygen (mg/L)	Nitrate as nitrogen (mg/L)	Ammonia as nitrogen (mg/L)	Chloride (mg/L)
							Benton County, Wash.--Continued							
09N/28E-04C04	461750	1191908	LRRG	--	--	--	09-05-86	600	--	--	--	<0.10	--	--
09N/28E-04G01	461739	1191849	SDLM	314	180	314	06-24-82	382	7.8	17.5	--	<.10	--	8.1
							09-16-86	378	--	--	--	<.10	--	--
							02-25-88	378	8.3	15.5	0.4	<.10	0.11	8.0
09N/28E-04G03	461740	1191849	MDRG	52	52	52	09-16-86	588	--	--	--	.40	--	--
							02-25-88	612	7.8	13.0	0.8	.68	.06	45
09N/28E-05A01D1	461754	1191935	SDLM	220	170	220	09-06-86	343	--	--	--	.10	--	--
09N/28E-05B01	461752	1192007	LRRG	68.7	68.7	68.7	09-06-86	562	--	--	--	<.10	--	--
09N/28E-05E01	461749	1192039	LRRG	73	67	73	09-06-86	682	--	--	--	<.10	--	--
							02-26-87	631	--	--	--	<.10	--	--
09N/28E-05F02	461744	1192020	PSCO	45	41	45	09-06-86	482	--	--	--	.40	--	--
09N/28E-05G01	461741	1191950	LRRG	107	102	107	09-06-86	489	--	--	--	<.10	--	--
09N/28E-05H01	461742	1191932	LRRG	93	93	93	09-06-86	434	--	--	--	<.10	--	--
09N/28E-06A02	461751	1192054	SDLM	90.2	76	90.2	06-24-82	633	8.0	18.5	--	<.10	--	15
09N/28E-08B01	461658	1191951	SDLM	354	18	354	09-08-86	390	--	--	--	<.10	--	--
							09-09-86	386	--	--	--	<.10	--	--
09N/28E-08C01	461706	1192018	SDLM	204	186	204	09-16-86	769	--	--	--	.60	--	--
							02-23-88	787	7.9	18.0	0.5	<.10	<.01	17
09N/28E-08R01	461623	1191937	SDLM	260	110	260	09-08-86	747	--	--	--	3.1	--	--
09N/28E-10F01	461656	1191749	MDRG	68	68	68	09-08-86	548	--	--	--	6.1	--	--
							02-24-88	715	7.4	15.5	5.9	3.8	<.01	18

Table 13.--*Concentrations of nitrate, ammonia, chloride, and dissolved oxygen and values of specific conductance, pH, and temperature in ground water in the eastern part of Pasco Basin, Washington--Continued*

Well number	Latitude	Longitude	Primary geohydrologic unit	Well depth (feet)	Open intervals of well (feet below land surface) Top	Bottom	Sampling date	Specific conductance (µS/cm)	pH (units)	Temperature (degrees Celsius)	Dissolved oxygen (mg/L)	Nitrate as nitrogen (mg/L)	Ammonia as nitrogen (mg/L)	Chloride (mg/L)
							Benton County, Wash.--Continued							
09N/28E-08K01	461638	1191955	SDLM	325	321	325	09-08-86	620	--	--	--	<0.10	--	--
					245	250	02-26-87	665	--	--	--	<.10	--	--
					300	315	04-11-88	630	7.9	18.5	<0.2	<.10	0.15	27
							09-14-88	683	7.5	17.0	7.1	5.7	<.01	17
09N/28E-11E01	461652	1191701	SDLM	135	130	135	09-09-86	260	--	--	--	<.10	--	--
							09-14-88	262	8.0	18.5	0.2	<.10	.17	2.9
09N/28E-12P01	461621	1191510	LRRG	130	114	126	09-10-86	303	--	--	--	<.10	--	--
					130	130								
09N/28E-14P01	461527	1191626	PSCO	46	41	46	09-09-86	522	--	--	--	1.3	--	--
							02-26-87	538	--	--	--	1.3	--	--
							09-14-88	576	7.7	17.0	1.1	1.0	<.01	18
09N/28E-15G01	461600	1191732	MDRG	95	95	95	09-09-86	740	--	--	--	6.7	--	--
							02-24-88	747	7.6	17.5	5.0	5.7	<.01	20
09N/28E-15H06D1	461552	1191703	PSCO	--	--	--	09-09-86	780	--	--	--	3.7	--	--
09N/28E-15H07D1	461601	1191703	PSCO	--	--	--	09-09-86	740	--	--	--	3.0	--	--
09N/28E-15J01	461543	1191704	PSCO	68.7	46	68	09-17-86	674	--	--	--	1.9	--	--
09N/28E-16A01	461613	1191823	MDRG	57.5	57.5	57.5	11-01-62	627	7.9	16.0	--	<.10	--	14
09N/28E-17A01	461611	1191950	WNPM	1,105	195	220	06-24-82	505	8.2	26.5	--	<.10	--	12
					455	480	08-27-82	514	8.0	26.5	1.4	<.10	--	13
					500	520	05-17-83	495	8.1	26.0	1.3	<.10	--	11
					718	739	02-25-88	450	8.5	26.0	--	.10	<.01	11
					760	781								
					990	1,031								
					1,073	1,105								

Table 13.--*Concentrations of nitrate, ammonia, chloride, and dissolved oxygen and values of specific conductance, pH, and temperature in ground water in the eastern part of Pasco Basin, Washington--Continued*

Well number	Latitude	Longitude	Primary geohydrologic unit	Well depth (feet)	Open intervals of well (feet below land surface) Top	Bottom	Sampling date	Specific conductance (µS/cm)	pH (units)	Temperature (degrees Celsius)	Dissolved oxygen (mg/L)	Nitrate as nitrogen (mg/L)	Ammonia as nitrogen (mg/L)	Chloride (mg/L)
							Benton County, Wash.--Continued							
09N/28E-17N01	461535	1192047	SDLM	270	123.7	270	09-09-86	821	--	--	--	13	--	--
							02-23-88	789	7.8	14.5	8.5	13	<0.01	28
09N/28E-18H01	461553	1192055	SDLM	308	200	220	09-09-86	1,370	--	--	--	41	--	--
					227	308	03-02-87	1,570	--	--	--	52	--	--
							02-24-88	1,510	7.6	16.0	3.8	44	.02	81
09N/28E-18L01	461550	1192127	SDLM	100	19	100	09-17-86	762	--	--	--	13	--	--
							03-02-87	651	--	--	--	8.9	--	--
							02-24-88	620	7.6	14.5	6.4	6.3	<.01	18
							09-10-88	732	7.6	16.0	6.4	9.1	<.01	24
09N/28E-20A01	461514	1191933	SDLM	102	79	102	09-09-86	1,260	--	--	--	24	--	--
							02-24-88	1,240	7.6	15.5	7.5	22	.04	67
09N/28E-21D01	461516	1191930	SDLM	240	74	240	09-18-86	164	--	--	--	13	--	--
09N/28E-22B01	461515	1191731	SDLM	172	85	172	09-17-86	974	--	--	--	1.4	--	--
							02-21-88	855	7.7	18.0	0.5	.20	<.01	17
							09-10-88	980	7.6	19.0	0.9	1.9	<.01	25
09N/28E-22B02	461522	1191736	SDLM	225	206	225	09-09-86	895	--	--	--	<.10	--	--
09N/28E-22F01D1	461459	1191756	SDLM	210	160	210	09-09-86	1,310	--	--	--	15	--	--
							02-21-88	1,360	7.7	16.5	5.6	12	<.01	99
							09-10-88	1,250	7.7	18.5	2.5	12	<.01	91
09N/28E-26R01D1	461339	1191601	SDLM	281	75	201	09-09-86	901	--	--	--	4.3	--	--
					210	220	03-02-87	1,100	--	--	--	12	--	--
					260	280	02-25-88	1,170	7.7	14.0	9.9	11	<.01	110
					281	281	09-10-88	885	7.8	18.0	3.7	.96	<.01	21
09N/28E-27D01	461427	1191801	SDLM	274	135	274	09-09-86	1,800	--	--	--	8.8	--	--
							02-21-88	1,080	7.6	18.0	8.0	8.1	<.01	84

Table 13.--*Concentrations of nitrate, ammonia, chloride, and dissolved oxygen and values of specific conductance, pH, and temperature in ground water in the eastern part of Pasco Basin, Washington--Continued*

Well number	Latitude	Longitude	Primary geohydrologic unit	Well depth (feet)	Open intervals of well (feet below land surface)		Sampling date	Specific conductance (µS/cm)	pH (units)	Temperature (degrees Celsius)	Dissolved oxygen (mg/L)	Nitrate as nitrogen (mg/L)	Ammonia as nitrogen (mg/L)	Chloride (mg/L)
					Top	Bottom								
						Benton County, Wash.--Continued								
09N/28E-27K01	461402	1191738	SDLM	525	168	525	06-24-82	1,010	7.3	19.0	--	8.2	--	47
09N/28E-31N01D1	461253	1192152	PSCO	215	214	214	09-03-86	547	--	--	--	12	--	--
09N/28E-31P01D1	461254	1192145	PSCO	217	207	217	09-03-86	697	--	--	--	24	--	--
							02-22-88	550	7.6	16.0	8.2	11	<0.01	15
							09-13-88	678	7.7	18.0	9.3	17	<.01	29
09N/29E-31L01	461302	1191402	PSCO	100	90	95	09-03-86	849	--	--	--	.40	--	--
					95	100								
09N/29E-33M01	461305	1191202	SDLM	292	181	292	08-27-82	575	8.0	17.5	--	3.6	--	24
							05-17-83	632	7.2	17.5	6.1	5.3	--	27
							07-22-83	650	7.3	17.5	6.0	5.6	--	30
							09-17-86	449	--	--	--	1.6	--	--
							04-12-88	560	7.7	19.0	--	4.2	<.01	22
09N/29E-36N02	461254	1190757	PSCO	41	39	41	09-06-86	592	--	--	--	3.5	--	--
							02-22-88	752	7.6	16.0	6.4	6.0	.02	30
10N/27E-11M02	462149	1192403	SDLM	147.5	58	147.5	09-16-86	738	--	--	--	3.5	--	--
							02-23-88	509	7.9	14.5	0.9	.35	<.01	34
							09-13-88	495	8.0	17.5	1.1	.21	.02	30
10N/27E-14F02	462119	1192350	PSCO	50	50	50	09-09-86	458	--	--	--	3.3	--	--
10N/27E-14P02	462053	1192350	PSCO	59	54	59	09-09-86	409	--	--	--	3.2	--	--
							02-22-88	670	7.6	14.5	4.8	7.1	<.01	75
							09-13-88	502	7.7	16.5	5.8	3.7	<.01	15
10N/27E-23L02	462009	1192354	SDLM	85	32	85	09-16-86	611	--	--	--	<.10	--	--
							02-22-88	589	8.0	15.5	0.4	<.10	.01	30

Table 13.--*Concentrations of nitrate, ammonia, chloride, and dissolved oxygen and values of specific conductance, pH, and temperature in ground water in the eastern part of Pasco Basin, Washington--Continued*

Well number	Lati-tude	Longi-tude	Primary geo-hydro-logic unit	Well depth (feet)	Open intervals of well (feet below land surface) Top	Bottom	Sampling date	Spe-cific con-duc- (µS/cm)	pH (units)	Tempe-rature (degrees Celsius)	Dis-solved oxy-gen (mg/L)	Nitrate as nitrogen (mg/L)	Am-monia as nitrogen (mg/L)	Chlo-ride (mg/L)
							Benton County, Wash.--Continued							
10N/27E-25R03	461856	1192208	PSCO	80	80	80	09-09-86	591	--	--	--	4.7	--	--
							02-23-88	591	7.8	15.0	4.6	5.2	<0.01	27
10N/27E-29R02	461903	1192707	SDLM	330	244	330	08-28-82	430	7.5	19.0	0.2	<0.10	--	7.2
							03-08-83	412	7.9	18.0	0.1	<.10	--	7.2
							07-22-83	435	8.0	19.5	0.2	<.10	--	6.9
							02-22-88	400	8.0	18.0	0.5	<.10	.07	7.0
10N/27E-32N01	461811	1192817	SDLM	187	89	187	09-10-86	792	--	--	--	1.7	--	--
10N/27E-33B01	461854	1192622	SDLM	250	223	244	02-22-88	548	7.5	17.0	0.4	.39	<.01	15
					246	250	09-13-88	525	7.5	18.0	0.6	.23	<.01	11
10N/27E-36J01	461817	1192158	WNPM	570	65	570	09-10-86	443	--	--	--	1.4	--	--
10N/28E-17B01D1	462118	1191958	SDLM	228	225	228	06-15-51	206	9.2	--	--	<.10	--	10
10N/28E-17B01	462118	1191958	PSCO	215	93	103	02-26-88	236	8.3	16.5	5.0	.85	<.01	5.3
10N/28E-18F01	462107	1192119	SDLM	386	217	286	09-05-86	242	--	--	--	<.10	--	--
					286	294	03-05-87	251	--	--	--	<.10	--	--
					322	386	02-25-88	250	8.1	18.0	4.8	<.10	.16	3.0
10N/28E-19R01	461948	1192044	MDRG	35	30	35	09-17-86	682	--	--	--	<.10	--	--
							02-25-87	700	--	--	--	<.10	--	--
							02-24-88	750	7.4	12.5	0.5	<.10	<.01	12
10N/28E-20N03	461945	1192035	ALVM	26	26	26	09-03-86	1,020	--	--	--	4.1	--	--
10N/28E-23E01	462025	1191653	PSCO	50	50	50	09-14-88	133	8.1	20.5	8.2	<.10	.04	0.9
10N/28E-29D02	461933	1192028	PSCO	30	30	30	09-03-86	1,360	--	--	--	7.3	--	--

Table 13.--*Concentrations of nitrate, ammonia, chloride, and dissolved oxygen and values of specific conductance, pH, and temperature in ground water in the eastern part of Pasco Basin, Washington--Continued*

Well number	Latitude	Longitude	Primary geohydrologic unit	Well depth (feet)	Open intervals of well (feet below land surface)		Sampling date	Specific conductance (µS/cm)	pH (units)	Temperature (degrees Celsius)	Dissolved oxygen (mg/L)	Nitrate as nitrogen (mg/L)	Ammonia as nitrogen (mg/L)	Chloride (mg/L)
					Top	Bottom								
						Benton County, Wash.--Continued								
10N/28E-29D03	461942	1192039	PSCO	30	30	30	04-13-88	703	7.3	14.5	0.3	0.80	<0.01	15
							10-13-88	820	7.4	15.5	--	1.3	<.01	27
10N/28E-31C01	461852	1192132	LRRG	65	65	65	09-03-86	508	--	--	--	1.4	--	--
							02-25-87	571	--	--	--	1.7	--	--
							02-22-88	660	7.4	13.0	2.4	2.5	<.01	18
10N/28E-35A04	461842	1191553	MDRG	36	31	36	09-04-86	568	--	--	--	5.1	--	--
10N/28E-35C03	461842	1191630	MDRG	50	45	50	09-04-86	662	--	--	--	6.2	--	--
							09-14-88	660	7.6	16.5	6.2	5.2	<.01	20
10N/28E-35D04	461838	1191657	MDRG	85	75	85	09-04-86	569	--	--	--	4.4	--	--
10N/28E-35H09	461838	1191555	MDRG	44	39	44	09-04-86	574	--	--	--	5.3	--	--
10N/28E-35K04	461823	1191604	MDRG	50	45	50	09-04-86	742	--	--	--	8.8	--	--
10N/28E-35K05	461817	1191609	PSCO	39	39	39	09-04-86	760	--	--	--	7.9	--	--
							02-26-87	694	--	--	--	7.6	--	--
							04-12-88	730	7.4	15.0	4.8	7.7	<.01	20
10N/28E-35N03	461805	1191644	MDRG	25	20	25	09-17-86	1,020	--	--	--	21	--	--

Table 13.--*Concentrations of nitrate, ammonia, chloride, and dissolved oxygen and values of specific conductance, pH, and temperature in ground water in the eastern part of Pasco Basin, Washington--Continued*

Well number	Latitude	Longitude	Primary geohydrologic unit	Well depth (feet)	Open intervals of well (feet below land surface) Top	Bottom	Sampling date	Specific conductance (µS/cm)	pH (units)	Temperature (degrees Celsius)	Dissolved oxygen (mg/L)	Nitrate as nitrogen (mg/L)	Ammonia as nitrogen (mg/L)	Chloride (mg/L)
							Franklin County, Wash.							
09N/29E-02A01	461759	1190808	PSCO	128	118	128	09-11-86	842	--	--	--	20	--	--
							02-24-88	853	7.7	16.5	5.5	19	<.01	45
09N/29E-02A02	461749	1190823	PSCO	132	127	132	09-26-86	839	--	--	--	19	--	--
09N/29E-02C04	461757	1190855	PSCO	134	129.9	134	09-11-86	810	--	--	--	14	--	--
09N/29E-02D03	461757	1190916	PSCO	160	130	160	09-11-86	671	--	--	--	7.2	--	--
							02-24-88	655	7.9	18.0	0.6	5.0	<0.01	47
09N/29E-02G02	461742	1190836	SDLM	470	460	470	05-18-83	445	7.9	22.0	<0.2	<.10	--	26
09N/29E-02G02D1	461742	1190836	SDLM	493	460	470	04-15-88	432	8.1	21.0	<0.2	<.10	.02	24
					470	493								
09N/29E-02G03	461739	1190836	SDLM	118	23.5	118	09-11-86	760	--	--	--	14	--	--
							03-03-87	736	--	--	--	13	--	--
							02-24-88	765	7.6	16.5	4.4	14	<.01	46
09N/29E-02G04	461742	1190836	PSCO	145	145	145	09-11-86	851	--	--	--	17.0	--	--
							03-03-87	822	--	--	--	17.0	--	--
							04-15-88	910	7.7	17.0	7.4	15.0	.01	79
09N/29E-02G06	461737	1190831	PSCO	133	123	133	09-26-86	832	--	--	--	18.0	--	--
09N/29E-06F01	461740	1191351	PSCO	160	160	160	09-07-88	830	7.5	18.5	5.5	5.6	<.01	--
09N/29E-06G01	461736	1191349	BSRG	230	230	230	09-10-86	315	--	--	--	<.10	--	--
							03-03-87	313	--	--	--	<.10	--	--
							02-25-88	316	8.1	16.5	0.2	.64	.04	6.6
09N/29E-10B01	461703	1190948	PSCO	200	200	200	09-12-86	728	--	--	--	13.0	--	--
							03-03-87	754	--	--	--	14.0	--	--
09N/29E-17L01	461545	1191240	SDLM	260	--	--	09-10-86	378	--	--	--	<.10	--	--

Table 13.--*Concentrations of nitrate, ammonia, chloride, and dissolved oxygen and values of specific conductance, pH, and temperature in ground water in the eastern part of Pasco Basin, Washington--Continued*

Well number	Latitude	Longitude	Primary geohydrologic unit	Well depth (feet)	Open intervals of well (feet below land surface): Top	Open intervals of well (feet below land surface): Bottom	Sampling date	Specific conductance (μS/cm)	pH (units)	Temperature (degrees Celsius)	Dissolved oxygen (mg/L)	Nitrate as nitrogen (mg/L)	Ammonia as nitrogen (mg/L)	Chloride (mg/L)
							Franklin County, Wash.--Continued							
09N/29E-21R01D1	461440	1191047	LRRG	59	54	58	09-10-86	620	--	--	--	6.6	--	--
							02-23-88	595	7.4	14.0	4.7	6.4	<.01	21
09N/29E-22D01	461512	1191029	PSCO	86	86	86	09-08-88	580	7.7	19.0	6.0	7.5	<.01	29
09N/29E-23J02	461448	1190829	PSCO	57.5	--	--	10-17-60	489	7.9	18.0	--	2.9	--	11
							05-04-61	428	7.9	18.0	--	1.4	--	16
09N/29E-23P01	461432	1190903	PSCO	28	--	--	04-28-42	326	--	15.0	--	.86	--	1.6
09N/29E-23P02	461433	1190852	PSCO	42	--	--	05-04-61	461	7.8	16.0	--	2.5	--	10
09N/29E-25N01	461349	1190814	PSCO	30	30	30	04-19-88	725	7.3	17.0	5.8	14.0	.01	44
							10-13-88	740	7.4	17.0	--	11.0	<.01	40
09N/29E-26J02	461400	1190823	PSCO	40	35	40	09-06-86	629	--	--	--	9.7	--	--
							04-19-88	695	7.4	17.0	5.6	13.0	.01	40
09N/29E-26L02	461400	1190910	PSCO	35	35	35	09-10-86	661	--	--	--	9.5	--	--
							02-23-88	645	7.3	14.5	5.5	10.0	.01	28
09N/30E-02R01	461712	1190041	SDLM	211	177.5	211	08-27-82	575	8.0	17.5	9.0	4.0	--	26
							03-08-83	575	7.8	16.0	8.4	4.3	--	25
							07-19-83	568	8.0	17.5	8.6	4.1	--	25
							09-09-86	573	--	--	--	4.6	--	--
							02-26-88	575	8.0	17.0	6.8	4.9	<.01	23
09N/30E-06L01	461727	1190630	PSCO	93	93	93	09-07-88	730	7.7	17.5	6.4	16.0	<.01	33
09N/30E-06Q01D1	461711	1190608	MDRG	154	149	154	09-11-86	750	--	--	--	15.0	--	--
							02-27-87	721	--	--	--	16.0	--	--
							02-24-88	753	7.7	17.0	5.2	15.0	<.01	36

