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Deployment of an Alternative Cover and Final Closure of the Mixed Waste Landfill, Sandia National Laboratories, Albuquerque, New Mexico

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Abstract

An alternative cover design consisting of a monolithic layer of native soil is proposed as the closure path for the Mixed Waste Landfill at Sandia National Laboratories, New Mexico. The proposed design would rely upon soil thickness and evapotranspiration to provide long-term performance and stability, and would be inexpensive to build and maintain. The proposed design is a 3-ft-thick, vegetated soil cover. The alternative cover meets the intent of RCRA Subtitle C regulations in that a) water migration through the cover is minimized; b) maintenance is minimized by using a monolithic soil layer; c) cover erosion is minimized by using erosion control measures; d) subsidence is accommodated by using a "soft" design; and e) the permeability of the cover is less than or equal to that of natural subsurface soil present.

Performance of the proposed cover is integrated with natural site conditions, producing a "system performance" that will ensure that the cover is protective of human health and the environment. Natural site conditions that will produce a system performance include a) extremely low precipitation and high potential evapotranspiration; b) negligible recharge to groundwater; c) an extensive vadose zone; d) groundwater approximately 500 ft below the surface; and e) a versatile, native flora that will persist indefinitely as a climax ecological community with little or no maintenance.

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Executive Summary

[*The Mixed Waste Landfill Alternative Cover Design Report was submitted to the New Mexico Environment Department in September 1999 for technical review and comment. The report went through numerous rounds of review and comments. The original report was revised based upon these review and comment response actions and is published herein in its final technical format.*]

Sandia National Laboratories/New Mexico (SNL/NM) is located within the boundaries of Kirtland Air Force Base (KAFB), immediately south of the city of Albuquerque in Bernalillo County, New Mexico. KAFB occupies 52,233 acres. SNL/NM is managed by the U.S. Department of Energy (DOE) and is operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation. SNL/NM performs research and development in support of various energy and weapons programs and national security. It also performs work for the U.S. Department of Defense, the U.S. Nuclear Regulatory Commission, and other federal agencies.

The Mixed Waste Landfill (MWL) is located 4 miles south of SNL/NM's central facilities and 5 miles southeast of Albuquerque International Sunport. The landfill is a fenced, 2.6-acre compound in the north-central portion of Technical Area (TA)-3. The MWL was established in 1959 as a disposal area for low-level radioactive and mixed waste generated by SNL/NM research facilities. The landfill accepted low-level radioactive and minor amounts of mixed waste from March 1959 through December 1988. Approximately 100,000 cubic feet (ft) of low-level radioactive and mixed waste containing approximately 6,300 curies of activity were disposed of in the landfill.

The MWL consists of two distinct disposal areas. The classified area occupies 0.6 acres and the unclassified area occupies 2.0 acres. Low-level radioactive and mixed waste was disposed of in each of these areas. Classified wastes were buried in unlined, cylindrical pits in the classified area. Unclassified wastes were buried in shallow, unlined trenches in the unclassified area.

A Phase 1 Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI) was conducted in 1989 and 1990 to determine if a release of RCRA contaminants had occurred at the MWL. The Phase 1 RFI indicated that tritium had been released to the environment. A Phase 2 RFI was conducted from 1992 to 1995 to determine the contaminant source, define the nature and extent of contamination, identify potential contaminant transport pathways, evaluate potential risks posed by the levels of contamination identified, and provide remedial action alternatives for the landfill.

The Phase 2 RFI confirmed that tritium is the contaminant of primary concern. Tritium has been a consistent finding at the MWL since environmental studies were initiated at SNL/NM in 1969. Tritium occurs in surface and near-surface soil in and around the classified area of the landfill at levels ranging from 1,100 picocuries (pCi) per gram (g) in surface soil to 206 pCi/g in subsurface soil. The highest tritium levels are found within 30 ft of the surface in soil adjacent to and directly below classified area disposal pits. Below 30 ft from the ground surface, tritium levels fall off rapidly to a few pCi/g of soil. Tritium also occurs as a diffuse air emission from the landfill, releasing 0.294 curies per year to the atmosphere.

The State of New Mexico is authorized by the U.S. Environmental Protection Agency (EPA) to implement the hazardous waste management provisions of RCRA for treatment, storage, and disposal facilities within the state. On August 26, 1993, EPA Region 6 issued the Part B Hazardous and Solid Waste Amendment (HSWA) Permit Module to the DOE and SNL/NM. The purpose of the permit was to establish specific guidelines for assessment, characterization, and remediation of Solid Waste Management Units (SWMUs) at SNL/NM. Under Module IV of the RCRA Part B Permit (HWSA Module), the MWL is identified as Activity Data Sheet 1289, Environmental Restoration Site No. 76, and RCRA Facility Assessment Site No. 24, 25, 26, 27, 28, 29, 30, 11, 5, and 116. The MWL is a SWMU regulated by the New Mexico Environment Department (NMED) under the corrective action provisions of the HSWA. In addition, DOE Orders provide requirements for landfill closure cover design and establish performance requirements for the closed facility.

HSWA corrective action regulations establish corrective action authority but, due to the delay in finalizing more definitive implementing provisions, do not provide prescriptive requirements. Because the HSWA regulations do not address technical specifications, such as those required for a SWMU cover, the more detailed RCRA operating unit regulations are often used as guidance. For the MWL cover design, SNL/NM has elected to use RCRA landfill (referred to here as “Subtitle C facilities”) regulations as guidance.

The goal of the EPA-recommended design of final covers for RCRA Subtitle C facilities is to minimize the formation of leachate by minimizing the contact of water with waste, to minimize further maintenance, and to protect human health and the environment taking into consideration the future use of the site. The EPA accepts alternative cover designs that consider site-specific conditions, such as climate and the nature of the waste, and also meet the intent of the regulations. A fundamental concern of the EPA with cover designs is that all cover components be stable, and that the cover performs as intended without posing a significant risk to human health and the environment.

An alternative cover design consisting of a thick layer of native soil is proposed as the closure path for the MWL. The proposed design would rely upon soil thickness and evapotranspiration to provide long-term performance and stability, and would be inexpensive to build and maintain because of the availability of suitable soil in TA-3.

A proposed alternative cover is hereby formally submitted to the NMED for final closure of the MWL. The proposed cover is a 3-ft-thick, vegetated soil cover. The proposed cover meets the intent of RCRA Subtitle C regulations, which include the following:

- Water migration through the cover is minimized.
- Maintenance is minimized by using a monolithic soil layer.
- Cover erosion is minimized by using erosion control measures.

- Subsidence is accommodated by using a “soft” design.
- Permeability of the cover is less than or equal to that of natural subsurface soil present.

Performance of the proposed cover will be integrated with the natural site conditions at TA-3, producing a “system performance” that will ensure that the cover protects both human health and the environment. The natural site conditions at the site include:

- Extremely low precipitation and high potential evapotranspiration

- Negligible recharge to groundwater

- An extensive vadose zone

- Groundwater approximately 500 ft below the surface

- A versatile, native flora that will persist indefinitely as a climax ecological community with little or no maintenance

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Acronyms and Abbreviations

Am-Be	Americium-Beryllium
amsl	above mean sea level
bgs	below ground surface
CAMU	Corrective Action Management Unit
CFR	Code of Federal Regulations
cm	centimeter(s)
cm^3	cubic centimeter(s)
CPN	California Pacific Nuclear
°	degree(s)
°F	degrees Fahrenheit
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
ER	Environmental Restoration
FOP	Field Operating Procedure
ft	foot (feet)
ft^2	square foot (feet)
HELP-3	Hydrologic Evaluation of Landfill Performance Model, Version 3
hr	hour
HSWA	Hazardous and Solid Waste Amendment
HWB	Hazardous Waste Bureau
in.	inches
INEEL	Idaho National Engineering and Environmental Laboratories
IP	instantaneous profile
KAFB	Kirtland Air Force Base
m	meter(s)
m^2	square meter(s)
mph	miles per hour
mrem	millirem(s)
MUSLE	modified universal soil loss equation
MWL	Mixed Waste Landfill
NMED	New Mexico Environment Department
OTDR	optical time-domain reflectometry
pCi	picocurie(s)
PET	potential evapotranspiration
RCRA	Resource Conservation and Recovery Act
RFI	RCRA Facility Investigation
RSI	request for supplemental information
s	second
SNL/NM	Sandia National Laboratories, New Mexico
SWMU	Solid Waste Management Unit
TA	Technical Area
TEDE	total effective dose equivalent
UNSAT-H	Unsaturated Soil Water and Heat Flow Model

USGS	U.S. Geological Survey
USLE	universal soil loss equation
VS2DT	Variably-Saturated 2-D Flow and Solute Transport Model
WEQ	wind erosion equation
yr	year
yd^3	cubic yard(s)

1. Introduction

Sandia National Laboratories/New Mexico (SNL/NM) is located within the boundaries of Kirtland Air Force Base (KAFB), immediately south of the city of Albuquerque in Bernalillo County, New Mexico (Figure 1-1). KAFB occupies 52,233 acres. SNL/NM research and administration facilities are divided into five technical areas (TAs), designated 1 through 5, and several additional test areas, occupying 2,842 acres. TA-1, TA-2, and TA-4 are separate research facilities in the northwestern portion of KAFB. TA-3 and TA-5 are contiguous research facilities forming a 4.5-square-mile, rectangular area in the southwestern portion of KAFB (Figure 1-2). TA-3 alone occupies 2,000 acres. The Mixed Waste Landfill (MWL) is a 2.6-acre, fenced compound located in north-central TA-3 at SNL/NM (Figure 1-3).

SNL/NM, which is owned by the U.S. Department of Energy (DOE), is co-operated by the DOE and Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation. SNL/NM performs research and development in support of various energy and weapons programs. It also performs work for the U.S. Department of Defense and the U.S. Nuclear Regulatory Commission.

The MWL is designated as a Soil Contamination Area, a Radioactive Materials Management Area, and a Hazardous and Solid Waste Amendments (HSWA) Solid Waste Management Unit (SWMU) subject to final closure under state and federal regulations. The New Mexico Environment Department (NMED), the lead regulatory agency, will oversee closure of the MWL.

This document outlines the deployment of an alternative cover for final closure of the MWL and addresses the alternative closure cover (Chapter 2), the regulatory basis (Chapter 3), MWL characteristics (Chapter 4), the technical basis for the proposed cover (Chapter 5), the proposed MWL alternative cover design (Chapter 6), and cover performance monitoring (Chapter 7).

Long-term stewardship of the MWL will be addressed in the "MWL Post-Closure Care Plan," scheduled for submittal to the NMED under separate cover. Planned monitoring activities and the frequency at which these will be performed will be determined in consultation with the NMED and described in detail in this post-closure care document.

1.1 Acknowledgements

The alternative cover design presented in this document is based upon fruitful collaborations with engineering firms, industry, and state and federal regulatory agencies. The authors benefited greatly from visits and discussions with the following individuals and organizations: William Moats, Rich Kilbury, and Bill McDonald of the NMED; Stu Rawlinson, Dan Levitt, Jeff Smith, Tom Fitzmaurice, and Dudley Emer at the Nevada Test Site; Greg Cotten of Idaho National Engineering and Environmental Laboratories (INEEL); Tim Reynolds of the Environmental Science and Research Foundation; Howard Stone and Robert Warder of Bohannan-Huston; and Paul Knight of Marron and Associates, Inc. The authors also acknowledge valuable discussions with Craig Benson at the University of Wisconsin at Madison, Rick Pruett of Pruett Industries, Jody Waugh of Weston-Grand Junction Project Office, Ross Wolford of Balleau Groundwater, and Dan Kwiecinski of URS, Inc. Charles Reith, Jack Caldwell, Jack Nyhan, Tom Hakonson, and Glendon Gee deserve special recognition for their pioneering work on alternative landfill covers.

2. Proposed Alternative Cover for the MWL

Due to the lack of specific HSWA technical requirements, SNL/NM has elected to use Resource Conservation and Recovery Act (RCRA) landfill regulations as guidance. The design of a final cover for RCRA Subtitle C facilities recommended by the U.S. Environmental Protection Agency (EPA) is, at a minimum, made up of three layers: (1) a vegetated or armored top layer comprised of 24 inches (in.) of soil graded at a slope of 3 to 5 percent; (2) a drainage layer, 12 in. thick, composed of a high-conductivity sand layer; and (3) a 24-in.-thick, low-conductivity compacted soil layer with a geomembrane (EPA 1991). The design of the cover elements must take into consideration failure caused by desiccation cracking, settling, and subsidence. The goal of the EPA-recommended design is to limit the formation of leachate by minimizing the contact of waste with water, minimize further maintenance, and protect human health and the environment under future land use conditions.

The fundamental concern of the EPA with cover designs is ensuring that all cover components are stable and the cover performs as intended, without posing a risk to human health and the environment (EPA 1991). The EPA accepts alternative designs that consider site-specific conditions, such as climate and the nature of the waste, and also meet the intent of the regulations. The EPA acknowledges that in arid regions where vegetation cannot be maintained, other materials for the surface cover layer should be selected to prevent erosion and allow for surface drainage, and the middle drainage layer can be eliminated from the design.

The proposed alternative cover for the MWL is a 3-foot (ft)-thick, vegetated soil cover that will be built by placing subgrade soil and lifts of native soil over the existing landfill surface. The topsoil layer will be seeded with native vegetation to mitigate surface erosion and promote evapotranspiration. During the 100-year (yr) institutional control period, native soil can be added to the cover as needed to correct subsidence resulting from degradation of buried waste containers and rills that result from surface erosion. At the end of the institutional control period, additional native soil can be added to compensate for future subsidence and erosion. Because the cover will be constructed without rigid layers, it can accommodate differential subsidence without undue impairment of its performance. This provides additional assurance for adequate long-term performance of the proposed cover.

The proposed alternative cover meets the RCRA requirements of Title 40 of the Code of Federal Regulations (CFR), Section 264.310, as follows:

- Water migration is minimized through the cover. The proposed 3-ft-thick, vegetated soil cover will minimize water migration into waste disposal cells.

- Maintenance will be minimized by using a monolithic soil layer. Individual layers, such as those used in traditional RCRA covers, are rigid and would require extensive maintenance and repair due to eventual degradation as well as tensile and shear failure.

- Cover erosion will be minimized by using erosion control measures. The proposed cover will be centrally crowned and sloped at 2 percent. The topsoil layer will be vegetated and admixed with 25 percent 3/8-in. crushed gravel.

- Subsidence will be accommodated by using a "soft" cover. During the long-term care period, soil can be added to the cover to repair erosion and subsidence as it occurs. At the end of this time, additional soil can be added to mitigate future erosion and subsidence.

- Permeability of the cover soil will be less than or equal to the permeability of MWL subsurface soil. The "bathtub" effect is unlikely to occur.

Performance of the proposed cover cannot be isolated from the performance of the site itself. Natural site conditions, integrated with the cover, produce a "system performance" that will ensure that the alternative design adequately meets the regulatory requirements. The natural site conditions of TA-3 that will be relied upon as part of the system include:

- Extremely low precipitation and high potential evapotranspiration (PET).

- Negligible recharge to groundwater. Chloride data collected from boreholes at the MWL indicate significant rainfall has not percolated beyond the upper 20 ft of soil in more than 30,000 yrs (Peace et al. 2002).

- An extensive vadose zone. Groundwater lies approximately 500 ft below ground surface (bgs).

- The site has low potential for volcanic and seismic activity, with low hazard potential. The Albuquerque volcanoes were active for only a short period about 190,000 yrs ago (Clary et al. 1984.)

- The vegetated soil cover will adapt to climatic change, will recover from severe damage (fire and drought), and will persist indefinitely with little or no maintenance.

2.1 Floodplain and Seismic Considerations

Performance of the proposed cover will not be impacted by natural environmental events such as flooding or earthquakes. The MWL is not located within the 100-yr or 500-yr floodplains (Figure 2-1) and the expected low recurrence interval and low expected ground motion of seismic events in the Albuquerque basin renders earthquakes of little significance (Figure 2-2).

3. Regulatory Basis

The DOE meets its responsibility for conducting and overseeing radioactive material operations at its contractor-operated facilities, under the Atomic Energy Act authority, through DOE Orders, which set requirements and standards for closures. DOE Orders and federal and state regulations that contain pertinent requirements for final closure of the MWL are as follows:

- DOE Order 5400.5, "Radiation Protection of the Public and the Environment" (DOE 1993)
- DOE Order 435.1, "Radioactive Waste Management" (DOE 1999)
- DOE Order 6430.1A, "General Design Criteria" (DOE 1989)
- 40 CFR 264, "Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities" (used as guidance)
- 10 CFR 835 "Occupational Radiation Protection"
- New Mexico Administrative Code, 20 NMAC 4.1, Subpart V, 40 CFR 264.101, "Corrective Action for Solid Waste Management Units"

Requirements for closure under federal and state regulations and DOE Orders are summarized in the following sections.

3.1 Corrective Action Requirements Under HSWA

The MWL was identified as a SWMU in the August 1993 issuance of the HSWA Module, the corrective action portion of the SNL/NM RCRA operating permit. Under the corrective action program, SNL/NM is required to investigate and remediate, if necessary, the SWMUs identified in the HSWA Module of the permit. For the MWL, SNL/NM has completed the assessment and characterization phase and has proposed to design and deploy an alternative cover as the final remedy.

Due to both the lack of prescriptive HSWA guidance and the practical similarities of landfill corrective action under HSWA and landfill closure under RCRA, SNL/NM has elected to use the RCRA landfill closure requirements as guidance for the MWL final remedy. The purpose of closure is to contain and prevent migration of hazardous waste and hazardous constituents from MWL disposal cells. Closure includes construction of engineered controls (i.e., closure cover) and implementation of an environmental monitoring and surveillance plan.

Hazardous waste landfill closure requirements are codified under 40 CFR 264, "Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities," Subpart G (Facility Closure Standards) and Subpart N (Landfills). These standards are performance-based regulations that specify performance criteria without specifying design, construction materials, or operating parameters. The EPA has provided numerous guidance documents to aid in interpreting the level of performance required to design, construct, and operate a compliant closure system. The closure performance standard is defined in 40 CFR 264.111 as follows:

> "The owner or operator must close the facility in a manner that:
>
> (a) Minimizes the need for further maintenance; and
>
> (b) Controls, minimizes or eliminates, to the extent necessary to protect human health and the environment, post-closure escape of hazardous waste, hazardous constituents, leachate, contaminated runoff, or hazardous waste decomposition products to the ground or surface waters or to the atmosphere; and
>
> (c) Complies with the closure requirements of this subpart, including, but not limited to, the requirements of . . . ."

The following performance-based requirements for landfill covers are established in 40 CFR 264.310:

> "At final closure of the landfill or upon closure of any cell, the owner or operator must cover the landfill or cell with a final cover designed and constructed to:
>
> (1) Provide long-term minimization of migration of water through the closed landfill;
>
> (2) Function with minimum maintenance;
>
> (3) Promote drainage and minimize erosion or abrasion of the cover;
>
> (4) Accommodate settling and subsidence so that the cover's integrity is maintained; and
>
> (5) Have permeability less than or equal to the permeability of any bottom liner system or natural subsoil present."

The NMED, the lead regulatory agency, has adopted the federal regulations as written, which are incorporated into the New Mexico Administrative Code, 20 NMAC 4.1, Subpart V, 40 CFR 264.101, "Corrective Action for Solid Waste Management Units."

3.2 Closure Requirements Under DOE Orders

Low-level radioactive and mixed waste disposal operations at the MWL followed the requirements set by DOE Order 5820.2, "Radioactive Waste Management" (DOE 1984) and those requirements subsequently set by DOE Order 5820.2A, "Radioactive Waste Management"

(DOE 1988). On July 9, 1999, DOE Order 5820.2A was cancelled and replaced by DOE Order 435.1 "Radioactive Waste Management" (DOE 1999). The objective of these Orders is to ensure that all DOE radioactive waste is managed in a manner that protects the health and safety of both workers and the public, and the environment.

DOE Order 435.1 does not set specific closure system design criteria, but establishes performance objectives for the closed facility. The objectives and limits are as follows:

a) Doses to representative members of the public shall not exceed 25 millirems (mrem) in a year total effective dose equivalent (TEDE) from all exposure pathways, excluding the dose from radon and its progeny in air.

b) Dose to representative members of the public via the air pathway shall not exceed 10 mrem in a year TEDE, excluding the dose from radon and its progeny in air.

c) Release of radon shall be less than an average flux of 20 picocuries (pCi) per square meters (m^2) per second (s) at the surface of the disposal facility.

3.3 Regulatory Review and Response Actions

In order to meet the challenge that came with approval and fielding of an innovative technology at the MWL, SNL/NM Environmental Restoration (ER) Project engineering design staff met with the NMED Hazardous Waste Bureau (HWB) on a regular basis throughout the alternative cover research and design process. The design of alternative covers has to date been an isolated activity at various sites in the United States. Meetings were held with the HWB to determine both specific risks at the MWL and construction and performance requirements. The HWB reviewed 30-percent, 60-percent, and 90-percent design specifications and grading plans for appropriateness. The final design report was submitted to the NMED on September 23, 1999.

The MWL alternative cover design was reviewed internally by the NMED, and externally by TechLaw Inc., a Lakewood, Colorado, civil engineering firm representing the NMED. The NMED issued a formal request for supplemental information (RSI) to SNL/NM on June 5, 2000, to address technical comments and questions raised by TechLaw Inc. and NMED technical and regulatory staff. SNL/NM submitted its response to the RSI to the NMED on September 8, 2000. The NMED issued a second RSI on February 16, 2001, to clarify certain subject areas of the September 8, 2000, SNL/NM response. The RSI process was closed in 2001 with no further technical comments or questions. Specific NMED RSI and SNL/NM response documents are available for review by submitting a request to the Integrated Safety and Security Records Center, Department 9212, SNL/NM, Albuquerque, New Mexico.

The MWL alternative cover design was reviewed by the EPA Region 6 in 2001 and 2002 for Toxic Substances Control Act (TSCA) approval for deployment at the SNL/NM Chemical Waste Landfill. EPA approval was obtained on June 26, 2002.

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4. MWL Characteristics

The weather for Albuquerque and vicinity, including SNL/NM, is typical of high-altitude, dry continental climates. The normal daily temperature ranges from 23 to 52 degrees Fahrenheit (°F) during winter months and from 57 to 91°F during summer months. The average annual relative humidity is 46 percent; however, the relative humidity can range from as low as 5 percent to as high as 70 percent (Bonzon et al. 1974).

Under normal conditions, wind speeds seldom exceed 32 miles per hour (mph) and are generally less than 8 mph (Bonzon et al. 1974). Strong winds, often accompanied by blowing dust, occur mostly in late winter and early spring. During these months, the prevailing surface winds are from the southwest. Rapid night-time ground-cooling produces strong temperature inversions and strong winds through mountain canyons.

The average annual precipitation for the Albuquerque area is 8.5 in. Monthly precipitation can range from a minimum of less than 0.5 in. during winter months to 1.5 in. during summer months. Average annual snowfall in the Albuquerque area is 11 in. Summer precipitation, particularly in July through August, is usually in the form of heavy thundershowers that typically last less than 1 hour (hr) at any given location (Williams 1986). Average annual Class A pan evaporation at Albuquerque International Sunport Station 224 is 89 in., approximately 10 times the average annual precipitation.

TA-3 is situated within coalescing alluvial fans emanating from the Manzanita Mountains to the east that form an expansive, relatively featureless, arid mesa. TA-3 is underlain by an extensive vadose zone comprised of unconsolidated, braided channel, interchannel, flood plain, and aeolian deposits. The water table beneath TA-3 occurs within the Santa Fe Group approximately 500 ft bgs. The MWL lies in the north-central portion of TA-3. Elevations at the MWL range from 5,385 ft above mean sea level (amsl) on the east to 5,375 ft amsl on the west. Mean elevation is 5,381 ft amsl.

There are no permanent structures at the MWL. All disposal pits and trenches were excavated below grade. The only visible surface features are the earthen berms above unclassified area trenches, and security fences that surround the compound. There are no perennial streams in the immediate area of the MWL. Surface runoff is regionally controlled and generally to the west. There are no man-made surface runoff controls. Surface runoff flows from the landfill surface to dirt roads that surround the fenced compound.

The MWL accepted containerized and uncontainerized low-level radioactive and mixed waste from SNL/NM research facilities and off-site generators from 1959 to 1988. Approximately 100,000 cubic ft of low-level radioactive and mixed waste (excluding waste containers, packaging, construction and demolition debris, and contaminated soil) containing 6,300 curies of activity (at the time of disposal) were disposed of at the MWL, which contains minor quantities of RCRA hazardous metals and solvents. Disposal cells at the landfill are unlined and have been compacted to grade with native soil.

There are two distinct disposal areas at the MWL that include the classified area (occupying 0.6 acres) and the unclassified area (occupying 2.0 acres) (Figure 1-3). Wastes in the classified area were disposed of in a series of vertical, cylindrical pits. Historical records indicate that early pits were 3 to 5 ft in diameter and 15 ft deep. Later pits were 10 ft in diameter and 25 ft deep. Once pits were filled with waste, they were backfilled with soil and capped with concrete. Wastes in the unclassified area were disposed of in a series of parallel, north-south, excavated trenches. Records indicate that the trenches were 15 to 25 ft wide, 150 to 180 ft long, and 15 to 20 ft deep. Trenches were reportedly backfilled with soil on a quarterly basis and, once filled with waste, capped with the original soil that had been excavated and locally stockpiled.

Containment and disposal of waste commonly occurred in tied, double polyethylene bags, sealed A/N cans (military ordnance metal containers of various sizes), fiberboard drums, wooden crates, cardboard boxes, 55-gallon steel and polyethylene drums. Larger items, such as glove boxes and spent fuel shipping casks, were disposed of in bulk without containment. Disposal of free liquids was not allowed at the MWL. Liquids such as acids, bases, and solvents were solidified with commercially available agents including Aquaset, Safe-T-Set, Petroset, vermiculite, marble chips, or yellow powder before containerization and disposal.

Most pits and trenches contain routine operational and miscellaneous decontamination waste including gloves, paper, mop heads, brushes, rags, tape, wire, metal and polyvinyl chloride piping, cables, towels, quartz cloth, swipes, disposable lab coats, shoes covers, coveralls, high-efficiency particulate air filters, prefilters, tygon tubing, watch glasses, polyethylene bottles, beakers, balances, pH meters, screws, bolts, saw blades, Kleenex, petri dishes, scouring pads, metal scrap and shavings, foam, plastic, glass, rubber scrap, electrical connectors, ground cloth, wooden shipping crates and pallets, wooden and lucite dosimetry holders, and expended or obsolete experimental equipment.

A detailed MWL waste inventory, by pit and trench, is provided in the Environmental Restoration Project Responses to NMED Technical Comments on the Report of the Mixed Waste Landfill Phase 2 RCRA Facility Investigation, June 15, 1998 (SNL/NM 1998). A copy of this report and copies of additional MWL reports can be found at the NMED HWB offices at 2905 Rodeo Park Drive East, Building 1, Santa Fe, New Mexico, and can be requested from the Integrated Safety and Security Records Center, Department 9212, SNL/NM, Albuquerque, New Mexico.

5. Technical Basis

The MWL alternative cover design is based upon federal regulations and guidance, DOE Orders and guidance, NMED regulations and guidance, an extensive review of published studies conducted over the past 15 yrs, and the geological, hydrological, and ecological conditions specific to TA-3 and the MWL. Performance of the overall "system" relies on both the proposed cover design and natural site characteristics. The objective was to capture and condense these design "elements," as appropriate, to design a cover that meets the intent of the regulations and that improves, rather than degrades, over time as inevitable natural processes act on the system. Engineered covers must be viewed as evolving components of larger, dynamic ecosystems (Waugh 1997).

The DOE has been actively pursuing alternative cover design and construction for more than 15 yrs. Most of the research to date has been conducted in arid and semiarid regions. Much of this research was evaluated and incorporated, as appropriate, in the design proposed for the MWL. Research and published information to date is limited to short-term demonstrations and monitoring, predictive models, and natural analogs. There is little information published on the long-term performance of alternative cover systems.

5.1 Potential Evapotranspiration

PET estimates have been made for TA-3 in support of predictive modeling. The Hydrologic Evaluation of Landfill Performance Model, Version 3 (HELP-3) (Schroeder et al. 1994) was used to estimate PET data with its built-in functions and localized database for Albuquerque, New Mexico. The resulting PET data are shown along with pan evaporation data from four New Mexico National Weather Service Stations in Figure 5-1. The average annual PET modeled by HELP-3 for the 65-yr period (1932 to 1996) was 75.4 in., approximately 9 times the average annual precipitation recorded at Albuquerque International Sunport.

5.2 MWL Vadose Zone Characteristics

Extensive field investigations and analytical studies have been undertaken in TA-3 and at the MWL to address regulatory-driven assessment and characterization requirements. A comprehensive RCRA Facility Investigation (RFI) Report (Peace et al. 2002) and two NMED Notice of Deficiency submittals, including an extensive inventory of wastes disposed of at the MWL, are available for review (SNL/NM 1998; SNL/NM 1999). Data collected from boreholes, groundwater monitoring wells, and instantaneous profile (IP) tests were used to measure saturated and unsaturated zone characteristics, augment characterization and assessment, and support final closure of the site. These data included volumetric water content, saturated and unsaturated hydraulic conductivity, bulk density, and isotopic chloride content. The data are summarized in Goering et al. (1995) and Wolford (1998).

5.2.1 Water Movement in the Unsaturated Zone Under Natural Conditions

MWL Phase 2 RFI characterization data show no evidence of significant water migration past the root zone of plants or the upper 2 ft of soil. Water infiltrating the surface returns to the atmosphere via evapotranspiration. Recharge to the water table at the MWL is insignificant under current climatic and vegetative conditions.

The following characteristics summarize the vadose zone in TA-3 and at the MWL.

- The underlying alluvium, which makes up the vadose zone, is a well-graded, very fine sand with occasional layers of gravel, coarse sand, silt, and clay. The relative percentages of silt and clay increase with depth, and predominate at depths greater than 250 ft bgs.

- Water content of the alluvium is very low near the surface and may decrease with depth. Soil-water contents average approximately 3 percent by weight and peak at about 13 percent by weight.

- Very little water infiltration occurs beyond the upper 2 ft of the surface. Unsaturated hydraulic conductivities are extremely low due to low soil-water contents. The operational unsaturated hydraulic conductivities of these soil are on the order of 10^{-9} to 10^{-10} centimeters (cm)/s.

- Soil profiles show an enrichment of stable chloride near the surface (Figure 5-2). Chloride in the top 20 ft of soil represents the accumulation of atmospheric chloride over tens of thousands of years. The implication of this chloride accumulation is that very little water has infiltrated beyond 20 ft bgs during that period of time. Water that exists deeper in the vadose zone probably entered the system much earlier and under much wetter climatic conditions.

5.2.2 The Bathtub Effect

RCRA Subtitle C regulations, specifically 40 CFR 264.310 (a) (5), states that at final closure of the landfill, the operator must cover the landfill with a final cover designed and constructed to: "have a permeability less than or equal to the permeability of any bottom liner system or natural subsoil present." This prescriptive requirement was established to prevent what is commonly referred to as the bathtub effect, which occurs when a more permeable cover is constructed over a less permeable bottom liner or natural subsurface soil. If the more permeable cover were to remain saturated during its design life, water would eventually accumulate in disposal cells, filling pits and trenches as if they were basins. Such an event could accelerate deterioration of waste containers, initiate subsidence of the cover, and mobilize hazardous constituents.

The proposed cover has been carefully designed using native soil selected from appropriate borrow areas to prevent the bathtub effect. This section presents the permeability (hydraulic conductivity) data for MWL subsurface soil and for the soil that will be used to construct the proposed cover. These data demonstrate that the MWL alternative cover meets the permeability requirements of 40 CFR 264.310, and that the bathtub effect is unlikely to occur.

5.2.2.1 MWL Subsurface Soil Hydraulic Conductivities

During the MWL Phase 2 RFI and in subsequent hydrologic studies, the permeability of MWL subsurface soil was determined by directly measuring the saturated hydraulic conductivity in the field, and by measuring the hydraulic conductivity of core samples in the laboratory.

Field measurements of Subsurface Soil Hydraulic Conductivity. The most representative measurement of saturated hydraulic conductivity is obtained *in situ* in the field, because the sampled areas are undisturbed and the area tested is considerably larger than the cross-sectional area of a core sample analyzed in the laboratory. In addition, field conductivity values reflect the presence of naturally occurring macropores (or channels of preferential flow), which may significantly affect the saturated hydraulic conductivity. Two *in situ* tests were conducted on surface soil west of the MWL to obtain measurements of the saturated hydraulic conductivity. The results from these tests are summarized in Table 5-1.

The first test was an IP test conducted on a 16- by-16-ft area that was flooded with more than 5,000 gallons of water over a two-day period. Water infiltration through the upper 6 ft of soil was monitored and measured over a period of 890 days. The saturated hydraulic conductivity determined from steady-state flow was 4.0 H 10^{-4} cm/s.

The second *in situ* test was conducted on an adjacent 10- by-10-ft area. This site was flooded to emulate a rainfall event, and the saturated hydraulic conductivity was determined to be 5.3 H 10^{-4} cm/s. The average (geometric mean) hydraulic conductivity from these two *in situ* tests is 4.6 H 10^{-4} cm/s.

Laboratory Measurements of Subsurface Soil Hydraulic Conductivity. During the MWL Phase 2 RFI, laboratory measurements of saturated hydraulic conductivity were obtained from 18 core samples collected from subsurface soil directly below the MWL at depths ranging from 10 to 104 ft bgs. Core samples were collected ahead of the drill bit using a California split-spoon sampler and brass rings. Laboratory measurements of hydraulic conductivity were also obtained from six core samples collected from the IP test site at depths ranging from 1 to 6 ft bgs. The IP test core samples were collected with a sliding hammer core sampler and brass rings. Hydraulic conductivities for core samples obtained from Phase 2 RFI drilling and from the IP test site were measured using the relatively undisturbed soil samples, without remolding. Two additional hydraulic conductivity measurements were obtained by remolding soil from the IP test site. The results from these tests are summarized in Table 5-1.

The average (geometric mean) of the 26 laboratory measurements of hydraulic conductivity is 1.1 H 10^{-4} cm/s. These results are very similar to the results obtained from the *in situ* hydraulic conductivity test at the IP test site west of the MWL, which yielded an average hydraulic conductivity of 4.6 H 10^{-4} cm/s.

5.2.2.2 MWL Alternative Cover Hydraulic Conductivity

Nine composite soil samples were collected from borrow areas west of the MWL and from existing Corrective Action Management Unit (CAMU) soil stockpiles in TA-3. The proposed cover will be constructed of soil from each of these borrow areas. Borrow soil was analyzed for a full suite of geotechnical parameters, including saturated hydraulic conductivity, moisture-density relationships, Atterberg Limits, grain-size analysis, and shear strength (Appendix A).

Saturated hydraulic conductivities were obtained at 90 percent of the maximum dry bulk density to satisfy earthwork specifications for percent (relative) compaction. Hydraulic conductivity data for the cover soil are presented in Table 5-2. The saturated hydraulic conductivity for borrow soil from areas west of the MWL averaged 3.6×10^{-5} cm/s, while the saturated hydraulic conductivity for the soil in the CAMU stockpiles averaged 1.6×10^{-5} cm/s. Fill for the subgrade and native soil layer will come from the CAMU stockpiles. Fill for the topsoil layer will come from areas west of the MWL. The average (geometric mean) hydraulic conductivity of all soil samples from both borrow areas is 2.1×10^{-5} cm/s, which is a realistic estimate of the saturated hydraulic conductivity of the final cover.

These data demonstrate that the saturated hydraulic conductivity of the proposed cover will be lower than the saturated hydraulic conductivity of the underlying natural subsurface soil. The estimated saturated hydraulic conductivity of the natural subsurface soil is 4.6×10^{-4} cm/s, while the estimated saturated hydraulic conductivity of the final cover is 2.1×10^{-5} cm/s. Thus, the bathtub effect is unlikely to occur.

5.2.2.3 Natural Analog of the MWL Cover

The most convincing evidence that the bathtub effect will not occur at the MWL lies in the analog of natural moisture conditions in soil in the vicinity of the MWL. Existing moisture contents in this soil provide an excellent natural analog for predicting moisture contents in the proposed cover. Soil at the MWL averages a moisture content of 3 percent by weight. Although the upper few inches of soil may become saturated briefly following rainfall events, evapotranspiration causes the soil to dry rapidly. Even during winter months, when plants are dormant and transpiration is low, saturated conditions rarely occur.

The vegetated soil cover for the MWL is designed to simulate natural conditions, utilizing evapotranspiration to remove excess moisture. When excess moisture is removed, water is no longer available to infiltrate downward into waste disposal cells. Because the alternative cover was designed to simulate natural site conditions, the cover is predicted to be unsaturated during most of its design life, which is consistent with the cover performance modeling results presented in Section 5.3.

Under these unsaturated conditions, the “operational hydraulic conductivity” of the cover will be orders of magnitude lower than the saturated hydraulic conductivity of both the cover and the natural subsurface soil. The operational hydraulic conductivity of the MWL cover is equal to the average flux through the cover, assuming a unit gradient. Performance modeling at the MWL using the Unsaturated Soil Water and Heat Flow Model (UNSAT-H) (Fayer and Jones 1990) predicted an average flux through the 3-ft cover to be 4.1×10^{-9} cm/s (see Section 5.3.3). HELP-3 and Variably-Saturated 2-D Flow and Solute Transport Model (VS2DT) predicted this value to be 7.1×10^{-11} cm/s and 2.1×10^{-10} cm/s, respectively. Thus, the operational hydraulic conductivity of the final cover is conservatively estimated to be 4.1×10^{-9} cm/s, which is five orders of magnitude lower than the estimated saturated hydraulic conductivity of the MWL subsurface soil (4.6×10^{-4} cm/s), and four orders of magnitude lower than the predicted saturated hydraulic conductivity of the cover (2.1×10^{-5} cm/s).

5.3 Cover Performance

Alteration of the MWL natural site conditions by regrading the land surface and removing the established native, vegetative cover, deploying an engineered cover, and building drainage swales will alter the site's hydrologic response. The long-range plan is to establish soil and vegetative conditions similar to existing natural conditions. Both the long-term as well as the short-term responses of the cover must be considered in its design. Engineering designs are analyzed under hypothetical scenarios that have a reasonable chance of future occurrence to demonstrate that the potential for infiltration and contaminant migration from waste disposal cells to the vadose zone and groundwater is unlikely, and to ensure that the intent of federal and state regulations and DOE orders is met.

The regulatory requirements for closure and post-closure of landfills are provided in several EPA guidance documents (EPA 1989; EPA 1991; EPA 1994). The primary closure requirement is that the owner must design and construct a low-permeability cover over the landfill to minimize infiltration of water into waste disposal cells and provide 30 yrs of post-closure care and maintenance in order to prevent releases of hazardous constituents to the environment.

5.3.1 Cover Performance Modeling

In order to demonstrate that the MWL alternative cover design complies with the regulatory guidance, it is necessary to model the hydrologic performance of the proposed cover. The EPA (EPA 1994) suggests that the water-balance model, HELP, be used for these demonstrations. Performance of the proposed cover was evaluated using HELP-3 (Schroeder et al. 1994) and two additional numerical, unsaturated flow models, UNSAT-H (Fayer and Jones 1990) and VS2DT (Healy 1990). Although HELP-3 is commonly used to predict infiltration through landfill covers and is widely accepted by the regulatory community, UNSAT-H and VS2DT are more numerically comprehensive and were used for comparison with the HELP-3 modeling results.

Performance modeling results were used to predict infiltration through the cover and to determine the optimal cover thickness. Because construction costs are directly proportionate to the thickness of a cover, the optimal cover design is one that meets the performance criteria with the least amount of thickness. Inherent in the determination of optimal cover thickness is the ability of the proposed cover design to limit infiltration of water into waste disposal cells. In order to model the hydrologic performance of the proposed cover, historical rainfall records from Albuquerque International Sunport, dating from 1919 to 1996, were used. This historical record provides data for assessing both the short- and long-term responses of the cover design as well as determining the performance criteria for the 30-yr post-closure care and maintenance period.

HELP-3 (Schroeder et al. 1994) was specifically developed for designing landfill covers, but lacks rigorous mathematical flow calculations. This water-balance model uses simplified schemes to model both the infiltration of water through soil layers and the removal of water by evapotranspiration and overland flow. HELP-3 contains databases describing soil parameters, meteorological conditions, and vegetation; however, site-specific data for the MWL were used wherever possible to more accurately model the performance of the proposed cover.

UNSAT-H (Fayer and Jones 1990) was designed to predict performance of waste burial sites at Hanford, Washington, an area with low rainfall and relatively dry soil, conditions similar to Albuquerque, New Mexico. UNSAT-H uses a finite-difference implementation of a modified form of Richards Equation to predict unsaturated liquid and vapor flow in soil layers as well as water removal through plant roots (transpiration). UNSAT-H employs some of the best procedures for simulating the hydrology of soil covers and surface conditions such as overland flow and evapotranspiration (Khire et al. 1997), and was used in this analysis to complement HELP-3 results.

VS2DT (Healy 1990) is a U.S. Geological Survey (USGS) program for flow and solute transport in variably-saturated, single-phase flow in porous media. VS2DT uses a finite-difference approximation to solve the Richards Equation for flow, and the advection-dispersion equation for transport. VS2DT can also solve for first order radioactive decay and geochemical retardation. While it offers rigorous unsaturated flow mathematics, VS2DT is designed more for transport estimation than for landfill cover design, and does not include flows past a particular depth among its output tables. VS2DT is the least user-friendly of the three codes, but was used in this analysis primarily because it is a well-validated USGS code commonly used to predict flow and transport of water in the vadose zone.

5.3.2 Model Input Parameters

Input parameters for the models included precipitation and climate data, evapotranspiration data, soil hydrologic properties, thickness, and miscellaneous model-dependent input parameters such as evaporative zone depth and leaf area index. Table 5-3 summarizes the input parameters specific to HELP-3, UNSAT-H, and VS2DT.

Numerous preliminary modeling studies of the proposed MWL alternative cover were conducted prior to the formulation of the final results presented in this report. These studies focused on the sensitivity of the selected models to various input parameters. The results of these sensitivity analyses are presented in “Preliminary Unsaturated Flow Modeling and Related Work Performed in Support of the Design of a Closure Cover for the MWL” (Wolford 1998). The modeling results presented in this design report vary slightly from preliminary modeling results, reflecting more consistent use of input parameters between models. During the 1998 modeling efforts for the proposed MWL alternative cover, slight variations existed between the models in parameters including rooting depth, atmospheric tension, and nodal spacing. The modeling results presented in this report used more consistent input parameters between each model to ensure compatibility between models and to facilitate comparison of the results.

Precipitation Data. All three models were run using two discrete sets of precipitation data. The first set, the “Historical Precipitation Data,” included 65 yrs of daily rainfall recorded from 1932 to 1996 at Albuquerque International Sunport. The second set, the “Maximum Precipitation Data,” included the 8 heaviest years’ rainfall between 1919 and 1996, repeated 8 times for a total of 64 yrs. The heaviest rainfall years were 1919, 1929, 1940, 1941, 1982, 1986, 1988, and 1992. These rainfall data are representative of a significant climate change, and would have the greatest influence on the long-term performance of any cover system. Precipitation during these years ranged from 12 in. to more than 15 in./yr (30.5 to 38.1 cm/yr). These annual totals contrast markedly with the current average annual precipitation for the Albuquerque area of 8.5 in./yr (21.6 cm/yr).

Ecological studies performed by Waugh (1997), using proxy paleoclimate data (tree rings, packrat middens, lake sediment pollen, and archeological records), indicate bounding conditions for future climate states of twice the current precipitation at Monticello, Utah. This 64-yr rainfall data set adequately approximates and addresses a similar climate change in New Mexico for the proposed cover.

Soil Parameters*.* The soil parameters for the models were selected based upon the results from field and laboratory tests conducted on soil near the MWL. Several large-scale infiltration tests were conducted on soil west of the MWL to measure water movement through the soil, the effects of evapotranspiration, and unsaturated flow parameters. Data collected during these tests were used to select the most applicable soil parameters and to calibrate the HELP-3, UNSAT-H, and VS2DT models.

Evapotranspiration Data. Each model used synthetic PET data generated separately by the HELP-3 code for both the 65-yr historical rainfall and the 64-yr maximum rainfall runs.

Lower Boundary Conditions. HELP-3 does not require lower boundary conditions, so it was not necessary to model the soil beneath the cover with the HELP-3 model. The UNSAT-H and VS2DT models, however, include the soil beneath the cover extending to a depth greater than 100 ft. This was done to limit the potential for lower boundary conditions to influence predicted infiltration through upper model layers. The lower boundary condition for the UNSAT-H model was a unit gradient, simulating drainage by gravity. The VS2DT model does not have a unit-gradient option for a lower boundary condition. Instead, a coarse sand layer with an initial water content of 0.036 cubic centimeters (cm^3)/cm^3 was used for its lower boundary condition. This water content remained constant during the model runs.

Leaf Area Index. A maximum leaf area index of 1.0 was used in the HELP-3 model, and a maximum leaf area index of 0.8 was used in the UNSAT-H model. VS2DT does not use the leaf-area index parameter. The model results were found to be relatively insensitive to the leaf area index.

Model Calibration and Sensitivity Analysis. Model input parameters were tested by modeling three field infiltration experiments conducted on the soil west of the MWL. The data from these infiltration experiments were used to calibrate the three models.

5.3.3 Model Results

HELP-3, UNSAT-H, and VS2DT predicted minimal infiltration through vegetated soil covers of 1, 2, 3, 4, and 5 ft in thickness, with infiltration varying as a function of cover thickness, the precipitation data set, and the model used. In each case, the models predicted an average infiltration rate of less than 4 percent of the total precipitation, regardless of cover thickness or the model used. The modeling results are discussed in detail below.

Modeling Results Using Historical Precipitation Data. During the 65-yr historical record (1932 to 1996), a total of 561.2 in. (1,425.6 cm) of rain and snowfall was measured at Albuquerque International Sunport. The average annual precipitation during this period was 8.5 in./yr (21.6 cm/yr). Daily precipitation values measured during the 65-yr period were input into the three models (HELP-3, UNSAT-H, and VS2DT) and the total infiltration through soil covers varying in thickness from 1 to 5 ft was predicted. These results are summarized in Table 5-4, which presents the cumulative infiltration in cm predicted through each cover during the 65-yr period, as well as the average flux in cm/s and the average infiltration rate in cm/yr. The maximum volumetric moisture content (θ) predicted for the 65-yr period is also presented in Table 5-4.

Average Annual Infiltration. The HELP-3 modeling using historical precipitation data predicted average annual infiltration ranging from 0.43 cm/yr for a 1-ft cover to 0 cm/yr for 4- and 5-ft covers (Figure 5-3). The HELP-3 modeling results indicate that average annual predicted infiltration will be less than 2 percent of the total precipitation, regardless of cover thickness.

The modeling results for UNSAT-H and VS2DT (Figures 5-4 and 5-5) were similar to the results for HELP-3. In each case, the predicted average annual infiltration through the various covers modeled was only a small percentage of the total precipitation. All three models showed a significant decrease in the average annual infiltration as the cover thickness was increased from 1 to 3 ft (Figures 5-3 through 5-5).

Cumulative Infiltration. Figures 5-6 and 5-7 present the cumulative infiltration predicted by UNSAT-H and VS2DT using historical precipitation data. The cumulative infiltration through a 1-ft cover over the 65-yr period of record varied from 41.5 cm (predicted by UNSAT-H) to 37.5 cm (predicted by VS2DT). HELP-3 predicted a cumulative infiltration of 28.0 cm through a 1-ft cover (see Table 5-3). A plot of cumulative infiltration versus time could not be generated for HELP-3 due to the limitations of the code.

For comparison, the total precipitation measured at Albuquerque International Sunport during the period from 1932 to 1996 was 561.2 in. (1,425.6 cm). The cumulative infiltration through a 1-ft cover predicted by HELP-3, VS2DT or UNSAT-H during this 65-yr period was less than 3 percent of the total precipitation, regardless of the model used, and was even less for covers of greater thickness.

Predicted Annual Infiltration through the Covers. The performance of the proposed cover was also evaluated on a year-to-year basis to compare infiltration rates between wetter and drier years. During the years of higher precipitation, the moisture content of the cover increases, and as a result, the hydraulic conductivity of the cover, which is a function of percent saturation, increases. Consequently, infiltration is greater during the wetter years. Similarly, during drier years, the lower moisture content of the cover results in a lower hydraulic conductivity and, therefore, lower infiltration.

Annual infiltration predicted by UNSAT-H through each cover using historical precipitation data is shown in Figures 5-8 through 5-12, which demonstrate cover performance under current climatic conditions, with higher infiltration during the wetter years, and lower infiltration during the drier years. Maximum infiltration during the wetter years falls off significantly as cover thickness is increased from 1 to 3 ft, but less significantly as cover thickness is increased to 4 and 5 ft. Negative infiltration values shown during several years for the 1- and 2-ft covers (Figures 5-8 and 5-9) indicate net upward flux during dry years, as evapotranspiration removes moisture from the soil below the cover.

Figures 5-13 through 5-17 show the corresponding annual flux through each cover in cm/s. The maximum annual flux through a 1-ft cover is predicted to be 8.1×10^{-8} cm/s. The maximum annual flux through a 3-ft cover is significantly lower, at 1.9×10^{-8} cm/s. As cover thickness is increased to 4 and 5 ft, maximum annual flux decreases only slightly, to 1.5×10^{-8} cm/s and 0.8×10^{-8} cm/s, respectively. Thus, the most significant performance is achieved by increasing cover thickness from 1 to 3 ft, with rapidly diminishing performance improvement achieved by increasing cover thickness to 4 and 5 ft.

Predicted Moisture Contents at Various Depths within the Proposed Cover. Figures 5-18 through 5-22 show predicted moisture contents at various depths in a 5-ft cover. These moisture contents were predicted by UNSAT-H using the historical precipitation data. Moisture contents in the upper few feet of the cover fluctuate dramatically (Figures 5-18 and 5-19), with increases due to precipitation, and decreases due to evapotranspiration. These fluctuations diminish with increasing depth, indicating that precipitation is stored primarily in the upper few ft of the cover, and is rapidly removed by evapotranspiration. Lower water contents at depth and the limited fluctuations of these water contents result in a unit gradient and a very low unsaturated hydraulic conductivity, which limits infiltration to very minute levels.

Modeling Results Using Maximum Precipitation Data. To be conservative and to approximate reasonable bounding conditions for future climate states, a second discrete set of precipitation data was modeled. These data included daily rainfall from Albuquerque International Sunport for the eight highest years on record. Precipitation during these years ranged from 12 to more than 15 in./yr (30.5 to 38.1 cm/yr). Maximum precipitation data was constructed by placing these 8 yrs of unusually high rainfall back-to-back, and repeating this series 8 times for a total of 64 yrs of (artificial) record. The total precipitation applied to the models in the maximum precipitation data was 855.9 in. (2,174.1 cm), approximately 50 percent greater than the precipitation applied in historical precipitation data. The results are summarized in Table 5-5 and discussed below.

Average Annual Infiltration. The HELP-3 model using the maximum precipitation data predicted average annual infiltration ranging from 0.55 cm/yr for a 1-ft cover to less than 0.02 cm/yr for covers ranging from 2 to 5 ft in thickness (Figure 5-23). Thus, even with the maximum precipitation data, average annual infiltration through the soil cover is still less than 2 percent of the total precipitation.

The modeling results for UNSAT-H and VS2DT (Figures 5-24 and 5-25) were similar using the maximum precipitation data. In each case, the average annual infiltration through the various covers was only a small percentage of the total precipitation. All three models showed a significant decrease in average annual infiltration as the cover thickness was increased from 1 to 3 ft (Figures 5-23 through 5-25).

Cumulative Infiltration. Figures 5-26 and 5-27 present the cumulative infiltration predicted by UNSAT-H and VS2DT using the maximum precipitation data. All soil covers ranging in thickness from 1 to 5 ft proved to be effective in minimizing infiltration, with cumulative infiltration predicted to be no more than 77.7 cm during the 64-yr period. This corresponds to less than 3.6 percent of the 855.9 in. (2,174.1 cm) of precipitation applied using the maximum precipitation data. These results indicate that even if the climate changes dramatically and precipitation increases by 50 percent, a vegetated soil cover would significantly reduce infiltration.

Predicted Annual Infiltration through the Covers. The performance of the proposed cover using maximum precipitation data was also evaluated on a year-to-year basis using the results from UNSAT-H. Figures 5-28 through 5-32 present the predicted annual infiltration through covers of varying thicknesses under significantly wetter climatic conditions. Using maximum precipitation data, infiltration exceeds 2.5 cm/yr through a 1-ft cover. Peak annual infiltration rates decrease to 1 cm/yr for a 3-ft cover and approximately 0.75 cm/yr for a 5-ft cover.

Figures 5-33 through 5-37 show the corresponding annual flux through each cover in cm/s under the maximum precipitation scenario. The maximum annual flux through a 1-ft cover was predicted to be 8.8 H 10^{-8} cm/s. The maximum annual flux through a 3-ft cover was predicted to be 3.1 H 10^{-8} cm/s, while the maximum annual flux through a 5-ft cover was 2.3 H 10^{-8} cm/s. Again, the most significant performance improvements are achieved by increasing cover thickness from 1 to 3 ft, with performance improvements rapidly diminishing when increasing cover thickness to 4 and 5 ft.

Performance Modeling Summary. As recommended by the EPA, performance modeling was conducted in order to demonstrate that the proposed cover minimizes infiltration and complies with the minimum 30-yr performance criteria. The water-balance model, HELP-3, along with two additional models, UNSAT-H and VS2DT, were used to predict the performance of soil covers ranging in thickness from 1 to 5 ft. All three models demonstrate that deployment of a vegetated soil cover for final closure of the MWL will reduce infiltration into the landfill to a small percentage of the total precipitation. The models also demonstrate that a 3-ft-thick vegetated soil cover is the minimum design. It is apparent that additional cover thickness does not lead to significantly better performance.

Although the modeling suggests that a 1- or 2-ft-thick cover will significantly limit the average rate of infiltration, "spikes" or peaks may occur during years with higher precipitation. These infiltration spikes are fewer and lower in magnitude as the cover thickness is increased to 3 ft, and as the storage capacity of the cover increases. The storage capacity of a 3-ft cover is 50 percent greater than the storage capacity of a 2-ft cover, and would provide an additional degree of conservatism should there be extreme precipitation events or significant, long-term climatic changes.

Increasing the cover thickness to 4 or 5 ft results in limited improvement in cover performance, yet increases construction costs significantly. Cover construction costs are directly proportionate to the thickness of the cover, and the optimal cover design is one that meets the performance criteria with the least cover thickness (Ankeny et al. 1997). A reduced finished elevation above grade would provide additional environmental benefits, reducing the cover's exposure to wind and water erosion.

Under current climatic conditions, annual infiltration through a 3-ft cover is typically less than 0.3 cm and rarely exceeds 0.5 cm (Figure 5-10). The proposed cover's performance will actually approximate that of a 4- or 5-ft cover due to the placement of subgrade soil. Several feet of compacted fill will be placed over the existing landfill surface prior to construction of the actual cover (see Plate 5—Final Cover Cross Sections).

5.4 Bio-Intrusion

Burrowing by small and large mammals is a potential pathway for transfer of hazardous constituents to the accessible environment (Kennedy et al. 1985; Hakonson et al. 1992; Gee and Ward 1997). Burrowing animals may physically transfer subsurface contaminated soil and waste to the surface and increase water infiltration by decreasing the bulk density of the soil or creating channels for preferential flow. Burrowing small mammals have been observed at the MWL and are a potential pathway for transfer of hazardous constituents from waste disposal cells to the accessible environment.

The presence of small and large animal burrows and their effect on cover performance has been a concern for scientists and engineers at the Hanford site in Washington for many years (Gee and Ward 1997). Gee summarizes observations at Hanford as follows:

> "From the results of lysimeter tests performed at the Animal Intrusion Lysimeter Facility, the presence of small mammal burrows does not appear to have a significant influence on the deep percolation of water. During the summer months, more water is lost from plots with animal burrows than from plots with no animal burrows. During winter months, plots with animal burrows and plots without animal burrows gain water. In addition, water does not infiltrate below 36 in., even though burrow depth exceeds 48 in. The lack of significant infiltration at depth and the overall loss of water in the lysimeters occurs even though 1) no vegetative cover exists, 2) no runoff is allowed, 3) burrow densities in the lysimeter are greater than burrow densities found in natural settings,

> 4) extreme rainfall events are applied frequently, and 5) animal burrows are deeper in the lysimeter than in natural settings. The overall water loss from soils with small mammal burrows appears to be enhanced by a combination of soil turnover and subsequent drying, ventilation effects, and high ambient temperature."

Similar water loss results have been observed at the Arid Land Ecology Reserve at the Hanford site for large mammal burrows excavated by coyotes and badgers in search of prey. Large mammals do appear to cause increased deep infiltration but much of this water is removed by co-located, dense vegetation. The density of vegetation near large mammal burrows was significantly greater than in adjacent, undisturbed areas away from the burrows (Gee and Ward 1997).

A bio-intrusion barrier consisting of rock (gravel and cobbles) could be placed at depth within a cover to restrict burrowing mammals. Plant root growth also may be restricted to soil above the bio-intrusion barrier. If roots are restricted to the soil above the intrusion barrier, the net evapotranspiration and effective water storage capacity of the cover system would be significantly reduced. In this case, depth of emplacement of a biological barrier within the soil profile is paramount.

In 1993, researchers at Idaho State University and the Environmental Research Foundation initiated a large-scale experiment to compare the performance of two soil-plant cover designs that included biological intrusion barriers at depths of 0.5 and 1.0 meters (m) (Anderson 1997). The objectives of the study were to examine the effects that placing a rock intrusion layer in a soil cap would have on water infiltration, water storage capacity, and plant rooting depths. Anderson summarizes their observations as follows:

> "Biobarriers are clearly an impediment to root growth. We have only seen extraction below the biobarriers when volumetric water content below the barrier was initially at least 25 percent. There may be a threshold of water content below which plants are unable to detect the presence of extractable water below a biobarrier. Plants can, however, penetrate biobarriers and extract water from the soil if water content is sufficiently high."

Another study performed by Anderson (Anderson and Forman 2002) determined that if a bio-intrusion barrier is used, a 0.5-m gravel/cobble barrier should be placed at the bottom of a 1.2-m homogeneous soil reservoir.

The final phase of nearly two decades of research on bio-intrusion by Idaho State University at INEEL was published in 2002 (Anderson and Forman 2002). Two cap configurations were recommended including a soil-only cap consisting of a 2-m depth of homogenous soil or a cap of a 1.2-m depth of homogenous soil overlying a 0.5-m thick gravel/cobble intrusion barrier. Caps constructed according to either of these configurations should preclude virtually any precipitation from reaching interred waste. A major advantage of the soil-only cap is simplicity of construction. Anderson and Forman (2002) recommend that if a biobarrier is used, it should be placed at the bottom of the soil reservoir.

Field studies at the MWL have shown that maximum root density occurs in the upper 6 to 8 in. of soil. Less dense roots have been observed to depths of 18 in., and root growth rarely exceeds 24 in. Root growth appears to be limited to a region within the upper 2 ft of the soil profile, most likely the area where extractable water is most available. Emplacement of a woven steel mesh at a shallow depth (e.g., below the topsoil layer) would discourage small and large mammals from burrowing deep into the cover and would have little effect on root density and depth or the effective water storage capacity of the cover system. The cost of such a barrier could be significant, however, and the durability of a steel bio-intrusion barrier has not been established. A 2-ft gravel/cobble intrusion barrier placed at the bottom of the soil reservoir would be a more suitable approach. Rock is less expensive, readily available from off-site suppliers, and more durable.

5.5 Subsidence

Waste in disposal cells at the MWL may contain significant void space resulting from incomplete filling of waste containers, limited internal compaction of contents, and void space between containers. These void spaces may induce subsidence as waste containers deteriorate and/or collapse over time. Rates of decay will vary for different containers. Although subsidence has the potential to damage a landfill cover, predicting subsidence effects is very difficult because of the heterogeneous nature of the waste forms, backfill materials, and local climatic conditions.

Cover designs that include compacted clay soil, flexible membrane liners, and geosynthetic clay liners would not function as intended when subject to tensile and shear stresses during differential subsidence. These common liners, geomembranes, and geosynthetic materials require rigorous quality control during construction and are easily damaged during installation on an operational scale. The proposed MWL alternative cover design, consisting of a thick layer of native soil, is constructed without rigid layers, and thus will accommodate differential subsidence without undue impairment of its performance. During the institutional control period, soil readily available in TA-3 will be added to the cover as needed to correct subsidence resulting from degradation of buried waste containers. Topsoil will be replaced according to original construction specifications. This provides additional assurance for adequate long-term performance of the cover system.

5.6 Runoff and Run-On Control

The amount of water available for infiltration is a function of the amount of precipitation that falls on the cover surface less the amount of water that runs off and away from the cover surface. The surface of the proposed cover has been designed with a central crown and a 2-percent slope to promote runoff of surface water while minimizing erosion of the topsoil layer.

A design requirement of RCRA is that the cover withstands a 25-yr, 24-hr storm event. Storm water run-on will be prevented from impacting the cover by constructing an earthen swale along the eastern perimeter of the site. Run-on will be diverted at the perimeter and directed to the south and the north toward the surrounding landscape. Cover surface erosion from storm water runoff will be mitigated by native vegetation and admixed gravel in the topsoil layer. Cover surface runoff will be directed toward the surrounding landscape.

For the Albuquerque area, the rainfall amount for a 25-yr, 24-hr storm is 2.5 in. (City of Albuquerque 1993). The calculations for a 25-yr, 24-hr storm are presented in Appendix B.

5.7 Erosion Control

Erosion of the proposed cover by wind and water is a significant design consideration. The design should minimize the effects of wind and water erosion of the surface, side slopes, and toe of the cover. The cover has been designed to have native vegetation growing over the surface, side-slopes, and toe throughout the design life. The presence of vegetation on the cover surface combined with the presence of gravel admixed with the topsoil layer will significantly reduce the amount of fine soil lost from wind and water erosion.

Wind erosion studies by Ligotke and Klopfer (1990) and Ligotke (1993; 1994) at the Pacific Northwest National Laboratory Aerosol Wind Tunnel Research Facility have demonstrated that soil and gravel admixtures with particle sizes of 3 to 7 millimeters provide superior surface protection. The best gravel admixtures reduced surface deflation rates by greater than 96 percent compared to unprotected surfaces. Water erosion studies by Walters et al. (1990) and Gilmore and Walters (1993) determined that the most dominant factor in reducing runoff and sediment yield was the presence of a vegetated cover.

Erosion studies by Finley et al. (1985) and soil water balance studies by Waugh et al. (1994) and Sackschewsky et al. (1995) demonstrate that moderate amounts of gravel mixed into cover topsoil will control both water and wind erosion with little effect on plant growth or soil-water balance. As wind and water pass over the surface, some winnowing of fines from the admixture occurs, leaving a vegetated erosion-resistant pavement (Waugh 1997). The amount of gravel used in the admixture is a major design consideration. If too much gravel is used, plant transpiration and surface evaporation could be significantly reduced which would increase the potential for water infiltration. Overall, the presence of a 15 to 30 percent gravel admixture is effective in reducing the deflation of fine soil from a cover surface by wind and water erosion (Ligotke 1994).

5.7.1 The Universal Soil Loss Equation

The empirical equation known as the universal soil loss equation (USLE) was devised by Wischmeier and Smith in 1965. The EPA recommends use of the equation to estimate average annual soil loss from a proposed cover. The equation is as follows:

$$A = R\ K\ LS\ C\ P$$

where

A	= Estimated average annual soil loss in tons/acre/yr;
R	= Rainfall erosivity factor;
K	= Soil erodibility factor;
LS	= Topographic factor;
C	= Surface-cover factor; and
P	= Management factor.

A modified version of the USLE (EPA 1980) was employed to estimate the soil erosion potential from the surface and side slopes of the proposed cover by overland runoff. The modified universal soil loss equation (MUSLE) is

$$A = R\ K\ (LS)\ (VM)$$

where

A	= Estimated average annual soil loss in tons/acre/yr;
R	= Rainfall factor;
K	= Soil erodibility factor;
LS	= Topographic factor; and
VM	= Erosion control factor.

Soil loss was calculated using the MUSLE for: 1) no vegetation yet established, straw mulch applied to cover and side slopes at 2 tons/acre, and 2) vegetation partially established over cover and side slopes 12 months after seeding, one-half of the straw mulch remaining. The estimated average annual soil loss from the cover surface and side slopes is 0.77 tons/acre/yr and 0.08 tons/acre/yr, respectively. These losses are well below the design requirement recommended by the EPA (EPA 1989) of less than 2 tons/acre/yr. The overland runoff erosion calculations using the MUSLE are presented in Appendix B.

The MUSLE contains inherent limitations. In general, erosion is not a steady, orderly, easily predictable process. Much of it takes place episodically. A single torrential rainfall striking a barren soil may cause more soil loss in a few hours than a whole season's "normal" rainfall over a fully vegetated cover. Inherent limitations include:

- The MUSLE is not intended for estimating erosion in a particular year, but rather estimating long-term averages.

- The condition of the cover is not static over time, so the erosion will vary from year to year. For example, the cover will initially have little vegetation and will be more susceptible to erosion. After initial erosion, remaining soil may be less susceptible than the initial surface, because the more susceptible fractions are lost first.

- The slope factor, LS, assumes that the central, gently sloping portion of the cover surface does not increase the amount of runoff that occurs down the side slopes, i.e., all rain falling on the cover surface infiltrates rather than running off the surface. This assumption may not be valid for the most intense storms.

- Wind may cause erosion from the cover that is not accounted for by the MUSLE.

5.7.2 The Wind Erosion Equation

The wind erosion equation (WEQ) was used to estimate the soil erosion potential from the surface and side slopes of the proposed cover by wind. The WEQ was introduced in 1963 because it was recognized that wind could be a major geological phenomenon for erosion. In 1997, the WEQ was modified by the U.S. Department of Agriculture (USDA 1997) in the National Agronomy Manual.

The WEQ is

$$E = f\,[(IKC)\,LV]$$

where

E	= Estimated average annual soil loss in tons/acre/yr;
I	= Soil erodibility index;
K	= Ridge roughness factor;
C	= Climatic factor;
L	= Unsheltered distance; and
V	= Vegetative factor.

Soil loss was calculated using the WEQ for: 1) no vegetation yet established, straw mulch applied to cover and side slopes at 2 tons/acre, and 2) vegetation partially established over cover and side slopes 12 months after seeding, one-half of the straw mulch remaining. In both cases, the estimated average annual soil loss from the cover surface and side slopes is 0 tons/acre/yr. The wind erosion calculations using the WEQ are presented in Appendix B.

A number of inherent limitations are also present in the WEQ. These limitations include:

- When the unsheltered distance, L, is sufficiently long, the transport capacity of the wind for saltation and creep is reached. If the wind is transporting all of the soil it can carry across a given surface, the inflow into the downwind is equal to the outflow for saltation and creep. The net soil loss is then only the suspension component. This does not imply a reduced soil erosion problem because theoretically there is still the estimated amount of soil loss in creep, saltation, and suspension leaving the downwind edge of the surface.

- Surface armoring by nonerodible gravel, snow cover, and inherent seasonal change is not addressed in the soil erodibility factor, I.

- The WEQ does not estimate soil erosion from single storm events.

5.8 Slope Stability

A common problem leading to cover failure is slope failure at barrier interfaces caused by excessive soil moisture, especially on steep side slopes. Documented slope failures have been attributed to slip planes created at synthetic layer interfaces (Daniel and Gross 1995). Covers usually contain multiple layers of earthen and synthetic materials. Performance usually depends upon maintaining discrete boundaries between earthen layers and synthetic materials during construction and throughout the design life of the cover system. Interfaces between layers are susceptible to lateral flow of infiltrating water that leads to reduced friction and subsequent failure. Layer interfaces are also susceptible to root and animal intrusion and soil illuviation.

The proposed cover has been designed to mitigate all such potential failure mechanisms. The proposed cover is centrally crowned and sloped at 2 percent to the side slopes that, in turn, are tied to the surrounding landscape at 6:1. The proposed cover will not be susceptible to failures common to conventional, multi-layer, multi-component designs. Slope stability calculations are presented in Appendix B.

5.9 Vegetated Cover

The influence of vegetation on the hydrologic relationships of the proposed cover cannot be overemphasized. Vegetation will play a key role in stabilizing the newly constructed surface by mitigating wind and water erosion. Vegetation will also play a key role in maintaining the cover's water balance, significantly reducing the amount of water available for contact with disposal cell waste and subsequent contaminant transport. Vegetated covers are also extremely versatile, adapting to climatic change through natural selection and severe disturbance (fire and drought). Once native flora is established, it will persist indefinitely with little or no maintenance.

The flora in the TA-3 area is predominantly Mesa and Desert Grassland and, to a lesser degree, Sandsage and Chihuahuan Desert Shrubland. Flora exhibit influences from the Great Basin Desert, Rocky Mountains, Chihuahuan Desert, and the Great Plains. Typical plant species occurring in the area include grasses (black grama, dropseed, galleta, burrograss, bush and ring muhly), wildflowers (globemallow, aster, spectacle pod), and shrubs (sandsage, winterfat, mormon tea, yuccas, prickly pear, snakeweed) (Sullivan and Knight 1992).

The vast majority of TA-3 is dominated by grassland vegetation. Specifically, it represents the Mesa and Desert Grassland habitat types. The extreme western portion of the TA-3 area falls into the Sandsage Shrubland vegetation habitat. Most of the vegetation at the MWL is composed of elements of the Black Grama Grass Series. This series includes black grama, dropseed, threeawn, galleta, Indian ricegrass, and burrograss.

The desired plant community for the MWL vegetated cover is a desert grassland. Grasses root at shallower depths than shrubs and, when they do root deeply, the roots are fibrous, thinner, and less damaging to the cover than the woody roots of shrubs and trees. Grass roots form a dense and interwoven fibrous network that binds the soil. Grasses concentrate their biomass close to the surface, forming a protective mat that provides protection against wind and water erosion.

5.10 Radon Gas Emission

Emission of radon gas from the MWL was investigated in 1997 by SNL/NM Environmental Management. No significant difference between the MWL and the background measurements in terms of median, mean, and standard deviation was observed. The radon flux measurement technique employed for this study was capable of detecting radon flux in the range of 1 to 2 percent of the 20 $pCi/m^2/s$ limit listed in 10 CFR 834.

6. Proposed MWL Alternative Cover Design

The proposed MWL alternative cover design drawings are provided on Plates 1 through 6. Construction specifications and the construction quality assurance plan are included in Appendices C and D, respectively. The design drawings include plates showing the MWL existing site plan, subgrade grading plan, final cover grading plan, final cover cross-sections, and miscellaneous details. The cover will be placed over the original 2.6-acre landfill surface and tied to the surrounding landscape. The cover will include six neutron probe access holes and fiber optics cables deployed in two lifts for monitoring water infiltration into the cover. A vegetated topsoil layer admixed with 25 percent 3/8-in. crushed gravel will be applied to maintain water balance and mitigate water and wind erosion. The components of the proposed cover are shown in Figure 6-1 and are discussed in the following sections.

6.1 Existing Landfill Surface

The existing landfill surface will be prepared for cover construction by clearing and grubbing. Perimeter fences will be removed and the landfill surface cleared of vegetation and rock. Grubbing will not exceed 3 in. in depth to minimize disturbance to surface soil and conform with radioactive area soil contamination requirements. Grubbed material will be disposed of according to SNL/NM waste management policy and procedures. The landfill surface will be compacted to achieve the appropriate density in preparation for subgrade fill.

6.2 Subgrade

Subgrade fill will be obtained from the CAMU soil stockpiles located approximately 1.5 miles south of the MWL. Soil stockpiled at the CAMU has been tested to verify engineering properties specified in the design. Subgrade fill will be placed in lifts of uniform thickness, moisture conditioned, and compacted by spreading and compacting equipment. Approximately 6,100 cubic yards (yd^3) of subgrade fill will be placed and graded to establish a central crown and uniform 2-percent slope in preparation for the native soil layer.

6.3 Native Soil Layer

Native soil layer fill will also be obtained from the CAMU soil stockpiles. Approximately 9,900 yd^3 will be placed and graded to construct the native soil layer, which will act as a water storage reservoir, retaining and storing water that infiltrates through the topsoil layer until it can be removed by evapotranspiration. Native soil layer fill will be placed in lifts of uniform thickness, moisture conditioned, and compacted by spreading and compacting equipment. The native soil layer will be graded to maintain the central crown and the uniform 2-percent slope. Any grade stakes used on the project will be removed and backfilled with cover material to meet design specifications.

6.4 Bio-Intrusion Barrier

Woven steel mesh placed between the native soil layer and the topsoil layer was considered as a potential barrier to burrowing mammals. The steel mesh would need to be galvanized or vinylized at a minimum, or made of stainless steel to provide adequate long-term protection from corrosion and leaching of metals. The capital cost of a galvanized or vinylized, 5/8-in. woven steel mesh barrier is \$1.89/square ft (ft^2) and \$2.10/ft^2, respectively (Mayes 1999). The capital cost of a stainless steel, 5/8-in. woven mesh barrier is \$13.44/ft^2 (Mayes 1999). The cost of a galvanized or vinylized bio-intrusion barrier would exceed \$300,000. The cost of a stainless steel bio-intrusion barrier would exceed \$2,000,000. If a steel mesh barrier were to be deployed, it would not be effective against ants, which represent the largest biomass that could invade a soil cover (Reynolds 1998). Placement of a woven steel mesh is a costly design consideration. The long-term performance of steel mesh is unknown and corrosion of the steel may pose additional risk to the environment due to the release of hazardous constituents.

A more suitable approach would be to place a gravel/cobble bio-intrusion barrier below the subgrade or below the native soil layer (Anderson and Forman 2002). This barrier would need to be a minimum of 2 ft thick. However, a bio-intrusion barrier is not considered a necessary design element for the MWL because burrowing by mammals has not been a significant problem at the site. The added height and footprint of a cover that includes a 2-ft-thick bio-intrusion barrier will increase construction cost, finished elevation, and exposure to the elements.

6.5 Topsoil Layer

The topsoil layer will serve as the vegetative cover and erosion protection layer. A 25-percent 3/8-in. crushed gravel admixture will be placed that is designed to control erosion without adversely affecting desirable vegetation and soil-water balance. The topsoil layer will consist of approximately 2,200 yd^3 of surface soil obtained from a site directly west of the MWL, minimally compacted to facilitate root development.

6.6 Vegetation

Following installation of the topsoil layer, reclamation seeding activities will take place. The designated native vegetative seed mix will be applied to the cover, lay-down area, borrow areas, and any other area disturbed by construction operations. The surface will be fertilized, drill-seeded, mulched and crimped. The native seed mixture is based upon recommendations from both the City of Albuquerque and biological assessments of TA-3. It will consist of black grama, alkali sacaton, sand dropseed, galleta grass, and crested wheat grass, which has become naturalized in western North America through its extensive use in range-land rehabilitation of disturbed sites. The initial plant community will be an approximation of the natural analog but will gradually develop into a climax community indistinguishable from the natural analog.

7. Cover Performance Monitoring

The proposed MWL alternative cover will incorporate a redundant infiltration monitoring system that will include both baseline, neutron probe access holes and advanced, distributed fiber optics. The cover infiltration monitoring system will be coupled with a shallow vadose zone monitoring system deployed directly beneath the landfill. The shallow vadose zone monitoring system will consist of three neutron probe access holes drilled at a 45 degree (°) angle to a depth of 142 ft bgs. The "close-coupled" cover and shallow vadose zone monitoring system will function as an "early warning system." Early detection of a potential threat to groundwater will allow corrective action to be initiated before significant contaminant migration occcurs. This redundant monitoring approach was designed to protect groundwater resources and is proposed for the MWL because of its simplicity, low cost, and long-term viability.

The close-coupled monitoring system will be monitored closely once the alternative cover has been deployed. The frequency and duration of post-closure monitoring will be established in consultation with the NMED and formally documented in the MWL post-closure care plan.

7.1 Cover and Vadose Zone Monitoring

The cover and vadose zone monitoring system will provide infiltration and performance information, early detection of potential contaminant migration from the landfill, as well as establishing background and trend analysis information. The MWL is one of three landfills at SNL/NM that will be covered and require long-term care, monitoring, and environmental surveillance. The close-coupled cover and shallow vadose zone monitoring system is a simple yet comprehensive system designed to meet the intent of long-term RCRA and DOE performance requirements and reduce labor-intensive, long-term groundwater monitoring, resulting in substantial cost savings.

7.1.1 Cover Infiltration Monitoring

The proposed MWL alternative cover will contain six vertical neutron probe access holes, two in each of the original disposal areas (Figure 7-1). Each access hole will be constructed of 2-in.-inside-diameter 6061-T6 aluminum (commonly known as aircraft aluminum) casings and extend through the cover an additional 2 ft into the original landfill surface. The casings, which will be fitted with locking top-caps, will extend 1 ft above the vegetated, topsoil layer for easy access (Figure 7-2).

Once the cover construction has been completed, the aluminum casings will be installed by hand-augering 2.5-in.-diameter boreholes through the cover and driving the aluminum casing to the proper depth. Each casing will be fitted with a perforated, tapered drive-tip. A 1- by-1-ft concrete pad will be placed at the collar of each casing to prevent preferential flow down the annulus.

The proposed MWL alternative cover will also contain a distributed fiber optics infiltration monitoring system that will be deployed in two lifts. The lowermost lift will be installed on the prepared subgrade surface (Figure 7-3). The uppermost lift will be installed 1.5 ft above the prepared subgrade surface between the third and fourth lifts of native soil (Figure 7-4). The uppermost fiber-optic grid will be transposed 90° from the lower grid to maximize spatial resolution and increase monitoring efficiency.

7.1.1.1 Neutron Moisture Monitoring

Neutron moisture probes take advantage of the neutron moderation process in which high-energy neutrons emitted from a radioactive source are moderated, or slowed, by collisions with surrounding atoms. Slowed neutrons, also called thermalized neutrons, emit a pulse of detectable energy, which is counted in a neutron detector contained in the neutron probe.

The neutron moderation process is dominated by neutron-hydrogen collisions that result in appreciable neutron moderation. Thus, relatively high hydrogen density (near the source) results in rapid neutron moderation. Hydrogen in geologic materials occurs as water, mineralogically bound H^+, organic soil components, and organic liquids (solvents, petroleum fuels). Water is nearly always the greatest source of hydrogen in soil. Therefore, as dry soil becomes wet, the thermalized neutron density near a neutron source and detector increases. The radius of influence for neutron moisture probes depends upon source strength, hydrogen density, soil density, and chemistry. Practical limits are from 6 to 24 in. from the point between probe source and detector. The cloud of thermalized neutrons is compact in wet and/or dense soil, and expanded in dry and/or loose soil (Jury et al. 1991).

A neutron probe consists of a compact americium-beryllium (Am-Be) source and a thermal neutron detector that can be lowered into an access hole for readings at discrete footage intervals. The Am-Be source emits high-energy neutrons that collide with hydrogen nuclei (moisture) in the surrounding soil. Hydrogen nuclei substantially slow the neutrons, and thus the neutron counts by the detector are linearly increased with the amount of hydrogen in the soil. A California Pacific Nuclear (CPN) Model 503DR Hydroprobe containing a 50-millicuries Am-241:Be neutron source will be used for monitoring the cover and shallow vadose zone.

The neutron moisture probe is increasingly being applied to address characterization and infiltration issues at environmental sites undergoing long-term care. Neutron moisture measurement was established in agriculture in the 1960s before environmental monitoring needs were identified (Kramer et al. 1992). Neutron moisture monitoring has become the industry standard for soil moisture measurement and its operation and data interpretation is well established. The technique's principal advantage is repeatability, precision, and long-term viability. The access-hole casings are not permanently installed, which allows for periodic calibration of the neutron probe.

The number and location of neutron probe access holes is guided by practical considerations and knowledge of vadose zone hydrologic processes. The number and location of the MWL cover and shallow vadose zone neutron probe access holes was determined in consultation with the NMED HWB and the Oversight Bureau staff. Neutron moisture monitoring and data collection will follow field operating procedures (FOP) as outlined in SNL/NM ER FOP 95-21, "Use of the CPN Model 503 Hydroprobe for Subsurface Moisture Measurement." The density and frequency of moisture measurements per neutron probe access hole will be determined in consultation with the NMED and included in the MWL post-closure care plan.

7.1.1.2 Fiber Optics Distributed Temperature Moisture Monitoring

When light is guided by an optical fiber, energy loss occurs because of Rayleigh, Raman, and Brillouin scattering. Rayleigh scattering arises as a result of variations in the density and composition (refractive index) of the fiber core. Raman scattering arises as a result of molecular vibrations, and Brillouin scattering arises as a result of bulk vibrations. A fraction of the scattered light is directed back to the source of the light and is split off by a directional coupler, optically filtered, and captured by a detector. By pulsing the input optical signal to a length of fiber and monitoring variations in the returned backscattered intensity, spatial variations in the fiber scattering coefficient, or attenuation, can be determined. This forms the basis of optical time-domain reflectometry (OTDR), which is a well-established technique for fault/imperfection location and diagnostics in fiber communications applications. In environmental sensing applications, OTDR can be used to detect localized measurand-induced (temperature) variations in the scattering coefficient of a continuous sensing fiber. This phenomenon forms the basis of the distributed (continuous length of fiber) temperature sensing system that will be deployed in the cover.

The basic Rayleigh scattering signal, although the strongest component of the scattered light spectrum, is only weakly sensitive to temperature. The Raman scattering signal, however, is temperature-sensitive, although it produces the lowest intensity of the backscatter components. The Raman signal is split into two bands displaced symmetrically about the incident wavelength: Stokes, which is the band of longer wavelengths; and Anti-Stokes, which is the band of shorter wavelengths. The Anti-Stokes band exhibits a distinct sensitivity to temperature, whereas the Stokes band is weakly sensitive to temperature. Thus, the Anti-Stokes band forms the temperature sensitive signal used for processing and the Stokes band forms the reference signal used for fiber integrity. For this reason, a measurement of the ratio of Stokes and Anti-Stokes backscattered light in a deployed fiber will provide an absolute indication of the temperature of the soil, irrespective of light intensity, launch conditions, fiber geometry, or even the material composition of the fiber (Dakin 1995).

The position of a measurement along a given fiber optic cable is calculated from the time taken for the signal to travel down and back within the fiber. This is possible because the speed of light propagation is known for each type of signal. Distributed fiber optic temperature sensing using propagation delays of light traveling through a fiber and the temperature dependence of Raman scattering was demonstrated in the mid-1980s and has since been developed into many commercial products. York Sensors Ltd. of the United Kingdom and Pruett Industries of Bakersfield, California, have deployed such fiber optic sensors in industrial, oil field, and geothermal applications in the United States.

The distributed fiber optics infiltration monitoring system proposed for the cover is based upon the observation that a change in water content in soil causes a corresponding change in the thermal conductivity of the soil. When constant power is dissipated from a line heat source (in this implementation an electrically conducting wire bundled with the optic fiber), the temperature increase near the heat source will depend upon the thermal conductivity of the surrounding medium. As the water content in soil increases, so does its thermal conductivity. The temperature increase as measured by the fiber optic will be reduced because of the conduction of the thermal energy away from the heat source. Measurement accuracy is +/- 1° Celsius with resolution of approximately 1 m over the entire length of the cable. The optical fiber and line heat source are bundled in a hermetically-sealed stainless steel cable that is 1/4 in. in diameter. The cable will be placed horizontally in surveyed grids in the lifts and configuration shown in Figures 7-3 and 7-4.

An important advantage of fiber optic sensors is the ability to provide passive sensing of a wide variety of physical parameters. This means not only that the sensor operates without the need for electrical power, but also that the overall system, including the input-output fibers which serve as the telemetry links, is electrically passive, and thus the whole system exhibits low intrinsic susceptibility to the effects of electromagnetic interference. Experience to date in environmental monitoring indicates that electrically-based sensors are extremely susceptible to electrical storms, particularly in the semiarid and arid west and southwest. Therefore, issues of electrical passivity are of paramount importance when a sensor is required for long-term monitoring and performance in an electrically noisy environment.

Optical sensors are found in two primary forms: intrinsic and extrinsic. Intrinsic sensors, or “all-fiber” sensors, indicate that the sensing takes place within the fiber itself. Extrinsic fiber optics sensors, or “hybrid sensors,” indicate that the sensing takes place in a region outside the fiber. Extrinsic sensors can be thought of as “black box” sensors for which fibers are used to transmit light to the box and transmit information back. The optical sensor to be deployed at the MWL is an intrinsic sensor.

Virtually any environmental effect can be converted to an optical signal for interpretation. The key is often to design the sensor so that the desired environmental effect is sensed. Intrinsic sensors are particularly suited for use in applications where monitoring of a single measurand is required at a large number of points or continuously over the path of a fiber. Examples of application areas include: 1) stress monitoring of large structures such as buildings, bridges, dams, storage tanks, aircraft, and spacecraft; 2) temperature profiling of power transformers, generators, reactor systems, furnaces, and fire detection systems; 3) leakage detection in pipelines; and 4) embedded sensors in composites for use in real-time evaluation of stress, vibration, and temperature (Kersey 1991).

7.2 Shallow Vadose Zone Moisture Monitoring

Three angled, 4.5-in.-outside-diameter, 3.75-in.-inside-diameter access holes will be installed in the shallow vadose zone directly beneath the MWL: two to the west and one to the east of the cover (Figure 7-5). The vadose zone access holes will be spaced at equal increments, with the east access hole bisecting the two west access holes, and will be installed under separate contract using the Resonant Sonic drilling technique. Resonant Sonic is the preferred drilling technique because it literally fluidizes and displaces the surrounding soil as the drill-string advances, creating a very tight fit between the drill-string and the formation. No cuttings are generated and no fluids are used to advance the drill-string.

Background values for the soil volumetric moisture content will be measured during installation of the neutron probe access holes. Each access hole will be collared approximately 10 ft outside the toe of the cover side slopes. Each access hole will be drilled 200 linear ft at 45° to a true vertical depth of 142 ft (Figure 7-6). As each access hole is completed at 200 ft, the 4.5-in. sonic drill-string will be left in place downhole and unscrewed at the surface leaving about 2 ft above grade. Each sonic drill-string will remain open to the vadose zone for future vadose zone monitoring. A protective cover constructed of steel pipe will extend 2 ft below grade and 3 ft above grade. Each protective cover will be fitted with locking caps and secured with locks. A 3- by-3-ft concrete pad will be placed around each protective cover to prevent preferential flow down the annulus. Protective stanchions, 4 in. in diameter, will be placed at the outer corners of the concrete pad. The stanchions will be set 2 ft below grade and 3 ft above grade.

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8. Conclusions

The EPA has established performance-based criteria for RCRA Subtitle C covers for hazardous and radioactive waste landfills, but allows for alternative designs based upon a demonstration that the alternative design, together with natural site conditions, prevents the future migration of hazardous constituents into the groundwater or surface water. The NMED, the lead regulatory agency, has adopted EPA's 40 CFR 264 regulations and likewise accepts alternative cover designs as long as the design meets the intent of the regulations.

In this report, SNL/NM has demonstrated that the proposed MWL alternative cover meets the performance-based criteria in 1) minimizing infiltration of water through the closure cover; 2) minimizing maintenance and erosion; 3) promoting drainage; 4) accommodating subsidence; and 5) having a permeability equal to or less than the MWL subsurface soil.

Performance modeling indicates that a 3-ft-thick, vegetated soil cover is the most propitious design for the MWL. The vegetated soil cover is a simple, elegant, and cost-effective design that takes advantage of TA-3 native soil and natural hydrological processes. The proposed cover adequately protects groundwater resources under historical and projected future climatic conditions. The 3-ft cover includes a reduced finished elevation above grade, minimizing the cover's exposure to wind and water erosion.

The proposed 3-ft-thick, vegetated soil cover, integrated with natural site conditions, produces a "system" performance that will ensure that federal and state regulatory requirements and DOE Orders are met. Specifically, the proposed vegetated soil cover will:

- Minimize water infiltration through the closure cover. The combined cover/subgrade with native vegetation will minimize water infiltration into waste disposal cells. Modeling data indicates that water does not migrate significantly past a 3-ft-thick layer of native soil.

- Function with minimum maintenance. Maintenance will be minimized by using a monolithic soil layer. Rigid, multi-layer, multi-component covers, such as those used in conventional designs, would require continuous maintenance and are more susceptible to failure.

- Promote drainage and minimize erosion of the cover surface. The proposed cover will be centrally crowned and sloped at 2 percent to the edge of the side slopes which, in turn, tie into the surrounding landscape at 6:1. Native vegetation will minimize wind and water erosion while promoting water removal from the cover through evapotranspiration.

- Accommodate settling and subsidence so that the integrity of the cover is maintained. Subsidence will be accommodated using a "soft" design. During the cover's design life, soil can be added to the cover to correct subsidence and erosion as it occurs.

- Have a permeability less than or equal to the permeability of the MWL subsurface soil. The cover will be constructed with soil native to TA-3. Evaluation of the bathtub effect demonstrates that the permeability of the cover soil is equal to or less than that of the natural subsurface soil present.

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9. References

Anderson, J.E., 1997. "Soil-Plant Cover Systems for Final Closure of Solid Waste Landfills in Arid Regions," in *Landfill Capping in the Semi-Arid West: Problems, Perspectives, and Solutions*, Timothy D. Reynolds and Randall C. Morris (eds.), Environmental Science and Research Foundation, Idaho Falls, Idaho, May 1997.

Anderson, J.E., and A. D. Forman, 2002. "The Protective Cap/Biobarrier Experiment: A Study of Alternative Evapotranspiration Caps for the Idaho National Engineering and Environmental Laboratory," Environmental Science and Research Foundation, Idaho Falls, Idaho, March 2002.

Ankeny, M.D., L.M. Coors, N. Majumdar, J. Kelsey, and M. Miller, 1997. "Performance and Cost Considerations for Landfill Caps in Semi-Arid Climates," in *Landfill Capping in the Semi-Arid West: Problems, Perspectives, and Solutions*, Timothy D. Reynolds and Randall C. Morris (eds.), Environmental Science and Research Foundation, Idaho Falls, Idaho, May 1997.

Bonzon, L.L., J.S. Philbin, B.F. Estes, and J.A. Reuscher, 1974. "Sandia Pulsed Reactor III (SPR III) Safety Analysis Report," SLA-74-0349, Sandia National Laboratories/New Mexico, Albuquerque, New Mexico.

City of Albuquerque, 1993. "Development Process Manual," Volume 2, *Design Criteria for the City of Albuquerque, New Mexico*, City of Albuquerque, New Mexico.

Clary, J.H., N.T. Korecki, and R.R. Mondragon, 1984. "Geology of Albuquerque, New Mexico, United States of America." Bulletin of the Association of Engineering Geologists, 21(2), May 1984.

Dakin, J.P., 1995. "Distributed Optical Fiber Sensors," in *Fiber Optic Smart Structures*, E. Udd (ed.), John Wiley and Sons, Inc., New York.

Daniel, D.E., and B.A. Gross, 1995. "Section 6: Caps," in *Assessment of Carrier Containment Technologies: A Comprehensive Treatment of Environmental Remediation Technologies*, R.R. Rumer and J.K. Mitchell (eds.), U.S. Department of Energy, U.S. Environmental Protection Agency and DuPont Company.

DOE, see U.S. Department of Energy.

EPA, see U.S. Environmental Protection Agency.

Fayer, M.J., and T.L. Jones, 1990. UNSAT-H Version 2.0: "Unsaturated Soil Water and Heat Flow Model," Document PNL-6779/UC-702, Pacific Northwest Laboratory, Richland, Washington.

Finley, J.B., M.D. Harvey, and C.C. Watson, 1985. "Experimental Study: Erosion of Overburden Cap Material Protected by Rock Mulch," in *Proceedings of Seventh Symposium on Management of Uranium Mill Tailings, Low-Level Waste, and Hazardous Waste*, Colorado State University, Fort Collins, Colorado.

Gee, G.W., and A.L. Ward, 1997. "Still in Quest of the Perfect Cap," in *Landfill Capping in the Semi-Arid West: Problems, Perspectives, and Solutions*, Timothy D. Reynolds and Randall C. Morris (eds.), Environmental Science and Research Foundation, Idaho Falls, Idaho, May 1997.

Gilmore, B.G., and W.H. Walters, 1993. "Water Erosion Field Tests for Hanford Protective Barriers: FY 1992 Status Report," PNL-8949, Pacific Northwest Laboratory, Richland, Washington.

Goering, T.J., M.D. McVey, W.R. Strong, H.A. Nguyen, and J.L. Peace, 1995. "Analysis of Instantaneous Profile Test Data from Soils Near the Mixed Waste Landfill, Technical Area 3, Sandia National Laboratories/New Mexico." SAND Report SAND95-1637, Sandia National Laboratories, Albuquerque, New Mexico, August 1995.

Hakonson, T.E., L.J. Lane, and E.P. Springer, 1992. "Biotic and Abiotic Processes," in *Deserts as Dumps? The Disposal of Hazardous Materials in Arid Ecosystems*, C.C. Reith and B.M. Thomson (eds.), University of New Mexico Press, Albuquerque, New Mexico.

Healy, R.W., 1990. "Simulation of Solute Transport in Variably-Saturated Porous Media with Supplemental Information on Modifications to the U.S. Geological Survey's Computer Program, VS2D." Water Resources Investigations Report 90-4025, U.S. Geological Survey, Denver, Colorado.

Jury, W.A., W.R. Gardner, and W.H. Gardner, 1991. *Soil Physics*, John Wiley and Sons, Inc., New York.

Kennedy, W.E., Jr., L.L. Cadwell, and D.H. McKenzie, 1985. "Biotic Transport of Radionuclides from Low-Level Radioactive Waste Sites," *Health Physics*, 49:11–24.

Kersey, A.D., 1991. "Distributed and Multiplexed Fiber Optic Sensors," in *Fiber Optic Sensors: An Introduction for Engineers and Scientists*, E. Udd (ed.), John Wiley and Sons, Inc., New York.

Khire, M.V., C.H. Benson, and P.J. Bosscher, 1997. "Water Balance Modeling of Earthen Final Covers," *Journal of Geotechnical and Geoenvironmental Engineering*, August 1997.

Kramer, J.H., S.J. Cullen, and L.G. Everett, 1992. "Vadose Zone Monitoring with the Neutron Moisture Probe," *Handbook of Vadose Zone Characterization and Monitoring*.

Ligotke, M.W., 1993. "Soil Erosion Rates Caused by Wind and Saltating Sand Stresses in a Wind Tunnel," PNL-8478, Pacific Northwest Laboratory, Richland, Washington.

Ligotke, M.W., 1994. "Control of Eolian Soil Erosion from Waste-Site Surface Barriers," in *In-Situ Remediation: Scientific Basis for Current and Future Technologies*, G.W. Gee and N.R. Wing (eds.), Battelle Press, Richland, Washington.

Ligotke, M.W., and D.C. Klopfer, 1990. "Soil Erosion Rates from Mixed Soil and Gravel Surfaces in a Wind Tunnel," PNL-7435, Pacific Northwest Laboratory, Richland, Washington.

Mayes, D., 1999. Personal communication, ACME Fences, Inc., Albuquerque, New Mexico.

Peace, J.L., T.J. Goering, and M.D. McVey, 2002. "Report of the Mixed Waste Landfill Phase 2 RCRA Facility Investigation, Sandia National Laboratories, Albuquerque, New Mexico." SAND Report SAND2002-2997, Environmental Restoration Project, Sandia National Laboratories, Albuquerque, New Mexico.

Reynolds, T., 1998. Personal communication, U.S. Department of Energy 1998 Technology Information Exchange Workshop, INEEL, Idaho Falls, Idaho, October 1998.

Sackschewsky, M.R., C.J. Kemp, S.O. Link, and W.J. Waugh, 1995. "Soil-Water Balance Changes in Engineered Soil Surfaces," *Journal of Environmental Quality*, 24:352–359.

Sandia National Laboratories/New Mexico (SNL/NM), 1998. "Responses to NMED Technical Comments on the Report of the Mixed Waste Landfill Phase 2 RCRA Facility Investigation Dated September 1996," Volumes 1 and 2. Environmental Restoration Project, Sandia National Laboratories, Albuquerque, New Mexico, June 15, 1998.

Sandia National Laboratories/New Mexico (SNL/NM), 1999. "Environmental Restoration Project Responses to NMED October 30 NOD for 'Report of the Mixed Waste Landfill Phase 2 RCRA Facility Investigation, Sandia National Laboratories, Albuquerque, New Mexico.'" Environmental Restoration Project, Sandia National Laboratories, Albuquerque, New Mexico, January 28, 1999.

Schroeder, P.R., T.S. Dozier, P.A. Zappi, B.M. McEnroe, J.W. Sjostrom, and R.L. Peyton, 1994. The Hydrologic Evaluation of Landfill Performance (HELP) Model: Engineering Documentation for Version 3. EPA/600/R-94/168b, Office of Research and Development, U.S. Environmental Protection Agency Washington, D.C., September, 1994.

SNL/NM, see Sandia National Laboratories/New Mexico.

Sullivan, R.M., and P.J. Knight, 1992. "Biological Assessment for the Sandia National Laboratories Coyote Canyon Test Complex, Kirtland Air Force Base, Albuquerque, New Mexico," Special Technical Report 1 (Contract AB4892), Physical Science Laboratory, Las Cruces, New Mexico, July 1992.

U.S. Department of Agriculture (USDA), 1997. "Wind Erosion Process, Prediction, and Control," Natural Resource Conservation Service, U.S. Department of Agriculture, Washington, D.C.

U.S. Department of Energy (DOE), 1984. "Radioactive Waste Management," DOE Order 5820.2, U.S. Department of Energy, Washington, D.C.

U.S. Department of Energy (DOE), 1988. "Radioactive Waste Management," DOE Order 5820.2A, U.S. Department of Energy, Washington, D.C.

U.S. Department of Energy (DOE), 1989. "General Design Criteria," DOE Order 6430.1A, U.S. Department of Energy, Washington, D.C.

U.S. Department of Energy (DOE), 1993. "Radiation Protection of the Public and the Environment," DOE Order 5400.5, U.S. Department of Energy, Washington, D.C.

U.S. Department of Energy (DOE), 1999. "Radioactive Waste Management," DOE Order 435.1, U.S. Department of Energy, Washington, D.C.

U.S. Environmental Protection Agency (EPA), 1980. An Approach to Water Resources Evaluation of Non-Point Silvicultural Sources (A Procedural Handbook), EPA/600/8-80-012, Environmental Research Laboratory, U.S. Environmental Protection Agency Athens, Georgia, August, 1980.

U.S. Environmental Protection Agency (EPA), 1989. "Technical Guidance Document: Final Covers on Hazardous Waste Landfills and Surface Impoundments," EPA/530-SW-89-047, U.S. Environmental Protection Agency, Washington, D.C., July 1989.

U.S. Environmental Protection Agency (EPA), 1991. "Design and Construction of RCRA/CERCLA Final Covers," EPA/625/4-91/025, U.S. Environmental Protection Agency, Washington, D.C.

U.S. Environmental Protection Agency (EPA), 1994. "The Hydrologic Evaluation of Landfill Performance (HELP) Model, User's Guide for Version 3," EPA/600/R94/168b, U.S. Environmental Protection Agency, Washington, D.C.

USDA, see United States Department of Agriculture.

Walters, W.H., K.A. Hoover, and L.L. Cadwell, 1990. "Project Test Plan for Runoff and Erosion on Fine-Soil Barrier Surfaces and Rock-Covered Side Slopes," PNL-6791, Pacific Northwest Laboratory, Richland, Washington.

Waugh, W.J., 1997. "Ecology of Uranium Mill Tailings Covers," in *Landfill Capping in the Semi-Arid West: Problems, Perspectives, and Solutions*, Timothy D. Reynolds and Randall C. Morris (eds.), Environmental Science and Research Foundation, Idaho Falls, Idaho, May 1997.

Waugh, W.J., M.E. Thiede, D.J. Bates, L.L. Cadwell, G.W. Gee, and C.J. Kemp, 1994. “Plant Cover and Water Balance in Gravel Admixtures at an Arid Waste-Burial Site,” *Journal of Environmental Quality*, 23:676–685.

Williams, J.L., 1986. “New Mexico in Maps,” 2nd Edition, University of New Mexico Press, Albuquerque, New Mexico, 1986.

Wischmeier, W.H., and D.D. Smith, 1965. “Predicting Rainfall-Erosion Losses From Cropland East of the Rocky Mountains. Handbook 282. U.S. Department of Agriculture, U.S. Government Printing Office, Washington, D.C.

Wolford, R.A., 1998. “Preliminary Unsaturated Flow Modeling and Related Work Performed in Support of the Design of a Closure Cover for the Mixed Waste Landfill, Environmental Restoration Program, Organization 6135, Sandia National Laboratories.” GRAM, Inc., Albuquerque, New Mexico, November 10, 1998.

