HYDROGEOLOGIC STUDY
WESTFORD WELLFIELD

WESTFORD, MASSACHUSETTS

Prepared for:

The Town of Westford
Massachusetts

Prepared by:

Goldberg-Zoino & Associates, Inc.
Newton Upper Falls, Massachusetts

File No. A-3249
October 1982

GZA
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GEOTECHNICAL · GEOHYDROLOGICAL CONSULTANTS

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October 1, 1982
File No. A-3249

Board of Selectmen
Westford Town Hall
Westford, Massachusetts 01886

Gentlemen:

GZA is pleased to present its final report, "Hydrogeologic Study, Westford Wellfield," which describes the results of our geohydrological and water quality investigation at the Town wellfield on Forge Village Road. As described in the report, the water quality data obtained during GZA's study did not indicate contamination of the wellfield by landfill leachate.

Lawrence Feldman of this office will call you to arrange a meeting with the Water Board so that we can formally present the study and discuss any points on which the board would like elaboration. Of course if a pressing question should arise in the interim, please call Dr. Feldman or myself.

Very truly yours,

John E. Ayres

John E. Ayres

JEA:crp

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1.00 INTRODUCTION

The following report presents the results of a hydrogeologic study of the Town of Westford's tubular wellfield. The purpose of the study was to assess groundwater flow directions, velocities, and water quality in the vicinity of the wellfield, and to establish a monitoring program to evaluate the potential for contamination of the water supply wells by leachate from the town landfill.

Please note that all analyses, conclusions, and recommendations presented in this report are subject to the limitations listed in Appendix A.

1.10 PROJECT SCOPE

As outlined in GZA's proposal dated July 31, 1981, the study consisted of several tasks. The first involved a preliminary data search and site reconnaissance. Five observation wells were then installed in test borings, and a topographic worksheet showing both new and existing wells was prepared. Preliminary water quality screening analyses and a more extensive water quality monitoring survey were performed. The results of GZA's investigations are presented below.

1.20 SITE DESCRIPTION

The Westford wellfield is located on the north side of Forge Village Road about 1000 feet west of its intersection with Cold Spring Road, in the west-central portion of the Town (Figure 1). A wellfield, consisting of a pumping station and a field of 2-1/2-inch and 8-inch-diameter wells, is at the edge of a wetland area at an elevation of about 185 feet, approximately 40 feet lower than Forge Village Road. The Town also has a gravel-pack well located several hundred feet to the west of the tubular wellfield. Although records show there to be over thirty wells in this field, only 20 wells (2-1/2-inch and 8-inch diameters) could be located.

The Westford sanitary landfill is located in a former gravel pit less than 1000 feet east of the wellfield. Between the landfill and the wellfield is a wetland area and a small ridge (see Figures 1 and 2).

1.30 PREVIOUS HYDROGEOLOGIC STUDIES

Previous hydrogeologic studies were performed near the wellfield by Whitman and Howard, Inc. in 1968[1]. This work dealt solely with an investigation for a proposed well and did not attempt to evaluate groundwater flow directions, overall aquifer properties, or any possible sources of contamination. Whitman and Howard performed a seven-day pumping test using a cluster of five wells located about 300 feet west of the wellfield. Chemical analyses of water samples taken during the pump test showed the water to be of good quality, although slightly corrosive. Based on the results of the pumping test, Whitman and Howard concluded that a 48" x 24" gravel packed well constructed at the site could theoretically yield about 500 gallons per minute.

Whitman and Howard also conducted a similar pump test at test wells off Patten Road, located to the south of Forge Village Road, in 1963[2]. The results of the water quality testing and the estimated potential well yield at this site were similar to that reported for the Forge Village Road site.

2.00 SUBSURFACE EXPLORATIONS, FIELD TESTING, AND WATER QUALITY PROGRAM

Field exploration and testing by GZA consisted of the installation of five observation wells in test boreholes, and three rounds of water level readings and water quality sampling, as described below.

2.10 TEST BORINGS AND OBSERVATION WELL INSTALLATION

Five test borings were executed in the vicinity of the wellfield in February 1982 by the Soil Exploration Corporation of Stow, Massachusetts; drilling operations were observed by GZA personnel. The locations of the test borings shown on Figure 2 were selected after a site reconnaissance by GZA on January 20, 1982. Boring B-1 was to be carried to refusal, but was terminated

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[1]Whitman and Howard, Inc. Report of Test Well Investigation, Forge Village Road near Pumping Station No. 1, Westford, Massachusetts, October, 1968.

[2]Whitman and Howard, Inc. Report on Pumping Test in the vicinity of Patten Road, Westford, Massachusets (letter report to Westford Board of Water Commissioners), October 31, 1963.

at a depth of 65 feet because of drilling difficulties. Each of the remaining borings was terminated at a depth of 20-25 feet. Boring logs are presented in Appendix B.

Split spoon samples were obtained at 5- to 10-foot intervals in each boring. The soil samples were visually classified and logged in the field by both the driller and a GZA geotechnical engineer. GZA screened the soil samples in the field using a Century Systems Standard Model OVA-128 organic vapor analyzer to measure total organic vapor levels in samples taken from the headspaces of sealed soil sample jars. The results of this screening program, which was designed to detect possible volatile organic contamination, are presented on the boring logs (Appendix B) and discussed in Section 5.00.

An observation well consisting of a 5- or 10-foot length of slotted 1-1/2-inch-diameter PVC wellscreen attached to solid PVC riser pipe was installed near the bottom of each of the test holes. A filter of clean silica sand (Ottawa sand) was placed around the wellscreen, and each well was equipped with a steel protective casing and cap.

The locations and top elevations of the new and existing wells and the topography of the wellfield area were surveyed for GZA in March 1982 by Thomas F. Moran, Inc. of Bedford, New Hampshire. The resultant map has been used as a site plan and base map for the current study.

2.20 WATER QUALITY SAMPLING AND ANALYSIS

Water quality sampling and analysis proceeded in a two-phase sequence. The first phase was conducted on February 26, 1982, after newly installed observation wells B-1, B-2, B-3, B-4 and B-5 had been allowed to stabilize for approximately three weeks. Because of extremely cold weather and a high water table, the water inside several of the observation wells had frozen, and a complete sampling round could not be completed. Testing and measurements for this earliest sampling round included water level, pH, temperature, conductivity, and volatile organics. The wellfield was resampled on April 29, 1982, for the previously mentioned parameters and for dissolved oxygen; sampling points included both the GZA wells and the four existing wells indicated on Figure 2.

Pursuant to indications of possible contamination from landfill leachate, an additional sampling and testing round for all nine wells and six surface water samples was authorized

by the Board of Selectmen. An attempt was made during this last round to sample a leachate discharge which had previously been observed along the eastern edge of the swamp (200 feet east of B-2). However, no such discharge could be located. This third round, completed by GZA on June 4, 1982, included testing for the screening parameters listed above; a volatile organic analysis for halogenated hydrocarbons; and analysis for alkalinity, chemical oxygen demand, total dissolved solids, chloride, calcium, potassium, and sodium. Chemical analyses on the nine groundwater samples and four of the surface water samples were performed by Energy Resources Company (ERCO) of Cambridge, Massachusetts. The results of ERCO's testing are presented in Appendix C. Results of measurements for pH, dissolved oxygen, and conductivity are presented in Tables 1, 2 and 3, respectively, and are discussed in Section 5.00.

2.30 WATER LEVEL MEASUREMENTS

Water levels were measured in the observation wells prior to sampling on February 26, April 29, and June 4, 1982. Measurements were made from the top of the wellpipe. The depth to water and groundwater elevations at the time of each sampling round are presented in Table 4.

3.00 SUBSURFACE MATERIALS

The Westford wellfield is located in an area of stratified glacial sediments deposited by meltwater streams during the retreat of the last continental ice sheet. Predominant subsurface materials encountered at the site are fine sands, with minor (0-10%) amounts of silt, overlain in places by fine to medium sand. A layer described as "coarse gravel" was noted as occurring at a depth of about 32-40 feet on logs of the tubular wells, but this material was not encountered in GZA's borings. Due to their well sorted nature and relatively low content of fine-grained fractions (silt), the site soils may be expected to be relatively permeable. Up to 65 feet of stratified sands were encountered at the site (boring B-1).

Swamp deposits consisting of varying amounts of organic silt, fine sand, and decaying vegetation, and ranging in thickness from 7.5 to 10 feet, were encountered at borings B-2 through B-5. Swamp deposits tend to have a lower vertical permeability than stratified sands, thus impeding the percolation of surface water into the underlying aquifer. The fine sands encountered

beneath borings B-2 through B-5 probably underlie most or all of the wetland area north of the wellfield.

