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WATER-QUALITY CONDITIONS IN SOUTHERN ROCKINGHAM COUNTY, NEW HAMPSHIRE

By William D. Silvey and Robert L. Wheeler

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WATER-QUALITY CONDITIONS IN SOUTHERN ROCKINGHAM COUNTY, NEW HAMPSHIRE

By

William D. Silvey[1] and Robert L. Wheeler[2]

ABSTRACT

Physical, chemical, and biological characteristics of water were measured at 26 surface-water sites, 17 ground-water sites, and in effluent from two sanitary landfills as part of planning for area-wide waste management in four watersheds within the Southern Rockingham Regional Planning District in Southern New Hampshire.

Specific-conductance data indicate that dissolved-minerals concentration in water at all but one of 26 surface-water-sampling sites is low and within maximum contaminant levels for drinking water established by the U.S. Environmental Protection Agency. Water at the 26 surface-water-sampling sites generally was enriched with nitrogen and phosphorus and contained at least some coliform bacteria, indicating contamination, probably from waste-disposal systems. PCB's (polychlorinated biphenyls) and pesticides were not present in the water, but small amounts of DDE, DDD, dieldrin, chlordane, and heptachlor were present in stream-bottom materials at 11 of the 26 sites, and PCB's were present at 7. Major constituents (silica, calcium, magnesium, sodium, potassium, bicarbonate, chloride, and sulfate) were present in relatively low concentrations; no major constituent was present in concentration that exceeded maximum contaminant levels of the U.S. Environmental Protection Agency.

At least one minor element (arsenic, boron, cadmium, chromium, cobalt, copper, fluoride, iron, lead, manganese, mercury, selenium, or zinc) was present in low concentrations at surface-water-sampling sites; only iron and manganese were present in concentrations that in some cases exceeded maximum contaminant levels of the U.S. Environmental Protection Agency. Chemical oxygen demand and total organic carbon values indicated the presence of oxygen-consuming components in the water, and the values were consistent with nutrient conditions in the water.

Ground-water samples were collected so as to be representative of ground water delivered to private homes and private and public institutions; accordingly, analyses of the water may not accurately reflect the quality of ground water as it occurs in aquifers in the study area. Specific conductance data show that major constituents are present in

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higher concentrations in samples from ground-water-sampling sites than in samples from surface-water-sampling sites, but that concentrations exceed recommended limits at only one site. Nitrogen and phosphorus were present in samples collected at most ground-water-sampling sites, but in concentrations much lower than those in samples from surface-water-sampling sites. Coliform bacteria were present at 5 of the 17 ground-water-sampling sites. Iron and manganese were present in most samples of water collected at ground-water-sampling sites; concentrations of iron exceeded recommended limits at eight sites, and manganese exceeded maximum contaminant levels at nine sites. PCB's and pesticides were not present in any samples collected at the ground-water-sampling sites.

Water-quality conditions in Beaver Brook at the Windham sampling site are strongly influenced by effluent discharged upstream at the Derry waste-water treatment plant. Concentrations of boron and fluoride were noticeably higher than at stream-sampling sites in other watersheds in the area, and concentrations of nutrients also were comparatively high.

Water-quality conditions in the Little River at the Westville sampling site probably are influenced by effluent entering upstream from individual onlot waste disposal in Plaistow. Nutrient concentrations at this site generally were higher than those in the Spicket and Powwow Rivers, but lower than concentrations at the Beaver Brook sampling site. Nutrient concentrations in the water of the Little River at Westville were higher than would be expected under conditions that support the heavy weed growth observed there during summer months.

General water-quality conditions in the Powwow River watershed are excellent compared to conditions in the Beaver, Spicket, and Little watersheds. Nutrients were present in all water samples collected in the Powwow watershed, but in relatively low concentrations compared to the Beaver, Spicket, and Little watersheds. Weed growth in some ponds and the apparent absence of plankton in the same ponds suggest that nutrients in bottom sediments are more readily available to rooted plants than to floating plants.

Water-quality conditions in the Spicket River watershed are influenced largely by variations in population concentrations. There is no pattern evident in the distribution of major dissolved minerals along the watershed; however, the general widespread occurrence of chloride in relatively high concentrations suggests influence of highway deicing chemicals, septic systems, or a combination of these. Nutrient concentrations along the Spicket River increased from less than 0.4 mg/L to about 0.8 mg/L between the Spicket River at Salem and the Spicket River near Salem, the most downstream sampling site, probably reflecting effluent contaminated by septic systems. There is also a nutrient pickup in Policy Brook between Canobie Lake outlet and Rockingham Boulevard, probably reflecting effluent contaminated by septic systems and Rockingham Park.

INTRODUCTION

An interim goal of Public Law 92-500, the Federal Water Pollution Control Act Amendments of 1972, is to achieve, by 1983, a level of water quality that would support aquatic life and recreation in and on the Nation's waters. Section 208 of the Act is to encourage development of area-wide waste-treatment-management plans to help achieve the goals of the Act. During 1975 and 1976, the Southern Rockingham Regional Planning District Commission of New Hampshire and the U.S. Geological Survey studied the quality of both surface and ground water within four basins comprising part of the Southern Rockingham Regional Planning District as part of the plan for area-wide waste management under the provisions of Section 208.

OBJECTIVES AND APPROACH

The main objective of this study is to describe physical, chemical, and biological characteristics of surface waters as they drain through the four watersheds of the study area (fig. 1) as a means to show relative water-quality conditions and how water-quality conditions vary in each watershed. Analytical determinations (table 1) were selected so as to present a broad picture of water-quality conditions during the study period. Sampling periods were selected to show changes of biological activity which occur seasonally in surface waters. Thus, the sampling periods included July, September, and November, 1975, and April, June, July, September, and November, 1976.

Samples of ground water were collected so as to be representative of water delivered to a range of consumers, such as in single family dwellings as well as public and private institutions. Accordingly, samples were collected at outlets used for consumption, such as taps at kitchen sinks or drinking fountains. In all, 17 sites were selected where water could be sampled from systems delivering ground water for human consumption. In addition, one sample of the effluent was collected from each of two sanitary landfills, an active landfill adjacent to Providence Hill Brook in Salem (fig. 3, site 18) and an inactive landfill in Atkinson (fig. 3, site 19).

DESCRIPTION OF STUDY AREA

The study area within the Southern Rockingham Regional Planning District includes four watersheds in the Towns of Windham, Salem, Atkinson, Plaistow, Newton, Hampstead, and Kingston (fig. 1). These watersheds, including parts of the basins outside of the study area, have a combined drainage area of about 158 square miles. Beaver Brook, in Windham, which forms the western boundary of the area and drains southward into the Merrimack River in Massachusetts, has a drainage area of 49 square miles. Adjacent to the Beaver Brook watershed on the east is the Spicket River watershed in Windham, Salem, Atkinson, and Hampstead. Streams of this watershed also flow southward and have a drainage area of 53 square miles. The Little River watershed, in Hampstead, Atkinson, Newton, and Plaistow east of the Spicket River watershed, drains southward

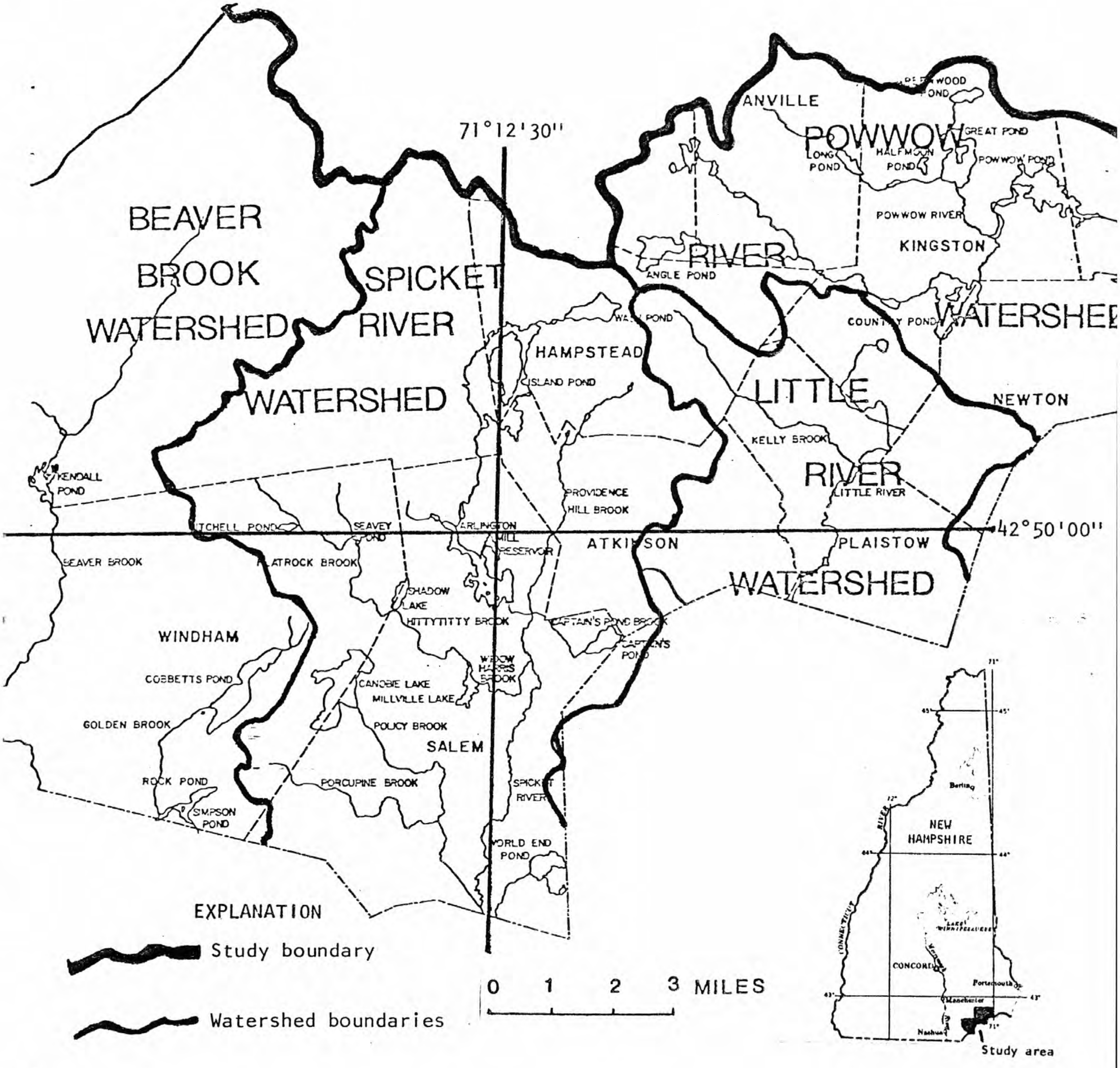

Figure 1. Major watersheds within the study area of the Southern Rockingham Regional Planning District, New Hampshire

Table 1.--Water-quality determinations performed during this study

Field measurements	Analytical determinations		
Physical properties (as shown)	Major constituents (mg/L)	Minor elements (µg/L)	Nutrients (mg/L)
Dissolved oxygen (mg/L)	Silica	Arsenic	Nitrate as N
pH (units)	Calcium	Cadmium	Nitrite as N
Specific conductance (µmho/cm at 25°C)	Magnesium	Chromium	Ammonia as N
Temperature (°C)	Sodium	Cobalt	Total organic nitrogen as N
Discharge (ft^3/s)	Potassium	Copper	Orthophosphate as P
	Bicarbonate	Iron	Total phosphorus as P
	Chloride	Lead	
	Sulfate	Manganese	
		Zinc	
		Selenium	
		Mercury	
		Flouride	
		Boron	
Bacteria (colonies per 100 mL)	Periphyton	Pesticides and Polychlorinated Biphenyls (µg/L)	
Total coliform bacteria	Biomass	Aldrin	Heptachlor epoxide
Fecal coliform bacteria	Chlorophyll	Chlordane	Lindane
Fecal streptococcal bacteria		DDT	Methoxychlor
	Organic chemicals	DDE	Toxaphene
		Dieldrin	Polychlorinated biphenyls
	Chemical oxygen demand	Endrin	
	Total organic carbon	Heptachlor	

and has a drainage area of 25 square miles. North of the Little River watershed, in Kingston, the Powwow River watershed drains eastward and has a drainage area of 31 square miles.

The area consists of rolling hills of low relief which are mostly forested. The area is underlain by crystalline bedrock that is veneered with unconsolidated deposits of till and stratified glacial deposits of varying thickness.

During the recent past, the area has undergone rapid urban and sub-urban development. Most of this development has occurred along the Spicket River and near the various ponds and lakes within that watershed. Population is increasing in the other three watersheds.

FIELD METHODS

Field and analytical methods used during this study are those utilized by the U.S. Geological Survey throughout the United States and are described in "Techniques of Water-Resources Investigations of the U.S. Geological Survey," book 5, chapters A1, A3, and A4 (Brown and others, 1970; Goerlitz and Brown, 1972; Greeson and others, 1977).

Field determinations were made for dissolved oxygen, pH (hydrogen ion activity), specific conductance, temperature, and stream discharge. Water samples collected for bacterial analyses were incubated in the field, and total coliform bacteria, fecal coliform bacteria, and fecal streptococcal bacteria counts were made in the field after incubation.

ANALYTICAL METHODS

Laboratory determinations included those for major constituents, minor elements, nutrients, chemical oxygen demand, total organic carbon, periphyton, pesticides, and PCB's (polychlorinated biphenyls). They were made in accordance with the general analytical techniques ("Techniques of Water-Resources Investigations of the U.S. Geological Survey", book 5, chapters A1, A3, and A4), which are those that have given a high degree of accuracy and reproducibility.

The field measurements and analytical determinations that were made during this study are listed in table 1. Twenty-six surface-water and 17 ground-water sites selected for sampling are shown in figures 2 and 3 and are listed in tables 2 and 3.

SURFACE-WATER QUALITY

Physical Conditions

Oxygen is one of the most significant of all chemical substances in natural surface waters because it regulates metabolic processes and, thus, is an indicator of biologic conditions in the stream or lake. Ellis and others (1946) believe that a concentration of 3.0 mg/L (milligrams per liter) or less of dissolved oxygen is hazardous or lethal to most aquatic organisms. Further, Doudoroff and Shumway (1970) believe that in order to maintain a varied fish fauna, dissolved oxygen concentrations should be at least 4.0 mg/L at all times.

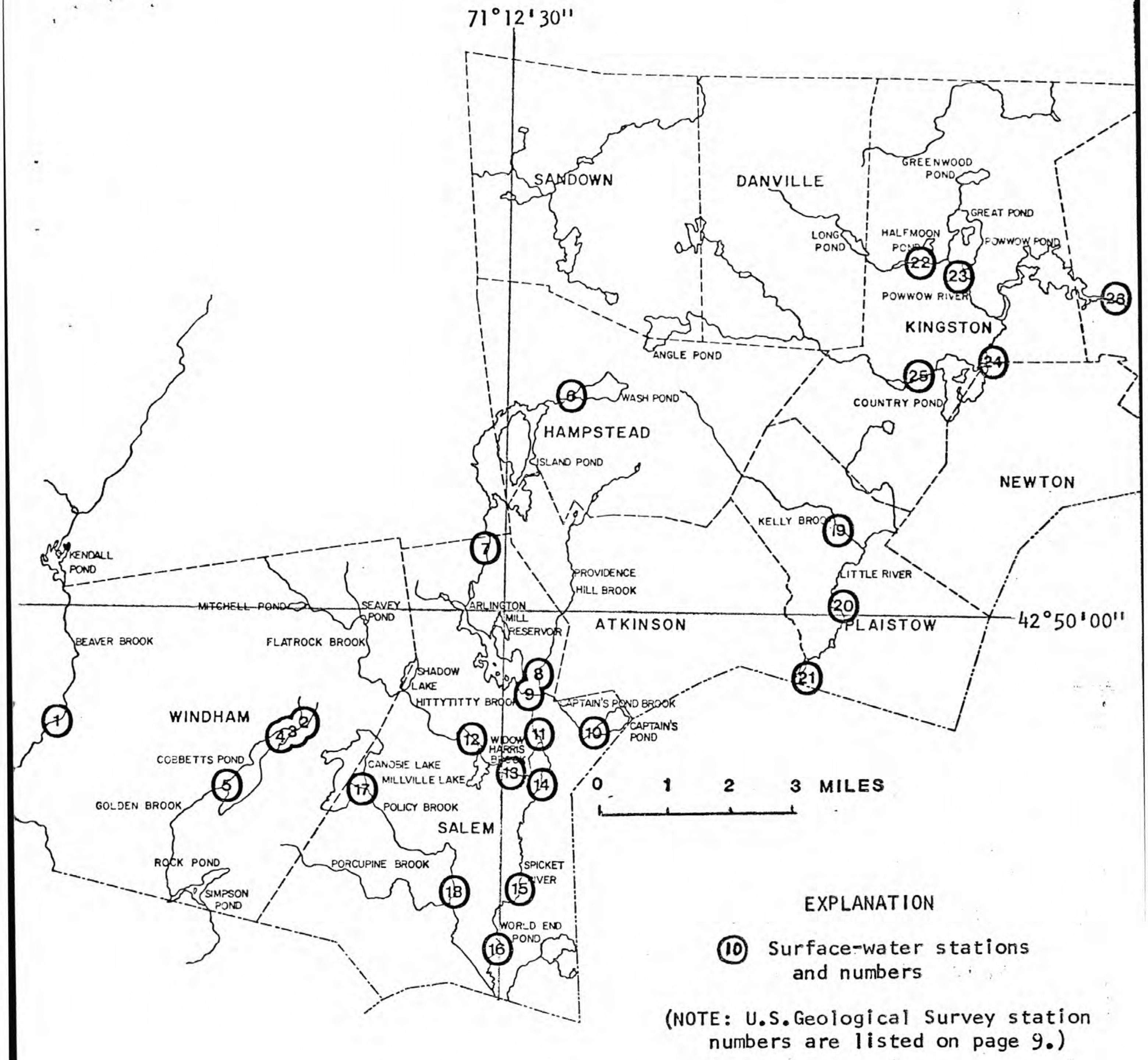

Figure 2.--Location of surface-water-sampling sites within the Southern Rockingham Regional Planning District, New Hampshire

