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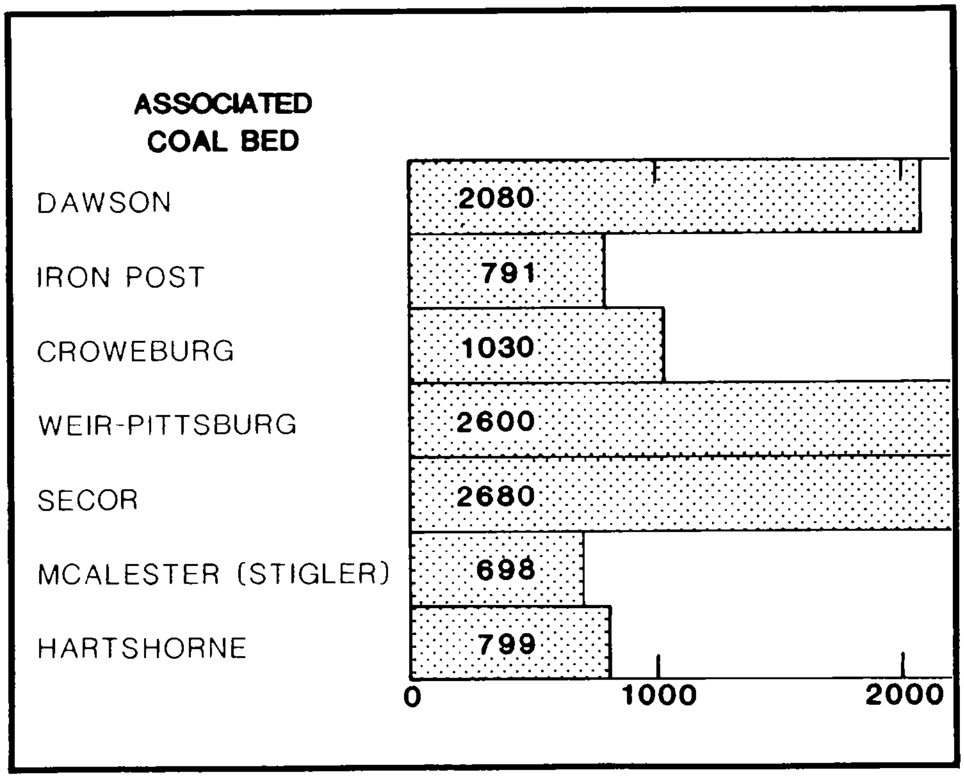
Larry J. Slack, Stephen P. Blumer



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PHYSICAL AND CHEMICAL CHARACTERISTICS OF WATER IN COAL-MINE PONDS, EASTERN OKLAHOMA, JUNE TO NOVEMBER 1977-81

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PHYSICAL AND CHEMICAL CHARACTERISTICS OF WATER IN COAL-MINE PONDS, EASTERN OKLAHOMA, JUNE TO NOVEMBER 1977-81

Larry J. Slack and Stephen P. Blumer

ABSTRACT

Water at 102 sites in 59 coal-mine ponds in eastern Oklahoma was sampled at least twice during June to November 1977-81 to determine temperature, specific conductance, dissolved oxygen, pH, and dissolved sulfate, chloride, iron, and manganese--as part of a study of the hydrology of the Oklahoma coalfield. These determinations show that during June to October water in ponds deeper than ~10 ft was stratified; ponds which had little or no change of temperature with depth generally were shallow or were sampled in early November. Temperature, dissolved oxygen, and pH usually decreased with depth, whereas specific conductance usually increased with depth. Concentrations of dissolved sulfate, chloride, iron, and manganese varied from site to site. Specific conductance, which is a measure of dissolved solids in the water, ranged from 93 to 4,800 μmho/cm at 25°C. Some physical and chemical characteristics of the mine-pond water are related to the coal bed adjacent to the pond. Mean specific-conductance values and dissolved-sulfate concentrations were greatest in ponds associated with mining of the Dawson, Weir-Pittsburg, and Secor coals. Mean dissolved-iron concentrations were greatest in ponds associated with mining of the Dawson, Secor, and Hartshorne coals. Mean dissolved-manganese concentrations were greatest in ponds

associated with mining of the Dawson, Weir-Pittsburg, and Secor coals, but greatly exceeded secondary drinking-water limits regardless of coal bed mined.

INTRODUCTION

The coal-mine ponds in eastern Oklahoma have a total area of ~4,000 acres (Johnson, 1974). The average measured depth of the ponds is ~25 ft; thus, the ponds provide storage for ~100,000 acre-ft of water. These ponds provide habitat for a variety of aquatic and semi-aquatic wildlife. Many of the ponds have been stocked with fish, and some are used for boating and swimming. Water from some of the ponds is used for stock, irrigation, and municipal supply.

Currently (1983), Red Oak (Latimer County) is the only city in the study area to use mine-pond water as a source for drinking water for a community system. Keota (Haskell County) and Gans (Sequoyah County) have used mine-pond water for their community system, but, because of inconsistent quantity, no longer do. An undetermined number of individual households use mine-pond water for domestic supply.

The origin of the coal-mine ponds, especially those formed prior to 1974, is illustrated by Figure 1 and the following generalized description summarized from Johnson (1974). First, a trench, or box cut, is made through the overburden to expose the coal, which is then removed. As each parallel cut is made, the overburden is placed as spoil material into the previously excavated cut. Successive cuts are mined until the overburden thickness becomes so great that the coal can no longer be mined profitably. The final cut leaves an open trench bound by the last spoil pile on one side and the highwall on the other.

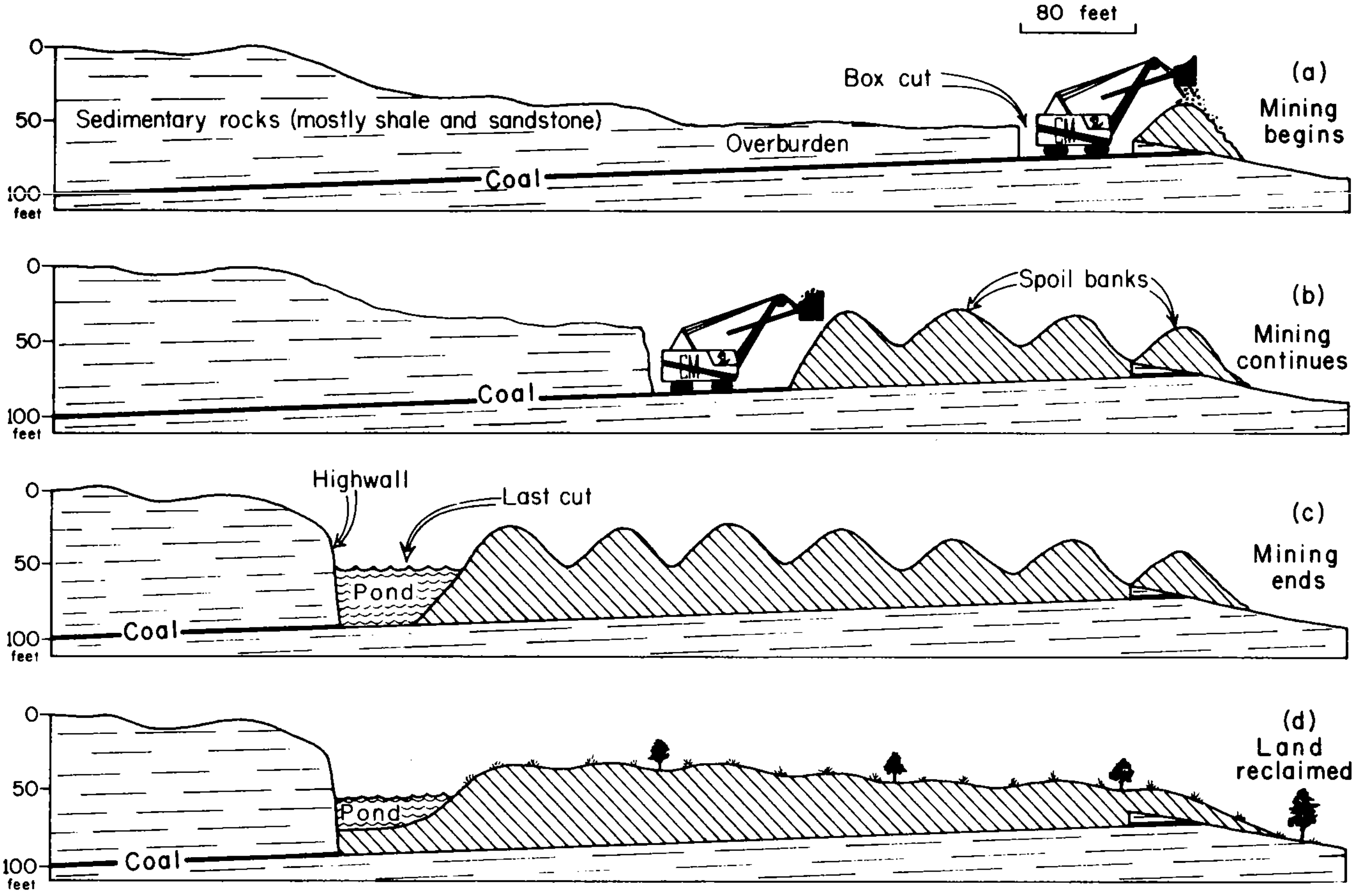


Figure 1.--Schematic sections showing stages of surface mining for coal (from Johnson, 1974).

Coal-mine ponds are formed by precipitation, ground-water seepage, and surface-water inflow partly filling the last cut and other depressions.

Prior to passage of Oklahoma's Open Cut Land Reclamation Act (effective January 1, 1968) and Mining Lands Reclamation Act (June 1971), most mined lands were left as shown in Figure 1C. In areas mined since the passage of the reclamation acts, ridges of spoil are graded, topsoil is replaced, and the area is revegetated by seeding or planting. Revegetation is most successful when the revegetated area is not used for pasture until the plants have become well established.

PURPOSE AND SCOPE

In 1977, the U.S. Geological Survey, in cooperation with the Oklahoma Geological Survey, began collecting data on coal-mine ponds as part of a regional study of the hydrology of the eastern Oklahoma coalfield (Fig. 2). The purpose of this report is to describe the physical and chemical characteristics of water in the eastern Oklahoma coal-mine ponds, based on samples collected from June to November 1977-81, and where possible to relate the water quality to the associated mined coal beds. Fifty-nine mine ponds were selected to represent the major mined beds. Most of the larger ponds were sampled at more than one site. Samples were collected at 102 sites in ponds associated with 7 named coal beds and 1 unnamed coal bed in 14 counties. Detailed maps of site locations are given in Figures 9-57.

Most ponds were sampled at least twice during June to November 1977-81. On-site measurements included temperature, specific conductance, dissolved oxygen, and pH. Measurements for most ponds were made at 2-ft intervals. At depths >30 ft, measurements usually were made at 5-ft intervals.

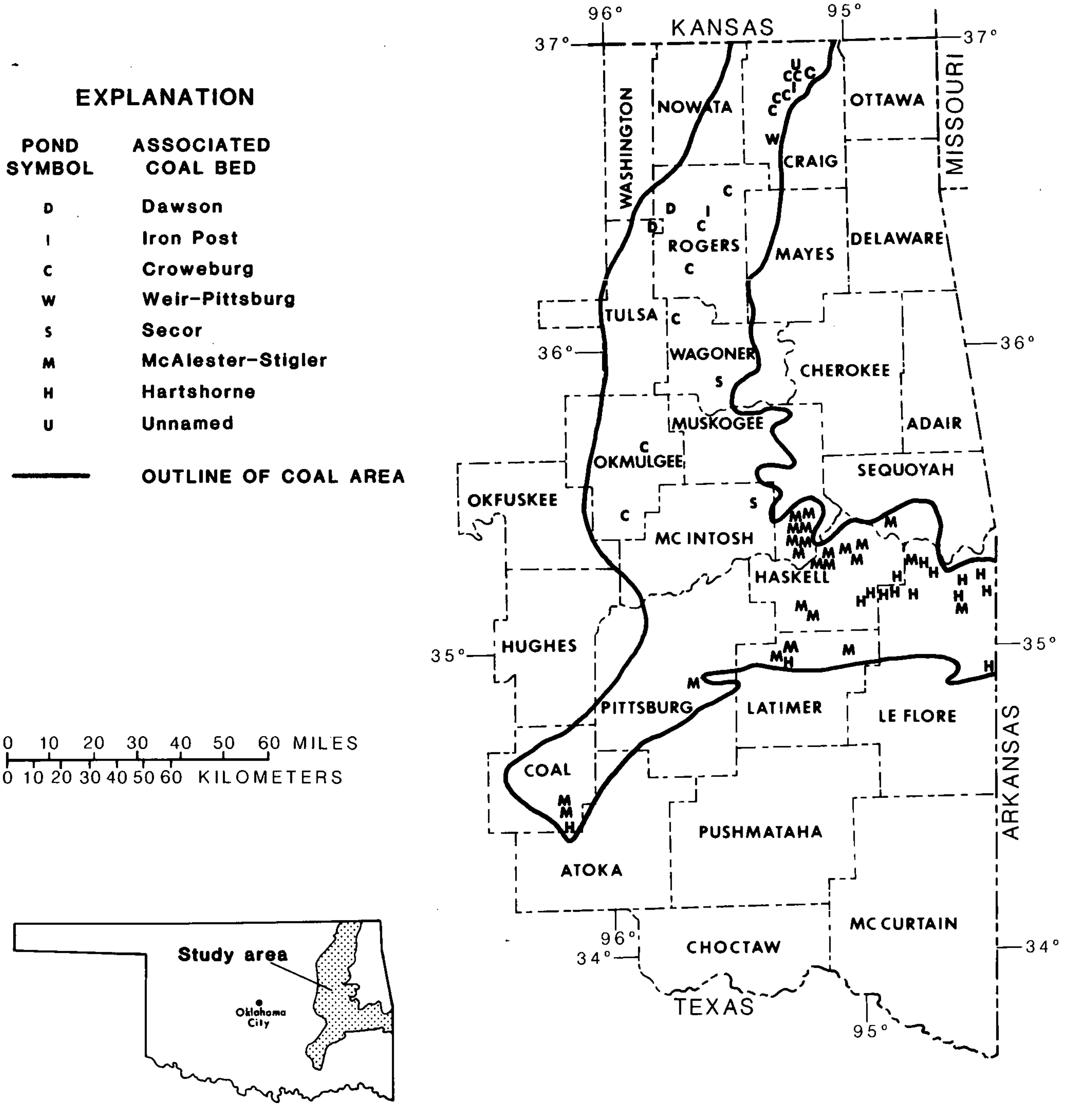


Figure 2.--Study area, location of coal-mine ponds, and associated coal beds.

In the deep ponds, water samples were collected at each site near the bottom, middle, and surface of the pond. Shallow ponds were sampled at only one or two depths. At each depth, two filtered samples were collected--one left untreated for determination of dissolved sulfate and chloride, and the other acidified for determination of dissolved iron and manganese.

ACKNOWLEDGMENTS

Special appreciation is extended to Kenneth S. Johnson, Samuel A. Friedman, William E. Harrison, Kenneth V. Luza, Stephen J. Weber, and Robert M. Powell of the Oklahoma Geological Survey for reviewing this report. Special appreciation is also extended to Stephen J. Weber and the Oklahoma Geological Survey analytical-chemistry staff for performing the laboratory analyses (sulfate, chloride, iron, and manganese) included in this report.

SITE-IDENTIFICATION SYSTEMS

Each site is identified by the following systems:

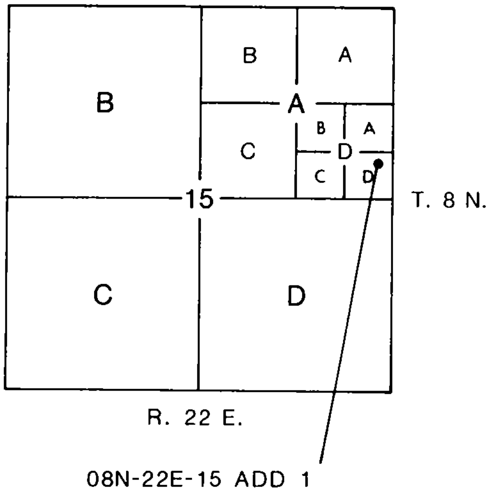
1) Map-index number: an order number assigned to the mine-pond sites after their geographic-coordinate (latitude-longitude) numbers were ranked from smallest to largest. (Table 1.)

2) Station number: determined by geographic coordinates at the site location. The site with map-index number 24 has a latitude of 35°10'03" N. and longitude of 94°57'50" E. and is identified as 351003094575001. The final two digits (01) represent the sequential number of a site at the specific coordinates.

3) Station name: based on township, range, section, mine pond, site, and quadrangle.

The standard method of giving location by fractional section, section, township, and range is replaced by the method illustrated below. The location of site 24 normally would be described as SE¼SE¼NE¼ sec. 15, T08N, R22E. The method used in this report reverses the order and indicates quarter subdivisions of the section by letters. By this method, the township-range-section part of the station name for site 24 is given as 08N-22E-15 ADD 1. The final digit (1) is the sequential number of a site within the smallest fractional subdivision.

Mine ponds are numbered sequentially from north to south in each 7.5' or 15' quadrangle. Within each pond, individual sites also are numbered sequentially. By this method, the mine-pond, site, quadrangle part of the station name for site 24 is given as pond 1, site 1, McCurtain Quadrangle.



STRATIGRAPHY OF THE STUDY AREA

The mine ponds sampled in the Oklahoma coalfield are located in pits associated with bituminous coal beds of Pennsylvanian age (Fig. 3). The northeastern part of the Oklahoma coalfield is in the "northeast shelf area," which contains sandstone, shale, and limestone, and the Dawson, Iron Post, Croweburg, Weir-Pittsburg, and Secor coals. Shelf-area rocks contain more limestone than the coal-bearing rocks of the Arkoma basin (Friedman, 1978a). The southern part of the coalfield is in the Arkoma basin--an eroded structural and depositional basin that contains sandstone, siltstone, shale, and the Secor, McAlester (Stigler), and Upper and Lower Hartshorne coals.

Other named coals in Oklahoma are omitted from the discussion because none of the sampled mine ponds are in contact with them. At least 20 named coals and several unnamed coals have been mined commercially in eastern Oklahoma during the last 100 years (Friedman, 1983).

The Dawson coal (Rogers, Tulsa, and Washington Counties) is in the middle part of the Seminole Formation. The Dawson coal has a mean sulfur content of 4.6% (Friedman, 1974). The Dawson, Weir-Pittsburg, and Secor coals have the largest sulfur content of the seven named coals in this study.

The Iron Post coal (Craig, Nowata, and Rogers Counties) is the upper principal coal of the Senora Formation, which comprises a series of sandstones, shales, coal, and usually a limestone capping the formation. The Iron Post coal has a mean sulfur content of 4.0% (Friedman, 1974).

The Croweburg coal (Craig, McIntosh, Okfuskee, Okmulgee, Rogers,

SYSTEM	SERIES	GROUP	FORMATION (Thickness in feet)	COAL
PENNSYLVANIAN	MISSOURIAN	SKIATOOK	Coffeyville Formation	CEDAR BLUFF
			Checkerboard Limestone 1 - 5	
			Seminole Formation 10 - 240	Tulsa
	DESMOINESIAN	MARMATON	**Holdenville Shale 40 - 250**	DAWSON
			Lenapah Limestone 50	
			Nowata Shale 110	
			Oologah Limestone 30	
			Labette Shale 120	Lexington
			Fort Scott Limestone 0 - 35	
		CABANISS	**Senora Formation 150 - 900**	IRON POST Bevier CROWEBURG FLEMING MINERAL (MORRIS) Tebo WEIR-PITTSBURG
			Stuart Shale 0 - 375	
			Thurman Sandstone 0 - 250	
		KREBS	**Boggy Formation 125 - 2,140**	BLUEJACKET PETERS CHAPEL SECOR RIDER SECOR LOWER WITTEVILLE
			Savanna Formation 180 - 2,500	DRYWOOD ROWE CAVANAL
			McAlester Formation 140 - 2,830	Upper McAlester MC ALESTER (STIGLER)
			Hartshorne Sandstone 3 - 316	HARTSHORNE {UPPER LOWER

(Modified from Friedman, 1974)

Figure 3.--Generalized geologic column showing sequence of coal beds of Pennsylvanian age in Oklahoma. Coal beds containing identified coal resources are shown in capitals.

Tulsa, and Wagoner Counties), unlike most of the other coal beds in the northeast Oklahoma shelf, has a mean sulfur content of 1.9% (Friedman, 1974). The Croweburg coal occurs about in the middle of the Senora Formation.

The Weir-Pittsburg coal (Craig, Mayes, Rogers, and Wagoner Counties) is the lowest coal of the Senora Formation and has a mean sulfur content of 4.8% (Friedman, 1974).

The Secor coal (McIntosh, Muskogee, Pittsburg, and Wagoner Counties) is the upper principal coal of the Boggy Formation, which comprises alternating shales and sandstones with local beds of blocky red clay. The Secor coal has the greatest mean sulfur content, 4.9% (Friedman, 1974), of the seven named coals in this study.

The Stigler coal of Haskell and Muskogee Counties is correlated with the McAlester coal of Coal, Pittsburg, northern Latimer, and Le Flore Counties (Friedman, 1983). The coal bed, usually 3-5 ft thick, is found 350-400 ft below the top of the McAlester Formation, which is composed mostly of shale and sandstone. The McAlester (Stigler) coal has a mean sulfur content of 1.8% (Friedman, 1974). The McAlester (Stigler) coal generally has many of the same impurities as the Hartshorne coal.

The Hartshorne coal, commonly 3-5 ft thick, has been mined in Atoka, Coal, Pittsburg, Latimer, Haskell, Le Flore, and Sequoyah Counties. In Atoka, Coal, and Pittsburg Counties, the bed is divided into the Upper and Lower Hartshorne coals (Fig. 3). The Upper Hartshorne coal is at the top of the Hartshorne Sandstone; the Lower Hartshorne coal is ~25 ft lower. East of Pittsburg County, the coals converge and in northernmost Haskell, Sequoyah, and Le Flore

Counties are no longer distinguished as two separate beds. Hartshorne coal with thin layers of shale and pyrite has a mean sulfur content of 1.8% (Friedman, 1974).

PHYSICAL AND CHEMICAL CHARACTERISTICS OF WATER IN COAL-MINE PONDS

The physical and chemical characteristics of the coal-mine pond water determined for this study included water temperature, specific conductance, dissolved oxygen, pH, and dissolved sulfate, chloride, iron, and manganese. Variations in degree of mixing of the water in the ponds caused a wide range of measured values for these properties and constituents from site to site within a pond and with depth at a single site. Profiles of temperature, specific conductance, dissolved oxygen, and pH for each sampling site and date are included in Figures 58-159. Statistical data (maximum, minimum, mean, and number of determinations) for selected physical and chemical characteristics for each of the 102 sites are summarized in Tables 1-4. Statistical data (number of analyses, standard deviation, and percentile) for selected characteristics for all 102 sites combined are presented in Table 5.

Dissolved sulfate and chloride are reported in milligrams per liter (mg/L) and dissolved iron and manganese are reported in micrograms per liter (µg/L). 1 mg/L = 1,000 µg/L.

Temperature

During sampling in the summer months, surface water heated by the sun was less dense and was not mixed well with the underlying colder, denser water. Lack of mixing, especially in the ponds deeper than ~10 ft, resulted in thermal stratification of the water. A trend of lower temperatures with increased depth was determined for most of the ponds. However, below a depth of ~30 ft the temperature usually showed no further change with depth.

From June to October, many Oklahoma coal-mine ponds were poorly mixed, and surface temperatures were as much as 23.5°C greater than bottom temperatures. This variation in temperature with depth was greatest in the ponds deeper than ~10 ft sampled during July and August. For example, the pond at site 24 was 42 ft deep and had a surface-to-bottom temperature difference of ~17°C in July 1977 and 19°C in August 1979. The pond at site 5 was 50 ft deep and had a temperature difference of 23.5°C. Typical temperatures of a 20-ft deep pond ranged from ~30°C at the surface to ~15°C at the bottom, as at sites 25 and 35 (see Figs. 62, 81, 82, 92).

Ponds that had little or no change of temperature with depth generally were shallow or were sampled in early November, when surface cooling causes ponds to become well mixed.

Specific Conductance

Specific conductance is a measure of the ability of a water to conduct an electrical current. Specific conductance is the reciprocal of the resistance, in ohms, measured between opposite faces of a cube with dimensions of 1 cm of an aqueous solution and is expressed in micromhos per centimeter at 25°C.

The ability of water to conduct an electrical current depends on the presence of ions (charged particles) in solution. As ion concentrations increase, conductance of the solution increases. Because of this relationship and the fact that specific-conductance determinations are relatively inexpensive and can be made quickly, they are widely used to estimate concentrations of individual ions and of dissolved solids in water.

The relationship between concentrations of ions and specific conductance is linear in dilute solution. As a solution becomes more concentrated, the relationship deviates from a straight line as further increases in concentration cause progressively smaller increases in specific conductance. The slope of the straight-line part of the curve depends on the dominant ions present in the solution and differs for natural waters of different chemical type. Because changes in concentrations of the dominant ions would obscure changes in concentrations of minor ions (such as iron and manganese), relationships between specific conductance and concentrations of minor ions are unreliable and highly variable.

The specific conductance of the studied coal-mine ponds ranged from 93 to 4,800 μmho, based on 1,292 measurements of 102 sites (Table 5). This variation can be partly attributed to precipitation. Periods of increased precipitation dilute the ponds, resulting in a decrease in specific conductance. Sulfate is the principal ion in mine-pond water. Consequently, the specific conductance of mine-pond water varies from pond to pond in direct proportion to sulfate concentration.

The largest mean specific conductances were in ponds resulting from mining of the Dawson, Weir-Pittsburg, and Secor coals (Fig. 4), which have mean sulfur contents of 4.6-4.9%--the greatest for the seven named coals in this report. The smallest specific conductances were for ponds associated with the McAlester (Stigler) coal. The mean specific conductances of the mine ponds associated with each of the coal beds are: Dawson, 2,080 μmho; Iron post, 791 μmho; Croweburg,

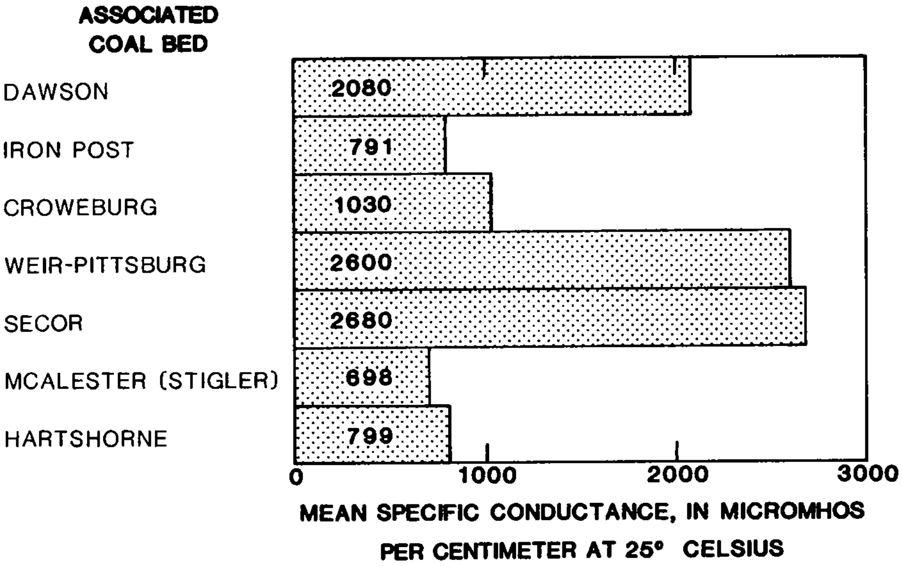


Figure 4.--Mean specific conductance in coal-mine pond water associated with each coal bed.

1,030 μmho; Weir-Pittsburg, 2,600 μmho; Secor, 2,680 μmho; McAlester (Stigler), 698 μmho; and Hartshorne, 799 μmho (see Fig. 4 and the pH and Dissolved Sulfate sections).

The specific conductance generally increased with depth for ~40% of the ponds, regardless of the coal bed that was mined, indicating that ionic concentration in those ponds also increased with depth. The greatest variation in specific conductance with depth was at site 24, with a specific conductance of 2,760 μmho at the surface (depth 1 ft) and 4,440 μmho at the bottom (depth 42 ft) in July 1977 (Fig. 81).

Dissolved Oxygen

The dissolved-oxygen concentration of the coal-mine ponds usually decreased with depth during June to early October. Thermal stratification resulted in warmer, less-dense water at the surface, insulating the colder, more-dense water below, preventing it from coming in contact with atmospheric oxygen. The largest decreases in dissolved oxygen with depth occurred at site 8 and site 57 (August 1979), with differences of 12.4 and 11.8 mg/L, respectively, from the surface to the bottom. By November, usually little or no variation in dissolved-oxygen concentration with depth was detected (Figs. 65, 114).

pH

The pH of a solution is the negative base-10 log of the hydrogen-ion activity and is approximately equal to the hydrogen-ion (H^{+1}) concentration expressed in moles per liter. The pH of pure water at 25°C is 7.0. In natural water, the pH usually is within the range 6.0-8.5, depending upon equilibria reactions of species in the water (Hem, 1985).

In coal-mine ponds, pH is governed by oxidation of sulfide minerals and subsequent buffering by carbonate minerals. Iron sulfide minerals, usually pyrite (FeS_2) and marcasite (FeS_2), exposed in spoil piles and highwalls of strip pits, react with oxygen (O_2) and water (H_2O) to produce sulfuric acid (H_2SO_4) and ferrous sulfate ($FeSO_4$), with a corresponding decrease in pH of the solution:

$$2FeS_2 + 7O_2 + 2H_2O \rightarrow 2FeSO_4 + 2H_2SO_4 \rightarrow 2Fe^{+2} + 4SO_4^{-2} + 4H^{+1}.$$

The iron is then oxidized from the ferrous (Fe^{+2}) to the ferric (Fe^{+3}) state:

$$4FeSO_4 + O_2 + 2H_2SO_4 \rightarrow 2Fe_2(SO_4)_3 + 2H_2O.$$

Hydrolysis occurs, and the ferric sulfate [$Fe_2(SO_4)_3$] is converted to ferric hydroxide [$Fe(OH)_3$], a reddish-brown precipitate commonly called "yellow boy," and to more sulfuric acid.

The oxidation reactions are bacterially mediated and complex (Stumm and Morgan, 1981; and Drever, 1982). The rate-determining (slowest) step is the oxidation of ferrous iron (Fe^{+2}) to ferric iron (Fe^{+3}). Even at a pH of 3, the preceding reaction has a half-time of ~1,000 days (Stumm and Morgan, 1981).

The net result, whether the pyrite is oxidized directly by oxygen or is dissolved and then oxidized, is that two molecular weights (or four equivalent weights) of sulfuric acid are released for each molecular weight of the original pyrite. If the concentration of sulfuric acid (as H^+ in milliequivalents per liter) is greater than carbonate and bicarbonate, the solution is acidic (pH <7). However, if concentrations of carbonate and bicarbonate (in milliequivalents per liter) are greater than that of the hydrogen ions, the solution is alkaline, or basic (pH >7).

If the pH in coal-mine ponds were dependent only upon the equilibria reactions of sulfate and ferrous iron, pH also could be correlated to the mined coal bed and the impurities present, especially pyrite. However, in the Oklahoma coal region, the median pH for the ponds associated with the Dawson, Iron Post, Croweburg, Weir-Pittsburg, McAlester (Stigler), and Hartshorne coals showed little variation (7.4-7.8; Table 6). The only significant difference was for the ponds associated with the Secor coal.

Sites 63, 64, and 65 (pond 1, Warner NW Quadrangle, Fig. 44) had a pH of 3.2-3.3 in June 1980. Sites 68 and 69 (pond 1, Red Bird Quadrangle, Fig. 46) had a pH of 7.3-8.1 in June 1980. Both the Warner and Red Bird ponds were identified as being associated with the Secor coal. The median pH for the ponds associated with the Secor coal was 3.3. Excluding the Warner pond, the median pH for the ponds associated with the Secor coal was 7.7, virtually the same as for the ponds associated with all other coal beds. The pH of water in the coal-mine ponds generally decreased with depth.

Dissolved Sulfate

Pyrite (FeS_2) contains most of the sulfur in Oklahoma coals (Friedman, 1974). The anaerobic conditions under which the coal was deposited was a favorable environment for the formation of pyrite. When the pyrite is later exposed to aerated water it is oxidized, producing sulfate ions in the water. (See also section on pH.)

Mean dissolved-sulfate concentrations were greatest for the water in ponds associated with the Dawson, Weir-Pittsburg, and Secor coal beds, which, of the seven named coals, also had the greatest sulfur content. (Plots of the mean concentrations of dissolved sulfate, chloride, iron, and manganese for the ponds associated with each of the coal beds are shown in Figures 5-8.) Sulfate concentrations were least for water associated with the McAlester (Stigler) and Hartshorne coals. Pond water associated with the Dawson, Weir-Pittsburg, and Secor coal beds had mean dissolved-sulfate concentrations of 900, 1,700, and 1,700 mg/L, respectively. The greatest increase in dissolved-sulfate concentration with depth was 1,200 mg/L at site 51.

More than 25% of the sulfate concentrations in water-quality samples from the mine-pond sites exceeded the 250-mg/L limit in the Secondary Drinking Water Regulations (U.S. Environmental Protection Agency, 1979). The sulfate concentrations ranged from 3.7 to 2,300 mg/L. The median sulfate concentration was 210 mg/L (Table 5).

Sulfate affects the taste of water and may produce laxative effects on some people but acclimation generally is rapid. Waters with large concentrations of sulfate used to irrigate crops grown on clayey soils may decrease soil permeability, but the sulfate itself has little effect on most plants.

Dissolved Chloride

The most common source of chloride in natural waters is sedimentary rocks. Fine-grained marine shales and clays commonly contain sodium chloride from sea water. As the ocean regressed, sodium accumulated in the form of sodium chloride crystals or as a brine in the sedimentary layers (Hem, 1985). Ground water permeating these deposits may leach the salts from the rocks or contact the brine. The chloride in most coal-mine ponds probably originated from leaching of sodium chloride from the surrounding shale, clay, and spoils by ground water and surface runoff. Disposal of brines from oil-field operations

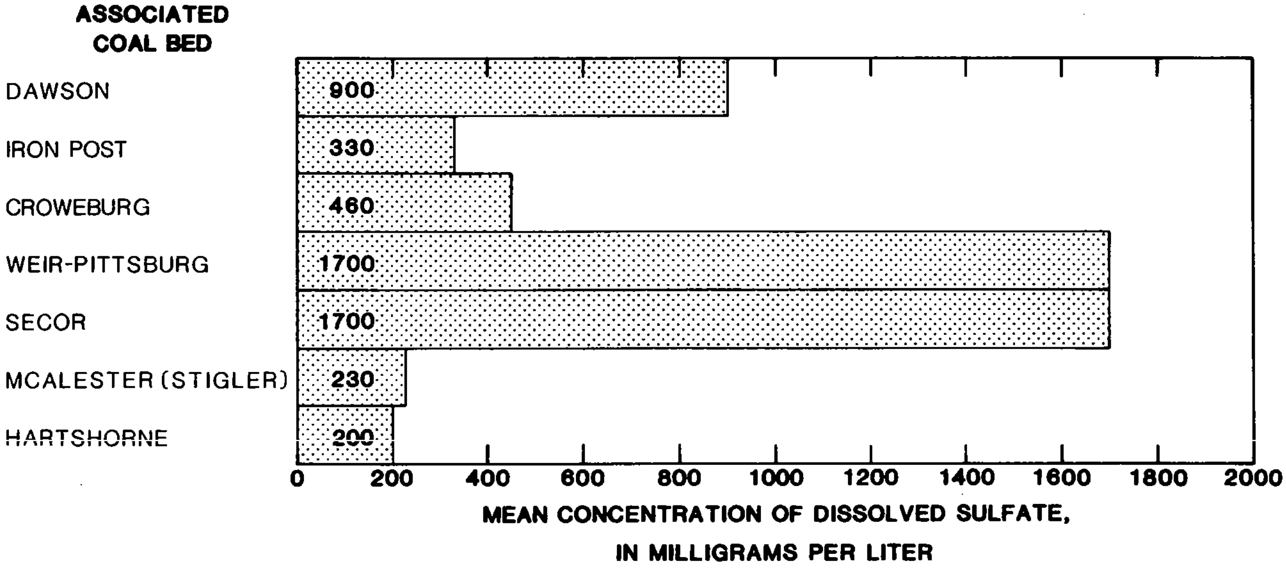


Figure 5.--Mean dissolved-sulfate concentration in coal-mine pond water associated with each coal bed.

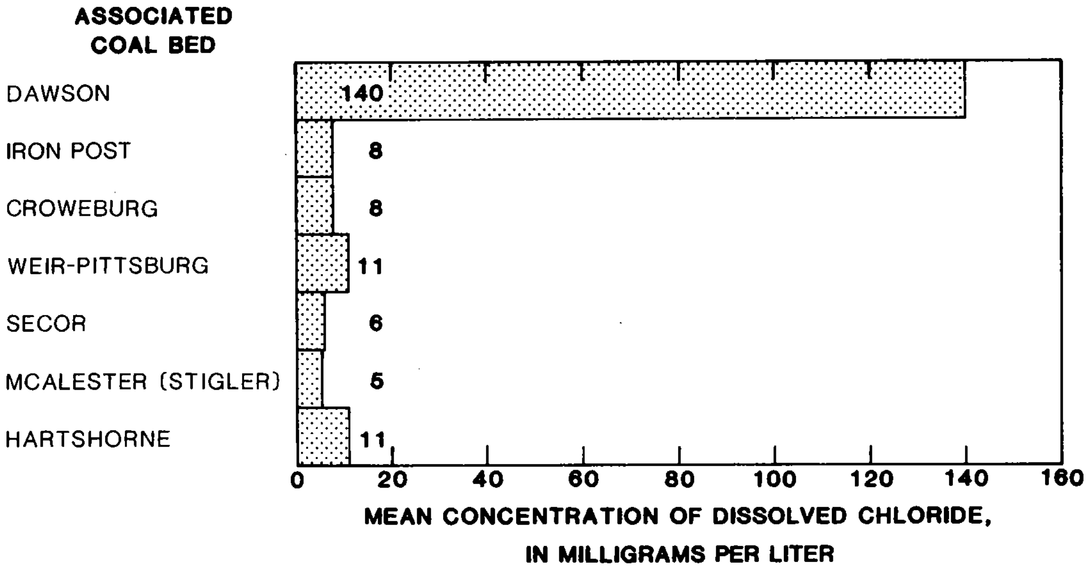


Figure 6.--Mean dissolved-chloride concentration in coal-mine pond water associated with each coal bed.

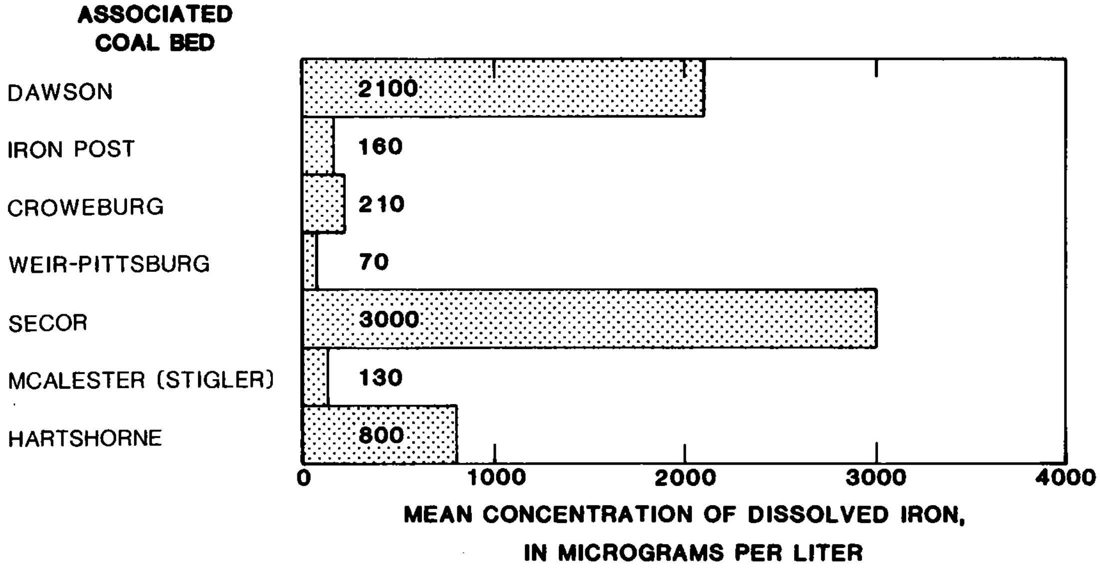


Figure 7.--Mean dissolved-iron concentration in coal-mine pond water associated with each coal bed.

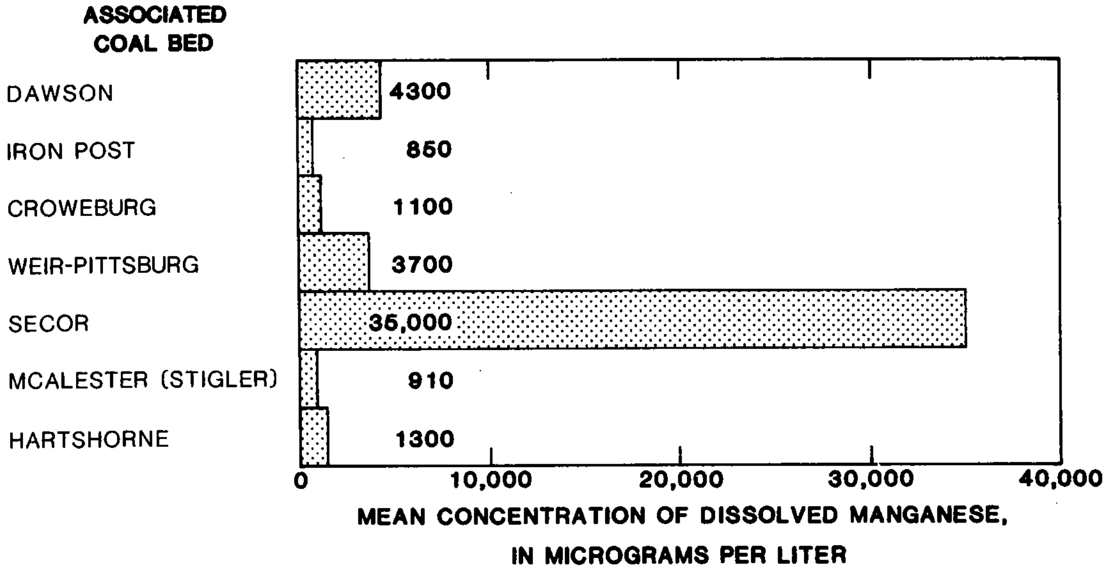


Figure 8.--Mean dissolved-manganese concentration in coal-mine pond water associated with each coal bed.

in ponds has occurred, but this probably has not been too common.

The mean concentration of dissolved chloride in the mine ponds was much less than the limit of 250 mg/L in the Secondary Drinking Water Regulations (U.S. Environmental Protection Agency, 1979). The mean dissolved-chloride concentration was 140 mg/L for water in mine ponds associated with the Dawson coal. For mine-pond water associated with all the other coal beds, the mean concentration of chloride was $\leq$11 mg/L (Fig. 6).

The dissolved-chloride concentration ranged from 0.1 to 240 mg/L for all 378 analyses of samples collected at the 102 mine-pond sites. For 90% of the analyses the chloride concentration was $\leq$13 mg/L. The median was 4.0 mg/L (Table 5).

Dissolved Iron

Iron is abundant in soils and sedimentary rocks both as ferrous (Fe^{+2}) and ferric (Fe^{+3}) iron (see pH section). Sources of iron in natural waters generally include soils enriched with organic material and iron-bearing minerals, chiefly sulfides, carbonates, and silicates. Iron is an essential element in both plant and animal metabolism. Dissolved-iron concentrations exceeding 300 µg/L impart an objectionable taste to water, cause staining and generally limit the water's use for many domestic and industrial purposes (U.S. Environmental Protection Agency, 1979).

Pyrite (FeS_2), a mineral commonly occurring in coal, contains iron in its reduced (ferrous) form. When exposed to aerated water, the pyrite is oxidized directly by oxygen or is dissolved and then oxidized. Conversely, ferric iron is dissolved in a reducing environment such as that at the bottom of a stratified lake.

The dissolved-iron concentration in the coal-mine ponds sampled in Oklahoma usually was small; 75% of the iron concentrations were ≤90 µg/L (Table 5). More than 10% of the dissolved-iron concentrations exceeded the 300-µg/L limit. The median for 357 samples was 40 µg/L. The greatest concentration (10,000 µg/L) was at site 77 (Dawson coal bed).

The mean concentration of dissolved iron was greatest in those ponds associated with the Dawson, Secor, and Hartshorne coal beds (Fig. 7). The mean dissolved-iron concentration for sampled ponds associated with the Dawson was 2,100 µg/L; Secor, 3,000 µg/L; and Hartshorne, 800 µg/L. The mean dissolved-iron concentrations for water in ponds associated with the Iron Post, Croweburg, Weir-Pittsburg, and McAlester (Stigler) coals were all less than the 300-µg/L secondary limit for drinking water (U.S. Environmental Protection Agency, 1979).

Dissolved Manganese

Hydrous manganese and iron oxides exist almost everywhere in soils and sediments where conditions are not strongly reducing. Manganese generally occurs as poorly crystallized birnessite or todorokite (Drever, 1982). Hydrous manganese oxides have extremely large adsorption capacities for heavy metals. In many minerals, manganese commonly substitutes for iron.

The limited mixing and thermal stratification commonly associated with coal-mine ponds create a reducing environment at the bottom of the ponds. In this environment, manganese oxides are dissolved. Therefore, an increase in dissolved manganese with depth would be expected. The increase occurs in many of the eastern Oklahoma coal-mine ponds. For several ponds, the concentration of dissolved manganese varied as much as several thousand micrograms per liter from the surface to the bottom. The mean concentration of dissolved manganese was greatest in those ponds associated with the Dawson (4,300 µg/L), Weir-Pittsburg (3,700 µg/L), and Secor (35,000 µg/L) (Fig. 8).

Dissolved-manganese concentrations exceeding the 50-µg/L limit in the Secondary Drinking Water Regulations (U.S. Environmental Protection Agency, 1979) impart an objectionable taste to water, cause staining, and limit the water's use for many domestic and industrial purposes. Manganese is readily removed by aeration or filtering and does not have significant effect on most irrigated crops.

The mean dissolved-manganese concentrations were least for waters associated with the Iron Post and McAlester (Stigler) coals, and greatest for waters associated with Dawson, Weir-Pittsburg, and Secor coals, but greatly exceeded secondary limits regardless of the coal bed mined (Fig. 8). Dissolved-manganese concentrations ranged from 0 to 56,000 µg/L in the 356 water-quality samples (Table 5). The median concentration was 80 µg/L. Consequently, more than 50% of the measured dissolved-manganese concentrations in the mine-pond water exceeded the 50-µg/L limit.

SUMMARY AND CONCLUSIONS

Water at 102 sites in 59 coal-mine ponds in eastern Oklahoma was sampled, generally at least twice, during June to November 1977-81 to determine temperature, specific conductance, dissolved oxygen, pH, and dissolved sulfate, chloride,iron, and manganese. These determinations indicate that, during June to October, water in the deeper ponds was stratified; temperature, dissolved oxygen, and pH usually decreased with depth, whereas specific conductance usually increased with depth. The variation of temperature with depth was greatest during July and August. Ponds which had little or no change of temperature with depth generally were shallow or were sampled in early November.

Concentrations of dissolved sulfate, chloride, iron, and manganese varied with depth and from site to site. Specific conductance ranged from 93 to 4,800 µmho/cm at 25°C. The physical and chemical characteristics of the pond water are related to the coal bed in which the pond is located. Mean specific-conductance values and concentrations of dissolved sulfate were greatest for the water in ponds associated with the Dawson, Weir-Pittsburg, and Secor coals. Mean concentrations of dissolved iron were greatest in ponds associated with mining of the Dawson, Secor, and Hartshorne coals.

More than 25% of the dissolved-sulfate concentrations, more than 10% of the dissolved-iron concentrations, and more than 50% of the dissolved-manganese concentrations in the water-quality samples exceeded the limit in the Secondary Drinking Water Regulations. The pH of the mine-pond water generally is in the range for most natural waters.

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TABLE 1. -- Maximum values for specific conductance, pH, and concentrations of dissolved sulfate, chloride, iron, and manganese for each site

(micromhos, micromhos per centimeter at 25° Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter)

Map-index number (Figs. 9-57)	Station Number	Station Name (Township - range - section and mine pond - site - quadrangle)	Specific conductance (micromhos)	pH (units)	Sulfate (mg/L)	Chloride (mg/L)	Iron (µg/L)	Manganese (µg/L)
1	342353096135301	02S-10E-11 BCB 2 POND 2 SITE 2 LEHIGH	400	7.3	33	3.0	80	2000
2	342358096135701	02S-10E-11 BCB 1 POND 2 SITE 1 LEHIGH	400	7.5	84	6.0	3600	3800
3	342807096133301	01S-10E-14 CAB 1 POND 1 SITE 1 LEHIGH	510	8.3	140	6.0	20	180
4	343106096133801	01N-10E-35 BBD 1 POND 1 SITE 1 COALGATE	190	7.6	19	2.0	3400	4500
5	345403094271301	05N-27E-16 DDC 1 POND 1 SITE 1 BATES	1810	9.0	60	9.0	70	4900
6	345440095404701	05N-15E-14 DDD 1 POND 1 SITE 1 KREBS	1650	7.2	16	3.0	490	2000
7	345506095190001	05N-19E-08 CAC 1 POND 1 SITE 1 WILBURTON	1070	6.8	59	85	50	50
8	345636095185601	06N-19E-32 DDD 1 POND 3 SITE 1 WILBURTON	990	8.9	260	4.0	60	350
9	345641095190301	06N-19E-32 DDB 1 POND 2 SITE 1 WILBURTON	785	8.9	260	4.0	10	10
10	345911095035101	06N-21E-14 CCD 1 POND 1 SITE 1 RED OAK NE	540	8.7	76	9.0	1900	5400
11	345915095033401	06N-21E-14 DCB 1 POND 1 SITE 2 RED OAK NE	300	8.2	28	4.0	60	110
12	345921095031801	06N-21E-14 DDB 1 POND 1 SITE 3 RED OAK NE	490	8.5	60	6.0	160	3100
13	350643095130001	07N-20E-05 ABC 1 POND 1 SITE 2 KINTA	466	8.2	63	3.2	40	130
14	350645095123401	07N-20E-05 AAD 1 POND 1 SITE 3 KINTA	517	8.3	63	2.4	310	2600
15	350645095124701	07N-20E-05 AAC 1 POND 1 SITE 1 KINTA	497	8.3	63	3.0	40	20
16	350702094350201	08N-26E-32 CCC 1 POND 1 SITE 1 POTEAU EAST	450	9.4	130	2.0	90	2200
17	350805095141701	08N-20E-30 CAC 2 POND 2 SITE 2 SANS BOIS	753	8.4	180	12	180	620
18	350805095142101	08N-20E-30 CAC 1 POND 2 SITE 1 SANS BOIS	794	8.4	180	10	110	400
19	350907094355001	08N-26E-19 DAB 1 POND 3 SITE 3 SPIRO	480	6.6	34	12	1500	70
20	350907094585001	08N-22E-22 CBB 1 POND 3 SITE 1 MCCURTAIN	1180	8.6	180	13	110	1900
21	350911094470901	08N-24E-16 CCD 1 POND 3 SITE 1 BOKOSHE	210	7.3	28	3.0	7100	6000
22	350913094351801	08N-26E-20 BDB 1 POND 3 SITE 1 SPIRO	480	8.5	30	13	1700	400
23	350918094352701	08N-26E-20 ACA 1 POND 3 SITE 2 SPIRO	480	8.5	29	13	360	30
24	351003094575001	08N-22E-15 ADD 1 POND 1 SITE 1 MCCURTAIN	4440	6.3	1600	56	1100	8000
25	351037094553001	08N-23E-07 CCA 1 POND 2 SITE 1 MCCURTAIN	1140	8.4	1100	10	40	720
26	351049094290701	08N-27E-08 CBB 1 POND 1 SITE 1 HACKETT	685	7.4	300	3.0	20	140
27	351130094520301	08N-23E-03 CDA 1 POND 1 SITE 1 BOKOSHE	970	8.4	250	7.0	490	13600
28	351230094340201	09N-26E-32 DAA 1 POND 2 SITE 1 SPIRO	215	8.1	12	4.0	8100	3400
29	351247094494801	09N-23E-36 BCB 1 POND 2 SITE 1 BOKOSHE	970	8.0	250	6.0	6600	4900
30	351343094300701	09N-26E-25 ABD 1 POND 1 SITE 1 SPIRO	375	8.3	50	11	600	10000
31	351436094420901	09N-25E-19 BAC 1 POND 1 SITE 1 PANAMA	4800	8.4	350	5.0	160	3300
32	351454095113301	09N-20E-16 DCB 1 POND 1 SITE 1 SANS BOIS	335	7.9	25	3.0	40	4100
33	351517095095801	09N-20E-14 BCC 1 POND 3 SITE 2 STIGLER WEST	450	8.8	40	7.0	760	5000
34	351517095121501	09N-20E-17 ADD 1 POND 2 SITE 2 STIGLER WEST	615	8.6	66	4.0	40	310
35	351518095095001	09N-20E-14 BCA 1 POND 3 SITE 1 STIGLER WEST	340	8.8	39	13	90	3300
36	351522095122201	09N-20E-17 ADB 1 POND 2 SITE 1 STIGLER WEST	685	8.5	78	4.0	30	6500
37	351602094435201	09N-24E-11 DBA 1 POND 1 SITE 1 MULDROW SW	1700	8.3	700	8.0	80	6100
38	351612094480301	09N-24E-07 ADB 1 POND 1 SITE 1 R.S.KERR DAM	1620	8.3	600	8.0	30	110
39	351632095003401	09N-22E-06 DDD 1 POND 2 SITE 1 STIGLER EAST	191	7.2	11	6.3	1800	5700
40	351925095034701	10N-21E-22 DAD 1 POND 1 SITE 1 STIGLER EAST	1380	8.3	550	8.0	2200	4400
41	352001094583101	10N-22E-16 DDD 1 POND 1 SITE 1 KEOTA	380	8.0	48	22	60	20
42	352001094583501	10N-22E-16 DDC 1 POND 1 SITE 2 KEOTA	475	8.0	48	21	180	4000
43	352001094583901	10N-22E-16 DDC 2 POND 1 SITE 3 KEOTA	360	7.9	49	20	90	10
44	352054095142601	10N-19E-12 DDD 1 POND 1 SITE 3 STIGLER WEST	940	8.0	190	13	640	6400
45	352100095142301	10N-19E-12 DDA 2 POND 1 SITE 2 STIGLER WEST	1080	8.4	220	2.0	940	22000
46	352105095142301	10N-19E-12 DDA 1 POND 1 SITE 1 STIGLER WEST	490	8.0	130	5.0	50	140
47	352222095150501	10N-19E-01 BDB 1 POND 1 SITE 1 PORUM	970	8.3	230	3.0	20	20
48	352231095145001	10N-19E-01 ABC 1 POND 3 SITE 2 HOLT MOUNTAIN	1030	8.2	310	3.0	580	3700
49	352237095143601	10N-19E-01 ABC 1 POND 3 SITE 1 HOLT MOUNTAIN	1400	8.2	430	3.0	1300	8700
50	352513094523201	11N-23E-16 DCC 1 POND 1 SITE 1 VIAN	944	8.2	340	7.0	60	1400

TABLE 1. -- Maximum values for specific conductance, pH, and concentrations of dissolved sulfate, chloride, iron, and manganese for each site (continued)

Map-index number (Figs. 9-57)	Station Number	Station name (Township - range - section and mine pond - site - quadrangle)	Specific conductance (micromhos)	pH (units)	Sulfate (mg/L)	Chloride (mg/L)	Iron (μg/L)	Manganese (μg/L)
51	352518095134601	11N-20E-18 DCC 1 POND 2 SITE 2 HOLT MOUNTAIN	2550	8.8	1500	12	50	510
52	352519094522501	11N-23E-16 DCA 1 POND 1 SITE 2 SALLISAW	991	8.4	350	4.7	20	300
53	352519095135001	11N-20E-18 CDD 2 POND 2 SITE 3 HOLT MOUNTAIN	900	8.1	300	3.7	--	--
54	352520095135301	11N-20E-18 CDD 1 POND 2 SITE 1 HOLT MOUNTAIN	2580	8.9	640	17	60	540
55	352521095140601	11N-20E-18 CCA 1 POND 1 SITE 2 HOLT MOUNTAIN	2200	8.6	770	6.0	530	10000
56	352521095142101	11N-19E-13 DDA 1 POND 1 SITE 1 HOLT MOUNTAIN	1550	8.6	730	6.0	90	20
57	352522095135601	11N-20E-18 CDB 1 POND 1 SITE 3 HOLT MOUNTAIN	1540	8.6	730	12	120	880
58	352611095150401	11N-19E-12 CDC 1 POND 1 SITE 3 WARNER	1230	8.5	630	7.0	50	3800
59	352612095152001	11N-19E-12 CCB 1 POND 1 SITE 1 WARNER	1210	8.5	540	22	40	1200
60	352617095151101	11N-19E-12 CCA 1 POND 1 SITE 2 WARNER	1850	8.8	570	5.9	140	400
61	352619095572301	11N-13E-08 CAD 1 POND 2 SITE 1 HENRYETTA	753	6.3	410	5.7	20	4200
62	352628095572601	11N-13E-08 CAB 1 POND 2 SITE 2 HENRYETTA	757	6.3	400	5.2	10	4200
63	352825095251901	12N-18E-32 ACA 2 POND 3 SITE 3 WARNER NW	3220	3.3	2200	9.8	4800	55000
64	352830095251501	12N-18E-32 ACA 1 POND 3 SITE 2 WARNER NW	3240	3.3	2200	6.6	4900	55000
65	352834095251001	12N-18E-32 AAC 1 POND 3 SITE 1 WARNER NW	3240	3.3	2200	8.1	5000	56000
66	353805095522501	13N-13E-01 ADA 1 POND 1 SITE 2 OKMULGEE NE	630	8.1	190	22	10	600
67	353811095522601	13N-13E-01 AAD 1 POND 1 SITE 1 OKMULGEE NE	657	7.9	200	22	10	1600
68	355323095330101	16N-17E-06 CCA 1 POND 1 SITE 1 RED BIRD	1840	8.1	1000	6.4	80	2400
69	355323095330601	16N-17E-06 CCB 1 POND 1 SITE 2 RED BIRD	1950	7.9	1100	4.1	80	16000
70	360526095435401	19N-15E-29 DCD 1 POND 1 SITE 3 ONETA	3690	8.2	2300	14	2600	6600
71	360533095440101	19N-15E-29 DCC 1 POND 1 SITE 2 ONETA	3730	8.2	2200	17	2700	11000
72	360552095435801	19N-15E-29 ACC 1 POND 1 SITE 1 ONETA	3460	8.3	2100	11	460	2600
73	361544095395101	21N-15E-36 BAB 1 POND 1 SITE 1 SAGEEYAH	506	8.2	99	3.8	90	1300
74	361549095394601	21N-15E-36 BAB 2 POND 1 SITE 2 SAGEEYAH	466	8.3	90	5.1	160	2200
75	362249095495501	22N-14E-17 DDD 1 POND 2 SITE 3 COLLINSVILLE NE	2520	8.1	900	230	2200	12000
76	362253095500201	22N-14E-17 DDB 2 POND 2 SITE 2 COLLINSVILLE NE	3000	8.1	1100	240	8700	13000
77	362257095495501	22N-14E-17 DDB 1 POND 2 SITE 1 COLLINSVILLE NE	2860	8.0	840	230	10000	13000
78	362333095365201	22N-16E-16 BBB 2 POND 2 SITE 1 FOYIL	917	8.4	310	29	40	400
79	362337095364601	22N-16E-16 BBB 1 POND 2 SITE 2 FOYIL	793	8.2	250	4.6	40	80
80	362618095352801	23N-16E-27 CDC 1 POND 1 SITE 3 FOYIL	554	7.9	160	8.2	70	850
81	362635095352701	23N-16E-27 CAA 1 POND 1 SITE 1 FOYIL	598	8.0	160	7.0	480	1600
82	362636095352801	23N-16E-27 CAC 1 POND 1 SITE 2 FOYIL	587	8.0	160	8.3	460	1800
83	362718095450201	23N-15E-19 CDA 1 POND 1 SITE 2 COLLINSVILLE NE	2020	8.2	1100	11	40	4400
84	362725095445801	23N-15E-19 CAD 1 POND 1 SITE 1 OOLOGAH	1730	8.2	950	6.7	40	760
85	363039095292401	24N-17E-33 DDD 1 POND 3 SITE 1 CHELSEA	552	8.4	220	6.4	30	70
86	363049095293201	24N-17E-33 DDC 1 POND 3 SITE 2 CHELSEA	559	8.4	210	6.7	40	70
87	363049095293801	24N-17E-33 DCD 1 POND 3 SITE 3 CHELSEA	588	8.3	230	6.5	40	1700
88	364109095183301	26N-19E-31 DDC 1 POND 2 SITE 2 ESTELLA	3080	7.6	2000	14	120	15000
89	364119095183101	26N-19E-31 DAC 1 POND 2 SITE 3 ESTELLA	2590	7.6	1700	12	40	2900
90	364125095182301	26N-19E-31 DAA 1 POND 2 SITE 1 ESTELLA	2710	7.7	1700	9.9	110	2200
91	364756095174101	27N-19E-29 ABB 1 POND 2 SITE 1 CENTRALIA	430	8.9	77	4.0	4200	1500
92	364756095174801	27N-19E-29 BAA 1 POND 2 SITE 2 CENTRALIA	440	8.5	72	5.0	400	1200
93	364831095172101	27N-19E-20 ADD 1 POND 1 SITE 3 CENTRALIA	3000	8.3	180	5.0	60	1100
94	364835095171801	27N-19E-20 ADA 1 POND 1 SITE 2 CENTRALIA	690	8.2	190	4.1	60	680
95	364841095171901	27N-19E-20 AAD 1 POND 1 SITE 1 CENTRALIA	695	9.1	180	5.1	200	90
96	364951095132801	27N-19E-12 DCC 2 POND 2 SITE 1 PYRAMID CORNERS	715	8.4	210	2.9	1000	4700
97	365119095124701	27N-20E-06 BBD 1 POND 1 SITE 1 PYRAMID CORNERS	1520	6.3	900	10	80	1200
98	365418095123701	28N-20E-18 CDB 1 POND 2 SITE 3 WELCH NW	970	7.9	440	5.0	120	590
99	365418095124201	28N-20E-18 CCA 2 POND 3 SITE 1 WELCH NW	700	8.3	230	13	60	60
100	365421095124001	28N-20E-18 CCA 1 POND 2 SITE 2 WELCH NW	960	8.1	450	5.7	130	1500
101	365424095124201	28N-20E-18 CBD 1 POND 2 SITE 1 WELCH NW	955	8.4	390	6.0	220	770
102	365549095121701	28N-20E-07 ABB 1 POND 1 SITE 1 WELCH NW	1500	8.2	690	9.1	610	15000

TABLE 2. -- Minimum values for specific conductance, pH, and concentrations of dissolved sulfate, chloride, iron, and manganese for each site

(micromhos, micromhos per centimeter at 25° Celsius; mg/L, milligrams per liter; μg/L, micrograms per liter)

Map-index number (Figs. 9-57)	Station Number	Station Name (Township - range - section and mine pond - site - quadrangle)	Specific conductance (micromhos)	pH (units)	Sulfate (mg/L)	Chloride (mg/L)	Iron (μg/L)	Manganese (μg/L)
1	342353096135301	02S-10E-11 BCB 2 POND 2 SITE 2 LEHIGH	180	6.3	28	3.0	10	20
2	342358096135701	02S-10E-11 BCB 1 POND 2 SITE 1 LEHIGH	160	6.6	11	3.0	10	10
3	342807096133301	01S-10E-14 CAB 1 POND 1 SITE 1 LEHIGH	460	7.3	130	6.0	10	10
4	343106096133801	01N-10E-35 BBD 1 POND 1 SITE 1 COALGATE	110	6.4	3.7	2.0	10	15
5	345403094271301	05N-27E-16 DDC 1 POND 1 SITE 1 BATES	200	7.3	7.6	4.0	10	5
6	345440095404701	05N-15E-14 DDD 1 POND 1 SITE 1 KREBS	120	6.8	5.1	2.0	50	20
7	345506095190001	05N-19E-08 CAC 1 POND 1 SITE 1 WILBURTON	1060	6.7	56	85	10	10
8	345636095185601	06N-19E-32 DDD 1 POND 3 SITE 1 WILBURTON	735	7.0	230	4.0	10	10
9	345641095190301	06N-19E-32 DDB 1 POND 2 SITE 1 WILBURTON	700	7.6	230	2.0	10	10
10	345911095035101	06N-21E-14 CCD 1 POND 1 SITE 1 RED OAK NE	150	6.6	16	4.0	10	10
11	345915095033401	06N-21E-14 DCB 1 POND 1 SITE 2 RED OAK NE	150	7.0	20	4.0	10	10
12	345921095031801	06N-21E-14 DDB 1 POND 1 SITE 3 RED OAK NE	150	6.3	9.0	3.0	10	10
13	350643095130001	07N-20E-05 ABC 1 POND 1 SITE 2 KINTA	455	7.6	62	3.1	30	20
14	350645095123401	07N-20E-05 AAD 1 POND 1 SITE 3 KINTA	445	6.8	51	2.3	10	40
15	350645095124701	07N-20E-05 AAC 1 POND 1 SITE 1 KINTA	446	7.5	63	2.9	20	10
16	350702094350201	08N-26E-32 CCC 1 POND 1 SITE 1 POTEAU EAST	305	7.3	60	1.0	10	5
17	350805095141701	08N-20E-30 CAC 2 POND 2 SITE 2 SANS BOIS	637	7.8	170	2.6	40	400
18	350805095142101	08N-20E-30 CAC 1 POND 2 SITE 1 SANS BOIS	645	7.5	160	3.0	30	10
19	350907094355001	08N-26E-19 DAB 1 POND 3 SITE 3 SPIRO	440	7.3	29	12	1300	20
20	350907094585001	08N-22E-22 CBB 1 POND 3 SITE 1 MCCURTAIN	610	6.9	140	8.0	10	5
21	350911094470901	08N-24E-16 CCD 1 POND 3 SITE 1 BOKOSHE	115	6.7	13	3.0	110	15
22	350913094351801	08N-26E-20 BDB 1 POND 3 SITE 1 SPIRO	370	7.4	20	5.0	10	20
23	350918094352701	08N-26E-20 ACA 1 POND 3 SITE 2 SPIRO	430	7.4	24	11	80	10
24	351003094575001	08N-22E-15 ADD 1 POND 1 SITE 1 MCCURTAIN	1260	7.2	380	8.0	20	5
25	351037094553001	08N-23E-07 CCA 1 POND 2 SITE 1 MCCURTAIN	980	7.1	360	7.0	20	5
26	351049094290701	09N-27E-08 CBB 1 POND 1 SITE 1 HACKETT	680	6.7	300	2.0	10	20
27	351130094520301	09N-23E-03 CDA 1 POND 1 SITE 1 BOKOSHE	490	6.7	140	3.0	20	20
28	351230094340201	09N-26E-32 DAA 1 POND 2 SITE 1 SPIRO	93	6.5	5.0	2.0	90	40
29	351247094494801	09N-23E-36 BCB 1 POND 2 SITE 1 BOKOSHE	230	6.7	40	2.0	30	5
30	351343094300701	09N-26E-25 ABD 1 POND 1 SITE 1 SPIRO	190	6.5	23	1.0	20	10
31	351436094420901	09N-25E-19 BAC 1 POND 1 SITE 1 PANAMA	780	7.1	280	1.0	10	10
32	351454095113301	09N-20E-16 DCB 1 POND 1 SITE 1 SANS BOIS	170	7.0	17	3.0	10	10
33	351517095095801	09N-20E-14 BCC 1 POND 3 SITE 2 STIGLER WEST	230	7.0	17	3.0	40	10
34	351517095121501	09N-20E-17 ADD 1 POND 2 SITE 2 STIGLER WEST	410	7.6	52	2.0	20	10
35	351518095095001	09N-20E-14 BCA 1 POND 3 SITE 1 STIGLER WEST	220	7.1	17	3.0	30	90
36	351522095122201	09N-20E-17 ADB 1 POND 2 SITE 1 STIGLER WEST	420	7.3	52	4.0	20	110
37	351602094435201	09N-24E-11 DBA 1 POND 1 SITE 1 MULDROW SW	1000	7.1	510	1.0	10	5
38	351612094480301	09N-24E-07 ADB 1 POND 1 SITE 1 R.S.KERR DAM	1140	7.3	520	4.0	20	5
39	351632095003401	09N-22E-06 DDD 1 POND 2 SITE 1 STIGLER EAST	114	7.1	7.6	5.0	40	80
40	351925095034701	10N-21E-22 DAD 1 POND 1 SITE 1 STIGLER EAST	1060	7.4	420	2.0	20	5
41	352001094583101	10N-22E-16 DDD 1 POND 1 SITE 1 KEOTA	360	7.7	45	19	60	20
42	352001094583501	10N-22E-16 DDC 1 POND 1 SITE 2 KEOTA	365	6.9	46	20	80	20
43	352001094583901	10N-22E-16 DDC 2 POND 1 SITE 3 KEOTA	355	7.7	48	20	40	10
44	352054095142601	10N-19E-12 DDD 1 POND 1 SITE 3 STIGLER WEST	360	6.6	93	1.0	20	10
45	352100095142301	10N-19E-12 DDA 2 POND 1 SITE 2 STIGLER WEST	350	6.6	94	0.1	10	10
46	352105095142301	10N-19E-12 DDA 1 POND 1 SITE 1 STIGLER WEST	350	6.6	93	0.1	10	10
47	352222095150501	10N-19E-01 BDB 1 POND 1 SITE 1 PORUM	730	6.1	190	1.0	20	10
48	352231095145001	10N-19E-01 ABC 1 POND 3 SITE 2 HOLT MOUNTAIN	657	5.1	190	1.0	10	5
49	352237095143601	10N-19E-01 ABC 1 POND 3 SITE 1 HOLT MOUNTAIN	647	6.5	180	1.0	10	20
50	352513094523201	11N-23E-16 DCC 1 POND 1 SITE 1 VIAN	894	7.4	330	4.5	30	20

