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Seismic Refraction and Gravity Investigation of Bedrock Topography at Lakeland Regional High School, Wanaque, Passaic County, New Jersey

Department of Environmental Protection
Division of Water Resources

1988

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SEISMIC REFRACTION AND GRAVITY INVESTIGATION OF BEDROCK TOPOGRAPHY AT LAKELAND REGIONAL HIGH SCHOOL, WANAQUE, PASSAIC COUNTY, NEW JERSEY

by
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ABSTRACT

Four seismic lines were completed in the Lakeland High School area to determine the topography on the Precambrian gneisses which are overlain by glacial deposits. Three of the seismic lines were nearly perpendicular to the regional strike. The fourth line was parallel to strike and intersected the center of each of the other lines. Gravity readings were taken at each of the shotpoints along a 1200-ft, strike-parallel seismic line and also at 100-ft intervals along a nearly perpendicular 2800-ft traverse.

Bedrock elevations determined from the seismic and gravity data were plotted and contoured. The bedrock surface slopes to the southeast. A constricted exit to the buried stream valley is implied from seismic, gravity, well and outcrop data in the southeastern part of the study area.

INTRODUCTION

An undetermined amount of heating fuel oil is known to have polluted the ground water in the Lakeland High School area in Wanaque, New Jersey. Ground-water flow is believed to be controlled by bedrock topography. The purpose of this study was to use seismic refraction and gravity profiling to delineate the bedrock topography for use in tracing the ground-water pollution distribution.

Acknowledgments

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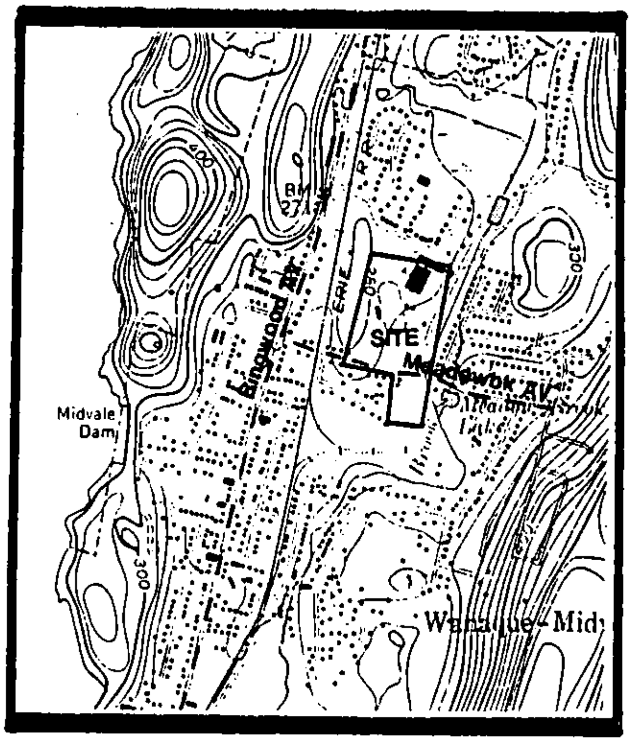
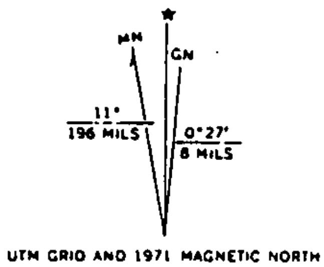
GEOLOGY AND SITE DESCRIPTION

The area of investigation is located in a valley just east of the Wanaque Reservoir in Wanaque Township (fig. 1). The bedrock is composed primarily of Precambrian gneiss ridges trending north-east-southwest. Overlying the gneisses are Wisconsinan Stage glacial sediments. The glacial deposits are composed of silts, sands and gravels. The area south of Meadowbrook Avenue, which is now Addice Park, is the site of a former lake that has been filled with excavated material.

USGS Wanaque Quadrangle
Passaic County

Inset from U.S. Geological survey Wanaque Quadrangle, photo revised 1971.





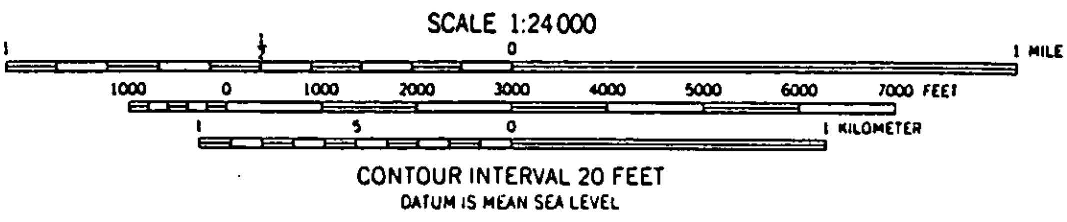


Figure 1 Study area near Lakeland Regional High School

A total of 21 monitor wells were installed in the area as part of an ongoing pollution investigation. These were placed in order to better define the subsurface lithology and provide hydrologic information. The depth to the water table, based on the well data, is generally between 15 and 25 ft.

The geophysical survey was conducted in the school's athletic fields and in Addice Park with the permission of the Wanaque Board of Education. It was necessary to extend the gravity line along Meadowbrook Avenue to gain better regional control.

