Ground-Water Flow and Water Quality in the Sand Aquifer of Long Beach Peninsula, Washington

U.S. GEOLOGICAL SURVEY
Water-Resources Investigations Report 95-4026

Prepared in cooperation with the
PACIFIC COUNTY DEPARTMENT OF COMMUNITY DEVELOPMENT
and WASHINGTON STATE DEPARTMENT OF ECOLOGY

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By Blakemore E. Thomas

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Tacoma, Washington
1995

U.S. DEPARTMENT OF THE INTERIOR

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CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
inch (in)	25.4	millimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
acre	4,047	square meter
square mile (mi^2)	2.590	square kilometer
acre-foot (acre-ft)	1,233	cubic meter
acre-foot per year (acre-ft/yr)	1,233	cubic meter per year
inch per hour (in/hr)	2.54	centimeter per hour
inch per year (in/yr)	2.54	centimeter per year
foot per foot (ft/ft)	1.0	meter per meter
foot per day (ft/d)	0.3048	meter per day
foot squared per day (ft^2/d)	0.0929	meter squared per day
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
gallon (gal)	3.785	liter
gallons per minute (gal/min)	0.06309	liters per second

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.

GROUND-WATER FLOW AND WATER QUALITY IN THE SAND AQUIFER OF LONG BEACH PENINSULA, WASHINGTON

by Blakemore E. Thomas

ABSTRACT

This report describes an investigation of ground-water flow and water quality in the sand aquifer of the Long Beach Peninsula. The peninsula is located in the southwestern corner of the State of Washington, is about 27 miles long, and has an average width of about 1.5 miles. It is surrounded by seawater, by the Pacific Ocean on the west and Willapa Bay on the east. Water supplies on the peninsula are derived mostly from a local water-table aquifer composed largely of sand.

The recent growth of population on the peninsula and the projected future growth have created concerns about the quantity and quality of the ground-water resource. Some issues include declining ground-water levels from increased pumpage, and ground-water contamination from seawater intrusion, pesticides or fertilizers from cranberry-growing areas, and septic-system effluent.

The ground-water system of the Long Beach Peninsula consists of a sand aquifer with some lenses of silt and clay that may act as confining beds in local areas. Data are lacking or inconsistent to define a confining bed that extends throughout the peninsula. Hydraulic conductivity calculated from slug tests in 58 shallow wells ranged from 10 to 37 feet per day with a median of 22 feet per day.

Average annual ground-water recharge by infiltration and percolation of precipitation is estimated to be about 58 inches or 111,000 acre-feet, which is 72 percent of the average annual precipitation of 80 inches. Average annual ground-water discharge is estimated to be about 30,200 acre-feet to the Pacific Ocean, 56,000 acre-feet to Willapa Bay, and 24,800 acre-feet to surface-water drainage channels.

Ground-water movement is generally perpendicular to the spine of the peninsula. A ground-water divide occurs along a north-south line and ground water flows west or east from the divide toward the Pacific Ocean or Willapa Bay. There does not appear to have been any long-term decline of the water table of the sand aquifer from 1974-92. Ground-water levels measured at three east-west cross sections in 1974-75 were at about the same altitude as water levels measured in 1992.

Relatively accurate individual regression relations were developed at 45 wells with ground-water altitude as a response variable and cumulative precipitation for 4 months as an explanatory variable. The average coefficient of determination for all individual relations was 0.77, with a range of 0.11 to 0.89.

Some empirical frequency or probability relations for precipitation and ground-water levels were used to estimate how often the maximum water levels measured in this study would be expected to occur in the future. These water levels reflected the lower-than-average precipitation that occurred during the study. Assuming that the annual maximum precipitation for 4 consecutive months is random and independent, the historical record of precipitation is representative of the future distribution of precipitation, and the relation between precipitation and water levels is accurate and stationary; a probability analysis of the historical record indicates that in any one year in the future there is a probability of 70 percent that the maximum water levels measured in wells during the winter of 1991-92 would be equaled or exceeded.

The shallow ground water had generally low dissolved-solids concentrations in July 1992, with a median concentration of 92 milligrams per liter (mg/L) and a range of 56 to 218 mg/L. Sodium was the dominant cation and bicarbonate was the dominant anion. The distribution of hardness of the water samples was 84 percent with soft water and 16 percent with moderately hard water.

The water quality of the shallow ground water was generally good, with a few small to moderate problems. A natural problem is locally high concentrations of dissolved iron. About 30 percent of the water samples had dissolved-iron concentrations of greater than 0.3 mg/L, which is the secondary maximum contaminant level established by the U.S. Environmental Protection Agency.

No appreciable amount of seawater has intruded into the sand aquifer. The samples of shallow ground water collected in July 1992 had a median chloride concentration of 15 mg/L and a maximum concentration of 52 mg/L. The heavy average annual precipitation of about 80 inches, large average annual ground-water recharge of about 58 inches or 111,000 acre-feet, and small ground-water withdrawal rate (about 780 acre-feet per year in 1992) combine to maintain a thick freshwater lens of ground water that prevents seawater intrusion throughout the year.

Agricultural activities do not appear to have appreciably affected the quality of shallow ground water on the Long Beach Peninsula. The concentration of nitrate in ground water was not significantly higher near cranberry-growing areas, and no sample of ground water or surface water had concentrations of selected pesticides or associated compounds that were above the analytical detection limits. Of the seven ground-water samples in which bacteria were detected, only one sample appeared to be related to agriculture; that sample was from a well located in an area where cattle graze for part of the year.

Septic systems probably caused an increase in the concentration of nitrate in shallow ground water in areas of higher population density. Concentrations of nitrate were significantly related to population density. However, the concentrations were not generally high; median concentrations of nitrate increased from less than 0.05 mg/L in areas of low population density to 0.74 mg/L in areas of high density. Septic systems did not cause regional bacterial contamination of the ground water. Bacteria were detected in seven ground-water samples; however, only two of those samples were from wells that are close to septic systems.

A limited amount of historical water-quality data is available for the peninsula; therefore, it is difficult to assess long-term changes. From 1968-92, chloride concentrations and values of specific conductance appear to have remained stable. Likewise, it appears that nitrate concentrations did not change from 1987-92.

INTRODUCTION

The Long Beach Peninsula, also known as the North Beach Peninsula, is a narrow strip of land extending northward from the mouth of the Columbia River in southwestern Washington (fig. 1). The peninsula lies between the Pacific Ocean on the west and Willapa Bay on the east. The study area in this report includes about 36 mi^2 of unconsolidated deposits, largely sand, that lie on top of bedrock composed of basalt or siltstone and sandstone.

Water supplies on the Long Beach Peninsula are derived mostly from a shallow water-table aquifer composed largely of sand. Typically, the water table is less than 10 ft below land surface, and in some locations, it is only a few feet below land surface during the winter. Water withdrawn from the aquifer is used for domestic purposes, tourist facilities, processing of oysters harvested from Willapa Bay, and processing of other seafood. There are claims that Willapa Bay ranks among the best of oyster-producing areas in the world, and there is widespread support to preserve this resource.

The population of the peninsula has been increasing, and there is concern that this increase may have a detrimental effect on the ground-water resource. Local planning and health agencies are concerned that ground-water levels may be dropping locally as a result of increased pumping, and that the shallow aquifer may become contaminated from septic systems, fertilizers and pesticides used in cranberry-growing areas, and seawater intrusion. These agencies need data on water-table altitudes to design and site septic systems; and to determine the directions and rates of ground-water flow, relations between precipitation and water levels, and historical trends in water levels. Data also are needed on water quality to assess the present quality of the peninsula's primary water supply, to determine if ground-water quality is being degraded, and to determine the quality of ground water discharging from the peninsula to Willapa Bay. In response to the concern about ground water and the need for information about the resource, the U.S. Geological Survey, in cooperation with the Pacific County Department of Community Development, conducted an investigation of ground-water flow and water quality in the sand aquifer of the peninsula.

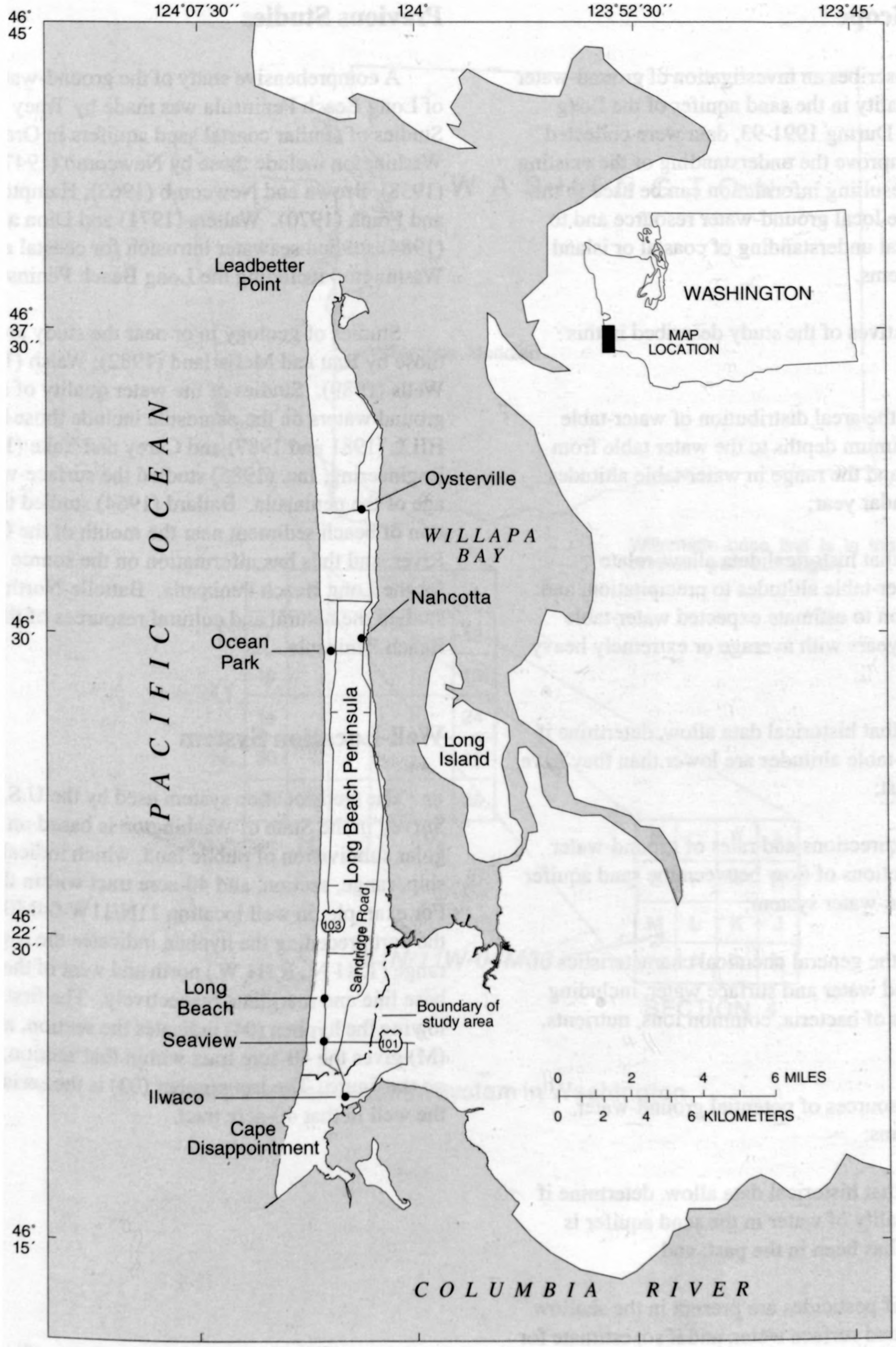

Figure 1.--Location of the study area.

Purpose and Scope

This report describes an investigation of ground-water flow and water quality in the sand aquifer of the Long Beach Peninsula. During 1991-93, data were collected and analyzed to improve the understanding of the existing conditions. The resulting information can be used in the management of the local ground-water resource and to improve the general understanding of coastal or island ground-water systems.

Specific objectives of the study described in this report were

1. To determine the areal distribution of water-table altitudes, minimum depths to the water table from land surface, and the range in water-table altitudes during 1 calendar year;

2. To the extent that historical data allow, relate measured water-table altitudes to precipitation, and use this relation to estimate expected water-table conditions in years with average or extremely heavy precipitation;

3. To the extent that historical data allow, determine if present water-table altitudes are lower than they have been in the past;

4. To determine directions and rates of ground-water flow, and directions of flow between the sand aquifer and the surface-water system;

5. To determine the general chemical characteristics of shallow ground water and surface water, including concentrations of bacteria, common ions, nutrients, and iron;

6. To determine sources of potential ground-water quality problems;

7. To the extent that historical data allow, determine if the present quality of water in the sand aquifer is poorer than it has been in the past; and

8. To determine if pesticides are present in the shallow ground water and surface water, and if so, estimate for a few selected sites the rate at which pesticides are likely to be transported by ground water to Willapa Bay.

Previous Studies

A comprehensive study of the ground-water resources of Long Beach Peninsula was made by Tracy (1978). Studies of similar coastal sand aquifers in Oregon and Washington include those by Newcomb (1947), Cooper (1958), Brown and Newcomb (1963), Hampton (1963), and Frank (1970). Walters (1971) and Dion and Sumioka (1984) studied seawater intrusion for coastal areas of Washington including the Long Beach Peninsula.

Studies of geology in or near the study area include those by Rau and McFarland (1982), Walsh (1987), and Wells (1989). Studies of the water quality of surface and ground waters on the peninsula include those by CH2M HILL (1981 and 1987) and Carey and Yake (1990). Pool Engineering, Inc. (1985) studied the surface-water drainage of the peninsula. Ballard (1964) studied the distribution of beach sediment near the mouth of the Columbia River, and thus has information on the source of sediment for the Long Beach Peninsula. Battelle-Northwest (1970) studied the natural and cultural resources of the Long Beach Peninsula.

Well-Location System

The well-location system used by the U.S. Geological Survey in the State of Washington is based on the rectangular subdivision of public land, which indicates township, range, section, and 40-acre tract within the section. For example, in well location 11N/11W-04M03 (fig. 2), the part preceding the hyphen indicates the township and range (T. 11 N., R. 11 W.) north and west of the Willamette base line and meridian, respectively. The first number following the hyphen (04) indicates the section, and the letter (M) gives the 40-acre tract within that section, as shown on the figure. The last number (03) is the serial number of the well in that 40-acre tract.

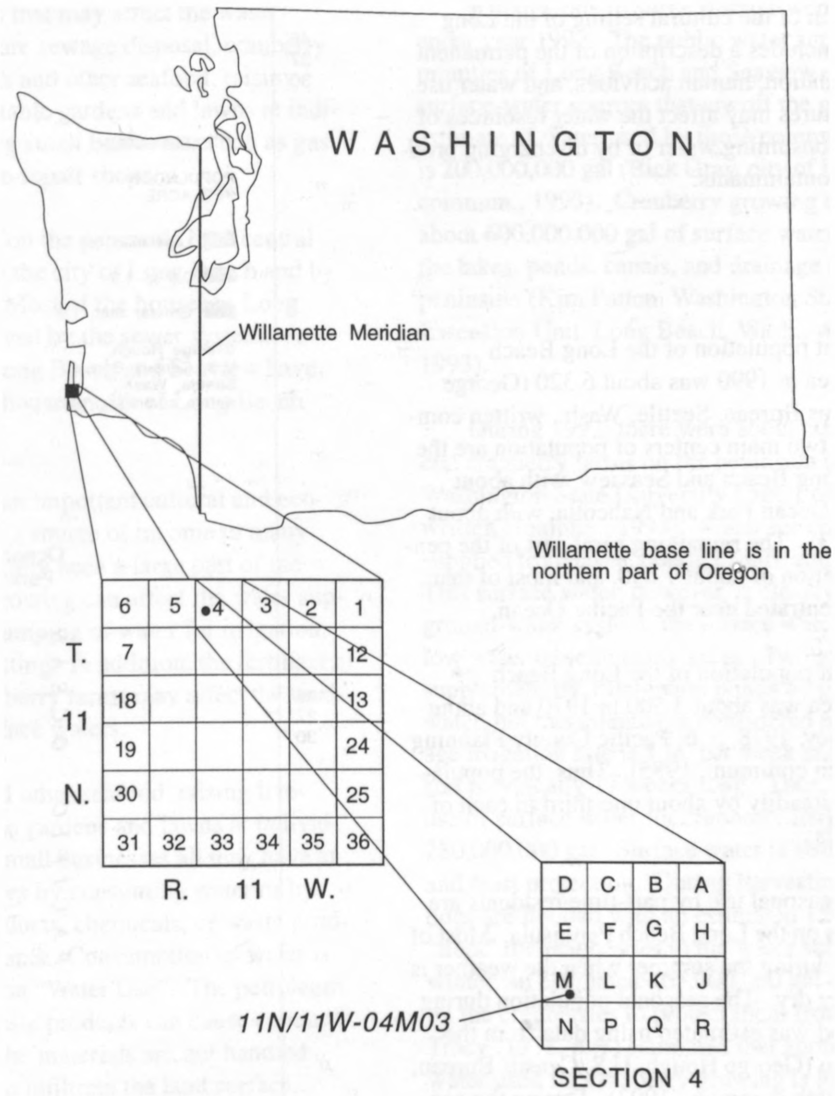

Figure 2.--Well-location system in Washington.

CULTURAL SETTING

This discussion of the cultural setting of the Long Beach Peninsula includes a description of the permanent and seasonal population, human activities, and water use. These cultural features may affect the water resources of the peninsula by consuming water or by discharging products that may be contaminants.

Population

The permanent population of the Long Beach Peninsula study area in 1990 was about 6,320 (George Hough, U.S. Census Bureau, Seattle, Wash., written commun., 1993). The two main centers of population are the communities of Long Beach and Seaview, with about 2,360 people, and Ocean Park and Nahcotta, with about 2,330 people (fig. 3). The remaining rural part of the peninsula has a population of about 1,630, and most of that population is concentrated near the Pacific Ocean.

The permanent population of the Long Beach Peninsula study area was about 3,500 in 1970 and about 4,800 in 1980 (Tracy, 1978, p. 6; Pacific County Planning Department, written commun., 1985). Thus, the population has increased steadily by about one-third in each of the last two decades.

Tourism and seasonal use by part-time residents are important activities on the Long Beach Peninsula. Most of the seasonal use is during the summer when the weather is warm and relatively dry. The seasonal population during this peak-use period was estimated using data from the U.S. Census Bureau (George Hough, U.S. Census Bureau, Seattle, Wash., written commun., 1993). During the census in April 1990, there were about 2,890 permanently occupied housing units and about 2,415 housing units that were classified as seasonal, recreational, or occasional. Assuming an average of 2.2 persons per housing unit results in a peak seasonal population of about 11,630, with 6,320 permanent residents and 5,310 seasonal residents. The transient tourist population residing in motels and trailer parks is not included in this estimate.

Population growth can affect the quantity and quality of the water resources. An increased amount of water needs to be withdrawn from ground-water or surface-water sources to meet the demands of a larger population. A larger population may also affect the quality of the water resources by causing contamination from increased septic-tank effluent, or by increased use of fertilizers and pesticides on private gardens and lawns.

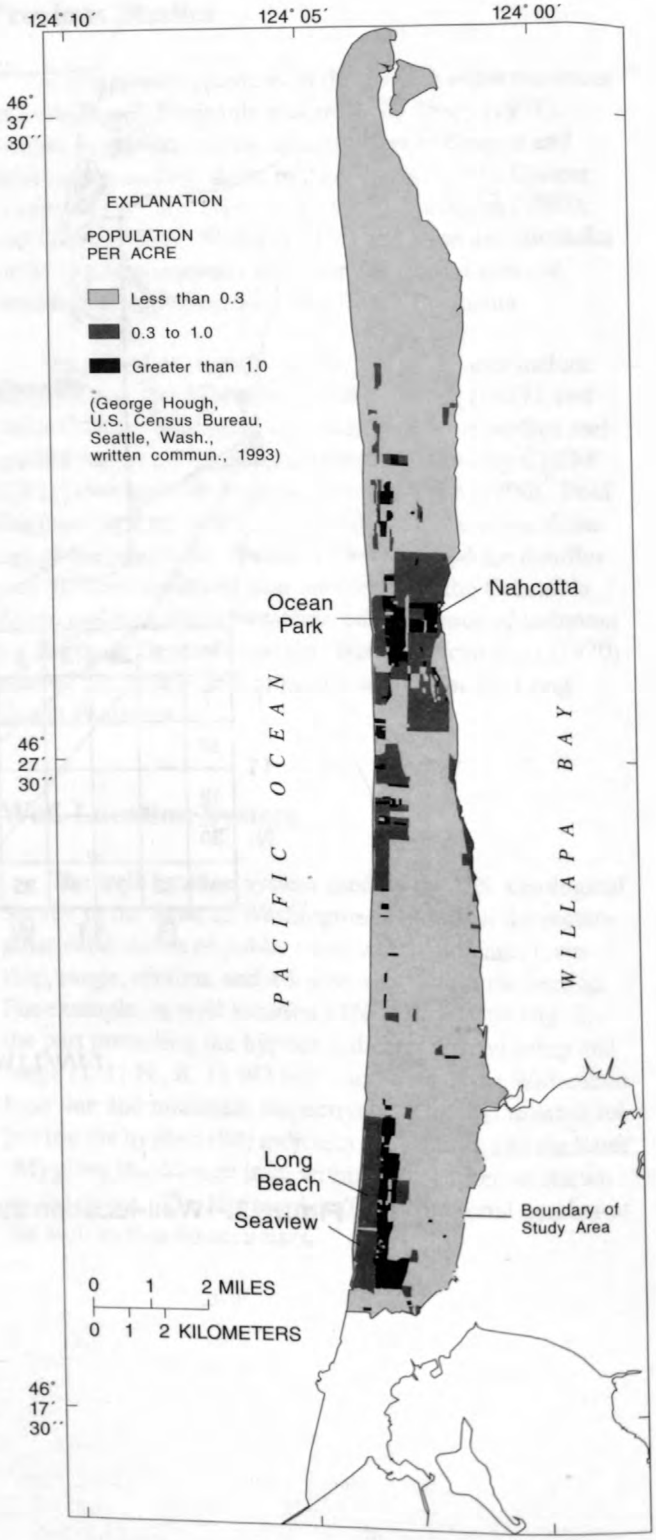

Figure 3.--Population density in 1990.

Human Activities

Some human activities that may affect the water resources of the peninsula are sewage disposal, cranberry growing, processing oysters and other seafood, raising livestock, growing of vegetable gardens and lawns at individual homes, and operating small businesses such as gas stations, laundries, and auto-repair shops.

Sewage is disposed of on the peninsula by a central sewage system operated by the city of Long Beach and by individual septic systems. Most of the houses in Long Beach and Seaview are served by the sewer system. A few houses to the east of Long Beach and Seaview have septic systems, and all the houses north of Long Beach have septic systems.

Cranberry growing is an important cultural and economic activity. It provides a source of income to many residents and it has historically been a large part of the local culture. Cranberry growing can affect the water supplies of the peninsula by pumping of water for irrigation, frost protection, and harvesting. In addition, the fertilizers and pesticides used in cranberry farms may affect the quality of both ground and surface waters.

Processing oysters and other seafood, raising livestock, growing of vegetable gardens and lawns at individual homes, and operating small businesses all may have an effect on the water resources by consuming water or by discharging petroleum products, chemicals, or waste products that may be contaminants. Consumption of water is addressed in the next section "Water Use". The petroleum products, chemicals, or waste products can cause contamination of ground water if the materials are not handled properly and are allowed to infiltrate the land surface.

Water Use

Surface and ground water are used on the peninsula for drinking water, cranberry growing, irrigating lawns, gardens, and other vegetation on private and commercial property, processing seafood, and livestock. In the communities of Long Beach and Seaview, a surface-water source that is off the peninsula supplies water for drinking and other domestic and commercial uses. North of those communities, ground water withdrawn from the local sand aquifer is the sole supply for all water use except cranberry growing. Nearly all water used in cranberry growing is obtained from surface water on the peninsula.

Surface Water

Withdrawals of surface water were estimated for calendar year 1992. The public water supplies for the communities of Long Beach and Seaview are withdrawn from surface-water sources that are off the peninsula. A rough estimate of water used by those communities during 1992 is 200,000,000 gal (Rick Gray, city of Long Beach, written commun., 1993). Cranberry growing during 1992 used about 600,000,000 gal of surface water withdrawn from the lakes, ponds, canals, and drainage channels on the peninsula (Kim Patten, Washington State University Extension Unit, Long Beach, Wash., written commun., 1993).

During 1992, there were about 605 acres of commercial cranberry farms on the peninsula (fig. 4) (Kim Patten, Washington State University Unit, Long Beach, Wash., written commun., 1993). Water for cranberry growing is supplied from lakes, ponds, canals, and drainage channels. This surface water, however, is closely connected to the ground-water system; the surface water intercepts the shallow water table in many areas. Two growers out of 33 supplement their irrigation ponds by pumping ground water, but this quantity is considered negligible. The average irrigation rate is 1 in. per week and the irrigation season is typically 17 weeks long. Thus, the average annual use of surface water for cranberry irrigation is about 280,000,000 gal. Surface water is also used for harvesting and frost protection. During harvesting, the cranberry bogs are flooded with an estimated 150,000,000 gal to "float" the cranberries to the water surface. During the winter, an estimated 165,000,000 gal of water is sprayed on the cranberries to protect them from frost damage. Tracy (1978, p. 7) estimated that about one-third of the water used for cranberry growing is lost to evapotranspiration; this would result in about 200,000,000 gal of water that is lost from the surface- and ground-water systems.

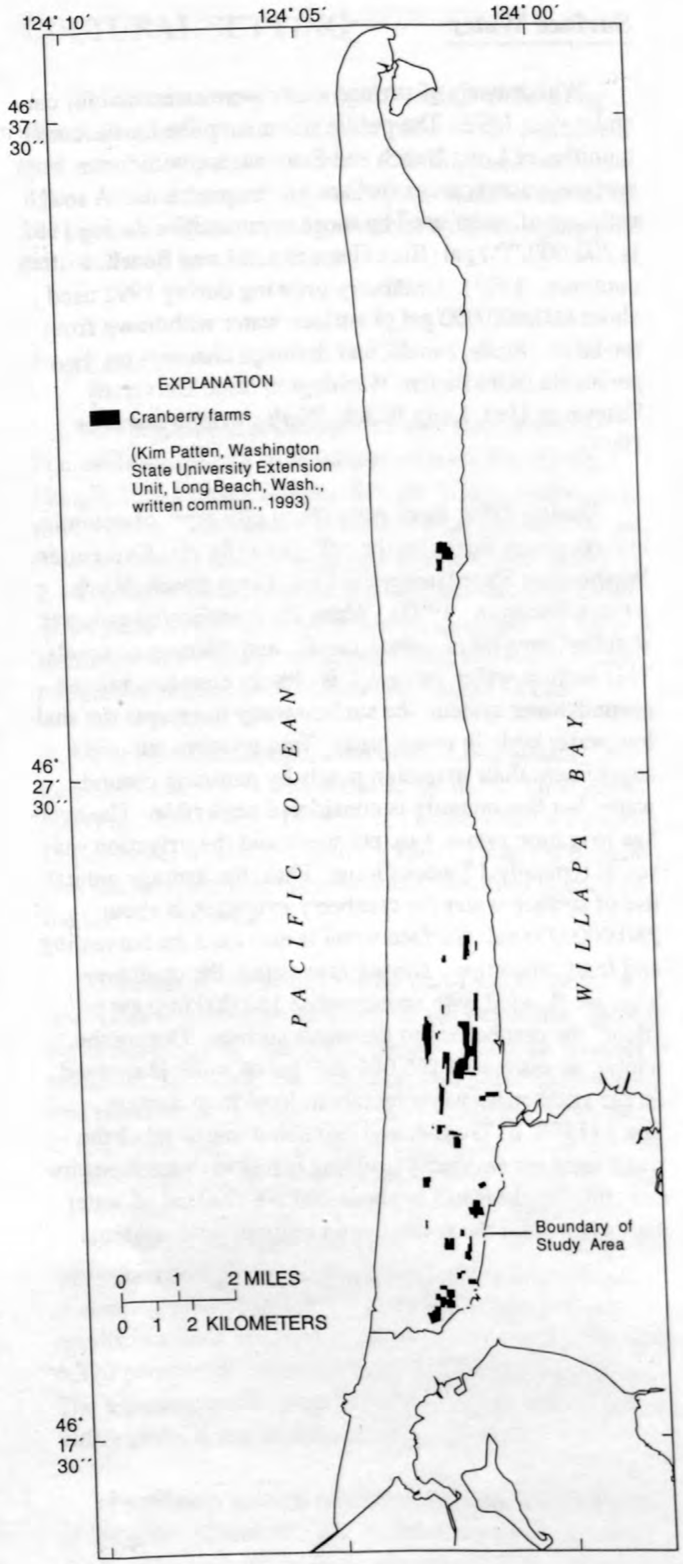

Figure 4.--Areas of commercial cranberry farms in 1992.

Ground Water

The withdrawals of ground water were estimated for calendar year 1992 (table 1); total withdrawals were 260,000,000 gal; withdrawals during the summer (June-August) were 100,000,000 gal and withdrawals for the remainder of the year were 160,000,000 gal. The much larger use of water in the summer is shown by comparing an average use of water per month; about 33,000,000 gal per month was used during the summer and almost half that quantity, 18,000,000 gal per month, was used during the remainder of the year.

The use of ground water was classified into five categories: public supply, domestic self supplied, irrigation, livestock, and cranberry processing. Three water systems supply about 90 percent of the public-supplied ground water. Ocean Park Water Company, which serves the community of Ocean Park and some areas to the south, supplies about 50 percent of the public-supplied ground water (Pete Christoson, Ocean Park Water Company, Ocean Park, Wash., written commun., 1993); Surfside Homeowners Association, which serves the Surfside development northwest of Ocean Park, supplies about 35 percent of the public-supplied ground water (Mike Zitur, Surfside Homeowners Association, Ocean Park, Wash., written commun., 1993); and Pacific Water Company, which serves a small area south of Ocean Park, supplies about 5 percent of the public-supplied ground water (Phil Leach, Pacific Water Company, Ocean Park, Wash., written commun., 1993). The remaining 10 percent of the public-supplied ground water is withdrawn for trailer parks and recreational businesses.

The estimated withdrawal of ground water for public supply in 1992 was 182,000,000 gal (table 1). This estimate was made using pumpage records from the water systems described in the previous paragraph. About 4,880 people that are part of the permanent population are served by public water supplies. During the peak-use period (June-August), the withdrawals were estimated to be 75,000,000 gal, or 25,000,000 gal per month. During the remainder of the year, the withdrawals were estimated to be 107,000,000 gal, or 11,900,000 gal per month. Thus, the rate of withdrawal of ground water for public supply is more than twice as large during the summer as during the winter.

The second major category of ground-water use is domestic self supplied. About 1,440 people that are part of the permanent population obtain their water from shallow, privately owned wells. The amount of withdrawal by this means was estimated using the population and an average per capita daily use of water of 110 gal per day. Thus, the withdrawal by the permanent population was estimated to be 57,800,000 gal. Seasonal use for this category was estimated by assuming that water use was uniform throughout individual months, and allocating 3 months of water for the peak-use period and 9 months of water for the low-use period.

The ground-water withdrawal of self-supplied domestic water by the seasonal population was estimated using the assumption that the percentage of self-supplied users of the seasonal population is the same as the percentage of self-supplied users of the permanent population (23 percent). Additional information is the peak seasonal population (5,310 people), the average per capita daily use of water (110 gal per day), and the number of days that the seasonal population uses water (3 months, or 91 days). Thus, the estimated ground-water withdrawal for the seasonal population is 12,200,000 gal, or 4,100,000 gal/month. To divide seasonal or recreational use into peak and low periods, 2 months was assumed for the peak period and 1 month for the low period.

The estimated withdrawal of ground water for non-public supplied irrigation of the Peninsula Golf Course was 2,440,000 gal (Jerry Zorich, Peninsula Golf Course, Long Beach, Wash., oral commun., 1993). This amount was estimated using 5 acres of irrigated land and 1.5 acre-ft of water for an irrigation season of May to September. Water use for the peak-use period was estimated as 1,460,000 gal and as 980,000 gal for the low-use period.

The estimated withdrawal of ground water for livestock (cows) was 181,000 gal. The estimate is based on the number of cows (142) times the average use of water per cow (7 gal/d) times the percentage of water consumed that is from ground-water sources (50 percent) (Pat Boyes, Washington State University extension agent, South Bend, Wash., oral commun., 1993). Both surface and ground water are used for livestock in about equal quantities.

The Ocean Spray Cranberry cooperative association uses ground water to wash cranberries during the harvesting season in the fall. The estimated withdrawal for 1992 was about 306,000 gal. In addition, during about 40 to 50 days in the summer of 1992, Ocean Spray conducted a one-time emergency transfer of about 5,430,000 gal of water from their well to a nearby lake (Paul Bauge, Ocean Spray Cranberry, Inc., Long Beach, Wash., oral commun., 1993).

Table 1.--*Seasonal ground-water withdrawals during 1992 on Long Beach Peninsula, Washington*

Category	Ground-water withdrawals, in gallons		
	High season (June to August)	Low season (September to May)	Total
Public supply	75,000,000	107,000,000	182,000,000
Domestic self supplied	18,600,000	51,400,000	70,000,000
Irrigation (non-public supply)	1,460,000	980,000	2,440,000
Livestock	45,000	136,000	181,000
Ocean Spray Cranberry Association			
Processing	0	306,000	306,000
Auxiliary use	5,430,000	0	5,430,000
All uses[1]	100,000,000	160,000,000	260,000,000
All uses minus auxiliary use of Cranberry Association[1]	94,600,000	160,000,000	255,000,000

[1]Total numbers may not add up due to rounding.

PHYSICAL SETTING

Climate and Vegetation

The Long Beach Peninsula has a temperate marine climate with cool, wet winters and warm, dry summers. The Pacific Ocean moderates the temperatures and provides a vast supply of moisture for storms that move from west to east across the peninsula. The average annual precipitation is about 80 in. The record of annual precipitation for 1954-92 (fig. 5) shows an apparent trend of decreasing magnitude; however, a nonparametric Mann-Kendall test (two-sided; Helsel and Hirsch, 1992, p. 326-328) made on the data found no statistically significant trend. During 1992, the year of data collection for this study, the precipitation was 62.46 in., which is 78 percent of the long-term average.

The distribution of precipitation varies throughout a typical year (fig. 6) and 75 percent of the annual precipitation occurs from October through March. The summers are typically dry, with only 8 percent of the annual precipitation occurring from June through August.

Temperatures are moderate throughout the year. The average monthly maximum temperature ranges from 49°F in January to 67°F in September (fig. 6); the average monthly minimum temperature ranges 35°F in January to 51°F in July. Temperatures in 1992 were generally higher than average; from January through August, maximum monthly temperatures were about 4 degrees higher than average, and from September through December the maximum monthly temperatures were about average.

Natural vegetation on the Long Beach Peninsula is abundant because of the moderate temperatures and copious rainfall. The type and location of vegetation is related to the sand-dune topography and depth to the water table. On the recently formed and unstable dunes on the western side of the peninsula, dunegrass, beachgrass, and shore pines are the dominant vegetation. On the more-stable interior dunes, conifers such as western hemlock, sitka spruce, douglas fir, and western red cedar form the overstory, and the understory consists of huckleberry, swordfern, salal, and salmonberry. Vegetation between the dunes is largely a function of soil moisture. On wetter soils, red alder, rushes, sedges, and labrador tea are found; on drier soils, the same forests are found that are on the stabilized dunes (Wiedermann, 1984, p. 48-59).

Geology

The Long Beach Peninsula was formed by the transport and deposition of sediment by ocean and longshore currents along the coast of Oregon and Washington. Most of the sediment is from the Columbia River (Ballard, 1964, p. 52), but minor amounts of sediment are from other rivers in Washington and Oregon or from erosion of rocks along the coast. Thousands of years of coastal marine and wind processes have resulted in several hundred feet of unconsolidated deposits of sediment (sand, silt, clay, and gravel). The sediment overlies basement rocks, which consist of basalts of Eocene Age or siltstones and sandstones of Eocene or Miocene Ages (Rau and McFarland, 1982; and Wells, 1989). The diverse assemblage of sediment on the peninsula indicates that the environment providing the source of the sediment varied widely during its formation. During the several glaciations of the past tens of thousands of years, the climate of the Pacific Northwest changed considerably, sea levels changed by more than several hundred feet, and the volume and nature of river sediment changed considerably (Wiedemann, 1984, p. 43).

During the past 100 years, the peninsula has grown westward by the addition of several hundred feet of sand; in the Long Beach-Seaview area, the beach has grown by more than 1,200 ft. The extent of the growth diminishes to the north. About 5 mi north of Ocean Park, the westward extent of the beach appears to have remained stable during 1870-1950 (Battelle-Northwest, 1970, p. 7). The cause of this rapid increase in width is unknown, but possibly is related to altered patterns of sediment deposition caused by the construction of jetties at the mouth of the Columbia River.

The thickness of the unconsolidated deposits on the peninsula increases from south to north. At the southern end of the peninsula, bedrock is exposed at land surface; at the northern end, about 1 mi northwest of the town of Oysterville, bedrock is at a depth of about 1,400 ft. The bedrock surface is not an evenly sloping plane; however, a general pattern is discerned with the surface having a northward dip (slope) of 50 to 80 ft per mile (1.0 to 1.5 percent; Rau and McFarland, 1982).

The unconsolidated deposits are a heterogeneous mixture of sand, silt, clay, and gravel. The deposits are mostly sand in the upper 100 ft, and between that level and bedrock many lenses of silt and clay are interspersed throughout the sand. There does not appear to be a uniform and consistent layer of silt or clay throughout the peninsula.

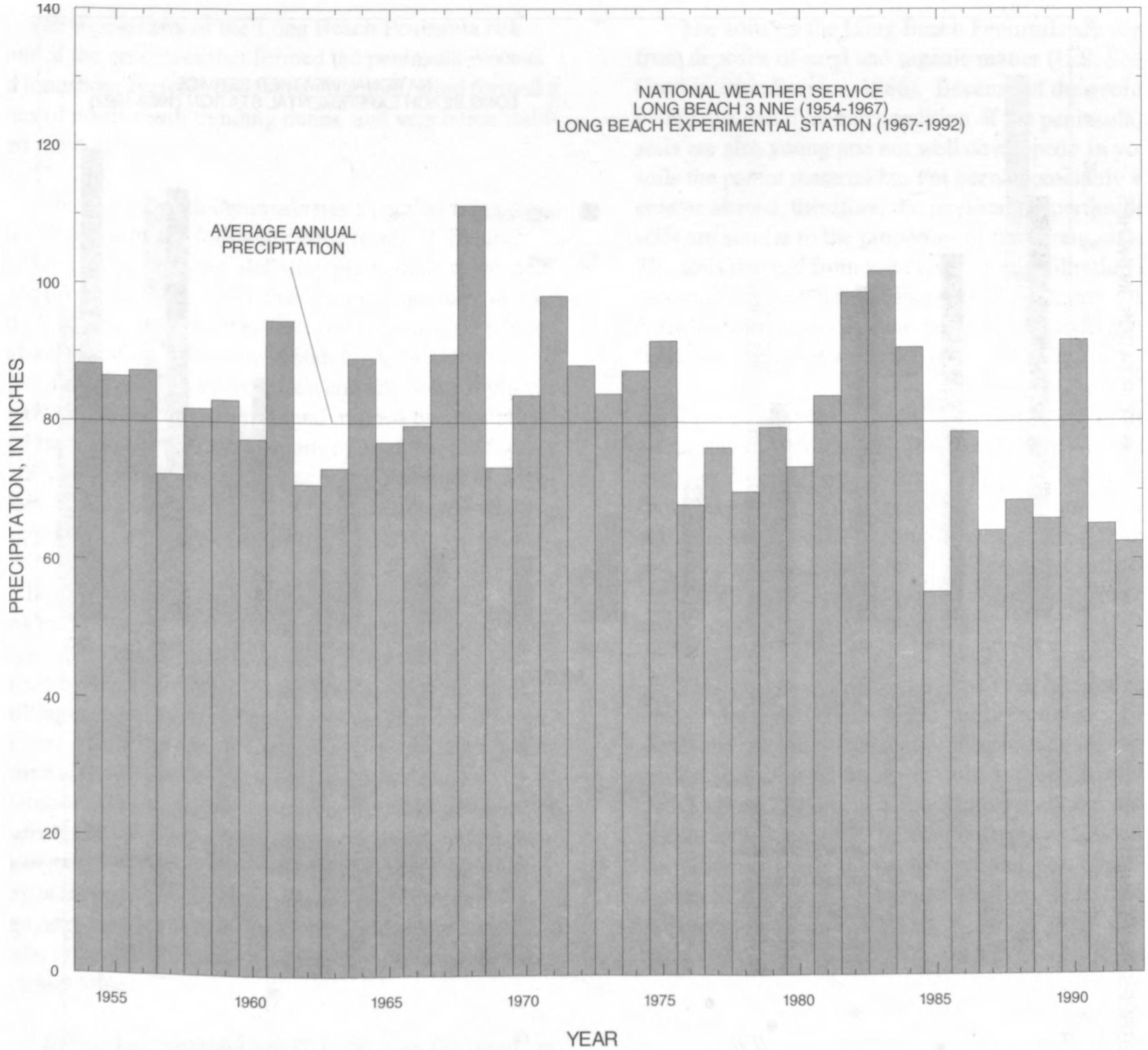

Figure 5.--Annual precipitation at Long Beach, Washington, 1954-92.

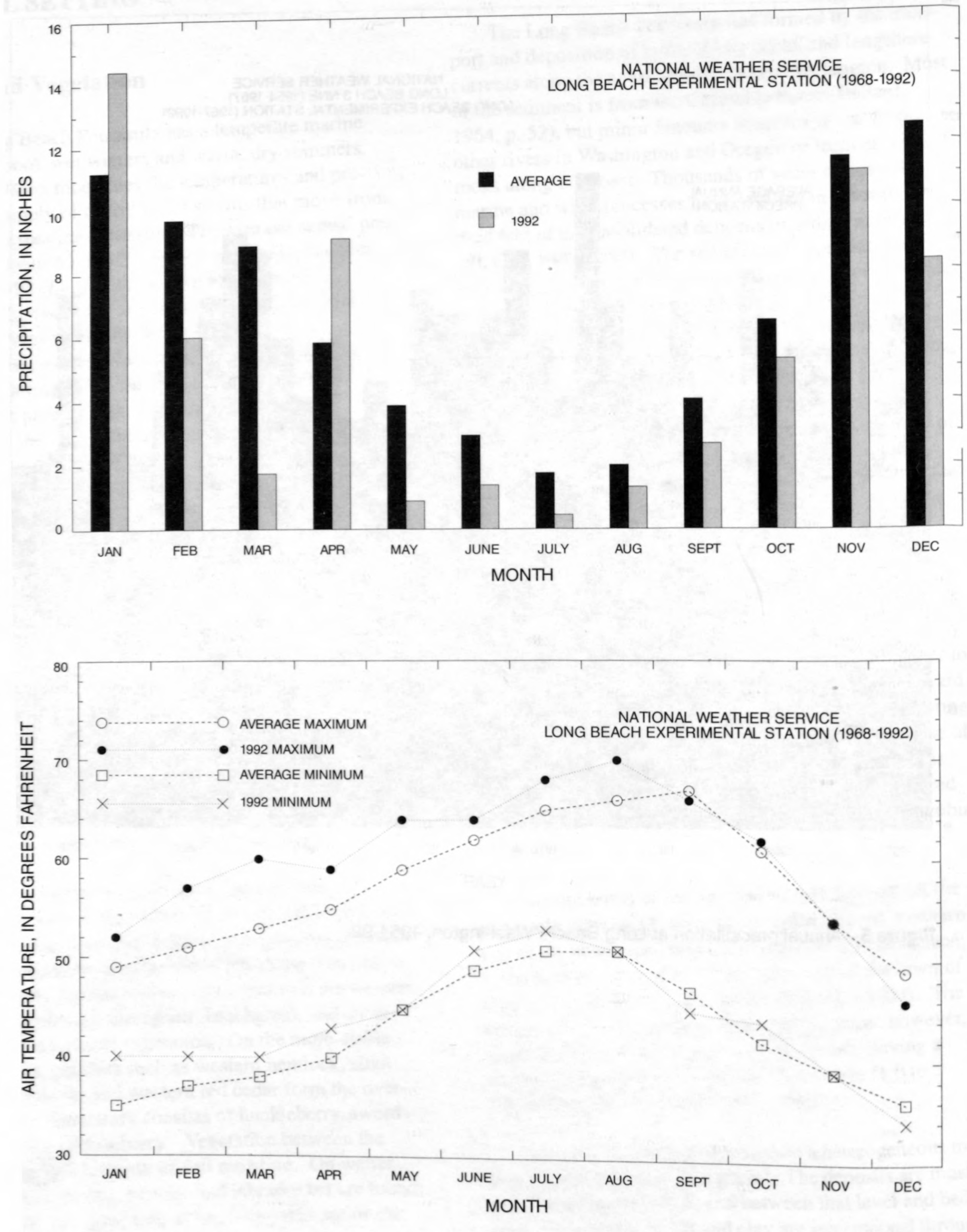

Figure 6.--Average and 1992 monthly precipitation and air temperatures at Long Beach, Washington.

Topography

The topography of the Long Beach Peninsula is a result of the processes that formed the peninsula—ocean and longshore currents deposited sediment, wind formed a series of north-south trending dunes, and vegetation stabilized the dunes.

The Long Beach Peninsula has a parallel ridge system and contains the following dune forms: foredune, sand hummock, blowout, deflation plain, dune ridge, and swale (Wiedermann, 1984). Foredunes, sand hummocks, and blowouts occur in areas west of Highway 103 where the land surface is relatively unstable. A foredune is a ridge of sand parallel to the beach and above the high-tide line that is formed by moving sand trapped by vegetation. Sand hummocks are small mounds of sand that are formed by moving sand that accumulates around clumps of vegetation. A blowout is a trough or bowl that occurs where vegetation is sparse and sand is exposed to the wind.

Deflation plains, dune ridges, and swales occur in areas east of Highway 103 where the land surface is more stable. A deflation plain is an area of flat land that was formed by erosion of sand down to near the water table, resulting in a wet-sand surface resistant to further erosion. The area east of the city of Long Beach is a deflation plain. A dune ridge is a sand ridge that has been stabilized by vegetation. The generally uninterrupted ridge just west of Sandridge Road is a dune ridge; several other smaller dune ridges exist throughout the peninsula. Swales are low-lying areas between the dune ridges. The water table is often near land surface in the swales, and many lakes, ponds, or marshes occur where the land surface intercepts the water table.

Land-surface altitudes are 50 to 70 ft on the foredune in the northwestern part of the peninsula, about 25 ft on many of the interior dune ridges, 10 to 15 ft in many of the swales between the dune ridges, and 5 to 15 ft in the deflation plain east of the city of Long Beach.

Soils

The soils on the Long Beach Peninsula are derived from deposits of sand and organic matter (U.S. Soil Conversation Service, 1986). Because of the geologically young age and dynamic condition of the peninsula, the soils are also young and not well developed. In young soils the parent material has not been appreciably weathered or altered; therefore, the physical properties of the soils are similar to the properties of the parent material. The soils derived from sand have rapid infiltration rates and small water-holding capacities. In contrast, the soils derived from mostly organic matter have moderate infiltration rates and large water-holding capacities.

Four soil types occur on about 88 percent of the peninsula (table 2 and fig. 7). The Netarts and Westport soils occur on dune ridges, are derived from sand, and cover about 50 percent of the peninsula. The Yaquina soil occurs in swales or deflation plains, is derived from sand, and covers about 22 percent. The Seastrand soils occur in swales or deflation plains, are derived mostly from organic matter, and cover about 16 percent.

The areal extent of soils can be used as a rough estimate of the land-surface-drainage characteristics of the peninsula. About 56 percent of the peninsula is well drained (Netarts and Westport soils, and beaches and dune lands), about 22 percent is moderately well drained (Yaquina soil), about 20 percent has poorly drained low-lying saturated soils (Ocosta, Seastrand, and Orcas soils), and about 2 percent is lakes and marshes (U.S. Soil Conversation Service, 1986).

Table 2.--*General physical properties of soils on Long Beach Peninsula, Washington*

[Modified from table 14, U.S. Soil Conservation Service (1986); in/hr, inch per hour; <, less than; >, greater than; --, no data]

Soil name	Percentage of study area with soil[1]	Depth (inches)	Clay (percent)	Organic matter (percent)	Permeability In/hr	Permeability Description
Beaches and dune land	6	>60	0	0	> 20	Very rapid
Lebham silt loam	<0.1	0-21	--	10-15	0.6-2.0	Moderate
		21-60	--	--	0.6-2.0	Moderate
Netarts fine sand	31	0-3	1-5	3-5	6.0-20	Rapid
		3-25	1-5	--	2.0-6.0	Moderately rapid
		25-60	1-5	--	6.0-20	Rapid
Ocosta silty clay loam	3	0-12	30-40	5-10	0.6-2.0	Moderate
		12-20	45-60	--	0.2-0.6	Moderately slow
		20-60	45-60	--	< 0.06	Very slow
Orcas peat	0.5	0-60	--	30-50	> 20	Very rapid
Palix silt loam	<0.1	0-18	--	10-15	0.6-2.0	Moderate
		18-58	--	--	0.6-2.0	Moderate
Seastrand mucky peat	15	0-30	--	70-90	0.6-2.0	Moderate
		30-60	0-2	--	2.0-6.0	Moderately rapid
Seastrand Variant muck	1	0-18	--	70-90	0.6-2.0	Moderate
		18-60	--	--	0.6-2.0	Moderate
Udorthents, level	<0.1	0-6	5-15	2-5	2.0-6.0	Moderately rapid
		6-60	5-15	--	2.0-6.0	Moderately rapid
Westport fine sand	19	0-7	3-7	2-5	> 20	Very rapid
		7-60	3-7	--	>20	Very rapid
Yaquina loamy fine sand	22	0-9	1-5	2-5	2.0-6.0	Moderately rapid
		9-24	1-2	--	2.0-6.0	Moderately rapid
		24-60	1-2	--	6.0-20	Rapid

[1]Number is based on the total study area, including the area covered by water, which is 2.5 percent of the area.

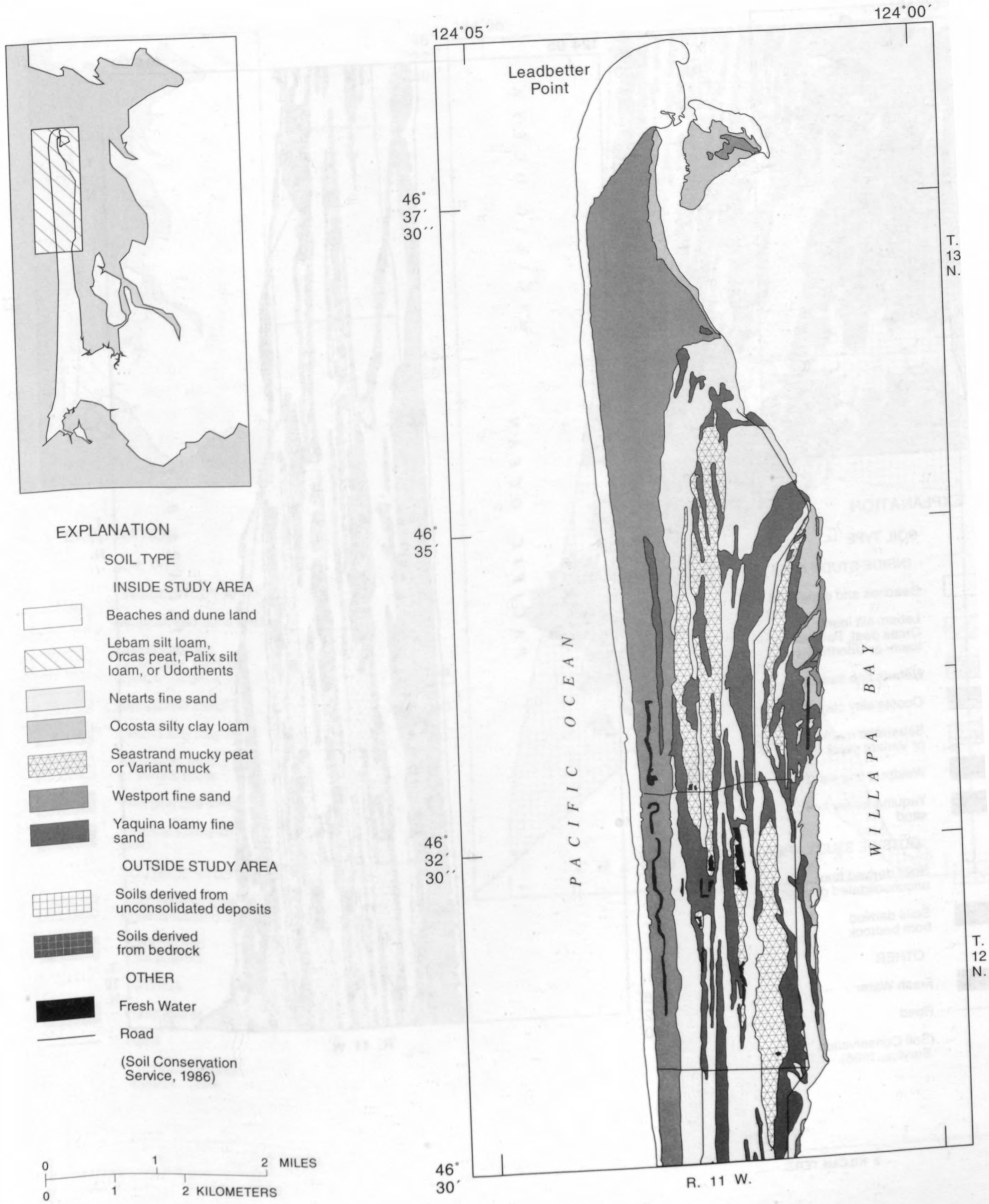

Figure 7.--Soil types and lakes.

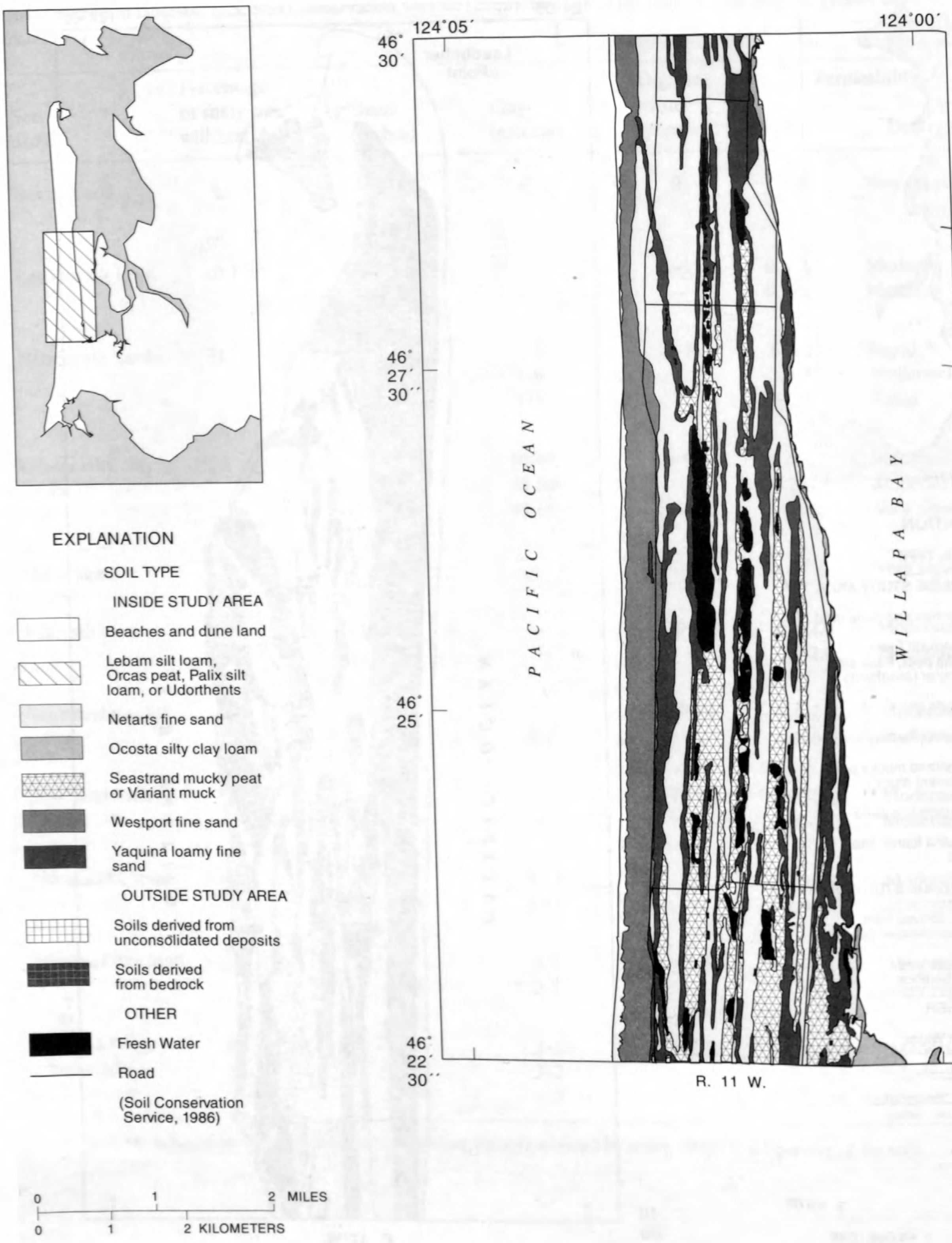

Figure 7.--Soil types and lakes--continued.

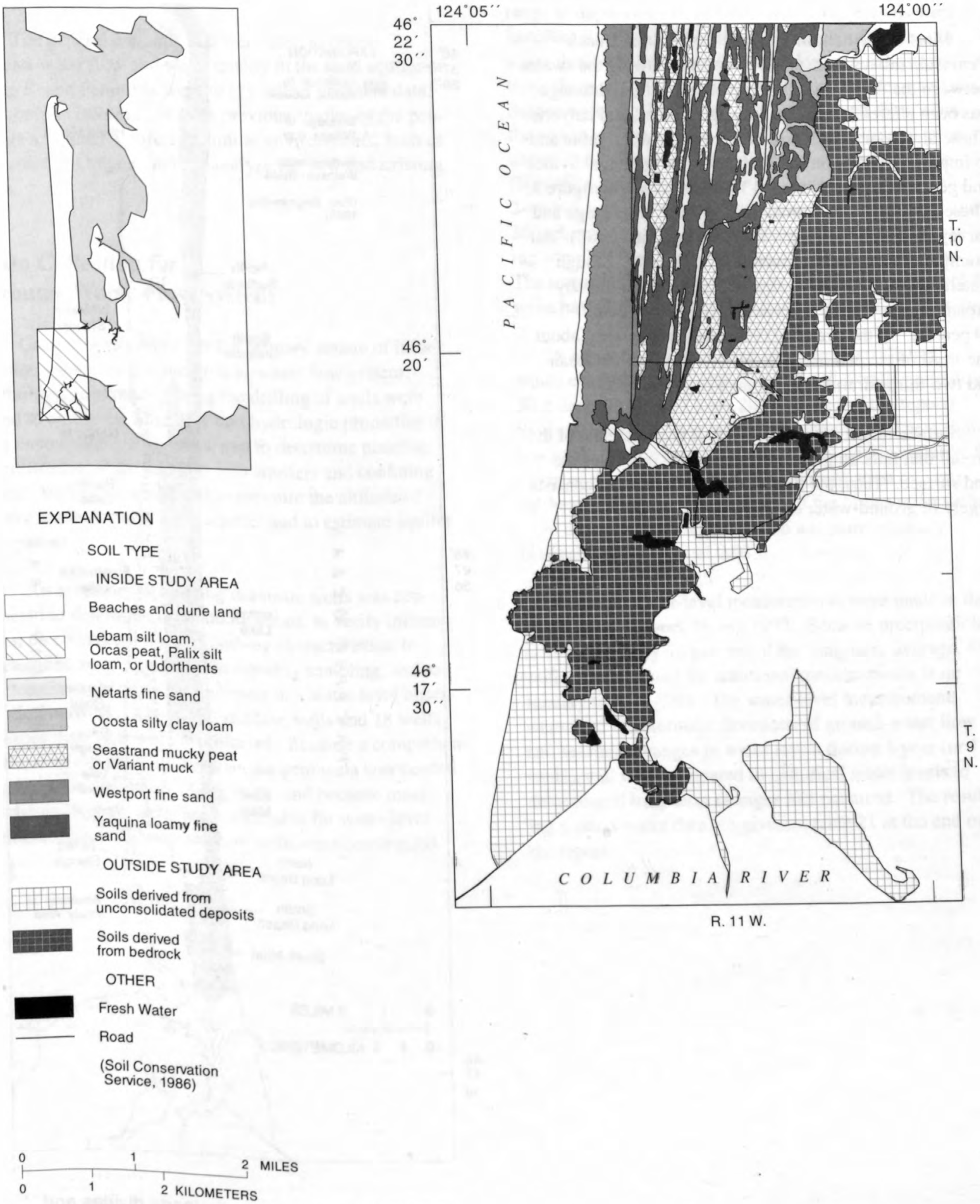

Figure 7.--Soil types and lakes--continued.