TABLE 2. -- Minimum values for specific conductance, pH, and concentrations of dissolved sulfate, chloride, iron, and manganese for each site (continued)

Map-index number (Figs. 9-57)	Station Number	Station Name (Township - range - section and mine pond - site - quadrangle)	Specific conductance (micromhos)	pH (units)	Sulfate (mg/L)	Chloride (mg/L)	Iron (µg/L)	Manganese (µg/L)
51	352518095134601	11N-20E-18 DCC 1 POND 2 SITE 2 HOLT MOUNTAIN	666	6.6	260	3.6	10	20
52	352519094522501	11N-23E-16 DCA 1 POND 1 SITE 2 SALLISAW	903	7.2	340	4.4	20	10
53	352519095135001	11N-20E-18 CDD 2 POND 2 SITE 3 HOLT MOUNTAIN	890	7.8	300	3.5	--	--
54	352520095135301	11N-20E-18 CDD 1 POND 2 SITE 1 HOLT MOUNTAIN	711	6.6	260	2.8	20	20
55	352521095140601	11N-20E-18 CCA 1 POND 1 SITE 2 HOLT MOUNTAIN	1040	6.5	7.7	1.0	10	10
56	352521095142101	11N-19E-13 DDA 1 POND 1 SITE 1 HOLT MOUNTAIN	1040	6.6	670	4.0	10	10
57	352522095135601	11N-20E-18 CDB 1 POND 1 SITE 3 HOLT MOUNTAIN	1040	6.6	330	2.0	10	8
58	352611095150401	11N-19E-12 CDC 1 POND 1 SITE 3 WARNER	1010	6.5	440	2.0	10	10
59	352612095152001	11N-19E-12 CCB 1 POND 1 SITE 1 WARNER	1000	6.8	440	3.0	20	10
60	352617095151101	11N-19E-12 CCA 1 POND 1 SITE 2 WARNER	1000	6.5	440	2.0	10	8
61	352619095572301	11N-13E-08 CAD 1 POND 2 SITE 1 HENRYETTA	750	6.1	400	5.0	10	4200
62	352628095572601	11N-13E-08 CAB 1 POND 2 SITE 2 HENRYETTA	755	6.1	400	4.2	10	4100
63	352825095251901	12N-18E-32 ACA 2 POND 3 SITE 3 WARNER NW	3210	3.2	2000	7.5	4800	54000
64	352830095251501	12N-18E-32 ACA 1 POND 3 SITE 2 WARNER NW	3220	3.2	2200	6.2	4800	54000
65	352834095251001	12N-18E-32 AAC 1 POND 3 SITE 1 WARNER NW	3220	3.2	2100	7.8	5000	55000
66	353805095522501	13N-13E-01 ADA 1 POND 1 SITE 2 OKMULGEE NE	624	7.6	190	22	10	100
67	353811095522601	13N-13E-01 AAD 1 POND 1 SITE 1 OKMULGEE NE	583	7.4	190	22	10	30
68	355323095330101	16N-17E-06 CCA 1 POND 1 SITE 1 RED BIRD	1820	7.7	1000	1.0	50	1600
69	355323095330601	16N-17E-06 CCB 1 POND 1 SITE 2 RED BIRD	1870	7.3	1000	0.7	80	3200
70	360526095435401	19N-15E-29 DCD 1 POND 1 SITE 3 ONETA	3330	7.0	2000	14	80	20
71	360533095440101	19N-15E-29 DCC 1 POND 1 SITE 2 ONETA	3340	7.1	2000	13	50	20
72	360552095435801	19N-15E-29 ACC 1 POND 1 SITE 1 ONETA	3290	7.3	2000	5.9	130	1200
73	361544095395101	21N-15E-36 BAB 1 POND 1 SITE 1 SAGEEYAH	454	7.1	95	3.7	70	820
74	361549095394601	21N-15E-36 BAB 2 POND 1 SITE 2 SAGEEYAH	433	7.2	74	4.9	50	20
75	362249095495501	22N-14E-17 DDD 1 POND 2 SITE 3 COLLINSVILLE NE	2090	7.1	770	220	50	400
76	362253095500201	22N-14E-17 DDB 2 POND 2 SITE 2 COLLINSVILLE NE	2150	7.0	790	220	60	320
77	362257095495501	22N-14E-17 DDB 1 POND 2 SITE 1 COLLINSVILLE NE	2150	7.0	780	220	120	320
78	362333095365201	22N-16E-16 BBB 2 POND 2 SITE 1 FOYIL	700	7.4	250	4.2	10	0
79	362337095364601	22N-16E-16 BBB 1 POND 2 SITE 2 FOYIL	790	7.8	250	4.6	40	80
80	362618095352801	23N-16E-27 CDC 1 POND 1 SITE 3 FOYIL	533	7.2	130	7.1	10	20
81	362635095352701	23N-16E-27 CAA 1 POND 1 SITE 1 FOYIL	490	7.1	110	6.1	40	40
82	362636095352801	23N-16E-27 CAC 1 POND 1 SITE 2 FOYIL	494	7.1	110	6.1	40	90
83	362718095450201	23N-15E-19 CDA 1 POND 1 SITE 2 COLLINSVILLE NE	1710	7.4	960	6.5	30	50
84	362725095445801	23N-15E-19 CAD 1 POND 1 SITE 1 OOLOGAH	1600	7.3	870	5.5	10	20
85	363039095292401	24N-17E-33 DDD 1 POND 3 SITE 1 CHELSEA	530	7.5	200	6.1	20	30
86	363049095293201	24N-17E-33 DDC 1 POND 3 SITE 2 CHELSEA	535	7.5	200	6.5	20	40
87	363049095293801	24N-17E-33 DCD 1 POND 3 SITE 3 CHELSEA	537	7.5	210	5.4	30	80
88	364109095183301	26N-19E-31 DDC 1 POND 2 SITE 2 ESTELLA	2520	6.6	1700	13	60	2000
89	364119095183101	26N-19E-31 DAC 1 POND 2 SITE 3 ESTELLA	2500	7.3	1700	6.9	40	1900
90	364125095182301	26N-19E-31 DAA 1 POND 2 SITE 1 ESTELLA	2510	7.2	1600	8.1	60	1600
91	364756095174101	27N-19E-29 ABB 1 POND 2 SITE 1 CENTRALIA	329	6.6	64	3.1	30	10
92	364756095174801	27N-19E-29 BAA 1 POND 2 SITE 2 CENTRALIA	333	6.5	61	2.6	10	5
93	364831095172101	27N-19E-20 ADD 1 POND 1 SITE 3 CENTRALIA	491	7.3	140	4.0	10	5
94	364835095171801	27N-19E-20 ADA 1 POND 1 SITE 2 CENTRALIA	502	7.6	140	3.5	10	20
95	364841095171901	27N-19E-20 AAD 1 POND 1 SITE 1 CENTRALIA	499	7.5	140	3.0	30	20
96	364951095132801	27N-19E-12 DCC 2 POND 2 SITE 1 PYRAMID CORNERS	561	7.5	170	2.2	80	60
97	365119095124701	27N-20E-06 BBD 1 POND 1 SITE 1 PYRAMID CORNERS	1480	6.3	900	10	80	1200
98	365418095123701	28N-20E-18 CDB 1 POND 2 SITE 3 WELCH NW	738	7.4	360	3.6	10	200
99	365418095124201	28N-20E-18 CCA 2 POND 3 SITE 1 WELCH NW	404	7.8	150	7.1	10	15
100	365421095124001	28N-20E-18 CCA 1 POND 2 SITE 2 WELCH NW	758	6.5	380	2.4	20	80
101	365424095124201	28N-20E-18 CBD 1 POND 2 SITE 1 WELCH NW	747	6.9	370	4.7	20	270
102	365549095121701	28N-20E-07 ABB 1 POND 1 SITE 1 WELCH NW	460	6.3	130	2.5	20	1

TABLE 3. -- Mean values for specific conductance and concentrations of dissolved sulfate, chloride, iron, and manganese for each site

(micromhos, micromhos per centimeter at 25° Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter)

Map-index number (Figs. 9-57)	Station Number	Station Name (Township - range - section and mine pond - site - quadrangle)	Specific conductance (micromhos)	Sulfate (mg/L)	Chloride (mg/L)	Iron (µg/L)	Manganese (µg/L)
1	342353096135301	02S-10E-11 BCB 2 POND 2 SITE 2 LEHIGH	230	30	3.0	40	1000
2	342358096135701	02S-10E-11 BCB 1 POND 2 SITE 1 LEHIGH	243	41	4.2	1400	1400
3	342807096133301	01S-10E-14 CAB 1 POND 1 SITE 1 LEHIGH	492	140	6.0	20	95
4	343106096133801	01N-10E-35 BBD 1 POND 1 SITE 1 COALGATE	140	11	2.0	820	1300
5	345403094271301	05N-27E-16 DDC 1 POND 1 SITE 1 BATES	513	44	6.3	40	1000
6	345440095404701	05N-15E-14 DDD 1 POND 1 SITE 1 KREBS	654	9.7	2.7	220	770
7	345506095190001	05N-19E-08 CAC 1 POND 1 SITE 1 WILBURTON	1060	58	85	30	30
8	345636095185601	06N-19E-32 DDD 1 POND 3 SITE 1 WILBURTON	824	240	4.0	30	120
9	345641095190301	06N-19E-32 DDB 1 POND 2 SITE 1 WILBURTON	744	240	3.5	10	10
10	345911095035101	06N-21E-14 CCD 1 POND 1 SITE 1 RED OAK NE	316	45	6.4	420	1900
11	345915095033401	06N-21E-14 DCB 1 POND 1 SITE 2 RED OAK NE	206	24	4.0	40	60
12	345921095031801	06N-21E-14 DDB 1 POND 1 SITE 3 RED OAK NE	287	30	4.5	70	1100
13	350643095130001	07N-20E-05 ABC 1 POND 1 SITE 2 KINTA	459	62	3.1	40	75
14	350645095123401	07N-20E-05 AAD 1 POND 1 SITE 3 KINTA	467	57	2.4	160	1300
15	350645095124701	07N-20E-05 AAC 1 POND 1 SITE 1 KINTA	462	63	3.0	30	15
16	350702094350201	08N-26E-32 CCC 1 POND 1 SITE 1 POTEAU EAST	344	80	1.5	50	590
17	350805095141701	08N-20E-30 CAC 2 POND 2 SITE 2 SANS BOIS	701	180	7.3	110	510
18	350805095142101	08N-20E-30 CAC 1 POND 2 SITE 1 SANS BOIS	733	170	6.7	70	180
19	350907094355001	08N-26E-19 DAB 1 POND 3 SITE 3 SPIRO	460	32	12	1400	45
20	350907094585001	08N-22E-22 CBB 1 POND 3 SITE 1 MCCURTAIN	704	160	9.8	30	580
21	350911094470901	08N-24E-16 CCD 1 POND 3 SITE 1 BOKOSHE	156	20	3.0	3600	3000
22	350913094351801	08N-26E-20 BDB 1 POND 3 SITE 1 SPIRO	422	26	10	700	140
23	350918094352701	08N-26E-20 ACA 1 POND 3 SITE 2 SPIRO	445	26	12	210	20
24	351003094575001	08N-22E-15 ADD 1 POND 1 SITE 1 MCCURTAIN	2280	1100	21	220	2000
25	351037094553001	08N-23E-07 CCA 1 POND 2 SITE 1 MCCURTAIN	1070	510	9.2	30	240
26	351049094290701	08N-27E-08 CBB 1 POND 1 SITE 1 HACKETT	653	300	2.5	20	80
27	351130094520301	08N-23E-03 CDA 1 POND 1 SITE 1 BOKOSHE	760	200	5.5	150	5000
28	351230094340201	09N-26E-32 DAA 1 POND 2 SITE 1 SPIRO	144	5.9	3.4	3100	1600
29	351247094494801	09N-23E-36 BCB 1 POND 2 SITE 1 BOKOSHE	538	100	4.0	3100	2300
30	351343094300701	09N-26E-25 ABD 1 POND 1 SITE 1 SPIRO	280	36	7.0	320	3100
31	351436094420901	09N-25E-19 BAC 1 POND 1 SITE 1 PANAMA	3240	310	2.4	60	1000
32	351454095113301	09N-20E-16 DCB 1 POND 1 SITE 1 SANS BOIS	210	20	3.0	30	1100
33	351517095095801	09N-20E-14 BCC 1 POND 3 SITE 2 STIGLER WEST	306	30	4.3	280	1900
34	351517095121501	09N-20E-17 ADD 1 POND 2 SITE 2 STIGLER WEST	475	60	3.0	30	160
35	351518095095001	09N-20E-14 BCA 1 POND 3 SITE 1 STIGLER WEST	269	25	5.4	50	1700
36	351522095122201	09N-20E-17 ADB 1 POND 2 SITE 1 STIGLER WEST	546	65	4.0	20	3300
37	351602094435201	09N-24E-11 DBA 1 POND 1 SITE 1 MULDROW SW	1160	560	3.2	50	1300
38	351612094480301	09N-24E-07 ADB 1 POND 1 SITE 1 R.S. KERR DAM	1330	570	4.5	30	34
39	351632095003401	09N-22E-06 DDD 1 POND 2 SITE 1 STIGLER EAST	142	9.3	5.6	920	2900
40	351925095034701	10N-21E-22 DAD 1 POND 1 SITE 1 STIGLER EAST	1210	470	3.8	470	1000
41	352001094583101	10N-22E-16 DDD 1 POND 1 SITE 1 KEOTA	372	46	20	60	20
42	352001094583501	10N-22E-16 DDC 1 POND 1 SITE 2 KEOTA	396	47	21	130	1400
43	352001094583901	10N-22E-16 DDC 2 POND 1 SITE 3 KEOTA	359	48	20	60	10
44	352054095142601	10N-19E-12 DDD 1 POND 1 SITE 3 STIGLER WEST	494	140	3.6	150	2100
45	352100095142301	10N-19E-12 DDA 2 POND 1 SITE 2 STIGLER WEST	595	160	1.4	150	7100
46	352105095142301	10N-19E-12 DDA 1 POND 1 SITE 1 STIGLER WEST	424	110	1.5	30	46
47	352222095150501	10N-19E-01 BDB 1 POND 1 SITE 1 PORUM	910	210	2.0	20	15
48	352231095145001	10N-19E-01 ABC 1 POND 3 SITE 2 HOLT MOUNTAIN	809	230	2.0	160	650
49	352237095143601	10N-19E-01 ABC 1 POND 3 SITE 1 HOLT MOUNTAIN	951	320	2.2	190	1600
50	352513094523201	11N-23E-16 DCC 1 POND 1 SITE 1 VIAN	923	340	5.8	40	710

TABLE 3. -- Mean values for specific conductance and concentrations of dissolved sulfate, chloride, iron, and manganese for each site

(continued)

Map-index number (Figs. 9-57)	Station Number	Station Name (Township - range - section and mine pond - site - quadrangle)	Specific conductance (micromhos)	Sulfate (mg/L)	Chloride (mg/L)	Iron (µg/L)	Manganese (µg/L)
51	352518095134601	11N-20E-18 DCC 1 POND 2 SITE 2 HOLT MOUNTAIN	1150	780	5.9	30	270
52	352519094522501	11N-23E-16 DCA 1 POND 1 SITE 2 SALLISAW	949	340	4.6	20	160
53	352519095135001	11N-20E-18 CDD 2 POND 2 SITE 3 HOLT MOUNTAIN	897	300	3.6	--	--
54	352520095135301	11N-20E-18 CDD 1 POND 2 SITE 1 HOLT MOUNTAIN	1200	410	7.6	40	270
55	352521095140601	11N-20E-18 CCA 1 POND 1 SITE 2 HOLT MOUNTAIN	1500	650	4.0	90	1400
56	352521095142101	11N-19E-13 DDA 1 POND 1 SITE 1 HOLT MOUNTAIN	1230	700	4.8	30	18
57	352522095135601	11N-20E-18 CDB 1 POND 1 SITE 3 HOLT MOUNTAIN	1260	620	4.8	50	260
58	352611095150401	11N-19E-12 CDC 1 POND 1 SITE 3 WARNER	1150	530	3.8	30	820
59	352612095152001	11N-19E-12 CCB 1 POND 1 SITE 1 WARNER	1080	500	7.6	30	260
60	352617095151101	11N-19E-12 CCA 1 POND 1 SITE 2 WARNER	1330	510	4.2	40	110
61	352619095572301	11N-13E-08 CAD 1 POND 2 SITE 1 HENRYETTA	752	400	5.4	20	4200
62	352628095572601	11N-13E-08 CAB 1 POND 2 SITE 2 HENRYETTA	756	400	4.7	10	4200
63	352825095251901	12N-18E-32 ACA 2 POND 3 SITE 3 WARNER NW	3210	2100	8.6	4800	54500
64	352830095251501	12N-18E-32 ACA 1 POND 3 SITE 2 WARNER NW	3230	2200	6.4	4800	54500
65	352834095251001	12N-18E-32 AAC 1 POND 3 SITE 1 WARNER NW	3230	2200	8.0	5000	55500
66	353805095522501	13N-13E-01 ADA 1 POND 1 SITE 2 OKMULGEE NE	626	190	22	10	350
67	353811095522601	13N-13E-01 AAD 1 POND 1 SITE 1 OKMULGEE NE	609	200	22	10	820
68	355323095330101	16N-17E-06 CCA 1 POND 1 SITE 1 RED BIRD	1840	1000	3.7	60	2000
69	355323095330601	16N-17E-06 CCB 1 POND 1 SITE 2 RED BIRD	1900	1000	2.4	80	9600
70	360526095435401	19N-15E-29 DCD 1 POND 1 SITE 3 ONETA	3440	2200	14	1300	3300
71	360533095440101	19N-15E-29 DCC 1 POND 1 SITE 2 ONETA	3490	2100	16	930	3700
72	360552095435801	19N-15E-29 ACC 1 POND 1 SITE 1 ONETA	3340	2000	8.4	300	1900
73	361544095395101	21N-15E-36 BAB 1 POND 1 SITE 1 SAGEEYAH	476	97	3.8	80	1100
74	361549095394601	21N-15E-36 BAB 2 POND 1 SITE 2 SAGEEYAH	452	82	5.0	100	1100
75	362249095495501	22N-14E-17 DDD 1 POND 2 SITE 3 COLLINSVILLE NE	2200	840	220	1100	6200
76	362253095500201	22N-14E-17 DDB 2 POND 2 SITE 2 COLLINSVILLE NE	2360	940	230	4400	6700
77	362257095495501	22N-14E-17 DDB 1 POND 2 SITE 1 COLLINSVILLE NE	2360	810	220	5100	6700
78	362333095365201	22N-16E-16 BBB 2 POND 2 SITE 1 FOYIL	798	280	16	30	240
79	362337095364601	22N-16E-16 BBB 1 POND 2 SITE 2 FOYIL	791	250	4.6	40	80
80	362618095352801	23N-16E-27 CDC 1 POND 1 SITE 3 FOYIL	546	140	7.6	40	440
81	362635095352701	23N-16E-27 CAA 1 POND 1 SITE 1 FOYIL	557	140	6.6	260	820
82	362636095352801	23N-16E-27 CAC 1 POND 1 SITE 2 FOYIL	557	140	7.2	250	940
83	362718095450201	23N-15E-19 CDA 1 POND 1 SITE 2 COLLINSVILLE NE	1820	1000	9.1	30	1500
84	362725095445801	23N-15E-19 CAD 1 POND 1 SITE 1 OOLOGAH	1640	920	6.2	30	270
85	363039095292401	24N-17E-33 DDD 1 POND 3 SITE 1 CHELSEA	538	210	6.2	20	50
86	363049095293201	24N-17E-33 DDC 1 POND 3 SITE 2 CHELSEA	544	200	6.6	30	55
87	363049095293801	24N-17E-33 DCD 1 POND 3 SITE 3 CHELSEA	562	220	6.0	40	890
88	364109095183301	26N-19E-31 DDC 1 POND 2 SITE 2 ESTELLA	2700	1800	13	80	6800
89	364119095183101	26N-19E-31 DAC 1 POND 2 SITE 3 ESTELLA	2530	1700	9.4	40	2400
90	364125095182301	26N-19E-31 DAA 1 POND 2 SITE 1 ESTELLA	2580	1600	9.0	80	1900
91	364756095174101	27N-19E-29 ABB 1 POND 2 SITE 1 CENTRALIA	378	70	3.7	900	360
92	364756095174801	27N-19E-29 BAA 1 POND 2 SITE 2 CENTRALIA	373	70	4.0	140	210
93	364831095172101	27N-19E-20 ADD 1 POND 1 SITE 3 CENTRALIA	1820	160	4.5	30	240
94	364835095171801	27N-19E-20 ADA 1 POND 1 SITE 2 CENTRALIA	580	170	3.9	30	140
95	364841095171901	27N-19E-20 AAD 1 POND 1 SITE 1 CENTRALIA	584	160	3.8	120	55
96	364951095132801	27N-19E-12 DCC 2 POND 2 SITE 1 PYRAMID CORNERS	628	190	2.6	540	2400
97	365119095124701	27N-20E-06 BBD 1 POND 1 SITE 1 PYRAMID CORNERS	1500	900	10	80	1200
98	365418095123701	28N-20E-18 CDB 1 POND 2 SITE 3 WELCH NW	862	390	4.0	40	360
99	365418095124201	28N-20E-18 CCA 2 POND 3 SITE 1 WELCH NW	582	190	10	40	37
100	365421095124001	28N-20E-18 CCA 1 POND 2 SITE 2 WELCH NW	864	410	4.1	60	460
101	365424095124201	28N-20E-18 CBD 1 POND 2 SITE 1 WELCH NW	835	380	5.2	90	430
102	365549095121701	28N-20E-07 ABB 1 POND 1 SITE 1 WELCH NW	804	250	4.9	120	2600

TABLE 4. -- Number of determinations for specific conductance, pH, and concentrations of dissolved sulfate, chloride, iron, and manganese for each site

Map-index number (Figs. 9-57)	Station Number	Station name (Township - range - section and mine pond - site - quadrangle)	Number of Determinations					
			Specific conductance	pH	Sulfate	Chloride	Iron	Manganese
1	342353096135301	02S-10E-11 BCB 2 POND 2 SITE 2 LEHIGH	9	9	2	2	2	2
2	342358096135701	02S-10E-11 BCB 1 POND 2 SITE 1 LEHIGH	13	13	5	5	5	5
3	342807096133301	01S-10E-14 CAB 1 POND 1 SITE 1 LEHIGH	6	4	2	2	2	2
4	343106096133801	01N-10E-35 BBD 1 POND 1 SITE 1 COALGATE	17	17	5	5	5	5
5	345403094271301	05N-27E-16 DDC 1 POND 1 SITE 1 BATES	22	22	6	6	6	6
6	345440095404701	05N-15E-14 DDD 1 POND 1 SITE 1 KREBS	18	6	3	3	3	3
7	345506095190001	05N-19E-08 CAC 1 POND 1 SITE 1 WILBURTON	2	2	2	2	2	2
8	345636095185601	06N-19E-32 DDD 1 POND 3 SITE 1 WILBURTON	12	12	3	3	3	3
9	345641095190301	06N-19E-32 DDB 1 POND 2 SITE 1 WILBURTON	9	9	4	4	4	4
10	345911095035101	06N-21E-14 CCD 1 POND 1 SITE 1 RED OAK NE	19	19	5	5	5	5
11	345915095033401	06N-21E-14 DCB 1 POND 1 SITE 2 RED OAK NE	6	6	2	2	2	2
12	345921095031801	06N-21E-14 DDB 1 POND 1 SITE 3 RED OAK NE	20	20	5	5	5	5
13	350643095130001	07N-20E-05 ABC 1 POND 1 SITE 2 KINTA	8	8	2	2	2	2
14	350645095123401	07N-20E-05 AAD 1 POND 1 SITE 3 KINTA	10	10	2	2	2	2
15	350645095124701	07N-20E-05 AAC 1 POND 1 SITE 1 KINTA	8	8	2	2	2	2
16	350702094350201	08N-26E-32 CCC 1 POND 1 SITE 1 POTEAU EAST	13	13	4	4	4	4
17	350805095141701	08N-20E-30 CAC 2 POND 2 SITE 2 SANS BOIS	9	9	2	2	2	2
18	350805095142101	08N-20E-30 CAC 1 POND 2 SITE 1 SANS BOIS	9	9	3	3	3	3
19	350907094355001	08N-26E-19 DAB 1 POND 3 SITE 3 SPIRO	9	9	2	2	2	2
20	350907094585001	08N-22E-22 CBB 1 POND 3 SITE 1 MCCURTAIN	28	25	8	8	8	8
21	350911094470901	08N-24E-16 CCD 1 POND 3 SITE 1 BOKOSHE	7	7	2	2	2	2
22	350913094351801	08N-26E-20 BDB 1 POND 3 SITE 1 SPIRO	25	25	5	5	5	5
23	350918094352701	08N-26E-20 ACA 1 POND 3 SITE 2 SPIRO	17	17	3	3	3	3
24	351003094575001	08N-22E-15 ADD 1 POND 1 SITE 1 MCCURTAIN	19	19	6	6	6	6
25	351037094553001	08N-23E-07 CCA 1 POND 2 SITE 1 MCCURTAIN	15	15	5	5	4	3
26	351049094290701	08N-27E-08 CBB 1 POND 1 SITE 1 HACKETT	6	6	2	2	2	2
27	351130094520301	08N-23E-03 CDA 1 POND 1 SITE 1 BOKOSHE	17	17	4	4	4	4
28	351230094340201	09N-26E-32 DAA 1 POND 2 SITE 1 SPIRO	17	17	5	5	5	5
29	351247094494801	09N-23E-36 BCB 1 POND 2 SITE 1 BOKOSHE	20	20	4	4	4	4
30	351343094300701	09N-26E-25 ABD 1 POND 1 SITE 1 SPIRO	14	14	5	5	5	5
31	351436094420901	09N-25E-19 BAC 1 POND 1 SITE 1 PANAMA	27	8	5	5	5	5
32	351454095113301	09N-20E-16 DCB 1 POND 1 SITE 1 SANS BOIS	12	11	4	4	4	4
33	351517095095801	09N-20E-14 BCC 1 POND 3 SITE 2 STIGLER WEST	12	12	3	3	3	3
34	351517095121501	09N-20E-17 ADD 1 POND 2 SITE 2 STIGLER WEST	3	3	2	2	2	2
35	351518095095001	09N-20E-14 BCA 1 POND 3 SITE 1 STIGLER WEST	16	16	5	5	5	5
36	351522095122201	09N-20E-17 ADB 1 POND 2 SITE 1 STIGLER WEST	7	7	2	2	2	2
37	351602094435201	09N-24E-11 DBA 1 POND 1 SITE 1 MULDROW SW	16	17	5	5	5	5
38	351612094480301	09N-24E-07 ADB 1 POND 1 SITE 1 R.S. KERR DAM	13	13	5	5	5	5
39	351632095003401	09N-22E-06 DDD 1 POND 2 SITE 1 STIGLER EAST	8	2	2	2	2	2
40	351925095034701	10N-21E-22 DAD 1 POND 1 SITE 1 STIGLER EAST	20	20	5	5	5	5
41	352001094583101	10N-22E-16 DDD 1 POND 1 SITE 1 KEOTA	5	5	2	2	2	2
42	352001094583501	10N-22E-16 DDC 1 POND 1 SITE 2 KEOTA	5	5	3	3	3	3
43	352001094583901	10N-22E-16 DDC 2 POND 1 SITE 3 KEOTA	5	5	2	2	2	2
44	352054095142601	10N-19E-12 DDD 1 POND 1 SITE 3 STIGLER WEST	33	33	5	5	5	5
45	352100095142301	10N-19E-12 DDA 2 POND 1 SITE 2 STIGLER WEST	43	43	13	13	10	10
46	352105095142301	10N-19E-12 DDA 1 POND 1 SITE 1 STIGLER WEST	16	16	5	5	5	5
47	352222095150501	10N-19E-01 BDB 1 POND 1 SITE 1 PORUM	4	4	2	2	2	2
48	352231095145001	10N-19E-01 ABC 1 POND 3 SITE 2 HOLT MOUNTAIN	20	19	6	6	6	6
49	352237095143601	10N-19E-01 ABC 1 POND 3 SITE 1 HOLT MOUNTAIN	31	31	10	10	8	8
50	352513094523201	11N-23E-16 DCC 1 POND 1 SITE 1 VIAN	10	10	2	2	2	2

TABLE 4. -- Number of determinations for specific conductance, pH, and concentrations of dissolved sulfate, chloride, iron, and manganese for each site

(continued)

Map-index number (Figs. 9-57)	Station Number	Station name (Township - range - section and mine pond - site - quadrangle)	Number of Determinations					
			Specific conductance	pH	Sulfate	Chloride	Iron	Manganese
51	352518095134601	11N-20E-18 DCC 1 POND 2 SITE 2 HOLT MOUNTAIN	9	10	4	4	4	4
52	352519094522501	11N-23E-16 DCA 1 POND 1 SITE 2 SALLISAW	8	8	2	2	2	2
53	352519095135001	11N-20E-18 CDD 2 POND 2 SITE 3 HOLT MOUNTAIN	4	4	2	2	0	0
54	352520095135301	11N-20E-18 CDD 1 POND 2 SITE 1 HOLT MOUNTAIN	8	9	3	3	3	3
55	352521095140601	11N-20E-18 CCA 1 POND 1 SITE 2 HOLT MOUNTAIN	31	36	12	12	9	9
56	352521095142101	11N-19E-13 DDA 1 POND 1 SITE 1 HOLT MOUNTAIN	13	16	5	5	5	5
57	352522095135601	11N-20E-18 CDB 1 POND 1 SITE 3 HOLT MOUNTAIN	14	18	5	5	5	5
58	352611095150401	11N-19E-12 CDC 1 POND 1 SITE 3 WARNER	24	26	6	6	6	6
59	352612095152001	11N-19E-12 CCB 1 POND 1 SITE 1 WARNER	15	21	6	6	6	6
60	352617095151101	11N-19E-12 CCA 1 POND 1 SITE 2 WARNER	29	35	11	11	8	8
61	352619095572301	11N-13E-08 CAD 1 POND 2 SITE 1 HENRYETTA	5	5	2	2	2	2
62	352628095572601	11N-13E-08 CAB 1 POND 2 SITE 2 HENRYETTA	6	6	2	2	2	2
63	352825095251901	12N-18E-32 ACA 2 POND 3 SITE 3 WARNER NW	3	3	2	2	2	2
64	352830095251501	12N-18E-32 ACA 1 POND 3 SITE 2 WARNER NW	4	4	2	2	2	2
65	352834095251001	12N-18E-32 AAC 1 POND 3 SITE 1 WARNER NW	4	4	2	2	2	2
66	353805095522501	13N-13E-01 ADA 1 POND 1 SITE 2 OKMULGEE NE	4	4	2	2	2	2
67	353811095522601	13N-13E-01 AAD 1 POND 1 SITE 1 OKMULGEE NE	4	4	2	2	2	2
68	355323095330101	16N-17E-06 CCA 1 POND 1 SITE 1 RED BIRD	7	4	2	2	2	2
69	355323095330601	16N-17E-06 CCB 1 POND 1 SITE 2 RED BIRD	6	6	2	2	2	2
70	360526095435401	19N-15E-29 DCD 1 POND 1 SITE 3 ONETA	10	10	2	2	2	2
71	360533095440101	19N-15E-29 DCC 1 POND 1 SITE 2 ONETA	8	8	3	3	3	3
72	360552095435801	19N-15E-29 ACC 1 POND 1 SITE 1 ONETA	7	7	2	2	2	2
73	361544095395101	21N-15E-36 BAB 1 POND 1 SITE 1 SAGEEYAH	7	7	2	2	2	2
74	361549095394601	21N-15E-36 BAB 2 POND 1 SITE 2 SAGEEYAH	8	8	2	2	2	2
75	362249095495501	22N-14E-17 DDD 1 POND 2 SITE 3 COLLINSVILLE NE	6	6	2	2	2	2
76	362253095500201	22N-14E-17 DDB 2 POND 2 SITE 2 COLLINSVILLE NE	7	7	2	2	2	2
77	362257095495501	22N-14E-17 DDB 1 POND 2 SITE 1 COLLINSVILLE NE	7	7	2	2	2	2
78	362333095365201	22N-16E-16 BBB 2 POND 2 SITE 1 FOYIL	19	18	6	6	3	3
79	362337095364601	22N-16E-16 BBB 1 POND 2 SITE 2 FOYIL	7	7	1	1	1	1
80	362618095352801	23N-16E-27 CDC 1 POND 1 SITE 3 FOYIL	5	5	2	2	2	2
81	362635095352701	23N-16E-27 CAA 1 POND 1 SITE 1 FOYIL	7	7	2	2	2	2
82	362636095352801	23N-16E-27 CAC 1 POND 1 SITE 2 FOYIL	6	6	2	2	2	2
83	362718095450201	23N-15E-19 CDA 1 POND 1 SITE 2 COLLINSVILLE NE	11	11	3	3	3	3
84	362725095445801	23N-15E-19 CAD 1 POND 1 SITE 1 OOLOGAH	7	7	6	6	6	6
85	363039095292401	24N-17E-33 DDD 1 POND 3 SITE 1 CHELSEA	6	6	2	2	2	2
86	363049095293201	24N-17E-33 DDC 1 POND 3 SITE 2 CHELSEA	7	7	2	2	2	2
87	363049095293801	24N-17E-33 DCD 1 POND 3 SITE 3 CHELSEA	11	11	2	2	2	2
88	364109095183301	26N-19E-31 DDC 1 POND 2 SITE 2 ESTELLA	9	9	3	3	3	3
89	364119095183101	26N-19E-31 DAC 1 POND 2 SITE 3 ESTELLA	7	7	2	2	2	2
90	364125095182301	26N-19E-31 DAA 1 POND 2 SITE 1 ESTELLA	10	10	2	2	2	2
91	364756095174101	27N-19E-29 ABB 1 POND 2 SITE 1 CENTRALIA	22	22	5	5	5	5
92	364756095174801	27N-19E-29 BAA 1 POND 2 SITE 2 CENTRALIA	21	21	6	6	6	6
93	364831095172101	27N-19E-20 ADD 1 POND 1 SITE 3 CENTRALIA	23	15	5	5	5	5
94	364835095171801	27N-19E-20 ADA 1 POND 1 SITE 2 CENTRALIA	26	21	8	8	6	6
95	364841095171901	27N-19E-20 AAD 1 POND 1 SITE 1 CENTRALIA	15	12	3	3	2	2
96	364951095132801	27N-19E-12 DCC 2 POND 2 SITE 1 PYRAMID CORNERS	6	6	2	2	2	2
97	365119095124701	27N-20E-06 BBD 1 POND 1 SITE 1 PYRAMID CORNERS	4	4	1	1	1	1
98	365418095123701	28N-20E-18 CDB 1 POND 2 SITE 3 WELCH NW	17	13	5	5	5	5
99	365418095124201	28N-20E-18 CCA 2 POND 3 SITE 1 WELCH NW	5	3	2	2	2	2
100	365421095124001	28N-20E-18 CCA 1 POND 2 SITE 2 WELCH NW	36	28	9	5	6	6
101	365424095124201	28N-20E-18 CBD 1 POND 2 SITE 1 WELCH NW	19	14	4	3	4	4
102	365549095121701	28N-20E-07 ABB 1 POND 1 SITE 1 WELCH NW	24	19	11	11	8	8

Table 5. -- Number of analyses, standard deviation, and percentile for selected physical and chemical characteristics of water from 102 mine-pond sites

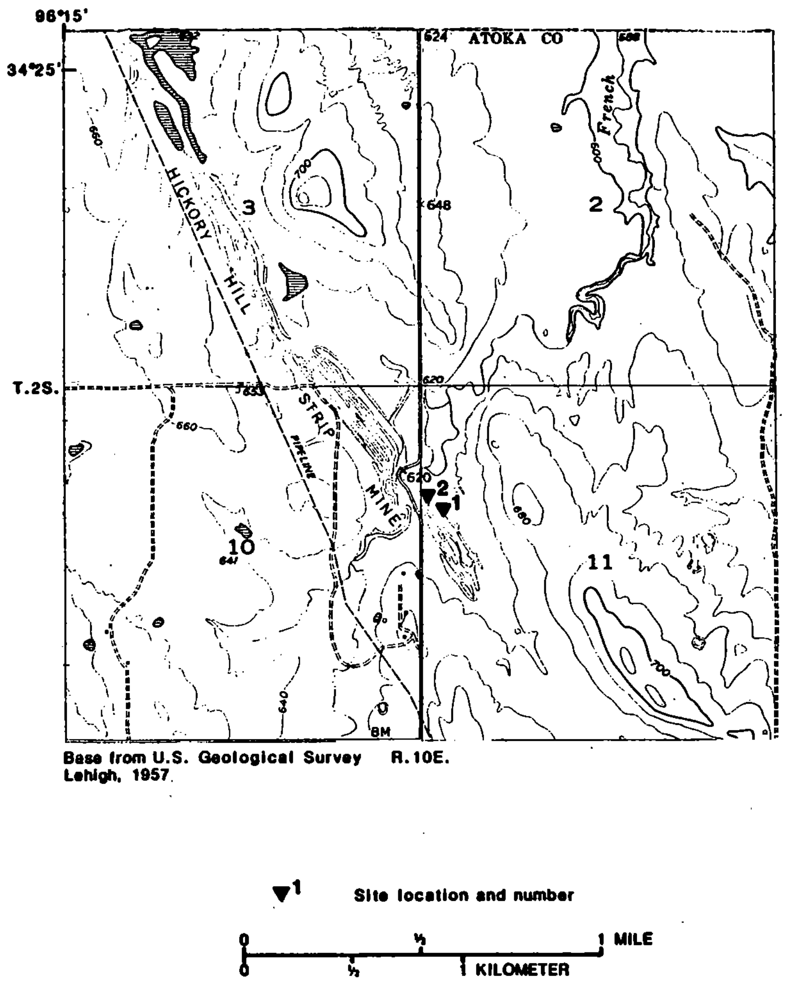
Physical or chemical characteristics	Recommended drinking-water limit*	Number of analyses	Standard deviation	Percentile						
				Minimum 0	10th	25th	Median 50th	75th	90th	Maximum 100th
Specific conductance** (µmho/cm)	---	1,292	835	93	260	440	700	1,090	2,090	4,800
pH	6.5-8.5	1,233	0.7	3.2	6.7	7.2	7.6	8.1	8.4	9.4
Sulfate (mg/L)	250	383	470	3.7	26	70	210	500	940	2,300
Chloride (mg/L)	250	378	29	0.1	2.0	3.0	4.0	7.1	13	240
Iron, dissolved (µg/L)	300	357	1,300	10	10	20	40	90	640	10,000
Manganese, dissolved (µg/L)	50	356	7,500	0	10	20	80	1,400	4,500	56,000

*U.S. Environmental Protection Agency, 1979.
**At 25°C.

Table 6. -- Minimum, median, maximum, and number of pH determinations of mine-pond water for each associated coal bed

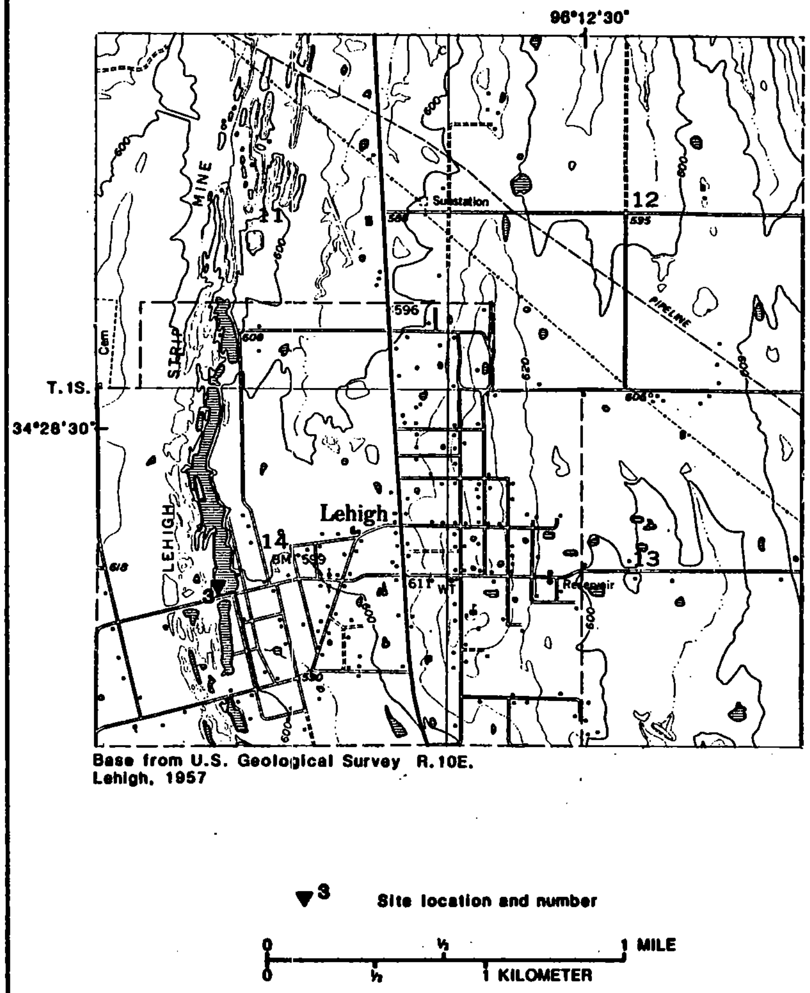
	pH of mine-pond water			
Associated coal bed	Minimum	Median	Maximum	Number of determinations
Dawson	7.0	7.7	8.2	38
Iron Post	6.3	7.4	8.0	22
Croweburg	6.1	7.8	9.1	263
Weir-Pittsburg	6.6	7.5	7.7	26
Secor	3.2	3.3	8.1	21
Secor*	7.3	7.7	8.1	10
McAlester (Stigler)	5.1	7.6	9.4	588
Hartshorne	6.3	7.5	9.0	262

*Excluding the pH values for Warner Pond.



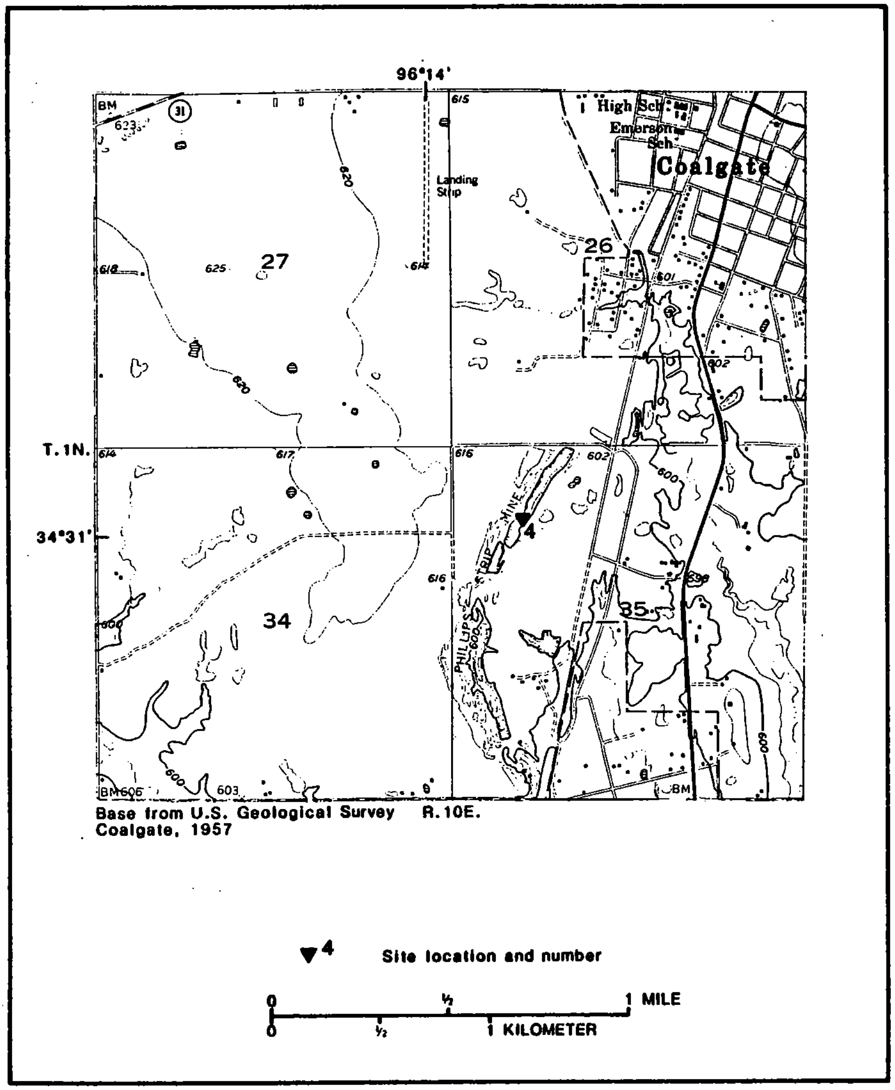
Base from U.S. Geological Survey R.10E.
Lehigh, 1957

Figure 9.--Sites 1-2.



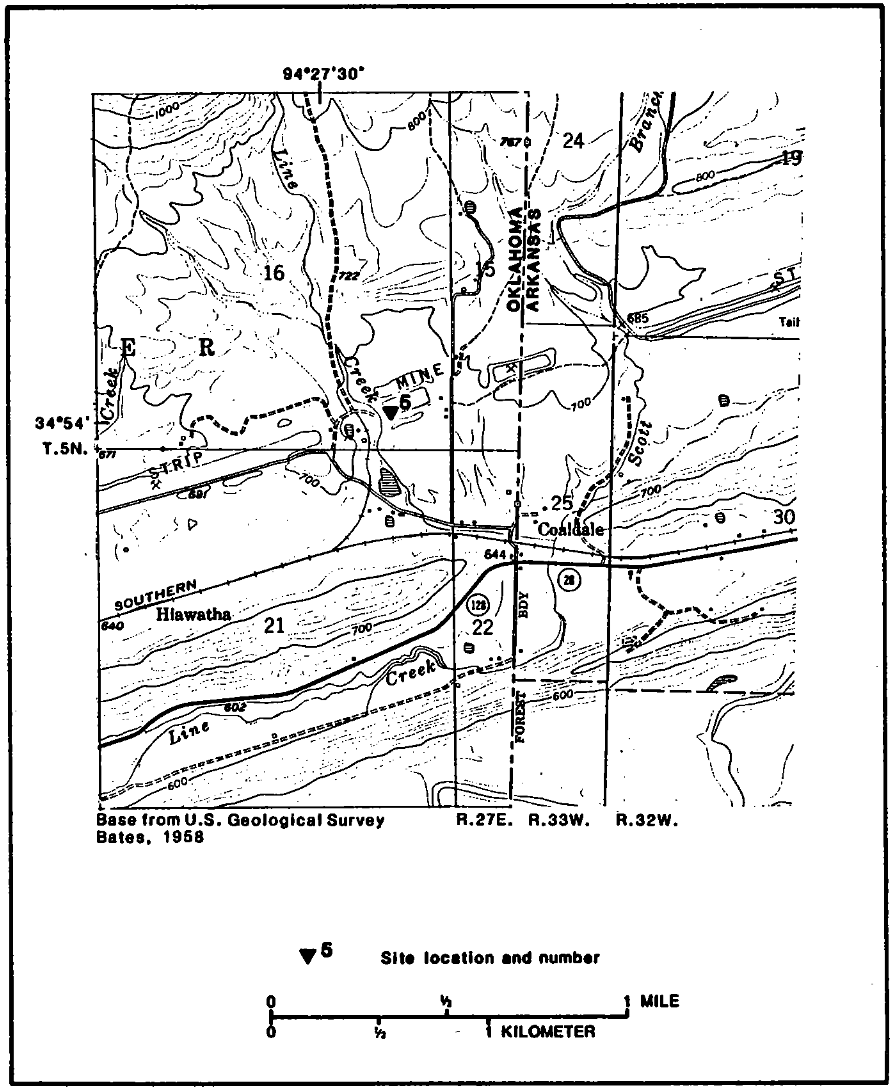
Base from U.S. Geological Survey R.10E.
Lehigh, 1957

Figure 10.--Site 3.



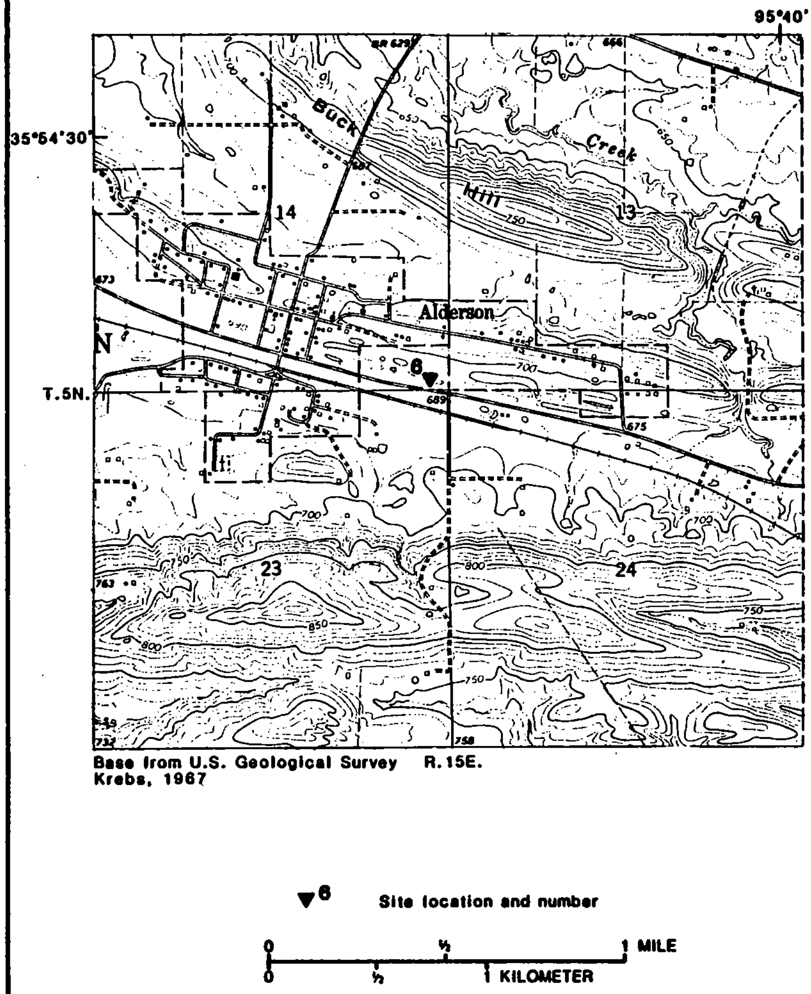
Base from U.S. Geological Survey Coalgate, 1957

Figure 11.--Site 4.



Base from U.S. Geological Survey Bates, 1958

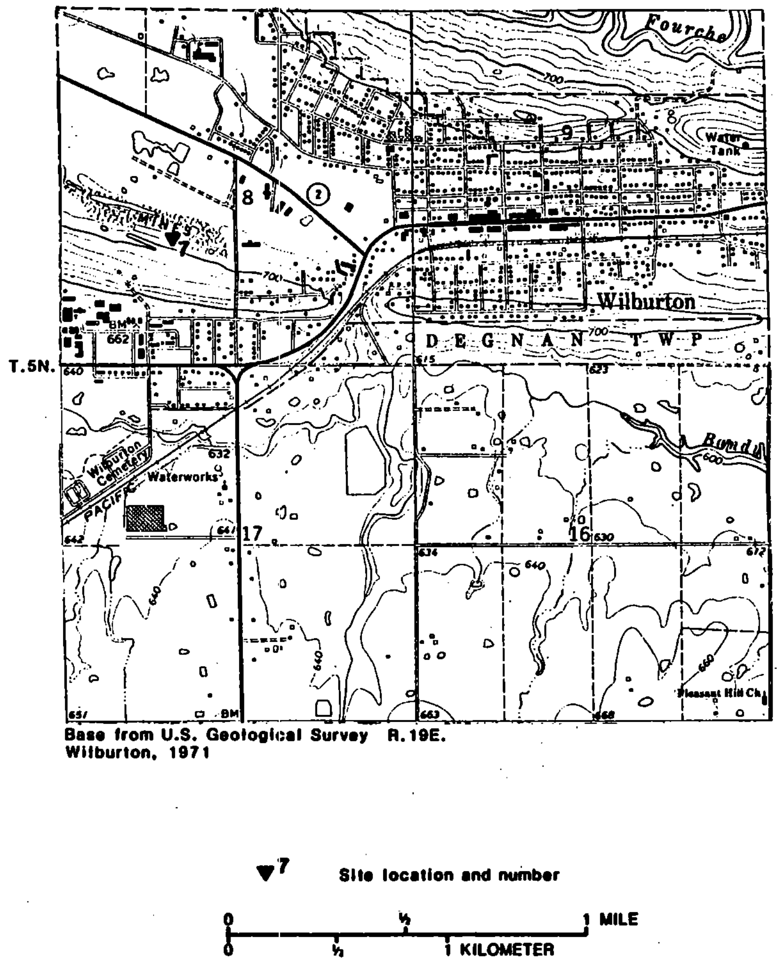
Figure 12.--Site 5.



Base from U.S. Geological Survey R.15E.
Krebs, 1967

▼6 Site location and number

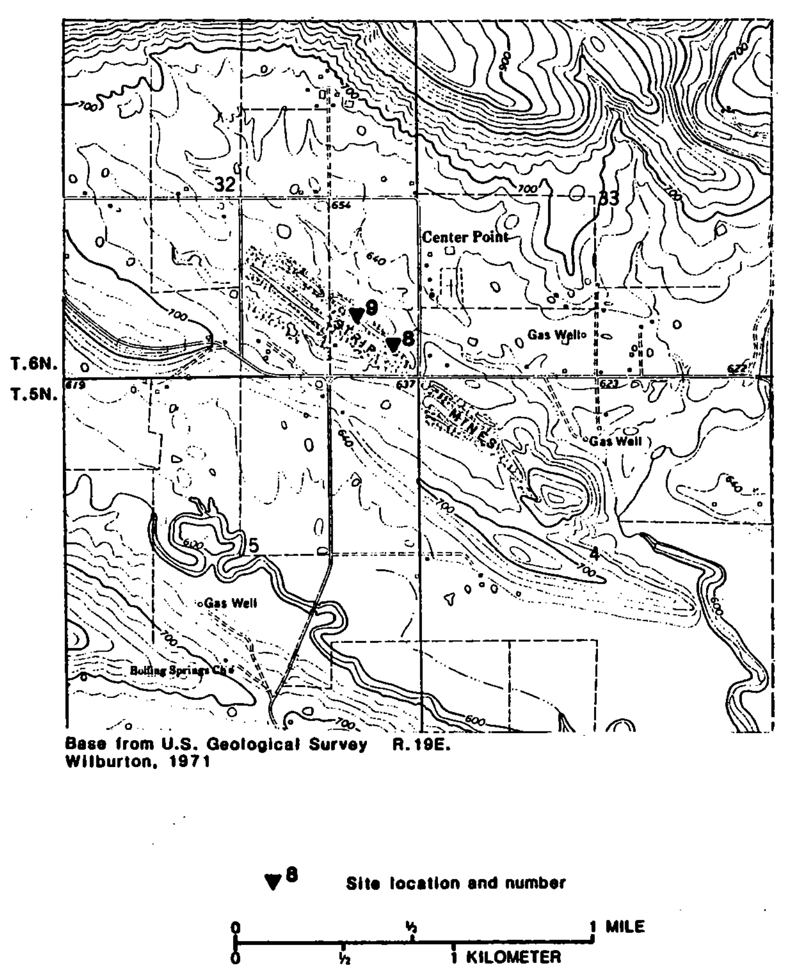
Figure 13.--Site 6.



Base from U.S. Geological Survey R.19E.
Wilburton, 1971

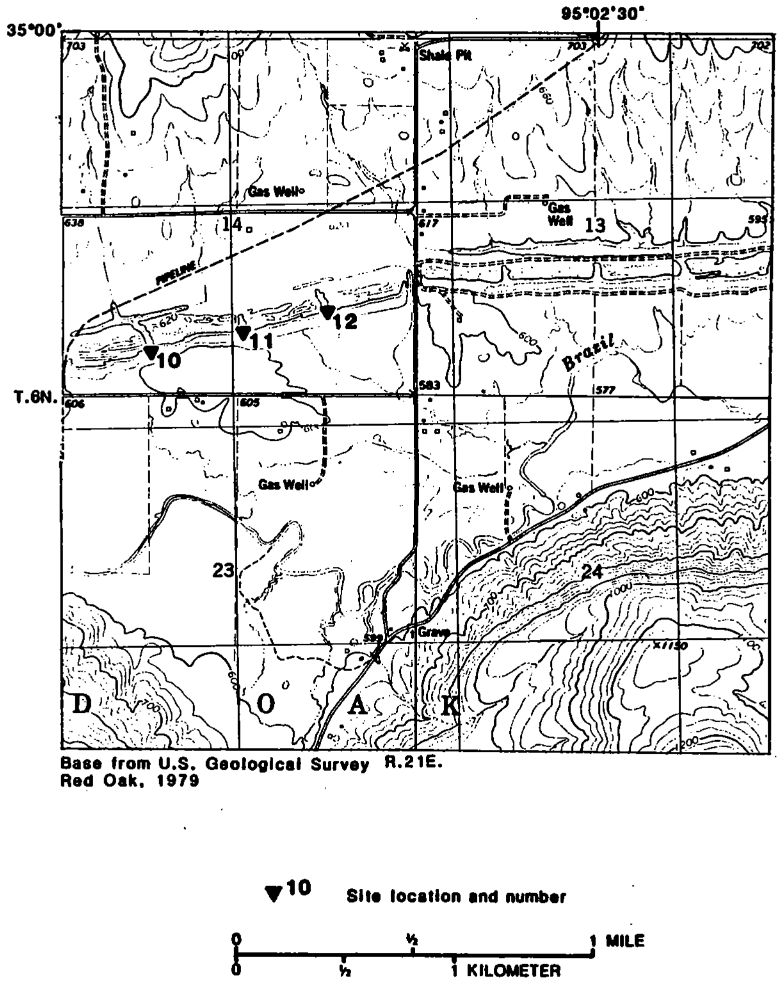
▼7 Site location and number

Figure 14.--Site 7.



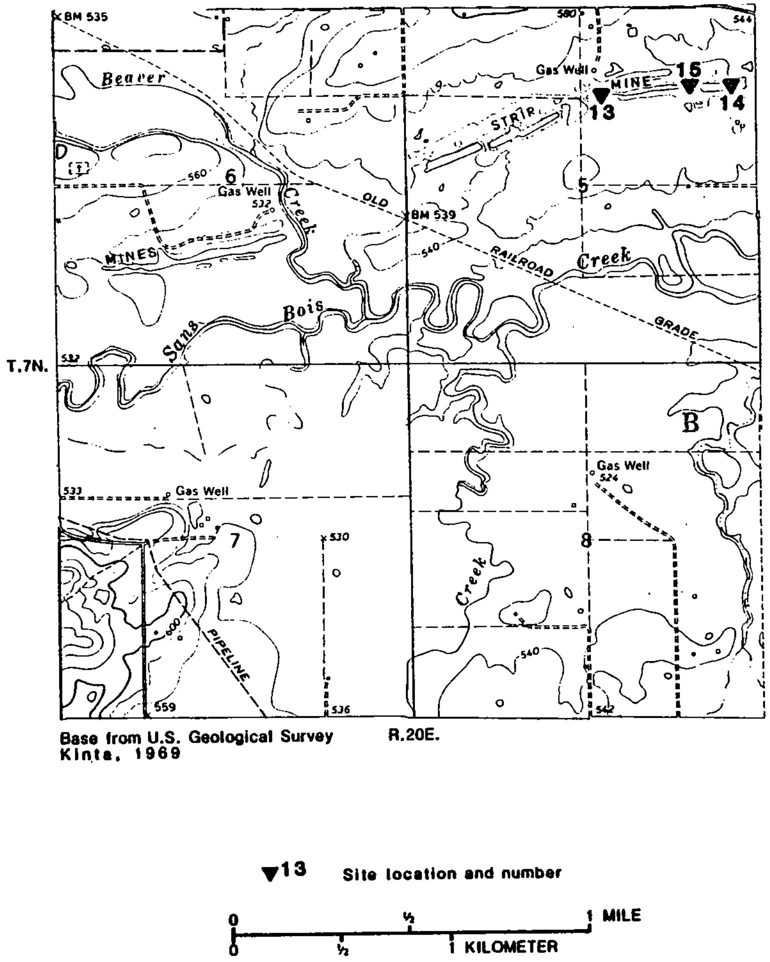
Base from U.S. Geological Survey
Wilburton, 1971

Figure 15.--Sites 8-9.



Base from U.S. Geological Survey
Red Oak, 1979

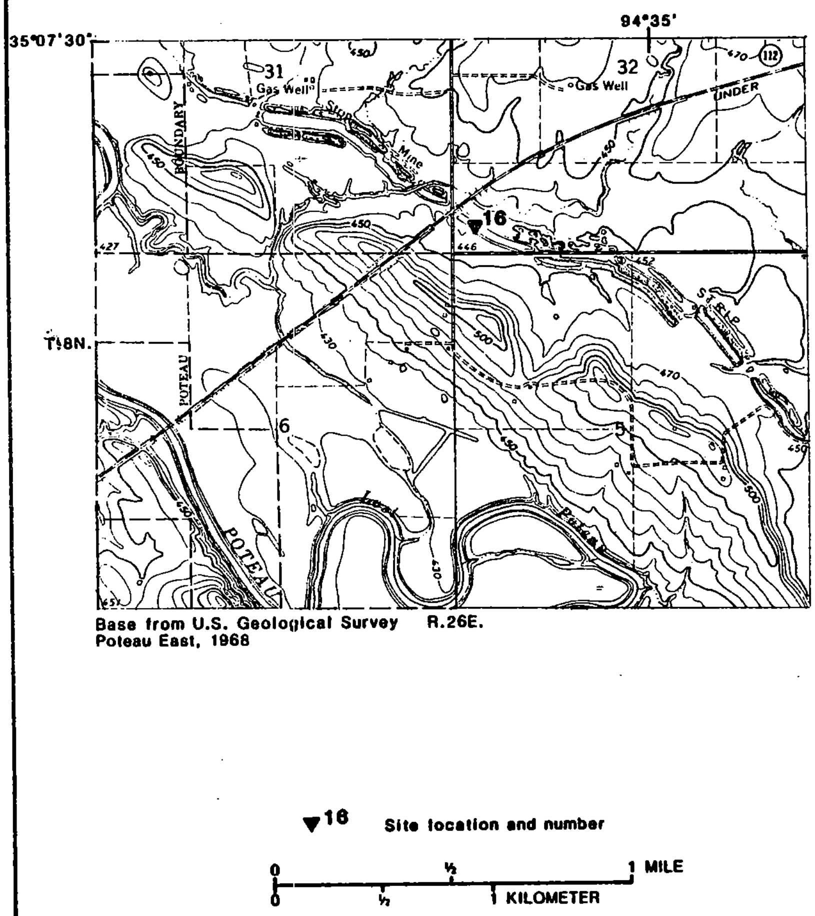
Figure 16.--Sites 10-12.



Base from U.S. Geological Survey
Kinta, 1969

▼13 Site location and number

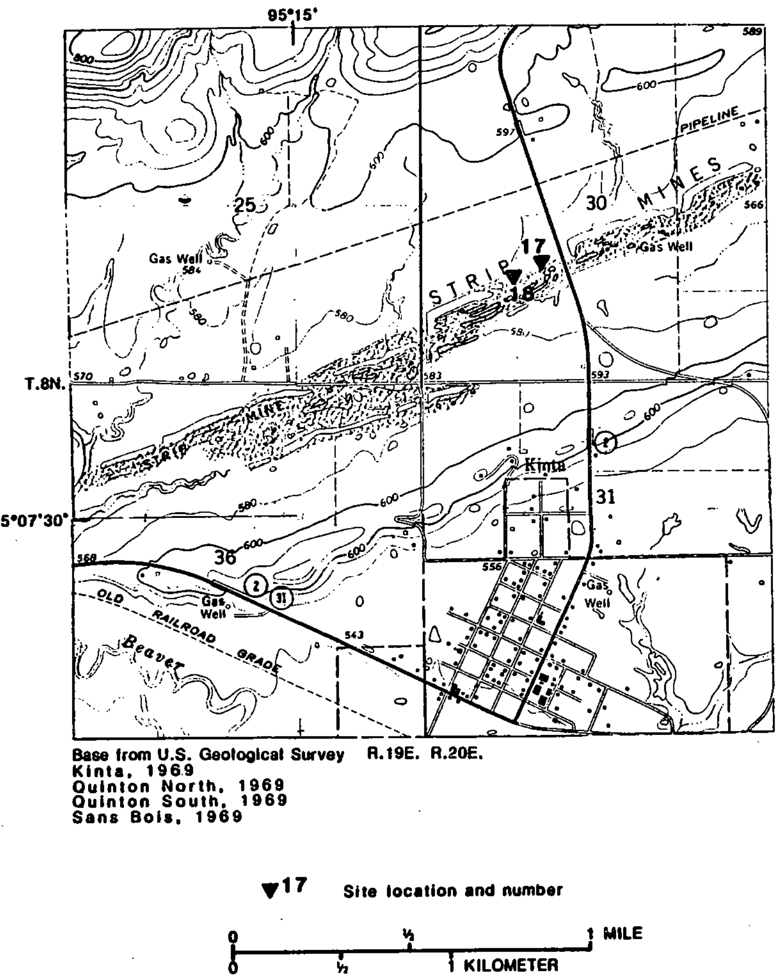
Figure 17.--Sites 13-15.



Base from U.S. Geological Survey
Poteau East, 1968

▼16 Site location and number

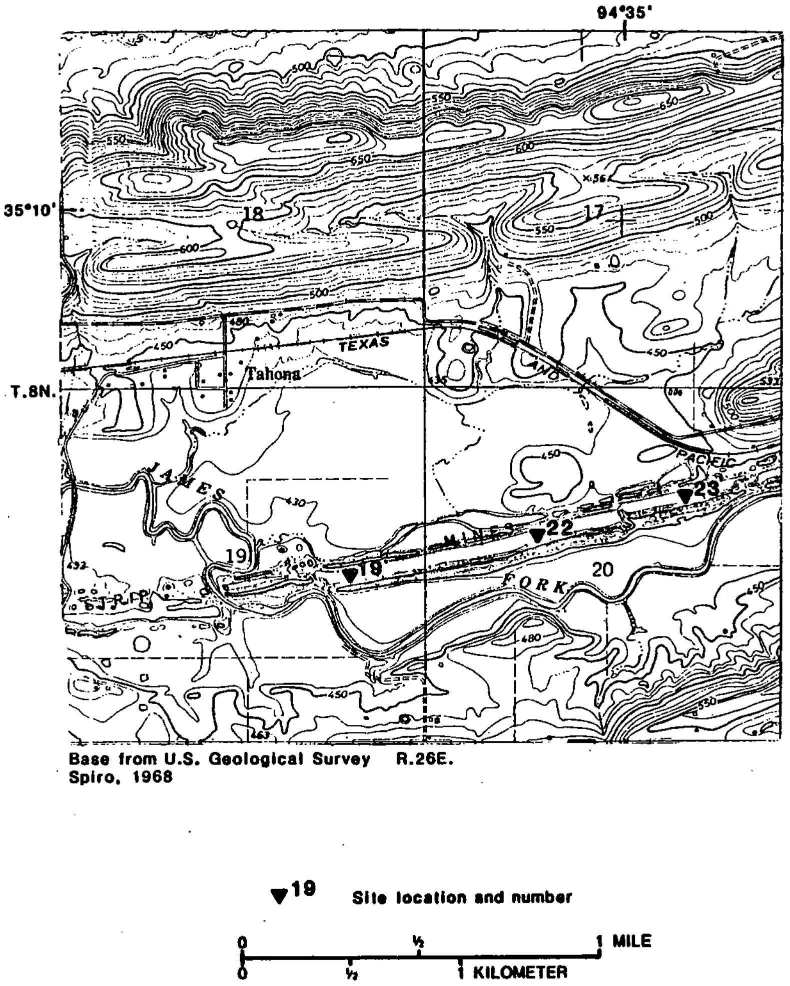
Figure 18.--Site 16.



