Department of Natural Resources
Resource Assessment Service
MARYLAND GEOLOGICAL SURVEY
Emery T. Cleaves, Director

INTERIM TECHNICAL REPORT

IMPACT OF A PUBLIC WATER-SUPPLY WELL ON AVAILABILITY OF GROUND WATER TO NEIGHBORING DOMESTIC WELLS NEAR BEL AIR, MARYLAND

by
Mark T. Duigon
and
Barbara F. Cooper

Prepared in cooperation with the
Maryland Department of the Environment
and the
Harford County Government

1999

CONVERSION FACTORS AND ABBREVIATIONS

The following factors may be used by those readers who wish to convert the inch-pound units published in this report to International System (SI) units.

Multiply Inch-Pound Unit	By	To obtain International System Unit
inch (in.)	2.540	centimeter (cm)
inch (in.)	25.40	millimeter (mm)
foot (ft)	.3048	meter (m)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer (km^2)
gallon (gal)	3.785	liter (L)
inch per year (in./yr)	25.40	millimeter per year (mm/yr)
foot squared per day (ft^2/d)	.09290	meter squared per day (m^2/d)
gallon per minute (gal/min)	.06309	liter per second (L/s)
gallon per day (gal/d)	.00004381	liter per second (L/s)
gallon per minute per foot [(gal/min)/ft]	.2070	liter per second per meter [(L/s)/m]
cubic foot per second (ft^3/s)	.02832	cubic meter per second (m^3/s)
cubic foot per second per square mile [(ft^3/s)/mi^2]	.01093	cubic meter per second per square kilometer [(m^3/s)/km^2]

Chemical concentration and water temperature are given in SI units. Chemical concentration is expressed in milligrams per liter (mg/L), micrograms per liter (µg/L), or micrograms per kilogram (µ/kg). Specific conductance of water is expressed in microsiemens per centimeter at 25°C (µS/cm). Temperature in degrees Celsius (°C) can be converted to degrees Fahrenheit (°F) using the following equation:

$$°F = 1.8\ (°C) + 32$$

"Sea level" as used in this report 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."

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ABSTRACT

The possible impact of a public water-supply well on the availability of ground water to neighboring domestic wells near Bel Air, Maryland, was investigated. The production well draws water from an unconfined, anisotropic, fractured metamorphic-rock aquifer and is located at the distal end of a ground-water flow system. This flow system originates northeast of Bel Air Acres and flows approximately southwest, discharging mainly to Winters Run. During low-water conditions in August 1998, the production well was pumped at about 123 gallons per minute for five days. Water levels were monitored in six wells equipped with pressure transducers (two water company observation wells and four domestic wells) located from 261 to almost 1,500 feet from the production well. Water levels in two of the domestic wells showed no response; water level in one declined by about 1 foot, and in another, by about 3 feet. A recharge boundary was reached after approximately 700 minutes of pumping. The distribution of drawdowns around the production well is elliptical, reflecting the non-uniform aquifer permeability, with greater drawdown (higher permeability) oriented approximately north-northeast.

Water-table drawdown due to prolonged pumping of the production well likely will not have a significant adverse impact on the availability of ground water to neighboring domestic wells.

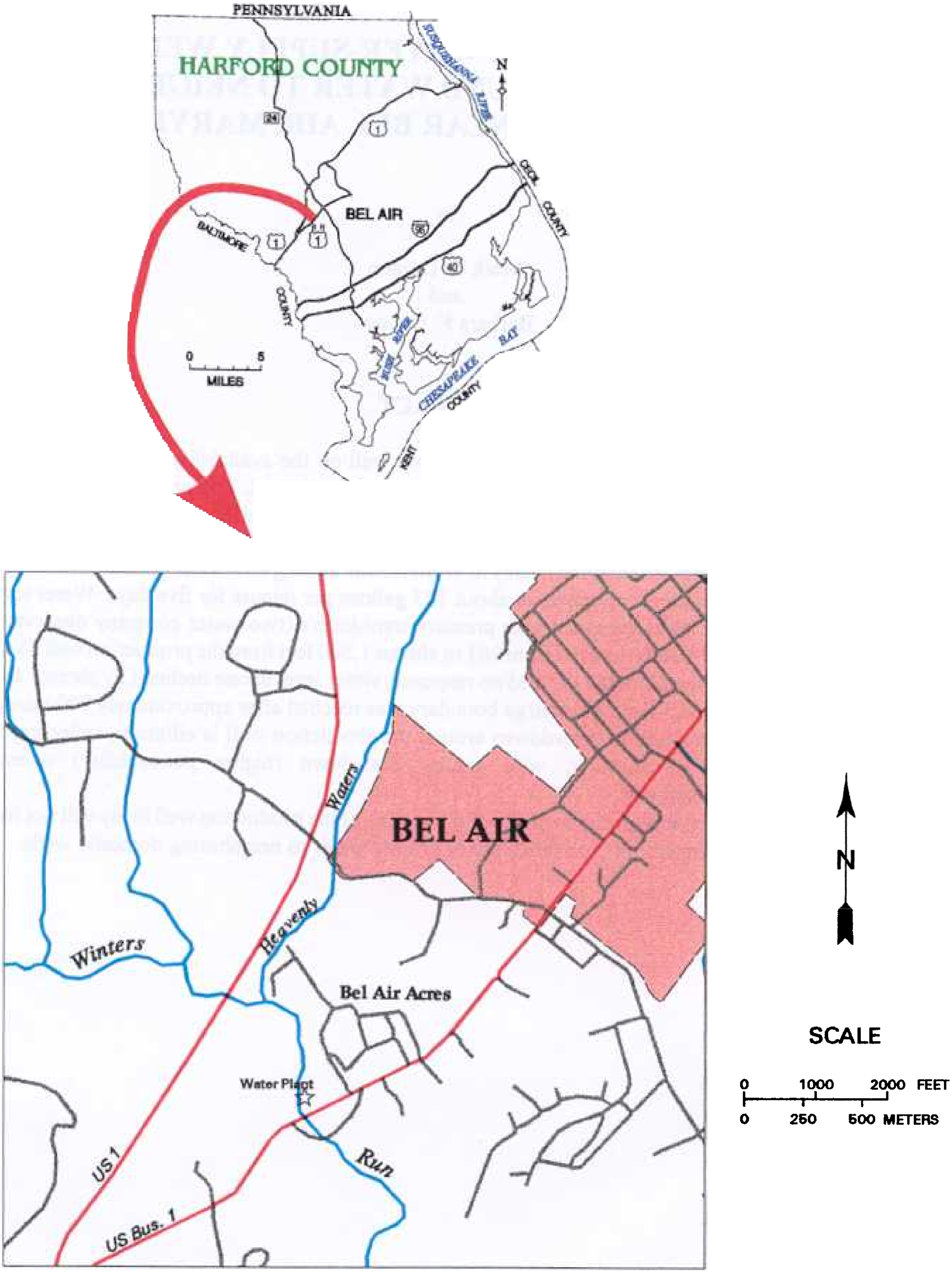

Figure 1.—Location of Winters Run-Bel Air Acres vicinity.

INTRODUCTION

The Maryland-American Water Company, a private company, supplies some of its customers with water withdrawn from Winters Run at a site located along U.S. Business Route 1, about 1 3/4 miles (mi) from the center of Bel Air (fig. 1). To meet rising demand for water without increasing withdrawals from Winters Run during periods of low flow, the water company installed a 540-foot (ft) deep well on the site and obtained a Groundwater Appropriation Permit from the Maryland Department of the Environment (MDE). As part of the standard procedure for granting the appropriation permit, MDE evaluated a report (R.E. Wright Environmental, Inc., 1995) prepared for the water company that concluded potential impacts on existing water use in the vicinity would not be unreasonable.

Purpose and Scope

In 1997, the Maryland General Assembly enacted House Bill 773, requiring the Department of Natural Resources to investigate how operation of the Maryland-American Water Company's public-supply water well might affect the availability of ground water to nearby domestic wells. The Maryland Geological Survey (MGS) conducted the investigation by means of an inventory of wells in the vicinity, identification of the construction and site characteristics of those wells, ground-water-level measurements, stream stage and flow measurements, and a pumping test.

Geologic Setting

The study area is located in the Piedmont physiographic province, a region of mostly low hills and ridges incised by streams (deeply, in some places). The Piedmont surface in the study area is developed on metamorphic rocks. Bedrock is weathered for a thickness of about 10 feet (ft) to a few tens of feet. Alluvial sand and gravel deposited along Winters Run reach 10 ft or so in thickness. About 10 ft of fill is reported (REWEI, 1995) at the sites of the water company wells.

The regional geology is complex and interpretations have evolved over the years. As a consequence of the ongoing reevaluation of Piedmont geology, and due in part also to limited rock exposure and data, a geologic map of the Bel Air quadrangle (P.D. Muller, mapped 1991, Maryland Geological Survey files) is significantly different than the county geologic map of Southwick and Owens (1968). According to the latter, a finger of Port Deposit Gneiss extends into Baltimore Gabbro in the vicinity of the study area, with smaller-scale interfingering at Bel Air Acres. Muller, on the other hand, places the Port Deposit Gneiss contact about 1,000 ft southeast of U.S. Business Route 1 and shows Bel Air Diamictite reaching the study area from the southwest, interfingering with Bel Air Metagabbro at Bel Air Acres. Based on REWEI's (1995) description of the rock at the water company wells ("...greenish-gray to greenish black, and dark gray to black..."), the rock could be metagabbro. The metagabbro is part of a layered igneous intrusion into the metamorphosed sedimentary sequence (rocks presently northwest of the study area). The Port Deposit Gneiss is part of a terrane derived from a volcanic-arc environment and later transported to its present location. It includes metamorphosed lava flows and volcaniclastic sediments that accumulated at about the same time as the mafic complexes (future metagabbro) were intruding. All of these units are crystalline metamorphic rocks with negligible primary permeability–they act as aquifers only to the extent that the fractures they contain store and transmit water.

Water Use and Supply

Homes in the residential subdivision of Bel Air Acres are supplied by individual water wells. Other subdivisions in the vicinity are connected to public supply. Water supplied to the dwellings in Bel Air Acres is not metered, so the amount of water used by the subdivision must be estimated:

$$75 \text{ (gallons/person)/day} \times 3 \text{ persons/house} \times 50 \text{ houses} = 11{,}250 \text{ gallons/day}$$

using estimates of per capita usage (U. S. Environmental Protection Agency, 1982), occupants, and number of houses in the subdivision. Waste water is disposed of through individual septic systems, thereby returning most of the pumped ground water to the subsurface.