SEISMIC REFRACTION

Field Procedures

The seismograph used in this survey was a Bison Instruments Geopro 8024A non-saturating, signal-enhancement instrument with analog-to-digital capabilities. A combination of 7-hz Bessel high-pass, 375-hz Chebyshev low-pass, and 200-hz Butterworth low- pass analog filters were used throughout the survey. The notch filter was not used due to the absence of 60-cycle noise. The data were recorded both on internal storage and digital tape for subsequent filtering and analysis. A single Terra Dynamics ADR 711 accelerometer was used per geophone takeout. The seismic source was of an EG&G vacuum-assisted weight drop (Dynasource).

A total of four seismic lines (LH1, LH2, LH3, and LH4) were collected and processed. Seismic line LH4 ran parallel to the trend of the gneiss ridges, roughly north-south. The other lines ran roughly perpendicular and crossed LH4 (fig. 3). Each seismic line, except LH4, consisted of two geophone spreads, with 12 geophone stations per spread, LH4 was composed of four spreads of 12 geophones each. The geophone interval was 20 ft, and the shotpoints were located 120 ft apart. A typical shotpoint to geophone configuration is shown below in figure 2.

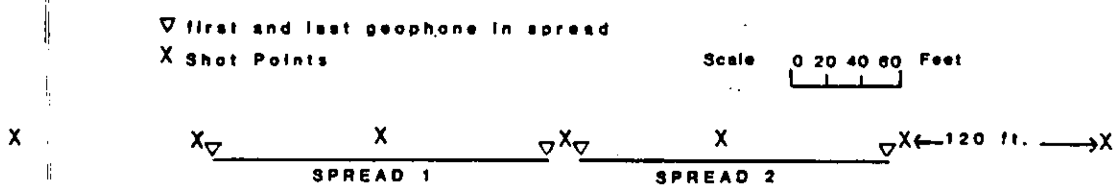


Figure 2. Geophone and shotpoint layout.

The shotpoints were later surveyed for elevation control using a plane table and alidade. The geophone elevations were interpolated from the shotpoint elevations.

Data Reduction and Interpretation

The first-break arrival times for each seismic event were determined by using the time lines on the seismograph. These data were then processed using the seismic refraction inverse modeling program of Scott (1977). This program incorporates the delay-time method with a ray-tracing procedure to calculate the acoustic interface depths below the geophone and shotpoint stations. Each seismic line was corrected to a mean datum elevation and compared to the tie lines which crossed it. The data were then reprocessed using an averaged value of 16,185 ft/sec for the bedrock velocity. The overburden velocity was not averaged due to the variable nature of the glacial deposits and the fill in Addice Park.

