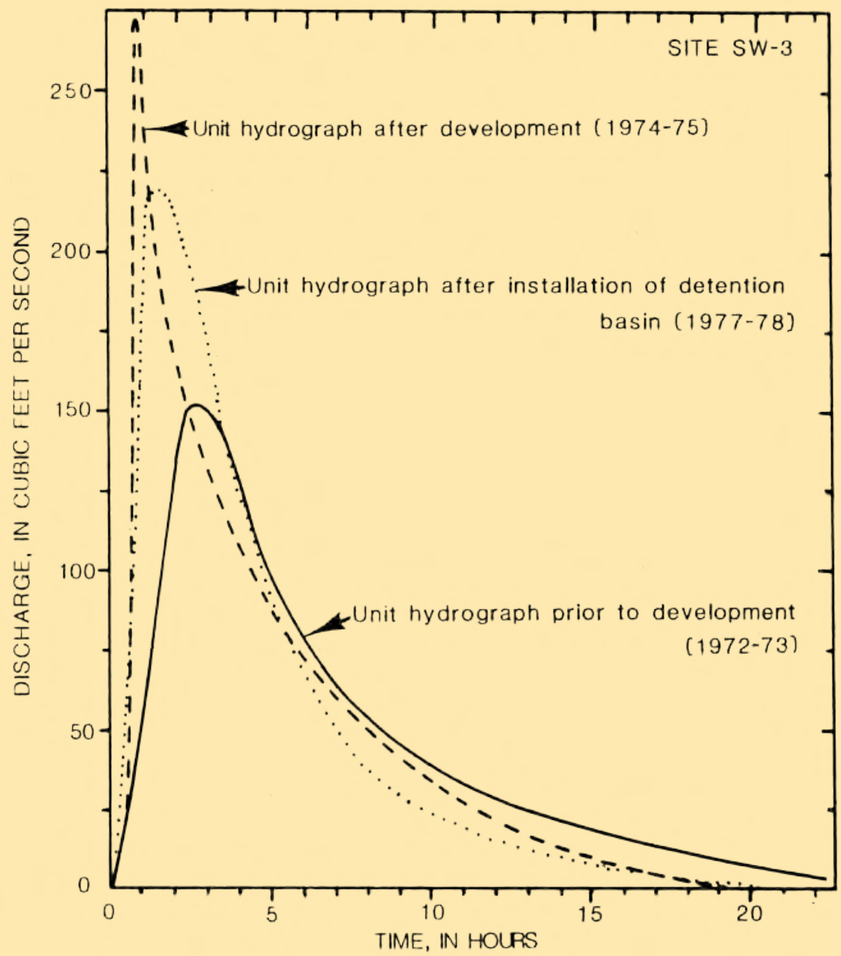
IMPACT OF SUBURBAN RESIDENTIAL DEVELOPMENT ON WATER RESOURCES IN THE AREA OF WINSLOW TOWNSHIP, CAMDEN COUNTY, NEW JERSEY

U.S. GEOLOGICAL SURVEY
Water-Resources Investigations 81–27



Prepared in cooperation with the NEW JERSEY
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16. Abstract (Limit: 200 words) Changes in land use as a result of large-scale residential development can have significant impact on water resources. Data on the quality and quantity of surface water and ground water in the vicinity of the Winslow Crossing residential development, in Winslow Township, New Jersey, were collected from 1972 to 1979.

Pumpage for water supply from the Cohansey Sand averaged 0.48 Million gallons per day during 1978 and had little effect on water levels in the aquifer. Water quality was variable in the observation wells sampled. High levels of dissolved solids, nitrate-nitrogen, and phosphorus were found in the shallow ground water surrounding the effluent infiltration ponds of a wastewater treatment plant. A treatment process change in 1974 reduced nitrate-nitrogen levels.

The development of 14 percent of a 1.64-square-mile drainage area resulted in an increase in the peak discharge of a 60-minute unit hydrograph from 150 cubic feet per second to 270 cubic feet per second. Installation of a stormwater detention basin reduced this peak discharge to 220 cubic feet per second.

Streams draining two highly developed drainage areas had significantly higher levels of calcium, magnesium, bicarbonate, and pH than streams draining less developed areas. Winslow Crossing's development had only a slight effect on Great Egg Harbor River in comparison with sources of contamination upstream from the study area.

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NEW JERSEY DEPARTMENT OF ENVIRONMENTAL PROTECTION,

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Trenton, New Jersey

1981

UNITED STATES DEPARTMENT OF THE INTERIOR

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CONVERSION FACTORS

Factors for converting inch-pound units to metric are shown to four significant figures. However, in the text the metric equivalents are shown only to the number of significant figures consistent with the values for the inch-pound units.

Multiply inch-pound units	by	To obtain SI units
foot (ft)	0.3048	meter (m)
foot per second (ft/s)	0.3048	meters per second (m/s)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
cubic foot per second per square mile [(ft^3/s)/mi^2]	0.01093	cubic meter per second per square kilometer [(m^3/s)/km^2]
million gallons per day (Mgal/d)	0.01081	cubic meter per second (m^3/s)
inch (in)	25.40	millimeters (mm)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer (km^2)

IMPACT OF SUBURBAN RESIDENTIAL DEVELOPMENT OF WATER RESOURCES IN THE AREA OF WINSLOW TOWNSHIP, CAMDEN COUNTY, NEW JERSEY

By Thomas V. Fusillo

ABSTRACT

Surface-water and ground-water quality, streamflow, and data on ground-water levels in the upper Great Egg Harbor River basin in the vicinity of the Winslow Crossing residential development in Winslow Township are evaluated. The data include continuous streamflow at four sites, monthly stream water quality at seven sites, ground-water levels and periodic ground-water quality in four wells from 1972 through 1978.

Pumpage from the Cohansey Sand in the study area was lower than anticipated because of a slowdown in construction. The average pumpage of 0.48 million gallons per day during 1978 had little effect on ground-water levels.

Dissolved-solids concentrations were lower in a well upgradient from the urbanized area. Elevated levels of dissolved solids, specific conductance, chloride, nitrate, and phosphorus were found in the shallow ground water in the vicinity of the Winslow wastewater treatment plant because of effluent infiltration ponds. Nitrate was greatly reduced in October 1974 by a change in the treatment process, which increased denitrification. Phosphorus concentrations in the ground water remained elevated, however.

Water from the most urbanized drainage basin was a magnesium bicarbonate type, while the less developed basins had sodium chloride sulfate type waters. Water from the two developed basins had higher median pH (7.1) compared with that of the other basins (5.6-6.3).

Winslow Crossing's development had only a slight effect on the quality of water in Great Egg Harbor River. The river receives point and non-point discharges upstream from Winslow Crossing, and the quality of the water generally improves as the river flows downstream.

Streamflow and rainfall were slightly above normal. Unit hydrograph analysis of one basin showed an 80 percent increase in the peak discharge of a 60-minute unit hydrograph (from approximately 150 to 270 cubic feet per second) after the development of 14 percent of the basin. Installation of a stormwater detention basin reduced the peak discharge to 220 ft^3/s. Sediment discharge from this basin averaged 0.24 $tons/d/mi^2$ during construction but decreased to the preconstruction level of 0.06 $tons/d/mi^2$ after the completion of construction and the installation of the detention basin.

INTRODUCTION

The U.S. Geological Survey and the New Jersey Department of Environmental Protection have cooperated in a study to evaluate the impact of the large-scale residential development of Winslow Crossing on the water resources of the area. Winslow Crossing, formerly a rural-agricultural area, is located in Winslow Township, Camden County, New Jersey. Construction of single-family houses and townhouses began in 1971, with a projection of 6,800 units to be completed by 1978 and 16,800 units by 1984, with a final population of over 55,000. As of December 1978, however, only 1,800 units had been completed, and the population of the development was less than 7,000.

Purpose and Scope

The purpose of this study is to assess the impact of the development of Winslow Crossing on water resources, including the quantity and quality of streamflow, the quality of ground water, and water levels of the aquifer. Streamflow and water-quality data were collected for 7 years at four sites on the tributaries and the main stem of the Great Egg Harbor River. Water-quality data were also collected at an additional four surface-water sites. Water levels were recorded at four observation wells. These wells were sampled periodically for water-quality analysis. Samples were also taken from the main production well for Winslow Crossing.

Acknowledgments

The author gratefully acknowledges Mrs. Alice Cooper of the Winslow Township Planning Board for information on the development of Winslow Crossing. Mr. Carl Birkhimer, formerly of the Winslow Sanitary Company, provided information concerning the operation of the treatment plant. The staff of Henderson and Bodwell, Consulting Engineers, in particular Messrs. R. Bodwell, P. Hewitt, W. Houck, H. Schagat, and J. Price, is also acknowledged.

DESCRIPTION OF THE STUDY AREA

The study area is located near Sicklerville in northwestern Winslow Township. (See fig. 1.) The Winslow Crossing area of the township is bounded by the Atlantic City Expressway to the southwest, the Cross Keys-Berlin Road (County Route 689) to the northwest, and the Great Egg Harbor River to the northeast.

Winslow Crossing is on the west edge of the Outer Atlantic Coastal Plain physiographic province of New Jersey and is to the west of the Pinelands National Reserve. The Reserve was created by the Parks and Recreation Act of 1978 for protection of the ecology, culture, recreational areas, and agriculture of the Pinelands region. Although Winslow Crossing is outside the

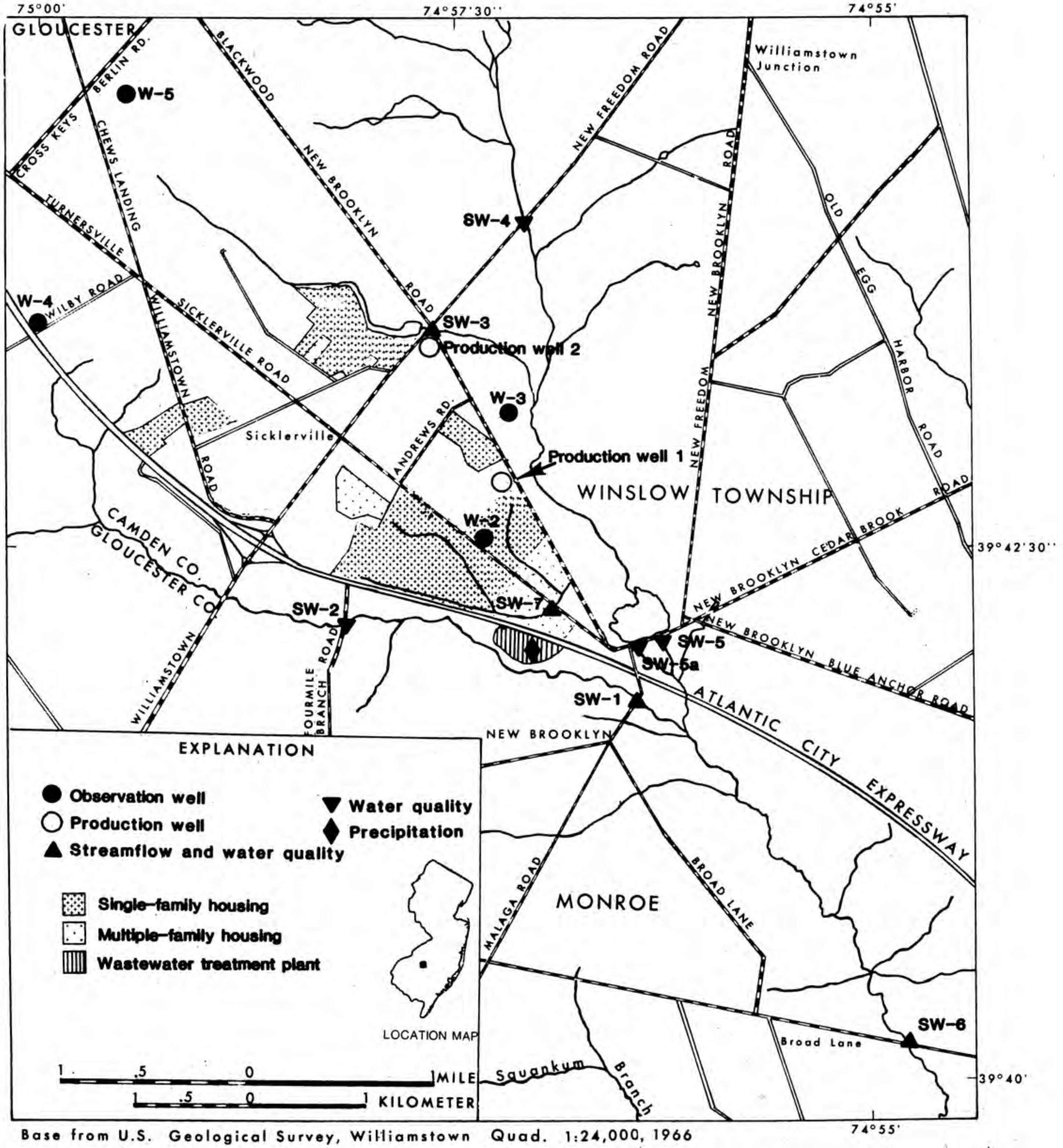


Figure 1.—Map of study area showing locations of data-collection sites.

Reserve area, the hydrology and geology of Winslow Crossing are similar to much of the western part of the Coastal Plain, and results of this study may be applicable elsewhere in the region.

The study area is in the Great Egg Harbor River drainage basin and is drained by several small unnamed tributaries to the Great Egg Harbor River and one larger tributary, Fourmile Branch. The Great Egg Harbor River flows into the Atlantic Ocean. The average runoff is approximately 22 in/yr, which is about 50 percent of precipitation.

Climate

The climate is continental, mild winters and warm summers. Mean annual precipitation at Glassboro, N.J. from 1972 through 1978 was 44.4 inches (U.S. National Oceanic and Atmospheric Administration, 1972-78), and the mean annual temperature was 54.4°F. July is the wettest and warmest month, with mean rainfall of 5.1 inches, a mean temperature of 76.1°F, and a mean daily temperature range of 65° to 88°F. January is the coldest and driest month, with a mean precipitation of 2.9 inches, a mean temperature of 32.7°F, and a mean daily temperature range of 25° to 43°F. Intense thunderstorms over small areas occur in summer, and more widespread, less intense storms occur in winter.

