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Rcd
Lord Shope
report
9-24-85

HYDROGEOLOGIC SUMMARY REPORT

SHOPE'S LANDFILL
GIRARD TOWNSHIP, PENNSYLVANIA

Prepared for

LORD CORPORATION
2000 W. Grandview Boulevard
Erie, Pennsylvania 16512

Prepared by

AWARE Incorporated
80 Airport Road
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September 1985

AWARE

consultants in environmental management

September 17, 1985

Mr. James Wright
Lord Corporation
2000 W. Grandview Blvd.
Erie, PA 16512

RE: Hydrogeologic Summary Report, Shope's Landfill

Dear Mr. Wright:

We are pleased to submit the final copy of the Hydrogeologic Summary Report for Shope's Landfill. This report describes the hydrogeologic conditions of the site with a particular emphasis on contaminant migration based upon existing and newly conducted hydrogeologic data.

A significant finding that has been reported herein is that several of the newly constructed deep wells including W-3C, W-12C, and W-20C appear to contain low levels of contaminants. However, due to hydrogeologic conditions of the zone in which these wells are screened, it is believed that the apparent contamination in these wells is a function of the well construction rather than evidence of actual contamination in the deep groundwater zone. As described in the report, the aquitard overlying the deep wells represents a significant confining bed and should control vertical migration of the plume. On this basis, we recommended that a lithium tracer test be conducted to determine whether or not downward leakage through the well annulus is occurring.

A lithium tracer test was performed by Lord on deep well W-20C subsequent to preparation of this report. The adjacent intermediate well, W-20B, was purged to dryness and then charged with a 5 percent LiCl solution. Water was then pumped from well W-20C. Groups of four replicate samples were collected at various times, between which the well was continuously pumped. Samples were collected as replicates to identify any natural variability that may be present. The analysis of the data indicates that the levels of lithium in well W-20C increased to levels significantly above background levels during the purging cycle after the shallower adjacent well was charged with lithium. This confirms that downward leakage through the annular well seal is causing this apparent contamination in the deep zone.

The data are presented as follows:

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Total Volume Purged (gal)	No. of Samples	Lithium (mg/l)
Background	4	0.020 ± .002
5	4	0.020 ± .002
10	4	0.020 ± .002
15	4	0.070 ± .001
20	4	0.180 ± .004

The deep wells in which this apparent annular leakage has occurred have been constructed in accordance with standard monitoring well installation practices. However, unusually difficult hydrogeologic conditions, including high downward hydraulic gradient coupled with the low well yields in the relatively impermeable deep zone, have created a situation in which very small amounts of contaminant leakage downward through the well seal cap have shown up as measurable levels in these deep wells.

We are also in the process of evaluating the effectiveness of the remedial measures implemented at the Shope's Landfill. Thus far our evaluation indicates that the plan's effectiveness coincides remarkably well with the predictions which accompanied its design. Water levels beneath the capped landfill have declined very nearly as predicted in the September 1982 "Flow Net Analysis of the Subsurface Cutoff Wall and Impervious Cap" report. Moreover, this decline has occurred in spite of the fact that groundwater levels outside the capped area are generally higher than the July 1981 levels upon which the flow net analysis was based. For example, water levels beneath the cap have declined from 2 to 3½ feet while outside the cap water levels have generally risen 1½ to 3 feet.

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As a result of this general decline in groundwater levels, the extent to which the groundwater table intersects the base of the waste is significantly less than it was prior to implementation of the remedial plan. As you will recall, the pre-remedial plan waste/groundwater table intersection was presented in Figure 1 of the September 1981 remedial action plan report. We are presently studying the impact of seasonal fluctuations in groundwater levels in an effort to estimate the actual effectiveness of the remedial in comparison to original projections.

If you have any questions or wish to discuss this further, please do not hesitate to contact us.

Very truly yours,

AWARE Incorporated

Scott D. MacMillin

Scott D. MacMillin
Senior Hydrogeologist

Robert D. Mutch Jr.

Robert D. Mutch, Jr., P.HG., P.E.
Vice President

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1.0 INTRODUCTION

The Shope's Landfill dates to the late 1950s when dumping in the rear portion of Melvin Shope's property began. The waste that was disposed at the site originated from the Lord Corporation where Mr. Shope was employed in the maintenance department. The waste consisted of scrap rubber, paper, wooden pallets, cement, oils, solvents, acids, and caustics. The landfill was closed after having covered an area of approximately 4.5 acres. (date —)

Hydrogeologic work at the landfill was conducted initially in 1979-80 by Dr. Samuel Harrison of Alleghany College. This work included the installation of 37 wells at well cluster numbers 1 through 11.

Further hydrogeologic work was conducted by Wehran Engineering in 1981 as a prelude to the development of a remedial program for the landfill. This investigation was intended to address several data gaps that were vital to the design of the remedial program. Furthermore, this investigation was intended to address the existence of groundwater contamination beyond the areas investigated by Dr. Harrison. This work was accomplished, in part, by the installation of a number of monitoring wells and piezometers at locations numbered 12 through 19.

On the basis of this hydrogeologic work, a number of remedial options were proposed. An option was selected that included the removal of exposed drums, regrading of the site, removal of standing pools of leachate, improvements to surface water drainage, installation of an impermeable cap, and construction of an upgradient groundwater cutoff wall. These remedial measures were implemented during the summer and fall of 1982.

A consent order was entered into by the Lord Corporation and the Pennsylvania Department of Environmental Protection (PADER) in which, in addition to the requirements associated with the implementation of the remedial plan, a comprehensive groundwater monitoring program was set forth. As such, quarterly monitoring was conducted for two years, followed by the preparation of a draft long-term monitoring program in October, 1984. The draft long-term monitoring plan set forth a major expansion of the existing monitoring well network in addition to the specification of a sampling and analytical schedule.

The installation of the new monitoring wells in November and December 1984, enabled the collection of a significant body of hydrogeologic data. This report serves to place hydrogeologic data from previous investigations into perspective with the newly collected data. In this way, significant additional conclusions have been drawn with respect to groundwater. The field methods utilized during the current work and the interpretation of the hydrogeologic conditions are discussed in detail in the following sections.

2.0 HYDROGEOLOGIC FIELD INVESTIGATION

A hydrogeologic field investigation of the Shope's Landfill site was undertaken by AWARE Incorporated during November and December 1984. The investigation was predicated upon the following criteria:

1. To construct 19 new monitoring wells and to replace one existing monitoring well as specified by the draft Long-Term Monitoring Plan.
2. To more fully define the extent and character of the geologic materials beneath the site.
3. To collect undisturbed soil samples for laboratory permeability testing.
4. To conduct in situ permeability testing on selected newly installed monitoring wells.
5. To measure static water levels at all new and existing monitoring wells for use in the determination of groundwater flow directions.

The Shope's site is depicted on the Site Plan, Sheet 1. This map indicates the location of all newly installed and existing monitoring wells.

2.1 Exploratory Drilling and Monitoring Well Installation

Twenty new monitoring wells were installed at the Shope's site. Fifteen of these were installed as triplets at five separate locations. These wells are designated W-20 through W-24 with A, B, and C suffixes corresponding, respectively, to shallow, intermediate and deep wells. Two wells, W-1WT and W-25WT were installed as replacement and new shallow wells, respectively. The remaining three wells, W-3C, W-7A, and W-12D were all installed as deep wells immediately adjacent to existing shallower wells. The drilling and well installation was conducted during November and December 1984.

All drilling was conducted by Empire Soils Investigations, Inc. of Orchard Park, New York. The drilling was completed under the supervision of an experienced geologist from AWARE. The geologist maintained a continuous log of the work as it proceeded and directed the well installation operation. The borings were advanced by one of two drill rigs. The drilling at the locations with the poorest access conditions was performed with a CME Model 45 drill rig mounted on a trailer that was moved into position with its integral winch and/or with the use of a small bulldozer equipped with a winch. The other borings were completed with a truck-mounted Acker Model 81 drill rig.

The drilling of all borings was initiated with the use of 3-3/4 inch I.D. hollow stem augers. Beyond a depth of approximately 60 feet, most borings were continued using the mud rotary method with a 3-5/8 inch roller bit. The drilling fluid was recirculated and a drilling mud consisting of pure bentonite was used only when required by drilling conditions.

The soils were sampled continuously with a split spoon sampler at all new boring locations. At the locations of existing wells, samples were collected at five foot intervals. The soils were visually classified in the field according to a system modified after Burmister (1958). Representative portions of each sample were stored in glass jars. Selected jar samples were subjected to laboratory grain size testing as discussed in Section 2.3. Complete geologic descriptions of the sampled soils are found in the Test Boring Logs (Appendix A) based upon both the visual and laboratory classification.

Undisturbed soil samples were collected from three of the borings. These were collected by pressing a three inch (I.D.) Shelby tube into the soils below the bottom of the boring. Following retrieval, the samples were sealed and transported to the laboratory by the field geologist. Particular care was exercised to avoid freezing and excess vibration of the sample. All undisturbed sample intervals are indicated on the appropriate boring logs.

Monitoring wells were constructed at each test boring location as previously discussed. These wells were constructed of two inch "black" steel pipe with welded couplings. Each well was equipped with a five foot length of wirewound stainless steel well screen with a 0.010 inch slot size. Each screen was packed with a uniform medium-grained sand and sealed with bentonite pellets or a tremie-emplaced bentonite slurry. The remaining annular space above the bentonite seal was filled with cement-bentonite grout by the tremie method. Each well was equipped with a lockable cap. Following their construction, each well was developed with compressed air to remove any fine materials and drilling fluids that may have been introduced during the drilling process. A drawing of record for each of the monitoring wells is presented on the test boring logs in Appendix A.

2.2 In Situ Permeability Testing

In situ permeability tests were performed on selected newly installed monitoring wells and well points by the use of the "variable head" method, as described below. The results of these tests represent determination of the horizontal permeability of the geologic materials adjacent to the screened interval of each well.

The particular "variable head" borehole test utilized for this project was developed by Hvorslev for the United States Army Corps of Engineers, and summarized in Cedergren (1977). These tests were conducted as follows:

1. The static water level in the well to be tested was measured and recorded.
2. The water level in the well was then lowered by bailing or pumping, and a measurement of the depressed water level or drawdown was recorded.
3. At frequent time intervals, the water level in the well and the respective time elapsed from the beginning of the recovery period were measured and recorded.

The method of analysis assumes that the rate of inflow to the well screen after evacuation is proportional to the hydraulic conductivity (k), expressed in cm/sec, and to the unrecovered head distance. A plot of the unrecovered head distance or Head Ratio versus Time (t) indicates an exponential decline in the recovery rate with time. Equation 2.1 is used to calculate the permeability.

$$k = \frac{r^2 \ln(L/R) \ln H_1 H_2)}{2L (t_2 - t_1)} \qquad \text{Eq. 2.1}$$

Where: R = sand pack radius (cm)
r = riser radius (cm)
L = effective intake length
t_1 = time interval corresponding to h_1 (sec)
t_2 = time interval corresponding to h_2 (sec)
h_1 = head ratio at t_1 (dimensionless)
h_2 = head ratio at t_2 (dimensionless)
k = permeability (cm/sec)

The individual permeability plots are presented in Appendix C. The results of the permeability testing are summarized on Table 2.1.

Several in situ permeability tests were conducted on shallow water table wells that recovered too rapidly to measure, given the equipment that was employed. On the basis of past experience, it is believed that the permeability of these particular soils is probably in excess of 1×10^{-3} cm/sec. - but is [illegible] stuff [illegible] ? yes

2.3 Laboratory Soils Testing

A number of soil samples were selected for laboratory soils testing. Eleven split spoon samples were subjected to mechanical grain size testing including mechanical sieving and Atterburg limits testing. In addition, four undisturbed tube samples were tested for permeability, mechanical sieving, hydrometer, Atterburg limits, and moisture content.

The soils were tested by the Wehran Engineering Soils Laboratory in Middletown, New York. The procedures followed in all of the testing performed were consistent with standard labortory procedures with the exception of the permeability testing. The permeability tests on the undisturbed tube samples were performed in a flexible-walled triaxial permeameter under falling head conditions. This apparatus is considered superior to a conventional rigid-walled permeameter because it allows placing the soil specimen under a confining pressure before and during testing. The confining pressure insures that sample fracturing and effluent bypass will not occur during testing. Also, the confining pressure can be adjusted to equal the in situ confining pressure experienced by the soil under natural conditions. Furthermore, this system allows application of the effluent under significant back pressures which insure saturation of specimens prior to actual testing.

The laboratory test data is presented in Appendix D.

TABLE 2.1

SUMMARY OF PERMEABILITY
TEST RESULTS

Geologic Unit	Boring	Test Interval	Test Type	Permeability (cm/sec)
Maumee IIIC Lacustrine Dep.				
(Coarse)	W-12C	15.5-21.5	In-Situ	2.9×10^{-5}
(Coarse)	W-22A	5.5-9	In-Situ	9.2×10^{-4}
(Fine)	W-20B	22-23	Lab	2.8×10^{-7}
(Fine)	W-20B	23-24	Lab	8.4×10^{-7}
Ashtabula Till-Ashtabula				
(Fine)	W-12D	22-24	Lab	1.0×10^{-7}
(Fine)	W-12B	24-28	In-Situ	8.3×10^{-7}
(Fine)	W-20B	34-36	Lab	1.4×10^{-7}
Maumee IIIB Lacustrine Dep.				
(Coarse)	W-12A	49-52.5	In-Situ	7.2×10^{-7}
(Coarse)	W-21B	43.5-49.5	In-Situ	5.2×10^{-7}
(Coarse)	W-22B	43-53	In-Situ	2.1×10^{-5}
(Coarse)	W-24B	54-59	In-Situ	2.6×10^{-6}
(Fine)	W-23B	34-37.5	In-Situ	1.8×10^{-7}
Maumee IIIA Lacustrine Dep.				
(Coarse)	W-21C	101-104.5	In-Situ	9.7×10^{-7}
(Coarse)	W-22C	76-79.5	In-Situ	1.1×10^{-6}
(Coarse)	W-23C	81-85	In-Situ	1.1×10^{-4}
(Coarse)	W-24C	81-87	In-Situ	5.3×10^{-4}

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2.4 Site Survey

Site survey work was completed in conjunction with the hydrogeologic field investigation by Urban Engineers, Inc. of Erie, Pennsylvania. This work was conducted during October and December, 1984.

The initial survey work was conducted to provide the locations of the new monitoring well clusters, W-20 through W-25. The locations have been provided within the context of a site grid. This grid has been referenced to the south property line which had been surveyed by Weislogel-Billie Associates in March 1983.

The locations of the existing monitoring well clusters were not surveyed by Urban Engineers, Inc. Locations of these clusters have been provided by site surveys conducted in July, 1981 and August, 1983 by Wehran Engineering Corporation. Locations of the existing clusters have been placed in the new grid system with the use of these existing surveys.

A second survey was conducted by Urban Engineering, Inc. to determine the elevation of all new and existing monitoring wells in the study area. The elevation of both the ground surface and the top of the well have been provided. This elevation survey has been referenced to the same datum that was employed for previous site surveys by Wehran Engineering Corporation. Wehran had referenced this datum approximately to mean sea level.

3.0 GEOLOGIC CONDITIONS

In this section, the characteristics and extent of the geologic materials encountered within the area under consideration are described. In order to put the site into perspective within the larger geologic framework of the region and to describe the geologic history that led to the formation of each of the stratum, a brief discussion of the regional geology is presented. This discussion of the regional geology is based on the published geologic data for the area, as well as the results of our field investigation. The geology of the actual site is then described in detail based upon our interpretation of the existing data.

3.1 Regional Geologic Setting

The Shope's site is situated on the edge of the Lake Plain subprovince of the Central Lowland physiographic province. The site is underlain by a thick sequence of glacially deposited materials that is in turn underlain by shales of Upper Devonian age. The region is geologically bounded to the south by the escarpment slope of the glaciated section of the Appalachian Plateaus Province and to the north by Lake Erie.

The bedrock consists of shale of the lower Conneaut Group which is locally termed the Girard Shale (Tomikel and Shepps, 1967). These shales were deposited during the Upper Devonian and serve as a transitional zone from fine grained shales of the underlying Canadaway Formation to coarse grained shales and sandstones of the overlying upper Conneaut group. The Girard Shale is locally exposed only in deeply eroded beds of major streams in the area.

The bedrock is overlain by a thick sequence of glacial material. These materials are reported by Shepps, et al (1959) to exist at a thickness of 40 to 80 feet, but locally may be significantly thicker. These glacial materials were deposited by a number of the seven separate advances of the continental ice sheet that blanketed the area during the Pleistocene Epoch. The glacial deposits that directly overlie the bedrock were deposited by the early glacial advances with the upper material being deposited by successively more recent glaciation.

Glacial till was deposited by the glacial ice which repeatedly advanced over the region. The materials in the glacial till had been picked up both locally in northeastern Pennsylvania and from other locations to the northeast. Other related glacial materials were deposited by meltwater flowing adjacent to or through the ice or emanating from the front of the ice sheet. Lacustrine deposits were laid down during interglacial events when lake waters filled what is now the Erie basin. Table 3.1 provides a perspective as to the overall sequence of the glacial advances and associated glacial depositions that took place during the Pleistocene Epoch.

PERIOD	EPOCH	STAGE	UNIT	THICKNESS (FT)	GENERALIZED DESCRIPTION
QUATERNARY	PLEISTOCENE	WISCONSIN	GLACIO-FLUVIAL DEPOSITS	0-5	Brown f-m SAND, little to and SILT, Stratified, well sorted.
			ASHTABULA TILL (GIRARD)	3-8	f-m SAND, some to and f-m GRAVEL, little to some SILT, non-stratified poorly sorted.
			MAUMEE III$_C$ LACUSTRINE DEPOSITS	10-31	Predominantly coarse grained consisting of SAND, trace to and SILT, trace to and GRAVEL, freq. interbedded with SILT & CLAY occ. fine zones consisting of laminated SILT to SILT & CLAY, no to and SAND. ?
			ASHTABULA TILL (ASHTABULA)	7-42	Fine grained zones consisting of CLAYEY SILT, little to and SAND, trace to little GRAVEL. Coarse grained zones consisting of SAND, little to some SILT, little to and GRAVEL.
			MAUMEE III$_B$ LACUSTRINE DEPOSITS	5-24	Coarse zones of stratified SAND, trace to some SILT, trace to and GRAVEL. Fine zones of laminated SILT, trace to some SAND. ?
			ASHTABULA TILL (PAINESVILLE)	14-41	Predominantly fine grained consisting of CLAYEY SILT, little to and SAND, tr GRAVEL grading to SILT & CLAY, trace to some SAND, tr GRAVEL. occ. coarse zones consisting of SAND, some SILT and CLAY, little to some GRAVEL.
			MAUMEE III$_A$ LACUSTRINE DEPOSITS	14-20	Fine zones of laminated CLAY & SILT, no to little SAND, no to trace GRAVEL, Coarse zones of stratified SAND, no to some SILT. ?
			ASHTABULA TILL (EUCLID)	?	SILT & CLAY, trace to little SAND, trace GRAVEL.

near shore lacustrine

who's interpretation?
no reference made
or in text
(not documented in text)

FIGURE 3

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GEOLOGIC SECTION

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TABLE 3.1
GLACIAL ADVANCES AND ASSOCIATED DEPOSITION IN NORTHWESTERN PENNSYLVANIA
(After Schooler, 1974, and Fullerton, 1980)

STAGE	SUBSTAGE	GLACIAL ADVANCE	MORAINE	GLACIAL TILL UNIT	GLACIAL LACUSTRINE UNIT	Before AGE (~~BEYOND~~ 1950
Wisconsin	Woodfordian	Ashtabula	Girard	Ashtabula		12,950
					Maumee IIIC	
			Ashtabula	Ashtabula		13,600
					Maumee IIIB	
			Painesville	Ashtabula		14,100
					Maumee IIIA	
			Euclid	Ashtabula		
					Maumee II	
	Cary	Hiram	Defiance	Hiram		14,500
		Lavery	Lavery	Lavery		15,500
		Kent	Cleveland	Kent		
	Farmdalian					
	Altonian	Titusville				
Sangamonian?						
Illinoian?		Maple Dale				
Pre-Illinoian?		Slippery Rock				

site?

Each successive glacial advance extended a lessor distance into northwestern Pennsylvania. The last three advances--the Lavery, Hiram and Ashtabula--extended only a few miles beyond the present Lake Erie shoreline. A series of closely spaced ridges parallel to the lake shore correspond to the end of each of these three glacial advances. These ridges, which are termed end moraines, consist of glacial till that were transported by and deposited at the leading edge of the ice that corresponds to each of the advances.

The Ashtabula advance had four minor subadvances and associated retreats. As a result the Ashtabula moraine can be subdivided into four additional moraines termed (from oldest to youngest) Euclid, Painesville, Ashtabula and Girard. This series of moraine ridges was termed the "Lake Escarpment Moraine System" by Leverett (1902). The Girard moraine was deposited as recently as 12,950 years before present (Fullerton, 1980).

A glacial meltwater lake filled the present day Erie basin contemporaneous with the Ashtabula advances. This lake, termed Maumee III, was dammed by the Ashtabula ice and drained westward to an outlet at Fort Wayne, Indiana. Maumee III had a surface elevation of approximatly 780 feet based upon the elevation of existing beach strand lines and ridges associated with this glacial lake (Schooler, 1974). As the Ashtabula ice temporarilly receded, the waters of Maumee III inundated the area between the ice front and the previously deposited moraine into which lacustrine deposits were then laid down. These lacustrine deposits were, in turn, overun by a successive ice advance with the deposition of additional glacial till. In this manner, a series of glacial tills corresponding to each of the Ashtabula end moraines was deposited in the area, each of which was separated by continuous deposits of glaciolacustrine material laid down during the inundation by glacial Lake Maumee III.

The vicinity of the Shopes site is depicted on Figure 3.2. The overlay to this figure depicts the surficial glacial deposits as they have been mapped by Schooler (1974). Of primary interest are the Ashtabula and Girard end moraines and a beach ridge formed along the shorline of the last inundation of Lake Maumee III.

3.2 Site Geology

Detailed descriptions of the materials encountered on site are presented on the boring logs in the Appendix to this report. The soil descriptions presented are based on visual examination, the results of laboratory grain size analysis, and index testing. The descriptions are in accordance with a modification of the soil classification system suggested by D. M. Burmister (1958). An outline of the modified Burmister system used in this study is presented on the "Key to Soils Identification", in Appendix B. The results of the laboratory tests are presented in Appendix D. The geologic strata are graphically depicted on the hydrogeologic cross sections on sheets 5 and 6 in the map pocket at the back of this report.

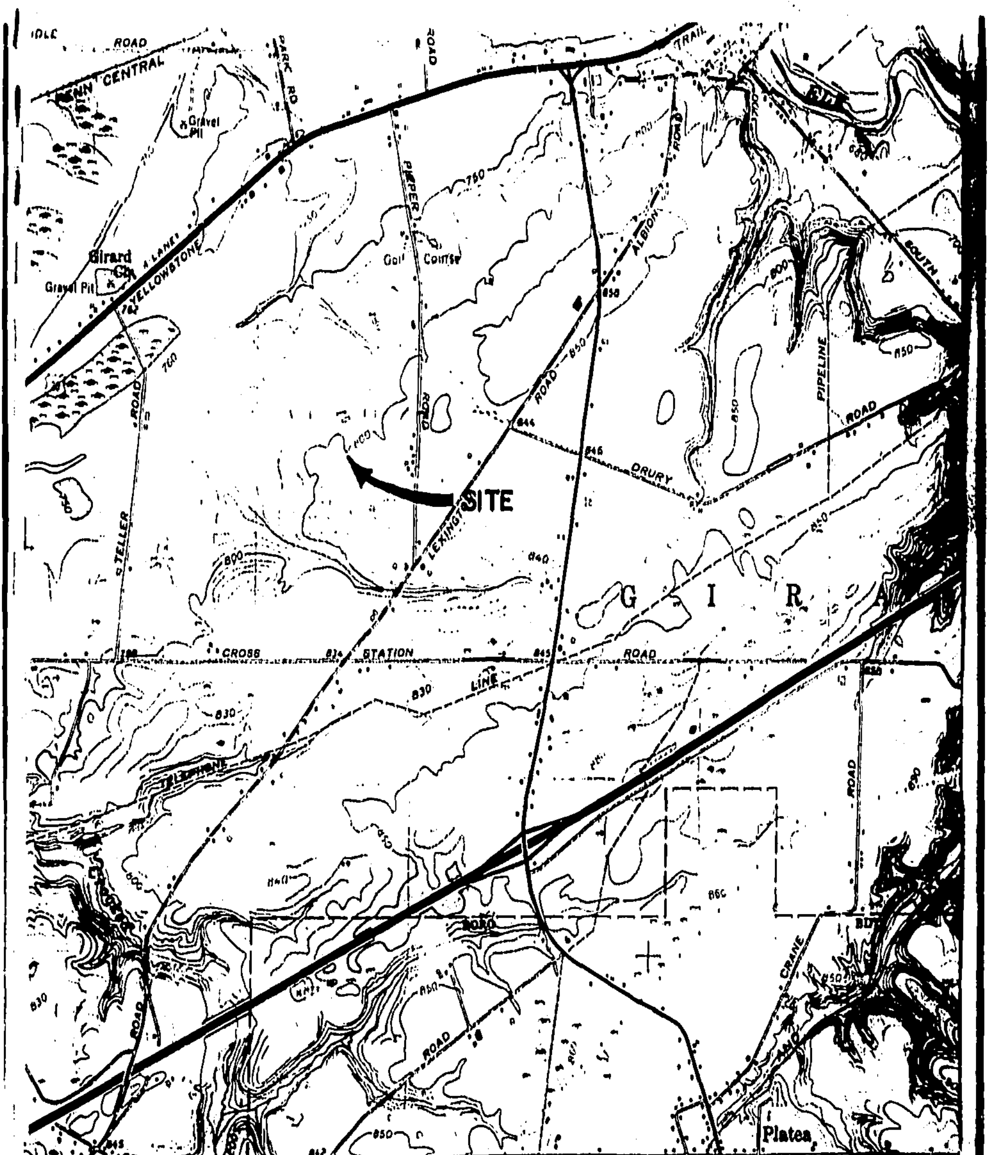

FIGURE 3.2A
LOCATION MAP OF
SHOPE'S [illegible]

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FROM: ALBION, PA. (1960, REV., 1977) USGS QUADRANGLE

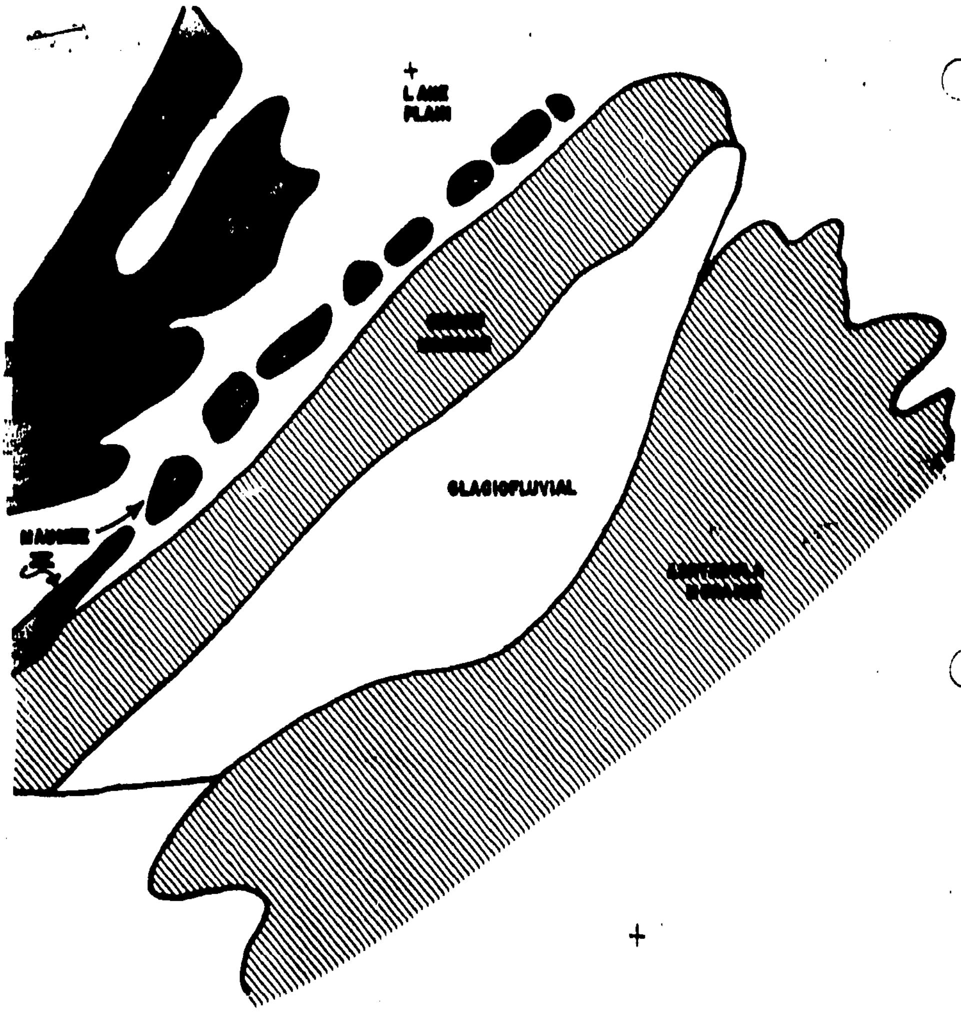

FIGURE 3.2B
REGIONAL SURFICIAL GEOLOGIC OVERLAY

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The geologic units that underlie the site have previously been described as they occur on a regional basis. The following sections will provide a more detailed description of these units as they were encountered beneath the Shope's site. The units will be described in reverse stratigraphic sequence, that is, in the order in which they were encountered from the land surface. In general, these units consist of a sequence of interbedded glacial tills and glaciolacustrine deposits with minor occurrences of glaciofluvial deposits. Bedrock has not been encountered in any of the borings that have been drilled, to date, at the Shope's site.