Table 13.--*Concentrations of nitrate, ammonia, chloride, and dissolved oxygen and values of specific conductance, pH, and temperature in ground water in the eastern part of Pasco Basin, Washington--Continued*

Well number	Lati-tude	Longi-tude	Primary geo-hydro-logic unit	Well depth (feet)	Open intervals of well (feet below land surface) Top	Bottom	Sampling date	Spe-cific con-duc- (µS/cm)	pH (units)	Tempe-rature (degrees Celsius)	Dis-solved oxy-gen (mg/L)	Nitrate as nitrogen (mg/L)	Am-monia as nitrogen (mg/L)	Chlo-ride (mg/L)
							Franklin County, Wash.--Continued							
09N/30E-08B02D1	461703	1190457	MDRG	135	--	--	09-09-86	660	--	--	--	12.0	--	--
							09-08-88	675	7.8	19.0	7.0	15.0	0.01	41
09N/30E-14A02	461612	1190044	MDRG	157.5	147	157.5	09-10-86	585	--	--	--	4.4	--	--
09N/30E-17K01D1	461545	1190501	PSCO	105	97	105	09-07-88	720	7.8	17.5	7.5	16	.01	33
09N/30E-17Q01	461532	1190458	MDRG	109.5	99.5	109.5	09-11-86	730	--	--	--	13	--	--
09N/30E-18J01	461538	1190554	MBTN	1,033	227	840	08-28-70	506	8.6	21.0	--	<.10	--	15
					900	1,033								
09N/30E-20D01	461513	1190540	PSCO	85	--	--	05-23-60	487	7.9	18.0	--	9.3	--	12
							10-17-60	594	7.7	18.5	--	17	--	16
							11-01-62	605	--	--	--	16	--	--
09N/30E-22K01	461439	1190216	PSCO	138	133	138	09-10-86	601	--	--	--	5.0	--	--
09N/30E-26F01	461409	1190126	PSCO	137	132	137	09-10-86	635	--	--	--	6.5	--	--
							09-26-86	779	--	--	--	12	--	--
09N/30E-27F01	461405	1190250	PSCO	120	115	120	02-25-88	685	7.8	16.0	5.7	7.2	<.01	32
							09-07-88	710	7.6	20.5	7.5	9.8	<.01	33
09N/30E-27H01	461407	1190216	PSCO	93	88	93	02-25-88	625	7.9	16.0	6.4	6.9	<.01	29
09N/30E-27H02	461407	1190218	PSCO	119	119	119	09-08-86	671	--	--	--	8.2	--	--
							09-10-86	671	--	--	--	10	--	--
09N/30E-27K01	461352	1190230	PSCO	116	95	111	10-17-60	480	7.9	19.0	--	2.7	--	22
							09-06-88	620	7.9	--	5.0	7.9	<.01	27
09N/30E-34D01	461335	1190311	PSCO	100	99	100.	09-08-86	750	--	--	--	9.6	--	--

Table 13.--*Concentrations of nitrate, ammonia, chloride, and dissolved oxygen and values of specific conductance, pH, and temperature in ground water in the eastern part of Pasco Basin, Washington--Continued*

Well number	Latitude	Longitude	Primary geohydrologic unit	Well depth (feet)	Open intervals of well (feet below land surface): Top	Open intervals of well (feet below land surface): Bottom	Sampling date	Specific conductance (µS/cm)	pH (units)	Temperature (degrees Celsius)	Dissolved oxygen (mg/L)	Nitrate as nitrogen (mg/L)	Ammonia as nitrogen (mg/L)	Chloride (mg/L)
							Franklin County, Wash.--Continued							
09N/31E-04N01	461705	1185700	SDLM	343			04-28-42	480	--	--	--	<0.10	--	9.5
							10-17-60	464	8.1	15.0	--	<.10	--	8.0
09N/31E-07Q03	461620	1185843	SDLM	425	196	425	09-24-86	558	--	--	--	<.10	--	--
							02-25-88	584	8.2	19.0	1.3	<.10	0.01	20
09N/31E-14G01	461546	1185349	SDLM	355	131	355	09-12-86	470	--	--	--	6.3	--	--
							04-27-88	450	7.8	18.0	7.3	6.4	<.01	9.1
09N/31E-19G01	461500	1185848	SDLM	558	158	558	09-24-86	433	--	--	--	<.10	--	--
							03-04-87	421	--	--	--	<.10	--	--
09N/31E-20C01	461513	1185746	SDLM	500	133	500	03-04-87	738	--	--	--	21	--	--
10N/28E-12F01	462210	1191508	RGLD	196	188	196	03-10-83	415	7.9	16.5	0.8	<.10	--	3.4
							09-27-86	429	--	--	--	<.10	--	--
							12-10-86	--	--	--	--	<.10	--	--
							01-14-87	--	--	--	--	<.10	--	--
							02-05-87	--	--	--	--	<.10	--	--
							03-04-87	--	--	--	--	<.10	--	--
							05-08-87	--	--	--	--	<.10	--	--
							07-01-87	--	--	--	--	<.10	--	--
							02-23-88	433	8.1	17.0	1.3	.10	.01	5.0
10N/28E-12J01	462152	1191435	MDRG	179	179	179	09-08-86	500	8.0	19.5	<0.2	.11	.04	16
10N/28E-12K01	462150	1191451	LRRG	192	192	192	09-09-86	489	--	--	--	<.10	--	--
10N/29E-02Q01	462227	1190837	SDLM	386	--	--	09-15-88	450	7.9	19.0	<0.2	.14	<.01	7.9
10N/29E-02Q02	462231	1190825	UPRG	66	61	66	02-23-88	--	--	--	--	8.6	.03	50

Table 13.--*Concentrations of nitrate, ammonia, chloride, and dissolved oxygen and values of specific conductance, pH, and temperature in ground water in the eastern part of Pasco Basin, Washington--Continued*

Well number	Latitude	Longitude	Primary geohydrologic unit	Well depth (feet)	Open intervals of well (feet below land surface) Top	Open intervals of well (feet below land surface) Bottom	Sampling date	Specific conductance (µS/cm)	pH (units)	Temperature (degrees Celsius)	Dissolved oxygen (mg/L)	Nitrate as nitrogen (mg/L)	Ammonia as nitrogen (mg/L)	Chloride (mg/L)
							Franklin County, Wash.--Continued							
10N/29E-03P01	462225	1191006	UPRG	75	62	72	09-27-86	442	--	--	--	0.80	--	--
					75	75	02-23-88	438	8.2	15.0	0.3	.86	<0.01	11
							09-13-88	435	8.0	17.0	<0.2	.65	<.01	11
10N/29E-03R01	462225	1190934	UPRG	95	90	90	09-27-86	820	--	--	--	20	--	--
							02-22-88	810	8.0	14.5	3.8	17	<.01	50
							09-12-88	780	7.8	14.5	4.0	13	<.01	48
10N/29E-03R02	462233	1190925	UPRG	110	90	110	09-14-88	823	7.8	15.0	7.4	14	<.01	21
10N/29E-04N01	462225	1191133	UPRG	110	88	110	09-12-86	788	--	--	--	8.4	--	--
10N/29E-06H01	462256	1191312	SDLM	466	466	466	09-12-86	740	--	--	--	<.10	--	--
							02-24-88	780	7.9	19.5	2.0	<.10	.04	8.8
10N/29E-08R01	462130	1191150		50	--	--	07-07-89	950	--	--	--	9.7	--	25
10N/29E-09Q01	462136	1191102	MDRG	147	147	147	09-27-86	621	--	--	--	6.3	--	--
							09-09-88	710	7.7	19.0	10.8	4.3	<.01	27
10N/29E-09R01	462133	1191041	SDLM	388	250.5	388	09-14-88	425	8.0	20.0	0.2	.11	<.01	6.2
10N/29E-10B01	462218	1190951	UPRG	55.5	35	55.5	09-14-88	924	7.6	16.0	0.3	16	<.01	54
10N/29E-10C01	462218	1191007	SDLM	397	207	397	09-15-88	496	8.1	20.0	2.5	4.3	<.01	12
10N/29E-10D01	462218	1191025	SDLM	618	290.6	340	12-00-53	409	7.8	--	--	<.10	--	12
					391.2	618	09-12-86	560	--	--	--	7.2	--	--
							04-15-88	560	7.9	19.0	5.9	9.0	<.01	16
10N/29E-10N01	462138	1191017	UPRG	45	42	45	07-17-88	--	--	--	--	2.5	<.01	22
							09-07-88	615	8.0	15.5	--	2.5	<.01	22
							11-17-88	615	7.9	13.0	--	2.5	--	22

Table 13.--*Concentrations of nitrate, ammonia, chloride, and dissolved oxygen and values of specific conductance, pH, and temperature in ground water in the eastern part of Pasco Basin, Washington--Continued*

Well number	Latitude	Longitude	Primary geohydrologic unit	Well depth (feet)	Open intervals of well (feet below land surface): Top	Open intervals of well (feet below land surface): Bottom	Sampling date	Specific conductance (μS/cm)	pH (units)	Temperature (degrees Celsius)	Dissolved oxygen (mg/L)	Nitrate as nitrogen (mg/L)	Ammonia as nitrogen (mg/L)	Chloride (mg/L)
							Franklin County, Wash.--Continued							
10N/29E-10N02	462137	1191017	PSCO	29	26	29	07-17-88	--	--	--	--	5.1	0.09	26
							09-07-88	850	7.6	15.5	--	5.3	.03	25
							11-17-88	845	7.6	13.0	--	5.2	--	26
10N/29E-10N03	462136	1191017	PSCO	22.5	19.5	22.5	07-17-88	--	--	--	--	21	.02	33
							09-07-88	1,140	7.4	15.0	--	20	.09	33
							11-17-88	1,150	7.4	13.0	--	21	--	35
10N/29E-10Q02	462132	1190957	RGLD	168	--	--	09-27-86	630	--	--	--	14	--	--
							02-24-88	625	7.8	14.0	--	12	<.01	32
							09-13-88	624	7.7	18.0	--	10	<.01	32
10N/29E-11C01	462220	1190855	UPRG	57	47	57	09-14-88	878	7.8	15.0	6.5	6.8	<.01	36
10N/29E-11N01	462135	1190909	UPRG	50	--	--	07-07-89	455	--	--	--	2.4	--	11
							02-26-88	422	8.1	15.0	1.4	1.1	<.01	10
10N/29E-12Q01	462134	1190718	MDRG	126	126	126	09-11-86	665	--	--	--	8.5	--	--
10N/29E-14D01	462126	1190909	UPRG	48	48	48	09-27-86	429	--	--	--	0.50	--	--
10N/29E-14R01	462038	1190805		50	--	--	07-08-89	440	--	18.0	--	2.0	--	8.7
10N/29E-15D01	462128	1191033	UPRG	40	--	--	07-09-89	498	--	14.5	--	1.3	--	10
10N/29E-15M01	462102	1191031	SDLM	350	195	350	09-27-86	--	--	--	--	1.8	--	--
							04-15-88	550	7.7	20.0	1.9	2.1	<.01	13
							09-10-88	525	7.9	17.5	1.1	1.6	<.01	13
10N/29E-16A01	462127	1191037	MDRG	144	144	144	09-10-86	808	--	--	--	7.2	--	--
10N/29E-16A02	462121	1191038	MDRG	102	102	102	09-11-86	785	--	--	--	14	--	--
10N/29E-25B01	461944	1190718	PSCO	90	90	90	09-11-86	612	--	--	--	4.8	--	--

Table 13.--*Concentrations of nitrate, ammonia, chloride, and dissolved oxygen and values of specific conductance, pH, and temperature in ground water in the eastern part of Pasco Basin, Washington--Continued*

Well number	Lati-tude	Longi-tude	Primary geo-hydro-logic unit	Well depth (feet)	Open intervals of well (feet below land surface) Top	Bottom	Sampling date	Spe-cific con-duc-(μS/cm)	pH (units)	Tempe-rature (degrees Celsius)	Dis-solved oxy-gen (mg/L)	Nitrate as nitrogen (mg/L)	Am-monia as nitrogen (mg/L)	Chlo-ride (mg/L)
							Franklin County, Wash.--Continued							
10N/29E-25G01	461929	1190714	MDRG	81	53	81	07-26-83	705	7.6	16.0	8.1	6.9	--	37
							03-23-87	--	--	--	--	8.5	--	--
							02-24-88	695	7.6	17.0	4.8	8.0	<0.01	33
10N/29E-26D01	461943	1190918	SDLM	274	151	274	09-10-88	730	7.9	17.5	6.7	15	.04	38
10N/29E-29L01	461913	1191241	MDRG	218	210	218	09-10-86	840	--	--	--	23	--	--
							02-23-88	775	7.8	17.5	5.6	19	<.10	34
10N/29E-33P01	461806	1191129	SDLM	325	267	325	09-11-86	370	--	--	--	<.10	--	--
10N/30E-03J01	462238	1190159	SDLM	230	70	230	08-27-82	690	8.0	18.0	--	9.2	--	39
							03-11-83	645	7.7	15.5	--	9.3	--	39
							07-21-83	660	8.0	18.5	9.7	9.5	--	38
							09-10-86	670	--	--	--	11	--	--
							02-26-88	639	8.0	15.5	7.8	9.9	<.01	33
10N/30E-04N01	462227	1190403	SDLM	121	81	121	09-10-86	708	--	--	--	14	--	--
10N/30E-05B01	462314	1190449	DUNE	27	5	27	07-08-89	645	--	14.5	--	6.3	--	16
10N/30E-05N01	462221	1190526	PSCO	49.5	--	--	07-08-89	630	--	--	--	4.2	--	18
10N/30E-09M01	462155	1190401	SDLM	180	110	180	09-10-86	620	--	--	--	9.5	--	--
10N/30E-11Q01	462139	1190058	SDLM	286.5	163.5	286.5	09-11-86	560	--	--	--	19	--	--
							02-26-88	550	7.8	18.0	8.7	19	<.01	15
							04-13-88	540	7.9	19.5	8.5	19	<.01	15
10N/30E-16P01D1	462041	1190347	PSCO	111	101	107	09-08-88	770	7.8	17.5	9.0	31	.02	34
					111	111								
10N/30E-19J01	462008	1190534	MDRG	122	117	122	04-16-88	610	7.9	14.5	--	9.2	.02	34

Table 13.--*Concentrations of nitrate, ammonia, chloride, and dissolved oxygen and values of specific conductance, pH, and temperature in ground water in the eastern part of Pasco Basin, Washington--Continued*

Well number	Lati-tude	Longi-tude	Primary geo-hydro-logic unit	Well depth (feet)	Open intervals of well (feet below land surface) Top	Bottom	Sampling date	Spe-cific con-duc-(µS/cm)	pH (units)	Tempe-rature (degrees Celsius)	Dis-solved oxy-gen (mg/L)	Nitrate as nitrogen (mg/L)	Am-monia as nitrogen (mg/L)	Chlo-ride (mg/L)
							Franklin County, Wash.--Continued							
10N/30E-21N01	461945	1190408	SDLM	366	211.7	366	09-11-86	443	--	--	--	1.2	--	--
							01-13-87	--	--	--	--	.40	--	--
							02-03-87	--	--	--	--	.40	--	--
							02-2887	440	--	--	--	1.3	--	--
							05-12-87	--	--	--	--	1.1	--	--
							07-06-87	--	--	--	--	.90	--	--
							09-18-87	--	--	--	--	.90	--	--
							02-26-88	450	8.1	18.5	1.1	1.6	<0.01	9.5
							09-08-88	435	8.2	20.0	0.6	.73	.01	9.3
10N/30E-21R01	461946	1190300	UPRG	50	5	50	07-09-89	590	--	--	--	1.9	--	11
10N/30E-22N01	461952	1190249	PSCO	16	--	--	11-19-88	--	--	--	--	3.6	--	9.6
10N/30E-27C01	461946	1190230	PSCO	13.3	--	--	11-18-88	1,000	7.5	14.0	--	4.4	--	8.7
10N/30E-28G01	461925	1190335	PSCO	12	--	--	11-19-88	--	7.4	12.5	--	24	--	74
10N/30E-33N04	461801	1190414	MDRG	228	218	228	09-11-86	665	--	--	--	18	--	--
							12-09-86	--	--	--	--	16	--	--
							01-13-87	--	--	--	--	16	--	--
							02-03-87	--	--	--	--	15	--	--
							02-28-87	642	--	--	--	16	--	--
							05-08-87	--	--	--	--	18	--	--
							07-01-87	--	--	--	--	20	--	--
							09-18-87	--	--	--	--	18	--	--
							02-26-88	665	7.7	17.5	6.6	16	<.01	39
							04-13-88	670	7.7	18.5	8.0	21	<.01	42
10N/30E-35R01	461807	1190036	PSCO	126.7	122	126.7	03-10-83	645	7.8	17.0	8.2	13	--	36
10N/31E-08A02	462209	1185705	PSCO	147	125.5	147	09-10-88	650	7.9	16.0	7.5	8.8	<.01	31

Table 13.--*Concentrations of nitrate, ammonia, chloride, and dissolved oxygen and values of specific conductance, pH, and temperature in ground water in the eastern part of Pasco Basin, Washington--Continued*

Well number	Latitude	Longitude	Primary geohydrologic unit	Well depth (feet)	Open intervals of well (feet below land surface) Top	Bottom	Sampling date	Specific conductance (µS/cm)	pH (units)	Temperature (degrees Celsius)	Dissolved oxygen (mg/L)	Nitrate as nitrogen (mg/L)	Ammonia as nitrogen (mg/L)	Chloride (mg/L)
							Franklin County, Wash.--Continued							
10N/31E-08E01	462201	1185815	SDLM	400	--	--	09-10-86	770	--	--	--	15	--	--
							02-27-88	712	7.8	15.0	9.2	15	0.03	33
10N/31E-09D01	462219	1185701	WNPM	310	160	274	07-21-83	622	8.0	17.5	7.2	5.6	--	31
							02-27-88	691	8.0	9.5	8.8	9.8	.02	34
10N/31E-32D01D1	461844	1185813	SDLM	275	--	--	10-01-86	470	--	--	--	3.3	--	--
10N/31E-32L02	461815	1185750	SDLM	350	310	350	08-30-82	415	8.0	19.5	2.4	1.6	--	9.9
							03-09-83	405	7.8	18.5	2.2	1.6	--	9.5
							07-20-83	412	7.8	19.0	1.7	1.7	--	11
							10-01-86	--	--	--	--	4.0	--	--
							03-23-87	418	--	--	--	2.1	--	--
							02-25-88	438	7.9	16.5	6.2	4.5	<.01	8.2
10N/31E-32L03	461824	1185747	SDLM	290	260	290	09-09-86	502	--	--	--	4.7	--	--
10N/31E-32M01	461822	1185812	SDLM	165	135	165	09-10-86	889	--	--	--	9.8	--	--
							02-25-88	760	7.8	15.0	8.0	9.3	<.01	62
10N/31E-32M02	461815	1185803	WNPM	400	186	280	09-09-86	459	--	--	--	1.3	--	--
					360	400	04-19-88	455	8.2	17.5	0.6	1.3	.01	15
10N/31E-32N03	461811	1185801	SDLM	295	262	295	09-09-86	536	--	--	--	13	--	--
							09-10-88	590	7.9	16.5	7.8	17	<.01	38
11N/28E-13C01	462640	1191510	MDRG	140	140	140	02-19-88	1,160	7.6	16.5	3.8	6.2	.02	81

Table 13.--*Concentrations of nitrate, ammonia, chloride, and dissolved oxygen and values of specific conductance, pH, and temperature in ground water in the eastern part of Pasco Basin, Washington--Continued*