Geology and Soils

Winslow Township lies on the unconsolidated sediments of the Cohansey Sand of Miocene age, which crops out in the eastern half of Camden County. The estimated thickness of the Cohansey Sand in Camden County ranges up to 140 ft. The Cohansey Sand consists of yellowish-orange, fine- to coarse-grained sand and fine gravel and contains lenses of silt and clay as much as 30 ft thick (Farlekas and others, 1976). The beds of silt and clay become thicker, more numerous, and more extensive in southeastern Camden County.

The Cohansey Sand lies unconformably on the Kirkwood Formation of Miocene age. The upper part of the Kirkwood is hydraulically connected with the overlying Cohansey. In upland areas the Cohansey Sand is overlain by the sand and gravel of the Bridgeton Formation of Miocene age. The thickness of the Bridgeton may range from 30 to 50 ft (Owens and Minard, 1979).

The soils range from well-drained sandy loam in upland areas to poorly drained muck along stream channels. The developed area of Winslow Crossing consists of the Aura-Downer soil association and the Muck-Alluvial land association (Markley, 1966). The Aura-Downer association occurs in irregularly shaped areas at elevations between 120 and 180 feet and occupies the divide between the Delaware River and Atlantic Ocean drainage systems. The major soils in the association are the Downer and Aura, which are classified as sandy loams or loamy sands. Most of the soils are well drained and have a natural growth of mixed oak and pine trees. The Muck-Alluvial land association occurs in nearly level areas adjacent to the Great Egg Harbor River and its tributaries. Muck and poorly drained sandy alluvial land, which are the major soil classifications in this association, have a high water table and are frequently flooded. White cedar and pine grow in this region.

Geohydrology

The Cohansey Sand is a major aquifer in Camden County. The Cohansey aquifer, which includes the overlying sediments, is essentially a locally confined water-table aquifer. The saturated thickness of the Cohansey aquifer ranges from 60 to 120 ft. Transmissivity in Camden County and nearby counties determined from aquifer tests ranged from 2,410 to 20,100 ft^2/d for part of the Cohansey aquifer. Hydraulic conductivity typically ranges from 100 to 134 ft/d. Specific capacity of large diameter wells ranges from 8 to 60 gal/min/ft of drawdown (Farlekas and others, 1976, p. 90-91).

The regional direction of ground-water flow is to the southeast. Streams that incise the Cohansey aquifer are mainly gaining streams, with ground water the predominant contributor. Ground-water runoff contributes approximately 20 inches per year to streamflow (Rhodehamel, 1970, p. 13). In undeveloped areas, overland runoff is slight.

Land Use

Winslow Crossing was primarily farmland and woodland before development. Carrots, tomatoes, and corn were major crops. Figure 2 compares aerial photographs taken in June 1963 and August 1977. In 1963, woodland and farmland dominated the area. The Atlantic City Expressway, which can be seen in the 1977 photograph, made the area more accessible to Philadelphia and Camden and hastened the development of Winslow Crossing.

Winslow Crossing was designed to be self-sufficient, with its own water supply and sewerage, schools, stores, and services. Development of the residential areas was accompanied by construction of gas stations, banks, stores, a swim club and recreational areas. Water supply was provided by the Winslow Water Company, which has two wells tapping the Cohansey Sand aquifer. Wastewater was handled by the Winslow Sanitary Company treatment plant, although older homes in the area utilize septic systems. In March 1979, the operations of the Winslow Water Company and Winslow Sanitary Company were assumed by the Winslow Township Water and Sewer Department.

Originally, 6,800 housing units were to be constructed by 1978, with an expected population of 22,675, and 16,800 units by 1984, with a population of 55,425. However, because of economic uncertainties during the mid 1970's, growth was much slower.

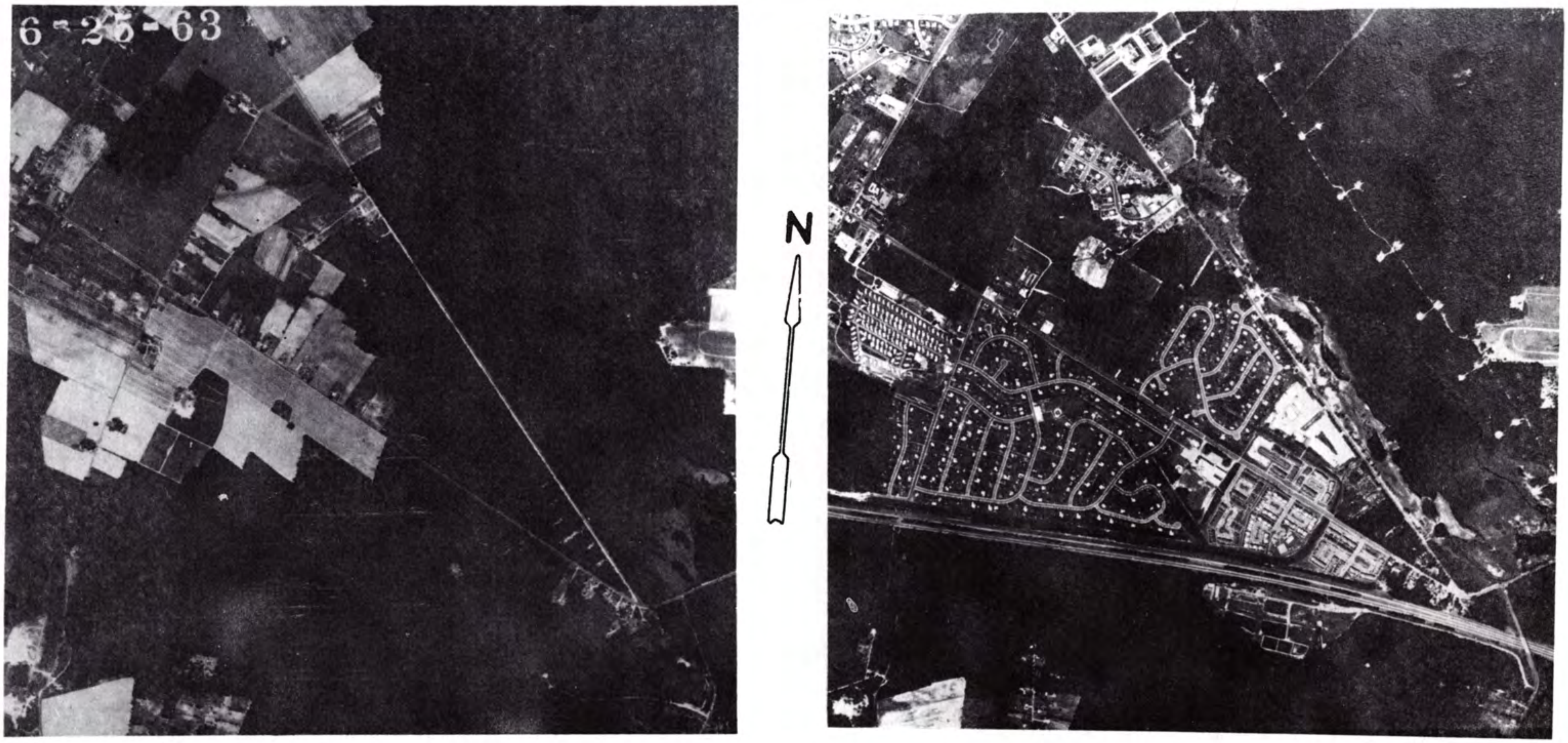


Photo by U.S. Department of Agriculture **1963**

Photo by Air-Ography Inc., Levittown,PA. **1977**

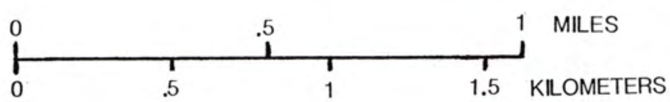


Figure 2.--Aerial photographs of a section of Winslow Township comparing land uses before and after development.

Table 1 lists the projected housing, population, and water consumption. Table 2 lists the housing units completed, population, water consumption, and wastewater treatment for the study period.

Table 1.--Projected levels of housing construction, population, and water consumption for Winslow Crossing development.

	1971	1974	1978	1984
Housing units	400	2,800	6,800	16,800
Population	1,425	9,575	22,675	55,425
Average daily water consumption (Mgal)	.121	.972	2.413	5.910

[Source: Bodwell (1971)]

Table 2.--Actual levels of housing construction, population, water consumption, and wastewater treatment for Winslow Crossing development.

	1972	1974	1976	1978
Housing units	500	1,283	1,663	1,792
Population (estimated)	1,750	4,380	5,680	6,130
Mean water use (estimated) (Mgal/d)	.172	.377	.474	.476
Per capita water use (gal/d/person)	98	86	83	78
Mean wastewater flow (Mgal/d)	.115	NA	.347	.356
Per capita wastewater flow (gal/d/person)	66	NA	61	58

DATA COLLECTION SITES

Surface Water

Two surface-water sampling sites were established on Fourmile Branch. The locations of all data collection sites are shown in figure 1. The drainage area of Fourmile Branch consists mostly of forested areas and cultivated fields, with slight urbanization. However, the water quality of the stream is affected by the Winslow wastewater treatment plant, which discharges effluent into the shallow water table, which slopes toward the stream.

Site SW-2 is on Fourmile Branch above the treatment plant and has a drainage area of 6.22 mi^2. This site was sampled monthly from January 1972 to December 1978 for inorganic compounds and nutrients. It was also sampled yearly from 1972 to 1975 and during 1978, for pesticides and metals in bottom material. Some discharge data are available for this site.

Site SW-1 is below the treatment plant and has a drainage area of 7.74 mi^2. This site was sampled monthly for inorganic compounds and nutrients and yearly from 1972 to 1978 for pesticides and metals in the bottom material. Continuous gage-height and discharge data were obtained from June 1972 to September 1979.

Stream-gage data and water-quality samples were collected at sites along two small tributaries to the Great Egg Harbor River. Site SW-3 has a drainage area of 1.64 mi^2. This area consisted of woodland and fields until the construction of single-family homes on 0.23 mi^2 at the lower end of the drainage basin. The development included the construction of a storm water detention basin upstream from site SW-3. This site was sampled monthly from January 1972 to December 1978 for inorganic constituents and nutrients, and yearly from 1972 to 1978 for pesticides and metals in the bottom material. Continuous gage-height and discharge records were collected at this site from January 1972 to September 1979.

Site SW-7 is at the outlet of a system of ditches that drain from 0.52 mi^2 of land developed with single-family homes and townhouses. The drainage ditches also detain storm water. Site SW-7 is used to measure the quantity and quality of streamflow from the residential area. This site was sampled monthly from April 1972 to December 1978 for inorganic constituents and nutrients and yearly from 1972 to 1978 for pesticides and metals in the bottom material. Continuous gage-height and discharge data was collected from 1973 to 1979.

Three surface-water sites were established on the Great Egg Harbor River. Site SW-6, near Blue Anchor, drains 37.3 mi^2 and is downstream from Winslow Crossing. This site was sampled monthly from February 1972 to January 1979 for inorganic compounds and nutrients and yearly from 1972 to 1978 for metals and pesticides in the bottom material. Continuous gage-height and discharge records were collected from June 1972 to September 1979.

Site SW-4 is a water-quality-sampling site upstream from the Winslow Crossing development, with a drainage area of 15.1 mi^2. This site was sampled monthly from January 1972 to January 1979 for inorganic compounds and nutrients and yearly from 1972 to 1978 for metals and pesticides in the bottom material. Sites SW-5 and SW-5a are water-quality-sampling sites on the Great Egg Harbor River at the outlets of New Brooklyn Lake. Site SW-5 was sampled at various intervals between January 1972 and January

1975 for nutrients and inorganic constituents and yearly between 1972 and 1974 for metals and pesticides in the bottom material. Site SW-5a was sampled monthly between December 1972 and December 1978 for nutrients and inorganic constituents and several times during 1973 and 1974 for metals and pesticides in the bottom material. No discharge data were collected at sites SW-5 and SW-5a.

Ground Water

Four observation wells were installed to monitor the level and quality of ground water in the Cohansey Sand. Observation wells W-2 and W-3 were drilled in the vicinity of Winslow Crossing and both are within 3,000 ft of the main Winslow Township production well, production well 1. Well W-2 is approximately 2,000 ft southwest of production well 1. Well W-2 is at land-surface datum 121.4 ft above the National Geodetic Vertical Datum of 1929[1/] and is screened from 73 to 78 ft below land surface. Well W-3 is approximately 3,000 ft north and upgradient from the production well and is near the Great Egg Harbor River. It is located at land-surface datum 116 ft above sea level and is also screened from 73 to 78 ft below land surface. Observation wells W-4 and W-5 are northwest of Winslow Crossing near the surface-water drainage divide between the Great Egg Harbor River and Big Timber Creek basins. Wells W-4 and W-5 are 2.6 and 3.0 mi, respectively, from production well 1, and 2.6 and 2.0 mi, respectively, from Great Egg Harbor River. Well W-4 is located at land-surface datum 145 ft above sea level and W-5 is 173.3 ft above sea level. Both W-4 and W-5 are screened from 71 to 76 ft below land surface.

Winslow Township production well 1 is located at land-surface datum 115 ft above sea level and is screened from 72 to 103 ft. Production well 2 is at land surface datum 120 ft above sea level and is screened from 64 to 90 ft below land surface,

A series if shallow 1-1/4-inch well points were driven into the shallow formation adjacent to the infiltration beds at the Winslow wastewater treatment plant. These wells are referred to as test wells in this report. Data will be presented for three test wells (Nos. 3, 4, and 6). (See fig 6.) Test well 3 (TW-3) is 11 ft deep, test well 4 (TW-4) is 12 ft deep, and test well 6 (TW-6) is 13 ft deep. Test well 4 is upgradient from the infiltration beds, whereas test wells 3 and 6 are adjacent to the beds.

[1/] 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 "Mean Sea Level." NGVD of 1929 will be referred to as sea level in this report.

RESULTS

Ground-Water Levels

Winslow Water Company filed an application in 1970 to withdraw up to 7.2 Mgal/d from the Cohansey Sand. The ground-water usage in the area has been much lower than expected, however, because of slow development. The highest monthly withdrawal was 0.78 Mgal/d during July 1977, and the average withdrawal during 1978 was 0.48 Mgal/d.