The Maryland-American Water Company holds a ground-water appropriation permit (GAP), number HA94G060, which allocates withdrawal of a daily average of 132,000 gallons (gal) (on a yearly basis) and a daily average of 246,000 gal (for the month of maximum use) from a production well located at their treatment plant on Winters Run. This appropriation is in addition to the permit for withdrawal of water from Winters Run, which allows an annual average of 1.4 million gallons per day (Mgal/d) (1.7 Mgal/d on the day of maximum withdrawal) to be withdrawn from Winters Run just above U.S. Business Route 1. Ground water is pumped into a cistern, as is the surface-water withdrawal, and the mixed water is pumped into the treatment plant. The ground water is metered between the well and the cistern, and the total water delivered is metered as it leaves the plant.

Acknowledgments

This study was conducted in cooperation with the Maryland Department of the Environment, Water Management Administration, and the Harford County Government. Donajean M. Appel, and David C. Andreasen (MGS) and Cynthia Johnson and Sam Glover (MDE) provided assistance in well inventory and conducting the pumping test. The Maryland-American Water Company permitted use of their wells for the pumping test and provided water-level, pumpage, and other data. The Maryland Geological Survey appreciates the permission granted by residents of Bel Air Acres to make water-level measurements in their wells.

WELL AND SPRING INVENTORY

Well-Construction Characteristics

MGS inventoried 73 wells in the vicinity (fig. 2 and tab. 1). The wells range from 26 to 300 ft deep (not including the three water company wells). Nearly all of the wells are completed in bedrock and most are finished as open holes—that is, the borehole drilled in bedrock will not collapse and no screen is necessary. One well was completed as open-end (no additional borehole below the bottom of the casing) and several monitoring wells for the Tollgate Landfill were completed with gravel-packed screens (Most of these wells were finished in overburden or less competent, fractured rock.). Casing depths range from 9 ft to 84 ft. Static water levels range from 2 to 69 ft below land surface.

Well Yields

Yields of wells constructed in the Piedmont vary considerably, even within the same geologic unit (Dingman and Ferguson, 1956; Nutter and Otton, 1969; Nutter, 1977; Duigon, 1992; Duigon, Cooper, and Tompkins, 1994). The reported yields of inventoried wells range from 0 ("dry hole") to 40 gallons per minute (gal/min) (excluding the water company wells, which reportedly yielded 5 to 215 gal/min). Specific capacity (discharge divided by drawdown) ranges from 0 to 8 gallons per minute per foot [(gal/min)/ft]. Most of these wells are domestic wells, and so need only meet modest demands (Current State regulations require a minimum yield of 1 gal/min.). Furthermore, relatively small lot sizes constrain the availability of optimum well sites.

The water company's production well (MGS inventory number HA Cc 144) has a rated yield of approximately 171 gal/min (REWEI, 1995, p. 16). This well was intended to meet the greater demands of a public supply, and its location was carefully chosen to maximize the odds of obtaining a high yield.

Springs

Two springs in the vicinity were inventoried (tab. 2). The springs are points where the water table intersects land surface and ground water discharges. They help define the shape of the water table. Spring HA Cc 177 is located in a draw, or small valley, eroded into the hillside south of Bel Air Acres. At this point, the water table, whose topography is less pronounced than land-surface topography, is intersected by the draw. Spring HA Cc 178, on the other hand, is located about 20 ft higher than Winters Run on a gentle, almost uniform slope. This spring lies near the end of a ground-water flow path (where there is an upward component of flow) that originates at the hilltop to the northeast (where there is a downward component of flow).

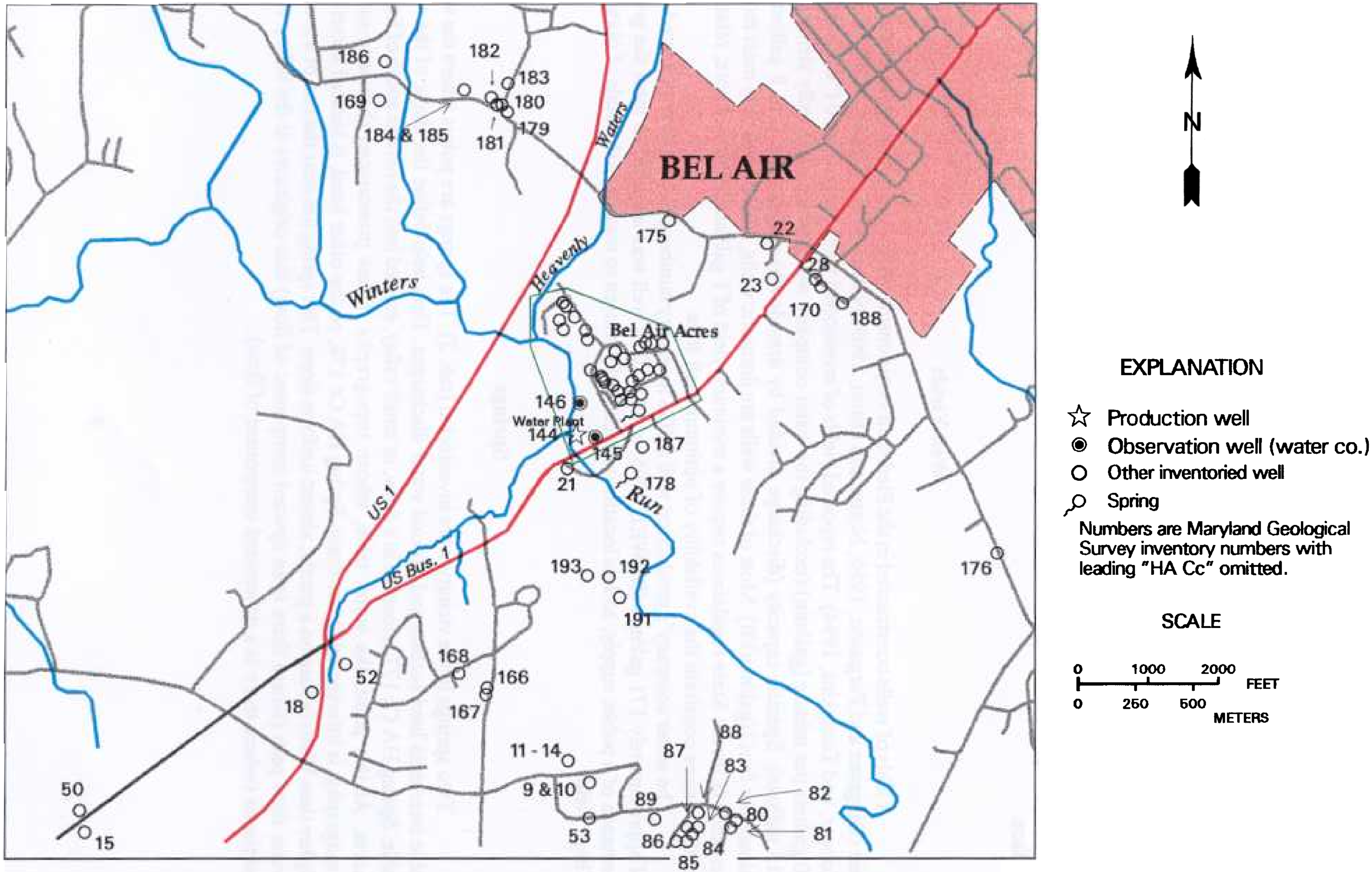

Figure 2.—Locations of inventoried wells and springs in the vicinity of the Winters Run water plant.

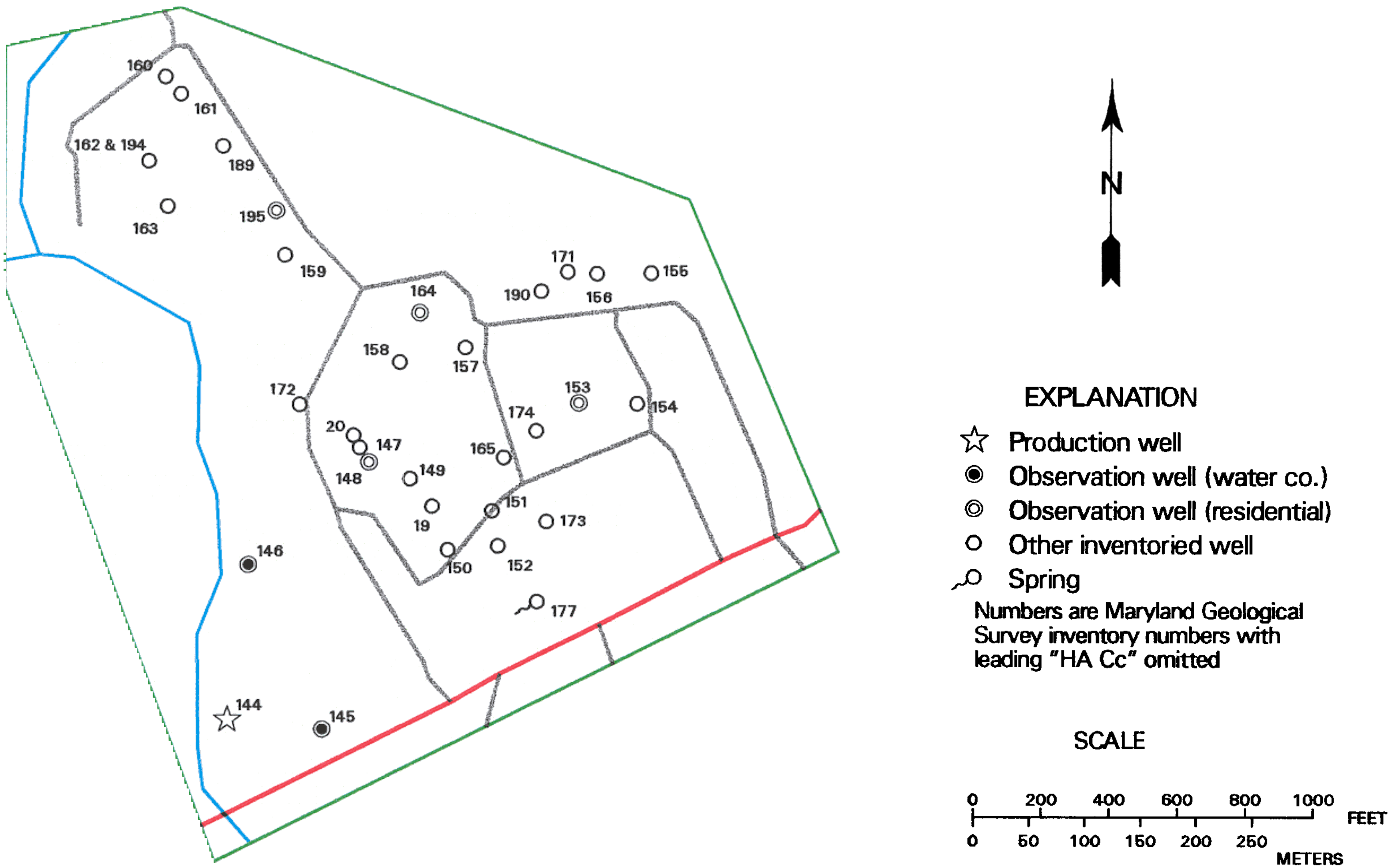

Figure 2.—Locations of inventoried wells and springs in the vicinity of the Winters Run water plant–Continued.