3.2.1 Glaciofluvial Deposits

Glaciofluvial deposits are found as a veneer of sediments only on the topographically higher areas of the southern portion of the site. These deposits range in thickness up to five feet. This unit is composed predominantly of stratified sand with minor amounts of silt. The glaciofluvial deposits represent the reworking of the glacial till by glacial meltwater along the margin of the retreating glacial ice.

3.2.2 Ashtabula Till

The Ashtabula Till has been encountered in all of the areas of the site that have been investigated. In all, four separate subunits of the Ashtabula Till have been observed. These subunits correspond to the Painesville, Ashtabula, Girard subadvances and possibly a later subadvance of the Ashtabula ice sheet as indicated on Table 3.1. Each subunit is described as follows:

<u>Girard Subunit</u>

The uppermost subunit of the Ashtabula Till corresponds to the last readvance of the Ashtabula ice sheet that occurred subsequent to the inundation by Lake Maumee III. This till forms the Girard Moraine which is the northern most ridge in the Lake Moraine System. This till has been observed only at the western limit of the study area in borings W-22 and W-24 at thicknesses ranging up to 8 feet. This subunit is relatively coarse grained consisting typically of "SAND, some to and Gravel, little to some Silt & Clay." The coarse grained nature of this till probably represents the scouring and subsequent redeposition of glacial lake beach deposits.

<u>Ashtabula Subunit</u>

The Ashtabula subunit was encountered in all of the borings in the study area, ranging in thickness from 7 to 42 feet. This subunit is predominately fine grained, consisting of "Clayey SILT, little to and SAND trace to little Gravel." Laboratory permeability tests conducted on this subunit indicate a mean permeability value of 1.2 x [illegible] Coarser grained deposits within this till subunit were observed in a number of borings, particularly in southern portions of the study area in the vicinity of the disposal area. These coarser grained deposits probably represent the reworking of lacustrine beach deposits and consist typically of "SAND, little to some Silt, trace to little Gravel". k = ?

Painesville Subunit

The Painesville subunit of the Ashtabula till was found to be substantially more fine grained than the overlying tills with a thickness ranging from 14 to 41 feet. This till, which was encountered in all of the deep borings, consists typically of "Clayey SILT, little to and SAND, trace Gravel". However, occasional coarse grained zones consisting of "SAND, little to some Silt, little to and Gravel" occur discontinuously within this subunit. It is believed that the bulk permeability of this subunit is somewhat less than 1 x 10^{-7} cm\sec on the basis of the visual differences in grain size between this subunit and the Ashtabula subunit compared to the measured permeability of the Ashtabula.

Euclid Subunit

The upper surface of the Euclid subunit was encountered in only two of the deepest borings W-20 and W- 21. However, the entire subunit is believed to continuously underlie the entire study area. The Euclid was observed to consist typically of SILT & CLAY, trace to little Sand, trace Gravel. The permeability of this subunit is presumed to be low.

3.2.3 Maumee III Lacustrine Deposits

Lacustrine deposits corresponding to Lake Maumee III have been observed as interbedded sequences between each of the subunits of the Ashtabula Till. The Maumee III has been subdivided, for the purpose of this report, into three subunits based upon their position relative to the till subunits. These lacustrine subunits have been designated Maumee III A, III B, and III C, as indicated on the geologic cross sections, sheets 5 and 6. The subunits of the Maumee III lacustrine deposits are described as follows:

III C Subunit

The III C was exposed at the ground surface and\or was encountered at shallow depth in nearly all of the borings. This subunit ranges in thickness from 10 to 31 feet. The III C is predominantly coarse grained and probably representative of lake shore, beach deposition. It consists typically of "SAND, trace to and Silt, trace to and Gravel," frequently interbedded with laminations of Silt & [illegible] permeability of the III C subunit is approximatly 1 x 10^{-4} cm\sec.

Fine grained zones of the III C were also encountered in a number of borings. These deposits consist of "laminated SILT & CLAY, none to and SAND". The mean permeability from two laboratory tests was determined to be 4.8×10^{-7} cm\sec.

vertical

IIIB Subunit

The IIIB subunit was encountered at intermediate depths beneath the study area at a thickness ranging between 5 and 24 feet. This subunit consists alternately of relatively coarse zones and fine zones with mean permeability values demonstrated to be 2×10^{-6} cm/sec and 1.4×10^{-7} cm/sec, respectively. The coarse zones can be described as "stratified fine SAND, trace to some Silt, trace to and Gravel", occasionally interbedded with laminations of Silt & Clay. The finer grained zones typically consist of "laminated SILT, trace to some Sand."

IIIA Subunit

The IIIA subunit was encountered at the bottom of each of the deep borings at a thickness ranging from 14 to more than 20 feet. The IIIA is more fine grained than the overlying lacustrine deposits, and is probably representative of an off-shore depositional environment. However, these coarser grained zones were occasionally encountered in each of the borings in which the deepest wells were screened. The fine grained zones consist of "laminated CLAY & SILT, no to little Sand, no to trace Gravel." The coarse zones consist of "stratified fine SAND, no to some Silt" and possess a mean permeability determined to be 1.6×10^{-5} cm/sec.

4.0 GROUNDWATER CONDITIONS

The geologic conditions beneath the study area have been described in detail in the preceeding section. This section describes the occurrence of groundwater as it is contained within the geologic framework. Groundwater has been observed to occur within three zones beneath the Shope's study area:

1. As an unconfined water table zone within the shallow soils.
2. As an intermediate depth confined zone within the coarser grained soils of the Maumee III B and the coarse-grained Ashtabula Till.
3. As a deep confined zone within the coarser grained deposits of the Maumee III A.

Monitoring wells have been installed in each of these zones, allowing the determination of their respective piezometric surfaces. Groundwater measurements from all of the monitoring wells are presented in Table 4.1.

Deeper water bearing zones probably exist below those that were studied as a part of this investigation. These zones may be contained within deeper glacial deposits and/or bedrock that underlies the site.

4.1 Water Table Aquifer

An unconfined water table aquifer occurs within the shallow soils beneath the study area and ranges in depth from 15 to 30 feet. These shallow soils primarily consist of the coarse grained Ashtabula Till and Maumee III C lacustrine deposits but intermittently consist of fine grained soils as well. In general, however, these shallow soils are among the most permeable that occur at the site, with an estimated permeability of approximatly $1x10^{-4}$ cm\sec.

The unconfined water table aquifer receives recharge predominantly through direct infiltration of precipitation. As such, the surface of this zone is especially subject to seasonal variations.

The surface of the unconfined aquifer occurs at relatively shallow depths beneath the site, ranging from zero to approximately nine feet below ground surface except below the waste disposal area where it is somewhat deeper. Contours of equal water table elevation were interpolated from water level data obtained from the wells. The water table surface generally reflects the ground surface topography with a gradient ranging from 0.03 to 0.07. The water table surface as shown on Sheet 2 is very similar to that configured by both Harrison (1980) and Wehran (1981).

The direction of lateral groundwater flow is assumed to be perpendicular to the groundwater contours as indicated on the water table contour map. Flow is generally to the north and west. This component of flow presumably discharges to the north and west of the site. The water table surface is shown to be nearly coincident with ground surface in the "northeast seep area", north central seep area" and the low, wet area immediately west of the site.

TABLE 4.1
SHOPE'S LANDFILL
WATER LEVEL DATA

Well	Well Depth	Ground-water Zone *	Ground Surface Elevation	Reference Point Elevation **	December 11, 1985 Water Depth	December 11, 1985 Water Elevation	January 16, 1985 Water Depth	January 16, 1985 Water Elevation
W-1	101.5	Deep	789.7	-	-		46.4	744.87
W-1A	28.0	Int.	790.2	791.87	6.6	785.27	6.8	785.07
W-1B	21.0	WT/Int	790.5	-	-		4.7	786.84
W-1WT	15.0	WT	790.2	793.26	8.65	784.61	8.2	785.06
W-2	61.3	Int.	827.3	829.55	17.55	812.05	17.8	811.75
W-2A	52.5	Int.	826.7	829.01	19.78	809.23	18.0	811.01
W-2B	37.5	WT/Int	827.3	829.55	19.4	810.15	-	829.55
W-2C	29.0	WT/Int	827.3	829.55	-	-	14.8	814.75
W-2WT	24.0	WT	815.5	818.72	-	-	5.9	812.82
W-3	37.0	Int.	799.2	800.66	-	-	5.4	795.26
W-3A	28.0	Int.	799.6	800.79	6.04	794.75	5.2	795.59
W-3B	15.8	WT/Int	800.0	800.84	5.44	795.4	5.2	795.64
W-3C	85.5	Deep	800.0	800.61	11.85	788.76	-	-
W-3WT	13.5	WT	800.2	803.83	-	-	3.8	800.03
W-4	48.8	Int.	794.7	797.22	19.72	777.5	18.0	779.22
W-4A	34.0	Int.	795.0	797.06	14.4	782.66	10.8	786.26
W-4WT	13.5	WT	795.0	796.70	-	-	2.8	793.90
W-5	51.3	Int.	812.5	815.20	13.23	801.97	11.0	804.20
W-5A	41.5	Int.	812.5	815.20	9.76	805.44	8.2	807.00
W-5B	19.3	WT/Int	810.9	814.33	7.44	806.89	5.1	809.23
W-5WT	10.0	WT	812.8	817.73	-	-	6.6	811.13
W-6A	27.2	Int.	790.9	793.60	0.6	793.00	0.2	793.40
W-6WT		WT	791.6	794.75	-	-	4.9	789.85
W-7	48.0	Int.	809.9	811.81	-	-	7.6	804.21
W-7A	107.0	Deep	809.6	812.56	63.15	749.41	64.0	748.56
W-7WT	13.0	WT	809.4	811.62	-	-	3.6	808.02
W-8			794.4	796.86	3.7	793.16	-	-
W-8A	28.5	Int.	794.4	796.86	2.95	793.91	2.4	794.46
W-8WT	9.5	WT	794.6	796.38	-	-	2.2	794.18
W-9	55.0	Int.	795.2	797.38	7.24	790.14	6.7	790.68
W-9A	31.0	Int.	795.2	797.38	2.78	794.68	2.8	794.58
W-9WT	8.5	WT	794.7	797.04	-	-	2.6	794.44

Well	Well Depth	Ground-Water Zone *	Ground Surface Elevation	Reference Point Elevation **	December 11, 1985 Water Depth	December 11, 1985 Water Elevation	January 16, 1985 Water Depth	January 16, 1985 Water Elevation
W-10	57.0	Int.	793.7	795.85	16.82	779.03	16.0	779.85
W-10A	32.5	Int.	793.7	795.85	16.32	779.53	14.4	781.45
W-10WT	24.0	WT	793.7	795.85	-	-	14.5	781.35
W-11	59.0	Int.	781.9	785.07	-	-	5.9	779.17
W-11A	31.1	Int.	781.9	785.07	-	-	6.0	779.07
W-11WT	7.5	WT	782.3	784.98	-	-	5.3	779.68
W-12A	52.5	Int.	788.8	790.83	-	-	7.0	783.83
W-12B	28.0	Int.	788.9	792.23	-	-	8.4	783.83
W-12C	20.0	WT	788.8	791.34	-	-	11.1	780.24
W-12D	94.0	Deep	788.2	791.13	16.5	774.63	43.0	748.13
W-14	11.0	WT	817.3	820.62	-	820.62	13.6	807.02
W-15	13.0	WT	819.1	820.97	17.4	803.57	16.8	804.17
W-16	18.0	WT	818.6	820.67	22.5	798.17	21.9	798.77
W-18	18.0	WT	812.4	816.41	-	816.41	20.2	796.21
W-20A	16.0	WT	787.9	790.52	5.6	784.92	5.8	784.72
W-20B	47.0	Int.	787.4	790.26	-	790.26	0.0	790.26
W-20C	86.0	Deep	788.1	791.14	12.75	778.39	41.9	749.24
W-21A	14.5	WT	782.7	786.04	7.98	778.06	7.1	778.94
W-21B	48.5	Int.	782.8	785.33	7.45	777.88	6.5	778.83
W-21C	105.5	Deep	783.1	785.57	33.46	752.11	33.1	752.47
W-22A	10.5	WT	775.0	777.74	4.4	773.34	4.7	773.04
W-22B	52.0	Int.	775.0	777.32	0.12	777.20	0.0	777.32
W-22C	80.0	Deep	775.0	777.37	29.32	748.05	28.9	748.47
W-23A	13.5	WT	776.5	779.28	3.38	775.90	2.1	777.18
W-23B	37.0	Int.	776.6	779.45	6.22	773.23	4.9	774.55
W-23C	84.0	Deep	776.4	779.09	35.02	744.07	34.7	744.39
W-24A	10.0	WT	783.8	786.66	3.47	783.19	4.2	782.46
W-24B	59.0	Int.	783.5	786.47	9.9	776.57	9.3	777.17
W-24C	86.0	Deep	783.1	786.03	42.95	743.08	42.6	743.43
W-25WT	15.0	WT	786.1	789.18	3.7	785.48	3.8	785.38

Notes: * Groundwater zones abbreviated as follows:

WT=Water Table Aquifer; Int.=Intermediate Depth Confined Zone; Deep=Deep Confined Zone

** Reference points as follows:
- -wells with steel protective casings: top of casing with cap off
- -steel wells without protective casings: top of locking cap with cap opened
- -PVC wells without protective casings: top of PVC with cap off.

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Therefore, these specific areas are most likely receiving groundwater discharge from the water table aquifer.

Slight vertical components of flow have been identified within the water table aquifer. A small downward flow component is present in the topographically higher areas and a slight upward flow component is present in the low lying discharge areas. This vertical flow would be expected to be somewhat more pronounced in the lower permeability soils but nearly absent in the coarse grained high permeability soils in which horizontal flow would be predominate.

The rate of horizontal groundwater flow within the water table aquifer can be estimated through the use of Equation 4.1

$$Vs = \frac{Ki}{N_e} \qquad \text{Eq. } 4.1$$

Where:

Vs = seepage velocity (cm\sec)
K = permeability (cm\sec)
i = hydraulic gradient (dimensionless)
N_e = effective porosity (dimensionless)

The permeability has been estimated to be $1x10^{-4}$ cm\sec. The average hydraulic gradient is 0.05. A typical value of the effective porosity can be assumed to be 0.3 (Freeze and Cherry, 1979). Insegting the above data in Equation 4.1 yields a horizontal flow rate of $1.7x10^{-5}$ cm\sec or 0.047 ft\day.

$$Vs = \frac{(1x10^{-4})\ (0.05)}{0.3}$$

$$= 1.7 \times 10^{-5} \text{ cm\sec} = 17 \text{ ft/yr}$$

4.2 Intermediate Depth Confined Zone

Groundwater occurs under confined conditions in a laterally continuous zone beneath the entire site. The confined zone is found primarily in the coarse grained soils of the Maumee III B lacustrine deposits but is also found in the coarse grained Ashtabula Till beneath the southern portion of the site. The geologic deposits comprising this zone have a moderately low permeability shown previously from in-situ test results to be on the order of $2x10^{-6}$ cm\sec. Further analysis, discussed subsequently, indicates that the actual permeability of this unit is probably somewhat higher, on the order of $5x10^{-5}$ cm\sec. However this unit cannot truly be termed an aquifer as it probably would not be capable of transmitting significant quantities of water under ordinary hydraulic gradients (Freeze and Cherry, 1979). Therefore, this unit will be termed a "water bearing zone". This water bearing zone is almost completly confined by overlying fine grained till and lacustrine deposits represented, respectively, by the Ashtabula subunit and the Maumee III B subunit. The permeability of these subunits has previously been [illegible] by laboratory testing to be on the order of $1x10^{-7}$ cm\sec.

B:

based on 2.7?

An area has been identified beneath the disposal area in which full confinement of this zone is not afforded, (Cross-Section B-B, Sheet 6). In this area, the potential exists for hydraulic communication between the overlying water table zone and the intermediate depth confined zone

The piezometric surface has been defined through the use of water level measurements from monitoring wells screened in the Maumee III B at elevations ranging from 723 to 760 feet. The use of water levels from slightly shallower monitoring wells in the same zone would have yielded a very similar piezometric surface configuration. The configuration of this surface has been depicted on the Intermediate Depth Piezometric Surface Contour Map (Sheet 3). This surface is shown to slope to the north west in a similar but more subdued manner than that of the overlying water table zone. The configuration of these contours is very similar to that which was depicted by Harrison (1980).

The intermediate depth confined zone receives recharge from the area south of the site where the Maumee III B is believed to outcrop at the surface. Flow through the zone is primarily horizontal toward the northwest to a discharge area represented by a low lying area beyond the border of the study area.

The direction of vertical flow through the overlying confining layer tends to be variable and is dependent upon the topographic position of the water table aquifer. In the topographically higher areas of the site such as beneath the landfill and the hill at W-2, the water table surface is significantly higher than the piezometric surface in the intermediate confined zone. This provides the potential for downward flow through the confining layer and through gaps in the confining layer that have been identified beneath the disposal area. In the topographically lower areas of the site such as the area to the north of the landfill, the piezometric surface is higher than the water table surface. In fact, at several locations, such as W-20 and W-22, the piezometric surface is above the ground surface. Under these conditions, the potential exists for upward flow through the confining layer. However, the actual rate of vertical flow through the confining layer is very slow, being limited by the low permeability of the unit.

The rate of horizontal flow through the intermediate depth confined zone can be estimated with the use of Equation 4.1. The data required for this calculation includes the permeability and hydraulic gradient that have been determined, respectively, to be $2x10^{-6}$ cm\sec and 0.05 and an effective porosity assumed to be 0.3.

$$Vs = \frac{(2x10^{-6})\ (0.05)}{0.3}$$

$$= 3.3x10^{-7} \text{ cm\sec} = 0.34 \text{ ft/yr}$$

It is known that the contaminants within this zone have involved approximately 200 feet over a period of 25 years. Back calulating on the basis of a flow rate of 8 ft/yr indicates that the in-situ permeability values that have been

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Absolute BS!

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incorporated in the initial calculation may not be representative of the unit as a whole. A more typical permeability value for the intermediate confined zone would appear to be approximatly 5×10^{-5} cm\sec.

OK

4.3 Deep Confined Zone

A deep confined water bearing zone has been identified at a depth ranging from approximatly 75 to 105 feet below the ground surface. This zone is contained within the coarser grained layers of the Maumee III A lacustrine deposits. The Maumee III A has been described previously as possessing a permeability on the order of 1×10^{-5} cm\sec. This zone is fully confined by the tills represented by the Ashtabula subunit with a permeability anticipated to be less than 1×10^{-7} cm\sec.

The piezometric surface in this deep zone has been depicted on the Deep Confined Zone, Piezometric Contour Map (Sheet 4). This map was prepared from water level measurements obtained from the deepest site wells. However, the water level datum from one well, W-3, was omitted from this map. This particular datum is believed to be in error based upon a comparison of water levels from the other wells on the same date and the data from the same well, W-3, on subsequent dates. The piezometric surface indicates, contrary to the shallower groundwater zones, that groundwater in the deep confined zone flows toward the southwest. Furthermore, the piezometric surface in this zone is very deep, some 25 to 50 feet deeper than that of the overlying zones.

The deep confined zone probably receives its recharge through the slow downward flow through the confining layer that necessarily would occur under the influence of the considerable downward vertical gradient that has been identified. The lateral flow direction within this zone was observed to be parallel to the strike of the glacial deposition. That is, this groundwater flow path passes through soil that should be fairly consistent in type and depth. This flow path is shown to be directly to the regionally low area represented by Crooked Creek. Therefore, Crooked Creek most likely serves as the discharge point of this deep confined zone.

The rate of recharge to the deep confined zone is likely to be very slow on account of the low permeability of the confining layer. This rate can be calculated with the use of Equation 4.1. The permeability of the confining layer is conservatively stated at 1×10^{-7} cm/sec. The vertical hydraulic gradient across the confining layer at W-12 is calculated to be 1.0. The effective porosity is assumed to be 0.3. On the basis of these data groundwater moves downward through the confining layer at a rate of 3.3×10^{-7} cm/sec or 0.001 ft/day.

$$V_s = \frac{(1 \times 10^{-7})(1.0)}{0.3}$$

OK

$$= 3.3 \times 10^{-7} \text{ cm/sec} = 0.34 \text{ ft/yr}$$

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The rate of horizontal flow through the deep confined zone can also be calculated with the use of Equation 4.1. The permeability of the zone has been shown to be 1 x 10^{-5} cm/sec, the hydraulic gradient is approximately 0.01 and the effective porosity is assumed to be 0.3. Based upon these data it can be seen that water moves through this zone at a very slow rate of approximately 0.001 ft/day.

Based on what?

$$V = \frac{(1 \times 10^{-5})(0.01)}{0.3}$$

$$= 3.3 \times 10^{-7} \text{ cm/sec} = 0.34 \text{ ft/yr}$$

4.4 Hydrogeologic Cross Section

A hydrogeologic cross section has been prepared (Sheet 7) in order to further define groundwater flow directions and the interrelationships between the various water bearing zones. The hydrogeologic section is drawn along the same orientation as the Geologic Cross Section B-B. Of particular note is that the hydrogeologic section depicts the vertical distribution of potential, or hydraulic head, through the geologic cross section. It achieves this by means of portraying lines of equal potential, or head, which are known as equipotential lines. By knowing the position of the equipotential lines, directions of groundwater movement throughout the cross section can be depicted. This results from the fact that the laws of groundwater hydraulics dictate that groundwater flow must be at right angles to the equipotentials. Although the exaggerated scale of the section (necessary for clarity) distorts the orthogonality to a degree, groundwater flow patterns are clearly outlined by the flow arrows accompanying the equipotentials.

This hydrogeologic section is not intended to be a rigorous quantitative representation of the actual system, but is intended to qualitatively portray the direction and relative quantity of groundwater flow.

The hydrogeologic section is based upon a number of assumptions that are consistent with the previous discussion. These assumptions are as follows:

- Water table aquifer represented by coarse grained Ashtabula Till and coarse grained Maumee IIIC lacustrine deposits.

- Intermediate water bearing zone represented by coarse grained Ashtabula Till and coarse grained Maumee IIIB lacustrine deposits.

- Deep water bearing zone represented by coarse grained Maumee IIIA lacustrine deposits.

- Confining layer (aquitards) represented by fine grained Ashtabula Till and fine grained Maumee III lacustrine deposits.

- Water table surface and piezometric surfaces as depicted on the respective contour maps.

The pattern and rates of groundwater flow can be summarized based upon the hydrogeologic cross sections, the groundwater contour maps, and the previously described calculations. Furthurmore, Table 4.2 summarizes the values for permeability, porosity, hydraulic gradient porosity, and ground water flow rates for each of the described strata.

A shallow water table aquifer exists within the highly permeable surficial soils which receive recharge directly from infiltrating precipitation. Lateral flow takes place to the north and west. Partial discharge of the water occurs in the low lying areas on the margin of the site.

An intermediate depth water bearing zone is confined by an aquitard that is nearly continuous beneath the study area. Water enters this moderately low peremability zone through infiltration of precipitation in a recharge area south of the site and through leakage through gaps in the confining layer. Flow within this zone is predominantly in a lateral direction toward discharge areas located beyond the site margin.

A deep water bearing zone is fully confined by a thick low permeability aquitard. Water enters this zone primarily through slow leakage downward through the aquitard under the influence of a strong downward gradient but limited by the low permeability of the unit. Due to the small volume of recharge to this confined zone, little driving force exists to cause water movement in a lateral direction. Therefore, lateral flow occurs slowly under a very low hydraulic gradient toward the southwest to be discharged to Crooked Creek.

Table 4.2
Summary Of Hydrogeologic Data

Hydrogeologic Zone	Permeability (cm/sec)	Porosity Dimensionless	Hydraulic Gradient (Dimensionless)	Groundwater Flow Rate (ft/yr)
Horizontal Flow				
Water Table Aquifer	$1x10^{-4}$	0.3	0.05	17
Intermediate Depth Confined Zone	$5x10^{-5}$	0.3	0.05	8
Deep Confined Zone	$1x10^{-5}$	0.3	0.01	0.34
Vertical Flow				
Deep Confining Layer	$1x10^{-7}$	0.3	1.0	0.34

5.0 GROUNDWATER QUALITY

The perspective gained from the analysis of groundwater flow conditions has aided greatly in the interpretation of groundwater quality data. This has allowed the determination and prediction of groundwater contaminant flow on a vertical basis as well as a lateral basis, something that was not possible at the time that the March 1984 Groundwater Quality Study (Wehran) was prepared.

Groundwater samples were obtained from all of the newly installed monitoring wells during January and April 1985, by personnel from Lord. These wells were sampled by the means of an ISCO Model 2600 submersible bladder pump. The pump was decontamination in the field prior to use in each of the wells. However, tubing used within the pump for the April sampling event was permanantly dedicated to each well. The sample analyses were performed by Lord. The parameters for which the samples were analyzed include a list of chlorinated and non-chlorinated hydrocarbons referred to in the Draft Long Term Monitoring Plan as Category A and C parameters, respectively. In addition, the samples were subjected to a total volatile organic scan (TVO) and a total halogenated volatile organic scan (THVO) in accordance with the method described in the Draft Long Term Monitoring Plan.

Groundwater samples have also been collected and analyzed from selected previously existing wells, as a part of the current monitoring plan. These wells were sampled both in December 1984, and March 1985, by personnel from Lord. The samples were analyzed for the same parameters as the newly installed wells in addition to a number of metals and indicator analyses.

