GEOHYDROLOGY AND WATER QUALITY IN THE VICINITY OF THE GETTYSBURG NATIONAL MILITARY PARK AND EISENHOWER NATIONAL HISTORIC SITE, PENNSYLVANIA

By Albert E. Becher

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 89-4154

Prepared in cooperation with the

NATIONAL PARK SERVICE

Harrisburg, Pennsylvania

1989

DEPARTMENT OF THE INTERIOR

MANUEL LUJAN, JR., Secretary

U.S. GEOLOGICAL SURVEY

Dallas L. Peck, Director

For additional information write to:

District Chief
U.S. Geological Survey
4th Floor, Federal Building
P.O. Box 1107
Harrisburg, Pennsylvania 17108-1107

Copies of this report can be purchased from:

U.S. Geological Survey
Books and Open-File Reports Section
Federal Center
Box 25425
Denver, Colorado 80225

ERRATA

Page 40, paragraph 3, line 7 should read:

sampling. On the other hand, wells in use known to yield water containing

Page 41, paragraph 1, line 9 should read:

in the Gettysburg Formation produce deep transmissive zones that may respond anti-

CONTENTS

ILLUSTRATIONS

TABLES

CONVERSION FACTORS AND ABBREVIATIONS

For the convenience of readers who prefer metric (International System) units rather than inch-pound units used in this report, values may be converted by using the following factors:

Multiply Inch-Pound Units	By	To Obtain Metric Units
	Length	
inch (in.)	2.54	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
gallon (gal)	3.785	liter (L)
	3,785	milliliter (mL)
	Temperature	
degree Fahrenheit (°F)	°C = 5/9 (°F - 32)	degree Celsius (°C)
	Flow	
gallon per minute (gal/min)	0.06308	liter per second (L/s)

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

GEOHYDROLOGY AND WATER QUALITY IN THE VICINITY OF THE GETTYSBURG NATIONAL MILITARY PARK AND EISENHOWER NATIONAL HISTORIC SITE, PENNSYLVANIA

by Albert E. Becher

ABSTRACT

Wells in the Gettysburg National Military Park, Eisenhower National Historic Site, and Gettysburg Borough supply drinking water to the park staff and, annually, more than 1 million visitors. These water resources are vulnerable to contamination by pollutants from activities in and outside park boundaries. This report describes the hydrogeology and ground-water quality of a 12-square-mile area of the park and vicinity, and outlines a ground-water-quality monitoring plan.

A network of about 60 wells was established to measure water levels and sample ground water. Water levels were measured continuously in five wells and synchronously in the larger network during spring and fall of 1986.

Shale, siltstone, and sandstone of the Gettysburg Formation, intruded by a 2,000-foot-thick diabase sill in the southeastern part of the area, form the bedrock framework. These rocks are tilted about 20 degrees to the northwest. Two vertical diabase dikes extend northward and form barriers to ground-water flow in the Gettysburg Formation.

The regolith and fractures near the surface in both the Gettysburg Formation rocks and the diabase sill contain a shallow water-table aquifer. In the Gettysburg Formation, the shallow aquifer is connected to deep, discontinuous, tabular aquifers in beds prone to fracturing. Ground-water flow tends to be anisotropic parallel to the strike of bedding both in the shallow and deep aquifers of the Gettysburg Formation. Pumping affects water levels in wells more than 2,500 feet apart along strike.

Calcium, magnesium, and bicarbonate are the dominant constituents in the ground water. Concentrations of dissolved solids are about 40 percent greater in water from the Gettysburg Formation than water from the diabase. Concentrations of nontoxic elements, iron and manganese, slightly exceed U.S. Environmental Protection Agency (USEPA) secondary maximum contaminant levels in 4 of 21 samples. No concentration of the toxic trace elements arsenic, barium, cadmium, chromium, lead, selenium, or mercury exceeds the maximum contaminant levels (MCLs) established by USEPA. A nitrate concentration in excess of the USEPA MCL of 10 milligrams per liter was found only in water from one well. Pesticides were present, at nontoxic concentrations (near minimum detection limits) in water from five wells, two of which are currently (1987) in use. TCE and PCE were the dominant purgeable organic compounds (POC) detected. No POC

were present in park wells above concentrations of 1 microgram per liter, and no concentration exceeded USEPA MCLs. POC were detected only in water from wells that are approximately aligned, and in a zone parallel to strike that extends into areas of known ground-water contamination and (or) production wells.

Water-quality monitoring in the park is most important in the zone where TCE and PCE were detected. Areas that have production wells in which other contaminants in water have been detected are areas to be monitored for changes in concentration of the detected contaminants. Continued control of potential contaminants placed on the land surface, especially agricultural chemicals and wastes, can prevent or mitigate most ground-water contamination. Future monitoring activities will be dictated by events and conditions where and as they occur.

INTRODUCTION

Wells in the Gettysburg National Military Park (GNMP) and the Eisenhower National Historic Site (ENHS) supply some drinking water to the staff and, annually, to more than 1 million park visitors. Public-supply wells of the Gettysburg Borough Authority, just outside the GNMP and ENHS property, supply most of the water. These water resources are vulnerable to contamination from agricultural fertilizers and pesticides used both within and outside park boundaries, and from known sources of purgeable organic compounds (POC) outside the park.

Purpose and Scope

In 1985, at the request of the National Park Service (NPS), the U.S. Geological Survey began a study of the movement and quality of ground water in the park area. This report describes the geohydrology of the rocks underlying the park and nearby areas, including the quality of ground water, and provides the framework for a ground-water quality monitoring plan. The report also describes the ground-water flow systems, the discharge of ground-water to surface streams, and the extent that ground-water quality has been affected by the introduction of contaminants. The potential for movement of POC from nearby sites, where they now contaminate the ground water, is discussed.

Description of the Study Area

The study encompasses an area of about 12 mi^2 (square miles) in Adams County in south-central Pennsylvania (fig. 1) near the Maryland border. The GNMP partly lies within and partly encircles the Borough of Gettysburg on the south and west sides (fig. 1). The ENHS abuts the GNMP to the southwest, and the two form one continuous property unit under NPS jurisdiction. Most of the area is gently rolling land between elevations of 500 and 580 ft (feet) above sea level. Round Top, Little Round Top, and Culps Hill form high points on the southeastern side of the park 140 to 200 ft above the surrounding landscape. Seminary Ridge forms a long, low, narrow north-south ridge on the western side, which stands as much as 60 ft above the adjacent landscape.

Soil drainage is poor, and infiltration and percolation of water to the ground-water table are slow. Shallow lenses or layers of low-permeability clay retard the downward movement of water through the soil.

Major surface drainage is southward, in Rock Creek to the east, and in Willoughby Run to the west (fig. 2). Within the park, tributaries to Rock Creek include Stevens Run, which drains to the north, and Plum Run, which drains to the south. Headwaters of both streams normally are dry from summer through fall, except during periods of direct runoff from storms.

Gettysburg has a humid, continental climate and an average annual precipitation of about 41 in. (inches). Nearly 55 percent of the precipitation falls from April through September. During the 2-year period of this study total precipitation was near the average for the period of record (1875-1982), but was more than an inch below normal during the first year and an inch above normal during the second year. In November 1985, precipitation was 8.35 in., or more than double the average monthly total (fig. 3). Similarly, in September 1987, precipitation was 8.15 in., or more than double the average for the month.

Methods of Study

A review of the geologic studies of Stose and Bascom (1929) and the ground-water studies of Wood (1980) and Taylor and Royer (1981) preceeded the planning and field data collection. From the inventory of wells in the area, about 60 wells were selected for a network to measure water levels and (or) collect water samples for chemical analysis. Six additional monitor wells were drilled where needed information was lacking. The qualitative relation between surface and ground water was determined from observation of streamflow and comparison of stream and pond elevations with ground-water levels. Water levels were measured and water samples collected for analysis to determine seasonal and areal conditions. Measurements from continuous water-level recorders on six wells, borehole geophysical logs, and aquifer tests contributed to the understanding of the ground-water flow systems.

Samples of water were collected, prepared, and shipped to the U.S. Geological Survey laboratory in Denver, Colorado, for analysis according to practices established by the laboratory and Pennsylvania district office of the USGS. Wells were pumped at rates of 5 to 200 gal/min (gallons per minute) for at least 30 minutes and until temperature, specific conductance, and pH reached stability before the water sample was collected. Wells that could not sustain 30 minutes of continuous pumping were pumped as long as possible, allowed to recover, and repumped until the required stability criteria were met. Samples were collected as close as possible to the well head. Samples intended for nitrogen-species analysis were collected in opaque polyethelene bottles and treated with mercuric chloride. All samples were packed in ice or refrigerated to 4°C (degrees Celsius) from collection through shipment. Vials for analysis of purgeable organics were filled to overflowing to avoid air bubbles and sealed. Samples were shipped to Denver for complete analysis or to the New Jersey District office of the U.S. Geological Survey for gas-chromatograph scans within 2 days of collection.

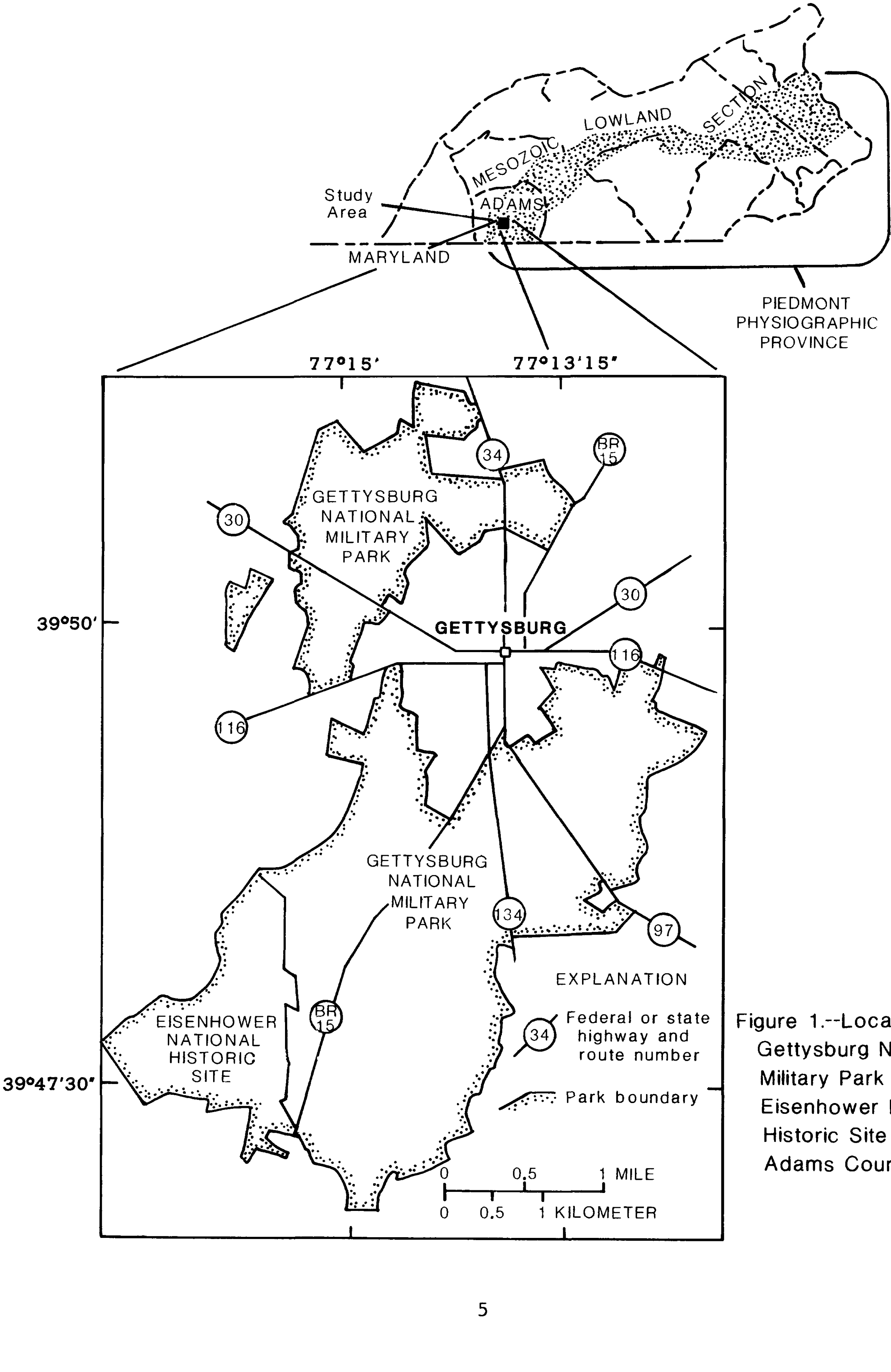
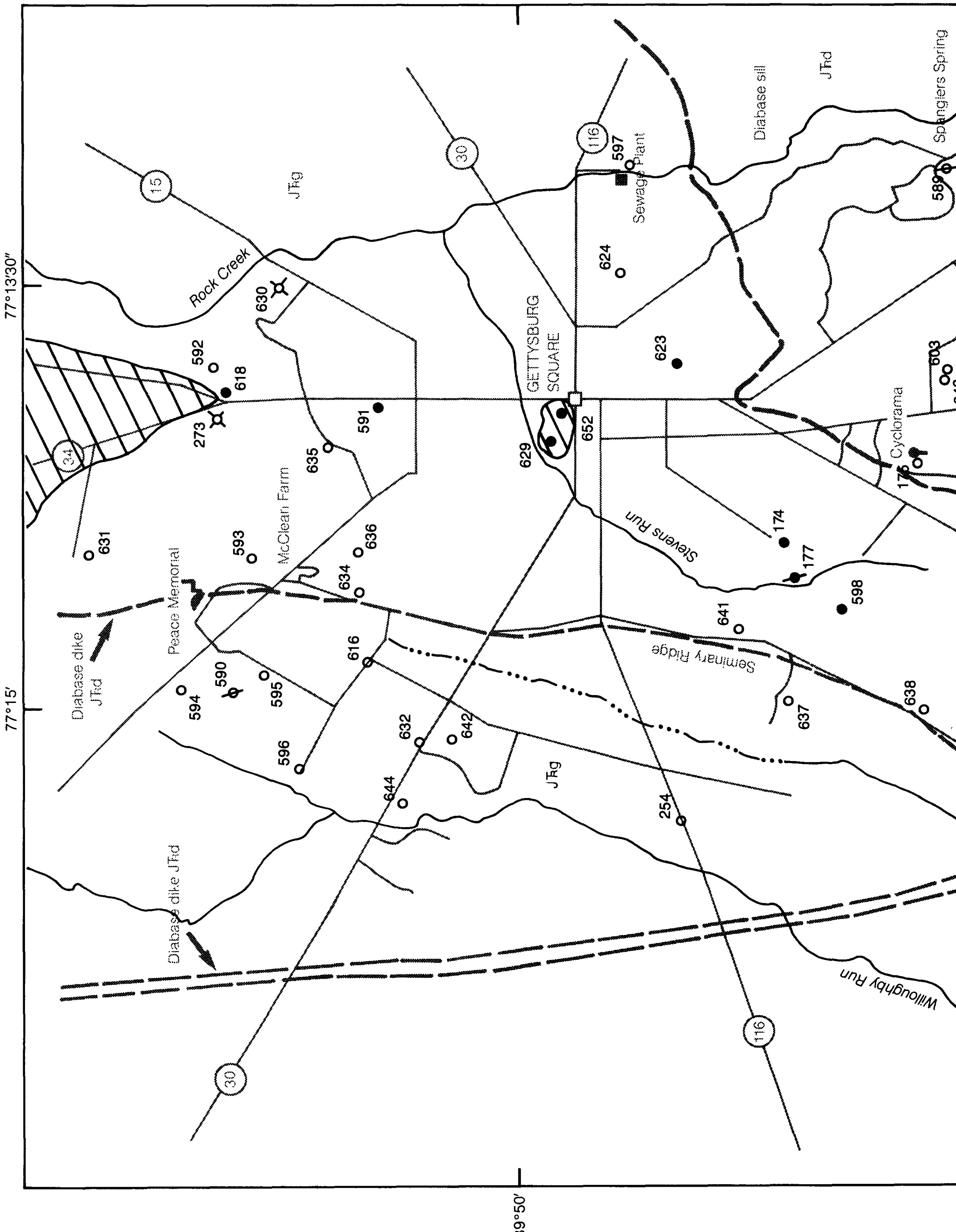
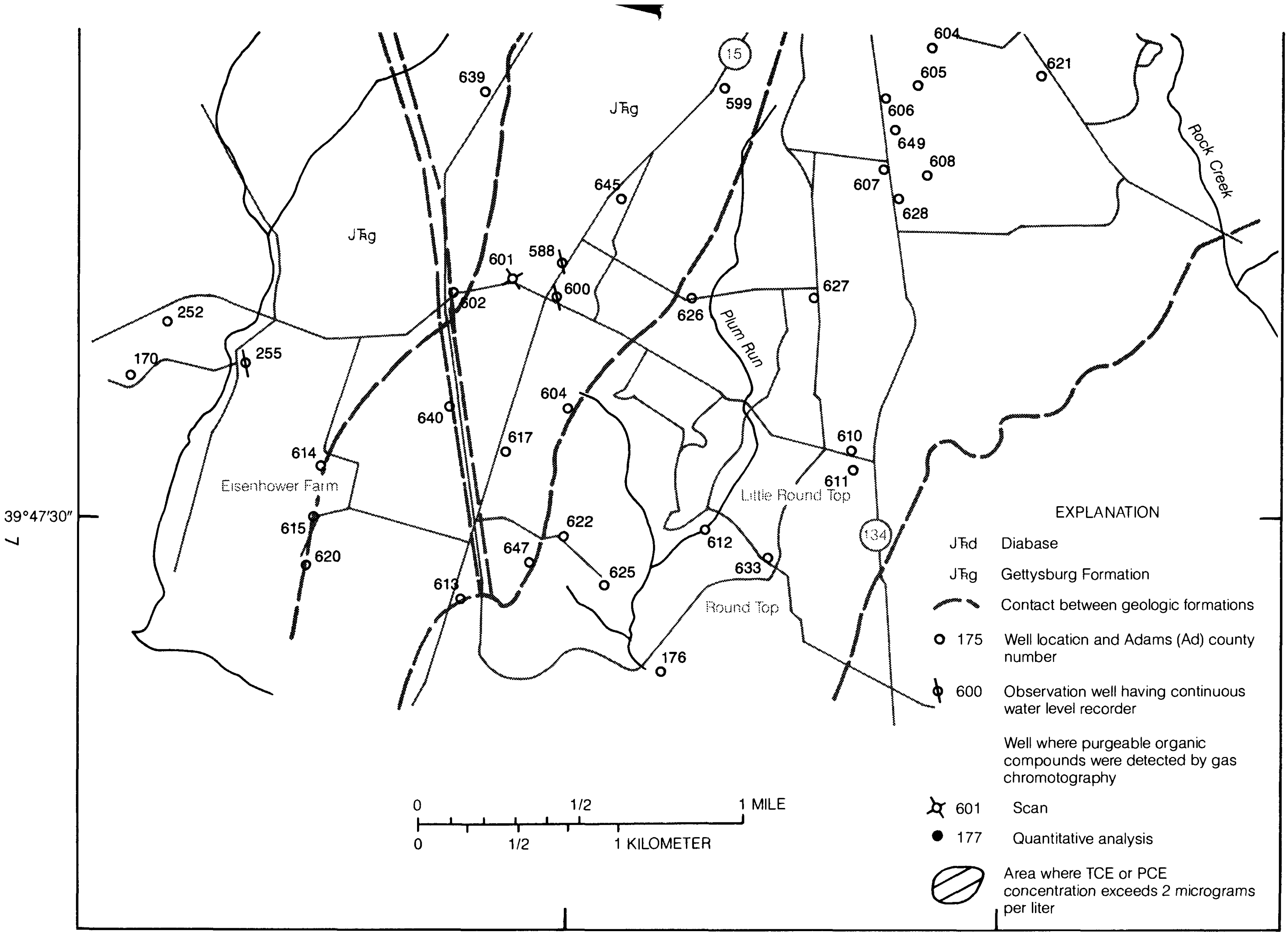