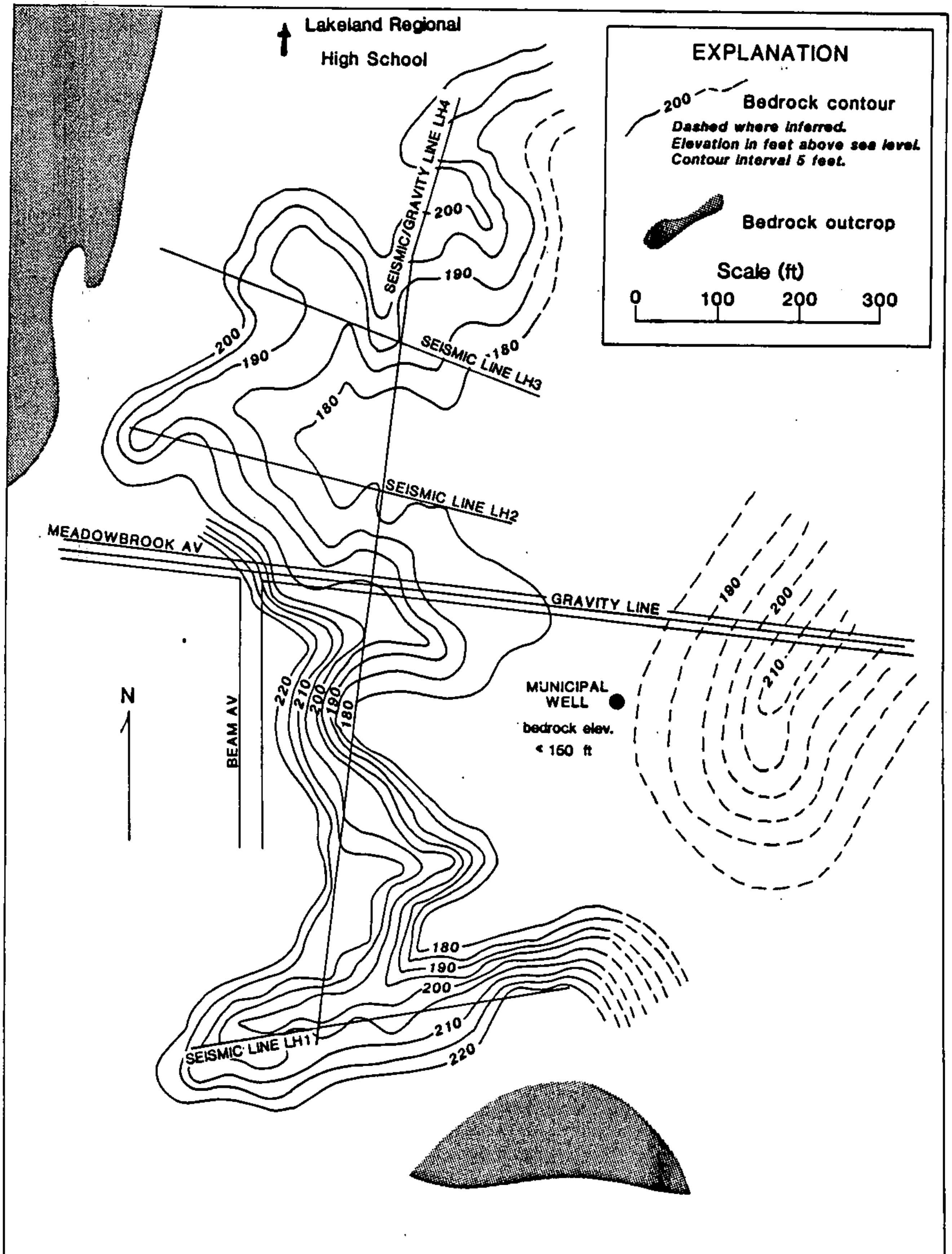


Figure 3 Bedrock topography

The saturated overburden velocities ranged from 5,615 ft/sec to 6,527 ft/sec. The unsaturated overburden velocities ranged from 1,627 ft/sec to 2,558 ft/sec. Depth sections of the overburden and acoustic basement were then generated using the calculated velocities. The depth to bedrock from seismic refraction ranged from 22 to 81 ft. These values were then compared with those based on gravity calculations and adjusted. Water table depth determinations were also calculated and, although based on few data points, were found to be consistent with the well data.

GRAVITY

Field Procedures

A LaCoste and Romberg gravimeter (Model D25) was used in this study. A field base was established on Meadowbrook Avenue 575 ft from the intersection of Ringwood Avenue at an elevation of 262.8 ft. This base station was tied to N. J. Gravity Station Network station NJ17 (Ghatge and Jagel, unpublished data). Base station NJ17 has an observed gravity of 980231.560 milligals (mgal) and is tied to a primary base station established by Bonini and Woolard (1957) at Princeton University.

Gravity data were collected along two lines; one along Meadowbrook Avenue and the other along seismic line LH4. The Meadowbrook Avenue line had a station spacing of 100 ft starting at the intersection of Meadowbrook Avenue and Ringwood Avenue (fig. 1) and continuing to the end of the road 2,876 ft to the southeast. Two of the stations were offset 30 ft because the 100-ft intervals were located on bridges. The gravity stations along seismic line LH4 were located at each of the seismic shotpoints. Spacing varied from 80 to 120 ft.

Elevations at all gravity stations were measured to $\pm$ 0.2 ft using a plane table and alidade. Multiple gravity readings were taken at each station to ensure a precision of 0.02 dial units. Each hour a reading was taken at the field base station to account for drift.

Data Reduction and Interpretation

Gravity data were reduced using a computer program, GRAVRED (Ghatge, written communication), to calculate the simple Bouguer anomaly. The program first calculates the tidal and instrumental drift to obtain the observed gravity. A latitude correction is then calculated with respect to the field base station and the theoretical sea-level gravity for each station elevation obtained. To account for the effect of elevation above sea level the free-air and Bouguer reductions are calculated. A density of 2.80 gm/cc was used in the Bouguer slab correction since this was the assumed background density of the Precambrian bedrock (Telford and others, 1976).

Interpretation was done using a 2-dimensional gravity inverse modeling program, G2D (Groenewold, written communication). The gravity line which coincides with seismic line LH4 was modeled first. Bedrock topography, for the initial model, was taken from seismic profile LH4. Density of the Precambrian bedrock was set at 2.80 gm/cc and the density of the glacial overburden at 2.01 gm/cc (Telford and others, 1976). A straight line regional was removed from the data. The vertices representing the contact between the bedrock and the overburden were adjusted manually and by computer until a satisfactory visual fit of the data was obtained.

The Meadowbrook Avenue gravity profile was modeled in the same manner. Constraints on the initial bedrock model along the profile include an outcrop of Precambrian amphibolite west of seismic line LH4 (fig. 3). The bedrock topography within the study area was modeled. The model was in good agreement with the surrounding geological and geophysical controls. A steep increase in the gravitational field was observed to the west of the study area and 300 ft east of Ringwood Avenue. The steep gradient was attributed to the contact between Precambrian amphibolite and silliminite gneiss shown on Geological Overlay Series Sheet #23 (New Jersey Geological Survey, undated). Data from the line were modeled by inserting a vertically dipping body with a density of 2.94 gm/cc. With this body, in place the bedrock model was fit to the remaining data (fig. 5). Although this body is implied by the gravity data, there is no known geological evidence to verify the existance of such a body.

BEDROCK TOPOGRAPHY

Bedrock elevations from the seismic and gravity interpretations were plotted and hand contoured using a five-foot contour interval (fig. 3). The bedrock topography is irregular with outcrop in the northwestern part of the study area sloping very steeply to the southeast. A bedrock high (ridge) which approximately parallels Meadowbrook Avenue was observed in the center of the study area. Bedrock generally slopes to the southeast and ground water is likely to flow in the same direction. South of Meadowbrook Avenue ground water may flow into the bedrock low (fig. 3) before exiting through a confined channel located in the southeastern part of the study area.