The TVO and THVO data from selected wells that were sampled as described above have been utilized for this water quality evaluation. These data are tabulated on Table 5.1. The well data have been separated into those from wells screened in the water table, the intermediate, and deep zones. In the case where more than one well is screened in a particular zone, only the data from the more contaminated well have been presented. Water quality data for Chloride, Specific Conductance, and metals are not available for the newly installed wells. Therefore, these parameters have not been utilized in this evaluation of water quality.

The shallow water table zone appears to be relatively uncontaminated on the basis of TVO and THVO data with the exception of the two wells located immediately downgradient of the disposal area. Wells W-1WT and W-3WT each had elevated levels of THVO in Dec/Jan at 51.4 ppb and 107.3 ppb, respectively. The THVO in 3WT decreased to BT in April. Levels of TVO in all wells, including W-1WT and W-3WT, were below the threshold.

In contrast to the conditions in the water table zone, the intermediate water bearing zone appears to be significantly contaminated. On the basis of the most recent TVO data, it appears that a contamination plume has spread approximately 200 feet downgradient of the margin of the waste disposal area. TVO levels within this plume range from a high of 48,357.5 ppb in well W-3 in Dec/Jan downward to the TVO threshold level of 100 ppb which is [illegible] be the outer margin of the plume. THVO levels within the plume closely print all sites, not just 6?

TABLE 5.1
SUMMARY OF TVO & THVO DATA
12/84 - 1/85

Water Table Zone			Intermediate Zone			Deep Zone		
Well	TVO	THVO	Well	TVO	THVO	Well	TVO	THVO
1WT	BT	51.4	1B	378	54.1	1	710	159
3WT	BT	107	3	48,400	765	3C	363	361
4WT	BT	BT	4A	172	173	-		
5WT	BT	BT	-			-		
6WT	BT	BT	6A	BT	BT	-		
7WT	BT	BT	-			7A	BT	28.5
8WT	BT	BT	-			-		
9WT	BT	BT	9A	BT	BT	-		
10WT	BT	BT	10	BT	BT	-		
11WT	BT	BT	11A	112	169	-		
12C	BT	BT	12A	BT	55.1	12D	BT	64.9
20A	BT	29.6	20B	2350	28.6	20C	815	BT
21A	BT	BT	21B	BT	BT	21C	BT	BT
22A	BT	BT	22B	BT	30.1	22C	BT	40.8
23A	BT	-	23B	BT	29.2	23C	BT	BT
24A	BT	BT	24B	BT	28.9	24C	BT	BT
25WT	BT	BT	-					
				4/85-5/85				
1WT	BT	54.8	1B	324	BT	1	365	85.2
3WT	BT	BT	3	40,100	736	3C	1050	52.3
4WT	BT	BT	4A	112	BT	-		
5WT	BT	BT	-			-		
6WT	BT	BT	-			-		
7WT	BT	BT	-			7A	BT	BT
9WT	BT	BT	-			-		
10WT	BT	BT	10	BT	BT	-		
11WT	BT	BT	-			-		
12C	BT	BT	12A	BT	BT	120	BT	BT
20A	BT	BT	20B	2,720	3.53	20C	1630	BT
21A	BT	BT	21B	BT	BT	21C	BT	30.9
22A	BT	BT	22B	BT	BT	22C	BT	BT
23A	BT	BT	23B	BT	50.0	23C	BT	BT
24A	BT	BT	24B	BT	27.3	24C	117	45.6
25WT	BT	BT	-	-	-	-	-	-

NOTES:
* Indicates data from samples collected 8/83
Bt indicates sample level does not exceed threshold levels, or follows:
TVO-100ppb
THVO-25ppb

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parallel the TVO levels. An exception to this is well W-12A in which the Dec/Jan THVO level of 55.1 was somewhat above the respective 25 ppm threshold while the TVO level at 66.6 ppb was somewhat below the respective 100 ppm threshold, suggesting that well W-12A is located on the edge of the existing plume. However, both TVO and THVO in 12A decreased to BT in March/April. The contamination plume within the intermediate zone is depicted on Sheet 8 on the basis of the TVO data.

So?

It is not possible to draw any firm conclusion as to water quality in the deep water bearing zone on the basis of the available data. It is believed that this deep zone is uncontaminated due to the fact that it is fully confined by a thick, continuous low permeability glacial till unit. However, this cannot be demonstrated at this time because no wells exist in the deep zone in a downgradient direction from the site. This is so because it has been determined that the deep zone flows to the southwest, which is nearly opposite of the flow direction of the overlying water table and intermediate zones.

Several of the deep wells located to the northwest of the site, W-1, W-3C, and W-12D, exhibit contaminant levels in excess of the threshold levels. However, based upon the observed hydrogeologic conditions as previously described, it is believed that these wells should not be contaminated.

The elevated levels of TVO and THVO in well W-1 which ranges from 3 to 7 times above the threshold are probably a result of preferential migration downward through the well seal. This may be because this is an older well which may have been installed using methods that would be considered outdated today, and because this well is under the influence of a significant downward gradient.

Despite the careful drilling and well installation practices that have been followed in the construction of W-3C and W-12D, it is possible that contaminants could have been carried down to the completion depth of these wells by the drilling process. Adequate development of these wells has been difficult to achieve due to the moderately low permeability of the strata in which they are screened. This has prevented rapid flushing of these wells. Therefore, it is likely that contaminants carried downward by drilling simply have not been removed from these wells by the development and well purging that have been conducted to date. However, continued purging of these wells over a period of several months has failed to achieve significant improvement in these wells.

The water quality in both the intermediate and deep zones at well location W-20B and W-20C, provides a paradox as compared to the other existing data. The intermediate zone at W-20B is relatively contaminated with a TVO level ranging up to 2720 ppb. This contamination has been corroborated by noticable odors in undisturbed Shelby tube soil samples that have been collected at intermediate depths in the boring in which this well was constructed. It is difficult to explain this contamination because W-20B is located cross gradient, not downgradient from the site. Furthermore, the observed contamination plume emanating from the site is separated from well W-20B by an uncontaminated well, W-9A, which makes it even more difficult [illegible] contamination in this well. This data suggests the possibility of a separate contaminant source other than the Shope's disposal area.

On the basis of the observed hydrogeologic conditions, it is most likely that the deep well, W-20C, is not actually contaminated. It is possible that the elevated TVO value of 814.9 ppb is a result of relict contamination from the drilling process in the same manner as that discussed for W-3C and W-12D. It is also conceivable that apparent contamination in this well could be attributed to preferential migration through the well seal.

In summary, groundwater within the shallow water table zone remains relatively uncontaminated except for that on the immediate margin of the site. The bulk of the groundwater contaminants have moved downward into the underlying intermediate zone under the influence of the downward vertical gradient that has been shown to exist beneath the entire disposal area. Contaminated groundwater within this intermediate zone has moved laterally to the northwest of the disposal area. The water bearing zone in the deep zone is confined from the overlying zones by a thick, low permeability till unit and is believed to be uncontaminated. Groundwater flow in this deep zone is toward the southwest.

6.0 CONCLUSIONS

The most significant aspects of the hydrogeologic investigation are summarized, as follows:

1) The study area is underlain by a thick sequence of glacial deposits. These deposits consist alternately of at least four continuous glacial tills interbedded with at least three continuous glaciolacustrine units.

2) Bedrock exists beneath the glacial deposits and consists of a Devonian shale. This bedrock has not been encountered during this investigtion on account of its great depth.

3) An unconfined water table aquifer exists within the surficial coarse grained tills and lacustrine deposits. Lateral flow within this shallow zone is toward the north and west in response to the ground surface topography.

4) An intermediate depth confined groundwater zone exists primarily within the relatively coarse grained materials of an interbedded lacustrine unit. The permeability of this unit is not sufficiently high for this zone to be termed an aquifer. Groundwater moves through this intermediate confined zone to the north and west at a relatively slow rate. This zone receives recharge from a recharge area located south of the site and through leakage and gaps in the confining layer beneath the disposal area. ~no

5) *A deep confined zone exists within a deeper interbedded lacustrine unit.* This unit flows to the southwest to a discharge area represented by Crooked Creek.

6) Groundwater contamination has been identified in the water table only on the downgradient margin of the disposal area. Contaminants have moved downward into the underlying intermediate depth confined zone under the influence of downward vertical gradients that exist beneath the disposal area. Contaminants have moved laterally within the intermediate zone to a point approximately 200 feet northwest of the disposal area. Groundwater within the deep confined zone is believed to be uncontaminated.

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APPENDIX A

TEST BORING LOG

THE AWARE CORPORATION

BORING NO. W-1WT (replacement)

PROJECT: SHORE'S LANDFILL	SHEET NO. 1 of 1
CLIENT: LORD CORP	PROJECT NO.: 6278
CONTRACTOR: EMPIRE SOIL	EQUIPMENT: CME-45 (TRAILER)

	RISER	INTAKE
TYPE	BLACK STEEL	STAINLESS
DIAMETER	2"	2"
COUPLING	WELDED	WELDED

DRILLING METHOD: AUGER

	CASING	SAMPLER	CORE	TUBE
TYPE	HSA	SS		
DIAM	3 3/4"	2"		
WEIGHT		140#		
FALL		30"		

	GROUND	WELL	PROTCSG
ELEV.:	790.2		793.26

DATE STARTED: 12/13/84
DATE COMPLETED: 12/13/84
DRILLER: SWINNICH
INSPECTOR: MACMILLIN

WELL CONSTRUCTION: Riser, Sand Pack, Bentonite Seal

DEPTH FT.	SAMPLE NO.	TYPE	BLOWS PER 6 inches	CLASSIFICATION	REMARKS
0	1	SS	3-10-9/0.2	FILL	
	2	SS	10-9 / 8-8	CLAY & SILT, some f Sand, little f Gravel, (reworked Glacial Till)	
5	3	SS	9-11 / 10-7	occ wood fragments	
	4	SS	14-12 / 11-11		
	5	SS	3-4 / 6-7		
10	6	SS	5-6 / 8-8	12'	
	7	SS	7-12 / 14-14	MAUMEE IIIc LACUSTRINE laminated SILT, some f Sand, occ med SAND interbeds 14'	
15	8	SS	4-6 / 8-10	ASHTABULA TILL SILT & CLAY, some f Sand, little f Gravel 16'	
				End of boring	

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THE AWARE CORPORATION

TEST BORING LOG

BORING NO. W-3C

PROJECT:	S HOPES LANDFILL	SHEET NO.	1 of 2
CLIENT:	LORD CORP	PROJECT NO.:	62-78
CONTRACTOR:	EMPIRE SOIL	EQUIPMENT:	ACKER 82

	RISER	INTAKE
TYPE	BLACK STEEL	STAINLESS
DIAMETER	2"	2"
COUPLING	WELDED	WELDED

DRILLING METHOD: AUGER / ROTARY

	CASING	SAMPLER	CORE	TUBE
TYPE	H.S.A.	SS		
DIAM	3¼"	2"		
WEIGHT		140#		
FALL		30"		

	GROUND	WELL	PROT. CSG
ELEV.:	800.0		800.61

DATE STARTED: 11/29/84

DATE COMPLETED: 12/5/84

DRILLER: SKURA

INSPECTOR: MACMILLIN

WELL CONSTRUCTION: Locking Cap; Riser; Cement-Bentonite Grout

DEPTH FT.	SAMPLE NO.	TYPE	BLOWS PER 6 inches	CLASSIFICATION	REMARKS
0	1	SS	3-2 / 4-2	MAUMEE III LACUSTRINE (Silt) laminated SILT & CLAY, interbedded w/ f-m SAND, some Silt & Clay	
5	2	SS	4-7 / 7-6		
10	3	SS	5-8 / 7-8	@ 9', become gray stratified SILT, some f Sand	become saturated @ 9'
				±12'	
15	4	SS	7-7 / 7-8	(Sand) grading to f SAND, little Silt. @ 15.5, become c-m SAND, little fs and f GRAVEL	
				19.5'	
20	5	SS	8-8 / 10-12	ASTABULA TILL (Coarse) m-f GRAVEL, some c-m-f Sand, some Silt & Clay, non-stratified, non sorted	Apparent solvent odor 19'-50', become less distinct with depth
25	6	SS	15-15 / 25-23		
30	7	SS	10-10 / 15-14		
				34.5'	
35	8	SS	5-4 / 6-7	MAUMEE III LACUSTRINE (Sand) f SAND, little Silt, stratified	
				39'	
40	9	SS	8-10 / 12-12	(Silt) laminated SILT, little f Sand, occ to freq interbedds f Sand.	
				45'	
45	10	SS	20-10 / 20-14	ASHTABULA TILL (Coarse)	

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THE AWARE CORPORATION

TEST BORING LOG

BORING NO. W-3C

PROJECT: SHOPE'S LANDFILL

CLIENT: LORD CORP

SHEET NO. 2 of 2

PROJECT NO. 6278

WELL CONSTRUCTION	DEPTH FT.	SAMPLE NO.	TYPE	BLOWS PER 6 inches	CLASSIFICATION	REMARKS
Cement-Bentonite Grout; Riser; Bentonite Slurry Seal					ASHTABULA TILL (Cont'd)	
					f SAND, some f Gravel, some Clayey Silt	
	50	11	SS	50-33 / 27-35	@49', become m SAND, trace Silt, non-stratified	
	55					
					58'	
	60	12	SS	55-100/0.4	(Fine) Clayey SILT, little f Gravel, little f Sand	
	65	13	SS	50-100/0.5		
	70	14	SS	75-100/0.3		
	75	15	SS	100/0.5		
Sand Pack					@ 79', become, SILT & CLAY, little f Sand, trace f-m Gravel	
	80	16	SS	100/0.5		
					±82'	
					MAUMEE III LACUSTRINE (Sand)	
	85	17	SS	40-60 / 103-65	med SAND, well sorted	
					88'	
					End of boring.	
	90					
	95					AR300039

TEST BORING LOG

THE AWARE CORPORATION

BORING NO. W-7A

PROJECT: SHOPES LANDFILL
CLIENT: LORD CORP
SHEET NO. 2 of 3
PROJECT NO. 6279

WELL CONSTRUCTION: Cement-Bentonite Grout; Riser; Bentonite Slurry Seal; Sand Pack

DEPTH FT.	SAMPLE NO.	TYPE	BLOWS PER 6 inches	CLASSIFICATION	REMARKS
	10	SS	12-15 / 19-15	MAUMEE III LAC (Conf'd)	
				gray laminated SILT & CLAY	
50	11	SS	12-13 / 14-16		
				@ 55', become laminated SILT, some f Sand	
55	12	SS	5-5 / 7-5		
				± 58'	
				ASHTABULA TILL (Fine)	
60	13	SS	19-18 / 24-25	CLAY & SILT, and f SAND, little f Gravel	
65	14	SS			
70	15	SS			
75	16	SS			
80				80'	
	17	SS		(Coarse) f SAND, some Clay & Silt, trace f Gravel	
				@ 85', grading to f SAND and SILT & CLAY, little Gravel	
85	18	SS	30-30 / 35-45		
90				90'	
	19	SS	30-30 / 38-40	(Fine) grading to CLAY & SILT, some f Sand, trace Gravel, medium	
95	20	SS	25-28 / 33-30		

AR300040

THE AWARE CORPORATION

TEST BORING LOG

BORING NO. W-7A

PROJECT: SHOPE'S LANDFILL

SHEET NO. 3 of 3

CLIENT: LORD CORP

PROJECT NO. 6278

WELL CONSTRUCTION	DEPTH FT.	SAMPLE NO.	TYPE	BLOWS PER 6 inches	CLASSIFICATION	REMARKS
Sand Pack		20		38-30	ASHTABULA TILL (Cont'd)	
					±99'	
	100				MAUMEE III & LACUSTRINE (Clay & Silt)	
		21		25-35	CLAY & SILT, little Sand trace	
				35-40	Gravel slightly stratified 103'	
					(Sand)	
	105				@ ± 103', become stratified	
		22		20-50	SAND, little Silt	
				60-100	108'	
					End of boring	
	110					

AR300041

THE AWARE CORPORATION

TEST BORING LOG

BORING NO. W-12D

PROJECT: SHORE'S LANDFILL		SHEET NO. 1 of 2	
CLIENT: LORD CORP.		PROJECT NO.: 6278	
CONTRACTOR: EMPIRE SOIL	EQUIPMENT: CME 45 (TRAILER		

	RISER	INTAKE
TYPE	BLACK STEEL	STAINLESS
DIAMETER	2"	2"
COUPLING	WELDED	WELDED

DRILLING METHOD: ROTARY

	CASING	SAMPLER	CORE	TUBE
TYPE	HSA	SS		ST
DIAM	3¾"	2"		3"
WEIGHT		140#		push
FALL		30"		

	GROUND	WELL	PROT.CSG
ELEV.:	789.2		791.19

DATE STARTED: 12/6/84
DATE COMPLETED: 12/13/84
DRILLER: SMITH /
INSPECTOR: MACMILLIN/MUTCH

WELL CONSTRUCTION	DEPTH FT.	SAMPLE NO.	SAMPLE TYPE	BLOWS PER 6 inches	CLASSIFICATION	REMARKS
Locking Cap	0				ASHTAHBULA TILL (Fine)	Drilled adjacent to existing Well Cluster W-12, A-B-C
					4'	
Cement Bentonite Grout	5				MAUMEE III @ LACUSTRINE	For complete soil description in 0'-55' interval, refer to Wehran log
	10					
	15					
	20				21'	
Riser		UD-12 1	ST		ASHTABULA TILL (Fine)	Noticeable odor in tube when opened in laboratory
	25					
	30					
	35					
	40					AR300042
	45				±45.5	
					MAUMEE III @ LACUSTRINE	

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THE AWARE CORPORATION

TEST BORING LOG

BORING NO. W-12D

PROJECT: SHOPE'S LANDFILL

CLIENT: LORD CORP

SHEET NO. 2 of 2

PROJECT NO. 6278

WELL CONSTRUCTION	DEPTH FT.	SAMPLE NO.	TYPE	BLOWS PER 6 inches	CLASSIFICATION	REMARKS
					MAUMEE III LAC (Cont'd) (Silt & Clay) ±48'	
	50				(Sand) ±54'	
	55	1	SS	64-100 100-150	ASHTABULA TILL (Fine) Clayey SILT and m-f SAND, trace fine Gravel	
	60	2	SS	58-50 58		
Bentonite Slurry Seal	65	3	SS	100/0.5'	@65', grading to CLAY & SILT, some f-m Sand, little f-m Gravel	
Riser	70	4	SS	100-100 120		
	75	5	SS	68-61 130	@75', grading to CLAY & SILT, little f-Sand, little to trace Gravel, massive	
	80	6	SS	32-36 64		
	85	7	SS	29-30 64	±88'	
Sand Pack	90	8	SS		MAUMEE III LACUSTRINE (Sand) f SAND, little Silt, freq laminations Silty Clay	Screen 91.5' to 95'
	95	9	SS		(Clay & Silt) @±94', becomes laminated CLAY & SILT 97' End of boring	

AR300043

THE AWARE CORPORATION

TEST BORING LOG

BORING NO. W-20A

PROJECT: SHOPE'S LANDFILL	SHEET NO. 1 of 1
CLIENT: LORD CORP	PROJECT NO.: 6278
CONTRACTOR: EMPIRE SOIL	EQUIPMENT: CME-45 (TRAILER)

	RISER	INTAKE
TYPE	BLACK STEEL	STAINLESS
DIAMETER	2"	2"
COUPLING	WELDED	WELDED

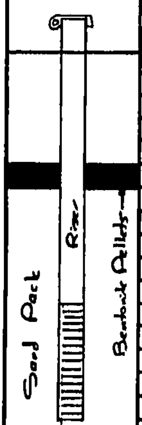
DRILLING METHOD: AUGER

	CASING	SAMPLER	CORE	TUBE
TYPE	H.S.A.			
DIAM	3 3/4"			
WEIGHT				
FALL				

	GROUND	WELL	PROTECTIVE
ELEV.:	787.9		790.82

DATE STARTED: 12/5/84
DATE COMPLETED: 12/5/84
DRILLER: SMITH
INSPECTOR: MACMILLIN

WELL CONSTRUCTION	DEPTH FT.	SAMPLE NO.	SAMPLE TYPE	BLOWS PER 6 Inches	CLASSIFICATION	REMARKS
	0				MAUMEE III ● LACUSTRINE (Sand)	For complete soil description, see log of adjacent boring, W-20C
	5					
	10					
	15				16.5'	
					End of boring	
	20					
	25					
	30					
	35					
	40					
	45					



AR300044

THE AWARE CORPORATION

TEST BORING LOG

BORING NO. W-20B

PROJECT: SHOPE'S LANDFILL	SHEET NO. 1 of 1
CLIENT: LORD CORP	PROJECT NO.: 6278
CONTRACTOR: EMPIRE SOIL	EQUIPMENT: CME 45 (TRAILER)

	RISER	INTAKE
TYPE	BLACK STEEL	STAINLESS
DIAMETER	2"	2"
COUPLING	WELDED	WELDED

DRILLING METHOD: AUGER

	CASING	SAMPLER	CORE	TUBE
TYPE	H.S.A.			ST
DIAM	3¼"			3"
WEIGHT				PUSH
FALL				

	GROUND	WELL	PROTCSG
ELEV.:	782.4		799.26

DATE STARTED: 12/4/84
DATE COMPLETED: 12/5/84
DRILLER: SMITH
INSPECTOR: MACMILLIN

WELL CONSTRUCTION	DEPTH FT.	SAMPLE NO.	SAMPLE TYPE	BLOWS PER 6 Inches	CLASSIFICATION	REMARKS
Locking Cap	0				MAUMEE III c LACUSTRINE (Sand)	For complete soil description, see log of adjacent boring, W-20C
Riser; Bentonite Slurry Seal	5–20					
	23–25	UD-20 1	ST		(Silt)	Noticeable odor in tubes when opened in laboratory
	31'				ASHTABULA TILL	
	35	UD-20 2	ST			
Sand Pack	38'				MAUMEE III c LACUSTRINE (Sand)	AR300045
	47.5'				End of boring	

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THE AWARE CORPORATION

TEST BORING LOG

BORING NO. W-20C

PROJECT:	SHOPE'S LANDFILL
CLIENT:	LORD CORP
CONTRACTOR:	EMPIRE SOILS
EQUIPMENT:	ACKER 82
DRILLING METHOD:	AUGER / MUD ROTARY
SHEET NO.	1 of 2
PROJECT NO.:	6278

	RISER	INTAKE
TYPE	BLACK STEEL	STAINLESS
DIAMETER	2"	2"
COUPLING	WELDED	WELDED

	CASING	SAMPLER	CORE	TUBE
TYPE	H.S.A.	SS		
DIAM	3 3/4"	2"		
WEIGHT		140#		
FALL		30"		

	GROUND	WELL	PROTECT
ELEV.:	793.1		796.14

DATE STARTED: 11/21/84
DATE COMPLETED: 11/28/84
DRILLER: SKURA
INSPECTOR: MACMILLAN

WELL CONSTRUCTION: Locking Cap; Riser; Cement-Bentonite Grout

DEPTH FT.	SAMPLE NO.	TYPE	BLOWS PER 6 Inches	CLASSIFICATION	REMARKS
0	1	SS	2-1 / 3-7	MAUMEE III LACUSTRINE (Sand) Brown SAND, little of Gravel little (-) Silt, non-stratified	
	2	SS	8-5 / 5-8	@ 3.5', become stratified	
5	3	SS	4-5 / 4-3	@ 6', become c-m-f SAND, some f-m-c Gravel, trace Clay & Silt, non-stratified	
	4	SS	3-2 / 2-2		become saturated @ 7.5'
	5	SS	2-2 / 2-2		
10	6	SS	3-2 / 1-1		
	7	SS	2-2 / 1-1	@ 12', become	
15	8	SS	1-2 / 1-2	Brown f-m SAND, no to little Silt, stratified	
	9	SS	2-1 / 2-9		
20	10	SS	8-11 / 5-5		
	11	SS	3-3 / 8-6	(Silt) Interbedded & interbedded, gray SILT with SILT & CLAY or f SAND & SILT	
25	12	SS	8-12 / 14-16		
	13	SS	8-10 / 10-14		
	14	SS	12-12 / 11-15		
30	15	SS	8-10 / 16-14	31' ASTABULA TILL (Fine) Clayey SILT and c-m-f SAND, little of Gravel	
	16	SS	6-6 / 8-8		
35	17	SS	9-9 / 9-6		
	18	SS	8-7 / 6-10	38'	
	19	SS	11-11 / 10-13	MAUMEE III LACUSTRINE (Sand)	
40	20	SS	16-20 / 17-19	f-m SAND, some to Silt,	
	21	SS	28-32 / 30-24	@ 40', grading to SAND, trace Silt @ 43', grading to SAND and f GRAVEL	
45	22	SS	23-30 / 34-38		

AR300046

THE AWARE CORPORATION

TEST BORING LOG

BORING NO. W-20C

PROJECT: SHOPE'S LANDFILL
CLIENT: LORD CORP.
SHEET NO. 2 of 2
PROJECT NO. 6278

WELL CONSTRUCTION: Cement - Bentonite Grout; Riser; Bentonite Slurry Seal; Sand Pack; Collapsed Soil

DEPTH FT.	SAMPLE NO.	TYPE	BLOWS PER 6 inches	CLASSIFICATION	REMARKS
				MAUMEE III & LAC. (Cont'd) (Sand)	
	23	SS	25-25, 30-45	@47.5', become laminated SILT, little f Sand — 49'	
			45-50		
50	24	SS	38-55	ASTABULA TILL (Fine) Gray SILT and f SAND, little f Gravel	
55	25	SS	100/0.5		
60	26	SS	38-100/0.4		
65	27	SS	65-100/0.5	@63', grading to Clayey SILT, some f Sand, little f Gravel	
70	28	SS	45-100/0.5		
75	29	SS	58-100/0.4	@73', grading to CLAY & SILT, little f Gravel, little f-m Sand	
80	30	SS	60-70, 100/0.5	82'	
85	31	SS	18-30, 40-55	MAUMEE III A LACUSTRINE (Sand) coarse SAND, little f Silt & Clay, well sorted — 87'	
90	32	SS	70-38, 50-70	ASTABULA TILL (Fine) CLAY & SILT, trace f Gravel, trace f Sand — ±91'	
95	33	SS	20-45, 38-50	MAUMEE III & LACUSTRINE Silt & Clay laminated SILT & CLAY — 97'	AR300047
				End of boring	

ORIGINAL

THE AWARE CORPORATION

TEST BORING LOG

BORING NO. W-21A

PROJECT: SHOPE'S LANDFILL	SHEET NO. 1 of 1
CLIENT: LORD CORP	PROJECT NO.: 6278
CONTRACTOR: EMPIRE SOILS	EQUIPMENT: ACKER 82

	RISER	INTAKE
TYPE	BLACK STEEL	STAINLESS
DIAMETER	2"	2"
COUPLING	WELDED	WELDED

DRILLING METHOD: AUGER

	CASING	SAMPLER	CORE	TUBE
TYPE	H.S.A.			
DIAM	3 3/4"			
WEIGHT				
FALL				

	GROUND	WELL	PROT.CSG.
ELEV.:	782.7		786.04

DATE STARTED: 11/20/84
DATE COMPLETED: 11/20/84
DRILLER: SKUKA
INSPECTOR: MACMILLIN

WELL CONSTRUCTION	DEPTH FT.	SAMPLE NO.	TYPE	BLOWS PER 6 Inches	CLASSIFICATION	REMARKS
Grout, Riser, Bentonite	0				ASTABULA TILL	For complete soil description, see log of adjacent boring, W-21C
	8				8'	
Sand Pack					MAUMEE III @ LACUSTRINE (Sand)	
	15				15'	
					End of boring	

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ORIGINAL

THE AWARE CORPORATION

TEST BORING LOG

BORING NO. W-21B

PROJECT: SHORE'S LANDFILL								SHEET NO. 1 of 2
CLIENT: LORD CORP								PROJECT NO.: 6278
CONTRACTOR: EMPIRE SOILS			EQUIPMENT: ACKER 82					
	RISER	INTAKE	DRILLING METHOD: AUGER					GROUND / WELL / PROTCOV
TYPE	BLACK STEEL	STAINLESS		CASING	SAMPLER	CORE	TUBE	ELEV.: 782.9 / / 785.33
DIAMETER	2"	2"	TYPE	HSA				DATE STARTED: 11/20/84
COUPLING	WELDED	WELDED	DIAM	3¾"				DATE COMPLETED: 11/20/84
			WEIGHT					DRILLER: SKUBA
			FALL					INSPECTOR: MACMILLIN

WELL CONSTRUCTION	DEPTH FT.	SAMPLE NO.	TYPE	BLOWS PER 6 Inches	CLASSIFICATION	REMARKS
Locking Cap	0				ASHTABULA TILL	For complete soil description, see log of adjacent boring, W-21C
	5					
	10				8' MAUMEE III a LACUSTRINE (Sand)	
Cement - Bentonite Grout	15				(Silt)	
	20				18' ASHTABULA TILL	
Riser	25					
Bentonite Slurry Seal	30					
	35				35' MAUMEE III a LACUSTRINE	
	40					
Sand Pack	45				(Sand)	

AR300049

THE AWARE CORPORATION

TEST BORING LOG

BORING NO. W-21B

PROJECT : SHOPFS LAND FILL

CLIENT : LORD CORP.