Bedrock was not encountered at any of the borings performed during the current study, and bedrock outcrops were not observed at the site or in the immediate vicinity. The depths of the wells in the wellfield range from 34-50 feet, and none of them end in bedrock. Refusal was encountered at 62 feet in one of the wells installed west of the wellfield during Whitman and Howard's 1968 pump test. It seems likely that the depth to bedrock probably exceeds 40 feet over much of the study area.

4.00 HYDROGEOLOGY

The hydrogeology of the wellfield site is fairly typical of conditions encountered in much of southern and central New England. While the watershed is defined by uplands of relatively impermeable till and bedrock, groundwater flow characteristics are related primarily to the overlying stratified glacial deposits.

4.10 SURFACE WATER HYDROLOGY

The wellfield is located in the Merrimack River watershed. Surface water runoff from the wellfield and Forge Village Road flows to the wetland north of the wellfield which is, in turn, drained by Stony Brook flowing across Westford to Chelmsford. The landfill apparently straddles a surface water divide, with runoff from most of the area flowing west and southwest to the wetland and Stony Brook, and runoff from the easternmost part of the landfill flowing east to Boutwell Brook.

4.20 GROUNDWATER HYDROLOGY

The aquifer containing the wellfield consists of stratified glacial deposits, probably about 40-60 feet in thickness, as described in the previous section. Almost the entire thickness is saturated at the low-lying wellfield site. Based on examination both in the field and on the USGS Westford Quadrangle topographic map of the landforms and topography of the area surrounding the wellfield, it appears that the aquifer extends for several thousand feet around the wellfield, although in places it is overlain by swamp deposits. The stratified materials pinch out against till and bedrock uplands, including Snake Meadow Hill and Kissacook Hill to the north and northwest, and unnamed hills to the northeast, east, and southwest of the site.

Figure 2 shows static (nonpumping) groundwater levels and groundwater contours for June 4, 1982. The water level contours indicate a northwesterly direction of flow. In particular, it appears that groundwater flows from the general direction of the high ground and the Water Department yards, across the wellfield, and into the swamp, which is a groundwater discharge area. Because the pump for the tubular wellfield was in disrepair during GZA's sampling and water level measurement rounds, groundwater contours during pumping conditions could not be measured.

Water level data from all sampling rounds is presented in Table 4. While fluctuations of up to almost one foot were observed, these fluctuations did not significantly affect the general groundwater flow direction.

4.21 Calculation of Groundwater Velocity

The transport velocity of groundwater moving across the wellfield site may be estimated using the equation:

$$V = \frac{ki}{n}$$

where V = Groundwater transport velocity (feet/day)

k = Hydraulic conductivity of the aquifer (feet/day)

i = Hydraulic gradient, or difference in groundwater elevations between two points along the flow path, divided by the distance between the measuring points

n = Porosity of aquifer material

In calculating the groundwater velocity, GZA considered hydraulic conductivities of 50 feet/day and 100 feet/day. The former figure is a representative value for materials such as those encountered in the wellfield aquifer. The latter figure, derived from the data presented in the 1968 Whitman & Howard report, may be influenced by induced infiltration from the wetlands adjacent to the wells. From Figure 2, a hydraulic gradient of approximately 0.5 feet/200 feet, or 0.0025, was estimated. The porosity of the aquifer was assumed to be 0.25. Using these values yields a groundwater velocity of approximately 0.5-1.0 feet/day toward the northwest under the conditions encountered in the wellfield in June 1982.

As discussed below, the low flow velocity across the wellfield made it possible to draw conclusions regarding contamination from the landfill even though water quality samples were taken under nonpumping conditions.

5.00 DISCUSSION OF CHEMICAL TEST RESULTS

Soil and water samples screened and tested for volatile organics showed little indication of organic contamination of the type that might be present in landfill leachate. Soil samples screened for volatile organics had high readings only at the interface between the swamp and the underlying sand, where naturally occurring methane was the volatile organic most frequently encountered. This soil interface is characterized by the presence of peat, fibrous organic material, and bits and pieces of vegetable matter such as wood, leaves, and grass; it is the anaerobic decomposition of this organic matter which generates the methane. Total organic vapor levels at this interface are several hundred times the concentrations characteristic of water near the swamp's surface and of groundwater.

Gas chromatographic screening of water samples showed a few small peaks (approximate concentration of 10-100 ppb) in addition to methane. Because of the possiblity that the peaks could represent small concentrations of organic pollutants, samples were submitted to ERCO for more extensive quantitative testing. Since the results of ERCO's testing of nine groundwater samples revealed no priority pollutant volatile organics at a 1 ppb limit of detection (Appendix C), GZA's screening results may have indicated the presence of low levels of organic constituents other than priority pollutants.

Screening and testing for other water quality parameters revealed only limited indications of materials typically associated with landfill leachate, and no indication of contamination of the wellfield from the landfill. In particular, the first round of screening, conducted 10 days after pumping of the tubular wells ceased due to pump failure, showed no signs of unusual values. Winter use of salt to de-ice the road probably accounts for the higher conductivities observed in February in OW-20, and in early spring (April 29, 1982) and late spring (June 4, 1982), particularly at B-2 (201 umho/cm), OW-6 (330 umho/cm) and OW-20 (426 and 315 umho/cm). Surface water conductivities taken in late spring range between 138 and 189 umho/cm; the highest values occur closer to Forge Village Road.

Testing by ERCO for seven inorganic indicators (see Appendix C) for landfill leachate constituents on samples taken June 4, 1982 indicated elevated concentrations of sodium (average 19.8 mg/l) and chloride (37.4 mg/l) in surface water, and slightly elevated concentrations of sodium (20 mg/l), chloride (94 mg/l), and total dissolved solids (360 mg/l) in groundwater at OW-20, where conductivity was also high. These values are consistent with the hypothesis that the groundwater and surface water near Forge Village Road and upgradient of the wellfield is slightly contaminated by road salt.

Dissolved oxygen concentrations show more undersaturation in groundwater samples than in surface water samples, but observed values are within the normal range of variation. However, the moderate saturations observed in wells in the wetland reflect the fact that groundwater is discharging to the swamp through the anoxic organic interface. The observed pH values fall within the normal range for groundwater and surface water.

The highest levels of potassium (9.1 mg/l) and alkalinity (43 mg/l as $CaCO_3$) were observed in B-1, the deep observation well. Although the alkalinity level is still within the normal range, potassium level appears slightly elevated above background.

6.00 CONCLUSIONS

Groundwater and surface water samples obtained from the Westford tubular wellfield under nonpumping conditions showed no detectable contamination from priority pollutant volatile halogenated organics, and only one sample which exceeded any current EPA primary or secondary drinking water standard. That sample, collected from OW-20 in June 1982, contained sodium at 28 mg/l. While there were also elevated concentrations (compared to mean values for analysis of samples taken on these dates) of total dissolved solids, sodium, chloride, and potassium, no pattern was observed which would indicate contamination from the landfill.

As noted in the preceding section, it is likely that at least some of the leachate from the landfill may be discharging into the adjacent wetland. However, levels of characteristic leachate indicator parameters were not encountered in the wetland wells or at surface water sampling stations in the wetland. It appears that leachate contaminants entering the wetland are subject to enough dilution and attenuation that they do not occur in significant concentrations near the wellfield.

The most plausible source for observed elevated concentrations of sodium and chloride in both surface and groundwater is salt from the road which lies upgradient and upslope of the wellfield. It is difficult to conceive of a mechanism which could prevent salt applied to Forge Village Road in the vicinity of the wellfield from entering the swamp and aquifer. However, inasmuch as road salt cannot account for all of the observed elevated concentrations of total dissolved solids and potassium, it is possible that a fraction of these constituents were derived from the landfill.

The above conclusions apply only for the climatic and pumping conditions obtaining during this study. As noted above, groundwater from most of the sampling locations was subjected to screening tests 10 days after pumping of the wellfield stopped. However, considering the calculated groundwater flow velocity of 0.5 to 1 ft/day, it is unlikely that contamination could have moved away from the aquifer sampling points in this short period. On the basis of this and other data considered, GZA feels that the aquifer is not presently contaminated. However, there is insufficient data with which to definitively extrapolate this conclusion to summer conditions when heavy pumping coincides with a period of no groundwater recharge.

7.00 RECOMMENDATIONS

Limited testing and observations should be continued to obtain groundwater elevation contours and water quality data which are representative of seasonal variations at maximum sustained pumping rates. The most critical data would be that for high pumping when the water table is lowest, in late summer. Once these data are available, they should be reviewed to determine if the preliminary conclusion that the landfill does not contaminate the wellfield aquifer can be extended to include those conditions more likely to result in contamination. If water quality data continue to indicate no degradation of the wellfield by leachate, a low frequency (annual) testing program should be sufficient to monitor for encroachment of landfill leachate and its potentially degrading effects.