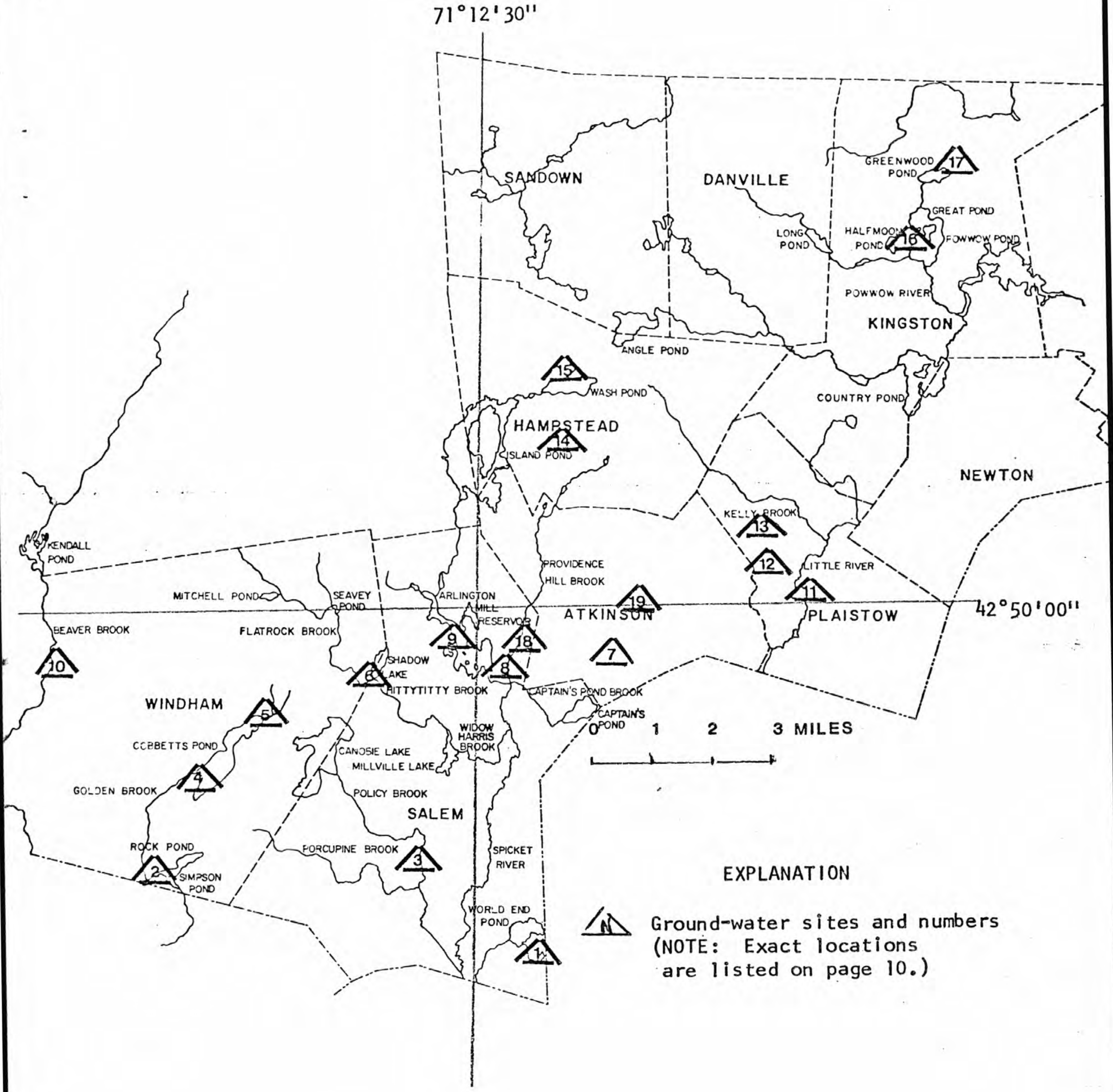

Figure 3.--Location of ground-water-sampling sites within the Southern Rockingham Regional Planning District, New Hampshire

Table 2.--Surface-water-sampling sites within the Southern Rockingham Regional Planning District, New Hampshire

U.S. Geological Survey Identification No.	Map No.	Station name
01096585	1	Beaver Brook at West Windham
01096587	2	Brook near Duncan Beach, Cobbetts Pond, Windham
01096588	3	Brook at Duncan Beach, Cobbetts Pond, Windham
01096589	4	Duncan Beach at Cobbetts Pond, Windham
01096590	5	Golden Brook at Windham
01100502	6	Wash Pond Outlet at Hampstead
01100505	7	Spicket River at North Salem
01100506	8	Providence Hill Brook, North Main St., Salem
01100507	9	Spicket River near Salem
01100515	10	Captain Pond Brook near Salem
01100520	11	Spicket River above Widow Harris Brook at Salem
01100530	12	Hittytity Brook near Salem
01100535	13	Widow Harris Brook at Salem
01100537	14	Spicket River at Route 97 bridge, Salem
01100538	15	Spicket River at Lawrence Hill, Salem
01100540	16	Spicket River at Salem
01100545	17	Policy Brook near Salem
01100550	18	Policy Brook at Rockingham Boulevard, Salem
01100675	19	Kelly Brook at Route 125, Plaistow
01100680	20	Little River below Process Engineering, Plaistow
01100684	21	Little River at Westville
01100825	22	Powwow River near Kingston
01100827	23	Powwow River at outlet of Great Pond, Kingston
01100830	24	Country Pond Outlet near Kingston
01100833	25	Unnamed stream near South Kingston
01100835	26	Powwow River near East Kingston

Table 3.--Ground-water-sampling sites within the Southern Rockingham Regional Planning District, New Hampshire

Site location	Map No.	Site name	Type well
424506071112101	1	Budron's Apartments, Pond Street, Salem	Drilled
424609071183601	2	Rock Pond, Windham	Do.
424615071133701	3	Rockingham Park, Salem	Do.
424733071173301	4	Cobbetts Pond Outlet, Windham	Dug
424822071163301	5	Duncan Beach, Windham	Drilled
424849071143001	6	Shadow Lake Trailer Park, Route 111, Salem	Do.
424914071095001	7	Bluebird Lane, Atkinson	Do.
424915071114901	8	Apartment complex, North Main St., Salem	Do.
424927071125401	9	Arlington Park, North Salem	Dug
424937071203701	10	Beaver Brook, Sirod Road, Windham	Drilled
425015071055601	11	Process Engineering, Plaistow	Do.
425037071065401	12	Timberlane School, Plaistow	Do.
425058071065001	13	Rolling Hills Development, Plaistow	Do.
425226071105401	14	Hampstead Gym, Route 121, Hampstead	Dug
425316071105801	15	North of Wash Pond, Hampstead	Do.
425517071041001	16	First Street, west of Great Pond, Kingston	Do.
425626071033001	17	Sandborn Regional High School, Kingston	Do.
424938071113201	18	Salem sanitary landfill site, Salem	Leachate
424958071092201	19	Atkinston sanitary landfill site, Atkinson	Do.

Dissolved-oxygen determinations were made 6 times at 16 surface-water sites and at least once at 10 other surface-water sites, most dissolved-oxygen concentrations observed were greater than 5.0 mg/L. Because they indicate when and where poor biologic conditions in stream waters occurred, the locations, dates, and times of dissolved-oxygen observations less than 5.0 mg/L are shown below:

Location, date and time	Concentration (mg/L)
Unnamed brook, tributary to Cobbetts Pond at Duncan's Beach (site 2), 6-21-76, 1245-----------------	3.4
Spicket River at Wash Pond outlet (site 6), 7-23-75, 1115-	4.0
Providence Hill Brook at Wilson's Gravel Pits (site 8), 7-20-76, 1200----------------------------------	3.2
Widow Harris Brook at Salem (site 13), 6-23-76, 0930------	2.3
Policy Brook at Rockingham Boulevard (site 18), 7-20-76, 1515--	2.4

Note that the dissolved-oxygen data are based on samples collected during daylight hours, when aquatic plants release oxygen to the water (aquatic plants consume oxygen during nighttime hours). Accordingly, the relatively low values of dissolved-oxygen concentrations in stream water at some sites during the period of the day when plants are adding oxygen to the water indicates the presence of decaying organic matter that is consuming oxygen at the same time. The areas above (upstream from) the sites listed above are heavily developed and are served partly by individual onsite sewage disposal systems, which are a potential source for this organic matter.

The pH of waters is a measure of their acidity--waters with a pH value lower than 7 are on the acid side, and waters with a pH value higher than 7 are on the basic side. The pH of potable water is not significant with respect to causing diseases in human beings, but, according to the U.S. Environmental Protection Agency (1975), waters with pH values of 6.0 and no more than 9.0 is equal to "high level protection" of fresh-water aquatic life and wildlife. During this study, pH was measured at 16 streamflow sampling sites during each of the 6 sampling periods; pH values ranged from 3.5 to 7.8; the pH value of 3.5 was measured at the Spicket River Highway 28 site. A pH as low as 3.5 rarely occurs in natural waters, and the pH value of 3.5 in the Spicket River at Highway 28 probably resulted from commercial and light industrial activities upstream.

Specific conductance is a measure of a water's capacity to conduct electrical current. Waters having high concentrations of dissolved minerals have a higher capacity to conduct electrical current than waters having low concentrations of dissolved minerals. Values range from near zero for distilled or demineralized water to approximately 50,000 for seawater. Specific-conductance measurements were made at all 26 stream-sampling sites during this study to provide an index of the total quantity of dissolved-mineral constituents and the variability of dissolved-mineral matter from time to time and from place to place throughout the study area.

The specific-conductance data (fig. 4) indicate that the total quantity of dissolved-mineral constituents in samples at all stream-sampling sites is low and within maximum contaminant levels established by the EPA (U.S. Environmental Protection Agency, 1975) and the PHS (U.S. Public Health Service, 1962).

A relative index of specific conductance is shown in table 4. The index was derived by dividing the average specific-conductance values obtained at all stream-sampling sites by the lowest average specific-conductance value, which was 76 micromhos at site 7 on the upper Spicket River. Table 4, for example, shows that Beaver Brook (site 1) contains 3.3 times as much dissolved constituents as the upper Spicket River (site 7).

In general, the values of specific conductance fluctuate with streamflow; the highest values of specific conductance (and therefore the highest concentrations of dissolved minerals) occur when the volume of water flowing in the streams is lowest. Conversely, the lowest values of specific conductance (and therefore the lowest concentrations of dissolved minerals) generally occur when the volume of water flowing in the streams is highest.

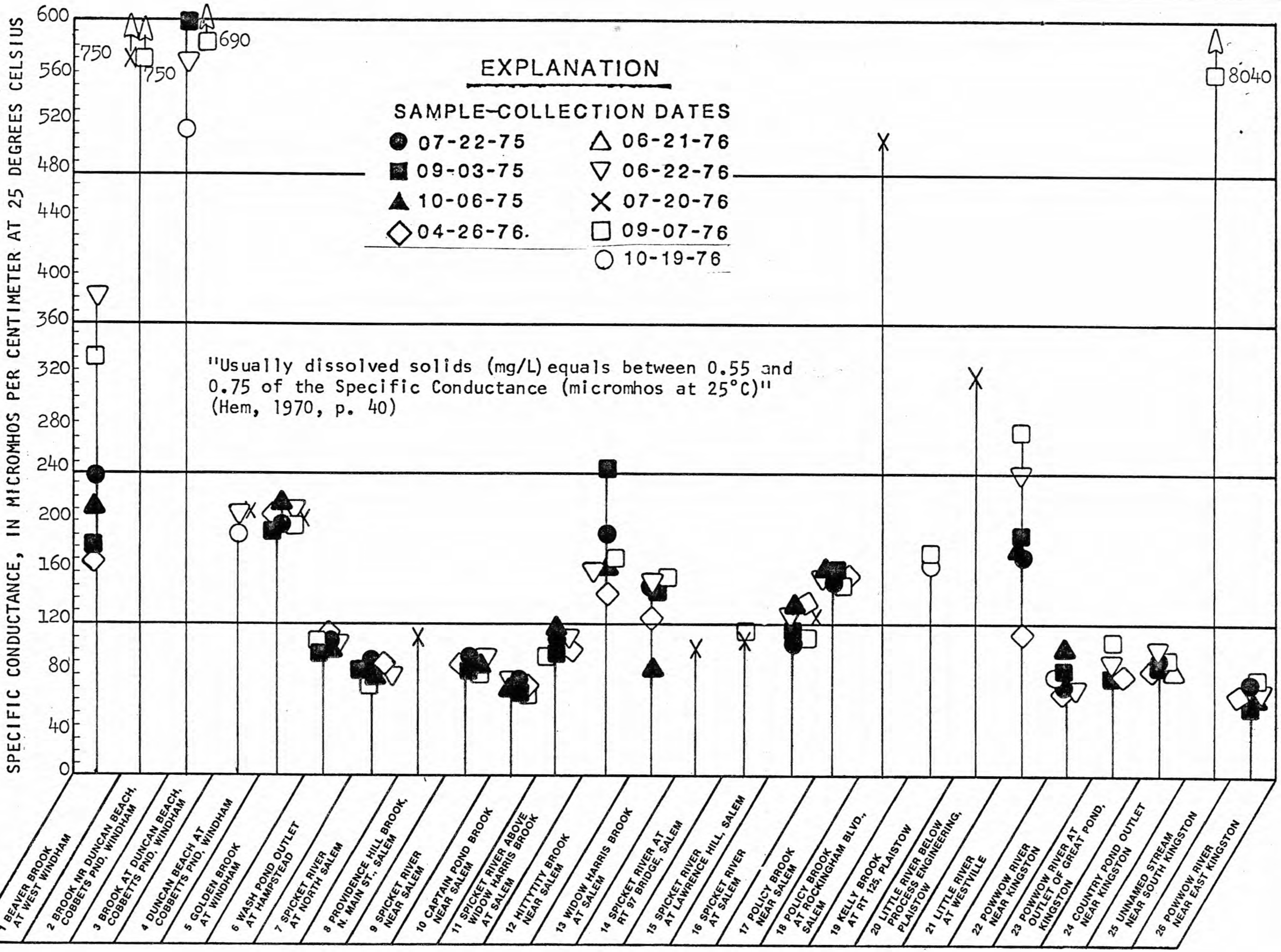

Figure 4.--Specific conductance at surface-water-sampling sites

The highest values of specific conductance were measured in a single measurement on an unnamed tributary to Country Pond (site 25, fig. 4) and in measurements on Policy Brook at Rockingham Boulevard (site 18, fig. 4), and on an unnamed tributary to Cobbetts Pond (sites 2 and 3, fig. 4), where runoff from an industrial site, Rockingham Race Track, and Interstate Highway 93, respectively, enters streams of very low flow (1 cubic foot per second or less).

Table 4.--An index of relative specific conductance of surface waters in the Southern Rockingham Regional Planning District, New Hampshire

Station name	Map No.	Relative index of specific conductance
Beaver Brook at West Windham	1	3.3
Brook near Duncan Beach, Cobbetts Pond, Windham	2	8.5
Brook at Duncan Beach, Cobbetts Pond, Windham	3	8.5
Duncan Beach at Cobbetts Pond, Windham	4	2.6
Golden Brook at Windham	5	2.7
Wash Pond Outlet at Hampstead	6	1.4
Spicket River at North Salem	7	1.1
Providence Hill Brook, North Main St., Salem	8	2.5
Spicket River near Salem	9	1.1
Captain Pond Brook near Salem	10	1.0
Spicket River above Widow Harris Brook at Salem	11	1.4
Hittytitty Brook near Salem	12	2.4
Widow Harris Brook at Salem	13	1.7
Spicket River at Route 97 bridge, Salem	14	1.5
Spicket River at Lawrence Hill, Salem	15	1.6
Spicket River at Salem	16	1.6
Policy Brook near Salem	17	2.0
Policy Brook at Rockingham Boulevard, Salem	18	6.7
Kelly Brook at Route 125, Plaistow	19	*
Little River below Process Engineering, Plaistow	20	4.2
Little River at Westville	21	2.2
Powwow River near Kingston	22	1.0
Powwow River at outlet of Great Pond, Kingston	23	1.1
Country Pond Outlet near Kingston	24	1.1
Unnamed stream near South Kingston	25	**
Powwow River near East Kingston	26	1.1

*Insufficient data. **One sample, conductance 8,000

Stream-water temperature fluctuates seasonally with air temperature. The lowest stream temperatures observed were generally 9 to 10°C during April and the highest between 20 and 25°C during July in 1975 and 1976. There is no indication that man's activity influences temperature of stream water.

Instantaneous measurements of streamflow were made during all of the water-sampling periods at all sites. The highest and lowest discharges measured at the most downstream sampling site in each of the four watersheds are shown below:

Location, site number, and date	Discharge (cubic feet per second)	(gallons per minute)
Beaver Brook at West Windham (site 1),		
4-26-76	65	29,000
9- 8-76	1.5	670
Spicket River at Salem (site 16)		
4-26-76	59	26,000
9- 8-76	11	4,900
Little River at Westville (site 21)		
4-27-76	68	30,000
9- 9-76	5.5	2,500
Powwow River near East Kingston (site 26)		
4-27-76	46	21,000
9- 9-76	1.5	670

As would be expected, April showed the highest flows due to snow runoff and September showed lowest flows, reflecting streamflow mostly due to ground-water contributions.

Bacteria

The presence of coliform group of bacteria are a direct indication of the sanitary condition of a stream, a reach of a stream, a pond or a lake. Members of the coliform group of bacteria may come from soil, water, and vegetation as well as from feces of warm blooded animals. A water sample that contains an appreciable coliform count is considered to also contain disease-producing organisms, unless evidence to the contrary is available. Fecal coliforms are that fraction of the coliform group that is present in the intestinal tract or feces of warm blooded animals, and the presence of fecal coliforms may indicate recent and possibly dangerous contamination. Fecal streptococci normally inhabit the intestines of man and animals, and the presence of fecal streptococci verify fecal pollution. The kinds of disease-producing organisms, if any, that may be present when high numbers of coliforms are present cannot be determined without further biological analyses. However, the presence of high numbers of total coliform bacteria and particularly the mere presence of fecal coliform and fecal streptococci bacteria in water strongly indicates that the water may be unsafe for either drinking or bathing.

During this study, approximately 288 determinations were made for the presence of total coliform bacteria, fecal coliform bacteria, and fecal streptococcal bacteria at the 16 primary surface-water sites and at 9 other miscellaneous surface-water sites as shown in figures 5, 6, and 7. The data obtained indicate that all of the surface-water sites sampled contained these three groups of bacteria. The numbers of colonies of these bacteria present at any instant of time varies widely, but at the time samples were collected, total coliforms ranged from none to 90,000, fecal coliforms from none to 11,000, and fecal streptococci coliforms from none to 9,000. Total coliform bacterial counts exceeded 50 colonies per 100 milliliters, the upper limit for Class A waters in New Hampshire, in about 90 percent of the samples collected: Total coliform counts exceeded 240 per 100 milliliters, the upper limit for Class B waters, in about 25 percent of the samples collected and exceeded this value in at least one sample from every site except Golden Brook at Windham.

The significance of the data on coliforms is not so much in the numbers of colonies present at any one time, or that the numbers vary widely from place to place and from time to time, but that their widespread occurrence indicates widespread contamination from animal wastes. The most likely source is from individual on-lot sewage-disposal systems, which are prevalent in most of the study area.

Major Constituents

Constituents that comprise the major proportion of the dissolved minerals content of water include silica, calcium, magnesium, sodium, potassium, bicarbonate, chloride, and sulfate. They are ordinarily present in all natural waters in varying concentrations. Calcium, sodium, bicarbonate, and chloride were present in the greatest concentrations; these ranged from 4.0-68 mg/L, 5.5-40 mg/L, 6-41 mg/L, and 6.5-110 mg/L, respectively. These concentrations are well below the maximum contaminant levels of the PHS (1962) and the EPA (1975), as are concentrations of the other major constituents, and suggest that, with respect to major constituents, the mineral quality of water is little affected by man. The highest concentrations of sodium and chloride occur in Beaver, Golden, Hittytitty, Widow Harris, and Policy Brooks and Little River and could result from effects of highway deicing chemicals, on-lot sewage disposal, or a combination of these.

