

INVESTIGATION OF A CLAY LINED STORAGE PIT

by

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Thesis and report submitted to the Faculty of the
Virginia Polytechnic Institute and State University
in partial fulfillment of the requirements for the degree of
MASTER OF SCIENCE
in
Civil Engineering

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July, 1984

Blacksburg, Virginia

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(ABSTRACT)

The geotechnical aspects of a hazardous waste disposal site located in Piney River, Nelson County, Virginia, were investigated. The waste material consisted primarily of a by-product of the production of titanium known as copperas which is highly acidic.

The investigatory program consisted of field and laboratory work. Objectives included delineating the pit geometry and liner system, assessing the characteristics of the natural soils at the site as well as the wastes, and evaluating the degree of contamination of the natural subsoils around the pit.

The field investigation findings show a more complex geometry for the pit than that suggested in the design documents. While shown on the plans, the presence of the bottom clay liner is questionable. Large depressions and numerous cracks were found in the waste area. Acid contamination of the groundwater and the subsoils exists to a considerable depth.

Laboratory tests illustrated the susceptibility of the copperas to dissolution under water seepage. This could have caused the large settlements.

Remedial actions could include grading the top of the pit for better drainage. Other actions could include redepositing the waste in

a burial pit which has a leachate collection system and properly compacted clay liners which include an impervious fabric. Perhaps the waste could be treated chemically prior to final disposition. In any case, some level of continual maintenance will be necessary.

ACKNOWLEDGEMENTS

This material is based upon work supported by the attorney general's office of the state of Virginia. This support is gratefully acknowledged.

The author wishes to express her gratitude to her major advisor Dr. G. W. Clough, and to the other members of her committee for their aid and patience in the preparation of this report.

TABLE OF CONTENTS

	<u>Page</u>
ACKNOWLEDGEMENTS.....	iv
LIST OF TABLES.....	vii
LIST OF FIGURES.....	viii
 <u>CHAPTER</u>	
I. INTRODUCTION.....	1
II. BACKGROUND.....	7
2.1 FACILITY DESIGN.....	7
2.2 LEGAL AND REGULATORY REVIEW.....	11
2.3 CLAYS IN BOTTOM AND SIDE-SLOPE LINERS.....	13
2.4 LABORATORY INVESTIGATIONS.....	13
2.5 FIELD INVESTIGATIONS.....	16
2.6 SUMMARY.....	18
III. PINEY RIVER DISPOSAL SITE.....	20
3.1 LOCATION.....	20
3.2 GEOLOGY.....	20
3.3 HISTORY OF INDUSTRIAL DEVELOPMENT.....	24
3.4 ATTEMPTED CLEANUP.....	26
IV. INVESTIGATIVE PROGRAM.....	30
4.1 GENERAL APPROACH.....	30
4.2 FIELD INVESTIGATION.....	30
4.2.1 SITE VISITS AND TRENCHING.....	31
4.2.2 DRILLING AT THE SITE.....	31
4.2.3 BORROW PIT.....	36
4.3 LABORATORY TESTING PROGRAM.....	36
4.4 SUMMARY.....	38
V. RESULTS OF FIELD TESTING PROGRAM.....	40
5.1 TRENCHING OBSERVATIONS.....	40
5.2 BORING PROGRAM RESULTS.....	42

<u>CHAPTER</u>	<u>Page</u>
5.2.1 GENERAL.....	42
5.2.2 MATERIAL DISTRIBUTION.....	44
5.2.3 DRIVING RESISTANCE.....	48
5.2.4 WATER TABLE.....	49
5.2.5 pH MEASUREMENTS.....	49
VI. RESULTS OF LABORATORY TESTING PROGRAM.....	60
6.1 SOIL CLASSIFICATION.....	60
6.2 ATTERBERG LIMITS.....	62
6.2.1 TESTS AND RESULTS.....	62
6.3 PARTICLE SIZE ANALYSIS.....	64
6.4 IN-SITU MOISTURE CONTENT.....	66
6.5 IN-SITU DENSITY.....	68
6.6 STANDARD PROCTOR COMPACTION TESTS.....	68
6.7 PERMEABILITY.....	71
6.7.1 TEST RESULTS.....	71
6.7.2 DISCUSSION OF RESULTS.....	74
6.7.3 EFFLUENT ANALYSIS.....	76
6.8 WATER SOLUBILITY POTENTIAL.....	76
6.9 X-RAY DIFFRACTION ANALYSIS.....	77
6.10 CONSOLIDATION CHARACTERISTICS.....	77
VII. DISCUSSION OF RESULTS.....	80
VIII. SUMMARY AND CONCLUSIONS.....	84
APPENDIX I TEST BORING LOGS.....	88
APPENDIX II X-RAY DIFFRACTION RESULTS.....	104
BIBLIOGRAPHY.....	122
VITA.....	125

LIST OF TABLES

<u>Table</u>	<u>Page</u>
2.1 Laboratory Research.....	14
2.2 Field Investigations.....	17
4.1 Drilling Program.....	34
4.2 Laboratory Testing Program.....	37
6.1 Soil Laboratory Test Results.....	61
6.2 Permeability.....	72
6.3 Coefficients of Permeability.....	73
6.4 X-Ray Diffraction Analysis.....	78

LIST OF FIGURES

<u>Figure</u>	<u>Page</u>
1.1 Approximate Location of Nelson County, Virginia.....	2
1.2 Sinkhole on Top of the New Storage Pit.....	4
1.3 A Spring of Leachate Located in the Northern Part of the New Storage Pit.....	5
2.1 Secure Landfill.....	8
2.2 Leachate Collection System.....	10
3.1 Project Location Plan.....	21
3.2 Topographic Map of the Site.....	22
3.3 Recommended Construction Plan According to Geonics.....	27
3.4 Detail of the Original Burial Pit Scheme as Recommended by Geonics.....	28
4.1 The Approximate Locations of Test Borings, Trenches, and Hand Augers.....	32
5.1 Typical Profile of Trenches.....	41
5.2 Approximate Location Plan.....	43
5.3 Sample Boring Log, B-7.....	45
5.4 Cross-Section Along North-South Trending Line.....	46
5.5 pH Profile of B-1, B-2, B-2a.....	51
5.6 pH Profile of B-3, B-3a, B-4.....	52
5.7 pH Profile of B-5.....	53
5.8 pH Profile of B-6 and B-7.....	54
5.9 pH Profile of B-8.....	55
5.10 pH Profile of B-9.....	56
5.11 pH Profile of B-10 and B-11.....	57

<u>Figure</u>		<u>Page</u>
6.1	Results of Atterberg Limit Tests.....	63
6.2	Effect of Anions on Cecil Soil (Kaolinite).....	65
6.3	Grain Size Analysis.....	67
6.4	Compaction Curve for Bulk-1 (2').....	69
6.5	Compaction Curve for Bulk-2 (10').....	70

CHAPTER I. INTRODUCTION

Burial of hazardous waste in a landfill site is a popular method of containment of such materials. This technique can be effective if proper design and construction procedures are used. However, it is unfortunately a relatively common experience to find that a hazardous waste burial site does not perform as expected, as described by Daniels [4].*

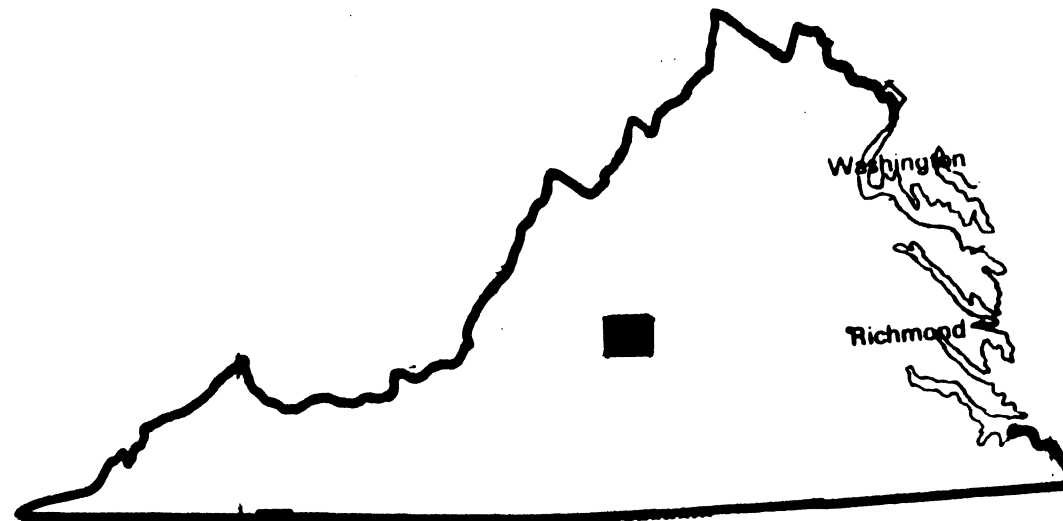
This investigation concerns a hazardous waste burial site in Nelson County, Virginia, located along the course of the Piney River as shown in Figure 1.1. Up until the mid-1970's, a titanium production plant operated at the site. In the process of producing titanium a waste product, called copperas, was produced and stored on a hillside just to the north of the Piney River.

Kraus et al. [15] describe copperas as follows:

Melanterite (Copperas), $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$. Monoclinic, prismatic class. Crystals are very rare. Usually as earthy, fibrous, or capillary crusts or efflorescences. Conchoidal to earthy fracture. Hardness, 2. Specific gravity, 1.8 to 1.9. Various shades of green in color, often yellowish after exposure. Transparent to translucent. Sometimes contains manganese, magnesium, copper, or zinc. Easily soluble to water. Loses water on exposure and crumbles to powder.

The process of storing copperas on the hillside and in a lagoon on top of the hill at the Piney River site created a number of environmental problems. Following the shut-down of the commercial operation at the site in the 1970's, 800,000 cu. yards of the waste material

*Numbers in brackets refer to references in the bibliography.



VIRGINIA

Figure 1.1 Approximate Location of Nelson County, Virginia

old storage lagoon. Very little documentation exists on the construction of the pit and the movement of the waste material into it.

At the time of initiation of this study the clay cover over the pit exhibited cracks, sinkholes, and depressions, Figure 1.2. Conversations with local contractors and other people familiar with this site reveal that depressions on the top of the landfill were observed soon after the new landfill was completed. Additionally, there are numerous springs of leachate on the outer edges of the landfill as shown in Figure 1.3. At spots where the leachate was seeping from the landfill onto the surface of the surrounding ground and into the woods there is dead vegetation. Because of these problems, this study was undertaken.

The objectives of this work are as follows:

1. Definition of actual geometry of burial pit.
2. Determine if liner present in thickness indicated.
3. Assess nature of liner material and its response to acidic waste exposure.
4. Assess nature of copperas and pit backfill.
5. Explain reasons for substantial subsurface leakage and sinkholes and surface cracks.
6. Definition of the extent of contamination of subsoils below the burial pit and in the old lagoon area.

The scope of the work in this study involves:

1. Establish topography.
2. Monitor the ground water.
3. Excavate trenches.

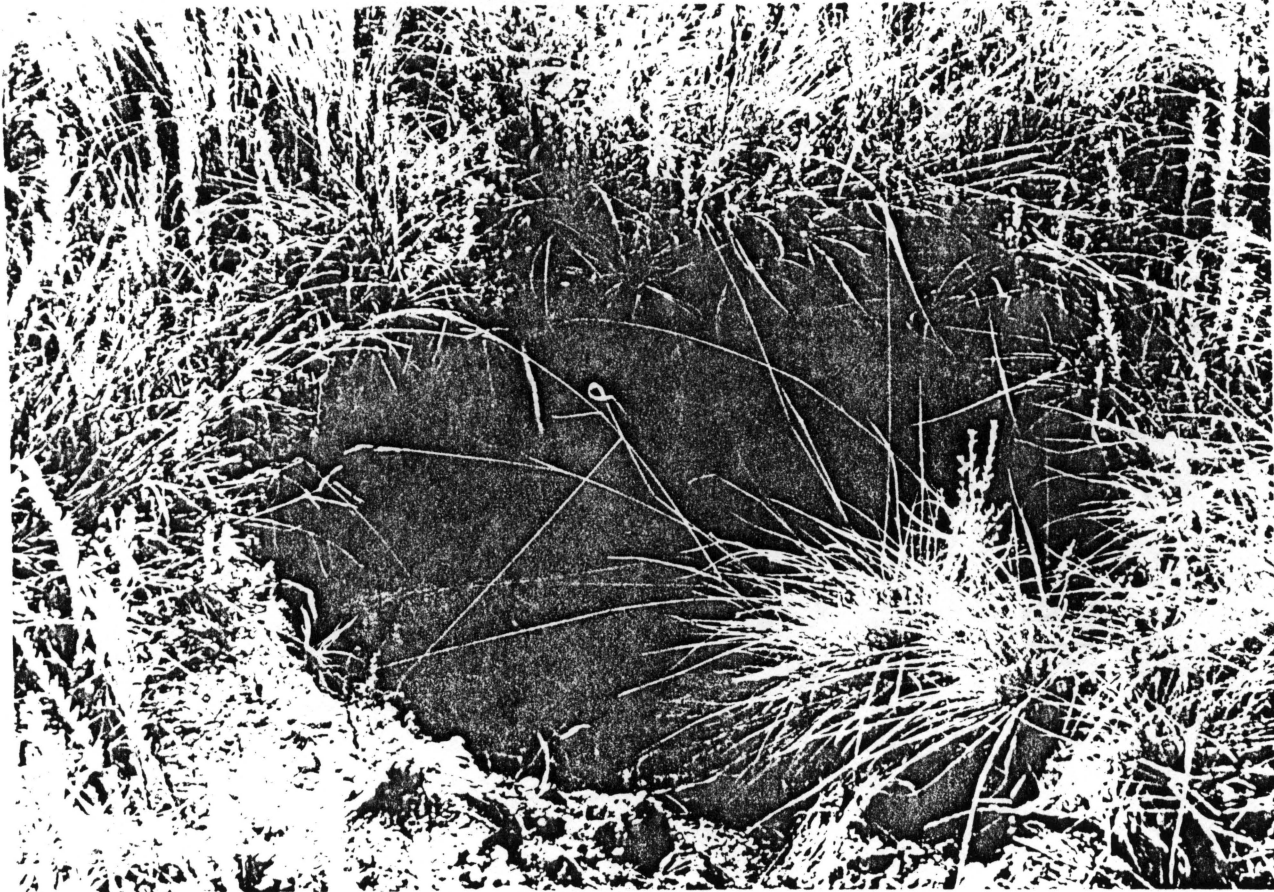


Figure 1.2 Sinkhole on Top of the New Storage Pit



Figure 1.3 A Spring of Leachate Located in the Northern Part of the New Storage Pit

4. Drill test boring holes.
5. Perform laboratory tests.

In Chapter II of this report the background for this investigation is explained. The main focus in Chapter III is the Piney River site, its topography, and the industrial history and problems which led to the construction of the new disposal pit. Chapter IV describes the investigation program adopted by the Civil Engineering Department at Virginia Tech consisting of field and laboratory phases. Chapter V deals with the results of the field investigative program and Chapter VI explains the outcome of the laboratory investigative program. In Chapter VII an overview is provided of the meaning of all of the data obtained, and summary and conclusions are presented in Chapter VIII.

CHAPTER II. BACKGROUND

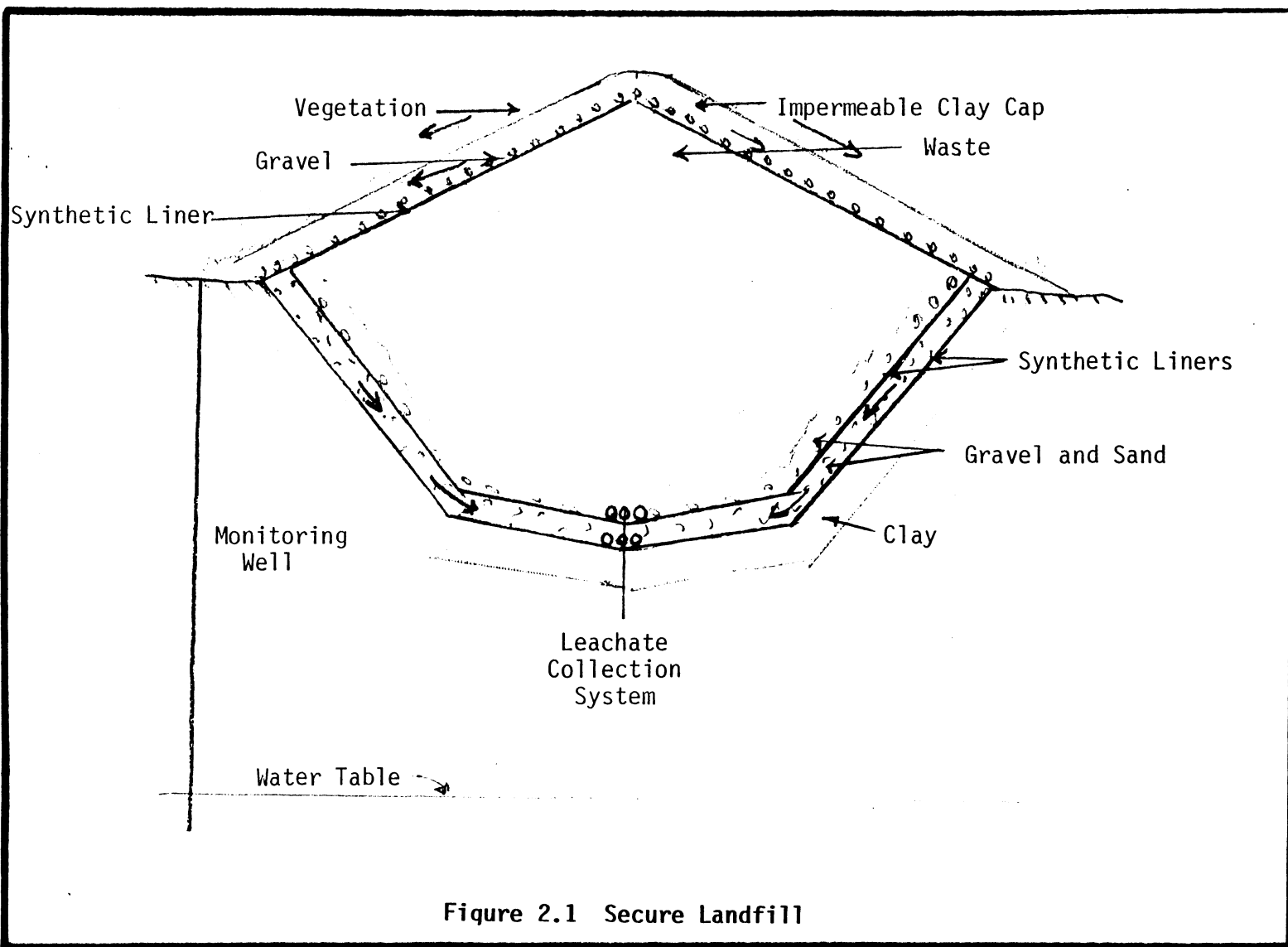
Hazardous waste burial problems fall into two categories. First, where the opportunity is available, there is the question of proper design of a landfill site, and the specifications for the construction and construction materials. Alternatively, there is the problem of investigating the failure of an old site, and proposing remedial measures. The following sections of this chapter report current methods that help to deal with these problems.

2.1 FACILITY DESIGN

A secure landfill is a depressed area in the ground in which wastes are buried. Montague [18] notes that there are four important factors in the design and construction of a landfill.

1. Bottom and side liner.
2. Leachate collection system.
3. Cover cap.
4. Natural hydrogeologic setting.

A sketch of a secure landfill is shown in Figure 2.1. The bottom and side liners usually consist of one or more layers of clay or compacted clay and a synthetic membrane basically serves as a "bathtub" in the ground which should inhibit leachate loss. The degree of compaction for the clay depends upon each project. Typically, the clay liner is at least one to two feet thick as is shown in Figure 2.1.



The leachate collection system is used to intercept any leakage and to transport the leakage to a treatment facility. Figure 2.2 shows two different types of typical collection designs. Basically, the leachate collections systems consist of a series of drains which intercept the leachate and channel it to a sump, a wet treatment system, or an appropriate surface discharge point.

The cover or cap over the pit is usually one or several feet of compacted clay and is intended to control surface infiltration. Use of sealants or membranes is recommended to make the system more impervious. Between the clay and the membrane there is normally a very permeable layer to promote surface runoff.

Geologic and hydrologic site conditions are very important factors in establishing the suitability of the area for a landfill site. Data on these factors are required to assess the pollution potential so that a rational decision can be made as to what must be done to the site to ensure that the movement of leachate from the landfill will not impair the quality of local ground water aquifers. The existing natural drainage and runoff characteristics as well as flooding must be studied.

The ability of soil to retard the movement of chemical substances leached from a waste is one of the important factors in the selection of a waste disposal site and in the subsequent design of the facility. Unless the soil can sufficiently retard waste-leachate movement or chemically correct pollution from the leachate, contamination of groundwater may result. Successful containment is determined by the chemical and physical composition of the soil.

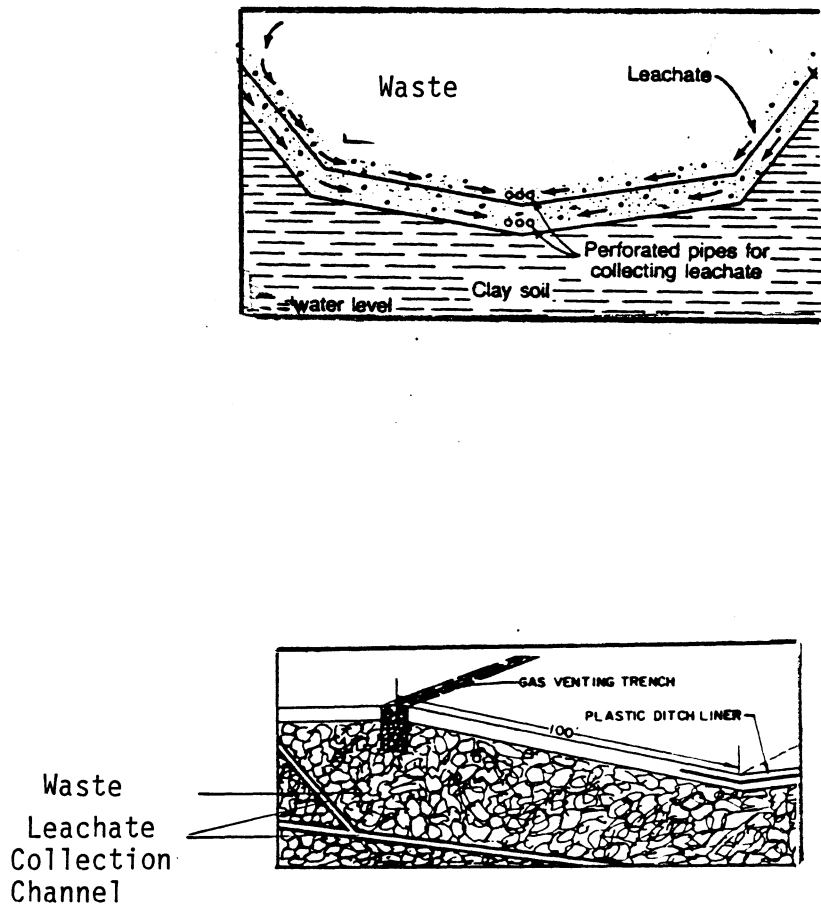


Figure 2.2 Leachate Collection System

Factors affecting this contamination potential from a site are as follows:

1. The composition of the waste.
2. Annual precipitation statistics.
3. The geology at the site.
4. Groundwater conditions.
5. Soil conditions.
6. Design of the landfill.
7. Quality of the construction and maintenance of the landfill facility.

2.2 LEGAL AND REGULATORY REVIEW

The definition of failure of landfills goes to the heart of regulatory philosophy. Although Congress passed the Resource Conservation and Recovery Act (RCRA) in 1976 and although roughly 80% of the nation's hazardous wastes go into landfills, the Environmental Protection Agency (EPA) has yet to promulgate final criteria for landfills. There have been two occasions on which the agency has announced elaborate landfill regulations, but they were withdrawn later. The first set of regulations dealt with facility design in order to improve the prediction methods of discharge or releases from landfill. The second set was comprised of standards that were intended to provide maximum containment in landfills. These standards stated that the bottom and sides of a landfill had to have a synthetic membrane liner overlain by six inches of sand or soil that in turn had to be covered by soil with a coefficient of permeability of 10^{-7} cm/sec or less.

Below the lining at the bottom of the pit, there had to be a leachate collection system. The EPA decided after the regulation was published that this did not adequately protect the groundwater and this is reflected in Public Law 19 as recorded on page 66817 of The Federal Register.

A new ERA approach calls for a "Risk Assessment" of any facility. It was recognized that all landfills leak to some degree, and that the real question is: "How much risk is created by various levels of leakage?" This new approach would supposedly help decide how much risk is acceptable in individual cases. The problem with this approach is the difficulty inherent in defining failure. There are few quantitative measures of adverse health or environmental effects concerning the majority of hazardous chemical wastes. According to Montague [18], Peter Skinner lists the most probable ways by which landfills fail as:

1. Operating methods may allow too much liquid to enter the landfill prior to closing it. Rainfall, the buried liquids, and the huge volumes of water used to fight occasional chemical fires at the site are all common avenues through which excess water will enter the landfill and ultimately results in the failure of the landfill.
2. Leachate collection systems may contain design or installation defects which result in excess leachate.
3. Consolidation, a result of several factors including lack of compaction of contents and pumping out of the leachate, may result in local or general subsidence of the clay cap.

If there are solutions to the above faults, they are mainly operational restrictions; however, the failures continue to occur.