Seasonal testing and observations in the immediate future could be adequately covered by the following program, once pumping at the wellfield is resumed. It would be most useful if observations were made under the most severe pumping conditions. The testing program should include the following:

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a. Sampling at locations B1-B5, OW-1, OW-6, OW-9 and OW-20.

b. Measurement of groundwater elevations at sampled wells.

c. Screening for temperature, pH, conductivity, dissolved oxygen, volatile organics (head space gas chromatography), nitrate, and ammonia.

d. Testing:

   a. For samples having conductivities greater than 150 umhos/cm at 20° C: sodium, potassium, chloride, sulfate, alkalinity, total dissolved solids, chemical oxygen demand.

   b. For samples showing peaks in screening for volatile organics: EPA method 624 (gas chromatograph/mass spectrometry for volatile priority pollutants including ethylbenzene and xylenes).

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TABLES

TABLE 1

pH OF SURFACE AND GROUNDWATER SAMPLES
FROM FORGE VILLAGE ROAD WELLFIELD

	pH		
WELL NO.	2/26/82	4/29/82	6/4/82
B-1	8.64	7.32	7.17
B-2	--	6.21	6.31
B-3	--	6.36	6.41
B-4	7.12	--	6.72
B-5	6.58	--	8.03
OW-1	7.59	6.84	6.60
OW-6	--	7.66	6.74
OW-9	--	6.56	6.76
OW-20	6.81	6.05	6.14
SURFACE WATER SAMPLING POINTS			
B-2	--	--	6.13
B-3	--	--	6.53
B-4	--	--	6.73
B-5	--	--	6.99
OW-1	--	--	6.38
OW-6	--	--	6.51

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TABLE 2

DISSOLVED OXYGEN CONCENTRATION IN SURFACE AND GROUNDWATER SAMPLES FROM FORGE VILLAGE WELLFIELD

	4/29/82		6/4/82	
	TEMPERATURE (°C)	D.O. (ppm)	TEMPERATURE (°C)	D.O. (ppm)
WELL NO.				
B-1	10.8	6.5	8	5.4
B-2	12.0	7.6	11	9.2
B-3	13.7	4.6	12	7.9
B-4	--	-	19 (1)	8.4
B-5	--	-	16.5 (1)	6.0
OW-1	11.6	6.0	11	4.0
OW-6	10.6	1.2	10	6.5
OW-9	9.0	2.8	9	7.2
OW-20	10.7	9.4	11	9.5
SURFACE WATER SAMPLING POINTS				
B-2	--	-	13	9.0
B-3	--	-	13	8.3
B-4	--	-	20.5 (1)	7.8
B-5	--	-	19 (1)	8.4
OW-1	--	-	15.2	9.7
OW-6	--	-	16	8.5

(1).. B-4 & B-5 measured after bringing samples back to shore, so temperature is higher than for other samples.

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TABLE 3

CONDUCTIVITY OF SURFACE AND GROUNDWATER SAMPLES
FROM FORGE VILLAGE ROAD WELLFIELD

WELL NO.	2/26/82 CONDUCTIVITY AT 25°C (µmho/cm)	4/29/82 CONDUCTIVITY AT 25°C (µmho/cm)	6/4/82 CONDUCTIVITY AT 25°C (µmho/cm)
B-1	82	113	122
B-2	--	97.3	201
B-3	--	175	145
B-4	69	--	103
B-5	97	--	69.6
OW-1	98	95.1	108
OW-6	--	330	126
OW-9	--	197	181
OW-20	150	426	315
SURFACE WATER SAMPLING POINTS			
B-2	--	--	138
B-3	--	--	177
B-4	--	--	189
B-5	--	--	186
OW-1	--	--	141
OW-6	--	--	160

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TABLE 4

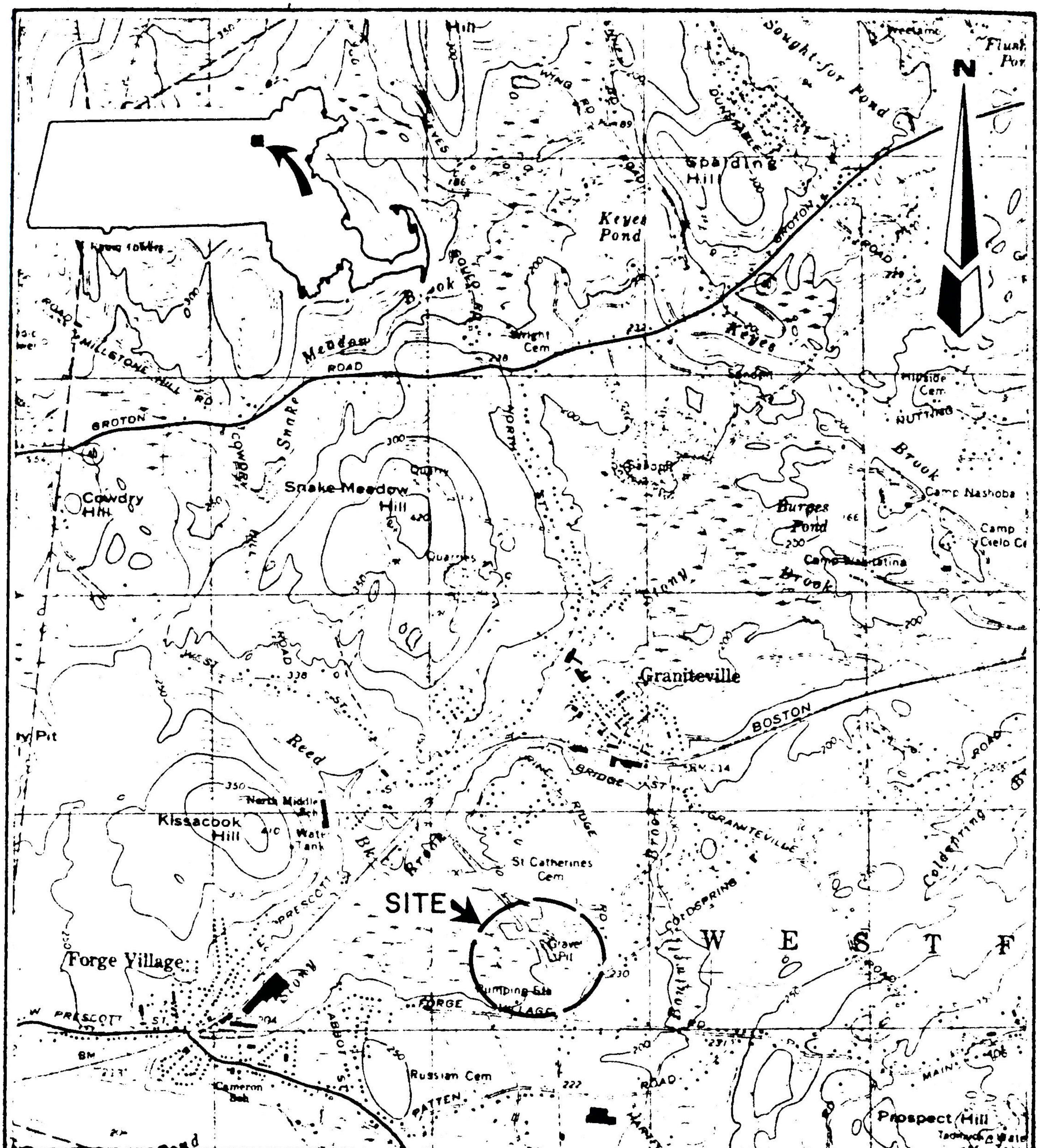
GROUNDWATER ELEVATION AT THE
FORGE VILLAGE WELLFIELD

WELL NO.	ELEVATION TOP OF PIPE (1)	2/26/82 DEPTH TO WATER	2/26/82 WATER ELEVATION	4/29/82 DEPTH TO WATER	4/29/82 WATER ELEVATION	6/4/82 DEPTH TO WATER	6/4/82 WATER ELEVATION
B-1	190.3	4.3	186.0	4.17	186.1	3.6	186.7
B-2	190.0	-	--	3.91	186.1	3.20	186.8
B-3	190.2	-	--	4.26	185.9	3.40	186.8
B-4	190.3	-	--	--	--	3.95	186.3
B-5	190.2	-	--	--	--	3.90	186.3
OW-1	188.0	2.4	185.6	2.29	185.7	1.5	186.5
OW-6	187.3	1.2	186.1	1.25	186.0	0.53	186.8
OW-9	187.7	1.35	186.3	1.34	186.4	0.60	187.1
OW-20	195.0	8.55	186.4	8.40	186.6	7.95	187.0

NOTES:

