DEPARTMENT OF ENVIRONMENTAL PROTECTION
DIVISION OF WATER RESOURCES
NEW JERSEY GEOLOGICAL SURVEY

INTRODUCTION

Ground water from Pleistocene sand and gravel valley-fill sediments in the Ramapo River drainage basin has been a reliable source of water for industrial use and provides the Townships of Oakland and Mahwah with more than 3 million gallons per day for public supply (N.J. Department of Environmental Protection, Bureau of Water Allocation, 1983). In addition, the ground water in the valley fill aquifer interacts closely with the Ramapo River. Under natural conditions ground-water discharge maintained drought and seasonal low flow in the Ramapo River. At present, due to pumpage of ground water for water supply, the Ramapo River is a source of recharge to valley-fill deposits, particularly in the vicinity of municipal well fields. Although the Ramapo River loses water to the aquifer naturally in some segments (Mary Hill, U.S. Geological Survey, 1985), additional large-volume pumpage would increase infiltration and reduce stream flow (Vecchioli and Miller, 1973).

As part of an assessment of the impact of existing and proposed water use on both surface and ground water, the New Jersey Geological Survey undertook the present study of the geologic framework of the Ramapo River and Masonicus Brook valleys. The results have been utilized by the U.S. Geological Survey in the development of a computer-based model of ground-water flow in the Ramapo River valley (Mary Hill, U.S. Geological Survey, 1985). This report summarizes the first phase of the effort: preparation of a map and profiles showing bedrock topography and seismic velocities of unconsolidated deposits and bedrock. This was done using records of wells and borings on file at the New Jersey Division of Water Resources, Bureau of Water Allocation, test drilling by the U.S. Geological Survey, and seismic reflection and refraction.

LOCATION AND GEOLOGIC SETTING

The Ramapo River watershed is located in Bergen and Passaic Counties, New Jersey, and Orange and Rockland Counties, New York. It covers an area of 160.7 sq mi, 50 of which are in New Jersey (Mary Hill, U.S. Geological Survey, 1985). The study area extends 8.3 mi along the Ramapo River valley and 3.0 mi along Masonicus Brook. Approximately 8.3 sq mi of the study area is underlain by stratified surficial sediments.

Within the study area the Ramapo River flows parallel to the Ramapo, or Border, Fault, which is a major fault zone that experienced at least 4200 ft of oblique, normal movement, primarily during the Jurassic Period (Ratcliffe, 1980). The fault separates the Newark Basin from the Ramapo Mountains. The Newark Basin, to the east, lies within the Appalachian Piedmont physiographic province. The Ramapo Mountains to the west lie within the Reading Prong of the New England physiographic province. The eastern face of the Ramapo Mountains is a continuous, steep escarpment.

Bedrock of the Newark Basin in this area is Jurassic in age (Froelich and Olsen, 1983) and consists of clastic sedimentary rock and basalt flows. The summit and western slope of Campgaw Mountain are formed by resistant basalt. Stratigraphically below the basalt to the east of Campgaw Mountain and above the basalt in the Oakland area are clastic rocks ranging in composition from shale to conglomerate. Bedrock of the Ramapo Mountains is granitoid gneiss of Precambrian age.

The unconsolidated valley-fill sediments, as much as 212 ft thick in places, were deposited during the late Wisconsinan glaciation, the most recent ice advance to affect New Jersey. Late Wisconsinan ice entered New Jersey approximately 22,000 years ago and had retreated from northeastern New Jersey before 15,000 years ago (Averill and others, 1980). Unconsolidated deposits predating the late Wisconsinan may lie beneath the valley fill at sites sheltered from glacial scouring. Postglacial alluvial deposits veneer the Ramapo River floodplain.

The surficial valley-fill sediments include till, ice-marginal deltaic sand and gravel, lake-bottom sediments, and alluvial sands and gravels. A thin veneer of till overlies igneous and metamorphic bedrock in the study area. Till is thicker atop the sedimentary rocks. The valley-fill aquifer consists of ice-contact stratified drift. It is irregular in distribution and ranges from a few feet to more than 200 ft in thickness. Interfingering with and commonly overlying the ice-contact sediment is lake-bottom sediment consisting of fine sand, silt, and clay. North of Fyke Brook, lake-bottom sediments form a discontinuous but effective confining layer as much as 110 ft thick.

Glacial lakes of the Ramapo River valley probably resulted from ponding of meltwater behind coarse glacio-fluvial sediments. Retreat of the ice-margin up the Ramapo valley may have caused a series of small glacial lakes to form (Byron Stone, personal communication, 1987).

PREVIOUS STUDIES

Geologic and ground-water studies of the Ramapo River basin were summarized in Vecchioli and Miller (1973), who documented the existence of extensive areas of stratified drift, primarily sand and gravel, in the Masonicus Brook valley and stratified drift as much as 212 ft thick in the Ramapo River valley. A maximum saturated thickness of 160 ft was reported at Oakland. It was estimated that 20-25 x 10^6 gallons of water per day were available for development from surface and ground-water sources upstream from Pompton Lakes after existing downstream requirements were supplied (Vecchioli and Miller, 1973).

Carswell and Rooney (1976) showed thickness of stratified drift in the Ramapo valley downstream from the study area. Perlmutter (1959), Moore (1982), and Moore and others (1982), relying on well records and borings, described areas of the aquifer in New York State.