2.3 CLAYS IN BOTTOM AND SIDE-SLOPE LINERS

The effect of leachate on the clay used in a liner is an important factor relative to the performance of a burial pit. A number of studies have been conducted to assess the permeability of clay under the action of a leachate solution subject to a seepage gradient.

There are a great many chemical substances produced at industrial units as waste material. Thus it is virtually impossible to determine the reaction of the variety of clays used for liners with all possible substances at all disposal sites. A few key studies have been performed which serve to illustrate the effect of wastes on clay. These are described in the following section.

2.4 LABORATORY INVESTIGATIONS

A number of laboratory investigations have been reported in which clay soils were subjected to the flow of various types of leachates. These are reviewed briefly but it should be noted that none of the investigations experimented with the type of leachate encountered at the Piney River site.

Table 2.1 provides pertinent information given in previous laboratory investigations of permeability of soils subjected to various permeants. Typically, the test programs involved subjecting a remolded clay specimen to a leachate-type fluid under sufficient head differential to cause seepage. The basic purpose was to determine if the

TABLE 2.1 LABORATORY RESEARCH			
REFERENCE	TYPE OF CLAY	TYPE OF LEACHATE	MAJOR CONCLUSIONS
Green, William J., Fred G. Lee, and R. Ann Jones [10]	Ranger Shale, Kosse Kaoline, Fire Clay	Water, Benzene, Xylene, Carbon Tetrachloride, Trichloroethylene Acetone, Methanol, Glycerol	1. High Kaolinite caly-soil show highest degree of Permeability. 2. The Dielectric Constant of chemicals are important in permeability predictions. 3. Some organic solvents can cause a breakthrough phenomenon in clay, forming channels for fluids to move easily.
Anderson, David [1]	Noncalcareous Smectitic, Calcareous Smectitic, Mixed Cation Kaolinitic, Mixed Cation Illitic	Water, Acetic Acid (Glacial) Acetone (99% pure), Methanol (20% H ₂ O), Xylene (99% pure mixed isomers)	In many cases clays show initial decreases in permeability, and later soil piping occurred. Acetic acid showed capability to dissolve soil minerals and permeate easily through the soil. The permeability of clays started to increase in time, almost in all cases.
Morrison, Allen [21]	Bentonite, and Expansive Clays	Pure Water, Aqueous Solution of Caustics?	The impermeability of clay barriers to hazardous waste can not be guaranteed. The impermeability of clay barriers can under some conditions be permanently destroyed.
Naxo, H. E., Jr. [11]	Polymeric liners, Compacted native soils and clays	HFL, HNO ₃ , HF, HOAC, 5% NaCl Solution, and Water	Soils were not exposed to HNO ₃ in this research. In 3 years rate of leakage was acceptable (10^{-8} - 10^{-7} cm/sec). The paper did not heavily emphasize on different types of soils.
Houle, M. J. and D. E. Long [14]	A gray silty clay from Indiana, a red clay from North Carolina, and a yellow silty clay from Kentucky	Zinc-carbon battery waste	The leaching of a waste by water or other solvents can be characterized and the ability of a soil to remove chemical substances from the waste leachate can be rapidly evaluated using batchwise extractions. This method is not very approximate for long term tests.
Haxo, H. E., Jr., R. M. White, P. D. Haxo, and M. A. Fong [12]	65 materials (admix materials, asphaltic membranes, commercial polymeric membrane, miscellaneous materials)	Municipal Solid Waste Leachate	Test period was 56 months, asphaltic materials did exhibit deficiencies. The properties of soil cement tended to improve during exposure.

clay soils showed unusual values of permeability when exposed to the various types of fluids. The devices used for the tests were not greatly dissimilar from a normal permeameter used in soil testing. In all cases special materials were used for the permeameters to prevent interaction between the permeant and the device.

In drawing general conclusions from Table 2.1 it should be noted that we cannot be certain that these tests were performed for a long enough period to know if permeability might change under long term field exposure. Based upon the data in Table 2.1, the following comments are pertinent:

1. The hydrophobic or hydrophilic nature of a liquid is perhaps more significant than density or viscosity in predicting its permeation through soils.
2. Dielectric constants of the chemicals in contact with clay are a measure of hydrophobic or hydrophilic nature of a chemical. Unfortunately, it is unlikely that a disposal system contains only one chemical substance and it is not practical and perhaps impossible to determine the dielectric constant of a mixture. Chemicals with high dielectric constant move quickly through channels of clay.
3. Expansive clays, upon exposure to liquids, may undergo swelling, which results in the clogging of soil pores and channels; but not all clays show this characteristic.
4. It has been observed that certain solvents cause compacted clay columns to shrink and crack. This provides a pipe or

pathway for rapid movement of chemicals through the clay columns.

2.5 FIELD INVESTIGATIONS

An important factor in the behavior of a clay liner in the field is the possible existence of features in the field which are not duplicated in lab tests on remolded or undisturbed samples of soil.

Table 2.2 provides a review of some significant references pertaining to field behavior of burial pit sites. Factors observed in the field which are important include shrink-swell phenomena, vegetation growth, erosion, and human modifications. Montague [18] reports the failure of four landfills in New Jersey. They had presumably been designed according to appropriate engineering standards. In all cases much higher than expected amounts of leachate were generated. The rates varied anywhere from one gallon to fifty gallons per day.

Daniel [4] examined case histories of landfill problems to determine causes for the discrepancies between laboratory data and in situ results. He concludes that "Even under the best of circumstances, laboratory permeability tests may yield significant underestimates of the hydraulic conductivity of the clay liner."

The engineer would probably be better off using the highest values of hydraulic conductivity measurement in the laboratory rather than the average values, because there is evidence that laboratory tests on undisturbed samples removed from the liner also may yield misleading hydraulic conductivities. The results of Daniel's [4] research are mainly based upon laboratory and field investigations of landfill sites

REFERENCE	TABLE 2.2 FIELD INVESTIGATIONS OBJECTIVES AND CONCLUSIONS
Daniel, David E. [4]	Field and laboratory research and the incompatibilities that exist between them. Choosing a representative sample, uneven hydration of large clods of clay, desiccation cracks in field, wrong permeant in laboratory can be some of the sources for the existent discrepancies.
Montague, Peter [18]	This paper studies four landfills in New Jersey that have failed. Design parameters such as liner, cover, leachate collecting systems, and site geological settings are discussed in relation to the failure of the landfills.
van Genuchten [24]	This paper analyzes a long list of available simulation models; their types and the related advantages and disadvantages. It is noted that the conceptual mathematical models are the promising models to simulate the physical, chemical, and biologic processes.
Gibb, J. P. [8]	This research is a field investigation to patternize the vertical and horizontal migration of chemical pollutants through the soil. Also, to examine the residual chemical build up in soils in the vicinity of pollution sources. Adapted Field Techniques were: disturbed and undisturbed sampling of soil, well construction, and water sampling. Metals like Zn, Cd, Cu and Pb were traced.
Moore, C. A., and M. Roulier [20]	This paper presents analytical techniques to evaluate the performance of landfill drain-liner system. Two drain-liner system designs are examined (a good and a poor one) to determine what design characteristics are most important. The procedures used rely upon two Technical Resource Documents. Hydrologic Simulation of Solid Waste Disposal Site Landfill and Surface Impoundment Performance Evaluation
Moore, C. A., and E. M. Ali [19]	This paper is a computer simulation results of the effects that cracks in clay liners on the containment capabilities of hazardous waste landfills. The flow of fluids in saturated cracked liners was investigated using a simplified, preliminary statistical flow model. The frequency of cracking and the penetration depth of the cracks are important of those studied.

in central Texas. The average rate of leakage through the liners was calculated to be between 20 and 30 grams per minute per storage pit. The average coefficient of permeability was computed to be 2×10^{-5} and 5×10^{-5} cm/sec. This was 100 times larger than values which were expected based on laboratory testing of undisturbed liner samples. A field test was designed and carried out at the sites to re-create a representative situation. This test included a very large volume of soil; the permeabilities were found close to the actual values of leakage rate. Daniel explains that the discrepancies between laboratory and in situ results are due to the presence of tiny desiccative cracks or similar defects in the liner which are often formed during the placement process.

2.6 SUMMARY

Hazardous waste disposal problems mainly fall within the following categories:

1. Design of a burial site, with adequate opportunity to consider all variables.
2. Appropriate methods of construction of burial sites.
3. Failure of an existing site and development of corrective measures for dealing with the problems.

The important factors in proper design of a secure landfill are:

1. Bottom and side liner.
2. Leachate collection system, below the liner.
3. Cover cap.
4. Natural hydrogeologic setting.

There are no standards or specifications as to how to construct different elements of a landfill system. Compaction of the bottom and side clay liners, installation of synthetic liners, leachate collection system, cover cap, and monitoring facilities vary in accordance with each particular project. The amount of leakage in each landfill is apparently the governing factor that defines failure. The affecting factors to predict and determine contamination potential from a site are:

1. The composition of the waste.
2. Annual precipitation statistics.
3. The geology at the site.
4. Groundwater conditions.

The possible interaction of the clay liner with the wastes should be studied prior to the disposal of the wastes. This is important since it is the impermeability of the liner material that secures the landfill. The following factors have been shown to be significant:

1. Dielectric constants of wastes which are a measure of hydrophobic or hydrophilic nature of a chemical.
2. The amount of shrink and/or swell that the chemical causes.
3. Viscosity and density of the waste fluids.

Case history studies of burial pit failures have shown that even well-designed systems can have problems. Difficulties have arisen due to unusual groundwater influxes and macro-level cracking or fissuring in the clay liner. Fissuring or cracking is postulated as being caused by drying of the clay during or after the placement process.

CHAPTER III. PINEY RIVER DISPOSAL SITE

3.1 LOCATION

This project concerns the site of the abandoned Piney River Plant formerly owned by the United States Titanium Corporation. The site is located in Nelson County, Virginia, with Route 151 bounding the west side of the site. The Piney River flows easterly along the southern edge of the area. The plant and the disposal site are shown on the project location plan in Figure 3.1. The disposal area is northeast of the abandoned processing plant. One can enter the site from Route 151 on a paved road that cuts through the old plant facility and then becomes unimproved. This unpaved road leads through the woods and up a hill to an almost level grassy plateau about one mile further on, which represents the top of the disposal area. On the north and west of the hill there are gently-sloped, thickly-wooded areas while to the east the hillside is very steep. At the toe of this slope there is a small creek which flows into the Piney River on the south; the slope is initially steep, but at the bottom the grade becomes gentle and this grades into the Piney River. These surface characteristics are detailed in the topographic map of the site shown in Figure 3.2.

3.2 GEOLOGY

The materials underlying the soil cover of the site consist of igneous and metamorphic crystalline rocks of the Blue Ridge Anticlinorium which are variously called the "Virginia Blue Ridge

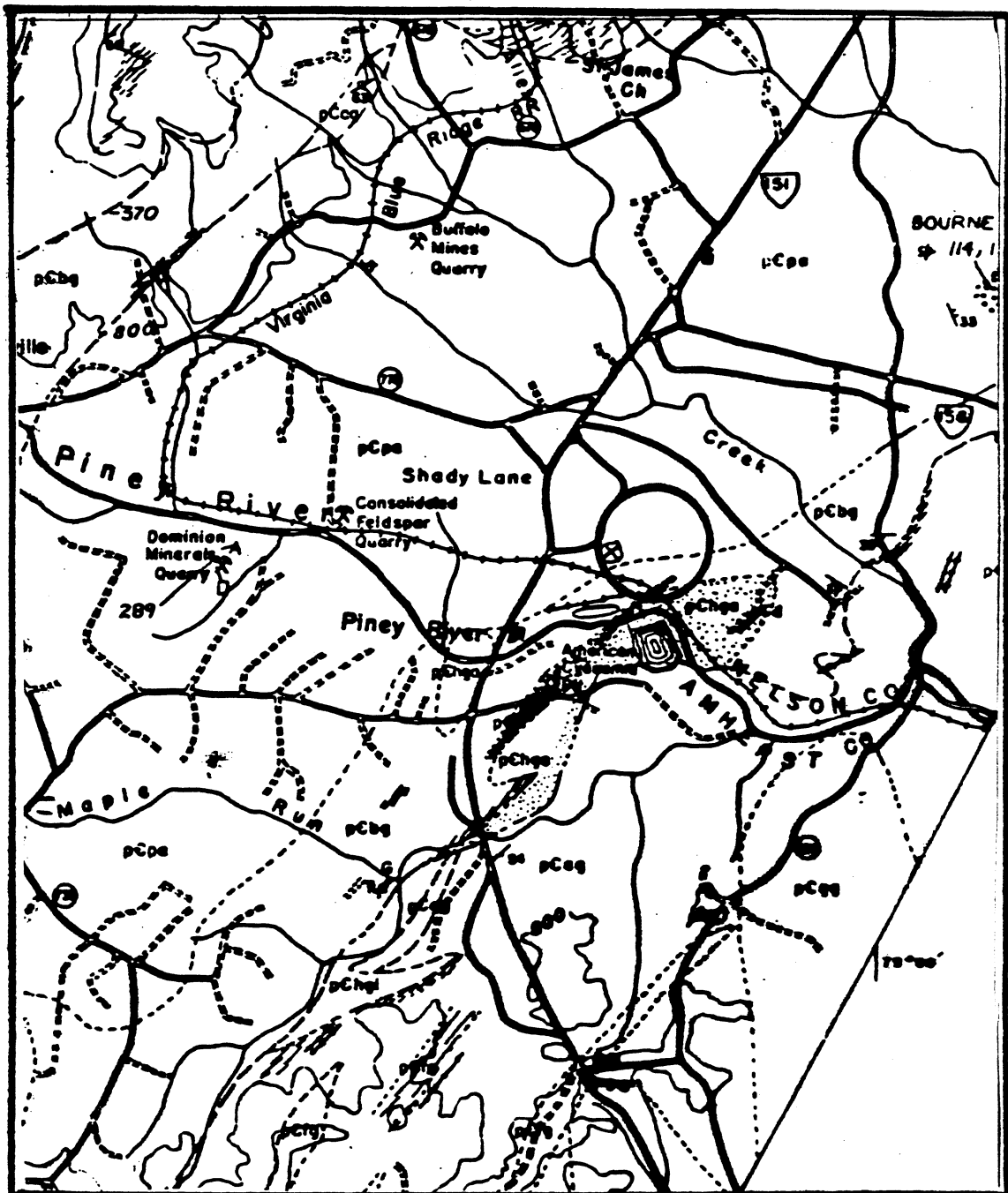


Figure 3.1 Project Location Plan ○



Figure 3.2 Topographic Map of the Site

Complex", the "Blue Ridge Basement Complex", or the "Injection Complex". See Hillhouse [13].

In the general area there are four major rock bodies. One is the ilmenite-apatite ore bearing deposit that is approximately 2300 feet long and 60 to 283 feet thick, and which spans the Piney River and extends to depths exceeding 400 feet. This rock mass is an apatite-rich, ilmenite nelsonite ore body. The minerals of commercial interest are apatite, $\text{Ca}_5\text{FeO}(\text{PO}_4)_3$, and ilmenite, FeTiO_3 . Lying to the south-east of the ore body is hypersthene granodiorite, which is basically a granite exceptionally high in ferro-magnesian minerals. Surrounding the ore body and the granodiorite is a border gneiss. The gneiss grades into pegmatitic anorthosite, but the transition is not sharp. The anorthosite is the chief basement rock in the area and surrounds the other three.

Using the pedological soil classification system, the soils at the disposal site can be classified as sandy loam, loamy to sandy loam, sandy clay loam, and clay. Most of them are floodplain deposits probably from the nearby Piney River but some of them developed on steep sideslopes. As a general rule these soils are well drained but if there is a high clay content present they tend to be poorly drained. The soils tend to be well developed pedologically, as soils commonly are in the Piedmont region, and extend to a depth of about 50 in. Below the soils there is weathered rock or coarse alluvium.

From an engineering point of view there are two distinct principal soil types. One is red clay, an end product of chemical alteration and weathering of plagioclase (anorthosite) feldspar in

the pegmatitic anorthosite. The pegmatitic anorthosite is nearly 100% feldspar and this weathers to soil in which the clay is mostly kaolinite. Undoubtedly the red coloration can be attributed to the iron oxides present in the soils common to the Piedmont. The red soils are from the lower B horizon. At the other end of the soil spectrum is a white silt. This constitutes the C horizon of the soils developed from the anorthosite. All of the soils in the immediate vicinity of the disposal site are residual; i.e., they have weathered in place.

Studies show that the water level in areas outside the disposal pit per se is found at depths of 31 to 39.5 ft. and flows toward the nearby Piney River in a generally southern direction.

3.3 HISTORY OF INDUSTRIAL DEVELOPMENT

In the early 1930's the site was mined for apatite. The Vanadium Corporation extracted phosphorous from this mineral. The industrial history of this site shows that at an early date the Southern Mineral Products Corporation mined the ilmenite for its titanium content. Subsequently, beginning around the late 1940's, the American Cyanamid Corporation took over the titanium mining.

Mining operations ceased in late 1971 and the plant was abandoned in 1972. Production of titanium at the site involved extracting titanium dioxide (TiO_2). This fine powdered material was processed using sulfuric acid (H_2SO_4).

Treatment of the ore for the production of titanium dioxide produced two types of waste products. One of them was an unreactive dark gray substance. The other byproduct was a bright yellow-green material

commonly referred to as "copperas" that consists of 50% to 70% ferrous FeSO_4 plus a variable number of water molecules and is characterized as $\text{FeSO}_4 \cdot x\text{H}_2\text{O}$.

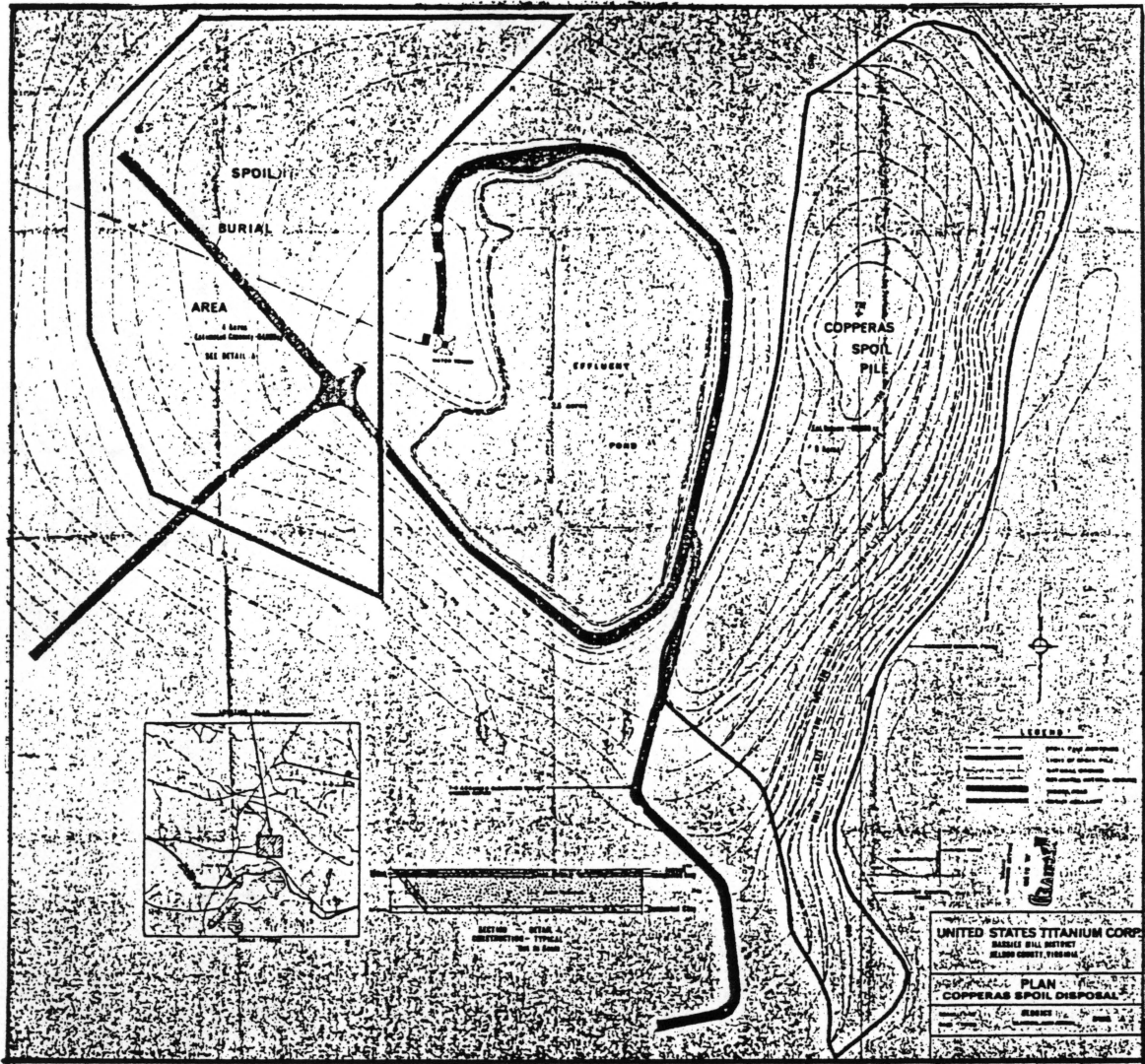
As the copperas was generated it was placed at the disposal site northeast of the plant as shown in Figure 3.1. The inactive ore residue was transported to the settling ponds located south of the landfill and next to the Piney River. These areas are indicated on the topographic map shown in Figure 3.2. Some of the copperas was dumped down the eastern slope of the disposal area. Very wet materials were stored in a lagoon area at the crest of the eastern slope. Also, a dike built across the small southerly flowing stream at the toe of the eastern slope served to trap large quantities of sediment from the copperas storage area.

While dating is uncertain because of lack of records for these industrial operations, in 1983 the NUS Corporation [22] reported discharges from this landfill area which resulted in fish kills in the Piney River, the Tye River, and as far downstream as in the James River. These kills were reported in 1956, in July 1977, with the last reported episode occurring in August 1979. The cause of these fish kills in every case was stated as "acidity". In other words, the pH level in this aquatic environment was too low to sustain fish life. This same source states that state water quality standards for pH levels were violated.

3.4 ATTEMPTED CLEANUP

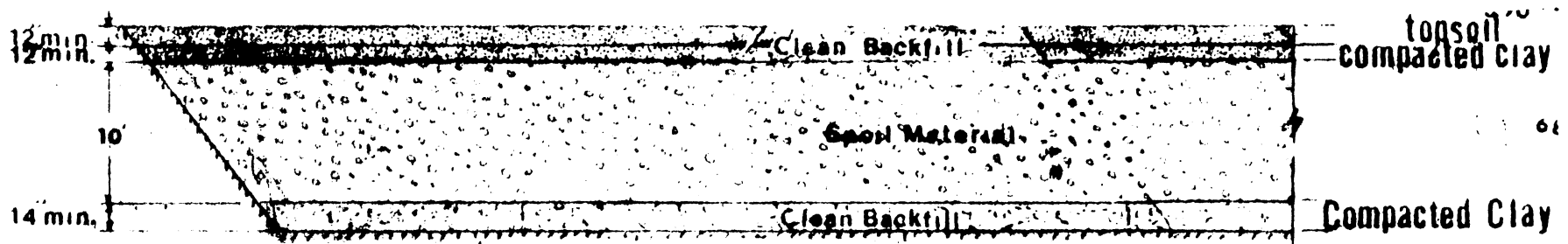
The fish kills alerted appropriate state agencies to the dangers inherent in the disposal site in the then-existing condition. A Geonics report [6] states that in 1979 topographic surveys were made of the copperas pile and the adjacent property. It is assumed that this survey covered what is now known as the old lagoon and the area that subsequently became the present burial pit. It was estimated at that time that the quantity of waste to be dealt with was something less than 110,000 cubic yards. The Geonics report stated that waste copperas was to be buried west of the old lagoon in a pit.

A geotechnical investigation was performed at the site of the proposed pit by E. O. Gooch and Associates [9] in 1979. This consisted of drilling five holes to a maximum depth of 35.0 feet. Blow counts were reported from Standard Penetration Testing; however, no other tests were apparently conducted. In their report, Geonics recommended construction of a disposal pit for the copperas as shown in Figure 3.3. The pit was to be lined using the red clay at the site. Initially, no lining was shown for the side slopes of the pit as is shown in Figure 3.4, but this was later changed and it was recommended that the liner cover the bottom as well as the side slopes. No mention was made of any compaction requirement for the red clay. This was apparently left up to the contractor. It was suggested that as the copperas waste was placed in the pit an attempt be made to compact it to reduce its volume. A clay cover was recommended for the top of the pit, to be composed of the red clay.



- From Geonics [7]

Figure 3.3 Recommended Construction Plan



SECTION — DETAIL A
CONSTRUCTION — TYPICAL
 Not to Scale

Figure 3.4 Detail of the Original Burial Pit Scheme As Recommended by Geonics

In late 1980 about 80,000 cubic yards of copperas waste were buried in clay lined trenches. NUS Corporation [22] mentioned how difficult it was to compact the waste material, but there are no daily operational records of activities available for inspection; construction methods at the new burial site and the end results can only be surmised.

Following this attempted cleanup, EPA monitored the pH of the groundwater and studied possible heavy metal contamination of the groundwater. In 1982 EPA [5] records show that in the groundwater and in Piney River the pH values were low and heavy metal contamination was high. Within a short period of time the new storage site is reported to have developed numerous cracks and sinkholes in the clay cover. Along the edges of the new burial site seeps of copperas contaminated fluid or leachate were observed. Over the next year or so an indeterminate amount of new fill was added. One local contractor who was interviewed stated that up to 10 feet of fill were added in some areas to bring the depressions up to original grade. This suggests a very large loss in volume was occurring in the pit. In spite of the new filling and grading, problems continued to develop at the site.