Figure 1.--Location of Gettysburg National Military Park and Eisenhower National Historic Site in Adams County, Pa.


77°13'30"
77°15'
39°50'
Rock Creek
JTRg
Diabase sill
JTRd
Spangiers Spring
Sewage Plant
GETTYSBURG SQUARE
Cyclorama
McClean Farm
Peace Memorial
Diabase dike JTRd
Stevens Run
Seminary Ridge
Willoughby Run
Diabase dike JTRd
15
30
116
34
597
589
624
623
603
643
630
592
618
273
591
635
652
629
174
177
598
641
631
593
636
634
616
590
594
595
596
632
642
644
254
637
638



Base from U.S. Geological Survey
Fairfield, 1973, and Gettysburg, 1973.

Geology modified from C.R. Wood (1980)

Figure 2.—Geology, principal streams, areas of TCE and PCE contamination and well network in Gettysburg National Military Park, Eisenhower National Historic Site, and vicinity.

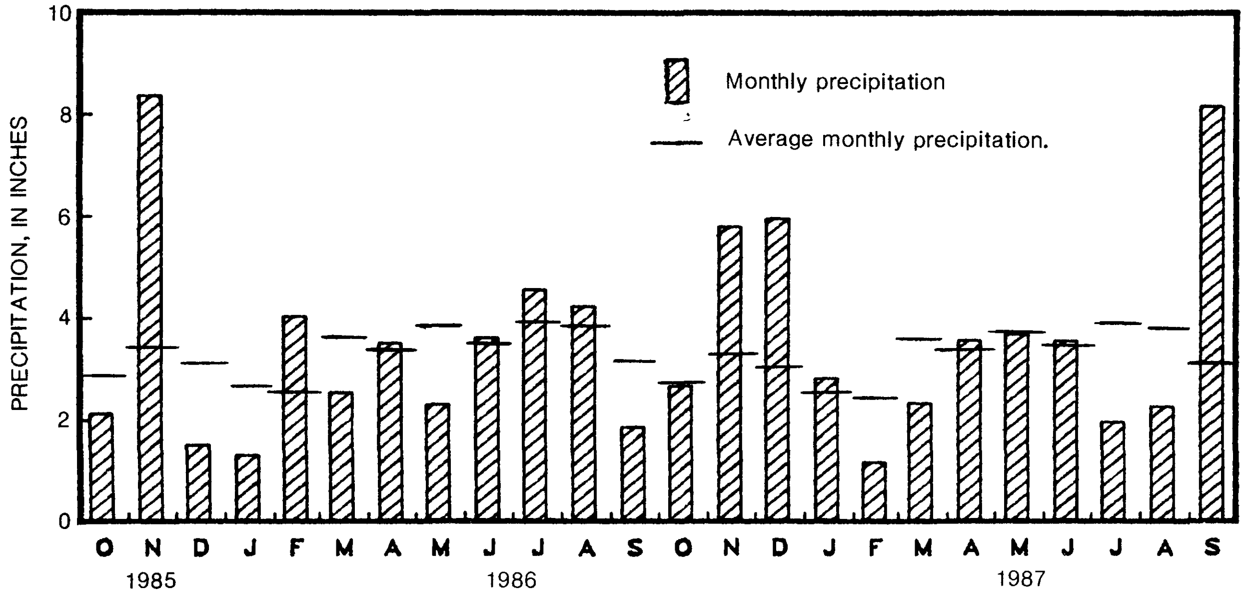


Figure 3.--Monthly precipitation during the 1986 and 1987 water years and average monthly precipitation from 1875 through 1982 at Eisenhower National Historic Site.

Acknowledgments

The pre-study inventory of wells in the park area done by William Werrell and Randall Stoner of the NPS was valuable to the establishment of a well network for the study. The cooperation and assistance of the Gettysburg staff of the NPS, especially John Earnst, Park Superintendent, is greatly appreciated. Throughout the study, Harold Greenlee, Resource Management Specialist, provided information and staff personnel to assist with some site preparations. He frequently made special arrangements for work that interfered with normal park operations but was essential to the study. Thanks are due Allen Larson and F. "Bucky" Alberts of the Gettysburg Municipal Authority for information about, and access to, the borough wells for water-level measurements and sample collection. Thanks also are given to the Operations and Maintenance staff of the Gettysburg Area School District for their help in sampling the high school irrigation well. The information provided by Rod Nesmith and Tom Miller, of the Pennsylvania Department of Environmental Resources, about POC in Gettysburg Borough was very helpful in selecting sites for ground-water sampling. I wish to offer thanks also to all individuals who allowed access to their wells for water-level measurements and water sampling. Illustrations for this report were prepared by Edward Pinto, a Masters degree candidate at Shippensburg University in Pennsylvania.

GEOHYDROLOGY

Geologic Setting

The park area is located in the Mesozoic Lowland section of the Piedmont physiographic province (fig. 1). Interbedded shale, siltstone, and sandstone of the Gettysburg Formation; a 2,000-ft-thick diabase sill; and two diabase dikes form the bedrock framework (fig. 2). The diabase sill in the southeastern part of the area and beds in the overlying Gettysburg Formation dip about 20 degrees to the northwest. North-south diabase dikes are vertical or near vertical rock masses, about 50 ft wide, that cut through the Gettysburg Formation. Both the dikes and sill were formed by the injection and subsequent cooling and crystallization of molten rock material from the earth's interior into the existing sedimentary rocks of the Gettysburg Formation.

Water-Bearing Characteristics of the Rocks

Water is present in and moves through narrow openings in the bedrock. The openings are separations between adjacent beds, fractures, and joints (breaks across the beds) that are oriented chiefly parallel or perpendicular to the strike (trend of a bed where it intersects land surface). These openings form a complex network of interconnected cracks through which water flows from areas of recharge to areas of discharge at streams. Some water also moves through pore spaces between grains where the cementing material adjacent to bedrock openings has been removed by solution.

Gettysburg Formation

The Gettysburg Formation of Late Triassic and Early Jurassic Age in the park area consists of red shale and red, brown, and gray siltstone and sandstone. In a mixed sequence of these rock types, the thin sandstone beds develop more joints than the thick beds (Wood, 1980, p. 16). Below the regolith and near surface bedrock, only a few beds in a thick sequence have openings well-developed enough to transmit significant amounts of water. Some of the beds have carbonate cement between grains that is easily removed by weak acids. Removal of the cement greatly enhances the ability of these beds to store and transmit water.

Wells in the Gettysburg Formation that supply a single residence with water have a median yield of about 12 gal/min. Wells that supply industry or a public system have a median yield of about 70 gal/min (Taylor and Royer, 1981). Almost any well in the Gettysburg Formation is capable of supplying the water needs of a single residence.

Diabase Sill and Dikes

Diabase sills and dikes are dense, massive bodies that weather into rounded boulders, which locally, litter the landscape. Water can enter the rock only through joints because the minerals form interlocking crystalline masses that are virtually impermeable. Weathering reaches a maximum depth of about 30 ft and most of the ground water is stored and transmitted in this zone of regolith and in shallow openings of the diabase. The number and size of water-bearing zones decrease rapidly with increasing depth. Most water-bearing zones are less than 100 ft deep and are rare below a depth of 150 ft.

Wells in the diabase sill commonly have low yields. Few wells yield more than 30 gal/min, and at least 10 percent fail to yield enough to supply the barest of domestic needs (Wood, 1980, p. 29).

Ground-Water-Flow Systems

There are two aquifer systems in the Gettysburg Formation but only one in the diabase sill. A shallow water-table-aquifer system is present in the soil and weathered bedrock everywhere except in the diabase dikes. Where the dikes transect the Gettysburg Formation, they form ground-water divides that are nearly impermeable to the flow of water. Surface water flows across the dike where the ridge is breached, but little if any ground water can pass as underflow.

A second aquifer system that is hydraulically connected, to a variable degree, to the water-table aquifer is present only in the Gettysburg Formation. Wood (1980, p. 16) writes, "As some beds contain more openings than others, the ground-water system consists of a series of alternating tabular aquifers that dip 20 to 40 degrees to the northwest. The network of water-bearing fractures in each tabular aquifer is more or less continuous along strike, but continuity of individual beds is limited by faulting, intrusion of diabase dikes, and pinching out. The beds are overlapping, lens-shaped, and discontinuous in all directions, but may extend for several thousand feet. These tabular aquifers generally extend downdip from a few hundred feet to as much as 3,000 feet below land surface."

Wood (1980, p. 18) continues, "The greatest permeability in the Gettysburg [Formation]* * * and thus the greatest movement of water in response to pumping is parallel to the strike of bedding." In the vicinity of the park, pumping of public-supply wells causes drawdown in wells at least half a mile away along strike. Figure 4 is a plot of drawdown, over a 13-day period, in wells Ad 591 (pumped) and Ad 629 (not pumped) that are 2,500 ft apart. Pumping over sustained periods, therefore, is capable of changing the flow regime over wide areas along strike and even moving water opposite to the direction of pre-pumping flow.

More than one tabular aquifer may be penetrated by a well. Wood (1980, p. 17-18) states, in such cases, "Where there are differences in hydraulic head between water-bearing openings internal flow occurs in wells, under nonpumping conditions, from the zone of higher head to that of lower head. Downward flow in wells located in valleys * * * suggests considerable lateral flow to points of discharge downstream from the well."