Base from U.S. Geological Survey
Kinta, 1969
Quinton North, 1969
Quinton South, 1969
Sans Bois, 1969

▼17 Site location and number

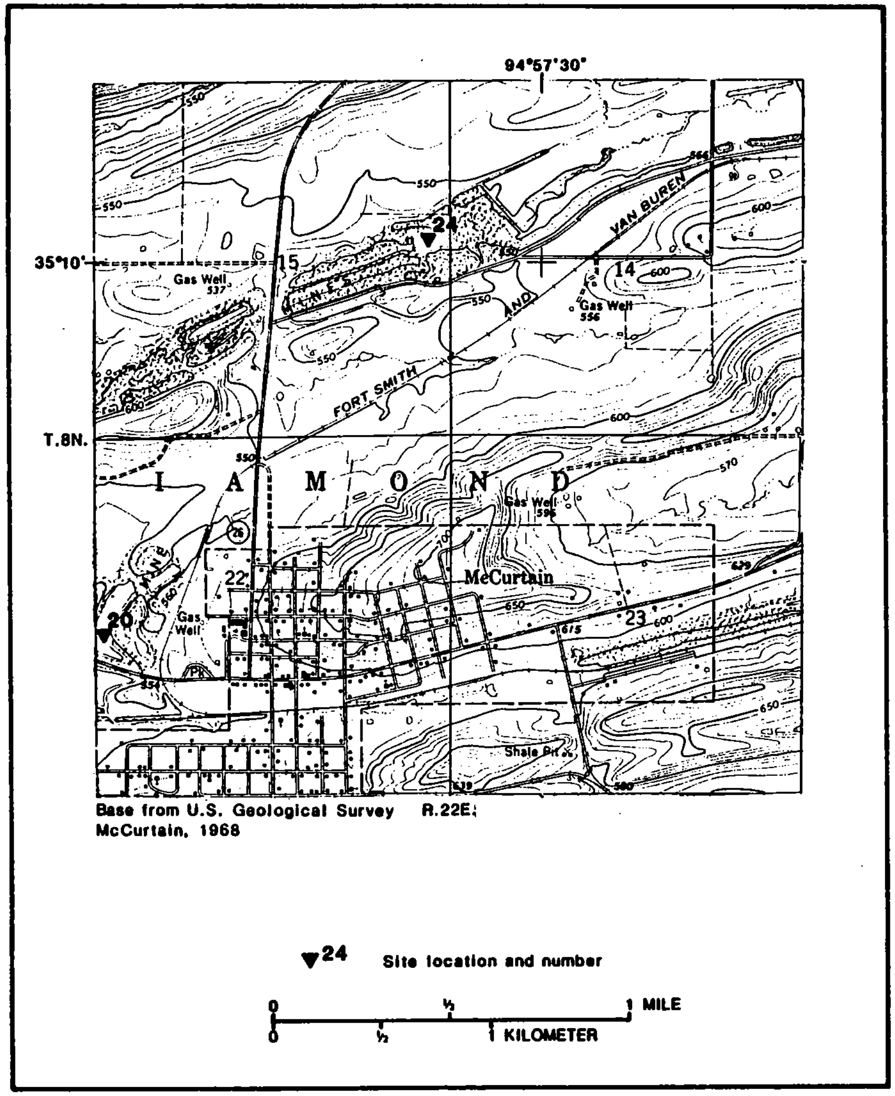
Figure 19.--Sites 17-18.



Base from U.S. Geological Survey
Spiro, 1968

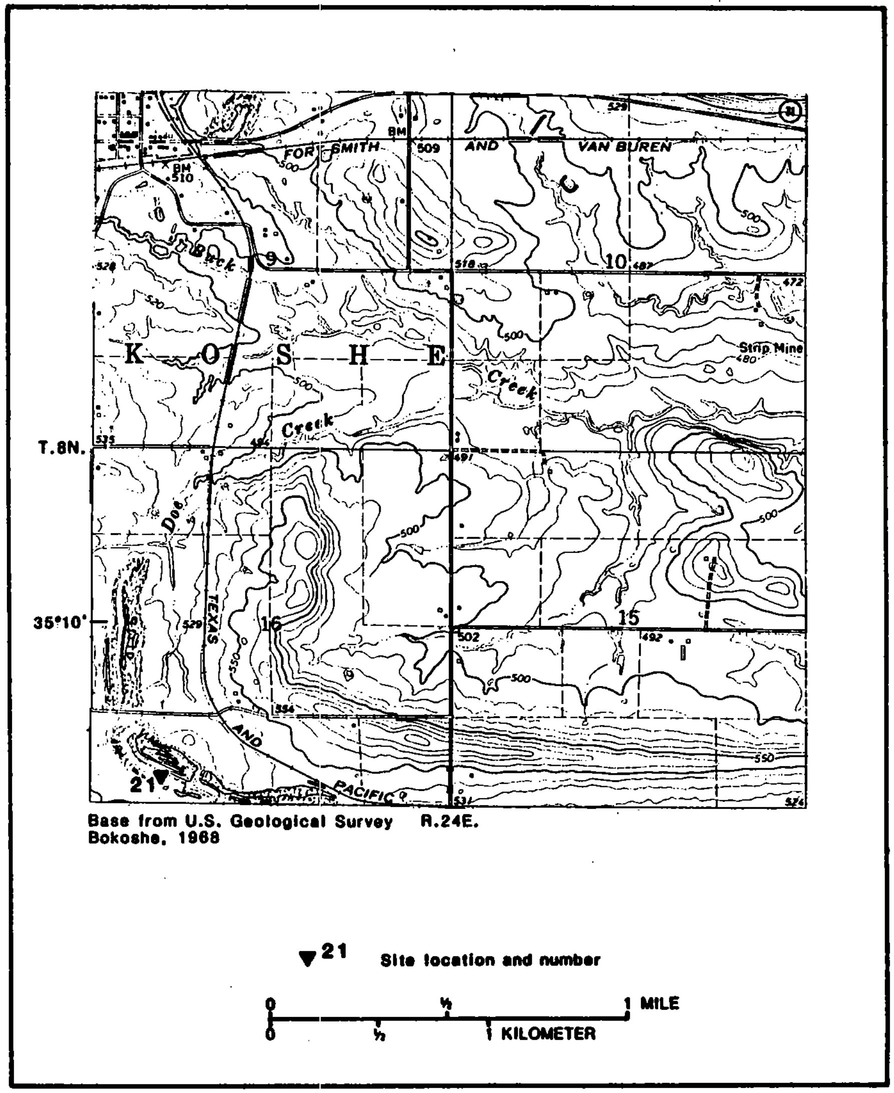
▼19 Site location and number

Figure 20.--Sites 19 and 22-23.



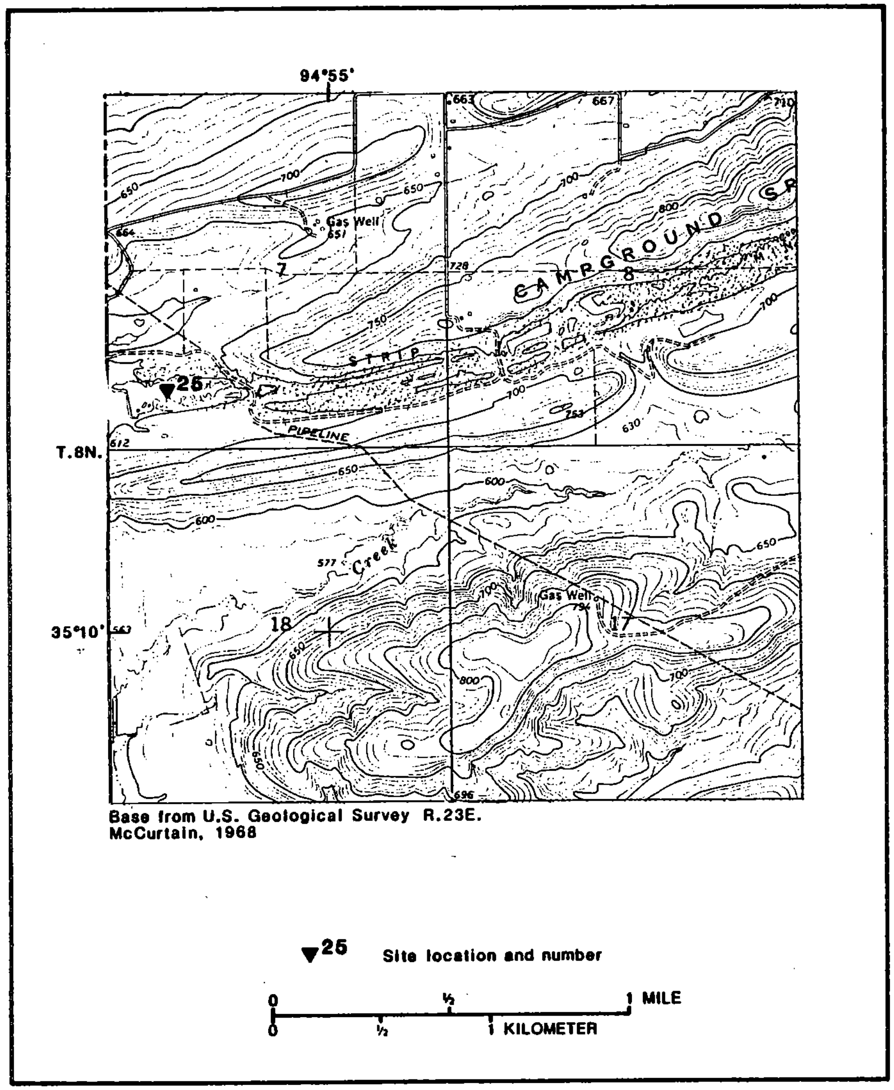
Base from U.S. Geological Survey McCurtain, 1968

Figure 21.--Sites 20 and 24.



Base from U.S. Geological Survey Bokoshe, 1968

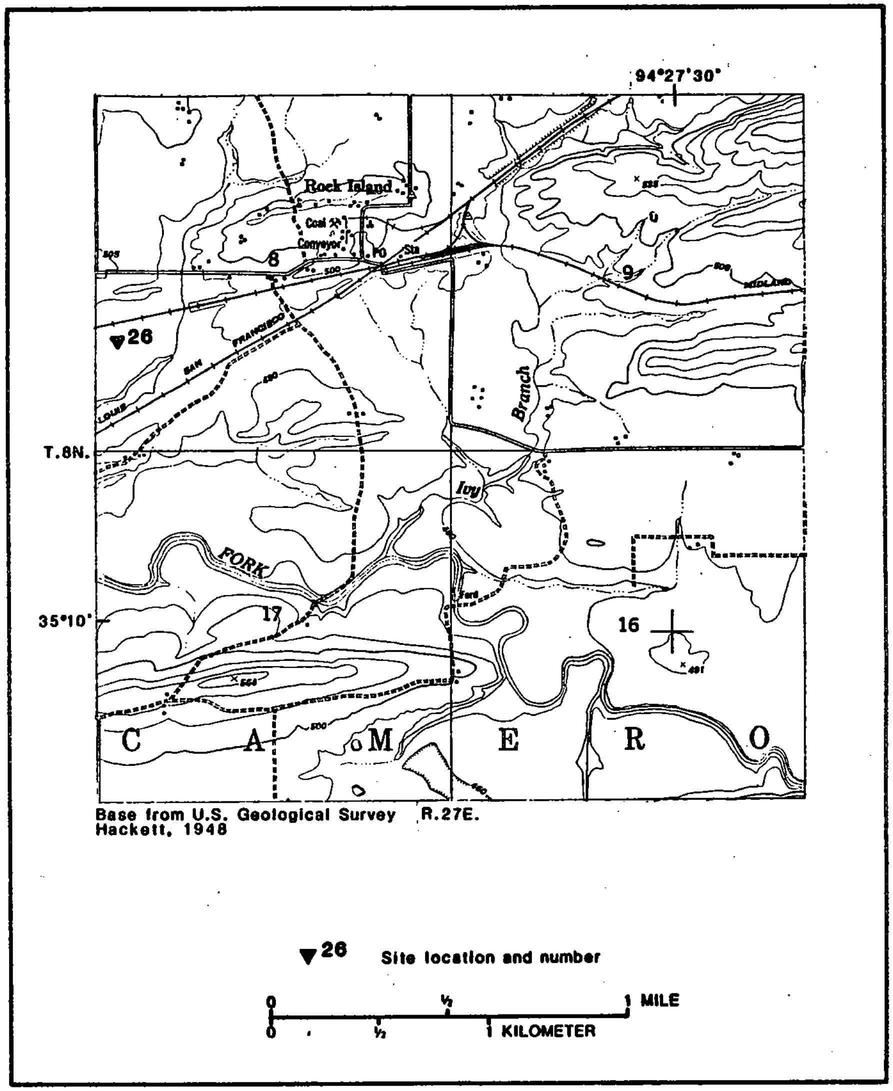
Figure 22.--Site 21.



Base from U.S. Geological Survey R.23E.
McCurtain, 1968

▼25 Site location and number

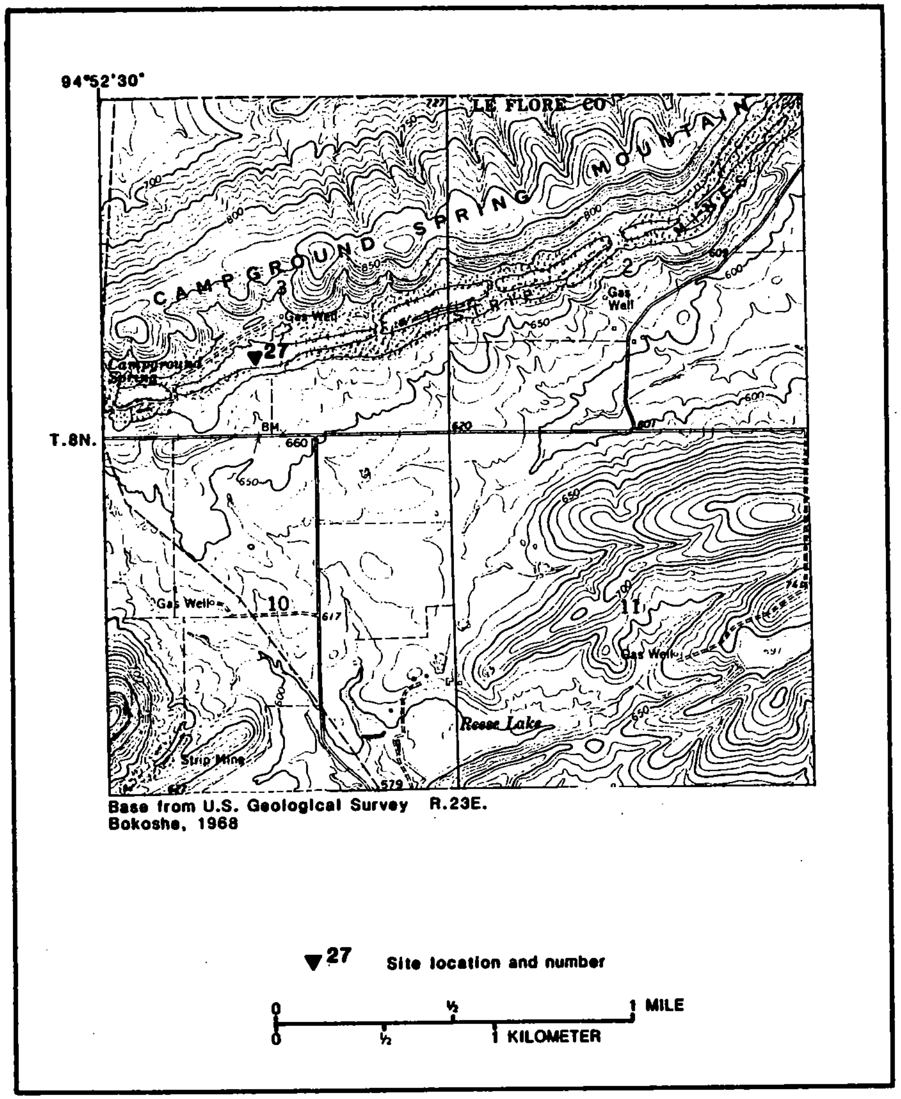
Figure 23.--Site 25.



Base from U.S. Geological Survey R.27E.
Hackett, 1948

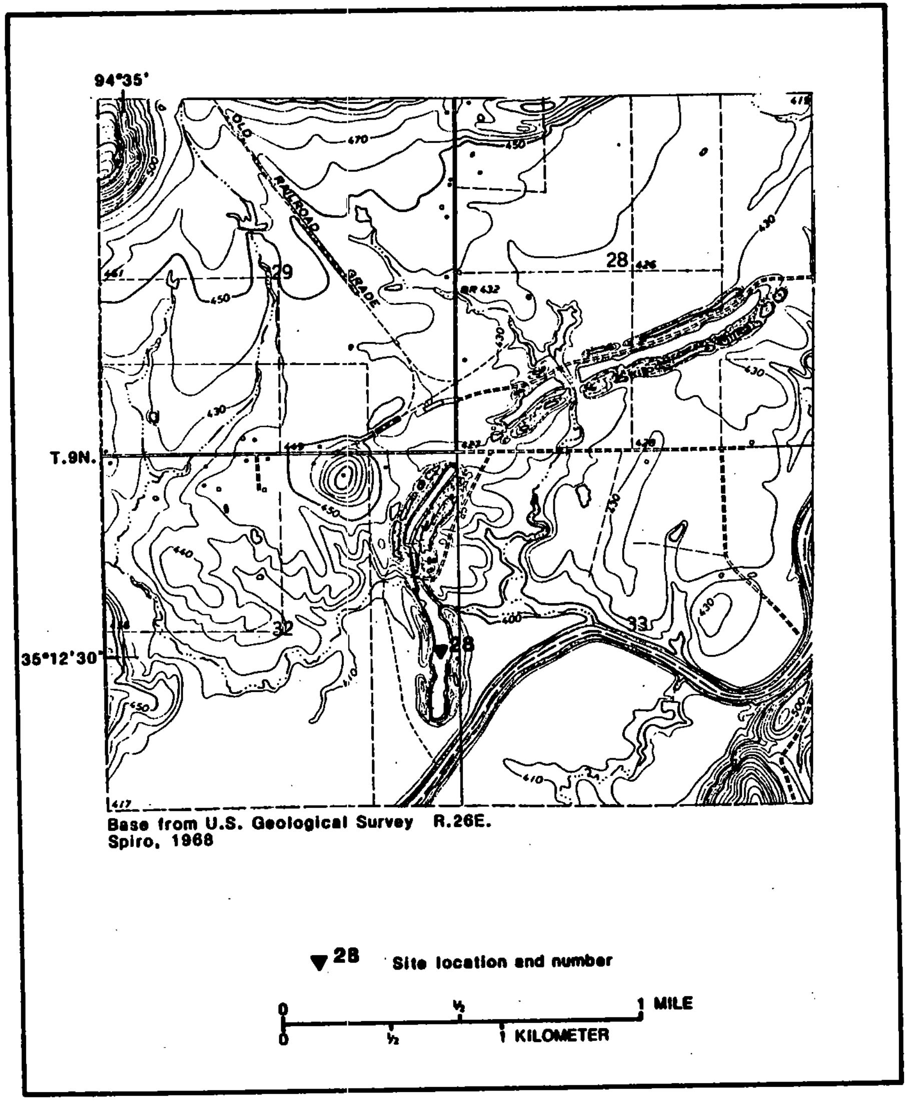
▼26 Site location and number

Figure 24.--Site 26.



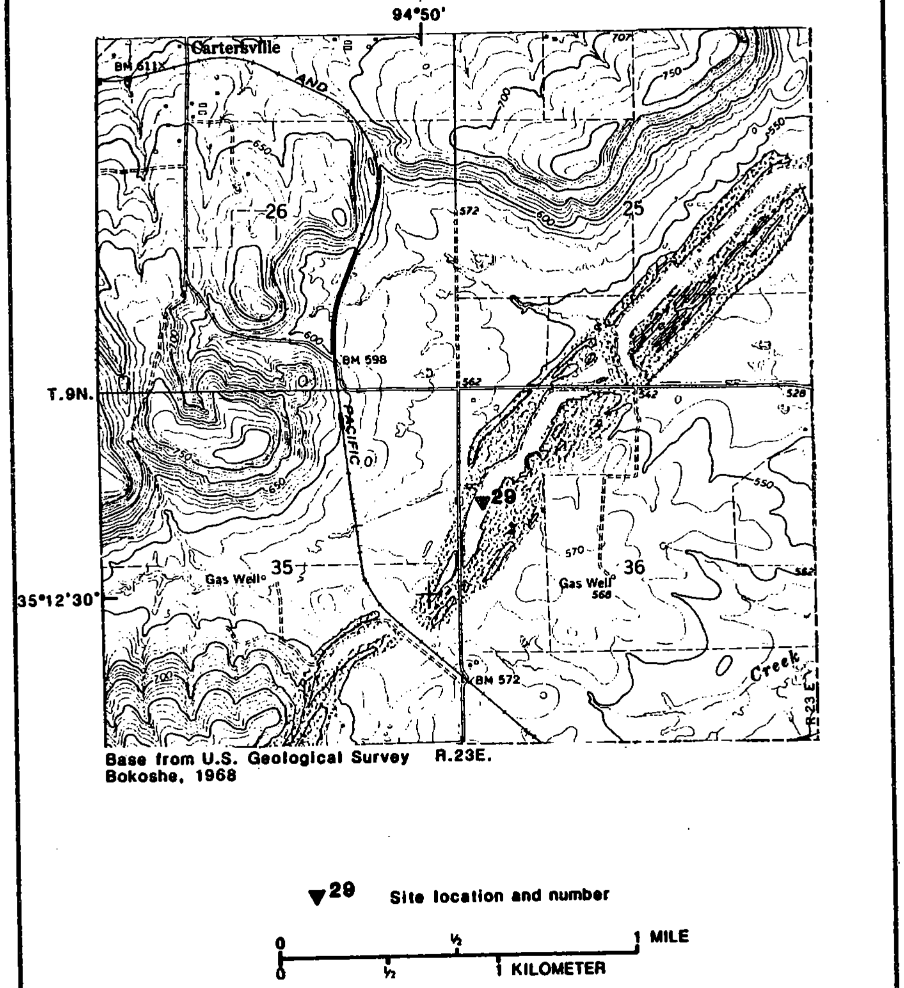
Base from U.S. Geological Survey
Bokoshe, 1968

Figure 25.--Site 27.



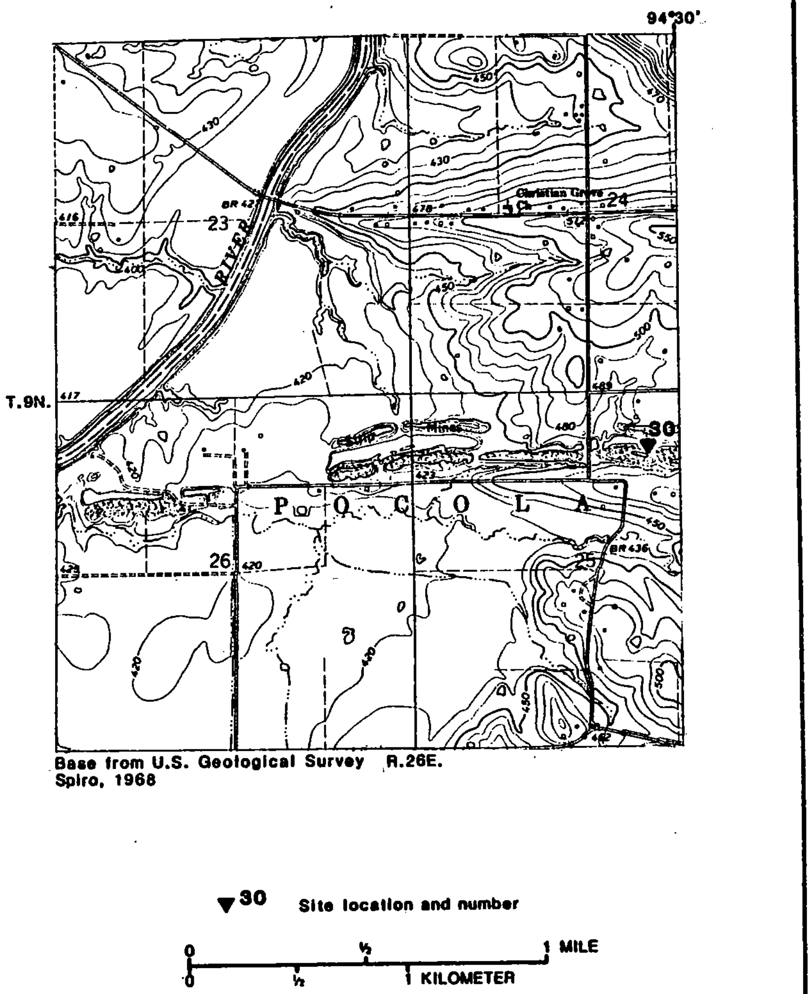
Base from U.S. Geological Survey
Spiro, 1968

Figure 26.--Site 28.



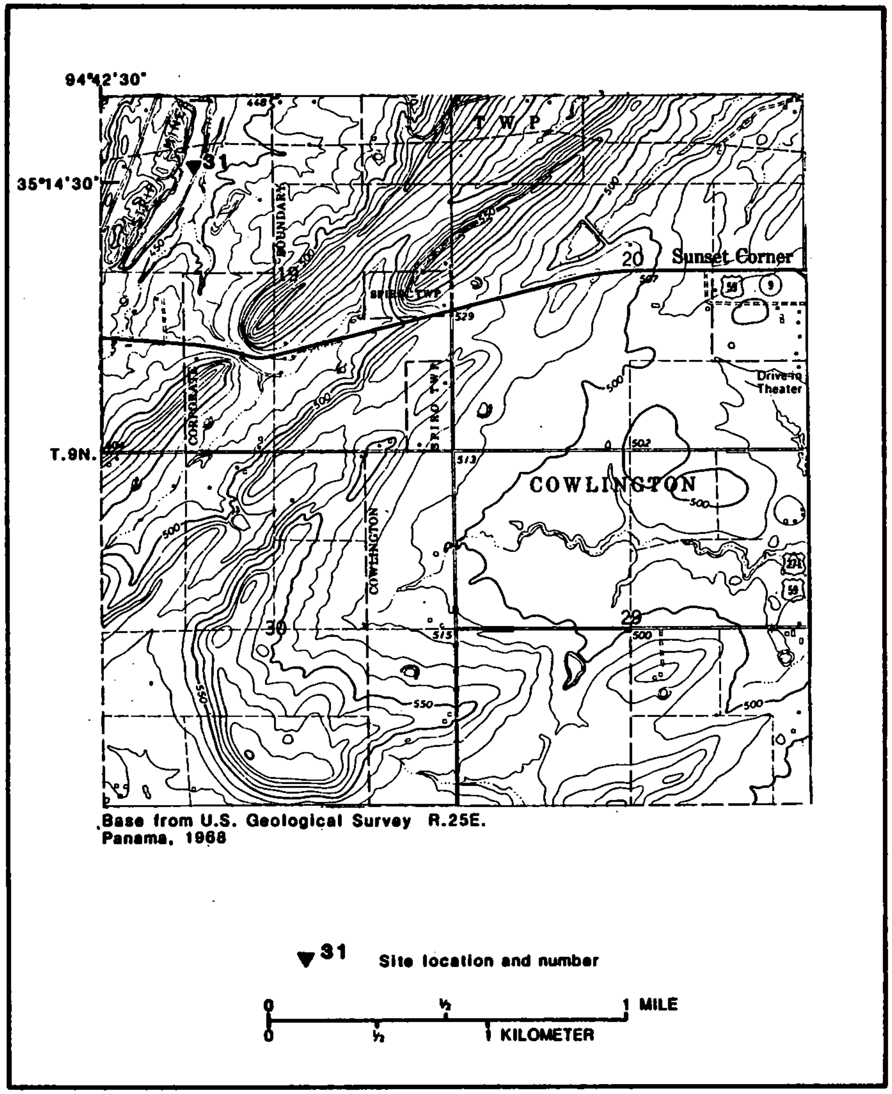
Base from U.S. Geological Survey R.23E.
Bokoshe, 1968

Figure 27.--Site 29.



Base from U.S. Geological Survey R.26E.
Spiro, 1968

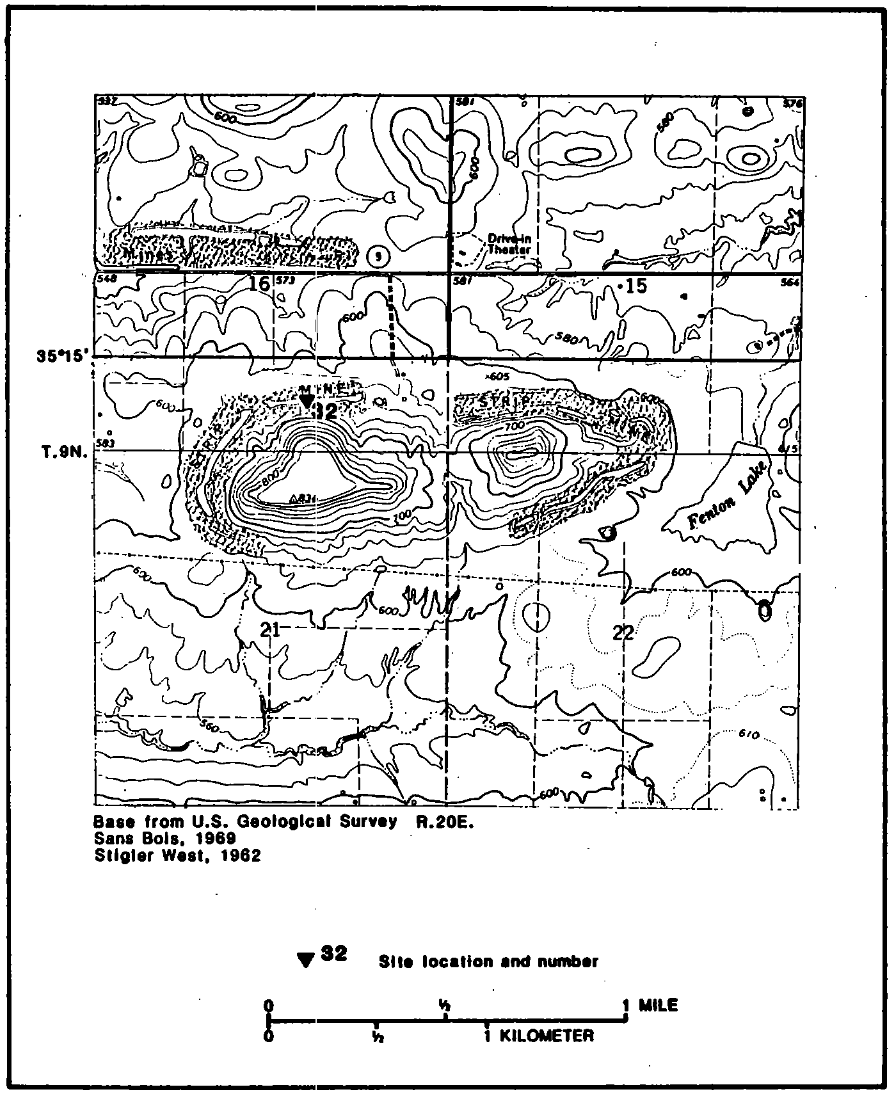
Figure 28.---Site 30.



Base from U.S. Geological Survey R.25E.
Panama, 1968

▼31 Site location and number

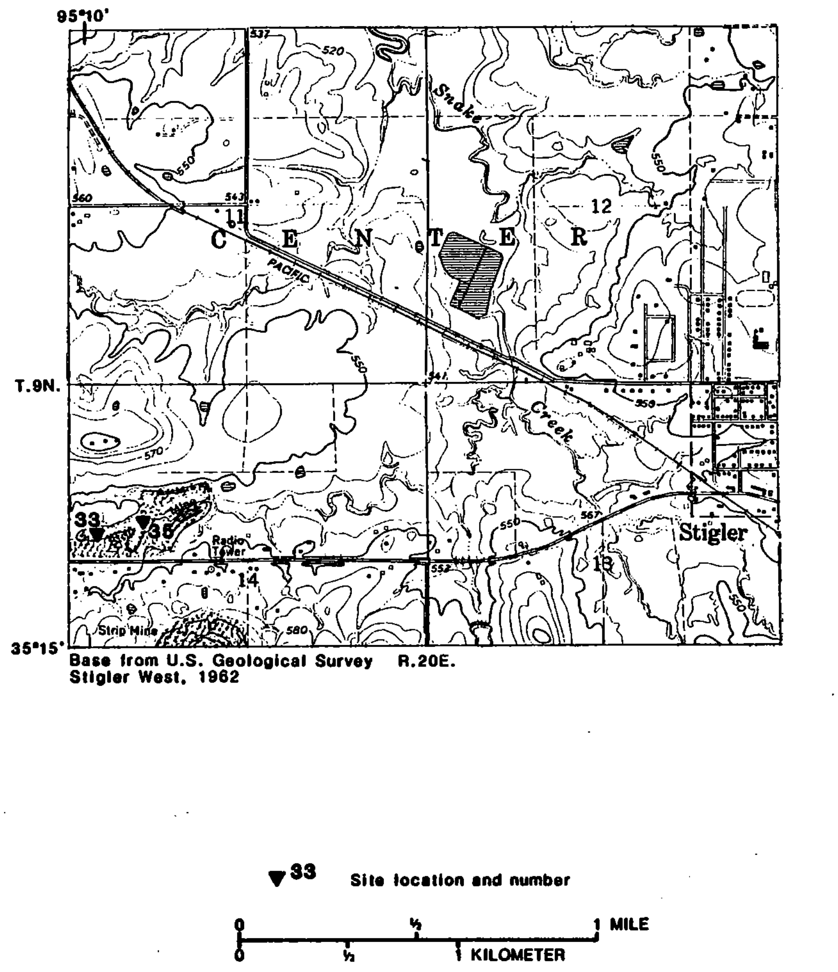
Figure 29.--Site 31.



Base from U.S. Geological Survey R.20E.
Sans Bois, 1969
Stigler West, 1962

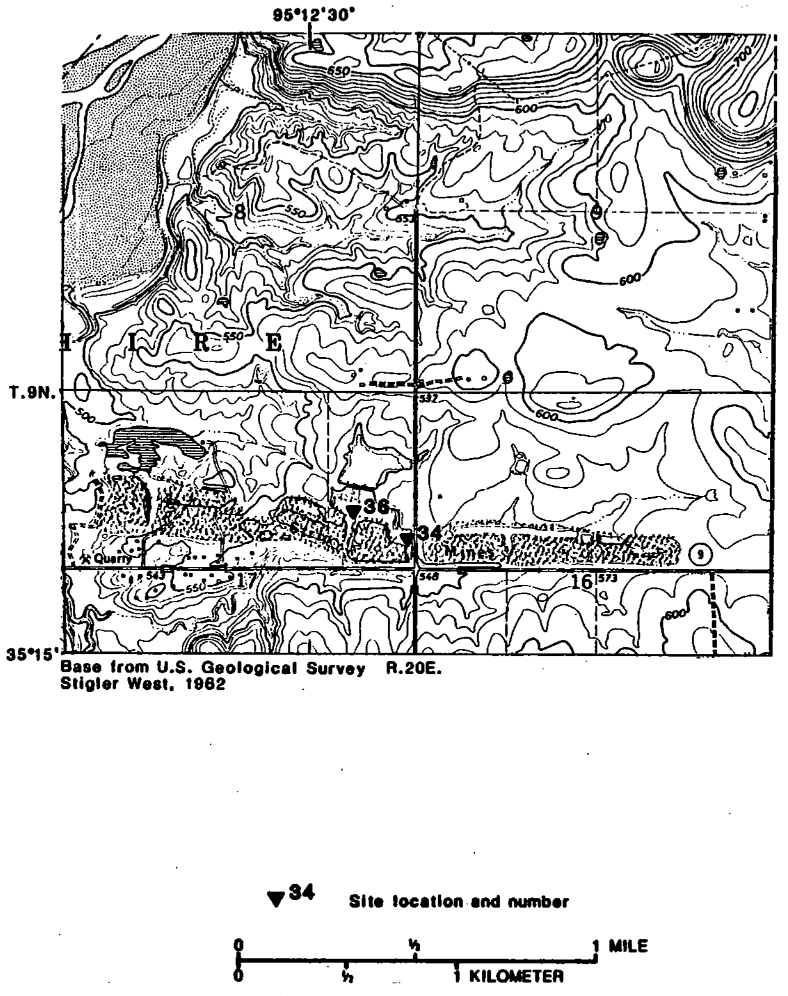
▼32 Site location and number

Figure 30.--Site 32.



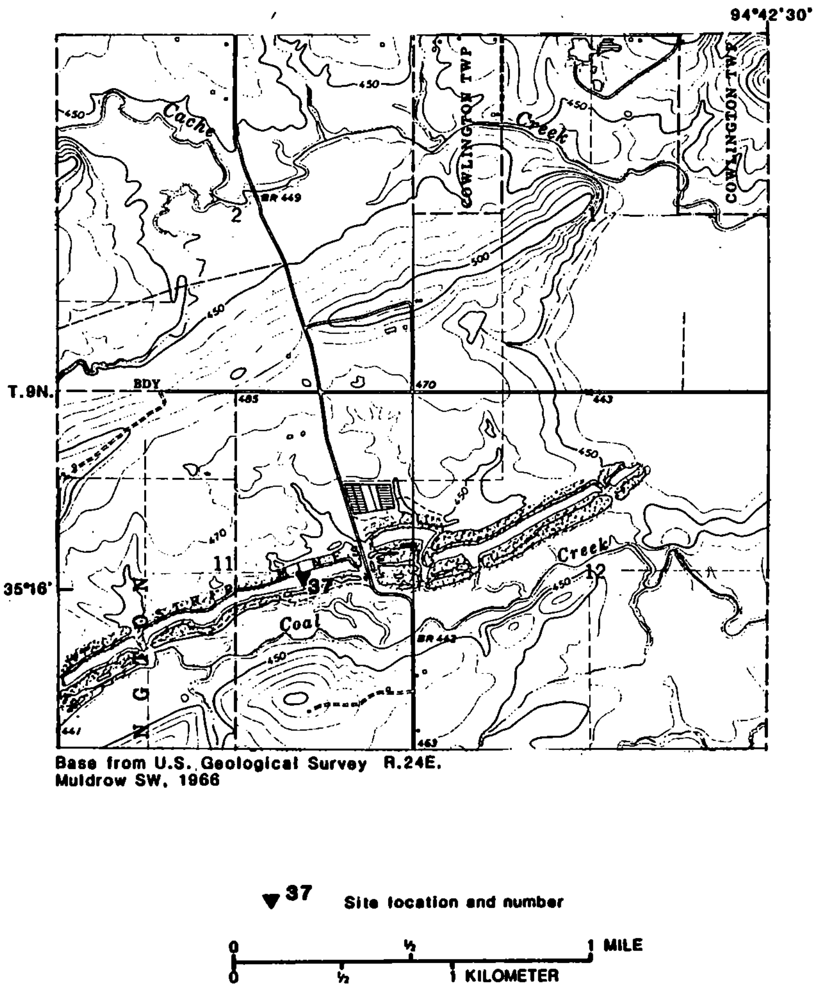
Base from U.S. Geological Survey R.20E.
Stigler West, 1962

Figure 31.--Sites 33 and 35.



Base from U.S. Geological Survey R.20E.
Stigler West, 1962

Figure 32.--Sites 34 and 36.

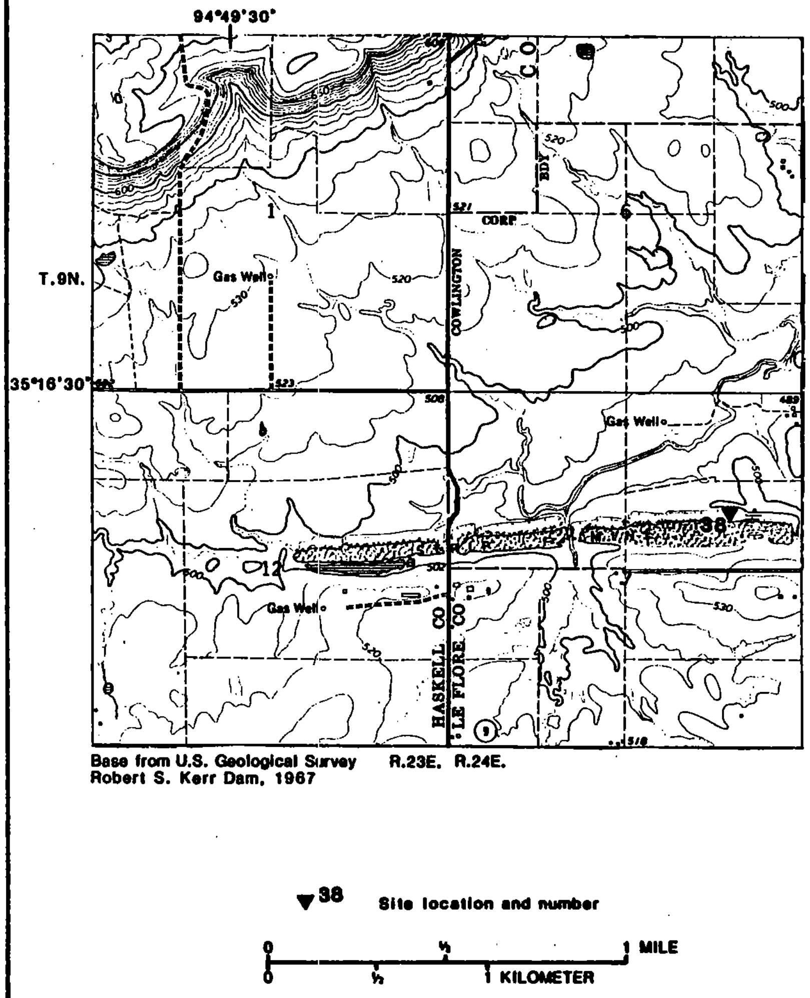


Base from U.S. Geological Survey Muldrow SW, 1966

R.24E.

▼37 Site location and number

Figure 33.--Site 37.

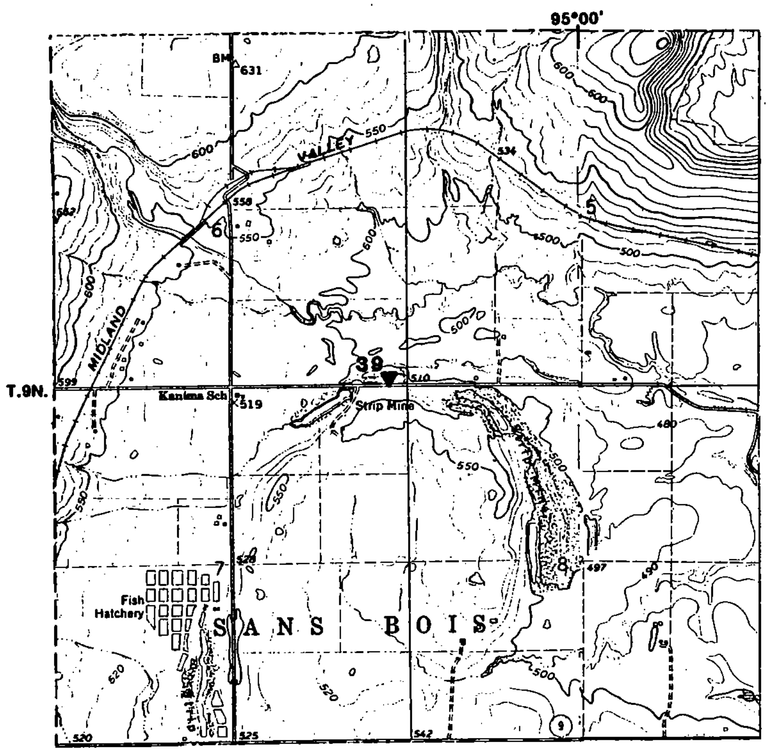


Base from U.S. Geological Survey Robert S. Kerr Dam, 1967

R.23E. R.24E.

▼38 Site location and number

Figure 34.--Site 38.

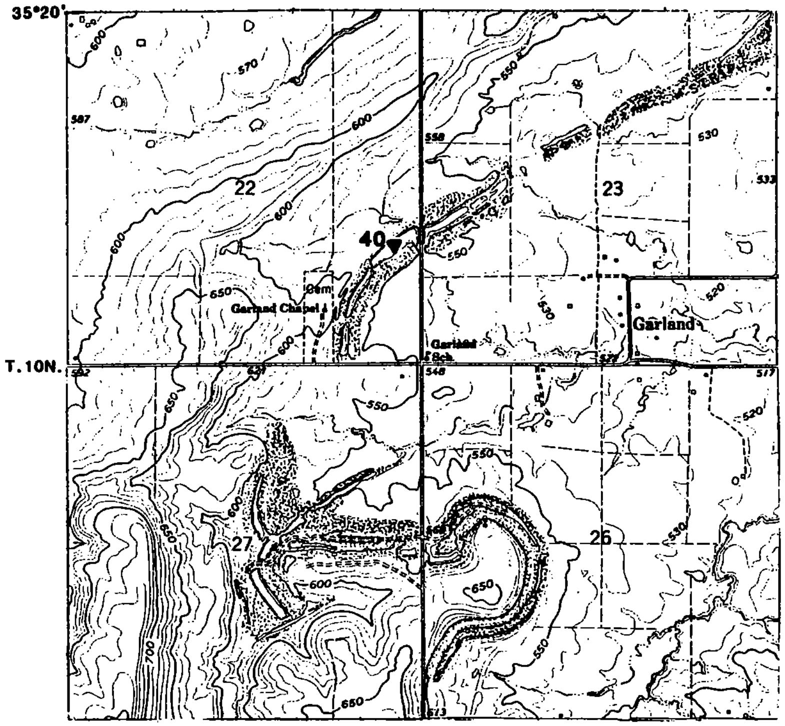


Base from U.S. Geological Survey R.22E.
Keota, 1967
Stigler East, 1962

▼39 Site location and number

0 ½ 1 MILE
0 ½ 1 KILOMETER

Figure 35.--Site 39.

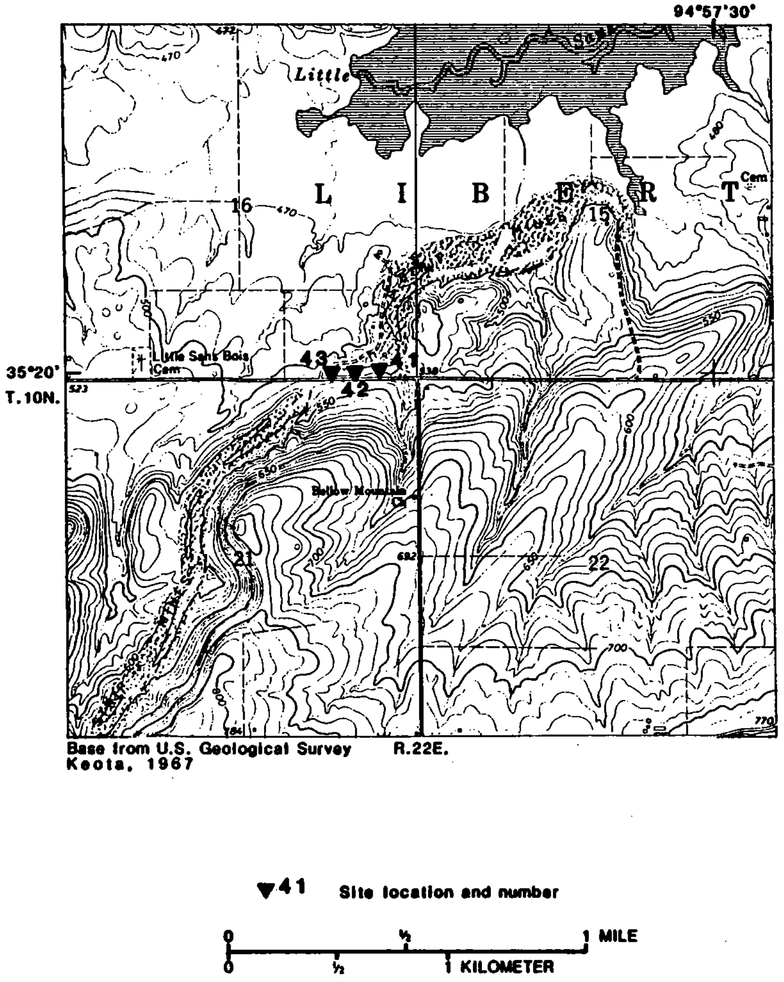


Base from U.S. Geological Survey R.21E.
Stigler East, 1962

▼40 Site location and number

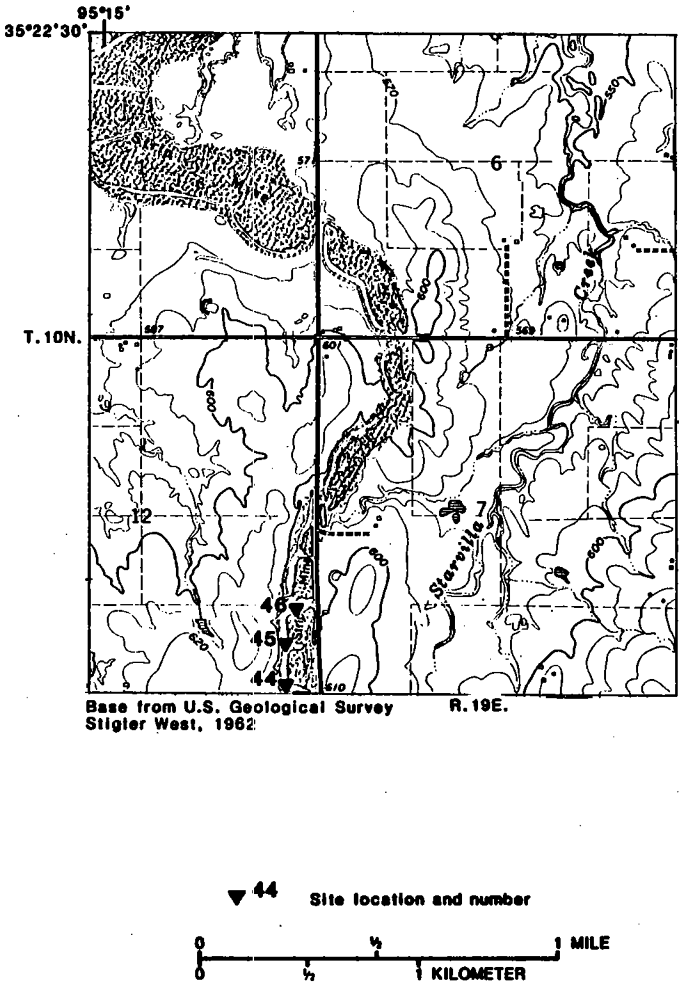
0 ½ 1 MILE
0 ½ 1 KILOMETER

Figure 36.--Site 40.



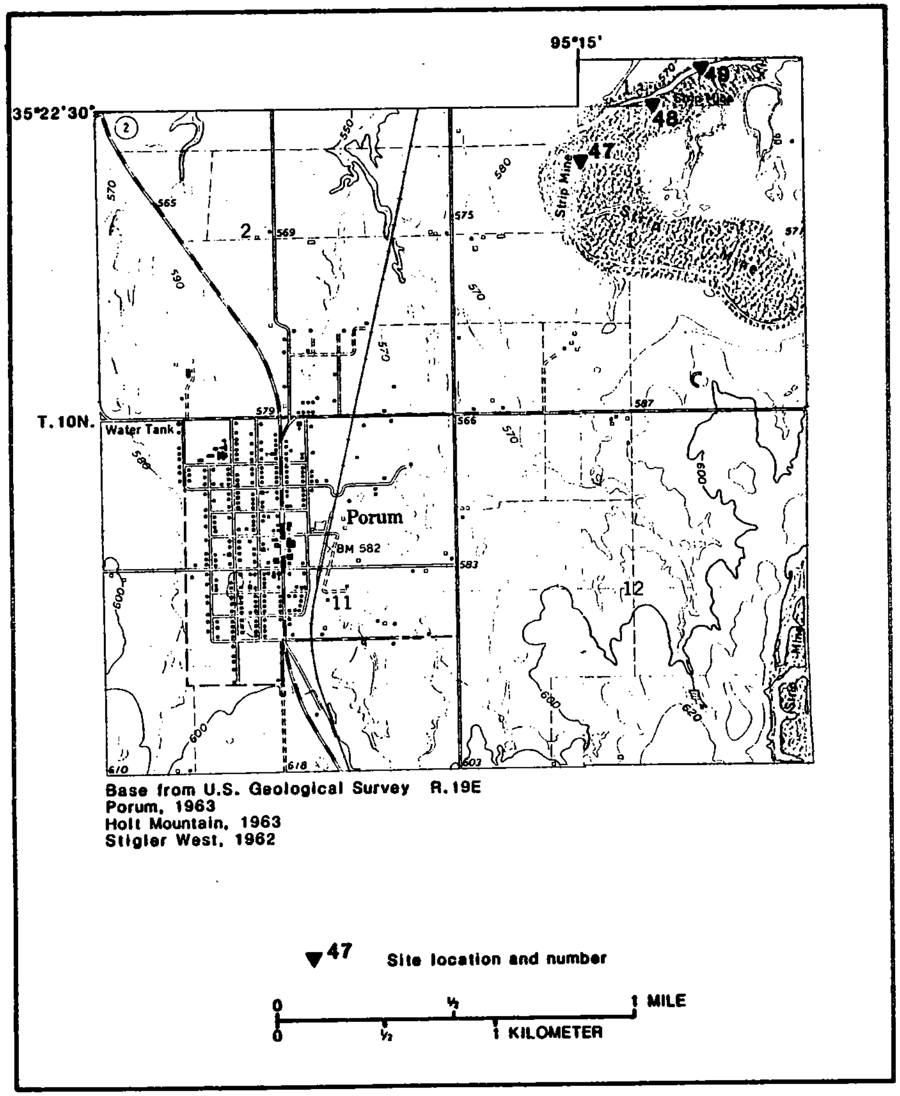
Base from U.S. Geological Survey
Keota, 1967

Figure 37.--Sites 41-43.



Base from U.S. Geological Survey
Stigler West, 1962

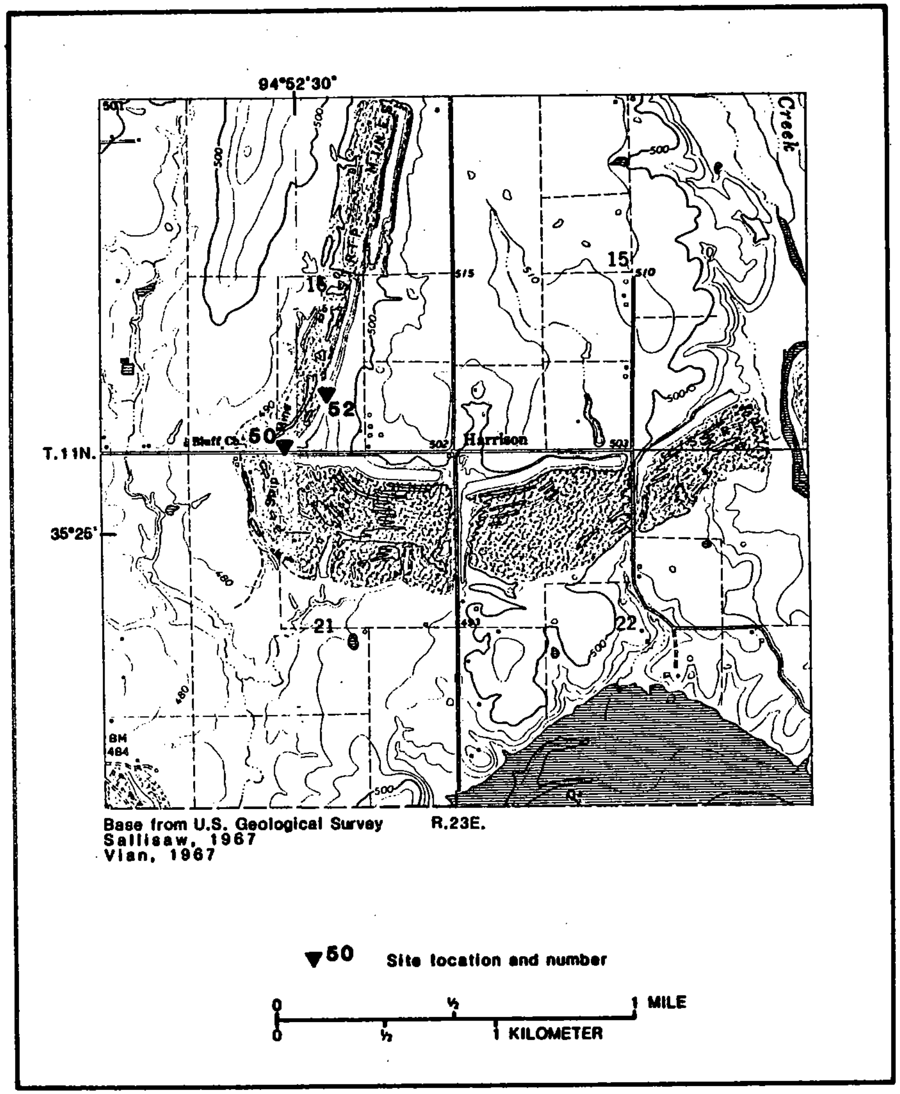
Figure 38.--Sites 44-46.



Base from U.S. Geological Survey
Porum, 1963
Holt Mountain, 1963
Stigler West, 1962

▼47 Site location and number

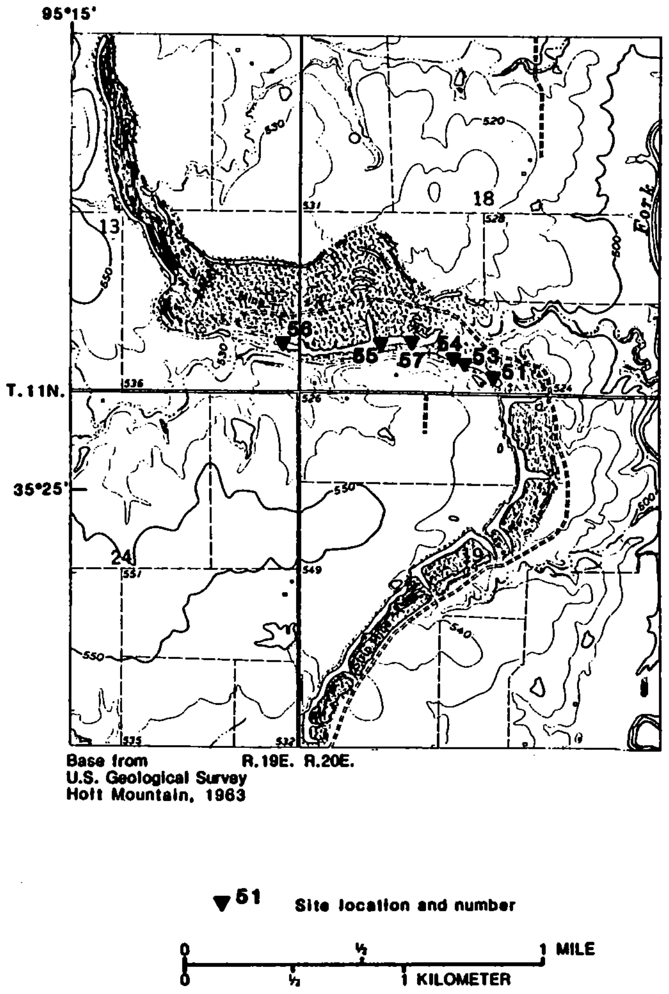
Figure 39.--Sites 47-49.



Base from U.S. Geological Survey
Sallisaw, 1967
Vian, 1967

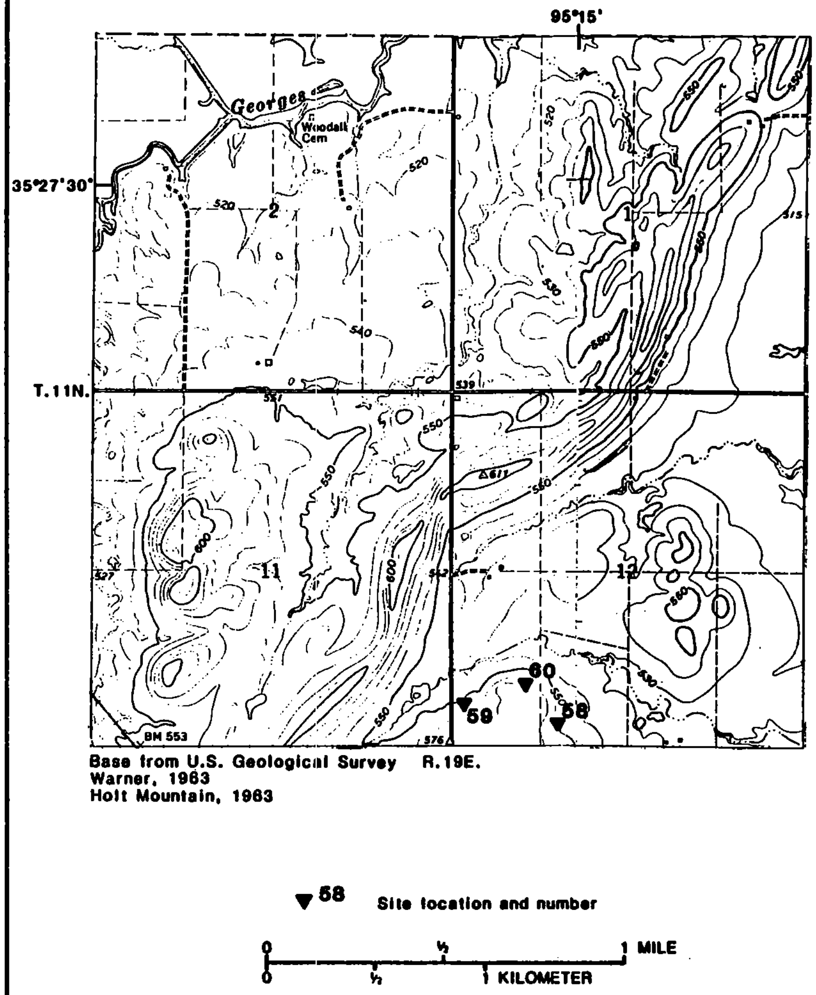
▼50 Site location and number

Figure 40.—Sites 50 and 52.



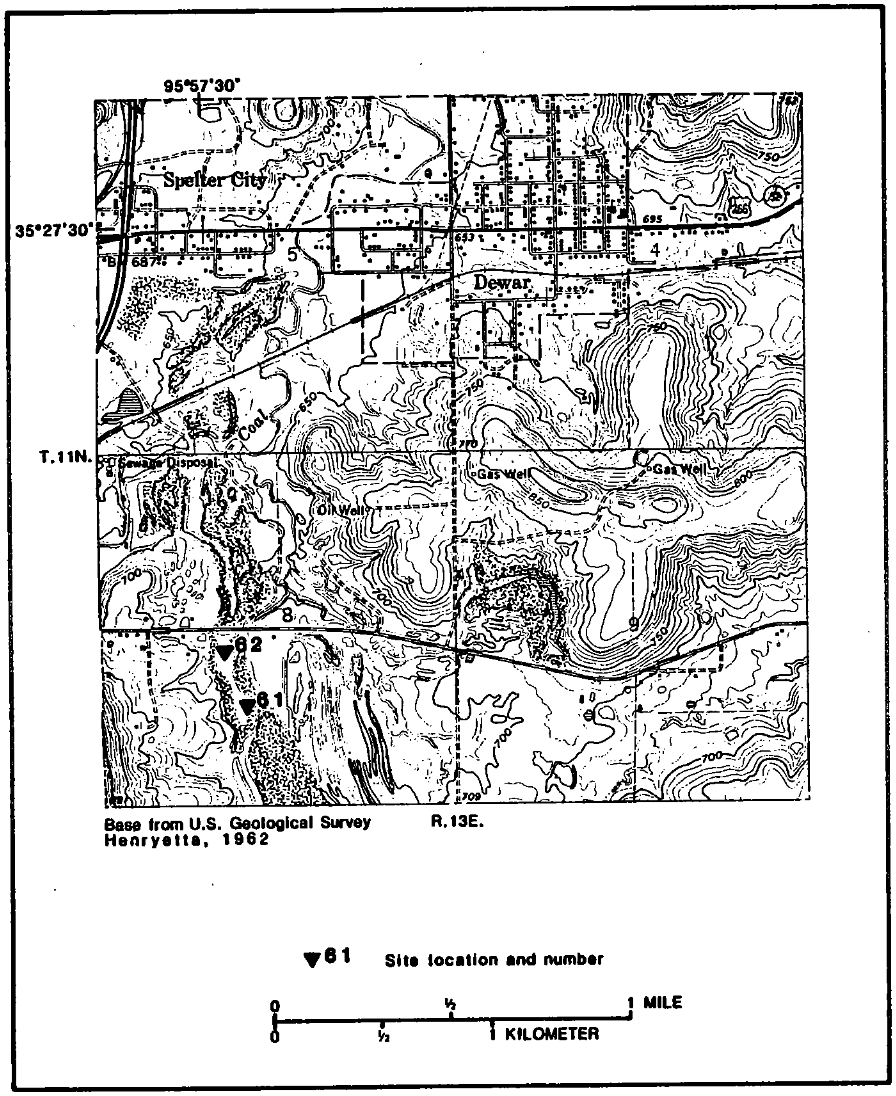
Base from
U.S. Geological Survey
Holt Mountain, 1963

Figure 41.--Sites 51 and 53-57.



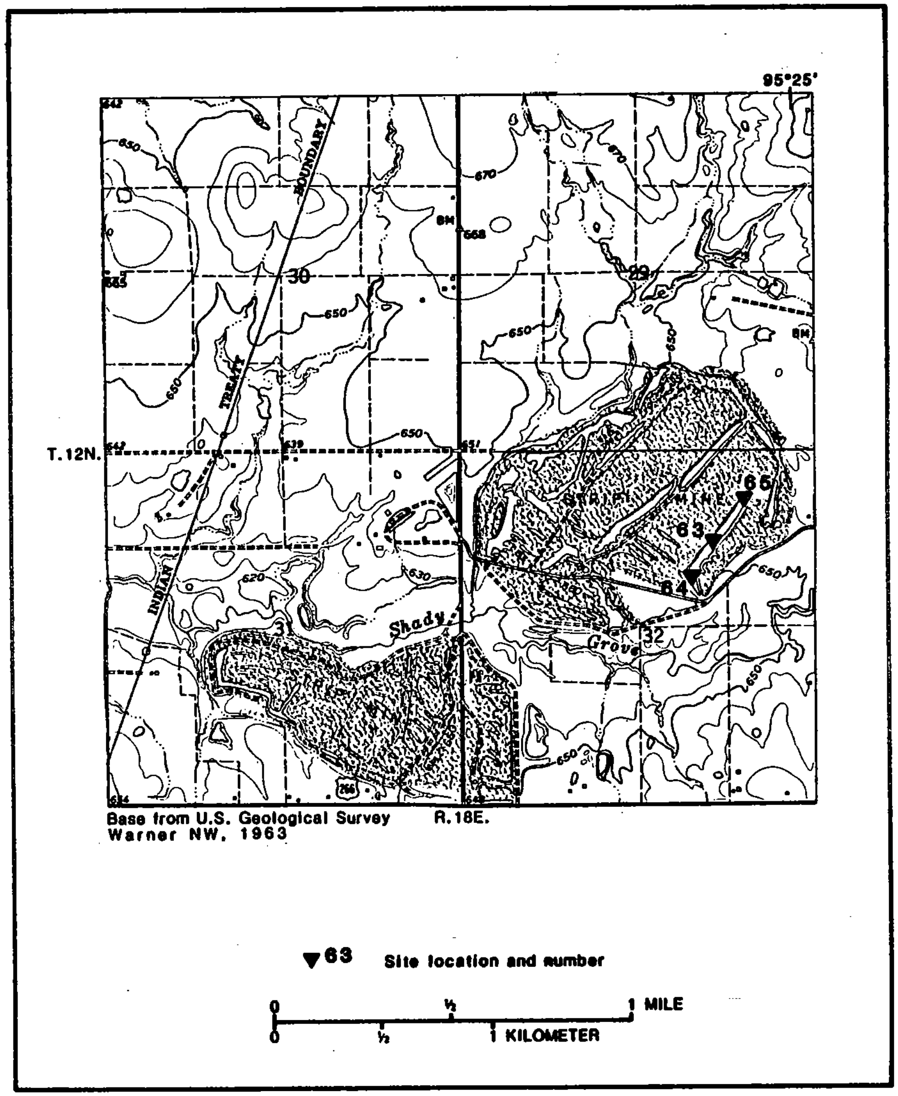
Base from U.S. Geological Survey
Warner, 1963
Holt Mountain, 1963

Figure 42.--Sites 58-60.



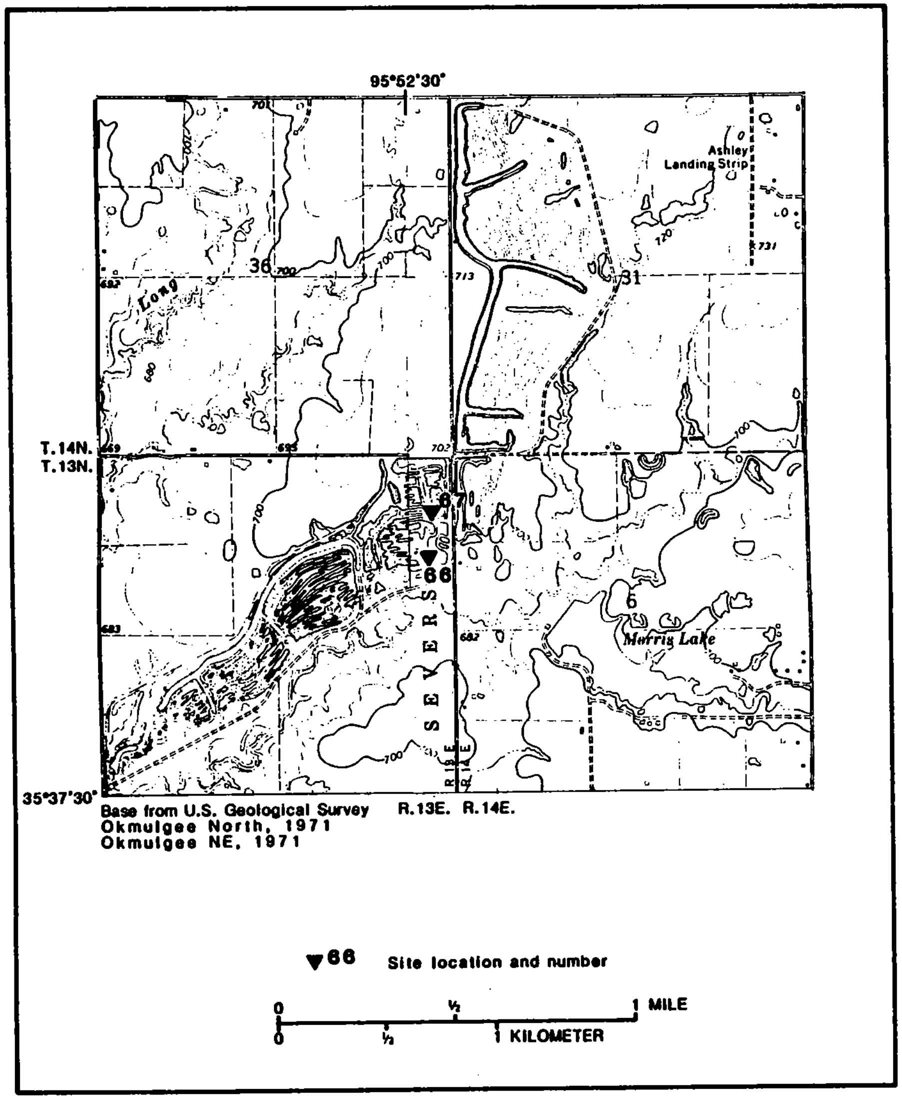
Base from U.S. Geological Survey Henryetta, 1962 R.13E.