SHEET NO. 2 of 2

PROJECT NO. 6278

WELL CONSTRUCTION	DEPTH FT	SAMPLE NO.	SAMPLE TYPE	BLOWS PER 6 inches	CLASSIFICATION	REMARKS
Seal Pack					MAUMEE III LAC. (Cont'd) 49.5'	
	50				End of boring	

AR300050

ORIGINAL

TEST BORING LOG

THE AWARE CORPORATION

BORING NO. W-21C

PROJECT: SHORES LANDFILL	SHEET NO. 1 of 2
CLIENT: LORD CORP.	PROJECT NO.: 6278
CONTRACTOR: EMPIRE SOIL	EQUIPMENT: ACKER 82

	RISER	INTAKE
TYPE	BLACK STEEL	STAINLESS
DIAMETER	2"	2"
COUPLING	WELDED	WELDED

DRILLING METHOD: AUGER/MUD ROTARY

	CASING	SAMPLER	CORE	TUBE
TYPE	H.S.A.	SS		
DIAM	3¾"	2"		
WEIGHT		140#		
FALL		30"		

	GROUND	WELL	PROT. CSG
ELEV.:	783.1		785.67

DATE STARTED: 11/13/84
DATE COMPLETED: 11/19/84
DRILLER: SKUBA
INSPECTOR: MACMILLIN

WELL CONSTRUCTION: Locking Cap; Riser; Cement - Bentonite Grout

DEPTH FT	SAMPLE NO.	TYPE	BLOWS PER 6 inches	CLASSIFICATION	REMARKS
0	1	SS	1-2, 2-6	ASHTABULA TILL	
	2	SS	8-8, 6-5	Brown m-f SAND, some f-m Gravel, little Silt & Clay, non stratified	
5	3	SS	4-3, 3-3		saturated @ 6'
	4	SS	2-1, 2-1	8'	
	5	SS	1-1, 2-2	MAUMEE III a LACUSTRINE (Sand)	
10	6	SS	1-1, 1-1	Brown m-f SAND, some f-m Gravel trace(+) Silt, & Clay	
	7	SS	1-1, 1-1		
15	8	SS	1-5, 3-4	(Silt)	
	9	SS	4-6, 7-5	brown, laminated Clayey SILT 18'	
	10	SS	6-9, 7-11	ASHTABULA TILL (Fine)	
20	11	SS	12-12, 10-14	Gray SILT & CLAY, some(+) f Sand, trace(+) f Gravel	
	12	SS	8-9, 14-13		
25	13	SS	6-6, 7-9	@24', grading to Clayey SILT and f-m SAND, trace f Gravel	
	14	SS	12-12, 13-14		
	15	SS	9-9, 11-12		
30	16	SS	7-7, 4-11		
	17	SS	8-8, 9-17	35'	
35	18	SS	9-15, 20-26	MAUMEE III a LACUSTRINE	
	19	SS	37-55, 65-90	(Silt)	
	20	SS	50-90, 100/3"	Gray laminated SILT, trace to little Sand, occ Clay & Silt laminations	
40	21	SS	18-38, 40-50		
	22	SS	28-40, 49-65		
45	23	SS	22-43, 59-100/3"	45' (Sand)	

AR300051

THE ATWARE CORPORATION

TEST BORING LOG

BORING NO. W-21C

PROJECT: SHOPE'S LANDFILL

SHEET NO. 2 of 3

CLIENT: LORD CORP

PROJECT NO. 6278

WELL CONSTRUCTION	DEPTH FT.	SAMPLE NO.	TYPE	BLOWS PER 6 inches	CLASSIFICATION	REMARKS
Cement-Bentonite Grout; Riser; Bentonite Slurry Seal					MAUMEE III LAC. (Cont'd) (Sand) @49', become stratified f SAND and SILT 49.5'	
	50	23 A	SS	18-16 30-45	ASHTABULA TILL (Fine) Gray SILT & f SAND, trace f Gravel	
	55	24	SS	42-50 55-60		
	60	25	SS	26-45 70-100/2"		
	65	26	SS	20-18 40-65		
	70	27	SS	20-40 100/2"		
	75	28	SS	40-52 100/4"	@73', grading to SILT, some f Sand, trace f-m Gravel	
	80	29	SS	20-32 55-70		
	85	30	SS	15-22 35-55	@83', grading to CLAY & SILT, trace f Sand, unstratified	
	90	31	SS	17-21 30-45	91'	
					MAUMEE III LACUSTRINE (Clay & Silt)	AR300052
	95	32	SS	22-25 30-40	gray CLAY & SILT, frequent Silt laminations	

THE AWARE CORPORATION

TEST BORING LOG

BORING NO W-21C

PROJECT: SHOPE'S LANDFILL

CLIENT: LORD CORP.

SHEET NO. 3 of 3

PROJECT NO. 6278

WELL CONSTRUCTION	DEPTH FT.	SAMPLE NO.	SAMPLE TYPE	BLOWS PER 6 inches	CLASSIFICATION	REMARKS
Sand Pack / Bentonite Seal					MAUMEE III LAC. (Cont'd) (Clay & Silt) 98.5'	
	100	33	SS	22-35 / 42-60	ASTABULA TILL (Fine) ±101	
	105	34	SS	25-40 / 85-100/5"	MAUMEE III LACUSTRINE (Sand) med. SAND, stratified 104.5'	
	110	35	SS	31-25 / 34-52	ASTABULA TILL (Fine) SILT & CLAY, little fine Sand trace fine Gravel 110'	
					End of boring	

AR300053

THE AWARE CORPORATION

TEST BORING LOG

BORING NO. [illegible]

PROJECT: SHOPPS LANDFILL				SHEET NO. [illegible]
CLIENT: [illegible] CORP.				PROJECT NO. [illegible]
CONTRACTOR: EMPIRE SOIL		EQUIPMENT: CME-45 (TRAKER)		[illegible]

	RISER	INTAKE
TYPE	BLACK STEEL	STAINLESS
DIAMETER	2"	2"
COUPLING	WELDED	WELDED

DRILLING METHOD	CASING	SAMPLER	CORE	TUBE
TYPE	HSA	SS		
DIAM	3¾"	2"		
WEIGHT		140 #		
FALL		30"		

GROUND [illegible]
ELEV.: 772.0 [illegible]
DATE STARTED: [illegible]
DATE COMPLETED: [illegible]
DRILLER: SKU[illegible]
INSPECTOR: MACMILLAN

WELL CONSTRUCTION	DEPTH FT.	SAMPLE NO.	SAMPLE TYPE	BLOWS PER 6 inches	CLASSIFICATION	REMARKS
	0				TOPSOIL 1'	For complete soil description, see log of adjacent boring, W-22-B
					ASHTABULA TILL 4'	
Bentonite	5				MAUMEE III LACUSTRINE (Sand)	
Sand Pack; Cement Grout	10				(Silt) 13'	
	15				End of Boring	
	20					
	25					
	30					
	35					
	40					
	45					

AR300054

THE AWARE CORPORATION

TEST BORING LOG

BORING NO. W-22 B

PROJECT: SHOPES LANDFILL				SHEET NO 1 of 2
CLIENT: LORD CORP				PROJECT NO.: 6278
CONTRACTOR: EMPIRE SOIL		EQUIPMENT: CME-45 (TRAILER)		

	RISER	INTAKE	DRILLING METHOD: HOLLOW STEM AUGER	CASING	SAMPLER	CORE	TUBE		GROUND	WELL	PROT.CSG
TYPE	BLACK STEEL	STAINLESS	TYPE	HSA	SS			ELEV.:	775.0		777.92
DIAMETER	2"	2"	DIAM	3 3/4"	2"			DATE STARTED: 11/5/84			
COUPLING	WELDED	WELDED	WEIGHT		140#			DATE COMPLETED: 11/7/84			
			FALL		30"			DRILLER: SKURA			
								INSPECTOR: MACMILLIN			

DEPTH FT.	SAMPLE NO.	TYPE	BLOWS PER 6 Inches	CLASSIFICATION	REMARKS
0	1	SS	2-3 10-11	TOPSOIL 1' ASHTABULA TILL (Coarse)	
	2	SS	3-6 5-3	c-m-f SAND and GRAVEL, some Silt & Clay 4'	become saturated @ 2'
5	3	SS	2-2 2-3	MAUMEE III o LACUSTRINE (Sand) f-m SAND, trace (+) Silt	
	4	SS	2-1 3-7	@ 5', grading to f-m-c SAND little f Gravel, stratified	
	5	SS	4-9 9-9	9' (Silt)	
10	6	SS	5-8 9-11	@ 9', become interbedded & interlaminated CLAY & SILT with SILT	
	7	SS	11-8 8-10		
15	8	SS	9-9 7-8	@ 16', become interbedded with f SAND, little (-) Silt, trace f Gravel	
	9	SS	5-6 8-12	18'	
	10	SS	6-6 9-9	ASHTABULA TILL (Fine)	
20	11	SS	1-4 6-6	Clayey SILT and fine SAND, trace Gravel, non stratified, massive	
	12	SS	4-4 6-6		
25	13	SS	8-14 20-28		
	14	SS	20-30 40-43		
	15	SS	6-9 11-18	@ 28', grading to Clayey SILT, little (-) f Sand, trace (+) f Gravel	
30	16	SS	10-13 18-21	32'	
	17	SS	8-9 14-20	(Coarse) become interbedded with stratified f-m SAND trace (-) to no Silt	
35	18	SS	8-13 14-20		
	19	SS	25-24 28-26		
	20	SS	10-9 13-23		
40	21	SS	13-13 23-55	@ 40' become f SAND, some Silt, trace (-) f Gravel	AR300055
	22	SS	36-45 80-100	non-stratified 44'	
45	23	SS	36-55 75-90	MAUMEE III o LACUSTRINE	

WELL CONSTRUCTION

Locking Cap

Cement - Bentonite Grout

Riser Pipe

Bentonite Seal

Sand Pack

THE AWARE CORPORATION

TEST BORING LOG

BORING NO. W-22B

PROJECT: Shopes Landfill	**SHEET NO.** 2 of 2
CLIENT: Lord Corp.	**PROJECT NO.** 6278

WELL CONSTRUCTION	DEPTH FT.	SAMPLE NO.	SAMPLE TYPE	BLOWS PER 6 inches	CLASSIFICATION	REMARKS
Sand Pack	45				MAUMEE III_B LAC. (Cont'd)	
		24	SS	60-100/6	stratified f-m SAND, no to little Silt	
		25	SS	100/6"	occationally interbedded with f SAND & SILT, trace to f Gravel, non sorted	
	50					
		26	SS	50-30 / 100/6"	53'	
	55				ASTABULA TILL (Fine) Clayey SILT and f SAND, little f Gravel	
		27	SS	25-36 / 50-51	60'	
	60				End of Boring	

AR300056

THE AWARE CORPORATION

TEST BORING LOG

BORING NO. W-22C

PROJECT: SHOPE'S LANDFILL	SHEET NO. 1 of 2
CLIENT: LORD CORP	PROJECT NO.: 6278
CONTRACTOR: EMPIRE SOIL	EQUIPMENT: CME 45 (TRAILER)

	RISER	INTAKE
TYPE	BLACK STEEL	STAINLESS
DIAMETER	2"	2"
COUPLING	WELDED	WELDED

DRILLING METHOD: MUD ROTARY

	CASING	SAMPLER	CORE	TUBE
TYPE	HSA	SS		
DIAM	3 3/4"	2"		
WEIGHT		140#		
FALL		30"		

	GROUND	WELL	PROT.CSG
ELEV.:	775.0		777.37

DATE STARTED: 11/9/84
DATE COMPLETED: 11/12/84
DRILLER: SKURA
INSPECTOR: MACMILLIN

WELL CONSTRUCTION	DEPTH FT	SAMPLE NO.	TYPE	BLOWS PER 6 inches	CLASSIFICATION	REMARKS
Locking Cap	0				TOPSOIL 1.0'	For complete soil description, see log of adjacent boring, W-22B
					ASTABULA TILL 4.0	
	5				MAUMEE IIIc LACUSTRINE (Sand)	
	10				(Silt)	
Cement - Bentonite Grout; Riser Pipe	15				18'	
	20				ASHTABULA TILL	
	25					
	30					
	35					
	40					AR300057
	45				44' MAUMEE IIIB LACUSTRINE (Sand)	

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THE AWARE CORPORATION

TEST BORING LOG

BORING NO. W-22C

PROJECT: SHOPE'S LANDFILL
CLIENT: LORD CORP.

SHEET NO. 2 of 2
PROJECT NO. 6278

WELL CONSTRUCTION	DEPTH FT.	SAMPLE NO.	TYPE	BLOWS PER 6 inches	CLASSIFICATION	REMARKS
Cement-Bentonite Grout; Riser Pipe	45				MAUMEE III & LAC. (Cont'd)	
	50					
					53'	
	55				ASHTABULA TILL (Fine)	
	60					
Bentonite Seal	65	28	SS	16-16 / 25-50	Gray Clayey SILT, little(-) f-m-c Sand, trace(-) f Gravel	
					± 67'	
					MAUMEE III A LACUSTRINE (Clay & Silt)	
	70	29	SS	20-22 / 28-24	CLAY & SILT, very slightly laminated	
Sand Pack	75	30	SS	14-26 / 28-30	76'	
					(Sand) f SAND, trace Silt, interbedded w/ Clay & Silt	
	80	31	SS	14-28 / 25-24	79.5'	
					(Clay & Silt) CLAY & SILT, laminated	
	85	32	SS	15-30 / 32-25	87'	
					End of boring	
	90					

AR300058

THE AWARE CORPORATION

TEST BORING LOG

BORING NO. W-23A

PROJECT: SHORES LANDFILL		SHEET NO. 1 of 1
CLIENT: LORD CORP		PROJECT NO.: 6287
CONTRACTOR: EMPIRE SOIL	EQUIPMENT: CME45 (TRAILER)	

	RISER	INTAKE
TYPE	BLACK STEEL	STAINLESS
DIAMETER	2"	2"
COUPLING	WELDED	WELDED

DRILLING METHOD: AUGER

	CASING	SAMPLER	CORE	TUBE
TYPE	H.S.A.			
DIAM	3 3/4"			
WEIGHT				
FALL				

	GROUND	WELL	PROT.CSG.
ELEV.:	776.5		778.2

DATE STARTED: 11/29/84
DATE COMPLETED: 11/29/84
DRILLER: SWINNICH
INSPECTOR: MACMILLIN

WELL CONSTRUCTION	DEPTH FT.	SAMPLE NO.	SAMPLE TYPE	BLOWS PER 6 inches	CLASSIFICATION	REMARKS
Grout	0				TOPSOIL MAUMEE III o LACUSTRINE (Clay & Silt) (Sand)	For complete soil description, see log of adjacent boring, W-23C
Riser; Bentonite Seal	5					
Sand Pack	10				(Silt)	
	15				15' End of boring	
	20					
	25					
	30					
	35					
	40					
	45					

AR300059

THE AWARE CORPORATION

TEST BORING LOG

BORING NO. W-23B

PROJECT: SHOPES LANDFILL			SHEET NO. 1 of 1
CLIENT: LORD CORP			PROJECT NO.: 6278
CONTRACTOR: EMPIRE SOIL		EQUIPMENT: CME 45 (TRAILER)	

	RISER	INTAKE
TYPE	BLACK STEEL	STAINLESS
DIAMETER	2"	2"
COUPLING	WELDED	WELDED

DRILLING METHOD: AUGER

	CASING	SAMPLER	CORE	TUBE
TYPE	H.S.A			ST
DIAM	3 1/4"			3"
WEIGHT				PUSH
FALL				

	GROUND	WELL	PROT.CSG
ELEV.:	776.6		779.45

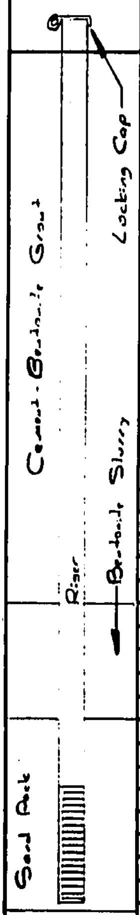
DATE STARTED: 11/29/84

DATE COMPLETED: 11/30/84

DRILLER: SWINNICH

INSPECTOR: MACMILLIN

WELL CONSTRUCTION



DEPTH FT.	SAMPLE NO.	SAMPLE TYPE	BLOWS PER 6 Inches	CLASSIFICATION	REMARKS
0				TOPSOIL 1.0	
				MAUMEE III c LACUSTRINE (Clay & Silt) 3'	For complete soil description, see log of adjacent boring, W-23-C
				(Sand)	
13'				(Silt)	
18–20	UD-23-1	ST			Noticeable odor in tube when opened in laboratory
23'				ASHTABULA TILL	
25–27	UD-23-2	ST			
34'				MAUMEE III a LACUSTRINE Silt	
37.5				End of boring	

AR300060

WEHRAN ENGINEERING
CONSULTING ENGINEERS

TEST BORING LOG

BORING NO. 16

PROJECT: Shope's Landfill Hydrogeologic Investigation, Erie, PA	SHEET NO. 1 OF 1
CLIENT: Lord Corporation, Erie, PA	JOB NO. 02361137
BORING CONTRACTOR: Empire Soils Investigations, Inc.	ELEVATION 815.3

GROUND WATER					CAS.	SAMP.	CORE	TUBE	
DATE	TIME	WATER EL.	SCREEN	TYPE	HSA	SS			DATE STARTED 7-21-81
			15.8'-17.8'	DIA.	3 3/4"	2"			DATE FINISHED 7-21-81
				WT.		140#			DRILLER Joe Genovese
				FALL		30"			INSPECTOR Ron Stoufer

DEPTH FEET	SAMPLE NO.	TYPE	BLOWS PER 6 INCHES	CLASSIFICATION	REMARKS
0				FILL:	
				Rubber waste and yellowish brown c-f SAND, little Silt.	At 10', encountered a liquid that smelled similar to acetone
5	1	SS	7 / 5 - 7 / 40/0.2'		
				13.5'	At 12.5', encountered black rubbery material (rubber cement?) the consistency of jello
				GLACIAL TILL DEPOSIT:	
10	2	SS	10 - 6 / 5 - 1	Gray SILT & CLAY, some f. Gravel - saturated, stiff	
	3	SS	12 / 4 - 7	17.0'	
15	4	SS	1 - 6 / 6 - 6	END OF BORING	
20					
25					
30					
35					
40					
45					

WELL CONSTRUCTION:

Cement & bentonite grout
Sand pack
1 1/2" I.D. steel casing
2 1/4" O.D. stainless steel screen

AR300061

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WEHRAN ENGINEERING
CONSULTING ENGINEERS

TEST BORING LOG

BORING NO. 17

PROJECT: Shope's Landfill Hydrogeologic Investigation, Erie, PA
CLIENT: Lord Corporation, Erie, PA
BORING CONTRACTOR: Empire Soils Investigations, Inc.

SHEET NO. 1 OF 1
JOB NO. 02361137
ELEVATION 800.2
DATE STARTED 7-17-81
DATE FINISHED 7-17-81
DRILLER Joe Genovese
INSPECTOR Ron Stoufer

GROUND WATER

DATE	TIME	WATER EL.	SCREEN
			4.0'-6.0'

	CAS.	SAMP.	CORE	TUBE
TYPE	HSA	SS		
DIA.	3 3/4"	2"		
WT.		140#		
FALL		30"		

WELL CONSTRUCTION	DEPTH FEET	SAMPLE NO.	TYPE	BLOWS PER 6 INCHES	CLASSIFICATION	REMARKS
	0	1	SS	2 - 2 3 - 2	GLACIAL TILL DEPOSIT:	
		2	SS	5 - 5 5 - 5	Gray SILT & CLAY, some to and f. Sand - medium, saturated below 1'.	
	5	3	SS	6 - 8 8 - 8	3.0'	
					ALLUVIAL DEPOSIT:	
	10				Brown f-m SAND, trace (+) Clay Silt - medium dense, saturated; at 5' becoming brown m-f SAND, trace Silt-saturated	
	15				6.0'	
					END OF BORING	Below 1', the samples had an organic solvent odor.
	20					
	25					
	30					
	35					
	40					
	45					

Well construction legend:
Cement & bentonite grout
Sand pack
1 1/2" I.D. steel casing
2 1/4" O.D. stainless steel screen
bentonite pellet seal

AR300062

WEHRAN ENGINEERING
CONSULTING ENGINEERS

TEST BORING LOG

BORING NO. 18

PROJECT: Shope's Landfill Hydrogeologic Investigation, Erie, PA	SHEET NO. 1 OF
CLIENT: Lord Corporation, Erie, PA	JOB NO. 02361137
BORING CONTRACTOR: Empire Soils Investigations, Inc.	ELEVATION 810.7

GROUND WATER					CAS.	SAMP.	CORE	TUBE	
DATE	TIME	WATER EL.	SCREEN	TYPE	HSA	SS			DATE STARTED 7-21-81
			16' - 18'	DIA.	3 3/4"	2"			DATE FINISHED 7-21-81
				WT.		140#			DRILLER Joe Genovese
				FALL		30"			INSPECTOR Ron Stoufer

WELL CONSTRUCTION	DEPTH IN FEET	SAMPLE NO.	TYPE	BLOWS PER 6 INCHES	CLASSIFICATION	REMARKS
	0				FILL:	
					Black rubber, paper, and sand, predominantly paper below 9', wet below 13'	
	5	1	SS	4 / 7 - 7 / 7		
					15.5'	
		2	SS	38 - 18 / 15 - 15	GLACIAL TILL DEPOSIT:	
	10	3	SS	7 - 5 / 5 - 9	Gray with mottled yellowish brown CLAY & SILT, trace c. Sand-moist, stiff	
		4	SS	15 - 22 / 5 - 5		
		5	SS	12 - 4 / 4 - 4	18.0'	
	15	6	SS	5 - 4 / 4 - 6	END OF BORING	
		7	SS	6 - 8		
	20					
	25					
	30					
	35					
	40					AR300063
	45					

Cement & bentonite grout
Sand pack
1 1/2" I.D. steel casing
2 1/4" O.D. stainless steel screen

WEHRAN ENGINEERING
CONSULTING ENGINEERS

TEST BORING LOG

BORING NO. 19

PROJECT: Shope's Landfill Hydrogeologic Investigation, Erie, PA	SHEET NO. 1 OF 1
CLIENT: Lord Corporation, Erie, PA	JOB NO. 02361137
BORING CONTRACTOR: Hand augered	ELEVATION 811.3
	DATE STARTED 7-21-81
	DATE FINISHED 7-21-81
	DRILLER Ron Stoufer
	INSPECTOR Ron Stoufer

GROUND WATER								
DATE	TIME	WATER EL.	SCREEN		CAS.	SAMP.	CORE	TUBE
			2.2'-3.5'	TYPE				
				DIA.				
				WT.				
				FALL				

WELL CONSTRUCTION	DEPTH FEET	SAMPLE NO.	SAMPLE TYPE	BLOWS PER 6 INCHES	CLASSIFICATION	REMARKS
backfill with cuttings; Sand pack; 1 1/2" slotted PVC screen; 1 1/2" PVC casing	0				GLACIAL TILL DEPOSIT:	
					Brown CLAY & SILT, at 0.8' becoming brown f. SAND, trace Silt, trace f. Gravel. 3.5'	
	5					
	10				END OF BORING	
	15					
	20					
	25					
	30					
	35					
	40					
	45					

AR300064

Appendix ...

Well Lithology

S.S. Harrison
9/16/80

#7

GLACIAL TILL

0-9½' brown + grey mottled sandy loam, some gravel; cohesive: grades to fine brown sand

9½-21' blue-grey gravelly silt loam and fine sand (plastic)

GLACIO-LACUSTRINE (SILT)

21'-48' blue-grey gravelly silt loam (bounces)

#8

GLACIAL TILL

0-10' brown gravelly sandy loam

10-25 grey fine gravelly loam: small seep at 20'

GLACIO-LACUSTRINE (SAND)

25-27 (casing settled as plug drilled out) gravelly fine sandy loam to loam (not very permeable; a little water)

GLACIO-LACUSTRINE (SILT)

27-40 fine gravelly silt loam

40-45 (heaving) grey silt (some water) (sensitive) no gravel

GLACIAL TILL

45-46' very gravelly silt loam. (drove illed; a little water)

#9

0-3' mottled silt loam

3-4½' mottled very fine sand

4½-12' fine gravelly sandy lo... grey, (WATER)

12'-31' grey very gravelly silt loam (heaves) grades to fine gravelly loam and then to 50/50 fine gravel and silt by 24 then back to blue-grey fine gravelly silt loam

31'-48' grey fine gravelly silt loam to clay loam (drives hard)

48'-50' grey coarse sand an... fine gravel (>10gpm

50-55' grey silt loam (t...

#10

0-24' Brown gravelly sandy loam (water at 18')

24'-40' grey gravelly clay loam ... silt loam (loose, drives eas...

40-42' drills very hard - no detec... lithologic change - no incr... in water

42'-56' grey fine gravelly silt lo...