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FIGURES

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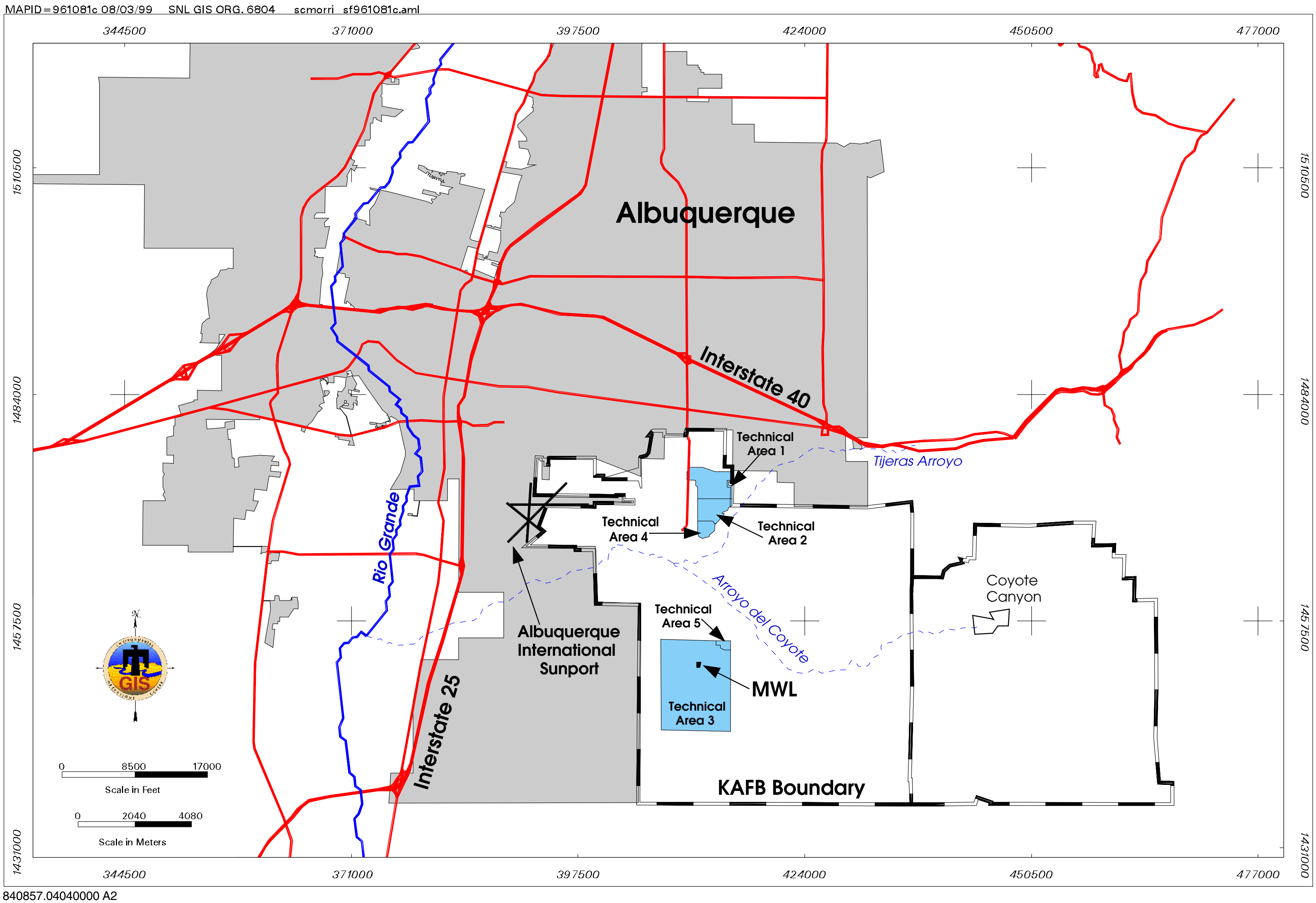

Figure 1-1 Location of Kirtland Air Force Base and Sandia National Laboratories, New Mexico Technical Areas

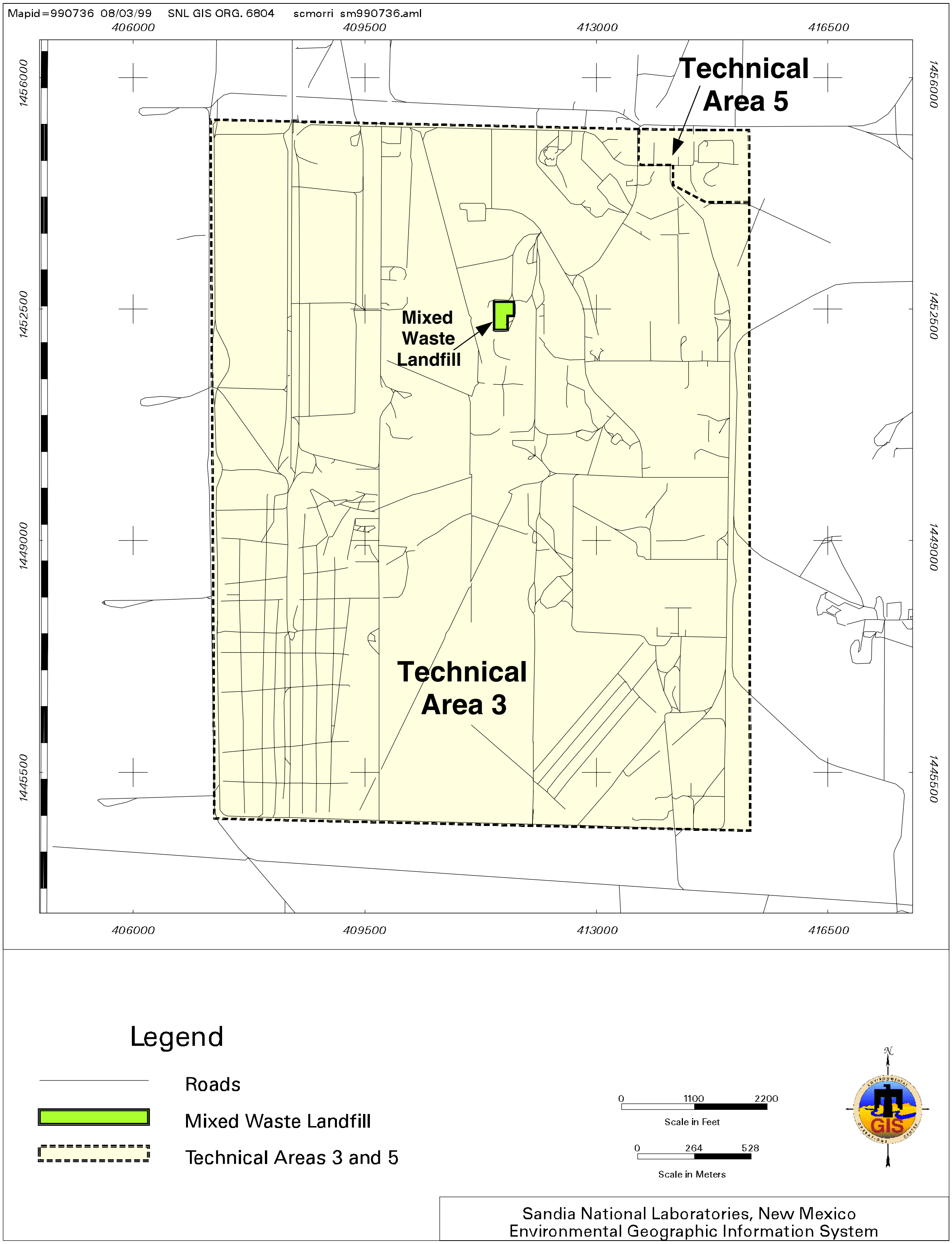

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Figure 1-2 Location of Technical Areas 3 and 5 and the Mixed Waste Landfill

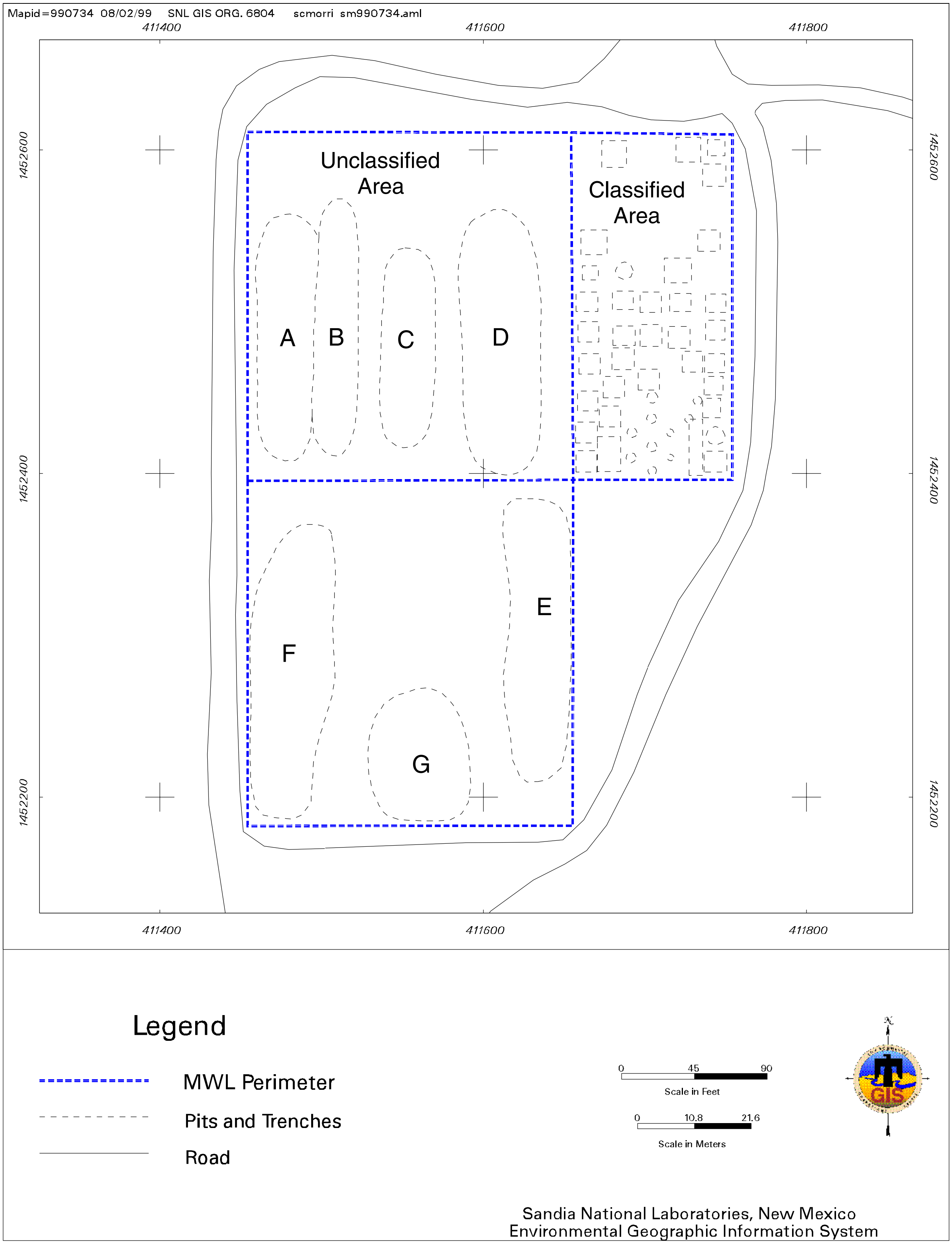

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Figure 1-3 Map of the Mixed Waste Landfill

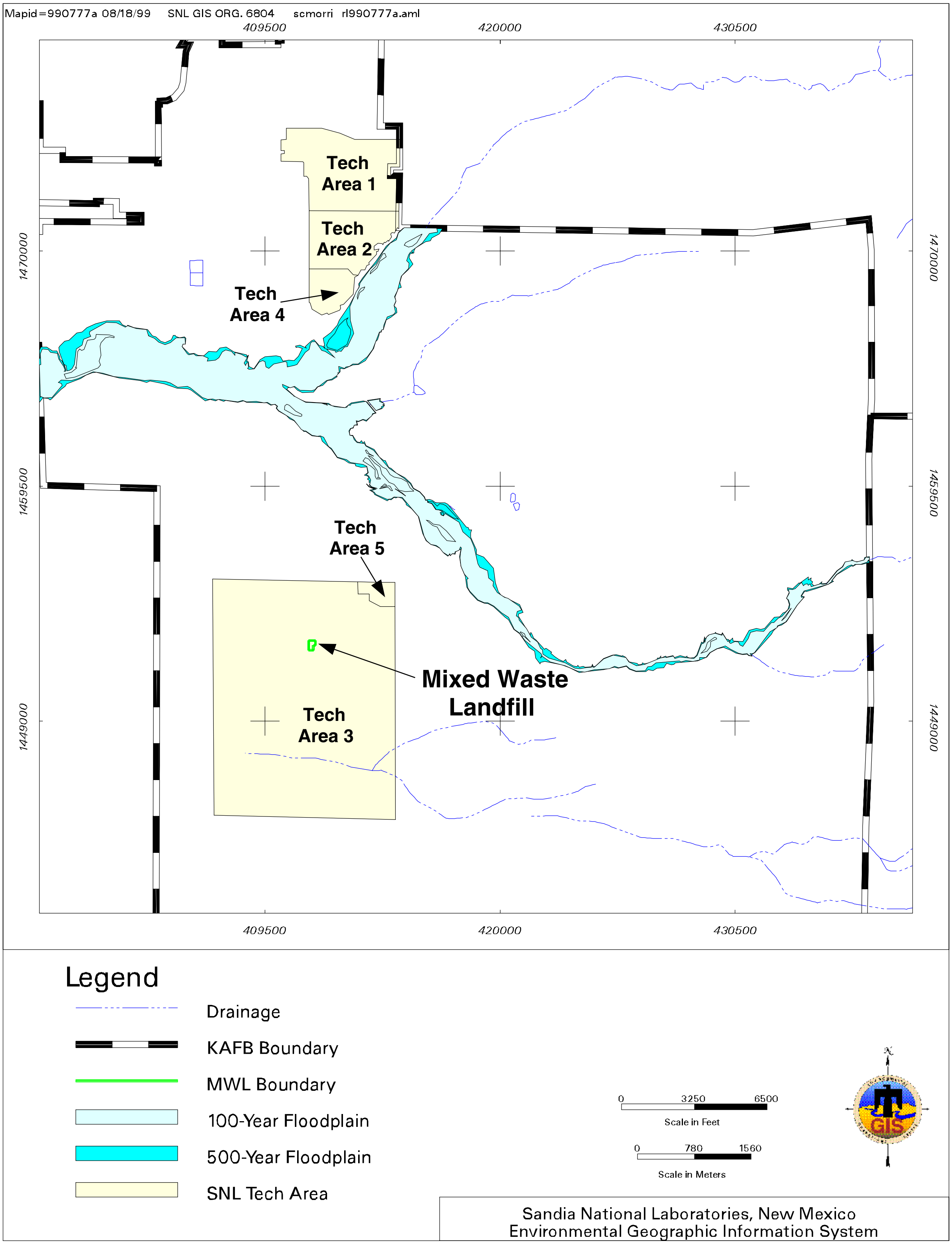

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Figure 2-1 Location of the 100-Year and 500-Year Floodplains at Kirtland Air Force Base

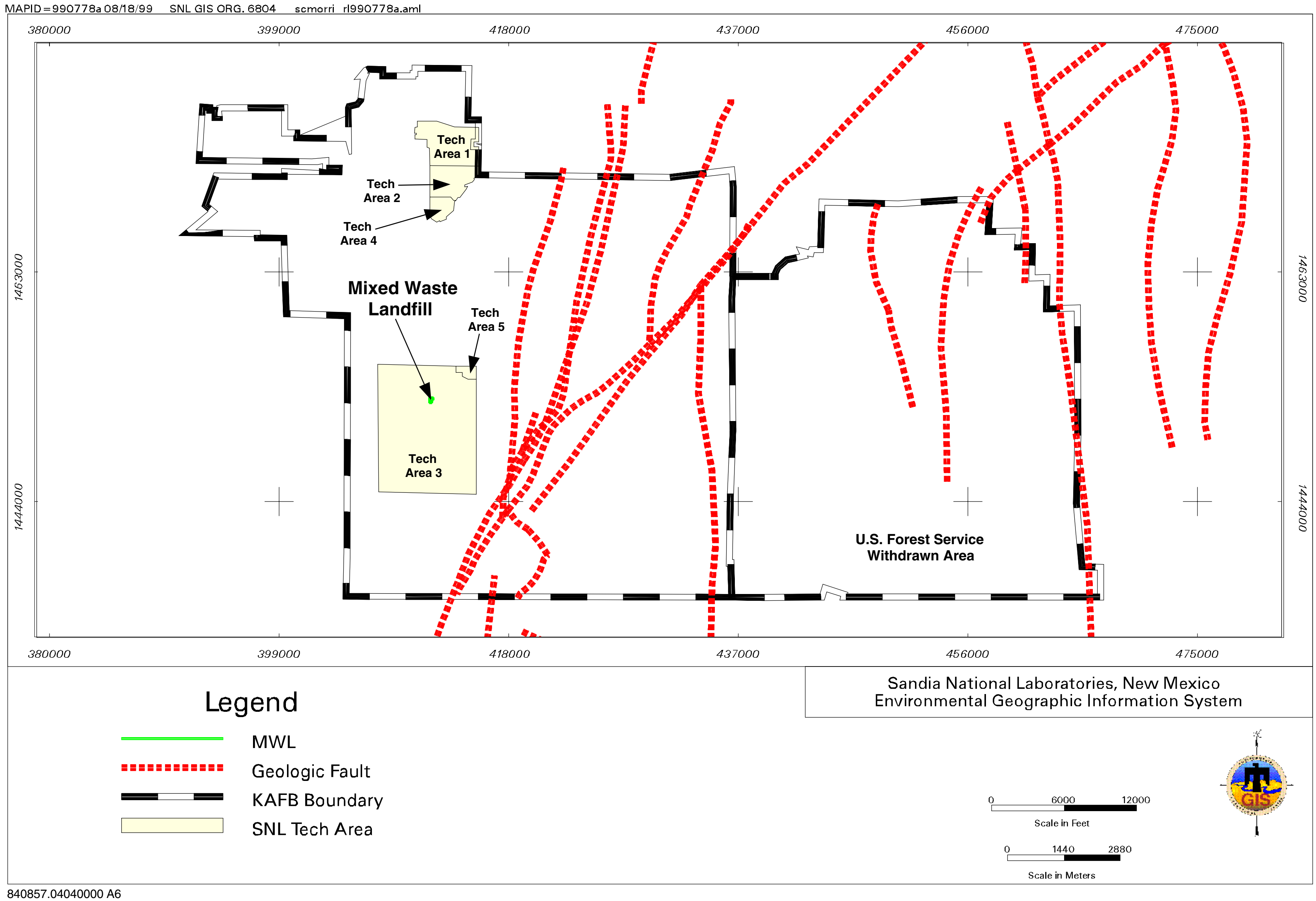


Figure 2-2 Location of Geologic Faults at Kirtland Air Force Base

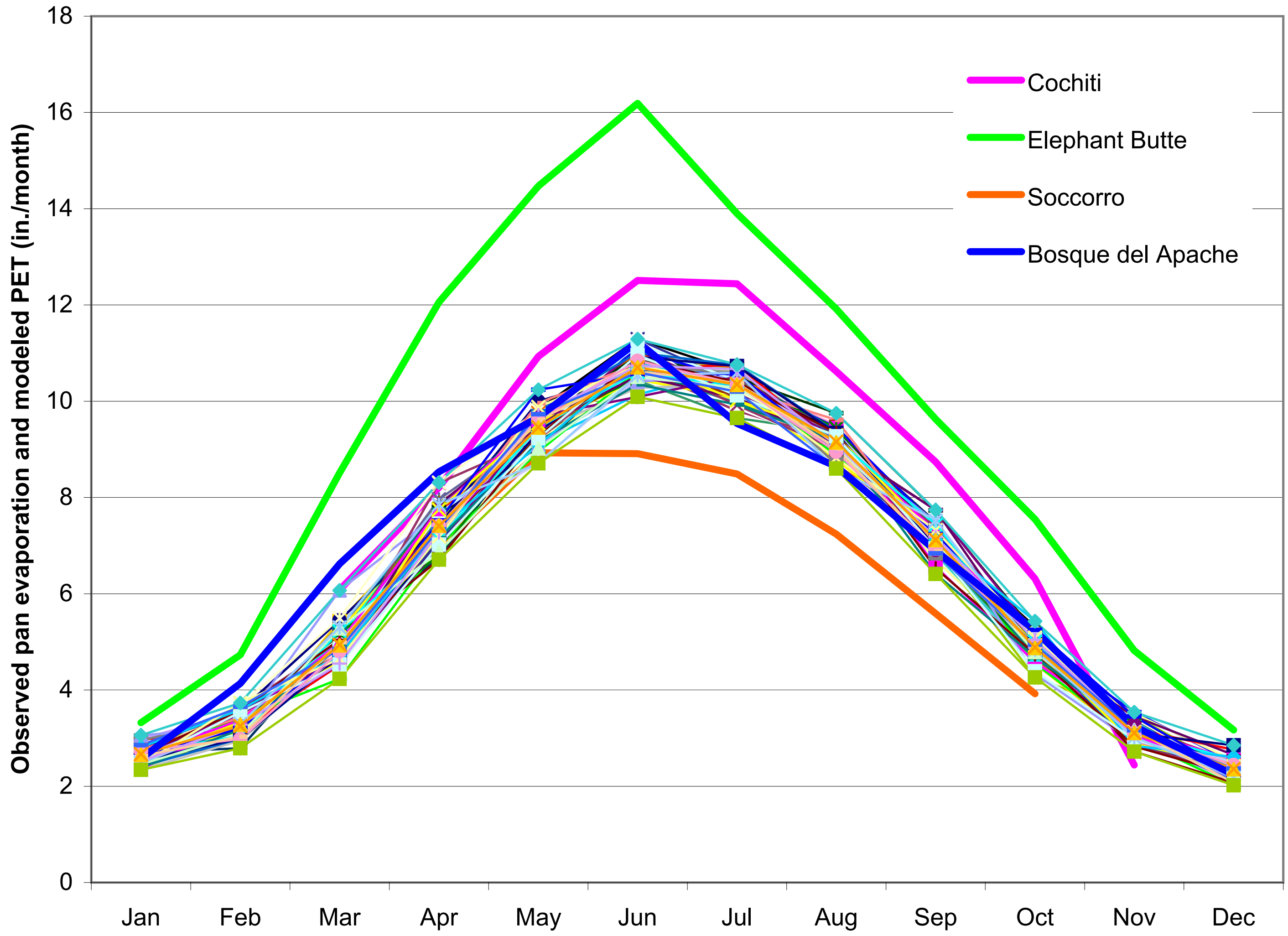


Figure 5-1 65 Years of Monthly PET Predicted by HELP-3 Shown with Average Monthly Pan Evaporation from Four National Weather Service Stations in New Mexico

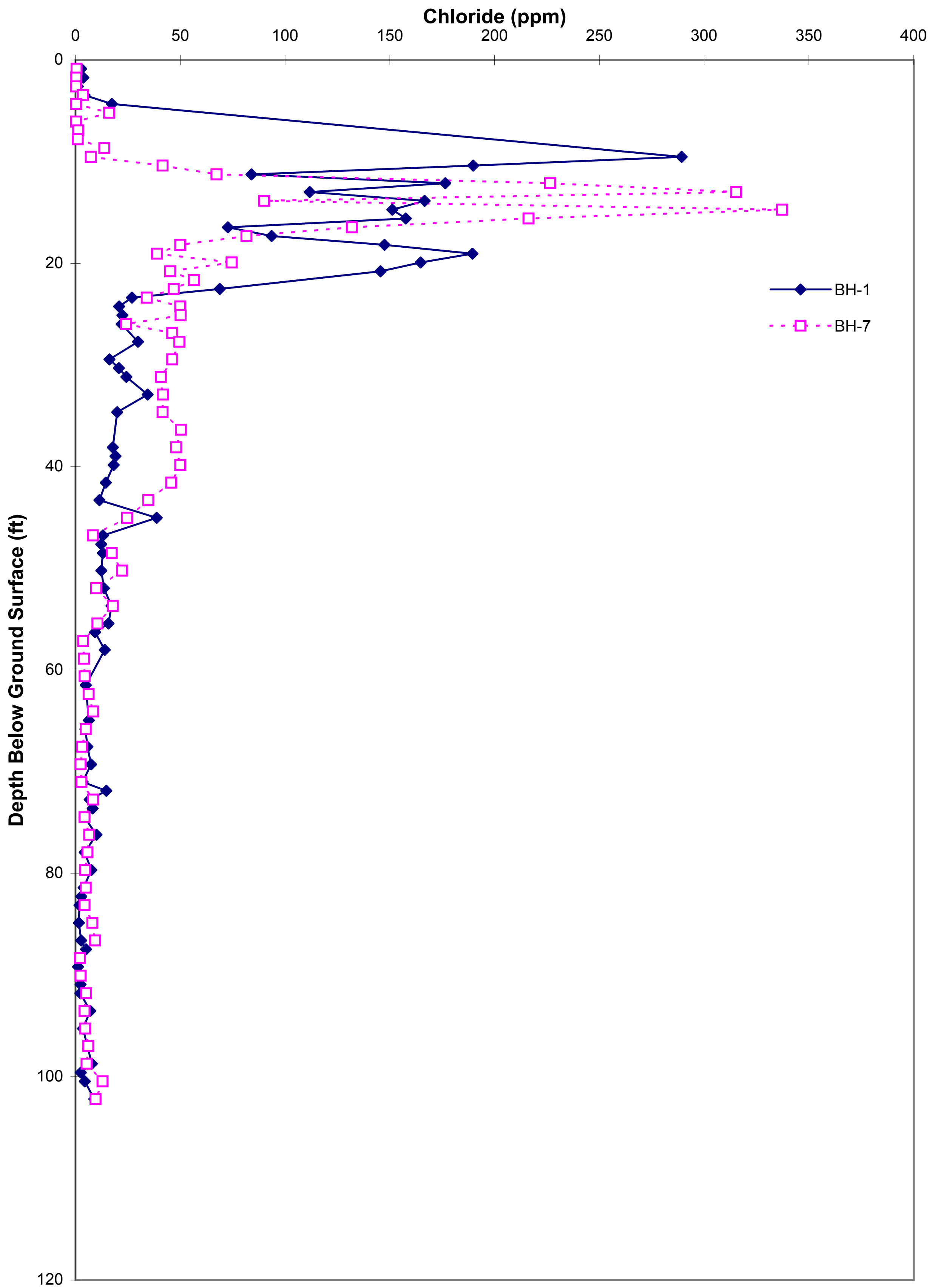


Figure 5-2 Chloride Concentration Profiles in Subsurface Soil at the Mixed Waste Landfill

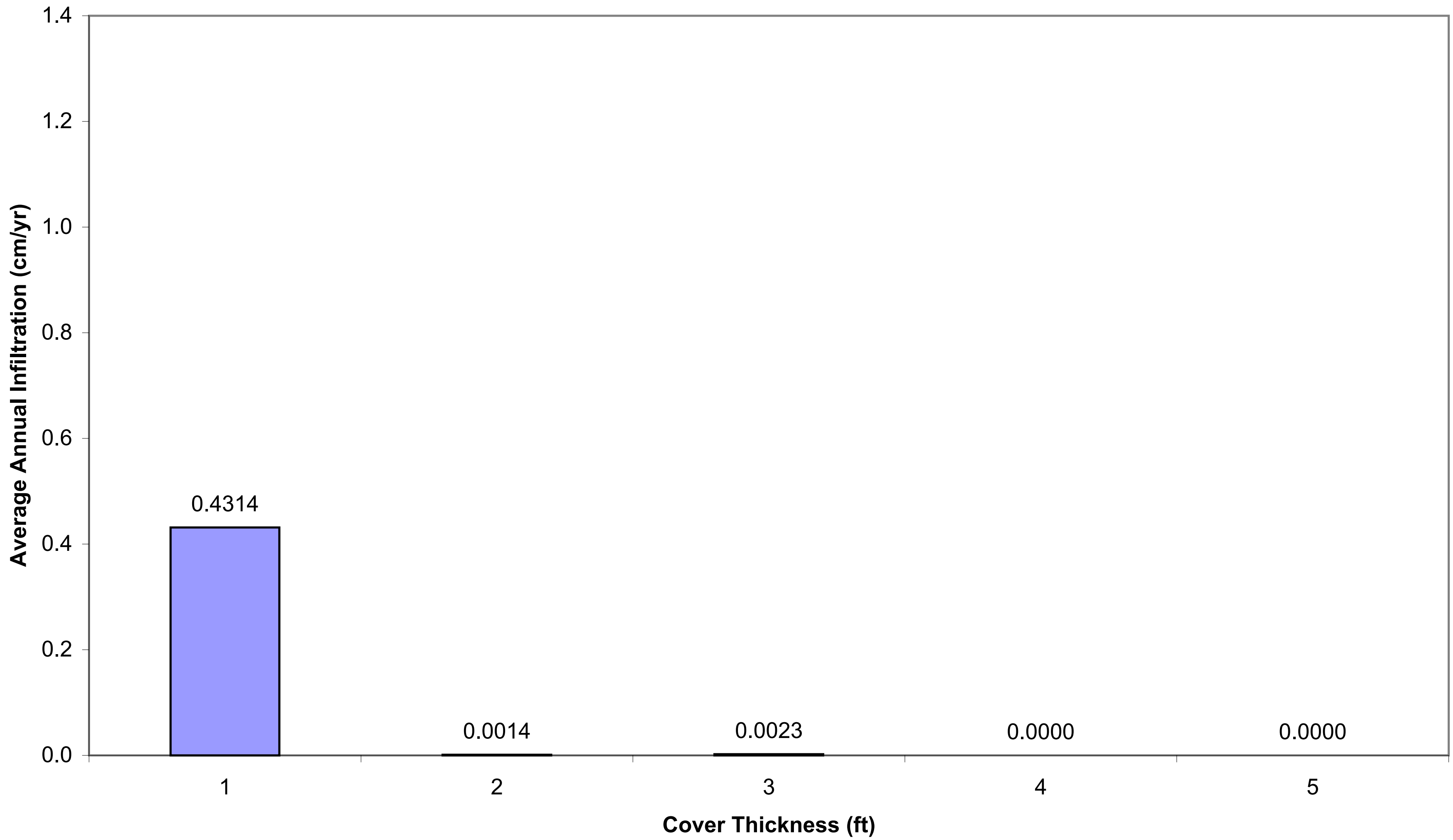


Figure 5-3 Average Annual Infiltration Predicted by HELP-3 Using Historical Precipitation Data

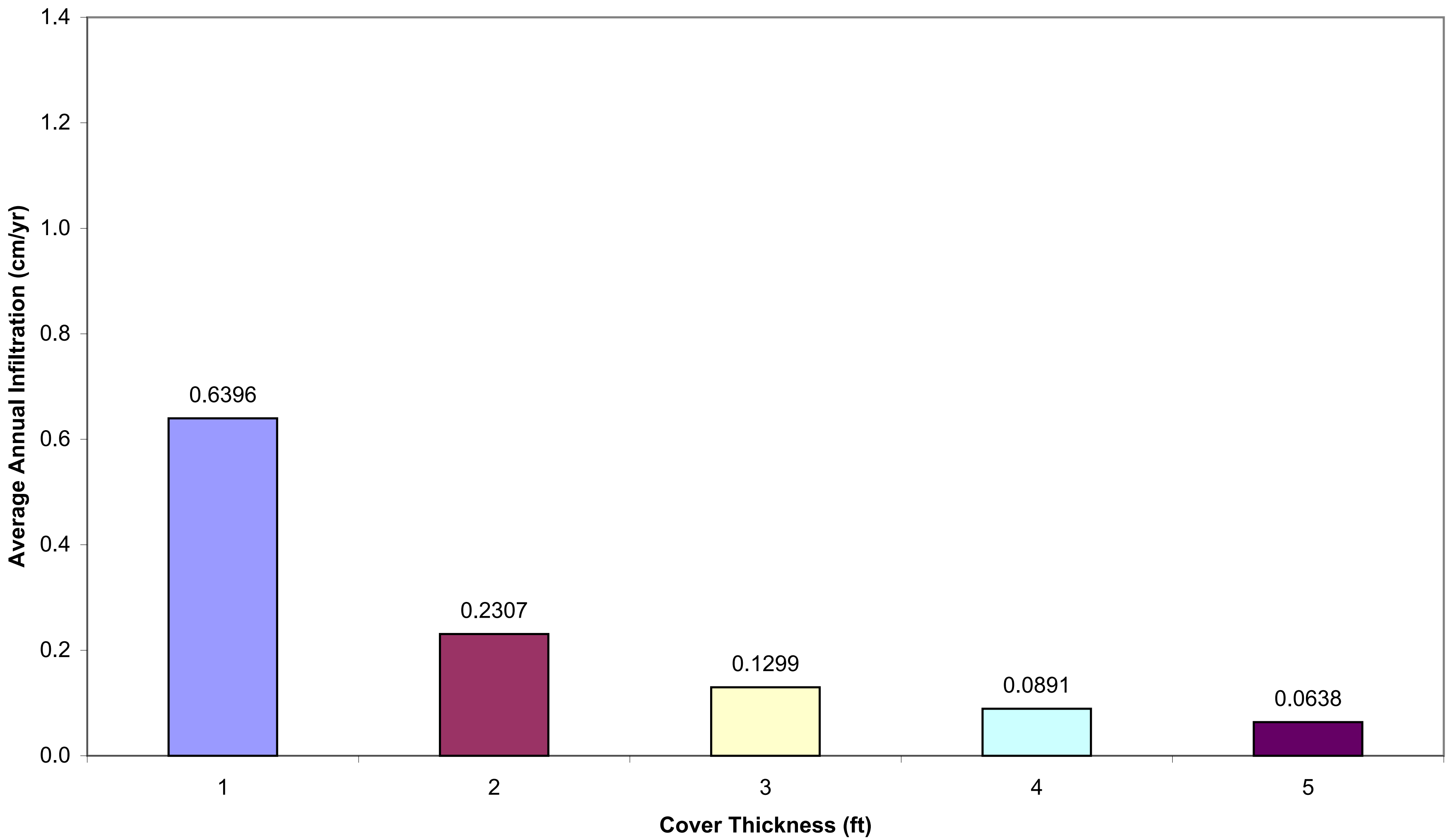


Figure 5-4 Average Annual Infiltration Predicted by UNSAT-H Using Historical Preciptiation Data

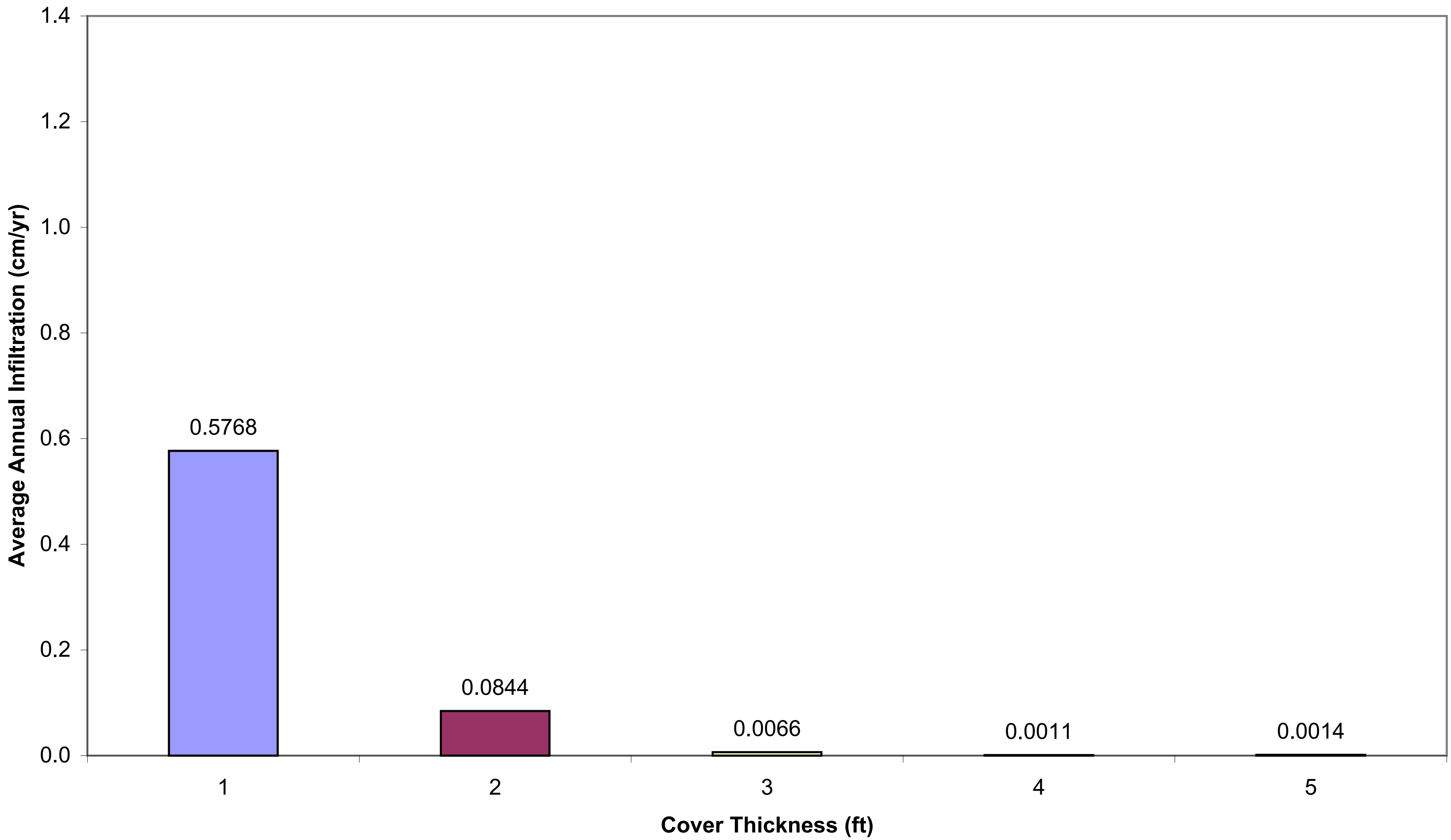


Figure 5-5 Average Annual Infiltration Predicted by VS2DT Using Historical Precipitation Data

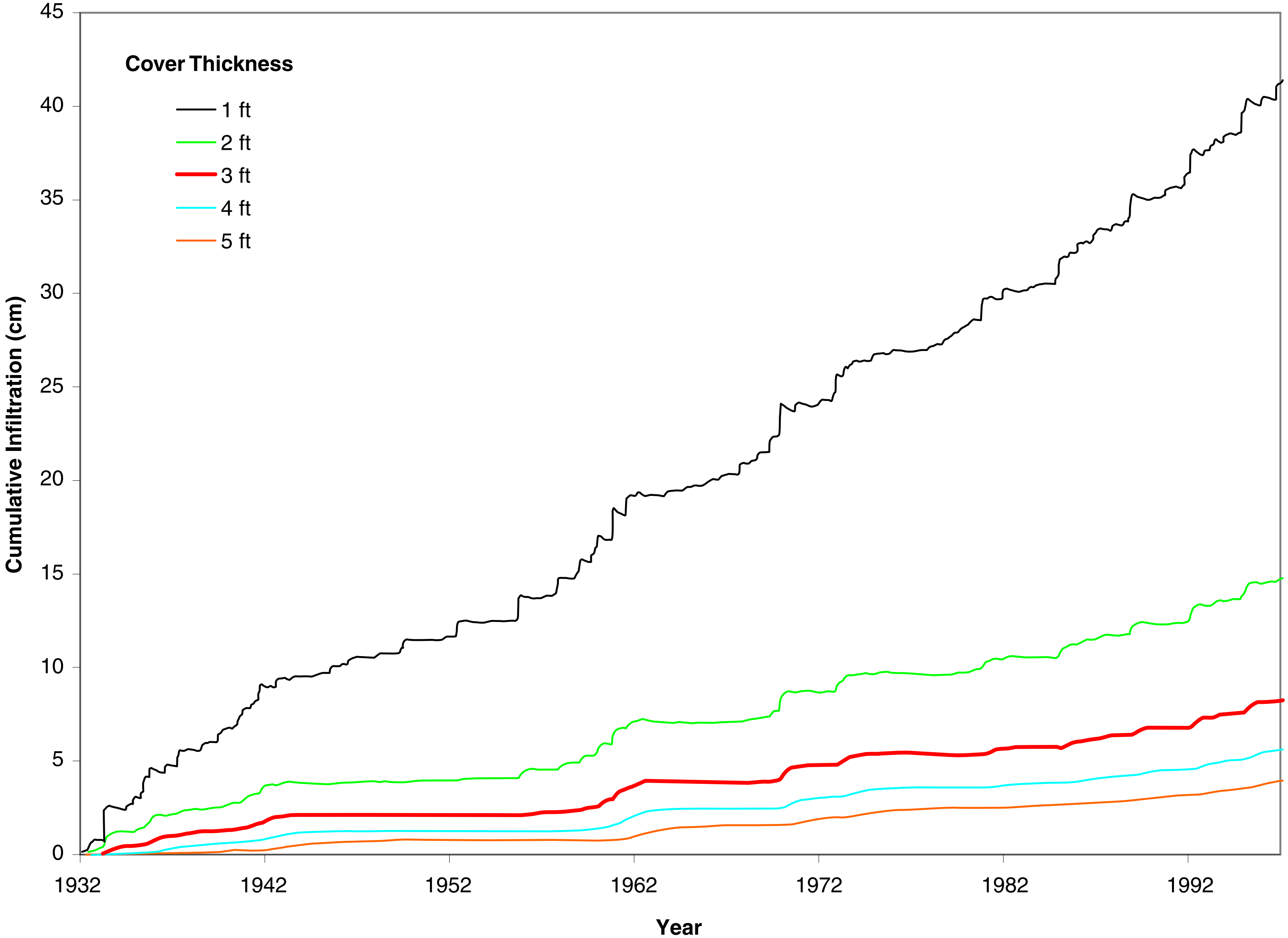


Figure 5-6 Cumulative Infiltration Predicted by UNSAT-H Using Historical Precipitation Data

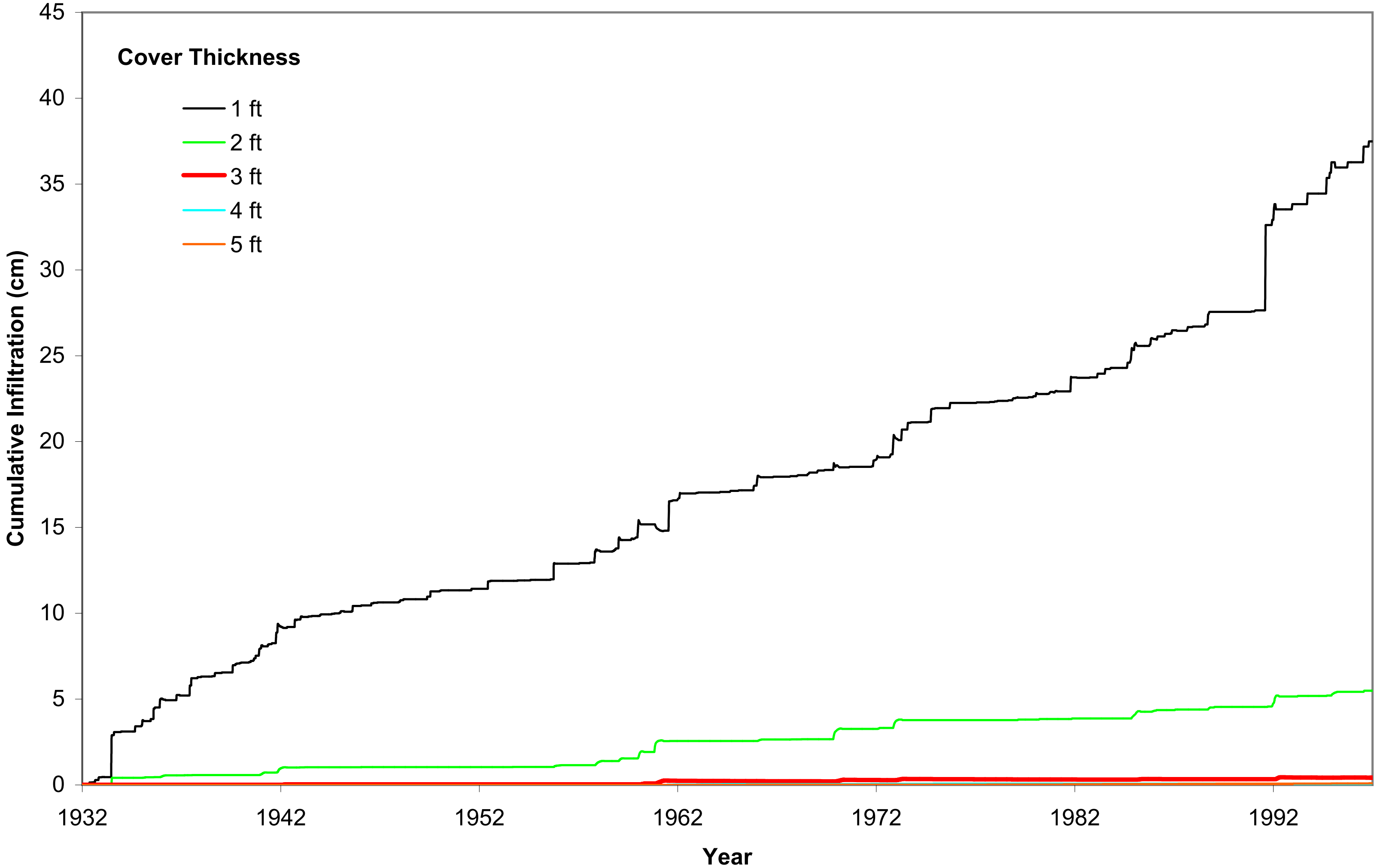


Figure 5-7 Cumulative Infiltration Predicted by VS2DT Using Historical Precipitation Data

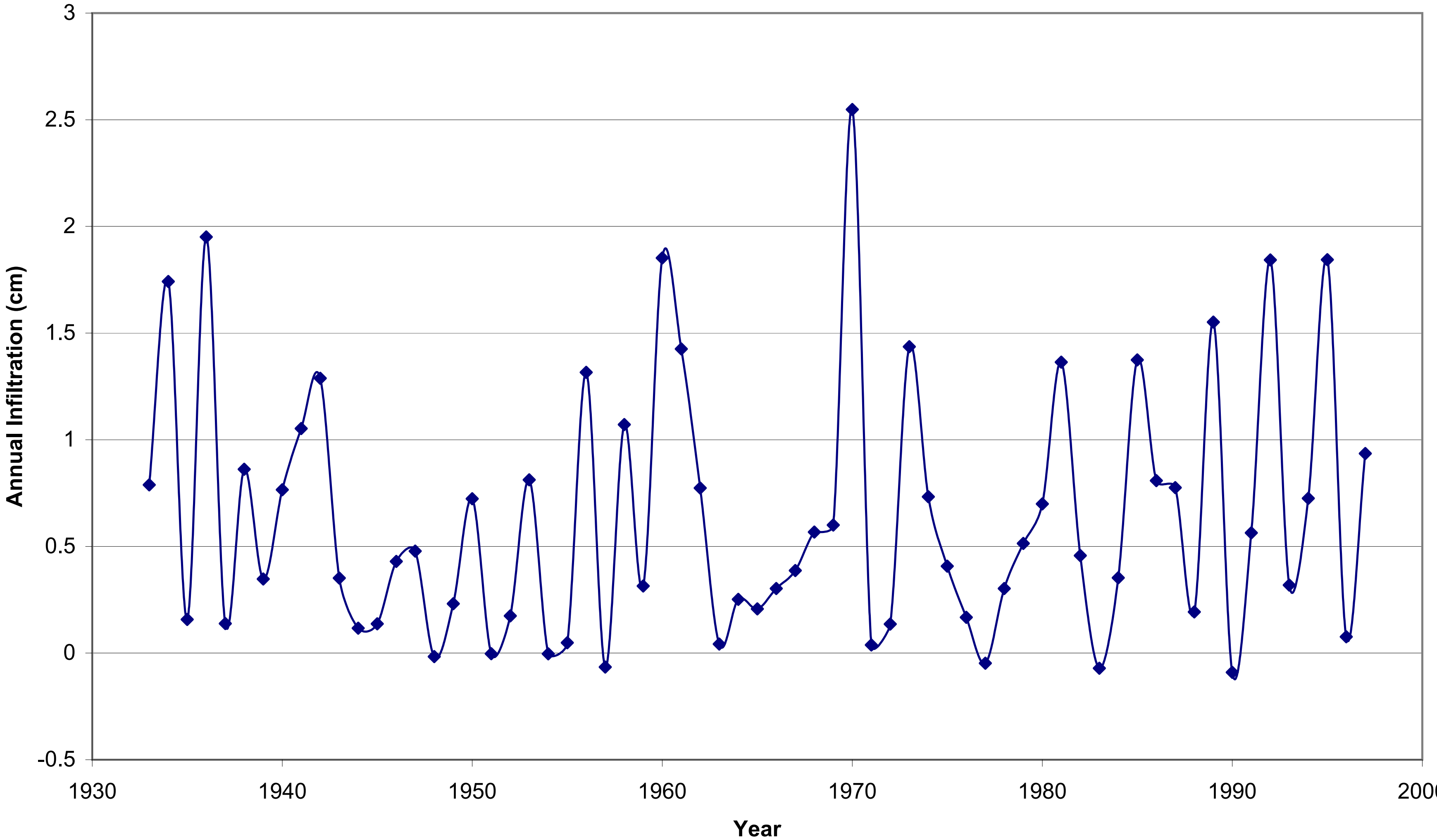


Figure 5-8 Annual Infiltration Through a 1-Ft Cover Predicted by UNSAT-H Using Historical Precipitation Data

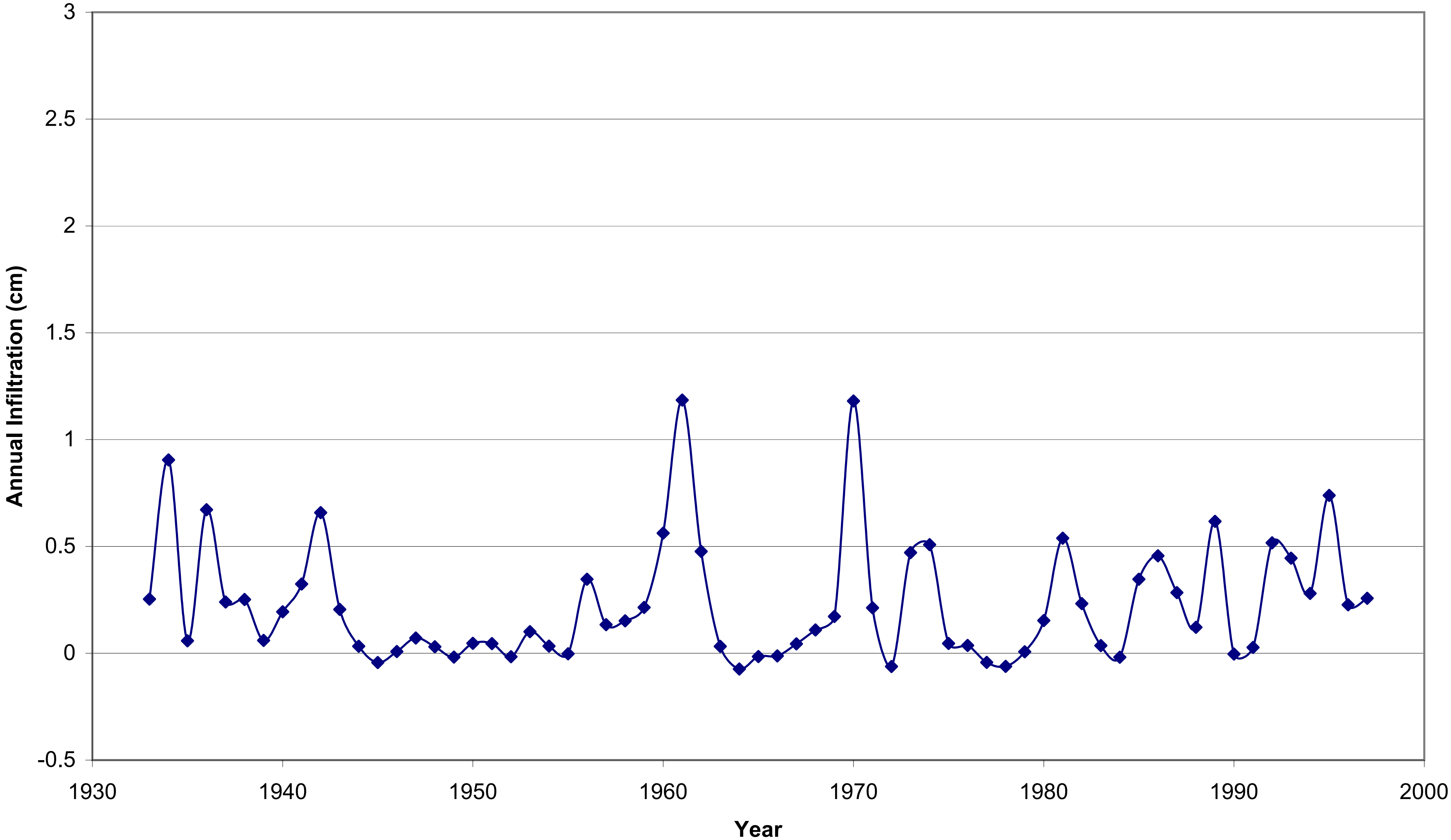


Figure 5-9 Annual Infiltration Through a 2-Ft Cover Predicted by UNSAT-H Using Historical Precipitation Data

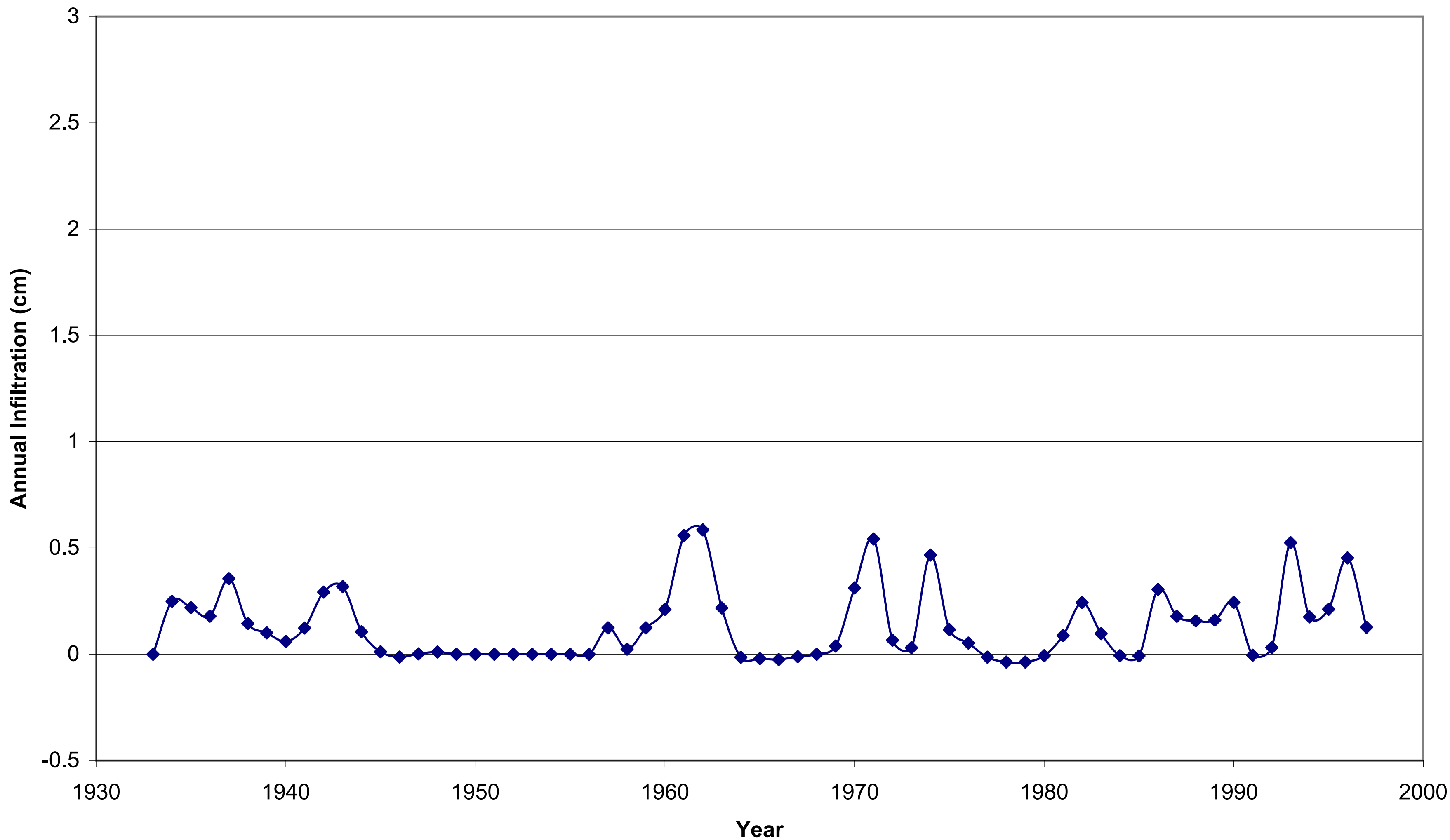
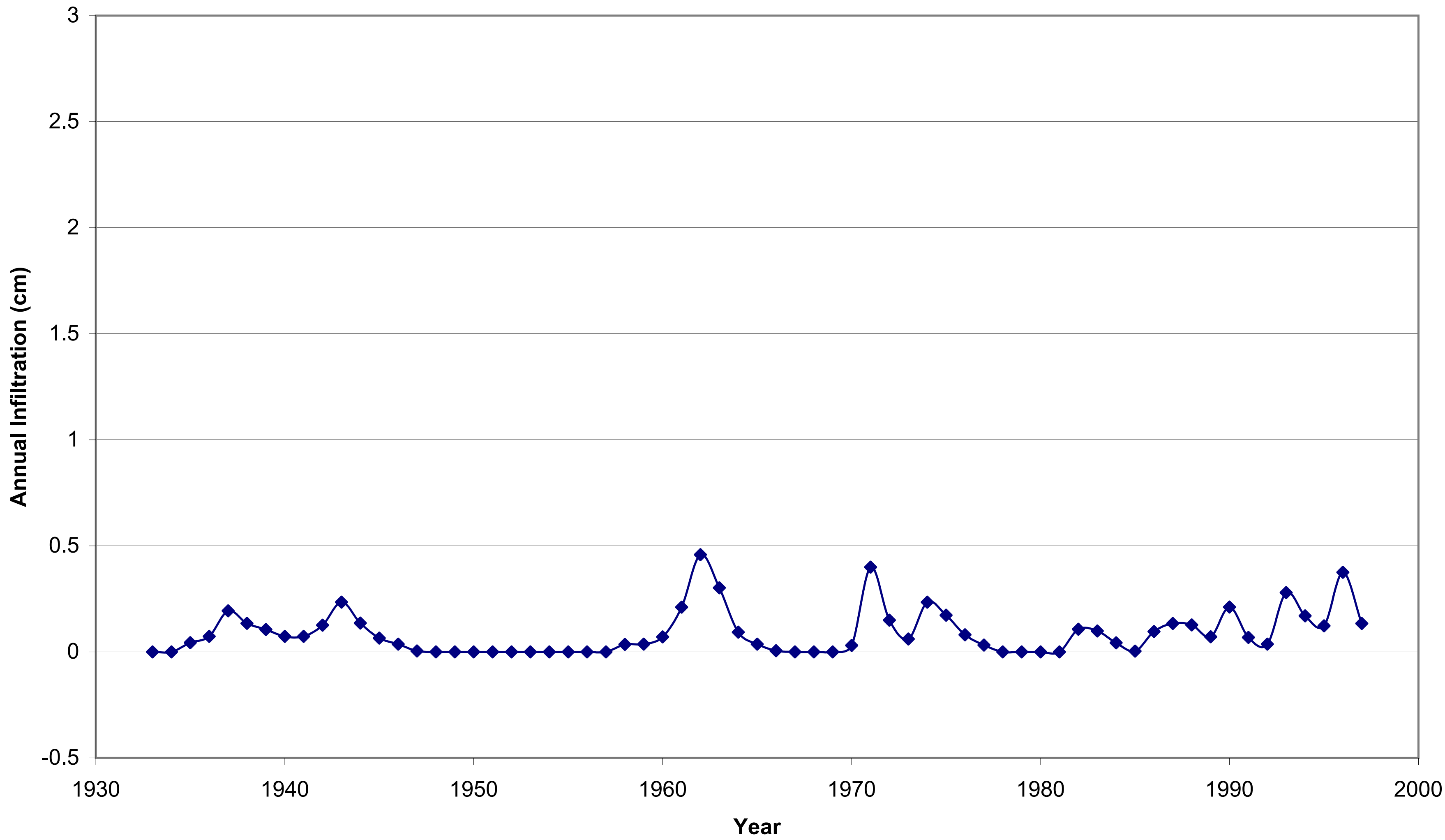


Figure 5-10 Annual Infiltration Through a 3-Ft Cover Predicted by UNSAT-H Using Historical Precipitation Data



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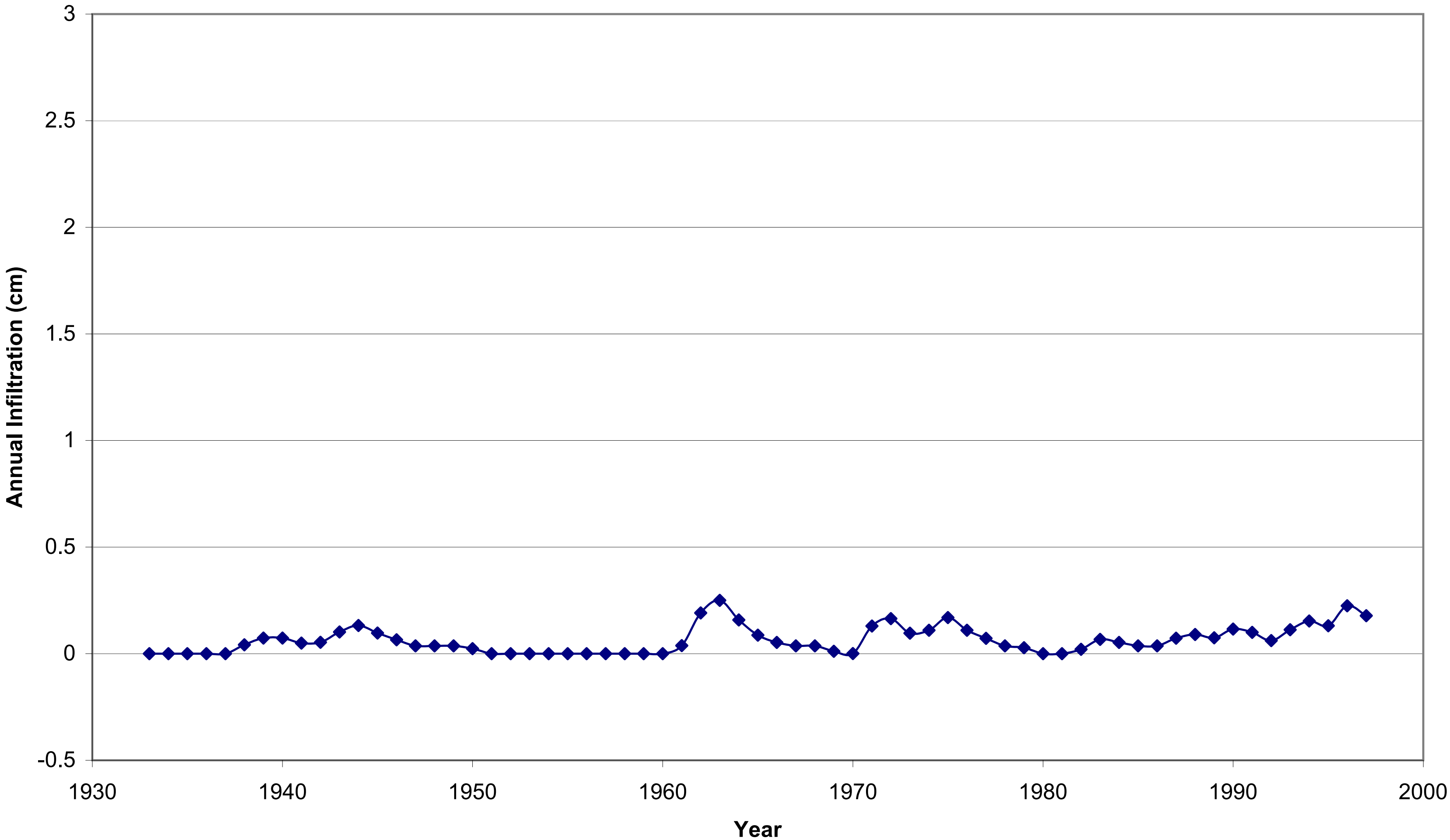

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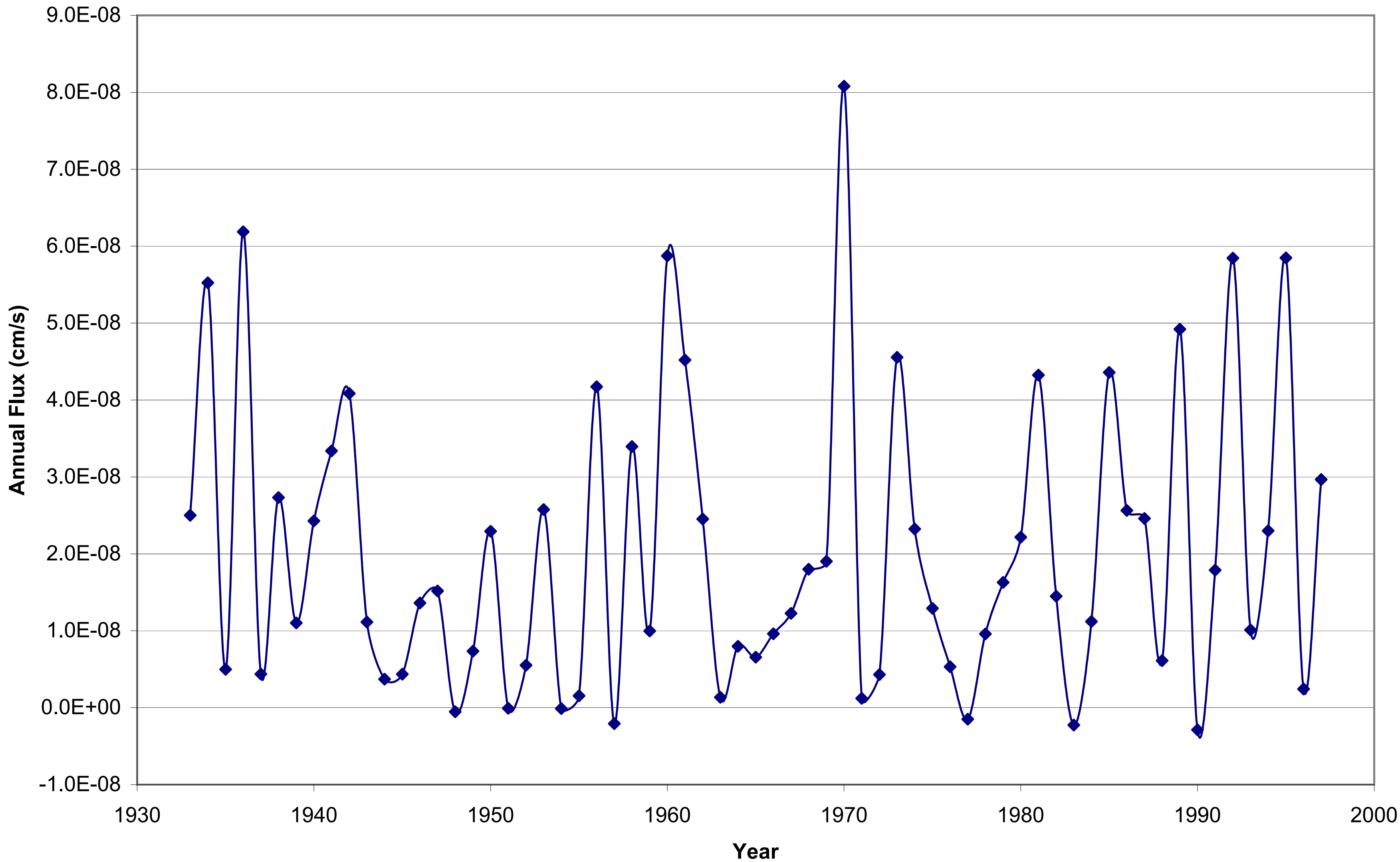
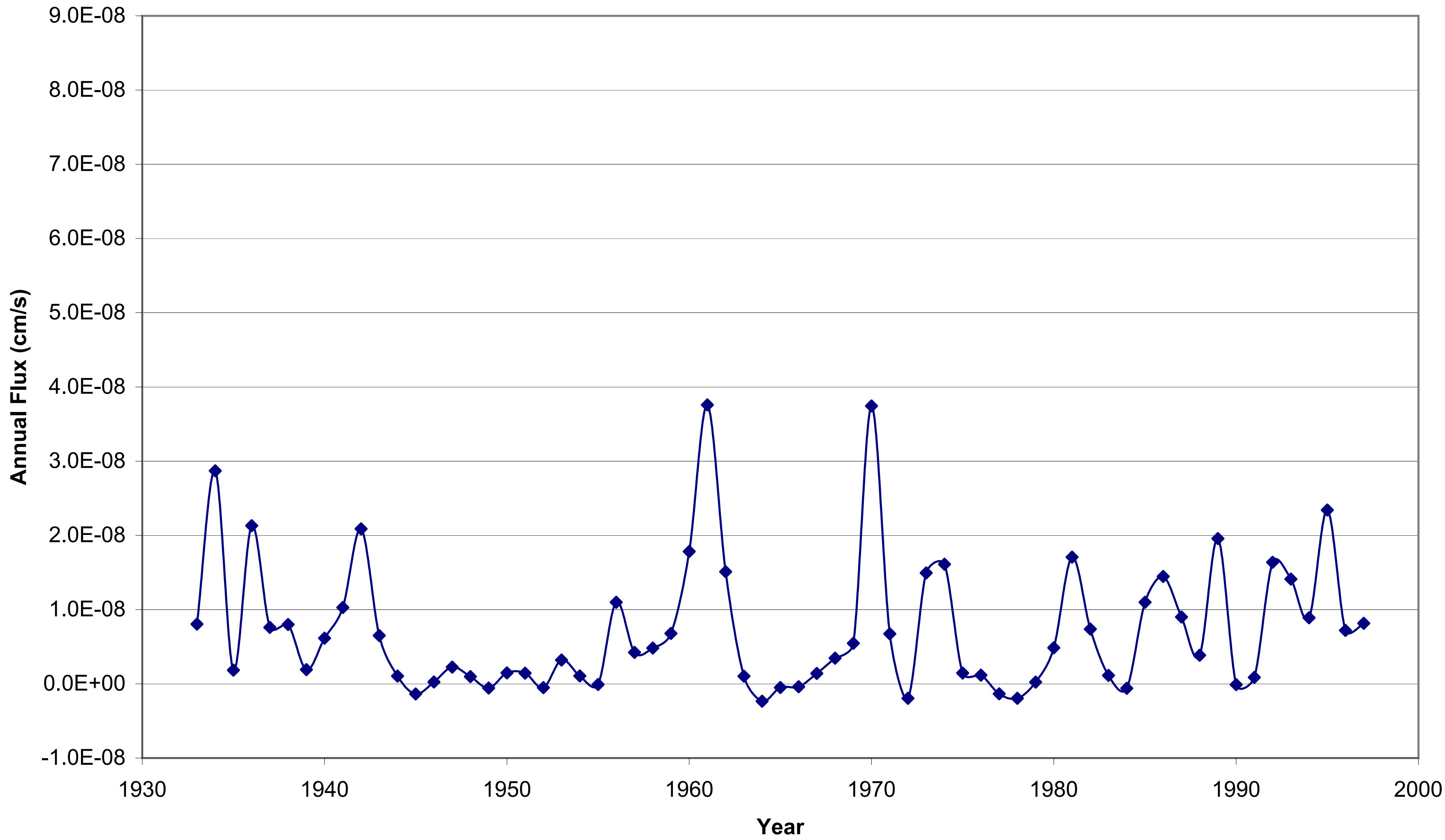


Figure 5-13 Annual Flux Through a 1-Ft Cover Predicted by UNSAT-H Using Historical Precipitation Data



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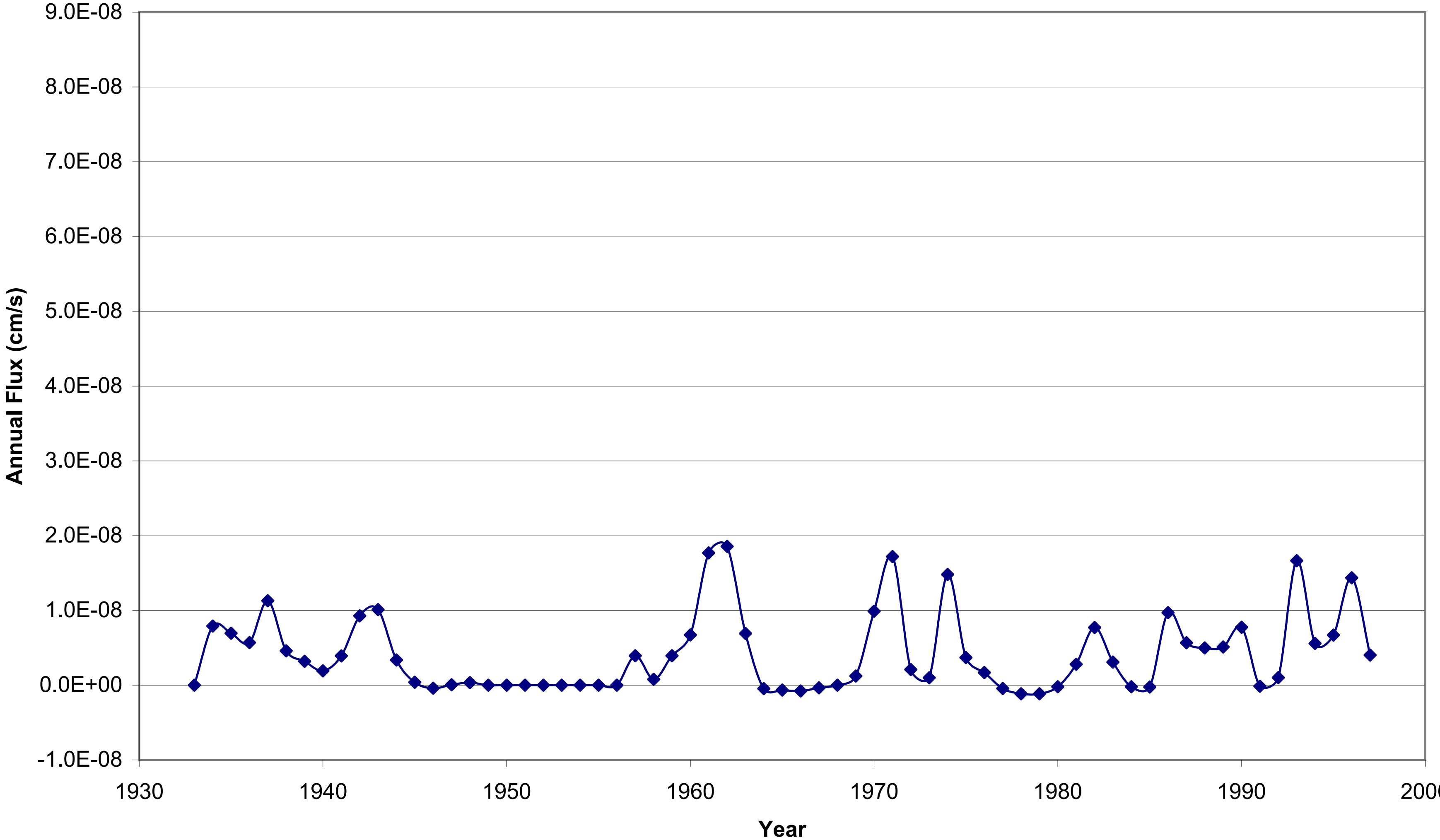

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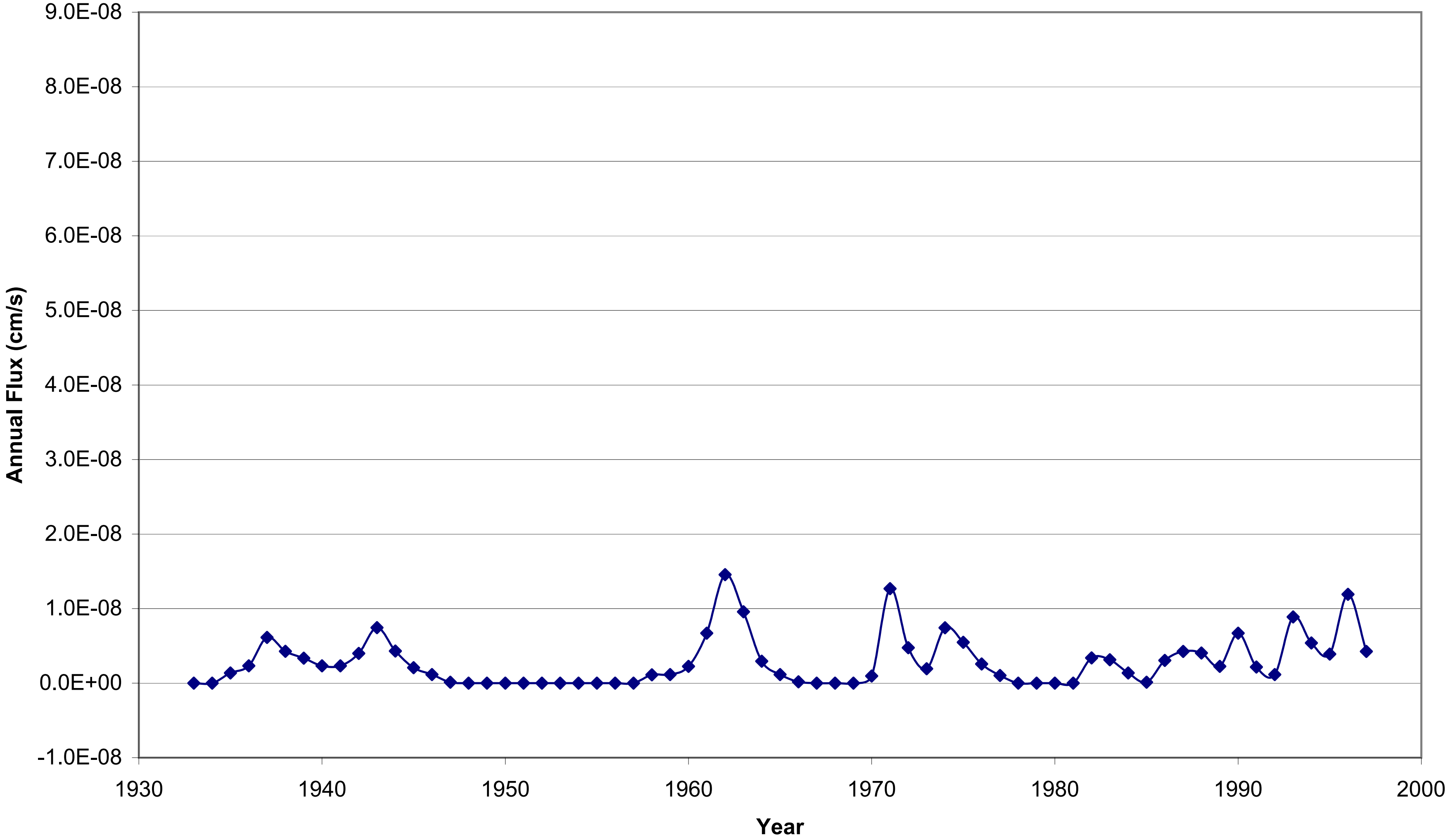

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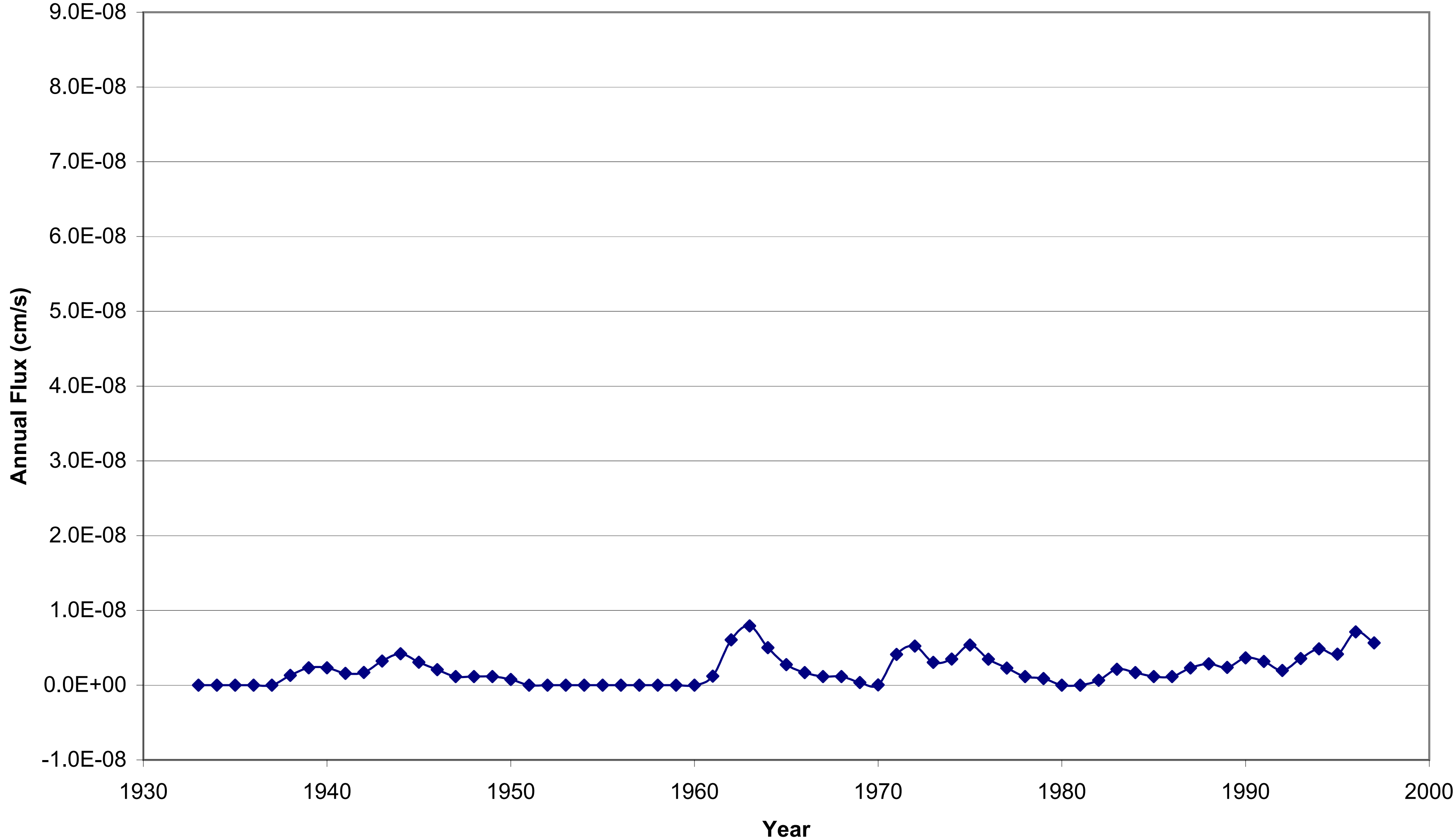

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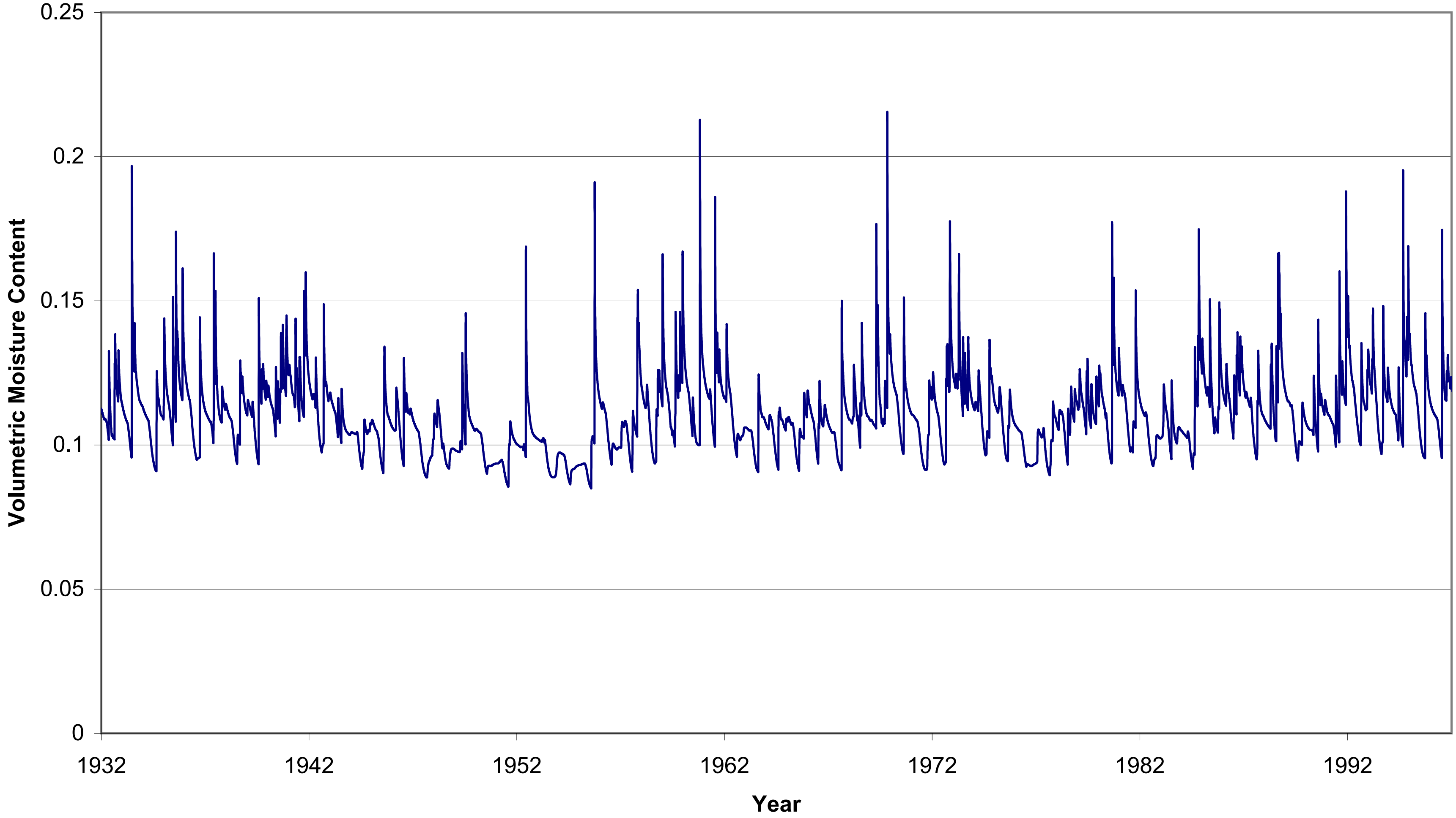
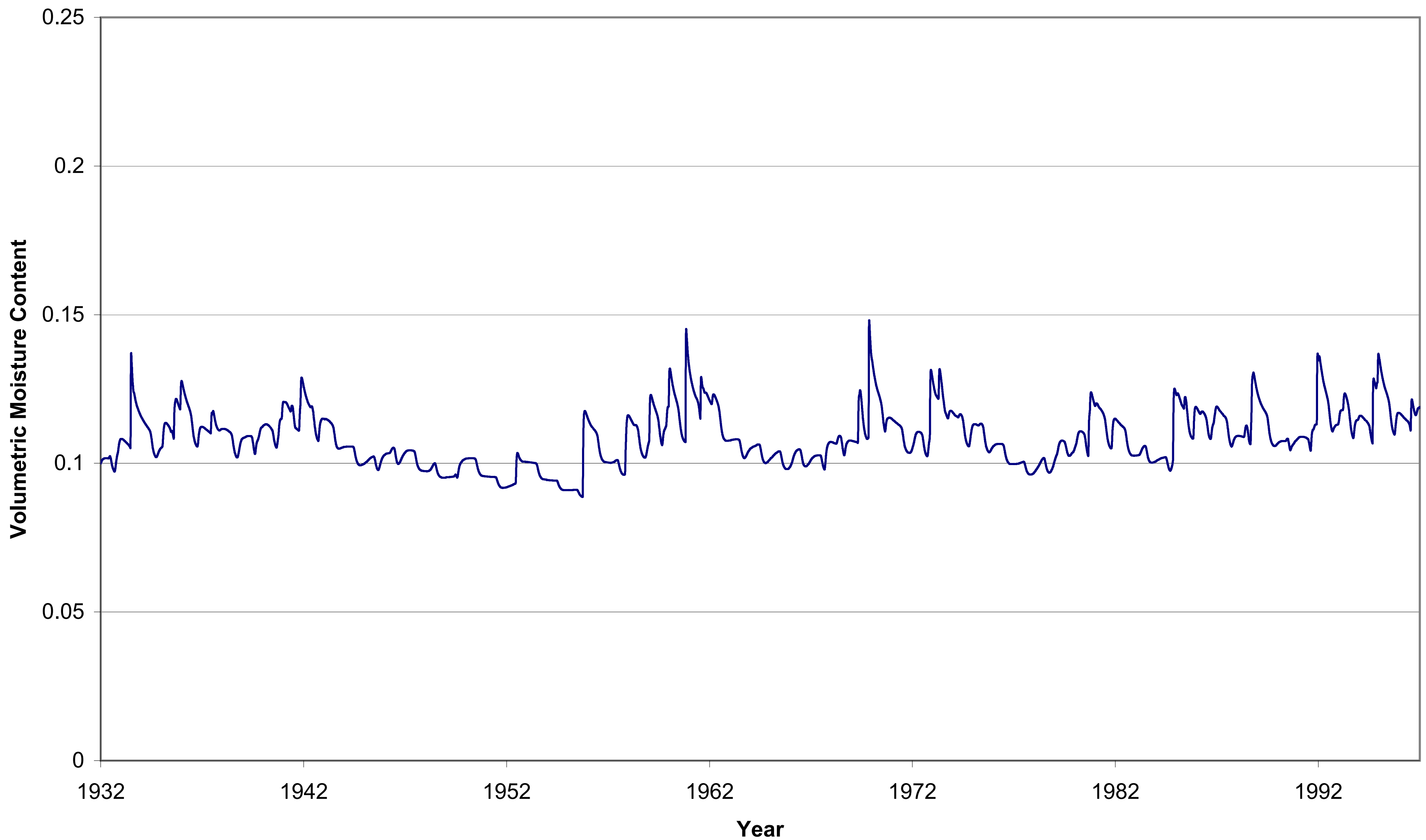


Figure 5-18 Moisture Content at 1-Ft Depth Predicted by UNSAT-H Using Historical Precipitation Data



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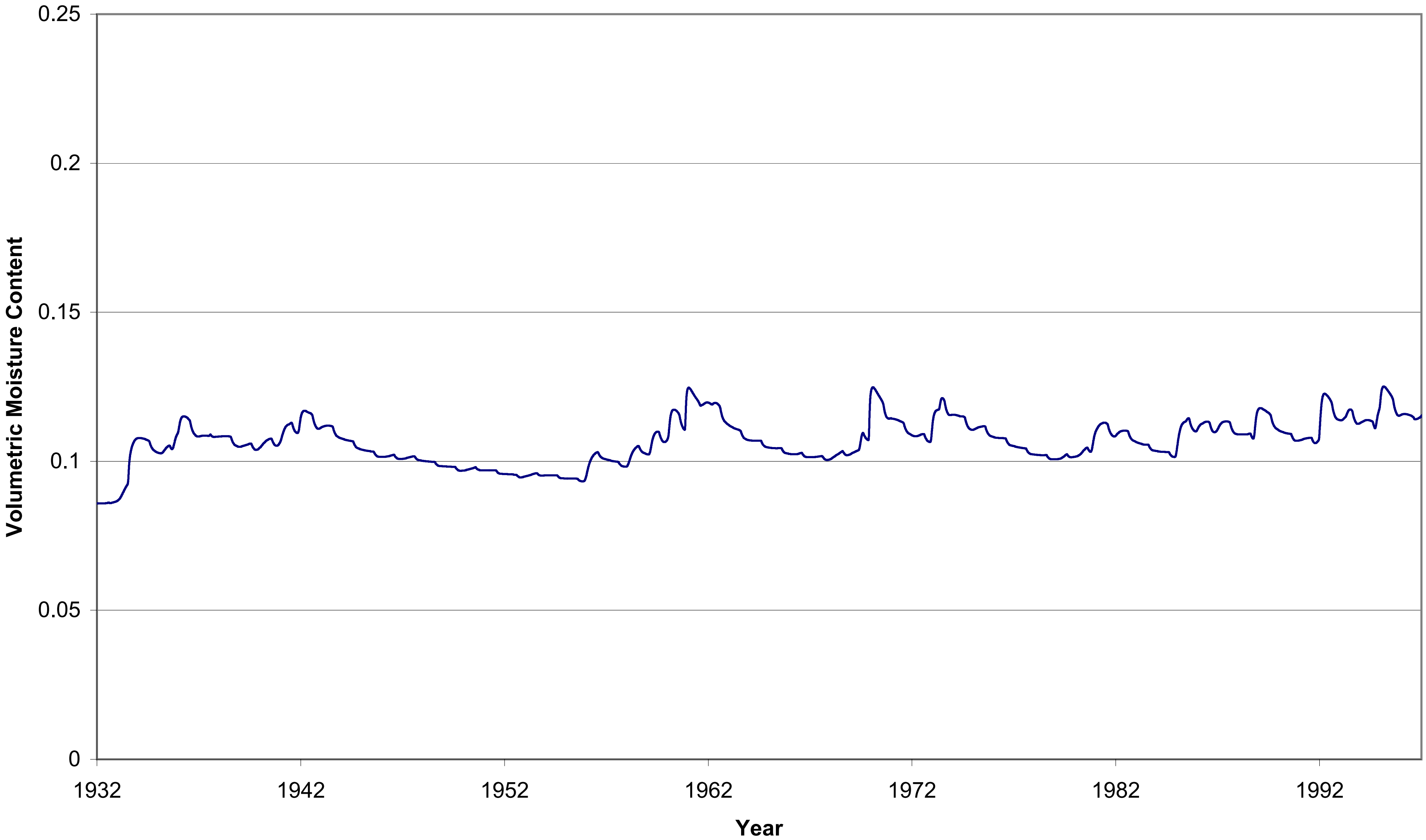

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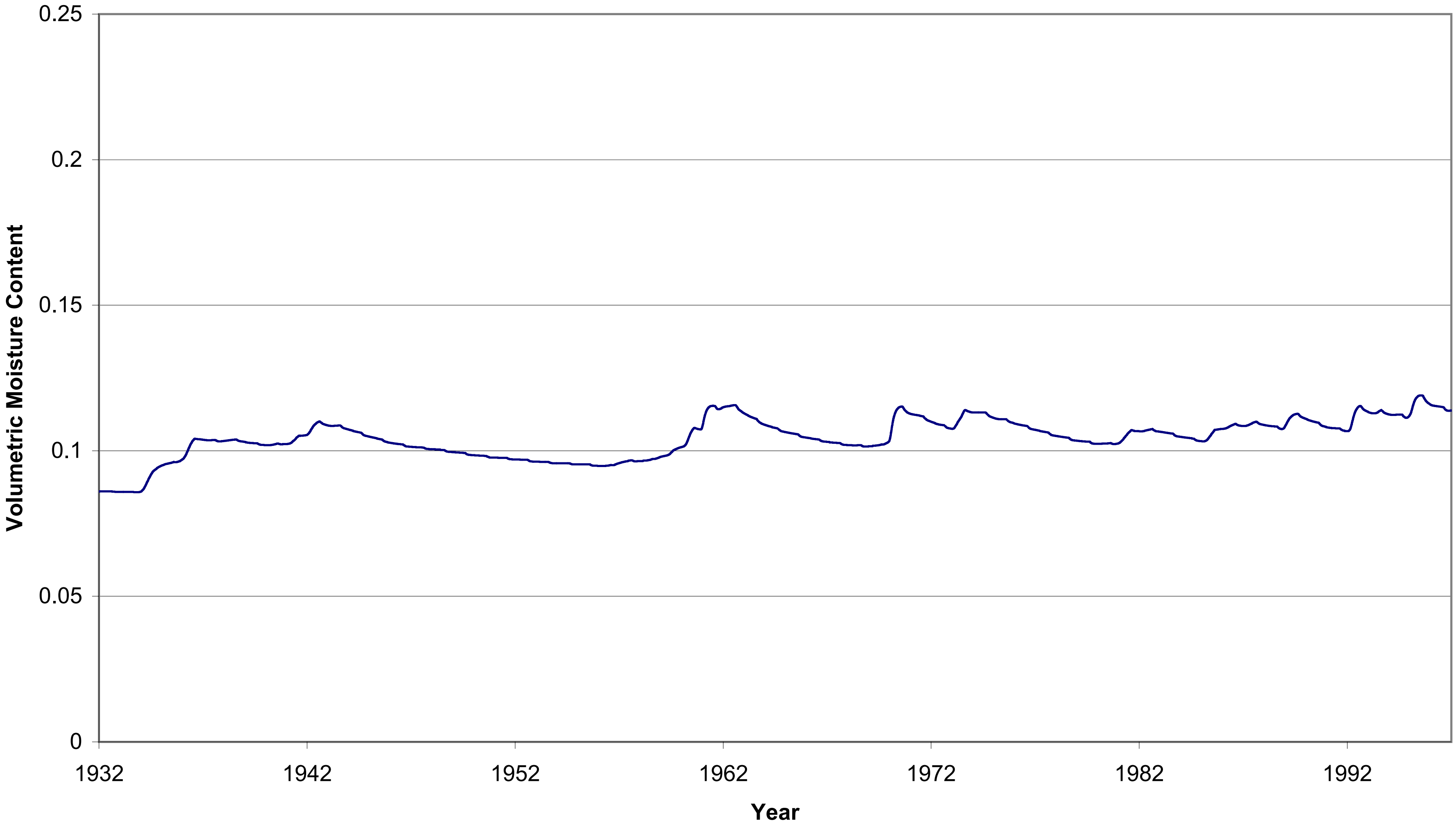

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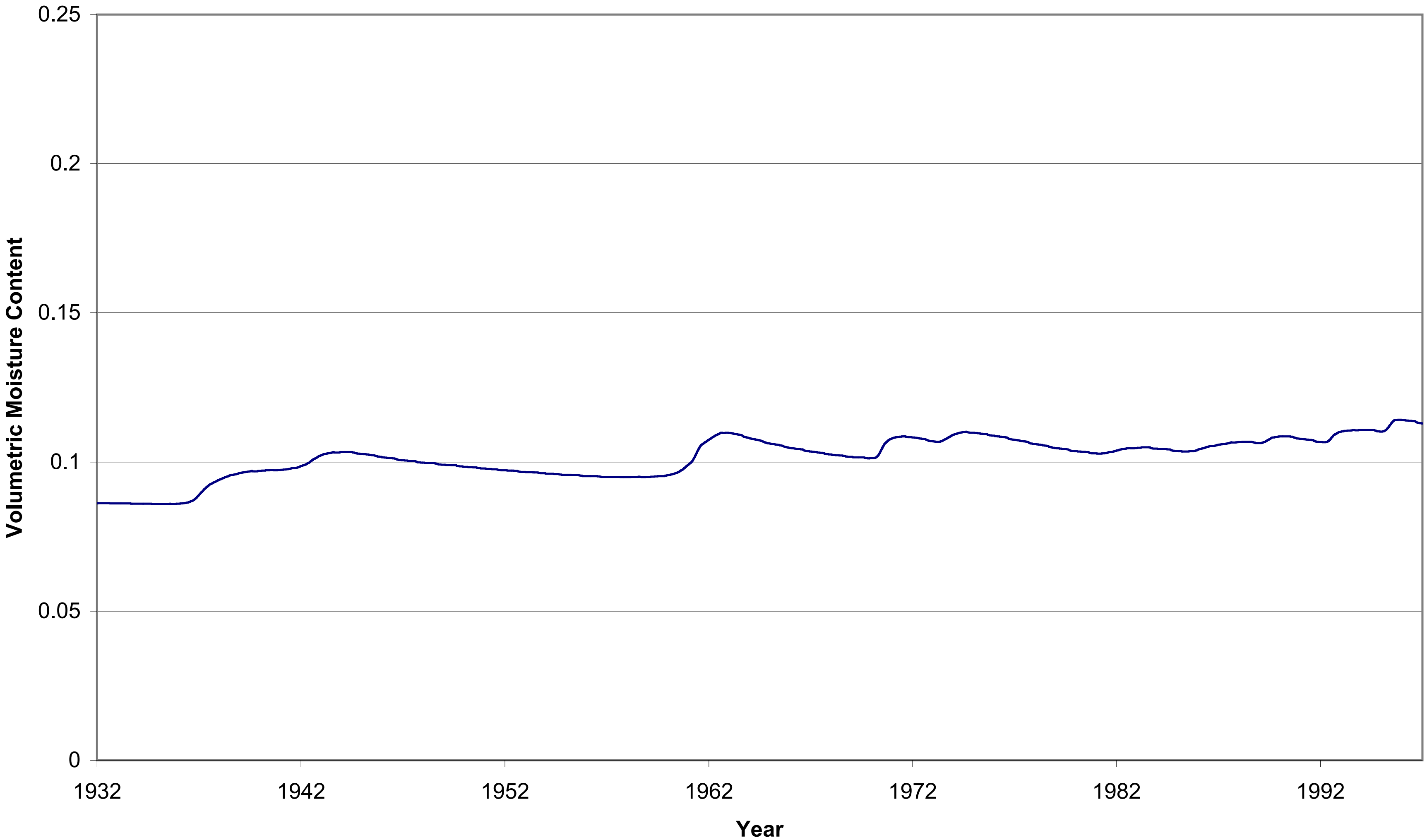

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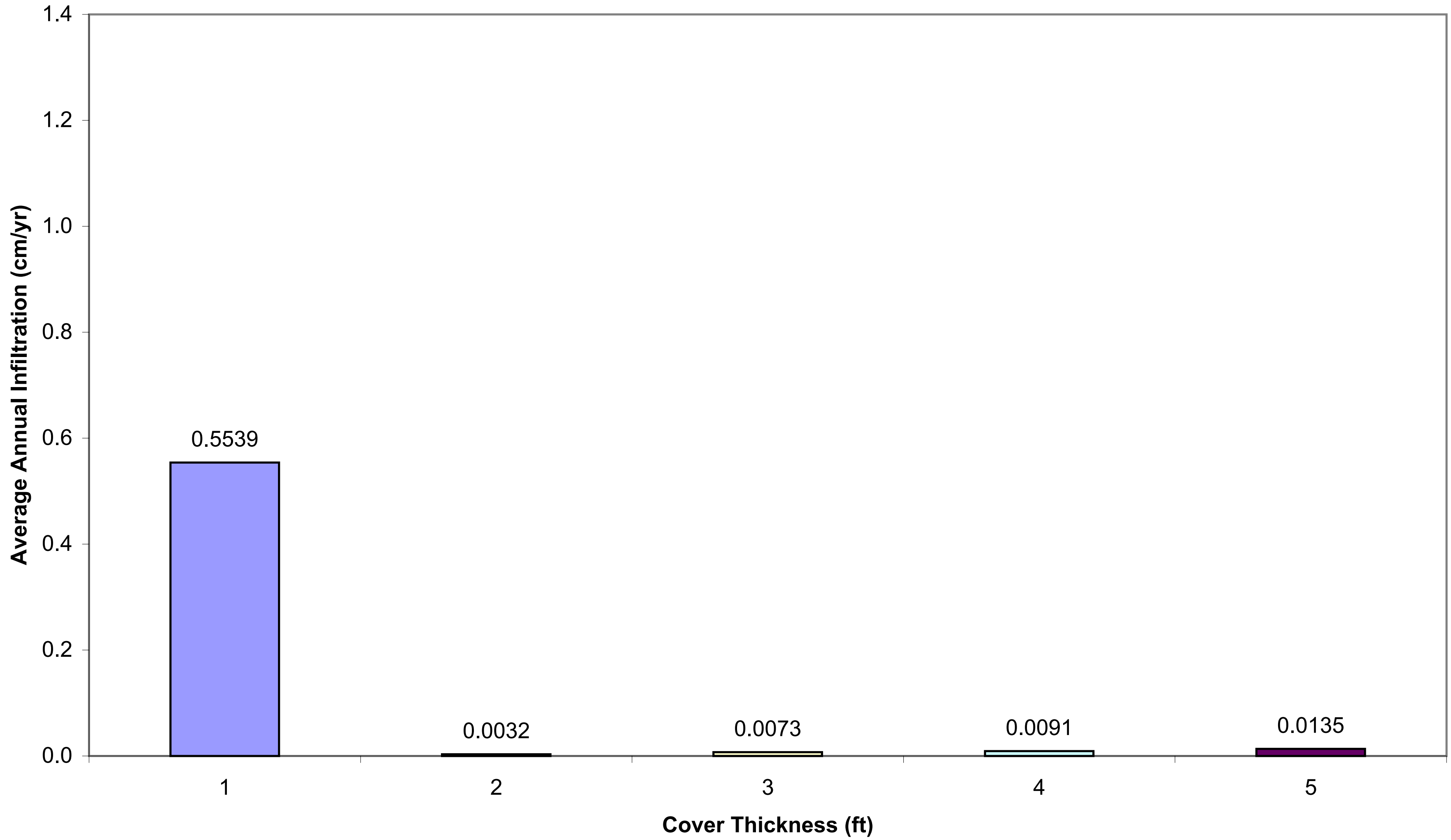

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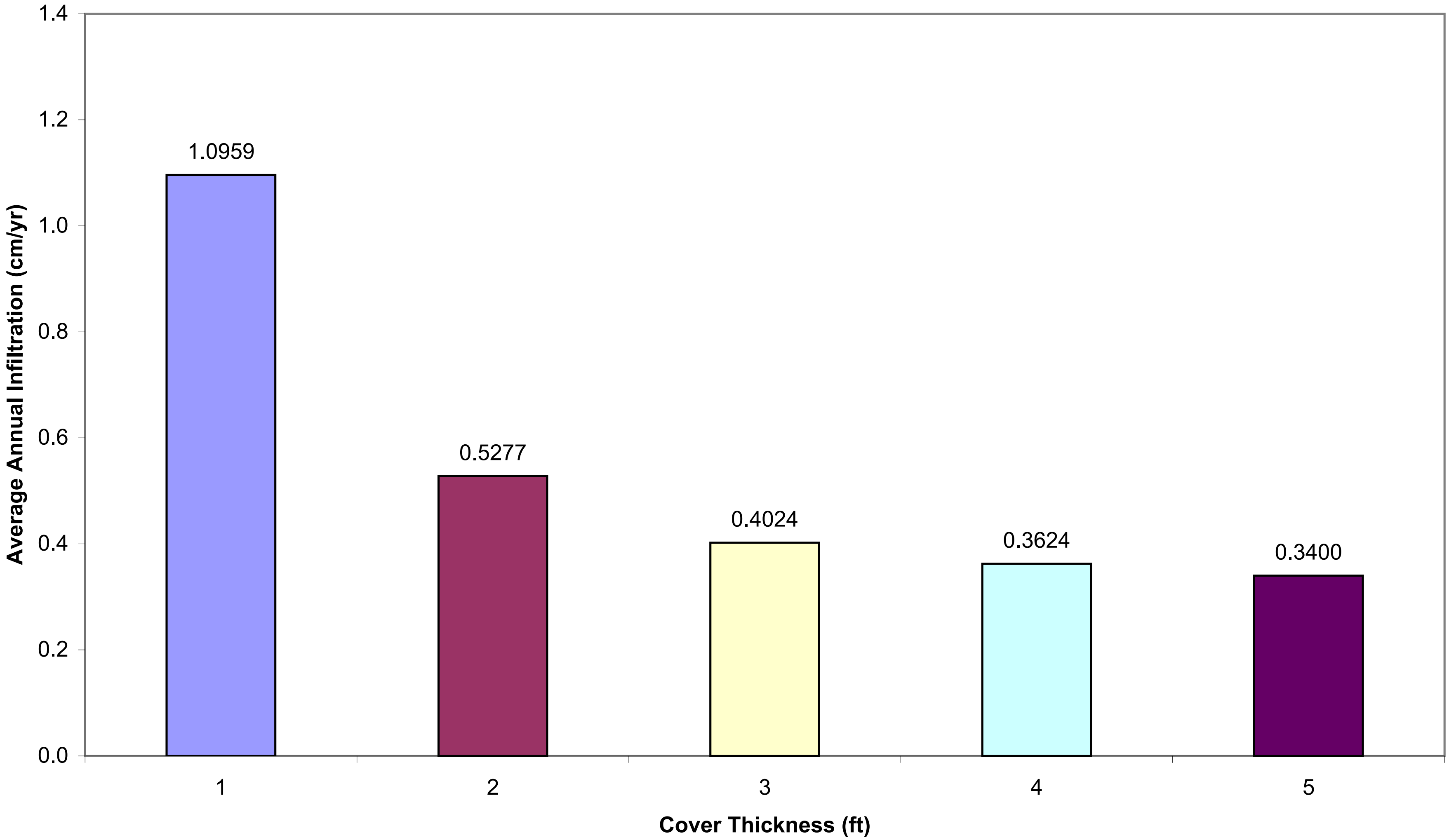

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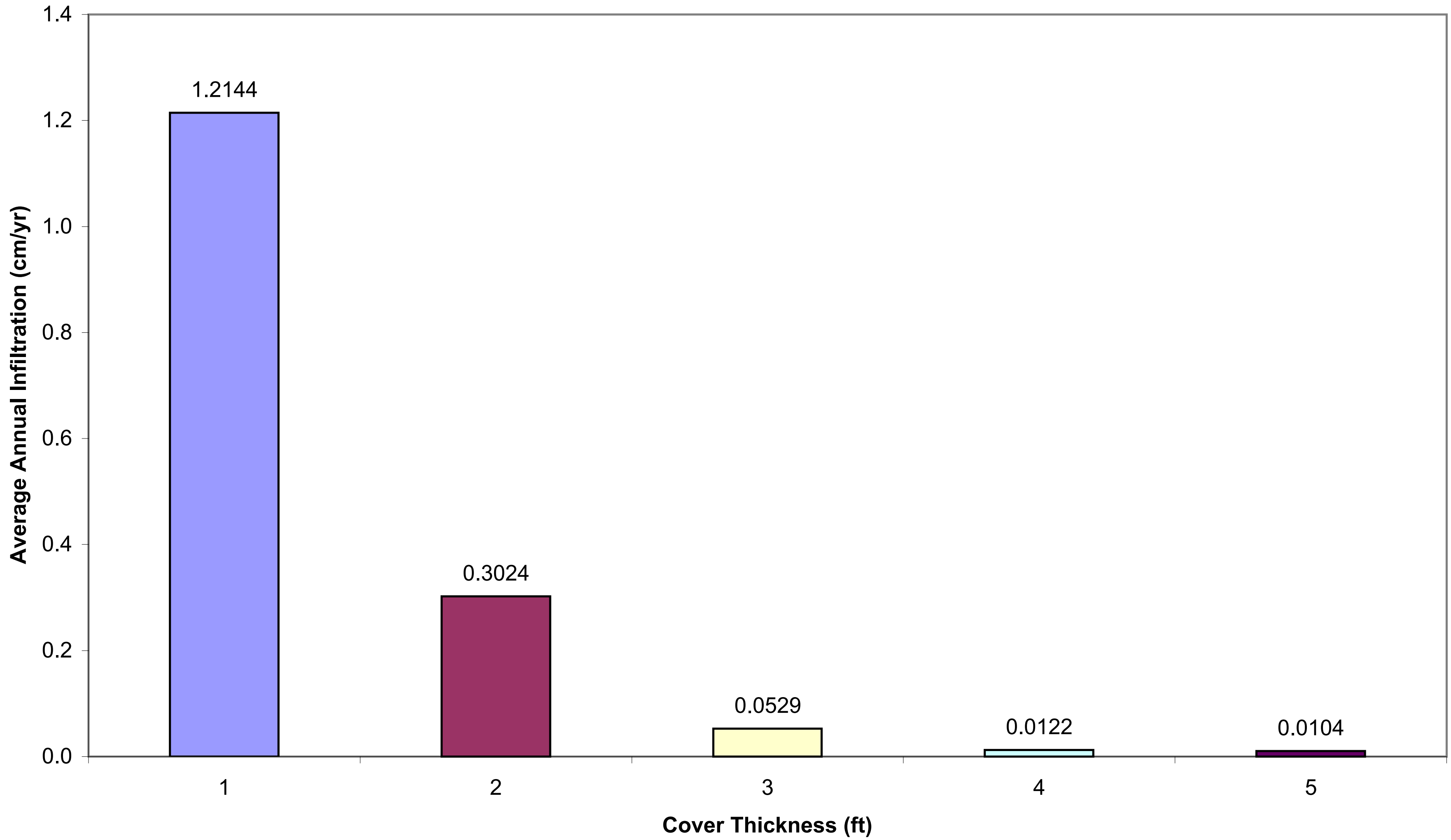

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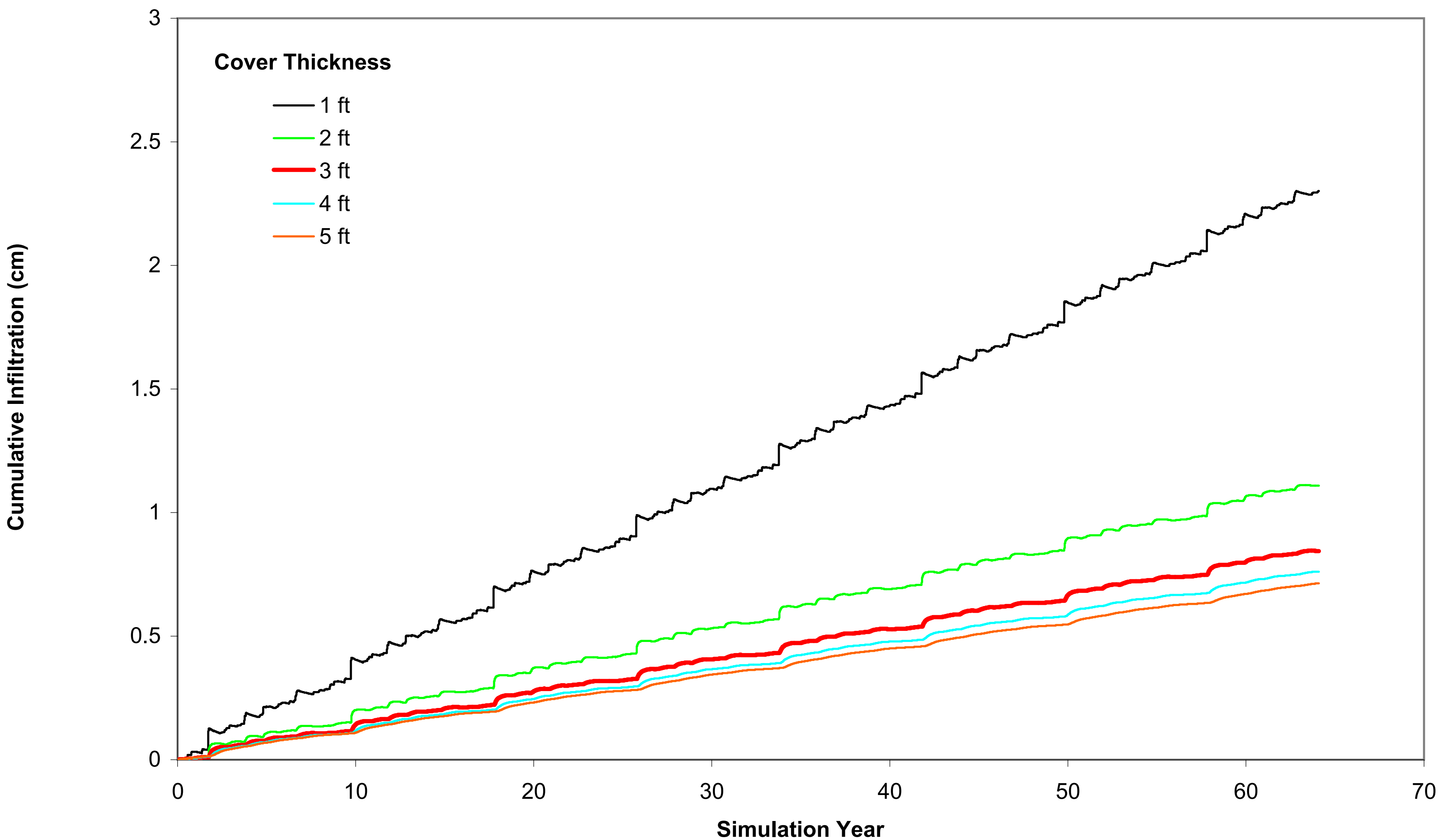

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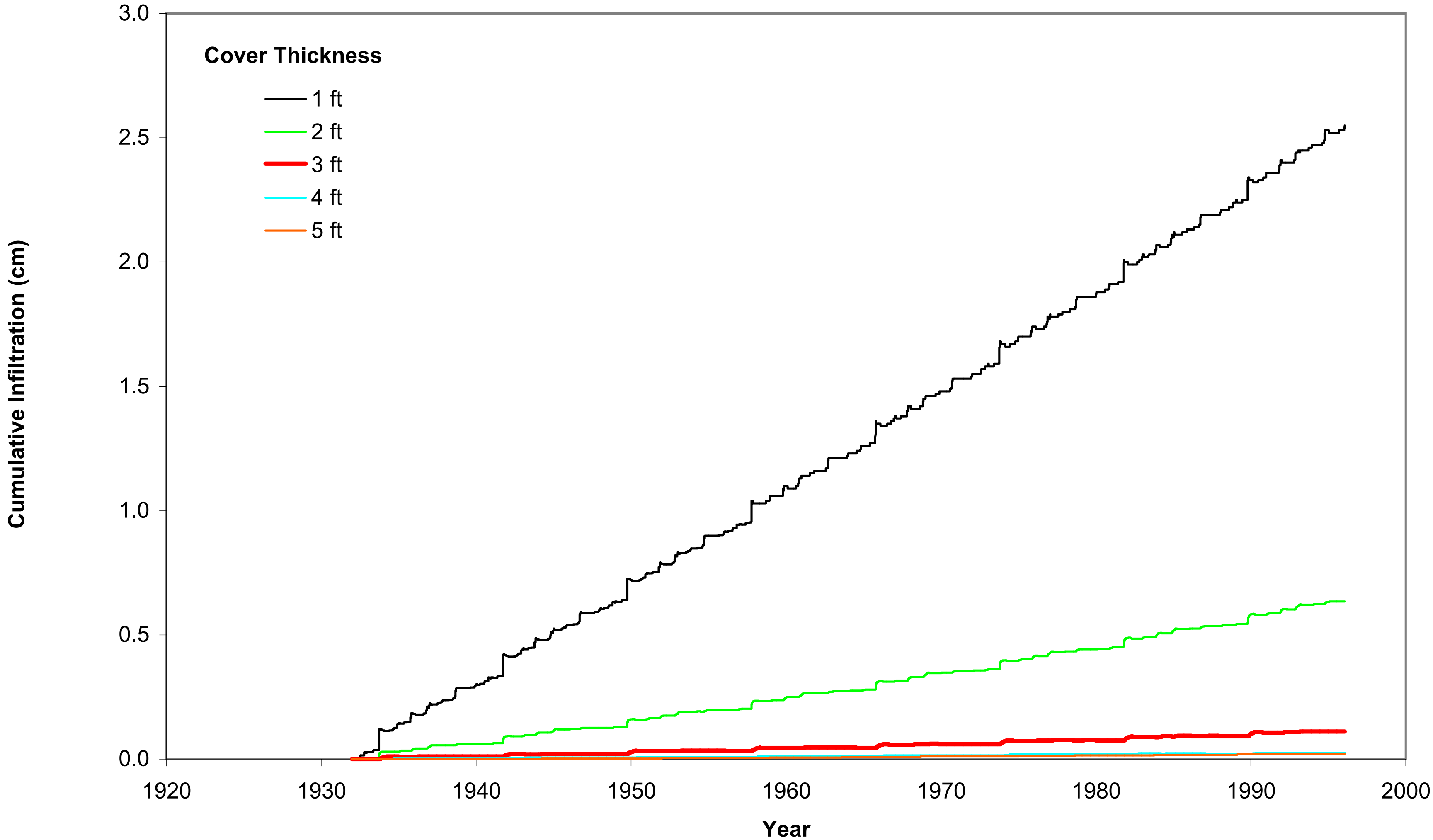

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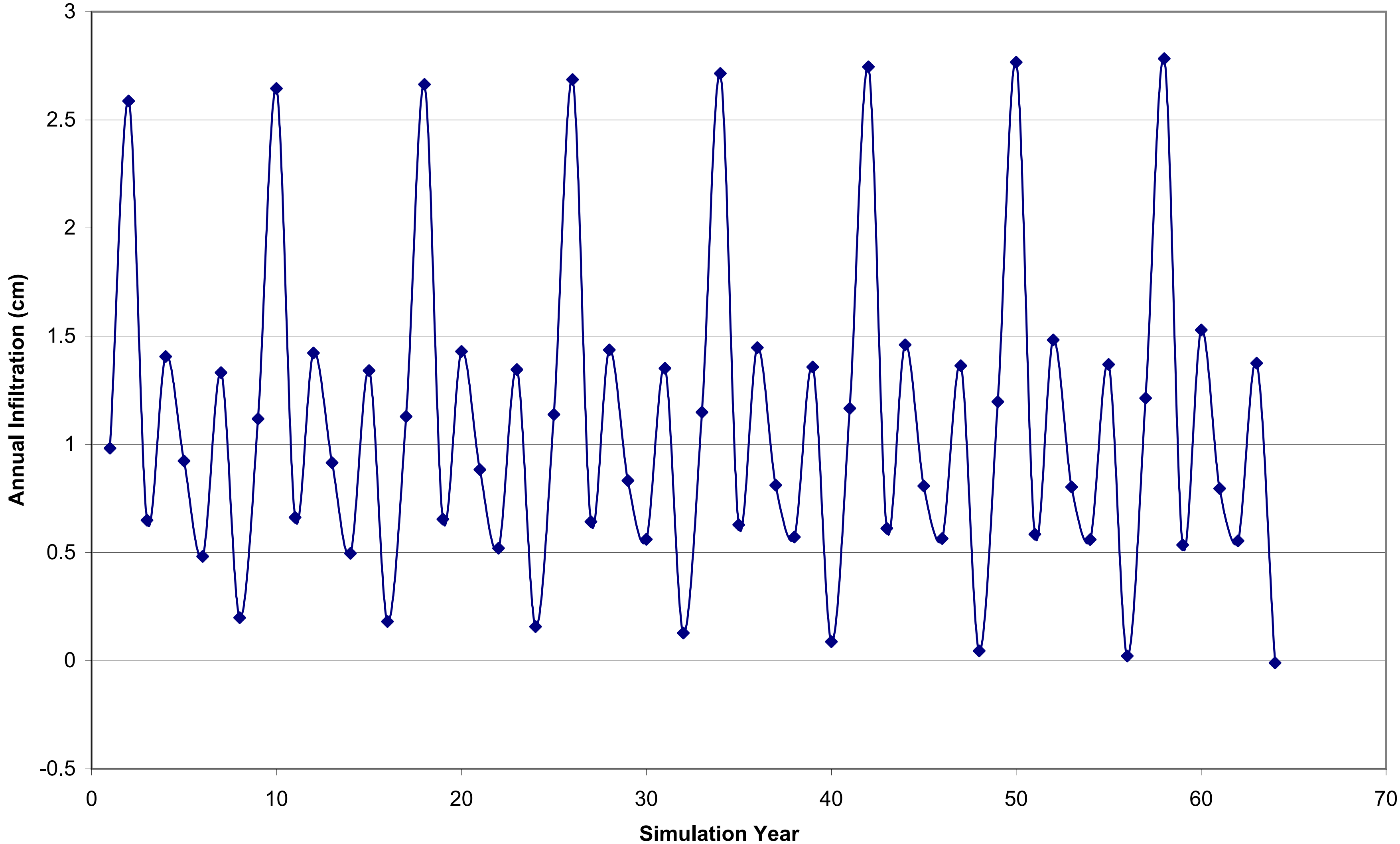