The on-going problems consisted of fresh openings of cracks in the clay cover over the pit, renewed formation of sinkholes and depressions, and leakage of leachate. It is of interest to note that even during the course of this work (January 1983 to January 1984) one could visibly observe growth of the cracks and depressions in the clay cover which suggests that the process causing this phenomenon was active and working at a rapid pace.

CHAPTER IV. INVESTIGATIVE PROGRAM

4.1 GENERAL APPROACH

At the time the Civil Engineering Department at Virginia Tech undertook the study of the Piney River disposal site the new storage system was evidencing distress. The geotechnical and environmental sections of the Civil Engineering Department undertook a joint investigation. This report deals only with those portions of the study involving or closely related to the geotechnical aspects of the problem. The objectives are:

1. Definition of actual geometry of burial pit.
2. Determine if liner present in thickness indicated on plans.
3. Assess nature of liner material and its response to acidic waste exposure.
4. Assess nature of copperas and pit backfill.
5. Explain reasons for substantial subsurface leakages, sink-holes, and surface cracks.

To achieve these objectives two courses of action were undertaken. One phase involved field investigations, which are discussed in Chapter V. The second phase consisted of laboratory investigations on the materials found at the site, and this is covered in Chapter VI.

4.2 FIELD INVESTIGATION

The field investigation was planned so that a proper evaluation could be made of the soils and wastes, the extent of these materials,

and what happened to create the problems. This work consisted of site visits, trenching operations, drilling to determine the vertical extent of the various materials present, and to obtain both disturbed and undisturbed samples.

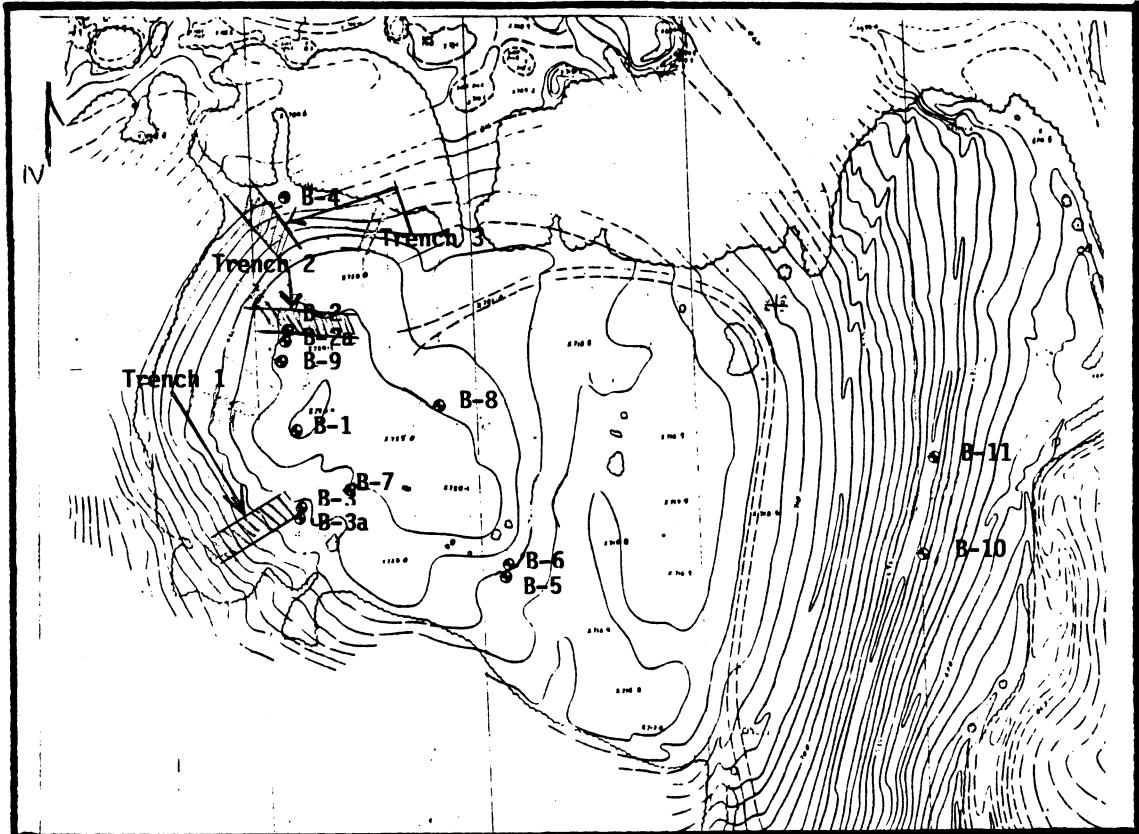
4.2.1 SITE VISITS AND TRENCHING

The initial field work commenced in July 1983. During July and in the following months several trips to the Piney River site were made. The disposal pit area evidenced sinkholes, cracks, and broad depressions. Patches of dead vegetation both on the top of the landfill and around the perimeter of the area were observed. In a number of areas there were zones where the leachate was seeping from the landfill onto the slope of the surrounding ground. There were also several direct springs of leachate on the outer edge of the landfill discharging a dark reddish-brown substance.

Trenching operations were conducted to expose different layers within the landfill. As shown in Figure 4.1, three trenches were excavated in the north and western regions of the landfill zone near the boundary of the pit. Excavation was accomplished using a backhoe. The trenches varied anywhere from 15 feet to 25 feet in length, with a width of two to three feet. The depth varied from 3 to 5 feet. One trench was intentionally centered over a leachate seep.

4.2.2 DRILLING AT THE SITE

Another part of the field investigation involved the drilling operations. A series of test borings were drilled in and adjacent to



Scale 1" = 200'



Test Boring Location



Trench Location

Note: In addition, approximately 80 hand auger sampling locations were distributed throughout the site.

Figure 4.1 The Approximate Locations of Test Borings, Trenches, and Hand Augers

burial pit and along a berm on the eastern slope. See Figure 4.1 and Table 4.1. Bowles [3] describes boring procedures.

The drilling program utilized both machine and hand auger procedures. Thirteen borings were drilled using a rig provided by the Virginia Tech Department of Agronomy. The drill rig utilized hollow stem auger flights. No drilling mud was needed to stabilize the holes. Bentonite and wet plastic clay were backfilled into holes which were in the pit per se to seal the hole and prevent any subsequent leakage of leachate. Samples were obtained by either driving a standard split spoon or by pushing a thin wall shelby tube. The split spoon conforms to ASTM Standard D 1586-67. The shelby tubes were 18 in. long and had an internal diameter of 3.0 inches. The tubes were coated on the inside with a silicon seal to minimize reaction between the steel of the tube and the acidic soil samples. There was no need for use of the silicon seal with the split spoon since the soil samples in this case were removed in the field and the split spoon could be washed following each usage.

The pH of the soil at different depths was determined from the samples and the results were compared to typical values for uncontaminated soils native to the area. This comparison was judged to be a reliable indicator of the extent of soil pollution. A large number of pH measurements were made at the site immediately as soil was brought to the surface at the same time as the borings were drilled. For each determination about 10 to 15 grams of soil were mixed with a volume of distilled water that was about twice the volume of the soil sample. The soil specimens were carefully taken from the interior of the sample so

Table 4.1 Drilling Program

Boring Number	Total Depth	Remarks
B-1	16.0'	Boring within the disposal pit to define the limits of the land fill.
B-2, B-2a	10.0', 19.0'	Borings 4' apart, in middle of pit to define the extent of pollution.
B-3, B-3a	16.0', 10.5'	Boring 3' apart in southwest margin of pit to find side liner.
B-4	13.4'	Boring located out of the pit, in northside to determine the bedrock depth.
B-5	60.0'	Boring in old lagoon area to detect contamination, and bedrock depth.
B-6	10.0'	Boring 6' north of B-5 to obtain undisturbed samples.
B-7	29.5'	Boring within the pit to define the pit configuration.
B-8	41.5'	Boring out of the pit to detect contamination, and bedrock depth.
B-9	29.0'	Boring in middle of the pit, to determine the vertical extent of the pollution.
B-10, B-11	13.0', 16.0'	Boring on eastern slope, out of the pit, to find contamination, and bedrock depth.

that possible contamination by water in the hole was eliminated. The soil - water suspension was thoroughly mixed and the glass beaker containing the suspension was set aside for at least five minutes. This was done to facilitate the dispersion of the clay component of the sample and to permit soluble components of the sample to dissolve. At the same time samples were taken for subsequent laboratory check determinations of pH values. The laboratory and field values generally agreed. pH results are reported on the boring logs at the depth of the sample where the measurements were made. Boring logs are given in Appendix I.

Split spoon sampling was accomplished in accordance with ASTM D 1586-67; a 140 pound drive weight falling 30 inches drove the sampler. The split spoon was driven for a total distance of 18 inches. The number of blows required of the falling weight to penetrate the last 12 inches into the ground is recorded as the blow count and this is shown on the logs. The spoon samples were used for classification and pH testing. The shelby tube specimens were generally obtained by hydraulically pushing the tubes into the ground. These samples were considered to be undisturbed and were used for permeability, compressibility, and in situ density testing. All machine drilled holes were logged as the soil was brought to the surface by the auger and in sampling devices.

Groundwater levels were measured in the holes after an overnight period for water level stabilization. The water in the holes generally rose to a stable level quickly.

In addition to the rig borings, about 80 locations at the site were probed with hand augers to a depth of 8 feet or less. The hand auger borings were used to determine if copperas or copperas-contaminated soils were present, based on a visual examination as well as by pH measurements.

4.2.3 BORROW PIT

During the first site visit a borrow pit south of the new disposal pit was identified as exhibiting a clean exposure of the native soil profile. Three bulk samples were obtained; one of the B horizon as an example of the red clay for the liner, one of the C horizon as an example of the mottled silty clay which underlies much of the site, and one of the white silty soil at this location. These were particularly useful for control testing since there was no contamination from previous waste storage or groundwater flow in this area.

4.3 LABORATORY TESTING PROGRAM

The laboratory testing program was oriented towards classification, definition of components, and engineering behavior. The basic test program is described in Table 4.2. For noncontaminated soils the tests could follow conventional lines. However, because the copperas and the copperas contaminated soils were generally highly acidic, these materials presented an unusual laboratory problem. Ordinary aluminum and steel laboratory equipment could not be used with these samples since the equipment would react with the acids. Consequently, all equipment coming in contact with the samples for more than a few hours

Table 4.2 Laboratory Testing Program

<u>Test</u>	<u>Number Performed</u>
In situ Moisture Content	12
In situ Density	8
Grain Size Analysis	6
Percent Fines	11
Limits	11
Permeability	10
Effluent Permeability Analysis	6
Diffraction X-Ray	2
Consolidation	2
Compaction	2
Solubility	3
In Laboratory pH Analysis	53

had to be fabricated from an acid resistant material, either polyvinyl-chloride (PVC) or glass. Minor expendable pieces of equipment made from steel and aluminum such as spatulas and tares suffered irreparable damage from even short-term contact with the acidic samples.

In performing the permeability tests the following describes the general procedure:

1. The tubes were cut into 4-inch portions and were pushed into the permeameters with a series of rubber O-rings in place to provide a secure seal between the tubes and the permeameter wall.
2. The soil in the tube was subjected to the flow of distilled and deaired water in the Standard Falling Head test method.*
3. Effluent from the permeability tests was collected and tested for metal content.

4.4 SUMMARY

The field investigation phase began with several trips to visually observe the nature of the site and to obtain quantities of disturbed samples from a borrow pit which exposed the natural soils. Subsequently, three trenches were excavated by backhoe to expose the soils along the fringes of the burial pit and to cut through some of the heaviest leachage seepage areas. This was followed by drilling 13 deep holes with a drill rig from which samples were obtained. In and around these

*One special test was performed using leachage as the permeant on un-contaminated, compacted clays of the site.

operations some 80 hand auger holes were advanced to probe the sub-soils for contamination levels.

Laboratory tests were performed on samples returned from the site. The tests were selected so as to classify the soils, define their composition, and determine key engineering parameters.

CHAPTER V. RESULTS OF FIELD TESTING PROGRAM

5.1 TRENCHING OBSERVATIONS

The trenches allowed direct observation of the material along the periphery of the western side of the disposal pit. Figure 5.1 illustrates the exposed materials in a typical observed sequence. The walls of these trenches would collapse within minutes of being excavated. A summary of the findings from the trenching operations is as follows:

1. If found in an almost pure form, the copperas was bright yellow and had a granular or flaky texture. It gave the impression of being relatively dry in comparison to the surrounding soils.
2. Pure seams of the copperas were rarely found. It was typically mixed with the red native soils, with a more yellowish color tinge indicating a higher copperas presence.
3. The contaminated soil-copperas mixture appeared considerably wetter than the copperas itself.
4. Local seeps quickly developed in a number of areas as the trenches were excavated. After a period of high flow for a few minutes, the seeps would slow to a trickle.
5. Only in trench 2 was there clear evidence of a pure red clay cap. Generally there were a few inches of top soil followed by the copperas-clay mixture.
6. The wet soil-copperas mixtures were very weak, and in a number of cases local sections of the trenches collapsed

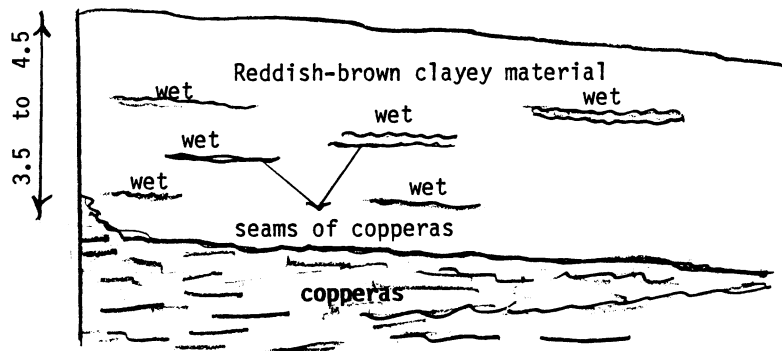


Figure 5.1 Typical Profile of Trenches

after they had been open for only about an hour.

7. Trench 1, which was located in a heavy seepage area below the crest of the pit and on the southwest corner, showed copperas and copperas rich soil to be present to a depth of three to four feet.

The observations from the trenches suggest that the geometry of the burial pit deviates from the type of diagram presented in Figure 3.4. The important finding was that the compacted red clay cap materials were not present in any significant thickness over the trenches.

5.2 BORING PROGRAM RESULTS

5.2.1 GENERAL

The borings provided information on the soils and materials in and outside the boundaries of the disposal pit. Locations of the thirteen borings advanced by the drill rig, B-1 through B-11, are indicated on Figure 5.2. Of them B-1, B-2, B-2a, B-3, B-3a, B-7, and B-9 were located in the pit area per se. Boring B-4, on the northern outer edge of the pit area, probed for copperas but found none. Borings B-5 and B-6 were located in the old lagoon area, while boring B-8 was sited specifically to be outside of the pit so as to test undisturbed material for contamination. Borings B-10 and B-11 were located on the eastern slope of the pit hillside to test for contamination in the old storage area.

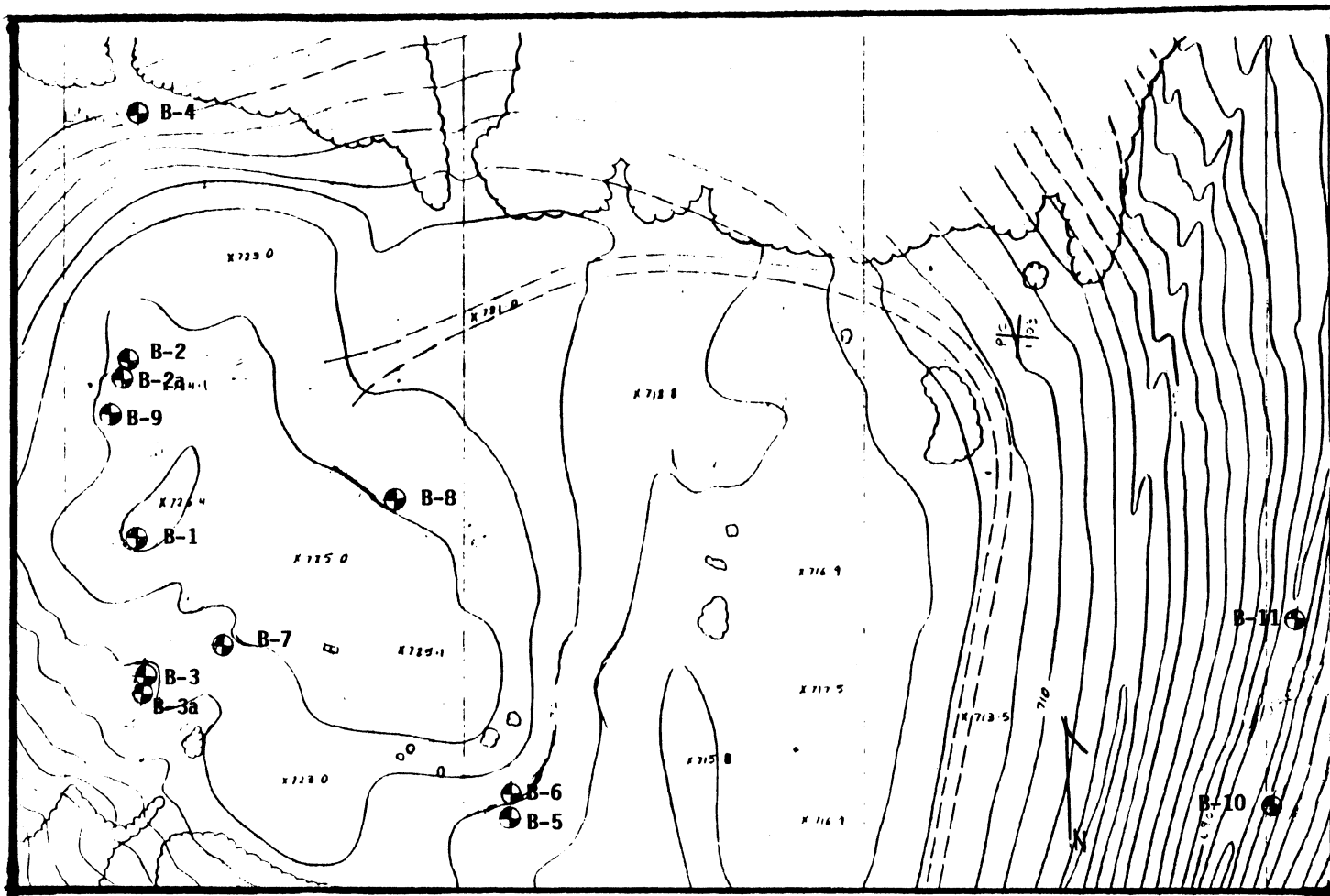


Figure 5.2 Approximate Location Plan

Records of the materials encountered in the drill rig borings are provided in the form of logs in Appendix I. As an example of these logs, Figure 5.3 shows the log for boring B-7. In addition to the basic material description on each log, records are given for locations of sampling activities and pH values. When they were measured, blow count values are indicated for each six inches of drive of the split spoon.

5.2.2 MATERIAL DISTRIBUTION

The distribution of materials in the disposal pit area is complex. This can be illustrated by the fact that boring B-1, which was sited in the central region of the pit, encountered no waste material. Moving only about 50 feet to the north of boring B-9, waste was found to a depth of 18 feet. It rapidly became apparent that the burial pit was actually composed of individual cells which could be distinguished by the fact that the surface in areas with copperas were clearly depressed below that where no copperas was present. The topographic lows associated with the copperas also evidenced cracks, sinkholes, and depressions in the clay cover.

A north-south section drawn across the pit area in Figure 5.4 illustrates the variability in materials. Beginning at boring B-4 on the north side, no copperas was found and only natural soils were encountered. This boring suggests a northern limit for the pit. Several hand auger borings in this vicinity also hit no copperas. Bedrock was located at a depth of 13 feet in boring B-4, and no groundwater table was observed. Borings B-2, B-2a, and B-9 were sited in a broad

BORING LOG									
Piney River Storage Area, Nelson County, Virginia									
Boring No	B-7	Total Depth	29.5'	Elevation	724.0±	Location	See Figure 4.1		
Type of Boring	Hollow Stem Auger	Started	9/8/83	Completed	9/8/83	Driller	-----		
724.0	0.0	DESCRIPTION OF MATERIALS (Classification)	Sample B overs	Sample Depth (Feet)	% Core Recovery	Field pH	REMARKS	Laboratory pH	
		Red clay, some fine to coarse sand moist - (CH)							
				4.0		5.20		4.03	
			11	5.5		3.41		3.59	
		Reddish brown clay and copperas, organic material, strong odor - wet (CH)	47	8.0					
	9.5		9	9.5		2.30	WATER TABLE ▼		
		Tube was pushed				2.40			
	11.5								
	13.0	Reddish brown clay, copperas - wet (CH)							
	14.5	Tube was pushed							
		Red & white mottled silty clay, with rock fragments & dark color minerals - moist (CL/ML)							
704.0	20.0		59	20.0					
			16	21.5		4.00		4.41	
				28.0					
694.5	29.5	pushed spoon	*	29.5		3.96		3.12	
		Boring terminated at 29.5							

Figure 5.3 Sample Boring Log, B-7

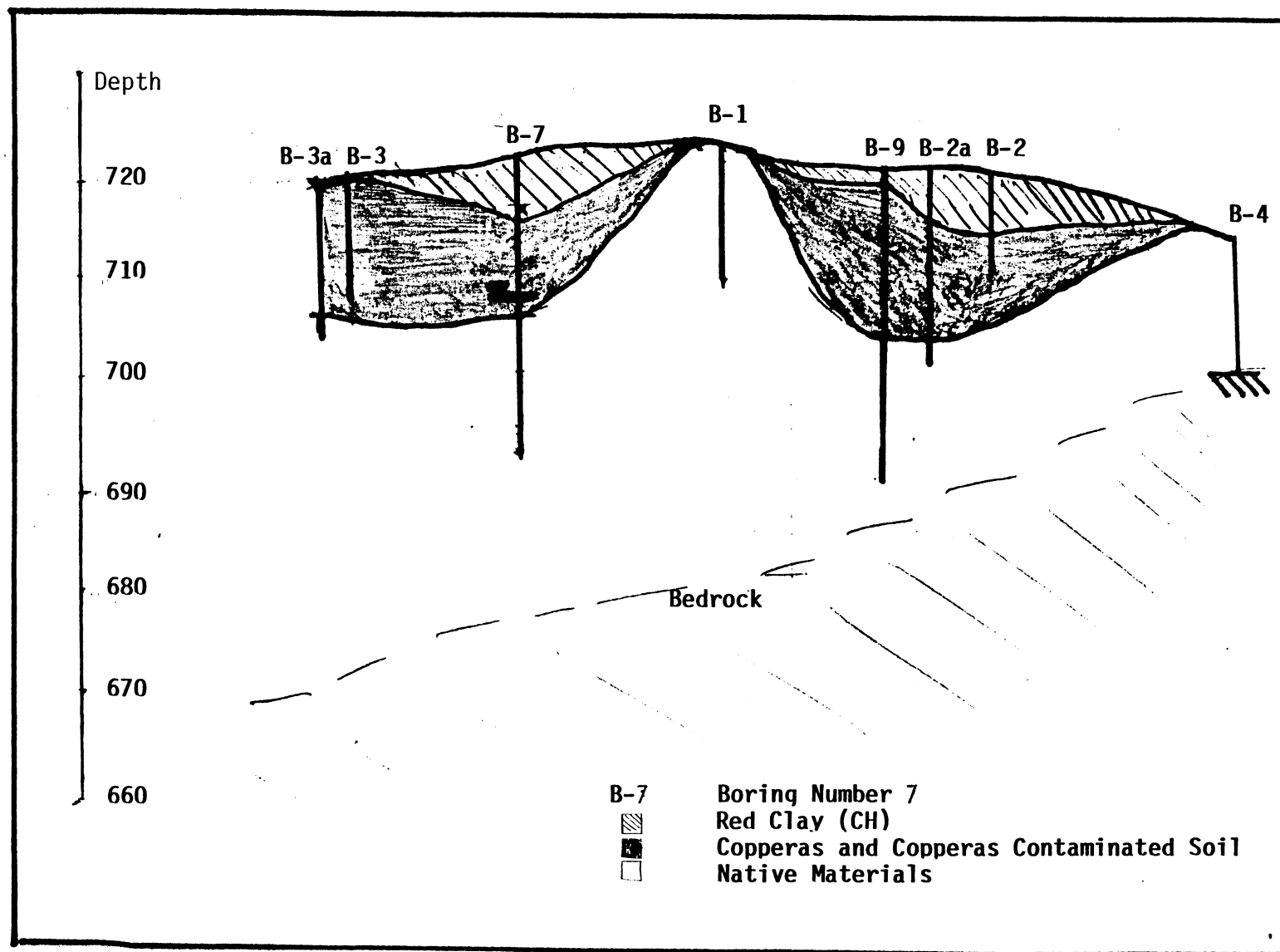


Figure 5.4 Cross-Section Along North-South Trending Line

depression and they all encountered copperas and copperas-rich clay with the thickness varying from 5 to 18 feet. As noted, B-1 showed no copperas contamination, but to the south of this, B-7 exhibited some 10 feet of copperas-contaminated soil. Moving to the southeastern corner of the pit, borings B-3 and B-3a encountered over 10 feet of waste soils.

The thickness of the clay cover in a rough way correlated inversely with the thickness of the copperas and copperas-contaminated clays. Thus, the smaller the amount of waste, the thicker the cover and vice-versa. This suggests that as the volume of the wastes have decreased in some areas over the past several years, clay has been brought in to level the grade, and therefore more "cover" is found.