Well number	Latitude	Longitude	Primary geohydrologic unit	Well depth (feet)	Open intervals of well (feet below land surface) Top	Open intervals of well (feet below land surface) Bottom	Sampling date	Specific conductance (µS/cm)	pH (units)	Temperature (degrees Celsius)	Dissolved oxygen (mg/L)	Nitrate as nitrogen (mg/L)	Ammonia as nitrogen (mg/L)	Chloride (mg/L)
							Franklin County, Wash.--Continued							
11N/28E-13C02	462639	1191510	MDRG	105	105	105	09-06-86	--	--	--	--	7.1	--	--
							01-14-87	--	--	--	--	5.7	--	--
							02-04-87	--	--	--	--	6.9	--	--
							03-05-87	1,090	--	--	--	7.7	--	--
							05-08-87	--	--	--	--	4.8	--	--
							07-01-87	--	--	--	--	6.2	--	--
							09-14-87	--	--	--	--	6.0	--	--
							02-19-88	1,220	7.5	11.5	2.8	9.0	0.03	--
11N/29E-01A01	462822	1190650	UPRG	40	36	40	09-05-86	692	--	--	--	7.9	--	--
11N/29E-03H01	462813	1190908	SDLM	552	395	552	05-23-83	296	8.1	22.0	0.1	<.10	--	6.4
							07-25-83	286	7.8	21.5	0.1	<.10	--	6.4
							03-05-87	282	--	--	--	<.10	--	--
							02-22-88	283	8.3	15.0	0.2	<.10	<.01	6.6
11N/29E-05D01	462830	1191254	UPRG	50	--	--	07-08-89	605	--	--	--	4.2	--	10
11N/29E-05R01	462740	1191150	SDLM	1,000	575	1,000	09-09-88	450	8.7	30.0	<0.2	<.10	.02	43
11N/29E-05R02	462736	1191142	UPRG	105	--	--	05-24-89	612	8.0	--	--	5.0	<.01	18
11N/29E-06C01	462832	1191337	UPRG	66	57	66	09-09-88	720	7.5	23.0	5.0	3.2	.01	13
11N/29E-07M01	462704	1191413	MDRG	590	540	550	09-05-86	478	--	--	--	<.10	--	--
					560	590								
11N/29E-10C01	462734	1190945	UPRG	46	43	46	07-16-88	--	--	--	--	4.7	<.01	46
							09-08-88	860	7.6	13.0	--	4.5	.02	48
							11-18-88	860	7.7	--	--	4.5	--	48
11N/29E-10C02	462735	1190945	UPRG	27	24	27	07-16-88	--	--	--	--	23	.04	330
							09-08-88	2,120	7.5	15.0	--	22	.05	320
							11-18-88	2,100	7.5	13.0	--	23	--	320

Table 13.--*Concentrations of nitrate, ammonia, chloride, and dissolved oxygen and values of specific conductance, pH, and temperature in ground water in the eastern part of Pasco Basin, Washington--Continued*

Well number	Lati-tude	Longi-tude	Primary geo-hydro-logic unit	Well depth (feet)	Open intervals of well (feet below land surface) Top	Bottom	Sampling date	Spe-cific con-duc- (µS/cm)	pH (units)	Tempe-rature (degrees Celsius)	Dis-solved oxy-gen (mg/L)	Nitrate as nitrogen (mg/L)	Am-monia as nitrogen (mg/L)	Chlo-ride (mg/L)
							Franklin County, Wash.--Continued							
11N/29E-10C03	462733	1190945	UPRG	14	11	14	07-16-88	--	--	--	--	25	<0.01	51
							09-08-88	1,360	7.4	--	--	27	.03	49
							11-18-88	1,400	7.4	13.5	--	26	--	44
11N/29E-10C04	462736	1190945	UPRG	10	8	10	11-18-88	1,350	7.4	14.5	--	29	--	32
11N/29E-12E01	462712	1190752	UPRG	105	65	85	09-05-86	778	--	--	--	4.6	--	--
					105	105	--	--	--	--	--	--	--	--
11N/29E-13C01	462639	1190728	UPRG	30	--	--	09-05-86	852	--	--	--	1.3	--	--
							02-18-88	808	7.7	12.0	6.4	1.3	<.01	23
11N/29E-14R01	462552	1190758	UPRG	50	--	--	07-08-89	835	--	--	--	7.8	--	11
11N/29E-16N01	462551	1191142	UPRG	50	--	--	07-08-89	1,270	--	--	--	<.10	--	27
11N/29E-19R01	462500	1191302	UPRG	50	--	--	04-15-88	2,200	7.7	15.5	--	12	.01	210
11N/29E-20N01	462501	1191251	SDLM	936	612	667	04-12-88	420	8.5	25.0	<0.2	<.10	.31	22
					669	936								
11N/29E-20N02	462502	1191252	UPRG	75	50	75	02-19-88	880	7.8	14.0	6.8	6.9	<.01	50
11N/29E-23C01	462550	1190836	SDLM	519	330	519	09-10-88	420	8.3	20.0	2.8	1.5	<.01	15
11N/29E-23N01	462507	1190857	MDRG	327	322	327	09-09-88	620	7.6	18.0	9.9	20	<.01	45
11N/29E-23N02	462507	1190901	UPRG	97.5	84.5	97.5	09-09-88	510	7.7	17.0	7.8	5.3	<.01	23
11N/29E-28R01	462414	1191040	UPRG	87	87	87	09-05-86	853	--	--	--	14	--	--
							03-03-87	843	--	--	--	15	--	--

Table 13.--*Concentrations of nitrate, ammonia, chloride, and dissolved oxygen and values of specific conductance, pH, and temperature in ground water in the eastern part of Pasco Basin, Washington--Continued*

Well number	Latitude	Longitude	Primary geohydrologic unit	Well depth (feet)	Open intervals of well (feet below land surface) Top	Open intervals of well (feet below land surface) Bottom	Sampling date	Specific conductance (µS/cm)	pH (units)	Temperature (degrees Celsius)	Dissolved oxygen (mg/L)	Nitrate as nitrogen (mg/L)	Ammonia as nitrogen (mg/L)	Chloride (mg/L)
							Franklin County, Wash.--Continued							
11N/29E-31N01	462321	1191415	SDLM	746	726	746	08-30-82	435	7.8	24.5	0.1	<0.10	--	19
							03-09-83	430	7.9	24.0	0.4	<.10	--	19
							07-25-83	423	7.5	24.5	0.1	.22	--	20
							09-27-86	--	--	--	--	<.10	--	--
11N/29E-32R01	462315	1191151	MDRG	363.5	352.5	363.5	02-22-88	1,040	7.7	19.5	1.1	12	0.02	14
11N/29E-34D02	462359	1191028	UPRG	78	--	--	09-08-86	635	--	--	--	1.1	--	--
11N/29E-34J02	462339	1190920	MDRG	211	211	211	02-18-88	580	7.8	15.0	6.1	10	<.01	37
							06-21-88	583	7.9	18.5	--	11	.03	35
11N/29E-34R02	462316	1190937	UPRG	160	150	160	09-08-86	608	--	--	--	6.7	--	--
11N/30E-02R01	462747	1190040	PSCO	124	124	124	03-10-83	555	7.8	14.5	8.8	4.0	--	23
							09-04-86	609	--	--	--	4.7	--	--
11N/30E-03L01	462754	1190233	SDLM	105	45	105	09-04-86	723	--	--	--	7.6	--	--
11N/30E-05N02	462737	1190524	SDLM	79.5	54.5	79.5	09-04-86	1,420	--	--	--	50	--	--
							02-25-87	--	--	--	--	50	--	--
							02-18-88	1,490	7.7	15.5	10.7	50	.02	110
11N/30E-08C01	462734	1190454	SDLM	52	23.7	52	04-12-88	880	7.7	13.5	--	9.0	<.01	25
11N/30E-10B01	462734	1190208	SDLM	115	20	115	09-06-86	582	--	--	--	5.4	--	--
11N/30E-11A01	462727	1190029	SDLM	290	20	290	09-04-86	833	--	--	--	8.6	--	--
11N/30E-11C01	462735	1190119		614	40	614	12-14-70	843	7.7	14.0	--	7.5	--	51

Table 13.--*Concentrations of nitrate, ammonia, chloride, and dissolved oxygen and values of specific conductance, pH, and temperature in ground water in the eastern part of Pasco Basin, Washington--Continued*

Well number	Lati-tude	Longi-tude	Primary geo-hydro-logic unit	Well depth (feet)	Open intervals of well (feet below land surface) Top	Bottom	Sampling date	Spe-cific con-duc-(μS/cm)	pH (units)	Tempe-rature (degrees Celsius)	Dis-solved oxy-gen (mg/L)	Nitrate as nitrogen (mg/L)	Am-monia as nitrogen (mg/L)	Chlo-ride (mg/L)
							Franklin County, Wash.--Continued							
11N/30E-12D01	462731	1190015	WNPM	410	18.5	410	08-30-82	585	8.2	17.5	0.8	1.7	--	31
							03-09-83	--	8.3	16.5	2.6	1.9	--	34
							07-21-83	588	8.3	17.5	0.6	1.6	--	29
							03-06-87	498	--	--	--	1.9	--	--
11N/30E-14K01	462615	1190054	SDLM	265	225	265	09-05-86	800	--	--	--	8.3	--	--
11N/30E-15B01	462643	1190202	PSCO	163	163	163	09-05-86	580	--	--	--	2.1	--	--
11N/30E-16C01	462642	1190343	SDLM	320	--	--	09-05-86	--	--	--	--	16	--	--
11N/30E-17B01	462643	1190440	SDLM	100	26	100	09-05-86	1,420	--	--	--	20	--	--
							02-24-87	1,250	--	--	--	19	--	--
11N/30E-25H01	462435	1185926	PSCO	133	113	133	09-10-88	725	7.8	15.5	7.7	8.2	<0.01	29
11N/30E-29C01	462450	1190501	MDRG	220	--	--	09-08-86	500	--	--	--	1.8	--	--
							02-17-88	490	8.0	13.5	3.3	2.0	<.02	13
11N/30E-34H01	462345	1190151	SDLM	105	20	105	09-11-86	1,140	--	--	--	9.0	--	--
							03-03-87	757	--	--	--	24	--	--
11N/30E-35J02	462341	1190031	SDLM	205	40	205	03-03-87	--	--	--	--	21	--	--
11N/30E-36M01	462336	1190024	SDLM	237	--	--	05-17-83	830	7.8	16.5	8.7	8.1	--	55
							07-22-83	838	7.8	17.0	8.5	13	--	54
							02-20-88	960	7.9	13.0	8.4	21	<.01	59
11N/31E-04P01	462737	1185625	WNPM	1,310	600	1,310	08-30-82	375	8.2	21.5	3.4	3.4	--	8.7
							05-18-83	380	7.8	21.0	3.3	4.1	--	8.0
							07-21-83	375	8.0	22.0	3.2	3.4	--	8.6
							09-13-88	360	8.0	21.5	3.0	3.0	.05	8.0

Table 13.--*Concentrations of nitrate, ammonia, chloride, and dissolved oxygen and values of specific conductance, pH, and temperature in ground water in the eastern part of Pasco Basin, Washington--Continued*

Well number	Latitude	Longitude	Primary geohydrologic unit	Well depth (feet)	Open intervals of well (feet below land surface): Top	Open intervals of well (feet below land surface): Bottom	Sampling date	Specific conductance (µS/cm)	pH (units)	Temperature (degrees Celsius)	Dissolved oxygen (mg/L)	Nitrate as nitrogen (mg/L)	Ammonia as nitrogen (mg/L)	Chloride (mg/L)
						Franklin County, Wash.--Continued								
11N/31E-14B01	462631	1185338	WNPM	621	125	445	04-26-88	415	7.8	18.5	6.2	6.5	<0.01	9.0
					445	621								
11N/31E-15G01	462621	1185449	WNPM	450	73	460	04-12-88	390	8.0	18.0	6.7	5.9	<.01	9.1
11N/31E-30E01	462438	1185900	SDLM	410	150	410	09-06-86	--	--	--	--	6.5	--	--
11N/31E-31H01	462343	1185817	PSCO	122	107	122	09-06-86	--	--	--	--	12	--	--
							04-13-88	805	7.8	17.5	7.4	17	<.01	42
11N/31E-33B01D1	462357	1185617	WNPM	700	327	425	04-13-88	398	8.0	22.0	3.4	4.8	<.01	8.6
				425	700									
12N/28E-12H01	463234	1191411	SDLM	450	300	450	04-27-42	459	--	--	--	<.10	--	9.5
							10-17-60	456	8.2	19.0	--	<.10	--	9.5
							09-09-86	463	--	--	--	<.10	--	--
							02-20-88	465	8.4	17.0	0.2	<.10	.02	12
12N/28E-23H01D1	463100	1191535	SDLM	413	242	413	08-30-82	395	8.2	18.5	0.2	<.10	--	19
							03-09-83	378	8.2	18.5	0.1	<.10	--	18
							07-26-83	386	8.1	19.0	0.2	<.10	--	20
							09-12-86	398	--	--	--	<.10	--	--
12N/28E-24F01S	463050	1191505		--	--	--	03-16-58	1,130	7.9	15.5	--	1.2	--	86
							09-12-86	1,040	--	--	--	8.4	--	--
							02-21-88	900	7.7	15.5	9.0	5.9	<.01	29
							09-12-88	847	8.0	15.5	--	5.6	<.01	26
12N/28E-25M01	462943	1191522	MDRG	95	95	95	09-12-88	340	8.1	15.0	<0.2	.26	<.01	7.8

Table 13.--*Concentrations of nitrate, ammonia, chloride, and dissolved oxygen and values of specific conductance, pH, and temperature in ground water in the eastern part of Pasco Basin, Washington--Continued*

Well number	Latitude	Longitude	Primary geohydrologic unit	Well depth (feet)	Open intervals of well (feet below land surface) Top	Bottom	Sampling date	Specific conductance (μS/cm)	pH (units)	Temperature (degrees Celsius)	Dissolved oxygen (mg/L)	Nitrate as nitrogen (mg/L)	Ammonia as nitrogen (mg/L)	Chloride (mg/L)
							Franklin County, Wash.--Continued							
12N/29E-01A01	463337	1190645	SDLM	313	128.2	313	09-09-86	1,020	--	--	--	15	--	--
							02-04-87	--	--	--	--	14	--	--
							02-27-87	--	--	--	--	14	--	--
							05-08-87	--	--	--	--	15	--	--
							07-01-87	--	--	--	--	15	--	--
							09-14-87	--	--	--	--	14	--	--
							02-17-88	1,000	7.9	17.5	3.5	13	<0.01	59
							09-12-88	990	7.8	16.5	3.8	14	<.01	60
12N/29E-01E01	463319	1190750	UPRG	50.3	5.3	50.3	02-21-88	1,260	7.6	22.5	4.0	6.5	.01	47
12N/29E-04N01	463258	1191138	SDLM	170	129.5	170	09-12-88	1,950	7.7	17.5	5.4	50	.04	110
12N/29E-11M01	463222	1190905	SDLM	212	188	212	09-24-86	313	--	--	--	<0.10	--	--
							03-03-87	309	--	--	--	<.10	--	--
							09-12-88	305	8.2	17.5	<0.2	<.10	.02	5.5
12N/29E-17K01	463124	1191203	SDLM	478	416	478	09-12-88	360	8.4	23.0	<0.2	<.10	<.01	8.5
12N/29E-25D01	463016	1190749	UPRG	50.5	5.5	50.5	07-08-89	966	--	--	--	9.9	--	29
12N/29E-28F01	462955	1191110	SDLM	699.8	455.5	699.8	01-01-53	282	8.0	20.0	--	<.10	--	11
							11-02-56	310	7.4	--	--	.27	--	12
12N/29E-34B01D1	462924	1190933		997	--	--	03-11-83	370	8.3	12.5	3.4	<.10	--	14
					525	535								
12N/29E-34K01	462859	1190943		971	417	971	09-26-86	382	--	--	--	<.10	--	--
12N/30E-04D01	463338	1190357	SDLM	290	63	290	09-26-86	1,110	--	--	--	12	--	--
							02-27-87	150	--	--	--	12	--	--
12N/30E-04L01	463308	1190343	SDLM	250	60.9	250	09-10-86	1,090	--	--	--	7.6	--	--

Table 13.--*Concentrations of nitrate, ammonia, chloride, and dissolved oxygen and values of specific conductance, pH, and temperature in ground water in the eastern part of Pasco Basin, Washington--Continued*

Well number	Lati-tude	Longi-tude	Primary geo-hydro-logic unit	Well depth (feet)	Open intervals of well (feet below land surface): Top	Open intervals of well (feet below land surface): Bottom	Sampling date	Spe-cific con-duc-(µS/cm)	pH (units)	Tempe-rature (degrees Celsius)	Dis-solved oxy-gen (mg/L)	Nitrate as nitrogen (mg/L)	Am-monia as nitrogen (mg/L)	Chlo-ride (mg/L)
							Franklin County, Wash.--Continued							
12N/30E-05B01	463341	1190428	SDLM	457.5	146.3	457.5	03-06-56	381	7.8	--	--	2.7	--	21
							09-01-82	745	7.8	17.5	7.8	8.2	--	54
							03-10-83	735	7.6	17.0	8.4	7.9	--	51
							07-22-83	735	7.7	17.5	7.5	7.6	--	53
							09-26-86	750	--	--	--	8.8	--	--
							02-27-87	753	--	--	--	9.0	--	--
							02-23-88	748	7.9	15.5	7.7	9.1	<0.01	50
12N/30E-12E01	463231	1190015	SDLM	121	120	121	09-13-88	560	8.6	14.0	--	15	<.01	33
12N/30E-16Q01	463117	1190315	SDLM	56.9	11.5	56.9	09-11-86	960	--	--	--	14	--	--
12N/30E-21G01	463044	1190330	SDLM	211	17	211	09-11-86	1,090	--	--	--	11	--	--
12N/30E-30L01	462946	1190616	SDLM	219	175	219	09-26-86	595	--	--	--	3.6	--	--
							02-23-88	660	7.8	15.0	5.0	5.4	<.01	23
12N/30E-33B01	462916	1190319	SDLM	374	20	374	09-11-86	1,140	--	--	--	14	--	--
							02-27-87	1,490	--	--	--	17	--	--
							02-18-88	1,200	7.6	14.5	5.9	13	.02	160.
12N/30E-34N01	462832	1190241	SDLM	328	--	--	09-04-86	970	--	--	--	17	--	--
							02-26-87	775	--	--	--	20	--	--
12N/31E-10M01	463222	1185534	WNPM	961	118	961	09-13-88	372	8.0	22.5	--	.94	.01	8.5
13N/28E-03N01	463806	1191809	UPRG	51	5.5	50.5	04-15-88	595	7.8	18.0	--	2.8	<.01	25
13N/28E-09L01	463729	1191852	SDLM	810	682	810	02-27-88	332	8.6	25.0	0.3	<.10	.03	13
13N/28E-11E01	463751	1191636	SDLM	727	488	727	02-26-88	410	7.9	22.0	0.2	1.8	<.01	11

Table 13.--*Concentrations of nitrate, ammonia, chloride, and dissolved oxygen and values of specific conductance, pH, and temperature in ground water in the eastern part of Pasco Basin, Washington--Continued*

Well number	Latitude	Longitude	Primary geohydrologic unit	Well depth (feet)	Open intervals of well (feet below land surface) Top	Bottom	Sampling date	Specific conductance (µS/cm)	pH (units)	Temperature (degrees Celsius)	Dissolved oxygen (mg/L)	Nitrate as nitrogen (mg/L)	Ammonia as nitrogen (mg/L)	Chloride (mg/L)
							Franklin County, Wash.--Continued							
13N/28E-13N01	463622	1191536	WNPM	1,119	1,029	1,119	10-00-54	388	8.6	--	--	<0.10	--	15
							11-10-70	386	8.6	27.5	--	<.10	--	14
							03-14-83	375	8.4	28.5	3.8	.22	--	14
							07-26-83	382	8.4	29.5	--	<.10	--	15
							04-14-88	410	8.7	--	--	<.10	<0.01	13
13N/28E-21J01	463543	1191822	UPRG	46	43	46	11-19-88	1,600	7.8	13.5	--	39	--	160
13N/28E-21J02	463544	1191822	UPRG	17	14	17	08-24-88	1,180	7.7	--	--	14	.03	40
							09-09-88	1,210	7.9	--	--	7.0	<.01	31
							11-19-88	1,090	7.8	13.5	--	5.4	--	24
13N/28E-21J03	463545	1191822	UPRG	27	24	27	08-24-88	1,680	7.4	--	--	35	.02	89
							09-09-88	1,710	7.5	17.5	--	36	<.01	93
							11-19-88	1,760	7.6	13.0	--	35	--	99
13N/28E-21J04	463542	1191822	UPRG	8	4	8	08-24-88	880	7.5	--	--	9.3	.03	11
13N/29E-03C01	463858	1191006	SDLM	260	259	260	09-03-86	1,010	--	--	--	32	--	--
							03-02-87	--	--	--	--	34	--	--
							09-14-88	975	7.3	17.0	3.8	26	<.01	42
13N/29E-04A01	463850	1191044	LRRG	294	294	294	02-26-88	535	7.6	15.5	3.1	5.2	<.01	15
							09-14-88	540	7.5	18.5	3.4	4.6	<.01	14
13N/29E-08H01	463747	1191202	SDLM	453	412	453	09-01-82	320	8.0	21.0	<0.2	<.10	--	10
							03-10-83	341	7.9	20.0	1.5	<.10	--	12
							07-22-83	435	7.9	20.5	<0.2	<.10	--	12
							09-03-86	448	--	--	--	<.10	--	--
							02-28-87	--	--	--	--	<.10	--	--
13N/29E-12L01	463739	1190725	SDLM	225	80	100	04-14-88	760	7.8	14.5	0.3	.15	.27	69
					120	140								

