RELATION BETWEEN GROUND WATER AND SURFACE WATER IN THE HILLSBOROUGH RIVER BASIN, WEST-CENTRAL FLORIDA

By Richard M. Wolansky and T.H. Thompson

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DONALD PAUL HODEL, Secretary

U.S. GEOLOGICAL SURVEY

Dallas L. Peck, Director

For additional information write to:

District Chief
U.S. Geological Survey
Suite 3015
227 North Bronough Street
Tallahassee, Florida 32301

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ABBREVIATIONS AND CONVERSION FACTORS

Factors for converting inch-pound units to metric units and abbreviations of units are as follow:

Multiply inch-pound unit	By	To obtain metric unit
	Length	
inch (in.)	25.4	millimeter (mm)
inch per year (in/yr)	25.4	millimeter per year (mm/yr)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
foot per mile (ft/mi)	0.189	meter per kilometer (m/km)
	Area	
square mile (mi^2)	2.590	square kilometer (km^2)
	Flow	
cubic foot per second (ft^3/s)	0.02827	cubic meter per second (m^3/s)
gallon per minute (gal/min)	0.00378	cubic meter per minute (m^3/min)
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)
	Transmissivity	
foot squared per second (ft^2/s)	0.0929	meter squared per second (m^2/s)
foot squared per day (ft^2/d)	0.0929	meter squared per day (m^2/d)
gallon per day per foot [(gal/d)/ft]	0.0124	meter squared per day (m^2/d)
	Hydraulic conductivity	
foot per day (ft/d)	0.3048	meter per day (m/d)
	Leakance coefficient	
foot per second per foot [(ft/s)/ft]	1.0	meter per second per meter [(m/s)/m]
foot per day per foot [(ft/d)/ft]	1.0	meter per day per meter [(m/d)/m]
gallon per day per cubic foot [(gal/d)/ft^3]	0.1337	meter per day per meter [(m/d)/m]

Specific capacity

cubic foot per minute per foot [$(ft^3/min)/ft$]	0.008616	cubic meter per minute per meter [$(m^3/min)/m$]
gallon per minute per foot [(gal/min)/ft]	0.001152	cubic meter per minute per meter [$(m^3/min)/m$]

Temperature in degrees Fahrenheit (^oF) can be converted to degrees Celsius (^oC) as follows:

$$^oC = 5/9\ (^oF - 32)$$

* * * * * * * * * * * *

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

* * * * * * * * * * * *

Additional abbreviations

microsiemens per centimeter	(uS/cm)
pi	(π)

RELATION BETWEEN GROUND WATER AND SURFACE WATER IN THE HILLSBOROUGH RIVER BASIN, WEST-CENTRAL FLORIDA

By Richard M. Wolansky and T.H. Thompson

ABSTRACT

The relation between ground water and surface water in the Hillsborough River basin was defined. The methods used include seismic-reflection profiling along selected reaches of the Hillsborough River and evaluation of streamflow, rainfall, ground-water levels, water quality, and geologic data.

Major municipal well fields in the basin are Morris Bridge and Cypress Creek where an average of 15.3 and 30.0 million gallons per day, respectively, was pumped in 1980. Mean annual rainfall for the study area is 53.7 inches. Average rainfall for 1980, determined from eight rainfall stations, was 49.7 inches. Evapotranspiration, corrected for the 5 percent of the basin that is standing water, was 35.7 inches per year.

The principal hydrogeologic units in the basin are the surficial aquifer, the intermediate aquifer and confining beds, the Upper Floridan aquifer, the middle confining unit, and the Lower Floridan aquifer. Total pumpage of ground water in 1980 was 98.18 million gallons per day. The surficial aquifer and the intermediate aquifer are not used for major ground-water supply in the basin.

Continuous marine seismic-reflection data collected along selected reaches of the Hillsborough River were interpreted to define the riverbed profile, the thickness of surficial deposits, and the top of persistent limestone. The top of the limestone exhibited an irregular surface that is typical of buried karst. A large sinkhole under the river was identified about 1 mile south of the river's confluence with Trout Creek.

Major areas of ground-water discharge near the Hillsborough River and its tributaries are the wetlands adjacent to the river between the Zephyrhills gaging station and Fletcher Avenue and the wetlands adjacent to Cypress Creek. An estimated 20 million gallons per day seeps upward from the Upper Floridan aquifer within those wetland areas. The runoff per square mile is greater at the Zephyrhills station than at Morris Bridge. However, results of ground-water flow models and potentiometric-surface maps indicate that ground water is flowing upward along the Hillsborough River between the Zephyrhills gage and the Morris Bridge gage. This upward leakage is lost to evapotranspiration.

An aquifer test conducted in 1978 at the Morris Bridge well field was evaluated by using an anisotropic method. Analytical results matched observed water levels within 0.1 foot. Analysis of aquifer-test results indicates that withdrawals of up to 28 million gallons per day would have a negligible effect on the river stage or flow.

A comparison of discharge measurements for the Hillsborough River at Fowler Avenue and daily discharge of the river near Tampa between 1945 and 1978 shows that discharge at Fowler Avenue, the upstream station, was greater than near Tampa. This streamflow loss to the Floridan aquifer system probably is due to a direct hydraulic connection between the river and the aquifer system.

INTRODUCTION

The Hillsborough River basin in west-central Florida (fig. 1) has a drainage area of 690 mi^2 (Foose, 1981). Ground-water contribution to the river is a relatively large portion of the river's mean annual runoff. Conversely, when river stages are high, a significant portion of the river flow could be recharging underlying aquifers. Well fields and urban areas adjacent to the Hillsborough River and its tributaries could affect base flow and water quality.

The U.S. Geological Survey, in cooperation with the City of Tampa, conducted a study to define the relation between ground water and surface water in the Hillsborough River basin. Identification of the quantity of river base flow from ground water and losses and where they occur and the nature of the hydraulic connection between the river and underlying aquifers can be used by agencies concerned with regulating ground-water withdrawals in the vicinity of the river. The information is also needed to quantify the potential effects of urbanization and water-supply development on base flow and water quality.

Purpose and Scope

The purpose of this study was to define the relation between ground water and surface water in the Hillsborough River basin (fig. 1), including the nature and extent of the hydraulic connection between the underlying aquifers and the Hillsborough River. Hydrologic and geologic records, including rainfall, streamflow, ground-water levels, water-quality data, and geologic and geophysical logs collected by the U.S. Geological Survey and other agencies, were examined and analyzed. Continuous seismic-reflection profiling was conducted on the Hillsborough River from near its mouth to the Morris Bridge well field (a distance of about 23 miles). The profiling was done to aid in determining the nature of the connection between the river and the aquifers.

This report presents a description of the hydrogeology of the basin. Areas of hydraulic connection between the Hillsborough River and the aquifers are identified, and the effect of well-field withdrawals on base flow of the Hillsborough River is evaluated.

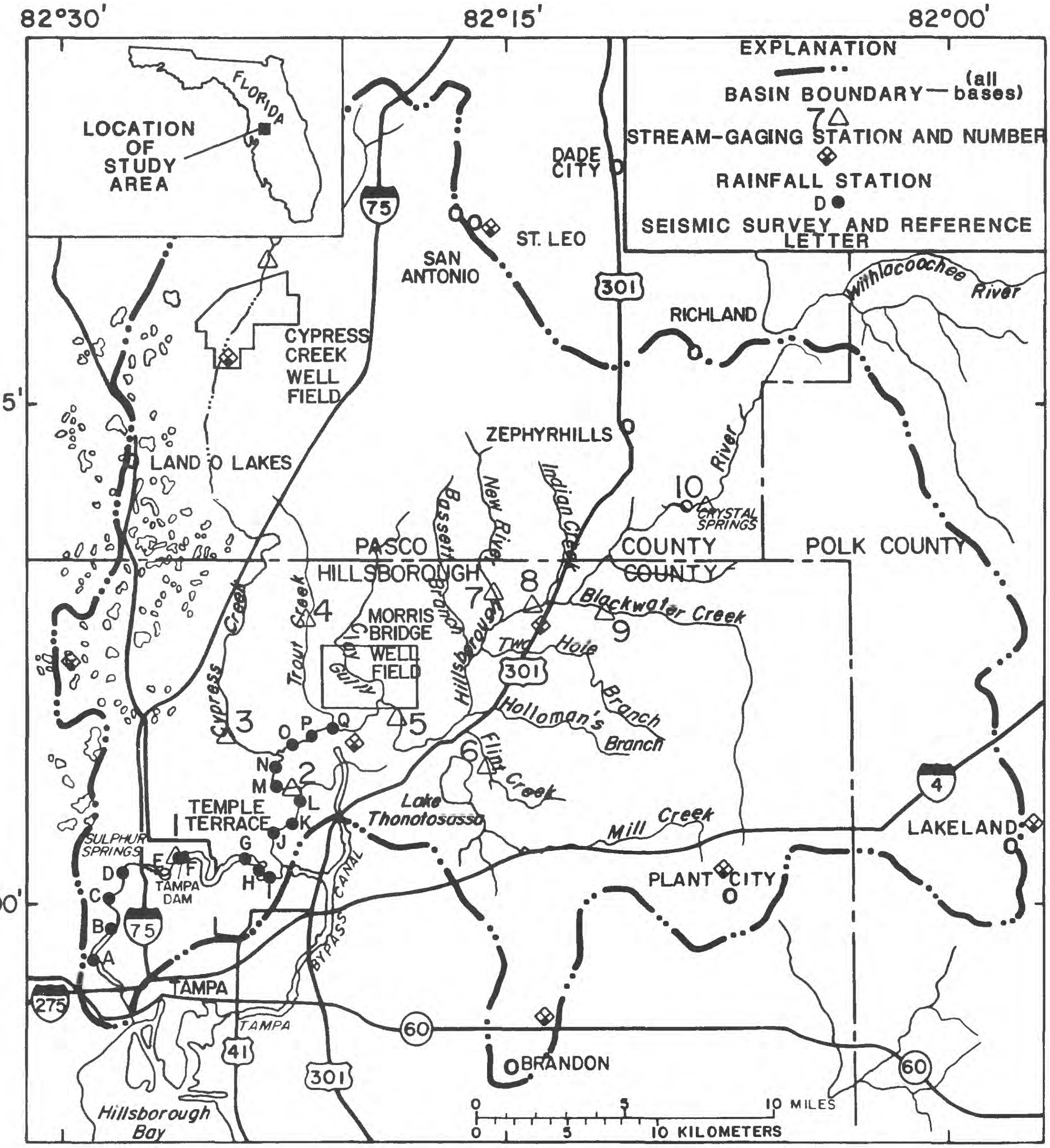

Figure 1.--Location of the Hillsborough River basin and data-collection stations.

Previous Investigations

The Hillsborough River basin has been included in several local, county, and statewide ground-water and surface-water resources investigations. However, evaluation of the relation between ground water and surface water has not been the principal subject of any previous investigation.

A discussion of the hydrology and geology of Hillsborough County is presented by Menke and others (1961). Motz (1975) and Knutilla and Corral (1984) studied the hydrologic effects of the Tampa Bypass Canal near the lower Hillsborough River. Stewart (1977) analyzed an aquifer test of a large sink near the Hillsborough River to determine the hydrologic effects of pumping from the sink. Stewart and others (1978) studied hydrogeologic factors that affect ground water in the Temple Terrace area adjacent to the Hillsborough River. Hutchinson (1984) completed a regional ground-water flow model of the Upper Floridan aquifer in a 932-mi^2 area that included most of the Hillsborough River basin. Ryder (1978) and Ryder and others (1980) used models of ground-water flow to describe the flow systems of the Cypress Creek and Morris Bridge well fields, respectively, adjacent to the Hillsborough River and its tributaries. Duerr (1979) presented hydrologic data for the Morris Bridge well-field area.

Turner (1974) completed flood profiles for the lower Hillsborough River, and Murphy (1978) completed flood profiles for Cypress Creek. Hydrograph simulation models and streamflow simulation for the Hillsborough River are presented in Turner (1972). A discussion of the water-supply potential of the lower Hillsborough River is presented by Goetz and others (1978). Fernandez and others (1984) completed a water-quality model of low flow of the Hillsborough River.

DESCRIPTION OF THE AREA

The Hillsborough River basin is about 34 miles long and 33 miles wide and covers an area of 690 mi^2 in parts of Pasco, Polk, and Hillsborough Counties (fig. 1). The Hillsborough River rises in swampy terrain in eastern Pasco County and flows 54 miles southwest to Hillsborough Bay. Tampa, Lakeland, Temple Terrace, Plant City, and Zephyrhills are major population centers in the basin. The Morris Bridge and Cypress Creek well fields are major municipal well fields within the basin. Crystal Springs and Sulphur Springs are second order (average discharge 10 to 100 ft^3/s) springs that flow into the Hillsborough River. The Tampa Dam (fig. 1) is on the river, 10 miles above its mouth. The reservoir above the dam is long and narrow and extends about 12.5 miles upstream. The reservoir meanders through urban areas of north Tampa and Temple Terrace and provides an impoundment for the water supply of Tampa.

Topography, Drainage, and Land Use

Land-surface altitudes in the Hillsborough River basin range from sea level at the mouth of the river to about 175 feet above sea level north of Lakeland (fig. 2). Tributaries to the Hillsborough River that have perennial

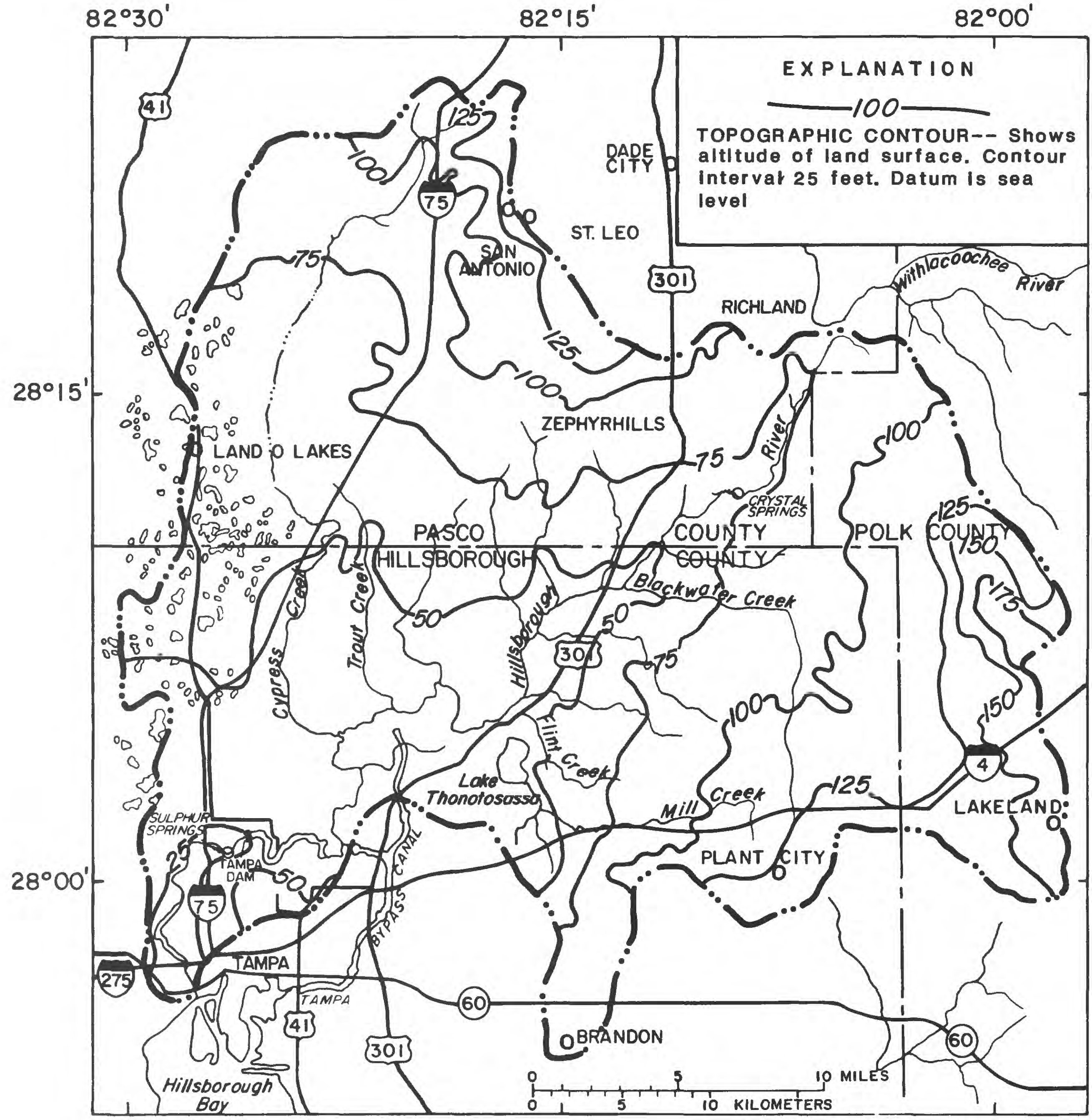

Figure 2.--Generalized topography.

flow are Big Ditch, Blackwater Creek, and Flint Creek (fig. 1). Nonperennial, or intermittent tributaries, are Indian Creek, New River, Two Hole Branch, Basset Branch, Hollomans Branch, Clay Gully, and Trout Creek. Cypress Creek, also a nonperennial stream, is tributary to the river by way of a swamp.

The Hillsborough River basin is predominantly rural. The central and northern parts are generally rural and agricultural and consist of open and wooded upland areas and numerous low-lying swamp areas that are covered with cypress heads and undergrowth. Agricultural development consists chiefly of pasture, citrus groves, and small row crops. The southern part of the basin is largely urban and industrial. Rural and agricultural areas near existing population centers in the basin are being urbanized and this trend will probably continue into the future.

Water Use

Ground-water pumpage and withdrawal from the Hillsborough River above the Tampa Dam are the major sources of water supply for the city of Tampa and Hillsborough County. Total pumpage of ground water in 1980 was 98.18 Mgal/d (table 1). About 59 percent was for public supply, irrigation use was about 27 percent, industrial use was about 9 percent, and rural domestic use was about 5 percent.

In 1980, five municipal well fields within and adjacent to the basin pumped water from the aquifer. The average 1980 daily pumping rates for the well fields were as follows:

County	Municipal well field	Pumping rate (Mgal/d)
Hillsborough	Morris Bridge	15.3
Hillsborough	Plant City	2.9
Hillsborough	Temple Terrace	2.1
Pasco	Cypress Creek	30.0
Polk	Lakeland	5.9

Surface-water withdrawal in 1980 was 50.57 Mgal/d (table 1). About 99 percent (49.87 Mgal/d) was withdrawn from the Hillsborough River at Tampa and used for public supply. Water withdrawn from various surface-water bodies for irrigation was about 1 percent of the total use.

Rainfall and Evapotranspiration

In the Hillsborough River basin, Whalen (1979) estimated that mean annual rainfall is 53.7 inches and is distributed unevenly based upon rainfall records from stations with 60 or more years of record in and near the basin. About 60 percent of the annual rainfall occurs in June through September. The dry season, October through May, is also the peak irrigation season. For

Table 1.--Water use in 1980

[From Duerr and Trommer, 1981. Mgal/d, million gallons per day]

Type of use	Hillsborough County (Mgal/d)	Pasco County (Mgal/d)	Polk County (Mgal/d)	Total (Mgal/d)
Ground water				
Public supply	20.89	31.08	5.90	57.87
Irrigation	16.18	8.78	1.85	26.81
Industrial	8.38	0.03	0	8.41
Rural domestic	2.95	1.31	0.83	5.09
Total	48.40	41.20	8.58	98.18
Surface water				
Public supply	49.87	0	0	49.87
Irrigation	0.50	.18	.02	0.70
Industrial	0	0	0	0
Rural domestic	0	0	0	0
Total	50.37	.18	.02	50.57

1980, the average rainfall determined from eight rainfall stations in and near the basin (fig. 1) was 49.7 inches. Annual totals ranged from 43.0 inches at St. Leo to 52.6 inches at Plant City.

Mean monthly temperatures range from about 82 °F in summer to 60 °F in winter, and the mean annual temperature is about 72 °F. The moderately high temperatures result in a large amount of rainfall being lost to evapotranspiration. The amount of loss will vary depending on rainfall, temperature, depth to water table, soil type, type and distribution of vegetation communities, and land-use patterns.

Evapotranspiration can be estimated based on evaporation rates from open-water bodies and evapotranspiration rates from vegetated areas. Open-water bodies occupy about 35 mi^2 or about 5 percent of the Hillsborough River basin. In areas where water is standing in ponds and depressions, evapotranspiration rates almost equal the yearly potential evapotranspiration rate of 49.0 inches (Visher and Hughes, 1975). Vegetated land areas occupy about 655 mi^2 or about 95 percent of the basin area. By use of a method described by Dohrenwend (1977) that is based on temperature, vegetation commumities, land use, and rainfall, an evapotranspiration rate of 35.0 in/yr was determined for the vegetated land areas. The annual evapotranspiration rate, based on the percentages of vegetated land and open-water bodies, is 35.7 in/yr.

HYDROGEOLOGIC FRAMEWORK

The Hillsborough River basin is underlain by a thick sequence of sedimentary rocks that are overlain by unconsolidated surficial sediments. The lithology and geologic structure control the occurrence and movement of ground water and its relation with surface water. The principal hydrogeologic units are (1) surficial aquifer, (2) intermediate aquifer and confining beds, (3) Upper Floridan aquifer, (4) middle confining unit (or base of the Upper Floridan aquifer), and (5) Lower Floridan aquifer (fig. 3). Geologic sections in figure 4 show the general distribution of the formations that compose the upper part of these units.