Table 1.--Wells in the Winters Run-Bel Air Acres vicinity

Well number	Permit number	Owner	Driller	Date of construction	Altitude of land surface (ft)	Topo-graphic setting	Depth (ft)	Use of water	Geologic unit
HA Cc 9	Well 1	Baltimore Fresh Air Camp	--	1905-04-14	300	S	110	T	300PRDP
HA Cc 10	Well 2	Baltimore Fresh Air Camp	--	--	290	S	75	U	300PRDP
HA Cc 11	Well 3	Baltimore Fresh Air Camp	--	--	340	S	139	T	300PRDP
HA Cc 12	Well 4	Baltimore Fresh Air Camp	--	--	325	S	190	U	300PRDP
HA Cc 13	Well 5	Baltimore Fresh Air Camp	--	--	340	S	70	T	300PRDP
HA Cc 14	Well 6	Baltimore Fresh Air Camp	--	--	340	S	127.6	U	300PRDP
HA Cc 18	HA-00-9349	Grafton, Darnel	H&H Drilling	1952-01-10	380	W	89	H	300BLMR
HA Cc 19	HA-00-8171	Irwin, Alton R.	Werneke Brothers	1951-07-18	240	S	52	H	300BLMR
HA Cc 20	HA-01-2531	Nagle, William	AC Reider & Sons	1953-06-06	250	H	66	H	300BLMR
HA Cc 21	HA-00-9022	Wells, J. E.	H&H Drilling	1952-01-02	260	S	49	H	300PRDP
HA Cc 22	HA-00-2821	Jackson, Clay	H A Thomas	1948-06-23	360	W	66	H	300BLMR
HA Cc 23	HA-00-2822	Murry, Bertha	H A Thomas	1948-06-21	340	W	56	H	300BLMR
HA Cc 28	--	Twin-Kiss Drive-In	H A Thomas	1954-04-15	340	W	64	C	300PRDP
HA Cc 52	--	MD State Police	Wash Pump & Well	1938-00-00	350	S	165	H	300BLMR
HA Cc 53	HA-72-0408	Zink, Mabel	G Edgar Harr	1971-12-16	260	S	300	H	300PRDP
HA Cc 80	HA-71-0239	Ferrarse, George	AC Reider & Sons	1971-01-05	220	S	96	H	300PRDP
HA Cc 81	HA-71-0556	Mackenzie, M. M.	AC Reider & Sons	1971-06-24	230	S	96	H	300PRDP
HA Cc 82	HA-73-0430	Zaeh, Robert	G Edgar Harr	1973-01-02	240	H	100	H	300PRDP
HA Cc 83	HA-72-0244	Everey	G Edgar Harr	1971-11-10	290	H	175	H	300PRDP
HA Cc 84	HA-72-0847	Speranzella	G Edgar Harr	1972-08-16	300	H	200	H	300PRDP
HA Cc 85	HA-72-0245	Bauersfeld, C.	G Edgar Harr	1971-11-10	300	H	125	H	300PRDP
HA Cc 86	HA-72-0846	Pellichiotti	G Edgar Harr	1972-08-16	300	H	100	H	300PRDP
HA Cc 87	HA-72-0545	Harvey, Douglas	G Edgar Harr	1972-03-21	300	H	275	H	300PRDP
HA Cc 88	HA-73-0543	Carty, W. J.	Jones Well Drlg.	1973-03-08	280	H	160	H	300PRDP
HA Cc 89	HA-73-0102	Kilduff, Francis	G Edgar Harr	1972-09-26	260	H	225	H	300PRDP
HA Cc 144	HA-94-0142	MD American Water Co.	AC Reider & Sons	1995-02-16	195	G	540	P	300PRDP
HA Cc 145	HA-94-0143	MD American Water Co.	AC Reider & Sons	1995-02-16	197	G	420	O	300PRDP
HA Cc 146	HA-94-0144	MD American Water Co.	AC Reider & Sons	1995-02-16	195	G	540	O	300PRDP
HA Cc 147	HA-68-0181	Thiel, August F.	AC Reider & Sons	1967-10-07	265	S	50	H	300PRDP
HA Cc 148	HA-94-0766	Cox, Kevin B.	Jones & Hamilton	1995-10-19	260	S	200	H	300PRDP
HA Cc 149	HA-94-2020	Wergin, Joergen T.	Jones Well Drlg.	1997-12-08	262	S	205	H	300PRDP
HA Cc 150	HA-73-6418	Hall, Mark D.	Barber Brothers	1981-01-17	290	S	200	H	300PRDP
HA Cc 151	HA-81-0239	Belschner, Leonard	Jones & Hamilton	1982-08-13	299	H	250	H	300PRDP
HA Cc 152	HA-94-0754	Keating, John W. III	Jones Well Drlg.	1995-10-23	285	S	205	H	300BLMR
HA Cc 153	HA-73-1606	Gastanski, Frank E. & Mary	AC Reider & Sons	1974-08-15	300	H	40	H	300PRDP
HA Cc 154	HA-01-5584	Graham, Kermit C.	Howard Thomas	1955-06-24	299	S	29	H	300BLMR
HA Cc 155	HA-01-1325	Bailey, R.	Werneke Brothers	1952-11-12	322	H	62	H	300BLMR
HA Cc 156	HA-81-0177	Schiaffino, Frank	Preston & Hamilton	1982-06-11	322	H	75	H	300BLMR
HA Cc 157	HA-73-3531	Cundiff, John R.	Gurvis Jones Well	1977-03-02	308	S	49	H	300BLMR
HA Cc 158	HA-02-1576	Mateer, Jim	H&H Drilling	1955-12-14	292	S	90	H	300PRDP
HA Cc 159	HA-02-5411	Graham, Lawrence J.	Fred Richardson	1956-11-24	262	S	90	H	300PRDP
HA Cc 160	HA-05-6922	Smith, Rosa	AC Reider & Sons	1964-04-07	225	S	49	H	300PRDP
HA Cc 161	HA-73-6858	Kuck, George Paul Jr.	Preston & Hamilton	1981-12-10	235	S	74	H	300PRDP
HA Cc 162	HA-81-0147	Petersen, Karl S.	Jones Well Drlg.	1982-06-10	220	S	149	H	300PRDP

Casing			Water level		Yield test					Well number
Depth (ft)	Diameter (in.)	Finish	Depth (ft below land surface)	Date measured	Yield (gal/min)	Drawdown (ft)	Specific capacity [(gal/min)/ft]	Hours pumped	Date	
--	6	--	2	1950-07-07	3.5	16	0.22	0.25	1950-07-07	HA Cc 9
--	6	--	--	--	--	--	--	--	--	HA Cc 10
--	6	--	--	--	2.5	--	--	--	1950-07-07	HA Cc 11
--	6	--	--	--	--	--	--	--	--	HA Cc 12
--	6	--	--	--	6.5	--	--	--	1950-07-07	HA Cc 13
--	6	--	16.8	1950-07-07	--	--	--	--	--	HA Cc 14
76	6	X	13	1952-01-10	20	47	0.43	1	1952-01-10	HA Cc 18
35	6	X	15	1951-07-18	20	15	1.33	1	1951-07-18	HA Cc 19
--	6	--	18	1953-06-06	4.5	37	0.12	2	1953-06-06	HA Cc 20
10	6	X	15	1952-01-02	15	20	0.75	1	1952-01-02	HA Cc 21
64	6	X	4	1948-06-23	8	36	0.22	1	1948-06-23	HA Cc 22
56	6	X	4	1948-06-21	8	36	0.22	1	1948-06-21	HA Cc 23
60	6	X	2	1954-04-15	40	5	8	1	1954-04-15	HA Cc 28
90	4	X	20	1938-00-00	15	85	0.18	--	1938-00-00	HA Cc 52
20	6	X	40	1971-12-16	2	250	0.01	4	1971-12-16	HA Cc 53
24	6	X	19	1971-05-01	12	75	0.16	1	1971-05-01	HA Cc 80
29	6	X	11	1971-06-24	23	83	0.28	1	1971-06-24	HA Cc 81
65	6	X	23	1973-01-02	10	67	0.15	4	1973-01-02	HA Cc 82
21	6	X	48	1971-11-10	4	117	0.03	4	1971-11-10	HA Cc 83
20	6	X	32	1972-08-16	12	158	0.08	4	1972-08-16	HA Cc 84
20	6	X	24	1971-11-10	6	91	0.07	4	1971-11-10	HA Cc 85
20	6	X	24	1972-08-16	8	66	0.12	4	1972-08-16	HA Cc 86
20	6	X	30	1972-03-21	2	235	0.01	6	1972-03-21	HA Cc 87
21	6	X	30	1973-03-08	4	115	0.03	6	1972-03-08	HA Cc 88
23	6	X	24	1972-09-26	3	191	0.02	4	1972-09-26	HA Cc 89
26	8	X	8	1995-02-16	215	492	0.44	14	1995-02-16	HA Cc 144
28	6	X	5	1995-02-16	5	410	0.01	3	1995-02-16	HA Cc 145
60	4	X	8	1995-02-16	60	492	0.12	3	1995-02-16	HA Cc 146
29	6.25	X	25	1967-10-07	20	23	0.87	1	1967-10-07	HA Cc 147
--	6	X	35	1995-10-19	4	165	0.02	3	1995-10-19	HA Cc 148
--	--	X	45	1997-12-08	15	150	0.1	1	1997-12-08	HA Cc 149
35	6	X	50	1981-01-17	4	125	0.03	6	1981-01-17	HA Cc 150
30	6	X	34	1982-08-13	2.5	216	0.01	3	1982-08-13	HA Cc 151
21	6	X	37	1995-10-23	8	163	0.05	1	1995-10-23	HA Cc 152
30	6	X	20	1974-08-15	35	18	1.94	1	1974-08-15	HA Cc 153
24	6	X	19	1955-06-24	6	7	0.86	1	1955-06-24	HA Cc 154
(?)	6	X	38	1952-11-12	8	--	--	1	1952-11-12	HA Cc 155
35	6	X	28	1982-06-11	10	47	0.21	3	1982-06-11	HA Cc 156
37	6	X	36	1977-03-02	10	2	5	5	1977-03-02	HA Cc 157
39	6	X	40	1955-12-14	1.75	50	0.04	1	1955-12-14	HA Cc 158
60	6	X	25	1956-11-24	20	5	4	3	1956-11-24	HA Cc 159
30	6.25	X	20	1964-04-07	10	27	0.37	1	1964-04-07	HA Cc 160
30	6	X	34	1981-12-10	15	40	0.38	3	1981-12-10	HA Cc 161
21	6	X	38	1982-06-10	12	110	0.11	3	1982-06-10	HA Cc 162