Table 13.--*Concentrations of nitrate, ammonia, chloride, and dissolved oxygen and values of specific conductance, pH, and temperature in ground water in the eastern part of Pasco Basin, Washington--Continued*

Well number	Lati-tude	Longi-tude	Primary geo-hydro-logic unit	Well depth (feet)	Open intervals of well (feet below land surface) Top	Bottom	Sampling date	Spe-cific con-duc-(µS/cm)	pH (units)	Tempe-rature (degrees Celsius)	Dis-solved oxy-gen (mg/L)	Nitrate as nitrogen (mg/L)	Am-monia as nitrogen (mg/L)	Chlo-ride (mg/L)
						Franklin County, Wash.--Continued								
13N/29E-16H01	463658	1191049	UPRG	104	76	104	02-26-88	860	7.9	15.0	9.3	4.7	<0.01	72
13N/29E-23M01	463544	1190910	SDLM	310	149	151	02-24-88	640	7.8	16.0	6.2	8.9	<.01	42
					160	162.5								
					169	310								
13N/29E-23P01	463538	1190843	WNPM	703	22	703	04-14-88	390	8.4	23.5	0.4	.82	<.01	12
13N/29E-26B01	463526	1190834	SDLM	175	27	175	12-10-54	458	7.7	15.5	--	3.2	--	23
13N/29E-27D01	463518	1191019	SDLM	75	25	75	09-03-86	845	--	--	--	4.9	--	--
							02-20-88	810	8.0	13.0	0.3	3.6	<.01	38
13N/29E-28A01	463528	1191038	PSCO	25	25	25	09-03-86	725	--	--	--	3.5	--	--
							02-27-87	850	--	--	--	5.0	--	--
13N/29E-32G01	463411	1191215	SDLM	264.5	168.5	264.5	09-09-86	521	--	--	--	3.6	--	--
							02-28987	508	--	--	--	3.6	--	--
13N/29E-32M01	463357	1191254		463	--	--	02-20-88	470	7.9	13.0	0.9	.15	.09	19
13N/29E-34N01	463345	1191024	SDLM	182	124.25	182	09-24-86	629	--	--	--	<.10	--	--
							02-27-87	635	--	--	--	<.10	--	--
13N/29E-35Q01	463347	1190826	SDLM	330	191	330	09-09-86	311	--	--	--	.20	--	--
							09-13-88	305	8.1	19.0	<0.2	.21	<.01	6.6
13N/29E-36A01D1	463435	1190654	SDLM	340	--	--	09-09-86	1,070	--	--	--	28	--	--
							02-27-87	977	--	--	--	24	--	--
							02-23-88	1,040	8.0	13.5	8.0	28	<.01	49
13N/30E-10R01	463718	1190137	SDLM	137	47	137	09-12-86	769	--	--	--	8.9	--	--
13N/30E-12N01	463715	1190014	SDLM	280	21	280	09-09-86	238	--	--	--	.70	--	--
							02-24-88	242	8.0	15.0	7.7	.67	<.01	2.7

Table 13.--*Concentrations of nitrate, ammonia, chloride, and dissolved oxygen and values of specific conductance, pH, and temperature in ground water in the eastern part of Pasco Basin, Washington--Continued*

Well number	Latitude	Longitude	Primary geohydrologic unit	Well depth (feet)	Open intervals of well (feet below land surface) Top	Bottom	Sampling date	Specific conductance (µS/cm)	pH (units)	Temperature (degrees Celsius)	Dissolved oxygen (mg/L)	Nitrate as nitrogen (mg/L)	Ammonia as nitrogen (mg/L)	Chloride (mg/L)
							Franklin County, Wash.--Continued							
13N/30E-13M01D1	463641	1190010	SDLM	196	--	--	09-09-86	760	--	--	--	16	--	--
							03-03-87	634	--	--	--	9.6	--	--
							02-25-88	618	7.9	13.0	7.4	7.1	0.01	26
							09-13-88	850	7.9	--	8.2	20	.01	62
13N/30E-16G01D2	463656	1190318	SDLM	160	--	--	09-09-86	850	--	--	--	4.6	--	--
							11-20-86	--	--	--	--	8.9	--	--
							12-10-86	--	--	--	--	10	--	--
							01-14-87	--	--	--	--	11	--	--
							02-04-87	--	--	--	--	9.8	--	--
							02-28-87	790	--	--	--	9.3	--	--
							05-08-87	--	--	--	--	10	--	--
							07-01-87	--	--	--	--	4.9	--	--
							09-14-87	--	--	--	--	4.5	--	--
							02-24-88	810	7.7	14.0	7.7	8.3	<.01	30
13N/30E-22N01	463529	1190236	SDLM	154	60	154	09-09-86	665	--	--	--	12	--	--
13N/30E-27J01	463458	1190140	SDLM	56	56	56	09-09-86	521	--	--	--	8.6	--	--
							02-25-88	574	7.8	14.0	9.2	12	<.01	4.3
13N/30E-31N01	463356	1190641	SDLM	235	135	235	09-01-82	925	7.9	16.0	8.0	8.0	--	49
							03-10-83	955	7.5	15.5	9.2	6.8	--	47
							07-26-83	845	7.6	16.0	9.2	7.4	--	47
							04-14-88	830	7.8	14.0	7.6	3.9	<.01	45
							09-14-88	840	7.8	16.0	7.4	4.4	<.01	53
13N/31E-01E01	463835	1185224	GDRD	1,325	750	800	08-31-82	560	7.6	20.5	3.0	2.0	--	19
					800	1,325	03-10-83	525	7.6	20.0	3.2	2.2	--	18
							07-21-83	545	7.6	20.5	3.1	2.3	--	21
13N/31E-24R01	463529	1185132	WNPM	537	100	537	03-13-58	322	7.8	11.0	--	.86	--	5.2
14N/27E-26E01	464025	1192434	TCHT	79.5	--	--	04-15-88	620	7.8	19.5	--	.99	.01	25

Table 13.--*Concentrations of nitrate, ammonia, chloride, and dissolved oxygen and values of specific conductance, pH, and temperature in ground water in the eastern part of Pasco Basin, Washington--Continued*

Well number	Latitude	Longitude	Primary geohydrologic unit	Well depth (feet)	Open intervals of well (feet below land surface) Top	Bottom	Sampling date	Specific conductance (µS/cm)	pH (units)	Temperature (degrees Celsius)	Dissolved oxygen (mg/L)	Nitrate as nitrogen (mg/L)	Ammonia as nitrogen (mg/L)	Chloride (mg/L)
						Franklin County, Wash.--Continued								
14N/28E-15E01	464204	1191809		9.6	1	20	11-06-89	850	--	--	--	1.6	--	14
14N/28E-15N01	464136	1191808		12.6	1	20	11-06-89	560	--	--	--	3.5	--	25
14N/28E-16A01	464221	1191800	UPRG	36	--	--	11-21-88	505	--	12.0	--	0.85	--	16
14N/28E-16R01	464147	1191810		20.8	1	36	11-06-89	522	--	14.5	--	4.4	--	68
14N/28E-21J01	464108	1191810	TCHT	35.5	1	35.5	11-06-89	1,120	--	13.0	--	36	--	45
14N/28E-28A01	464042	1191810		43	1	43	11-06-89	2,200	--	15.5	--	29	--	81
14N/28E-28C01	464042	1191847		20	--	--	09-17-88	1,080	8.0	21.5	--	11	<.01	31
14N/28E-29B01	464034	1191953	SDLM	666	--	--	09-14-88	450	8.0	--	--	3.4	<.01	11
					500	666								
14N/29E-05A01	464412	1191157	SDLM	305	165	305	08-31-82	560	8.2	19.0	5.8	4.0	--	32
							03-15-83	557	7.8	14.0	8.4	4.1	--	32
							07-26-83	580	8.3	18.5	8.2	4.4	--	34
							09-24-86	--	--	--	--	5.0	--	--
							03-02-87	619	--	--	--	5.0	--	--
14N/29E-05M01	464342	1191258	WNPM	550	440	550	09-25-86	850	--	--	--	9.5	--	--
14N/29E-09A01	464321	1191048	WNPM	863	218	863	03-20-52	373	8.0	15.5	--	.16	--	13
							04-23-53	378	8.0	--	--	<.10	--	12
							10-28-53	377	8.2	--	--	.23	--	11
							08-18-54	378	7.7	--	--	.13	--	12
							09-29-55	386	8.1	20.5	--	.20	--	11
							09-13-56	385	8.1	21.5	--	.18	--	13
							11-08-57	398	8.0	--	--	.45	--	13
							06-28-60	378	7.9	--	--	.14	--	11
							10-19-60	411	8.0	23.5	--	.43	--	10
							10-05-61	377	7.9	--	--	.18	--	12
							10-09-62	386	7.9	21.5	--	.23	--	11
							04-29-64	403	7.8	22.5	--	.41	--	14
							01-26-65	395	7.9	22.5	--	.36	--	13

Table 13.--*Concentrations of nitrate, ammonia, chloride, and dissolved oxygen and values of specific conductance, pH, and temperature in ground water in the eastern part of Pasco Basin, Washington--Continued*

Well number	Latitude	Longitude	Primary geohydrologic unit	Well depth (feet)	Open intervals of well (feet below land surface): Top	Open intervals of well (feet below land surface): Bottom	Sampling date	Specific conductance (µS/cm)	pH (units)	Temperature (degrees Celsius)	Dissolved oxygen (mg/L)	Nitrate as nitrogen (mg/L)	Ammonia as nitrogen (mg/L)	Chloride (mg/L)
							Franklin County, Wash.--Continued							
14N/29E-09A01	464321	1191048	WNPM	863	218	863	01-27-66	395	8.2	15.5	--	0.25	--	14
							02-13-67	389	8.1	21.0	--	.20	--	14
							03-15-67	388	7.9	--	--	.52	--	14
							04-26-67	407	7.9	--	--	.32	--	14
							03-04-68	410	8.0	--	--	.47	--	17
							06-12-69	412	7.9	--	--	.59	--	17
14N/29E-09B02	464316	1191052	WNPM	725	--	--	12-10-86	--	--	--	--	3.4	--	--
							01-14-87	--	--	--	--	3.2	--	--
							02-04-87	--	--	--	--	3.4	--	--
							03-02-87	613	--	--	--	3.5	--	--
							05-12-87	--	--	--	--	.90	--	--
							07-01-87	--	--	--	--	2.5	--	--
							09-14-87	--	--	--	--	2.7	--	--
14N/29E-09R01	464231	1191035	SDLM	360	95	360	09-24-86	650	--	--	--	8.2	--	--
14N/29E-14C01	464219	1190841	WNPM	350	90	350	07-09-89	765	--	--	--	12	--	24
14N/29E-19Q01	464043	1191322	SDLM	420	284	420	08-31-82	660	7.8	22.5	4.2	12	--	30
							03-10-83	645	7.6	20.0	5.7	11	--	29
							07-27-83	661	7.7	20.0	5.5	12	--	30
							02-26-88	630	7.9	16.5	5.2	9.5	<0.01	27
							09-14-88	620	7.8	21.0	4.7	7.8	<.01	26
14N/29E-20M02D1	464107	1191302		920	610	910	04-15-88	318	7.6	19.5	<0.2	<.10	.04	8.2
14N/29E-21J01	464108	1191038	SDLM	260	132	260	09-24-86	1,580	--	--	--	51	--	--
							03-04-87	1,600	--	--	--	48	--	--
							04-16-88	1,420	7.6	16.5	5.3	42	.02	72
14N/29E-27E01	464025	1191014	WNPM	498	435	498	02-22-88	460	8.0	18.5	3.5	1.9	<.01	15

Table 13.--*Concentrations of nitrate, ammonia, chloride, and dissolved oxygen and values of specific conductance, pH, and temperature in ground water in the eastern part of Pasco Basin, Washington--Continued*

Well number	Latitude	Longitude	Primary geohydrologic unit	Well depth (feet)	Open intervals of well (feet below land surface) Top	Bottom	Sampling date	Specific conductance (µS/cm)	pH (units)	Temperature (degrees Celsius)	Dissolved oxygen (mg/L)	Nitrate as nitrogen (mg/L)	Ammonia as nitrogen (mg/L)	Chloride (mg/L)
							Franklin County, Wash.--Continued							
14N/29E-27N01	463955	1191025	SDLM	273	229	273	09-03-86	1,150	--	--	--	34	--	--
							03-02-87	1,440	--	--	--	33	--	--
							11-04-89	1,220	--	17.5	--	41	0.02	42
14N/29E-28A01	464044	1191033	UPRG	51	--	--	11-04-89	885	--	--	--	4.8	<.01	10
14N/29E-28C01	464041	1191125	SDLM	343	161	343	09-24-86	2,740	--	--	--	100	--	--
							03-04-87	2,550	--	--	--	95	--	--
							02-25-88	2,280	7.7	15.0	9.7	81	.01	74
							04-16-88	2,700	7.7	17.5	9.2	92	.02	57
							11-04-89	2,160	--	16.0	--	84	.02	70
14N/29E-32N01	463904	1191300	SDLM	592	576	596	02-26-88	417	8.0	19.0	3.6	2.4	<.01	13
							09-14-88	395	8.0	21.0	1.5	1.8	<.01	12
14N/29E-32Q01	463910	1191209	SDLM	330	306	330	02-27-88	519	7.9	18.0	5.3	7.5	.02	22
14N/30E-08G01	464304	1190438	WNPM	371	231	251	08-00-52	449	--	--	--	<.10	--	--
					271	291	03-13-58	1,570	7.9	13.5	--	22	--	130
					351	371	06-19-62	992	--	--	--	9.7	--	--
14N/30E-10P01	464234	1190227	WNPM	433	30	75	07-00-52	396	8.5	19.5	--	.97	--	15
					75	433	08-31-82	375	7.7	16.5	7.6	1.2	--	7.7
							03-14-83	370	7.5	15.0	8.5	1.4	--	8.3
							07-26-83	375	7.7	16.5	8.2	1.3	--	7.9
							02-25-88	398	7.7	15.0	7.2	1.8	<.01	13
14N/30E-20A01	464136	1190409	WNPM	717	157	430	01-00-52	503	7.9	19.0	--	<.10	--	14
					430	717	03-13-58	735	7.7	11.5	--	12	--	66
							06-20-62	544	--	--	--	6.8	--	--
14N/30E-27J01	464010	1190146	WNPM	381	301	321	11-01-53	587	7.5	--	--	3.8	--	42
					341	361								

Table 13.--*Concentrations of nitrate, ammonia, chloride, and dissolved oxygen and values of specific conductance, pH, and temperature in ground water in the eastern part of Pasco Basin, Washington--Continued*

Well number	Latitude	Longitude	Primary geohydrologic unit	Well depth (feet)	Open intervals of well (feet below land surface)		Sampling date	Specific conductance (μS/cm)	pH (units)	Temperature (degrees Celsius)	Dissolved oxygen (mg/L)	Nitrate as nitrogen (mg/L)	Ammonia as nitrogen (mg/L)	Chloride (mg/L)
					Top	Bottom								
						Grant County, Wash.								
14N/27E-03L01	464344	1192525	TCHT	8.1	--	--	11-16-88	630	7.9	14.5	--	<0.10	--	9.6
14N/27E-03P01D1	464327	1192526	TCHT	85	75	85	11-20-88	743	8.2	14.5	--	2.2	--	32

Table 14.--*Variability of nitrate concentrations in water from wells sampled more than one time, Pasco Basin, Washington*

[SDLM, Saddle Mountains Basalt; PSCO, Pasco gravels of the Hanford formation; WNPM, Wanapum Basalt; ALVM, alluvium of Pleistocene-Recent age; LRRG, lower unit of the Ringold Formation; MDRG, middle unit of the Ringold Formation; BSRG, basal unit of the Ringold Formation; UPRG, upper unit of the Ringold Formation; RGLD, undifferentiated Ringold Formation; --, value not computed; <, less than]

Table 14.--*Variability of nitrate concentrations in water from wells sampled more than one time, Pasco Basin, Washington--Continued*

Well number	Geo-hydro-logic unit	Depth of well (feet)	Number of samples	Nitrate as nitrogen (milligrams per liter) Mini-mum	Maxi-mum	Mean	Stan-dard devia-tion	Coef-ficent of varia-tion (percent)
			Benton County, Wash.					
07N/30E-01Q02	SDLM	175	2	2.1	3.0	2.6	0.64	25
07N/31E-06N01	SDLM	250	2	2.3	4.7	3.5	1.7	48
08N/27E-01B01	PSCO	160	3	12	16	14	2.0	14
08N/28E-01R01	PSCO	74	2	5.1	5.3	5.2	.14	2.7
08N/28E-01R03	SDLM	180	2	<.10	.10	<.10	--	--
08N/28E-11R01	SDLM	320	3	<.10	.30	.10	<.17	<173
08N/28E-12B02	SDLM	105	2	1.5	1.5	1.5	0.0	0.0
08N/28E-14C02	PSCO	140	3	2.8	3.0	2.9	.12	3.9
08N/28E-15P01	PSCO	108	11	7.6	17	11.3	3.1	28
08N/28E-16R01	PSCO	114	3	20	29	25	4.6	18
08N/28E-21A01	PSCO	120	8	7.4	17	11.8	4.1	35
08N/28E-21H01	PSCO	125	3	1.2	1.4	1.3	.12	8.7
08N/29E-01F02	PSCO	93	2	5.9	5.9	5.9	0.0	0.0
08N/29E-07B01	PSCO	154	3	5.0	8.2	6.3	1.70	27
08N/29E-10C01	PSCO	90	3	4.5	5.8	5.0	.68	14
08N/29E-12B01	SDLM	64	2	7.6	7.9	7.8	.21	2.7
08N/29E-12H01	SDLM	125	2	.62	1.7	1.2	.76	66
08N/29E-13A01	SDLM	160	8	<.10	<.10	<.10	--	--
08N/29E-17G02	SDLM	245	3	2.5	2.6	2.6	.06	2.3
08N/30E-05J01	SDLM	125	2	<.10	<.10	<.10	--	--
08N/30E-05K01	PSCO	36	3	5.8	8.3	7.2	1.29	18
08N/30E-07E02	PSCO	55	2	4.5	5.0	4.8	.35	7.4
08N/30E-07J02	PSCO	45	3	3.7	6.8	4.8	1.76	37
08N/30E-07Q04	PSCO	38	3	9.2	10	9.5	.46	4.9
08N/30E-09C01	SDLM	182	2	<.10	.10	<.10	--	--
08N/30E-09C02	SDLM	94	2	<.10	1.9	.95	<1.34	<141
08N/30E-09L02	PSCO	43	3	2.2	6.9	4.2	2.44	59
08N/30E-10M03	PSCO	49	2	.47	.70	.58	.16	28
08N/30E-14M01	SDLM	160	2	.26	.30	.28	.03	10
08N/30E-16F01	PSCO	50	4	3.4	5.3	4.2	.80	19
08N/30E-17R01	PSCO	40	3	5.5	12	8.6	3.3	38
08N/30E-20A01	SDLM	155	3	<.10	<.10	<.10	--	--
08N/30E-20R01	SDLM	350	2	<.10	<.10	<.10	--	--
08N/30E-21C03	PSCO	35	4	1.4	11	5.9	4.24	72
08N/30E-21C04	PSCO	28	3	2.4	5.9	4.3	1.76	41

Table 14.--*Variability of nitrate concentrations in water from wells sampled more than one time, Pasco Basin, Washington--Continued*