Figure 43.--Sites 61-62.



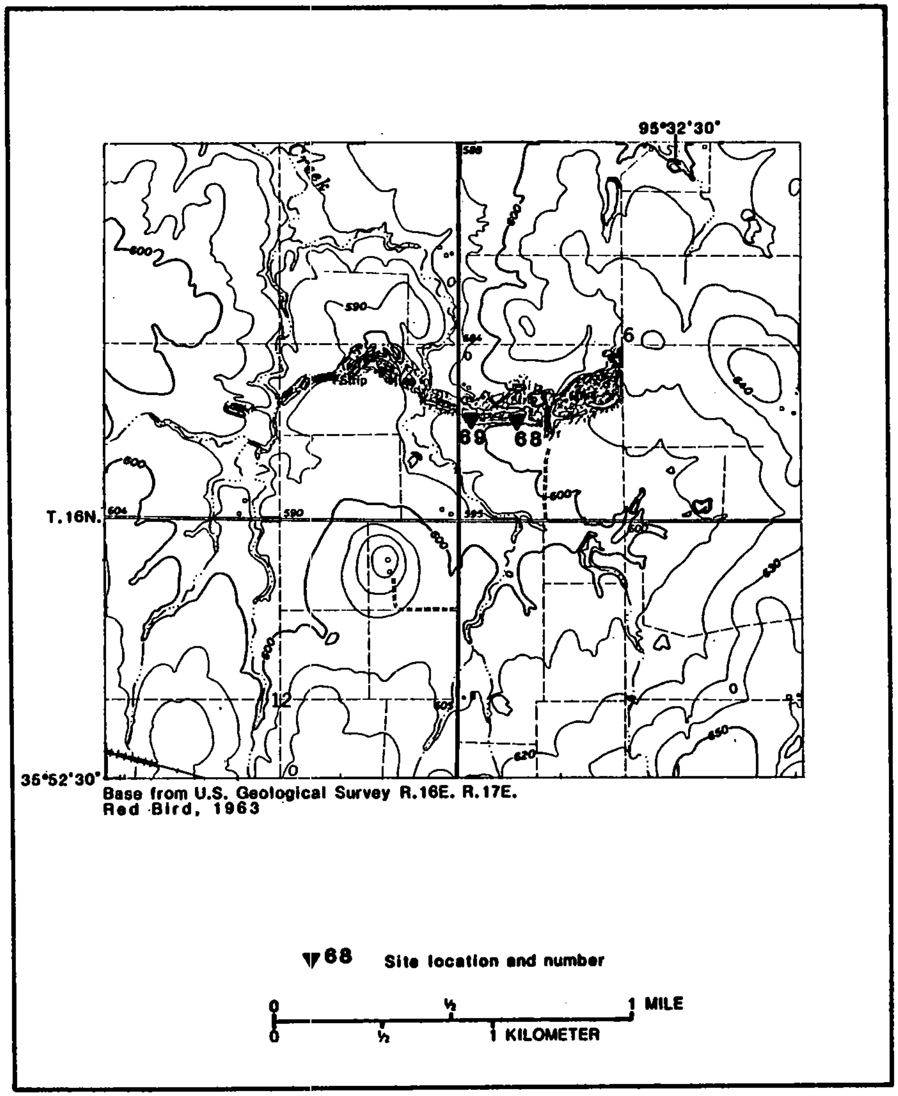
Base from U.S. Geological Survey Warner NW, 1963 R.18E.

Figure 44.--Sites 63-65.



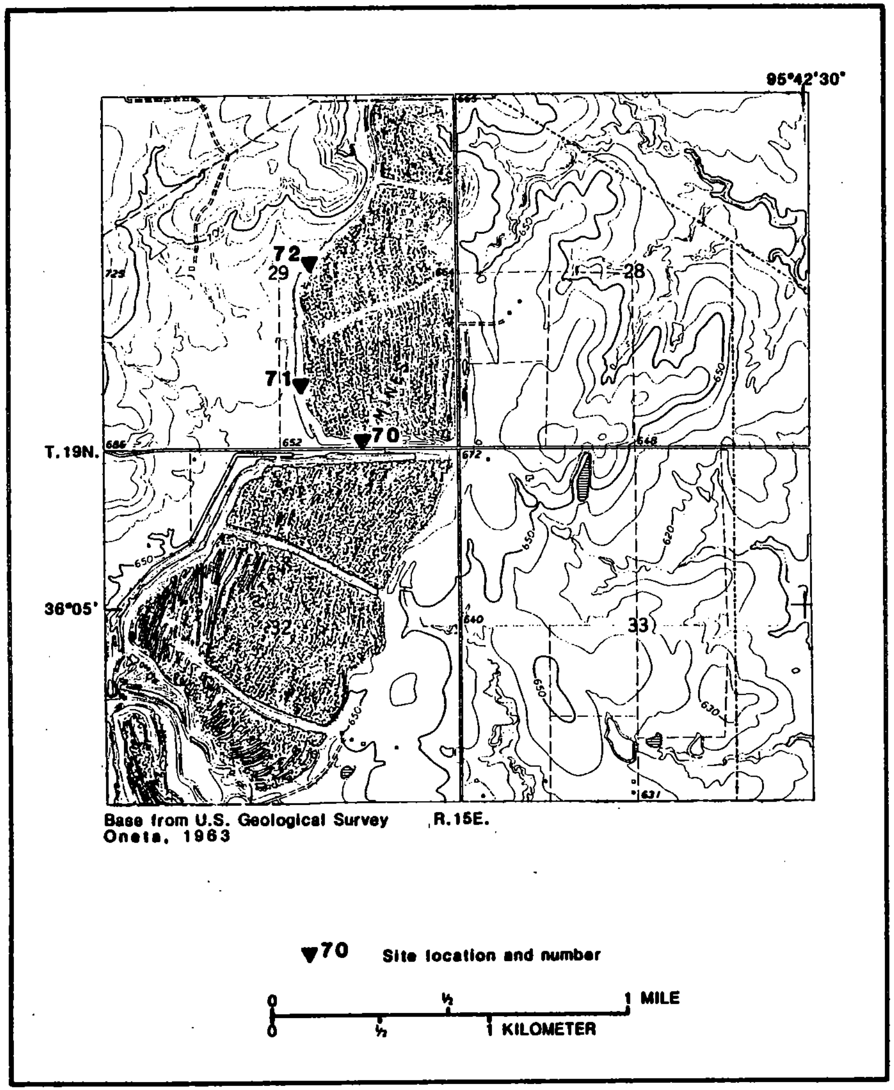
Base from U.S. Geological Survey
Okmulgee North, 1971
Okmulgee NE, 1971

Figure 45.—Sites 66-67.



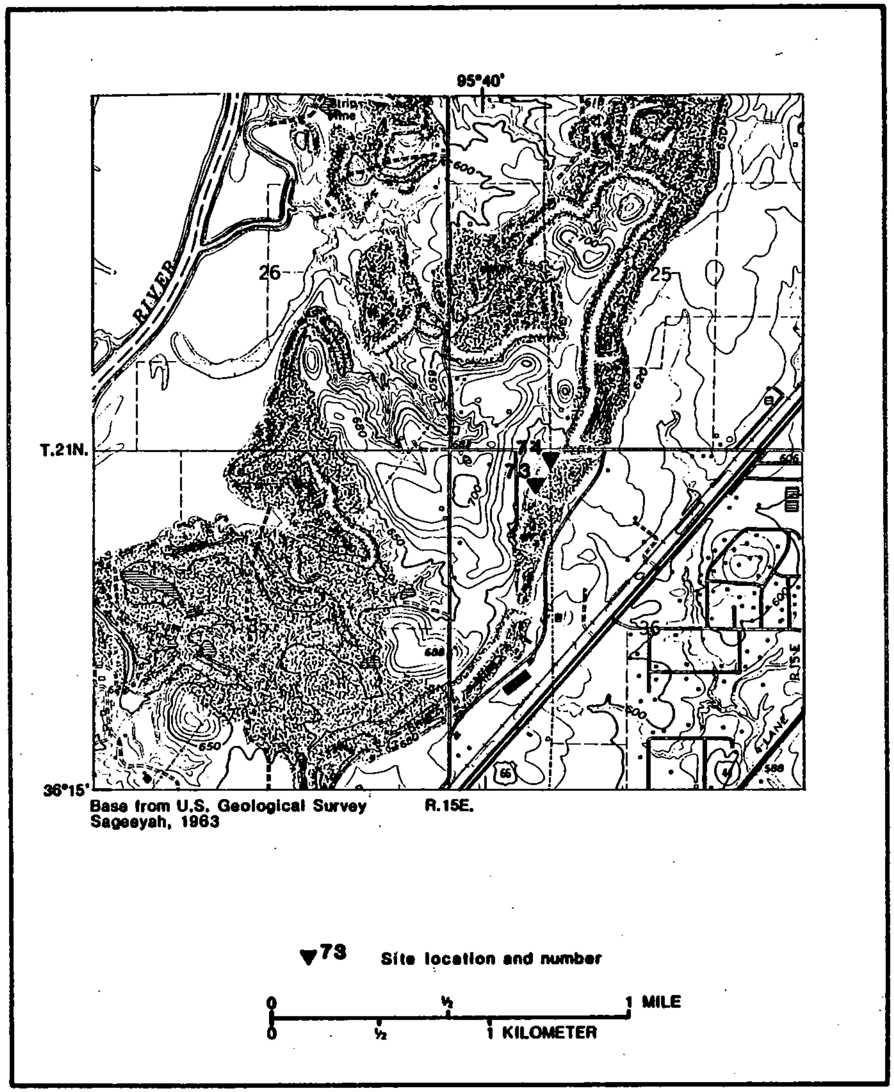
Base from U.S. Geological Survey
Red Bird, 1963

Figure 46.—Sites 68-69.



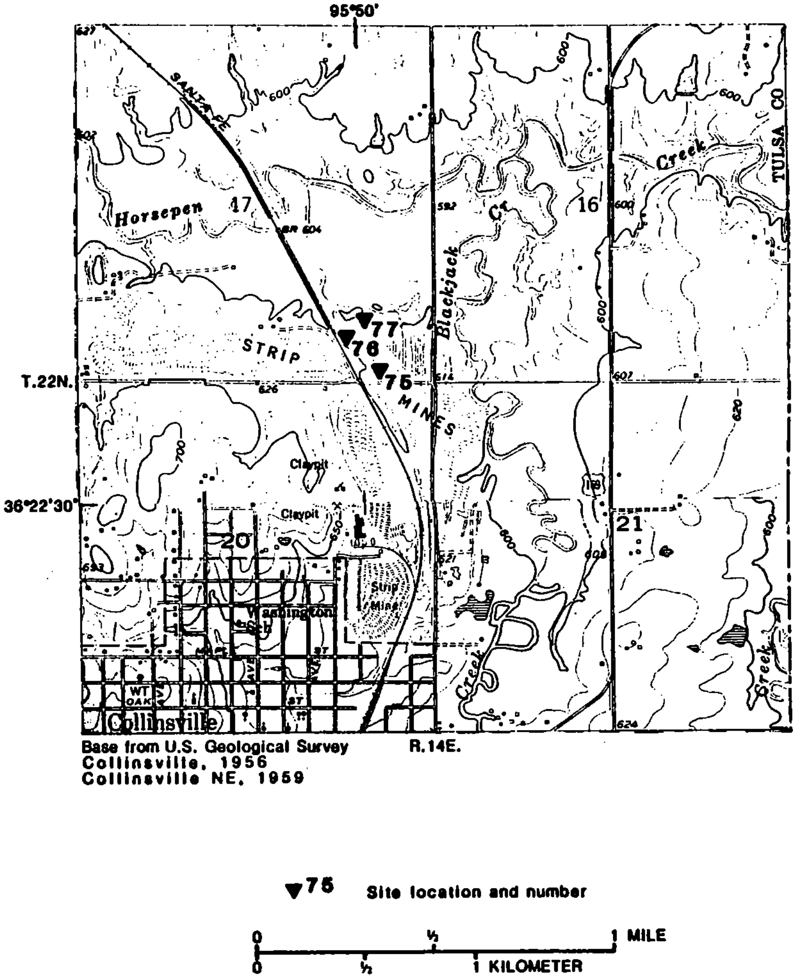
Base from U.S. Geological Survey
Oneta, 1963

Figure 47.--Sites 70-72.



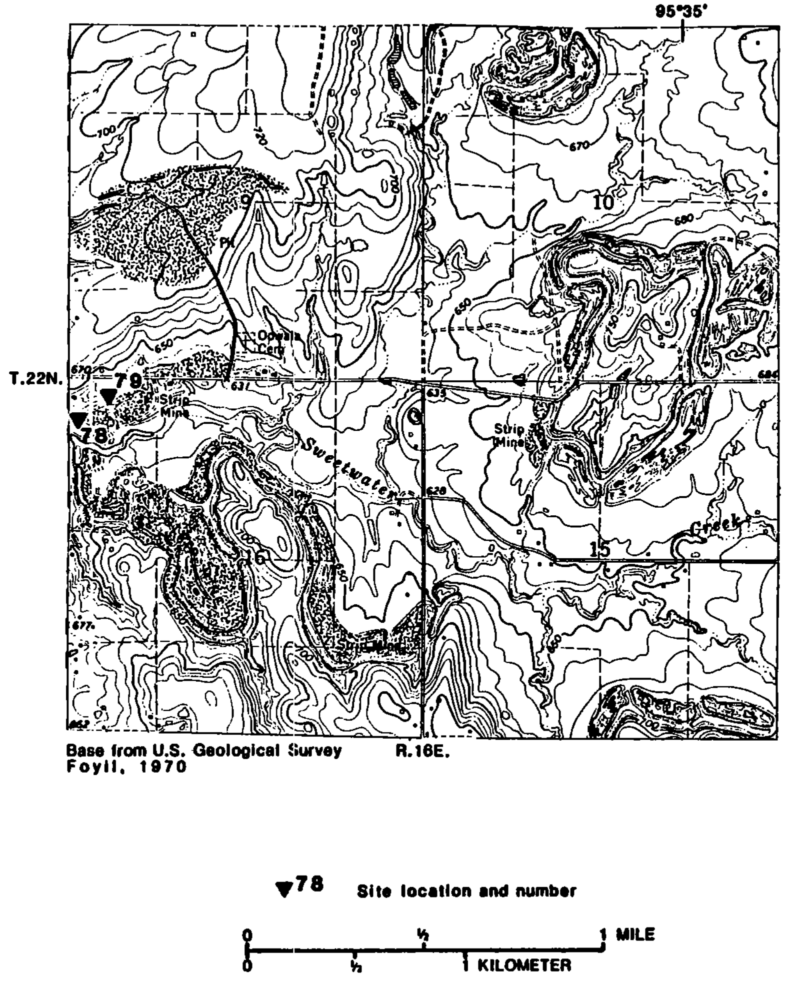
Base from U.S. Geological Survey
Sageeyah, 1963

Figure 48.--Sites 73-74.



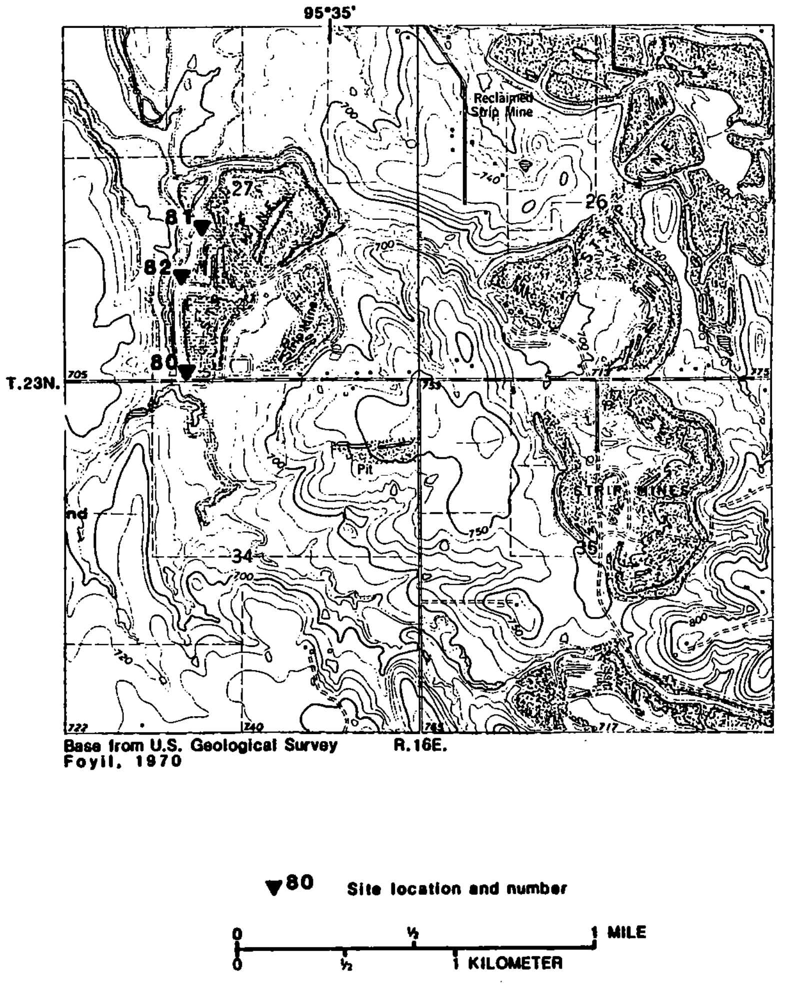
Base from U.S. Geological Survey
Collinsville, 1956
Collinsville NE, 1959

Figure 49.—Sites 75-77.



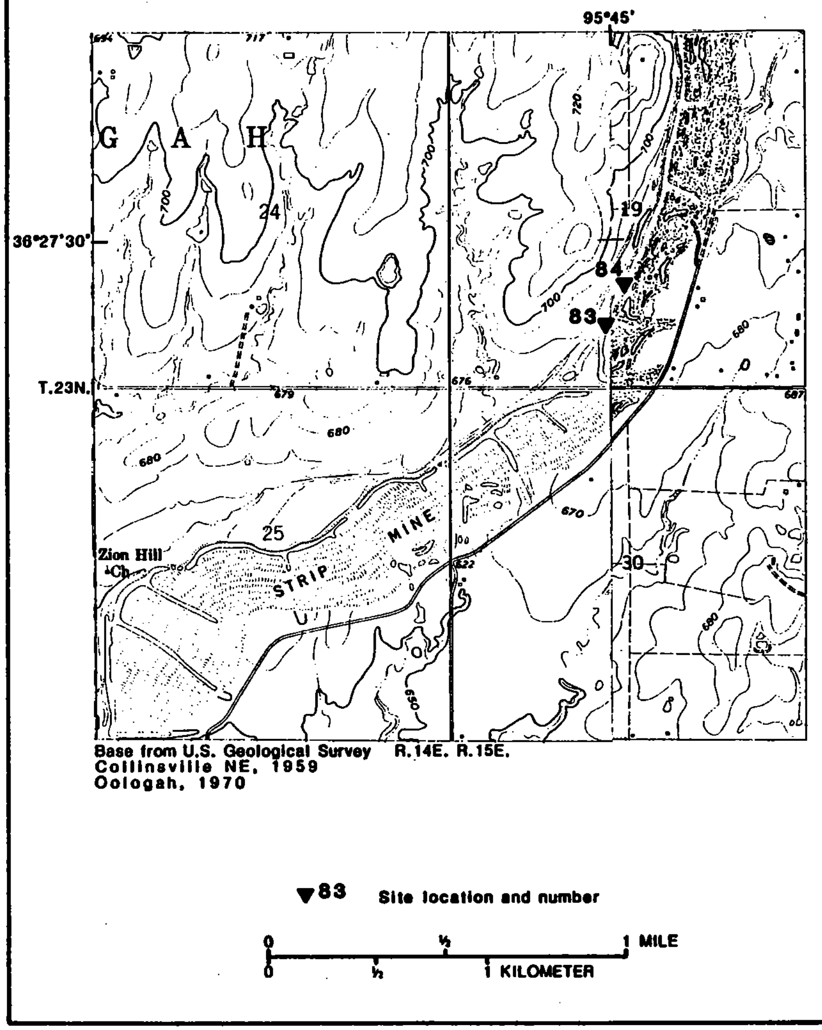
Base from U.S. Geological Survey
Foyil, 1970

Figure 50.—Sites 78-79.



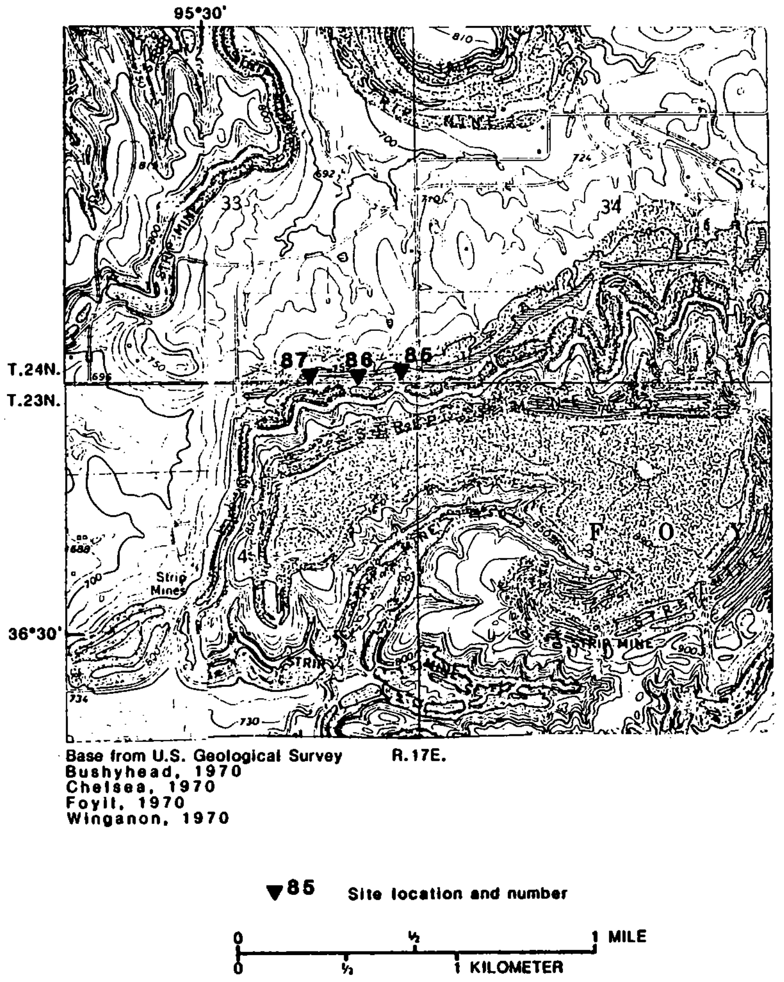
Base from U.S. Geological Survey
Foyil, 1970

Figure 51.--Sites 80-82.



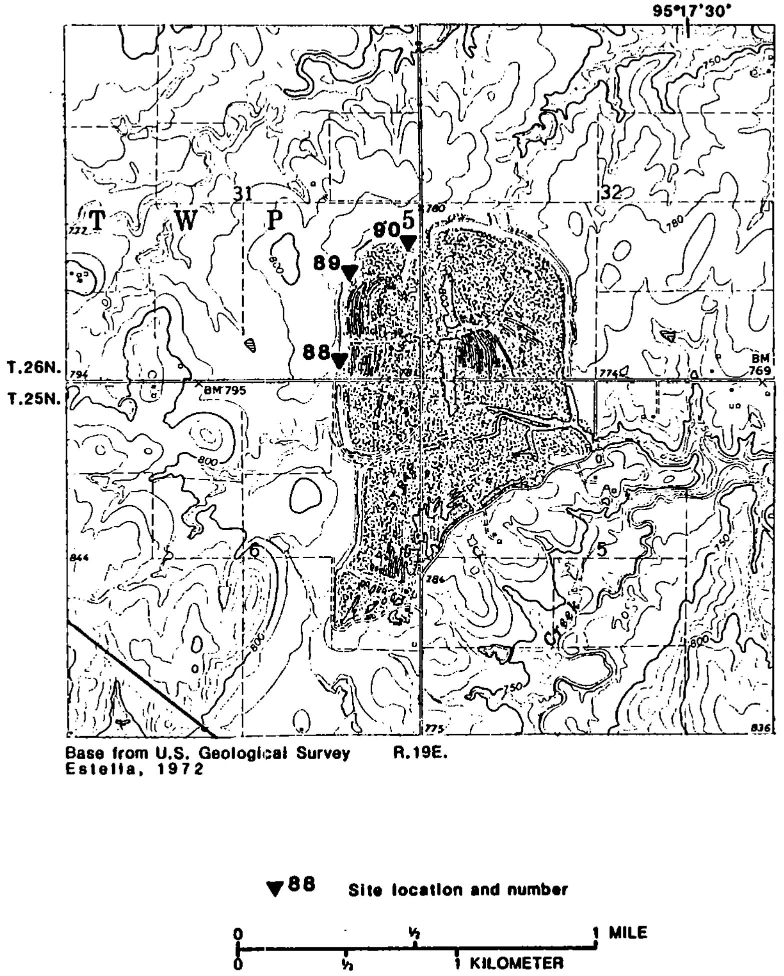
Base from U.S. Geological Survey
Collinsville NE, 1959
Oologah, 1970

Figure 52.--Sites 83-84.



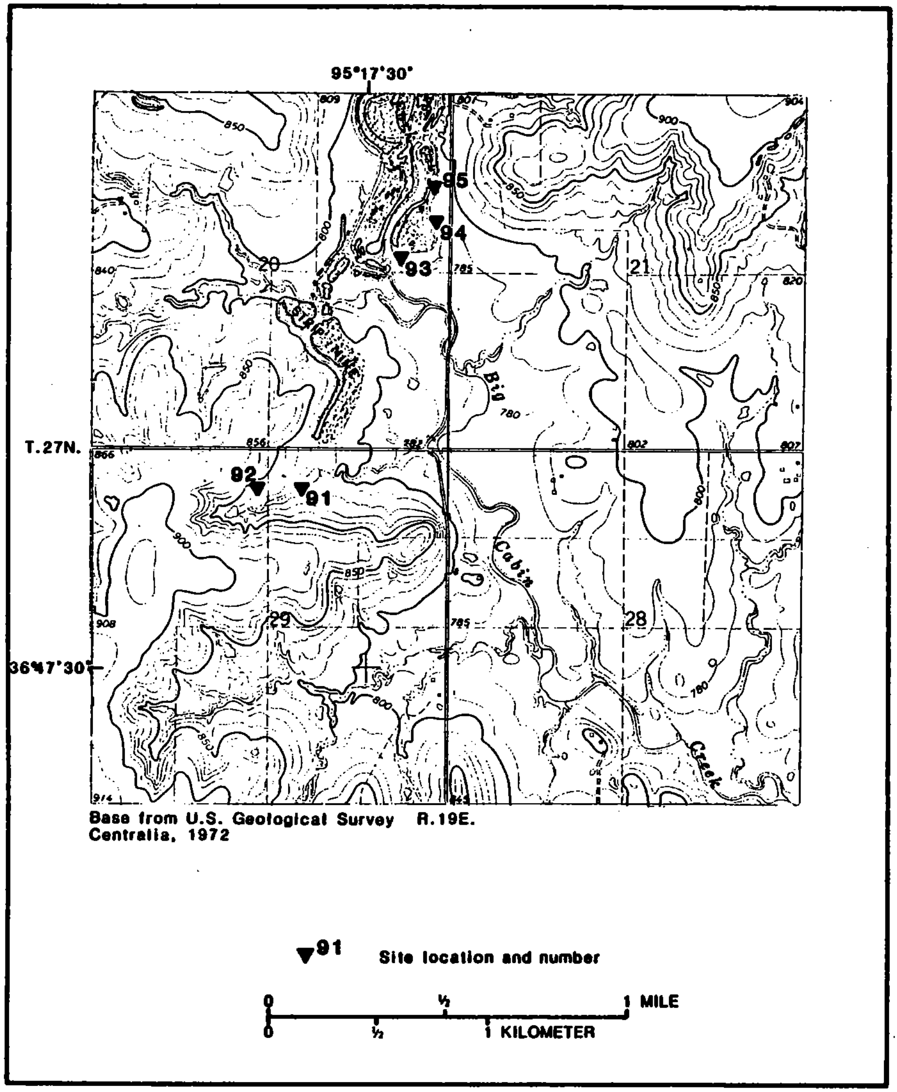
Base from U.S. Geological Survey
Bushyhead, 1970
Chelsea, 1970
Foyil, 1970
Winganon, 1970

Figure 53.—Sites 85-87.



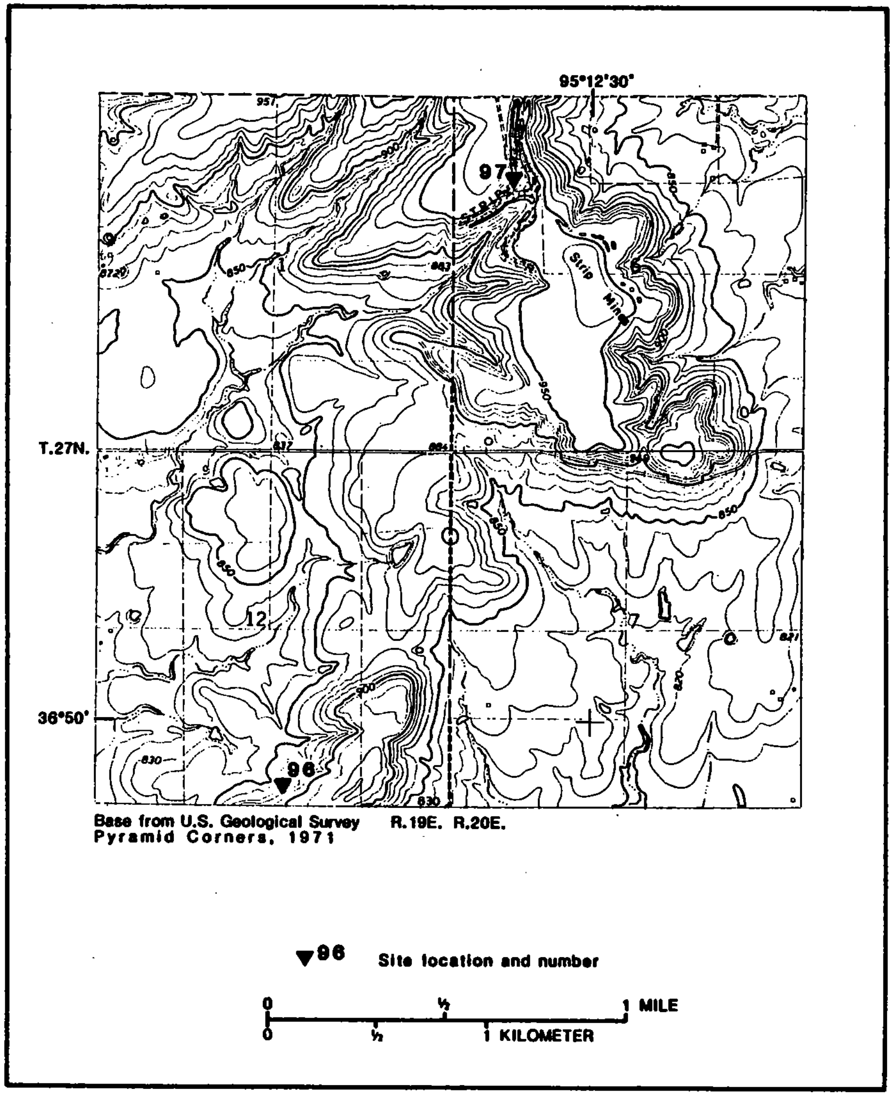
Base from U.S. Geological Survey
Estella, 1972

Figure 54.—Sites 88-90.



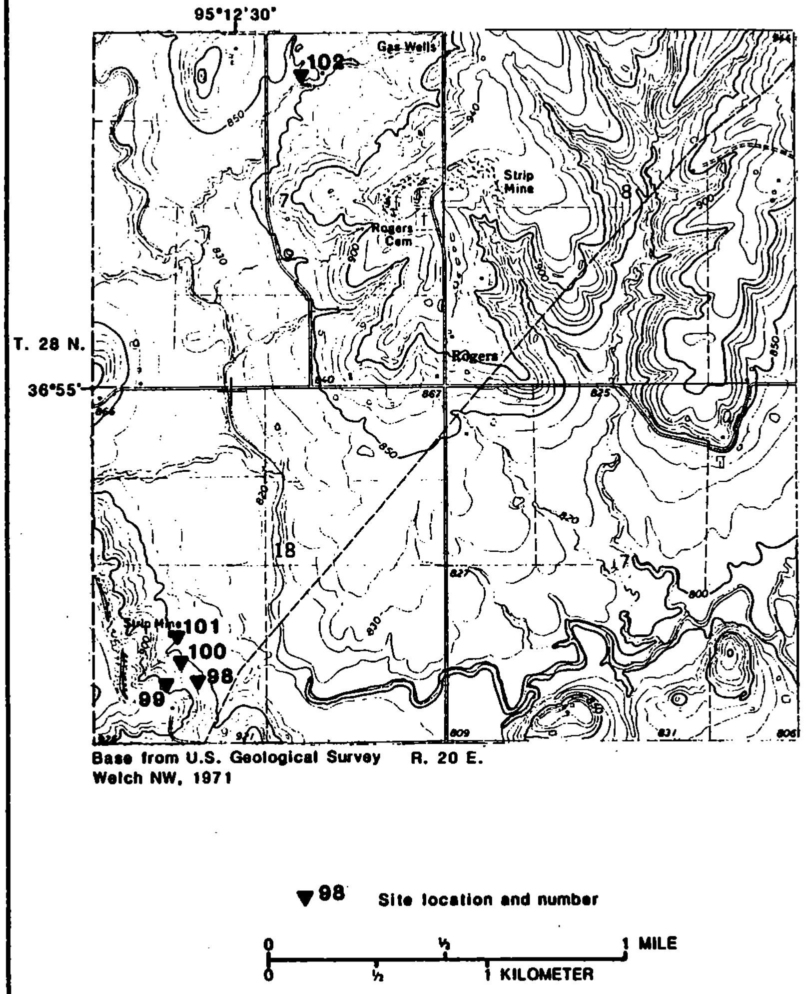
Base from U.S. Geological Survey
Centralia, 1972

Figure 55.--Sites 91-95.



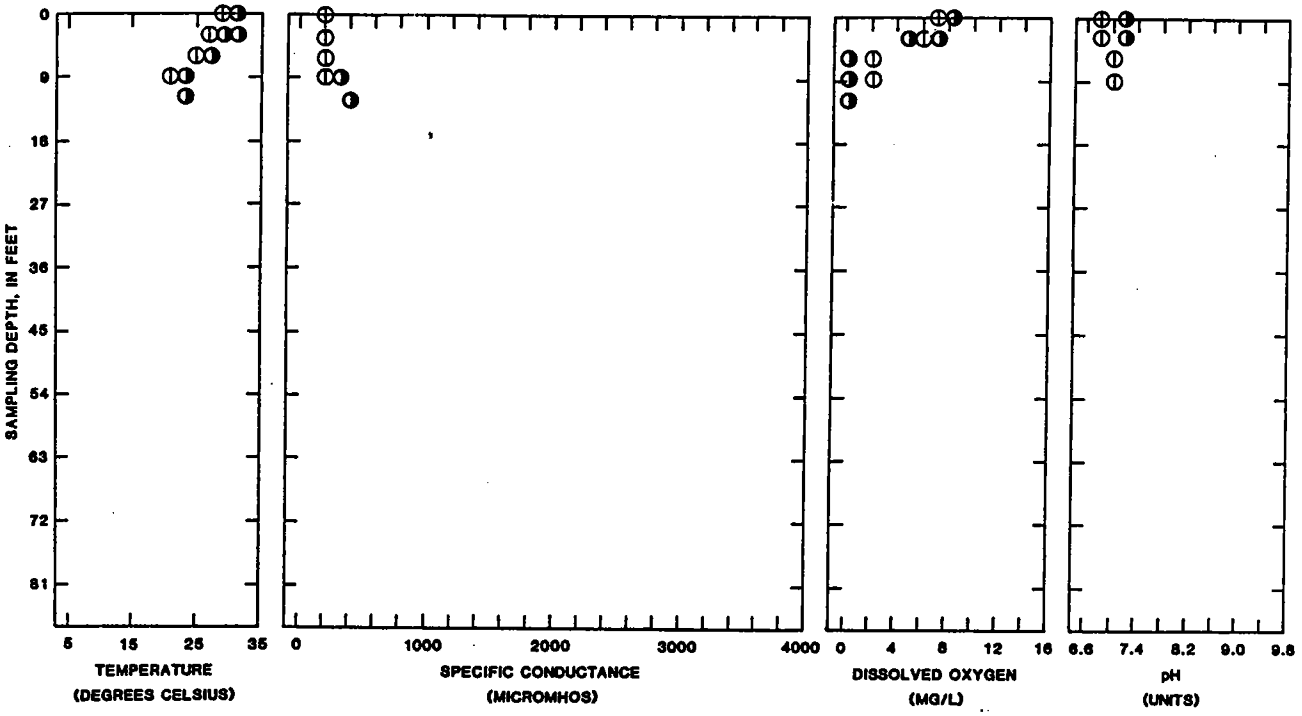
Base from U.S. Geological Survey
Pyramid Corners, 1971

Figure 56.--Sites 96-97.



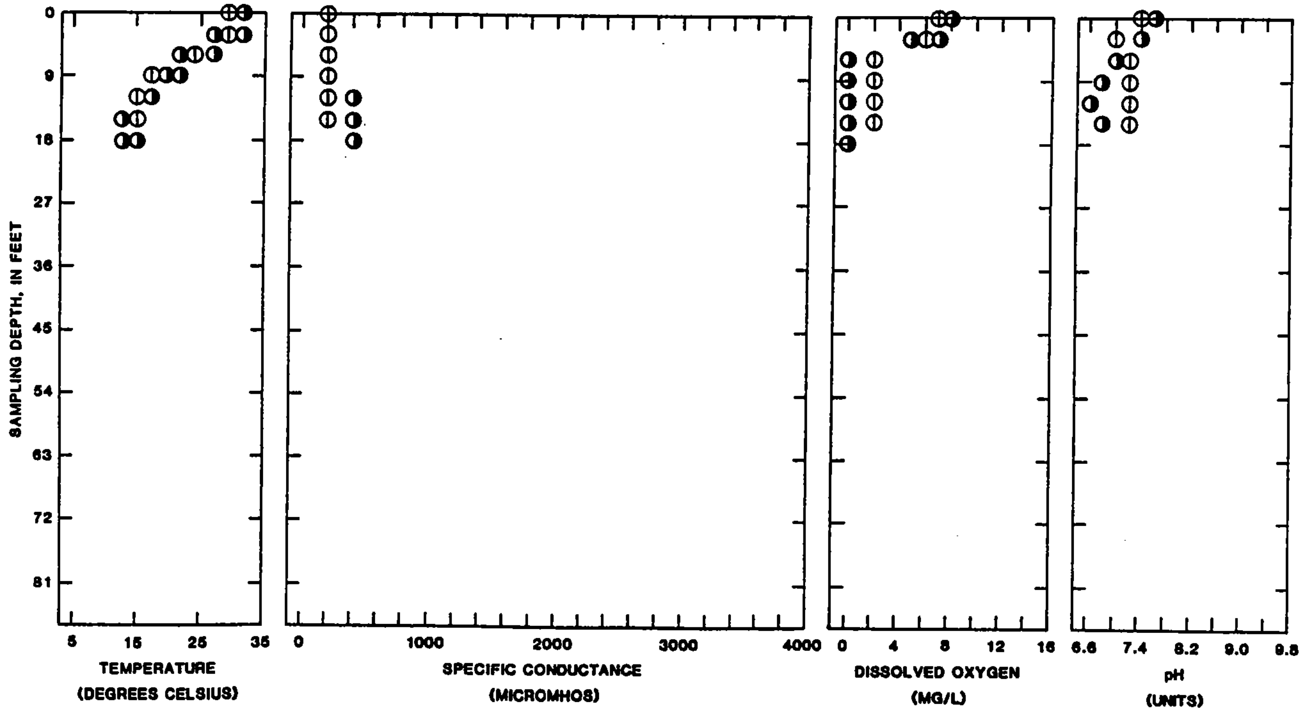
Base from U.S. Geological Survey R. 20 E.
Welch NW, 1971

Figure 57.—Sites 98-102.



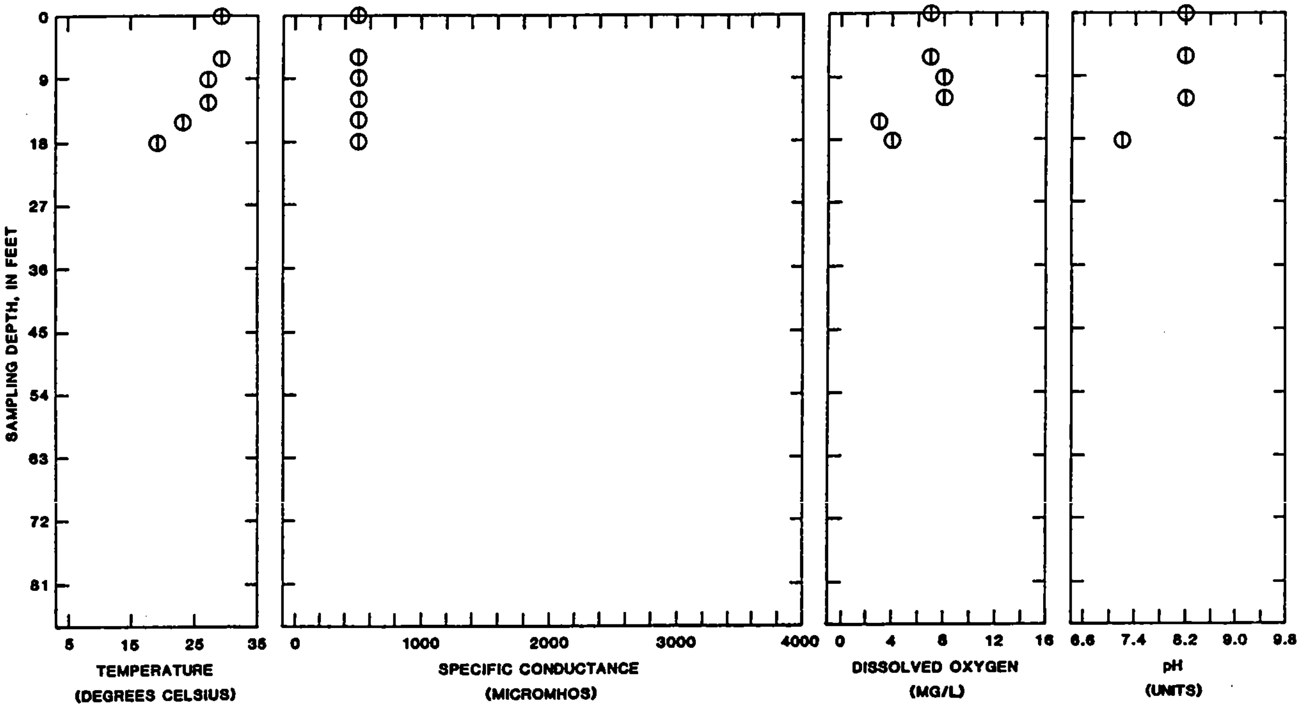
PLOT SYMBOL	DATE OF SAMPLE
⦶	July 20, 1977
◐	August 7, 1979

Figure 58.--Site 1.



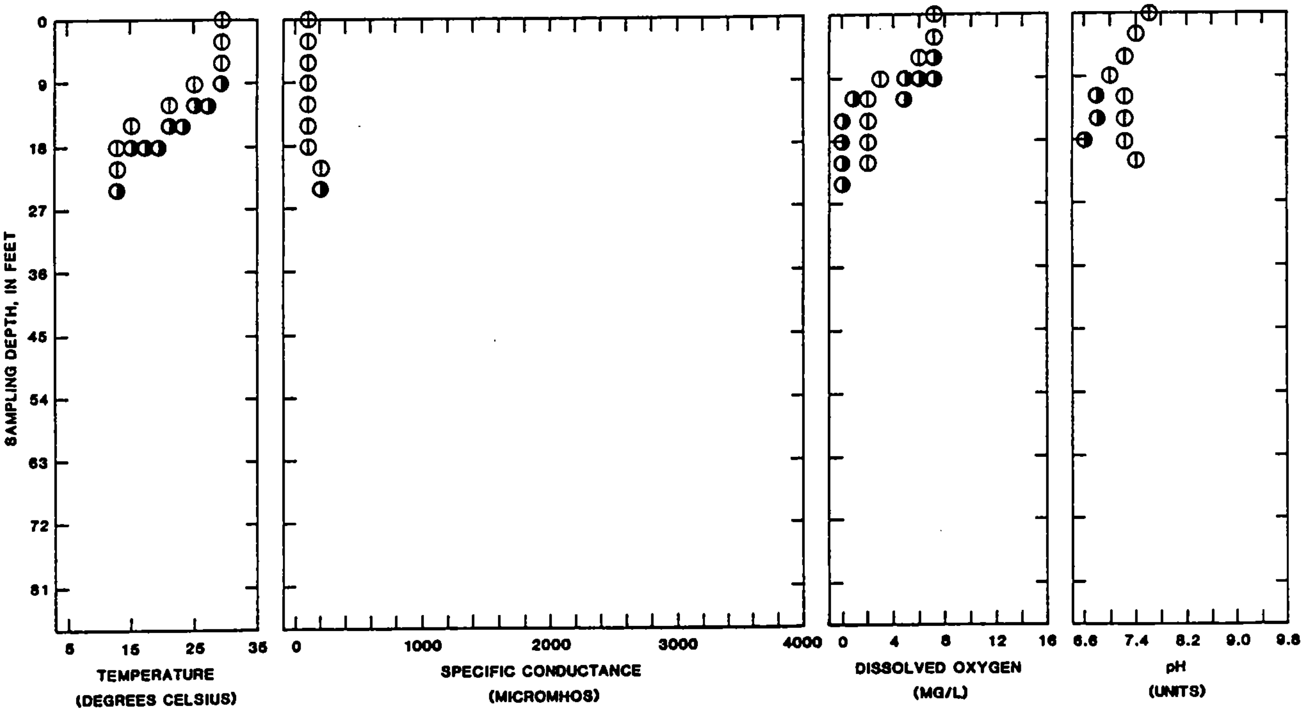
PLOT SYMBOL	DATE OF SAMPLE
⦶	July 20, 1977
◐	August 7, 1979

Figure 59.--Site 2.



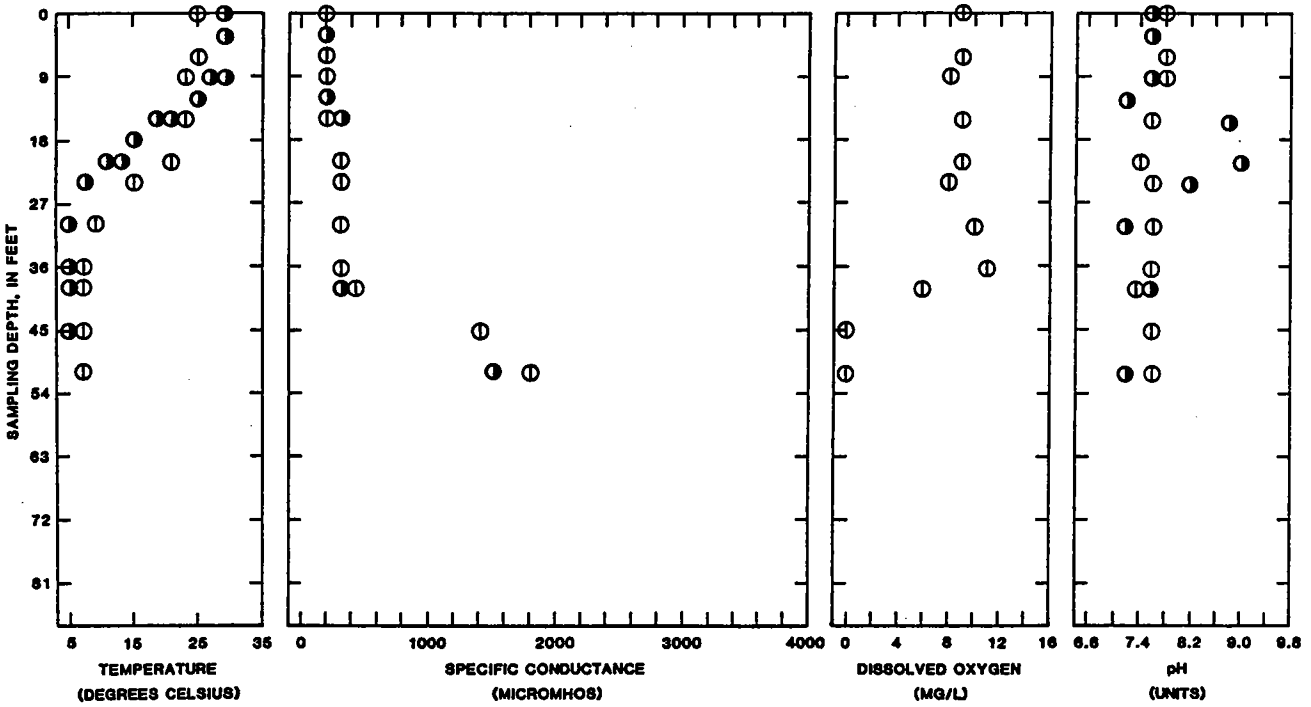
PLOT SYMBOL	DATE OF SAMPLE
◐	July 21, 1977

Figure 60.--Site 3.



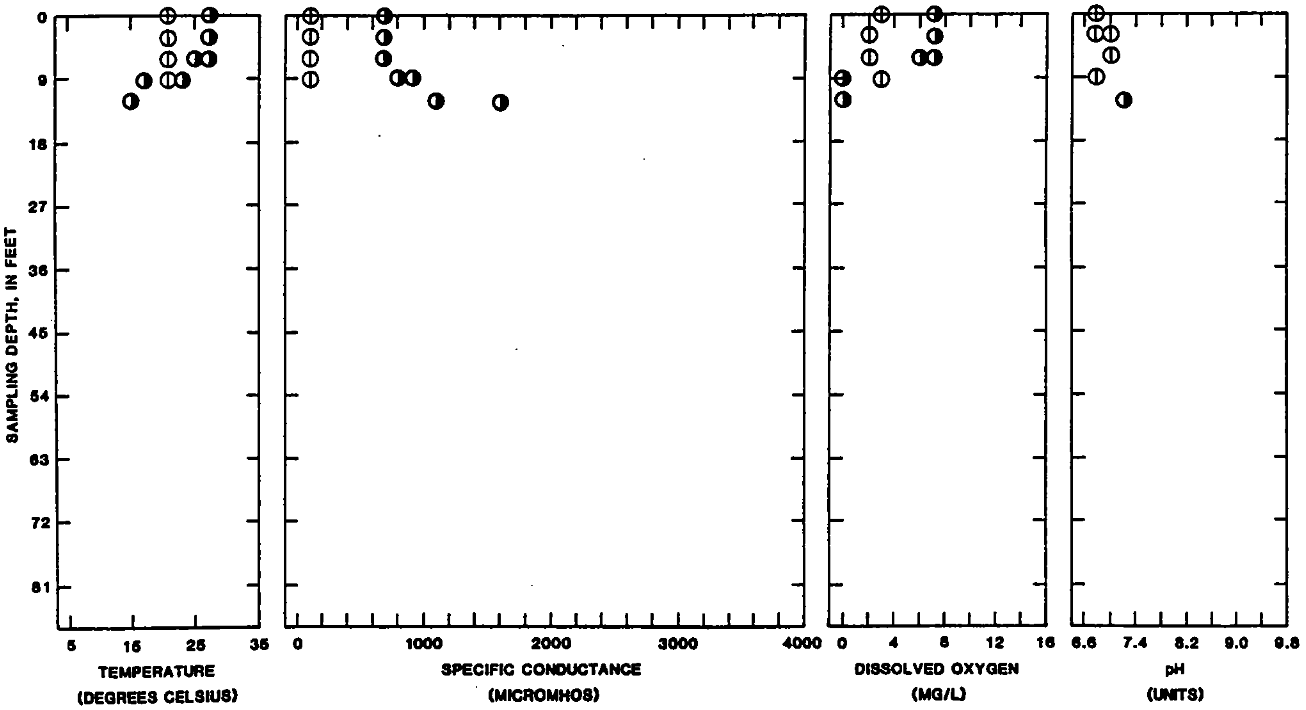
PLOT SYMBOL	DATE OF SAMPLE
◐	July 20, 1977
◑	August 7, 1979

Figure 61.--Site 4.



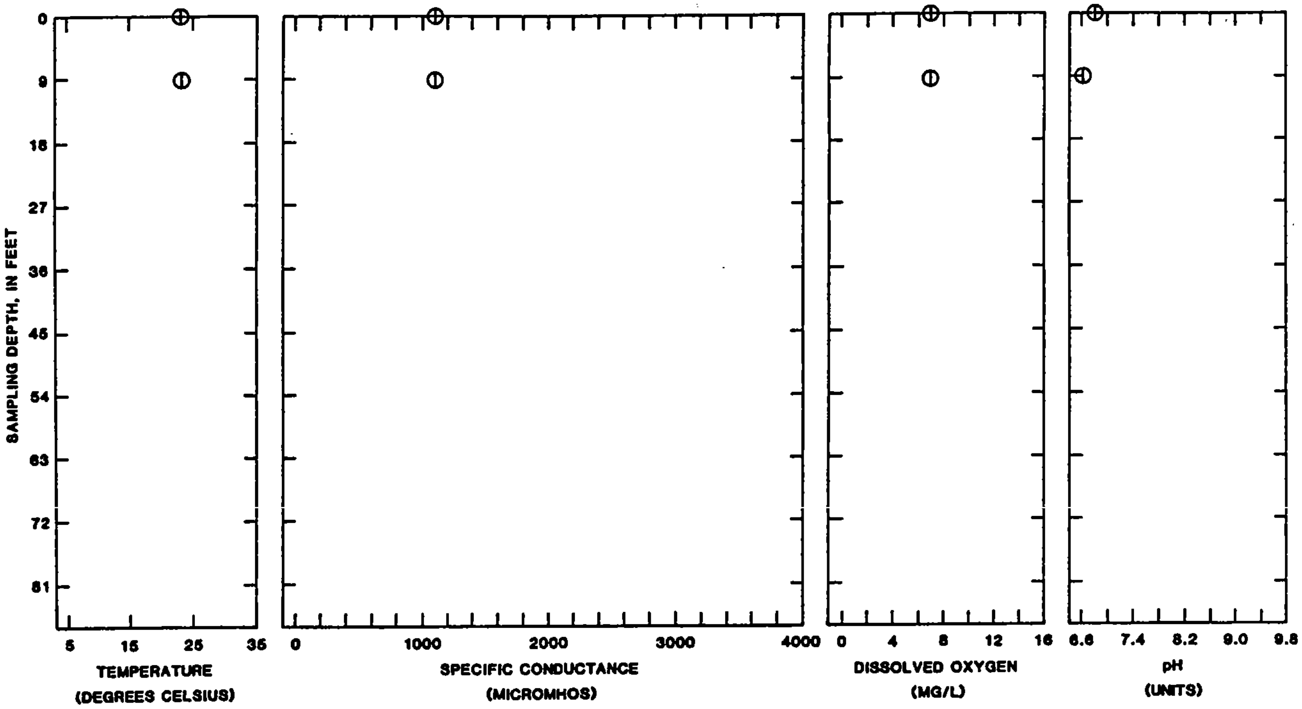
PLOT SYMBOL	DATE OF SAMPLE
⦶	October 4, 1977
◑	August 7, 1979

Figure 62.--Site 5.



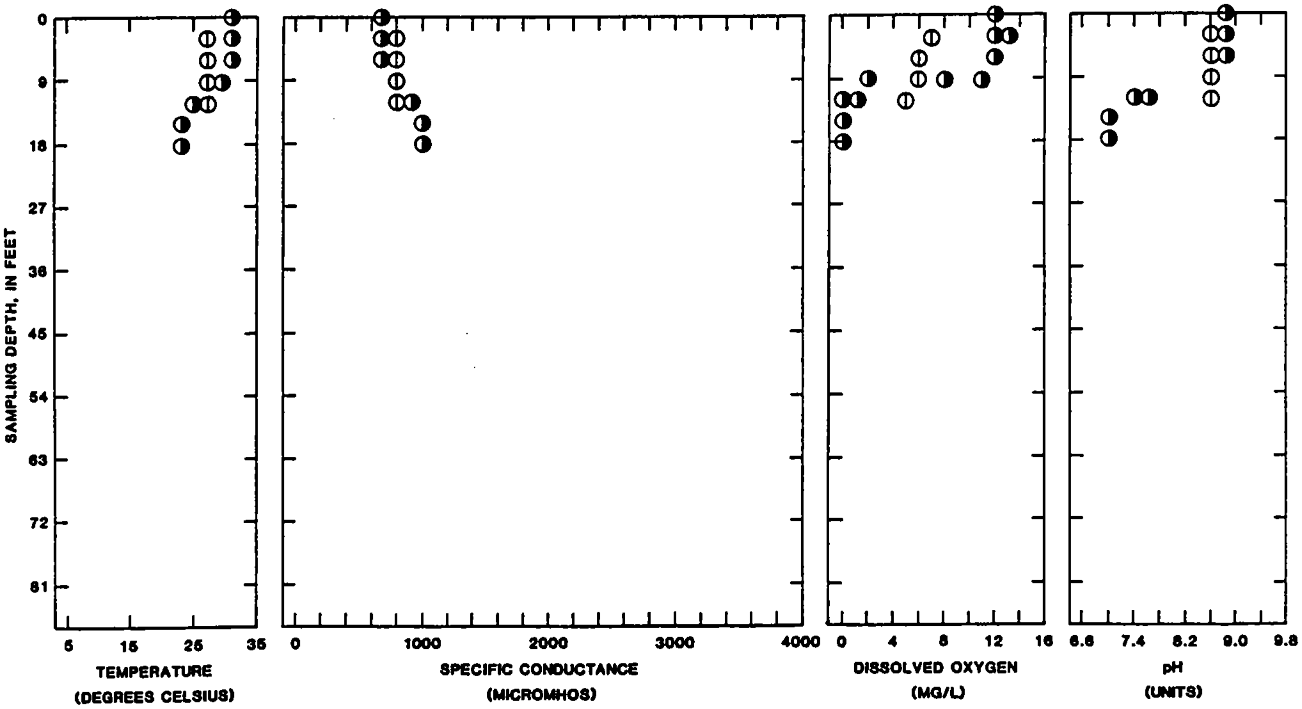
PLOT SYMBOL	DATE OF SAMPLE
⦶	September 15, 1977
◑	August 15, 1979

Figure 63.--Site 6.



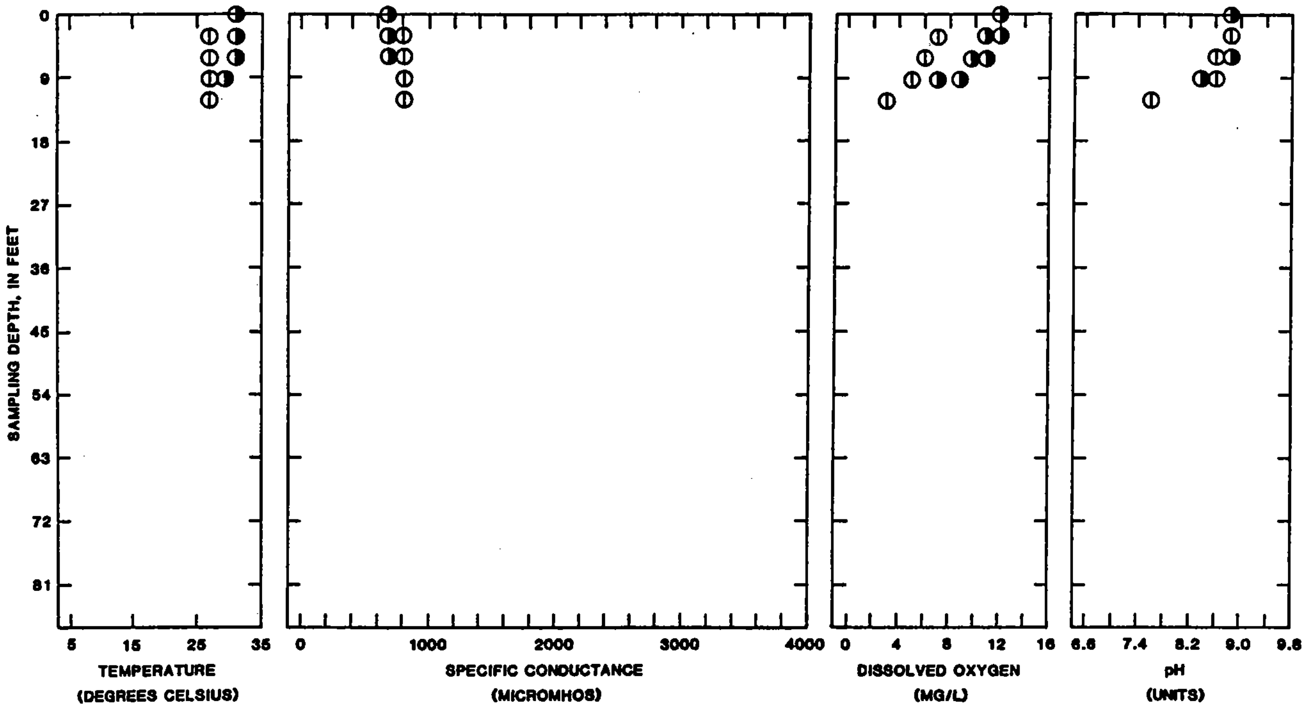
PLOT SYMBOL	DATE OF SAMPLE
⦶	October 5, 1977

Figure 64.--Site 7.



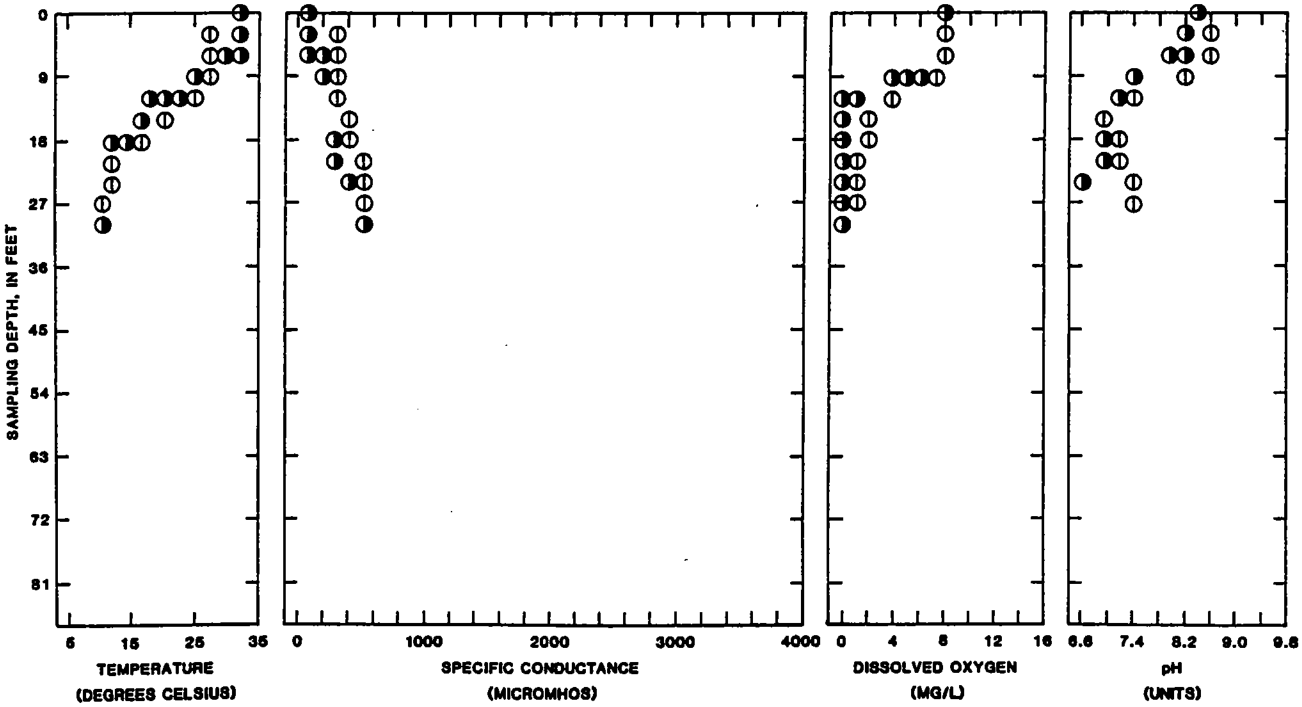
PLOT SYMBOL	DATE OF SAMPLE
⦶	August 30, 1977
◑	August 9, 1979

Figure 65.--Site 8.



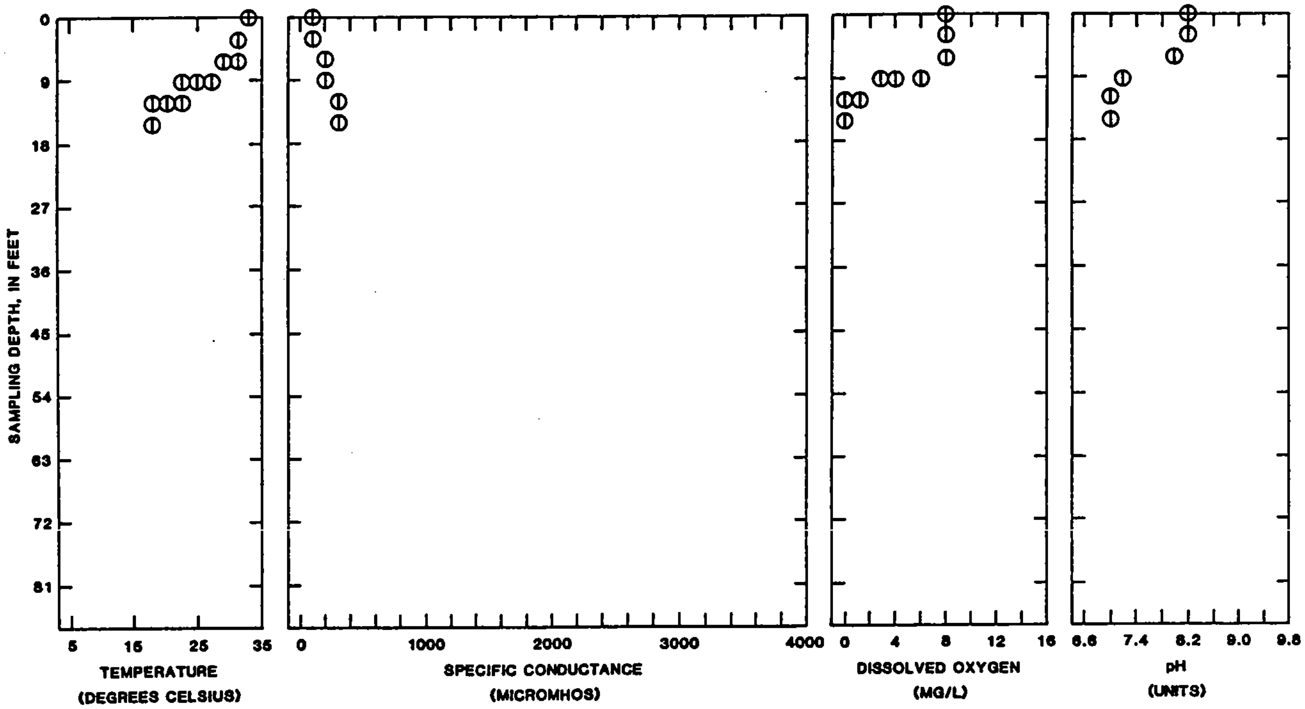
PLOT SYMBOL	DATE OF SAMPLE
⦶	August 30, 1977
◑	August 9, 1979

Figure 66.--Site 9.



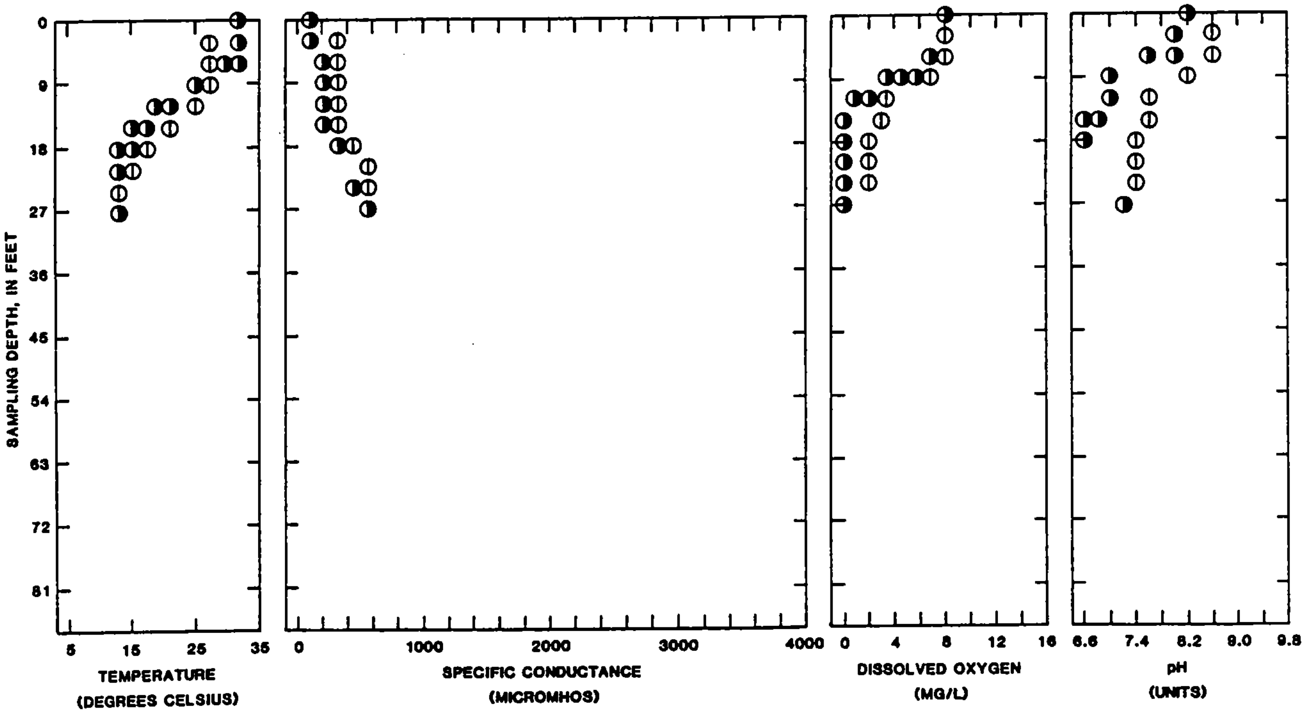
PLOT SYMBOL	DATE OF SAMPLE
⦶	August 31, 1977
◑	August 8, 1979

Figure 67.--Site 10.