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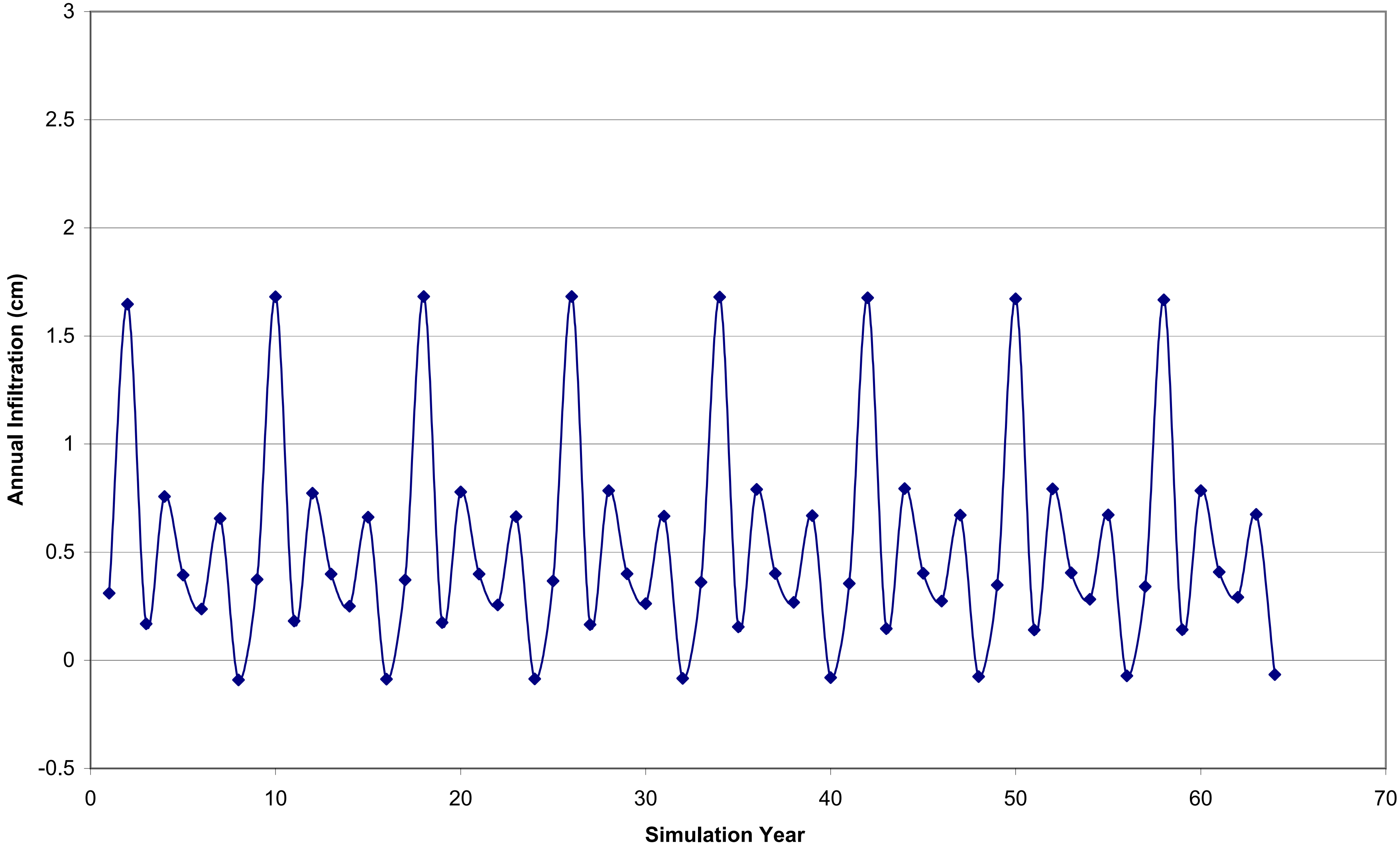

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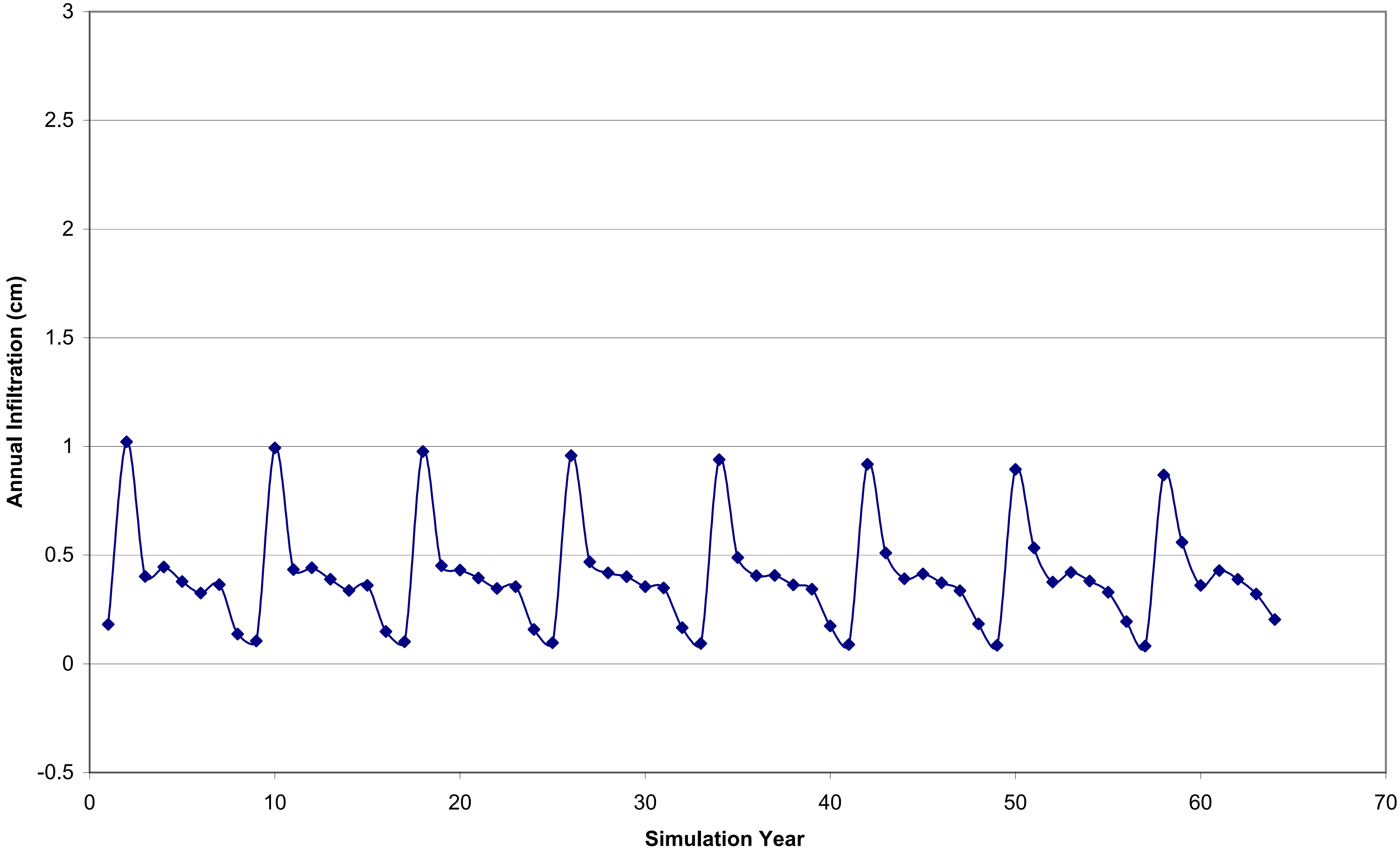

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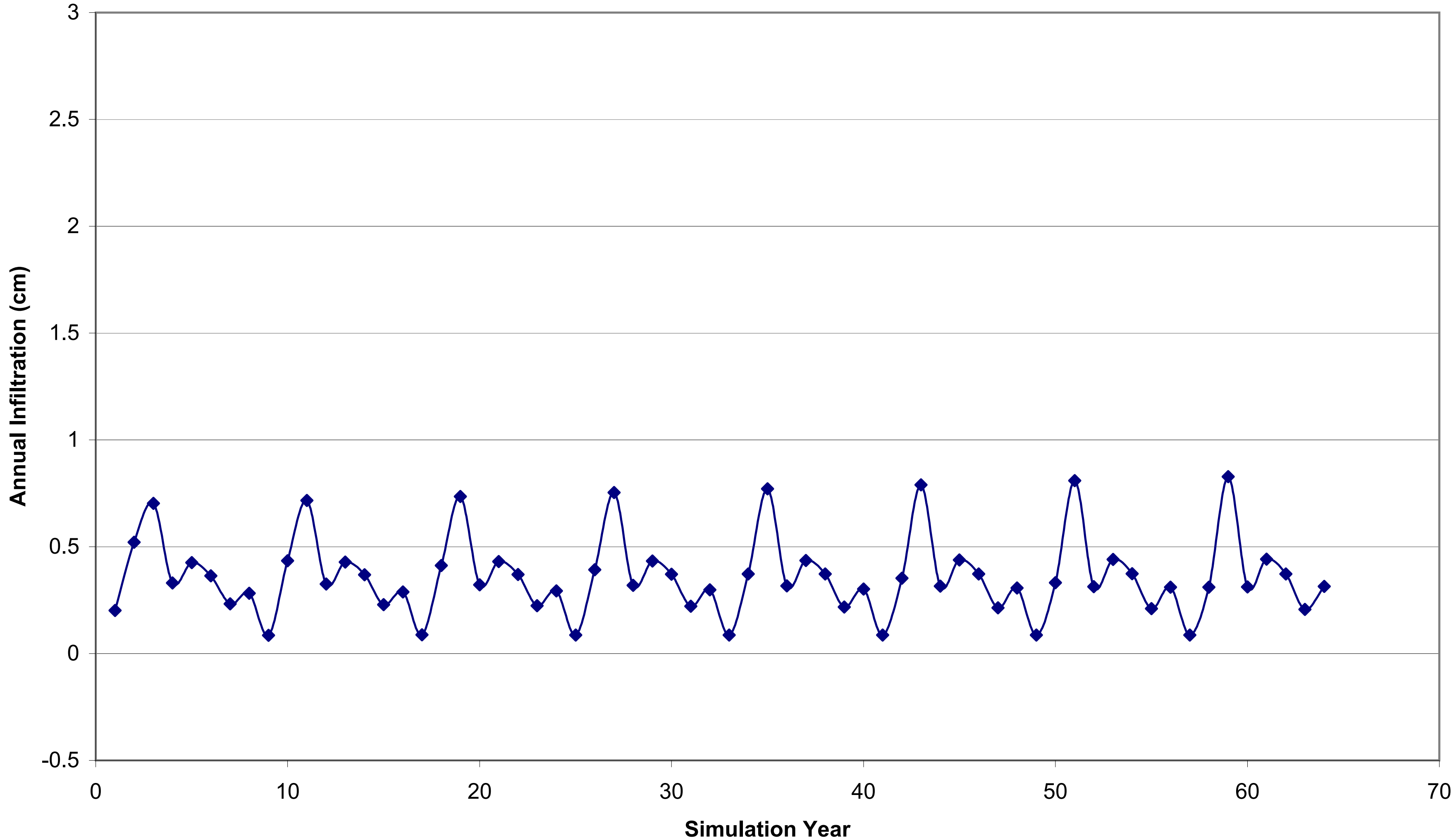

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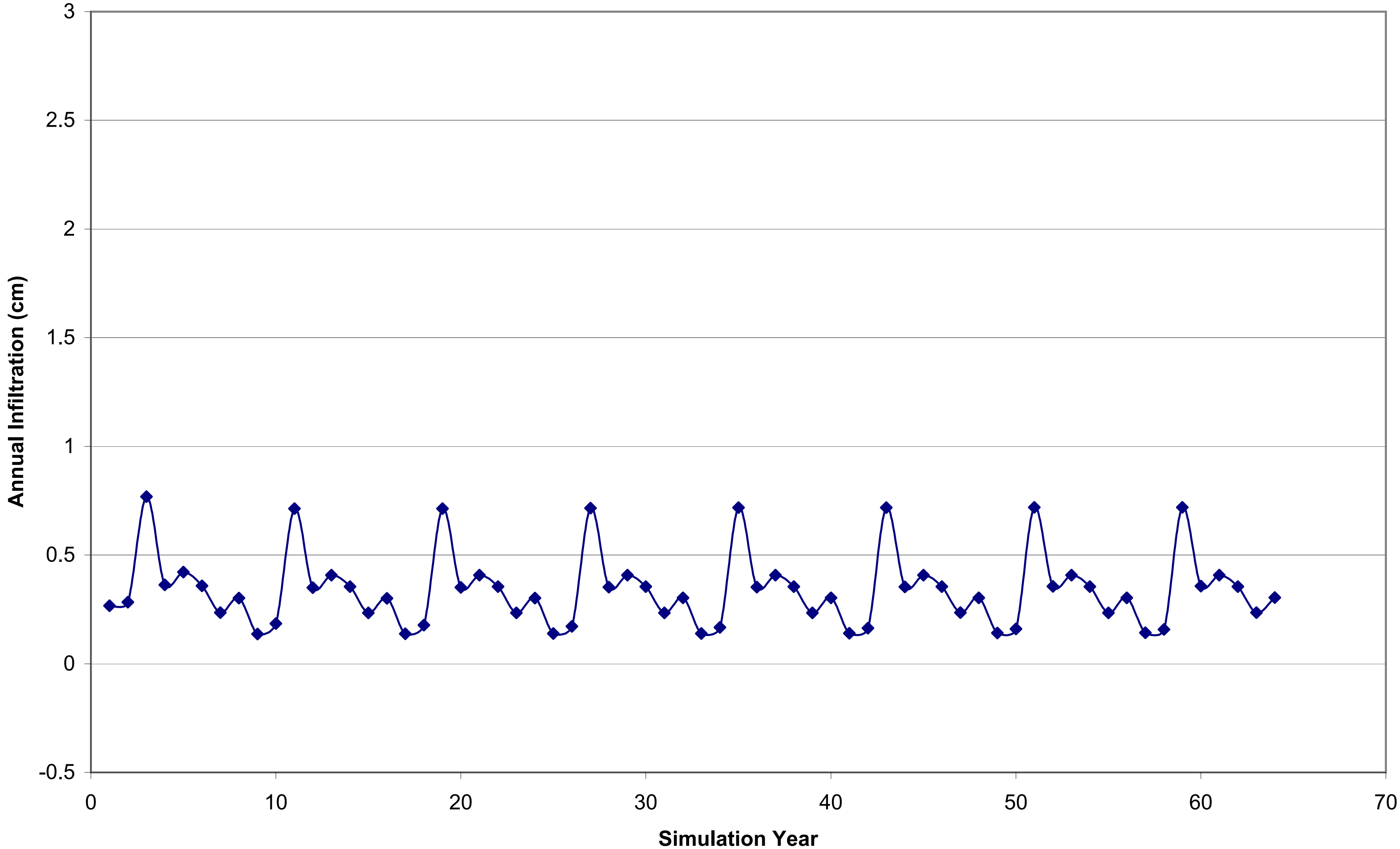

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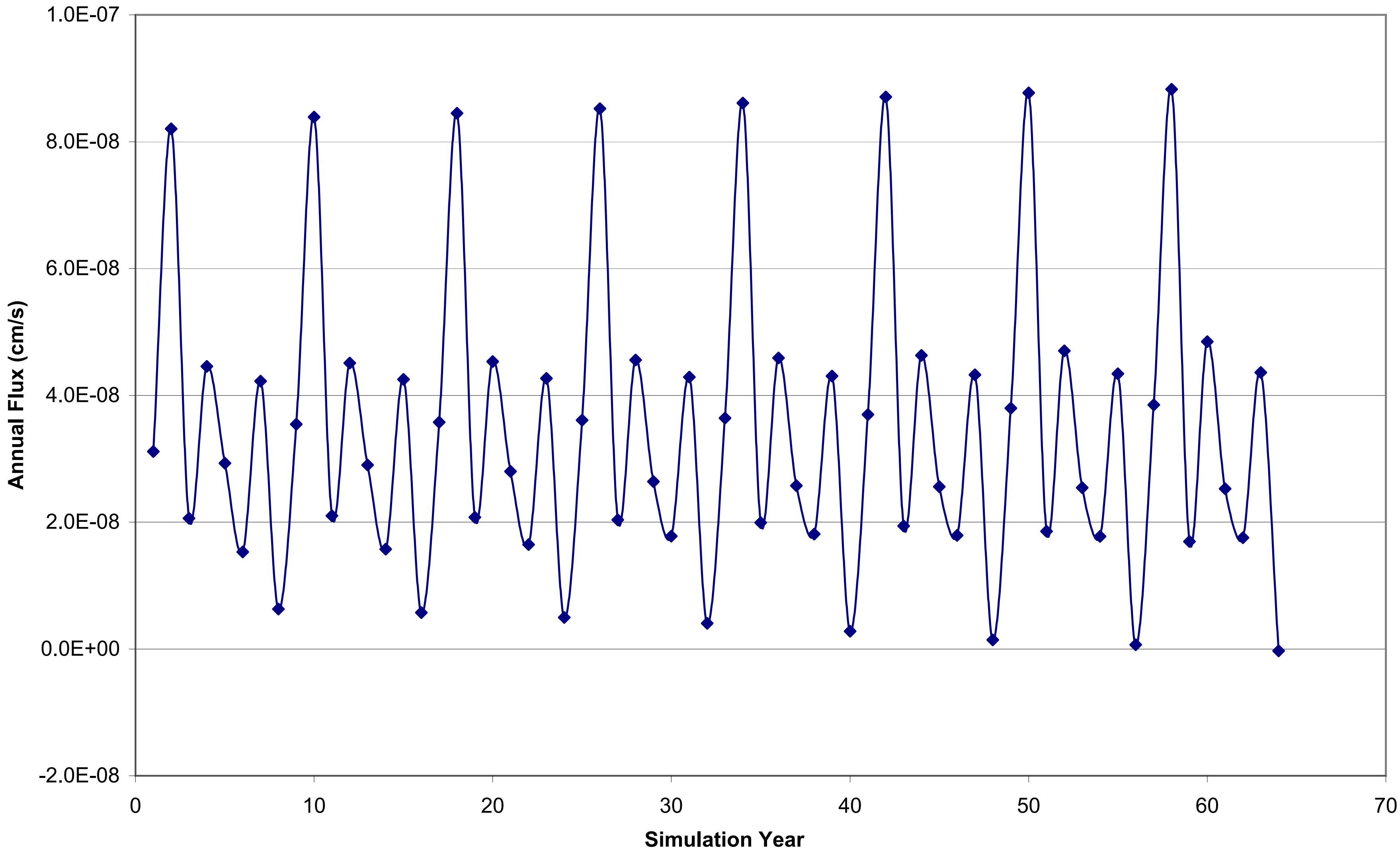


Figure 5-33 Annual Flux Through a 1-Ft Cover Predicted by UNSAT-H Using Maximum Precipitation Data

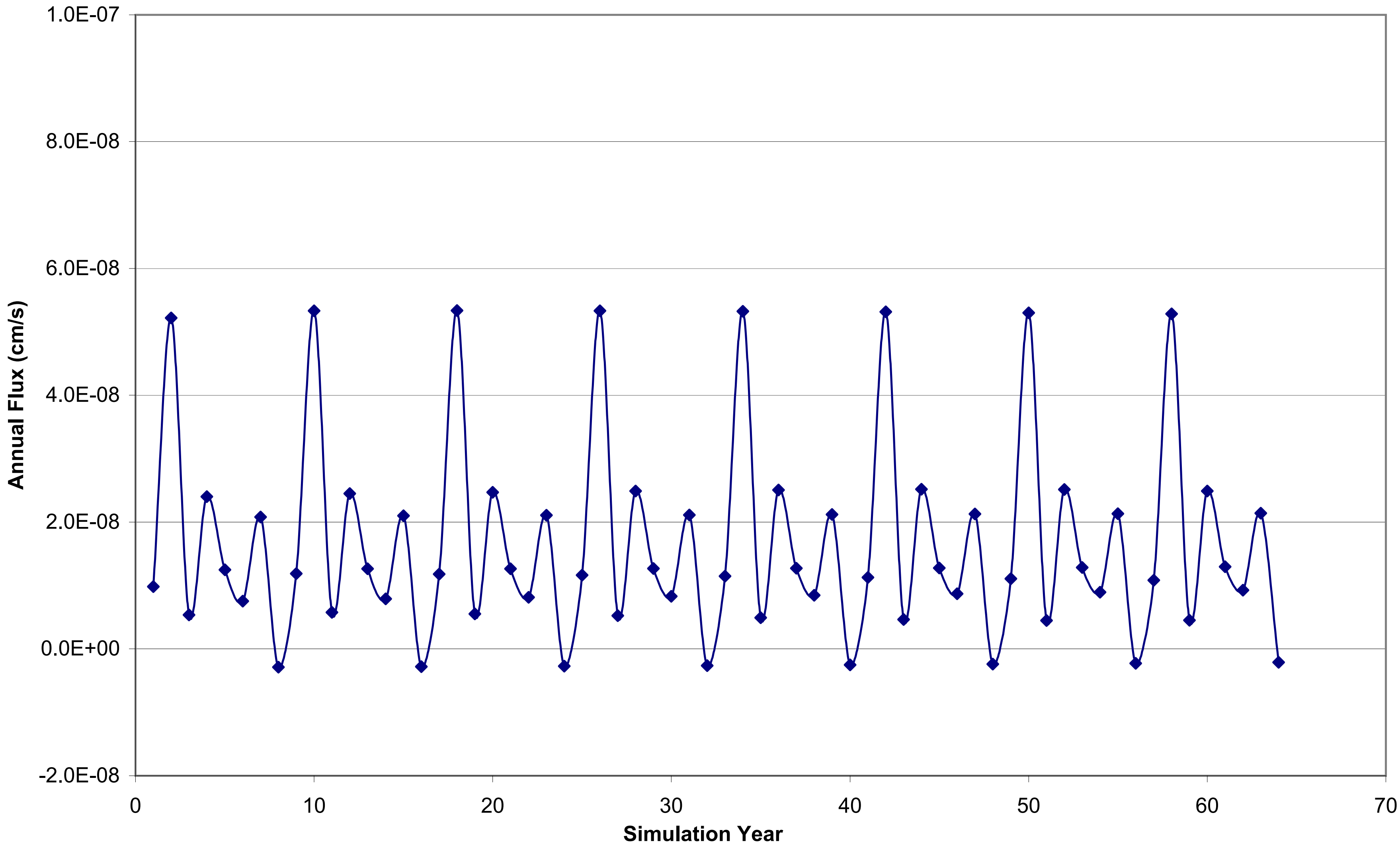


Figure 5-34 Annual Flux Through a 2-Ft Cover Predicted by UNSAT-H Using Maximum Precipitation Data

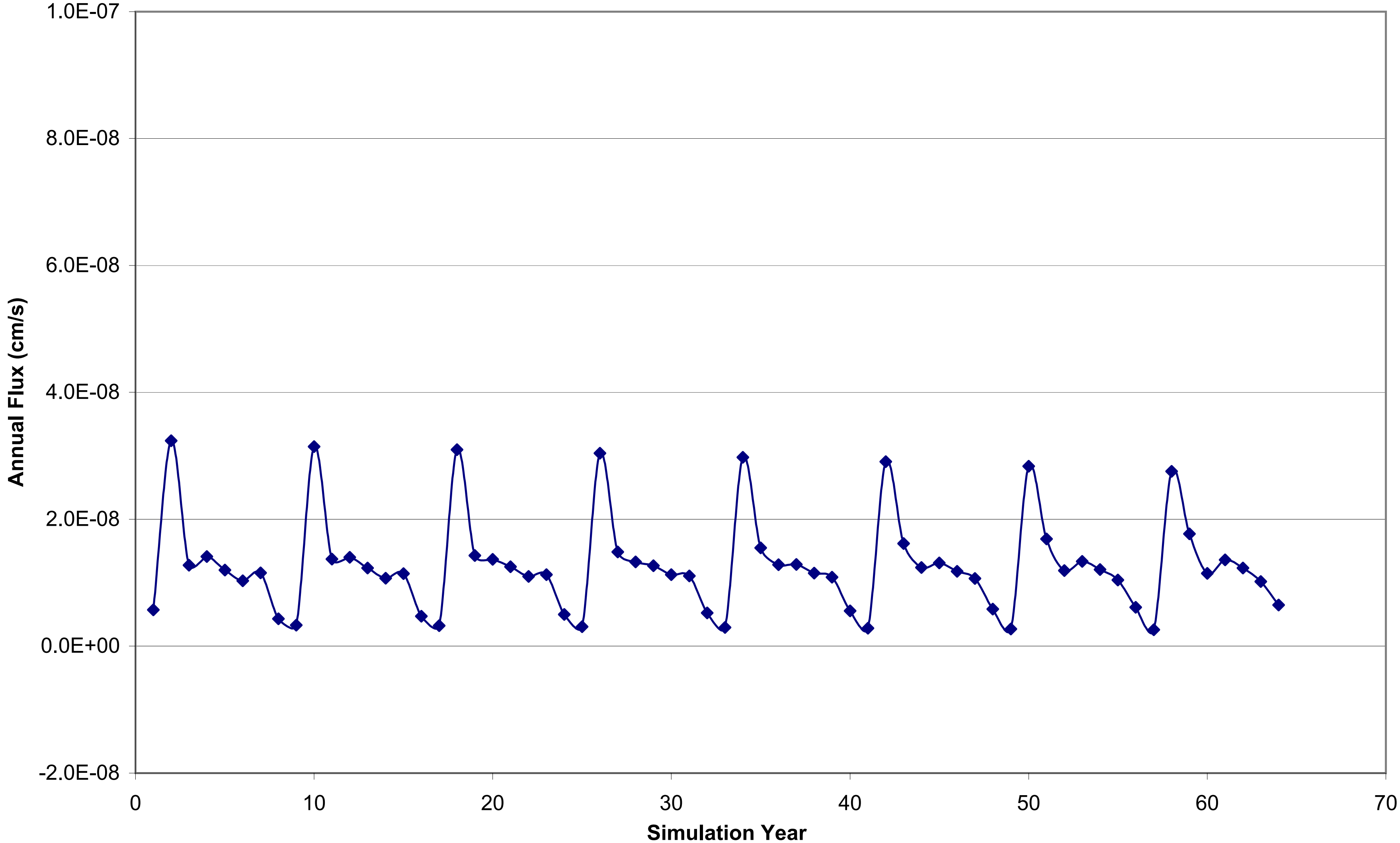


Figure 5-35 Annual Flux Through a 3-Ft Cover Predicted by UNSAT-H Using Maximum Precipitation Data

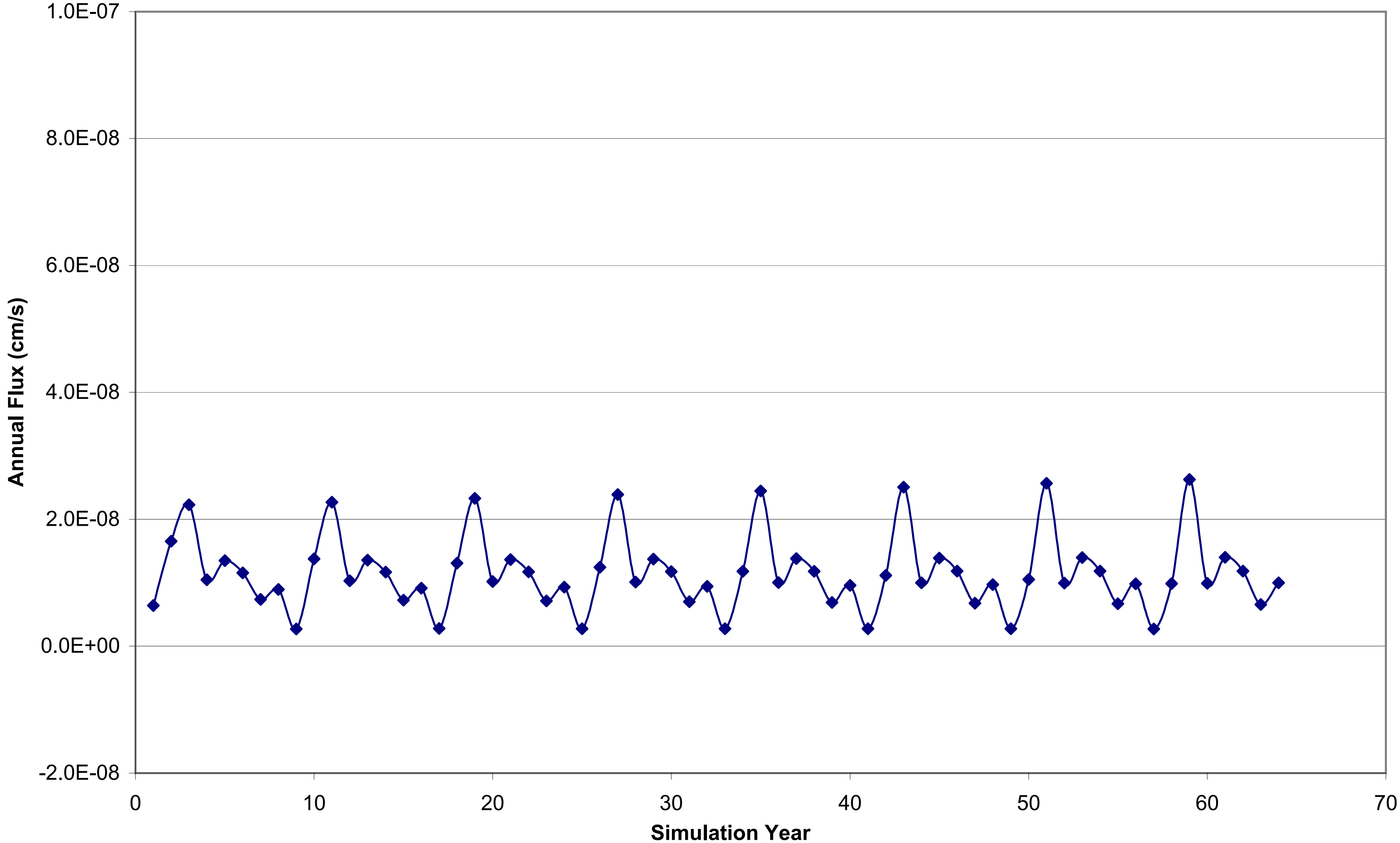


Figure 5-36 Annual Flux Through a 4-Ft Cover Predicted by UNSAT-H Using Maximum Precipitation Data

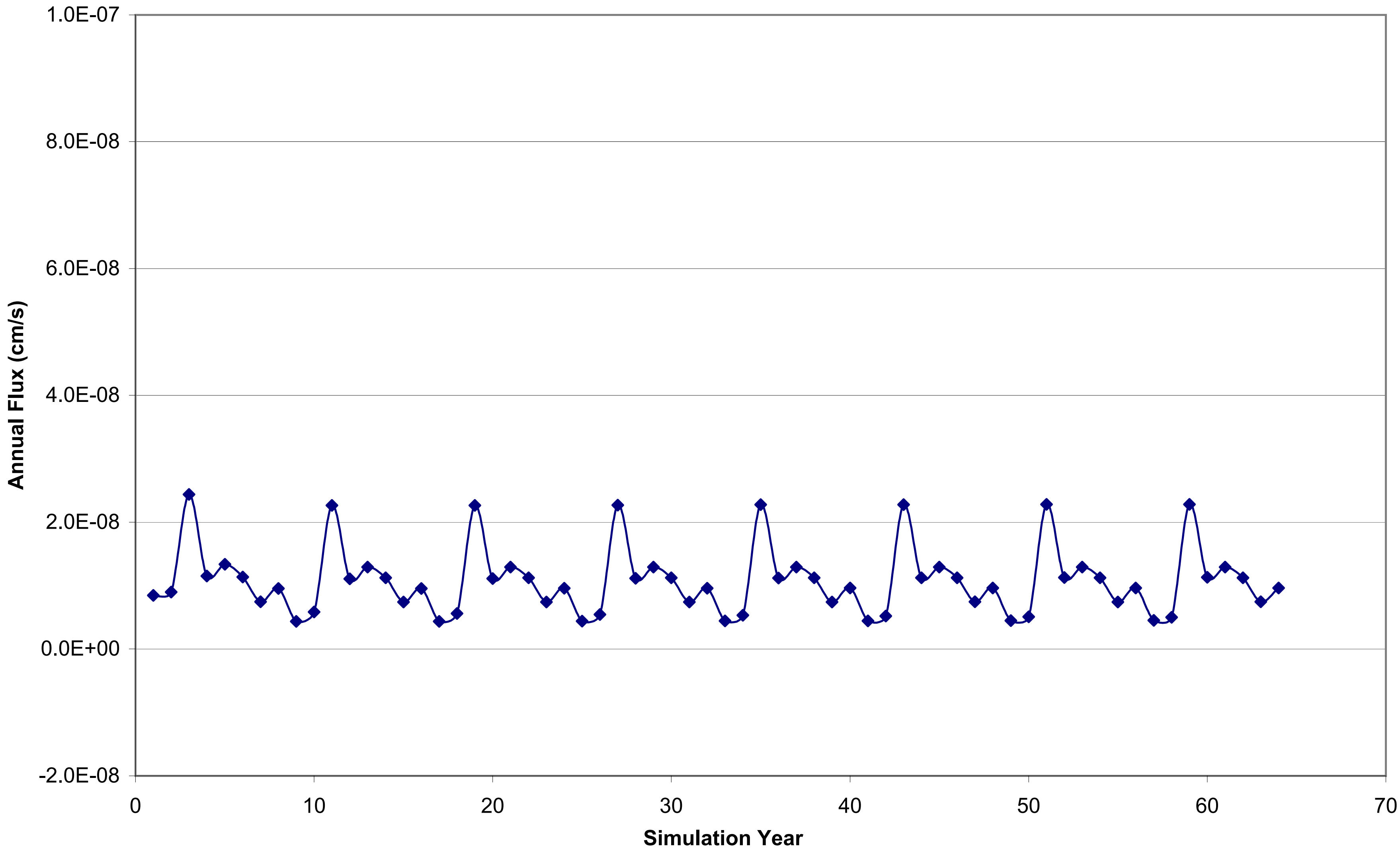


Figure 5-37 Annual Flux Through a 5-Ft Cover Predicted by UNSAT-H Using Maximum Precipitation Data

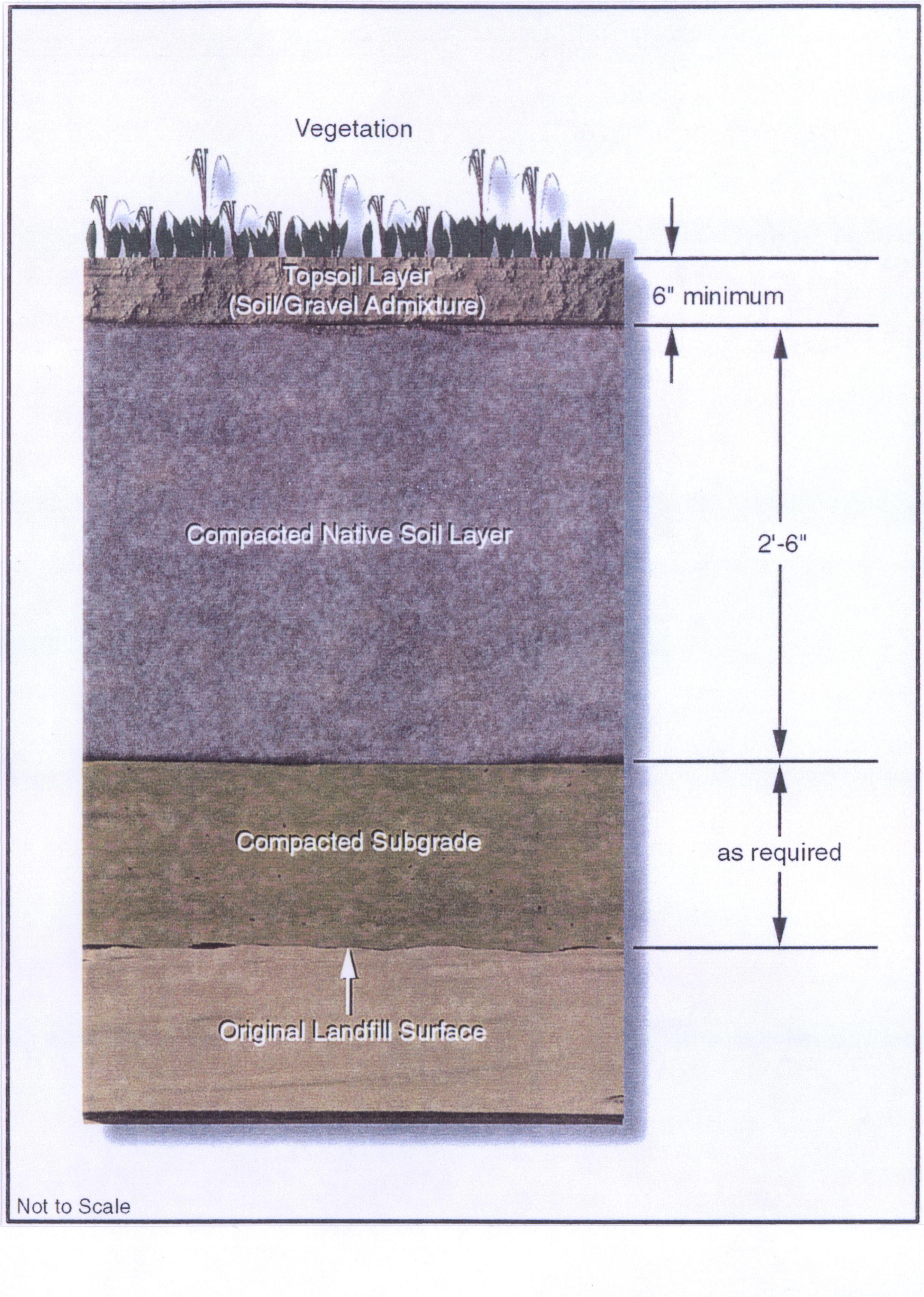
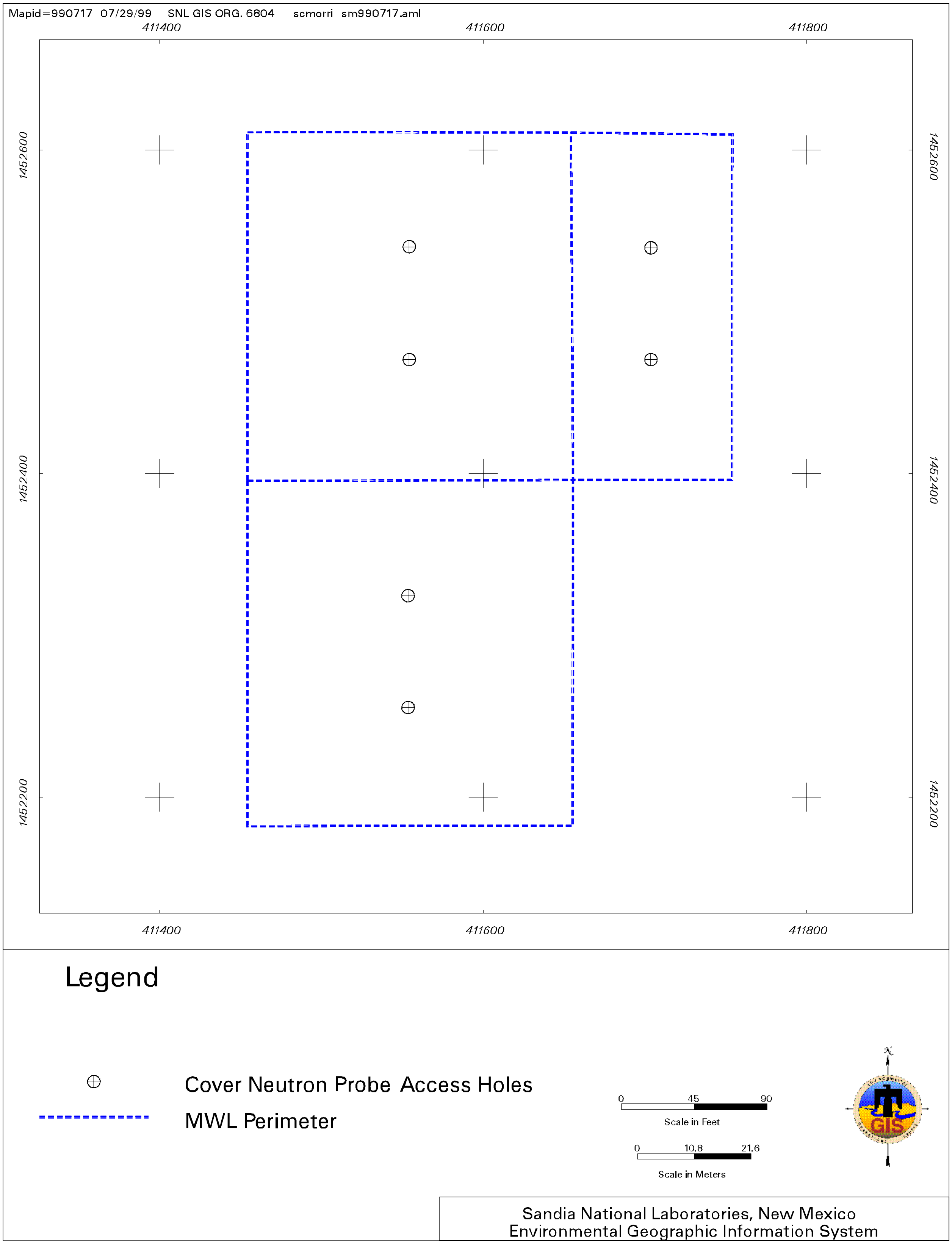


Figure 6-1 Schematic of Mixed Waste Landfill Alternative Cover



840857.04040000 A7

Figure 7-1 Location of Cover Neutron Probe Access Holes

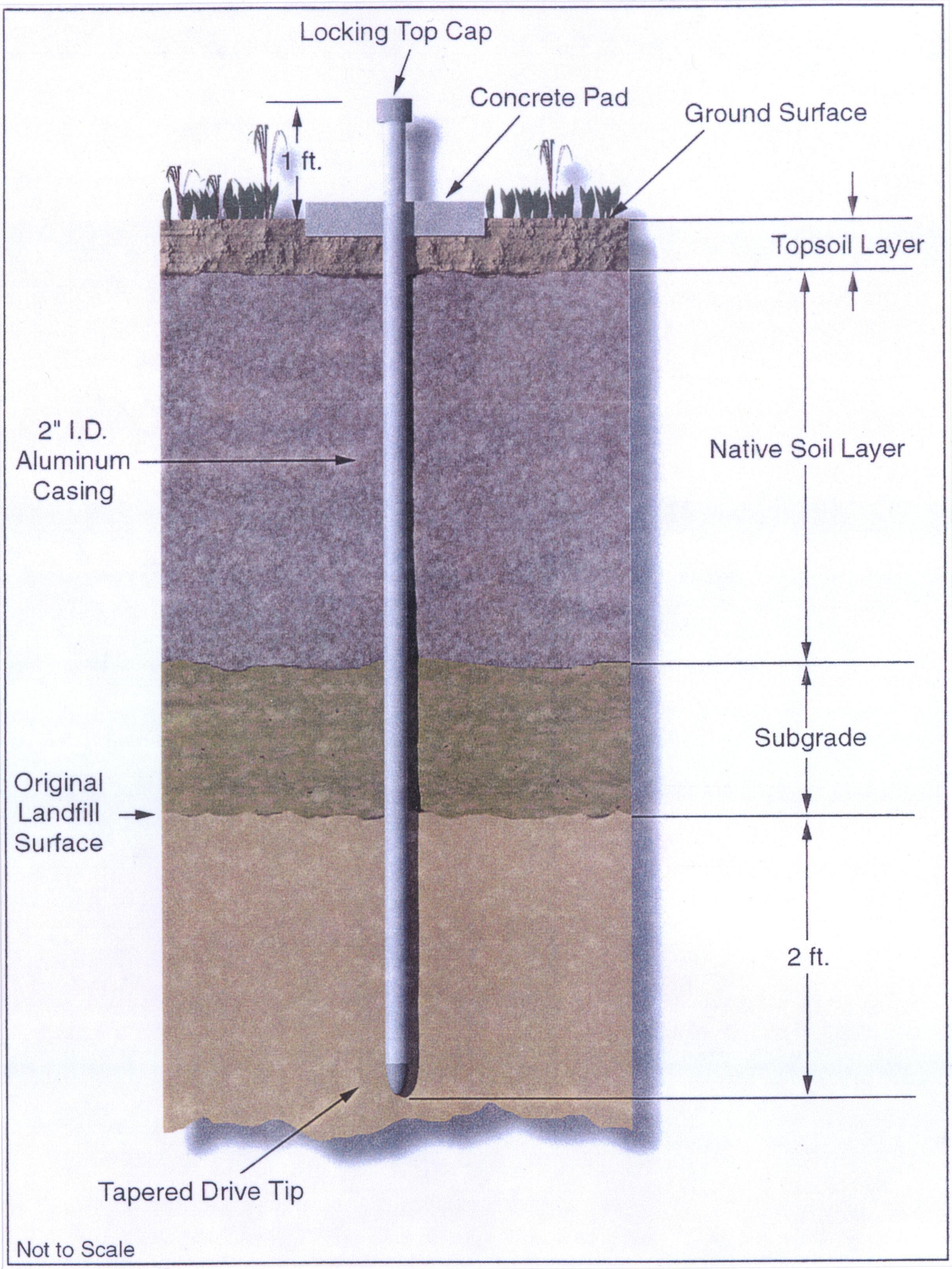
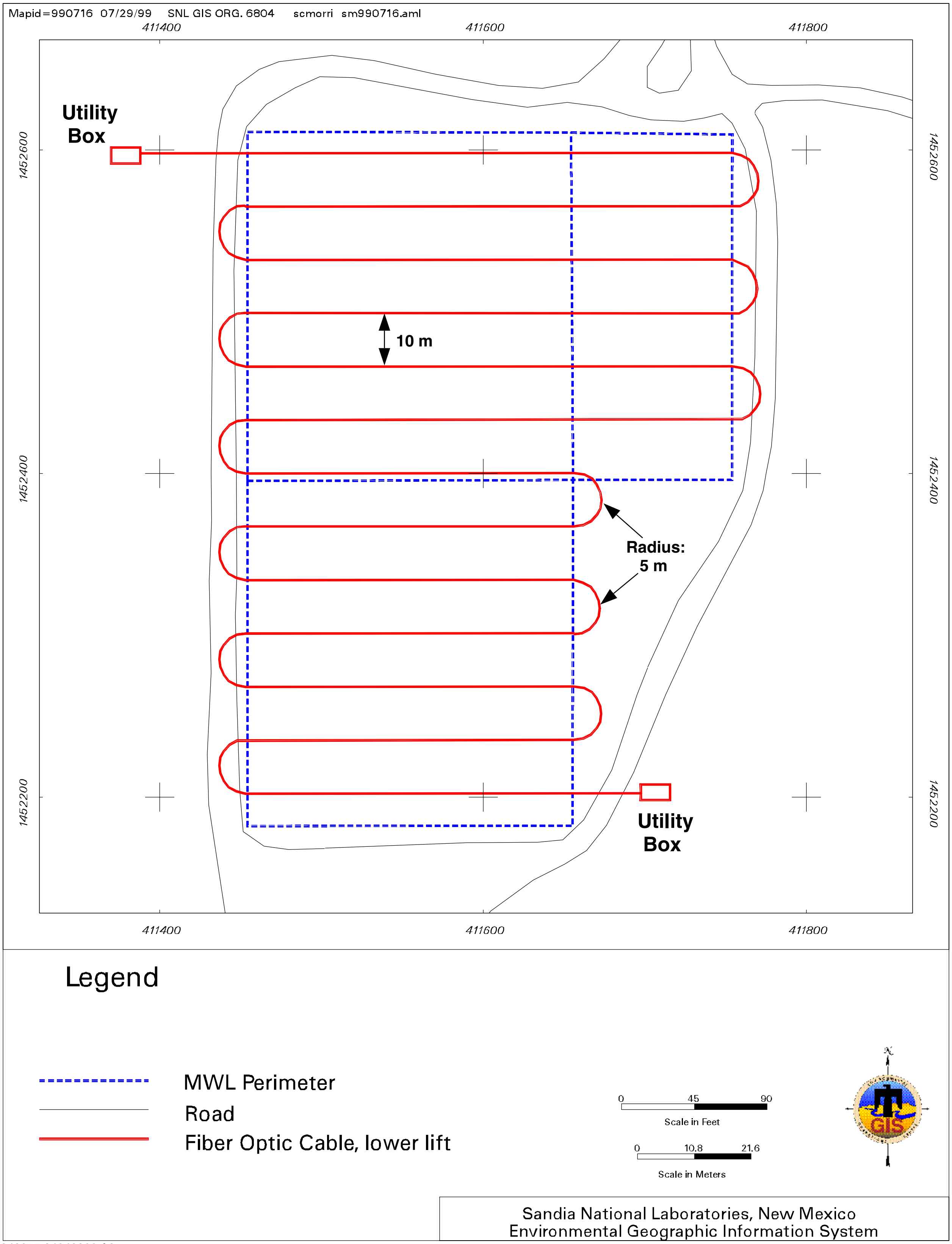


Figure 7-2 Schematic of Cover Neutron Probe Access Holes and Casings



840857.04040000 A8

Figure 7-3 Schematic of Lowermost Fiber Optics Deployment

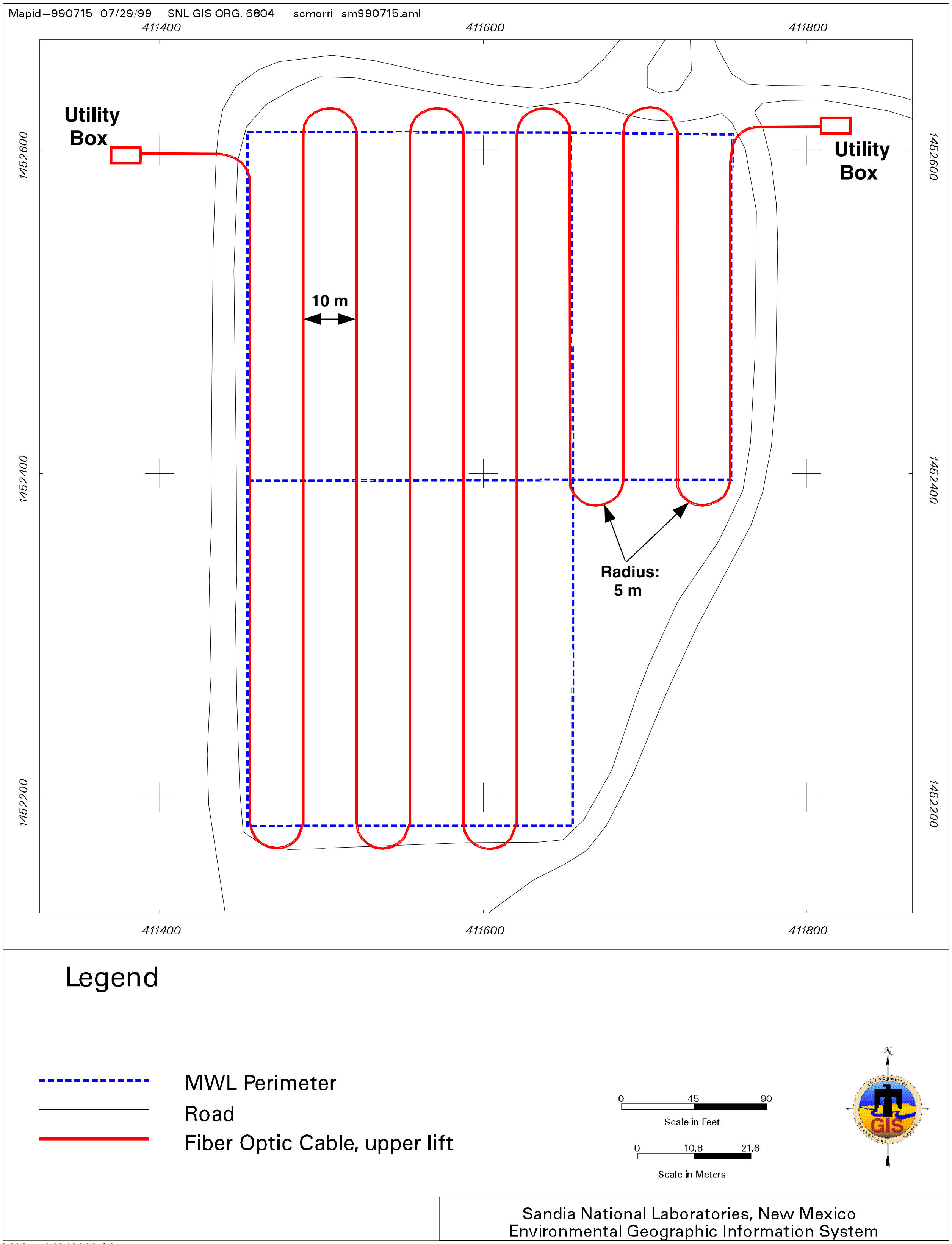


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Figure 7-4 Schematic of Uppermost Fiber Optics Deployment

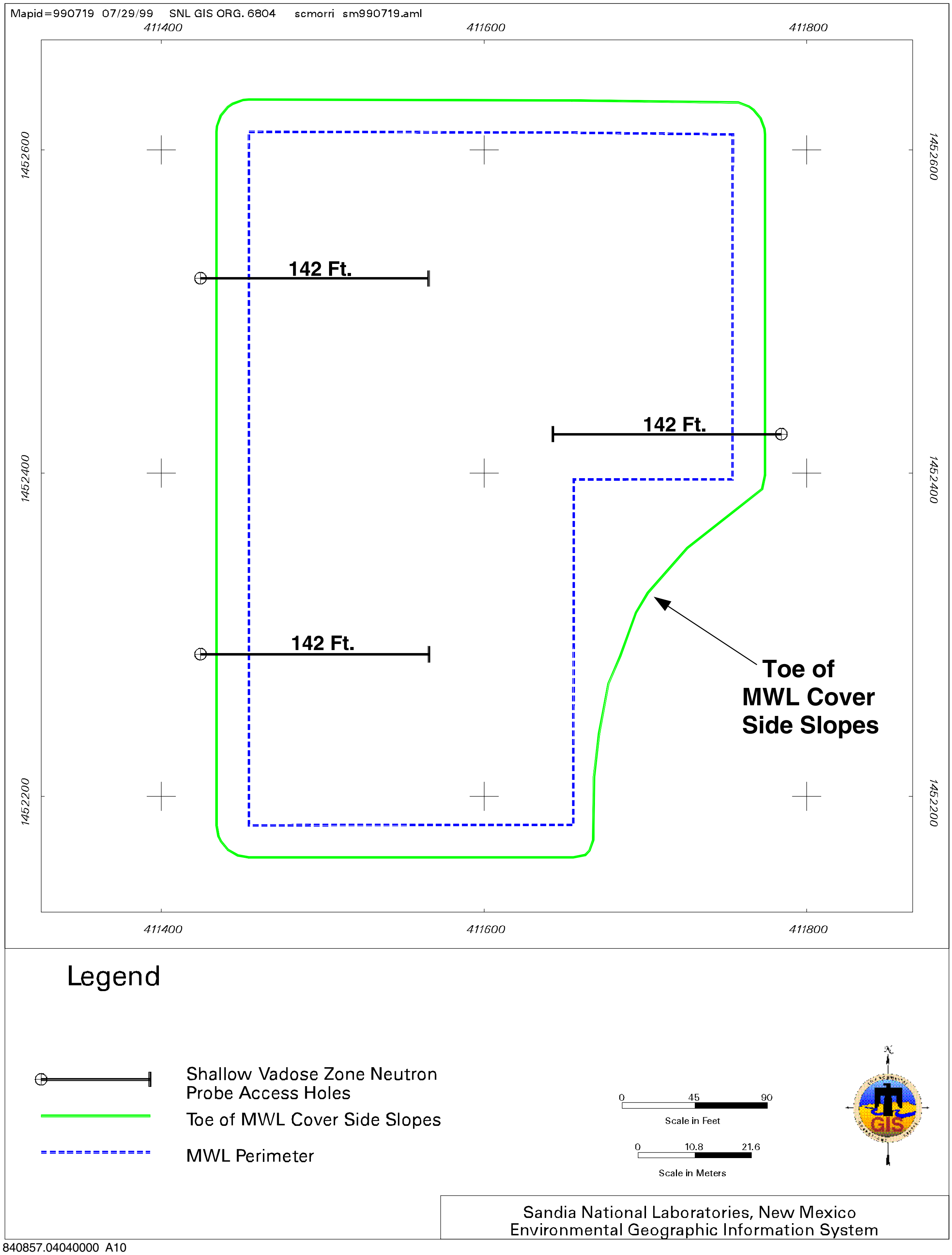

Figure 7-5 Location of Shallow Vadose Zone Neutron Probe Access Holes

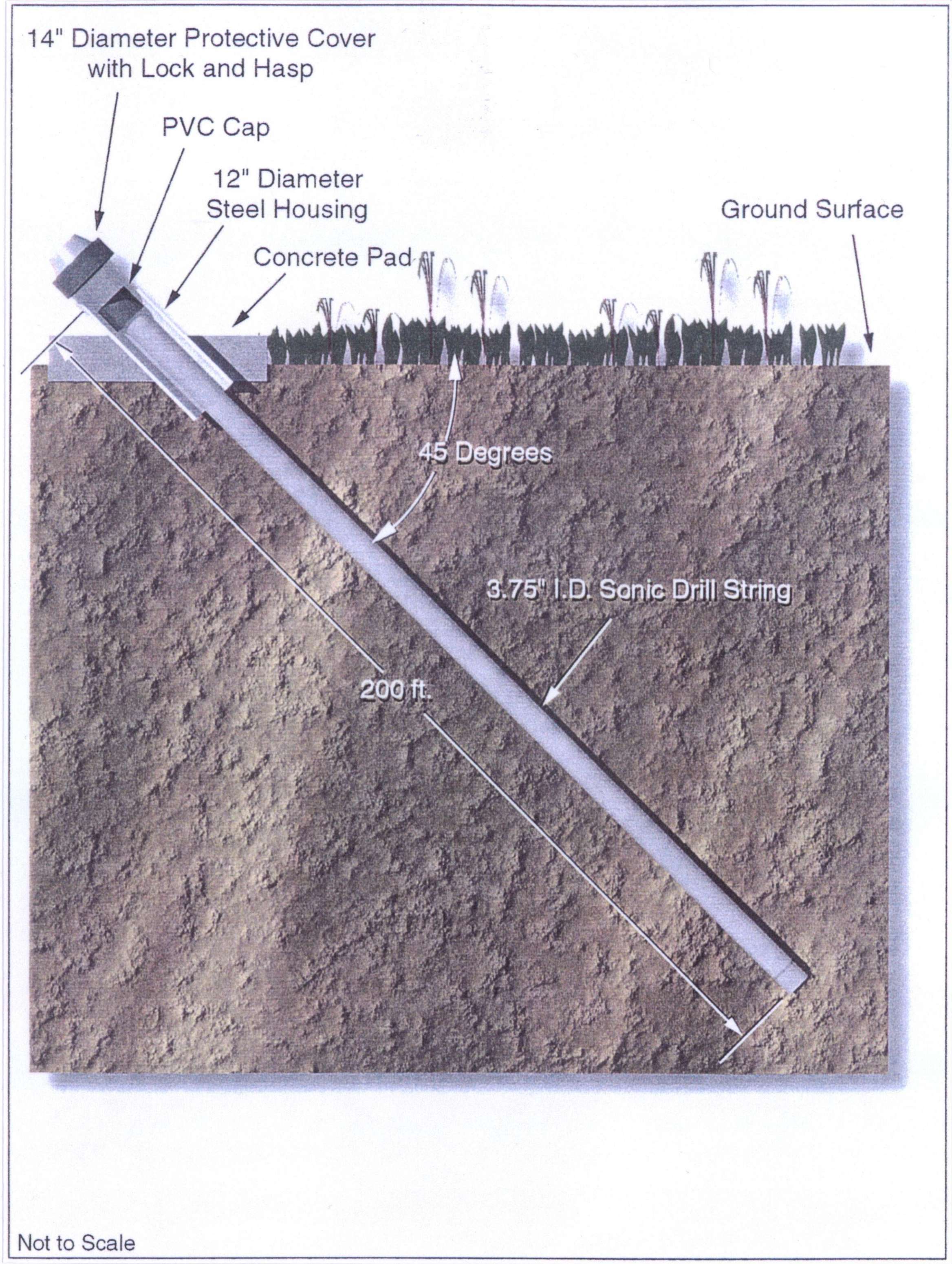

Figure 7-6 Schematic of Vadose Zone Neutron Probe Access Holes and Casings

TABLES

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Table 5-1
Hydraulic Conductivity Data for Subsurface Soil at the Mixed Waste Landfill

Sample Location	Sample/Borehole	Average Depth (ft)	Saturated Hydraulic Conductivity (cm/s)	Laboratory
Field Measurements:				
60 feet north of IP Test Site	Artificial Rainfall Test	2	5.3E-04	*In Situ* Field Measurement
MWL IP Test Site	IP Test	3	4.0E-04	*In Situ* Field Measurement
Geometric Mean of Field Measurements:			***4.6E-04***	**NA**
Laboratory Measurements:				
MWL Perimeter	MWL-BH-01	10	3.8E-05	SNL Hydrology Laboratory
MWL Perimeter	MWL-BH-01	26	1.1E-05	SNL Hydrology Laboratory
MWL Perimeter	MWL-BH-01	52	9.3E-05	SNL Hydrology Laboratory
MWL Perimeter	MWL-BH-01	78	3.0E-04	SNL Hydrology Laboratory
MWL Perimeter	MWL-BH-03	26	8.3E-05	SNL Hydrology Laboratory
MWL Perimeter	MWL-BH-03	52	5.0E-04	SNL Hydrology Laboratory
MWL Perimeter	MWL-BH-03	78	4.4E-06	SNL Hydrology Laboratory
MWL Perimeter	MWL-BH-04	98	2.6E-04	SNL Hydrology Laboratory
MWL Perimeter	MWL-BH-07	26	1.1E-03	SNL Hydrology Laboratory
MWL Perimeter	MWL-BH-07	52	1.7E-05	SNL Hydrology Laboratory
MWL Perimeter	MWL-BH-07	78	7.5E-05	SNL Hydrology Laboratory
MWL Perimeter	MWL-BH-07	104	9.2E-06	SNL Hydrology Laboratory
MWL Perimeter	MWL-BH-09	30	2.1E-04	SNL Hydrology Laboratory
MWL Perimeter	MWL-BH-09	52	8.4E-04	SNL Hydrology Laboratory
MWL Perimeter	MWL-BH-11	26	6.8E-04	SNL Hydrology Laboratory
MWL Perimeter	MWL-BH-11	56	1.0E-05	SNL Hydrology Laboratory
MWL Perimeter	MWL-BH-13	15	4.8E-05	SNL Hydrology Laboratory
MWL Perimeter	MWL-BH-13	36	1.6E-04	SNL Hydrology Laboratory
MWL IP Test Site	015-045	1	2.3E-05	SNL Hydrology Laboratory
MWL IP Test Site	045-075	2	2.0E-04	SNL Hydrology Laboratory

Refer to footnotes at end of table.

Table 5-1 (Continued)
Hydraulic Conductivity Data for Subsoil at the Mixed Waste Landfill

Sample Location	Sample/Borehole	Average Depth (ft)	Saturated Hydraulic Conductivity (cm/s)	Laboratory
MWL IP Test Site	075-105	3	1.0E-04	SNL Hydrology Laboratory
MWL IP Test Site	105-135	4	2.0E-03	SNL Hydrology Laboratory
MWL IP Test Site	135-165	5	1.0E-04	SNL Hydrology Laboratory
MWL IP Test Site	165-195	6	9.0E-04	SNL Hydrology Laboratory
MWL Test Pit Area 2	Knight Piesold 1a	0.33	3.1E-04	Knight Piesold Laboratory
MWL Test Pit Area 2	Knight Piesold 1b	1.50	2.1E-04	Knight Piesold Laboratory
Geometric Mean of Laboratory Measurements:			***1.1E-04***	**NA**

BH Borehole
cm/s Centimeter(s) per second
ft Foot (feet)
IP Instantaneous profile
MWL Mixed Waste Landfill
NA Not applicable
SNL Sandia National Laboratories

Table 5-2
Hydraulic Conductivity Data for Mixed Waste Landfill Cover Soil at 90 Percent Compaction

Sample Location	Sample	Depth Range (ft)	Average Depth (ft)	Saturated Hydraulic Conductivity (cm/s)	Percent Compaction	Laboratory
MWL Test Pit Area 2	Composite 2A	0–2	1	1.0E-05	90	AGRA Earth & Environmental, Inc.
MWL Test Pit Area 1	Composite 1A	0–2	1	1.1E-04	90	AGRA Earth & Environmental, Inc.
MWL Test Pit Area 1	Composite 1B	> 2	3	4.3E-05	90	AGRA Earth & Environmental, Inc.
Geometric Mean of Proposed Cover Soils from MWL Borrow Areas:				***3.6E-05***	**NA**	**NA**
CAMU Soil Piles	Native Soil 1 of 3	Upper 2	1	1.5E-05	90	AGRA Earth & Environmental, Inc.
CAMU Soil Piles	Native Soil 2 of 3	Upper 2	1	1.7E-05	90	AGRA Earth & Environmental, Inc.
CAMU Soil Piles	Native Soil 3 of 3	Upper 2	1	3.2E-05	90	AGRA Earth & Environmental, Inc.
CAMU Soil Piles	Subgrade Soil 1 of 3	Surface to 5	3	1.0E-05	90	AGRA Earth & Environmental, Inc.
CAMU Soil Piles	Subgrade Soil 2 of 3	Surface to 5	3	2.0E-05	90	AGRA Earth & Environmental, Inc.
CAMU Soil Piles	Subgrade Soil 3 of 3	Surface to 5	3	1.0E-05	90	AGRA Earth & Environmental, Inc.
Geometric Mean of Proposed Cover Soils from CAMU Stockpiles:				***1.6E-05***	**NA**	**NA**
Geometric Mean of Proposed Cover Soils from MWL Borrow Areas & CAMU Stockpiles:				***2.1E-05***	**NA**	**NA**

CAMU Corrective Action Management Unit
cm/s Centimeter(s) per second
ft Foot (feet)
MWL Mixed Waste Landfill
NA Not applicable

Table 5-3
Summary of Input Parameters Used for HELP-3, UNSAT-H, and VS2DT Predictive Modeling

Parameter	HELP-3[a]	UNSAT-H	VS2DT
Porosity, cm^3/cm^3	0.453	0.4	0.4
Field Capacity cm^3/cm^3	0.19	NA	NA
Residual Water Content cm^3/cm^3	NA	0.08	0.08
Wilting Point cm^3/cm^3	0.085	NA	NA
Head at Wilting or Pressure Head in Roots	NA	345 ft (10508 cm)	330 ft (10,058 cm)
Air Entry Parameter Alpha	NA	0.641 ft^{-1} (0.021 cm^{-1})	0.641 ft^{-1} (α' = -1.56 ft)
Van Genuchten "n"	NA	2.00	2.00
Initial Water Content	0.085	0.0862	0.0862
Initial Head, ft	NA	80 ft (2438 cm)	80 ft (2438 cm)
Saturated Hydraulic Conductivity	2.04 ft/day	0.85 ft/day (1.08 cm/hr)	0.85 ft/day
Slope	0.02 ft/ft	0 (1-dimensional)	0 (1-dimensional)
Drainage Length	200 ft	NA	NA
Maximum Root Depth	NA	3.25 ft	3.28 ft
Evaporative Zone Depth	42 inches	NA	NA
Atmospheric Pressure Potential	NA	750 ft (22860 cm)	500 ft to 1,000 ft
Head where Transpiration Starts to Decrease	NA	165 ft (5029 cm)	NA
Temperature	Air temp varies	293°K	NA
Membrane Defects	No membrane	NA	NA

[a]HELP-3 runs used HELP-3's default Type 6 soil because the model was very sensitive and inconsistent in its response to soil parameters.

cm	Centimeter(s)
cm^3	Cubic centimeter(s)
HELP-3	Hydrologic Evaluation of Landfill Performance Model, Version 3
°K	Degree(s) Kelvin
ft	Foot (feet)
hr	Hour
NA	Not applicable
UNSAT-H	Unsaturated Soil Water and Heat Flow Model
VS2DT	Variably-Saturated 2-D Flow and Solute Transport Model

Table 5-4
Summary of Mixed Waste Landfill Cover Modeling Results Using Historical Precipitation Data

Model	Parameter	1-ft Cover	2-ft Cover	3-ft Cover	4-ft Cover	5-ft Cover
HELP-3	Cumulative Infiltration (cm)	28.0	0.09	0.15	0.00	0.00
UNSAT-H	Cumulative Infiltration (cm)	41.5	15.00	8.44	5.79	4.15
VS2DT	Cumulative Infiltration (cm)	37.5	5.49	0.43	0.07	0.09
HELP-3	Average Flux (cm/s)	1.4E-08	4.3E-11	7.1E-11	0.0E+00	0.0E+00
UNSAT-H	Average Flux (cm/s)	2.0E-08	7.3E-09	4.1E-09	2.8E-09	2.0E-09
VS2DT	Average Flux (cm/s)	1.8E-08	2.7E-09	2.1E-10	3.6E-11	4.5E-11
HELP-3	Average Infiltration Rate (cm/yr)	0.4314	0.0014	0.0023	0.0000	0.0000
UNSAT-H	Average Infiltration Rate (cm/yr)	0.6396	0.2307	0.1299	0.0891	0.0638
VS2DT	Average Infiltration Rate (cm/yr)	0.5768	0.0844	0.0066	0.0011	0.0014
HELP-3	Maximum Volumetric Moisture Content	0.28	0.18	0.17	0.16	0.16
UNSAT-H	Maximum Volumetric Moisture Content	0.21	0.15	0.13	0.12	0.11
VS2DT	Maximum Volumetric Moisture Content	0.20	0.13	0.10	0.09	0.09

cm Centimeter(s)
ft Foot (feet)
HELP-3 Hydrologic Evaluation of Landfill Performance Model, Version 3
s Second
UNSAT-H Unsaturated Soil Water and Heat Flow Model
VS2DT Variably-Saturated 2-D Flow and Solute Transport Model
yr Year

Table 5-5
Summary of Mixed Waste Landfill Cover Modeling Results Using Maximum Precipitation Data

Model	Parameter	1-ft Cover	2-ft Cover	3-ft Cover	4-ft Cover	5-ft Cover
HELP-3	Cumulative Infiltration (cm)	35.4	0.20	0.47	0.58	0.86
UNSAT-H	Cumulative Infiltration (cm)	70.1	33.8	25.8	23.2	21.8
VS2DT	Cumulative Infiltration (cm)	77.7	19.4	3.38	0.78	0.66
HELP-3	Average Flux (cm/s)	1.8E-08	1.0E-10	2.3E-10	2.9E-10	4.3E-10
UNSAT-H	Average Flux (cm/s)	3.5E-08	1.7E-08	1.3E-08	1.1E-08	1.1E-08
VS2DT	Average Flux (cm/s)	3.8E-08	9.6E-09	1.7E-09	3.9E-10	3.3E-10
HELP-3	Average Infiltration Rate (cm/yr)	0.5539	0.0032	0.0073	0.0091	0.0135
UNSAT-H	Average Infiltration Rate (cm/yr)	1.0959	0.5277	0.4024	0.3624	0.3400
VS2DT	Average Infiltration Rate (cm/yr)	1.2144	0.3024	0.0529	0.0122	0.0104
HELP-3	Maximum Volumetric Moisture Content	0.30	0.20	0.18	0.17	0.17
UNSAT-H	Maximum Volumetric Moisture Content	0.24	0.17	0.14	0.14	0.13
VS2DT	Maximum Volumetric Moisture Content	0.22	0.15	0.12	0.10	0.10

cm	Centimeter(s)
ft	Foot (feet)
HELP-3	Hydrologic Evaluation of Landfill Performance Model, Version 3
s	Second
UNSAT-H	Unsaturated Soil Water and Heat Flow Model
VS2DT	Variably-Saturated 2-D Flow and Solute Transport Model
yr	Year

PLATES

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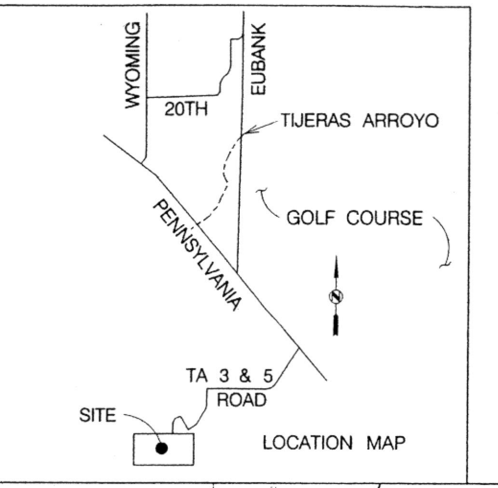
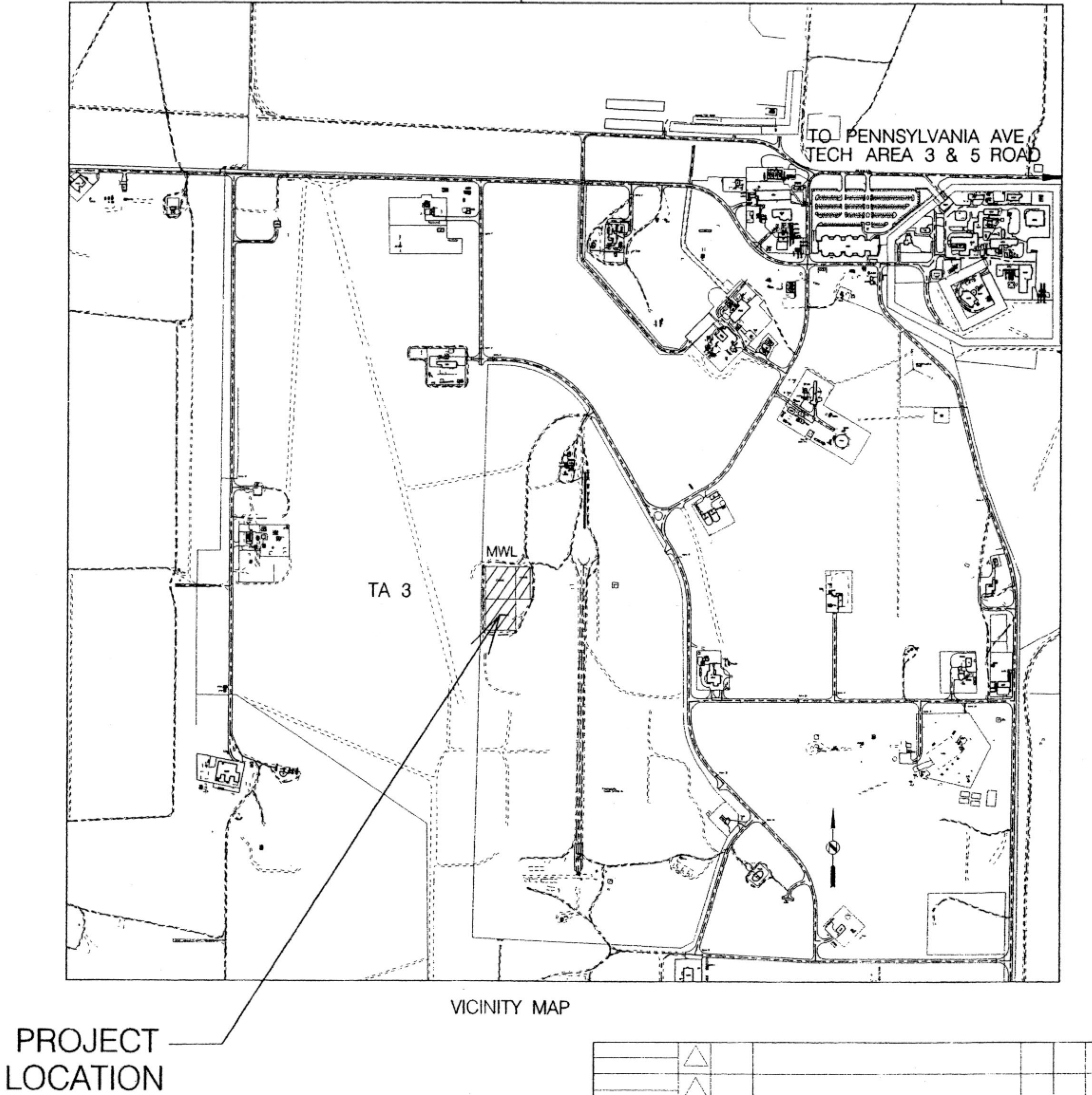
CONSTRUCTION PLANS FOR

MIXED WASTE LANDFILL FINAL CLOSURE
SANDIA NATIONAL LABORATORIES

ALBUQUERQUE, NEW MEXICO



LOCATION MAP



VICINITY MAP

INDEX TO DRAWINGS

PLATE	REVISION	TITLE	DRAWING NUMBER
1		TITLE SHEET/INDEX TO DRAWINGS/PROJECT LOCATION MAP	999997/A6.88
2		EXISTING SITE PLAN	999997/A6.89
3		SUBGRADE GRADING PLAN	999997/A6.90
4		FINAL COVER GRADING PLAN	999997/A6.91
5		FINAL COVER CROSS SECTIONS	999997/A6.92
6		MISCELLANEOUS DETAILS	999997/A6.93

P.O. OR W.O. / PROJECT NO.	REV	DATE	DESCRIPTION	DWN	CKD	APP
	A	9/23/98	ISSUED FOR REGULATORY REVIEW	S.F.G.	R.A.W.	H.C.S.

U.S. DEPARTMENT OF ENERGY
KIRTLAND AREA OFFICE
ALBUQUERQUE, NEW MEXICO

SANDIA NATIONAL LABORATORIES
ALBUQUERQUE, NEW MEXICO

TITLE SHT./INDEX TO DWGS./PROJ. LOCATION MAP

MIXED WASTE LANDFILL
PROJECT LOCATION MAP

P.O. OR W.O.	XX
PROJECT NO.	F01671
DRAWN BY	M.T.D./S.F.G.
CHECKED BY	R.W.
APPROVED BY	H.C.S./xx
DATE	09.0199

HOWARD C. STONE, NEW MEXICO 9098, REGISTERED PROFESSIONAL ENGINEER

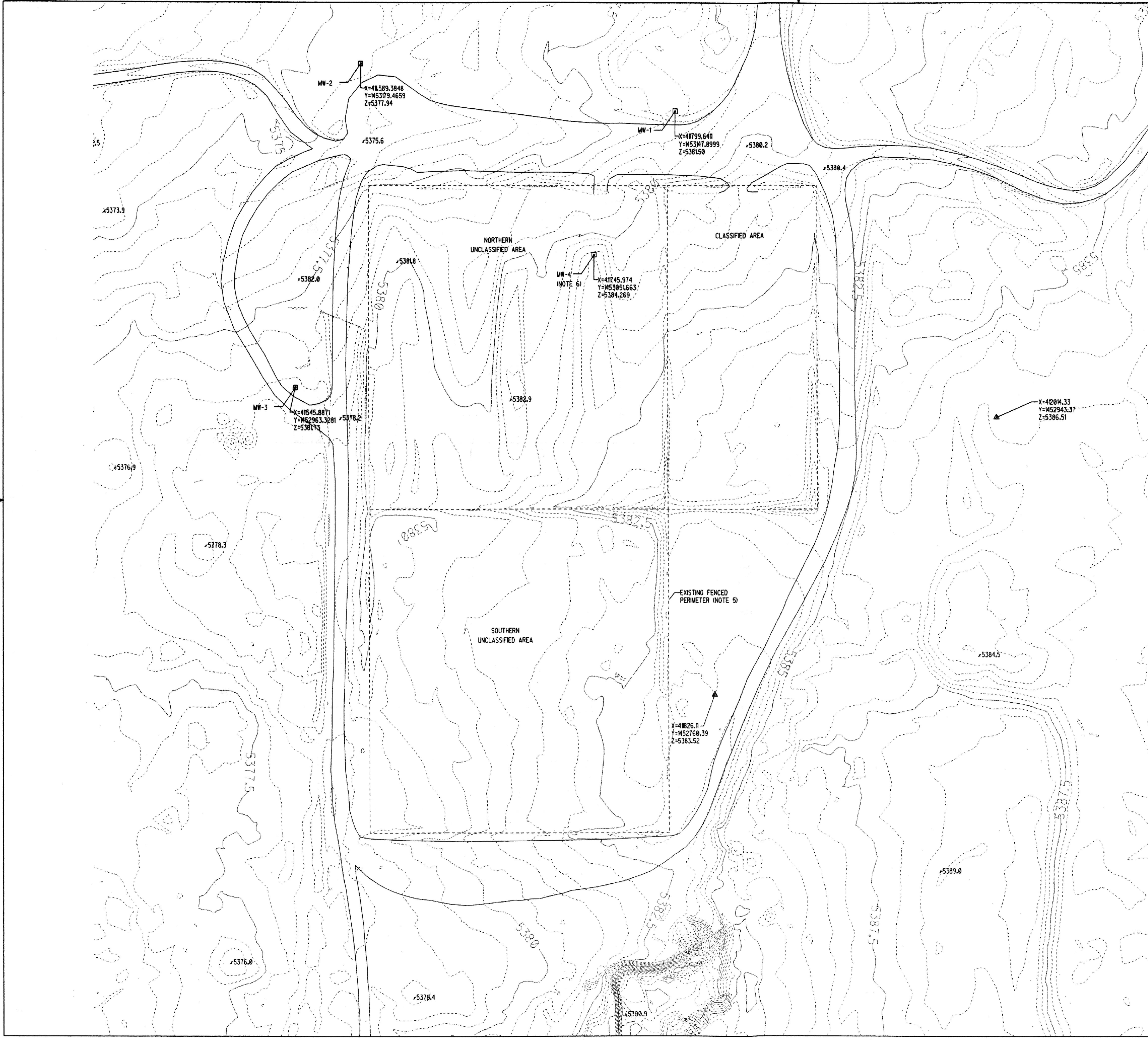
CAD DRAWING
COMPUTER SYSTEMS DEPT. 7901

FILE NAME: 999997A6.88

REFERENCE FILES:

Bohannan Huston
ENGINEERS PLANNERS PHOTOGRAMMETRISTS SURVEYORS SOFTWARE DEVELOPERS

SIZE D+ DRAWING NO./SHEET 999997/A6.88 PLATE 1



GENERAL NOTES

1. THE VECTOR IMAGES ON THIS COMPUTER PLOTTED MAP WERE GENERATED FROM DATA COMPILED BY DIGITAL STEREOPHOTOGRAMMETRIC METHODS USING 1:2000 NOMINAL SCALE VERTICAL AERIAL PHOTOGRAPHY EXPOSED ON MARCH 22, 1999 AT A FLIGHT HEIGHT OF APPROXIMATELY 1,000 FEET ABOVE MEAN TERRAIN. THE FILM WAS EXPOSED IN A ZEISS RMKA 15/23 AERIAL CAMERA, SERIAL NUMBER 127792, CALIBRATED FOCAL LENGTH 153.509 mm.

2. THE TOPOGRAPHIC IMAGES ON THIS MAP WERE GENERATED FROM DIGITAL TERRAIN MODEL (DTM) DATA ACQUIRED FROM THE AERIAL PHOTOGRAPHY. THE DATA DEPICTED ON THIS MAP IS INTENDED FOR USE AT A SCALE OF 1:360 (1"=30') AND A CONTOUR INTERVAL OF 0.5 FEET FOR THE PURPOSE OF PLANNING AND SITE DESIGN. BOHANNAN HUSTON, INC. ASSUMES NO RESPONSIBILITY FOR THE QUALITY, ACCURACY OR COMPLETENESS OF THE DATA WHEN USED FOR OTHER THAN THE INTENDED PURPOSE OR WHEN USED AT OTHER THAN THE COMPILED SCALE.

3. THIS MAP WAS COMPILED TO MEET AMERICAN SOCIETY FOR PHOTOGRAMMETRY AND REMOTE SENSING (ASPRS) CLASS 1 ACCURACY STANDARDS FOR A SCALE OF 1:30 AND A CONTOUR INTERVAL OF 1.0 FOOT. THE ROOT MEAN SQUARE ERROR (RMSE) OF COORDINATES OF WELL DEFINED FEATURES SHOULD BE EXPECTED TO BE LESS THAN 0.3 FEET. THE RMSE OF ELEVATIONS OF BREAK LINES AND MASS POINTS COMPRISING THE DTM SHOULD BE EXPECTED TO BE LESS THAN 0.33 FEET UNLESS OBSCURED BY CULTURAL FEATURES, VEGETATION OR SHADOWS.

4. COORDINATE SYSTEM IS BASED ON THE NEW MEXICO STATE PLANE COORDINATE SYSTEM, CENTRAL ZONE, NAD27. THE VERICAL DATUM IS BASED ON NGVD29
GRID TO GROUND= 1.000348922
BASED ON CONTROL POINT LIM NO. 34
DELTA ALPHA -00 10' 07".

5. THE CONTRACTOR SHALL PREPARE EXISTING LANDFILL SURFACE BY CLEARING, GRUBBING AND COMPACTION. EXISTING PERIMETER FENCES SHALL BE REMOVED BY SANDIA NATIONAL LABORATORIES PRIOR TO BEGINNNING CONSTRUCTION. CONTRACTOR SHALL INSTALL NEW ADMINISTRATIVE CONTROL FENCE AND GATE. SEE DETAIL F, PLATE 6.

6. MONITORING WELL MW-4 SHALL BE PRESERVED AND EXTENDED SUCH THAT THE TOP OF THE WELL CASING IS LOCATED A MINIMUM OF 30 INCHES ABOVE THE FINAL GRADE OF THE COVER. THE WELL CASING SHALL BE FIT WITH A STEEL PROTECTIVE COVER AND LOCKING TOP CAP.

   THE PROTECTIVE COVER SHALL BE CONSTRUCTED OF STEEL PIPE MEETING ASTM STANDARD A 120-78 OR API STANDARD 5L, AND SHALL EXTEND A MINIMUM OF 12 INCHES BELOW FINAL GRADE AND A MINIMUM OF 30 INCHES ABOVE THE FINAL GRADE OF THE COVER. THE OUTER CASING AND TOP CAP SHALL BE PAINTED WITH A RUST PREVENTIVE PRIMER COAT AND A FINAL COAT OF RUST PREVENTIVE PAINT (SAFETY YELLOW), AS MANUFACTURED BY RUSTOLEUM, OR APPROVED EQUIVALENT.

   A CONCRETE PAD SHALL BE PROVIDED AT THE GROUND SURFACE AROUND THE OUTER WELL CASING. THE CONCRETE PAD SHALL MEASURE THREE FEET BY THREE FEET, AND BE A MINIMUM OF SIX INCHES THICK. REFER TO DETAIL G, PLATE 6. SOIL BENEATH THE CONTRETE PAD SHALL BE COMPACTED TO NOT LESS THAN 90 PERCENT OF MAXIMUM DRY DENSITY AT -2 TO +2 PERCENT OF OPTIMUM MOISTURE CONTENT, AS DETERMINED BY ASTM D698 (STANDARD PROCTOR TESTING).

   MONITORING WELL MW-4 EXTENSION SHALL BE CONSTRUCTED OF SCHEDULE 80 PVC WITH AN ID OF 4.768" AND AN OD OF 5.563".

7. CONTRACTOR SHALL BE SUPPLIED SUBGRADE AND FINAL GRADING PLANS IN HARDCOPY AND MICROSTATION FORMAT.

8. EXISTING LANDFILL ROADS SHALL BE ABANDONED. CONTRACTOR SHALL CONSTRUCT A NEW PERIMETER ROAD OUTSIDE OF ADMINISTRATIVE FENCE BOUNDARY BY BLADING A 10' WIDE EARTHEN ROAD FOLLOWING EXISTING GROUND.

9. WATER TO BE USED DURING CONSTRUCTION IS WITHIN 0.5 MILES OF PROJECT AREA. LOCATION WILL BE PROVIDED BY SANDIA NATIONAL LABORATORIES.

LEGEND

- - - - - - -	EXISTING FENCE
—5384.5—	EXISTING INDEX CONTOUR
-------------	EXISTING INTERMEDIATE CONTOUR
═══════	EXISTING GRADED ROAD
◘	EXISTING GROUNDWATER MONITORING WELLS
△	PROJECT BENCHMARKS

HOWARD C. STONE — NEW MEXICO — 9098 — REGISTERED PROFESSIONAL ENGINEER — 9/21/99

SCALE 1"=30'
CONTOUR INTERVAL 0.5'

	REV	DATE	DESCRIPTION	DWN	CKD	APP
	△					
	△					
	△					
	A	9/23/99	ISSUED FOR REGULATORY REVIEW	S.F.G.	R.A.W.	H.C.S.
P.O. OR W.O. / PROJECT NO.	REV	DATE	DESCRIPTION	DWN	CKD	APP

U.S. DEPARTMENT OF ENERGY
KIRTLAND AREA OFFICE
ALBUQUERQUE, NEW MEXICO

SANDIA NATIONAL LABORATORIES
ALBUQUERQUE, NEW MEXICO

EXISTING SITE

MIXED WASTE LANDFILL EXISTING SITE PLAN

P.O. OR W.O.	XX
PROJECT NO.	F01671
DRAWN BY	M.T.D./S.F.G.
CHECKED BY	R.W.
APPROVED BY	H.C.S./XX
DATE	09.01.99

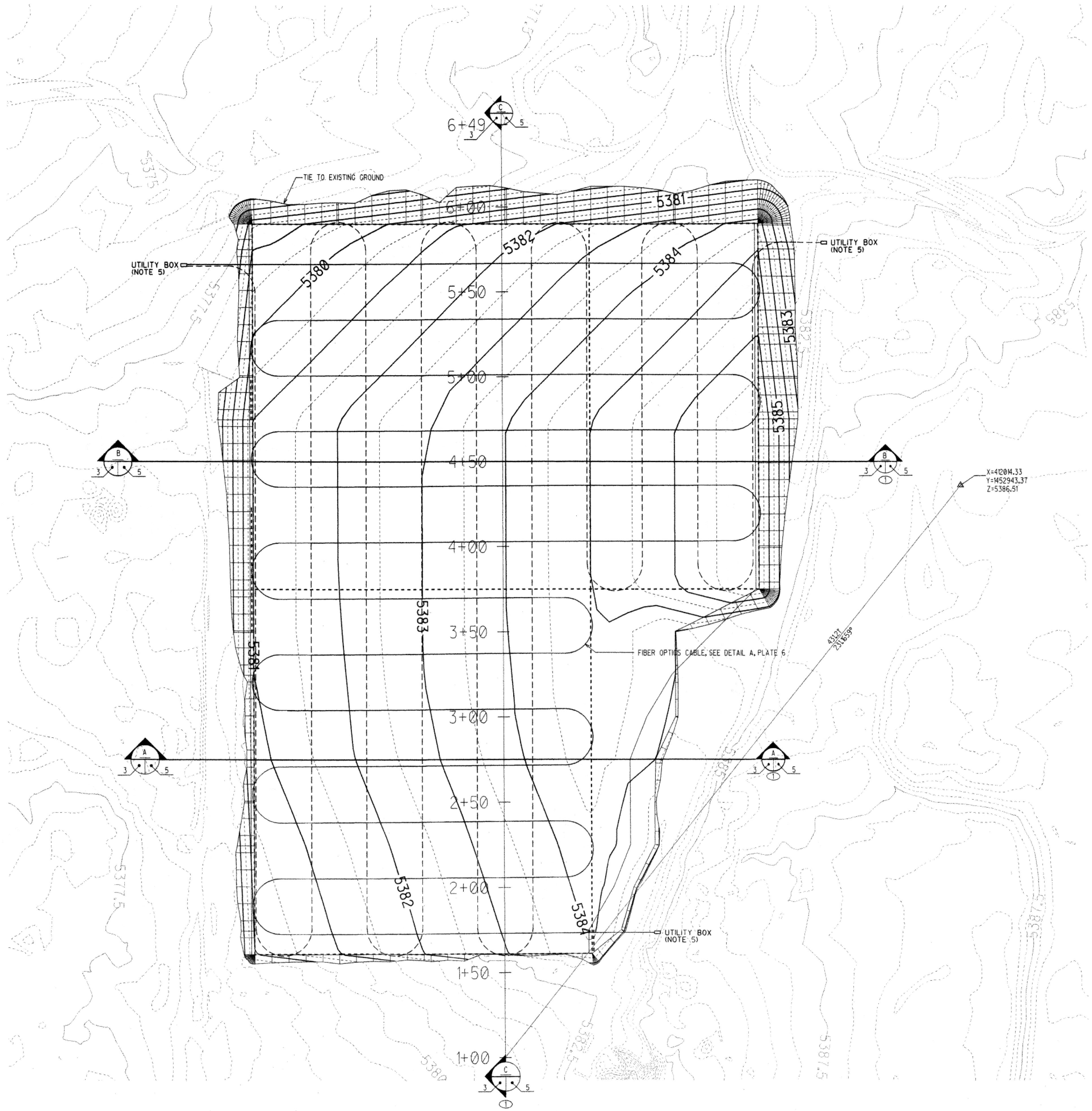
CAD DRAWING
COMPUTER SYSTEMS DEPT. 7901
SITE UTILITIES DEPT. 7821/7823

FILE NAME: 999997A6.89

Bohannan Huston
ENGINEERS PLANNERS PHOTOGRAMMETRISTS SURVEYORS SOFTWARE DEVELOPERS

SIZE: D+ | DRAWING NO./SHEET: 999997/A6.89 | PLATE: 2

REFERENCE FILES:



GENERAL NOTES

1. THE SUBGRADE GRADING PLAN SHOWS THE CONTOURS FOR THE TOP OF THE SUBGRADE.
2. BORROW SITE FOR SUBGRADE FILL IS APPROXIMATELY 1.5 MILES SOUTH OF PROJECT AREA.
3. CONTRACTOR SHALL CLEAR, GRUB, PREPARE, AND COMPACT EXISTING LANDFILL SURFACE PRIOR TO PLACEMENT OF SUBGRADE FILL. THE EXISTING LANDFILL SURFACE SHALL BE COMPACTED TO NOT LESS THAN 90 PERCENT OF MAXIMUM DRY DENSITY AT -2 TO +2 PERCENT OF OPTIMUM MOISTURE CONTENT, AS DETERMINED BY ASTM D698 (STANDARD PROCTOR TESTING).
4. SUBGRADE FILL SHALL BE OBTAINED FROM CAMU SOIL STOCKPILES. FILL SHALL BE PLACED IN MAXIMUM 8-INCH LOOSE LIFTS TO ATTAIN MAXIMUM 6-INCH COMPACTED LIFT THICKNESS. FILL SHALL BE COMPACTED TO NOT LESS THAN 90 PERCENT OF MAXIMUM DRY DENSITY AT -2 TO +2 PERCENT OF OPTIMUM MOISTURE CONTENT, AS DETERMINED BY ASTM D698 (STANDARD PROCTOR TESTING). SUBGRADE SHALL BE PLACED TO ACHIEVE A CENTRAL CROWN AND A UNIFORM 2 PERCENT GRADE. APPROXIMATELY 6100 CY OF FILL SHALL BE REQUIRED FOR SUBGRADE.
5. FIBER OPTICS CABLE SHALL BE DEPLOYED IN TWO DISCRETE LIFTS. THE LOWER LIFT (SHOWN WITH A SOLID LINE) SHALL BE DEPLOYED IN AN EAST-WEST ORIENTATION. THE UPPER LIFT (SHOWN WITH A DASHED LINE) SHALL BE DEPLOYED IN A NORTH-SOUTH ORIENTATION. FIBER OPTICS CABLE SHALL BE DEPLOYED IN ACCORDANCE WITH DETAIL A, PLATE 6. UTILITY BOXES SHALL BE NEMA 4 ENCLOSURES TERMINATING 3 FEET ABOVE GRADE.
6. ASSUMED SHRINKAGE FACTOR FOR FILL IS 25 PERCENT.
7. CONTRACTOR SHALL SURVEY ELEVATIONS OF SUBGRADE TO MEET CONSTRUCTION SPECIFICATIONS.

KEYED NOTES

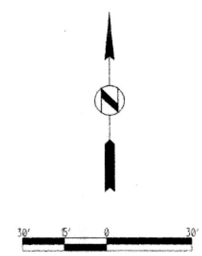
(1) SECTIONS A, B, AND C ON PLATE 5 SHOW SUBGRADE AND FINAL GRADING SECTIONS.

ESTIMATED BORROW QUANTITIES	
CUT	0.60 CY
FILL	6,100 CY

LEGEND

- 5388 — EXISTING INDEX CONTOUR
- EXISTING INTERMEDIATE CONTOUR
- 5390 — SUBGRADE INDEX CONTOUR
- SUBGRADE INTERMEDIATE CONTOUR
- FIBER OPTICS CABLE (LOWER LIFT)
- FIBER OPTICS CABLE (UPPER LIFT)
- PROJECT BENCHMARKS

HOWARD C. STONE, NEW MEXICO, 9099, REGISTERED PROFESSIONAL ENGINEER



SCALE 1"=30'
CONTOUR INTERVAL 0.5'

P.O. OR W.O. / PROJECT NO.	REV	DATE	DESCRIPTION	DWN	CKD	APP
	A	9/23/99	ISSUED FOR REGULATORY REVIEW	S.F.G.	H.C.S.	H.C.S.

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ALBUQUERQUE, NEW MEXICO

SANDIA NATIONAL LABORATORIES
ALBUQUERQUE, NEW MEXICO

SUBGRADE

MIXED WASTE LANDFILL SUBGRADE GRADING PLAN

P.O. OR W.O.	XX
PROJECT NO.	F01671
DRAWN BY	M.T.D./S.F.G.
CHECKED BY	R.W.
APPROVED BY	H.C.S./XX
DATE	09.01.99

CAD DRAWING
COMPUTER SYSTEMS DEPT. 7901
SITE UTILITIES DEPT. 7821/7823
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REFERENCE FILES:

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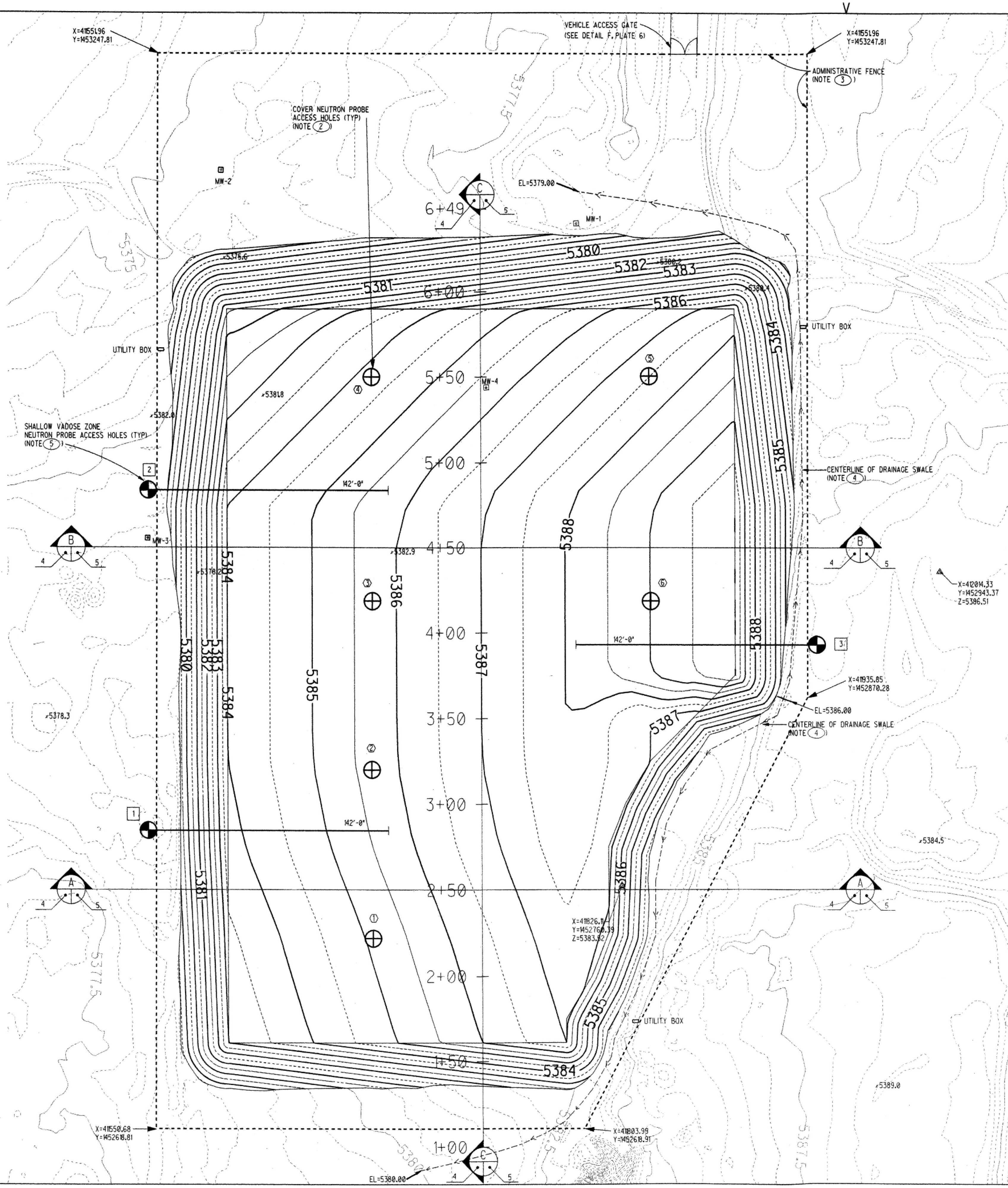
SIZE: D+ DRAWING NO./SHEET: 999997/A6.90 PLATE: 3



COVER NEUTRON PROBE ACCESS HOLES		
HOLE	X	Y
1	411679	1452729.746
2	411678.28	1452827.976
3	411678.647	1452926.532
4	411678.156	1453057.962
5	411842.379	1453058.333
6	411843.389	1452926.538

SHALLOW VADOSE ZONE NEUTRON PROBE ACCESS HOLES					
HOLE	SURFACE LOCATION X	SURFACE LOCATION Y	MEASURED DEPTH (FT)	ANGLE	AZIMUTH
1	411546.155	1452792.603	200	45°	90°
2	411546.155	1452991.693	200	45°	90°
3	411941.355	1452901.054	200	45°	270°

GENERAL NOTES

1. BORROW SITE FOR NATIVE SOIL LAYER FILL IS APPROXIMATELY 1.5 MILES SOUTH OF THE PROJECT AREA. THE BORROW SITE FOR THE TOPSOIL LAYER IS DIRECTLY WEST OF THE PROJECT AREA.
2. NATIVE SOIL LAYER FILL SHALL BE OBTAINED FROM CAMU SOIL STOCKPILES. APPROXIMATELY 9,900 CUBIC YARDS OF FILL SHALL BE REQUIRED FOR THE NATIVE SOIL LAYER. FILL SHALL BE PLACED IN MAXIMUM 8-INCH LOOSE LIFTS TO ATTAIN MAXIMUM 6-INCH COMPACTED LIFT THICKNESS. FILL SHALL BE COMPACTED TO NOT LESS THAN 90 PERCENT OF MAXIMUM DRY DENSITY AT -2 TO +2 PERCENT OF OPTIMUM MOISTURE CONTENT, AS DETERMINED BY ASTM D698 (STANDARD PROCTOR TESTING). ANY GRADE STAKES USED ON THE PROJECT SHALL BE REMOVED AND BACKFILLED WITH COVER MATERIAL TO MEET CONSTRUCTION SPECIFICATIONS.
3. THE TOPSOIL LAYER SHALL BE PLACED IN A MAXIMUM 8-INCH LOOSE LIFT. THE TOPSOIL LAYER SHALL BE MINIMALLY COMPACTED TO NOT LESS THAN 80 PERCENT AND NOT GREATER THAN 85 PERCENT OF MAXIMUM DRY DENSITY AT -2 TO +2 PERCENT OF OPTIMUM MOISTURE CONTENT, AS DETERMINED BY ASTM D698 (STANDARD PROCTOR TESTING). TOPSOIL SHALL BE ADMIXED 25 PERCENT BY VOLUME WITH 3/8-INCH CRUSHED GRAVEL (ASTM SIZE #8). APPROXIMATELY 2,200 CY WILL BE REQUIRED FOR THE TOPSOIL LAYER.

KEYED NOTES

(1) THE FINAL COVER CONTOURS INDICATE TOP OF THE FINAL COVER.

(2) COVER NEUTRON PROBE ACCESS HOLES SHALL BE CONSTRUCTED IN ACCORDANCE WITH DETAIL C, PLATE 6.

(3) CONTRACTOR SHALL INSTALL AN ADMINISTRATIVE FENCE AROUND PERIMETER OF CONSTRUCTED LANDFILL COVER. ADMINISTRATIVE FENCE SHALL BE CONSTRUCTED ACCORDING TO DETAIL F, PLATE 6.

(4) CONTRACTOR SHALL CONSTRUCT A DRAINAGE SWALE IN ACCORDANCE WITH DETAIL E, PLATE 6. DRAINAGE SWALE SHALL BE CONSTRUCTED TO ENSURE POSITIVE DRAINAGE USING ELEVATIONS SHOWN ON THIS PLAN AS A GENERAL GUIDE.

(5) SHALLOW VADOSE ZONE NEUTRON PROBE ACCESS HOLES SHALL BE INSTALLED UNDER SEPARATE CONTRACT USING RESONANT SONIC DRILLING.

SEEDING PLAN

1. SEEDING SHALL COMPLY WITH CONSTRUCTION SPECIFICATION 02930, RECLAMATION SEEDING AND MULCHING.
2. THE FOLLOWING SEED MIX SHALL BE USED FOR SEEDING OF THE FINAL GRADE, BORROW LOCATION, LAYDOWN AREAS, AND OTHER LOCATIONS IMPACTED BY CONSTRUCTION ACTIVITIES:

SEED SPECIES	SEEDING RATE PURE LIVE SEED (POUNDS PER ACRE)
BLUE GRAMA	3.0
CRESTED WHEATGRASS	5.0
INDIAN RICEGRASS	5.0
ALKALI SACATON	1.5
SAND DROPSEED	1.5
GALLETA GRASS	4.0

3. FERTILIZER SHALL BE APPLIED AT 10 POUNDS PER ACRE AND SHALL HAVE A 22-20-0-22 (NITROGEN-PHOSPHOROUS-POTASSIUM-SULFUR) NUTRIENT COMPOSITION. LIQUID FERTILIZER CONTAINING THE MINIMUM PERCENTAGE OF AVAILABLE NUTRIENTS MAY BE USED.