Table 1.--Continued

Well number	Permit number	Owner	Driller	Date of construction	Altitude of land surface (ft)	Topo-graphic setting	Depth (ft)	Use of water	Geologic unit
HA Cc 163	HA-72-0322	Lambert	Jones Well Drlg.	1972-03-24	215	S	82	H	300PRDP
HA Cc 164	HA-93-0536	Angevine / Hutchin	Jones Well Drlg.	1994-05-23	280	S	300	H	300BLMR
HA Cc 165	HA-81-3439	Roemer, Robert	Barber Brothers	1986-01-28	308	S	300	H	300PRDP
HA Cc 166	HA-72-0340	Murray, Lois	AC Reider & Sons	1971-12-21	330	S	126	H	300BLMR
HA Cc 167	HA-72-0371	Ritter, Scott	AC Reider & Sons	1972-01-17	335	S	82	H	300BLMR
HA Cc 168	HA-94-1674	Monaghan, Donald	Jones Well Drlg.	1997-07-11	350	S	145	H	300BLMR
HA Cc 169	HA-73-0128	Winter's Run Golf Course	AC Reider & Sons	1972-10-01	290	S	111	H	300BLMR
HA Cc 170	HA-88-0265	Sullivan, Ruth	Barber Brothers	1989-05-19	360	H	175	H	300PRDP
HA Cc 171	HA-00-9373	Gilbert, David	H&H Drilling	1952-01-29	322	H	64	H	300BLMR
HA Cc 172	HA-02-1855	Brackens, Virginia	H&H Drilling	1956-01-13	240	S	55	H	300PRDP
HA Cc 173	HA-05-7203	Riggin, John W.	Jack D Jones	1964-05-26	288	S	80	H	300PRDP
HA Cc 174	HA-01-5030	Graf, Leonard M. Jr.	Howard Thomas	1954-04-22	302	H	44	H	300PRDP
HA Cc 175	HA-02-2430	Brodnax, Cameron Jr.	H&H Drilling	1956-05-25	280	S	45	H	300BLMR
HA Cc 176	HA-01-4730	Dyer, Chanie	Howard Thomas	1954-04-03	318	H	63	H	300PRDP
HA Cc 179	HA-81-1830	Harford County - DPW	Jones Well Drlg.	1985-02-25	285	S	50	U	300BLMR
HA Cc 180	HA-73-3036	State of MD - WRA	John D. Falk	1973-05-09	282	S	26.5	U	300BLMR
HA Cc 181	HA-92-0227	Harford County - DPW	Jones Well Drlg.	1992-06-18	280	S	50	U	300BLMR
HA Cc 182	HA-92-0226	Harford County - DPW	Jones Well Drlg.	1992-06-18	278	S	50	U	300BLMR
HA Cc 183	HA-81-2407	Harford County - DPW	Jones Well Drlg.	1985-12-04	298	S	50	U	300BLMR
HA Cc 184	HA-92-0277	Harford County - DPW	Jones Well Drlg.	1992-06-26	290	S	99	U	300BLMR
HA Cc 185	HA-92-0225	Harford County - DPW	Jones Well Drlg.	1992-06-17	290	S	60	U	300BLMR
HA Cc 186	HA-81-0583	Gallagher, Terrence	Jones Well Drlg.	1983-04-30	322	S	150	H	300BLMR
HA Cc 187	HA-71-0252	Carozza, Max F. III	Jones Well Drlg.	1970-02-04	240	S	120	H	300PRDP
HA Cc 188	HA-05-4494	Miller, Edward	AC Reider & Sons	1963-11-19	356	H	68	H	300PRDP
HA Cc 189	HA-72-0293	Catania, Francis S.	Jones Well Drlg.	1971-11-27	242	S	95	H	300PRDP
HA Cc 190	HA-04-0597	Wagner, Bob & Carol	Jack D Jones	1960-10-15	320	H	60	H	300BLMR
HA Cc 191	HA-81-3829	Pons, Ellen	Barlow's Well Drlg.	1987-07-30	200	S	270	H	300PRDP
HA Cc 192	HA-81-3910	Hopkins, Miles B. Jr.	Barlow's Well Drlg.	1987-08-01	250	S	85	H	300PRDP
HA Cc 193	HA-81-2205	Pons, Mike	Gurvis Jones Well	1985-08-31	300	S	175	H	300PRDP
HA Cc 194	HA-81-0147	Petersen, Karl S.	Jones Well Drlg.	1982-06-10	220	S	150	U	300PRDP
HA Cc 195	--	Ciborowski, Mitchell	--	1958-00-00	258	S	47	H	300PRDP

Casing		Water level		Yield test					Well number
Depth (ft)	Finish	Depth (ft below land surface)	Date measured	Yield (gal/min)	Drawdown (ft)	Specific capacity [(gal/min)/ft]	Hours pumped	Date	
	X	20	1972-03-24	5	50	0.1	6	1972-03-24	HA Cc 163
	X	20	1994-05-23	4	213	0.02	3	1994-05-23	HA Cc 164
	X	34	1986-01-28	2	216	0.01	6	1986-01-28	HA Cc 165
	X	12	1971-12-21	6	112	0.05	1	1971-12-21	HA Cc 166
	X	9	1972-01-17	12	71	0.17	1	1972-01-17	HA Cc 167
	X	19	1997-07-11	12	26	0.46	3	1997-07-11	HA Cc 168
	X	15	1972-10-01	15	94	0.16	1	1972-10-01	HA Cc 169
	X	30	1989-05-19	8	130	0.06	3	1989-05-19	HA Cc 170
	X	27	1952-01-29	15	18	0.83	2	1952-01-29	HA Cc 171
	X	25	1956-01-13	20	15	1.33	1	1956-01-13	HA Cc 172
	X	12	1964-05-26	8	58	0.14	2	1964-05-26	HA Cc 173
	X	27	1954-04-22	30	--	--	1	1954-04-22	HA Cc 174
	X	18	1956-05-25	20	7	2.86	1	1956-05-25	HA Cc 175
	X	26	1954-04-03	5	34	0.15	1	1954-04-03	HA Cc 176
	G	22	1985-02-25	3	23	0.13	2	1985-02-25	HA Cc 179
	G	--	--	--	--	--	--	--	HA Cc 180
	G	15	1992-06-18	30	4	7.5	1	1992-06-18	HA Cc 181
	G	11	1992-06-18	27	6	4.5	1	1992-06-18	HA Cc 182
	G	10	1985-12-04	1	30	0.03	2	1985-12-04	HA Cc 183
	G	16	1992-06-26	<0.25	82	<0.01	1	1992-06-26	HA Cc 184
	G	15	1992-06-17	2	43	0.05	1	1992-06-17	HA Cc 185
	X	2	1983-04-30	3	143	0.02	6	1983-04-30	HA Cc 186
	X	30	1970-02-04	3	80	0.04	2	1970-02-04	HA Cc 187
	X	25	1963-11-19	4	42	0.1	1	1963-11-19	HA Cc 188
	X	40	1971-11-27	30	40	0.75	4	1971-11-27	HA Cc 189
	X	14	1960-10-15	5	36	0.14	2	1960-10-15	HA Cc 190
	X	69	1987-07-30	15	29	0.52	3	1987-07-30	HA Cc 191
	X	26	1987-08-01	15	3	5	3	1987-08-01	HA Cc 192
	X	45	1985-08-31	8	23	0.35	3	1985-08-31	HA Cc 193
	--	--	--	0	0	0	0	1982-06-10	HA Cc 194
		31.65	1998-04-28	--	--	--	--	--	HA Cc 195

EXPLANATION OF CODES

Owner

- WRA Water Resources Administration
- DPW Harford County Department of Public Works

Topographic setting

- G Flood plain
- H Hilltop
- S Hillside
- W Upland draw

Use of water

- C Commercial
- H Domestic
- O Observation
- P Production
- T Institutional
- U Unused

Geologic unit*

- 300BLMR Baltimore Gabbro Complex
- 300PRDP Port Deposit Gneiss

Finish

- G Gravel pack
- X Open hole

*Based on geologic map of Southwick and Owens, 1968. (See geology section of report.)

Table 2.—Springs inventoried in the vicinity of the Maryland-American Water Company plant at Winters Run

Spring number	Owner	Use of water	Altitude of land surface (ft)	Geologic unit*	Improvements
HA Cc 177	Strokes	Domestic	250	Port Deposit Gneiss	Springhouse
HA Cc 178	W. Arthur Benson	Domestic	200	Quaternary alluvium	Springhouse

*Based on the geologic map of Southwick and Owens, 1968.

STREAMFLOW

The Winters Run Drainage Basin

Winters Run, above the water company plant, drains an area of crystalline bedrock that exhibits the rolling topography typical of the Piedmont. Flows are generally highest during winter and spring, and lowest during summer. A U.S. Geological Survey (USGS) gage is located approximately 2,400 ft upstream from the water company intake on Winters Run (USGS Station Number 01581700, Winters Run near Benson, Maryland; site number 3 on fig. 3). Streamflow records have been collected at this site since August 1967. The drainage area above the gage is 34.8 square miles (mi^2); an additional 1.93 mi^2 drain into Winters Run between the gage and the water company intake. Annual mean flow past the gaging station during water years 1967-97 is 53.7 cubic feet per second (ft^3/s); the lowest annual mean, 22.9 ft^3/s, occurred in 1981. Three dates—August 28 and 29, 1981, and September 7, 1995, are tied for having the lowest daily mean flow (6.3 ft^3/s). The lowest annual seven-day minimum flow (7.5 ft^3/s) began September 2, 1995. Flow exceeded 16 ft^3/s 90 percent of the time during the period of record.