METHOD OF STUDY

Records of wells and borings in the Ramapo River valley provided general information on the composition of the valley fill and allowed preparation of a preliminary map showing bedrock topography. Single-channel seismic reflection and refraction and drilling were used to determine depths to the saturated zone and bedrock surface where existing data were unavailable or inadequate for ground-water modeling.

One hundred and sixty five seismic traverses were used to construct 14 profiles of the valley fill. Information from wells located along or in close proximity to lines was used to evaluate the seismic data and refine the profiles.

In general, the following approach was used in the geophysical work:

1. Bedrock outcrops were sought at both ends of a proposed profile. If no bedrock outcrop could be located, the line was begun where it was inferred from well records or topography that bedrock was within 50 ft of the surface.

2. Single-channel seismic refraction surveys were performed with a sledge hammer and strike plate to determine the depth to the saturated zone and, if possible, the bedrock surface. Seismic velocities in bedrock can be measured at depths of up to about 100 ft using this method. With the 250 ft traverse length used in most traverses, the depth of investigation was approximately 80 ft. All seismic velocities shown on profile lines or in table 2 are from 2-way traverses.

3. Seismic reflection traverses were conducted where refraction traverses or well records indicated that bedrock was more than 80 ft below the ground surface. Reflection traverses were usually 50 ft in length. Seismic velocities were measured from refraction traverses or were back-calculated where bedrock depth was known from drilling records. Back-calculated overburden velocities were used at distances of up to one mile from reference wells.

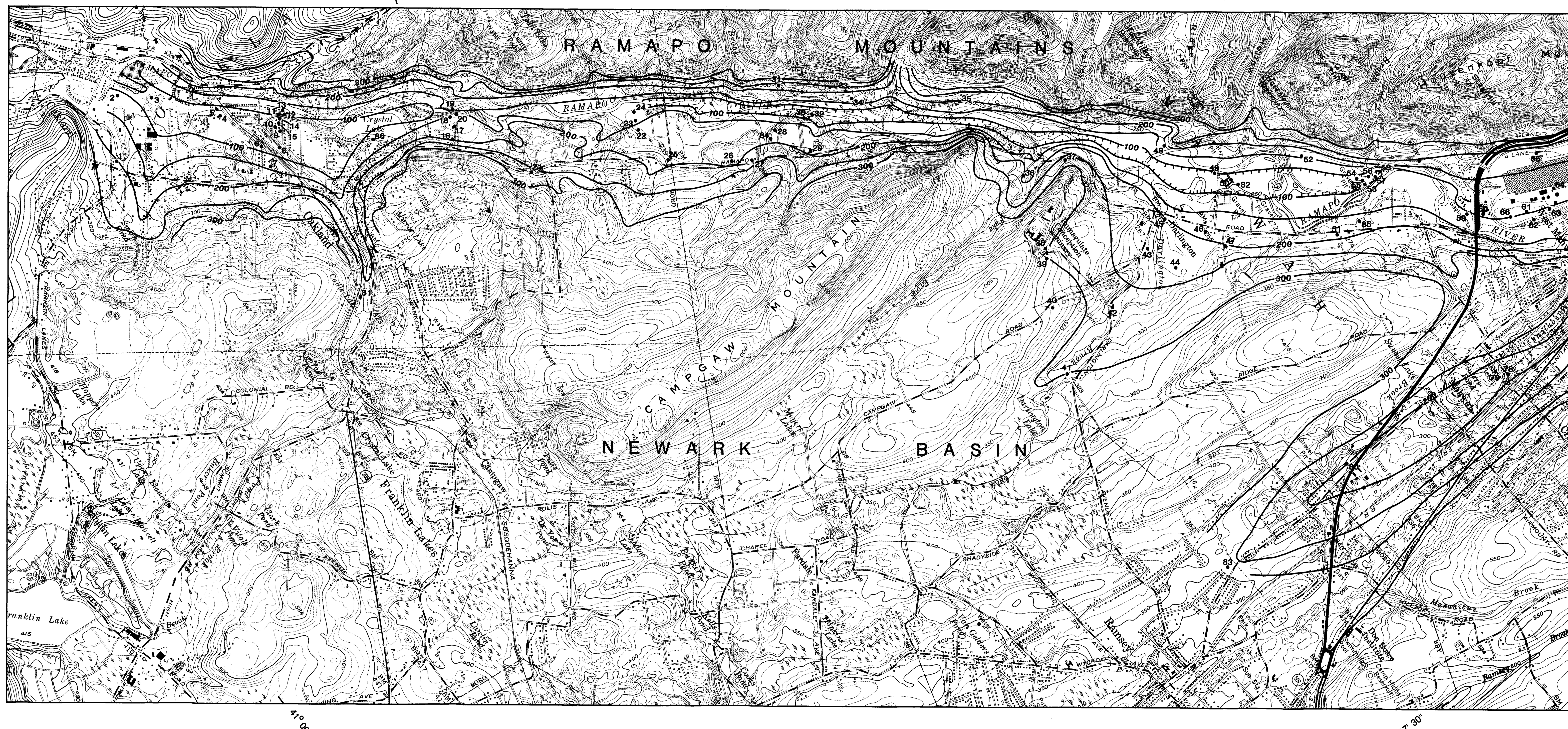
Eighty reflection traverses and 85 refraction traverses were performed. Individual seismic traverses were performed parallel to inferred bedrock contours to minimize difficulties which arise in the interpretation of seismic data from surfaces which slope along the line of traverse.