Minor Elements

Among the minor elements, determinations in this study were made for arsenic, boron, cadmium, chromium, cobalt, copper, fluoride, iron, lead, manganese, mercury, selenium, and zinc (table 1). Not all of these elements were present in water samples collected at each stream-sampling site; however, each element listed, except mercury, was present at one site or more at one time or another during the study. Concentrations of these elements were low, well below the maximum contaminant levels of the EPA (1975), with the exception of iron and manganese. Iron and manganese were present in all surface-water samples collected (figs. 8 and 9) and were present in amounts exceeding the EPA maximum contaminant levels at some stream-sampling sites. However, in the concentrations present, iron

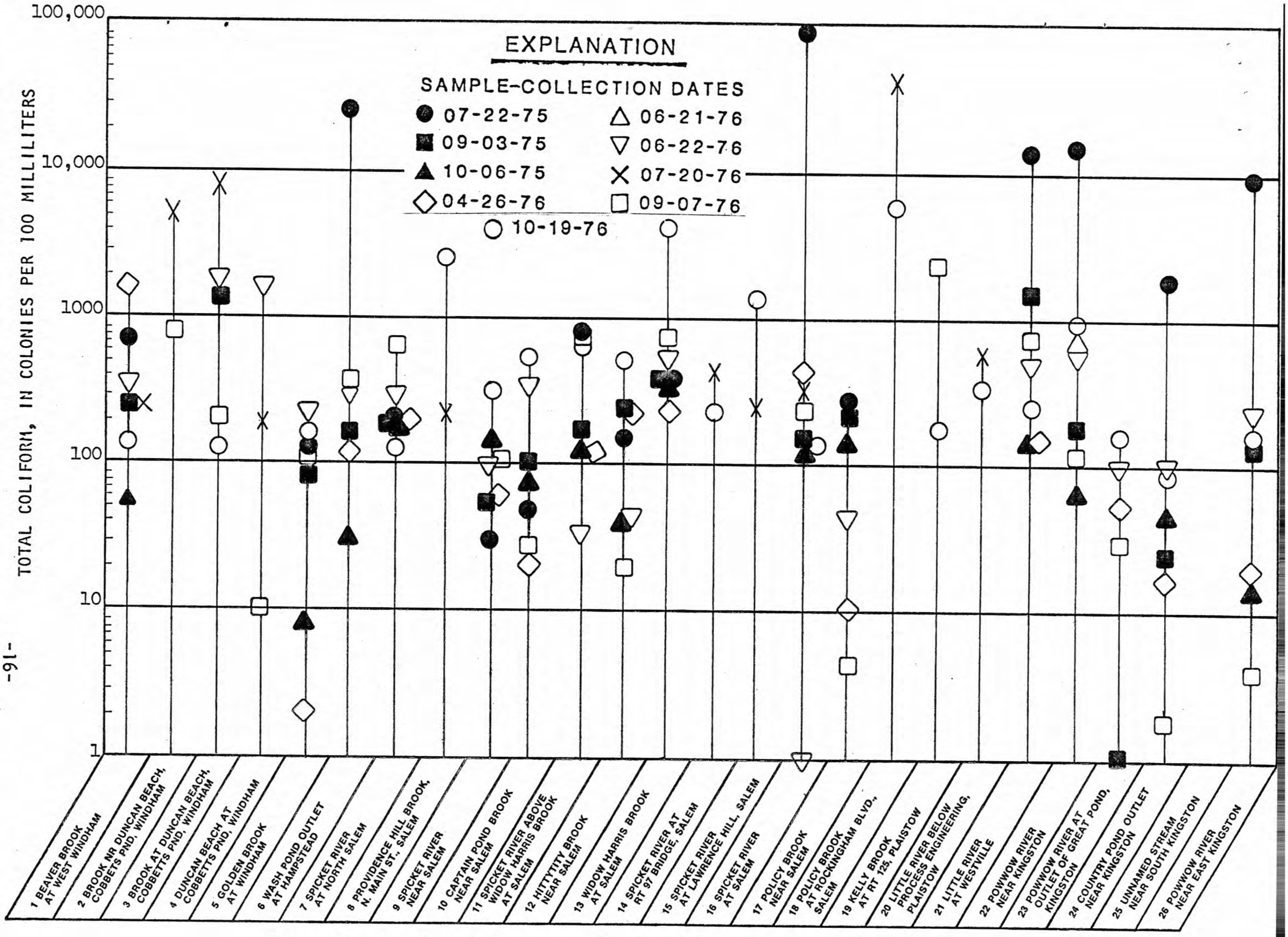

Figure 5.--Total coliform bacteria at surface-water-sampling sites

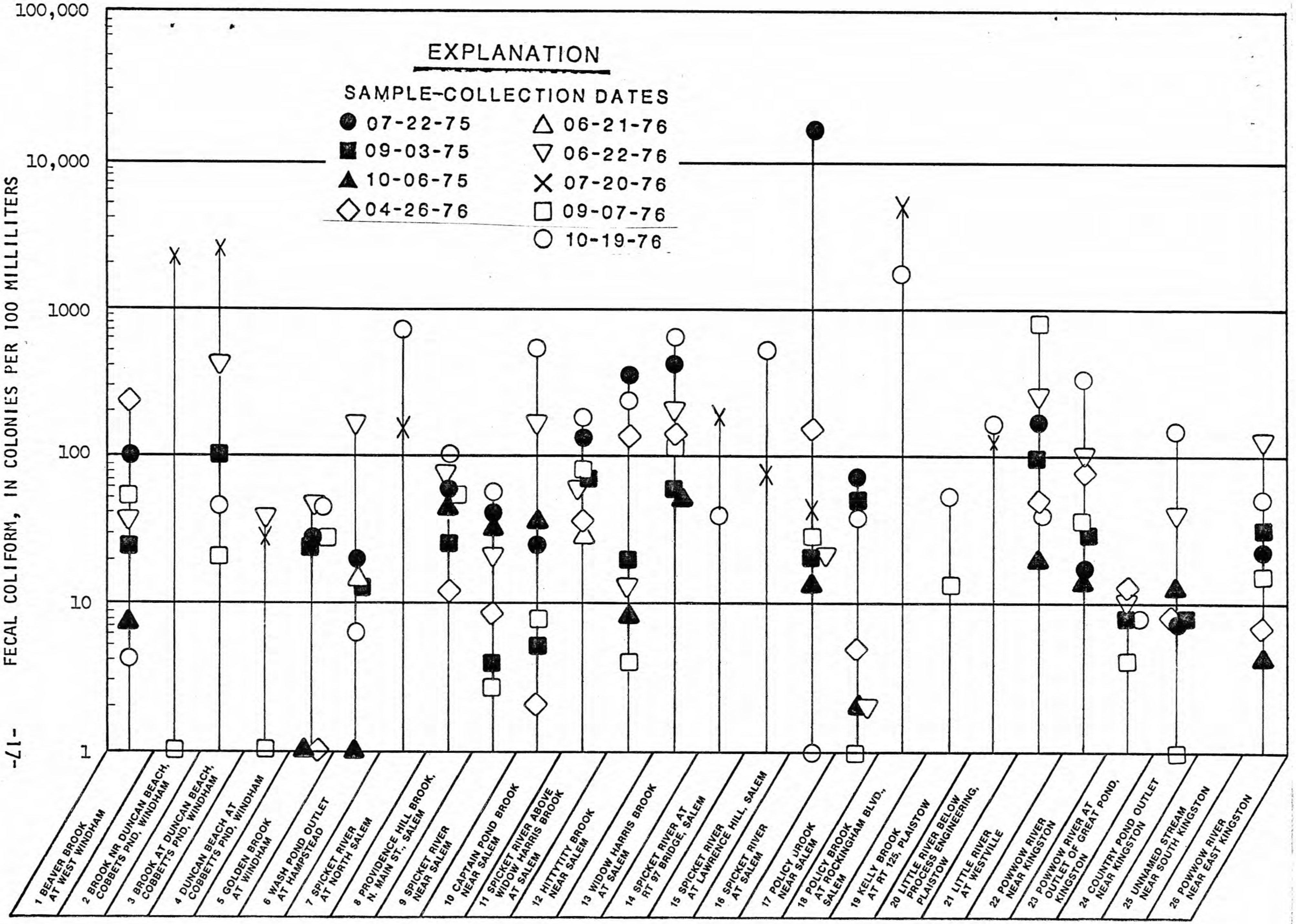

Figure 6.--Fecal coliform bacteria at surface-water-sampling sites

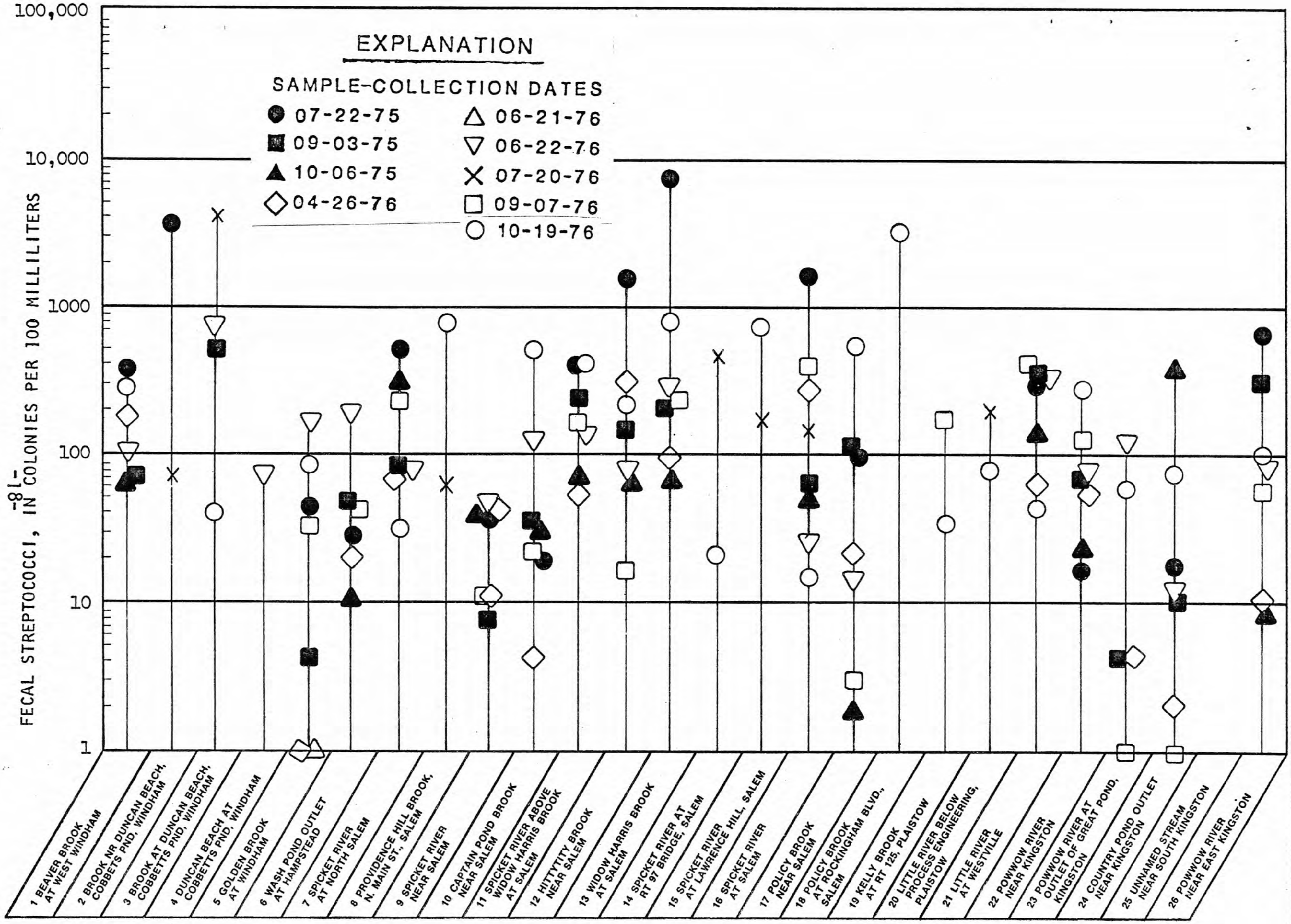

Figure 7.--Fecal streptococci bacteria at surface-water-sampling sites

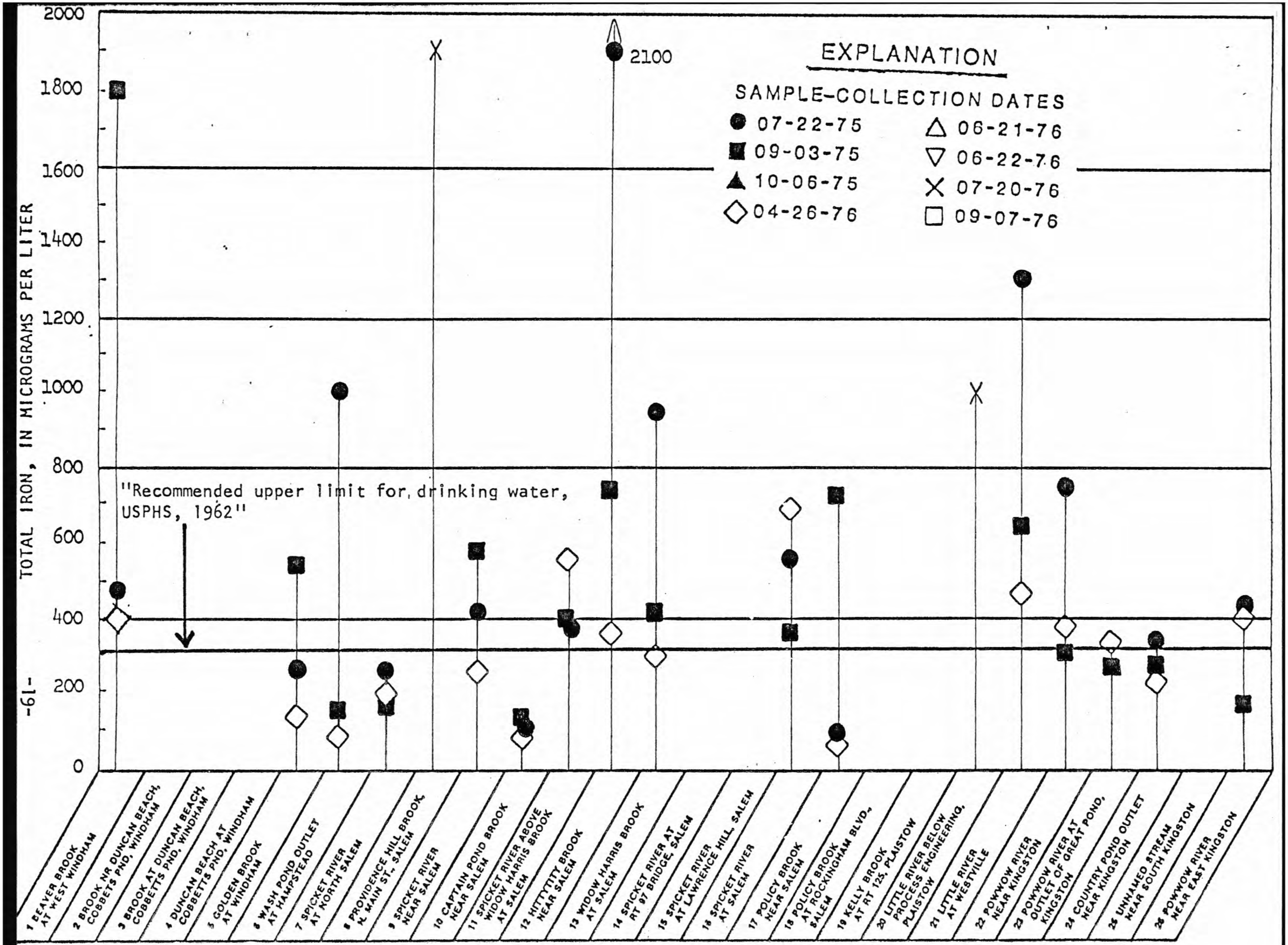

Figure 8.--Total iron concentrations in water samples at surface-water-sampling sites

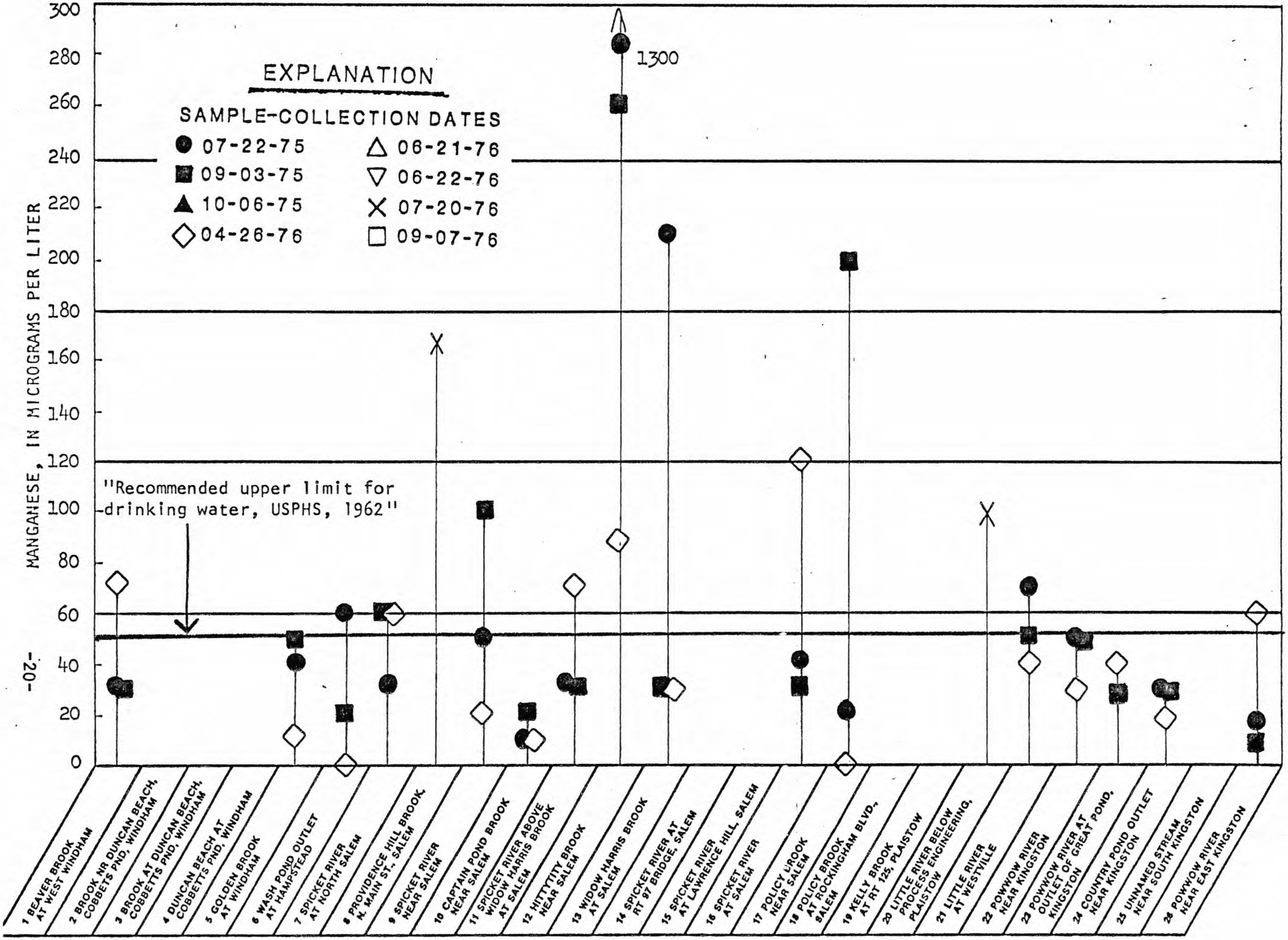

Figure 9.--Total manganese concentrations in water samples at surface-water-sampling sites

and manganese are more of a nuisance rather than a health hazard, having the potential to impart a taste to the water and to discolor clothes and utensils. The presence of elements, such as arsenic, boron, cadmium, chromium, cobalt, copper, lead, mercury, selenium, and zinc, even in the small concentrations detected, strongly suggests influences of man's activities on water quality.

Nutrients

Nitrogen and Phosphorus

Nitrogen and phosphorus are two nutrients that are essential to the growth of living organisms. Nitrate is usually the most prevalent form of nitrogen in water and can be derived through oxidation of atmospheric nitrogen by bacteria (nitrogen fixation), from precipitation, and from the decomposition of organic material in soil. Nitrate and chloride are major components of human and animal wastes, and abnormally high amounts of both may indicate pollution. Nitrite and ammonia nitrogen are present in very small amounts in most natural waters; the presence of ammonia in concentrations higher than 0.1 mg/L strongly suggests organic pollution. Nitrate also may be added to water directly from fertilizers. High concentrations of nitrate nitrogen, more than 10 mg/L, may cause methemoglobinemia "blue baby" in infants who ingest it in baby formula or drinking water. Phosphorus in water may be derived from precipitation, leaching of rocks and soil, from fertilizer, decomposition of plants and animals, sewage, and industrial effluents. In amounts found in water, phosphorus is not known to be toxic to human beings, animals, or fish but can stimulate excessive growth of algae and aquatic weeds.