1) Top of pipe elevations from survey by Thomas F. Moran, Inc., March, 1982

FIGURES

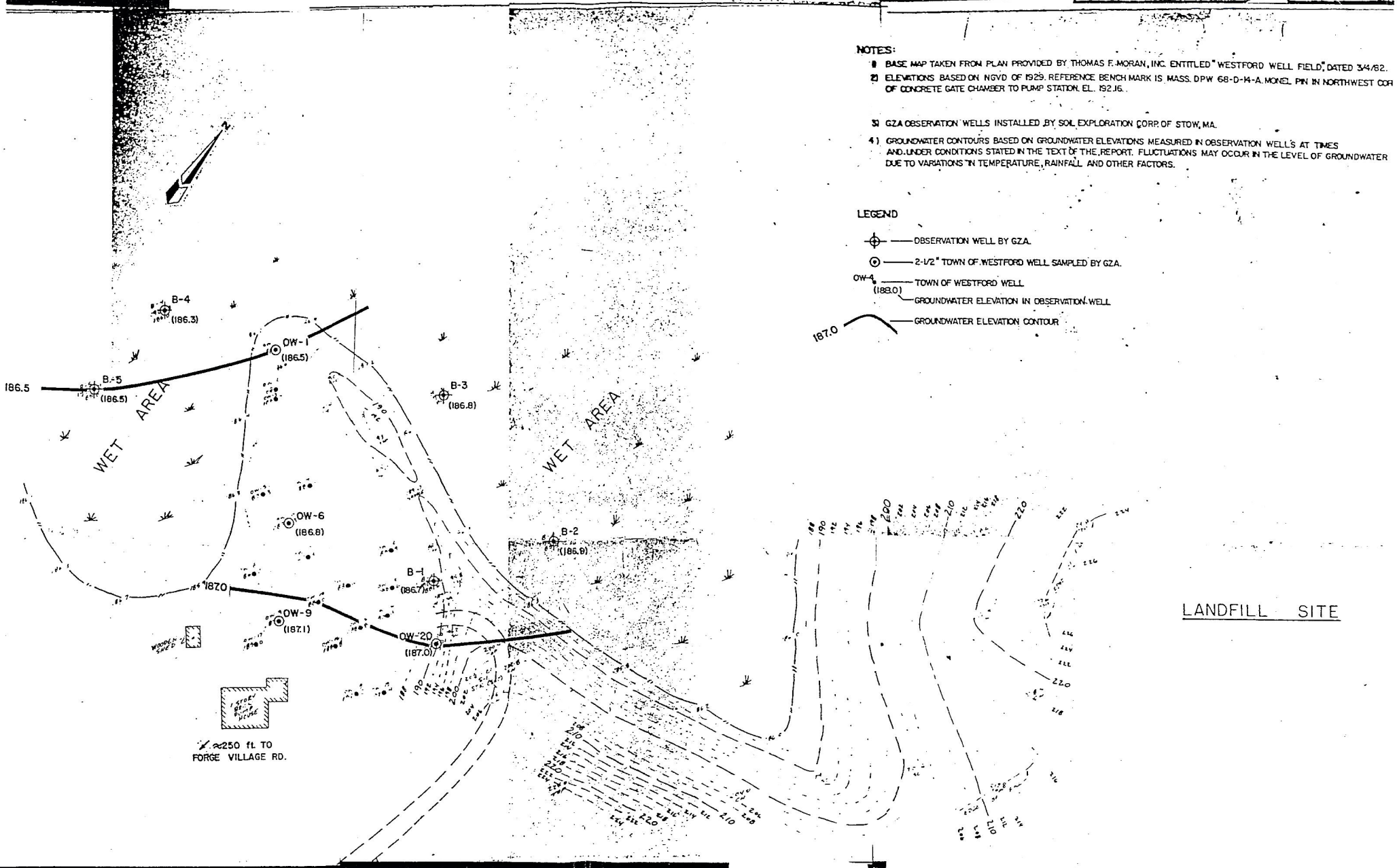


FILE No. A-3249

0 1000 2000 4000 (FT.)

FROM USGS WESTFORD, MASS. QUADRANGLE MAP

GZA	HYDROGEOLOGIC STUDY WESTFORD, MA.	LOCUS PLAN AUGUST 1982 FIGURE No. 1


NOTES:
1) BASE MAP TAKEN FROM PLAN PROVIDED BY THOMAS F. MORAN, INC. ENTITLED "WESTFORD WELL FIELD," DATED 3/4/82.
2) ELEVATIONS BASED ON NGVD OF 1929. REFERENCE BENCH MARK IS MASS. DPW 68-D-14-A. MONEL PIN IN NORTHWEST COR OF CONCRETE GATE CHAMBER TO PUMP STATION. EL. 192.16.
3) GZA OBSERVATION WELLS INSTALLED BY SOIL EXPLORATION CORP. OF STOW, MA.
4) GROUNDWATER CONTOURS BASED ON GROUNDWATER ELEVATIONS MEASURED IN OBSERVATION WELLS AT TIMES AND UNDER CONDITIONS STATED IN THE TEXT OF THE REPORT. FLUCTUATIONS MAY OCCUR IN THE LEVEL OF GROUNDWATER DUE TO VARIATIONS IN TEMPERATURE, RAINFALL AND OTHER FACTORS.
LEGEND
OBSERVATION WELL BY GZA.
2-1/2" TOWN OF WESTFORD WELL SAMPLED BY GZA.
OW-4 TOWN OF WESTFORD WELL
(188.0) GROUNDWATER ELEVATION IN OBSERVATION WELL
187.0 GROUNDWATER ELEVATION CONTOUR
B-4
(186.3)
OW-1
(186.5)
B-5
(186.5)
186.5
B-3
(186.8)
WET AREA
OW-6
(186.8)
B-2
(186.9)
B-1
(186.7)
187.0
OW-9
(187.1)
OW-20
(187.0)
1 STORY BRICK PUMP STATION
≈250 ft. TO FORGE VILLAGE RD.
WET AREA
LANDFILL SITE

APPENDIX A

LIMITATIONS

LIMITATIONS

Explorations

1. The analyses and recommendations submitted in this report are based in part upon the data obtained from subsurface explorations. The nature and extent of variations between these explorations may not become evident until further investigation. If variations then appear evident, it will be necessary to reevaluate the recommendations of this report.

2. The generalized soil profile described in the text is intended to convey trends in subsurface conditions. The boundaries between strata are approximate and idealized and have been developed by interpretations of widely spaced explorations and samples; actual soil transitions are probably more gradual. For specific information, refer to the boring logs.

3. Water level readings have been made in the drill holes and observation wells at times and under conditions stated on the boring logs. These data have been reviewed and interpretations have been made in the text of this report. However, it must be noted that fluctuations in the level of the groundwater may occur due to variations in rainfall, temperature, pumping conditions, and other factors not accounted for at the time measurements were made.

4. The analysis and conclusions submitted in this report are based in part upon chemical data and are contingent upon their validity. These data have been reviewed and interpretations made in the the text of this report. It should also be noted that fluctuations in the types and levels of contaminants and variations in their flow paths may occur due to seasonal water table fluctuations, variations in well pumping rates, and other factors.

Use of Report

5. This report has been prepared for the exclusive use of the Town of Westford for specific application to the Westford Wellfield Hydrogeologic Study in Westford, Massachusetts, in accordance with generally accepted hydrogeologic practices. No other warranty, expressed or implied, is made.

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APPENDIX B

BORING LOGS

GZA Boring Logs
Soil Exploration Logs

GZA BORING LOGS

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GOLDBERG · ZOINO & ASSOC., INC.
GEOTECHNICAL/GEOHYDROLOGICAL CONSULTANTS

PROJECT
TOWN WELLFIELDS
WESTFORD, MA

REPORT OF BORING NO. B-1
SHEET 1 OF 2
DATE 2/4/82 FILE A-3249

BORING CO. Soil Exploration
FOREMAN Paul Curran
G-Z-A ENGINEER James Schiff

BORING LOCATION See Location Plan
GROUND ELEV.
DATE START 2/4/82 DATE END 2/5/82

CASING
SIZE: 3" I.D. Casing
HAMMER: 300 lb.
FALL: 24"

SAMPLER
TYPE: 1 3/8" Split Spoon OTHER:
HAMMER 140 lb.
FALL: 30"
(3" Hollow Stem Auger)

GROUNDWATER READINGS

DATE	DEPTH	CASING AT	STABILIZATION TIME
2/5/82	3'	Removed	Completion

DEPTH	NOTE	SAMPLE NO.	PEN./REC.	SAMPLE DEPTH	BLOWS/6"	STRTA CHG. and GEN. DESC.	SAMPLE DESCRIPTION Burmister CLASSIFICATION	OVA
		S-1	18/12	0-.5	2	TOPSOIL	Dark brown fine to medium SAND, trace roots, decayed leaves changing	0
				.5-1.5	3-2		to loose light brown medium SAND, trace -Silt	0.6
5		S-2	18/15	5-6.5	4-4-4	MEDIUM SAND	Loose light brown medium SAND, trace -Silt	.4
10		S-3	18/14	10-11.5	4-5-5	10.0'	Medium dense light brown fine SAND, trace -Silt	0
15		S-4	18/16	15-16.5	5-6-6		Medium dense light brown fine SAND, trace -Silt	.2
20		S-5	18/16	20-21.5	7-8-8	Fine SAND, Trace SILT	Medium dense light brown fine SAND, trace -Silt	0
25		S-6	18/14	25-26.5	7-6-6		Medium dense light brown fine SAND, trace -Silt	.4
30		S-7	18/16	30-31.5	7-10-12		Medium dense light brown fine SAND trace -Silt	.2

REMARKS:

NOTES: 1) THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY BETWEEN SOIL TYPES AND THE TRANSITION MAY BE GRADUAL.
2) WATER LEVEL READINGS HAVE BEEN MADE IN THE DRILL HOLES AT TIMES AND UNDER CONDITIONS STATED ON THE BORING LOGS. FLUCTUATIONS IN THE LEVEL OF THE GROUNDWATER MAY OCCUR DUE TO OTHER FACTORS THAN THOSE PRESENT AT THE TIME MEASUREMENTS WERE MADE.