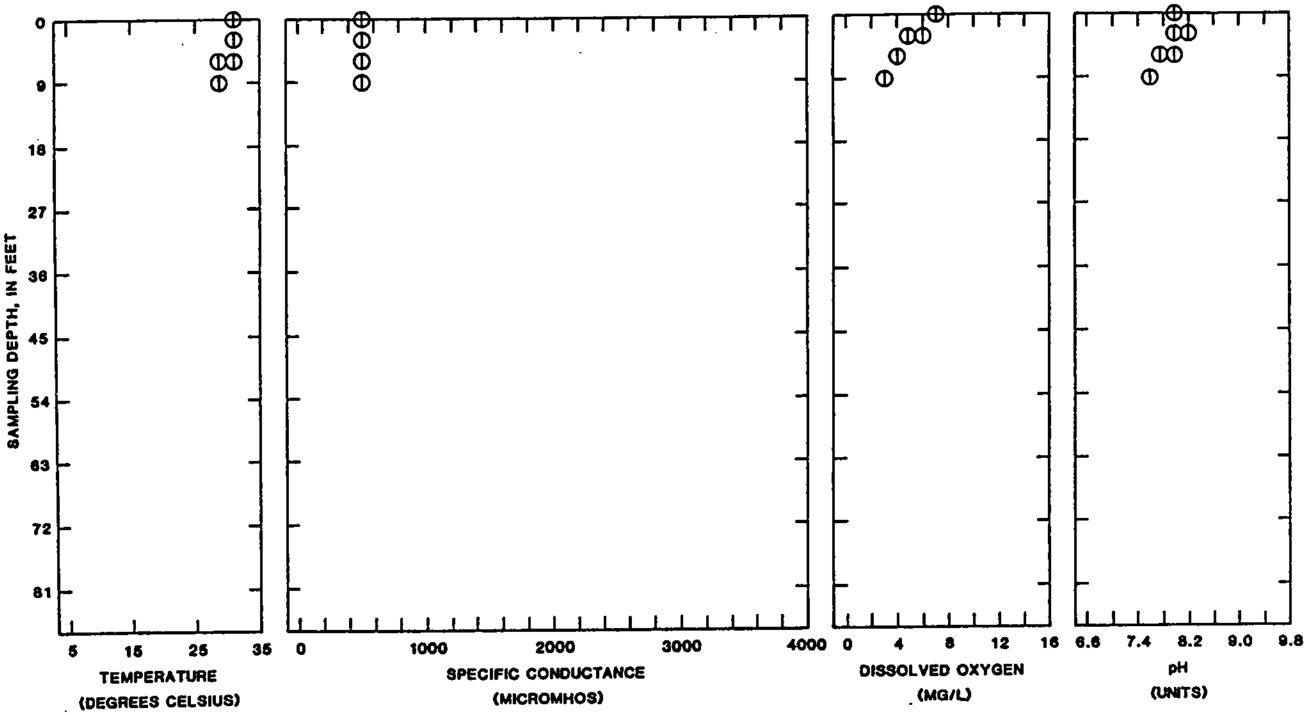
PLOT SYMBOL	DATE OF SAMPLE
⦶	August 8, 1979

Figure 68.--Site 11.



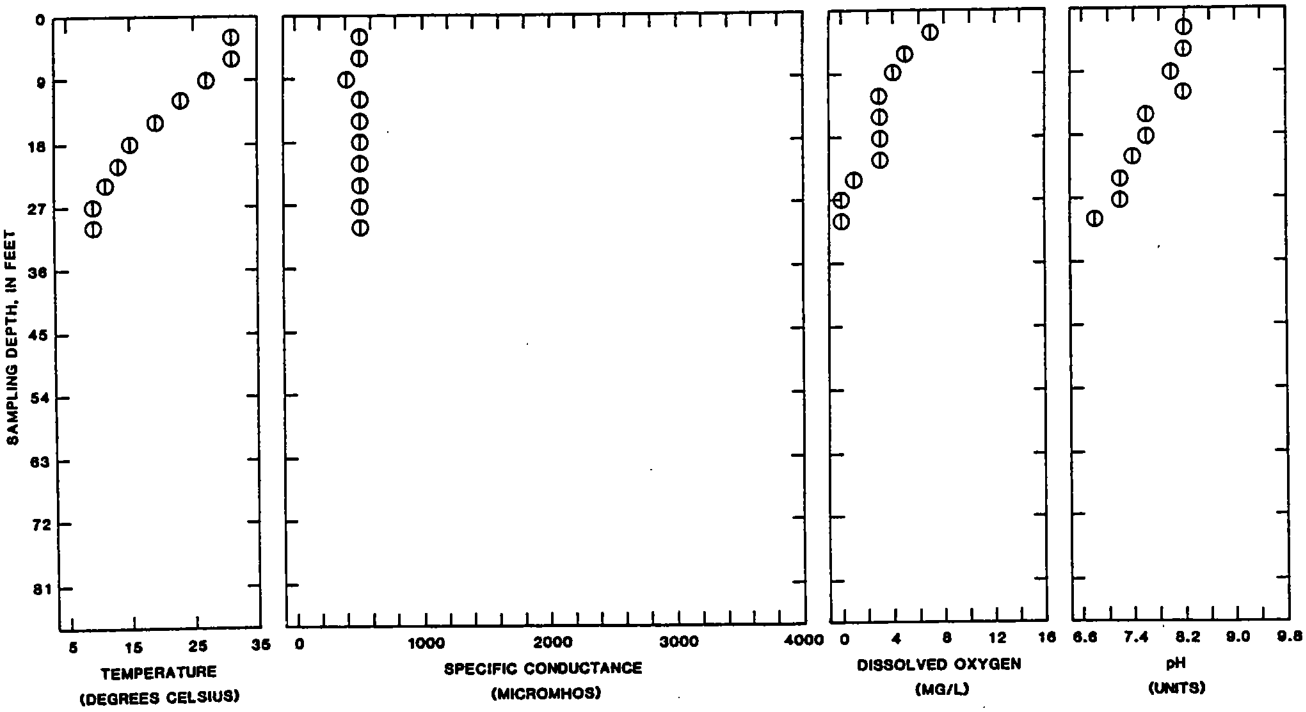
PLOT SYMBOL	DATE OF SAMPLE
⦶	August 31, 1977
◐	August 8, 1979

Figure 69.--Site 12.



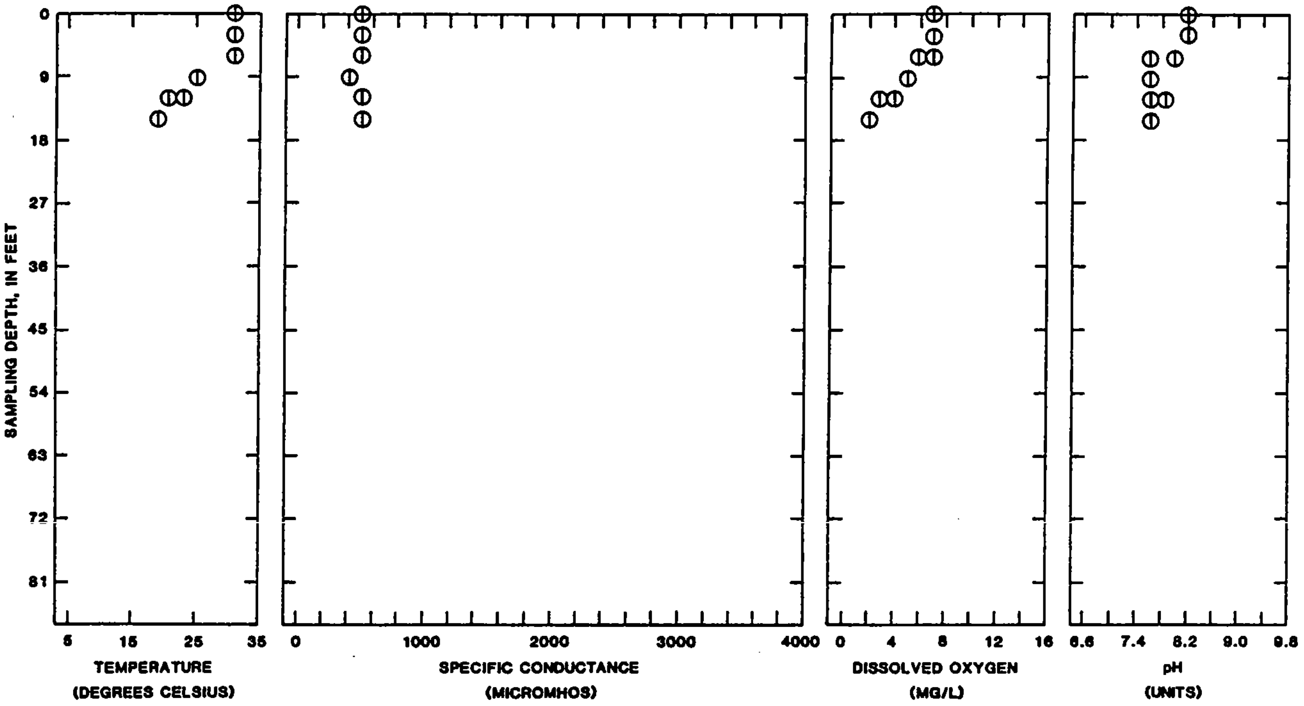
PLOT SYMBOL	DATE OF SAMPLE
Φ	July 1, 1980

Figure 70.--Site 13.



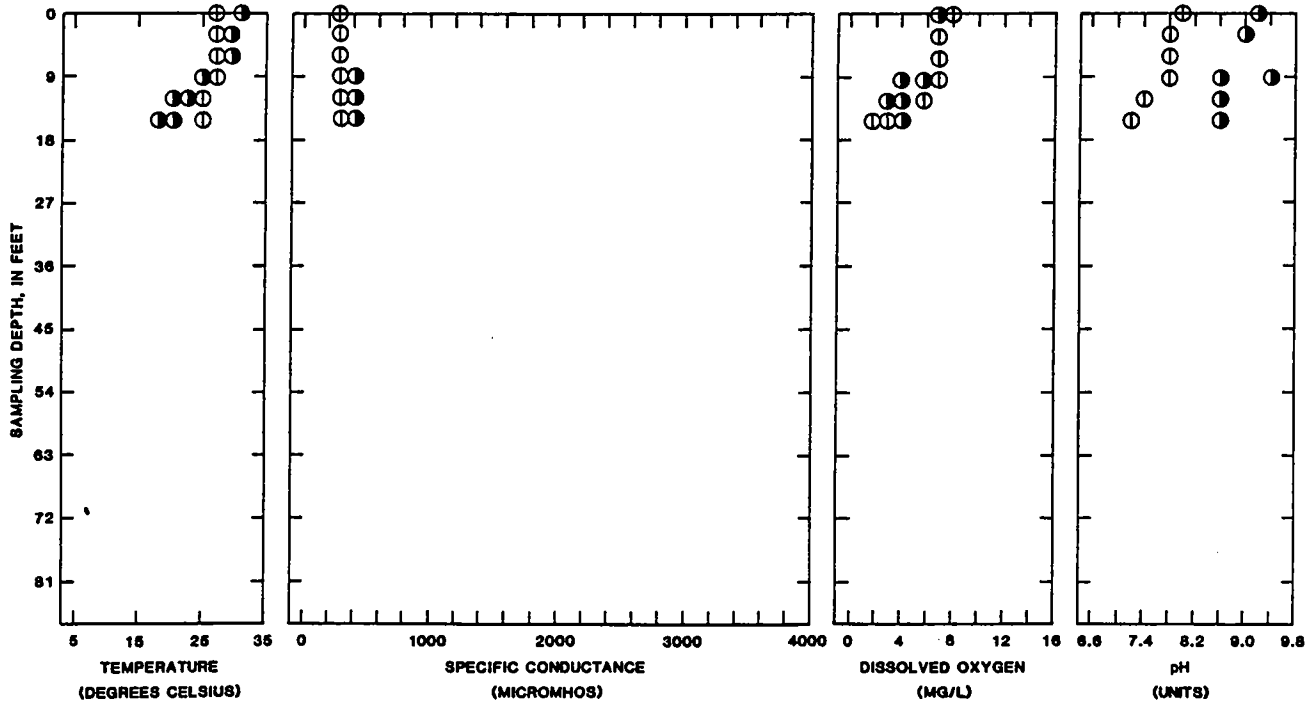
PLOT SYMBOL	DATE OF SAMPLE
Φ	July 1, 1980

Figure 71.--Site 14.



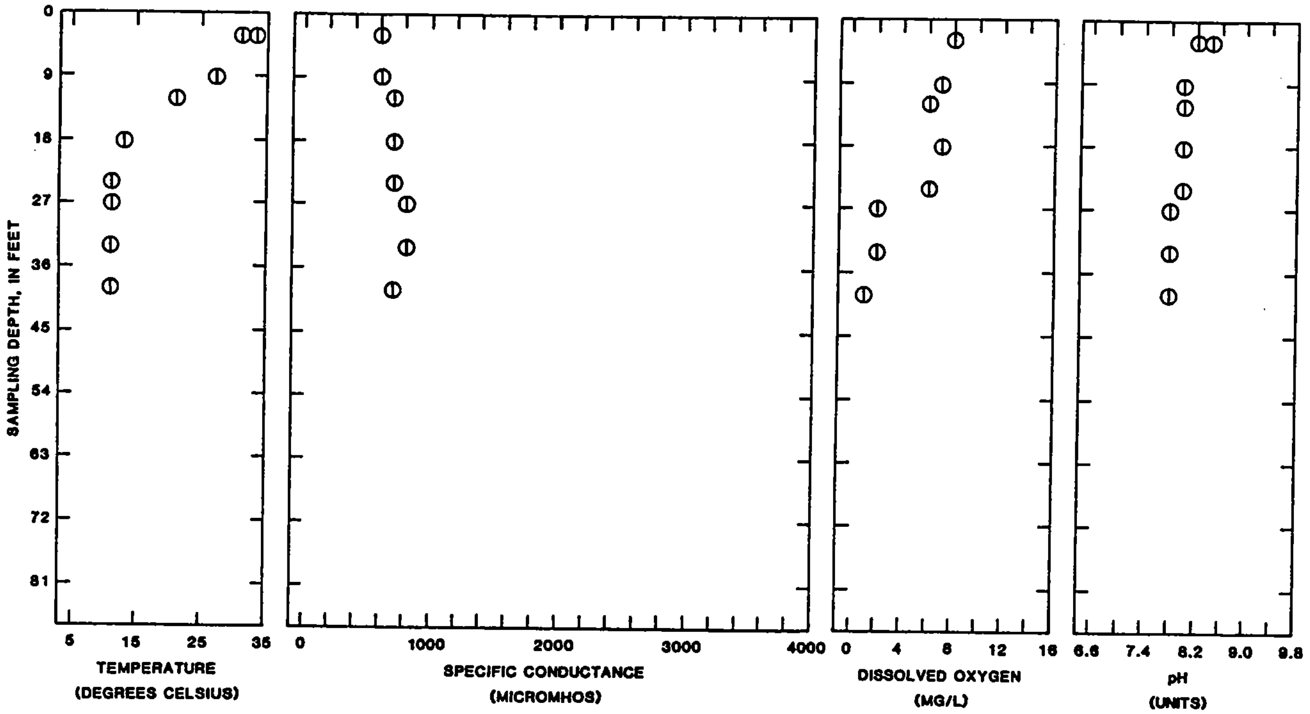
PLOT SYMBOL	DATE OF SAMPLE
⦶	July 1, 1980

Figure 72.—Site 15.



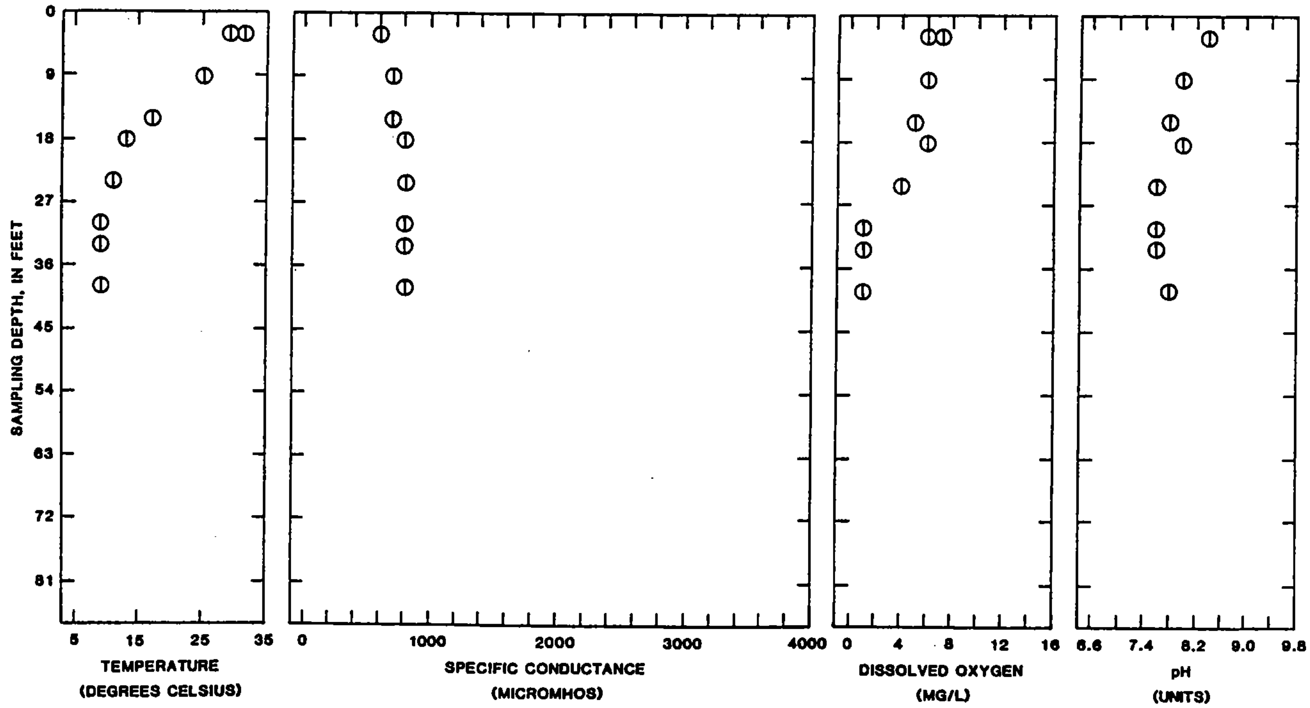
PLOT SYMBOL	DATE OF SAMPLE
⦶	September 28, 1977
◑	August 6, 1979

Figure 73.—Site 16.



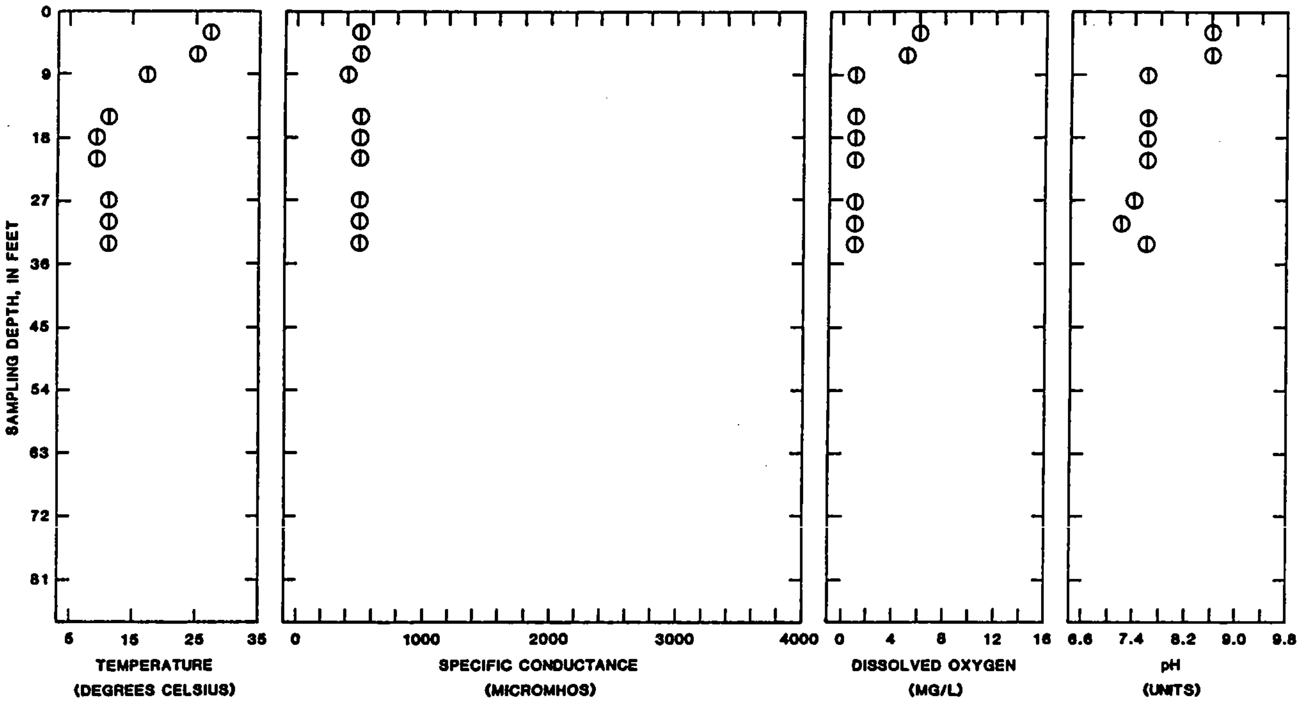
PLOT SYMBOL	DATE OF SAMPLE
⦶	July 1, 1980

Figure 74.--Site 17.



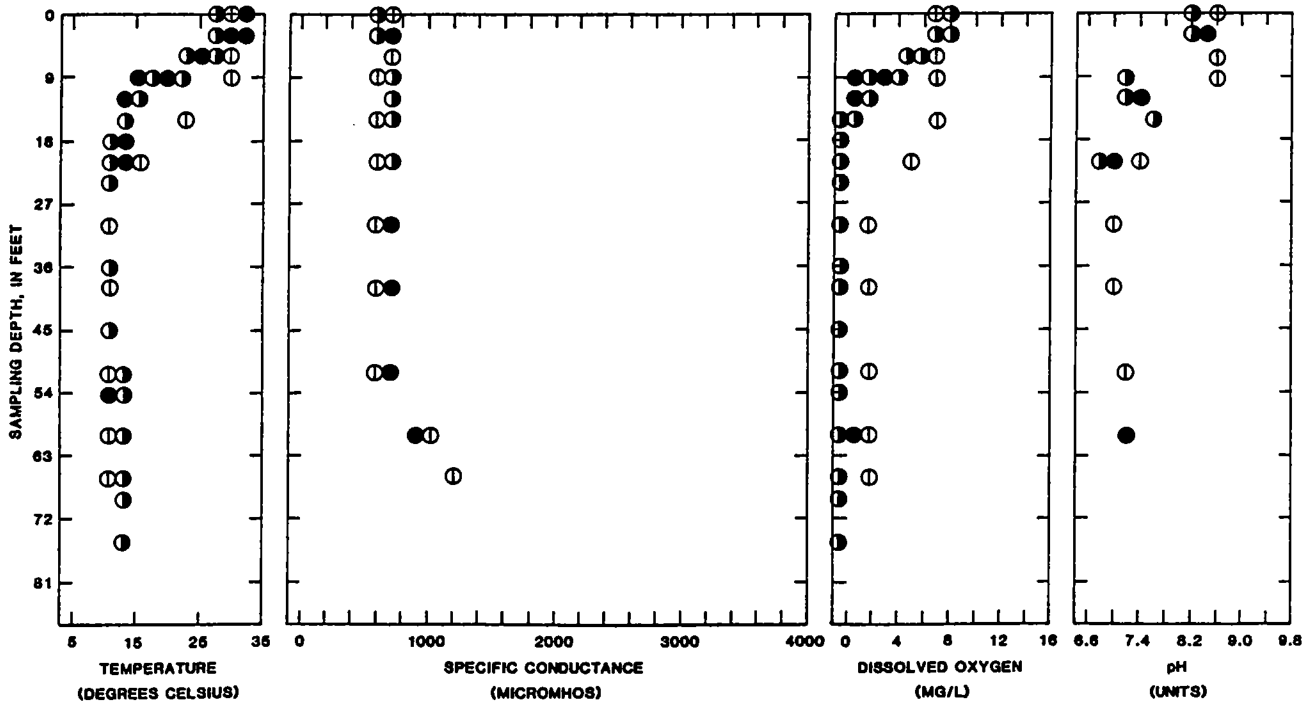
PLOT SYMBOL	DATE OF SAMPLE
⦶	July 1, 1980

Figure 75.--Site 18.



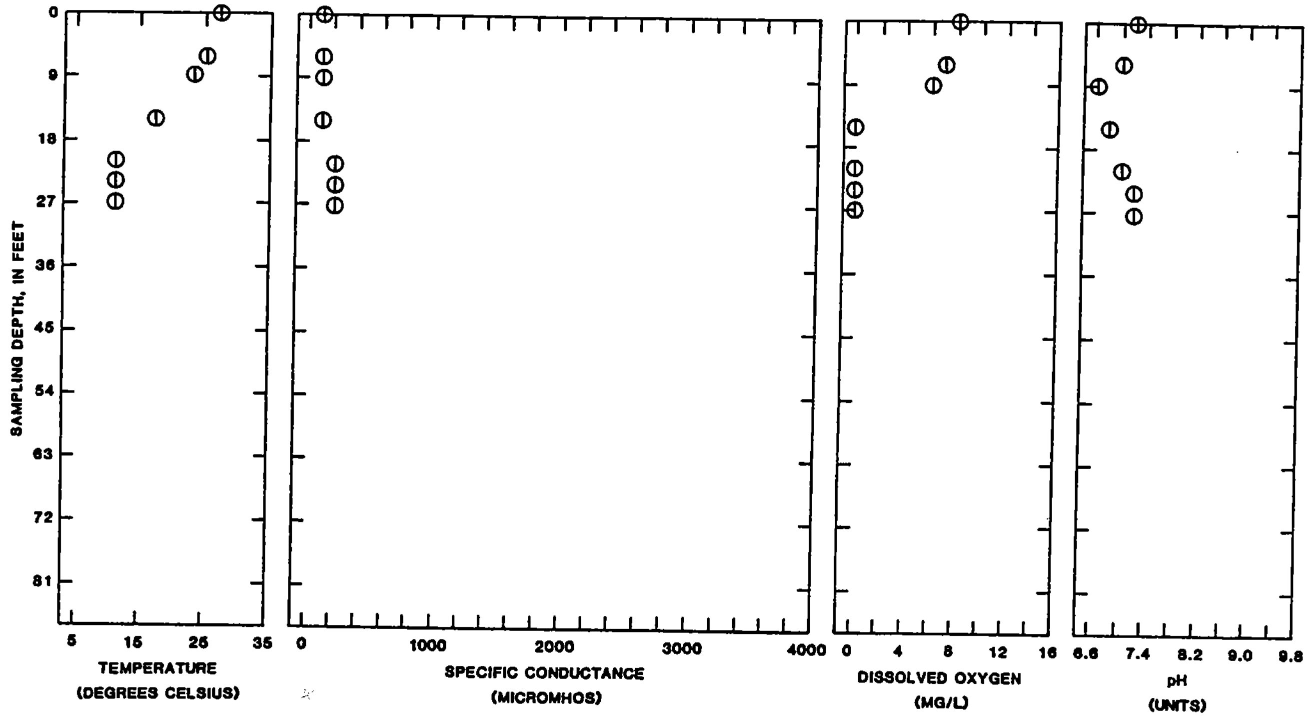
PLOT SYMBOL DATE OF SAMPLE
⦶ July 24, 1980

Figure 76.—Site 19.



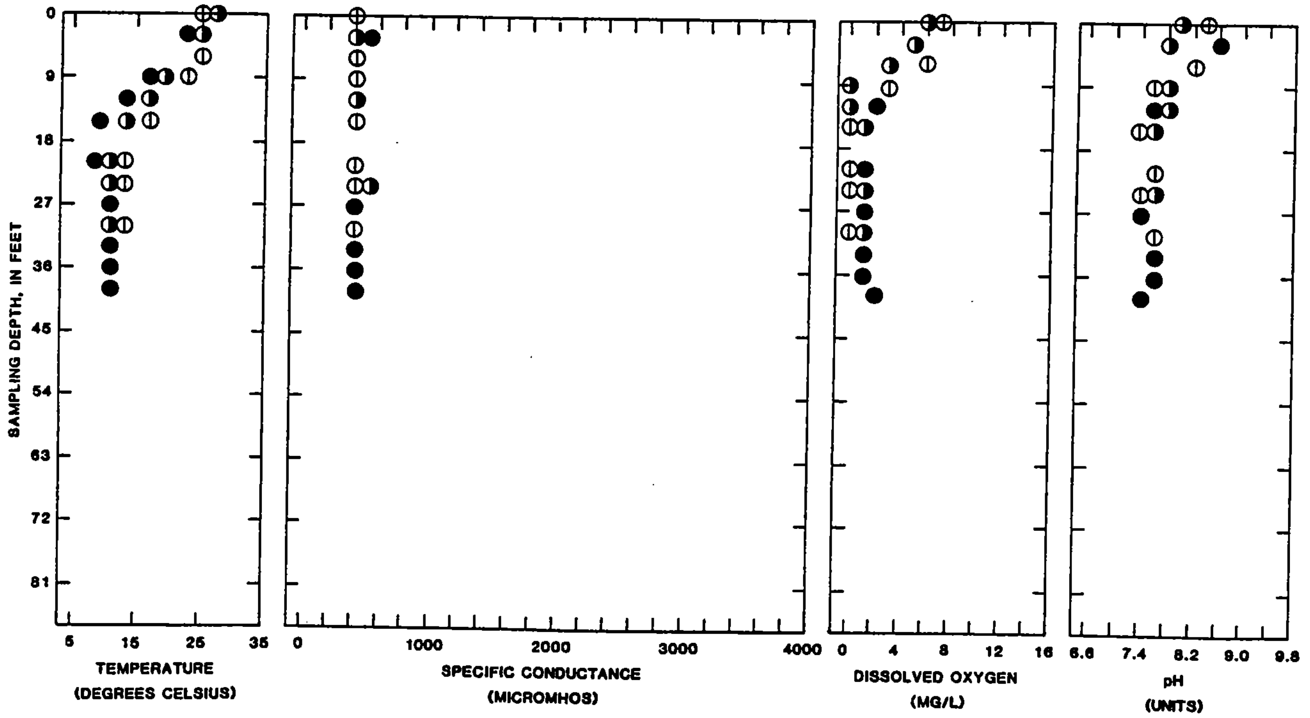
PLOT SYMBOL DATE OF SAMPLE
⦶ July 26, 1977
◑ July 31, 1979
● August 6, 1979

Figure 77.—Site 20.



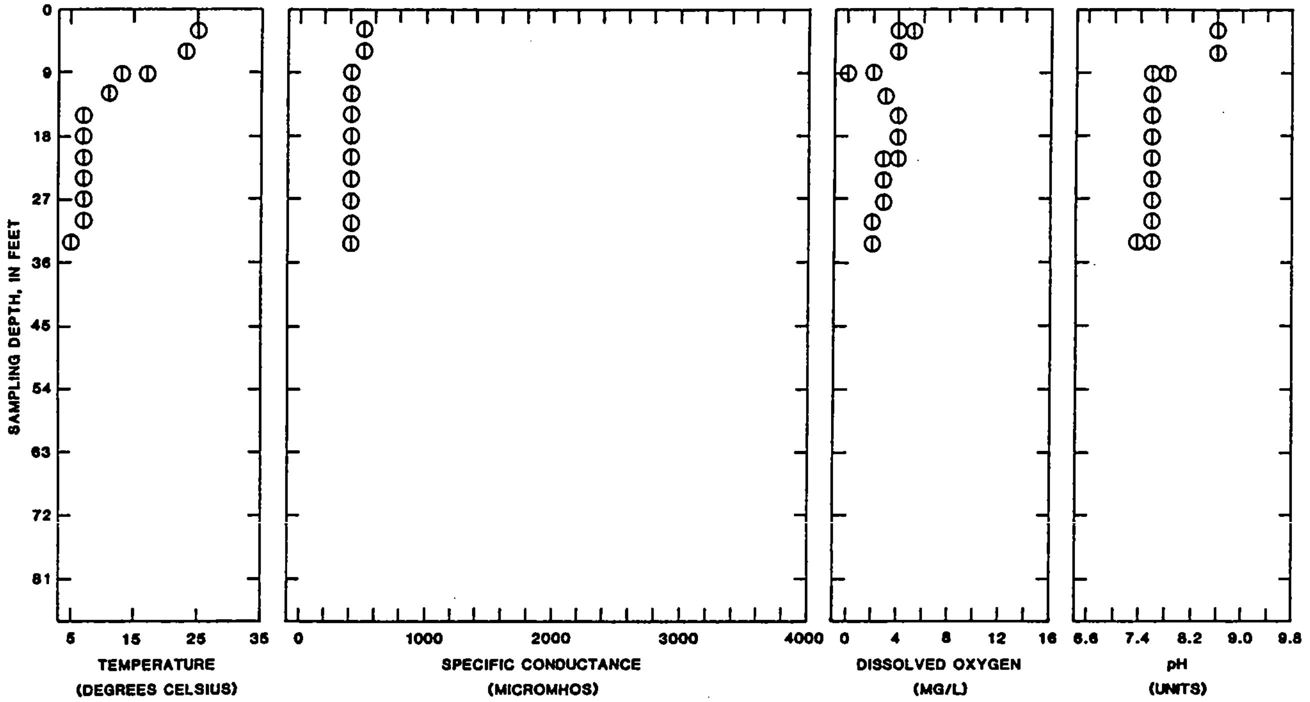
PLOT SYMBOL	DATE OF SAMPLE
⦶	September 29, 1977

Figure 78.--Site 21.



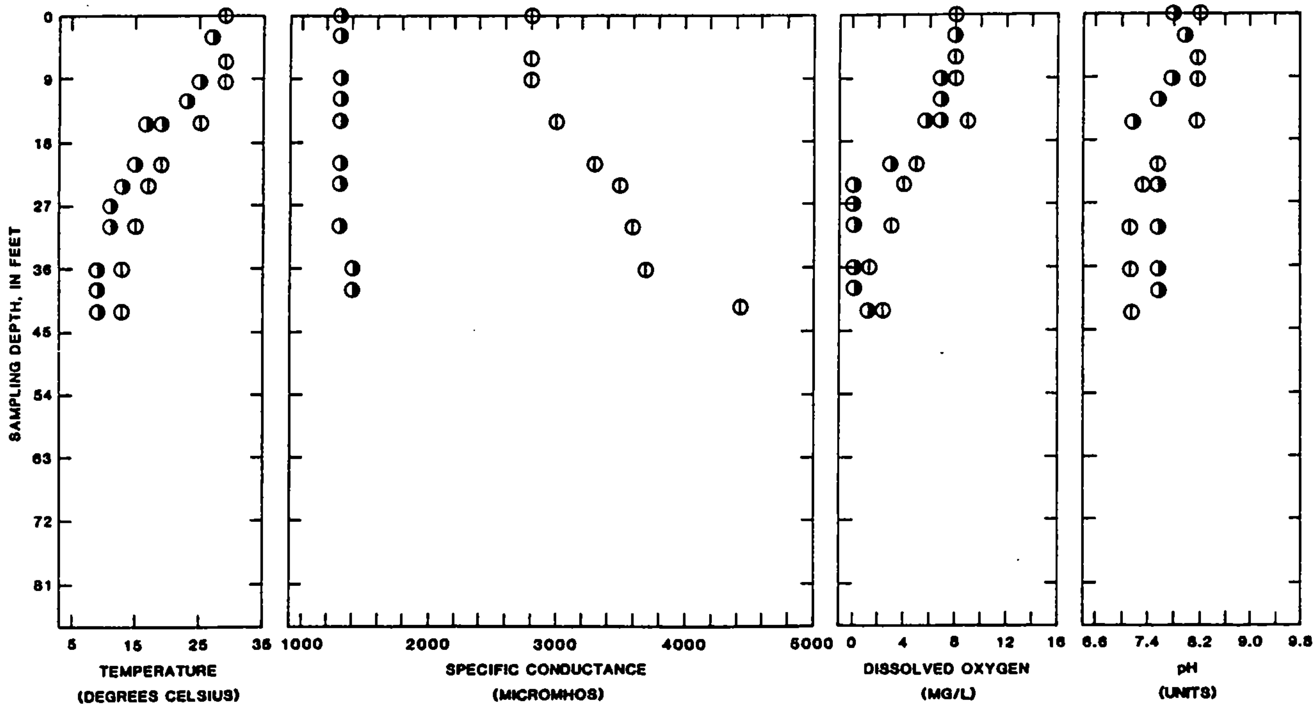
PLOT SYMBOL	DATE OF SAMPLE
⦶	September 27, 1977
◐	August 15, 1979
●	July 24, 1980

Figure 79.--Site 22.



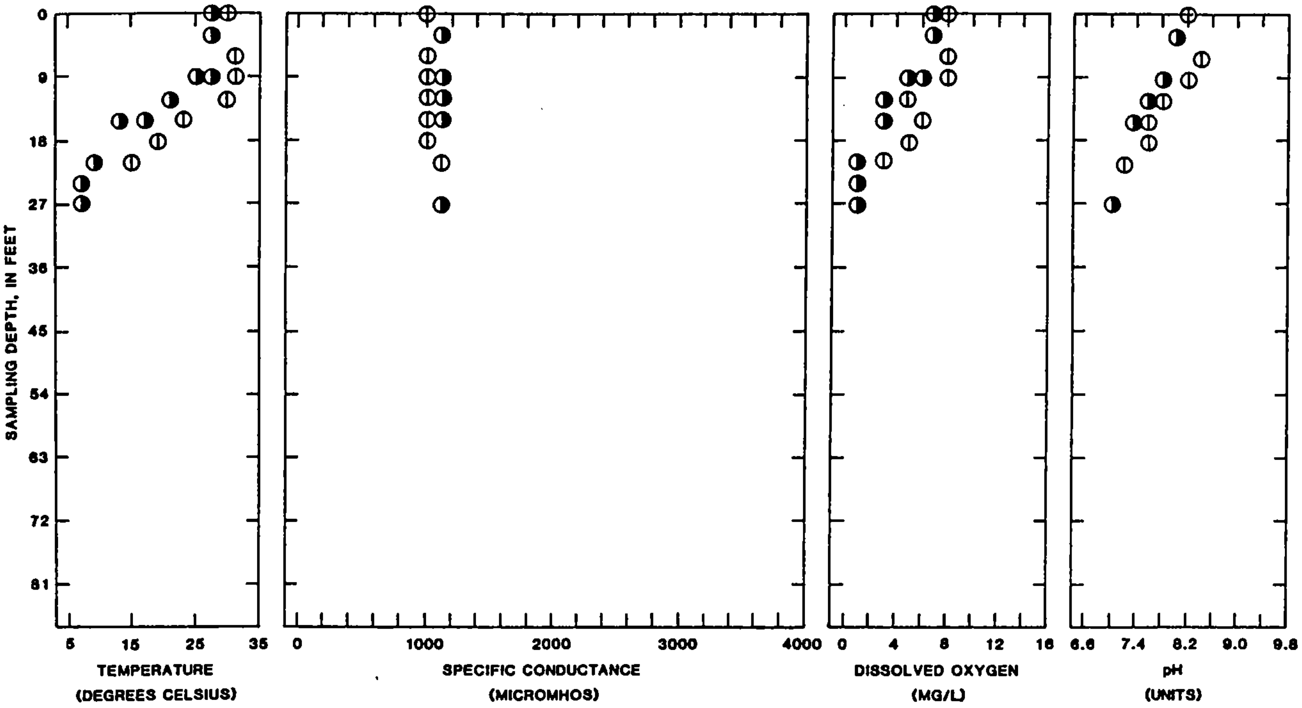
PLOT SYMBOL	DATE OF SAMPLE
⦶	July 24, 1980

Figure 80.--Site 23.



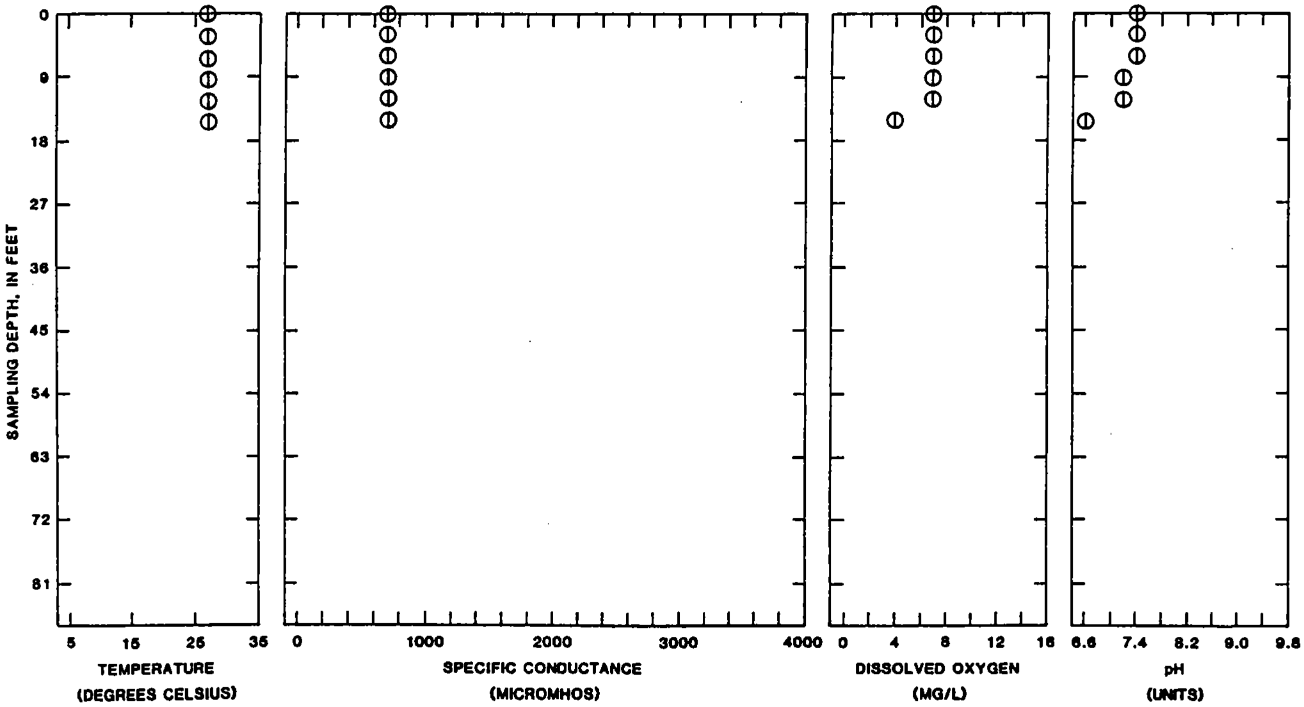
PLOT SYMBOL	DATE OF SAMPLE
⦶	July 27, 1977
◑	August 13, 1979

Figure 81.--Site 24.



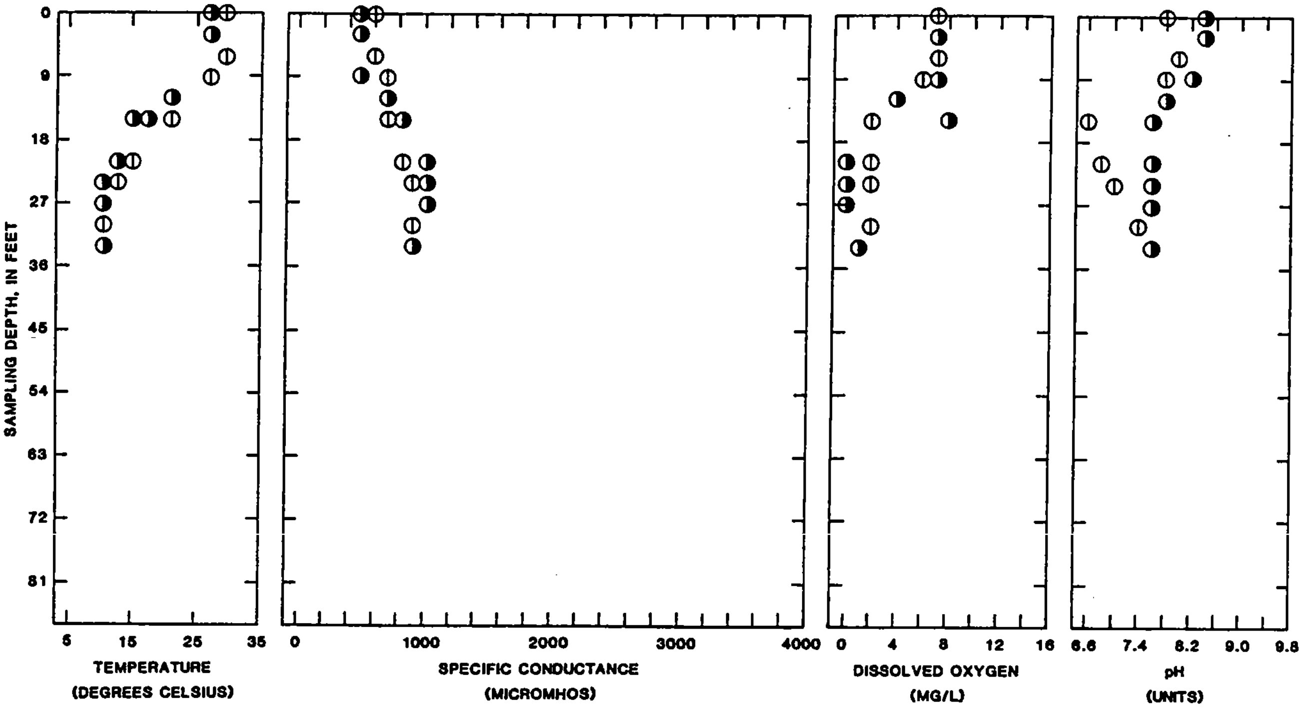
PLOT SYMBOL	DATE OF SAMPLE
⦶	July 26, 1977
◑	August 14, 1979

Figure 82.--Site 25.



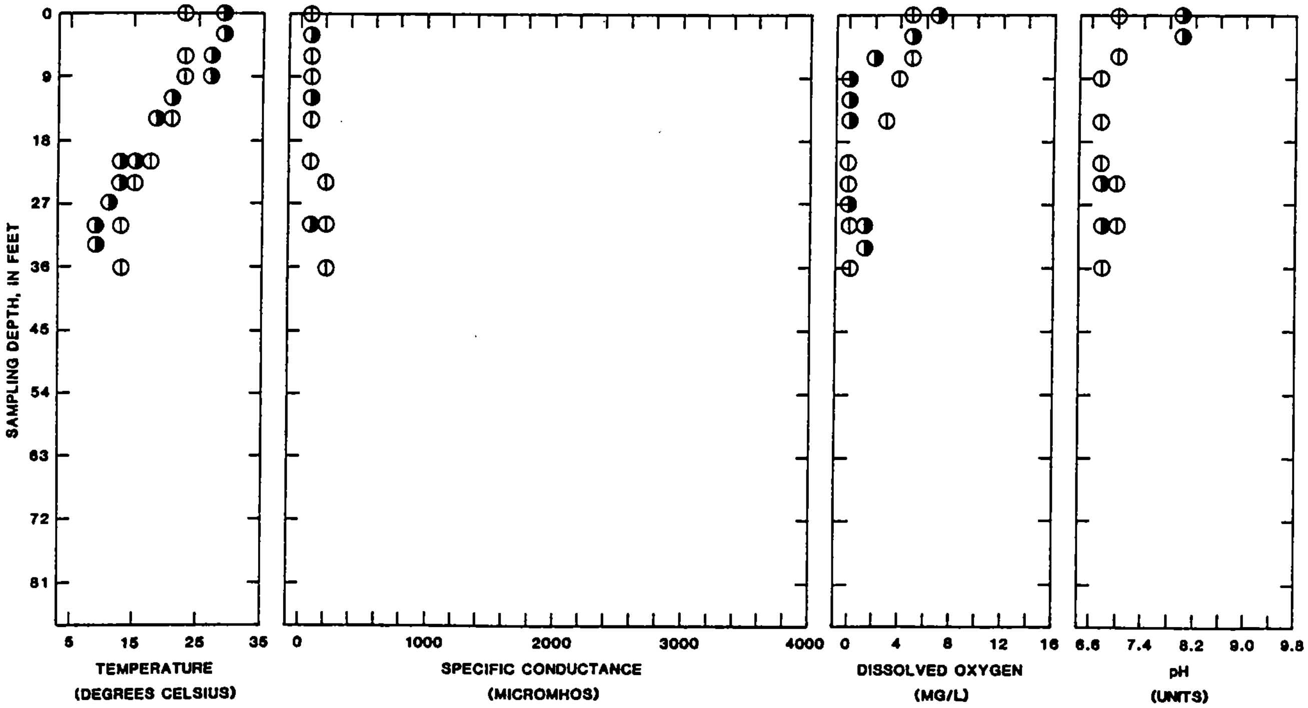
PLOT SYMBOL	DATE OF SAMPLE
⦶	September 28, 1977

Figure 83.--Site 26.



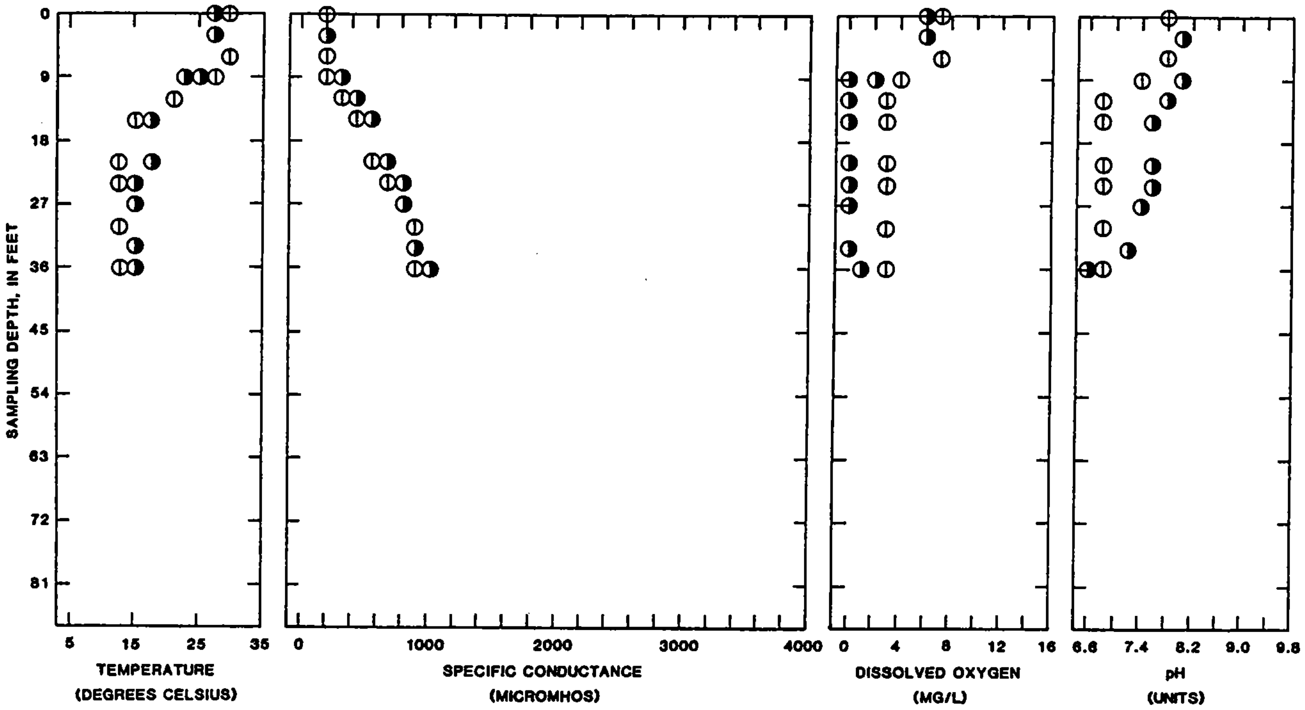
PLOT SYMBOL	DATE OF SAMPLE
⦶	July 28, 1977
◑	August 16, 1979

Figure 84.--Site 27.



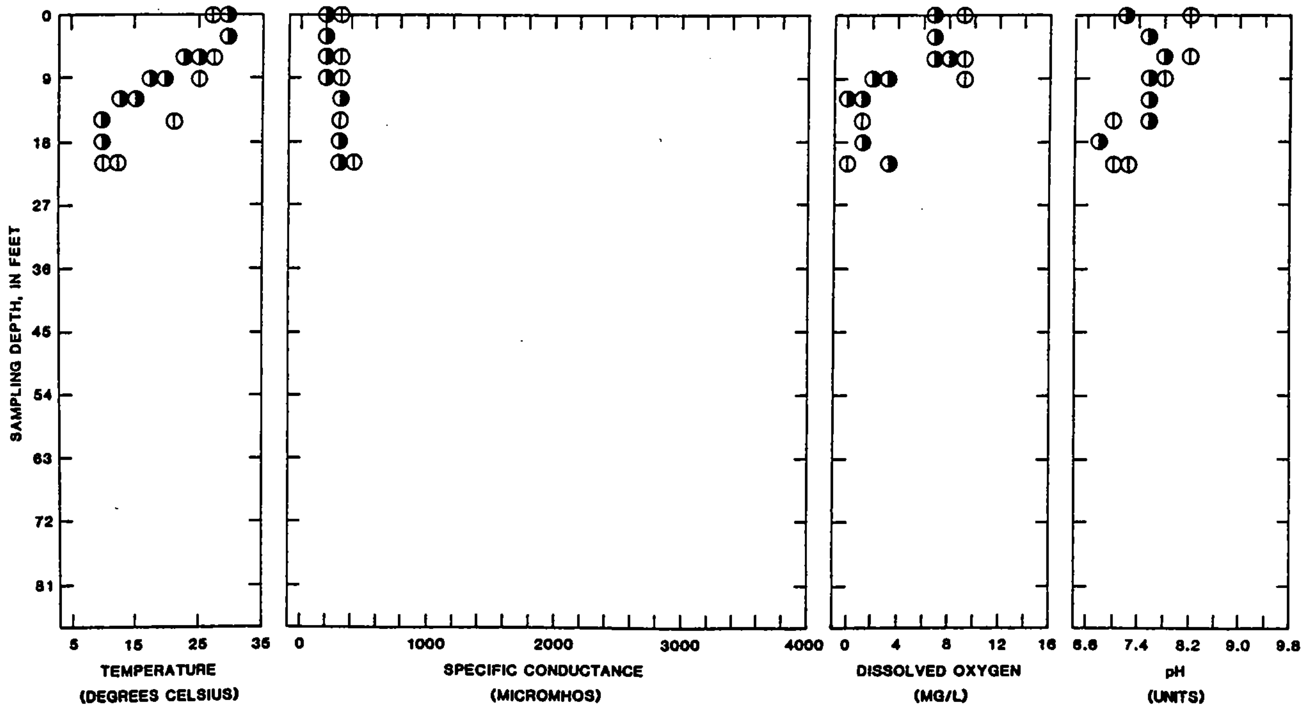
PLOT SYMBOL	DATE OF SAMPLE
⦶	October 5, 1977
◑	August 8, 1979

Figure 85.--Site 28.



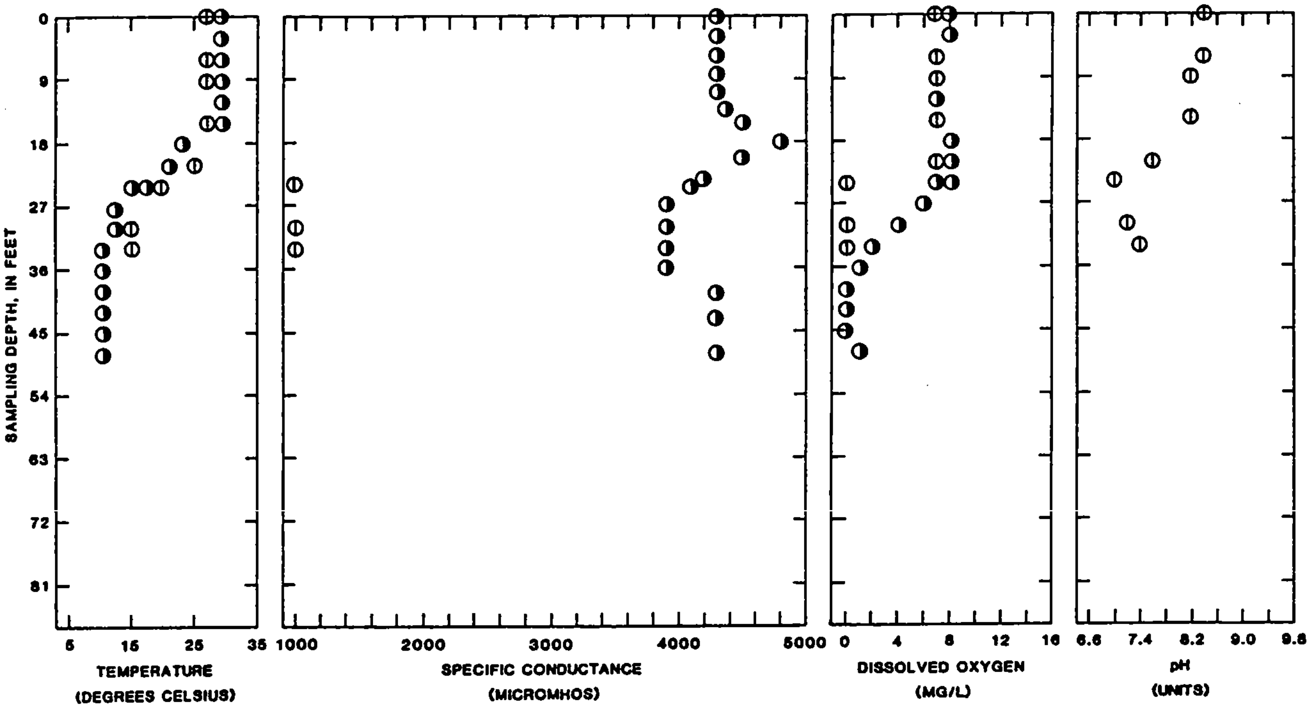
PLOT SYMBOL	DATE OF SAMPLE
⦶	July 27, 1977
◑	August 16, 1979

Figure 86.--Site 29.



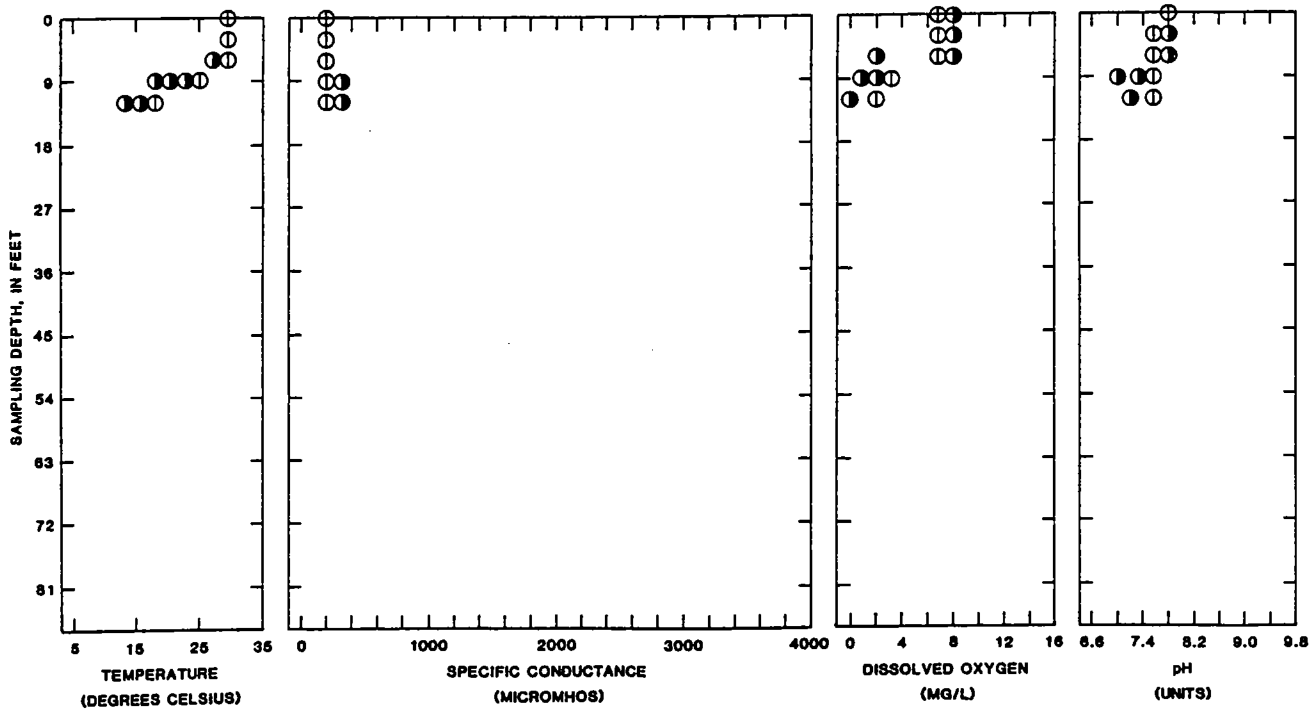
PLOT SYMBOL	DATE OF SAMPLE
⦶	September 27, 1977
◑	August 8, 1979

Figure 87.--Site 30.



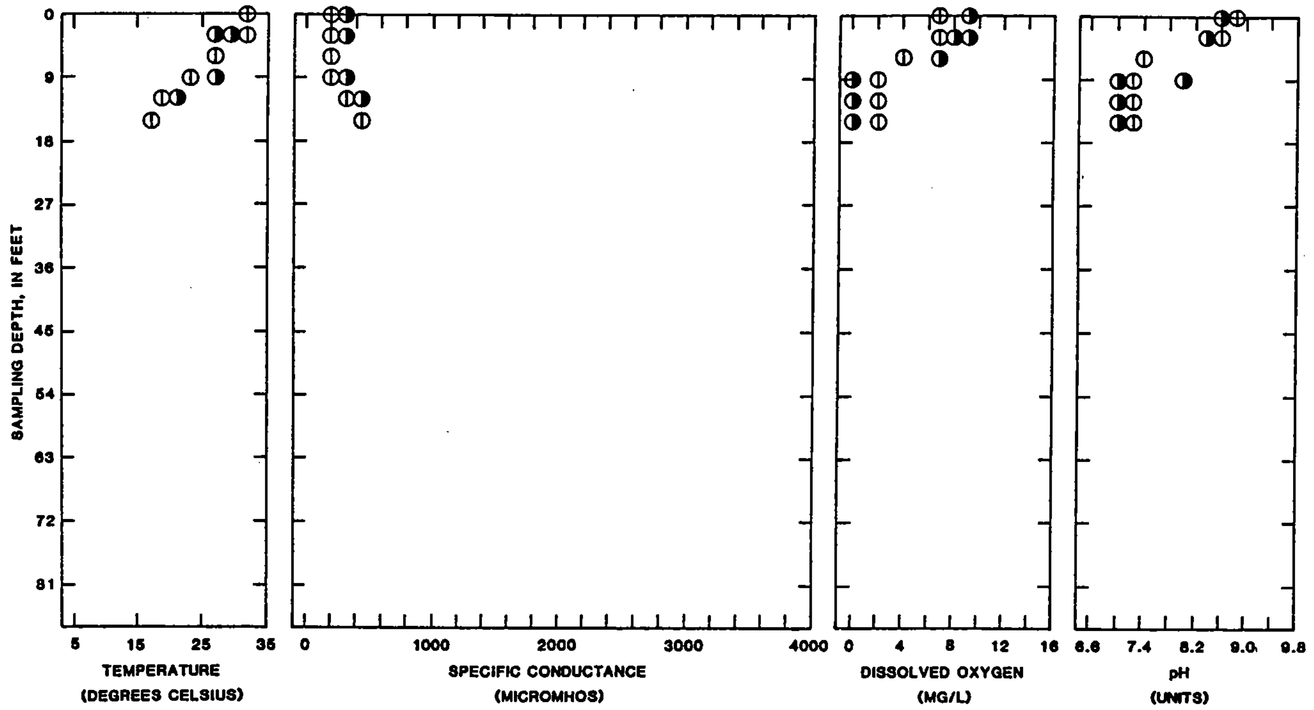
PLOT SYMBOL	DATE OF SAMPLE
⦶	September 29, 1977
◑	August 16, 1979

Figure 88.--Site 31.



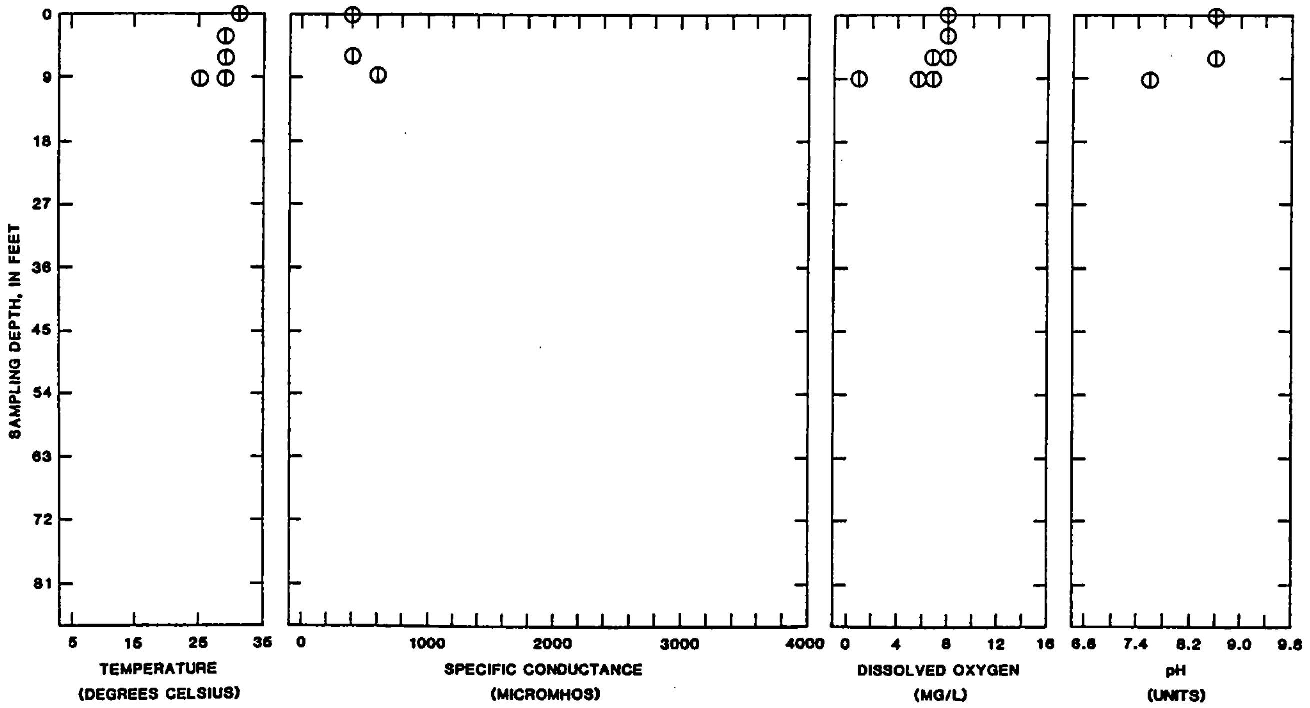
PLOT SYMBOL	DATE OF SAMPLE
⦶	July 19, 1977
◑	August 2, 1979

Figure 89.--Site 32.