Surficial Aquifer

The surficial aquifer consists of permeable units of undifferentiated surficial sediments of Holocene, Pleistocene, and Miocene age and, where present, permeable parts of the sand and phosphorite unit of the Hawthorn Formation. These units are discontinuous and result in a surficial aquifer of variable thickness and permeability. The units are predominantly layers of fine to medium quartz sand, clayey sand with some phosphate gravel, and stringers of marl. The aquifer is generally unconfined; however, lenses of sand and marl within silt and clay layers contain water under confined conditions in some areas. The thickness of the surficial aquifer ranges from about 20 to 50 feet, although it could be less, along the eroded valley of the Hillsborough River (fig. 5). Regionally, the aquifer is about 20 feet thick. The base of the aquifer generally consists of clayey sand and sandy clay in the lower part of the undifferentiated surficial sediments or impermeable material in the sand and phosphate unit of the Hawthorn Formation.

Most wells that derive water from the surficial aquifer are small-diameter, drive-point wells. The wells are generally less than 20 feet deep and yield about 5 gal/min. Because of low yield and iron in solution that causes staining unless treated, the aquifer generally is not an important source of water in the basin.

Water Table, Ground-Water Movement, Recharge, and Discharge

The depth to the water table of the surficial aquifer is generally less than 5 feet. In areas of high altitude (greater than 125 feet), such as in northern and eastern parts of the basin (fig. 2), the water table may be more than 15 feet below land surface. In areas of poor drainage and low topographic relief, the water table may be less than 1 foot below land surface. The water table fluctuates seasonally and varies within about a 5-foot range. Maximum depth to water occurs during the spring and early summer months. Water levels generally recover during the wet summer months to their annual high in September or October.

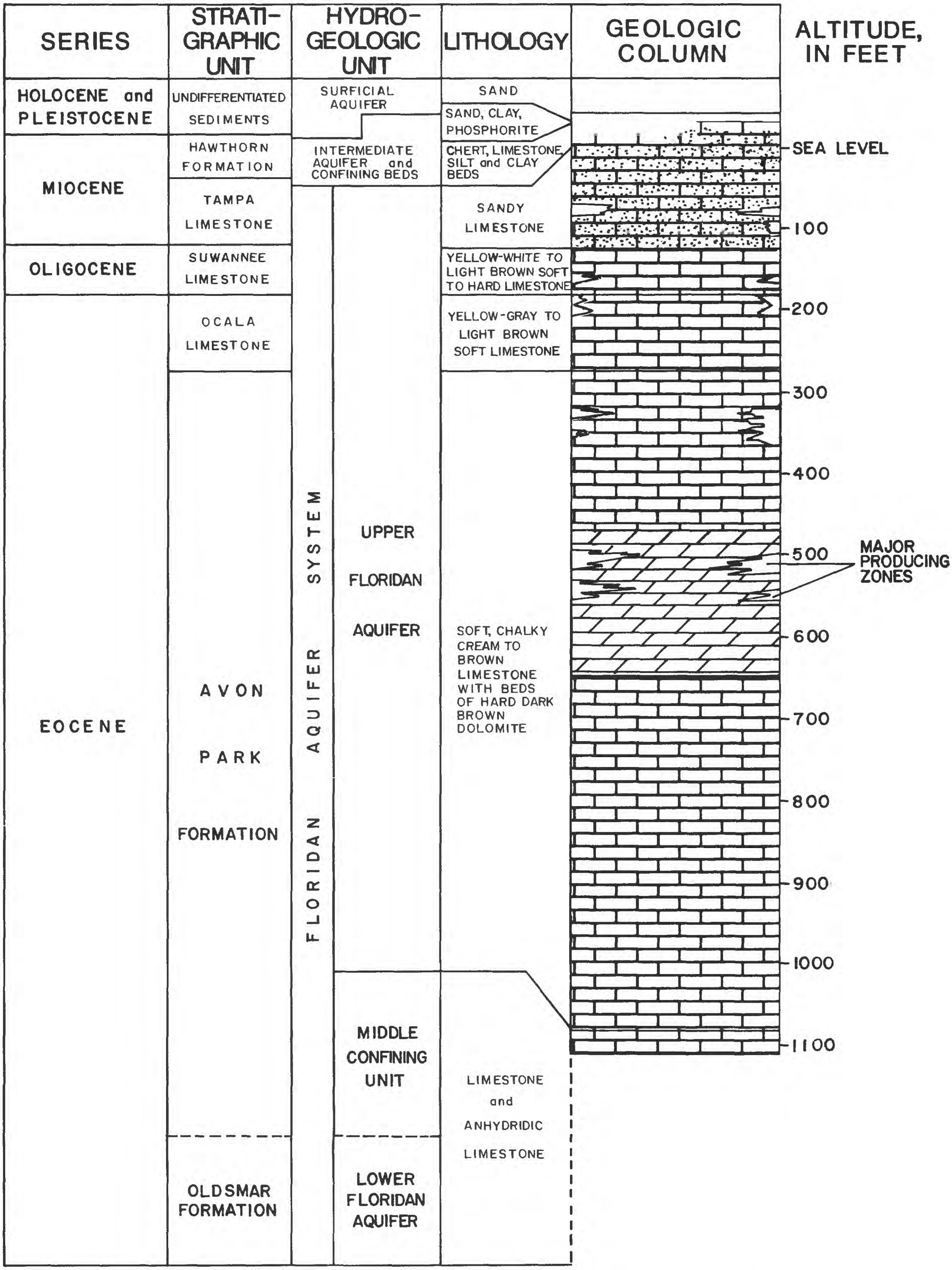

Figure 3.--Generalized hydrogeologic column of the Morris Bridge well-field area. (Modified from Ryder and others, 1980.)

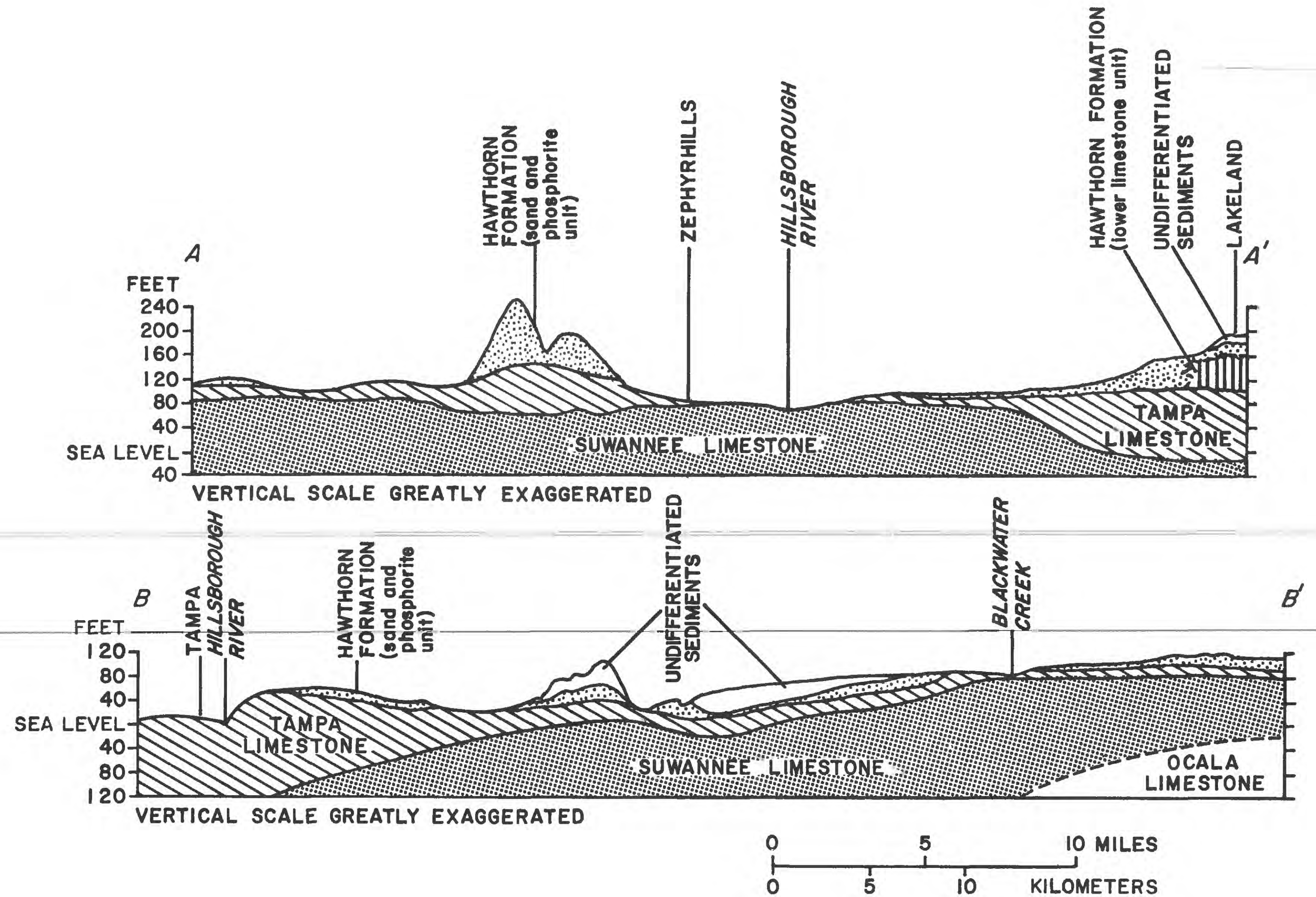

Figure 4.--Geologic sections. (Location of section shown in figure 8. Modified from Carr and Alverson, 1959.)

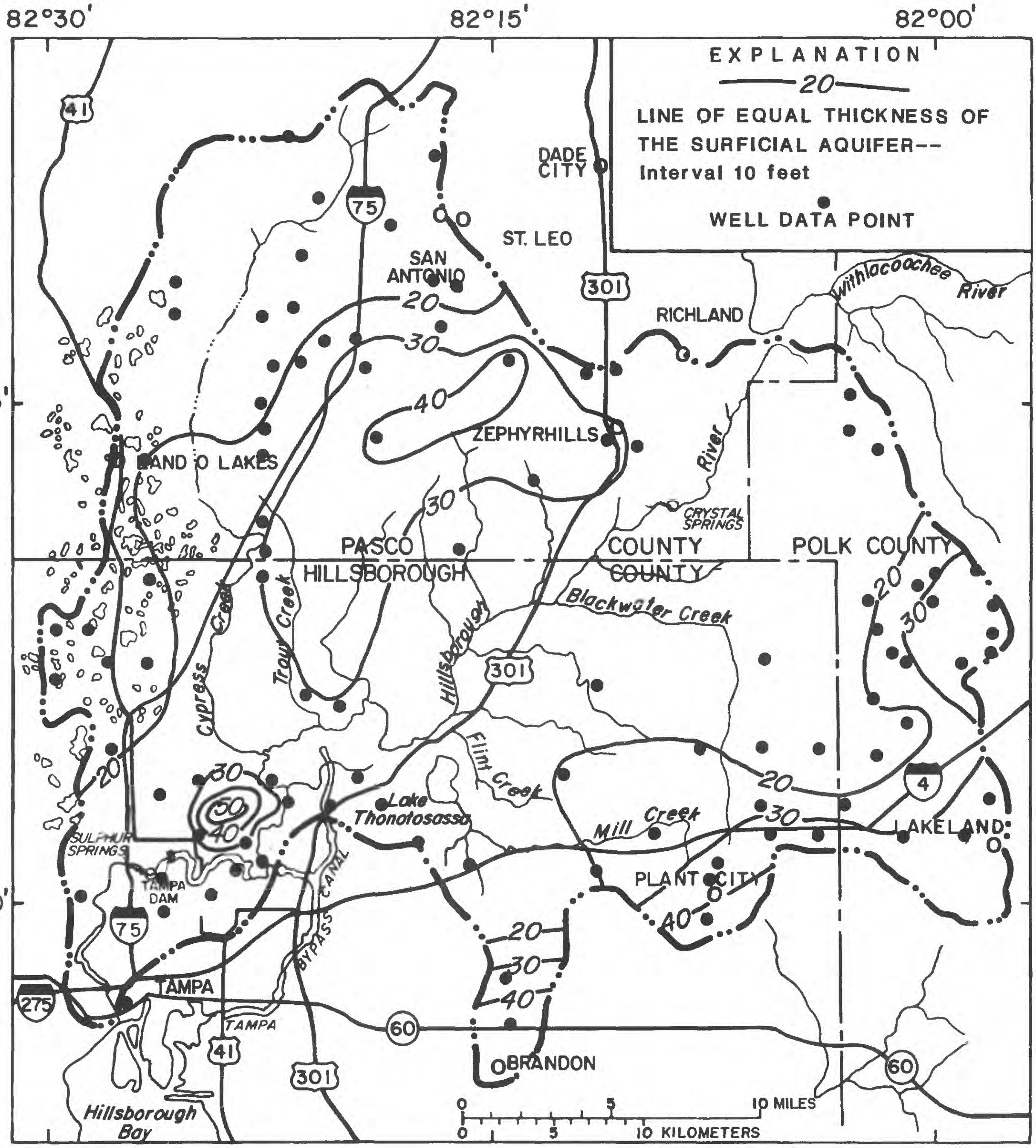

Figure 5.--Generalized thickness of the surficial aquifer.

The configuration of the water table in the surficial aquifer (fig. 6) reflects, in a subdued manner, the surface topography. The altitude of the water table ranges from a high of about 160 feet in the extreme eastern part of the basin to less than 10 feet near the mouth of the Hillsborough River. Ground-water flow is downgradient and normal to the contour lines. The flow trends southward and westward except near stream channels, lakes, and low swampy areas where water flows laterally to these depressions rather than following regional patterns.

Major sources of recharge to the surficial aquifer are: (1) rainfall, (2) upward leakage from the Upper Floridan aquifer along the Hillsborough River and Cypress Creek where the altitude of the potentiometric surface is higher than the water table (fig. 7) in the surficial aquifer, and (3) infiltration of irrigation water. Major types of discharge from the surficial aquifer are: (1) evapotranspiration; (2) downward leakage in the central and eastern parts of the study area where the altitude of the water table is higher than the potentiometric surface of the Upper Floridan aquifer (fig. 7); and (3) seepage into streams, drainage ditches, lakes, and swamps.

Intermediate Aquifer and Confining Beds Unit

The intermediate aquifer and confining beds unit is between the surficial and Upper Floridan aquifers (fig. 3). The aquifer consists of sandy and clayey limestone and dolomite beds in the Hawthorn Formation and in the upper part of Tampa Limestone that are interbedded with discontinuous lenses of sand and clay (Corral and Wolansky, 1984). Figure 8 shows where the Hawthorn Formation and Tampa Limestones are at or near land surface. The upper confining bed within the unit consists of sandy clay and marl and immediately underlies the surficial aquifer. The confining bed retards downward movement of water from the surficial aquifer to the intermediate aquifer, where present, or to the Upper Floridan aquifer. The confining bed is areally persistent in most of the basin except in stream valleys where it may be thin or absent and in the northwest and extreme western section where it is absent or breached by numerous lakes and sinkholes. The thickness of the upper confining bed generally ranges from about 1 to 20 feet and averages about 5 feet.

Where the interbedded permeable and poorly permeable sand and carbonate material are of great enough thickness, the beds function regionally as an aquifer. The aquifer is an important source of water south of the study area. Within most of the Hillsborough River basin, however, the water-bearing beds within the unit generally are not thick enough to have any potential as a water supply and contribute to the thickness of the upper confining bed of the Floridan aquifer system.

Floridan Aquifer System

The Floridan aquifer system is the most productive aquifer in the basin. The aquifer is composed of a thick, stratified sequence of limestone and dolomite. The Floridan aquifer system is defined by Ryder (1984) to include, in

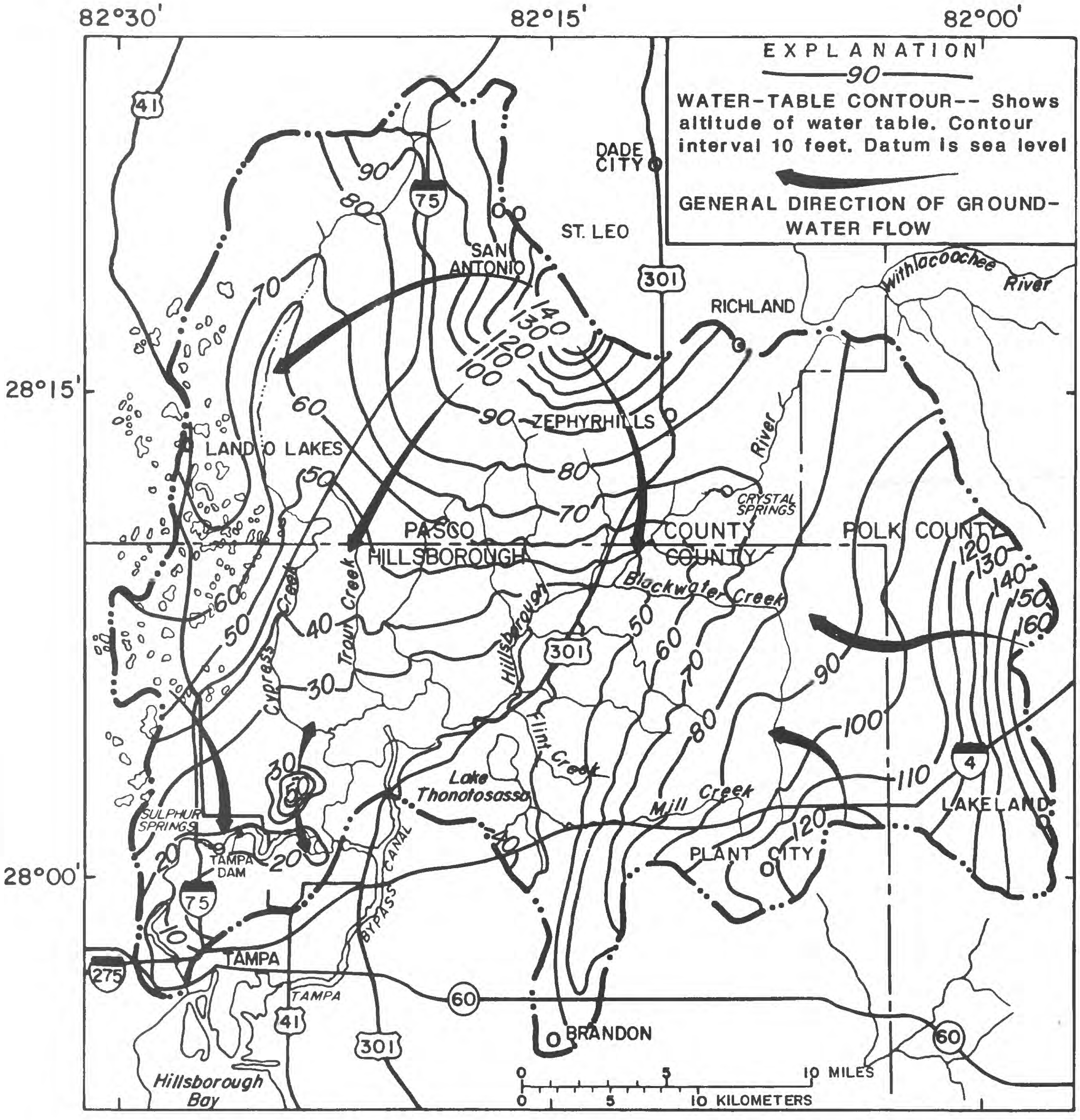

Figure 6.--Altitude of the water table in the surficial aquifer, September 1980. (Modified from Yobbi, Mills, and Woodham, 1981.)

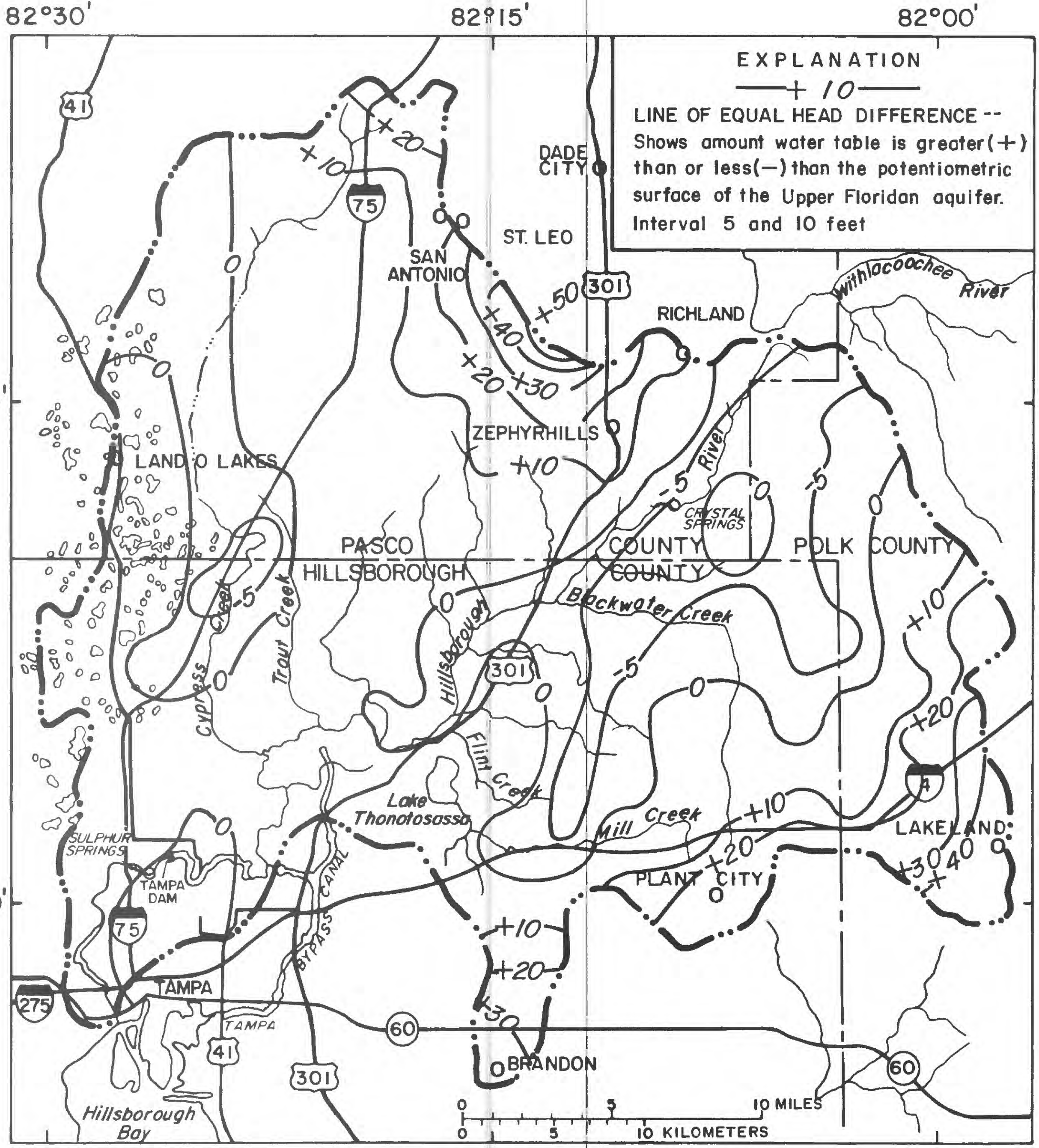

Figure 7.--Head difference between the water table in the surficial aquifer and potentiometric surface of the Upper Floridan aquifer, September 1980.