GOLDBERG · ZOINO & ASSOC., INC.
GEOTECHNICAL/GEOHYDROLOGICAL CONSULTANTS

PROJECT
TOWN WELLFIELDS
WESTFORD, MA

REPORT OF BORING NO. B-1
SHEET 2 OF 2
DATE 2/4/82 FILE A3249

DEPTH	NOTE	SAMPLE NO.	SAMPLE PEN./REC.	SAMPLE DEPTH	SAMPLE BLOWS/6"	STRTA CHNG and GEN. DESC.	SAMPLE DESCRIPTION	OVA
35		S-8	18/4	35-36.5	20-14-11		Medium dense light brown fine SAND trace -Silt	0.0
40		S-9	18/16	40-41.5	11-15-21		Medium dense light brown fine SAND trace -Silt	0.0
45		S-10	18/12	45-46.5	19-18-14	FINE SAND TRACE SILT	Dense light brown fine SAND, trace -Silt	0.0
55							Light brown fine SAND, trace -Silt	(1)
65						65.0'		(2)
							Bottom of boring @ 65'	

REMARKS: 1) Unable to sample from 50ft to 65ft due to running sand in casing.

2) Installed observation well at 63ft, 10ft of slotted screen plus 55ft of solid PVC pipe. well screen packed with Ottawa SAND, 2ft stickup.

Field Test results represent total organic vapor levels (referenced to a methane-in-air standard) measured in head spaces of sealed soil sample jars. A Century Systems Standard ModelOVA-128 organic vapor analyzer was employed for all analyses. Injected volume of 3.0cc except where otherwise indicated. Results in ppm.

NOTES: 1) THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY BETWEEN SOIL TYPES AND THE TRANSITION MAY BE GRADUAL.
2) WATER LEVEL READINGS HAVE BEEN MADE IN THE DRILL HOLES AT TIMES AND UNDER CONDITIONS STATED ON THE BORING LOGS. FLUCTUATIONS IN THE LEVEL OF THE GROUNDWATER MAY OCCUR DUE TO OTHER FACTORS THAN THOSE PRESENT AT THE TIME MEASUREMENTS WERE MADE.

GOLDBERG · ZOINO & ASSOC., INC.
GEOTECHNICAL/GEOHYDROLOGICAL CONSULTANTS

PROJECT
TOWN WELLFIELDS
WESTFORD, MA

REPORT OF BORING NO. B-2
SHEET 1 OF 1
DATE 2/2/82 FILE A-3249

BORING CO. Soil Exploration
FOREMAN Paul Curran
G-Z-A ENGINEER James Schiff

BORING LOCATION See Location Plan
GROUND ELEV.
DATE START 2/2/82 DATE END 2/3/82

CASING
SIZE: 3" I.D. Casing
HAMMER: 300 lb.
FALL: 24"

SAMPLER
TYPE: 1 3/8" Split Spoon OTHER:
HAMMER 140 lb.
FALL: 30"

(Bob-Wash boring with Trypod rig)

GROUNDWATER READINGS

DATE	DEPTH	CASING AT	STABILIZATION TIME

DEPTH	NOTE	SAMPLE NO.	SAMPLE PEN./REC.	SAMPLE DEPTH	SAMPLE BLOWS/6"	STRTA CHG. and GEN. DESC.	SAMPLE DESCRIPTION Burmister CLASSIFICATION	OVA
						WATER		
						2.5		
		S-1	18/4	2.5-4	WOH		Very soft black fine SAND, trace Peat, organic Silt -swamp marsh-	740
5						FINE SAND ORGANIC SILT		
10		S-2	18/4	10-11.5	WOH		Very soft reddish brown fine SAND, trace -Peat, organic Silt	240
		S-3	18/6	12.5-14	3-5-5	12.5'	Medium dense reddish brown medium to fine SAND, trace -Silt	1.0
15						FINE SAND, TRACE SILT		
20		S-4	18/--	20-21.5	5-4-7		No recovery	
		S-5	18/18	22-23.5	6-6-7	23.5'	Medium dense light brown fine SAND, trace -Silt	0
25							Bottom of boring @ 23.5'	

REMARKS: Field Test results represent total organic vapor levels (referenced to a methane-in-air standard) measured in head spaces of sealed soil sample jars. A Century Systems Standard Model OVA-128 organic vapor analyzer was employed for all analyses. Injected volume of 3.0 cc except where otherwise indicated. Results in ppm.
WOH = Weight of Hammer
Installed observation well at 20ft. 5ft slotted screen plus 25ft of solid PVC pipe, stick-up 4ft. 15ft protective casing installed over well.

NOTES: 1) THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY BETWEEN SOIL TYPES AND THE TRANSITION MAY BE GRADUAL.
2) WATER LEVEL READINGS HAVE BEEN MADE IN THE DRILL HOLES AT TIMES AND UNDER CONDITIONS STATED ON THE BORING LOGS. FLUCTUATIONS IN THE LEVEL OF THE GROUNDWATER MAY OCCUR DUE TO OTHER FACTORS THAN THOSE PRESENT AT THE TIME MEASUREMENTS WERE MADE.

GOLDBERG · ZOINO & ASSOC., INC.
GEOTECHNICAL/GEOHYDROLOGICAL CONSULTANTS

PROJECT
TOWN WELLFIELDS
WESTFORD, MA

REPORT OF BORING NO. B-3
SHEET 1 OF 1
DATE 2/2/82 FILE A-3249

BORING CO. Soil Exploration
FOREMAN Paul Curran
G-Z-A ENGINEER James Schiff

BORING LOCATION See Location Plan
GROUND ELEV.
DATE START 2/2/82 DATE END 2/3/82

CASING
SIZE: 3" I.D. Casing
HAMMER: 300 lb.
FALL: 24"

SAMPLER
TYPE: 1 3/8" Split Spoon OTHER:
HAMMER 140 lb.
FALL: 30"

(Bob-Wash boring with Trypod rig)

GROUNDWATER READINGS

DATE	DEPTH	CASING AT	STABILIZATION TIME

DEPTH	NOTE	SAMPLE NO.	SAMPLE PEN./REC.	SAMPLE DEPTH	SAMPLE BLOWS/6"	STRTA CHG. and GEN. DESC.	SAMPLE DESCRIPTION Burmister CLASSIFICATION	OVA
						WATER 1.5'		
		S-1	18/--	1.5-3	WOH		No recovery	-
5						ORGANIC SILT, TRACE FINE SAND 10.0'		
		S-2	18/4	8-9.5	WOH		Very soft black Organic SILT, decayed leaves, wood fragments	70
10						FINE TO MEDIUM SAND 15.0'		
		S-3	18/6	12.5-14	2-1-3		Soft brownish red fine to medium SAND, trace -Silt	400
15		S-4	18/6	15-16.5	4-5-3		Soft light brown fine SAND, trace -Silt	1.0
20						FINE SAND, TRACE SILT		
		S-5	18/18	22-23.5	6-5-7	23.5'	Medium dense light brown fine SAND, trace -Silt	0
25							Bottom of boring @ 23.5 ft.	