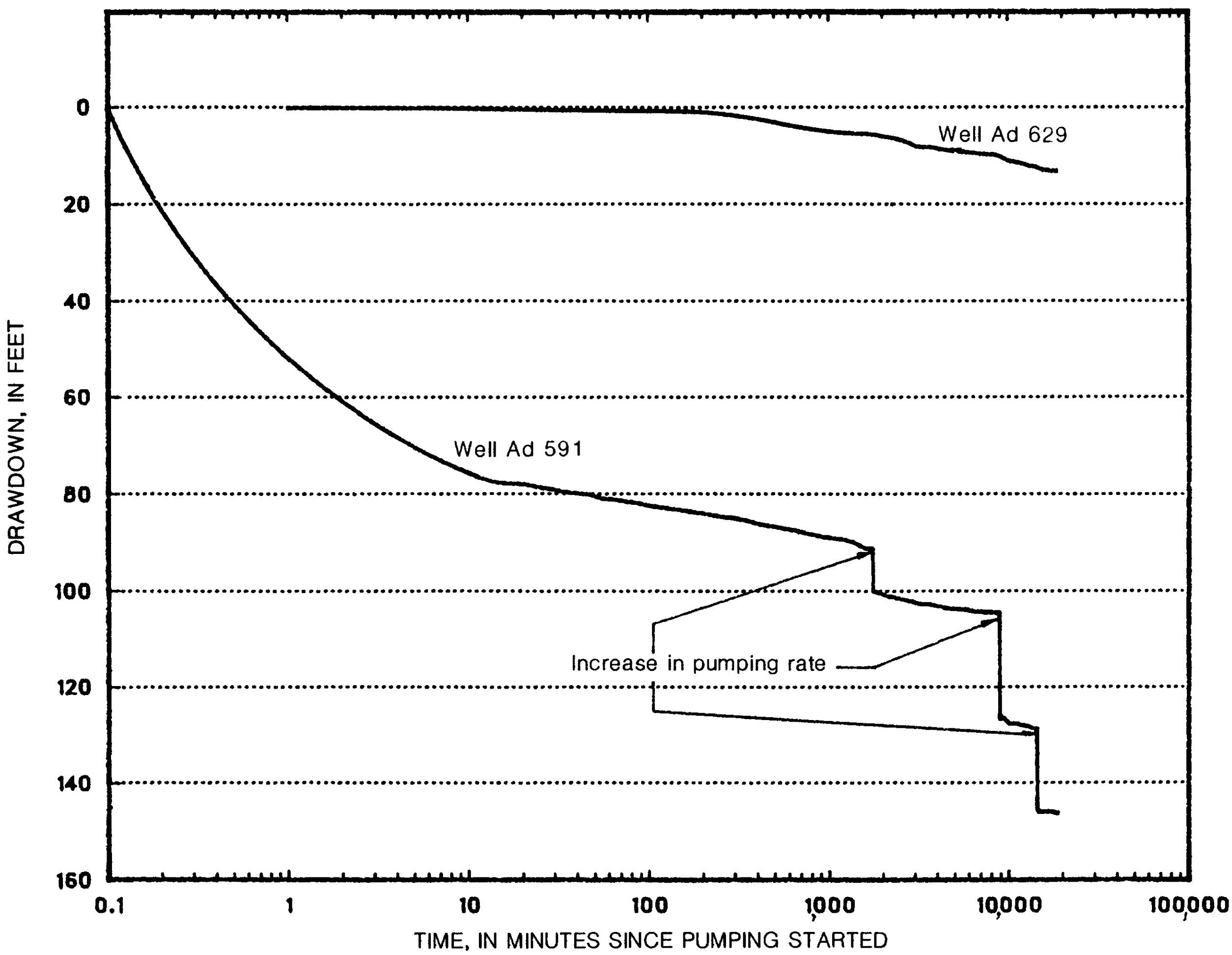
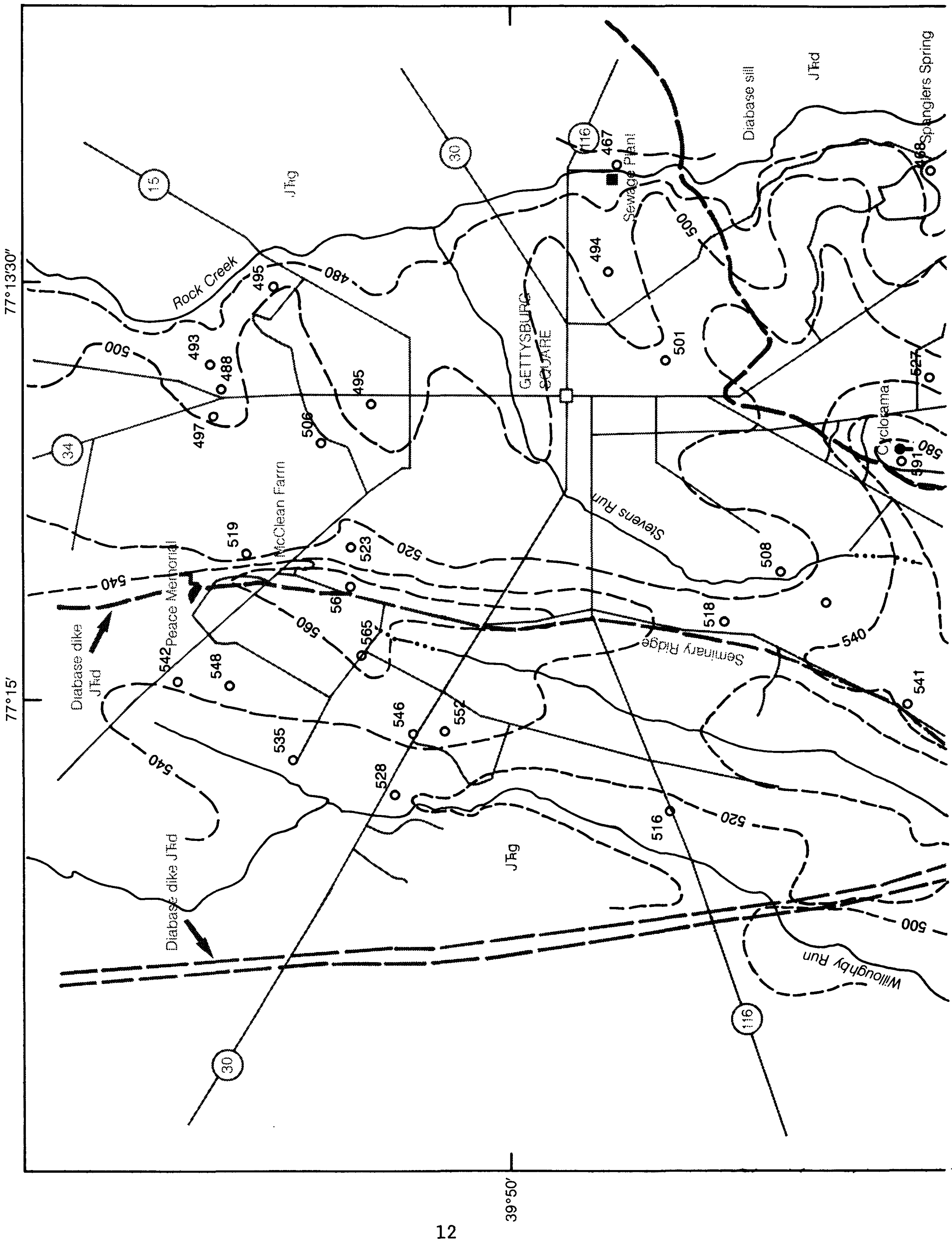
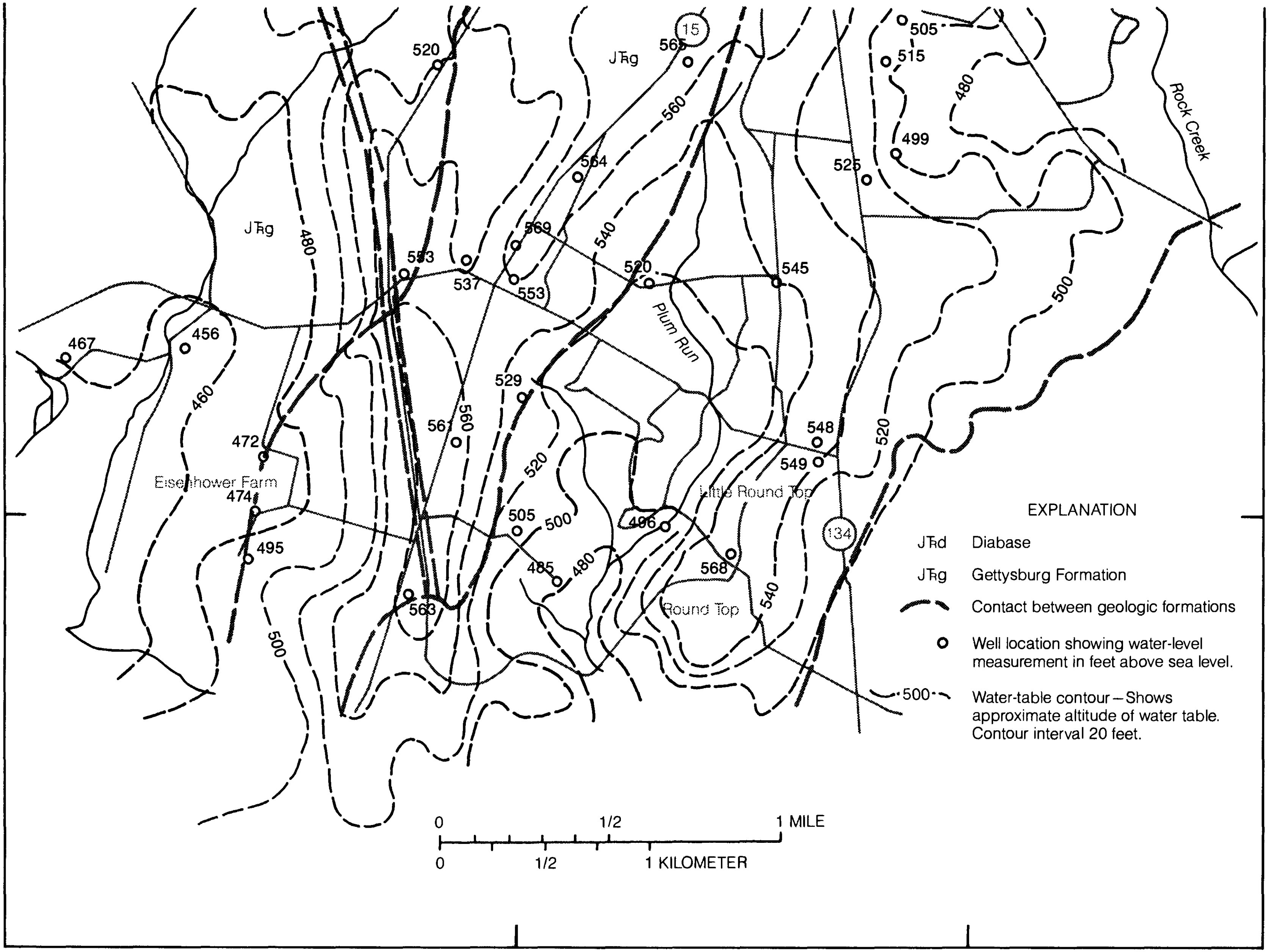


Figure 4.--Effects of 13-day aquifer test on water levels in wells Ad 591 (pumped) and Ad 629 (observed).

Figure 5 is a contour map of the water table on April 24, 1986. The water table, which was contoured from measurements made on October 9-10, 1986 (fig. 6), has the same basic configuration as shown in the April map, although the water table is lower on the October map. Therefore, the basic ground-water flow pattern is fairly consistent from season to season. Shallow ground water generally moves perpendicular to contours, away from the divides, and down the water-table gradient toward local streams. Ground- and surface-water flow, in outcrop areas of the Gettysburg Formation, tend to parallel the strike of bedding.



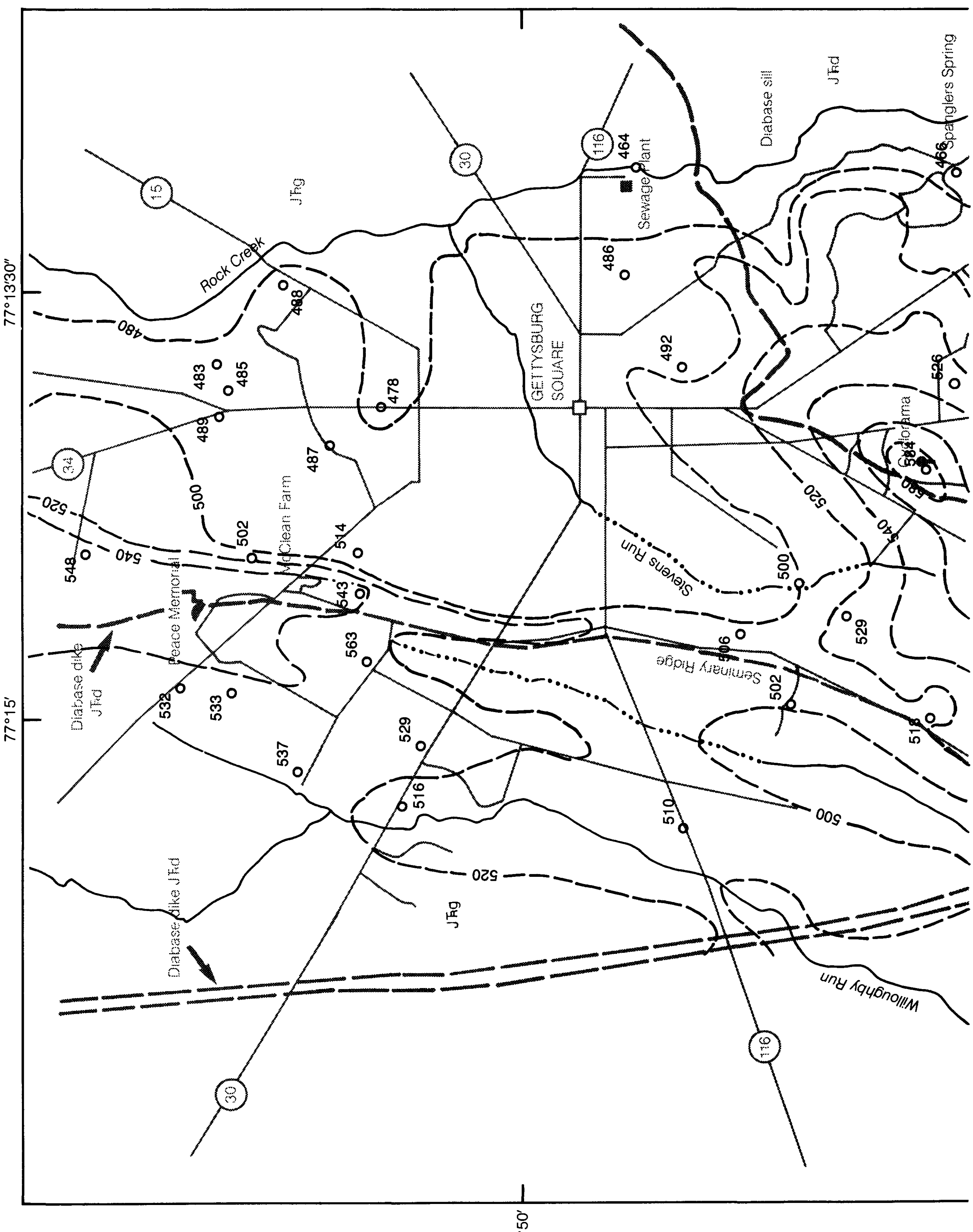
77°13'30"
77°15'
39°50'
Rock Creek
GETTYSBURG SQUARE
Sewage Plant
Diabase sill
Spanglers Spring
Cyclorama
Stevens Run
Seminary Ridge
Peace Memorial
McClean Farm
Diabase dike
Willoughby Run
480
500
520
540
560
580

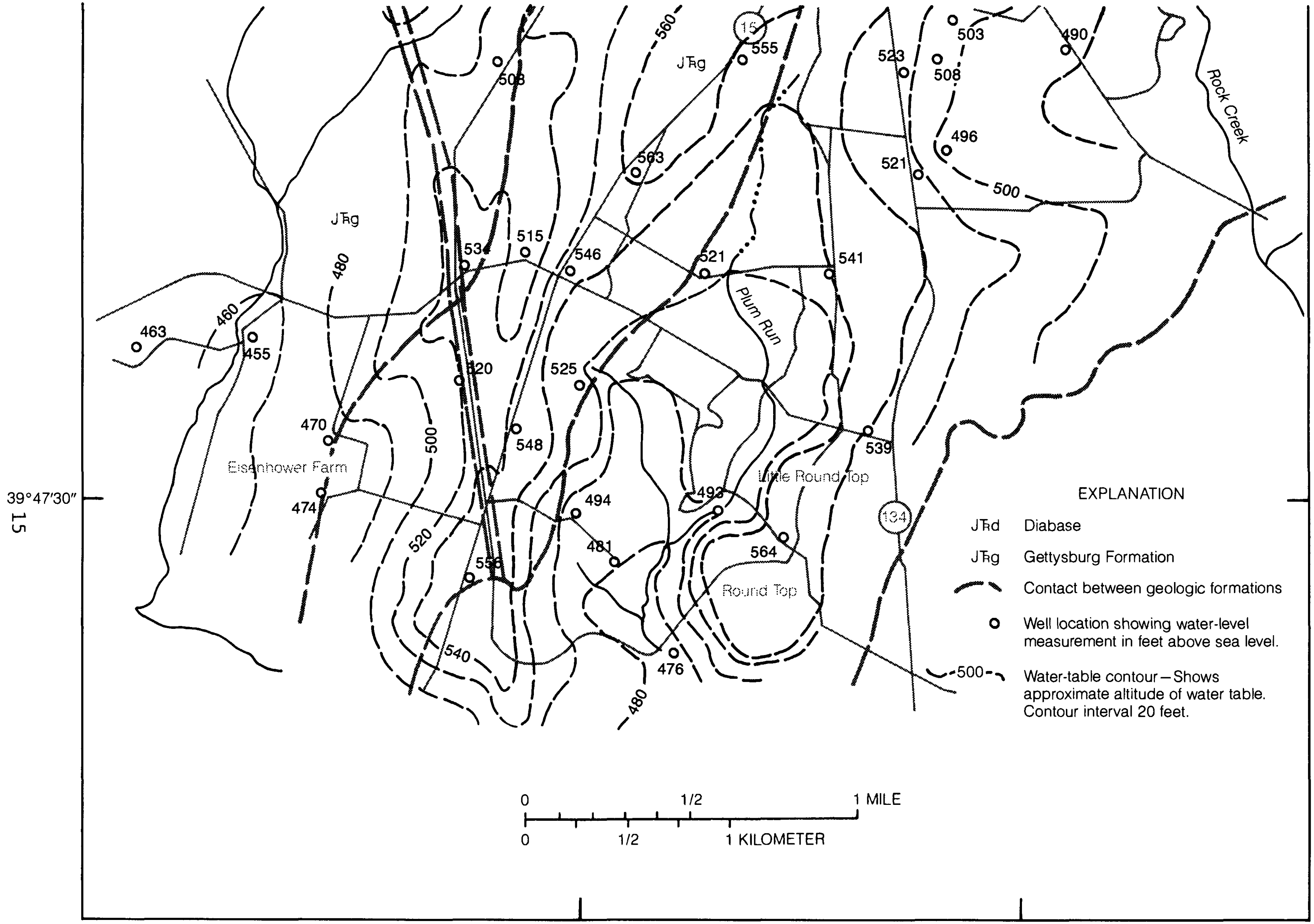


Base from U.S. Geological Survey
Fairfield, 1973, and Gettysburg, 1973.