Withdrawals did not significantly affect ground-water levels in the area. Figure 3 and 4 compare the hydrographs of water levels for the four observation wells with the mean monthly pumpage and the total monthly precipitation. The period of record (1972-78) is too short to indicate any long-term trends in water levels in the Cohansey Sand, but the short-term trends are evaluated.

The two observation wells closest to the main production well (production well 1) are W-2 and W-3. Well W-3 is near the Great Egg Harbor River and W-2 is between the Great Egg Harbor River and Fourmile Branch. These two wells show no short-term decreasing trend in water levels. The water levels do, however, decrease in the summer mainly because of an increase in evapotranspiration and also some decrease in recharge.

Water levels in observation wells W-4 and W-5, which are in the upland area vary seasonally and show slight downward trends. Below normal rainfall, which reduced recharge during 1976 and the first 9 months of 1977, is the reason for the downward trend in wells W-4 and W-5.

Figure 5 illustrates the variations in water levels at observation wells W-2 and W-3 during and after 2.0 inches of rain in 150 minutes on August 31, 1977. Water levels in the two wells, increased $^{1}/_{2}$ foot in a few hours and then receded slowly. The hydrograph for well W-2 shows the hourly and daily fluctuations in the well caused by intermittent pumping from production well 1, located 2,000 ft away.

Water Quality of the Cohansey Sand

Water in the Cohansey Sand has been characterized as having low pH and high levels of iron and color. The water is generally suitable for use after treatment (Farlekas and others, 1976). Analyses of samples from three observation wells and one production well are listed in table 3. Analyses of samples from the shallow test wells at the Winslow wastewater treatment plant will be discussed in the following section. Well W-5 was not sampled during the study. Nitrate-nitrogen concentrations ranged from 0.03 mg/L (W-4) to 5.8 mg/L (W-2), indicating that farms, septic systems, or residential areas are contributing to the

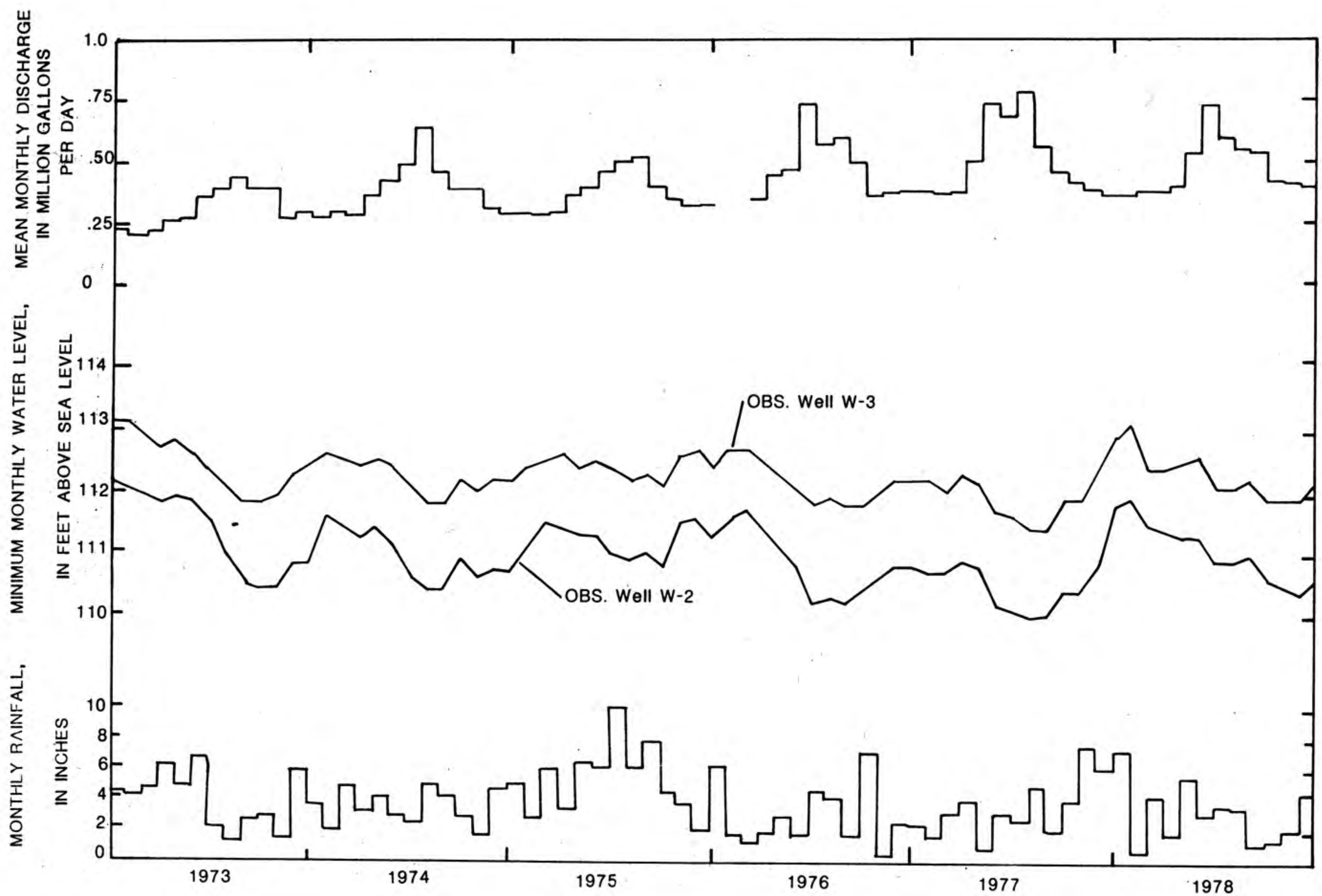


Figure 3.--Comparison of water levels in observation wells W-2 and W-3 with mean monthly pumpage and monthly precipitation, 1973-78.[Precipitation data from U.S. National Oceanic and Atmospheric Administration, 1973-78.]

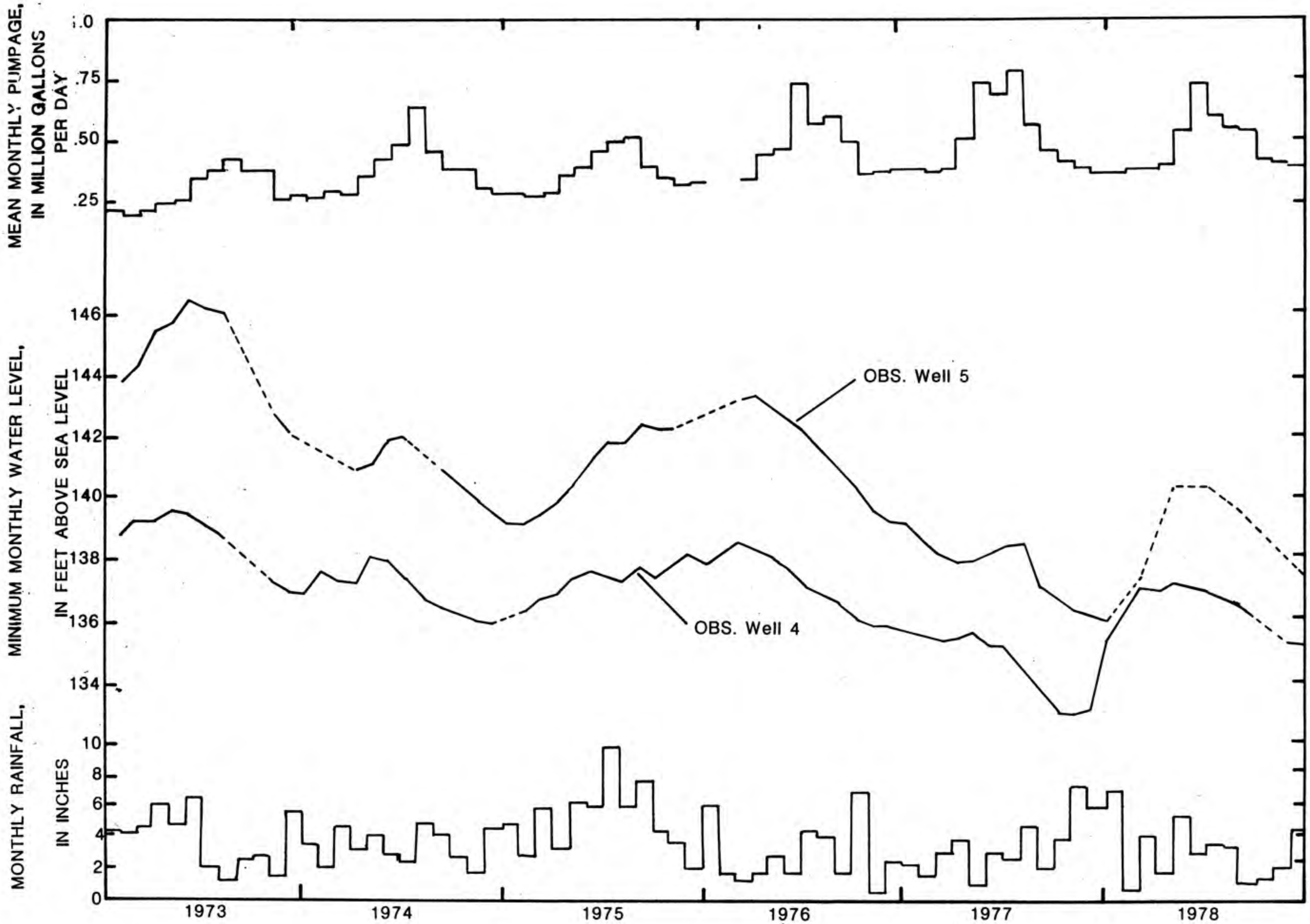


Figure 4.--Comparison of water levels in observation wells W-4 and W-5 with mean monthly pumpage and monthly precipitation, 1973-78. [Precipitation data from U.S. National Oceanic and Atmospheric Administration, 1973-78.]

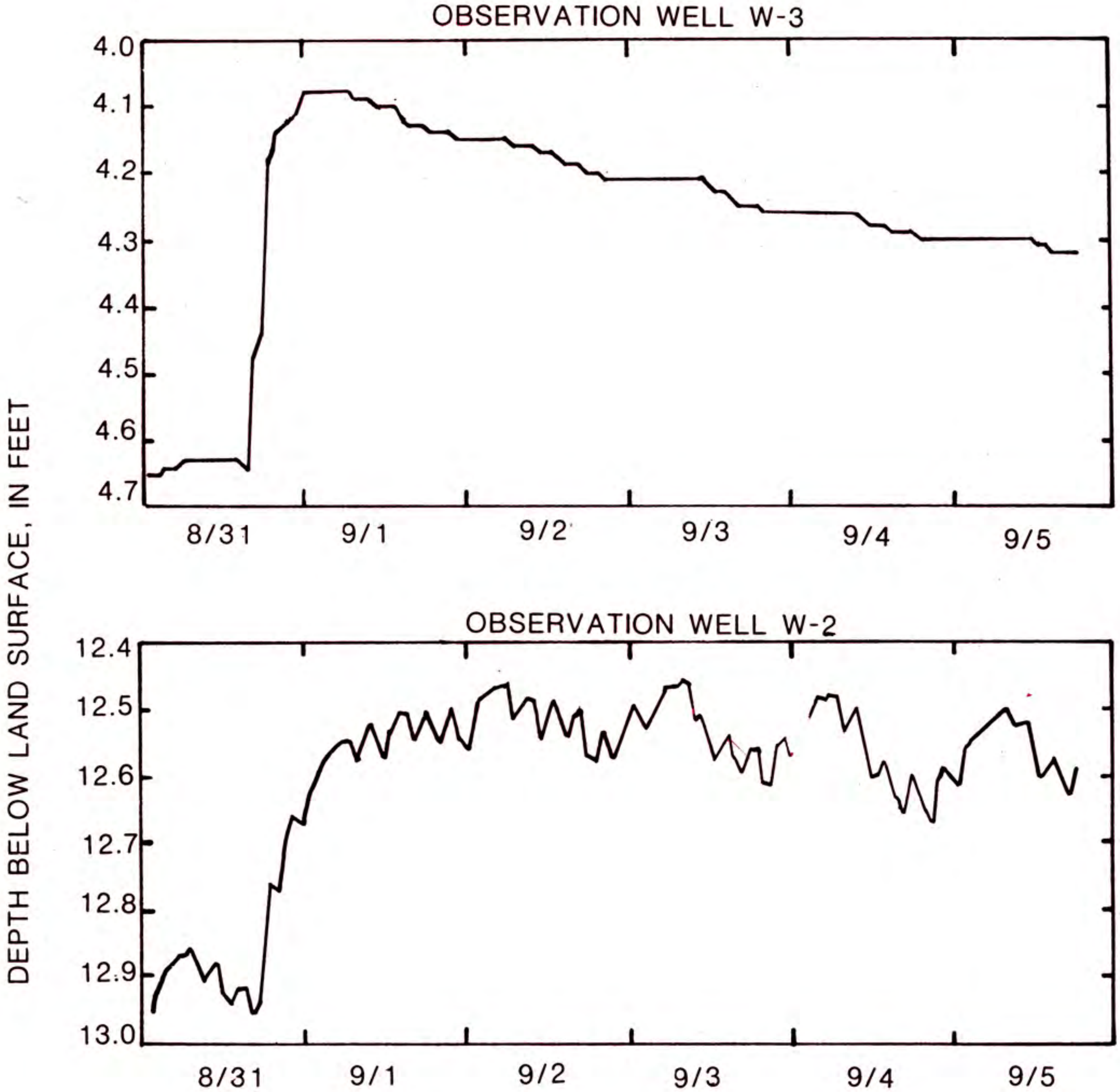


Figure 5.--Hydrographs of water levels in observation wells W-2 and W-3 after rainfall on August 31, 1977.