SEISMIC VELOCITIES

Seismic velocities obtained from refraction traverses within the valley range from 600 ft/s to 23,000 ft/s. Velocities corresponding to different sediment and rock types (table 1) were determined from two-way traverses at stations where the stratigraphic sequence was known from well logs. The values are within the ranges reported by Clark (1966, tables 9-1, 9-4, 9-5) and Mooney (1977, table 1). In some cases, the seismic data did not permit a clear interpretation of stratigraphy. In most traverses depth to saturated sediment and depth to bedrock could be measured with an accuracy of about 10 percent. To estimate aquifer dimensions, it was necessary to estimate the proportion of permeable and less permeable units within the valley fill on the basis of well record information.

BEDROCK ELEVATION

Bedrock elevation along the Ramapo River valley shows a net decrease southwestward from more than 120 ft at Suffern to approximately 50 ft at Oakland. This is a gradient of less than 5.6 ft/mi, compared to the present 7.0 ft/mi gradient of the Ramapo River in the same area. The southwestward gradient indicates that prior to glaciation, as now, the valley was host to a southwestward-flowing river. Consistent with this, the gradient of the bedrock floor of the valley slopes to the south, both north (Moore and others, 1982) and south of the study area. To the south, well records of the N.J. Department of Environmental Protection, Bureau of Water Allocation, indicate a southward-trending bedrock valley with elevations of 23 ft at Pompton Lakes Borough and between sea level and 25 ft below sea level at Pequannock. Localized reversals in the overall southward gradient are attributed to glacial scour. These reversals show on the bedrock topography map as closed depressions.



1 .5 0 KILOMETERS 1 2
1000 0 METERS 1000 2000
1 .5 0 MILES 1

EXPLANATION

—300— BEDROCK CONTOUR - Shows altitude of the bedrock surface. Contour interval 50 ft. Datum is National Geodetic Vertical Datum of 1929.

•27 WELL OR BORING - Number corresponds to WELL NO. in Table 1.

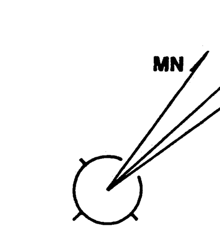
BEDROCK TOPOGRAPHY AND PROFILES OF VALLEY-FILL DEPOSITS IN THE RAMAPO RIVER VALLEY, NEW JERSEY

by

Robert Canace and Wayne Hutchinson

1988

SHEET 1 OF 2. TOPOGRAPHY OF THE BEDROCK SURFACE AND LOCATIONS OF SELECTED WELLS IN THE RAMAPO RIVER VALLEY.



Base from U.S. Geological Survey Ramsey, NJ - NY, 7.5' topographic quadrangle, 1955; Wanaque, NJ, 7.5' topographic quadrangle, 1954, photorevised 1971; Park Ridge, NJ - NY, 7.5' topographic quadrangle, 1955; Paterson, NJ, 7.5' topographic quadrangle, 1955; and Sloatsburg, NY - NJ, 7.5' topographic quadrangle, 1955.

Geophysical studies by Robert Canace, Wayne Hutchinson, Lloyd Mullikin, and Thomas Bambrick, 1981 - 1983. Manuscript reviewed by Mary Hill, U.S. Geol. Survey, Water Resources Division, and Byron Stone, U.S. Geol. Survey, Geologic Division.

Foot-pound-second units of measurement are used on this map. These can be converted to International System (SI) units as follows:

feet x 3.05 x 10^{-1} = meters

gallons x 3.79 x 10^{-3} = meters^3

WELL NO.	NJ PERMIT NO.	OWNER	YEAR DRILLED	SURFACE ELEV (ft)	WELL DEPTH (ft)	BEDROCK ELEV (ft)	BEDROCK TYPE	LITHIC LOG AVAIL	COMMENT
1	23-5862	Muller Park	1973	225	55	<205	NR*	yes	
2	23-7535	Oakland Borough	1984	205	90	115	Shale	yes	test well no. 2
3	23-7585	"	1984	205	141	64	Conglom.	yes	test well no. 3
4	23-0994	"	1954	221	128	102	NR	yes	test well no. 5
5	23-0345	"	1950	220	126	<99	"	yes	test well no. 4
6	23-5246	"	1968	260	157	97	"	no	test well, Oak and Memorial
7	23-5281	"	1968	270	160	130	Shale	yes	test well, Boro. yard, Oak St.
8	-	Weston and Sampson	1924	244	198	69	SS/Shale	yes	dam site 1, test boring no. 6
9	-	"	1924	265	233	53	Sandstone	yes	" , test boring no. 5
10	23-0373	Oakland Borough	1931	265	190	<75	NR	yes	Pine St. well no. 1
11	-	Weston and Sampson	1924	215	87	148	Gneiss	yes	dam site 1, test boring no. 3
12	23-7519	Oakland Borough	1983	210	70	143	Granite	yes	River Road test well no. 1
13	-	Weston and Sampson	1924	216	92	150	Gneiss	yes	dam site 1, test boring no. 1
14	-	"	"	264	141	143	"	yes	" , test boring no. 2
15	-	"	"	264	210	73	"	yes	" , test boring no. 4
16	-	"	"	270	108	182	Trap**	yes	dam site 3, test boring no. 4
17	-	"	"	281	129	173	"	yes	" , test boring no. 3
18	-	"	"	282	147	155	"	yes	" , test boring no. 5
19	-	"	"	213	69	165	Gneiss	yes	" , test boring no. 1
20	-	"	"	279	165	135	"	yes	" , test boring no. 2
21	23-2105	George Steidton	1957	300	280	250	Trap	yes	
22	23-2197	Oakland Borough	1957	235	100	154	Red Rock***	yes	Soons well no. 7
23	23-1929	"	1959	235	96	142	Gneiss	yes	Soons well no. 6
24	23-2507	"	"	235	112	<123	NR	yes	Soons well no. 8
25	23-5338	Cornelius Koedam	1969	235	210	175	Red Rock	yes	
26	23-3769	Eloise Fagan	1963	295	97	<198	NR	yes	
27	23-3810	Dr. Donald Ford	1964	290	235	215	Trap	yes	
28	23-2186	W. W. Patterson	1957	285	52	<233	Red Rock	yes	
29	23-6294	Tad Development Co.	1976	300	152	190	Shale	yes	
30	23-6600	J.H. Const. Co.	1969	280	152	<123	NR	no	
31	23-1687	Fred Owens	1955	285	90	270	Gneiss	yes	
32	23-6599	J. H. Const. Co.	1979	260	152	<109	NR	no	
33	23-6156	Ronald Little	1975	270	270	249	"	no	
34	23-6149	John Harrington	1975	265	130	170	"	no	
35	23-4227	Fred Wahran	1965	255	100	207	Trap	yes	
36	23-2251	Immac. Concep. Sem.	1957	290	110	185	"	yes	
37	23-6430	Dr. Arnold Taub	1978	295	580	290	"	yes	
38	23-0080	Immac. Concep. Sem.	1949	385	415	302	NR	no	well no. 1
39	23-0080	"	1948	400	435	300	"	no	well no. 2
40	23-0727	Constant Okonski	1952	385	95	339	Sandstone	yes	
41	23-0631	E. L. Wehran	1952	310	50	300	"	yes	
42	23-2253	Allen Dixon	1957	290	115	265	Red Rock	yes	
43	23-2524	Thomas Helas	1958	265	71	228	Sandstone	yes	
44	23-7369	Ramapo ValleyCollege	1983	265	35	<230	NR	yes	U.S. Geological Survey TB2
45	23-5102	Isaac Deganaars	1968	255	400	190	Red Rock	yes	