Geology modified from C.R. Wood (1980)

Figure 5.—Configuration and altitude of water table on April 24, 1986 in Gettysburg and vicinity.


77°13'30"
77°15'
39°50'
GETTYSBURG SQUARE
Rock Creek
Stevens Run
Seminary Ridge
Willoughby Run
Sewage Plant
Spanglers Spring
Diabase sill
Diabase dike
Peace Memorial
McClean Farm
Cyclorama
JTRg
JTRd
480
500
520
540
464
466
478
483
485
486
487
488
489
492
500
502
506
510
514
516
526
529
532
533
537
543
548
563
584
15
30
34
116



Base from U.S. Geological Survey
Fairfield, 1973, and Gettysburg, 1973.

Geology modified from C.R. Wood (1980)

Figure 6.—Configuration and altitude of water table on October 9-10, 1986 in Gettysburg and vicinity.

Water Levels

Water levels measured in about 60 wells were used in conjunction with topography, the location of dikes, and the elevation of springs and streams, to contour the water table. Water levels measured in deep wells of the network probably represent a composite of the multiple aquifers penetrated in each well. However, the lack of measurable vertical movements of injected brine, as a tracer, in the boreholes of eight deep wells suggests that there is little difference in head between aquifers that are at different depths below a given point at land surface. Vertical movement of brine, where it was observed at all depths in the deep wells, was barely discernible. This suggests that the shallow and deep aquifers are in good hydraulic connection in the Gettysburg area.

A comparison of the contour maps in the area of the diabase sill reveals only minor declines in water level between the spring and fall measurements, possibly because (1) only a small quantity of the water can be discharged between spring and fall because the horizontal permeability of the aquifer is low, or (2) a decline of only a few feet in level is sufficient to trap water behind unfractured diabase. The latter is considered to be the more likely of the two.

Water levels in the few deep wells in the project area indicate that the natural flow of ground water tends to parallel the strike of bedding. Monitoring of water levels in two deep wells, Ad 177 and Ad 255, has shown the connection between water-bearing zones within the deeper aquifer. When pumping of a few hundred gallons per minute is sustained for as little as a few hours, from deep Gettysburg Borough wells, drawdown (decline in water level) occurs in deep observation wells nearby. Drawdown from pumping wells Ad 252 and Ad 174 is shown on the hydrographs of Ad 255 (fig. 7) and Ad 177 (fig. 8), respectively. These well pairs intercept some of the same water-bearing zones. The paired wells, Ad 252 and Ad 255, are 1,400 ft apart, separated by Willoughby Run, and are nearly perpendicular to strike. The other paired wells are nearly parallel to strike and about 500 ft apart.

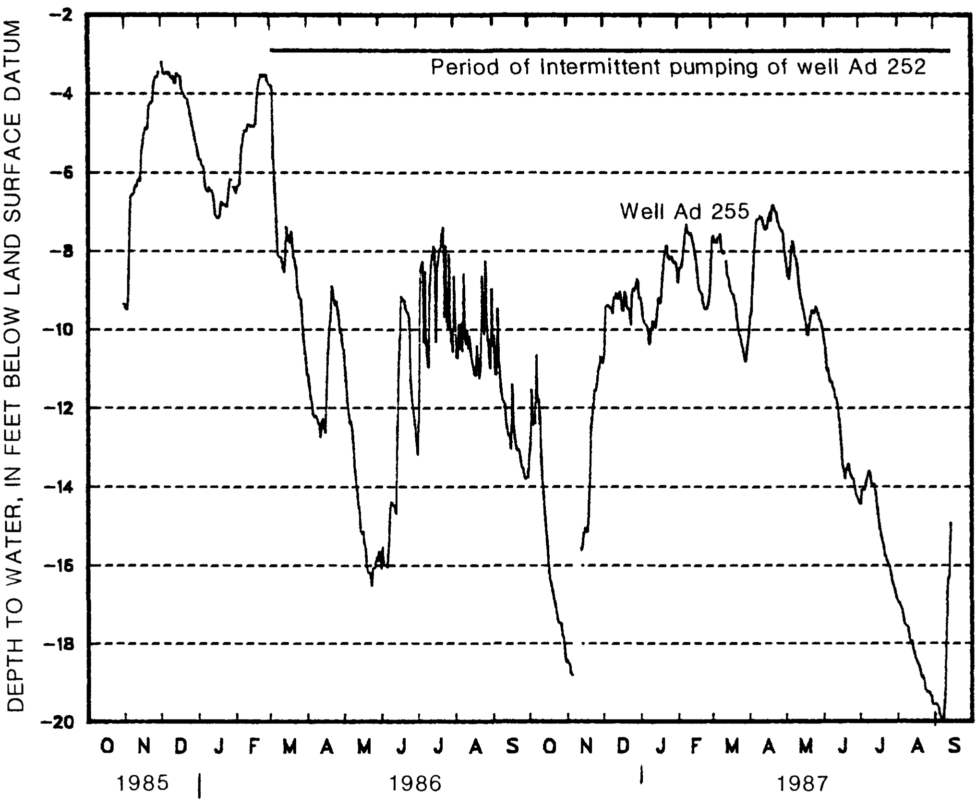


Figure 7.--Hydrograph showing the effect of pumping well Ad 252 on water levels at well Ad 255.

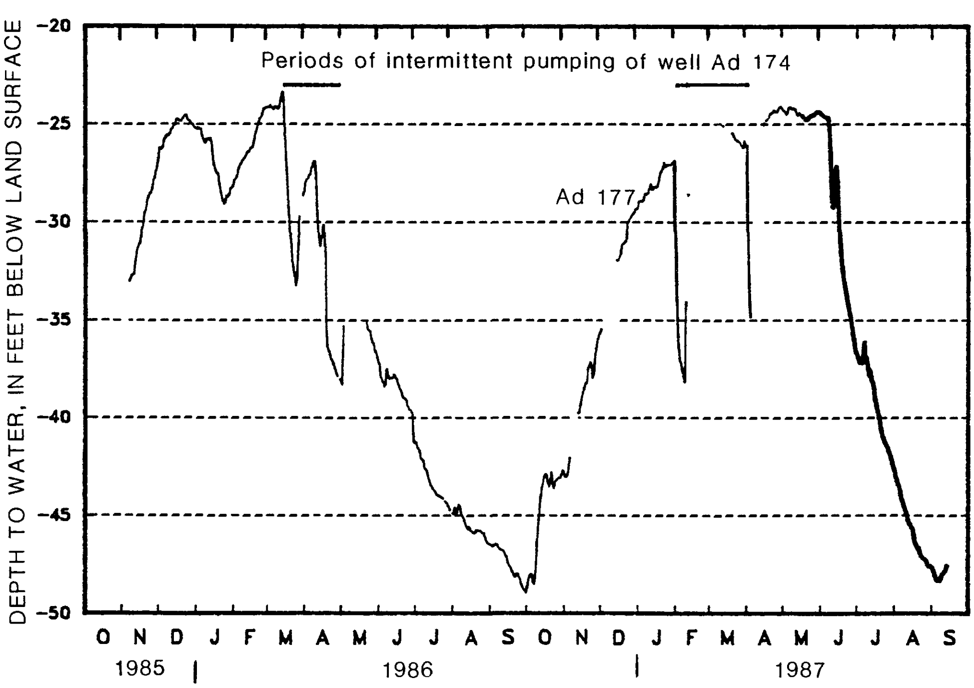


Figure 8.--Hydrograph showing the effect of pumping well Ad 174 on water levels of Ad 177.

WATER QUALITY

Samples were analysed for one or more of five general groups of chemicals that either occur naturally in water or could have been introduced by man's activities. These groups and the period(s) during which they were collected are shown below:

Chemical group	1986			1987
	Spring	Summer	Fall	Spring/Summer
Major chemical constituents			X	
Selected trace elements	X		X	
Nitrogen species	X	X	X	X
Pesticides (herbicides and insecticides)	X	X	X	X
Purgeable organic compounds	X		X	X

Wells were selected for sampling based chiefly on their location, both to characterize water quality in the flow systems, and to maximize the chance of intercepting any contaminated water that could move into park property from known sources. Samples were collected in spring, summer, and fall of 1986 and spring/summer of 1987.

During the spring, sampling was delayed until a week or more after rain had fallen on newly planted crops so that any applied nitrate and pesticides flushed into the ground water could be intercepted. Samples were collected from Plum Run only during baseflow periods, when ground water was the only source of water to the stream. Sites for nitrogen-species and pesticide sampling were selected to intercept ground-water flow from all agricultural areas. Samples from all agricultural areas were collected for analysis of pesticides used in the past. Analyses of samples collected for pesticides currently used were limited to areas of their use.

Description

Physical Characteristics and Major Chemical Constituents

The general quality of ground water in the GNMP and ENHS is suitable for drinking. Table 1 shows selected physical characteristics and major chemical constituents for well-water samples. Statistical analysis of the data indicates the chemistry of water from wells in the Gettysburg Formation is significantly different from the chemistry of water from wells in the diabase sill. For example, the median values of specific conductance, hardness, and dissolved solids in water from the Gettysburg Formation are about 40 percent greater than median values of water from the diabase. With the exception of silica, the median values of all constituents in water from the Gettysburg Formation exceed the median values of water from the diabase. Several factors contribute to this relationship. The minerals that comprise the diabase are much less soluble than minerals in the Gettysburg Formation. Calcium, magnesium, and bicarbonate[1] are the major constituents in all samples, and the presence of calcareous cements in the Gettysburg Formation provides a readily soluble mineral source for these constituents. Another factor is the shallow flow system in the diabase. Flow paths and contact time between water and rock in the diabase is shorter than in the Gettysburg Formation.

Of the constituents for which the USEPA (U.S. Environmental Protection Agency) has established secondary maximum contaminant levels (SMCLs), only concentrations of iron in three samples and manganese in two samples exceed these concentrations. Only water from well Ad 631 (Butterfield Farm), of all the wells in use, exceeded the iron and manganese SMCLs of the USEPA (1977). Neither of these elements is toxic, but, even at the low concentrations reported, they impart a slight taste to the water and also may stain articles in contact with the water.

[1]Although bicarbonate is not reported as a constituent in table 1, in the range of pH of these samples it is the major ion accounting for the alkalinity values reported (Hem, 1985, p. 104-109).

Table 1.--Major chemical constituents and properties in ground water

[deg C, degrees Celsius; mg/L, milligrams per liter; μg/L, micrograms per liter; μS/cm, microsiemens per centimeter at 25 degrees Celsius; <, less than; a double dash indicates no data]

Local identifier	Date	Geologic unit	Specific conductance (μS/cm)	pH (standard units)	Temperature water (deg C)	Alkalinity lab (mg/L as $CaCO_3$)	Hardness (mg/L as $CaCO_3$)	Calcium dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)
177	06-30-86	Gettysburg Fm	360	7.6	12.0	--	--	--	--
	10-08-86	Gettysburg Fm	375	7.7	11.5	--	--	--	--
	07-01-87	Gettysburg Fm	360	8.0	12.0	--	--	--	--
254	05-29-86	Gettysburg Fm	525	7.4	14.0	--	--	--	--
255	06-17-86	Gettysburg Fm	395	7.6	13.0	--	--	--	--
	07-28-86	Gettysburg Fm	425	7.4	13.0	--	120	--	--
	10-07-86	Gettysburg Fm	420	7.4	12.5	167	190	58	11
	07-01-87	Gettysburg Fm	425	8.0	13.0	--	--	--	--
589	06-08-87	Diabase	265	7.4	11.0	--	--	--	--
590	06-08-87	Gettysburg Fm	500	7.7	12.0	--	--	--	--
591	06-26-86	Gettysburg Fm	490	7.4	13.0	--	--	--	--
	08-06-86	Gettysburg Fm	490	7.3	13.0	--	--	--	--
	10-15-86	Gettysburg Fm	455	7.6	12.0	--	--	--	--
592	06-03-87	Gettysburg Fm	880	7.2	14.0	--	--	--	--
593	07-30-86	Gettysburg Fm	816	7.8	13.5	--	240	--	--
	10-15-86	Gettysburg Fm	790	7.4	12.0	262	380	110	26
	06-03-87	Gettysburg Fm	820	7.2	13.0	--	--	--	--
594	10-06-86	Gettysburg Fm	825	7.3	12.0	--	--	--	--
596	05-29-86	Gettysburg Fm	525	7.3	13.0	--	--	--	--
	07-30-86	Gettysburg Fm	575	9.5	13.0	--	190	--	--
	10-06-86	Gettysburg Fm	570	7.0	12.0	--	--	--	--
	06-02-87	Gettysburg Fm	580	7.7	13.0	--	--	--	--
598	05-27-86	Gettysburg Fm	370	--	--	--	--	--	--
	08-05-86	Gettysburg Fm	405	7.6	12.5	--	--	--	--
	10-08-86	Gettysburg Fm	385	7.7	12.0	164	170	43	15
	07-01-87	Gettysburg Fm	370	8.1	12.5	--	--	--	--
599	07-02-87	Gettysburg Fm	610	7.7	13.0	--	--	--	--
601	05-23-86	Gettysburg Fm	690	7.3	14.0	--	--	--	--
	07-28-86	Gettysburg Fm	770	7.2	13.0	--	210	--	--
	10-07-86	Gettysburg Fm	720	7.2	12.5	215	320	81	29
	06-29-87	Gettysburg Fm	780	7.8	13.0	--	--	--	--
608	05-27-86	Diabase	268	--	--	--	--	--	--
	08-05-86	Diabase	285	7.0	12.5	--	--	--	--
	10-16-86	Diabase	280	7.2	12.0	98	140	31	15
	06-02-87	Diabase	270	7.6	13.0	--	--	--	--
609	06-16-86	Diabase	410	7.7	13.0	--	--	--	--
	07-30-86	Diabase	423	7.6	13.0	--	120	--	--
	10-15-86	Diabase	415	7.3	12.0	160	180	52	13
612	06-17-86	Diabase	240	6.4	11.0	--	--	--	--
	08-06-86	Diabase	258	6.2	11.0	--	--	--	--