Table 3.--Analyses of ground water in Winslow Township, N.J., 1973-78
[Results in mg/L, except as noted]

Parameter	Observation Well W-2			Observation Well W-3		Observation Well W-4	Winslow Water Company Production Well No. 1		
	1973	1974	1978	1974	1978	1973	1970	1973	1974
pH	7.7	5.5	4.7	4.6	5.1	7.1	5.0	7.8	5.2
Specific conductance[1]	122	110	87	55	30	35	-	127	67
Dissolved solids	-	63	62	40	28	-	38	82	47
Total hardness	24	21	16	12	5	8	20	17	16
Sodium	-	6.0	6.0	2.5	2.0	-	-	-	4.2
Calcium	6.0	5.0	3.0	3.0	1.2	1.9	-	3.8	7.0
Potassium	-	1.9	1.7	1.1	.7	-	-	-	1.5
Alkalinity	34	6	-	5	-	11	12	35	6
Chloride	11	10	9.4	6.0	2.2	2.8	8	6.5	7.0
Sulfate	6.4	1.4	1.2	1.7	1.9	2.3	7	4.2	4.6
Nitrate (as N)	.2	5.8	4.5	3.3	1.2	.03	4.1	3.2	3.0
Total nitrogen	3.3	5.9	4.6	3.3	1.3	-	-	-	3.2
Phosphorus	-	.10	.01	0	.03	-	-	-	.02
Organic carbon	-	1.4	1.0	7.1	1.2	-	-	-	6.4
Manganese[2]	-	750	30	30	20	-	<50	-	10
Total iron[2]	-	2300	-	580	-	-	300	0	110
Dissolved iron[2]	-	250	190	180	140	-	-	-	60
Lead[2]	-	11	1	2	3	-	-	-	2
Zinc[2]	-	50	20	20	0	-	-	-	100

[1] µmhos/cm @ 25°C
[2] µg/L

concentrations in some areas. The nitrate-nitrogen levels in the observation wells, however, were below the Primary Drinking Water Standard of 10 mg/L (U.S. Environmental Protection Agency, 1976).

One sample at W-2 contained 750 µg/L and 2,300 µg/L of manganese and iron, respectively. Both were in excess of the standards of the Secondary Drinking Water Regulations, 50 µg/L for manganese and 300 µg/L for iron (U.S. Environmental Protection Agency, 1976). These standards were established on esthetic considerations, however, and concentrations of iron and manganese exceeding the standards do not pose a health threat. Three samples taken from Production Well 1 did not show high concentrations of iron or manganese, implying that these constituents are found only in localized areas.

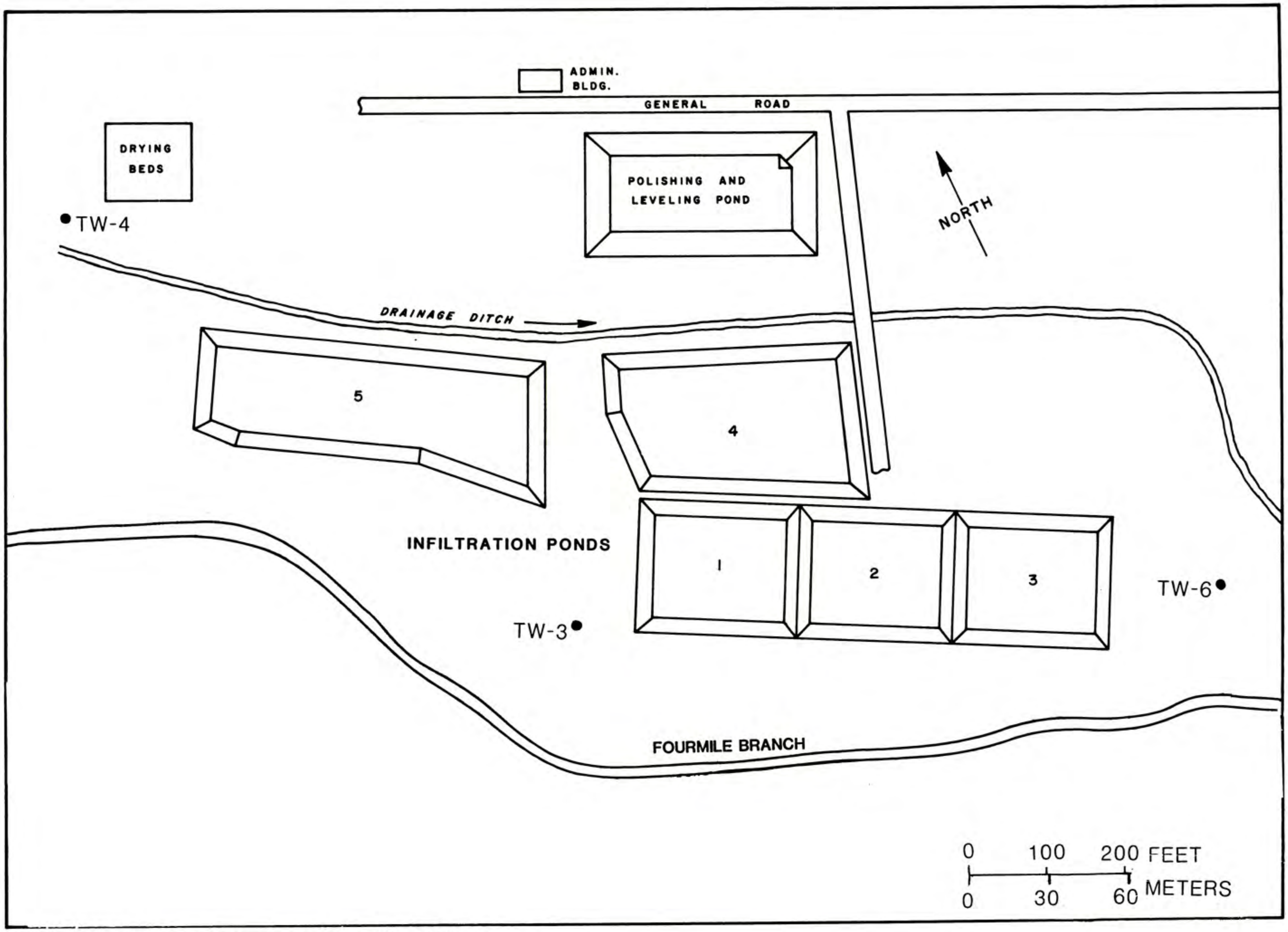
The pH values ranged from 4.6 to 7.8, with most values below 6.0. Specific conductance ranged from 30 to 127 µmhos/cm at 25°C in observation-well samples.

Chloride, calcium, potassium, sodium, total hardness, and dissolved solids were lower in samples from observation well W-3 than from well W-2 and Production Well 1, probably because of its location away from populated and agricultural areas. All were well within drinking water standards.

Shallow Ground-Water Quality

The Winslow wastewater treatment plant has an oxidation ditch and pressure sand filter and disposes of its effluent into sand-lined infiltration ponds. From the plant's opening in 1972 until 1974, high concentrations of nitrate-nitrogen in the effluent caused high levels in the underlying ground water. The plant and the locations of the test wells are shown in figure 6. Figure 7 illustrates the nitrate-nitrogen concentrations in three test wells at the treatment plant from 1973 to 1979. Test well 4 is representative of the natural water quality of the area. The nitrate-nitrogen in water from test well 4 ranged between 0 and 1 mg/L during the study. Test wells 3 and 6 are adjacent to the infiltration ponds and were affected by infiltration from the ponds. The nitrate-nitrogen concentrations in water from these wells ranged from 2 to 28 mg/L from January 1973 to October 1974, and many samples contained nitrate-nitrogen concentrations in excess of the 10 mg/L standard.

The treatment process was altered in October 1974, resulting in denitrification of much of the nitrate in the oxidation ditch and a reduction in the nitrate-nitrogen concentration in the effluent. Nitrate-nitrogen concentrations in test well 3 dropped quickly to near zero and has ranged from 0 to 3 mg/L since that time. In test well 6, the change was not as immediate as it was in test well 3. The nitrate-nitrogen concentration in water from test well 6 increased to 26 mg/L in December 1974 before dropping to 12.6 mg/L in March 1975 and 9.0 in April 1975. Since that time, the nitrate-nitrogen



Base from Levitt Residential Communities,Inc. 1:600, 1973

Figure 6.--Location of test wells at the Winslow wastewater treatment plant, Winslow Township, New Jersey.

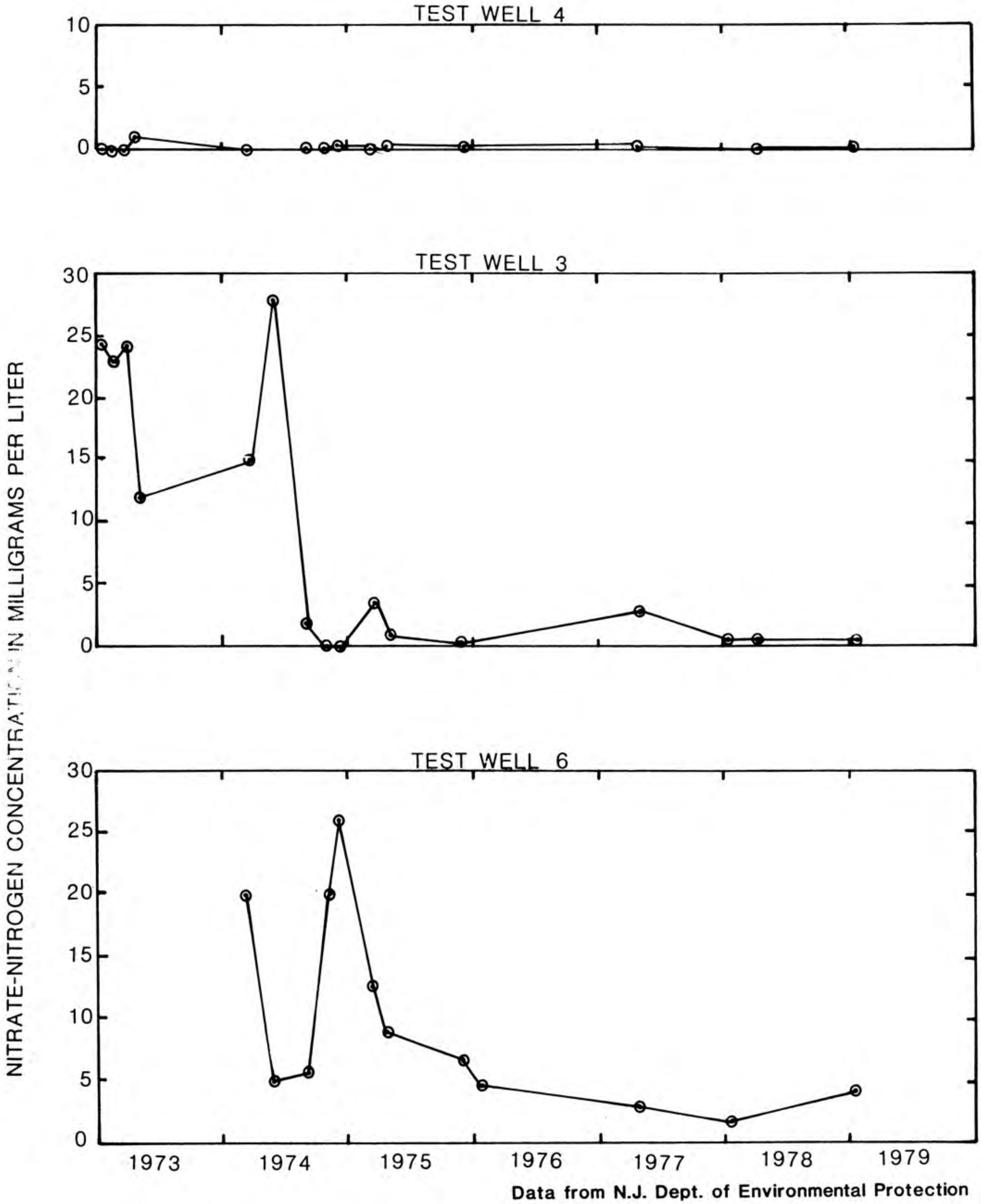


Figure 7.--Nitrate-nitrogen concentrations in three test wells at the Winslow wastewater treatment plant, 1973-78.

concentration in water from test well 6 is below the standard of 10 mg/L and fluctuates between 1.5 and 4.0 mg/L. The treatment change reduced the nitrate in the effluent, thus reducing the concentration in the ground water downgradient from the waste-treatment plant.

Analyses of two samples from test wells 3 and 4 are shown in table 4. Water from test well 3 had higher concentrations of all constituents as well as higher pH and specific conductance than water from test well 4. The greatest differences between the two wells were in concentrations of total phosphorus (14 and 9.5 mg/L in test well 3, and 0.02 and 0 mg/L in test well 4), orthophosphate (4.7 mg/L in test well 3 and 0 mg/L in test well 4), ammonia-nitogen (1.7 and 2.3 mg/L in test well 3, and 0.01 and 0 mg/L in test well 4), dissolved solids (250 mg/L in test well 3 and 70 mg/L in test well 4), and nitrate-nitrogen (2.3 and 0.45 mg/L in test well 3 and 0.03 and 0.04 mg/L in test well 4). The increases in orthophosphate and total phosphorus in water from test well 3 are significant. Some of the phosphorus in the effluent may be removed from ground water by adsorption to clay particles. However, the variable distribution of clay in the Cohansey Sand allows some of the phosphorus to enter the ground water. Based on water-level measurements, ground-water flow near the infiltration ponds is in the direction of the nearby stream, Fourmile Branch. The effects of the effluent infiltration ponds on the water quality of Fourmile Branch will be discussed in a later section.

Table 4.--Chemical analyses of samples from two test wells adjacent to infiltration ponds at the Winslow wastewater treatment plant

[Results in mg/L except as noted]

	Test Well 4		Test Well 3	
	August 1974	April 1978	August 1974	April 1978
pH (units)	6.4	5.5	6.7	6.5
Specific conductance (μmhos)	130	83	356	335
Dissolved solids	70	-	250	-
Chloride	10	14	39	31
Organic-Nitrogen	.02	.07	.30	.40
Ammonia (as N)	0	.01	1.7	2.3
Nitrate (as N)	.03	.04	2.3	.45
Total nitrogen	.05	.12	4.4	3.2
Orthophosphorus (as P)	0	0	-	4.7
Total phosphorus	.02	0	14	9.5

Surface-Water Hydrology

The drainage basin of Great Egg Harbor River in the vicinity of Winslow Crossing consists of relatively flat terrain underlain by the sand beds of the Cohansey aquifer. Infiltration and ground-water recharge limits overland runoff into streams. Swamps are common throughout the basin, particularly in the flood plains.