WELL NO.	NJ PERMIT NO.	OWNER	YEAR DRILLED	SURFACE ELEV (ft)	WELL DEPTH (ft)	BEDROCK ELEV (ft)	BEDROCK TYPE	LITHIC LOG AVAIL	COMMENT
46	23-4813	Robert Gresner	1966	265	148	180	Sandstone	yes	
47	23-0975	Stephen Birch	1953	275	252	195	"	yes	
48	23-7417	Bergen County Park	1983	250	35	215	NR	yes	U.S. Geological Survey TW3
49	23-6668	Mahwah Township	1980	255	149	<96	"	yes	production well no. 16
50	23-6933		1981	255	161	82	Sandstone	yes	production well no. 17
51	23-7367	Ramapo Valley College	1983	275	42	<233	NR	yes	U.S. Geological Survey TW1
52	23-7418	Mary B. Patrick	1983	258	60	<198	"	yes	U.S. Geological Survey TW6
53	-	Mahwah Township	1959	260	116	<145	"	yes	Ford field, test well no. 1
54	23-0940	"	1953	270	140	<130	"	yes	Ford field well no 2
55	-	"	1960	260	114	140	"	yes	Ford field, test well no. 2
56	23-0891	"	1953	260	103	<151	"	yes	Ford field well no. 1
57	23-0991	"	1953	254	95	<159	"	no	Ford field well no. 4
58	23-0990	"	1053	256	95	<161	"	no	Ford field well no 3
59	23-2845	William Drobesh	1960	260	200	155	Shale	yes	
60	23-7366	U.S. Geological Survey	1983	268	86	<182	NR	yes	Geol. Div. Byron no. 4
61	23-7012	Ford Motor Co.	1982	271	27	<244	"	yes	Mahwah assembly plant
62	23-7011	"	"	270	26	<244	"	yes	
63	23-7010	"	"	"	26	<244	"	yes	
64	23-7009	"	"	286	28	<258	"	yes	
65	23-7014	"	"	288	16	240	"	yes	
66	23-7013	"	"	269	30	<239	"	yes	
67	-	Suffern Village	1974	255	127	155	"	yes	test well no 6
68	-	"	1936	275	97	<178	"	yes	well no 2
69	-	"	1974	275	117	163	"	yes	test well no. 4
70	-	"	"	279	155	124	"	yes	test well no. 5, prod. no. 4
71	-	"	1932	274	95	<179	"	no	Perlmutter, 1959, table 17
72	-	Avon	1939	310	718	202	"	no	"
73	-	Erie Railroad	1954	270	121	154	"	no	"
74	23-7368	Mahwah Township	1983	265	27	<238	"	yes	U.S. Geological Survey TW5
75	23-0884	American Brake Shoe	1953	290	301	195	"	yes	well no. 2
76	23-0862	"	"	"	203	185	"	yes	well no. 1
77	23-0932	"	"	"	42	207	Red Rock	yes	well no. 3
78	23-5533	Mahwah Township	1970	276	101	<175	NR	yes	test well no. 1
79	23-5532	"	"	295	95	190	"	yes	test well no. 2
80	23-0829	Ramsey Borough	1953	305	107	205	"	yes	test well no. 4
81	23-5006	Oakland Borough	1967	310	150	222	Red Rock	yes	well no. 9
82	23-7365	Charles Elmes	1983	255	53	<202	NR	yes	U.S. Geological Survey TW7
83	23-4125	Ramsey Borough	1965	345	400	252	Sandstone	yes	
84	23-6765	Kelley	1980	285	450	175	NR	no	
85	23-0926	O'Mahoney	1953	270	126	155	Sandstone	yes	
86	23-7790	Oakland Borough	1985	225	117	108	NR	yes	test well tw-r4