Well number	Geo-hydro-logic unit	Depth of well (feet)	Number of samples	Nitrate as nitrogen (milligrams per liter) Mini-mum	Maxi-mum	Mean	Stan-dard devia-tion	Coef-ficent of varia-tion (percent)
				Benton County, Wash.--Continued				
08N/30E-22D04	PSCO	26	2	4.4	4.8	4.6	0.28	6.2
08N/30E-22G02D1	SDLM	250	2	<.10	<.10	<.10	--	--
08N/30E-22J02	PSCO	30	2	4.1	4.6	4.4	.35	8.1
08N/30E-22M02	PSCO	29	3	3.2	3.5	3.3	.17	5.3
08N/30E-22R04	SDLM	52	2	2.5	3.5	3.0	.71	24
08N/30E-23E03	SDLM	47	2	<.10	<.10	<.10	--	--
08N/30E-25D01	SDLM	40	2	7.2	7.7	7.5	.35	4.8
08N/30E-27B02	SDLM	124	2	<.10	.10	<.10	--	--
08N/30E-29A01	SDLM	215	10	25	28	26.5	1.0	3.7
08N/30E-29D01	PSCO	120	9	3.3	3.9	3.6	.20	5.6
08N/30E-29R01	WNPM	380	3	4.3	9.4	7.4	2.72	37
08N/30E-34B02	SDLM	56	3	7.5	12	10.2	2.4	23
08N/30E-34K01	PSCO	60	2	4.0	5.1	4.6	.78	17
08N/30E-35E02	PSCO	50	3	11	19	16	4.4	27
08N/30E-35K01	SDLM	177	2	<.10	<.10	<.10	--	--
09N/27E-02E01	SDLM	273	2	5.3	6.9	6.1	1.13	19
09N/27E-02L01	SDLM	120	2	5.7	5.9	5.8	.14	2.4
09N/27E-03R02	SDLM	280	2	<.10	<.10	<.10	--	--
09N/27E-05E01	ALVM	38	2	<.10	<.10	<.10	--	--
09N/27E-08N01	WNPM	638	2	<.10	.10	<.10	--	--
09N/27E-12F02	SDLM	180	3	4.9	6.7	5.6	.96	17
09N/27E-16B01	SDLM	290	3	<.10	<.10	<.10	--	--
09N/27E-17P01	SDLM	252	2	5.7	6.2	6.0	.35	5.9
09N/27E-19J01	PSCO	113	3	2.7	2.9	2.8	.10	3.6
09N/27E-19K02	PSCO	100	3	9.5	11	10.5	.87	8.3
09N/27E-19P01	SDLM	438	6	.62	.70	.69	.03	4.8
09N/27E-29J01	PSCO	67	2	5.4	5.9	5.7	.35	6.3
09N/27E-35E01	SDLM	160	3	1.1	2.1	1.6	.50	31
09N/28E-03P01	LRRG	115	2	<.10	<.10	<.10	--	--
09N/28E-04G01	SDLM	314	2	<.10	<.10	<.10	--	--
09N/28E-04G03	MDRG	52	2	.40	.68	.54	.20	37
09N/28E-05E01	LRRG	73	2	<.10	<.10	<.10	--	--
09N/28E-08B01	SDLM	354	2	<.10	<.10	<.10	--	--
09N/28E-08C01	SDLM	204	2	<.10	.60	.30	<.42	<141
09N/28E-08K01	SDLM	325	3	<.10	<.10	<.10	--	--

Table 14.--*Variability of nitrate concentrations in water from wells sampled more than one time, Pasco Basin, Washington--Continued*

Well number	Geo-hydro-logic unit	Depth of well (feet)	Number of samples	Nitrate as nitrogen (milligrams per liter) Mini-mum	Maxi-mum	Mean	Stan-dard devia-tion	Coef-ficent of varia-tion (percent)
				Benton County, Wash.--Continued				
09N/28E-10F01	MDRG	68	3	3.8	6.1	5.2	1.23	24
09N/28E-11E01	SDLM	135	2	<.10	<.10	<.10	--	--
09N/28E-14P01	PSCO	46	3	1.0	1.3	1.2	.17	14
09N/28E-15G01	MDRG	95	2	5.7	6.7	6.2	.71	11
09N/28E-17N01	SDLM	270	2	13	13	13	0.0	0.0
09N/28E-18H01	SDLM	308	3	41	52	45.7	5.7	12
09N/28E-18L01	SDLM	100	4	6.3	13	9.3	2.8	30
09N/28E-20A01	SDLM	102	2	22	24	23	1.4	6.2
09N/28E-22B01	SDLM	172	3	.20	1.9	1.17	.87	75
09N/28E-22F01D1	SDLM	210	3	12	15	13	1.7	13
09N/28E-26R01D1	SDLM	281	4	.96	12	7.1	5.3	75
09N/28E-27D01	SDLM	274	2	8.1	8.8	8.5	.49	5.9
09N/28E-31P01D1	PSCO	217	3	11	24	17.3	6.5	38
09N/29E-33M01	SDLM	292	2	1.6	4.2	2.9	1.84	63
09N/29E-36N02	PSCO	41	2	3.5	6.0	4.8	1.77	37
10N/27E-11M02	SDLM	147	3	.21	3.5	1.4	1.86	140
10N/27E-14P02	PSCO	59	3	3.2	7.1	4.7	2.12	45
10N/27E-23L02	SDLM	85	2	<.10	<.10	<.10	--	--
10N/27E-25R03	PSCO	80	2	4.7	5.2	5.0	.35	7.1
10N/27E-33B01	SDLM	250	2	.23	.39	.31	.11	37
10N/28E-18F01	SDLM	386	3	<.10	<.10	<.10	--	--
10N/28E-19R01	MDRG	35	3	<.10	<.10	<.10	--	--
10N/28E-29D03	PSCO	30	2	.80	1.3	1.1	.35	35
10N/28E-31C01	LRRG	65	3	1.4	2.5	1.9	.57	30
10N/28E-35C03	MDRG	50	2	5.2	6.2	5.7	.71	12
10N/28E-35K05	PSCO	39	3	7.6	7.9	7.7	.15	2.0
				Franklin County, Wash.				
09N/29E-02A01	PSCO	128	2	19	20	19.5	.7	3.6
09N/29E-02D03	PSCO	160	2	5.0	7.2	6.1	1.56	26
09N/29E-02G03	SDLM	118	3	13	14	13.7	0.6	4.2
09N/29E-02G04	PSCO	145	3	15	17	16.3	1.2	7.1
09N/29E-06G01	BSRG	230	3	<.10	.64	.21	<.37	<173

Table 14.--*Variability of nitrate concentrations in water from wells sampled more than one time, Pasco Basin, Washington--Continued*

				Nitrate as nitrogen (milligrams per liter)				
Well number	Geo-hydro-logic unit	Depth of well (feet)	Number of samples	Mini-mum	Maxi-mum	Mean	Stan-dard devia-tion	Coef-ficent of varia-tion (percent)
			Franklin County, Wash.--Continued					
09N/29E-10B01	PSCO	200	2	13	14	13.5	0.7	5.2
09N/29E-21R01D1	LRRG	59	2	6.4	6.6	6.5	.14	2.2
09N/29E-25N01	PSCO	30	2	11	14	12.5	2.1	17
09N/29E-26J02	PSCO	40	2	9.7	13	11.4	2.3	21
09N/29E-26L02	PSCO	35	2	9.5	10	9.8	.4	3.6
09N/30E-02R01	SDLM	211	2	4.6	4.9	4.8	.21	4.5
09N/30E-06Q01D1	MDRG	154	3	15	16	15.3	.6	3.8
09N/30E-08B02D1	MDRG	135	2	12	15	13.5	2.1	16
09N/30E-27F01	PSCO	120	3	7.2	12	9.7	2.4	25
09N/30E-27H02	PSCO	119	2	8.2	10	9.1	1.3	14
09N/31E-07Q03	SDLM	425	2	<.10	<.10	<.10	--	--
09N/31E-14G01	SDLM	355	2	6.3	6.4	6.4	.07	1.1
09N/31E-19G01	SDLM	558	2	<.10	<.10	<.10	--	--
10N/28E-12F01	RGLD	196	8	<.10	<.10	<.10	--	--
10N/29E-03P01	UPRG	75	3	.65	.86	.77	.11	14
10N/29E-03R01	UPRG	95	3	13	20	16.7	3.5	21
10N/29E-06H01	SDLM	466	2	<.10	<.10	<.10	--	--
10N/29E-09Q01	MDRG	147	2	4.3	6.3	5.3	1.4	27
10N/29E-10D01	SDLM	618	2	7.2	9.0	8.1	1.3	16
10N/29E-10N01	UPRG	45	3	2.5	2.5	2.5	0.0	0.0
10N/29E-10N02	PSCO	29	3	5.1	5.3	5.2	.10	1.9
10N/29E-10N03	PSCO	22	3	20	21	20.7	.60	2.8
10N/29E-10Q02	UPRG	168	3	10	14	12	2.0	16.7
10N/29E-14D01	UPRG	48	2	.50	1.1	.80	.42	53
10N/29E-15M01	SDLM	350	3	1.6	2.1	1.8	.25	14
10N/29E-25G01	MDRG	81	2	8.0	8.5	8.3	.35	4.3
10N/29E-29L01	MDRG	218	2	19	23	21	2.8	13
10N/30E-03J01	SDLM	230	2	9.9	11	10.5	.78	7.4
10N/30E-11Q01	SDLM	286	3	19	19	19	0.0	0.0
10N/30E-21N01	SDLM	366	9	.40	1.6	.95	.40	42
10N/30E-33N04	MDRG	228	10	15	21	17.4	2.0	11
10N/31E-08E01	SDLM	400	2	15	15	15	0.0	0.0
10N/31E-32L02	SDLM	350	3	2.1	4.5	3.5	1.3	36
10N/31E-32M01	SDLM	165	2	9.3	9.8	9.6	.35	3.7
10N/31E-32M02	WNPM	400	2	1.3	1.3	1.3	0.0	0.0

Table 14.--*Variability of nitrate concentrations in water from wells sampled more than one time, Pasco Basin, Washington--Continued*

Well number	Geo-hydro-logic unit	Depth of well (feet)	Number of samples	Nitrate as nitrogen (milligrams per liter) Mini-mum	Maxi-mum	Mean	Stan-dard devia-tion	Coef-ficent of varia-tion (percent)
				Franklin County, Wash.--Continued				
10N/31E-32N03	SDLM	295	2	13	17	15	2.8	19
11N/28E-13C02	MDRG	105	8	4.8	9.0	6.7	1.2	20
11N/29E-03H01	SDLM	552	2	<.10	<.10	<.10	--	--
11N/29E-10C01	UPRG	46	3	4.5	4.7	4.6	.12	2.5
11N/29E-10C02	UPRG	27	3	22	23	22.7	0.6	2.6
11N/29E-10C03	UPRG	14	3	25	27	26	1.0	3.9
11N/29E-13C01	UPRG	30	2	1.3	1.3	1.3	0.0	0.0
11N/29E-28R01	UPRG	87	2	14	15	14.5	.70	4.9
11N/29E-34J02	MDRG	211	2	10	11	10.5	.70	6.7
11N/30E-05N02	SDLM	79	3	50	50	50	0.0	0.0
11N/30E-17B01	SDLM	100	2	19	20	19.5	.70	3.6
11N/30E-29C01	MDRG	220	2	1.8	2.0	1.9	.14	7.4
11N/30E-34H01	SDLM	105	2	19	24	21.5	3.5	16
11N/31E-31H01	PSCO	122	2	12	17	14.5	3.5	24
12N/28E-12H01	SDLM	450	2	<.10	<.10	<.10	--	--
12N/29E-01A01	SDLM	313	8	13	15	14.3	.70	5.0
12N/29E-11M01	SDLM	212	3	<.10	<.10	<.10	--	--
12N/30E-04D01	SDLM	290	2	12	12	12	0.0	0.0
12N/30E-05B01	SDLM	457	3	8.8	9.1	9.0	.15	1.7
12N/30E-30L01	SDLM	219	2	3.6	5.4	4.5	1.3	28
12N/30E-33B01	SDLM	374	3	13	17	14.7	2.1	14
12N/30E-34N01	SDLM	328	2	17	20	18.5	2.1	11
13N/28E-21J02	UPRG	17	3	5.4	14	8.8	4.6	52
13N/28E-21J03	UPRG	27	3	35	36	35.3	0.6	1.6
13N/29E-03C01	SDLM	260	3	26	34	30.7	4.2	14
13N/29E-04A01	LRRG	294	2	4.6	5.2	4.9	.42	8.7
13N/29E-08H01	SDLM	453	2	<.10	<.10	<.10	--	--
13N/29E-27D01	SDLM	75	2	3.6	4.9	4.3	.92	22
13N/29E-28A01	PSCO	25	2	3.5	5.0	4.3	1.1	25
13N/29E-32G01	SDLM	264	2	3.6	3.6	3.6	0.0	0.0
13N/29E-34N01	SDLM	182	2	<.10	<.10	<.10	--	--
13N/29E-35Q01	SDLM	330	2	.20	.21	.20	.01	3.5
13N/29E-36A01D1	SDLM	340	3	24	28	26.7	2.3	8.7
13N/30E-12N01	SDLM	280	2	0.67	.70	.68	0.02	3.1
13N/30E-13M01D1	SDLM	196	4	7.1	20	13.2	5.9	45

Table 14.--*Variability of nitrate concentrations in water from wells sampled more than one time, Pasco Basin, Washington--Continued*

Well number	Geo-hydro-logic unit	Depth of well (feet)	Number of samples	Nitrate as nitrogen (milligrams per liter) Mini-mum	Maxi-mum	Mean	Stan-dard devia-tion	Coef-ficent of varia-tion (percent)
			Fraklin County, Wash.--Continued					
13N/30E-16G01D2	SDLM	160	10	4.5	11	8.1	2.5	31
13N/30E-27J01	SDLM	56	2	8.6	12	10.3	2.4	23
13N/30E-31N01	SDLM	235	2	3.9	4.4	4.2	.35	8.5
14N/29E-05A01	SDLM	305	2	5.0	5.0	5.0	0.0	0.0
14N/29E-09B02	WNPM	725	8	.90	3.5	2.8	.92	33
14N/29E-19Q01	SDLM	420	2	7.8	9.5	8.7	1.2	14
14N/29E-21J01	SDLM	260	3	42	51	47	4.6	10
14N/29E-27N01	SDLM	273	3	33	41	36	4.4	12
14N/29E-28C01	SDLM	343	5	81	100	90	7.8	8.7
14N/29E-32N01	SDLM	592	2	1.8	2.4	2.1	.42	20

Table 15.--*Concentrations of nitrate, ammonia, and chloride in surface-water samples from the eastern part of Pasco Basin, Washington*

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; --, no data; <, less than; KID, Kennewick Irrigation District; CID, Columbia Irrigation District; SCBID, South Columbia Irrigation District; FCID, Franklin County Irrigation District]

Table 15.--*Concentrations of nitrate, ammonia, and chloride in surface-water samples from the eastern part of Pasco Basin, Washington--Continued*

Site name	Number on Plate 3	Date	Temperature water (degress Celsius)	Specific conductance (µS/cm)	pH (standard units)	Nitrate (mg/L as N)	Nitrogen, ammonia dissolved (mg/L as N)	Chloride dissolved (mg/L as N)
			<u>Benton County, Wash.</u>					
KID Canal near	1	04-14-88	17.5	258	8.55	0.780	<0.010	5.4
Chandler, Wash.		06-22-88	24.0	380	8.45	1.10	<.010	5.9
		09-07-88	20.0	282	8.22	1.30	.040	5.7
KID Canal at Badger	2	04-14-88	17.5	243	8.69	.670	<.010	5.4
Canyon Road near		06-22-88	25.0	275	8.96	.910	<.010	5.8
Kiona, Wash.		09-07-88	19.5	275	8.17	1.30	.040	5.7
KID Canal at	3	04-14-88	17.0	235	8.79	.590	<.010	5.2
Clodfelter Road near		06-22-88	25.5	272	9.20	.750	<.010	5.8
Kennewick, Wash.		09-07-88	18.5	272	8.24	1.20	.030	5.7
KID Division 4 Canal	4	04-14-88	18.5	225	9.03	.420	.010	5.3
between Amon and		06-21-88	23.5	252	9.22	.580	.040	7.7
Hover Roads		09-06-88	22.0	268	9.04	.930	<.010	5.6
KID Division 4 Wasteway	5	04-14-88	19.5	228	8.30	.520	.060	5.3
near mouth near Finley,		06-21-88	20.0	252	8.92	.170	.030	5.8
Wash.		09-06-88	19.0	282	8.69	.760	.020	6.4
KID Badger East Lateral	6	04-14-88	19.5	234	8.89	.550	.010	5.2
at Gage Road near		06-22-88	24.5	265	9.13	.710	.010	5.8
Richland, Wash		09-08-88	20.0	285	8.58	1.10	.020	5.7
KID Badger East Lateral	7	04-14-88	16.5	225	8.64	.400	.010	5.1
at end near Richland,		06-22-88	27.5	255	9.52	.290	.030	5.7
Wash.		09-07-88	20.0	268	8.67	1.20	.020	5.6
Amon Wasteway below	8	04-14-88	17.0	236	8.83	.540	.010	5.1
KID pump near		06-22-88	25.5	270	9.23	.720	.010	5.8
Kennewick, Wash.		09-07-88	19.0	269	8.33	1.20	.030	5.9
Amon Wasteway	9	04-14-88	19.0	720	8.52	5.00	.020	39
Tributary at Meadow		06-22-88	20.0	682	8.29	4.20	.030	34
Springs at Richland, Wash.		09-08-88	17.0	675	8.15	4.10	.030	31
Amon Wasteway near	10	04-14-88	17.5	320	8.31	.990	.040	10
mouth near Richland,		06-22-88	24.0	380	8.24	1.30	.090	12
Wash.		09-08-88	19.5	359	8.28	1.50	.020	9.7

Table 15.--*Concentrations of nitrate, ammonia, and chloride in surface-water samples from the eastern part of Pasco Basin, Washington--Continued*

Site name	Number on Plate 3	Date	Temperature water (degress Celsius)	Specific conductance (μS/cm)	pH (standard units)	Nitrate (mg/L as N)	Nitrogen, ammonia dissolved (mg/L as N)	Chloride dissolved (mg/L as N)
			Benton County, Wash.--Continued					
KID Highlift Canal	11	04-13-88	19.0	218	9.10	0.380	<0.010	5.0
dump to Corp drain near		06-21-88	25.0	269	8.50	.910	.100	5.9
Kennewick, Wash.		09-06-88	22.0	277	8.68	1.00	<.010	6.0
Zintel Canyon	12	04-14-88	18.5	328	8.95	1.10	.020	9.7
Wasteway near mouth		06-22-88	25.0	372	8.92	1.30	.040	9.9
near Kennewick, Wash.		09-08-88	17.0	410	8.25	2.00	.020	11
CID Canal at Horn	13	04-14-88	16.5	240	8.43	.620	.020	5.5
Rapids Dam near West		06-22-88	25.5	289	8.62	.880	.020	6.4
Richland, Wash.		09-07-88	20.5	288	8.40	1.10	.040	6.1
CID Canal at	14	04-13-88	18.0	225	9.20	.290	<.010	5.2
Grant Street Bridge at		06-21-88	26.5	278	8.92	.760	.030	6.4
Kennewick, Wash.		09-08-88	20.0	285	8.30	1.10	.030	6.2
CID No. 2 Canal	16	04-13-88	18.0	228	9.55	<.100	<.010	4.9
Wasteway near		06-21-88	24.5	283	8.46	.770	.050	6.5
Finley, Wash.		09-06-88	23.0	290	8.28	1.10	.030	6.1
CID No. 2 Canal at end	17	04-13-88	18.5	220	9.27	<.100	<.010	4.9
at Finley, Wash.		06-21-88	24.0	268	8.86	.550	.070	6.1
		09-06-88	23.5	289	8.69	1.20	.020	6.3
CID No. 3 Canal at	18	04-13-88	19.5	226	9.30	.220	<.010	5.3
19th Street at		06-21-88	26.5	282	8.81	.810	.040	6.6
Kennewick, Wash.		09-08-88	19.0	290	8.13	1.10	.040	6.3
CID No. 3 Canal at	19	04-13-88	17.0	250	8.83	.600	.020	7.2
Nine Canyon Road near		06-21-88	23.5	323	8.16	<.100	.010	9.2
Finley, Wash.		09-06-88	23.0	343	8.21	1.60	.030	9.6
CID No. 3 Canal at end	20	04-13-88	17.0	288	8.64	.750	.030	9.0
near Finley, Wash.		06-21-88	23.5	341	7.95	1.10	.060	9.7
		09-06-88	21.0	347	8.37	1.50	.030	11
CID No. 3 Canal	21	04-13-88	18.5	940	8.15	8.40	.050	46
Tributary below Eliot		06-21-88	24.0	872	8.36	7.20	.070	48
Lake near Kennewick, Wash.		09-07-88	19.0	875	8.27	8.30	.030	50