Table 1.--Major chemical constituents and properties in ground water--Continued

Local identi- fier	Sodium, dis- solved (mg/L as Na)	Potas- sium, dis- solved (mg/L as K)	Sulfate dis- solved (mg/L as SO_4)	Chlo- ride, dis- solved (mg/L as Cl)	Fluo- ride, dis- olved (mg/L as F)	Silica, dis- solved (mg/L as SiO_2)	Solids, sum of consti- tuents, dis- solved (mg/L)	Iron, dis- solved (μg/L as Fe)	Manga- nese, dis- solved (μg/L as Mn)	Carbon, organic total (mg/L as C)
177	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--	--
254	--	--	--	--	--	--	--	16	1	--
255	--	--	--	--	--	--	--	--	--	0.1
	--	--	--	--	--	--	--	--	--	--
	13	1.8	18	9.9	0.10	29	240	35	1	--
	--	--	--	--	--	--	--	--	--	--
589	--	--	--	--	--	--	--	--	--	--
590	--	--	--	--	--	--	--	--	--	--
591	--	--	--	--	--	--	--	700	10	.5
	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	100	<1	--
592	--	--	--	--	--	--	--	--	--	--
593	--	--	--	--	--	--	--	--	--	--
	19	.50	33	86	<.10	39	470	99	6	--
	--	--	--	--	--	--	--	--	--	--
594	--	--	--	--	--	--	--	<8	2	--
596	--	--	--	--	--	--	--	--	--	1.1
	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--	--
598	--	--	--	--	--	--	--	--	--	5.0
	--	--	--	--	--	--	--	--	--	--
	14	2.0	17	8.6	.30	28	230	63	<1	--
	--	--	--	--	--	--	--	--	--	--
599	--	--	--	--	--	--	--	--	--	--
601	--	--	--	--	--	--	--	--	--	2.7
	--	--	--	--	--	--	--	--	--	--
	25	3.0	31	79	<.10	38	420	240	590	--
	--	--	--	--	--	--	--	--	--	--
608	--	--	--	--	--	--	--	70	<10	1.6
	--	--	--	--	--	--	--	--	--	--
	5.0	.30	23	11	<.10	56	200	51	5	--
	--	--	--	--	--	--	--	--	--	--
609	--	--	--	--	--	--	--	--	--	<.1
	--	--	--	--	--	--	--	--	--	--
	14	.90	19	23	<.10	26	240	15	<1	--
612	--	--	--	--	--	--	--	4	<1	<.1
	--	--	--	--	--	--	--	--	--	--

Table 1.--Major chemical constituents and properties in ground water--Continued

Local identifier	Date	Geologic unit	Specific conductance (µS/cm)	pH (standard units)	Temperature water (deg C)	Alkalinity lab (mg/L as $CaCO_3$)	Hardness (mg/L as $CaCO_3$)	Calcium dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)
612	10-08-86	Diabase	255	7.6	10.0	95	120	26	14
	06-01-87	Diabase	250	7.3	11.0	--	--	--	--
613	06-18-86	Diabase	362	6.9	--	--	--	--	--
	10-07-86	Diabase	390	7.2	13.0	--	--	--	--
618	05-28-86	Gettysburg Fm	525	7.3	13.0	--	--	--	--
	07-30-86	Gettysburg Fm	578	7.7	13.0	--	--	--	--
	10-07-86	Gettysburg Fm	550	7.3	11.5	196	260	49	33
620	06-18-86	Gettysburg Fm	215	6.5	12.5	--	--	--	--
	07-28-86	Gettysburg Fm	225	6.7	12.0	--	68	--	--
	10-15-86	Gettysburg Fm	215	6.7	11.0	--	--	--	--
	06-29-87	Gettysburg Fm	220	7.6	13.0	--	--	--	--
623	06-18-86	Gettysburg Fm	405	6.8	14.0	--	--	--	--
	10-16-86	Gettysburg Fm	410	7.2	13.0	--	--	--	--
625	06-25-86	Diabase	380	6.8	14.0	--	--	--	--
	10-15-86	Diabase	380	6.9	13.0	--	--	--	--
	06-01-87	Diabase	370	7.2	12.0	--	--	--	--
629	06-25-86	Gettysburg Fm	530	7.5	14.0	--	--	--	--
630	05-28-87	Gettysburg Fm	500	7.5	12.0	--	--	--	--
631	06-17-86	Gettysburg Fm	515	7.3	13.0	--	--	--	--
	10-15-86	Gettysburg Fm	540	7.4	13.0	258	290	69	29
	06-02-87	Gettysburg Fm	560	7.7	13.0	--	--	--	--
632	07-01-87	Gettysburg Fm	385	7.9	20.0	--	--	--	--
636	08-05-86	Gettysburg Fm	750	7.5	12.5	--	--	--	--
	10-16-86	Gettysburg Fm	615	7.1	12.0	--	--	--	--
	06-03-87	Gettysburg Fm	500	7.7	12.0	--	--	--	--
637	06-26-86	Gettysburg Fm	520	--	13.0	--	--	--	--
638	07-29-86	Gettysburg Fm	377	7.4	12.0	--	150	--	--
	10-08-86	Gettysburg Fm	320	7.4	12.5	--	--	--	--
	06-29-87	Gettysburg Fm	345	8.0	13.0	--	--	--	--
639	05-23-86	Gettysburg Fm	375	7.5	14.0	--	--	--	--
	07-28-86	Gettysburg Fm	438	7.5	12.0	--	170	--	--
	10-06-86	Gettysburg Fm	410	7.0	11.5	--	--	--	--
	06-29-87	Gettysburg Fm	410	7.9	12.5	--	--	--	--
643	06-26-86	Diabase	330	6.8	12.0	--	--	--	--
	08-06-86	Diabase	370	6.2	12.0	--	--	--	--
	10-07-86	Diabase	370	7.1	12.5	134	180	46	17
	06-01-87	Diabase	390	7.8	11.0	--	--	--	--
647	08-06-86	Gettysburg Fm	810	7.4	14.0	--	--	--	--
	11-17-86	Gettysburg Fm	750	7.6	13.0	229	330	83	31
	06-02-87	Gettysburg Fm	800	7.8	14.0	--	--	--	--
649	06-02-87	Diabase	510	7.8	13.0	--	--	--	--

Table 1.--Major chemical constituents and properties in ground water--Continued

Local identi-fier	Sodium, dis-solved (mg/L as Na)	Potas-sium, dis-solved (mg/L as K)	Sulfate dis-solved (mg/L as SO_4)	Chlo-ride, dis-solved (mg/L as Cl)	Fluo-ride, dis-olved (mg/L as F)	Silica, dis-solved (mg/L as SiO_2)	Solids, sum of consti-tuents, dis-solved (mg/L)	Iron, dis-solved (µg/L as Fe)	Manga-nese, dis-solved (µg/L as Mn)	Carbon, organic total (mg/L as C)
612	3.8	0.50	10	2.9	<0.10	53	170	4	<1	--
	--	--	--	--	--	--	--	--	--	--
613	--	--	--	--	--	--	--	--	--	1.6
	--	--	--	--	--	--	--	--	--	--
618	--	--	--	--	--	--	--	10	13	1.6
	--	--	--	--	--	--	--	--	--	--
	25	1.0	60	30	<.10	20	340	15	6	--
620	--	--	--	--	--	--	--	--	--	.5
	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--	--
623	--	--	--	--	--	--	--	16	5	6.2
	--	--	--	--	--	--	--	--	--	--
625	--	--	--	--	--	--	--	--	--	.9
	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--	2.6
629	--	--	--	--	--	--	--	21	4	.4
630	--	--	--	--	--	--	--	--	--	--
631	--	--	--	--	--	--	--	480	160	.5
	9.8	.90	40	6.1	<.10	34	340	84	10	--
	--	--	--	--	--	--	--	--	--	--
632	--	--	--	--	--	--	--	--	--	--
636	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--	--
637	--	--	--	--	--	--	--	--	--	--
638	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--	--
639	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--	--
643	--	--	--	--	--	--	--	--	--	1.0
	--	--	--	--	--	--	--	--	--	--
	6.7	1.0	32	14	<.10	46	240	820	9	--
	--	--	--	--	--	--	--	--	--	--
647	--	--	--	--	--	--	--	--	--	--
	1	1.8	58	66	.10	29	420	17	1	--
	--	--	--	--	--	--	--	--	--	--
649	--	--	--	--	--	--	--	--	--	--

Trace Elements

The results of analyses for selected trace elements show no evidence of toxic concentrations in ground water (table 2). All concentrations of reported elements are below the maximum contaminant levels (MCLs) established by the USEPA (1976) with two possible exceptions. Sample results for lead in water from well Ad 608 and Plum Run were reported only to a detection limit of 100 μg/L (micrograms per liter). Although lead was not detected, this concentration is double the MCL established by USEPA.

Nitrogen Species

Nitrogen occurs in several different forms in the ground water. Concentrations of several nitrogen species are reported in table 3. Of these, high nitrite and nitrate concentrations can have adverse health effects. Water containing nitrate in excess of 10 mg/L (milligrams per liter) may cause life threatening methemoglobenemia in infants (U.S. Environmental Protection Agency, 1976, p. 81). The combined concentrations of nitrite and nitrate were less than about 3 mg/L as nitrogen for most of the study area; higher concentrations were reported from three wells (Ad 255, Ad 596, Ad 620) in agricultural areas along Willoughby Run. Two of these wells are on the ENHS. The only well where water consistently exceeds the MCL of 10 mg/L established by the USEPA (1976) is the Granite farm well (Ad 625). This well was drilled inside a 12-ft-deep, hand-dug well. The construction may permit water that has entered the dug well from the surface to enter the drilled well. Because no high nitrate concentrations were found in areas upgradient from the well, it is believed that on-site practices are the source of nitrates. The absence of pesticides in any analysis of water from Ad 625 and little seasonal change in nitrate concentration suggest a human- or animal-waste source rather than inorganic fertilizer spread on crops. Above-average (but below the MCL) concentrations of nitrate at wells Ad 255, Ad 596, Ad 620, and Ad 639 are attributed to fertilizer application. The above-average nitrate concentrations in the Devils Den well (Ad 612) may be related to the on-site sanitary facilities and to sheep grazing nearby. The shallow flow-system and water table in the diabase sill and regolith facilitate the movements of contaminants from the surface to the aquifer.

Pesticides

Of the 39 insecticides and herbicides for which analyses were made, 8 were detected in 5 of the 39 water samples shown in table 4. The concentrations of those detected were less than 1.0 μg/L and were at or slightly above the minimum detection level. Water from two wells in current use by the NPS contained trace levels of pesticides, the insecticides malathion and diazinon in the McClean Farm well (Ad 593) and the herbicide picloram in the Eisenhower Show Barn well (Ad 620). Other herbicides detected in the wells are 2,4-D, atrazine, dicamba, silvex, and prometon. The USEPA has no MCL for any of the pesticides detected in water except 2,4-D (U.S. Environmental Protection Agency, 1986b). They have proposed an interim MCL of 100 μg/L for 2,4-D. Three of the pesticides were detected in water from Ad 649, a well with an open casing, at the site of a recently demolished house.

Table 2.--Selected trace elements in ground water and Plum Run at Round Top

[µg/L, micrograms per liter; <, less than, a double dash indicates no data]

Local identifier	Date	Geologic unit	Arsenic dissolved (µg/L as As)	Barium, dissolved (µg/L as Ba)	Beryllium, dissolved (µg/L as Be)	Cadmium dissolved (µg/L as Cd)	Chromium, dissolved (µg/L as Cr)	Copper, dissolved (µg/L as Cu)	Lead, dissolved (µg/L as Pb)	Mercury dissolved (µg/L as Hg)	Nickel, dissolved (µg/L as Ni)	Selenium, dissolved (µg/L as Se)	Zinc, dissolved (µg/L as Zn)
254	05-29-86	Gettysburg Fm	5	--	<0.5	<1	<10	<10	<10	<0.1	<100	<1	39
591	06-26-86	Gettysburg Fm	7	--	<.5	<1	<10	<10	<10	<.1	<100	1	23
	10-15-86	Gettysburg Fm	7	71	<.5	<1	<10	<10	<10	<.1	<100	<1	17
594	10-06-86	Gettysburg Fm	1	15	<.5	<1	<10	<10	<10	<.1	<100	<1	26
598	10-08-86	Gettysburg Fm	--	<2	--	--	--	--	--	--	--	--	--
608	05-27-86	Diabase	<1	--	<10	<10	10	<10	<100	<.1	<100	<1	20
	10-16-86	Diabase	--	<2	--	--	--	--	--	--	--	--	--
612	06-17-86	Diabase	<1	--	<.5	<1	10	<10	<10	<.1	<100	<1	3
	10-08-86	Diabase	--	<2	--	--	--	--	--	--	--	--	--
618	05-28-86	Gettysburg Fm	10	--	<.5	<1	<10	<10	<10	<.1	<100	<1	17
	10-07-86	Gettysburg Fm	14	300	<.5	1	<10	<10	<10	<.1	<100	<1	32
623	06-18-86	Gettysburg Fm	<1	--	<.5	1	<10	<10	<10	<.1	<100	<1	780
629	06-25-86	Gettysburg Fm	3	--	<.5	<1	<10	20	<10	<.1	<100	2	11
631	06-17-86	Gettysburg Fm	6	--	<.5	<1	<10	40	20	<.1	<100	<1	36
643	10-07-86	Diabase	--	<2	--	--	--	--	--	--	--	--	--
Plum Run at Round Top	10-08-86		1	--	<10	<10	<10	<10	<100	<.1	<100	<1	<10

Table 3.--Nitrogen species in ground water and Plum Run at Round Top

[mg/L, milligrams per liter; <, less than; a double dash indicates no data]