Drainage

Most of the natural drainage of the Long Beach Peninsula moves from south to north following the swales between the dune ridges. Some of this natural drainage has been altered by canals, drainage ditches, and culverts. These alterations were made to lower the water table and to improve flood control. Surface-water drainage divides and general flow directions in 1985 are shown on figure 8. These divides were estimated using local knowledge and surveying techniques (Pool Engineering, Inc., 1985). An example of an altered drainage is the Whiskey Slough watershed where a dune ridge was penetrated, thereby expanding the size of the watershed by more than 50 percent. In the present (1992) drainage system, about one-third of the peninsula drains into the Pacific Ocean and two-thirds drains into Willapa Bay.

Surface runoff of rainfall is small because most of the rainfall that falls on the peninsula rapidly infiltrates the land surface. Thus, the flow in drainage channels consists largely of ground-water discharge.

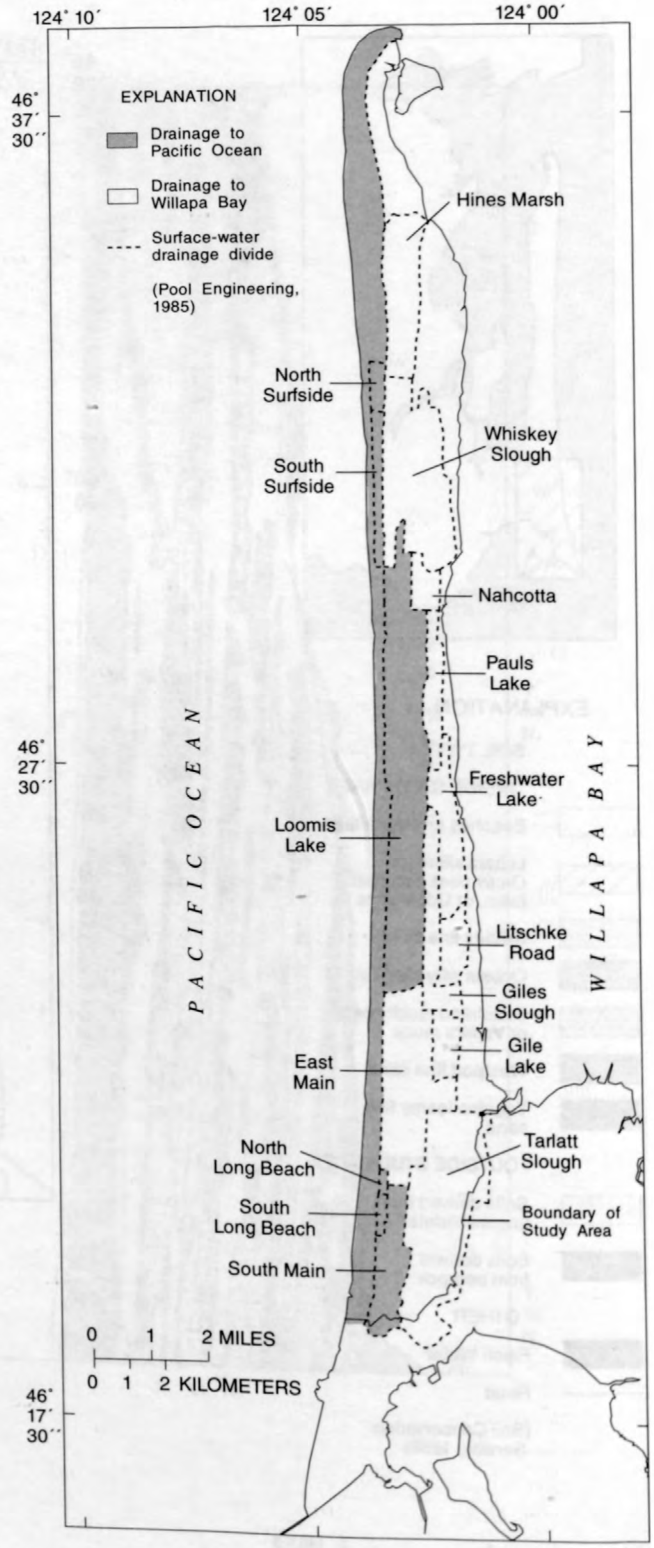

Figure 8.--Surface-water drainage divides and general flow directions.

DATA AND METHODS

The general methods that were used to define ground-water flow and water quality in the sand aquifer of Long Beach Peninsula were to (1) collect pertinent data, (2) compile information from previous studies of the peninsula and other aquifers in similar environments, such as the coast of Oregon, and (3) analyze the new and existing data.

Data Collection for Ground-Water Flow System

Ground-water wells are the primary source of information used to define the ground-water flow system. Lithologic logs made during the drilling of wells were used to assess the lithologic and hydrologic properties of the unconsolidated deposits, and to determine possible stratification of the deposits into aquifers and confining beds. Wells also were used to measure the altitude of water levels (heads) in the aquifer and to estimate aquifer properties.

An inventory of existing domestic wells was conducted to determine accurate locations, to verify information on construction and plumbing characteristics, to determine suitability for water-quality sampling, and to determine suitability for inclusion in a water-level observation network. About 150 shallow wells and 18 wells deeper than 50 ft were inventoried. Because a comprehensive areal coverage of wells on the peninsula was needed to meet the objectives of the study, and because most existing shallow wells are not suitable for water-level measurements, 90 new shallow wells were constructed.

The 90 new wells are an average of 18 ft deep and range in depth from 11 to 38 ft. Six of these wells were installed in pairs at three sites to evaluate differences in water quality between shallow and deeper conditions at those three sites. The shallow wells are 18 ft deep and the deeper wells are 38 ft deep. Excluding these three pairs, the screens of the remaining wells were positioned to be about 10 ft below the water table at the time of drilling (November and December 1991). Sixty wells made of 2-inch-diameter PVC casing were installed by jetting, and 30 wells made of 1.5-inch-diameter galvanized steel casing were installed by driving the casing into the ground. The screens of both types of wells are 2.5 ft long (except 3 wells have 5-foot screens) and have a slot size of 0.006 in.

A network of observation wells was established, which consisted of 97 shallow wells and 7 wells more than 50 ft deep (fig. 9, and table 20 at the end of the report). Seven existing shallow wells augmented the 90 new shallow wells. Shallow wells were installed within about 50 ft of six of the deep wells to provide information on vertical-head gradients. The altitudes of the observation wells were determined by leveling with a closure accuracy between benchmarks of 0.03 ft.

Monthly water-level measurements were made in the observation network during 1992. Because precipitation in 1992 was only 78 percent of the long-term average, 48 wells were selected for additional measurements from January to June 1993. The water-level measurements were used to determine directions of ground-water flow and seasonal changes in water levels during 1 year (or 1.5 years), and were compared to historical water levels to determine if long-term changes had occurred. The resulting ground-water data are given in table 21 at the end of the report.

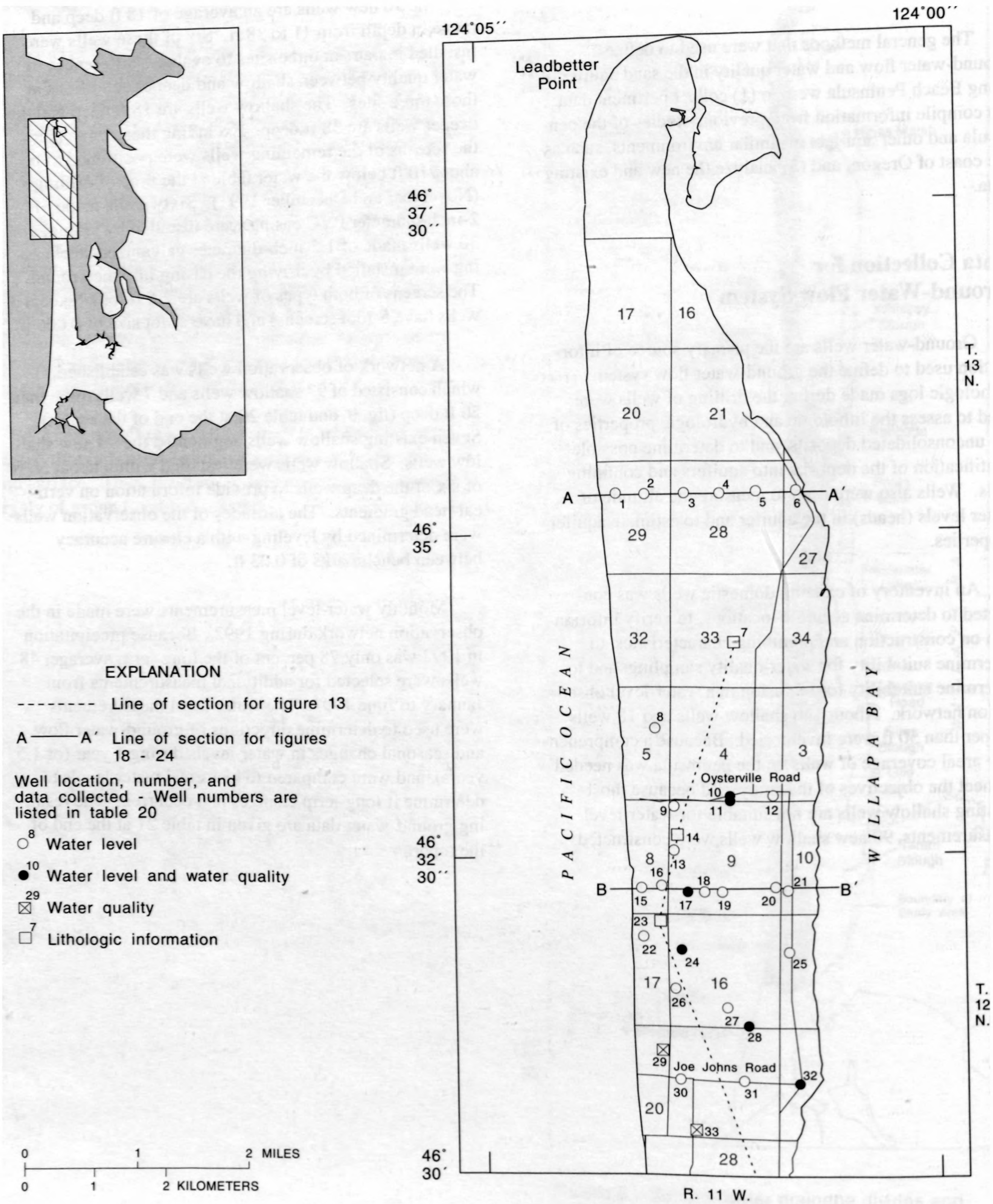

Figure 9.--Locations of wells.

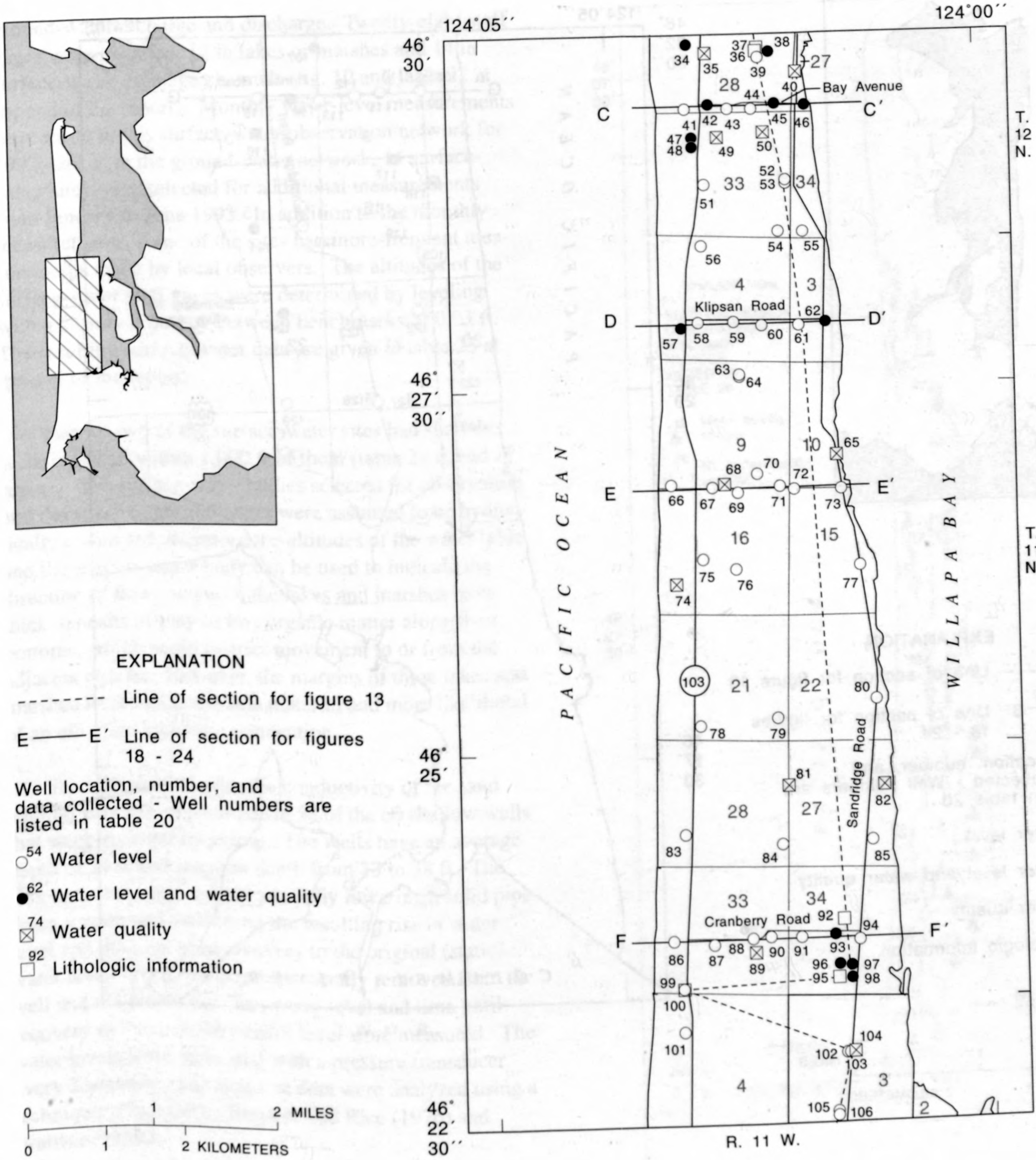

Figure 9.--Locations of wells--continued.

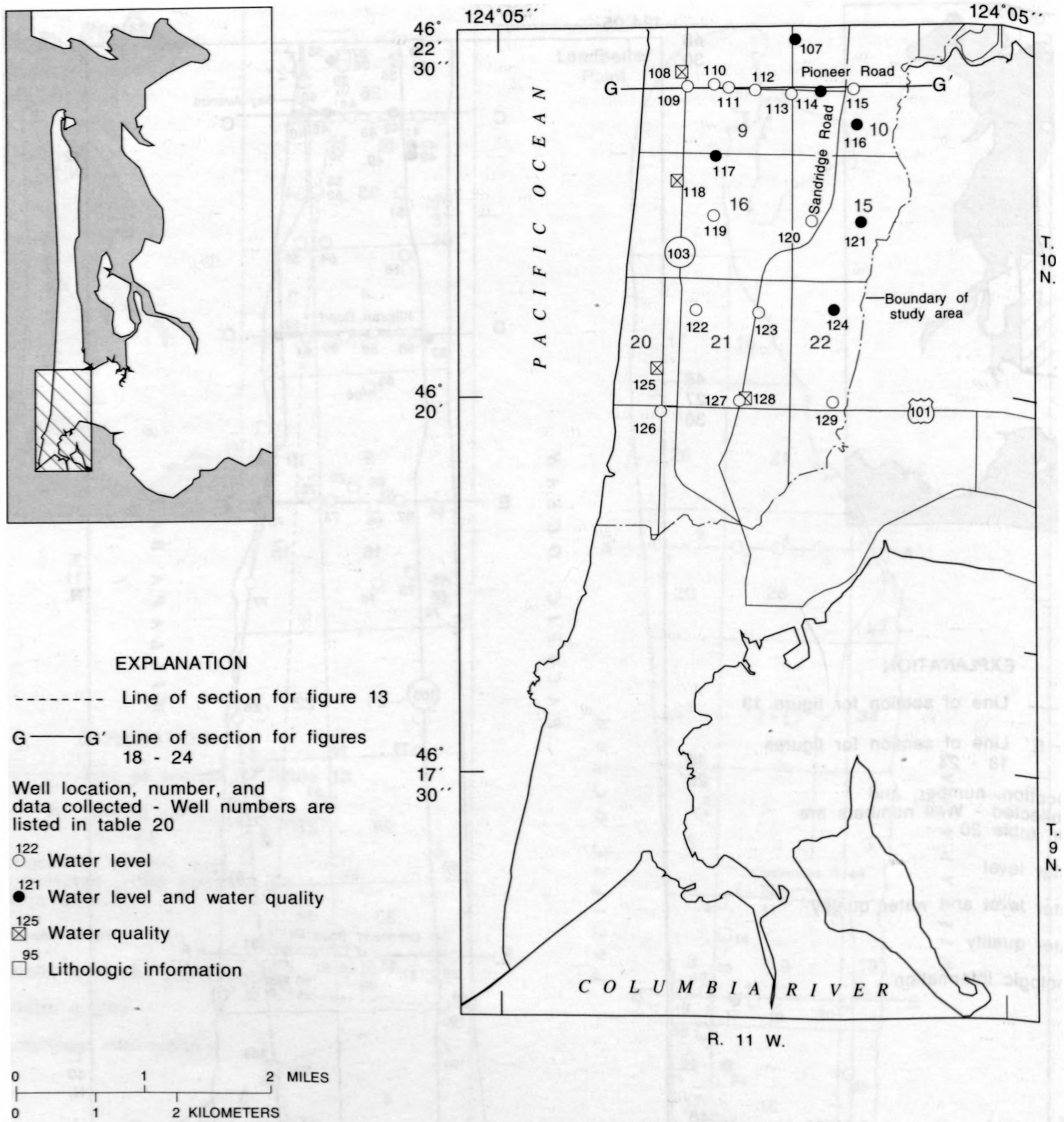

Figure 9.--Locations of wells--continued.

The direction of flow between ground water and surface water was investigated to facilitate the evaluation of ground-water recharge and discharge. Twenty-eight staff gages were installed: 14 in lakes or marshes and 14 in surface-water drainage channels (fig. 10 and table 22 at the end of the report). Monthly water-level measurements were made in this surface-water observation network for 1992, and as in the ground-water network, 14 surface-water sites were selected for additional measurements from January to June 1993. In addition to the monthly measurements, some of the sites had more-frequent measurements made by local observers. The altitudes of the surface-water staff gages were determined by leveling with a closure accuracy between benchmarks of 0.03 ft. The resulting surface-water data are given in table 23 at the end of the report.

Twenty-two of the surface-water sites had shallow wells installed within 1,000 ft of them (table 22 at end of report). The surface-water bodies selected for observation and the adjacent ground water were assumed to be hydraulically connected, therefore the altitudes of the water table and the surface-water body can be used to indicate the direction of flow. Some of the lakes and marshes have thick deposits of clay or fine organic matter along their bottoms, which could restrict movement to or from the adjacent aquifer. However, the margins of these lakes and marshes have much less fine material and more likelihood of an effective hydraulic connection.

To estimate the hydraulic conductivity of the sand aquifer, slug tests were made in 58 of the 60 shallow wells that were installed by jetting. The wells have an average depth of 21 ft and range in depth from 13 to 38 ft. The slug tests were performed by rapidly lowering a solid pipe down a well, and measuring the resulting rise in water level and the time until recovery to the original (static) water level. Then, the pipe was rapidly removed from the well and the resulting fall in water level and time until recovery to the original (static) level were measured. The water levels were measured with a pressure transducer every 2 seconds. The slug-test data were analyzed using a technique presented by Bouwer and Rice (1976) and Bouwer (1989).

An aquifer test was made at a 235-ft well (well 98), which was screened from 230 to 235 ft. The well was pumped at a rate of about 120 gal/min for 24 hours. Water levels were measured in the pumped well and in two nearby shallow wells during the pumping and for 24 hours after the pump stopped. Total drawdown in the pumped well was 14 ft and no drawdown was observed in the nearby shallow wells. Jacob's straight-line method was used to analyze the drawdown data and the residual-drawdown method was used to analyze the recovery data (Driscoll, 1986, p. 219-260).

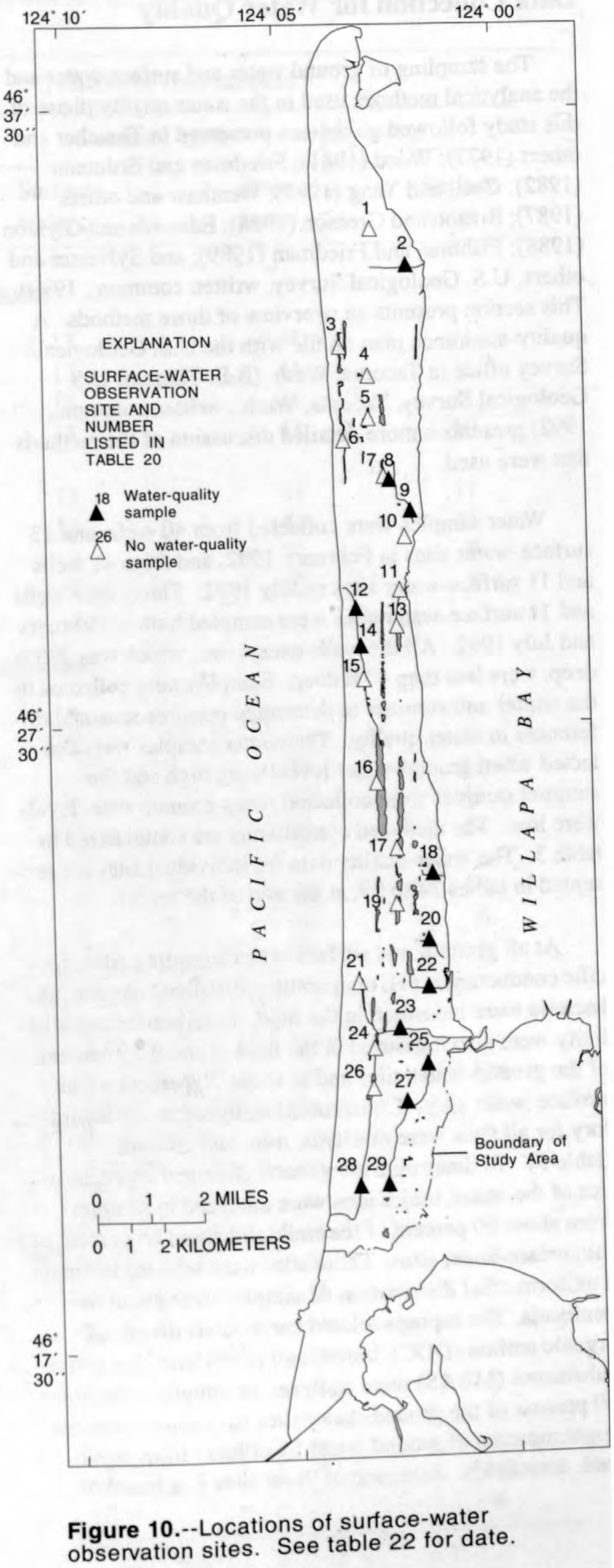

Figure 10.--Locations of surface-water observation sites. See table 22 for date.

Data Collection for Water Quality

The sampling of ground water and surface water and the analytical methods used in the water-quality phase of this study followed guidelines presented in Thatcher and others (1977); Wood (1981); Friedman and Erdmann (1982); Cecil and Yang (1987); Wershaw and others (1987); Britton and Greeson (1988); Edwards and Glysson (1988); Fishman and Friedman (1989); and Sylvester and others, U.S. Geological Survey, written commun., 1990). This section presents an overview of those methods. A quality-assurance plan on file with the U.S. Geological Survey office in Tacoma, Wash. (B.E. Thomas, U.S. Geological Survey, Tacoma, Wash., written commun., 1992) presents a more detailed discussion of the methods that were used.

Water samples were collected from 40 wells and 13 surface-water sites in February 1992, and from 41 wells and 11 surface-water sites in July 1992. Thirty-nine wells and 11 surface-water sites were sampled both in February and July 1992. All the wells except one, which was 235 ft deep, were less than 40 ft deep. Samples were collected in the winter and summer to determine possible seasonal differences in water quality. The winter samples were collected when ground-water levels were high and the summer samples were collected when ground-water levels were low. The analyzed constituents are summarized in table 3. The water-quality data for individual sites are presented in tables 24 to 29, at the end of the report.

At all ground- and surface-water sampling sites, specific conductance, pH, temperature, dissolved oxygen, and bacteria were measured in the field. Bicarbonate and alkalinity were also measured in the field at about 55 percent of the ground-water sites and at about 70 percent of the surface-water sites. Constituents analyzed in the laboratory for all sites were nutrients, iron, and chloride (table 3). To determine the general chemical characteristics of the water, major ions were analyzed in samples from about 60 percent of the wells and about 65 percent of the surface-water sites. Those sites were selected to obtain a uniform areal distribution of samples throughout the peninsula. The septage-related compounds dissolved organic carbon (DOC), boron, and methylene blue active substances (MBAS) were analyzed in samples from about 50 percent of the ground-water sites to examine possible contamination of ground water by effluent from septic-tank drainfields. Selection of those sites was based on population density, which was assumed to be a surrogate for septic-tank density. To examine possible contamination from cranberry-growing areas, pesticides were analyzed in samples from about half the ground-water and surface-water sites. Those sites were selected on the basis of proximity to cranberry-growing areas. Samples from 10 ground-water sites were collected in February 1992 and analyzed for radon. Samples of bottom sediments in three drainage channels near cranberry-growing areas were analyzed for pesticides.

Ground-water samples were collected from 16 shallow domestic wells, 1 shallow irrigation well, 1 deep commercial well, and 24 shallow monitoring wells. The sampling technique that was used depended on the type of well.

At the domestic, irrigation, and commercial wells, water samples were collected from a hose faucet in the well's distribution system as close to the wellhead as possible. All samples were collected prior to any water treatment, such as filtration, chlorination, fluoridation, or softening. Where feasible, samples were collected upstream of any holding tank. Sample water was directed from the hose faucet through nylon tubing to a flow-directing stainless-steel manifold mounted in a mobile water-quality laboratory; a diagram of the system is shown on figure 11. At least 10 casing volumes were purged and then temperature, pH, specific conductance, and dissolved-oxygen concentration were monitored continuously at the flow chamber. Once these readings were constant for 10 minutes, indicating that all water from the plumbing system had been flushed and water was being drawn from the aquifer, unfiltered and filtered (0.45-micron pore size) samples were collected from the appropriate manifold outlet. At sites where the dissolved-oxygen meter measured a concentration of less than 1.0 mg/L (milligrams per liter), an unfiltered water sample was collected and a colorimetric method was used to estimate the dissolved-oxygen concentration. Samples for DOC were collected directly from the stainless-steel manifold and then were filtered through a silver filter (0.45-micron pore size) in a stainless-steel filtration unit. Unfiltered samples to be analyzed for concentrations of pesticides, radon, and bacteria were collected last, directly from the hose faucet. After collection, samples were treated and preserved according to standard USGS procedures (Pritt and Jones, 1989). All equipment and hoses were cleaned and rinsed between each sample site to prevent cross contamination of samples.

Table 3.--*Analyzed constituents and properties of ground water and surface water, Long Beach Peninsula, Washington*

Constituent or property	February 1992 Ground water	February 1992 Surface water	July 1992 Ground water	July 1992 Surface water
	Number of sites sampled			
Field measured				
Specific conductance	40	13	41	11
pH	40	13	41	11
Temperature	40	13	41	11
Dissolved oxygen	40	13	41	10
Bacteria				
Fecal coliform	40	13	41	11
Fecal streptococci	40	13	41	11
Bicarbonate	22	9	23	8
Alkalinity	22	9	23	8
Laboratory measured				
Nutrients				
Nitrite	40	13	40	11
Nitrite plus nitrate	40	13	40	11
Ammonia	40	13	40	11
Orthophosphate	40	13	40	11
Septage-related compounds				
Dissolved organic carbon	10	0	20	0
Boron	20	0	20	0
Methylene blue active substances (MBAS)	20	0	20	0
Major ions				
Calcium	22	9	26	7
Magnesium	22	9	26	7
Sodium	22	9	26	7
Potassium	22	9	26	7
Sulfate	22	9	26	7
Chloride	40	13	41	11
Fluoride	22	9	26	7
Silica	22	9	26	7
Total dissolved solids	21	9	24	7
Iron	40	13	41	11
Manganese	22	9	26	7
Radon	10	0	0	0
Pesticides				
Carbamates	19	6	21	6
Dichlobinel	19	6	21	6
Diuron	0	0	21	6

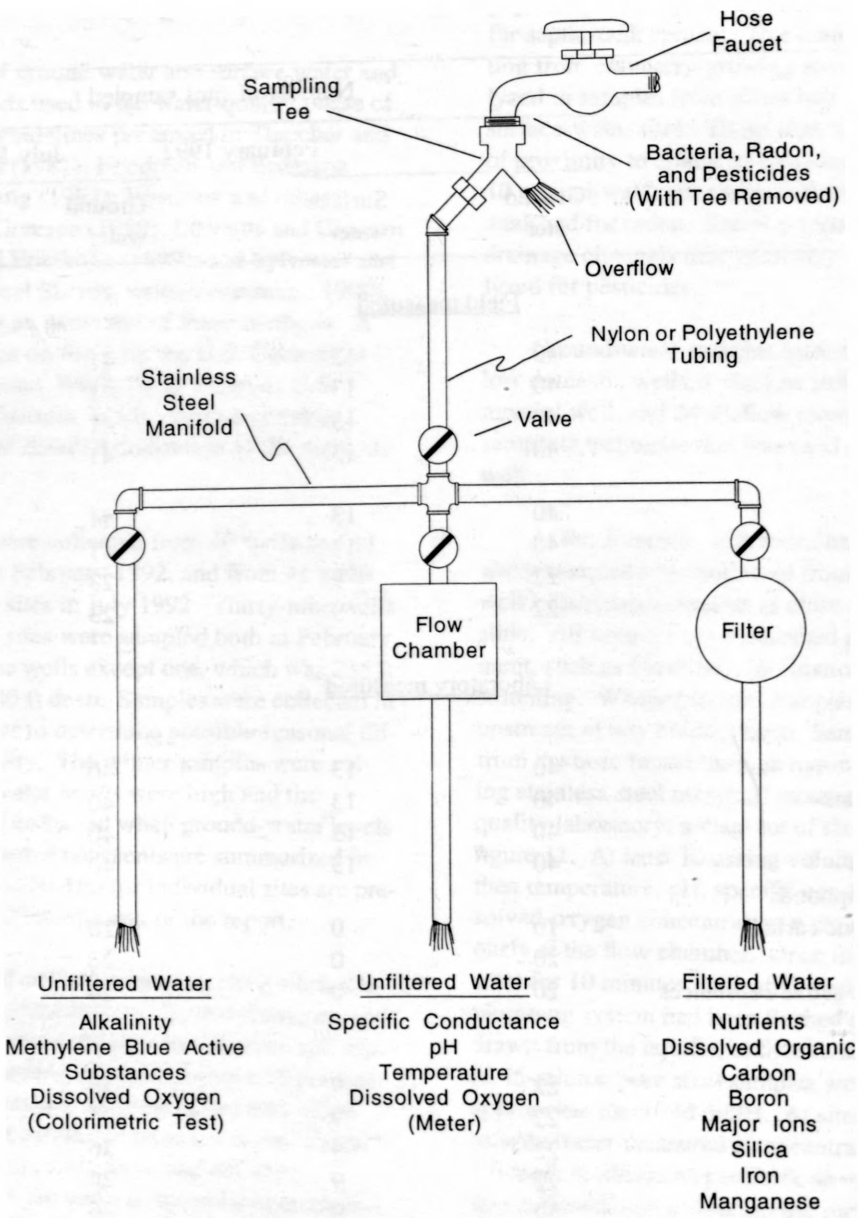

Figure 11.--Ground-water sampling system for domestic wells.

The water-collection procedures for monitoring wells were different from that described above because a portable pump or bailer was needed to withdraw the water. The first step was to pump at least 30 casing volumes of water from the well to ensure that the sample was representative of the aquifer. This was accomplished by using a centrifugal pump to withdraw water from the well for a minimum of 10 minutes at a rate of about 8 to 10 gal/min. A nylon tube was then dropped below the water table and a peristaltic pump was used to collect the water sample. Specific conductance and pH were monitored every 5 minutes until they stabilized, then the appropriate unfiltered and filtered samples were collected. Because of the order of sample collection at monitoring wells, samples of unfiltered water were collected from the peristaltic pump and the colorimetric method was used to estimate dissolved-oxygen concentrations at all sites. The colorimetric estimate, however, was retained only when the dissolved-oxygen meter measured a concentration of less than 1.0 mg/L. Samples for DOC were collected from the peristaltic pump and the water was filtered through the stainless-steel filtration unit and stainless-steel filter using nitrogen-gas pressure. Temperature and dissolved oxygen were measured by lowering the probes down the well. Unfiltered samples for pesticides were collected with a stainless-steel bailer. After collection, samples were treated and preserved according to standard USGS procedures (Pritt and Jones, 1989). All equipment and hoses were cleaned and rinsed between each sample site to prevent cross contamination of samples.

Standard USGS techniques were used to collect water samples from the surface-water sites (Edwards and Glysson, 1988; and Sylvester and others, U.S. Geological Survey, written commun., 1990). In February 1992, the samples were collected using a standard depth-integrating method to obtain representative samples. In July 1992, the flow of water was insufficient to use the standard methods; therefore, incremental samples were obtained by hand dipping bottles into the shallow water. The collected water from both methods was composited in a churn splitter from which samples were withdrawn for analysis.

Laboratory analyses were made at the USGS National Water Quality Laboratory (NWQL) in Arvada, Colo. Dissolved concentrations were determined for all inorganic constituents and DOC; total concentrations were determined for radon, MBAS, and pesticides. Analytical procedures used at the NWQL are described by Wershaw and others (1987) and Fishman and Friedman (1989).

Initially, 15 surface-water sites were selected for sampling; these sites included most of the surface-water drainage systems of the peninsula (see figs. 8 and 10). All surface-water samples were collected from drainage channels where water flows for at least part of the year. All sampling was done at or near low tide, but water samples from a few sites had to be discarded because of saltwater contamination. At those sites, the saltwater from Willapa Bay moved up the channels with the rising tide and displaced or mixed with the freshwater runoff. The following four sites had one or two water samples affected by tides; the July sample at Whiskey Slough (9); the February and July samples at Pauls Lake drainage (11); the February sample at unnamed drainage (10); and the July sample at unnamed drainage (2).

In sampling the bottom sediment of drainage channels, glass beakers were used to scoop the sediment from the bottom of the channel to a maximum depth of about 2 in. At least 10 samples were collected at each channel and then placed in a stainless steel bowl for thorough mixing. A stainless steel spoon was then used to transfer the sediment to glass sample bottles. The sampling equipment was cleaned in the laboratory before the field trip, and different beakers, bowls, and spoons were used at each site to prevent cross-contamination of samples.

Statistical Data Analysis

Several statistical methods were used in this report to help analyze and interpret the hydrologic data. Hydrologic data are usually quite variable and relations among the data are difficult to determine. Statistical methods are useful for describing characteristics of the data, and they provide support and objective criteria for making decisions about the data. Descriptive statistics, regression analysis, and hypothesis testing were used in this study.

Descriptive statistics provide a summary of a sample of data. The mean of a sample of observations is the most common statistic and it describes the most representative value. In most samples of hydrologic data, however, the median is used as the most representative value instead of the mean because the median is not affected by extreme values which are common in hydrologic samples. The median is the central value of a sample when the data are ranked in order of magnitude; half the data exceed it and half the data are less than it. In addition to the most representative value of a sample, the dispersion of the sample also needs to be described. The minimum and maximum values provide the range of values in the sample. The 25th and 75th percentiles describe in more detail the shape of the dispersion. The 25th percentile is the value that is exceeded by 75 percent of the data, and the 75th percentile is the value that is exceeded by 25 percent of the data.

Regression analyses are made to determine the relation between two variables by expressing one variable in terms of a function of the other variable. The function is a mathematical relation that can be used to estimate what value of variable Y corresponds to a given value of variable X. The variable Y is the response variable and the variable X is the explanatory variable. Multiple-regression analyses can also be made where several explanatory variables are used to develop the functional relation of the response variable. The following is an example of a hydrologic relation where regression analysis can be applied: at a particular well, the ground-water level rises and falls in response to precipitation. Using the ground-water level as the response variable (Y) and the precipitation as the explanatory variable (X), a functional relation or regression equation can be developed using data collected on water levels and precipitation at the well site. This relation can then be used to estimate water levels on the basis of precipitation.

Hypothesis testing is a powerful statistical method that is useful in making objective decisions about relations between data. Hypotheses are ideas or concepts that describe systems or populations. In order to test a hypothesis, data are collected to provide a sample that represents a population. Statistical tests are then applied to such data, and the results of the tests can be used to substantiate a hypothesis or to determine if a hypothesis must be modified or rejected.

Most of the hypothesis testing in this report was done to evaluate and compare groups of data. An example is a hypothesis that says two groups are from the same population. The two groups may be nitrate concentrations from water samples collected in the winter and in the summer. The hypothesis is that the nitrate concentrations from both groups are from the same population, and therefore seasons of the year have no effect on nitrate concentrations. If this hypothesis is rejected, then nitrate concentrations are significantly related to seasons of the year.

An important feature of the statistical methods used to test hypotheses is the computed probability or significance level (p-value), which is a measure of the strength of evidence (data) for supporting or rejecting the hypothesis. For example, a p-value of 0.03 means that there is a 0.03 probability (or a 3 percent chance) that the conclusion of the statistical test is incorrect. Before the test is made, a threshold significance level is selected at which the hypothesis is rejected or not rejected. For this report, the threshold level is a p-value of 0.05; a p-value of less than 0.05 is significant and a p-value of more than 0.05 is not significant. Thus, using the example in the previous paragraph, if a test computes a p-value of less than 0.05, the hypothesis (that two groups are from the same population) is rejected and we say that the two groups are significantly different and that nitrate concentrations are significantly related to seasons of the year (Sokal and Rohlf, 1973, p. 116-132).

GROUND-WATER FLOW SYSTEM

A ground-water flow system is a body of porous material that is saturated with flowing water. The body of porous material can be fractured rock or the weathering products of rock, such as sand. A typical definition of a ground-water system includes descriptions of (1) the boundaries of the system, (2) the inflow and outflow of water through the boundaries (recharge and discharge), (3) the hydraulic properties of the body of material, and (4) the directions and rates of ground-water flow within the system.

Ground-water flow systems typically consist of aquifers and confining beds. An aquifer is a body of porous material that will yield water in a usable quantity to a well or spring. A confining bed is a body of porous material having very low permeability that restricts the movement of ground water either into or out of adjacent aquifers.

The boundaries of a ground-water flow system define a three-dimensional surface that encloses the aquifers and confining beds. The specified positions of the boundaries describe the internal and external geometry of the flow system. An example of an internal boundary is the plane of contact between an aquifer and confining bed. Examples of external boundaries are (1) the water table, (2) the surface marking the lower limit of the flow system where an aquifer abuts against a relatively impermeable surface such as bedrock, (3) the zone of contact between an aquifer and a river or lake, or (4) the zone of contact between an aquifer and a saline water body such as the ocean.

Three flow conditions can occur at a ground-water boundary: no-flow, inflow (recharge), or outflow (discharge). The flow condition is dependent on the direction of ground-water flow at the boundary, the relation between the heads or fluid density on either side of the boundary, and the permeability of the material on either side of the boundary. An example of an outflow or discharge boundary is a stream that is hydraulically connected to an aquifer and the adjacent ground-water level is higher than the surface-water level. The quantity of discharge is dependent on the water-level gradient between the surface water and ground water, and the thickness and hydraulic conductivity of the streambed material that separates the surface water and ground water.

The hydraulic properties of an aquifer can be described using the hydraulic conductivity and storage capacity. Hydraulic conductivity is a measure of the relative ease with which a body of porous material can transmit a liquid under a potential gradient. The size and arrangement of the pores of the porous material are the major factors controlling the magnitude of hydraulic conductivity.

The storage capacity of an aquifer influences the amount of water that is available for withdrawal. In an unconfined aquifer, such as the sand aquifer on the Long Beach Peninsula, specific yield is a measure of the storage capacity. Specific yield of a rock or soil is the ratio of the volume of water that the saturated rock or soil will yield by gravity, to the total volume of the rock or soil.

The direction of ground-water flow is determined by comparing hydraulic heads. Ground water moves from higher to lower head. Heads are determined by measuring the position of the water level in a well and relating the measurement to a datum plane. A datum that is common to all wells in an area is used for comparisons. Sea level is the most widely used datum, and this datum, as referenced to the National Geodetic Datum of 1929, is used in this report (Heath, 1989, p. 6 and 10). Thus, measured water levels are reported as an altitude in feet above or below sea level. The term "water table" is used often in this report, and the water table is defined as the surface of a ground-water body at which the water pressure is the same as atmospheric pressure. In the sand aquifer investigated in this report, a water level measured in a shallow well closely defines the water table at that site.

A ground-water flow system may be in a steady-state or transient-state condition in relation to time. In a steady-state system, the quantity of inflow is balanced by the quantity of outflow. Under such conditions water levels may fluctuate seasonally in response to variations in precipitation; however, the long-term average of the water levels remains constant. In contrast, a system in a transient-state condition will have long-term changes in water levels.

Boundaries

The external boundaries of the freshwater ground-water system in the Long Beach Peninsula are similar to the boundaries of a homogeneous "island" ground-water flow system that can be defined by some physical principles (fig. 12). In this system, the freshwater "floats" on saltwater as a lens-shaped body. This relation occurs because the density of freshwater (1.000) is slightly less than the density of seawater (1.025).

In an island ground-water flow system, the higher the water table is above sea level, the thicker is the freshwater lens. This relation is known as the Ghyben-Herzberg principle, named after the two scientists who first discovered it. The Ghyben-Herzberg principle states that at any particular location, for every 1 ft of altitude the water table is above sea level, fresh ground water will extend 40 ft below sea level. For example, if the water table at a given site is 5 ft above sea level, the freshwater-saltwater interface is theoretically at 200 ft below sea level. The thickness of the freshwater body is, therefore, 205 ft at that site. The principle also implies that if the water table is lowered 1 ft, the interface will rise 40 ft, thereby reducing the total thickness of the freshwater lens by 41 ft.

In addition to the relative densities of freshwater and seawater, the position of the interface at any one time is also affected by the seasonal position of the water table, the hydraulic characteristics of the aquifer, recharge-discharge relations within the aquifer, and tides. The interface is not sharp, but rather is a diffusion zone in which the chloride and salt concentration of the freshwater gradually increases with distance from the freshwater body until it reaches the concentration of the surrounding saltwater body. This zone may be narrow or broad, depending on the above-mentioned factors.

The upper external boundary of the ground-water system in the Long Beach Peninsula is the water table. The water table is a dynamic boundary whose vertical position fluctuates over time. All the possible flow conditions can occur at the water-table boundary; recharge occurs from percolation of rainfall, discharge occurs by evapotranspiration, and no-flow occurs in areas with no recharge or discharge, where ground water flows parallel to the water table. The flow condition that occurs at a particular location of the water table is dependent on the complex interaction among the flow conditions at all the boundaries of the ground-water system.

The lateral and lower external boundaries of the freshwater ground-water system in the Long Beach Peninsula mostly coincide with the interface between freshwater and saltwater as described in the Ghyben-Herzberg principle and shown on figure 12. Thus, the thickness of the ground-water system is dependent on the height of the water table above sea level (altitude). During the winter, the maximum altitude of the water table is about 15 ft, and therefore the maximum thickness of the ground-water system would be about 600 ft. During the fall, ground-water levels decline and the maximum thickness would decrease to about 400 ft. Three wells on the peninsula appear to have penetrated the diffusion zone of the freshwater-saltwater interface. A water sample collected in 1968 from a 164-ft well (well 95) had a chloride concentration of 566 mg/L (Tracy, 1978, table 6) and a water sample collected in July 1982 from a nearby 235-foot well (well 98) had a chloride concentration of 250 mg/L. Well 14, which was abandoned immediately after drilling, encountered saltwater at a depth of about 250 ft (Economic and Engineering Services, Inc., written commun., October 19, 1983). The typical chloride concentration of seawater is about 19,000 mg/L and the average chloride concentration of the shallow freshwater aquifer in 1992 was about 18 mg/L.

The saltwater bodies outside of the fresh ground-water lens are the Pacific Ocean on the western side of the peninsula and Willapa Bay on the eastern and northern sides. The lower boundary is probably a combination of saltwater from the Pacific Ocean and Willapa Bay. The flow of fresh ground water will be mostly parallel to this boundary (fig. 12), but some water can move in both directions across the interface.

In two areas, the external boundary of the ground-water system of the peninsula does not coincide with the freshwater-saltwater interface. A no-flow boundary exists at the southern lateral boundary, which is the contact between the unconsolidated deposits and bedrock (fig. 7). In the southern part of the peninsula, where bedrock is shallow and less than the depth prescribed by the Ghyben-Herzberg principle, the lower boundary of the ground-water system is the contact with bedrock rather than the freshwater-saltwater interface.

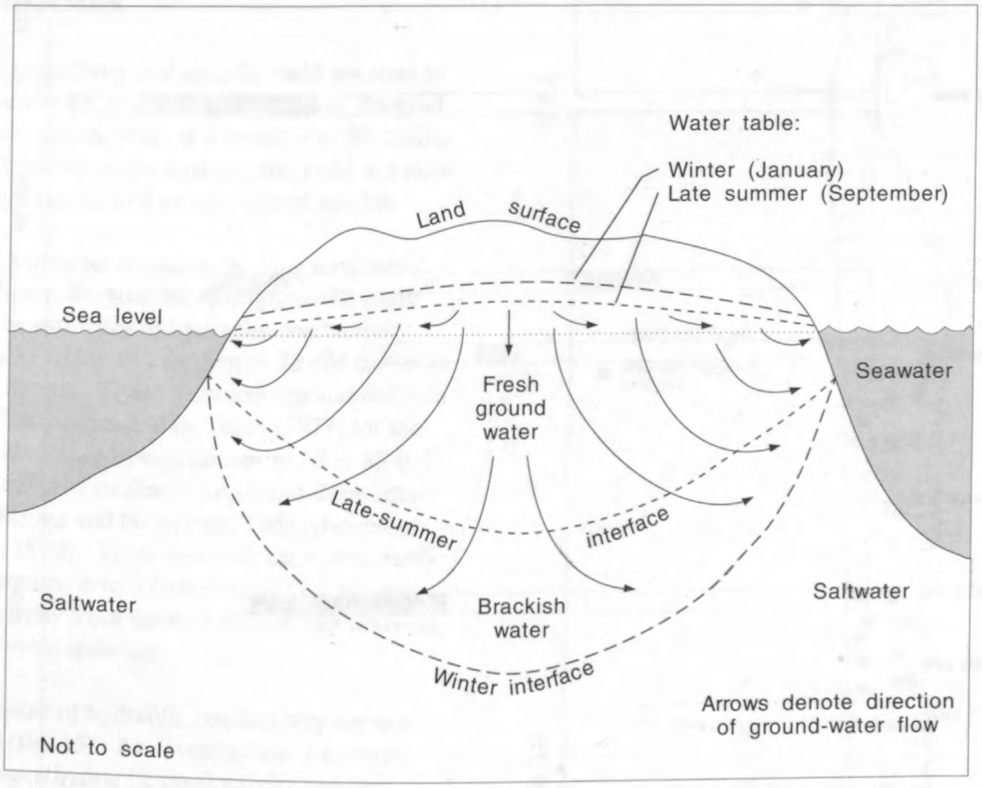

Figure 12.--Generalized flow pattern of a homogeneous island aquifer.

Many surface-water bodies, including lakes, marshes, and drainage channels, form boundaries with the ground-water system. In most areas, the permeability of the material between the surface-water body and the aquifer is sufficient to allow water to flow across the boundary. Such boundaries can be either recharge or discharge boundaries; the flow condition is dependent on the relative altitudes of the surface-water body and nearby water levels in the aquifer.

The ground-water system in the Long Beach Peninsula consists of a sand aquifer with some local lenses of silt or clay (fig. 13) that may act as confining beds. The silt or clay lenses are interspersed throughout the body of sand and the available information is not sufficient to determine if the lenses may connect to form a continuous confining bed across the entire peninsula. Near Cranberry Road, the lithologic information from several well logs and an aquifer test made on a 235-foot well (well 98) indicate that a local confining bed probably exists between altitudes of about -120 to -210 ft. In the northern part of the peninsula, lithologic data indicate that a confining bed might exist between altitudes of about -230 to -280 ft.

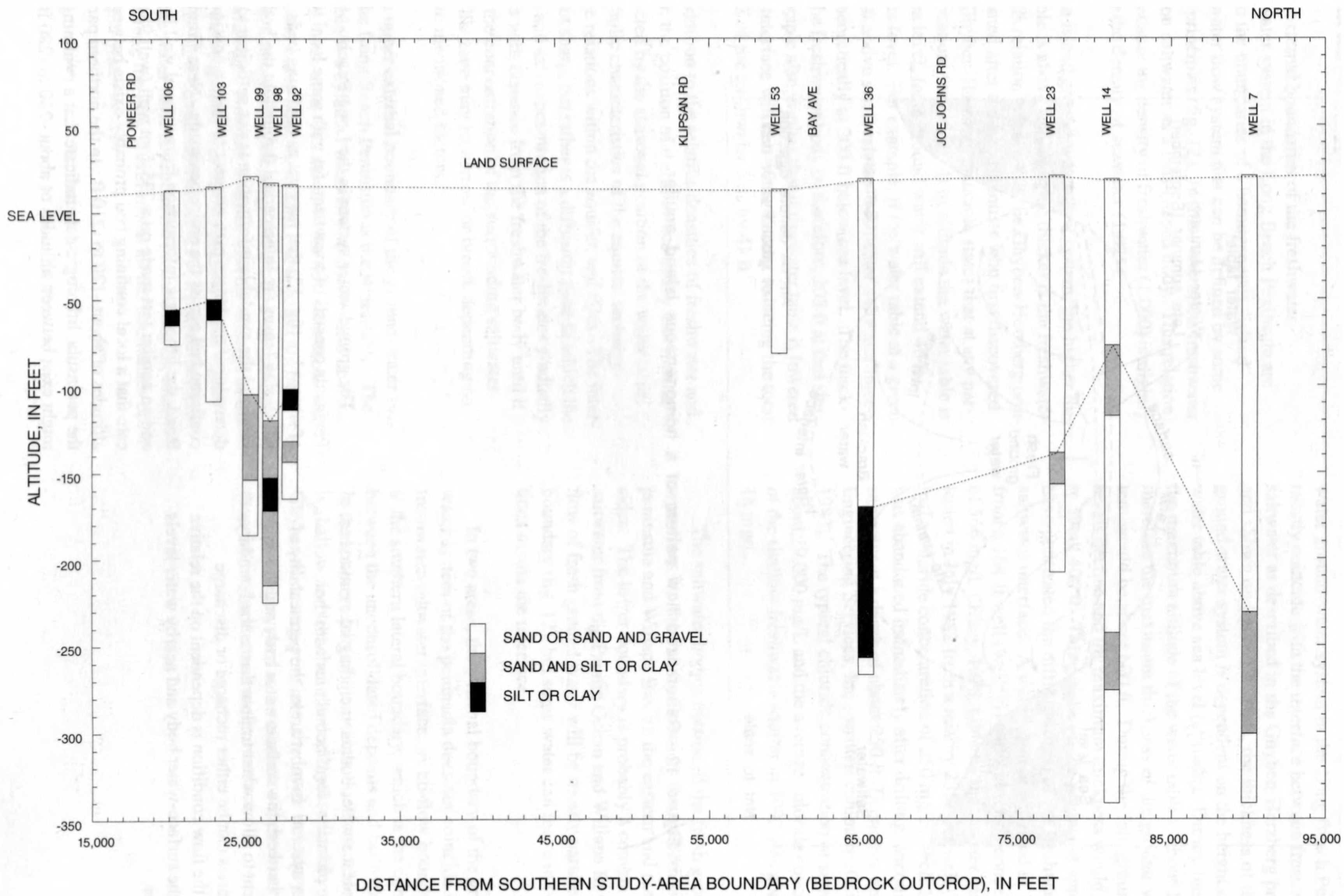

Figure 13.--Lithologic information from the logs of wells drilled through the unconsolidated deposits along a south-north section of the Long Beach Peninsula, Washington.

Hydraulic Properties

Hydraulic conductivity and specific yield are used in this study to describe the hydraulic properties of the sand aquifer. Hydraulic conductivity is a measure of the ability of an aquifer to transmit water, and specific yield is a measure of the storage capacity of an unconfined aquifer.

To estimate hydraulic conductivity, slug tests were made in 58 shallow wells situated throughout the study area (fig. 14). The estimates of hydraulic conductivity range from 10 to 37 ft/d with a median of 22 ft/d (table 20 at the end of the report). These estimates are smaller than the average of 37 ft/d estimated by Tracy (1978) for the Long Beach Peninsula, and the estimates of 35 to 85 ft/d from previous studies of similar coastal sand-dune aquifers in Oregon (Brown and Newcomb, 1963; Hampton, 1963; and Frank, 1970). Those previous estimates, however, were not based on actual field tests. The estimates of hydraulic conductivity from the slug tests in this study are considered to be more accurate.

The 58 estimates of hydraulic conductivity are normally distributed (fig. 15). An investigation was made of the relations between hydraulic conductivity and well depth, altitude of land surface at the well, altitude of the bottom of the screened interval, soil type at the well, and geographic position (latitude and longitude). The variable with the most accurate relation to conductivity was altitude of the bottom of the screened interval, which had an inverse relation where conductivity increased as altitude decreased (fig. 15).

Results of a 24-hour aquifer test made by pumping a 235-foot well (well 98) did not meet the necessary assumptions to estimate hydraulic properties of the aquifer. The aquifer-test data, however, do provide evidence for a confining bed in the local area. No drawdowns were observed in nearby shallow wells, and lenses of silt and clay are found between 130 and 230 ft below land surface.

No field tests were made to estimate the specific yield of the aquifer. Estimates of 0.32 to 0.37 for specific yield were made in previous studies of similar coastal sand-dune aquifers in Oregon (Brown and Newcomb, 1963; Hampton, 1963; and Frank, 1970). In a previous study of the Long Beach Peninsula, Tracy (1978, p. 25) used an estimate of 0.33 in his computation of a water budget for a cross section of the peninsula. Those estimates are considered valid for the sand aquifer of the Long Beach Peninsula.

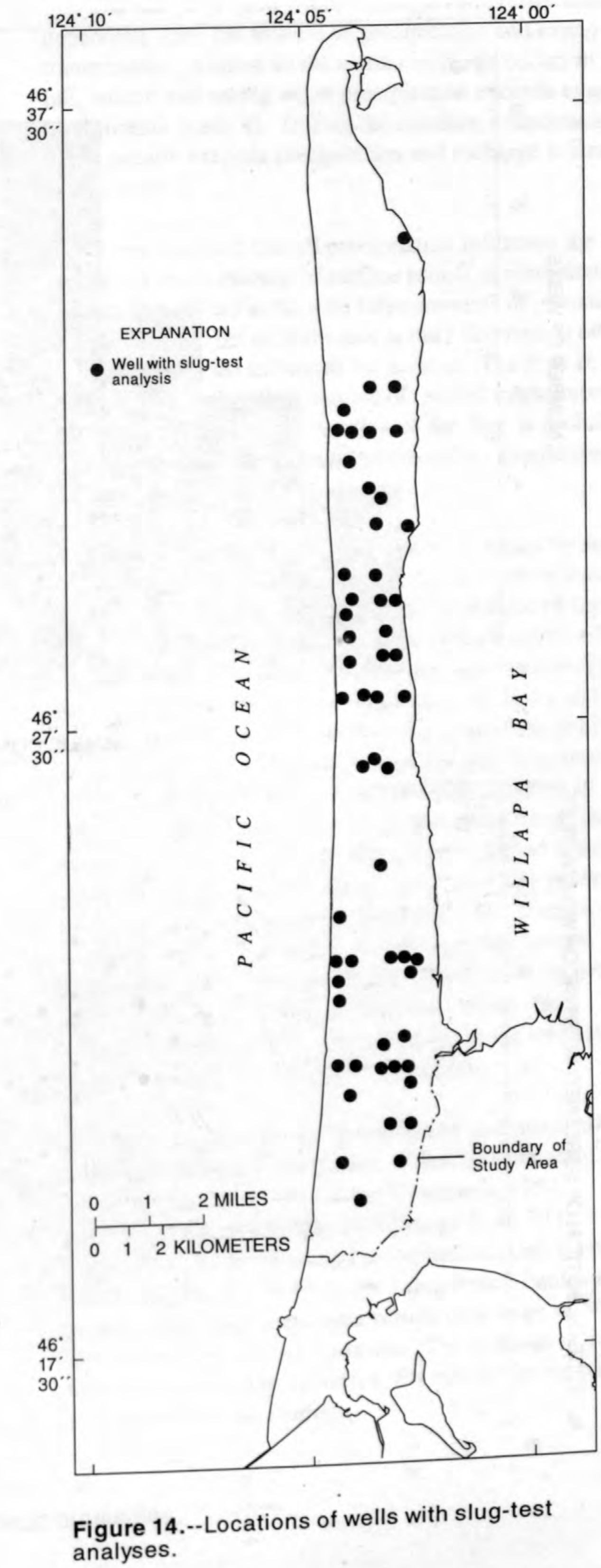

Figure 14.--Locations of wells with slug-test analyses.