Seepage runs

Two seepage runs were conducted during a period of low flow to evaluate ground-water/surface-water relations in the study area with and without the influence of ground-water pumpage. For each seepage run, a set of streamflow-measurements were made within a short period, and changes in flow between points along Winters Run and its tributary, Heavenly Waters, were calculated (fig. 3, tab. 3). It had rained between the first (August 14) and second (August 21) seepage runs; consequently, the second seepage run was conducted under slightly higher flow conditions, judging by the gage near Benson (23.9 ft^3/s on August 21, compared with 20.5 ft^3/s on August 14).

On August 14, 1998 (well not pumping), there was an overall gain in flow in Winters Run of about 0.5 ft^3/s between the gage at U.S. Route 1 and Lake Fanny Road (downstream of the water company plant). This included 0.590 ft^3/s coming into Winters Run from Heavenly Waters, and about 0.094 ft^3/s coming from an unnamed tributary to the right bank of Winters Run above U.S. Business Route 1. Heavenly Waters

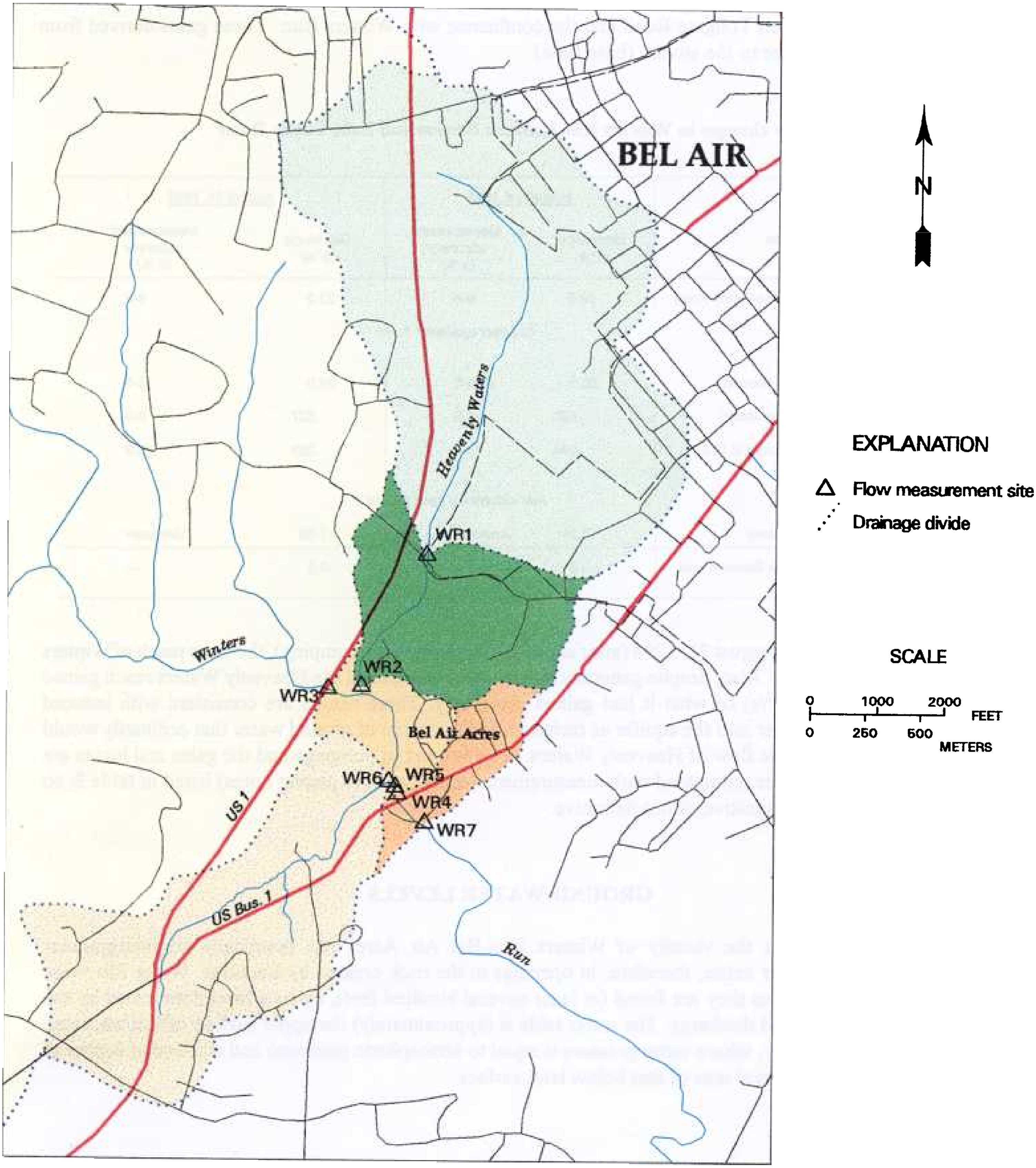

Figure 3.—Locations of seepage-run measurement sites.

gained 0.2 ft^3/s between Tollgate Road and the confluence with Winters Run. These gains derived from ground-water discharge to the stream (base flow).

Table 3.–Streamflow changes in Winters Run between Benson and Lake Fanny Road

Site no.	Site	August 14, 1998 Discharge (ft^3/s)	August 14, 1998 Measurement accuracy (± %)	August 21, 1998 Discharge (ft^3/s)	August 21, 1998 Measurement accuracy (± %)
WR7	Winters Run at Lake Fanny Road	19.5	6-8	23.2	6-8
	Subtract upstream flows:				
WR3	Winters Run near Benson	20.5	3-5	24.6	3-5
	Heavenly Waters at Mouth	.590	3-5	.527	6-8
	Winters Run Tributary at U.S. Business Route 1	.094	>8	.263	6-8
	Add withdrawal back to total:				
WR5	Water company intake	2.21	Unknown	1.88	Unknown
Flow gain or loss between Benson and Lake Fanny Road		0.5	—	-0.3	—

In contrast, on August 21, 1998 (after about 3 ½ days of steady pumping), the same reach of Winters Run lost about 0.3 ft^3/s. Also, despite generally higher water conditions, the Heavenly Waters reach gained only about half (0.1 ft^3/s) of what it had gained previously. These results are consistent with induced recharge of stream water into the aquifer as recharge, and diversion of ground water that ordinarily would have contributed to base flow of Heavenly Waters. The amount of pumpage and the gains and losses are relatively small, however, compared with measurement accuracy (from gaging notes) listed in table 3, so this evidence, while suggestive, is not definitive.

GROUND-WATER LEVELS

The bedrock in the vicinity of Winters Run-Bel Air Acres has practically no intergranular porosity—ground water exists, therefore, in openings in the rock created by fractures. Water fills these fractures from as deep as they are found (at least several hundred feet), up to a level determined by the amounts of recharge and discharge. The water table is (approximately) the upper surface of this saturated zone (or, more precisely, where water pressure is equal to atmospheric pressure) and is found at depths of from several feet to several tens of feet below land surface.

Water-Table Configuration

The water table, being a surface (like the surface of land), has shape, or topography. In the vicinity of Winters Run-Bel Air Acres, it slopes southwestwardly toward Winters Run, and, presumably, westward toward Heavenly Waters (fig. 4). The slope of the water table marks the hydraulic gradient. If permeability were uniform, ground water would flow in the direction of the steepest slope, perpendicular to the water-table contours. However, permeability in this area is anisotropic, causing the flow paths to be somewhat oblique to the contours. The relevant ground-water flow system is inferred to extend from the high ground northeast of Bel Air Acres towards Winters Run and Heavenly Waters, where discharge occurs as base flow.

Fluctuations

Ground-water levels in the study area exhibit natural seasonal fluctuations of up to several feet (fig. 5). They decline as the aquifer drains to the streams, and rise as the aquifer is recharged. Precipitation, the source of recharge, may vary somewhat during the year, but a substantial portion of infiltrating precipitation is lost by seasonal consumption of soil water by vegetation, which uses up infiltrating water before it percolates to the water table.

In Relation to Stream Stage

Water-levels recorded at the two water company observation wells reveal a close correspondence with water levels in Winters Run, as well as response to daily pumping of the production well (fig. 5). The figure shows stream stage at the gage near Benson (at U.S. Route 1), which is unaffected by withdrawals. The correspondence of ground-water levels with stream stage suggests an intimate connection of the aquifer with Winters Run.

PUMPING TEST

A pumping test was conducted to evaluate properties of the aquifer and help assess the potential impact of the production well on availability of ground water to domestic wells. The test comprised a 5-day pumping period, followed by a 5-day recovery period. The two water company observation wells and four residential wells were equipped with pressure transducers for monitoring water levels; a transducer could not successfully be placed in the production well. Water levels in the production well were measured using a previously installed air line.