Records of the gaging station, 01411000 Great Egg Harbor River at Folsom, N.J., approximately 10 miles downstream from Winslow Crossing, were analyzed to determine if streamflow from 1972 to 1978 was representative of the long-term streamflow pattern. Figure 8 compares the flow-duration curve at Folsom for the period of record (1927-78) to the curve for the study period (1972-78). The flow-duration curves show the percentage of time that a discharge was equalled or exceeded. The curve for the study period was generally higher than the curve for the period of record. The extremely wet year of 1975, when 64 inches of rainfall was measured at Glassboro, N.J., raised the flow-duration curve above the long-term average. The streamflow during the remaining years of the study was similar to the long-term average.

Figure 9 illustrates the runoff at four stream-gaging sites after a storm on August 31, 1977. Sites SW-3 and SW-7, which drain small, urbanized areas, had rapid changes in discharge and a short-duration peak discharge. This large amount of runoff at a rapid rate is due to residential land uses and the use of storm sewers. The peak discharge was probably higher because these gaging stations measured outflow from the detention basins, not inflow to the basin. Sites SW-1 and SW-6, which drain larger, less developed drainage basins, reacted more slowly to rainfall, with a slower rise and a prolonged peak discharge.

The drainage area of gaging station SW-3 was the only gaged area that had a major change in land use during this study. The gaging station SW-3 was installed in January 1972, when land use in the basin consisted chiefly of fields and woodland. In early 1973, land clearing began for the Arbor Meadows development of Winslow Crossing, and, by September 1973, the first 105 single-family homes were completed. By November 1974, 188 of the planned 299 homes were constructed. The development is in the downstream end of the drainage area, shown in figure 10, and consists of approximately 1/4-acre lots. The percentage of impervious surface within the development is not known, but is probably high, because of the density of the development.

Rainfall and discharge for eight storms was evaluated by unit-hydrograph analysis. The storms were chosen to satisfy the assumptions of unit-hydrograph theory, as described by Chow (1964, Chap. 14, p. 13) regarding the distribution of rainfall and the physical effects of the rainfall on the drainage basin. Two storms during 1973, before development (Phase 1 of the study) were

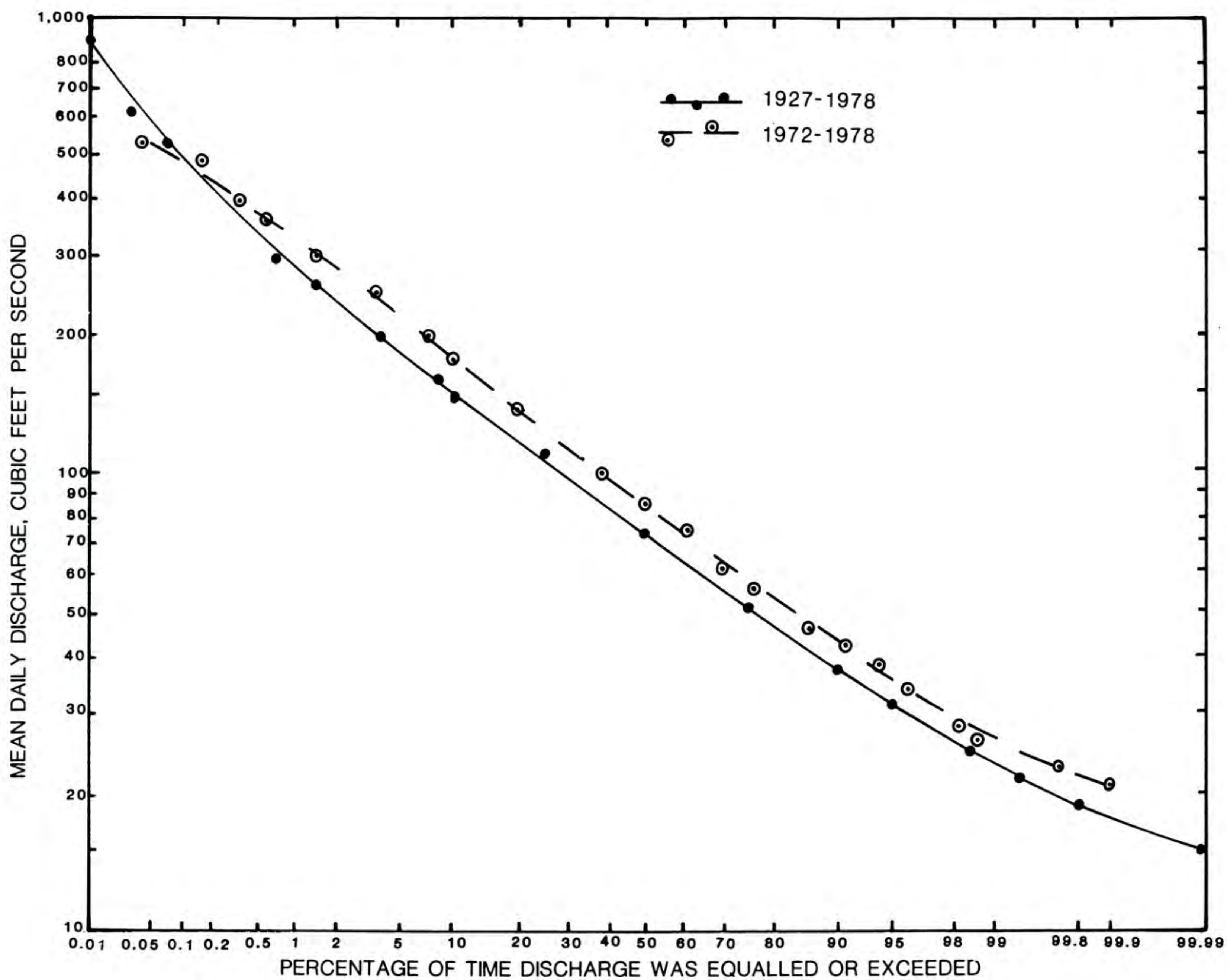


Figure 8.--Flow-duration curves for the Great Egg Harbor River at Folsom for the period of record (1927-78) and for the period of this study (1972-78).

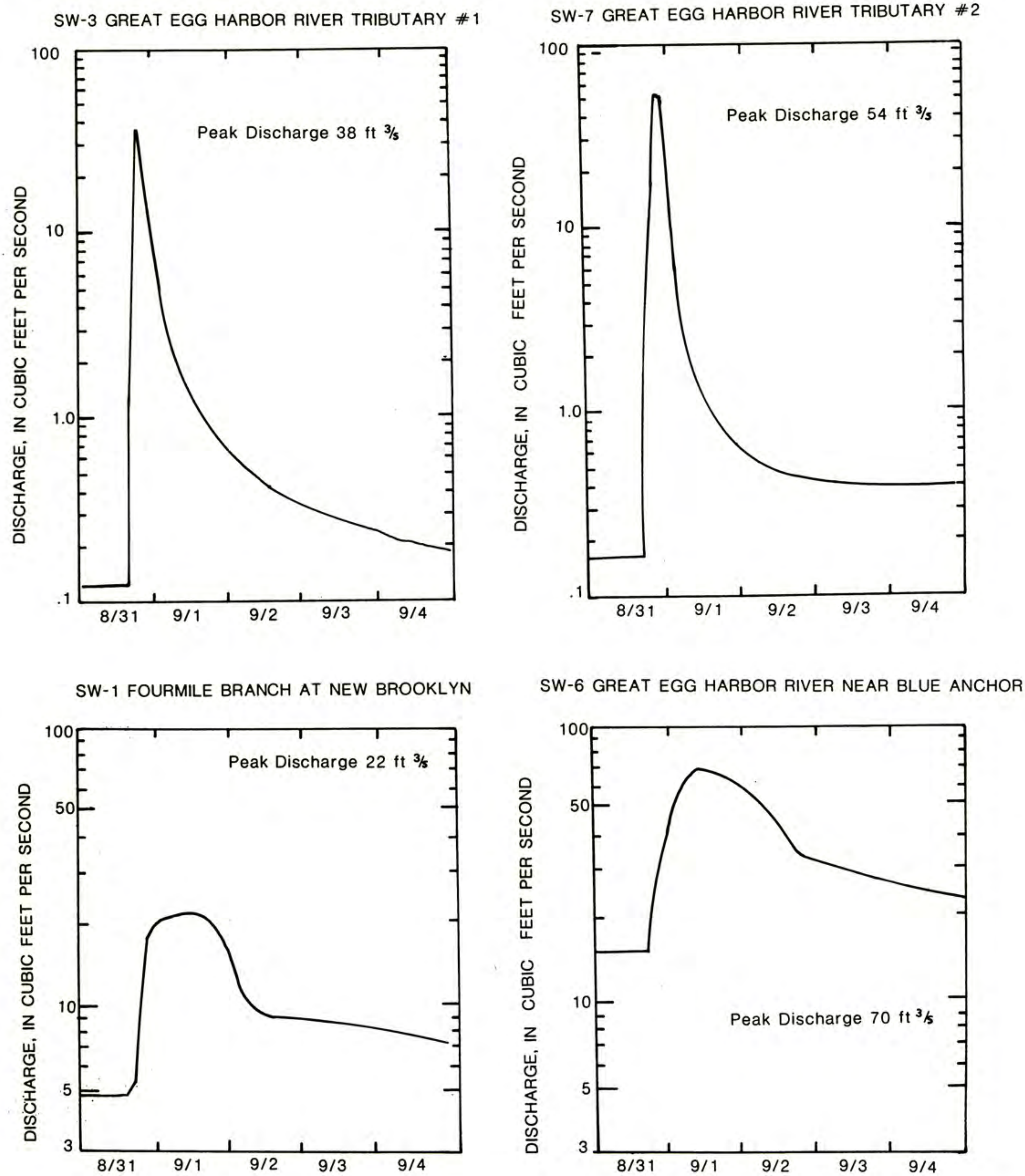
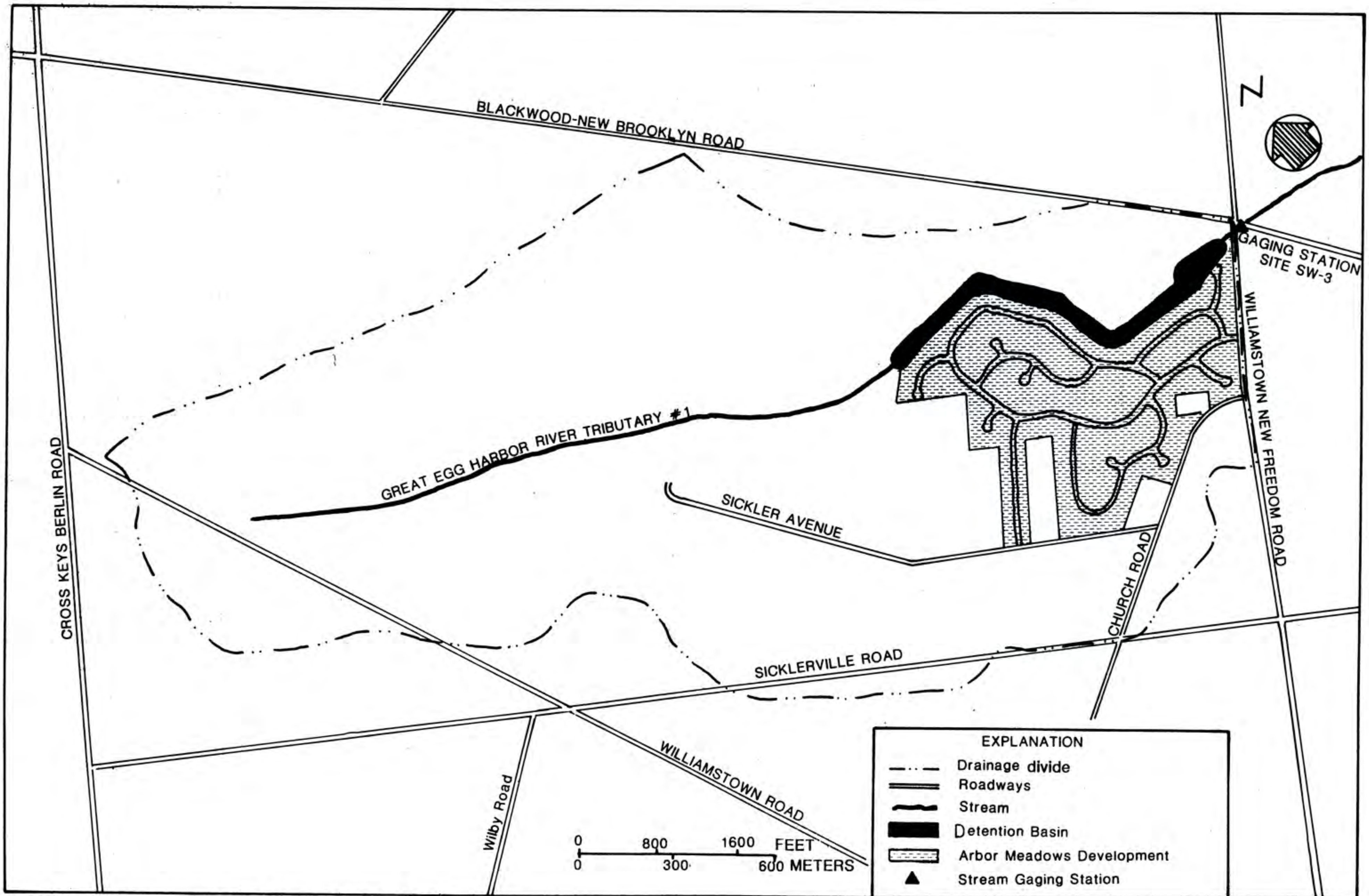


Figure 9.--Storm hydrographs at four gaging stations resulting from rainfall on August 31, 1977.