Depth profiles generated along lines LH3 and LH4 illustrate the undulating nature of the bedrock surface (fig. 4). Profile LH4 shows both seismic and gravity interpretations. Differences between the seismic and gravity interpretations can be attributed to the following: 1) closer spacing of seismic data points which resulted in higher resolution, 2) local variations in bedrock density (although probably a minor effect) and, 3) three- dimensional effects of the abruptly changing bedrock topography which were assumed to be two dimensional in modeling. The Meadowbrook Avenue gravity profile (fig. 5) shows the abrupt changes in bedrock topogaphy on a larger scale. The municipal well in figure 2 is approximately 500 ft from a bedrock outcrop. This well was drilled to a depth of 105 ft and completed in glacial material, illustrating the magnitude of bedrock relief.

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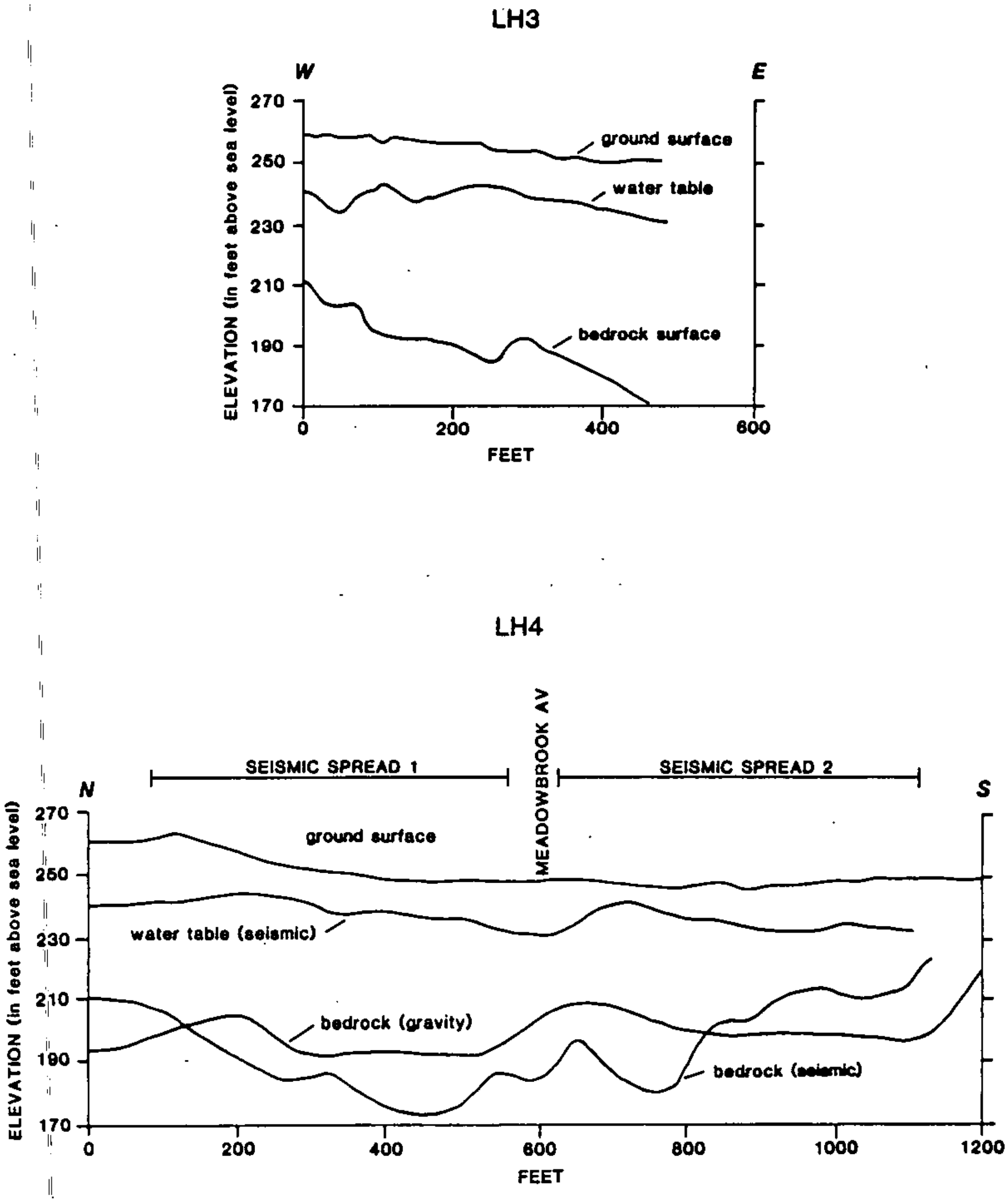


Figure 4 Geologic profiles along lines LH3 and LH4.