ESTIMATED BORROW QUANTITES
NATIVE SOIL LAYER 9900 CY
TOPSOIL LAYER 2200 CY

LEGEND

—5384.5—	EXISTING INDEX CONTOUR
------------	EXISTING INTERMEDIATE CONTOUR
- - - - - -	FINAL ADMINISTRATIVE FENCE
—5384.5—	FINAL COVER INDEX CONTOUR
------------	FINAL COVER INTERMEDIATE CONTOUR
MW-4	GROUNDWATER MONITORING WELL
⊕	COVER NEUTRON PROBE ACCESS HOLES
	DRAINAGE SWALE CENTERLINE
	SHALLOW VADOSE ZONE NEUTRON PROBE ACCESS HOLES
	PROJECT BENCHMARKS

HOWARD C. STONE — NEW MEXICO — 9088 — REGISTERED PROFESSIONAL ENGINEER — 9/21/99

SCALE 1"=30'
CONTOUR INTERVAL 0.5'

P.O. OR W.O. / PROJECT NO.	REV	DATE	DESCRIPTION	DWN	CKD	APP
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SANDIA NATIONAL LABORATORIES
ALBUQUERQUE, NEW MEXICO

FINAL COVER

MIXED WASTE LANDFILL
FINAL COVER GRADING PLAN

P.O. OR W.O.	XX
PROJECT NO.	FO1671
DRAWN BY	M.T.D./S.F.G.
CHECKED BY	R.W.
APPROVED BY	H.C.S./xx
DATE	09.01.99

SIZE D+ DRAWING NO./SHEET 999997/A6.91 PLATE 4

CAD DRAWING
COMPUTER SYSTEMS DEPT. 7901
SITE UTILITIES DEPT. 7821/7823
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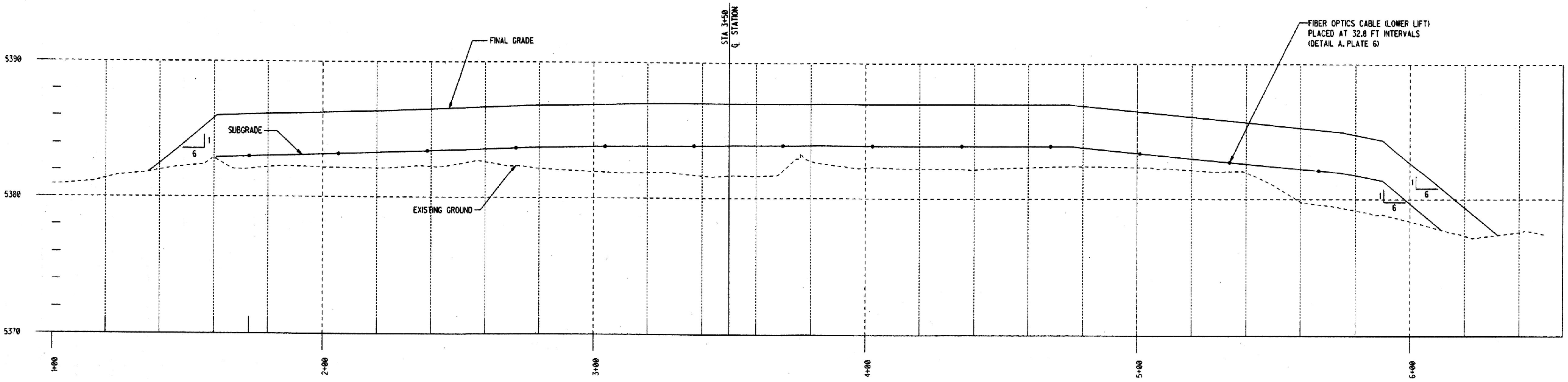
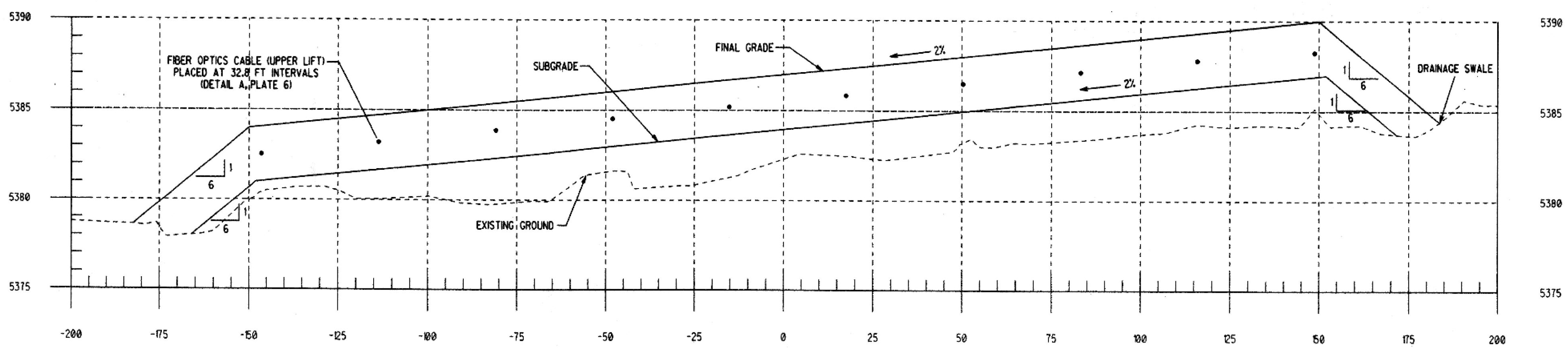
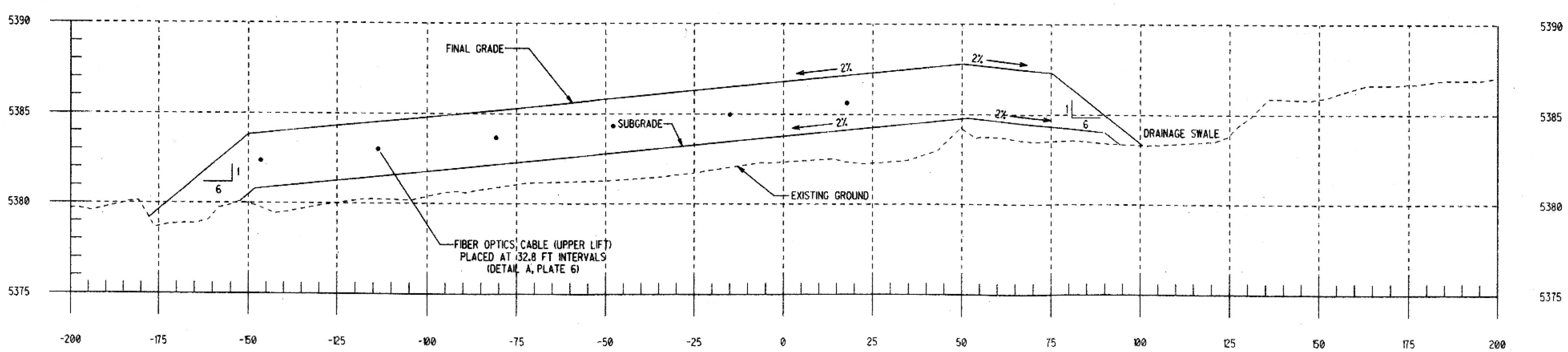


SECTION C-C



STA 4+50.00

SECTION B-B



STA 2+75.00

SECTION A-A

HORIZ. SCALE 1"=20'
VERT. SCALE 1"=4'

REV	DATE	DESCRIPTION	DWN	CKD	APP
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ALBUQUERQUE, NEW MEXICO

CROSS SECTIONS

MIXED WASTE LANDFILL
FINAL COVER CROSS SECTIONS

P.O. OR W.O.	XX
PROJECT NO.	FO1671
DRAWN BY	M.T.D./S.F.G.
CHECKED BY	R.W.
APPROVED BY	H.C.S./xx
DATE	09.01.99

SIZE D | DRAWING NO./SHEET 999997/A6.92 | PLATE 5

CAD DRAWING
COMPUTER SYSTEMS DEPT. 7901
SITE UTILITIES DEPT. 7825/7825
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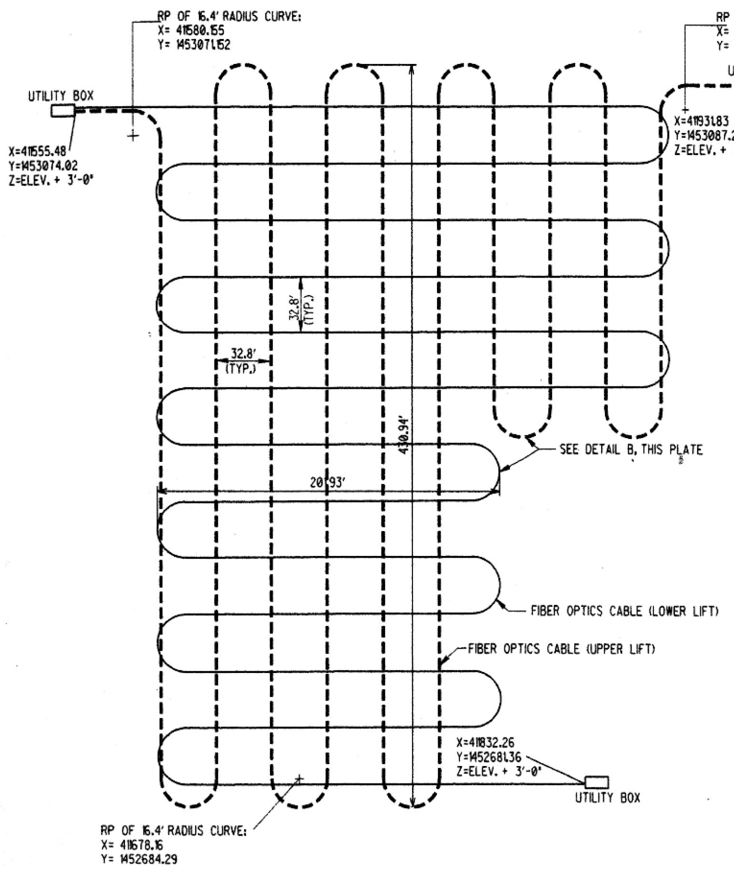
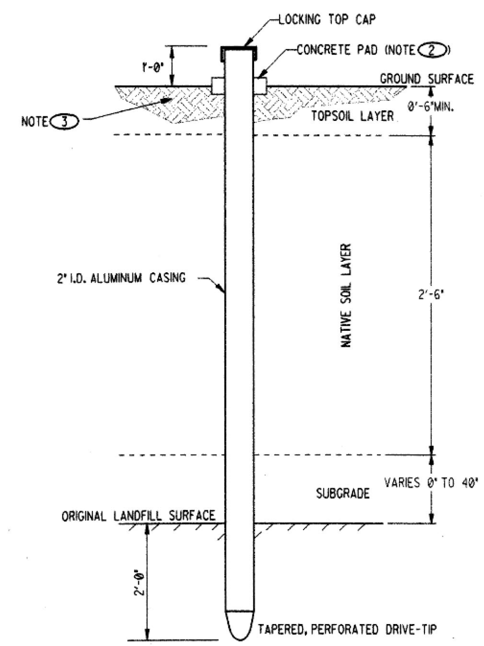


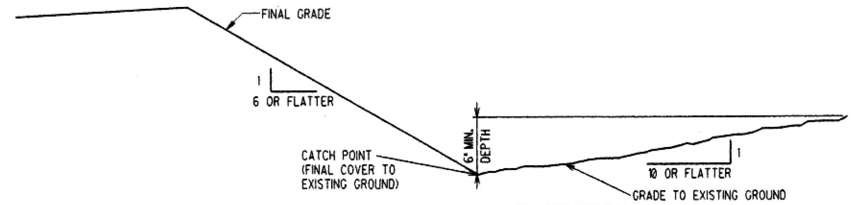
FIBER OPTIC CABLE DEPLOYMENT

A DETAIL 3 6 NTS



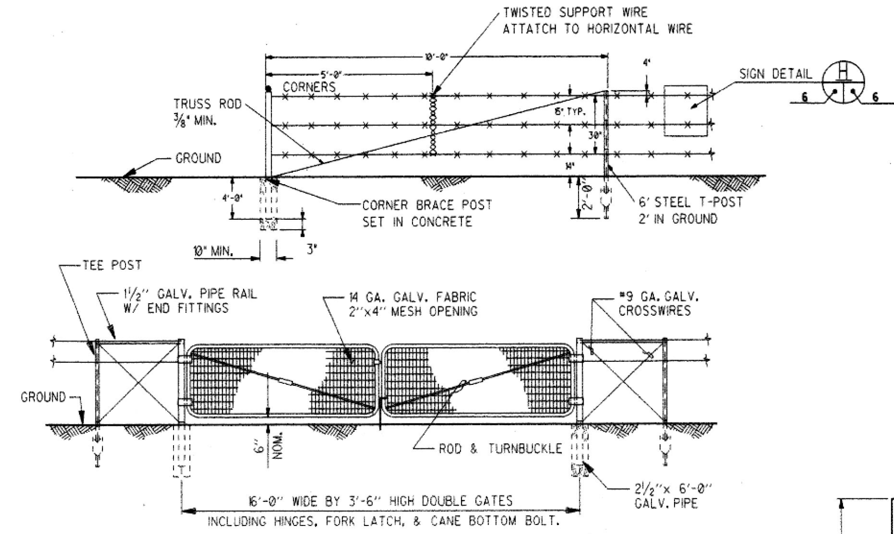
COVER NEUTRON PROBE ACCESS HOLE

C DETAIL 4 6 NTS



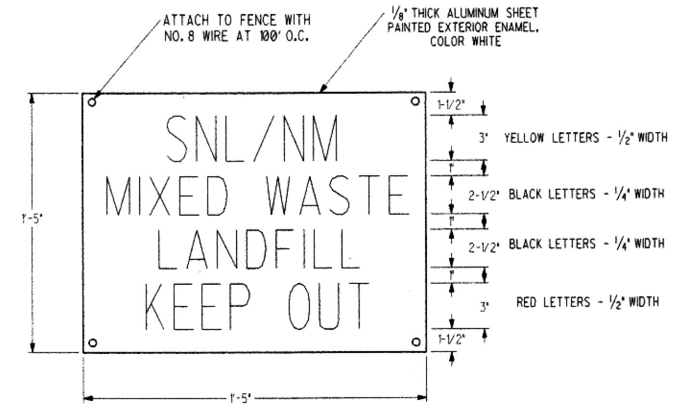
TYPICAL DRAINAGE SWALE SECTION

E DETAIL 4 6 NTS



ADMINISTRATIVE CONTROL FENCE AND GATE

F DETAIL 4 6 NTS 5



SIGNAGE

H DETAIL 6 6 NTS

KEYED NOTES

(1) SHALLOW VADOSE ZONE NEUTRON PROBE ACCESS HOLES SHALL BE INSTALLED UNDER SEPARATE CONTRACT USING RESONANT SONIC DRILLING (NOTE 5, PLATE 4).

(2) CONCRETE SHALL HAVE A MINIMUM F'c OF 3000 P.S.I.

(3) SOIL DIRECTLY BELOW CONCRETE PADS SHALL BE COMPACTED TO NOT LESS THAN 90 PERCENT OF MAXIMUM DRY DENSITY AT -2 TO +2 PERCENT OF OPTIMUM MOISTURE CONTENT, AS DETERMINED BY ASTM D698 (STANDARD PROCTOR TESTING).

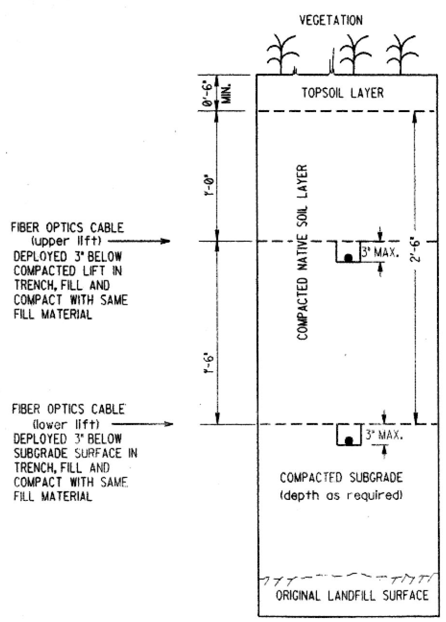
(4) THE EXISTING LANDFILL SURFACE SHALL BE COMPACTED TO NOT LESS THAN 90 PERCENT OF MAXIMUM DRY DENSITY AT -2 TO +2 PERCENT OF OPTIMUM MOISTURE CONTENT, AS DETERMINED BY ASTM D698 (STANDARD PROCTOR TESTING).

SUBGRADE FILL SHALL BE PLACED IN MAXIMUM 8-INCH LOOSE LIFTS TO ATTAIN MAXIMUM 6-INCH COMPACTED LIFT THICKNESS. SUBGRADE FILL SHALL BE COMPACTED TO NOT LESS THAN 90 PERCENT OF MAXIMUM DRY DENSITY AT -2 TO +2 PERCENT OF OPTIMUM MOISTURE CONTENT, AS DETERMINED BY ASTM D698 (STANDARD PROCTOR TESTING).

THE NATIVE SOIL LAYER SHALL BE PLACED IN MAXIMUM 8-INCH LOOSE LIFTS TO ATTAIN MAXIMUM 6-INCH COMPACTED LIFT THICKNESS. NATIVE SOIL LAYER SHALL BE COMPACTED TO NOT LESS THAN 90 PERCENT OF MAXIMUM DRY DENSITY AT -2 TO +2 PERCENT OF OPTIMUM MOISTURE CONTENT, AS DETERMINED BY ASTM D698 (STANDARD PROCTOR TESTING).

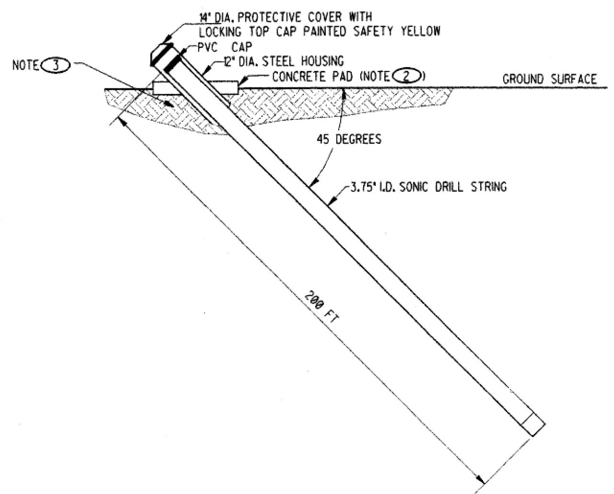
TOPSOIL LAYER SHALL BE PLACED IN A MAXIMUM 8-INCH LOOSE LIFT. THE TOPSOIL SHALL BE MINIMALLY COMPACTED TO NOT LESS THAN 80 PERCENT AND NOT GREATER THAN 85 PERCENT OF MAXIMUM DRY DENSITY AT -2 TO +2 PERCENT OF OPTIMUM MOISTURE CONTENT, AS DETERMINED BY ASTM D698 (STANDARD PROCTOR TESTING).

(5) ADMINISTRATIVE CONTROL FENCE SHALL BE STRAND BARBED WIRE WITH TEE-POSTS DRIVEN INTO THE GROUND AND STEEL CORNER POSTS SET IN CONCRETE. GATE SHALL BE A TUBULAR STEEL GALVANIZED GATE, 2 INCH DIAMETER, 40 INCHES IN HEIGHT. ALL END AND CORNER POSTS SHALL BE BRACED BY MEANS OF DIAGONAL TRUSS RODS.



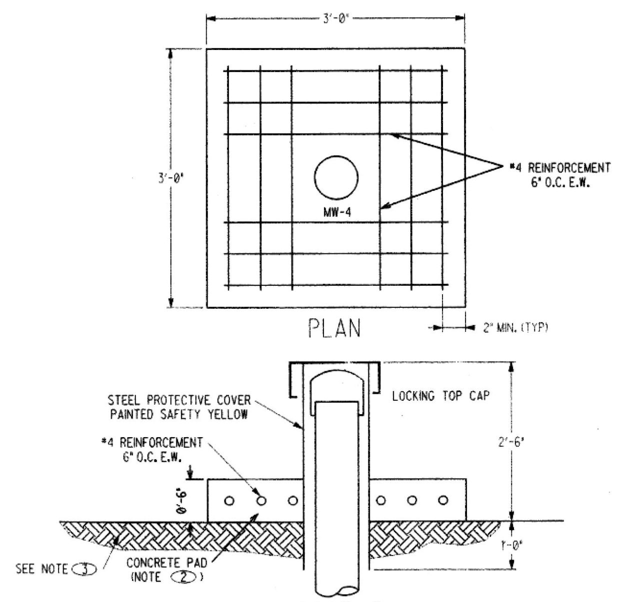
COVER CROSS SECTION

B DETAIL 4 6 NTS 4



SHALLOW VADOSE ZONE NEUTRON PROBE ACCESS HOLE

D DETAIL 4 6 NTS 1



MW-4 EXTENSION

G DETAIL 4 6 NTS

	REV	DATE	DESCRIPTION	DWN	CKD	APP
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	△					
	△					
	A	9/23/99	ISSUED FOR REGULATORY REVIEW	S.F.G.	R.A.W.	H.C.S.
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ALBUQUERQUE, NEW MEXICO

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ALBUQUERQUE, NEW MEXICO

MISCELLANEOUS DETAILS

MIXED WASTE LANDFILL MISCELLANEOUS DETAILS

P.O. OR W.O.	XX
PROJECT NO.	FQ1671
DRAWN BY	M.T.D./S.F.G.
CHECKED BY	R.W.
APPROVED BY	H.C.S./XX
DATE	09.01.99

CAD DRAWING
COMPUTER SYSTEMS DEPT. 7901
SITE UTILITIES DEPT. 7821/7823

FILE NAME: 999997A6.93

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SIZE D+ DRAWING NO./SHEET 999997/A6.93 PLATE 6

REFERENCE FILES:

APPENDIX A

Geotechnical Report

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Geotechnical Report
June 1999

Contents

List of Figures

List of Attachments

Geotechnical Report

General

An area occupied by a relatively low-lying topographic swale northwest of the Mixed Waste Landfill (MWL) has been subjected to geologic and geotechnical analysis via a series of soil pits. On March 11, and April 27, 1999, ERFO excavated five soil pits with a backhoe to 6 ft in each of two areas: Area 1, northeast of the IP site, and Area 2, northwest of the IP site. The two areas are separated by a buried sanitary sewer line trending NNW, and each area is further divided by a buried electrical line trending W-E (Figure 1).

Each pit was excavated in a manner to produce one steep wall which, that with one exception, was cut to face south for maximum illumination from the sun. A series of steps were shaped on the opposite side of the pits for safety, easy access, and available working surfaces.

The geologic sequence in each pit consists of a series of pedogenic (soil) units. Soil geologists have their own descriptive jargon which is useful for regional studies involving relative dating of geomorphic surfaces. In this project the soil-geologic description is less rigorous, and emphasis is placed on geotechnical units that can be easily recognized in the field. The two terminologies are summarized in Table 1.

Table 1. Geologic and Geotechnical Terminology

<table>
<tr><th colspan="4">Soil Terminology</th><th colspan="2">TA3 Geotechnical Terminology</th></tr>
<tr><th></th><th>Master Horizon</th><th>Sub-horizon</th><th>Characteristics</th><th>MWL Area Soil Pits</th><th>Characteristics</th></tr>
<tr><td rowspan="6">Pedo-genic

Modifi-cation</td><td colspan="2">“A”</td><td>Relatively high organic content; substantial eolian material</td><td rowspan="3">TOPSOIL

Unit 1:
Upper Topsoil

Unit 2:
Lower Topsoil</td><td rowspan="2">Moisture & root zone; soft; Munsell Color Value 4 to 5; 1 to 2 1/2 ft thick</td></tr>
<tr><td rowspan="5">“B”</td><td rowspan="2">“Bt”</td><td rowspan="2">Secondary clay translocation (“t”) & accumulation</td></tr>
<tr><td>Dry & harder; few roots; Munsell Color Value 5 to 6; 0 to I ft thick</td></tr>
<tr><td rowspan="3">“Bk”</td><td rowspan="3">Significant Secondary $CaCO_3$ (“k”) accumulation; MWL area = Stage III (II in places)</td><td>Unit 3: Upper Transition Zone</td><td>Discrete caliche blebs; 1 to 2 ft thick; top at 2 to 3 ft</td></tr>
<tr><td>Unit 4: Massive Bk (Caliche)</td><td>Hard, dry, massive Bk; Munsell Color Value 7 to 8; -2 11 thick; top generally at 3 ft</td></tr>
<tr><td>Unit 5: Lower Transition Zone</td><td>Softer; Munsell Color Value 7 to 6; sometimes difficult to recognize</td></tr>
<tr><td></td><td colspan="2">“C”</td><td>Unaltered sediment</td><td>Unit 6</td><td>Rarely penetrated by soil pits</td></tr>
</table>

Field sketches of the 10 soil pits are included as Attachment A. The six geotechnical units described above in Table 1 and encountered in the soil pits are correlated in Figure 2 (Area 1) and Figure 3 (Area 2). An isopach of the topsoil, i.e., Units 1 and 2, over both areas is presented by Figure 4.

Geotechnical Characteristics of Near-Surface Sediments

Soil Moisture. Sleeved percussion samples were taken for moisture content. The results are summarized in Attachment B. Moisture content generally reaches a maximum of about 15% in those samples taken, and decreases downward to a minimum of about 5%. However, temporal control on the sampling was poor due to the staggered excavation of pits and sampling equipment breakage.

March 31, 1999	Pit 1B	Continuous 0 - 42 inches	Discrete 3.6 feet and 4.2 feet
	Pit 1C	Continuous 0 - 24 inches	
April 1, 1999	Pit 1A	Continuous 0 - 36 inches	
	Pit 1C		Discrete 3.5 feet and 4.8 feet
	Pit 1D	Continous 0 - 24 inches	Discrete 3.0 feet, 4.3 feet, and 5.0 feet

April 15,1999	Pit 1B(r)*	Continuous 0 - 30 inches	
April 29, 1999	Pit 1E	Continuous 0 - 30 inches	Discrete 3.0 feet and 4.0 feet
	Pit 2A	Continuous 0 - 30 inches	
	Pit 2C	Continuous 0 - 18 inches	
	Pit 2E	Continuous 0 - 24 inches	

* Resampling of Pit 1B

Grain-Size Distribution. Grain-size sieve analyses were performed on 34 samples by AGRA Earth & Environmental, Inc., of Albuquerque. The first 21 samples were run through an eight-unit stack consisting of 1/2 inch, 3/8 inch, #4, #10, #40, #100, #200, plus the pan. The second 13 samples were run through an 11-unit stack consisting of the previous array plus a #70, #80, and #170 sieves. The latter stack was more compatible with the sieve analyses done at the SNL Hydrology Laboratory in 1998 (Van Hart, 1998). The results conform to the 1998 findings that the near-surface sediments consist mainly of very fine sand and silt. The data are tabulated in Attachment C, and the AGRA lab data sheets are in Attachment D. The grain-size distributions, Attachment E, are plotted in two formats: 1) logarithmic weight-percent-passing (E-1), and 2) logarithmic weight-percent-retained (E-2).

Sediment Density via Sand-Cone Method. Sediment densities were taken by the sand-cone method. The test sand used was Ottawa 20-30 Silica Sand. Its bulk density was determined by gently filling a graduated cylinder with the test sand to the 1000 ml mark and then weighing the contents. Eight weights, ranging from about 1640 to 1652 g, were averaged for a bulk-density value of 1.645 g/cc. The sediment densities derived via the sand-cone method are tabulated in Attachment F.

Standard Proctor Tests. Thirty four samples were subjected to Standard Proctor compaction tests by AGRA Earth & Environmental. These included: 26 from the soil pits 1A (6), 1B (4), 1C (5), 1D (6), and 2A (5); one composite sample from Area 1 from depths 0 - 2 ft; one composite sample from Area 1 from depths deeper than 2 ft; three samples from the CAMU “native soil” pile; and three samples from the CAMU “subgrade prep” pile. AGRA determined maximum dry densities and optimum water contents. In addition, Knight PiJsold LLC of Elko, Nevada, performed two Standard Proctors on samples taken during the Air Entry Permeameter (AEP) tests done about 240 ft NW of the IP Site (Figure 1) on September 15, 1998. All Standard Proctor test results are tabulated in Attachment C. The AGRA and Knight PiJsold lab data sheets are in Attachment G.

Hydraulic Conductivity. Falling-head permeability tests were performed by AGRA on two composite samples. The samples were compacted to 90% maximum dry density as per ASTM D-698:

1. Composite 1A - “native soils”: 12 samples from depths of 0.4 to 2.0 ft taken from Soil Pits 1A, 1B, 1C, and 1D. Sample was remolded to 104.8 lbs/ft^3.

K_{sat} 1.10 x $10^{!4}$ cm/sec 113.8 ft/yr

2. Composite 1B - “subgrade preparation” material: 9 samples from depths of 2.6 to 5.0 ft taken from Soil Pits 1A, 1B, 1C, and 1D. Sample was remolded to 101.0 lbs/ft^3.

K_{sat} 4.33 x $10^{!5}$ cm/sec 44.8 ft/yr

The AGRA data sheets for falling head K_{sat}, are in Attachment H.

Knight PiJsold performed two flexible-wall permeability tests on the two remolded samples taken from the AEP site:

1. AEP-1a (0.3 ft):

K_{sat} 3.1 x $10^{!4}$ cm/sec 320.7 ft/yr

2. AEP-1b (1.5 ft):

K_{sat} 2.1 x $10^{!4}$ cm/sec 217.3 ft/yr

Atterherg Limits. Atterberg limits were determined from 13 samples from Area 1 (2), Area 2 (5) and CAW (6). The values are tabulated in Attachment E.

Direct-Shear Tests. These tests were performed on eight samples:
(1) Area 1 composite sample of 1A-2.0 feet, 1A-2.6 feet, and 1A-3.6 feet
(1) Area 2 composite sample of 2A-1.5 feet and 2A-1.7 feet
(3) CAMU Native Soil samples 1 of 3, 2 of 3, and 3 of 3
(3) CAMU Subgrade Prep samples 1 of 3, 2 of 3, and 3 of 3

The data are tabulated in Attachment I.

Summary

The remaining five figures summarize the field data, and the lab data generated by AGRA Earth & Environmental. Figure 5 is a plot of sediment moisture (taken April 1, 1999), sand-cone density, and maximum dry density (Standard Proctor) for Pit 1A. The high moisture and low density from about 0.5 to 1.75 ft is likely a composite function of root content and maximum bioturbation.

Figures 6 and 7 are plots of the relationship of weight-percent fine fractions vs. the Proctor maximum dry densities for samples taken from Areas 1 and 2 and from CAMU. Three “fields” are shown: 1) Areas 1 and 2, depth 0 to 2 ft; 2) Areas 1 and 2, depth 2 ft and deeper; and 3) the two dirt piles sampled at CAMU. It seems intuitive that there should be a relationship between compactibility and percent of fine-grained fractions in the sediment. However, little correlation is apparent, other than a slightly less compactibility of the samples taken from below 2 ft, and a slightly higher compactibility of the samples taken from CAMU. Average maximum dry density for depths 0 to 2 ft is 116.7 lbs/ft^3, for depths greater than 2 ft, 112.2 lbs/ft^3, and for CAMU, 119.9 lbs/ft^3.

Figure 8 is a comparison of the grain-size distributions for two composite samples taken from Area 1. Composite 1A was made up of “grabs” from 12 samples from depths 0.4 to 2.0 ft, and Composite 1B from nine samples from depths 2.6 to 5.0 ft. The percent of material passing the #200 sieve is exceptionally high (56%) for Composite 1A (it is one of the two points in the isolated field on the high-fine side of Figures 6 and 7).

Figure 9 compares average plots for 0 to 2 ft depth and greater than 2 ft depth for Areas 1 and 2, and for the two dirt piles at CAMU. In apparent contradiction to Figure 8 the average of grain-size distribution plots for 17 analyses from depths 0 to 2 ft shows a #200-passing value of about 32%, vs. 68% in Composite 1A. Figure 9 also shows that at Areas 1 and 2, average grain-size distributions for depths greater than 2 ft are virtually identical to those for depths 0 - 2 ft. Finally, the material at CAMU has a slightly lower percent of fines (22-23%) and a slightly higher percent of gravel and coarse sand than Areas 1 and 2.

References Cited

Machette, M.N., 1985. Calcic Soils of the Southwestern United States, in Geological Society of America Special Paper 203, Soils and Quaternary Geology of the Southwestern United States, p. 1-21.

Van Hart, D., 1998. Geologic Study of Near-Surface Sediments, Technical Area 3, Sandia National Laboratories, prepared for ER Organization 6134, September 30, 1998.

Figures

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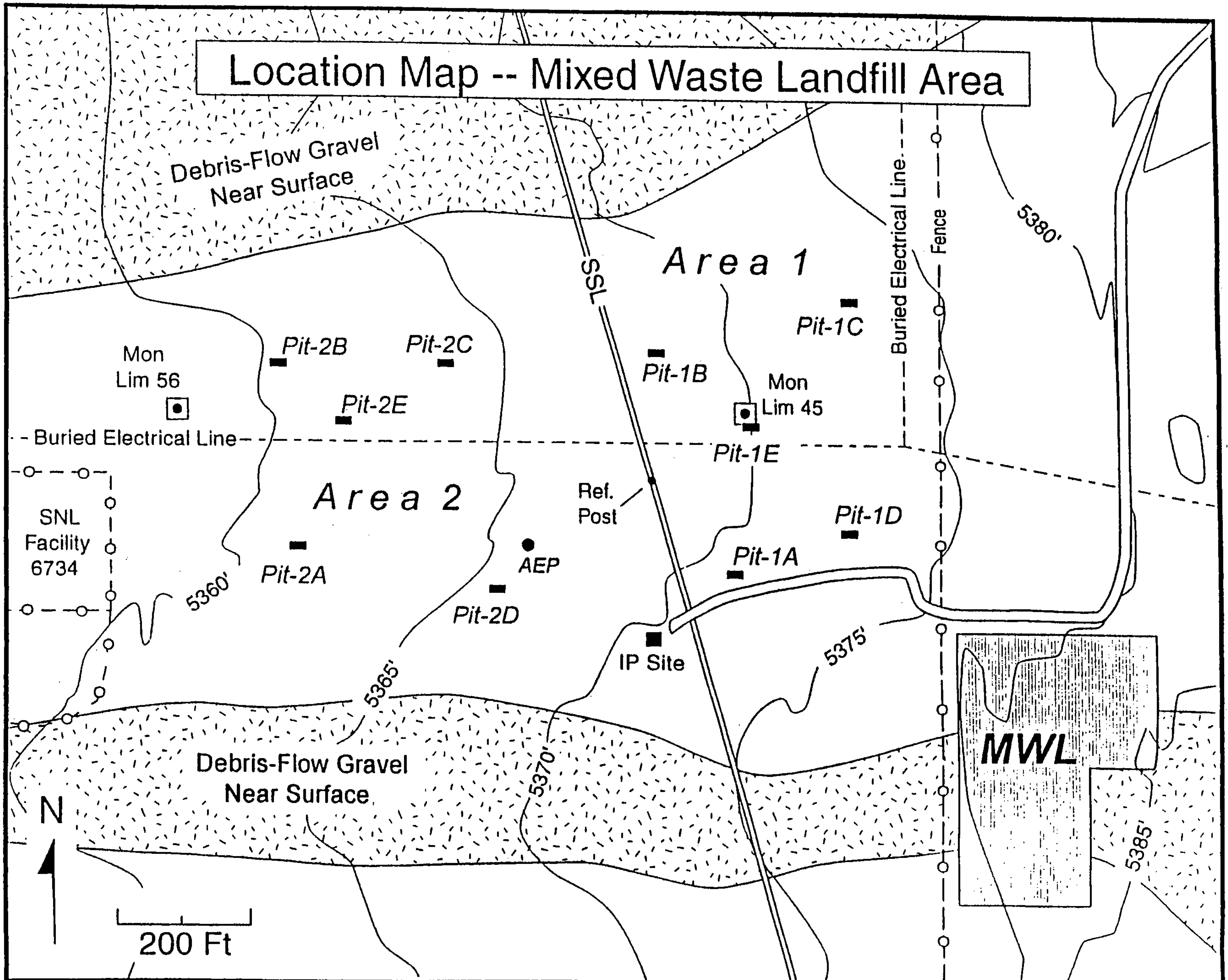

Figure 1. Location Map -- MWL Areas 1 and 2

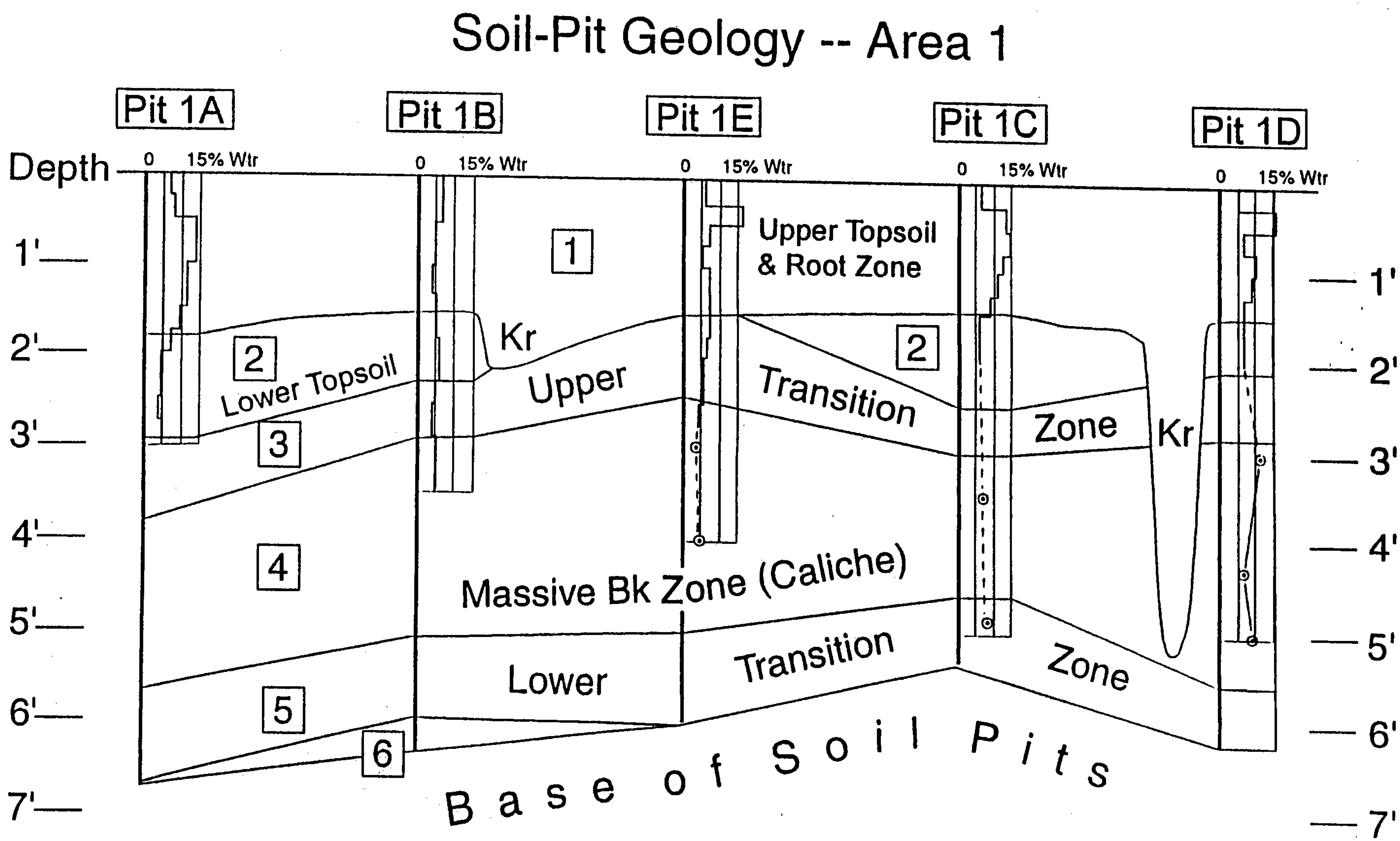

Figure 2. Soil-Pit Geology -- Area 1

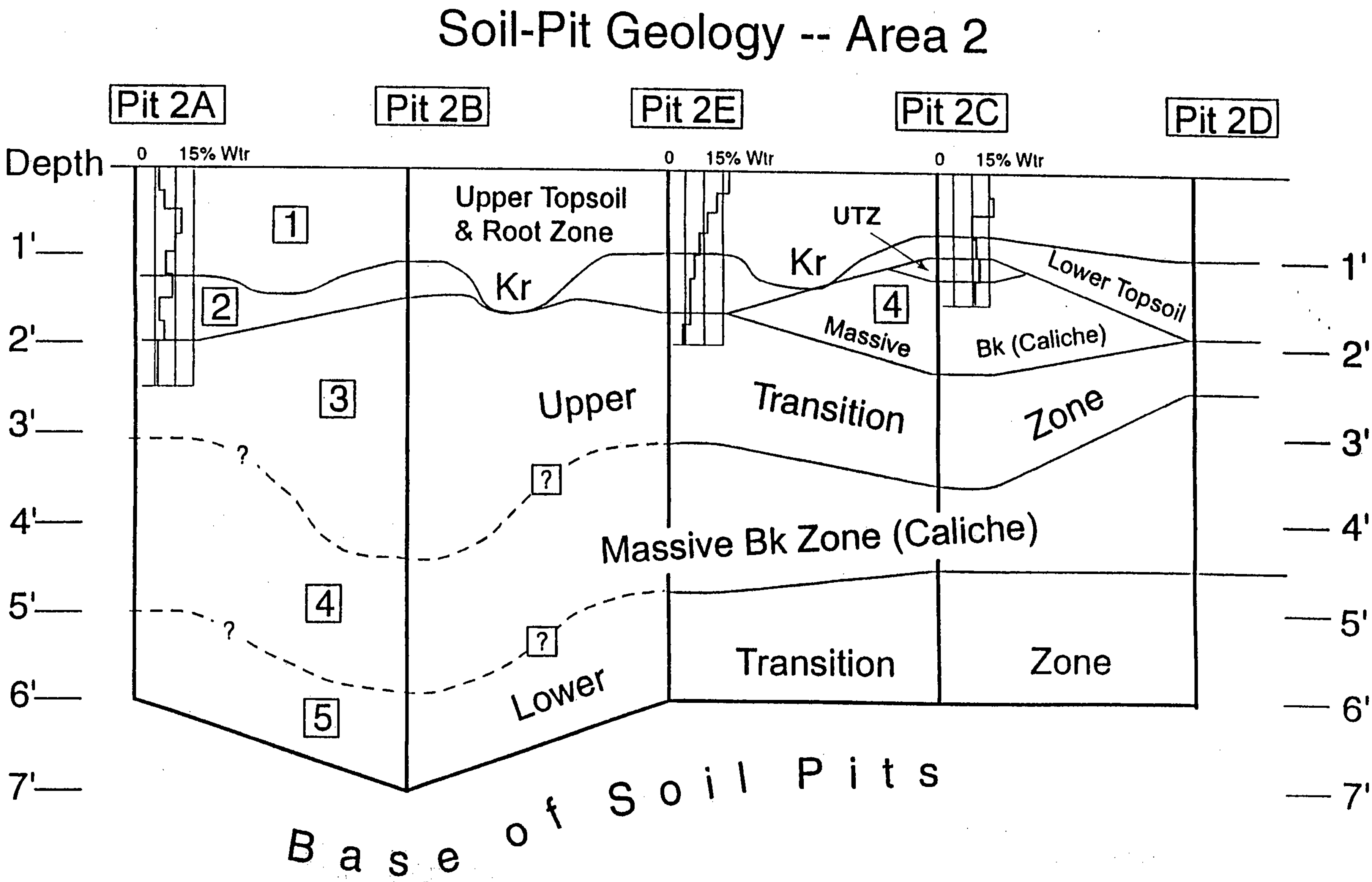

Figure 3. Soil-Pit Geology -- Area 2

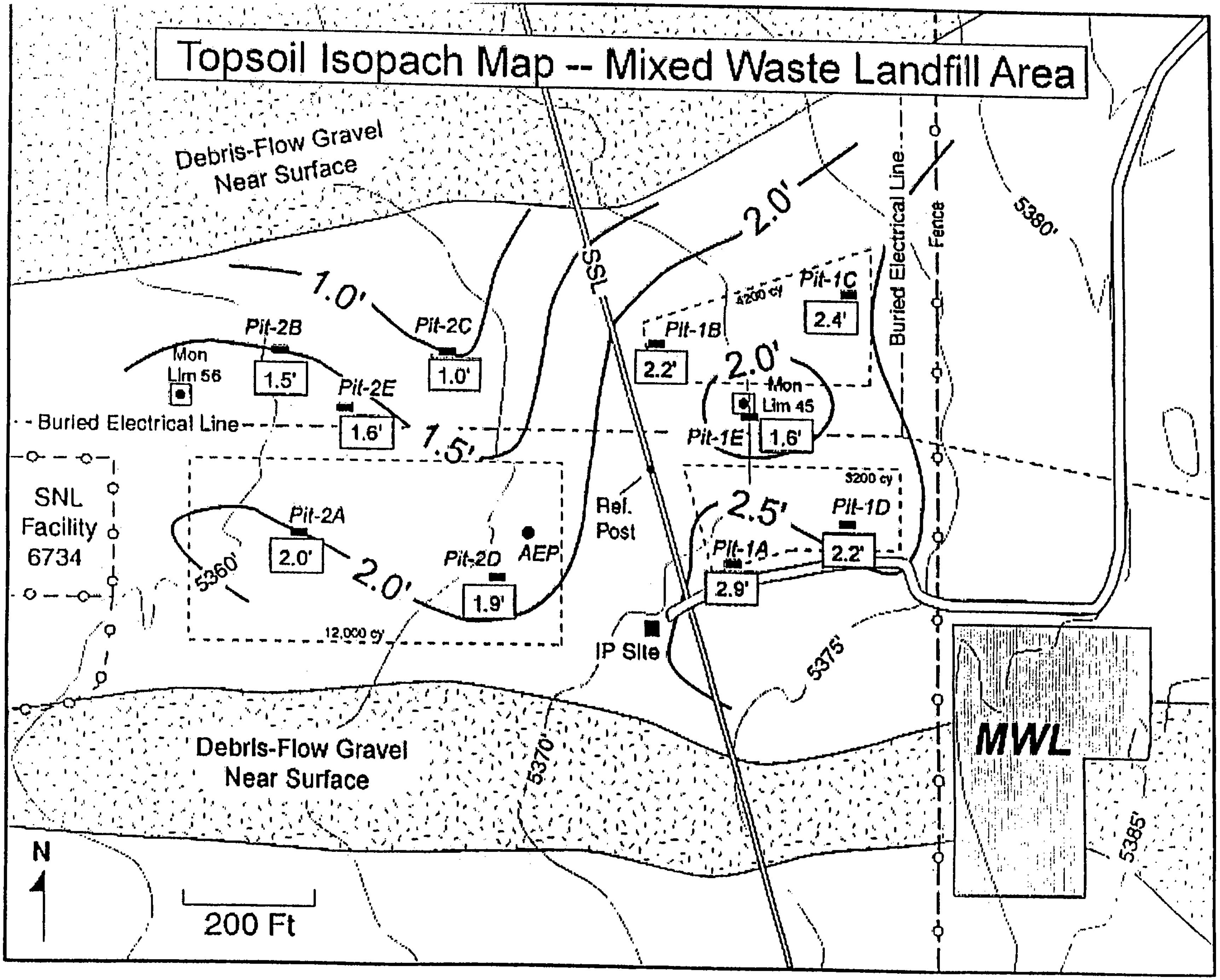

Figure 4. Topsoil Isopach Map -- Areas 1 and 2

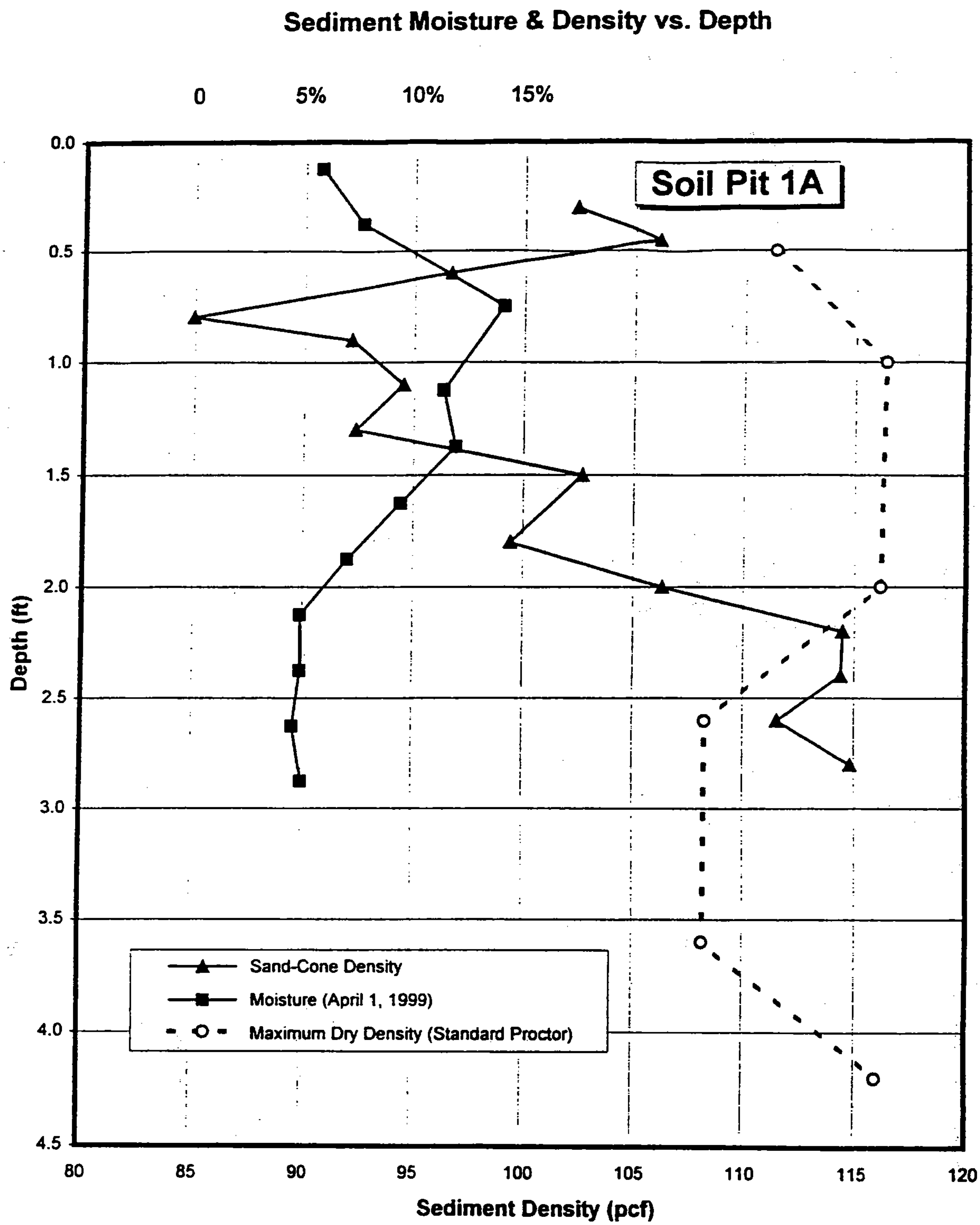

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Figure 5. Sediment Moisture and Density vs. Depth

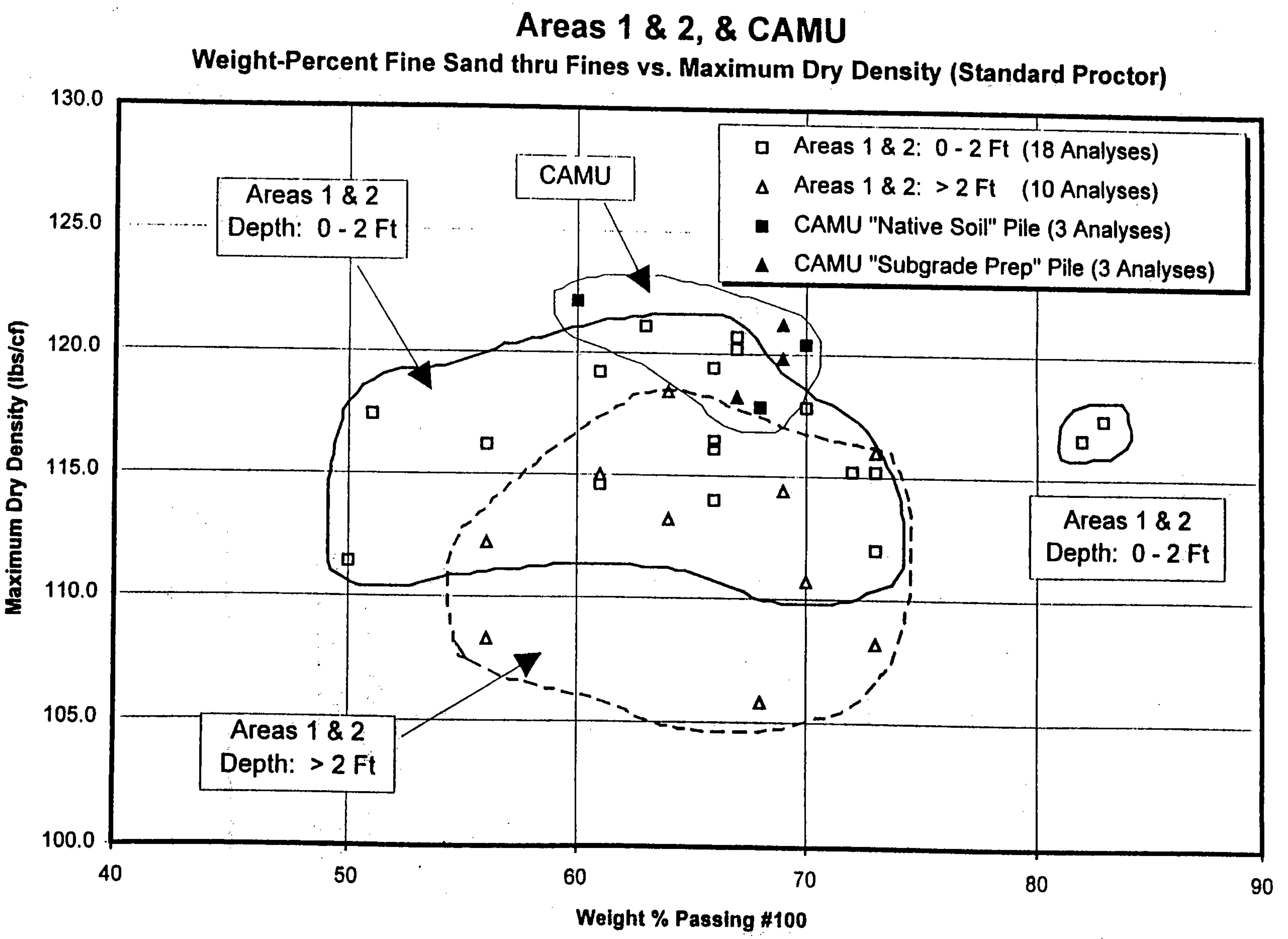

Figure 6. Weight-Percent Fine Sand to Fines (Passing #100 Sieve) vs. Maximum Dry Density (Standard Proctor)

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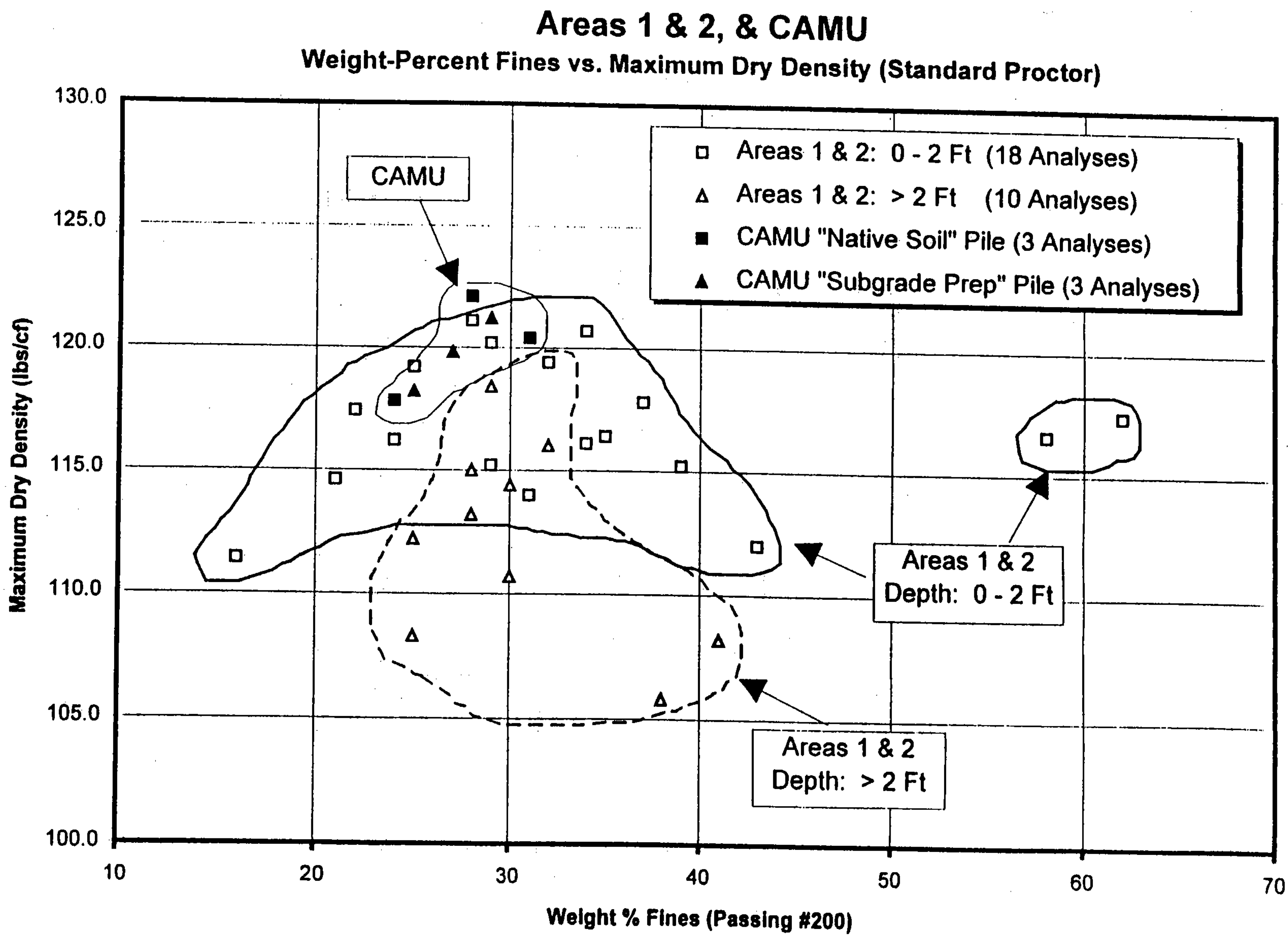

Figure 7. Weight-Percent Fines (Passing #200 Sieve) vs. Maximum Dry Density (Standard Proctor)

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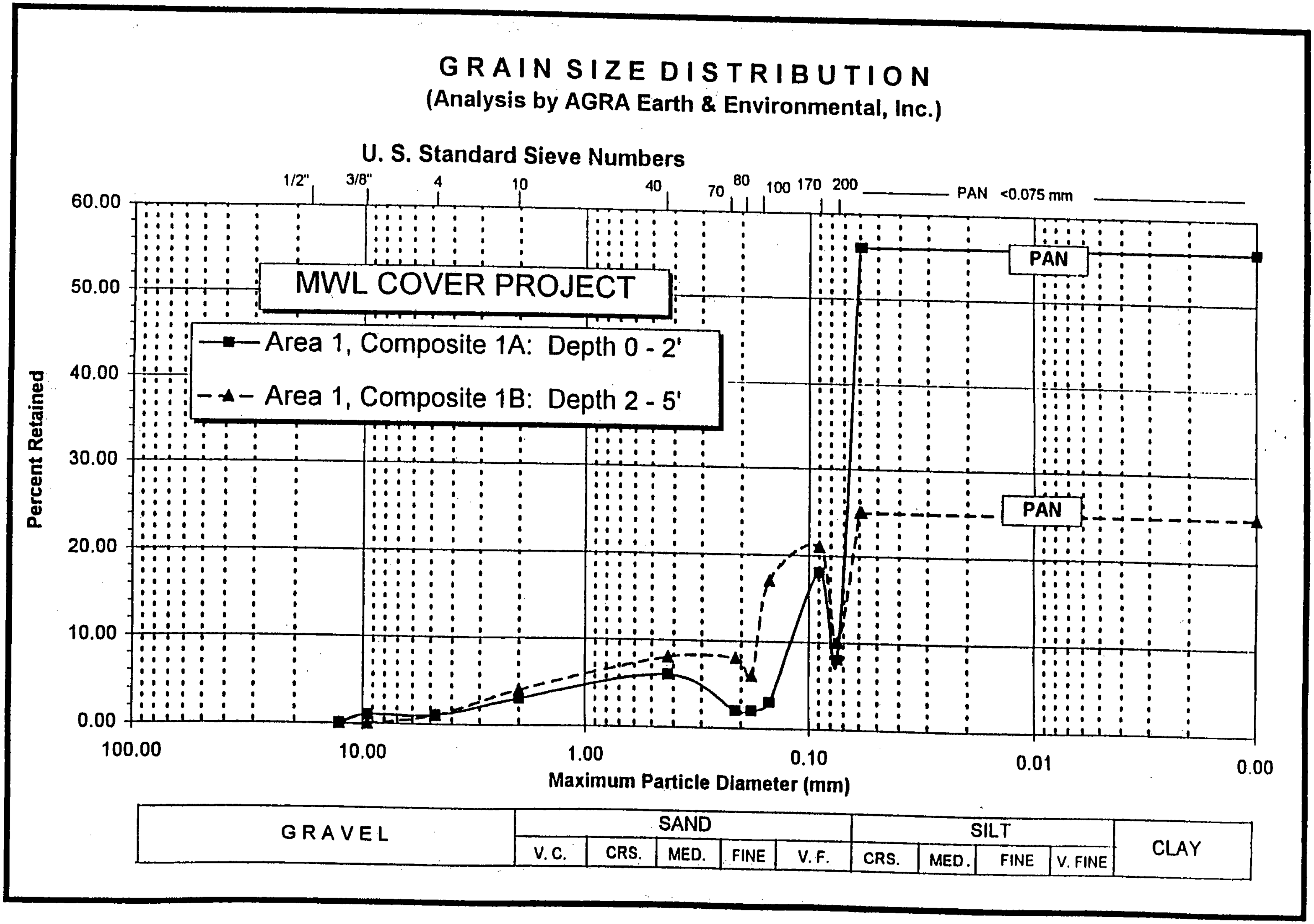

Figure 8. Grain-Size Comparison: Area 1, Composite Samples 0-2' vs. 2'+

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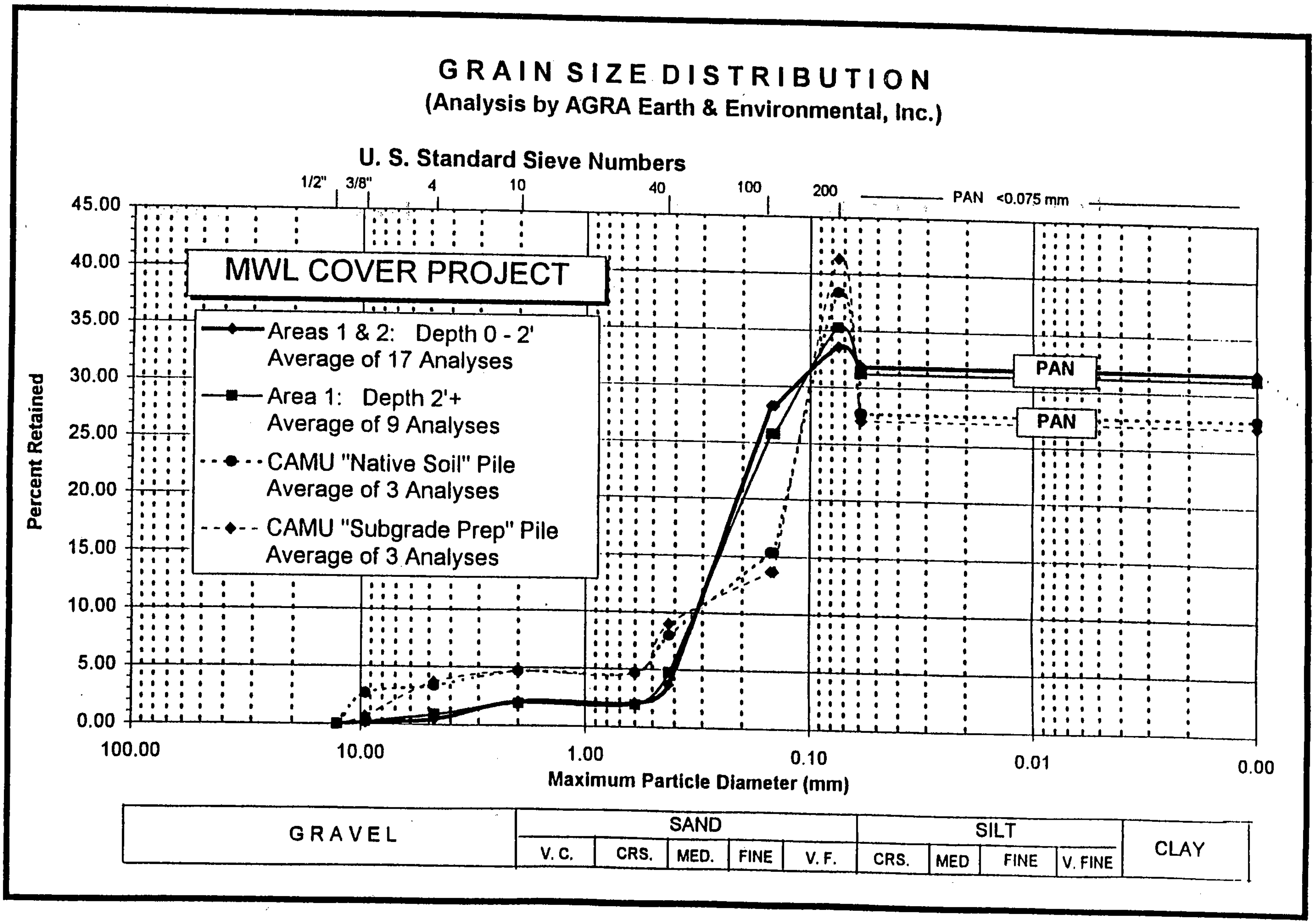

Figure 9. Grain-Size Comparison: Averages of Areas 1, 2, and CAMU

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Attachment A

Geologic Sketches of Soil Pits

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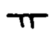
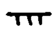
Geologic Sketches of Soil Pits

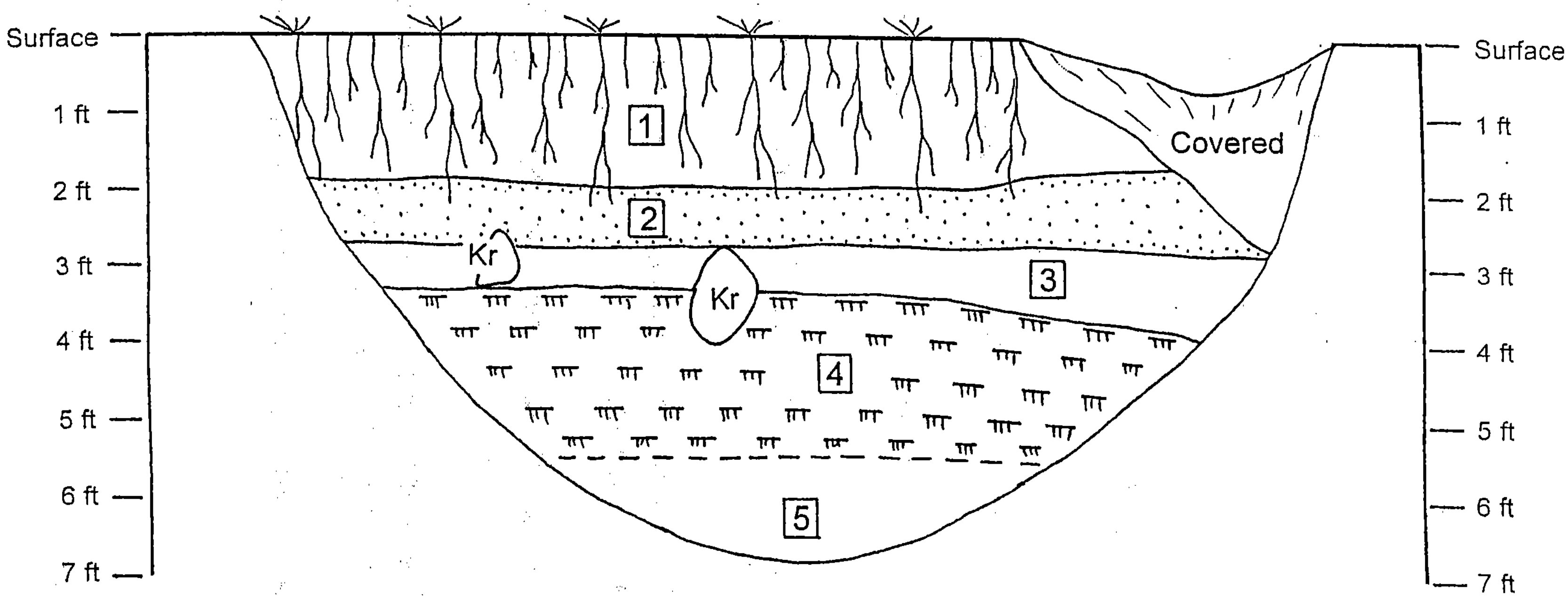
LEGEND

□	Geologic Unit #
	Stage II secondary calcite morphology
	Stage III secondary calcite morphology
Kr	Krotovina (in-filled burrow)

"Normal" Geologic Sequence

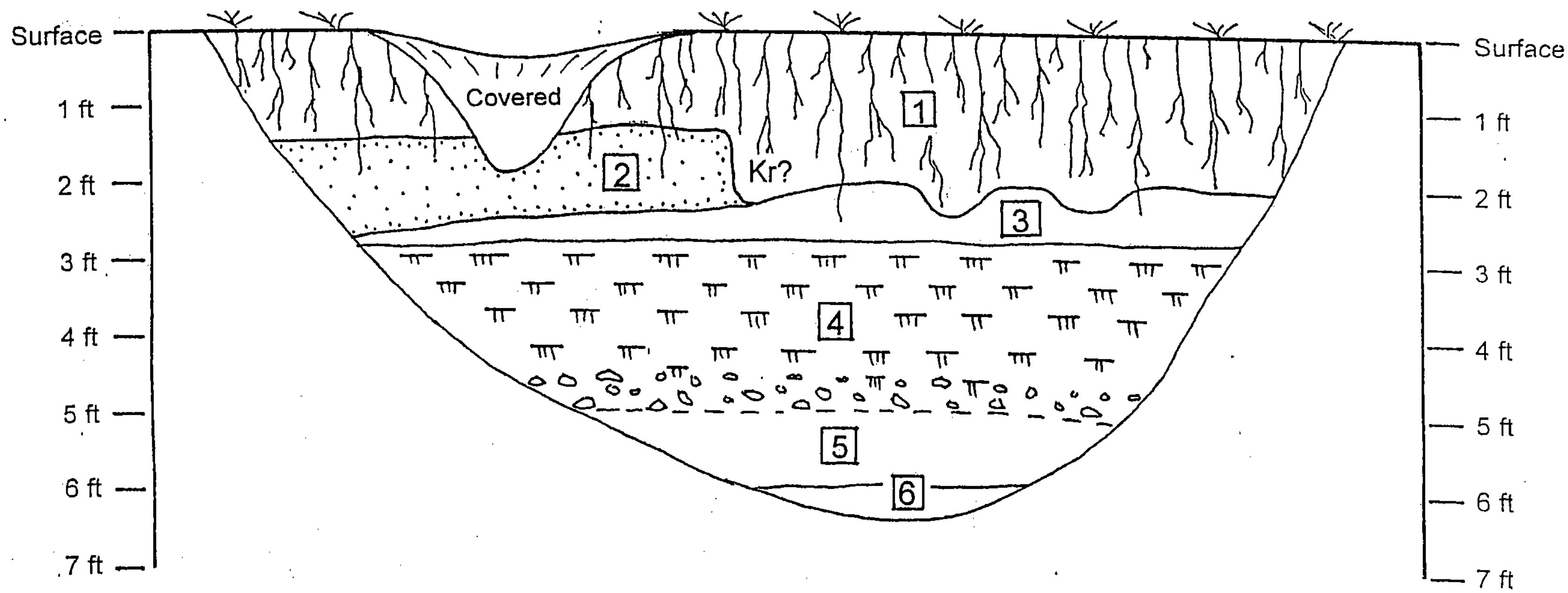
Unit 1	Root & moisture zone; soft, loose, very fine sand; Munsell color values 4 to 5.
Unit 2	Harder, dryer, very fine sand; few roots; lighter Munsell color values 5 to 6.
Unit 3	Upper Transition Zone to massive Bk; caliche blebs coalescing downward; rare roots.
Unit 4	Massive Bk Zone; hard; dry, very fine sand; light Munsell color values 7 to 8.
Unit 5	Lower Transition Zone to unaltered very fine sand; softer; darker Munsell color values 7 to 6.
Unit 6	Unaltered sediment; Munsell color value 6; rarely penetrated by pits.

Soil Pit 1A



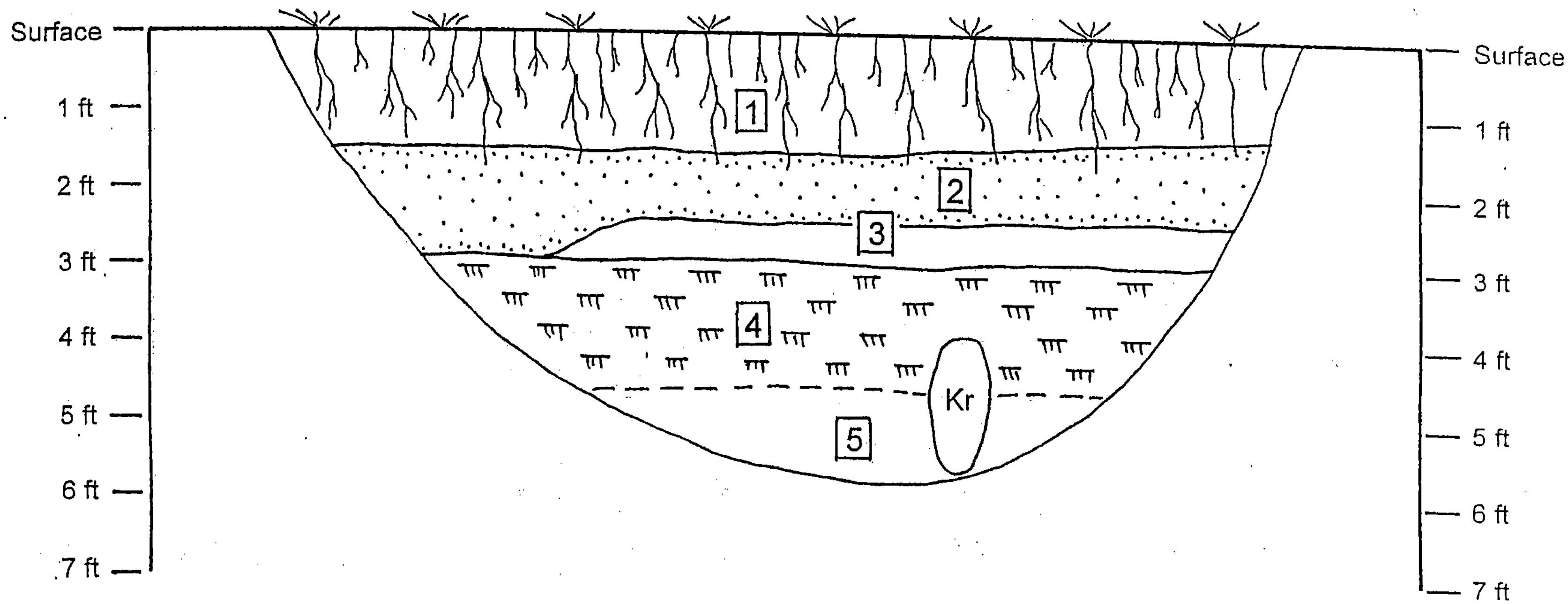
Soil Pit Sketches
Areas 1 & 2

Soil Pit 1B



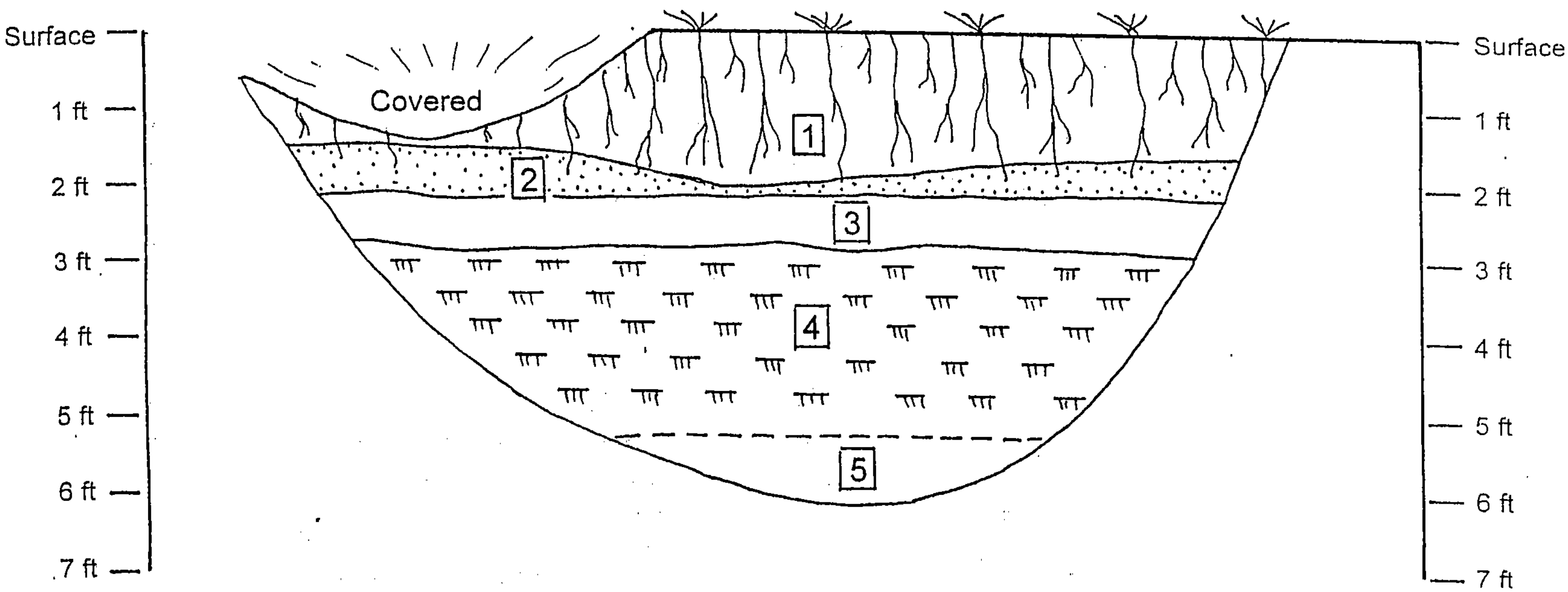
Soil Pit Sketches
Areas 1 & 2

Soil Pit 1C



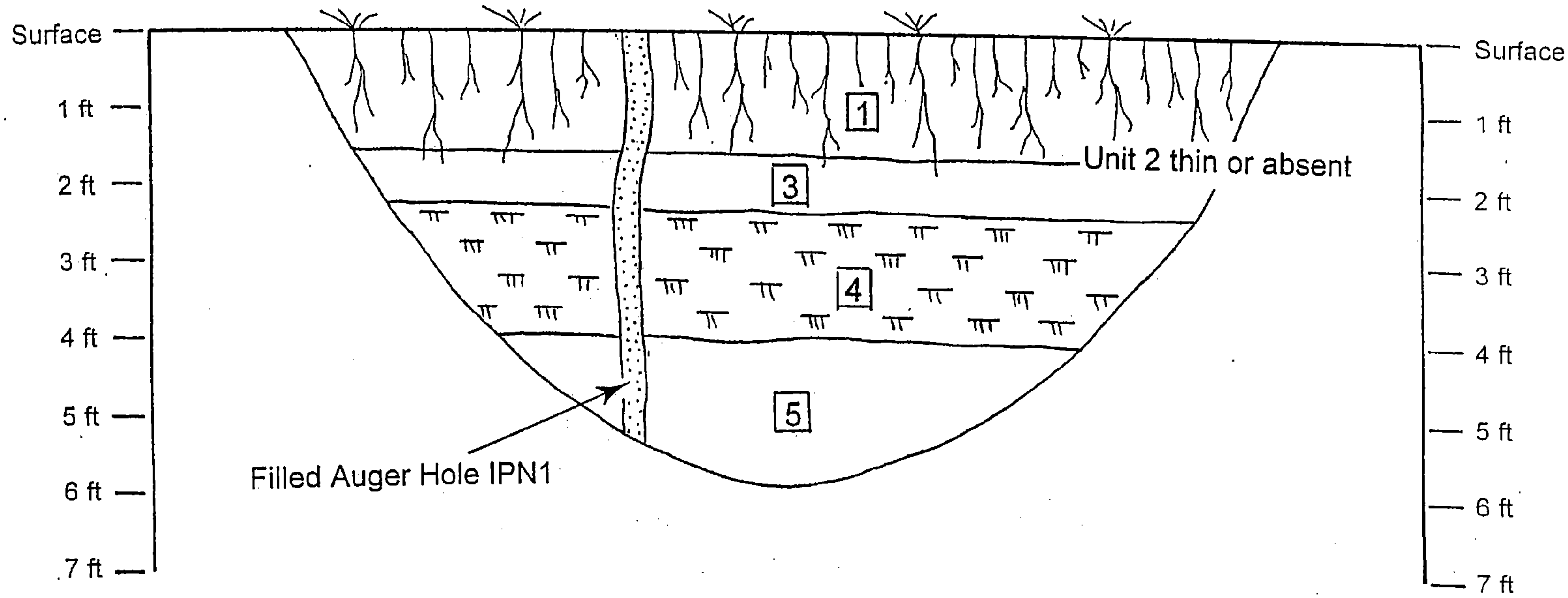
Soil Pit Sketches
Areas 1 & 2

Soil Pit 1D

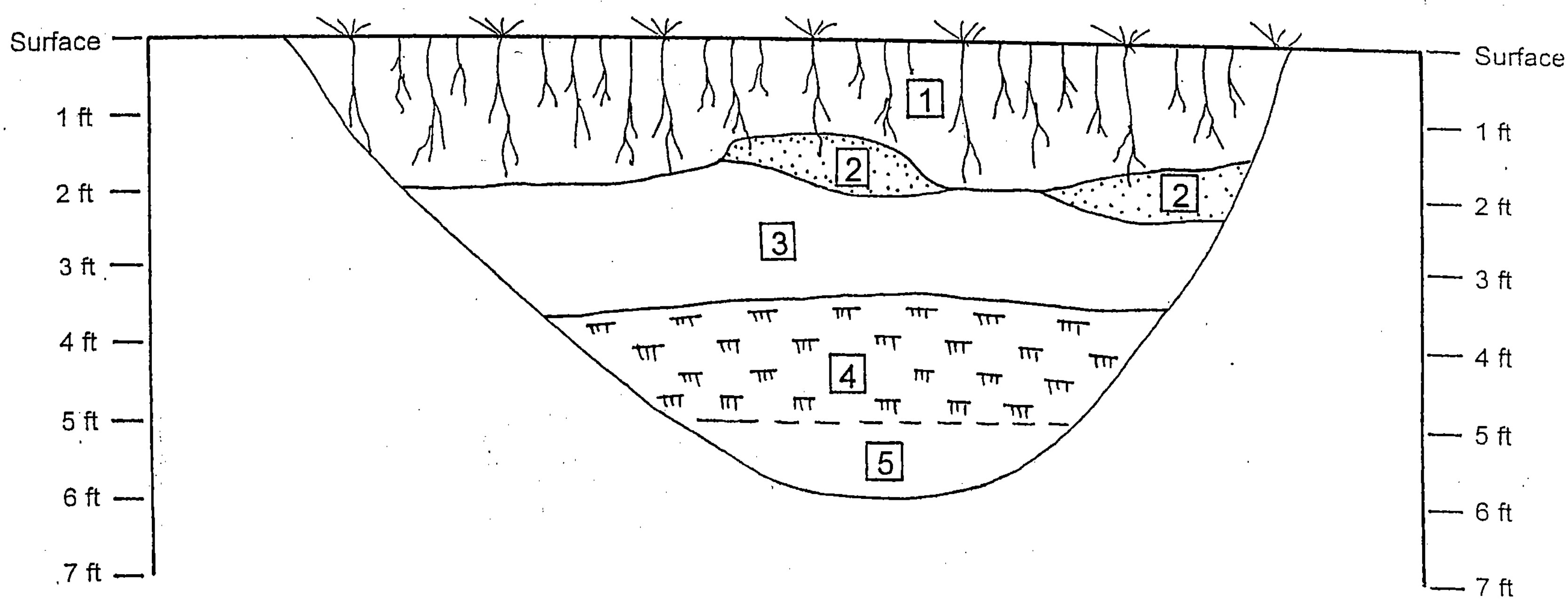


Surface
1 ft
2 ft
3 ft
4 ft
5 ft
6 ft
7 ft
Covered
1
2
3
4
5
Surface
1 ft
2 ft
3 ft
4 ft
5 ft
6 ft
7 ft

Soil Pit 1E

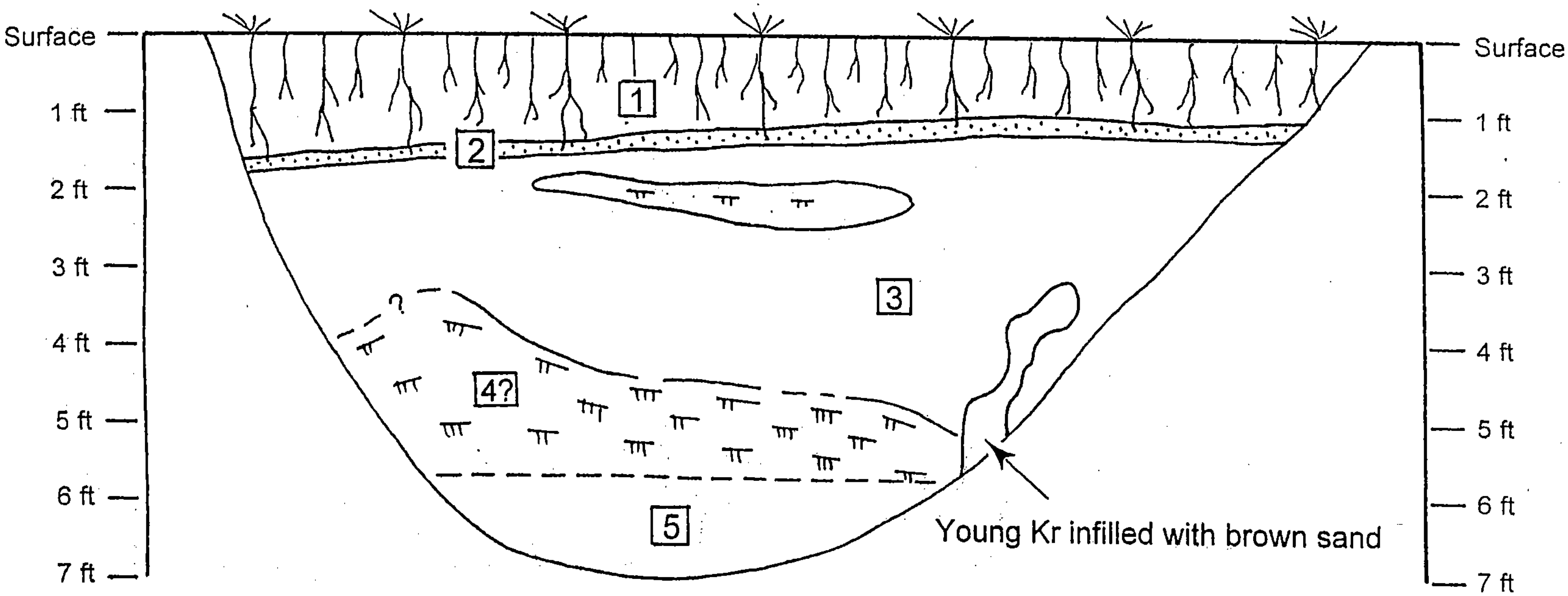

Surface
1 ft
2 ft
3 ft
4 ft
5 ft
6 ft
7 ft
1
Unit 2 thin or absent
3
4
5
Filled Auger Hole IPN1
Surface
1 ft
2 ft
3 ft
4 ft
5 ft
6 ft
7 ft

Soil Pit 2A



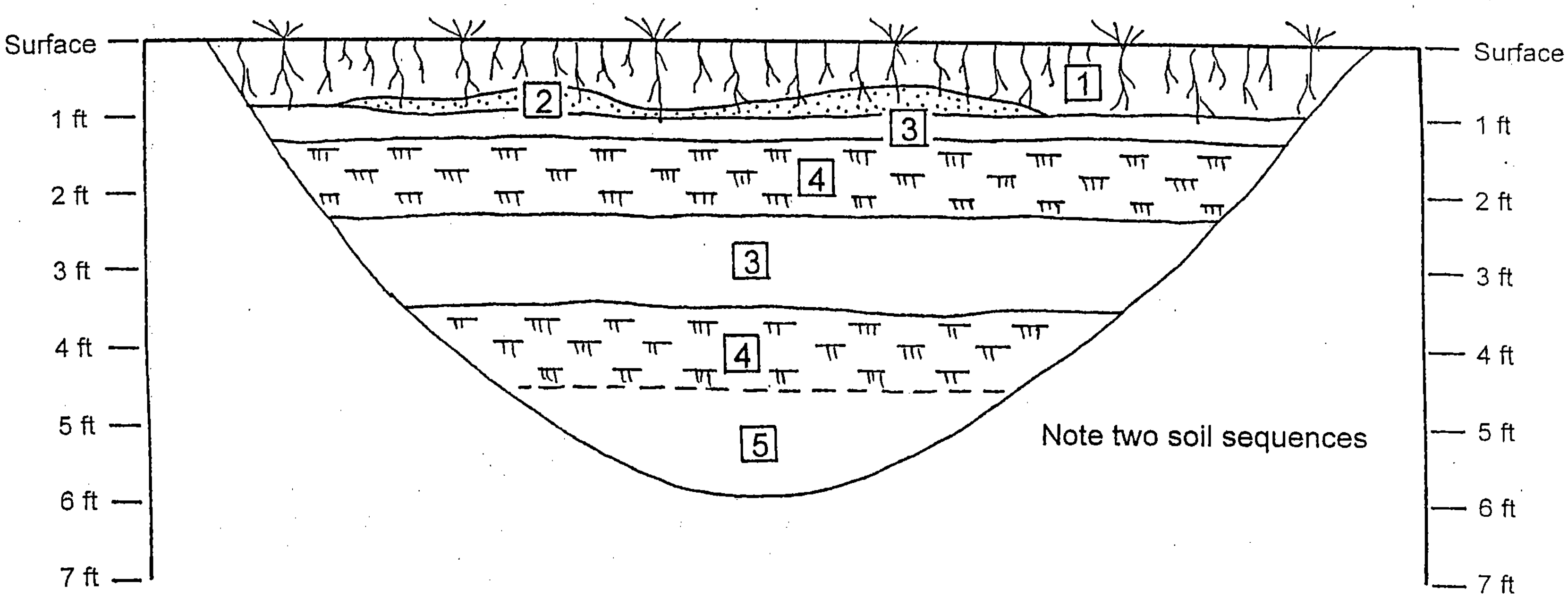
Soil Pit Sketches
Areas 1 & 2

Soil Pit 2B



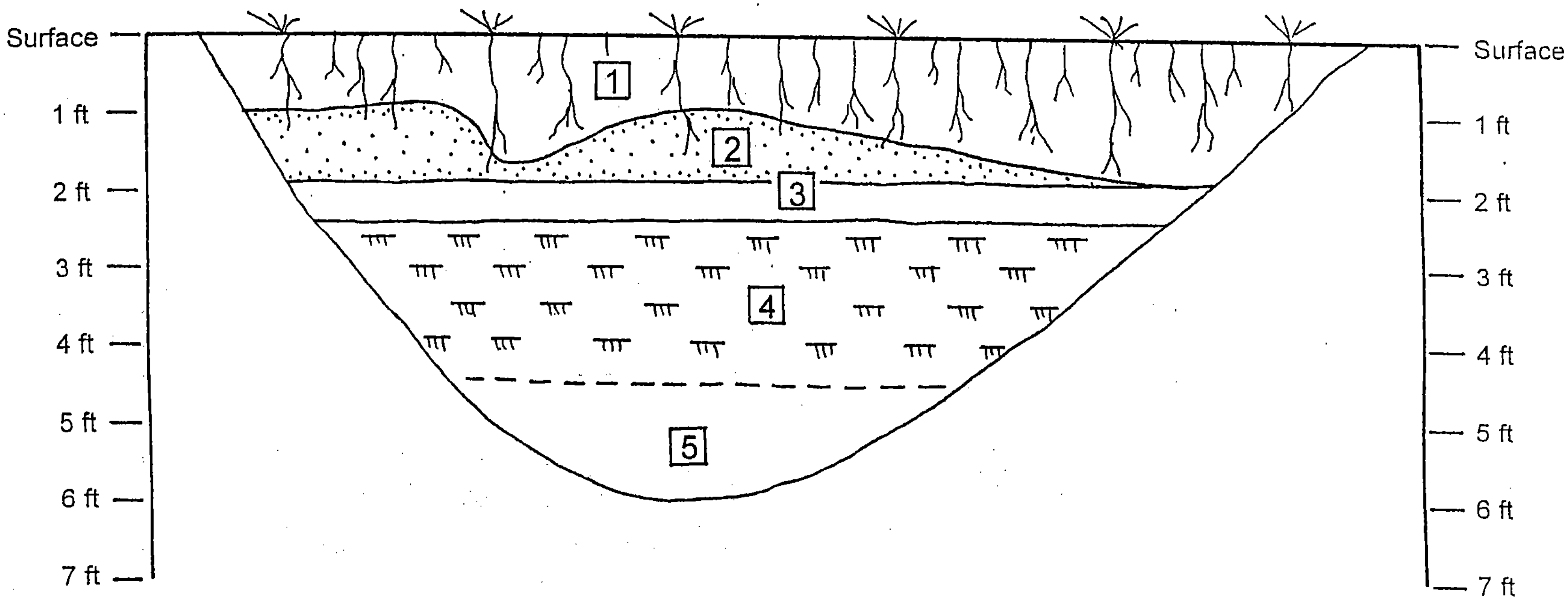
Surface
1 ft
2 ft
3 ft
4 ft
5 ft
6 ft
7 ft
1
2
3
4?
?
5
Young Kr infilled with brown sand
Surface
1 ft
2 ft
3 ft
4 ft
5 ft
6 ft
7 ft

Soil Pit 2C



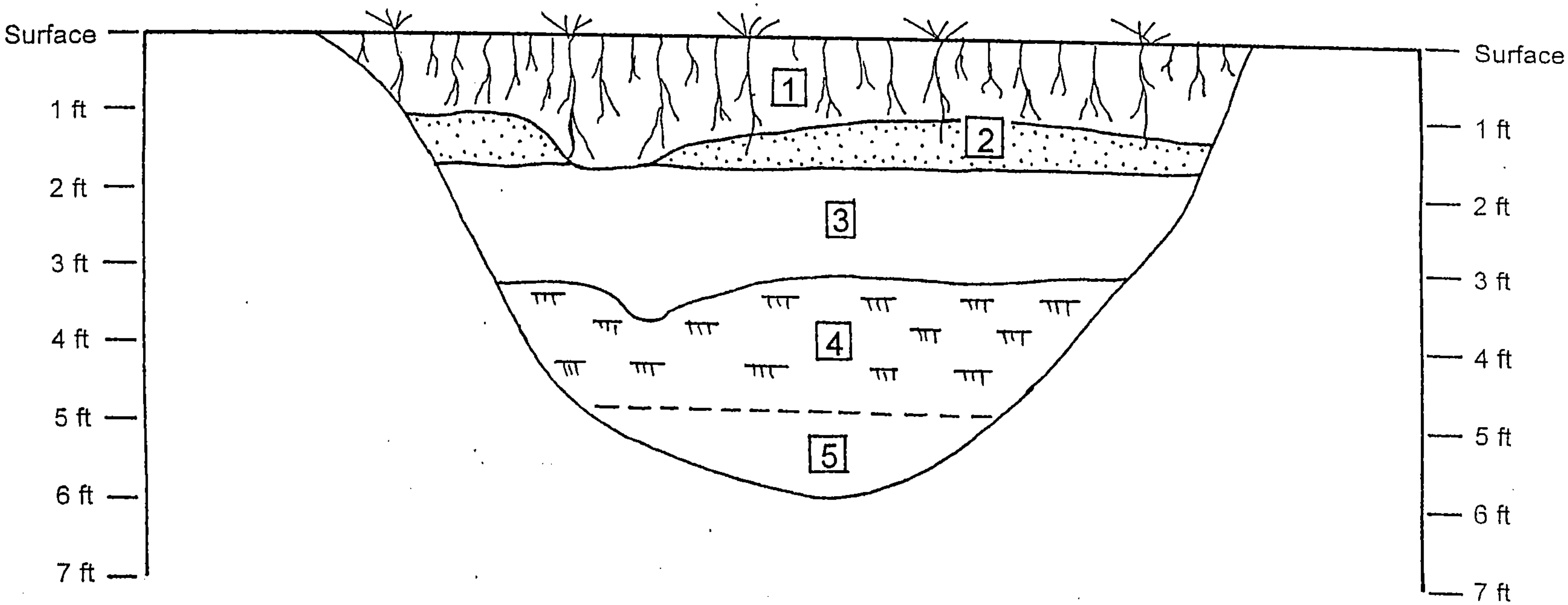
Soil Pit Sketches
Areas 1 & 2

Soil Pit 2D



Soil Pit Sketches
Areas 1 & 2

Soil Pit 2E


Surface
1 ft
2 ft
3 ft
4 ft
5 ft
6 ft
7 ft
1
2
3
4
5
Surface
1 ft
2 ft
3 ft
4 ft
5 ft
6 ft
7 ft

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Attachment B

Sediment-Moisture Readings (Sleeved Samples)

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Moisture Contents of Sleeved Samples from Soil Pits

Soil Pit	Depth (ft)	Wet Wt.(g)	Dry Wt.(g)	Wt. % Water	Volume Wtr. (cc) Vol./sample	Cum.Vol./Pit
P1A	0.125	229.91	217.39	5.76	8.03	8.03
P1A	0.375	250.62	232.78	7.66	10.68	18.71
P1A	0.75	208.99	183.21	14.07	19.62	38.33
P1A	1.125	156.52	140.55	11.36	15.84	54.17
P1A	1.375	237.23	211.96	11.92	16.62	70.79
P1A	1.625	249.52	227.97	9.45	13.18	83.96
P1A	1.875	253.01	236.37	7.04	9.81	93.78
P1A	2.125	196.91	187.67	4.92	6.86	100.64
P1A	2.375	128.9	122.84	4.93	6.88	107.52
P1A	2.675	234.91	224.57	4.60	6.42	113.94
P1A	2.875	265.34	252.67	5.01	6.99	120.93
P1B	0.125	209.37	197.78	5.86	8.17	8.17
P1B	0.375	256.23	242.56	5.64	7.86	16.03
P1B	0.625	201.31	193.04	4.28	5.97	22.00
P1B	0.875	45.62	43.48	4.92	6.86	28.86
P1B	1.125	232.28	223.24	4.05	5.64	34.50
P1B	1.375	252.16	241.95	4.22	5.88	40.39
P1B	1.625	219.47	210.64	4.19	5.84	46.23
P1B	1.875	257.75	242.62	6.24	8.69	54.92
P1B	2.125	215.13	203.83	5.54	7.73	62.65
P1B	2.375	221.03	210.49	5.01	6.98	69.63
P1B	2.625	210.72	201.48	4.59	6.39	76.02
P1B	2.875	213.12	203.43	4.76	6.64	82.66
P1B	3.125	221.77	212.27	4.48	6.24	88.90
P1B	3.375	255.52	245.24	4.19	5.84	94.75
PIBr	0.125	169.10	157.98	7.04	9.81	9.81
PIBr	0.375	236.89	226.54	4.57	6.37	16.18
PIBr	0.625	214.77	205.64	4.44	6.19	22.37
PIBr	0.875	182.54	174.66	4.51	6.29	28.66
PIBr	1.125	232.83	223.87	4.00	5.58	34.24
PIBr	1.375	233.06	223.84	4.12	5.74	39.98
PIBr	1.625	170.14	163.91	3.80	5.30	45.28
PIBr	1.875	185.93	175.76	5.79	8.07	53.34
PIBr	2.125	102.63	97.80	4.94	6.88	60.23
PIBr	2.375	138.76	132.49	4.73	6.60	66.83

Moisture Contents of Sleeved Samples from Soil Pits (cont.)

					Volume Wtr. (cc)	
Soil Pit	Depth (ft)	Wet Wt.(g)	Dry Wt.(g)	Wt. % Water	Vol./sample	Cum.Vol./Pit
P1C	0.125	211.85	199.2	6.35	8.85	8.85
P1C	0.375	246.13	217.07	13.39	18.66	27.51
P1C	0.625	160.88	140.56	14.46	20.15	47.67
P1C	0.875	114.86	102.23	12.35	17.22	64.89
P1C	1.125	192.24	172.57	11.40	15.89	80.78
P1C	1.375	219.02	200.92	9.01	12.56	93.34
P1C	1.625	189.54	179.07	5.85	8.15	101.49
P1C	1.875	210.79	199.82	5.49	7.65	109.14
P1C	3.5'	200.70	188.38	6.54	9.12	
P1C	4.8'	254.19	236.48	7.49	10.44	
P1D	0.125	198.14	189.94	4.32	6.02	6.02
P1D	0.375	253.82	221.79	14.44	20.13	26.15
P1D	0.625	115.59	108.80	6.24	8.70	34.85
P1D	0.875	244.00	219.70	11.06	15.42	50.27
P1D	1.125	237.57	218.02	8.97	12.50	62.77
P1D	1.375	216.52	202.19	7.09	9.88	72.65
P1D	1.625	118.11	111.91	5.54	7.72	80.37
P1D	1.875	159.80	151.01	5.82	8.11	88.48
P1D	3.0'	258.78	232.20	11.45	15.96	
P1D	4.3'	261.20	247.68	5.46	7.61	
P1D	5.0'	261.31	238.48	9.57	13.34	

Moisture Contents of Sleeved Samples from Soil Pits (cont.)

					Volume Wtr. (cc)	
Soil Pit	Depth (ft)	Wet Wt.(g)	Dry Wt.(g)	Wt. % Water	Vol./sample	Cum.Vol./Pit
P1E	0.125	194.89	182.27	6.92	9.65	9.65
P1E	0.375	261.64	225.30	16.13	22.48	32.14
P1E	0.625	207.51	185.05	12.14	16.92	49.06
P1E	0.875	229.72	207.98	10.45	14.57	63.63
P1E	1.125	143.91	133.47	7.82	10.90	74.53
P1E	1.375	219.51	203.70	7.76	10.82	85.35
P1E	1.625	213.12	198.76	7.22	10.07	95.42
P1E	1.875	246.05	230.22	6.88	9.59	105.01
P1E	2.125	233.39	220.12	6.03	8.40	113.41
P1E	2.375	238.12	225.73	5.49	7.65	121.06
P1E	3.0'	192.79	184.81	4.32	6.02	
P1E	4.0'	273.61	260.23	5.14	7.17	
P2A	0.125	211.75	201.01	5.34	7.45	7.45
P2A	0.375	288.02	267.85	7.53	10.50	17.95
P2A	0.625	204.71	184.28	11.09	15.45	33.40
P2A	0.875	231.72	209.88	10.41	14.51	47.91
P2A	1.125	187.54	174.11	7.71	10.75	58.66
P2A	1.375	158.20	146.16	8.24	11.48	70.14
P2A	1.625	187.26	175.80	6.52	9.09	79.23
P2A	1.875	251.95	235.16	7.14	9.95	89.18
P2A	2.125	230.11	216.49	6.29	8.77	97.95
P2A	2.375	235.88	224.25	5.19	7.23	105.18
P2C	0.125	207.54	180.29	15.11	21.07	21.07
P2C	0.375	231.12	200.23	15.43	21.51	42.58
P2C	0.625	218.25	198.28	10.07	14.04	56.62
P2C	0.875	239.06	214.61	11.39	15.88	72.50
P2C	1.125	155.00	137.73	12.54	17.48	89.98
P2C	1.375	233.11	208.75	11.67	16.27	106.24
P2E	0.125	191.57	163.61	17.09	23.82	23.82
P2E	0.375	218.03	193.12	12.90	17.98	41.80
P2E	0.625	234.74	212.05	10.70	14.92	56.72
P2E	0.875	257.34	238.89	7.72	10.77	67.49
P2E	1.125	131.12	122.29	7.22	10.07	77.55
P2E	1.375	157.95	147.43	7.14	9.95	87.50
P2E	1.625	151.90	143.42	5.91	8.24	95.74
P2E	1.875	131.73	125.68	4.81	6.71	102.45

Comments:

1) Samples from P1A, P1B, P1C, P1D taken 3/31/99 & 4/1/99
2) P1Br is repeat of upper part of P1B, taken 4/15/99 for Q/A.
3) Samples from P1E, P2A, P2C, & P2E taken 4/29/99.
4) Samples taken generally every 3". Depth taken as mid-point in feet.

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Attachment C

Summary Tabulation of Grain-Size Distribution Data, Standard Proctor Moisture-Density Data, and Atterberg Limits

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Grain-Size Distribution, Proctor Compaction Data, & Atterberg Limits

	Grain-Size Analysis (Wt. % Passing)							Standard Proctor			
	U.S. Standard Sieve Numbers							Max. Dry	Opt. Wtr.	Atterberg Limits	
Sample	Thru #10	#40	#70	#80	#100	#170	#200	Dens.(lbs/cf)	(%)	LL	PI
P1A-0.5'	100	98			50		16	111.4	11.4	NV	NP
P1A-1.0'	99	98			66		35	116.4	13.3	NV	NP
P1A-2.0'	97	93			56		24	116.2	11.2	NV	NP
P1A-2.6'	96	90			56		25	108.3	10.4	NV	NP
P1A-3.6'	96	90			73		41	108.2	15.1	24	5
P1A-4.2'	97	92			73		32	116.0	11.2	22	4
P1B-0.4'	98	95			72		29	115.2	12.1	NV	NP
P1B-1.0'	98	94			67		34	120.7	11.4	25	9
P1B-1.5'	96	91			66		32	119.4	11.7	24	6
P1B-3.0'	94	88			61		28	115.0	10.0	NV	NP
P1C-0.5'	99	96			73		39	115.2	13.6	28	10
P1C-1.0'	98	94			66		34	116.1	13.1	24	5
P1C-1.6'	94	88			51		22	117.4	11.9	NV	NP
P1C-3.5'	99	94			64		29	118.4	10.7	NV	NP
P1C-4.8'	98	94			64		28	113.2	13.2	NV	NP
P1D-0.4'	89	82			61		21	114.6	11.3	NV	NP
P1D-0.9'	98	94			67		29	120.2	12.5	NV	NP
P1D-1.2'	96	92			66		31	114.0	12.8	NV	NP
P1D-3.0'	97	91			68		38	105.8	12.7	NV	NP
P1D-4.3'	98	95			69		30	114.4	14.2	NV	NP
P1D-5.0'	98	96			70		30	110.7	11.1	NV	NP
Composite-1A: 0-2'	95	89	87	85	82	64	58	106.1	9.7	NV	NP
Composite-1B: 2-5'	95	87	79	73	56	35	25	103.7	10.2	NV	NP
P2A-0.6'	99	96	88	82	73	43	43	112.0	15.1	NV	NP
P2A-1.5'	96	92	81	73	63	36	28	121.1	11.9	NV	NP
P2A-1.7'	98	94	82	72	61	33	25	119.2	11.0	NV	NP
P2D-0.6'	100	97	88	80	70	45	37	117.8	11.6	23	7
P2E-1.0'	99	97	92	88	83	67	62	117.4	10.8	NV	NP
AEP 1a (0.3')								116.6	12.3		
AEP 1b (1.5')								117.5	11.2		
CAMU NS1	90	83	78	74	68	35	24	117.8	11.7	NV	NP
CAMU NS2	91	84	78	75	70	42	31	120.4	11.6	22	6
CAMU NS3	87	77	70	66	60	38	28	122.1	10.3	NV	NP
CAMU SGP1	91	82	78	75	69	40	29	121.2	9.8	NV	NP
CAMU SGP2	91	81	76	73	67	36	25	118.2	10.2	NV	NP
CAMU SGP3	91	83	78	75	69	38	27	119.8	11.5	NV	NP

AEP (Air-Entry Permeameter) analyses done by Knight Piesold; all others by AGRA Earth & Environmetal
"P" = Soil Pit Sample

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Attachment D

AGRA Earth & Environmental
Lab Data Sheets
(Grain-Size Distribution,
Atterberg Limits,
and Standard Proctor Compaction Data)

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AGRA Earth & Environmental, Inc.
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Fax (505) 821-7371

April 20, 1999

AGRA Job No. 9-519-001154

Sandia National Laboratories
ORG7914/MS0908
PO Box 5800
Albuquerque, NM 87185

Attn: Evelyn Tuttle

Project: Mixed Waste Landfill Cover
SO#FQ2059
Gilbert Aldez-Inspector

Lab No. 4454: Client Sample ID - P1A @ 0.5'.

SIEVE ANALYSIS

Sieve Size	Percent Passing	% Retained
No. 10	100	0
No. 40	98	2
No. 100	50	48
No. 200	16	34
	Pan	16

LIQUID LIMIT NV*

PLASTICITY INDEX NP

U.S. CLASSIFICATION SM

MOISTURE-DENSITY RELATIONSHIP (ASTM D698)

Maximum Dry Density (pcf) 111.4

Optimum Moisture (%) 11.4

*Could not be determined in accordance with ASTM D4318.

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Gilbert Aldez-Inspector

Lab No. 4455: Client Sample ID - P1A @ 1.0'.

SIEVE ANALYSIS

Sieve Size	Percent Passing	% Retained
No. 4	100	0
No. 10	99	1
No. 40	98	2
No. 100	66	32
No. 200	35	31
		Pan 35

LIQUID LIMIT NV*

PLASTICITY INDEX NP

U.S. CLASSIFICATION SM

MOISTURE-DENSITY RELATIONSHIP (ASTM D698)

Maximum Dry Density (pcf) 116.4

Optimum Moisture (%) 13.3

*Could not be determined in accordance with ASTM D4318.

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Gilbert Aldez-Inspector

Lab No. 4456: Client Sample ID - P1A @ 2.0'.

SIEVE ANALYSIS

Sieve Size	Percent Passing	% Retained
1/2 inch	100	0
3/8 inch	99	1
No. 4	99	0
No. 10	97	2
No. 40	93	4
No. 100	56	37
No. 200	24	32
	Pan	24

LIQUID LIMIT NV*

PLASTICITY INDEX NP

U.S. CLASSIFICATION SM

MOISTURE-DENSITY RELATIONSHIP (ASTM D698)

Maximum Dry Density (pcf) 116.2

Optimum Moisture (%) 11.2

*Could not be determined in accordance with ASTM D4318.

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Lab No. 4457: Client Sample ID - P1A @ 2.6'.

SIEVE ANALYSIS

Sieve Size	Percent Passing	% Retained
3/8 inch	100	0
No. 4	99	1
No. 10	96	3
No. 40	90	6
No. 100	56	34
No. 200	25	31
Pan		25

LIQUID LIMIT NV*

PLASTICITY INDEX NP

U.S. CLASSIFICATION SM

MOISTURE-DENSITY RELATIONSHIP (ASTM D698)

Maximum Dry Density (pcf) 108.3

Optimum Moisture (%) 10.4

*Could not be determined in accordance with ASTM D4318.

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Lab No. 4458: Client Sample ID - P1A @ 3.6'.

SIEVE ANALYSIS

Sieve Size	Percent Passing	% Retained
3/8 inch	100	0
No. 4	98	2
No. 10	96	2
No. 40	90	6
No. 100	73	17
No. 200	41	32
		Pan 41

LIQUID LIMIT 24

PLASTICITY INDEX 5

U.S. CLASSIFICATION SC-SM

MOISTURE-DENSITY RELATIONSHIP (ASTM D698)

Maximum Dry Density (pcf) 108.4

Optimum Moisture (%) 15.1

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Lab No. 4459: Client Sample ID - P1A @ 4.2'.

SIEVE ANALYSIS

Sieve Size	Percent Passing	% Retained
3/8 inch	100	0
No. 4	99	1
No. 10	97	2
No. 40	92	5
No. 100	73	19
No. 200	32	41
		Pan 32

LIQUID LIMIT 22

PLASTICITY INDEX 4

U.S. CLASSIFICATION SC-SM

MOISTURE-DENSITY RELATIONSHIP (ASTM D698)

Maximum Dry Density (pcf) 116.0

Optimum Moisture (%) 11.2

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Lab No. 4460: Client Sample ID - P1B @ 0.4'.

SIEVE ANALYSIS

Sieve Size	Percent Passing	% Retained
3/8 inch	100	0
No. 4	99	1
No. 10	98	1
No. 40	95	3
No. 100	72	23
No. 200	29	43
		Pan 29

LIQUID LIMIT NV*

PLASTICITY INDEX NP

U.S. CLASSIFICATION SM

MOISTURE-DENSITY RELATIONSHIP (ASTM D698)

Maximum Dry Density (pcf) 115.2

Optimum Moisture (%) 12.1

*Could not be determined in accordance with ASTM D4318.

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Lab No. 4461: Client Sample ID - P1B @ 1.0'.

SIEVE ANALYSIS

Sieve Size	Percent Passing	% Retained
1/2 inch	100	0
3/8 inch	99	1
No. 4	99	0
No. 10	98	1
No. 40	94	4
No. 100	67	27
No. 200	34	33
		Pan 34

LIQUID LIMIT 25

PLASTICITY INDEX 9

U.S. CLASSIFICATION SC

MOISTURE-DENSITY RELATIONSHIP (ASTM D698)

Maximum Dry Density (pcf) 120.7

Optimum Moisture (%) 11.4

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Lab No. 4462: Client Sample ID - P1B @ 1.5'.

SIEVE ANALYSIS

Sieve Size	Percent Passing	% Retained
3/8 inch	100	0
No. 4	98	2
No. 10	96	2
No. 40	91	5
No. 100	66	25
No. 200	32	34
		Pan 32

LIQUID LIMIT 24

PLASTICITY INDEX 6

U.S. CLASSIFICATION SC-SM

MOISTURE-DENSITY RELATIONSHIP (ASTM D698)

Maximum Dry Density (pcf) 119.4

Optimum Moisture (%) 11.7

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Lab No. 4463: Client Sample ID - P1B @ 3.0'.

SIEVE ANALYSIS

Sieve Size	Percent Passing	% Retained
1/2 inch	100	0
3/8 inch	99	1
No. 4	98	1
No. 10	94	4
No. 40	88	6
No. 100	61	27
No. 200	28	33
		Pan 28

LIQUID LIMIT NV*

PLASTICITY INDEX NP

U.S. CLASSIFICATION SM

MOISTURE-DENSITY RELATIONSHIP (ASTM D698)

Maximum Dry Density (pcf) 115.0

Optimum Moisture (%) 10.0

*Could not be determined in accordance with ASTM D4318.

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Lab No. 4464: Client Sample ID - P1C @ 0.5'.

SIEVE ANALYSIS

Sieve Size	Percent Passing	% Retained
No. 4	100	0
No. 10	99	1
No. 40	96	3
No. 100	73	23
No. 200	39	34
Pan		39

LIQUID LIMIT 28

PLASTICITY INDEX 10

U.S. CLASSIFICATION CL

MOISTURE-DENSITY RELATIONSHIP (ASTM D698)

Maximum Dry Density (pcf) 115.2

Optimum Moisture (%) 13.6

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Lab No. 4465: Client Sample ID - P1C @ 1.0'.

SIEVE ANALYSIS

Sieve Size	Percent Passing	% Retained
3/8 inch	100	0
No. 4	99	1
No. 10	98	1
No. 40	94	4
No. 100	66	28
No. 200	34	32
		Pan 34

LIQUID LIMIT 24

PLASTICITY INDEX 5

U.S. CLASSIFICATION SC-SM

MOISTURE-DENSITY RELATIONSHIP (ASTM D698)

Maximum Dry Density (pcf) 116.1

Optimum Moisture (%) 13.1

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Lab No. 4466: Client Sample ID - P1C @ 1.6'.

SIEVE ANALYSIS

Sieve Size	Percent Passing	% Retained
3/8 inch	100	0
No. 4	98	2
No. 10	94	4
No. 40	88	6
No. 100	51	37
No. 200	22	29
		Pan 22

LIQUID LIMIT NV*

PLASTICITY INDEX NP

U.S. CLASSIFICATION SM

MOISTURE-DENSITY RELATIONSHIP (ASTM D698)

Maximum Dry Density (pcf) 117.4

Optimum Moisture (%) 11.9

*Could not be determined in accordance with ASTM D4318.

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Lab No. 4467: Client Sample ID - P1C @ 3.5'

SIEVE ANALYSIS

Sieve Size	Percent Passing	% Retained
No. 4	100	0
No. 10	99	1
No. 40	94	4
No. 100	64	30
No. 200	29	35
		Pan 29

LIQUID LIMIT NV*

PLASTICITY INDEX NP

U.S. CLASSIFICATION SM

MOISTURE-DENSITY RELATIONSHIP (ASTM D698)

Maximum Dry Density (pcf) 118.4

Optimum Moisture (%) 10.7

*Could not be determined in accordance with ASTM D4318.

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Lab No. 4468: Client Sample ID - P1C @ 4.8'.

SIEVE ANALYSIS

Sieve Size	Percent Passing	% Retained
3/8 inch	100	0
No. 4	99	1
No. 10	98	1
No. 40	94	4
No. 100	64	30
No. 200	28	36
	Pan	28

LIQUID LIMIT NV*

PLASTICITY INDEX NP

U.S. CLASSIFICATION SM

MOISTURE-DENSITY RELATIONSHIP (ASTM D698)

Maximum Dry Density (pcf) 113.2

Optimum Moisture (%) 13.2

*Could not be determined in accordance with ASTM D4318.