56-57' medium gravel and sand (lots of water)

#11

0-5' brown gravelly sandy loam
5-11' mottled olive fine sand
11'-31' grey very fine gravelly silt loam
31'-54' as above, but more gravel (very little water)
54'-59' 2B-size gravel

#2A-WT (located adj to well #2 ... of hill)

0-11½' red-brown sandy loam
11½'-13½ very coarse gravelly Sandy loam (cobbles) - No water or mottling W.T. below 13½' - no pipe set

#2B + 2C + 2WT

0'-29' Brown gravelly sandy loam (loose, caving settles)
29'-38' grey very gravelly silt loam (lots of water at upper contact)

10 WT

0-6" dark brown loam topsoil
6"-13ft reddish brown gravelly sandy loam grading to greenish-tan; no mo
13'-15½ tan sand and greenish tan gr sandy loam - no mottles

No Water - No well install
W.T. below 15½' here

8WT

0-8" black silt loam topsoil
8-32" mottled tan and grey loam (dense)
32-78" tan sandy loam
78-114" dense mottled grey and brown fine sand

9WT

0-6" black silt loam topsoil
6-36" grey and yellow mottled silt loam
36-48" grey and tan mottled very fine sand + silt (plastic-sensitive)
48-54" grey fine sand + silt
54-92 grey gravelly sandy loam (water)

7 WT

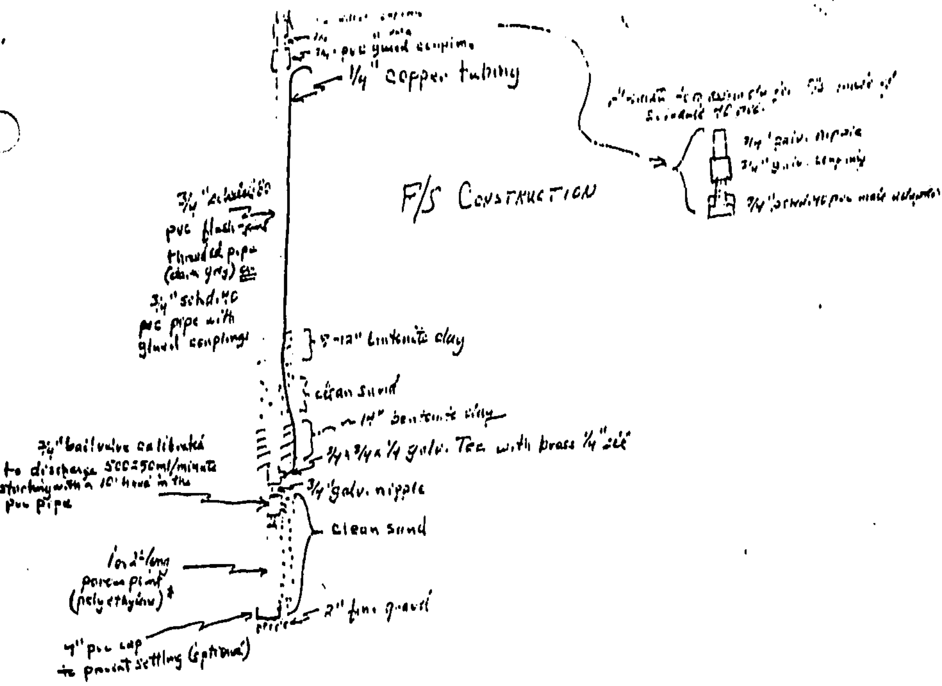
0-36" mottled loam
36-108" fine brown sand
108"-13' grey fine sand and some coarse silt

11 WT

0-4" black loam topsoil
4-18" tan loam
18-60" brown gravelly loam to gravelly sandy loam (lots of water and caving)
60-92" dense mottled olive brown fine sa (compact, dense, water at top of contact)

AR300066

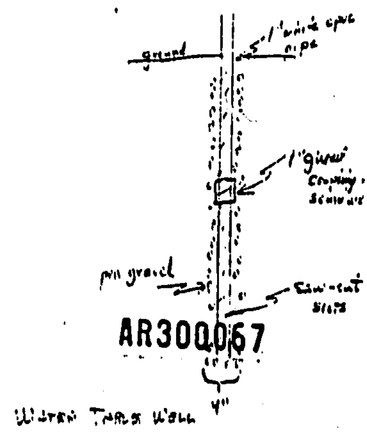
AR300066



* P/S 2B+2C have tips made of 3/4" sched. 40 pvc slotted and covered with nylon mesh affixed with black plastic electricians' tape.

The following P/S are made of schedule 40 pvc with cemented couplings: 2C, 3A, 3B, 5A, 5B, 8A, 9A, 10A, 11A.
Other P/S are schedule 80 threaded joint.

Appendix 3. Construction of P/S and Water Table Wells.



APPENDIX B

KEY TO SOILS IDENTIFICATION

Granular Soils - Particle Size Classification

Material		Fractions	Passing	Retains On
BOULDERS	Material retained on the 9-in. sieve			9 in.
COBBLES	Material passing on the 9-in. sieve and retained on the 3-in. sieve		9 in.	3 in.
GRAVEL	Material passing on the 3 in. sieve and retained on the No. 10 sieve	Coarse (c) Medium (m) Fine (f)	3 in. 1 in. 3/8 in.	1 in. 3/8 in. No. 10
SAND	Material passing the No. 10 sieve and retained on the No. 200 sieve	Coarse (c) Medium (m) Fine (f)	No. 10 No. 30 No. 60	No. 30 No. 60 No. 200
SILT	Material passing the No. 200 sieve that is non-plastic in character and exhibits little or no strength when air dried.		No. 200	

Penetration Resistance and Soil Properties On Basis of the Standard Penetration Test

(After Peck, Hanson and Thornburg, 1974)

Sands (Fairly Reliable)		Clays (Rather Unreliable)	
Number of Blows Per Foot, N	Relative Density	Number of Blows Per Foot, N	Consistency
0-4	Very Loose	Below 2	Very Soft
4-10	Loose	2-4	Soft
10-30	Medium	4-8	Medium
30-50	Dense	8-15	Stiff
Over 50	Very Dense	15-30	Very Stiff
		Over 30	Hard

Clay Soils - Plasticity Classification

Material*	Degree of Overall Plasticity	Overall Plasticity Inde Sand - Silt - Clay Compo
Clayey SILT	Slight	1 to 5
SILT & CLAY	Low	5 to 10
CLAY & SILT	Medium	10 to 20
Silty CLAY	High	20 to 40
CLAY	Very High	40 and greater

* Soils passing the No. 200 sieve which can be made to exhibit plasticity and clay qualities within a certain range of moisture content, and which exhibits considerable strength when air dried.

Terms Identifying Composition of Soil

Written*	Defining Range of Percentage by Weight
and	35 to 50
some	20 to 35
little	10 to 20
trace	0 to 10

* Plus (+) or minus (-) sign used after identifying term denotes extremes of range; e.g., "some (-) Gravel" indicates 20 to 24 percent Gravel; "some (+) Gravel" indicates 31 to 35 percent Gravel.

AR300069

GLOSSARY

1. alluvium - A general term for deposits resulting from the operations of modern rivers. These include deposits of riverbeds, flood plains, lakes, and fans at the foot of steep slopes.

2. anisotropic - having physical properties that vary in different directions.

3. annulus - The circular opening around a pipe or tube placed into a borehole; that area between the outside of the pipe and the sides of the borehole.

4. aquifer - A distinct water-bearing zone or stratum capable of producing water.

5. aquifer, artesian - An aquifer which is confined under pressure by impermeable formations above and below and from which water levels (hydrostatic head) in wells will rise above the base of the confining bed.

6. aquifer, unconfined - An aquifer in which the ground-water table is open to the atmosphere, i.e., the aquifer is not under pressure from confinement.

7. aquitard - A saturated formation which yields insignificant amounts of water compared to an aquifer, but through which considerable leakage of water occurs.

8. basalt - An extrusive rock composed primarily of calcic plagioclase and pryoxene, with or without olivine. More generally, any fine-grained, dark-colored igneous rock.

9. bedding plane - dividing surfaces which separate individual units within sedimentary or stratified rock; or a tendency for massive rock (no beds) to split generally parallel to ground surface.

10. bedrock - solid rock exposed at land surface or overlain by unconsolidated material.

11. bentonite - A clay mineral which is an altered volcanic ash. It exhibits an unusual property of expanding several times its original volume when mixed in water. For this reason, bentonite is used to seal the annulus around piezometers and wells to prevent interaquifer exchange or contamination by surface waters.

12. diabase - A rock of basaltic composition, consisting essentially of labradorite and pyroxene, and characterized by ophitic (coarse-grained) texture.

13. dip - The angle at which a unit layer or planar feature is inclined from the horizontal. The dip occurs at right angles to the strike.

14. fluvial - of, or relating to, rivers, or produced by river action.

15. fractures - breaks in rocks due to intense folding or faulting.

16. glaciolacustrine - pertaining to lakes produced by glacial action or materials deposited from them.

17. ground water - Subsurface water occurring in a zone of saturation.

18. in situ - In its natural position or place.

19. interbedded - occurring between beds, or lying in a bed parallel to other beds of a different material.

20. joints - fractures in rock, more or less vertical or transverse to bedding, where no movement has occurred.

21. joint sets - groups of generally parallel joints.

22. lacustrine - produced by, belonging or pertaining to, or growing (forming) in lakes.

23. lens - a body of sand or rock thick in the middle, thinning at its edges.

24. lignite - A brownish-black coal in which the alteration of vegetal material has proceeded further than in peat but not so far as sub-bituminous coal.

25. litho-stratigraphic - based only on the physical and petrographic features of rocks.

26. metamorphic - Includes all those rocks which have formed in the solid state in response to pronounced changes of temperature, pressure, and chemical environment.

27. moraine - An accumulation of drift having initial constructional topography, built within a glaciated region chiefly by the direct action of glacier ice.

28. NX bit - part of the drilling apparatus used in test borings. Consists of a hollow core 2 1/8" in diameter which makes a hole 3" in diameter.

29. outwash - Sediments deposited by streams originating from glaciers.

30. peridotite - A coarse-grained, ultramafic rock consisting of olivine and pyroxene with accessory constituents.

31. permeability - The ability of a porous medium (i.e., soil, rock) to transmit water.

32. piezometer - A tube or pipe placed into water-bearing zones in soil or rock to enable measurement of water level.

33. piezometric surface - The surface to which confined water will rise if given its full head, i.e., the level which water will rise in a well or piezometer placed at the bottom of a confined aquifer.

34. porosity - Ratio of the volume of space in soil or rock not occupied by soil particles or rock to a total unit volume of soil or rock, usually stated as a percentage.

35. PVC well screen - A slotted well point or perforated pipe which is installed below ground surface at a depth to collect ground water inflow and keep out sediment. PVC is the abbreviation for polyvinyl chloride, the material of construction.

36. sill - An intrusive body of igneous rock of approximately uniform thickness and relatively thin compared with its lateral extent, which has been emplaced parallel to the bedding or schistosity of the intruded rocks.

37. slickensides - polished and striated (scratched) surfaces resulting from friction along a fault plane.

38. split spoon - drilling tool used to obtain a sample, standard size 2 feet long, 1 1/2 inch inside diameter; pushed into boring with hammer.

39. static water level - The elevation at which the water surface equilibrates in a well or piezometer.

40. stratified - formed or lying in beds, layers, or strata.

41. strike - the course or bearing of the line generated by any imaginary horizontal plane (e.g., the earth's surface) intersecting an inclined bed or other structural plane. The bearing of a horizontal line in an inclined plane. Strike is always perpendicular to the dip of the inclined plane.

42. till - Heterogeneous, non-stratified sediment deposited by a glacier. It is characterized by its wide spectrum and variable ratio of soil particle sizes and by its high density.

43. time-stratigraphic - Term applied to rock units with boundaries based on geologic time.

44. unconformable - A distinct break in the continuity of deposition of successive strata; not succeeding the underlying strata in immediate order of age or in parallel position.

45. varves - Sedimentary beds or laminations deposited within one year's time; or a pair of contrasting laminae representing seasonal deposition within one year.

46. water table - The upper surface of the zone of saturation when the aquifer is unconfined as measured by the water levels in wells. Unconfined water in which the hydrostatic pressure is equal to the atmospheric pressure.

47. well cluster - Two or more well points set within the same boring, but sealed off from each other in order to monitor ground water at different depths. Also, separate wells in adjacent borings intended to monitor different zones of saturation.

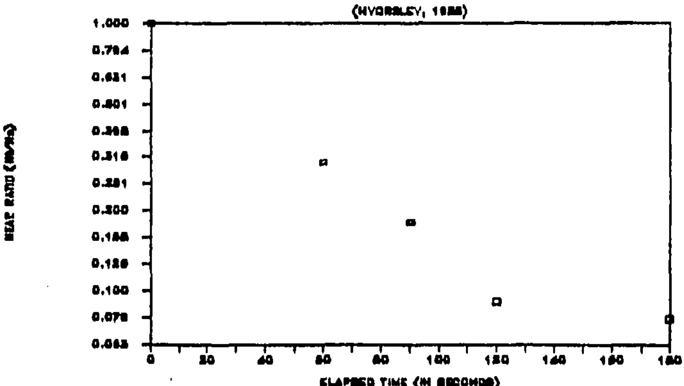
APPENDIX C

AWARE, INC.
VARIABLE HEAD
PERMEABILITY TEST

PIEZOMETER NO. W-22A

		TEST DATA	
		ELAPSED TIME	HEAD RATIO
PROJECT NO:	6279	0	1.000
CLIENT:	LORD CORP	60	0.303
GEOLOGIC UNIT:	MAUMEE III_C LACUSTRINE (SAND)	90	0.182
SOIL CLASSIFICATION:	f-m SAND tr Silt, grading to fmc SAND, little f Gravel	120	0.091
TESTED BY:	PDM	180	0.079
DATE OF TEST:	12-12-84		

GRAPHICAL ANALYSIS
(HVORSLEV, [illegible])



METHOD:

$$k = \frac{r^2}{2L(t_2 - t_1)} \ln(L/R) \ln(H_1/H_2)$$

Where:

K= permeability in cm/sec

r = well radius 2.54 cm

R = bore radius 10.16 cm

L = sand length 198.12 cm

K = 9.2E-04 cm/sec

H1 = head ratio at t1 1 (dimensionless)

t1 = elapsed time at H1 0 seconds

H2 = head ratio at t2 0.182 (dimensionless)

t2 = elapsed time at H2 90 seconds

AR300075

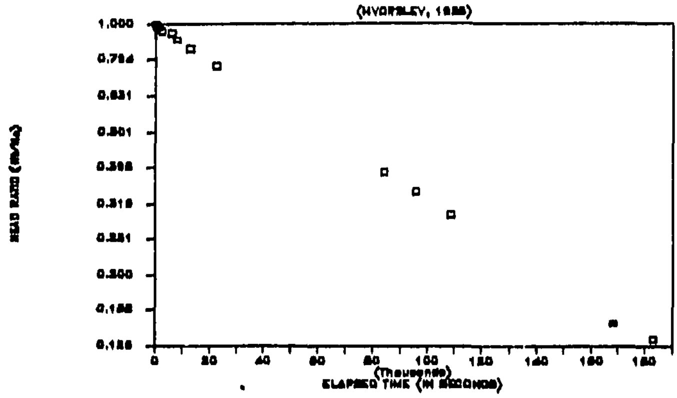
AWARE, INC.

VARIABLE HEAD
PERMEABILITY TEST

PIEZOMETER NO. W-21B

		TEST DATA	
PROJECT NO:	6279	ELAPSED TIME	HEAD RATIO
CLIENT:	LORD CORP	0	1.000
GEOLOGIC UNIT:	MAUMEE III$_{B}$ LACUSTRINE (SAND)	300	0.993
		600	0.987
SOIL CLASSIFICATION:	m-f SAND, grading to f SAND and SILT	900	0.982
		1500	0.976
		2400	0.961
		6000	0.943
TESTED BY:	PDM	7800	0.906
DATE OF TEST:	12-12-84	12540	0.855
		22440	0.768
		84240	0.387
		95640	0.340
		108540	0.293
		168360	0.146

GRAPHICAL ANALYSIS



METHOD:

$$k = \frac{r^2}{2L(t_2 - t_1)} \ln(L/R) \ln(H_1/H_2)$$

Where:

K= permeability in cm/sec

K = 5.2E-07 cm/sec

r = well radius 2.54 cm

R = bore radius 10.16 cm

L = sand length 213.36 cm

H1 = head ratio at t1 0.387 (dimensionless)

t1 = elapsed time at H1 84240 seconds

H2 = head ratio at t2 0.131 (dimensionless)

t2 = elapsed time at H2 183180 seconds

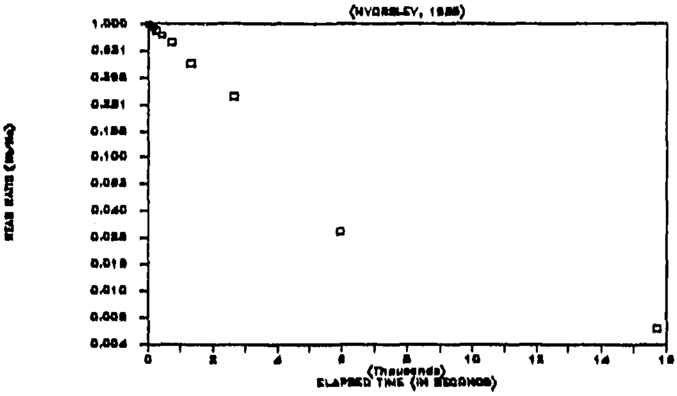
AR300076

AWARE, INC.
VARIABLE HEAD
PERMEABILITY TEST

PIEZOMETER NO. W-22-B

		TEST DATA	
PROJECT NO:	6279	ELAPSED TIME	HEAD RATIO
CLIENT:	LORD CORP	0	1.000
GEOLOGIC UNIT:	MAUMEE III$_B$ LACUSTRINE (SAND)	120	0.935
		240	0.886
SOIL CLASSIFICATION:	f-m SAND, no to little Silt interbedded with f Sand & Silt, tr Gravel (GT?)	420	0.816
		720	0.733
		1320	0.510
		2640	0.285
		5940	0.028
TESTED BY:	PDM	15720	0.005
DATE OF TEST:	12-12-84		

GRAPHICAL ANALYSIS
(HVORSLEV, 1951)



METHOD:

$$k = \frac{r^2}{2L(t_2 - t_1)} \ln(L/R) \ln(H_1/H_2)$$

Where:

K= permeability in cm/sec — K = 2.1E-05 cm/sec

r = well radius 2.54 cm

R = bore radius 10.16 cm

L = sand length 198.12 cm

H1 = head ratio at t1 0.510 (dimensionless)

t1 = elapsed time at H1 1320 seconds

H2 = head ratio at t2 0.285 (dimensionless)

t2 = elapsed time at H2 2640 seconds

AR300077

AWARE, INC.

VARIABLE HEAD
PERMEABILITY TEST

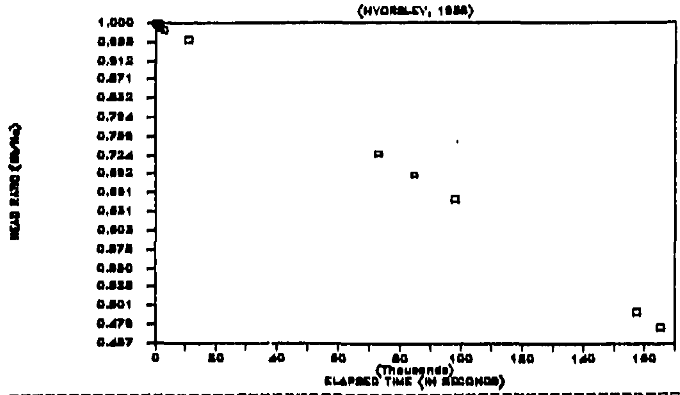
PIEZOMETER NO. W-23B

PROJECT NO:	6279
CLIENT:	LORD CORP
GEOLOGIC UNIT:	MAUMEE III_B LACUSTRINE (SILT)
SOIL CLASSIFICATION:	massive SILT, interbedded with SILT & CLAY and with GT
TESTED BY:	PDM
DATE OF TEST:	12-12-84

TEST DATA

ELAPSED TIME	HEAD RATIO
0	1.000
600	0.997
900	0.997
1140	0.993
1440	0.990
2940	0.983
11040	0.960
72840	0.727
84540	0.691
97740	0.651
157440	0.494
165240	0.475

GRAPHICAL ANALYSIS
(HVORSLEV, 1951)



METHOD:

$$k = \frac{r^2}{2L(t_2 - t_1)} \ln(L/R) \ln(H_1/H_2)$$

Where:

K= permeability in cm/sec

K = 1.8E-07 cm/sec

r = well radius 2.54 cm

R = bore radius 10.16 cm

L = sand length 243.84 cm

H1 = head ratio at t1 0.993 (dimensionless)

t1 = elapsed time at H1 1140 seconds

H2 = head ratio at t2 0.651 (dimensionless)

t2 = elapsed time at H2 97740 seconds

AR300078

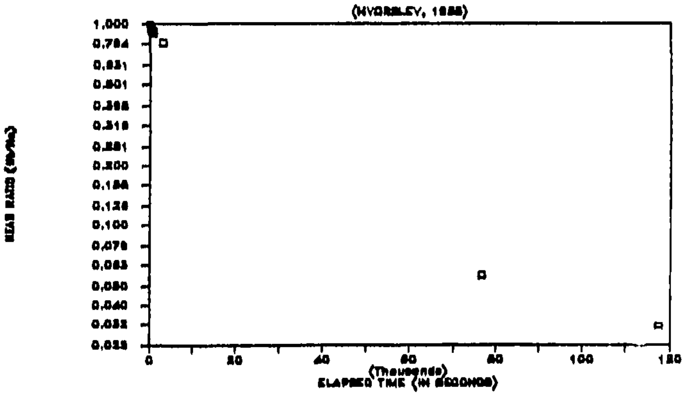
AWARE, INC.

VARIABLE HEAD
PERMEABILITY TEST

PIEZOMETER NO. W-24B

		TEST DATA	
PROJECT NO:	6279	ELAPSED TIME	HEAD RATIO
CLIENT:	LORD CORP	0	1.000
GEOLOGIC UNIT:	MAUMEE III_{B}	300	0.948
		600	0.927
SOIL CLASSIFICATION:	m-f SAND, trace to little Silt	900	0.913
		3120	0.816
		76800	0.056
		117300	0.031
TESTED BY:	PDM		
DATE OF TEST:	12-12-84		

GRAPHICAL ANALYSIS
(HVORSLEV, 1951)



METHOD:

$$k = \frac{r^2}{2L(t_2 - t_1)} \ln(L/R) \ln(H_1/H_2)$$

Where:

K= permeability in cm/sec K = 2.6E-06 cm/sec
r = well radius 2.54 cm
R = bore radius 5.08 cm
L = sand length 152.4 cm

H1 = head ratio at t1 0.816 (dimensionless)
t1 = elapsed time at H1 3120 seconds
H2 = head ratio at t2 0.056 (dimensionless)
t2 = elapsed time at H2 76800 seconds

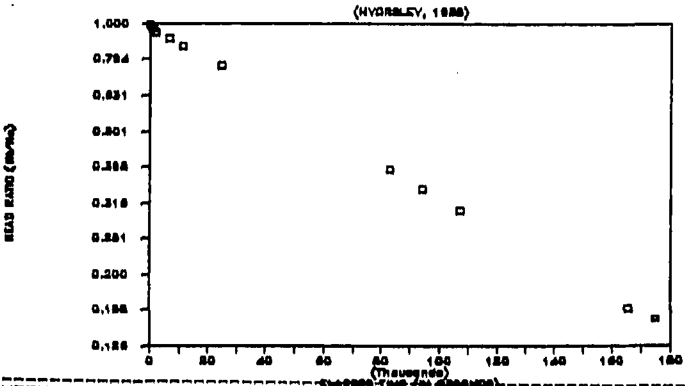
AR300079

AWARE, INC.
VARIABLE HEAD
PERMEABILITY TEST

PIEZOMETER NO. W-21C

PROJECT NO:	6279	TEST DATA	
		ELAPSED TIME	HEAD RATIO
CLIENT:	LORD CORP	0	1.000
GEOLOGIC UNIT:	MAUMEE III LACUSTRINE (SAND)	120	0.989
		960	0.971
SOIL CLASSIFICATION:	m SAND, trace SILT	2040	0.950
		6300	0.908
		11160	0.863
		24600	0.767
		82860	0.393
TESTED BY:	PDM	94260	0.347
		107160	0.302
DATE OF TEST:	12-12-84	165642	0.161
		174660	0.150

GRAPHICAL ANALYSIS
(HVORSLEV, 19[illegible])



METHOD:

$$k = \frac{r^2}{2L(t_2 - t_1)} \ln(L/R) \ln(H_1/H_2)$$

Where:

K= permeability in cm/sec

r = well radius 2.54 cm

R = bore radius 5.08 cm

L = sand length 106.68 cm

K = 9.7E-07 cm/sec

H1 = head ratio at t1 0.393 (dimensionless)

t1 = elapsed time at H1 82860 seconds

H2 = head ratio at t2 0.150 (dimensionless)

t2 = elapsed time at H2 174660 seconds

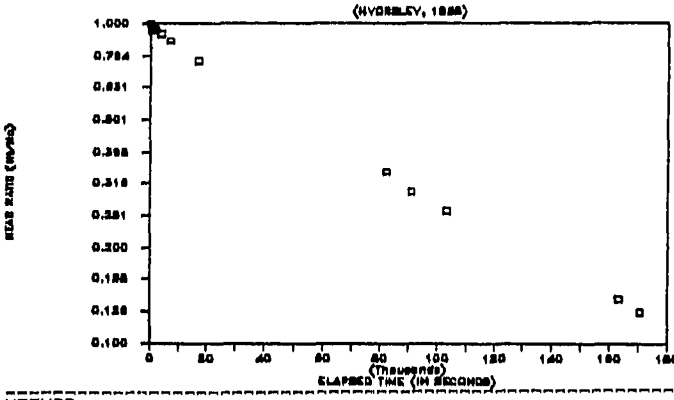
AR300080

AWARE, INC.
VARIABLE HEAD
PERMEABILITY TEST

PIEZOMETER NO. W-22C

		TEST DATA	
PROJECT NO:	6279	ELAPSED TIME	HEAD RATIO
CLIENT:	LORD CORP	0	1.000
GEOLOGIC UNIT:	MAUMEE III$_A$ LACUSTRINE (SAND)	300	0.957
SOIL CLASSIFICATION:	f SAND, trace Silt interbedded with Clay & Silt	900	0.962
TESTED BY:	PDM	1800	0.948
DATE OF TEST:	12-12-84	3660	0.924
		7200	0.882
		16920	0.763
		81960	0.346
		90900	0.299
		103200	0.261
		163140	0.137
		170700	0.126

GRAPHICAL ANALYSIS



METHOD:

$$k = \frac{r^2}{2L(t_2 - t_1)} \ln(L/R) \ln(H_1/H_2)$$

Where:

K= permeability in cm/sec

K = 1.1E-06 cm/sec

r = well radius 2.54 cm
R = bore radius 5.08 cm
L = sand length 106.68 cm

H1 = head ratio at t1 0.763 (dimensionless)
t1 = elapsed time at H1 16920 seconds
H2 = head ratio at t2 0.126 (dimensionless)
t2 = elapsed time at H2 170700 seconds

AR300081

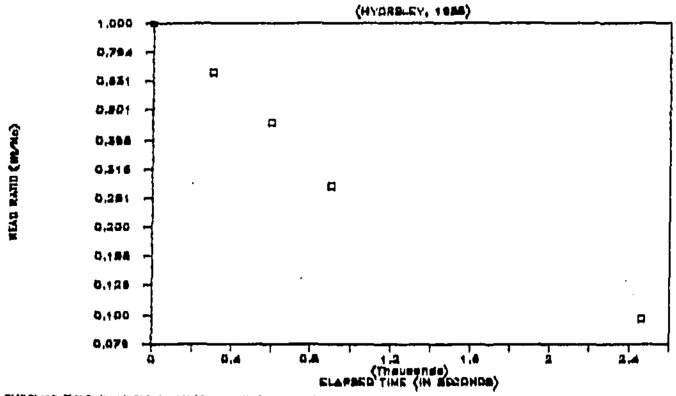
AWARE, INC.