Reid and Wood (1976) state that, with respect to nitrogen in natural waters, "Nitrogen is central to all ecosystems because of its role in the synthesis and maintenance of protein which is, along with carbohydrates and fats, a major constituent of living substance." In streams, ponds, and lakes, the life building process begins with algal production and the uptake of inorganic nitrogen in the form of nitrate and nitrite nitrogen and, to a lesser extent, ammonia nitrogen. This process--the synthesis of organic nitrogen from inorganic forms--provides the primary source of the food that supports the aquatic food chain. Generally speaking, the amount of algal production is proportional to the amount of inorganic nitrogen present in the water. When the amount of inorganic nitrogen becomes excessive, very high algal production occurs. Despite considerable knowledge about the effects of nitrogen inputs to aquatic systems on algal productivity, there are no widely accepted ranges of nitrogen concentrations that can be used to predict potential problems. Generally, preventive action has consisted of the elimination or attempted elimination of man-introduced nitrogen.

Excessive algal production has an adverse effect on the entire aquatic food chain and also diminishes or even destroys the esthetic value of the water. A second effect of high algal production occurs in the death phase during mid to late fall each year. In this phase, bacterial decomposition accompanying the death of algal cells uses up dissolved oxygen in the water thereby stressing the aquatic environment. Another effect caused by the bacterial conversion of the cell materials to the inorganic state is that some inorganic nitrogen as nitrates and nitrites is produced again and enters the water, thereby completing an annual cycle. Thus, a key to healthy aquatic systems is control of the amount of nitrogen that can enter them.

During this study, nitrogen concentrations in various inorganic and organic states varied seasonally with biological events (algal production) at most of the surface-water-sampling sites. The data are shown in figures 10-12. Figure 10 shows that concentrations are relatively low during the spring and summer months; conversely, figure 11 shows that total organic nitrogen is relatively high in spring and summer months, indicating the incorporation of nitrate plus nitrite into the organic form. Figure 12, depicting concentration of nitrogen in all forms, shows that all of the streams are enriched with respect to nitrogen and that excessive algal growth conditions could result, with accompanying loss of esthetic value. Not shown on the figures are data on the occurrence of ammonia nitrogen. Almost all stream-sampling sites yielded samples containing small concentrations of ammonia nitrogen--mostly less than 0.05 mg/L--at one time or another. One site, Beaver Brook at West Windham (site 1, fig. 2), yielded a water sample that contains 2.9 mg/L of ammonia nitrogen, strongly indicating organic pollution.

Phosphorus is another nutrient that is essential to algal productivity. However, relatively small concentrations of phosphorus in natural waters--between 0.01 to 0.04 milligrams per liter--can be present and still support large algal populations, assuming there is enough nitrogen present in the water. As is the case with nitrogen, phosphorus is a cyclic element wherein inorganic phosphorus (orthophosphate) in water is converted to organic phosphorus and incorprated in the biological (algal) materials that later die and release inorganic phosphorus to the stream system. This is illustrated in figures 13 and 14, where it is shown that the total phosphorus (biologically incorporated plus orthophosphate) concentrations (fig. 14) are in the order of 20 to 40 times as great as the orthophosphate concentrations (fig. 13).

The chemical nature of phosphorus is much different than that of nitrogen in that orthophosphate phosphorus is adsorbed by soils and stream sediments and thus may be less available than nitrogen to support algal and weed growth.

Note that significant conversion of inorganic nitrogen to organic nitrogen did not occur at every surface-water-sampling site. The sites where noticeable uptake of inorganic nitrogen did not occur include the Spicket River above Widow Harris Brook (site 11, fig. 2), Widow Harris Brook (site 13, fig. 2), and Spicket River at Salem (site 16, fig. 2). It is possible that algal and weed production, and accompanying uptake of nitrogen, at these sites was limited by the amount of phosphorus that was available. On the other hand, at two sites--Beaver Brook (site 1, fig. 2) and Little River at Westville (site 21, fig. 2)--evidence from the abundant growth of aquatic weeds and algae and relatively large amounts of inorganic nitrogen and phosphorus in the water indicates that the input of these two nutrients was in excess of the cabability of aquatic weeds and algae to use them up.

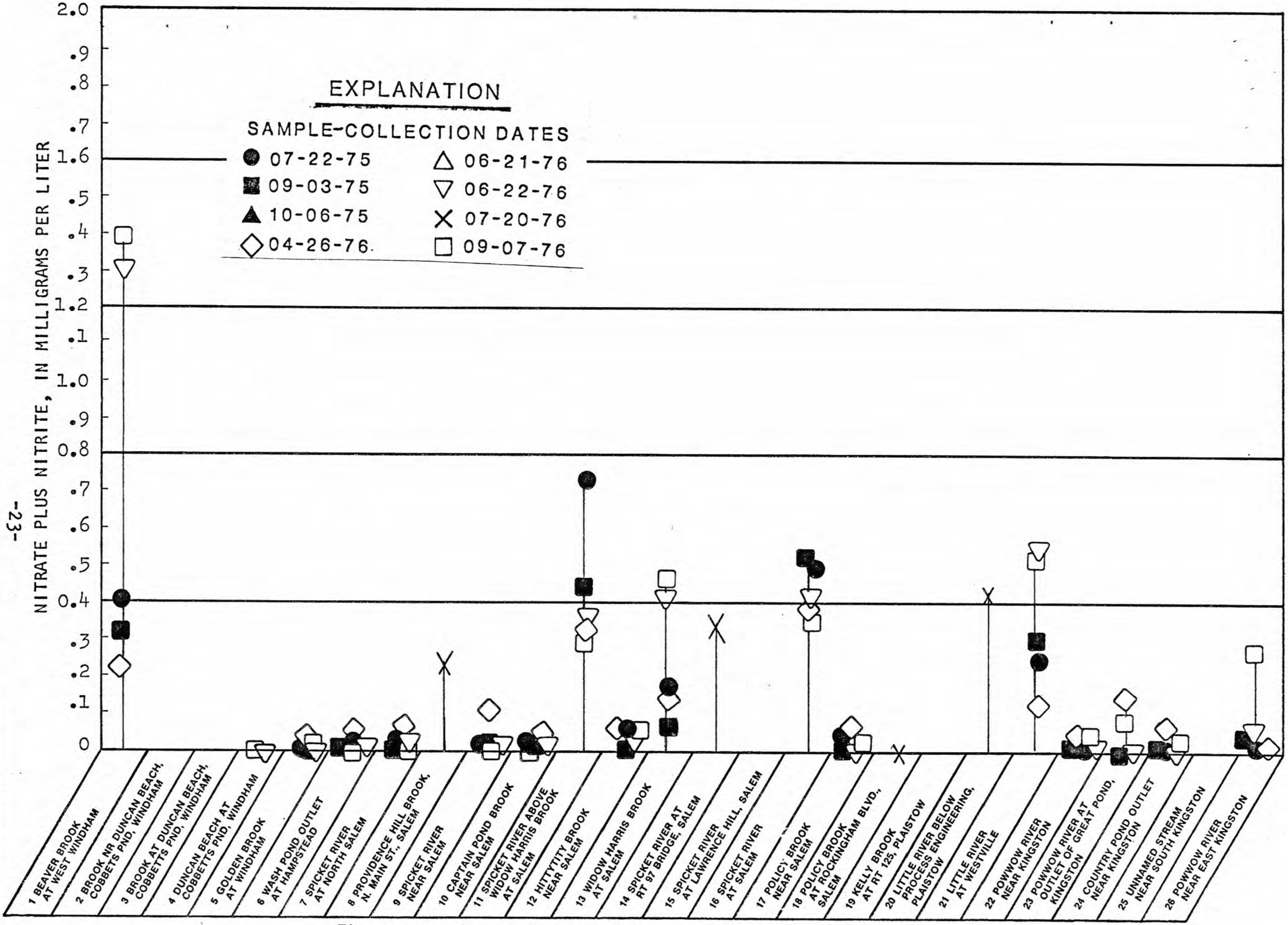

Figure 10.--Total nitrate plus nitrite concentration in water samples at surface-water-sampling sites

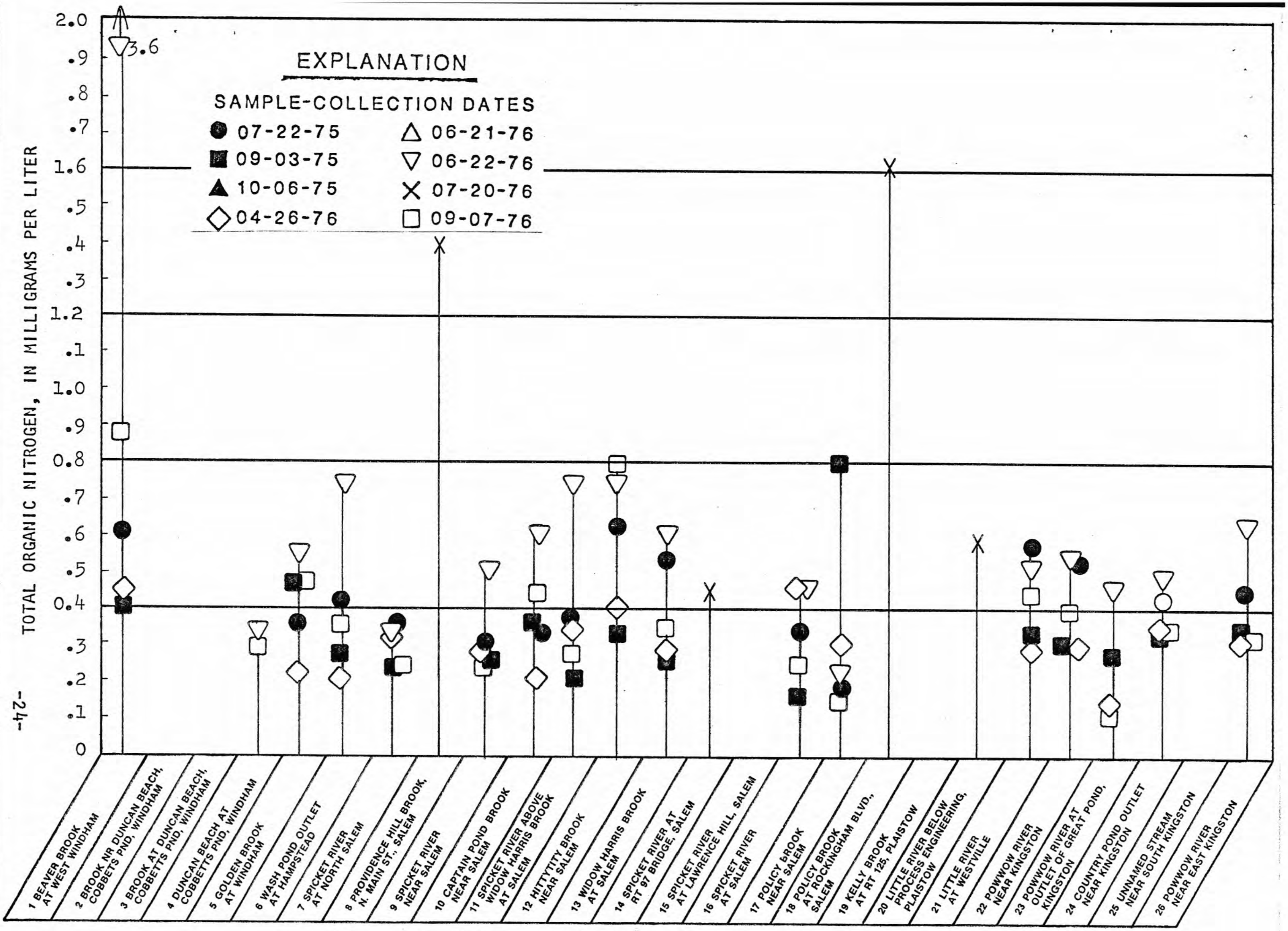

Figure 11.--Total organic nitrogen concentration in water samples at surface-water-sampling sites

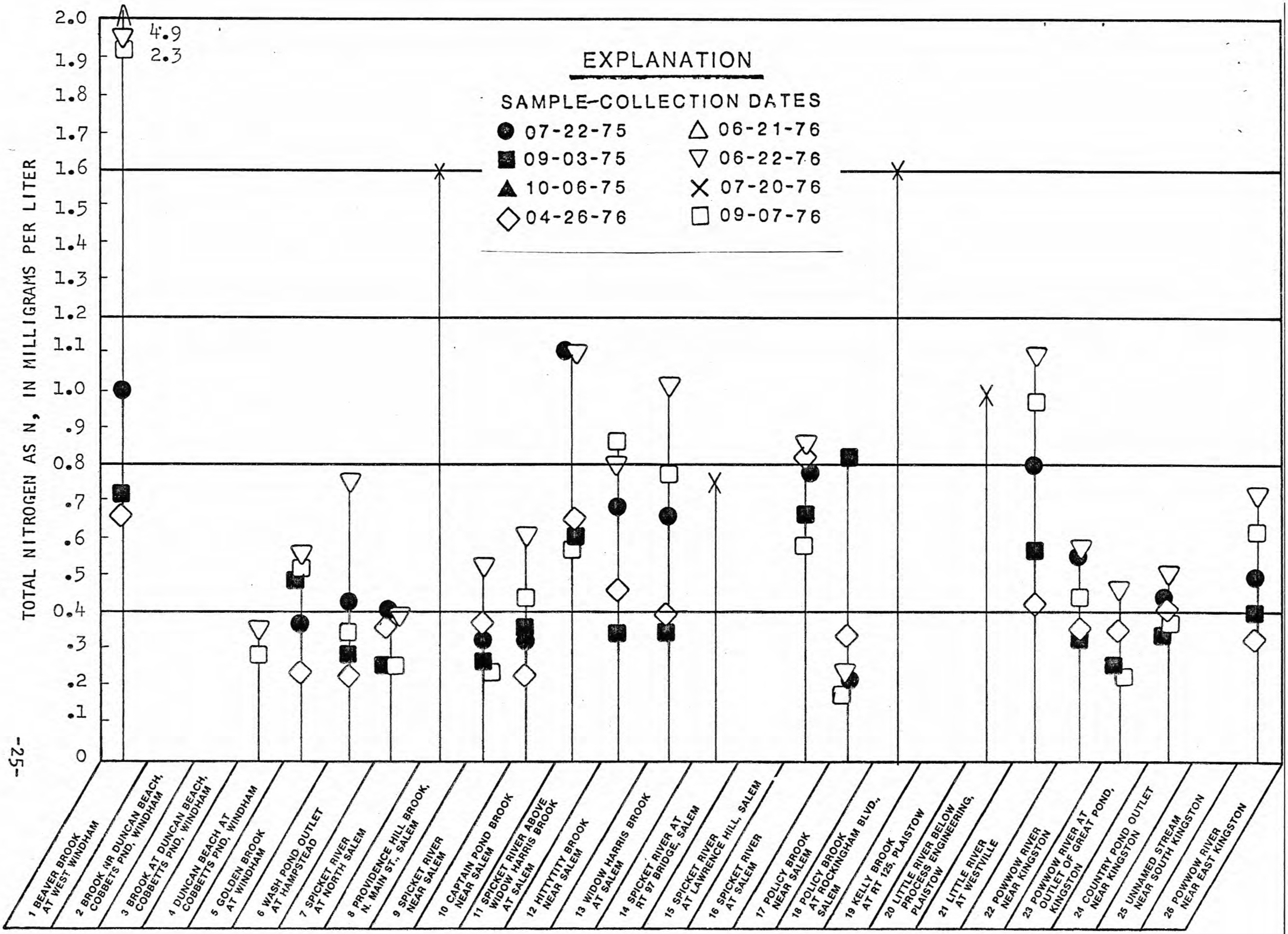

Figure 12.--Total nitrogen concentrations in water samples at surface-water-sampling sites

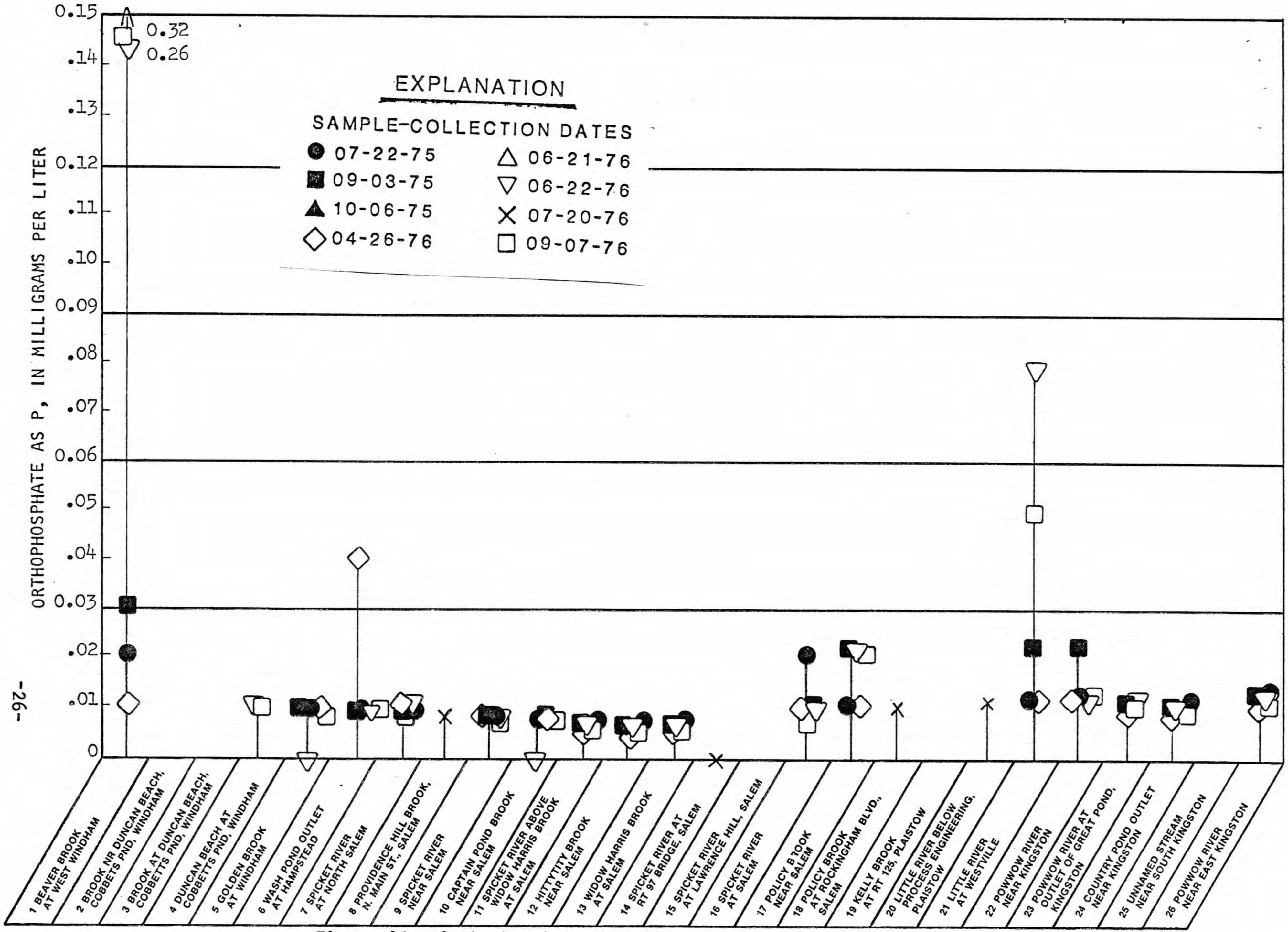

Figure 13.--Orthophosphate phosphorus concentrations in water samples at surface-water-sampling sites