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Lab No. 4469: Client Sample ID - P1D @ 0.4'.

SIEVE ANALYSIS

Sieve Size	Percent Passing	% Retained
No. 4	100	0
No. 10	89	11
No. 40	82	7
No. 100	61	21
No. 200	21	40
	Pan	21

LIQUID LIMIT NV*

PLASTICITY INDEX NP

U.S. CLASSIFICATION SM

MOISTURE-DENSITY RELATIONSHIP (ASTM D698)

Maximum Dry Density (pcf) 114.6

Optimum Moisture (%) 11.3

*Could not be determined in accordance with ASTM D4318.

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Lab No. 4470: Client Sample ID - P1D @ 0.9'.

SIEVE ANALYSIS

Sieve Size	Percent Passing	% Retained
No. 4	100	0
No. 10	98	2
No. 40	94	4
No. 100	67	27
No. 200	29	38
	Pan	29

LIQUID LIMIT NV*

PLASTICITY INDEX NP

U.S. CLASSIFICATION SM

MOISTURE-DENSITY RELATIONSHIP (ASTM D698)

Maximum Dry Density (pcf) 120.2

Optimum Moisture (%) 12.5

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Lab No. 4471: Client Sample ID - P1D @ 1.2'.

SIEVE ANALYSIS

Sieve Size	Percent Passing	% Retained
1/2 inch	100	0
3/8 inch	99	1
No. 4	98	1
No. 10	96	2
No. 40	92	4
No. 100	66	26
No. 200	31	35
		Pan 31

LIQUID LIMIT NV*

PLASTICITY INDEX NP

U.S. CLASSIFICATION SM

MOISTURE-DENSITY RELATIONSHIP (ASTM D698)

Maximum Dry Density (pcf) 114.0

Optimum Moisture (%) 12.8

*Could not be determined in accordance with ASTM D4318.

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Lab No. 4472: Client Sample ID - P1D @ 3.0'.

SIEVE ANALYSIS

Sieve Size	Percent Passing	% Retained
3/8 inch	100	0
No. 4	99	1
No. 10	97	2
No. 40	91	6
No. 100	68	23
No. 200	38	30
		Pan 38

LIQUID LIMIT NV*

PLASTICITY INDEX NP

U.S. CLASSIFICATION SM

MOISTURE-DENSITY RELATIONSHIP (ASTM D698)

Maximum Dry Density (pcf) 105.8

Optimum Moisture (%) 12.7

*Could not be determined in accordance with ASTM D4318.

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Lab No. 4473: Client Sample ID - P1D @ 4.3'.

SIEVE ANALYSIS

Sieve Size	Percent Passing	% Retained
1/2 inch	100	0
3/8 inch	99	1
No. 4	99	0
No. 10	98	1
No. 40	95	3
No. 100	69	26
No. 200	30	39
		Pan 30

LIQUID LIMIT NV*

PLASTICITY INDEX NP

U.S. CLASSIFICATION SM

MOISTURE-DENSITY RELATIONSHIP (ASTM D698)

Maximum Dry Density (pcf) 114.4

Optimum Moisture (%) 14.2

*Could not be determined in accordance with ASTM D4318.

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Lab No. 4474: Client Sample ID - P1D @ 5.0'.

SIEVE ANALYSIS

Sieve Size	Percent Passing	% Retained
3/8 inch	100	0
No. 4	99	1
No. 10	98	1
No. 40	96	2
No. 100	70	26
No. 200	30	40
	Pan	30

LIQUID LIMIT NV*

PLASTICITY INDEX NP

U.S. CLASSIFICATION SM

MOISTURE-DENSITY RELATIONSHIP (ASTM D698)

Maximum Dry Density (pcf) 110.7

Optimum Moisture (%) 11.1

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8519 Jefferson NE
Albuquerque, NM 87113
Tel (505) 821-1801
Fax (505) 821-7371

June 9, 1999

Sandia National Laboratories
ORG7914/MS0908
PO Box 5800
Albuquerque, NM 87185

AGRA Job No. 9-519-001154

Attn: Evelyn Tuttle

Project: Mixed Waste Landfill Cover
SO#FQ2059
Gilbert Aldez-Inspector

Lab No. 4571: Client Sample P2-A @ 0.6'

SIEVE ANALYSIS

Sieve Size	Percent Passing	% Retained
No. 4	100	0
No. 10	99	1
No. 40	96	3
No. 70	88	8
No. 80	82	6
No. 100	73	9
No. 170	43	30
No. 200	43	0
	Pan	43

LIQUID LIMIT NV*

PLASTICITY INDEX NP

U.S. CLASSIFICATION SM

MOISTURE-DENSITY RELATIONSHIP (ASTM D698)

Maximum Dry Density (pcf) 112.0

Optimum Moisture (%) 15.1

*Could not be determined in accordance with ASTM D4318.

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Attn: Evelyn Tuttle

Project: Mixed Waste Landfill Cover
SO#FQ2059
Gilbert Aldez-Inspector

Lab No. 4572: Client Sample P2-A @ 1.5'

SIEVE ANALYSIS

Sieve Size	Percent Passing	% Retained
3/8 inch	100	0
No. 4	99	1
No. 10	96	3
No. 40	92	4
No. 70	81	11
No. 80	73	8
No. 100	63	10
No. 170	36	27
No. 200	28	8
	Pan	28

LIQUID LIMIT NV*

PLASTICITY INDEX NP

U.S. CLASSIFICATION SM

MOISTURE-DENSITY RELATIONSHIP (ASTM D698)

Maximum Dry Density (pcf) 121.1

Optimum Moisture (%) 11.9

*Could not be determined in accordance with ASTM D4318.

[signature]
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SO#FQ2059
Gilbert Aldez-Inspector

Lab No. 4573: Client Sample P2-A @ 1.7'

SIEVE ANALYSIS

Sieve Size	Percent Passing	% Retained
3/8 inch	100	0
No. 4	100	0
No. 10	98	2
No. 40	94	4
No. 70	82	12
No. 80	72	10
No. 100	61	11
No. 170	33	28
No. 200	25	8
	Pan	25

LIQUID LIMIT NV*

PLASTICITY INDEX NP

U.S. CLASSIFICATION SM

MOISTURE-DENSITY RELATIONSHIP (ASTM D698)

Maximum Dry Density (pcf) 119.2

Optimum Moisture (%) 11.0

*Could not be determined in accordance with ASTM D4318.

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Project: Mixed Waste Landfill Cover
SO#FQ2059
Gilbert Aldez-Inspector

Lab No. 4574: Client Sample P2-D @ 0.6'

SIEVE ANALYSIS

Sieve Size	Percent Passing	% Retained
No. 4	100	0
No. 10	100	0
No. 40	97	3
No. 70	88	9
No. 80	80	8
No. 100	70	10
No. 170	45	25
No. 200	37	8
	Pan	37

LIQUID LIMIT 23

PLASTICITY INDEX 7

U.S. CLASSIFICATION SM-SC

MOISTURE-DENSITY RELATIONSHIP (ASTM D698)

Maximum Dry Density (pcf) 117.8

Optimum Moisture (%) 11.6

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SO#FQ2059
Gilbert Aldez-Inspector

Lab No. 4575: Client Sample P2-E @ 1.0'

SIEVE ANALYSIS

Sieve Size	Percent Passing	% Retained
No. 4	100	0
No. 10	99	1
No. 40	97	2
No. 70	92	5
No. 80	88	4
No. 100	83	5
No. 170	67	16
No. 200	62	5
	Pan	62

LIQUID LIMIT NV*

PLASTICITY INDEX NP

U.S. CLASSIFICATION ML

MOISTURE-DENSITY RELATIONSHIP (ASTM D698)

Maximum Dry Density (pcf) 117.4

Optimum Moisture (%) 10.8

*Could not be determined in accordance with ASTM D4318.

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Project: Mixed Waste Landfill Cover
SO#FQ2059
Gilbert Aldez-Inspector

Lab No. 4557: Composite MWL 1-A @ 0-2.0'

SIEVE ANALYSIS

Sieve Size		Percent Passing	% Retained
1/2	inch	100	0
3/8	inch	99	1
No.	4	98	1
No.	10	95	3
No.	40	89	6
No.	70	87	2
No.	80	85	2
No.	100	82	3
No.	170	64	18
No.	200	58	6
		Pan	58

LIQUID LIMIT NV*

PLASTICITY INDEX NP

U.S. CLASSIFICATION ML

MOISTURE-DENSITY RELATIONSHIP (ASTM D698)

Maximum Dry Density (pcf) 106.1

Optimum Moisture (%) 9.7

*Could not be determined in accordance with ASTM D4318.

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Project: Mixed Waste Landfill Cover
SO#FQ2059
Gilbert Aldez-Inspector

Lab No. 4560: Composite MWL 1-B @ 2.0'+

SIEVE ANALYSIS

Sieve Size	Percent Passing	% Retained
3/8 inch	100	0
No. 4	99	1
No. 10	95	4
No. 40	87	8
No. 70	79	8
No. 80	73	6
No. 100	56	17
No. 170	35	21
No. 200	25	10
	Pan	25

LIQUID LIMIT NV*

PLASTICITY INDEX NP

U.S. CLASSIFICATION SM

MOISTURE-DENSITY RELATIONSHIP (ASTM D698)

Maximum Dry Density (pcf) 103.7

Optimum Moisture (%) 10.2

*Could not be determined in accordance with ASTM D4318.

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Project: Mixed Waste Landfill Cover
SO#FQ2059
Gilbert Aldez-Inspector

Lab No. 4565: Native Soil 1 of 3

SIEVE ANALYSIS

Sieve Size	Percent Passing	% Retained
1/2 inch	100	0
3/8 inch	97	3
No. 4	94	3
No. 10	90	4
No. 40	83	7
No. 70	78	5
No. 80	74	4
No. 100	68	6
No. 170	35	33
No. 200	24	11
	Pan	24

LIQUID LIMIT NV*

PLASTICITY INDEX NP

U.S. CLASSIFICATION SM

MOISTURE-DENSITY RELATIONSHIP (ASTM D698)

Maximum Dry Density (pcf) 117.8

Optimum Moisture (%) 11.7

*Could not be determined in accordance with ASTM D4318.

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Project: Mixed Waste Landfill Cover
SO#FQ2059
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Lab No. 4566: Native Soil 2 of 3

SIEVE ANALYSIS

Sieve Size	Percent Passing	% Retained
1/2 inch	100	0
3/8 inch	98	2
No. 4	96	2
No. 10	91	5
No. 40	84	7
No. 70	78	6
No. 80	75	3
No. 100	70	5
No. 170	42	28
No. 200	31	11
	Pan	31

LIQUID LIMIT 22

PLASTICITY INDEX 6

U.S. CLASSIFICATION SM-SC

MOISTURE-DENSITY RELATIONSHIP (ASTM D698)

Maximum Dry Density (pcf) 120.4

Optimum Moisture (%) 11.6

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Project: Mixed Waste Landfill Cover
SO#FQ2059
Gilbert Aldez-Inspector

Lab No. 4567: Native Soil 3 of 3

SIEVE ANALYSIS

Sieve Size	Percent Passing	% Retained
1/2 inch	100	0
3/8 inch	97	3
No. 4	92	5
No. 10	87	5
No. 40	77	10
No. 70	70	7
No. 80	66	4
No. 100	60	6
No. 170	38	22
No. 200	28	10
	Pan	28

LIQUID LIMIT NV*

PLASTICITY INDEX NP

U.S. CLASSIFICATION SM

MOISTURE-DENSITY RELATIONSHIP (ASTM D698)

Maximum Dry Density (pcf) 122.1

Optimum Moisture (%) 10.3

*Could not be determined in accordance with ASTM D4318.

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Project: Mixed Waste Landfill Cover
SO#FQ2059
Gilbert Aldez-Inspector

Lab No. 4568: Subgrade Soil 1 of 3

SIEVE ANALYSIS

Sieve Size	Percent Passing	% Retained
1/2 inch	100	0
3/8 inch	99	1
No. 4	96	3
No. 10	91	5
No. 40	82	9
No. 70	78	4
No. 80	75	3
No. 100	69	6
No. 170	40	29
No. 200	29	11
	Pan	29

LIQUID LIMIT NV*

PLASTICITY INDEX NP

U.S. CLASSIFICATION SM

MOISTURE-DENSITY RELATIONSHIP (ASTM D698)

Maximum Dry Density (pcf) 121.2

Optimum Moisture (%) 9.8

*Could not be determined in accordance with ASTM D4318.

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Project: Mixed Waste Landfill Cover
SO#FQ2059
Gilbert Aldez-Inspector

Lab No. 4569: Subgrade Soil 2 of 3

SIEVE ANALYSIS

Sieve Size	Percent Passing	% Retained
1/2 inch	100	0
3/8 inch	99	1
No. 4	96	3
No. 10	91	5
No. 40	81	10
No. 70	76	5
No. 80	73	3
No. 100	67	6
No. 170	36	31
No. 200	25	11
	Pan	25

LIQUID LIMIT NV*

PLASTICITY INDEX NP

U.S. CLASSIFICATION SM

MOISTURE-DENSITY RELATIONSHIP (ASTM D698)

Maximum Dry Density (pcf) 118.2

Optimum Moisture (%) 10.2

*Could not be determined in accordance with ASTM D4318.

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Attn: Evelyn Tuttle

Project: Mixed Waste Landfill Cover
SO#FQ2059
Gilbert Aldez-Inspector

Lab No. 4570: Subgrade Soil 3 of 3

SIEVE ANALYSIS

Sieve Size	Percent Passing	% Retained
3/8 inch	100	0
No. 4	95	5
No. 10	91	4
No. 40	83	8
No. 70	78	5
No. 80	75	3
No. 100	69	6
No. 170	38	31
No. 200	27	11
	Pan	27

LIQUID LIMIT NV*

PLASTICITY INDEX NP

U.S. CLASSIFICATION SM

MOISTURE-DENSITY RELATIONSHIP (ASTM D698)

Maximum Dry Density (pcf) 119.8

Optimum Moisture (%) 11.5

*Could not be determined in accordance with ASTM D4318.

[signature]
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Attachment E

Grain-Size Distribution Plots

E-1 **Weight % Passing Plots**
E-2 **Weight % Retained Plots**

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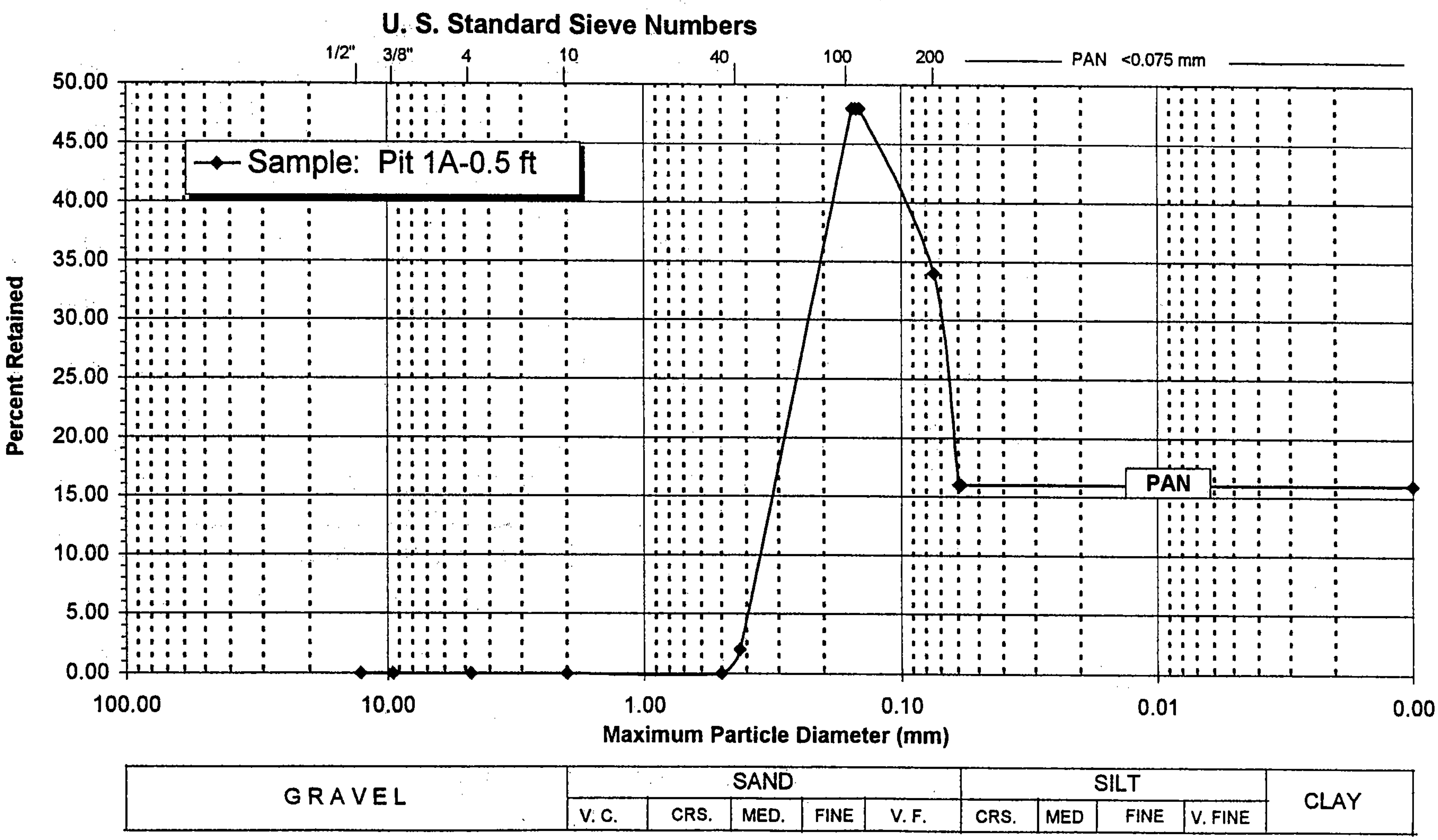
GRAIN SIZE DISTRIBUTION

(Analysis by AGRA Earth & Environmental, Inc.)



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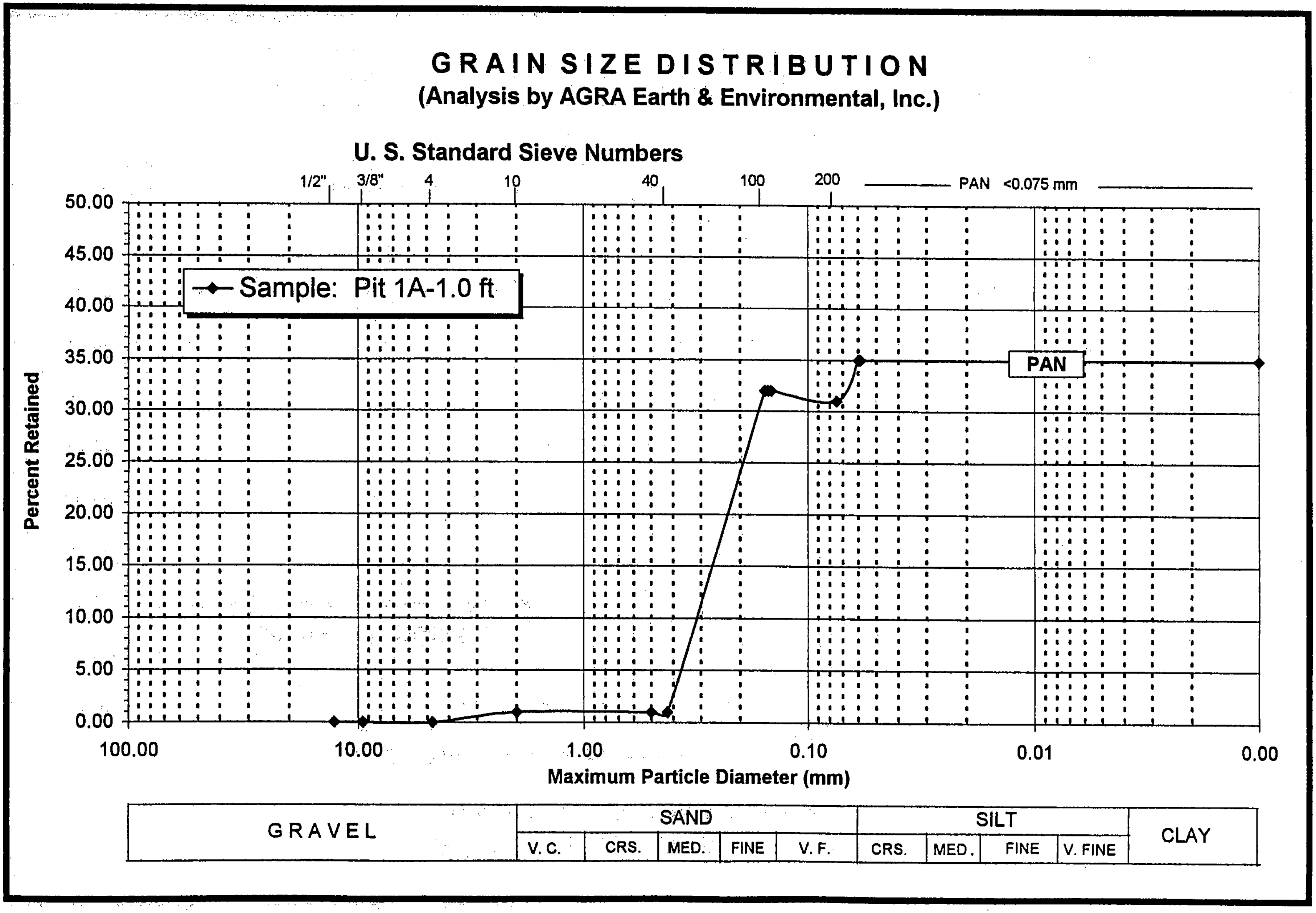

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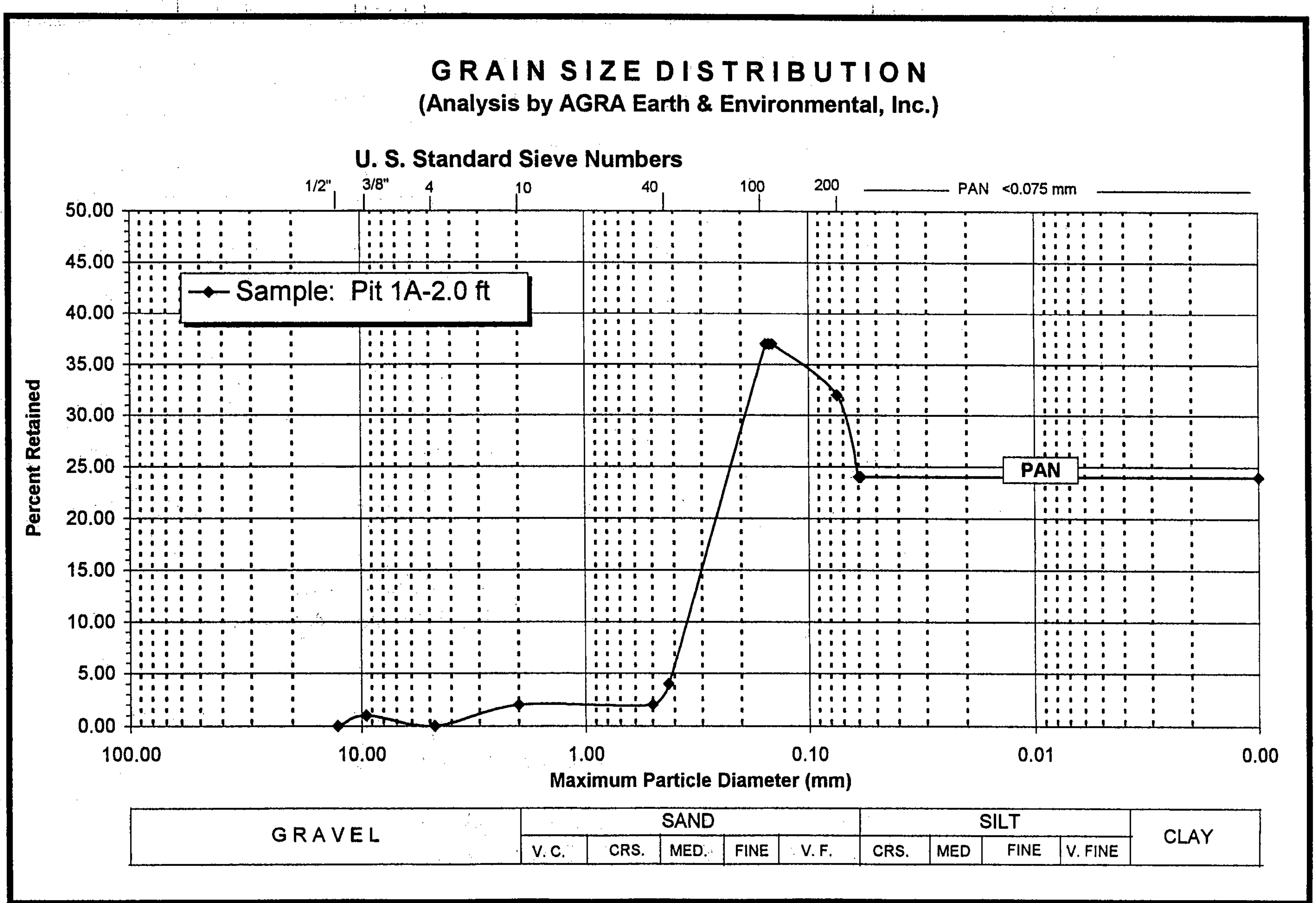

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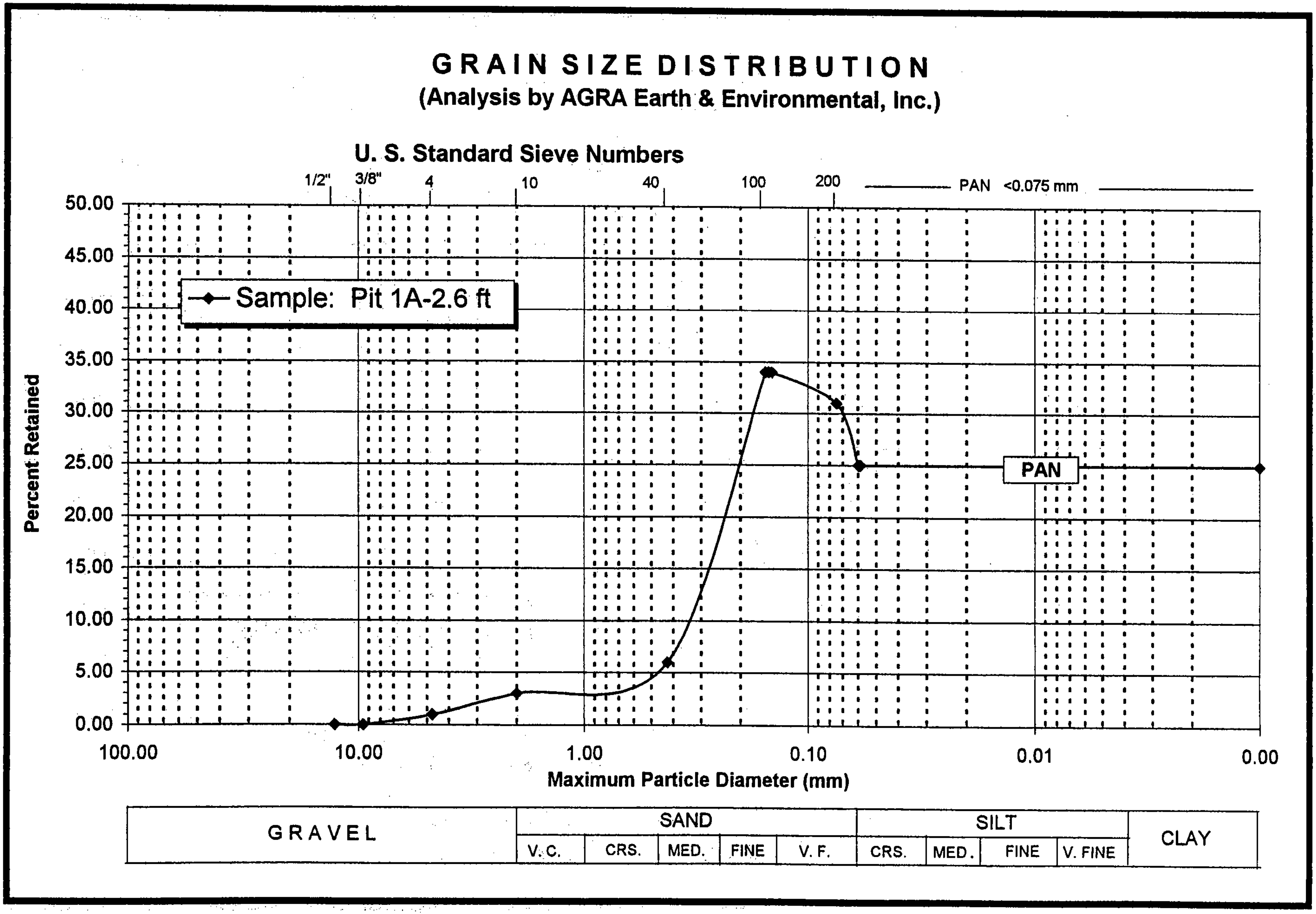
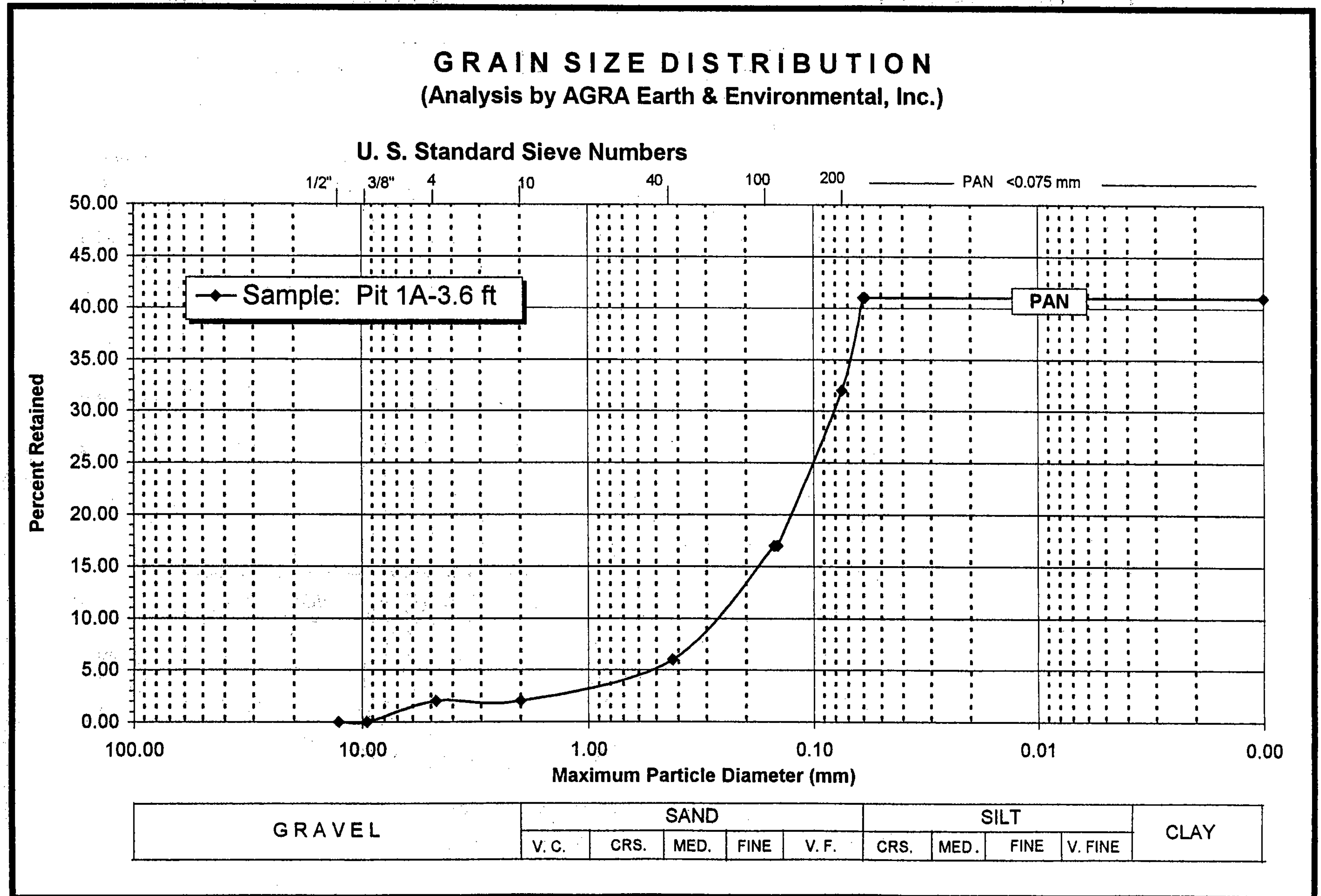

GRAIN SIZE DISTRIBUTION
(Analysis by AGRA Earth & Environmental, Inc.)
U. S. Standard Sieve Numbers
1/2"
3/8"
4
10
40
100
200
PAN <0.075 mm
Sample: Pit 1A-2.6 ft
PAN
Percent Retained
50.00
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
100.00
10.00
1.00
0.10
0.01
0.00
Maximum Particle Diameter (mm)
GRAVEL
SAND
V. C.
CRS.
MED.
FINE
V. F.
SILT
CRS.
MED.
FINE
V. FINE
CLAY



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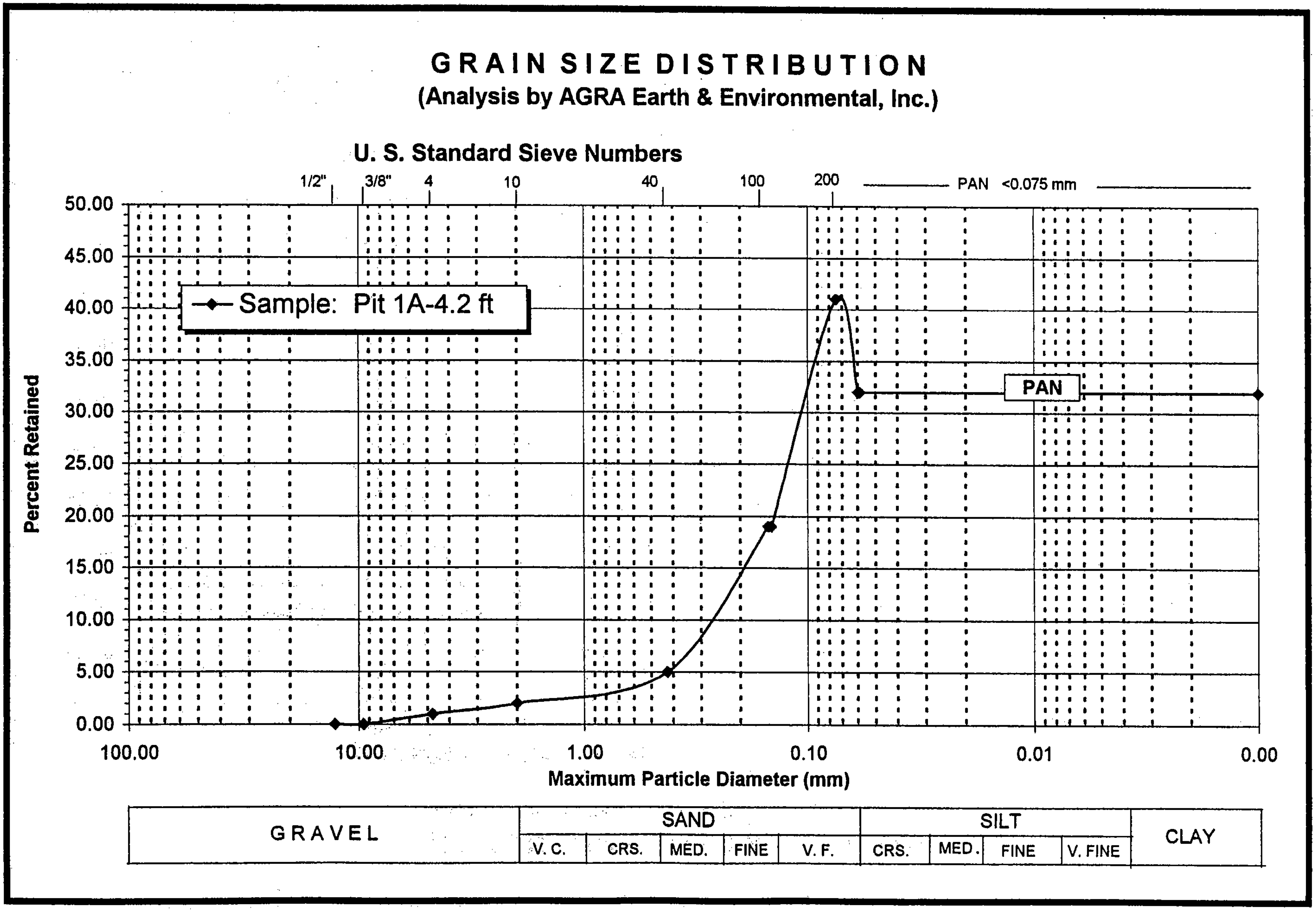
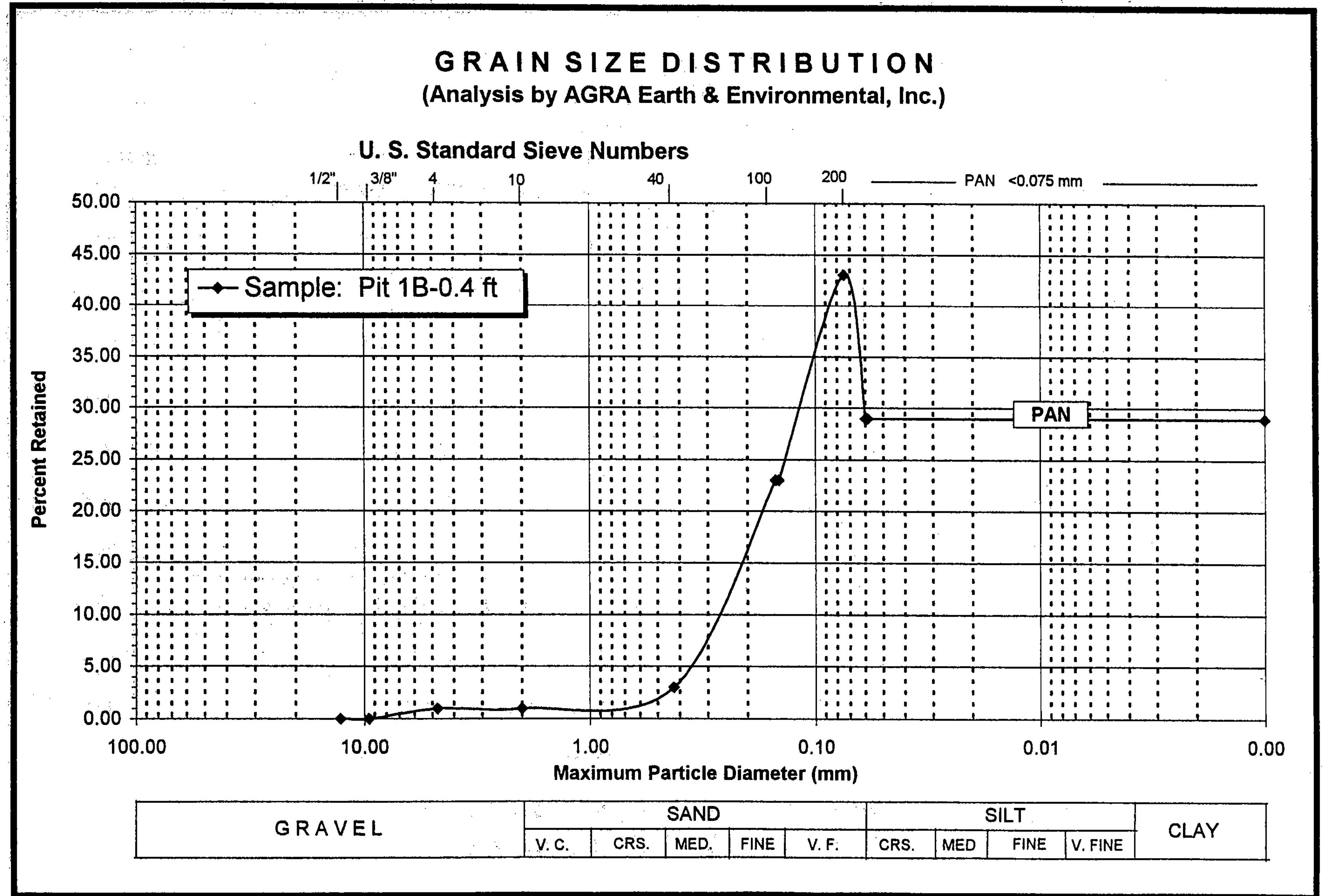

GRAIN SIZE DISTRIBUTION
(Analysis by AGRA Earth & Environmental, Inc.)
U. S. Standard Sieve Numbers
1/2"
3/8"
4
10
40
100
200
PAN <0.075 mm
Sample: Pit 1A-4.2 ft
PAN
Percent Retained
50.00
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
100.00
10.00
1.00
0.10
0.01
0.00
Maximum Particle Diameter (mm)
GRAVEL
SAND
V. C.
CRS.
MED.
FINE
V. F.
SILT
CRS.
MED.
FINE
V. FINE
CLAY



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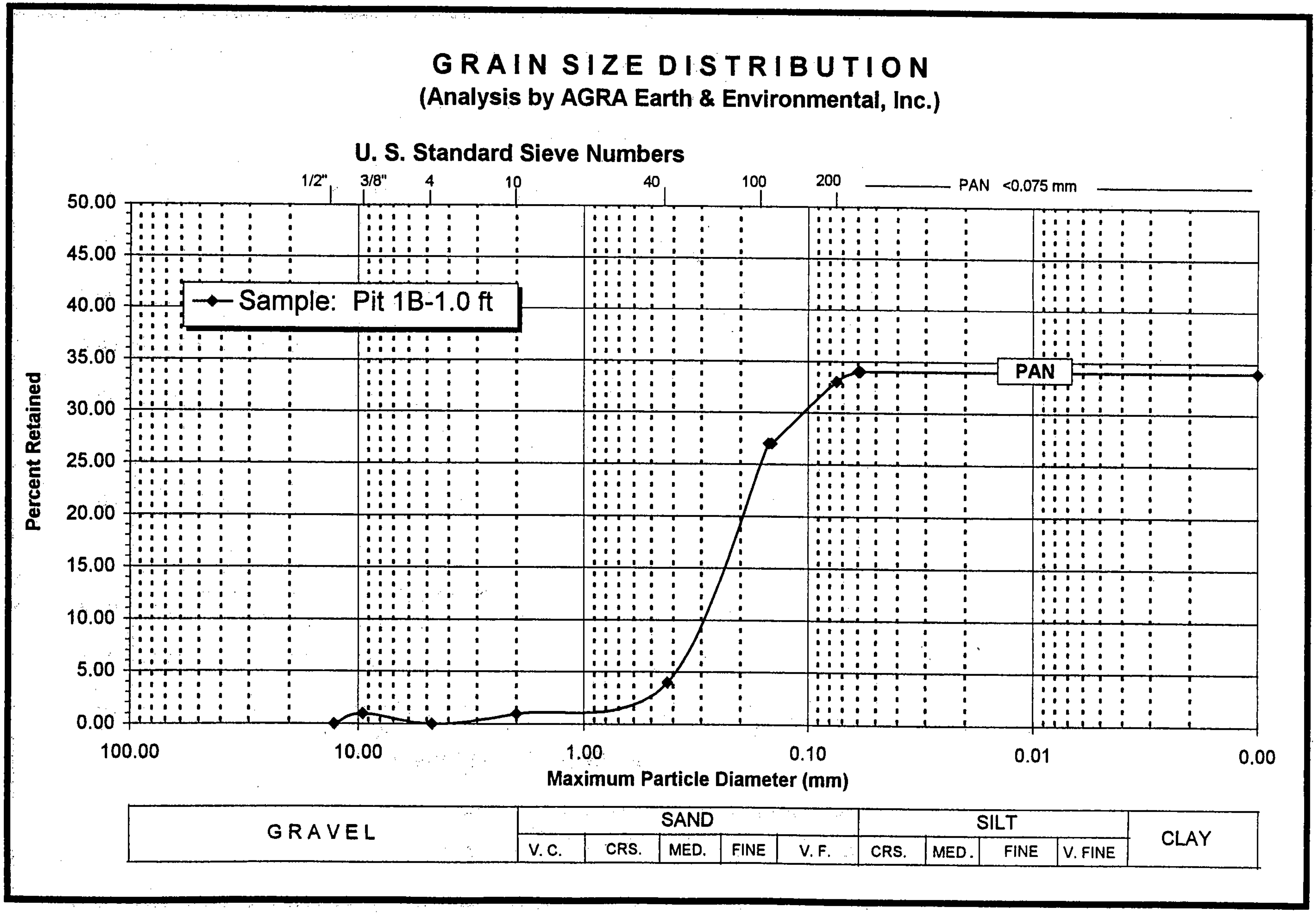

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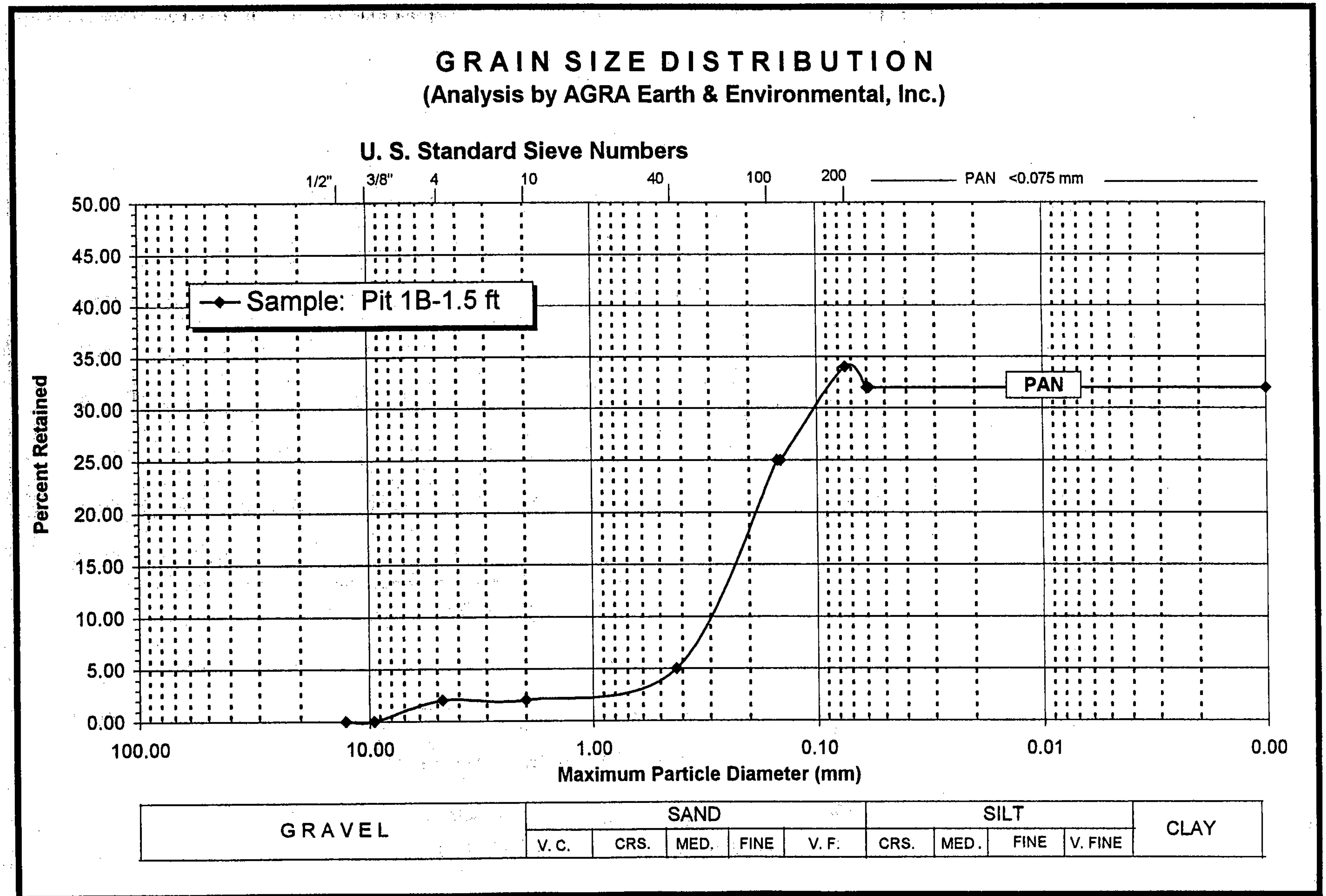

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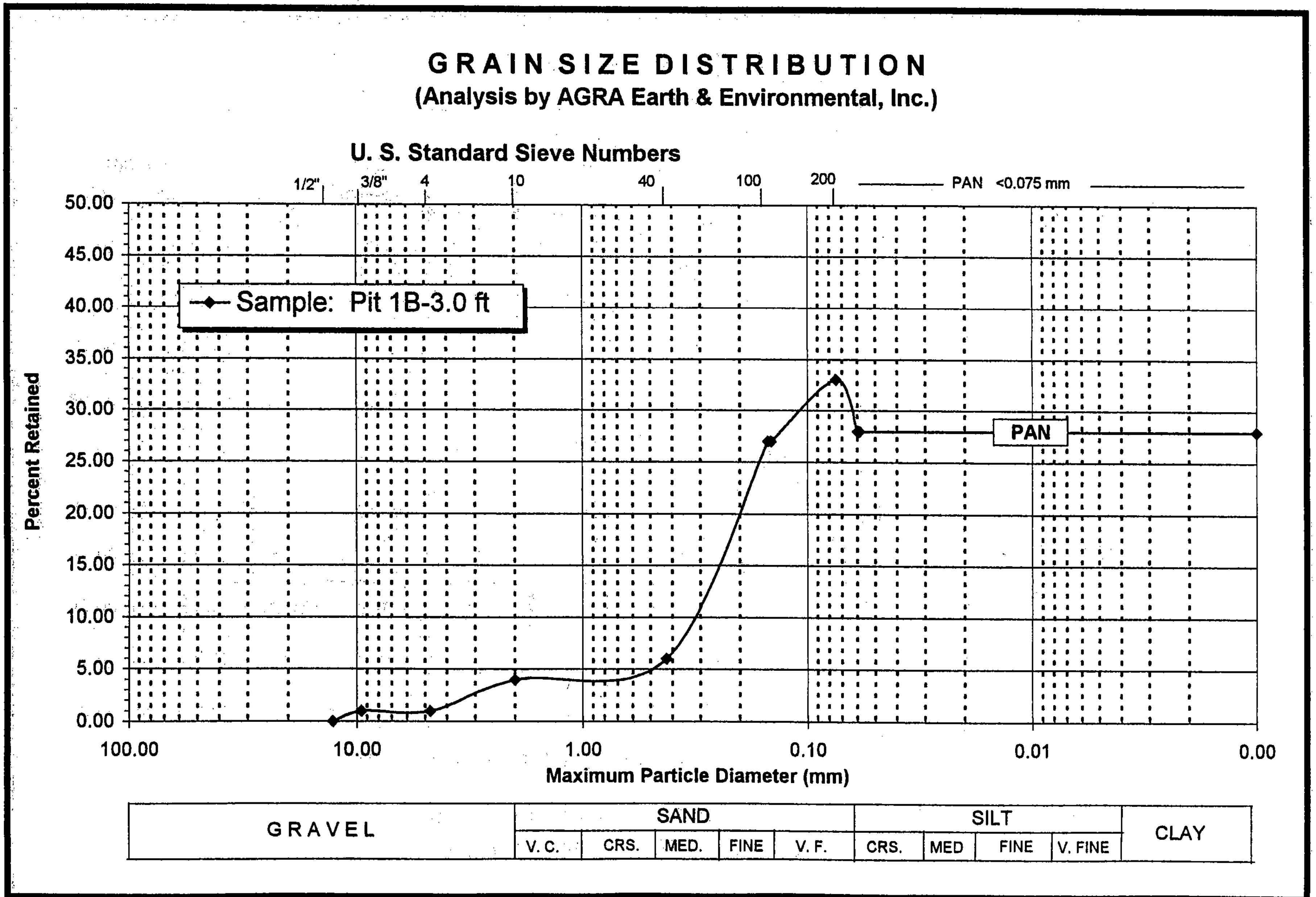

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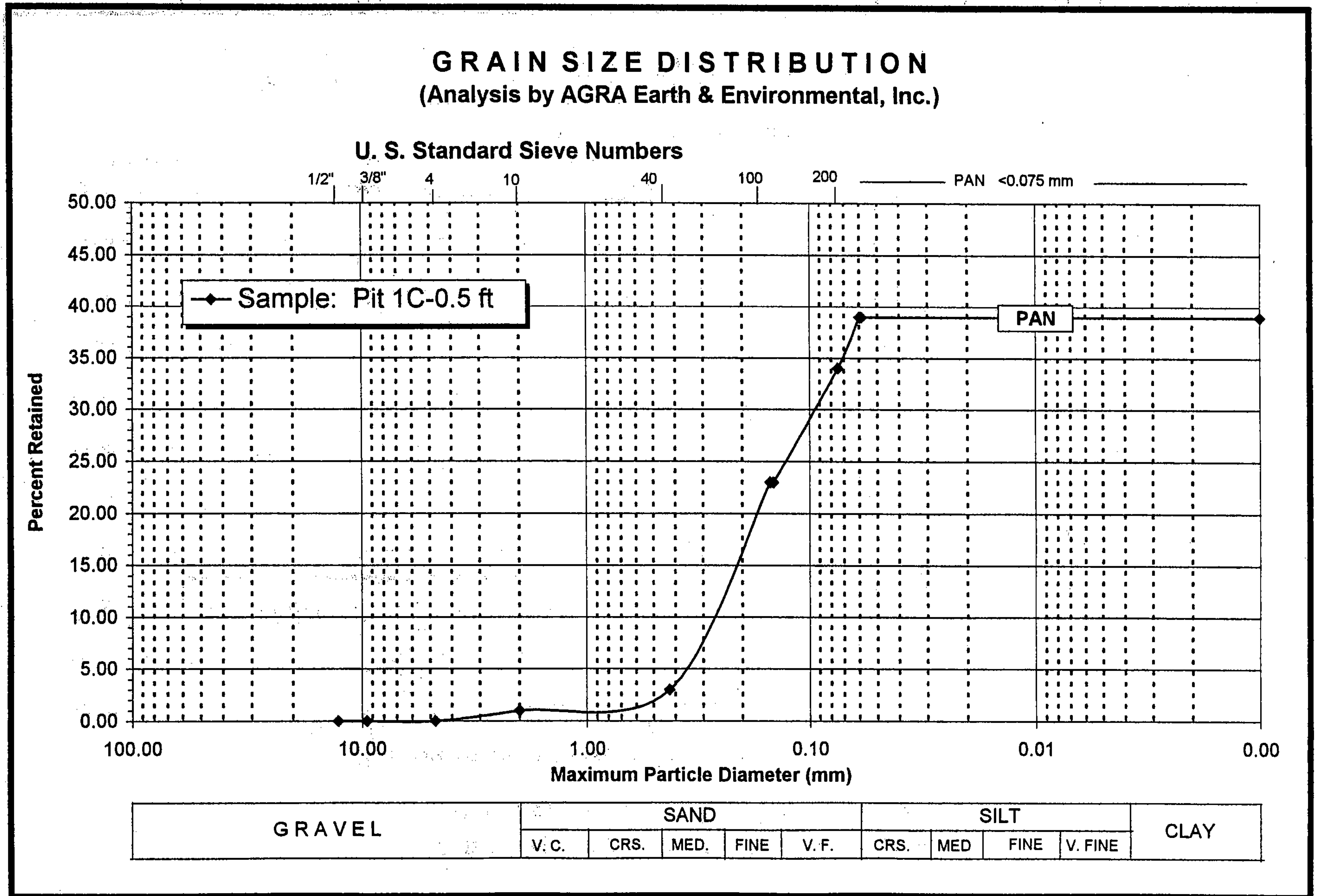

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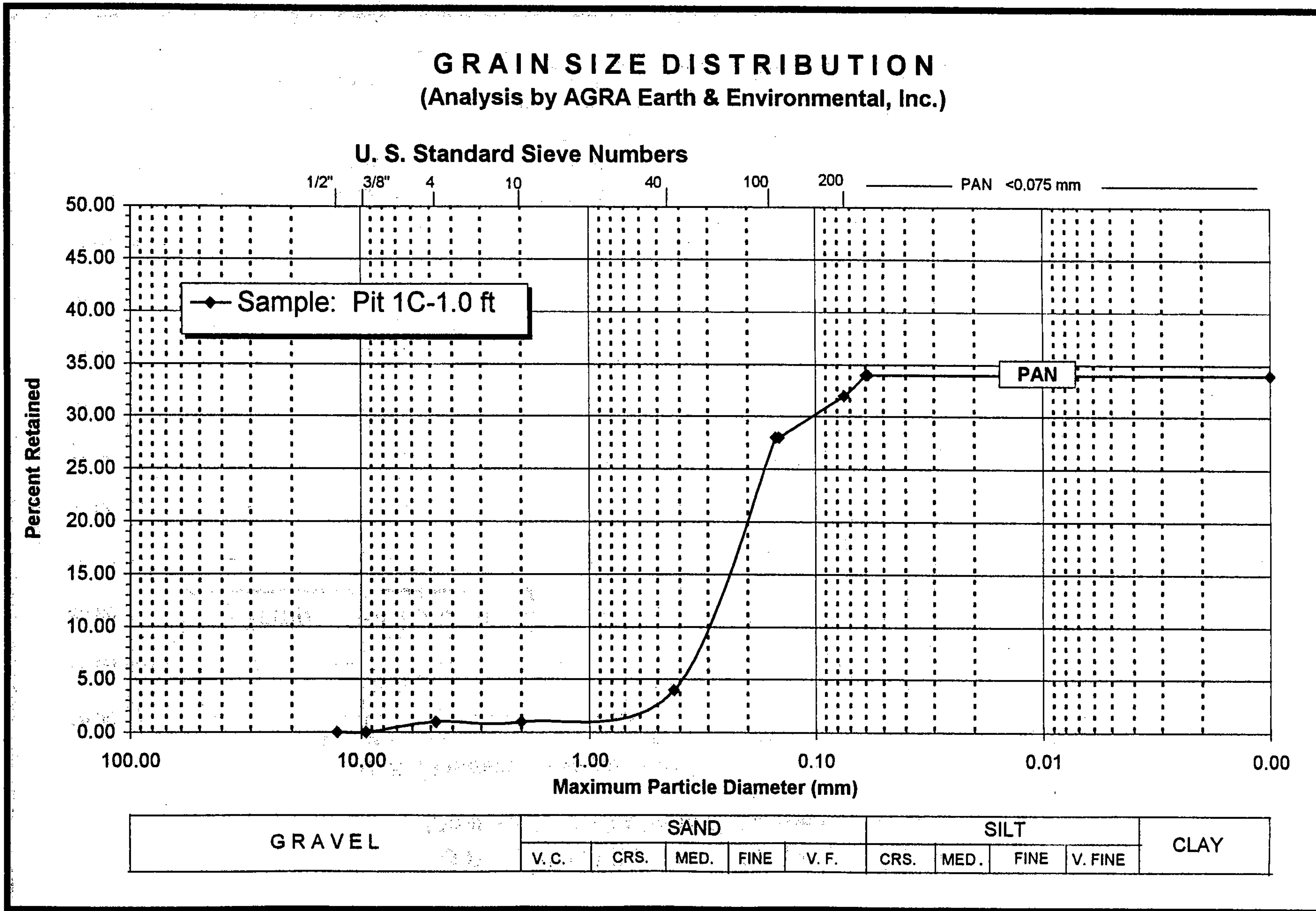

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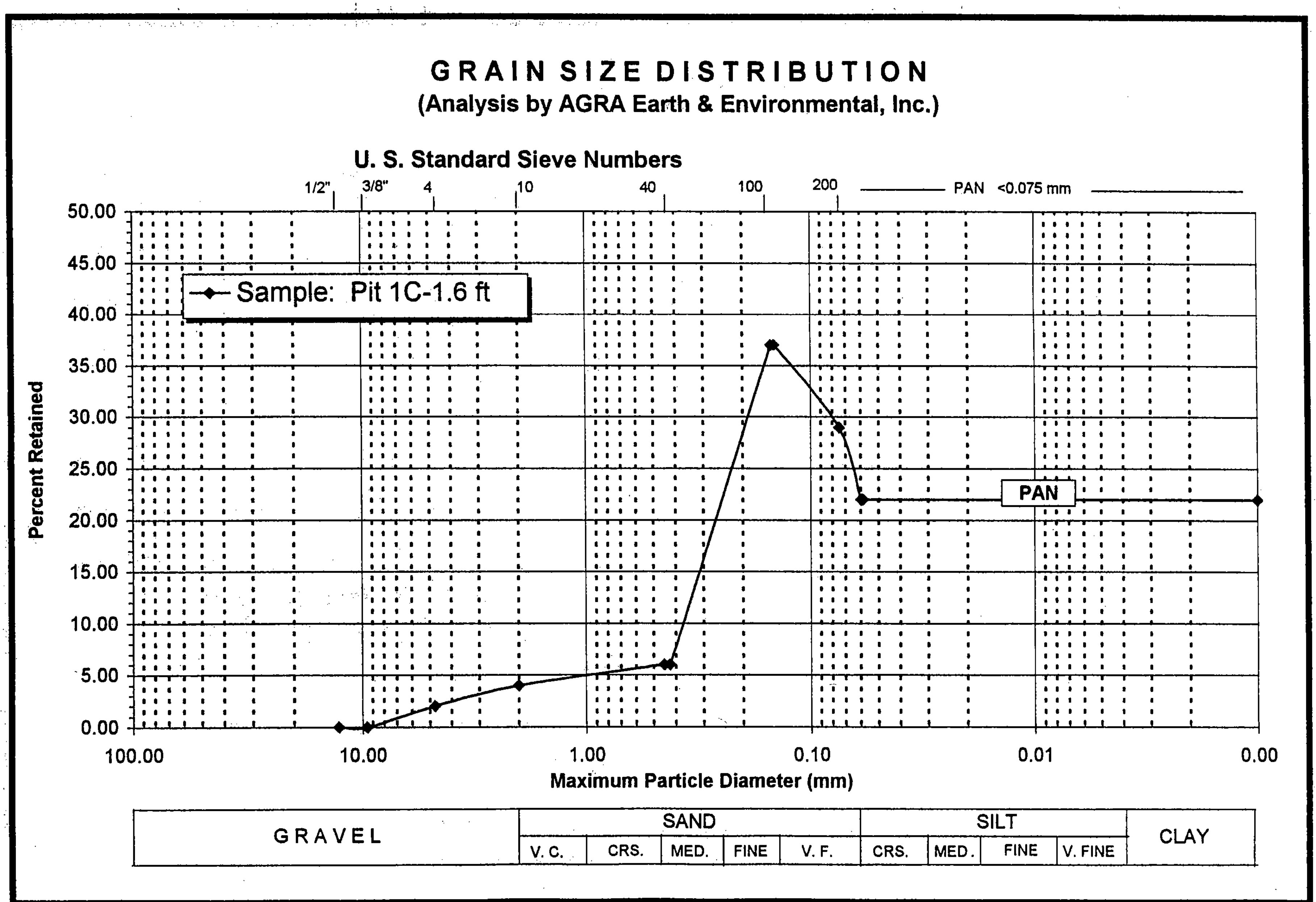

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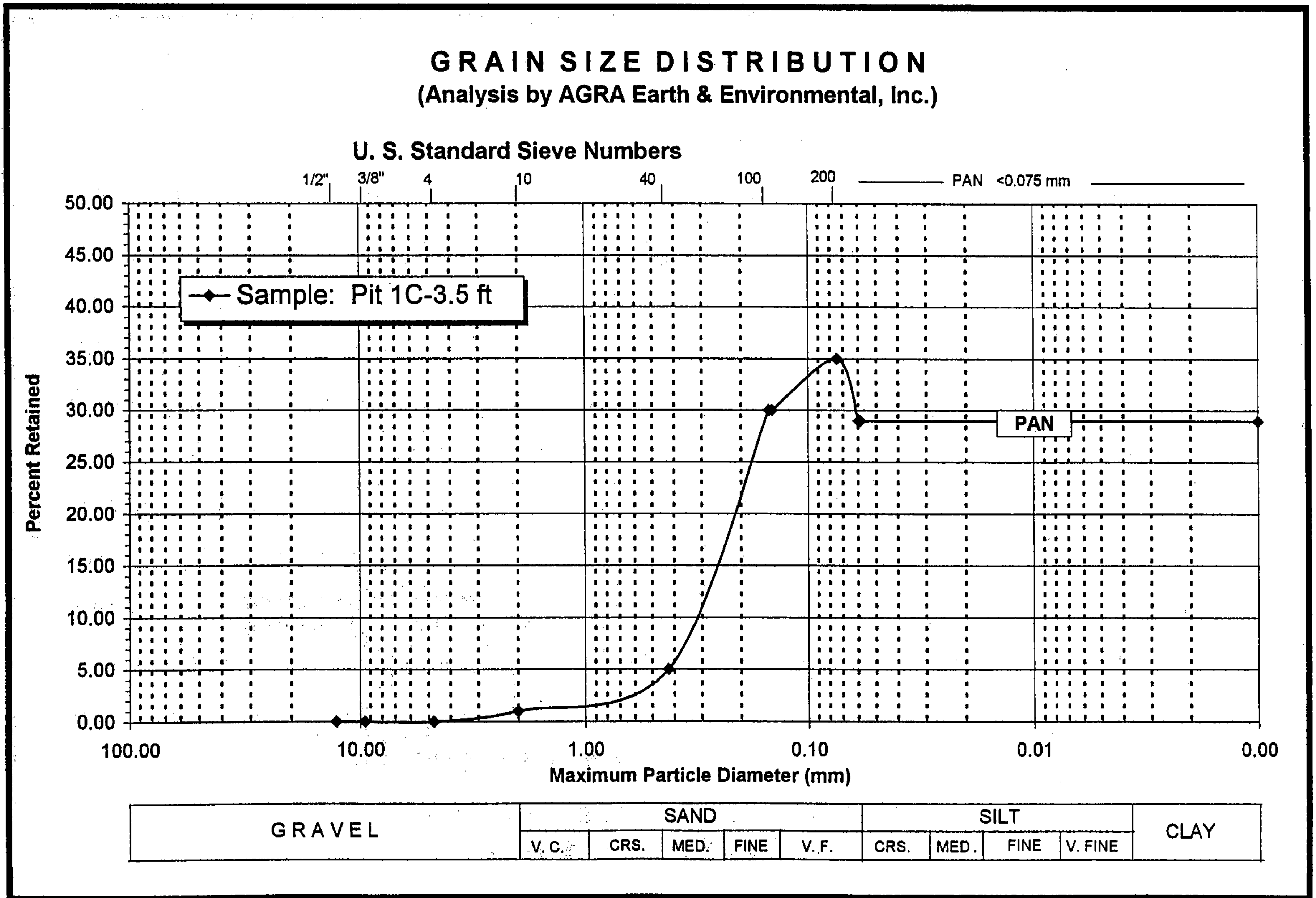

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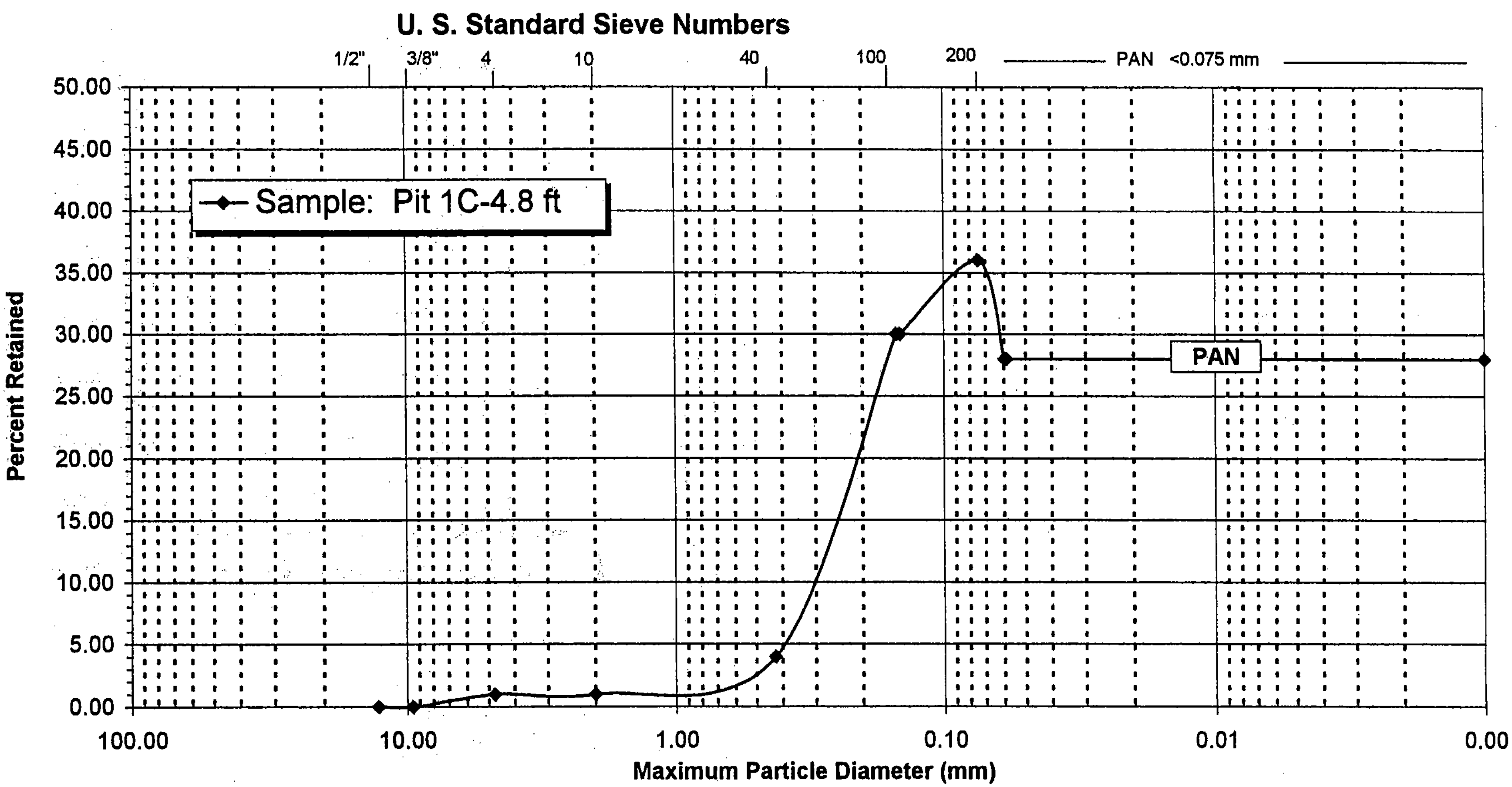
GRAIN SIZE DISTRIBUTION

(Analysis by AGRA Earth & Environmental, Inc.)



GRAVEL	SAND					SILT				CLAY
	V. C.	CRS.	MED.	FINE	V. F.	CRS.	MED.	FINE	V. FINE	

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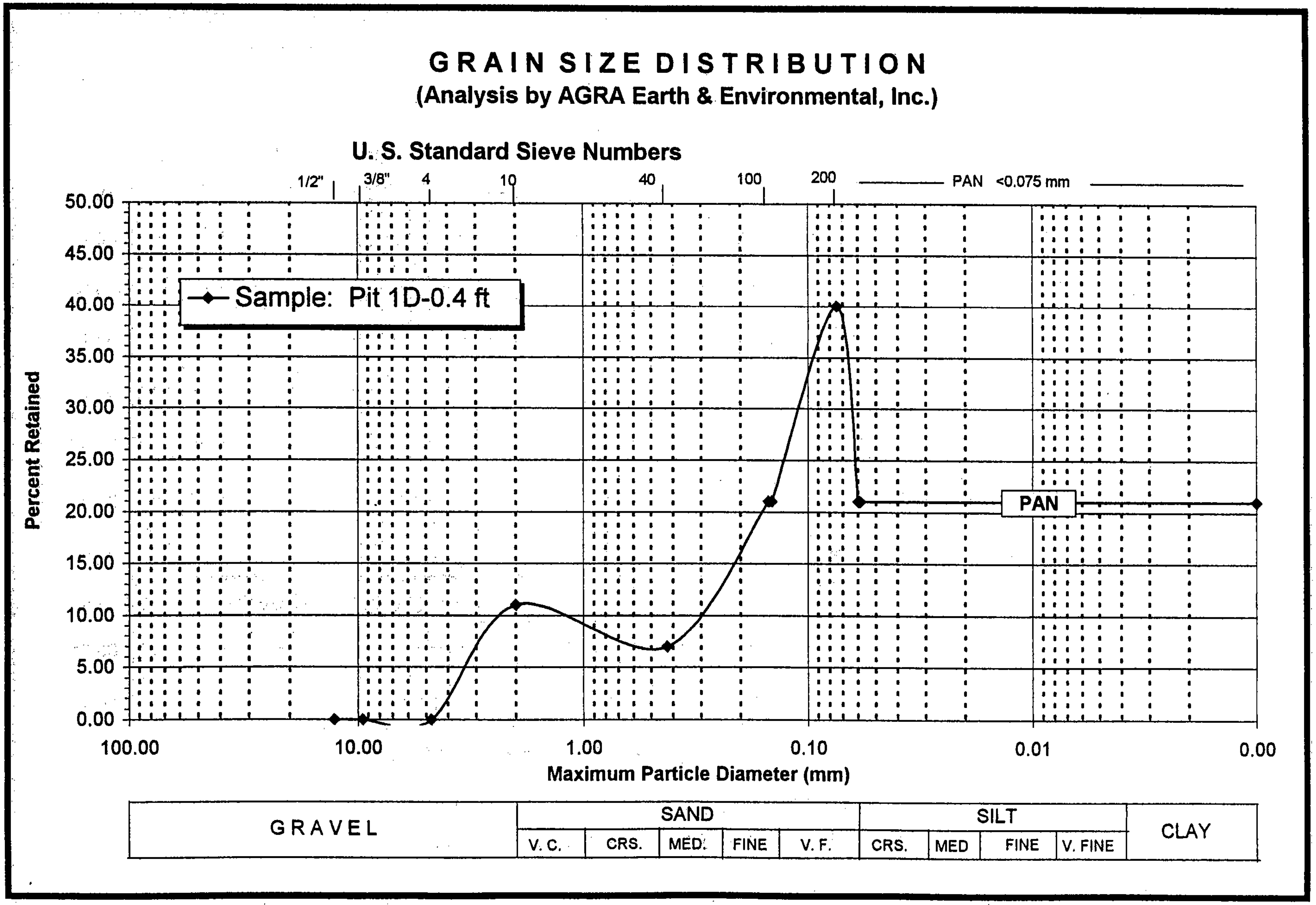

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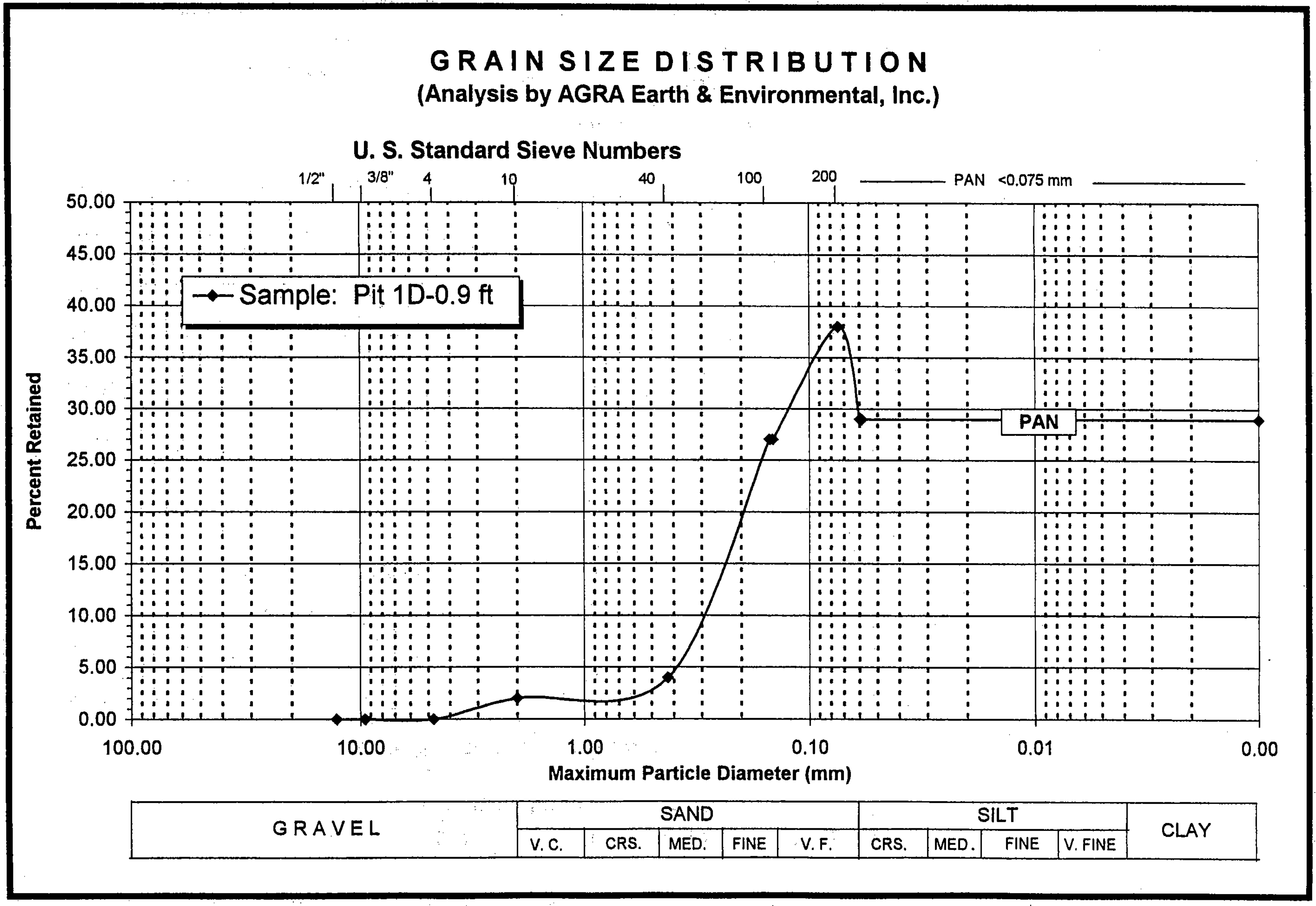

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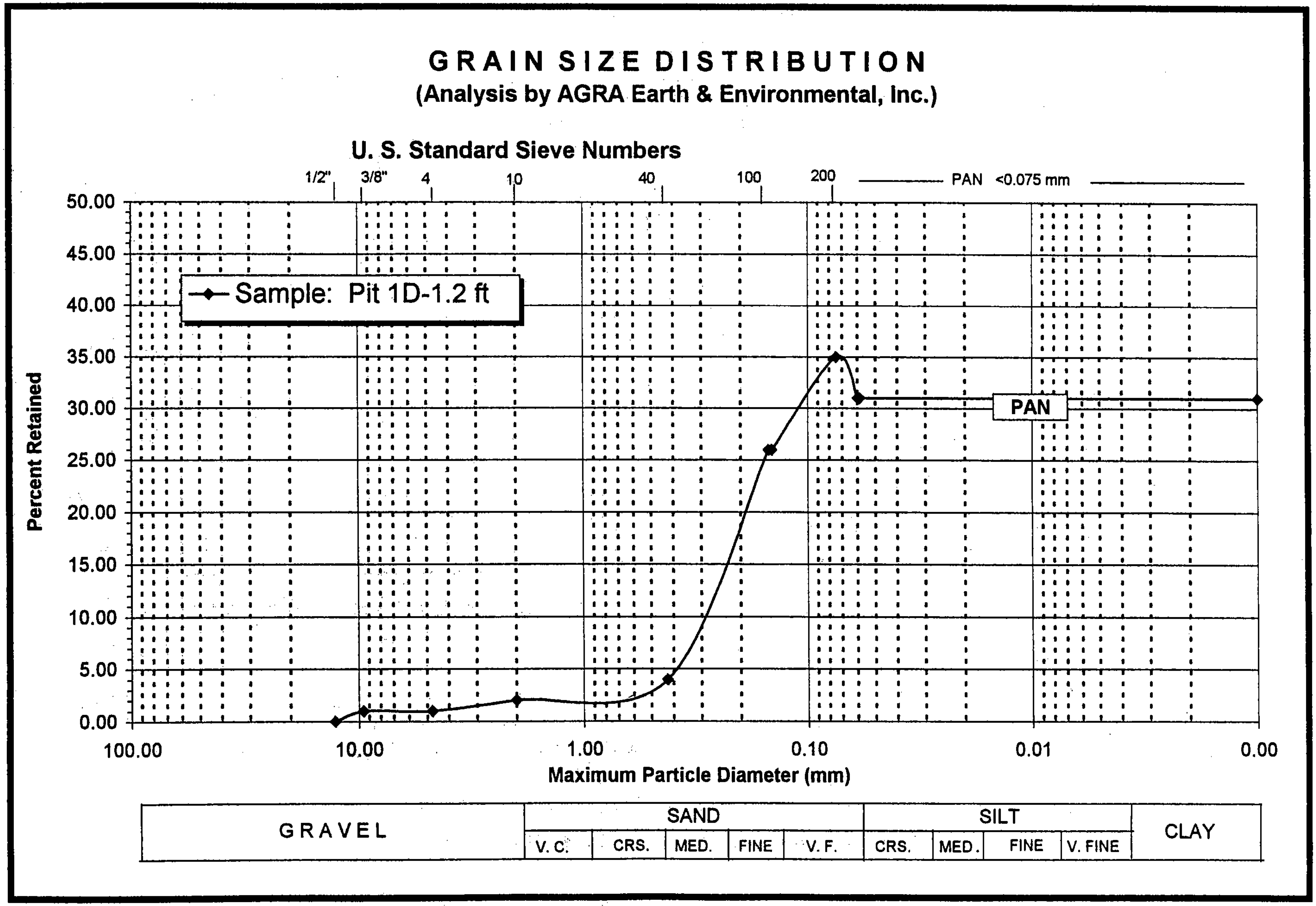

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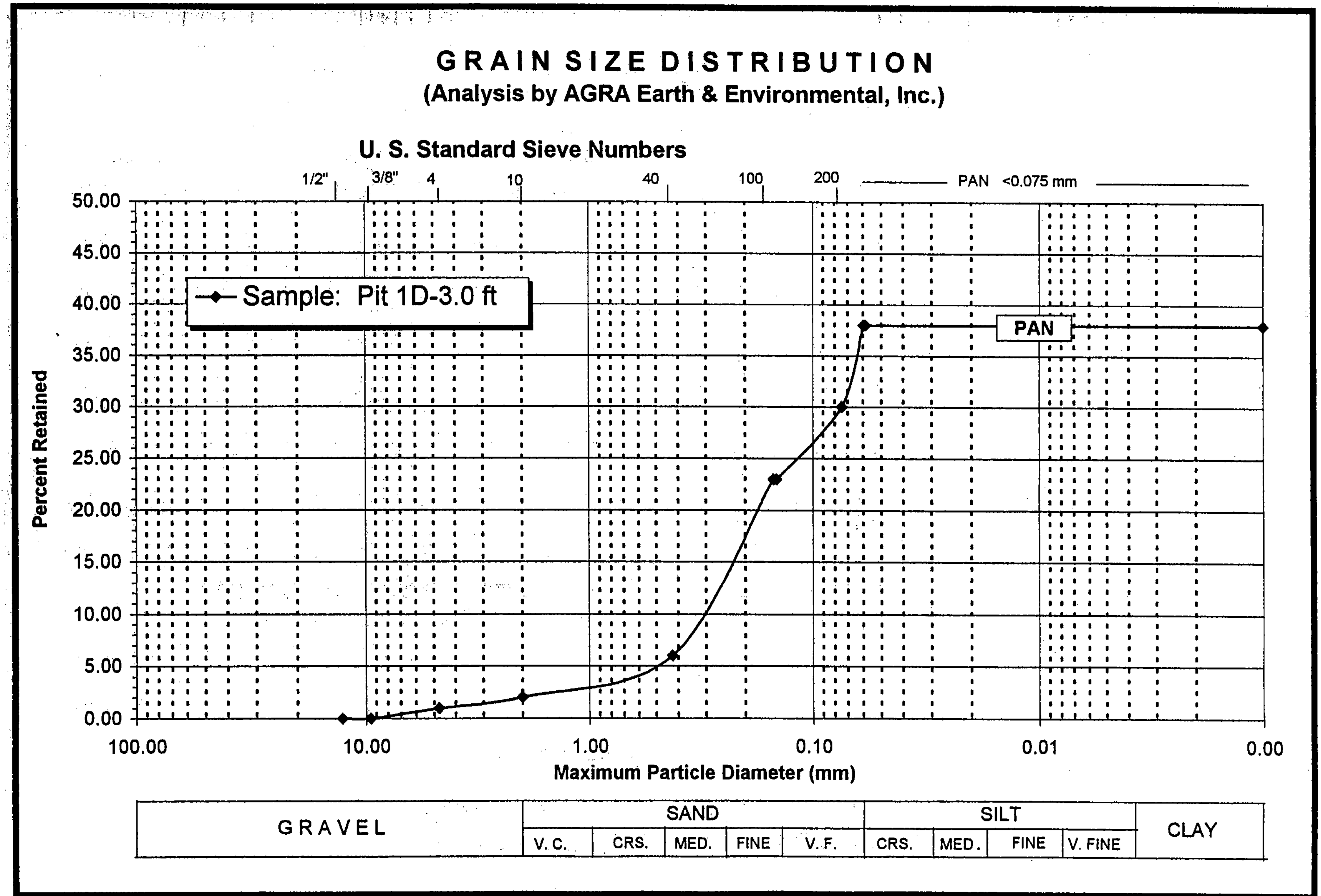

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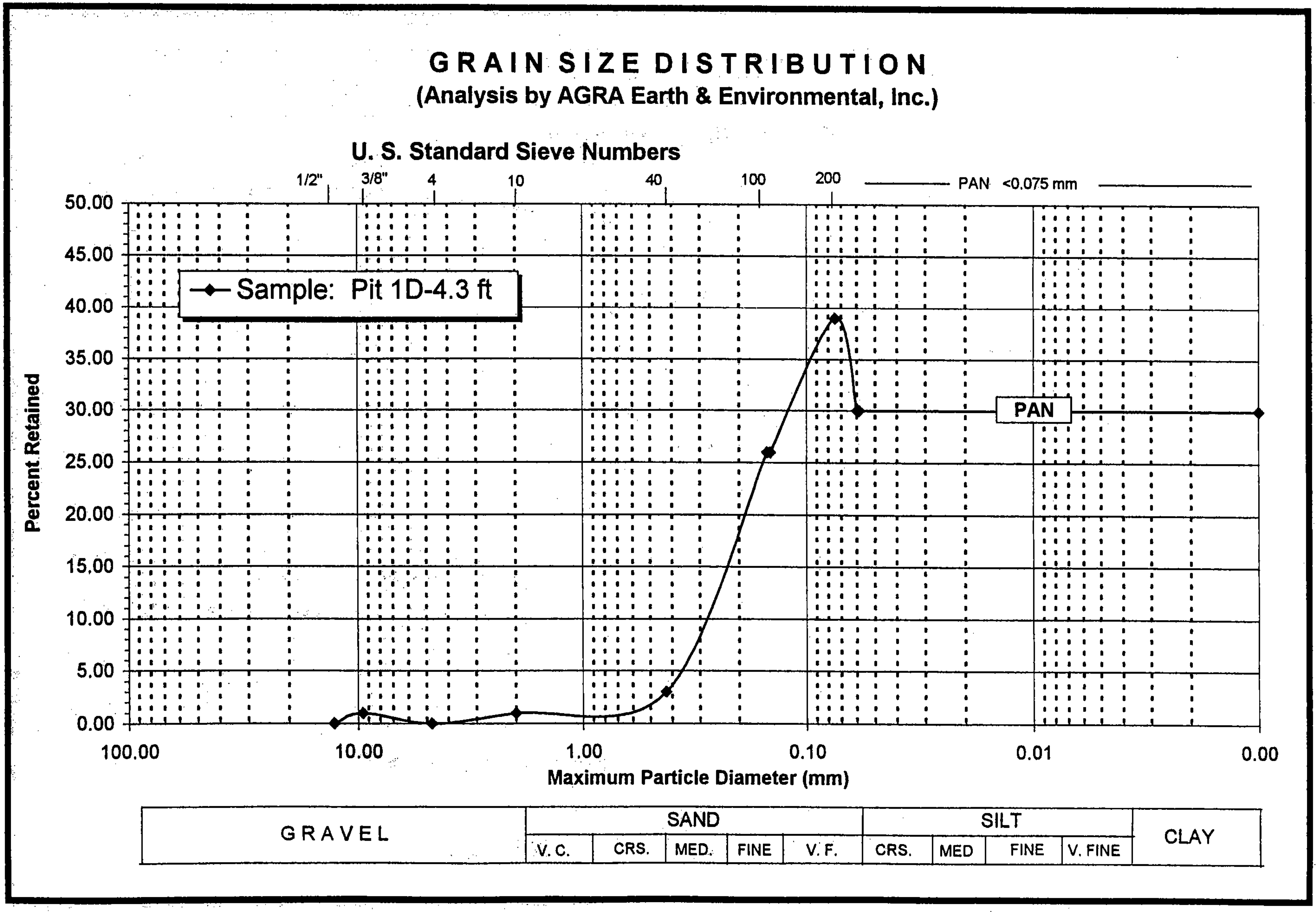
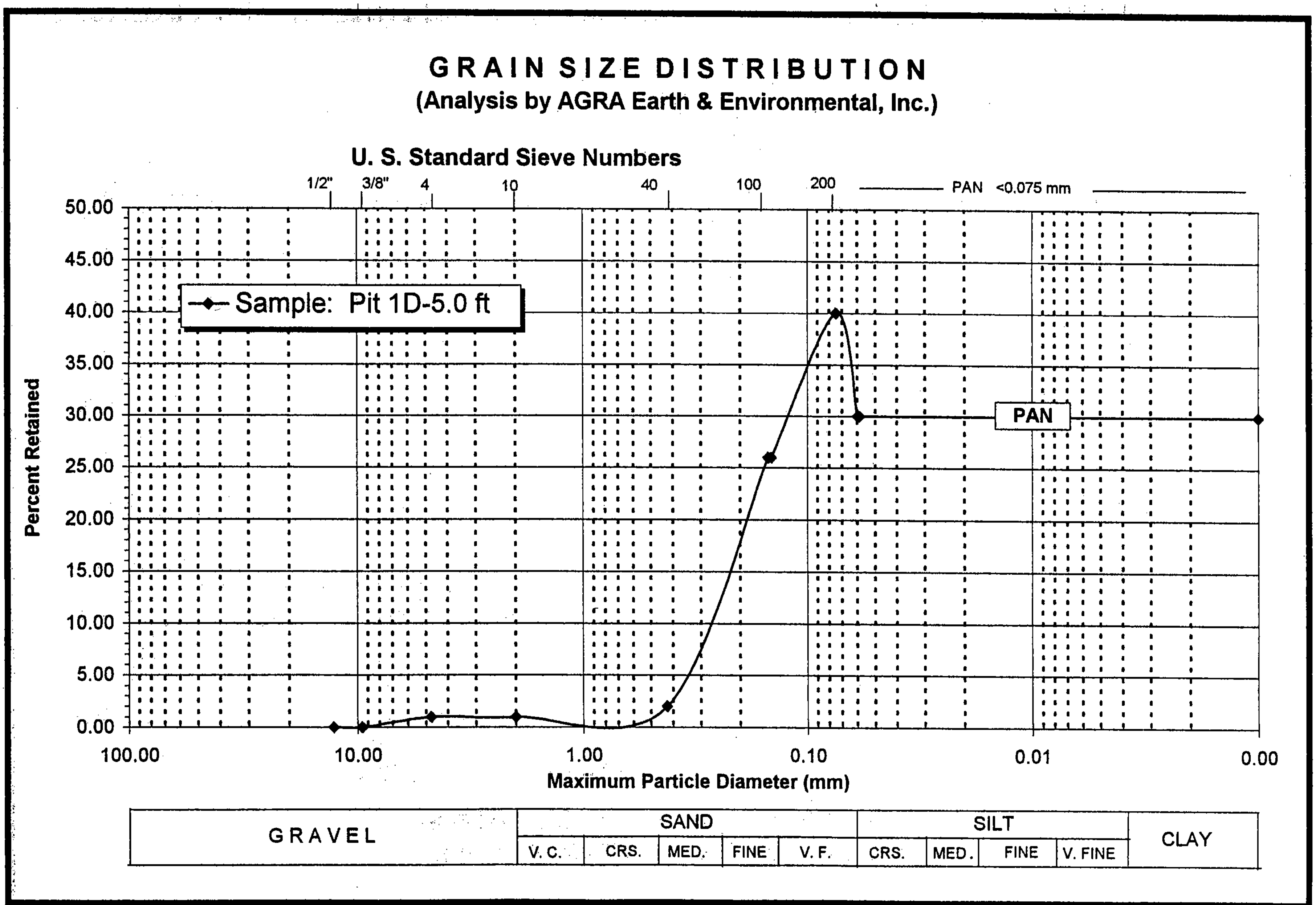

GRAIN SIZE DISTRIBUTION
(Analysis by AGRA Earth & Environmental, Inc.)
U. S. Standard Sieve Numbers
1/2"
3/8"
4
10
40
100
200
PAN <0.075 mm
Sample: Pit 1D-4.3 ft
PAN
Percent Retained
50.00
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
100.00
10.00
1.00
0.10
0.01
0.00
Maximum Particle Diameter (mm)
GRAVEL
SAND
V. C.
CRS.
MED.
FINE
V. F.
SILT
CRS.
MED
FINE
V. FINE
CLAY



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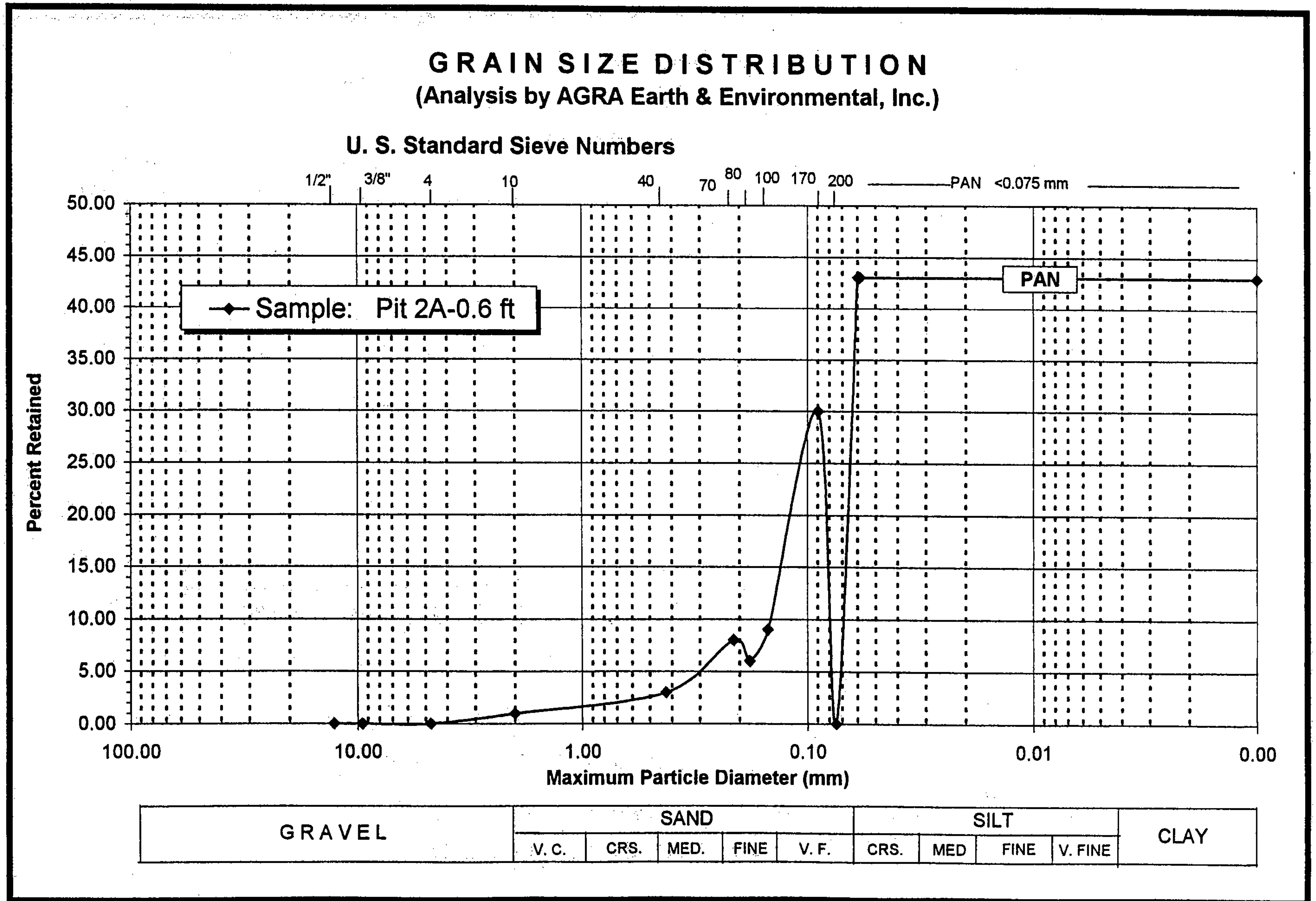

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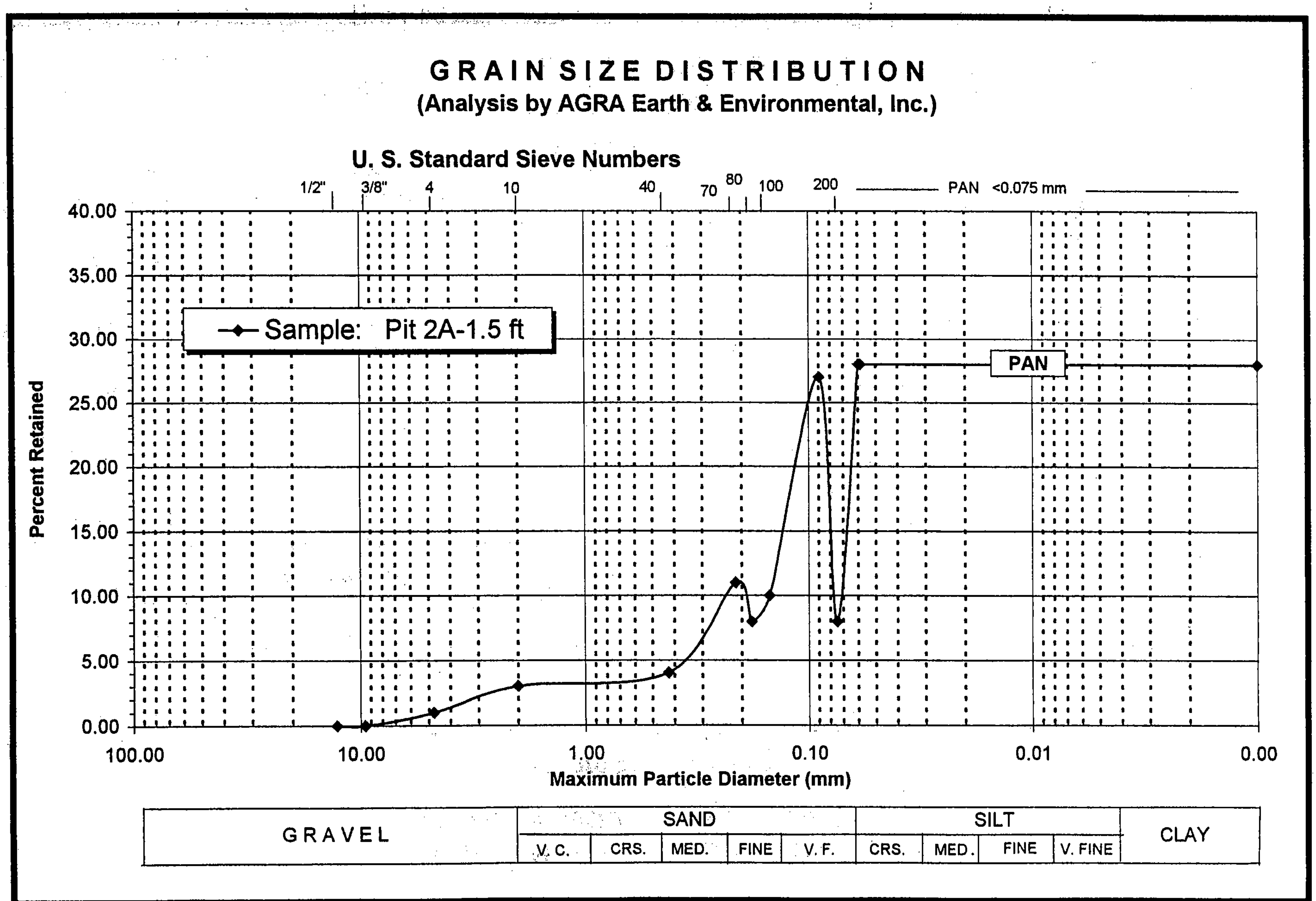
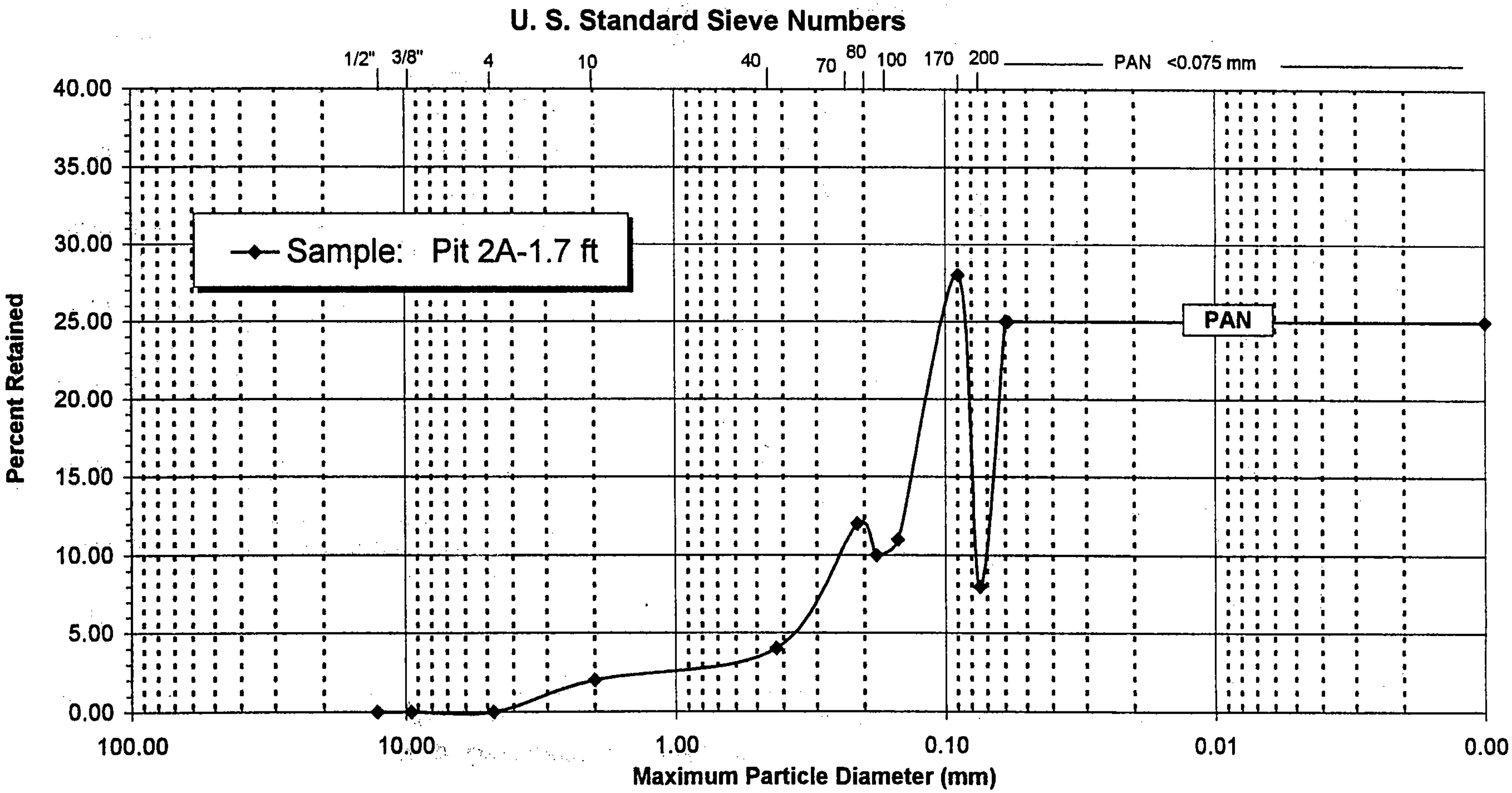

GRAIN SIZE DISTRIBUTION
(Analysis by AGRA Earth & Environmental, Inc.)
U. S. Standard Sieve Numbers
1/2"
3/8"
4
10
40
70
80
100
200
PAN <0.075 mm
Sample: Pit 2A-1.5 ft
PAN
Percent Retained
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
100.00
10.00
1.00
0.10
0.01
0.00
Maximum Particle Diameter (mm)
GRAVEL
SAND
V. C.
CRS.
MED.
FINE
V. F.
SILT
CRS.
MED.
FINE
V. FINE
CLAY

GRAIN SIZE DISTRIBUTION
(Analysis by AGRA Earth & Environmental, Inc.)