VARIABLE HEAD
PERMEABILITY TEST

PIEZOMETER NO. W-23C

PROJECT NO:	6279	TEST DATA	
CLIENT:	LORD CORP	ELAPSED TIME	HEAD RATIO
		0	1.000
GEOLOGIC UNIT:	MAUMEE III$_A$ LACUSTRINE	300	0.679
		600	0.455
SOIL		900	0.276
CLASSIFICATION:	f SAND, trace Silt, interbedded with laminated Clay & Silt	2460	0.097
TESTED BY:	PDM		
DATE OF TEST:	12-12-84		
		0	-2.597
		0	-2.597

GRAPHICAL ANALYSIS



METHOD:

$$K = \frac{r^2}{2L(t_2 - t_1)} \ln(L/R) \ln(H_1/H_2)$$

Where:

K= permeability in cm/sec — K = 1.1E-04 cm/sec

r = well radius 2.54 cm

R = bore radius 5.08 cm

L = sand length 167.64 cm

H1 = head ratio at t1 0.455 (dimensionless)

t1 = elapsed time at H1 600 seconds

H2 = head ratio at t2 0.276 (dimensionless)

t2 = elapsed time at H2 900 seconds

AR300082

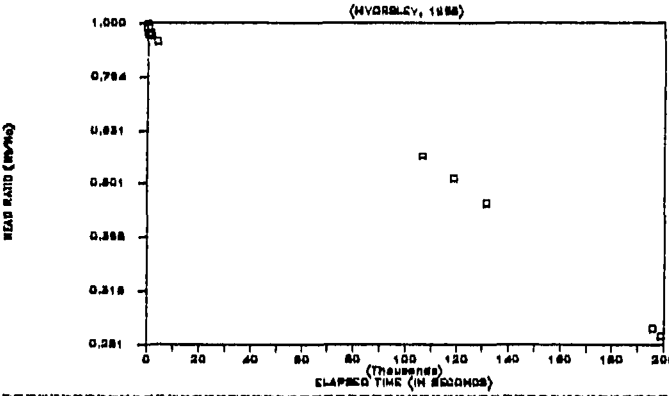
AWARE, INC.

VARIABLE HEAD
PERMEABILITY TEST

PIEZOMETER NO. W-24C

		TEST DATA	
PROJECT NO:	6279	ELAPSED TIME	HEAD RATIO
CLIENT:	LORD CORP	0	1.000
GEOLOGIC UNIT:	MAUMEE III$_A$ LACUSTRINE	300	0.981
		660	0.955
SOIL		960	0.955
CLASSIFICATION:	f SAND, little Silt, with	1260	0.948
	laminations Clay & Silt	1500	0.948
		3900	0.922
		106260	0.565
TESTED BY:	PDM	118560	0.513
		131460	0.461
DATE OF TEST:	12-12-84	195900	0.269
		198960	0.261

GRAPHICAL ANALYSIS
(HVORSLEY, [illegible])



METHOD:

$$k = \frac{r^2}{2L(t_2 - t_1)} \ln(L/R) \ln(H_1/H_2)$$

Where:

K= permeability in cm/sec   K = 5.3E-07 cm/sec

r = well radius 2.54 cm

R = bore radius 5.08 cm

L = sand length 182.88 cm

H1 = head ratio at t1 0.461 (dimensionless)

t1 = elapsed time at H1 131460 seconds

H2 = head ratio at t2 0.261 (dimensionless)

t2 = elapsed time at H2 198960 seconds

AR300083

THE AWARE CORPORATION

VARIABLE HEAD PERMEABILITY TEST

PIEZOMETER No. W-12A

PROJECT: SHOPES LANDFILL

CLIENT: LORC CORP.

JOB NO: 6279

DATE OF TEST: 7/22/81 (R.S. - WE)

SCREENED INTERVAL:

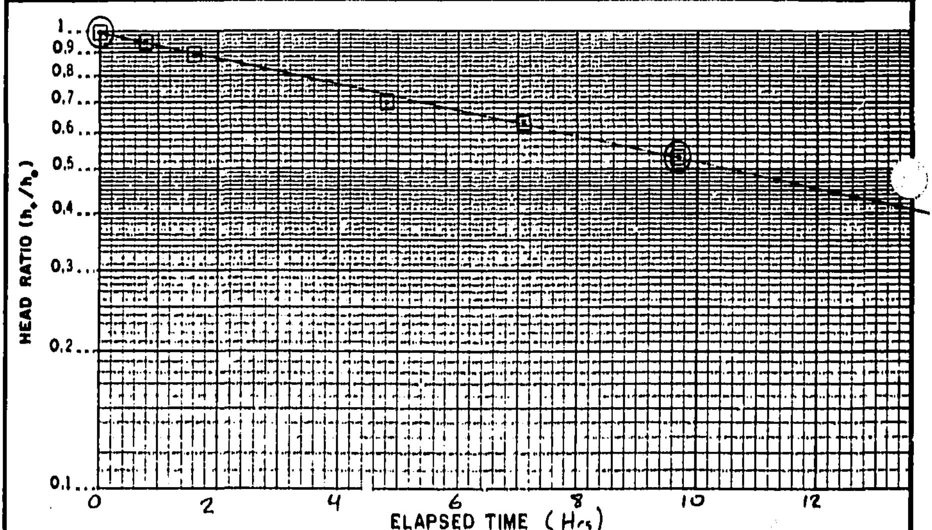
MAUMEE III B (Coarse)

METHOD:

$$K = \frac{r^2}{2L(t_2 - t_1)} \ln(L/R) \ln(H_1/H_2)$$

TEST DATA

ELAPSED TIME (hrs)	HEAD RATIO (h_t / h_0)
0.00	1.00
0.78	.95
1.61	.89
4.42	.70
7.12	.63
9.72	.53
14.03	.40



CALCULATIONS:

$$K = \frac{(1.9)^2 \ln(106.7/10.2)}{2(106.7)(34992-0)} \ln\left(\frac{1.00}{0.53}\right)$$

$$K = 7.2 \times 10^{-7} \text{ cm/sec}$$

r = 1.9 cm
R = 10.2 cm
L = 106.7 cm
H_1 = 1.00
t_1 = 0 sec
H_2 = 0.53
t_2 = 9.72 hrs = 34,992 sec

AR300084

THE AWARE CORPORATION

VARIABLE HEAD PERMEABILITY TEST

PIEZOMETER No. W-12 B

PROJECT: SHOPE'S LANDFILL

CLIENT: LORD CORP.

JOB NO: 6279

DATE OF TEST: 7/22/81 (R.S. - WE)

SCREENED INTERVAL:

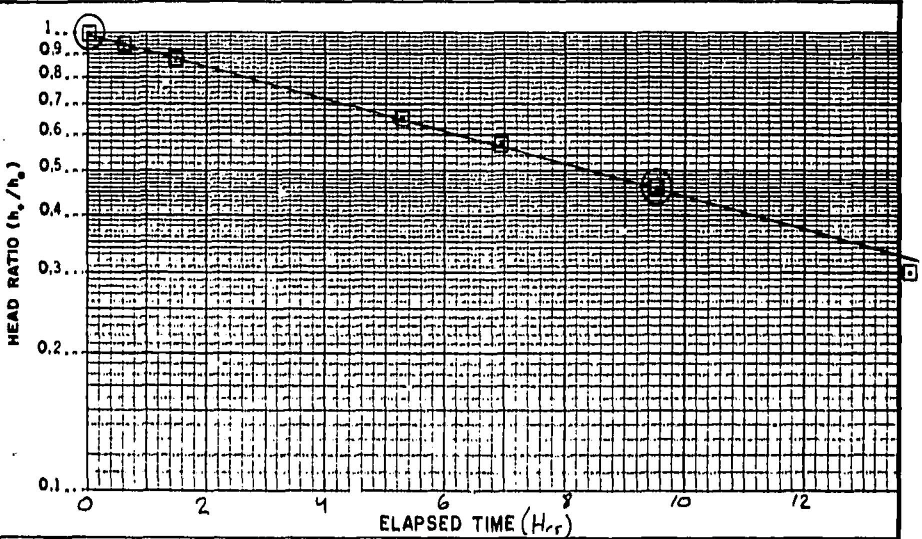
ASHTABULA TILL - ASHTABULA (Fine)

METHOD:

$$K = \frac{r^2}{2L(t_2 - t_1)} \ln(L/R) \ln(H_1/H_2)$$

TEST DATA

ELAPSED TIME (Hrs)	HEAD RATIO (h_t / h_0)
0.00	1.00
0.63	.94
1.46	.88
5.28	.65
6.95	.57
9.57	.46
13.88	.31



CALCULATIONS:

r = 1.9 cm
R = 10.2 cm
L = 122 cm
H_1 = 1.00
t_1 = 0 sec
H_2 = .46
t_2 = 9.57 hr = 34440 sec

$$K = \frac{(1.9)^2 \ln(122/10.2)}{2(122)(34440-0)} \ln\left(\frac{1.00}{.46}\right)$$

$$K = 8.3 \times 10^{-7} \text{ cm/sec}$$

AR300085

THE AWARE CORPORATION

VARIABLE HEAD PERMEABILITY TEST

PIEZOMETER No. W-12C

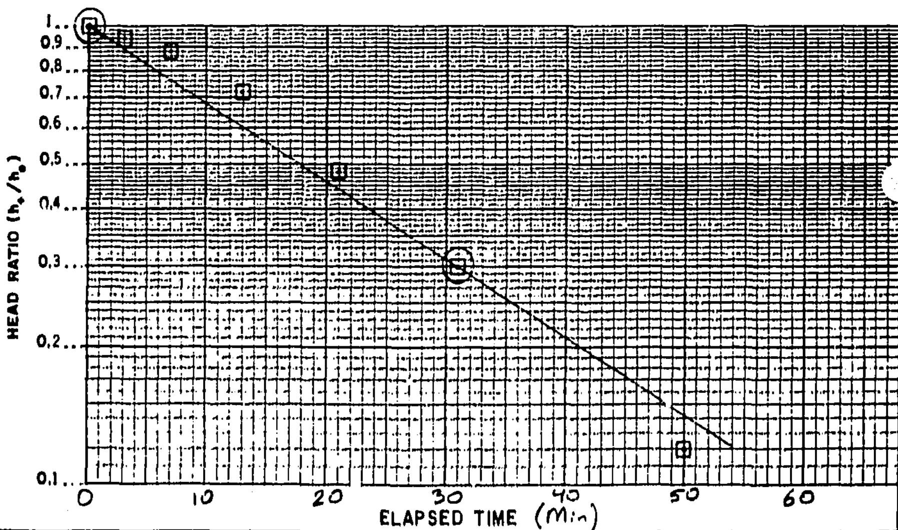
PROJECT:	SHOPES LANDFILL
CLIENT:	LORD CORP
JOB NO:	6279
DATE OF TEST:	7/22/91 (R.S. - WE)
SCREENED INTERVAL:	MAUMEE III C (Coarse)

METHOD:

$$K = \frac{r^2}{2L(t_2 - t_1)} \ln(L/R) \ln(H_1/H_2)$$

TEST DATA

ELAPSED TIME (Min)	HEAD RATIO (h_t / h_0)
0.0	1.00
3.0	.94
7.0	.88
13.0	.72
21.0	.48
31.0	.30
50.0	.12



CALCULATIONS:

$$K = \frac{(1.9)^2 \ln(91/10.2)}{2(91)(1800.0)} \ln\left(\frac{1.00}{.30}\right)$$

$$K = 2.9 \times 10^{-5} \text{ cm/sec}$$

AR300086

r = 1.9 cm
R = 10.2 cm
L = 91 cm
H_1 = 1.00
t_1 = 0 sec
H_2 = .30
t_2 = 31 min = 1800 sec

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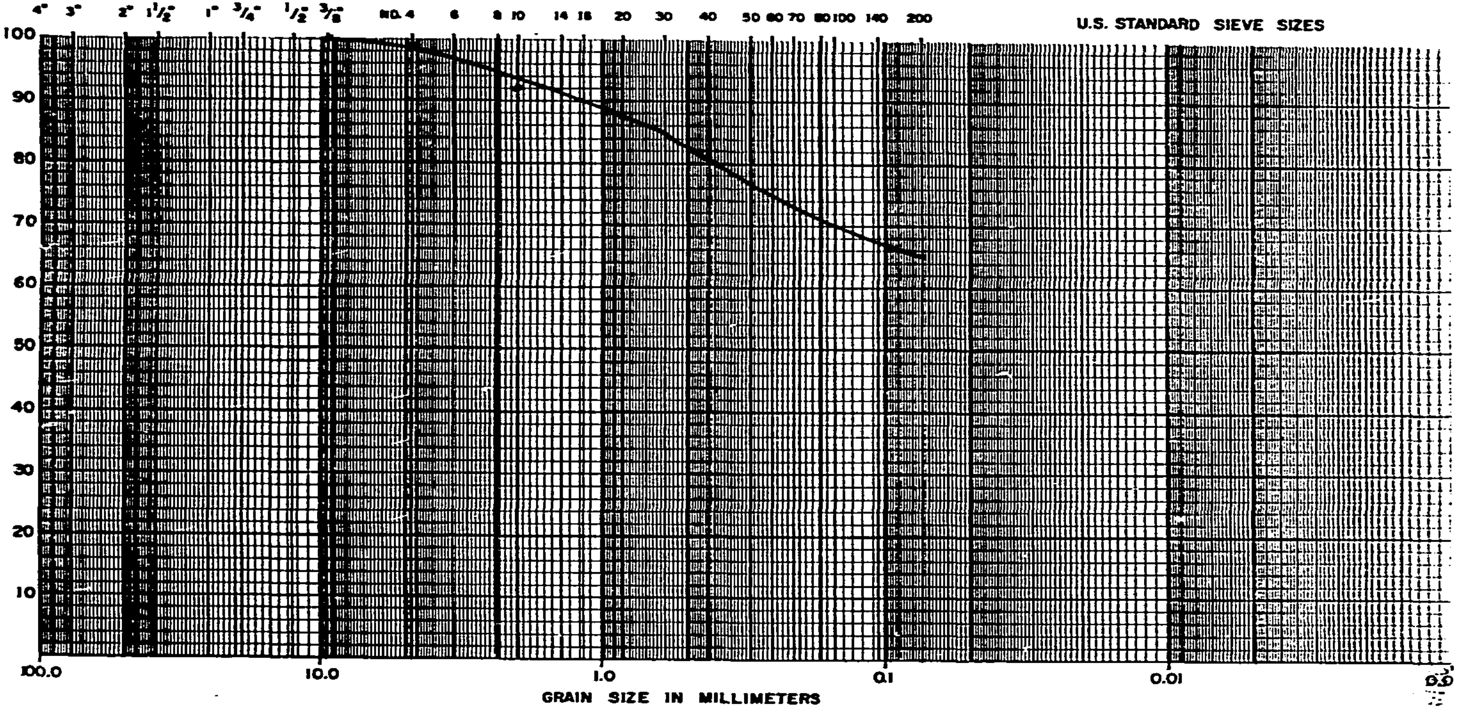
ORIGINAL

APPENDIX D

AR300087



	3"	1"	3/8"	2.0mm	0.60	0.25	0.74	0.005	
COBBLES	COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	SILT		CLAY
	GRAVEL			SAND					

BORING NO. SAMPLE NO.	DEPTH	ELEV.	IDENTIFICATION	MOIST. CONT.	L.L.%	P.L.%	P.I.
B-3C	58'-66		Gray SILT & CLAY Some + mf Sand, trace (+) of Gravel.	10.5%	23	15	8
S-12							

MECHANICAL ANALYSIS

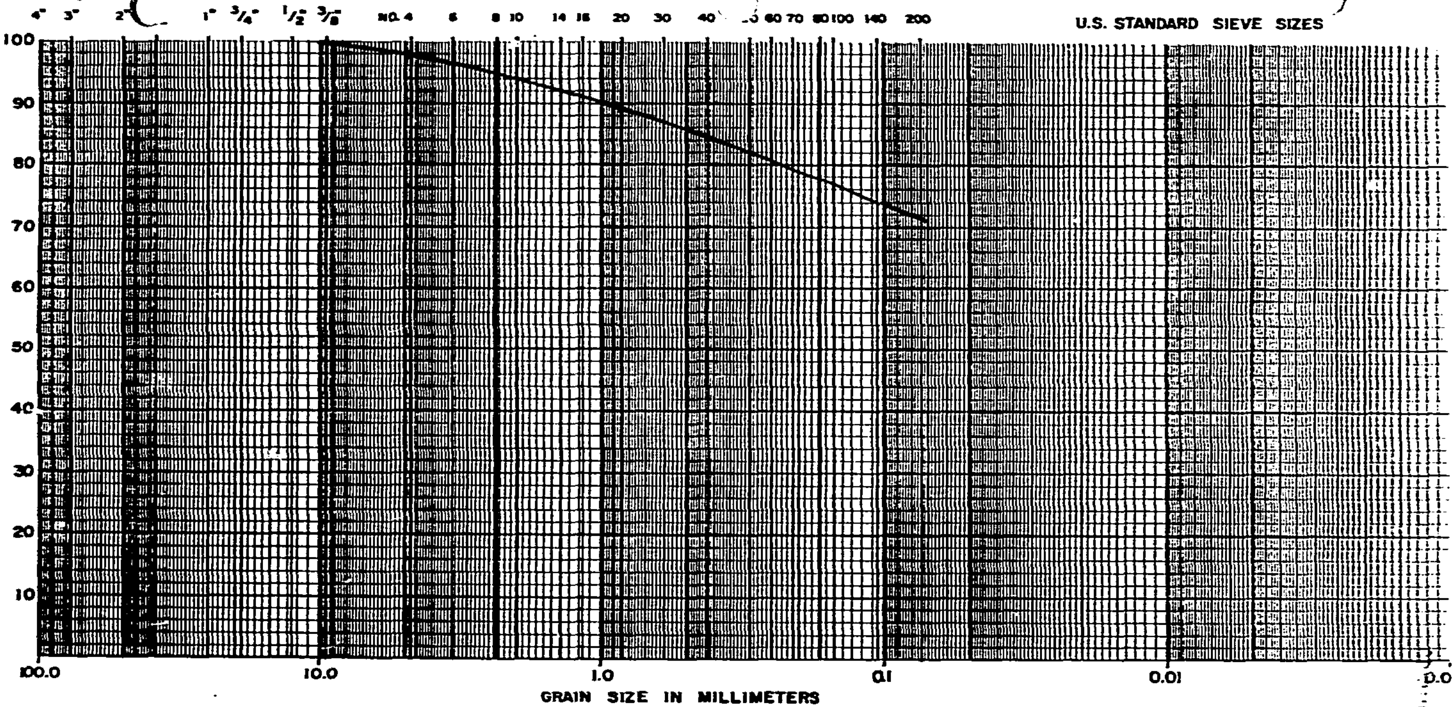
Client: AWARE

Project:

Project Number: WESL #254

Date: 1-22-85 Figure No.:

WEHRAN ENGINEERING



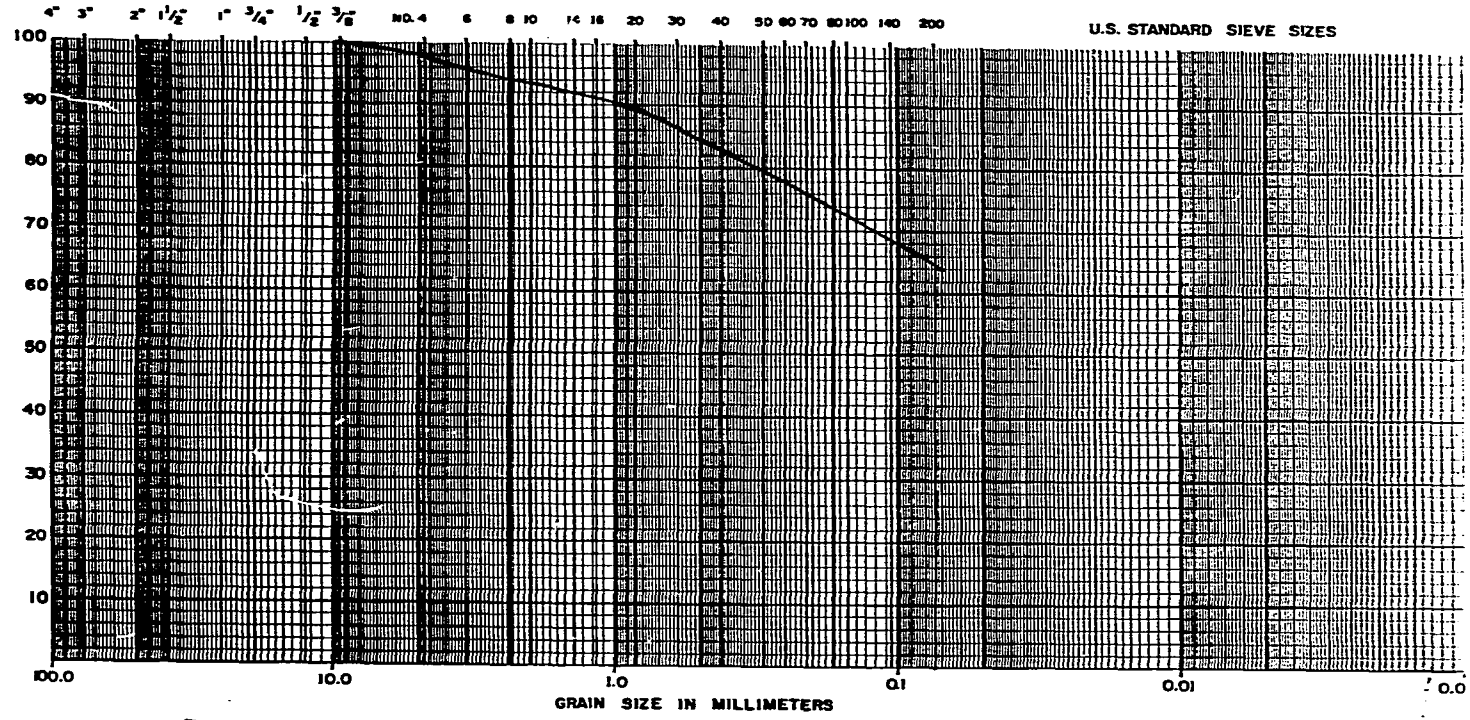
3"		3/8"	2.0mm	0.60	0.25	0.74	0.005
COBBLES	COARSE / MEDIUM (GRAVEL)	FINE (GRAVEL)	COARSE (SAND)	MEDIUM (SAND)	FINE (SAND)	SILT	CLAY

BORING NO. SAMPLE NO.	DEPTH	ELEV.	IDENTIFICATION	MOIST. CONT.	L.L.%	P.L.%	P.I.
B-36	7.0		Gray SILT & CLAY some m-f	8.6%			
	-[illegible]		Sand, trace fine Gravel.				
S-16							

MECHANICAL ANALYSIS

Client: AWARE
Project:
Project Number: WESL # 254
Date: 1-22-85 Figure No.:

WEHRAN ENGINEERING



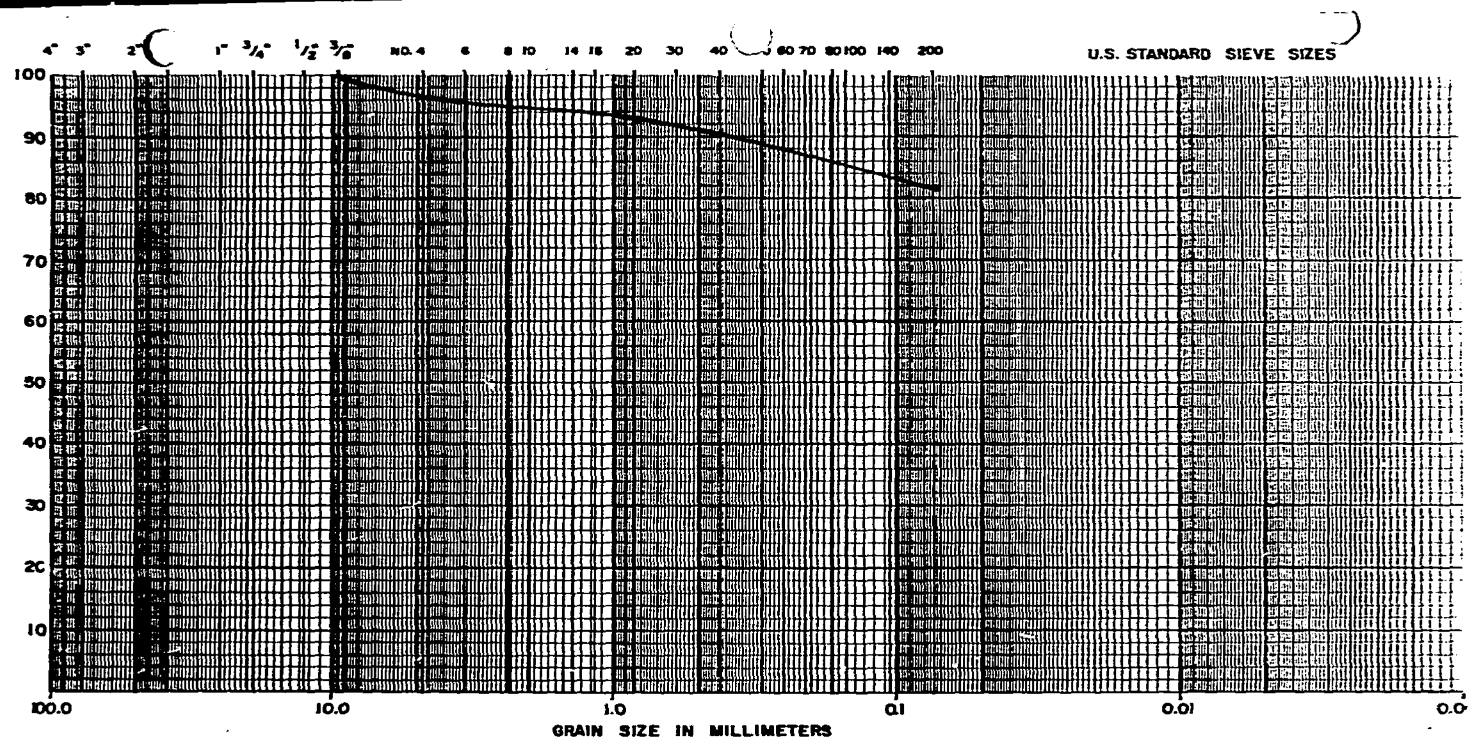
	3"		3/4"	3/8"	2.0mm	0.80	0.25	0.74	0.005
COBBLES	COARSE	MEDIUM	FINE		COARSE	MEDIUM	FINE	SILT	CLAY
	GRAVEL				SAND				

BORING NO. SAMPLE NO.	DEPTH	ELEV.	IDENTIFICATION	MOIST. CONT.	L.L. %	P. L.%	P. I.
B-12D	55-57'		Gray Clayey SILT and - , m-f Sand trace fine Gravel	11.2%			
S-1							

MECHANICAL ANALYSIS

Client: AWARE
Project:
Project Number: WESL #254
Date: 1-22-85 Figure No.:

WEHRAN ENGINEERING



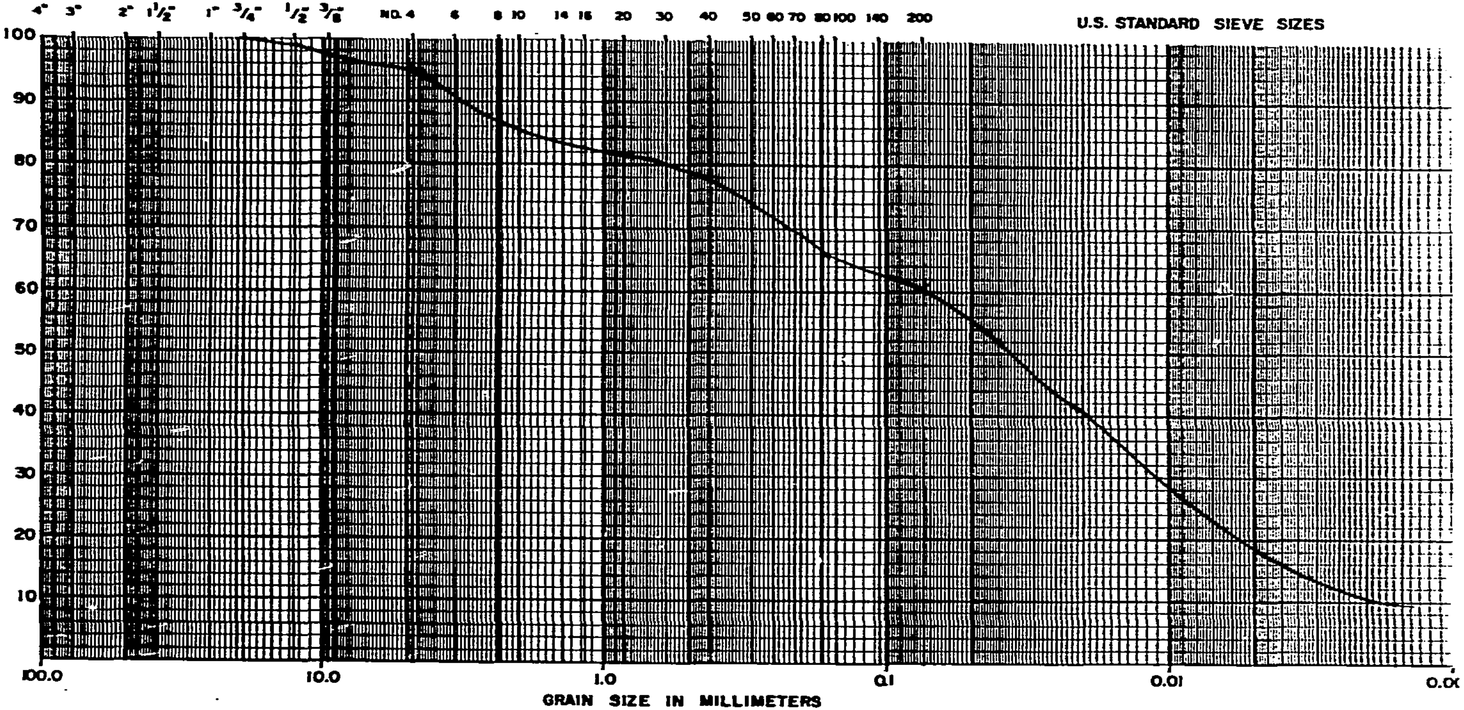
3"	1"	3/8"	2.0mm	0.60	0.25	0.74	0.005	
COBBLES	COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	SILT	CLAY
	GRAVEL			SAND				

BORING NO. SAMPLE NO.	DEPTH	ELEV.	IDENTIFICATION	MOIST. CONT.	L.L.%	P.L.%	P.I.
B-120	8.0		Gray CLAY & SILT little f	14.6%	28	17	10
	8.5		Sand, trace fine Gravel.				
S-6							

MECHANICAL ANALYSIS

Client: AWARE
Project:
Project Number: WESL # 254
Date: 1.22.85 Figure No.:

WEHRAN ENGINEERING



3"		3/4"	3/8"	2.0mm	0.60	0.25	0.74	0.005	
COBBLES	COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	SILT		CLAY
	GRAVEL			SAND					

BORING NO. SAMPLE NO.	DEPTH	ELEV.	IDENTIFICATION	MOIST. CONT.	L.L.%	P.L.%	P.I.
10-12-1	10-12'		Gray clayey SILT and, c-m-f Sand, little m-f Gravel.	12.5%	17	15	2
B-12							

MECHANICAL ANALYSIS

Client: AWARE

Project: AWARE #6278

Project Number: WESL #254

Date: 1.21.85 Figure No.:

WEHRAN E[illegible]NEERING

AR300[illegible]

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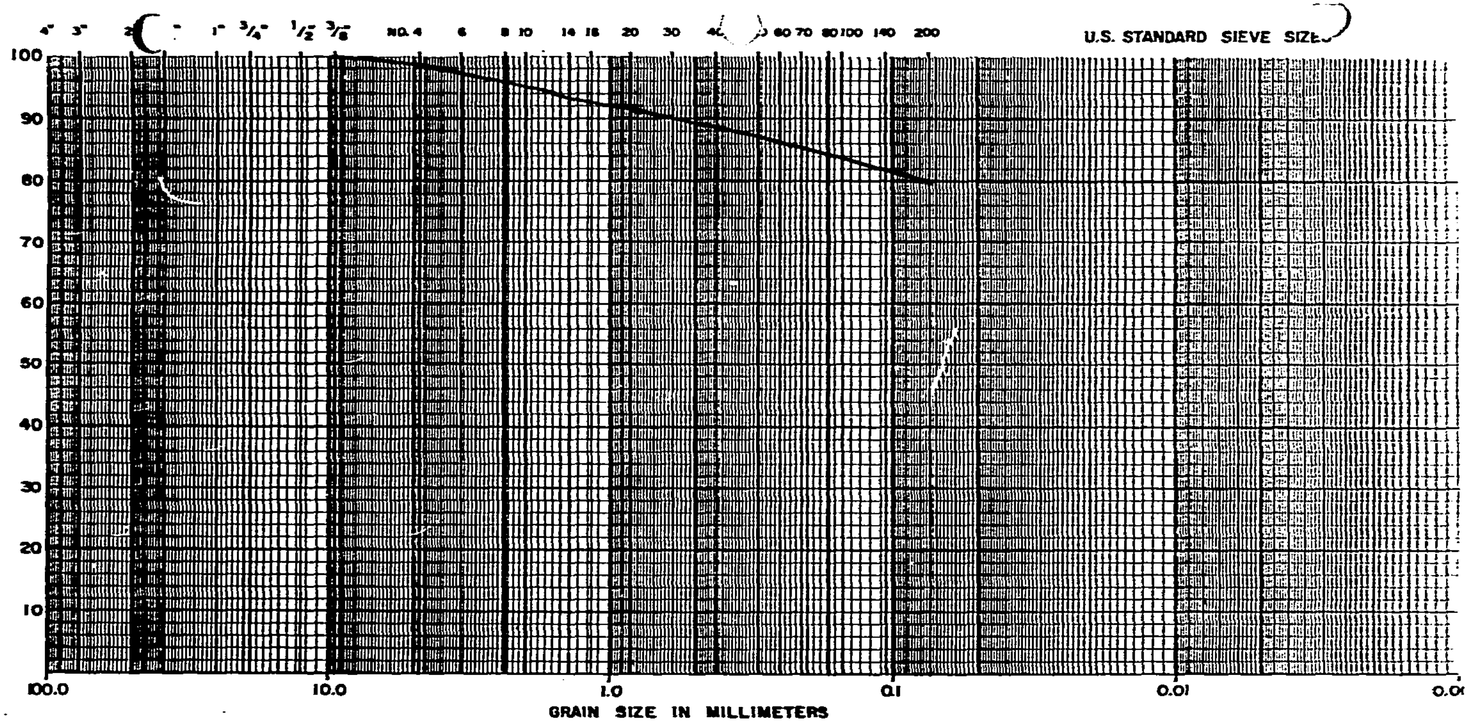


3"	1"	3/8"	2.0mm	0.80	0.25	0.74	0.005			
COBBLES	COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	SILT	CLAY
	GRAVEL			SAND				

AR300093

BORING NO. SAMPLE NO.	DEPTH	ELEV.	IDENTIFICATION	MOIST. CONT.	L.L.%	P.L.%	P.I.
B-20C	93		Gray SILT & CLAY some(-) w/	10 1%			
	97'		Sand, trace fine Gravel.				
S-29							

MECHANICAL ANALYSIS

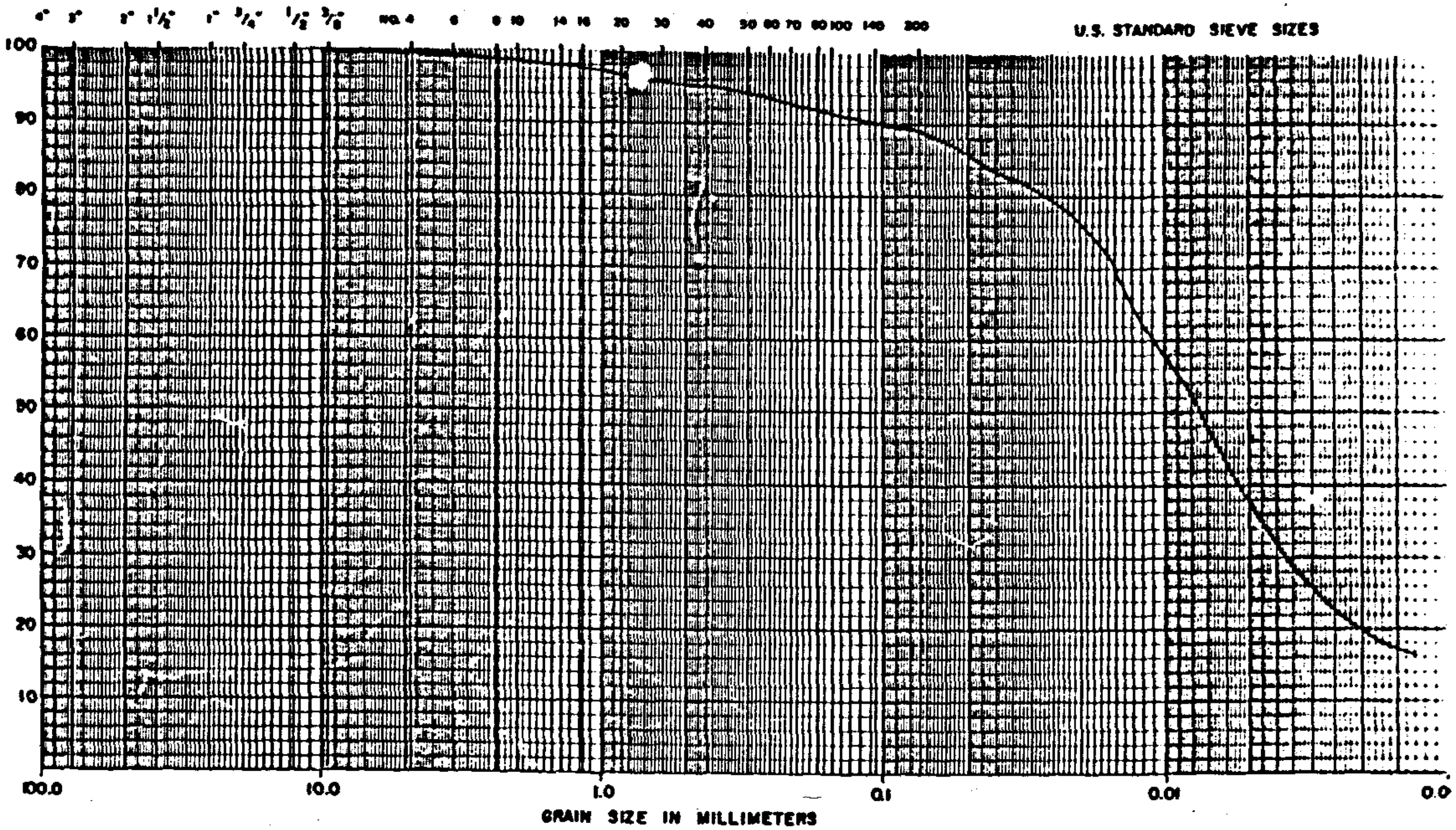
Client: AWARE

Project:

Project Number: WESL #254

Date: 1-22-85 Figure No.:

WEHRAN ENGINEERING



3"	1"	3/8"		2.0mm	0.60	0.25	0.74	0.005
COBBLES	COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	SILT	CLAY
	GRAVEL			SAND				

BORING NO. SAMPLE NO.	DEPTH	ELEV.	IDENTIFICATION	MOIST. CONT.	L.L. %	P.L.%	P.I.
III-20-1			Gray Br SILT & CLAY Little mf		27	19	8
TOP			Sand trace of Gravel				
13-20							

AR300005

MECHANICAL ANALYSIS

Client: Auhle

Project: Auhle # 6271

Project Number: WESL #...

Date: 1 21 75 Figure No.:

WEHRAN ENGINEERING

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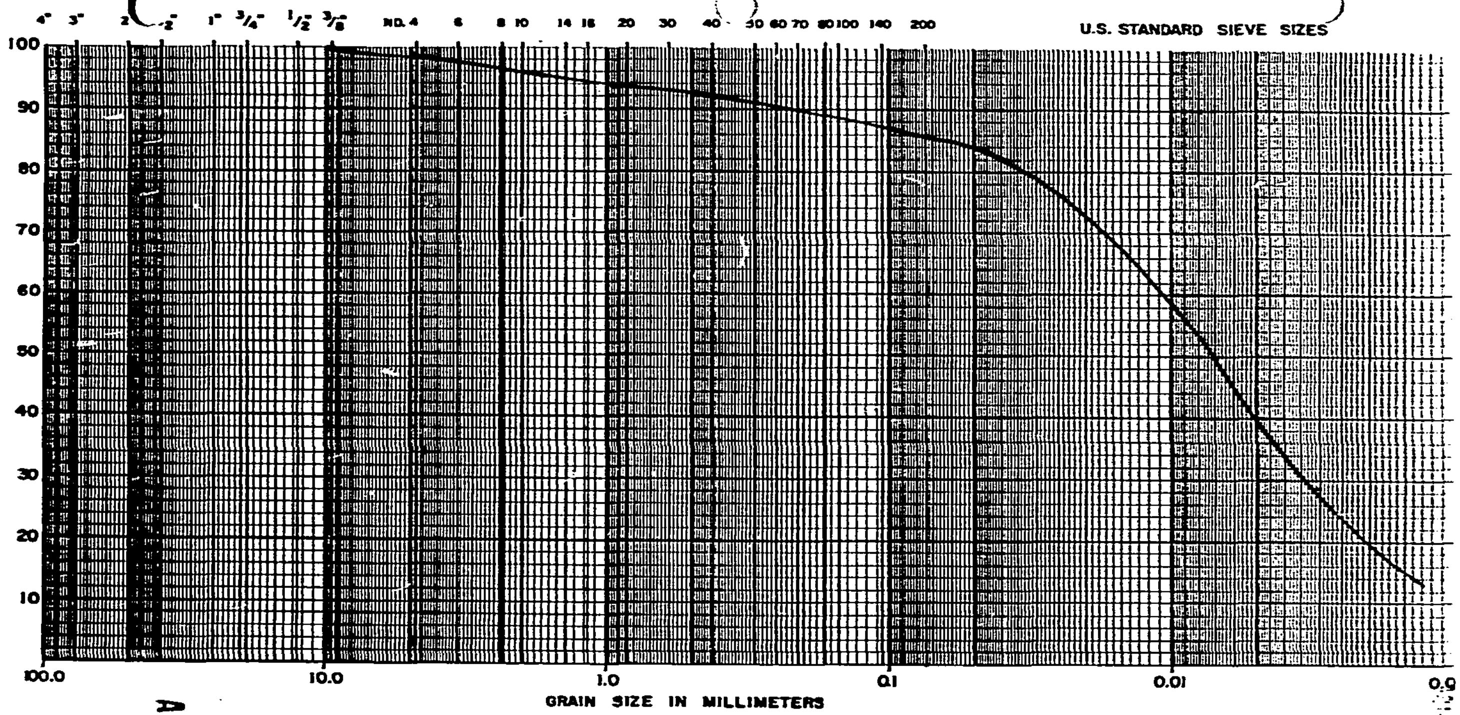


3"	1"	3/8"	2.0mm	0.60	0.25	0.74	0.005	
COBBLES	COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	SILT	CLAY
	GRAVEL			SAND				

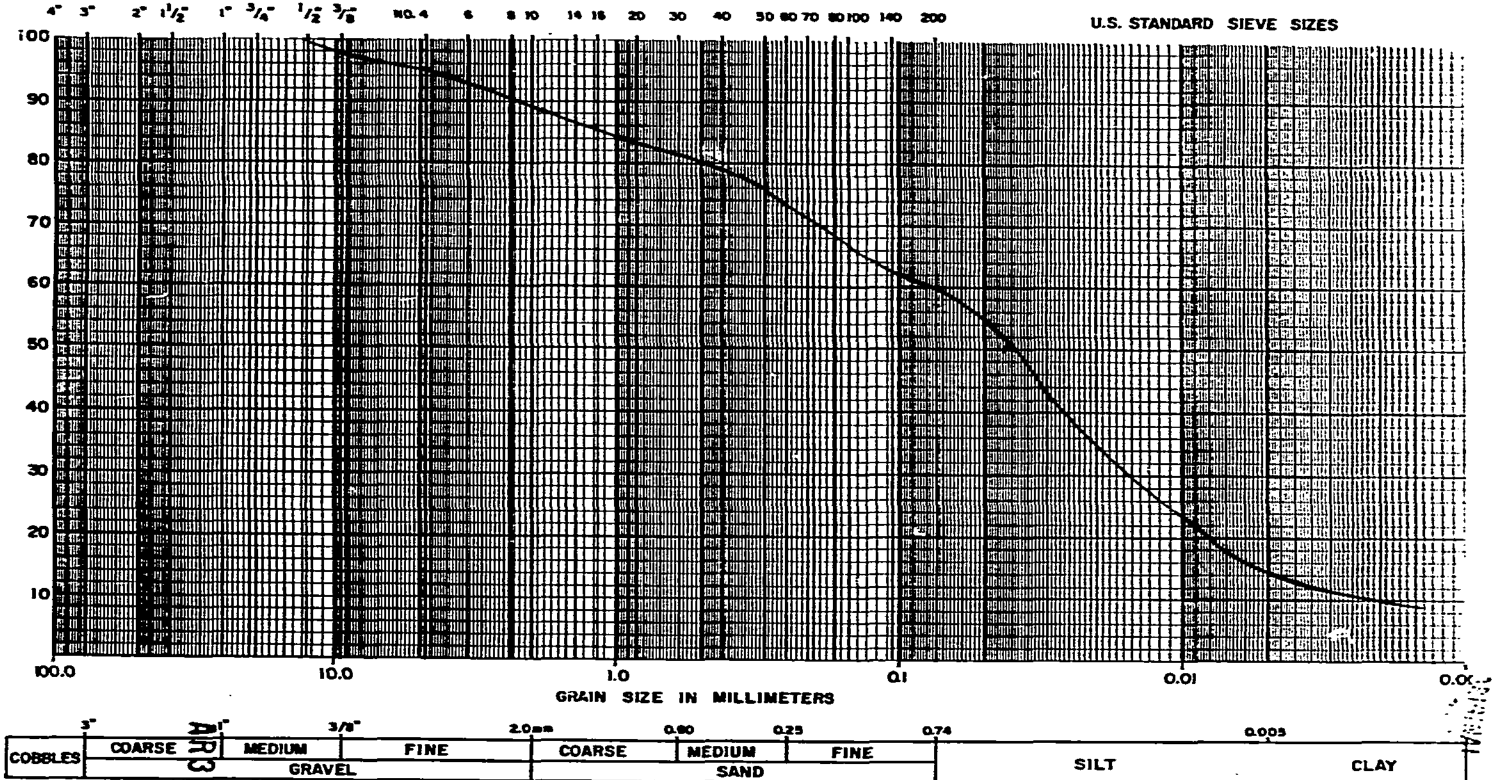
AR300

BORING NO. SAMPLE NO.	DEPTH	ELEV.	IDENTIFICATION	MOIST. CONT.	L.L.%	P.L.%	P.I.
UD-20-1	23-25'		Gray Br. clayey SILT little, mf Sand, trace of Gravel.	22.9	23	18	5
Bottom of the tube							
B-20							

MECHANICAL ANALYSIS

Client: AWARE
Project: AWARE #627F
Project Number: WESL #254
Date: 1-21-85 Figure No.: ____

WEHRAN ENGINEERING



BORING NO. SAMPLE NO.	DEPTH	ELEV.	IDENTIFICATION	MOIST. CONT.	L.L.%	P.L.%	P.I.
UD-20-2	34		Tan Clayey SILT and, and	12.5%	16	15	1
	36		Sand, little(-) and Gravel				
B-20							

MECHANICAL ANALYSIS

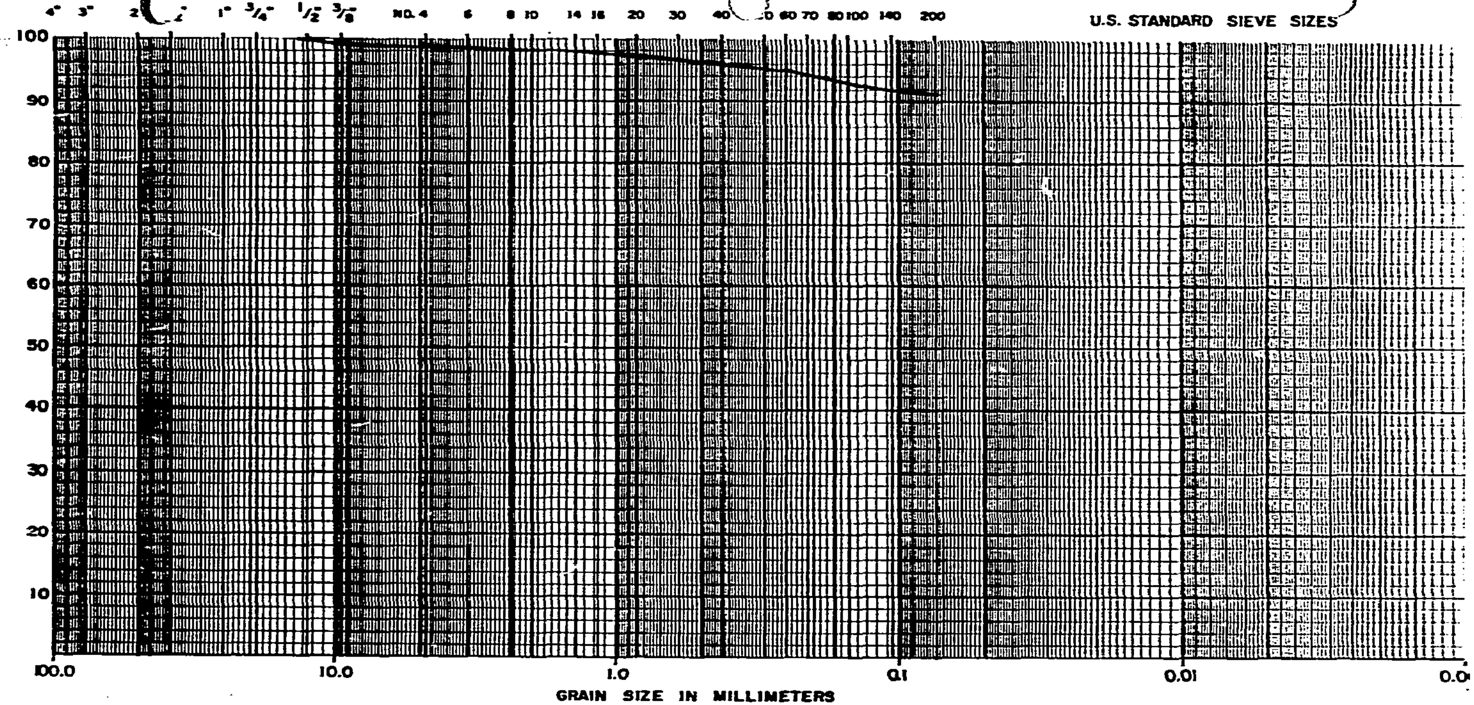
Client: AWARE

Project: AWARE #6278

Project Number: WESL #254

Date: 1-21-85 Figure No.: ______

WE WEHRAN ENGINEERING



3"		3/8"	2.0mm	0.60	0.25	0.74	0.005	
COBBLES	COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	SILT	CLAY
	GRAVEL			SAND				

BORING NO. SAMPLE NO.	DEPTH	ELEV.	IDENTIFICATION	MOIST. CONT.	L.L.%	P.L.%	P.I.
B-21C	38'		Gray Clayey SILT trace+,	13.5%	23	19	4
			m-f Sand, trace(-) fine				
S-20	40'		Gravel				

MECHANICAL ANALYSIS

Client: AWARE

Project:

Project Number: WESL #1254

Date: 1-22-85 Figure No.:

WEHRAN ENGINEERING

AR300097

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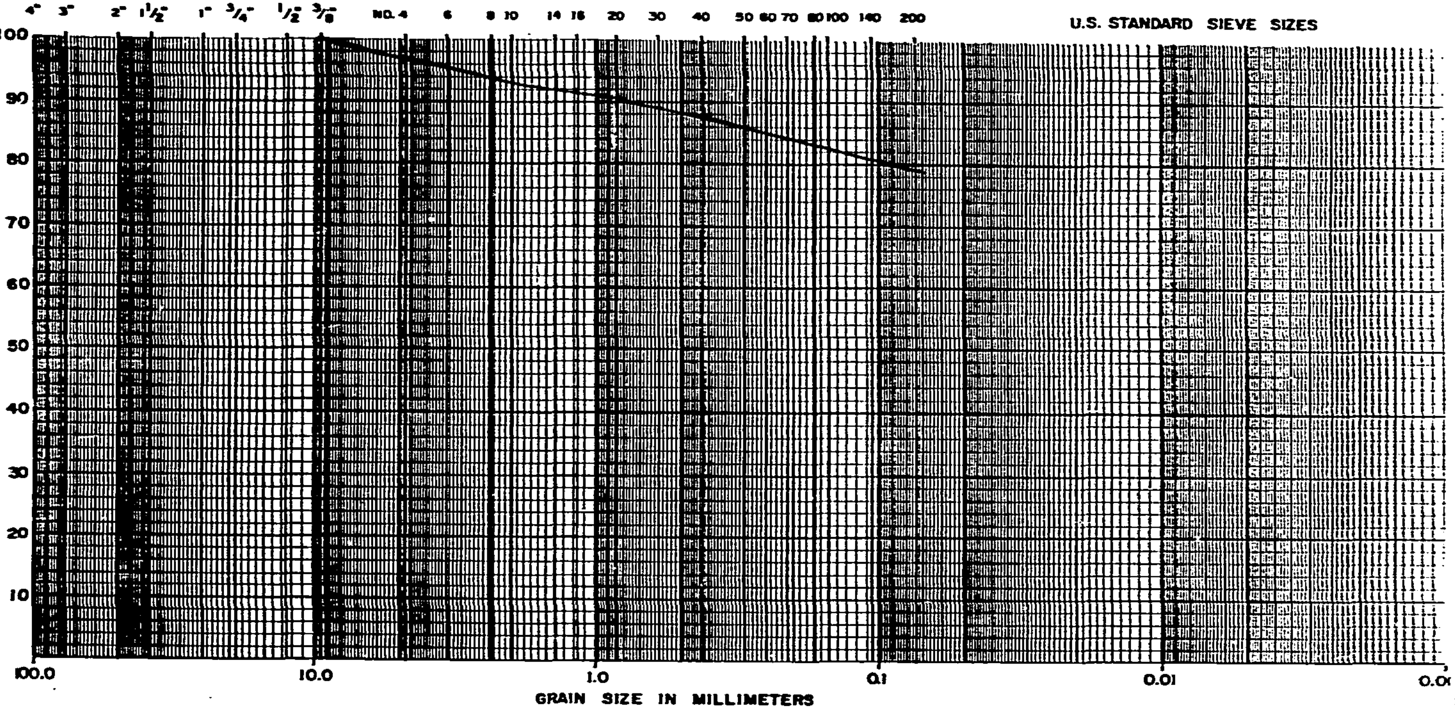