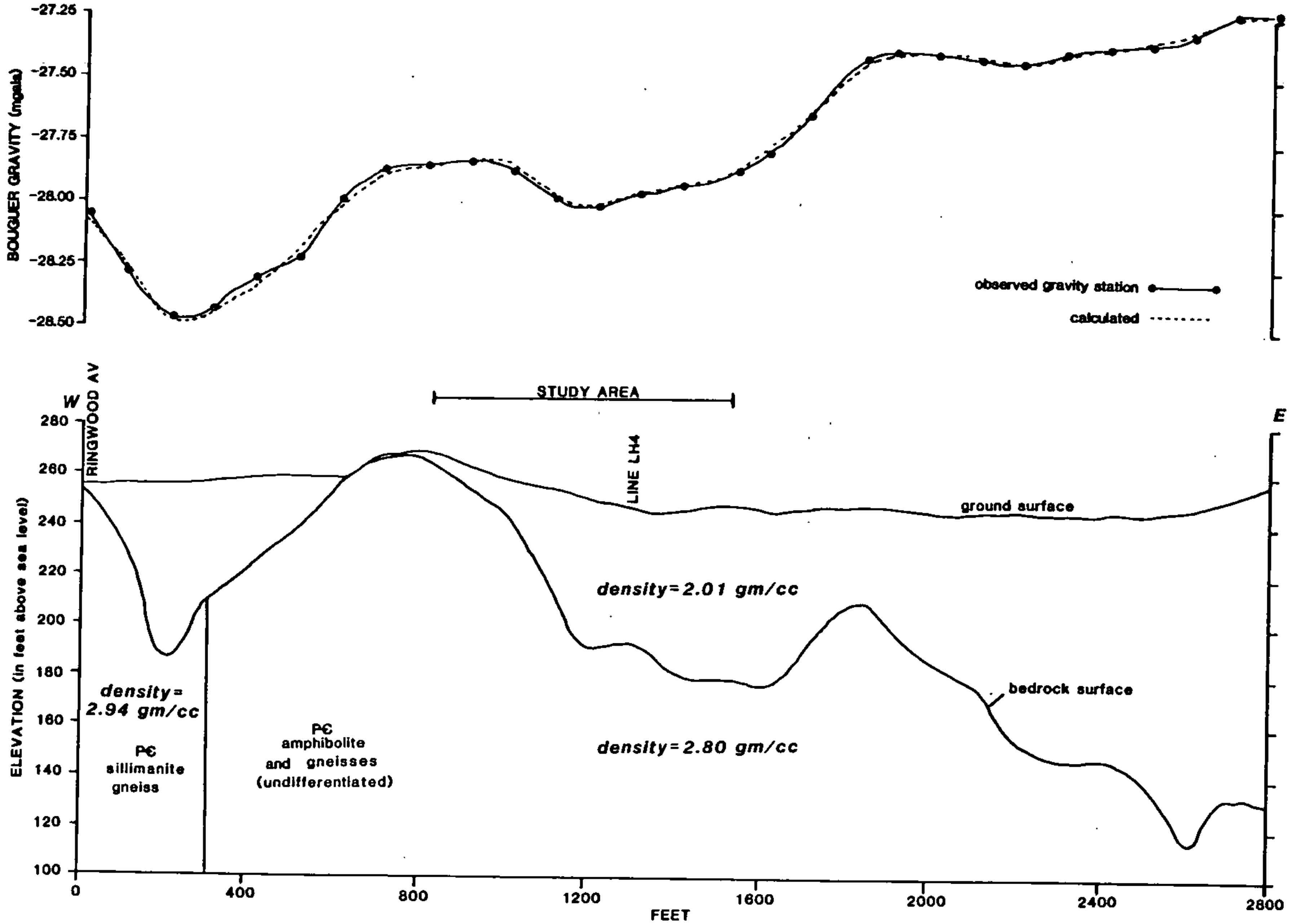


Figure 5 Interpretation of gravity data along Meadowbrook Avenue.

APPENDIX 1

ARRIVAL TIMES FOR LH-1 (milliseconds)

geophone	shot 1	shot 2	shot 3	shot 4	shot 5	shot 6
Shot Location	(10'F)	(6&7)	(12&13)	(18&19)	(10'R)	(75'R)
1	7.400	36.50	40.00	44.20	52.40	62.80
2	21.80	33.10	38.60	43.00	50.80	60.40
3	28.20	28.10	37.80	41.80	49.40	58.00
4	35.00	22.90	36.10	40.20	48.20	56.80
5	39.80	18.70	35.70	38.60	47.00	55.20
6	41.00	4.300	34.90	37.80	46.60	54.00
7	42.20	5.100	33.90	36.20	45.80	52.80
8	43.80	16.90	32.10	35.00	45.00	51.60
9	44.20	21.70	27.10	33.80	44.20	50.20
10	44.60	25.10	23.90	32.20	43.00	49.00
11	45.80	27.10	19.10	31.00	42.20	47.80
12	47.00	28.90	7.500	29.80	41.00	46.60
13	48.60	29.90	8.500	28.60	40.20	45.00
14	50.20	30.90	19.30	27.80	38.60	43.80
15	51.00	31.70	24.30	24.20	37.00	42.20
16	52.20	32.70	29.50	21.00	35.80	41.00
17	53.00	33.90	33.10	17.00	34.20	39.80
18	54.60	34.90	34.10	5.400	32.60	38.20
19	55.40	35.70	35.10	5.800	31.00	37.00
20	54.20	36.70	36.50	15.80	29.80	35.40
21	55.60	37.90	37.80	19.80	26.60	34.20
22	56.80	39.00	38.80	23.00	23.40	32.60
23	58.60	40.40	40.60	27.40	19.00	31.40
24	60.40	41.40	41.80	31.00	6.600	29.80