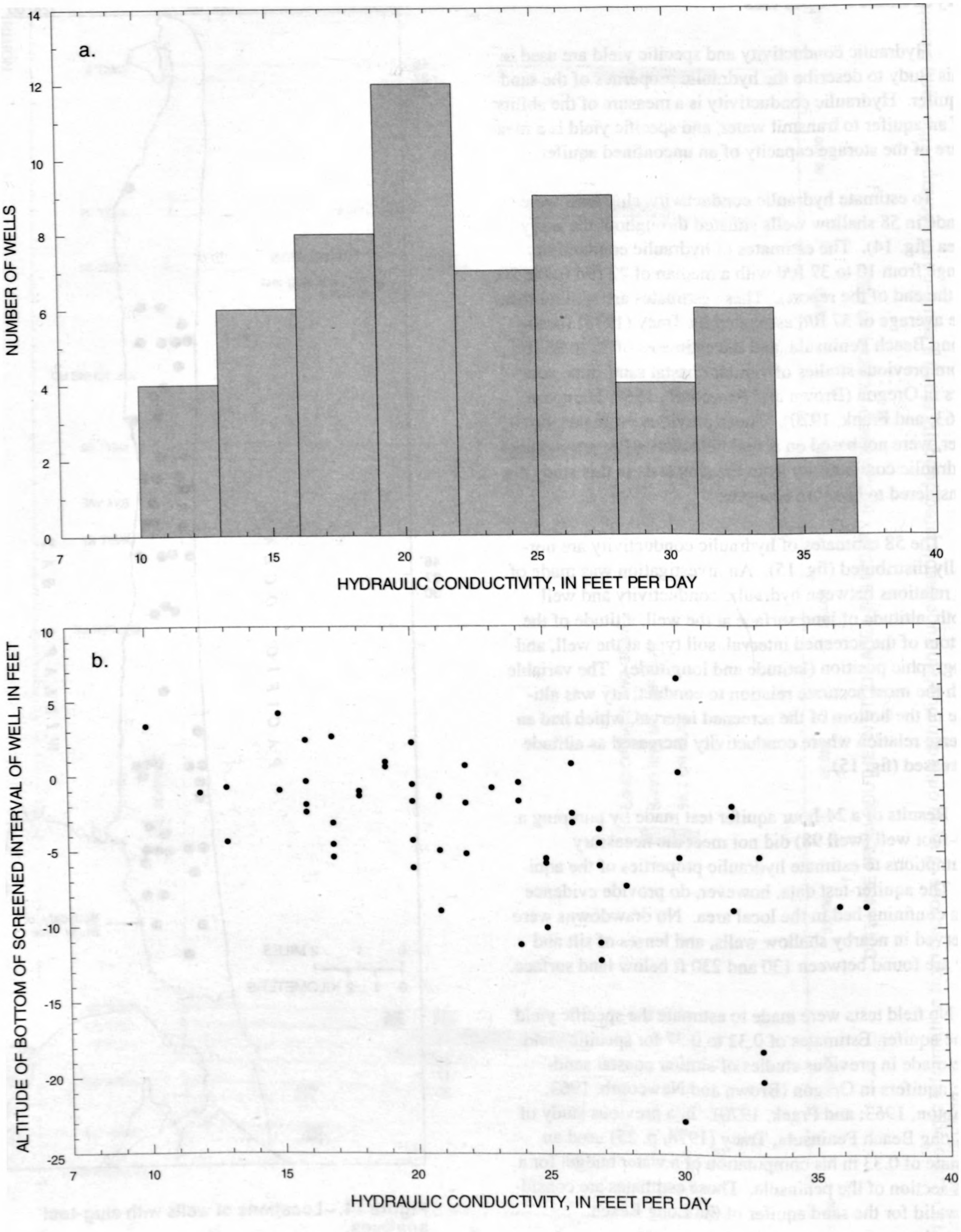

Figure 15.--Frequency distribution of hydraulic conductivity (a) and relation between hydraulic conductivity and altitude of bottom of screened interval of well (b) on the Long Beach Peninsula, Washington.

Recharge

Recharge to the ground-water system occurs by infiltration and percolation of rainfall, and by a small amount by seepage from lakes and marshes. Most of the rainfall that falls on the peninsula becomes ground-water recharge because of the rapid infiltration and percolation rates of most of the soils on the peninsula. Seventy-eight percent of the land surface is covered with soils that have a permeability that is at least moderately rapid (see table 2).

Average annual recharge by infiltration and percolation of rainfall is estimated to be about 58 in. (table 4). Applying the 58 in. to the total land-surface area of 36 mi^2 results in a recharge volume of about 111,000 acre-ft. This estimate is equal to the sum of the average monthly precipitation minus estimated monthly potential evapotranspiration. As rainfall infiltrates and percolates through a soil, some of the water stays in the soil and the remainder percolates down to the water table. The estimated potential evapotranspiration shown in table 4 is for the water that stays in the soil and is returned to the atmosphere by direct evaporation from the soil or by transpiration from plants.

For a conservative estimate of ground-water recharge, actual evapotranspiration was assumed to equal potential evapotranspiration. Potential evapotranspiration is the maximum amount possible, based on the principal factors that influence evapotranspiration (temperature, incident solar radiation, wind, and vegetative cover). Actual evapotranspiration may be less than the potential if the available water in the soil is not sufficient to meet the potential demand. On the Long Beach Peninsula, actual evapotranspiration probably is within a few percent of the potential because of the cool temperatures, abundant precipitation, thick vegetative cover, and deep soils (Tracy, 1978, p. 21).

The potential evapotranspiration of 24.7 in/yr used in this study was estimated by Tracy (1978) using a modified Blaney-Criddle method. A similar estimate of potential evapotranspiration (22 in.) was obtained during this study using the Thornthwaite method (Dunne and Leopold, 1978, p. 136-138). Measured pan evaporation at the Long Beach Experimental Weather Station for June-September was an average of 14 in. during 1978-84 (Kim Patten, Washington State University Extension Unit, Long Beach, Wash., written commun., 1993), which is close to the 11.2 in. of potential evapotranspiration during June-September that was used in this study (table 4).

The rate of ground-water recharge varies seasonally, depending upon the amount of precipitation and evapotranspiration. Almost all the annual recharge occurs in the fall, winter, and spring when precipitation exceeds evapotranspiration (table 4). During the summer, evapotranspiration usually exceeds precipitation and recharge is small or nonexistent.

It was assumed that all precipitation infiltrates the ground. A small amount of surface runoff of precipitation does occur in urban areas with large amounts of pavement or cement, but most of that water is only diverted to other areas, where it then infiltrates the ground. The flow in drainage channels during periods of rainfall might represent some surface runoff, but most of the flow is probably increased ground-water discharge caused by a rapid rise in the water table.

A small amount of recharge probably occurs by seepage from lakes and marshes. Water can flow from these bodies to the ground-water system if the altitude of the surface-water body is higher than the altitude of the adjacent ground-water level. The potential area of recharge from this source is small; the surface area of lakes and marshes that were defined on the soils map of the peninsula is about 1 mi^2, or 2.5 percent of the total area (see fig. 7). Analysis of the measured monthly altitudes of 14 lakes and marshes and adjacent ground water found that the direction of flow between these bodies varied seasonally and that, over a year, ground-water recharge probably occurs about 55 percent of the time (fig. 16). Thus, some net annual recharge probably occurs from this source, but because the amount is minimal compared to the recharge from infiltration of rainfall on the land surface, the recharge from this source was not added to the estimate of 111,000 acre-ft from infiltration of rainfall.

Estimates of recharge by infiltration and percolation of rainfall from previous studies of similar sand aquifers on the Oregon coast (Brown and Newcomb, 1963; Hampton, 1963; and Frank, 1970) range from 70 to 85 percent of the mean annual precipitation. Using a mean annual precipitation of 80 in. for Long Beach Peninsula and the 70-85 percent estimate results in a range of 56 to 68 in. of recharge for the peninsula. The recharge estimate of 58 in. for this study, therefore, fits into the lower part of the range for similar studies.

Table 4.--*Monthly distribution of average precipitation and estimated potential evapotranspiration, ground-water recharge, and ground-water discharge to surface-water drainage channels, Long Beach Peninsula, Washington*

[--, not applicable]

				Surface-water drainage channels		
Month	Average precipitation, (inches)	Potential evapotranspiration (inches)[1]	Average ground-water recharge (inches)	Average water-level gradient between surface water and ground water[2]	Average percentage of recharge that discharges to surface water[3]	Average ground-water discharge to surface water (inches)
January	11.2	1.2	10.0	1.8	40	4.0
February	9.7	1.2	8.5	1.2	27	2.3
March	8.9	1.8	7.1	0.7	16	1.1
April	5.8	2.2	3.6	0.7	16	0.6
May	3.8	2.8	1.0	0.8	18	0.2
June	2.9	3.0	0	0.3	7	0
July	1.7	3.2	0	0.4	9	0
August	2.0	2.8	0	-0.1	0	0
September	4.0	2.2	1.8	-0.1	0	0
October	6.4	1.8	4.6	0.2	4	0.2
November	11.5	1.3	10.2	0.9	20	2.0
December	12.5	1.2	11.3	1.0	22	2.5
Total annual	80.4	24.7	58.1	--	--	12.9

[1]Estimated by Tracy (1978, p. 21).

[2]Value was determined from measurements at eight pairs of wells and surface-water drainage channels.

[3]See text for explanation of how this value was determined.

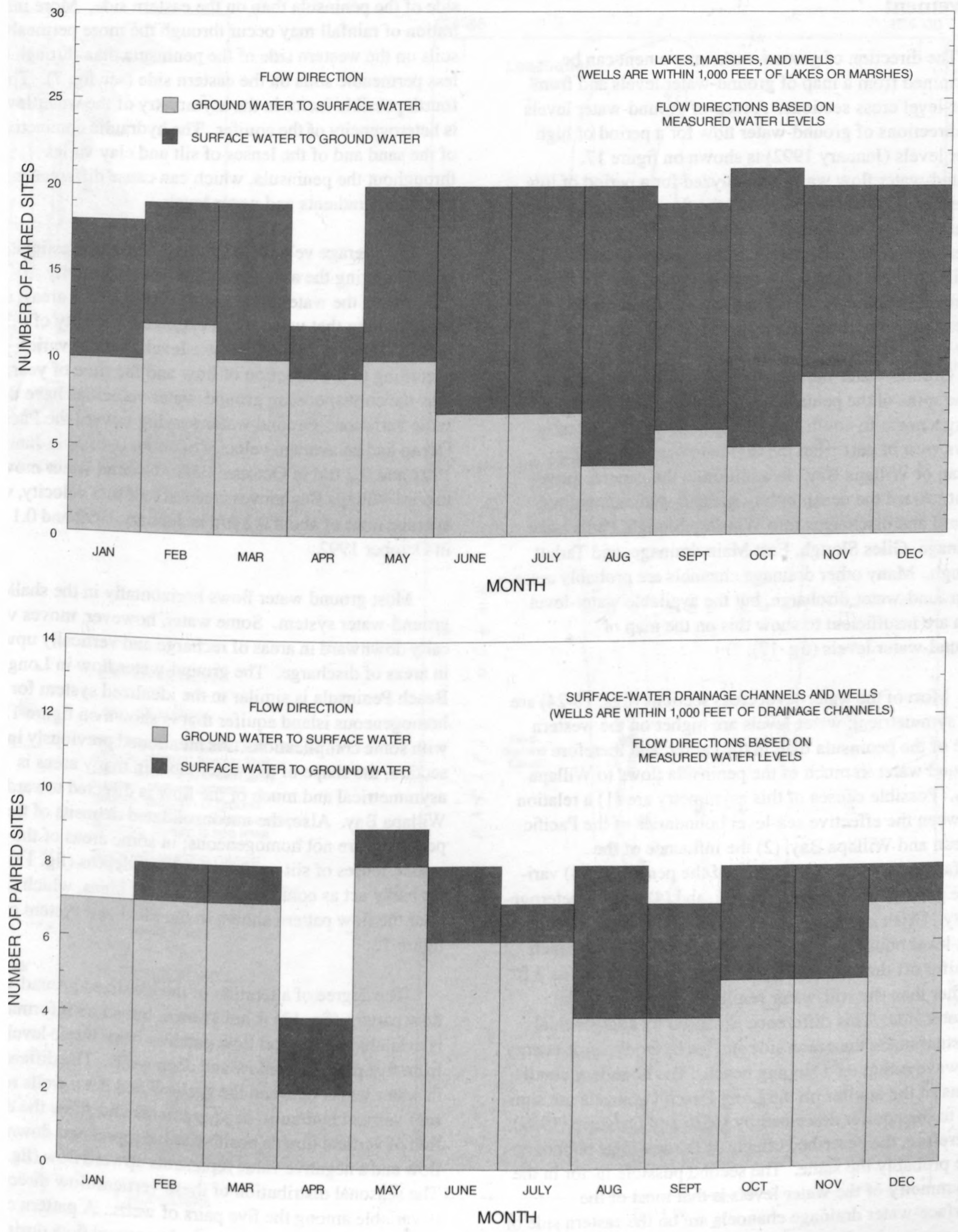

Figure 16.--Seasonal distribution of flow directions between selected surface-water bodies and ground water during 1992 on the Long Beach Peninsula, Washington.

Movement

The direction of ground-water movement can be determined from a map of ground-water levels and from water-level cross sections. A map of ground-water levels and directions of ground-water flow for a period of high water levels (January 1992) is shown on figure 17. Ground-water flow was also analyzed for a period of low water levels (October 1992) and the flow directions were generally the same for both periods. Seven east-to-west water-level cross sections were constructed to show a detailed picture of the shape and position of the water table during high (January 1992) and low (October 1992) water-level conditions (figs. 18-24)

Ground-water movement is generally perpendicular to the spine of the peninsula. A ground-water divide exists along a north-to-south line, and ground water generally flows west or east from the divide toward the Pacific Ocean or Willapa Bay. In addition to the general movement toward the ocean or bay, ground water also moves toward and discharges into Whiskey Slough, Pauls Lake drainage, Giles Slough, East Main drainage, and Tarlatt Slough. Many other drainage channels are probably areas of ground-water discharge, but the available water-level data are insufficient to show this on the map of ground-water levels (fig. 17).

Most of the water-level cross sections (figs. 18-24) are not symmetrical; water levels are higher on the western side of the peninsula than in the center, and therefore ground water in much of the peninsula flows to Willapa Bay. Possible causes of this asymmetry are (1) a relation between the effective sea-level boundaries of the Pacific Ocean and Willapa Bay, (2) the influence of the surface-water drainage system of the peninsula, (3) variable ground-water recharge rates, and (4) aquifer heterogeneity. Urish and Ozbilgin (1989) found that the effective sea-level boundary on the ocean side of a barrier-beach aquifer off the coast of Rhode Island was as much as 2 ft higher than the still-water sea-level boundary on the lagoon side. This difference is caused by a larger tidal fluctuation on the ocean side and the hydrodynamic energy of wave runup on a sloping beach. The boundary conditions of the aquifer on the Long Beach Peninsula are similar to the aquifer described by Urish and Ozbilgin (1989); therefore, the described effects on the sea-level boundaries are probably the same. The second possible factor in the asymmetry of the water levels is that most of the surface-water drainage channels are on the eastern side of the peninsula. Because these drainage channels act as ground-water boundaries, ground-water levels in those areas are kept relatively low. The third possible factor in the asymmetry of the water-level cross sections is that more ground-water recharge may occur on the western side of the peninsula than on the eastern side. More infiltration of rainfall may occur through the more permeable soils on the western side of the peninsula than through the less permeable soils on the eastern side (see fig. 7). The fourth possible factor in the asymmetry of the water levels is heterogeneity of the aquifer. The hydraulic conductivity of the sand and of the lenses of silt and clay varies throughout the peninsula, which can cause differences in hydraulic gradients and water levels.

The average velocity of ground water was estimated by multiplying the average hydraulic conductivity (22 ft/d) by the water-level gradient in selected areas, and then dividing that value by an estimated porosity of 0.35 (Heath, 1989, p. 25). The water-level gradient varies according to the direction of flow and the time of year; thus the corresponding ground-water velocities have the same variation. Ground water moving toward the Pacific Ocean had an average velocity of about 0.4 ft/d in January 1992 and 0.2 ft/d in October 1992. Ground water moving toward Willapa Bay moves at about half that velocity, with average rates of about 0.2 ft/d in January 1992 and 0.1 ft/d in October 1992.

Most ground water flows horizontally in the shallow ground-water system. Some water, however, moves vertically downward in areas of recharge and vertically upward in areas of discharge. The ground-water flow in Long Beach Peninsula is similar to the idealized system for a homogeneous island aquifer that is shown on figure 12, with some complications. As mentioned previously in this section, the shape of the water table in many areas is asymmetrical and much of the flow is directed toward Willapa Bay. Also, the unconsolidated deposits of the peninsula are not homogeneous; in some areas of the peninsula, lenses of slit or clay at various depths (fig. 13) probably act as confining beds in local areas, which could alter the flow pattern shown in the idealized system on figure 12.

The degree of alteration of the idealized ground-water flow pattern (fig. 12) is not known, but some information is available on vertical flow patterns from water-level data from five pairs of shallow and deep wells. The differences in water levels between the shallow and deep wells represent vertical hydraulic-head gradients and show the direction of vertical flow; a positive value represents downward flow and a negative value represents upward flow (fig. 25). The seasonal distribution of these vertical-flow directions is variable among the five pairs of wells. A pattern common to most of the well pairs is downward flow during the months of heavy precipitation, which is probably caused by rapid recharge of the upper part of the aquifer, thereby causing a rapid rise in the water level of that upper part. Water levels in the deeper part of the aquifer would respond more slowly to recharge at the water table.

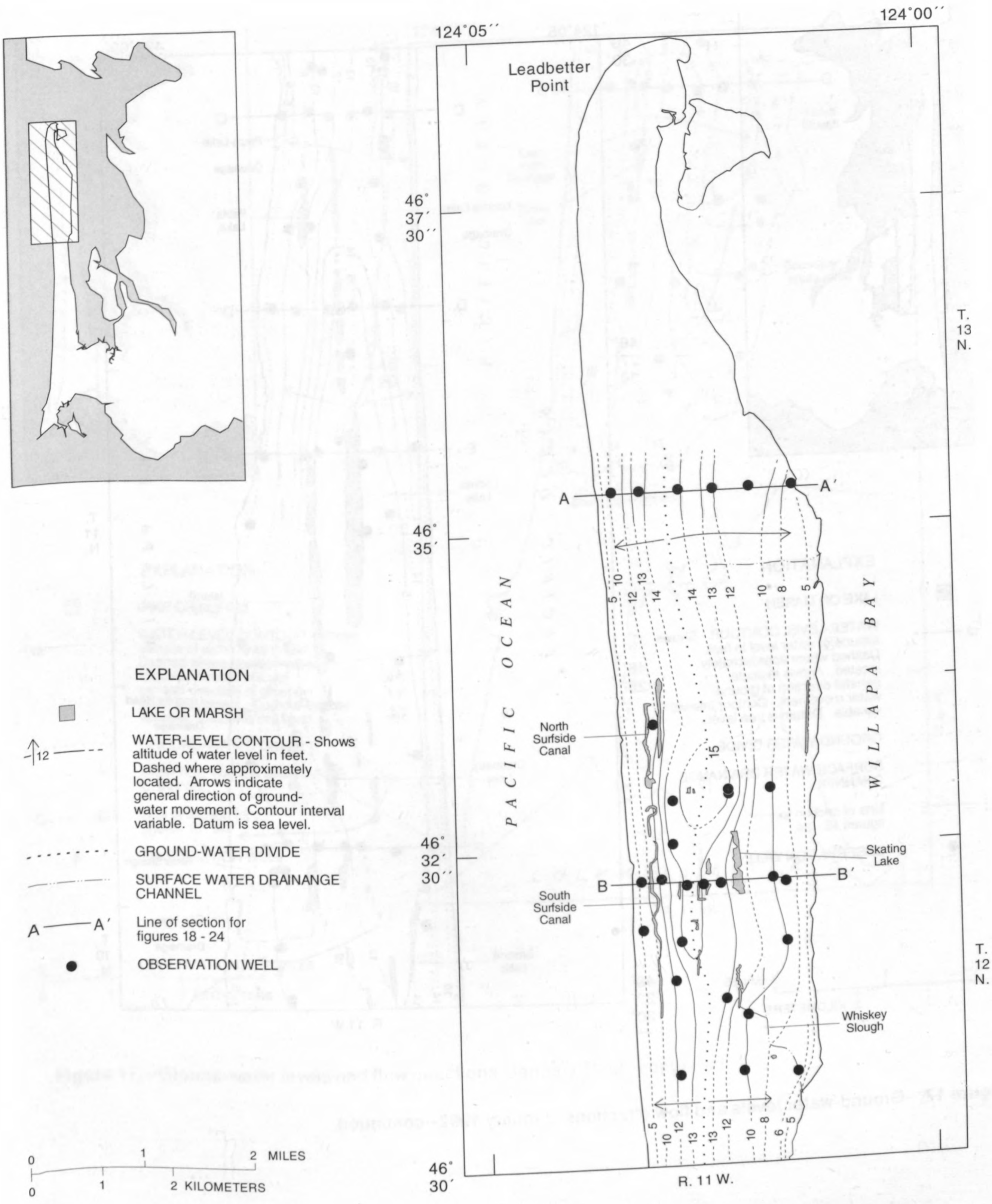

Figure 17.--Ground-water levels and flow directions, January 1992.

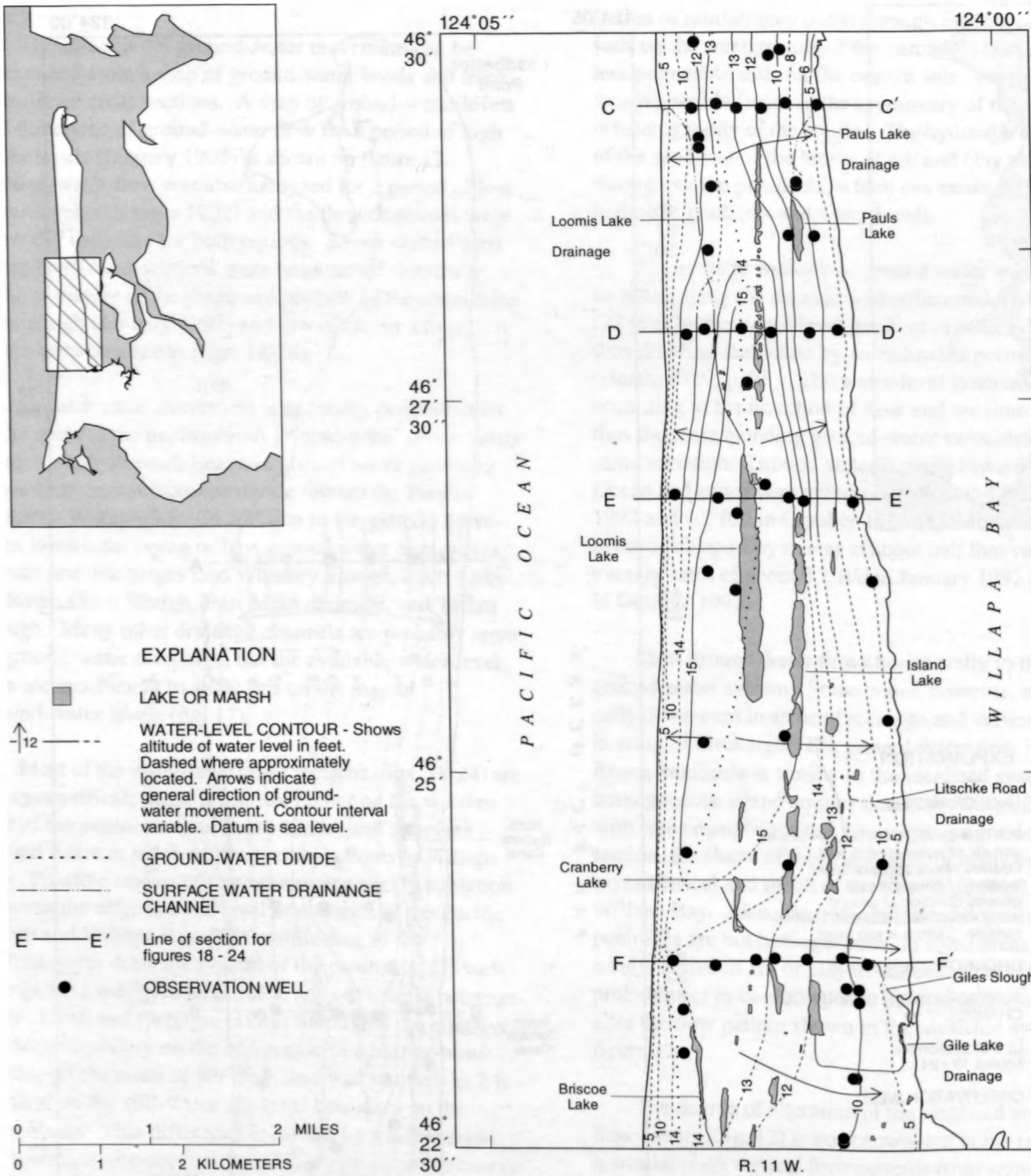

Figure 17.--Ground-water levels and flow directions, January 1992--continued.

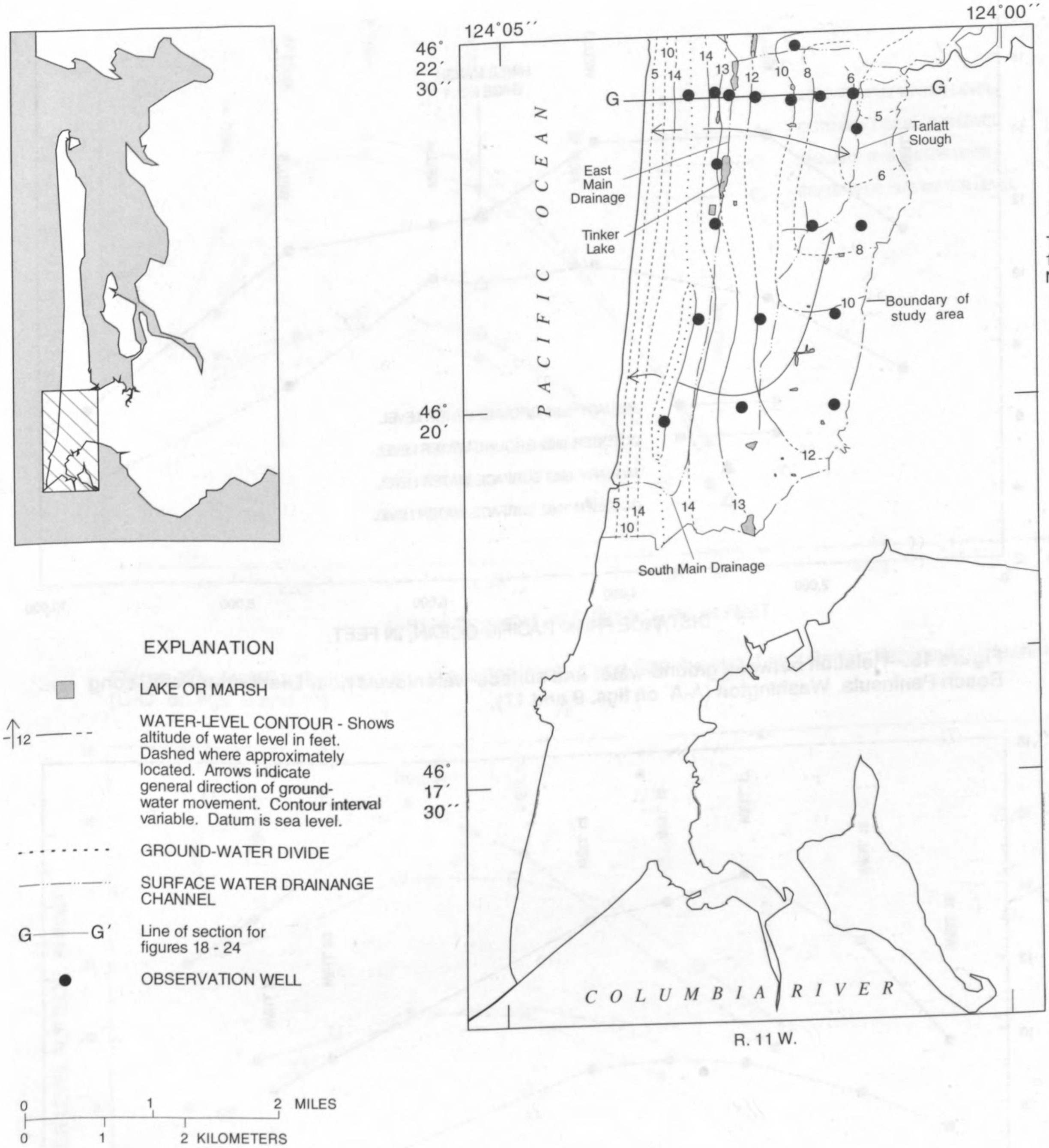

Figure 17.--Ground-water levels and flow directions, January 1992--continued.

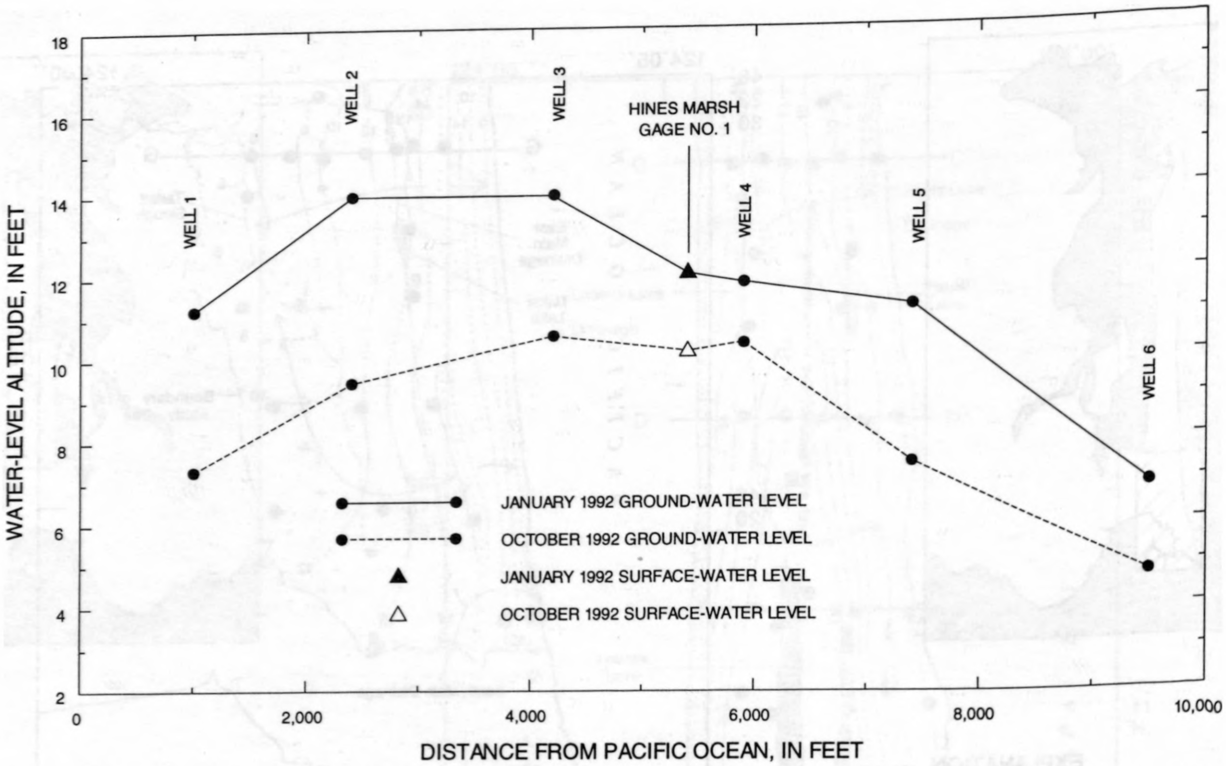

Figure 18.--Relation between ground-water and surface-water levels near Leadbetter Point, Long Beach Peninsula, Washington (A-A′ on figs. 9 and 17).

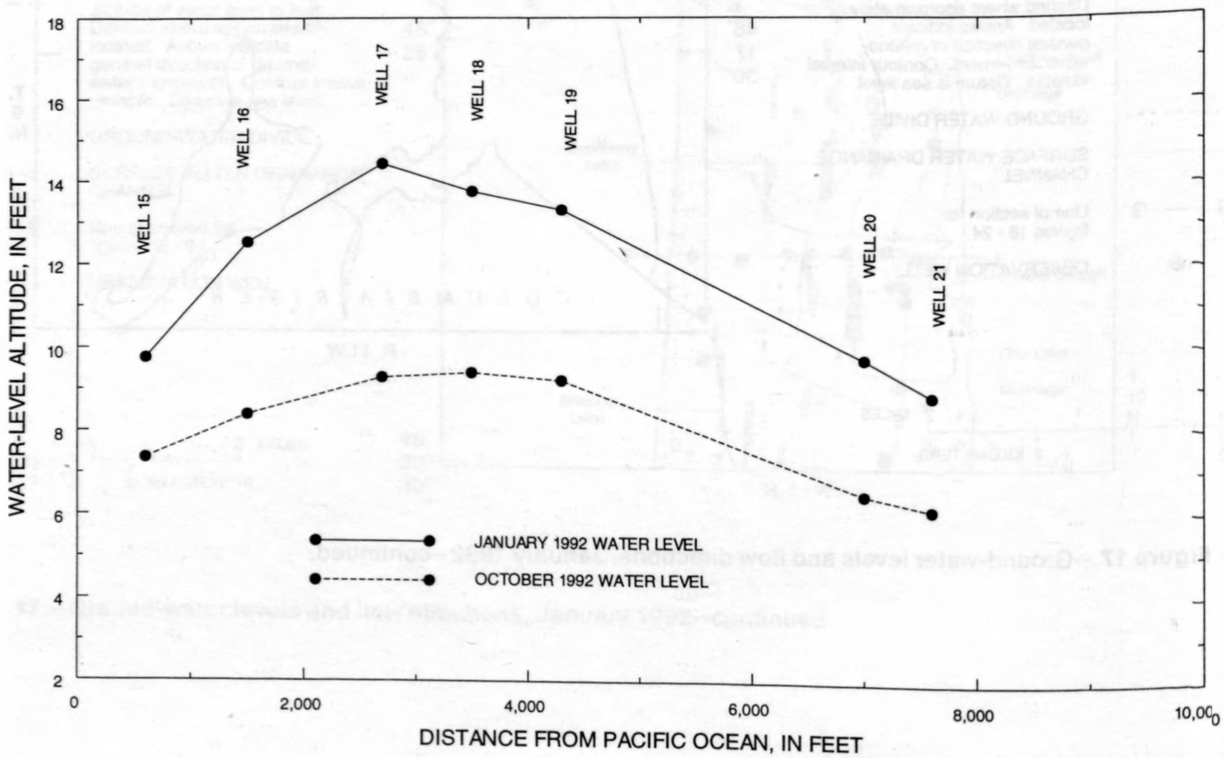

Figure 19.--Relation between ground-water levels near Oysterville Road, Long Beach Peninsula, Washington (B-B′ on figs. 9 and 17).

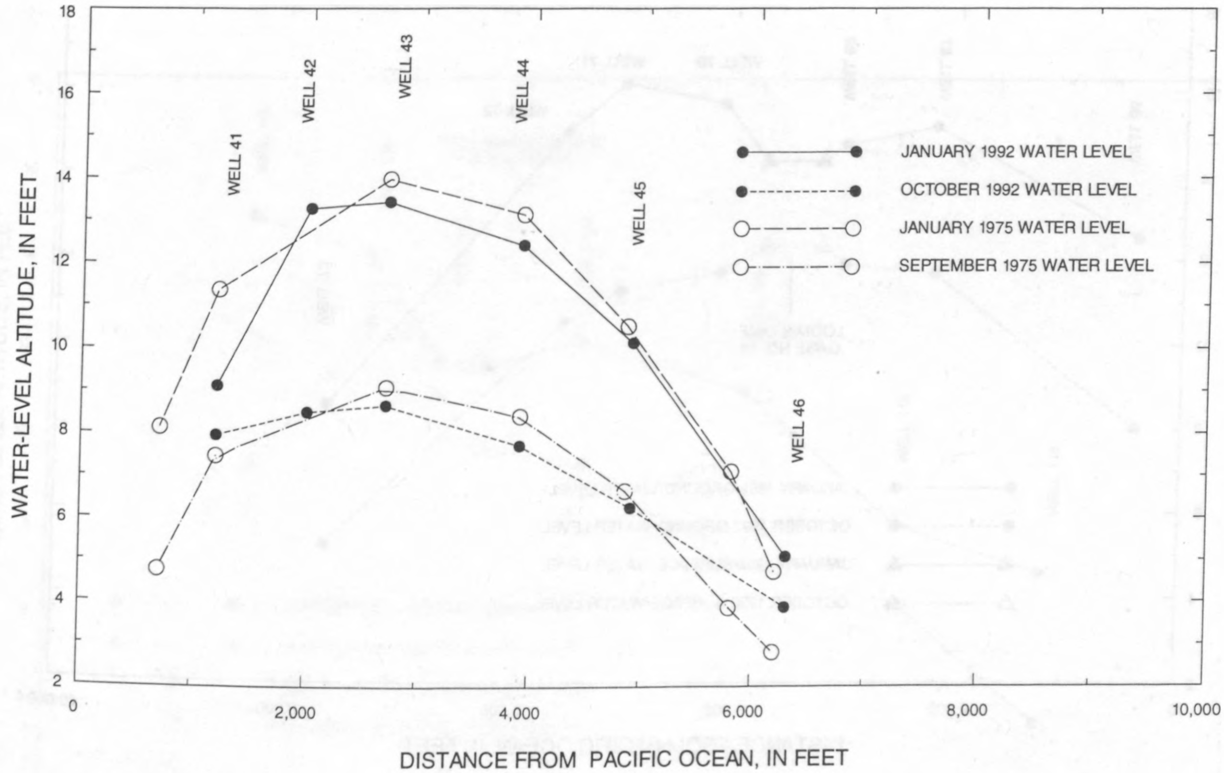

Figure 20.--Relation between ground-water levels along Bay Avenue, Long Beach Peninsula, Washington (C-C´ on figs. 9 and 17).

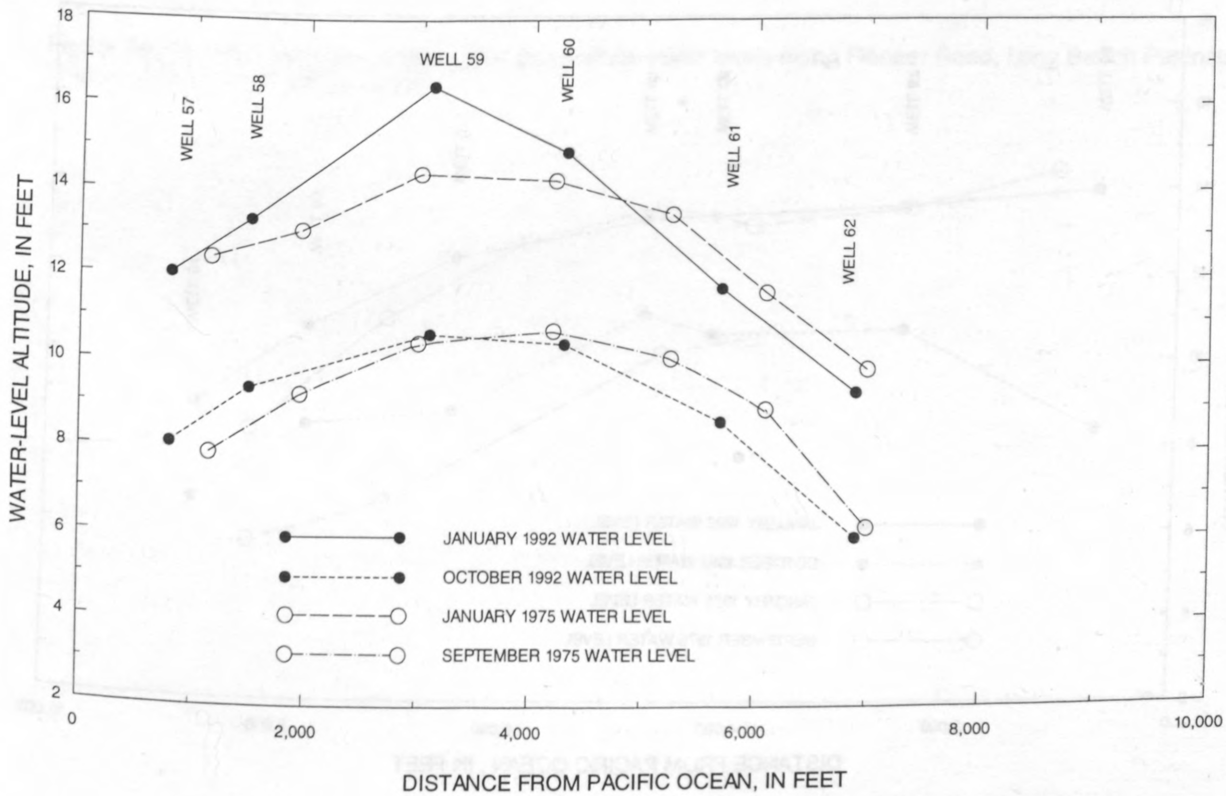

Figure 21.--Relation between ground-water levels along Klipsan Road, Long Beach Peninsula, Washington (D-D´ on figs. 9 and 17).

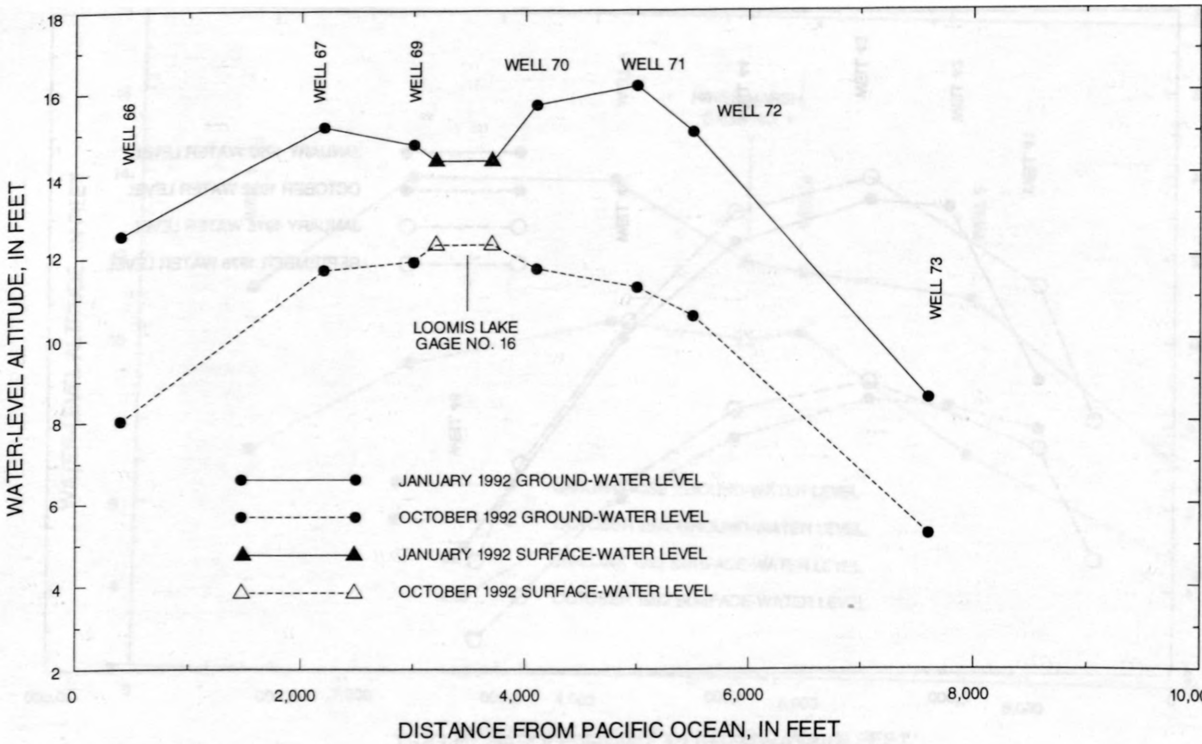

Figure 22.--Relation between ground-water and surface-water levels between Klipsan and Cranberry Roads, Long Beach Peninsula, Washington (E-E′ on figs. 9 and 17).

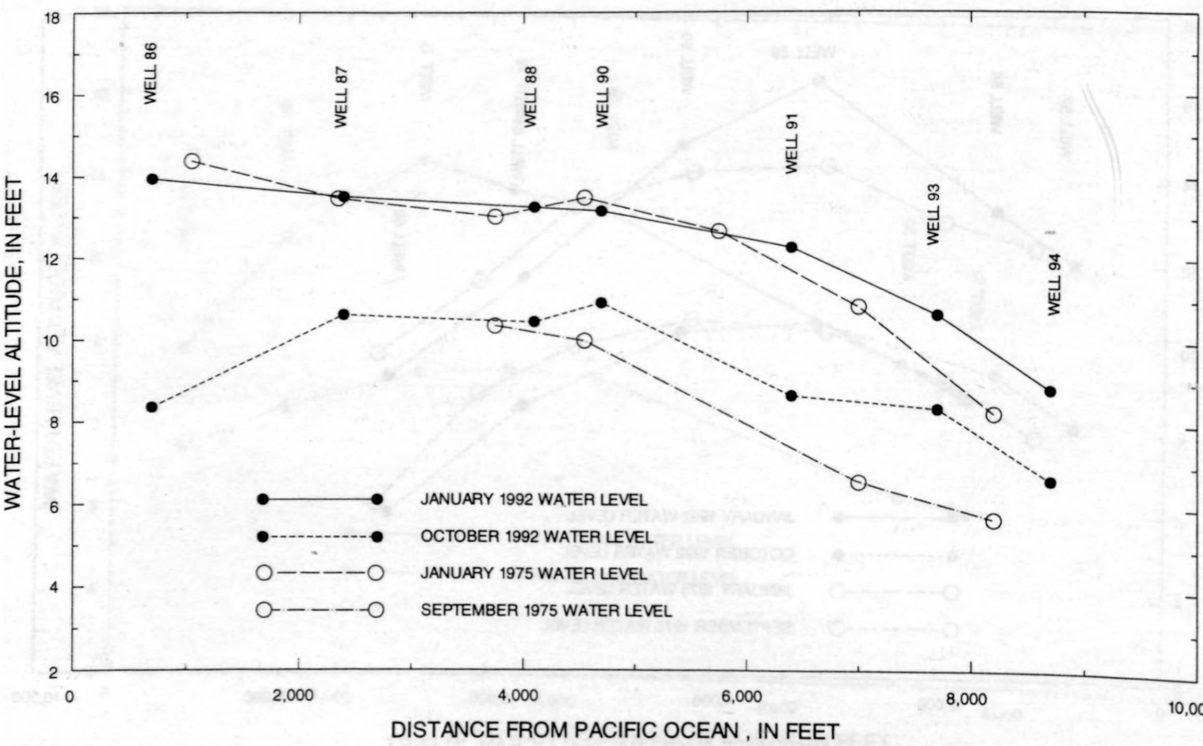

Figure 23.--Relation between ground-water levels along Cranberry Road, Long Beach Peninsula, Washington (F-F′ figs. 9 and 17).

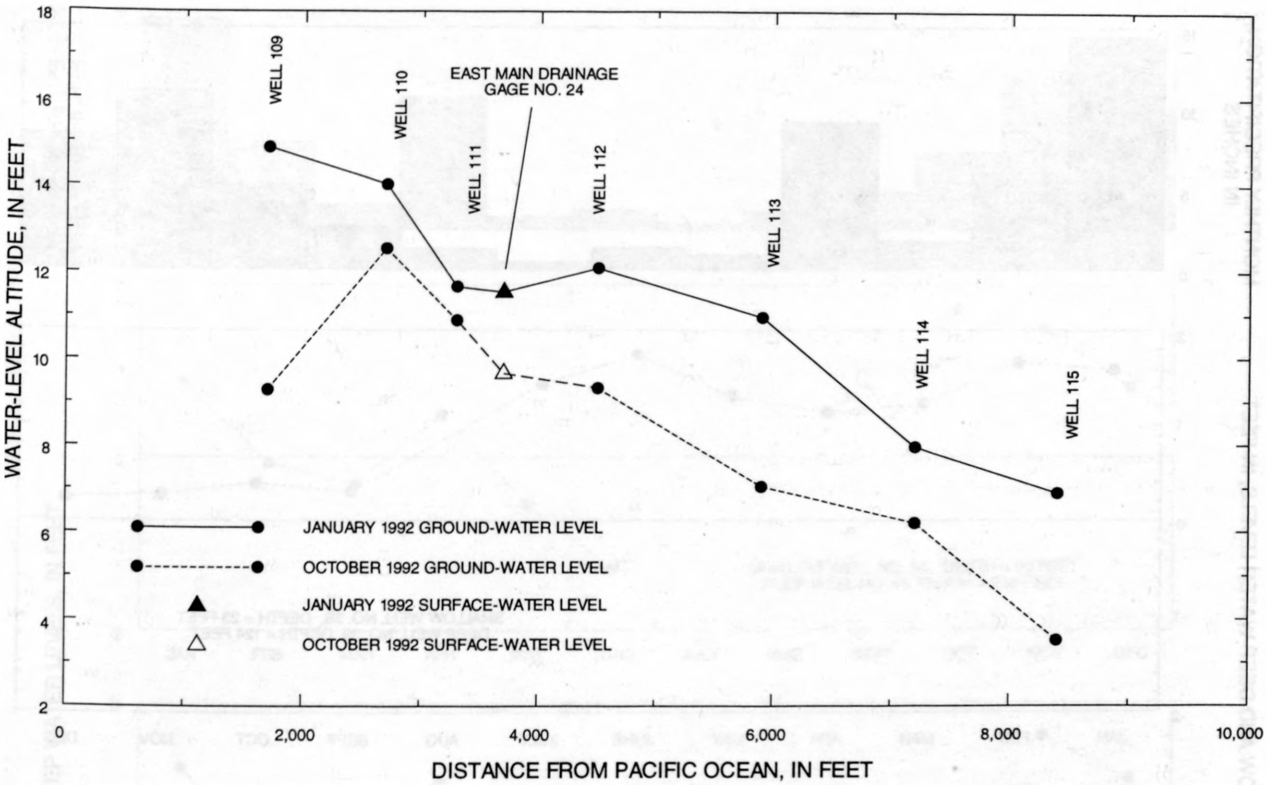

Figure 24.--Relation between ground-water and surface-water levels along Pioneer Road, Long Beach Peninsula, Washington (G-G´ on figs. 9 and 17).

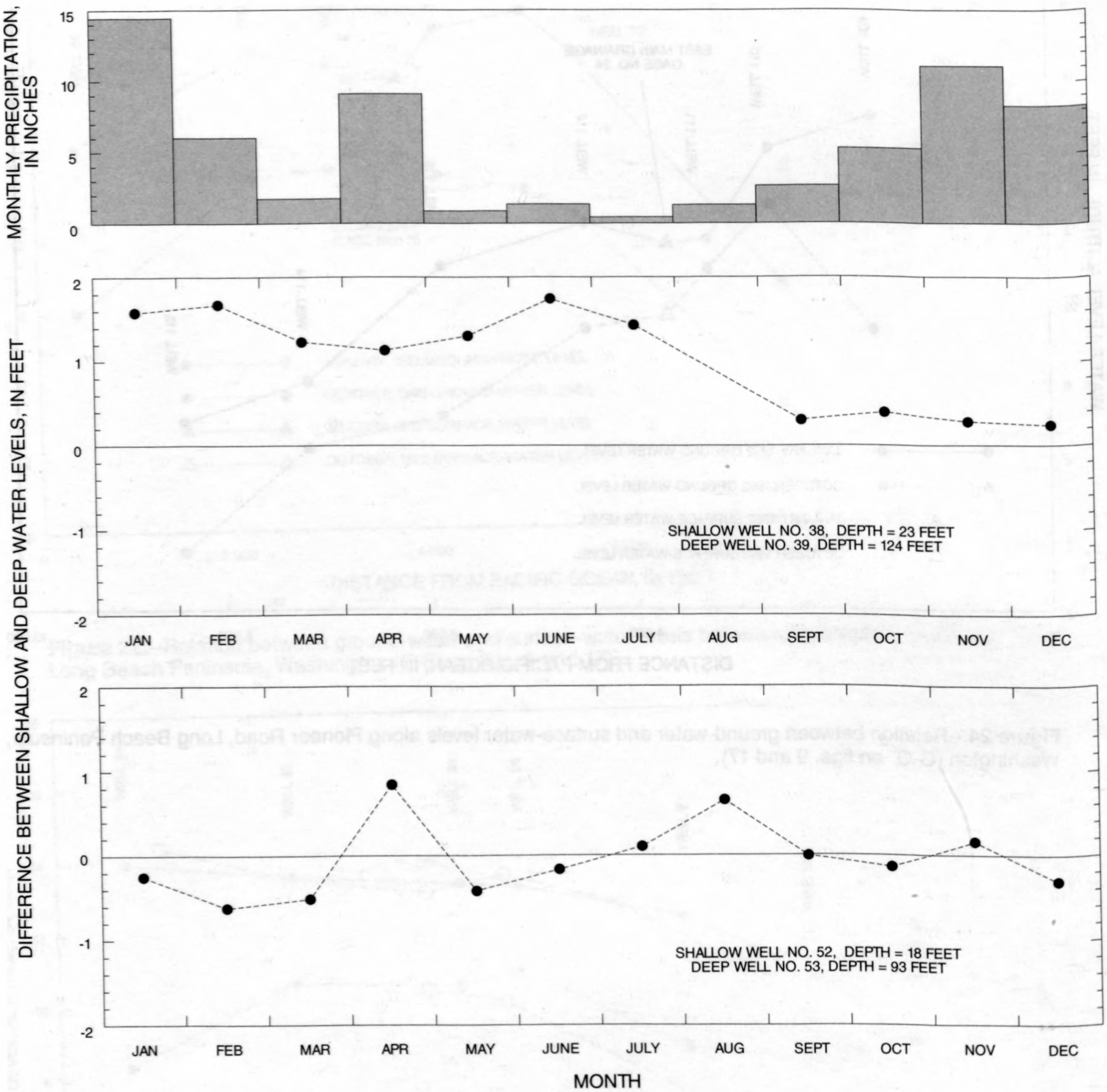

Figure 25.--Relation between monthly precipitation and seasonal distribution of differences between shallow and deep water levels in 1992 for selected pairs of wells, Long Beach Peninsula, Washington.

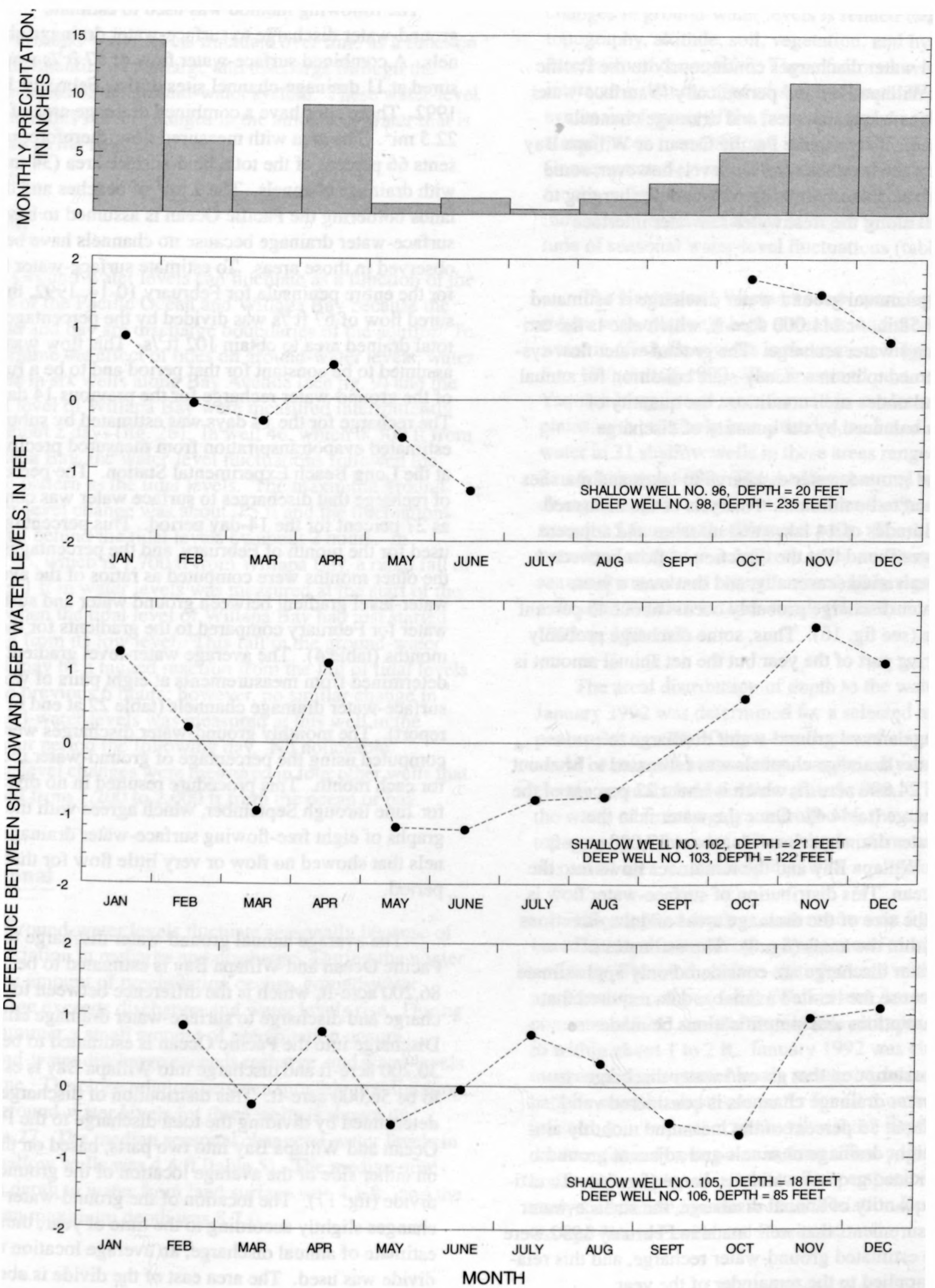

Figure 25.--Relation between monthly precipitation and seasonal distribution of differences between shallow and deep water levels in 1992 for selected pairs of wells, Long Beach Peninsula, Washington--continued.

Discharge

Ground water discharges continuously to the Pacific Ocean and Willapa Bay and periodically to surface-water bodies such as lakes, marshes, and drainage channels. Most of the discharge to the Pacific Ocean or Willapa Bay occurs along the beaches near sea level; however, some freshwater is constantly mixing with and discharging to saltwater all along the freshwater-seawater interface (fig. 12).

Average annual ground-water discharge is estimated to be about 58 in. or 111,000 acre-ft, which also is the estimated ground-water recharge. The ground-water flow system is assumed to be in a steady-state condition for annual periods, and under such conditions the quantity of recharge is balanced by the quantity of discharge.

Annual ground-water discharge to lakes and marshes was assumed to be minimal. Analysis of the measured monthly altitudes of 14 lakes and marshes and adjacent ground water found that the direction of flow between these bodies varied seasonally, and that over a year, ground-water discharge probably occurs about 45 percent of the time (see fig. 16). Thus, some discharge probably occurs during part of the year but the net annual amount is minimal.

Average annual ground-water discharge to surface-water drainage channels was estimated to be about 12.9 in. or 24,800 acre-ft, which is about 22 percent of the total discharge (table 4). Once the water is in the surface-water drainage channels, about 17,000 acre-ft flows into Willapa Bay and the remainder flows into the Pacific Ocean. This distribution of surface-water flow is based on the size of the drainage areas and the directions of flow within the areas (fig. 8). The estimates of ground-water discharge are considered only approximate values because the limited available data required that many assumptions and simplifications be made.

The assumption that ground water discharges to surface-water drainage channels is considered valid because about 75 percent of the measured monthly altitudes of eight drainage channels and adjacent ground water indicated ground-water discharge (fig. 16). To estimate the quantity of annual discharge, the surface-water flow measurements that were made in February 1992 were related to estimated ground-water recharge, and this relation was applied to the remainder of the year.

The following method was used to estimate ground-water discharge to surface-water drainage channels. A combined surface-water flow of 67 ft^3/s was measured at 11 drainage-channel sites during February 10-14, 1992. These sites have a combined drainage area of about 22.5 mi^2. The area with measured flow, therefore, represents 66 percent of the total land-surface area (34 mi^2) with drainage channels. The 2 mi^2 of beaches and dune lands bordering the Pacific Ocean is assumed to have no surface-water drainage because no channels have been observed in those areas. To estimate surface-water flow for the entire peninsula for February 10-14, 1992, the measured flow of 67 ft^3/s was divided by the percentage of total drained area to obtain 102 ft^3/s. This flow was assumed to be constant for that period and to be a function of the ground-water recharge for the previous 14 days. The recharge for the 14 days was estimated by subtracting estimated evapotranspiration from measured precipitation at the Long Beach Experimental Station. The percentage of recharge that discharges to surface water was computed as 27 percent for the 14-day period. This percentage was used for the month of February, and the percentages for the other months were computed as ratios of the average water-level gradient between ground water and surface water for February compared to the gradients for the other months (table 4). The average water-level gradient was determined from measurements at eight pairs of wells and surface-water drainage channels (table 22 at end of report). The monthly ground-water discharges were then computed using the percentage of ground-water recharge for each month. This procedure resulted in no discharge for June through September, which agrees with the hydrographs of eight free-flowing surface-water drainage channels that showed no flow or very little flow for that same period.