As was the case in the trenches, copperas rarely appeared in the borings in a pure form for any significant thickness. More commonly the waste was in the form of red clay mixed with copperas. This type of material was normally very wet and appeared saturated.

There was no clear indication of a bottom liner of red clay in the borings, although before natural soils were encountered the level of the copperas in the clay diminished. It seems possible that the red clay for the liner was placed in a very wet condition and, in the process of placing the waste in the pit, the waste and the red clay were mixed to some degree. As will be shown later by the laboratory results, the lower soil samples from the pit were indeed very wet.

Below the pit, mottled red and white silty clay was found. This soil is native to the area. No bedrock was encountered in any of the pit borings to a depth of 30 feet. Boring B-8, which was located just

to the east of the pit, showed no copperas contamination and hit bedrock at a depth of 40 feet. Further to the south in the old lagoon area, boring B-5 was drilled to a depth of 60 feet before hitting bedrock. Remembering that bedrock in boring B-4 to the north of the pit was at a depth of 13 feet, it seems that the bedrock surface slopes to the south resulting in increasing soil depths to the south. This agrees with the finding of Gooch Associates [9].

No copperas was found in borings B-8, B-10, or B-11, outside of the pit area; B-10 and B-11 were located on the easterly slope in the old storage area. These three borings were advanced to bedrock.

Borings B-5 and B-6, sited in the old lagoon area, showed a direct copperas presence in the soils to a depth of about 10 feet. Below this natural mottled clay was encountered. Apparently the copperas-contaminated soil in the upper 10 feet was deemed "clean" enough not to be buried in the pit area when the original work was done to correct the site problems. However, as will be shown by the pH measurements, this area represents a strong source of contamination and no liner is in place beneath it to help restrain leachate seepage.

Based on these borings and the findings in these borings the existent outline of the pit area, whatever it may be, is different from that shown in Figure 3.3.

5.2.3 DRIVING RESISTANCE

Driving resistances measured during Standard Penetration Testing produced some interesting findings, particularly where a seam of almost pure copperas was encountered. The copperas proved to be highly

resistant to penetration, yielding blow counts of over 50 blows per foot. This is normally an indication of a very dense soil material. It was found that the drill rig could not push a shelby tube into a copperas seam. Thus the copperas itself is a very resistant material and not inherently compressible.

5.2.4 WATER TABLE

In the borings outside of the pit area (B-5 and B-8), the water table was observed at a depth of about 31 and 39.5 feet respectively. However, boring B-7, located in the southeast part of the pit, showed the water table at a depth of 9.5 feet. It appears that in the disposal pit a perched water table exists, possibly due to the liner preventing, to some degree, the complete escape of fluids from the landfill. This is supported by the very wet appearance of the samples from the pit area.

Based on the analysis of the observation well data in the environmental phase of this study, the flow of the underground water system is in a southerly direction towards the Piney River. This followed the general slope of the bedrock in the area.

5.2.5 pH MEASUREMENTS

The soil science literature suggests that pH values of uncontaminated soils of the types found at the site should be in the vicinity of 5.0 [23]. Direct measurements on the bulk samples obtained from the borrow pit area yielded pH values which averaged 5.0, suggesting that this soil was uncontaminated.

Profiles of the pH measurements for all of the logged holes are shown in Figures 5.5 through 5.11. The following trends were observed:

1. Borings B-1 and B-8: These borings may be lumped together as being in the level area on top of the hill, and not encountering any copperas or copperas contaminated soil. Both holes showed pH values ranging from 4.5 to as low as 2.5. pH values were below 4 in all cases to depths below 40 feet in boring B-8.
2. Boring B-4: Located outside the north boundary of the pit. This hole showed no copperas. It was uphill of the general trend of the groundwater flow. pH values in the upper portions of the hole were low, but at a depth of 13.5 feet above bedrock, the pH in this hole reached a value of 5.5, typical of normal values.
3. Borings B-2, B-2a, B-3, B-3a, B-7, and B-9: Copperas and copperas-contaminated soil were found in all of these borings which were all located in the disposal pit area. At depths where the contamination was very obvious, pH values were typically below 3. In those cases where the borings apparently passed through the pit and into the natural soil (see B-2a, B-7, and B-9) there is an indication that the pH increases. However, values above 4 were not observed.
4. Borings B-5 and B-6: These holes were located in the old lagoon area, and copperas contamination was found to a depth of around 10 ft. Importantly, low pH values were measured (3 or below) in B-5 for the entire soil profile depth of 60 ft.

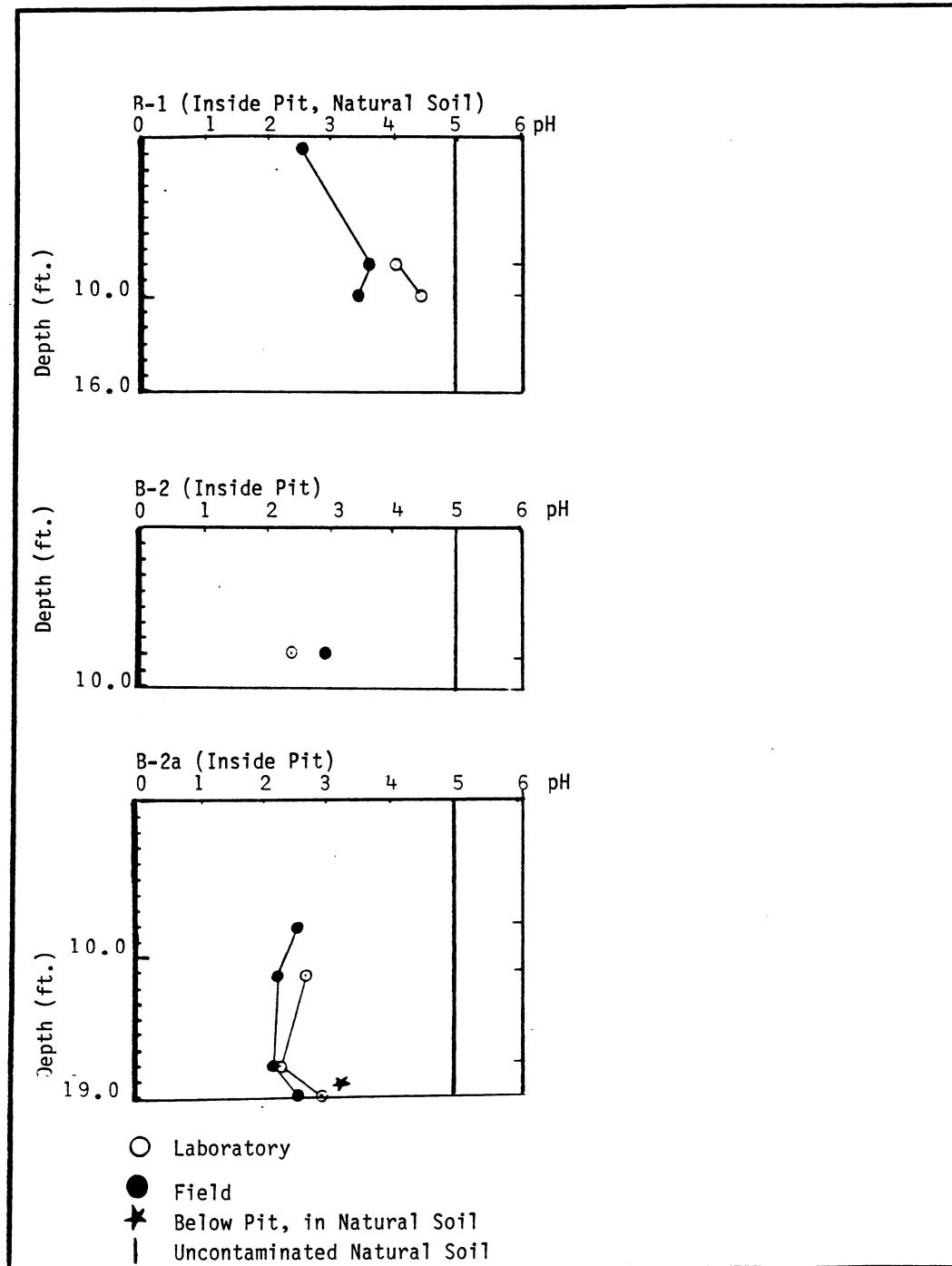


Figure 5.5 pH Profile of B-1, B-2, B-2a

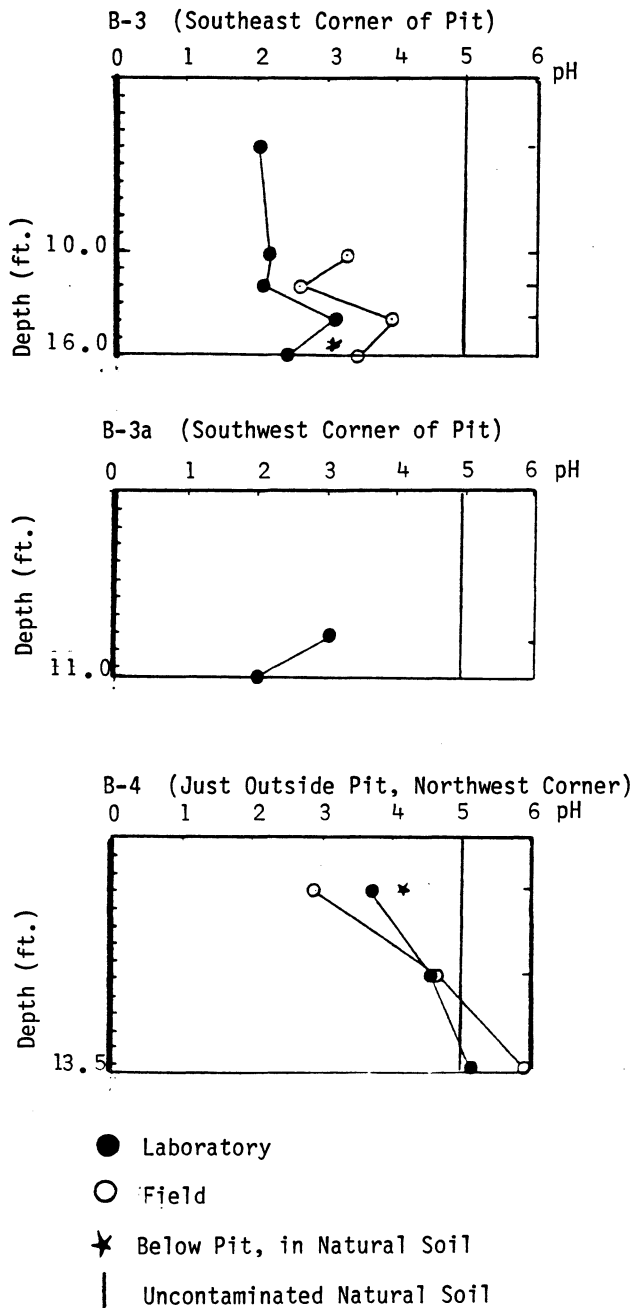


Figure 5.6 pH Profile of B-3, B-3a, B-4

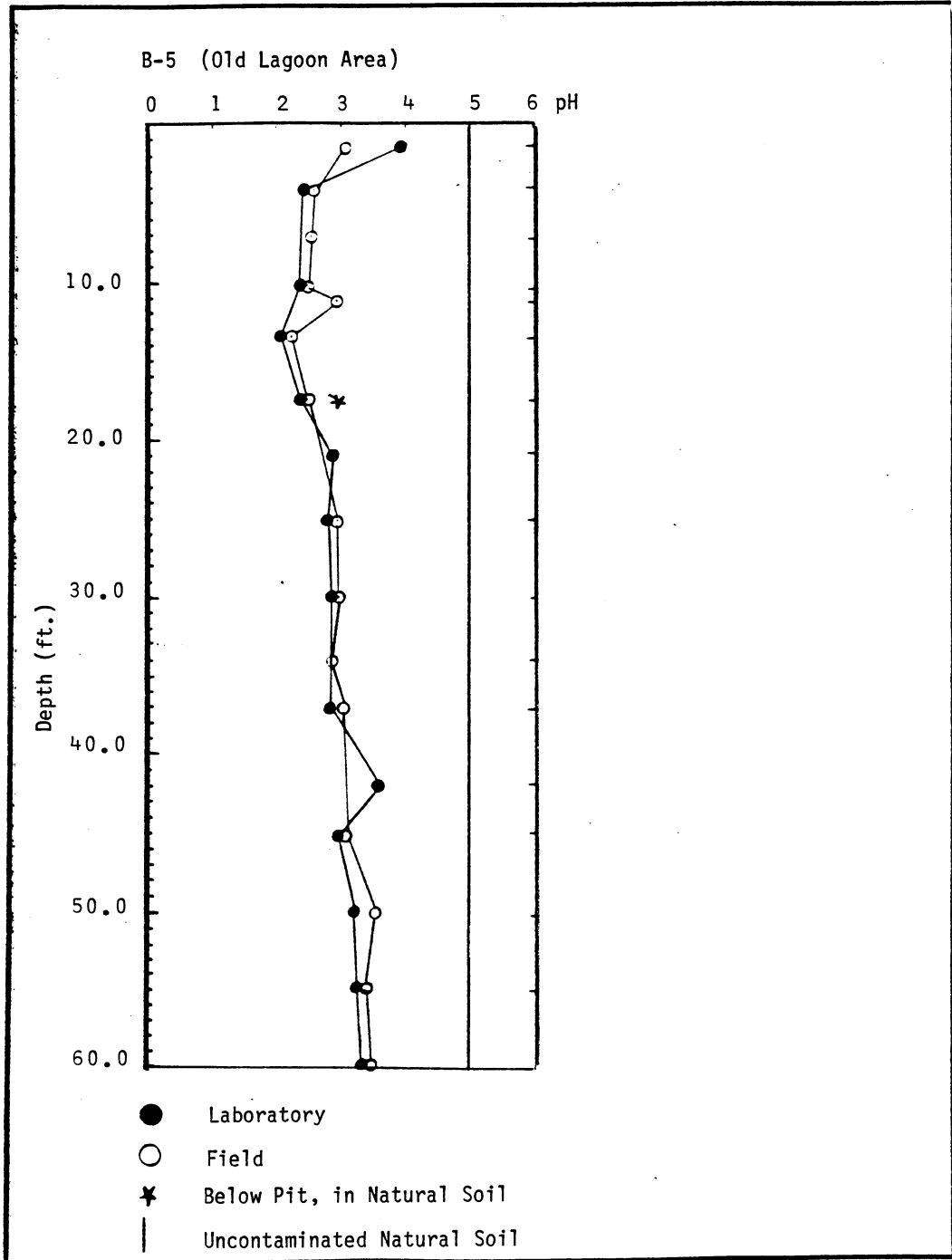


Figure 5.7 pH Profile of B-5

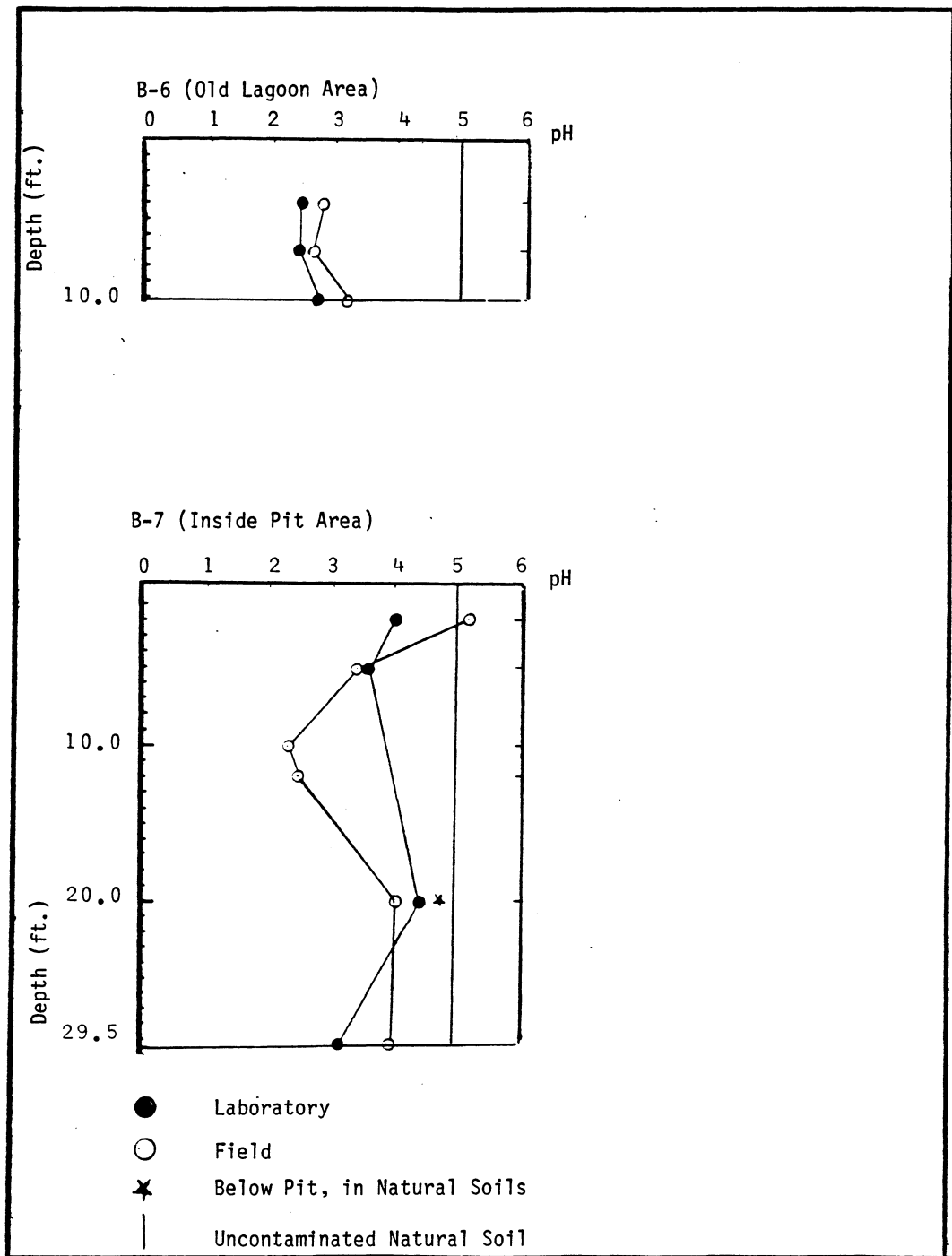


Figure 5.8 pH Profile of B-6, and B-7

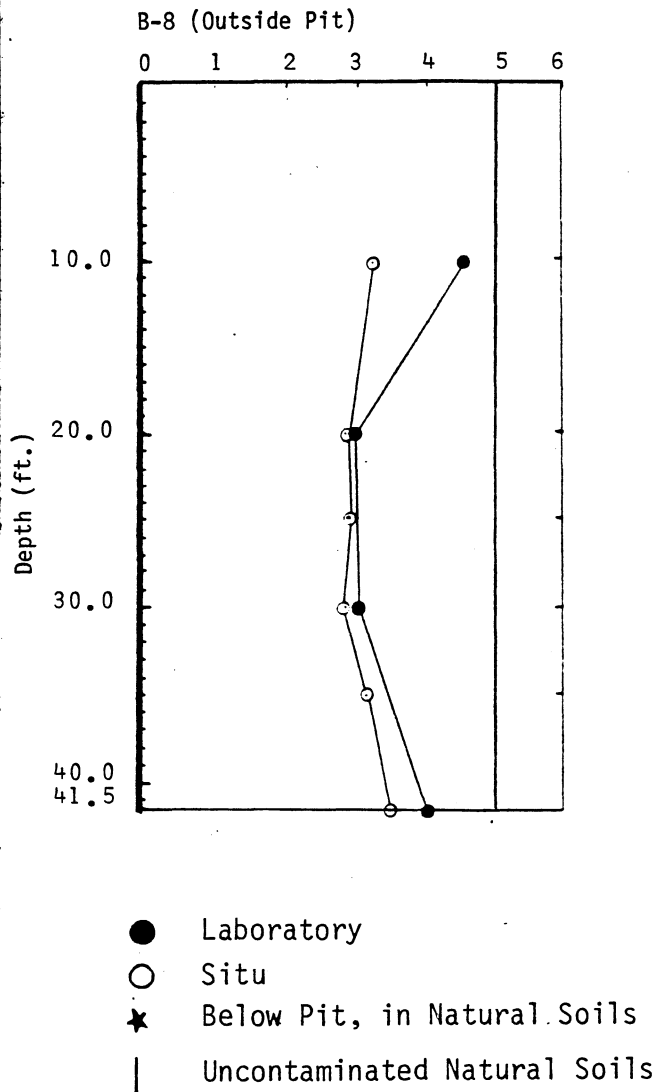


Figure 5.9 pH Profile of B-8

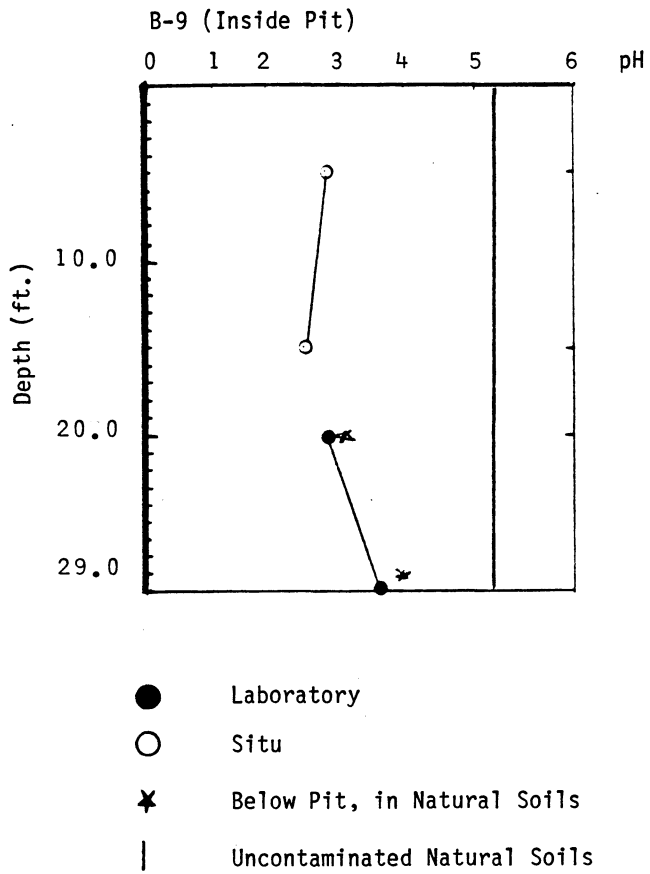


Figure 5.10 pH Profile of B-9

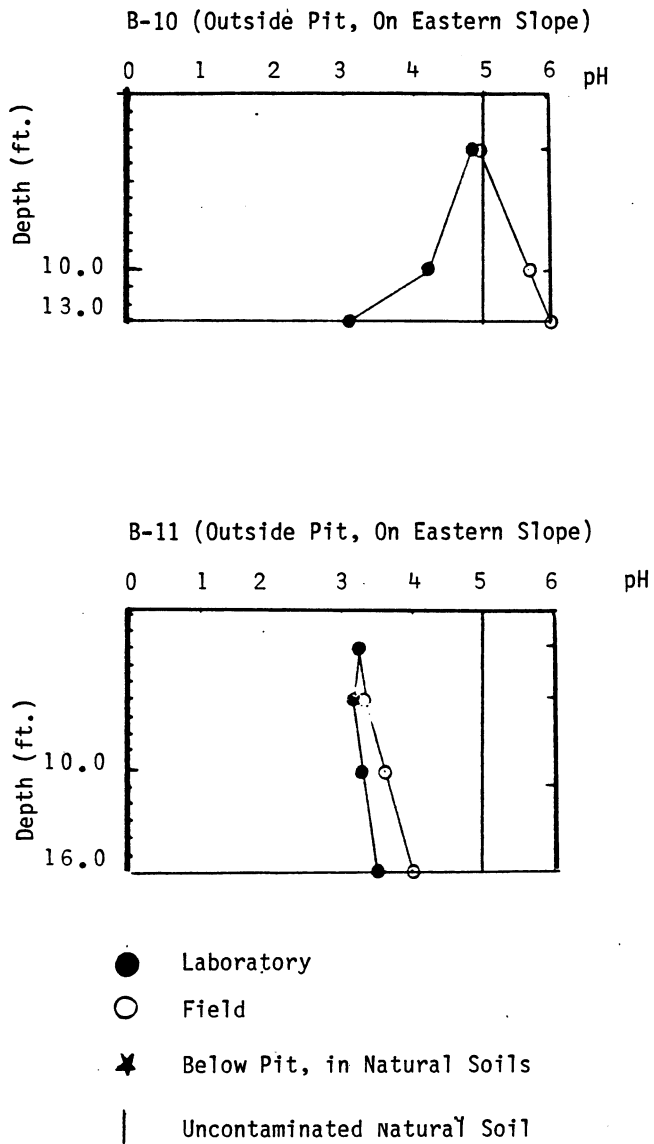


Figure 5.11 pH Profile of B-10, and B-11

5. Borings B-10 and B-11: Located on the eastern hillslope in the old storage area, the pH results for these holes were somewhat contradictory. However, there is a definite trend showing values for pH below those for natural soil in the area.