* NR - No record
** Trap - Inferred to represent basalt
*** Red Rock - Inferred to represent sedimentary clastics of the Newark Sequence

Table 1. Data for selected wells in the Ramapo River Valley (Well number corresponds to number on map)

AQUIFER DIMENSIONS

Although the purpose of this phase of the investigation was to determine the dimensions of the valley-fill deposit, the well records and seismic interpretations allowed a preliminary estimate of the volume of water in the aquifer. The volume of saturated sediment, the total volume of ground water in storage, and the ground-water reservoir (the total volume of water which could theoretically be drained from storage) in the valley-fill aquifer underlying the Ramapo River between Oakland, New Jersey, and profile M, at the Suffern, New York, well field, were calculated using the following method, similar to that used by Vecchioli and Miller (1973):

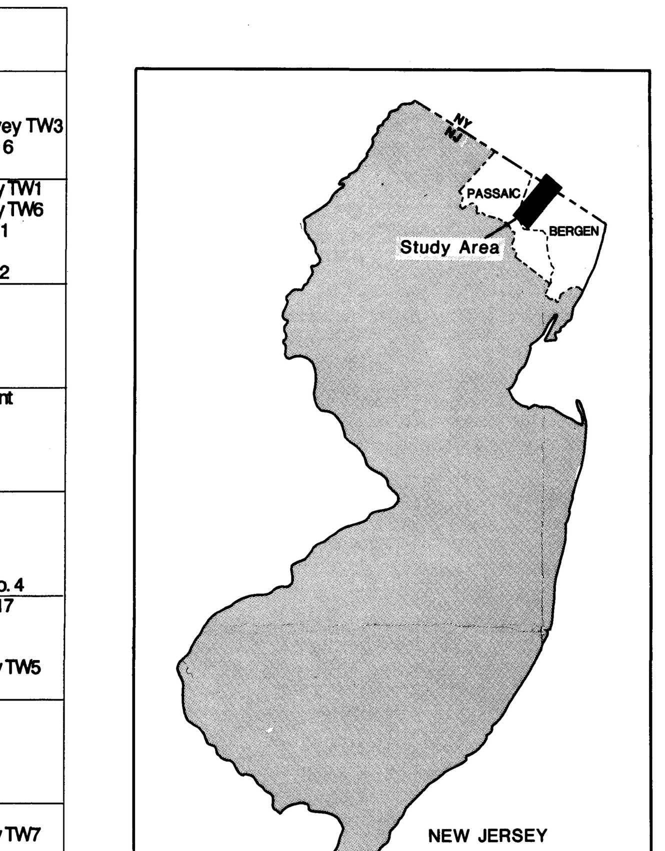
1. For each of the 14 profiles, the cross-sectional area of valley fill beneath the water table was measured by planimeter.

2. The total volume of saturated sediment in the valley was estimated by multiplying the area of saturated sediment shown on each profile by the distance to the next downstream profile and summing these values. The estimated total volume of saturated sediment is 17.8 x 10^7 ft^3.

3. The total volume of water in storage in the aquifer was estimated by multiplying volume of saturated sediment by porosity. The volume in storage was calculated separately for areas north and south of Fyke Brook. Between the termination of Preakness Mountain in Oakland and Fyke Brook in Mahwah, fine-grained, lake-bottom sediments are a minor portion of the total sediment volume. For this approximation it was assumed that the entire sediment volume consists of sand and gravel. Porosities of sand and gravel mixtures range from 20 to 50 percent (Fetter, 1980). Using an intermediate value of 35 percent, a volume of 14.5 x 10^9 (14.5 billion) gallons was estimated. North of Fyke Brook, fine-grained glacial lake-bottom sediment is a significant proportion of the total sediment volume and must be taken into account. This was done by determining the percentage of fine-grained sediments present in the Mahwah well field (60 percent) and applying this value for profiles G through M within the Ramapo River valley. Porosity was assumed to be 35 percent for the sand and gravel and 40 percent for lake-bottom sediments. The total volume of water in storage in the valley-fill aquifer between Fyke Brook and the Suffern well field estimated by this method is 35.8 x 10^9 (35.8 billion) gallons. Therefore, the total volume of ground water in storage in the Ramapo valley-fill aquifer between the end of Preakness Mountain in Oakland and the Suffern well field is estimated to be 50.3 x 10^9 (50.3 billion) gallons.

4. The volume of water which could theoretically be drained from valley-fill sediments may be referred to as the ground-water reservoir within these sediments. This volume was estimated by multiplying the volume of saturated sediment by its specific yield. Specific yield is the ratio between the volume of water a given mass of saturated sediment will yield to gravity and the volume of that mass. In physical terms the ground-water reservoir is the total volume of water present in the sediment, calculated above, minus the amount of water which would be retained by capillary attraction if the sediments were completely drained by gravity. As with total water volume, separate values were calculated for the valley north and south of Fyke Brook. For the confined aquifer lying below lake-bottom sediments north of Fyke Brook, the simplifying assumption was made that specific yield is equivalent to that of similar, unconfined materials. The calculated volume of the ground-water reservoir depends upon the specific yield assumed for aquifer materials (fig. 1). Specific yields of 25 percent for sand and gravel and 5 percent for lake-bottom sediments are reasonable (see Fetter, 1980, table 4.2, and Todd, 1959, table 2.5). Using these values the total volume of the ground water reservoir was calculated to be 20.0 x 10^9 (20.0 billion) gallons for the two valley segments together.