The average annual ground-water discharge to the Pacific Ocean and Willapa Bay is estimated to be 86,200 acre-ft, which is the difference between total discharge and discharge to surface-water drainage channels. Discharge into the Pacific Ocean is estimated to be 30,200 acre-ft and discharge into Willapa Bay is estimated to be 56,000 acre-ft. This distribution of discharge was determined by dividing the total discharge to the Pacific Ocean and Willapa Bay into two parts, based on the areas on either side of the average location of the ground-water divide (fig. 17). The location of the ground-water divide changes slightly according to the time of year; thus, for an estimate of annual discharge, an average location of the divide was used. The area east of the divide is about 65 percent of the total area; therefore, the areal recharge that occurs on this area and that moves to discharge in Willapa Bay is about 65 percent of 86,200 acre-ft, or 56,000 acre-ft.

Water-Level Fluctuations

Ground-water levels fluctuate over time as a function of the quantity of recharge and discharge through the boundaries of the ground-water system. These water-level fluctuations reflect changes in the amount of water that is stored in the aquifer.

Tidal

Ground-water levels can fluctuate as a function of the tides of the Pacific Ocean and Willapa Bay because the ocean and bay are discharge boundaries of the aquifer. To determine the effect of tides on ground-water levels, water levels in six wells along Bay Avenue (see fig. 9) and the tidal level of Willapa Bay were measured intermittently for about 2 days (fig. 26). In well 46, which is 300 ft from Willapa Bay, the water-level fluctuations followed the same pattern as the tidal levels. The maximum ground-water-level change was about 0.5 ft and the fluctuations lagged behind the tidal levels by about 2 hours. In well 45, which is 1,700 ft from Willapa Bay, a rapid fall of about 1 ft in water levels was measured at the start of the test when the tidal level of Willapa Bay had just started rising from its low level. This fall in the ground-water level may be a lagged reaction from the fall of tidal levels in the previous 6 hours; however, no similar change in ground-water levels was measured at this well in the 12-hour period the following day. No noticeable water-level changes were measured in four other wells that ranged from 1,200 to 2,000 ft from the ocean or bay.

Seasonal

Ground-water levels fluctuate seasonally because of the variation in recharge and discharge. During the winter a large amount of precipitation occurs, ground-water recharge exceeds discharge, and water levels rise. During the summer a small amount of precipitation occurs, ground-water discharge exceeds recharge, and water levels decline. The close relation between monthly precipitation and ground-water levels for three wells is shown on figure 27. The median seasonal change of water levels in 96 shallow wells was 4.4 ft (table 5). The median minimum depth to water from land surface was 4.1 ft., and the median maximum depth was 8.7 ft.

The areal variation of the magnitude of seasonal changes in ground-water levels is related to climate, topography, altitude, soil, vegetation, and hydraulic characteristics of the aquifer. These factors have a complex interaction, but the type of soil in a particular area is a synthesis of many of the factors. Because the soils have already been measured and mapped (U.S. Soil Conservation Service, 1986) and the climate is the same for the entire peninsula, the type of soil can be a useful indicator of areal variations of depth to water and magnitude of seasonal water-level fluctuations (table 5).

The Netarts and Westport sands were formed on dune ridges with relatively high altitudes, and median depths to water in 65 shallow wells in these areas ranged from about 5 to 10 ft during 1992. The Seastrand peat or muck and Yaquina loamy sand were formed in swales or deflation plains with relatively low altitudes, and median depths to water in 31 shallow wells in these areas ranged from about 2 to 6 ft during 1992. The median seasonal water-level changes ranged from about 3 ft under the Seastrand soils to about 5 ft under the Westport soils. These relations between soil type and depth to water and magnitude of seasonal water-level changes were highly significant using a Kruskal Wallis test (two-sided) (Helsel and Hirsch, 1992, p. 159-163).

The areal distribution of depth to the water table in January 1992 was determined for a selected area of the peninsula (fig. 28). Only a small area of about 530 acres could be mapped because that was the only area with sufficiently accurate land-surface-altitude data. The depth to the water table is largely controlled by the sand-dune topography in this area. The altitude of the water table in this small area is relatively flat, with a range of only 2 ft.

The zones of depth to water shown on figure 28 are based on depth contours that are accurate to within about 1 or 2 feet. The land-surface altitudes used in this analysis are accurate to about 1.0 ft (Walker and Associates, oral commun., 1994), and the water-table altitudes are accurate to within about 1 to 2 ft. January 1992 was chosen for the mapping because water levels measured during that month had the smallest depths to water for all months of data collection. It is important to note that these depth-to-water data are for only one point in time. That point in time, however, was placed in a historical perspective in the analysis described in the section "Relation Between Ground-Water Levels and Precipitation."

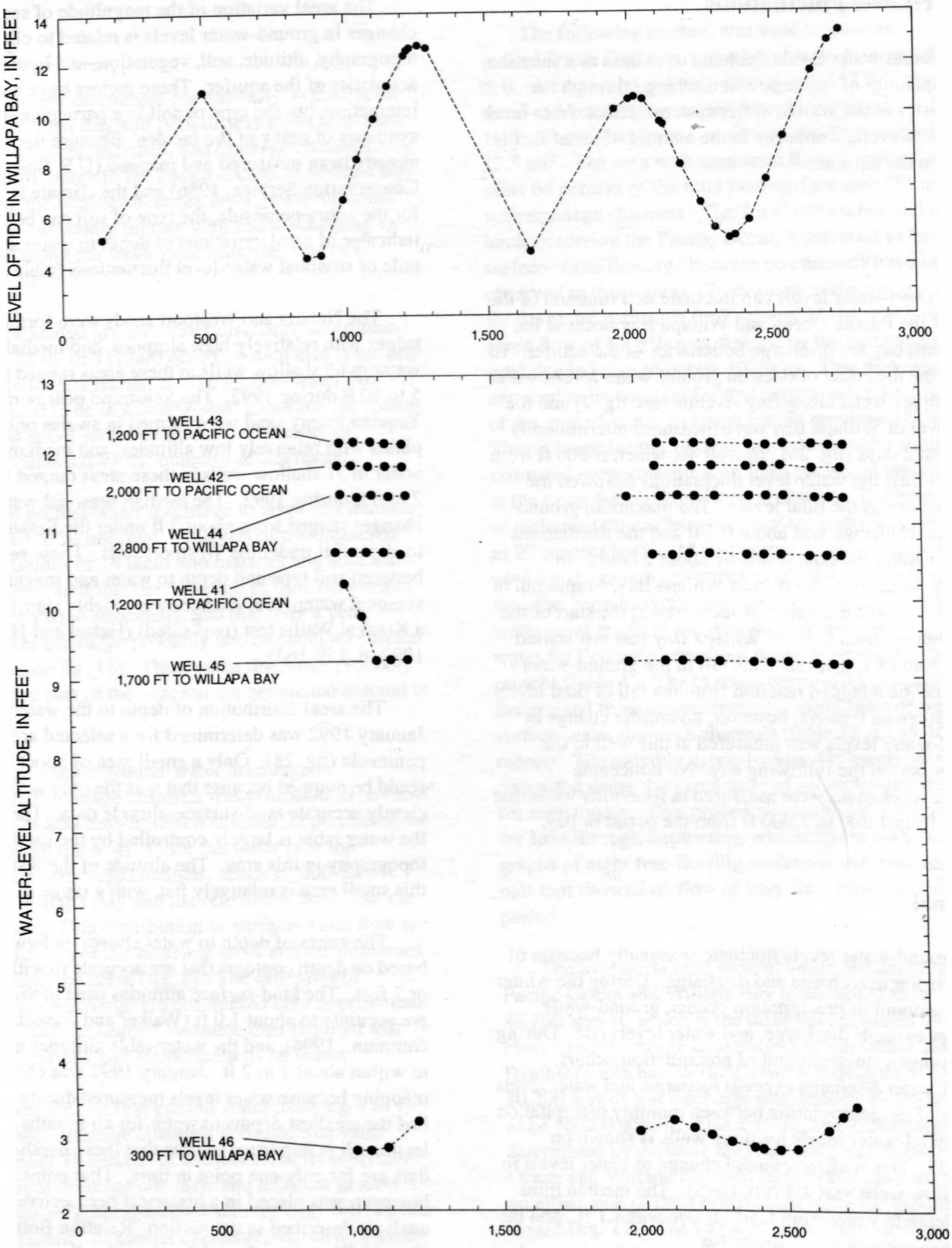

Figure 26.--Relation between ground-water levels for wells along Bay Avenue and tidal levels for Willapa Bay for 2-day period starting midnight, June 7, 1992, Long Beach Peninsula, Washington.

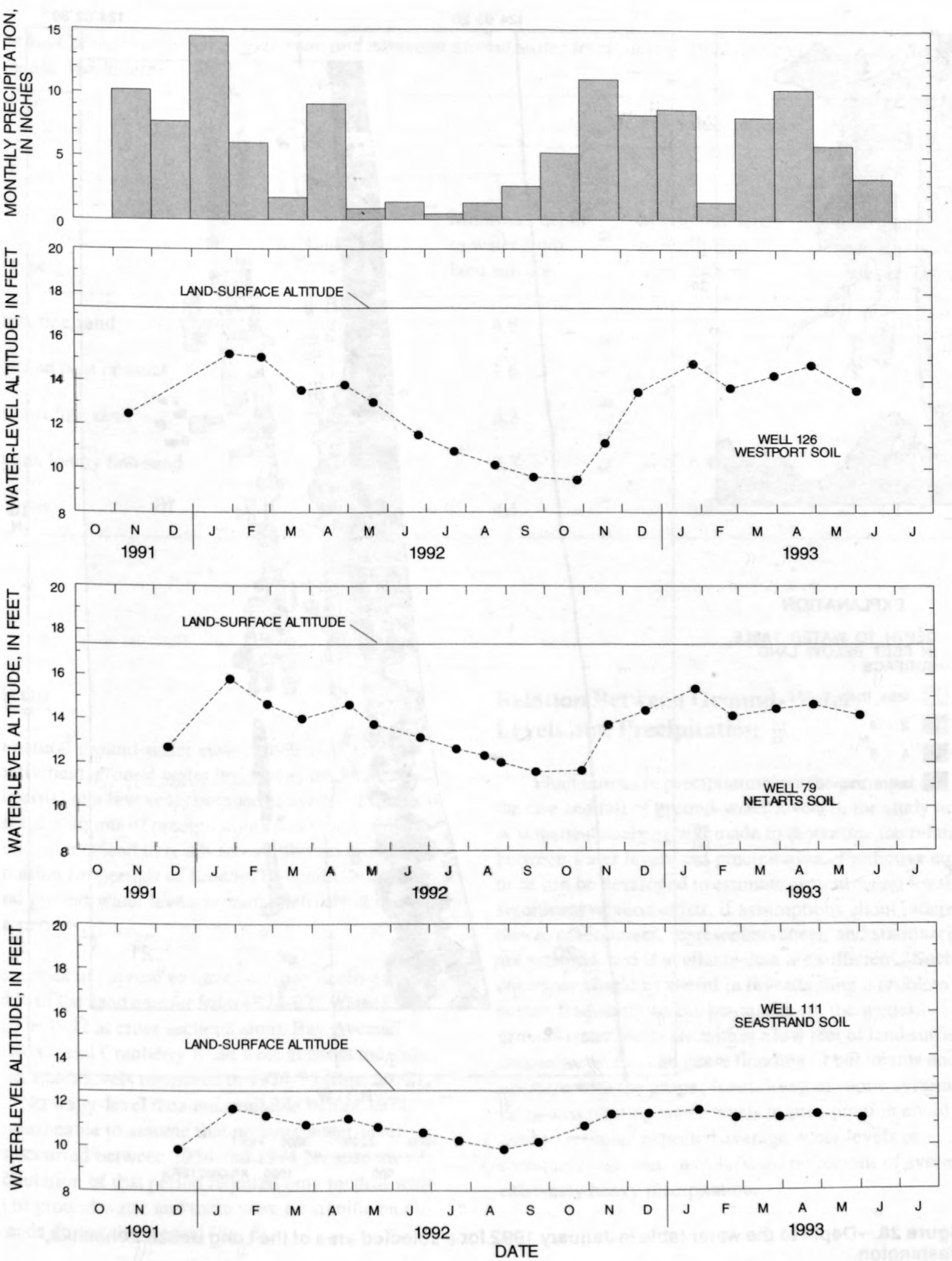

Figure 27.--Relation between monthly precipitation and seasonal changes in water levels in selected wells, Long Beach Peninsula, Washington.

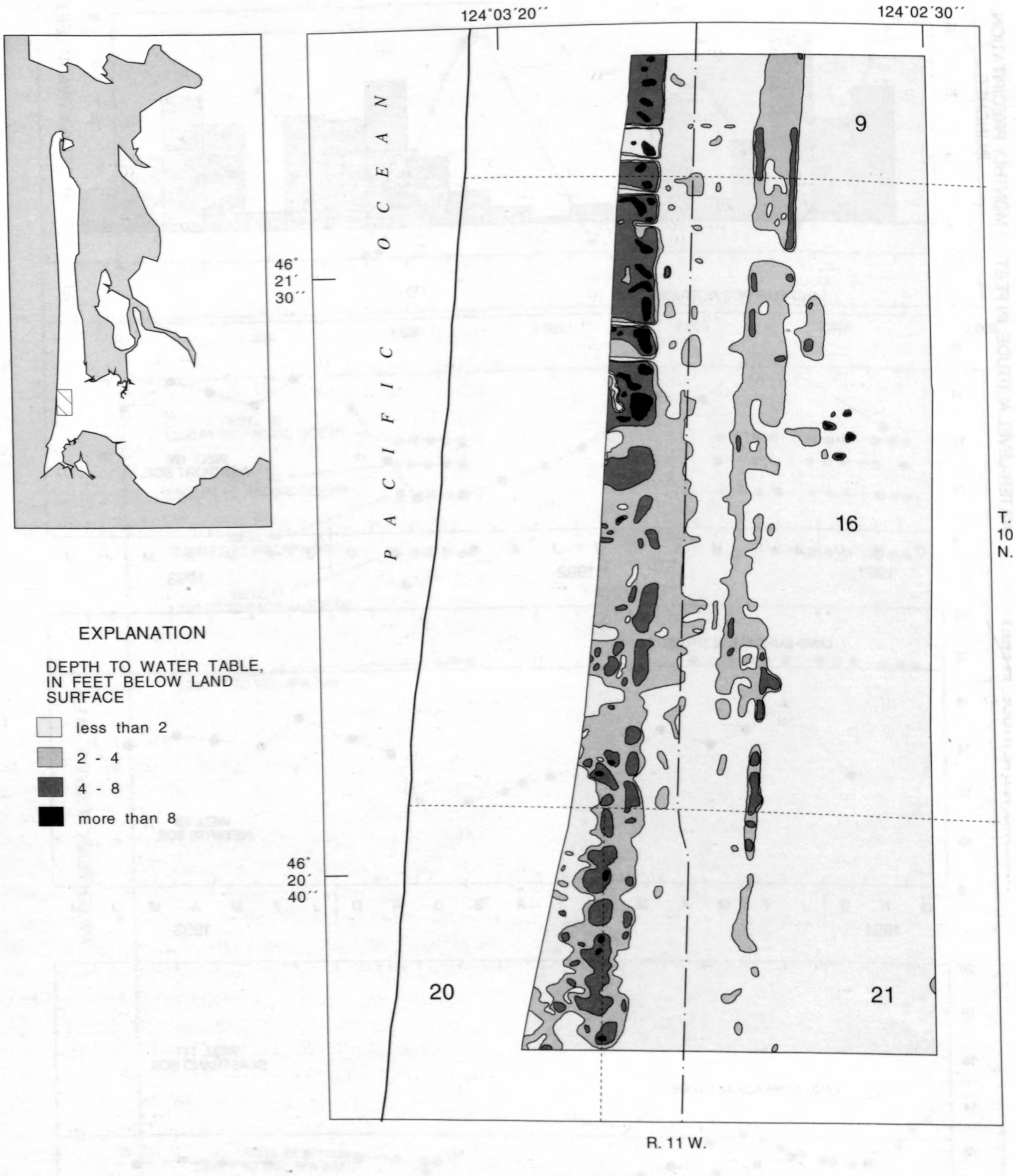

Figure 28.--Depth to the water table in January 1992 for a selected area of the Long Beach Peninsula, Washington.

Table 5.--*Comparison between maximum and minimum ground-water levels during 1992 and soil type, Long Beach Peninsula, Washington*

Soil type	Number of wells	Median value, in feet: Minimum depth to water from land surface	Maximum depth to water from land surface	Difference between maximum and minimum water levels
Netarts fine sand	49	4.9	9.9	4.4
Seastrand peat or muck	11	1.6	5.6	3.3
Westport fine sand	16	5.2	9.4	5.2
Yaquina loamy fine sand	20	2.3	6.8	3.8
All types	96	4.1	8.7	4.4

Long-Term

In a natural ground-water system (one unaffected by human activities), ground-water levels may decline or rise during a period of a few years because of lower- or higher-than-average amounts of precipitation and recharge. However, such systems tend to reach an equilibrium or steady-state condition for periods of decades or hundreds of years, and ground-water levels remain relatively constant for those periods.

There does not appear to have been any decline in the water table of the sand aquifer from 1974-92. Water levels measured in 1992 at cross sections along Bay Avenue, Klipsan Road, and Cranberry Road were at about the same altitude as water levels measured in 1974-75 (figs. 20, 21, and 23). No water-level data are available before 1974, but it is reasonable to assume that no large water-level declines occurred between 1954 and 1974 because the small population of that period required only modest withdrawals of ground water and there were no significant climatic trends during that period (fig. 5).

Relation Between Ground-Water Levels and Precipitation

Fluctuations in precipitation are the principal cause of the rise and fall of ground-water levels in the study area. A statistical analysis was made to determine the relation between water levels and precipitation. Predictive equations can be developed to estimate ground-water levels if a significant relation exists, if assumptions about independence, randomness, representativeness, and stationarity are satisfied, and if available data are sufficient. Such equations would be useful in investigating a problem that occurs frequently on the peninsula. In the winter, ground-water levels are within a few feet of land surface in certain areas; this can cause flooding of basements and can interfere with the proper functioning of septic systems. Equations relating water levels to precipitation could be used to estimate expected average water levels or extremely high water levels based on periods of average or extremely heavy precipitation.

The first step in the analysis of precipitation and ground-water levels was to evaluate the available data. The available data are not sufficient to estimate relations between water levels and years with larger than average precipitation. Precipitation data are available for Long Beach, Wash., for 1954-92; however, only a limited amount of water-level data is available for the peninsula. Although hundreds of water levels were measured for this study from November 1991 to June 1993, the precipitation for that period was only about 80 percent of the long-term average. A few wells had water levels measured as part of other studies in 1974-75 and 1988-90, when precipitation was about average. Despite these limitations of the available data, a regression analysis of water levels and precipitation can be made to improve the understanding of the ground-water system and to determine if it is possible to develop accurate relations for predicting water levels.

The first step in the regression analysis was to determine the relation between water-level altitudes and cumulative precipitation for different lengths of time. Water level records that are sufficiently long to ensure some reliability in the resulting relations were available at four wells; the records contain between 46 and 64 water levels that were measured during 1974-75 and 1988-91. The monthly precipitation for these periods ranged from 0.18 to 17.4 in. Periods of 2, 3, 4, 5, 6, and 7 consecutive months of cumulative precipitation were examined as the explanatory variable. The cumulative precipitation for the 4 months prior to the water-level measurement had the best accuracy (smallest standard error of estimate) of all the periods (fig. 29).

The second step in the regression analysis was to compare relations computed from the longer records of only a few wells to relations computed from the short (1.5 years) records that were available for 45 wells in this study. The relations computed for the two periods of record for wells 41, 43, and 44 are similar (fig. 29), and it appears that the short records are at least adequate to determine the feasibility of developing accurate relations.

The third step in the analysis was to compute individual relations between water levels and precipitation for all the wells with 1.5 years of record (table 6). The relations are generally accurate; there is a good agreement between the computed relations and the data. All relations except one (for well 110) are highly significant. The standard error of estimate ranged from 0.16 to 1.09 ft, with an average of about 0.63 ft. The average coefficient of determination (r squared value) for all individual relations was 0.77. This means that about 77 percent of the variation in water-level altitudes is explained by the regression relations. It is important to note that the relations are only valid at the well site and for the range of precipitation used to develop the equations—4 to 38 in. for 4 consecutive months. The relations could be extended to within about a 50-foot radius without much loss in accuracy because the maximum measured water-level gradient on the peninsula is only about 0.005 ft/ft; this would change the water level by 0.25 ft at the 50-foot distance.

The results of the regression analysis at individual wells indicate that accurate predictive relations can be developed between ground-water levels and cumulative precipitation. More data are needed, however, to extend the relations so they could be used to predict high water levels in years with above-average precipitation. Slight downward curves observed in plots of the data for 11 wells at the larger amounts of available precipitation data show that potential errors are involved in extending regression relations beyond the range of data used to calibrate them.

The fourth step in the regression analysis of water levels and precipitation was to investigate if a regional relation could be developed to estimate water levels at any site on the peninsula. Multiple-regression techniques were used to analyze the significance of additional explanatory variables such as soil type, distance from a north-south centerline of the peninsula, and whether the site is west or east of that centerline. The soil type and side of peninsula were represented in the regression analysis using dummy variables.

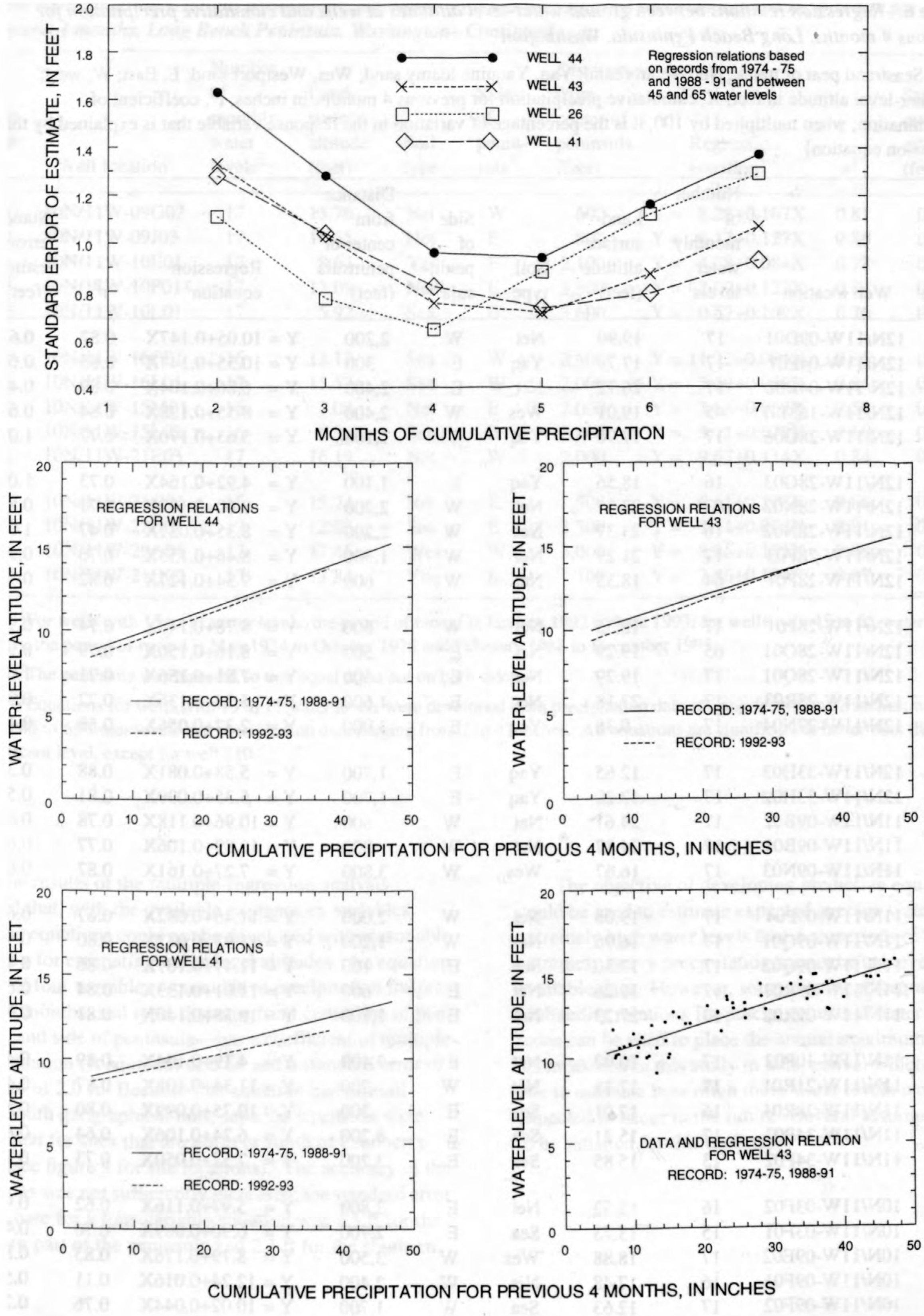

Figure 29.--Accuracy of regression relations between ground-water levels and cumulative precipitation, and comparison of relations for different periods of record, Long Beach Peninsula, Washington.

Table 6.--*Regression relations between ground-water-level altitudes at wells and cumulative precipitation for previous 4 months, Long Beach Peninsula, Washington*

[Sea, Seastrand peat or muck; Net, Netarts sand; Yaq, Yaquina loamy sand; Wes, Westport sand; E, East; W, west; Y, water-level altitude in feet; X, cumulative precipitation for previous 4 months, in inches; r^2, coefficient of determination; when multiplied by 100, it is the percentage of variation in the response variable that is explained by the regression equation]

Well number	Well location	Number of monthly water levels[1]	Land-surface altitude (feet)	Soil type	Side of peninsula[2]	Distance from center of peninsula (feet)	Regression equation[3]	r^2	Standard error of estimate (feet)
9	12N/11W-09D01	17	19.90	Net	W	2,200	Y = 10.05+0.147X	0.87	0.63
10	12N/11W-04P01	17	17.79	Yaq	E	300	Y = 10.55+0.147X	0.85	0.66
12	12N/11W-04R02	17	26.72	Net	E	2,400	Y = 6.86+0.104X	0.89	0.41
26	12N/11W-16M01	45	19.01	Wes	W	2,400	Y = 8.55+0.128X	0.84	0.64
38	12N/11W-28G06	17	17.96	Yaq	E	1,100	Y = 5.63+0.170X	0.77	1.01
39	12N/11W-28G03	16	18.56	Yaq	E	1,100	Y = 4.92+0.164X	0.73	1.00
41	12N/11W-28N02	63	23.37	Net	W	2,200	Y = 8.60+0.102X	0.71	0.82
41	12N/11W-28N02	16	23.37	Net	W	2,200	Y = 8.35+0.087X	0.47	1.05
42	12N/11W-28P03	17	21.29	Net	W	1,300	Y = 8.46+0.153X	0.76	0.94
43	12N/11W-28P01	64	18.35	Net	W	600	Y = 9.54+0.127X	0.82	0.75
43	12N/11W-28P01	17	18.35	Net	W	600	Y = 8.78+0.148X	0.74	0.97
44	12N/11W-28Q01	65	19.29	Net	E	500	Y = 8.16+0.150X	0.79	0.97
44	12N/11W-28Q01	17	19.29	Net	E	500	Y = 7.81+0.156X	0.71	1.09
45	12N/11W-28R03	17	27.18	Net	E	1,600	Y = 6.26+0.136X	0.72	0.92
46	12N/11W-27N04	17	9.38	Yaq	E	3,000	Y = 2.37+0.056X	0.68	0.42
52	12N/11W-33H03	17	12.65	Yaq	E	1,700	Y = 5.58+0.081X	0.88	0.34
53	12N/11W-33H02	17	12.20	Yaq	E	1,700	Y = 5.35+0.099X	0.81	0.52
63	11N/11W-09B02	17	24.61	Net	W	800	Y = 10.96+0.118X	0.78	0.68
64	11N/11W-09B01	17	24.87	Net	W	800	Y = 10.89+0.106X	0.77	0.63
66	11N/11W-09N03	17	16.67	Wes	W	3,800	Y = 7.27+0.161X	0.87	0.67
67	11N/11W-09P04	17	19.08	Net	W	2,000	Y = 11.46+0.082X	0.67	0.64
69	11N/11W-09Q01	17	16.96	Net	W	1,200	Y = 11.93+0.077X	0.80	0.42
70	11N/11W-09Q02	17	17.30	Sea	E	100	Y = 11.49+0.107X	0.86	0.48
71	11N/11W-09R01	17	19.26	Net	E	600	Y = 11.01+0.133X	0.84	0.63
72	11N/11W-09R02	17	27.23	Net	E	1,100	Y = 10.38+0.140X	0.81	0.74
73	11N/11W-10P02	17	10.02	Net	E	3,400	Y = 4.19+0.104X	0.89	0.40
79	11N/11W-21R01	17	17.31	Net	W	200	Y = 11.34+0.108X	0.87	0.46
84	11N/11W-28R01	16	17.01	Sea	E	200	Y = 10.75+0.099X	0.80	0.56
96	11N/11W-34P03	17	15.21	Sea	E	3,200	Y = 6.24+0.106X	0.64	0.88
98	11N/11W-34P02	13	15.85	Sea	E	3,200	Y = 7.57+0.050X	0.73	0.27
102	10N/11W-03F02	16	13.52	Net	E	2,800	Y = 5.97+0.116X	0.62	0.94
103	10N/11W-03F01	15	13.73	Sea	E	2,700	Y = 6.90+0.069X	0.70	0.47
109	10N/11W-09E02	17	18.88	Wes	W	3,500	Y = 8.79+0.176X	0.85	0.82
110	10N/11W-09F01	16	17.48	Net	W	2,400	Y = 12.74+0.016X	0.11	0.50
111	10N/11W-09F02	17	12.63	Sea	W	1,700	Y = 10.02+0.044X	0.76	0.27

Table 6.--*Regression relations between ground-water-level altitudes at wells and cumulative precipitation for previous 4 months, Long Beach Peninsula, Washington--Continued*

Well number	Well location	Number of monthly water levels[1]	Land-surface altitude (feet)	Soil type	Side of peninsula[2]	Distance from center of peninsula (feet)	Regression equation[3]	r^2	Standard error of estimate (feet)
112	10N/11W-09G02	17	15.76	Net	W	600	Y = 8.22+0.107X	0.81	0.58
113	10N/11W-09J03	17	18.55	Net	E	800	Y = 6.17+0.127X	0.86	0.56
114	10N/11W-10E01	17	8.64	Yaq	E	2,100	Y = 4.78+0.084X	0.72	0.57
115	10N/11W-10F01	17	13.09	Net	E	3,300	Y = 2.00+0.127X	0.84	0.61
116	10N/11W-10L01	17	5.92	Sea	E	3,600	Y = 0.57+0.107X	0.76	0.66
117	10N/11W-16C01	16	13.17	Sea	W	2,500	Y = 11.32+0.034X	0.85	0.16
119	10N/11W-16L01	17	15.57	Sea	W	2,000	Y = 5.59+0.058X	0.86	0.26
120	10N/11W-15M01	16	7.08	Net	E	2,000	Y = 2.66+0.069X	0.57	0.65
121	10N/11W-15L02	16	6.96	Sea	E	3,900	Y = 3.11+0.078X	0.60	0.69
122	10N/11W-21E03	17	16.19	Net	W	2,000	Y = 9.63+0.114X	0.84	0.54
123	10N/11W-21G01	15	15.74	Net	E	500	Y = 6.61+0.138X	0.80	0.68
124	10N/11W-22C01	17	12.03	Sea	E	3,500	Y = 7.11+0.086X	0.81	0.46
126	10N/11W-29A01	17	17.46	Wes	W	3,000	Y = 8.86+0.173X	0.89	0.67
127	10N/11W-21Q02	17	13.84	Yaq	E	100	Y = 7.46+0.134X	0.87	0.56

[1]For wells with 13 to 17 water levels, the period of record is January 1992 to June 1993; for wells with 45 to 65 water levels, the period of record is May 1974 to October 1975 and February 1988 to December 1991.

[2]The peninsula was bisected so that equal areas are on both sides.

[3]Equations for wells with 13 to 17 water levels were developed from precipitation data ranging from 4 to 38 inches; wells with 45 to 65 water levels had precipitation data ranging from 7 to 47 inches. All equations are significant at better than the 1 percent level, except for well 110.

The results of the multiple-regression analysis showed that, with the available explanatory variables, regional equations could not be developed with reasonable accuracy for estimating water-level altitudes. An equation using all four variables—cumulative precipitation for previous 4 months, soil type, distance from centerline of peninsula, and side of peninsula—has a coefficient of multiple determination (R squared) of 0.66 and a standard error of estimate of 2.0 ft. Because that equation had a small north-south geographical bias, separate equations were developed for sites that are north or south of Cranberry Road (see figure 9 for site locations). The accuracy of the equations was not sufficiently increased; the standard error of estimate for a four-variable equation was 1.5 ft for the northern part of the peninsula and 2.1 ft for the southern part.

The objective of developing predictive equations that could be used to estimate expected average water levels or extremely high water levels based on periods of average or extremely heavy precipitation cannot be achieved with the available data. However, some empirical frequency or probability relations for precipitation and water-level altitudes can be used to place the annual maximum water levels measured in this study in perspective, which allows one to estimate how often these water levels would be expected to occur in the future. Several assumptions need to be satisfied for this analysis.

1. Annual precipitation and maximum precipitation for any 4 consecutive months in a year are random and independent events.

2. The historical record of precipitation is representative of the past and future distribution of precipitation. In other words, the sample of precipitation is representative of the population of precipitation in the study area.

3. Precipitation is stationary; that is, no trends or long-term changes in precipitation have occurred in the past or will occur in the future. A nonparametric Mann-Kendall test (two-sided) made on the record of annual precipitation and annual-maximum 4-month precipitation determined that no statistically significant trend is present in the historical precipitation data.

4. The cumulative precipitation for the previous 4 months accurately predicts water-level altitudes, and in particular it accurately predicts the annual maximum water-level altitudes. The regression analyses in this study found an accurate relation between ground-water levels and previous 4-month cumulative precipitation. The assumption of the accuracy of relations between annual-maximum precipitation and water levels could not be evaluated, but it seems reasonable.

5. The relation between ground-water levels and precipitation that was determined in this study is representative of both the past and future.

6. The relation between ground-water levels and precipitation is stationary—the response of water levels to precipitation did not change in the past and will not change in the future.

These six assumptions appear reasonable and are probably satisfied; therefore, the probability or frequency of occurrence of annual maximum water levels and precipitation could be analyzed. The 39-year record of precipitation at Long Beach, Wash., was used to represent the distribution of past and future precipitation. Using the relation between precipitation and ground-water levels, it was assumed that ground-water levels follow the same frequency distribution as precipitation.

During the winter of 1991-92, the maximum cumulative 4 months of precipitation was 38 in. The 38-in. amount fits at about the 30th percentile of the 39-year record of annual maximum cumulative 4 months of precipitation (fig. 30), meaning that 30 percent of the years had less precipitation and 70 percent of the years had more precipitation. Transferring this empirical frequency or probability relation from precipitation to ground-water levels and applying it to the future means that in any one year in the future, there is a probability of 70 percent that the maximum water levels measured in wells during the winter of 1991-92 would be equaled or exceeded. From another perspective, in the next 10 years one would expect that the maximum ground-water levels would be lower in 3 of the years and higher in 7 of the years.

The same empirical probability concepts can be applied to annual precipitation for another view of the conditions measured in this study. The annual precipitation of 65 in. for 1991 and 62 in. for 1992 fit at less than the 20th percentile of the record for the past 39 years (fig. 30). Thus, the annual precipitation had an even lower probability of occurrence than the annual maximum cumulative 4-month precipitation.

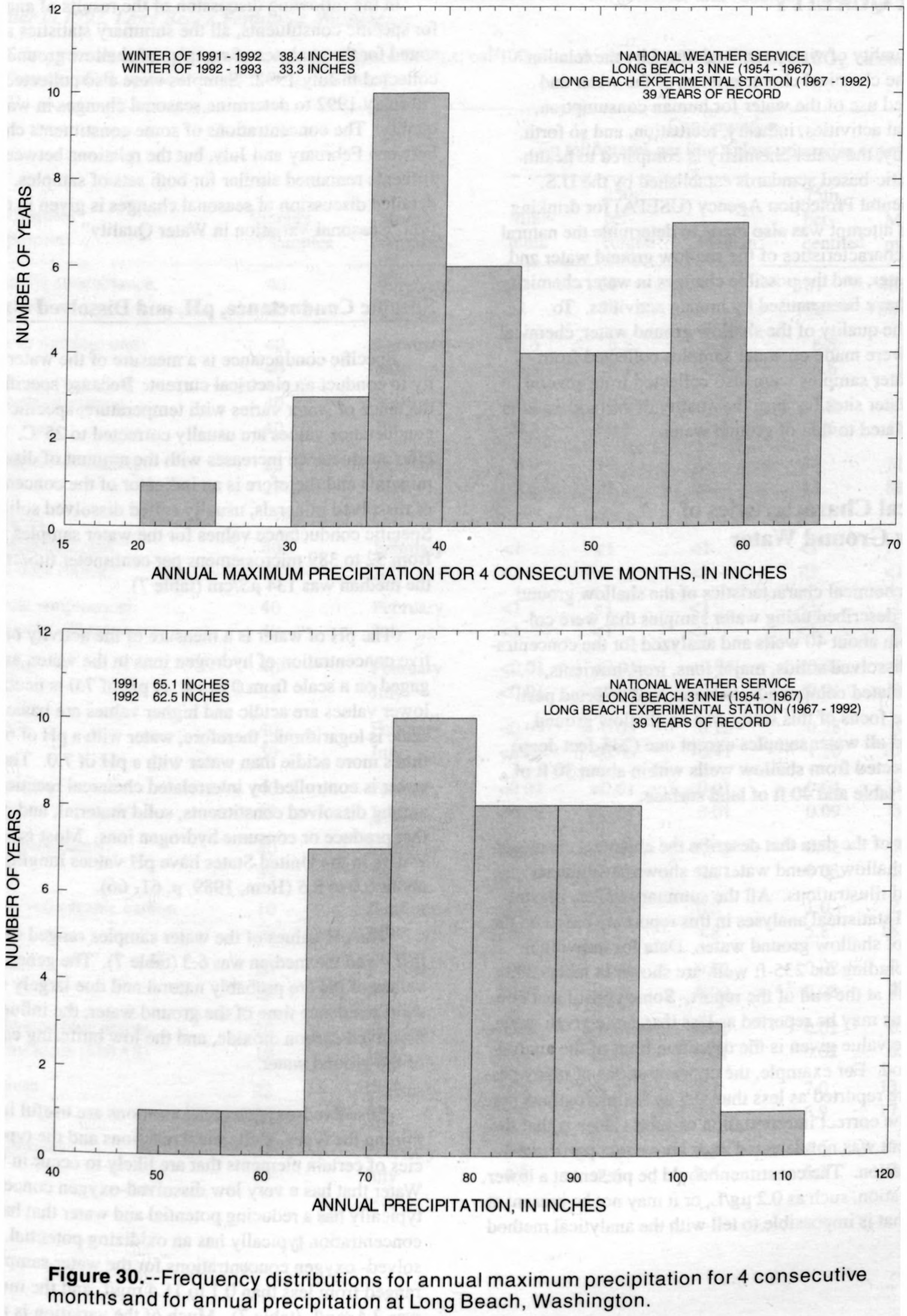

Figure 30.--Frequency distributions for annual maximum precipitation for 4 consecutive months and for annual precipitation at Long Beach, Washington.

WATER QUALITY

The quality of water can be defined by the relation between the chemical characteristics of the water and the intended use of the water for human consumption, commercial activities, industry, recreation, and so forth. In this study, the water chemistry is compared to health- and aesthetic-based standards established by the U.S. Environmental Protection Agency (USEPA) for drinking water. An attempt was also made to determine the natural chemical characteristics of the shallow ground water and surface water, and the possible changes in water chemistry that may have been caused by human activities. To describe the quality of the shallow ground water, chemical analyses were made on water samples collected from wells. Water samples were also collected from several surface-water sites because the quality of surface water is closely related to that of ground water.

Chemical Characteristics of Shallow Ground Water

The chemical characteristics of the shallow ground water are described using water samples that were collected from about 40 wells and analyzed for the concentrations of dissolved solids, major ions, iron, nutrients, septage-related compounds, bacteria, and selected pesticides. The focus of this study was on shallow ground water, and all water samples except one (235-feet deep) were collected from shallow wells within about 30 ft of the water table and 40 ft of land surface.

Most of the data that describe the chemical characteristics of shallow ground water are shown in summary tables and illustrations. All the summary tables, illustrations, and statistical analyses in this report are based on the samples of shallow ground water. Data for individual wells, including the 235-ft well, are shown in tables 24, 26, and 28 at the end of the report. Some constituent concentrations may be reported as less than (<) a given value, where the value given is the detection limit of the analytical method. For example, the concentrations of many pesticides are reported as less than 0.5 μg/L (micrograms per liter). The correct interpretation of such values is that the constituent was not detected at or above that particular concentration. The constituent could be present at a lower concentration, such as 0.2 μg/L, or it may not be present at all, but that is impossible to tell with the analytical method used.

In the following discussion of the results of analyses for specific constituents, all the summary statistics are stated for the analyses of samples of shallow ground water collected in July 1992. Samples were also collected in February 1992 to determine seasonal changes in water quality. The concentrations of some constituents changed between February and July, but the relations between constituents remained similar for both sets of samples. A detailed discussion of seasonal changes is given in the section "Seasonal Variation in Water Quality".

Specific Conductance, pH, and Dissolved Oxygen

Specific conductance is a measure of the water's ability to conduct an electrical current. Because specific conductance of water varies with temperature, specific conductance values are usually corrected to 25°C. Specific conductance increases with the amount of dissolved minerals and therefore is an indicator of the concentration of dissolved minerals, usually called dissolved solids. Specific conductance values for the water samples ranged from 52 to 389 microsiemens per centimeter (μS/cm) and the median was 134 μS/cm (table 7).

The pH of water is a measure of the activity or effective concentration of hydrogen ions in the water, and is gaged on a scale from 0 to 14. A pH of 7.0 is neutral; lower values are acidic and higher values are basic. The scale is logarithmic; therefore, water with a pH of 6.0 is 10 times more acidic than water with a pH of 7.0. The pH of water is controlled by interrelated chemical reactions among dissolved constituents, solid material, and gases that produce or consume hydrogen ions. Most ground waters in the United States have pH values ranging from about 6.0 to 8.5 (Hem, 1989, p. 61- 66).

The pH values of the water samples ranged from 5.5 to 7.4 and the median was 6.3 (table 7). The generally low values of pH are probably natural and due largely to the short residence time of the ground water, the influence of dissolved carbon dioxide, and the low buffering capacity of the ground water.

Dissolved-oxygen concentrations are useful in determining the types of chemical reactions and the type of species of certain elements that are likely to occur in water. Water that has a very low dissolved-oxygen concentration typically has a reducing potential and water that has a high concentration typically has an oxidizing potential. Dissolved- oxygen concentrations for the water samples ranged from less than 0.1 to 11.4 mg/L and the median was 2.4 mg/L (table 7). Much of the variation is natural and is due to reactions between the water and minerals or the water and organic matter.

Table 7.--*Summary of concentrations of selected chemical characteristics, bacteria, and radon of shallow ground water in 1992, Long Beach Peninsula, Washington*

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; col/100mL, colonies per 100 milliliters; $CaCO_3$, calcium carbonate; pCi/L, picocuries per liter; <, less than]

Constituent or property	Number of samples	Month sampled	Concentration (in milligrams per liter unless otherwise noted) Minimum	25th percentile[1]	Median[2]	75th percentile[3]	Maximum
Specific conductance,	40	February	50	88	132	181	482
in µS/cm	40	July	52	98	134	188	389
pH, in standard units	40	February	5.5	6.2	6.4	6.5	7.5
	40	July	5.5	6.1	6.3	6.6	7.4
Dissolved oxygen	40	February	<0.1	0.6	3.6	7.2	10.1
	40	July	<0.1	0.3	2.4	6.6	11.4
Hardness as $CaCO_3$	22	February	6.0	18	28	34	71
	25	July	7.0	21	28	43	88
Bacteria							
Fecal coliform,	40	February	<1	<1	<1	<1	1
in cols/100mL	40	July	<1	<1	<1	<1	<1
Fecal streptococci,	40	February	<1	<1	<1	<1	1
in cols/100 mL	40	July	<1	<1	<1	<1	5
Nitrite	40	February	<0.01	<0.01	<0.01	<0.01	0.01
	39	July	<0.01	<0.01	<0.01	<0.01	0.02
Nitrate	40	February	<0.05	0.05	0.28	0.78	8.6
	39	July	<0.05	<0.05	0.41	1.50	10.0
Ammonia	40	February	<0.01	<0.01	<0.01	0.04	0.43
	39	July	<0.01	<0.01	0.01	0.09	0.36
Orthophosphate	40	February	<0.01	<0.01	<0.01	0.02	1.30
	39	July	<0.01	<0.01	0.01	0.03	1.60
Dissolved organic carbon	10	February	0.4	0.6	0.8	1.0	2.1
	20	July	0.7	4.2	4.8	5.8	18
Boron	20	February	<0.01	0.01	0.02	0.02	0.26
	20	July	<0.01	0.01	0.02	0.08	0.29
Methylene blue active	20	February	<0.01	0.01	0.01	0.02	0.03
substances (MBAS)	19	July	<0.01	<0.01	0.01	0.02	0.03
Calcium	22	February	1.2	3.3	4.7	7.0	13
	25	July	1.5	3.9	5.8	6.9	17
Magnesium	22	February	0.6	2.1	3.6	4.6	9.4
	25	July	0.8	2.6	3.6	5.3	17

Table 7.--*Summary of concentrations of selected chemical characteristics, bacteria, and radon of shallow ground water in 1992, Long Beach Peninsula, Washington--Continued*

Constituent or property	Number of samples	Month sampled	Concentration (in milligrams per liter unless otherwise noted)				
			Mini-mum	25th per-centile[1]	Median[2]	75th per-centile[3]	Maxi-mum
Sodium	22	February	5.9	7.0	11	12	32
	25	July	6.4	8.1	12	15	28
Potassium	22	February	0.5	0.9	1.1	1.7	8.2
	25	July	0.5	0.9	1.2	2.9	9.2
Bicarbonate	22	February	15	18	24	41	176
	22	July	15	23	29	57	150
Alkalinity, as $CaCO_3$	22	February	12	14	20	32	144
	22	July	12	19	24	41	123
Sulfate	22	February	<0.1	2.4	5.2	7.7	17
	25	July	<0.1	2.0	5.6	8.3	38
Chloride	40	February	5.8	9.4	13	24	47
	40	July	6.0	11	15	25	52
Fluoride	22	February	0.1	0.1	0.1	0.2	0.2
	25	July	<0.1	<0.1	<0.1	<0.1	0.2
Silica	22	February	15	18	23	28	55
	25	July	15	17	23	28	60
Total dissolved solids	21	February	46	70	88	116	240
	24	July	56	78	92	130	218
Iron	40	February	<0.003	0.009	0.018	3.6	42
	40	July	0.004	0.010	0.020	4.1	37
Manganese	22	February	<0.001	<0.001	<0.001	0.056	0.65
	25	July	<0.001	<0.001	0.002	0.068	0.44
Radon, in pCi/L	10	February	81	150	195	245	300

[1]The value which is exceeded by 75 percent of the data.

[2]The central value of sample when the data are ranked in order of magnitude; 50 percent of the data exceed it and 50 percent are less than it.

[3]The value which is exceeded by 25 percent of the data.

Dissolved Solids

The concentration of dissolved solids is a measure of all the minerals dissolved in the water. The major components of dissolved solids usually include calcium, magnesium, sodium, potassium, bicarbonate, sulfate, chloride and silica. Other constituents, such as carbonate, fluoride, nitrate, and metals such as iron and manganese, are usually minor components. Higher dissolved-solids concentrations may be caused by increased residence time of water in an aquifer; water that has been in the ground for a longer time generally has had the opportunity to dissolve more minerals than water with a shorter residence time. In addition, salt spray and evaporation can increase dissolved-solids concentrations.

Water samples had concentrations of dissolved solids that ranged from 56 to 218 mg/L and the median was 92 mg/L (table 7). No pattern is apparent in the areal distribution of the dissolved-solids concentrations (fig. 31).

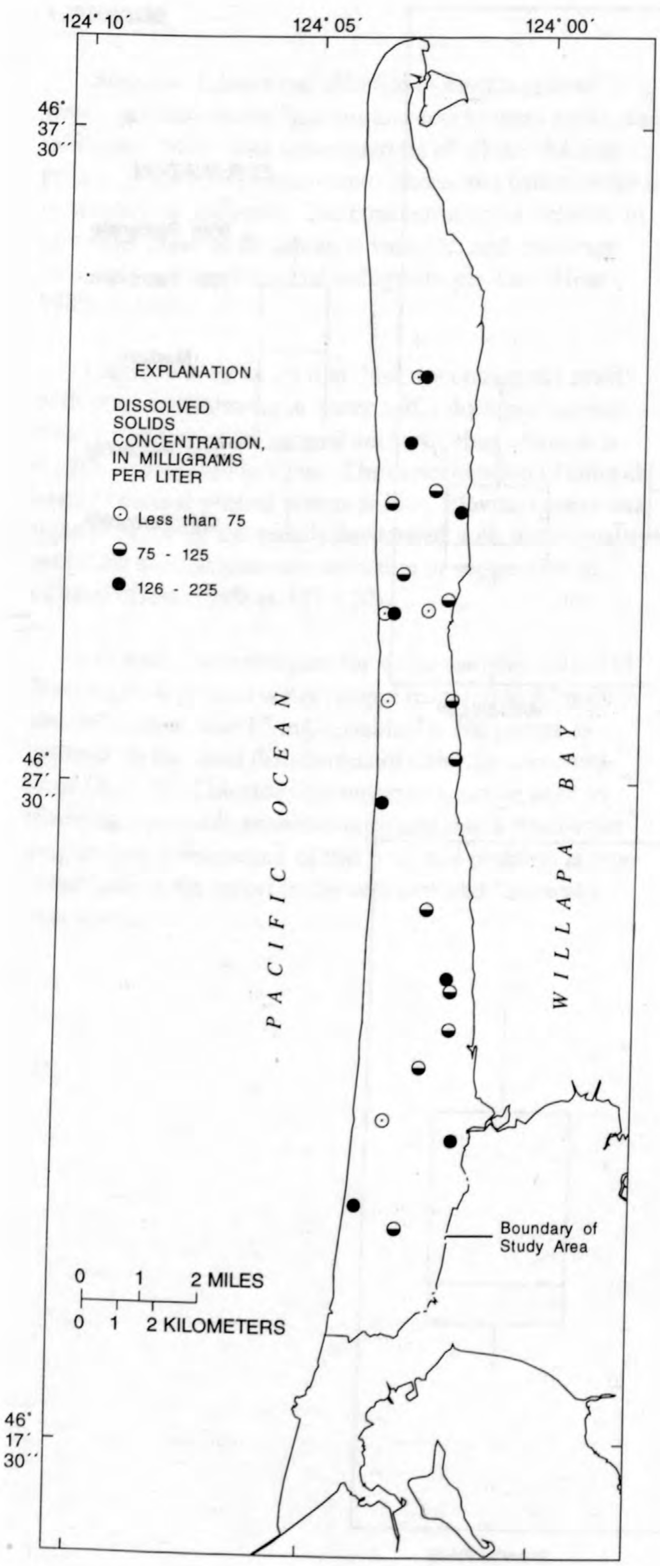

Figure 31.--Concentrations of dissolved solids in shallow ground water, July 1992.

Major Ions

Most of the major components of dissolved solids are ions, meaning they have an electrical charge. Cations are ions with a positive charge and they include calcium, magnesium, sodium, potassium, and most metals. Anions are ions with a negative charge and they include bicarbonate, sulfate, chloride, nitrate, carbonate, and fluoride. Silica has no charge and it is the only major component of dissolved solids that is not a cation or anion.

Concentrations of major ions in ground-water samples are shown on figure 32. Sodium was the dominant cation in most samples and had a median concentration of 12 mg/L; the cations with the next highest median concentrations were calcium with 5.8 mg/L and magnesium with 3.6 mg/L. Bicarbonate was the dominant anion in the ground water with a median concentration of 29 mg/L; the anions with the next highest median concentrations were chloride with 15 mg/L and sulfate with 5.6 mg/L. Silica was also a major component of the dissolved solids with a median concentration of 23 mg/L.

All the water samples were classified as soft or moderately hard, as defined by the following scheme (Hem, 1989).

Description	Hardness range (milligrams per liter of $CaCO_3$)	Number of samples	Percentage of samples
Soft	0-60	21	84
Moderately hard	61-120	4	16
Hard	121-180	0	0
Very hard	Greater than 180	0	0

Hardness is calculated from the concentrations of calcium and magnesium. The most familiar effect of increased hardness is a decreased production of lather from a given amount of soap introduced into the water. Hard water may also cause deposits to form on the inside of plumbing pipes, around plumbing fixtures, and in water containers.

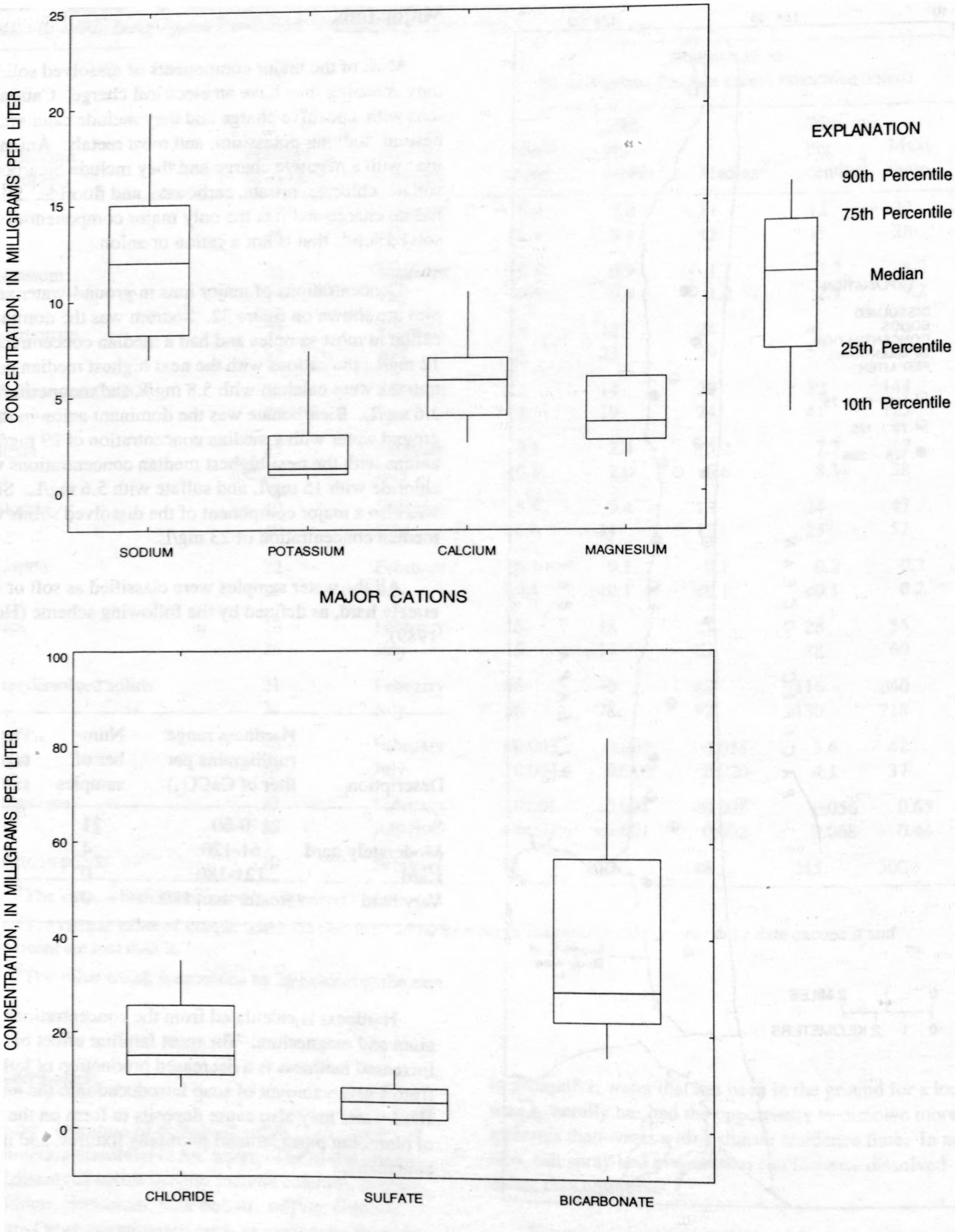

Figure 32.-- Distribution of major-ion concentrations in shallow ground water, July 1992, Long Beach Peninsula, Washington.

Chloride

Sources of dissolved chloride in natural ground waters are the oceans, igneous and sedimentary rocks, and rainwater. More than three quarters of all the chloride present in the earth's crust, atmosphere, and hydrosphere is in solution in seawater. The concentration of chloride in rainwater close to the ocean is variable, and can range from one to several tens of milligrams per liter (Hem, 1989, p. 119).

Chloride is an anion that does not commonly react with other constituents in water and it does not become strongly adsorbed on mineral surfaces; thus chloride is readily transported in water. The concentration of chloride in most natural ground waters is low. Elevated concentrations of chloride are usually associated with water-quality problems such as seawater intrusion or septic-system effluent (Hem, 1989, p. 117-120).

Chloride concentrations for water samples collected from shallow ground water ranged from 6.0 to 52 mg/L and the median was 15 mg/L (table 7). No pattern is apparent in the areal distribution of chloride concentrations (fig. 33). Chloride concentrations can be used to investigate possible seawater intrusion into a freshwater aquifer, and a discussion of this potential problem is provided later in the report in the section titled "Seawater Intrusion".