Results from the pumping test are complicated by the effects of aquifer heterogeneity and aquifer anisotropy, boundary conditions, and deviations from the Dupuit assumptions that are difficult to account for. The Dupuit assumptions simplify analysis of water-table aquifers by presuming horizontal flow occurring uniformly through a vertical strip of the aquifer. Vertical flow components likely affected data

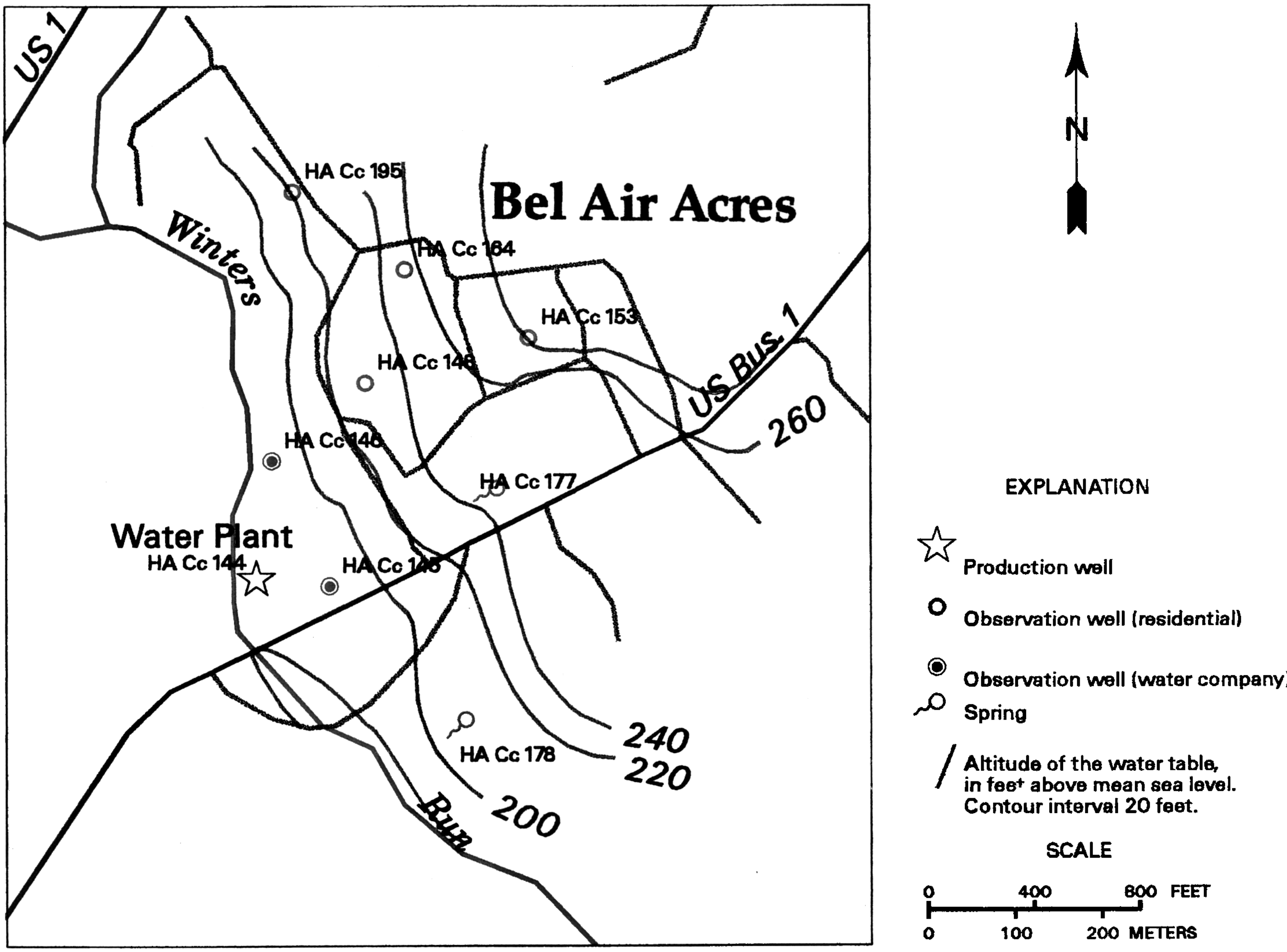

Figure 4.—Altitude of the water table in the Winters Run-Bel Air Acres vicinity. Contour lines are based on measurements made August 13, 1998, a few days prior to the pumping test.

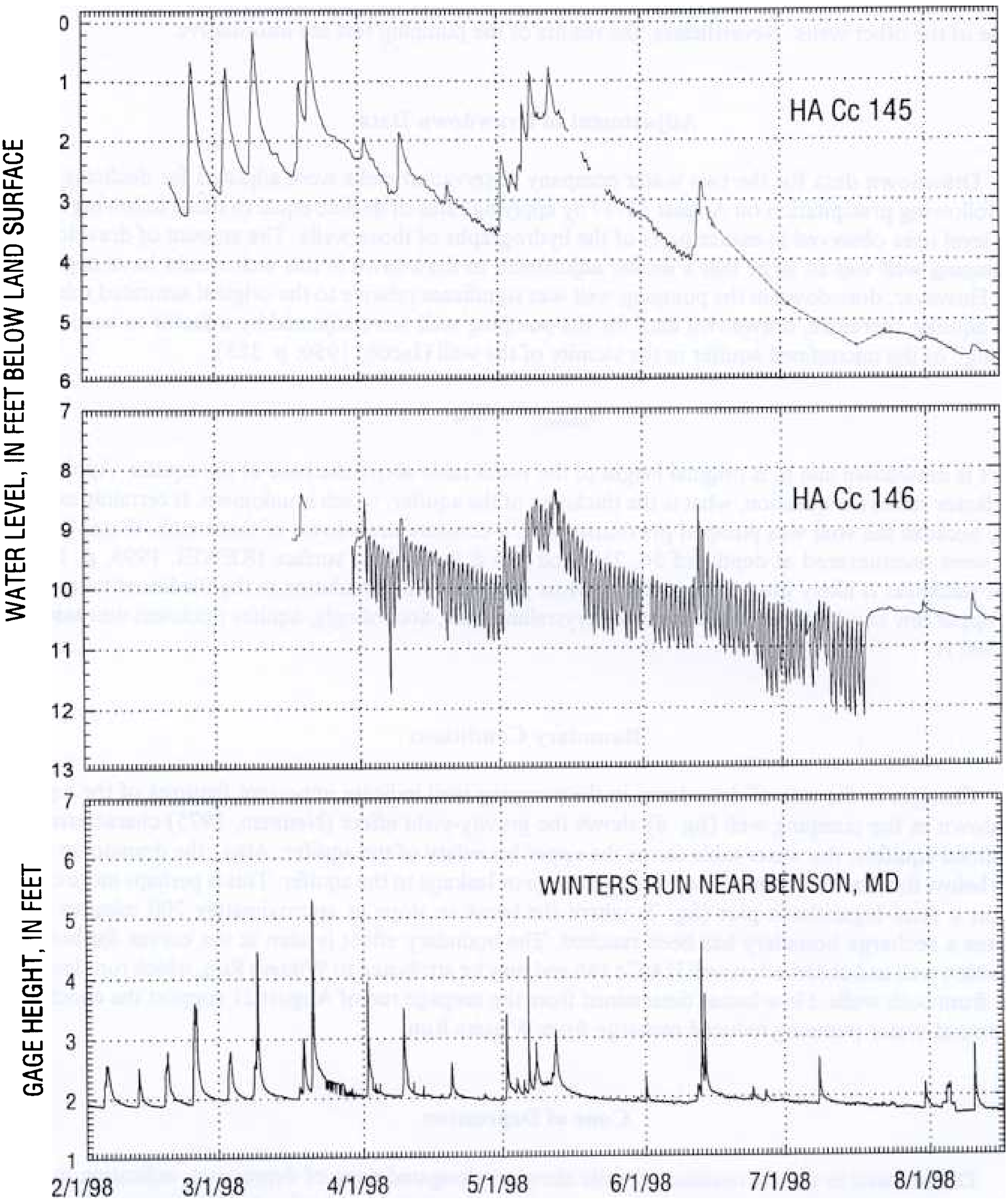

Figure 5.—Ground-water levels in the vicinity of Bel Air Acres and water level in Winters Run. Winters Run near Benson, Maryland, gage height data from U.S. Geological Survey unit values.

observed at well HA Cc 145, located only 261 ft from the pumping well, and, perhaps, drawdowns measured at some of the other wells. Nevertheless, the results of the pumping test are informative.

Adjustment of Drawdown Data

Drawdown data for the two water company observation wells were adjusted for declining static levels following precipitation on August 16-17 by applying rates of decline equal to those following similar water-level rises observed in earlier parts of the hydrographs of those wells. The amount of drawdown in the pumping well was so large that a similar adjustment to drawdown in this well would have negligible effect. However, drawdown in the pumping well was significant relative to the original saturated thickness of the aquifer; therefore, drawdown data for the pumping well were adjusted by a factor to account for "thinning" of the unconfined aquifer in the vicinity of the well (Jacob, 1950, p. 385):

$$s_{adjusted} = s^2/2h_0$$

where s is drawdown and h_0 is original height of the water table above the base of the aquifer. Application of the factor raises the question, what is the thickness of the aquifer, which is unknown. It certainly exceeds 200 ft, because the well was pumped previously with a constant drawdown of that much. Water-bearing zones were encountered at depths of 36, 210, and 415 ft below land surface (REWEI, 1995, p. 12), so aquifer thickness is likely greater than 400 ft. Most ground-water circulation in the Piedmont takes place in the upper few hundred feet of the fractured crystalline rock, accordingly, aquifer thickness was assumed to be 500 ft.

Boundary Conditions

Changes in the rate of drawdown in the pumping well indicate important features of the aquifer. Drawdown in the pumping well (fig. 6) shows the gravity-yield effect (Neuman, 1975) characteristic of unconfined aquifers; the water table forms the upper boundary of the aquifer. Also, the drawdown curve trends below the late Theis curve, indicating recharge or leakage to the aquifer. This is perhaps more clearly seen on a semi-logarithmic plot (fig. 7) where the break in slope at approximately 700 minutes (min) indicates a recharge boundary has been reached. The boundary effect is seen in the curves for both the production well and observation well HA Cc 146 and may be attributed to Winters Run, which runs less than 100 ft from both wells. Flow losses determined from the seepage run of August 21 support the conclusion that ground-water pumping induced recharge from Winters Run.

Cone of Depression

Drawdowns in the six monitored wells show an elongated cone of depression, indicating that the aquifer is anisotropic, that is, permeability is not uniform in all directions (fig. 8). Maximum permeability is oriented approximately north-northeast–south-southwest. No observation wells were available west of

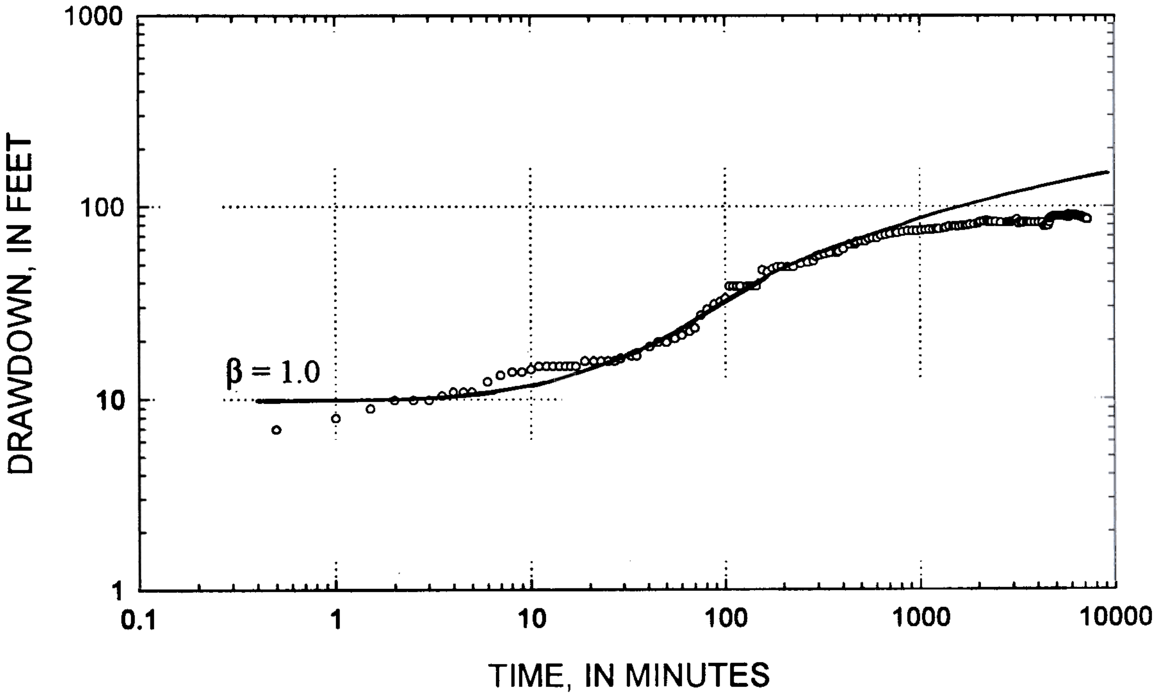

Figure 6.—Log-log graph of drawdown in the production well (HA Cc 144) during pumping test of August 17-22, 1998. Line is Neuman type B curve for β = 1.0.