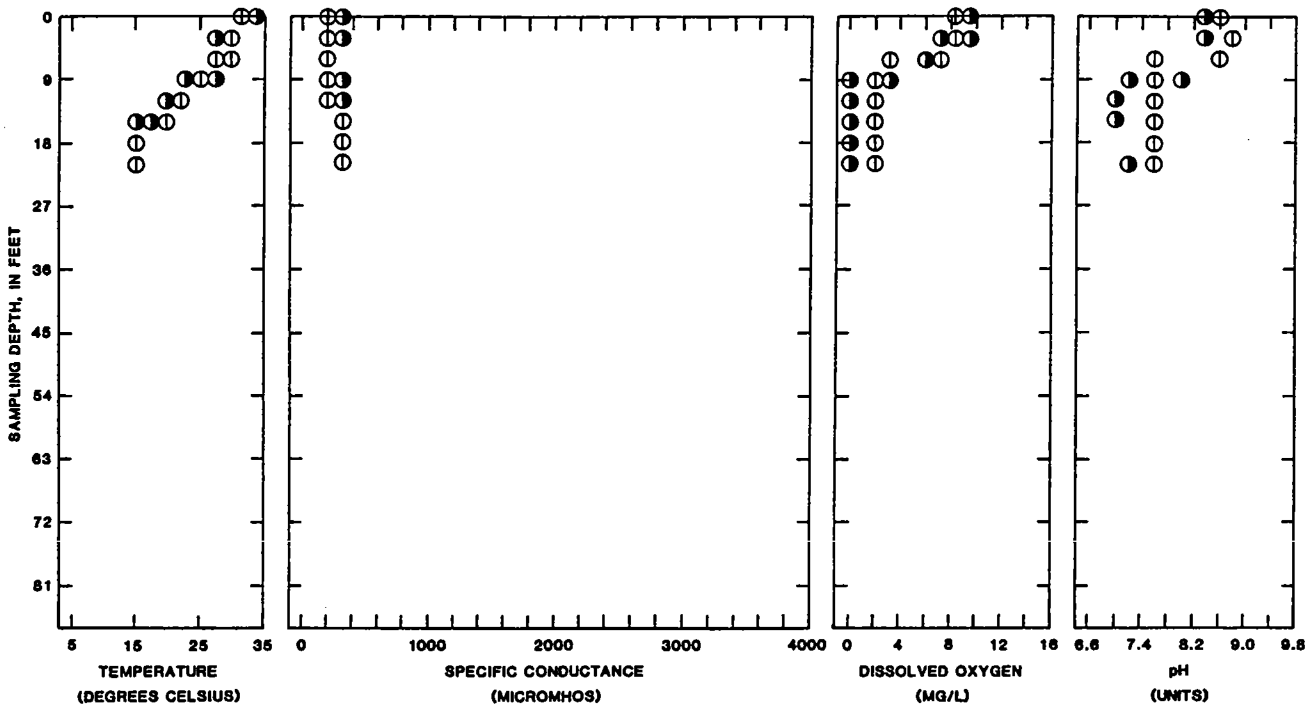
PLOT SYMBOL	DATE OF SAMPLE
⦶	July 19, 1977
◑	August 1, 1979

Figure 90.--Site 33.



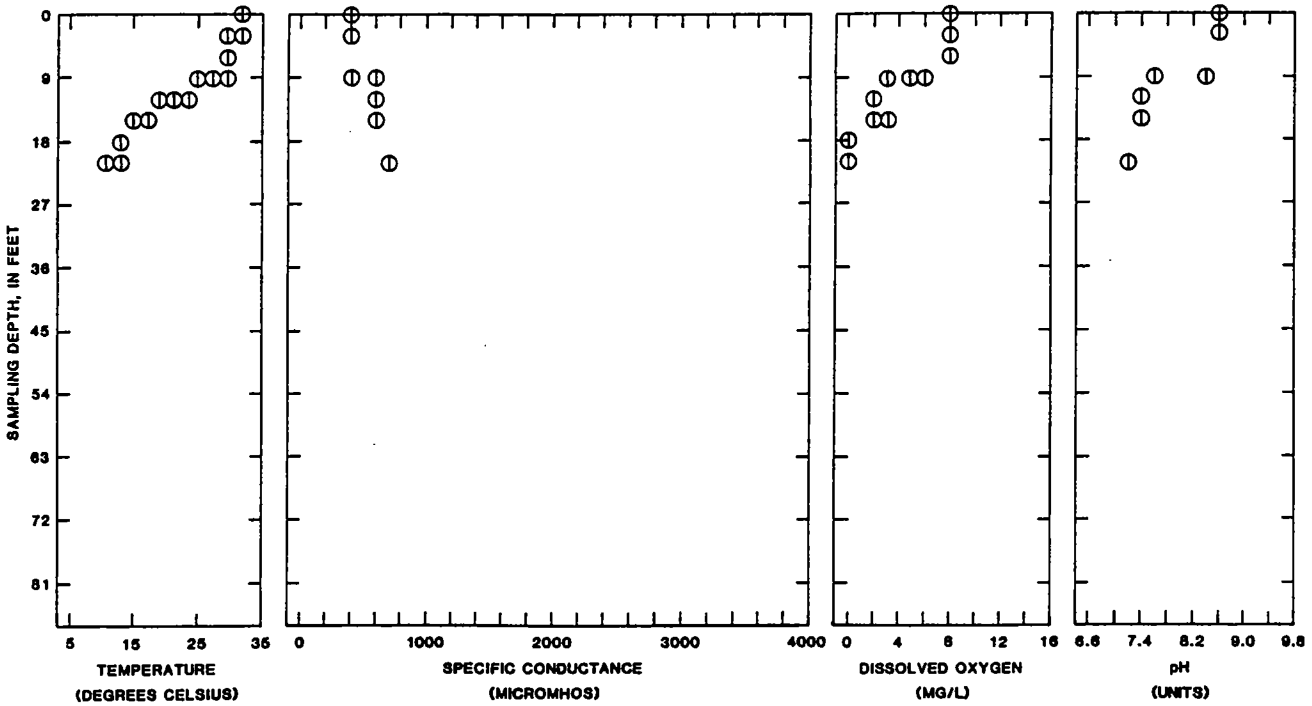
PLOT SYMBOL	DATE OF SAMPLE
⦶	August 2, 1979

Figure 91.--Site 34.



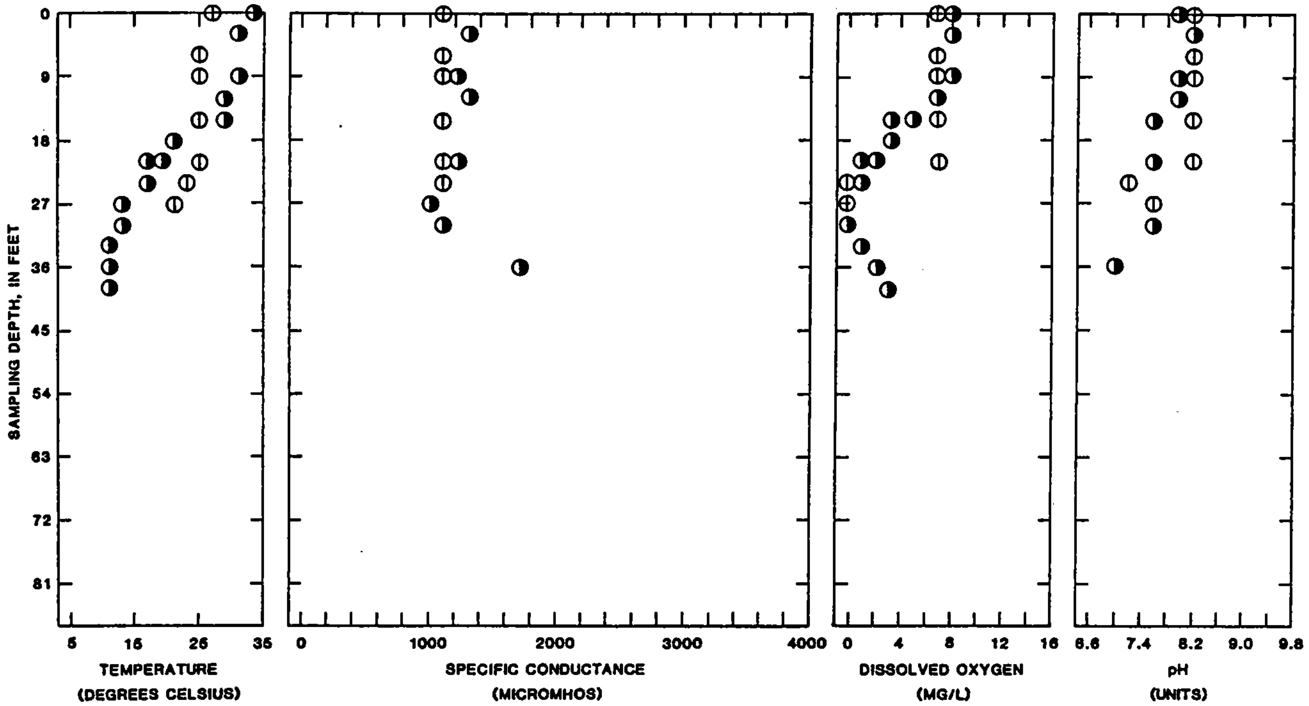
PLOT SYMBOL	DATE OF SAMPLE
⦶	July 19, 1977
◑	August 1, 1979

Figure 92.--Site 35.



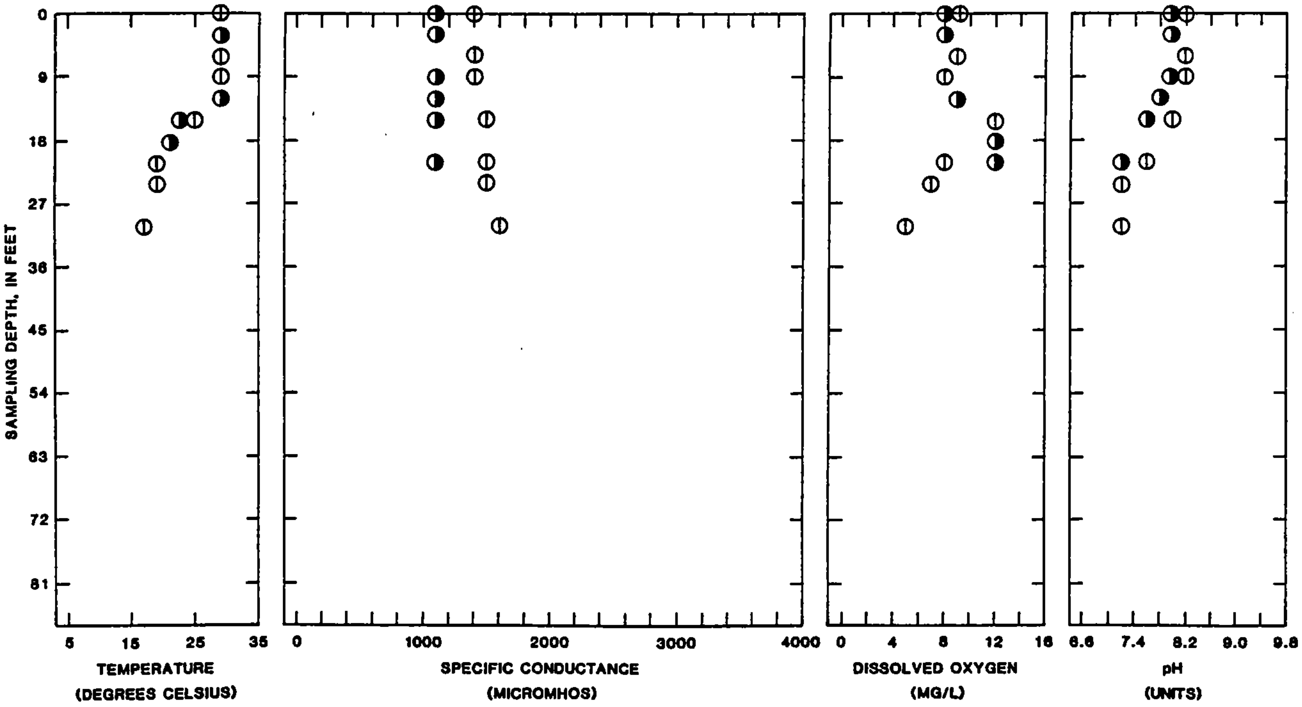
PLOT SYMBOL	DATE OF SAMPLE
⦶	August 2, 1979

Figure 93.--Site 36.



PLOT SYMBOL	DATE OF SAMPLE
⦶	September 29, 1977
◑	August 9, 1979

Figure 94.—Site 37.



PLOT SYMBOL	DATE OF SAMPLE
⦶	July 28, 1977
◑	August 14, 1979

Figure 95.—Site 38.

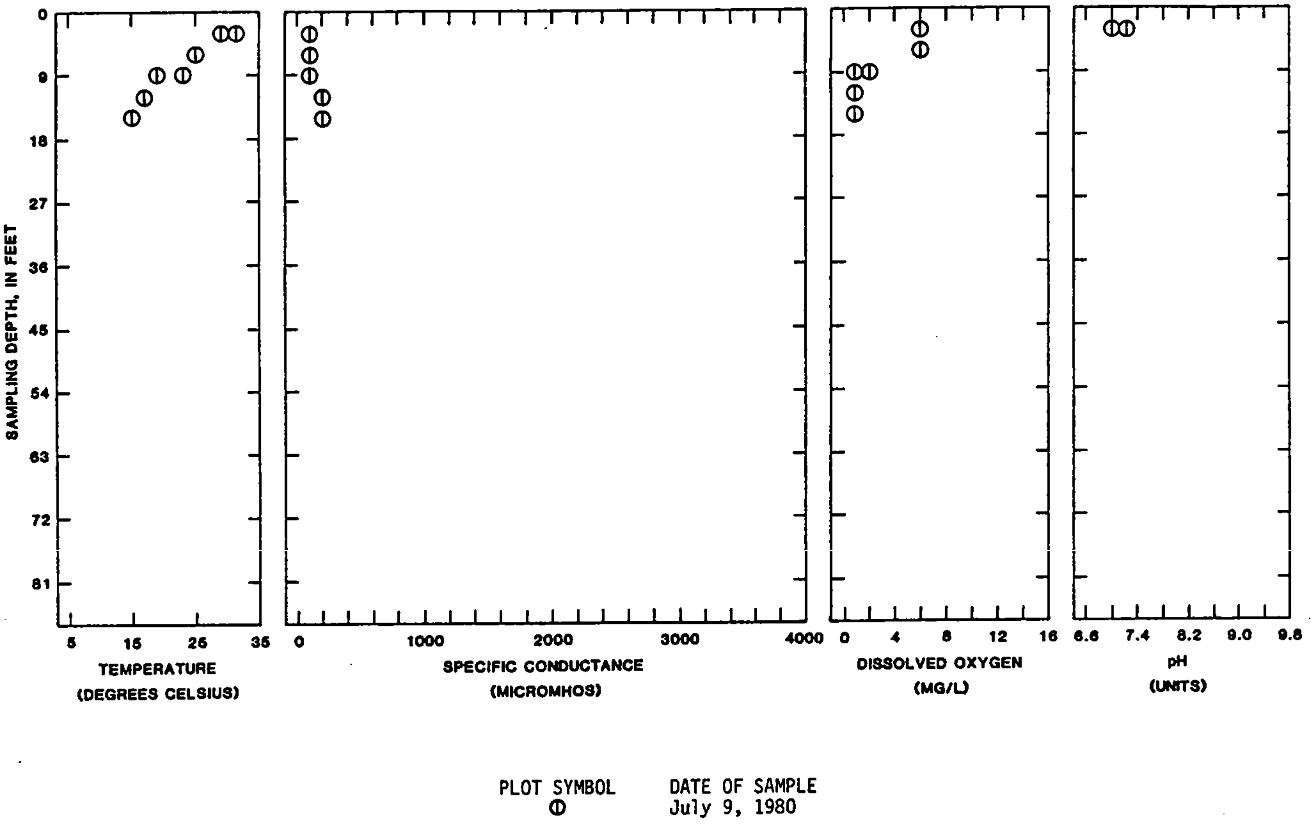


Figure 96.--Site 39.

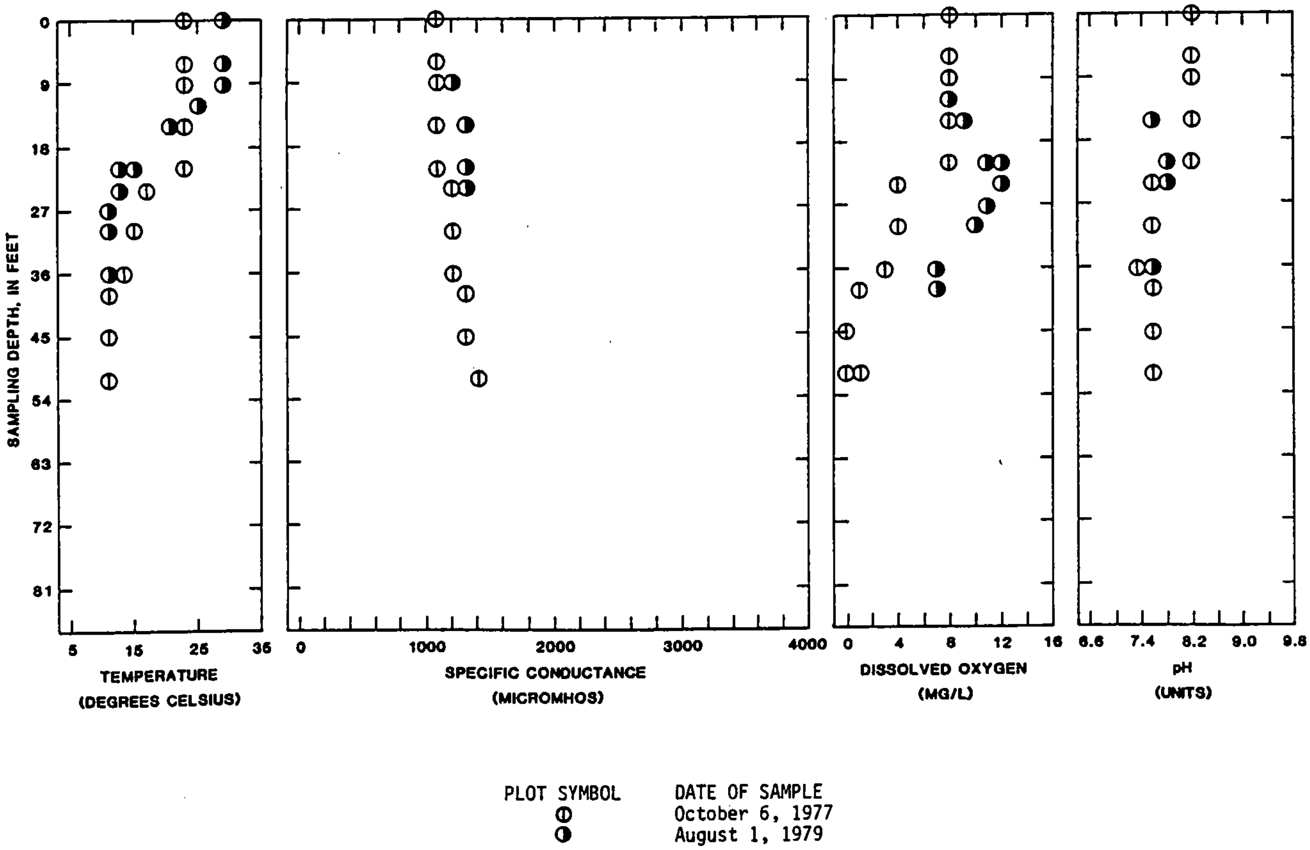
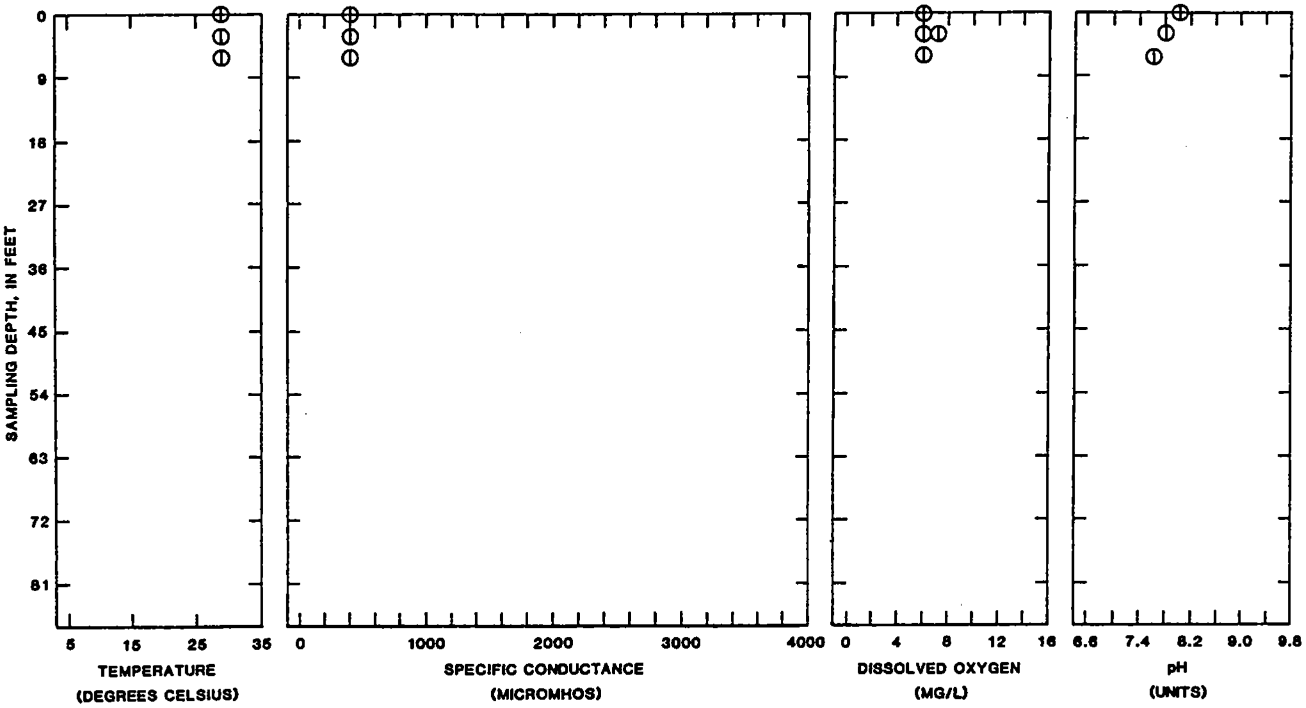
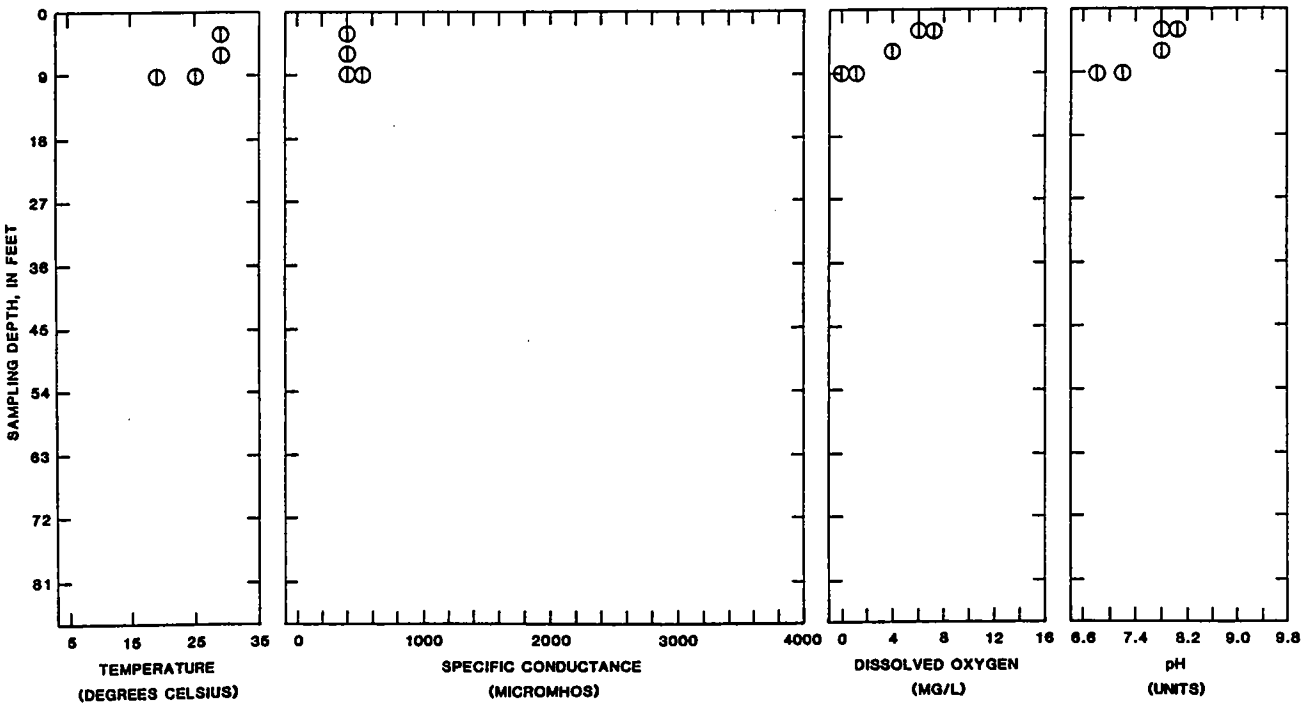


Figure 97.--Site 40.



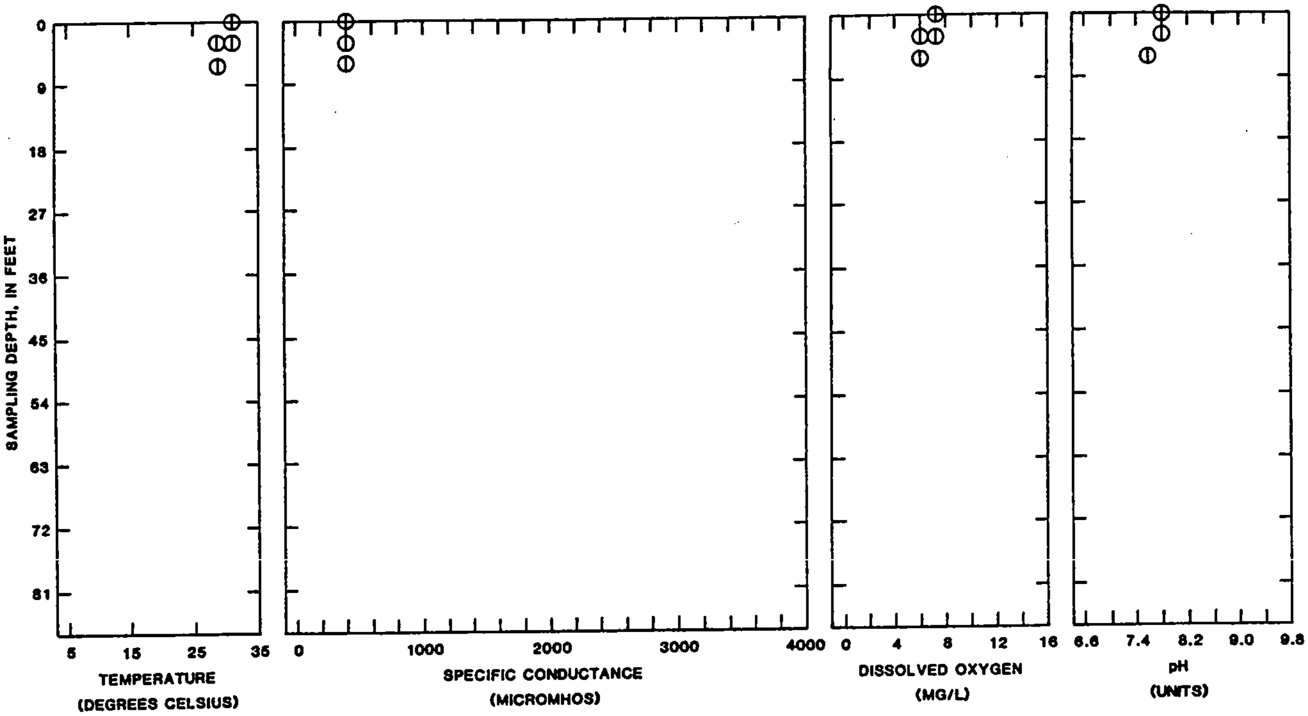
PLOT SYMBOL ⦶ DATE OF SAMPLE July 22, 1980

Figure 98.--Site 41.



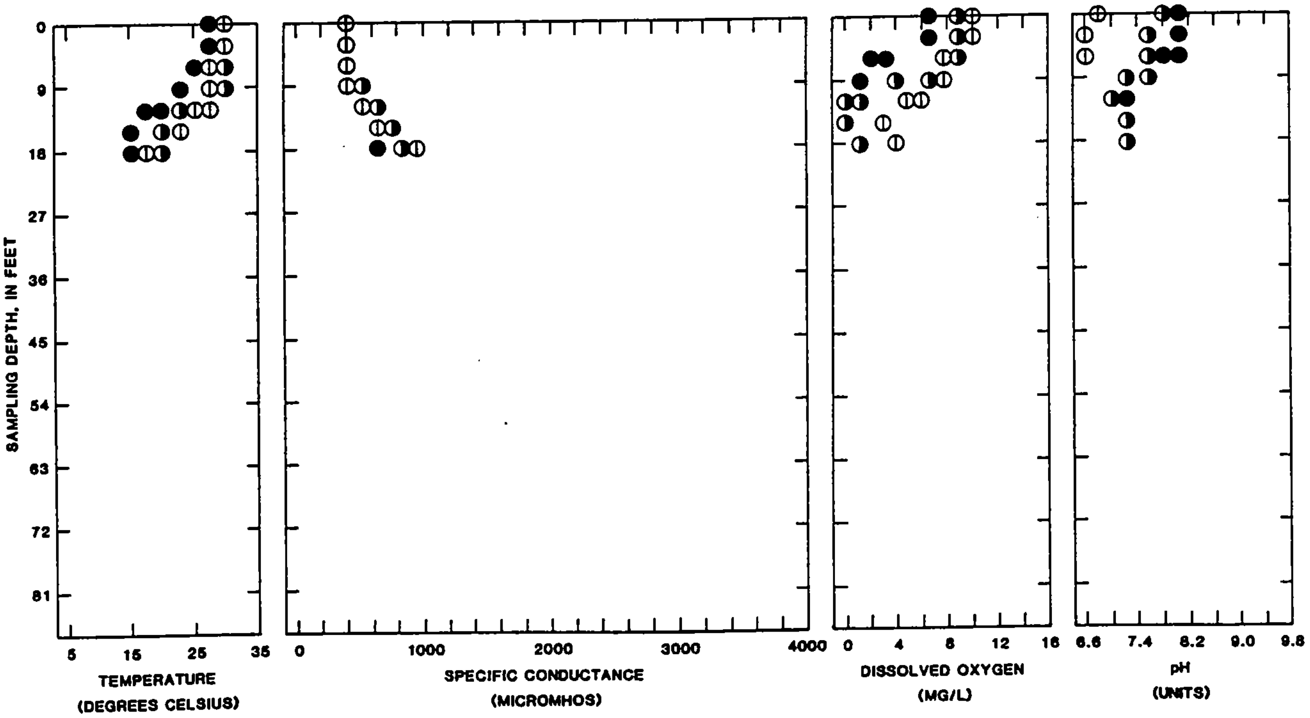
PLOT SYMBOL ⦶ DATE OF SAMPLE July 22, 1980

Figure 99.--Site 42.



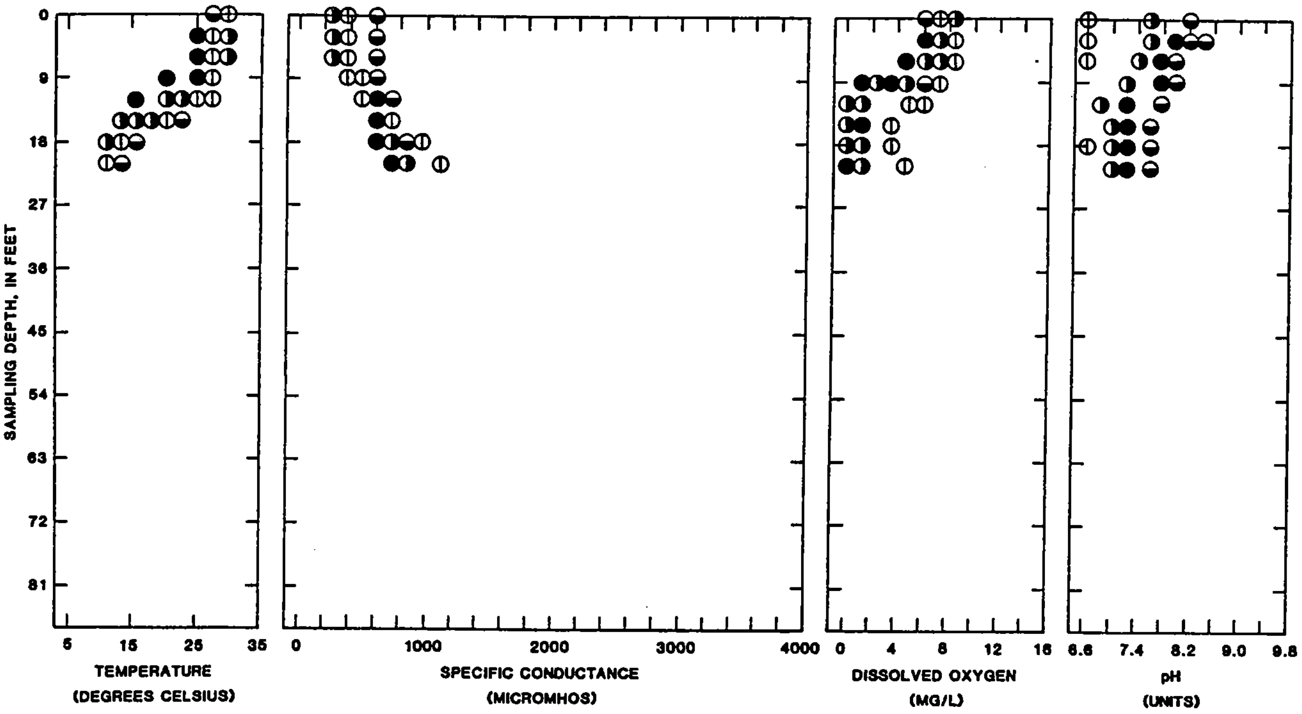
PLOT SYMBOL	DATE OF SAMPLE
⌽	July 22, 1980

Figure 100.--Site 43.



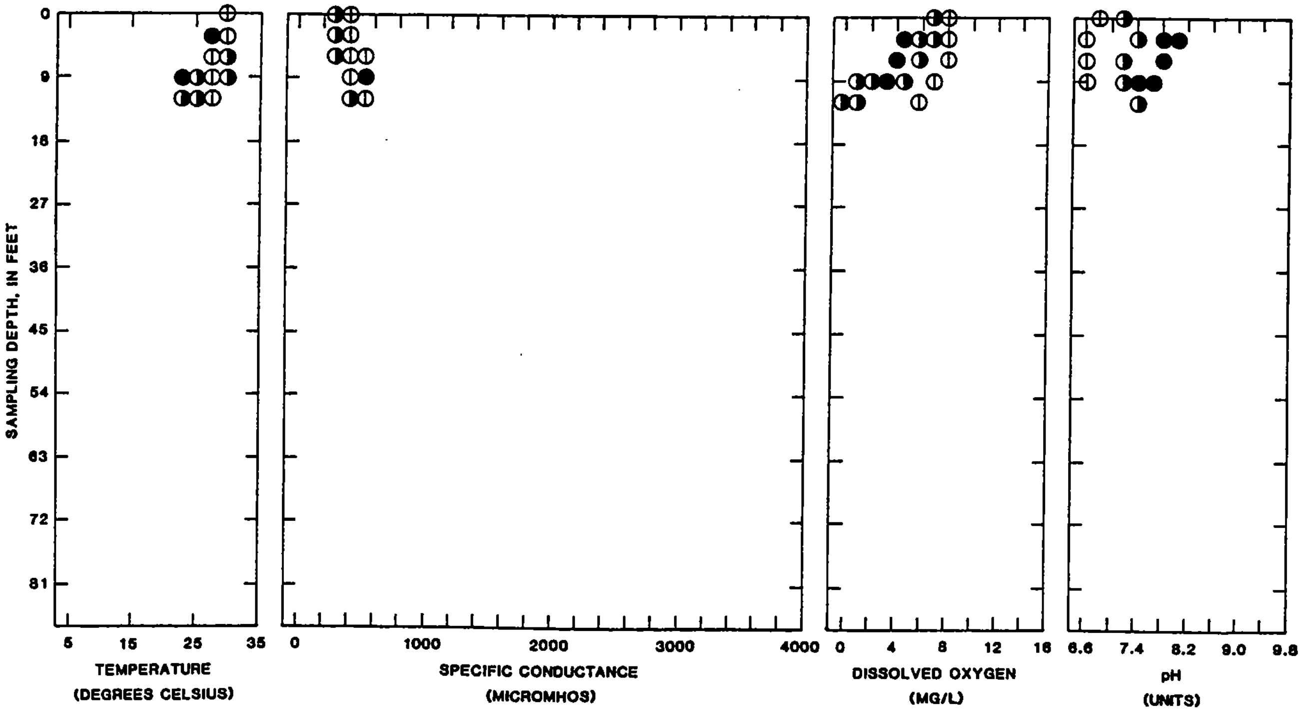
PLOT SYMBOL	DATE OF SAMPLE
⌽	September 6, 1978
◑	July 23, 1979
●	June 10, 1980

Figure 101.--Site 44.



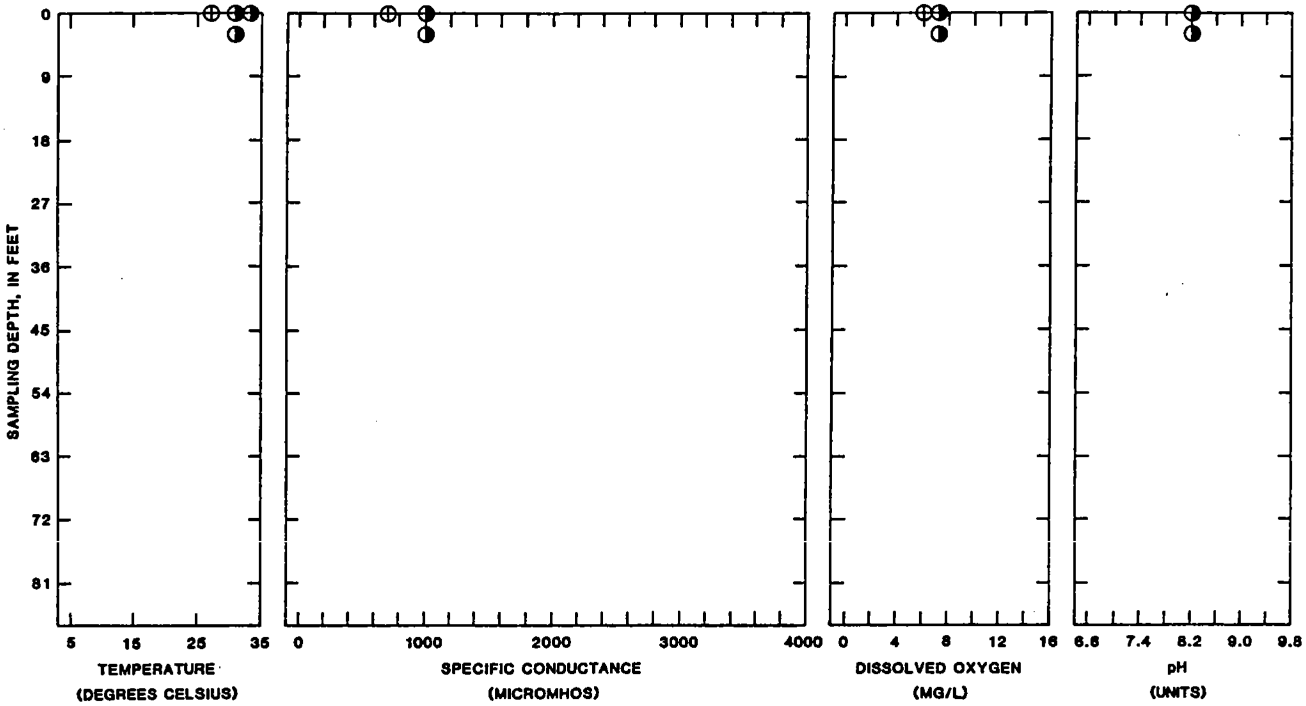
PLOT SYMBOL	DATE OF SAMPLE
⦶	September 6, 1978
◑	July 24, 1979
●	June 10, 1980
◒	July 8, 1981

Figure 102.--Site 45.



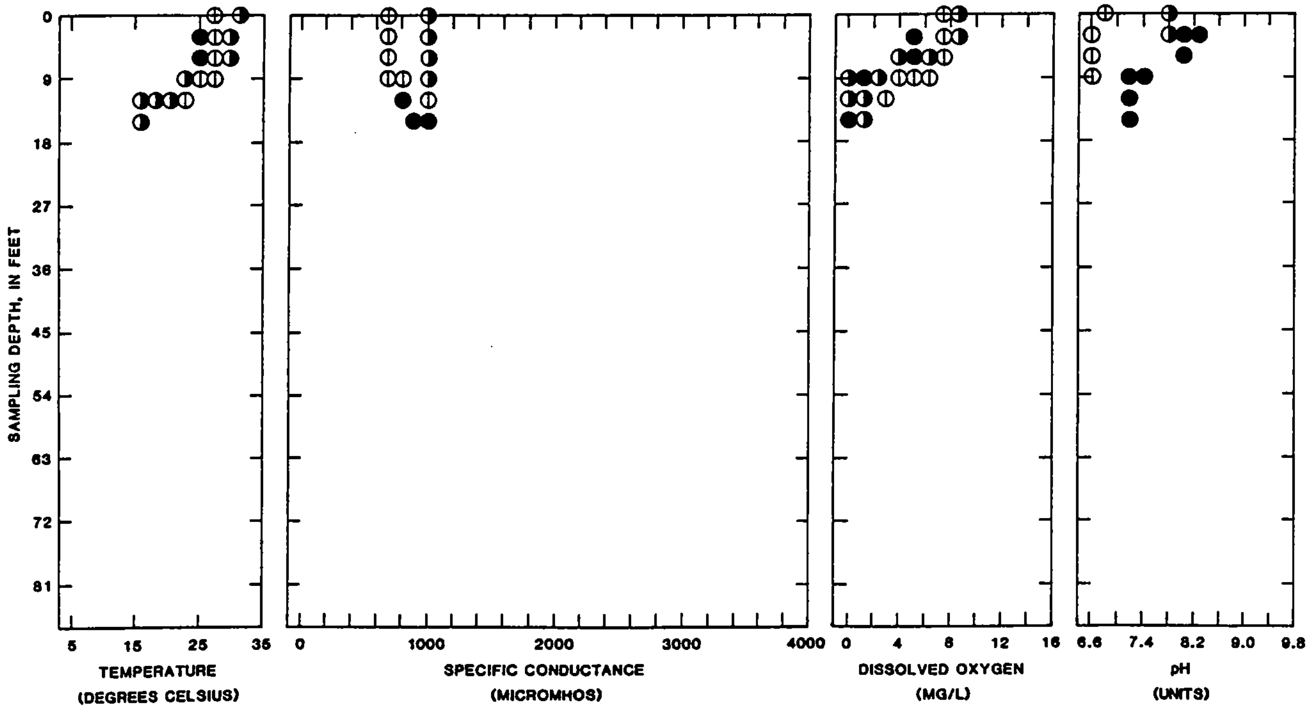
PLOT SYMBOL	DATE OF SAMPLE
⦶	September 6, 1978
◑	July 24, 1979
●	June 10, 1980

Figure 103.--Site 46.



PLOT SYMBOL	DATE OF SAMPLE
⦶	September 6, 1978
◑	July 24, 1979

Figure 104.--Site 47.



PLOT SYMBOL	DATE OF SAMPLE
⦶	September 6, 1978
◑	July 24, 1979
●	June 10, 1980

Figure 105.--Site 48.

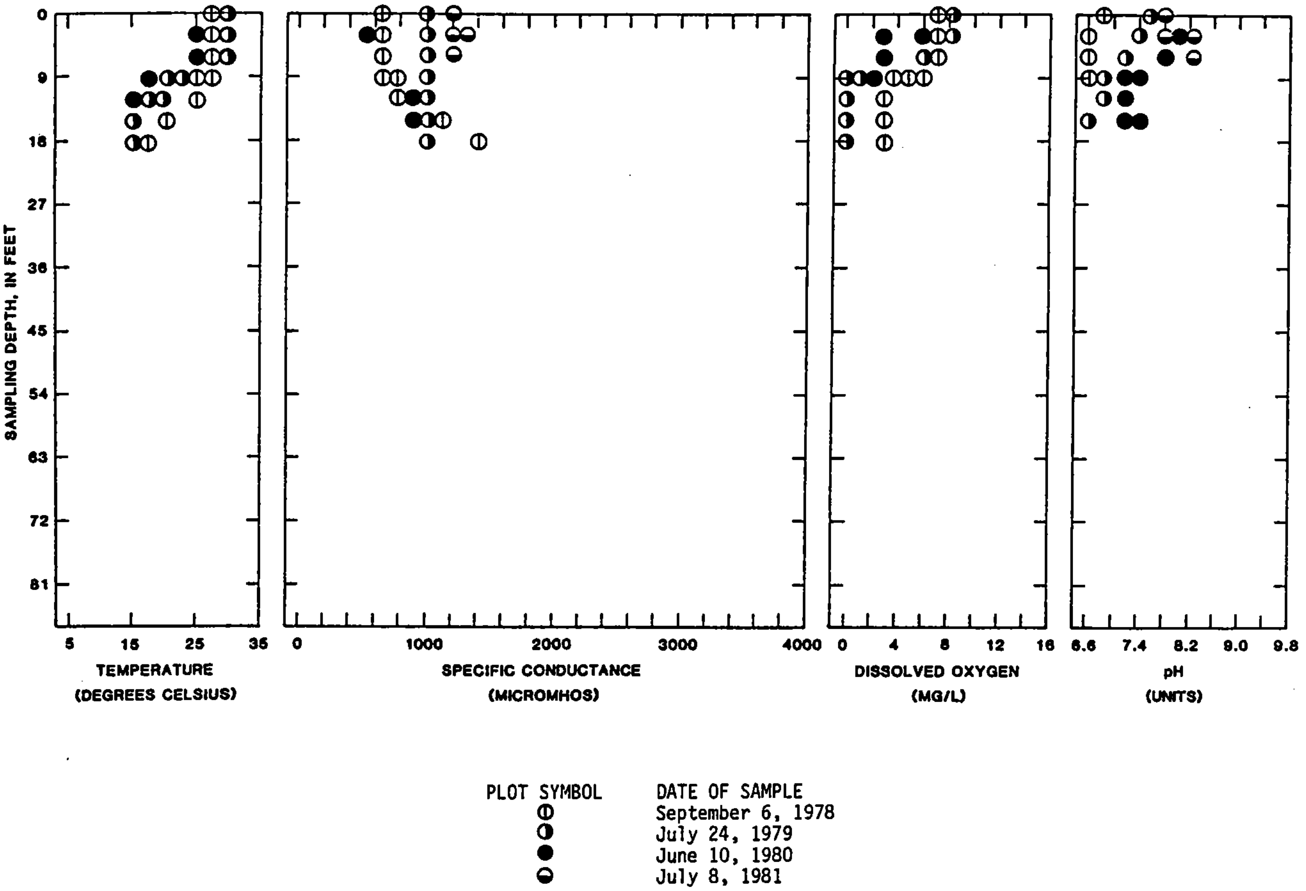


Figure 106.—Site 49.

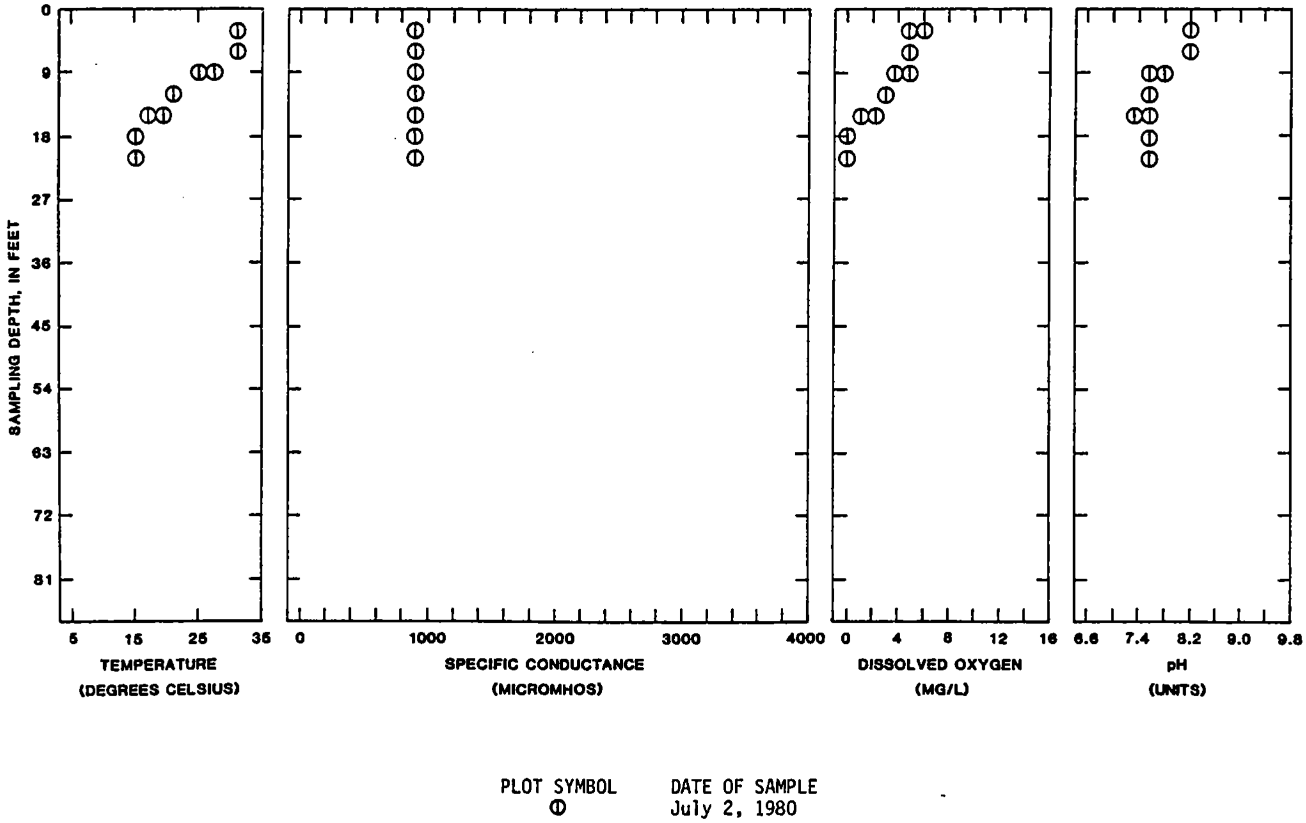
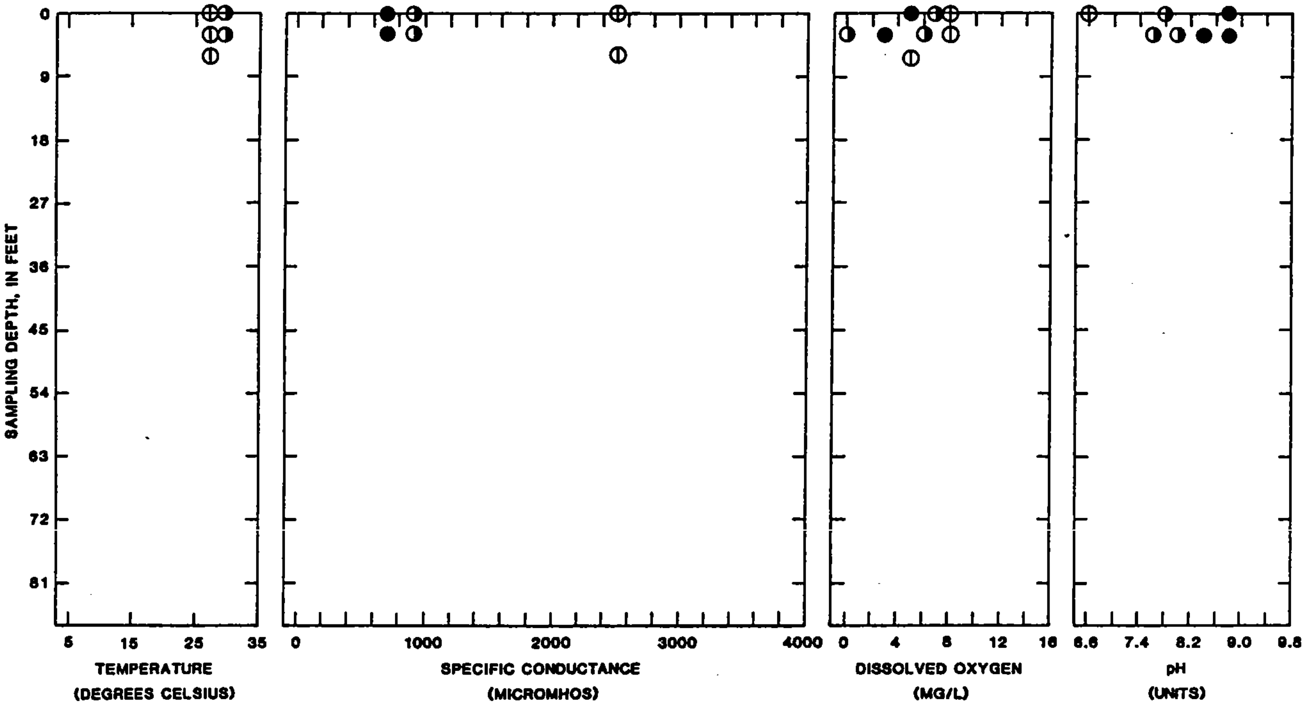
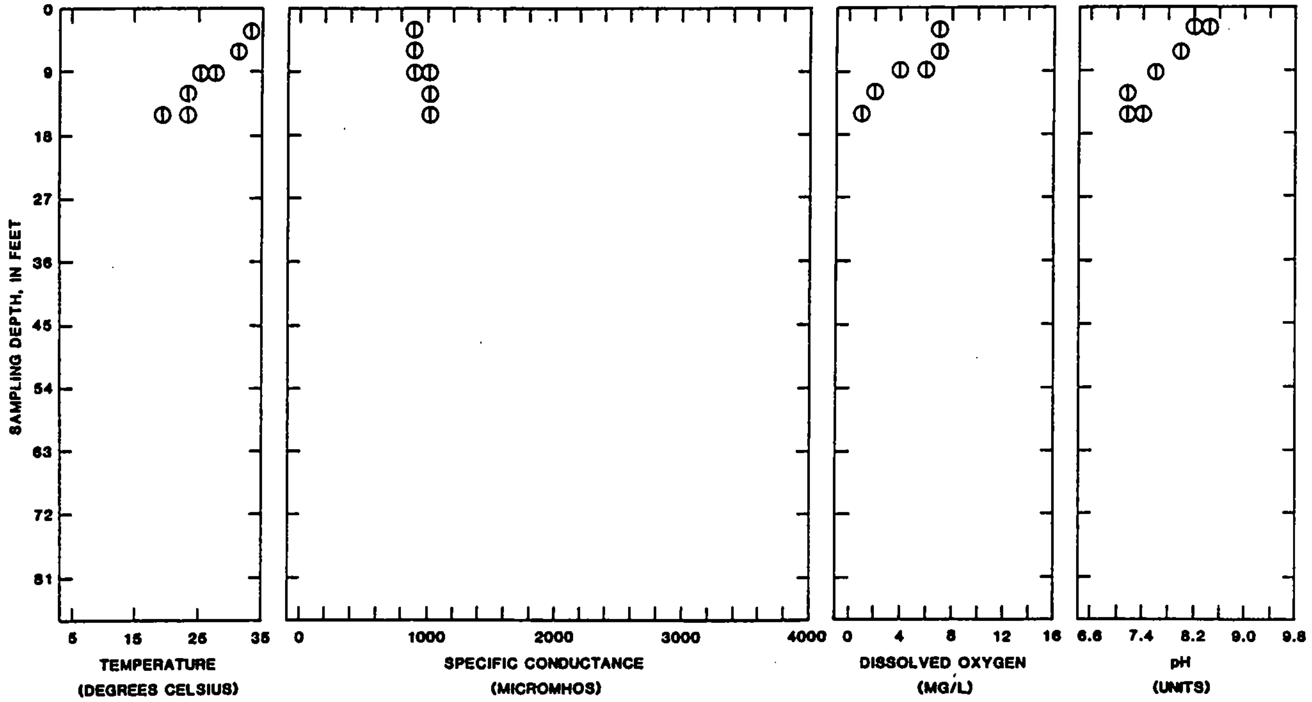


Figure 107.—Site 50.



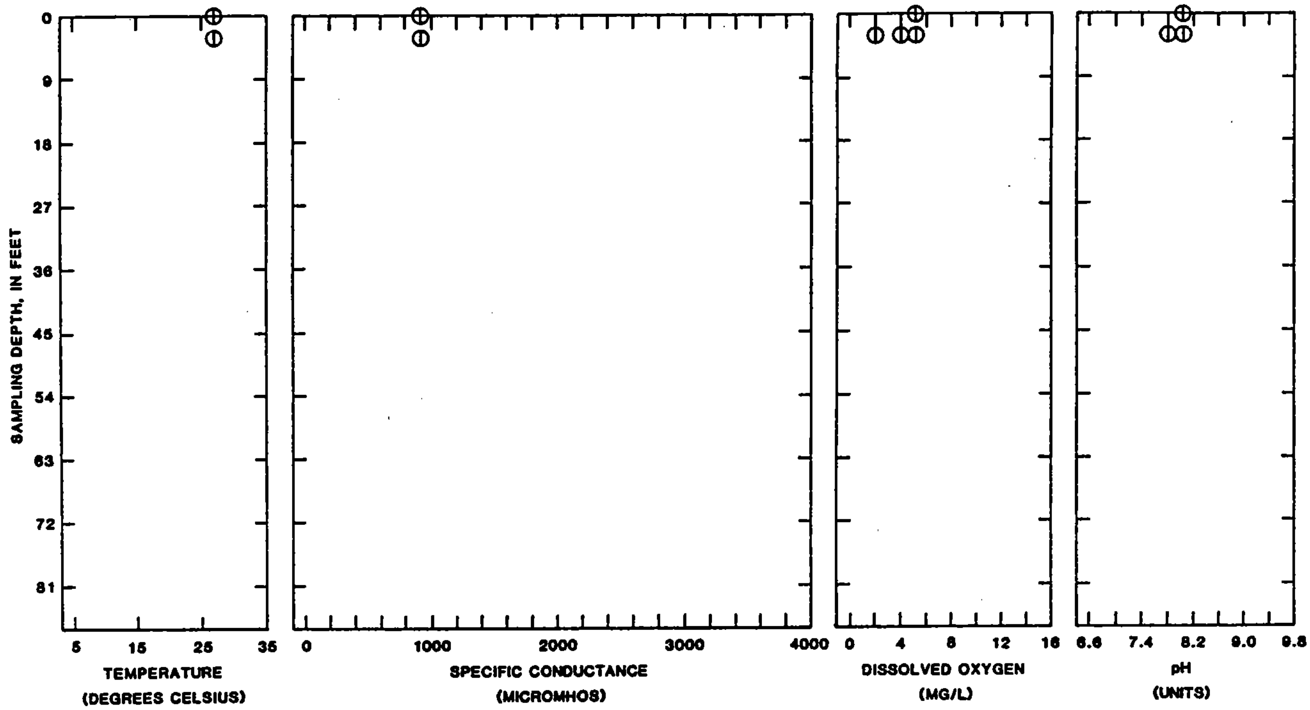
PLOT SYMBOL	DATE OF SAMPLE
⦶	September 6, 1978
◑	July 25, 1979
●	June 11, 1980

Figure 108.--Site 51.



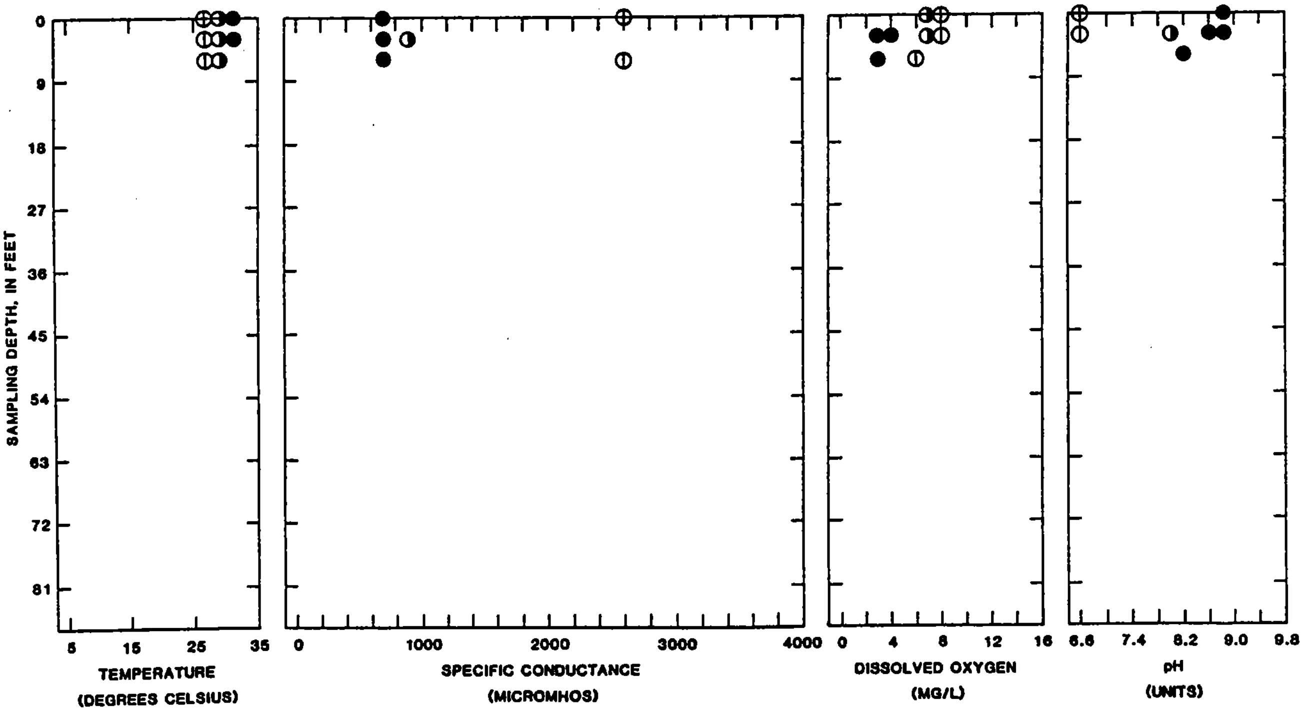
PLOT SYMBOL	DATE OF SAMPLE
⦶	July 2, 1980

Figure 109.--Site 52.



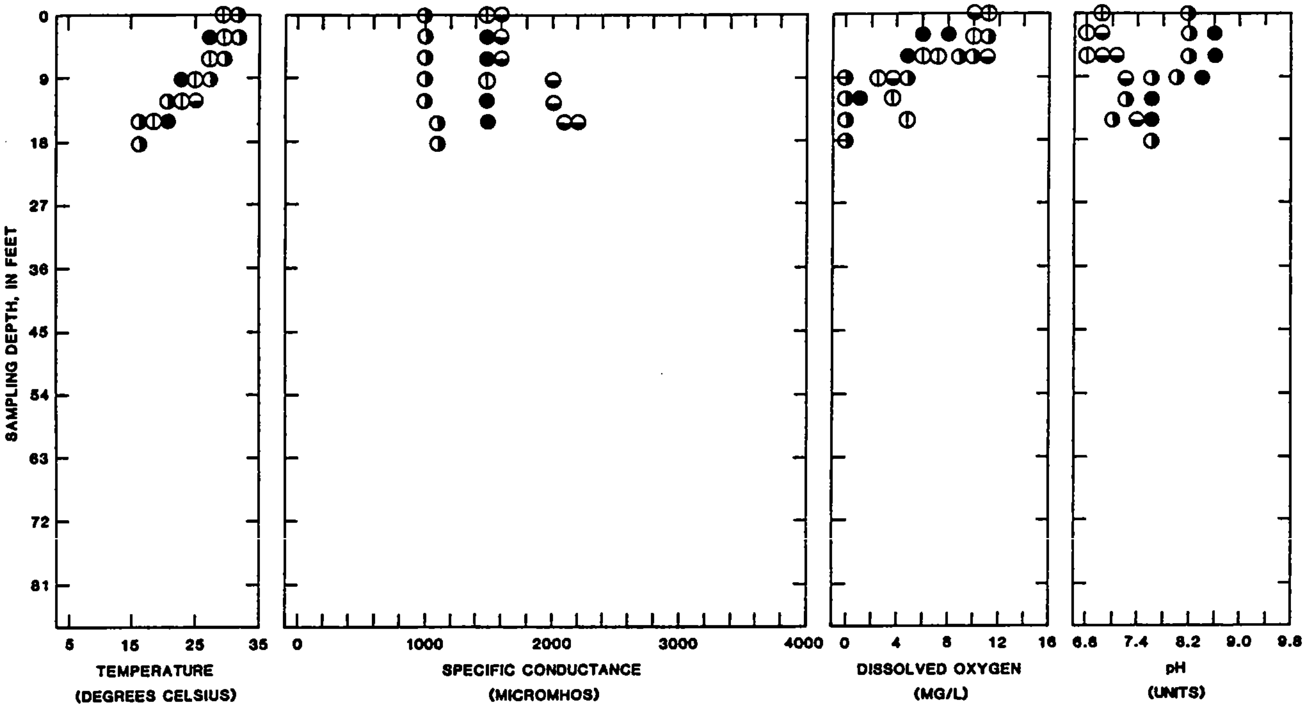
PLOT SYMBOL	DATE OF SAMPLE
⦶	July 7, 1981

Figure 110.--Site 53.



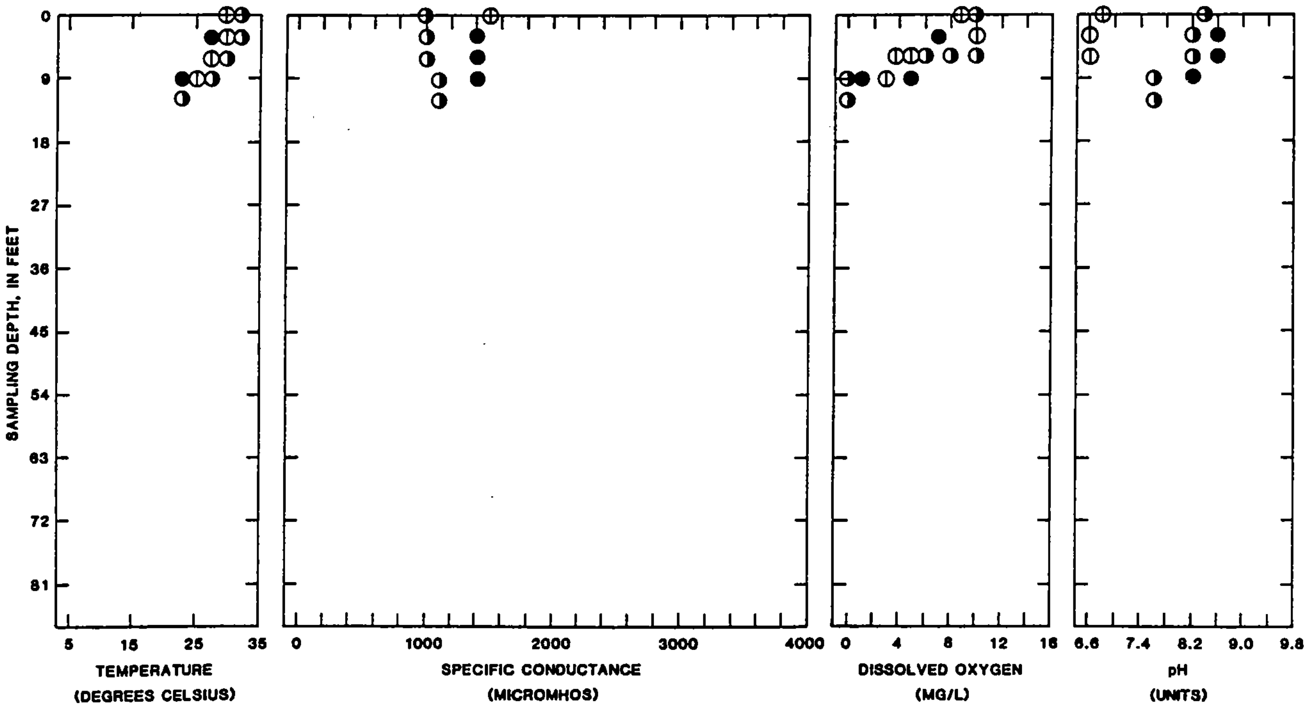
PLOT SYMBOL	DATE OF SAMPLE
⦶	September 6, 1978
◑	July 25, 1979
●	June 11, 1980

Figure 111.--Site 54.



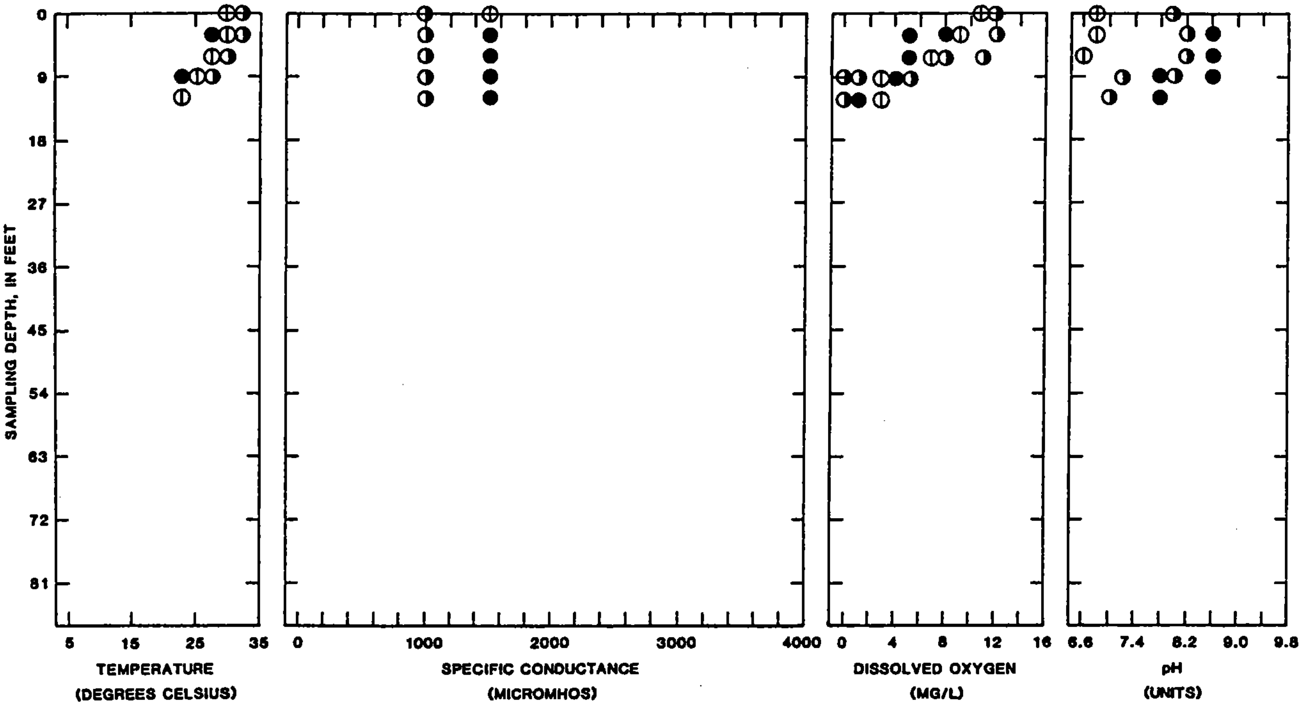
PLOT SYMBOL	DATE OF SAMPLE
⦶	September 5, 1978
◐	July 25, 1979
●	June 11, 1980
⊖	July 6, 1981

Figure 112.--Site 55.