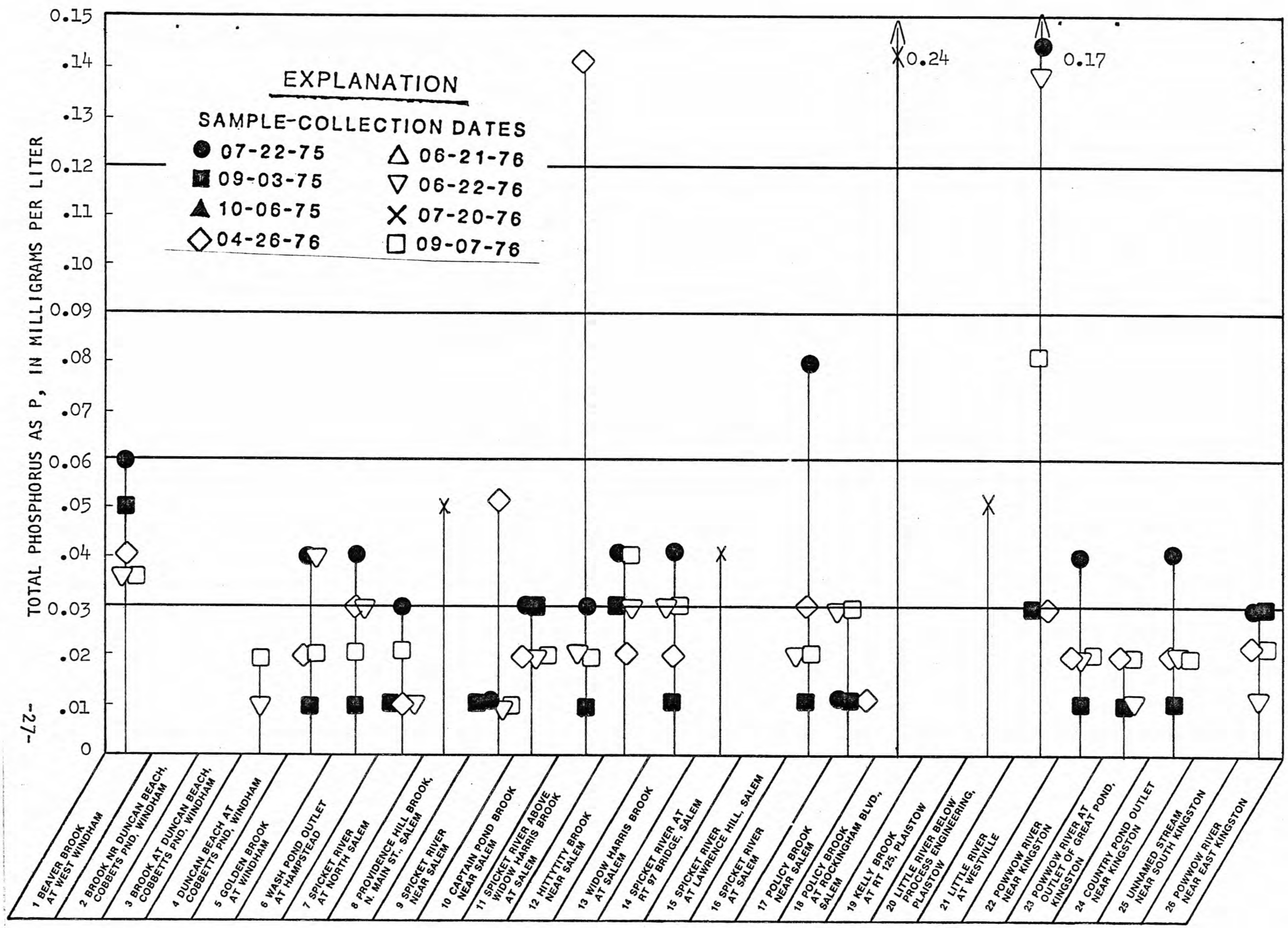

Figure 14.--Total phosphorus concentrations in water samples at surface-water-sampling sites

COD (Chemical Oxygen Demand) and TOC (Total Organic Carbon)

COD (chemical oxygen demand) furnishes an estimate of the amount of organic and reducing materials in water; TOC (total organic carbon) is an accurate measure of dissolved and suspended organic carbon in water and provides a truer measure of organic material in water than a COD determination. The significance of the COD and TOC determinations shown in figures 15 and 16, respectively, is that they indicate the presence in waters at each stream-sampling site of oxygen-consuming materials; the TOC values indicate that at least some of these materials are organic, and at sites with the highest TOC values most of the materials are organic. These data along with data on bacteria and nutrient concentrations tend to corroborate rather widespread pollution of stream waters from human and animal wastes.

The effect of high COD and TOC concentrations in the stream waters is that dissolved oxygen concentrations are reduced. This, in turn, places a stress on the upper part of the food chain.

Periphyton

An attempt was made during this study to determine the relative quantity (biomass) of periphyton growth (micro-organisms that attach to or live on submerged solid surfaces) as another index of the relative abundance of nutrients in stream waters. Periphyton samples were collected by placing substrate material (polyethylene strips 4 inches long and 2 inches wide) on the stream bottoms at the sampling sites to provide standard substrate environments at each site. The strips were left in place for about 2 weeks at each site sampled. After removal and preservation, the mass of organism on each strip was weighed (fig. 17), and a spectrophotometric analysis was made to measure the chlorophyl *a* and chlorophyl *b* concentrations (fig. 18) of each biomass. These analyses provide estimates of the variations in the quantity of periphyton growth from place to place and from time to time.

The scant data available show that greatest productivity occurred at the sampling sites on Powwow River (site 24, fig. 2), the Spicket River at North Salem (site 7, fig. 2) near Salem (site 9, fig. 2) and at Salem (site 16, fig. 2), and Little River (site 21, fig. 2). In general, these sites correspond with those where nitrogen and phosphorus also are relatively abundant and thus provide an index to the relative concentrations of nutrients.

Pesticides and PCB's (Polychlorinated Biphenyls)

Both stream water and stream-bottom materials were analyzed for pesticides and PCB's (polychlorinated biphenyls). Only one of 16 samples of surface water contained a detectable amount of one pesticide (DDT). This sample was collected from the Spicket River at Salem (site 16) and contained 0.03 ug/L of DDT. However, analyses of stream-bottom materials (table 5) indicate that the pesticides DDD and DDE are present in most of the surface-water systems sampled in the study area. Dieldrin, chlordane, and heptachlor epoxide also are present at some sites.

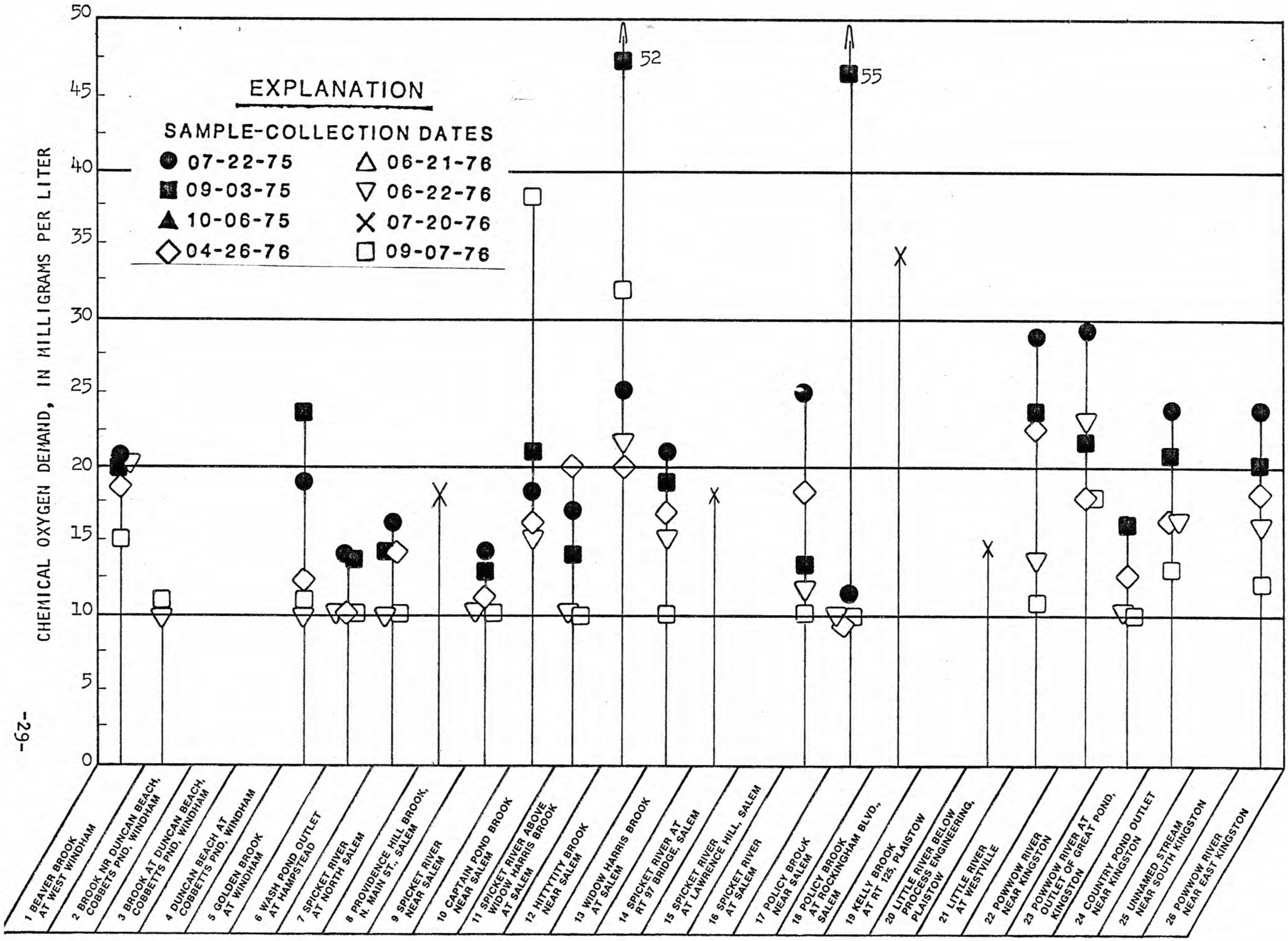

Figure 15.--COD (chemical oxygen demand) in water samples at surface-water-sampling sites

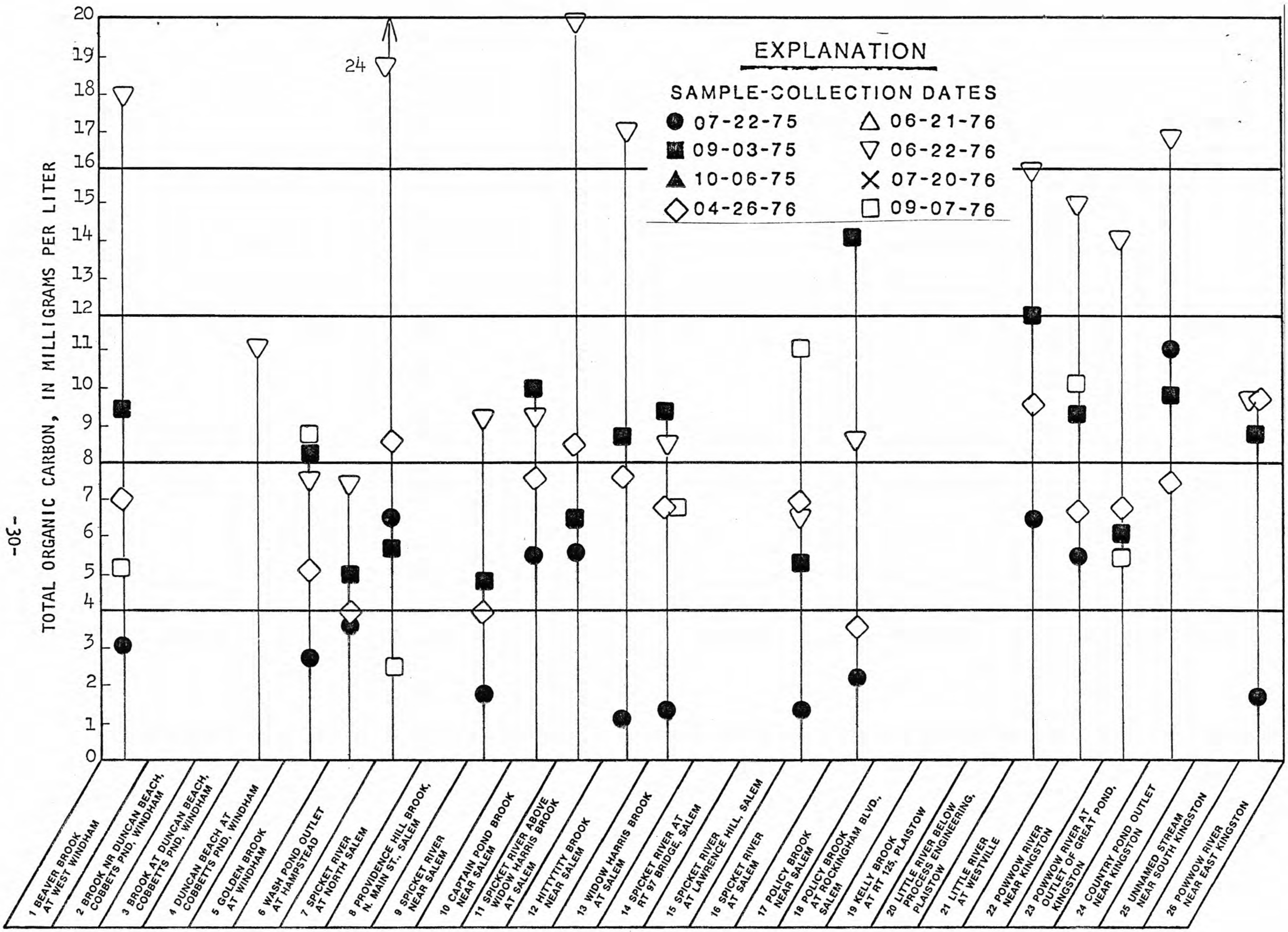

Figure 16.--TOC (total organic carbon) in water samples at surface-water-sampling sites

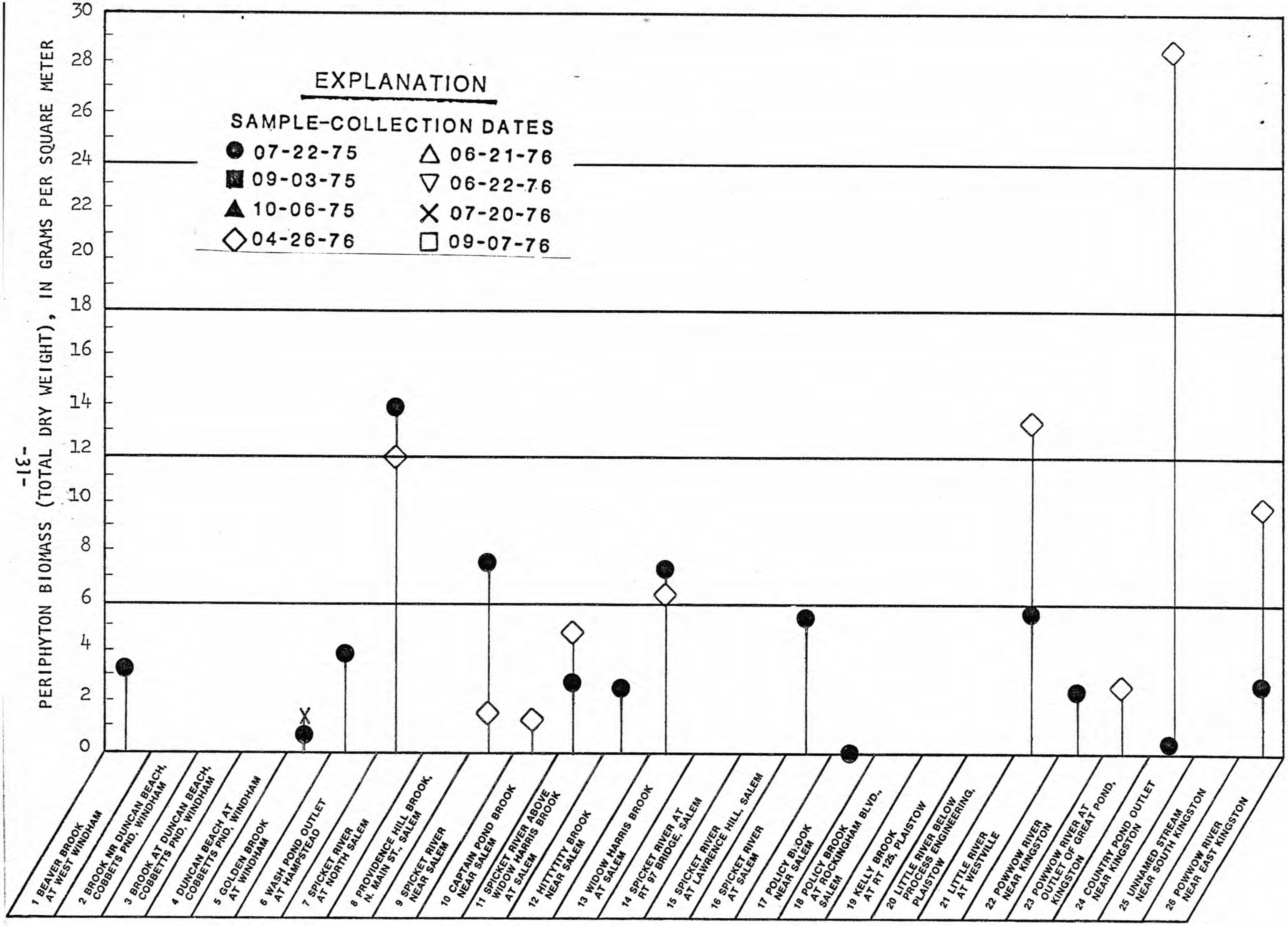

Figure 17.--Periphyton biomass production at surface-water-sampling sites

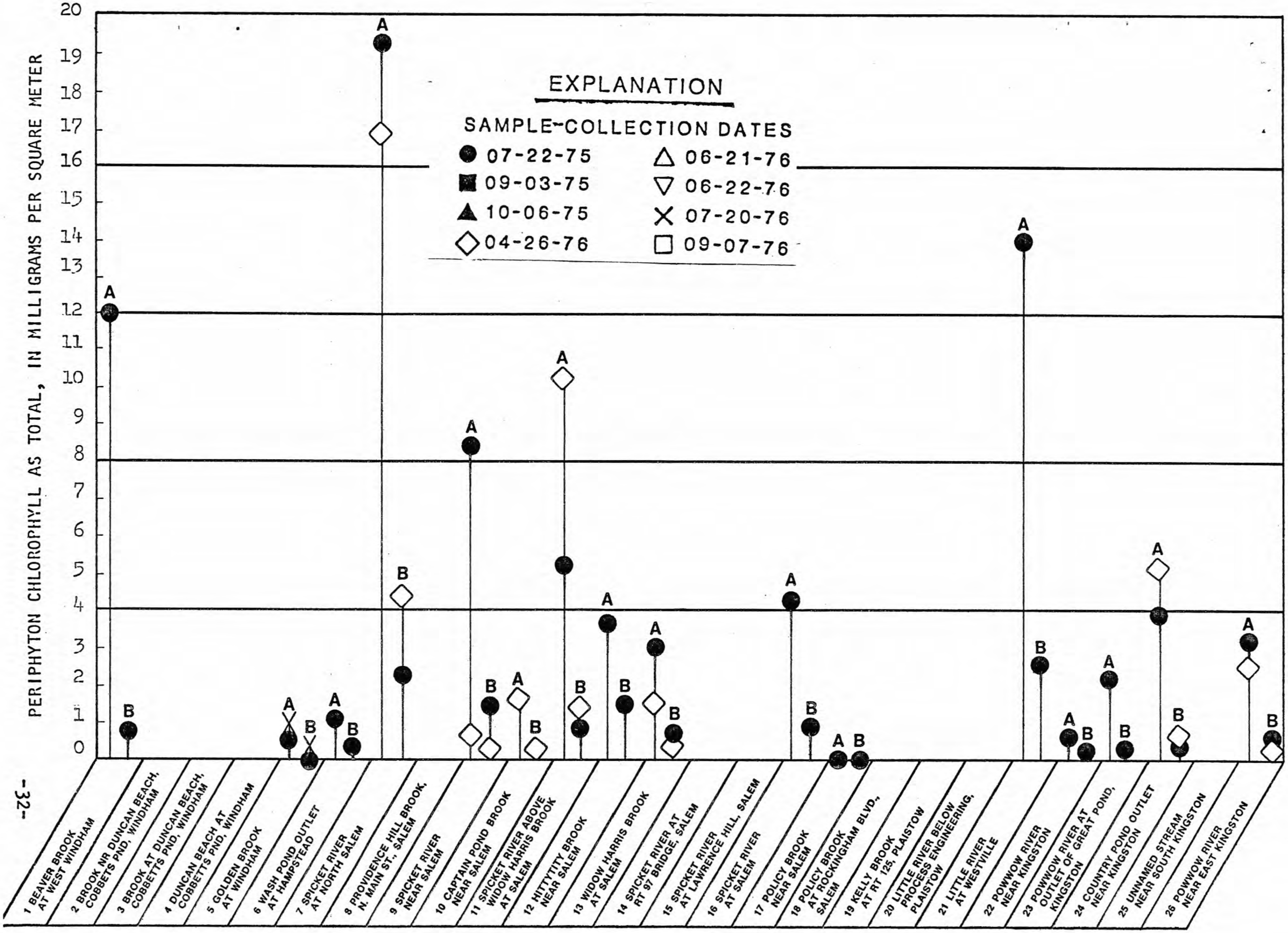

Figure 18.--Chlorophyll *a* and *b* development (concentrations) as a result of periphyton productivity at surface-water-sampling sites