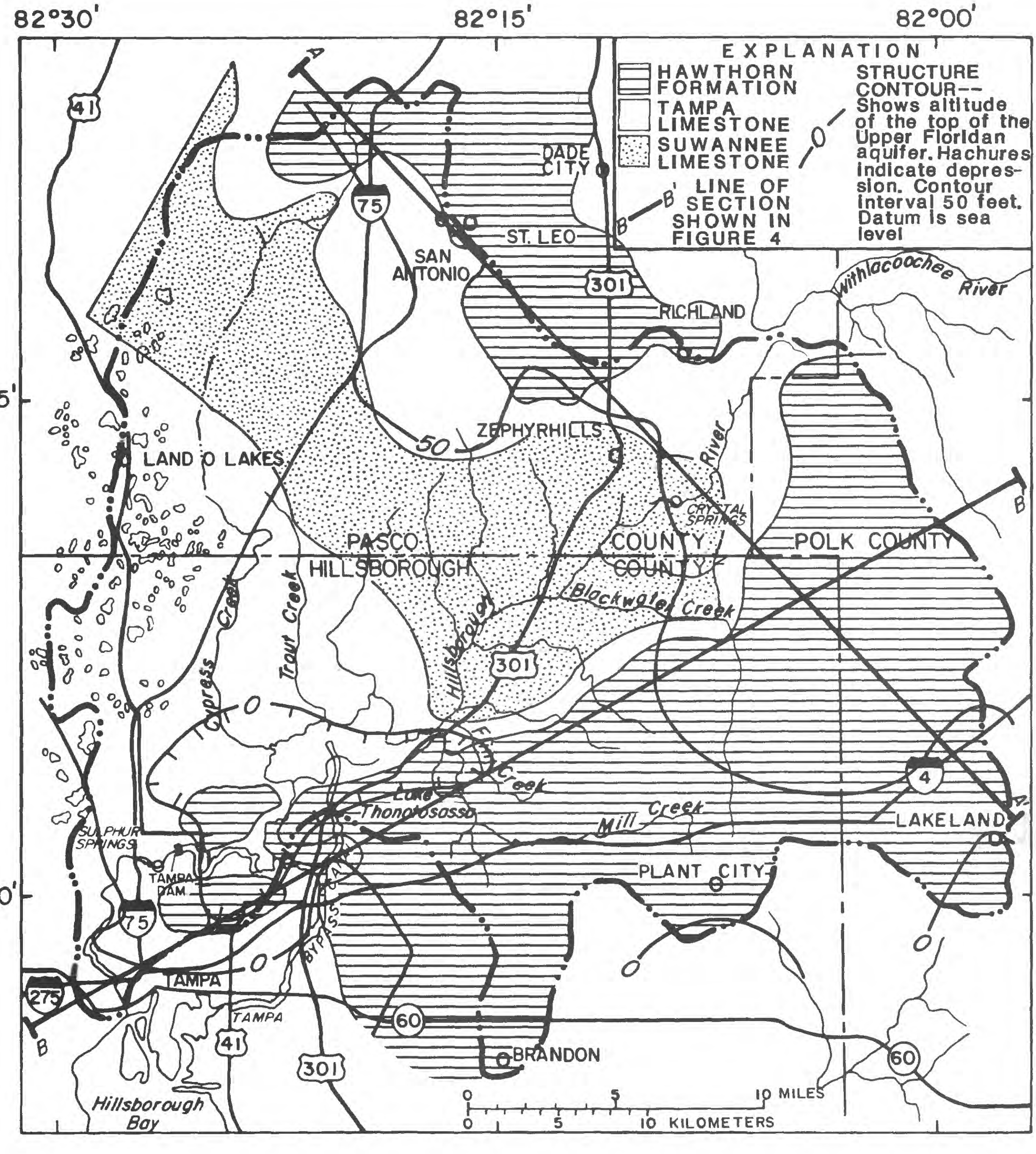

Figure 8.--Altitude of the top of the Upper Floridan aquifer (from Buono and Rutledge, 1978) and subcrops of geologic units (from Carr and Alverson, 1959).

ascending order, all or parts of the Oldsmar and Avon Park Formations, the Ocala and Suwannee Limestones, and permeable parts of the Tampa Limestone that are in hydrologic connection with the rest of the aquifer system (fig. 3). The Floridan aquifer system is subdivided into three parts. In this report, the top of the Floridan aquifer system (Upper Floridan aquifer) is a limestone defined as the first areally persistent rock of Miocene age, or older, below which clay confining beds do not occur. This surface generally coincides with the top of the Tampa Limestone or, where the Tampa is not present, the top of the Suwannee Limestone. Underlying the Upper Floridan aquifer is the middle confining bed that generally occurs in the Avon Park Formation where persistent intergranular anhydrite and gypsum occur. The Lower Floridan aquifer, which is in the Oldsmar Formation, contains highly mineralized water and is not used as a source of water in the study area.

The upper limestone and dolomite sequence functions as a single hydrogeologic unit. The altitude of the top of the Upper Floridan aquifer ranges from about 100 feet above sea level in the north to about sea level in the south (figs. 3 and 4), and its average thickness is about 1,100 feet.

Potentiometric Surface, Ground-Water Movement, Recharge, and Discharge

The potentiometric surface represents levels to which water would rise in tightly cased wells that tap the Upper Floridan aquifer. Uniformity in spacing of potentiometric-surface contours is an indication of uniformity in geology, transmissivity, recharge, and discharge. Close spacing of contours and potentiometric highs generally indicate low transmissivity or local recharge. Conversely, wide spacing of contours and lows in the potentiometric surface generally indicate high transmissivity or local discharge.

The altitude of the potentiometric surface of the Upper Floridan aquifer for September 1980, representing wet season conditions, is shown in figure 9. The surface ranges in altitude from about 110 feet above sea level in the eastern part of the basin to less than 5 feet above sea level near the mouth of the Hillsborough River. The potentiometric surface slopes toward the mouth of the Hillsborough River from potentiometric-surface highs centered in Polk County on the eastern boundary of the basin and in the northwestern part of the basin. Between the two highs is a reentrant that generally follows the Hillsborough River. The reentrant is most pronounced southwest of Crystal Springs.

The regional gradient and direction of flow in the Upper Floridan aquifer trends to the west and south (fig. 9). The arrows represent the general direction that water moves through the aquifer. On the assumption that the aquifer exhibits steady-state, two-dimensional flow and that the aquifer is homogeneous and isotropic, flow lines were drawn to intersect the potentiometric-surface contours at right angles. The flow lines start at the potentiometric-surface highs on the eastern boundary and in the northern part of the basin. From these highs, flow lines converge at principal points of discharge. Two of these points of discharge are at well fields. Their discharge rates are given below in terms of millions of gallons per day and inches per year. The discharge or pumpage, in inches per year, is prorated

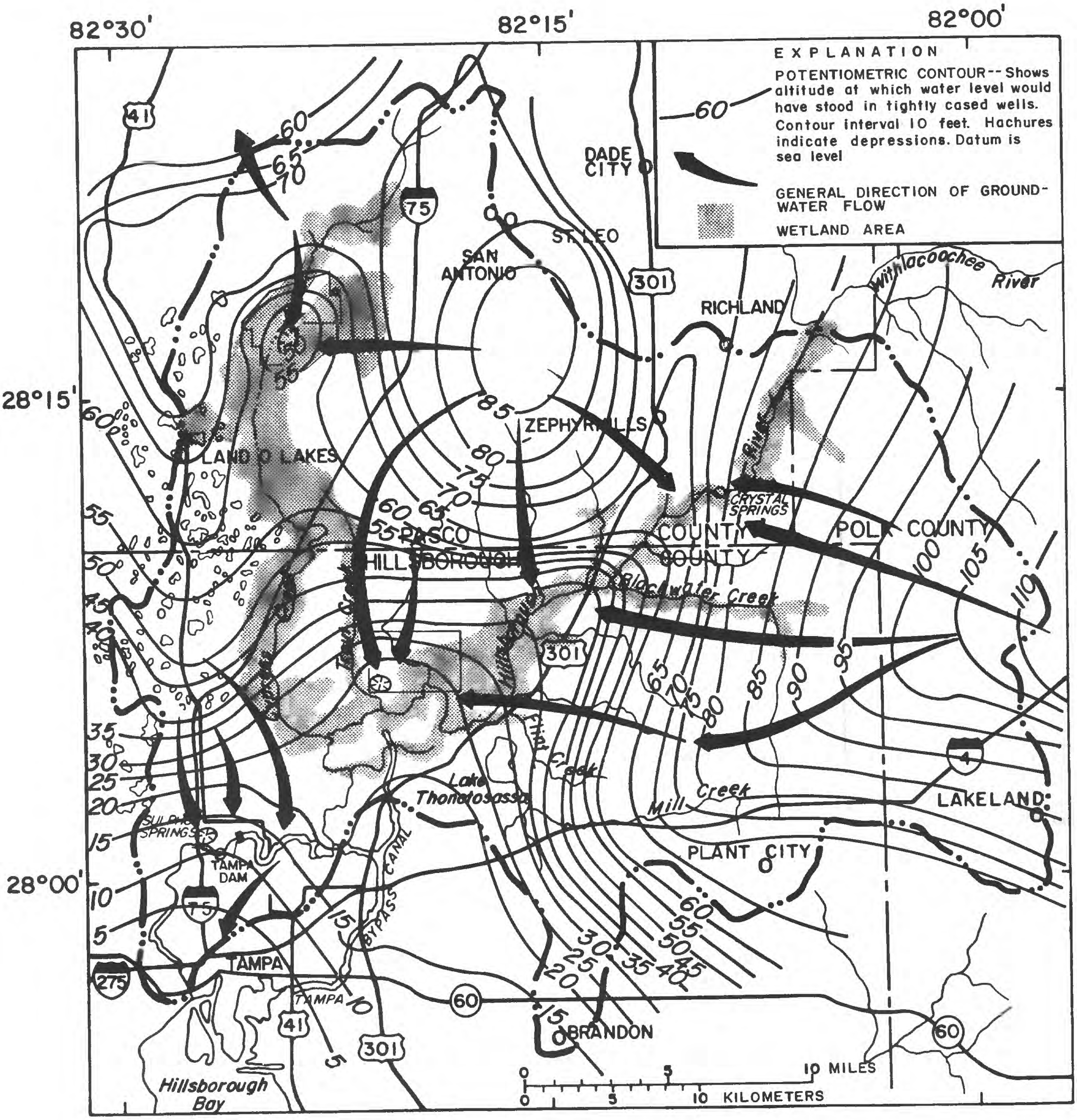

Figure 9.--Altitude of the potentiometric surface of the Upper Floridan aquifer (modified from Yobbi, Woodham, and Schiner, 1981) and generalized flow lines and wetland areas, September 1980.

over the entire drainage basin, although the effects are local. Well-field pumpage was the average daily rate in 1982 (Duerr and Sohm, 1983).

Artificial Discharge
(well-field pumping)

Well field	Pumpage Mgal/d	in/yr
Cypress Creek	30	0.9
Morris Bridge	15	0.5

Other points of discharge are at springs and wetland areas. Natural discharge at Crystal Springs has been measured periodically since 1923. Average discharge shown below is based upon 350 measurements. Discharge at Sulphur Springs has been measured periodically starting in 1917. The average discharge shown below is based upon 23 years of continuous record from 1959-82. Discharges from upward leakage in the Hillsborough River wetlands and Cypress Creek wetlands (fig. 9) were estimated from the differences in streamflow measurements made upstream from and downstream from the wetlands in June 1983 and from simulations of the ground-water flow system by Ryder and others (1980) and Hutchinson (1984). Natural discharge, in inches per year, is prorated over the entire 690-mi^2 drainage basin and indicated below.

Natural Discharge
(springs and wetland areas)

Discharge point	Discharge Mgal/d	in/yr
Crystal Springs	38	1.2
Sulphur Springs	27	0.8
Hillsborough River wetlands	20	0.6
Cypress Creek wetlands	20	0.6

HILLSBOROUGH RIVER BASIN

The Hillsborough River drains 690 mi^2 of land. During periods of high water, the Withlacoochee River (fig. 1) may overflow into the Hillsborough River basin east of Richland. The Hillsborough River's average slope, from its headwaters to Tampa Dam, is 1.8 ft/mi. Upstream from Blackwater Creek to the Tampa Dam, the slope is 1.3 ft/mi. Numerous lakes occur along the western basin divide north of Tampa. The largest lake is Lake Thonotosassa, east of Temple Terrace (fig. 1).

Crystal Springs, southeast of Zephyrhills (no. 9, fig. 1), supplies the major portion of the discharge in the Hillsborough River during low-flow periods. Average discharge for Crystal Springs, based on 350 measurements made between 1923 and 1982, is about 59 ft^3/s. The Hillsborough River at Morris Bridge (no. 5, fig. 1), near the southeastern corner of Morris Bridge well field, drains about 375 mi^2. The Hillsborough River near Tampa, at the Tampa Dam (no. 1, fig. 1), drains about 650 mi^2. Since May 1979, water from the river has been diverted occasionally during periods of high flow into Hillsborough Bay by way of the Tampa Bypass Canal (fig. 1).

Principal tributaries to the Hillsborough River are New River, Trout Creek, and Cypress Creek on the north and Blackwater Creek and Flint Creek on the south. Together, New River and Trout Creek have a combined drainage area of about 50 mi^2 (Foose, 1981).

Cypress Creek rises in Pasco County, northwest of San Antonio, and flows southwest and south through a region of lakes and marshes to the Hillsborough River where it discharges through a large swampy area. Blackwater Creek rises west of Lakeland and flows north and west to the Hillsborough River. Flint Creek, the outlet of Lake Thonotosassa, flows north approximately 2 miles tc the Hillsborough River. A summary of the principal drainage basins, their size, and average discharge is given in table 2.

SEISMIC-REFLECTION SURVEY ALONG THE HILLSBOROUGH RIVER

Continuous seismic-reflection data were collected along selected reaches of the Hillsborough River between Hillsborough Bay and Trout Creek (fig. 1) to define the configuration and thickness of shallow sedimentary layers underlying the river. It was not possible to collect continuous data upstream of the confluence of the Hillsborough River and Trout Creek due to logs and vegetation in the river channel. The seismic profiling was conducted over a distance of about 25 miles using a uniboom (high-resolution boomer) whose energy was capable of penetrating 200 feet of sediment with a resolution of 1 to 3 feet.

The continuous-reflection technique uses a boat to tow an energy source that emits acoustical impulses or pressure waves at regular intervals. Each transmitted impulse, or seismic wave, is reflected from layer interfaces that have different acoustic characteristics, such as the water, channel bottom, and subsurface layers that have different densities. The reflected acoustic waves are received by a line of hydrophones that convert them to electrical signals and transmit them to an amplifier and band-pass filter before being displayed on a variable-density analog recorder. The recorder display is a permanent paper record of the reflected signals that shows the bottom and subbottom in cross-sectional view.

Continuous lateral definition of sedimentary layers by seismic reflection aids in interpretation of contacts between geologic units. Interpretation of seismic data requires knowledge of local geology and of the average seismic velocities for the geologic unit that is penetrated. The configuration of the sediment-water interface, thickness of the surficial deposits, and configura-

Table 2.--Principal drainage basins and average discharge within the Hillsborough River basin

[mi^2, square mile; ft^3/s, cubic foot per second; in., inch]

Index No. (fig. 1)	Station name	Approximate drainage area (mi^2)	Mean discharge (ft^3/s)	Unit runoff (in.)	Period of record
1	Hillsborough River at Tampa Dam	650	593	12.39	1939-78
2	Hillsborough River near Temple Terrace	630	(1)	(1)	
3	Cypress Creek near Sulphur Springs	160	90.4	7.67	1964-82
4	Trout Creek near Sulphur Springs	23	18.3	10.80	1974-82
5	Hillsborough River at Morris Bridge	375	240	8.69	1973-82
6	Flint Creek near Lake Thonotosassa	60	35.7	8.08	1957-58, 1971-80
7	New River near Zephyrhills	15	8.98	10.16	1964-74
8	Hillsborough River near Zephyrhills	220	257	11.62	1939-82
9	Blackwater Creek near Knights	110	82.3	10.16	1951-82
10	Crystal Springs near Zephyrhills	--	2/58.7	--	

1/Stage only. Occasional instantaneous discharge measurement.
2/Average of 353 measurements made between 1923 and 1983.

tion of the top of limestone have been interpreted from the seismic profiles by tracking distinctive reflecting beds across the seismic record from known or inferred points.

Seismic-profile records for subreaches of the Hillsborough River are shown in the supplemental data section. Geologic sections constructed from the seismic records are shown in figure 10. Locations of the subreaches are shown in figure 1. The sections show the riverbed profile, the thickness of the surficial deposits, and the top of the limestone. The configuration of the riverbed profile and top of persistent limestone have been interpreted from the seismic profiles.

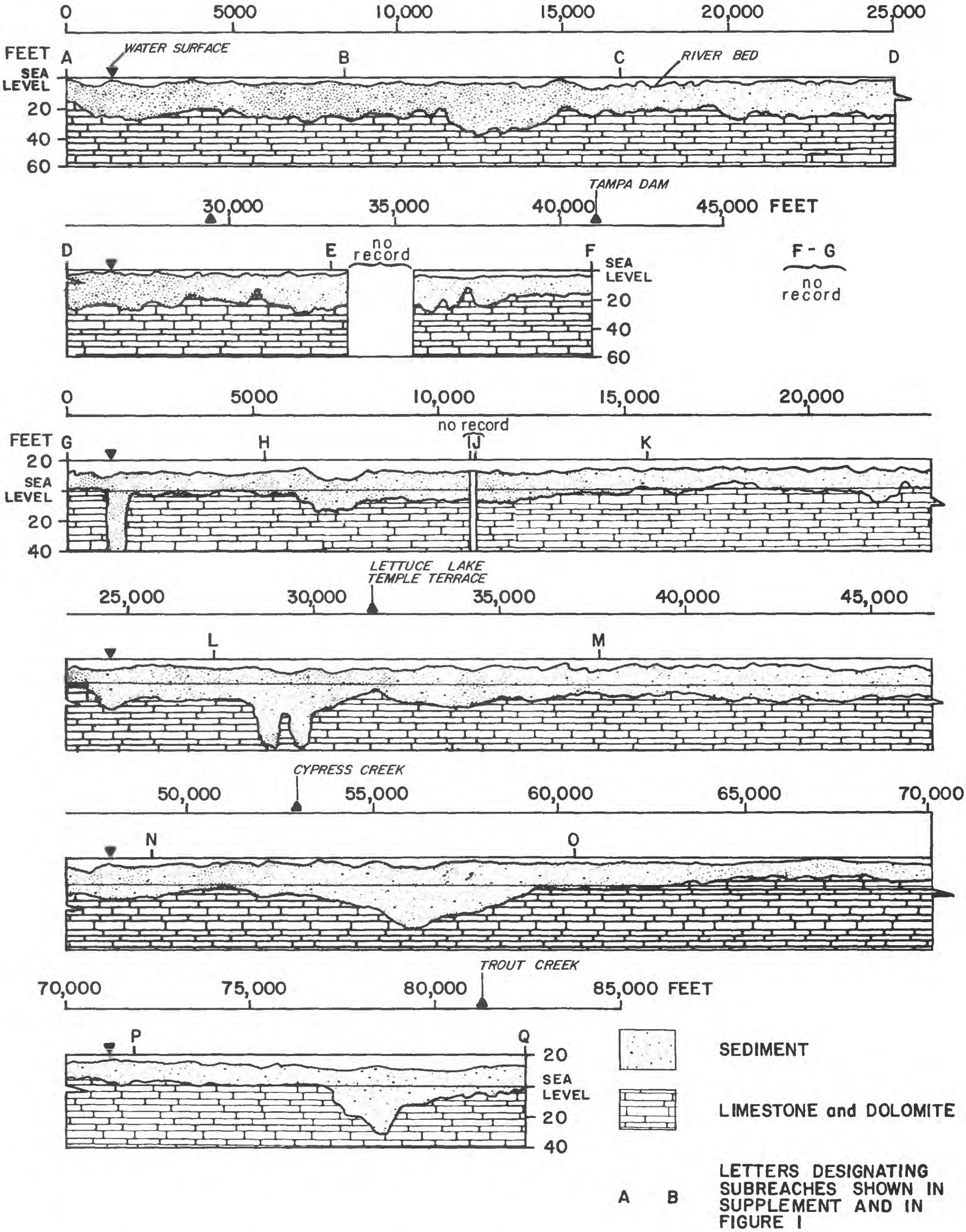

Figure 10.--Generalized geologic sections of the Hillsborough River survey defined from seismic profile records. (Line of profile is shown in figure 1.)