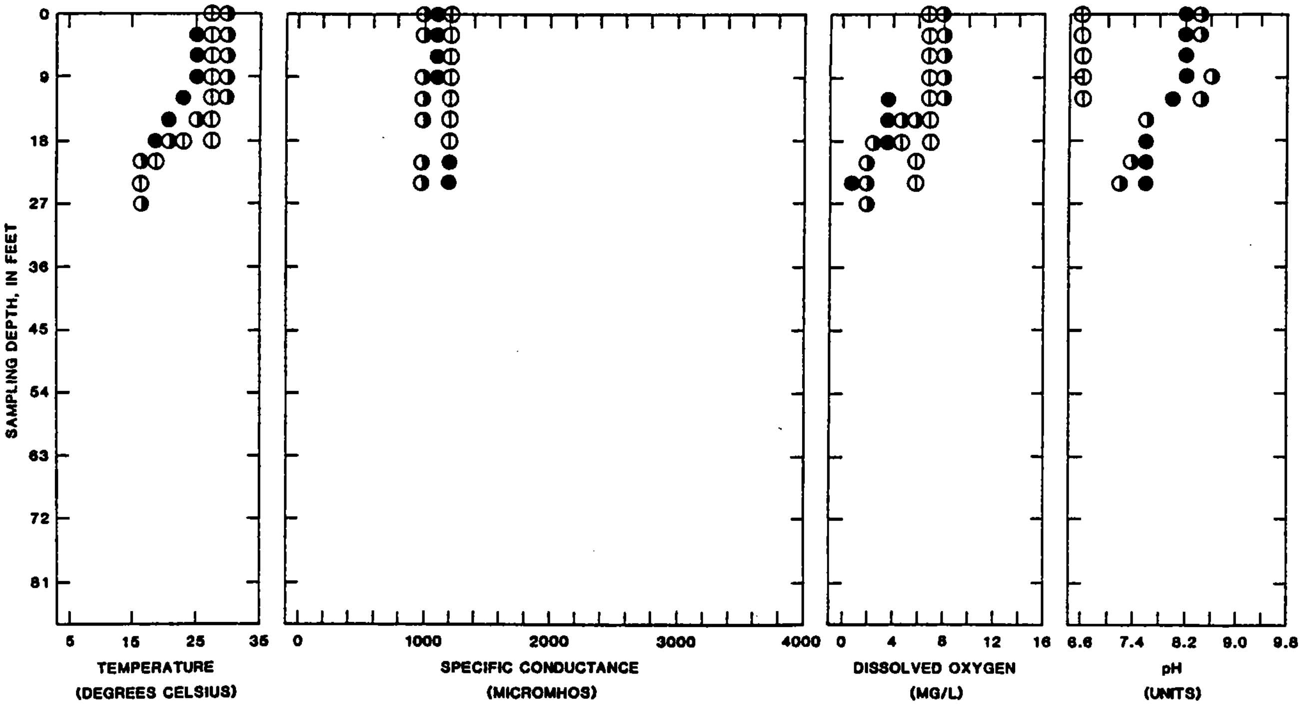
PLOT SYMBOL	DATE OF SAMPLE
⦶	September 5, 1978
◐	July 25, 1979
●	June 11, 1980

Figure 113.--Site 56.



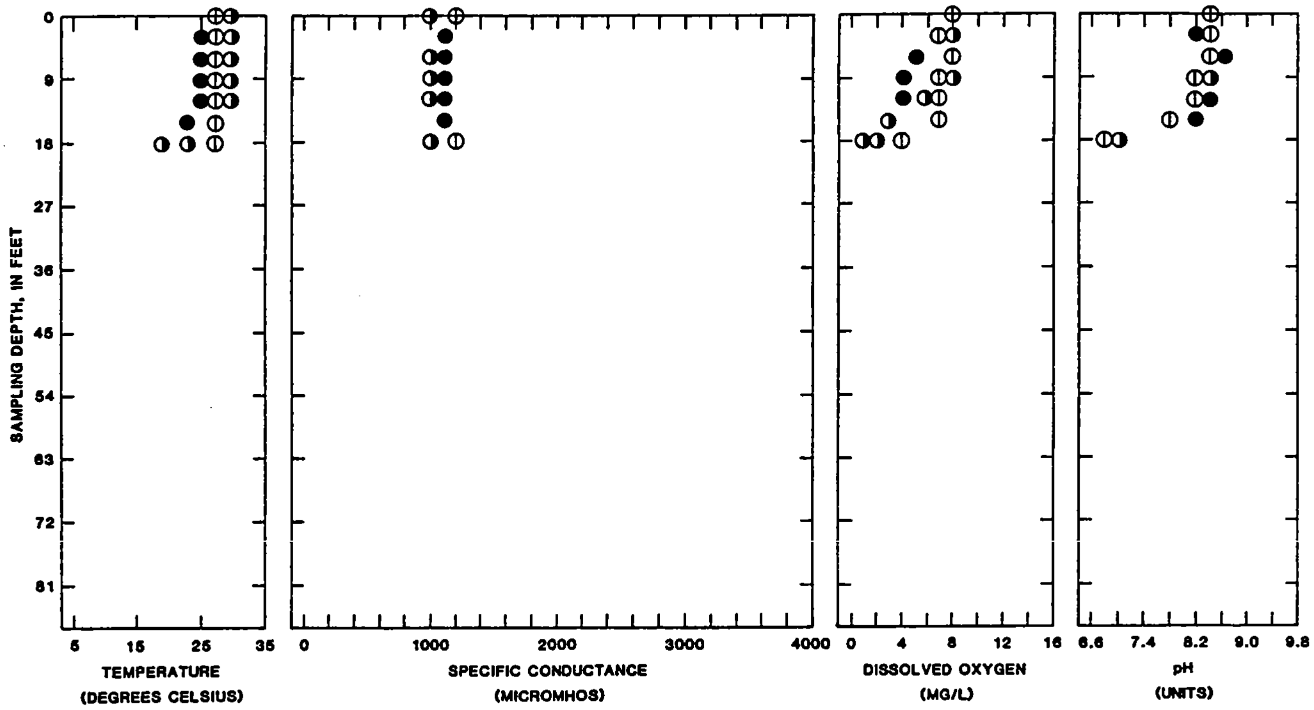
PLOT SYMBOL	DATE OF SAMPLE
⦶	September 5, 1978
◑	July 25, 1979
●	June 11, 1980

Figure 114.--Site 57.



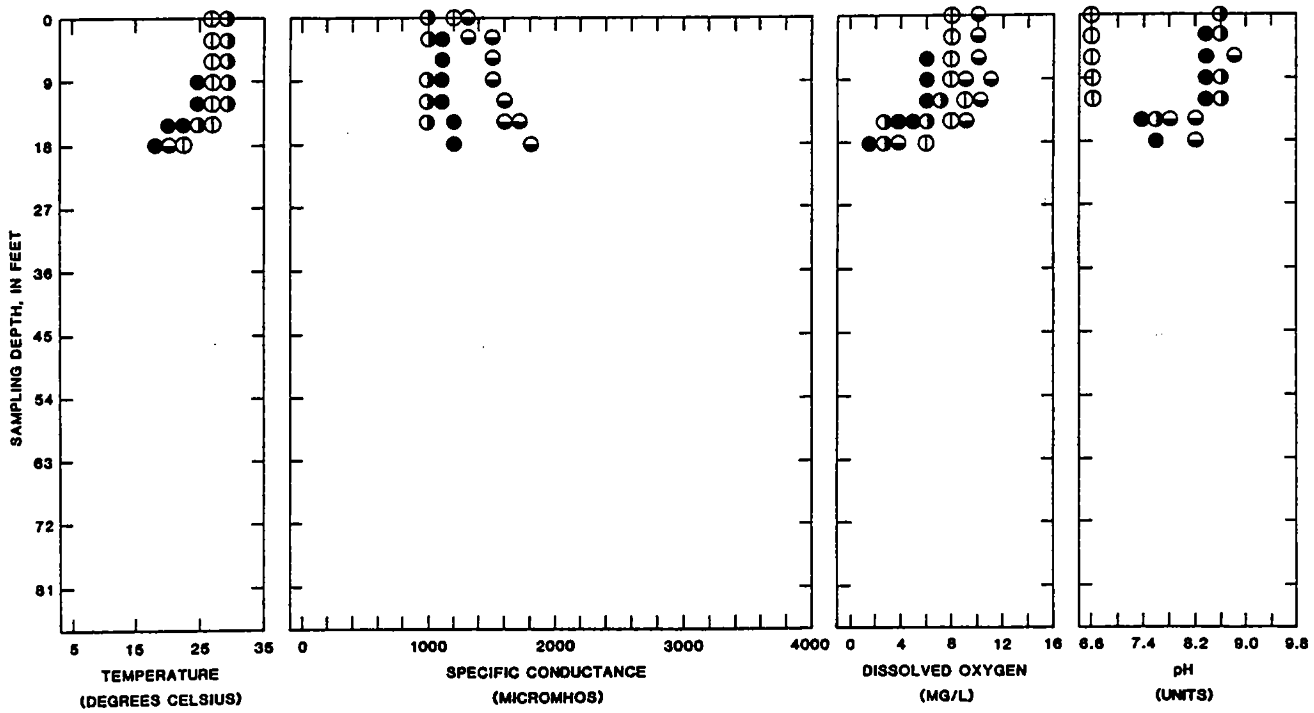
PLOT SYMBOL	DATE OF SAMPLE
⦶	September 5, 1978
◑	July 26, 1979
●	June 11, 1980

Figure 115.--Site 58.



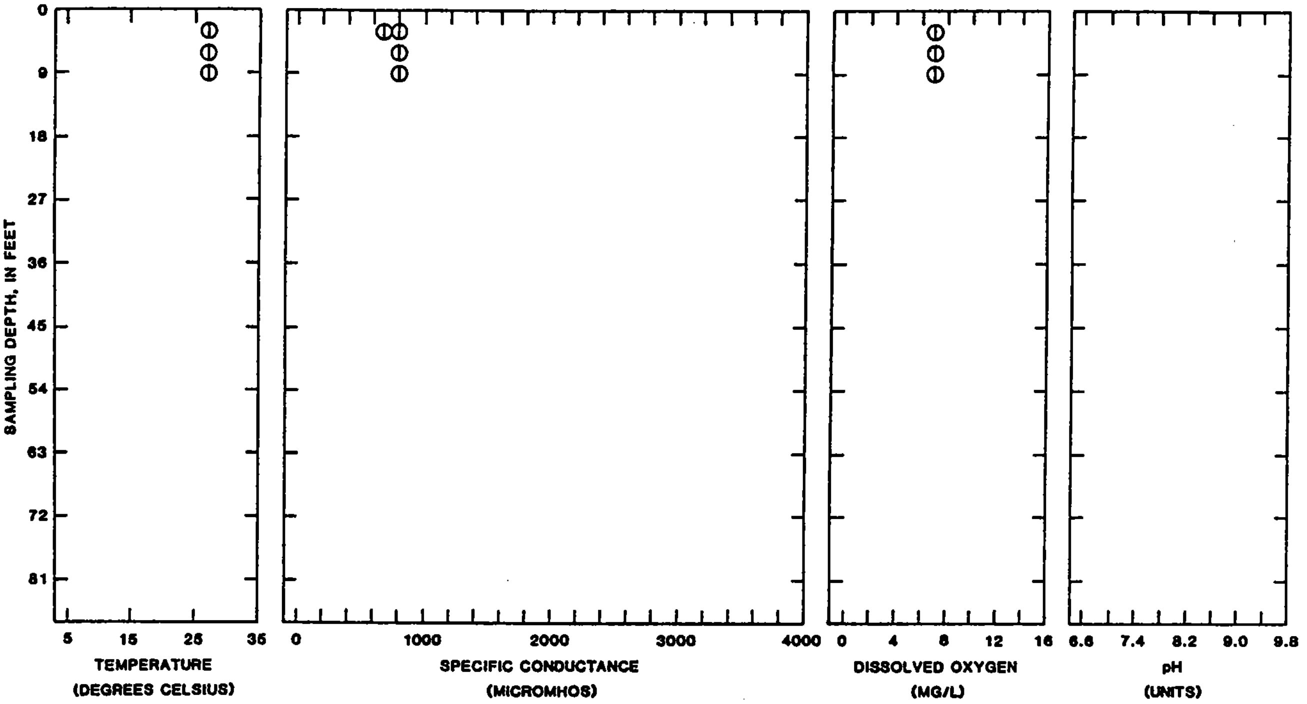
PLOT SYMBOL	DATE OF SAMPLE
⦶	September 5, 1978
◑	July 26, 1979
●	June 12, 1980

Figure 116.—Site 59.



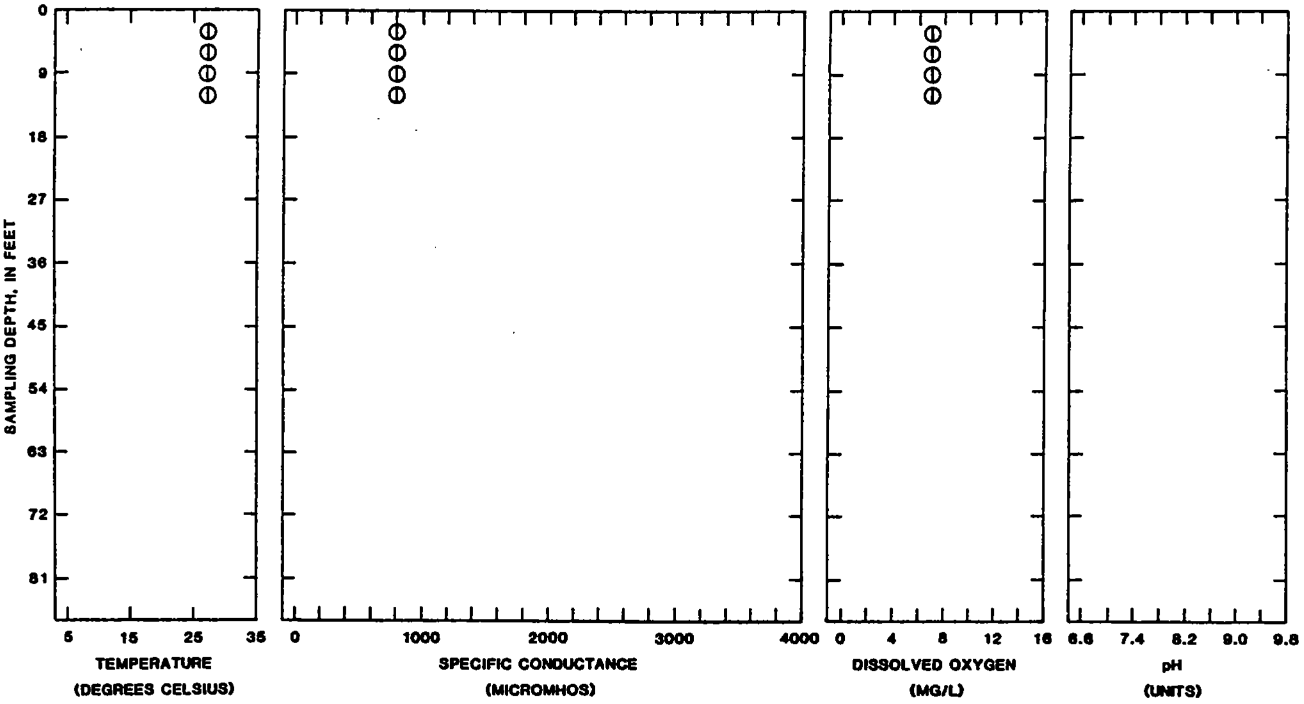
PLOT SYMBOL	DATE OF SAMPLE
⦶	September 5, 1978
◑	July 26, 1979
●	June 12, 1980
⊖	June 29, 1981

Figure 117.—Site 60.



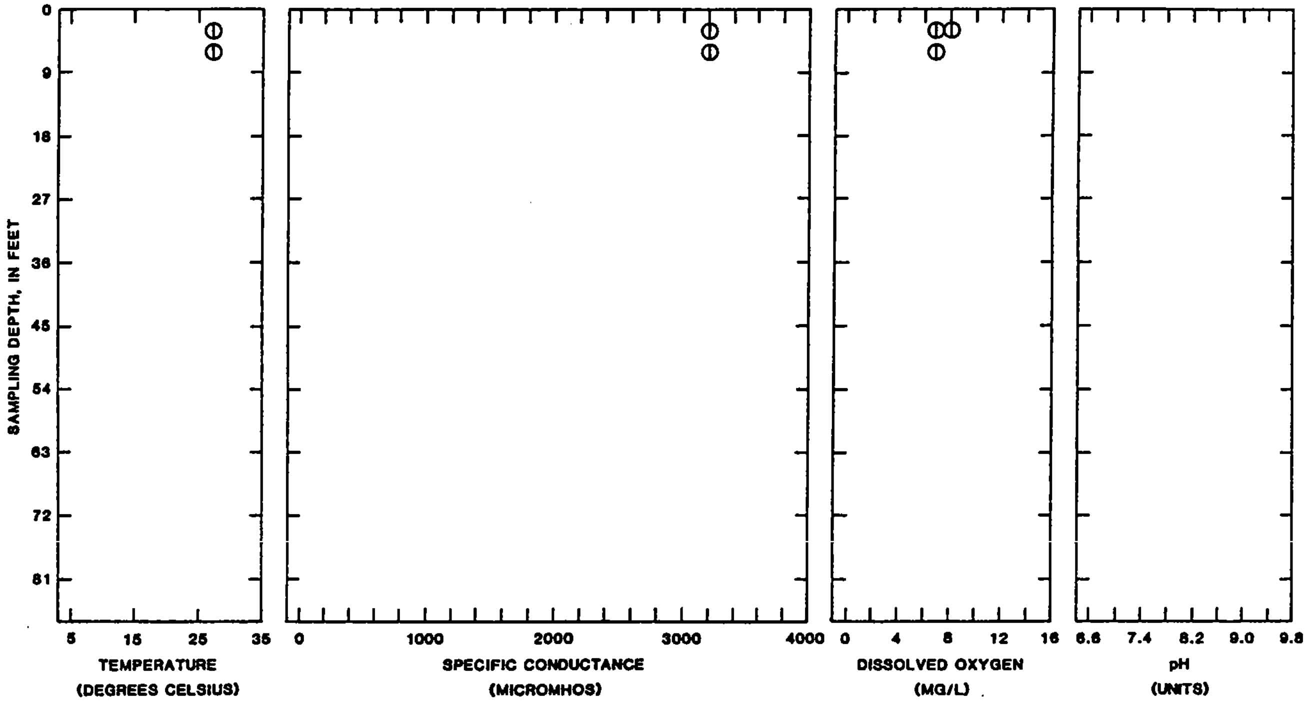
PLOT SYMBOL ⊕ DATE OF SAMPLE June 10, 1980

Figure 118.--Site 61.



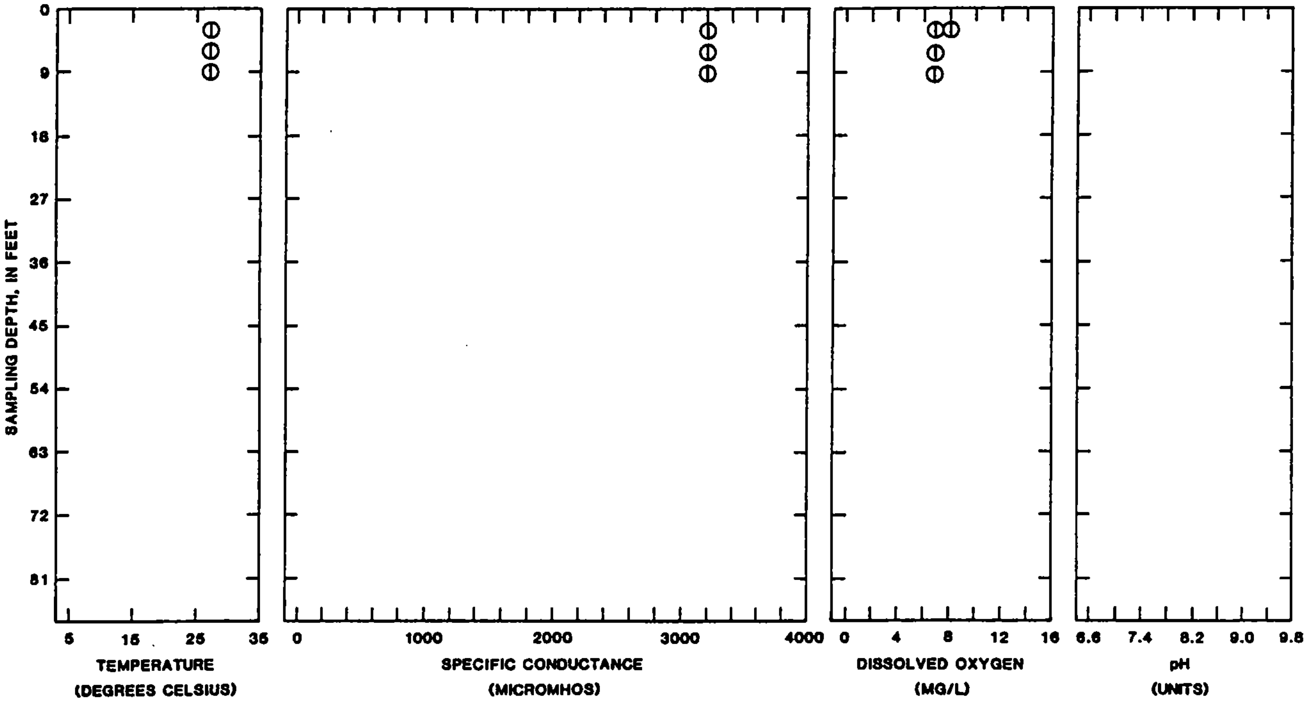
PLOT SYMBOL ⊕ DATE OF SAMPLE June 10, 1980

Figure 119.--Site 62.



PLOT SYMBOL	DATE OF SAMPLE
⦶	June 11, 1980

Figure 120.—Site 63.



PLOT SYMBOL	DATE OF SAMPLE
⦶	June 11, 1980

Figure 121.—Site 64.

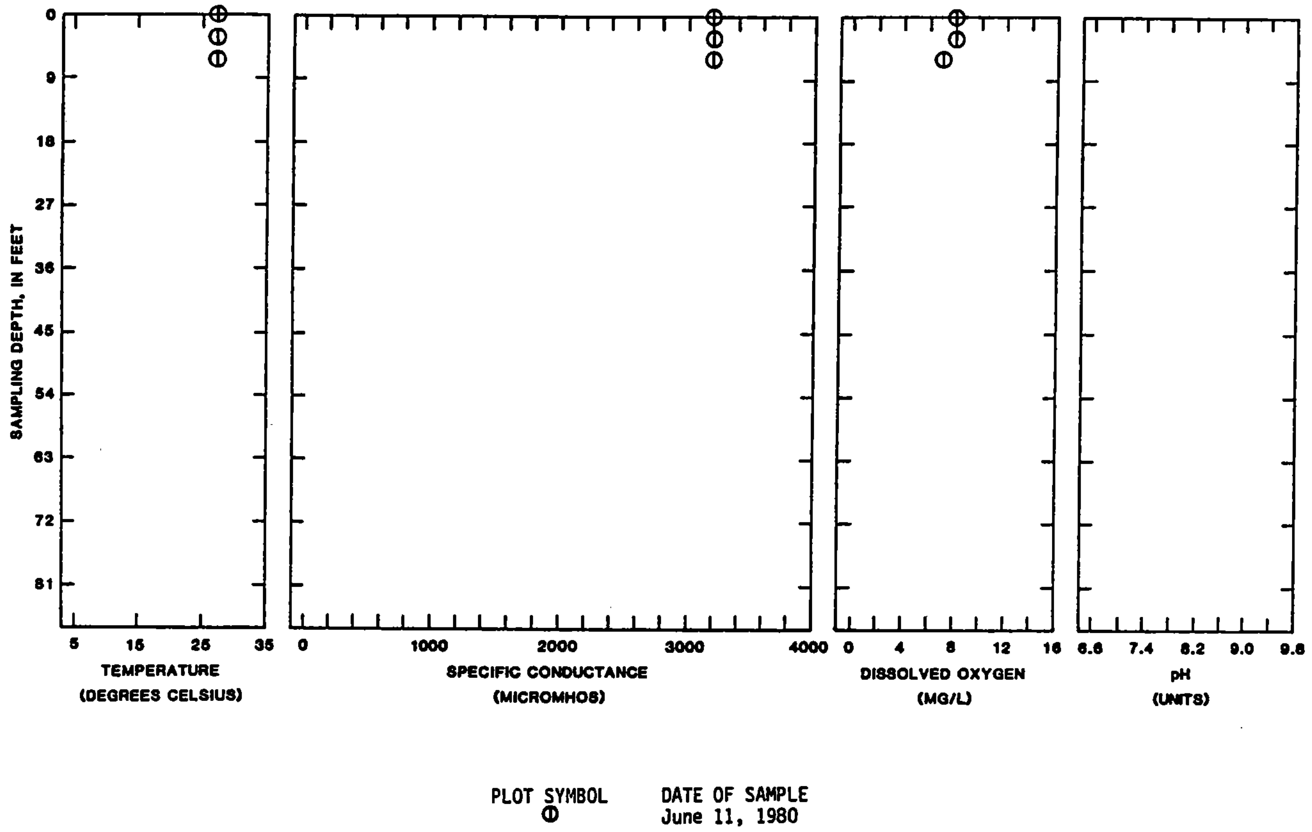


Figure 122.--Site 65.

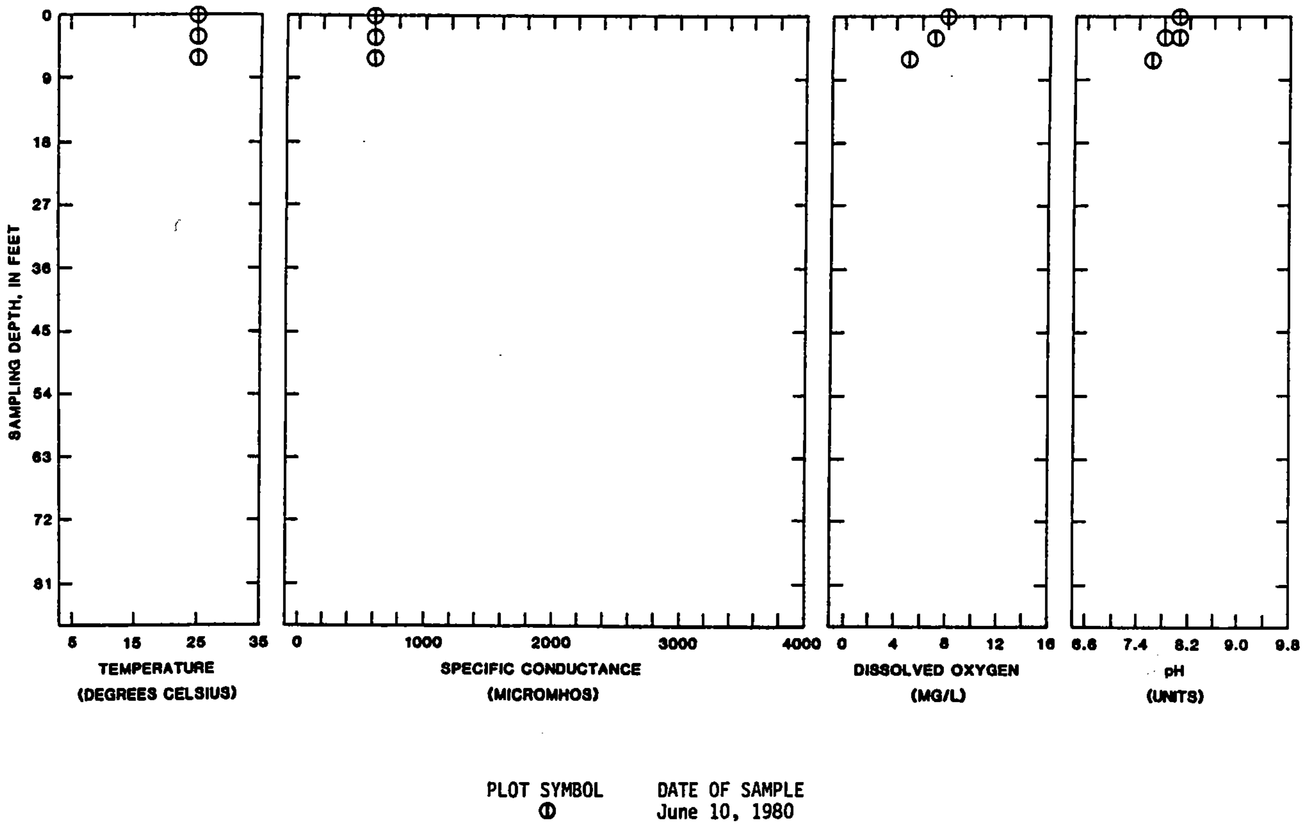
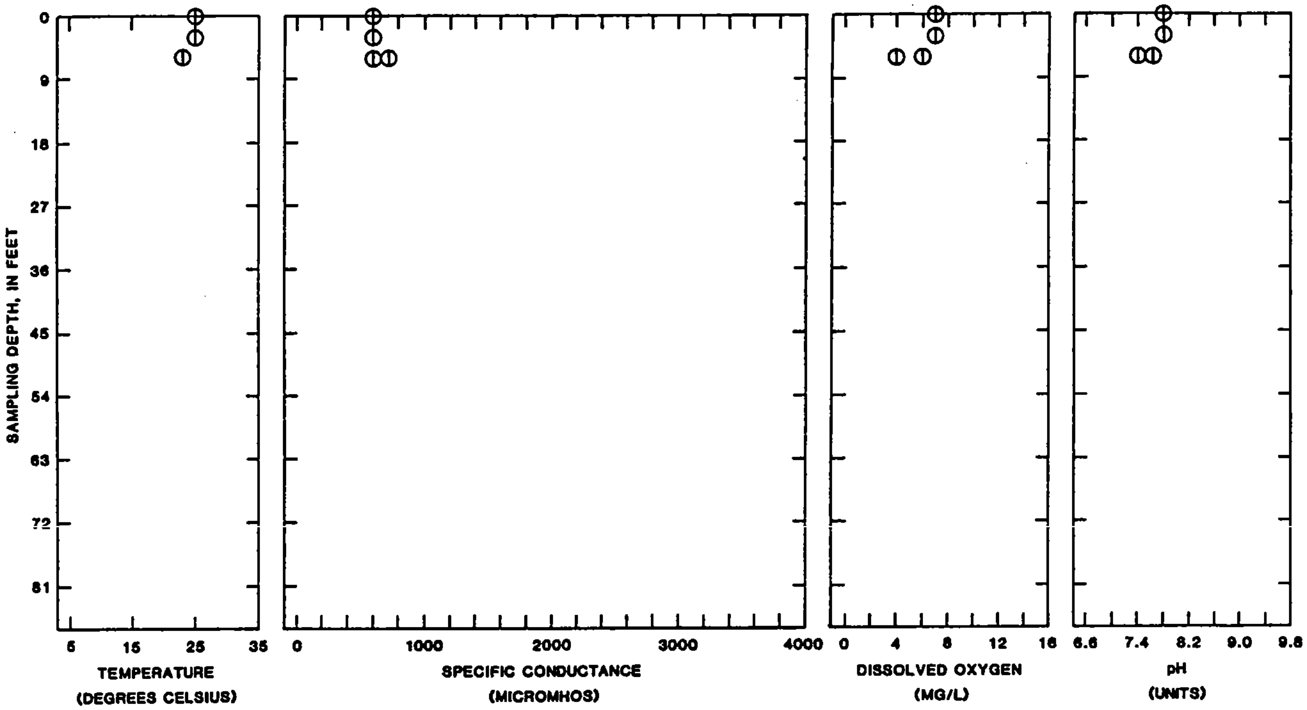
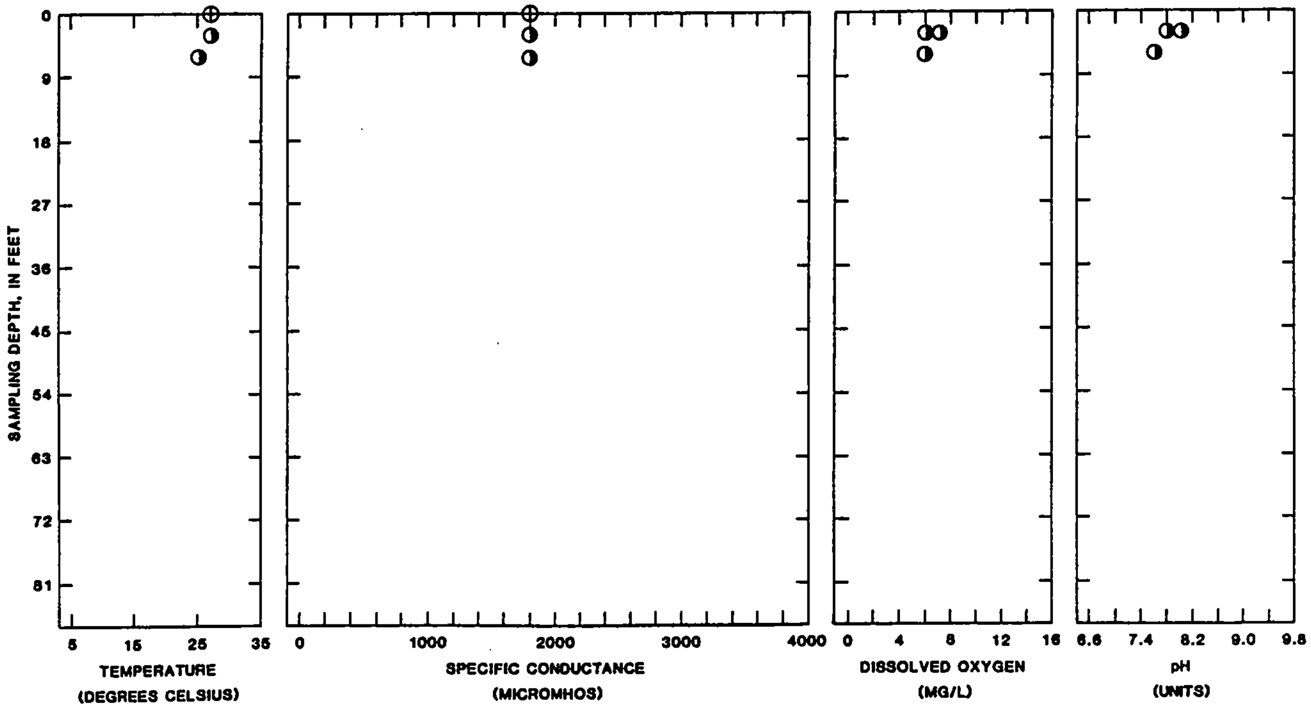


Figure 123.--Site 66.



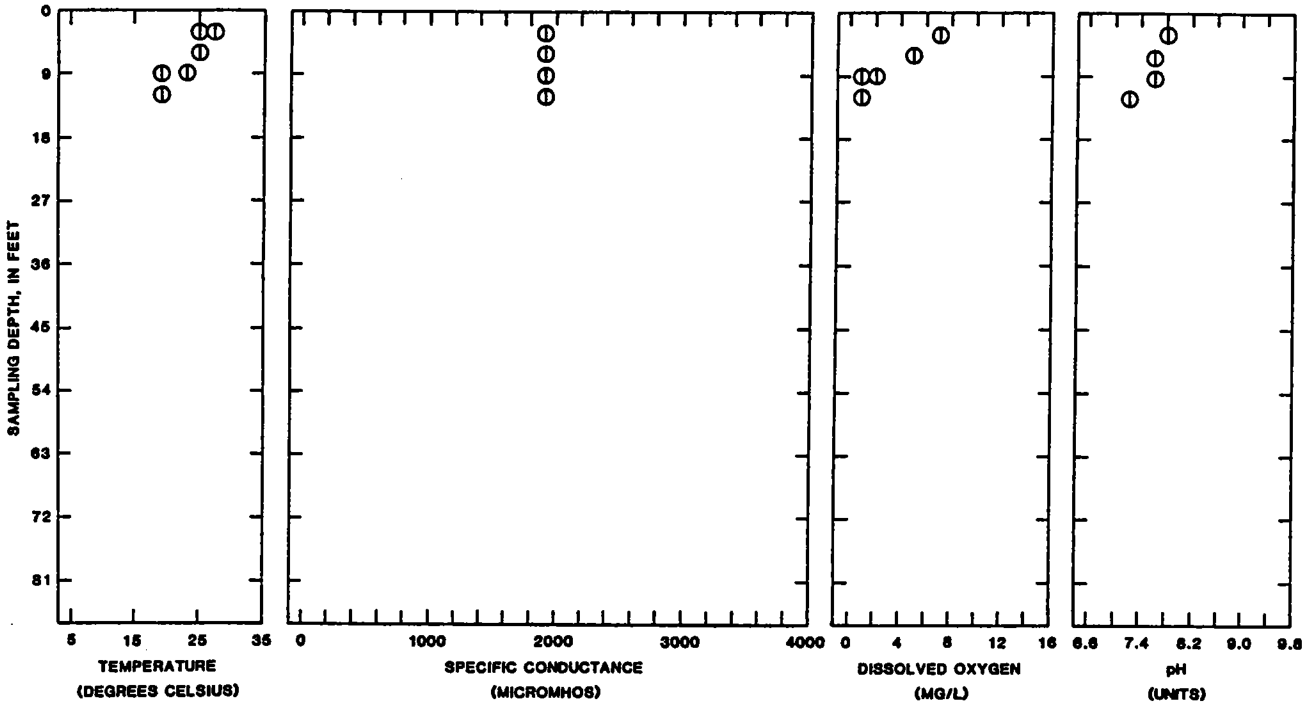
PLOT SYMBOL	DATE OF SAMPLE
⦶	June 10, 1980

Figure 124.--Site 67.



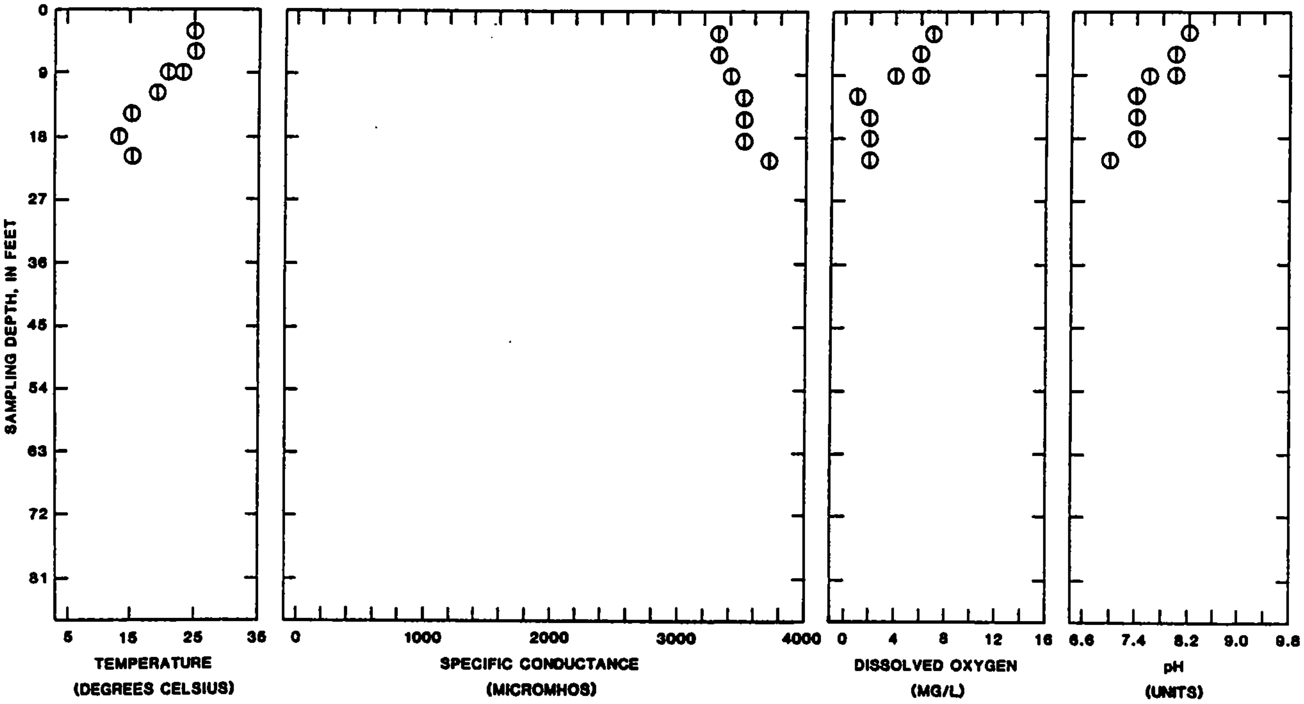
PLOT SYMBOL	DATE OF SAMPLE
⦶	June 1, 1980
◐	June 4, 1980

Figure 125.--Site 68.



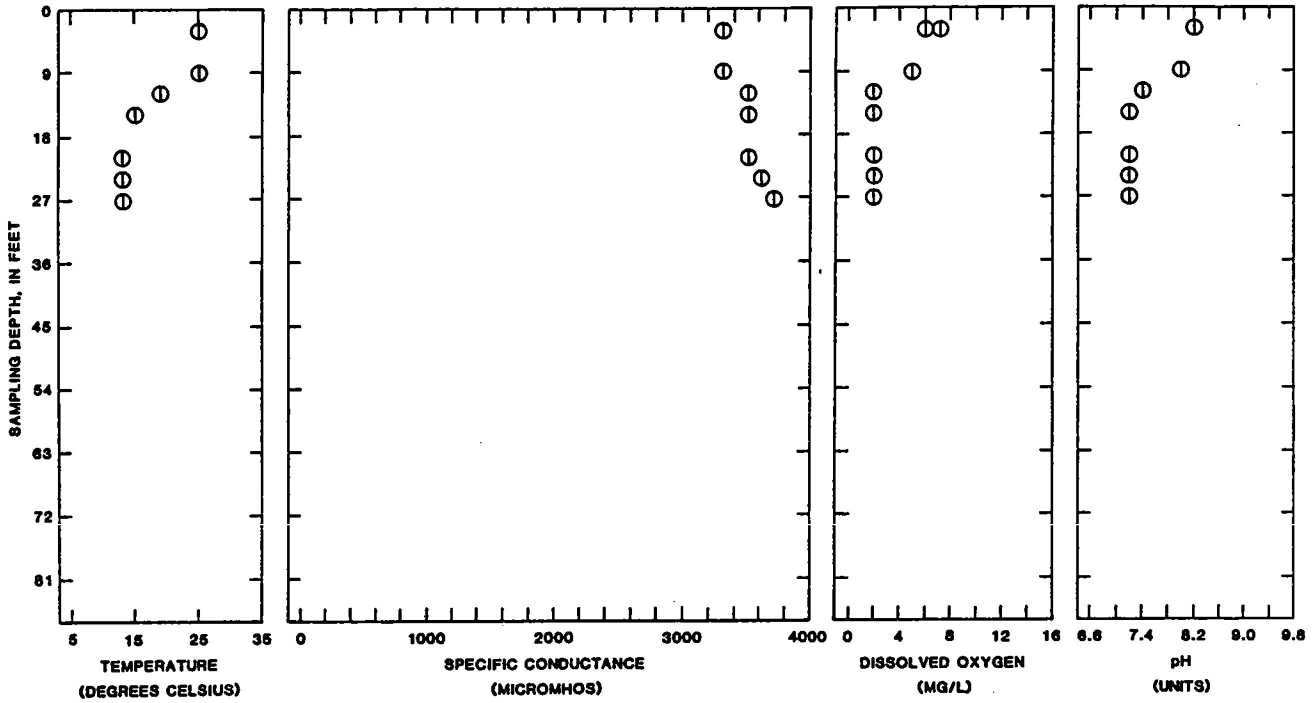
PLOT SYMBOL	DATE OF SAMPLE
Φ	June 4, 1980

Figure 126.—Site 69.



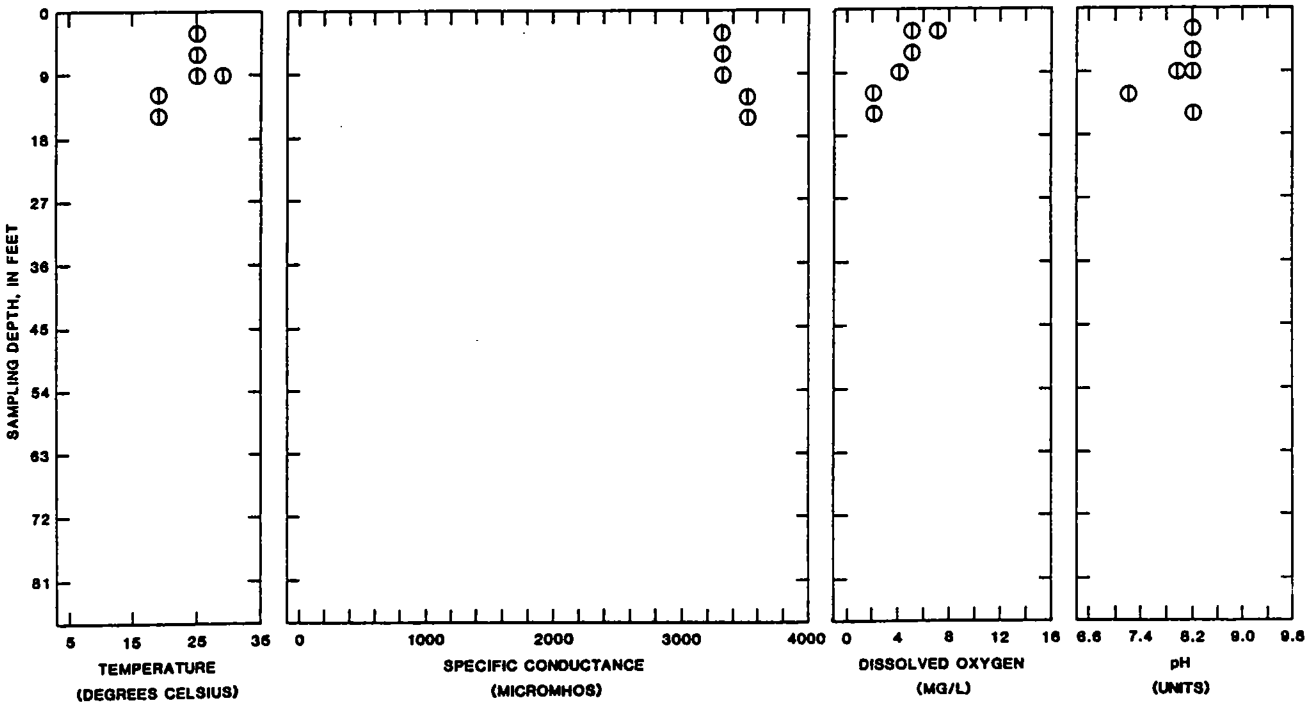
PLOT SYMBOL	DATE OF SAMPLE
Φ	June 4, 1980

Figure 127.—Site 70.



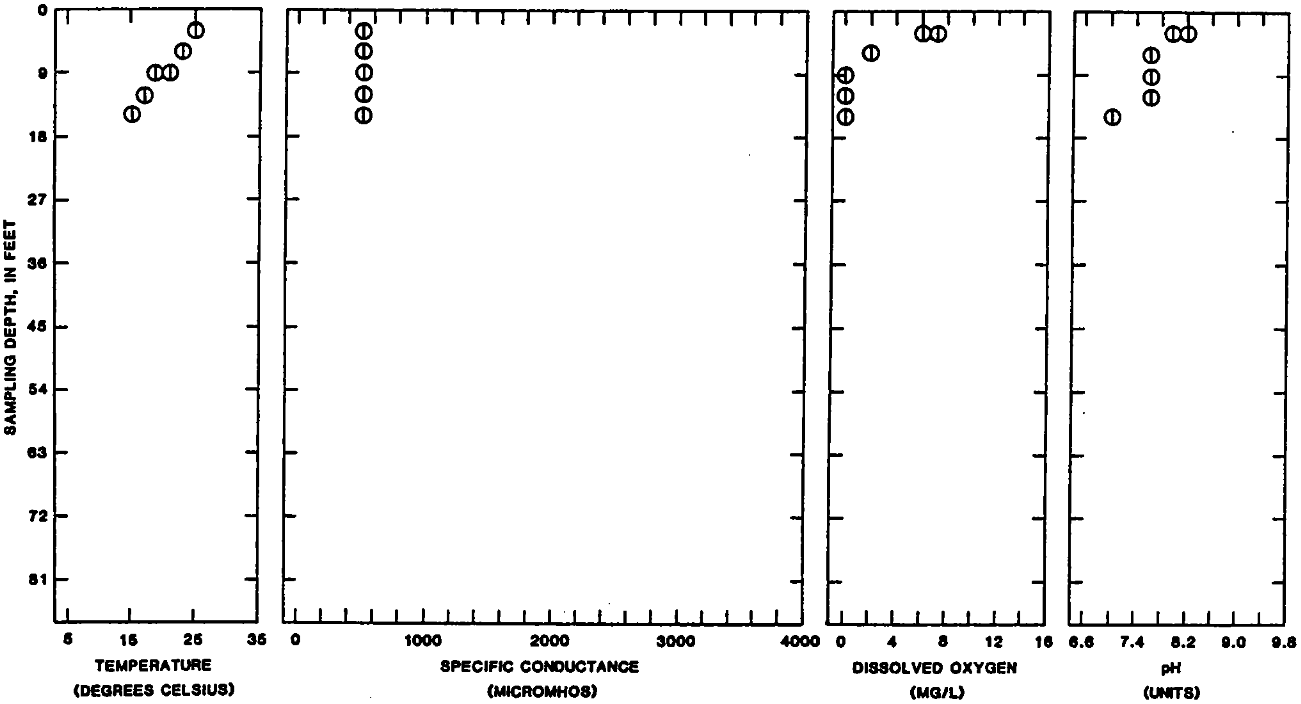
PLOT SYMBOL DATE OF SAMPLE
⦶ June 4, 1980

Figure 128.--Site 71.



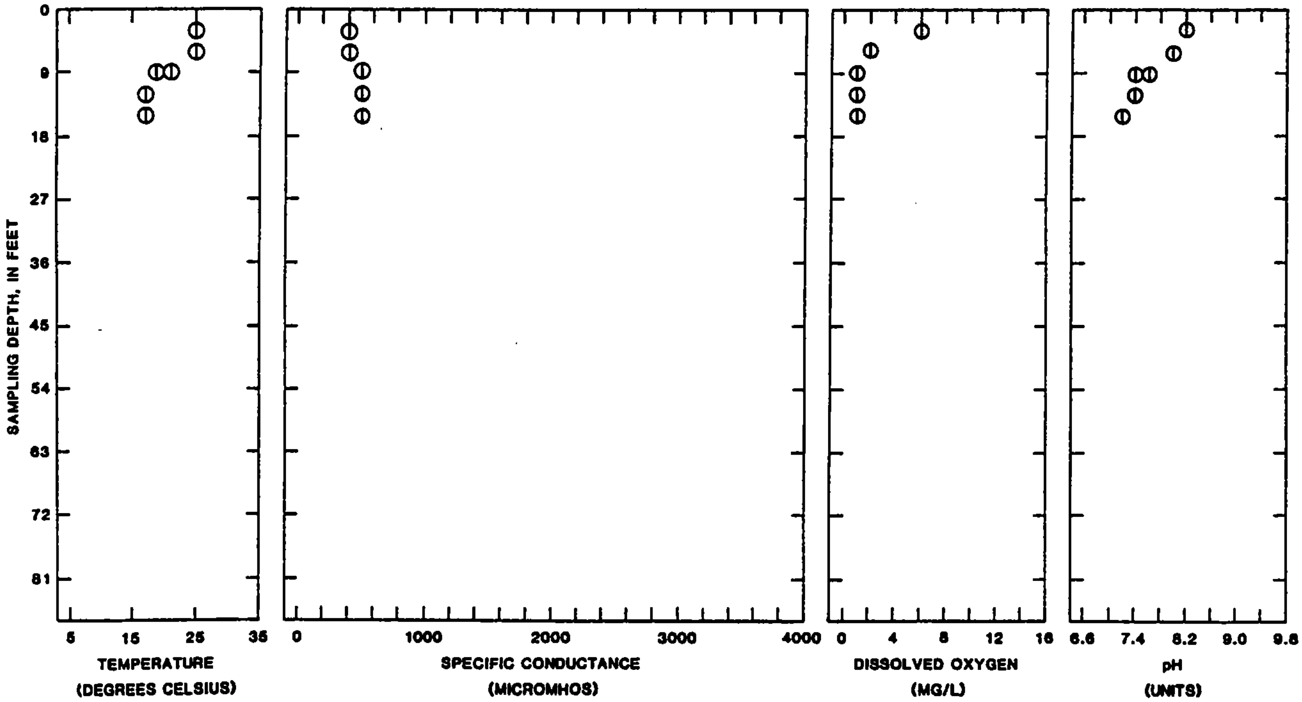
PLOT SYMBOL DATE OF SAMPLE
⦶ June 4, 1980

Figure 129.--Site 72.



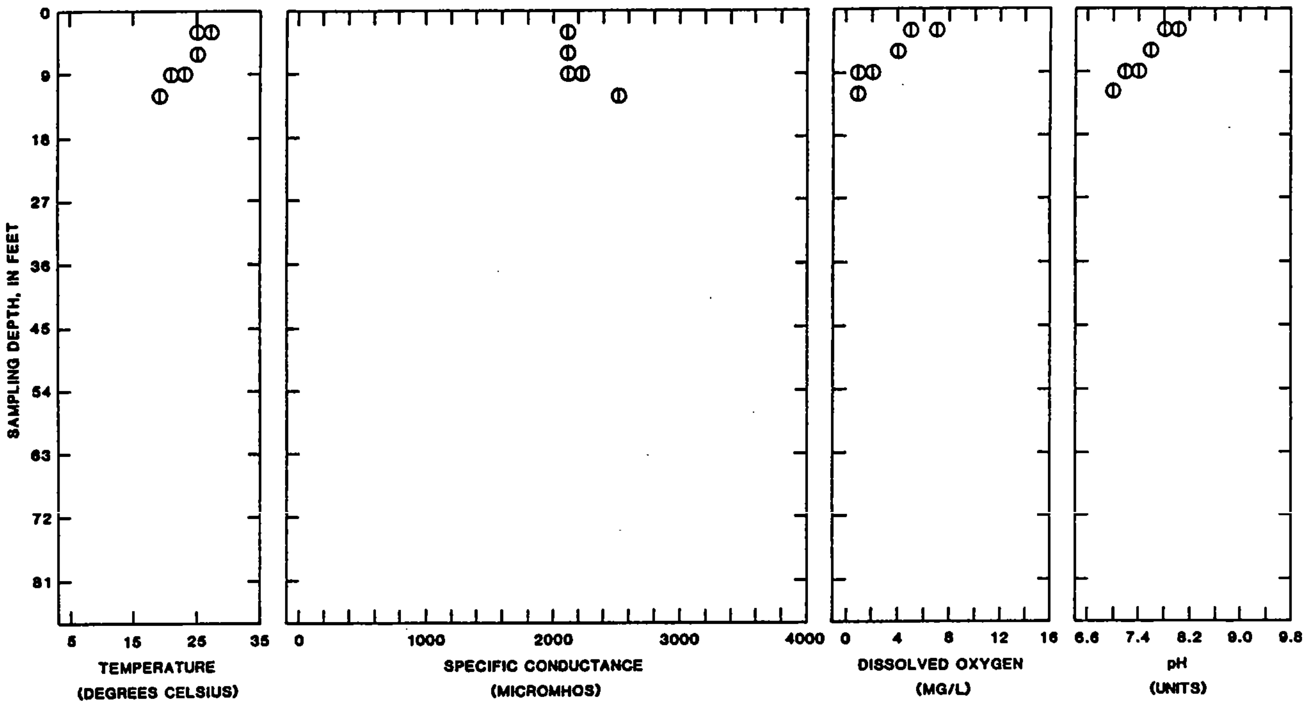
PLOT SYMBOL DATE OF SAMPLE
⦶ June 3, 1980

Figure 130.--Site 73.



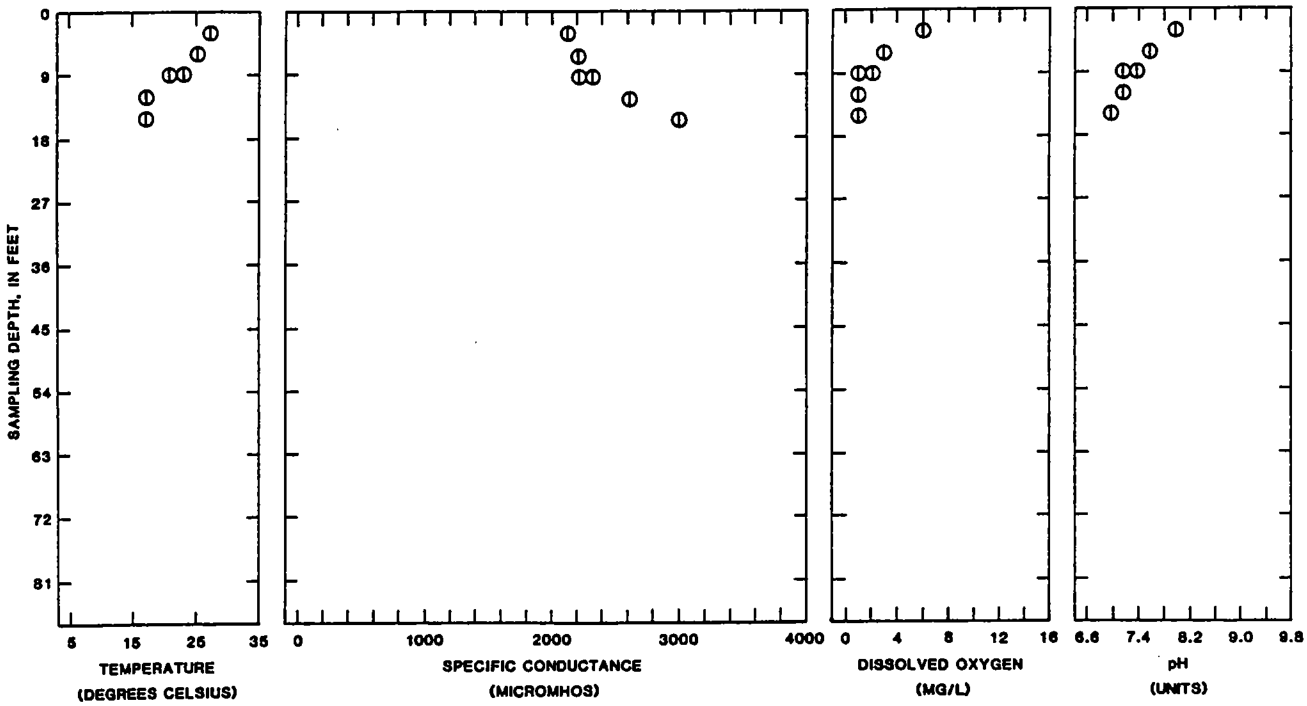
PLOT SYMBOL DATE OF SAMPLE
⦶ June 3, 1980

Figure 131.--Site 74.



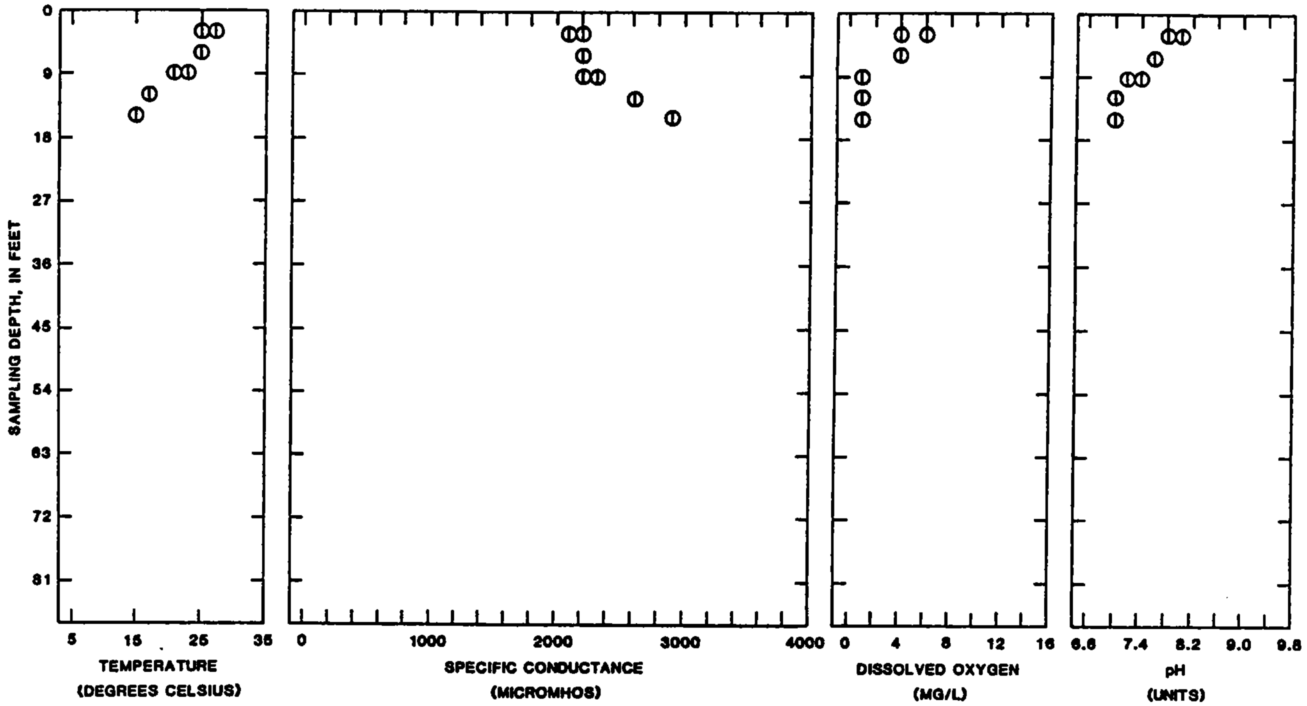
PLOT SYMBOL DATE OF SAMPLE
Φ June 3, 1980

Figure 132.—Site 75.



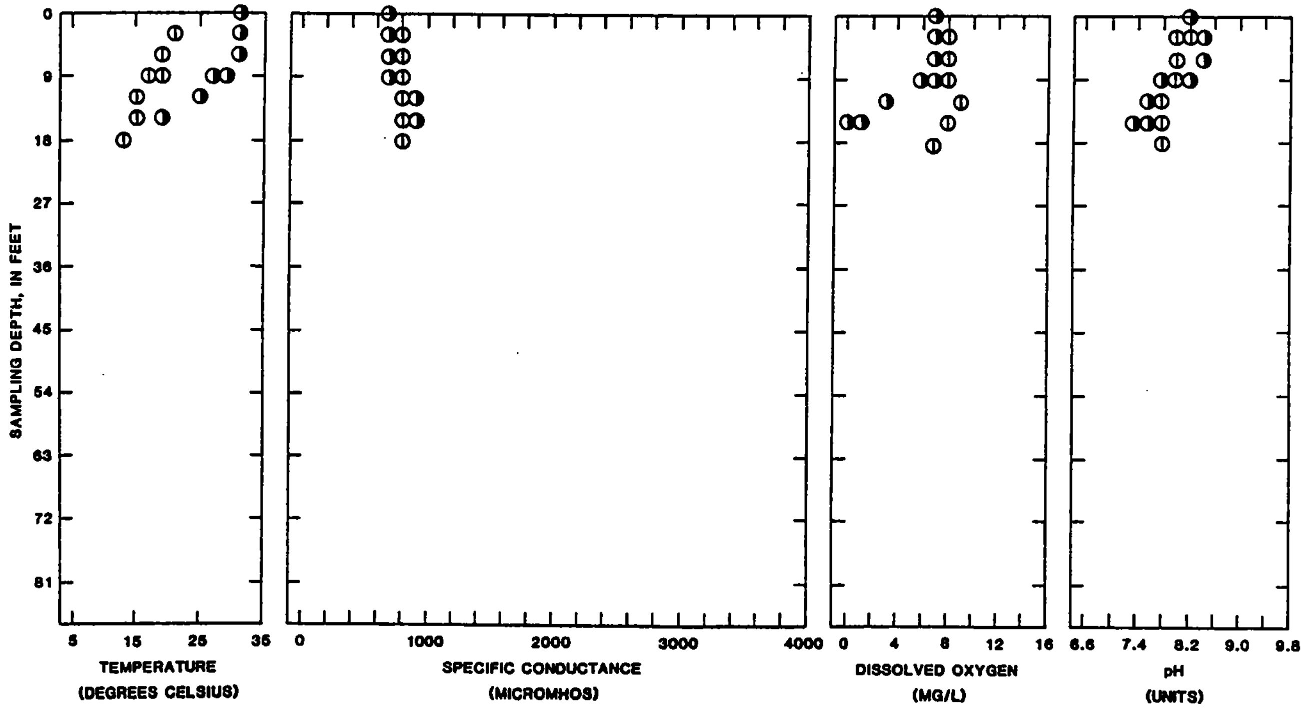
PLOT SYMBOL DATE OF SAMPLE
Φ June 3, 1980

Figure 133.—Site 76.



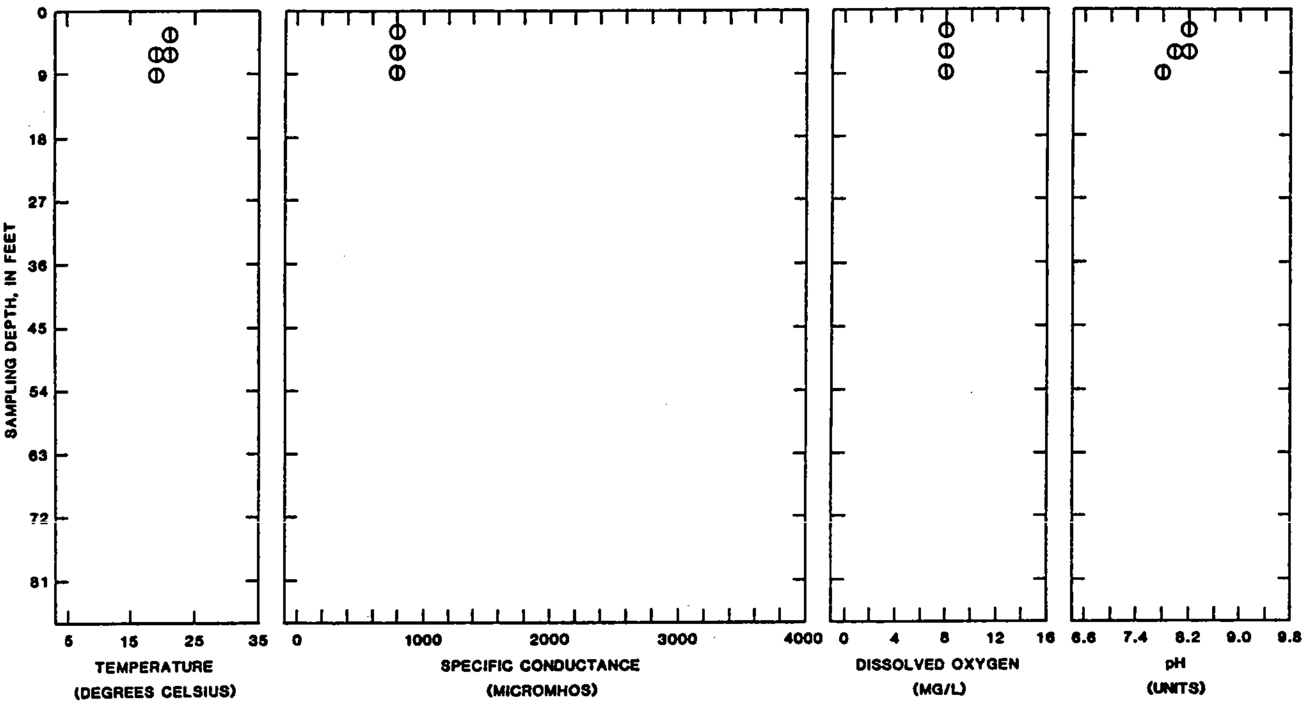
PLOT SYMBOL	DATE OF SAMPLE
⦶	June 3, 1980

Figure 134.—Site 77.