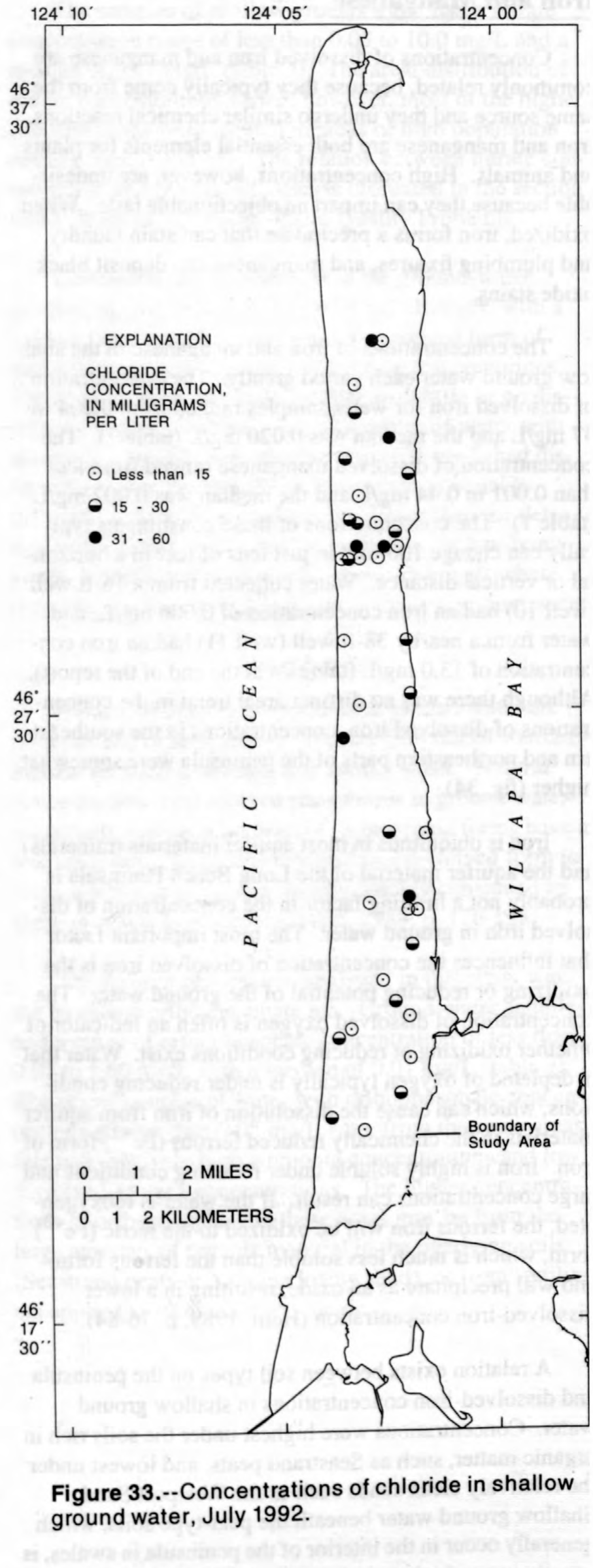

Figure 33.--Concentrations of chloride in shallow ground water, July 1992.

Iron and Manganese

Concentrations of dissolved iron and manganese are commonly related, because they typically come from the same source and they undergo similar chemical reactions. Iron and manganese are both essential elements for plants and animals. High concentrations, however, are undesirable because they can impart an objectionable taste. When oxidized, iron forms a precipitate that can stain laundry and plumbing fixtures, and manganese can deposit black oxide stains.

The concentrations of iron and manganese in the shallow ground water each varied greatly. The concentration of dissolved iron for water samples ranged from 0.004 to 37 mg/L and the median was 0.020 mg/L (table 7). The concentration of dissolved manganese ranged from less than 0.001 to 0.44 mg/L and the median was 0.002 mg/L (table 7). The concentrations of these constituents typically can change 100 fold in just tens of feet in a horizontal or vertical distance. Water collected from a 16-ft well (well 10) had an iron concentration of 0.006 mg/L; and water from a nearby 38-ft well (well 11) had an iron concentration of 13.0 mg/L (table 24 at the end of the report). Although there was no distinct areal trend in the concentrations of dissolved iron, concentrations in the southeastern and northeastern parts of the peninsula were somewhat higher (fig. 34).

Iron is ubiquitous in most aquifer materials (minerals) and the aquifer material of the Long Beach Peninsula is probably not a limiting factor in the concentration of dissolved iron in ground water. The most important factor that influences the concentration of dissolved iron is the oxidizing or reducing potential of the ground water. The concentration of dissolved oxygen is often an indicator of whether oxidizing or reducing conditions exist. Water that is depleted of oxygen typically is under reducing conditions, which can cause the dissolution of iron from aquifer materials in the chemically reduced ferrous (Fe^{+2}) form of iron. Iron is highly soluble under reducing conditions and large concentrations can result. If the water is reoxygenated, the ferrous iron will be oxidized to the ferric (Fe^{+3}) form, which is much less soluble than the ferrous form and will precipitate as an oxide, resulting in a lower dissolved-iron concentration (Hem, 1989, p. 76-84).

A relation exists between soil types on the peninsula and dissolved-iron concentrations in shallow ground water. Concentrations were highest under the soils rich in organic matter, such as Seastrand peats, and lowest under the relatively clean sands such as the Westport Sand. Shallow ground water beneath the peat-type soils, which generally occur in the interior of the peninsula in swales, is usually in a reducing environment. Shallow ground water beneath the clean-sand soils, which occur on dunes, is usually in an oxidizing environment (fig. 7).

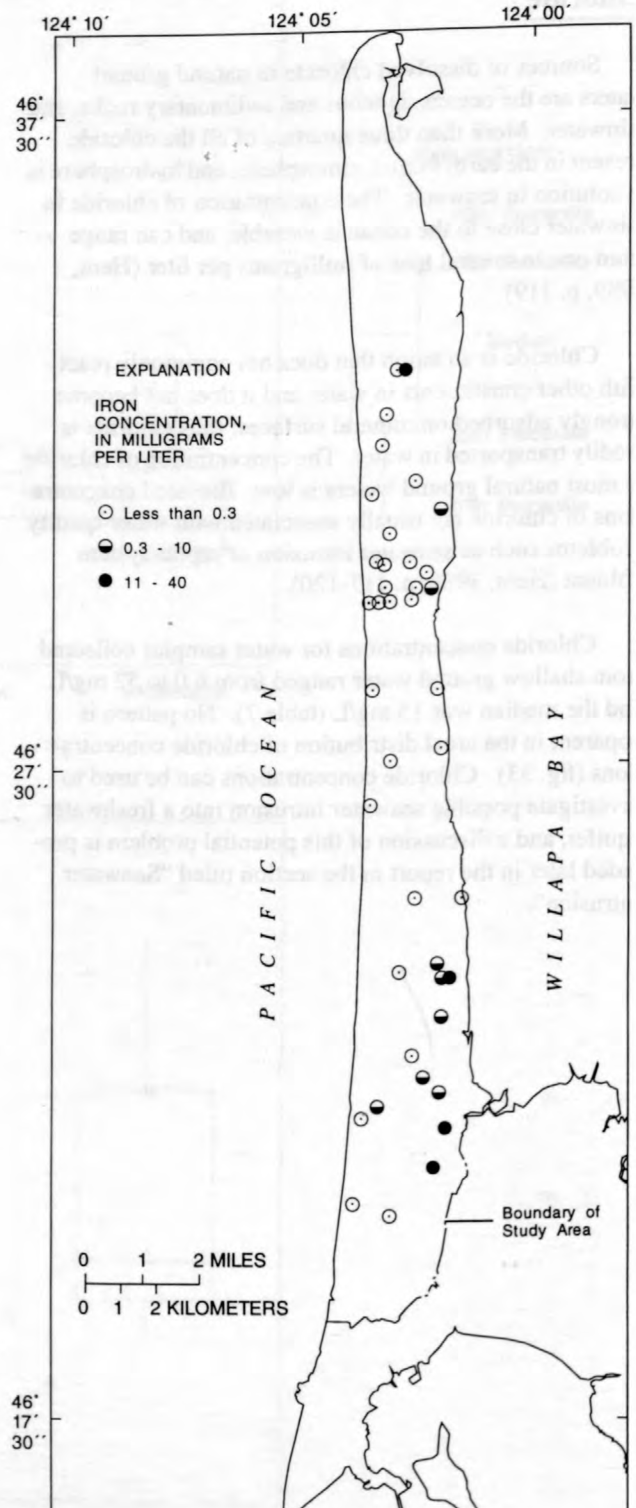

Figure 34.--Concentrations of iron in shallow ground water, July 1992.

Nutrients

Nitrogen and phosphorus are two of the principal nutrients that are essential for plant growth. Natural sources of dissolved nitrogen and phosphorus in ground water are organic matter, minerals, and the atmosphere. In most natural ground-water systems, concentrations of nutrients are usually low. Elevated concentrations of nutrients in ground water may result from a disturbance to the system, such as excessive applications of fertilizer or poorly functioning septic systems. Elevated nutrient concentrations can cause eutrophication of lakes or streams, and high nitrogen concentrations in the form of dissolved nitrate can cause problems with human health.

Nitrogen

The sources of nitrogen in ground water are usually in solid form as ammonia. The most common natural source of ammonia is organic matter or plant residues, and human-introduced sources include fertilizers, sewage, or animal wastes from dairies or feedlots. Ammonia dissolves to form ammonium ion that has a plus one charge, and this ion is usually strongly adsorbed to clay or organic particles. In most natural aerobic ground waters, ammonia is converted to nitrite and then to nitrate by the process of nitrification. Nitrate is the form of nitrogen most commonly used by plants. Nitrate is an anion that is readily transported in water and is stable over a considerable range of conditions. In natural anaerobic ground waters, denitrification often occurs, which is the conversion of nitrate to nitrous oxide or nitrogen gas (Hem, 1989, p. 124-126).

Three forms of dissolved nitrogen were analyzed in this study—ammonia, nitrite, and nitrite plus nitrate. The reported nitrite-plus-nitrate concentrations can generally be considered to be entirely nitrate because nitrite concentrations are usually negligibly small. The nitrite concentrations in samples of ground water in this study confirmed this assumption (table 26 at the end of the report). Ninety-six percent of the samples had nitrite concentrations below the detection limit of 0.01 mg/L, and the remaining 4 percent had concentrations of less than 0.02 mg/L. In the text and summary tables of this report, all the nitrite-plus-nitrate concentrations are reported as a nitrate concentration. In the data tables, however, which show results of actual analysis, the nitrite-plus-nitrate designation is reported.

The samples of shallow ground water had a nitrate concentration range of less than 0.05 to 10.0 mg/L and a median of 0.41 mg/L (table 7). The areal distribution of nitrate concentrations varied; however, most of the higher concentrations were located in areas of high population density (figs. 3 and 35). The relation between nitrate concentration and human activities is discussed in the section titled "Sources of Ground-Water Quality Problems".

Concentrations of ammonia in the ground-water samples ranged from less than 0.01 to 0.36 mg/L with a median of 0.01 mg/L. Ammonia is a reduced form of nitrogen that tends to occur under anaerobic conditions. Therefore, it tends to occur in water with little or no dissolved oxygen or nitrate. The 10 samples of water with ammonia concentrations greater than 0.05 mg/L had dissolved-oxygen concentrations lower than or equal to 0.5 mg/L and nitrate concentrations lower than the detection limit of 0.05 mg/L. All these sites are in low-lying swales or deflation plains with organic-rich soils where reducing conditions tend to occur in shallow ground water.

Phosphorus

Natural sources of phosphorus in ground water are minerals and organic matter. Human-introduced sources include fertilizers, sewage, and animal waste. Natural concentrations of dissolved phosphorus in ground water are usually low because most of its inorganic forms have a low solubility. When it is released in a dissolved form to surface water or soils, it is usually quickly consumed by algae or plants as a nutrient (Hem, 1989, p. 126-128).

The form of phosphorus analyzed in this study was the inorganic orthophosphate ion. Ground-water samples had a range of orthophosphate concentration of less than 0.01 to 1.60 mg/L with a median of 0.01 mg/L (table 7). The seven samples of water with orthophosphate concentrations greater than 0.05 mg/L were from the same areas that had relatively high ammonia concentrations and low dissolved-oxygen concentrations. The higher concentrations of orthophosphate in these areas may be from the large amounts of organic material in the overlying soils (Seastrand peats or Yaquina loamy sand), or from fertilizers applied to local cranberry fields.

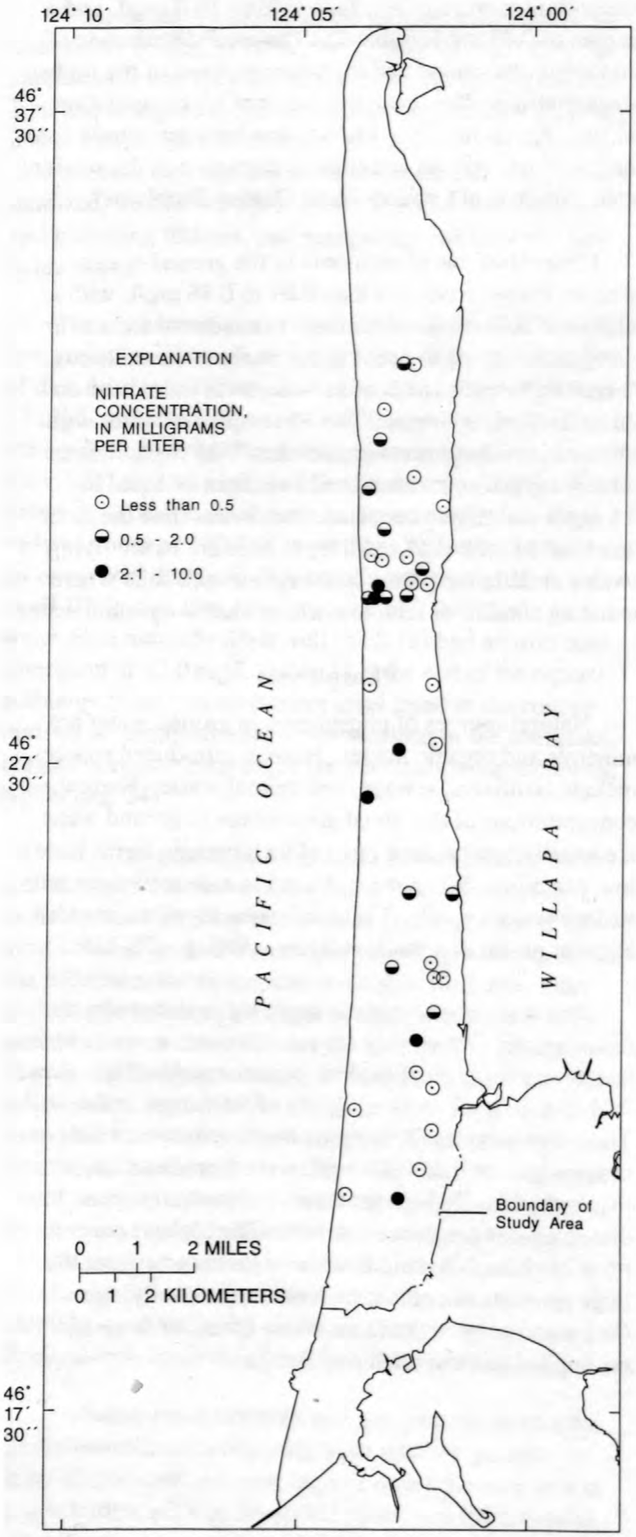

Figure 35.--Concentrations of nitrate in shallow ground water, July 1992.

Septage-Related Compounds

Concentrations of dissolved organic carbon (DOC), boron, and methylene blue active substances (MBAS) were determined for samples from 20 wells located mostly in residential areas served by septic systems. Large concentrations of dissolved organic carbon may be the result of decaying vegetation, or they may indicate the presence of several types of organic contaminants, including septage, oil and grease, and solvents. Boron and MBAS are present in household wastewater as detergent residues and have been identified in septage-contaminated ground water (LeBlanc, 1984).

Ground-water samples had concentrations of dissolved organic carbon that ranged from 0.7 to 18 mg/L with a median of 4.8 mg/L, concentrations of boron that ranged from less than 0.01 to 0.29 mg/L with a median of 0.02 mg/L, and concentrations of MBAS that ranged from less than 0.01 to 0.03 with a median of 0.01 mg/L (table 7). A discussion of the relation between the concentrations of these constituents and septic systems is given in the section titled "Septic Systems".

Bacteria

Concentrations of fecal coliform and fecal streptococcal bacteria were determined in all ground-water samples. Both types of bacteria are indicators; that is, they are not pathogenic bacteria themselves but can occur in conjunction with pathogenic bacteria. Fecal coliform are the only bacteria for which a quantitative relation with a pathogen (Salmonella) has been observed (Geldreich and Van Donsel, 1970). The presence of bacteria may be related to improperly functioning septic systems or animal waste material.

A concentration of 1 colony per 100 milliliters (col/100 mL) of fecal coliform bacteria was found in a water sample collected in February 1992 at well 107; however, no bacteria were found in a water sample collected in July 1992 at the same well. A range of 1 to 5 col/100 mL of fecal streptococcal bacteria was found in water samples from six wells; three samples were collected in February and three samples were collected in July. At five of the six wells, the bacteria were not found in the second sample. The sixth well had only one sample collected (table 26 at the end of the report).

The source of the bacteria in samples from each well appears to be site specific, and is not from a regional source of contamination. Well 107 is near a septic system and is located about 150 ft from East Main drainage channel, which carries treated sewage from the city of Long Beach. Well 114 is located next to a field where cattle graze during part of the year. Well 117 is located next to a storm drain in the city of Long Beach. Wells 29 and 125 are located in areas with a medium population density. Wells 11 and 62 are located in areas of low population density and the potential source of bacteria is unknown.

Pesticides

Pesticides are used on the peninsula for the control of weeds, insects, and fungi. Pesticides are used in commercial agriculture such as cranberry growing, in the control of weeds on road shoulders, and by individual homeowners on their vegetable gardens and lawns. Samples of water were analyzed for a suite of insecticides named Carbamates, a herbicide named Dichlobinel (also called Casoron or Novosac), and a herbicide named Diuron (table 8). These pesticides are not a complete sample of those used on the peninsula, but they are some of the most commonly used pesticides in cranberry growing. No pesticides were found in the February or July ground-water samples at concentrations above the analytical detection limits of 0.5 μg/L.

Radon

Radon is a naturally occurring element and is part of the radioactive decay chain of uranium. Radon is soluble in water and also can be transported in the gas phase. Many ground waters contain detectable quantities of radon, which is derived mostly from radium in the solids of the aquifer (Hem, 1989, p. 149). Radon is reported in picocuries per liter (pCi/L), which is a measurement of radioactivity, not mass.

The 10 samples of ground water collected in February 1992 had radon concentrations that ranged from 81 to 300 pCi/L with a median of 195 pCi/L (table 7). In 1991, the USEPA proposed a maximum contaminant level (MCL) of 300 pCi/L for radon (see section on Drinking Water Regulations for Ground Water for discussion of MCL's). Thus, the water sample collected from well 81 with a radon concentration of 300 pCi/L would equal this proposed level.

Comparison of Ground-Water Quality From Different Depths

Most ground-water samples in this study were collected from within about 15 ft of the water table. To determine the differences in chemical characteristics with depth, samples were collected at three sites that had wells at different depths located within 15 ft of each other. At one site (wells 96 to 98), three wells are within 15 ft of each other and have depths of 20, 38, and 235 ft (table 9). At two other sites, two wells (wells 10 and 11) have depths of 16 and 38 ft, and two wells (wells 47 and 48) have depths of 26 and 38 ft. At all three sites, the shallow and intermediate-depth wells are finished in deposits of fine sand. The lithologic and aquifer-test data for the 235-ft well (well 98) indicate that lenses of clay and sandy clay occurring between about 130 and 200 ft below land surface act as a local confining bed. Samples from this well, therefore, are from a deep, locally confined aquifer. The water sample from the 235-ft well may not represent the average or natural chemical conditions for water in that deep aquifer because, prior to the date of sampling, the well had been pumped continuously at a rate of about 80 gal/min for about 3 weeks. Nevertheless, the resulting data are still useful for comparisons.

At all three sites, the dissolved-solids concentration increased as the depth of the water sample increased (table 9). At two sites, the concentrations of iron and manganese also increased with depth. The relation between concentrations of nutrients and depth of samples varied. The proportions of cations and anions were similar for the shallow and intermediate-depth wells, as were the water types (sodium-bicarbonate). The sample from the 235-ft well, however, had water with calcium and chloride as the dominant ions. This deep, locally confined aquifer appeared to be contaminated with seawater; the water sample had a high dissolved-solids concentration (654 mg/L) and a high chloride concentration (290 mg/L). As mentioned in the previous paragraph, the chemical characteristics of this deep-water sample may not represent average conditions because of the pumping from this well prior to sampling. The pumping may have caused the freshwater-seawater boundary to rise closer to the bottom of the well than it would be in undisturbed or steady-state conditions.

Table 8.--*Pesticides analyzed in ground and surface waters, Long Beach Peninsula, Washington*

Pesticides analyzed	Number of ground-water sites sampled (wells)	Number of surface-water sites sampled	Number of sites with pesticide detected[1]
	February 1992		
Carbamates	19	6	0
Aldicarb			0
Aldicarb sulfone			0
Aldicarb sulfoxide			0
Carbaryl (Sevin)			0
Carbofuran			0
Hydroxycarbofuran			0
Methiocarb			0
Methomyl			0
1-Naphthol			0
Oxamyl			0
Propham			0
Propoxur			0
Dichlobinel	19	6	0
	July 1992		
Carbamates	21	6	0
Aldicarb			0
Aldicarb sulfone			0
Aldicarb sulfoxide			0
Carbaryl (sevin)			0
Carbofuran			0
Hydroxycarbofuran			0
Methiocarb			0
Methomyl			0
1-Naphthol			0
Oxamyl			0
Propham			0
Propoxur			0
Dichlobinel	21	6	0
Diuron	21	6	0

[1]The detection limit for all pesticides was 0.5 microgram per liter.

Table 9.--*Comparison of selected chemical characteristics among samples of ground water from different depths in July 1992, Long Beach Peninsula, Washington*

[Values are concentrations in milligrams per liter unless otherwise noted; µS/cm, microsiemens per centimeter at 25 degrees Celsius; $CaCO_3$, calcium carbonate; ft, feet; <, less than; --, no data]

Constituent or property	Well number and depth below land surface (10) 16 ft	(11) 38 ft	(47) 26 ft	(48) 38 ft	(96) 20 ft	(97) 38 ft	(98) 235 ft
Specific conductance, in µS/cm	79	177	77	269	100	143	1,120
pH, in standard units	6.1	7.0	6.4	6.4	6.2	6.6	7.0
Dissolved oxygen	6.3	<0.1	9.4	4.2	0.2	3.5	--
Nitrite	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02
Nitrate	1.5	<0.05	1.2	10	<0.05	<0.05	<0.05
Ammonia	<0.01	0.09	0.02	0.01	0.15	0.15	0.40
Orthophosphate	<0.01	0.02	<0.01	<0.01	0.01	0.13	0.10
Dissolved organic carbon	5.6	--	5.5	13	--	--	--
Boron	0.010	--	<0.01	0.010	--	--	--
Calcium	3.9	6.2	3.8	17	5.3	6.0	90
Magnesium	2.3	4.1	2.7	11	2.6	2.7	54
Sodium	7.0	11	6.9	18	6.4	12	41
Potassium	0.70	1.7	0.90	2.8	1.1	0.70	3.2
Bicarbonate	17	43	24	68	53	68	244
Alkalinity, as $CaCO_3$	15	35	20	56	43	56	200
Sulfate	2.2	6.3	2.1	13	5.6	<0.10	6.3
Chloride	9.6	32	8.0	19	6.0	14	290
Fluoride	<0.10	<0.10	<0.10	<0.10	<0.01	<0.10	0.20
Silica	15	33	23	31	17	48	41
Total dissolved solids	56	129	65	190	76	--	654
Iron	0.006	13	0.013	0.005	5.3	13	7.0
Manganese	<0.001	0.17	<0.001	<0.001	0.062	0.14	0.90

Drinking Water Regulations for Ground Water

The U.S. Environmental Protection Agency (USEPA) has established drinking water regulations under the Public Health Service Act, as amended by the Safe Drinking Water Act of 1986. These regulations are categorized as primary or secondary. Primary drinking water regulations were established to control contaminants that affect human health. The maximum allowable concentration determined for a constituent is referred to as a maximum contaminant level, or MCL, and is legally enforceable by regulatory agencies. Secondary drinking water regulations were established to provide guidelines for the control of contaminants that affect the aesthetic qualities of drinking water. The secondary maximum contaminant level, or SMCL, is not enforceable by regulatory agencies. Both sets of regulations legally apply only to public systems, but can also be used to help assess the quality of private systems (U.S. Environmental Protection Agency, 1989, 1991a, and 1991b).

Primary and secondary maximum contaminant levels for constituents analyzed in this study are shown in table 10, along with the number of samples that exceeded the standard. Because the regulations are revised frequently, the regulations used in this report are those in effect at the time both sets of samples were collected (February and July 1992; U.S. Environmental Protection Agency, 1992). The State of Washington has the same standards as those specified by the USEPA (Washington Administrative Code, 1990).

Only one primary MCL was exceeded. Total coliform bacteria were not analyzed for, but one colony of fecal coliform bacteria was detected in a 100-milliliter water sample collected in February 1992 at well 107 (tables 10 and 26). A second analysis of water collected in July 1992 at the same well failed to detect fecal coliform bacteria. Thus, the coliform MCL was exceeded at one well, but only in one of the two samples at the well.

The primary MCL for nitrate, which is 10 mg/L, was equaled in the July 1992 sample from well 48 (tables 26). A sample collected in February 1992 from the same well had a nitrate concentration of 2.0 mg/L. The nitrate MCL is based on the concentration at which methemoglobinemia may occur in infants. This disease can result in suffocation because the oxygen-carrying capacity of hemoglobin is impaired by large concentrations of nitrate in the blood. Older children and adults generally are not affected.

The SMCL's were not met in many samples for iron, manganese, and pH. At about 30 percent of the sampled sites the SMCL of 0.3 mg/L for iron was exceeded. At about 32 percent of the sampled sites the SMCL of 0.05 mg/L for manganese was exceeded. The SMCL for iron was exceeded at all but one of the sites where the SMCL for manganese was exceeded. These high concentrations of iron and manganese are from natural sources, as was discussed in an earlier section of this report. Concentrations of iron or manganese above the SMCL's can cause staining of laundry and plumbing fixtures, and the taste becomes objectionable. Some industrial applications, such as paper production, food processing, and chemical production, may require concentrations below the SMCL's.

Samples from about two-thirds of the wells had pH values less than the lower SMCL of 6.5 (table 10). Most of the samples had pH values between 6.0 and 6.5, and only two had values below 6.0. A pH range from 5 to 9 is generally considered acceptable for public water supply because the pH of water can be easily adjusted prior to and during water treatment (U.S. Environmental Protection Agency, 1986). The adjustment of pH at wells owned by individual homeowners is more difficult, and the effect of having ground water with relatively low pH is that the water may be corrosive to pipes and plumbing and corrosion can increase concentrations of copper, lead, zinc, and cadmium.

Table 10.--*Drinking water regulations of the U.S. Environmental Protection Agency in February and July 1992 and the number of shallow ground-water samples that did not meet them, Long Beach Peninsula, Washington*

[Primary MCL, maximum contaminant level that is enforceable by law; Secondary SMCL, a secondary maximum contaminant level that is not enforceable; mg/L, milligrams per liter; --, not established]

Constituent	Drinking water regulations: Primary MCL (mg/L)	Drinking water regulations: Secondary SMCL (mg/L)	Number of samples that did not meet the specified level: February 1992	Number of samples that did not meet the specified level: July 1992
		Inorganic		
Sulfate	--	250	0	0
Chloride	--	250	0	0
Fluoride	4.0	2.0	0	0
Total dissolved solids	--	500	0	0
Nitrate	10.0	--	0	0
Iron	--	0.3	11	12
Manganese	--	0.05	7	8
		Microbiological		
Total coliforms[1]	--	--	[2]1	0
		Miscellaneous properties		
pH	--	[3]6.5-8.5	24	27
		Organic compounds		
Aldicarb	0.003	--	0	0
Aldicarb sulfone	0.002	--	0	0
Aldicarb sulfoxide	0.004	--	0	0
Carbofuran	0.04	--	0	0

[1]The MCL for total coliform bacteria is less than 1 colony per 100-milliliter sample of water.

[2] Sample had a concentration of 1colony per 100-milliliter sample of fecal coliform bacteria.

[3]Standard pH units.

Relation Between Quality of Ground Water and Surface Water

The quality of ground water is closely related to that of surface water because ground water and surface water are interchanged throughout the year. Ground water discharges to most of the surface-water drainage channels during the entire year. The relation between lakes and ground water is more variable; at many lakes the flow is from ground water to surface water in the winter and from surface water to ground water in the summer (see fig. 16). To investigate the relation between the quality of ground water and surface water, water samples were collected from about 13 surface-water drainage channels and from about 40 shallow wells in February and July 1992. Only surface-water drainage channels were selected for sampling because (1) lakes are difficult to sample, and (2) much of the water flowing in the surface-water drainage channels is representative of ground-water discharge.

The concentrations of selected chemical characteristics of shallow ground water and surface water are compared in table 11. To identify significant differences between the two sources of water, a nonparametric rank-sum test (two-sided) was made to determine if the constituents in the two waters are from the same population. Another comparison of the two waters is shown using box-plots of the distributions of selected constituents in the water sampled in July 1992 (fig. 36).

For most of the chemical characteristics that were analyzed, concentrations in ground water were significantly different than those in surface water. Surface water had a higher pH; higher concentrations of dissolved solids, ammonia, and orthophosphate; higher and less variable concentrations of dissolved oxygen, iron, and manganese; and a lower concentration of nitrate (table 11 and fig. 36). The distribution of major ions, however, was similar for both ground and surface waters, with both having dominant ions of sodium and bicarbonate.

The pH is lower in the shallow ground water than in the surface water because the shallow ground water is close to the soil and root zone where dissolved carbon dioxide reacts with water and lowers the pH. The principal reason for the higher dissolved-solids concentrations in surface water was probably evaporation of surface water, which would concentrate the remaining amount of dissolved solids.

Concentrations of ammonia and orthophosphate probably were higher in surface water than in ground water because the surface water is an active zone of production for these constituents; sources of nitrogen and phosphorous such as leaves or fine particulate organic matter are constantly being introduced to the surface water. Nitrate concentrations probably were lower in surface water than in ground water because there had not been enough time for nitrification to convert all the introduced ammonia to nitrate, and the load of nitrogen from sources such as fertilizers and septic-system effluent may be larger for ground water than for surface water.

The higher concentrations of dissolved oxygen in surface water are expected because the surface water is in contact with the atmosphere and it is aerated from turbulence as it flows over rough surfaces.

The generally higher concentrations of dissolved iron in surface water are unusual and were not expected because the surface water has moderate or high levels of dissolved oxygen and one would expect the iron to have precipitated in such an aerobic and oxidizing environment. A possible cause of the high iron concentration is that much of the measured dissolved-iron concentration is actually iron that was attached to colloidal material that passed through the 0.45-micron filters used in the collection procedure.

Pesticides were analyzed for in ground-water and surface-water samples (table 8). Samples of water were analyzed for a suite of insecticides named Carbamates, a herbicide named Dichlobinel (also called Casoron or Novosac), and for a herbicide named Diuron (table 8). These pesticides are not a complete sample of those used on the peninsula, but they are some of the most commonly used pesticides in cranberry growing. No pesticides were found in the ground water or in the surface water at concentrations above the analytical detection limits of 0.5 µg/L.

Samples of bottom sediment were collected in June 1992 in three surface-water drainage channels and analyzed for a suite of pesticides, polychlorinated biphenyls (PCB's), and polychlorinated naphthalenes (PCN's; table 12). These three channels drain cranberry fields and some of the analyzed pesticides are used on the cranberry fields. Dichloro Diphenyl Trichloroethane (DDT) and its breakdown products, Dichloro Diphenyl Dichloroethane (DDD), and Dichloro Diphenyldichloro Ethylene (DDE), were found in low concentrations at all three sites. The concentrations were just above detection limits and were about an order of magnitude lower than the median level of DDT, DDD, and DDE (50 µg/kg) found in streambed sediment of the Yakima River in central Washington (Rinella and others, 1993). Tarlatt Slough had the highest concentrations, followed by Gile Lake drainage; Whiskey Slough had the lowest concentration. DDT has not been used since the early 1970's, thus the concentrations of the breakdown products were higher than those of the parent material. DDT and its breakdown products are chemically stable and can remain in the environment for many years (U.S. Environmental Protection Agency, 1976). Diazinon, a common insecticide, was found in concentrations just above the detection limit at two of the three sites.

Table 11.--*Comparison of concentrations of selected chemical characteristics and bacteria in shallow ground water and surface water in 1992, Long Beach Peninsula, Washington*

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; cols/100mL, colonies per 100 milliliters; mg/L, milligrams per liter; <, less than]

	Water samples			Concentration (in mg/L unless otherwise noted)			
Constituent or property	Source	Month	Number	25th per-centile	Median	75th per-centile	Signifi-cance level[1]
Specific conductance, in µS/cm	Ground	February	40	88	132	181	0.13
	Surface	February	13	132	159	189	
	Ground	July	40	98	134	188	<0.01
	Surface	July	11	186	213	257	
pH, in standard units	Ground	February	40	6.2	6.4	6.5	<0.01
	Surface	February	13	6.6	6.6	6.8	
	Ground	July	40	6.1	6.3	6.6	<0.01
	Surface	July	11	7.0	7.1	7.5	
Dissolved oxygen	Ground	February	40	0.6	3.6	7.2	0.34
	Surface	February	13	3.0	6.0	6.2	
	Ground	July	40	0.3	2.4	6.6	0.33
	Surface	July	10	2.0	3.6	5.7	
Fecal coliform bacteria, in cols/100mL	Ground	February	40	<1	<1	<1	<0.01
	Surface	February	13	8	10	16	
	Ground	July	40	<1	<1	<1	<0.01
	Surface	July	11	23	94	320	
Fecal streptococci bacteria, in cols/100mL	Ground	February	40	<1	<1	<1	<0.01
	Surface	February	13	6	10	28	
	Ground	July	40	<1	<1	<1	<0.01
	Surface	July	11	60	79	130	
Nitrate	Ground	February	40	0.05	0.28	0.78	<0.01
	Surface	February	13	<0.05	<0.05	0.08	
	Ground	July	39	<0.05	0.41	1.50	0.01
	Surface	July	11	<0.05	<0.05	0.25	
Ammonia	Ground	February	40	<0.01	<0.01	0.04	<0.01
	Surface	February	13	0.07	0.10	0.24	
	Ground	July	39	<0.01	0.01	0.09	<0.01
	Surface	July	11	0.03	0.07	0.18	

Table 11.--*Comparison of concentrations of selected chemical characteristics and bacteria in shallow ground water and surface water in 1992, Long Beach Peninsula, Washington--Continued*

Constituent or property	Water samples			Concentration (in mg/L unless otherwise noted)			
	Source	Month	Number	25th per-centile	Median	75th per-centile	Signifi-cance level[1]
Orthophosphate	Ground	February	40	<0.01	<0.01	0.02	<0.01
	Surface	February	13	0.04	0.06	0.09	
	Ground	July	39	<0.01	0.01	0.03	0.02
	Surface	July	11	0.04	0.05	0.10	
Calcium	Ground	February	22	3.3	4.7	7.0	0.60
	Surface	February	9	4.4	4.9	7.4	
	Ground	July	25	3.9	5.8	6.9	<0.01
	Surface	July	7	7.2	9.5	10	
Magnesium	Ground	February	22	2.1	3.6	4.6	0.04
	Surface	February	9	4.4	5.3	6.6	
	Ground	July	25	2.6	3.6	5.3	<0.01
	Surface	July	7	7.4	9.0	11	
Sodium	Ground	February	22	7.0	11	12	0.02
	Surface	February	9	13	16	18	
	Ground	July	25	8.1	12	15	<0.01
	Surface	July	7	15	20	22	
Potassium	Ground	February	22	0.90	1.1	1.7	<0.01
	Surface	February	9	2.0	2.8	3.8	
	Ground	July	25	0.90	1.2	2.9	<0.01
	Surface	July	7	4.3	6.7	7.7	
Bicarbonate	Ground	Feb.	22	18	24	41	0.04
	Surface	Feb.	8	30	42	62	
	Ground	July	22	23	29	57	<0.01
	Surface	July	8	66	88	123	
Alkalinity	Ground	Feb.	22	14	20	32	0.04
	Surface	Feb.	8	24	34	51	
	Ground	July	22	19	24	41	<0.01
	Surface	July	8	54	72	100	

Table 11.--*Comparison of concentrations of selected chemical characteristics and bacteria in shallow ground water and surface water in 1992, Long Beach Peninsula, Washington--Continued*

Constituent or property	Water samples			Concentration (in mg/L unless otherwise noted)			Significance level[1]
	Source	Month	Number	25th percentile	Median	75th percentile	
Sulfate	Ground	February	22	2.4	5.2	7.7	0.16
	Surface	February	9	2.0	3.3	4.7	
	Ground	July	25	2.0	5.6	8.3	0.07
	Surface	July	7	1.0	2.3	3.5	
Chloride	Ground	February	40	9.4	13	24	<0.01
	Surface	February	13	26	28	30	
	Ground	July	40	11	15	25	<0.01
	Surface	July	11	23	29	35	
Fluoride	Ground	February	22	0.1	0.1	0.2	0.63
	Surface	February	9	0.1	0.2	0.2	
	Ground	July	25	<0.1	<0.1	<0.1	<0.01
	Surface	July	7	<0.1	0.1	0.2	
Silica	Ground	February	22	18	23	28	0.37
	Surface	February	9	18	19	26	
	Ground	July	25	17	23	28	0.10
	Surface	July	7	27	35	40	
Total dissolved solids	Ground	February	21	70	88	116	0.15
	Surface	February	9	94	107	124	
	Ground	July	24	78	92	130	0.01
	Surface	July	7	120	148	174	
Iron	Ground	February	40	<0.01	0.018	3.6	<0.01
	Surface	February	13	1.4	2.3	4.6	
	Ground	July	40	0.010	0.020	4.1	0.02
	Surface	July	11	0.93	1.8	4.6	
Manganese	Ground	February	22	<0.001	<0.001	0.056	<0.01
	Surface	February	9	0.15	0.17	0.22	
	Ground	July	25	<0.001	0.002	0.068	<0.01
	Surface	July	7	0.090	0.13	0.30	

[1]The rank-sum nonparametric test (two-sided) was used to test the hypothesis that the two groups of samples are from the same population.

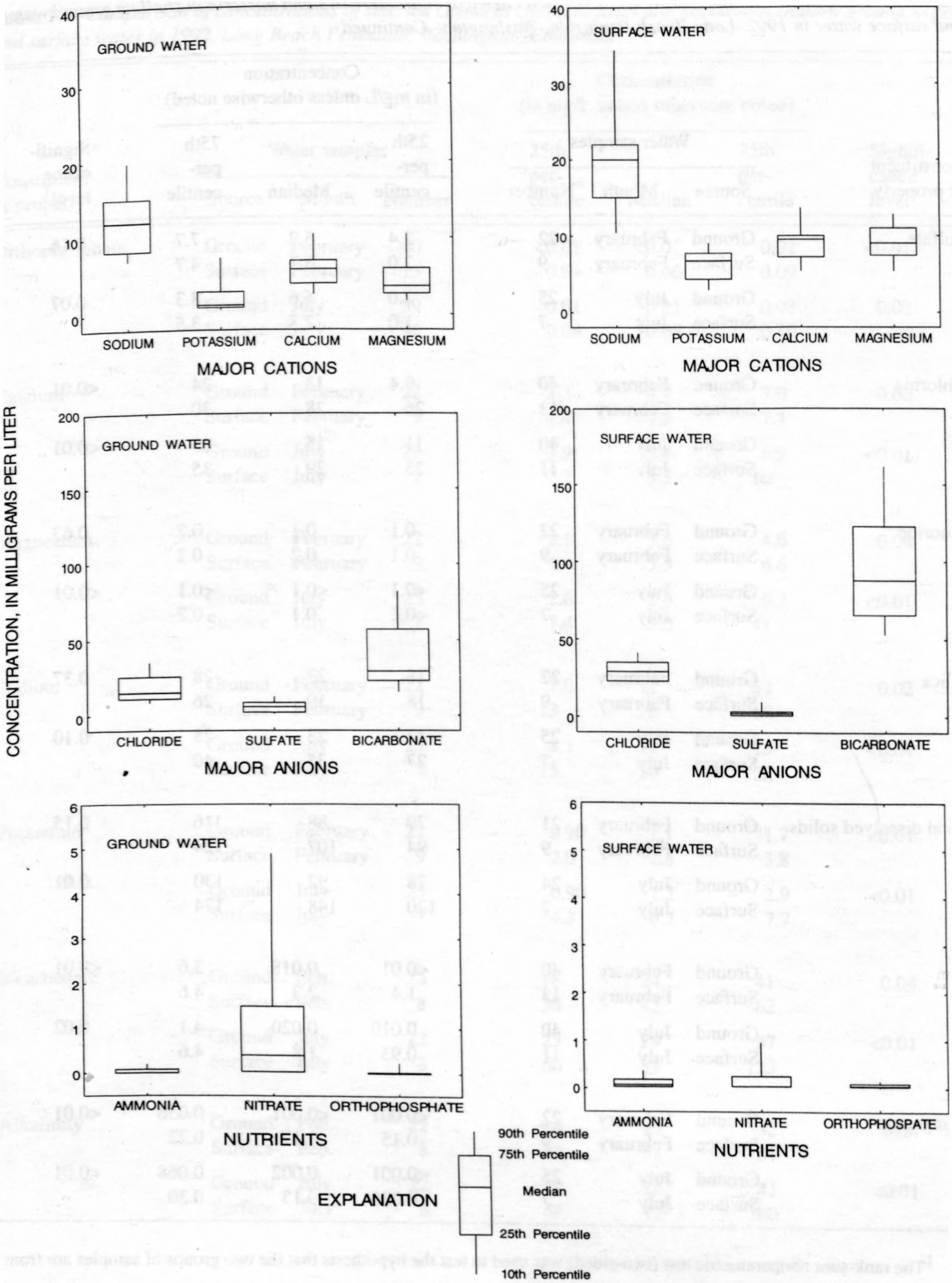

Figure 36.--Distributions of selected constituent concentrations in shallow ground water and surface water, July 1992, Long Beach Peninsula, Washington.

Table 12.--*Concentrations of selected pesticides, PCB, and PCN in bottom sediment of surface-water drainage channels, Long Beach Peninsula, Washington*

[All concentrations are in micrograms per kilogram; PCB, polychlorinated biphenyl; PCN, polychlorinated napthalene; DDE, Dichloro Diphenyldichloro Ethylene; DDD, Dichloro Diphenyl Dichloroethane; DDT, Dichloro Diphenyl Trichloroethane; <, less than]

Site number	Name	Date	PCB	PCN	Aldrin	Chlordane	DDD
9	Whiskey Slough (lower)	06-10-93	<1	<1.0	<0.1	<1.0	0.6
22	Gile Lake drainage	06-10-93	<1	<1.0	<0.1	<1.0	4.4
29	Tarlatt Slough (upper)	06-10-93	<1	<1.0	<0.1	<1.0	16

Site number	Name	DDE	DDT	Diazinon	Dieldrin	Endosulfan	Endrin
9	Whiskey Slough (lower)	0.7	0.1	<0.1	<0.1	<0.1	<0.1
22	Gile Lake drainage	3.8	1.0	0.4	0.1	<0.1	<0.1
29	Tarlatt Slough (upper)	3.0	0.3	1.6	<0.1	<0.1	<0.1

Site number	Name	Ethion	Heptachlor	Heptachlor epoxide	Lindane	Malathion	Methoxychlor
9	Whiskey Slough (lower)	<0.1	<0.1	<0.1	<0.1	<0.1	<3.0
22	Gile Lake drainage	<0.1	<0.1	<0.1	<0.1	<0.1	<3.0
29	Tarlatt Slough (upper)	<0.1	<0.1	<0.1	<0.1	<0.1	<3.0

Site number	Name	Methyl parathion	Mirex	Parathion	Perthane	Toxaphene	Trithion
9	Whiskey Slough (lower)	<0.1	<0.1	<0.1	<1.0	<10	<0.1
22	Gile Lake drainage	<0.1	<0.1	<0.1	<1.0	<10	<0.1
29	Tarlatt Slough (upper)	<0.1	<0.1	<0.1	<1.0	<10	<0.1

Seasonal Variation of Water Quality

The quality of ground and surface waters can vary seasonally. The primary causes of seasonal variation of ground-water quality are (1) changes in the recharge and discharge of the aquifer, (2) changes in water-level gradients and the resulting velocity of ground water, and (3) changes in human activities, such as application of fertilizers and pesticides, domestic and agricultural uses of water, and production of septic-tank effluent. The primary causes of seasonal variation of surface-water quality are (1) changes in the quantity of flow resulting from variations in precipitation and ground-water discharge, (2) changes in the sources of surface-water flow, and (3) changes in human activities. To examine the seasonal variation of water quality, samples were collected in the winter (February 1992) and summer (July 1992); these periods are representative of the extreme seasonal hydrologic conditions.

Shallow Ground Water

The seasonal differences in the concentrations of selected constituents of shallow ground water are shown in table 13. To determine if these differences are significant, a nonparametric Wilcoxon signed-ranks test (two-sided; Helsel and Hirsch, 1992, p. 142-147) was made to determine if the samples of water from February and from July are from the same population.

The constituents with concentrations that were significantly higher in the summer were nitrate, ammonia, orthophosphate, dissolved organic carbon, bicarbonate, and alkalinity. The increase in concentrations of nutrients and dissolved organic carbon may have been caused by the use of fertilizers in the summer or increased septic-tank effluent from the large increase in population that occurs in the summer. The small seasonal changes in bicarbonate, alkalinity, and fluoride concentrations are statistically significant, but these changes are not important and have no obvious physical explanation.

Surface Water

The seasonal differences in the concentrations of selected constituents in surface-water drainage channels are shown in table 14. To determine if these differences are significant, a nonparametric Wilcoxon signed-ranks test (two-sided) was made to determine if the samples of water from February and from July are from the same population.

The properties or constituents with values or concentrations that were significantly higher in the summer were specific conductance, pH, major cations, bicarbonate, alkalinity, and total dissolved solids. Specific conductance and concentrations of major cations, bicarbonate, alkalinity, and total dissolved solids were probably higher in summer because of the decreased volume of water. The measured discharge in the sampled drainage channels in winter ranged from 1 to 21 ft^3/s; the summer discharge ranged from less than 0.1 to 1 ft^3/s (table 15). The winter and summer samples probably had similar masses of dissolved material, but the smaller volume of water in the summer would cause higher concentrations of dissolved material. The increase in pH in the summer was probably caused by the increase in primary productivity and photosynthesis of the algae and larger plants in the surface water.

Sources of Potential Ground-Water-Quality Problems

Several constituents in ground water can cause a health or aesthetic problem when their concentrations are particularly high or occasionally when their concentrations are low. Sometimes such a condition may be a health concern; other times it may only affect the aesthetic qualities of the water. In either case, it is helpful to understand the source of the undesirable concentration. The principal sources of potential water-quality problems in the Long Beach Peninsula are natural conditions, seawater intrusion, agricultural activities, and septic systems. These sources were investigated as part of this study. However, identifying the source of a particular problem is difficult because of insufficient data and the complexities of ground-water systems.

Table 13.--*Seasonal differences of selected chemical characteristics of shallow ground water in 1992, Long Beach Peninsula, Washington*

[mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; $CaCO_3$, calcium carbonate; <, less than; --, not possible to compute]

Constituent or property	Number of paired samples	Median concentration (mg/L unless otherwise noted) February	July	Difference in median concentrations	Significance level[1]
Specific conductance, µS/cm	39	132	134	-2	0.86
pH, in standard units	39	6.3	6.3	0.0	0.58
Dissolved oxygen	39	3.5	2.6	0.9	0.18
Nitrite	38	<0.01	<0.01	--	0.56
Nitrate	38	0.32	0.44	-0.12	0.03
Ammonia	38	<0.01	0.01	--	<0.01
Orthophosphate	38	<0.01	0.01	--	0.01
Dissolved organic carbon	10	0.75	4.8	-4.05	0.01
Boron	20	0.015	0.020	-0.005	0.12
Methylene blue active substances (MBAS)	19	0.01	0.01	0.0	0.44
Calcium	21	4.8	5.7	-0.9	0.49
Magnesium	21	3.8	3.3	0.5	0.28
Sodium	21	11	12	-1	0.64
Potassium	21	1.1	1.1	0.0	0.94
Bicarbonate	21	24	29	-5	0.02
Alkalinity, as $CaCO_3$	21	20	24	-4	0.01
Sulfate	21	5.5	5.0	0.5	0.63
Chloride	39	13	15	-2	0.32
Fluoride	21	0.10	<0.10	--	<0.01
Silica	21	23	23	0	0.91
Total dissolved solids	20	92	92	0	0.51
Iron	39	0.017	0.020	-0.003	0.28
Manganese	21	<0.001	0.002	--	0.55

[1]The Wilcoxon signed-ranks test (two-sided) was used to test the hypothesis that the two groups of samples are from the same population. It is a test on the paired seasonal samples.

Table 14.--*Seasonal differences of selected chemical characteristics of surface water in 1992, Long Beach Peninsula, Washington*

[mg/L, milligrams per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; $CaCO_3$, calcium carbonate; <, less than; --, not possible to compute]

Constituent or property	Number of paired samples	Median concentration (mg/L unless otherwise noted) February	July	Difference in median concentrations	Significance level[1]
Specific conductance in uS/cm	11	170	213	-43	<0.01
pH, in standard units	11	6.6	7.1	-0.5	<0.01
Dissolved oxygen	10	6.0	3.6	2.4	0.51
Nitrite	11	<0.01	<0.01	--	0.30
Nitrate	11	<0.05	<0.05	--	0.75
Ammonia	11	0.10	0.07	0.03	0.50
Orthophosphate	11	0.06	0.05	0.01	0.93
Calcium	7	5.6	9.5	-3.9	0.03
Magnesium	7	5.4	9.0	-3.6	0.02
Sodium	7	18	20	-2	0.02
Potassium	7	3.2	6.7	-3.5	0.02
Bicarbonate	6	51	88	-37	[2]--
Alkalinity, as $CaCO_3$	6	42	67	-25	[2]--
Sulfate	7	4.2	2.3	1.9	0.11
Chloride	11	27	29	-2	0.40
Fluoride	7	0.20	0.10	0.10	0.80
Silica	7	19	35	-16	0.18
Total dissolved solids	7	109	148	-39	0.03
Iron	11	2.3	1.8	0.5	0.48
Manganese	7	0.16	0.13	0.03	0.93

[1]The Wilcoxon signed-ranks test (two-sided) was used to test the hypothesis that the two groups of samples are from the same population. It is a test on the paired seasonal samples.

[2]Sample size is too small to compute significance level.

Table 15.--*Discharge measured at time of surface-water sampling, Long Beach Peninsula, Washington*

[<, less than; ft^3/s, cubic feet per second]

Site number	Name	Date	Discharge (ft^3/s)
2	Unnamed drainage channel near Stackpole Road	02-11-92	1.0
8	Whiskey Slough (upper part)	02-11-92	2.9
		07-30-92	<0.1
9	Whiskey Slough (lower part)	02-12-92	13
12	Loomis Lake drainage (lower part)	02-11-92	8.5
		07-29-92	<0.1
14	Loomis Lake drainage (upper part)	02-11-92	3.0
		07-29-92	<0.1
18	Litschke Road drainage	02-10-92	4.4
		07-30-92	<0.1
20	Giles Slough	02-10-92	6.7
		07-30-92	<0.1
22	Gile Lake drainage	02-12-92	1.3
		07-28-92	<0.1
23	East Main drainage (lower part)	02-12-92	21
		07-27-92	0.9
25	Tarlatt Slough (lower part)	02-12-92	2
		07-27-92	<0.1
27	Tarlatt Slough (middle part)	02-13-92	1.2
		07-27-92	0.2
28	South Main drainage	02-13-92	2.1
		07-28-92	<0.1
29	Tarlatt Slough (upper part)	02-13-92	3.1
		07-28-92	<0.1

Natural Water-Quality Conditions

Natural concentrations of several constituents may cause water-quality problems if their presence prevents or restricts the use of the water. The natural concentration of a constituent is that which occurs in areas unaffected by human activities. The natural ground-water quality on the Long Beach Peninsula is difficult to define because of the prevalence of human activities such as agriculture or waste disposal through septic systems. Of the 40 wells sampled, only five are located in areas of low population density and in areas away from agricultural activity. In addition, the natural variations of some chemical characteristics of ground water can be large.

The principal natural water-quality problem identified on the Long Beach Peninsula was high concentrations of dissolved iron and manganese. About 30 percent of the shallow ground-water samples had concentrations of dissolved iron and manganese that exceeded the USEPA SMCL's of 0.3 mg/L for iron and 0.05 mg/L for manganese. A useful indicator of the concentrations of these constituents is the soil type overlying the ground water (table 16). Dissolved iron and manganese concentrations were much higher under the Seastrand and Yaquina soils than under the Netarts or Westport soils. All ground-water samples collected from under the Seastrand soils and 50 percent of the samples from under the Yaquina soils had dissolved-iron concentrations exceeding the USEPA SMCL, whereas less than 10 percent of the samples from under the Netarts and Westport soils exceeded the SMCL for iron. An important factor in this relation is the oxidizing or reducing condition of the ground water. Ground waters under the Seastrand and Yaquina soils typically had lower dissolved-oxygen concentrations than under the Netarts and Westport soils.

A minor natural water-quality problem identified on the peninsula was low values of pH. About two-thirds of the shallow ground-water samples had pH values that were less than the lower USEPA SMCL of 6.5. No areal pattern was apparent in the distribution of pH values in shallow ground water, and there was no relation between pH and the overlying soil type.

Table 16.--*Comparison between soils and selected chemical characteristics of shallow ground water in July 1992, Long Beach Peninsula, Washington*

[(N), indicates number of samples; $CaCO_3$, calcium carbonate; µS/cm, microsiemens per centimeter at 25 degrees Celsius; <, less than; --, not available]

Constituent or property	Median concentration, in milligrams per liter							
	Seastrand	(N)	Yaquina	(N)	Netarts	(N)	Westport	(N)
Specific conductance, in µS/cm	122	4	124	10	134	21	175	4
pH, in standard units	6.4	4	6.4	10	6.3	21	6.2	4
Dissolved oxygen	<0.1	4	1.1	10	4.4	21	1.2	4
Nitrate	<0.01	3	<0.01	10	<0.01	21	<0.01	4
Nitrate	<0.05	3	0.06	10	0.62	21	0.66	4
Ammonia	0.15	3	0.06	10	0.01	21	<0.01	4
Orthophosphate	0.13	3	0.02	10	<0.01	21	0.02	4
Dissolved organic carbon	4.9	1	5.1	6	4.4	11	6.0	2
Boron	0.020	1	0.020	6	0.020	11	0.015	2
Methylene blue active substance (MBAS)	--	0	0.02	6	<0.01	11	0.03	2
Calcium	5.3	3	5.3	6	5.7	13	8.0	3
Magnesium	2.6	3	4.1	6	3.2	13	8.6	3
Sodium	7.9	3	9.9	6	14	13	12	3
Potassium	1.1	3	2.3	6	0.90	13	3.0	3
Bicarbonate	53	3	43	5	24	12	58	2
Alkalinity, as $CaCO_3$	43	3	35	5	20	12	47	2
Sulfate	2.3	3	3.6	6	6.1	13	8.7	3
Chloride	12	4	13	10	19	21	18	4
Silica	28	3	30	6	23	13	27	3
Total dissolved solids	74	2	111	6	90	13	129	3
Iron	9.2	4	2.4	10	0.011	21	0.015	4
Manganese	0.068	3	0.076	6	<0.001	13	0.029	3

Seawater Intrusion

Seawater intrusion, which is the movement of saltwater into a freshwater aquifer, can be a water-quality problem. In addition to raising the concentrations of sodium and chloride, intrusion can also lead to increased concentrations of calcium, magnesium, potassium, sulfate, barium, and some trace elements. Seawater intrusion can be caused by decreased ground-water recharge or increased ground-water discharge. Lower-than-average precipitation over several years could cause a decrease in recharge, but the most common cause of seawater intrusion is from increased discharge by a human-induced stress such as ground-water withdrawals.

Fresh ground water in the Long Beach Peninsula is surrounded by saltwater: by the Pacific Ocean on the west, by Willapa Bay on the east, and by saltwater underneath the freshwater lens. The relation between fresh ground water and saltwater is explained in the section titled "Boundaries", and a simplified picture of the relation is shown on figure 12. Thus, the natural condition of the aquifer is to be surrounded by saltwater, and seawater intrusion will always be a concern.

The extent of seawater intrusion can be determined by measuring the chloride concentration of the ground water. Chloride is chemically stable and it moves through an aquifer at virtually the same rate as the intruding seawater. The typical chloride concentration of seawater is about 19,000 mg/L (Hem, 1989, p. 7). Chloride concentrations above 50 mg/L are a general indication that some seawater intrusion has occurred (Walters, 1971, p. 13).

As of 1992, no appreciable amount of seawater has intruded into the sand aquifer of the Long Beach Peninsula. The samples of shallow ground water collected in February and July 1992 had a median chloride concentration of 14 mg/L and a maximum concentration of 52 mg/L. Only six samples had concentrations above 30 mg/L.

In most areas of the peninsula, the water-level altitudes of the freshwater aquifer remain relatively high for the entire year; the high water levels help to prevent seawater intrusion. During 1992, the ground-water divide ranged from an average altitude of about 14 ft in winter to about 10 ft in summer. The heavy average annual precipitation of about 80 in., the large average annual ground-water recharge of about 58 in. or 111,000 acre-ft, and a small ground-water withdrawal rate (about 780 acre-ft in 1992) combine to maintain a thick freshwater lens of ground water throughout the year.

The areas of the peninsula where freshwater levels are low enough to be of concern are within a few hundred feet of the Pacific Ocean or Willapa Bay, and near the lower part of Tarlatt Slough (fig. 17). In these areas, ground water altitudes in a few wells were measured at less than 2.5 ft in the summer of 1992. The area of low water levels near lower Tarlatt Slough is defined by the area inside the perimeter of a line connecting wells 115, 116, 120, and 121 (fig. 9). Depth to saltwater in the summer is probably less than 100 ft in these areas, and sustained pumping of ground water could cause seawater intrusion.

Agricultural Activities

Water-quality problems that may be caused by agricultural activities include elevated nutrient concentrations, the presence of pesticides and associated compounds, and the presence of bacteria. Many activities associated with agriculture can introduce chemicals to the ground water. Fertilizers are applied to soils and plants to promote growth, and pesticides are applied to inhibit the growth of undesirable plants or pests such as insects. Ideally, the fertilizers or pesticides are applied in optimum amounts such that the plants and soils will absorb all of the applied material. However, it is usually difficult to determine the optimum plant requirements or soil absorptive capacity. Excessive amounts of fertilizers or pesticides are sometimes applied and the excess amount either is carried by surface water to streams or lakes or it percolates to the ground-water system.

Fertilizers commonly consist of mixtures of nitrogen, phosphorus, and potassium. Dissolved forms of nitrogen include ammonia, nitrite, and nitrate. Under most conditions, ammonia is either strongly sorbed to soil material or is converted to nitrate in the process of nitrification. Thus, most of the dissolved nitrogen in ground water is in the form of nitrate. The amount of phosphorous and potassium in fertilizers is usually much smaller than nitrogen, and dissolved forms of phosphorous and potassium are not nearly as mobile as nitrate. Therefore, phosphorus and potassium from fertilizers usually do not contribute to ground-water-quality problems to nearly the extent as nitrogen.

Cranberry growing is the principal agricultural activity on the Long Beach Peninsula. A smaller localized activity is the growing of lawns and vegetable gardens by individual homeowners. Excessive application of fertilizers and pesticides in these activities is a common source of water-quality problems. The cattle that graze in a few small parts of the peninsula are another potential source of problems. Ground waters in areas of grazing cattle can become contaminated by nitrates and bacteria from animal-waste products.

The possible contamination of ground water by activities associated with cranberry growing was statistically tested by comparing concentrations of selected constituents in ground water to the distance of the sampled wells to cranberry fields. Sampled wells were placed into two groups, based on distance from a cranberry field and relation to direction of ground-water flow. The following distance criteria were used: wells that were within 1,500 ft of a cranberry field and downgradient of ground-water flow were classified as "close" to a field; wells that were more than 1,500 ft away or up-gradient of a field were classified as "far" from a field. The differences in chemical characteristics of those two groups were compared (table 17). A nonparametric rank-sum test was made to determine if the two samples were from the same population.

Cranberry growing does not appear to have appreciably affected the quality of ground water on the Long Beach Peninsula. The concentration of nitrate in shallow ground water was not significantly higher near cranberry-growing areas, and no samples of ground water had concentrations of selected pesticides or associated compounds that were above the analytical detection limits. The concentrations of ammonia and orthophosphate, both constituents of fertilizers, were significantly higher in ground-water samples close to cranberry fields. The concentrations, however, were low and are not a major water-quality problem.