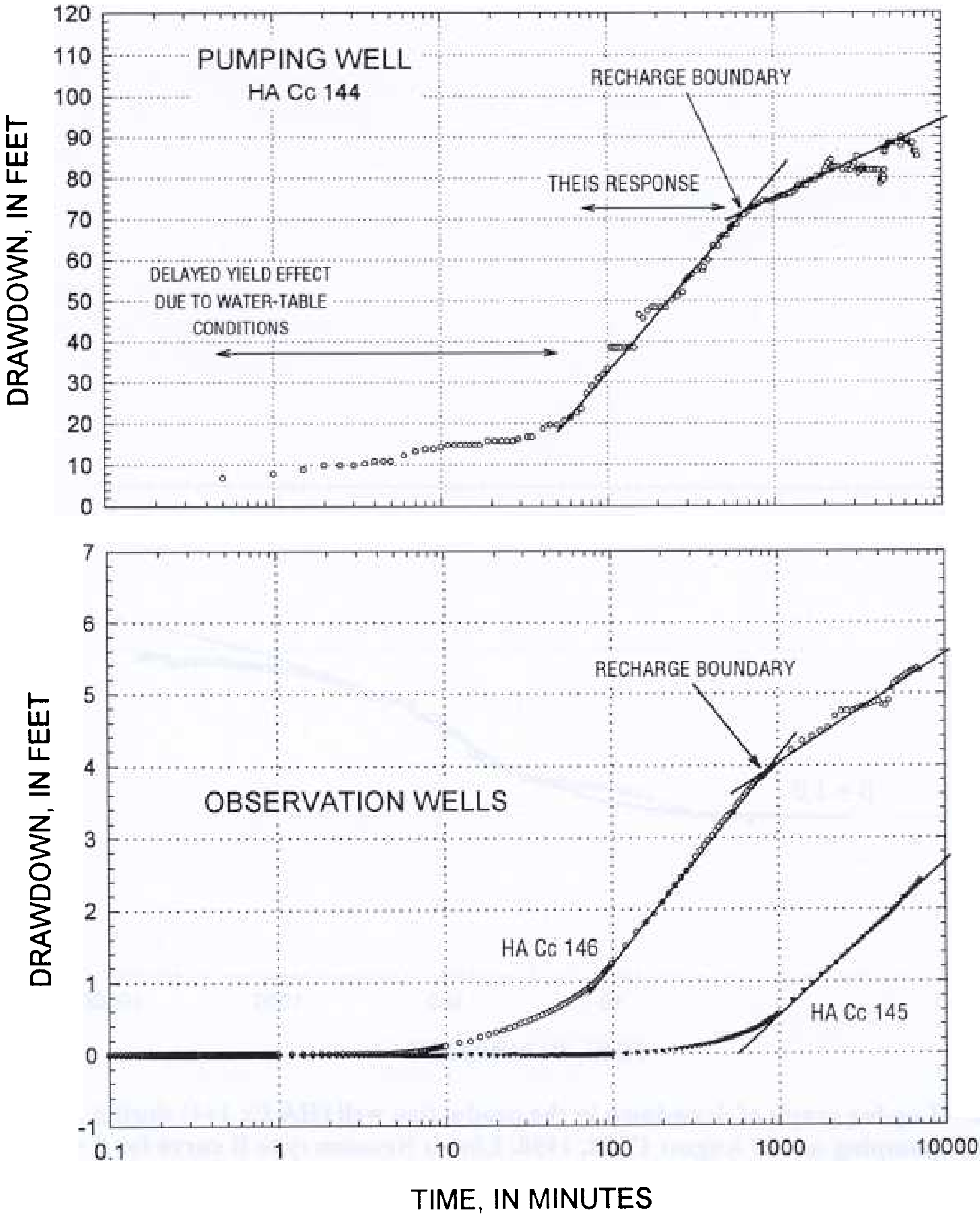

Figure 7.—Semilog graphs of drawdown versus time for the pumping well (top) and observation wells (bottom) for the pumping test of August 17-22, 1998.

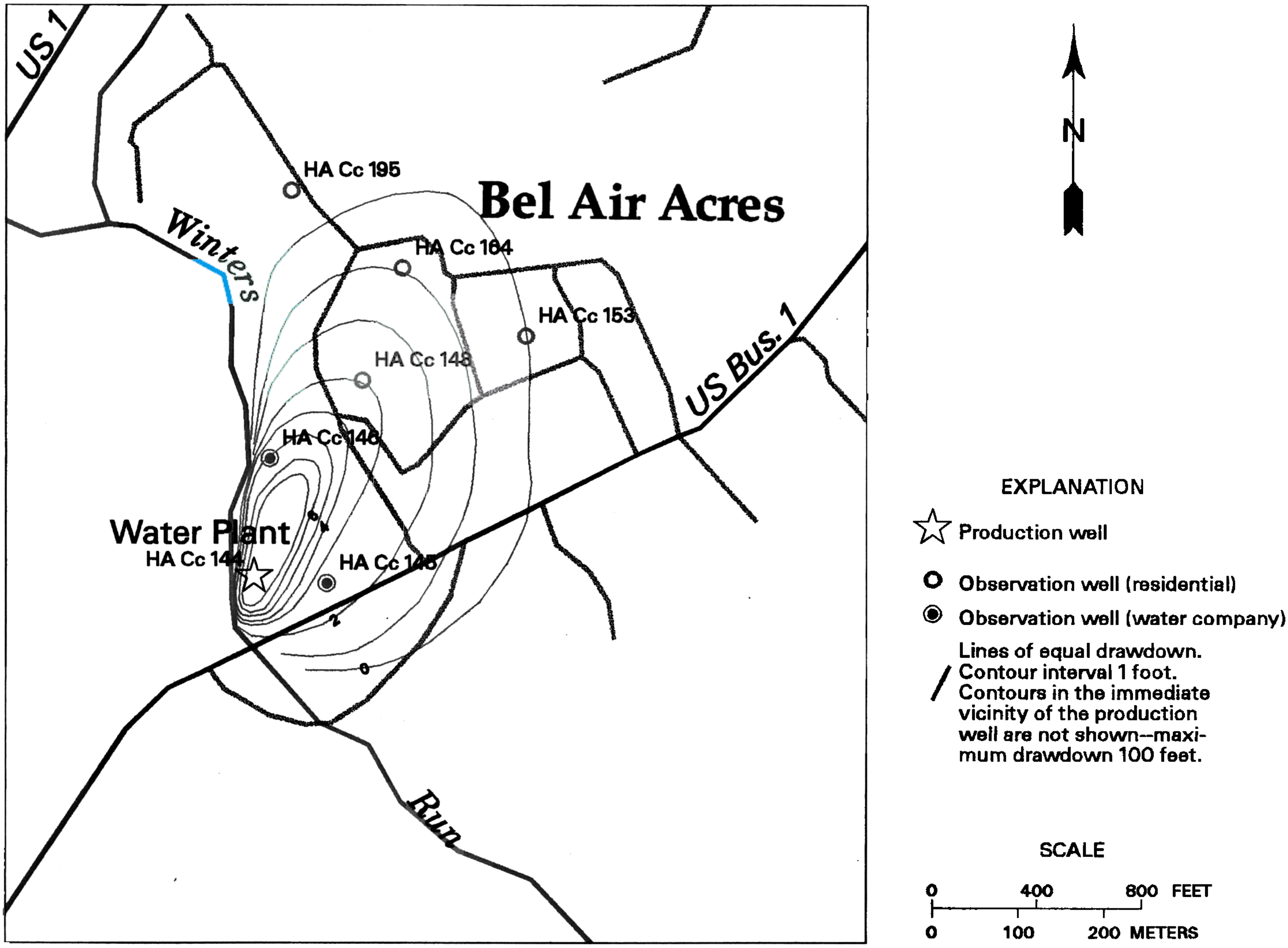

Figure 8.—Drawdown on August 21, 1998, after approximately 5 days of pumping at 123 gallons per minute. The elongate shape of the cone of depression indicates aquifer anisotropy. Contours for drawdowns greater than 6 ft (nearest the pumping well) are not shown: maximum drawdown was nearly 100 ft.