Local identi-fier	Date	Geo-logic unit	Nitro-gen dis-solved (mg/L as N)	Nitro-gen, organic dis-solved (mg/L as N)	Nitro-gen, ammonia dis-solved (mg/L as N)	Nitro-gen, nitrite dis-solved (mg/L as N)	Nitro-gen, nitrate dis-solved (mg/L as N)	Nitro-gen, NO_2+NO_3 dis-solved (mg/L as N)
177	06-30-86	Gettysburg Fm	--	0.18	0.02	<0.01	--	1.30
	10-08-86	Gettysburg Fm	--	.87	.03	<.01	--	1.40
	07-01-87	Gettysburg Fm	--	--	<.01	<.01	--	.79
255	06-17-86	Gettysburg Fm	4.3	.38	.02	<.01	--	3.90
	07-28-86	Gettysburg Fm	--	--	.02	<.01	--	4.10
	10-07-86	Gettysburg Fm	--	.57	.03	<.01	--	4.00
589	06-08-87	Diabase	--	.47	.03	<.01	--	<.10
590	06-08-87	Gettysburg Fm	--	.36	.04	<.01	--	1.40
591	06-26-86	Gettysburg Fm	3.6	.37	.03	<.01	--	3.20
	08-06-86	Gettysburg Fm	3.2	.28	.02	<.01	--	2.90
	10-15-86	Gettysburg Fm	--	--	<.01	<.01	--	2.90
592	06-03-87	Gettysburg Fm	--	--	.03	<.01	--	1.20
593	07-30-86	Gettysburg Fm	2.4	.26	.04	<.01	--	2.10
	10-15-86	Gettysburg Fm	--	--	<.01	<.01	--	2.00
	06-03-87	Gettysburg Fm	--	.97	.03	<.01	--	1.90
594	10-06-86	Gettysburg Fm	--	--	.13	<.01	--	.26
596	05-29-86	Gettysburg Fm	4.1	.48	.02	<.01	--	3.60
	07-30-86	Gettysburg Fm	4.0	.36	.04	.01	3.59	3.60
	10-06-86	Gettysburg Fm	--	.67	.03	.02	3.18	3.20
	06-02-87	Gettysburg Fm	--	--	<.01	<.01	--	4.30
598	05-27-86	Gettysburg Fm	3.4	--	<.01	<.01	--	3.20
	08-05-86	Gettysburg Fm	3.7	--	<.01	<.01	--	3.20
	10-08-86	Gettysburg Fm	--	.27	.03	<.01	--	3.30
	07-01-87	Gettysburg Fm	--	--	<.01	<.01	--	2.90
599	07-02-87	Gettysburg Fm	--	--	<.01	<.01	--	2.00
601	05-23-86	Gettysburg Fm	3.9	.43	.07	<.01	--	3.40
	07-28-86	Gettysburg Fm	5.6	.27	.03	<.01	--	5.30
	10-07-86	Gettysburg Fm	--	.68	.02	<.01	--	5.50
	06-29-87	Gettysburg Fm	--	.47	.03	<.01	--	2.70
608	05-27-86	Diabase	2.2	.39	.01	<.01	--	1.80
	08-05-86	Diabase						
	10-16-86	Diabase	--	--	<.01	<.01	--	2.00
	06-02-87	Diabase	--	--	<.01	<.01	--	1.50
609	06-16-86	Diabase	2.4	.37	.03	<.01	--	2.00
	07-30-86	Diabase	2.4	.28	.02	<.01	--	2.10
	10-15-86	Diabase	--	--	<.01	<.01	--	2.10
612	06-17-86	Diabase	6.7	.48	.02	<.01	--	6.20
	08-06-86	Diabase	6.1	--	<.01	<.01	--	5.80
	10-08-86	Diabase	--	1.7	.03	<.01	--	6.30
	06-01-87	Diabase	--	--	<.01	<.01	--	6.60

Table 3.--Nitrogen species in ground water and Plum Run at Round Top--Continued

Local identi- fier	Date	Geo- logic unit	Nitro- gen dis- solved (mg/L as N)	Nitro- gen, organic dis- solved (mg/L as N)	Nitro- gen, ammonia dis- solved (mg/L as N)	Nitro- gen, nitrite dis- solved (mg/L as N)	Nitro- gen, nitrate dis- solved (mg/L as N)	Nitro- gen, NO_2+NO_3 dis- solved (mg/L as N)
613	06-18-86	Diabase	1.1	0.18	0.02	<0.01	--	0.91
	10-07-86	Diabase	--	.86	.04	<.01	--	1.20
	07-30-86	Gettysburg Fm	2.2	.36	.04	.03	1.77	1.80
	10-07-86	Gettysburg Fm	--	.55	.05	.02	0.90	.92
620	06-18-86	Gettysburg Fm	6.8	.28	.02	<.01	--	6.50
	07-28-86	Gettysburg Fm	6.9	.29	.01	<.01	--	6.60
	10-15-86	Gettysburg Fm	--	--	<.01	<.01	--	6.80
	06-29-87	Gettysburg Fm	--	--	<.01	<.01	--	5.50
623	06-18-86	Gettysburg Fm	3.0	.37	.03	<.01	--	2.60
	10-16-86	Gettysburg Fm	--	--	<.01	<.01	--	2.60
625	06-25-86	Diabase	12	--	<.01	<.01	--	11.0
	10-15-86	Diabase	--	--	<.01	<.01	--	12.0
	06-01-87	Diabase	--	--	<.01	<.01	--	9.00
629	06-25-86	Gettysburg Fm	3.1	.48	.02	<.01	--	2.60
630	05-28-87	Gettysburg Fm	--	.67	.03	<.01	--	2.00
631	06-17-86	Gettysburg Fm	.77	.17	.03	<.01	--	.57
	10-15-86	Gettysburg Fm	--	--	<.01	<.01	--	.61
	06-02-87	Gettysburg Fm	--	--	<.01	<.01	--	.66
632	07-01-87	Gettysburg Fm	--	.57	.03	.02	1.48	1.50
636	08-05-86	Gettysburg Fm	--	.25	.05	.01	--	<.10
	10-16-86	Gettysburg Fm	--	14	.66	<.01	--	<.10
	06-03-87	Gettysburg Fm	--	.70	1.20	<.01	--	<.10
637	06-26-86	Gettysburg Fm	--	.66	.04	<.01	--	<.10
638	07-29-86	Gettysburg Fm	1.6	.26	.04	<.01	--	1.30
	10-08-86	Gettysburg Fm	--	.70	.10	<.01	--	.93
	06-29-87	Gettysburg Fm	--	--	<.01	<.01	--	.54
639	05-23-86	Gettysburg Fm	2.8	.26	.04	<.01	--	2.50
	07-28-86	Gettysburg Fm	1.5	.59	.11	<.01	--	.83
	10-06-96	Gettysburg Fm	--	.41	.09	<.01	--	.77
	06-29-87	Gettysburg Fm	--	.89	.01	.01	8.19	8.20
643	06-26-86	Diabase	3.5	.36	.04	<.01	--	3.10
	08-06-86	Diabase	2.7	.38	.02	<.01	--	2.30
	10-07-86	Diabase	--	.46	.04	<.01	--	1.70
	06-01-87	Diabase	--	--	<.01	<.01	--	2.40
647	08-06-86	Gettysburg Fm	3.3	.36	.04	<.01	--	2.90
	11-17-86	Gettysburg Fm	--	--	--	--	--	2.90
	06-02-87	Gettysburg Fm	--	.59	.01	<.01	--	2.70
649	06-02-87	Diabase	--	.64	.16	.02	2.08	2.10
Plum Run	10-08-86		--	.28	.02	<.01	--	<.10
at Round Top	06-01-87		--	1.1	.08	.02	.28	.30

Table 4.--Pesticides in ground water and Plum Run at Round Top

[µg/L, micrograms per liter; <, less than; a double dash indicates no data]

Local identifier	Date	Geo logic unit	Phorate total (µg/L)	Propazine total (µg/L)	Perthane total (µg/L)	Simetryne total (µ/L)	Simazine total (µ/L)	Prometon total (µ/L)	Prometryne total (µ/L)
177	06-30-86	Gettysburg Fm	--	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	07-01-87	Gettysburg Fm	--	<.1	<.1	<.1	<.1	<.1	<.1
255	06-17-86	Gettysburg Fm	--	--	<.1	--	--	--	--
	10-07-86	Gettysburg Fm	--	<.1	--	<.1	<.1	<.1	<.1
	07-01-87	Gettysburg Fm	--	<.1	<.1	<.1	<.1	<.1	<.1
593	06-03-87	Gettysburg Fm	--	<.1	<.1	<.1	<.1	<.1	<.1
594	06-16-86	Gettysburg Fm	--	<.1	--	<.1	<.1	<.1	<.1
596	10-16-86	Gettysburg Fm	--	<.1	--	<.1	<.1	<.1	<.1
	06-02-87	Gettysburg Fm	--	<.1	<.1	<.1	<.1	<.1	<.1
598	05-27-86	Gettysburg Fm	--	<.1	<.1	<.1	<.1	<.1	<.1
	10-08-86	Gettysburg Fm	--	<.1	<.1	<.1	<.1	<.1	<.1
	07-01-87	Gettysburg Fm	--	<.1	<.1	<.1	<.1	<.1	<.1
599	07-02-87	Gettysburg Fm	--	<.1	<.1	<.1	<.1	.2	<.1
601	10-07-86	Gettysburg Fm	--	<.1	--	<.1	<.1	<.1	<.1
	06-29-87	Gettysburg Fm	--	--	<.1	--	--	--	--
608	05-27-86	Diabase	<0.01	<.1	<.1	<.1	<.1	<.1	<.1
	10-16-86	Diabase	--	<.1	--	<.1	<.1	<.1	<.1
609	06-16-86	Diabase	--	<.1	--	<.1	<.1	<.1	<.1
	10-15-86	Diabase	--	<.1	--	<.1	<.1	<.1	<.1
612	06-17-86	Diabase	--	<.1	<.1	<.1	<.1	<.1	<.1
	10-08-86	Diabase	--	<.1	--	<.1	<.1	<.1	<.1
	06-01-87	Diabase	--	--	<.1	--	--	--	--
620	10-15-86	Gettysburg Fm	--	<.1	--	<.1	<.1	<.1	<.1
	11-17-86	Gettysburg Fm	--	--	--	--	--	--	--
	06-29-87	Gettysburg Fm	--	<.1	--	<.1	<.1	<.1	<.1
625	06-25-86	Diabase	--	--	<.1	--	--	--	--
	10-15-86	Diabase	--	<.1	<.1	<.1	<.1	<.1	<.1
	06-08-87	Diabase	--	--	--	--	--	--	--
629	06-26-86	Gettysburg Fm	--	<.1	--	<.1	<.1	<.1	<.1
631	06-02-87	Gettysburg Fm	--	<.1	--	<.1	<.1	<.1	<.1
632	07-01-87	Gettysburg Fm	--	<.1	--	<.1	<.1	<.1	<.1
638	06-29-87	Gettysburg Fm	--	<.1	--	<.1	<.1	<.1	<.1
639	06-29-87	Gettysburg Fm	--	<.1	--	<.1	<.1	<.1	<.1
643	06-01-87	Diabase	--	--	--	--	--	--	--
647	06-02-87	Gettysburg Fm	--	--	--	--	--	--	--
	11-17-86	Gettysburg Fm	--	--	--	--	--	--	--
649	06-02-87	Diabase	--	--	<.1	--	--	--	--
Plum Run at Round Top	10-08-86		--	<.1	<.1	<.1	<.1	<.1	<.1
	06-01-87		--	<.1	<.1	<.1	<.1	<.1	<.1

Table-4.--Pesticides in ground water and Plum Run at Round Top--Continued

Local identi- fier	Aldrin, total (µg/L)	Lindane total (µg/L)	Chlor- dane, total (µg/L)	DDD, total (µg/L)	DDE, total (µg/L)	DDT, total (µg/L)	Di- eldrin totaL (µg/L)	Endo- sulfan, total (µg/L)
177	<0.01	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01	<0.01
	<.01	<.01	<.1	<.01	<.01	<.01	<.01	<.01
255	<.01	<.01	<.1	<.01	<.01	<.01	<.01	<.01
	--	--	--	--	--	--	--	--
	<.01	<.01	<.1	<.01	<.01	<.01	<.01	<.01
593	<.01	<.01	<.1	<.01	<.01	<.01	<.01	<.01
594	--	--	--	--	--	--	--	--
596	--	--	--	--	--	--	--	--
	<.01	<.01	<.1	<.01	<.01	<.01	<.01	<.01
598	<.01	<.01	<.1	<.01	<.01	<.01	<.01	<.01
	<.01	<.01	<.1	<.01	<.01	<.01	<.01	<.01
	<.01	<.01	<.1	<.01	<.01	<.01	<.01	<.01
599	<.01	<.01	<.1	<.01	<.01	<.01	<.01	<.01
601	--	--	--	--	--	--	--	--
	<.01	<.01	<.1	<.01	<.01	<.01	<.01	<.01
608	<.01	<.01	<.1	<.01	<.01	<.01	<.01	<.01
	--	--	--	--	--	--	--	--
609	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--
612	<.01	<.01	<.1	<.01	<.01	<.01	<.01	<.01
	--	--	--	--	--	--	--	--
	<.01	<.01	<.1	<.01	<.01	<.01	<.01	<.01
620	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--
625	<.01	<.01	<.1	<.01	<.01	<.01	<.01	<.01
	<.01	<.01	<.1	<.01	<.01	<.01	<.01	<.01
	--	--	--	--	--	--	--	--
629	--	--	--	--	--	--	--	--
631	--	--	--	--	--	--	--	--
632	--	--	--	--	--	--	--	--
638	--	--	--	--	--	--	--	--
639	--	--	--	--	--	--	--	--
643	--	--	--	--	--	--	--	--
647	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--
649	<.01	<.01	<.1	<.01	<.01	<.01	<.01	<.01
Plum Run	<.01	<.01	<.1	<.01	<.01	<.01	<.01	<.01
at Round Top	<.01	<.01	<.1	<.01	<.01	<.01	<.01	<.01

Table 4.--Pesticides in ground water and Plum Run at Round Top--Continued

Local identi-fier	Endrin, total (µg/L)	Ethion, total (µg/L)	Tox-aphene, total (µg/L)	Hepta-chlor, total (µg/L)	Hepta-chlor epoxide total (µg/L)	Meth-oxy-chlor, total (µg/L)	PCB, total (µg/L)	Mala-thion, total (µg/L)
177	<0.01	<0.01	<1	<0.01	<0.01	<0.01	<0.1	<0.01
	<.01	<.01	<1	<.01	<.01	<.01	<.1	<.01
255	<.01	<.01	<1	<.01	<.01	<.01	<.1	<.01
	--	--	--	--	--	--	--	--
	<.01	<.01	<1	<.01	<.01	<.01	<.1	<.01
593	<.01	<.01	<1	<.01	<.01	<.01	<.1	.01
594	--	--	--	--	--	--	--	--
596	--	--	--	--	--	--	--	--
	<.01	<.01	<1	<.01	<.01	<.01	<.1	<.01
598	<.01	<.01	<1	<.01	<.01	<.01	<.1	<.01
	<.01	<.01	<1	<.01	<.01	<.01	<.1	<.01
	<.01	<.01	<1	<.01	<.01	<.01	<.1	<.01
599	<.01	<.01	<1	<.01	<.01	<.01	<.1	<.01
601	--	--	--	--	--	--	--	--
	<.01	<.01	<1	<.01	<.01	<.01	<.1	<.01
608	<.01	<.01	<1	<.01	<.01	<.01	<.1	<.01
609	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--
612	<.01	<.01	<1	<.01	<.01	<.01	<.1	<.01
	--	--	--	--	--	--	--	--
	<.01	<.01	<1	<.01	<.01	<.01	<.1	<.01
620	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--
625	<.01	<.01	<1	<.01	<.01	<.01	<.1	<.01
	<.01	<.01	<1	<.01	<.01	<.01	<.1	<.01
	--	--	--	--	--	--	--	--
629	--	--	--	--	--	--	--	--
631	--	--	--	--	--	--	--	--
632	--	--	--	--	--	--	--	--
638	--	--	--	--	--	--	--	--
639	--	--	--	--	--	--	--	--
643	--	--	--	--	--	--	--	--
647	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--
649	<.01	<.01	<1	<.01	<.01	<.01	<.1	<.01
Plum Run	<.01	<.01	<1	<.01	<.01	<.01	<.1	<.01
at Round Top	<.01	<.01	<1	<.01	<.01	<.01	<.1	<.01