REMARKS: Field Test results represent total organic vapor levels (referenced to a methane-in-air standard) measured in head spaces of sealed soil sample jars. A Century Systems Standard Model OVA-128 organic vapor analyzer was employed for all analyses. Injected volume of 3.0 cc except where otherwise indicated. Results in ppm.
WOH = Weight of Hammer
Installed observation well at 20ft. 5ft slotted screen plus 25ft of solid PVC pipe, stick-up 4ft. 15ft protective casing over well

NOTES: 1) THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY BETWEEN SOIL TYPES AND THE TRANSITION MAY BE GRADUAL.
2) WATER LEVEL READINGS HAVE BEEN MADE IN THE DRILL HOLES AT TIMES AND UNDER CONDITIONS STATED ON THE BORING LOGS. FLUCTUATIONS IN THE LEVEL OF THE GROUNDWATER MAY OCCUR DUE TO OTHER FACTORS THAN THOSE PRESENT AT THE TIME MEASUREMENTS WERE MADE.

GOLDBERG · ZOINO & ASSOC., INC.
GEOTECHNICAL/GEOHYDROLOGICAL CONSULTANTS

PROJECT
TOWN WELLFIELDS
WESTFORD, MA

REPORT OF BORING NO. B-4
SHEET 1 OF 1
DATE 2/4/82 FILE A-3249

BORING CO. Soil Exploration
FOREMAN Paul Curran
G-Z-A ENGINEER James Schiff

BORING LOCATION See Location Plan
GROUND ELEV.
DATE START 2/4/82 DATE END 2/4/82

CASING
SIZE: 3" I.D. Casing
HAMMER: 300 lb.
FALL: 24"

SAMPLER
TYPE: 1 3/8" Split Spoon OTHER:
HAMMER 140 lb.
FALL: 30"

(Bob-Wash boring with Trypod rig)

GROUNDWATER READINGS

DATE	DEPTH	CASING AT	STABILIZATION	TIME

DEPTH	NOTE	SAMPLE NO.	PEN./REC.	SAMPLE DEPTH	BLOWS/6"	STRTA CHG. and GEN. DESC.	SAMPLE DESCRIPTION Burmister CLASSIFICATION	OVA
						WATER 1.5'		
		S-1	18/--	2-3.5	WOR		No recovery	
5		S-2	18/4	5-6.5	WOR	ORGANIC SILT 9.0'	Very soft dark brownish red fine SAND, decomposed leaves, wood chip, trace organic Silt -Marsh-	400
10		S-3	18/8	10-11.5	2-3-3	RED FINE SAND 14.0'	Loose, red fine SAND, trace -Silt	2.0
15		S-4	18/6	14-15.5	4-3-4	FINE SAND, TRACE SILT	Loose brown fine SAND, trace -Silt	0
20		S-5	18/12	20-21.5	4-5-4	21.5'	Loose brown fine SAND, trace -Silt	0
							Bottom of boring @ 21.5'	
25								

REMARKS: Field Test results represent total organic vapor levels (referenced to a methane-in-air standard) measured in head spaces of sealed soil sample jars. A Century Systems Standard ModelOVA-128 organic vapor analyzer was employed for all analyses. Injected volume of 3.0 cc except where otherwise indicated. Results in ppm.
WOR = Weight of Rods.
Installed observation well at 20ft. 5ft slotted screen plus 25ft of solid PVC pipe, stick-up 4ft, 15ft protective casing installed over well.

NOTES: 1) THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY BETWEEN SOIL TYPES AND THE TRANSITION MAY BE GRADUAL.
2) WATER LEVEL READINGS HAVE BEEN MADE IN THE DRILL HOLES AT TIMES AND UNDER CONDITIONS STATED ON THE BORING LOGS. FLUCTUATIONS IN THE LEVEL OF THE GROUNDWATER MAY OCCUR DUE TO OTHER FACTORS THAN THOSE PRESENT AT THE TIME MEASUREMENTS WERE MADE.

GOLDBERG · ZOINO & ASSOC., INC. GEOTECHNICAL/GEOHYDROLOGICAL CONSULTANTS	PROJECT TOWN WELLFIELDS WESTFORD, MA	REPORT OF BORING NO. B-5 SHEET 1 OF 1 DATE 2/5/82 FILE A-3249

BORING CO. Soil Exploration — BORING LOCATION See Location Plan
FOREMAN Paul Curran — GROUND ELEV.
G-Z-A ENGINEER James Schiff — DATE START 2/5/82 DATE END 2/5/82

CASING
SIZE: 3" I.D. Casing
HAMMER: 300 lb.
FALL: 24"

SAMPLER
TYPE: 1 3/8" Split Spoon OTHER:
HAMMER 140 lb.
FALL: 30"

(Bob-Wash boring with Trypod rig)

GROUNDWATER READINGS

DATE	DEPTH	CASING AT	STABILIZATION TIME

DEPTH	NOTE	SAMPLE NO.	SAMPLE PEN./REC.	SAMPLE DEPTH	SAMPLE BLOWS/6"	STRTA CHG and GEN. DESC.	SAMPLE DESCRIPTION Burmister CLASSIFICATION	OVA
						WATER 2.0		
		S-1	18/2	2-3.5	WHR		Soft black organic SILT, decayed leaves, trace -fine Sand	
5						ORGANIC SILT, TRACE -FINE SAND		
		S-2	18/3	8-9.5	WHR	9.5'	Soft brownish black Organic SILT, decayed leaves, trace -fine Sand	700
10		S-3	18/8	10-11.5	2-3-3		Loose grey fine SAND, trace -Silt	200
15		S-4	18/6	15-16.5	3-4-3	FINE SAND, TRACE -SILT	Loose grey fine SAND, trace -Silt	1.0
20		S-5	18/12	20-21.5	6-5-6	21.5'	Medium dense gray fine SAND, trace -Silt	0.0
25							Bottom of boring @ 21.5'	

REMARKS: Field Test results represent total organic vapor levels (referenced to a methane-in-air standard) measured in head spaces of sealed soil sample jars. A Century Systems Standard Model OVA-128 organic vapor analyzer was employed for all analyses. Injected volume of 3.0 cc except where otherwise indicated. Results in ppm.
WHR = Weight of Hammer and Rods
Installed observation well at 20ft 5ft slotted screen plus 25ft of solid PVC pipe, stick-up 4ft. 15ft protective casing installed over well

NOTES: 1) THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY BETWEEN SOIL TYPES AND THE TRANSITION MAY BE GRADUAL.
2) WATER LEVEL READINGS HAVE BEEN MADE IN THE DRILL HOLES AT TIMES AND UNDER CONDITIONS STATED ON THE BORING LOGS. FLUCTUATIONS IN THE LEVEL OF THE GROUNDWATER MAY OCCUR DUE TO OTHER FACTORS THAN THOSE PRESENT AT THE TIME MEASUREMENTS WERE MADE.