The pH data from the boreholes allow a number of conclusions to be drawn. First, as expected, the contaminated waste materials in the pit area have a very low pH, typically in the range of 2 to 3, with values closer to 2 indicating the presence of a higher percentage of copperas. Keeping in mind that a pH of 5 is apparently representative of the natural soil which is not contaminated, the relative position of the pH between 2 and 5 provides an indication of level of contamination of the soil. Using this as a basis, the following interpretations may be made:

1. Because of the trend of the contaminated groundwater flow to the south and southeast, the soils on the north side of the site are not heavily contaminated. pH values on the north side of the site in natural soil are high since the pH values were between 5 and 6 at a depth of 13 feet in B-4. This is true in spite of definite leachate contamination near the surface on the north side.
2. Moderate contamination exists in the natural soils in areas in the central or southerly regions of the pit site. Measurements in borings B-1 and B-8 illustrate this effect with pH levels generally between 3 and 4. Also natural soils directly below the pit exhibited a similar level of

contamination. This evidence suggests that there is leachate seepage from the pit into the lower and surrounding soils. Perhaps this is not surprising given that the trenches and borings rarely exposed what could be identified as an intact clay liner. The leachate seepage apparently moves with the groundwater flow to the south and southeast and eventually into the Piney River. Analysis of the well contamination data by the environmental group of Virginia Tech supports this conclusion.

3. The rather heavy degree of contamination in boring B-5 to a depth of 60 feet (pH = 3) in the old lagoon area has significant consequences. This contamination is more severe than that in the natural soils near the disposal pit, and presumably is due to the past storage of fluid wastes in the old lagoon and the present condition of copperas in the upper 10 ft. The problems in this area may also be accentuated by the contaminated groundwater flow from the pit. Regardless of the cause, the contamination in the old lagoon area is strong and has affected the entire depth of the soil profile.

In summary, the pH measurements support the basic findings that:

- (a) the liner is not preventing leachate seepage from the pit; (b) leachate seepage has contaminated the natural soils below and around the pit, particularly following the south-southeasterly flow of the groundwater; and (c) the natural soils below the old lagoon area have been heavily contaminated for the full depth of the soil profile. No evidence to contradict these statements was found in any of the hand augered holes.

CHAPTER VI. RESULTS OF LABORATORY TESTING PROGRAM

As noted in Chapter IV, the laboratory testing program was designed to allow classification of the soils, components determination, and assessment of key engineering parameters. For convenience, key parameters from the laboratory test results are tabulated in Table 6.1. The results are discussed in the following sections of this chapter.

6.1 SOIL CLASSIFICATION

Samples for classification from the Piney River disposal site were collected, examined, stored in sealed plastic bags or glass jars or shelby tubes, and transported by automobile to the soils laboratory at Virginia Tech. There were 4 bulk samples, 8 undisturbed shelby tube samples, and a large number of disturbed samples obtained by the split spoon.

Each sample was examined as the soils were obtained. The samples were identified and described according to the ASTM D-2488 standards [2] where possible, and assigned a preliminary classification in the Unified Soil Classification System.

It is to be noted that several of the samples collected were mixed with copperas, or had been contaminated with effluent from the copperas. Classification by the standard Unified System was used in all cases. In some instances this involved judgement on the part of the investigator.

Table 6.1 SOIL LABORATORY TEST RESULTS

SAMPLE I.D.	SAMPLE - DESCRIPTION	% NATURAL WATER CONTENT	IN-SITU DRY-DENSITY PCF	ATTERBERG LIMITS			MAXIMUM DRY DENSITY PCF	CONPACTION % OPTIMUM MOISTURE	pH	COEFFICIENT OF PERMEABILITY CM/SEC	PERCENT FINES	REMARKS
				LL	PL	PI						
Bulk-1 (2')	Red clay, trace fine sand (CH) uncontaminated	23	---	53	20	33	108.3	19.5	4.92	1.9×10^{-8}	86	This sample was obtained from the borrow area 2' below the ground surface
Bulk-2	Red and white silty clay, little to some fine to coarse sand (CL) uncontaminated	34	---	45	27	18	106.0	20.0	5.00	---	74	This sample was obtained from the borrow area 10 to 15' below the ground surface
Jar-1 (0-2')	Reddish brown silty clay, little fine to coarse sand (CL) Contaminated	32	---	43	24	19	---	---	2.63	---	77	This sample was obtained from the top of the new storage pit
Jar -2 (0-2')	Reddish brown clay, little fine sand mixed with leachate	37	---	37	33	4	---	---	2.19	---	91	This sample was obtained from a pool of leachate. Atterberg limits do not correlate with the apparent nature of the sample.
B-2 (8'-10')	Reddish brown silty clay, some fine to coarse sand, with some pockets of Copperas (CL)	45	81	33	20	13	---	---	2.14	1.1×10^{-4}	64	After permeability tests about 40% of the sample had dissolved away
B-3 (8'-8.5')	Reddish brown silty clay, some fine to coarse sand, little Copperas and some organic material (CL)	38	74	37	25	12	---	---	2.21	1.2×10^{-2}	71	This sample was from the layer just below the disposed waste. Permeability was very high.
B-2 (17'-19')	Light gray silty, fine to coarse sand, with weathered rock fragments (SM)	30	92	--	--	--	---	---	2.49	3.7×10^{-5}	75	This sample was predominantly weathered Aplite and showed some contamination.
B-3 (2'-4')	Yellow Copperas, little reddish brown silty clay, very moist	40	72	N	-	P	---	---	2.79	1.2×10^{-3}	---	Almost 90% of the tube was Copperas. Solubility of Copperas was confirmed.
B-3 (8.5'-10.5')	Reddish brown clay, some fine to coarse sand, some Copperas pockets and organic material, very moist	40	97	40	27	13	---	---	2.65	5.1×10^{-7} 1.2×10^{-6}	61	Two permeability tests were performed on this undisturbed sample. Swelling was observed in both tests.
B-6 (8'-10')	Reddish brown clay, some fine to coarse sand, little Copperas with organic material, wet	42	62	43	31	12	---	---	2.51	3.4×10^{-4}	28	This sample was obtained from the old storage area. The Atterberg limits do not correlate with the apparent nature of the sample
B-7 (9'-11')	Reddish brown clay, little fine to coarse sand, little Copperas pockets with organic material, wet (CL)	45	84	36	25	11	---	---	2.40	3.2×10^{-4}	86	This sample had noticeable amount of organic material with a strong odor.
B-7 (12'-14')	Red and white silt, some fine to coarse sand, very moist - contaminated	40	78	N	-	P	---	---	2.69	1.5×10^{-5}	83	There was no clay liner between this sample and the waste material above this.

It should be noted that whenever soil classification symbols such as CH or ML or any other coding appears in this paper such codings are based on field identification alone. The following sections detail the tests as they were conducted.

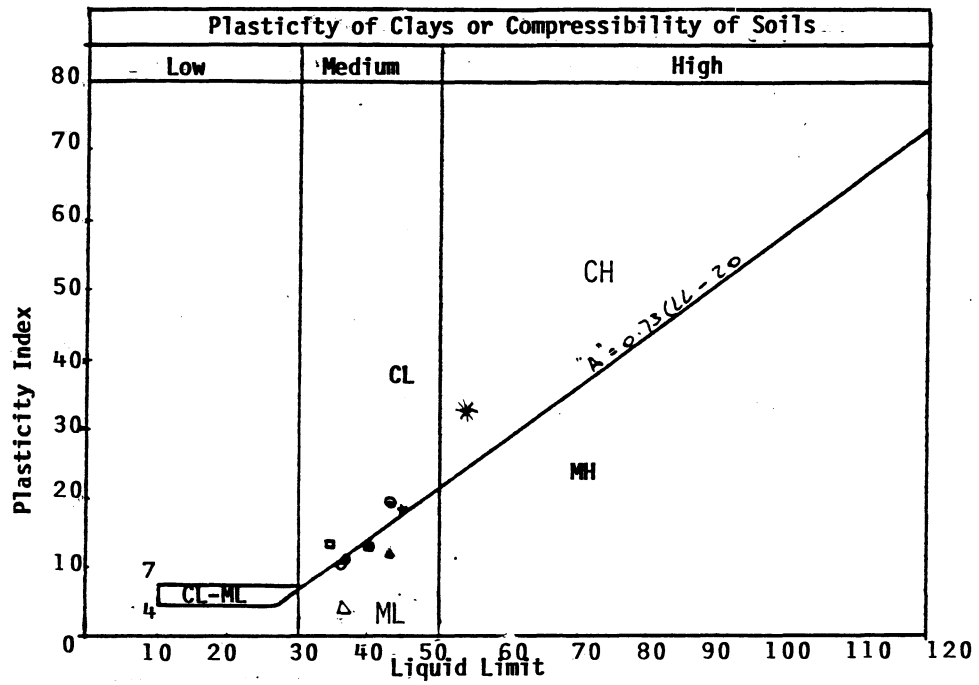
6.2 ATTERBERG LIMITS

6.2.1 TESTS AND RESULTS

Atterberg limits of the samples were performed in accordance with standard procedures. Eleven samples were chosen as being representative of the range of soils appearing at the site, and limits were determined for all of them. The results of tests are plotted on the plasticity chart in Figure 6.1.

Two samples from this group are shown in Table 6.1 as being non-plastic. Sample B-3 (2'-4') appeared to be almost pure copperas; copperas is certainly not an ordinary soil, and was found to behave as a gritty, granular, non-adhesive material. The other non-plastic sample, B-7 (12'-14'), was composed of mostly granular material derived from weathered native bedrock. The most plastic material was the natural specimen of red clay obtained from the borrow pit area. It classifies as a CH or highly plastic clay.

The plasticity results show that the plasticity indices (PI) of the contaminated samples were consistently low when compared with those of similar soils which were uncontaminated. For example, samples Bulk-1 (2') and Jar-2 (0'-½') were very similar visually, but sample Jar-2 (0'-½') was taken from the bottom of a pool of leachate while



⊙ Jar-1 (0-2')

△ B-3 (8½'-10½')

□ Jar-2 (0-½')

○ B-6 (8'-10')

+ Bulk-1 (2')

* Bulk-2 (10')

▲ B-3 (8'-8½')

■ B-7 (9'-11')

● B-2 (8'-10')

Figure 6.1 Results of Atterberg Limit Tests

sample Bulk-1 (2') was not contaminated. The plasticity chart shows the uncontaminated soil to have a markedly higher PI than does the acid contaminated sample.

Previous studies by Krebs, Thomas, and Moore [16] investigated the effects of acids on the Cecil soil series which is the same soil found at the Piney River site. Soils in the Cecil soil series have predominantly kaolinitic clay minerals. Krebs et al. found that exposing Cecil clays to acid resulted in a reduction of the negative charge on the kaolinitic mineral fragments. This drastically alters the physical properties of the soil and is, perhaps, most significantly reflected by the Atterberg limits.

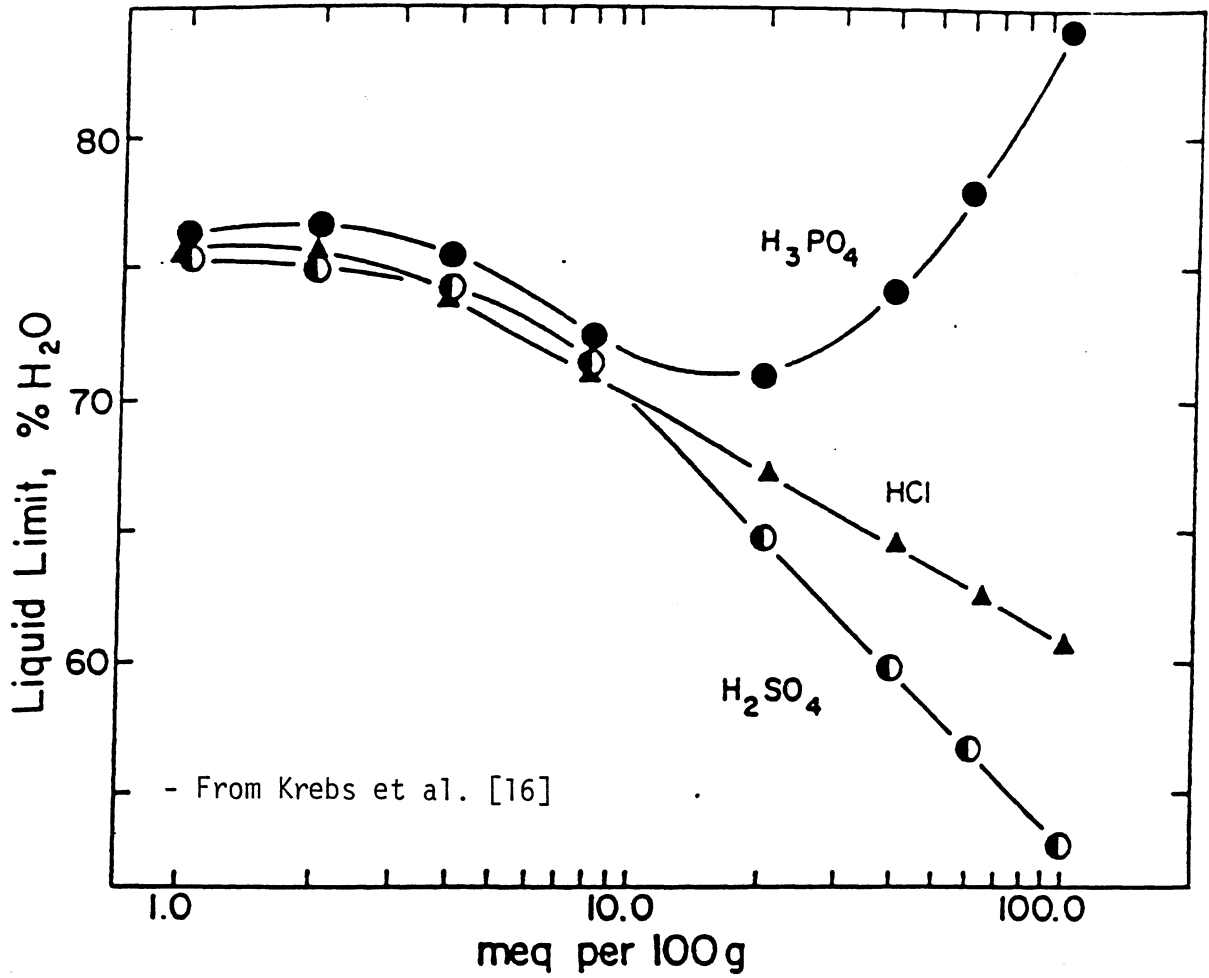
Figure 6.2 from Krebs et al. [16] shows that sulfuric acid reduces the liquid limit or plasticity of the Cecil soil more than any other acid tested. Also they note:

The effect of the additional anions seems to be that of encouraging a degree of dispersion, although the suspensions become highly viscous. Evidentially in this latter condition, either because of some unique structure or because of its virtual "chargelessness", the clay is unable to hold as much water as in its natural condition.

These findings support the data of this investigation in that the presence of acidic copperas or leachate from copperas reduces the plasticity of the clays at the Piney River site.

6.3 PARTICLE SIZE ANALYSIS

A series of tests were conducted to determine the percentage by weight of particles finer than the No. 200 sieve for the soils at this site. The group of samples contained no significant sizes larger than



—Liquid limit (percent H₂O) of Cecil soil after additions of H

Figure 6.2 Effect of Anions on Cecil Soil (kaolinite)

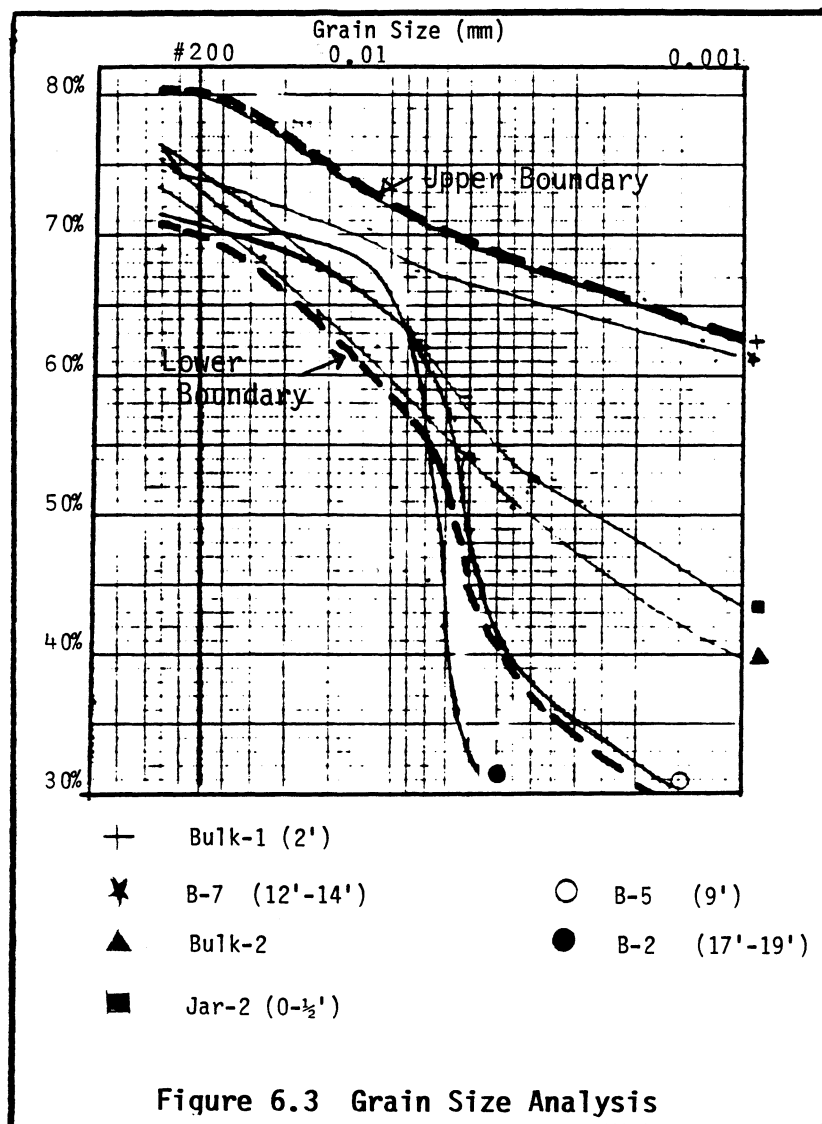
the No. 200 sieve size. Particles with sizes greater than the No. 200 sieve were observed more frequently in the deeper soil beneath the new storage pit. Thus the particle size analysis was conducted using only the hydrometer test. The results are shown in Figure 6.3.

A number of problems occurred in conducting these tests. Many of the samples had to be tested a number of times before a successful run could be obtained. Some of the samples were highly acidic, and difficulties with rapid flocculation occurred. Attempts were made to prevent flocculation by adding more dispersing agent (calgon) and samples were fluxed with distilled water in attempts to wash out the contamination. These attempts were successful in the selected six samples. Figure 6.3 shows the results of the particle size analysis.

6.4 IN SITU MOISTURE CONTENT

Moisture contents were measured using standard procedures whereby the soils were dried in an oven at 105° C for 24 hours. The results showed that the soils from the pit or immediately below it exhibited high moisture contents. The values were essentially equal to the liquid limits of the samples.

It is of interest to note that samples contaminated with copperas appeared to retain moisture. For example, one bulk sample contaminated with copperas continued to appear to be very wet in the laboratory even though it was open and exposed to air for 10 days or more at ambient laboratory temperatures and humidities.



6.5 IN SITU DENSITY

Determination of the in situ density of the materials found at the Piney River site is necessary for their description and for the understanding of the conditions existing there. Undisturbed samples in the Shelby tubes were utilized for this purpose. Lengths of tubing were cut and weighed. The sample was extruded and the section of tubing was measured. The sample was then weighed in its in situ water content condition, dried to constant weight at 105° C to 110° C in an oven, and then weighed dry. These measurements permitted calculation of the in situ density. The dry unit weights are reported in Table 6.1.

The densities of all the samples are low. This apparently reflects the fact that all of the soils and the copperas were very wet when placed in the pit, ruling out the possibility of effective compaction.

6.6 STANDARD PROCTOR COMPACTION TEST

Standard Proctor compaction tests were conducted only on uncontaminated bulk samples. It was expected that this would characterize the soils that were probably used as liner and cover material at the time of construction of the new burial pit. Two tests were run using the standard Proctor compaction procedure (ASTM D-698). The results of these tests are shown in Figure 6.4 and 6.5.

No unusual difficulties were encountered in running these tests. Sample bulk-1, the red clay, compacted into very firm, stiff layers. The maximum dry density was 108.3 pcf and the optimum moisture content was about 20%. The mottled sample which had a lower plasticity,

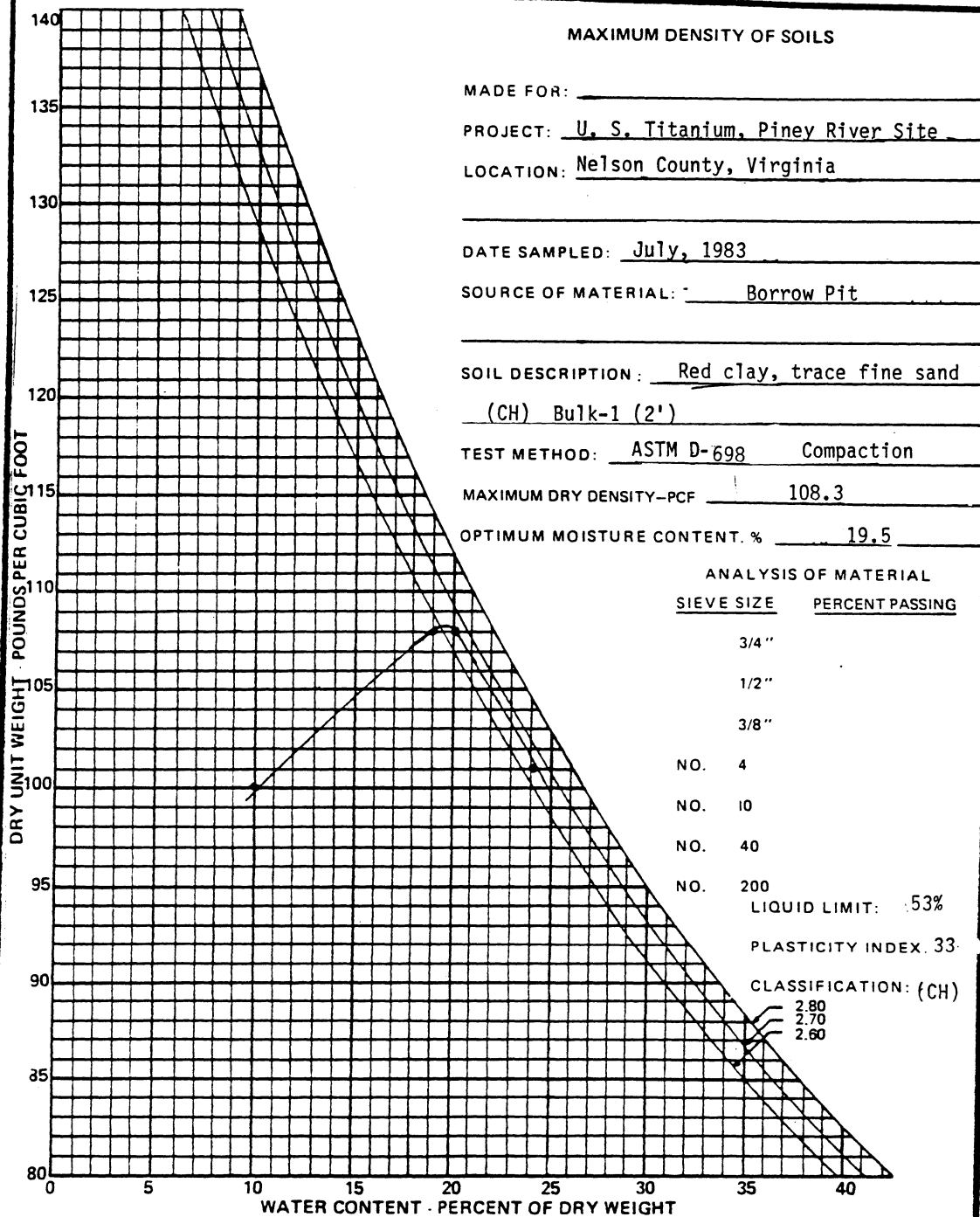


Figure 6.4 Compaction Curve for Bulk-1 (2')

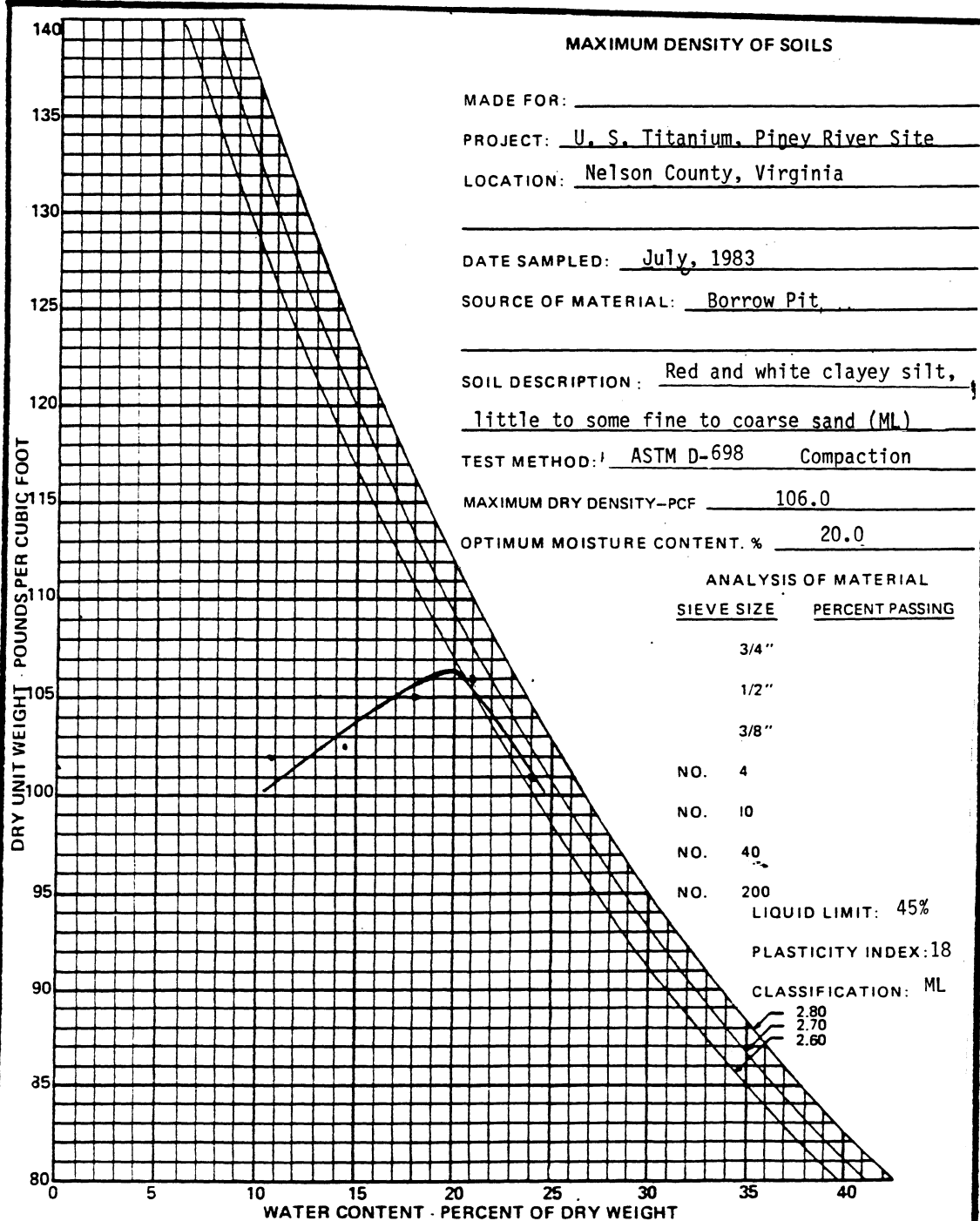


Figure 6.5 Compaction Curve for Bulk-2 (10')

bulk-2, had a maximum dry density of 106.0 pcf and an optimum moisture content of 20%. It is notable that the water contents of the soils in the pit are almost twice the optimum values. This supports the supposition that they have not been well compacted and thus have a low density.