The irregular surface of the top of limestone is characteristic of buried karst. A significant erosional feature is apparent in the seismic record about 1 mile south of the confluence of the Hillsborough River with Trout Creek (river distance 77,000 to 79,000 feet, fig. 10). The erosional feature is a sinkhole that penetrates the Tampa Limestone. The sinkhole was probably formed by development of large solution openings in the limestone followed by collapse or subsidence of the roofs of these openings. Several sinkholes were reported in the river bottom downstream from Fletcher Avenue by Goetz and others (1978, p. 6). These determinations were based upon a profile of the river bottom from a bathymetric survey. The seismic-profile record confirms the existence of the sinkholes reported by Goetz and others (1978) and Stewart and Mills (1984) in subreaches G-H and L-M. Two additional sinkholes are probably in subreach K-L near river distance 29,000 feet. The poor quality of the seismic record in some areas precluded positive identification or verification of other sinkholes. It is also possible that the seismic profile was not along the same line as the bathymetric survey.

HYDRAULIC CONNECTION BETWEEN THE HILLSBOROUGH RIVER AND THE UPPER FLORIDAN AQUIFER

There have been several studies within the Hillsborough River basin that have included an evaluation of the connections between the aquifer and the river. Some of these data appear to be contradictory. The interpretations that follow are based upon an integration of previous studies and data collected as part of the study.

Results of the seismic survey and the studies of Stewart and Mills (1984) and Goetz and others (1978) indicate the occurrence of numerous sinkholes that are potential paths for connection between the river and the aquifer. The degree of connection between the Hillsborough River and its tributaries and the Upper Floridan aquifer depends on the leakance properties of the riverbed material and the differences between stages of the rivers and water levels of the Upper Floridan aquifer. Within the basin, there are areas where water from the Upper Floridan aquifer is seeping upward into the Hillsborough River and its tributaries and areas where stream water is seeping downward into the Upper Floridan aquifer. The wetland areas adjacent to the Hillsborough River upstream from the confluence with Cypress Creek and wetlands along the lower reaches of Cypress Creek (fig. 9) are major areas of ground-water discharge. It is estimated that about 20 Mgal/d of water from the Upper Floridan aquifer seeps upward along the Hillsborough River and a like amount along Cypress Creek (Hutchinson, 1984). A large amount of this discharge is lost to evapotranspiration.

Figure 11 shows the influence of the Tampa Bypass canal on the potentiometric surface of the Upper Floridan aquifer. Knutilla and Corral (1984) discussed the connection between the Hillsborough River near Harney Canal (fig. 11) and the Upper Floridan aquifer. They showed that water levels in selected wells near the river and the stage of the river are virtually the same and that canal construction has probably enhanced the hydraulic connection between the river and the Upper Floridan aquifer. Geraghty and Miller, Inc. (1982), described an aquifer test that pumped the standing water from

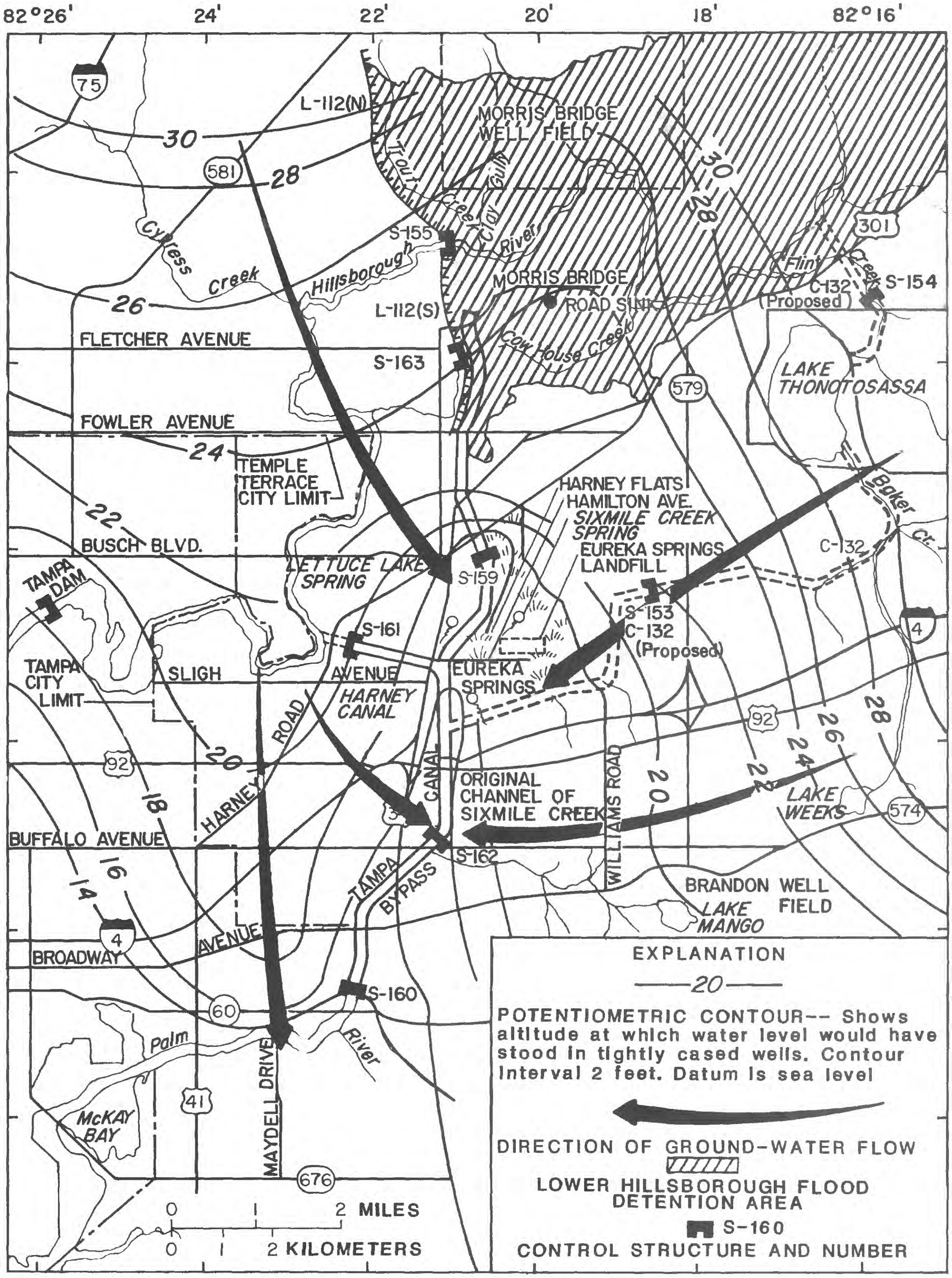

Figure 11.--Potentiometric surface of the Upper Floridan aquifer, May 1983, in the vicinity of the Tampa Bypass Canal. (From Knutilla and Corral, 1984.)

Harney Canal that breaches the Upper Floridan aquifer near structure S-161 (fig. 11) during a period when water was not being diverted through the canal. Water was pumped into the Hillsborough River. Their analysis of test data (drawdown in the Upper Floridan aquifer and a flow net) showed that approximately 0.5 Mgal/d (about 2 percent of the pumpage) was recirculated between the river and canal during the test period. The analysis substantiates a connection between the river and the Upper Floridan aquifer near structure S-161.

An evaluation of the connection between the Hillsborough River and its tributaries and the underlying aquifers was made for the reach between the gaging station on Morris Bridge Road and the station near Zephyrhills, sites 5 and 8 (fig. 1). The drainage area of the Morris Bridge station is 1.7 times larger than the Zephyrhills station. Based upon 10 concurrent years of record (1973-82), the average discharge at Morris Bridge is only 1.1 times larger than that at Zephyrhills, indicating a much reduced amount of runoff per square mile from the intervening drainage area.

Further inspection of the record indicates that, at times, the discharge at Morris Bridge is less than at Zephyrhills, and frequently, the increase in discharge between the two sites is less than 10 percent. Periods when the discharge at the downstream station is less than at the upstream station occur primarily during low-flow periods. Months when there is an increase in discharge between the two stations are months of higher runoff and reflect overland flow resulting from rainfall.

Data for the two gaging stations suggest that water from the river is recharging the Upper Floridan aquifer along parts of the intervening reach of stream. Loss of flow from downward seepage would account for some of the lower relative discharges at the Morris Bridge station in relation to that at the Zephyrhills station. However, ground-water flow model results (Ryder and others, 1980; Hutchinson, 1984) indicate this area to be one of upward leakage, which is probably the case throughout most of the reach. Most of the upward leakage is lost to evaporation and transpiration. According to the U.S. Fish and Wildlife Service (1982), the area is one of small relief and extensive swamps and wetlands (fig. 9) that account for the large water losses.

Hydrographs of the Hillsborough River stage at Morris Bridge and the water levels in Morris Bridge (Floridan) deep well 12, about 500 feet from the river gaging station, are shown in figure 12 for the period 1978-80. The river stages at Morris Bridge and the water levels in deep well 12 generally parallel each other. The water level in deep well 12 is generally a foot or more higher than the river stage. Occasionally, during periods of extended rainfall, the stage of the river is higher than the water level in the well. As such, the area is one of upward leakage from the Upper Floridan aquifer to the river except during periods when streamflow is high.

Records of water levels for shallow well 12, adjacent to deep well 12, were also evaluated. Shallow well 12 has open hole at depths from 20 to 25 feet, whereas deep well 12 has open hole from 238 to 520 feet. Generally, the water level in deep well 12 is a few tenths of a foot higher than the water level in shallow well 12. The only exceptions were following periods of heavy

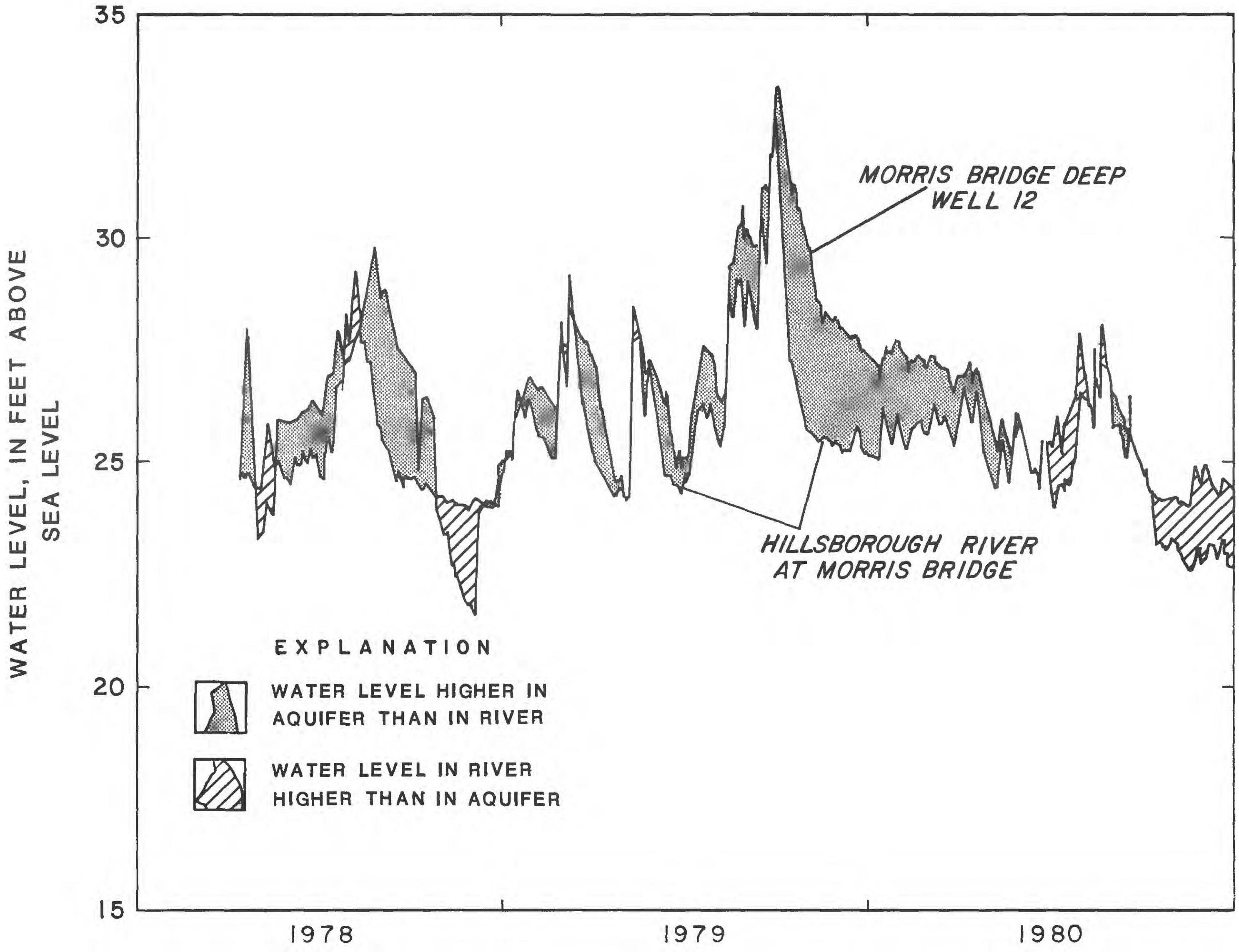

Figure 12.--Water levels in Morris Bridge deep well 12 and Hillsborough River at Morris Bridge.

rainfall when, because of more rapid recharge, the water levels in shallow well 12 were higher for short periods (1 to 3 weeks) than those in deep well 12. These data also indicate that the area is one of upward leakage from the Upper Floridan aquifer.

Because of differences in the chemical characteristics of surface and ground water, water-quality data, primarily specific-conductance data, were evaluated to help assess river-aquifer connections. The specific conductance of water is a function of the concentration of ions in solution. A large percentage of dissolved constituents in natural water are comprised of bicarbonate, carbonate, calcium, magnesium, sodium, potassium, sulfate, and silica. Specific-conductance data for the Hillsborough River during the low-flow months (April and May) were compared to data for the high-flow months (September and October). The specific conductance during periods of low flow, when most of the streamflow is derived from ground-water sources, were significantly higher than during periods of high flow (table 3). The lower values of specific conductance during the high-flow period in September and October are due to the diluting effect of rainfall because of its low specific conductance in comparison to that of ground water or streams at low flow. The Hillsborough River at Tampa has the highest average specific conductance during the low-flow season and the greatest variation between periods of low and high flow. This is the result (in part) of the occasional addition of water from Sulphur Springs that is pumped into the river above Tampa Dam. The water from Sulphur Springs is used to augment water supplies and has a specific conductance of more than 1,000 µS/cm (microsiemens per centimeter). Because of the limited ranges in specific conductance observed at the various sampling points, it is not possible to use these data to quantify the rate of ground-water seepage into the river.

Table 3.--Comparison of specific conductance for low-flow and high-flow seasons at selected stations on the Hillsborough River

[All values are in microsiemens per centimeter at 25 degrees Celsius]

Year	Near Zephyrhills		At Morris Bridge		At Fowler Avenue		At Tampa	
	Low flow	High flow	Low flow	High flow	Low flow	High flow	Low flow	High flow
1974	370	250	320	215	360	190	300	230
1975	330	220	350	195	335	200	490	190
1976	360	235	350	260	340	230	360	220
1977	340	240	320	240	340	250	975	200
1978	390	210	335	280	360	200	370	250
1979	340	220	360	220	340	225	225	230
1980	360	260	350	230	330	160	270	175
1981	320	295	330	280	330	250	970	265
1982	300	205	340	220	330	180	260	175
1983	310	220	300	250	240	220	180	220
Average	340	285	335	240	330	210	440	215

Specific-conductance data were collected at selected sites along the Hillsborough River in June 1984. Specific conductance was higher along the river near its confluence with Trout Creek than upstream from Morris Bridge. This would indicate possible upward ground-water seepage along that section of the river. The occurrence of a sinkhole at river distance 78,000 feet near Trout Creek (fig. 10) supports the probability that there is a connection between the river and the Upper Floridan aquifer near Trout Creek.

The water table-potentiometric surface difference map (fig. 7) indicates areas of recharge to and discharge from the Upper Floridan aquifer. Generally, in the reach between the confluence of Trout Creek and the Hillsborough River and Morris Bridge, the stage of the river and the potentiometric surface of the Upper Floridan aquifer are equal (fig. 12). Upstream from the confluence, the river stage and the water table are lower and the river has the potential to be a gaining stream, whereas downstream from the confluence, levels are higher than the Upper Floridan aquifer and it has the potential to be a losing stream.

To quantify the amount of gain or loss, streamflow measurements were made at several points along the Hillsborough River during low flow in April and May 1985. Differences in flow between points reflect gains or losses that may be occurring in the channel. However, measuring conditions along the channel are poor due to the very low velocities. The percentage error of the measurement may be greater than 10 percent and there may be very large percentage errors in the differences. Table 4 shows the discharge measured at three points: (1) Hillsborough River near Zephyrhills (no. 8, fig. 1); (2) Hillsborough River at Morris Bridge (no. 5, fig. 1); and (3) Hillsborough River at Lettuce Lake near Temple Terrace (no. 2, fig. 1), 2 miles downstream from Fletcher Avenue. Although there may be difference errors, the relative consistency of the differences add to their credence. The difference in flow between the station near Zephyrhills and the station at Morris Bridge is both positive and negative, indicating the reach may be either a gaining or losing reach, whereas the lower reach is consistantly showing a loss in flow. These data generally support the model results of Hutchinson (1984) that the Hillsborough River is probably a gaining river upstream of Trout Creek and a losing river downstream of Trout Creek.

Table 4.--Discharge along the Hillsborough River, April and May 1985

Date of measurement	Discharge of Hillsborough River, in cubic feet per second		
	Near Zephyrhills	At Morris Bridge	At Lettuce Lake
4-10-85	58.4	60.9	51.9
5-09-85	49.9	43.3	--
5-10-85	49.0	45.7	42.7
5-24-85	49.0	43.6	41.4

Nineteen discharge measurements made between 1945 and 1978 at the Hillsborough River at Fowler Avenue were compared with daily discharges for the Hillsborough River at the Tampa Dam (fig. 11). Seventeen measurements at Fowler Avenue had discharges that were higher than the discharge at the Tampa Dam. It was not possible to fully quantify these differences, however, because of lag time between the two stations and water going into and out of storage in the impoundment above the dam. Possible diversions into and out of the impoundment also complicated attempts to quantify the differences in discharge. Because the preponderance of measurements shows a loss in discharge, these data serve as further evidence that the river is losing water to the Upper Floridan aquifer between the two stations. The amount of seepage would vary seasonally, depending upon relative stages of the river and head in the Upper Floridan aquifer. Construction of Tampa Dam in 1945 artificially raised the level of the river relative to the potentiometric surface of the Upper Floridan aquifer. This would increase the amount of downward leakage and result in a net loss in streamflow.

Effects of the Morris Bridge Well Field on Hillsborough River Flow

The Morris Bridge well field is in northern Hillsborough County (fig. 1) in the central part of the Hillsborough River basin. Its area of 6 mi^2 is a wilderness area owned by the Southwest Florida Water Management District. The Hillsborough River flows along the southern and eastern boundaries of the well field and, for about 1 mile, flows within its southern boundary. The city of Tampa developed the well field to augment water supplied by the Hillsborough River. The well field has a peak pumping capacity of 40 Mgal/d, but 1984 pumpage rates averaged about 15 Mgal/d.

The well field is within the boundaries of the Central Swamp physiographic unit (Hutchinson, 1984). Generally, the Central Swamp is an area of low recharge and high evapotranspiration due to a high water table that is maintained by upward leakage from the Upper Floridan aquifer. The well-field flora generally consists of Florida flatwoods (pine forest-palmetto scrubland) and the southern section generally includes hardwood swamp. Land-surface altitudes in the well field range from about 50 feet above sea level in the north to about 25 feet near the Hillsborough River.

The well-field area is drained by the Hillsborough River and its tributaries, Trout Creek and Clay Gully. Drainage also occurs by way of many small shallow ponds and cypress heads that are interconnected by drainageways. Water flows through these drainageways mostly during the wet summer season when the surficial aquifer is saturated. The Hillsborough River is abruptly angular in the vicinity of the well field. This angularity is indicative of structural features within the limestone bedrock that control the course of the river (Menke and others, 1961, p. 74).

Most of the Morris Bridge well field is situated within the Lower Hillsborough Flood Detention Area, an adjunct to the Tampa Bypass Canal system. The Tampa Bypass Canal system was constructed to divert flood waters and reduce flooding of urbanized areas in Tampa and Temple Terrace. The system consists of two canals, a series of control structures, and the flood-detention area (fig. 11). The flood-detention area consists of a levee, a floodway, and the flood-storage area. The levee is about one-half mile west of the well field and parallel to Trout Creek; south of the river, it is parallel to the bypass canal. When structure S-155 on the Hillsborough River is closed, the levee causes a portion of the river flow to back up into the flood-detention area and the remainder to drain by way of the floodway to the canal system. The south loop road in the well field was built 4 to 7 feet above land surface and was provided with spillways and control gates to provide a surface-water retention system within the well field. The system allows impoundment of runoff from tributaries and the well-field area to provide a source of recharge.