GRAVEL	SAND					SILT				CLAY
	V. C.	CRS.	MED.	FINE	V. F.	CRS.	MED	FINE	V. FINE	

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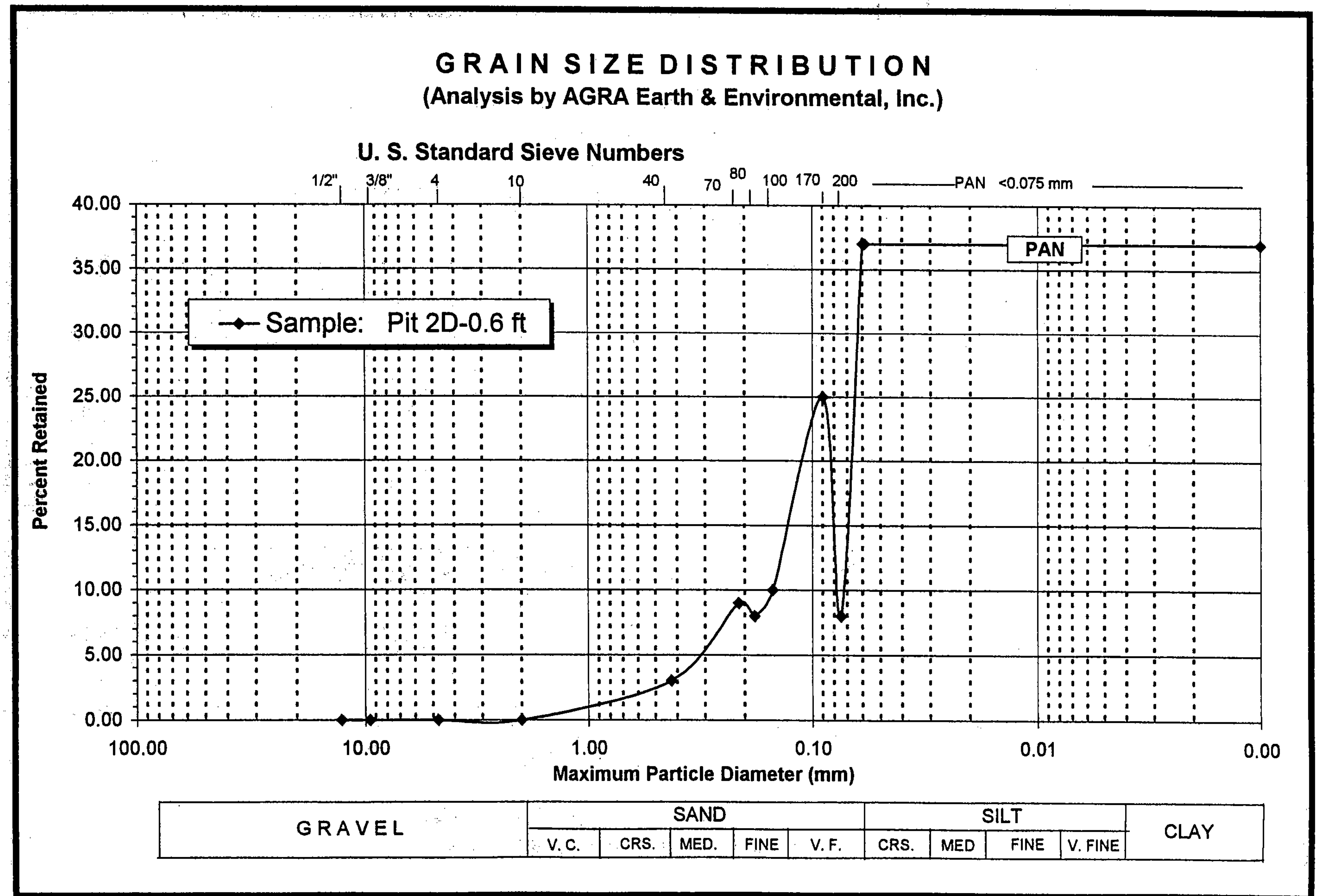

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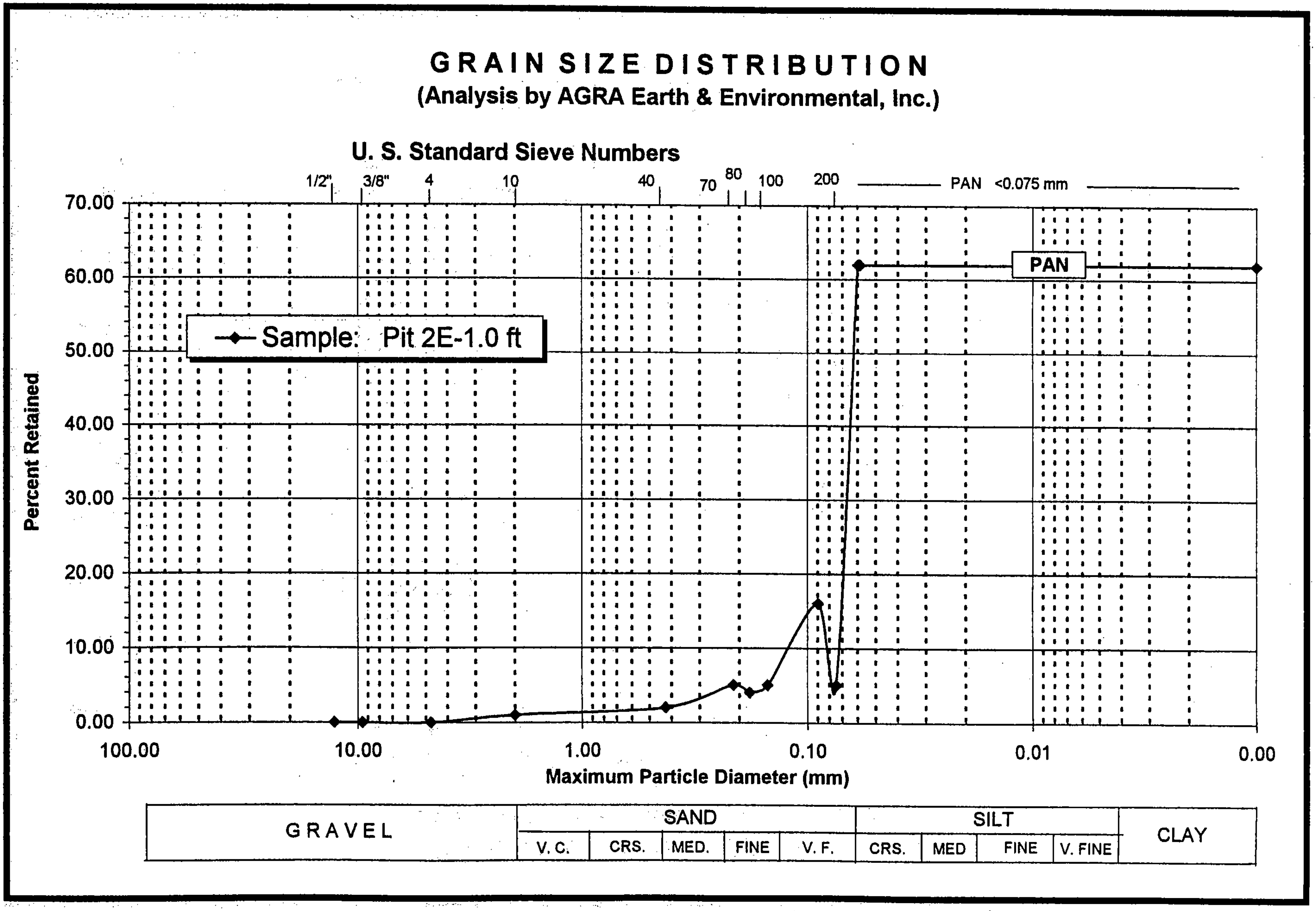

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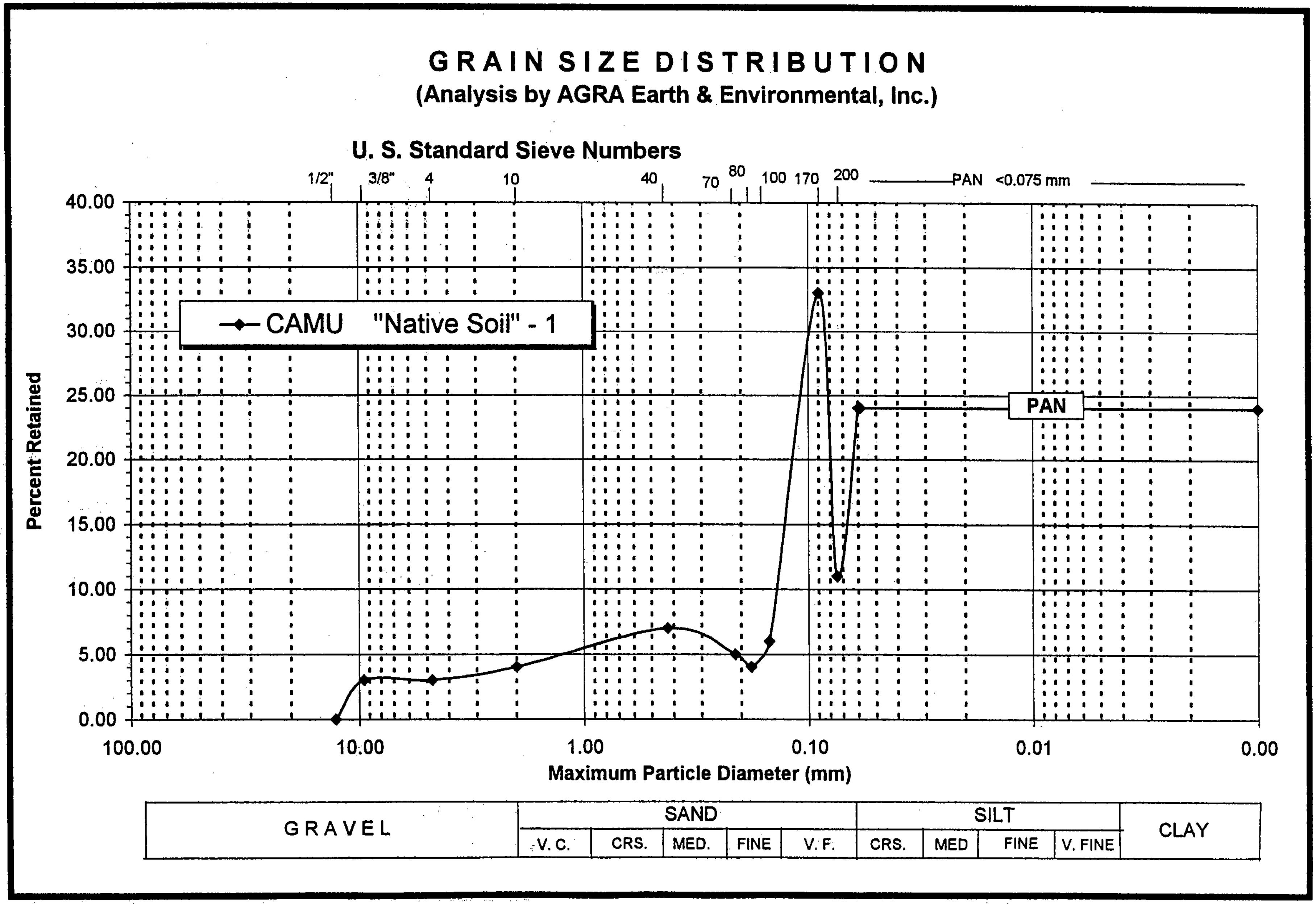

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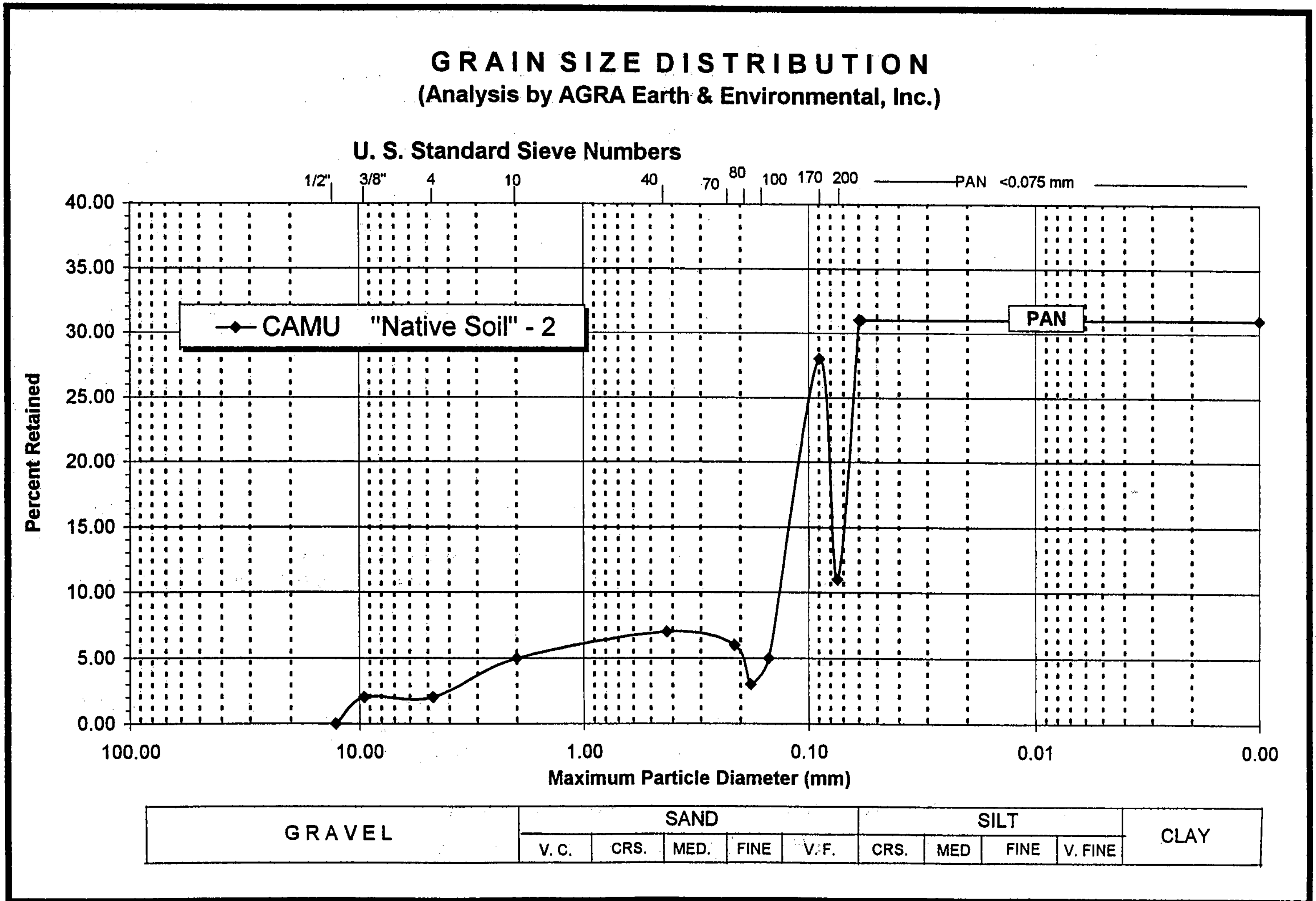

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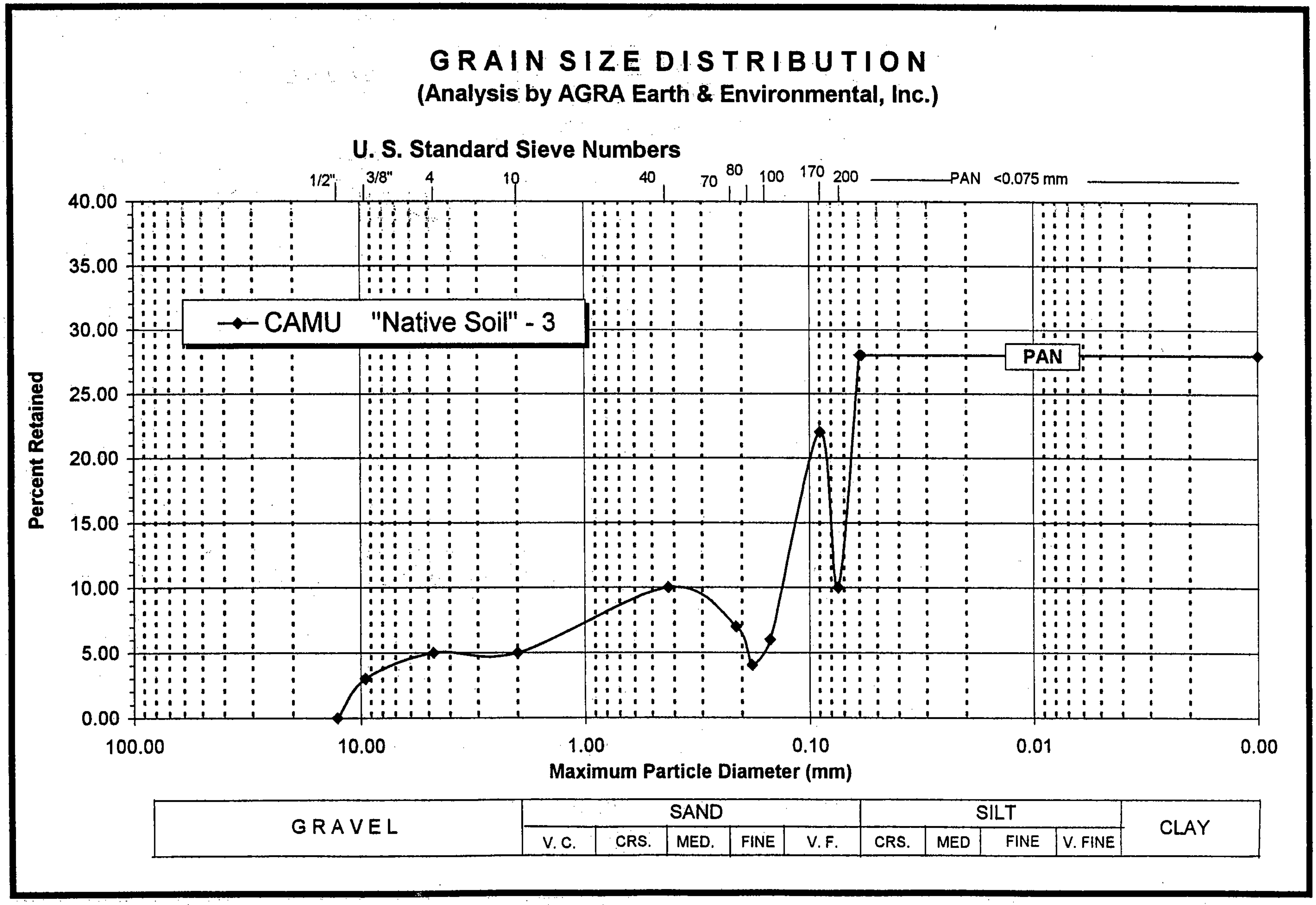

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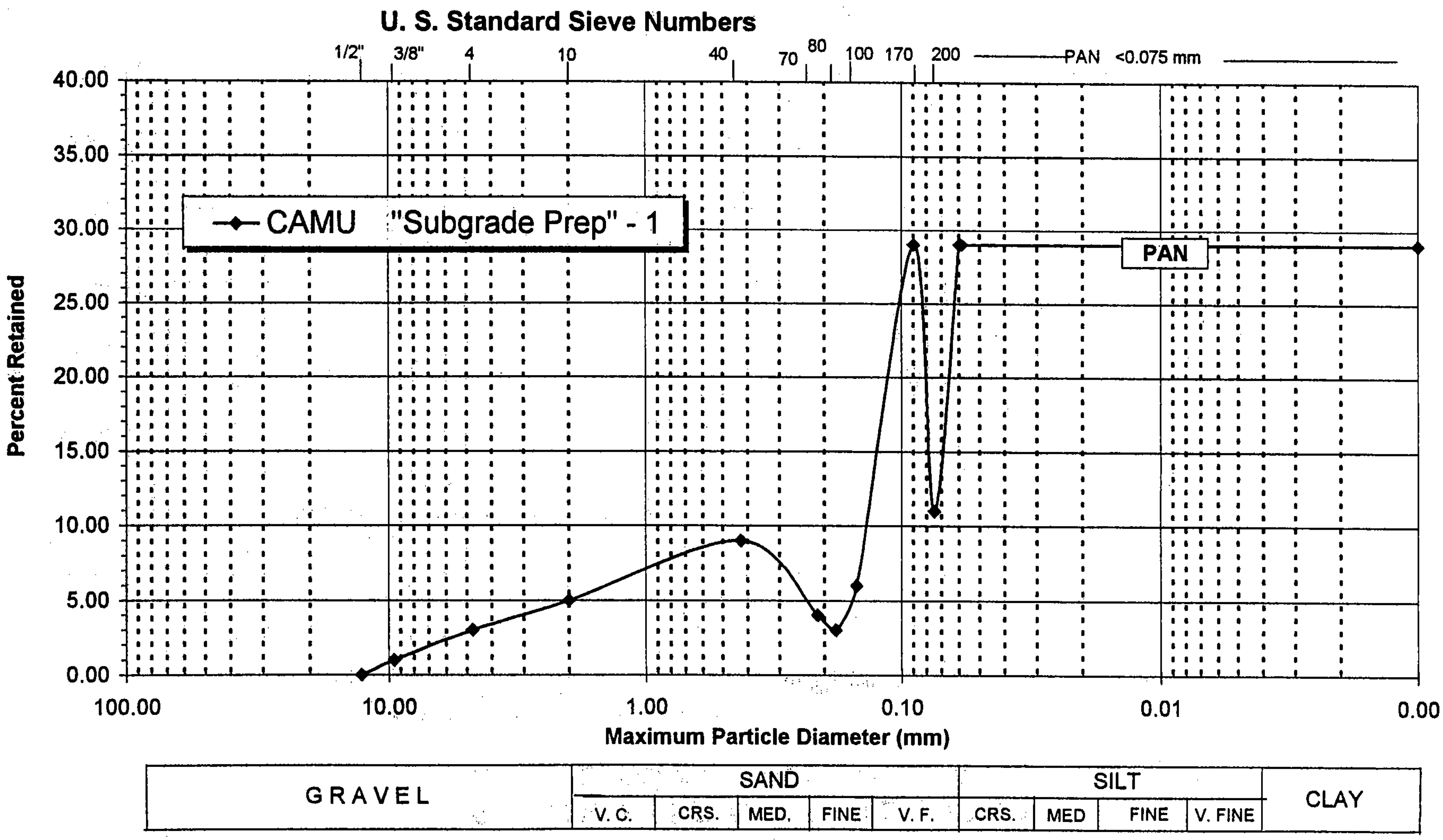

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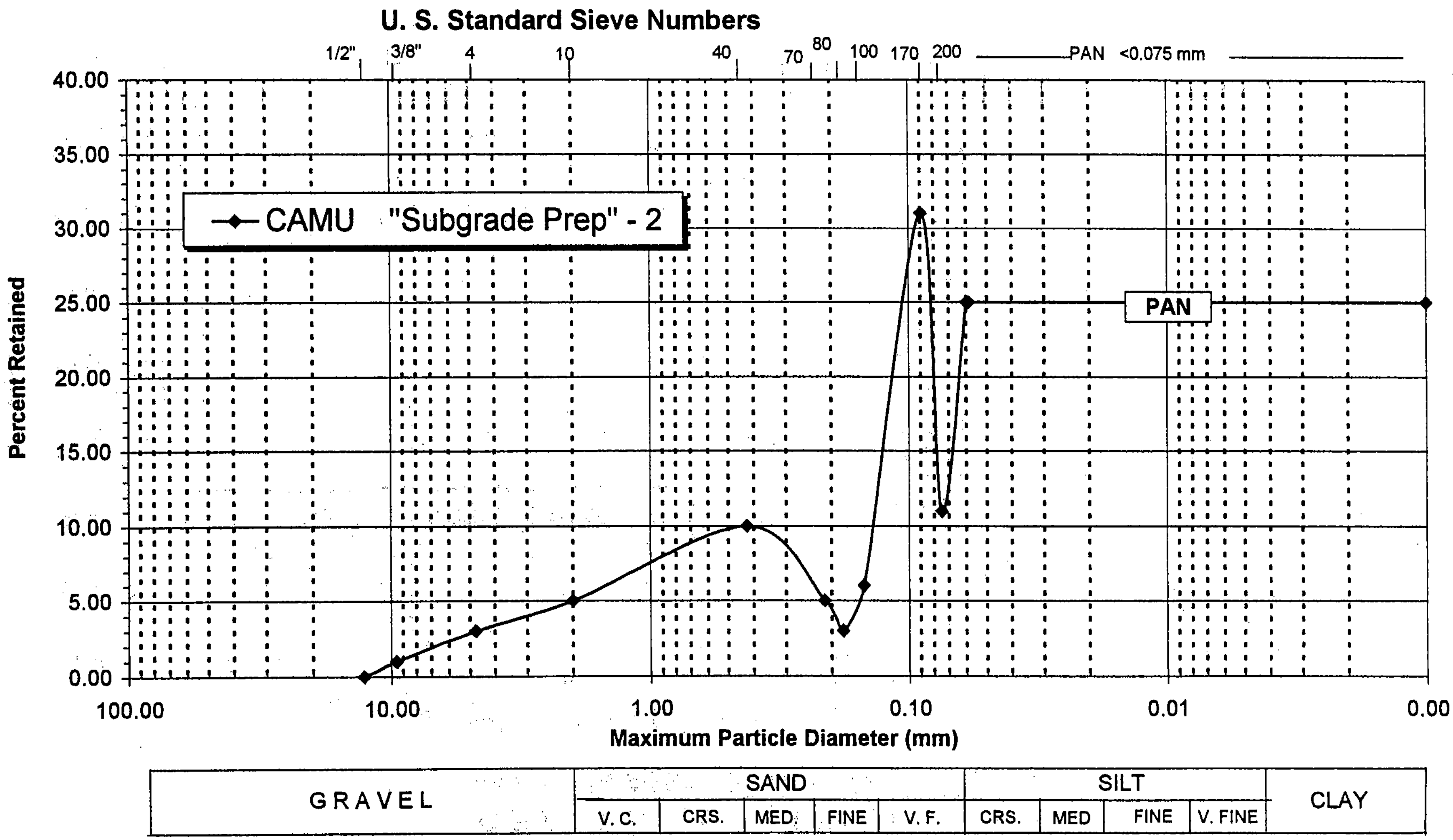

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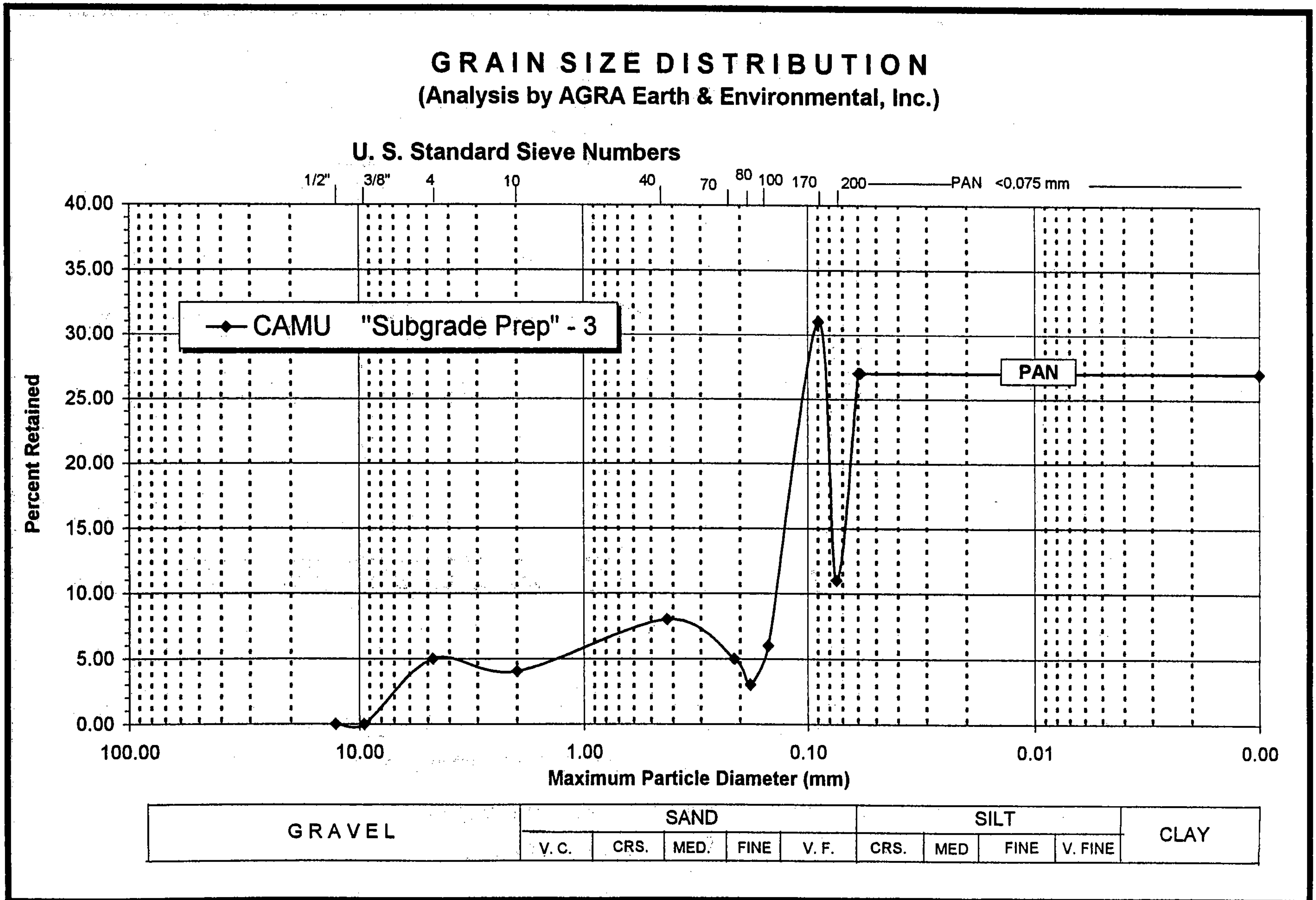

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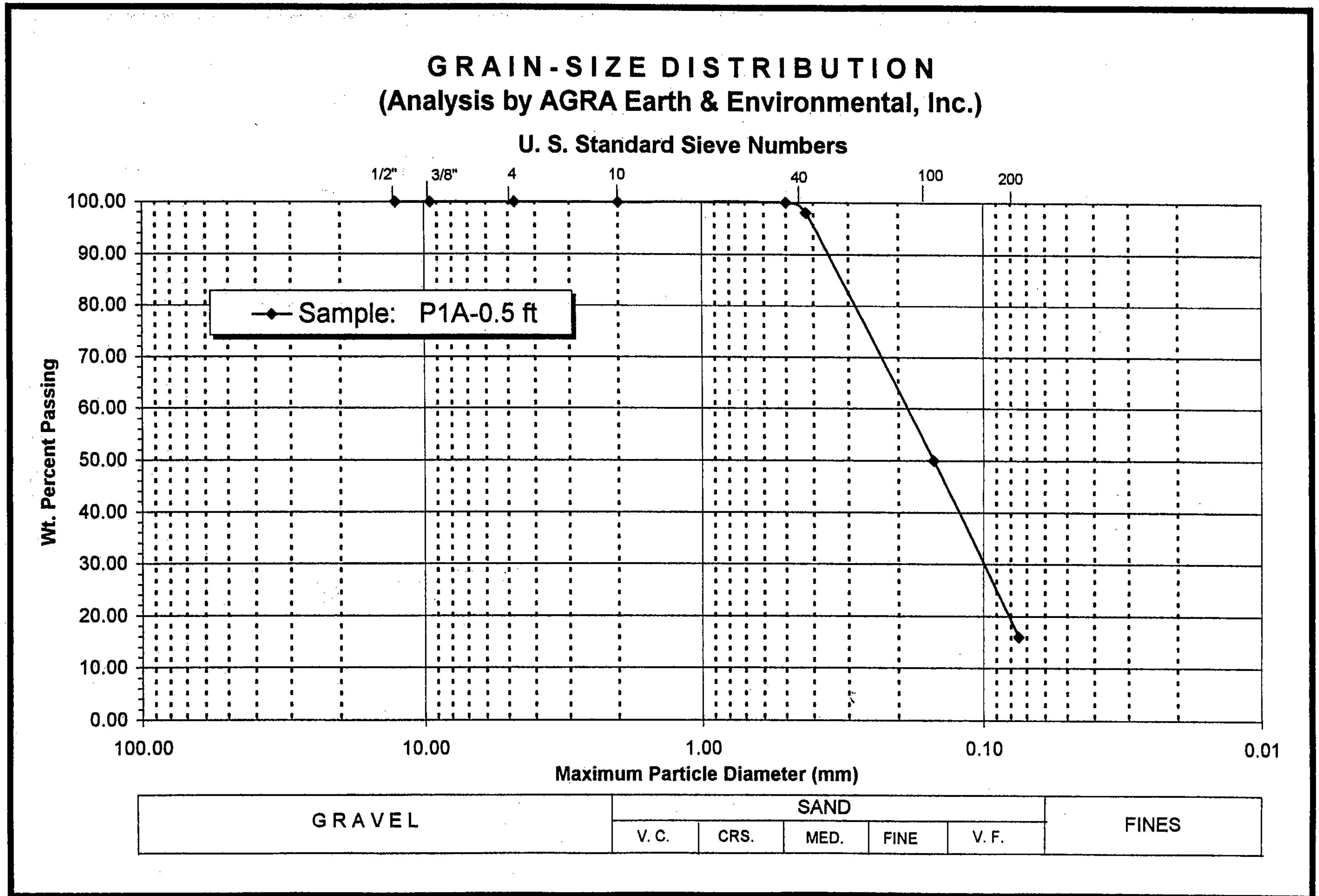

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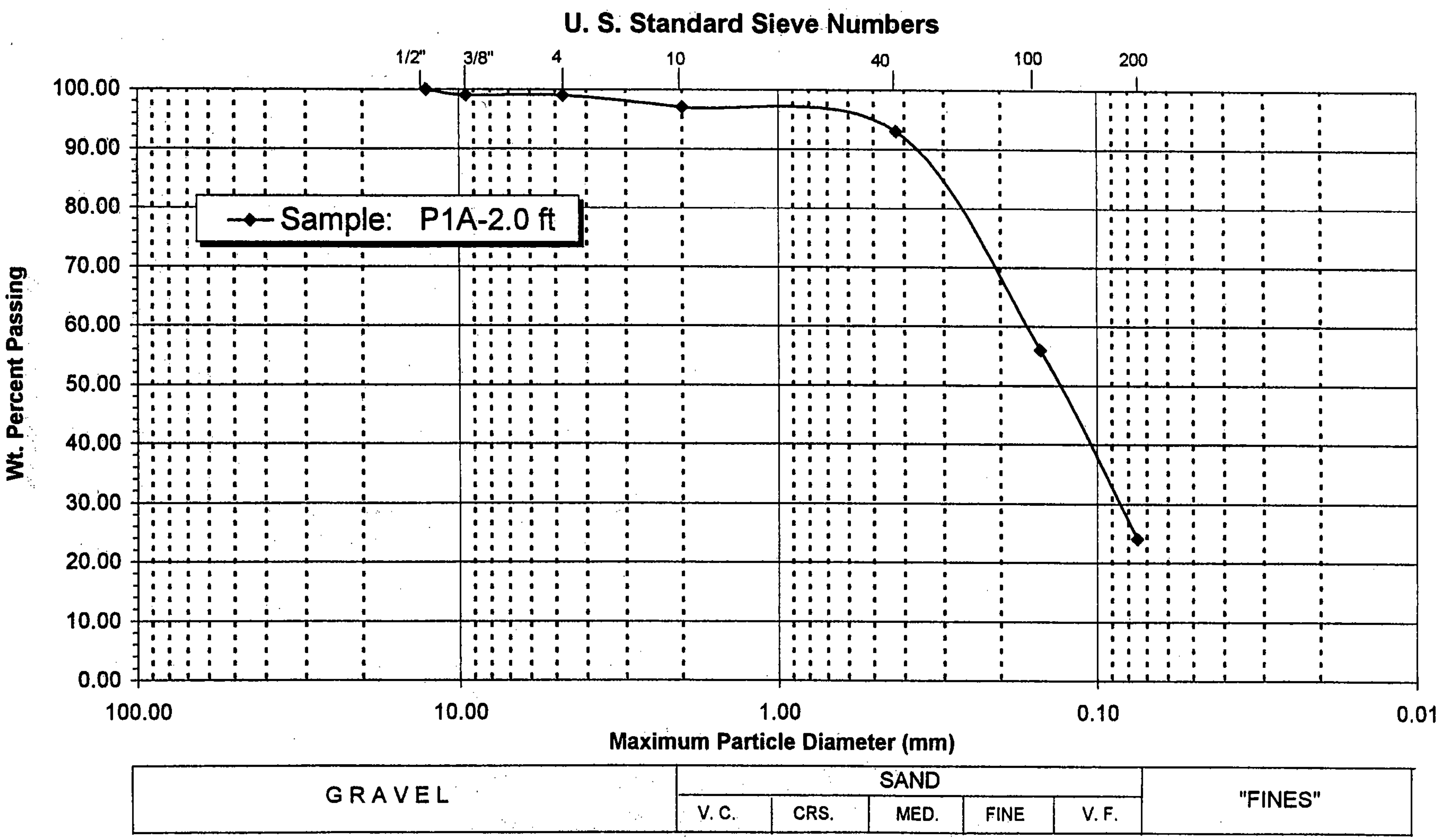

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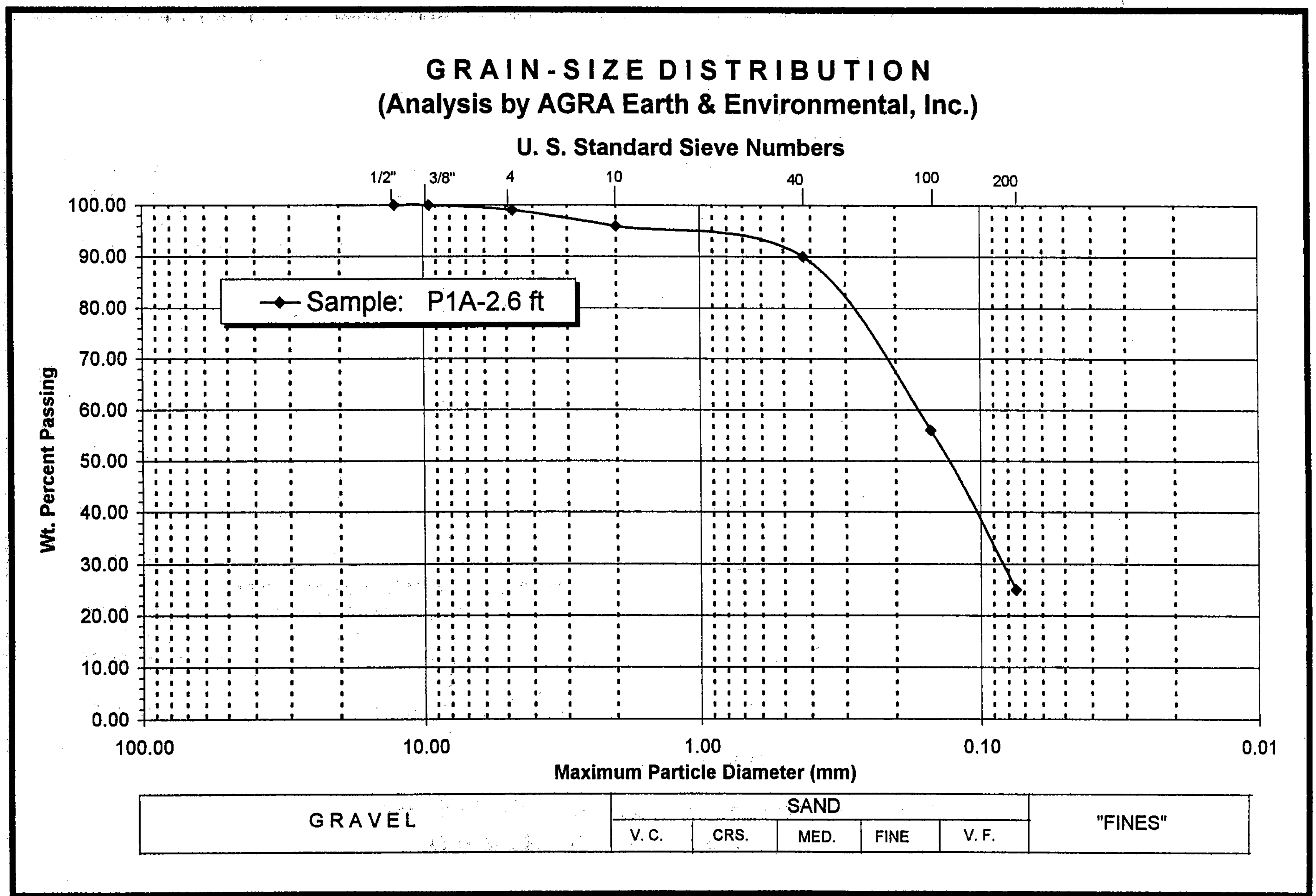

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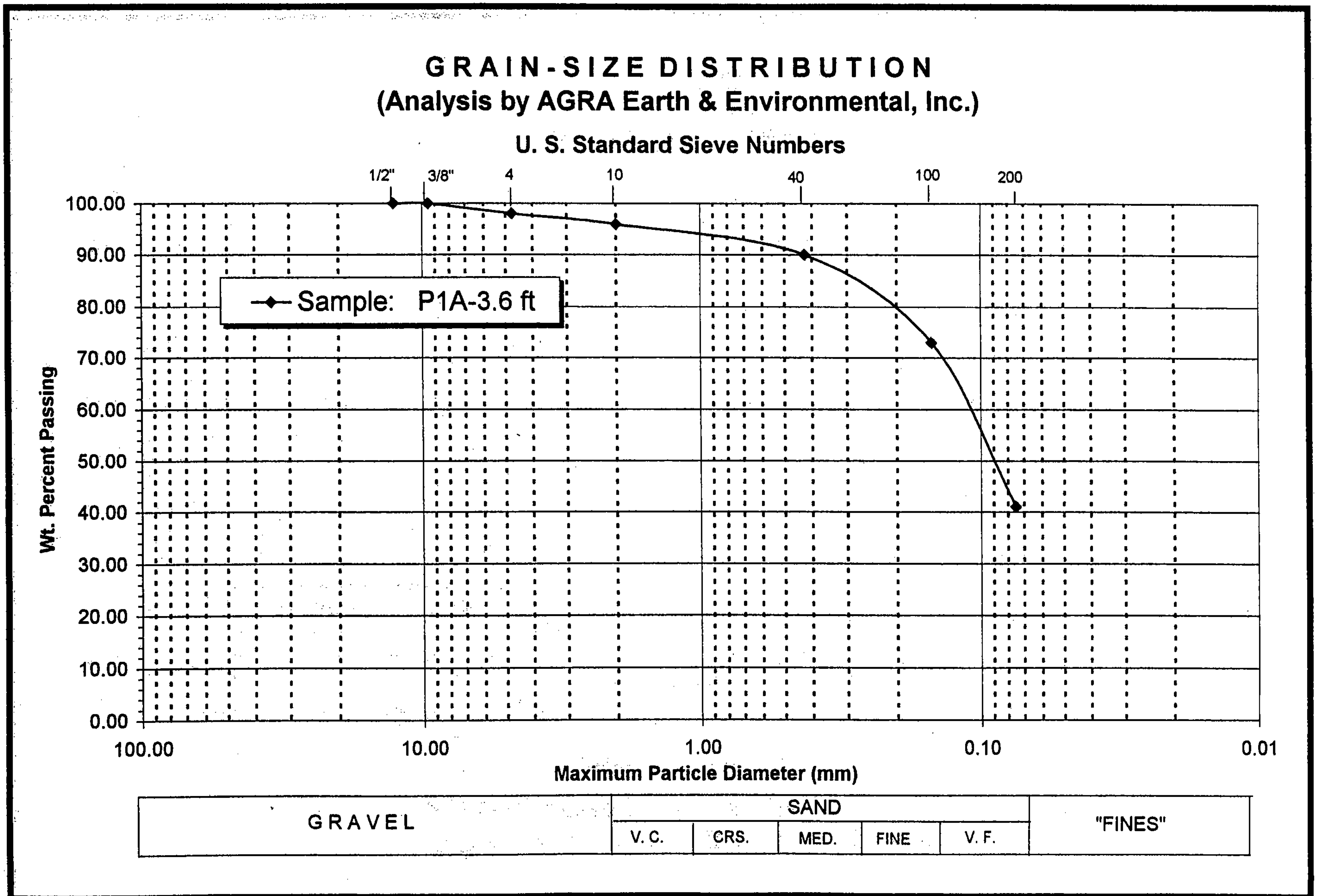

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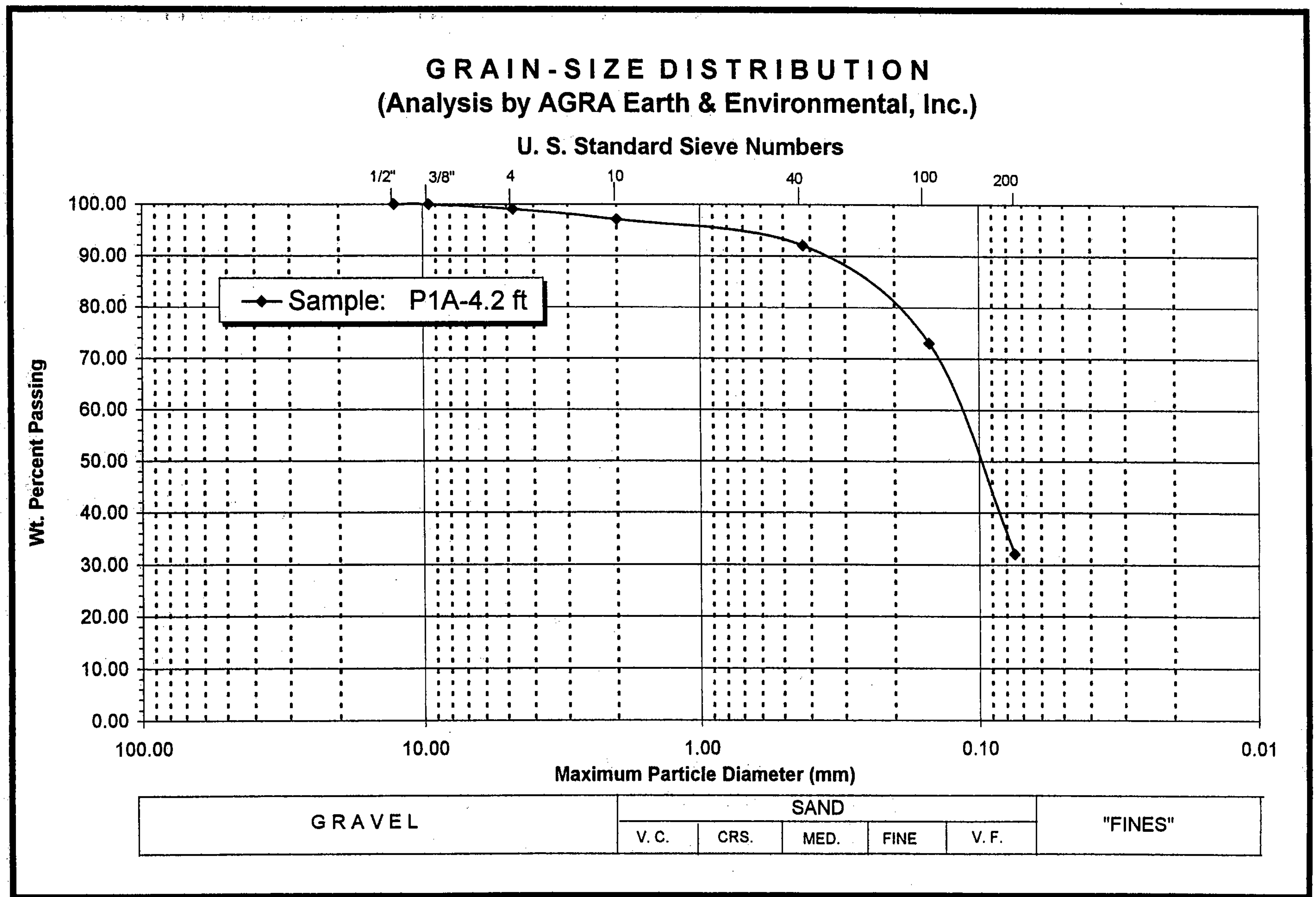

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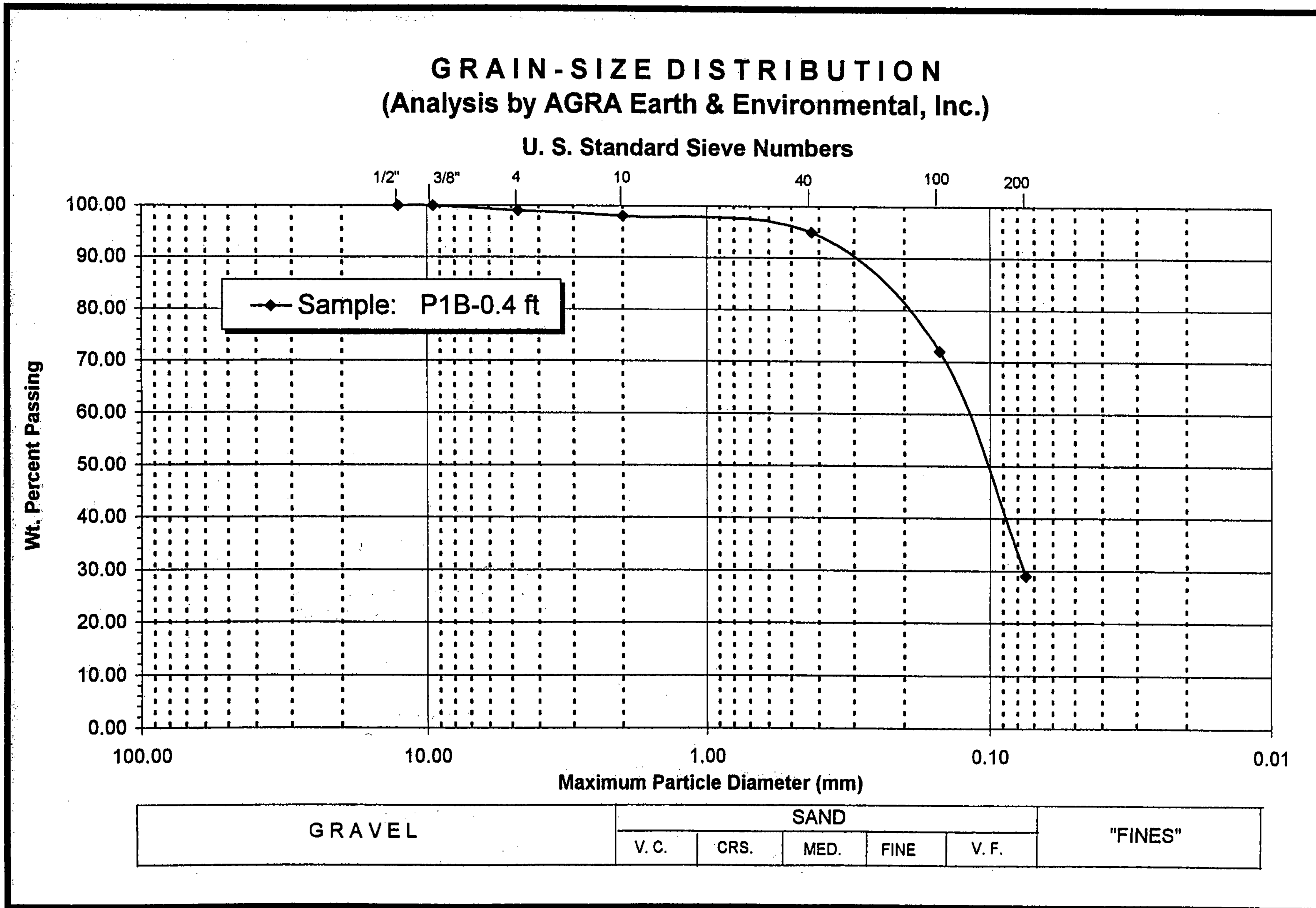

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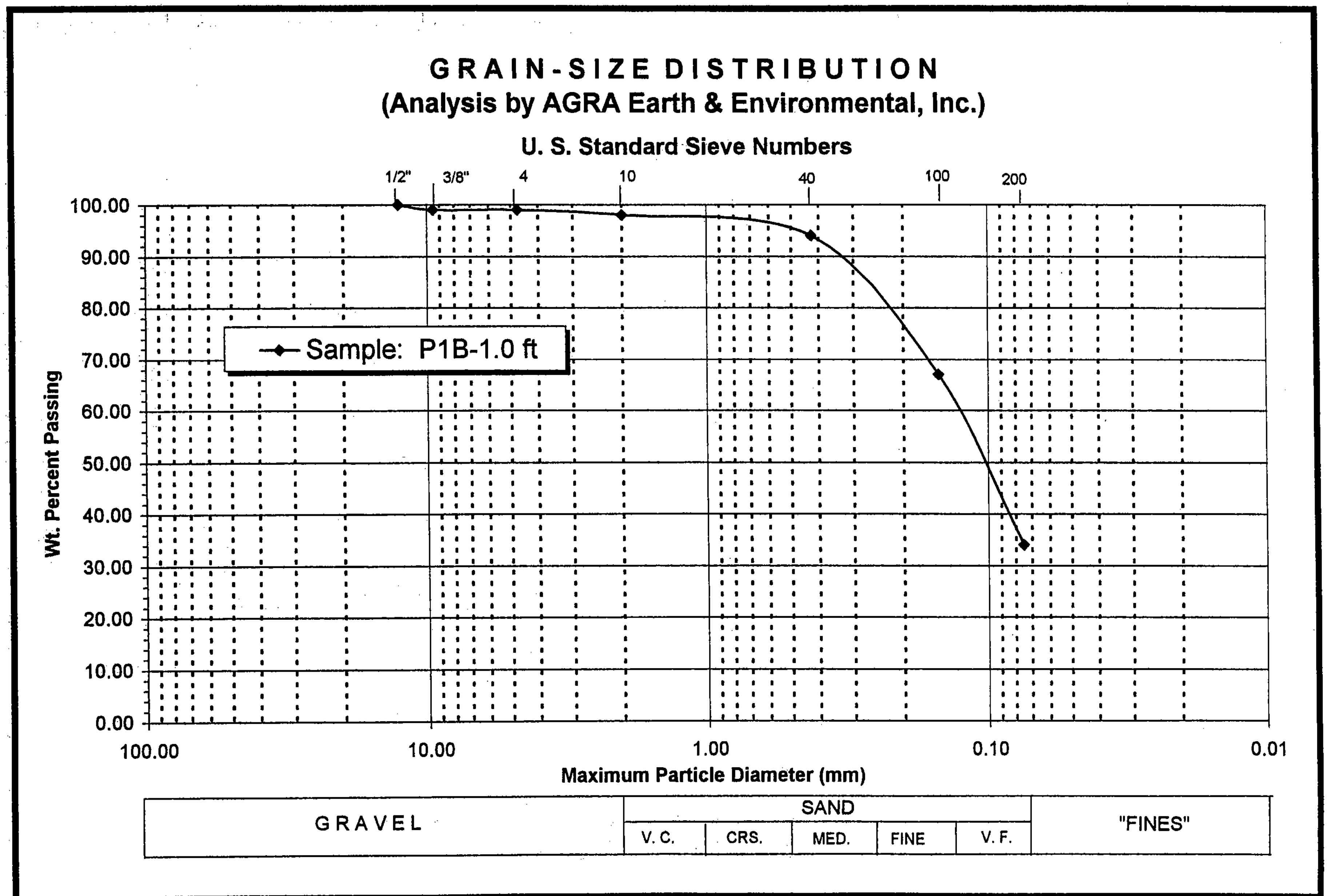

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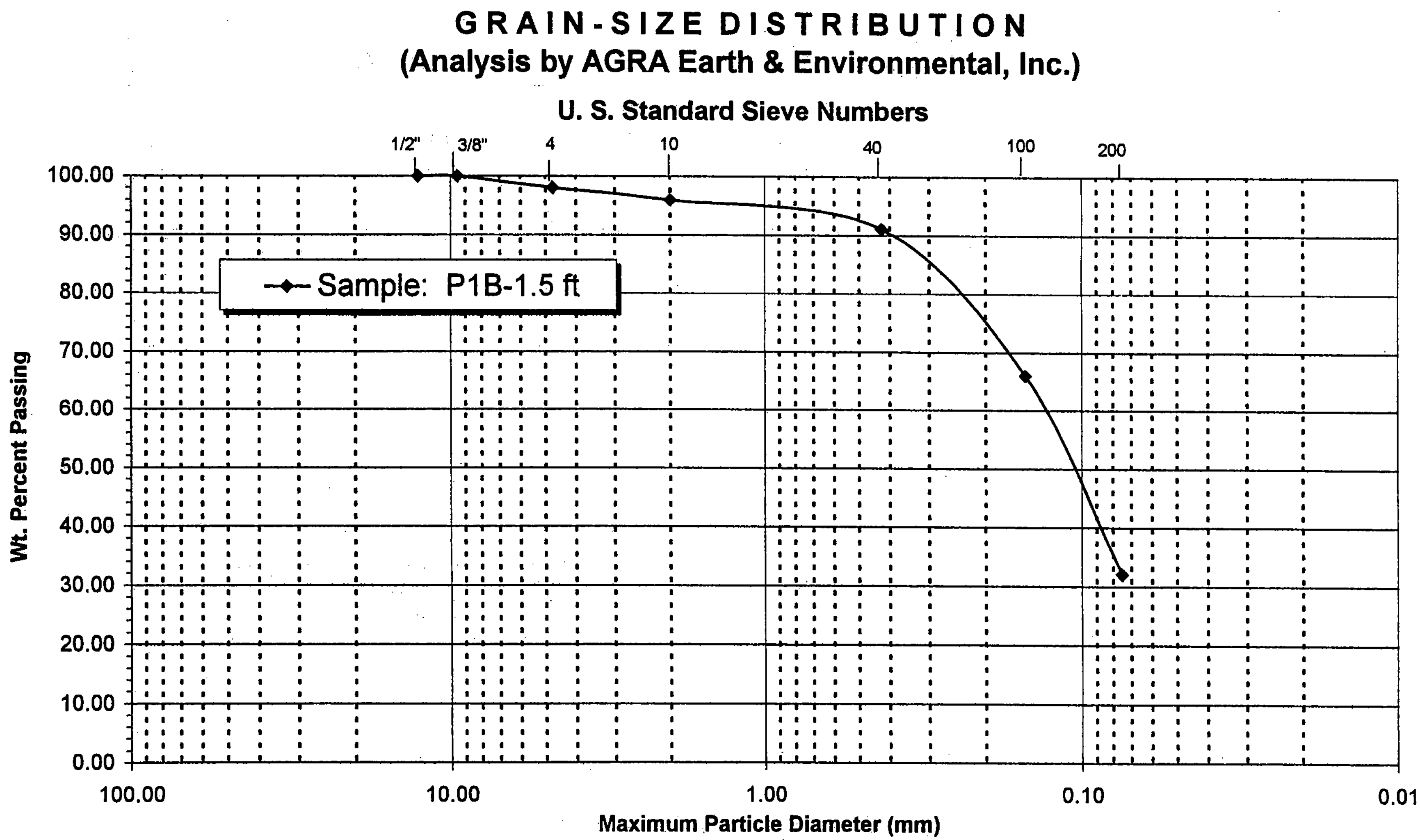
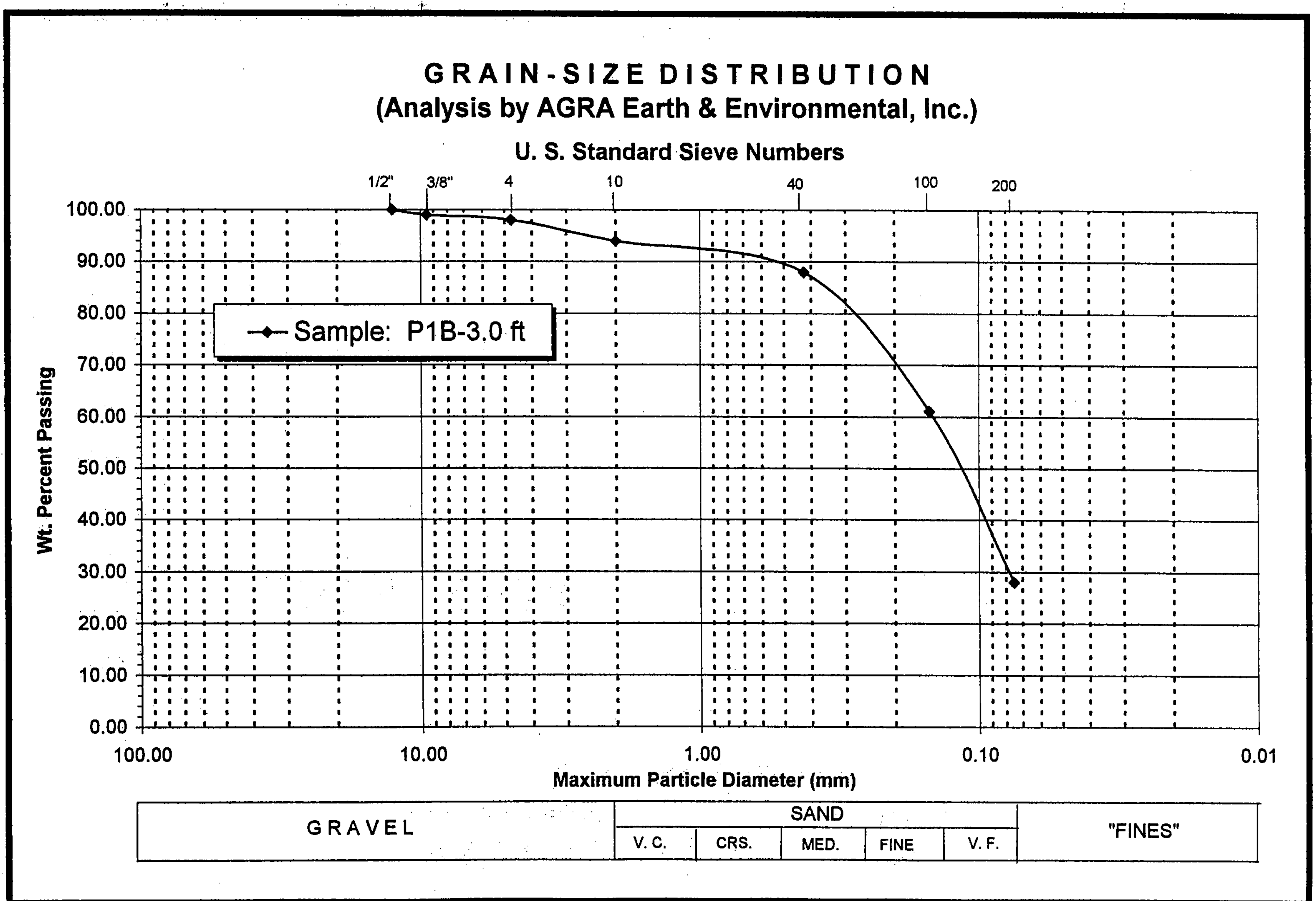


GRAVEL	SAND					"FINES"
	V. C.	CRS.	MED.	FINE	V. F.	

C:\DVH\AS686\AGRA\1B1_5PAS.XLS



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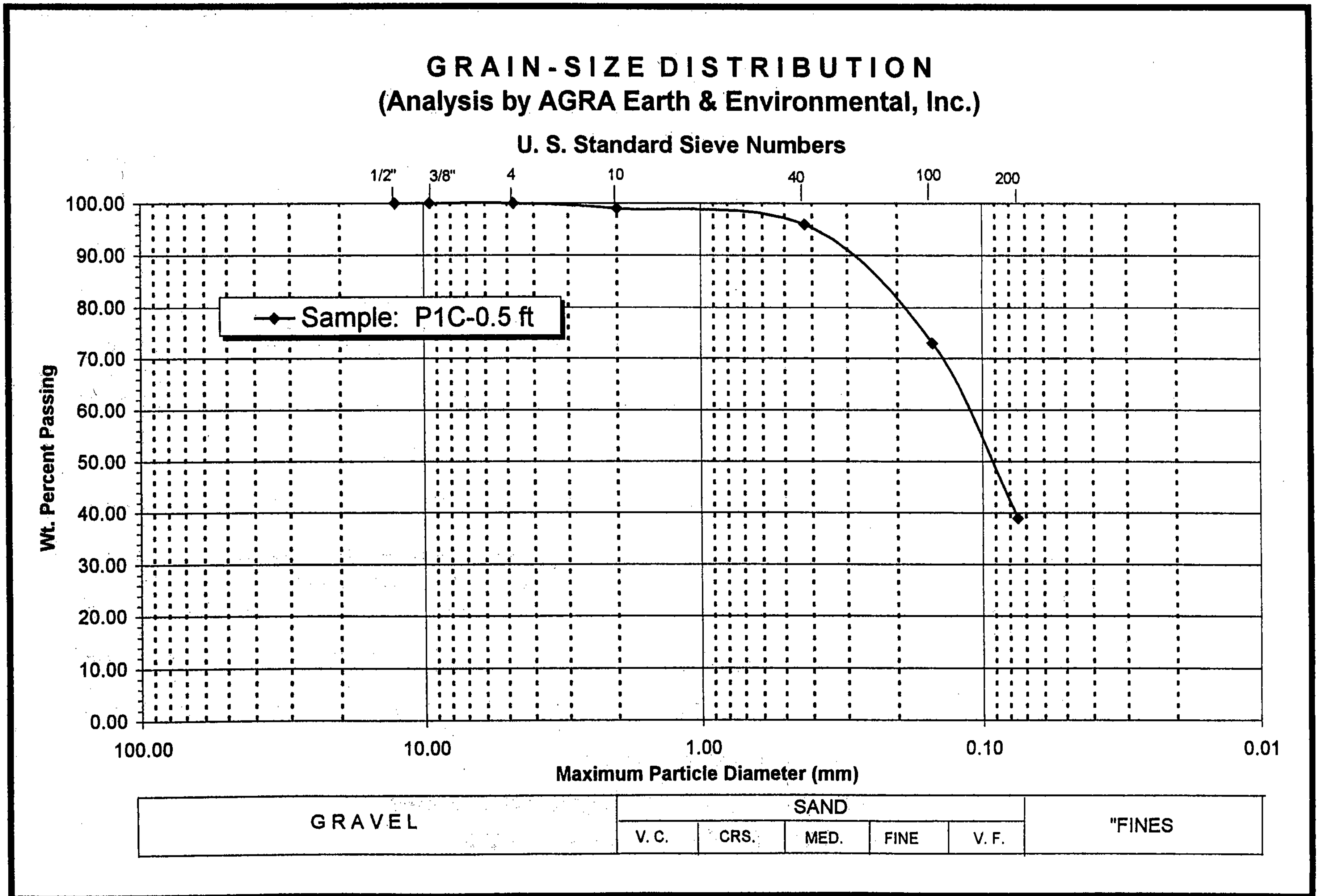

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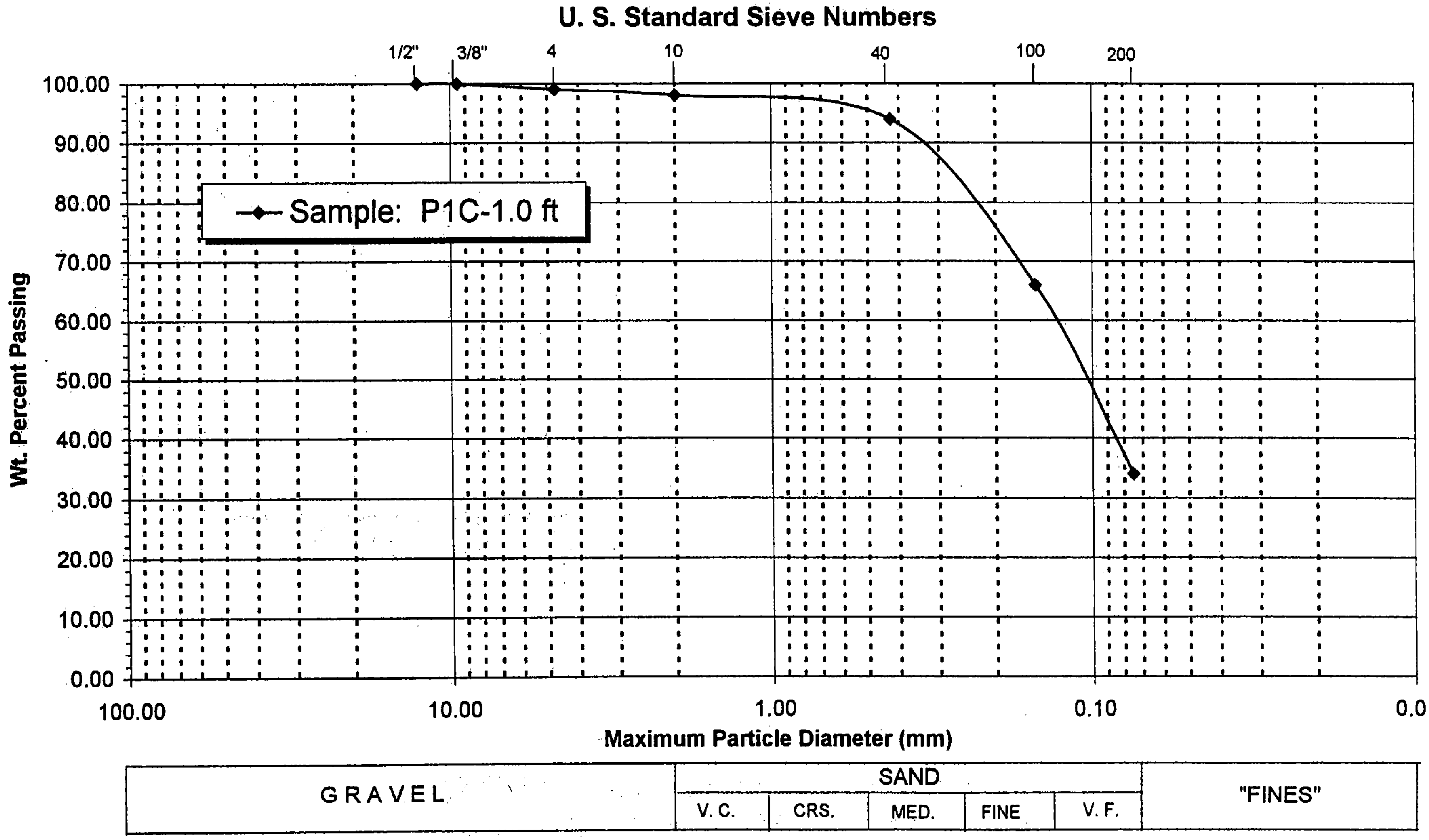
(Analysis by AGRA Earth & Environmental, Inc.)



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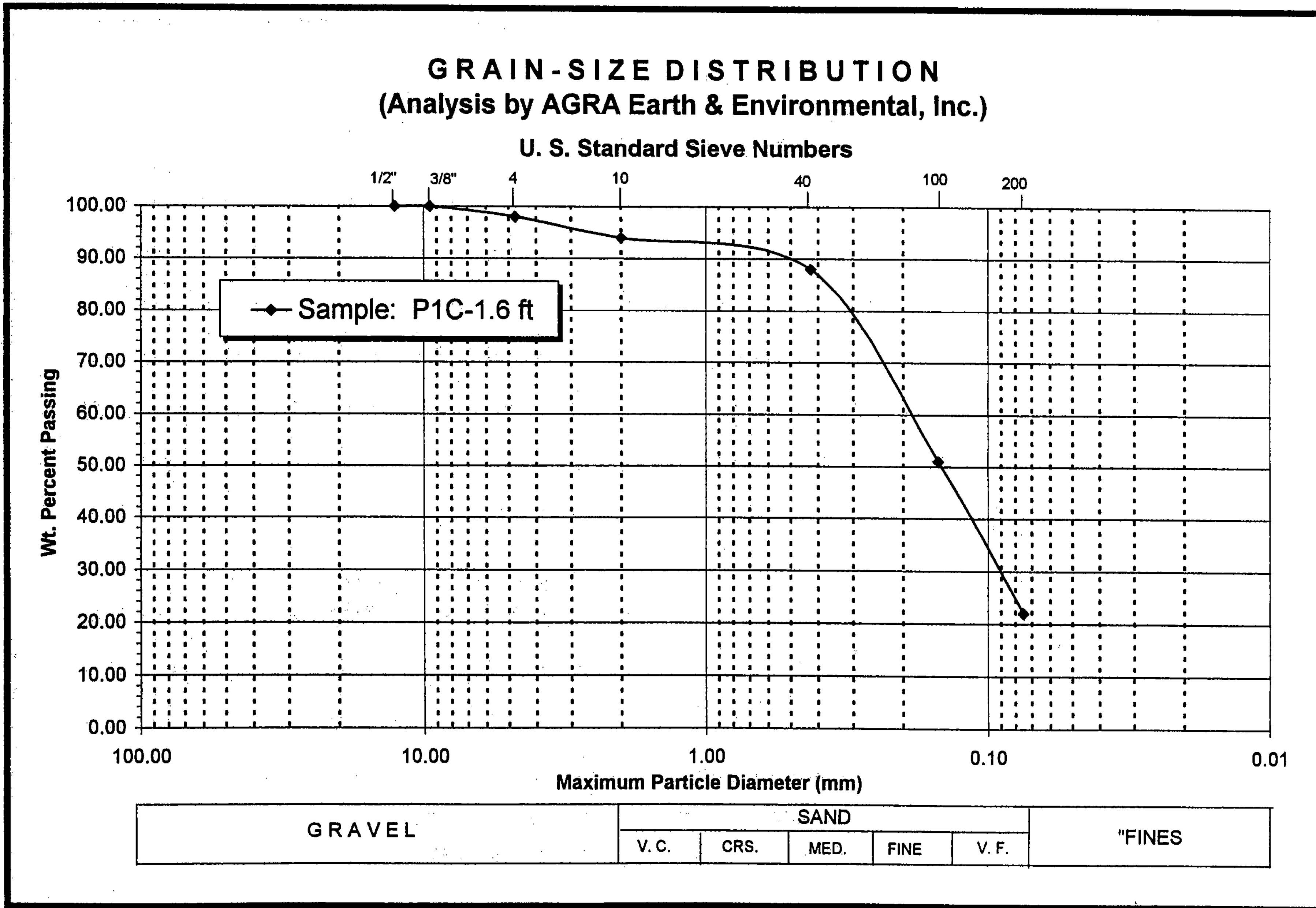
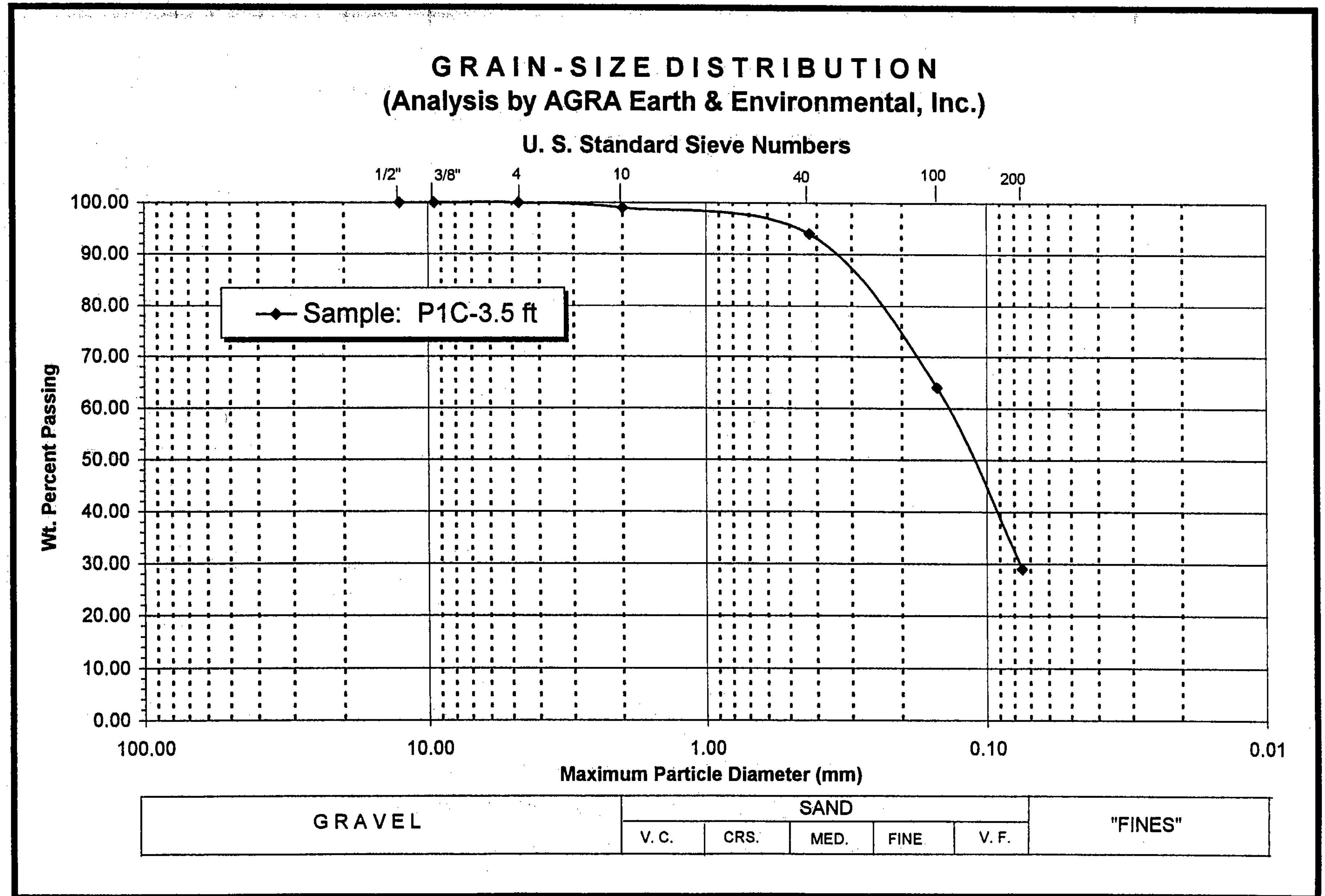
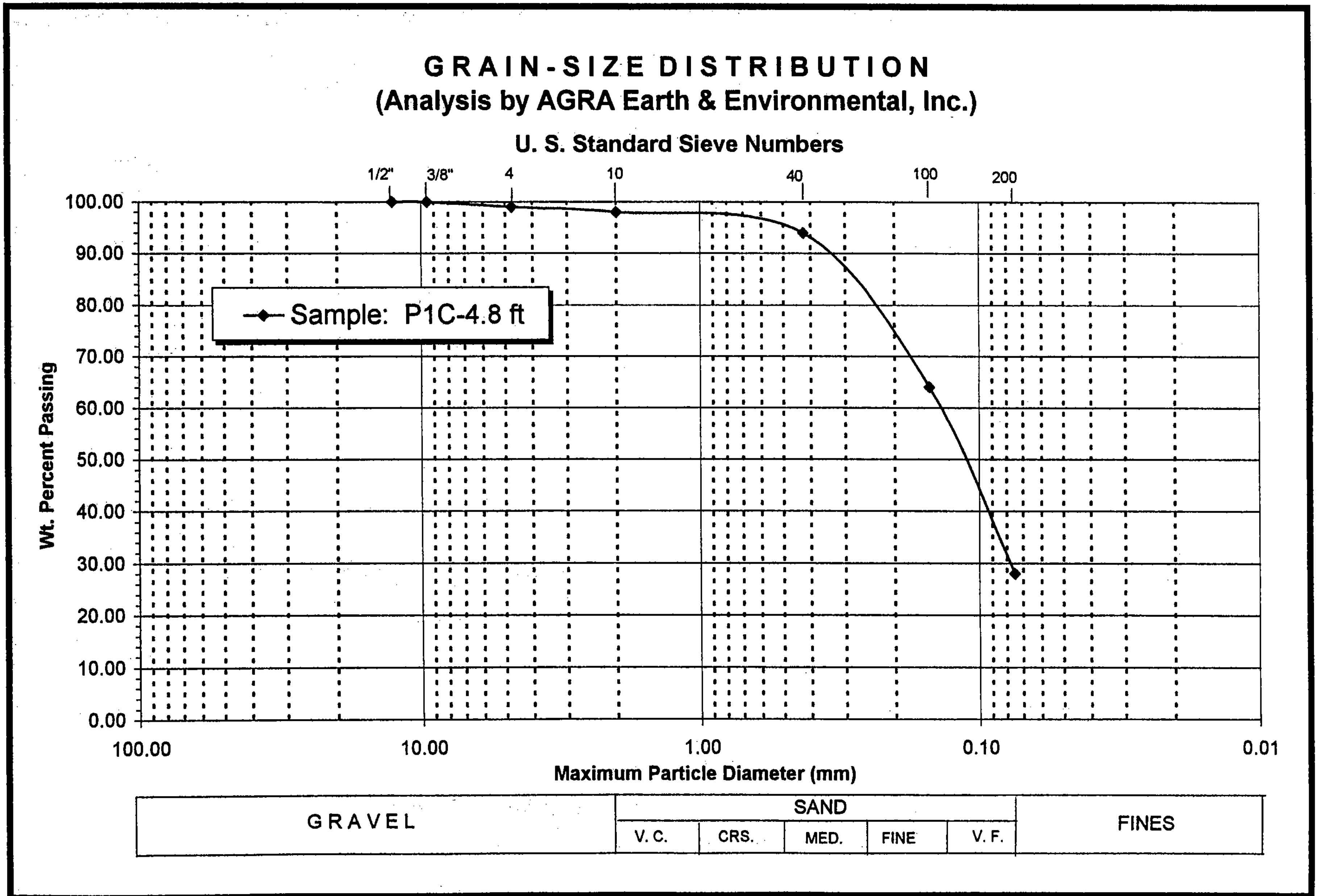

GRAIN-SIZE DISTRIBUTION
(Analysis by AGRA Earth & Environmental, Inc.)
U. S. Standard Sieve Numbers
1/2"
3/8"
4
10
40
100
200
Sample: P1C-1.6 ft
Wt. Percent Passing
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
100.00
10.00
1.00
0.10
0.01
Maximum Particle Diameter (mm)
GRAVEL
SAND
V. C.
CRS.
MED.
FINE
V. F.
"FINES


GRAIN-SIZE DISTRIBUTION
(Analysis by AGRA Earth & Environmental, Inc.)
U. S. Standard Sieve Numbers
1/2"
3/8"
4
10
40
100
200
Sample: P1C-3.5 ft
Wt. Percent Passing
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
100.00
10.00
1.00
0.10
0.01
Maximum Particle Diameter (mm)
GRAVEL
SAND
V. C.
CRS.
MED.
FINE
V. F.
"FINES"



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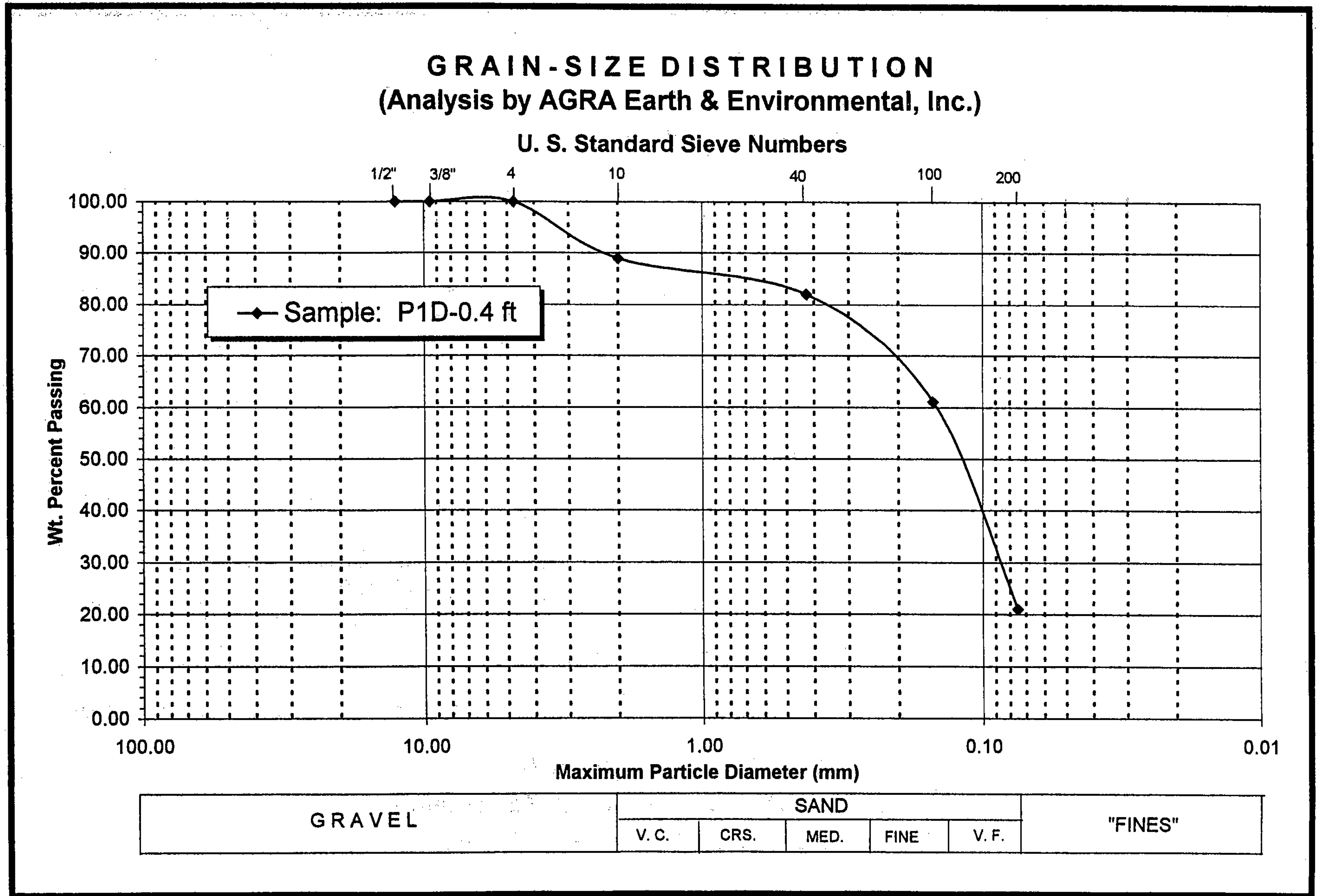

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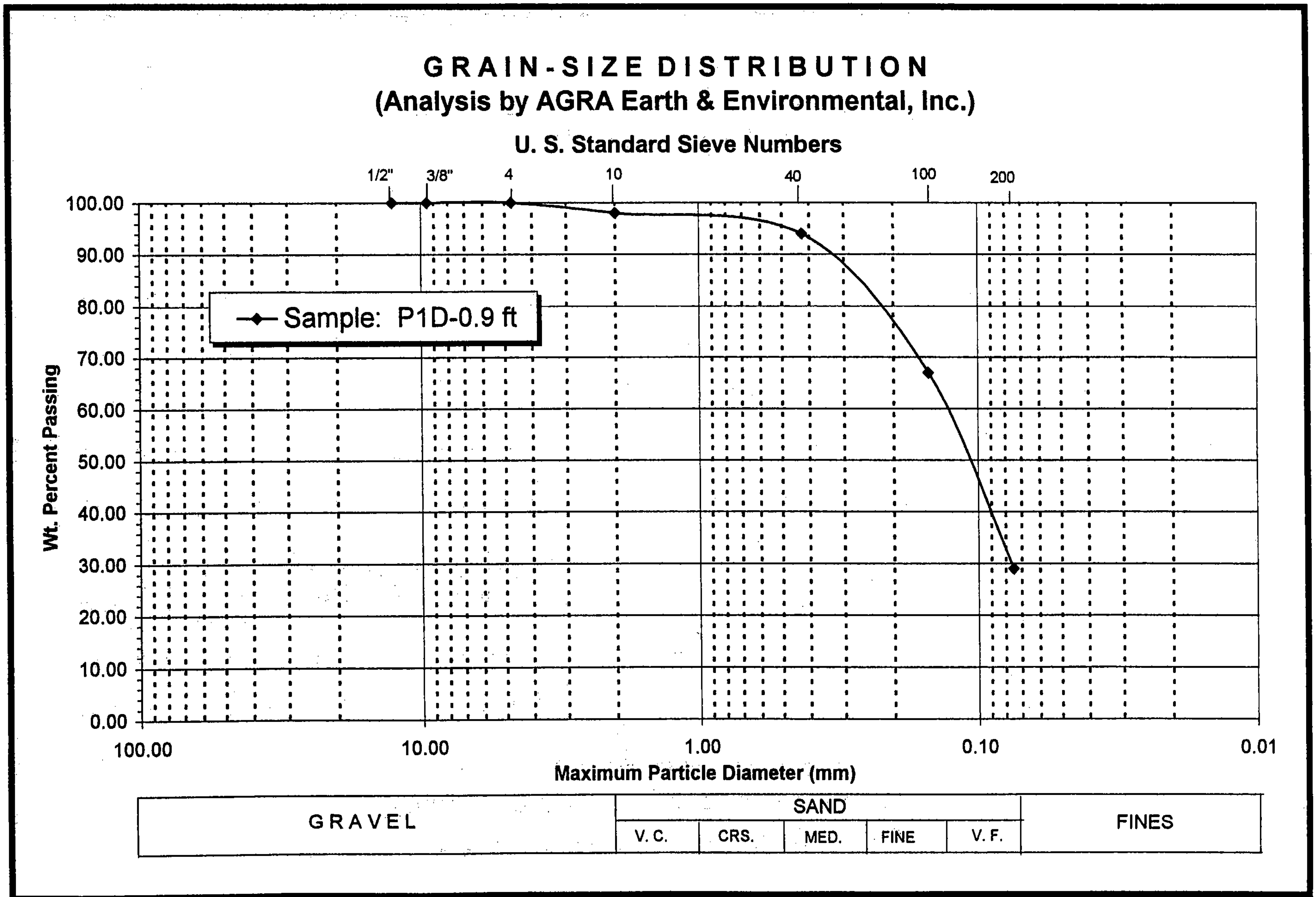

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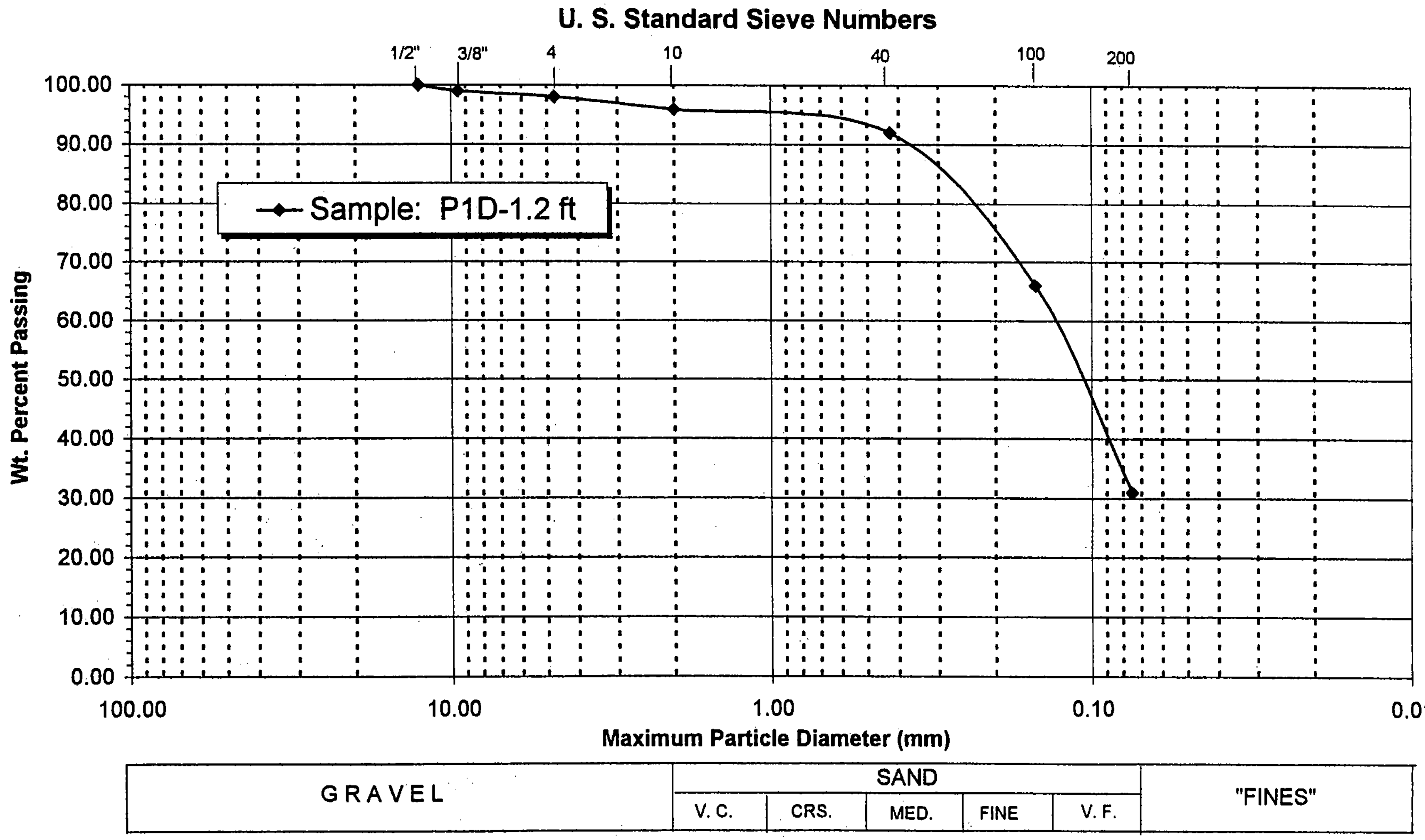

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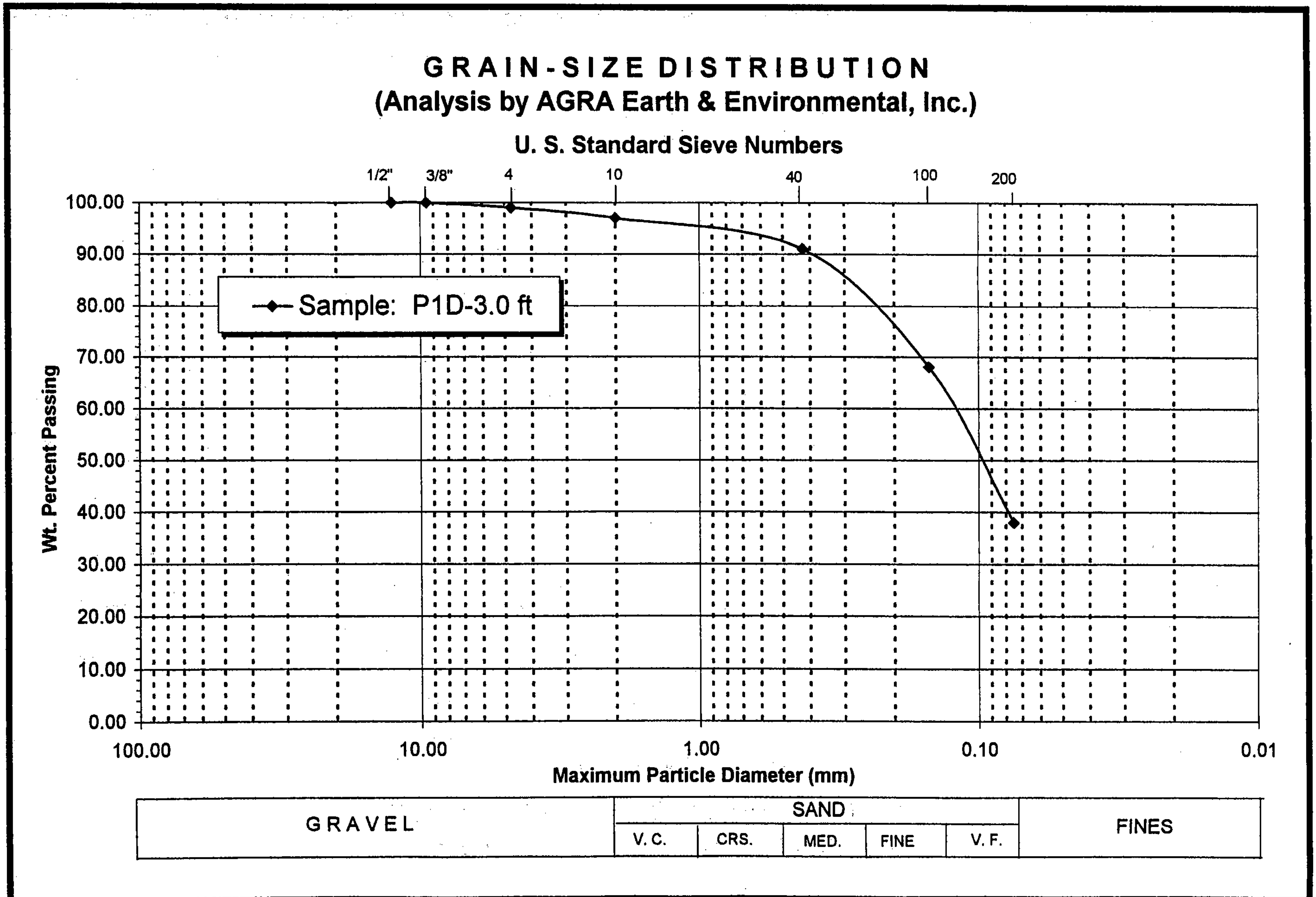
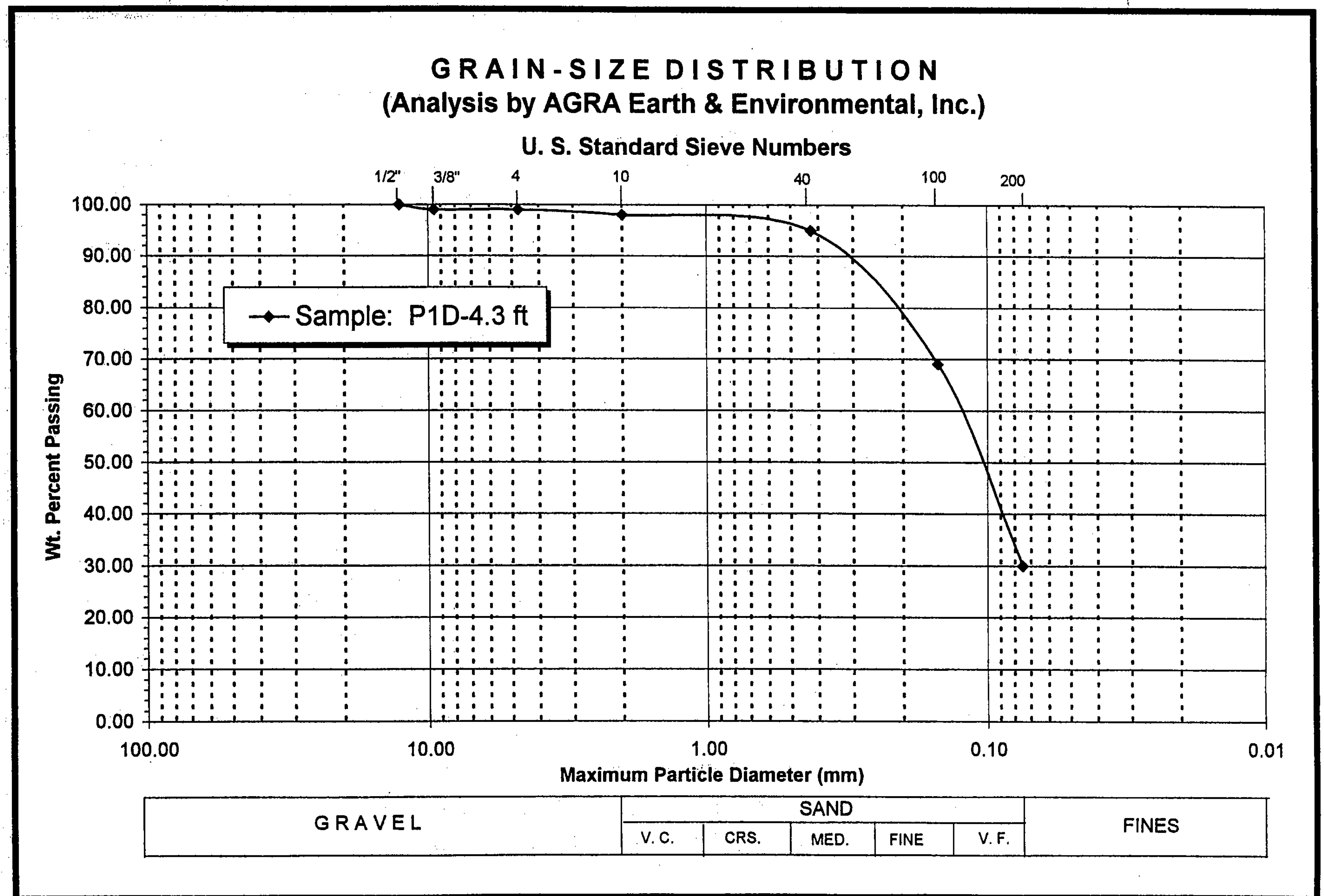
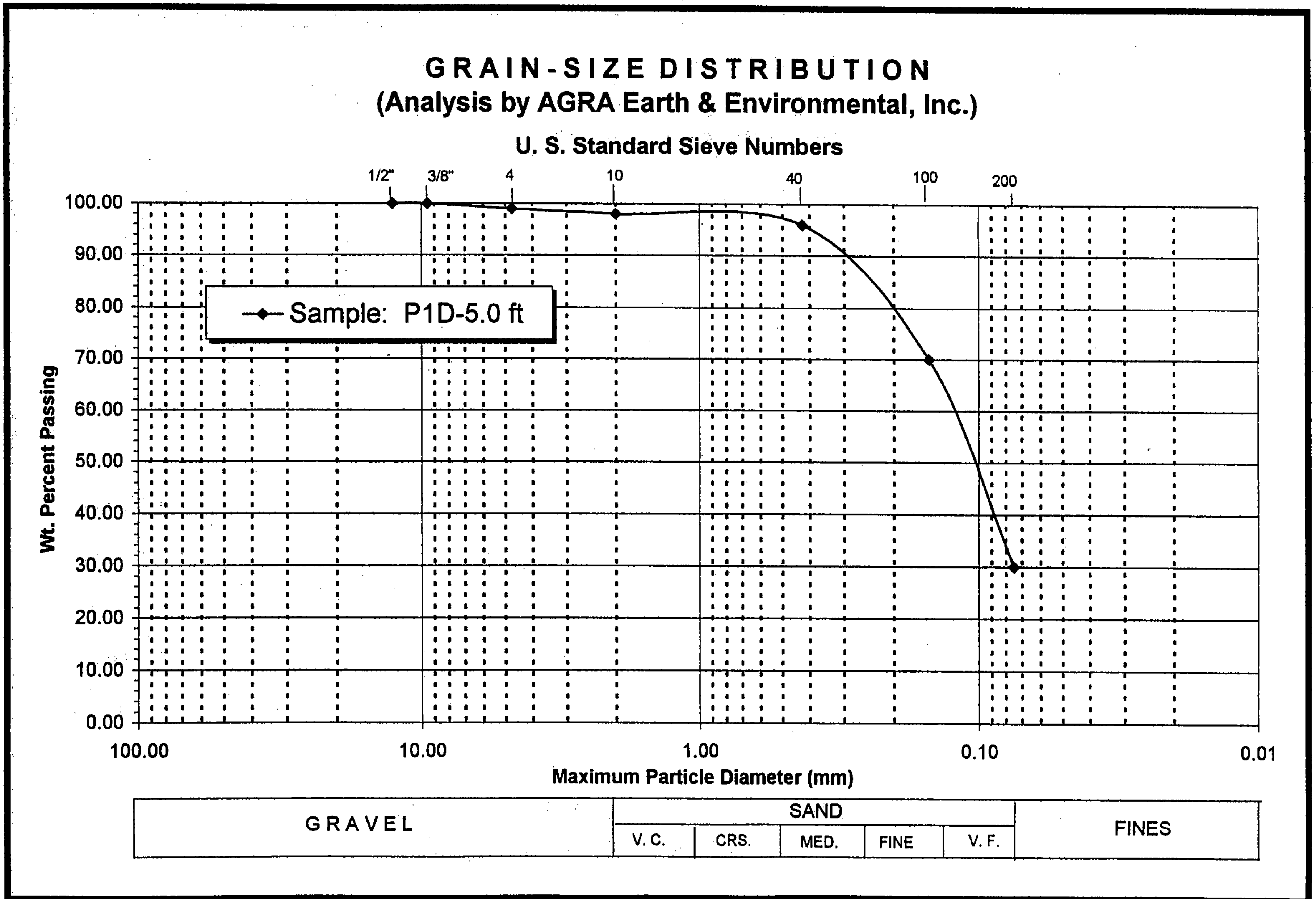

GRAIN-SIZE DISTRIBUTION
(Analysis by AGRA Earth & Environmental, Inc.)
U. S. Standard Sieve Numbers
1/2"
3/8"
4
10
40
100
200
Sample: P1D-3.0 ft
Wt. Percent Passing
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
100.00
10.00
1.00
0.10
0.01
Maximum Particle Diameter (mm)
GRAVEL
SAND
V. C.
CRS.
MED.
FINE
V. F.
FINES


GRAIN-SIZE DISTRIBUTION
(Analysis by AGRA Earth & Environmental, Inc.)
U. S. Standard Sieve Numbers
1/2"
3/8"
4
10
40
100
200
Sample: P1D-4.3 ft
Wt. Percent Passing
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
100.00
10.00
1.00
0.10
0.01
Maximum Particle Diameter (mm)
GRAVEL
SAND
V. C.
CRS.
MED.
FINE
V. F.
FINES



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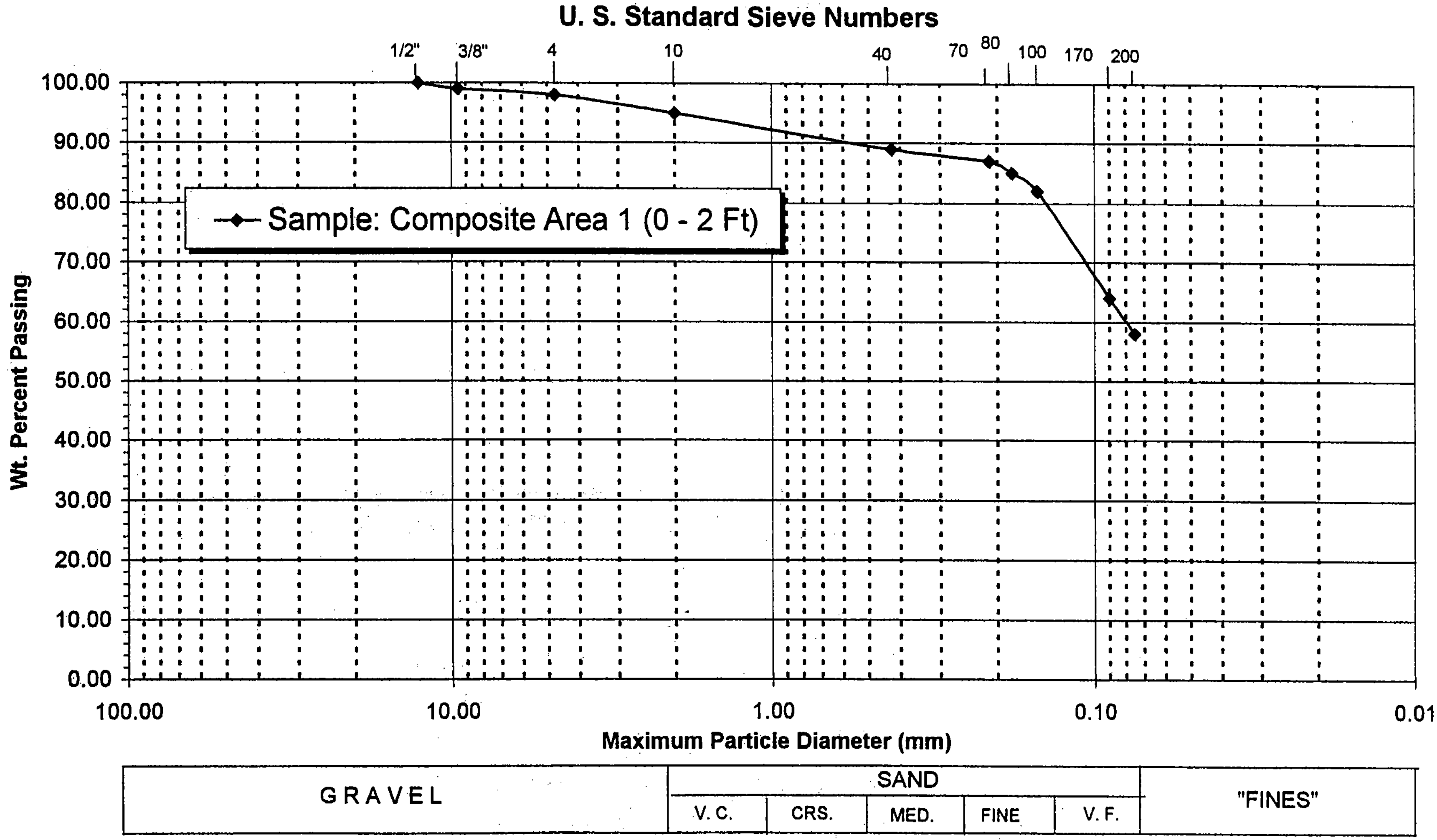

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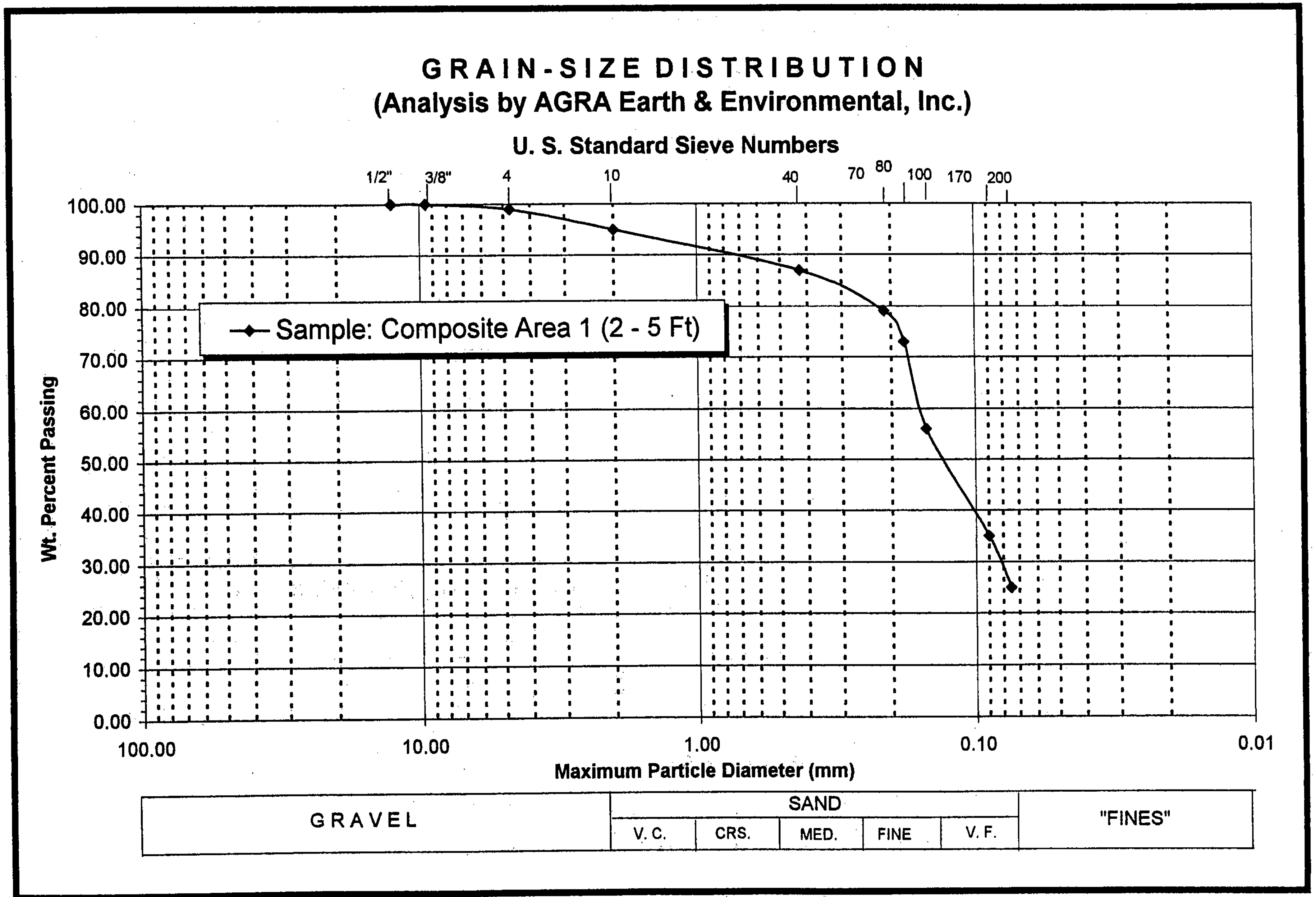

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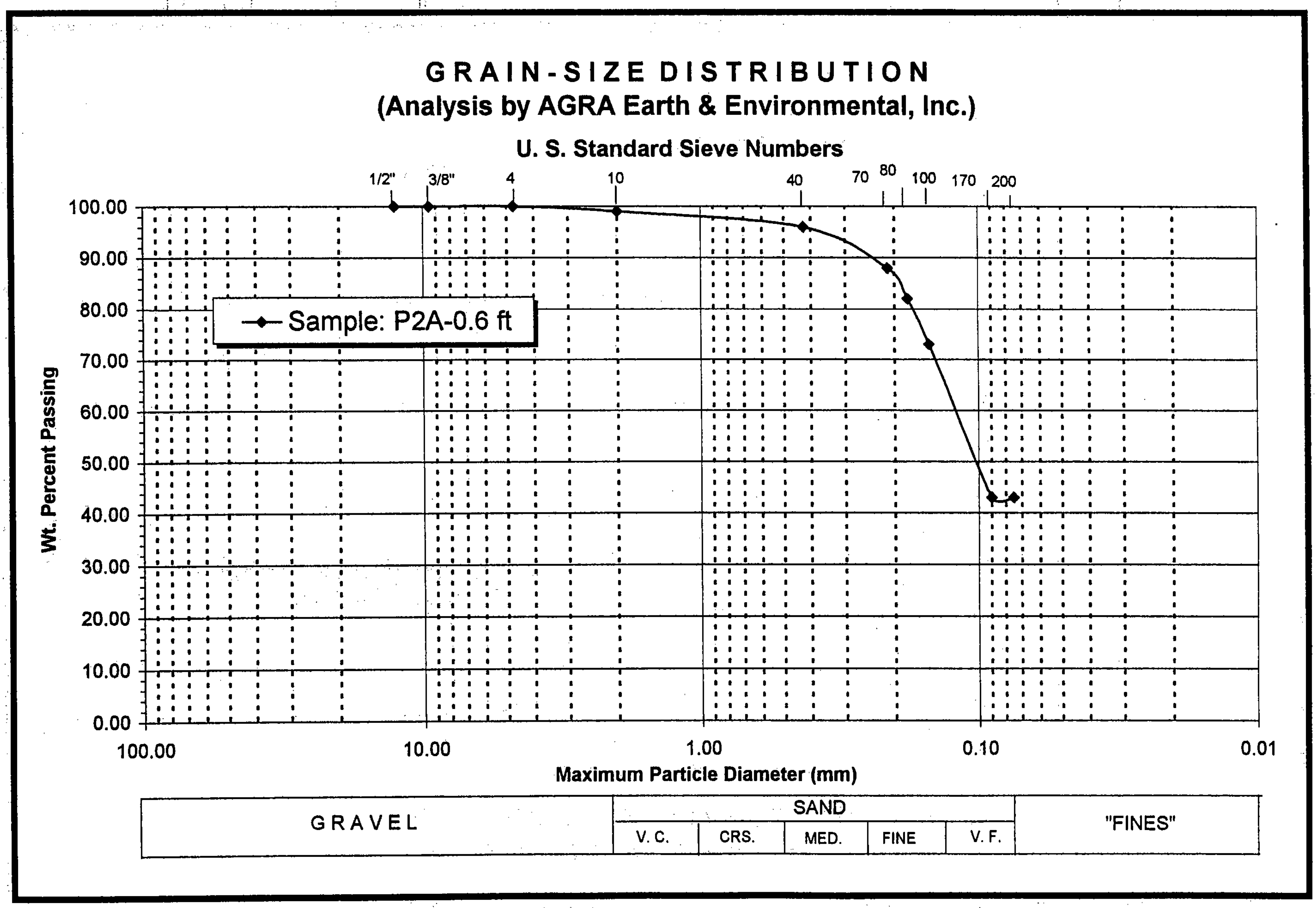

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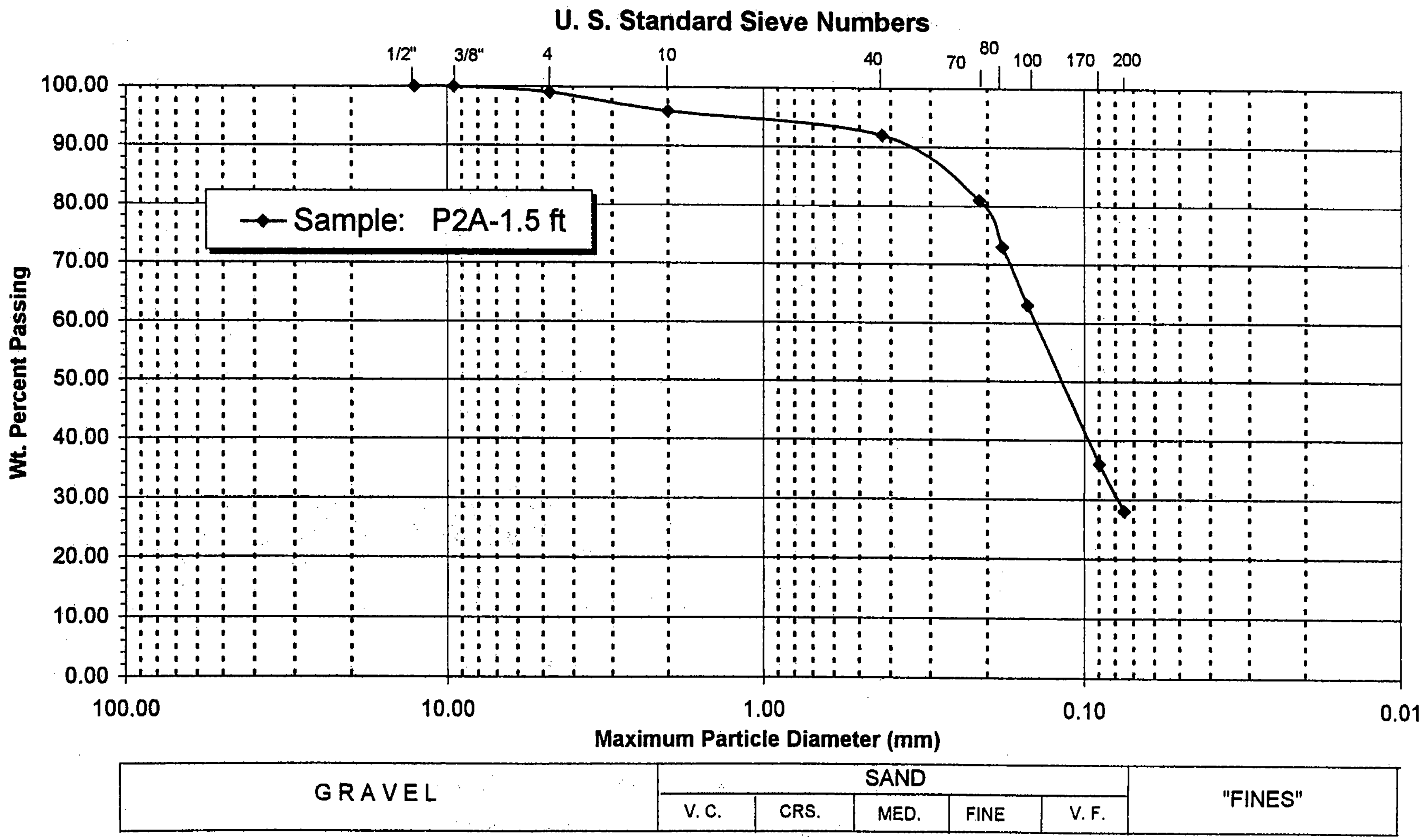