6.7 PERMEABILITY

Table 6.2 is a summary of values of permeability, pH of effluent, in situ water content, in situ density, and heavy metal concentrations in the effluent from the permeability tests.

6.7.1 TEST RESULTS

The overall purpose of solid waste disposal in a landfill is containment of the waste so that it is removed from the environment. One of the most important factors is the rate at which fluid can migrate through the landfill. This rate is referred to as the coefficient of permeability or the hydraulic conductivity at the site.

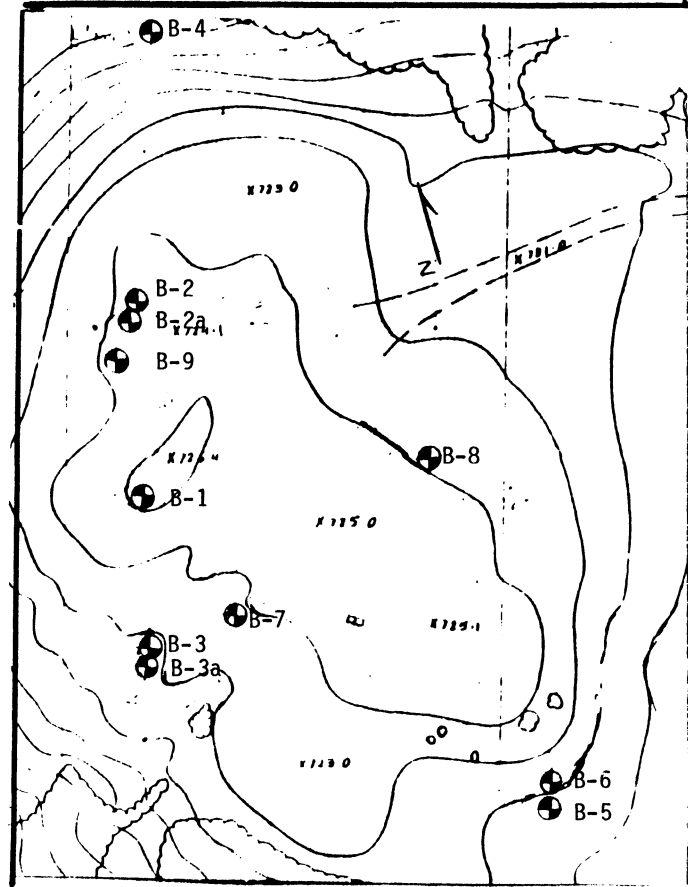
Samples were tested as they were obtained. Only vertical coefficients of permeability were evaluated. All of the tests were performed by percolation of distilled water except in one case where the contaminating leachate was used. Values of the permeability for the individual samples are reported in Table 6.3. Note that these values apply only to the samples themselves; the complexity of the landfill prohibits extrapolation of these values to the entire landfill.

Table 6.2 PERMEABILITY

SAMPLE I.D.	SAMPLE - DESCRIPTION	COEFFICIENT of PERMEABILITY cm/sec	pH of EFFLUENT	NATURAL WATER-CONTENT %	IN-SITU DENSITY PCF	REMARKS	Al	Zn	Cd	Fe	Mn	Cu	Ni	Cr	Pb	As	So ₄ ⁻	TOTAL SOLIDS
							mg/lit	mg/lit	mg/lit	mg/lit	mg/lit	mg/lit	mg/lit	mg/lit	mg/lit	mg/lit	mg/lit	mg/lit
Bulk - 1 (2')	Red clay, trace fine sand (CH) Uncontaminated	1.9×10^{-8}	---	23	101.3	The permeability test was performed on a sample compacted 95% of its maximum dry density.	---	---	---	---	---	---	---	---	---	---	---	---
B-3 (8.5' - 10.5')	Reddish brown clay, some fine to coarse sand, some copperas pockets and organic material, very moist	5.7×10^{-7}	---	38	96.8	Swelling of about .4 cm. was observed in the permeameter.	---	---	---	---	---	---	---	---	---	---	---	---
B-3 (8.5' - 10.5')	Reddish brown clay, some fine to coarse sand, some copperas pockets and organic material very moist	1.2×10^{-6}	---	40	96.8	Swelling of about .3 cm. was observed in the permeameter.	---	---	---	---	---	---	---	---	---	---	---	---
B-7 (12'-14')	Red and white silt, some fine to coarse sand, very moist - contaminated	1.5×10^{-5}	2.64	40	77.7	The effluent from this sample showed very little discoloration.		12.4	<0.01	30300	122	.62	1.70	.46	<0.1		58000	102.11
B-2 (17'-19')	Light gray silty, fine to coarse sand, with weathered rock fragments (SM)	3.7×10^{-5}	2.70	30	91.6	This sample contained natural soils from beneath the liner at the center of the new storage pit.		25.6	<0.01	65000	502	1.00	5.6	.30	<0.1		25200	307.7
B-2 (8'-10')	Reddish brown silty clay, some fine to coarse sand, with some pockets of copperas (CL)	1.1×10^{-4}	2.35	45	81.1	After the permeability test 40% of the sample had dissolved away.		23.8	<0.01	81300	500	.32	2.06	.27	<0.1		10000	167.53
B-7 (9'-11')	Reddish brown clay, little fine to coarse sand, little copperas pockets, with some organic material, wet (CL)	3.2×10^{-4}	2.41	45	83.6	This sample had organic material with a strong odor.	2390	10.2	0.14	21000	294	2.56	3.04	1.02	<0.1		14000	27.14
B-6 (8'-10')	Reddish brown clay, some fine to coarse sand, with organic material, little copperas, wet	3.4×10^{-4}	2.35	42	61.7	This sample was obtained from an area where the old lagoon was located.		5.36	<0.01	9690	52	.57	.62	.09	<0.1		11000	23.26
B-3 (2'-4')	Yellow copperas, little reddish brown silty clay, very moist	1.2×10^{-3}	2.06	40	71.7	This sample contained almost nothing but Copperas. At the end of the permeability test 80% of the sample had dissolved												
B-3 (8'-8.5')	Reddish brown silty clay, some fine to coarse sand, little copperas and some organic material (CL)	1.2×10^{-2}	3.00	40	73.8	This sample was from the layer above Copperas and showed the highest permeability	2930	20.6	0.07	21000	294	2.56	3.04	1.02	<0.1		58000	87.53

Table 6.3 Coefficients of Permeability

Sample ID	Coefficient of Permeability cm/sec
Bulk-1 (2')	1.9×10^{-8}
B-3a ($8\frac{1}{2}'$ - $10\frac{1}{2}'$)	5.7×10^{-7}
B-3a ($8\frac{1}{2}'$ - $10\frac{1}{2}'$)	1.2×10^{-6}
B-7 (12'-14')	1.5×10^{-5}
B-2a (17'-19')	3.7×10^{-5}
B-2 (8'-10')	1.1×10^{-4}
B-7 (9'-11')	3.2×10^{-4}
B-6 (8'-10')	3.4×10^{-4}
B-3 (2'-4')	1.2×10^{-3}
B-3a (8'- $8\frac{1}{2}'$)	1.2×10^{-2}
Bulk-1 (2')	1.2×10^{-8}



6.7.2 DISCUSSION OF RESULTS

The permeability tests on the contaminated soils produced some very interesting phenomena. First, however, it is useful to consider the results of a test on the uncontaminated material. In this case the red clay sample from the borrow pit was compacted to 95% of the dry density obtained as the maximum from the Proctor test. The moisture content used was 19.5%, the same as the optimum value found in the Proctor test. These conditions are representative of those which could be readily achieved by good compaction practice in the field. The permeability in this case was found to be 1.9×10^{-8} cm/sec, a value consistent with what would be expected for such a plastic clay. This is representative of an "impervious" material.

Tests on the contaminated soils gave widely varying permeabilities. Samples with high copperas contents have the highest permeabilities. Copperas dissolved during the tests. For example, the sample from B-3 (2'-4') was almost pure copperas. Because it was disturbed during sampling (the tube had to be driven in), the copperas was recompactd using a standard Proctor procedure. The permeability of the recompactd sample was a very high 1.2×10^{-3} cm/sec. Perhaps more importantly, as the water passed through the specimen over 75% of it dissolved. The effluent became highly discolored and showed a very high metals content as is shown in Table 6.2.

Samples B-2 (8'-10') and B-3a (8'-8½') also contained a considerable amount of copperas. They both yielded high permeabilities of 1.1×10^{-4} and 1.2×10^{-2} cm/sec respectively. They also both partially

dissolved during the tests, losing approximately 30% of their original volumes.

The two tests on portions of sample B-3a (8'-10') also produced interesting results. This sample had a high organic content and exhibited a foul odor. During the course of the tests these samples swelled some 3% to 4%. Upon cutting into the soils after the test, voids were found. It seems likely gas bubbles were formed as a result of the organic matter and these caused the swelling.

The tests on the other contaminated samples yielded permeabilities in the 10^{-4} to 10^{-6} cm/sec range. Evidence for dissolution was not obvious in these cases, but the effluent exhibited a high metals content which requires some solution.

The remaining permeability test was designed to allow an uncontaminated soil sample of red clay to be subjected to a heavily contaminated leachate. The dark red leachate was collected from a seepage source at the site. The soil was the red clay from the borrow pit and it was compacted to 95% of the maximum Proctor value at 19.8% moisture content. This test was carried out over an 11-week period. The permeability of the soil appeared to be low, with a value calculated at 1.2×10^{-8} cm/sec. This is similar to that obtained for the test with distilled water. However, it is notable that after about 7 to 8 weeks, small horizontal cracks appeared in the soil. Apparently they did not affect the vertical permeability because the cracks were horizontal. However, it is clear they would have a drastic effect on horizontal permeability. It raises a serious question in regard to the basic stability of the clay in the presence of the leachate.

6.7.3 EFFLUENT ANALYSIS

The effluents from the permeability tests were monitored closely. In all tests with distilled water, with the exception of the one performed on the uncontaminated soil, the effluent was discolored and exhibited low pH values. Most of the effluents were chemically analyzed, and in each case they showed high amounts of heavy metals and sulfates. In some cases the amount of leachate was not enough to be tested. The results are given in Table 6.2.

6.8 WATER SOLUBILITY POTENTIAL

The permeability tests exhibited the potential for copperas to dissolve in water. This property of copperas was first noticed when a permeability test was run on sample B-3 (2'-4') which is almost all copperas, and over 75% of the sample dissolved during the test. When the permeability test was performed on sample B-2 (8'-10') it was noticed that this sample contained pockets of copperas. At the conclusion of the test about 30% by volume of the sample had dissolved away. Tests on the effluent from copperas-contaminated samples demonstrated that the percolating water became acidic and, in addition, contained significant amounts of heavy metals.

The water solubility potential for a copperas-clay mixture was further demonstrated through a simple test. A sample of soil was selected from one of the trenches at the site. A visual examination showed it to be mixed with copperas. The dry weight of the solids was determined. The sample was then washed in distilled water by placing the soil-water suspension in a 1,000 ml sedimentation chamber and

permitting the suspension to remain overnight. Again the dry weight was determined. It was found that about 40% of the soil solids had been decanted in the liquid phase of the suspension.

6.9 X-RAY DIFFRACTION ANALYSIS

Four samples of the soils, both contaminated and uncontaminated, were processed to recover the clay fraction for x-ray diffraction analysis by the Department of Agronomy at Virginia Tech. Diffractograms were generated and the results were submitted [25]. This information is included in Appendix II. Table 6.4 shows the interpretative summary for two of the samples considered typical of the materials at the site, one is contaminated with leachate and the other is uncontaminated. Since the two samples were thought to be of the same geologic origin, the B horizon of well-drained soil derived from pegmatitic anorthosite, some of the differences in their mineralogical makeup may be a result of aluminum removal by acidic leachate. Much of it, however, can be expected to occur as a result of normal variation from sample to sample. In either case, the clay is clearly mainly kaolinite.

6.10 CONSOLIDATION CHARACTERISTICS

The field inspection reports for the Piney River disposal site disclosed considerable settlement distress as demonstrated by the cracking, sinkholes, and depressions that were reported in Chapters III and IV. Without laboratory tests on the materials at the site a first impression was that the contents of the landfill were consolidating. Consolidation tests were included in the overall investigative

Table 6.4 X-Ray Diffraction Analysis

<u>Constituents</u>	<u>Red Clay Bulk-1 (2') Uncontaminated</u>	<u>Red Clay Jar-2 (0-$\frac{1}{2}$') Contaminated</u>
Kaolinite	68%	71%
Quartz	10	TRACE
Mica	5	4
Chloritized Vermiculite	10	5
Montmorillonite	7	20
Gibbsite	TRACE	NONE

plan. However, conducting consolidation tests on soluble material is, to say the least, fraught with difficulties and proved essentially impossible.

Two consolidation tests were attempted with little success. The samples are from two different boreholes but each sample contained considerable copperas. Other than using acid resistant materials for the consolidometer the procedures specified by ASTM D-2435 were followed. Both samples showed solution activity during the run of the test, thus invalidating normal test procedure. The only conclusion which can be made from the results is that the soils did show a rapid response to the loading; this supports the idea that these materials are relatively pervious.

CHAPTER VII. DISCUSSION OF RESULTS

The present burial pit at Piney River occupies an area of about five acres immediately west of the old lagoon as is shown in Figure 2.1. The storage area is about three years old, as of now.

The cover of the disposal pit area has obvious features such as cracks, sinkholes, and depressions. Small cracks are very frequent, but some of the cracks are 6 inches wide and run for yards. The top of the new landfill is dimpled with a number of sinkholes between two and four feet in diameter. At the time of the field work there was also a series of saucer-shaped depressions in the top of the clay cover. These depressions were from one to four feet lower than the surrounding fill surface. Conversations with local contractors and other people familiar with the site revealed that some depressions in the top of the landfill were observed soon after the new landfill was completed. One report noted that depressions of 6 feet in depth had to be filled. Based on a description of this area it would appear that the location had settled an additional four feet, making a total of 10 feet of settlement in about three years. The few months which elapsed during the course of this study brought about additional cracks and deepened existing depressions. As a result of all of this extensive localized subsidence, the top of the landfill no longer is properly sloped to direct the surface water away from the fill. On the contrary, the sunken spots tend to direct flow into the fill and thus the subsidence may feed upon itself.

The results of this investigation allow one to make interesting postulations of the reasons for the problems which have developed in the disposal pit area. Key pieces of information are as follows:

1. The basic design of the pit did not emphasize back-up support systems. No leachate collection systems or impervious fabric layers were utilized.
2. No records are available to this investigator indicating that control tests were performed to evaluate susceptibility of the clay liners to the influence of the waste. Also no compaction tests were reported which would indicate that known standards could be applied in compaction control.
3. No records are available indicating that careful engineering control was exercised as to waste placement, liner placement, and liner thickness.
4. The boring logs suggest that a liner may not be in place in a number of areas in the pit.
5. Groundwater contamination is indicated in areas near and beneath the pit suggesting that leachate is seeping from the pit and moving with the groundwater.
6. The copperas is readily soluble in water. Laboratory tests show it dissolves rapidly under a modest seepage gradient.
7. Sinkholes, depressions, and cracks seem to grow steadily once such a feature appears at the surface.
8. Sinkholes, depressions, and cracks in the clay cap serve as conduits of surface water into the underlying wastes.

9. The permeability of the copperas and heavily copperas contaminated soils is very high relative to the natural soils, making the waste deposit itself a likely conduit for groundwater.
10. In spite of loss of leachate through numerous seeps out of the pit, the waste materials remain in a very wet state and a high fluid level is found inside the pit relative to that outside the pit.

The major factors which appear to be contributing to the failure of the pit are the inability of what there is of a clay liner to retain the leachate, the lack of any backup system to assist in leachate control, and the dissolution of the copperas as the water-leachate fluid flows downward and laterally. Most of the fluid flow is probably lateral since the copperas itself can serve as a conduit, and intermittent less contaminated wet clay layers likely serve as vertical aquicludes. With the dissolution of the copperas, the clay cover would exhibit cracking or depressions due to the nonuniform copperas removal process. These features then serve to collect surface water and allow the water to enter the waste system, accentuating the dissolution process. Thus, existing cracks and depressions grow steadily and this was observed in the field.

The disposal pit and the nearby remnant copperas waste in the old lagoon area will likely remain as a pollutant source into the future, particularly with the present topography. Surface water is being contaminated in the depressions and cracks of the disposal pit and in the topographic low which is the old lagoon site.

There are no easy solutions to the problems in the disposal pit and the lagoon area. As a minimum the pit should be graded level, covered with an impervious fabric and topped off with a crowned clay cap which is compacted under controlled engineering supervision. Similar treatment is needed in the lagoon area. Alternatively a new and appropriately designed pit could be created with suitable leachage controls. This could possibly entail treating the copperas with lime after it is removed and before it is replaced in the new pit. Even this would not guarantee elimination of problems given the propensity for the copperas to dissolve. A regular program of grading and renewing the clay cap may be needed.

CHAPTER VIII. SUMMARY AND CONCLUSIONS

This investigation is directed primarily towards the geotechnical aspects associated with the failure of a recently developed burial pit at the site of the now defunct U. S. Titanium Corporation plant along the Piney River. The site is in Nelson County, Virginia, some 20 miles north of Lynchburg, Virginia.

The pit was designed to retain a waste material known as copperas, which is mainly formed from the compound $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$. This material when combined with water or moisture creates a highly acidic leachate. The copperas had previously been stored on a hillside of an area to the east of the old plant. Wetter residues were held in a lagoon just to the west of the hillside. In 1980 the most concentrated of the copperas wastes were placed in the burial pit which was excavated on the remainder of the hilltop to the west of the lagoon area. Design drawings show the pit was to be about 12 ft. deep and to be lined with a 2 ft. thick liner of compacted red, plastic clay. The clay is a material native to the locality of the site. No back-up leachate containment facilities were included beyond the liner system. Further, no control tests have been found to indicate that the clay liner was ever tested for its behavior in the presence of the leachate. Also, no compaction test records and no evidence of field control exerted during construction are available.

The new disposal pit was constructed in 1980, but in the next several years major signs of distress began to develop. Significant

leachate seeps formed along the downhill slopes below the pit and vegetation was killed in the path of the leachate. Severe settlement was observed in the clay cover of the pit according to local observers. Sinkholes, cracks, and depressions were among the features which developed.

This investigation was undertaken to evaluate the performance of this waste pit after it was filled with copperas. Definition of the mechanism of the pit failure naturally followed. In addition, it seemed appropriate to suggest some remedial actions for future considerations.

The investigation consisted of two primary phases, field and laboratory. The field program consisted of:

1. Site visits.
2. Excavation of three trenches.
3. Drilling of thirteen test borings in and outside of the new burial pit, and about 80 hand augered holes.
4. Sampling of the surface and subsurface materials for a laboratory investigation.
5. On-site measurements of soil pH levels.

The laboratory test program was designed to classify the materials, to define the components of the landfill system, and to determine the engineering parameters of the materials at the disposal site and in the surrounding areas. The tests included:

1. Moisture content
2. Density
3. Grain size distribution

4. Atterberg limits
5. Permeability
6. Permeability effluent measurements
7. Mineralogical evaluation of the clays using X-ray diffraction analysis
8. Consolidation
9. Compaction
10. Solubility potential
11. Acidity level measurement

Disturbed and undisturbed samples were used for the above tests. Modifications in the devices were required because of the acidic nature of the materials involved.

The findings from the field investigation indicate that:

1. The liner is not preventing leachate seepage from the pit.
2. The leachate seepage has contaminated the natural soils below and around the pit, following the generally southerly flow direction of the groundwater.
3. Heavy contamination exists below the old lagoon area all the way to bedrock.

The laboratory tests on uncontaminated and contaminated soils indicate that the pollutant has significant effects on the soil behavior. The acid environment noticeably affected behavior in such tests as Atterberg limits and permeability. High permeability was found for copperas and copperas-contaminated soils. Importantly, the copperas and copperas-contaminated soils showed a significant solubility in the presence of water. The major contributing factor to the existence of

the surface cracks, fissures, and depressions appears to be the dissolution of the waste by groundwater flow.

A complete solution to the soil and groundwater contamination problems at the site is not readily available. Grading of the surface of the site would help by preventing concentration of water in the pit and old lagoon area. Presently the sinkholes and depressions in the pit cover and the topographic low in the lagoon area accentuate problems. The entire burial pit could also be excavated, treated with lime, and re-done with a proper leachate collection system and engineered compacted clay liner and cap. If this action were taken, the pit should be deepened to accommodate the less heavily contaminated soils from the old lagoon area. Even with such substantial modifications, the deep contamination of the subsoils around the pit and the old lagoon would not be affected. Also, problems with dissolution of copperas would continue. A continual program of maintenance of the grading at the site would be needed.