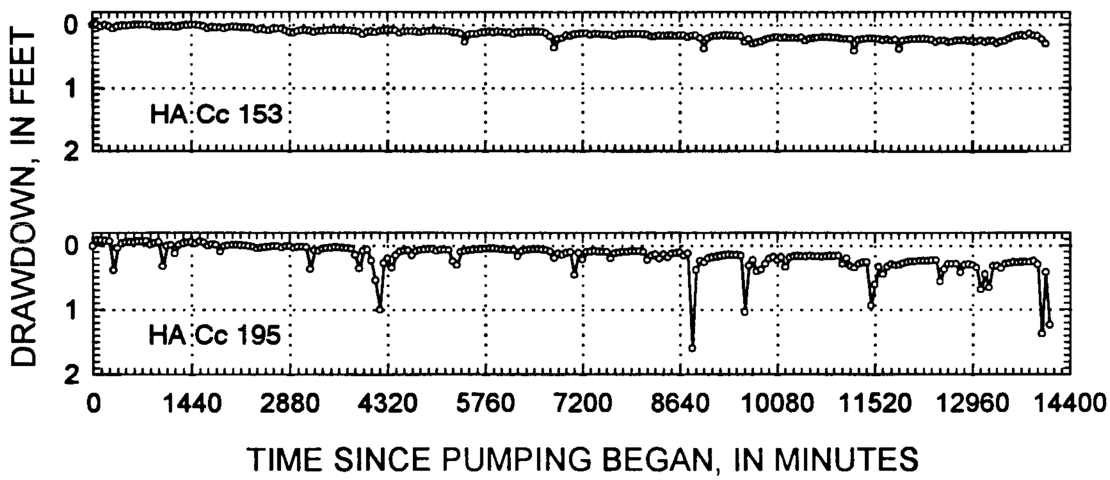

Figure 9.—Response of the four instrumented residential wells to pumping and recovery at the water company production well. ***Above:*** **No response is evident in wells HA Cc 153 and HA Cc 195, located 1,391 ft and 1,490 ft, respectively, from the production well.** ***Right:*** **Drawdown and recovery can be seen in wells HA Cc 148 (about 3 ft of drawdown) and HA Cc 164 (about 1 ft of drawdown). Instruments recorded drawdown every 30 or 60 minutes.**

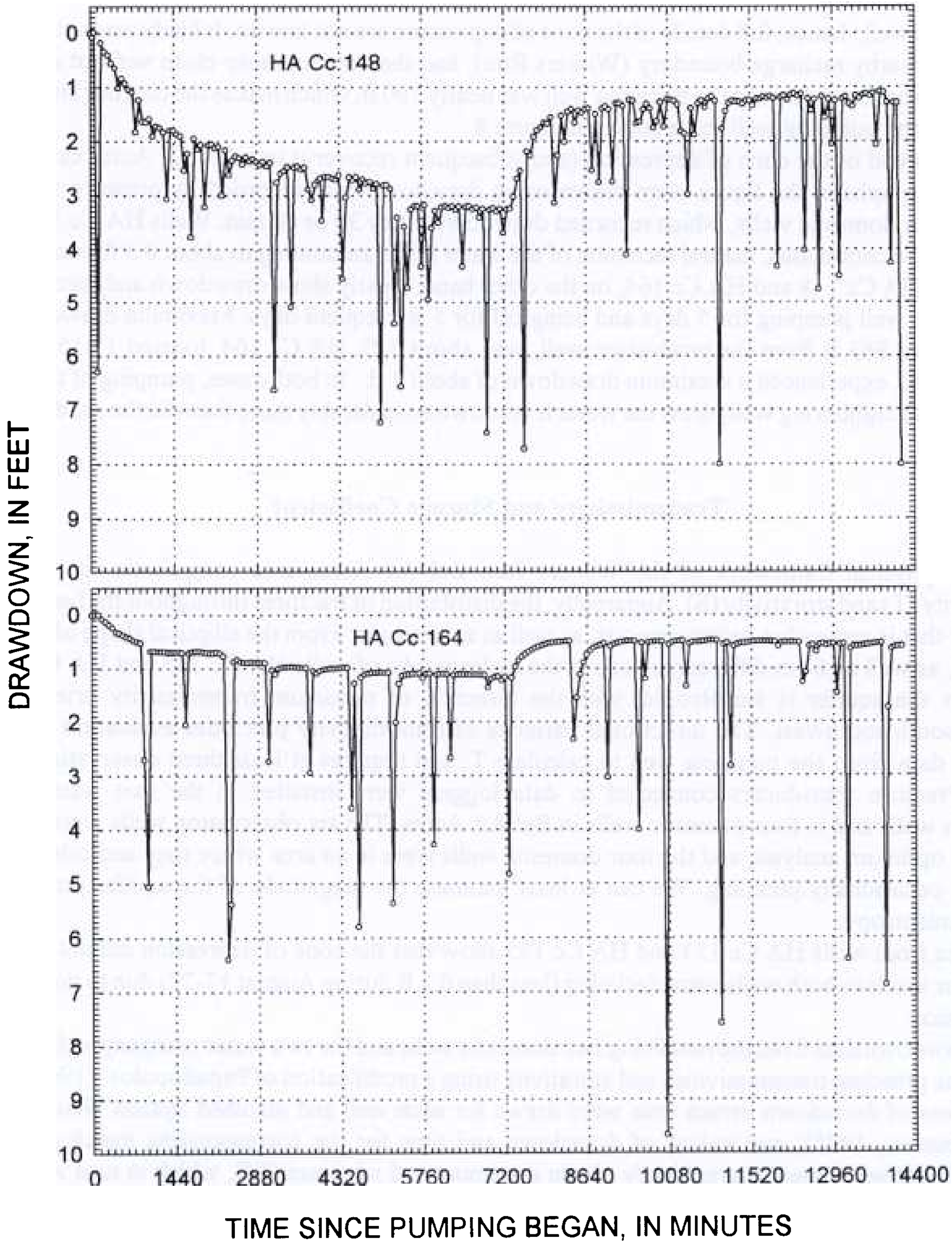

Figure 9.—Response of the four instrumented residential wells to pumping and recovery at the water company production well–Continued.

the production well; hence, full details of the cone of depression are not known. It likely was not symmetric, owing to the nearby recharge boundary (Winters Run), and the contours may close without crossing the stream. Maximum drawdown in the pumping well was nearly 100 ft, which makes the contour lines too close together near the pumping well to be shown in figure 8.

The spread of the cone of depression (and subsequent recovery) into Bel Air Acres can be seen in figure 9. The graphs in the figure were drawn using drawdown data recorded by pressure transducers installed in four domestic wells, which recorded drawdown every 30 or 60 min. Wells HA Cc 153 and HA Cc 195 show the continuous, natural recession of the water table, amounting to about 0.3 ft over the 10-day period. Wells HA Cc 148 and HA Cc 164, on the other hand, clearly show drawdown and recovery due to the production well pumping for 5 days and being off for 5 subsequent days. Maximum drawdown in HA Cc 148, located 863 ft from the production well, was about 3 ft; HA Cc 164, located 1,315 ft from the production well, experienced a maximum drawdown of about 1 ft. In both cases, pumping of the domestic well itself (or a neighboring well) drew the water level down considerably more than did the production well.

Transmissivity and Storage Coefficient

The physical framework of the Winters Run–Bel Air Acres area complicates an analysis for transmissivity (T) and storativity (S). Apparently, the distribution of fractures throughout the bedrock forms a geometry that is somewhat heterogeneous, as well as anisotropic. From the elliptical shape of the cone of depression, as well as from differences seen in the hydrographs of wells HA Cc 145 and HA Cc 146, it is known that the aquifer is anisotropic, with the direction of maximum transmissivity oriented north-northeast–south-southwest. The directional variance of transmissivity precludes evaluation using time-drawdown data from the pumping well to calculate T, and requires at least three observation wells for solution. Pressure transducers connected to data loggers were installed in the two water company observation wells and in four domestic wells in Bel Air Acres. The six observation wells were not ideally located for optimum analysis, and the four domestic wells were in an area where they and other domestic wells were occasionally pumping. We can at least estimate the magnitude of the aquifer properties and degree of anisotropy.

Data from wells HA Cc 153 and HA Cc 195 show that the cone of depression did not reach these wells. Water levels in both wells were declining (less than 0.3 ft during August 17-27) due to normal water-table recession.

Drawdown data from the remaining two domestic wells and the two water company wells were used to determine principal transmissivities and storativity using a modification of Papadopulos' (1967) method. Log-log plots of drawdown versus time were drawn for each well and matched against Neuman type B curves (Neuman, 1975), and values of drawdown and time for the corresponding match points were obtained. These were used to graphically obtain maximum and minimum T/S, which in turn were used to calculate S and maximum and minimum T. An internal check suggested a problem with data from well HA Cc 164 (probably owing to aquifer heterogeneity), so this site was given no weight in the final calculations. Maximum transmissivity is estimated to be 7,500 feet squared per day (ft^2/d), minimum T as 120 ft^2/d, and storativity as 0.01. Had well HA Cc 164 been given equal weight, S would be estimated as 0.02, and the principal transmissivities doubled. In either case, maximum T is about 60 times minimum T.

CONCLUSIONS

The Maryland-American Water Company production well (HA Cc 144) derives water from an unconfined, anisotropic, fractured, metamorphic-rock aquifer. The production well is located at the distal end of a ground-water flow system that begins in the highlands northeast of Bel Air Acres and flows approximately southwest, discharging mainly to Winters Run (as well as to a tributary, Heavenly Waters, located upstream on Winters Run northwest of Bel Air Acres).

Prolonged pumping of the production well produces an elongated cone of depression as a consequence of aquifer anisotropy—maximum transmissivity is approximately 7,500 ft^2/d and is oriented approximately north-northeast. Minimum transmissivity is approximately 120 ft^2/d. Storativity is about 0.01, which is in the range of specific yield of unconfined aquifers. Observation wells were not available to completely describe the cone of depression that developed during 5 days of pumping, but it is likely that additional distortion of the cone resulted from recharge induced from Winters Run. Evidence for induced recharge comes from decreases in the rates of drawdown, seen in drawdown versus time plots of data from the production well and observation well HA Cc 146, the relatively early recovery of water level in the pumping well, and from stream-discharge measurements made before and during the pumping test.

Extrapolation of drawdown at domestic well HA Cc 148 (which had shown the greatest drawdown) for 30 days of pumping at the tested rate (123.4 gal/min) predicts about 5 ft of total drawdown, which should not unduly impact the yield of that well. Water-level declines in Bel Air Acres due to pumping the production well are mitigated by recharge apparently induced from Winters Run.

Where will the water discharged by the water company production well come from? Theis (1940) provided a clear summary of the general question, with a reminder that the water discharged by a well is balanced by a loss taken from somewhere else. Assuming the well is not pumped continuously, some water can be derived from ground-water storage, the amount of water that can be taken when lowering the water table by a given amount. How much water is obtained from ground-water storage depends in part on the extent to which the water table recovers after each pumping period. A portion (approximately 27 percent; Dingman and Ferguson, 1956, p. 48) of annual precipitation recharges the aquifer, and some of this may be captured before discharging to Winters Run. Finally, water from the Winters Run channel may be induced to move into the aquifer if the cone of depression is allowed to grow large enough to reverse the ground-water gradient at the stream. As the cone of depression grows, an increasing amount of recharge is induced from the stream.

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