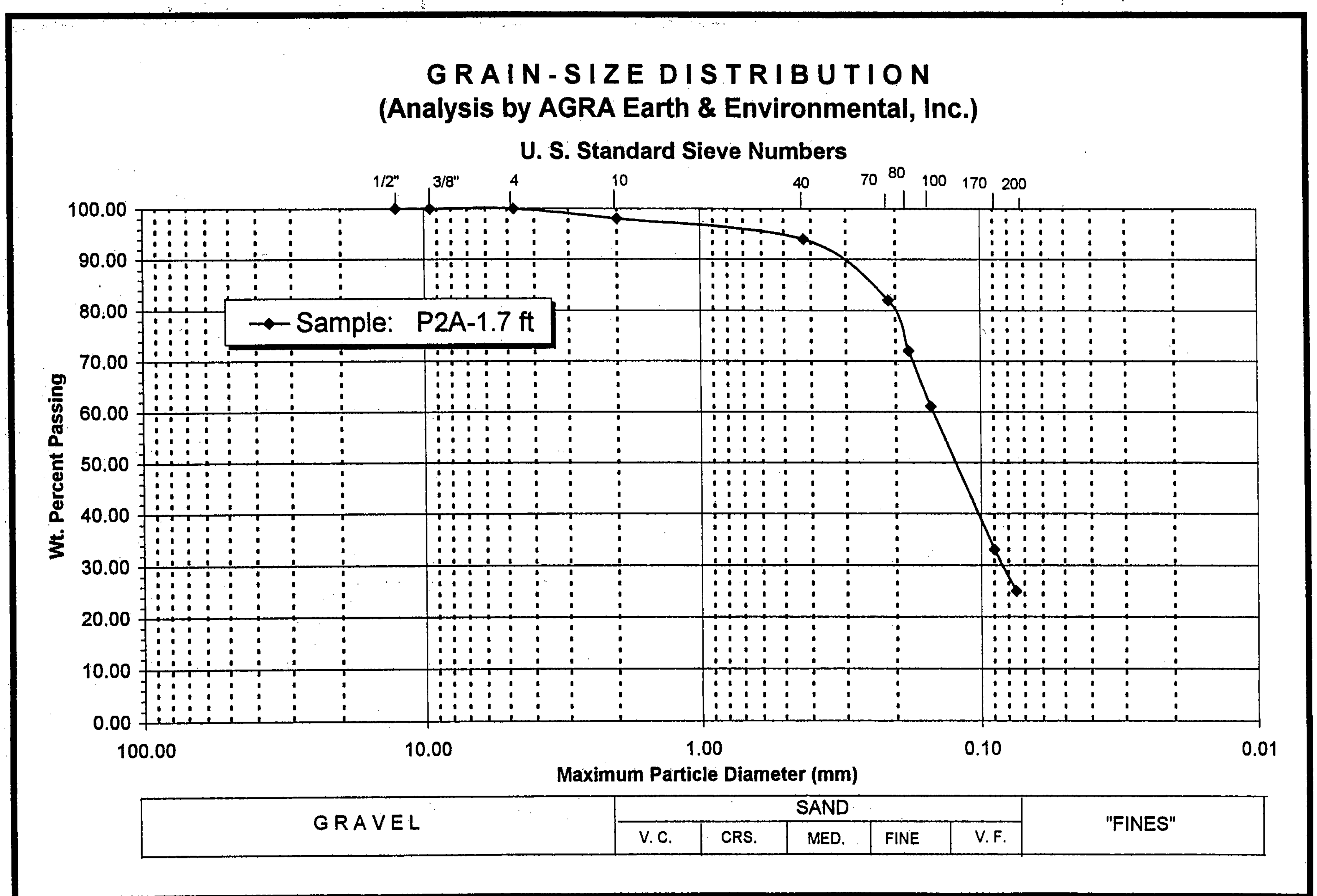

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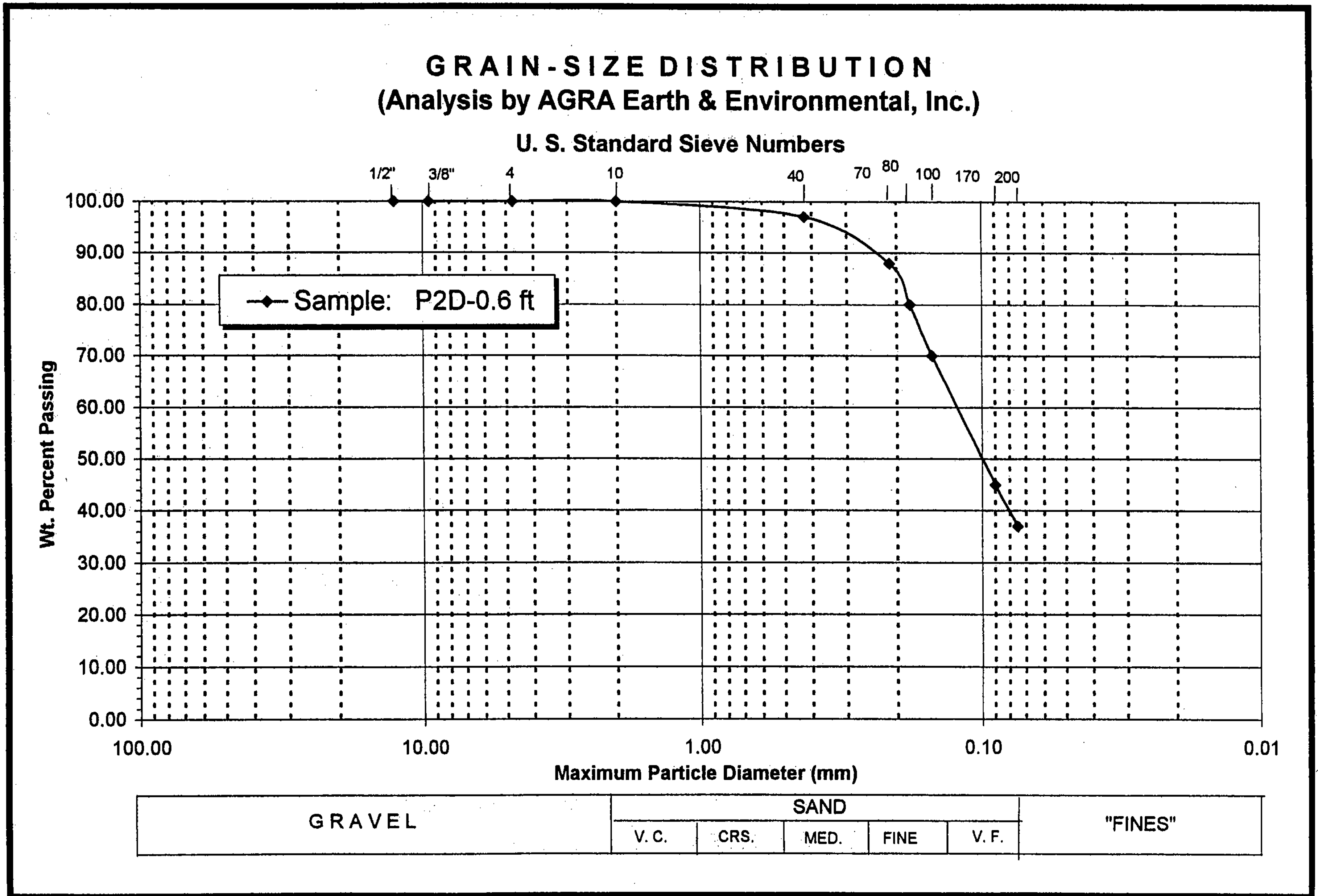

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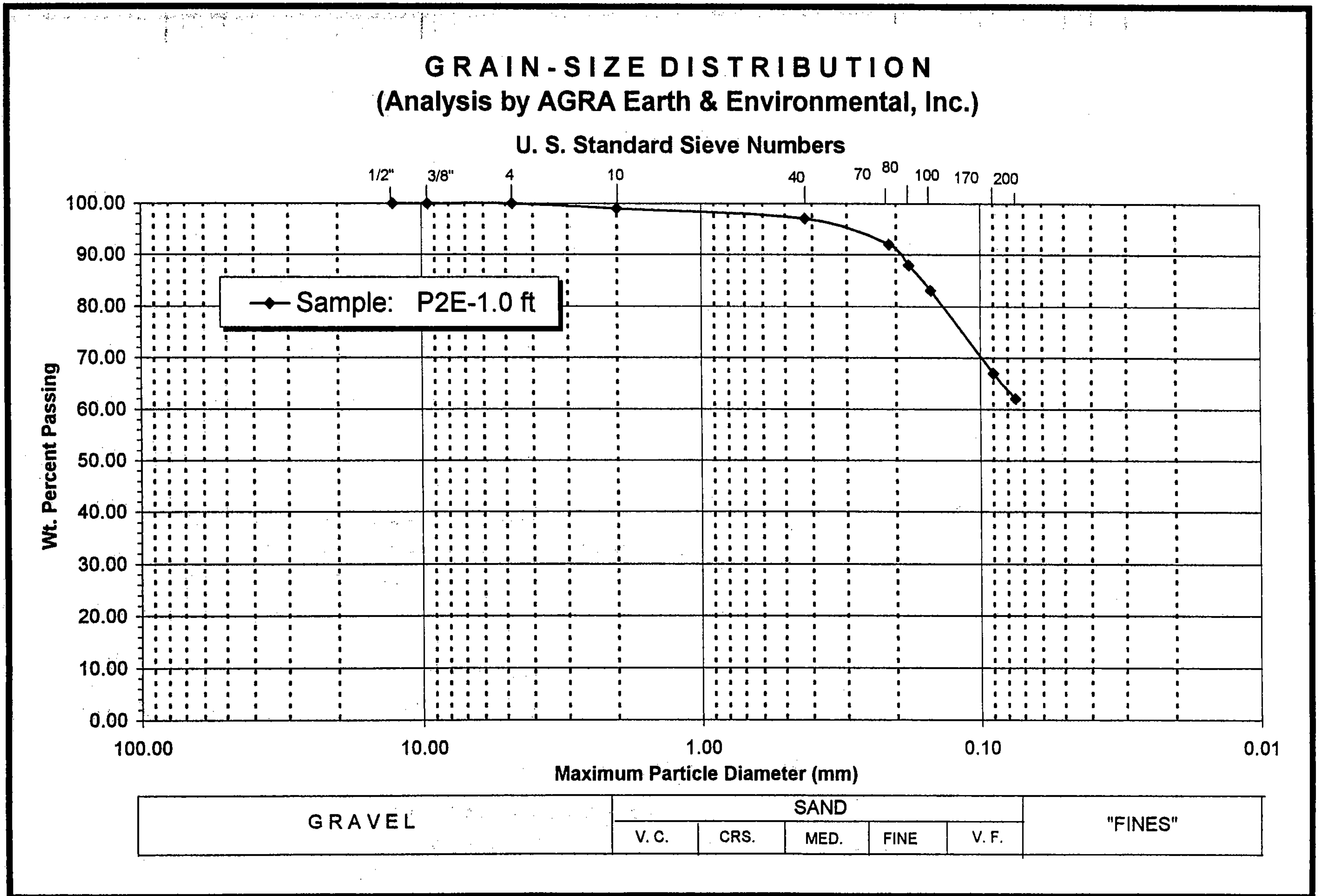

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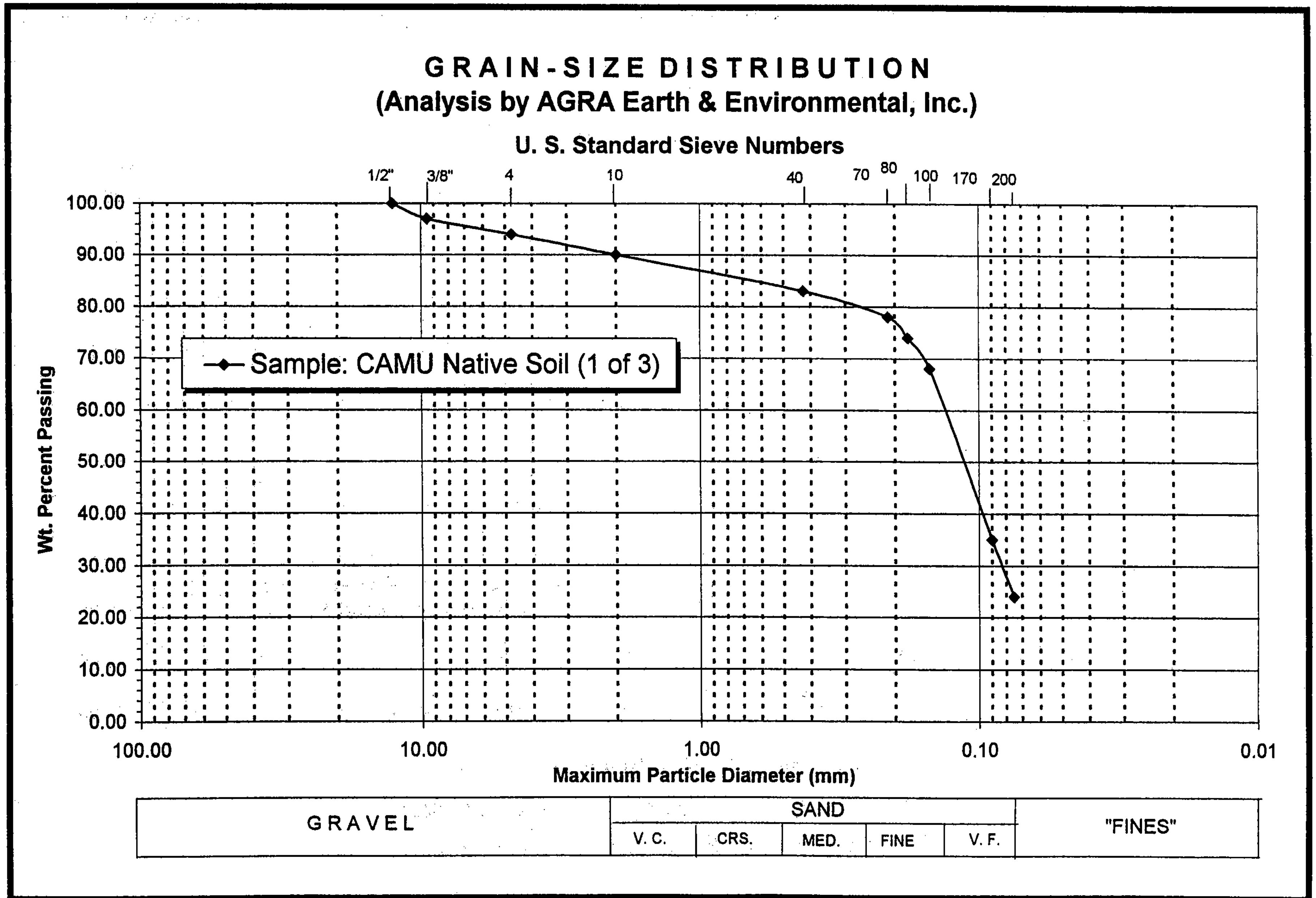

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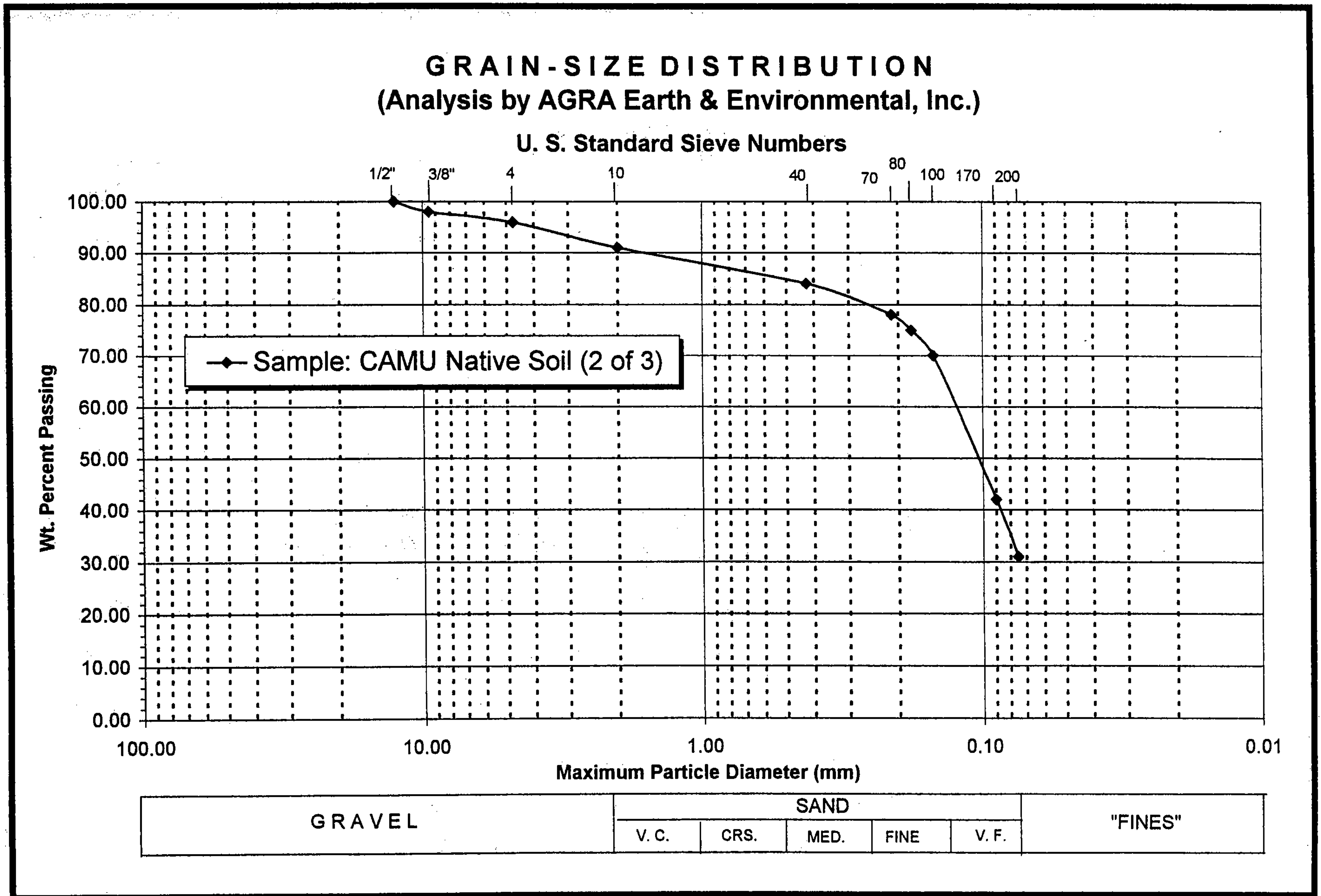

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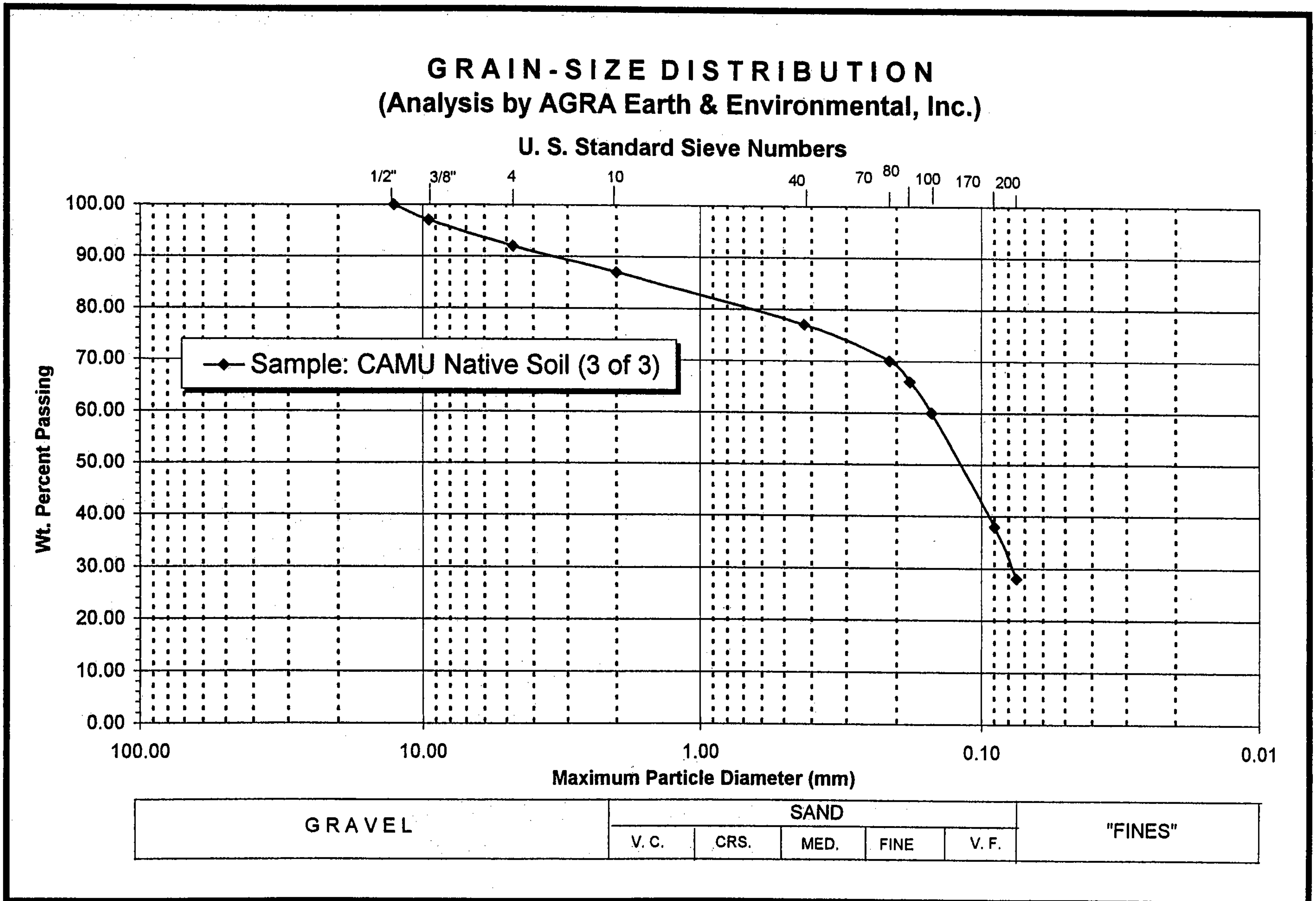
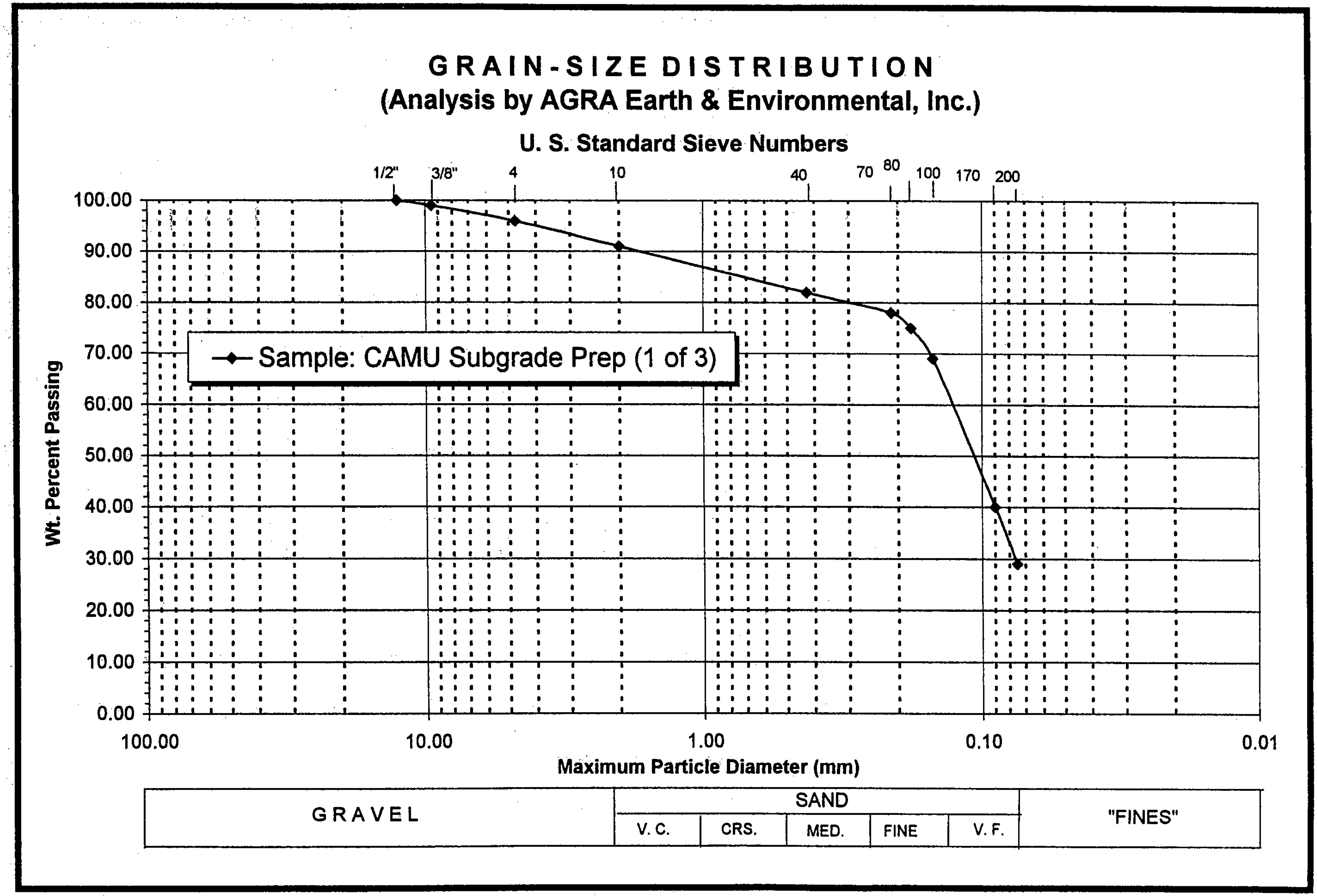

GRAIN-SIZE DISTRIBUTION
(Analysis by AGRA Earth & Environmental, Inc.)
U. S. Standard Sieve Numbers
1/2"
3/8"
4
10
40
70
80
100
170
200
Sample: CAMU Native Soil (3 of 3)
Wt. Percent Passing
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
100.00
10.00
1.00
0.10
0.01
Maximum Particle Diameter (mm)
GRAVEL
SAND
V. C.
CRS.
MED.
FINE
V. F.
"FINES"



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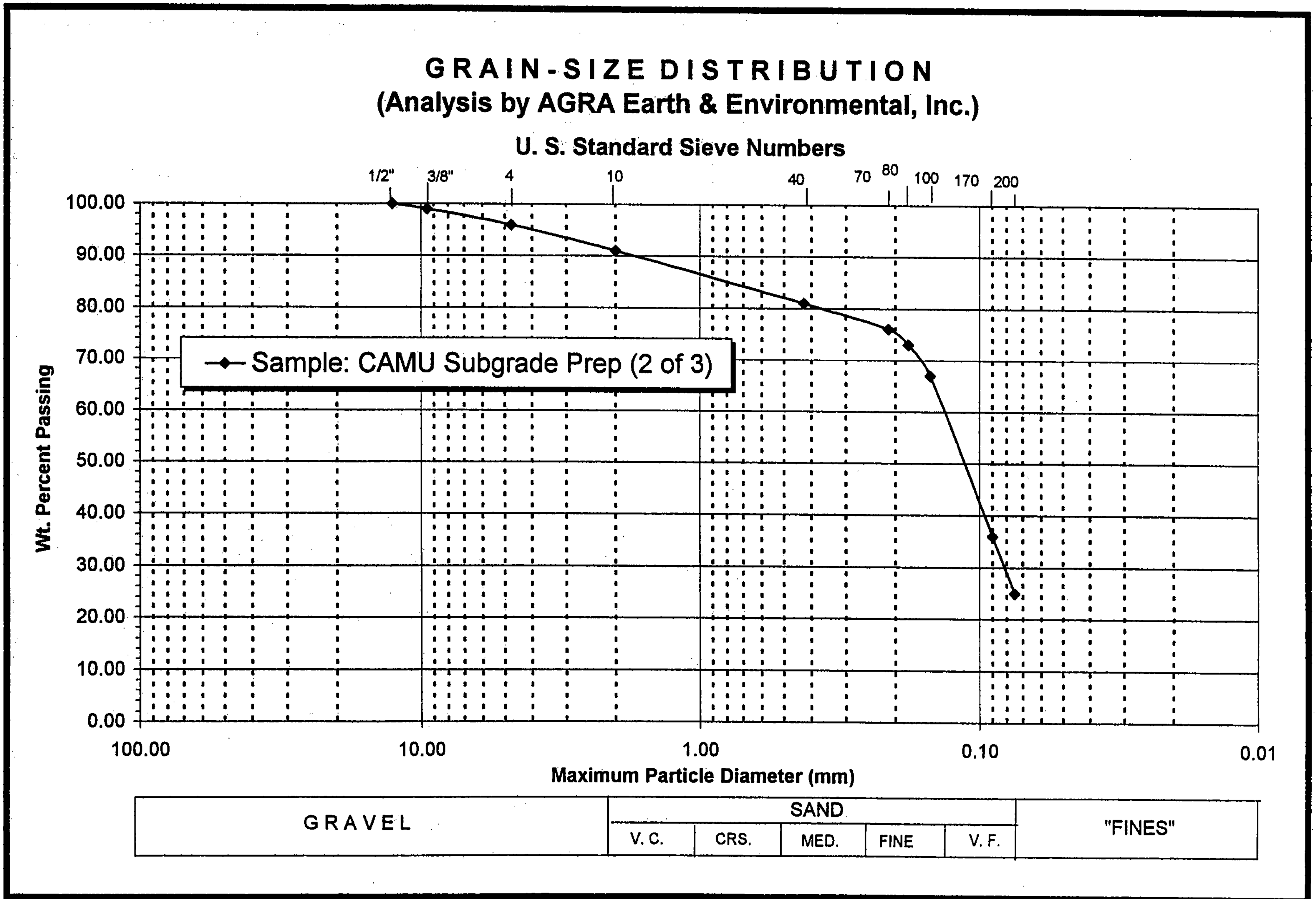

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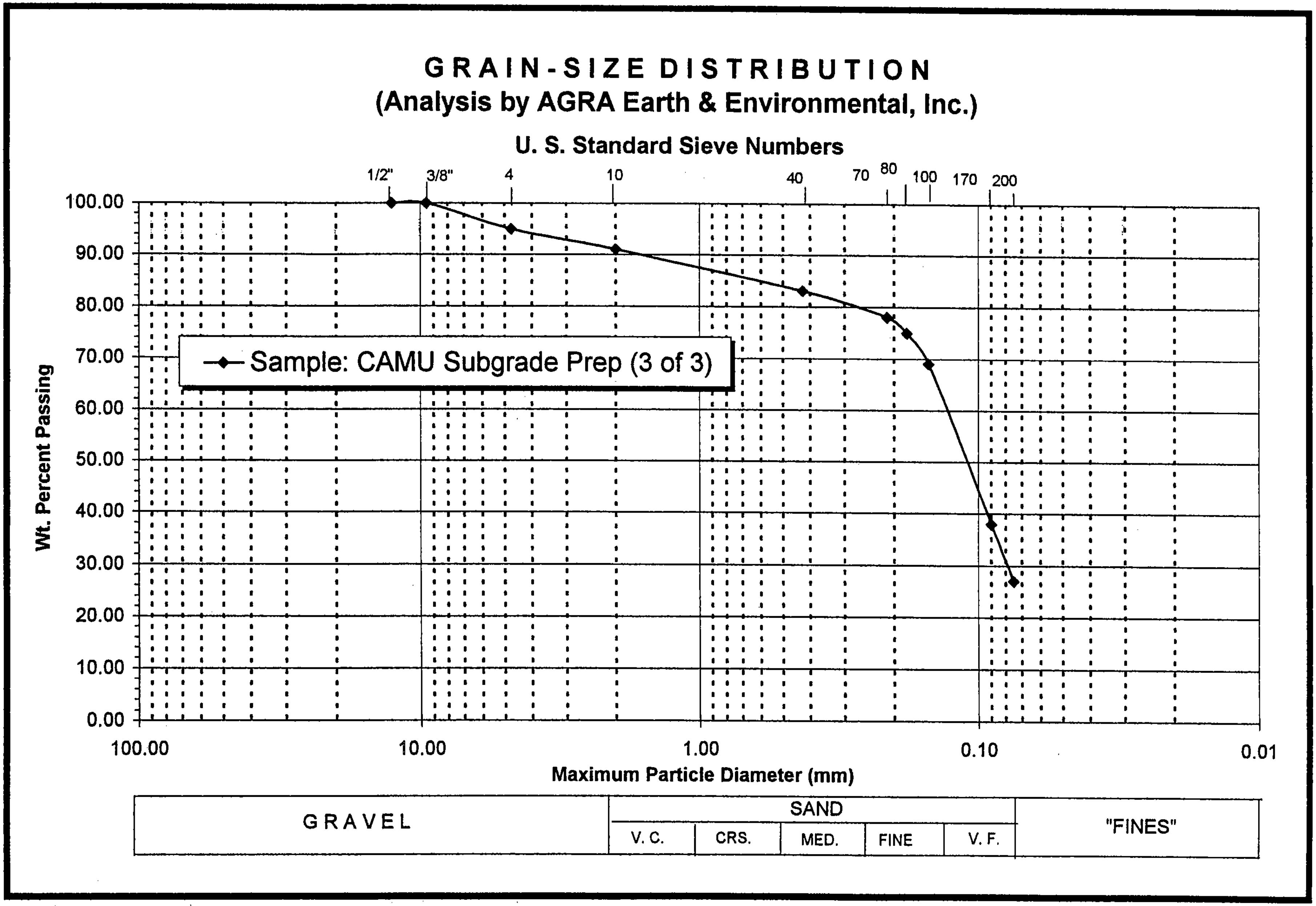

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Attachment F

Sediment-Density Measurements via Sand-Cone Method

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Sediment Densities via Sand-Cone Method

Test Sand: Ottawa 20-30 Silica Sand (1.645 g/cc)

Pit	Depth (ft)	Dry Sed. Wt. (g)	Net Sand in Test (g)	Sand Cap. of Cone (g) *	Net Sand in Hole (g)	Sediment Density (g/cc)	Sediment Density (lbs/cf)
P1A	0.1 - 0.5	834.79	2575.79	1738	837.79	1.64	102.40
P1A	0.3 - 0.6	1154.39	2855.53	1738	1117.53	1.70	106.16
P1A	0.5 - 0.7	804.43	2593.21	1738	855.21	1.55	96.67
P1A	0.7 - 0.9	608.20	2473.66	1738	735.66	1.36	84.96
P1A	0.8 - 1.0	651.45	2464.35	1738	726.35	1.48	92.17
P1A	1.0 - 1.2	776.22	2581.91	1738	843.91	1.51	94.53
P1A	1.2 - 1.4	823.68	2654.46	1738	916.46	1.48	92.37
P1A	1.4 - 1.6	732.79	2471.37	1738	733.37	1.64	102.69
P1A	1.7 - 1.9	780.51	2544.69	1738	806.69	1.59	99.44
P1A	1.9 - 2.1	769.42	2481.65	1738	743.65	1.70	106.33
P1A	2.1 - 2.3	698.28	2364.79	1738	626.79	1.83	114.49
P1A	2.3 - 2.5	727.29	2391.32	1738	653.32	1.83	114.41
P1A	2.5 - 2.7	822.37	2495.65	1738	757.65	1.79	111.55
P1A	2.7 - 2.9	753.94	2412.65	1738	674.65	1.84	114.85
P1D	0.6 - 0.9	1089.58	2890.19	1738	1152.19	1.56	97.19
P1D	0.9 - 1.2	852.01	2689.17	1738	951.17	1.47	92.06
P1D	0.6 - 0.9	757.70	2509.87	1744.98	764.89	1.63	101.80
P1D	0.85 - 1.1	791.23	2602.35	1757.18	845.17	1.54	96.21
P1D	1.1 - 1.3	707.72	2552.83	1783.27	769.56	1.51	94.51
P1D	1.3 - 1.55	778.35	2551.01	1709.21	841.80	1.52	95.02
P1D	1.55 - 1.8	870.10	2672.92	1780.56	892.36	1.60	100.21
P1D	1.85 - 2.15	881.77	2582.23	1704.00	878.23	1.65	103.19
P1D	2.2 - 2.5	1237.80	2773.29	1793.21	980.08	2.08	129.80
P2D	0.4 - 0.7	835.85	2619.17	1738	881.17	1.56	97.49
P2D	0.6 - 0.9	606.59	2423.96	1738	685.96	1.45	90.88
P2D	1.0 - 1.4	919.96	2875.73	1738	1137.73	1.33	83.10
P2D	1.4 - 1.8	1056.08	2807.16	1738	1069.16	1.62	101.51
P2D	1.6 - 1.8	814.23	2516.73	1738	778.73	1.72	107.46
P2D	1.8 - 2.0	721.22	2520.23	1738	782.23	1.52	94.76
P2D	2.0 - 2.2	891.52	2708.33	1738	970.33	1.51	94.42
P2D	2.2 - 2.4	756.03	2549.61	1738	811.61	1.53	95.73

Total measurements = 31

* 1738 g = average sand capacity of cones measured in field at 3 levels at Pit 1A.
Other capacities measured in field at indivual levels in Pit 1D prior to test.

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Attachment G

Standard Proctor Moisture-Density Plots (AGRA and Knight Piésold)

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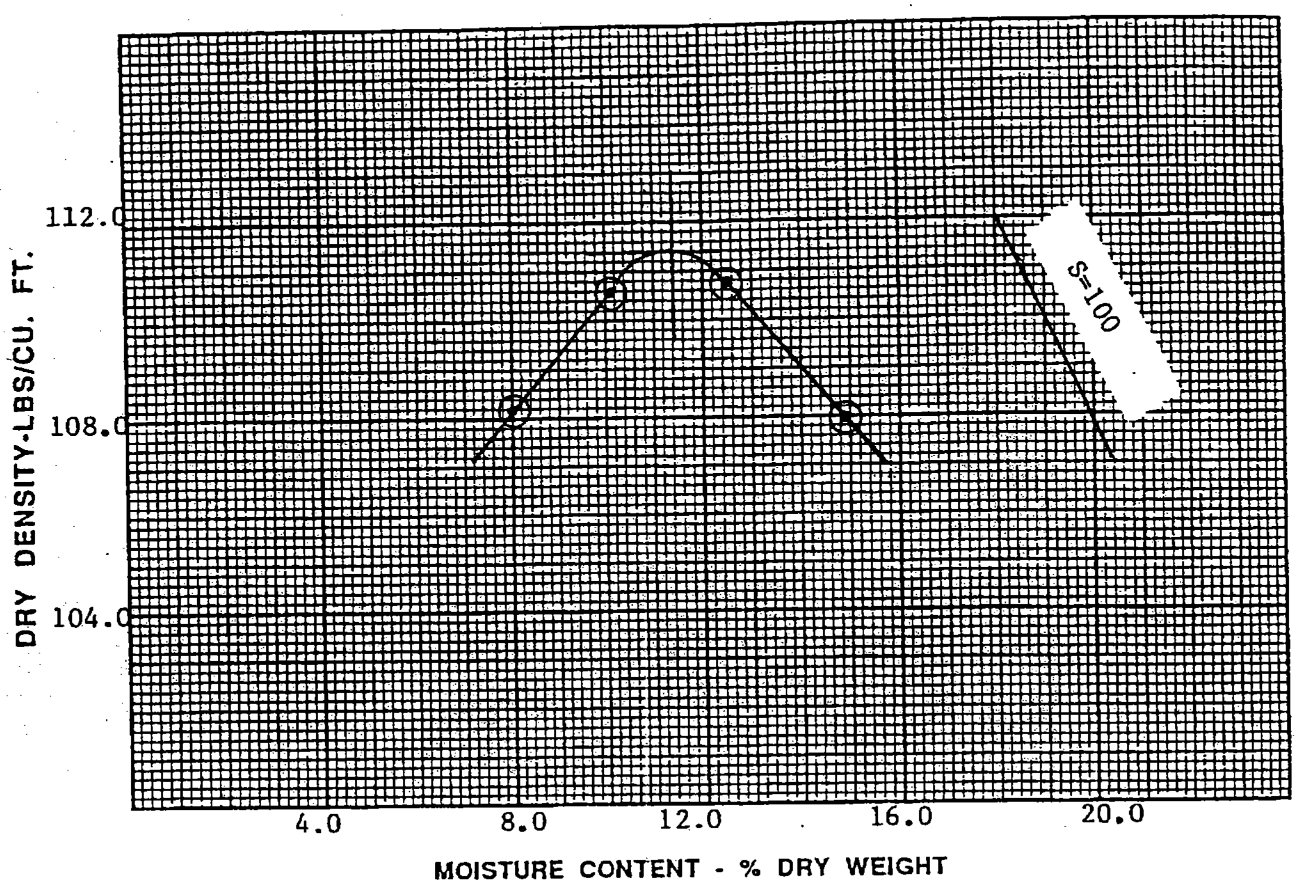
SUMMARY OF MOISTURE DENSITY RELATIONSHIP TESTS

PROJECT Mixed Waste Landfill Cover JOB NO. 9-519-001154



SOURCE	OPTIMUM MOISTURE CONTENT % DRY WT.	MAXIMUM DRY DENSITY LBS/CU. FT.	TEST DESIGNATION	TEST METHOD	LAB NO.
P1A @ 0.5'	11.4	~~114.4~~	D698	A	4454
		111.4			

MOISTURE-DENSITY RELATIONSHIP TEST METHOD DATA

ASTM D698 (Standard Proctor)

METHOD	MATERIAL	MOLD DIAMETER	MOLD HEIGHT	NO. OF LAYERS	BLOWS PER LAYER	HAMMER WEIGHT	HEIGHT OF FALL	COMPACTIVE EFFORT FT. LBS./CU. FT.
A	-#4	4"	4.58"	3	25	5.5 lbs	12"	12,375
B	-#4	4"	4.58"	3	25	5.5 lbs	12"	12,317
C	-3/4	6"	4.58"	3	56	5.5 lbs	12"	12,317

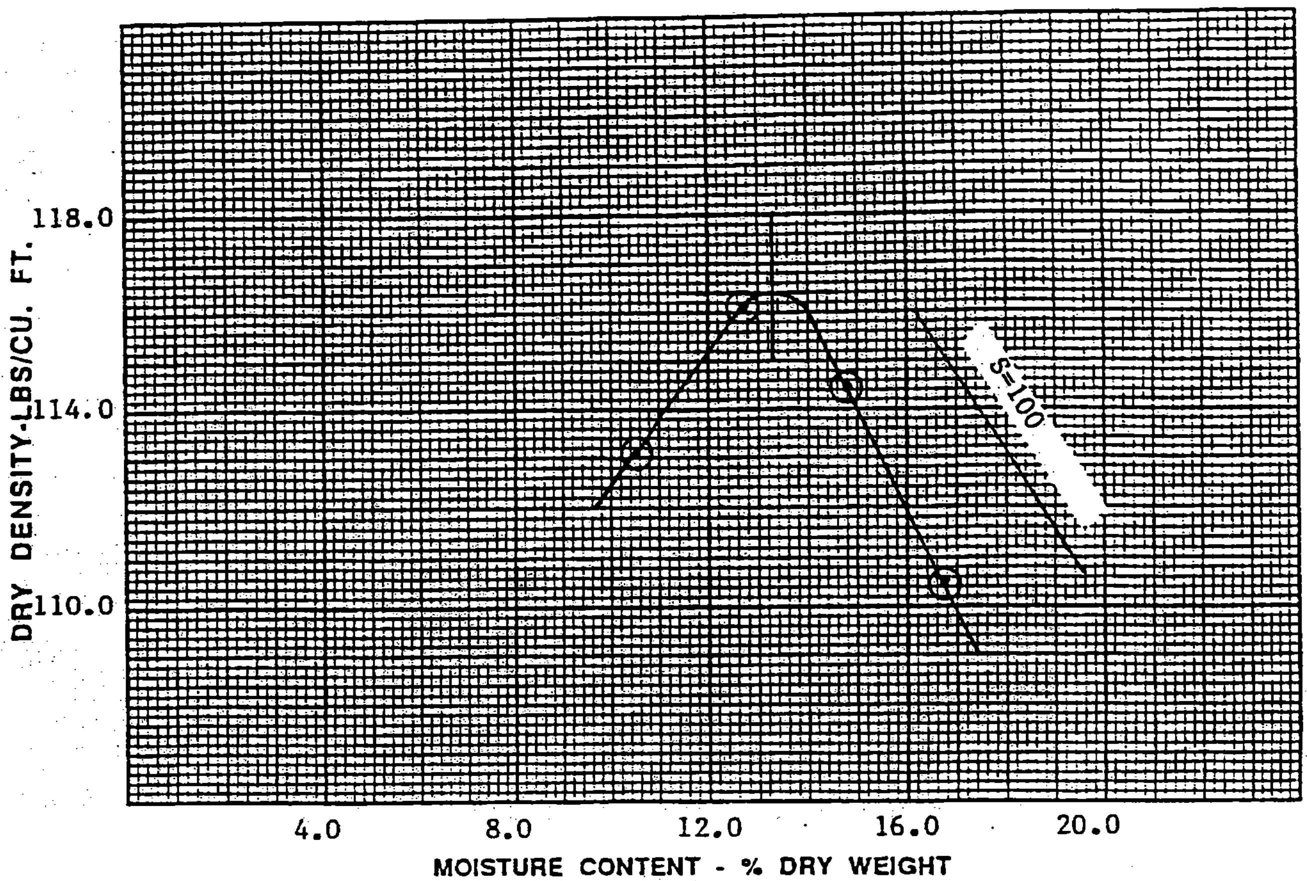
ASTM D1557 (Modified Proctor)

METHOD	MATERIAL	MOLD DIAMETER	MOLD HEIGHT	NO. OF LAYERS	BLOWS PER LAYER	HAMMER WEIGHT	HEIGHT OF FALL	COMPACTIVE EFFORT FT. LBS./CU. FT.
A	-#4	4"	4.58"	5	25	10.0 lbs	18"	56,250
B	-3/8	4"	4.58"	5	25	10.0 lbs	18"	55,986
C	-3/4	6"	4.58"	5	56	10.0 lbs	18"	55,986

AGRA

SUMMARY OF MOISTURE DENSITY RELATIONSHIP TESTS

PROJECT Mixed Waste Landfill Cover JOB NO. 9-519-001154



SOURCE	OPTIMUM MOISTURE CONTENT % DRY WT.	MAXIMUM DRY DENSITY LBS/CU. FT.	TEST DESIGNATION	TEST METHOD	LAB NO.
P1A @ 1.0'	13.3	116.4	D698	A	4455

MOISTURE-DENSITY RELATIONSHIP TEST METHOD DATA

ASTM D698 (Standard Proctor)

METHOD	MATERIAL	MOLD		NO. OF LAYERS	BLOWS PER LAYER	HAMMER WEIGHT	HEIGHT OF FALL	COMPACTIVE EFFORT FT. LBS./CU. FT.
		DIAMETER	HEIGHT					
A	-#4	4"	4.58"	3	25	5.5 lbs	12"	12,375
B	-#4	4"	4.58"	3	25	5.5 lbs	12"	12,317
C	-3/4	6"	4.58"	3	56	5.5 lbs	12"	12,317

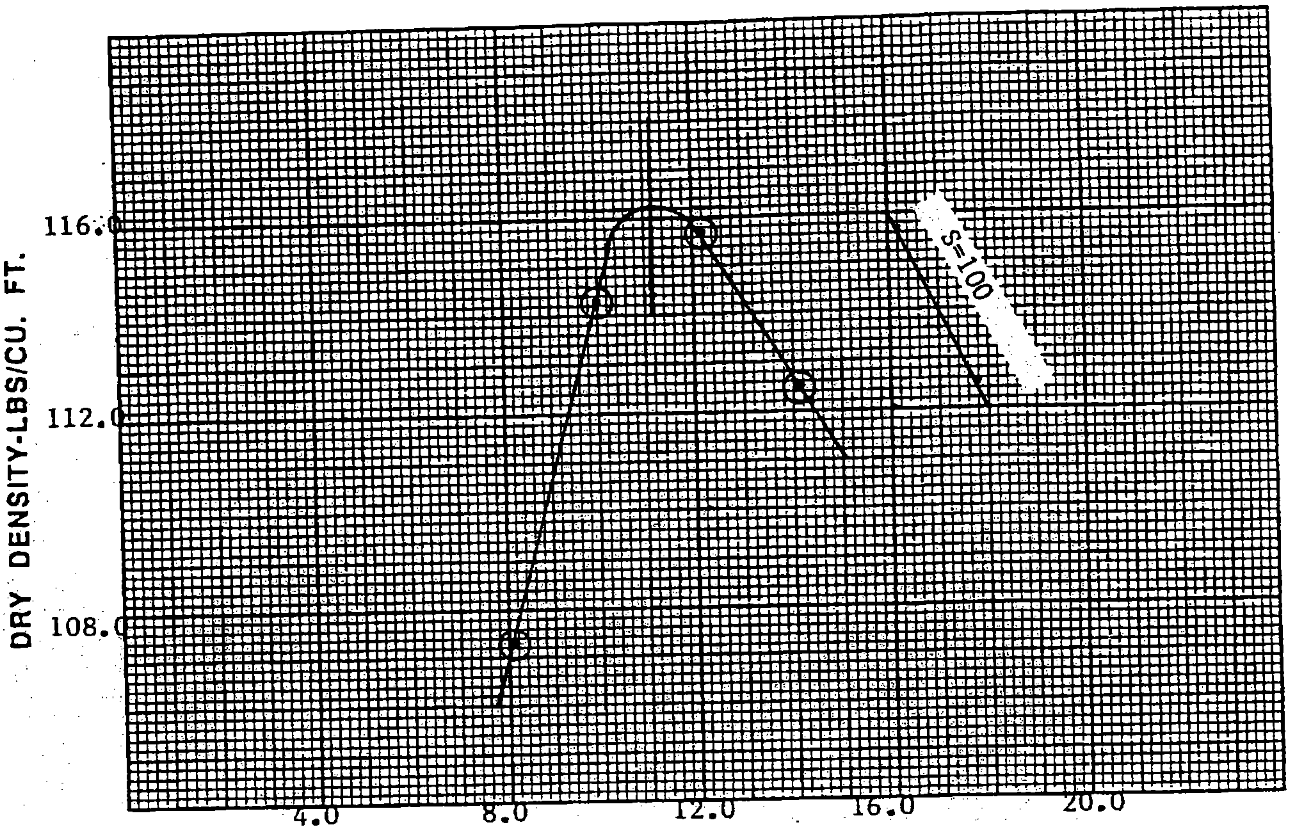
ASTM D1557 (Modified Proctor)

METHOD	MATERIAL	MOLD		NO. OF LAYERS	BLOWS PER LAYER	HAMMER WEIGHT	HEIGHT OF FALL	COMPACTIVE EFFORT FT. LBS./CU. FT.
		DIAMETER	HEIGHT					
A	-#4	4"	4.58"	5	25	10.0 lbs	18"	56,250
B	-3/8	4"	4.58"	5	25	10.0 lbs	18"	55,986
C	-3/4	6"	4.58"	5	56	10.0 lbs	18"	55,986

AGRA

SUMMARY OF MOISTURE DENSITY RELATIONSHIP TESTS

PROJECT Mixed Waste Landfill Cover JOB NO. 9-519-001154



SOURCE	OPTIMUM MOISTURE CONTENT % DRY WT.	MAXIMUM DRY DENSITY LBS/CU. FT.	TEST DESIGNATION	TEST METHOD	LAB NO.
P1A @ 2.0'	11.2	116.2	D698	A	4456

MOISTURE-DENSITY RELATIONSHIP TEST METHOD DATA

ASTM D698 (Standard Proctor)

METHOD	MATERIAL	MOLD DIAMETER	MOLD HEIGHT	NO. OF LAYERS	BLOWS PER LAYER	HAMMER WEIGHT	HEIGHT OF FALL	COMPACTIVE EFFORT FT. LBS./CU. FT.
A	-#4	4"	4.58"	3	25	5.5 lbs	12"	12,375
B	-#4	4"	4.58"	3	25	5.5 lbs	12"	12,317
C	-3/4	6"	4.58"	3	56	5.5 lbs	12"	12,317

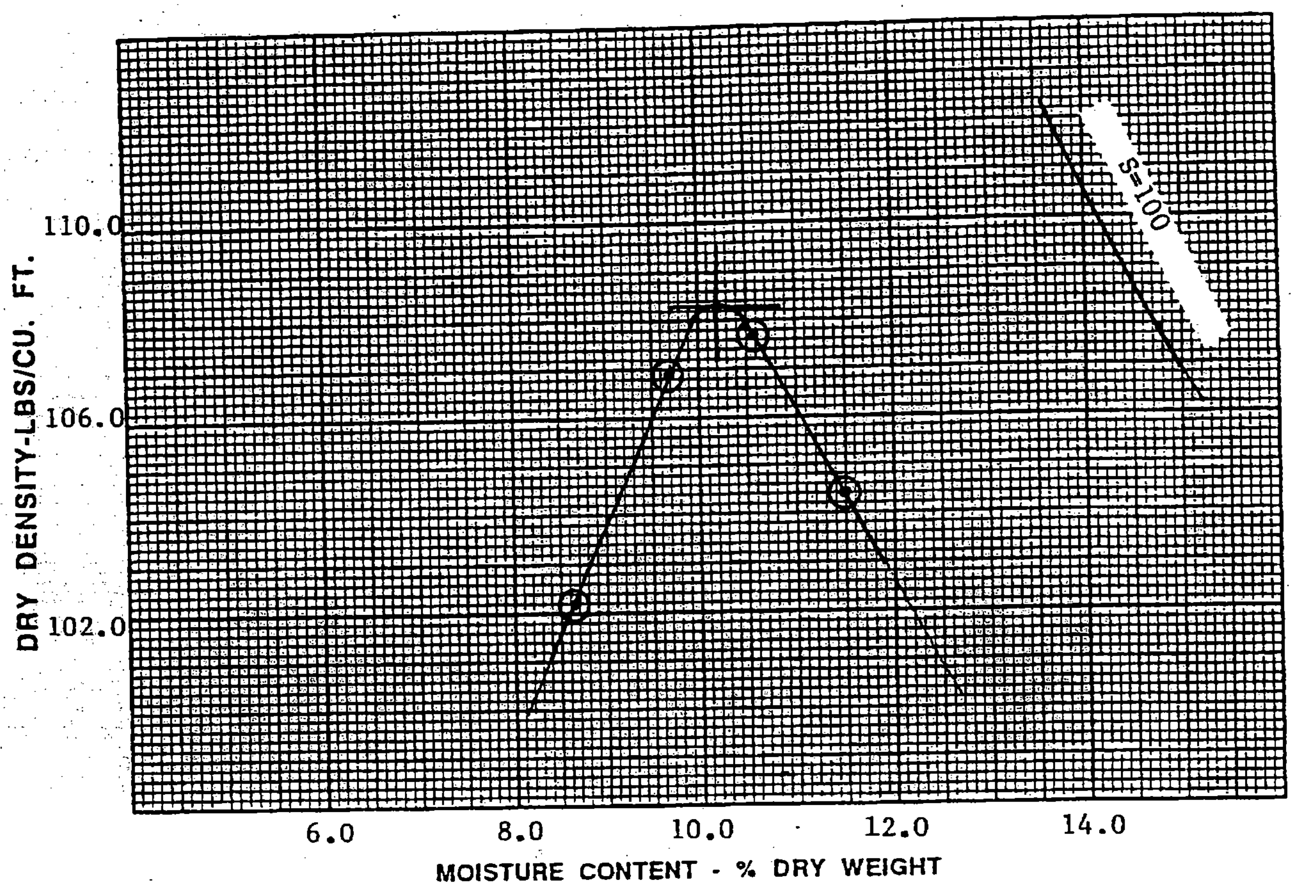
ASTM D1557 (Modified Proctor)

METHOD	MATERIAL	MOLD DIAMETER	MOLD HEIGHT	NO. OF LAYERS	BLOWS PER LAYER	HAMMER WEIGHT	HEIGHT OF FALL	COMPACTIVE EFFORT FT. LBS./CU. FT.
A	-#4	4"	4.58"	5	25	10.0 lbs	18"	56,250
B	-3/8	4"	4.58"	5	25	10.0 lbs	18"	55,986
C	-3/4	6"	4.58"	5	56	10.0 lbs	18"	55,986

AGRA

SUMMARY OF MOISTURE DENSITY RELATIONSHIP TESTS

PROJECT Mixed Waste Landfill Cover JOB NO. 9-519-001154



SOURCE	OPTIMUM MOISTURE CONTENT % DRY WT.	MAXIMUM DRY DENSITY LBS/CU. FT.	TEST DESIGNATION	TEST METHOD	LAB NO.
P1A @ 2.6'	10.4	108.3	D698	A	4457

MOISTURE-DENSITY RELATIONSHIP TEST METHOD DATA

ASTM D698 (Standard Proctor)

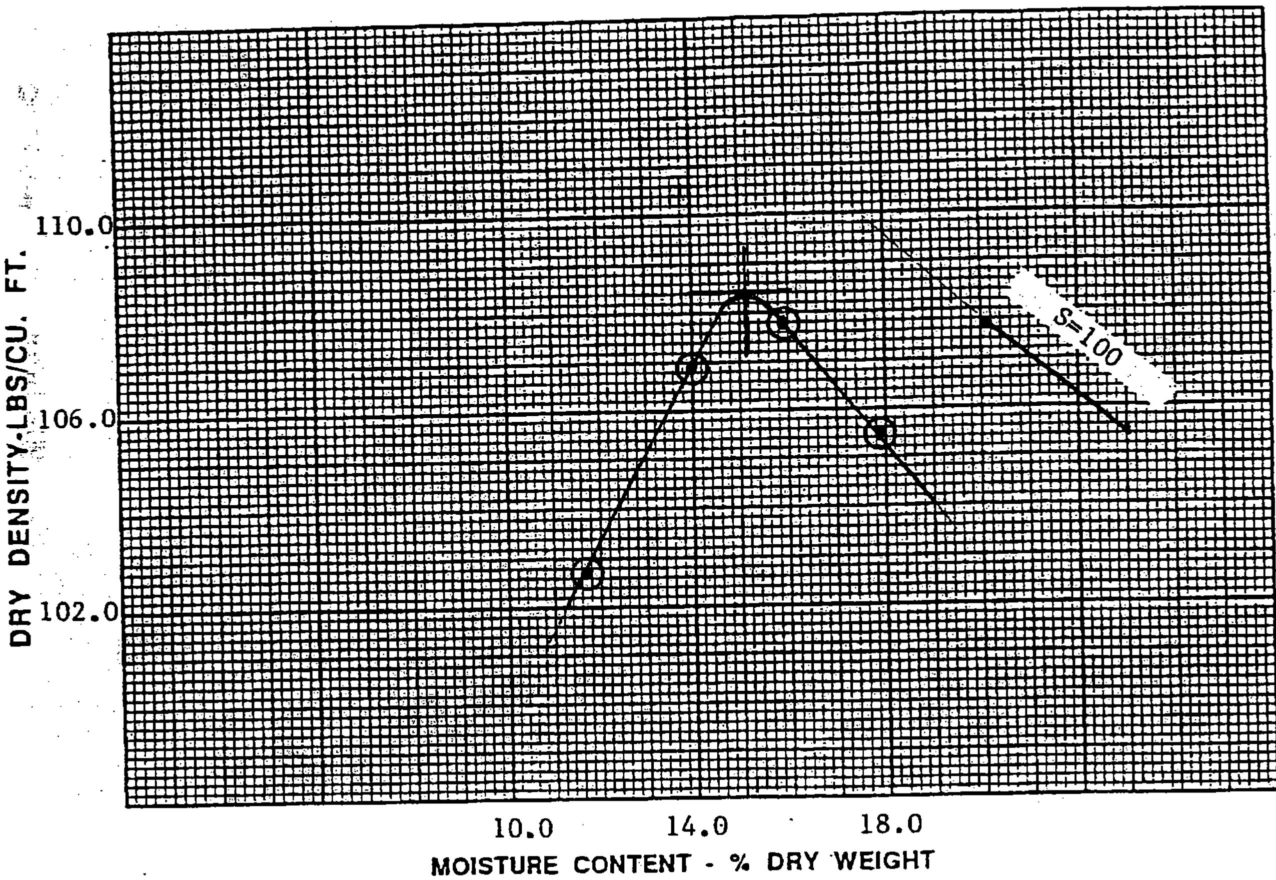
METHOD	MATERIAL	MOLD		NO. OF LAYERS	BLOWS PER LAYER	HAMMER WEIGHT	HEIGHT OF FALL	COMPACTIVE EFFORT FT. LBS./CU. FT.
		DIAMETER	HEIGHT					
A	-#4	4"	4.58"	3	25	5.5 lbs	12"	12,375
B	-#4	4"	4.58"	3	25	5.5 lbs	12"	12,317
C	-3/4	6"	4.58"	3	56	5.5 lbs	12"	12,317

ASTM D1557 (Modified Proctor)

METHOD	MATERIAL	MOLD		NO. OF LAYERS	BLOWS PER LAYER	HAMMER WEIGHT	HEIGHT OF FALL	COMPACTIVE EFFORT FT. LBS./CU. FT.
		DIAMETER	HEIGHT					
A	-#4	4"	4.58"	5	25	10.0 lbs	18"	56,250
B	-3/8	4"	4.58"	5	25	10.0 lbs	18"	55,986
C	-3/4	6"	4.58"	5	56	10.0 lbs	18"	55,986

SUMMARY OF MOISTURE DENSITY RELATIONSHIP TESTS

PROJECT Mixed Waste Landfill Cover JOB NO. 9-519-001154



SOURCE	OPTIMUM MOISTURE CONTENT % DRY WT.	MAXIMUM DRY DENSITY LBS/CU. FT.	TEST DESIGNATION	TEST METHOD	LAB NO.
P1A @ 3.6'	15.1	108.4	D698	A	4458

MOISTURE-DENSITY RELATIONSHIP TEST METHOD DATA

ASTM D698 (Standard Proctor)

METHOD	MATERIAL	MOLD DIAMETER	MOLD HEIGHT	NO. OF LAYERS	BLOWS PER LAYER	HAMMER WEIGHT	HEIGHT OF FALL	COMPACTIVE EFFORT FT. LBS./CU. FT.
A	-#4	4"	4.58"	3	25	5.5 lbs	12"	12,375
B	-#4	4"	4.58"	3	25	5.5 lbs	12"	12,317
C	-3/4	6"	4.58"	3	56	5.5 lbs	12"	12,317

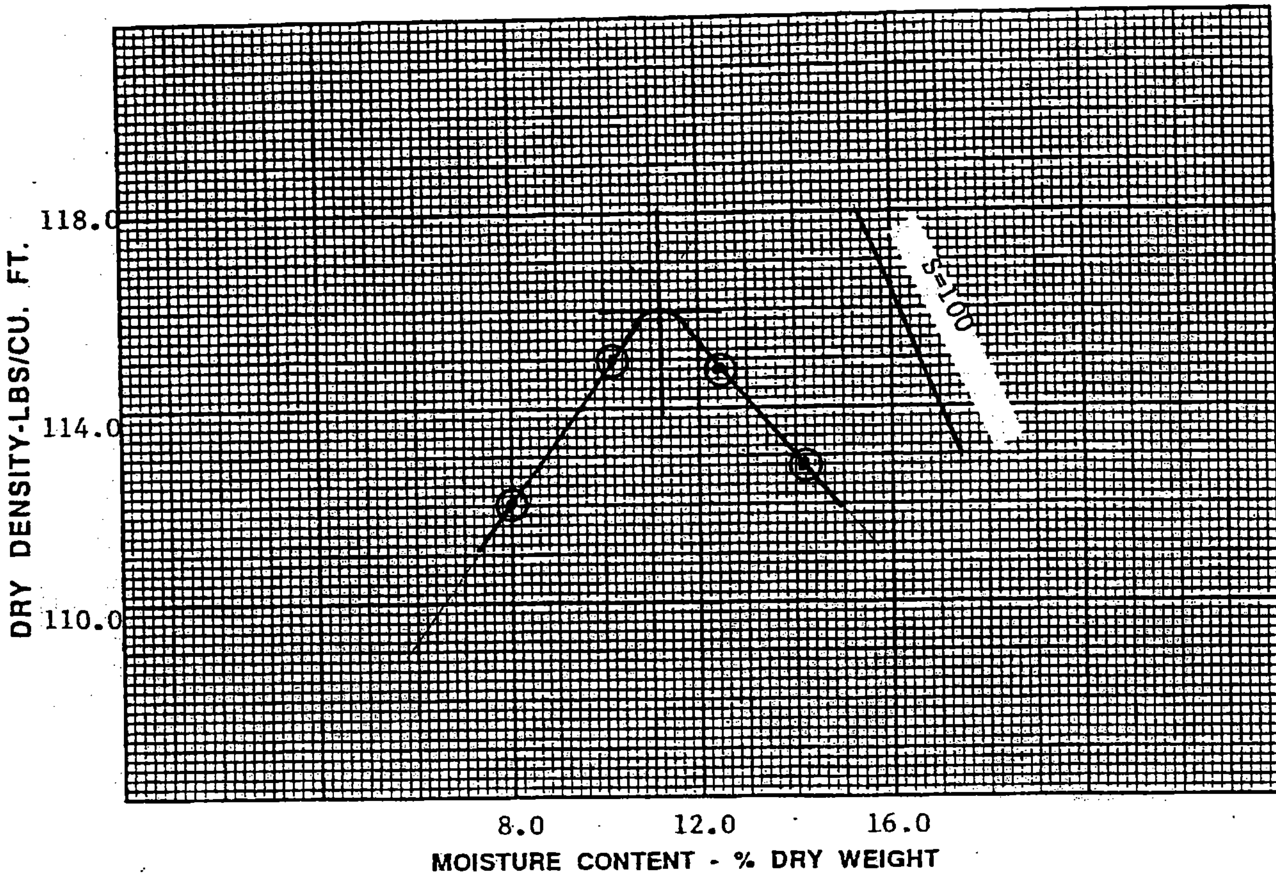
ASTM D1557 (Modified Proctor)

METHOD	MATERIAL	MOLD DIAMETER	MOLD HEIGHT	NO. OF LAYERS	BLOWS PER LAYER	HAMMER WEIGHT	HEIGHT OF FALL	COMPACTIVE EFFORT FT. LBS./CU. FT.
A	-#4	4"	4.58"	5	25	10.0 lbs	18"	56,250
B	-3/8	4"	4.58"	5	25	10.0 lbs	18"	55,986
C	-3/4	6"	4.58"	5	56	10.0 lbs	18"	55,986

AGRA

SUMMARY OF MOISTURE DENSITY RELATIONSHIP TESTS

PROJECT Mixed Waste Landfill Cover **JOB NO.** 9-519-001154



SOURCE	OPTIMUM MOISTURE CONTENT % DRY WT.	MAXIMUM DRY DENSITY LBS/CU. FT.	TEST DESIGNATION	TEST METHOD	LAB NO.
P1A @ 4.2'	11.2	116.0	D698	A	4459

MOISTURE-DENSITY RELATIONSHIP TEST METHOD DATA

ASTM D698 (Standard Proctor)

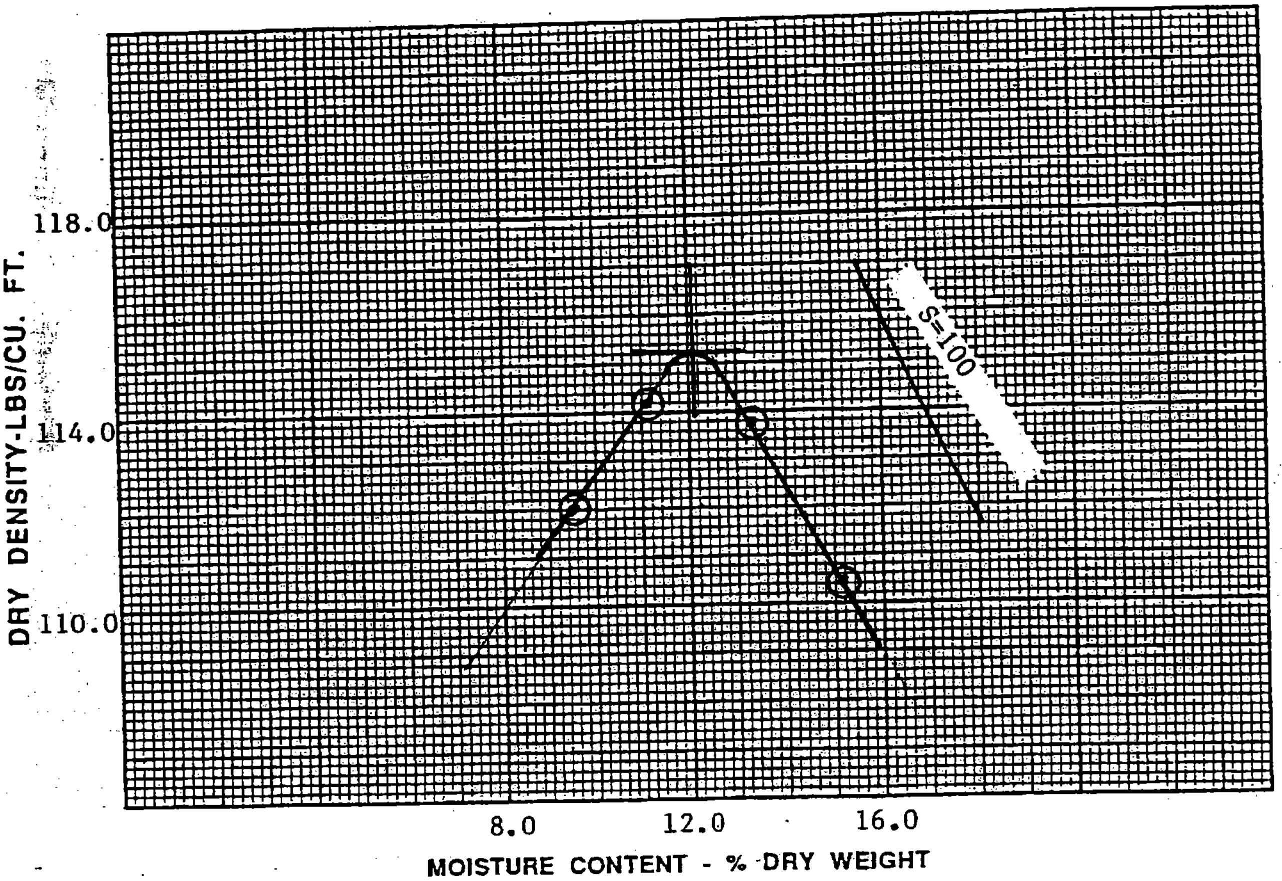
METHOD	MATERIAL	MOLD DIAMETER	MOLD HEIGHT	NO. OF LAYERS	BLOWS PER LAYER	HAMMER WEIGHT	HEIGHT OF FALL	COMPACTIVE EFFORT FT. LBS./CU. FT.
A	-#4	4"	4.58"	3	25	5.5 lbs	12"	12,375
B	-#4	4"	4.58"	3	25	5.5 lbs	12"	12,317
C	-3/4	6"	4.58"	3	56	5.5 lbs	12"	12,317

ASTM D1557 (Modified Proctor)

METHOD	MATERIAL	MOLD DIAMETER	MOLD HEIGHT	NO. OF LAYERS	BLOWS PER LAYER	HAMMER WEIGHT	HEIGHT OF FALL	COMPACTIVE EFFORT FT. LBS./CU. FT.
A	-#4	4"	4.58"	5	25	10.0 lbs	18"	56,250
B	-3/8	4"	4.58"	5	25	10.0 lbs	18"	55,986
C	-3/4	6"	4.58"	5	56	10.0 lbs	18"	55,986

SUMMARY OF MOISTURE DENSITY RELATIONSHIP TESTS

PROJECT Mixed Waste Landfill Cover JOB NO. 9-519-001154



SOURCE	OPTIMUM MOISTURE CONTENT % DRY WT.	MAXIMUM DRY DENSITY LBS/CU. FT.	TEST DESIGNATION	TEST METHOD	LAB NO.
P1B @ 0.4'	12.1	115.2	D698	A	4460

MOISTURE-DENSITY RELATIONSHIP TEST METHOD DATA

ASTM D698 (Standard Proctor)

METHOD	MATERIAL	MOLD DIAMETER	MOLD HEIGHT	NO. OF LAYERS	BLOWS PER LAYER	HAMMER WEIGHT	HEIGHT OF FALL	COMPACTIVE EFFORT FT. LBS./CU. FT.
A	-#4	4"	4.58"	3	25	5.5 lbs	12"	12,375
B	-#4	4"	4.58"	3	25	5.5 lbs	12"	12,317
C	-3/4	6"	4.58"	3	56	5.5 lbs	12"	12,317

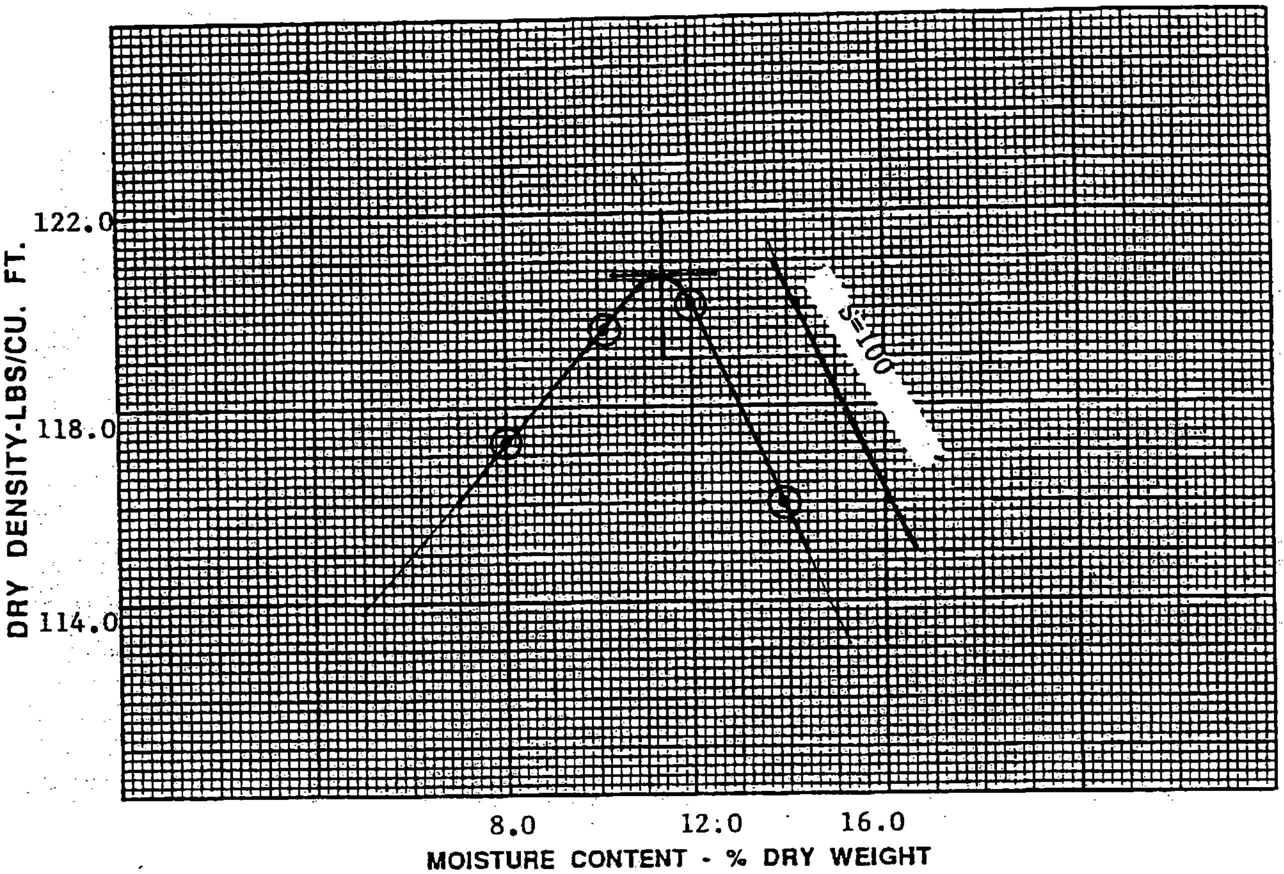
ASTM D1557 (Modified Proctor)

METHOD	MATERIAL	MOLD DIAMETER	MOLD HEIGHT	NO. OF LAYERS	BLOWS PER LAYER	HAMMER WEIGHT	HEIGHT OF FALL	COMPACTIVE EFFORT FT. LBS./CU. FT.
A	-#4	4"	4.58"	5	25	10.0 lbs	18"	56,250
B	-3/8	4"	4.58"	5	25	10.0 lbs	18"	55,986
C	-3/4	6"	4.58"	5	56	10.0 lbs	18"	55,986

AGRA

SUMMARY OF MOISTURE DENSITY RELATIONSHIP TESTS

PROJECT Mixed Waste Landfill Cover JOB NO. 9-519-001154



SOURCE	OPTIMUM MOISTURE CONTENT % DRY WT.	MAXIMUM DRY DENSITY LBS/CU. FT.	TEST DESIGNATION	TEST METHOD	LAB NO.
P1B @ 1.0'	11.4	120.7	D698	A	4461

MOISTURE-DENSITY RELATIONSHIP TEST METHOD DATA

ASTM D698 (Standard Proctor)

METHOD	MATERIAL	MOLD DIAMETER	MOLD HEIGHT	NO. OF LAYERS	BLOWS PER LAYER	HAMMER WEIGHT	HEIGHT OF FALL	COMPACTIVE EFFORT FT. LBS./CU. FT.
A	-#4	4"	4.58"	3	25	5.5 lbs	12"	12,375
B	-#4	4"	4.58"	3	25	5.5 lbs	12"	12,317
C	-3/4	6"	4.58"	3	56	5.5 lbs	12"	12,317

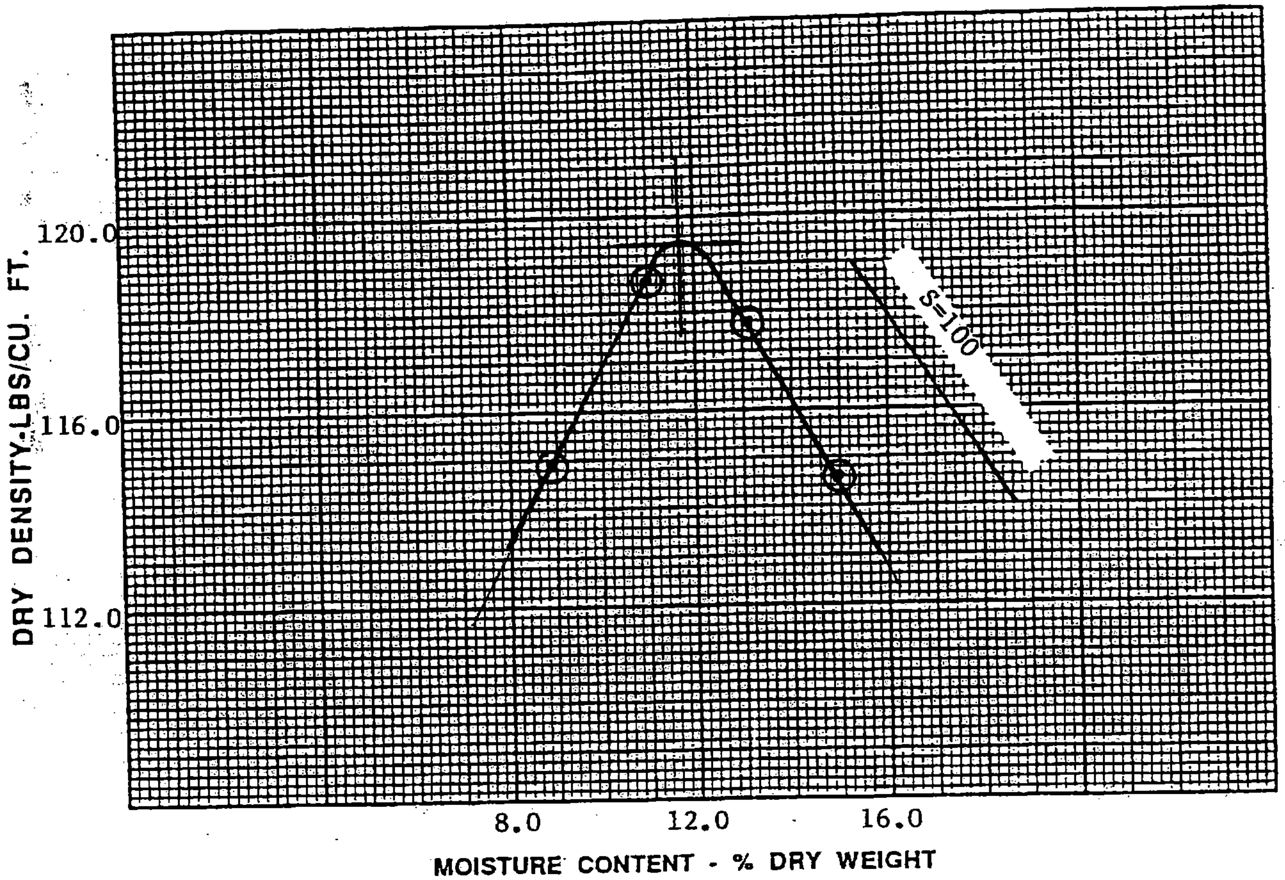
ASTM D1557 (Modified Proctor)

METHOD	MATERIAL	MOLD DIAMETER	MOLD HEIGHT	NO. OF LAYERS	BLOWS PER LAYER	HAMMER WEIGHT	HEIGHT OF FALL	COMPACTIVE EFFORT FT. LBS./CU. FT.
A	-#4	4"	4.58"	5	25	10.0 lbs	18"	56,250
B	-3/8	4"	4.58"	5	25	10.0 lbs	18"	55,986
C	-3/4	6"	4.58"	5	56	10.0 lbs	18"	55,986

AGRA

SUMMARY OF MOISTURE DENSITY RELATIONSHIP TESTS

PROJECT Mixed Waste Landfill Cover JOB NO. 9-519-001154



SOURCE	OPTIMUM MOISTURE CONTENT % DRY WT.	MAXIMUM DRY DENSITY LBS/CU. FT.	TEST DESIGNATION	TEST METHOD	LAB NO.
P1B @ 1.5'	11.7	119.4	D698	A	4462

MOISTURE-DENSITY RELATIONSHIP TEST METHOD DATA

ASTM D698 (Standard Proctor)

METHOD	MATERIAL	MOLD DIAMETER	MOLD HEIGHT	NO. OF LAYERS	BLOWS PER LAYER	HAMMER WEIGHT	HEIGHT OF FALL	COMPACTIVE EFFORT FT. LBS./CU. FT.
A	-#4	4"	4.58"	3	25	5.5 lbs	12"	12,375
B	-#4	4"	4.58"	3	25	5.5 lbs	12"	12,317
C	-3/4	6"	4.58"	3	56	5.5 lbs	12"	12,317

ASTM D1557 (Modified Proctor)

METHOD	MATERIAL	MOLD DIAMETER	MOLD HEIGHT	NO. OF LAYERS	BLOWS PER LAYER	HAMMER WEIGHT	HEIGHT OF FALL	COMPACTIVE EFFORT FT. LBS./CU. FT.
A	-#4	4"	4.58"	5	25	10.0 lbs	18"	56,250
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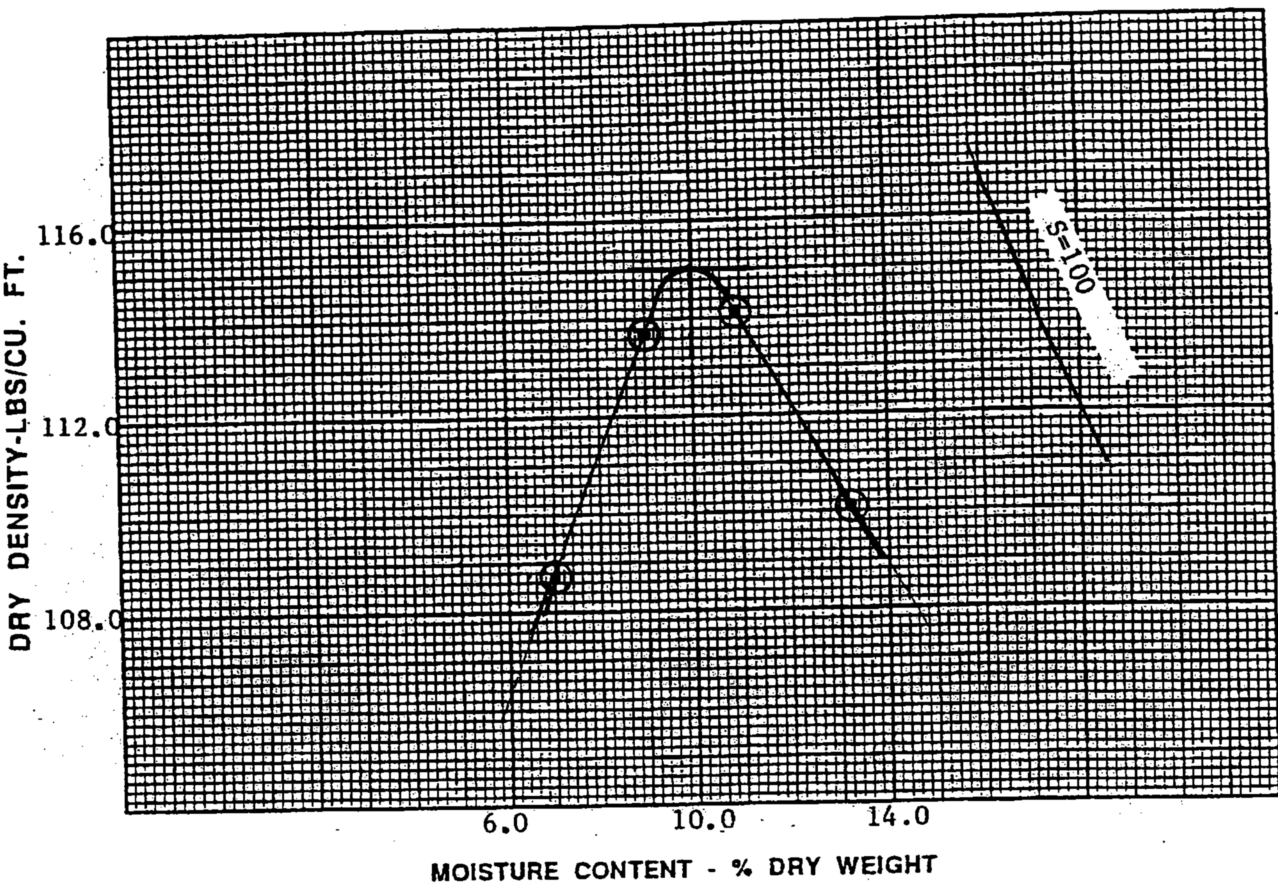
C	-3/4	6"	4.58"	5	56	10.0 lbs	18"	55,986

SUMMARY OF MOISTURE DENSITY RELATIONSHIP TESTS

PROJECT Mixed Waste Landfill Cover JOB NO. 9-519-001154



SOURCE	OPTIMUM MOISTURE CONTENT % DRY WT.	MAXIMUM DRY DENSITY LBS/CU. FT.	TEST DESIGNATION	TEST METHOD	LAB NO.
P1B @ 3.0'	10.0	115.0	D698	A	4463

MOISTURE-DENSITY RELATIONSHIP TEST METHOD DATA

ASTM D698 (Standard Proctor)

METHOD	MATERIAL	MOLD DIAMETER	MOLD HEIGHT	NO. OF LAYERS	BLOWS PER LAYER	HAMMER WEIGHT	HEIGHT OF FALL	COMPACTIVE EFFORT FT. LBS./CU. FT.
A	-#4	4"	4.58"	3	25	5.5 lbs	12"	12,375
B	-#4	4"	4.58"	3	25	5.5 lbs	12"	12,317
C	-3/4	6"	4.58"	3	56	5.5 lbs	12"	12,317

ASTM D1557 (Modified Proctor)

METHOD	MATERIAL	MOLD DIAMETER	MOLD HEIGHT	NO. OF LAYERS	BLOWS PER LAYER	HAMMER WEIGHT	HEIGHT OF FALL	COMPACTIVE EFFORT FT. LBS./CU. FT.
A	-#4	4"	4.58"	5	25	10.0 lbs	18"	56,250
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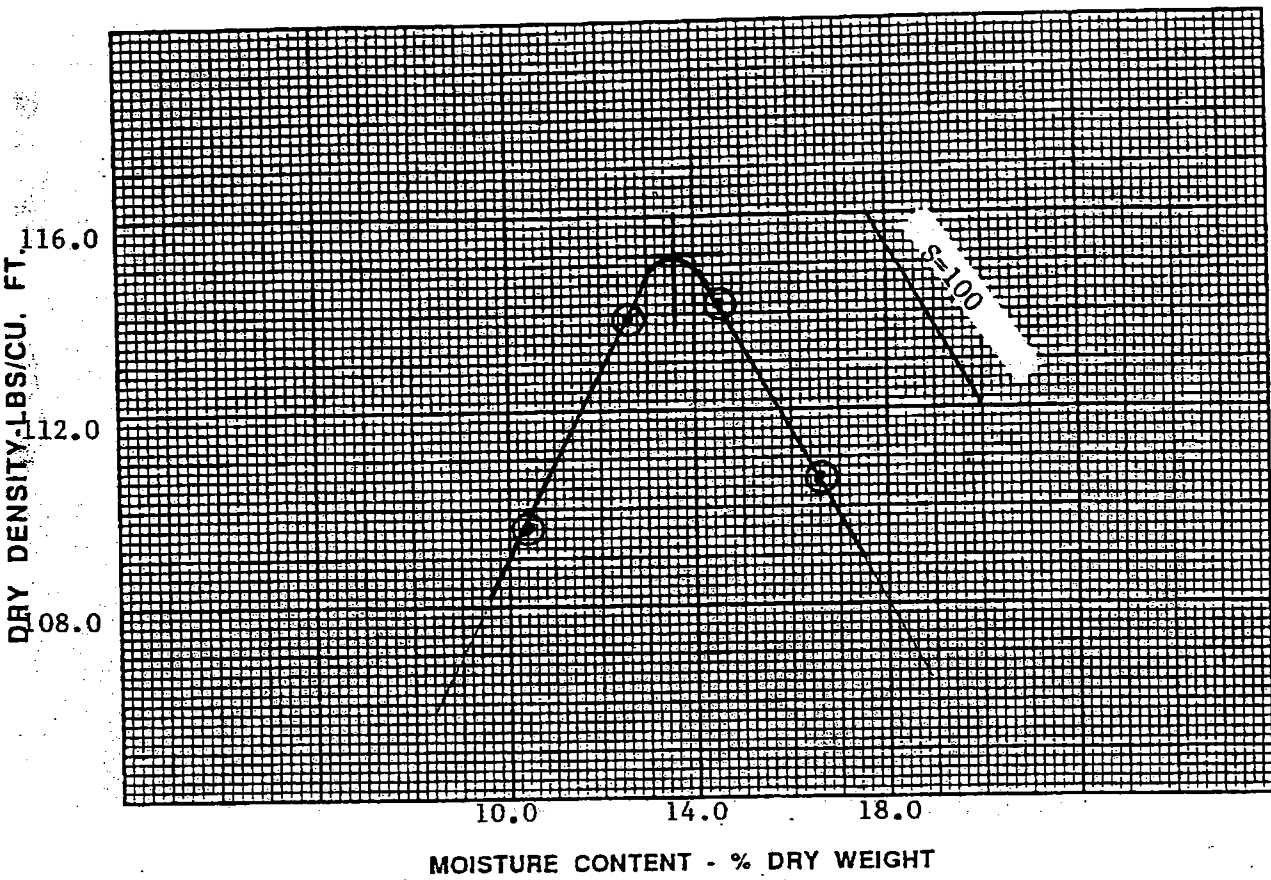
AGRA

SUMMARY OF MOISTURE DENSITY RELATIONSHIP TESTS

PROJECT Mixed Waste Landfill Cover JOB NO. 9-519-001154



SOURCE	OPTIMUM MOISTURE CONTENT % DRY WT.	MAXIMUM DRY DENSITY LBS/CU. FT.	TEST DESIGNATION	TEST METHOD	LAB NO.
P1C @ 0.5'	13.6	115.2	D698	A	4464

MOISTURE-DENSITY RELATIONSHIP TEST METHOD DATA

ASTM D698 (Standard Proctor)

METHOD	MATERIAL	MOLD DIAMETER	MOLD HEIGHT	NO. OF LAYERS	BLOWS PER LAYER	HAMMER WEIGHT	HEIGHT OF FALL	COMPACTIVE EFFORT FT. LBS./CU. FT.
A	-#4	4"	4.58"	3	25	5.5 lbs	12"	12,375
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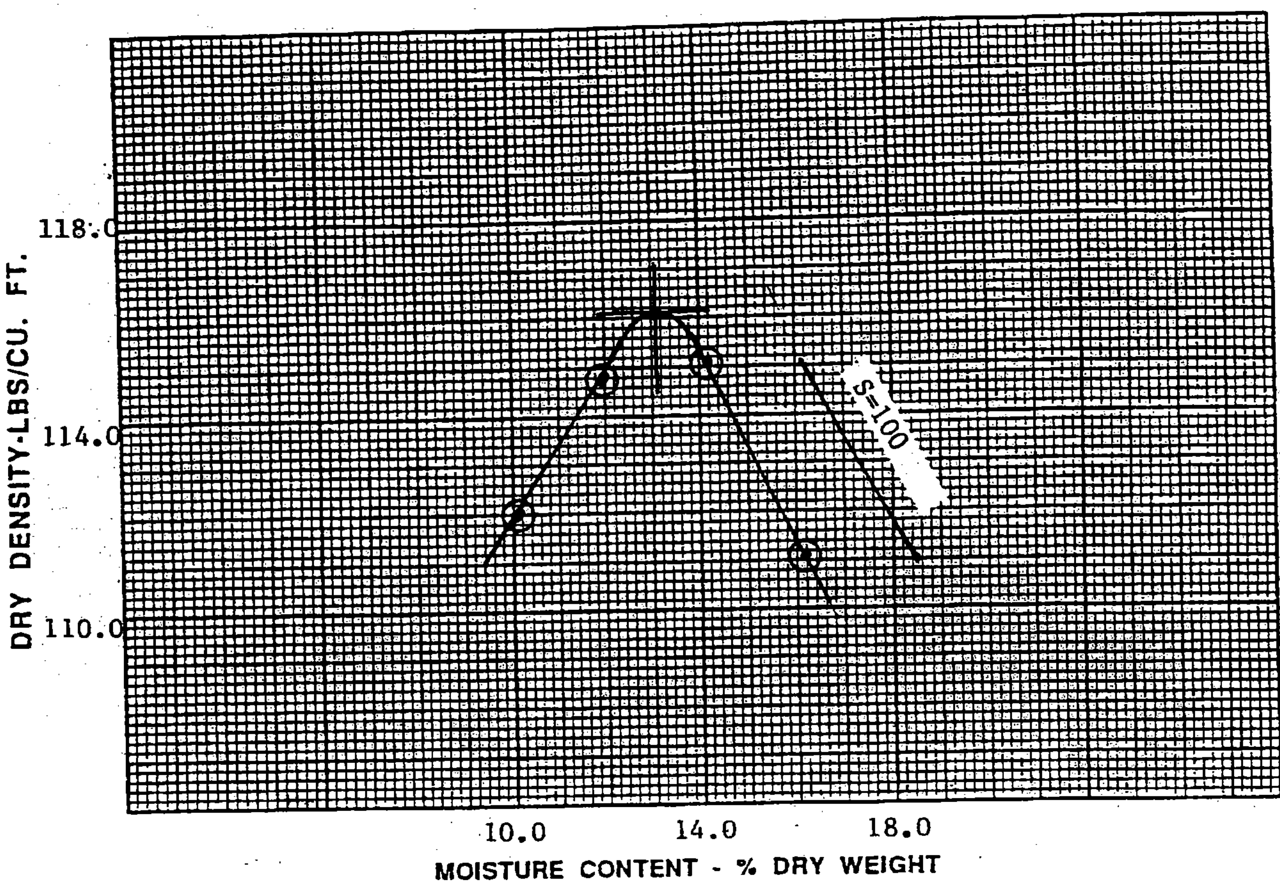
ASTM D1557 (Modified Proctor)

METHOD	MATERIAL	MOLD DIAMETER	MOLD HEIGHT	NO. OF LAYERS	BLOWS PER LAYER	HAMMER WEIGHT	HEIGHT OF FALL	COMPACTIVE EFFORT FT. LBS./CU. FT.
A	-#4	4"	4.58"	5	25	10.0 lbs	18"	56,250
B	-3/8	4"	4.58"	5	25	10.0 lbs	18"	55,986
C	-3/4	6"	4.58"	5	56	10.0 lbs	18"	55,986

AGRA

SUMMARY OF MOISTURE DENSITY RELATIONSHIP TESTS

PROJECT Mixed Waste Landfill Cover **JOB NO.** 9-519-001154



SOURCE	OPTIMUM MOISTURE CONTENT % DRY WT.	MAXIMUM DRY DENSITY LBS/CU. FT.	TEST DESIGNATION	TEST METHOD	LAB NO.
P1C @ 1.0'	13.1	116.1	D698	A	4465

MOISTURE-DENSITY RELATIONSHIP TEST METHOD DATA

ASTM D698 (Standard Proctor)

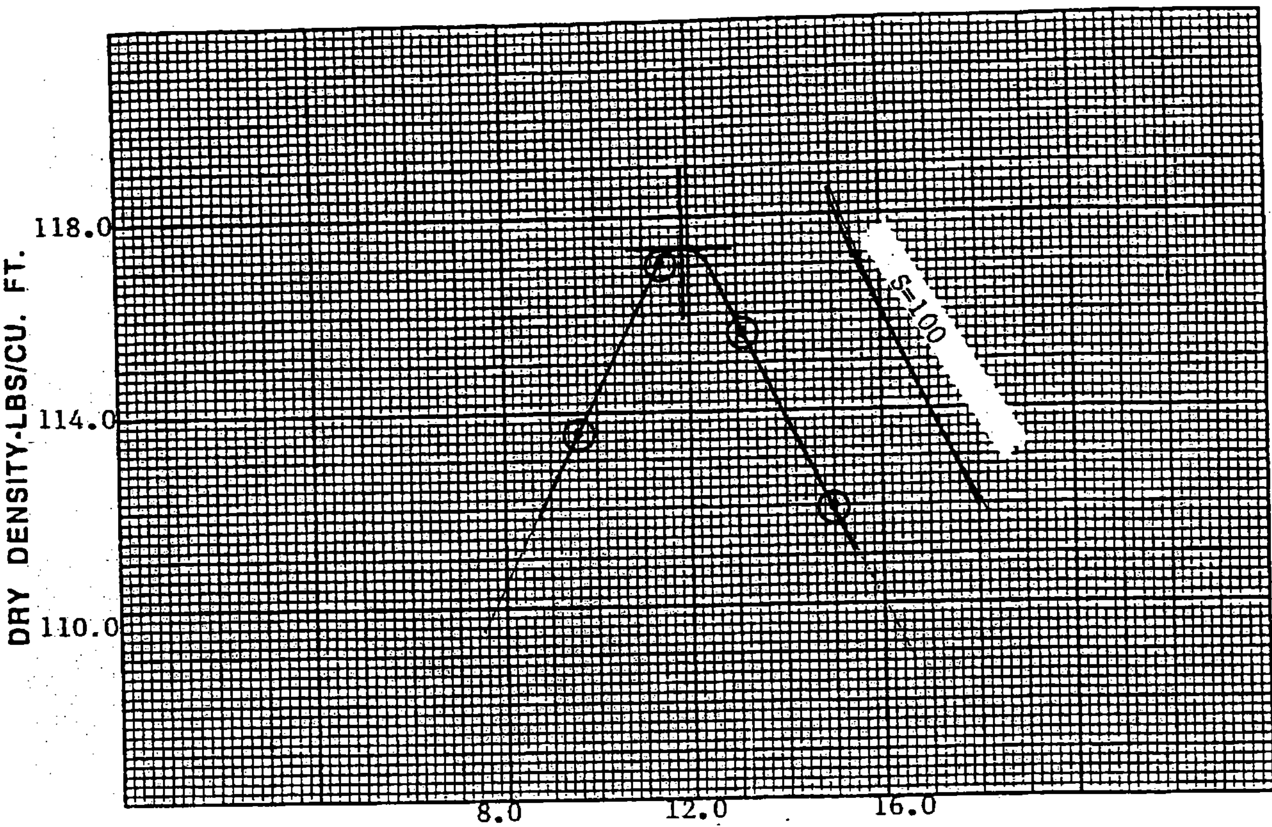
METHOD	MATERIAL	MOLD DIAMETER	MOLD HEIGHT	NO. OF LAYERS	BLOWS PER LAYER	HAMMER WEIGHT	HEIGHT OF FALL	COMPACTIVE EFFORT FT. LBS/CU. FT.
A	-#4	4"	4.58"	3	25	5.5 lbs	12"	12,375
B	-#4	4"	4.58"	3	25	5.5 lbs	12"	12,317
C	-3/4	6"	4.58"	3	56	5.5 lbs	12"	12,317

ASTM D1557 (Modified Proctor)

METHOD	MATERIAL	MOLD DIAMETER	MOLD HEIGHT	NO. OF LAYERS	BLOWS PER LAYER	HAMMER WEIGHT	HEIGHT OF FALL	COMPACTIVE EFFORT FT. LBS/CU. FT.
A	-#4	4"	4.58"	5	25	10.0 lbs	18"	56,250
B	-3/8	4"	4.58"	5	25	10.0 lbs	18"	55,986
C	-3/4	6"	4.58"	5	56	10.0 lbs	18"	55,986

SUMMARY OF MOISTURE DENSITY RELATIONSHIP TESTS

PROJECT Mixed Waste Landfill Cover **JOB NO.** 9-519-001154



SOURCE	OPTIMUM MOISTURE CONTENT % DRY WT.	MAXIMUM DRY DENSITY LBS/CU. FT.	TEST DESIGNATION	TEST METHOD	LAB NO.
P1C @ 1.6'	11.9	117.4	D698	A	4466

MOISTURE-DENSITY RELATIONSHIP TEST METHOD DATA

ASTM D698 (Standard Proctor)

METHOD	MATERIAL	MOLD DIAMETER	MOLD HEIGHT	NO. OF LAYERS	BLOWS PER LAYER	HAMMER WEIGHT	HEIGHT OF FALL	COMPACTIVE EFFORT FT. LBS./CU. FT.
A	-#4	4"	4.58"	3	25	5.5 lbs	12"	12,375
B	-#4	4"	4.58"	3	25	5.5 lbs	12"	12,317
C	-3/4	6"	4.58"	3	56	5.5 lbs	12"	12,317

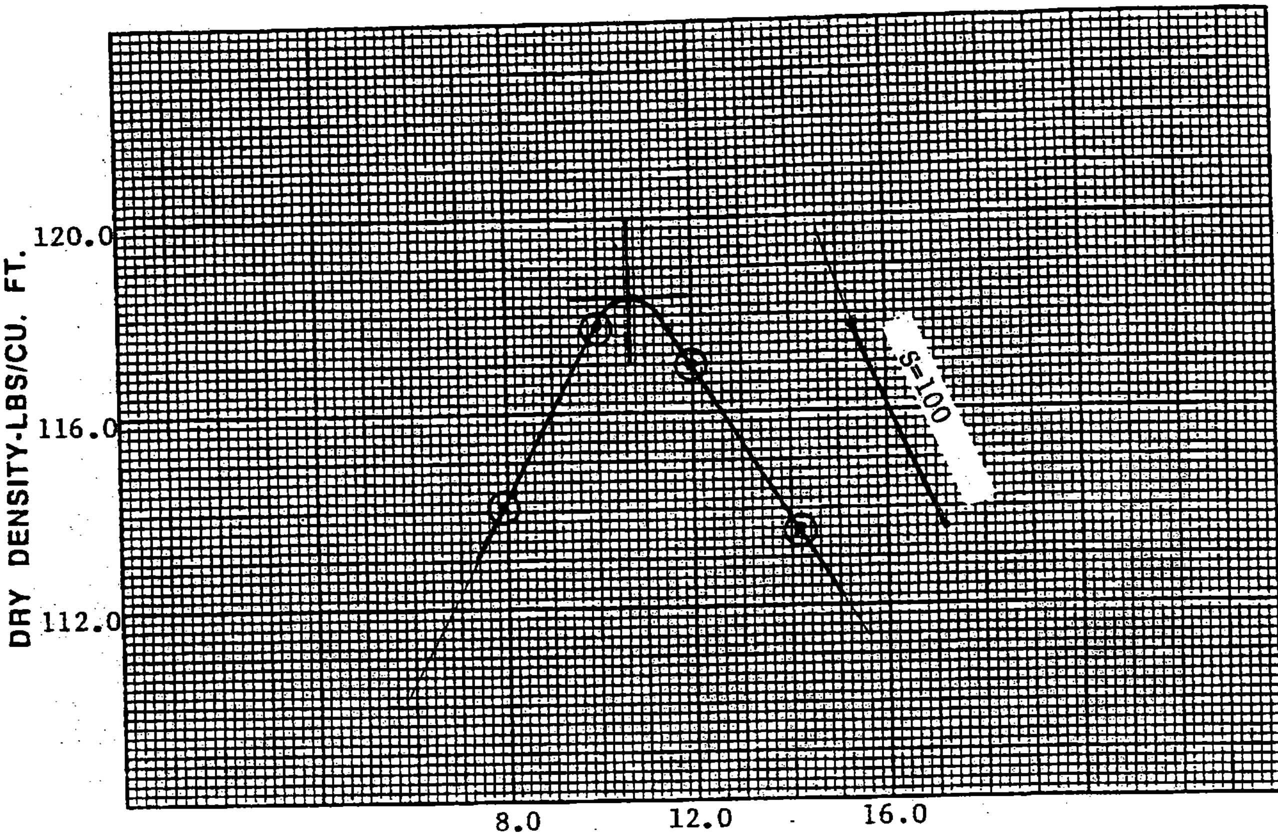
ASTM D1557 (Modified Proctor)

METHOD	MATERIAL	MOLD DIAMETER	MOLD HEIGHT	NO. OF LAYERS	BLOWS PER LAYER	HAMMER WEIGHT	HEIGHT OF FALL	COMPACTIVE EFFORT FT. LBS./CU. FT.
A	-#4	4"	4.58"	5	25	10.0 lbs	18"	56,250
B	-3/8	4"	4.58"	5	25	10.0 lbs	18"	55,986
C	-3/4	6"	4.58"	5	56	10.0 lbs	18"	55,986

AGRA

SUMMARY OF MOISTURE DENSITY RELATIONSHIP TESTS

PROJECT Mixed Waste Landfill Cover JOB NO. 9-519-001154



SOURCE	OPTIMUM MOISTURE CONTENT % DRY WT.	MAXIMUM DRY DENSITY LBS/CU. FT.	TEST DESIGNATION	TEST METHOD	LAB NO.
P1C @ 3.5'	10.7	118.4	D698	A	4467

MOISTURE-DENSITY RELATIONSHIP TEST METHOD DATA

ASTM D698 (Standard Proctor)

METHOD	MATERIAL	MOLD		NO. OF LAYERS	BLOWS PER LAYER	HAMMER WEIGHT	HEIGHT OF FALL	COMPACTIVE EFFORT FT. LBS./CU. FT.
		DIAMETER	HEIGHT					
A	-#4	4"	4.58"	3	25	5.5 lbs	12"	12,375
B	-#4	4"	4.58"	3	25	5.5 lbs	12"	12,317
C	-3/4	6"	4.58"	3	56	5.5 lbs	12"	12,317

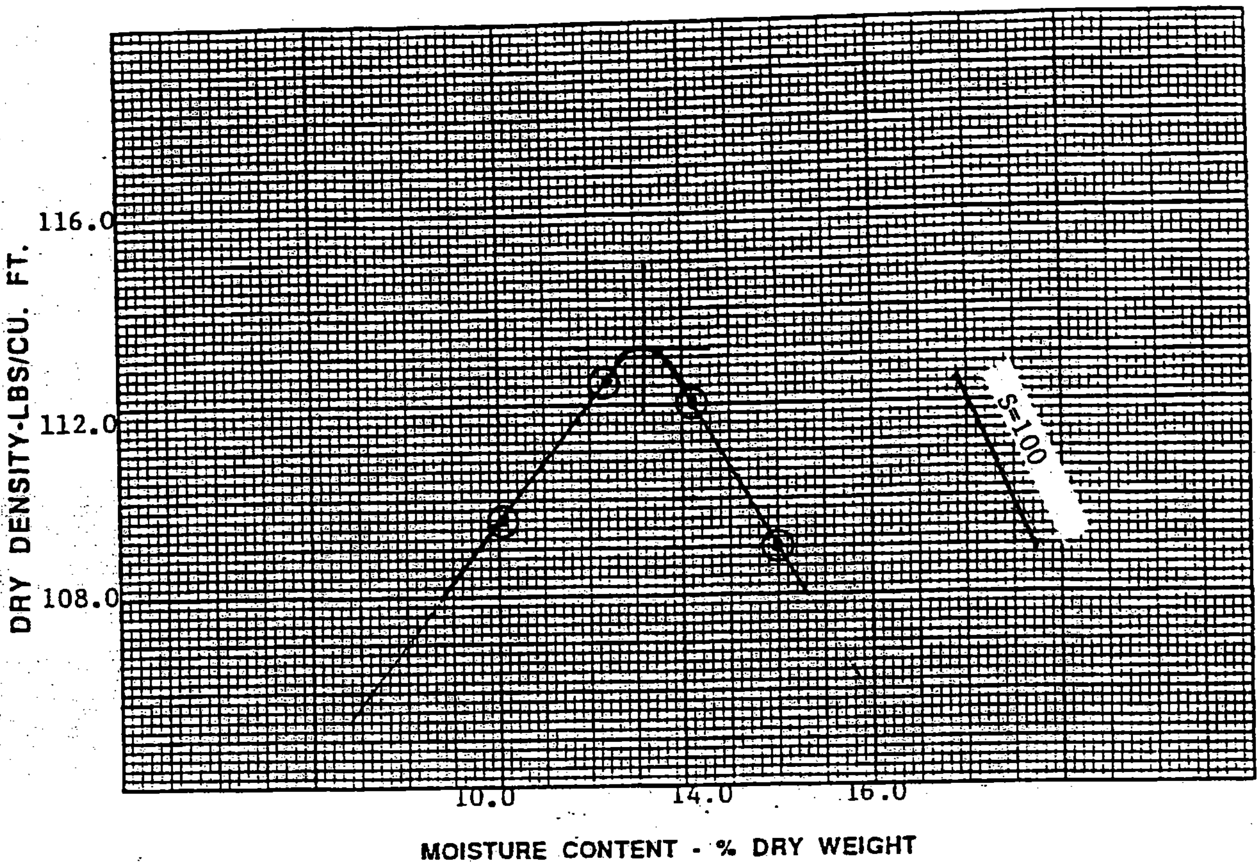
ASTM D1557 (Modified Proctor)

METHOD	MATERIAL	MOLD		NO. OF LAYERS	BLOWS PER LAYER	HAMMER WEIGHT	HEIGHT OF FALL	COMPACTIVE EFFORT FT. LBS./CU. FT.
		DIAMETER	HEIGHT					
A	-#4	4"	4.58"	5	25	10.0 lbs	18"	56,250
B	-3/8	4"	4.58"	5	25	10.0 lbs	18"	55,986
C	-3/4	6"	4.58"	5	56	10.0 lbs	18"	55,986