Table 15.--*Concentrations of nitrate, ammonia, and chloride in surface-water samples from the eastern part of Pasco Basin, Washington--Continued*

Site name	Number on Plate 3	Date	Temperature water (degress Celsius)	Specific conductance (µS/cm)	pH (standard units)	Nitrate (mg/L as N)	Nitrogen, ammonia dissolved (mg/L as N)	Chloride dissolved (mg/L as N)
Benton County, Wash.--Continued								
McWhorter Canal near West Richland, Wash.	23	04-14-88	19.5	250	9.13	0.230	0.020	6.9
		06-22-88	26.0	271	9.16	.240	.010	6.3
		09-08-88	20.5	292	8.88	.840	.020	6.3
Yakima River Tributary at I-182 Bridge at Richland, Wash.	24	04-14-88	15.5	1,000	8.69	16.0	.010	52
		06-22-88	18.0	1,000	8.20	16.0	.020	53
		09-07-88	19.5	970	8.40	17.0	.020	51
Franklin County, Wash.								
SCBID EL 85 JJ Lateral at head near Mesa, Wash.	25	04-13-88	15.0	135	8.22	<.100	.010	0.90
		06-23-88	21.0	159	8.58	<.100	<.010	1.1
		09-12-88	18.0	138	8.46	<.100	<.010	0.90
Esquatzel Coulee at Connell, Wash.	27	06-23-88	24.5	190	9.34	.610	.010	1.5
		09-12-88	17.5	176	9.19	.640	<.010	1.5
Esquatzel Coulee at Mesa, Wash.	28	04-13-88	19.0	386	8.29	2.40	<.010	13
		06-22-88	21.0	289	8.20	1.10	<.010	8.3
		09-12-88	18.0	265	8.21	.780	<.010	6.5
Esquatzel Coulee at Eltopia, Wash.	29	06-21-88	27.5	320	8.91	1.00	.010	9.5
		09-12-88	15.0	347	8.47	1.30	.020	8.0
Esquatzel Coulee at Diversion pump near Pasco, Wash.	30	04-16-88	17.5	639	8.56	7.00	.020	22
		06-21-88	17.5	580	8.15	5.50	.020	17
		09-09-88	15.0	635	8.10	6.30	<.010	23
SCBID Esquatzel Wasteway near End near Richland, Wash.	31	04-17-88	--	--	8.47	3.30	.030	15
		06-21-88	21.5	450	8.72	2.60	.010	12
		09-10-88	16.0	508	8.28	3.30	<.010	14
SCBID Potholes East Canal below Scooteney Reservoir near Mesa, Wash.	32	04-13-88	12.5	373	8.99	1.20	.010	9.9
		06-23-88	21.5	319	8.71	--	--	7.1
		09-12-88	19.0	340	8.66	1.00	.020	7.2

Table 15.--*Concentrations of nitrate, ammonia, and chloride in surface-water samples from the eastern part of Pasco Basin, Washington--Continued*

Site name	Number on Plate 3	Date	Temperature water (degress Celsius)	Specific conductance (µS/cm)	pH (standard units)	Nitrate (mg/L as N)	Nitrogen, ammonia dissolved (mg/L as N)	Chloride dissolved (mg/L as N)
			Franklin County, Wash.--Continued					
SCBID Pasco Wasteway near Richland, Wash.	33	04-17-88	13.0	--	8.85	1.20	0.020	10
		06-21-88	22.5	328	8.79	.800	.010	7.4
		09-09-88	20.5	372	8.63	1.20	<.010	8.7
SCBID PE 27L Lateral at Hendricks Road near Mesa, Wash.	34	04-13-88	17.0	352	9.14	1.10	.010	9.9
		06-23-88	21.5	315	8.87	.820	.200	7.4
		09-12-88	20.0	332	8.96	1.10	<.010	7.6
SCBID PE 41.2 Lateral below siphon near Basin City, Wash.	35	04-13-88	12.5	369	9.10	1.20	<.010	9.8
		06-22-88	23.0	319	8.86	.720	.010	7.0
		09-12-88	19.5	342	8.77	.980	<.010	7.4
SCBID PE 41.2 Lateral at end near Ringold, Wash.	36	04-13-88	18.0	469	8.92	1.90	.030	16
		06-22-88	24.5	490	8.72	1.50	.010	15
		09-17-88	16.0	551	8.62	2.20	<.010	16
SCBID PE 41.2C Lateral at end near Ringold, Wash.	37	04-13-88	16.0	402	9.01	1.30	.010	11
		06-22-88	25.5	340	8.83	.810	.030	8.4
		09-12-88	22.0	384	8.75	1.20	<.010	9.0
SCBID PE 41.2D Lateral at end near Ringold, Wash.	38	04-13-88	17.5	352	9.18	.960	.010	9.9
		06-22-88	28.0	309	8.99	.590	<.010	7.1
		09-12-88	23.5	341	9.02	.940	<.010	7.8
Eltopia Branch Canal at Ironwood Road near Ringold, Wash.	39	04-16-88	14.5	368	9.21	1.10	.020	9.6
		06-21-88	22.5	320	8.92	.740	.010	7.2
		09-12-88	20.0	340	8.77	1.00	.040	7.3
SCBID Eltopia Branch Canal above falls near Pasco, Wash.	40	04-16-88	17.5	373	9.07	1.10	.040	10
		06-23-88	23.5	333	8.54	.700	.020	7.9
		09-12-88	16.5	364	8.55	1.10	<.010	8.3
SCBID PE 54.9 Lateral at Birch Rd near Eltopia, Wash.	41	09-15-88	19.5	360	8.68	1.20	<.010	8.3

Table 15.--*Concentrations of nitrate, ammonia, and chloride in surface-water samples from the eastern part of Pasco Basin, Washington--Continued*

Site name	Number on Plate 3	Date	Temperature water (degress Celsius)	Specific conductance (µS/cm)	pH (standard units)	Nitrate (mg/L as N)	Nitrogen, ammonia dissolved (mg/L as N)	Chloride dissolved (mg/L as N)
			Franklin County, Wash.--Continued					
SCBID PE 54.9 Lateral at Farm Unit 205 near Pasco, Wash.	42	09-10-88	18.5	370	8.63	1.30	<0.010	8.5
Pasco Pump Lateral	43	04-17-88	14.5	--	8.92	1.10	.050	10.
Wasteway at Dent		06-21-88	22.0	330	8.73	.770	.040	7.5
Road near Pasco		09-09-88	20.0	379	8.45	1.20	<.010	8.6
SCBID PE 16.4	44	04-13-88	16.5	615	8.78	2.10	.020	25
Wasteway below Eagle		06-23-88	24.0	540	8.59	1.30	.070	19
Lakes near Basin City, Wash.		09-10-88	19.0	562	8.54	1.60	.050	16
SCBID PE 16.4	45	04-13-88	16.0	601	8.70	2.40	.010	24
Wasteway at Highway 170		06-22-88	24.5	555	8.57	--	--	19
near Basin City, Wash.		09-10-88	18.0	560	8.44	1.70	<.010	16
SCBID PE 16.4	46	04-16-88	17.0	495	9.00	2.20	.020	15
Wasteway near Rickert		06-22-88	20.5	450	8.46	1.60	<.010	12
Road near Ringold, Wash.		09-09-88	18.0	560	8.46	2.20	<.010	16
SCBID Wahluke Branch	48	04-13-88	10.5	382	8.95	1.30	.010	10
Canal below siphon near		06-23-88	20.5	320	8.80	.600	.020	7.9
Othello, Wash.		09-10-88	19.0	339	8.49	.840	.050	7.8
SCBID Wahluke Branch	49	04-17-88	17.5	--	9.07	1.20	.020	9.4
Canal at Franklin County		06-23-88	21.5	317	8.86	.600	.020	7.5
line		09-10-88	18.5	338	8.57	.840	.030	7.9
SCBID WB 5 Wasteway	50	04-16-88	18.0	512	8.76	2.90	.040	15
at drop 14 near		06-22-88	21.5	455	8.64	2.70	.100	11
Ringold, Wash.		09-10-88	15.0	515	8.62	3.50	<.010	13
SCBID WB 10 Wasteway	51	04-14-88	19.5	788	8.73	.870	.020	38
near mouth near		06-23-88	27.5	815	9.65	1.40	<.010	39
White Bluffs, Wash.		09-10-88	16.0	590	8.92	.100	<.010	18
FCID Wasteway at	52	04-16-88	15.5	173	8.55	<.100	.040	1.9
Pasco, Wash.		06-21-88	16.5	138	8.49	<.100	.020	1.3
		09-08-88	17.5	151	7.97	<.100	.040	1.

Table 15.--*Concentrations of nitrate, ammonia, and chloride in surface-water samples from the eastern part of Pasco Basin, Washington--Continued*

Site name	Number on Plate 3	Date	Temperature water (degress Celsius)	Specific conductance (µS/cm)	pH (standard units)	Nitrate (mg/L as N)	Nitrogen, ammonia dissolved (mg/L as N)	Chloride dissolved (mg/L as N)
			Franklin County, Wash.--Continued					
Ringold Springs South near Ringold, Wash.	53	04-16-88	15.5	708	8.59	5.10	0.030	25
		06-22-88	16.0	625	8.36	4.20	<.010	20
		09-09-88	17.5	660	8.46	4.20	<.010	19
Baxter Canyon Springs near Richland, Wash.	54	04-16-88	18.1	799	8.63	3.40	.020	35
		06-21-88	20.0	752	8.61	2.80	.030	30
		09-09-88	14.3	845	8.62	3.10	<.010	41

Table 16--*Concentrations of nitrate, ammonia, and chloride, and values of temperature and specific conductance in drain-water samples from Franklin County, Washington*

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; --, no data; <, less than; all concentrations are in milligrams per liter]

Sampling site	Date	Temperature water (degrees Celsius)	Specific conductance (µS/cm)	Chloride	Ammonia as N	Nitrate as N	Mean nitrate as N	Nitrate coefficient of variation in percent
			Sampling sites located near field site 1					
D16-179E-0+00	09-16-88	--	680	19	<0.01	6.5	6.5	--
D16-179F-0+00	09-16-88	--	1,060	32	<.01	12	12	--
D16-179H-0+00	05-18-88	--	738	21	--	6.9	8.6	24
	07-14-88	16.7	735	20	<.01	7.2	--	--
	09-16-88	16.8	728	22	<.01	7.2	--	--
	01-10-89	10.0	705	--	--	8	--	--
	05-24-89	13.2	744	21	--	10	--	--
	07-09-89	15.2	743	19	--	12	--	--
D16-179J-0+00	05-18-88	--	1,000	15	--	13	11.1	11
	07-14-88	15.6	970	15	<.01	10	--	--
	09-16-88	16.2	978	16	<.01	9.8	--	--
	01-10-89	10.9	878	--	--	11	--	--
	05-24-89	12.5	928	15	--	11	--	--
	07-09-89	14.0	944	14	--	12	--	--
D16-179K-0+00	07-14-88	16.8	885	16	<.01	10	11.6	35
	09-16-88	17.7	724	14	<.01	7.4	--	--
	11-21-88	--	928	18	--	12	--	--
	07-09-89	15.1	940	19	--	17	--	--
D16-198S-0+00	09-15-88	15.8	1,065	15	<.01	9.2	9.2	--
D16-198T-0+00	09-15-88	15.3	1,120	16	<.01	10	10	--
D16-198P1-NORTH	09-16-88	--	1,080	16	<.01	18	18	--
D16-198P1-WEST	07-16-88	15.2	1,020	41	<.01	7.4	13.1	25
	09-16-88	15.2	1,010	17	<.01	12	--	--
	11-17-88	--	1,130	17	--	15	--	--
	01-10-89	12.0	998	--	--	17	--	--
	05-24-89	12.9	962	16	--	14	--	--
	07-09-89	--	995	15	--	13	--	--
D16-205F-2316	09-15-88	18.8	1,020	16	<.01	6.7	6.7	--

Table 16--*Concentrations of nitrate, ammonia, and chloride, and values of temperature and specific conductance in drain-water samples from Franklin County, Washington--Continued*

Sampling site	Date	Temperature water (degrees Celsius)	Specific conductance (µS/cm)	Chloride	Ammonia as N	Nitrate as N	Mean nitrate as N	Nitrate coefficient of variation in percent
			Sampling sites located near field site 1--Continued					
D16-207-3581	09-10-88	--	630	18	<0.01	5.1	5.1	--
D16-207-6097	09-10-88	16.7	604	14	<.01	4.7	4.7	--
D16-207-8598	11-17-88	--	645	10	--	5.0	5.0	--
D16-207-9321	07-14-88	15.0	835	21	<.01	15	14	16
	09-10-88	16.2	812	17	<.01	12	--	--
D16-207G-0+00	07-14-88	21.6	350	8.0	.03	1.1	5.5	84
	09-10-88	15.5	974	26	<.01	8.8	--	--
	11-17-88	--	970	27	--	10	--	--
	07-09-89	20.3	418	9.4	--	2.0	--	--
D16-207H-0+00	09-10-88	16.8	631	17	<.01	5.1	6.3	20
	01-10-89	11.2	756	--	--	6.2	--	--
	07-09-89	13.1	920	49	--	7.6	--	--
D16-267-8071	05-17-88	16.1	473	12	.01	2.1	1.6	35
	07-14-88	18.3	410	9.0	<.01	1.0	--	--
	11-17-88	--	472	9.9	--	1.7	--	--
			Sampling sites located near field site 2					
D15-65-2F-700	09-08-88	19.9	--	9.1	.02	4.5	4.5	--
D15-65-2F-4148	08-26-88	20.0	489	9.4	.01	15	9.7	77
	09-08-88	15.2	--	9.0	.02	4.4	--	--
D15-65-2H-0+00	05-17-88	--	1,240	74	--	22	22	--
D15-112P-3471	05-18-88	11.9	1,180	68	.02	20	25	32
	08-25-88	15.7	1,180	48	.02	37	--	--
	09-16-88	15.3	1,200	48	<.01	22	--	--
	11-21-88	13.9	1,180	48	--	21	--	--

Table 16--*Concentrations of nitrate, ammonia, and chloride, and values of temperature and specific conductance in drain-water samples from Franklin County, Washington--Continued*

Sampling site	Date	Temperature water (degrees Celsius)	Specific conductance (µS/cm)	Chloride	Ammonia as N	Nitrate as N	Mean nitrate as N	Nitrate coefficient of variation in percent
			Sampling sites located near field site 2--Continued					
D15-112P1-0+00	09-08-88	14.2	--	54	0.02	14	18	21
	11-18-88	12.2	1,480	94	--	20	--	--
	07-09-89	12.1	1,500	84	--	21	--	--
D15-112P12-0+00	09-16-88	13.7	1,360	74	<.01	27	25	17
	11-21-88	12.4	1,350	73	--	28	--	--
	07-09-89	12.6	1,118	39	--	20	--	--
			Sampling sites located near field site 3					
D23-39E-0+00	11-19-88	--	1,425	26	--	31	31	--
D23-39H-0+00	11-21-88	15.7	463	8.6	--	0.27	0.27	--
D23-43B-0+00	09-09-88	17.3	797	11	<.01	3.5	3.5	--
D23-44-1469	09-17-88	17.3	666	11	<.01	3.5	3.5	--
D23-44J-0+00	09-17-88	16.8	891	16	<.01	8.1	8.1	--
D23-44K-0+00	09-17-88	17.3	897	17	<.01	7.5	9.3	27
	11-19-88	14.3	1,005	17	--	11	--	--
			Miscellaneous sampling sites					
D16-65A-196	05-18-88	--	730	26	--	7.2	7.2	--
D16-133A-1412	08-24-88	16.5	880	32	.01	12	12	--
D16-147N3-0+00	05-17-88	--	1,080	51	--	8.7	9.1	39
	07-15-88	14.3	--	18	<.01	14	--	--
	09-17-88	15.2	933	36	<.01	5.6	--	--
	11-21-88	13.2	1,140	61	--	8.2	--	--

Table 16--*Concentrations of nitrate, ammonia, and chloride, and values of temperature and specific conductance in drain-water samples from Franklin County, Washington--Continued*

Sampling site	Date	Temperature water (degrees Celsius)	Specific conductance (µS/cm)	Chloride	Ammonia as N	Nitrate as N	Mean nitrate as N	Nitrate coefficient of variation in percent
			Miscellaneous sampling sites--Continued					
D16-174-2-2525	08-25-88	18.1	890	30	<0.01	4.5	4.5	--
D16-174-2AA-0+00	08-25-88	17.1	1,020	35	.10	18	18	--
D16-174L2-0+00	05-17-88	--	835	26	--	7.8	6.3	18
	07-16-88	15.7	832	19	<.01	6.5	--	--
	09-17-88	14.8	838	17	<.01	5.6	--	--
	11-21-88	14.2	794	17	--	5.3	--	--
D16-208D-0+00	08-25-88	--	646	13	.03	4.2	4.2	--
D16-266-1195	07-16-88	16.1	758	23	<.01	6.7	6.7	--
D16-266A-0+00	07-17-88	14.5	--	31	<.01	7.1	7.0	6.4
	08-26-88	14.5	893	31	.02	7.3	--	--
	09-16-88	14.1	905	30	<.01	6.3	--	--
	11-21-88	12.4	--	31	--	7.1	--	--
D20-11489-0+00	11-19-88	11.0	--	22	--	11	--	--
D23-37D-0+00	11-19-88	12.5	--	18	--	7.9	--	--
D19-183-0+00	09-17-88	16.0	1,230	16	<0.01	12	--	--
D19-33-0+00	11-21-88	12.5	--	90	--	23	--	--
D16-330-8444	05-18-88	--	711	11	--	1.3	--	--
D16-330-2F-0+00	11-21-88	--	--	15	--	2.2	2.2	4.5
	05-18-88	13.5	1,100	18	0.03	2.3	--	--
D161-14M-611	08-24-88	16.5	956	39	0.02	26	20	30
	11-21-88	--	--	39	--	15	--	--
D16-266C-0+00	07-16-88	--	--	23	<0.01	5.1	--	--

Table 17.--*Concentrations of major ions in drain-water samples from Franklin County, Washington*

[mg/L, milligrams per liter; --, no data; <, less than]

Sampling site	Date	pH, standard units	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg))	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)	Alkalinity, lab (mg/L as $CaCO_3$)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)	Silica, dissolved (mg/L as SiO_2)
				Sampling sites located near field site 1							
D16-179F-0+00	09-16-88	7.6	71	30	130	9.5	358	100	32	0.70	46
D16-179J-0+00	09-16-88	7.4	65	29	110	9.7	365	77	16	.80	46
D16-179K-0+00	09-16-88	7.5	59	25	67	6.1	290	54	14	.60	43
D16-198P1-WEST	09-16-88	7.5	67	29	110	13	334	78	17	.80	46
D16-207-9321	09-10-88	7.3	68	36	57	5.6	314	60	17	1.0	50
D16-207G-0+00	09-10-88	7.7	98	42	57	1.4	355	92	26	.50	46
				Sampling site located near field site 2							
D15-112P12-0+00	09-16-88	7.3	97	47	130	3.2	267	240	74	.30	42
				Sampling sites located near field site 3							
D23-44-1469	09-17-88	7.6	50	30	53	5.1	259	64	11	.50	35
D23-44J-0+00	09-17-88	7.5	62	42	79	5.3	356	83	16	.50	45
				Miscellaneous sampling sites							
D16-147N3-0+00	09-17-88	7.7	50	45	93	3.3	315	120	36	.60	50
D16-174L2-0+00	09-17-88	7.6	65	33	71	7.0	327	79	17	.80	46
D16-266A-0+00	09-16-88	7.5	81	30	75	5.4	284	120	30	.40	49
	11-21-88	--	83	31	74	5.0	294	120	31	.50	49
D20-114Q9-0+00	11-19-88	7.8	38	24	100	1.3	237	110	22	.60	45

Table 18.--*Concentrations of fluoride and other major ions in ground water in the eastern part of Pasco Basin, Washington*

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; --, no data; <, less than]