F= forward shot
R= reverse shot

ARRIVAL TIMES FOR LH-2 (milliseconds)

Shot Location	(21'F)	(6&7)	(12&13)	(18&19)	(10'R)	(118'R)
geophone	shot 1	shot 2	shot 3	shot 4	shot 5	shot 6
1	13.40	30.20	49.20	51.20	56.80	55.60
2	16.60	26.60	48.40	50.00	55.60	54.00
3	20.60	23.80	44.40	47.60	54.80	52.80
4	23.80	20.60	39.20	46.40	54.00	51.60
5	27.00	15.80	36.40	45.60	53.20	50.00
6	30.20	5.400	35.20	44.80	52.40	49.20
7	33.40	5.800	31.60	43.60	51.20	48.00
8	37.00	17.80	29.00	42.00	50.40	47.20
9	40.20	20.60	25.80	41.20	49.60	46.00
10	43.00	23.80	22.20	39.00	48.80	44.40
11	46.60	27.80	18.60	38.40	48.00	43.60
12	49.00	31.00	4.600	36.00	47.20	42.80
13	50.20	33.40	4.200	34.00	46.80	41.60
14	51.40	36.20	15.40	31.60	46.00	40.80
15	50.50	39.00	21.40	26.20	45.20	38.40
16	51.40	41.40	28.60	21.40	44.40	37.00
17	51.80	43.80	32.00	13.40	43.60	36.60
18	52.60	45.00	34.00	5.000	42.60	37.00
19	53.40	46.20	38.80	5.400	36.20	36.20
20	54.60	47.40	40.40	15.00	32.60	35.40
21	55.80	48.60	42.40	21.00	27.80	34.60
22	56.20	49.40	43.20	28.20	21.40	33.00
23	57.20	50.20	44.80	30.80	14.20	31.80
24	58.00	50.60	45.20	32.80	5.400	30.00

ARRIVAL TIMES FOR LH-3 (milliseconds)

Shot Locations	(10'F)	(6&7)	(12&13)	(18&19)	(10'R)	(75'R)
geophone	shot 1	shot 2	shot 3	shot 4	shot 5	shot 6
1	3.800	33.00	52.40	50.00	55.60	61.60
2	16.60	28.60	48.20	48.80	54.40	60.40
3	23.00	24.60	44.20	47.20	53.20	58.00
4	27.80	19.80	41.00	46.00	52.40	55.20
5	29.80	10.20	37.40	44.80	50.20	53.60
6	33.00	3.400	33.80	43.60	47.00	52.00
7	36.60	3.400	29.80	41.00	44.60	50.00
8	39.00	10.60	27.00	39.00	43.40	48.80
9	41.80	18.20	25.00	37.80	42.20	47.60
10	45.80	23.40	21.80	36.20	41.00	46.00
11	48.60	26.60	14.60	35.00	40.60	44.40
12	52.40	30.20	4.200	33.80	39.80	42.80
13	53.20	33.80	4.200	32.20	38.60	39.40
14	54.00	37.80	14.60	29.80	37.80	37.40
15	54.80	41.80	21.00	25.80	37.00	36.20
16	55.60	43.40	25.40	17.40	36.20	35.40
17	56.80	44.20	28.20	11.00	35.00	34.20
18	57.20	45.40	31.80	4.200	33.40	33.00
19	58.40	46.20	35.40	4.200	30.20	31.80
20	59.60	46.60	36.60	12.20	26.60	30.60
21	60.80	47.40	37.40	19.80	23.00	29.80
22	61.60	49.00	39.00	25.40	20.20	28.60
23	62.40	50.20	40.60	30.60	12.20	27.40
24	63.00	51.20	41.80	35.80	5.000	26.20

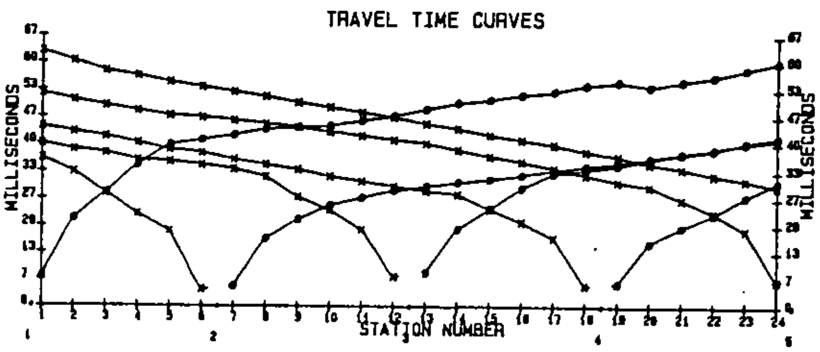
ARRIVAL TIMES FOR LH-4 (milliseconds)