SOIL EXPLORATION LOGS

GZA

425 TAYLOR ROAD
STOW, MASSACHUSETTS 01775
(617) 897-8737

SOIL EXPLORATION CORPORATION

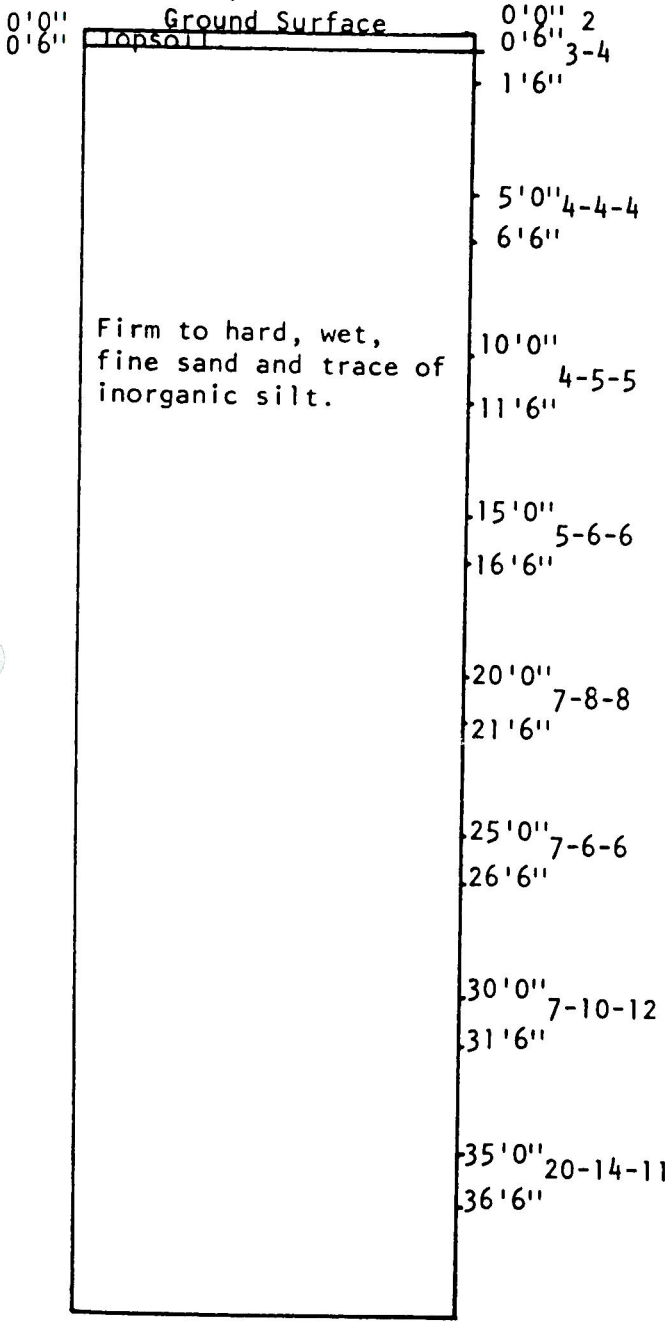
TEST BORINGS • GEOLOGICAL CONSULTING

OAK HILL PROFESSIONAL PARK
LONDONDERRY, N.H. 03053
(603) 627-3051

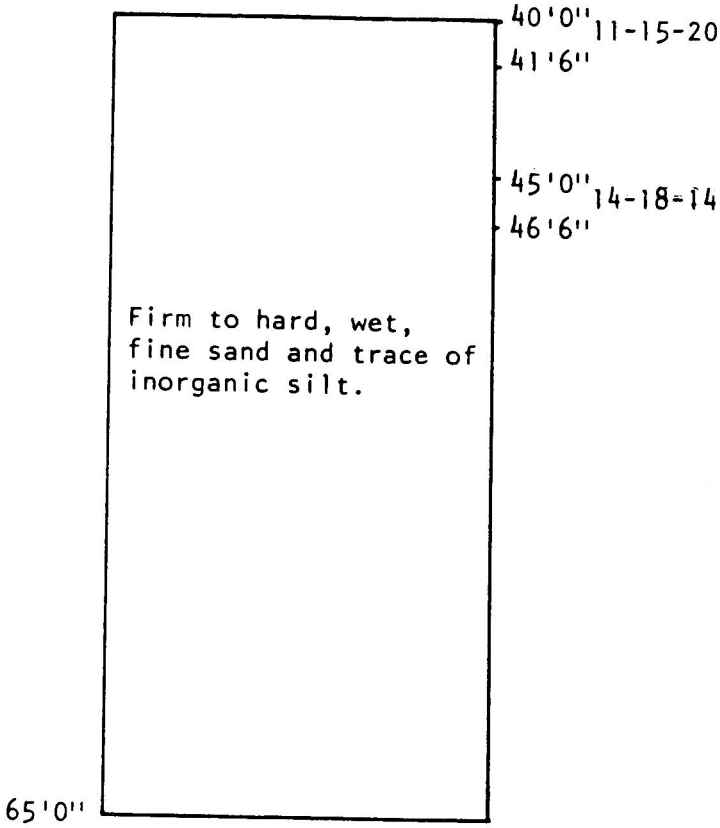
To Goldberg-Zoino & Assocs., Inc. Date 2/6/82 Job No. 82-025

Location Westford, Mass. Scale 1" = 6 ft.

Observation Well No. 1
2/4-5/82
Ground Surface



Observation Well No. 1
continued



End of OB Well 65'0"
Water Level 3'0"
upon completion.

Installed well at 65'0"

MATERIALS USED:
15' Protective casing
1 80 Lb. bag of cement

Figures in Right Hand Column Indicate the Number of Blows Necessary to Drive spoon 6" using 140 lb. weight falling 30 inches.	Casing Data HOLLOW STEM AUGER Casing O.D. ____ I.D. ____ Hammer Fall ____ Weight of Hammer ____	Sampler Data Sampler O.D. 2" I.D. 1-3/8" Inside Length of Sampler 18" Hammer Fall 30" Weight of Hammer 140#

425 TAYLOR ROAD
STOW, MASSACHUSETTS 01775
(617) 897-8737

SOIL EXPLORATION CORPORATION

TEST BORINGS • GEOLOGICAL CONSULTING

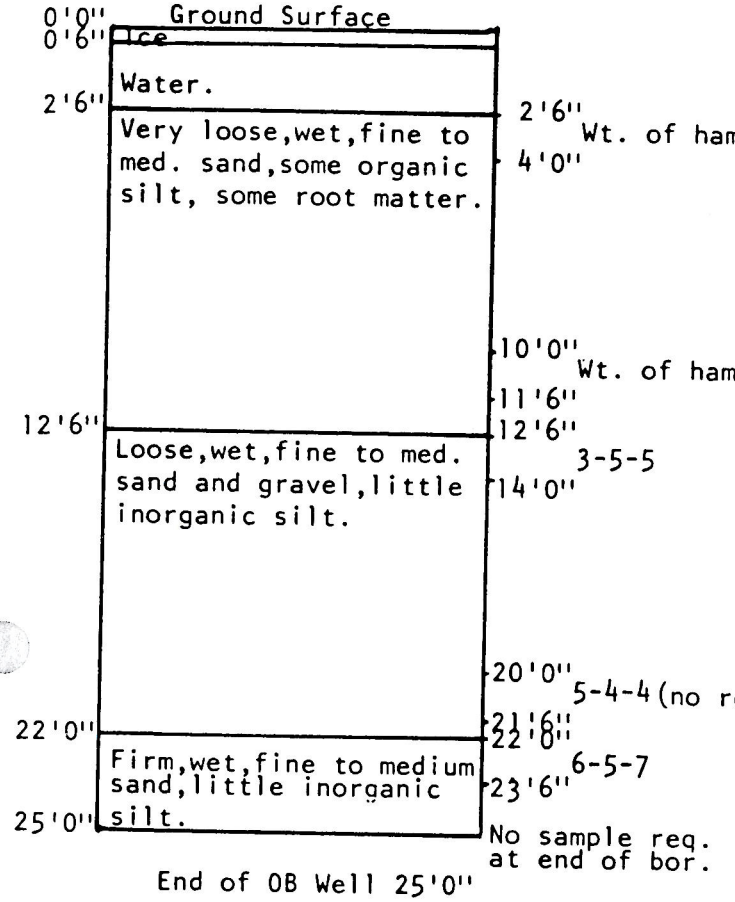
OAK HILL PROFESSIONAL PARK
LONDONDERRY, N.H. 03053
(603) 627-3051

To Goldberg-Zoino & Assocs., Inc. Date 2/6/82 Job No. 82-025

Location Westford, Mass. Scale 1" = 6 ft.

Observation Well No. 2

2/2-4/82



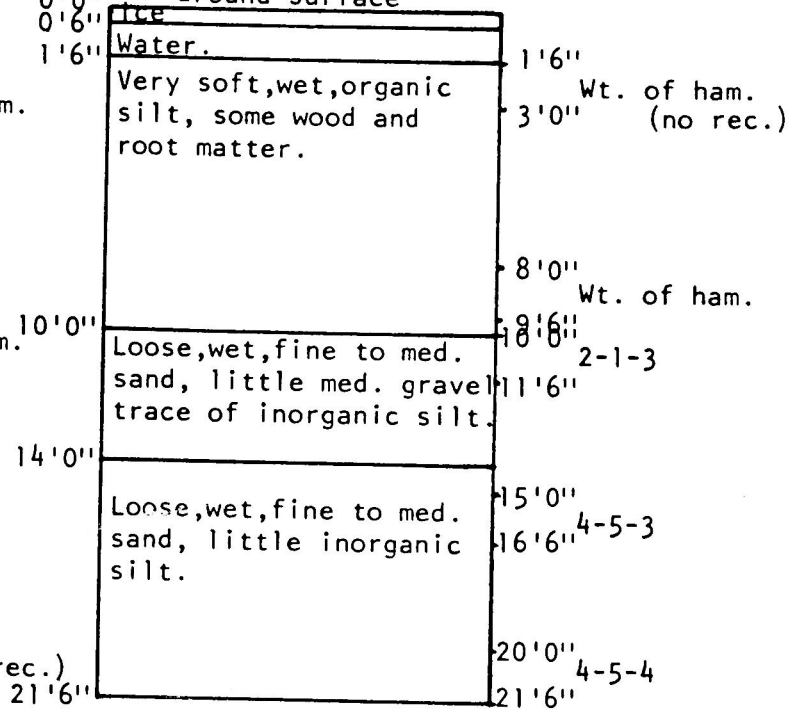
End of OB Well 25'0"
Water at surface

Installed well at 20'0"

MATERIALS USED:
15' Protective casing 2-1/2"
1 Cap

Observation Well No. 3

2/4/82



End of OB Well 21'6"
Water at surface

Installed well at 20'0"

MATERIALS USED:
15' Protective casing 2-1/2"
2 Couplings 2-1/2"
1 Cap

Figures in Right Hand Column Indicate the Number of Blows Necessary to Drive spoon 6" using 140 lb. weight falling 30 inches.	Casing Data HOLLOW STEM AUGER Casing O.D. _____ I.D. _____ Hammer Fall _____ Weight of Hammer _____	Sampler Data Sampler O.D. 2" I.D. 1-3/8" Inside Length of Sampler 18" Hammer Fall 30" Weight of Hammer 140#