The concentrations of dissolved oxygen, iron, and manganese were significantly related to distance from the cranberry fields. These constituents, however, are not commonly associated with agricultural activities. The apparent relations probably are not a result of cranberry growing, but are related to the sampling design and the oxidizing or reducing conditions of the ground water. Such conditions are indicated by the soils overlying the ground water. Ground water under Seastrand and Yaquina soils commonly had reducing conditions and naturally higher concentrations of iron and manganese and lower concentrations of dissolved oxygen than ground water under Netarts or Westport soils (table 16). Fifty percent of the wells selected for sampling in areas close to cranberry fields are beneath Seastrand or Yaquina soils; only 27 percent of the wells in areas far from cranberry fields are beneath those soils.

Bacteria are often related to animal-waste material. Thus, dairies, feedlots, or other activities that restrict a large number of animals to a small area can create conditions favorable for the growth of bacteria. Bacteria can multiply to large concentrations in soils and can contaminate surface-water runoff from areas with animal-waste material. However, bacteria are uncommon in ground water because soils act as filters and because ground-water conditions in general are not favorable for the growth of bacteria. Concentrations of fecal coliform bacteria as large as 750 col/100 mL were found in surface-water drainage channels (table 27 at the end of the report), but bacteria were found in only seven wells and in relatively small concentrations. Only one of these wells (well 114) was located in an area where cattle graze. The sources of contamination in the other six wells do not appear to be related to agricultural activities.

Table 17.--*Comparison between distance from cranberry fields and selected chemical characteristics of shallow ground water in July 1992, Long Beach Peninsula, Washington*

[(N), indicates number of samples; $CaCO_3$, calcium carbonate; <, less than; --, sample size is too small to compute significance level]

Constituent	Median concentrations (milligrams per liter) Close[1]	(N)	Far[2]	(N)	Significance level[3]
Dissolved oxygen	0.2	14	4.3	26	<0.01
Nitrate	<0.05	14	0.46	25	0.12
Ammonia	0.12	14	0.01	25	<0.01
Orthophosphate	0.02	14	0.01	25	0.03
Dissolved organic carbon	4.6	2	4.8	18	--
Boron	20	2	20	18	--
Methylene blue active substance (MBAS)	0.02	2	<0.01	17	--
Calcium	6.0	9	5.8	16	0.27
Magnesium	4.1	9	3.2	16	0.26
Sodium	12	9	12	16	0.75
Potassium	1.2	9	1.3	16	1.00
Bicarbonate	36	8	29	14	0.97
Alkalinity, as $CaCO_3$	30	8	24	14	0.92
Sulfate	5.6	9	5.6	16	0.57
Chloride	14	14	16	26	0.92
Silica	23	9	23	16	0.24
Total dissolved solids	108	8	92	16	0.28
Iron	4.2	14	0.012	26	<0.01
Manganese	0.062	9	<0.001	16	0.03

[1]Close to a field, the well is less than 1,500 feet from a field and downgradient of ground-water flow.

[2]Far from a field, the well is greater than 1,500 feet or upgradient of ground-water flow.

[3]A rank-sum nonparametric test (two-sided) was used to test the hypothesis that the two groups of samples are from the same population.

Septic Systems

A septic system, consisting of a septic tank and drainfield, can be the source of several constituents in ground water. The most familiar of these is nitrate, but others include bacteria, sodium, potassium, sulfate, chloride, phosphorous, ammonia, dissolved organic carbon, boron, and MBAS (Canter and Knox, 1985, p. 45-59).

In the operation of a septic system, household sewage is piped into a tank. Solids settle to the bottom of the tank and liquids discharge to a drainfield, which consists of perforated pipe in one or several subsurface trenches filled with permeable material such as sand or gravel. The effluent from the drainfield infiltrates the natural soil or geologic formation and flows down through the unsaturated zone. If the volume of effluent is large enough, it may reach the water table. In the unsaturated zone, the individual constituents in the effluent are subject to physical, chemical, and biological transformations. Urea is transformed by bacteria to ammonia and eventually to nitrate. Nitrate and chloride usually do not react with other constituents, and they flow through the unsaturated material at virtually the same rate as water. Sodium, potassium, sulfate, MBAS, and other constituents, however, may undergo sorption, ion exchange, or degradation reactions in the unsaturated zone that can hinder their transport to the water table.

A properly working septic system allows the solid sewage to settle in the tank and the liquid sewage to slowly move into the surrounding soil or geologic formation. An improperly working system, however, allows the sewage effluent to move to the water table before the constituents have had the opportunity to be transformed or consumed. Factors that may cause a septic system not to work properly are (1) a tank that is too full of material so the settling of solids does not occur, (2) a soil or geologic formation with such a high permeability that water moves too quickly to the water table and natural transformations or degradations do not have sufficient time to occur, and (3) a water table that is too close to the drainfield, which causes the same problem as stated in number (2).

The most common water-quality problems from failed septic systems are elevated nitrate concentrations and the presence of bacteria (Canter and Knox, 1985, p. 59). The presence of septage-related compounds (dissolved organic carbon, boron, and MBAS) in ground water can also be indicative of failing septic systems.

The possible contamination of ground water by septic-system effluent was tested statistically by comparing concentrations of selected constituents in ground water to population density. As densities of septic systems were not available, population density was used as a surrogate for septic-system density. Accordingly, the concentrations of nutrients, septage-related compounds, and other selected constituents of the ground water in July 1992 were compared to three classes of population density (table 18). Samples from the wells were placed into three groups of population density: low density was less than 0.3 person per acre, medium density was 0.3 to 1 person per acre, and high density was greater than 1 person per acre. Samples from three wells in the sewered area of the city of Long Beach were not used in this analysis. The density for each sampled well was determined by drawing a circle with a radius of 300 ft around the well. The area of this circle was then intersected with the population density in the census blocks for 1990. A nonparametric Kruskal-Wallis test (two-sided) was made to determine if the three groups of samples were from the same population.

Septic systems probably caused an increase in the concentration of nitrate in shallow ground water in areas of higher population density. Concentrations of nitrate in July 1992 were significantly related to population density (table 18). However, the concentrations were not generally high; median concentrations of nitrate were less than 0.05, 0.72, and 0.74 mg/L in areas of low, medium, and high population density, respectively. The percentage of samples with elevated concentrations, considered to be higher than 2.0 mg/L (Carey and Yake, 1990, p. 20), was only 6 percent in areas of low population density but 30 percent in areas of high density. The number of samples analyzed for septage-related compounds (dissolved organic carbon, boron, and MBAS) was too small for a statistical test. However, it appears that concentrations of these constituents were not related to population density.

The areal distribution of nitrate concentrations was variable, but there appeared to be a pattern of increased nitrate concentrations in the areas of high population density (figs. 3 and 35, and table 18). The three classes of nitrate concentrations shown on figure 35 conform to a rough classification of essentially background levels (less than 0.5 mg/L), moderately elevated levels (from 0.5 to 2.0 mg/L), and elevated levels (greater than 2.0 mg/L; Carey and Yake, 1990, p. 20). Fifteen percent of all the samples were in the elevated level class. The reason for the areal variability of nitrate concentrations in areas of similar population density is not known. Possibly, some septic systems function more efficiently than others, or other factors such as the use of fertilizers on homeowners' lawns and gardens may be involved.

Other constituents besides nitrate whose concentrations were significantly related to population density are dissolved oxygen, ammonia, and iron (table 18). These significant relations were not expected. Ammonia is part of the effluent of septic systems, but the concentration of ammonia decreased with increased population density. Dissolved oxygen and iron are not commonly associated with ground-water contamination from septic-system effluent (Canter and Knox, 1985, p. 45-59). The apparent relation between these constituents and population density is probably not a result of septic systems, but is related to the sampling design and the oxidizing or reducing conditions of the ground water. Such conditions are indicated by the soils overlying the ground water. Ground water under Seastrand and Yaquina soils commonly had naturally higher concentrations of ammonia and iron and lower concentrations of dissolved oxygen than ground water under Netarts or Westport soils (table 16). Fifty-six percent of the wells selected for sampling in areas of low population density are beneath Seastrand or Yaquina soils, and only 10 percent of the wells in areas of high population density are beneath those soils.

Septic systems have not caused regional problems of bacterial contamination of the shallow ground water. Colonies of bacteria were found in samples from only seven wells. Two of those samples were from wells 29 and 107 that are close to septic systems; however, the second seasonal sample at both sites had no detected bacteria. In addition, well 107 has another possible source of bacteria; the well is located about 150 ft from East Main drainage channel, which carries the treated sewage from the city of Long Beach.

Table 18.--*Comparison between population density and selected chemical characteristics of shallow ground water in July 1992, Long Beach Peninsula, Washington*

[(N), indicates number of samples; $CaCO_3$, calcium carbonate; --, sample size is too small to compute significance level; <, less than]

Constituent	Median concentration, in milligrams per liter						Significance level[4]
	Low[1]	(N)	Medium[2]	(N)	High[3]	(N)	
Dissolved oxygen	0.2	16	6.8	11	3.8	10	0.01
Nitrate	<0.05	16	0.72	11	0.74	10	0.02
Ammonia	0.10	16	0.01	11	0.01	10	0.01
Orthophosphate	0.02	16	0.01	11	0.01	10	0.10
Dissolved organic carbon	4.4	3	4.8	7	5.2	8	--
Boron	0.020	3	0.13	7	0.020	8	--
Methylene blue active substance (MBAS)	<0.01	3	0.02	7	<0.01	8	--
Calcium	6.1	12	5.0	6	5.8	5	--
Magnesium	3.4	12	3.9	6	3.2	5	--
Sodium	13	12	12	6	13	5	--
Potassium	1.0	12	2.0	6	0.9	5	---
Bicarbonate	36	10	23	5	29	5	--
Alkalinity, as $CaCO_3$	30	10	19	5	24	5	--
Sulfate	4.4	12	6.2	6	6.1	5	--
Chloride	18	16	14	11	15	10	0.85
Silica	23	12	20	6	23	5	--
Total dissolved solids	92	11	95	6	84	5	--
Iron	4.2	16	0.010	11	0.016	10	0.01
Manganese	0.055	12	0.002	6	<0.001	5	--

[1]Low density is less than 0.3 person per acre. Density was determined using a circle with a radius of 300 feet around the well and 1990 census blocks. See text for detailed explanation.

[2]Medium density is 0.3 to 1 person per acre.

[3]High density is greater than 1 person per acre.

[4]A Kruskal-Wallis nonparametric test (two-sided) was used to test the hypothesis that all three groups of samples are from the same population.

Long-Term Changes in Ground-Water Quality

The population of the Long Beach Peninsula has been steadily increasing over the past 20 years, and there is concern that the associated activities may have affected the ground-water quality. Because only a limited amount of historical water-quality data is available for the peninsula, it is difficult to assess any possible long-term changes. From 1968-92, chloride concentrations appear to have decreased slightly and values of specific conductance have remained stable. From 1987-92, it appears that nitrate concentrations have not changed. Other historical water-quality data are insufficient to assess long-term changes.

Water samples collected from 15 wells in 1975 were analyzed for dissolved solids, iron, and nitrate (Tracy, 1978). Although these ground-water samples were not sufficient to describe the conditions for the entire peninsula, Tracy concluded that no large problems existed with respect to seawater intrusion or elevated nitrate concentrations. A problem of naturally high iron concentrations also was mentioned by Tracy (1978, p. 29).

No appreciable amount of seawater has intruded into the sand aquifer in the past 25 years. Four studies have investigated possible seawater intrusion by analyzing ground-water samples for specific conductance and chloride (table 19). A Kruskal-Wallis test (two-sided) was made on the four groups of historical specific conductance and chloride data. These data are from different wells, therefore, in addition to time, other factors such as location of the wells and seasonal variation may also influence the differences in concentrations among the groups. The median values of specific conductance are not significantly different for samples of water collected in 1968, 1978, 1987, and 1992. The median concentrations of chloride for those samples, however, are significantly different, and the concentrations are lower in the more recent samples. The percentage of samples with chloride concentrations greater than 50 mg/L has changed from about 12 percent in 1968 to 11 percent in 1978 to about 3 percent in 1987 and 1992 (Walters, 1971; Dion and Sumioka, 1984; and Carey and Yake, 1990). The reason for the lower chloride concentrations in 1987 and 1992 than in 1968 and 1978 is probably because more of the earlier samples were collected closer to the Pacific Ocean or Willapa Bay where salt spray can cause an increase in chloride concentration. About 80 percent of the samples in 1968 and 1978 and about 40 percent of the samples in 1987 and 1992 were within 2,000 ft of a coastline.

The concentrations of nitrate and chloride in the sand aquifer do not appear to have changed between 1987 and 1992. A study by Carey and Yake (1990) in 1987-88 found median concentrations of 1.38 mg/L for nitrate and 18 mg/L for chloride in samples from 36 wells. These nitrate and chloride concentrations cannot be directly compared with those measured in this study because most of the sampled wells are different and different geographic areas were covered. The best comparison can be made by selecting wells from this study that are in the same geographic area as those selected by Carey and Yake (1990), which is south of Oysterville Road and north of Cranberry Road (fig. 9). Twenty-seven wells in this study are located in that common area, and the median concentrations of the samples collected in July 1992 were 0.56 mg/L for nitrate and 19 mg/L for chloride. A two-sided rank-sum test shows no significant difference in nitrate and chloride concentrations between the 1987-88 samples and the 1992 samples.

Table 19.--*Summary of specific-conductance values and chloride concentrations of shallow ground water from 1968 to 1992, Long Beach Peninsula, Washington*

[(N), number of samples; µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter]

Constituent or property	Median value for samples collected in summer of							
	[1]1968	(N)	[2]1978	(N)	[3]1987	(N)	[4]1992	(N)
Specific conductance, in µS/cm	150	41	168	52	142	28	134	40
Chloride, in mg/L	21	41	23	52	16	22	15	40

[1]Walters (1971).
[2]Dion and Sumioka (1984).
[3]Carey and Yake (1990).
[4]This study.

ADDITIONAL DATA AND STUDIES

Additional data and studies would provide a better understanding of ground-water flow and water quality in the sand aquifer of Long Beach Peninsula. Components of the ground- water system that are currently uncertain include the lower boundaries of the ground-water system, possible confining beds within the system, storage properties of the sand aquifer, altitude and frequency of occurrence of high ground-water levels, the relation between cranberry growing and ground-water quality, and the relation between septic-system effluent and ground-water quality.

The position of the lower boundary of the ground-water system, which is the freshwater-seawater interface in most areas, is uncertain. The Ghyben-Herzberg principle can be used only to make an approximate estimate because of the heterogeneity of the unconsolidated deposits. Chloride concentrations of water samples from existing and new deep wells, both static and after pumping, would help define this boundary.

Within the ground-water system, several local lenses of silt and clay may act as confining beds, but the available information is not sufficient to determine if there is a confining bed that extends throughout the peninsula. More information on the lithology of the unconsolidated deposits that are more than 50 ft below land surface could be obtained from lithologic logs of new deep wells and from geophysical surveys.

The storage properties of the sand aquifer are uncertain. The storage properties and hydraulic conductivity are important for assessing the volume of ground water available for development. Aquifer tests could define storage properties and help confirm or refine the estimates of hydraulic conductivity made from slug tests in this study.

The high ground-water levels that occur in some winters are a concern for siting septic systems and for dealing with local flooding of basements. Information on the altitude and frequency of occurrence of high ground-water levels would facilitate the management of land use. A monitoring network of wells spread throughout the peninsula could provide this information if water levels were measured bimonthly for March-November and monthly for December-February on a long-term basis, possibly tens of years. The water-level data could be used to develop equations for predicting ground-water levels on the basis of cumulative precipitation. The high water levels in the winter could be used to develop relations between ground-water altitudes and frequency of occurrence. An additional benefit of this monitoring network would be to detect any long-term decline of water levels caused by ground-water withdrawals.

Fertilizers and pesticides are used to improve the yield of cranberries on the commercial farms of the peninsula. No appreciable contamination of nutrients or pesticides was found in ground water near cranberry farms in this study; however, only a few of the pesticides that are currently used were analyzed in this study. Samples of ground water and surface water could be analyzed for the pesticides that were not analyzed in this study to determine if they posed a water-quality concern.

Contamination of ground water by septic-system effluent is a concern because of the shallow ground water and the increasing population. In the ground-water samples collected in this study, a significant relation was found between population density and nitrate concentration. Nitrate concentrations were significantly higher in areas of high population density. The concentrations were still variable, however, and additional data on the sources of nitrate could be used to investigate this variability. A survey of septic systems to investigate possible failures and a survey of fertilizer use by residents could help define the source and variability of nitrate concentrations. In addition to information on sources of nitrate, a water-quality monitoring program could be established to investigate the variability of nitrate concentrations and to provide information on possible future degradation of ground-water quality. Ground-water samples from a denser network of wells in areas of medium- and high-population density would be useful. An annual sampling program could be established to monitor any future contamination. An analysis of samples for bacteria, nitrate, and chloride could detect contamination from septic systems.

SUMMARY AND CONCLUSIONS

The study described in this report was undertaken to improve the understanding of ground-water flow and water quality in the sand aquifer of the Long Beach Peninsula. The peninsula is a narrow strip of land extending northward from the mouth of the Columbia River in the southwestern corner of the State of Washington. It is surrounded by seawater, by the Pacific Ocean on the west and Willapa Bay on the east. Water supplies on the peninsula are derived mostly from a local water-table aquifer composed largely of sand.

The recent growth of population on the peninsula and the projected future growth have created concerns about the quantity and quality of the ground-water resource. Some issues include declining ground-water levels from increased pumping and ground-water contamination from seawater intrusion, pesticides or fertilizers from cranberry-growing areas, and septic-system effluent.

Ground-water flow in the sand aquifer was defined in this study by determining ground-water flow directions, seasonal fluctuations of the water table, flow directions between ground water and surface water, historical trends in water levels, and relations between precipitation and water levels. Water quality of the sand aquifer was defined by determining the general chemical characteristics of both ground and surface waters. Areas of possible contamination and historical trends in water quality also were investigated.

The Long Beach Peninsula was formed by the transport and deposition of sediment by ocean and longshore currents along the coast of Oregon and Washington. The sediment is mostly sand with some gravel, silt, and clay. The thickness of these deposits increases from about 200 ft in the southern end of the peninsula to more than 1,000 ft at the northern end. The ground-water system consists of a sand aquifer with some lenses of slit or clay that may act as confining beds in local areas of the peninsula. Data are lacking or inconsistent to define a confining bed that extends throughout the peninsula. The lateral and lower external boundaries of the ground-water system are at a freshwater-saltwater interface and the freshwater occurs as a lens-shaped body over the saltwater.

To help define the ground-water flow system, an observation network was established of 97 wells less than 50 ft deep, 7 wells greater than 50 ft deep, and 28 surface-water sites. The surface-water sites consisted of 14 lakes and 14 drainage channels. Water levels were measured monthly at these sites for about 1 year, and monthly measurements were made in about one-half of the sites for an additional half year.

To estimate the hydraulic conductivity of the shallow aquifer, slug tests were made in 58 shallow wells that are located throughout the peninsula. The distribution of the estimates of hydraulic conductivity is statistically normal, with a range of 10 to 37 feet per day (ft/d) and a median of 22 ft/d.

Average annual ground-water recharge by infiltration and percolation of precipitation is estimated to be about 58 inches, or 111,000 acre-feet. Average annual ground-water discharge is estimated to be about 30,200 acre-feet to the Pacific Ocean, 56,000 acre-feet to Willapa Bay, and 24,800 acre-feet to surface-water drainage channels.

Ground-water movement is generally perpendicular to the spine of the peninsula. A ground-water divide exists along a north-south line, and ground water flows west or east from the divide toward the Pacific Ocean or Willapa Bay. In addition to the movement toward the ocean or bay, ground water also moves toward and discharges into several of the surface-water drainage channels that are located primarily on the east side of the peninsula.

Ground-water levels fluctuate over time because of the variations in recharge and discharge over time. In 1992 the median seasonal change in water levels for all wells was 4.4 ft. There does not appear to have been any long-term decline of the water table of the sand aquifer from 1974-92. Ground-water levels measured at three east-west cross sections in 1992 were at about the same altitudes as water levels measured in 1974-75.

A regression analysis was made to determine the significance of the relation between ground-water altitude as a response variable and precipitation as an explanatory variable. The most accurate relation was obtained using cumulative precipitation for the previous 4 months as the explanatory variable. Relatively accurate individual relations were developed at 45 wells; the standard error of estimate ranged from 0.16 to 1.09 feet with an average error of about 0.63 feet, which is less than 10 percent of the mean water-level altitude at each site. However, an accurate relation could not be developed for estimating ground-water levels anywhere on the peninsula. Using a multiple-regression analysis based on cumulative precipitation, soil type, side of peninsula, and distance from centerline of peninsula as explanatory variables resulted in a standard error of estimate of 2.0 feet.

Empirical frequency or probability relations for precipitation and ground-water levels can be used to place the water levels measured in this study in perspective, which allows one to estimate how often these water levels would be expected to occur in the future. These water levels reflected the lower-than-average precipitation that occurred during the study. Assuming that annual maximum precipitation for 4 consecutive months is random and independent, that the historical record of precipitation is representative of the future distribution of precipitation, and that the relation between precipitation and water levels is accurate and stationary, a probability analysis of the historical record indicates that in any one year in the future there is a probability of 70 percent that the maximum water levels measured in wells during the winter of 1991-92 would be equaled or exceeded. From another perspective, in the next 10 years one would expect that the annual maximum ground-water levels would be lower in 3 of the years and higher in 7 of the years.

To describe the quality of shallow ground water, water samples were collected from about 40 wells and 13 surface-water sites in February and July 1992. Analyses were made of general chemical characteristics such as pH, dissolved oxygen, major ions, and alkalinity. To evaluate possible contamination of the water, analyses were also made for nutrients, bacteria, septage-related compounds, and selected pesticides.

The shallow ground water had generally low dissolved-solids concentrations in July 1992 with a median concentration of 92 milligrams per liter (mg/L) and a range of 56 to 218 mg/L. Sodium was the dominant cation and bicarbonate was the dominant anion. With respect to hardness, most (84 percent) of the samples were soft and the remaining samples (16 percent) were moderately hard.

The water quality of the shallow ground water was generally good with a few small to moderate problems. A natural problem is locally high concentrations of dissolved iron. About 30 percent of the water samples had dissolved-iron concentrations greater than 0.3 mg/L, which is the secondary maximum contaminant level established by the U.S. Environmental Protection Agency. This level is based on aesthetic qualities where the taste of the water can become objectionable and precipitates can form that can stain laundry and plumbing fixtures.

Potential human-related sources of contamination of ground water in the Long Beach Peninsula are seawater intrusion caused by ground-water withdrawals, agricultural activities—primarily cranberry growing, and sewage effluent from septic systems. No large problems of ground-water contamination were found; however, a few small to moderate problems were found and each of the three stated sources merits a brief discussion.

Although no appreciable amount of seawater has intruded into the sand aquifer of the Long Beach Peninsula, seawater intrusion will always be a concern because the fresh ground water on the peninsula is surrounded by seawater. Seawater intrusion was investigated by measuring the concentration of chloride in ground-water samples throughout the peninsula. The samples of shallow ground water collected in July 1992 had a median chloride concentration of 15 mg/L and a maximum concentration of 52 mg/L. The heavy average annual precipitation of about 80 inches, large average annual ground-water recharge of about 58 inches, or 111,000 acre-ft, and small ground-water withdrawal rate (about 780 acre-ft/yr in 1992) combines to maintain a thick freshwater lens of ground water throughout the year.

Agricultural activities do not appear to have appreciably affected the quality of shallow ground water on the Long Beach Peninsula. The concentration of nitrate in ground water was not significantly higher near cranberry-growing areas, and no samples of ground water or surface water had concentrations of selected pesticides or associated compounds that were above the analytical detection limits. The concentrations of ammonia and orthophosphate were slightly higher in ground-water samples close to cranberry fields; however, the concentrations were low and are not a major water-quality problem. Of the seven ground-water samples in which bacteria were detected, only one sample appeared to be related to agriculture; that sample was from a well located in an area where cattle graze periodically.

Septic systems probably caused an increase in the concentration of nitrate in shallow ground water in areas of higher population density. Concentrations of nitrate in July 1992 were significantly related to population density. However, the concentrations were not generally high; median concentrations of nitrate were less than 0.05, 0.72, and 0.74 mg/L in areas of low, medium, and high population density, respectively. The number of samples with elevated concentrations, considered to be greater than 2.0 mg/L, increased from 6 percent in areas of low population density to 30 percent in areas of high density. Septic systems did not cause regional problems of bacterial contamination of the ground water. Of the seven ground-water samples that had bacteria detected, only two were from wells that are close to septic systems.

The population of the Long Beach Peninsula has been steadily increasing over the past 20 years, so there is concern that the associated activities may have affected the ground-water quality. A limited amount of historical water-quality data is available for the peninsula; therefore, it is difficult to assess long-term changes. From 1968-92, chloride concentrations and values of specific conductance appear to have remained stable. From 1987-92, it appears that nitrate concentrations have not changed. Historical water-quality data are insufficient to assess other long-term changes.

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Table 20.--*Description of wells, Long Beach Peninsula, Washington*

[Net, Netarts fine sand; Oco, Ocosta silty clay loam; Sea, Seastrand peat or muck; Wes, Westport fine sand; Yaq, Yaquina loamy fine sand; Use of well, A, abandoned; C, commercial; D, domestic; I, irrigation; O, observation of water levels; P, public supply; Construction, C, cable; D, driven; J, jetting; and R, rotary; Owner, PC, Pacific County; PR, private; US, U.S. Geological Survey; WA, Washington State Department of Ecology; ft/d, feet per day; <, less than; --, not available]

Well number	Well location	Altitude of land surface (feet)	Depth (feet)	Soil type	Hydraulic conductivity (ft/d)	Use of well	Construction	Water-quality sample	Owner
1	13N/11W-29G01	21.24	20.3	Wes	--	O	D	No	US
2	13N/11W-29H01	17.52	13.5	Wes	--	O	D	No	US
3	13N/11W-28E01	18.54	14.0	Net	--	O	D	No	US
4	13N/11W-28F01	14.46	10.8	Yaq	--	O	D	No	US
5	13N/11W-28G01	12.54	10.9	Net	--	O	D	No	US
6	13N/11W-27E01	9.23	18.0	Yaq	32	O	J	No	PC
7	13N/11W-33K01	20	4,035	Net	--	A	--	No	PR
8	12N/11W-05H01	16.67	27.0	Wes	--	O	J	No	PR
9	12N/11W-09D01	19.90	15.0	Net	--	O	D	No	US
10	12N/11W-04P01	17.79	15.5	Yaq	20	O	J	Yes	PC
11	12N/11W-04P02	17.81	37.9	Yaq	33	O	J	Yes	PC
12	12N/11W-04R02	26.72	28.0	Net	21	O	J	No	PC
13	12N/11W-09E01	16.05	18.0	Net	32	O	J	No	PC
14	12N/11W-09E05	15	360	Oco	--	A	R	No	PR
15	12N/11W-08R01	15.99	15.0	Wes	--	O	D	No	US
16	12N/11W-08R02	34.65	28.2	Wes	30	O	J	No	PC
17	12N/11W-09N01	18.26	18.0	Yaq	30	O	J	Yes	PR
18	12N/11W-09P01	16.01	11.2	Yaq	--	O	D	No	US
19	12N/11W-09Q01	17.64	18.0	Yaq	24	O	J	No	PC
20	12N/11W-38E01	26.77	28.0	Net	21	O	J	No	PC
21	12N/11W-38F01	16.38	15.0	Net	--	O	D	No	US
22	12N/11W-17A03	16.38	30.0	Wes	--	O	J	No	PR
23	12N/11W-17A05	25	227	Wes	--	C	C	No	PR
24	12N/11W-16E03	19.02	18.0	Net	19	O	J	Yes	PC
25	12N/11W-38P01	14.70	15.0	Net	--	O	D	No	US
26	12N/11W-16M01	19.01	11.0	Wes	--	O	--	No	WA
27	12N/11W-16Q02	18.77	18.0	Yaq	22	O	J	No	PC
28	12N/11W-16Q01	14.56	18.0	Net	27	O	J	Yes	PC
29	12N/11W-20A02	--	24.0	Wes	--	D	J	Yes	PR
30	12N/11W-21E02	17.78	14.7	Net	--	O	D	No	US
31	12N/11W-21G01	22.42	22.7	Net	16	O	J	No	PC
32	12N/11W-22E03	8.80	17.6	Net	21	O	J	Yes	PC
33	12N/11W-21P02	--	20.0	Net	--	D	J	Yes	PR
34	12N/11W-28E01	20.40	23.0	Net	32	O	J	Yes	PC

Well number	Well location	Altitude of land surface (feet)	Depth (feet)	Soil type	Hydraulic conductivity (ft/d)	Use of well	Construction	Water-quality sample	Owner
35	12N/11W-28L01	--	25.0	Net	--	D	J	Yes	PR
36	12N/11W-28G01	20	276	Yaq	--	P	C	No	PR
37	12N/11W-28G02	20	730	Yaq	--	A	C	No	PR
38	12N/11W-28G06	17.96	23.0	Yaq	22	O	J	Yes	PC
39	12N/11W-28G03	18.56	124	Yaq	--	P,O	C	No	PR
40	12N/11W-27M02	--	24.0	Yaq	--	D	J	Yes	PR
41	12N/11W-28N02	23.37	20.0	Net	--	O	--	No	US
42	12N/11W-28P03	21.29	23.0	Net	22	O	J	Yes	PC
43	12N/11W-28P01	18.35	20.0	Net	--	O	--	No	US
44	12N/11W-28Q01	19.29	20.0	Net	--	O	--	No	US
45	12N/11W-28R03	27.18	28.1	Net	18	O	J	Yes	PC
46	12N/11W-27N04	9.38	18.0	Yaq	36	O	J	Yes	PC
47	12N/11W-33D01	20.18	25.5	Net	33	O	J	Yes	PC
48	12N/11W-33D02	19.93	38.0	Net	33	O	J	Yes	PC
49	12N/11W-33C02	--	<40.0	Net	--	D	J	Yes	PR
50	12N/11W-33B03	--	32.0	Net	--	D	J	Yes	PR
51	12N/11W-33M02	21.42	23.0	Net	20	O	J	No	PC
52	12N/11W-33H03	12.65	18.0	Yaq	25	O	J	No	PC
53	12N/11W-33H02	14.00	93.0	Yaq	--	O	R	No	PR
54	12N/11W-33R01	17.14	18.0	Net	15	O	J	No	PC
55	12N/11W-34N03	19.98	23.0	Net	26	O	J	No	PC
56	11N/11W-04C01	17.54	18.0	Yaq	20	O	J	No	PC
57	11N/11W-04M03	21.42	23.0	Net	24	O	J	Yes	PC
58	11N/11W-04M04	20.79	14.5	Net	--	O	D	No	US
59	11N/11W-04K06	20.47	18.0	Net	16	O	J	No	PC
60	11N/11W-04J02	16.37	13.0	Net	10	O	J	No	PC
61	11N/11W-03M04	14.97	11.0	Sea	--	O	D	No	US
62	11N/11W-03M03	19.87	22.9	Net	17	O	J	Yes	PC
63	11N/11W-09B02	24.61	23.0	Net	--	O	J	No	PC
64	11N/11W-09B01	24.87	90	Net	--	O	--	No	PR
65	11N/11W-10L02	--	29.0	Net	--	D	J	Yes	PR
66	11N/11W-09N03	16.67	12.7	Wes	--	O	D	No	US
67	11N/11W-09P04	19.08	15.0	Net	--	O	D	No	US
68	11N/11W-09P03	--	<30.0	Net	--	D	J	Yes	PR
69	11N/11W-09Q01	16.96	18.0	Net	12	O	J	No	PC
70	11N/11W-09Q02	17.30	18.0	Sea	23	O	J	No	PC
71	11N/11W-09R01	19.26	12.9	Net	--	O	D	No	US
72	11N/11W-09R02	27.23	23.0	Net	15	O	J	No	PC
73	11N/11W-10P02	10.02	11.3	Net	--	O	D	No	US

Table 20.--*Description of wells, Long Beach Peninsula, Washington--Continued*

Well number	Well location	Altitude of land surface (feet)	Depth (feet)	Soil type	Hydraulic conductivity (ft/d)	Use of well	Construction	Water-quality sample	Owner
74	11N/11W-16N04	--	35.0	Wes	--	D	J	Yes	PR
75	11N/11W-16L01	16.82	13.2	Wes	--	O	D	No	US
76	11N/11W-16K01	15.91	13.5	Yaq	--	O	D	No	US
77	11N/11W-15K02	15.74	15.0	Net	--	O	D	No	US
78	11N/11W-21N04	16.79	13.0	Wes	--	O	D	No	US
79	11N/11W-21R01	17.31	18.0	Net	13	O	J	No	PC
80	11N/11W-22K03	15.51	14.7	Net	--	O	D	No	US
81	11N/11W-28H01	--	27.0	Net	--	D	J	Yes	PR
82	11N/11W-27H01	--	25.0	Net	--	D	J	Yes	PR
85	11N/11W-27Q01	16.56	14.9	Yaq	--	O	D	No	US
83	11N/11W-28N02	21.77	23.0	Wes	18	O	J	No	PC
84	11N/11W-28R01	17.01	10.9	Sea	--	O	D	No	US
86	11N/11W-33M05	16.86	25.5	Wes	37	O	J	No	PC
87	11N/11W-33L02	18.70	18.0	Net	19	O	J	No	PC
88	11N/11W-33K03	14.57	11.0	Sea	--	O	D	No	US
89	11N/11W-33K02	--	25.0	Net	--	D	J	Yes	PR
90	11N/11W-33J02	15.96	13.5	Sea	--	O	D	No	US
91	11N/11W-34M01	15.68	18.0	Net	16	O	J	No	PC
92	11N/11W-34F02	15	179	Net	--	I	R	No	PR
93	11N/11W-34L01	12.17	18.0	Yaq	27	O	J	Yes	PC
94	11N/11W-34K01	13.69	18.0	Net	13	O	J	No	PC
95	11N/11W-34P01	15	164	Net	--	C	--	No	PR
96	11N/11W-34P03	15.21	20.5	Sea	17	O	J	Yes	PC
97	11N/11W-34P04	15.19	38.0	Sea	30	O	J	Yes	PC
98	11N/11W-34P02	15.85	235	Sea	--	C,O	--	Yes	PR
99	11N/11W-33N05	20	205	Wes	--	C	C	No	PR
100	11N/11W-33N03	20.61	23.0	Wes	26	O	J	No	PC
101	10N/11W-04E02	20.69	18.0	Wes	17	O	J	No	PC
102	10N/11W-03F02	13.52	21.0	Net	--	O	J	No	PR
103	10N/11W-03F01	13.73	122	Sea	--	I,O	R	No	PR
104	10N/11W-03F03	--	21.0	Net	--	D	J	Yes	PR
105	10N/11W-03P03	12.33	18.0	Yaq	25	O	J	No	PC
106	10N/11W-03P05	11.13	85.0	Yaq	--	D,O	C	No	US
107	10N/11W-09A01	15.82	23.0	Net	28	O	J	Yes	PC
108	10N/11W-09E01	--	21.0	Wes	--	D	J	Yes	PR
109	10N/11W-09E02	18.88	18.0	Wes	26	O	J	No	PC
110	10N/11W-09F01	17.48	15.0	Net	--	O	D	No	US
111	10N/11W-09F02	12.63	18.0	Sea	30	O	J	No	PC
112	10N/11W-09G02	15.76	12.9	Net	--	O	D	No	US

Table 20.--*Description of wells, Long Beach Peninsula, Washington--Continued*

Well number	Well location	Altitude of land surface (feet)	Depth (feet)	Soil type	Hydraulic conductivity (ft/d)	Use of well	Construction	Water-quality sample	Owner
113	10N/11W-09J03	18.55	23.0	Net	17	O	J	No	PC
114	10N/11W-10E01	8.64	13.0	Yaq	27	O	J	Yes	PC
115	10N/11W-10F01	13.09	23.0	Net	25	O	J	No	PC
116	10N/11W-10L01	5.92	17.9	Oco	27	O	J	Yes	PC
117	10N/11W-16C01	13.17	18.0	Sea	21	O	J	Yes	PC
118	10N/11W-16D01	--	25.0	Wes	--	D	J	Yes	PR
119	10N/11W-16L01	15.57	200	Sea	--	O	--	No	WA
121	10N/11W-15L02	6.96	18.0	Yaq	24	O	J	Yes	PC
120	10N/11W-15M01	7.08	18.0	Yaq	27	O	J	No	PC
122	10N/11W-21E03	16.19	18.0	Net	16	O	J	No	PC
123	10N/11W-21G01	15.74	11.3	Net	--	O	D	No	US
124	10N/11W-22C01	12.03	18.0	Sea	20	O	J	Yes	PC
125	10N/11W-21M02	--	24.0	Wes	--	I	J	Yes	PR
126	10N/11W-29A01	17.46	16.6	Wes	--	O	D	No	US
127	10N/11W-21Q02	13.84	18.0	Yaq	20	O	J	No	PC
128	10N/11W-21Q01	--	25.0	Yaq	--	D	J	Yes	PR
129	10N/11W-22N01	12.47	16.5	Sea	--	O	J	No	PC

Table 21.--*Water-level altitudes measured in wells, Long Beach Peninsula, Washington*

Well number	Well location	Date	Water-level altitude (feet)
1	13N/11W-29G01	11-17-91	8.14
		01-28-92	11.20
		02-25-92	12.19
		03-24-92	10.98
		05-20-92	10.12
		06-24-92	8.75
		07-21-92	8.01
		08-25-92	7.42
		09-21-92	7.19
		10-26-92	7.30
		11-17-92	8.14
		12-15-92	9.73
		01-28-93	11.20
		02-25-93	12.19
		03-24-93	10.98
		05-20-93	10.12
2	13N/11W-29H01	11-17-91	11.52
		01-28-92	13.95
		02-25-92	14.14
		03-24-92	13.80
		04-29-92	13.97
		05-20-92	13.39
		06-24-92	11.88
		07-21-92	11.12
		08-25-92	10.36
		09-21-92	9.82
		10-26-92	9.43
		11-17-92	10.19
		12-15-92	12.04
3	13N/11W-28E01	11-17-91	12.54
		01-28-92	13.97
		02-25-92	14.28
		03-24-92	13.30
		04-29-92	13.54
		05-20-92	13.32
		06-24-92	12.43
		07-21-92	11.88
		08-25-92	11.28
		09-21-92	10.81
		10-26-92	10.55
		11-17-92	11.39
		12-15-92	12.91
4	13N/11W-28F01	11-17-91	12.36
		01-28-92	11.83
		02-25-92	11.89
		03-24-92	11.70
		04-29-92	11.79
		05-20-92	11.62
		06-24-92	11.30
		07-21-92	11.41
		08-25-92	10.77
		09-21-92	10.47
		10-26-92	10.36
		11-17-92	10.83
		12-15-92	11.46
5	13N/11W-28G01	11-17-91	9.74
		01-28-92	11.27
		02-25-92	11.43
		03-24-92	10.73
		04-29-92	11.59
		05-20-92	10.74
		06-24-92	8.76
		07-21-92	7.90
		08-25-92	7.32
		09-21-92	7.05
		10-26-92	7.49
		11-17-92	9.60
		12-15-92	10.82
6	13N/11W-27E01	12-03-91	4.23
		01-28-92	6.88
		02-25-92	6.43
		03-24-92	5.34
		04-29-92	5.79
		05-20-92	4.78
		06-24-92	3.83
		07-21-92	3.71
		08-10-92	3.78
		08-25-92	3.52
		09-21-92	3.35
		10-26-92	4.76
		11-17-92	4.99
		12-15-92	5.85

Table 21.--*Water-level altitudes measured in wells, Long Beach Peninsula, Washington--Continued*

Well number	Well location	Date	Water-level altitude (feet)
8	12N/11W-05H01	01-28-92	11.45
		02-25-92	10.82
		03-24-92	9.91
		04-29-92	11.09
		05-19-92	9.60
		06-24-92	8.76
		07-21-92	8.39
		08-25-92	7.94
		09-21-92	7.83
		10-27-92	8.05
		11-17-92	9.28
		12-16-92	10.98
9	12N/11W-09D01	11-18-91	11.70
		01-28-92	14.78
		02-25-92	15.26
		03-24-92	14.03
		04-29-92	14.86
		05-19-92	13.30
		06-24-92	12.45
		07-21-92	11.86
		08-25-92	11.14
		09-21-92	10.61
		10-26-92	10.35
		11-17-92	11.86
		12-16-92	13.82
		01-27-93	14.98
		02-25-93	14.18
		03-31-93	14.74
		04-29-93	15.22
		06-02-93	14.30
10	12N/11W-04P01	12-03-91	13.79
		01-28-92	15.58
		02-11-92	15.19
		02-25-92	15.43
		03-24-92	14.50
		04-29-92	15.37
		05-19-92	14.36
		06-24-92	13.13
		07-10-92	11.91
		07-21-92	12.33
		08-25-92	11.50
		09-21-92	10.90
		10-26-92	10.72
		11-17-92	12.56
		12-16-92	14.84
		01-27-93	15.39
		02-25-93	14.68
		03-31-93	15.10
		04-29-93	15.43
		06-02-93	14.30
11	12N/11W-04P02	12-03-91	13.81
		01-28-92	15.61
		02-25-92	15.44
		03-24-92	14.52
		04-29-92	15.29
		05-19-92	14.36
		06-24-92	13.11
		07-21-92	12.33
		08-10-92	11.89
		08-25-92	11.51
		09-21-92	10.89
		10-26-92	10.72
		11-17-92	12.59
		12-16-92	14.88
		01-27-93	15.65
		02-25-93	14.64
		03-31-93	15.14
		04-29-93	15.42
		06-02-93	14.27

Table 21.--*Water-level altitudes measured in wells, Long Beach Peninsula, Washington--Continued*

Well number	Well location	Date	Water-level altitude (feet)
12	12N/11W-04R02	12-03-91	8.82
		01-28-92	10.15
		02-25-92	10.41
		03-24-92	9.93
		04-29-92	10.09
		05-19-92	9.61
		06-24-92	8.68
		07-21-92	8.03
		08-25-92	7.28
		09-21-92	6.94
		10-26-92	7.35
		11-17-92	8.52
		12-16-92	9.68
		01-27-93	10.24
		02-25-93	9.78
		03-31-93	10.07
		04-29-93	10.20
		06-02-93	9.71
13	12N/11W-09E01	12-04-91	11.85
		01-28-92	14.65
		02-26-92	15.01
		03-24-92	13.65
		04-29-92	14.19
		05-19-92	13.14
		06-24-92	12.12
		07-21-92	11.40
		08-13-92	10.89
		08-25-92	10.53
		09-22-92	10.03
		10-27-92	9.56
		11-17-92	11.21
		12-16-92	13.66

Well number	Well location	Date	Water-level altitude (feet)
15	12N/11W-08R01	11-18-91	8.79
		01-28-92	9.76
		02-26-92	9.46
		03-24-92	8.84
		04-29-92	9.31
		05-19-92	8.52
		06-24-92	6.85
		07-21-92	7.53
		08-25-92	7.04
		09-22-92	6.81
		10-27-92	7.36
		11-17-92	7.86
		12-16-92	8.83
16	12N/11W-08R02	12-04-91	14.95
		01-28-92	12.54
		02-26-92	13.54
		03-24-92	12.32
		04-30-92	12.16
		05-19-92	11.01
		06-24-92	10.66
		07-21-92	9.92
		08-13-92	9.46
		08-25-92	9.20
		09-22-92	8.73
		10-27-92	8.40
		11-17-92	9.55
		12-16-92	11.80
17	12N/11W-09N01	12-04-91	12.16
		01-28-92	14.46
		02-11-92	14.20
		02-26-92	14.40
		03-24-92	13.22
		04-30-92	13.96
		05-19-92	12.96
		06-24-92	11.83
		07-21-92	11.08
		08-13-92	10.58
		08-25-92	10.23
		09-22-92	9.70
		10-27-92	9.32
		11-17-92	10.87
		12-16-92	13.27

Table 21.--*Water-level altitudes measured in wells, Long Beach Peninsula, Washington--Continued*

Well number	Well location	Date	Water-level altitude (feet)
18	12N/11W-09P01	11-18-91	11.81
		01-28-92	13.79
		02-26-92	13.37
		03-24-92	12.92
		04-30-92	13.14
		05-19-92	12.60
		06-24-92	11.97
		07-21-92	11.06
		08-25-92	10.13
		09-22-92	9.65
		10-27-92	9.44
		11-17-92	10.79
		12-16-92	12.56
19	12N/11W-09Q01	12-04-91	12.04
		01-28-92	13.35
		02-26-92	12.97
		03-24-92	12.13
		04-30-92	12.79
		05-19-92	12.03
		06-24-92	11.44
		07-21-92	10.84
		08-13-92	10.31
		08-25-92	9.94
		09-22-92	9.37
		10-27-92	9.26
		11-17-92	10.92
		12-16-92	12.62
20	12N/11W-38E01	12-10-91	9.67
		01-28-92	9.76
		02-25-92	9.94
		03-24-92	9.07
		04-30-92	9.50
		05-19-92	8.64
		06-24-92	7.68
		07-21-92	7.03
		08-13-92	6.66
		08-25-92	6.33
		09-21-92	5.97
		10-27-92	6.51
		11-17-92	8.55
		12-16-92	9.31
21	12N/11W-38F01	11-18-91	7.48
		01-28-92	8.87
		02-25-92	10.14
		03-24-92	9.58
		04-29-92	10.06
		05-19-92	9.43
		06-24-92	8.98
		07-21-92	8.14
		08-25-92	6.21
		09-21-92	5.94
		10-27-92	6.16
		11-17-92	6.53
		12-16-92	7.10
22	12N/11W-17A03	01-28-92	8.46
		02-25-92	8.33
		03-24-92	7.06
		04-30-92	9.82
		05-19-92	5.75
		06-24-92	4.49
		07-21-92	4.13
		08-25-92	3.83
		09-22-92	4.22
		10-27-92	5.04
		11-17-92	6.66
		12-16-92	8.73
24	12N/11W-16E03	12-04-91	11.52
		01-28-92	14.07
		02-11-92	14.48
		02-26-92	14.76
		03-24-92	13.16
		04-29-92	13.65
		05-19-92	12.90
		06-24-92	11.36
		07-21-92	10.54
		08-13-92	10.12
		09-22-92	9.25
		10-27-92	8.82
		11-17-92	10.24
		12-16-92	12.58

Table 21.--*Water-level altitudes measured in wells, Long Beach Peninsula, Washington--Continued*

Well number	Well location	Date	Water-level altitude (feet)
25	12N/11W-38P01	11-18-91	7.10
		01-31-92	10.04
		02-25-92	9.29
		03-24-92	8.30
		04-29-92	9.07
		05-19-92	7.78
		06-24-92	6.76
		07-21-92	6.10
		08-25-92	5.86
		09-21-92	5.43
		10-27-92	6.02
		11-17-92	7.15
		12-16-92	7.88
26	12N/11W-16M01	01-28-92	12.49
		02-26-92	13.76
		03-24-92	12.39
		04-29-92	12.36
		05-19-92	11.95
		06-24-92	10.57
		07-21-92	9.87
		08-25-92	9.14
		09-22-92	8.63
		10-27-92	8.31
		11-17-92	9.40
		12-16-92	11.11
27	12N/11W-16Q02	12-04-91	11.07
		01-28-92	13.00
		02-26-92	13.63
		03-24-92	12.43
		04-30-92	12.97
		05-19-92	12.09
		06-24-92	11.08
		07-21-92	10.48
		08-13-92	10.06
		08-25-92	9.76
		09-22-92	9.23
		10-27-92	8.79
		11-17-92	10.15
		12-16-92	12.09
28	12N/11W-16Q01	12-04-91	8.86
		01-28-92	9.87
		02-11-92	9.81
		02-26-92	9.85
		03-24-92	9.18
		04-29-92	10.08
		06-24-92	8.78
		07-21-92	7.87
		08-13-92	7.98
		08-25-92	7.73
		09-22-92	7.62
		10-27-92	7.60
		11-17-92	8.58
		12-16-92	9.26
30	12N/11W-21E02	11-19-91	9.68
		01-28-92	12.52
		02-25-92	14.27
		03-24-92	13.15
		04-29-92	13.20
		05-19-92	12.39
		06-24-92	11.06
		07-21-92	10.21
		08-25-92	9.24
		09-22-92	8.62
		10-26-92	8.15
		11-17-92	8.97
		12-16-92	10.88
31	12N/11W-21G01	12-02-91	10.82
		01-28-92	10.00
		02-25-92	12.14
		03-24-92	11.50
		04-29-92	11.36
		05-19-92	10.97
		06-24-92	10.08
		07-21-92	9.42
		08-13-92	8.94
		08-25-92	8.61
		09-22-92	8.18
		10-26-92	7.85
		11-17-92	8.56
		12-16-92	10.06

Table 21.--*Water-level altitudes measured in wells, Long Beach Peninsula, Washington--Continued*

Well number	Well location	Date	Water-level altitude (feet)
32	12N/11W-22E03	12-02-91	4.30
		01-28-92	6.67
		02-12-92	5.96
		02-25-92	6.06
		03-24-92	4.94
		04-29-92	5.50
		05-19-92	4.76
		06-24-92	4.07
		07-21-92	4.00
		08-13-92	4.05
		08-25-92	3.85
		09-22-92	3.78
		10-26-92	4.46
		11-17-92	4.86
		12-16-92	5.49
34	12N/11W-28E01	12-10-91	10.90
		01-28-92	11.96
		02-12-92	13.28
		02-25-92	13.72
		03-23-92	12.71
		04-30-92	12.62
		05-18-92	11.90
		06-23-92	10.62
		07-21-92	9.73
		08-13-92	9.10
		08-26-92	8.72
		09-22-92	8.38
		10-27-92	7.66
		11-17-92	8.54
		12-17-92	10.45
38	12N/11W-28G06	12-10-91	8.56
		01-28-92	10.82
		02-12-92	12.27
		02-25-92	12.59
		03-23-92	11.50
		04-29-92	11.58
		05-19-92	10.46
		06-23-92	8.77
		07-21-92	7.71
		08-13-92	6.99
		08-26-92	6.51
		09-22-92	6.39
		10-27-92	6.13
		11-17-92	6.99
		12-17-92	8.95
		01-27-93	10.47
		02-25-93	10.33
		03-31-93	11.04
		04-29-93	10.71
		06-03-93	10.62
39	12N/11W-28G03	01-28-92	9.24
		02-25-92	10.92
		03-23-92	10.27
		04-29-92	10.45
		05-19-92	9.16
		06-23-92	7.03
		07-21-92	6.28
		09-22-92	6.09
		10-27-92	5.74
		11-17-92	6.71
		12-17-92	8.71
		01-27-93	9.63
		02-25-93	9.53
		03-31-93	10.75
		04-29-93	11.28
		06-03-93	9.81

Table 21.--*Water-level altitudes measured in wells, Long Beach Peninsula, Washington--Continued*

Well number	Well location	Date	Water-level altitude (feet)
41	12N/11W-28N02	01-28-92	9.12
		02-25-92	11.92
		03-23-92	11.84
		04-29-92	11.33
		05-18-92	11.20
		06-23-92	10.31
		07-22-92	9.67
		08-26-92	8.92
		09-22-92	8.40
		10-27-92	7.96
		11-17-92	8.47
		12-16-92	9.97
		01-27-93	11.25
		02-25-93	11.41
		03-31-93	11.42
		04-29-93	11.96
42	12N/11W-28P03	12-10-91	11.59
		01-28-92	13.29
		02-12-92	14.05
		02-25-92	14.57
		03-23-92	13.19
		04-29-92	13.52
		05-19-92	12.57
		06-23-92	11.34
		07-22-92	10.50
		08-12-92	10.02
		08-26-92	9.62
		09-22-92	8.99
		10-28-92	8.51
		11-18-92	9.74
		12-16-92	11.57
		01-27-93	13.09
		02-25-93	12.36
		03-31-93	13.20
		04-29-93	14.12
		06-03-93	13.00
43	12N/11W-28P01	01-28-92	13.45
		02-25-92	14.46
		03-23-92	13.30
		04-30-92	13.82
		05-19-92	13.15
		06-23-92	11.67
		07-22-92	10.79
		08-26-92	9.83
		09-22-92	9.22
		10-27-92	8.67
		11-18-92	9.87
		12-16-92	11.77
		01-27-93	13.45
		02-25-93	12.63
		03-31-93	13.41
		04-29-93	14.11
		06-03-93	13.13
44	12N/11W-28Q01	01-28-92	12.43
		02-25-92	14.11
		03-23-92	12.87
		04-29-92	13.09
		05-19-92	12.19
		06-23-92	10.92
		07-22-92	9.97
		08-26-92	8.97
		09-22-92	8.31
		10-28-92	7.73
		11-18-92	8.72
		12-16-92	10.73
		01-27-93	12.45
		02-25-93	11.92
		03-31-93	12.74
		04-29-93	13.49
		06-03-93	12.45

Table 21.--*Water-level altitudes measured in wells, Long Beach Peninsula, Washington--Continued*

Well number	Well location	Date	Water-level altitude (feet)
45	12N/11W-28R03	12-02-91	7.88
		01-28-92	10.14
		02-12-92	11.60
		02-25-92	11.65
		03-23-92	10.69
		04-29-92	10.62
		05-19-92	10.67
		06-23-92	8.69
		07-22-92	7.98
		08-12-92	7.48
		08-26-92	7.14
		09-22-92	6.61
		10-28-92	6.25
		11-18-92	7.24
		12-16-92	9.34
		01-27-93	10.27
		02-25-93	9.88
		03-31-93	10.41
		04-29-93	11.00
		06-03-93	10.36
46	12N/11W-27N04	12-02-91	3.08
		01-28-92	5.07
		02-12-92	4.41
		02-25-92	4.08
		03-23-92	3.82
		04-30-92	4.26
		05-20-92	3.25
		06-23-92	2.54
		07-22-92	2.67
		08-12-92	3.11
		08-25-92	2.45
		09-22-92	2.80
		10-27-92	3.86
		11-18-92	3.40
		12-15-92	4.01
		01-27-93	4.41
		02-25-93	3.46
		03-31-93	3.82
		04-29-93	4.05
		06-03-93	3.95
47	12N/11W-33D01	12-10-91	10.68
		01-28-92	11.10
		02-26-92	11.45
		03-24-92	10.47
		04-30-92	10.68
		05-18-92	10.14
		06-23-92	9.50
		07-22-92	9.11
		08-12-92	8.82
		08-26-92	8.32
		09-22-92	8.18
		10-28-92	7.98
		11-17-92	9.19
		12-16-92	10.65
48	12N/11W-33D02	12-10-91	10.43
		01-28-92	11.12
		02-13-92	11.33
		02-26-92	11.47
		03-24-92	10.45
		04-29-92	10.73
		05-18-92	10.12
		06-23-92	9.52
		07-22-92	9.13
		08-12-92	8.82
		08-26-92	8.31
		09-22-92	8.18
		10-28-92	7.98
		11-17-92	9.14
		12-16-92	10.67

Table 21.--*Water-level altitudes measured in wells, Long Beach Peninsula, Washington--Continued*

Well number	Well location	Date	Water-level altitude (feet)
51	12N/11W-33M02	12-11-91	11.22
		01-29-92	12.04
		02-26-92	13.02
		03-24-92	11.86
		04-30-92	12.59
		05-20-92	11.39
		06-23-92	10.57
		07-22-92	10.03
		08-12-92	9.63
		08-26-92	9.29
		09-22-92	8.86
		10-28-92	8.48
		11-17-92	9.47
		12-15-92	11.24
52	12N/11W-33H03	12-11-91	7.05
		01-29-92	8.87
		02-26-92	8.37
		03-23-92	7.82
		04-29-92	8.16
		05-19-92	7.40
		06-23-92	6.88
		07-22-92	6.56
		08-14-92	6.37
		08-26-92	6.19
		09-22-92	6.00
		10-28-92	5.92
		11-18-92	6.52
		12-17-92	7.59
		01-27-93	8.39
		02-25-93	7.75
		03-31-93	7.97
		04-29-93	8.35
		06-03-93	7.70
53	12N/11W-33H02	01-29-92	9.12
		02-26-92	8.99
		03-23-92	8.33
		04-30-92	7.32
		05-20-92	7.82
		06-23-92	7.05
		07-22-92	6.46
		08-26-92	5.54
		09-22-92	6.00
		10-28-92	6.06
		11-18-92	6.36
		12-17-92	7.90
		01-27-93	8.87
		02-25-93	8.11
		03-31-93	8.49
		04-29-93	8.87
		06-03-93	8.17
54	12N/11W-33R01	12-11-91	10.74
		01-29-92	13.01
		02-26-92	13.07
		03-23-92	12.28
		04-29-92	12.58
		05-19-92	11.99
		06-23-92	11.00
		07-22-92	10.19
		08-14-92	10.52
		08-24-92	9.19
		09-22-92	8.52
		10-28-92	8.07
		11-18-92	8.90
		12-17-92	11.25

Table 21.--*Water-level altitudes measured in wells, Long Beach Peninsula, Washington--Continued*

Well number	Well location	Date	Water-level altitude (feet)
55	12N/11W-34N03	12-11-91	8.88
		01-29-92	10.26
		02-26-92	10.66
		03-23-92	9.90
		04-30-92	9.85
		05-19-92	9.48
		06-23-92	8.67
		07-22-92	8.00
		08-14-92	8.13
		08-24-92	7.28
		09-22-92	6.75
		10-28-92	6.48
		11-18-92	7.18
		12-17-92	9.11
56	11N/11W-04C01	12-03-91	10.94
		01-28-92	12.24
		02-26-92	12.07
		03-24-92	11.43
		04-30-92	12.11
		05-18-92	11.96
		06-23-92	11.17
		07-22-92	10.51
		08-12-92	10.15
		08-26-92	9.78
		09-22-92	9.31
		10-28-92	8.91
		11-17-92	9.94
		12-15-92	11.78
57	11N/11W-04M03	12-03-91	10.02
		01-29-92	12.01
		02-13-92	13.13
		02-27-92	12.99
		03-25-92	11.95
		04-30-92	11.62
		05-18-92	10.95
		06-23-92	9.92
		07-22-92	9.27
		08-12-92	8.94
		08-26-92	8.65
		09-22-92	8.26
		10-28-92	8.08
		11-18-92	8.91
		12-15-92	11.05
58	11N/11W-04M04	11-15-91	10.49
		01-29-92	13.28
		02-27-92	13.70
		03-25-92	12.69
		04-30-92	12.66
		05-18-92	12.45
		06-23-92	11.42
		07-22-92	10.83
		08-26-92	10.16
		09-22-92	9.71
		10-28-92	9.33
		11-18-92	10.30
		12-18-92	12.40
59	11N/11W-04K06	12-03-91	13.47
		01-31-92	16.43
		02-27-92	15.15
		03-23-92	14.10
		04-29-92	14.62
		05-18-92	13.79
		06-23-92	12.91
		07-22-92	12.31
		08-12-92	11.91
		08-26-92	11.55
		09-22-92	10.99
		10-28-92	10.57
		11-18-92	12.05
		12-18-92	14.31

Table 21.--*Water-level altitudes measured in wells, Long Beach Peninsula, Washington--Continued*