On September 5, 1978, a three-step aquifer test was begun at Morris Bridge well field using five production wells withdrawing a total of 10 Mgal/d (fig. 13). Withdrawal was stepped up to 15 to 20 Mgal/d after October 4 when five additional wells began pumping. From October 10 to October 23, withdrawal decreased to 7.5 Mgal/d when four wells were inoperative, but pumping rates subsequently returned to 20 Mgal/d. On November 10, the third step of the test began with the addition of four more wells, increasing withdrawal to 27 Mgal/d. Figure 13 shows the daily pumping rates during the September to December test and pumpage for the remainder of 1978.

One of the objectives of the September to December aquifer test was to determine what effect well-field withdrawals might have on the discharge of the Hillsborough River. Examination of hydrographs of the Hillsborough River near Zephyrhills and at Morris Bridge for the test period show that river stages at both stations exhibited parallel trends (fig. 14), whereas water levels in the Morris Bridge deep well 10, a few hundred feet from the Morris Bridge gaging station, does not parallel the river levels. Figures 15 and 16 show 5-day and 1-day double-mass discharge curves, respectively, for the river near Zephyrhills and at Morris Bridge. The curves do not show any correlation between well-field pumping for 1978 and for the September to December test period. A break in the curve that showed less flow for the river at Morris Bridge during a specific well-field pumping period would be evidence of river-aquifer interconnection; however, all breaks in the curves can be explained by seasonal changes in runoff. However, the Morris Bridge gaging station is not central to the well field, and thus, the full impacts of well-field pumpage would not be measured by the station. Some of the water that may be captured due to well-field pumpage is downstream from the gage and is not reflected in the record. An evaluation of the Morris Bridge well-field area by Ryder and others (1980, p. 56) indicated that only about 0.1 percent of the well-field pumpage comes from the river. Such a low percentage change would not be detectable in the double-mass curves.

An aquifer test was conducted just south of the well field in 1972. Stewart (1977) reported on the hydrologic effects of pumping Morris Bridge Road Sink about 0.5 mile south of the Hillsborough River and about 1.5 miles south of the Morris Bridge well field (fig. 11). The limestone sink, about 200 feet deep, was pumped for 25 days at an average rate of 5.8 Mgal/d to test the possible use of the sink as a water-supply source. At the end of the test period, drawdown was 5.3 feet in the sink and 1.5 feet in an observation well 655 feet northeast of the sink. No drawdown was detected in an observation well 2,500 feet southeast of the sink. According to Stewart (1977), no change

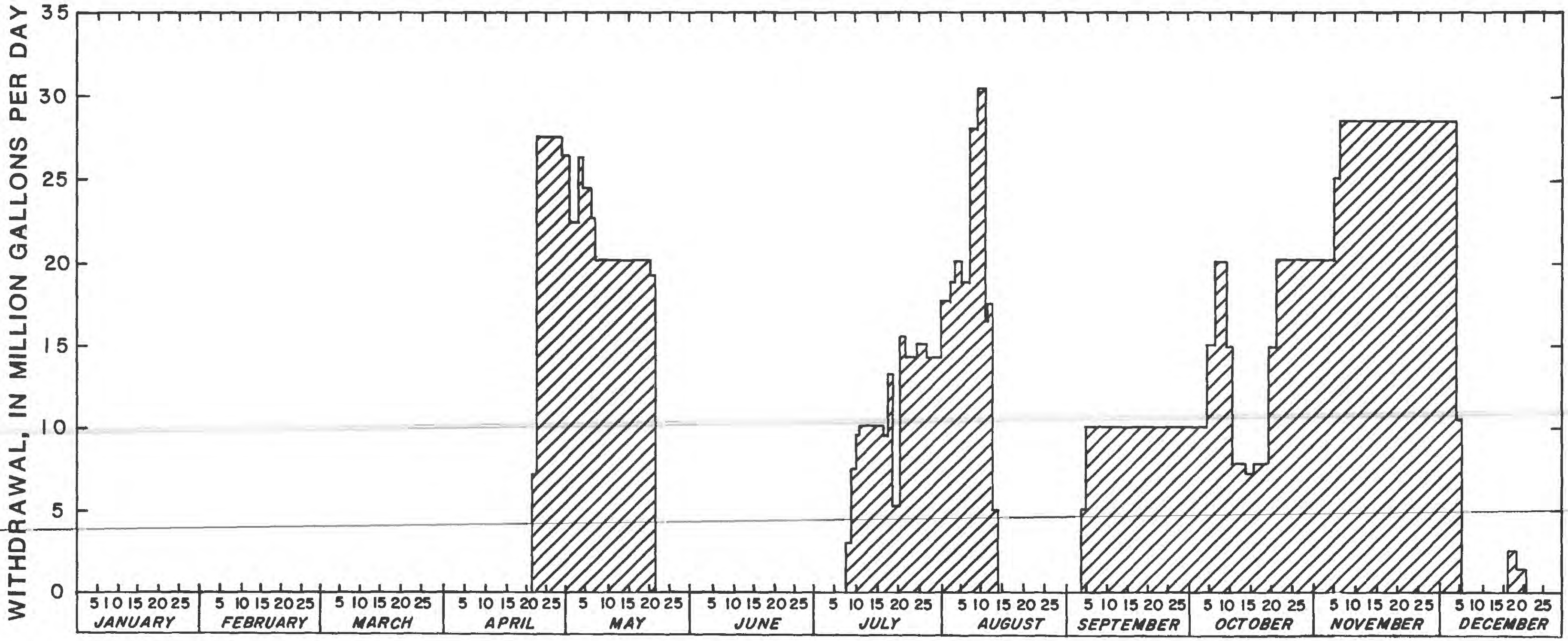

Figure 13.--Daily pumping rate at Morris Bridge well field, 1978.

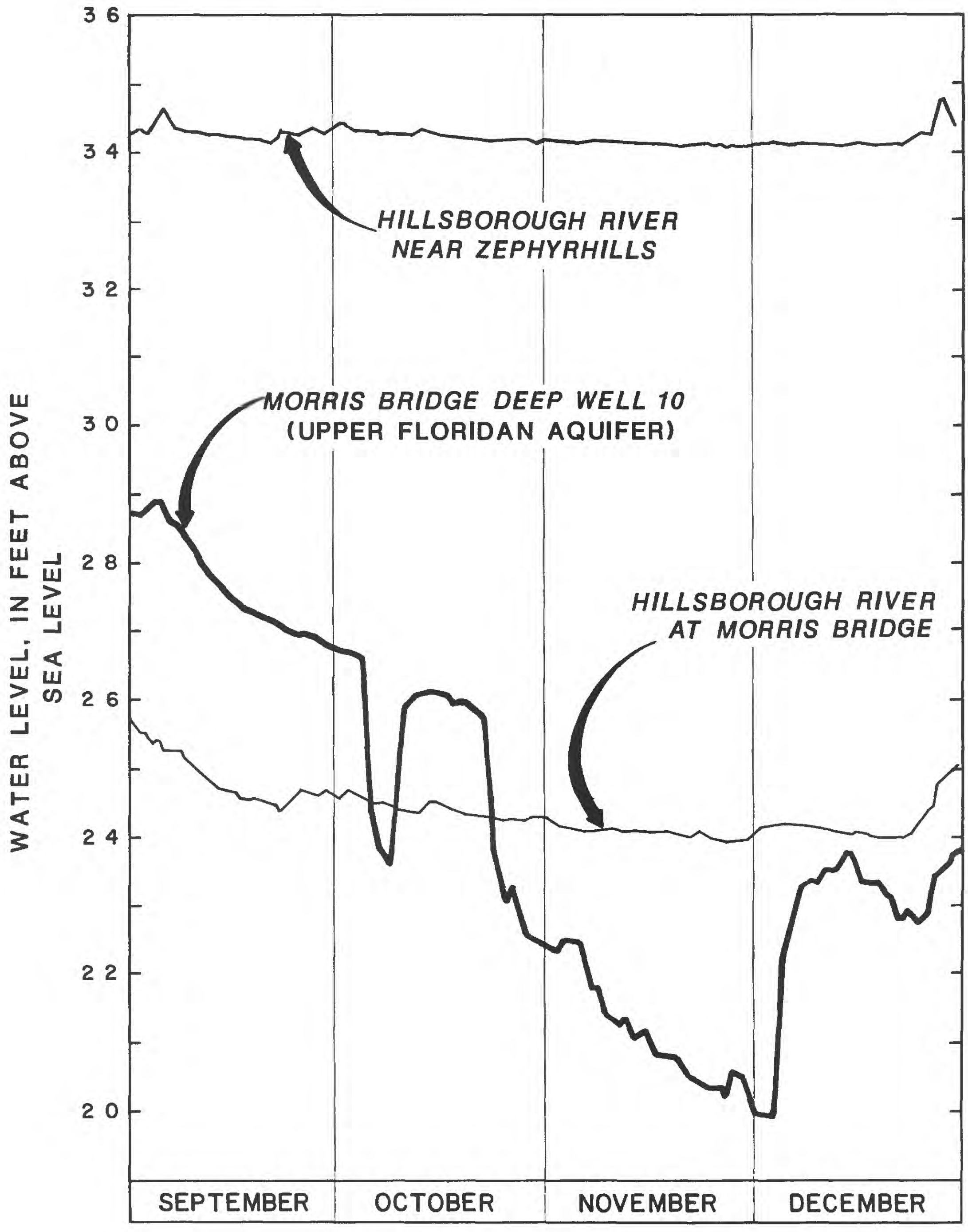

Figure 14.--Water levels during an aquifer test of the Upper Floridan aquifer at Morris Bridge well field, September to December 1978.

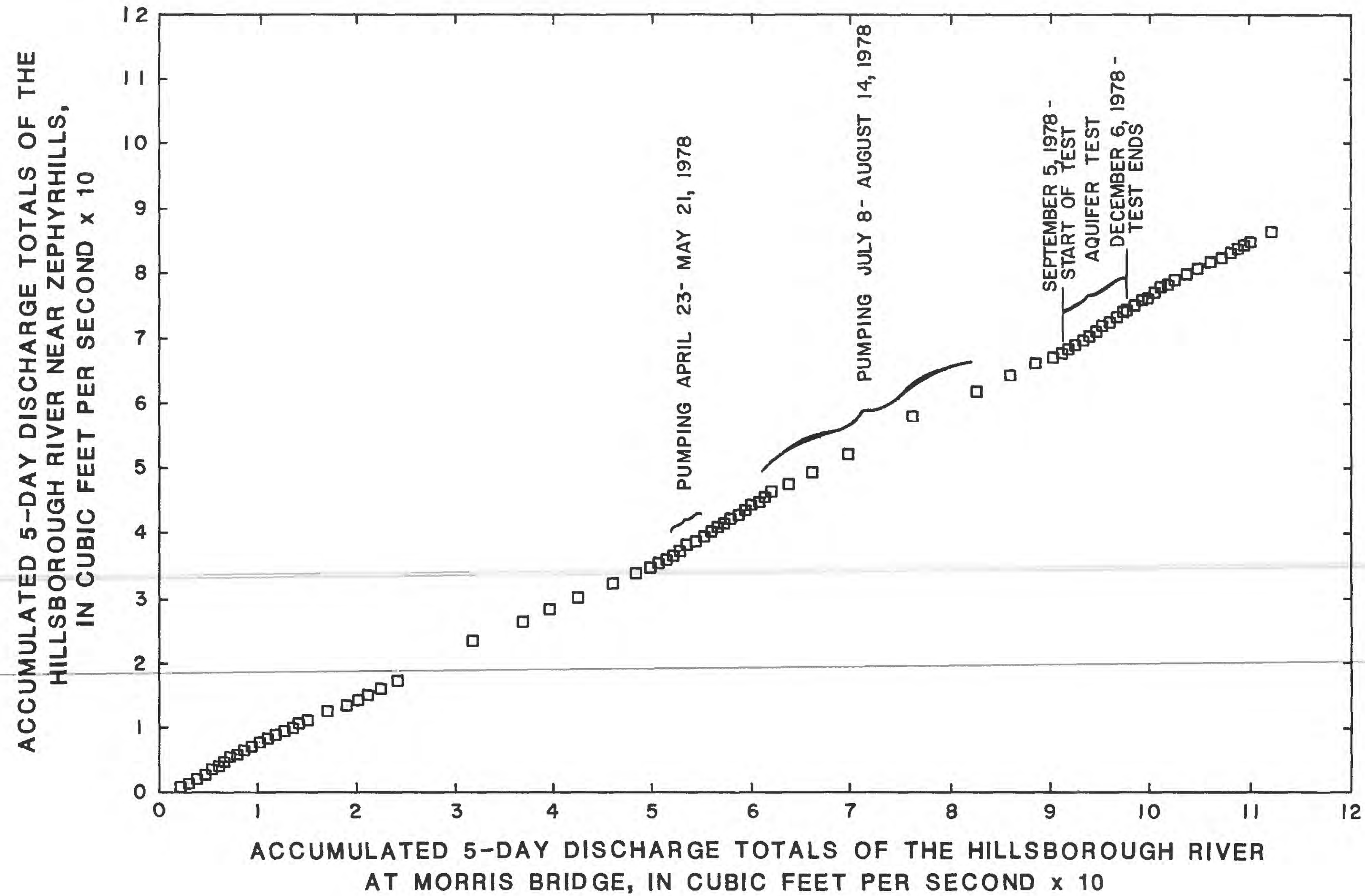

Figure 15.--Double-mass curve of 5-day sums of discharge for Hillsborough River near Zephyrhills and Hillsborough River at Morris Bridge, October 1, 1977, to February 28, 1979.

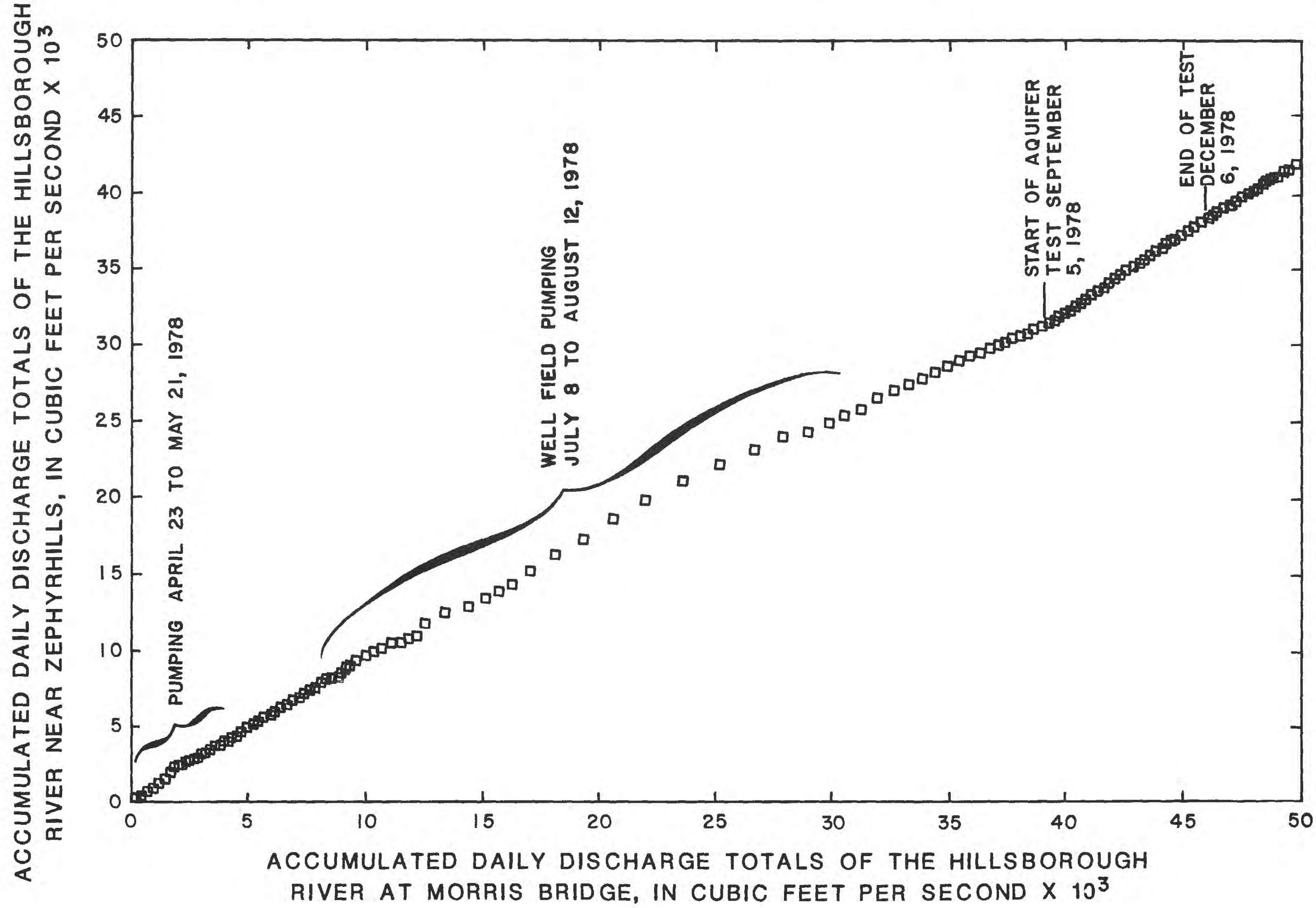

Figure 16.--Double-mass curve of daily discharge sums for Hillsborough River Near Zephyrhills and Hillsborough River at Morris Bridge, April 17, 1978, to January 13, 1979.

in stage or flow of the Hillsborough River was detected that could be attributed to pumping the sink. However, the pumping rate for the test was less than 5 percent of the river discharge and falls within the range of possible discharge measurement error.

Wolansky and Corral (1985, p. 74-85) presented the results of four aquifer tests in the Morris Bridge well field. Results of three of the tests show that the Upper Floridan aquifer is anisotropic in the horizontal plane. Following are the averages of the hydraulic characteristics determined from the tests:

Transmissivity in the major direction of anisotropy = 101,000 ft^2/d

Transmissivity in the minor direction of anisotropy = 22,000 ft^2/d

The major direction of anisotropy = north 78^o east

Leakance ranged from $1.2x10^{-3}$ to $5.3x10^{-4}$ (ft/d)/ft for individual tests. Leakance derived from a ground-water flow-model calibration of the well field by Ryder and others (1980) ranged from $8x10^{-5}$ to $5x10^{-4}$ (ft/d)/ft. A leakance of $5x10^{-4}$ (ft/d)/ft is assumed for the following computation.

The major and minor directions of anisotropy are shown in figure 17. Drawdowns for selected pumping rates were calculated along the major and minor axis using the anisotropic analytical method developed by Hantush (1966). Steady-state (long-term) drawdown was calculated along the major and minor axis using:

$$s = (Q/2\pi T_e)\ K_o\ (r/B)$$

where s = steady-state drawdown, in feet;

Q = pumping rate, in cubic feet per second;

T_e = effective transmissivity, in square feet per second;

K_o = zero-order Bessel function (tabular values in DeWeist, 1965);

r = radial distance from the pumping center, in feet; and

$B = (T_a/K'/b')^{1/2}$;

where T_a = transmissivity along the major or minor axis, in square feet per second; and

K'/b' = leakance, in feet per second per foot.

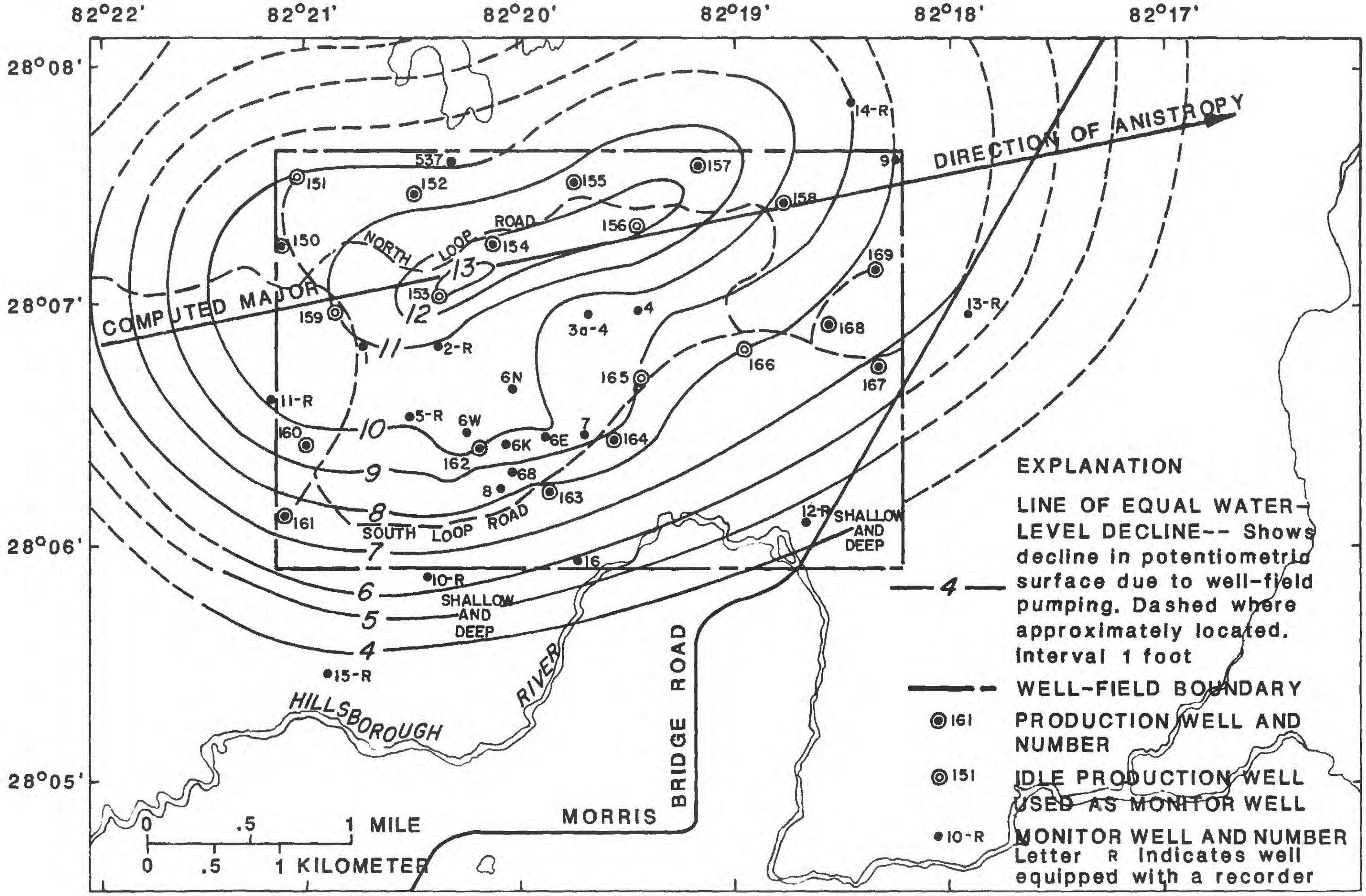

Figure 17.--Observed decline of the potentiometric surface of the Upper Floridan aquifer due to well-field pumpage for a 90-day period at Morris Bridge well field. (Modified from Tampa Water Department, 1980.)