425 TAYLOR ROAD
STOW, MASSACHUSETTS 01775
(617) 897-8737

SOIL EXPLORATION CORPORATION

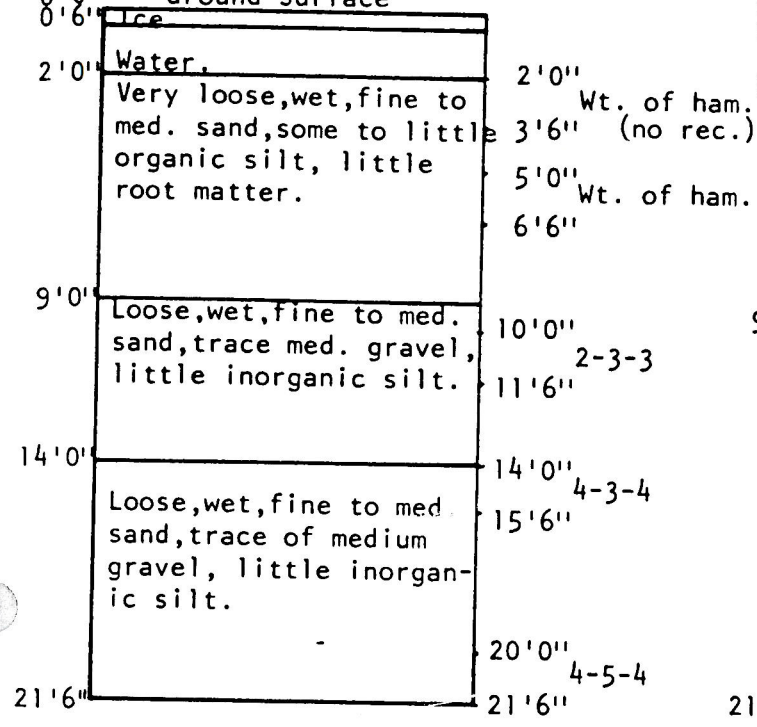
TEST BORINGS • GEOLOGICAL CONSULTING

OAK HILL PROFESSIONAL PARK
LONDONDERRY, N.H. 03053
(603) 627-3051

To Goldberg-Zoino & Assocs., Inc. Date 2/6/82 Job No. 82-025

Location Westford, Mass. Scale 1" = 6 ft.

Observation Well No. 4
2/4/82
Ground Surface

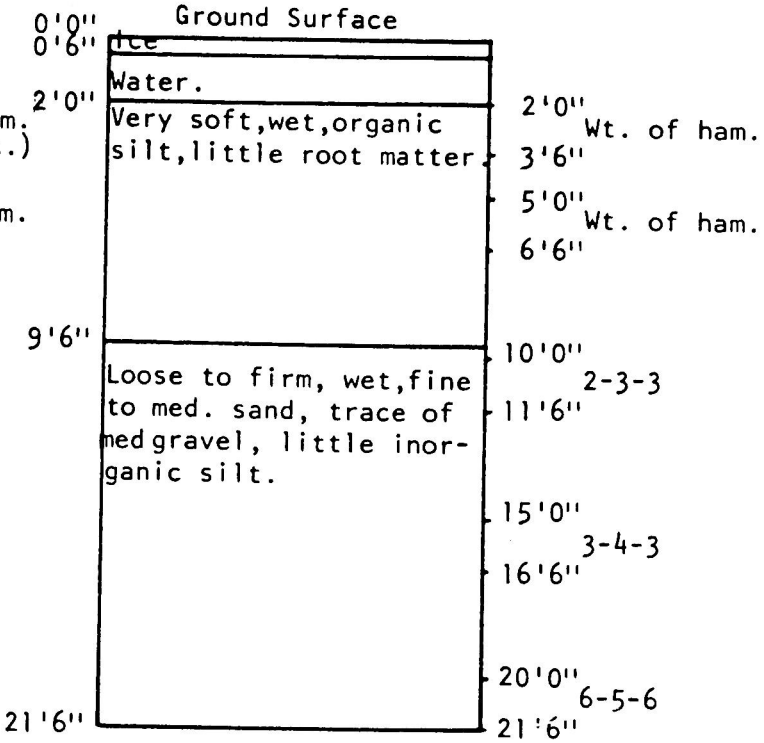


End of OB Well 21'6"
Water at surface

Installed well at 20'0"

MATERIALS USED:
15' Protective casing 2-1/2"
2 Couplings 2-1/2"
1 Cap

Observation Well No. 5
2/5/82
Ground Surface



End of OB Well 21'6"
Water at surface

Installed well at 20'0"

MATERIALS USED:
15' Protective casing 2-1/2"
2 Couplings 2-1/2"
1 Cap

Figures in Right Hand Column Indicate the Number of Blows Necessary to Drive spoon 6" using 140 lb. weight falling 30 inches.	Casing Data HOLLOW STEM AUGER Casing O.D. _____ I.D. _____ Hammer Fall _____ Weight of Hammer _____	Sampler Data Sampler O.D. 2" I.D. 1-3/8" Inside Length of Sampler 18" Hammer Fall 30" Weight of Hammer 140#

APPENDIX C

ERCO CHEMICAL DATA

ERCO | Energy Resources Co. Inc.

One Alewife Place
Cambridge, Massachusetts 02138
(617) 661-3111 TWX 710-320-0721

Denver, Colorado
Houston, Texas
La Jolla, California
Midland, Texas
Oklahoma City, Oklahoma

Paris, France
Walnut Creek, California
Washington, D.C.
Zurich, Switzerland

July 12, 1982

Dr. Gary Williams
Goldberg, Zoino & Associates
30 Tower Road
Upper Newton Falls, MA

Dear Gary:

Enclosed are the results for those water samples delivered to us on June 7, 1982 for VOA, Alkali-Alkali Earth metals, Alkalinity, TDS, and COD analyses. The report sheet for volatile organics had previously been forwarded to you by Ed Lawler.

If there are any questions regarding these results, please do not hesitate to call.

Sincerely,

Nile A. Luedtke

NAL:eve
Encl.

An Equal Opportunity Employer M/F

ENERGY RESOURCES CO. INC

INORGANIC ANALYSIS

- Report Sheet -
mg/l (ppm)

Analyzed for: Goldberg, Zoino & Assoc.

ERCO ID	CLIENT ID	Ca	K	Na	Cl	Alk	COD	TDS
IC-82	A-3249							
	Surface Waters							
1816	B-2	8.9	1.1	17	30	-	-	-
1816	ERCO dupl.	7.6	0.85	16	30	-	-	-
1817	B-3	9.3	1.3	20	38	-	-	-
1818	B-4	12	1.8	23	40	-	-	-
1819	B-5	11	7.7	23	49	-	-	-
	Well Waters							
1820	B-1	20	9.8	5.4	9	43	6	88
1821	B-2	19	1.4	9.6	35	15	<5	107
1822	B-3	18	1.6	7.4	15	37	7	67
1823	B-4	13	2.5	4.6	12	27	6	93
1824	B-5	6.0	1.8	3.4	8	16	13	47
1825	OW-1	10	1.7	9.5	10	29	5	73(77*)
1826	OW-6	18	1.8	4.3	19	27	9	142
1826	ERCO dupl.	18	1.7	4.0	-	-	11	-
1827	OW-9	17	1.8	13	38	23	10	240
1828	OW-20	32	1.6	28	94	12	10	360

If customer has any questions regarding analysis, refer to sample in question by its ERCO ID#.

- Not Analyzed
* ERCO Duplicate

Sample Rcvd. 6/7/82 Reported by

Date Analysis Completed 7/9/82 Checked by

Sample Rcvd: June 8, 1982

Date Analysis Completed: June 15, 1982

All Results In: µg/l (ppb)

Reported By: EL

Checked By: EL

ENERGY RESOURCES CO. INC.

VOLATILE ORGANICS ANALYSIS
BY EPA METHOD 601
- Report Sheet -

Analyzed for: Goldberg, Zoino & Assoc.

Compounds (in order of elution)	OW1	OW6	OW9	OW20	B1	B2	B3	B4	B5
Vinyl chloride/Freon 12*									
Methylene chloride									
1,1-dichloroethylene									
1,1-dichloroethane									
1,2-dichloroethylene									
Chloroform									
1,2-dichloroethane									
1,1,1-trichloroethane									
Carbon tetrachloride									
Bromodichloromethane									
Trichloroethylene									
Dibromochloromethane									
Bromoform									
Tetrachloroethylene									

Comments: All blank spaces are ND's (none detected).
*Approxmate concentration.