Well number	Date	Specific conductance (µS/cm)	pH (standard units)	Fluoride, dis solved (mg/L as F)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Sodium (percent)	Potassium, dissolved (mg/L as K)	Alkalinity (mg/L as $CaCO_3$)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Silica, dissolved (mg/L as SiO_2)
						Benton County, Wash.							
08N/27E-01A01D1	08-27-82	574	7.9	0.50	63	22	23	17	3.6	147	84	22	50
	03-08-83	550	7.8	.50	58	22	23	17	3.3	160	79	21	49
	07-22-83	595	7.8	.40	58	22	23	17	3.5	151	80	22	47
08N/27E-01G01	02-20-88	382	8.5	1.4	9.3	4.1	68	70	18	181	3.7	13	75
08N/27E-01K01	08-27-82	464	7.9	.50	41	17	22	21	9.2	131	87	7.0	61
08N/28E-01R01	02-19-88	591	7.9	.20	66	27	15	10	4.1	158	96	28	40
08N/28E-01R03	02-17-88	1,220	7.5	.50	140	61	40	12	12	164	490	29	41
08N/28E-06G01	09-23-71	487	7.6	.40	40	17	27	25	8.0	135	65	15	59
	05-23-72	502	--	--	44	18	--	--	--	--	--	15	--
08N/28E-07M01	09-15-88	393	8.1	1.4	9.4	5.1	68	77	.60	181	1.5	13	70
08N/28E-07P01	08-27-82	579	8.1	1.3	19	12	81	60	16	184	88	15	71
08N/28E-12B02	09-12-88	452	7.8	.40	42	24	24	20	3.2	186	39	11	38
08N/28E-15P01	02-19-88	1,030	7.8	.50	34	26	140	58	21	279	110	67	48
08N/28E-17P01	09-11-88	1,190	7.5	.40	38	56	140	48	1.4	524	74	8.8	51
08N/28E-21H01	02-17-88	380	8.0	.40	39	14	23	23	7.6	171	24	7.0	58
08N/29E-01F02	04-11-88	770	7.5	.30	82	29	45	23	6.3	262	88	32	40
08N/29E-13A01	02-17-88	338	8.4	.40	14	4.6	46	57	16	107	51	8.9	51
08N/29E-17G01D1	08-28-82	570	7.5	.40	46	19	34	27	7.3	175	56	27	56
	03-09-83	495	7.7	.40	42	17	30	26	8.2	149	58	29	58
	07-25-83	525	7.7	.40	45	18	32	26	7.8	162	58	30	57
08N/29E-17G02	06-25-82	820	7.9	.60	77	40	53	24	5.1	369	65	19	50
08N/29E-17K01D1	02-18-88	471	8.3	.90	18	9.0	64	62	3.9	186	48	11	55
08N/29E-22A01	11-17-70	1,240	7.3	.40	100	72	58	18	17	151	510	16	53
08N/30E-05J01	02-18-88	252	8.4	.50	18	4.9	30	48	3.7	117	5.2	10	58

Table 18.--*Concentrations of fluoride and other major ions in ground water in the eastern part of Pasco Basin, Washington--Continued*

Well number	Date	Specific conductance (µS/cm)	pH (standard units)	Fluoride, dis solved (mg/L as F)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Sodium (percent)	Potassium, dissolved (mg/L as K)	Alkalinity (mg/L as $CaCO_3$)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Silica, dissolved (mg/L as SiO_2)
					Benton County, Wash.--Continued								
08N/30E-05K01	02-22-88	755	7.3	0.30	92	21	42	22	10	284	70	28	39
08N/30E-07E02	02-18-88	675	7.5	.30	81	23	34	19	9.1	275	54	19	40
08N/30E-07G04	06-24-82	730	7.5	.30	87	21	45	24	7.6	276	67	29	39
08N/30E-09L02	02-20-88	535	7.4	.80	67	14	32	23	7.0	213	43	15	39
08N/30E-10M03	02-19-88	260	7.6	.20	34	6.6	6.3	10	3.9	113	12	2.8	25
08N/30E-14M01	04-27-88	1,120	4.2	.90	140	27	11	5.0	14	<1.0	730	1.5	62
08N/30E-17D02	06-25-82	605	7.4	.40	77	17	35	22	7.1	267	41	15	40
08N/30E-17R01	04-11-88	885	7.4	.40	110	33	34	15	7.1	302	120	32	39
	09-08-88	855	7.4	.30	100	32	43	19	6.6	242	130	34	41
08N/30E-19M01	06-24-82	550	7.6	.40	41	23	39	29	12	149	94	21	50
08N/30E-22M02	06-24-82	570	7.5	.70	52	16	50	35	4.8	215	51	19	35
08N/30E-22M02	02-22-88	1,220	7.5	.40	140	57	61	18	9.9	395	210	67	37
	10-13-88	598	7.6	.40	55	23	41	27	4.8	242	47	17	35
08N/30E-22R04	02-20-88	590	7.4	.50	64	19	38	25	6.0	237	41	18	38
08N/30E-23E03	02-22-88	398	8.2	.70	21	12	46	46	11	187	.50	18	63
08N/30E-24N02	10-30-59	238	7.9	.20	30	6.9	7.6	13	4.1	112	9.1	1.2	25
08N/30E-25D01	02-18-88	840	7.4	.40	100	25	44	21	10	284	97	27	40
08N/30E-29A01	02-18-88	2,040	7.7	.40	270	85	65	12	6.4	115	700	170	29
08N/30E-29D01	02-20-88	549	7.8	.90	49	27	21	16	5.2	137	62	41	39
08N/30E-34B02	09-09-88	1,170	7.5	.50	110	47	57	21	1.9	265	230	66	36
08N/30E-35E02	02-18-88	935	7.6	.40	100	35	49	21	3.8	269	110	35	34
08N/30E-35K01	09-09-88	410	7.9	.40	30	19	26	26	8.2	148	49	10	55
09N/27E-02E01	02-20-88	523	7.9	.70	48	23	29	22	7.2	156	66	27	50
09N/27E-03R02	02-20-88	489	8.0	.60	40	20	32	26	10	153	80	13	59
09N/27E-08N01	04-19-88	352	8.1	1.0	7.1	1.2	73	82	9.0	168	18	5.4	64

Table 18.--*Concentrations of fluoride and other major ions in ground water in the eastern part of Pasco Basin, Washington--Continued*

Well number	Date	Specific conductance (μS/cm)	pH (standard units)	Fluoride, dis solved (mg/L as F)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Sodium (percent)	Potassium, dissolved (mg/L as K)	Alkalinity (mg/L as $CaCO_3$)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Silica, dissolved (mg/L as SiO_2)
						Benton County, Wash.--Continued							
09N/27E-12F02	04-11-88	508	7.9	0.90	42	23	32	26	2.1	150	66	22	54
	04-19-88	510	7.9	.80	40	22	32	26	2.2	151	67	23	53
09N/27E-16B01	02-19-88	320	8.1	.80	18	12	30	38	9.0	132	35	2.7	56
09N/27E-17P01	09-13-88	608	8.1	.20	55	25	25	18	8.5	137	96	28	45
09N/27E-19K02	02-19-88	820	7.8	.40	99	35	23	11	8.3	186	150	39	50
09N/27E-21D01	08-28-82	400	8.0	.70	14	4.9	56	63	14	131	57	4.4	61
09N/27E-35E01	09-15-88	398	7.8	.20	50	15	14	13	13	171	29	6.7	48
09N/27E-36M01	09-12-88	532	7.6	.50	54	22	22	17	3.4	131	49	23	47
09N/28E-03P01	09-10-88	215	8.1	.30	23	7.8	9.2	18	3.7	97	10	2.3	42
09N/28E-04G01	06-24-82	382	7.8	1.5	11	2.2	72	76	9.4	192	5.0	8.1	60
09N/28E-06A02	06-24-82	633	8.0	.80	48	26	42	28	10	160	140	15	55
09N/28E-08K01	04-11-88	630	7.9	.60	43	25	47	31	11	167	110	27	61
09N/28E-10F01	02-24-88	715	7.5	.20	91	20	31	17	9.0	272	64	18	38
09N/28E-11E01	09-14-88	262	8.0	.20	20	7.8	24	37	5.8	122	12	2.9	52
09N/28E-16A01	11-01-62	627	7.9	.20	58	29	34	21	11	266	56	14	39
09N/28E-17A01	06-24-82	505	8.2	1.7	14	6.2	86	71	13	207	34	12	74
	08-27-82	514	8.0	1.5	14	6.0	86	71	13	210	35	13	74
	05-17-83	495	8.1	1.6	14	6.2	85	71	12	209	32	11	72
09N/28E-18H01	02-24-88	1,510	7.7	.60	98	120	47	12	4.0	181	360	81	59
09N/28E-22B01	09-10-88	980	7.6	.60	78	54	53	21	14	206	270	25	58
09N/28E-22F01D1	09-10-88	1,250	7.7	.80	100	80	49	15	4.5	151	360	91	57
09N/28E-27K01	06-24-82	1,010	7.3	.30	86	47	57	23	13	281	180	47	73
09N/28E-31P01D1	02-22-88	550	7.7	.70	50	29	21	15	5.5	147	81	15	55

Table 18.--*Concentrations of fluoride and other major ions in ground water in the eastern part of Pasco Basin, Washington--Continued*

Well number	Date	Specific conductance (μS/cm)	pH (standard units)	Fluoride, dis solved (mg/L as F)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Sodium (percent)	Potassium, dissolved (mg/L as K)	Alkalinity (mg/L as $CaCO_3$)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Silica, dissolved (mg/L as SiO_2)
						Benton County, Wash.--Continued							
09N/29E-33M01	08-27-82	575	8.0	0.40	47	26	31	22	7.9	228	35	24	47
	05-17-83	632	7.2	.30	52	32	34	21	7.0	255	47	30	44
	04-12-88	560	7.7	.40	46	29	35	24	7.9	236	34	22	49
10N/27E-25R03	02-23-88	591	7.8	.30	61	19	34	24	7.6	189	66	27	35
10N/27E-29R02	08-28-82	430	7.5	.70	28	18	29	29	8.4	139	64	7.2	59
	03-08-83	412	7.9	.80	29	19	29	28	8.2	146	67	7.2	60
	07-22-83	435	8.0	.60	28	19	29	28	8.4	148	67	6.9	58
	02-22-88	400	8.1	.80	27	18	29	29	9.3	144	59	7.0	59
10N/27E-33B01	02-22-88	548	7.5	.70	49	21	31	23	9.3	164	98	15	54
10N/28E-17B01D1	06-15-51	206	9.2	1.0	9.2	3.8	25	55	4.8	74	2.1	10	18
10N/28E-17B01	02-26-88	236	8.3	.20	28	5.9	8.7	16	4.7	94	17	5.3	35
10N/28E-29D03	04-13-88	703	7.3	.30	68	23	64	34	5.8	344	42	15	37
10N/28E-35C03	09-14-88	660	7.6	.20	79	18	26	17	7.0	220	39	20	34
10N/28E-35K05	04-12-88	730	7.4	.30	95	22	28	15	7.5	292	49	20	35
						Franklin County, Wash.							
09N/29E-02A01	02-24-88	853	7.7	.40	79	31	51	25	9.3	202	99	45	40
09N/29E-02G02	05-18-83	445	7.9	1.5	5.2	2.4	90	84	12	198	.20	26	62
09N/29E-02G02D1	04-15-88	432	8.1	1.6	4.5	2.0	90	85	12	193	.40	24	61
09N/29E-06G01	02-25-88	316	8.1	.90	23	6.9	35	45	6.7	158	4.4	6.6	47
09N/29E-21R01D1	02-23-88	595	7.4	.30	77	15	26	18	7.3	198	61	21	35
09N/29E-23J02	10-17-60	489	7.9	.50	51	15	28	24	6.4	185	40	11	33
	05-04-61	428	7.9	.40	40	13	26	26	5.7	133	52	16	32
09N/29E-23P01	04-28-42	326	--	.30	38	11	16	19	5.1	156	18	1.6	26

Table 18.--*Concentrations of fluoride and other major ions in ground water in the eastern part of Pasco Basin, Washington--Continued*

Well number	Date	Specific conductance (µS/cm)	pH (standard units)	Fluoride, dis solved (mg/L as F)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Sodium (percent)	Potassium, dissolved (mg/L as K)	Alkalinity (mg/L as $CaCO_3$)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Silica, dissolved (mg/L as SiO_2)
					Franklin County, Wash.--Continued								
09N/29E-23P02	05-04-61	461	7.8	0.40	61	14	14	12	5.6	182	38	10	33
09N/30E-02R01	08-27-82	575	8.0	.50	47	24	31	23	4.8	167	76	26	41
	03-08-83	575	7.8	.60	46	25	31	23	4.7	176	75	25	41
	07-19-83	568	8.0	.50	48	26	32	23	4.8	177	72	25	41
09N/30E-06L01	09-07-88	730	7.7	.40	69	25	51	28	6.8	206	74	33	43
09N/30E-06Q01D1	02-24-88	753	7.7	.50	75	28	37	20	7.7	193	82	36	38
09N/30E-08B02D1	09-08-88	675	7.8	.50	65	25	36	22	7.4	144	78	41	42
09N/30E-18J01	08-28-70	506	8.6	1.8	1.9	.50	110	92	11	244	0.0	15	54
09N/30E-20D01	05-23-60	487	7.9	.40	47	14	32	27	7.0	162	36	12	38
	10-17-60	594	7.7	.60	58	18	33	24	8.1	166	46	16	38
09N/30E-27K01	10-17-60	480	7.9	.60	42	14	34	30	6.7	148	55	22	39
09N/31E-04N01	04-28-42	480	--	.90	21	12	61	52	15	143	86	9.5	50
	10-17-60	464	8.1	1.2	20	7.9	58	60	1.8	141	72	8.0	50
09N/31E-07Q03	02-25-88	584	8.2	.70	22	7.6	81	62	17	107	140	20	53
10N/28E-12F01	03-10-83	415	7.9	.50	28	14	34	35	8.3	132	81	3.4	43
	02-23-88	433	8.2	.50	31	15	37	35	9.7	129	87	5.0	46
10N/29E-02Q01	09-15-88	450	7.9	.50	34	18	33	30	9.5	133	86	7.9	60
10N/29E-03P01	09-13-88	435	8.0	.60	29	21	37	33	3.7	175	42	11	42
10N/29E-03R01	09-12-88	780	7.8	.70	47	42	54	29	1.7	153	110	48	41
10N/29E-03R02	09-14-88	823	7.8	.60	72	23	100	43	7.8	318	90	21	44
10N/29E-09Q01	09-09-88	710	7.8	.80	48	27	73	40	4.2	238	88	27	33
10N/29E-09R01	09-14-88	425	8.0	.50	27	15	40	38	11	140	71	6.2	64
10N/29E-10B01	09-14-88	924	7.6	.60	51	34	72	37	2.6	168	92	54	39

Table 18.--*Concentrations of fluoride and other major ions in ground water in the eastern part of Pasco Basin, Washington--Continued*

Well number	Date	Specific conductance (µS/cm)	pH (standard units)	Fluoride, dis solved (mg/L as F)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Sodium (percent)	Potassium, dissolved (mg/L as K)	Alkalinity (mg/L as $CaCO_3$)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Silica, dissolved (mg/L as SiO_2)
					Franklin County, Wash.--Continued								
10N/29E-10C01	09-15-88	496	8.1	0.40	32	17	43	37	9.2	113	98	12	42
10N/29E-10D01	12-00-53	409	7.8	.80	29	14	38	37	7.8	140	63	12	--
10N/29E-10N01	11-17-88	615	7.9	1.4	28	25	67	45	1.5	212	54	22	54
10N/29E-10N02	11-17-88	845	7.7	.50	69	26	77	37	6.3	327	84	26	40
10N/29E-10N03	09-07-88	1,140	7.4	.30	110	38	87	30	12	324	110	33	43
	11-17-88	1.150	7.4	.30	100	36	89	32	9.8	394	120	35	43
10N/29E-10Q02	09-13-88	624	7.7	1.4	47	31	38	25	3.2	151	32	41	
10N/29E-11C01	09-14-88	878	7.8	.90	64	41	75	33	1.2	292	89	36	47
10N/29E-11N01	07-07-89	455	--	.80	34	19	32	29	7.8	171	40	11	51
10N/29E-14R01	07-08-89	440	--	.40	45	14	28	26	5.3	178	33	8.7	38
10N/29E-15M01	09-10-88	525	7.9	.50	40	22	32	26	9.2	140	110	13	53
10N/29E-25G01	07-26-83	705	7.6	.40	57	23	54	33	2.8	203	90	37	46
10N/30E-03J01	08-27-82	690	8.0	.50	43	35	35	22	11	193	70	39	56
	03-11-83	645	7.7	.60	44	36	35	22	11	188	68	39	57
	07-21-83	660	8.0	.60	44	36	36	22	11	190	67	38	55
	02-26-88	639	8.0	.60	42	35	35	22	11	181	64	33	56
10N/30E-21N01	09-08-88	435	8.2	.30	18	9.3	60	55	20	135	66	9.3	40
10N/30E-21R01	07-09-89	590	--	.40	46	15	60	41	11	246	48	11	47
10N/30E-35R01	03-10-83	645	7.8	.60	59	23	35	23	6.6	156	75	36	44
10N/31E-09D01	07-21-83	622	8.0	.40	61	23	31	21	6.6	182	87	31	39
10N/31E-32L02	08-30-82	415	8.0	.80	24	19	30	30	10	131	53	9.9	58
	03-09-83	405	7.8	.90	24	19	29	29	10	145	52	9.5	59
	07-20-83	412	7.8	.90	24	19	30	30	10	144	52	11	56
	02-25-88	438	7.9	.60	25	16	39	37	13	144	58	8.2	56
10N/31E-32M02	04-19-88	455	8.2	.60	24	12	49	46	11	128	78	15	51

Table 18.--*Concentrations of fluoride and other major ions in ground water in the eastern part of Pasco Basin, Washington--Continued*

Well number	Date	Specific conductance (µS/cm)	pH (standard units)	Fluoride, dis solved (mg/L as F)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Sodium (percent)	Potassium, dissolved (mg/L as K)	Alkalinity (mg/L as $CaCO_3$)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Silica, dissolved (mg/L as SiO_2)
						Franklin County, Wash.--Continued							
10N/31E-32N03	09-10-88	590	7.9	0.50	42	30	25	19	7.6	132	47	38	52
11N/29E-03H01	05-23-83	296	8.1	.70	18	5.9	32	47	6.2	114	23	6.4	51
	07-25-83	286	7.8	.60	18	5.9	31	47	6.3	118	24	6.4	50
11N/29E-05D01	07-08-89	605	--	.70	36	9.9	91	59	11	135	22	43	66
11N/29E-05R02	05-24-89	612	8.0	.30	58	33	26	--	1.2	207	75	18	42
11N/29E-10C01	09-08-88	860	7.7	.30	69	45	52	24	1.8	224	150	48	40
	11-18-88	860	7.7	.30	74	46	44	20	1.7	223	150	48	41
11N/29E-10C02	11-18-88	2,100	7.6	.30	200	120	52	10	1.8	233	360	320	47
11N/29E-10C03	09-08-88	1,360	7.4	.40	80	46	160	47	4.4	365	200	49	52
11N/29E-14R01	07-08-89	835	--	.60	57	14	110	54	6.1	344	62	11	40
11N/29E-20N01	04-12-88	420	8.5	2.0	9.3	2.4	78	77	13	155	29	22	66
11N/29E-20N02	02-19-88	880	7.8	.70	53	72	39	16	1.4	249	160	50	43
11N/29E-23C01	09-10-88	420	8.3	1.0	16	6.1	69	65	11	141	49	15	58
11N/29E-23N01	09-09-88	620	7.6	.40	53	24	27	20	3.1	112	61	45	33
11N/29E-23N02	09-09-88	510	7.7	.50	35	36	14	11	0.60	151	67	23	54
11N/29E-31N01	08-30-82	435	7.8	.80	20	7.4	60	58	11	196	10	19	68
	03-09-83	430	7.9	.90	20	7.8	60	58	11	202	0.90	19	72
	07-25-83	423	7.5	.80	20	7.6	59	57	11	204	1.6	20	68
11N/29E-32R01	02-22-88	1,040	7.7	.40	110	56	34	12	11	12	380	14	45
1N/30E-02R01	03-10-83	555	7.8	.30	53	22	29	21	6.9	187	68	23	41
11N/30E-11C01	12-14-70	843	7.7	.40	90	39	21	10	4.6	172	160	51	45

Table 18.--*Concentrations of fluoride and other major ions in ground water in the eastern part of Pasco Basin, Washington--Continued*