Results of the analyses are shown in table 5. For the major transmissivity direction, drawdown was calculated at a radius of 3.5 miles, and for the minor transmissivity direction, drawdown was calculated at 1.5 miles. The radii correspond to the approximate distances between the center of the well field and the Hillsborough River east and south of the well field. The observed drawdown in the Upper Floridan aquifer for the September to December aquifer test is shown in figure 17. The calculated drawdown using a discharge of 28 Mgal/d for the two points on the axis is within 1.0 foot of the observed drawdown.

Changes in the water table in the surficial aquifer during the test are much smaller than in the potentiometric surface of the Upper Floridan aquifer. As shown in figure 18, the drawdown of the water table is generally 1 foot or less within the well-field boundary, except in the vicinity of pumping wells where a maximum drawdown of 5 feet was observed.

Table 5 shows that, for the permitted pumping rate of 18 Mgal/d, calculated drawdowns 3.5 miles east of the center of the well field and 1.5 miles to the south are 2.4 feet and 2.7 feet, respectively. For 40 Mgal/d (approximate 1982 needs of the city of Tampa), the calculated drawdowns are 5.2 feet at 3.5 miles to the east and 6.0 feet at 1.5 miles south of the well field.

Table 5.--Simulated declines of the Upper Floridan aquifer potentiometric surface using an anisotropic analytical method

$$[s = \frac{Q}{2\pi T_e} K_o\ r/B;\ T_e = 0.523\ ft^2/s]$$

Pumping rate (Q): Million gallons per day	Pumping rate (Q): Cubic feet per second	Drawdown (s) at 3.5 miles along major axis, in feet $r/B = 1.3$ and $K_o = 0.214$	Drawdown (s) at 1.5 miles along minor axis, in feet $r/B = 1.19$ and $K_o = 0.269$
10	15.5	1.3	1.5
18	27.9	2.4	2.7
20	30.9	2.6	3.0
28	43.3	3.7	4.2
40	61.9	5.2	6.0

The effect of pumping from the well field at peak capacity of 40 Mgal/d on upward seepage in the wetland area near the well field (fig. 17) was calculated. Aquifer tests of the Morris Bridge well field (Wolansky and Corral, 1985) show that leakance ranges from $0.5x10^{-3}$ to $3.0x10^{-3}$ (ft/d)/ft. The possible leakage from the Upper Floridan aquifer to the surficial aquifer that results from various head differences for a range in leakance values is given

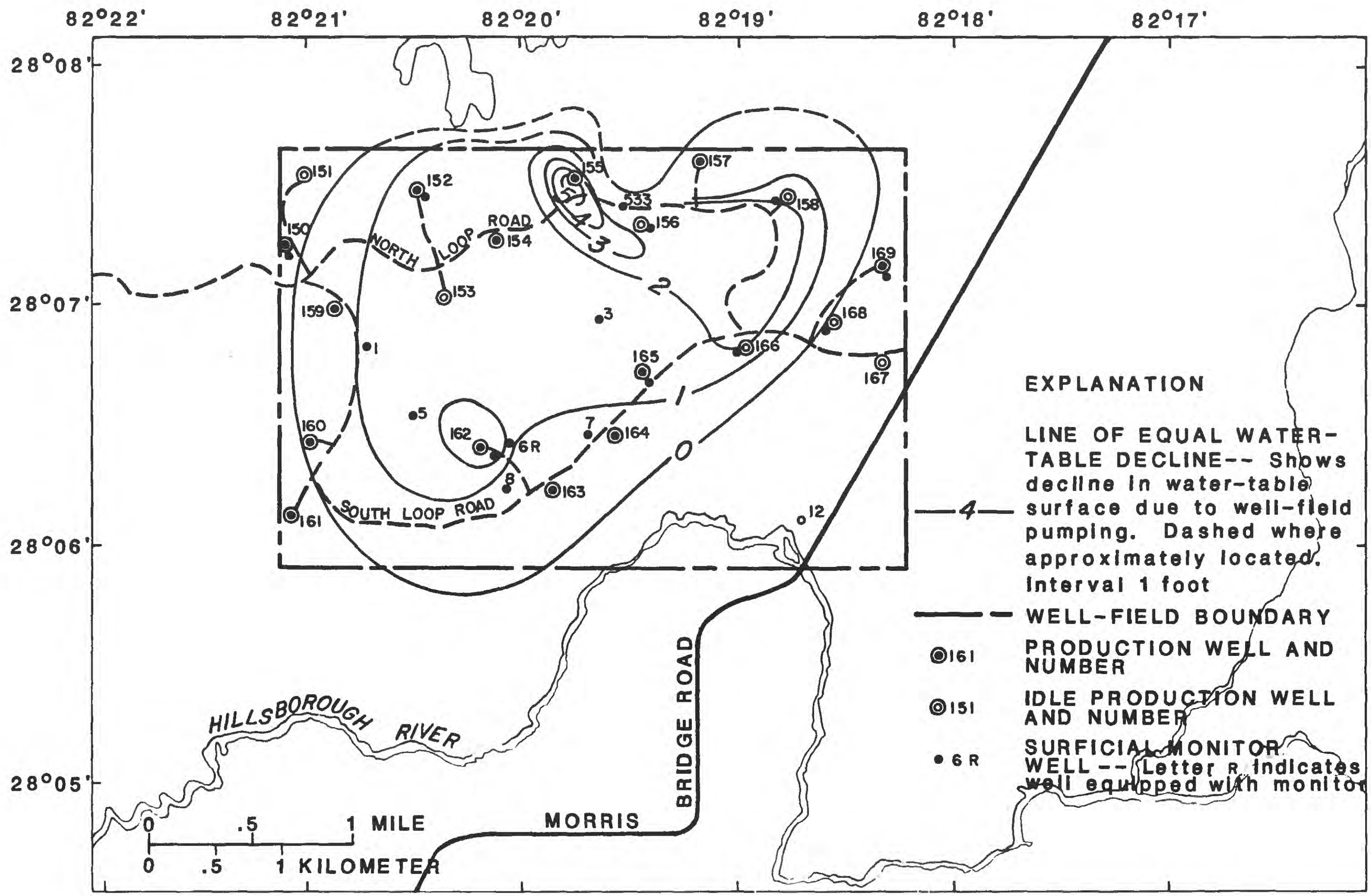

Figure 18.--Observed decline in the water table of the surficial aquifer due to well-field pumpage for a 90-day period at Morris Bridge well field. (Modified from Tampa Water Department, 1980.)

in table 6. Assuming an average decline of about 2 feet in the Upper Floridan aquifer potentiometric surface and the average leakance from the aquifer tests of $2x10^{-3}$ (ft/d)/ft, there would be approximately 10.8 Mgal/d less upward seepage occurring within the 13-mi^2 wetland area east and south of the well field (table 6). The possible reduction of 17.5 in/yr (10.8 Mgal/d) of ground-water seepage would probably have a significant impact on the wetland area.

Table 6.--Possible changes in ground-water discharge to the Hillsborough River wetlands due to pumping 40 million gallons per day from the Morris Bridge well field

[(ft/d)/ft, feet per day per foot; Mgal/d, million gallons per day; in/yr, inches per year]

Leakance, K'/b' [(ft/d)/ft]	Assumed change in head difference (feet)	Change in upward discharge	
		Mgal/d	in/yr
$0.5x10^{-3}$	1	1.4	2.2
	2	2.7	4.4
	3	4.1	6.6
	4	5.4	8.8
	5	6.8	11.0
$1.0x10^{-3}$	1	2.7	4.4
	2	5.4	8.8
	3	8.1	13.1
	4	10.8	17.5
	5	13.5	21.9
$2.0x10^{-3}$	1	5.4	8.8
	2	10.8	17.5
	3	16.2	26.2
	4	21.6	35.0
	5	27.0	43.7
$3.0x10^{-3}$	1	8.1	13.1
	2	16.2	26.2
	3	24.3	43.7
	4	32.4	52.5
	5	40.5	65.6

SUMMARY

The Hillsborough River basin encompasses an area of 690 mi^2 in west-central Florida. The Hillsborough River rises in swampy terrain in eastern Pasco County and flows 54 miles southwest to Hillsborough Bay. The Morris Bridge and Cypress Creek well fields are major municipal well fields within the basin that pumped an average of 15.3 and 30.0 Mgal/d, respectively, in 1980. Total pumpage of ground water in the basin in 1980 was 98.18 Mgal/d. Of a total 50.6 Mgal/d of surface-water withdrawn in the basin in 1980, 49.9 Mgal/d was withdrawn from Tampa Reservoir and used for public supply by the city of Tampa.

The mean annual rainfall is 53.7 inches and is distributed unevenly within the basin. About 60 percent of the annual rainfall occurs in June through September. For 1980, rainfall determined from the average of eight rainfall stations was 49.7 inches. The adjusted evapotranspiration was calculated to be 35.7 in/yr.

The principal hydrogeologic units in the basin are (1) surficial aquifer, (2) intermediate aquifer and confining beds, (3) Upper Floridan aquifer, (4) middle confining bed (or base of the Upper Floridan aquifer), and (5) Lower Floridan aquifer. The surficial aquifer consists primarily of permeable units of the undifferentiated surficial sediments of Holocene, Pleistocene, and Miocene age and, where present, permeable parts of the sand and phosphorite unit of the Hawthorn Formation. The thickness of the aquifer ranges from less than 20 feet along the eroded valley of the Hillsborough River to about 50 feet in highlands areas near San Antonio, Lakeland, and Temple Terrace and averages about 20 feet in thickness. The altitude of the water table ranges from a high of about 160 feet in the extreme eastern part of the basin to less than 5 feet near the mouth of the Hillsborough River. The upper confining bed at the base of the surficial aquifer consists of sandy clay, clay, and marl that retard the downward movement of water from the surficial aquifer to the intermediate aquifer, where present, or to the Upper Floridan aquifer. The upper confining bed generally ranges from less than 1 foot to about 20 feet in thickness and averages about 5 feet.

The intermediate aquifer consists of sandy and clayey limestone and dolomite beds in the Hawthorn Formation that are interbedded with sand and clay. Within most of the basin, the intermediate aquifer generally is not thick enough to have any potential as a water supply. However, where present, it contributes to the thickening of the upper confining bed in the southeastern and northern parts of the basin.

The Upper Floridan aquifer is the most productive aquifer in the basin and consists of a thick, stratified sequence of limestone and dolomite that has an average thickness of about 1,100 feet. The altitude of the top of the aquifer ranges from about 100 feet above sea level in the north to about sea level in the south. Its potentiometric surface ranges from about 110 feet above sea level in the eastern part of the basin to less than 5 feet above sea level near the mouth of the Hillsborough River. The Lower Floridan aquifer is not used as a source of water in the area because the aquifer contains saline water.

Continuous marine seismic-reflection data were collected along selected reaches of the Hillsborough River to define the configuration and thickness of shallow sedimentary layers that underlie the river. The riverbed profile, the thickness of the surficial deposits, and the top of the vertically persistent limestone have been interpreted from the seismic profiles by tracking distinctive reflecting beds across the seismic record. The irregular surface of the top of the limestone is characteristic of buried karst. A sinkhole several hundred feet in diameter that breaches the Tampa Limestone was identified about 1 mile south of the river's confluence with Trout Creek.

The magnitude of hydraulic connection between the Hillsborough River and its tributaries and the Upper Floridan aquifer depends on the leakance of the riverbed materials and the difference in water levels between the Upper Floridan aquifer and the river stage. Major areas of ground-water discharge near the Hillsborough River and its tributaries occur in the wetlands adjacent to the river between the Zephyrills station and Fletcher Avenue and the wetlands adjacent to Cypress Creek. An estimated 20 Mgal/d of ground water from the Upper Floridan aquifer discharges upward along the Hillsborough River and a like amount along Cypress Creek.

A comparison of discharge between the Hillsborough River at Morris Bridge and the discharge for the upstream station at Zephyrhills for the years 1975-82 shows that annual runoff per square mile of drainage area was less at Morris Bridge than at Zephyrhills. This decline in unit runoff between the Hillsborough River near Zephyrhills and the river at Morris Bridge probably is due to high evapotranspiration losses from the wetlands between gages. Shallow and deep wells in the Upper Floridan aquifer near the Hillsborough River at Morris Bridge indicate that ground water probably is discharging upward in the vicinity of the Hillsborough River near Morris Bridge.

Ground water from the Upper Floridan aquifer generally has more dissolved solids (and a higher specific conductance) than the Hillsborough River. The river has a higher specific conductance near its confluence with Trout Creek than at a site upstream of the Morris Bridge well field. The downstream measurement is where a sinkhole under the river was located by using seismic reflection. The presence of the sinkhole and the higher specific conductance of the river at this point tend to confirm that ground water is discharging into the river in the vicinity of Trout Creek.

The potentiometric surface along the river from the vicinity of Morris Bridge well field to the Hillsborough-Pasco County line generally is higher than the water table of the surficial aquifer, which indicates upward leakage of ground water along the wetlands surrounding the river and within the river channel. Downstream of the confluence of Trout Creek and the Hillsborough River to near the Tampa Dam, discharge measurements indicate leakage of river water to the Upper Floridan aquifer. A comparison of instantaneous discharge measurements of the Hillsborough River at several points from Zephyrhills to Lettuce Lake and between Fowler Avenue and the river near Tampa shows that discharge generally decreases downstream from Morris Bridge to Tampa Dam.

Morris Bridge well field in northern Hillsborough County has an area of 6 mi^2. The Hillsborough River flows past the southern and eastern boundaries of the well field and for about 1 mile flows within its southern boundary. A three-step aquifer test was conducted in 1978. One of the objectives of the test was to determine the effect of well-field withdrawals on the flow of the Hillsborough River. Results indicated no change in river flow for withdrawals up to 28 Mgal/d.

The observed drawdown from the well-field aquifer test was analyzed by use of an anisotropic analytical method. Computed drawdowns duplicated observed drawdowns within 0.1 foot. The calculated drawdown (1.5 to 1.8 feet for the pumping rate of 18 Mgal/d) in the Upper Floridan aquifer under the Hillsborough River would not change upward ground-water discharge enough to be detected by a change in river flow. Results of the test were used to estimate the possible changes in upward leakage in a 13-mi^2 wetland area. The test indicated that pumping 40 Mgal/d could reduce the upward flow by several million gallons per day.