Shot Locations geophone	(90'F) shot 1	(10'F) shot 2	(6&7) shot 3	(12&13) shot 4	(18&19) shot 5	(10'R) shot 6
1	30.60	5.000	37.30	43.00	48.10	62.00
2	34.60	18.60	35.60	41.80	46.90	60.80
3	38.60	22.20	30.70	39.00	45.50	59.20
4	43.00	25.40	25.10	36.20	44.10	58.00
5	48.20	29.80	19.10	34.20	43.10	56.00
6	49.80	32.60	13.30	32.60	41.90	54.60
7	51.80	34.20	13.30	30.60	40.70	53.40
8	53.40	35.80	18.70	26.60	39.30	51.80
9	54.40	37.40	24.70	22.60	38.10	50.60
10	55.60	38.60	28.70	17.80	36.90	48.60
11	56.40	39.80	31.60	12.60	35.10	47.00
12	57.60	41.00	35.00	4.200	33.70	43.00
13	58.80	41.80	37.00	4.200	31.90	41.00
14	60.40	43.00	38.60	13.80	28.50	39.40
15	61.60	44.20	40.00	20.20	24.90	37.00
16	63.20	45.80	42.40	24.60	21.50	35.80
17	64.40	47.00	44.20	27.00	17.50	33.00
18	65.60	48.20	45.40	29.40	7.300	31.00
19	66.40	49.40	46.40	33.00	7.300	29.40
20	68.00	51.00	47.60	36.20	16.90	25.00
21	69.20	52.80	49.20	39.00	20.30	21.40
22	70.40	54.00	50.80	41.40	23.50	18.60
23	71.60	55.20	52.00	44.60	26.90	15.00
24	72.40	56.80	53.20	46.60	30.50	5.400
Shot Location	(10'F)	(6&7)	(12&13)	(18&19)	(10'R)	(100'R)
1	11.00	23.90	33.60	42.20	51.60	55.40
2	14.00	20.90	31.80	41.00	50.40	53.80
3	17.40	17.10	30.20	39.60	49.40	52.60
4	20.20	14.10	28.90	38.60	48.20	50.60
5	22.20	10.90	27.70	37.80	47.00	49.40
6	23.40	2.500	26.50	36.60	45.20	47.80
7	25.00	2.300	25.30	35.60	44.00	45.80
8	27.00	12.50	23.90	33.60	42.40	45.00
9	29.00	17.50	21.50	32.40	41.20	43.00
10	30.60	20.10	16.50	31.40	40.40	41.80
11	31.80	23.30	10.70	30.60	39.20	40.20
12	33.40	24.50	3.700	29.80	38.00	38.60
13	35.00	25.70	3.700	28.30	36.20	36.60
14	36.20	26.70	12.10	26.50	34.80	35.00
15	38.20	27.90	18.50	24.30	33.60	33.00
16	38.60	28.90	23.30	20.10	32.60	31.80
17	40.60	30.00	27.10	16.30	31.80	29.80
18	43.80	32.20	30.20	3.900	31.00	28.60
19	46.60	33.60	33.20	3.300	30.20	27.00
20	47.40	34.80	34.20	13.70	27.10	25.00
21	49.00	36.40	35.40	19.10	23.30	23.80
22	50.20	37.60	36.40	23.90	20.70	22.20
23	52.20	39.00	37.60	26.70	16.50	21.00
24	54.20	40.80	39.00	30.00	4.700	19.40