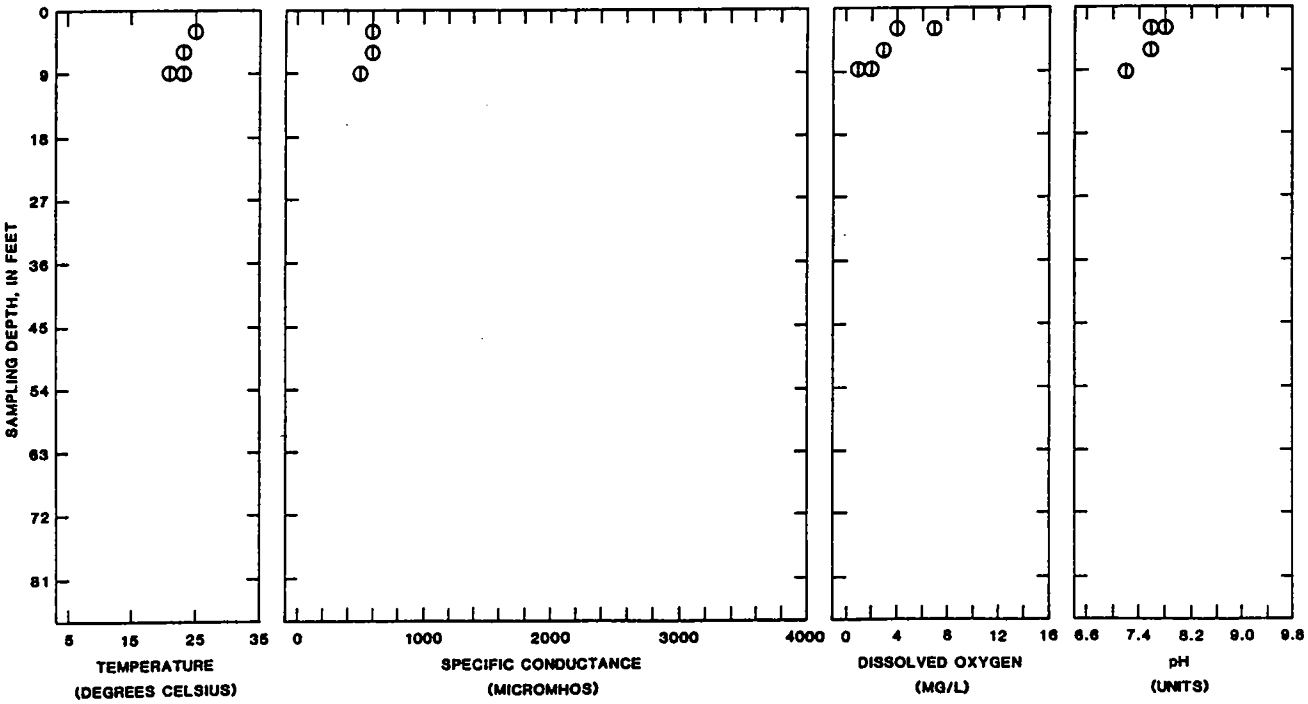
PLOT SYMBOL	DATE OF SAMPLE
⦶	May 6, 1980
◑	July 14, 1981

Figure 135.—Site 78.



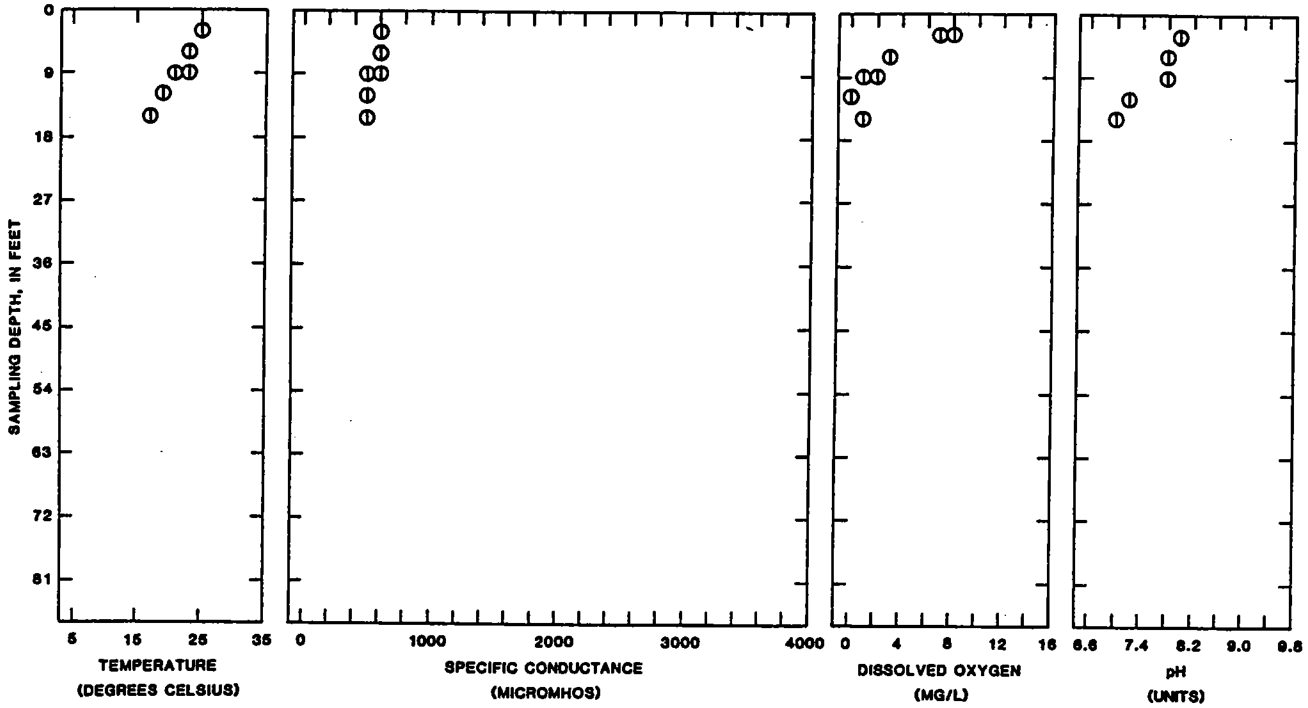
PLOT SYMBOL	DATE OF SAMPLE
⦶	May 6, 1980

Figure 136.--Site 79.



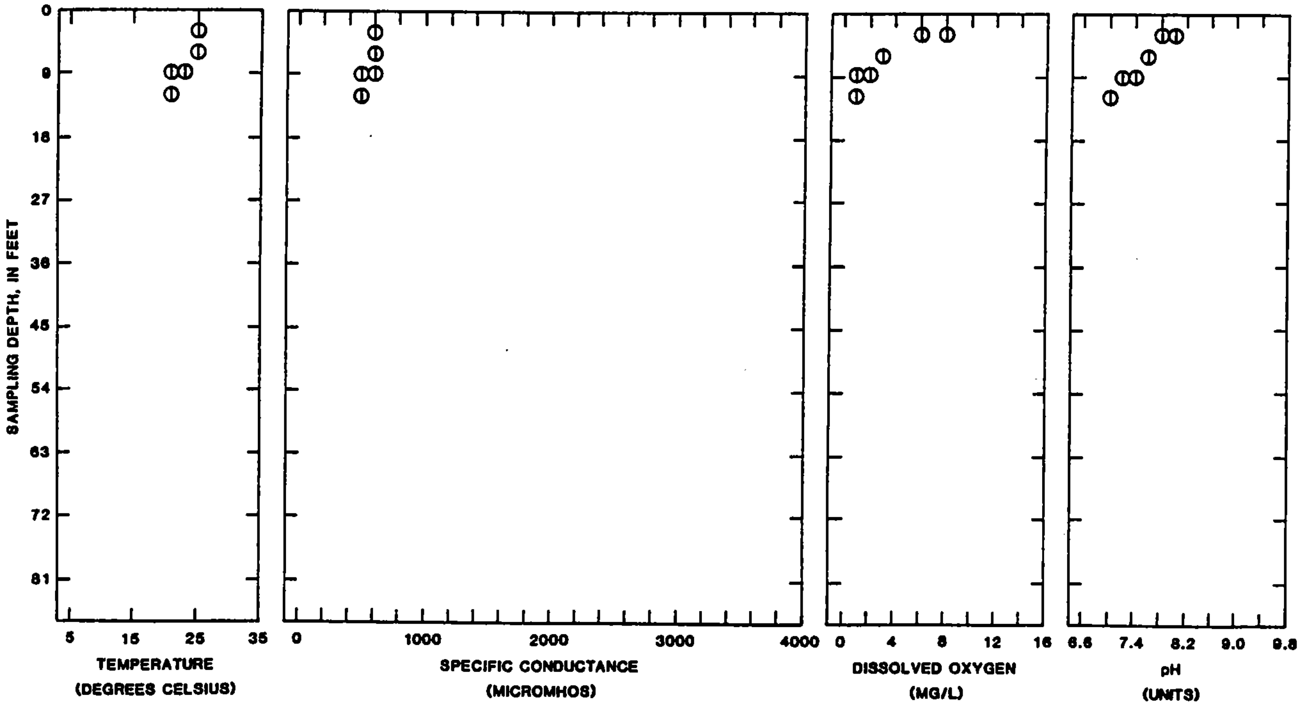
PLOT SYMBOL	DATE OF SAMPLE
⦶	June 5, 1980

Figure 137.--Site 80.



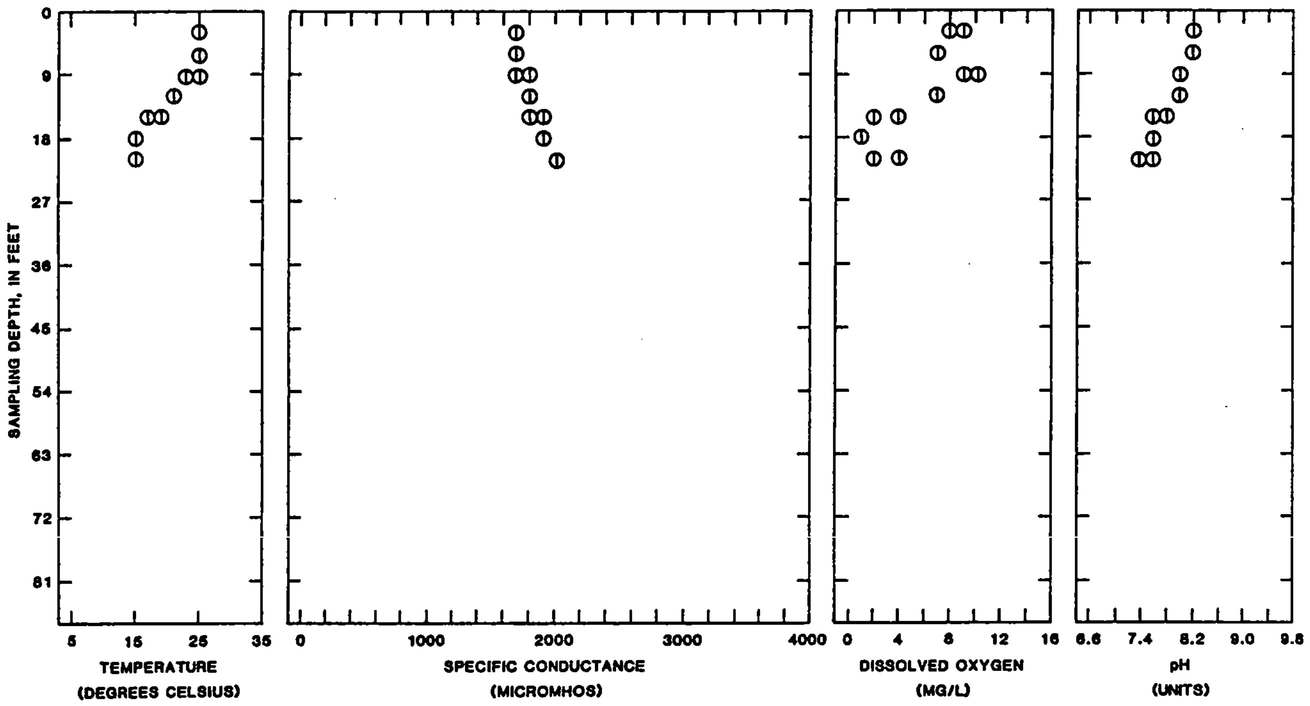
PLOT SYMBOL DATE OF SAMPLE
⦶ June 5, 1980

Figure 138.—Site 81.



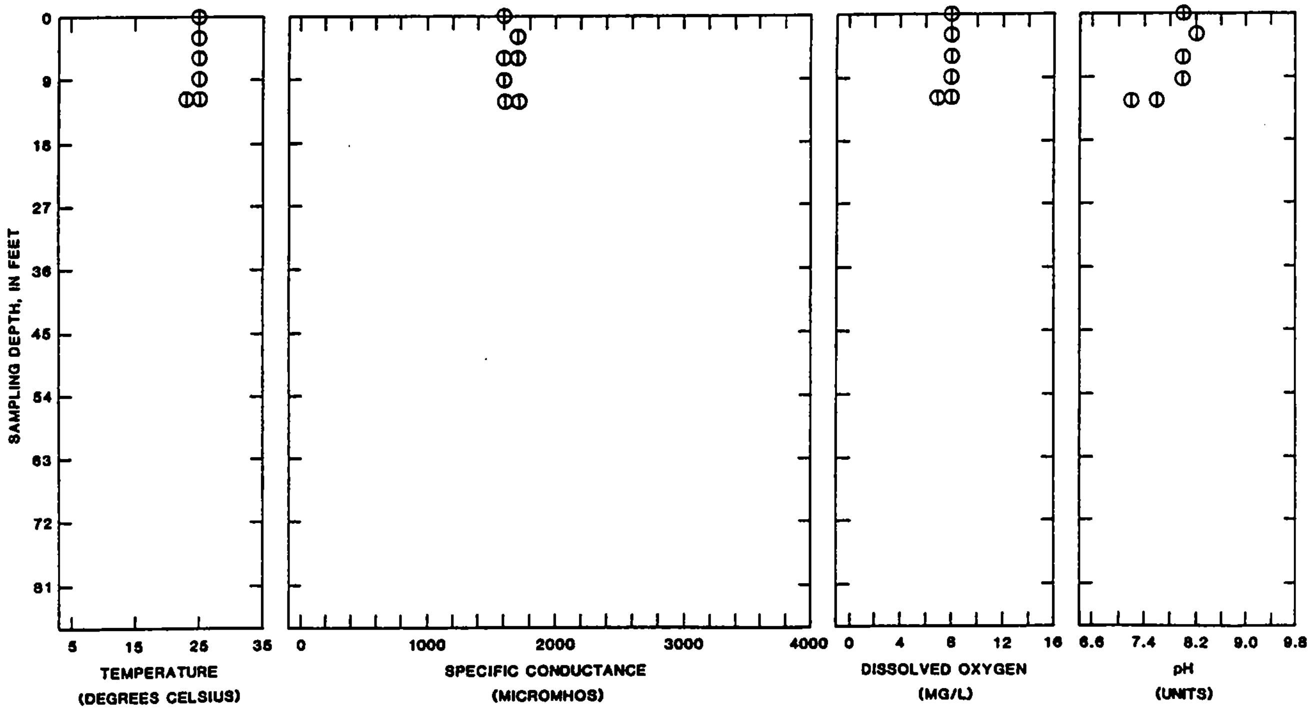
PLOT SYMBOL DATE OF SAMPLE
⦶ June 5, 1980

Figure 139.—Site 82.



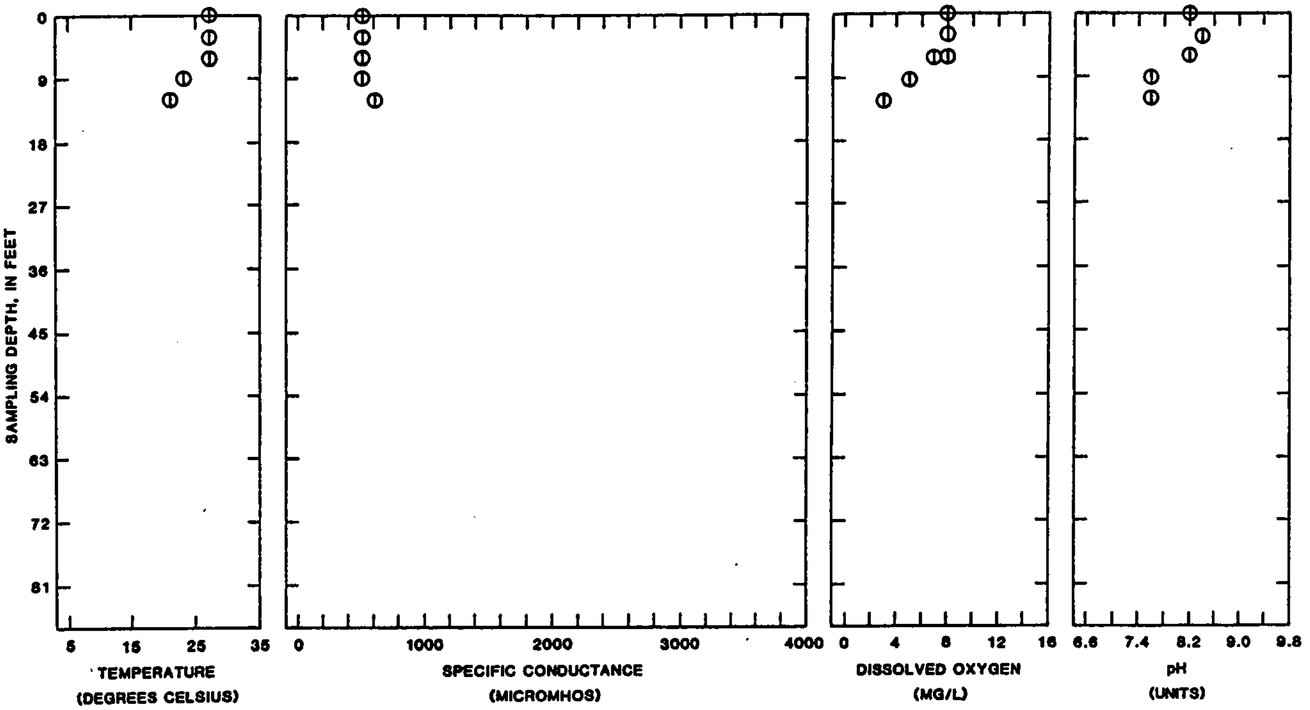
PLOT SYMBOL	DATE OF SAMPLE
⦶	June 3, 1980

Figure 140.--Site 83.



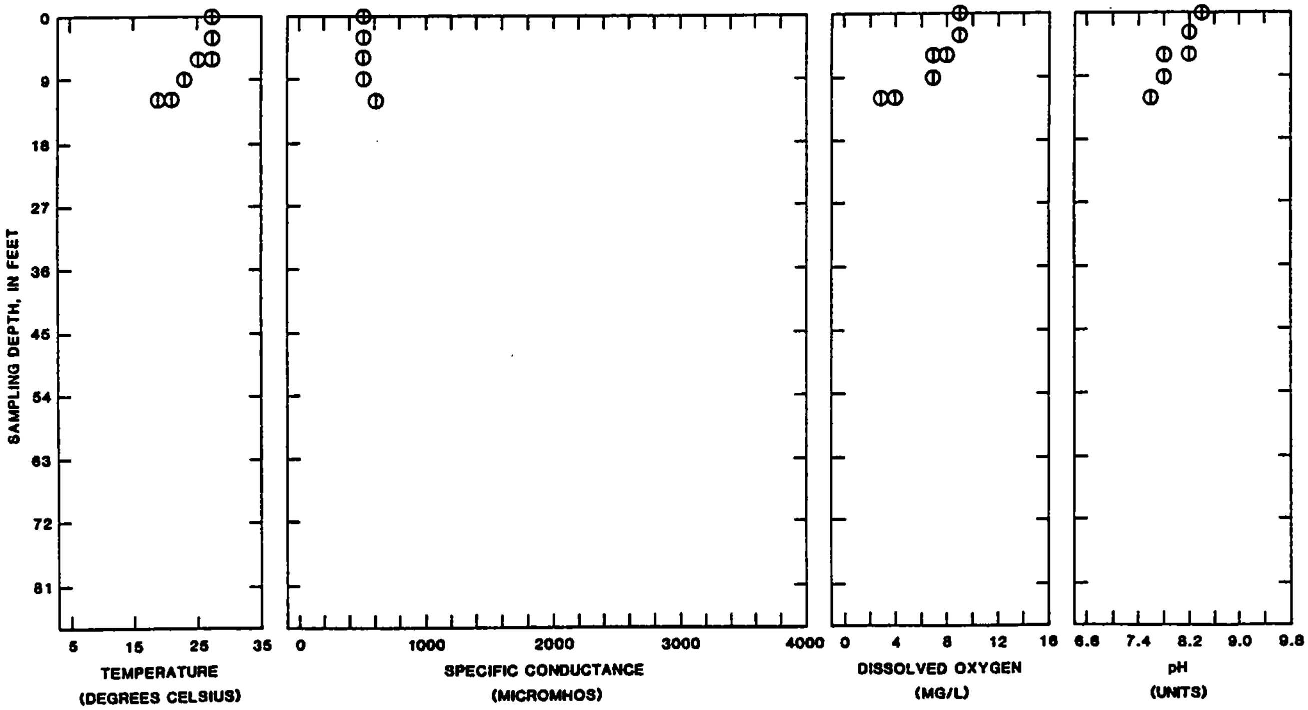
PLOT SYMBOL	DATE OF SAMPLE
⦶	June 8, 1980

Figure 141.—Site 84.



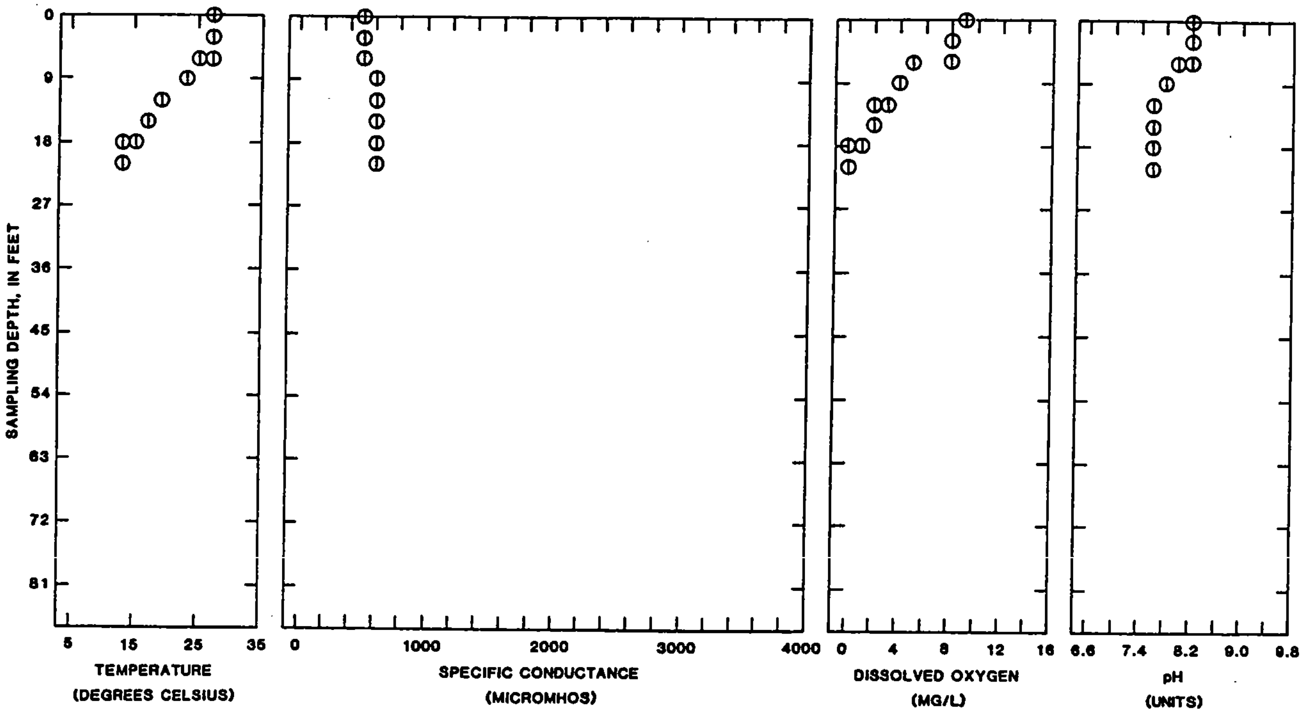
PLOT SYMBOL	DATE OF SAMPLE
⊕	June 5, 1980

Figure 142.--Site 85.



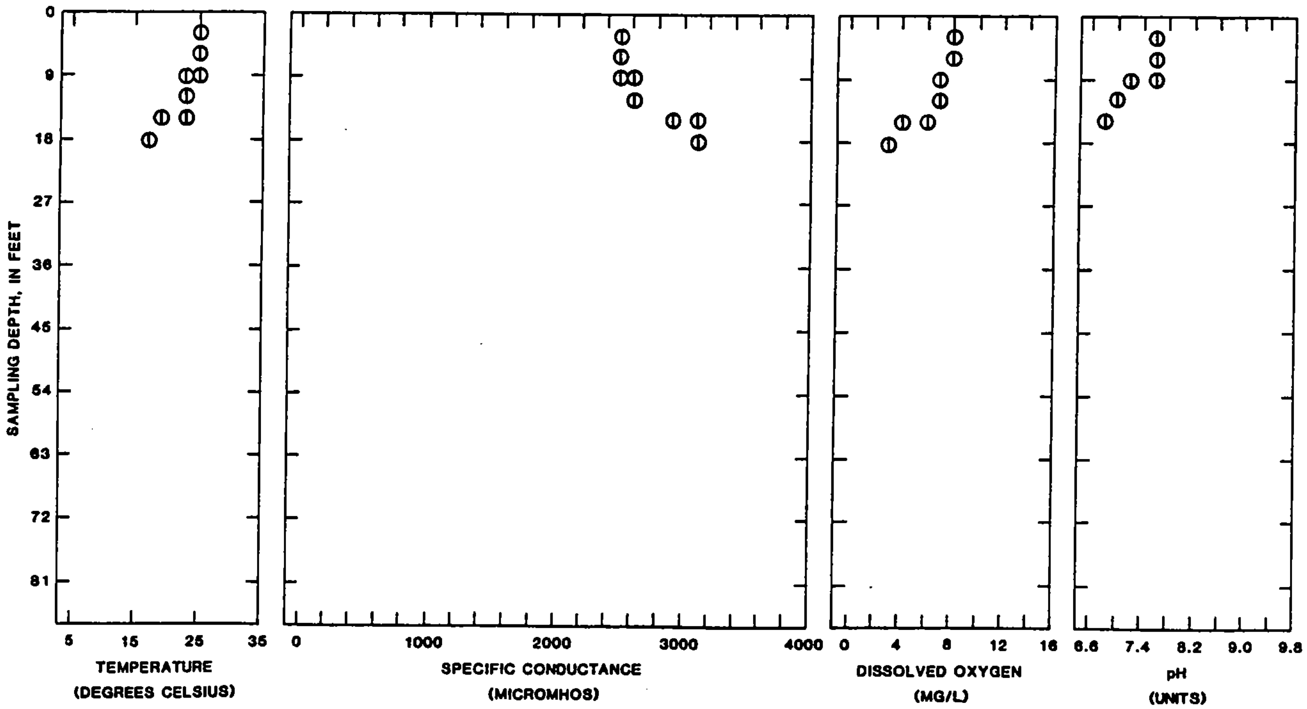
PLOT SYMBOL	DATE OF SAMPLE
⊕	June 5, 1980

Figure 143.--Site 86.



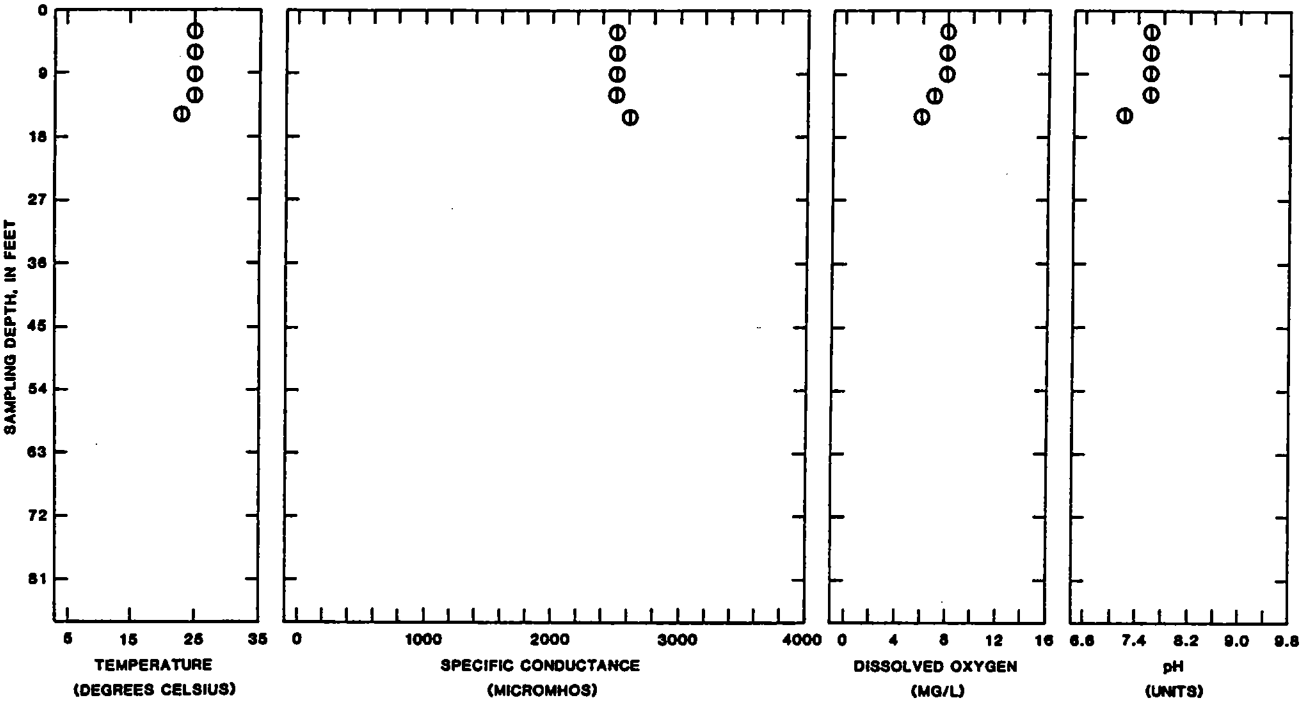
PLOT SYMBOL DATE OF SAMPLE
⦶ June 5, 1980

Figure 144.--Site 87.



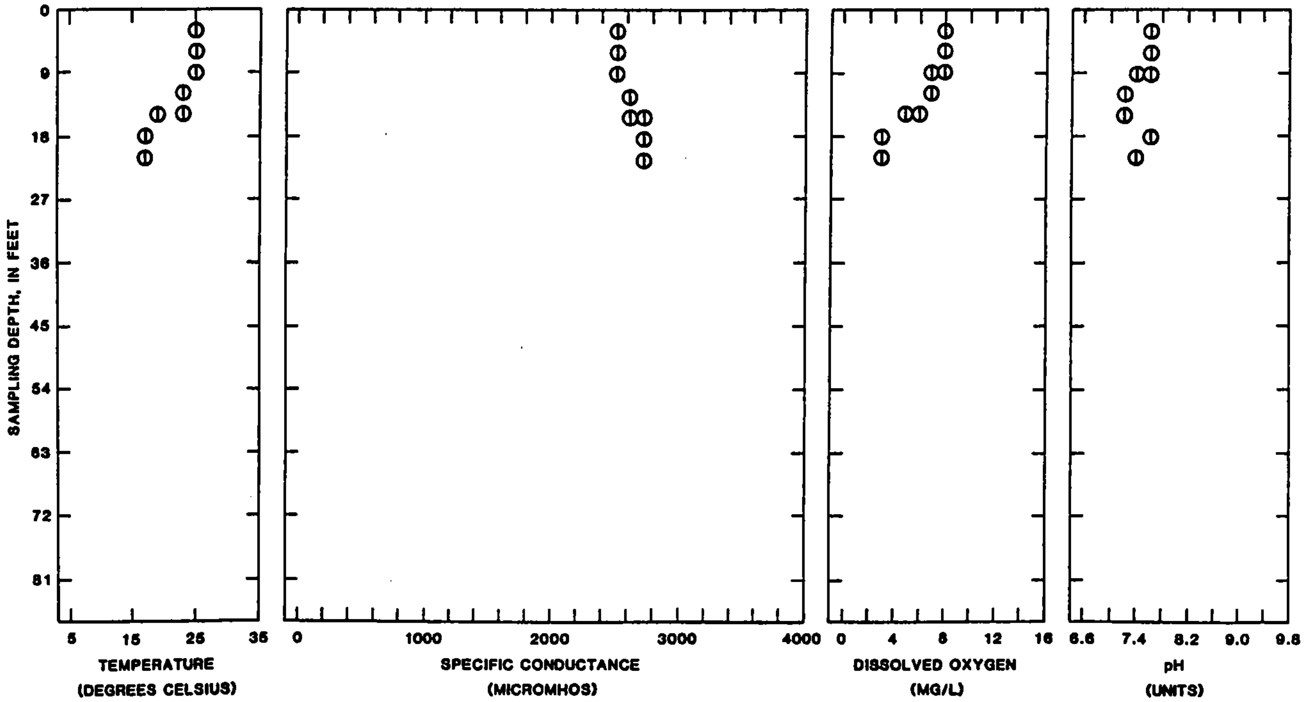
PLOT SYMBOL DATE OF SAMPLE
⦶ June 4, 1980

Figure 145.--Site 88.



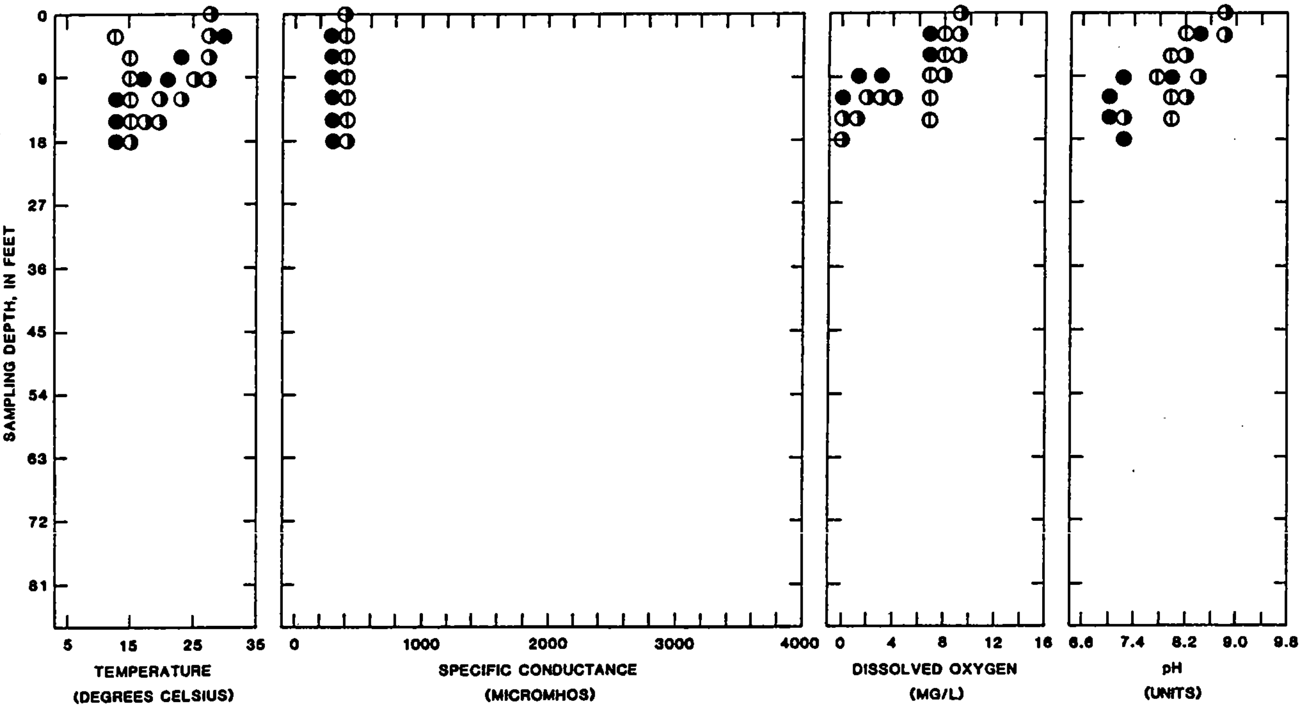
PLOT SYMBOL DATE OF SAMPLE
① June 4, 1980

Figure 146.--Site 89.



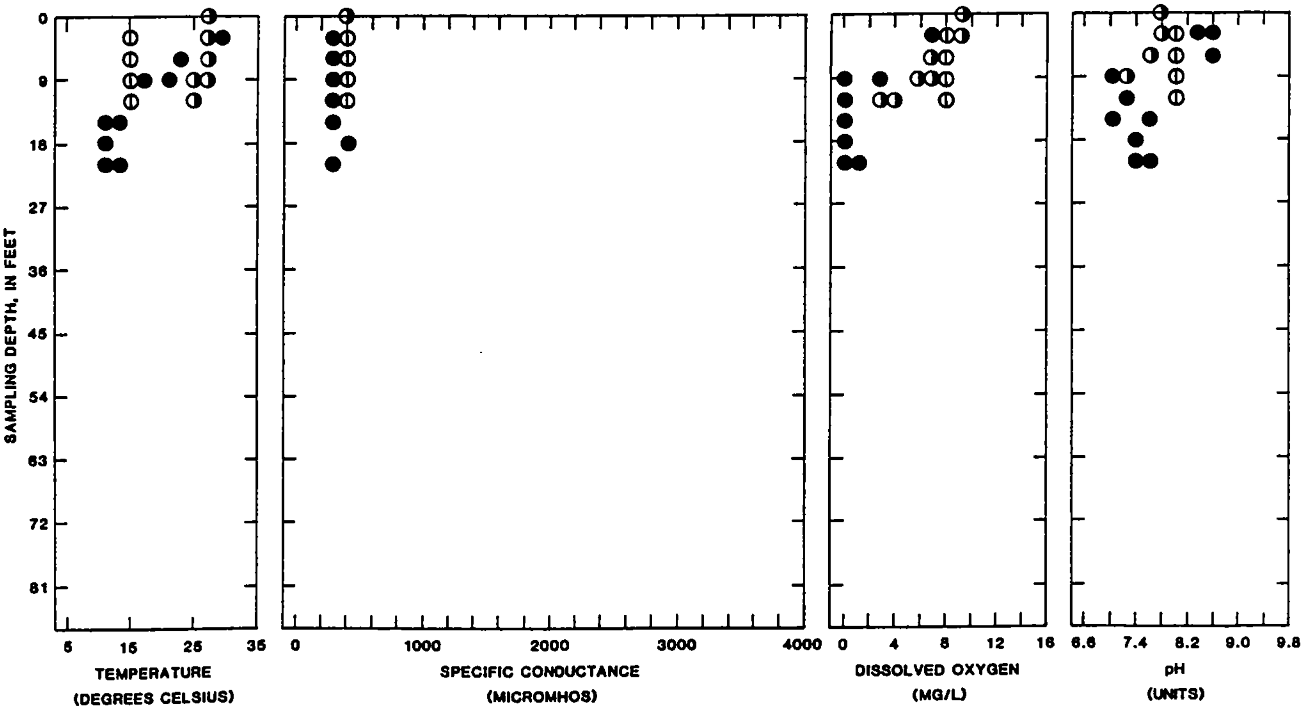
PLOT SYMBOL DATE OF SAMPLE
① June 4, 1980

Figure 147.--Site 90.



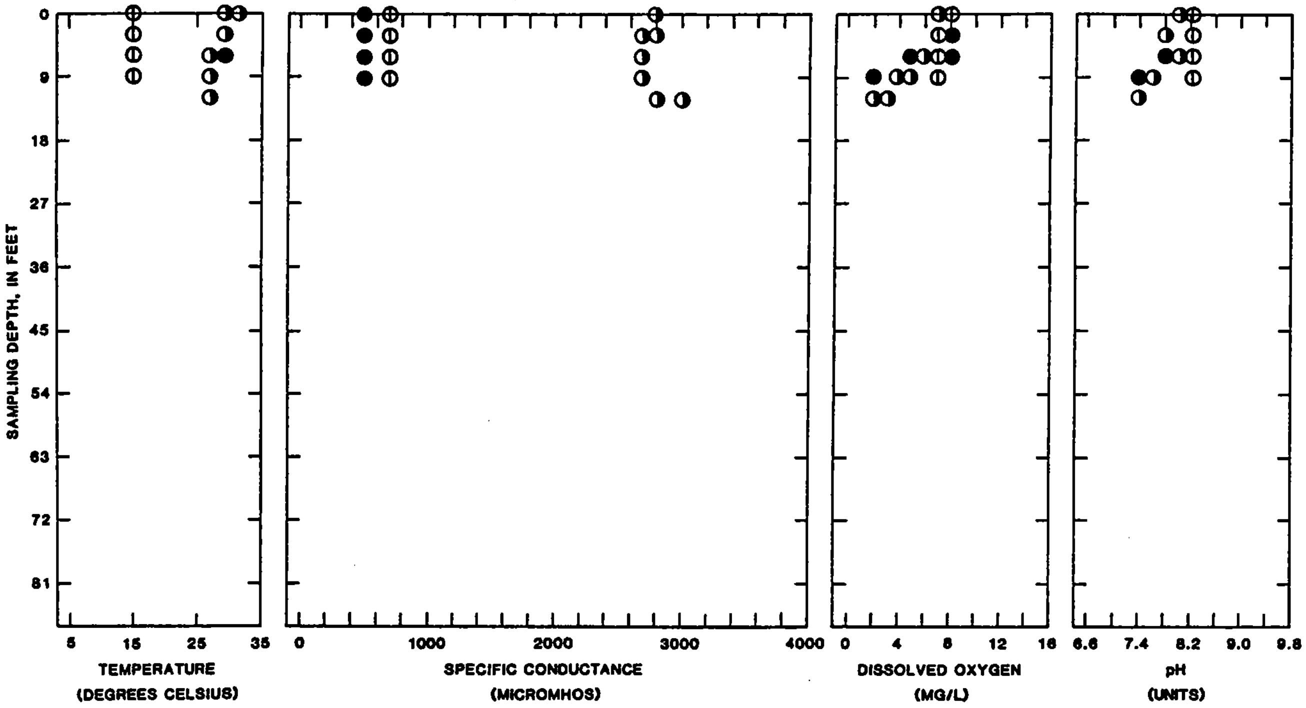
PLOT SYMBOL	DATE OF SAMPLE
⦶	November 1, 1978
◑	August 2, 1979
●	June 25, 1980

Figure 148.—Site 91.



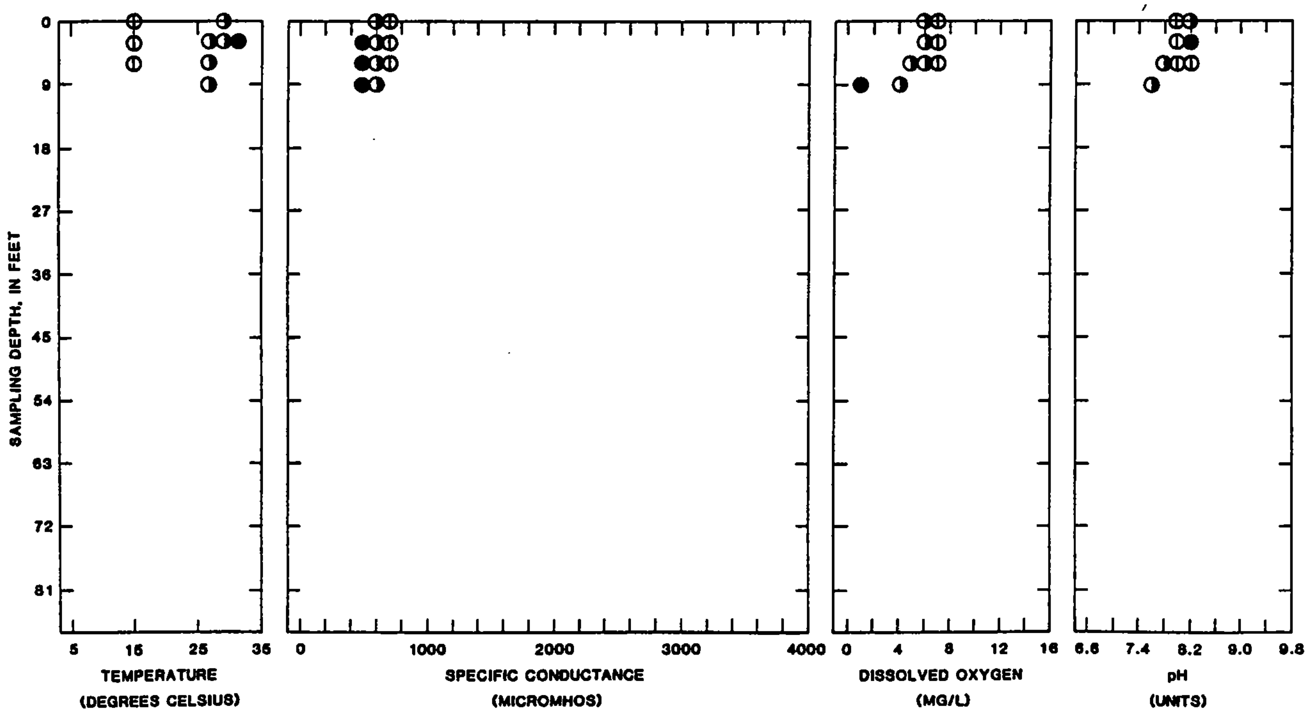
PLOT SYMBOL	DATE OF SAMPLE
⦶	November 1, 1978
◑	August 2, 1979
●	June 25, 1980

Figure 149.—Site 92.



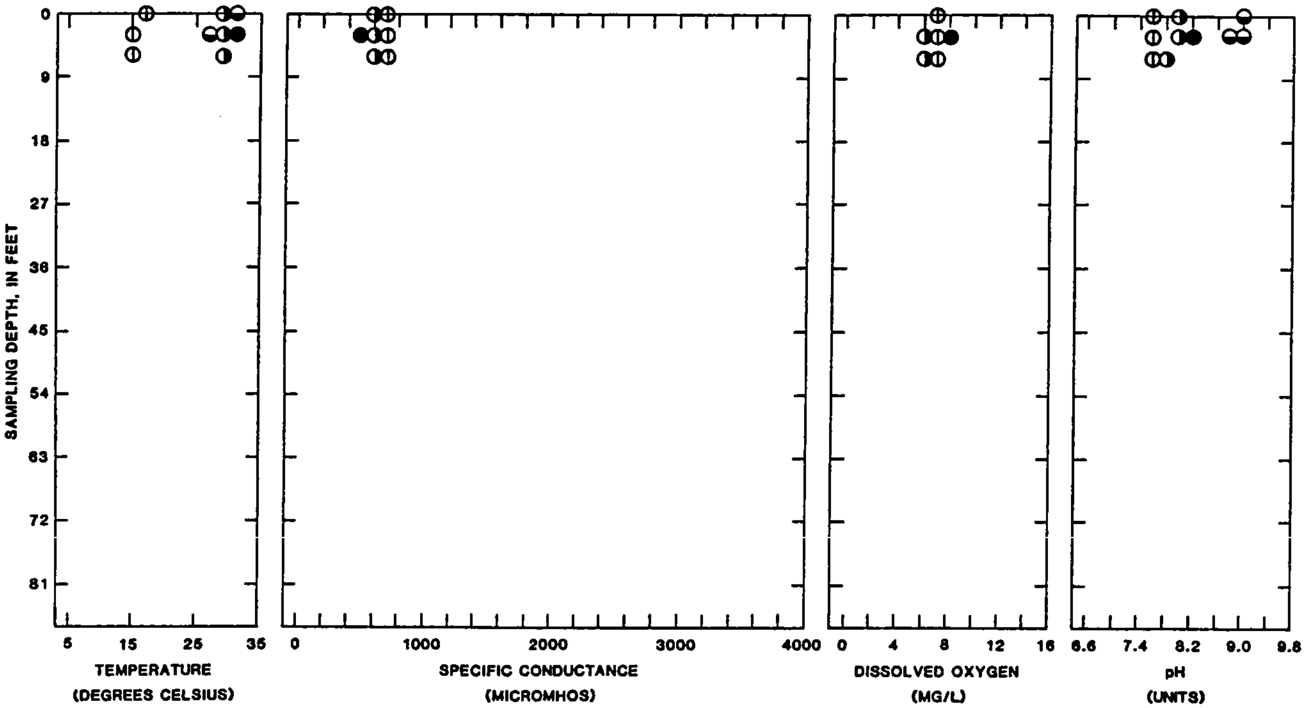
PLOT SYMBOL	DATE OF SAMPLE
⦶	November 1, 1978
◑	August 13, 1979
●	June 25, 1980

Figure 150.--Site 93.



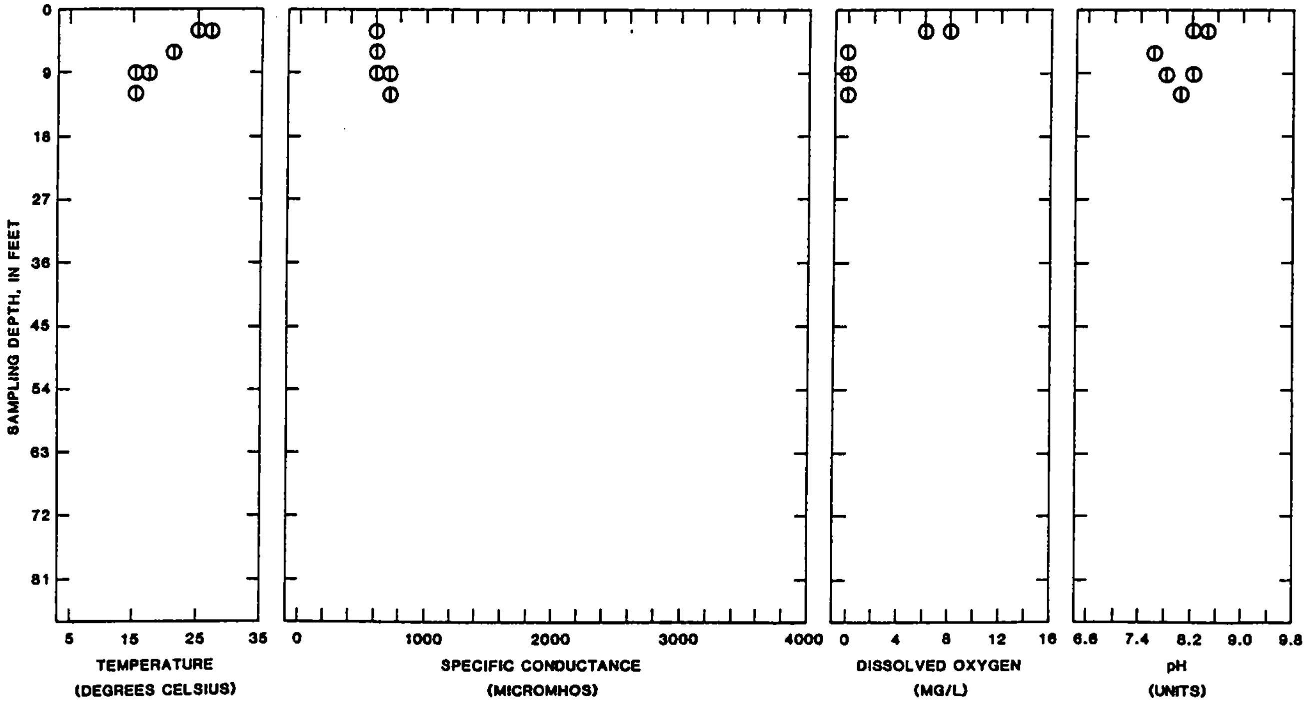
PLOT SYMBOL	DATE OF SAMPLE
⦶	November 1, 1978
◑	August 13, 1979
●	June 25, 1980
◒	July 9, 1981

Figure 151.--Site 94.



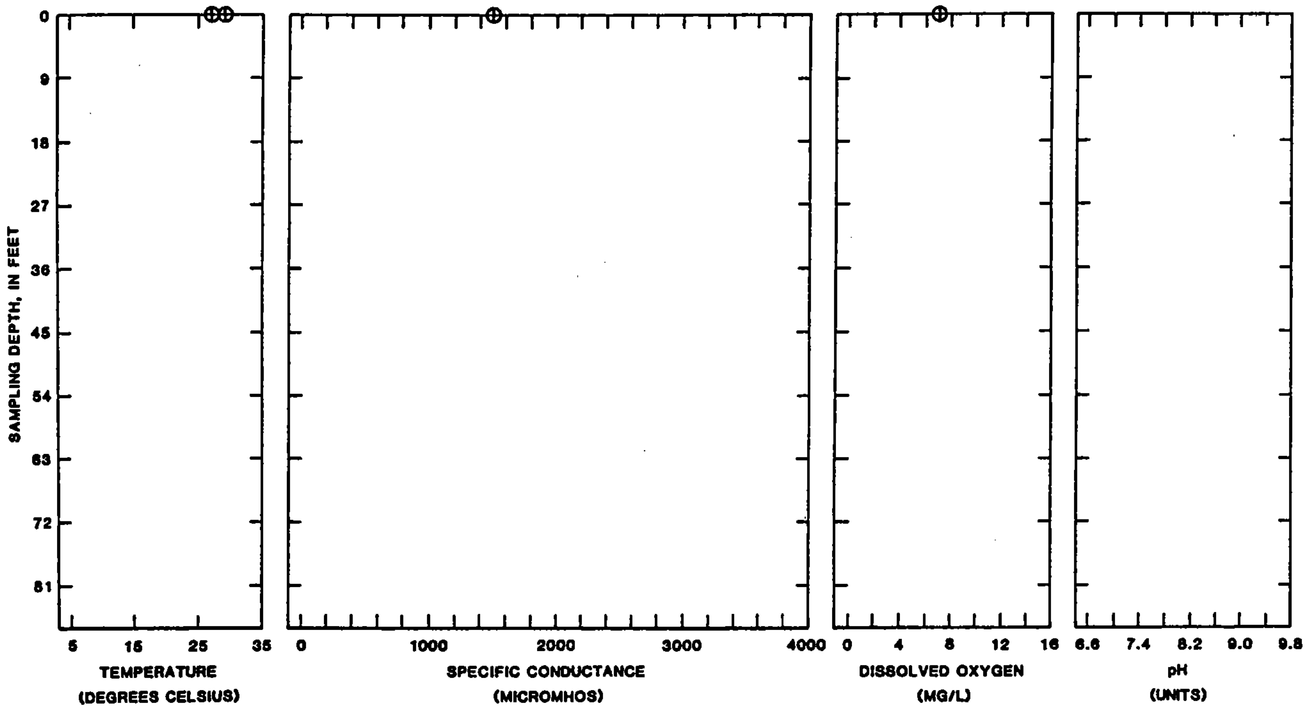
PLOT SYMBOL	DATE OF SAMPLE
⦶	November 1, 1978
◐	August 13, 1979
●	June 25, 1980
◒	July 9, 1981

Figure 152.—Site 95.



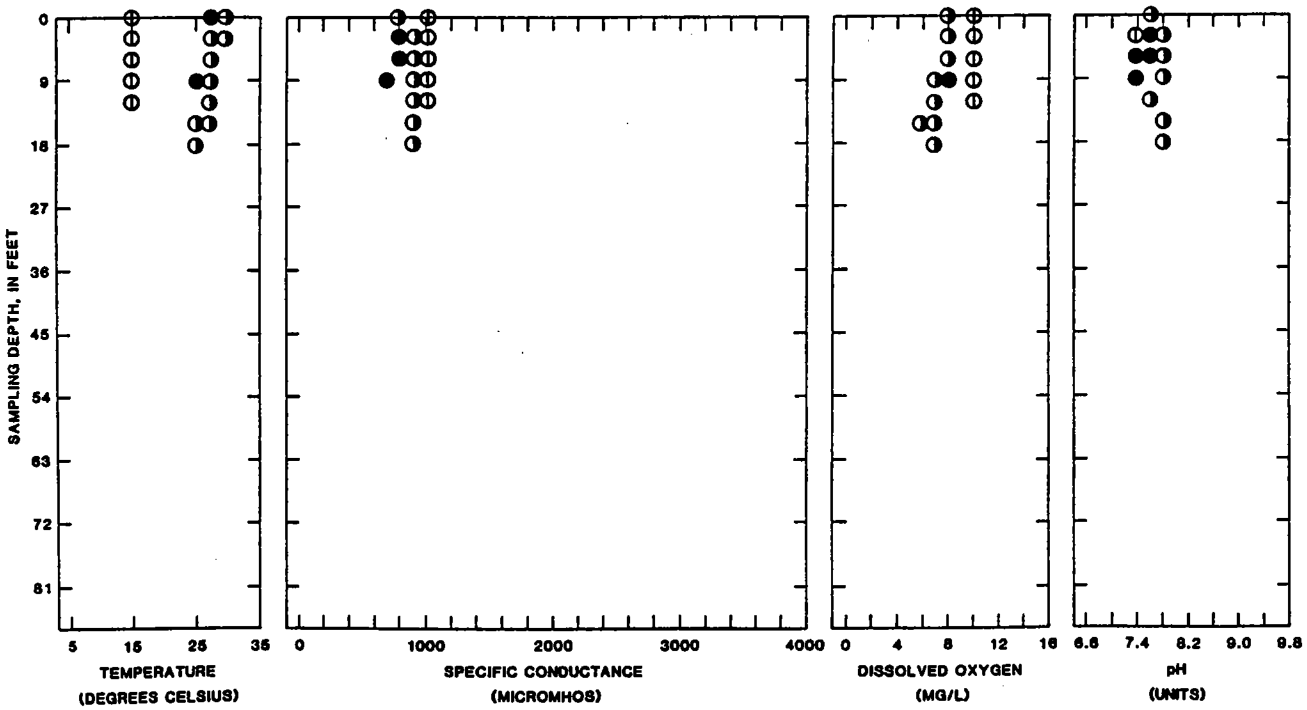
PLOT SYMBOL	DATE OF SAMPLE
⦶	June 24, 1980

Figure 153.—Site 96.



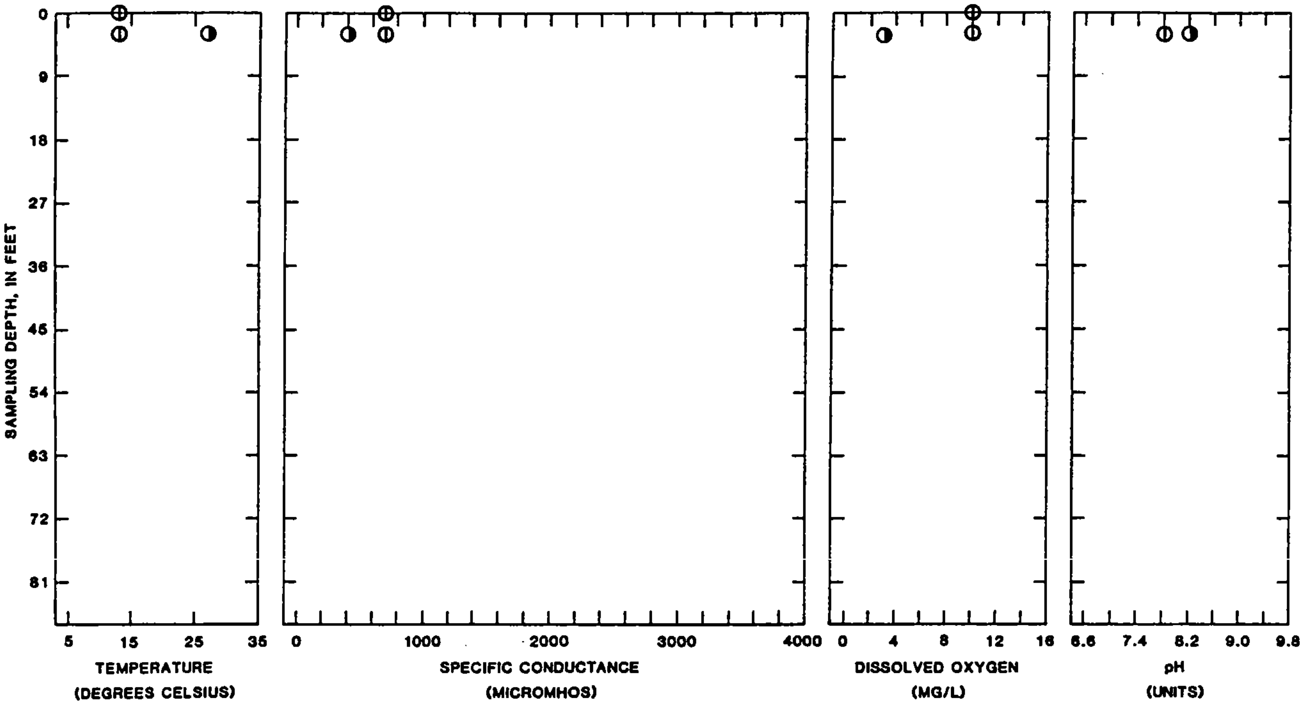
PLOT SYMBOL	DATE OF SAMPLE
⦶	June 2, 1980

Figure 154.--Site 97.



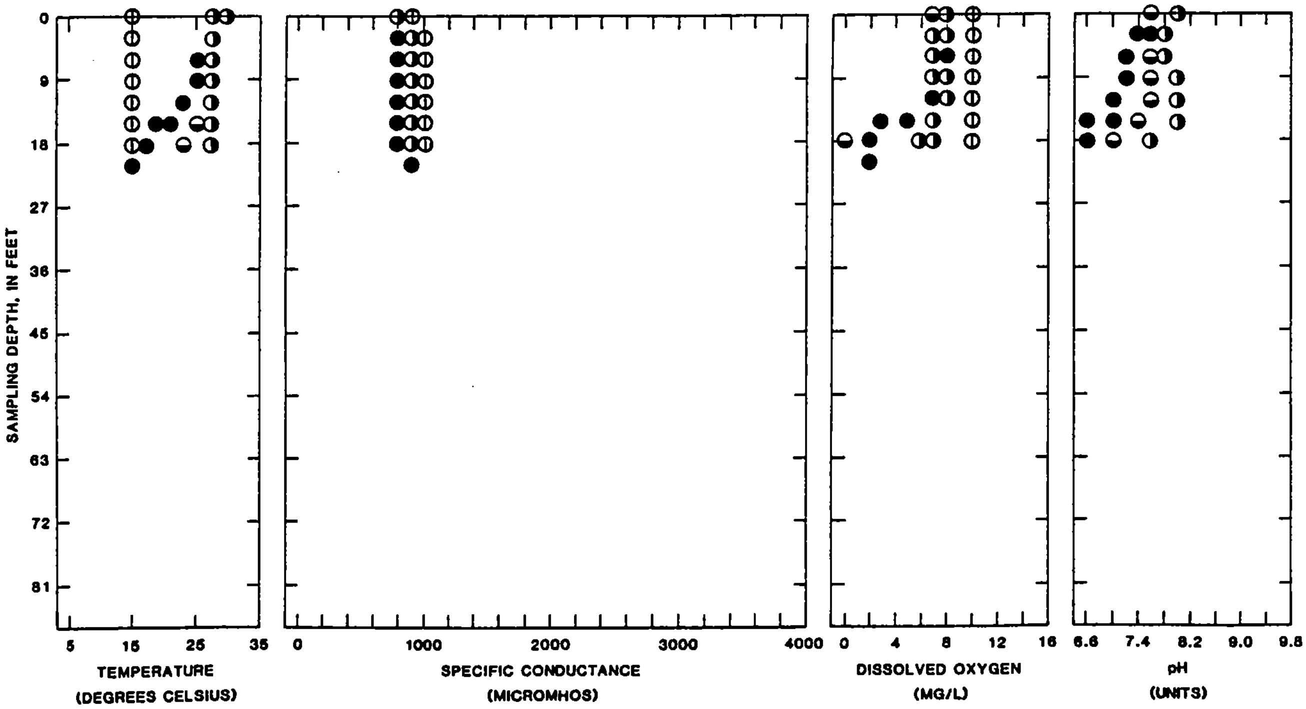
PLOT SYMBOL	DATE OF SAMPLE
⦶	November 2, 1978
◑	August 1, 1979
●	June 24, 1980

Figure 155.--Site 98.



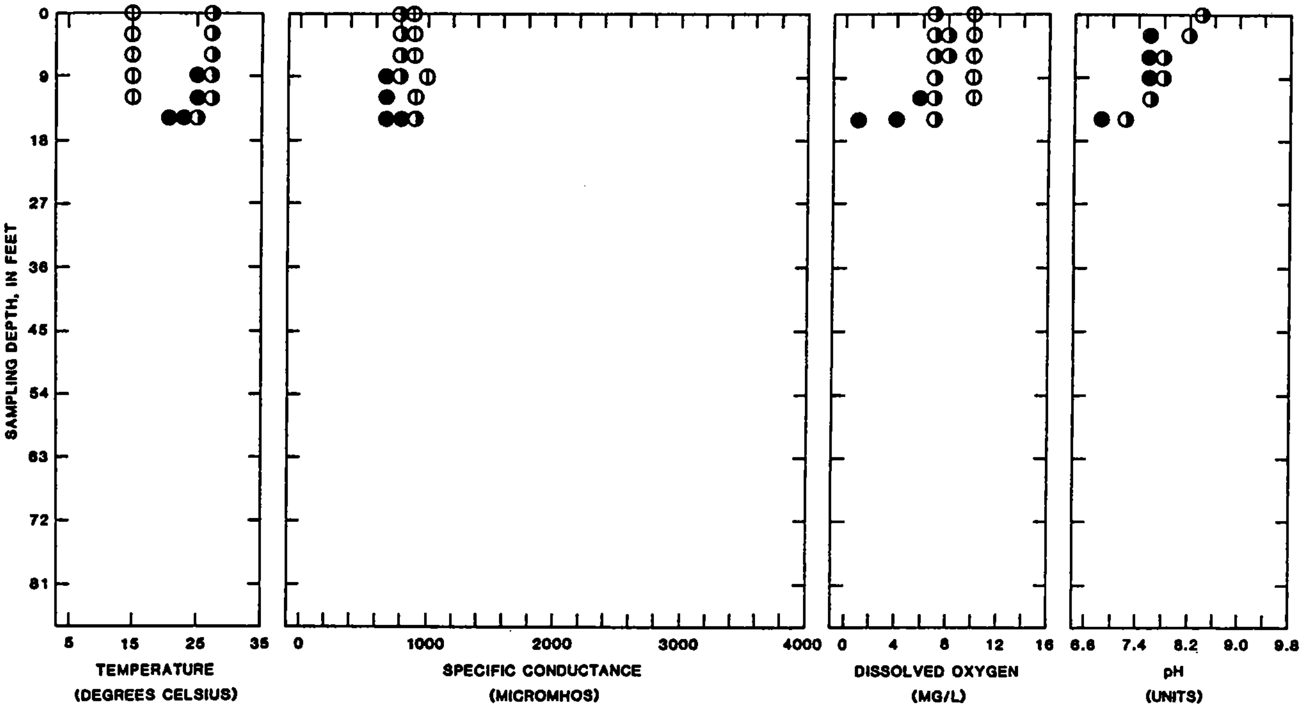
PLOT SYMBOL	DATE OF SAMPLE
⦶	November 2, 1978
◑	June 18, 1980

Figure 156.—Site 99.



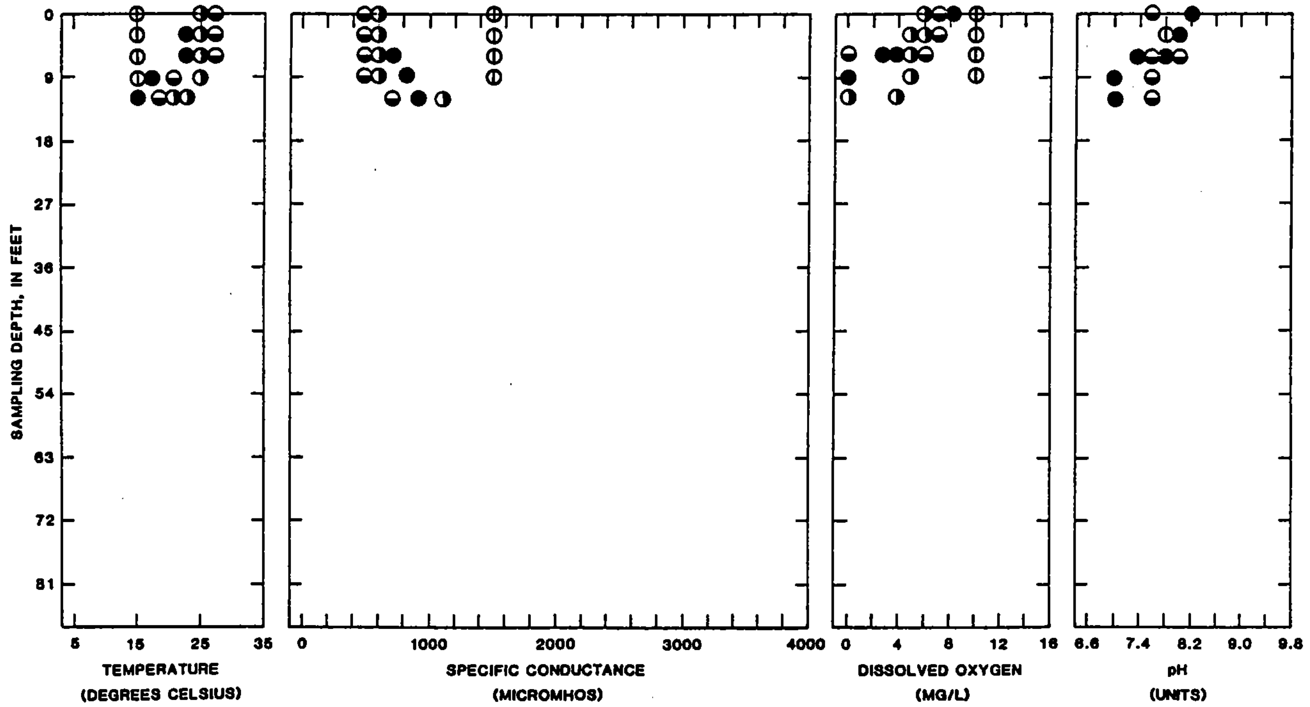
PLOT SYMBOL	DATE OF SAMPLE
⦶	November 2, 1978
◑	August 1, 1979
●	June 24, 1980
⊖	July 9, 1981

Figure 157.—Site 100.



PLOT SYMBOL	DATE OF SAMPLE
⦶	November 2, 1978
◑	August 1, 1979
●	June 24, 1980

Figure 158.—Site 101.



PLOT SYMBOL	DATE OF SAMPLE
⦶	November 2, 1978
◑	August 1, 1979
●	June 18, 1980
◒	July 9, 1981

Figure 159.--Site 102.