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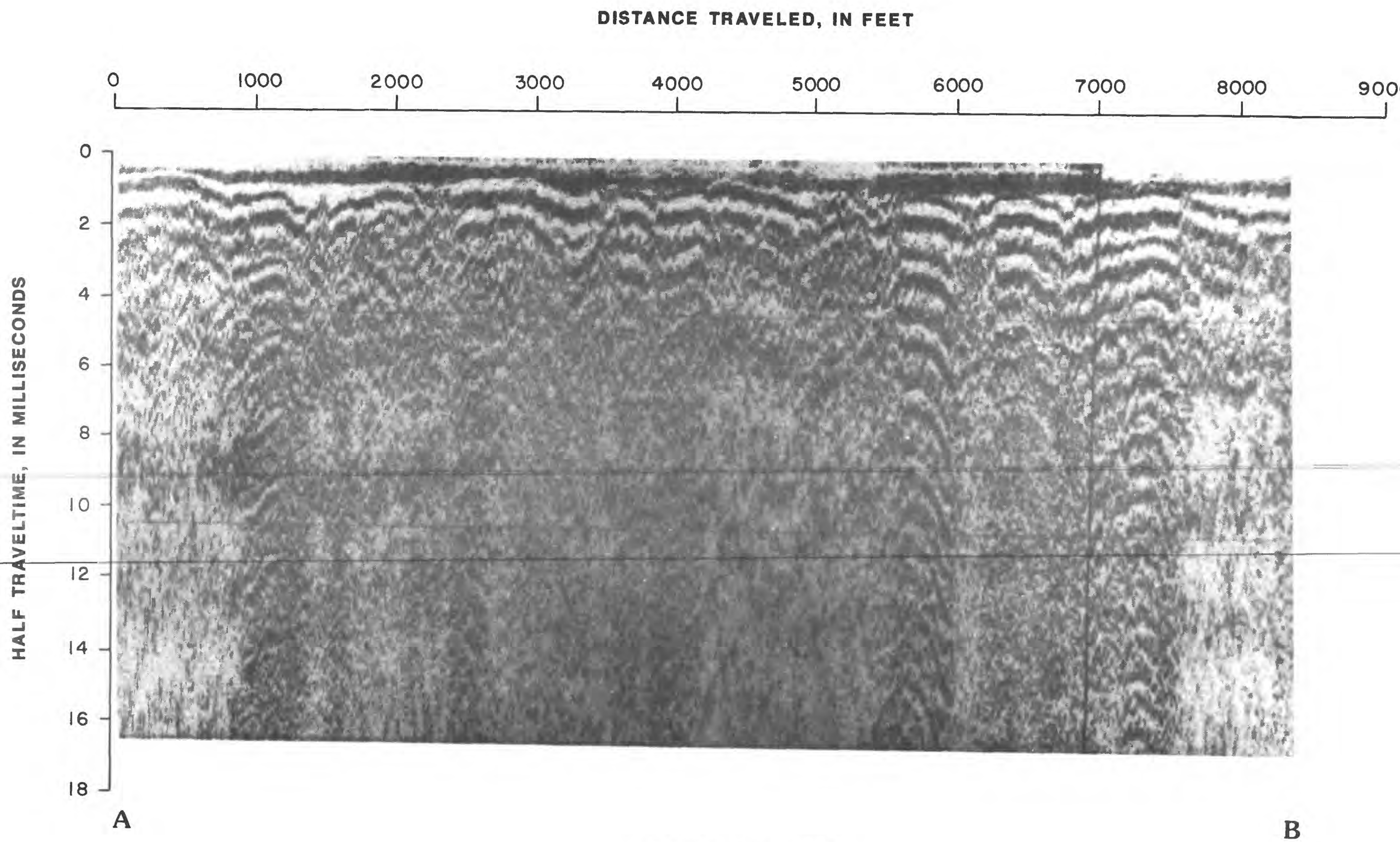
SUPPLEMENTAL DATA: SEISMIC-REFLECTION RECORD OF SELECTED REACHES OF THE HILLSBOROUGH RIVER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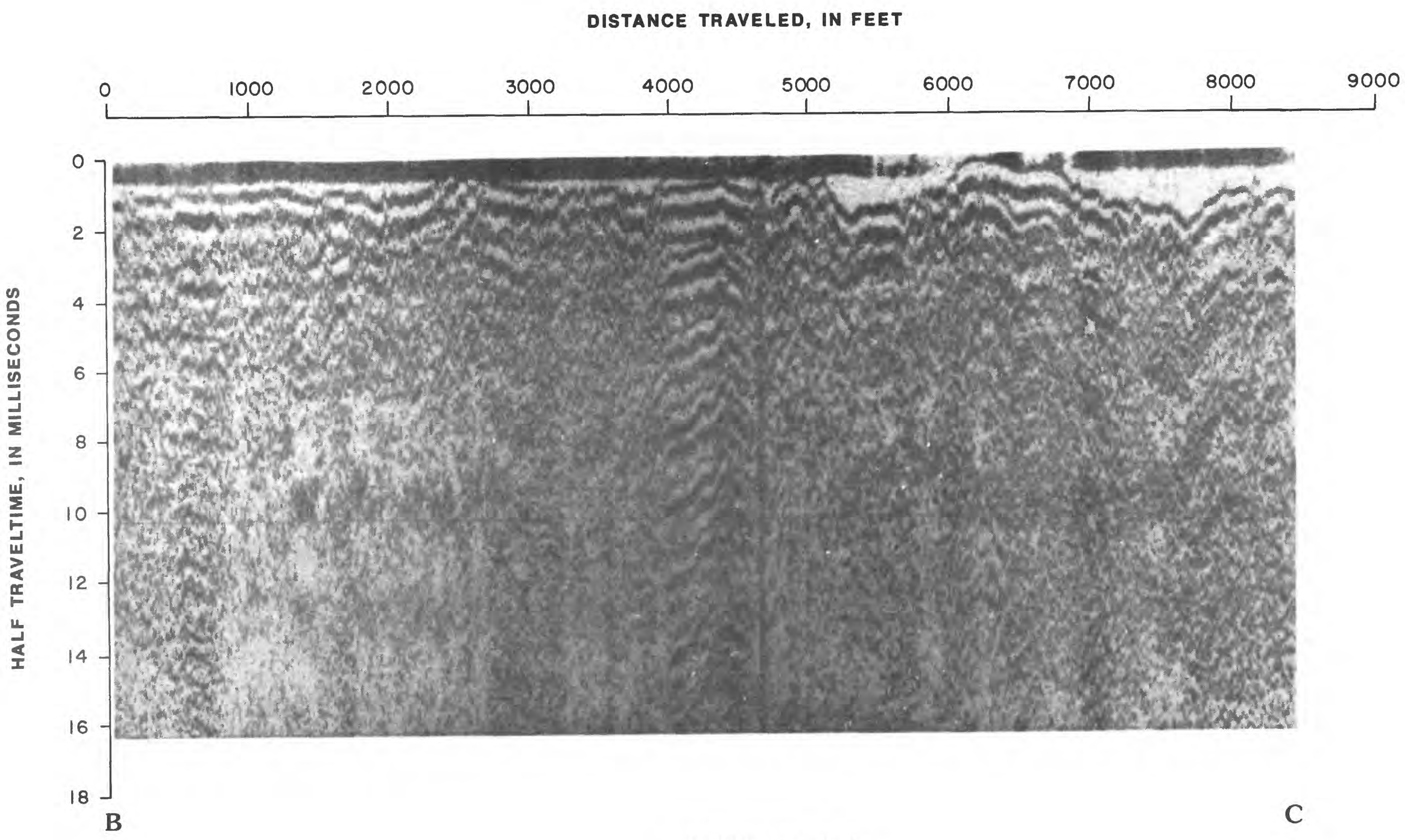
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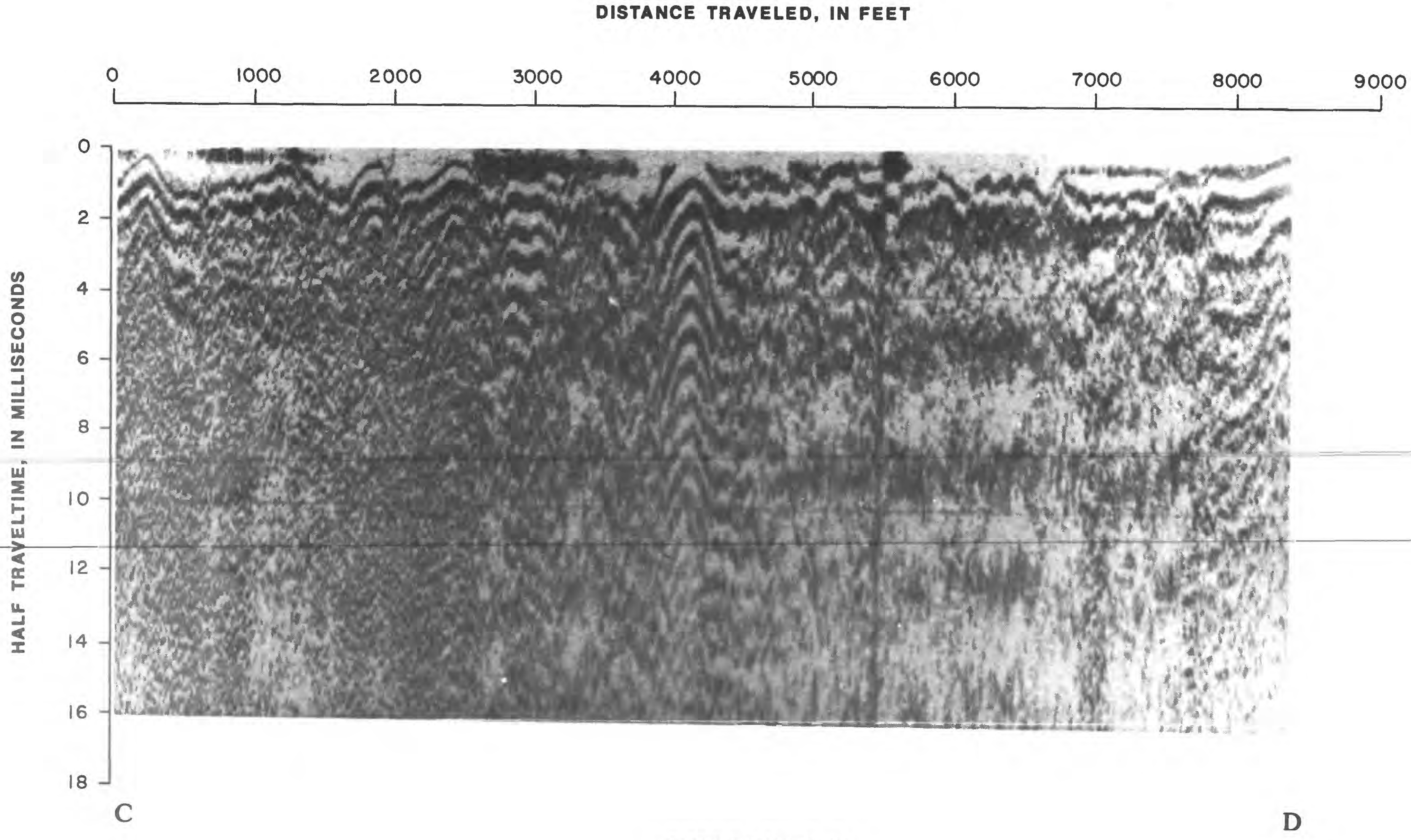
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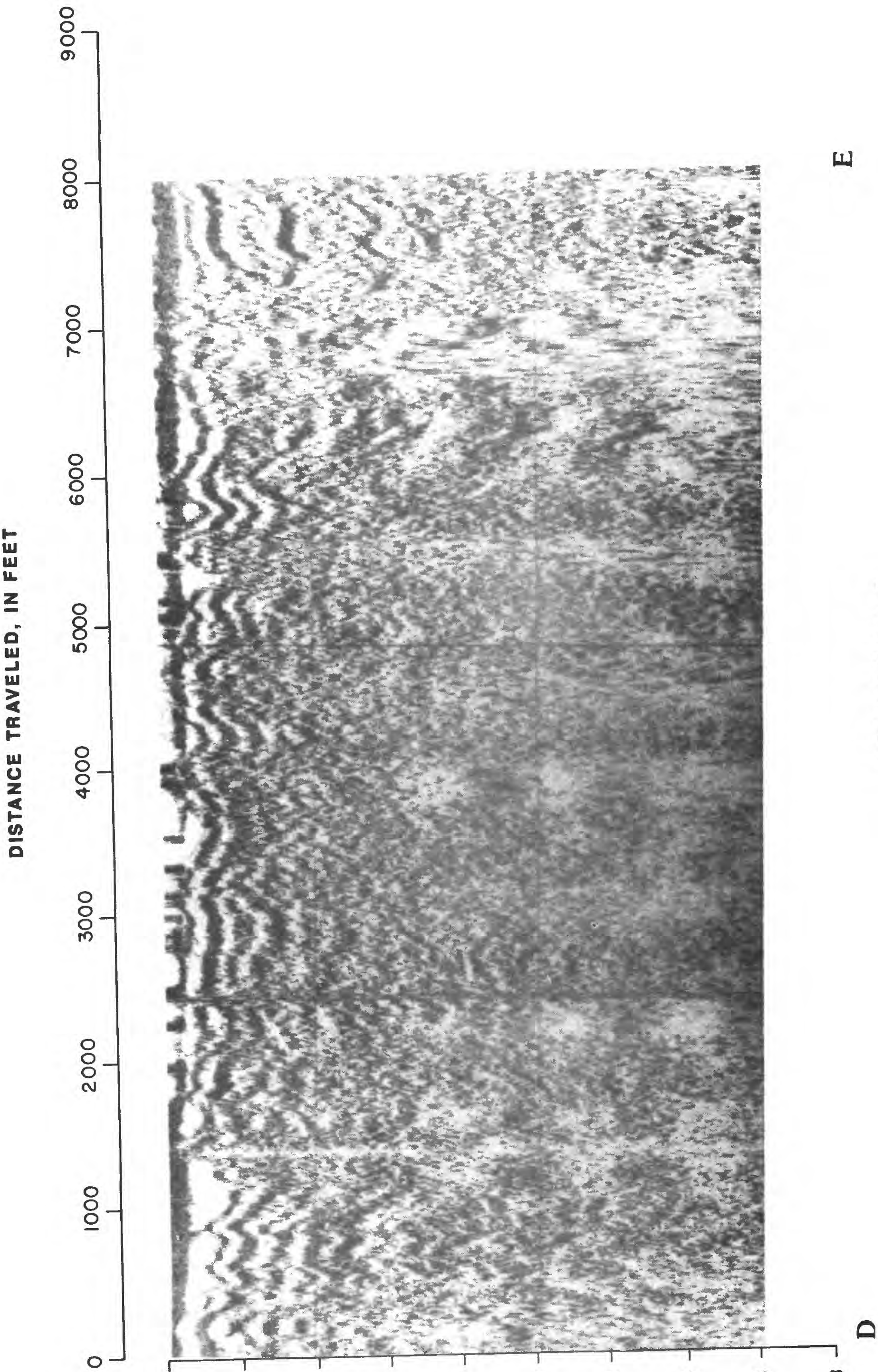
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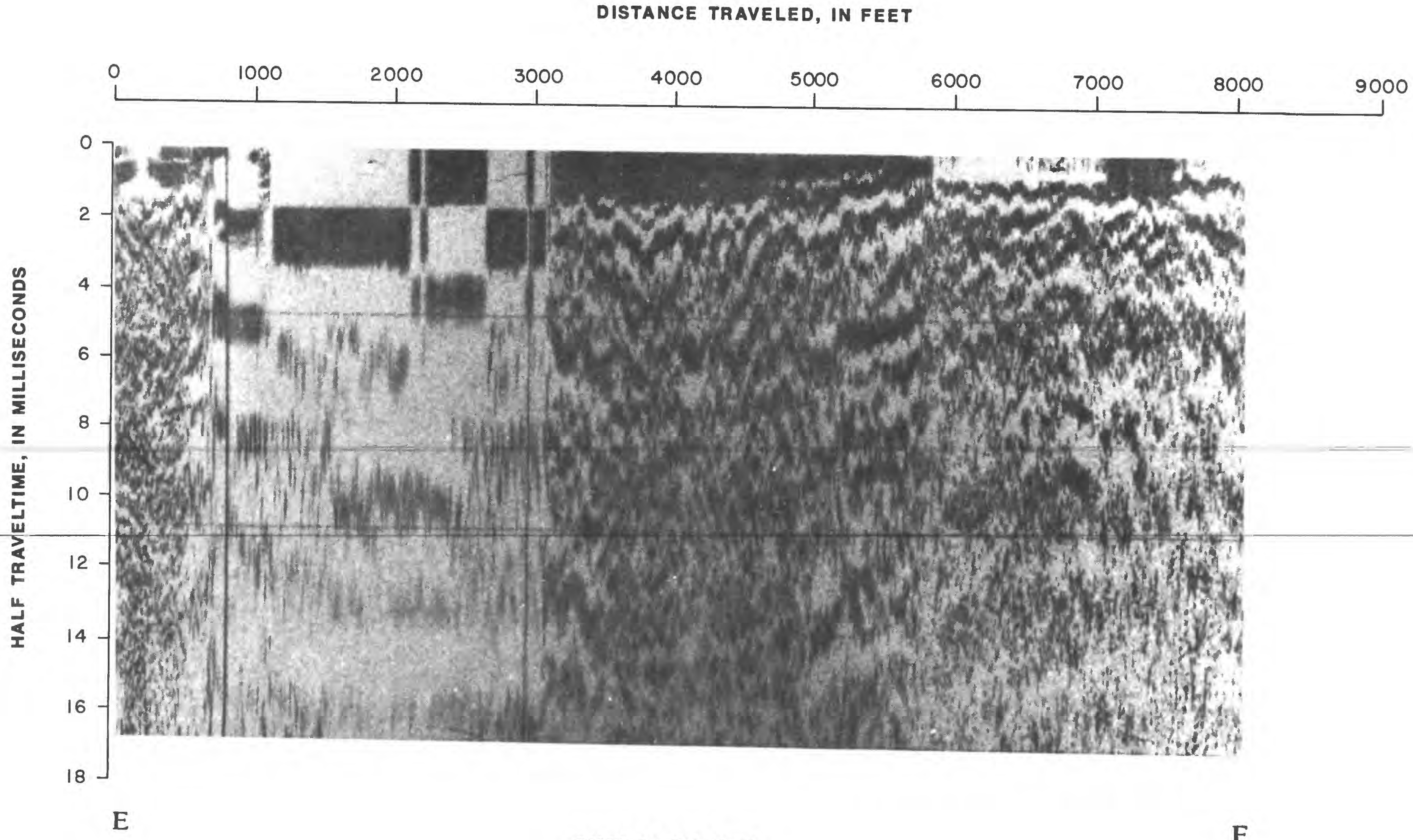
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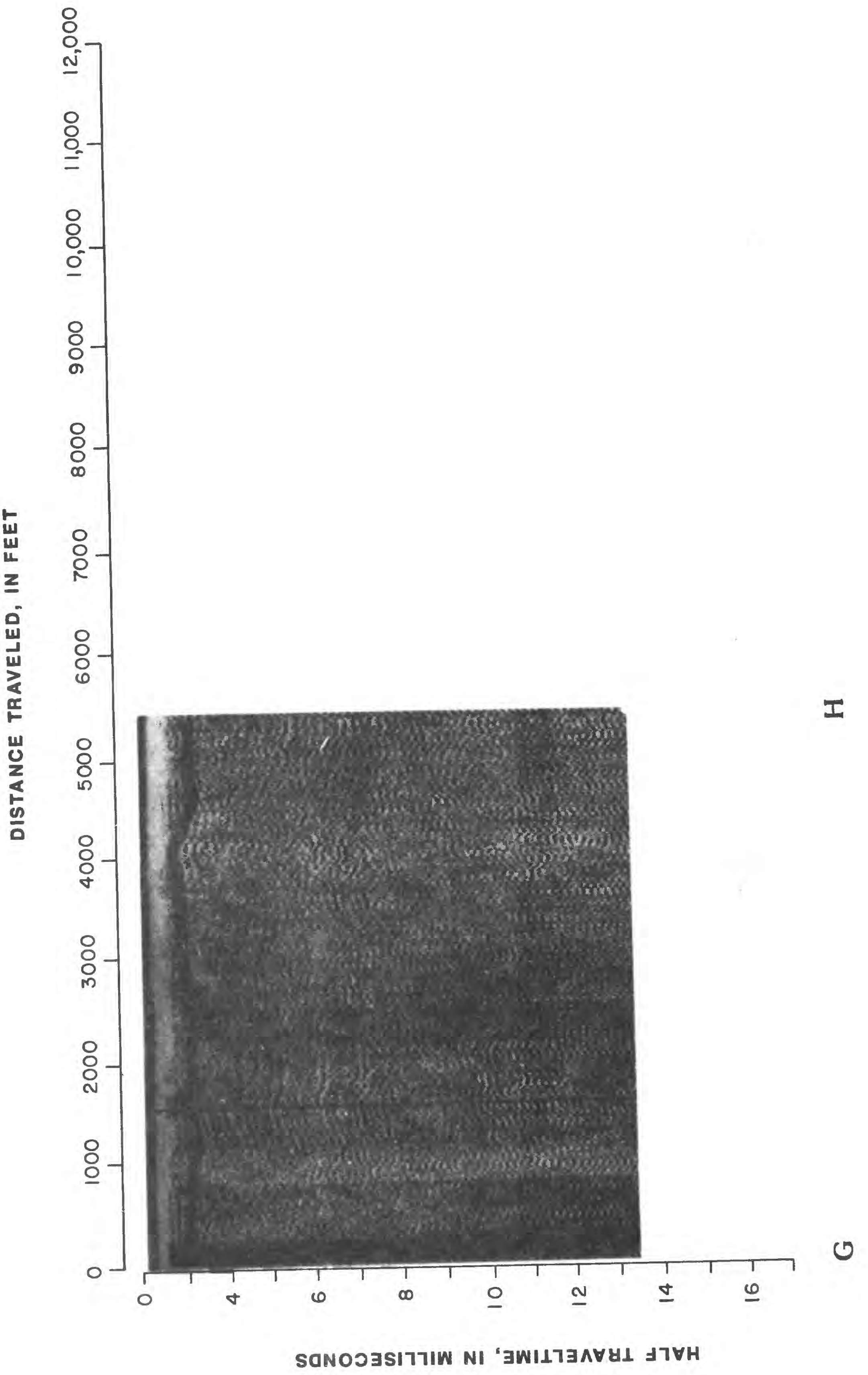
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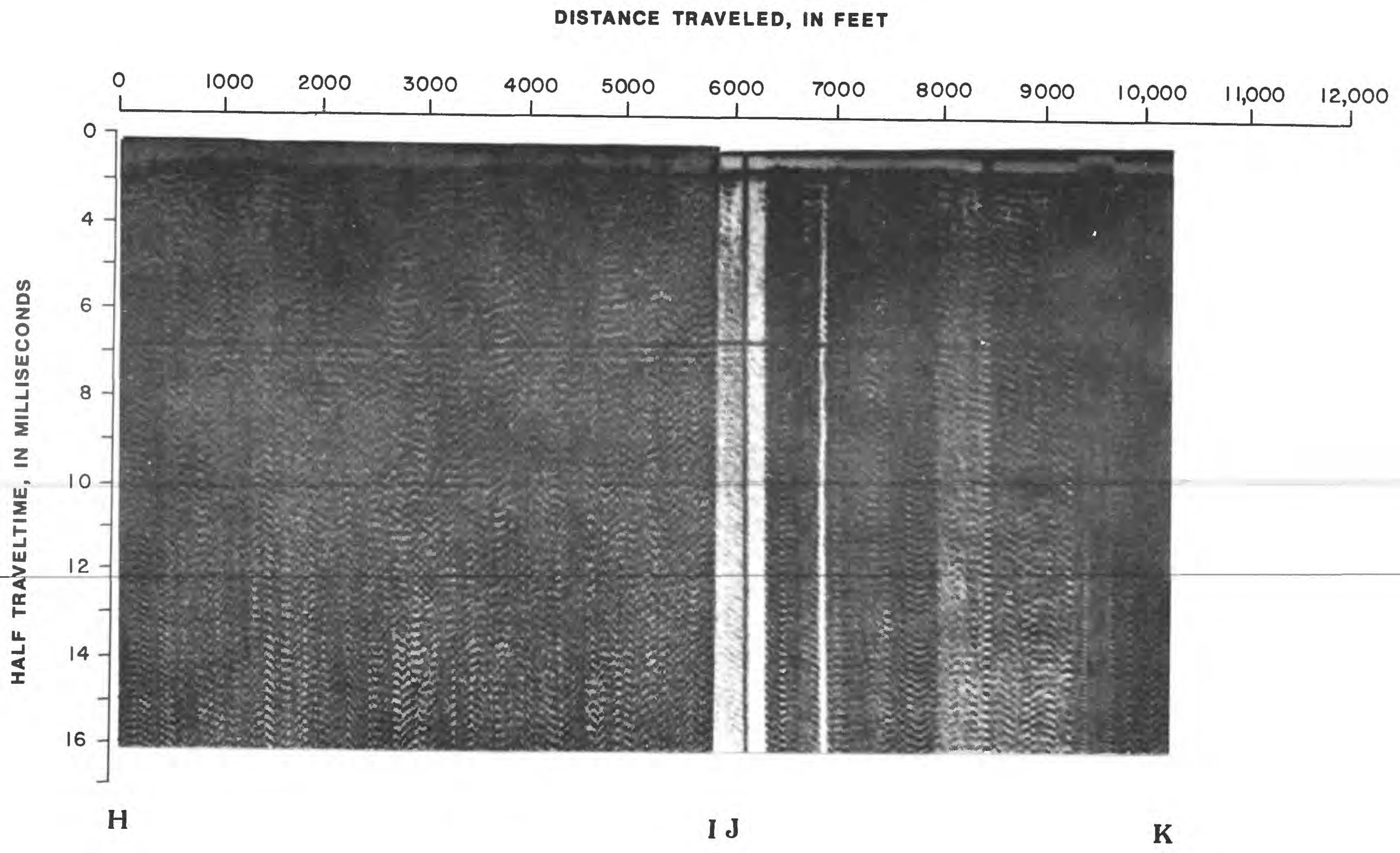