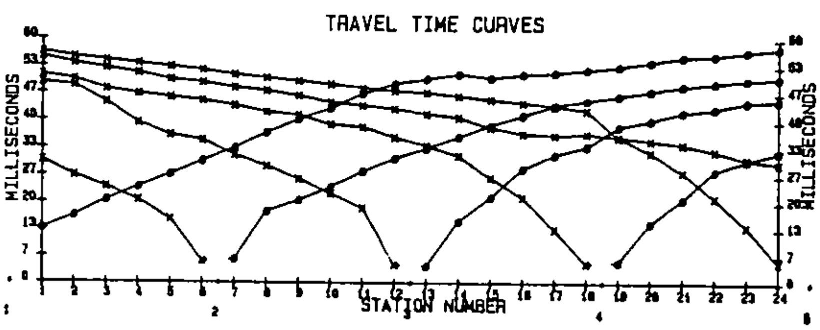
APPENDIX 2

Seismic Travel Time Curves

SEISMIC LINE LH1



SEISMIC LINE LH2



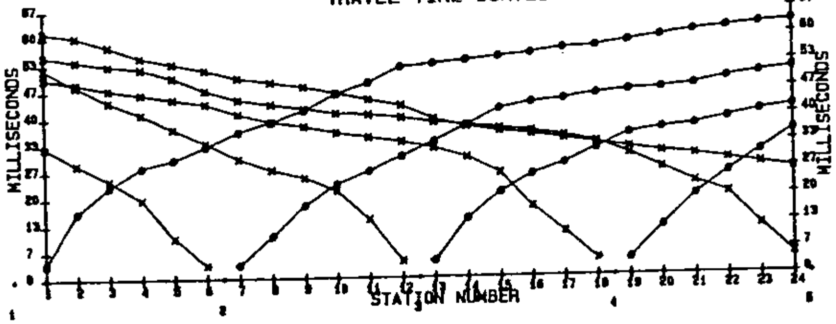
SCALE

FEET 40 20 0 20 40 60 FEET

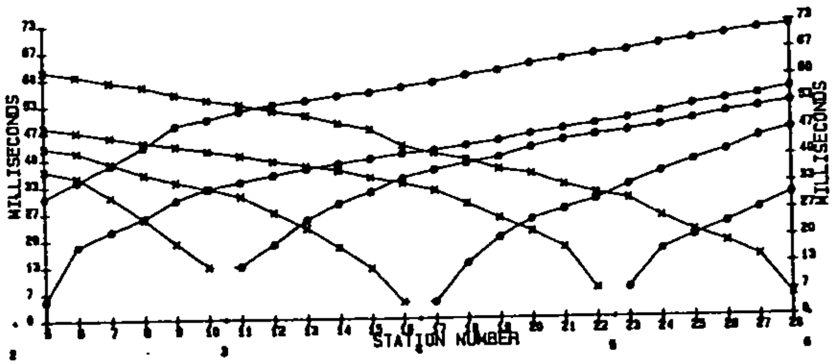
SCALE
FEET 40 20 0 20 40 60 FEET

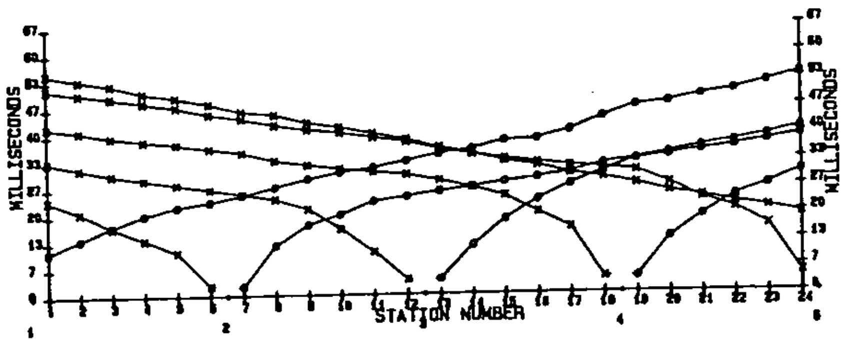
SEISMIC LINE LH3

TRAVEL TIME CURVES



SEISMIC LINE LH4





APPENDIX 3

Gravity data along line LH4

Location along line	N-S distance from base	Elev. (ft)	Observed gravity	Bouguer anomaly background density = 2.80 gm/cm
LH4, spread 1, sp1	407	261.6	980231.207	-28.306
LH4, spread 1, sp2	327	260.9	980231.246	-28.283
LH4, spread 1, sp3	210	258.6	980231.435	-28.204
LH4, spread 1, sp4	92	252.2	980231.878	-28.106
LH4, spread 1, sp5	-28	250.0	980232.029	-28.051
LH4, spread 1, sp6	-147	248.8	980232.145	-27.978
LH4, spread 2, sp1	-194	248.3	980232.281	-27.858
LH4, spread 2, sp2	-313	246.0	980232.447	-27.794
LH4, spread 2, sp3	-433	246.0	980232.434	-27.782
LH4, spread 2, sp4	-553	247.2	980232.339	-27.776
LH4, spread 2, sp5	-673	248.5	980232.364	-27.648
LH4, spread 2, sp6	-762	249.3	980232.418	-27.522

NOTE: Gravity measured with respect to base station at latitude 41 3.417 N, longitude 74 17.000 W. Observed gravity at this station was 980231.560 mgal.

Gravity data along Meadowbrook Avenue

Distance east of the intersection of Meadowbrook Ave. and Ringwood Ave. (ft)	N-S distance from base	Elev. (ft)	Observed gravity	Bouguer anomaly, background density = 2.80 gm/cm (mgal)
0	238	258.0	980231.627	-28.050
100	257	257.3	980231.442	-28.266
200	152	257.7	980231.223	-28.450
300	112	258.7	980231.175	-28.432
400	71	260.8	980231.184	-28.293
500	31	260.4	980231.268	-28.220
600	-8	261.1	980231.431	-28.006
700	-12	267.9	980231.183	-27.857
800	-40	270.3	980231.048	-27.484
900	-71	265.0	980231.366	-27.828
1000	-102	260.0	980231.644	-27.837
1100	-126	256.2	980231.736	-27.956
1200	-149	251.7	980231.949	-28.000
1300	-170	248.8	980232.163	-27.950
1400	-184	247.9	980232.249	-27.917
1530	-205	249.9	980232.180	-27.865
1600	-219	247.9	980232.369	-27.784
1700	-249	248.7	980232.454	-27.649
1830	-304	250.2	980232.611	-27.389
1900	-325	248.6	980232.704	-27.383
2000	-354	247.2	980232.781	-27.385
2100	-385	248.1	980232.707	-27.399
2200	-412	248.4	980232.659	-27.419
2300	-430	247.4	980232.751	-27.385
2400	-452	248.4	980232.714	-27.354
2500	-471	249.1	980232.669	-27.356
2600	-491	250.1	980232.641	-27.322
2700	-510	253.6	980232.516	-27.236
2800	-534	260.4	980232.131	-27.220
2876	-548	264.5	980231.877	-27.228

NOTE: Gravity measured with respect to base station at latitude 41 3.417 N, longitude 74 17.000 W. Observed gravity at this station was 980231.560 mgal

SEISMIC REFRACTION AND GRAVITY INVESTIGATION OF BEDROCK TOPOGRAPHY AT LAKELAND REGIONAL HIGH SCHOOL, WANAQUE, PASSAIC COUNTY, NEW JERSEY (N.J. Geological Survey Technical Memorandum 88-1)