Table 4.--Pesticides in ground water and Plum Run at Round Top--Continued

Local identifier	Parathion, total (μg/L)	Diazinon, total (μg/L)	Methyl parathion, total (μg/L)	Atrazine, total (μg/L)	Picloram (Tordon) (Amdon) total (μg/L)	2,4-D, total (μg/L)	2,4,5-T total (μg/L)	Mirex, total (μg/L)
177	<0.01	<0.01	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01
	<.01	<.01	<.01	<.1	--	--	--	<.01
255	<.01	<.01	<.01	--	--	--	--	<.01
	--	--	--	<.1	--	--	--	--
	<.01	<.01	<.01	<.1	--	--	--	<.01
593	<.01	.01	<.01	<.1	<.01	<.01	<.01	<.01
594	--	--	--	<.1	<.01	<.01	<.01	--
596	--	--	--	<.1	<.01	<.01	<.01	--
	<.01	<.01	<.01	<.1	<.01	<.01	<.01	<.01
598	<.01	<.01	<.01	<.1	--	--	--	<.01
	<.01	<.01	<.01	<.1	--	--	--	<.01
	<.01	<.01	<.01	<.1	--	--	--	<.01
599	<.01	<.01	<.01	<.1	--	--	--	<.01
601	--	--	--	.1	<.01	<.01	<.01	--
	<.01	<.01	<.01	--	--	--	--	<.01
608	<.01	<.01	<.01	<.1	--	--	--	<.01
	--	--	--	<.1	--	--	--	--
609	--	--	--	<.1	--	--	--	--
	--	--	--	<.1	--	--	--	--
612	<.01	<.01	<.01	<.1	<.01	<.01	<.01	<.01
	--	--	--	<.1	<.01	<.01	<.01	--
	<.01	<.01	<.01	--	<.01	<.01	<.01	<.01
620	--	--	--	<.1	.01	<.01	<.01	--
	--	--	--	--	--	--	--	--
	--	--	--	<.1	--	--	--	--
625	<.01	<.01	<.01	--	<.01	<.01	<.01	<.01
	<.01	<.01	<.01	<.1	--	--	--	<.01
	--	--	--	--	<.01	<.01	<.01	--
629	--	--	--	<.1	<.01	<.01	<.01	--
631	--	--	--	<.1	<.01	<.01	<.01	--
632	--	--	--	<.1	--	--	--	--
638	--	--	--	<.1	--	--	--	--
639	--	--	--	<.1	--	--	--	--
643	--	--	--	--	<.01	<.01	<.01	--
647	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--
649	<.01	.01	<.01	--	<.01	.01	<.01	<.01
Plum Run	<.01	<.01	<.01	<.1	--	--	--	<.01
at Round Top	<.01	<.01	<.01	<.1	--	--	--	<.01

Table 4.--Pesticides in ground water and Plum Run at Round Top--Continued

Local identifier	Silvex, total (μg/L)	Total Trithion (μg/L)	Methyl Trithion, total (μg/L)	Cyanazine total (μg/L)	Dicamba (Mediben) (Banvel D) total (μg/L)	2,4-DP total (μg/L)	Ametryne total	Metolachlor water whole tot.rec (μg/L)
177	<0.01	<0.01	<0.01	<0.10	<0.01	<0.01	<0.10	--
	--	<.01	<.01	<.10	--	--	<.10	<0.1
255	--	<.01	<.01	--	--	--	--	--
	--	--	--	<.10	--	--	<.10	<.1
	--	<.01	<.01	<.10	--	--	<.10	<.1
593	<.01	<.01	<.01	<.10	<.01	<.01	<.10	<.1
594	<.01	--	--	<.10	<.01	<.01	<.10	--
596	<.01	--	--	<.10	<.01	<.01	<.10	<.1
	<.01	<.01	<.01	<.10	<.01	<.01	<.10	<.1
598	--	<.01	<.01	<.10	--	--	<.10	--
	--	<.01	<.01	<.10	--	--	<.10	<.1
	--	<.01	<.01	<.10	--	--	<.10	<.1
599	--	<.01	<.01	<.10	--	--	<.10	<.1
601	<.01	--	--	<.10	<.01	<.01	<.10	--
	--	<.01	<.01	--	--	--	--	--
608	--	<.01	<.01	<.10	--	--	<.10	--
	--	--	--	<.10	--	--	<.10	<.1
609	--	--	--	<.10	--	--	<.10	--
	--	--	--	<.10	--	--	<.10	<.1
612	<.01	<.01	<.01	<.10	<.01	<.01	<.10	--
	<.01	--	--	<.10	<.01	<.01	<.10	<.1
	<.01	<.01	<.01	--	<.01	<.01	--	--
620	<.01	--	--	<.10	<.01	<.01	<.10	<.1
	--	--	--	--	--	--	--	--
	--	--	--	<.10	--	--	<.10	<.1
625	<.01	<.01	<.01	--	<.01	<.01	--	--
	--	<.01	<.01	<.10	--	--	<.10	<.1
	<.01	--	--	--	<.01	<.01	--	--
629	<.01	--	--	<.10	<.01	<.01	<.10	--
631	<.01	--	--	<.10	<.01	<.01	<.10	<.1
632	--	--	--	<.10	--	--	<.10	<.1
638	--	--	--	<.10	--	--	<.10	<.1
639	--	--	--	<.10	--	--	<.10	<.1
643	<.01	--	--	--	<.01	<.01	--	--
647	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--
649	.01	<.01	<.01	--	.03	<.01	--	--
Plum Run	--	<.01	<.01	<.10	--	--	<.10	<.1
at Round Top	--	<.01	<.01	<.10	--	--	<.10	<.1

Purgeable Organic Compounds

Synthetic purgeable organic compounds (POCs) have been identified in ground water adjacent to the NPS property. One source north of Gettysburg and on the USEPA National Priority List of hazardous-waste sites has contaminated many residential wells northeast of the Peace Memorial and east of Route 34 (fig. 2). Contaminant concentrations ranging from one to several thousand micrograms per liter have been reported in water from wells southeast of the source (Rod Nesmith, Pennsylvania Department of Environmental Resources, written commun., 1985). Trichloroethylene (TCE) is the dominant contaminant, but 1,1,1-trichloroethane, tetrachloroethylene (PCE), degradation products of these compounds and other POCs also have been identified.

Another source of POC, which was discovered in the fall of 1986 near the square in Gettysburg (Thomas Miller, Pennsylvania Department of Environmental Resources, written commun., 1986), contains PCE as the dominant POCs and TCE, dichlorethylene, and vinyl chloride in lesser amounts. Concentrations reported by the Pennsylvania Department of Environmental Resources laboratory in water collected on December 19, 1986, from well Ad 652 (fig. 2) at the suspected source are shown below.

	Concentrations in micrograms per liter	
Purgeable Organic Compound	After pumping 25 minutes	After pumping 95 minutes
PCE	25,000	1,200
TCE	4,000	180
cis-1,2-dichloroethylene	2,600	150
trans-1,2-dichloroethylene	600	not reported
vinyl chloride	~ 200	not reported

This source was discovered when analyses of water from the public supply well Ad 629 (fig. 2) was reported by a commercial laboratory to contain 10 $\mu g/L$ of PCE on October 6, 1986. The well had been in service less than 6 months. Another public supply well, Ad 174 (fig. 2) located 0.75 mi southwest of Ad 629, has not been used since November 1983 because of PCE contamination. Reported concentrations of PCE in samples of water collected from this well on September 11, 1985 and on May 2, 1986, were 6.1 $\mu g/L$ and 5.8 $\mu g/L$, respectively. The well had been pumped to waste for 10 days prior to collection of the 1986 sample.

The USEPA drinking-water MCL for POCs (U.S. Environmental Protection Agency 1986a) are as follows:

benzene -- 5 $\mu g/L$
carbon tetrachloride -- 5 $\mu g/L$
1,2-dichloroethene -- 5 $\mu g/L$
trichloroethylene -- 5 $\mu g/L$
paradichlorobenzene -- 75 $\mu g/L$
1,1-dichloroethylene -- 7 $\mu g/L$
1,1,1-trichloroethane -- 200 $\mu g/L$
vinyl chloride -- 2 $\mu g/L$

Concentrations

Samples for POC were analysed in two ways. Most samples were analysed quantitatively using gas chromatography and mass spectrometry. Gas chromatographic scans were done on some of the 1987 samples from wells that had prior positive POC results or were outside the area of potential contamination from known sources. Scans provide only qualitative determinations.

The results of the gas chromatographic scans are shown below:

County well number	Sample date	Compounds detected
Ad 273	06-03-87	trichloroethylene
589	06-08-87	none
590	06-08-87	none
592	06-03-87	none
593	06-03-87	none
599	07-02-87	none
601	07-08-87	1,2-dichloroethylene
608	06-02-87	none
618	06-03-87	none
630	05-28-87	tetrachloroethylene
631	06-03-87	none
636	06-03-87	none
638	07-08-87	none
649	06-02-87	none

The compounds detected were present at low concentrations, probably not greater than 1 $\mu g/L$.

Table 5 shows the results of quantitative analyses of well water for POCs. In water from five of the eight wells sampled, one or more POCs was detected. All POCs detected were at concentrations less than 1 $\mu g/L$. Water from only one well, Ad 631, in current use by the NPS was analysed. In two analyses, no POC was detected in water from this well.

page 36 follows

Table 5.--Purgeable organic compounds in ground water

[μg/L, micrograms per liter; <, less than; a double dash indicates no data]

Local identifier	Date	Geologic unit	Dichlorobromomethane total (μg/L)	Carbontetrachloride total (μg/L)	1,2-Dichloroethane total (μg/L)	Bromoform total (μg/L)	Chlorodibromomethane total (μg/L)	Chloroform total (μg/L)	Toluene total (μg/L)	Benzene total (μg/L)
177	06-30-86	Gettysburg Fm	<0.20	<0.20	<0.20	<0.20	<0.20	0.30	<0.20	<.20
	07-13-87	Gettysburg Fm	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
254	05-29-86	Gettysburg Fm	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
591	06-26-86	Gettysburg Fm	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
	10-15-86	Gettysburg Fm	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
598	05-27-86	Gettysburg Fm	<.20	<.20	<.20	<.20	<.20	.30	<.20	.20
	07-13-87	Gettysburg Fm	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
608	10-16-86	Diabase	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
618	05-28-86	Gettysburg Fm	<.20	<.20	<.20	<.20	<.20	.20	.20	<.20
	10-07-86	Gettysburg Fm	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
623	06-18-86	Gettysburg Fm	<.20	<.20	<.20	<.20	<.20	.20	<.20	<.20
	10-16-86	Gettysburg Fm	<.20	<.20	<.20	<.20	<.20	.20	<.20	<.20
631	06-17-86	Gettysburg Fm	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
	10-15-86	Gettysburg Fm	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20

Local identifier	Chlorobenzene total (μg/L)	Chloroethane total (μg/L)	Ethylbenzene total (μg/L)	Methylbromide total (μg/L)	Methylchloride total (μg/L)	Methylene chloride total (μg/L)	Tetrachloroethylene total (μg/L)	Trichlorofluoromethane total (μg/L)	1,1-Dichloroethane total (μg/L)	1,1-Dichloroethylene total (μg/L)
177	0.40	<0.20	<0.20	<0.20	<0.20	<2.0	0.90	<0.20	<0.20	<0.20
	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
254	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
591	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
598	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
608	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
618	<.20	<.20	<.20	<.20	<.20	<.20	.20	<.20	<.20	<.20
	<.20	<.20	<.20	<.20	<.20	<.50	<.20	<.20	<.20	<.20
623	<.20	<.20	<.20	<.20	<.20	<.20	0.0	<.20	<.20	<.20
	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
631	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20

Table 5.--Purgeable organic compounds in ground water--Continued

Local identifier	1,1,1-Trichloroethane total (μg/L)	1,1,2-Trichloroethane total (μg/L)	1,1,2,2 Tetrachloroethane total (μg/L)	1,2-Dichlorobenzene total (μg/L)	1,2-Dichloropropane total (μg/L)	1,2-Transdichloroethylene total (μg/L)	1,3-Dichloropropane total (μg/L)	1,3-Dichlorobenzene total (μg/L)	1,4-Dichlorobenzene total (μg/L)	2-Chloroethylvinylether total (μg/L)
177	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
254	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
591	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
598	.30	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
608	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
618	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
623	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
631	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20
	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20	<.20

Local identifier	Dichlorodifluoromethane total (μg/L)	Trans-1,3-dichloropropene total (μg/L)	Cis 1,3-dichloropropene total (μg/L)	1,2-Dibromo ethylene total (μg/L)	Vinyl chloride total (μg/L)	Trichloroethylene total (μg/L)	Naphthalenes, polychlor. total (μg/L)	Styrene total (μg/L)	Xylene water whole tot rec (μg/L)
177	<0.20	<0.20	<0.20	<0.2	<0.20	<0.2	<0.10	<0.2	<0.2
	<.20	<.20	<.20	<.2	<.20	<.2	--	<.2	<.2
254	<.20	<.20	<.20	<.2	<.20	<.2	--	<.2	--
591	<.20	<.20	<.20	<.2	<.20	<.2	--	<.2	--
	<.20	<.20	<.20	<.2	<.20	.5	--	<.2	--
598	<.20	<.20	<.20	<.2	<.20	<.2	<.10	<.2	--
	<.20	<.20	<.20	<.2	<.20	<.2	--	<.2	<.2
608	<.20	<.20	<.20	<.2	<.20	<.2	--	<.2	<.2
618	<.20	<.20	<.20	<.2	<.20	.2	--	<.2	--
	<.20	<.20	<.20	<.2	<.20	<.2	--	<.2	--
623	<.20	<.20	<.20	<.2	<.20	<.2	--	<.2	--
	<.20	<.20	<.20	<.2	<.20	<.2	--	<.2	--
631	<.20	<.20	<.20	<.2	<.20	<.2	--	<.2	--
	<.20	<.20	<.20	<.2	<.20	<.2	--	<.2	--

Movement

Wells in which POCs were detected are in a zone roughly parallel to the strike of the Gettysburg Formation and aligned with both major source areas of PCE and TCE. POCs were not detected in water from any wells outside the zone. Although this configuration suggests the movement of some contaminants southwestward from identified contaminant source areas for distances of 1 mi or more, such movement would be opposite to the direction of shallow ground-water flow. Only trace amounts of POCs have been found in park wells, but it is possible that concentrations may increase if such movements are occurring and continue. The alternative is that POCs in park wells came from minor sources near each well.

The detected POCs range in density from about 1.3 to 1.6. Therefore, these contaminants can move downward as a fluid with higher density than that of the ambient ground waters, through fractures and along bedding surfaces. Density flows of POC masses along an impermeable surface that is tilted opposite to the flow of ground water are also possible (Dragun, 1988, p. 50). However, density flow alone probably cannot account for movements of 1 mile along strike opposite the flow of ground water. POCs also can move in solution with the flow of water. TCE is soluble up to a concentration of 1,100 mg/L and PCE is soluble up to a concentration of 6,300 mg/L in water.

One possible explanation for movement over long distances is shown in figure 9 and involves both density flow of POCs into deeper parts of the aquifer and the pumping of ground water containing POC in solution. Several high-yield wells along strike penetrate deep, interconnected water-bearing zones (fig. 10). These wells are in the contaminated zone or its extension along strike, yield water containing dissolved POC, and are pumped for long periods, or intermittently, at high rates. Pumping lowers the water level in the well and reduces water pressure in interconnected water-bearing zones around the pumped well. A reduction of pressure in the highly transmissive beds in deep parts of the aquifer caused by pumping can spread widely. The shape of the effected area is probably elongate in response to the anisotropic nature of the aquifer. Water and contaminants are induced to move toward the point of lowest pressure (the pumping well) through the deep beds. Overlapping areas of drawdown between wells, and periodic cycles of pumping in different wells, will tend to move the contaminants along the line of pumping wells.