The amount of water in the ground-water reservoir is not the safe yield (the amount of water which can be pumped from the aquifer on a continuous basis). The withdrawal of large volumes of water from the valley-fill aquifer would bring about a significant lowering of the piezometric surface, causing further leakage from the bed of the Ramapo River or upward flow from underlying aquifers. Under such conditions, water from the river or bedrock aquifers would contribute a significant proportion of the pumpage. Although more water could be pumped than would be estimated simply by analyzing aquifer storage, the pumping would affect river flow, surface-water bodies, and water levels in wells. It is anticipated that the ground-water flow model under development will be helpful in estimating the magnitude of such impacts.



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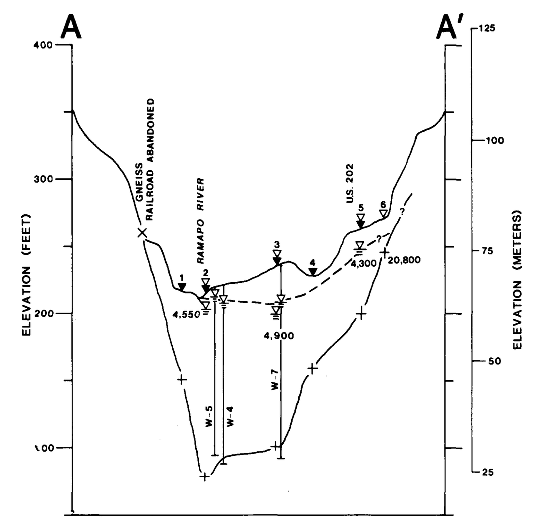
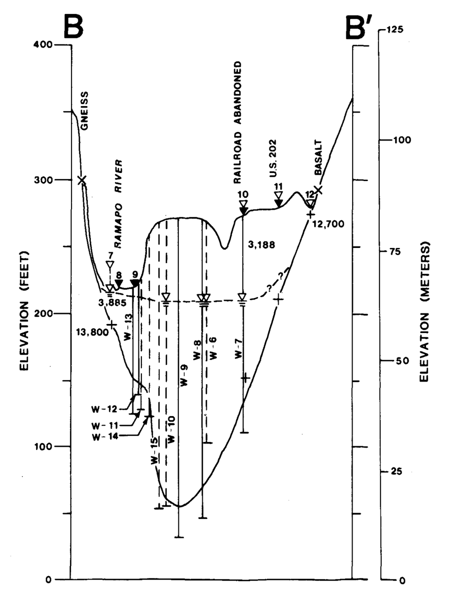
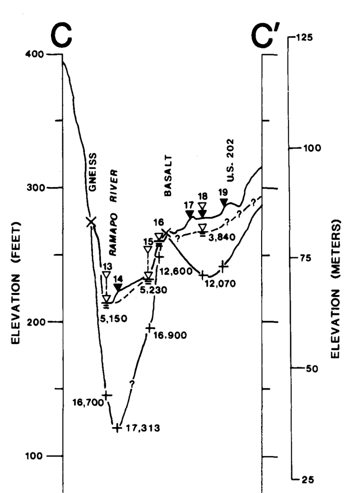
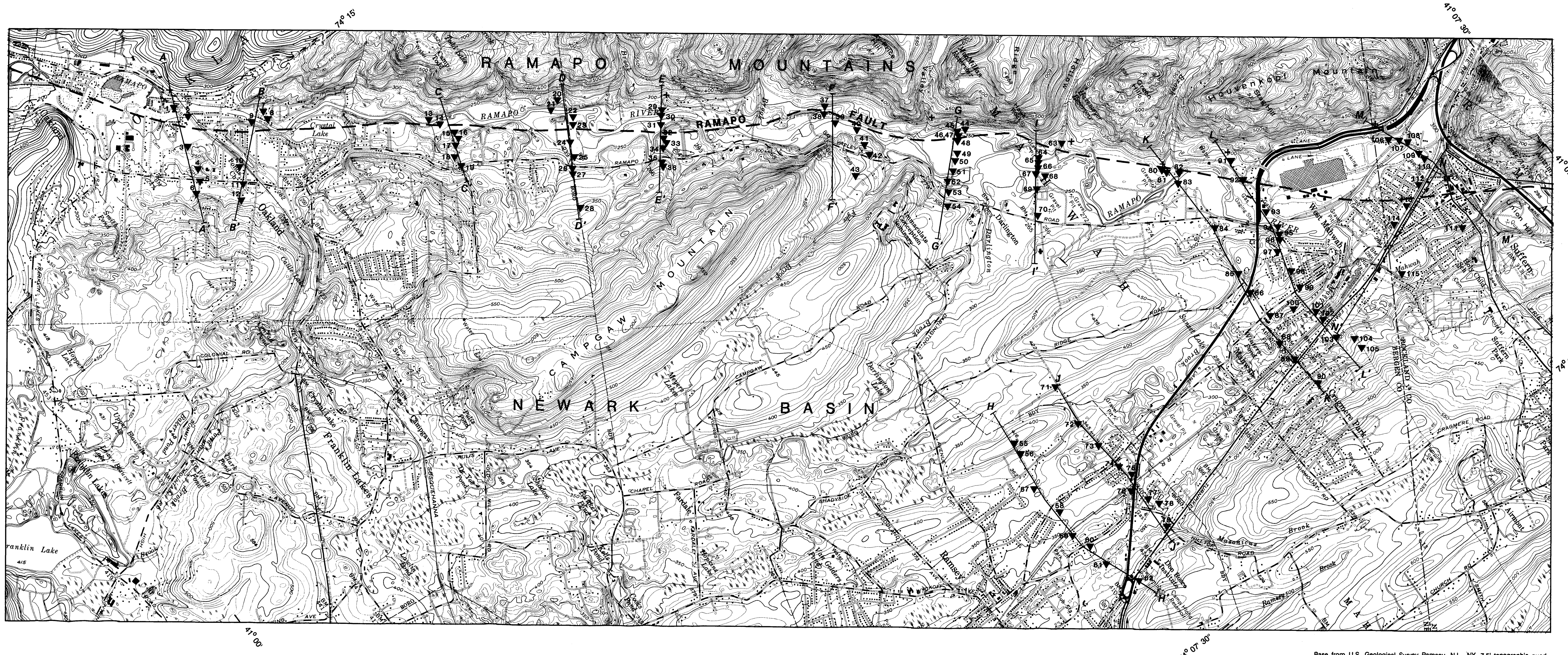
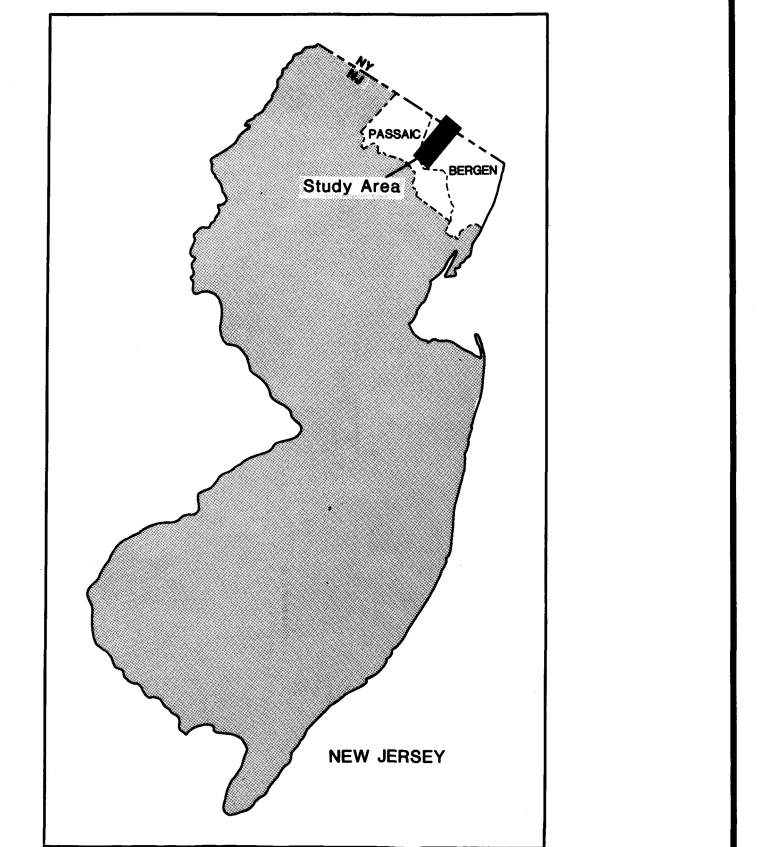
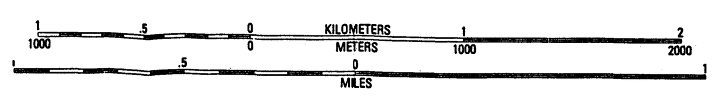