APPENDIX I
TEST BORING LOGS

BORING LOG							
Piney River Storage Area, Nelson County, Virginia							
Boring No	Total Depth		Elevation	Location			
B-1	16.0'		726.4±	See Figure 4.1			
Type of Boring	Started		Completed		Driller		
Hollow Stem Auger	9/6/1983		9/6/1983		---		
Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	Sample Blows	Sample Depth (Feet)	% Core Recovery	Field pH	REMARKS Laboratory pH
726.4±	0.0	Red clay, little fine to coarse sand moist - (CH)				2.51	<u>GROUNDWATER DATA</u>
	7.0	Red silty clay, trace fine sand, slightly moist (CL)		8.0		4.00	3.55
				10.0		3.20	4.55
		Red and white silty clay, with weathered rock, drier than the previous samples					
710.4	16.0			16.0			Dry Upon Completion
		Boring terminated at 16.0'					No copperas was encountered in this hole

BORING LOG							
Piney River Storage Area, Nelson County, Virginia							
Boring No.	Total Depth		Elevation	Location			
B-2	10.0'		724.1±	See Figure 4.1			
Type of Boring	Started		Completed		Driller		
Hollow Stem Auger	9/6/1983		9/6/1983		----		
Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	Sample Blows	Sample Depth (Feet)	Core Recovery	Field pH	Laboratory pH
724.1±	0.0	Red clay, trace fine sand, moist (CH)					
	3.0	Red clay, little fine to medium sand size rock fragments, moist (CH)					
	8.0	Red clay mixed with pockets of copperas		8.0		2.91	2.33
714.1	10.0	Auger Refusal at 10.0'		10.0		Dry Upon Completion	

BORING LOG							
Piney River Storage Area, Nelson County, Virginia							
Boring No.	Total Depth	Elevation	Location		See Figure 4.1		
B-2a	19.0'	724.1±					
Type of Boring	Started	Completed	Driller				
Hollow Stem Auger	9/6/83	9/6/83	-----				
Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	Sample Blows	Sample Depth (Feet)	% Core Recovery	Field pH	Laboratory pH
724.1	0.0	Red clay, trace fine sand, moist- (CH)					
		Red clay, trace fine sand, moist (CH)					
	8.5	Tube was pushed		8.5		2.70	
	10.0	Pockets of copperas mixed with clay reddish brown		10.0		2.68	2.14
	12.0	Tube was pushed		12.0			
	14.0	Tube was pushed, material was too wet, no recovery.		14.0			
	17.0	Red & white clay & rock fragments		17.0		2.27	2.32
		Tube was pushed					
705.1	19.0			19.0		2.58	2.89
		Boring terminated at 19.0'					

BORING LOG							
Piney River Storage Area, Nelson County, Virginia							
Boring No.	Total Depth	Elevation	Location		See Figure 4.1		
Type of Boring	Hollow Stem Auger	Started	9/6/83	Completed	9/6/83	Driller -----	
Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	Sample Blows	Sample Depth (Feet)	% Core Recovery	Field pH	Laboratory pH
721.0	0.0	Pockets of copperas mixed with clay Reddish brown - moist					
	2.0			2.0			
	4.0	Tube was driven		4.0			
		Pockets of copperas mixed with clay, reddish brown - very moist (CL)					
	12.0			12.0		3.26	2.19
		Red & white silty clay, the mater- ial was getting noticeably drier than the previous samples (CL/ML)				2.57	2.12
	16.0			16.0		3.32	2.35
		Boring terminated at 16.0					

BORING LOG							
Piney River Storage Area, Nelson County, Virginia							
Boring No: B-3a		Total Depth: 10.5'		Elevation: 721.0±		Location: See Figure 4.1	
Type of Boring: Hollow Stem Auger		Started: 9/6/1983		Completed: 9/6/1983		Driller: -----	
Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	Sample Blows	Sample Depth (Feet)	Core Recovery	Field pH	REMARKS Laboratory pH
721.0	0.0	Pockets of copperas mixed with clay, reddish brown - wet (CH)					GROUNDWATER DATA Dry Upon Completion
	8.0	Pockets of pure copperas, yellow- moist					3.05
	8.5	*					
	10.5	Tube was pushed		10.5			2.06
710.0	11.0	Boring terminated at 11.0					
		* Tube was pushed					

BORING LOG		Piney River Storage Area, Nelson County, Virginia					
Boring No.	Total Depth	Elevation	Location				
B-4	13.4'	710.0±	See Figure 4.1				
Type of Boring	Started	Completed	Driller				
Hollow Stem Auger	9/7/83	9/7/83	-----				
Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	Sample Blows	Sample Depth (Feet)	% Core Recovery	Field pH	Laboratory REMARKS pH
710.0	0.0	Red & white silty clay, some fine to coarse sand, moist (CL)					
	3.0						
		Mottled clayey silt, weathered rock fragments, moist (ML)	37	4.0		2.87	3.64
			10	5.5		Dry Upon Completion	
			58	8.0		4.58	4.52
			9	9.5			
			162	12.0			
696.6	13.4	Auger refusal at 13.4	50	13.4		6.00	5.07

BORING LOG							
Piney River Storage Area, Nelson County, Virginia							
Boring No: B-5		Total Depth: 60.0'		Elevation 720.0±		Location See Figure 4.1	
Type of Boring: Hollow Stem Auger		Started: 9/7/83		Completed: 9/7/83		Driller: -----	
Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	Sample Blows	Sample Depth (Feet)	% Core Recovery	Field pH	REMARKS Laboratory pH
720.0±	0.0						
700.0	27.0	Red & white silty clay, some fine to coarse sand, with weathered fragments, moist (CL)					GROUNDWATER DATA
			11	4.0		2.56	2.38
			1	5.5			
		Reddish brown clay mixed with little copperas, organic material, decomposed wood, odor, wet (CL)				2.50	
			WOH	8.0			
			1	9.5		2.41	2.36
						2.80	
			2	12.0			
			23	13.5		2.17	2.07
		Grading to the same material with increased rock fragments					
			24	16.0			
			4	17.5		2.40	2.31
			2	20.0		2.87	2.80
			4 6	21.5			
		22	24.0				
		5	25.5		2.90	2.80	
		24	28.0				
		7	29.5		2.90	2.81	

BORING LOG							
Piney River Storage Area, Nelson County, Virginia							
Boring No. B-5 (cont)		Total Depth: 60.0'	Elevation	Location See Figure 4.1			
Type of Boring: Hollow Stem Auger		Started: 9/7/83	Completed: 9/7/83	Driller: -----			
Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	Sample Blows	Sample Depth (Feet)	% Core Recovery	REMARKS	
170.0	50.0	Mottled fine to coarse silty sand trace clay, wet - (SM)	36	40.0		<u>GROUNDWATER DATA</u> 3.54 3.54	
			12	41.5			
				44.0			
			517	45.5			
			17	45.5			
				49.0			
			no sample	*			50.5
				54.0			
			no sample	*			55.0
				59.0			
160.0	60.0	no sample	*	60.0		3.51 3.32	
		. Auger Refusal at 60.0					

BORING LOG							
Piney River Storage Area, Nelson County, Virginia							
Boring No.: B-6		Total Depth: 10.0'		Elevation: 720.0±		Location: See Figure 4.1	
Type of Boring: Hollow Stem Auger		Started: 9/8/83		Completed: 9/8/83		Driller: -----	
Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	Sample Blows	Sample Depth (Feet)	% Core Recovery	Field pH	Laboratory pH
720.0	0.0	Reddish brown clay mixed with little copperas, organic material, decomposed wood, odor - wet (CL/CH)				GROUNDWATER DATA	
						2.73	2.45
	8.0					2.60	2.42
710.0	10.0	Tube was pushed		10.0		3.17	2.71
		Boring terminated at 10.0					

BORING LOG							
Piney River Storage Area, Nelson County, Virginia							
Boring No. B-7		Total Depth: 29.5'	Elevation: 724.0±	Location: See Figure 4.1			
Type of Boring: Hollow Stem Auger		Started: 9/8/83	Completed: 9/8/83	Driller: -----			
Station	Depth	DESCRIPTION OF MATERIALS (Classification)	Sample Blows	Sample Depth (Feet)	% Core Recovery	Field pH	Laboratory pH
724.0	0.0	Red clay, some fine to coarse sand moist - (CH)					
				4.0		5.20	4.03
			11	5.5		3.41	3.59
		Reddish brown clay and copperas, organic material, strong odor - wet (CH)	47	8.0			
	9.5		9	9.5		2.30	WATER TABLE
		Tube was pushed				2.40	
	11.5						
	13.0	Reddish brown clay, copperas - wet (CH)					
	14.5	Tube was pushed					
		Red & white mottled silty clay, with rock fragments & dark color minerals - moist (CL/ML)					
				20.0			
704.0	20.0		59	21.5		4.00	4.41
				28.0			
694.5	29.5	pushed spoon	*	29.5		3.96	3.12
		Boring terminated at 29.5					

BORING LOG		Piney River Storage Area, Nelson County, Virginia						
Boring No.	Total Depth	Elevation	Location					
B-8	41.5'	724.0±	See Figure 4.1					
Type of Boring	Started	Completed	Driller					
Hollow Stem Auger	9/8/83	9/8/83	-----					
Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	Sample Blows	Sample Depth (Feet)	% Core Recovery	Field pH	REMARKS	Laboratory pH
724.0	0.0							
		Red clay, little fine to coarse sand, moist (CH)						
				10.0				
			3	11.5		3.26		4.56
		Red & white silty clay, some fine to coarse sand size rock fragments moist (CL)	5					
				20.0				
704.0	20.0	Grading the the same with lighter color	4	21.5		2.83		2.95
			5					
				30.0		2.97		
			1	31.5		2.82		3.01
			3			3.15		
184.0								
						WATER TABLE		

BORING LOG						
Piney River Storage Area, Nelson County, Virginia						
Boring No. B-8 (cont)		Total Depth:	Elevation	Location		
Type of Boring:	Started	Completed		Driller		
Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	Sample Blows	Sample Depth (Feet)	% Core Recovery	REMARKS
182.5	41.5	Boring terminated at 41.5	41 16	40.0 41.5		3.22 GROUNDWATER DATA 3.78

BORING LOG									
Piney River Storage Area, Nelson County, Virginia									
Boring No.	Total Depth		Elevation		Location				
B-9	29.0		724.1±		See Figure 4.1				
Type of Boring	Started		Completed		Driller				
Hollow Stem Auger	9/8/83		9/8/83		*****				
Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	Sample Blows	Sample Depth (Feet)	% Core Recovery	Field pH	REMARKS	Laboratory pH	
724.1	0.0	Reddish brown clay mixed with copperas, very moist (CA)				2.84			
		Grading to the same with increasing rock fragments				2.68			
704.1	20.0	Light gray fine to coarse silty sand, trace clay - Moist (SM)	5	20.0					
			7	21.5				2.67	
							Dry Upon Completion		
695.1	29.0	Auger Refusal at 29.0		29.0				3.58	

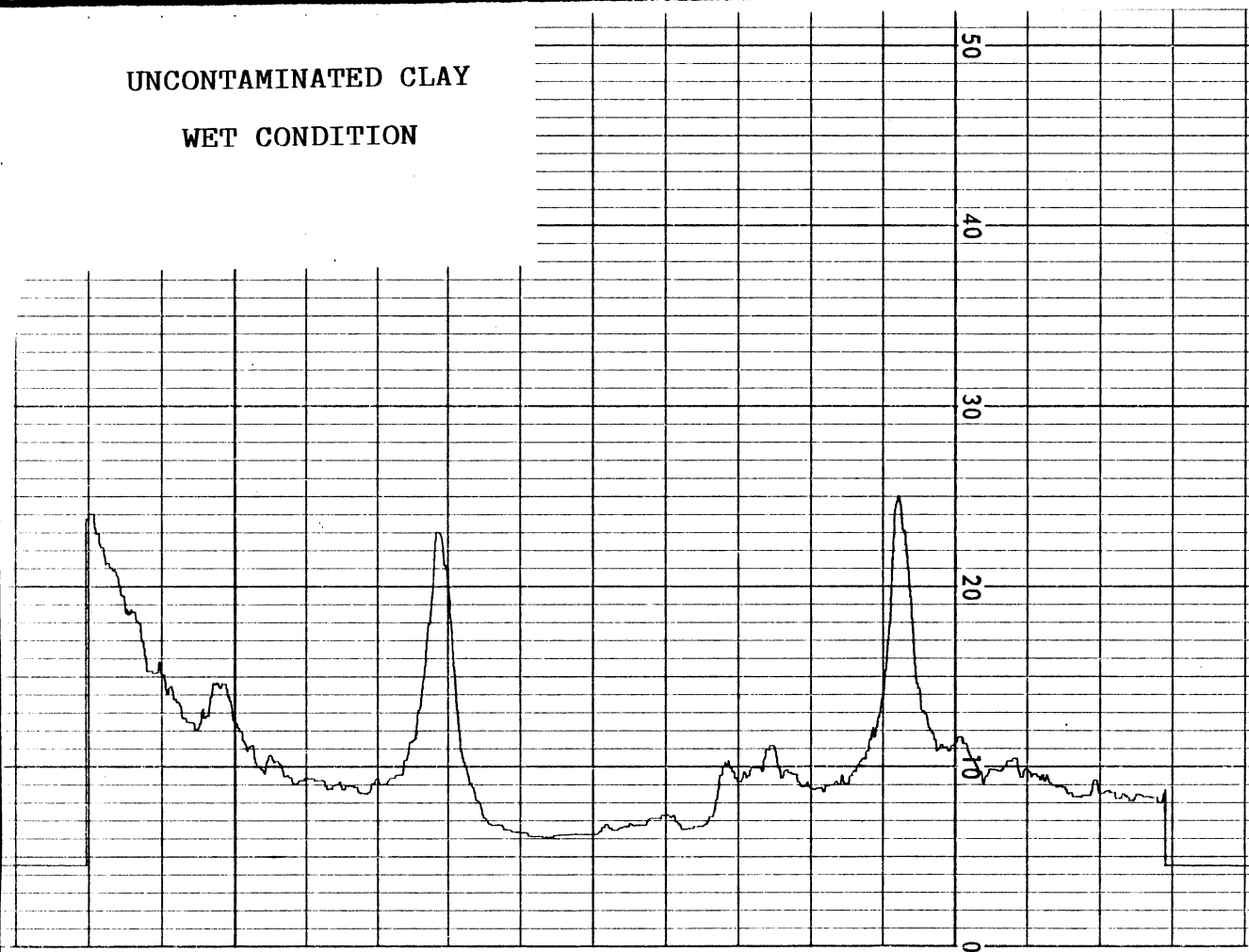
BORING LOG		Piney River Storage Area, Nelson County, Virginia					
Boring No.	B-10	Total Depth	13.0	Elevation	684.0±	Location	See Figure 4.1
Type of Boring	Hollow Stem Auger	Started	9/9/83	Completed	9/9/83	Driller	-----
Elevation	Depth	DESCRIPTION OF MATERIALS (Classification)	Sample Blows	Sample Depth (Feet)	% Core Recovery	Field pH	REMARKS Laboratory pH
684.0	0.0	Red & white silty clay, some fine to coarse sand, with rock fragments (CL)				4.90	4.82
		Grading to the same with increased rock fragments	16 30 35	10.0 11.5 13.0		5.70	4.28
671.0	13.0	Auger Refusal at 13.0'				6.10	3.11

APPENDIX II
X-RAY DIFFRACTION RESULTS

Enclosed are the X-ray diffraction results for uncontaminated clays and contaminated clays from the site. The clays were potassium saturated and tested after heat treatments at room temperatures of 110° C, 300° C and 500° C, the magnesium saturated and glycerol solvated and tested at room temperature and 110° C. They also were tested in the wet condition.

UNCONTAMINATED CLAY

WET CONDITION



OUTPUT FILE: 1

TTL,TTH:

#2,32

SLIT WIDTH? .2

COARSE TIME,RATE: 3,2

CORRECTED SLOPE,SMOOTHING ANGLE: .3,.5

LORENTZ CORRECTION (Y/N)? N

SUMMARIZE INT(P/I)? I

OUTPUT,XOFF: 0,1

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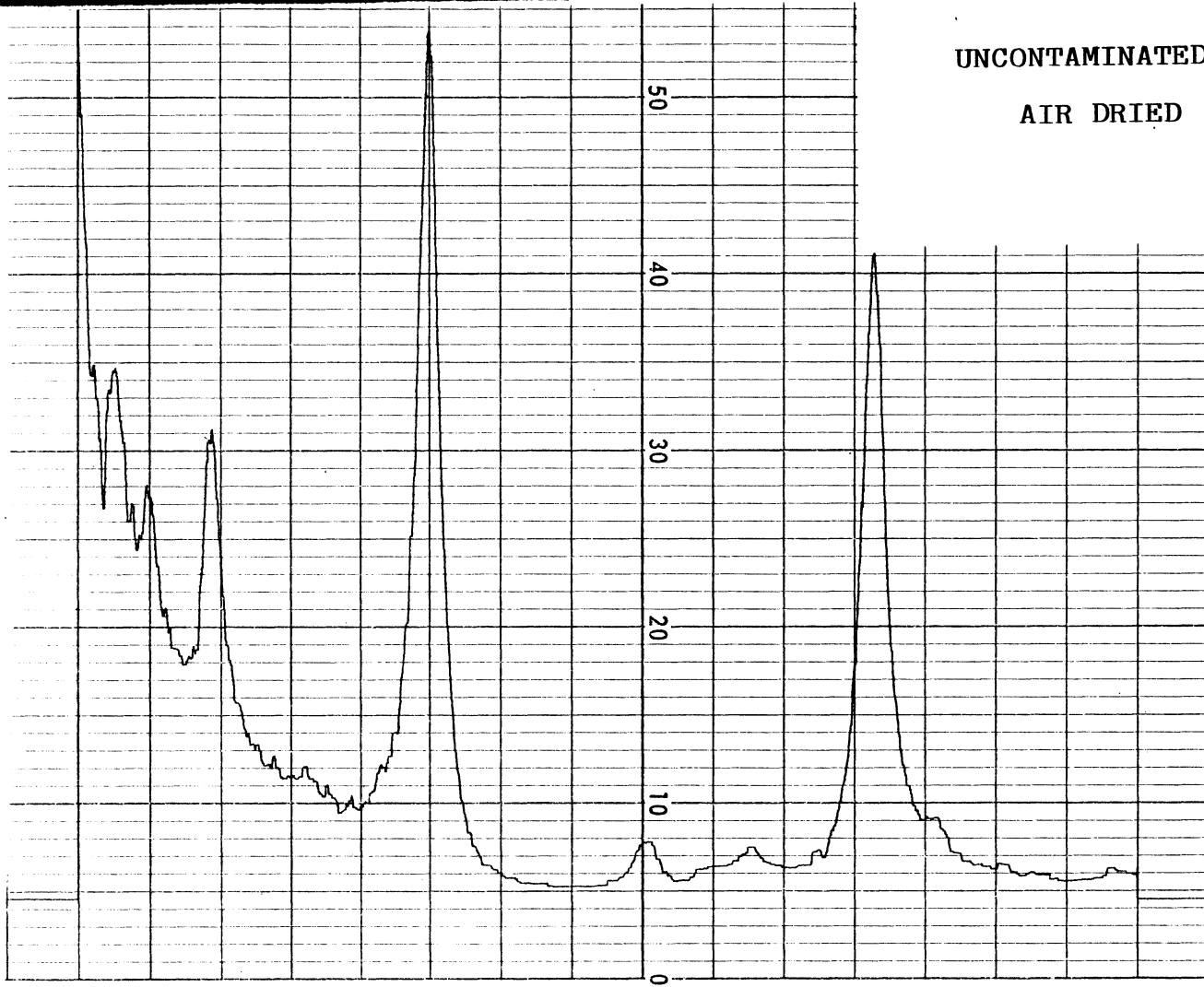
U05-03 28-SEP-83 11:43:21

1	5.740	40.09	5.778	381.74	0.806	1.568
2	11.930	158.06	11.834	1465.00	0.846	4.978
3	19.750	38.88	19.710	229.78	0.571	2.438
4	20.973	50.66	20.805	454.88	1.154	2.874
5	24.626	196.48	24.535	2459.34	0.751	8.265
6	26.294	53.27	26.347	414.26	0.879	2.970
7	27.718	41.69	27.551	390.36	1.124	2.542

U05-03 28-SEP-83 11:45:28

				D-SPACINGS		
RANK	TT PEAK	INTG INT	REL(%)	KA1	KA2	KB1
1	24.626	2459.34	100.00	3.6119	3.6209	3.2641
2	11.930	1465.00	59.57	7.4117	7.4300	6.6980
3	20.973	454.88	18.50	4.2321	4.2426	3.8246
4	26.294	414.26	16.84	3.3865	3.3949	3.0604
5	27.718	390.36	15.87	3.2156	3.2236	2.9060
6	5.740	381.74	15.52	15.3828	15.4209	13.9015
7	19.750	229.78	9.34	4.4914	4.5025	4.0589

UNCONTAMINATED CLAY
AIR DRIED



OUTPUT FILE: 1AIR
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 \$2,32
 SLIT WIDTH? .2
 COARSE TIME,RATE: 3,2
 CORRECTED SLOPE,SMOOTHING ANGLE: .3,.5
 LORENTZ CORRECTION (Y/N)? N
 SUMMARIZE INT(P/I)? I
 OUTPUT,XOFF: 0,1

V05-03 29-SEP-83 10:34:09
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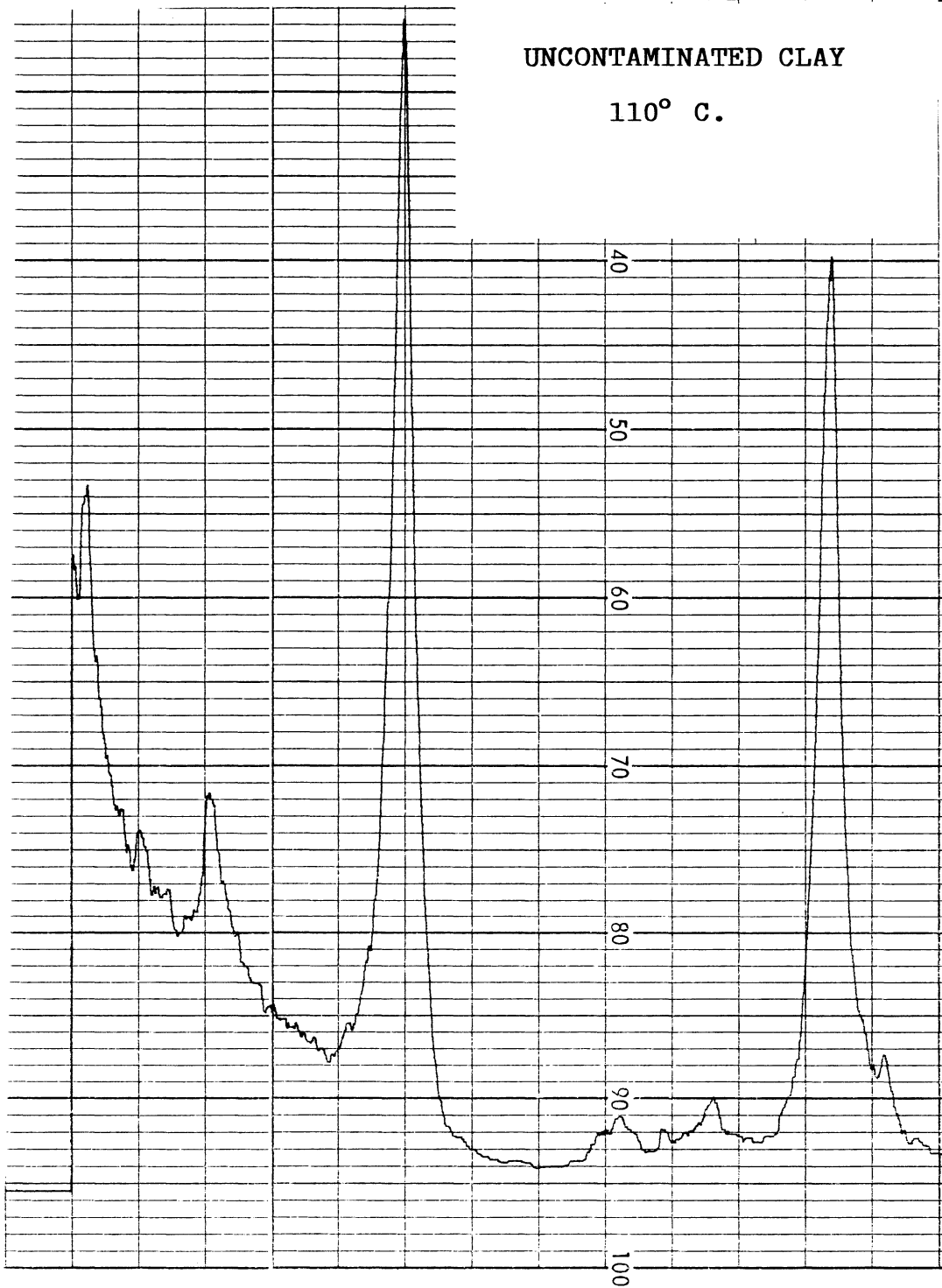
1	3.010	78.86	2.986	315.71	0.412	1.325
2	5.720	160.97	5.688	912.07	0.530	2.294
3	11.924	495.10	11.828	4361.28	0.697	14.606
4	18.129	29.86	17.992	241.28	0.755	3.589
5	21.182	24.68	20.718	333.39	1.021	3.140
6	24.613	381.50	24.555	3960.33	0.768	34.079
7	26.350	42.40	26.517	378.31	0.629	4.677
8	28.146	12.86	28.142	65.70	0.508	2.115
9	28.886	9.40	28.973	52.75	0.399	1.804

V05-03 29-SEP-83 10:51:36

RANK	TT PEAK	INTG INT	REL(%)	D-SPACINGS		
				KA1	KA2	KB1
1	11.924	4361.28	100.00	7.4153	7.4337	6.7013
2	24.613	3960.33	90.81	3.6139	3.6228	3.2659
3	5.720	912.07	20.91	15.4382	15.4765	13.9517
4	26.350	378.31	8.67	3.3794	3.3878	3.0540
5	21.182	333.39	7.64	4.1909	4.2013	3.7873
6	3.010	315.71	7.24	29.3269	29.3996	26.5029
7	18.129	241.28	5.53	4.8892	4.9013	4.4184
8	28.146	65.70	1.51	3.1678	3.1756	2.8627
9	28.886	52.75	1.21	3.0883	3.0959	2.7909

UNCONTAMINATED CLAY

110° C.