Table 5.--Types and concentrations of pesticides present in stream-bottom materials

Station name	Map No.	Pesticide type	Concentration (ug/L)
Beaver Brook at West Windham	1	DDE	1.1
Brook near Duncan Beach, Cobbetts Pond, Windham	2	NS	
Brook at Duncan Beach, Cobbetts Pond, Windham	3	NS	
Duncan Beach at Cobbetts Pond, Windham	4	NS	
Golden Brook at Windham	5	ND	
Wash Pond Outlet at Hampstead	6	DDE	.8
		DDD	.9
Spicket River at North Salem	7	Dieldrin	.3
Providence Hill Brook, North Main St., Salem	8	NS	
Spicket River near Salem	9	DDT	.03
		DDE	.5
Captain Pond Brook near Salem	10	ND	
Spicket River above Widow Harris Brook at Salem	11	DDD	3.0
		DDE	1.5
Hittytitty Brook near Salem	12	ND	
Widow Harris Brook at Salem	13	Chlordane	36
Spicket River at Route 97 bridge, Salem	14	NS	
Spicket River at Lawrence Hill, Salem	15	NS	
Spicket River at Salem	16	DDE	1.2
		Dieldrin	.3
Policy Brook near Salem	17	DDD	9.9
Policy Brook at Rockingham Boulevard, Salem	18	NS	
Kelly Brook at Route 125, Plaistow	19	NS	
Little River below Process Engineering, Plaistow	20	NS	
Little River at Westville	21	ND	
Powwow River near Kingston	22	DDE	4.4
Powwow River at outlet of Great Pond, Kingston	23	ND	
Country Pond Outlet near Kingston	24	DDD	.5
		Dieldrin	19
Unnamed stream near South Kingston	25	NS	
Powwow River near East Kingston	26	Heptachlor	1.9

NS, Not sampled.
ND, Not detected.

The pesticides and PCB's are manmade chemical compounds. PCB's are used as nonconducting fluids in electrical capacitors and transformers, as hydraulic fluids, and as heat transfer fluids; they also have been widely used as placticizers and solvents in adhesives, sealants, paints, and printing inks. The widespread absence of pesticides and PCB's in solution in surface waters probably reflects the sharp reduction in availability and use of these compounds during the 2 or 3 years before 1976. These compounds, however, are easily adsorbed by stream-bottom materials and persist attached to these materials long after their disappearance in water. Some pesticides have proved to be very resistent to environmental degradation, but little is known about the length of time they will persist nor the ease with which they reenter stream water.

GROUND-WATER QUALITY

The chemical quality of the ground water as discussed in this report is based on analyses of 25 samples collected at 8 homes, 2 apartment houses, a factory, Rockingham Park, 3 schools, a trailer park, and a housing development scattered throughout the area. As indicated previously, samples of ground water were collected after having been delivered at taps in the homes or public institutions so as to be representative of water as delivered for human consumption. Accordingly, the analyses of the water may not accurately reflect the quality of ground water as it occurs in aquifers in the study area.

Eleven drilled wells and six dug wells were sampled. Specific-ductance data (fig. 20) show that the water sampled at the 17 ground-water-sampling sites contains higher concentrations of dissolved-mineral matter than the surface water in the study area. For comparison, specific-conductance values range from 76 to 236 micromhos in surface-water samples and from 125 to 1,800 micromhos in water at the ground-water-sampling sites. The data indicate that total dissolved solids at all but one site, site 14 on figure 3, are within the maximum contaminant levels of the PHS (1962) and the EPA (1975).

Specific-conductance values and, therefore, dissolved-mineral concentrations, are generally higher in water from drilled wells than from dug wells (fig. 20). This is a generally normal condition, as water from deeper drilled wells has travelled farther through earth materials from points of recharge to points of discharge at the wells. Water samples from three dug wells (sites 14, 15, and 16, fig. 3), however, had specific-conductance values that seem abnormally high. Waters from these wells also had relatively high concentrations of chloride (fig. 21) and nitrate (fig. 24), and water from the well at site 14 contained relatively high concentrations of calcium and sodium; these data suggest the water from these wells may be contaminated from road salt, from onsite sewage-disposal systems, or a combination of these.

Chloride concentrations are well below the PHS (1962) and the EPA (1975) maximum contaminant level of 250 mg/L--the level at which water begins to taste salty--at all ground-water-sampling sites but two--sites 14 and 15. At about half the sites, chloride concentrations are within the range to be expected in ground water under natural conditions. However, chloride concentrations (fig. 21) are relatively high in drilled wells at sites 1, 5, 6, 8, and 11 and at a dug well at site 9, figure 3, suggesting the water may be affected by road salt.

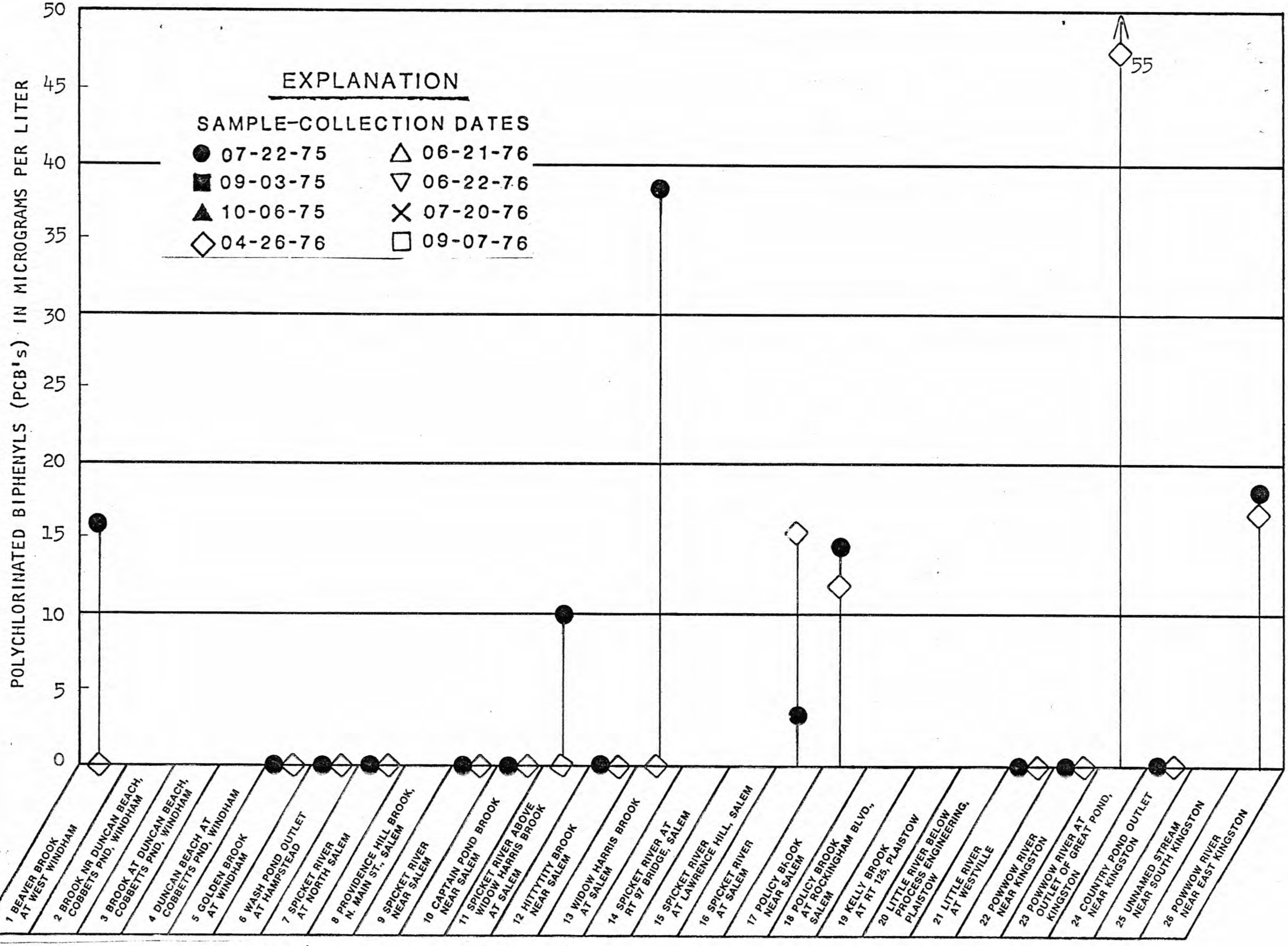

Figure 19.--PCB (polychlorinated biphenyl) concentrations in samples of stream-bottom materials

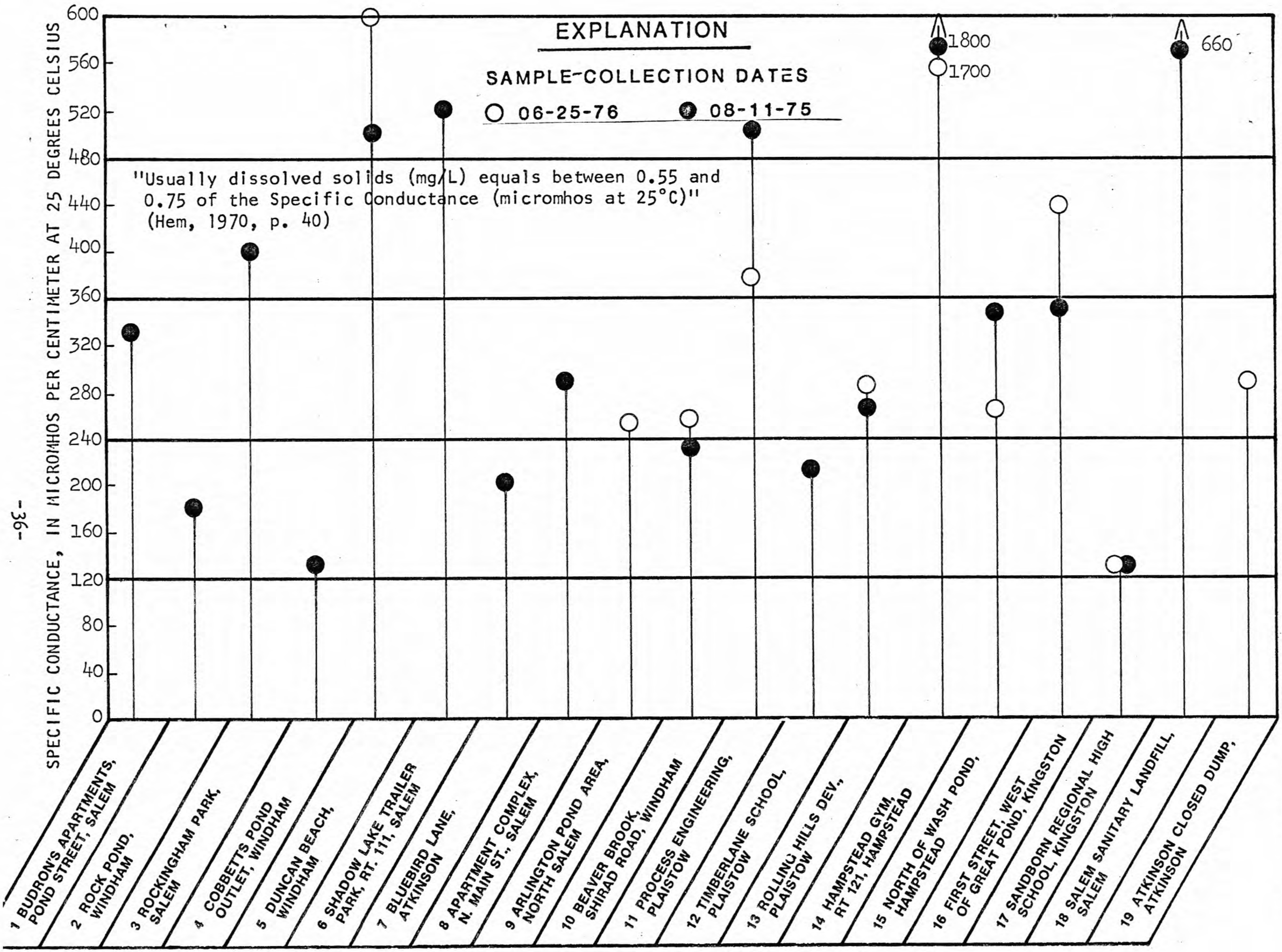

Figure 20.--Specific conductance of water at ground-water-sampling sites

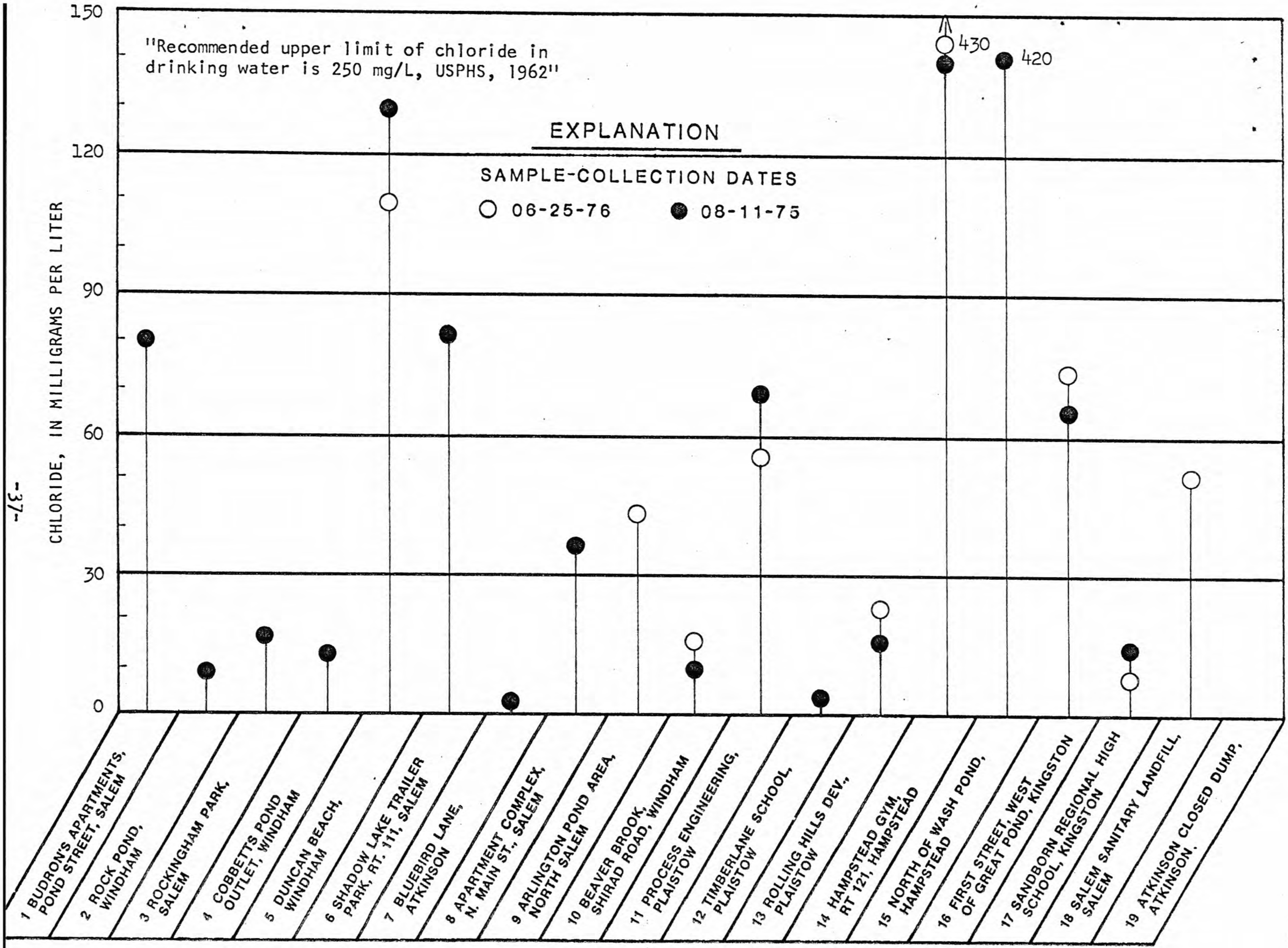

Figure 21.--Chloride concentrations in water samples at ground-water-sampling sites

Minor elements present in water collected at ground-water-sampling sites include iron, manganese, copper, lead, and zinc. A sample of water collected at site 11 in Plaistow contained 1,100 ug/L of copper, the highest concentration of copper in water at the ground-water-sampling sites. This exceeds the PHS maximum contaminant level by only 100 ug/L. Zinc and lead were present in samples from 15 of the 17 ground-water sites sampled, but in low concentrations.

Iron and manganese (figs. 22 and 23) are troublesome but not toxic constituents in amounts present in water from ground-water-sampling sites throughout the area. Iron in concentrations greater than about 300 micrograms per liter and manganese in concentrations greater than about 500 micrograms per liter may cause stains on laundry and plumbing fixtures. Iron concentrations range from 90 to 5,200 micrograms per liter and exceed maximum contaminant levels of the EPA (1975) at 8 of the 17 sites sampled. Manganese ranges from 10 to 990 micrograms per liter and exceeds maximum contaminant levels of the EPA (1975) at 9 of the 17 sites sampled.