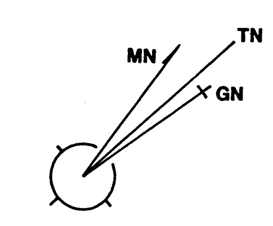
BEDROCK TOPOGRAPHY AND PROFILES OF VALLEY-FILL DEPOSITS IN THE RAMAPO RIVER VALLEY, NEW JERSEY

by

Robert Canace and Wayne Hutchinson

1988

SHEET 2 OF 2. SEISMIC TRAVERSE LOCATIONS AND PROFILES THROUGH VALLEY-FILL DEPOSITS OF THE RAMAPO RIVER VALLEY.



Base from U.S. Geological Survey Ramsey, NJ - NY, 7.5' topographic quadrangle, 1955; Wanaque, NJ, 7.5' topographic quadrangle, 1954, photorevised 1971; Park Ridge, NJ - NY, 7.5' topographic quadrangle, 1955; Paterson, NJ, 7.5' topographic quadrangle, 1955; and Sloatsburg, NY - NJ, 7.5' topographic quadrangle, 1955.

Geophysical studies by Robert Canace, Wayne Hutchinson, Lloyd Mullikin, and Thomas Bambrick, 1981 - 1983. Manuscript reviewed by Mary Hill, U.S. Geol. Survey, Water Resources Division, and Byron Stone, U.S. Geol. Survey, Geologic Division.