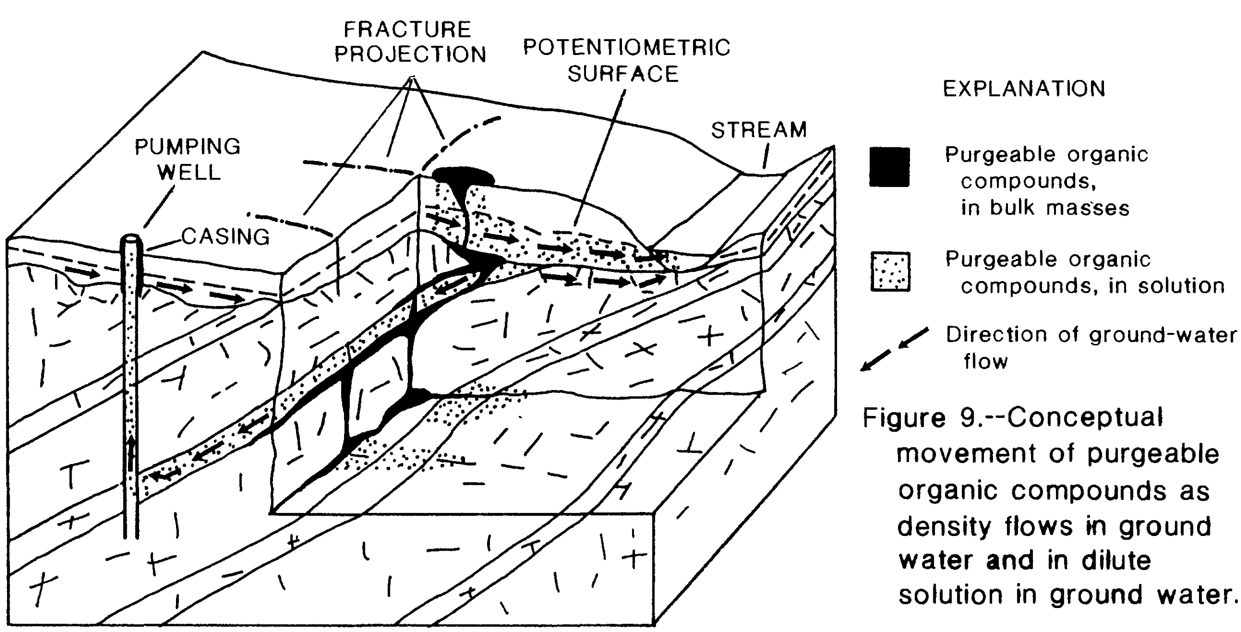


Figure 9.--Conceptual movement of purgeable organic compounds as density flows in ground water and in dilute solution in ground water.

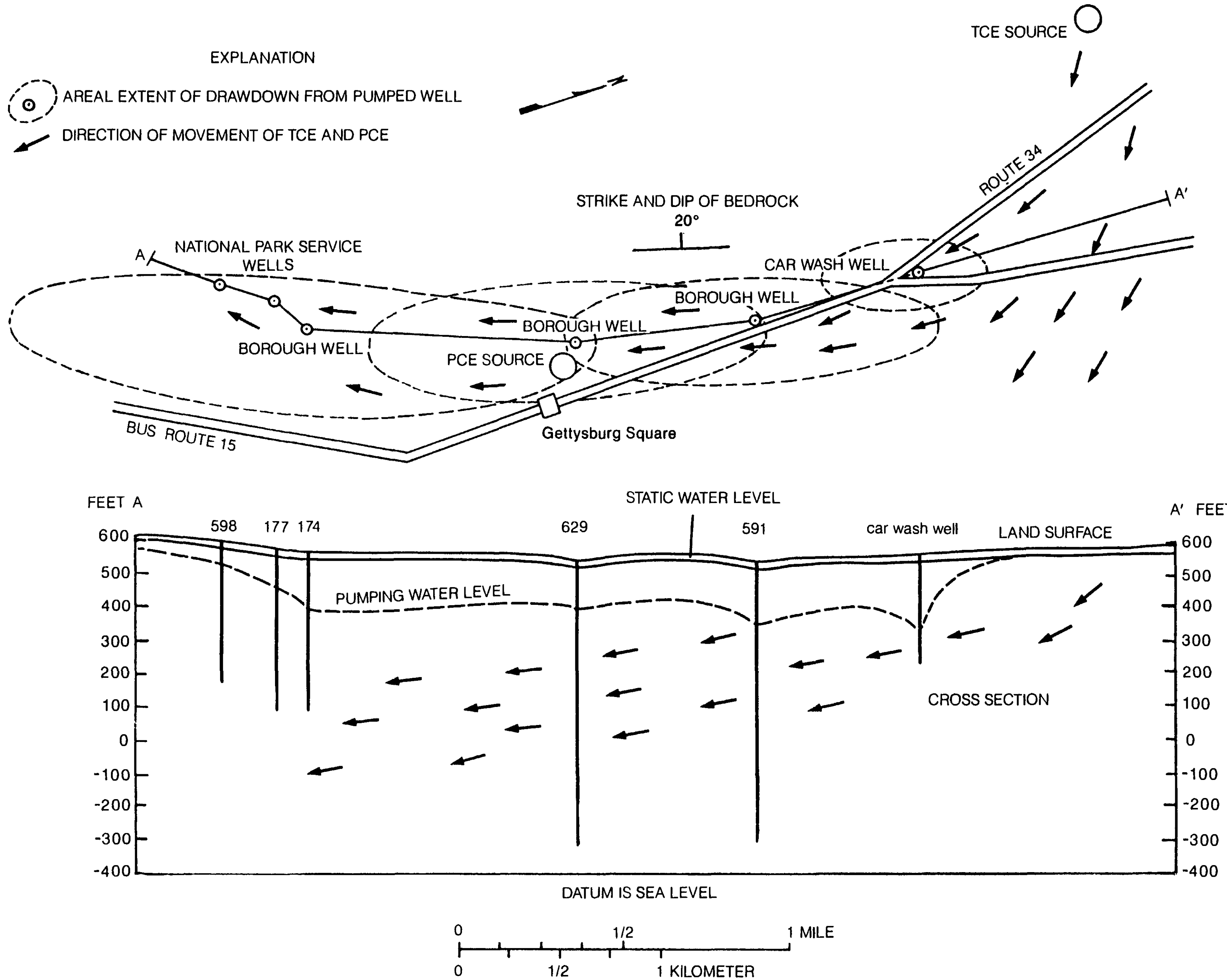


Figure 10.—Theoretical movement of contaminants by pumping.

Monitoring Ground-Water Quality

The information obtained in this study may be used to establish a ground-water monitoring system in conjuction with the current NPS environmental protection practices. Continued control of fertilizer and pesticide applications will limit the amounts of these chemicals that enter the ground-water system in agricultural areas. Any contaminants, including fertilizers, pesticides, and animal wastes, applied to the land surface will likely contaminate the thin, shallow aquifer in the area underlain by the diabase sill.

The area most subject to contamination is between Business Route 15 and Seminary Ridge because of the threat of contamination by POCs, pesticides, and waste from residential and commercial activities. The monitoring of changes in water quality caused by human activities and in water levels would be most informative if concentrated in that area. Because some of the key wells for monitoring belong to and are operated by the Gettysburg Borough Authority, a cooperative arrangement of data sharing would be mutually beneficial. Water from Gettysburg Authority wells 2 (Ad 174), 6 (Ad 629), and 7 (Ad 591) already contains either TCE or PCE. Continued analyses of water from these wells will provide early warning of any further spread of the areas of contamination by indicating a trend of increasing concentrations of the contaminants in these wells. Wells Ad 177 and Ad 598 may either substitute or supplement monitoring at well Ad 174. There are no deep NPS wells between Seminary Ridge and the Gettysburg Borough Authority wells Ad 591 and Ad 629 to monitor ground-water quality in park land north of Gettysburg. Therefore, the presence of POC in deep parts of the aquifer in that area is unknown.

Ground-water quality in other parts of the park cannot be monitored adequately by the network of existing wells. The wells are either too few or not located where needed to sample each of the many small ground water basins and the construction of many of the wells does not permit the collection of representative samples of the ground water. For example, dug wells or drilled wells that permit surface water to directly enter the borehole are unsuitable for sampling. On the other hand, wells in use are known to yield water containing contaminants or above average nitrate concentrations would be useful for continued monitoring of those constituents. Other wells in use would be sampled only if a problem is suspected because of a nearby potential contaminant source. Wells that would be suitable, or that could be made suitable for monitoring, are listed in table 6.

Well water in agricultural areas can be analysed for nitrate and any pesticides being supplied. Samples collected at least 1 week after a soaking rain on an area to which fertilizer and pesticides were applied are most likely to contain near-maximum concentrations of these substances. A second sampling each year, following the fall-season rise in ground-water levels, will likely contain persistent residues that have not been degraded or otherwise been removed from the unsaturated zone.

Annual or more frequent gas-chromatographic scans of water from wells in the flow system between Business Route 15 and Seminary Ridge likely would indicate the need for continued monitoring. Quantitative analysis could be limited to samples that gas-chromatographic scans show contain POC. Other sampling would be dictated by events and conditions as and where they develop.

Table 6.--Potential monitor wells and their suitability for sampling

Well number	National Park Service well number	Suitability for monitoring	Modifications that will make well suitable for monitoring[1]
Ad 594	D-5	Unsuitable	FP, EC, C, NP
596	D-8	Suitable	
630	D-126	Unsuitable	C, NP
618	D-59	Do	FP, EC, C, NP
632	D-66	do	FP, EC, C, NP
643	D-108	Do	FP, C, NP
608	D-28	Suitable	Pump requires 110 V power source
255	D-37	Do	NP
620	D-41	Unsuitable	FP, EC, C
615	D-40	Do	FDW, EC, C, NP
625	D-31	Do	FDW, EC, C
612	D-34	Suitable	
609	D-29	Do	

[1]FP - fill pit
EC - extend casing above land
C - add casing cap
FDW - fill dug well
NP - portable or permanent pump needed to collect samples

SUMMARY

The major aquifers in the Gettysburg National Military Park and the Eisenhower National Historic Site are the deep, interconnected systems in fractured beds of sandstone and shale of the Gettysburg Formation that dip about 20 degrees to the northwest. These aquifers are connected to the shallow water-table system developed in the regolith and shallow bedrock of the Gettysburg Formation and in a thick diabase sill. Water-level data show the presence of several flow systems, the major divides of which coincide with thin, vertical diabase dikes that are impermeable to water. Intensive fracturing of some beds in the Gettysburg Formation produce deep transmissive that may respond anti-sotropically to pumping. Drawdown was observed in several deep wells at least 0.5 mi along strike from a pumped well that penetrates deep transmissive zones.

Ground water in the park is suitable for drinking with minor exceptions. Dominant constituents in ground water are calcium, magnesium, and bicarbonate. Water from the Gettysburg Formation has about 40 percent greater concentrations of dissolved solids content than has water from the diabase. No evidence of trace metals at toxic concentrations was found in any samples. Most nitrate concentration in samples are less than 3 mg/L, but greater concentrations, believed to result from on-site practices, were found in a few analyses. Only water from the Granite Farm well (Ad 625) contains nitrate as nitrogen that exceeds the USEPA's MCL of 10 mg/L.

Trace amounts of the insecticides malathion and diazinon were found in one potable supply well, and trace amounts of the herbicide picloram were found in another. In three other wells, one or more of the herbicides 2,4-D, atrazine, dicamba, silvex, and prometon were detected in trace amounts.

TCE, PCE, and related POCs have been identified in ground water in two areas, one north of Gettysburg and the other in the center of Gettysburg Borough. Water from wells in the GNMP, between Seminary Ridge and Business Route 15 along strike and aligned with these areas, contain trace amounts of POC. Water-quality monitoring of this zone can provide warning of the spread of POC into the GNMP.

SELECTED REFERENCES

Buckwalter, T.F., Dodge, C.H., Schiner, G.R., and Koester, H.E., 1981, Water resources of the Clarion River and Redbank Creek Basins, Northwestern Pennsylvania: U.S. Geological Survey Open-File Report 81-70, 111 p.

Dragun, James, 1988, The soil chemistry of hazardous materials: Silver Spring, Maryland, The Hazardous Materials Control Research Institute, 458 p.

Farm Chemicals Handbook, 1988, Willoughby, Ohio, Meister Publishing Co., 523 p.

Fischer, A.J., Rowan, E.A., and Spalding, R.F., 1987, VOC's in ground water influenced by large scale withdrawals: Ground Water, v. 25, no. 5, p. 407-413.

Gibbons, Robert D., 1987, Statistical models for the analysis of volatile organic compounds in waste disposal sites: Ground Water, v. 25, no. 5, p. 572-580.

Goodenkauf, Owen, and Atkinson, Jon C., 1986, Occurrence of volatile organic chemicals in Nebraska ground water: Ground Water, v. 24, no. 2, p. 231-233.

Hem, John D., 1985, Study and interpretation of the chemical characteristics of natural water: U.S. Geological Survey Water Supply Paper 2254, 263 p.

Kleopfer, R.D., Easley, D.M., Haas, B.B., Jr., Delhi, T.G., Jackson, D.E., and Wurrey, C.J., 1985, Anaerobic degradation of trichloroethylene in soil: Environmental Science Technology, v. 19, no. 3, p. 277-280.

Lappenbusch, William L., 1986, Contaminated drinking water and your health: Alexandria, Virginia, Lappenbusch Environmental Health, Inc., 190 p.

Mackey, D.M., Roberts, P.V., and Cherry, J.A., 1985, Transport of organic contaminants in groundwater: Environmental Science Technology, v. 19, no. 5, p. 384-392.

Ogawa, I., Junk, G.A., and Svec, H.J., 1981, Degradation of aromatic compounds in groundwater and methods of sample preservation: Talanta, v. 28, p. 725-729.

Pettyjohn, W.A., Dunlap, W.J., Cosby, Roger, and Keeley, J.W., 1981, Sampling ground water for organic contaminants: Ground Water, v. 19, no. 2, p. 180-189.

Schwille, F., 1981, Groundwater pollution in porus media by fluids immiscible with water: The Science of the Total Environment, v. 21-23, p. 173-185.

Stoner, R.C., 1985, Inventory of wells, springs, and cisterns at Gettysburg National Military Park and Eisenhower National Historic Site: unpublished National Park Service Report, v. 1, 250 p., v. 2, 350 p.

Stose, G.W., and Bascom, Florence, 1929, Description of the Fairfield and Gettysburg quadrangles, Pennsylvania: U.S. Geological Survey Atlas, Folio 225.

Taylor, L.E., and Royer, D.W., 1981, Summary groundwater resources of Adams County, Pennsylvania: Pennsylvania Topographic and Geological Survey, 4th ser., Water Resources Report 52, 50 p.

U.S. Department of Commerce, Environmental Data Service (published annually, 1875-1987), Climatological data, Pennsylvania.

U.S. Environmental Protection Agency, 1975, National interim primary drinking water regulations: Federal Register, v. 40, no. 248, December 24, 1975, p. 59566-59588.

-----U.S. Environmental Protection Agency, 1976, National interim primary drinking water regulations: EPA-570/9-76-003, 159 p.

-----1977, National secondary drinking water regulations: Federal Register, v. 42, no. 62., March 31, 1977, Part I, p. 17143-17147.

-----1986a, National primary drinking water regulations: Code of Federal Regulations, Federal Register, v. 40, Part 141, July 1, 1986, p. 521-528.

-----1986b, National secondary drinking water regulations: Code of Federal Regulations, Federal Register, v. 42, Part 143, July 1, 1986, p. 587-590.

U.S. Geological Survey, 1987, Methods for the determination of organic substances in water and fluvial sediments: Techniques of water-resources investigations, book 5., chap. A3, 80 p.

Wood, Charles R., 1980, Groundwater resources of the Gettysburg and Hammer Creek Formations, southeastern Pennsylvania: Pennsylvania Topographic and Geological Survey, 4th ser., Water Resources Report 49, 87 p.

Zoeteman, B.C.J., De Greef, E., and Brinkmann, F.J.J., 1981, Persistency of organic contaminants in groundwater, lessons from soil pollution incidents in the Netherlands: The Science of the Total Environment, v. 21-22, p. 187-202.