Well number	Well location	Date	Water-level altitude (feet)
60	11N/11W-04J02	12-03-91	13.07
		01-29-92	14.88
		02-27-92	14.62
		03-23-92	13.89
		04-30-92	14.24
		06-24-92	12.77
		07-22-92	12.13
		08-12-92	11.68
		08-26-92	11.21
		09-22-92	10.61
		10-28-92	10.35
		11-18-92	12.01
		12-18-92	13.70
61	11N/11W-03M04	11-15-91	10.87
		01-29-92	11.66
		02-27-92	11.90
		03-23-92	11.68
		04-30-92	11.82
		05-18-92	11.99
		06-23-92	10.78
		07-22-92	10.61
		08-26-92	9.23
		09-22-92	8.73
		10-28-92	8.57
		11-18-92	9.85
		12-18-92	10.96
62	11N/11W-03M03	12-03-91	7.47
		01-29-92	9.28
		02-13-92	9.67
		02-27-92	9.62
		03-25-92	8.67
		04-30-92	8.67
		05-18-92	8.04
		06-23-92	7.24
		07-22-92	6.80
		08-12-92	6.50
		08-26-92	6.28
		09-22-92	5.91
		10-28-92	5.93
		11-18-92	6.58
		12-18-92	8.33
63	11N/11W-09B02	01-31-92	15.48
		02-27-92	14.63
		03-23-92	13.98
		04-30-92	14.32
		05-18-92	13.92
		06-23-92	13.24
		07-20-92	12.58
		08-24-92	11.82
		09-21-92	11.23
		10-27-92	10.86
		11-16-92	12.18
		12-18-92	14.32
		01-27-93	15.04
		02-25-93	13.80
		03-31-93	14.37
		04-29-93	14.65
		06-03-93	13.99
64	11N/11W-09B01	01-31-92	15.26
		02-27-92	14.43
		03-23-92	13.87
		04-30-92	14.23
		05-18-92	13.75
		06-23-92	13.06
		07-20-92	12.43
		08-24-92	11.69
		09-21-92	11.04
		10-27-92	10.70
		11-16-92	12.08
		12-18-92	13.83
		01-27-93	14.02
		02-25-93	13.62
		03-31-93	14.08
		04-29-93	14.43
		06-03-93	13.80

Table 21.--*Water-level altitudes measured in wells, Long Beach Peninsula, Washington--Continued*

Well number	Well location	Date	Water-level altitude (feet)
66	11N/11W-09N03	11-14-91	8.87
		01-29-92	12.52
		02-27-92	13.21
		03-25-92	12.12
		05-01-92	11.83
		05-20-92	11.08
		06-24-92	9.80
		07-22-92	9.06
		08-26-92	8.36
		09-22-92	7.98
		10-28-92	8.02
		11-16-92	8.92
		12-15-92	11.43
		01-27-93	12.77
		02-24-93	11.99
		03-31-93	12.32
		04-29-93	12.81
		06-03-93	11.75
67	11N/11W-09P04	11-15-91	12.78
		01-29-92	15.15
		02-27-92	14.35
		03-25-92	14.25
		05-01-92	14.06
		05-20-92	13.99
		06-24-92	13.23
		07-22-92	12.62
		08-26-92	11.86
		09-22-92	11.48
		10-28-92	11.69
		11-16-92	12.01
		12-15-92	13.04
		01-27-93	13.27
		02-24-93	13.63
		03-31-93	13.80
		04-29-93	14.07
		06-03-93	14.14
69	11N/11W-09Q01	12-11-91	13.46
		01-29-92	14.72
		02-27-92	14.44
		03-25-92	14.04
		05-01-92	14.32
		05-20-92	13.94
		06-24-92	13.48
		07-22-92	13.02
		08-13-92	12.73
		08-25-92	12.45
		09-22-92	12.10
		10-28-92	11.88
		11-16-92	12.73
		12-15-92	14.09
		01-27-93	14.69
		02-24-93	14.00
		03-31-93	14.21
		04-29-93	14.51
		06-03-93	14.03
70	11N/11W-09Q02	12-11-91	13.70
		01-29-92	15.68
		02-27-92	14.93
		03-23-92	14.28
		04-30-92	14.78
		05-18-92	14.07
		06-24-92	13.31
		07-22-92	12.80
		08-14-92	12.52
		08-26-92	12.24
		09-22-92	11.90
		10-28-92	11.71
		11-18-92	12.90
		12-18-92	14.57
		01-27-93	15.42
		02-25-93	14.29
		03-31-93	14.70
		04-29-93	14.97
		06-03-93	14.26

Table 21.--*Water-level altitudes measured in wells, Long Beach Peninsula, Washington--Continued*

Well number	Well location	Date	Water-level altitude (feet)
71	11N/11W-09R01	11-15-91	12.26
		01-29-92	16.15
		02-27-92	15.37
		03-23-92	14.55
		04-30-92	15.23
		05-18-92	14.26
		06-24-92	13.25
		07-22-92	12.66
		08-26-92	12.02
		09-22-92	11.57
		10-28-92	11.26
		11-18-92	12.41
		12-18-92	14.61
		01-27-93	15.84
		02-25-93	14.47
		03-31-93	15.01
		04-29-93	15.38
		06-03-93	14.39
72	11N/11W-09R02	12-11-91	13.63
		01-29-92	15.02
		02-27-92	15.34
		03-23-92	14.47
		04-30-92	14.60
		05-18-92	13.95
		06-24-92	12.87
		07-22-92	12.18
		08-14-92	11.72
		08-26-92	11.43
		09-22-92	10.98
		10-28-92	10.56
		11-18-92	11.47
		12-18-92	13.75
		01-27-93	15.61
		02-25-93	14.40
		03-31-93	14.70
		04-29-93	15.15
		06-03-93	14.11
73	11N/11W-10P02	11-15-91	5.42
		01-29-92	8.56
		02-27-92	7.79
		03-25-92	6.78
		05-01-92	7.22
		05-20-92	6.21
		06-24-92	5.44
		07-22-92	5.23
		08-26-92	4.97
		09-22-92	4.75
		10-29-92	5.26
		11-18-92	5.64
		12-17-92	7.00
		01-27-93	8.22
		02-24-93	6.77
		03-30-93	7.06
		04-29-93	7.56
		06-03-93	6.88
75	11N/11W-16L01	11-14-91	11.62
		01-29-92	15.45
		02-27-92	15.94
		03-25-92	14.68
		05-01-92	14.59
		05-20-92	13.74
		06-23-92	12.65
		07-20-92	11.89
		08-25-92	11.09
		09-22-92	10.59
		10-27-92	10.22
		11-16-92	11.08
		12-15-92	13.48

Table 21.--*Water-level altitudes measured in wells, Long Beach Peninsula, Washington--Continued*

Well number	Well location	Date	Water-level altitude (feet)
76	11N/11W-16K01	11-14-91	12.91
		01-29-92	14.60
		02-26-92	14.80
		03-25-92	14.18
		05-01-92	14.41
		05-20-92	13.97
		06-23-92	13.52
		07-20-92	13.04
		08-25-92	12.48
		09-22-92	12.20
		10-28-92	12.16
		11-16-92	12.95
		12-15-92	13.53
77	11N/11W-15K02	11-15-91	5.24
		01-29-92	8.78
		02-27-92	8.35
		03-25-92	7.24
		05-01-92	7.61
		05-19-92	6.92
		06-24-92	5.96
		07-22-92	5.60
		08-26-92	5.21
		09-22-92	4.97
		10-29-92	5.33
		11-18-92	6.12
		12-17-92	7.90
78	11N/11W-21N04	11-14-91	11.59
		01-29-92	15.71
		02-27-92	15.79
		03-25-92	14.69
		05-01-92	15.05
		05-20-92	13.75
		06-24-92	12.38
		07-20-92	11.64
		08-26-92	11.02
		09-23-92	10.35
		10-28-92	10.01
		11-16-92	11.14
		12-15-92	13.84

Well number	Well location	Date	Water-level altitude (feet)
79	11N/11W-21R01	12-11-91	12.71
		01-29-92	15.80
		02-27-92	14.65
		03-25-92	13.99
		05-01-92	14.62
		05-20-92	13.73
		06-25-92	13.14
		07-23-92	12.62
		08-14-92	12.32
		08-27-92	12.01
		09-23-92	11.58
		10-29-92	11.64
		11-19-92	13.71
		12-18-92	14.36
		01-26-93	15.34
		02-24-93	14.10
		03-30-93	14.42
		04-28-93	14.62
		06-03-93	14.14
80	11N/11W-22K03	11-16-91	6.21
		01-29-92	9.55
		02-27-92	8.60
		03-25-92	7.20
		05-01-92	8.02
		05-20-92	6.76
		06-24-92	5.70
		07-22-92	5.47
		08-26-92	5.03
		09-23-92	4.78
		10-29-92	5.33
		11-18-92	6.18
		12-17-92	8.13

Table 21.--*Water-level altitudes measured in wells, Long Beach Peninsula, Washington--Continued*

Well number	Well location	Date	Water-level altitude (feet)
83	11N/11W-28N02	12-11-91	12.77
		01-29-92	15.14
		02-27-92	15.51
		03-25-92	14.38
		05-01-92	14.37
		05-20-92	14.05
		06-24-92	12.37
		07-20-92	11.48
		08-13-92	10.86
		08-26-92	10.50
		09-23-92	9.91
		10-28-92	9.53
		11-16-92	10.50
		12-15-92	13.16
84	11N/11W-28R01	11-13-91	12.81
		01-29-92	14.38
		02-27-92	13.84
		03-25-92	13.42
		05-01-92	13.66
		06-25-92	12.76
		07-23-92	12.19
		08-27-92	11.42
		09-23-92	10.97
		10-29-92	11.00
		11-19-92	11.58
		12-18-92	13.64
		01-26-93	14.33
		02-24-93	13.34
		03-30-93	13.97
		04-28-93	14.22
		06-03-93	13.63
85	11N/11W-27Q01	11-16-91	8.86
		01-29-92	10.46
		02-27-92	9.61
		03-25-92	8.80
		05-01-92	9.82
		05-20-92	8.67
		06-24-92	7.49
		07-22-92	6.85
		08-26-92	6.22
		09-23-92	5.87
		10-29-92	6.44
		11-18-92	8.02
		12-17-92	9.53
86	11N/11W-33M05	12-17-91	10.86
		01-29-92	13.95
		02-27-92	14.35
		03-25-92	13.02
		05-20-92	12.17
		06-24-92	10.83
		07-20-92	10.04
		08-12-92	9.48
		08-27-92	9.09
		09-23-92	8.59
		10-29-92	8.36
		11-16-92	9.37
		12-15-92	12.03
87	11N/11W-33L02	12-11-91	12.20
		01-29-92	13.52
		02-27-92	12.65
		03-25-92	11.89
		04-29-92	12.49
		05-20-92	11.77
		06-25-92	11.24
		07-23-92	10.98
		08-12-92	10.88
		08-27-92	10.70
		09-23-92	10.43
		10-29-92	10.63
		11-19-92	11.80
		12-15-92	12.46

Table 21.--*Water-level altitudes measured in wells, Long Beach Peninsula, Washington--Continued*

Well number	Well location	Date	Water-level altitude (feet)	Well number	Well location	Date	Water-level altitude (feet)
88	11N/11W-33K03	11-13-91	11.87	93	11N/11W-34L01	12-11-91	8.67
		01-29-92	13.26			01-29-92	10.60
		02-27-92	12.69			02-27-92	9.52
		03-25-92	11.94			03-25-92	8.46
		04-29-92	12.68			07-23-92	7.50
		05-20-92	11.93			08-27-92	7.24
		06-25-92	11.18			09-23-92	7.30
		07-23-92	10.63			10-29-92	8.32
		09-24-92	10.39			11-19-92	9.86
		10-29-92	10.46			12-15-92	9.43
		11-19-92	12.20				
		12-15-92	12.50	94	11N/11W-34K01	12-11-91	7.69
						01-29-92	8.80
90	11N/11W-33J02	11-13-91	10.66			02-27-92	7.87
		01-29-92	13.06			03-25-92	6.91
		02-27-92	12.68			05-01-92	7.77
		03-25-92	12.54			05-20-92	6.79
		06-25-92	11.84			06-25-92	6.11
		07-23-92	12.02			07-22-92	5.82
		08-27-92	10.00			08-27-92	5.67
		09-23-92	9.96			09-23-92	5.77
		10-29-92	10.92			10-29-92	6.60
		11-19-92	11.37			11-18-92	7.29
		12-15-92	12.46			12-15-92	7.97
91	11N/11W-34M01	12-11-91	10.88	96	11N/11W-34P03	12-11-91	8.51
		01-29-92	12.25			01-30-92	10.47
		02-27-92	11.44			02-27-92	9.31
		03-25-92	10.34			03-25-92	8.80
		05-01-92	11.40			05-01-92	9.44
		05-20-92	10.49			05-20-92	8.31
		06-25-92	9.95			06-25-92	7.11
		07-22-92	9.34			07-22-92	6.53
		08-27-92	8.81			08-26-92	6.06
		09-23-92	8.49			09-23-92	5.84
		10-29-92	8.65			10-29-92	9.47
		11-19-92	10.14			11-19-92	9.78
		12-15-92	10.70			12-15-92	9.44
						01-26-93	10.05
						02-24-93	9.39
						03-30-93	9.33
						04-28-93	9.26
						06-02-93	8.59

Table 21.--*Water-level altitudes measured in wells, Long Beach Peninsula, Washington--Continued*

Well number	Well location	Date	Water-level altitude (feet)
97	11N/11W-34P04	12-17-91	8.69
		01-30-92	10.40
		02-27-92	9.29
		03-25-92	8.78
		05-01-92	9.39
		05-20-92	8.29
		06-25-92	7.09
		07-22-92	6.51
		08-26-92	6.06
		09-23-92	5.89
		10-29-92	9.43
		11-19-92	9.77
		12-15-92	9.41
		01-26-93	10.00
		02-24-93	9.41
		03-30-93	9.32
		04-28-93	9.26
		06-02-93	8.54
98	11N/11W-34P02	01-30-92	9.59
		02-27-92	9.38
		03-25-92	9.11
		05-01-92	8.95
		05-20-92	8.85
		06-10-92	8.69
		06-25-92	8.40
		10-29-92	7.75
		11-19-92	8.28
		12-15-92	8.62
		01-26-93	9.08
		03-30-93	8.93
		04-28-93	8.98
		06-02-93	9.29

Well number	Well location	Date	Water-level altitude (feet)
100	11N/11W-33N03	12-17-91	13.11
		01-29-92	14.76
		02-27-92	14.77
		03-25-92	13.95
		04-29-92	14.21
		05-20-92	13.71
		06-25-92	12.16
		07-20-92	11.46
		08-26-92	10.86
		09-23-92	10.31
		10-28-92	9.96
		11-16-92	11.28
		12-15-92	13.49
101	10N/11W-04E02	12-17-91	13.09
		01-29-92	14.98
		02-27-92	15.14
		03-25-92	14.13
		04-29-92	14.39
		05-20-92	13.55
		06-25-92	12.39
		07-20-92	11.70
		08-26-92	10.82
		09-23-92	10.33
		10-28-92	9.99
		11-16-92	11.07
		12-15-92	13.48
102	10N/11W-03F02	01-30-92	10.79
		02-26-92	9.44
		03-25-92	7.57
		05-01-92	9.22
		05-20-92	7.83
		06-25-92	6.86
		07-22-92	6.48
		08-26-92	5.94
		10-29-92	8.09
		11-19-92	10.02
		12-15-92	9.97
		01-26-93	10.69
		02-24-93	9.17
		03-30-93	9.10
		04-28-93	9.83
		06-02-93	8.82

Table 21.--*Water-level altitudes measured in wells, Long Beach Peninsula, Washington--Continued*

Well number	Well location	Date	Water-level altitude (feet)
103	10N/11W-03F01	01-30-92	9.53
		02-26-92	9.24
		03-25-92	8.54
		05-01-92	8.10
		05-20-92	9.03
		06-25-92	8.09
		07-22-92	7.29
		08-26-92	6.71
		10-29-92	7.47
		11-19-92	8.39
		12-15-92	8.85
		01-26-93	9.39
		03-30-93	9.03
		04-28-93	9.20
		06-02-93	9.01
105	10N/11W-03P03	12-17-91	8.23
		01-30-92	10.57
		02-26-92	9.82
		03-26-92	8.43
		05-01-92	9.74
		05-20-92	8.92
		06-25-92	6.65
		07-22-92	5.93
		08-26-92	5.29
		09-23-92	5.10
		10-29-92	5.97
		11-19-92	9.07
		12-15-92	9.72
106	10N/11W-03P05	02-26-92	8.99
		03-26-92	8.70
		05-01-92	8.99
		05-20-92	9.47
		06-25-92	6.70
		07-22-92	5.21
		08-26-92	4.97
		09-23-92	5.61
		10-29-92	6.65
		11-19-92	8.11
		12-15-92	8.63
107	10N/11W-09A01	12-17-91	6.72
		01-29-92	8.74
		02-14-92	7.63
		02-26-92	8.00
		03-26-92	6.77
		05-01-92	7.52
		05-20-92	6.22
		06-25-92	5.33
		07-22-92	5.04
		08-26-92	4.94
		09-23-92	5.06
		10-29-92	5.53
		11-19-92	7.02
		12-15-92	7.66
109	10N/11W-09E02	12-17-91	12.58
		01-29-92	14.87
		02-24-92	15.36
		03-26-92	13.79
		04-28-92	13.73
		05-20-92	13.18
		06-25-92	11.67
		07-23-92	10.84
		08-24-92	10.11
		09-23-92	9.56
		10-29-92	9.28
		11-18-92	10.59
		12-18-92	13.00
		01-26-93	14.82
		02-24-93	13.81
		03-30-93	14.30
		04-28-93	14.99
		06-02-93	13.68

Table 21.--*Water-level altitudes measured in wells, Long Beach Peninsula, Washington--Continued*

Well number	Well location	Date	Water-level altitude (feet)
110	10N/11W-09F01	11-13-91	10.48
		01-29-92	14.02
		02-24-92	13.85
		03-26-92	13.30
		05-19-92	14.12
		06-25-92	13.49
		07-23-92	13.15
		08-27-92	12.79
		09-23-92	12.71
		10-29-92	12.54
		11-19-92	12.52
		12-18-92	12.67
		01-26-93	12.85
		02-24-93	12.87
		03-30-93	12.96
		04-28-93	12.93
		06-02-93	12.79
111	10N/11W-09F02	12-17-91	9.83
		01-29-92	11.66
		02-24-92	11.34
		03-26-92	10.93
		04-28-92	11.21
		05-21-92	10.82
		06-25-92	10.58
		07-23-92	10.22
		08-27-92	9.83
		09-23-92	10.15
		10-29-92	10.88
		11-19-92	11.40
		12-18-92	11.44
		01-26-93	11.59
		02-24-93	11.25
		03-30-93	11.26
		04-28-93	11.40
		06-02-93	11.21

Well number	Well location	Date	Water-level altitude (feet)
112	10N/11W-09G02	11-13-91	11.66
		01-29-92	12.09
		02-24-92	11.59
		03-26-92	10.58
		04-28-92	11.46
		05-21-92	10.39
		06-25-92	9.60
		07-23-92	9.00
		08-27-92	8.49
		09-23-92	8.31
		10-29-92	9.32
		11-19-92	11.58
		12-18-92	12.28
		01-26-93	11.86
		02-24-93	10.90
		03-30-93	11.35
		04-28-93	11.41
		06-02-93	10.89
113	10N/11W-09J03	12-17-91	8.75
		01-29-92	10.95
		02-26-92	10.15
		03-26-92	9.11
		04-28-92	9.75
		05-21-92	9.01
		06-25-92	8.10
		07-23-92	7.20
		08-27-92	6.64
		09-23-92	6.43
		10-29-92	7.04
		11-19-92	9.59
		12-18-92	10.22
		01-26-93	10.89
		02-24-93	9.42
		03-30-93	9.85
		04-28-93	10.20
		06- 2-93	9.63

Table 21.--*Water-level altitudes measured in wells, Long Beach Peninsula, Washington--Continued*

Well number	Well location	Date	Water-level altitude (feet)	Well number	Well location	Date	Water-level altitude (feet)
114	10N/11W-10E01	12-17-91	7.14	116	10N/11W-10L01	12-17-91	5.41
		01-31-92	7.96			01-31-92	3.61
		02-14-92	7.05			02-14-92	4.03
		02-26-92	7.12			02-26-92	2.75
		03-26-92	6.69			03-26-92	4.10
		04-28-92	7.21			04-28-92	2.17
		05-21-92	6.46			06-25-92	1.48
		06-25-92	5.68			07-23-92	1.14
		07-23-92	4.98			08-26-92	0.94
		08-27-92	4.60			09-23-92	1.53
		09-23-92	5.06			10-29-92	2.33
		10-29-92	6.20			11-18-92	2.85
		11-19-92	7.75			12-14-92	4.16
		12-18-92	7.66			01-26-93	4.46
		01-26-93	7.85			02-24-93	2.59
		02-24-93	6.94			03-30-93	3.36
		03-30-93	7.35			04-28-93	4.28
		04-28-93	7.28			06-02-93	3.47
		06-02-93	7.00				
				117	10N/11W-16C01	12-18-91	10.07
115	10N/11W-10F01	12-17-91	4.59			01-30-92	flowing
		01-29-92	6.90			02-14-92	12.28
		02-26-92	6.98			02-24-92	12.45
		03-26-92	4.77			03-26-92	12.10
		04-28-92	5.40			04-28-92	12.32
		05-21-92	3.59			05-21-92	12.02
		06-25-92	3.92			06-25-92	11.82
		07-23-92	2.44			07-23-92	11.68
		08-27-92	3.00			08-24-92	11.36
		09-23-92	2.89			09-23-92	11.40
		10-29-92	3.52			10-28-92	11.56
		11-19-92	4.93			11-19-92	12.38
		12-18-92	6.23			12-14-92	12.39
		01-26-93	6.93			01-26-93	12.57
		02-24-93	5.13			02-24-93	12.19
		03-30-93	5.70			03-30-93	12.29
		04-28-93	6.08			04-28-93	12.41
		06-02-93	4.97			06- 2-93	12.29

Table 21.--*Water-level altitudes measured in wells, Long Beach Peninsula, Washington--Continued*

Well number	Well location	Date	Water-level altitude (feet)
118	10N/11W-16L01	01-30-92	7.74
		02-24-92	7.76
		03-26-92	6.78
		04-29-92	7.97
		05-21-92	6.82
		06-25-92	6.28
		07-23-92	6.20
		08-24-92	5.94
		09-23-92	5.82
		10-28-92	6.11
		11-19-92	6.56
		12-14-92	7.13
		01-26-93	7.10
		02-24-93	7.23
		03-30-93	7.27
		04-28-93	7.38
		06-02-93	7.22
120	10N/11W-15M01	12-17-91	4.08
		01-30-92	flowing
		02-24-92	5.10
		03-26-92	3.89
		04-28-92	4.43
		05-21-92	3.69
		06-25-92	3.37
		07-28-92	2.22
		08-26-92	3.15
		09-23-92	3.42
		10-29-92	3.82
		11-18-92	4.61
		12-14-92	4.96
		01-26-93	6.42
		02-24-93	4.14
		03-30-93	4.48
		04-28-93	4.78
		06-02-93	4.38
121	10N/11W-15L02	12-18-91	4.36
		01-30-92	flowing
		02-14-92	5.22
		02-24-92	5.85
		03-26-92	4.35
		04-28-92	5.60
		05-21-92	3.99
		06-25-92	3.57
		07-23-92	3.18
		08-26-92	2.54
		09-23-92	4.30
		10-29-92	4.97
		11-18-92	5.57
		12-14-92	5.95
		01-26-93	6.02
		02-24-93	5.05
		03-30-93	5.43
		04-28-93	5.60
		06- 2-93	5.07
122	10N/11W-21E03	12-18-91	11.29
		01-30-92	15.05
		02-24-92	14.03
		03-26-92	12.01
		04-29-92	12.70
		05-21-92	12.02
		06-25-92	11.41
		07-23-92	10.79
		08-24-92	10.30
		09-23-92	10.09
		10-28-92	10.57
		11-18-92	12.25
		12-14-92	13.00
		01-26-93	13.35
		02-24-93	12.33
		03-30-93	12.58
		04-28-93	12.85
		06-02-93	12.45

Table 21.--*Water-level altitudes measured in wells, Long Beach Peninsula, Washington--Continued*

Well number	Well location	Date	Water-level altitude (feet)
123	10N/11W-21G01	11-12-91	9.54
		01-30-92	12.17
		02-24-92	11.13
		03-26-92	11.14
		04-28-92	10.24
		05-21-92	10.18
		06-25-92	8.87
		09-23-92	6.63
		10-27-92	7.53
		11-18-92	9.70
		12-14-92	10.51
		01-26-93	11.42
		02-24-93	9.48
		03-30-93	10.27
		04-28-93	11.09
		06-02-93	9.78
124	10N/11W-22C01	12-18-91	5.63
		01-30-92	10.22
		02-14-92	9.60
		02-24-92	9.93
		03-26-92	9.19
		04-28-92	9.90
		05-21-92	9.05
		06-25-92	8.24
		07-23-92	7.49
		08-27-92	7.18
		09-23-92	7.26
		10-27-92	8.68
		11-18-92	9.53
		12-14-92	9.79
		01-26-93	10.70
		02-24-93	9.16
		03-30-93	9.44
		04-28-93	9.46
		06-02-93	9.06
126	10N/11W-29A01	11-12-91	12.46
		01-30-92	15.21
		02-24-92	15.07
		03-26-92	13.56
		04-29-92	13.81
		05-21-92	13.01
		06-25-92	11.52
		07-23-92	10.77
		08-24-92	10.15
		09-23-92	9.60
		10-27-92	9.47
		11-18-92	11.14
		12-14-92	13.48
		01-26-93	14.78
		02-24-93	13.67
		03-30-93	14.25
		04-28-93	14.73
		06-02-93	13.57
127	10N/11W-21Q02	12-18-91	9.44
		01-30-92	12.56
		02-24-92	11.87
		03-26-92	10.50
		04-29-92	11.64
		05-21-92	10.21
		06-25-92	9.13
		07-23-92	8.40
		08-27-92	7.90
		09-23-92	7.74
		10-27-92	9.01
		11-18-92	11.34
		12-14-92	11.62
		01-26-93	12.04
		02-24-93	10.87
		03-30-93	11.22
		04-28-93	11.62
		06-02-93	10.86

Table 21.--*Water-level altitudes measured in wells, Long Beach Peninsula, Washington--Continued*

Well number	Well location	Date	Water-level altitude (feet)
129	10N/11W-22N01	01-30-92	10.22
		02-24-92	11.47
		03-26-92	11.64
		04-29-92	12.33
		05-21-92	11.57
		06-25-92	10.63
		07-23-92	10.04
		08-27-92	9.53
		09-23-92	9.33
		10-27-92	10.67
		11-18-92	12.09
		12-14-92	12.17
		01-26-93	12.33
		02-24-93	11.95
		03-30-93	12.12
		04-28-93	12.26
		06-02-93	12.05

Table 22.--*Surface-water sites in observation network, Long Beach Peninsula, Washington*

[--, not available]

Site number	Name	Location of staff gage: Latitude (degrees)	Location of staff gage: Longitude (degrees)	Type of site	Water-quality sample	Well number within 1,000 feet of surface-water body
1	Hines Marsh (northern part)	46 35 16	124 02 38	Marsh	No	3, 4
2	Unnamed drainage near Stackpole Road	46 34 41	124 01 48	Drainage channel	Yes	--
3	North Surfside canal	46 33 20	124 03 24	Lake	No	8
4	Hines Marsh (southern part)	46 32 52	124 02 42	Marsh	No	10
5	Unnamed lake west of Skating Lake	46 32 11	124 02 41	Lake	No	18, 19
6	South Surfside canal	46 31 49	124 03 19	Lake	No	22
7	Unnamed lake south of Skating Lake	46 31 15	124 02 22	Lake	No	27, 28
8	Whiskey Slough (upper part)	46 31 12	124 02 14	Drainage channel	Yes	28
9	Whiskey Slough (lower part)	46 30 42	124 01 42	Drainage channel	Yes	32
10	Unnamed drainage in Nahcotta	46 30 16	124 01 53	Drainage channel	No	--
11	Pauls Lake drainage	46 29 25	124 01 58	Drainage channel	No	--
12	Loomis Lake drainage (lower part)	46 29 07	124 03 03	Drainage channel	Yes	--
13	Pauls Lake	46 28 50	124 02 04	Lake	No	54, 55
14	Loomis Lake drainage (upper part)	46 28 31	124 02 57	Drainage channel	Yes	56
15	Unnamed lake near Klipson Road	46 27 59	124 02 51	Lake	No	58, 59
16	Loomis Lake	46 26 17	124 02 35	Lake	No	70, 76
17	Island Lake	46 25 14	124 02 08	Lake	No	79
18	Litschke Road drainage	46 24 50	124 01 18	Drainage channel	Yes	--
19	Cranberry Lake	46 24 21	124 02 08	Lake	No	84
20	Giles Slough	46 23 47	124 01 24	Drainage channel	Yes	94
21	Briscoe Lake	46 23 06	124 03 05	Lake	No	101

Table 22.--*Surface-water sites in observation network, Long Beach Peninsula, Washington--Continued*

Site number	Name	Location of staff gage: Latitude (degrees)	Location of staff gage: Longitude (degrees)	Type of site	Water-quality sample	Well number within 1,000 feet of surface-water body
22	Gile Lake drainage	46 23 03	124 01 26	Drainage channel	Yes	102
23	East Main drainage (lower part)	46 22 22	124 02 07	Drainage channel	Yes	107
24	East Main drainage (upper part)	46 22 03	124 02 43	Marsh	No	111, 112
25	Tarlatt Slough (lower part)	46 21 49	124 01 29	Drainage channel	Yes	116
26	Tinker Lake	46 21 25	124 02 45	Lake	No	117
27	Tarlatt Slough (middle part)	46 21 12	124 01 58	Drainage channel	Yes	120
28	South Main drainage	46 19 52	124 03 06	Drainage channel	Yes	--
29	Tarlatt Slough (upper part)[1]	46 19 54	124 02 26	Drainage channel	Yes	--

[1]No staff gage for measurements of water-level altitude.

Table 23.--*Water-level altitudes measured at surface-water sites, Long Beach Peninsula, Washington*

Site number	Site name	Date	Water-level altitude (feet)
1	Hines Marsh (northern part)	01-28-92	12.04
		02-25-92	12.11
		02-29-92	12.01
		03-07-92	11.93
		03-16-92	11.81
		03-21-92	11.75
		03-24-92	11.71
		03-29-92	11.74
		04-04-92	11.77
		04-12-92	11.85
		04-18-92	12.20
		04-25-92	12.18
		04-29-92	12.05
		05-02-92	12.33
		05-09-92	12.24
		05-16-92	12.17
		05-20-92	12.11
		05-23-92	12.07
		05-30-92	11.98
		06-06-92	11.87
		06-13-92	11.80
		06-20-92	11.70
		06-24-92	11.61
		06-27-92	11.59
		07-04-92	11.53
		07-11-92	11.48
		07-18-92	11.33
		07-21-92	11.29
		07-25-92	11.23
		08-02-92	11.10
		08-08-92	11.08
		08-15-92	10.95
		08-23-92	10.84
		08-25-92	10.79
		08-30-92	10.71
		09-13-92	10.50
		09-19-92	10.38
		09-21-92	10.33
		09-26-92	10.38
		10-03-92	10.27
		10-10-92	10.15
		10-18-92	10.06
		10-26-92	10.15
		10-31-92	10.51
		11-11-92	10.81
1	Hines Marsh (northern part)--Cont.	11-17-92	10.80
		11-19-92	11.01
		11-25-92	11.38
		12-02-92	11.59
		12-11-92	11.73
		12-15-92	11.79
		12-26-92	11.93
		01-11-93	11.79
		01-25-93	12.09
		03-01-93	10.91
2	Unnamed drainage near Stackpole Road	01-28-92	7.67
		02-25-92	6.35
		02-29-92	7.12
		03-07-92	6.26
		03-24-92	6.04
		03-29-92	7.04
		04-04-92	7.02
		04-12-92	7.13
		04-18-92	6.34
		04-25-92	6.16
		04-29-92	6.26
		05-02-92	6.24
		05-09-92	6.25
		05-16-92	6.02
		05-20-92	6.01
		05-23-92	6.03
		05-30-92	6.00
		06-06-92	5.96
		06-13-92	5.96
		06-20-92	5.95
		06-24-92	5.32
		06-27-92	5.94
		07-04-92	5.76
		07-11-92	5.92
		07-21-92	5.90
		07-25-92	5.90
		08-02-92	5.96
		08-08-92	5.91
		08-15-92	5.90
		08-23-92	5.90
		08-25-92	5.90
		08-30-92	5.89
		09-13-92	5.89

Table 23.--*Water-level altitudes measured at surface-water sites, Long Beach Peninsula, Washington--Continued*

Site number	Site name	Date	Water-level altitude (feet)
2	Unnamed drainage near Stackpole Road-Cont.	09-19-92	5.91
		09-21-92	5.90
		09-26-92	5.91
		10-03-92	5.92
		10-10-92	5.90
		10-18-92	5.91
		10-20-92	5.93
		10-31-92	6.00
		11-11-92	6.04
		11-17-92	6.00
		11-19-92	6.07
		11-25-92	7.18
		12-02-92	6.16
		12-11-92	7.61
		12-15-92	6.12
		12-18-92	6.12
		12-26-92	8.26
		01-11-93	7.37
		01-25-93	6.87
		03-01-93	5.98
3	North Surfside canal	01-28-92	11.65
		02-25-92	11.10
		03-24-92	10.76
		04-29-92	10.91
		05-19-92	10.57
		06-24-92	10.11
		07-21-92	9.61
		08-25-92	9.32
		09-21-92	9.11
		10-27-92	9.51
		11-17-92	9.99
		12-16-92	11.19
4	Hines Marsh (southern part)	01-28-92	14.13
		02-25-92	14.41
		03-24-92	13.93
		04-29-92	14.49
		05-19-92	14.25
		06-24-92	13.59
		07-21-92	13.05
		08-25-92	12.33
		09-21-92	11.41
4	Hines Marsh (southern part)--Cont.	10-26-92	11.79
		11-17-92	12.93
		12-16-92	13.83
		01-27-93	14.58
		02-25-93	14.39
		03-31-93	14.76
		04-29-93	14.94
		06-02-93	13.74
5	Unnamed lake west of Skating Lake	01-28-92	15.81
		02-26-92	16.61
		03-24-92	15.23
		04-30-92	15.49
		05-19-92	15.23
		06-24-92	14.69
		07-21-92	14.03
		08-25-92	13.21
		10-27-92	12.41
		11-17-92	13.76
		12-16-92	15.47
6	South Surfside canal	01-28-92	10.04
		02-26-92	9.63
		03-24-92	9.22
		04-30-92	9.41
		05-19-92	9.01
		06-24-92	8.51
		07-21-92	8.17
		08-25-92	7.67
		09-22-92	7.35
		10-27-92	7.43
		11-17-92	9.59
		12-16-92	9.61
		12-25-92	5.09

Table 23.--*Water-level altitudes measured at surface-water sites, Long Beach Peninsula, Washington--Continued*

Site number	Site name	Date	Water-level altitude (feet)
7	Unnamed lake south of Skating Lake	01-28-92	13.12
		02-26-92	13.07
		03-24-92	12.59
		04-30-92	12.95
		05-19-92	12.51
		06-24-92	12.23
		07-21-92	11.88
		08-25-92	10.95
		09-22-92	11.05
		10-27-92	10.70
		11-17-92	11.80
		12-16-92	12.73
8	Whiskey Slough (upper part)	01-28-92	8.40
		02-26-92	8.24
		03-24-92	7.83
		04-30-92	9.29
		05-19-92	7.97
		06-24-92	8.19
		07-21-92	7.51
		08-25-92	7.43
		09-22-92	7.43
		10-08-92	7.41
		10-27-92	7.43
		11-17-92	7.55
		12-16-92	8.01
9	Whiskey Slough (lower part)	01-28-92	6.18
		02-25-92	5.65
		03-24-92	4.79
		04-29-92	5.53
		05-19-92	4.59
		06-24-92	4.41
		07-21-92	4.35
		08-25-92	4.27
		09-22-92	4.20
		10-01-92	4.27
		10-08-92	4.07
		10-16-92	4.29
		10-22-92	4.49
		10-26-92	4.90
		10-31-92	4.67
		11-05-92	4.67
9	Whiskey Slough (lower part)--Cont.	11-12-92	4.69
		11-17-92	4.69
		11-19-92	4.93
		11-26-92	4.99
		12-03-92	5.05
		12-12-92	5.19
		12-16-92	5.09
		12-17-92	5.29
		01-08-93	5.21
		01-14-93	5.21
		01-21-93	5.51
		01-29-93	5.81
		02-04-93	5.27
		02-11-93	5.11
		02-20-93	4.93
		02-25-93	4.93
		03-04-93	5.27
		03-11-93	5.11
		03-18-93	5.29
		03-25-93	4.53
10	Unnamed drainage in Nahcotta	01-28-92	4.92
		02-25-92	4.82
		03-12-92	4.53
		03-21-92	4.51
		03-24-92	4.49
		03-28-92	4.55
		04-02-92	4.43
		04-10-92	4.47
		04-17-92	4.83
		04-23-92	4.57
		04-30-92	4.65
		05-07-92	4.45
		05-14-92	5.43
		05-19-92	4.39
		05-21-92	4.35
		05-28-92	3.35
		06-04-92	4.37
		06-11-92	4.35
		06-18-92	4.27
		06-23-92	4.21
		06-26-92	4.25
		07-04-92	4.25
		07-09-92	4.23

Table 23.--*Water-level altitudes measured at surface-water sites, Long Beach Peninsula, Washington--Continued*

Site number	Site name	Date	Water-level altitude (feet)
10	Unnamed drainage in Nahcotta--Cont.	07-16-92	4.21
		07-21-92	4.11
		07-23-92	4.19
		07-30-92	4.01
		08-06-92	4.03
		08-13-92	4.01
		08-20-92	3.91
		08-25-92	4.06
		09-21-92	4.10
		10-01-92	3.69
		10-08-92	3.69
		10-16-92	3.69
		10-22-92	3.69
		10-31-92	4.49
		11-05-92	4.33
		11-12-92	4.35
		11-17-92	4.36
		11-19-92	4.49
		11-26-92	4.45
		12-03-92	4.47
		12-12-92	4.57
		12-16-92	4.51
		12-17-92	4.61
		12-25-92	4.51
		01-08-93	4.49
		01-14-93	4.45
		01-21-93	4.73
		01-29-93	4.75
		02-04-93	4.57
		02-11-93	4.55
		02-20-93	4.57
		02-25-93	4.57
		03-04-93	4.67
		03-11-93	4.61
		03-18-93	4.59
		03-25-93	4.65
11	Pauls Lake drainage	01-29-92	5.94
		02-25-92	3.04
		03-12-92	2.86
		03-21-92	2.82
		03-23-92	2.78
		03-28-92	2.74
		04-02-92	2.62
11	Pauls Lake drainage--Cont.	04-10-92	2.70
		04-17-92	3.86
		04-23-92	2.84
		04-29-92	3.06
		04-30-92	2.98
		05-07-92	2.76
		05-14-92	2.72
		05-19-92	2.70
		05-21-92	2.69
		05-28-92	2.68
		06-04-92	2.68
		06-11-92	2.64
		06-18-92	2.62
		06-23-92	2.58
		06-26-92	2.60
		07-04-92	2.64
		07-09-92	2.58
		07-16-92	2.56
		07-22-92	2.54
		07-23-92	2.54
		07-30-92	2.54
		08-06-92	2.58
		08-13-92	2.54
		08-20-92	2.54
		08-24-92	2.50
		08-27-92	2.52
		09-03-92	2.52
		09-10-92	2.54
		09-17-92	2.56
		09-22-92	3.09
		09-25-92	2.54
		10-01-92	2.54
		10-08-92	2.54
		10-16-92	2.64
		10-22-92	2.60
		10-27-92	3.14
		10-31-92	2.94
		11-05-92	2.58
		11-12-92	2.58
		11-18-92	2.66
		11-19-92	2.64
		11-26-92	2.66
		12-03-92	2.64
		12-12-92	2.76
		12-15-92	2.86

Table 23.--*Water-level altitudes measured at surface-water sites, Long Beach Peninsula, Washington--Continued*

Site number	Site name	Date	Water-level altitude (feet)
11	Pauls Lake drainage--Cont.	12-17-92	2.80
		12-25-92	2.74
		01-08-93	2.96
		01-14-93	2.38
		01-21-93	3.16
		01-29-93	3.18
		02-04-93	2.99
		02-11-93	3.00
		02-20-93	2.84
		02-25-93	2.82
		03-04-93	3.04
		03-11-93	2.80
		03-18-93	2.94
		03-25-93	3.02
12	Loomis Lake drainage (lower part)	01-28-92	9.68
		02-26-92	9.45
		03-24-92	9.18
		04-30-92	9.21
		05-18-92	8.10
		06-23-92	9.04
		07-22-92	8.92
		08-26-92	8.36
		09-22-92	8.02
		10-28-92	7.84
		11-17-92	8.91
		12-16-92	9.72
13	Pauls Lake	01-29-92	11.45
		02-26-92	11.39
		03-23-92	11.24
		05-19-92	11.13
		06-23-92	10.23
		07-22-92	9.35
		08-24-92	8.51
		09-22-92	8.07
		10-28-92	7.47
		11-18-92	8.35
		12-17-92	10.67
14	Loomis Lake drainage (upper part)	01-28-92	11.39
		02-26-92	10.69
		03-24-92	10.46
		04-30-92	10.70
		05-18-92	11.78
		06-23-92	10.96
		07-22-92	10.32
		08-26-92	9.86
		09-22-92	9.38
		10-28-92	9.16
		11-17-92	9.98
		12-15-92	11.10
15	Unnamed lake near Klipson Road	01-29-92	12.95
		02-27-92	12.26
		03-25-92	12.08
		04-30-92	12.18
		05-18-92	12.40
		06-23-92	12.21
		07-22-92	11.66
		08-26-92	10.94
		09-22-92	10.50
		10-28-92	10.10
		11-18-92	11.35
		12-18-92	12.22
16	Loomis Lake	01-29-92	14.32
		02-26-92	14.18
		03-25-92	13.90
		05-01-92	14.10
		05-20-92	13.87
		06-23-92	13.50
		07-20-92	13.14
		08-25-92	12.68
		09-22-92	12.36
		10-28-92	12.30
		11-16-92	12.84
		12-15-92	13.90
		01-27-93	14.28
		02-25-93	13.88
		03-31-93	14.02
		04-29-93	14.18
		06-03-93	13.93

Table 23.--*Water-level altitudes measured at surface-water sites, Long Beach Peninsula, Washington--Continued*

Site number	Site name	Date	Water-level altitude (feet)
17	Island Lake	01-29-92	15.08
		02-27-92	14.89
		03-25-92	14.63
		05-01-92	14.84
		05-20-92	14.50
		06-25-92	13.92
		07-23-92	13.48
		08-27-92	12.96
		09-23-92	12.58
		10-29-92	12.53
		11-19-92	13.33
		12-18-92	14.38
		01-26-93	14.98
		02-24-93	14.65
		03-30-93	14.80
		04-28-93	14.88
		06-03-93	14.64
18	Litschke Road drainage	01-29-92	8.13
		02-27-92	7.18
		03-25-92	6.73
		05-01-92	7.11
		05-20-92	6.63
		06-24-92	6.49
		07-22-92	6.39
		08-26-92	6.06
		09-23-92	5.71
		10-29-92	6.17
		11-18-92	6.60
		12-17-92	7.17
19	Cranberry Lake	01-29-92	14.19
		02-27-92	13.80
		03-25-92	13.38
		05-01-92	13.62
		05-20-92	13.62
		06-25-92	12.86
		07-23-92	12.26
		08-27-92	11.42
		09-23-92	11.02
		10-29-92	11.00
		11-19-92	12.29
		12-18-92	13.64
19	Cranberry Lake--Cont.	01-26-93	14.31
		02-24-93	13.34
		03-30-93	14.00
		04-28-93	14.28
		06-03-93	13.66
20	Giles Slough	01-29-92	7.97
		02-27-92	6.90
		03-08-92	6.70
		03-15-92	6.50
		03-23-92	6.20
		03-25-92	6.18
		04-03-92	6.10
		04-08-92	6.34
		04-13-92	6.50
		04-23-92	6.20
		04-29-92	6.40
		05-01-92	6.91
		05-08-92	6.43
		05-11-92	6.35
		05-19-92	6.20
		05-20-92	6.18
		05-27-92	6.20
		06-04-92	6.20
		06-12-92	6.20
		06-18-92	6.20
		06-25-92	5.80
		07-12-92	5.80
		07-21-92	5.80
		07-22-92	5.78
		08-04-92	5.75
		08-27-92	5.76
		09-10-92	5.76
		09-23-92	5.76
		10-29-92	5.92
		11-18-92	6.30
		12-15-92	6.96

Table 23.--*Water-level altitudes measured at surface-water sites, Long Beach Peninsula, Washington--Continued*

Site number	Site name	Date	Water-level altitude (feet)
21	Briscoe Lake	01-29-92	13.71
		02-27-92	13.71
		02-28-92	13.75
		03-06-92	13.71
		03-13-92	13.55
		03-20-92	13.60
		03-25-92	13.43
		03-27-92	13.45
		04-03-92	13.37
		04-10-92	13.35
		04-17-92	13.75
		04-24-92	13.75
		04-29-92	13.75
		05-01-92	13.75
		05-08-92	13.38
		05-15-92	13.17
		05-20-92	12.99
		05-22-92	12.95
		05-29-92	12.85
		06-05-92	12.65
		06-12-92	12.45
		06-19-92	12.30
		06-25-92	12.12
		07-03-92	12.05
		07-10-92	11.85
		07-17-92	11.75
		07-20-92	11.59
		07-24-92	11.55
		07-31-92	11.35
		08-07-92	11.35
		08-14-92	11.25
		08-21-92	11.15
		08-26-92	11.11
		09-23-92	10.65
		10-28-92	10.57
		11-06-92	11.35
		11-13-92	11.55
		11-16-92	11.61
		11-20-92	12.05
		11-27-92	12.55
		12-04-92	12.85
		12-11-92	13.15
		12-15-92	13.23
		12-18-92	13.25
		12-25-92	13.45
22	Gile Lake drainage	01-30-92	7.47
		02-26-92	6.30
		03-08-92	6.19
		03-15-92	6.09
		03-23-92	5.94
		03-25-92	5.98
		04-03-92	5.99
		04-08-92	6.04
		04-13-92	6.18
		04-29-92	6.94
		05-01-92	6.41
		05-08-92	6.09
		05-11-92	6.24
		05-20-92	5.95
		05-27-92	5.89
		06-04-92	5.86
		06-12-92	5.93
		06-18-92	5.93
		06-23-92	5.84
		06-25-92	5.81
		07-12-92	5.81
		07-21-92	5.79
		07-22-92	5.73
		08-04-92	5.59
		08-26-92	5.37
		09-10-92	5.59
		09-23-92	5.83
		10-29-92	6.66
		11-19-92	6.98
		12-15-92	7.55
23	East Main drainage (lower part)	01-29-92	7.78
		02-26-92	6.58
		03-26-92	5.87
		05-01-92	6.35
		05-20-92	5.05
		06-25-92	4.71
		07-22-92	4.61
		08-26-92	4.75
		09-23-92	4.75
		10-29-92	4.87
		11-19-92	7.11
		12-15-92	6.61

Table 23.--*Water-level altitudes measured at surface-water sites, Long Beach Peninsula, Washington--Continued*

Site number	Site name	Date	Water-level altitude (feet)
24	East Main drainage (upper part)	01-29-92	11.53
		02-24-92	11.12
		03-02-92	10.84
		03-09-92	10.72
		03-16-92	10.66
		03-23-92	10.52
		03-26-92	10.52
		03-30-92	10.50
		04-06-92	10.68
		04-13-92	11.05
		04-20-92	10.96
		04-27-92	10.92
		04-28-92	10.90
		05-04-92	10.83
		05-11-92	10.73
		05-18-92	10.64
		05-21-92	10.63
		05-26-92	10.58
		06-01-92	10.50
		06-08-92	10.28
		06-15-92	10.36
		06-22-92	10.14
		06-25-92	10.02
		06-29-92	10.02
		07-07-92	9.78
		07-23-92	9.60
		08-27-92	9.18
		09-23-92	9.26
		10-20-92	9.64
		10-29-92	9.66
		11-19-92	11.33
		11-23-92	11.38
		11-30-92	11.66
		12-07-92	10.96
		12-14-92	11.14
		12-18-92	11.10
		12-21-92	11.38
		12-28-92	11.16
		01-26-93	11.34
		02-24-93	10.86
		03-30-93	11.02
		04-28-93	11.11
		06-02-93	10.97
25	Tarlatt Slough (lower part)	01-30-92	0.75
		02-26-92	1.72
		03-26-92	1.06
		04-28-92	2.13
		06-25-92	-0.40
		07-23-92	-0.44
		08-26-92	-0.40
		09-23-92	0.28
		10-29-92	1.39
		11-18-92	-0.49
		12-14-92	1.73
		01-26-93	2.11
		02-24-93	-0.60
		03-30-93	-0.38
		04-28-93	1.65
		06-02-93	1.57
26	Tinker Lake	01-31-92	12.33
		02-24-92	12.16
		03-08-92	12.01
		03-15-92	12.03
		03-22-92	11.99
		03-26-92	11.98
		03-29-92	11.98
		04-19-92	12.55
		04-26-92	12.06
		04-29-92	12.17
		05-10-92	12.05
		05-17-92	11.99
		05-19-92	11.97
		05-24-92	11.95
		05-31-92	11.89
		06-07-92	11.81
		06-14-92	11.83
		06-21-92	11.81
		06-25-92	11.74
		07-05-92	11.73
		07-12-92	11.71
		07-19-92	11.65
		07-23-92	11.59
		07-26-92	11.61
		08-02-92	11.61
		08-24-92	11.49
		09-23-92	11.38

Table 23.--*Water-level altitudes measured at surface-water sites, Long Beach Peninsula, Washington--Continued*

Site number	Site name	Date	Water-level altitude (feet)
26	Tinker Lake--Cont.	10-28-92	11.61
		11-19-92	12.13
		12-14-92	12.11
		01-26-93	12.23
		02-24-93	12.01
		03-30-93	12.09
		04-28-93	12.18
		06-02-93	12.18
27	Tarlatt Slough (middle part)	01-30-92	8.64
		02-24-92	6.73
		03-26-92	5.49
		04-28-92	5.05
		05-21-92	5.49
		06-25-92	5.41
		07-23-92	5.27
		08-26-92	5.33
		09-23-92	5.27
		10-29-92	5.53
		11-18-92	6.15
		12-14-92	6.51
		01-26-93	7.94
		02-24-93	5.61
		03-30-93	6.04
		04-28-93	6.23
		06-02-93	5.72
28	South Main drainage	01-31-92	11.18
		02-24-92	10.19
		03-26-92	9.36
		04-29-92	9.96
		06-25-92	9.94
		07-23-92	9.54
		08-24-92	9.36
		10-27-92	10.08
		11-18-92	10.42
		12-14-92	10.64
		01-26-93	10.97
		02-24-93	10.38
		03-30-93	9.88
		04-28-93	10.00
		06-02-93	10.27

Table 24.--*Values and concentrations of common constituents and radon in ground water, Long Beach Peninsula, Washington*

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; deg C, degrees Celsius; mg/L, milligrams per liter; $CaCO_3$, calcium carbonate; pCi/L, picocuries per liter; <, less than; --, not available]

Well number	Well location	Date	Time	Specific conductance (µS/cm)	pH, field (standard units)	Temperature, water (deg C)	Oxygen dissolved (mg/L)	Hardness, total (mg/L as $CaCO_3$)	Calcium, dissolved (mg/L as Ca)
10	12N/11W-04P01	02-11-92	1030	72	6.1	11.0	6.2	15	3.2
		07-28-92	1030	79	6.1	13.0	6.3	19	3.9
11	12N/11W-04P02	02-11-92	1210	188	6.8	9.5	0.4	32	6.4
		07-28-92	1115	177	7.0	13.5	<0.1	32	6.2
17	12N/11W-09N01	02-11-92	1415	145	6.0	10.0	3.5	--	--
		07-28-92	1340	114	6.1	12.0	3.2	--	--
24	12N/11W-16E03	02-11-92	1540	290	6.9	11.5	4.7	43	7.7
		07-28-92	1510	214	6.9	14.0	1.9	34	6.0
28	12N/11W-16Q01	02-11-92	1730	194	6.5	11.5	7.8	33	7.1
		07-28-92	1715	140	6.5	12.0	8.2	28	5.7
29	12N/11W-20A02	02-12-92	1020	132	6.4	12.0	6.7	--	--
		07-29-92	0940	153	6.4	13.0	6.8	39	6.9
32	12N/11W-22E03	02-12-92	0920	139	6.0	11.5	0.1	33	4.8
		07-30-92	1000	176	5.9	11.5	0.1	43	6.3
33	12N/11W-21P02	02-12-92	1200	63	6.3	12.0	8.0	--	--
		07-30-92	1510	68	6.3	13.5	7.1	--	--
34	12N/11W-28E01	02-12-92	1250	135	6.1	12.5	0.7	--	--
		07-30-92	1310	96	6.1	13.5	4.5	--	--
35	12N/11W-28L01	02-12-92	1545	206	6.5	11.5	5.8	51	11
		07-28-92	1545	132	6.6	12.0	8.4	28	5.8
38	12N/11W-28G06	02-12-92	1105	86	6.5	10.5	10.1	--	--
		07-30-92	1140	76	6.5	12.5	11.4	--	--
40	12N/11W-27M02	02-13-92	1650	90	6.3	12.0	3.6	--	--
		07-28-92	1710	111	6.4	12.5	3.4	--	--
42	12N/11W-28P03	02-12-92	1525	128	6.4	10.0	6.4	--	--
		07-31-92	1350	324	6.1	16.0	0.4	--	--
45	12N/11W-28R03	02-12-92	1655	215	6.5	11.0	9.7	--	--
		07-30-92	1620	220	6.4	12.0	10.4	--	--
46	12N/11W-27N04	02-12-92	1345	142	6.3	11.5	0.2	26	2.9
		07-30-92	1425	110	6.4	12.5	0.5	21	2.4

Table 24.--*Values and concentrations of common constituents and radon in ground water, Long Beach Peninsula, Washington--Continued*

Well number	Well location	Date	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)	Bicarbonate water, whole, field (mg/L as HCO_3)	Alkalinity. water, whole, field (mg/L as $CaCO_3$)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)
10	12N/11W-04P01	02-11-92	1.7	7.0	0.70	18	15	2.6	6.6
		07-28-92	2.3	7.0	0.70	17	15	2.2	9.6
11	12N/11W-04P02	02-11-92	4.0	11	1.7	38	31	6.5	36
		07-28-92	4.1	11	1.7	43	35	6.3	32
17	12N/11W-09N01	02-11-92	--	--	--	--	--	--	9.6
		07-28-92	--	--	--	--	--	--	11
24	12N/11W-16E03	02-11-92	5.7	32	8.2	74	61	7.7	41
		07-28-92	4.7	28	7.6	82	68	6.1	26
28	12N/11W-16Q01	02-11-92	3.8	22	1.1	23	19	10	38
		07-28-92	3.3	17	0.90	23	19	1.8	35
29	12N/11W-20A02	02-12-92	--	--	--	--	--	--	14
		07-29-92	5.3	12	2.7	--	--	8.7	19
32	12N/11W-22E03	02-12-92	5.2	11	0.90	18	15	16	22
		07-30-92	6.6	14	0.90	29	24	38	21
33	12N/11W-21P02	02-12-92	--	--	--	--	--	--	6.9
		07-30-92	--	--	--	--	--	--	8.4
34	12N/11W-28E01	02-12-92	--	--	--	--	--	--	18
		07-30-92	--	--	--	--	--	--	15
35	12N/11W-28L01	02-12-92	5.6	18	1.3	24	20	7.6	47
		07-28-92	3.2	13	0.90	24	20	7.9	21
38	12N/11W-28G06	02-12-92	--	--	--	--	--	--	7.7
		07-30-92	--	--	--	--	--	--	8.4
40	12N/11W-27M02	02-13-92	--	--	--	--	--	--	8.5
		07-28-92	--	--	--	--	--	--	15
42	12N/11W-28P03	02-12-92	--	--	--	--	--	--	6.5
		07-31-92	--	--	--	--	--	--	37
45	12N/11W-28R03	02-12-92	--	--	--	--	--	--	44
		07-30-92	--	--	--	--	--	--	52
46	12N/11W-27N04	02-12-92	4.6	11	4.4	50	41	17	8.0
		07-30-92	3.7	8.8	3.6	48	39	5.0	12

Table 24.--*Values and concentrations of common constituents and radon in ground water, Long Beach Peninsula, Washington--Continued*

Well number	Well location	Date	Fluoride, dissolved (mg/L as F)	Silica, dissolved (mg/L as SiO_2)	Solids, sum of constituents, dissolved (mg/L)	Iron, dissolved (mg/L as Fe)	Manganese, dissolved (mg/L as Mn)	Radon 222, total (pCi/L)
10	12N/11W-04P01	02-11-92	0.20	16	52	<0.003	<0.001	200
		07-28-92	<0.10	15	56	0.006	<0.001	--
11	12N/11W-04P02	02-11-92	0.20	33	132	14	0.23	--
		07-28-92	<0.10	33	129	13	0.17	--
17	12N/11W-09N01	02-11-92	--	--	--	<0.010	--	--
		07-28-92	--	--	--	0.040	--	--
24	12N/11W-16E03	02-11-92	0.20	19	159	0.005	<0.001	--
		07-28-92	0.20	17	139	0.067	<0.001	--
28	12N/11W-16Q01	02-11-92	0.20	21	116	0.005	<0.001	--
		07-28-92	<0.10	20	97	0.004	<0.001	--
29	12N/11W-20A02	02-12-92	--	--	--	<0.010	--	240
		07-29-92	<0.10	20	97	0.010	0.002	--
32	12N/11W-22E03	02-12-92	0.20	23	96	3.8	0.095	81
		07-30-92	<0.10	23	130	5.4	0.098	--
33	12N/11W-21P02	02-12-92	--	--	--	<0.010	--	--
		07-30-92	--	--	--	0.010	--	--
34	12N/11W-28E01	02-12-92	--	--	--	<0.010	--	--
		07-30-92	--	--	--	0.010	--	--
35	12N/11W-28L01	02-12-92	0.20	20	123	0.090	<0.001	160
		07-28-92	<0.10	19	84	0.065	0.005	--
38	12N/11W-28G06	02-12-92	--	--	--	<0.010	--	--
		07-30-92	--	--	--	0.020	--	--
40	12N/11W-27M02	02-13-92	--	--	--	0.050	--	--
		07-28-92	--	--	--	0.090	--	--
42	12N/11W-28P03	02-12-92	--	--	--	<0.010	--	--
		07-31-92	--	--	--	0.010	--	--
45	12N/11W-28R03	02-12-92	--	--	--	<0.010	--	--
		07-30-92	--	--	--	<0.010	--	--
46	12N/11W-27N04	02-12-92	0.20	26	106	6.2	0.052	--
		07-30-92	<0.10	28	93	5.4	0.031	--

Table 24.--*Values and concentrations of common constituents and radon in ground water, Long Beach Peninsula, Washington--Continued*

Well number	Well location	Date	Time	Specific conductance (µS/cm)	pH, field (standard units)	Temperature, water (deg C)	Oxygen dissolved (mg/L)	Hardness, total (mg/L as $CaCO_3$)	Calcium, dissolved (mg/L as Ca)
47	12N/11W-33D01	02-13-92	0930	80	6.4	10.5	4.9	19	3.6
		07-31-92	0905	77	6.4	12.5	9.4	21	3.8
48	12N/11W-33D02	02-13-92	1045	135	6.7	10.5	2.5	36	7.0
		07-31-92	1030	269	6.4	12.5	4.2	88	17
49	12N/11W-33C02	02-12-92	1715	50	6.1	11.0	8.0	--	--
		07-28-92	1330	52	6.1	12.5	6.8	--	--
50	12N/11W-33B03	02-12-92	1430	58	6.5	11.5	9.6	12	2.6
		07-28-92	1425	76	6.6	11.0	8.0	16	3.6
57	11N/11W-04M03	02-13-92	1255	99	6.4	11.0	1.0	21	3.9
		07-31-92	1210	94	6.3	12.0	0.4	22	4.0
62	11N/11W-03M03	02-13-92	1405	153	6.1	11.0	8.1	--	--
		07-29-92	1850	135	6.0	11.0	6.4	13	2.6
65	11N/11W-10L02	02-11-92	1630	94	6.2	11.5	9.5	17	4.1
		07-30-92	1240	134	6.1	12.0	4.4	26	6.2
68	11N/11W-09P03	02-11-92	1500	174	5.8	12.0	1.9	--	--
		07-27-92	1735	146	6.0	12.5	2.3	--	--
74	11N/11W-16N04	02-11-92	1330	212	6.2	11.5	0.6	50	7.5
		07-27-92	1615	236	6.2	11.5	0.4	56	8.4
81	11N/11W-28H01	02-13-92	1100	141	6.5	11.0	1.7	36	7.8
		07-27-92	1300	178	6.5	15.5	0.4	46	10
82	11N/11W-27H01	02-10-92	1520	85	6.1	12.5	6.2	--	--
		07-27-92	1445	98	6.1	11.5	3.8	--	--
89	11N/11W-33K02	02-10-92	1400	112	6.2	12.0	5.4	--	--
		07-28-92	0935	108	6.3	12.0	3.9	--	--
93	11N/11W-34L01	02-13-92	1515	285	7.1	11.0	<0.1	--	--
		07-29-92	1640	275	7.4	11.5	<0.1	87	7.0
96	11N/11W-34P03	02-10-92	1130	98	6.2	11.0	0.3	22	4.6
		07-29-92	1150	100	6.2	13.0	0.2	24	5.3
97	11N/11W-34P04	02-10-92	1535	160	6.6	10.5	0.5	30	6.9
		07-29-92	1500	143	6.6	12.5	<0.1	26	6.0