Foot-pound-second units of measurement are used on this map. These can be converted to International System (SI) units as follows:

feet x 3.05×10^{-1} = meters

gallons x 3.79×10^{-3} = $meters^3$

EXPLANATION

MAP

G——G′ PROFILE LOCATIONS

27 GEOPHYSICAL TRAVERSE LOCATION - Number corresponds to geophysical traverse number on profile.

PROFILES

× BEDROCK OUTCROP

27 SEISMIC REFLECTION TRAVERSE LOCATION - Number corresponds to geophysical traverse number on map.

27 SEISMIC REFRACTION TRAVERSE LOCATION - Number corresponds to geophysical traverse number on map.

27 SEISMIC REFLECTION AND REFRACTION TRAVERSE LOCATION - Number corresponds to geophysical traverse number on map.

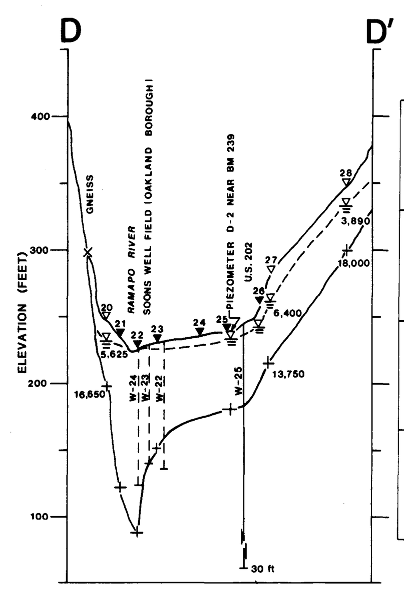
W-27 WELL OR BORING - Dashed if projected onto section from distance greater than 500 ft. Number corresponds to that on map and in Table 1.

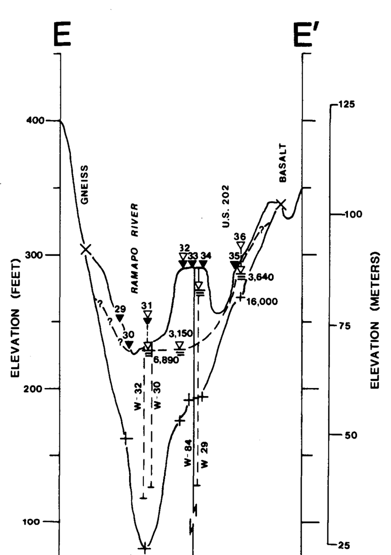
TOP OF SATURATED ZONE

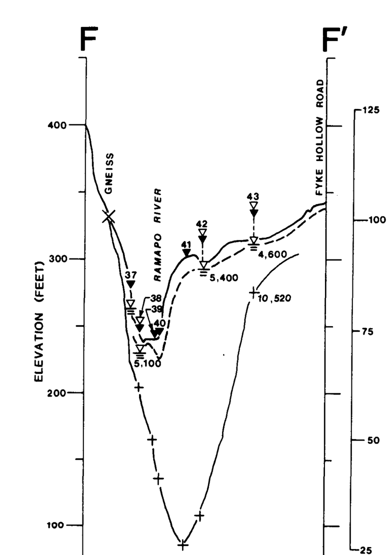
27 TOP OF SATURATED ZONE - From piezometer or geophysical traverse.

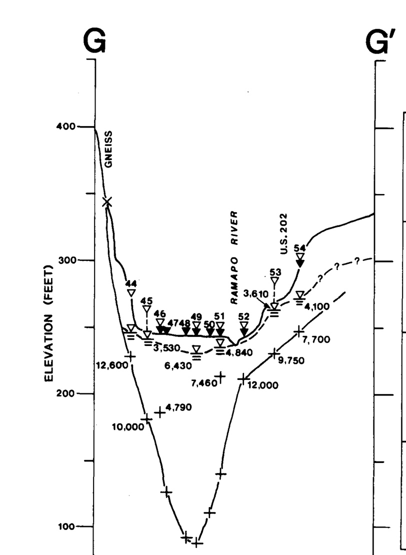
+ SEISMIC VELOCITY BOUNDARY

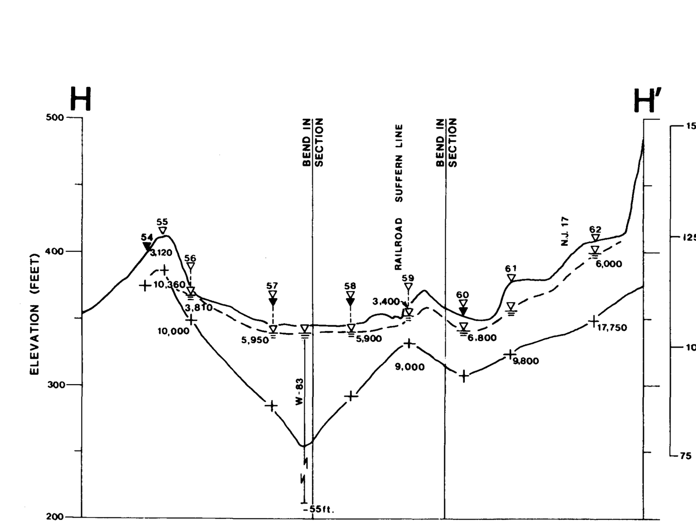
24,000 SEISMIC VELOCITY - Average value for layer (ft/sec).











Material	Number of traverses	Seismic velocities (ft/sec,P-wave)		
		minimum	maximum	mean
Unsaturated valley fill	40	--	3,700	--
Saturated valley fill*	40	3,700	7,600	5,260
Jurassic bedrock**	27	8,200	23,300	13,485
Precambrian bedrock	11	9,900	20,360	13,975

* Includes till ** Includes basalt

Table 2. Seismic velocity values from two-way refraction traverses in the Ramapo River and Masonicus Brook valleys.