Base from Winslow Township zoning map 1:24,000, 1976

Figure 10.--Drainage area map of Great Egg Harbor River tributary no. 1 showing the extent and location of the Arbor Meadows development.

chosen. Three storms during 1975, when most construction had been completed (Phase 2) were chosen. Three storms during August 1977 to August 1978, after the installation of a stormwater detention basin (Phase 3), were also chosen.

Unit hydrographs were developed for each storm utilizing a computer program developed by Nathan and others (1970). The unit hydrograph represents the discharge from a 60-minute rainfall that produces 1 inch of runoff over the basin. The unit hydrographs for each phase of development were used to construct one average unit hydrograph for that phase by using the average peak flow and average time to peak, as described by Linsley and others (1975, p. 238).

The storms analyzed by unit hydrographs averaged 1.6 inches of rain with an average duration of about 80 minutes. These were storms of relative high intensity but short duration, which occur several times each year. These small storms tend to exaggerate the effects of urbanization more than large storms which cause saturation of the soil. Small storms normally will not saturate the soil, therefore the difference between runoff from pervious and impervious surfaces is more pronounced.

The use of small storms in the unit hydrograph analysis exaggerates the peak discharge. The use of large storms would result in a lower peak discharge for the unit hydrographs. For a small drainage area (1.64 square miles), however, large rainfalls do not satisfy the assumptions of the unit hydrograph theory.

The results of the unit hydrograph analysis, shown in figure 11, illustrate the magnitude of the changes in runoff patterns from small storms after urbanization of part of the drainage basin. The Phase 1 curve shows the slow rise and low peak-flow characteristic of a natural drainage area. The Phase 2 curve illustrates the change in runoff caused by urbanization. About 12 percent of the drainage area had been developed by Phase 2. Peak discharge increased from approximately 150 ft^3/s in Phase 1 to 270 ft^3/s in Phase 2. During Phase 3, when 14 percent of the basin was developed and a large stormwater detention basin was installed, peak runoff was approximately 220 ft^3/s.

Surface-Water Quality

The quality of water is the net result of the sources of solutes to the system, weathering of rock and soil, atmospheric inputs, geochemical reactions beneath the surface, and cultural activities (Hem, 1970, p. 1). This section evaluates the cultural effects on water quality after development of Winslow Crossing.

The quality of surface water in the vicinity of Winslow Crossing varied both temporally and areally during this study. Figure 12 compares the mean concentrations of the major ionic species at the seven surface-water sites during water years 1976 through 1978 through the use of Stiff diagrams. These

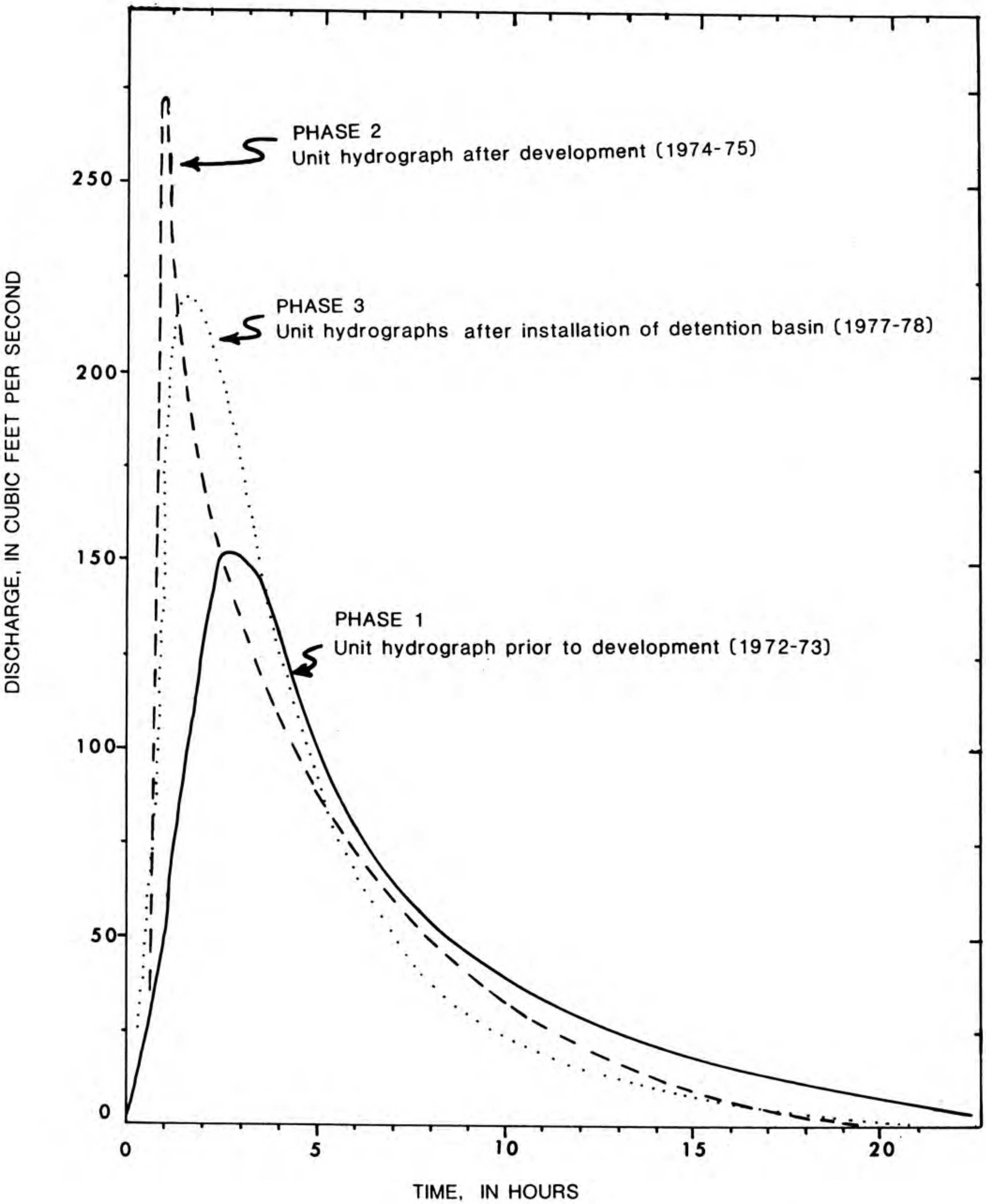


Figure 11.--Comparison of unit hydrographs at site SW-3 before and after development and after the construction of a storm-water detention basin.

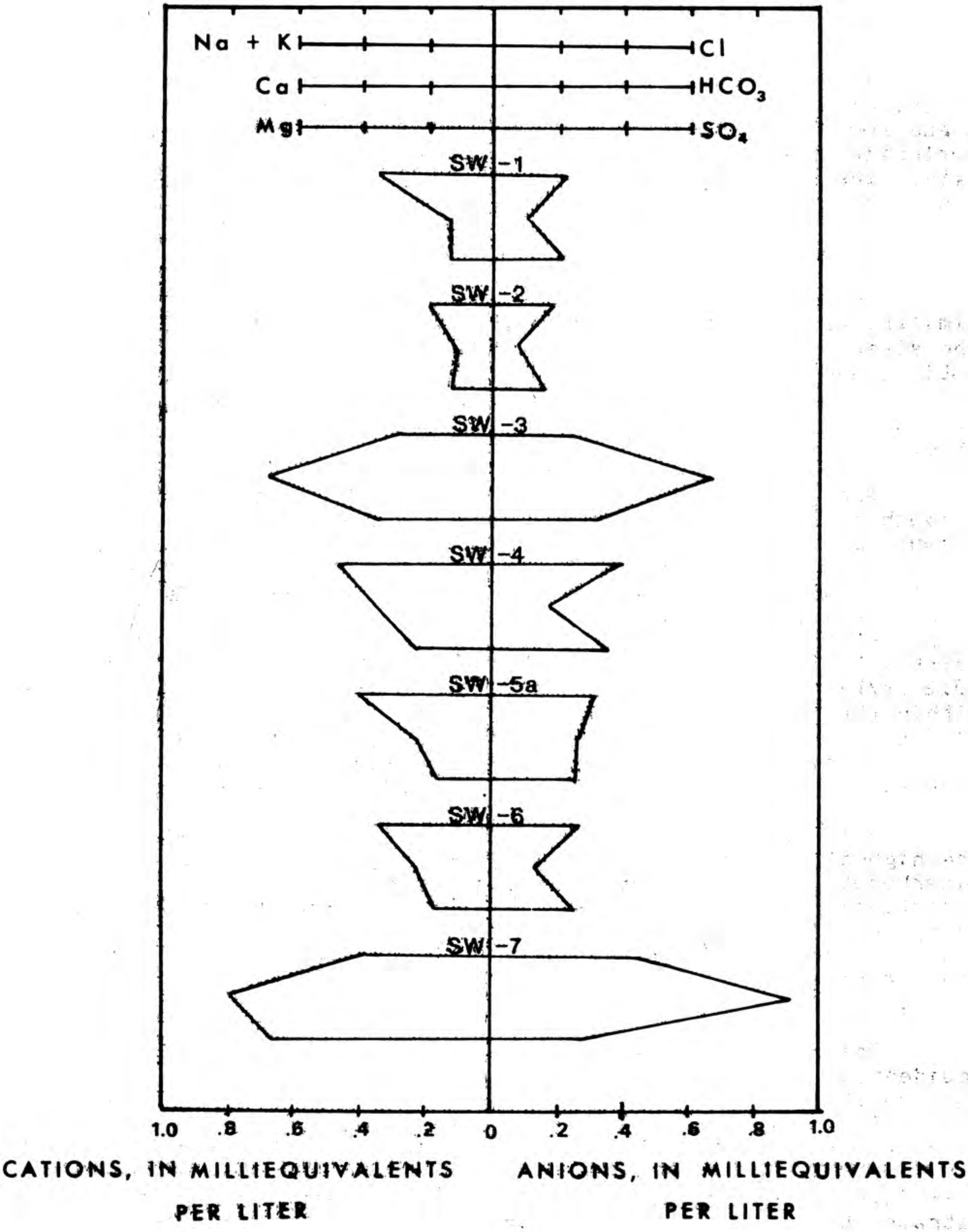


Figure 12.--Stiff diagrams of mean concentrations of major ions at the seven surface-water sampling sites, water years 1976-78.

diagrams illustrate the concentration, in milliequivalents per liter, of the major cations (sodium and potassium, calcium, and magnesium) to the left of the vertical axis, and the major anions (chloride, bicarbonate, and sulfate) to the right of the vertical axis. The size of each figure is an approximation of the total ionic content at that site. Comparison of Stiff diagrams for different sites can show differences in the water quality between the sites by changes in the pattern.

The water composition at five of the seven sites is similar, as indicated by the shape of the Stiff diagram. At all the sites except SW-3 and SW-7, sodium was the most abundant cation, and chloride and sulfate were the most abundant anions. Sites SW-3 and SW-7, which drain urbanized areas, show higher mean levels of bicarbonate, calcium, and magnesium compared with the other five sites.

Analyses of the surface-water sites for water years 1976 through 1978 are summarized in table 5. This time was chosen because most construction was completed by 1976. Water samples at site SW-2 had the lowest mean concentration of dissolved solids and the lowest concentrations of most other constituents. This site is the least developed of the seven sites and is representative of the preconstruction water quality. The relatively high mean levels of DDT (20 μg/kg) and dieldrin (0.2 μg/kg) in the bottom material are the result of crop spraying within the basin. The high mean concentration of nitrate-nitrogen (1.3 mg/L) may have resulted from agricultural runoff or malfunctioning septic systems in the headwaters of Fourmile Branch.

Site SW-7, an almost entirely developed drainage area, had the highest mean concentrations of specific conductance, hardness, bicarbonate, dissolved solids, total nitrogen and nitrate-nitrogen. Concentrations of all dissolved constituents, except dissolved organic carbon (DOC), are higher at site SW-7 than at site SW-2. The low level of DOC at SW-7 is due to the absence of swamps, which contribute organic matter to the drainage basin.

The drainage area of site SW-3 underwent partial residential development during the study. During 1976-78, when most construction was completed, site SW-3 showed higher mean levels of specific conductance, hardness, bicarbonate, pH, and dissolved solids than site SW-2. Calcium and sulfate were also noticeably higher at SW-3 (11 and 15 mg/L, respectively) than at SW-2 (2.0 and 6.6 mg/L, respectively). The mean concentration of nitrate at site SW-3, however, was lower than at any other site. This may have been owing to the absence of active agriculture in the basin before development.

Twelve-month moving averages were analyzed to compare the trends in water quality at various sites. Moving averages were used because they dampen the magnitude of short-term fluctuations

Table 5.--Mean values of water-quality parameters at seven surface-water sampling sites, water years 1976-78

[Results in milligrams per liter, except as noted]

Parameter	SW-1	SW-2	SW-3	SW-4	SW-5a	SW-6	SW-7
Specific conductance (μmhos)	74	57	134	118	132	84	202
pH (units) [median]	6.1	5.6	7.1	6.1	6.3	6.1	7.1
Dissolved oxygen	9.6	9.1	9.4	7.4	7.3	9.2	10
BOD	1.3	1.0	2.6	1.9	2.3	1.6	2.0
Dissolved solids	60	48	86	78	66	-67	113
Calcium	2.6	2.3	14	7.1	4.6	4.6	16
Magnesium	1.6	1.6	4.3	2.8	2.1	2.1	8.2
Sodium	7.1	3.9	5.0	9.5	8.0	6.8	8.0
Potassium	1.8	1.3	2.3	2.3	2.2	1.9	1.7
Chloride	8.2	6.4	8.6	14	11	9.5	16
Sulfate	10	7.4	15	17	12	12	12
Bicarbonate	7.0	5.0	48	12	19	9.7	66
Total alkalinity	5.8	4.0	39	9.5	15	7.8	54
Total hardness	13	12	53	30	20	20	73
Total nitrogen	1.9	1.6	1.0	2.2	1.8	1.6	2.2
Organic nitrogen	.37	.31	.42	.53	.50	.41	.41
Ammonia (as N)	.10	.02	.08	.22	.09	.09	.04
Nitrate (as N)	1.4	1.3	.51	1.5	1.2	1.2	1.7
Total phosphorus	.32	.02	.05	.52	.15	.20	.06
Orthophosphorus (as P)	.29	.01	.02	.40	.08	.15	.02
Total organic carbon	8.7	6.8	7.6	8.8	9.6	8.0	6.5
Dissolved organic carbon	5.8	6.0	4.8	8.6	9.1	8.0	4.2
Turbidity (JTU)	2.3	1.8	5.8	3.1	2.4	2.1	4.8
In bottom material							
DDT (and metabolites)[1]	1	20	16	22	3	2	15
Chlordane[1]	0	3	8	2	2	0	8
Dieldrin[1]	0	0.2	0	0.6	0	0	0.1
PCB[1]	0	10	10	0	2	0	8
Iron[2]	2000	2800	1850	520	-	140	4300
Lead[2]	10	25	100	<10	-	6	22

[1] μg/kg
[2] μg/g

while illustrating the overall trend of the data (Anderson and others, 1968). Moving median values were used for analysis of pH trends. Figure 13 plots the moving averages of specific conductance and moving medians of pH for three stations: SW-2, the least-developed site; SW-3, partly developed; and SW-7, totally developed. The pH curves for sites SW-2 and SW-7 roughly parallel each other, with the pH at site SW-7 approximately 1.0 to 1.5 units higher than at SW-2. The pH at site SW-3 in 1972 was the lowest of the three sites. The pH at SW-3 rose rapidly during 1973, during land clearing and construction, and reached a level nearly equal to the pH at site SW-7. The pH remained approximately the same at sites SW-3 and SW-7 during the rest of the study.