OUTPUT FILE: 1110

TTL,TTH:

\$2.\.\,32

SLIT WIDTH? .2

COARSE TIME,RATE: 3,2

CORRECTED SLOPE,SMOOTHING ANGLE: .3,.5

LORENTZ CORRECTION (Y/N)? N

SUMMARIZE INT(P/I)? I

OUTPUT,XOFF: 0,1

V05-03 30-SEP-83 09:24:42

V05-03 30-SEP-83 09:39:58

1	6.065	111.26	6.066	879.71	0.560	1.767
2	11.911	697.41	11.798	6492.08	0.750	12.597
3	18.308	30.23	18.185	296.40	1.102	2.335
4	19.638	20.81	19.577	96.78	0.400	1.919
5	21.026	41.78	20.922	445.66	0.859	2.845
6	22.081	15.50	22.098	53.93	0.355	1.685
7	24.572	581.24	24.525	5910.35	0.754	26.672
8	26.278	69.32	26.336	375.36	0.444	4.061
9	27.278	15.40	27.370	62.84	0.283	1.680

V05-03 30-SEP-83 09:42:10

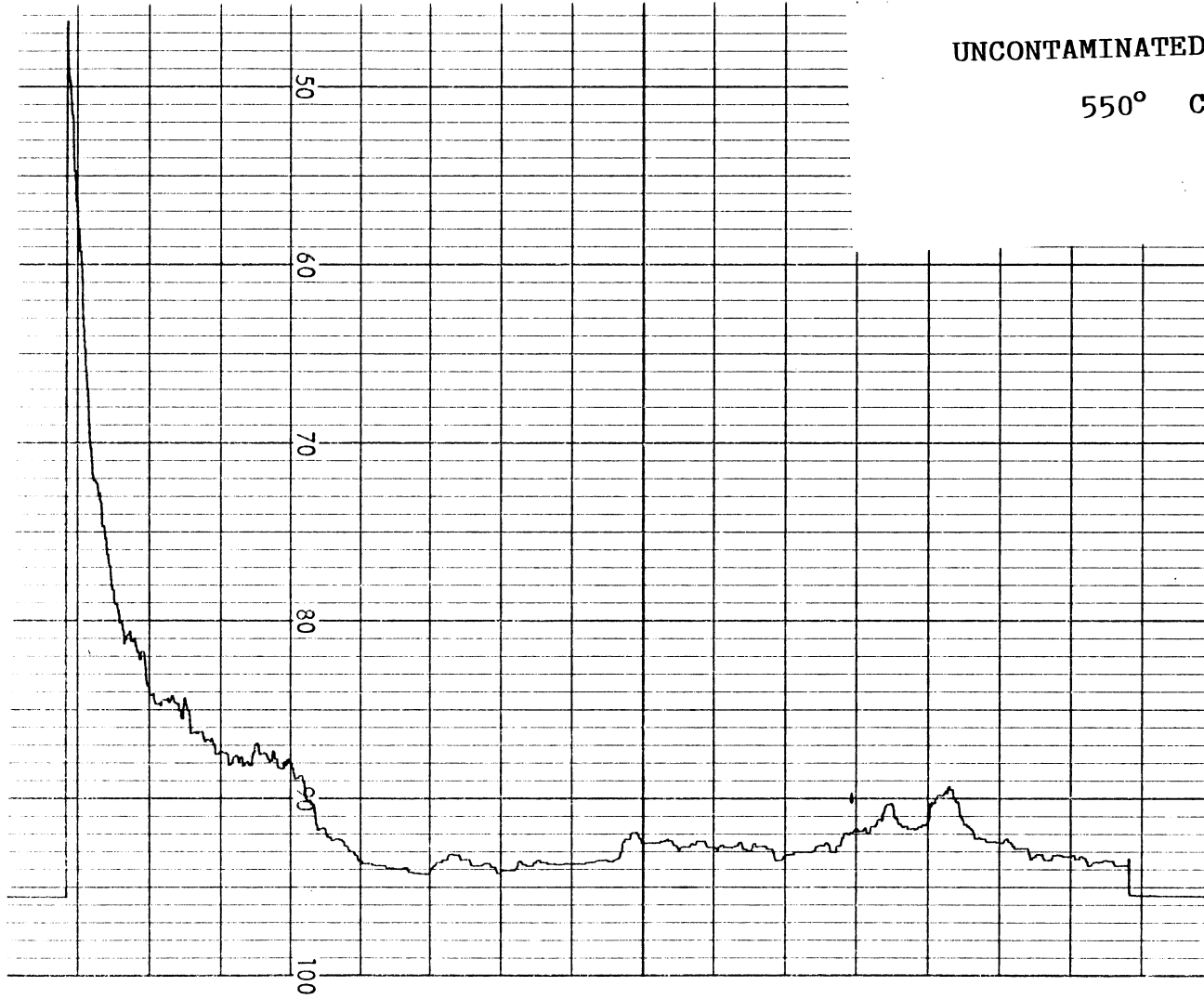
D-SPACINGS

RANK	TT PEAK	INTG INT	REL(%)	KA1	KA2	KB1
1	11.911	6492.08	100.00	7.4236	7.4420	6.7088
2	24.572	5910.35	91.04	3.6197	3.6287	3.2711
3	6.065	879.71	13.55	14.5588	14.5949	13.1569
4	21.026	445.66	6.86	4.2216	4.2321	3.8151
5	26.278	375.36	5.78	3.3885	3.3969	3.0622
6	18.308	296.40	4.57	4.8417	4.8537	4.3755
7	19.638	96.78	1.49	4.5167	4.5279	4.0818
8	27.278	62.84	0.97	3.2665	3.2746	2.9520
9	22.081	53.93	0.83	4.0222	4.0321	3.6349

V05-03 30-SEP-83 09:42:34

UNCONTAMINATED CLAY

550° C.



OUTPUT FILE: 1550
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 #2,32
 SLIT WIDTH? .2
 COARSE TIME,RATE: 3,2
 CORRECTED SLOPE,SMOOTHING ANGLE: .3,.5
 LORENTZ CORRECTION (Y/N)? N
 SUMMARIZE INT(P/I)? I
 OUTPUT,XOFF: 0,1

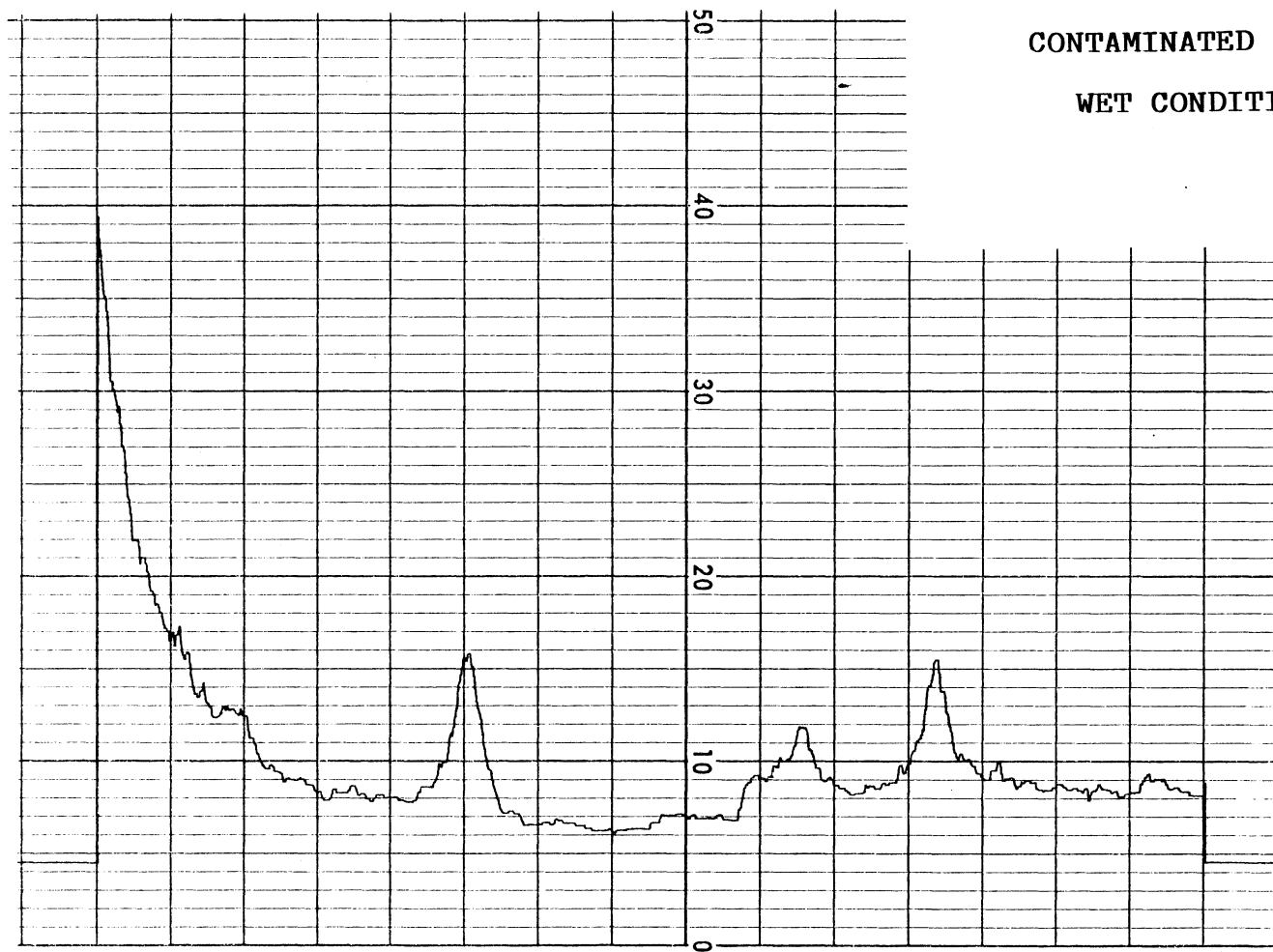
V05-03 04-OCT-83 09:06:49
 V05-03 04-OCT-83 09:22:06

1	17.976	19.64	17.909	103.12	0.552	1.813
2	18.856	14.15	18.724	99.71	0.746	1.586
3	19.869	14.73	19.703	99.52	0.812	1.610
4	20.910	13.08	20.726	88.85	1.025	1.541
5	21.462	12.61	21.481	53.38	0.606	1.516
6	26.968	29.07	26.855	219.92	0.765	1.724

V05-03 04-OCT-83 09:24:10

RANK	TT	PEAK	INTG	INT	REL(%)	D-SFACINGS		KB1
						KA1	KA2	
1		26.968		219.92	100.00	3.3033	3.3115	2.9852
2		17.976		103.12	46.89	4.9304	4.9426	4.4556
3		18.856		99.71	45.34	4.7022	4.7139	4.2495
4		19.869		99.52	45.25	4.4647	4.4758	4.0348
5		20.910		88.85	40.40	4.2446	4.2551	3.8359
6		21.462		53.38	24.27	4.1368	4.1471	3.7385

V05-03 04-OCT-83 09:24:28



CONTAMINATED CLAY

WET CONDITION

OUTPUT FILE: 5
 TTL,TTH:
 #2,32
 SLIT WIDTH? .2
 COARSE TIME,RATE: 3,2
 CORRECTED SLOPE,SMOOTHING ANGLE: .3,.5
 LORENTZ CORRECTION (Y/N)? N
 SUMMARIZE INT(P/I)? I
 OUTPUT,XOFF: 0,1

V05-03 28-SEP-83 13:48:10
 V05-03 28-SEP-83 14:03:30

1	11.959	88.66	11.845	821.08	0.783	3.632
2	21.090	61.72	20.889	967.77	1.198	3.522
3	24.697	97.64	24.559	1440.61	0.898	4.991
4	26.402	36.30	26.436	250.48	0.794	2.484
5	27.178	26.12	27.243	154.71	0.642	2.068
6	27.976	23.50	27.978	146.09	0.654	1.960
7	28.568	21.36	28.534	78.82	0.379	1.873
8	29.045	23.76	29.165	173.54	0.821	1.971

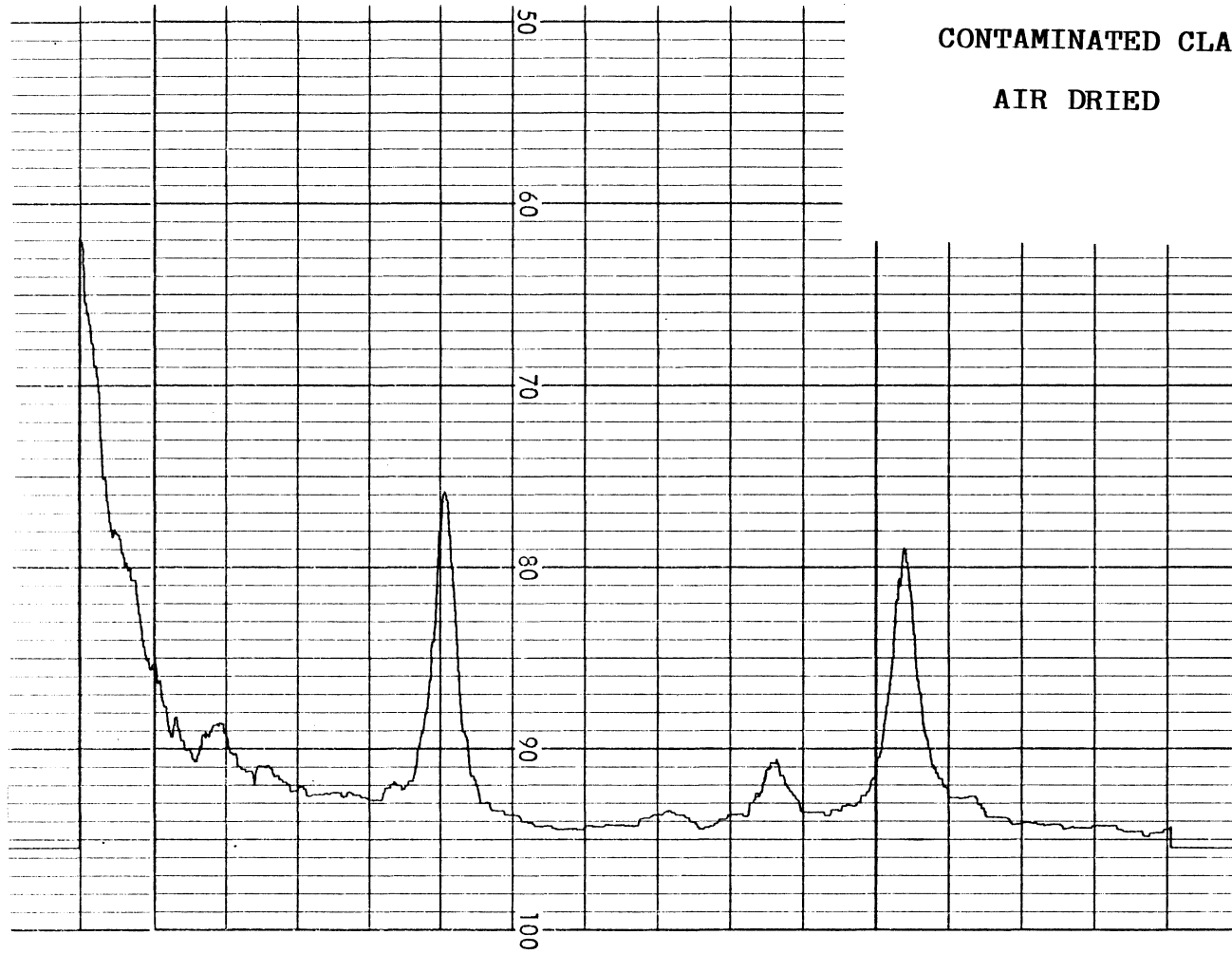
V05-03 28-SEP-83 14:05:38

RANK	TT PEAK	INTG INT	REL(%)	D-SPACINGS		
				KA1	KA2	KB1
1	24.697	1440.61	100.00	3.6017	3.6106	3.2548
2	21.090	967.77	67.18	4.2089	4.2193	3.8036
3	11.959	821.08	57.00	7.3941	7.4124	6.6821
4	26.402	250.48	17.39	3.3728	3.3812	3.0480
5	29.045	173.54	12.05	3.0716	3.0793	2.7759
6	27.178	154.71	10.74	3.2783	3.2864	2.9626
7	27.976	146.09	10.14	3.1865	3.1944	2.8797
8	28.568	78.82	5.47	3.1219	3.1296	2.8213

V05-03 28-SEP-83 14:06:00

CONTAMINATED CLAY

AIR DRIED



OUTPUT FILE: SAIR
 TTL,TTH:
 #2,32
 SLIT WIDTH? .3
 COARSE TIME,RATE: 3,2
 CORRECTED SLOPE,SMOOTHING ANGLE: .3,.5
 LORENTZ CORRECTION (Y/N)? N
 SUMMARIZE INT(P/I)? I
 OUTPUT,XOFF: 0,1

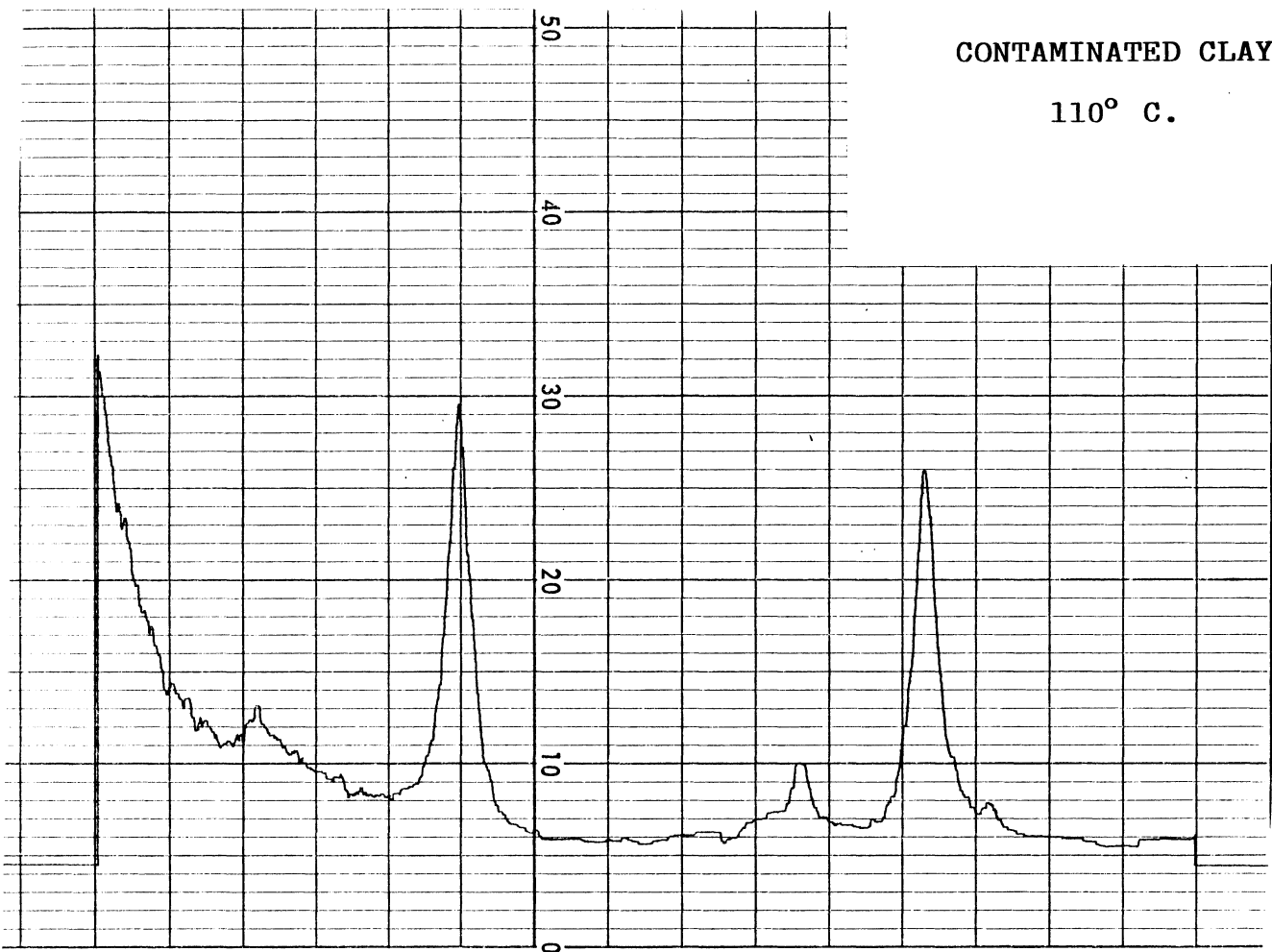
V05-03 29-SEP-83 10:59:21
 V05-03 29-SEP-83 11:14:37

1	5.728	26.94	5.664	169.29	0.621	1.519
2	11.909	183.90	11.856	1407.66	0.643	6.962
3	21.035	31.67	20.993	254.48	0.733	2.429
4	24.612	152.49	24.549	1417.94	0.754	7.177
5	26.377	12.57	26.302	52.30	0.458	1.544
V05-03	29-SEP-83	11:16:41				

RANK	TT PEAK	INTG INT	REL(%)	D-SPACINGS		
				KA1	KA2	KB1
1	24.612	1417.94	100.00	3.6139	3.6229	3.2659
2	11.909	1407.66	99.27	7.4249	7.4433	6.7099
3	21.035	254.48	17.95	4.2197	4.2302	3.8134
4	5.728	169.29	11.94	15.4168	15.4550	13.9322
5	26.377	52.30	3.69	3.3760	3.3844	3.0509
V05-03	29-SEP-83	11:16:56				

CONTAMINATED CLAY

110° C.



OUTPUT FILE: 5110
 TTL,TTH:
 \$2,32
 SLIT WIDTH? .2
 COARSE TIME,RATE: 3,2
 CORRECTED SLOPE,SMOOTHING ANGLE: .3,.5
 LORENTZ CORRECTION (Y/N)? N
 SUMMARIZE INT(P/I)? I
 OUTPUT,XOFF: 0,1

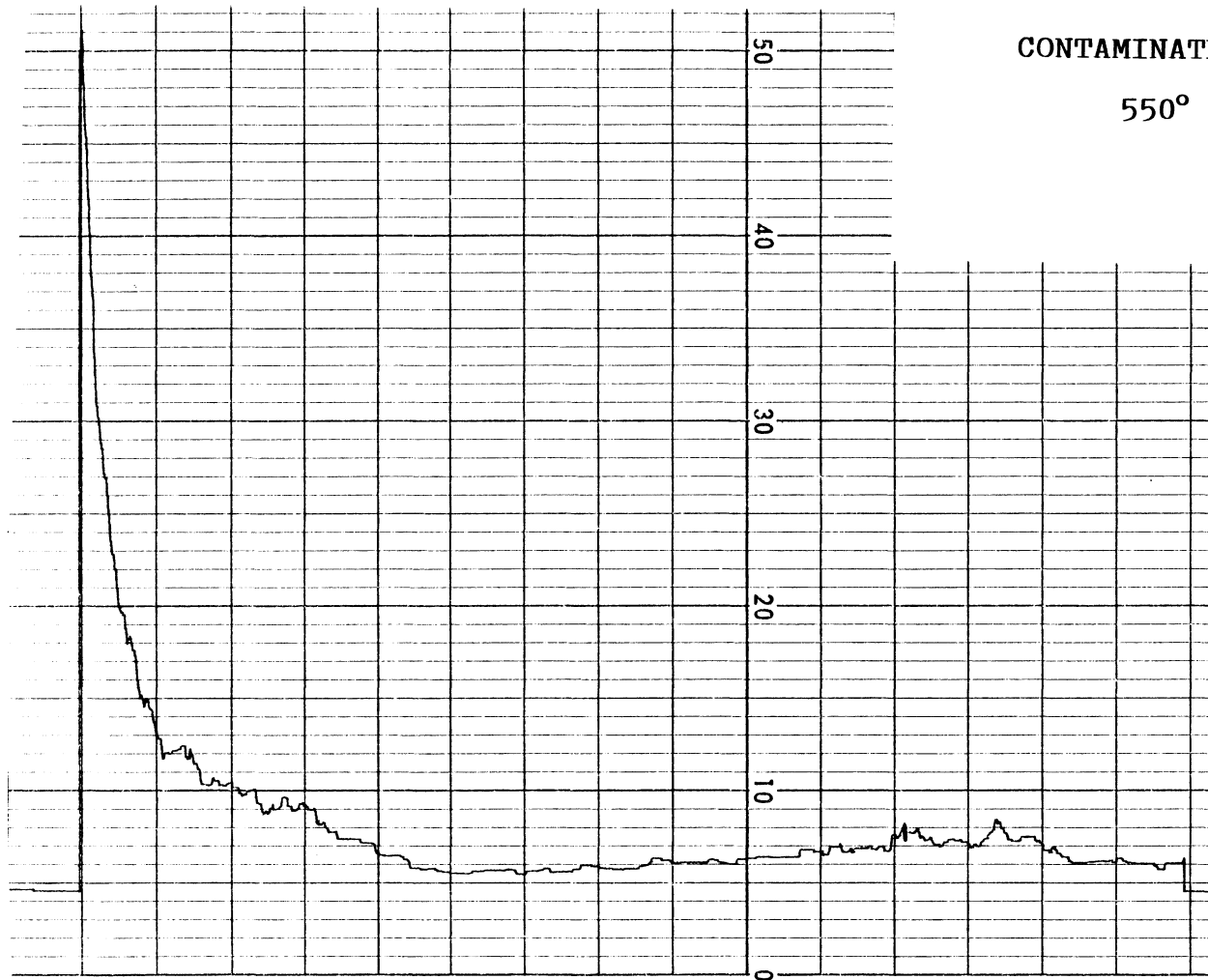
V05-03 30-SEP-83 09:44:30
 V05-03 30-SEP-83 09:59:46

1	6.222	33.53	6.254	326.47	0.594	1.525
2	11.900	235.98	11.826	2053.76	0.725	8.531
3	21.019	51.39	20.822	567.42	0.640	4.281
4	22.094	12.48	22.200	62.89	0.602	1.797
5	24.571	213.73	24.515	2166.19	0.744	14.645
6	26.320	25.66	26.361	145.18	0.473	2.638
V05-03	30-SEP-83		10:01:53			

RANK	TT PEAK	INTG INT	REL(%)	D-SPACINGS		
				KA1	KA2	KB1
1	24.571	2166.19	100.00	3.6199	3.6289	3.2713
2	11.900	2053.76	94.81	7.4308	7.4492	6.7153
3	21.019	567.42	26.19	4.2230	4.2334	3.8163
4	6.222	326.47	15.07	14.1928	14.2280	12.8262
5	26.320	145.18	6.70	3.3831	3.3915	3.0574
6	22.094	62.89	2.90	4.0198	4.0298	3.6327
V05-03	30-SEP-83		10:02:11			

CONTAMINATED CLAY

550° C.



PEAK 0
OUTPUT FILE: 5550
TTL,TTH:
\$2,32
SLIT WIDTH? .2
COARSE TIME,RATE: 3,2
CORRECTED SLOPE,SMOOTHING ANGLE: .3,.5
LORENTZ CORRECTION (Y/N)? N
SUMMARIZE INT(P/I)? I
OUTPUT,XOFF: 0,M1\1M\1

V05-03	03-OCT-83	16:25:39
V05-03	03-OCT-83	16:40:55
NO PEAKS FOUND!		
V05-03	03-OCT-83	16:42:47

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