Well number	Date	Specific conductance (µS/cm)	pH (standard units)	Fluoride, dis solved (mg/L as F)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Sodium (percent)	Potassium, dissolved (mg/L as K)	Alkalinity (mg/L as $CaCO_3$)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Silica, dissolved (mg/L as SiO_2))
					Franklin County, Wash.--Continued								
11N/30E-12D01	08-30-82	585	8.2	0.30	30	8.5	81	57	18	158	94	31	37
	03-09-83	--	8.3	.30	33	8.9	80	55	19	165	100	34	32
	07-21-83	588	8.3	.40	29	8.1	80	57	20	169	89	29	35
11N/30E-29C01	02-17-88	490	8.0	.70	35	24	39	31	1.9	194	47	13	23
11N/30E-36M01	05-17-83	830	7.8	.30	60	57	25	12	2.1	195	120	55	50
	07-22-83	838	7.8	.40	60	60	27	13	2.0	214	120	54	51
11N/30E-36M01	02-20-88	960	7.9	.40	69	66	39	16	2.5	221	140	59	52
11N/31E-04P01	08-30-82	375	8.2	.90	18	6.9	46	53	11	131	27	8.7	85
	05-18-83	380	7.8	1.0	19	7.3	47	53	11	140	27	8.0	84
	07-21-83	375	8.0	1.0	19	7.2	46	52	11	142	27	8.6	80
	09-13-88	360	8.0	1.0	19	7.3	47	52	13	136	28	8.0	81
11N/31E-14B01	04-26-88	415	7.8	.70	24	10	45	46	9.4	144	30	9.0	74
11N/31E-15G01	04-12-88	390	8.0	.80	23	9.9	43	46	9.7	140	29	9.1	71
11N/31E-31H01	04-13-88	805	7.8	.40	77	33	35	18	8.2	191	110	42	39
11N/31E-33B01D1	04-13-88	398	8.0	.90	21	9.1	45	49	11	142	31	8.6	75
12N/28E-12H01	04-27-42	459	--	1.0	8.8	4.6	83	75	14	161	59	9.5	52
	10-17-60	456	8.2	1.2	7.5	1.9	84	80	16	157	57	9.5	53
	02-20-88	465	8.4	.90	18	4.8	73	63	22	154	66	12	59
12N/28E-23H01D1	08-30-82	395	8.2	.80	15	3.7	62	68	9.6	159	11	19	62
	03-09-83	378	8.2	.90	15	3.9	63	68	9.6	168	9.6	18	62
	07-26-83	386	8.1	.90	16	4.0	62	66	9.3	172	9.6	20	61
12N/28E-24F01S	03-16-58	1,130	7.9	.50	110	43	68	24	11	152	320	86	32
	02-21-88	900	7.7	.40	81	33	71	30	15	276	160	29	42

Table 18.--*Concentrations of fluoride and other major ions in ground water in the eastern part of Pasco Basin, Washington--Continued*

Well number	Date	Specific conductance (μS/cm)	pH (standard units)	Fluoride, dis solved (mg/L as F)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Sodium (percent)	Potassium, dissolved (mg/L as K)	Alkalinity (mg/L as $CaCO_3$)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Silica, dissolved (mg/L as SiO_2)
						Franklin County, Wash.--Continued							
12N/28E-24N01	09-15-70	468	8.7	4.2	3.7	0.70	94	89	11	153	29	29	56
12N/28E-25M01	09-12-88	340	8.2	.30	24	7.9	38	45	6.3	132	46	7.8	41
12N/29E-01A01	09-12-88	990	7.8	.30	89	50	41	16	23	187	190	60	56
12N/29E-04N01	09-12-88	1,950	7.7	.30	230	62	100	20	16	83	680	110	54
12N/29E-11M01	09-12-88	305	8.2	.50	18	5.9	40	53	6.1	126	30	5.5	53
12N/29E-17K01	09-12-88	360	8.4	.70	11	3.3	65	73	9.0	141	33	8.5	46
12N/29E-28F01	01-01-53	282	8.0	1.0	9.4	4.6	46	66	6.3	100	35	11	--
	11-02-56	310	7.4	4.7	9.0	4.5	45	66	6.6	89	40	12	
	12-27-56	343	7.7	1.5	13	3.9	48	63	9.4	85	50	11	--
12N/29E-34B01D1	03-11-83	370	8.3	1.7	6.8	1.9	72	79	13	167	14	14	61
12N/30E-05B01	03-06-56	381	7.8	.70	31	21	15	16	3.9	128	30	21	--
	09-01-82	745	7.8	.30	72	39	22	12	5.1	150	120	54	57
	03-10-83	735	7.6	.30	66	38	21	12	5.1	157	120	51	56
	07-22-83	735	7.7	.30	69	38	21	12	5.1	158	130	53	55
12N/30E-33B01	02-18-88	1,200	7.6	.30	120	50	44	16	4.2	249	87	160	49
12N/31E-10M01	09-13-88	372	8.0	.70	19	8.7	50	53	10	149	39	8.5	65
13N/28E-09L01	02-27-88	332	8.6	.60	5.4	1.1	61	81	11	122	27	13	64
13N/28E-13N01	10-00-54	388	8.6	2.0	1.6	0.20	78	86	17	145	20	15	--
13N/28E-13N01	11-10-70	386	8.6	2.2	0.80	0.40	78	87	17	145	19	14	67
	03-14-83	375	8.4	2.4	0.77	0.34	76	87	16	149	20	15	64
13N/28E-21J01	11-19-88	1,600	7.8	.30	150	83	45	12	6.8	289	260	31	43
	11-19-88	1,090	7.8	.50	49	27	160	59	3.8	317	210	24	44
13N/28E-21J03	09-09-88	1,710	7.5	.30	100	54	200	48	5.6	281	330	93	43
	11-19-88	1,760	7.6	.30	110	57	190	45	1.4	311	350	99	43

Table 18.--*Concentrations of fluoride and other major ions in ground water in the eastern part of Pasco Basin, Washington--Continued*

Well number	Date	Specific conductance (μS/cm)	pH (standard units)	Fluoride, dis solved (mg/L as F)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Sodium (percent)	Potassium, dissolved (mg/L as K)	Alkalinity (mg/L as $CaCO_3$)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Silica, dissolved (mg/L as SiO_2)
						Franklin County, Wash.--Continued							
13N/29E-03C01	09-14-88	975	7.4	0.50	99	49	33	14	7.4	212	130	42	64
13N/29E-04A01	09-14-88	540	7.5	<.10	46	26	30	22	6.6	196	48	14	65
13N/29E-08H01	09-01-82	320	8.0	.50	19	8.2	38	48	6.8	140	11	10	64
	03-10-83	341	7.9	.50	22	9.4	40	46	7.1	167	13	12	61
	07-22-83	435	7.9	.40	31	14	38	36	8.0	202	17	12	61
13N/29E-12L01	04-14-88	760	7.8	.30	65	36	31	17	10	179	120	69	54
13N/29E-23M01	02-24-88	640	7.8	.30	52	25	38	25	11	146	82	42	52
13N/29E-26B01	12-10-54	458	7.7	.50	35	22	24	22	5.5	111	71	23	--
13N/29E-32M01	02-20-88	470	8.0	.40	4.0	7.9	45	40	8.6	135	76	19	67
13N/29E-35Q01	09-13-88	305	8.1	.20	15	6.0	42	57	6.4	124	25	6.6	52
13N/30E-12N01	02-24-88	242	8.0	.30	28	10	6.9	12	2.6	110	13	2.7	40
13N/30E-13M01D1	02-25-88	618	7.9	.30	76	27	11	7	2.8	171	89	26	42
13N/30E-31N01	09-01-82	925	7.9	.30	86	41	52	23	4.8	241	150	49	48
	03-10-83	955	7.5	.30	80	39	51	23	4.3	255	150	47	46
	07-26-83	845	7.6	.80	77	39	52	24	4.2	255	120	47	51
	04-14-88	830	7.8	.30	74	34	50	25	3.0	262	110	45	42
13N/31E-01E01	08-31-82	560	7.6	.30	53	22	25	19	7.3	206	32	19	54
	03-10-83	525	7.6	.40	52	21	24	19	6.7	226	30	18	54
	07-21-83	545	7.6	.30	55	23	26	19	7.2	232	31	21	54
13N/31E-24R01	03-13-58	322	7.8	.50	22	12	27	34	6.4	138	17	5.2	42
14N/27E-26E01	04-15-88	620	7.8	.40	56	25	55	32	9.8	276	79	25	29
14N/28E-15E01	11-06-89	850	--	1.0	49	31	80	40	6.6	381	55	14	32
14N/28E-15N01	11-06-89	560	--	.90	38	27	37	28	2.9	211	42	25	46
14N/28E-16A01	11-21-88	--	--	.90	42	27	35	26	1.0	211	44	16	60
14N/28E-16R01	11-06-89	522	--	.50	38	20	43	34	1.0	141	9.0	68	39

Table 18.--*Concentrations of fluoride and other major ions in ground water in the eastern part of Pasco Basin, Washington--Continued*

Well number	Date	Specific conductance (µS/cm)	pH (standard units)	Fluoride, dis solved (mg/L as F)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Sodium (percent)	Potassium, dissolved (mg/L as K)	Alkalinity (mg/L as $CaCO_3$)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Silica, dissolved (mg/L as SiO_2)
					Franklin County, Wash.--Continued								
14N/28E-21J01	11-06-89	1,120	--	0.80	68	60	64	25	0.90	238	120	45	46
14N/28E-28A01	11-06-89	2,200	--	.50	190	98	230	36	5.7	465	730	81	46
14N/28E-28C01	09-17-88	1,080	8.0	.40	100	37	47	19	19.0	209	90	31	55
14N/28E-29B01	09-14-88	450	8.0	.50	36	18	34	30	7.8	156	53	11	63
14N/29E-05A01	08-31-82	560	8.2	.50	38	30	32	24	5.9	149	76	32	57
	03-15-83	557	7.8	.70	41	33	34	23	6.0	161	80	32	59
	07-26-83	580	8.3	.60	37	32	32	23	6.0	162	80	34	56
14N/29E-09A01	03-20-52	373	8.0	1.0	15	10	48	54	7.5	149	26	13	59
	04-23-53	378	8.0	1.0	20	12	44	--	--	152	26	12	57
	10-28-53	377	8.2	1.0	19	11	45	49	7.8	154	24	11	62
	08-18-54	378	7.7	1.0	21	12	43	46	6.9	154	27	12	55
	09-29-55	386	8.1	0.90	20	9.9	44	49	7.6	153	24	11	55
	09-13-56	385	8.1	1.0	20	10	44	49	7.6	153	25	13	56
	11-08-57	398	8.0	.90	21	12	43	45	8.1	153	30	13	49
	06-28-60	378	7.9	1.1	18	11	45	49	7.8	153	24	11	56
	10-19-60	411	8.0	1.0	21	11	43	46	8.2	152	29	10	56
	10-05-61	377	7.9	1.1	20	10	45	49	8.1	153	25	12	57
	10-09 62	386	7.9	1.0	20	10	45	49	7.6	155	24	11	57
	04-29-64	403	7.8	1.0	22	11	44.	46.	8.2	149	33	14	57
	01-26-65	395	7.9	1.0	21	12	43	46	7.9	153	31	13	55
	01-27-66	395	8.2	1.1	20	12	45	47	8.0	149	30	14	52
	02-13-67	389	8.1	1.0	20	11	44	48	7.7	149	28	14	28
	03-15-67	388	7.9	1.0	21	12	42	45	7.8	148	28	14	60
	04-26-67	407	7.9	1.0	20	12	43	46	8.3	148	32	14	58
	03-04-68	410	8.0	1.0	22	12	44	46	8.0	148	34	17	59
	06-12-69	412	7.9	.70	22	12	44	46	7.0	148	34	17	54

Table 18.--*Concentrations of fluoride and other major ions in ground water in the eastern part of Pasco Basin, Washington--Continued*

Well number	Date	Specific conductance (µS/cm)	pH (standard units)	Fluoride, dis solved (mg/L as F)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Sodium (percent)	Potassium, dissolved (mg/L as K)	Alkalinity (mg/L as $CaCO_3$)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Silica, dissolved (mg/L as SiO_2)
					Franklin County, Wash.--Continued								
14N/29E-14C01	07-09-89	765	--	0.40	66	44	32	16	7.4	233	100	24	54
14N/29E-19Q01	08-31-82	660	7.8	.50	49	27	41	26	11	143	100	30	61
	03-10-83	645	7.6	.60	50	29	42	26	11	149	110	29	63
	07-27-83	661	7.7	.50	50	28	42	26	11	157	110	30	60
	09-14-88	620	7.8	.20	44	27	40	27	10	147	93	26	60
14N/29E-27N01	11-04-89	1,220	--	.50	110	64	56	18	10	196	230	42	63
14N/29E-28A01	11-04-89	885	--	1.0	40	15	150	66	6.4	409	57	10	42
14N/29E-28C01	02-25-88	2,280	7.7	.50	130	79	250	45	19	170	630	74	16
	11-04-89	2,160	--	.50	130	75	230	43	19	173	630	70	61
14N/29E-32N01	09-14-88	395	8.0	.40	26	16	33	34	9.1	142	41	12	60
14N/30E-08G01	03-13-58	1,570	7.9	.30	140	110	42	10	7.8	241	370	130	40
14N/30E-10P01	07-00-52	396	8.5	1.1	26	19	30	30	5.1	146	--	43	15
	08-31-82	375	7.7	.40	3.0	19	22	23	4.8	150	28	7.7	53
	03-14-83	370	7.5	.50	29	18	21	23	4.7	156	29	8.3	51
	07-26-83	375	7.7	.50	28	19	21	23	5.1	158	31	7.9	51
	02-25-88	398	7.7	.40	29	19	22	23	5.1	148	35	13	51
14N/30E-20A01	01-00-52	503	7.9	.50	20	9.4	62	57	11	183	42	14	
	03-13-58	735	7.7	.40	74	32	24	14	7.8	128	93	66	25
14N/30E-27J01	11-01-53	587	7.5	.60	44	37	19	13	5.9	138	100	42	
					Grant County, Wash								
14N/27E-03P01D1	11-20-88	743	8.2	.90	37	16	97	56	4.4	176	140	32	25

Table 19.--*Nitrite and nitrate concentrations in selected ground-water samples from the eastern part of Pasco Basin, Washington*

[mg/L, milligrams per liter; <, less than]

Well number	Date sampled	Nitrite (mg/L as N)	Nitrate (mg/L as N)
	Benton County, Wash.		
07N/30E-01Q02	09-08-86	<0.01	3.0
07N/31E-06N01	09-08-86	<.01	2.3
08N/30E-14M01	09-06-86	<.01	.30
08N/30E-17L01	09-06-86	<.01	8.5
08N/30E-22G02D1	09-10-86	<.01	<.10
08N/30E-26B01	09-08-86	<.01	4.0
08N/30E-27F01	09-09-86	<.01	<.10
08N/30E-29R01	09-10-86	<.01	4.3
08N/30E-34Q02	09-09-86	<.01	3.9
09N/27E-03R02	09-06-86	<.01	<.10
09N/27E-12F02	09-06-86	<.01	6.7
09N/27E-17P02	09-06-86	<.01	6.0
09N/28E-05A01D1	09-06-86	<.01	.10
09N/28E-05H01	09-06-86	<.01	<.10
09N/28E-08B01	09-08-86	<.01	<.10
	09-09-86	<.01	<.10
09N/28E-15G01	09-09-86	<.01	6.7
09N/28E-20A01	09-09-86	<.01	24
09N/29E-36N02	09-06-86	<.01	3.5
	Franklin County, Wash.		
09N/29E-17L01	09-10-86	<.01	<.10
09N/30E-08B02D1	09-09-86	<.01	12
09N/30E-22K01	09-10-86	<.01	5.0
09N/30E-34D01	09-08-86	<.01	9.6
09N/31E-07Q03	09-24-86	<.01	<.10
10N/30E-04N01	09-10-86	<.01	14
11N/28E-13C02	09-06-86	<.01	7.1
11N/30E-29C01	09-08-86	<.01	1.8
11N/31E-30E01	09-06-86	<.01	6.5
12N/28E-12H01	09-09-86	<.01	<.10
13N/30E-10R01	09-12-86	<.01	8.9
14N/29E-28C01	09-24-86	<.01	100

Table 20.--*Nitrate concentrations in duplicate water samples from eastern Pasco Basin, Washington*

[mg/L, milligrams per liter; <, less than]

Well number or sampling location	Date sampled	Concentrations of Nitrate as N: Analytical results for duplicates in mg/L	Concentrations of Nitrate as N: Percent difference[1]
07N/30E-01Q02	02-19-88	2.1/2.	10.0
08N/29E-12H01	04-13-88	.62/.62	0.0
08N/30E-05K01	09-07-88	7.7/7.6	1.3
08N/30E-27B02	02-18-88	<.10/<.10	0.0
09N/28E-20A01	02-24-88	20/22	9.5
09N/29E-02D03	02-24-88	5.3/5.0	5.8
09N/30E-08B02D1	09-08-88	15/.15	0.0
12N/30E-30L01	02-23-88	5.5/5.0	1.8
13N/29E-12L01	04-14-88	.13/.15	14.0
14N/29E-28C01	02-25-88	81/82	1.2
CID No. 3 Canal	04-13-88	.21/.22	4.7
08N/28E-15P01	07-01-87	16/16	0.0
08N/28E-21A01	07-01-87	16/16	0.0
08N/29E-13A01	07-01-87	<.10/<.10	0.0
08N/30E-29A01	07-01-87	26/26	0.0
08N/30E-29D01	07-01-87	3.8/3.8	0.0
09N/27E-19P01	07-01-87	.80/.70	13.0
10N/28E-12F01	07-01-87	<.10/<.10	0.0
10N/30E-21N01	07-06-87	.70/.90	25.0
10N/30E-33N04	07-01-87	20/20	0.0
11N/28E-13C02	07-01-87	6.2/6.0	3.3
12N/29E-01A01	07-01-87	15/15	0.0
13N/30E-16G01D2	07-01-87	4.9/5.0	2.0
14N/29E-09B02	07-01-87	2.5/2.5	0.0

[1]Median difference: 0.0 percent.
Mean difference: 3.4 percent.

Table 21.--*Duplicate analyses of soil and sediment samples*

[5.4 / 3.7 (37), analytical results for sample pair and percent difference in parentheses]

Sampling location	Depth (feet)	Nitrate as N, in milligrams per kilogram dry weight		Percent moisture	
Borehole No. 1, 09N/27E-26N	9-10.5	5.4/3.7	(37)	6.7/4.1	(48)
	24-25.5	2.9/2.7	(7.1)	6.3/5.6	(12)
Borehole No. 2, 09N/27E-26M	4- 5.5	.80/.80	(0.0)	4.8/6.5	(30)
	9-10.5	4.7/5.5	(16)	5.0/5.1	(2.0)
	14-15.5	16.8/17.3	(2.9)	5.4/5.2	(3.8)
	19-20.5	18.4/20.5	(11)	7.1/5.2	(31)
	24-25.5	20.2/20	(1.0)	4.9/4.6	(6.3)
Corehole No. 1, 09N/27E-35D	4-4.2	9.4/10.2	(8.2)	4.0/4.1	(2.5)
	8-8.4	.70/.50	(33)	5.0/5.4	(7.7)
Corehole No. 2, 09N/27E-35D	1-1.4	9 /12	(20)	14.6/16.4	(12)
Corehole No. 3, 09N/27E-35H	1-1.4	27.4/23.3	(16)	21.4/21.5	(0.5)
Jackass Mountain corehole	1	1.0/1.0	(0.0)	8.5/8.4	(1.2)
White Bluffs outcrop, 13N/27E-11	6	1.5/1.0	(40)	4.8/4.2	(13)
	50	24.3/24	(1.2)	3.0/2.9	(3.4)
	100	4.3/4.5	(4.5)	4.6/5.7	(21)
White Bluffs outcrop, 14N/27E-16L	71	.30/0.30	(0.0)	7.7/8.2	(6.3)
Borehole AH18 14N/27E-23M	4-6	.80/1.5	(61)	2.0/2.2	(9.5)
	18-20	2.8/2.0	(33)	10.8/ 12.3	(13)
	25	3.0/2.5	(18)	21.6/ 20.9	(3.3)
	45	1.0/1.5	(40)	12.2/ 12.9	(5.6)
Borehole AH20 14N/27E-24L	4-6	.80/2.0	(86)	10/9.8	(2.0)
	18-20	.80/1.3	(48)	11.3/ 11.3	(0.0)
	41	1.80/1.0	(57)	6.5/6.5	(0.0)
	Median percent difference:		16		6.3
	Mean percent difference:		24		10