Specific conductance remained fairly constant at site SW-2 but increased at SW-3 and SW-7. Construction probably caused the rise at SW-3; whereas, the rise at SW-7 may be the result of construction or the increased use of road salts and fertilizers in the newly developed residential area.

During construction, vegetation is cleared from the land surface and soil is disturbed and removed. This usually accelerates soil erosion. Daily suspended sediment samples were collected at site SW-3 from April 1974 through August 1978 and at site SW-1 from April 1974 through March 1976 and from October 1977 until August 1978. Figure 14 is a comparison of the monthly mean suspended sediment discharge per unit area for sites SW-1, which had no construction, and SW-3, which had approximately 14 percent of its drainage area developed. The annual mean suspended-sediment discharges for the two sites are listed in table 6.

Table 6.--Mean suspended sediment discharge at sites SW-1 and SW-3, 1974-78
[Tons per day per square mile]

Water year	Site SW-1	Site SW-3
1974 (April-September)	.06	.24
1975	.04	.20
1976 (October-March	.06	.12
(April-September)	-	.04
1977	-	.06
1978	.07	.06

Suspended-sediment discharge was high at site SW-3 during 1974 and 1975, during construction, compared with the discharge at SW-1 during the same period. Construction slowed in early 1976.

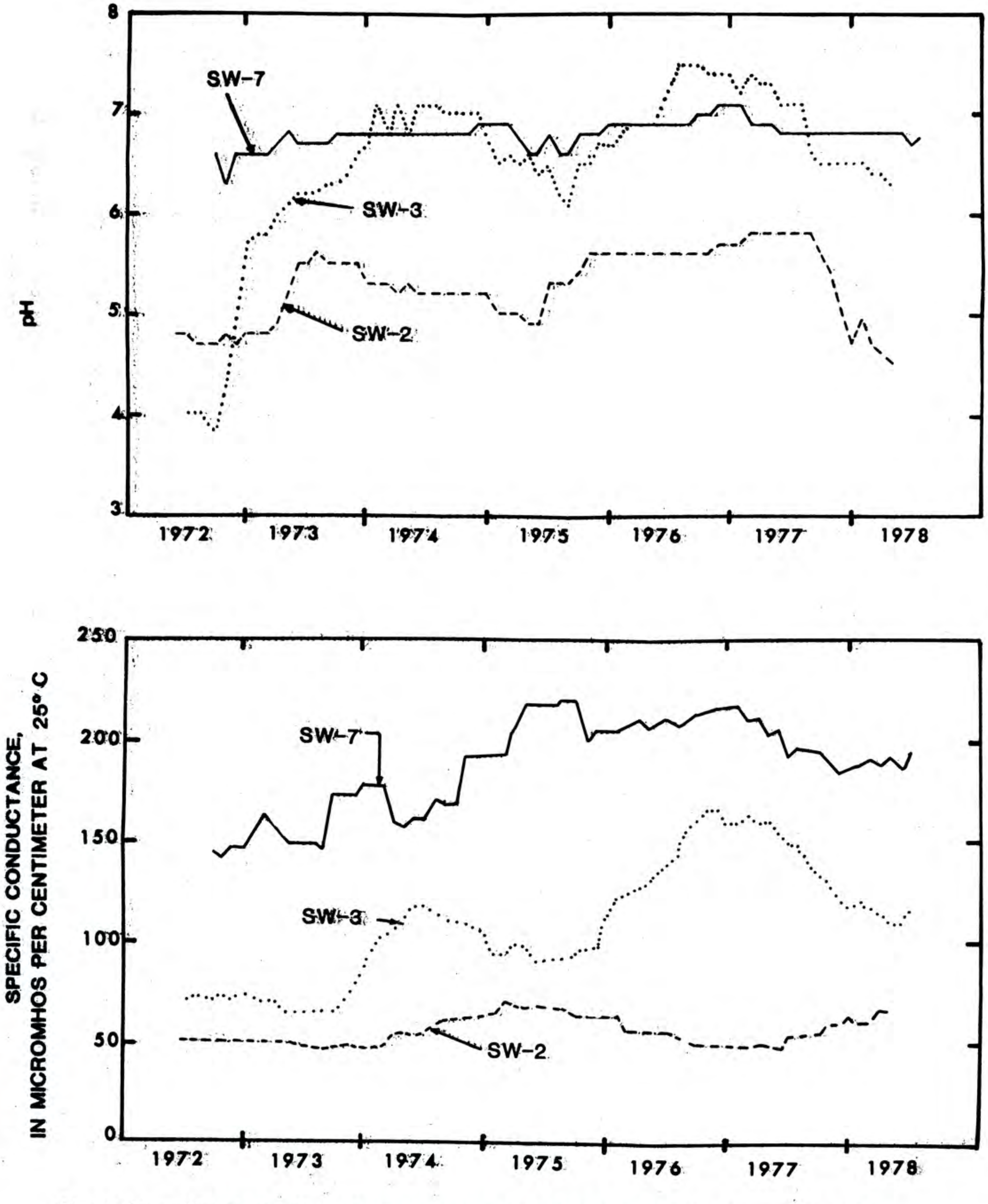


Figure 13.--Twelve-month moving averages of specific conductance and twelve-month moving medians of pH at three surface-water sampling sites, 1972-78.

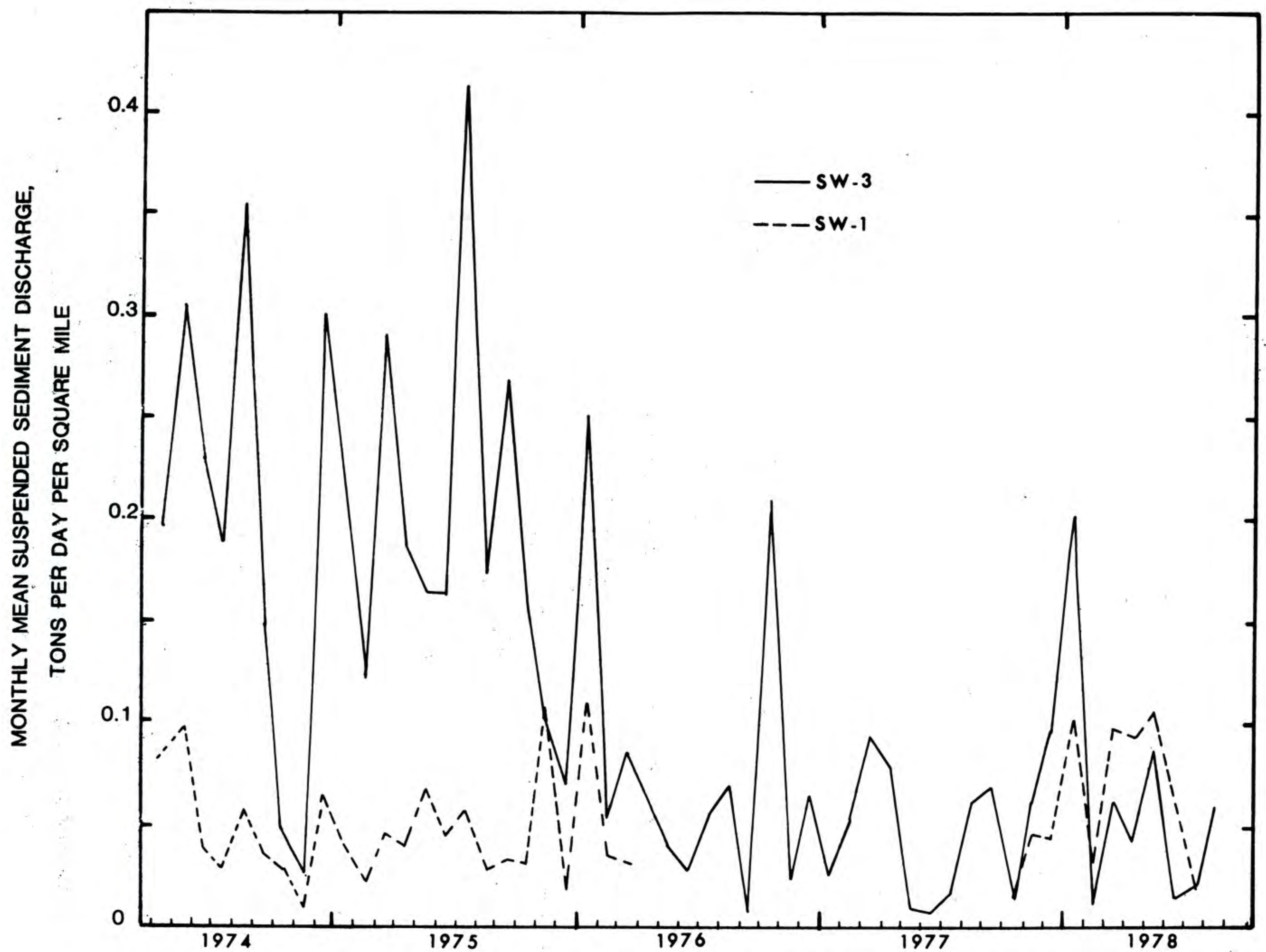


Figure 14.--Graphs comparing monthly mean suspended sediment discharge at sites SW-1 and SW-3, 1974-78.

This, together with the construction in late 1975 of a stormwater detention basin immediately upstream from the sampling site at SW-3, resulted in a decrease in suspended sediment discharge from 0.24 tons/d/mi^2 in 1974 and 0.20 tons/d/mi^2 in 1975 to 0.06 tons/d/mi^2 during 1977 and 1978. The mean sediment discharge at SW-1 was also 0.06 tons/d/mi^2, indicating that after completion of contruction at SW-3 the sediment discharge decreased to the preconstruction level.

The Winslow wastewater treatment plant is adjacent to Fourmile Branch between sampling sites SW-2 and SW-1. The treatment plant discharges effluent through infiltration ponds into the water-table aquifer, raising the concentration of various constituents in the surrounding water table. The water table is generally higher than the stream in the area of the treatment plant, and ground water discharges into Fourmile Branch, affecting the quality of the stream.

The results of analyses of effluent from the treatment plant are presented in table 7. Nitrate-nitrogen and total phosphorus were very high in the 1973 sample (26 and 14 mg/L, respectively), but nitrate-nitrogen levels decreased significantly after a change in the treatment process in October 1974 to achieve increased denitrification. The highest nitrate-nitrogen concentration in the later samples was 5.9 mg/L.

Table 7.--Analyses of effluent from the Winslow wastewater treatment plant, 1973-78

[Results in milligrams per liter, except as noted]

Parameter	1973	1976	1977	1978
Specific conductance[1]	440	428	-	418
Dissolved solids	-	260	329	-
Sodium	-	60	85	-
Chloride	-	41	57	36
Total nitrogen	27	6.4	5.6	9.1
Organic nitrogen	0.60	0.93	0.65	2.0
Ammonia (as N)	0.35	0.05	0	1.2
Nitrate (as N)	26	5.4	4.9	5.9
Total phosphorus	14	8.8	7.5	6.6

[1]μmhos/cm @ 25°C

Total phosphorus concentrations were also lower in the effluent samples taken after 1974, but did not show as significant a decrease as nitrate-nitrogen concentrations. From 1972 to 1978 total phosphorus in Fourmile Branch increased below the treatment plant and remained constant above the plant. (See fig. 15.) The nitrate-nitrogen concentration in Fourmile Branch from 1972 to 1974 was also higher below the treatment plant, but from 1975 to