Coliform bacteria were present in water samples from 5 of the 17 sites sampled as shown below:

Location and well-site number	Total coliform bacteria	Fecal coliform bacteria	Fecal streptococcal bacteria
		(colonies/100 mL)	
Rockingham Park (site 3)	5	7	26
Cobbetts Pond Outlet (site 4)			
8-11-75	250	0	190
8-14-75	130	0	430
Rolling Hills (site 13)	5	0	2
Hampstead Gym (site 14)	8	0	0
Wash Pond (site 15)			
8-12-75	7	0	0
10-20-76	12	0	13

These data, along with data on chloride and nitrate concentrations in water samples from these sampling sites, suggest contamination, possibly from onsite sewage-disposal systems.

Nutrients in various states, including nitrate plus nitrite, ammonia, total organic nitrogen, orthophosphate, and total phosphorus were present in water samples collected at most ground-water-sampling sites. Concentrations of these constituents varied widely from site to site. Nitrates plus nitrites were present at all 17 ground-water sites sampled (fig. 24) and ammonia nitrogen was present in small concentrations (less than 0.01 mg/L) in some water samples. However, samples collected in 1975 and 1976 from a drinking water fountain on the grounds of the Sandborn Regional High School (site 17, fig. 3) contained 0.30 and 0.49 mg/L of ammonia, respectively, indicating the possibility that the water is contaminated. Total organic nitrogen concentrations were low in all water

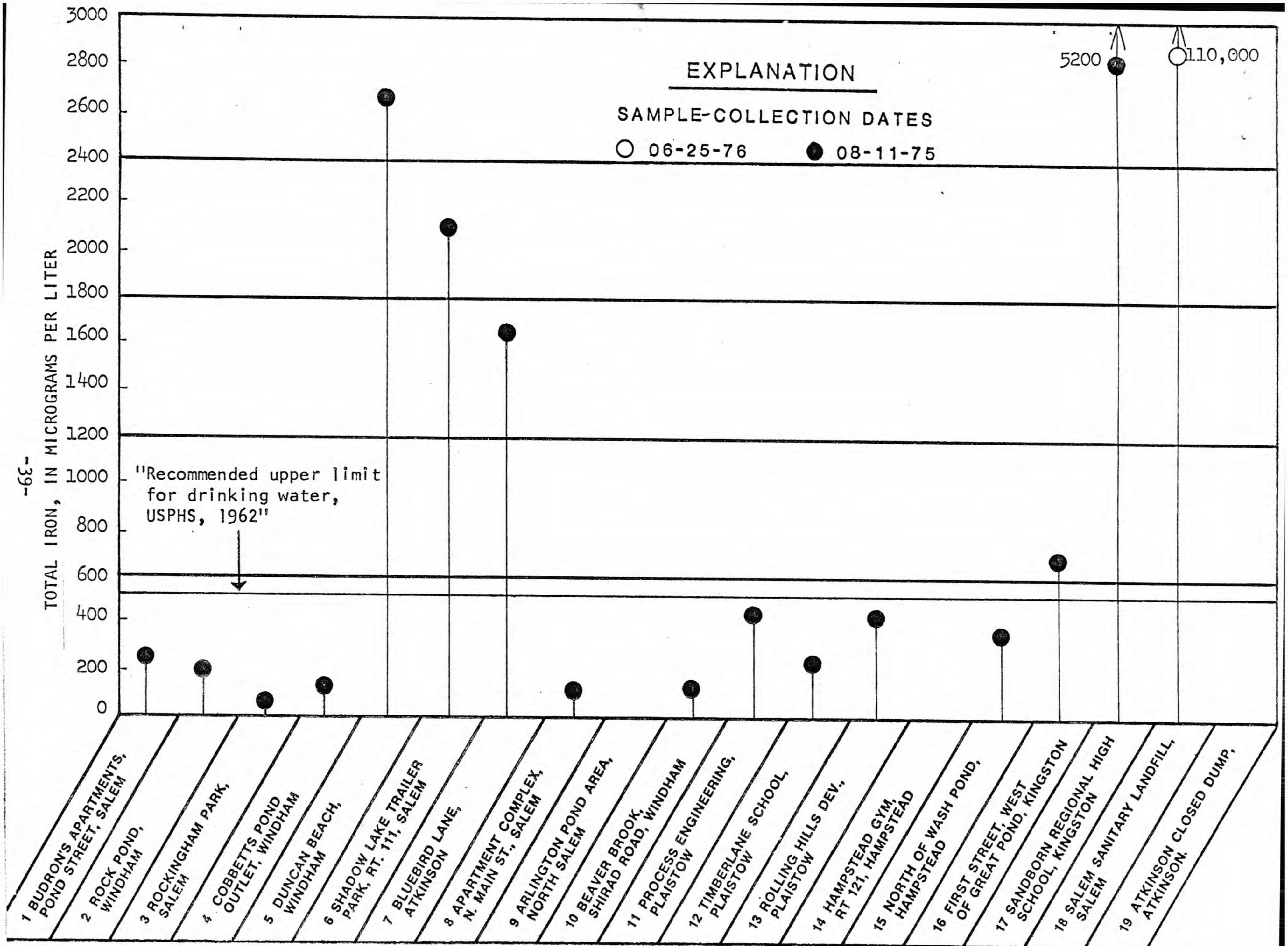

Figure 22.--Iron concentrations in water samples at ground-water sampling sites

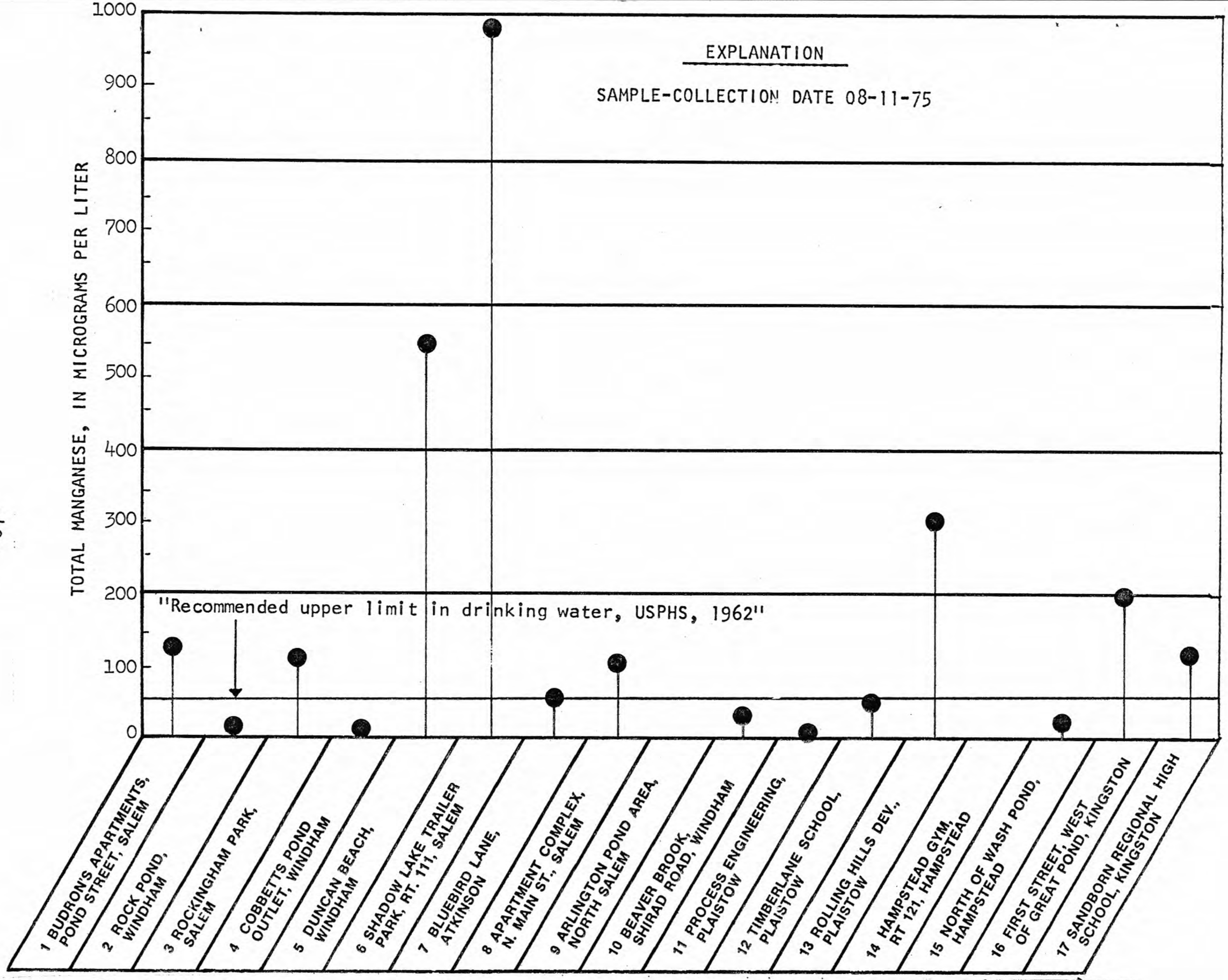

Figure 23.--Manganese concentrations in water samples at ground-water sampling sites

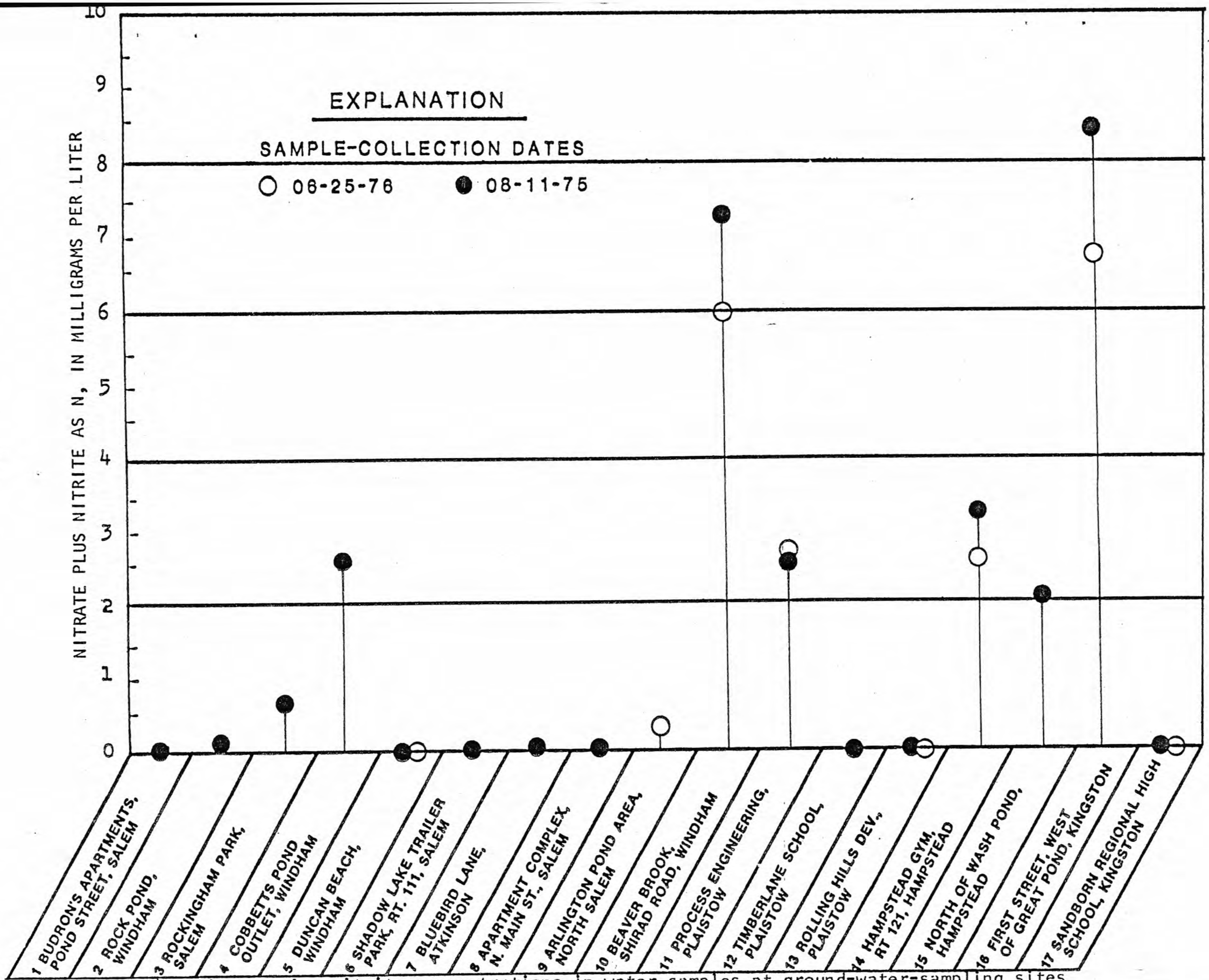

Figure 24.--Nitrate plus nitrite concentrations in water samples at ground-water-sampling sites

samples collected, as shown in figure 25. Orthophosphate and total phosphorus were present in samples collected at all of the ground-water-sampling sites, but concentrations ranged from only about 0.01 to 0.02 mg/L. Water samples collected at about half the ground-water-sampling sites contained nitrogen and phosphorus concentrations in ranges that could be expected in ground water under natural conditions. Water samples at sites 3, 4, 10, 11, 14, 15, 16, and 17, however, contained concentrations that are sufficiently high to suggest, along with data from chloride concentrations (fig. 21) and presence of coliforms (page 38), contamination from sewage. The data suggest that water from dug wells is more susceptible to contamination than water from drilled wells.

The values of both COD and TOC in water samples collected at the ground-water-sampling sites are lower than values of COD and TOC in samples collected at the surface-water-sampling sites in the area, as shown in figures 26 and 27. There is little correlation between COD and TOC concentrations in water samples indicating only that oxygen-consuming materials in the water are not necessarily organic.

None of the samples collected at the ground-water-sampling sites contained any of the 11 pesticides for which analyses were made, nor did any sample contain PCB's.

WATER-QUALITY CONDITIONS IN FOUR MAJOR WATERSHEDS IN THE SOUTHERN ROCKINGHAM REGION OF NEW HAMPSHIRE

Beaver Brook Watershed

The Beaver Brook watershed is lightly populated, with the exception of the Town of Derry. Although located outside of the Southern Rockingham Region, effluent from Derry's domestic waste-treatment plant empties into Beaver Brook, provides much of the stream discharge, and strongly influences water quality downstream, as shown by conditions at the sampling site in Windham (fig. 2, site 1).

Specific-conductance values measured at this site were somewhat higher (380 micromhos on June 21, 1976) than are generally found at most sites in the Region (table 4), indicating that dissolved-mineral content is also somewhat higher. Measurements of temperature, dissolved oxygen, and pH were in ranges considered suitable for maintaining most aquatic fresh-water life.

Major constituents are sodium, chloride, calcium, and bicarbonate. Several other constituents, including boron and fluoride, were detected in high concentrations. Boron values of 220, 180, and 180 ug/L (micrograms per liter) were present in three samples collected on June 21, 1976, September 7, 1976, and October 19, 1976. Fluoride was also detected in high concentrations, with the maximum observed being 1.8 mg/L (milligrams per liter). Concentrations of both boron and fluoride were noticeably higher at the sampling site in the Beaver Brook watershed than at the sampling sites at other locations in the Southern Rockingham Region. Both are constituents of products extensively used by man and probably are contributed by effluent from the Town of Derry's domestic waste-treatment system.

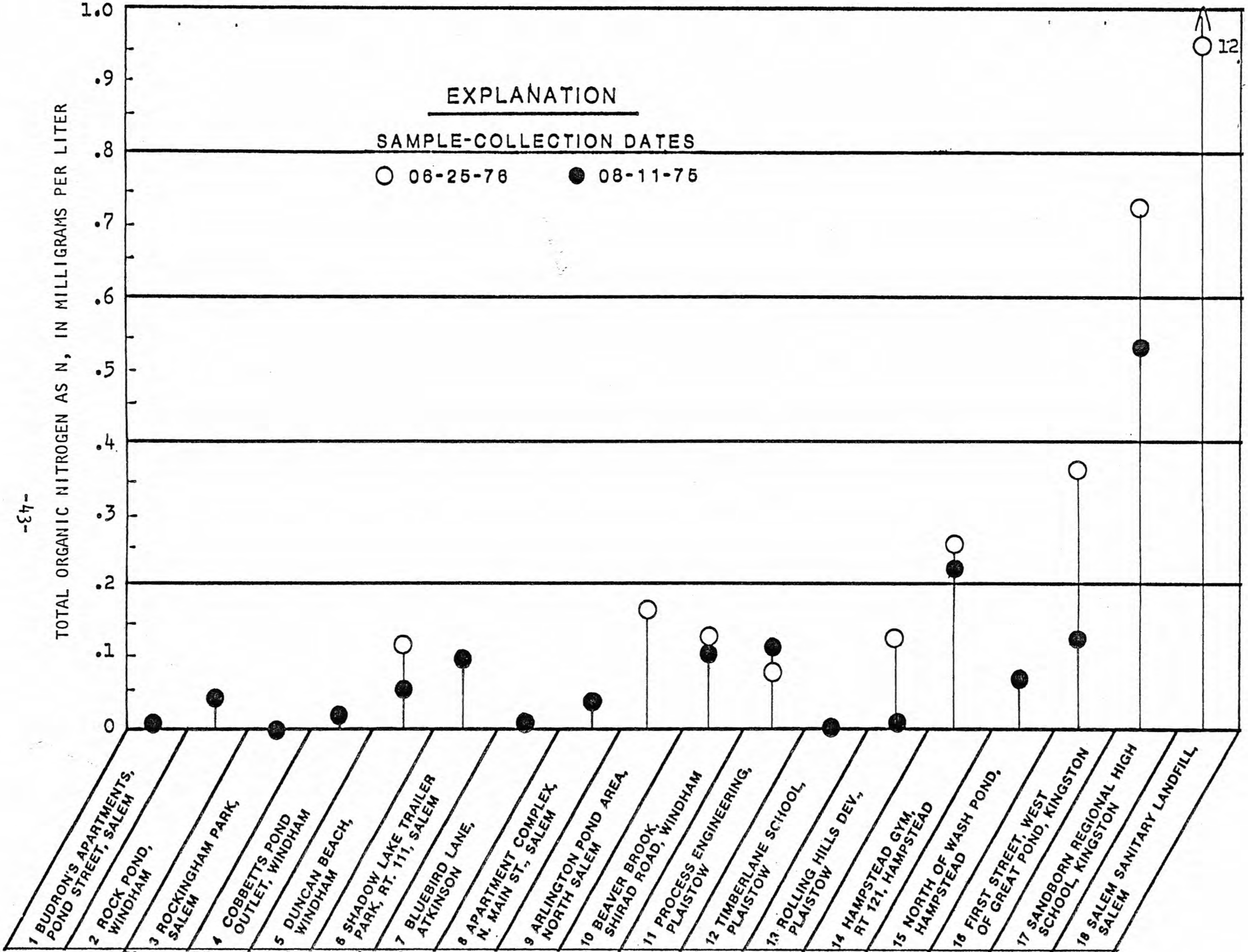

Figure 25.--Total organic nitrogen concentrations in water samples at ground-water-sampling sites