Table 24.--*Values and concentrations of common constituents and radon in ground water, Long Beach Peninsula, Washington--Continued*

Well number	Well location	Date	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)	Bicarbonate water, whole, field (mg/L as HCO_3)	Alkalinity. water, whole, field (mg/L as $CaCO_3$)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)
47	12N/11W-33D01	02-13-92	2.5	6.9	0.90	23	19	2.5	11
		07-31-92	2.7	6.9	0.90	24	20	2.1	8.0
48	12N/11W-33D02	02-13-92	4.5	10	1.7	46	37	3.3	9.9
		07-31-92	11	18	2.8	68	56	13	19
49	12N/11W-33C02	02-12-92	--	--	--	--	--	--	5.8
		07-28-92	--	--	--	--	--	--	8.3
50	12N/11W-33B03	02-12-92	1.3	6.3	0.50	15	12	1.8	8.8
		07-28-92	1.8	8.1	0.60	15	12	1.2	9.4
57	11N/11W-04M03	02-13-92	2.7	11	0.90	26	21	1.7	15
		07-31-92	2.8	11	0.90	29	24	3.6	13
62	11N/11W-03M03	02-13-92	--	--	--	--	--	--	31
		07-29-92	1.6	21	0.50	--	--	11	24
65	11N/11W-10L02	02-11-92	1.6	11	0.70	21	17	7.7	13
		07-30-92	2.5	14	0.90	24	20	3.1	27
68	11N/11W-09P03	02-11-92	--	--	--	--	--	--	13
		07-27-92	--	--	--	--	--	--	11
74	11N/11W-16N04	02-11-92	7.6	17	2.8	24	20	13	33
		07-27-92	8.6	19	3.0	35	28	12	35
81	11N/11W-28H01	02-13-92	3.9	13	1.2	39	32	5.5	18
		07-27-92	5.0	14	1.4	44	36	8.3	25
82	11N/11W-27H01	02-10-92	--	--	--	--	--	--	9.9
		07-27-92	--	--	--	--	--	--	11
89	11N/11W-33K02	02-10-92	--	--	--	--	--	--	15
		07-28-92	--	--	--	--	--	--	14
93	11N/11W-34L01	02-13-92	--	--	--	--	--	--	33
		07-29-92	17	15	9.2	--	--	0.70	36
96	11N/11W-34P03	02-10-92	2.5	6.2	1.1	36	30	4.5	9.8
		07-29-92	2.6	6.4	1.1	53	43	5.6	6.0
97	11N/11W-34P04	02-10-92	3.0	12	0.90	65	54	<0.10	15
		07-29-92	2.7	12	0.70	68	56	<0.10	14

Table 24.--*Values and concentrations of common constituents and radon in ground water, Long Beach Peninsula, Washington--Continued*

Well number	Well location	Date	Fluoride, dissolved (mg/L as F)	Silica, dissolved (mg/L as SiO_2)	Solids, sum of constituents, dissolved (mg/L)	Iron, dissolved (mg/L as Fe)	Manganese, dissolved (mg/L as Mn)	Radon 222, total (pCi/L)
47	12N/11W-33D01	02-13-92	0.10	24	66	0.017	<0.001	--
		07-31-92	<0.10	23	65	0.013	<0.001	--
48	12N/11W-33D02	02-13-92	0.10	30	98	0.009	<0.001	--
		07-31-92	<0.10	31	190	0.005	<0.001	--
49	12N/11W-33C02	02-12-92	--	--	--	0.020	--	--
		07-28-92	--	--	--	0.010	--	--
50	12N/11W-33B03	02-12-92	0.20	17	46	<0.003	<0.001	230
		07-28-92	<0.10	16	57	0.006	<0.001	--
57	11N/11W-04M03	02-13-92	0.10	25	74	0.024	<0.001	--
		07-31-92	<0.10	24	74	0.018	0.001	--
62	11N/11W-03M03	02-13-92	--	--	--	<0.010	--	--
		07-29-92	<0.10	15	89	0.005	<0.001	--
65	11N/11W-10L02	02-11-92	0.20	22	71	0.004	<0.001	--
		07-30-92	<0.10	23	90	0.011	<0.001	--
68	11N/11W-09P03	02-11-92	--	--	--	0.010	--	150
		07-27-92	--	--	--	0.020	--	--
74	11N/11W-16N04	02-11-92	0.20	25	136	0.026	0.024	--
		07-27-92	<0.10	27	151	0.007	0.029	--
82	11N/11W-27H01	02-10-92	--	--	--	0.15	--	260
		07-27-92	--	--	--	0.18	--	--
81	11N/11W-28H01	02-13-92	0.10	30	102	0.014	<0.001	300
		07-27-92	<0.10	32	123	0.045	0.002	--
89	11N/11W-33K02	02-10-92	--	--	--	0.010	--	--
		07-28-92	--	--	--	0.020	--	--
93	11N/11W-34L01	02-13-92	--	--	--	6.5	--	--
		07-29-92	0.20	47	195	7.5	0.12	--
96	11N/11W-34P03	02-10-92	0.10	18	70	4.8	0.072	--
		07-29-92	<0.10	17	76	5.3	0.062	--
97	11N/11W-34P04	02-10-92	0.10	46	--	14	0.20	--
		07-29-92	<0.10	48	--	13	0.14	--

Table 24.--*Values and concentrations of common constituents and radon in ground water, Long Beach Peninsula, Washington--Continued*

Well number	Well location	Date	Time	Specific conductance (µS/cm)	pH, field (standard units)	Temperature, water (deg C)	Oxygen dissolved (mg/L)	Hardness, total (mg/L as $CaCO_3$)	Calcium, dissolved (mg/L as Ca)
98	11N/11W-34P02	07-29-92	1125	1,210	7.0	14.5	6.0	450	90
104	10N/11W-03F03	02-11-92	1030	131	5.5	11.5	2.3	21	3.4
		07-29-92	1400	148	5.5	14.5	2.6	25	4.0
107	10N/11W-09A01	02-14-92	0945	110	6.3	9.5	8.6	28	5.7
		07-27-92	1125	100	6.3	11.0	10.2	26	5.2
108	10N/11W-09E01	02-13-92	1235	65	6.5	12.0	7.6	14	2.9
114	10N/11W-10E01	02-14-92	1145	482	7.5	10.5	0.6	--	--
		07-29-92	0945	389	7.4	13.0	0.2	--	--
116	10N/11W-10L01	02-13-92	1640	132	6.7	11.0	0.3	--	--
		07-27-92	1350	138	6.6	13.5	0.2	--	--
117	10N/11W-16C01	02-14-92	1410	68	7.1	11.0	<0.1	6	1.2
		07-31-92	1540	75	7.2	15.0	<0.1	7	1.5
118	10N/11W-16D01	02-10-92	1045	78	6.2	12.0	2.7	--	--
		07-27-92	1045	97	6.2	12.5	2.0	--	--
121	10N/11W-15L02	02-14-92	1720	315	6.7	11.0	<0.1	71	13
		07-27-92	1555	270	6.7	13.5	<0.1	64	11
124	10N/11W-22C01	02-14-92	1545	256	6.2	11.5	<0.1	--	--
		07-27-92	1745	240	6.2	12.0	<0.1	--	--
125	10N/11W-21M02	07-28-92	1120	197	6.3	12.5	0.5	61	8.0
128	10N/11W-21Q01	02-13-92	1435	115	6.2	13.0	3.8	27	4.2
		07-29-92	1615	134	6.3	12.5	1.7	28	4.4

Table 24.--*Values and concentrations of common constituents and radon in ground water, Long Beach Peninsula, Washington--Continued*

Well number	Well location	Date	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)	Bicarbonate water, whole, field (mg/L as HCO_3)	Alkalinity. water, whole, field (mg/L as $CaCO_3$)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)
98	11N/11W-34P02	07-29-92	54	41	3.2	244	200	6.3	290
104	10N/11W-03F03	02-11-92	3.0	14	1.4	15	12	10	27
		07-29-92	3.6	15	1.4	16	13	9.3	26
107	10N/11W-09A01	02-14-92	3.4	7.6	0.90	17	14	1.0	9.9
		07-27-92	3.2	7.4	0.90	15	13	1.2	10
108	10N/11W-09E01	02-13-92	1.7	6.6	0.60	15	12	2.3	9.3
114	10N/11W-10E01	02-14-92	--	--	--	--	--	--	25
		07-29-92	--	--	--	--	--	--	21
116	10N/11W-10L01	02-13-92	--	--	--	--	--	--	10
		07-27-92	--	--	--	--	--	--	12
117	10N/11W-16C01	02-14-92	0.61	5.9	2.6	28	23	2.9	8.3
		07-31-92	0.79	7.9	3.0	29	24	2.3	10
118	10N/11W-16D01	02-10-92	--	--	--	--	--	--	11
		07-27-92	--	--	--	--	--	--	16
121	10N/11W-15L02	02-14-92	9.4	10	2.9	176	144	5.0	13
		07-27-92	8.9	8.4	2.9	150	123	2.0	12
124	10N/11W-22C01	02-14-92	--	--	--	--	--	--	14
		07-27-92	--	--	--	--	--	--	15
125	10N/11W-21M02	07-28-92	10	11	7.2	81	66	7.9	16
128	10N/11W-21Q01	02-13-92	3.9	11	1.1	17	14	5.7	13
		07-29-92	4.1	12	1.2	22	19	7.5	14

Table 24.--*Values and concentrations of common constituents and radon in ground water, Long Beach Peninsula, Washington--Continued*

Well number	Well location	Date	Fluoride, dissolved (mg/L as F)	Silica, dissolved (mg/L as SiO_2)	Solids, sum of constituents, dissolved (mg/L)	Iron, dissolved (mg/L as Fe)	Manganese, dissolved (mg/L as Mn)	Radon 222, total (pCi/L)
98	11N/11W-34P02	07-29-92	0.20	41	654	7.0	0.90	--
104	10N/11W-03F03	02-11-92	0.10	18	88	0.20	0.036	--
		07-29-92	<0.10	17	92	0.38	0.048	--
107	10N/11W-09A01	02-14-92	0.10	23	83	0.014	<0.001	--
		07-27-92	<0.10	23	80	0.007	<0.001	--
108	10N/11W-09E01	02-13-92	0.10	15	47	0.018	<0.001	150
114	10N/11W-10E01	02-14-92	--	--	--	3.7	--	--
		07-29-92	--	--	--	4.8	--	--
116	10N/11W-10L01	02-13-92	--	--	--	3.5	--	--
		07-27-92	--	--	--	3.6	--	--
117	10N/11W-16C01	02-14-92	0.10	29	70	5.1	0.060	--
		07-31-92	<0.10	28	72	4.6	0.068	--
118	10N/11W-16D01	02-10-92	--	--	--	0.020	--	--
		07-27-92	--	--	--	0.020	--	--
121	10N/11W-15L02	02-14-92	0.10	55	240	42	0.65	--
		07-27-92	<0.10	60	218	37	0.44	--
124	10N/11W-22C01	02-14-92	--	--	--	31	--	--
		07-27-92	--	--	--	31	--	--
125	10N/11W-21M02	07-28-92	<0.10	27	129	0.24	0.068	--
128	10N/11W-21Q01	02-13-92	0.10	23	84	<0.003	<0.001	190
		07-29-92	<0.10	21	92	0.009	0.002	--

Table 25.--*Values and concentrations of common constituents in surface water, Long Beach Peninsula, Washington*

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; deg C, degrees Celsius; mg/L, milligrams per liter; $CaCO_3$, calcium carbonate; --, not available]

Site number	Name	Date	Time	Specific conductance (µS/cm)	pH, field (standard units)	Temperature, water (deg C)	Oxygen dissolved (mg/L)	Hardness, total (mg/L as $CaCO_3$)
2	Unnamed drainage near Stackpole Road	02-11-92	1200	159	6.6	9.0	4.6	29
8	Whiskey Slough (upper)	02-11-92	1415	123	6.5	9.5	6.1	--
		07-30-92	1130	144	6.5	12.0	2.1	--
9	Whiskey Slough (lower)	02-12-92	1030	141	6.6	9.5	6.3	29
12	Loomis Lake drainage (lower)	02-11-92	0945	170	6.6	9.5	3.3	34
		07-29-92	1730	225	7.3	15.5	3.3	52
14	Loomis Lake drainage (upper)	02-11-92	1600	153	6.6	10.5	2.6	--
		07-29-92	1550	186	7.1	15.5	1.9	--
18	Litschke Road drainage	02-10-92	1445	91	6.4	9.5	6.0	--
		07-30-92	1350	208	7.1	17.0	5.0	--
20	Giles Slough	02-10-92	1600	89	6.3	10.5	7.0	14
		07-30-92	1540	204	7.6	20.5	8.5	62
22	Gile Lake drainage	02-12-92	1215	170	6.9	10.5	7.1	48
		07-28-92	1320	186	7.0	19.5	7.7	54
23	East Main drainage (lower)	02-12-92	1650	146	6.7	11.0	6.2	30
		07-27-92	1130	257	7.1	13.0	2.8	67
25	Tarlatt Slough (lower)	02-12-92	1500	199	7.0	11.0	6.0	47
		07-27-92	1800	236	7.7	22.0	--	59
27	Tarlatt Slough (middle)	02-13-92	1215	283	7.1	11.0	2.1	--
		07-27-92	1530	286	7.3	17.5	4.0	--
28	South Main drainage	02-13-92	1020	202	6.7	10.0	0.7	50
		07-28-92	0900	213	7.0	16.5	3.8	53
29	Tarlatt Slough (upper)	02-13-92	0900	179	6.6	10.0	5.9	36
		07-28-92	1100	408	7.5	15.0	0.7	110

Table 25.--*Values and concentrations of common constituents in surface water, Long Beach Peninsula, Washington--Continued*

Site number	Name	Date	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)	Bicarbonate water, dissolved (mg/L as HCO_3)	Alkalinity. water, dissolved (mg/L as $CaCO_3$)
2	Unnamed drainage near Stackpole Road	02-11-92	4.7	4.3	15	1.8	38	31
8	Whiskey Slough (upper)	02-11-92	--	--	--	--	--	--
		07-30-92	--	--	--	--	--	--
9	Whiskey Slough (lower)	02-12-92	4.5	4.4	16	2.3	24	20
12	Loomis Lake drainage (lower)	02-11-92	4.9	5.3	18	2.8	28	23
		07-29-92	6.7	8.6	22	3.6	65	53
14	Loomis Lake drainage (upper)	02-11-92	--	--	--	--	--	--
		07-29-92	--	--	--	--	--	--
18	Litschke Road drainage	02-10-92	--	--	--	--	--	--
		07-30-92	--	--	--	--	--	--
20	Giles Slough	02-10-92	2.3	2.1	9.9	1.2	--	--
		07-30-92	9.9	9.0	15	5.1	81	66
22	Gile Lake drainage	02-12-92	7.7	6.9	11	4.4	57	47
		07-28-92	9.5	7.4	13	6.7	59	48
23	East Main drainage (lower)	02-12-92	4.4	4.5	16	2.6	34	28
		07-27-92	8.8	11	19	7.1	99	81
25	Tarlatt Slough (lower)	02-12-92	7.2	7.1	19	4.9	67	55
		07-27-92	7.2	9.9	22	7.9	95	78
27	Tarlatt Slough (middle)	02-13-92	--	--	--	--	--	--
		07-27-92	--	--	--	--	131	107
28	South Main drainage	02-13-92	9.5	6.3	18	3.3	63	52
		07-28-92	10	6.7	20	4.3	68	56
29	Tarlatt Slough (upper)	02-13-92	5.6	5.4	18	3.2	45	37
		07-28-92	17	16	43	7.7	176	142

Table 25.--*Values and concentrations of common constituents in surface water, Long Beach Peninsula, Washington--Continued*

Site number	Name	Date	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)	Solids, sum of constituents, dissolved (mg/L)	Iron, dissolved (mg/L as Fe)	Manganese, dissolved (mg/L as Mn)
2	Unnamed drainage near Stackpole Road	02-11-92	1.4	30	0.10	23	107	7.5	0.17
8	Whiskey Slough (upper)	02-11-92	--	21	--	--	--	0.65	--
		07-30-92	--	22	--	--	--	0.18	--
9	Whiskey Slough (lower)	02-12-92	3.3	29	0.20	19	93	2.3	0.17
12	Loomis Lake. drainage (lower)	02-11-92	3.2	29	0.20	19	98	1.4	0.16
		07-29-92	2.3	35	0.10	4.4	116	0.93	0.12
14	Loomis Lake drainage (upper)	02-11-92	--	27	--	--	--	1.5	--
		07-29-92	--	35	--	--	--	1.8	--
18	Litschke Road drainage	02-10-92	--	25	--	--	--	1.0	--
		07-30-92	--	34	--	--	--	2.1	--
20	Giles Slough	02-10-92	1.9	52	0.10	10	87	1.6	0.054
		07-30-92	3.5	24	0.10	40	148	1.3	0.090
22	Gile Lake drainage	02-12-92	5.4	20	0.20	24	112	3.5	0.23
		07-28-92	2.5	23	<0.10	27	120	0.60	0.30
23	East Main drainage (lower)	02-12-92	2.2	28	0.20	17	94	2.3	0.14
		07-27-92	1.9	29	0.30	41	174	4.6	0.29
25	Tarlatt Slough (lower)	02-12-92	4.5	26	0.20	28	135	4.1	0.22
		07-27-92	3.7	23	0.20	36	158	1.4	0.086
27	Tarlatt Slough (middle)	02-13-92	--	29	--	--	--	8.9	--
		07-27-92	--	26	--	--	--	2.0	--
28	South Main drainage	02-13-92	4.9	33	0.10	35	147	5.0	0.38
		07-28-92	0.70	32	<0.10	32	144	4.6	0.13
29	Tarlatt Slough (upper)	02-13-92	4.2	27	0.10	19	109	3.1	0.16
		07-28-92	1.0	43	0.20	35	260	9.6	0.30

Table 26.--*Concentrations of bacteria, nutrients, and septage-related compounds in ground water, Long Beach Peninsula, Washington*

[cols./100 mL, colonies per 100 milliliters; mg/L, milligrams per liter; K in front of concentration denotes nonideal number of colonies on counting plate; <, less than; --, not available]

Well number	Well location	Date	Time	Coliform, fecal, cols. per 100 mL	Streptococci, fecal, cols. per 100 mL	Nitrogen, nitrite dissolved (mg/L as N)	Nitrogen, NO_2+NO_3 dissolved (mg/L as N)
10	12N/11W-04P01	02-11-92	1030	<1	<1	<0.01	1.10
		07-28-92	1030	<1	<1	<0.01	1.50
11	12N/11W-04P02	02-11-92	1210	<1	<1	<0.01	<0.05
		07-28-92	1115	<1	K4	<0.01	<0.05
17	12N/11W-09N01	02-11-92	1415	<1	<1	<0.01	0.65
		07-28-92	1340	<1	<1	<0.01	0.39
24	12N/11W-16E03	02-11-92	1540	<1	<1	<0.01	0.22
		07-28-92	1510	<1	<1	<0.01	0.62
28	12N/11W-16Q01	02-11-92	1730	<1	<1	<0.01	0.43
		07-28-92	1715	<1	<1	<0.01	0.41
29	12N/11W-20A02	02-12-92	1020	<1	K1	<0.01	0.84
		07-29-92	0940	<1	<1	<0.01	0.93
32	12N/11W-22E03	02-12-92	0920	<1	<1	<0.01	<0.05
		07-30-92	1000	<1	<1	<0.01	<0.05
33	12N/11W-21P02	02-12-92	1200	<1	<1	<0.01	0.67
		07-30-92	1510	<1	<1	<0.01	0.72
34	12N/11W-28E01	02-12-92	1250	<1	<1	<0.01	0.27
		07-30-92	1310	<1	<1	<0.01	0.46
35	12N/11W-28L01	02-12-92	1545	<1	<1	<0.01	0.06
		07-28-92	1545	<1	<1	<0.01	0.27
38	12N/11W-28G06	02-12-92	1105	<1	<1	<0.01	0.10
		07-30-92	1140	<1	<1	<0.01	0.08
40	12N/11W-27M02	02-13-92	1650	<1	<1	<0.01	0.59
		07-28-92	1710	<1	<1	<0.01	0.87
42	12N/11W-28P03	02-12-92	1525	<1	<1	<0.01	0.73
		07-31-92	1350	<1	<1	0.01	9.80
45	12N/11W-28R03	02-12-92	1655	<1	<1	<0.01	0.14
		07-30-92	1620	<1	<1	<0.01	0.15
46	12N/11W-27N04	02-12-92	1345	<1	<1	<0.01	0.11
		07-30-92	1425	<1	<1	<0.01	<0.05

Table 26.--*Concentrations of bacteria, nutrients, and septage-related compounds in ground water, Long Beach Peninsula, Washington--Continued*

Well number	Well location	Date	Nitrogen ammonia, dissolved (mg/L as N)	Phosphorus ortho, dissolved (mg/L as P)	Boron, dissolved (mg/L as B)	Carbon, organic dissolved (mg/L as C)	Methylene blue active substance (mg/L)
10	12N/11W-04P01	02-11-92	<0.01	<0.01	0.010	--	0.02
		07-28-92	<0.01	<0.01	0.010	5.6	<0.01
11	12N/11W-04P02	02-11-92	0.08	0.04	--	--	--
		07-28-92	0.09	0.02	--	--	--
17	12N/11W-09N01	02-11-92	<0.01	<0.01	<0.010	--	0.01
		07-28-92	<0.01	<0.01	<0.010	5.4	0.01
24	12N/11W-16E03	02-11-92	<0.01	0.02	0.040	--	0.01
		07-28-92	<0.01	0.02	0.040	17	0.03
28	12N/11W-16Q01	02-11-92	0.02	<0.01	--	--	--
		07-28-92	<0.01	<0.01	--	--	--
29	12N/11W-20A02	02-12-92	<0.01	0.01	0.020	0.6	<0.01
		07-29-92	0.02	0.01	0.020	7.8	0.02
32	12N/11W-22E03	02-12-92	0.17	<0.01	--	--	--
		07-30-92	0.19	0.02	--	--	--
33	12N/11W-21P02	02-12-92	<0.01	<0.01	0.260	0.6	0.01
		07-30-92	0.02	<0.01	0.240	4.0	<0.01
34	12N/11W-28E01	02-12-92	<0.01	<0.01	--	--	--
		07-30-92	0.01	0.01	--	--	--
35	12N/11W-28L01	02-12-92	<0.01	<0.01	0.010	0.4	0.01
		07-28-92	<0.01	<0.01	0.020	4.8	<0.01
38	12N/11W-28G06	02-12-92	<0.01	<0.01	0.020	--	<0.01
		07-30-92	0.01	0.01	0.130	0.9	0.02
40	12N/11W-27M02	02-13-92	<0.01	<0.01	0.010	2.1	0.01
		07-28-92	<0.01	0.01	0.020	7.0	0.03
42	12N/11W-28P03	02-12-92	<0.01	0.02	<0.010	--	0.01
		07-31-92	0.01	0.03	0.020	18	<0.01
45	12N/11W-28R03	02-12-92	<0.01	<0.01	0.020	--	0.01
		07-30-92	0.02	<0.01	0.290	5.9	0.02
46	12N/11W-27N04	02-12-92	0.04	0.09	0.020	--	0.02
		07-30-92	0.09	0.11	0.230	4.6	0.03

Table 26.--*Concentrations of bacteria, nutrients, and septage-related compounds in ground water, Long Beach Peninsula, Washington--Continued*

Well number	Well location	Date	Time	Coliform, fecal, cols. per 100 mL	Streptococci, fecal, cols. per 100 mL	Nitrogen, nitrite dissolved (mg/L as N)	Nitrogen, NO_2+NO_3 dissolved (mg/L as N)
47	12N/11W-33D01	02-13-92	0930	<1	<1	<0.01	0.78
		07-31-92	0905	<1	<1	<0.01	1.20
48	12N/11W-33D02	02-13-92	1045	<1	<1	<0.01	2.00
		07-31-92	1030	<1	<1	<0.01	10.0
49	12N/11W-33C02	02-12-92	1715	<1	<1	<0.01	0.60
		07-28-92	1330	<1	<1	<0.01	0.59
50	12N/11W-33B03	02-12-92	1430	<1	<1	<0.01	0.09
		07-28-92	1425	<1	<1	<0.01	1.90
57	11N/11W-04M03	02-13-92	1255	<1	<1	<0.01	0.17
		07-31-92	1210	<1	<1	<0.01	0.16
62	11N/11W-03M03	02-13-92	1405	<1	K1	<0.01	0.37
		07-29-92	1850	<1	<1	<0.01	0.19
65	11N/11W-10L02	02-11-92	1630	<1	<1	<0.01	0.10
		07-30-92	1240	<1	<1	<0.01	0.18
68	11N/11W-09P03	02-11-92	1500	<1	<1	<0.01	8.60
		07-27-92	1735	<1	<1	<0.01	4.90
74	11N/11W-16N04	02-11-92	1330	<1	<1	0.01	4.10
		07-27-92	1615	<1	<1	<0.01	4.70
81	11N/11W-28H01	02-13-92	1100	<1	<1	<0.01	0.68
		07-27-92	1300	<1	<1	<0.01	0.56
82	11N/11W-27H01	02-10-92	1520	<1	<1	<0.01	0.81
		07-27-92	1445	<1	<1	<0.01	0.88
89	11N/11W-33K02	02-10-92	1400	<1	<1	<0.01	1.70
		07-28-92	0935	<1	<1	<0.01	1.80
93	11N/11W-34L01	02-13-92	1515	<1	<1	<0.01	<0.05
		07-29-92	1640	<1	<1	<0.01	<0.05
96	11N/11W-34P03	02-10-92	1130	<1	<1	<0.01	<0.05
		07-29-92	1150	<1	<1	<0.01	<0.05
97	11N/11W-34P04	02-10-92	1535	<1	<1	<0.01	<0.05
		07-29-92	1500	<1	<1	<0.01	<0.05

Table 26.--*Concentrations of bacteria, nutrients, and septage-related compounds in ground water, Long Beach Peninsula, Washington--Continued*

Well number	Well location	Date	Nitrogen ammonia, dissolved (mg/L as N)	Phosphorus ortho, dissolved (mg/L as P)	Boron, dissolved (mg/L as B)	Carbon, organic dissolved (mg/L as C)	Methylene blue active substance (mg/L)
47	12N/11W-33D01	02-13-92	<0.01	<0.01	0.010	--	0.01
		07-31-92	0.02	<0.01	<0.010	5.5	<0.01
48	12N/11W-33D02	02-13-92	<0.01	<0.01	0.020	--	0.01
		07-31-92	0.01	<0.01	0.010	13	<0.01
49	12N/11W-33C02	02-12-92	<0.01	<0.01	<0.010	0.6	0.01
		07-28-92	<0.01	0.01	0.010	2.6	<0.01
50	12N/11W-33B03	02-12-92	<0.01	<0.01	--	--	--
		07-28-92	<0.01	0.01	--	--	--
57	11N/11W-04M03	02-13-92	<0.01	<0.01	--	--	--
		07-31-92	0.01	<0.01	--	--	--
62	11N/11W-03M03	02-13-92	<0.01	<0.01	--	--	--
		07-29-92	<0.01	<0.01	--	--	--
65	11N/11W-10L02	02-11-92	0.01	0.01	0.010	0.7	<0.01
		07-30-92	0.02	0.02	0.130	0.7	<0.01
68	11N/11W-09P03	02-11-92	<0.01	0.01	0.010	0.8	0.02
		07-27-92	0.01	0.01	0.020	4.4	<0.01
74	11N/11W-16N04	02-11-92	<0.01	0.04	--	--	--
		07-27-92	<0.01	0.03	--	--	--
81	11N/11W-28H01	02-13-92	<0.01	<0.01	--	--	--
		07-27-92	<0.01	0.01	--	--	--
82	11N/11W-27H01	02-10-92	0.03	0.01	--	--	--
		07-27-92	0.02	0.02	--	--	--
89	11N/11W-33K02	02-10-92	<0.01	<0.01	--	--	--
		07-28-92	<0.01	<0.01	--	--	--
93	11N/11W-34L01	02-13-92	0.24	0.60	--	--	--
		07-29-92	0.25	0.61	--	--	--
96	11N/11W-34P03	02-10-92	0.17	0.01	--	--	--
		07-29-92	0.15	0.01	--	--	--
97	11N/11W-34P04	02-10-92	0.12	0.14	--	--	--
		07-29-92	0.15	0.13	--	--	--

Table 26.--*Concentrations of bacteria, nutrients, and septage-related compounds in ground water, Long Beach Peninsula, Washington--Continued*

Well number	Well location	Date	Time	Coliform, fecal, cols. per 100 mL	Streptococci, fecal, cols. per 100 mL	Nitrogen, nitrite dissolved (mg/L as N)	Nitrogen, NO_2+NO_3 dissolved (mg/L as N)
98	11N/11W-34P02	07-29-92	1125	<1	<1	0.02	<0.05
104	10N/11W-03F03	02-11-92	1030	<1	<1	<0.01	0.77
		07-29-92	1400	<1	<1	<0.01	1.60
107	10N/11W-09A01	02-14-92	0945	K1	<1	<0.01	5.20
		07-27-92	1125	<1	<1	<0.01	4.90
108	10N/11W-09E01	02-13-92	1235	<1	<1	<0.01	0.28
114	10N/11W-10E01	02-14-92	1145	<1	<1	<0.01	<0.05
		07-29-92	0945	<1	K1	<0.01	<0.05
116	10N/11W-10L01	02-13-92	1640	<1	<1	<0.01	<0.05
		07-27-92	1350	<1	<1	<0.01	<0.05
117	10N/11W-16C01	02-14-92	1410	<1	K1	<0.01	<0.05
		07-31-92	1540	<1	<1	--	--
118	10N/11W-16D01	02-10-92	1045	<1	<1	<0.01	0.15
		07-27-92	1045	<1	<1	<0.01	0.23
121	10N/11W-15L02	02-14-92	1720	<1	<1	<0.01	<0.05
		07-27-92	1555	<1	<1	<0.01	<0.05
124	10N/11W-22C01	02-14-92	1545	<1	<1	<0.01	<0.05
		07-27-92	1745	<1	<1	<0.01	<0.05
125	10N/11W-21M02	07-28-92	1120	<1	K5	<0.01	0.39
128	10N/11W-21Q01	02-13-92	1435	<1	<1	<0.01	3.10
		07-29-92	1615	<1	<1	0.02	3.90

Table 26.--*Concentrations of bacteria, nutrients, and septage-related compounds in ground water, Long Beach Peninsula, Washington--Continued*

Well number	Well location	Date	Nitrogen ammonia, dissolved (mg/L as N)	Phosphorus ortho, dissolved (mg/L as P)	Boron, dissolved (mg/L as B)	Carbon, organic dissolved (mg/L as C)	Methylene blue active substance (mg/L)
98	11N/11W-34P02	07-29-92	0.40	0.10	--	--	--
104	10N/11W-03F03	02-11-92	0.01	<0.01	0.030	1.9	0.03
		07-29-92	0.02	<0.01	0.020	4.4	0.02
107	10N/11W-09A01	02-14-92	<0.01	<0.01	--	--	--
		07-27-92	0.01	<0.01	--	--	--
108	10N/11W-09E01	02-13-92	<0.01	<0.01	--	--	--
114	10N/11W-10E01	02-14-92	0.43	1.30	--	--	--
		07-29-92	0.36	1.60	--	--	--
116	10N/11W-10L01	02-13-92	0.09	0.09	--	--	--
		07-27-92	0.10	0.09	--	--	--
117	10N/11W-16C01	02-14-92	0.05	0.03	0.010	--	<0.01
		07-31-92	--	--	0.020	4.9	<0.01
118	10N/11W-16D01	02-10-92	<0.01	0.02	0.020	0.8	0.02
		07-27-92	<0.01	0.02	0.010	4.3	0.03
121	10N/11W-15L02	02-14-92	0.24	0.54	--	--	--
		07-27-92	0.25	0.56	--	--	--
124	10N/11W-22C01	02-14-92	0.19	0.24	--	--	--
		07-27-92	0.20	0.24	--	--	--
125	10N/11W-21M02	07-28-92	0.01	0.05	--	--	--
128	10N/11W-21Q01	02-13-92	<0.01	<0.01	0.020	1.2	0.01
		07-29-92	0.02	0.02	0.020	4.8	0.01

Table 27.--*Concentrations of bacteria and nutrients in surface water, Long Beach Peninsula, Washington*

[cols. per 100 mL, colonies per 100 milliliters; mg/L, milligrams per liter; K in front of concentration denotes nonideal number of colonies on counting plate; >, greater than; <, less than]

Site number	Name	Date	Time	Coliform, fecal (cols. per 100 mL)	Streptococci, fecal (cols. per 100 mL)	Nitrogen, nitrite, dissolved (mg/L as N)	Nitrogen, NO_2+NO_3 dissolved (mg/L as N)	Nitrogen, ammonia, dissolved (mg/L as N)	Phosphorus ortho, dissolved (mg/L as P)
2	Unnamed drainage near Stackpole Road	02-11-92	1200	K7	<2	<0.01	<0.05	0.14	0.09
8	Whiskey Slough (upper)	02-11-92	1415	K20	K22	<0.01	0.07	0.03	<0.01
		07-30-92	1130	320	58	0.02	1.10	0.07	<0.01
9	Whiskey Slough (lower)	02-12-92	1030	K8	K7	<0.01	0.06	0.08	0.01
12	Loomis Lake drainage (lower)	02-11-92	0945	K10	<5	<0.01	0.10	0.10	0.05
		07-29-92	1730	K23	120	<0.01	<0.05	0.05	0.04
14	Loomis Lake drainage (upper)	02-11-92	1600	K13	K16	<0.01	<0.05	0.08	0.06
		07-29-92	1550	K24	>1,000	<0.01	<0.05	0.11	0.01
18	Litschke Road drainage	02-10-92	1445	<10	<10	<0.01	<0.05	0.05	0.02
		07-30-92	1350	140	210	0.03	0.41	0.18	0.05
20	Giles Slough	02-10-92	1600	<10	K33	<0.01	<0.05	0.06	0.05
		07-30-92	1540	200	120	<0.01	<0.05	0.03	0.07
22	Gile Lake drainage	02-12-92	1215	<10	K36	<0.01	0.08	0.23	0.09
		07-28-92	1320	>600	K60	<0.01	<0.05	0.39	0.04
23	East Main drainage (lower)	02-12-92	1650	K4	K5	0.01	<0.05	0.09	0.06
		07-27-92	1130	94	130	<0.01	0.25	0.26	0.14
25	Tarlatt Slough (lower)	02-12-92	1500	62	K13	<0.01	0.09	0.22	0.08
		07-27-92	1800	750	K30	<0.01	<0.05	0.01	0.10
27	Tarlatt Slough (middle)	02-13-92	1215	K33	<10	<0.01	<0.05	0.27	0.42
		07-27-92	1530	K42	K79	0.01	0.07	0.13	0.10
28	South Main drainage	02-13-92	1020	K6	K35	<0.01	<0.05	0.24	0.09
		07-28-92	0900	K10	79	<0.01	<0.05	0.03	0.05
29	Tarlatt Slough (upper)	02-13-92	0900	<10	<10	<0.01	0.15	0.25	0.06
		07-28-92	1100	K2	64	<0.01	<0.05	0.06	0.16

Table 28.--*Concentrations of pesticides in ground water, Long Beach Peninsula, Washington*

[All analyses were made on whole-water samples; µg/L, micrograms per liter; <, less than; --, not available]

Well number	Well location	Date	Time	Aldicarb (µg/L)	Aldicarb sulfone (µg/L)	Aldicarb sulfoxide (µg/L)	Sevin, total (µg/L)	Carbofuran (µg/L)	Dichlobinel (µg/L)	Diuron (µg/L)
10	12N/11W-04P01	02-11-92	1030	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	--
		07-28-92	1030	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
24	12N/11W-16E03	02-11-92	1540	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	--
		07-28-92	1510	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
28	12N/11W-16Q01	07-28-92	1715	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
32	12N/11W-22E03	02-12-92	0920	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	--
		07-30-92	1000	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
46	12N/11W-27N04	02-12-92	1345	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	--
		07-30-92	1425	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
47	12N/11W-33D01	02-13-92	0930	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	--
		07-31-92	0905	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
74	11N/11W-16N04	02-11-92	1330	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	--
		07-27-92	1615	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
81	11N/11W-28H01	02-13-92	1100	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	--
		07-27-92	1300	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
82	11N/11W-27H01	02-10-92	1520	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	--
		07-27-92	1445	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
89	11N/11W-33K02	02-10-92	1400	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	--
		07-28-92	0935	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
93	11N/11W-34L01	02-13-92	1515	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	--
		07-29-92	1640	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
96	11N/11W-34P03	02-10-92	1130	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	--
		07-29-92	1150	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
97	11N/11W-34P04	02-10-92	1535	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	--
		07-29-92	1500	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
98	11N/11W-34P02	07-29-92	1125	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
104	10N/11W-03F03	02-11-92	1030	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	--
		07-29-92	1400	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
107	10N/11W-09A01	02-14-92	0945	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	--
		07-27-92	1125	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5

Table 28.--*Concentrations of pesticides in ground water, Long Beach Peninsula, Washington--Continued*

Well number	Well location	Date	3-Hydroxy-carbo-furan (µg/L)	Methio-carb (µg/L)	Metho-myl (µg/L)	1-Naph-thol (µg/L)	Oxamyl water (µg/L)	Propham (µg/L)	Propo-xur (µg/L)
10	12N/11W-04P01	02-11-92	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
		07-28-92	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
24	12N/11W-16E03	02-11-92	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
		07-28-92	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
28	12N/11W-16Q01	07-28-92	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
32	12N/11W-22E03	02-12-92	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
		07-30-92	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
46	12N/11W-27N04	02-12-92	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
		07-30-92	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
47	12N/11W-33D01	02-13-92	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
		07-31-92	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
74	11N/11W-16N04	02-11-92	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
		07-27-92	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
81	11N/11W-28H01	02-13-92	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
		07-27-92	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
82	11N/11W-27H01	02-10-92	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
		07-27-92	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
89	11N/11W-33K02	02-10-92	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
		07-28-92	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
93	11N/11W-34L01	02-13-92	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
		07-29-92	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
96	11N/11W-34P03	02-10-92	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
		07-29-92	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
97	11N/11W-34P04	02-10-92	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
		07-29-92	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
98	11N/11W-34P02	07-29-92	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
104	10N/11W-03F03	02-11-92	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
		07-29-92	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
107	10N/11W-09A01	02-14-92	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
		07-27-92	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5

Table 28.--*Concentrations of pesticides in ground water, Long Beach Peninsula, Washington--Continued*

Well number	Well location	Date	Time	Aldicarb (µg/L)	Aldicarb sulfone (µg/L)	Aldicarb sulfoxide (µg/L)	Sevin, total (µg/L)	Carbofuran (µg/L)	Dichlobinel (µg/L)	Diuron (µg/L)
114	10N/11W-10E01	02-14-92	1145	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	--
		07-29-92	0945	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
116	10N/11W-10L01	02-13-92	1640	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	--
		07-27-92	1350	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
121	10N/11W-15L02	02-14-92	1720	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	--
		07-27-92	1555	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
124	10N/11W-22C01	02-14-92	1545	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	--
		07-27-92	1745	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
128	10N/11W-21Q01	02-13-92	1435	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	--
		07-29-92	1615	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5

Well number	Well location	Date	3-Hydroxycarbofuran (µg/L)	Methiocarb (µg/L)	Methomyl (µg/L)	1-Naphthol (µg/L)	Oxamyl water (µg/L)	Propham (µg/L)	Propoxur (µg/L)
114	10N/11W-10E01	02-14-92	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
		07-29-92	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
116	10N/11W-10L01	02-13-92	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
		07-27-92	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
121	10N/11W-15L02	02-14-92	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
		07-27-92	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
124	10N/11W-22C01	02-14-92	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
		07-27-92	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
128	10N/11W-21Q01	02-13-92	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
		07-29-92	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5

Table 29.--*Concentrations of pesticides in surface water, Long Beach Peninsula, Washington*

[µg/L, micrograms per liter; <, less than; --, not available]

Site number	Name	Date	Time	Aldicarb (µg/L)	Aldicarb sulfone (µg/L)	Aldicarb sulfoxide (µg/L)	Sevin, total (µg/L)	Carbofuran (µg/L)	Dichlobinel (µg/L)	Diuron (µg/L)
2	Unnamed drainage near Stackpole Road	02-11-92	1200	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	--
8	Whiskey Slough (upper)	07-30-92	1130	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
9	Whiskey Slough (lower)	02-12-92	1030	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	--
18	Litschke Road drainage	07-30-92	1350	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
22	Gile Lake drainage	02-12-92	1215	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	--
		07-28-92	1320	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
23	East Main drainage (lower)	02-12-92	1650	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	--
		07-27-92	1130	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
25	Tarlatt Slough (lower)	02-12-92	1500	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	--
		07-27-92	1800	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
29	Tarlatt Slough (upper)	02-13-92	0900	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	--
		07-28-92	1100	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5

Site number	Name	Date	3-Hydroxy carbofuran (µg/L)	Methiocarb (µg/L)	Methomyl (µg/L)	1-Naphthol (µg/L)	Oxamyl water (µg/L)	Propham (µg/L)	Propoxur (µg/L)
2	Unnamed drainage near Stackpole Road	02-11-92	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
8	Whiskey Slough (upper)	07-30-92	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
9	Whiskey Slough (lower)	02-12-92	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
18	Litschke Road drainage	07-30-92	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
22	Gile Lake drainage	02-12-92	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
		07-28-92	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
23	East Main drainage (lower)	02-12-92	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
		07-27-92	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
25	Tarlatt Slough (lower)	02-12-92	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
		07-27-92	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
29	Tarlatt Slough (upper)	02-13-92	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
		07-28-92	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5

Appendix A.--Assurance Assessment of Water-Quality Control Data

ASSURANCE ASSESSMENT OF WATER-QUALITY CONTROL DATA

The quality-assurance plan for this study (B.E. Thomas, U.S. Geological Survey, written commun., 1992) called for quality-control procedures at all levels of data collection and analysis. Many of the procedures addressed methodology, and some required the collection and analysis of quality-control samples. The analysis of the quality-control samples is discussed in this appendix.

The data-quality objectives of this study were specified in the quality-assurance plan. These study objectives matched the objectives specified by a Washington State program established to administer State-sponsored investigations of ground-water quality (Carey, 1986). Those State-specified objectives were selected to ensure the collection of high-quality data and to ensure that the data are usable by State and local agencies. Objectives for precision and bias of the data were within 20 percent for pesticides and metals such as iron and manganese and within 10 percent for nutrients, inorganics, and DOC (Carey, 1986, table 4-1).

The quality of the water-quality data used in this study appears to have met the data-quality objectives. The precision and bias of most reference and duplicate samples were within project criteria for most constituents. Exceptions occurred where constituent concentrations were near detection limits and small absolute difference between sample concentrations resulted in large percentage differences. Concentrations in blanks were within acceptable limits for most constituents and samples. The results of the quality-assurance analyses did not affect any interpretations of the water-quality data.

Standard Reference Samples for Laboratory Analyses

The U.S. Geological Survey (USGS) conducts an external blind sample quality-assurance project for its water-quality analysis laboratory, National Water Quality Laboratory (NWQL), in Arvada, Colo. Standard reference samples containing selected inorganic and nutrient constituents are disguised as environmental samples and are sent periodically through USGS offices to NWQL for analysis. The most probable value (MPV) for the concentration of each constituent in each standard reference sample had been determined previously on the basis of analyses from as many as 150 independent laboratories. The quality of the analytical data produced by the laboratory can be estimated by comparing the MPV's of the constituents in the standard reference samples with values determined by NWQL (Lucey, 1990).

To estimate the quality of the laboratory analyses of water samples collected during this study, the blind-sample quality-assurance data for the NWQL were retrieved for the periods when the samples from this study were being analyzed. Two 30-day periods were used, which started the days that the first samples were received at the NWQL: February 12 to March 14, 1992, and July 29 to August 28, 1992. The reference samples selected for evaluation had constituent concentrations that were close to the range of constituent concentrations of all samples collected for this study.

The average precision of the analysis for a particular constituent was assessed by using a weighted average coefficient of variation. For each constituent, several standard reference samples with a range of concentrations were prepared. For each reference sample, several replicate samples were submitted to the laboratory. A standard deviation and mean were computed for the concentrations of the replicates for each reference sample, and the coefficient of variation was computed by dividing the standard deviation by the mean and multiplying by 100 to obtain a percentage value. The average precision for each constituent was for all reference samples and was weighted by the number of submittals as shown in the following equation:

$$P = \frac{\sum_{i=1}^{n} \left(\frac{s_i}{m_i}\right) n_i}{\sum_{i=1}^{n} n_i} \times 100 \quad , \qquad (1)$$

where

P = average precision in percent;

m_i = mean of submittals for ith standard reference sample;

s_i = standard deviation about m_i; and

n_i = number of submittals for ith standard reference sample.

The bias of the analysis for a particular constituent was assessed by using a weighted average percentage difference between the MPV's of the reference samples and the means of the computed values of the submitted replicates for each reference sample. The following equation was used to compute the average bias:

$$B = \frac{\sum_{i=1}^{n} (\mathrm{MPV}_i - m_i)\, n_i}{\sum_{i=1}^{n} n_i} \times 100 \quad , \qquad (2)$$

where

B = average bias in percent;

MPV_i = most probable value for ith standard reference sample;

m_i = mean of submittals for ith standard reference sample; and

n_i = number of submittals for ith standard reference sample

The average precision in the laboratory analyses of inorganic constituents is small (table A1). The average precision is less than 10 percent for all constituents except ammonia, with a precision of 12 percent, and boron, with a precision of 23 percent. The precision for ammonia is close to 10 percent, which was the specified quality-assurance criterion for most constituents. The 23-percent precision for boron is relatively large, but the absolute concentrations are low and this difference is considered to be acceptable.

The bias in the laboratory analyses of inorganic constituents is small, with a bias of less than 5 percent in all analyzed constituents except chloride and boron (table A1). The analysis for chloride had a bias of -8.1 percent and the analysis for boron had a bias of 9.7 percent. These biases are still less than the accuracy criterion of 10 percent specified in the quality-assurance plan for the study.

Table A1.--*Estimated precision and bias in laboratory analyses of inorganic constituents*

{Laboratory standards and statistics based on data for February 12 to March 14, 1992, and July 29 to August 28, 1992; mg/L, milligrams per liter; <, less than; --, no data]

Constituent	Number of standards	Number of times standard submitted	Range of concentration of standards (mg/L)	Median concentration in ground-water samples (mg/L)	Median concentration in surface-water samples (mg/L)	Range of concentration in ground- and surface-water samples (mg/L)	Average[1] precision, in percent	Average[2] bias, in percent
Calcium	4	28	4.8 - 22	5.7	7.2	1.2 - 17	2.5	-2.7
Magnesium	5	37	1.2 - 22	3.6	6.8	0.6 - 17	3.2	0.3
Sodium	4	26	6.8 - 59	11	18	5.9 - 43	3.5	1.0
Potassium	6	36	0.5 - 2.7	1.1	4.0	0.5 - 9.2	7.4	2.4
Sulfate	5	27	6.3 - 113	5.5	2.8	<0.1 - 38	5.8	-3.8
Chloride	6	36	9.8 - 46	14	28	5.8 - 52	5.4	-8.1
Fluoride	3	18	0.2 - 0.5	0.1	0.2	<0.1 - 0.3	5.6	-4.0
Silica	9	50	2.6 - 8.4	23	26	4.4 - 60	3.6	2.0
Nitrite + Nitrate	4	76	0.14 - 1.0	0.39	<0.05	<0.05 - 10	5.8	3.6
Ammonia	3	57	0.05 - 0.88	0.01	0.10	<0.01 - 0.43	12.0	-0.7
Orthophosphate	4	76	0.09 - 0.88	0.01	0.06	<0.01 - 1.6	5.0	3.9
Boron	4	29	0.024 - 0.074	0.020	--	<0.01 - 0.29	23.2	9.7
Iron	2	31	0.12 - 0.25	0.020	2.0	<0.003 - 42	4.1	1.0
Manganese	2	31	0.030 - 0.061	0.002	0.16	<0.001 - 0.65	4.8	3.6

[1]See equation 1 in Appendix A.

[2]See equation 2 in Appendix A.

Duplicate Samples

Duplicate pairs of samples were collected for all types of analyses. For ground-water samples, the sampling apparatus was set up and the regular field samples were collected by filling bottles of water from the appropriate plumbing outlet or bailer. Immediately after the field samples were collected, the bottles for duplicate analyses were filled. The same equipment, hoses, bailers, filters, and so forth were used for all samples. For surface-water samples, the regular field sample was collected from the surface water, the sample water was placed in a churn splitter, and bottles were filled from the splitter. For a duplicate sample, the entire procedure was repeated.

The established precision criteria for duplicate samples were a maximum 10-percent difference for cations, anions, silica, dissolved solids, nutrients, DOC, and MBAS, and a maximum 20-percent difference for iron, manganese, and pesticides. The difference for each pair was computed as a percentage of the average concentration for the pair. The average absolute difference for all pairs of ground-water samples and the number of pairs exceeding the difference criteria are listed for each constituent in table A2.

For most of the constituents analyzed in ground-water samples, the average percentage difference is well within the specified criteria. The criteria were exceeded for one pair for dissolved solids, two pairs for ammonia, and one pair for methylene blue active substance (MBAS). These exceedences are not considered to be a serious problem.

The pair for dissolved solids had a 11 percent difference, the two pairs for ammonia had low average concentrations of 0.02 and 0.16 milligrams per liter (mg/L), and the pair for MBAS had a low average concentration of 0.02 mg/L.

Two duplicate pairs of surface-water samples were collected. Unfortunately, one of the duplicate pairs was collected at a site with a tidally affected sample that could not be used in the analysis. The field and duplicate sample did not match well because of the extremely variable chemical conditions in the water of the drainage channel. Thus, any comparisons of that pair are not useful. The duplicate pair collected at the other site had good agreement between the field and duplicate sample. The concentrations of major cations and anions, nitrogen, and manganese all agreed within 5 percent and no pesticides were detected in either sample. Two constituents did not meet the criteria; orthophosphate had a 20 percent difference and iron had a 23 percent difference. The average concentration of orthophosphate was 0.1 mg/L and the average concentration of iron was 4.0 mg/L.

Table A2.--*Average absolute differences in constituent values and concentrations determined for duplicate ground-water samples*

Constituent	Number of duplicate pairs	Average absolute difference, in percent	Number of duplicate pairs exceeding difference criteria[1]
Calcium	4	1.8	0
Magnesium	4	0.7	0
Sodium	4	2.2	0
Potassium	4	4.0	0
Sulfate	4	3.1	0
Chloride	6	0.4	0
Fluoride	4	0.0	0
Silica	4	1.4	0
Dissolved solids	4	6.0	1
Nitrite + Nitrate	4	0.2	0
Nitrite	4	0.0	0
Ammonia	4	22	2
Orthophosphate	4	0.0	0
Boron	3	0.0	0
Iron	6	3.0	0
Manganese	4	3.0	0
Dissolved organic carbon (DOC)	2	3.5	0
Methylene blue active substances (MBAS)	3	13	1
All pesticides	4	0.0	0

[1]Difference criterion is 10 percent for cations, anions, silica, dissolved solids, nutrients, boron, DOC, and MBAS. Difference criterion is 20 percent for iron, manganese, and pesticides.

Blank Samples

Blanks of deionized water were processed in the same manner as the regular field samples. Blanks were collected at the same sites as the duplicate samples. For ground-water samples, the sampling apparatus was set up and the regular field samples and duplicates were collected first by filling bottles of water from the appropriate plumbing outlet or bailer. Then all the sampling equipment was cleaned and rinsed as specified in the quality-assurance plan to prevent cross-contamination between wells. Blank samples were then collected by flushing deionized water through the plumbing apparatus with a peristaltic pump for 3 to 5 minutes, then filling the bottles from the appropriate plumbing outlet. For samples collected from a bailer, the bailer was filled with deionized water and emptied into the appropriate bottle.

For surface-water samples, the regular field samples and duplicate samples were collected from the surface water, the sample waters were placed in a churn splitter, and bottles were filled from the splitter. Then all the sampling equipment was cleaned and rinsed as specified in the quality-assurance plan to prevent cross-contamination between surface-water sites. Blank samples were then collected by placing about a liter of deionized water in the churn splitter and filling the bottles.

Although no criteria were specified for constituent concentrations in blanks, the importance of any constituent present in a blank is based on how close the constituent concentration is to the detection limit and how the concentration compares to the minimum and median concentrations of the field samples collected at the same site as the blank samples. Also important is the number of times the constituent was detected in the blank samples.

The constituent concentrations in the blanks associated with the ground-water samples are considered acceptable for all the constituents except dissolved organic carbon (DOC) (table A3). The blanks generally had concentrations near the detection limits, and the concentrations of the blanks were generally less than 5 percent of the minimum concentration of the paired field samples. Four exceptions to the less-than-5-percent criterion were for chloride, fluoride, ammonia, and orthophosphate. The concentrations of the field samples and blanks for fluoride, ammonia, and orthophosphate were low and near the detection limit, and these concentrations for blanks are considered acceptable. Of the six paired samples for chloride, the blank concentrations for five pairs were less than 6 percent of their corresponding field samples. For one pair, the blank chloride concentration is 22 percent of the field concentration; there may have been some contamination from equipment or handling for that sample (well 96, July sample). The concentrations of DOC in the blanks were higher than the concentrations in two of the three paired field samples. The cause of these high concentrations of DOC in the blanks is probably from the source of the deionized water. The deionized water was from the USGS Washington District Field Service Unit, which used a carbon filter. In addition, the deionized water for blanks was stored in plastic containers. Therefore, the blanks with high DOC concentrations are not considered to undermine the reliability of the field concentrations of DOC, so the field concentrations of DOC were left in the data base.

Two blank samples were collected for surface-water sites; the concentrations of cations, anions, nutrients, iron, manganese, and pesticides were all acceptable, being either below or very close to the detection limit.

Table A3.--*Summary of constituent concentrations determined for blank ground-water samples*

{Concentrations are in milligrams per liter unless otherwise noted; <, less than; paired field samples, field samples collected at the same sites as the blank samples; col/100 mL, colonies per 100 milliliters; <, less than]

Constituent	Number of blanks	Detection limit	Number or blanks equal to or exceeding detection limit	Median concentration of blanks	Maximum concentration of blanks	Minimum concentration of paired field samples	Median concentration of paired field samples
Calcium	4	0.02	2	0.03	0.04	3.4	4.3
Magnesium	4	.01	3	.02	.05	2.5	2.8
Sodium	4	.2	0	<.2	<.2	6.2	10
Potassium	4	.1	0	<.1	<.1	1.1	1.2
Sulfate	4	.1	4	.2	.2	4.5	7.4
Chloride	6	.1	6	.5	1.4	6.0	18
Fluoride	4	.1	1	<.1	.1	<.1	0.1
Silica	4	.1	2	.1	.3	17	18
Nitrite + Nitrate	4	.05	0	<.05	<.05	<.05	.4
Nitrite	4	.01	0	<.01	<.01	<.01	<.01
Ammonia	4	.01	3	.02	.03	.01	.08
Orthophosphate	4	.01	1	<.01	.02	<.01	.01
Boron	3	.01	0	<.01	<.01	<.01	130
Iron	6	.003	3	.004	.006	<.003	.29
Manganese	4	.001	0	<.001	<.001	.036	.055
Dissolved organic carbon (DOC)	3	.1	3	7.6	8.4	.4	1.9
Methylene blue active substance (MBAS)	3	.02	0	<.02	<.02	<.02	<.02
All pesticides	4	.0005	0	<.0005	<.0005	<.0005	<.0005
Fecal coliform (col/100 mL)	21	1	0	<1	<1	<1	<1
Fecal streptococci (col/100 mL)	21	1	0	<1	<1	<1	<1

Cation-Anion Balance

The cation-anion balance can be used to judge the accuracy and completeness of the chemical analysis of a water sample. After converting concentrations of ions to milliequivalents to compensate for the electrical charges of the ions, the sum of the milliequivalent concentrations of cations should equal the sum of the anions. The cation-anion balance was computed as the difference in these sums, divided by the total sum of cations and anions, and multiplied by 100 to obtain a percent value. Ideally, the cation-anion balance is zero, but nonzero values occur when a cation or anion concentration is erroneous or when an ion present in high concentrations (commonly a metal) is not analyzed for. The acceptable percentage difference varies with the total sum of cations and anions, as shown on figure A1 (Friedman and Erdman, 1982).

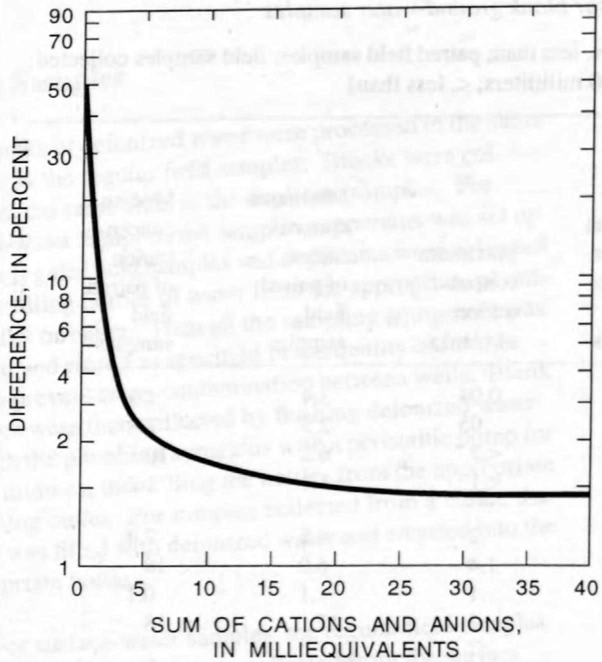

Figure A1.--Cation and anion percent difference curve (Friedman and Erdmann, 1992).

The cation-anion balances for the 48 ground-water samples that had analyses for major ions are generally good; only seven analyses exceeded the percentage difference criterion. Of these, five analyses had percentage differences of less than 5 percent and they exceeded the criterion by less than 1 percent. The two samples with percentage differences larger than 5 percent had values of 6.3 percent and 8.7 percent. These samples have low ionic strength, with sums of cations and anions of about 2.5 milliequivalents; as the potential errors in analysis and missing constituents are large for these waters, the exceedence of the percentage difference criterion is considered acceptable. All seven analyses with excessive percentage differences were kept and used because the indicated differences are not large enough to affect interpretations of the data.

The cation-anion balances for the 17 surface-water samples are generally good; five analyses exceeded the percentage difference criterion. Of these, three analyses had percentage differences of less than 6 percent, one analysis had a percentage difference of 8 percent, and one analysis had a percentage difference of 30 percent. These percentage differences are not as small as with the ground-water samples, but they are not large enough to warrant deleting the data. Only the site with the percentage difference of 30 percent has a questionable analysis, and it was still used because it had a low total ionic strength of 2.5 milliequivalents and it had a small effect on the overall analysis of surface-water quality.