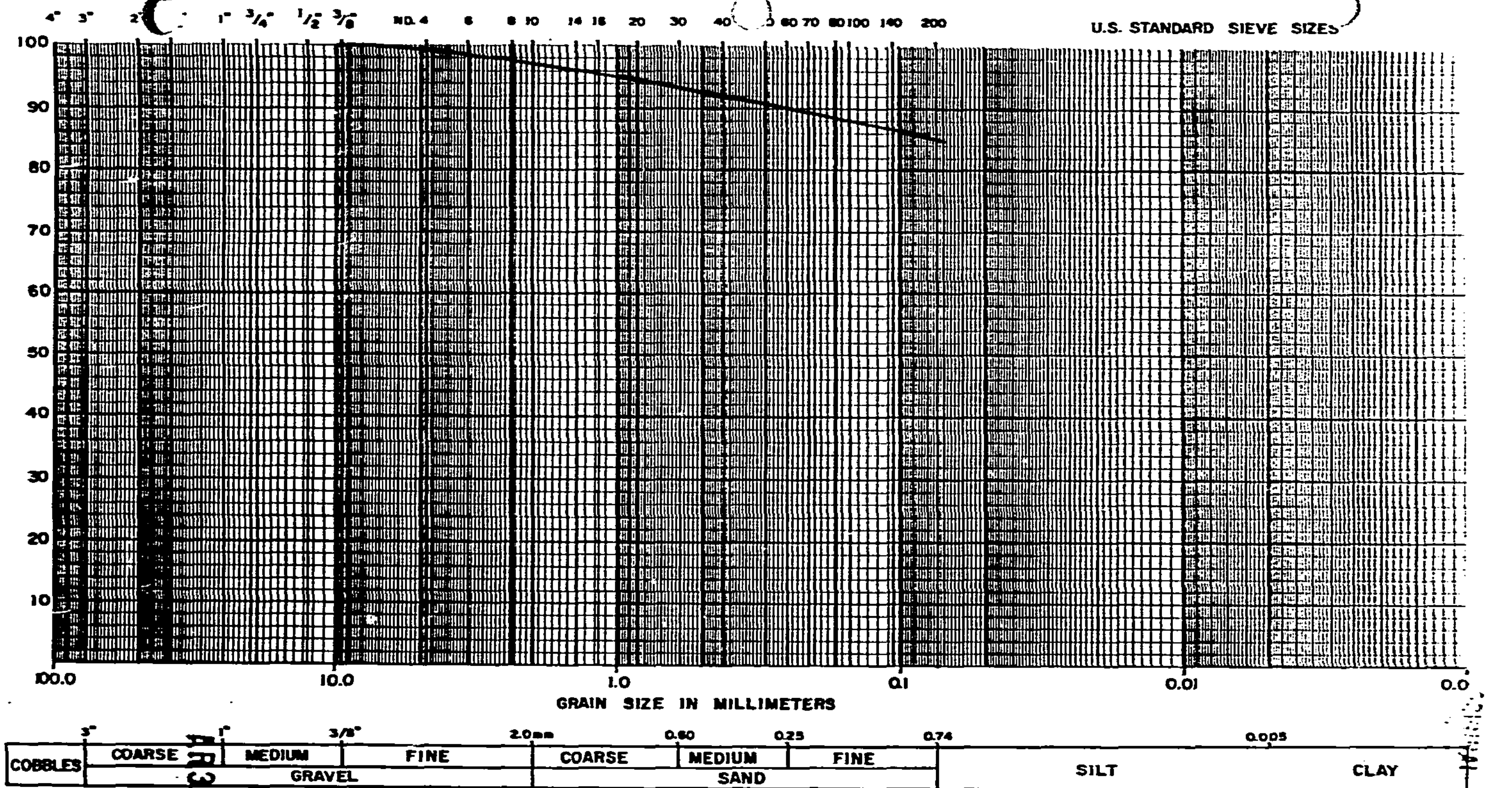
3"		3/4"	3/8"	2.0mm	0.60	0.25	0.74	0.005	
COBBLES	COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	SILT		CLAY
	GRAVEL			SAND					

BORING NO. SAMPLE NO.	DEPTH	ELEV.	IDENTIFICATION	MOIST. CONT.	L.L.%	P.L.%	P.I.
B-21C	76		Gray SILT & CLAY Some(-),	11.9%			
	80		m/f Sand, trace fine				
S-29	80'		Gravel				

MECHANICAL ANALYSIS

Client: AWARE
Project:
Project Number: WESL # 254
Date: 1-22-85 Figure no.:

WEHRAN ... NEERING

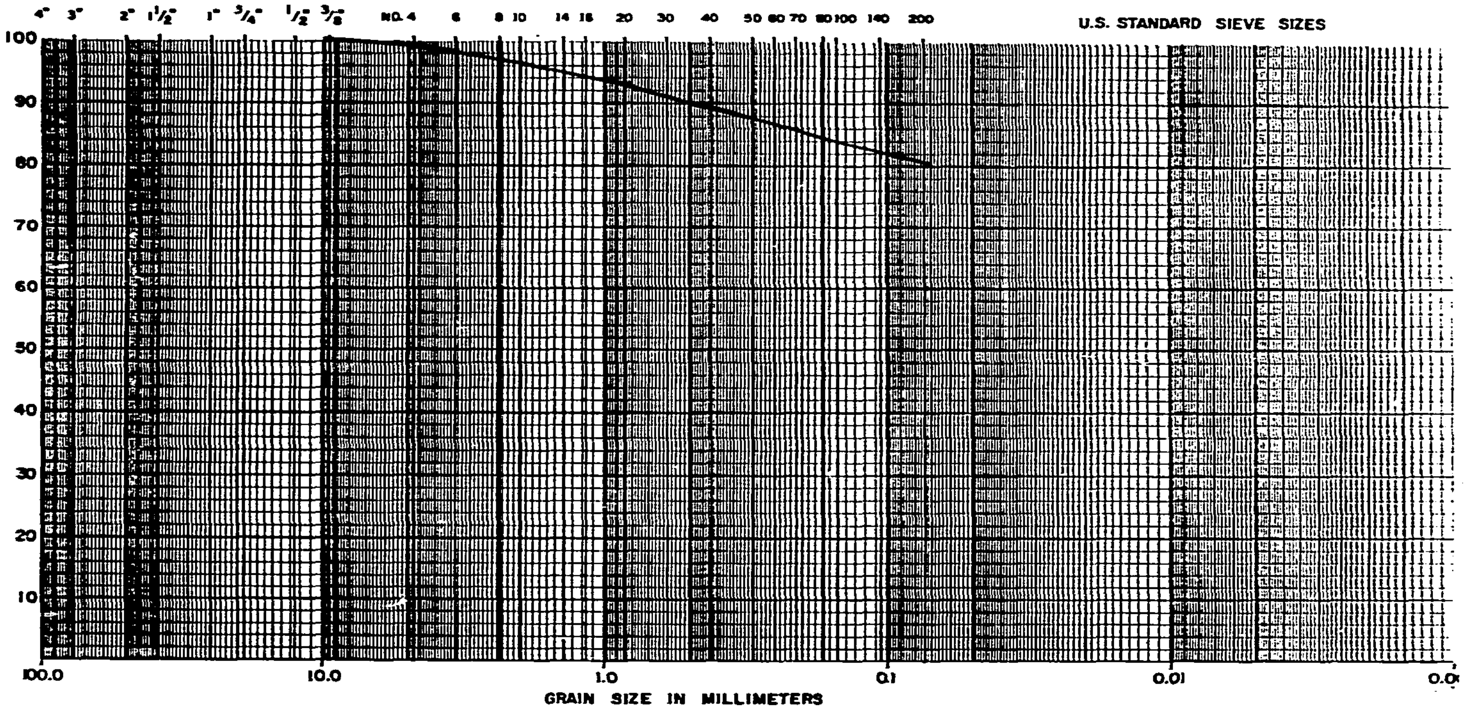


BORING NO. SAMPLE NO.	DEPTH	ELEV.	IDENTIFICATION	MOIST. CONT.	L.L.%	P.L.%	P.I.
B-22C	28'		Gray SILT&CLAY little, wet	15.7%	25	17	8
			Sand, trace(-) of Gravel				
S-29.	70'						

MECHANICAL ANALYSIS

Client: AWARE
Project:
Project Number: WESL 31254
Date: 1-22-85 Figure No.:

WEHRAN ENGINEERING



3"	1"	3/8"	2.0mm	0.60	0.25	0.74	0.005	
COBBLES	COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	SILT	CLAY
	GRAVEL			SAND				

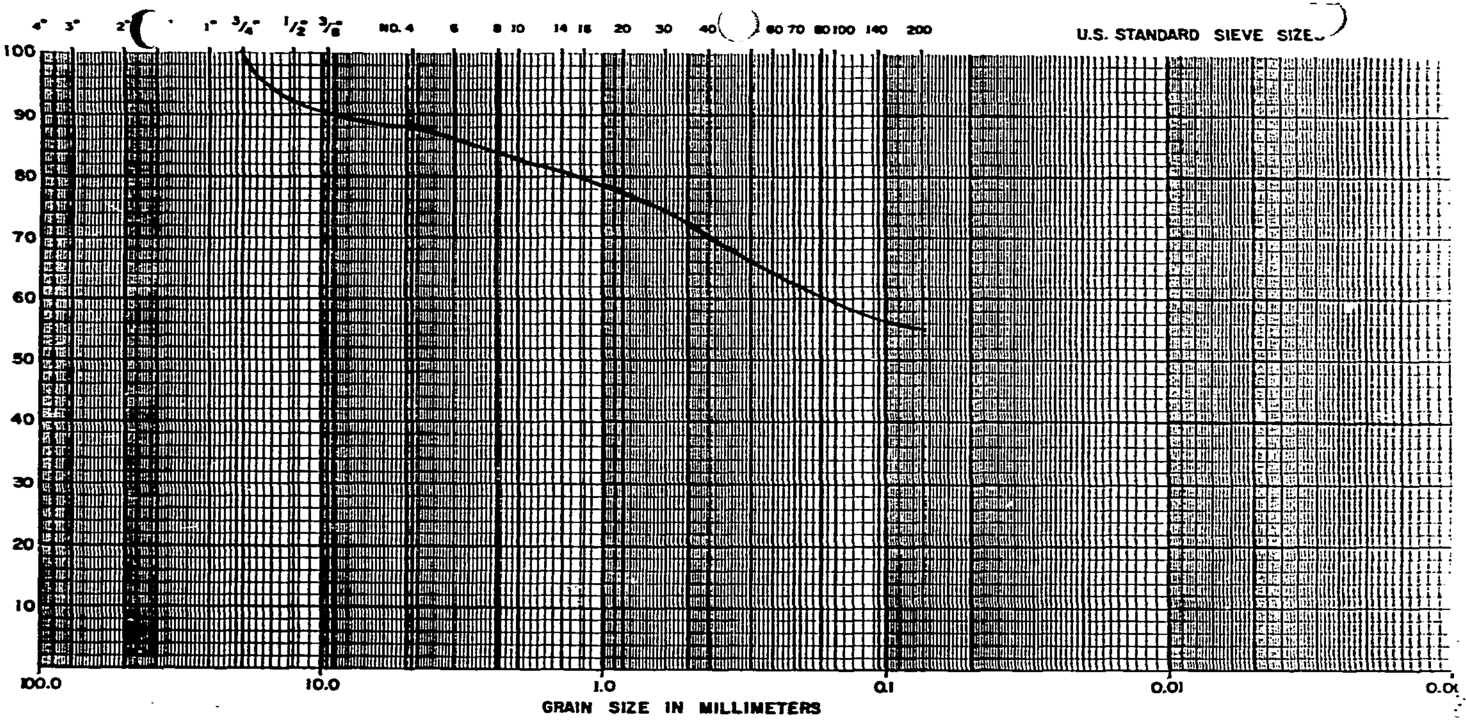
AR300100

BORING NO. SAMPLE NO.	DEPTH	ELEV.	IDENTIFICATION	MOIST. CONT.	L.L.%	P.L.%	P.I.
B-23C	[illegible]'		Gray. SILT & CLAY; little	14.1%	25	17	8
			m/f Sand, trace fine				
S-27	70'		Gravel.				

MECHANICAL ANALYSIS

Client: AWARE
Project:
Project Number: WESL #154
Date: 1-22-85 Figure No.:

WEHRAN ENGINEERING



COBBLES	COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	SILT	CLAY
	GRAVEL			SAND				

BORING NO. SAMPLE NO.	DEPTH	ELEV.	IDENTIFICATION	MOIST. CONT.	L.L. %	P.L.%	P.I.
B-24C	18'-20'		Gray Clayey SILT and f, m f Sand, little f m f Gravel	10.8%			
S-10							

MECHANICAL ANALYSIS

Client: AWARE
Project:
Project Number: WESL #254
Date: 1-22-85 Figure No.:

WEHRAN ENGINEERING

AR30

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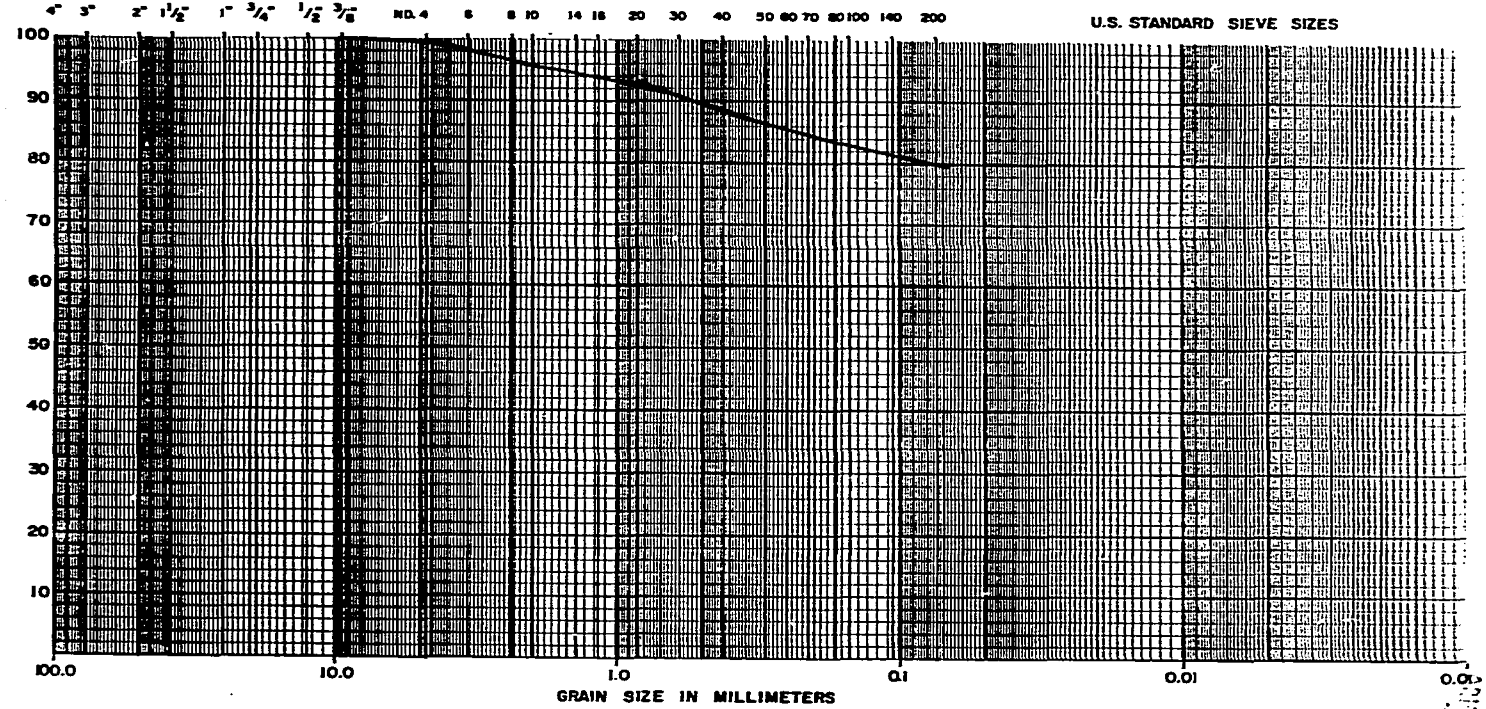

3"		1"	3/8"	2.0mm	0.60	0.25	0.74	0.005	
COBBLES	COARSE	MEDIUM	FINE	COARSE	MEDIUM	FINE	SILT		CLAY
	GRAVEL			SAND					

AR30

BORING NO. / SAMPLE NO.	DEPTH	ELEV.	IDENTIFICATION	MOIST. CONT.	L.L.%	P.L.%	P.I.
B-24	73'		Gray CLAY & SILT some [illegible], m-f	11.1%			
	75'		Sand, trace f fine Gravel				
S-30							

MECHANICAL ANALYSIS

Client: AWARE
Project: WESL #254
Project Number:
Date: 1 22-85 Figure No.:

WEHRAN ENGINEERING

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ORIGI...

WEHRAN ENGINEERING SOILS LAB

PERMEABILITY TEST BY TRIAXIAL CELL WITH BACK PRESSURE

Constant Head Method

Project: Acme #6278 — Project No. W.C.K. #2591
Sample No. UD-12-1 — Date: 1-15-85
22-24'

Dimensions of Specimen:

Height (Inches)	Diameter (Inches)
1. 4.000	1. 2.828
2. 4.000	2. 2.827
3. 4.000	3. 2.829
4. 4.00	4. 2.828
5. 4.00	5. 2.827

Avg. 4.00 In. / 10.16 CMS — Ave. 2.8278 In. / 7.1826 CMS

Weight of Specimen:

Initial Weight 963.0 Grams / Lbs
Final Weight 951.4 Grams / Lbs
Dry Weight 854.7 Grams / Lbs

R =

Moisture Content:

Initial 12.7 %
Final 11.3 %

Area 6.28039 In^2 40.51862 CMS^2

Volume 25.1215975 In^3 .0145379 Cft.

Density, Wet Initial 146.0 pcf

Density, Wet Final: 144.3 pcf

Density, Dry 129.6 pcf

Back Pressure: 90 psi

Efft. Confining Pressure: 0.5 tsf

Saturation: 100.5%

Sp.Gr.: 2.71

$$K_{20} = \frac{Q \times L \times Rt}{h \times A \times t}$$

	Trial 1	Trial 2	Trial 3	Trial 4
Q cc	.32 x .6	.18 x .6	.29 x .6	.26 x .6
L cms	10.16	10.16	10.16	10.16
Rt (Temp 18.3°)	1.043	1.043	1.043	1.043
h cms	17 x 14.12	17 x 14.12	17 x 14.12	17 x 14.12
A Sq. cms	40.5186	40.5186	40.51..	40.5186
t Sec.	1832	1154	1856	1688
K_{20} cm/sec	1.141 x 10-7	1.019 x 10-7	1.021 x 10-7	1.006 x 10-7

Remarks: Gray clayey Silt and fine Sand, little [illegible]

AR300103

1.0[illegible] x 10-7

K_{20} Avg. cm/sec

WEHRAN ENGINEERING
CONSULTING ENGINEERS

LOG OF UNDISTURBED SOIL SAMPLES

Project: AWARE #6275	Project Number: WE #2254
Client: AWARE	Dia. 3 Inches
Sample: WD-12-1 22-24'	Recovery: 2'
Date: 1-15-85	Remarks

TOP OF SAMPLE	INCHES		TYPE OF TEST PERFORMED
	23		
	22		
	21		
	20		
	19		
	18		
	17		
	16		
	15	very slight odor.	
	14	Gray clayey SILT and, c-f Sand,	
	13	little m-f Gravel	
	12		
	11		
	10		
	9		
	8		
	7		
	6		
	5		
	4		
	3		
	2		
	1		
BOTTOM OF SAMPLE	0		

AR300104

LEHIGH ENGINEERING SOILS LAB

PERMEABILITY TEST BY TRIAXIAL CELL WITH BACK PRESSURE

Constant Head Method

Project: Avaxe 4.6277 Project No. 64-45C 4-254
Sample No. SILT UD-2-1 Date: 1-15-85

Dimensions of Specimen:

Height (Inches)	Diameter (Inches)
1. 3.710	1. 2.800
2. 3.715	2. 2.890
3. 3.718	3. 2.965
4. 3.717	4. 2.966
5. 3.717	5. 2.890

Avg. 3.7162 In. 9.43914 CMS Ave. 2.9022 In. 7.37158 CMS

Area 6.61522 In^2 42.6787 CMS^2

Volume 24.5834 In^3 .014226 Cft.

Weight of Specimen:

Initial Weight 857.7 Grams
Lbs
Final Weight 843.2 Grams
Lbs
Dry Weight 673.7 Grams
Lbs

L

R =

Moisture Content:

Initial 23.6 %
Final 21.55 %

Density, Wet Initial 132.9 pcf

Density, Wet Final: 130.7 pcf **Density, Dry** 107.5 pcf

Back Pressure: 90 psi **Efft. Confining Pressure:** 0.5 tsf

Saturation: 100.5 %

Sp. Gr. : 2.732

$$K_{20} = \frac{Q \times L \times Rt}{h \times A \times t}$$

	Trial 1	Trial 2	Trial 3	Trial 4
Q cc	.157.6	.257.6	.457.6	.527.6
L cms	9.43914	9.43914	9.43914	9.43914
Rt (Temp 18.8)	1.043	1.043	1.043	1.043
h cms	17x14.12	17x14.12	17x14.12	17x14.12
A Sq. cms	42.6787	42.6787	42.6787	42.6787
t Sec.	298	525	946	1104
K_{20} cm/sec	2.902x10-7	2.745x10-7	2.742x10-7	2.715x10-7

Remarks: Gray Br. clayey SILT little, very Sand, trace of gravel.

2.776x10-7

K_{20} Avg. cm/sec

← Slump during setup and testing

WE WEHRAN ENGINEERING CONSULTING ENGINEERS

LOG OF UNDISTURBED SOIL SAMPLES

Project AWAPE # 6278	Project Number WESL # 254
Client AWAPE	Dia. 3 Inches
Sample UD-20-1	Recovery 2' 22"
Date 1-15-84	Remarks

TOP OF SAMPLE	INCHES		TYPE OF TEST PERFORMED
	23		
	22		
	21	Brown c-f Sand, some Silt little m-f GVL.	↑
	20		
	19	Gray & Brown SILT, some f Sand.	K ~~Test~~
	18	sample showing different lenses	Bag.
	17	Gray Brown Clayey SILT little	↓
	16	some f Sand, trace f gravel.	
	15		
	14		↑
	13		J
	12		A R
	11		S
	10		A M
	9		P
	8		L E
	7		↓ ↑
	6		
	5		K
	4		
	3		↓
	2		
	1		
BOTTOM OF SAMPLE	0		

AR300106

WEHRAN ENGINEERING SOILS LAB

PERMEABILITY TEST BY TRIAXIAL CELL WITH BACK PRESSURE

Constant Head Method

Project: AWARE #6278 Project No. WESL #754
Sample No. 20-2 Date: 1.15.85
34.36

Dimensions of Specimen:

Height (Inches)	Diameter (Inches)
1. 3.981	1. 2.828
2. 3.982	2. 2.827
3. 3.983	3. 2828
4. 3.982	4. 2.829
5. 3.982	5. 2.827

Avg. 3.982 In. 10.1141 CMS Ave. 2.8278 In. 7.1826 CMS

Weight of Specimen:

Initial Weight 966.6 Grams ____ Lbs
Final Weight 955.0 Grams ____ Lbs
Dry Weight 862.4 Grams ____ Lbs

K
R =

Moisture Content:

Initial 12.0 %
Final 10.7 %

Area 6.28039 In^2 40.51862 CMS^2

Volume 25.0085 In^3 .014472 Cft.

Density, Wet Initial 147.2 pcf

Density, Wet Final: 145.5 pcf

Density, Dry 131.36 pcf

Back Pressure: 90 psi

Efft. Confining Pressure: 0.5 tsf

Saturation: 100.9 %

Sp.Gr. 2.71

$$K_{20} = \frac{Q \times L \times Rt}{h \times A \times t}$$

	Trial 1	Trial 2	Trial 3	Trial 4
Q cc	.48x.618	.17x.618	.1x.618	.27x.618
L cms	10.11428	10.11428	10.11428	10.11428
Rt (Temp 11.3°)	1.043	1.043	1.043	1.043
h cms	17x14.12	17x14.12	17x14.12	17x14.12
A Sq. cms	40.51862	40.51862	40.51862	40.51862
t Sec.	2149	824	468	1234
K_{20} cm/sec	1.497×10^{-7}	1.382×10^{-7}	1.414×10^{-7}	1.466×10^{-7}

Remarks: [illegible]

AR300107

[illegible]

K_{20} Avg. cm/sec

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WEHRAN ENGINEERING SOILS LAB

PERMEABILITY TEST BY TRIAXIAL CELL WITH BACK PRESSURE

Constant Head Method

Project: AWARE # 6278 Project No. UPSL #254
Sample No. UD 20-1 Date: 1-15-85

Dimensions of Specimen:

Height (Inches)	Diameter (Inches)
1. 3.980	1. 2.840
2. 3.980	2. 2.840
3. 3.981	3. 2.840
4. 3.981	4. 2.840
5. 3.981	5. 2.840

Weight of Specimen:

Initial Weight 870.4 Grams / Lbs
Final Weight 866.2 Grams / Lbs
Dry Weight 711.4 Grams / Lbs

R = 22

Moisture Content:

Initial 22.4 %
Final 21.75 %

Avg. 3.9806 In. 10.110724 CMS Ave. 2.840 In. 7.2136 CMS

Area 6.33470 In^2 40.86877 CMS^2

Volume 25.2157 In^3 .01459 Cft.

Density, Wet Initial 131.5 pcf

Density, Wet Final: 130.9 pcf

Density, Dry 107.5 pcf

Back Pressure: 90 psi

Efft. Confining Pressure: 0.5 tsf

Saturation: 101.4 %

$K_{20} = \frac{Q \times L \times Rt}{h \times A \times t}$

S.G. : 2.732

	Trial 1	Trial 2	Trial 3	Trial 4
Q cc	3x.6	2x.6	2x.6	1x.6
L cms	10.1107	10.1107	10.1107	10.1107
Rt (Temp 18.3°)	1.043	1.043	1.043	1.043
h cms	17x14.12	17x14.12	17x14.12	17x14.12
A Sq. cms	40.86877	40.86877	40.86877	40.86877
t Sec.	207	155	161	80
K_{20} cm/sec	9.347×10^{-7}	8.327×10^{-7}	8.012×10^{-7}	8.062×10^{-7}

Remarks: [illegible]

AR300108

9.035×10^{-7}

K_{20} Avg. cm/sec

WEHRAN ENGINEERING CONSULTING ENGINEERS	LOG OF UNDISTURBED SOIL SAMPLES
Project [illegible]	Project Number [illegible]
Client [illegible]	Dia. 3 Inches
Sample 20-2	Recovery 26"
Date	Remarks

TOP OF SAMPLE	INCHES		TYPE OF TEST PERFORMED
	26"	Upper 3" c.f Sand, tr f [illegible] little silt	highly odorous.
	23	Tan clayey SILT and [illegible], and Sand,	
	22	little [illegible] f Gravel.	
	21		
	20		
	19		
	18		
	17		
	16		
	15		
	14		
	13		
	12		
	11		
	10		
	9		
	8		
	7		
	6		
	5		
	4		k
	3	AR300109	
	2		[illegible]
	1		[illegible]
BOTTOM OF SAMPLE	0		

WEHRAN ENGINEERING
CONSULTING ENGINEERS

LOG OF UNDISTURBED SOIL SAMPLES

Project AWARE #6278	Project Number WESL #251
Client AWARE	Dia. 3 Inches
Sample 23-1	Recovery
Date	Remarks

TOP OF SAMPLE	INCHES		TYPE OF TEST PERFORMED
	23	Gray cf SAND, l$, l[illegible]	
	22		
	21		
	20		
	19	Gray cm/f SAND, s$, lmy [illegible]	NO
	18	slightly odorous upon	
	17	extrusion	LOAD
	16		
	15		NO
	14		
	13		TESTING
	12		
	11		
	10		
	9		
	8		
	7		
	6		
	5		
	4	Gray cf Sand, s$, l[illegible]	
	3		
	2		
	1		
BOTTOM OF SAMPLE	0		

AR300110

PLEASE REFER TO THE ADMINISTRATIVE
RECORD FILE
FOR THE MAP THAT CORRESPONDS WITH
PAGES
AR300111 THROUGH AR300118

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