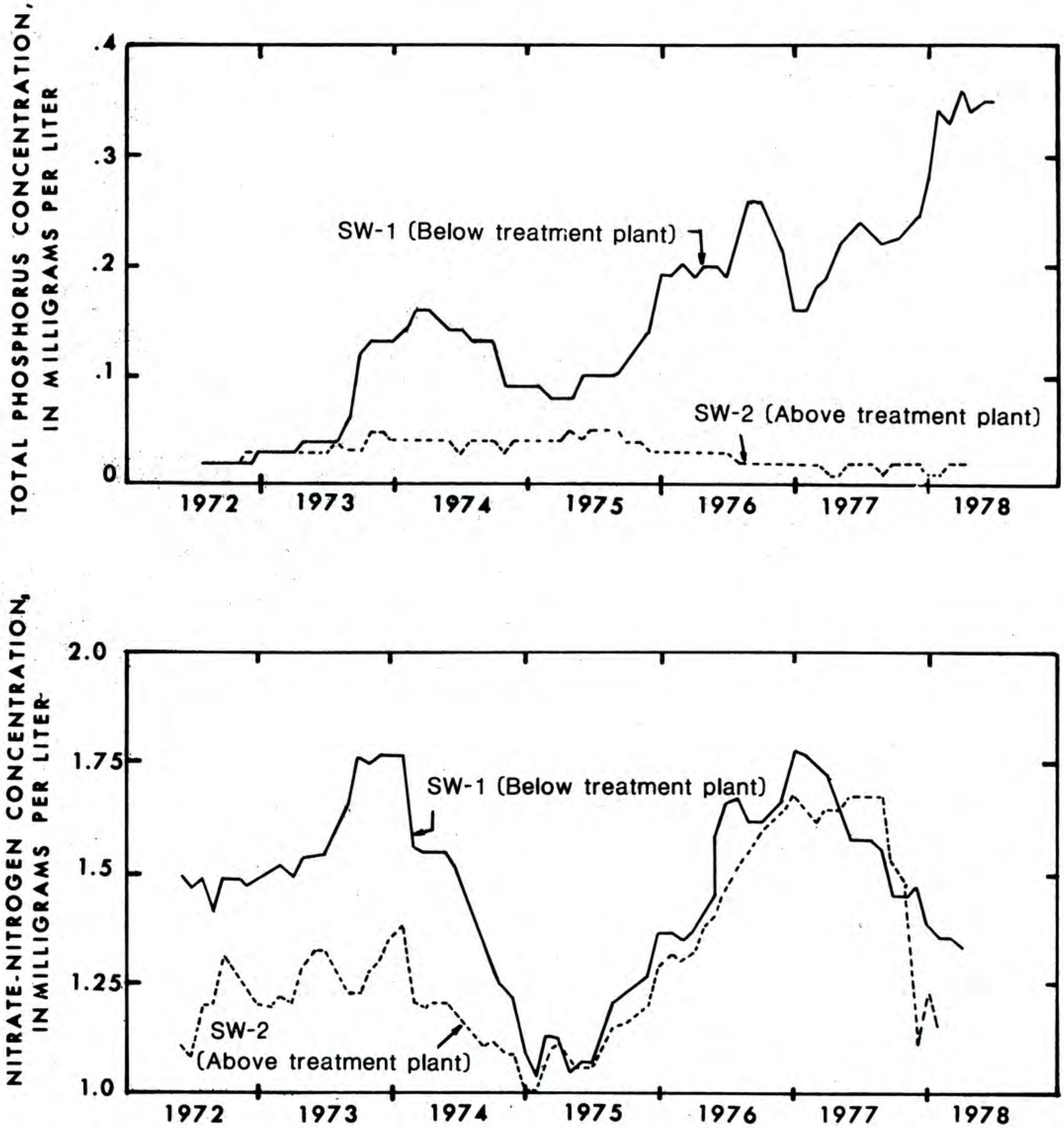


Figure 15.--Graphs comparing 12-month moving averages of total phosphorus and total nitrate-nitrogen concentrations at sites SW-2 and SW-1, upstream and downstream of the wastewater treatment plant, 1972-78.

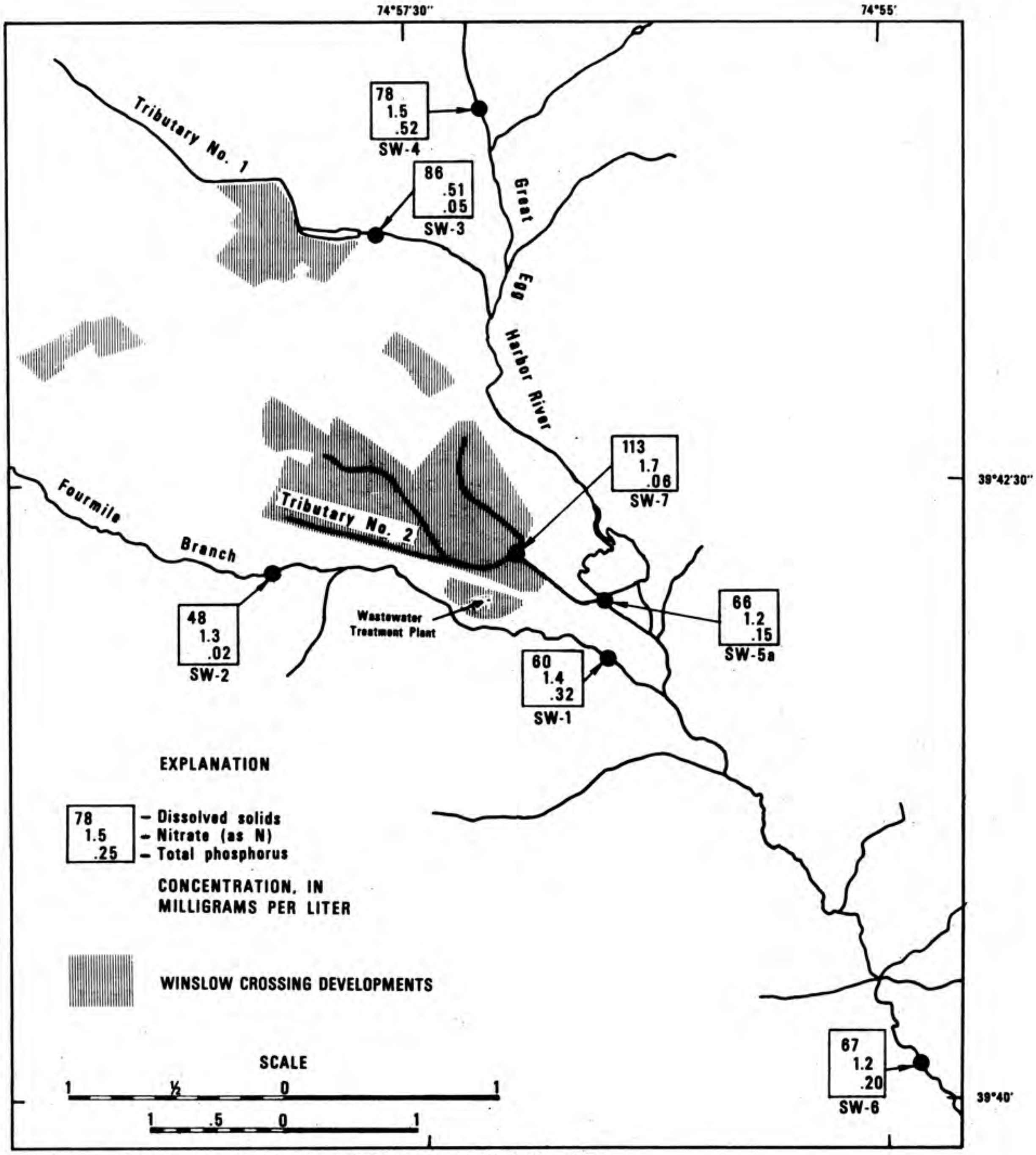
1978 the concentrations at SW-1 and SW-2 were similar. During 1975-78, inflow of treated effluent did not raise the stream nitrate-nitrogen level significantly. Malfunctioning septic systems in upper Fourmile Branch combined with below-normal rainfall through 1976 and 1977 probably caused the increased concentration of nitrate-nitrogen at both sites.

Increased phosphorus concentrations in Fourmile Branch below the treatment plant resulted from high concentrations in the plant effluent. The effluent infiltrated through sandy soils to the water-table aquifer, which discharges into the stream. The soil in the vicinity of the treatment plant is sand of the Lakehurst-Lakewood Association and contains little silt and clay to adsorb the phosphorus in the effluent. The high phosphorus concentration indicates that a significant percentage of the phosphorus in the effluent must be entering the stream. As a result, aquatic vegetation and algae have grown in the small ponds in the vicinity of the treatment plant and also in the channel of Fourmile Branch.

Development has affected the quality of water of the streams that drain Winslow Crossing. It has had less of an effect on Great Egg Harbor River, into which these streams flow. The headwaters of the Great Egg Harbor River are in the urbanized area of Berlin, N.J., and receive inputs from point and non-point sources (Delaware Valley Regional Planning Commission, 1977, p. 2:76). The quality of water below Winslow Crossing (SW-6) is slightly better than above Winslow Crossing (SW-4).

Figure 16 illustrates the mean concentrations of total phosphorus, nitrate-nitrogen, and dissolved solids for all sampling sites from 1976 through 1978, a period of little additional development. Site SW-4 had the highest mean concentrations of total phosphorus (0.52 mg/L), nitrate-nitrogen (1.5 mg/L), and dissolved solids (78 mg/L) of the three sites on the Great Egg Harbor River. Farther downstream, at site SW-5a, the water quality improved. The mean concentrations of total phosphorus (.15 mg/L), nitrate-nitrogen (1.2 mg/L), and dissolved solids (66 mg/L) were all lower than at SW-4. Also, site SW-5a is downstream from New Brooklyn Lake, which is highly eutrophic and acts as a sink for nutrients and suspended matter.

Site SW-6, the most downstream study site on the Great Egg Harbor River, had mean concentrations of dissolved solids (67 mg/L) and nitrate-nitrogen (1.2 mg/L). These figures were almost identical to those at the upstream site, SW-5a. The mean total phosphorus concentration, however, increased from 0.15 mg/L at SW-5a to 0.20 mg/L at SW-6. This was probably the result of the inflow of Fourmile Branch, which had a mean total phosphorus concentration of 0.32 mg/L during water years 1976 through 1978. In general, however, the concentrations of most parameters were lower at site SW-6, below Winslow Crossing, than at SW-4, above



Base from U.S. Geological Survey, Williamstown 1:24,000, 1966

Figure 16.—Mean concentrations of total phosphorus, nitrate-nitrogen, and dissolved solids at seven surface-water sampling sites after development, water years 1976-78.

the development. This only indicates, however, that the input of constituents to the Great Egg Harbor River is greater from sources above Winslow Crossing than from Winslow Crossing.

SUMMARY AND CONCLUSIONS

The impact of the development of Winslow Crossing on water resources was investigated from 1972 to 1978. Water levels were monitored in four wells with continuous recorders and sampled periodically for chemical analysis. Streamflow was monitored at four sites with continuous recorders. Stream samples for water-quality analysis were taken at the four streamflow sites and three additional sites. Three of the sites are on Great Egg Harbor River and four on tributaries to the river.

The development of Winslow Crossing proceeded more slowly than expected; originally 6,800 housing units were to be completed by 1978, but only 1,800 units were completed. Water-supply withdrawals from the Cohansey Sand also were below projected levels; the average water consumption during 1978 was under 0.5 Mgal/d. The projected withdrawal was 2.4 Mgal/d.

Withdrawals have had only a slight effect on levels in the Cohansey Sand. Levels did decrease in two wells, but these wells are several miles from the pumping center and the declines were probably caused by the below normal rainfall during 1976 and 1977.

Iron, manganese, pH, specific conductance, and nitrate-nitrogen concentrations varied in the observation wells sampled. Nitrate-nitrogen concentration varied from .03 to 5.8 mg/L, pH from 4.6 to 7.8, specific conductance from 30 to 127 μmhos/cm, total iron from 0 to 2,300 μg/L, and dissolved manganese from 10 to 750 μg/L. The maximum concentrations of iron and manganese exceeded Secondary Drinking Water Standards; all other constituents were within drinking-water standards. Dissolved solids and the major inorganic ions, such as sodium, potassium and chloride, were lower in samples from observation well W-3 than in those from observation well W-2 and production well 1, which are in developed areas. It is unclear whether urbanization or agriculture is responsible for the higher levels in the latter two wells.

The Winslow wastewater treatment plant had a significant effect on ground-water and surface-water quality in the vicinity of the plant. Nitrate-nitogen levels in excess of 10 mg/L were found in water from test wells surrounding the infiltration ponds of the treatment plant during 1973 and 1974. Ground water in the area discharges into nearby Fourmile Branch. Nitrate-nitrogen concentrations in Fourmile Branch were also higher below the treatment plant. The treatment process at the plant was modified in October 1974 to increase denitrification and this reduced the nitrate in the effluent, in the ground water, and in Fourmile Branch. Nitrate concentrations in Fourmile Branch since 1974 are the same upstream and downstream from the treatment plant.

Phosphorus levels, however, have remained high in the test wells at the plant and have increased since 1973 in Fourmile Branch below the plant. In 1978, the mean total phosphorus concentration in Fourmile Branch was 0.35 mg/L below and 0.02 mg/L above the treatment plant, compared with 0.03 mg/L downstream and 0.02 mg/L upstream during 1973.

Sodium chloride and sulfate were the most abundant ions in the water at five less urbanized sites. The two sites draining Winslow Crossing's developments had higher concentrations of bicarbonate, calcium, and magnesium. Site SW-7 was higher in calcium, magnesium, and bicarbonate. Site SW-3 was higher in calcium and bicarbonate.

Sites in urbanized areas had higher concentrations of the major inorganic ions, dissolved solids, specific conductance and pH than sites in less developed areas. Site SW-2 on upper Fourmile Branch, in the least urbanized area, had the lowest concentrations of most constituents.

Winslow Crossing's development has had only a slight effect on the quality of water in Great Egg Harbor River. Water quality is poorer at site SW-4 upstream from Winslow Crossing than downstream, because of point and non-point inputs in the headwaters of the river. Phosphorus concentrations were high at SW-4, averaging 0.53 mg/L. Water quality improves below New Brooklyn Lake at site SW-5a because the lake acts as a sink for nutrients and suspended matter. Farther downstream at site SW-6, the water quality was similar to that at SW-5a, except for a slightly higher level of phosphate from 1976 to 1978 because of the inflow from Fourmile Branch.

The suspended-sediment discharge from the basin of SW-3 was 0.24 tons/d/mi^2 in 1974 during construction. This decreased to 0.06 tons/d/mi^2 in 1977 and 1978 after construction and the installation of a stormwater detention basin. The latter sediment discharge is the preconstruction level, as indicated by data for site SW-1, where little or no construction occurred and the mean sediment discharge was 0.06 tons/d/mi^2.

Streamflow during the study was slightly higher than the long-term average for the area, as determined from analysis of records from 1928 to 1978 at Great Egg Harbor River at Folsom. Unit hydrograph analysis was used to evaluate changes in the rainfall-runoff relationship at site SW-3 as the drainage basin was developed. After development was completed, the peak discharge for a 60-minute unit hydrograph increased from approximately 150 ft^3/s to 270 ft^3/s. Installing a stormwater detention basin decreased the peak discharge to approximately 220 ft^3/s.

The impact of the development of Winslow Crossing on the water resources of the area has been relatively small owing in part, to the slow development. Continued monitoring and analysis will be necessary as development continues.

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