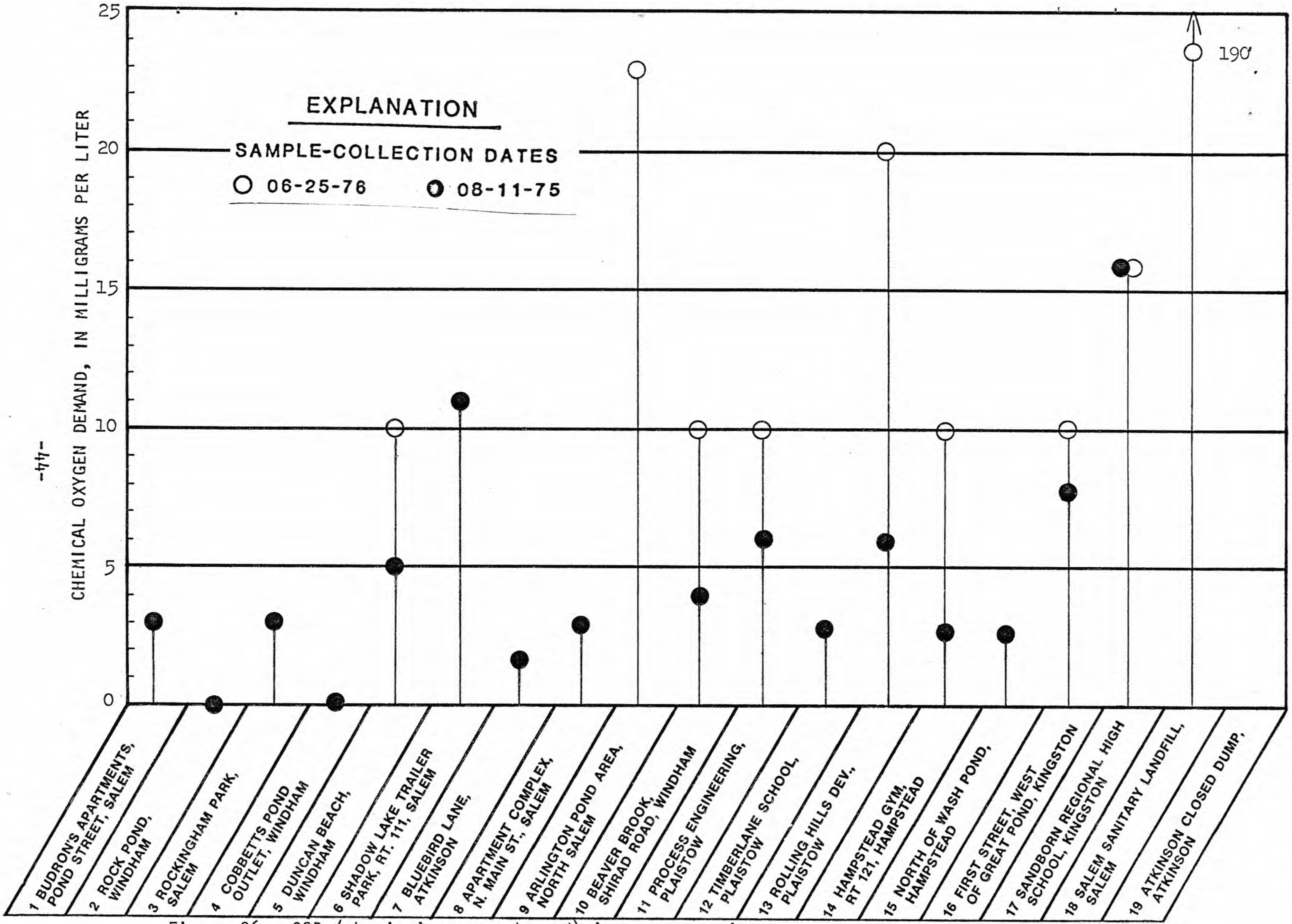

Figure 26.--COD (chemical oxygen demand) in water samples at ground-water sampling sites

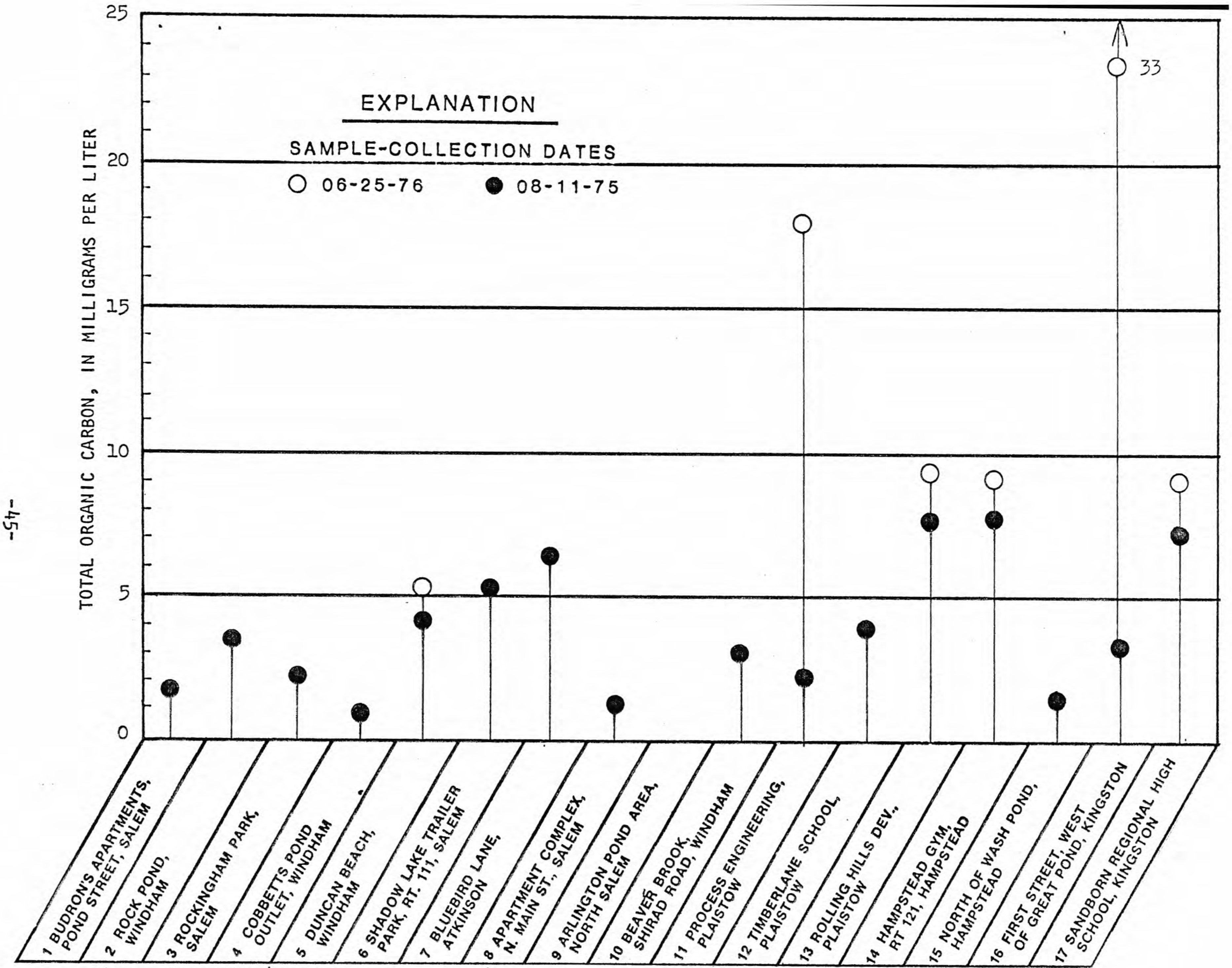

Figure 27.--TOC (total organic carbon) in water samples at ground-water-sampling sites

The minor elements, with the exception of iron and manganese, were either not detected or were detected in extremely low concentrations. Iron and manganese were the most prevalent minor elements; the maximum observed iron concentration was 1,800 ug/L on September 3, 1975; manganese concentrations were relatively low (30 to 70 ug/L) compared with values obtained at other surface-water sites. Iron and manganese concentrations observed pose no threat to aquatic life.

Nutrients, consisting of nitrogen and phosphorus compounds, were present in most samples collected at this site in relatively high concentrations compared with other sampling sites. Ammonia nitrogen, for example, was present in concentrations of 2.9 mg/L (June 21, 1976) and 1.4 mg/L (October 19, 1976) compared with values at other sites in the range of 0.01 to 0.04 mg/L. The concentrations in samples from Beaver Brook suggest that the Derry domestic waste-treatment plant is the primary source of ammonia nitrogen in the brook. Nitrite plus nitrate nitrogen concentrations were also relatively high at this site, more than 1 mg/L compared with values less than 1 mg/L and generally less than 0.5 mg/L, as nitrogen, at other sites. Total nitrogen was relatively high at the Beaver Brook site during most sampling periods, and total phosphorus showed the highest concentrations, ranging from 0.04 to 0.64 mg/L, observed at the surface-water-sampling sites. The most likely source of the nitrogen and phosphorus is the Derry domestic waste-treatment plant.

Golden Brook, a tributary of Beaver Brook that joins it south of the study area, is of particular interest because its headwaters contain Cobbetts Pond, an important recreational resource. Specific-conductance values of water in two small, unnamed tributaries that flow into Cobbetts Pond (fig. 2, sites 2 and 3) were among the highest for stream waters in the area (fig. 4 and p. 11). Also, one of the unnamed tributaries (fig. 2, site 2) had a low dissolved-oxygen concentration on one date sampled (see p. 10), and both tributaries contained total coliform bacteria that ranged from about 100 colonies per 100 milliliters to about 8,800 colonies per 100 milliliters (fig. 5). The relatively high specific conductance is attributed to highway runoff from Interstate Highway I-91, which passes about one-fourth mile northeast of the inlet, and the presence of coliform bacteria is attributed to effluent from a private waste-water treatment facility just northeast of the highway.

Spicket River Watershed

Water-quality conditions along the Spicket River are influenced largely by variations throughout the drainage basin in population density, runoff containing highway deicing chemicals, effluent from a sanitary landfill, and possibly livestock.

Along the Spicket River between North Salem (fig. 2, site 7) and Salem (fig. 2, site 16), specific conductance values, measured in the field, increased from approximately 80 micromhos at North Salem to 130 micromhos at Salem, indicating an increase in the dissolved-mineral content of approximately 60 percent. Dissolved oxygen, water temperature, and pH, also measured in the field, showed no definite trends along the same reach. One unusual pH value (3.5 units) was observed on July 21, 1976 at Salem, the most downstream site (fig. 2, site 16) probably as a result of commercial and light industrial activities upstream.

Major chemical constituents were generally found in concentrations well below those that would influence the normal stream biota and showed no pattern of distribution that could be used to identify potential sources. The general widespread occurrence of higher chloride concentrations than would be expected for the inland location of the Spicket River indicate the possibility of inputs from highway deicing chemicals, septic system effluents, or both.

Based on mean concentrations observed, total phosphorus and orthophosphate phosphorus showed no trends along the Spicket River. These constituents are present in low concentrations and, due to their retention in soils and the respective uptake and release by actively growing or dying biota, would not necessarily be expected to show trends along the streams.

Total nitrogen values, however, increased from less than 0.4 mg/L to approximately 0.8 mg/L between the Spicket River near Salem (fig. 2, site 9) and the Spicket River at Salem (site 16). The increase in total nitrogen is most probably due to the pickup of nitrite plus nitrate entering the Spicket River and its tributaries as they flow through or drain areas served by septic systems. Organic-nitrogen values changed little along this reach. Unlike nitrite plus nitrate, organic nitrogen is retained in the soil and little would be expected to reach the streams from septic-system effluent. In addition, much of the organic nitrogen in streams is normally in the form of attached plant matter which is not represented in a water sample unless the sample is collected during a period of time when the plants are sloughing away from their places of attachment and being carried downstream by the flow. Particularly heavy growth of aquatic plant material was observed in the vicinity of the Spicket River at North Salem. Their presence is accompanied by generally lower nitrite plus nitrate and orthophosphate, suggesting the uptake of these constituents by the plant materials.

The presence of ponds and wetland areas along the Spicket River and the tributaries tends to obscure seasonal changes related to changing stream conditions particularly with respect to the nutrients. Entrapment, cycling within the ponds, and regulation of outflow from the ponds tends to alter the relationship of the nutrients incorporated in plant materials to those present in the inorganic forms.

The influence of the nutrient concentrations in the tributaries on the Spicket River is generally small due to the relatively smaller flow in the tributaries. Nutrient concentrations in the Spicket River increase noticeably between the confluence of the Spicket River (fig. 2, site 9) Providence Hill Brook (fig. 2, site 8), and Captains Pond Brook (fig. 2, site 10) and the Spicket River above Widow Harris Brook (fig. 2, site 11). In the latter vicinity, the Spicket River passes through a wetland area and, therefore, it is not possible to specifically attribute the increased concentrations in the Spicket River above Widow Harris Brook to the influence of Providence Hill Brook and Captains Brook. The flow in Widow Harris Brook is greater than that of the other tributaries; however, the concentration of nutrients is less than in the Spicket River above Widow Harris Brook. No increase in the concentration of nutrients in the Spicket River can be associated with the input from Widow Harris Brook, therefore. One of the more concentrated inputs of nutrients to the Spicket River comes from Policy Brook. From the site (fig. 2, site 17) just below Canobie Lake to the site (fig. 2, site 18) at Rockingham Boulevard, nutrient concentrations increase nearly threefold, based on mean values. The probable sources are the unsewered residences and Rockingham Park, located between these two sites.

Higher concentrations of iron and manganese were observed in Hittytitty (fig. 2, site 12) and Widow Harris Brooks (fig. 2, site 13) than at other sites sampled, probably resulting from stronger reducing conditions in the ground-water environment near these streams.

In both the Spicket River near Salem and Providence Hill Brook, PCB's were present in detectable concentrations in bottom sediments. Both sites are in the vicinity of the Salem Sanitary Landfill, which is the probable source of these compounds. PCB's were also present in detectable concentrations in bottom sediments from Policy Brook (fig. 2, site 17); no potential source was identified in Policy Brook drainage basin.

Concentrations of the major constituents in the tributary streams are not greatly different from those in the Spicket River except for those constituents related to highway deicing chemicals. Concentrations of sodium and chloride, the principal constituents of highway deicing chemicals, are approximately twice as high in the tributaries as in the Spicket River. Note that, although the concentrations are higher in the tributaries than in the Spicket River, the flow volumes are less; therefore, the influence of the tributaries on the Spicket River is less than concentration alone would indicate. Concentrations of sodium and chloride in the tributaries are also related to the ratio of the amount of highway deicing chemicals used within the drainage basin of the tributary to the volume of flow from the basin.

Based on mean nutrient concentrations, the tributaries generally reflect enriched conditions probably due to effluent from numerous septic systems in the areas they drain.

Pesticides in the form of chlordane, DDE, dieldrin, and DDD were present in detectable concentrations in bottom sediments at several sites. The single chlordane value detected was 36 ug/kg at the Hittytitty Brook (site 12); DDE and dieldrin were found in concentrations ranging from 0.5 to 5.9 ug/kg and 0.2 to 0.6 ug/kg, respectively. DDD was found in bottom sediments at three sites and ranged from 0.8 to 9.9 ug/kg. Only one water sample contained a detectable concentration of a pesticide; DDT was detected in a sample taken from the Spicket River at Salem on July 21, 1976.

Both fecal coliform and fecal streptococcal bacteria were found at every stream-sampling site. Considering the inability of these organisms to reproduce themselves in the aquatic environment, the source must be ample and widespread to provide the numbers and distribution of organisms found. With the exception of Providence Hill Brook, which drains an area near which livestock are kept, the source is probably septic-system effluent discharging to the streams in the ground water.

Ground waters sampled within the watershed showed a wide range of quality. The data from the individual wells sampled are not closely related to the Spicket River system and are adequately described previously in this report. One notable exception, however, was the tap water sampled at the Hampstead Gymnasium. This source showed indications of possible organic contamination in several parameters including COD, ammonia, and nitrite plus nitrate. In addition, the indication of contamination by highway deicing chemicals was given by sodium and chloride concentrations of 190 mg/L and 430 mg/L, respectively.

Little River Watershed

Physical measurements made in the Little River watershed at Westville (fig. 2, site 21) indicated no conditions that would stress the aquatic environment. Dissolved oxygen and pH values were in an optimum range, 11.4 to 6.2 mg/L and 7.0 to 5.3 units, respectively, for maintaining most aquatic fresh-water life.

Major constituent concentrations indicated that sodium, calcium bicarbonate, and chloride constituted most of the dissolved solids at this site. These low concentrations probably reflect a natural source. All other major constituents were present but in extremely low concentrations.

Minor elements, with the exception of iron, were either not detected at all or were detected in low concentrations. Observed concentrations of iron are not considered detrimental to the aquatic environment.

Nutrient concentrations were higher at the Little River sampling site, in general, than at sampling sites in the Spicket or Powwow River systems, but were much lower than concentrations observed at the Beaver Brook site. Total nitrogen values were in the order of 1 mg/L, and total phosphorus concentrations in several samples were in excess of 0.10 mg/L. Nutrients in these concentrations will support and enhance the production of aquatic plants, including algae.

Nutrient concentrations measured in the water samples do not entirely reflect the true condition of this stream with respect to nutrient input and the capability to support plant growth. Ordinarily, water in a stream or lake that supports heavy growth of aquatic plants, as the Little River does, would not be expected to contain the concentrations of nutrients that were present in water samples collected at the sampling site. During the growing season, the nutrients would be almost entirely taken up by the growing plants. The significance of coincident overproduction of weeds and algae and relatively high nutrient concentrations in the water is that a relatively large amount of nitrogen and phosphorus is probably entering from an upstream source. The most probable source of the nutrients is onsite waste-disposal systems in the Town of Plaistow, just upstream from this site. The town is not served by a waste-treatment plant and relies wholly on individual onlot leachfield disposal systems.

Total coliform, fecal coliform, and fecal streptococcal bacteria were present in all of the samples collected at the Little River site. The presence of fecal coliforms and fecal streptocci provide further evidence that domestic waste is entering Little River upstream from the sampling site.

None of the 11 pesticides were detected in water samples or stream-bottom materials at the Little River site. PCB's were also not detected in stream water or bottom materials at this site.

Powwow River Watershed

General water-quality conditions along the Powwow River are excellent compared with the conditions noted in the Beaver, Spicket, and Little River watersheds. Although the shorelines of the five main ponds along the Powwow River are populated, there does not seem to be a related influence on the water-quality conditions of the pond water or the water in the Powwow River. Specific-conductance values, and, thus, dissolved-mineral concentrations, were comparatively low, and dissolved oxygen and pH values were in ranges favorable to maintaining most aquatic fresh-water life. The highest value of specific conductance measured in the study area was in the water of an unnamed tributary to Country Pond and probably reflects instantaneous runoff from an industrial site upstream. The major constituents were present in very low concentrations. The minor elements, with the exception of iron and manganese, were either not detected or were present in very low concentrations. Iron and manganese were present in all of the samples collected, but in relatively low concentrations when compared with concentrations present in samples from the other three watersheds.

Nitrogen and phosphorus were present in all water samples collected along the Powwow River. However, the observed concentrations were relatively low compared with concentrations of either total nitrogen or total phosphorus in most samples from the Beaver, Spicket, and Little watersheds. In spite of these low concentrations of nitrogen and phosphorus in water samples, prolific growth of aquatic weeds was observed in some of the ponds during the summer periods. It was also observed that these ponds do not seem to support a large plankton population during the summer. Apparently, the bottom materials in most of the ponds contain an abundance of nitrogen and phosphorus, which are more available to support the growth of rooted aquatic weeds than floating plants.

Total coliform, fecal coliform, and fecal streptoccal bacteria were present in almost all samples collected along the Powwow River. However, the number of colonies present in most samples was relatively low when compared with the numbers in samples collected in the other watersheds. The COD determination indicated that concentrations of organic compounds in the samples collected along the Powwow River were similar to those values obtained from samples collected in three other watersheds. This was also true of the TOC determinations on samples collected along the Powwow River. The values obtained were similar to the values found in samples in the three other watersheds.

Neither pesticides nor PCB's were detected in water samples collected along the Powwow River. However, dieldrin, in a concentration of 19 ug/kg, was detected in a bottom-material sample collected at the outlet of Country Pond, and heptachlor epoxide was detected in a sample of bottom material collected at the outlet of Powwow Pond. PCB's were detected in bottom materials collected at the outlet of Great Pond (55 ug/kg PCB's) and two samples collected at the outlet of Powwow Pond (18 and 17 ug/kg PCB's).

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