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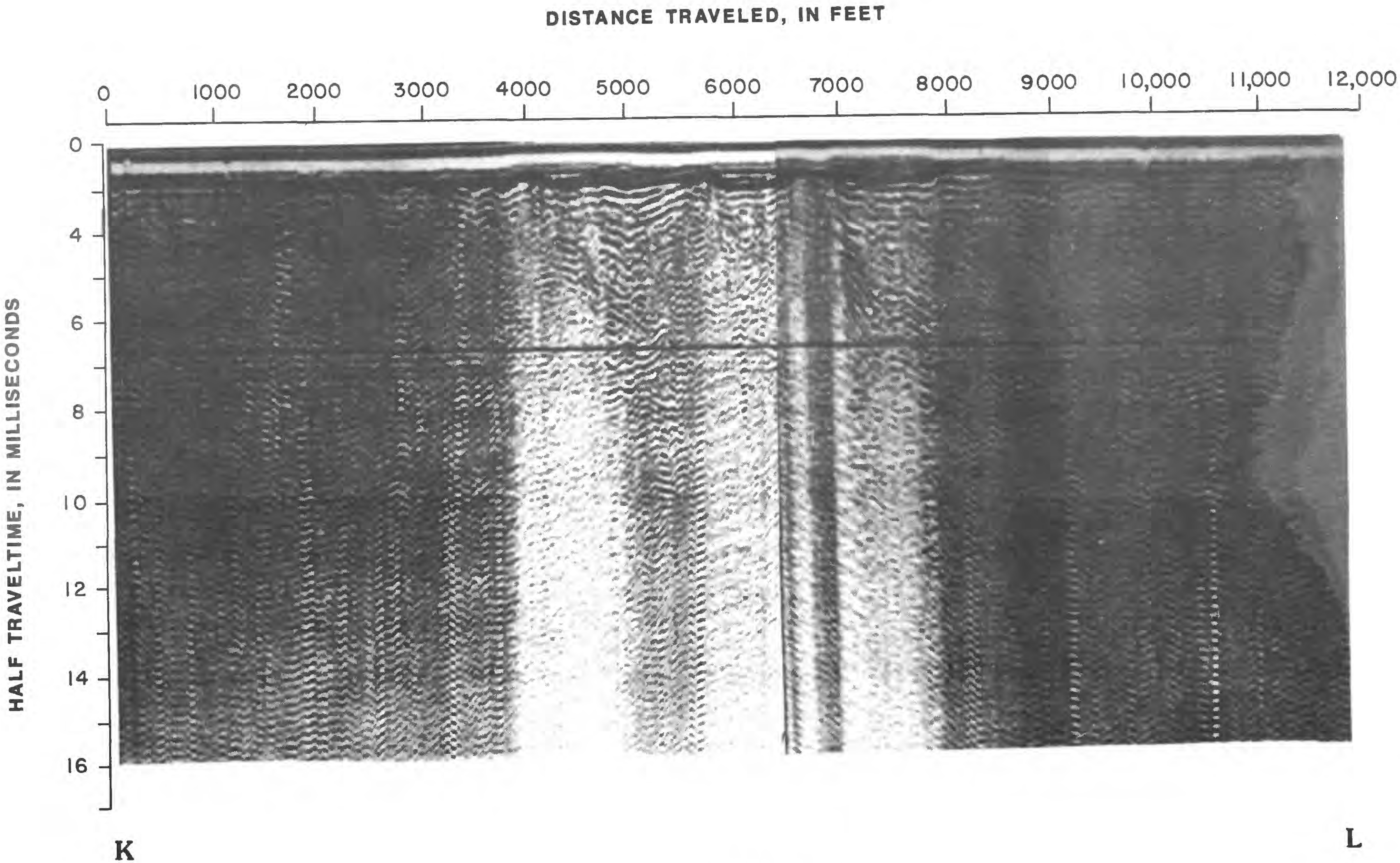
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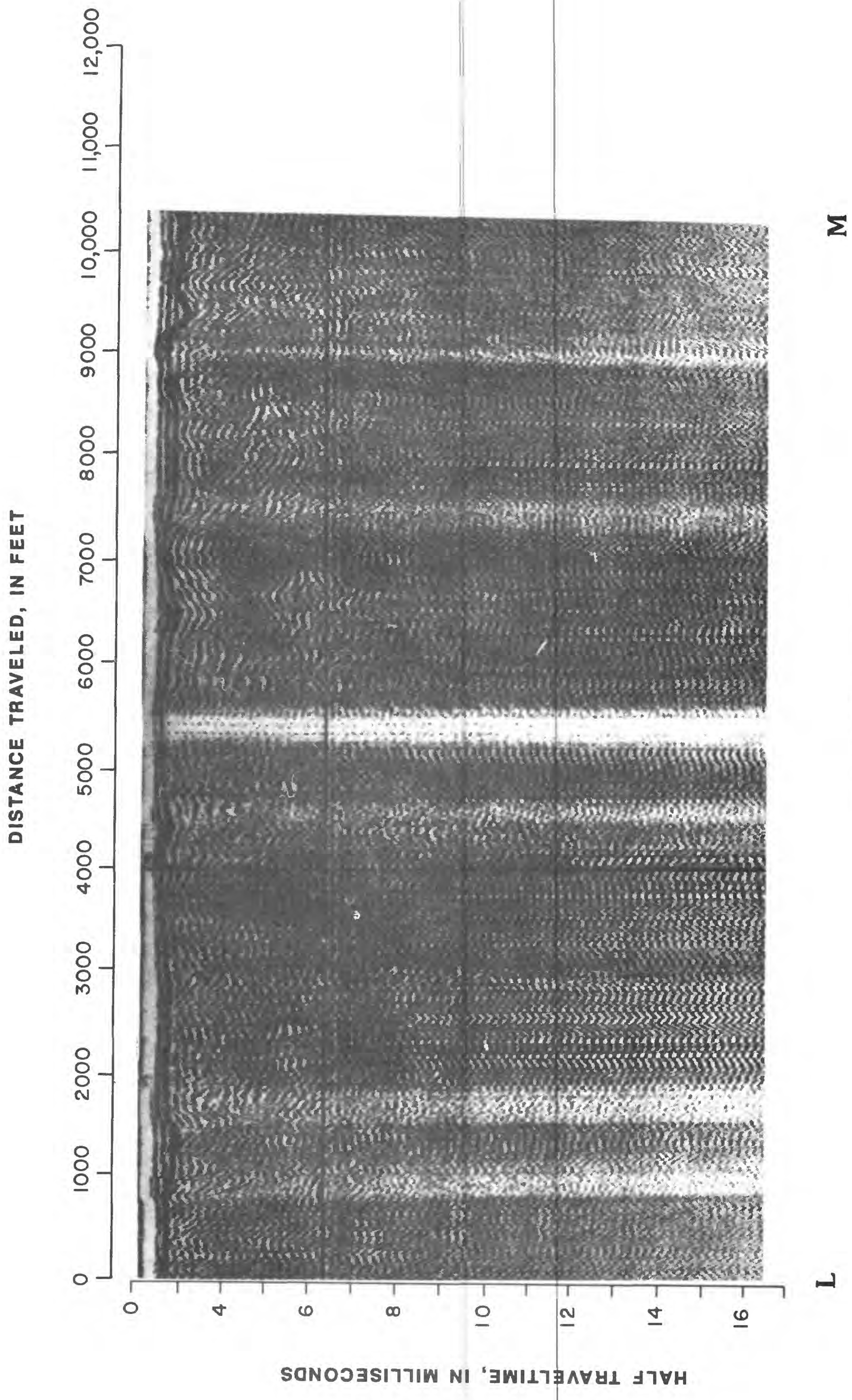
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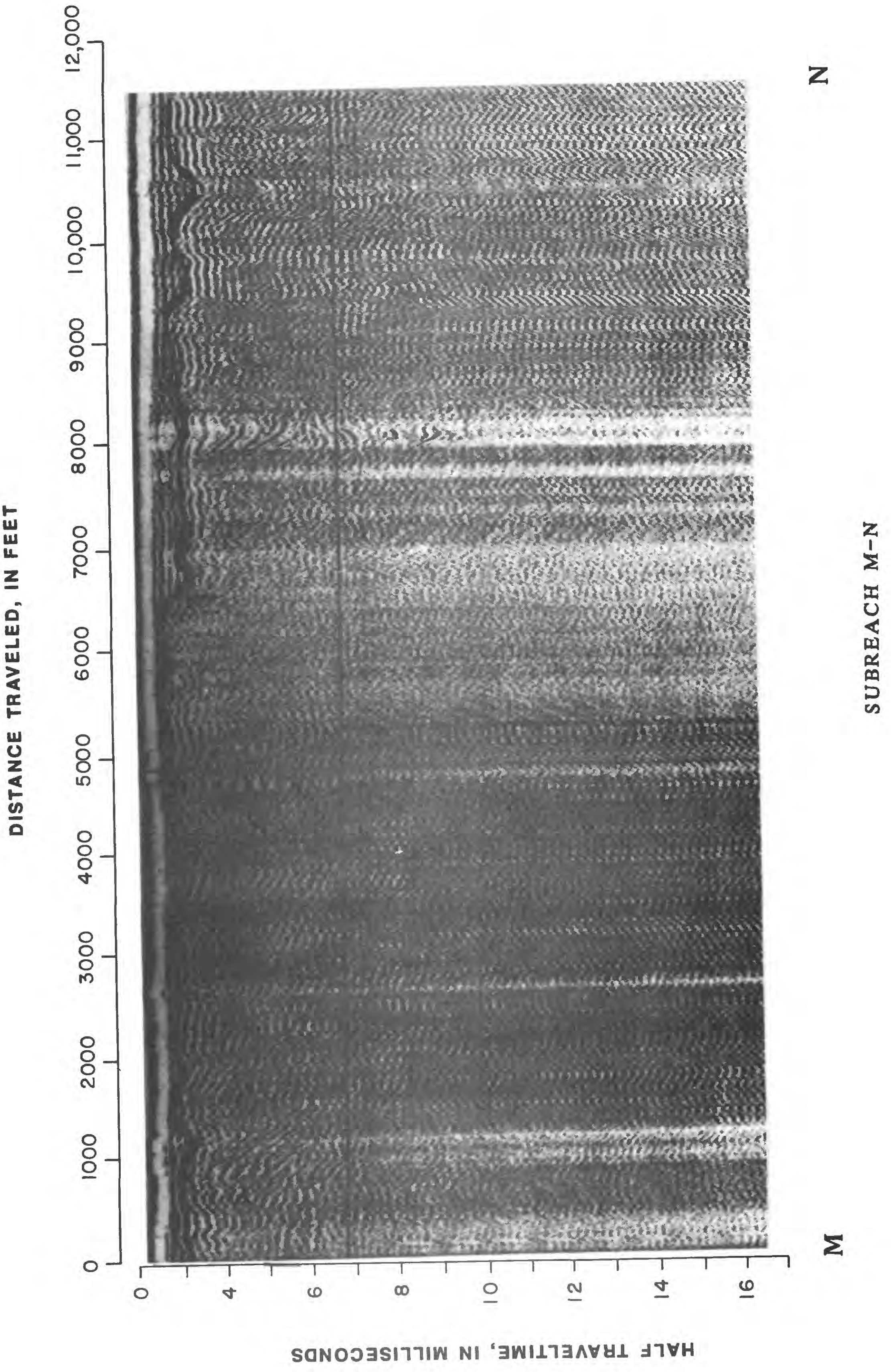
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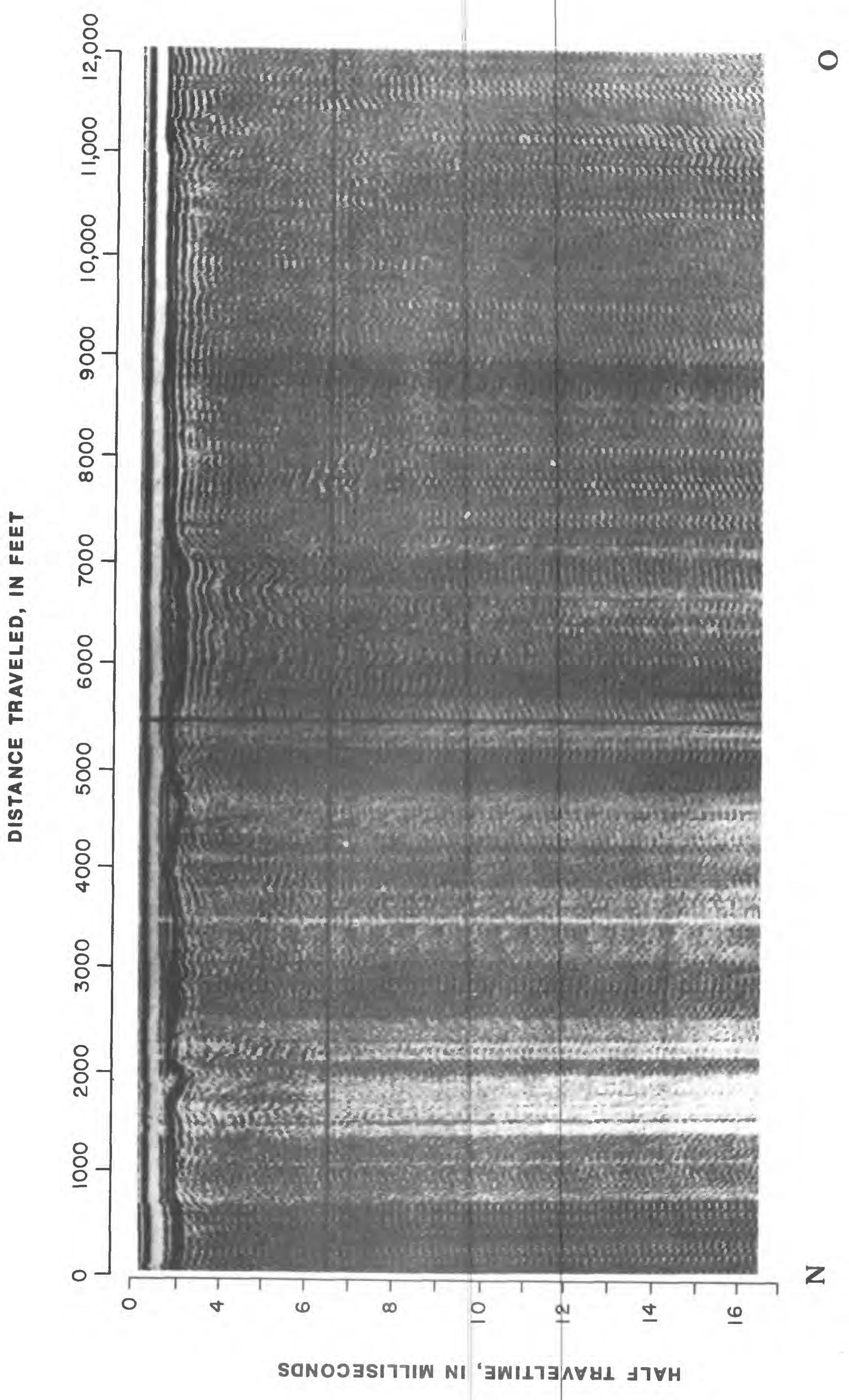
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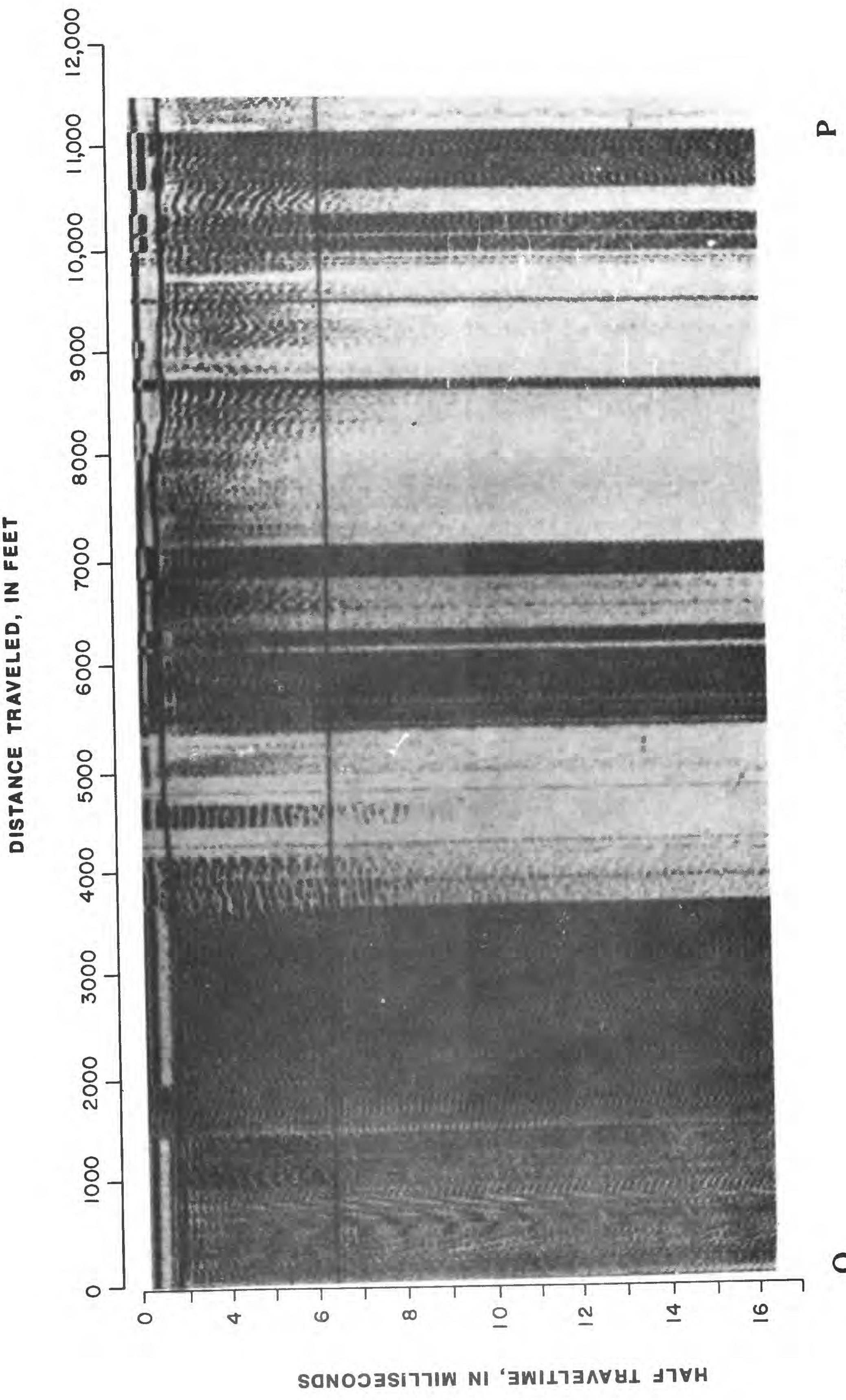
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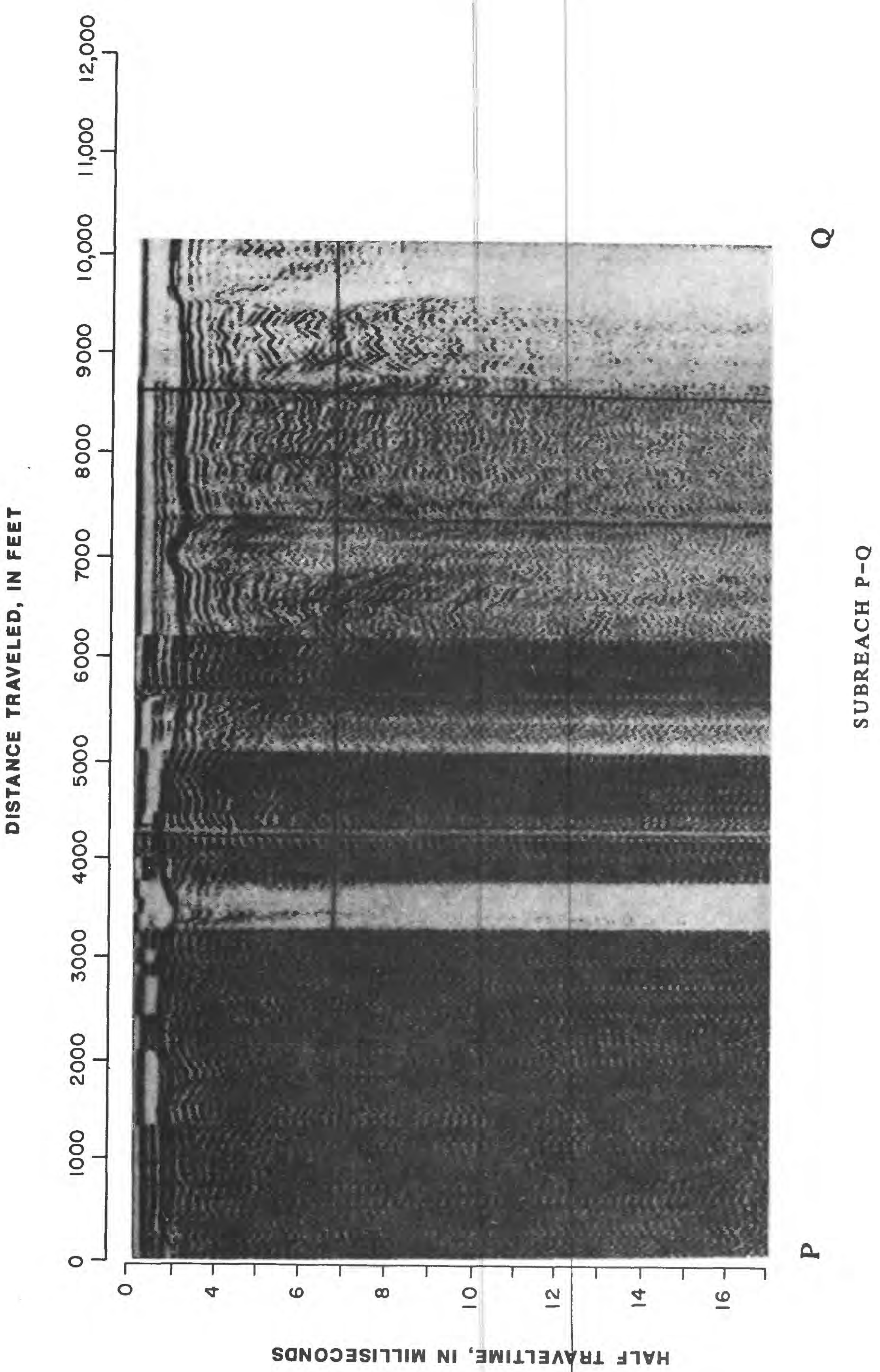

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