AGRA

SUMMARY OF MOISTURE DENSITY RELATIONSHIP TESTS

PROJECT Mixed Waste Landfill Cover **JOB NO.** 9-519-001154



SOURCE	OPTIMUM MOISTURE CONTENT % DRY WT.	MAXIMUM DRY DENSITY LBS/CU. FT.	TEST DESIGNATION	TEST METHOD	LAB NO.
P1C @ 4.8'	13.2	113.2	D698	A	4468

MOISTURE-DENSITY RELATIONSHIP TEST METHOD DATA

ASTM D698 (Standard Proctor)

METHOD	MATERIAL	MOLD DIAMETER	MOLD HEIGHT	NO. OF LAYERS	BLOWS PER LAYER	HAMMER WEIGHT	HEIGHT OF FALL	COMPACTIVE EFFORT FT. LBS./CU. FT.
A	-#4	4"	4.58"	3	25	5.5 lbs	12"	12,375
B	-#4	4"	4.58"	3	25	5.5 lbs	12"	12,317
C	-3/4	6"	4.58"	3	56	5.5 lbs	12"	12,317

ASTM D1557 (Modified Proctor)

METHOD	MATERIAL	MOLD DIAMETER	MOLD HEIGHT	NO. OF LAYERS	BLOWS PER LAYER	HAMMER WEIGHT	HEIGHT OF FALL	COMPACTIVE EFFORT FT. LBS./CU. FT.
A	-#4	4"	4.58"	5	25	10.0 lbs	18"	56,250
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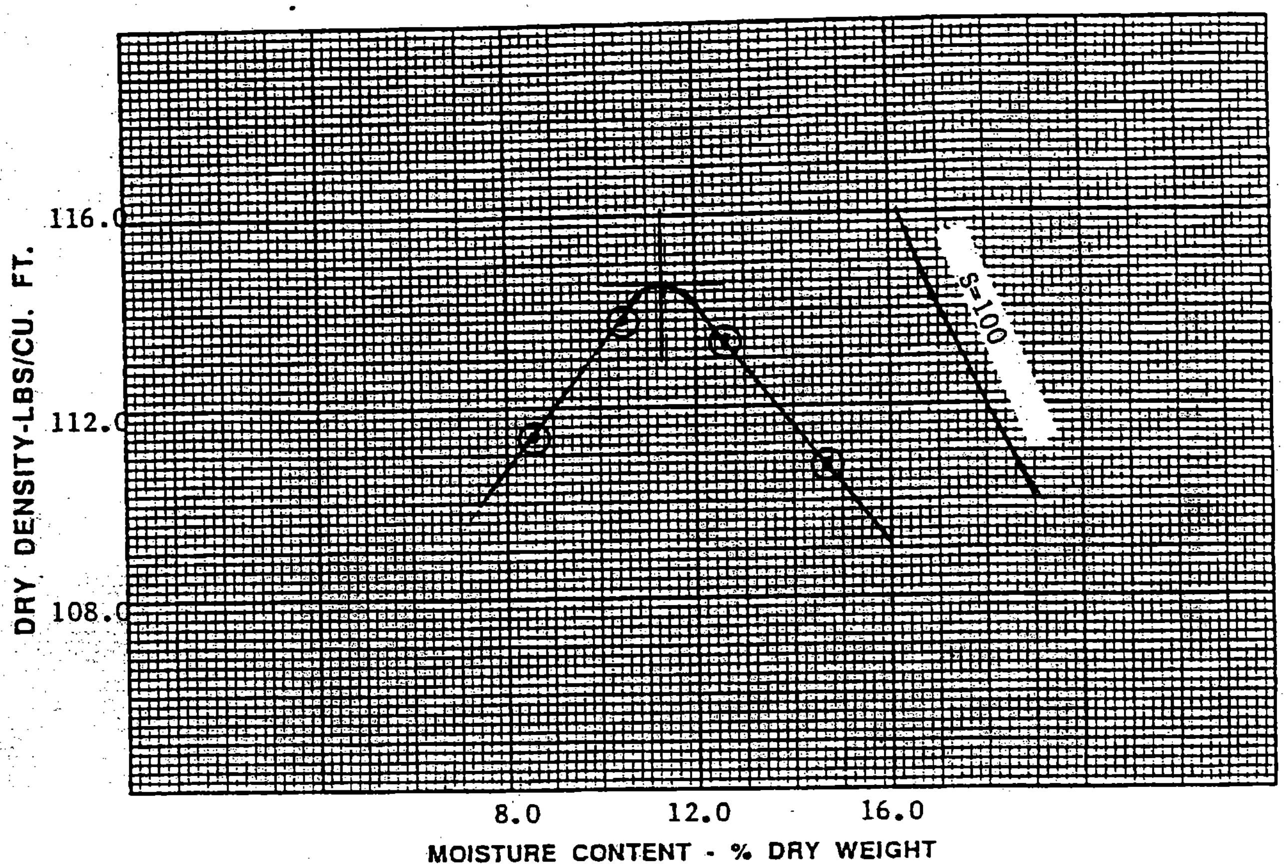
AGRA

SUMMARY OF MOISTURE DENSITY RELATIONSHIP TESTS

PROJECT: Mixed Waste Landfill Cover JOB NO. 9-519-001154



SOURCE	OPTIMUM MOISTURE CONTENT % DRY WT.	MAXIMUM DRY DENSITY LBS/CU. FT.	TEST DESIGNATION	TEST METHOD	LAB NO.
P1D @ 0.4'	11.3	114.6	D698	A	4469

MOISTURE-DENSITY RELATIONSHIP TEST METHOD DATA

ASTM D698 (Standard Proctor)

METHOD	MATERIAL	MOLD		NO. OF LAYERS	BLOWS PER LAYER	HAMMER WEIGHT	HEIGHT OF FALL	COMPACTIVE EFFORT FT. LBS/CU. FT.
		DIAMETER	HEIGHT					
A	-#4	4"	4.58"	3	25	5.5 lbs	12"	12,375
B	-#4	4"	4.58"	3	25	5.5 lbs	12"	12,317
C	-3/4	6"	4.58"	3	56	5.5 lbs	12"	12,317

ASTM D1557 (Modified Proctor)

METHOD	MATERIAL	MOLD		NO. OF LAYERS	BLOWS PER LAYER	HAMMER WEIGHT	HEIGHT OF FALL	COMPACTIVE EFFORT FT. LBS/CU. FT.
		DIAMETER	HEIGHT					
A	-#4	4"	4.58"	5	25	10.0 lbs	18"	56,250
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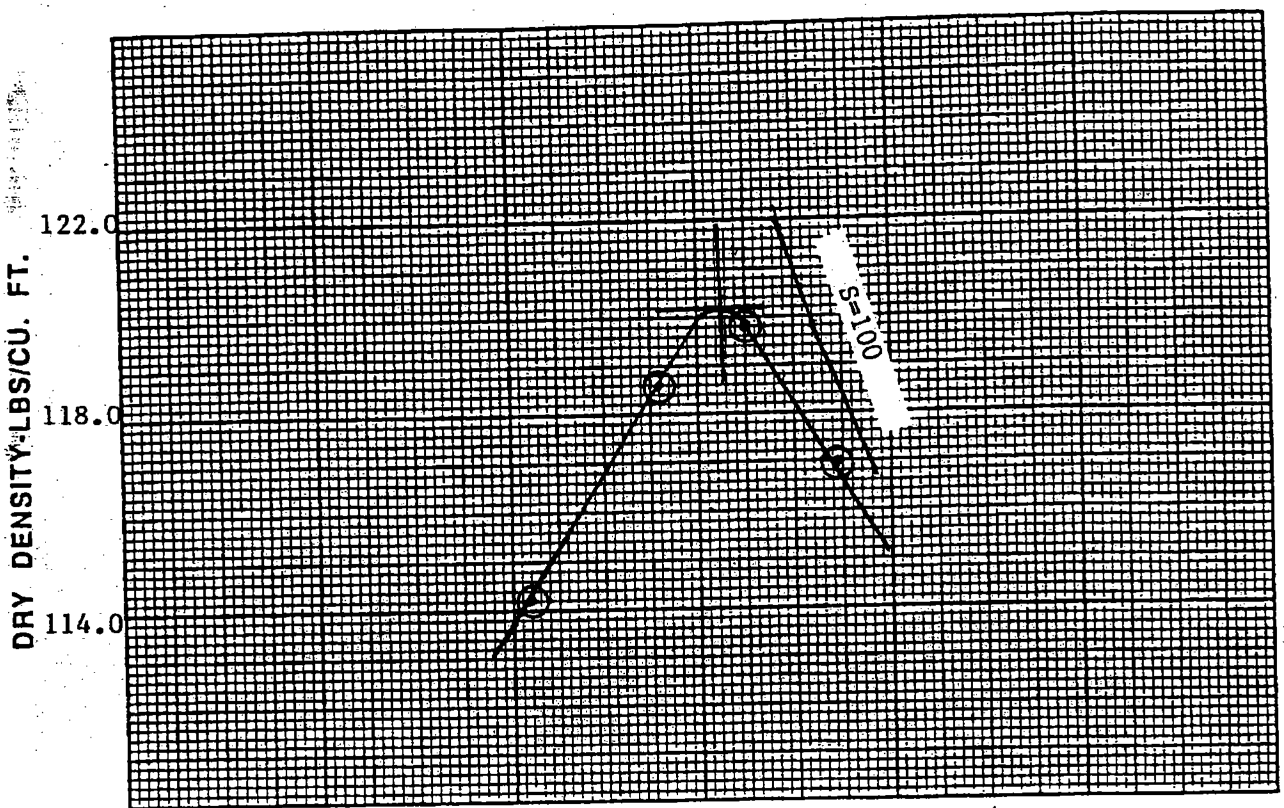
C	-3/4	6"	4.58"	5	56	10.0 lbs	18"	55,986

SUMMARY OF MOISTURE DENSITY RELATIONSHIP TESTS

PROJECT Mixed Waste Landfill Cover JOB NO. 9-519-001154



SOURCE	OPTIMUM MOISTURE CONTENT % DRY WT.	MAXIMUM DRY DENSITY LBS/CU. FT.	TEST DESIGNATION	TEST METHOD	LAB NO.
P1D @ 0.9'	12.5	120.2	D698	A	4470

MOISTURE-DENSITY RELATIONSHIP TEST METHOD DATA

ASTM D698 (Standard Proctor)

METHOD	MATERIAL	MOLD DIAMETER	MOLD HEIGHT	NO. OF LAYERS	BLOWS PER LAYER	HAMMER WEIGHT	HEIGHT OF FALL	COMPACTIVE EFFORT FT. LBS./CU. FT.
A	-#4	4"	4.58"	3	25	5.5 lbs	12"	12,375
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C	-3/4	6"	4.58"	3	56	5.5 lbs	12"	12,317

ASTM D1557 (Modified Proctor)

METHOD	MATERIAL	MOLD DIAMETER	MOLD HEIGHT	NO. OF LAYERS	BLOWS PER LAYER	HAMMER WEIGHT	HEIGHT OF FALL	COMPACTIVE EFFORT FT. LBS./CU. FT.
A	-#4	4"	4.58"	5	25	10.0 lbs	18"	56,250
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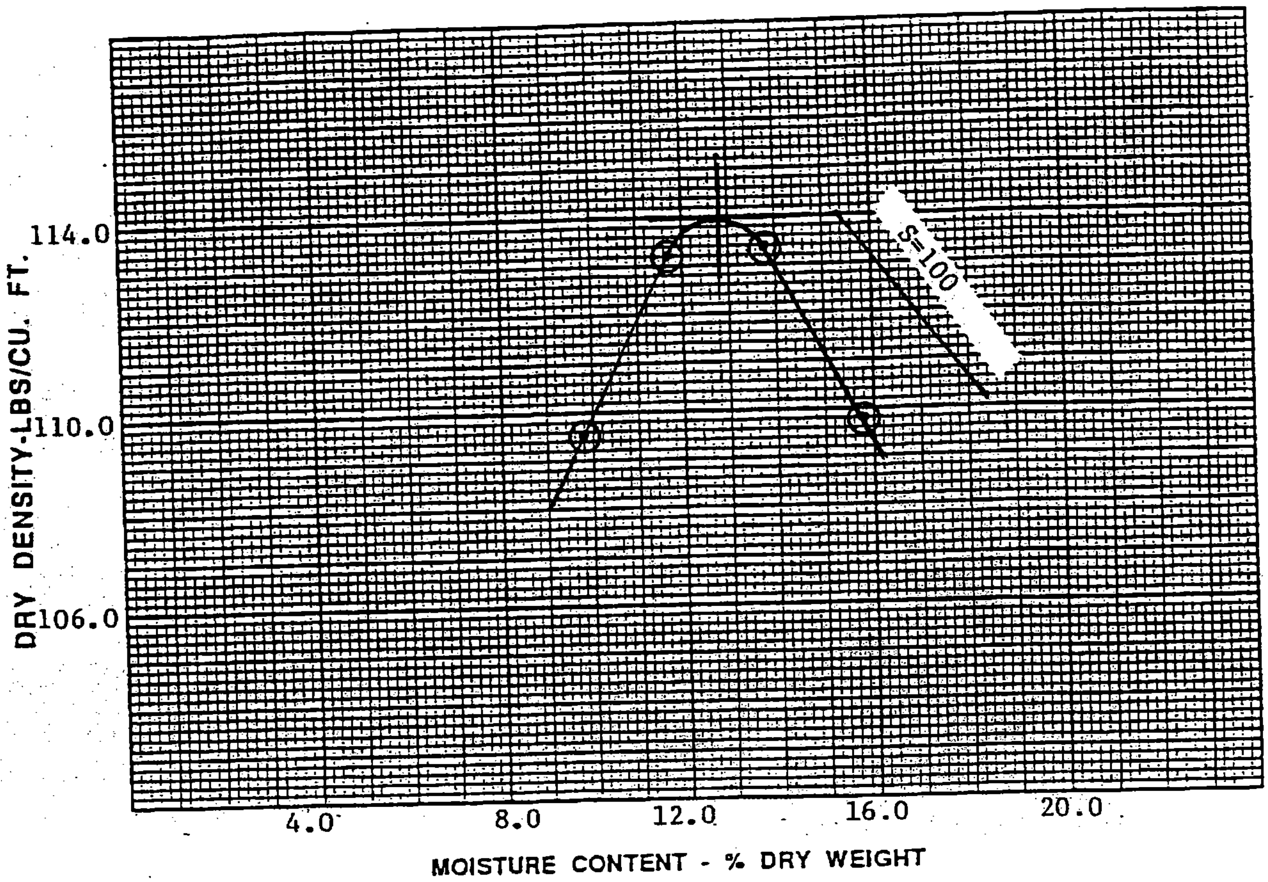
C	-3/4	6"	4.58"	5	56	10.0 lbs	18"	55,986

SUMMARY OF MOISTURE DENSITY RELATIONSHIP TESTS

PROJECT Mixed Waste Landfill Cover JOB NO. 9-519-001154



SOURCE	OPTIMUM MOISTURE CONTENT % DRY WT.	MAXIMUM DRY DENSITY LBS/CU. FT.	TEST DESIGNATION	TEST METHOD	LAB NO.
P1D @ 1.2'	12.8	114.0	D698	A	4471

MOISTURE-DENSITY RELATIONSHIP TEST METHOD DATA

ASTM D698 (Standard Proctor)

METHOD	MATERIAL	MOLD DIAMETER	MOLD HEIGHT	NO. OF LAYERS	BLOWS PER LAYER	HAMMER WEIGHT	HEIGHT OF FALL	COMPACTIVE EFFORT FT. LBS/CU. FT.
A	-#4	4"	4.58"	3	25	5.5 lbs	12"	12,375
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C	-3/4	6"	4.58"	3	56	5.5 lbs	12"	12,317

ASTM D1557 (Modified Proctor)

METHOD	MATERIAL	MOLD DIAMETER	MOLD HEIGHT	NO. OF LAYERS	BLOWS PER LAYER	HAMMER WEIGHT	HEIGHT OF FALL	COMPACTIVE EFFORT FT. LBS/CU. FT.
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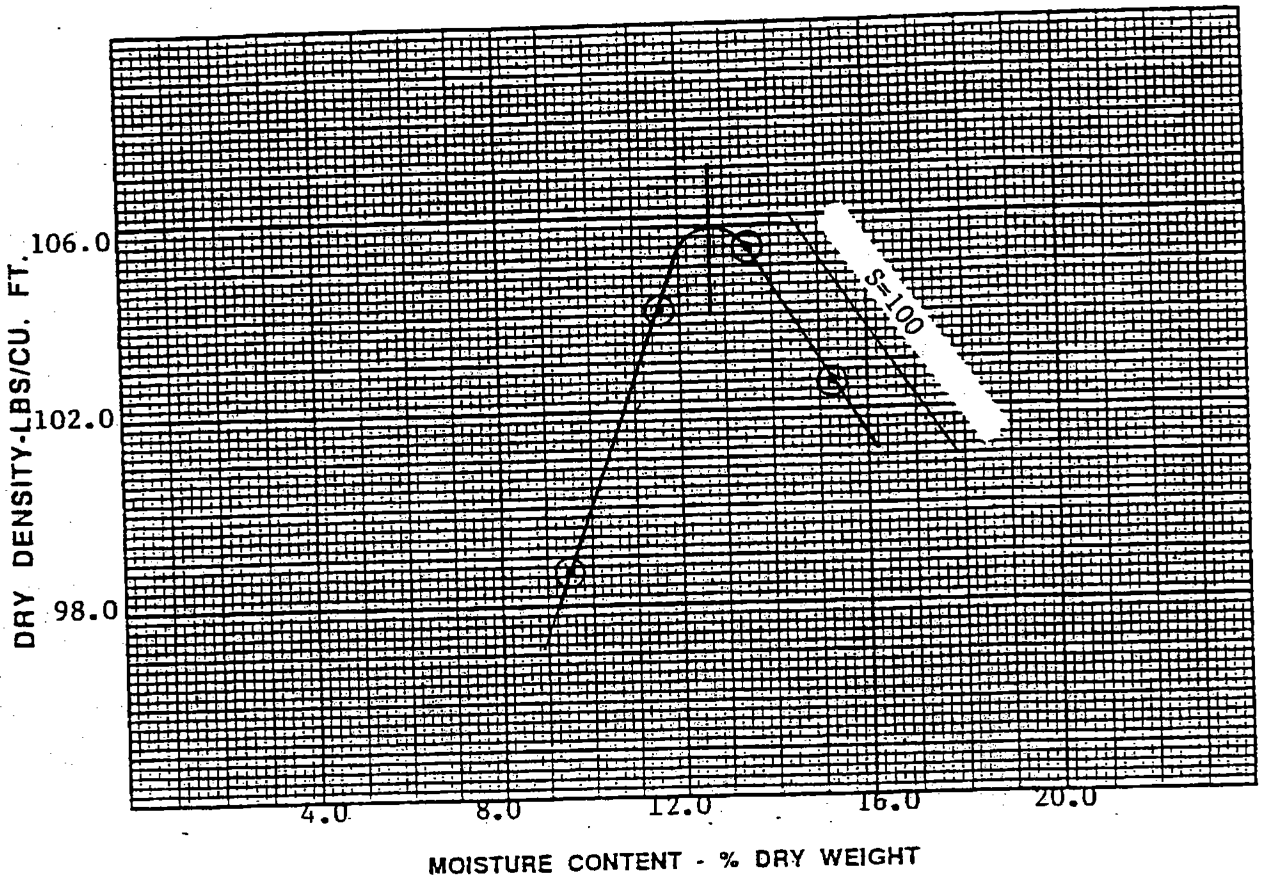
B	-3/8	4"	4.58"	5	25	10.0 lbs	18"	55,986
C	-3/4	6"	4.58"	5	56	10.0 lbs	18"	55,986

AGRA

SUMMARY OF MOISTURE DENSITY RELATIONSHIP TESTS

PROJECT Mixed Waste Landfill Cover JOB NO. 9-519-001154



SOURCE	OPTIMUM MOISTURE CONTENT % DRY WT.	MAXIMUM DRY DENSITY LBS/CU. FT.	TEST DESIGNATION	TEST METHOD	LAB NO.
P1D @ 3.0'	12.7	105.8	D698	A	4472

MOISTURE-DENSITY RELATIONSHIP TEST METHOD DATA

ASTM D698 (Standard Proctor)

METHOD	MATERIAL	MOLD		NO. OF LAYERS	BLOWS PER LAYER	HAMMER WEIGHT	HEIGHT OF FALL	COMPACTIVE EFFORT FT. LBS./CU. FT.
		DIAMETER	HEIGHT					
A	-#4	4"	4.58"	3	25	5.5 lbs	12"	12,375
B	-#4	4"	4.58"	3	25	5.5 lbs	12"	12,317
C	-3/4	6"	4.58"	3	56	5.5 lbs	12"	12,317

ASTM D1557 (Modified Proctor)

METHOD	MATERIAL	MOLD		NO. OF LAYERS	BLOWS PER LAYER	HAMMER WEIGHT	HEIGHT OF FALL	COMPACTIVE EFFORT FT. LBS./CU. FT.
		DIAMETER	HEIGHT					
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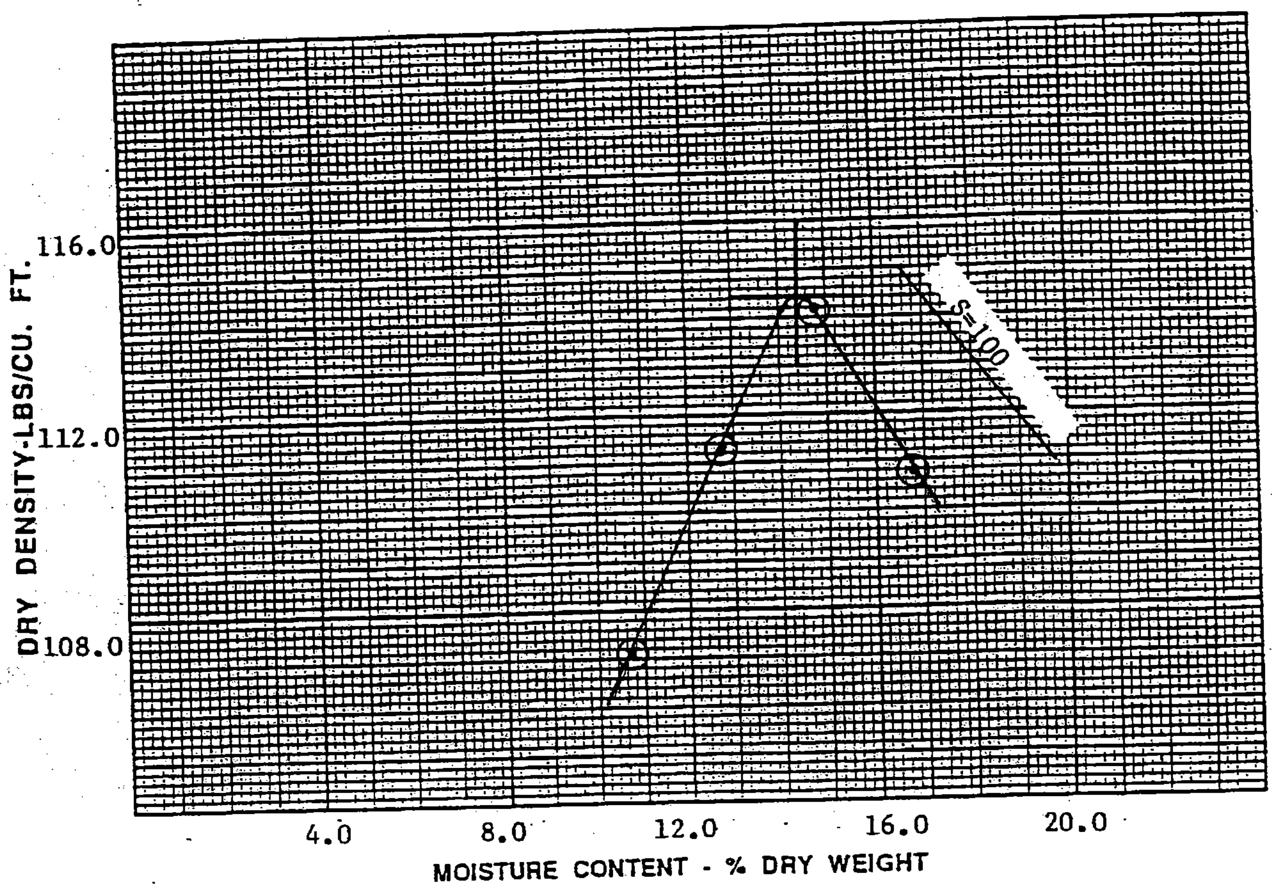
AGRA

SUMMARY OF MOISTURE DENSITY RELATIONSHIP TESTS

PROJECT Mixed Waste Landfill Cover JOB NO. 9-519-001154



SOURCE	OPTIMUM MOISTURE CONTENT % DRY WT.	MAXIMUM DRY DENSITY LBS/CU. FT.	TEST DESIGNATION	TEST METHOD	LAB NO.
P1D @ 4.3'	14.2	114.4	D698	A	4473

MOISTURE-DENSITY RELATIONSHIP TEST METHOD DATA

ASTM D698 (Standard Proctor)

METHOD	MATERIAL	MOLD DIAMETER	MOLD HEIGHT	NO. OF LAYERS	BLOWS PER LAYER	HAMMER WEIGHT	HEIGHT OF FALL	COMPACTIVE EFFORT FT. LBS/CU. FT.
A	-#4	4"	4.58"	3	25	5.5 lbs	12"	12,375
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ASTM D1557 (Modified Proctor)

METHOD	MATERIAL	MOLD DIAMETER	MOLD HEIGHT	NO. OF LAYERS	BLOWS PER LAYER	HAMMER WEIGHT	HEIGHT OF FALL	COMPACTIVE EFFORT FT. LBS/CU. FT.
A	-#4	4"	4.58"	5	25	10.0 lbs	18"	56,250
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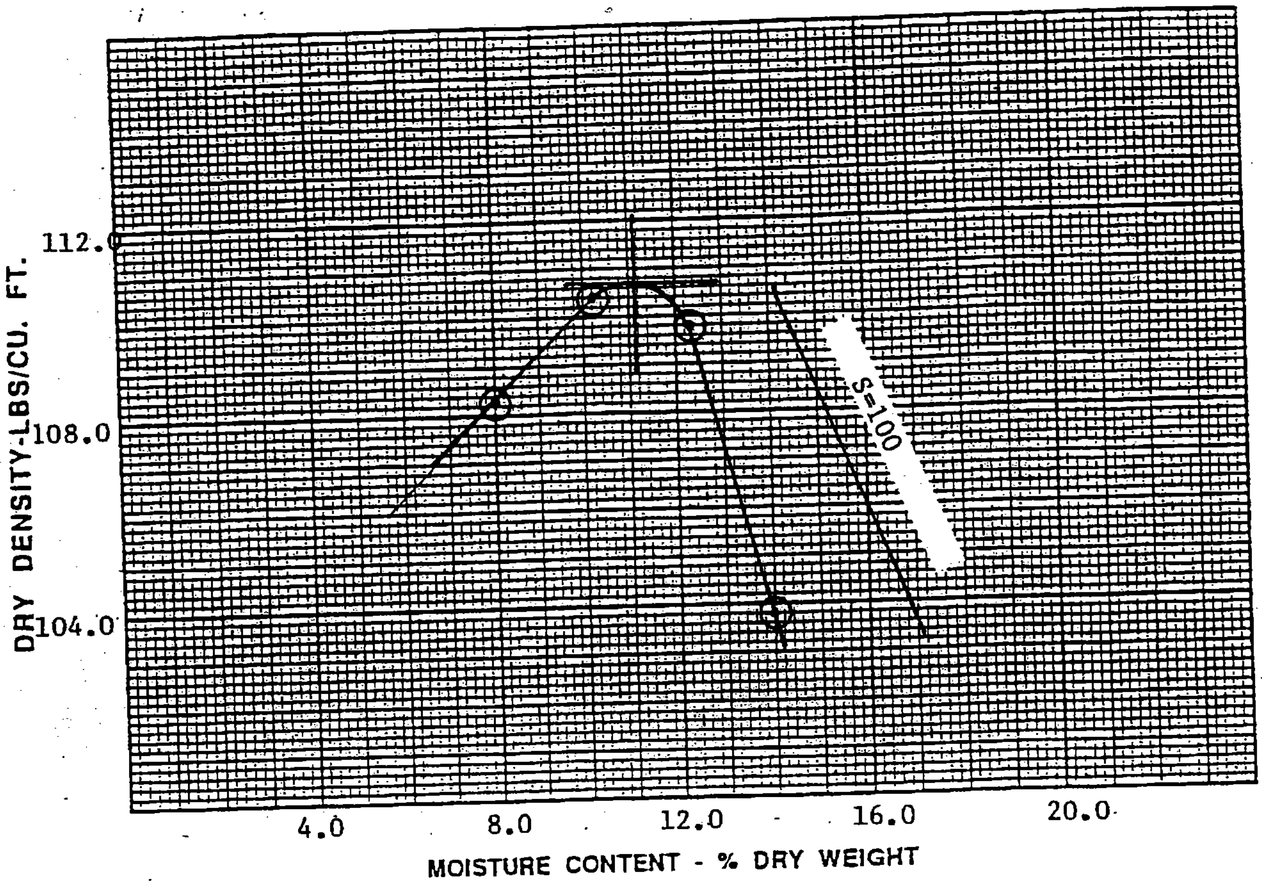
C	-3/4	6"	4.58"	5	56	10.0 lbs	18"	55,986

SUMMARY OF MOISTURE DENSITY RELATIONSHIP TESTS

PROJECT Mixed Waste Landfill Cover JOB NO. 9-519-001154



SOURCE	OPTIMUM MOISTURE CONTENT % DRY WT.	MAXIMUM DRY DENSITY LBS/CU. FT.	TEST DESIGNATION	TEST METHOD	LAB NO.
P1D @ 5.0'	11.1	110.7	D698	A	4474

MOISTURE-DENSITY RELATIONSHIP TEST METHOD DATA

ASTM D698 (Standard Proctor)

METHOD	MATERIAL	MOLD DIAMETER	MOLD HEIGHT	NO. OF LAYERS	BLOWS PER LAYER	HAMMER WEIGHT	HEIGHT OF FALL	COMPACTIVE EFFORT FT. LBS./CU. FT.
A	-#4	4"	4.58"	3	25	5.5 lbs	12"	12,375
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C	-3/4	6"	4.58"	3	56	5.5 lbs	12"	12,317

ASTM D1557 (Modified Proctor)

METHOD	MATERIAL	MOLD DIAMETER	MOLD HEIGHT	NO. OF LAYERS	BLOWS PER LAYER	HAMMER WEIGHT	HEIGHT OF FALL	COMPACTIVE EFFORT FT. LBS./CU. FT.
A	-#4	4"	4.58"	5	25	10.0 lbs	18"	56,250
B	-3/8	4"	4.58"	5	25	10.0 lbs	18"	55,986
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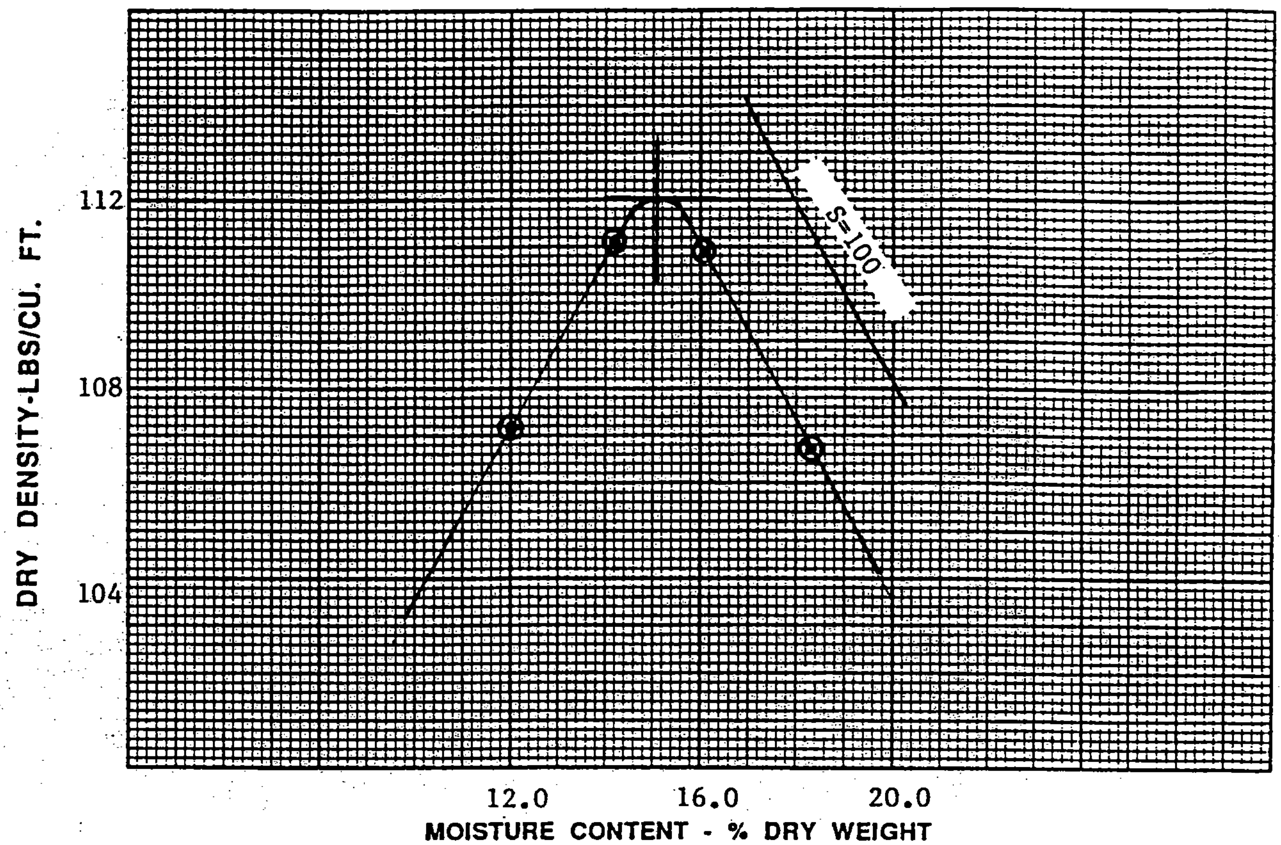
AGRA Earth & Environmental

SUMMARY OF MOISTURE DENSITY RELATIONSHIP TESTS

PROJECT Mixed Waste Landfill Cover JOB NO. 9-519-001154



SOURCE	OPTIMUM MOISTURE CONTENT % DRY WT.	MAXIMUM DRY DENSITY LBS/CU. FT.	TEST DESIGNATION	TEST METHOD	LAB NO.
P2-A @ 0.6'	15.1	112.0	D698 -		4571

MOISTURE-DENSITY RELATIONSHIP TEST METHOD DATA

ASTM D698 (Standard Proctor)

METHOD	MATERIAL	MOLD		NO. OF LAYERS	BLOWS PER LAYER	HAMMER WEIGHT	HEIGHT OF FALL	COMPACTIVE EFFORT FT. LBS./CU. FT.
		DIAMETER	HEIGHT					
A	-#4	4"	4.58"	3	25	5.5 lbs	12"	12,375
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ASTM D1557 (Modified Proctor)

METHOD	MATERIAL	MOLD		NO. OF LAYERS	BLOWS PER LAYER	HAMMER WEIGHT	HEIGHT OF FALL	COMPACTIVE EFFORT FT. LBS./CU. FT.
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A	-#4	4"	4.58"	5	25	10.0 lbs	18"	56,250
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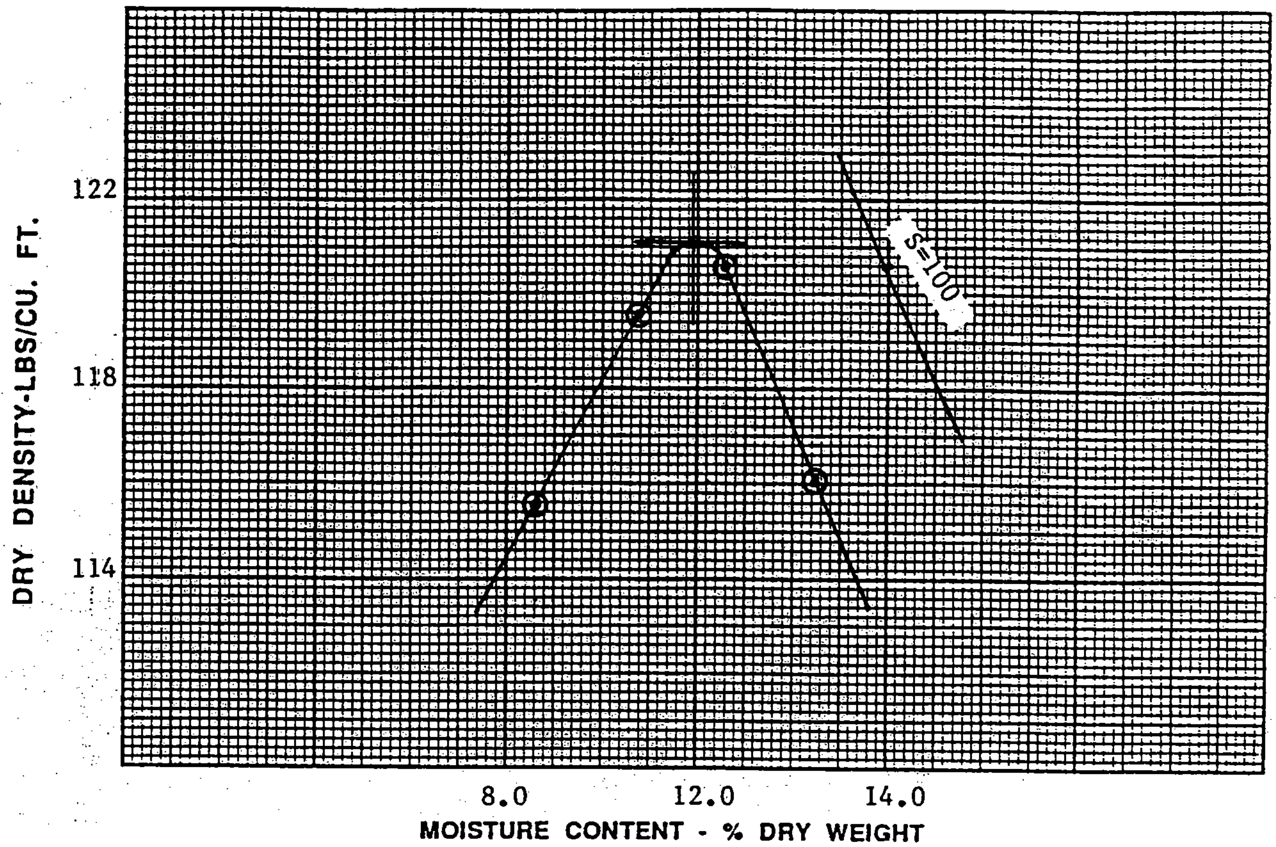
AGRA
Earth & Environmental

SUMMARY OF MOISTURE DENSITY RELATIONSHIP TESTS

PROJECT Mixed Waste Landfill Cover JOB NO. 9-519-001154



SOURCE	OPTIMUM MOISTURE CONTENT % DRY WT.	MAXIMUM DRY DENSITY LBS/CU. FT.	TEST DESIGNATION	TEST METHOD	LAB NO.
P2-A @ 1.5'	11.9	121.1	D698		4572

MOISTURE-DENSITY RELATIONSHIP TEST METHOD DATA

ASTM D698 (Standard Proctor)

METHOD	MATERIAL	MOLD		NO. OF LAYERS	BLOWS PER LAYER	HAMMER WEIGHT	HEIGHT OF FALL	COMPACTIVE EFFORT FT. LBS./CU. FT.
		DIAMETER	HEIGHT					
A	-#4	4"	4.58"	3	25	5.5 lbs	12"	12,375
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ASTM D1557 (Modified Proctor)

METHOD	MATERIAL	MOLD		NO. OF LAYERS	BLOWS PER LAYER	HAMMER WEIGHT	HEIGHT OF FALL	COMPACTIVE EFFORT FT. LBS./CU. FT.
		DIAMETER	HEIGHT					
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B	-3/8	4"	4.58"	5	25	10.0 lbs	18"	55,986
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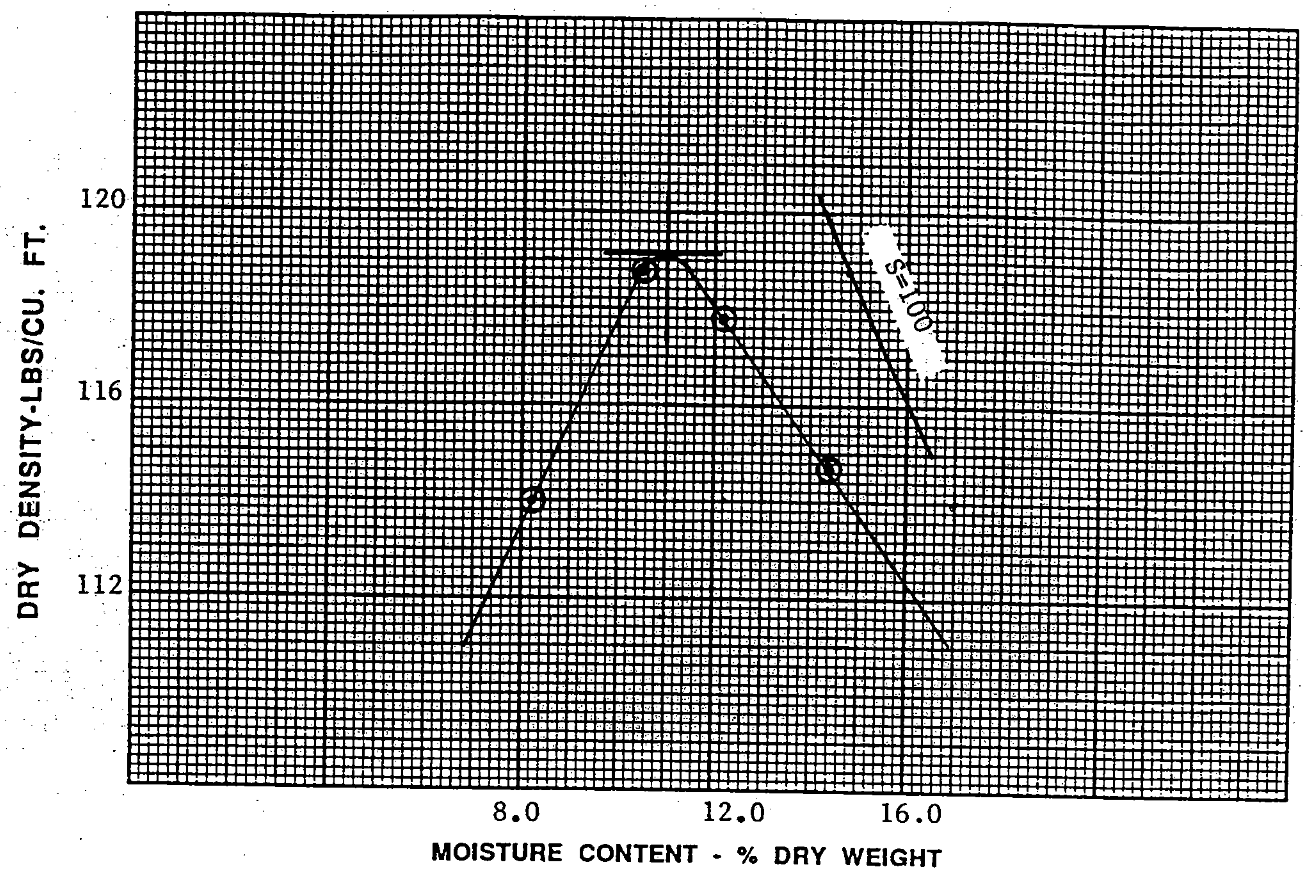
AGRA
Earth & Environmental

SUMMARY OF MOISTURE DENSITY RELATIONSHIP TESTS

PROJECT Mixed Waste Landfill Cover JOB NO. 9-519-001154



SOURCE	OPTIMUM MOISTURE CONTENT % DRY WT.	MAXIMUM DRY DENSITY LBS/CU. FT.	TEST DESIGNATION	TEST METHOD	LAB NO.
P2-A @ 1.7'	11.0	119.2	D698	-	4573

MOISTURE-DENSITY RELATIONSHIP TEST METHOD DATA

ASTM D698 (Standard Proctor)

METHOD	MATERIAL	MOLD DIAMETER	MOLD HEIGHT	NO. OF LAYERS	BLOWS PER LAYER	HAMMER WEIGHT	HEIGHT OF FALL	COMPACTIVE EFFORT FT. LBS./CU. FT.
A	-#4	4"	4.58"	3	25	5.5 lbs	12"	12,375
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ASTM D1557 (Modified Proctor)

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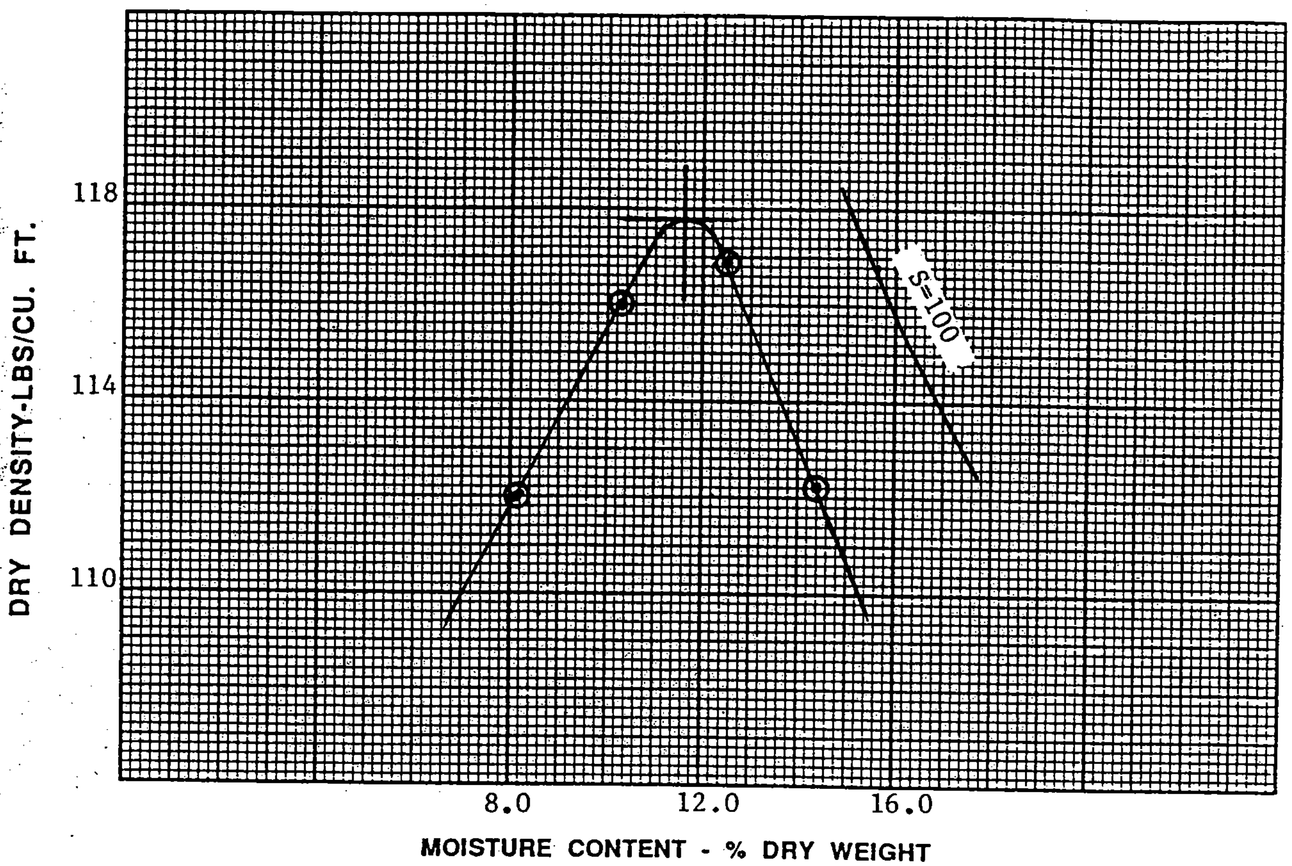
AGRA

SUMMARY OF MOISTURE DENSITY RELATIONSHIP TESTS

PROJECT Mixed Waste Landfill Cover **JOB NO.** 9-519-001154



SOURCE	OPTIMUM MOISTURE CONTENT % DRY WT.	MAXIMUM DRY DENSITY LBS/CU. FT.	TEST DESIGNATION	TEST METHOD	LAB NO.
P2-D @ 0.6'	11.6	117.8	D698		4574

MOISTURE-DENSITY RELATIONSHIP TEST METHOD DATA

ASTM D698 (Standard Proctor)

METHOD	MATERIAL	MOLD		NO. OF LAYERS	BLOWS PER LAYER	HAMMER WEIGHT	HEIGHT OF FALL	COMPACTIVE EFFORT FT. LBS./CU. FT.
		DIAMETER	HEIGHT					
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ASTM D1557 (Modified Proctor)

METHOD	MATERIAL	MOLD		NO. OF LAYERS	BLOWS PER LAYER	HAMMER WEIGHT	HEIGHT OF FALL	COMPACTIVE EFFORT FT. LBS./CU. FT.
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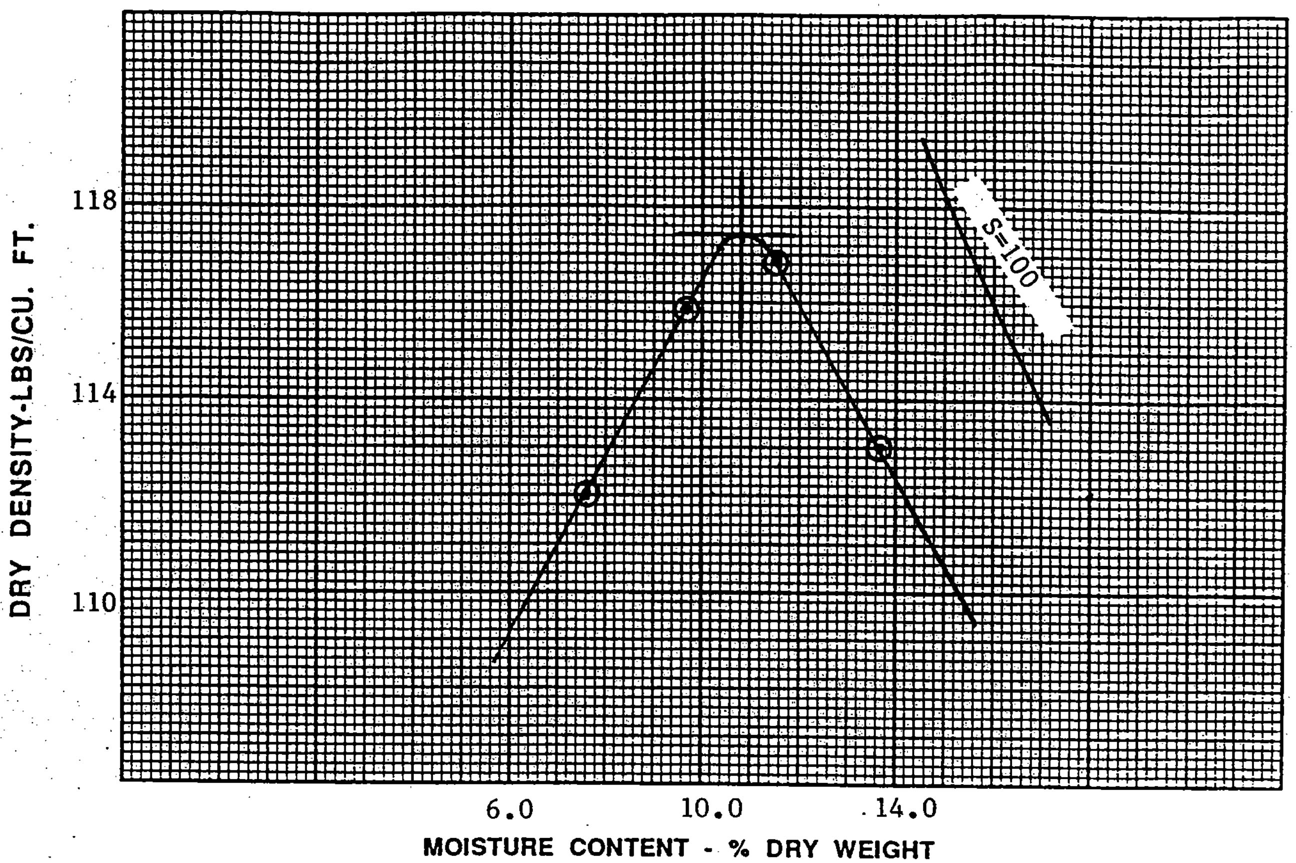
AGRA

SUMMARY OF MOISTURE DENSITY RELATIONSHIP TESTS

PROJECT Mixed Waste Landfill Cover JOB NO. 9-519-001154



SOURCE	OPTIMUM MOISTURE CONTENT % DRY WT.	MAXIMUM DRY DENSITY LBS/CU. FT.	TEST DESIGNATION	TEST METHOD	LAB NO.
P2-E @ 1.0'	10.8	117.4	D698		4575

MOISTURE-DENSITY RELATIONSHIP TEST METHOD DATA

ASTM D698 (Standard Proctor)

METHOD	MATERIAL	MOLD DIAMETER	MOLD HEIGHT	NO. OF LAYERS	BLOWS PER LAYER	HAMMER WEIGHT	HEIGHT OF FALL	COMPACTIVE EFFORT FT. LBS./CU. FT.
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ASTM D1557 (Modified Proctor)

METHOD	MATERIAL	MOLD DIAMETER	MOLD HEIGHT	NO. OF LAYERS	BLOWS PER LAYER	HAMMER WEIGHT	HEIGHT OF FALL	COMPACTIVE EFFORT FT. LBS./CU. FT.
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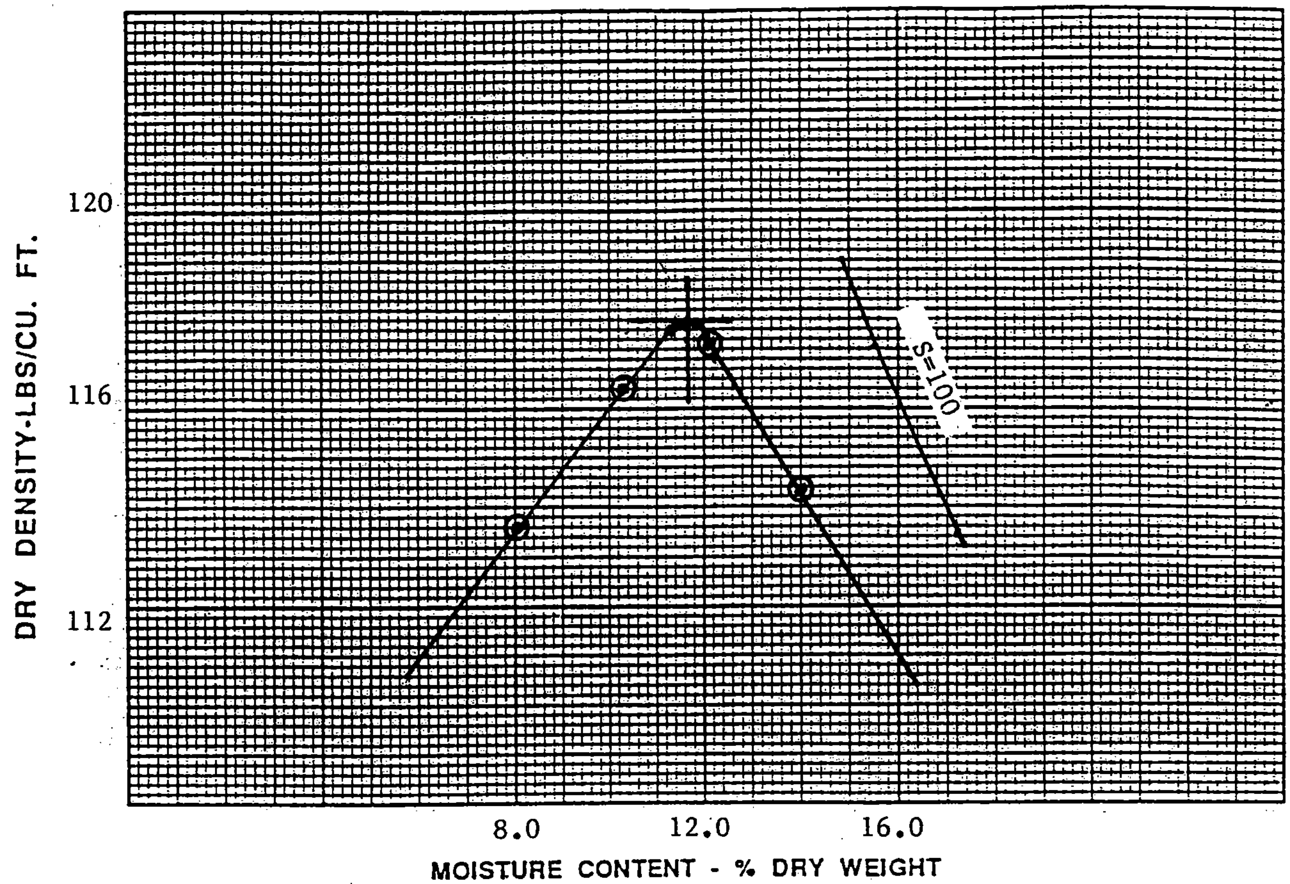
AGRA

SUMMARY OF MOISTURE DENSITY RELATIONSHIP TESTS

PROJECT Mixed Waste Landfill Cover JOB NO. 9-519-001154



SOURCE	OPTIMUM MOISTURE CONTENT % DRY WT.	MAXIMUM DRY DENSITY LBS/CU. FT.	TEST DESIGNATION	TEST METHOD	LAB NO.
Native Soil 1 of 3	11.7	117.8	D698		4565

MOISTURE-DENSITY RELATIONSHIP TEST METHOD DATA

ASTM D698 (Standard Proctor)

METHOD	MATERIAL	MOLD		NO. OF LAYERS	BLOWS PER LAYER	HAMMER WEIGHT	HEIGHT OF FALL	COMPACTIVE EFFORT FT. LBS./CU. FT.
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C	-3/4	6"	4.58"	3	56	5.5 lbs	12"	12,317

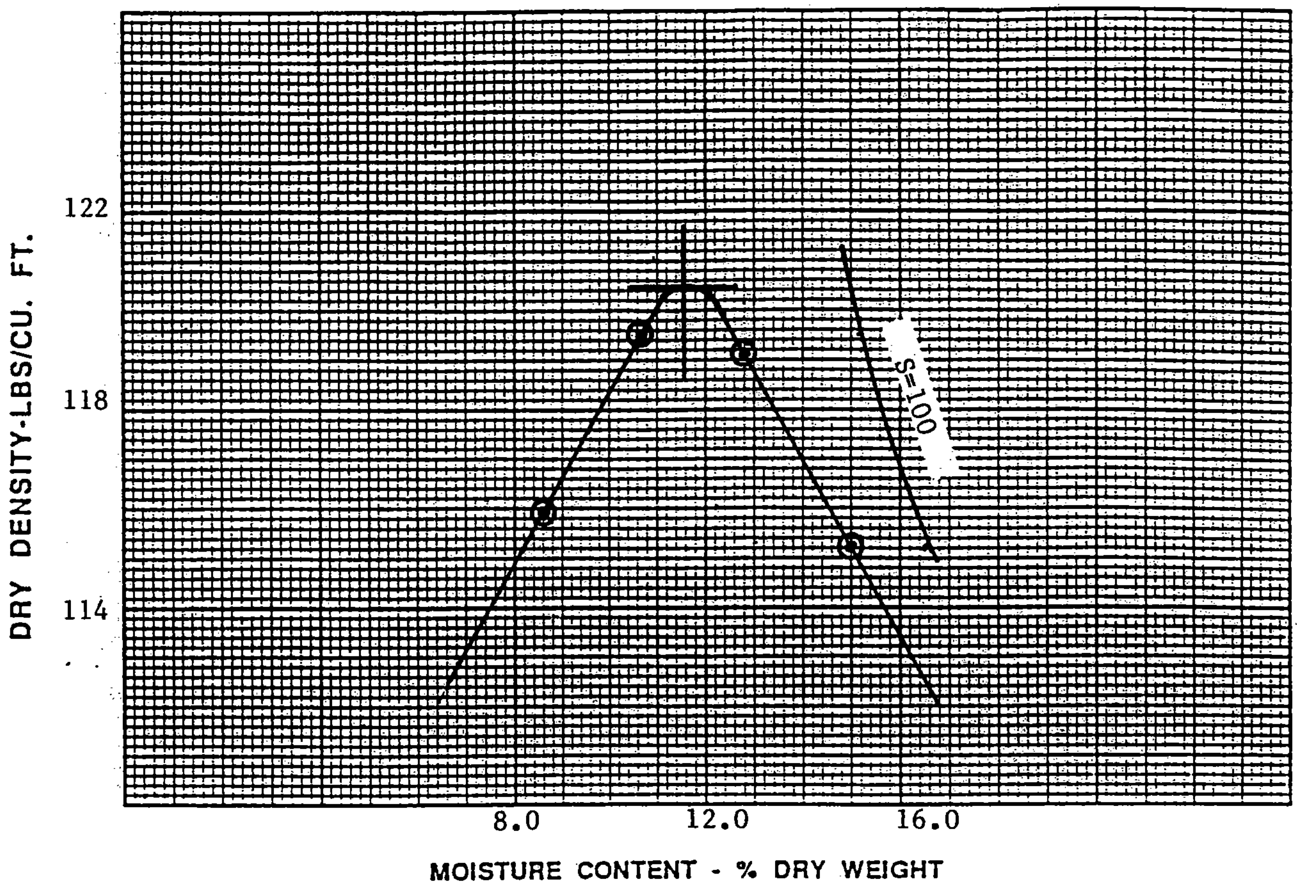
ASTM D1557 (Modified Proctor)

METHOD	MATERIAL	MOLD		NO. OF LAYERS	BLOWS PER LAYER	HAMMER WEIGHT	HEIGHT OF FALL	COMPACTIVE EFFORT FT. LBS./CU. FT.
		DIAMETER	HEIGHT					
A	-#4	4"	4.58"	5	25	10.0 lbs	18"	56,250
B	-3/8	4"	4.58"	5	25	10.0 lbs	18"	55,986
C	-3/4	6"	4.58"	5	56	10.0 lbs	18"	55,986

AGRA
Earth & Environmental, Inc.
8519 Jefferson NE

SUMMARY OF MOISTURE DENSITY RELATIONSHIP TESTS

PROJECT Mixed Waste Landfill Cover **JOB NO.** 9-519-001154



SOURCE	OPTIMUM MOISTURE CONTENT % DRY WT.	MAXIMUM DRY DENSITY LBS/CU. FT.	TEST DESIGNATION	TEST METHOD	LAB NO.
Native Soil 2 of 3	11.6	120.4	D698		4566

MOISTURE-DENSITY RELATIONSHIP TEST METHOD DATA

ASTM D698 (Standard Proctor)

METHOD	MATERIAL	MOLD DIAMETER	MOLD HEIGHT	NO. OF LAYERS	BLOWS PER LAYER	HAMMER WEIGHT	HEIGHT OF FALL	COMPACTIVE EFFORT FT. LBS./CU. FT.
A	-#4	4"	4.58"	3	25	5.5 lbs	12"	12,375
B	-#4	4"	4.58"	3	25	5.5 lbs	12"	12,317
C	-3/4	6"	4.58"	3	56	5.5 lbs	12"	12,317

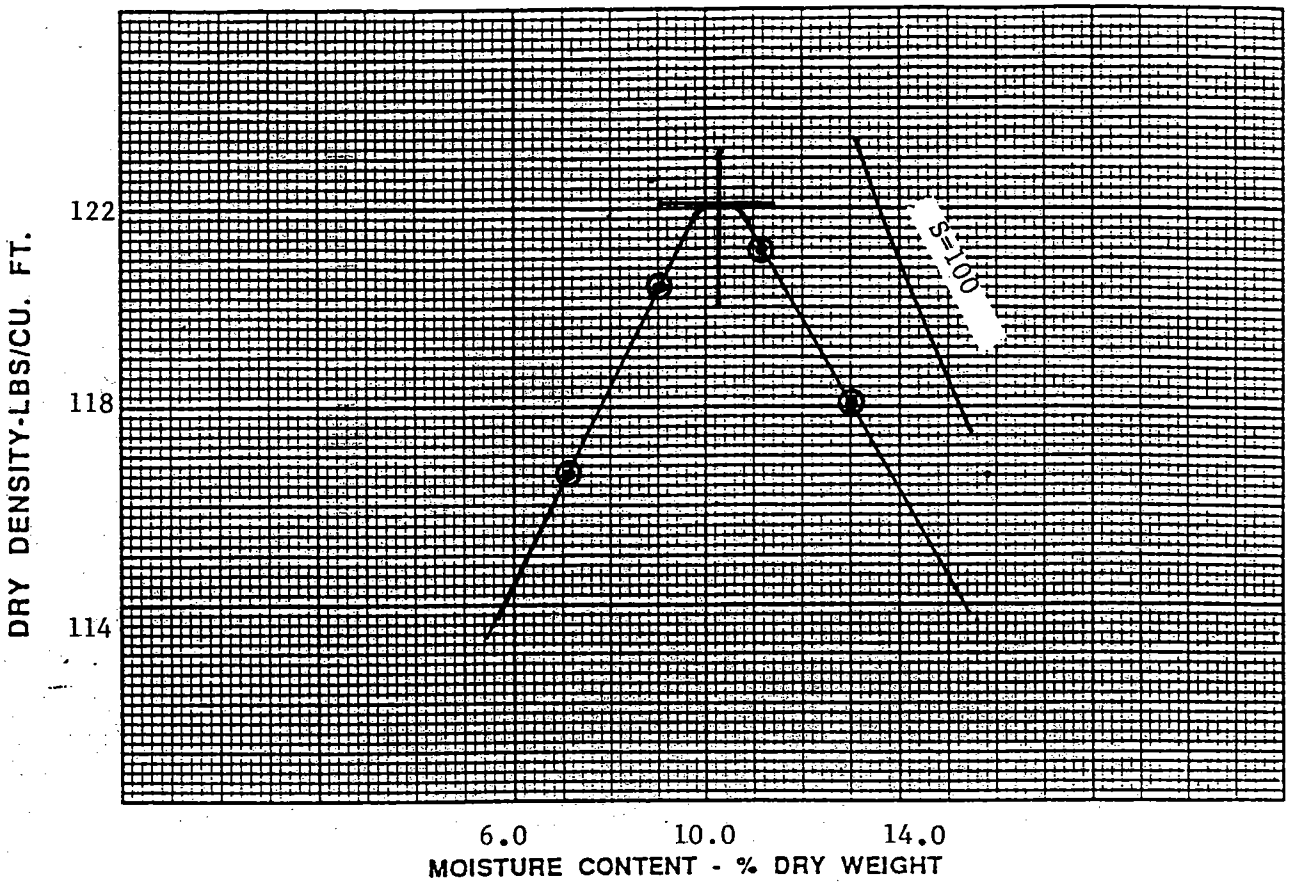
ASTM D1557 (Modified Proctor)

METHOD	MATERIAL	MOLD DIAMETER	MOLD HEIGHT	NO. OF LAYERS	BLOWS PER LAYER	HAMMER WEIGHT	HEIGHT OF FALL	COMPACTIVE EFFORT FT. LBS./CU. FT.
A	-#4	4"	4.58"	5	25	10.0 lbs	18"	56,250
B	-3/8	4"	4.58"	5	25	10.0 lbs	18"	55,986
C	-3/4	6"	4.58"	5	56	10.0 lbs	18"	55,986

AGRA
Earth & Environmental, Inc.

SUMMARY OF MOISTURE DENSITY RELATIONSHIP TESTS

PROJECT Mixed Waste Landfill Cover JOB NO. 9-519-001154



SOURCE	OPTIMUM MOISTURE CONTENT % DRY WT.	MAXIMUM DRY DENSITY LBS/CU. FT.	TEST DESIGNATION	TEST METHOD	LAB NO.
Native Soil 3 of 3	10.3	122.1	D698		4567

MOISTURE-DENSITY RELATIONSHIP TEST METHOD DATA

ASTM D698 (Standard Proctor)

METHOD	MATERIAL	MOLD DIAMETER	MOLD HEIGHT	NO. OF LAYERS	BLOWS PER LAYER	HAMMER WEIGHT	HEIGHT OF FALL	COMPACTIVE EFFORT FT. LBS./CU. FT.
A	-#4	4"	4.58"	3	25	5.5 lbs	12"	12,375
B	-#4	4"	4.58"	3	25	5.5 lbs	12"	12,317
C	-3/4	6"	4.58"	3	56	5.5 lbs	12"	12,317

ASTM D1557 (Modified Proctor)

METHOD	MATERIAL	MOLD DIAMETER	MOLD HEIGHT	NO. OF LAYERS	BLOWS PER LAYER	HAMMER WEIGHT	HEIGHT OF FALL	COMPACTIVE EFFORT FT. LBS./CU. FT.
A	-#4	4"	4.58"	5	25	10.0 lbs	18"	56,250
B	-3/8	4"	4.58"	5	25	10.0 lbs	18"	55,986
C	-3/4	6"	4.58"	5	56	10.0 lbs	18"	55,986

AGRA
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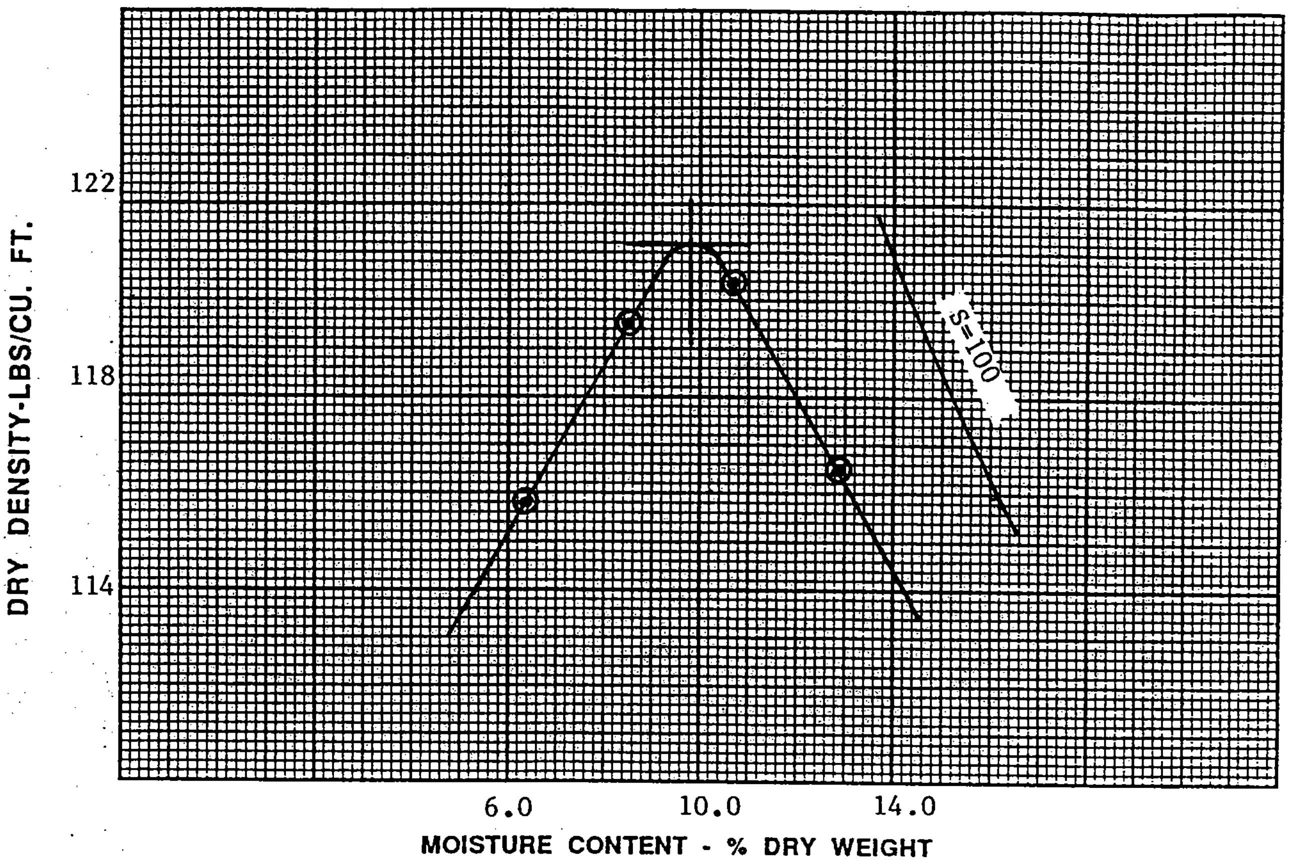
8519 Jefferson NE

SUMMARY OF MOISTURE DENSITY RELATIONSHIP TESTS

PROJECT Mixed Waste Landfill Cover **JOB NO.** 9-519-001154



SOURCE	OPTIMUM MOISTURE CONTENT % DRY WT.	MAXIMUM DRY DENSITY LBS/CU. FT.	TEST DESIGNATION	TEST METHOD	LAB NO.
Subgrade Soil 1 of 3	9.8	121.2	D698		4568

MOISTURE-DENSITY RELATIONSHIP TEST METHOD DATA

ASTM D698 (Standard Proctor)

METHOD	MATERIAL	MOLD DIAMETER	MOLD HEIGHT	NO. OF LAYERS	BLOWS PER LAYER	HAMMER WEIGHT	HEIGHT OF FALL	COMPACTIVE EFFORT FT. LBS./CU. FT.
A	-#4	4"	4.58"	3	25	5.5 lbs	12"	12,375
B	-3/8	4"	4.58"	3	25	5.5 lbs	12"	12,317
C	-3/4	6"	4.58"	3	56	5.5 lbs	12"	12,317

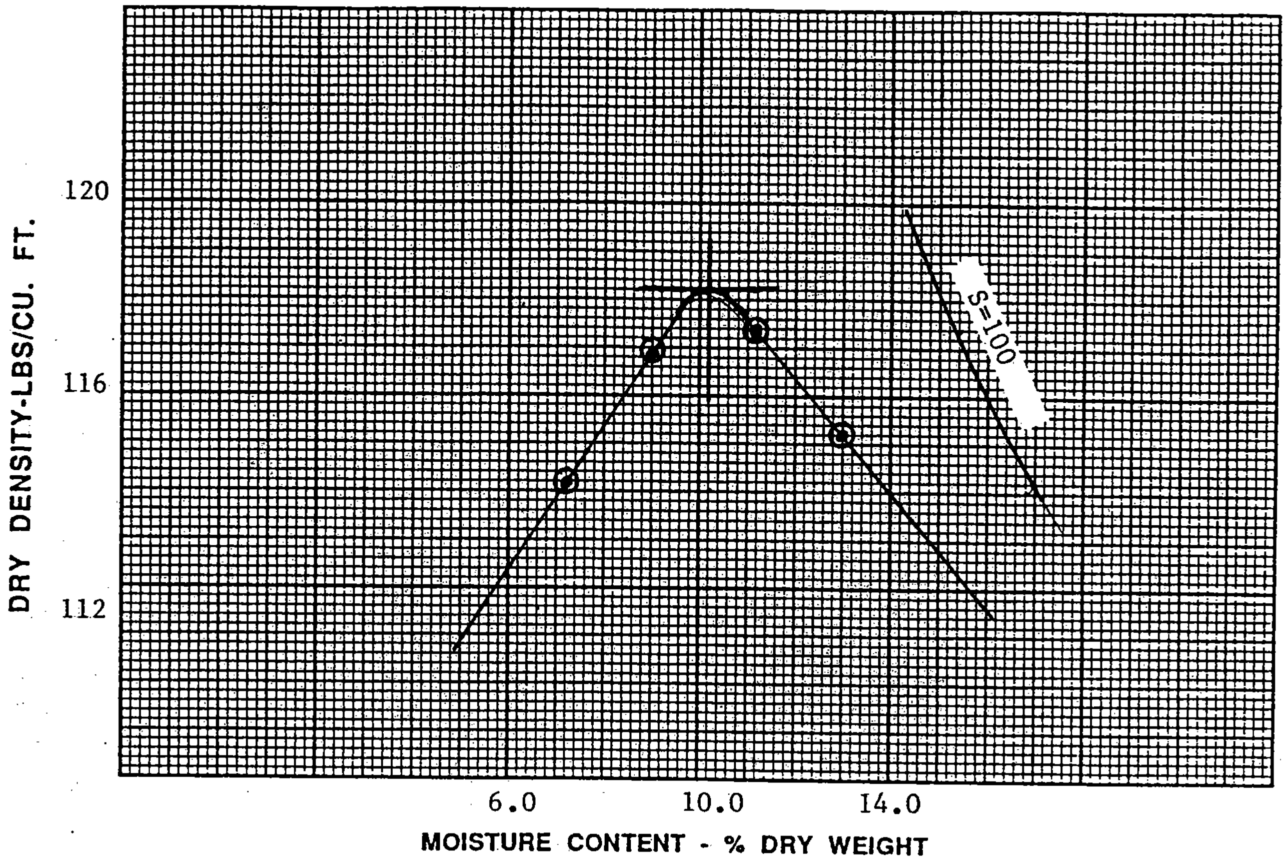
ASTM D1557 (Modified Proctor)

METHOD	MATERIAL	MOLD DIAMETER	MOLD HEIGHT	NO. OF LAYERS	BLOWS PER LAYER	HAMMER WEIGHT	HEIGHT OF FALL	COMPACTIVE EFFORT FT. LBS./CU. FT.
A	-#4	4"	4.58"	5	25	10.0 lbs	18"	56,250
B	-3/8	4"	4.58"	5	25	10.0 lbs	18"	55,986
C	-3/4	6"	4.58"	5	56	10.0 lbs	18"	55,986

AGRA

SUMMARY OF MOISTURE DENSITY RELATIONSHIP TESTS

PROJECT Mixed Waste Landfill Cover JOB NO. 9-519-001154



SOURCE	OPTIMUM MOISTURE CONTENT % DRY WT.	MAXIMUM DRY DENSITY LBS/CU. FT.	TEST DESIGNATION	TEST METHOD	LAB NO.
Subgrade Soil 2 of 3	10.2	118.2	D698	-	4569

MOISTURE-DENSITY RELATIONSHIP TEST METHOD DATA

ASTM D698 (Standard Proctor)

METHOD	MATERIAL	MOLD DIAMETER	MOLD HEIGHT	NO. OF LAYERS	BLOWS PER LAYER	HAMMER WEIGHT	HEIGHT OF FALL	COMPACTIVE EFFORT FT. LBS./CU. FT.
A	-#4	4"	4.58"	3	25	5.5 lbs	12"	12,375
B	-3/8	4"	4.58"	3	25	5.5 lbs	12"	12,317
C	-3/4	6"	4.58"	3	56	5.5 lbs	12"	12,317

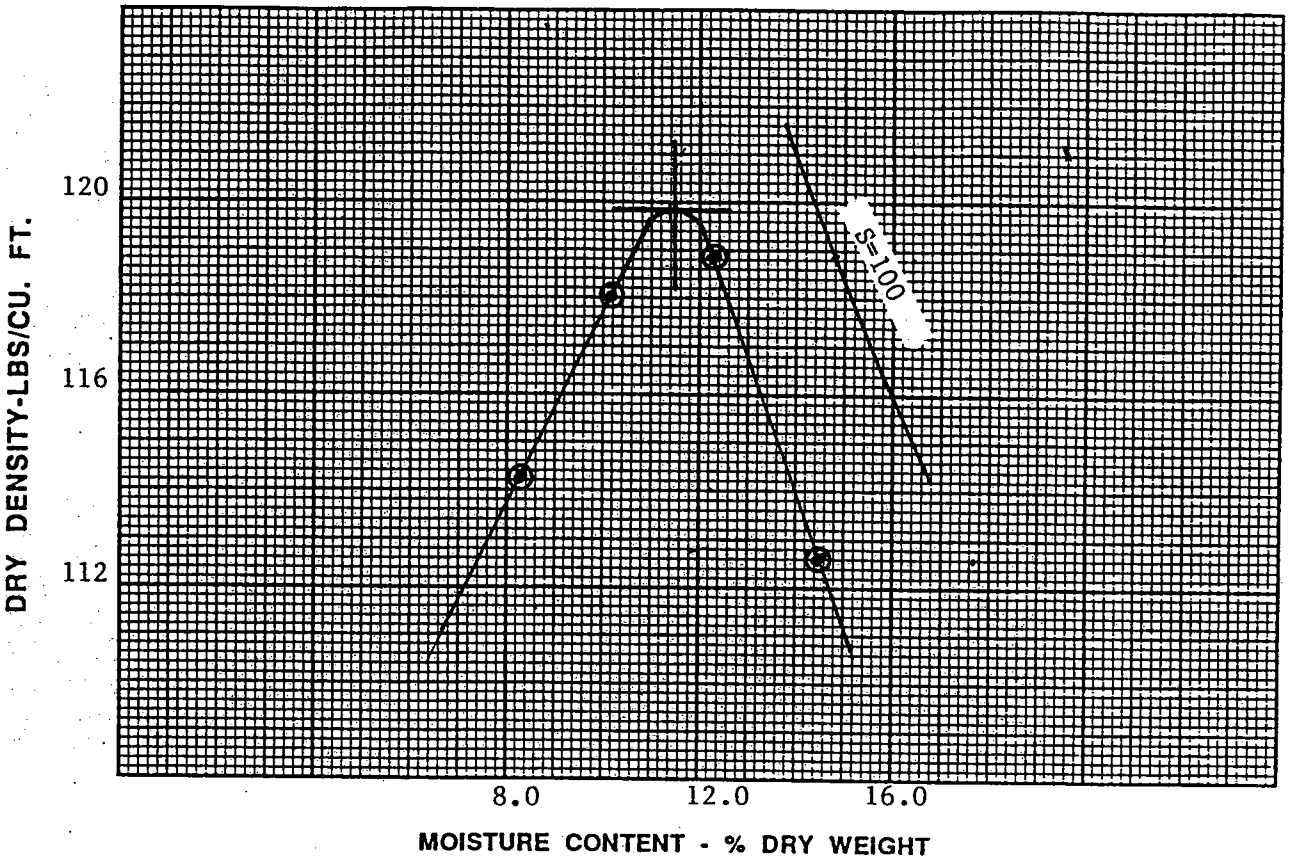
ASTM D1557 (Modified Proctor)

METHOD	MATERIAL	MOLD DIAMETER	MOLD HEIGHT	NO. OF LAYERS	BLOWS PER LAYER	HAMMER WEIGHT	HEIGHT OF FALL	COMPACTIVE EFFORT FT. LBS./CU. FT.
A	-#4	4"	4.58"	5	25	10.0 lbs	18"	56,250
B	-3/8	4"	4.58"	5	25	10.0 lbs	18"	55,986
C	-3/4	6"	4.58"	5	56	10.0 lbs	18"	55,986

AGRA

SUMMARY OF MOISTURE DENSITY RELATIONSHIP TESTS

PROJECT Mixed Waste Landfill Cover **JOB NO.** 9-519-001154



SOURCE	OPTIMUM MOISTURE CONTENT % DRY WT.	MAXIMUM DRY DENSITY LBS/CU. FT.	TEST DESIGNATION	TEST METHOD	LAB NO.
Subgrade Soil 3 of 3	11.5	119.8	D698		4570

MOISTURE-DENSITY RELATIONSHIP TEST METHOD DATA

ASTM D698 (Standard Proctor)

METHOD	MATERIAL	MOLD DIAMETER	MOLD HEIGHT	NO. OF LAYERS	BLOWS PER LAYER	HAMMER WEIGHT	HEIGHT OF FALL	COMPACTIVE EFFORT FT. LBS./CU. FT.
A	-#4	4"	4.58"	3	25	5.5 lbs	12"	12,375
B	-3/8	4"	4.58"	3	25	5.5 lbs	12"	12,317
C	-3/4	6"	4.58"	3	56	5.5 lbs	12"	12,317

ASTM D1557 (Modified Proctor)

METHOD	MATERIAL	MOLD DIAMETER	MOLD HEIGHT	NO. OF LAYERS	BLOWS PER LAYER	HAMMER WEIGHT	HEIGHT OF FALL	COMPACTIVE EFFORT FT. LBS./CU. FT.
A	-#4	4"	4.58"	5	25	10.0 lbs	18"	56,250
B	-3/8	4"	4.58"	5	25	10.0 lbs	18"	55,986
C	-3/4	6"	4.58"	5	56	10.0 lbs	18"	55,986

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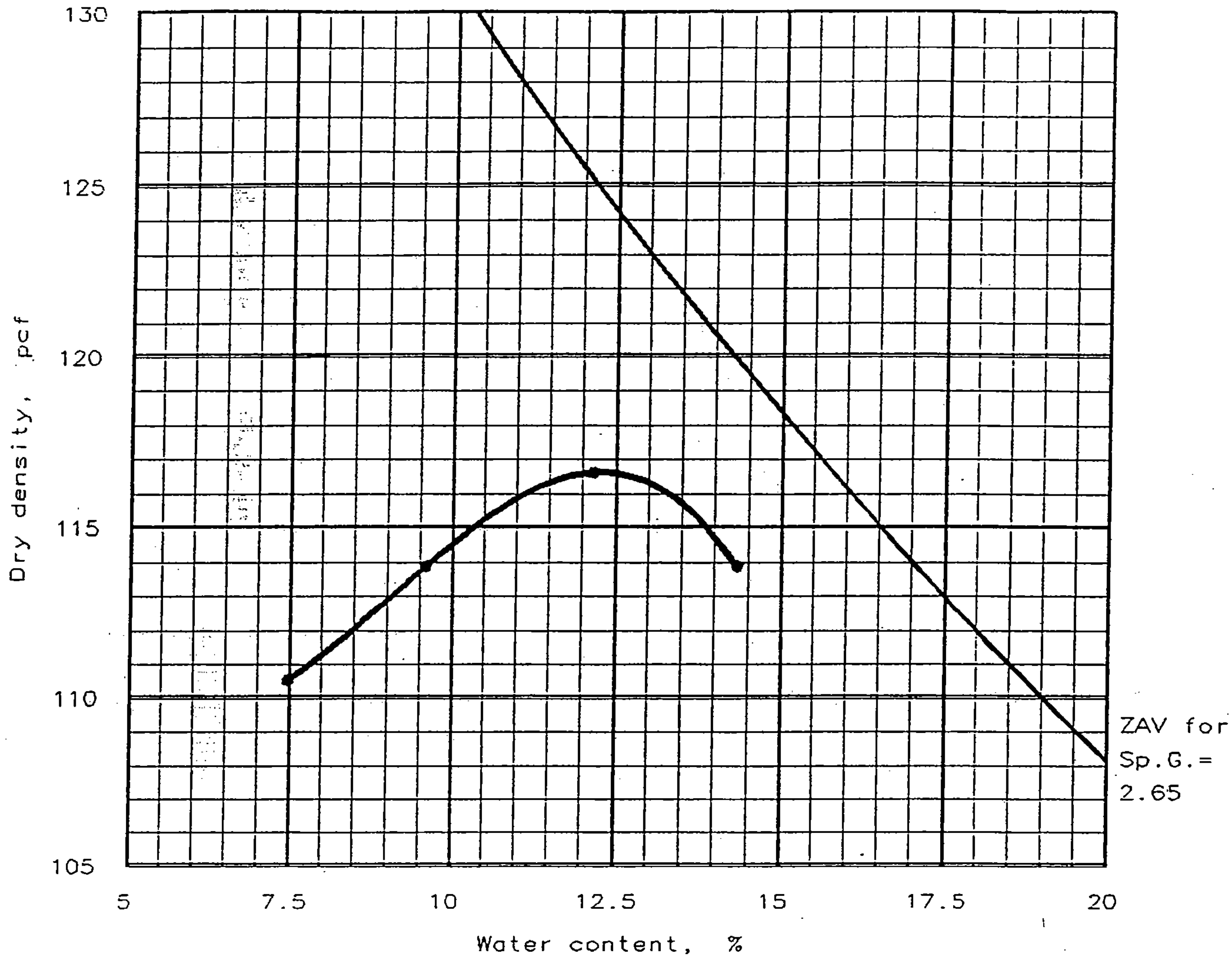
MOISTURE-DENSITY RELATIONSHIP TEST



Test specification: ASTM D 698-91 Procedure A, Standard

Oversize correction applied to each point

Elev/ Depth	Classification		Nat. Moist.	Sp.G.	LL	PI	% > No.4	% < No.200
	USCS	AASHTO						
4"	SM		3.6 %	2.65	N/A	N/A	N/A %	N/A %

ROCK CORRECTED TEST RESULTS	UNCORRECTED	MATERIAL DESCRIPTION
Maximum dry density = 116.6 pcf Optimum moisture = 12.3 %	116.6 pcf 12.3 %	Silty SAND

Project No.: 1643A

Project: Sandia National Labs Permeability Tests

Location: AEP-1a (surface)

Date: 10/19/98

Remarks:

Tested By: JP

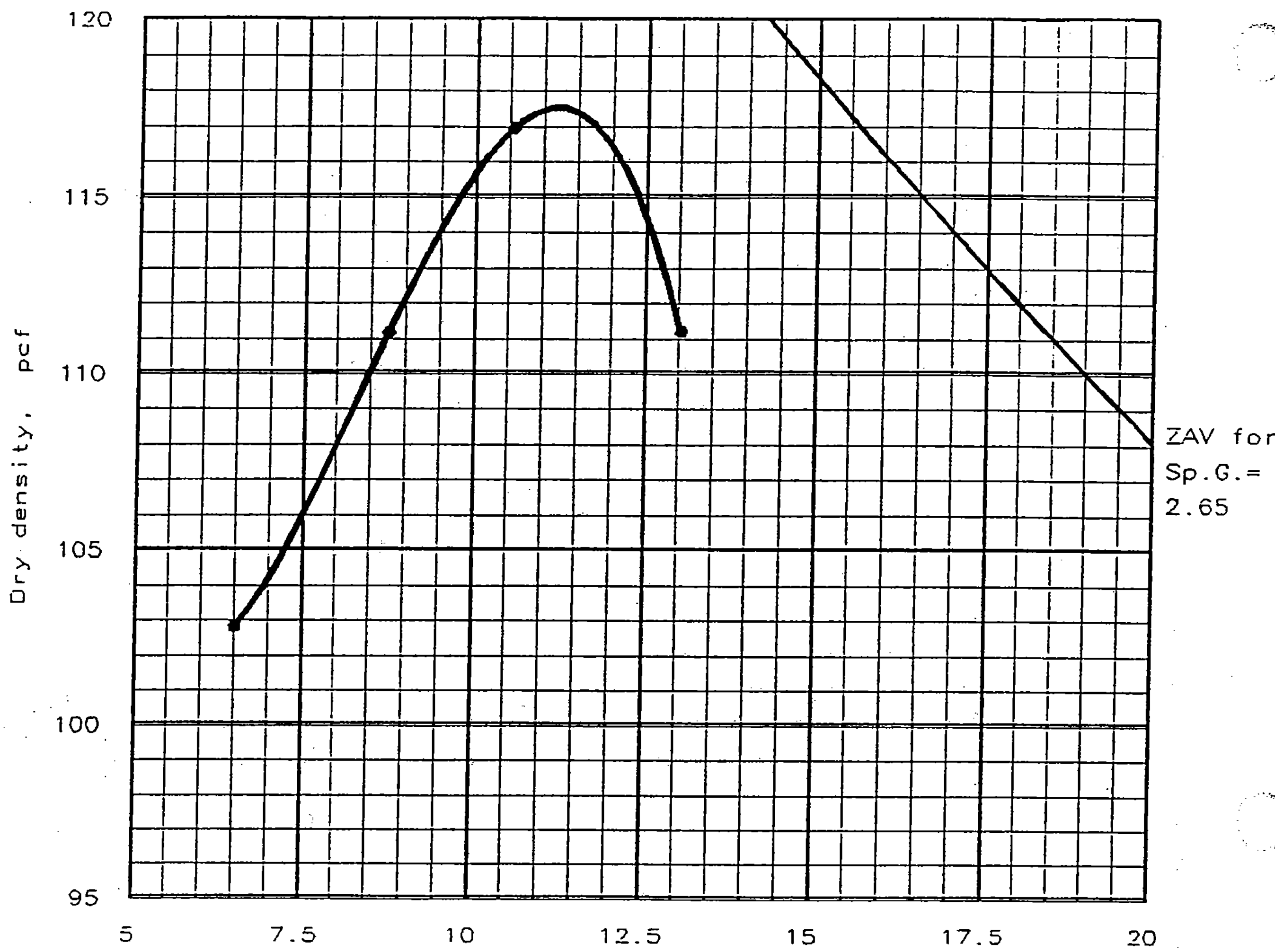
Sampled By: RW

MOISTURE-DENSITY RELATIONSHIP TEST

Knight Piesold and Co.

AEP-1a

MOISTURE-DENSITY RELATIONSHIP TEST



Test specification: ASTM D 698-91 Procedure A, Standard

Oversize correction applied to each point

Elev/ Depth	Classification		Nat. Moist.	Sp.G.	LL	PI	% > No.4	% < No.200
	USCS	AASHTO						
18"	SM		9.9 %	2.65	N/A	N/A	N/A %	N/A %

ROCK CORRECTED TEST RESULTS	UNCORRECTED	MATERIAL DESCRIPTION
Maximum dry density = 117.5 pcf Optimum moisture = 11.2 %	117.5 pcf 11.2 %	Silty SAND

Project No.: 1643A

Project: Sandia National Labs Permeability Tests

Location: AEP-1b

Date: 10/19/98

Remarks:

Tested By: JP

Sampled By: RW

MOISTURE-DENSITY RELATIONSHIP TEST

Knight Piesold and Co.

AEP-1b

Attachment H

Falling-Head Permeabilities
(AGRA Earth & Environmental)

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AGRA Earth &
Environmental, Inc.
8519 Jefferson NE
Albuquerque
New Mexico 87109
Tel (505) 821-1801
Fax (505) 821-7371

PROJECT:	MIXED WASTE LANDFILL COVER	JOB NO.	9-517-001154
SAMPLE:	COMPOSITE MWL 1-A @ 0-2'	W.O. NO.	-
		LAB NO.	4557
		DATE	05/07/99

PERMEABILITY (ASTM D2434)

WET DENSITY	124.8	pcf
DRY DENSITY	106.1	pcf
VOLUME	943.694	cc
INITAL MOISTURE	9.7%	
MOISTURE @ SATURATION	17.6%	
MAXIMUM DRY DENSITY (PCF)	116.4	
PERCENT COMPACTION	91.2%	

HEAD		Q	TIME	K	K
inches	PSI	cc	sec.	cm/sec	ft/yr
14.27	0.52	56	2010.0	1.10E-04	1.14E+02

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PROJECT:	MIXED WASTE LANDFILL COVER	JOB NO.	9-517-001154
SAMPLE:	COMPOSITE MWL 1-B @ 2'+	W.O. NO.	-
		LAB NO.	4560
		DATE	05/07/99

PERMEABILITY (ASTM D2434)

WET DENSITY	119.7 pcf
DRY DENSITY	103.7 pcf
VOLUME	943.694 cc
INITAL MOISTURE	10.2%
MOISTURE @ SATURATION	15.4%
MAXIMUM DRY DENSITY (PCF)	112.2
PERCENT COMPACTION	92.4%

HEAD inches	PSI	Q cc	TIME sec.	K cm/sec	K ft/yr
13.50	0.49	81	7800.0	4.33E-05	4.48E+01

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PROJECT MIXED WASTE LANDFILL COVER
CLIENT: SNL
SAMPLE: NATIVE SOIL CAMU 1 OF 3

JOB NO. 9-517-001154
LAB NO. 4565
DATE 07/14/99

PERMEABILITY (ASTM D2434)

WET DENSITY SATURATED	126.6	pcf
WET DENSITY	118.1	pcf
DRY DENSITY	106.0	pcf
VOLUME	943.694	cc
INITAL MOISTURE	11.4%	
MOISTURE @ SATURATION	19.3%	
MAXIMUM DRY DENSITY (PCF)	117.8	
OPTIMUM MOIST. CONTENT (%)	11.7	
PERCENT COMPACTION	90.0%	
% SATURATION	91.6	

HEAD Inches	PSI	Q cc	TIME sec.	K cm/sec	K ft/yr
15.53	0.56	15	3600.0	1.5E-05	1.6E+01

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New Mexico 87109
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Fax (505) 821-7371

PROJECT MIXED WASTE LANDFILL COVER
CLIENT: SNL
SAMPLE: NATIVE SOIL CAMU 2 OF 3

JOB NO. 9-517-001154
LAB NO. 4566
DATE 07/14/99

PERMEABILITY (ASTM D2434)

WET DENSITY SATURATED	127.9	pcf
WET DENSITY	124.0	pcf
DRY DENSITY	110.8	pcf
VOLUME	943.694	cc
INITAL MOISTURE	11.9%	
MOISTURE @ SATURATION	15.5%	
MAXIMUM DRY DENSITY (PCF)	120.4	
OPTIMUM MOIST. CONTENT (%)	11.6	
PERCENT COMPACTION	92.0%	
% SATURATION	83.2	

HEAD inches	PSI	Q cc	TIME sec.	K cm/sec	K ft/yr
15.50	0.56	16	3600.0	1.7E-05	1.7E+01

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PROJECT MIXED WASTE LANDFILL COVER
CLIENT: SNL
SAMPLE: NATIVE SOIL CAMU 3 OF 3

JOB NO. 9-517-001154
LAB NO. 4567
DATE 07/14/99

PERMEABILITY (ASTM D2434)

WET DENSITY SATURATED	125.6 pcf
WET DENSITY	121.3 pcf
DRY DENSITY	110.9 pcf
VOLUME	943.694 cc
INITAL MOISTURE	9.4%
MOISTURE @ SATURATION	13.2%
MAXIMUM DRY DENSITY (PCF)	122.1
OPTIMUM MOIST. CONTENT (%)	10.3
PERCENT COMPACTION	90.9%
% SATURATION	71.2

HEAD inches	PSI	Q cc	TIME sec.	K cm/sec	K ft/yr
15.06	0.54	30	3600.0	3.2E-05	3.3E+01

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New Mexico 87109
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Fax (505) 821-7371

PROJECT MIXED WASTE LANDFILL COVER
CLIENT: SNL
SAMPLE: SUBGRADE SOIL 1 OF 3

JOB NO. 9-517-001154
LAB NO. 4568
DATE 07/14/99

PERMEABILITY (ASTM D2434)

WET DENSITY SATURATED	125.9 pcf
WET DENSITY	122.5 pcf
DRY DENSITY	110.1 pcf
VOLUME	943.694 cc
INITAL MOISTURE	11.2%
MOISTURE @ SATURATION	14.3%
MAXIMUM DRY DENSITY (PCF)	121.2
OPTIMUM MOIST. CONTENT (%)	9.8
PERCENT COMPACTION	90.9%
% SATURATION	75.6

HEAD Inches	PSI	Q cc	TIME sec.	K cm/sec	K ft/yr
15.59	0.56	13	4800.0	1.0E-05	1.0E+01

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Fax (505) 821-7371

PROJECT MIXED WASTE LANDFILL COVER
CLIENT: SNL
SAMPLE: SUBGRADE SOIL 2 OF 3

JOB NO. 9-517-001154
LAB NO. 4569
DATE 07/14/99

PERMEABILITY (ASTM D2434)

WET DENSITY SATURATED	125.6	pcf
WET DENSITY	120.9	pcf
DRY DENSITY	108.6	pcf
VOLUME	943.694	cc
INITAL MOISTURE	11.3%	
MOISTURE @ SATURATION	15.6%	
MAXIMUM DRY DENSITY (PCF)	118.2	
OPTIMUM MOIST. CONTENT (%)	10.2	
PERCENT COMPACTION	91.9%	
% SATURATION	79.1	

HEAD inches	PSI	Q cc	TIME sec.	K cm/sec	K ft/yr
15.40	0.56	19	3600.0	2.0E-05	2.0E+01

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New Mexico 87109
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Fax (505) 821-7371

PROJECT	MIXED WASTE LANDFILL COVER	JOB NO.	9-517-001154
CLIENT:	SNL	LAB NO.	4570
SAMPLE:	SUBGRADE SOIL 3 OF 3	DATE	07/14/99

PERMEABILITY (ASTM D2434)

WET DENSITY SATURATED	125.8 pcf
WET DENSITY	123.2 pcf
DRY DENSITY	110.1 pcf
VOLUME	943.694 cc
INITAL MOISTURE	11.9%
MOISTURE @ SATURATION	14.2%
MAXIMUM DRY DENSITY (PCF)	119.8
OPTIMUM MOIST. CONTENT (%)	11.5
PERCENT COMPACTION	91.9%
% SATURATION	74.9

HEAD inches	PSI	Q cc	TIME sec.	K cm/sec	K ft/yr
15.69	0.57	10	3600.0	1.0E-05	1.1E+01

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8519 Jefferson NE
Albuquerque
New Mexico 87109
Tel (505) 821-1801
Fax (505) 821-7371

PROJECT: MIXED WASTE LANDFILL COVER
CLIENT: SNL
SAMPLE: BLEND LAB #4771, 4772, 4773, 4774, & 4775

JOB NO. 9-517-001154
LAB NO. COMPOSITE
DATE 07/14/99

PERMEABILITY (ASTM D2434)

WET DENSITY SATURATED	125.0	pcf
WET DENSITY	122.3	pcf
DRY DENSITY	108.4	pcf
VOLUME	943.694	cc
INITAL MOISTURE	12.8%	
MOISTURE @ SATURATION	15.3%	
MAXIMUM DRY DENSITY (PCF)	117.4	
OPTIMUM MOIST. CONTENT (%)	12.1	
PERCENT COMPACTION	92.4%	
% SATURATION	77.3	

HEAD Inches	PSI	Q cc	TIME sec.	K cm/sec	K ft/yr
15.69	0.57	10	3600.0	1.0E-05	1.1E+01

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Attachment I

Direct-Shear Test Data
(AGRA Earth & Environmental)

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AGRA EARTH & ENVIRONMENTAL, INC.
DIRECT SHEAR TESTS

Project: Mixed Waste Landfill Cover

Date: 06/14/99

Location: CAMU 1 of 3

Job No: 9-519-001154

Lab No: 4664

Saturated - Point No. 1 (= ± 0.5 KSF)

Initial Moisture Content	16.6	%
Dry Density	103.8	
Moisture @ Saturation	18.5	%
Maximum Vertical Strain @ T Max.	(+) 0.001	inches
Shearing Stress T Max.	0.6	KSF

Saturated - Point No. 2 (= ± 1.0 KSF)

Initial Moisture Content	14.6	%
Dry Density	108.5	PCF
Moisture @ Saturation	16.4	%
Maximum Vertical Strain @ T Max.	(-) 0.002	inches
Shearing Stress T Max.	0.8	KSF

Saturated - Point No. 3 (= ± 2.0 KSF)

Initial Moisture Content	16.3	%
Dry Density	105.3	PCF
Moisture @ Saturation	19.1	%
Maximum Vertical Strain @ T Max.	(-) 0.005	inches
Shearing Stress T Max.	1.7	KSF

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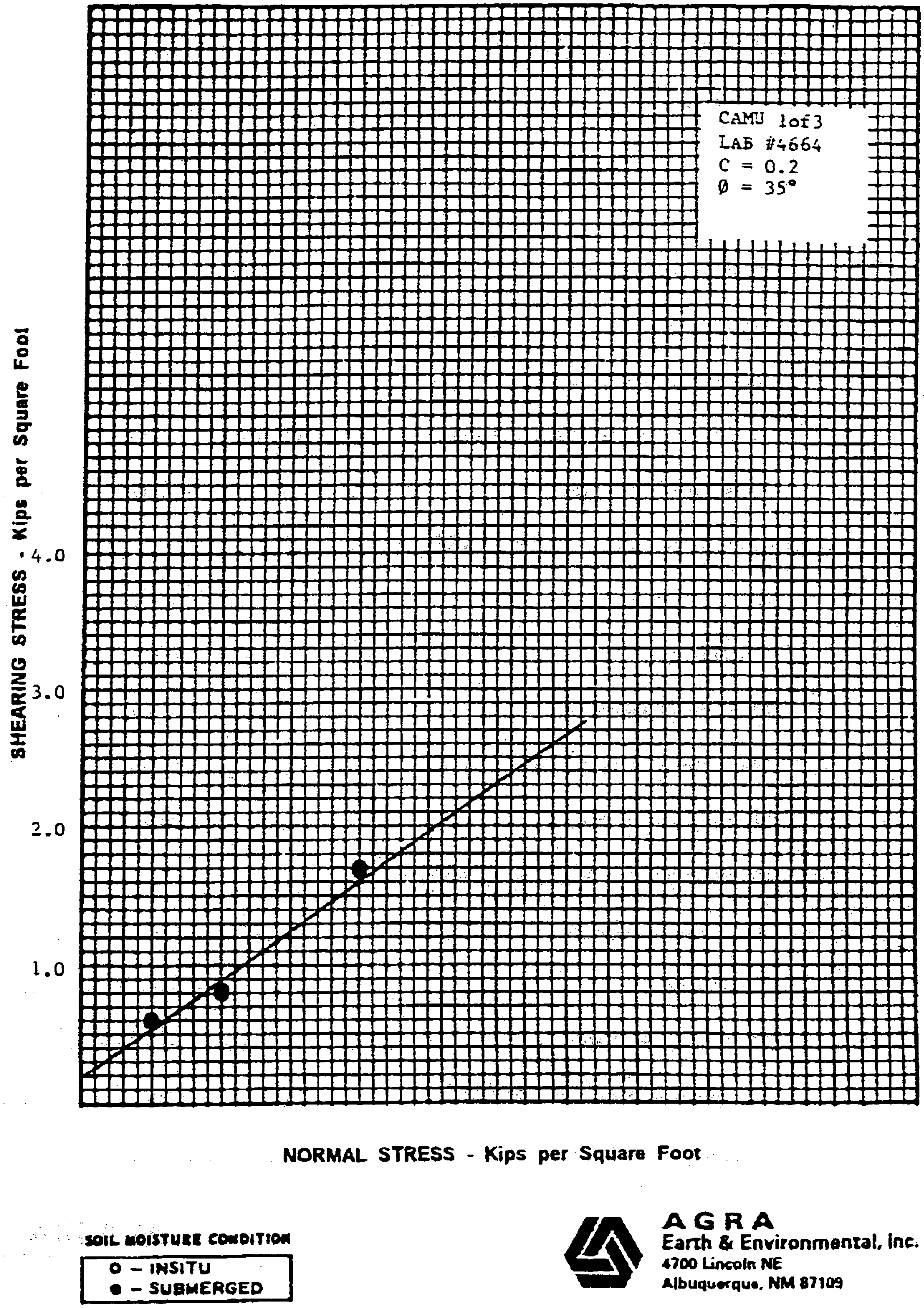
SUMMARY OF DIRECT SHEAR TESTS

PROJECT MIXED WASTE LANDFILL COVER JOB NO. 9-519-001154



AGRA
Earth & Environmental, Inc.
4700 Lincoln NE
Albuquerque, NM 87109

AGRA EARTH & ENVIRONMENTAL, INC.
DIRECT SHEAR TESTS

Project: Mixed Waste Landfill Cover
Date: 06/14/99

Location: CAMU 2 of 3
Job No: 9-519-001154

Lab No: 4665

Saturated - Point No. 1 (= ± 0.5 KSF)

Initial Moisture Content	12.6	%
Dry Density	111.8	
Moisture @ Saturation	17.0	%
Maximum Vertical Strain @ T Max.	(-) 0.001	inches
Shearing Stress T Max.	0.6	KSF

Saturated - Point No. 2 (= ± 1.0 KSF)

Initial Moisture Content	13.1	%
Dry Density	112.7	PCF
Moisture @ Saturation	16.8	%
Maximum Vertical Strain @ T Max.	(-) 0.009	inches
Shearing Stress T Max.	0.9	KSF

Saturated - Point No. 3 (= ± 2.0 KSF)

Initial Moisture Content	14.9	%
Dry Density	110.2	PCF
Moisture @ Saturation	15.6	%
Maximum Vertical Strain @ T Max.	(-) 0.005	inches
Shearing Stress T Max.	1.7	KSF

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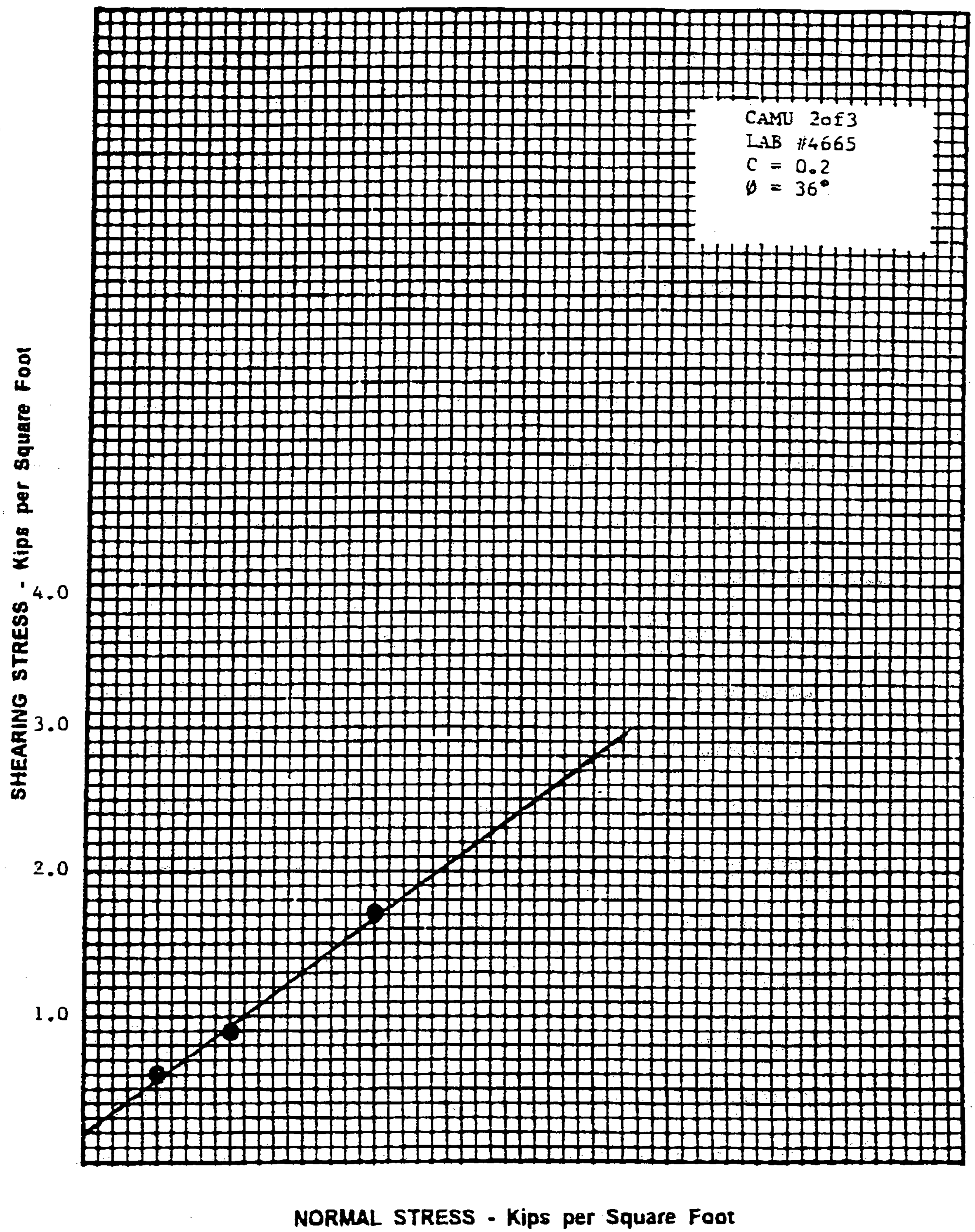
ENGINEERING GLOBAL SOLUTIONS

SUMMARY OF DIRECT SHEAR TESTS

PROJECT MIXED WASTE LANDFILL COVER **JOB NO.** 9-519-001154



SOIL MOISTURE CONDITION

○ – INSITU
● – SUBMERGED

AGRA
Earth & Environmental, Inc.
4700 Lincoln NE
Albuquerque, NM 87109

AGRA EARTH & ENVIRONMENTAL, INC.
DIRECT SHEAR TESTS

Project: Mixed Waste Landfill Cover

Date: 06/14/99

Location: CAMU 3 of 3

Job No: 9-519-001154

Lab No: 4666

Saturated - Point No. 1 (= ± 0.5 KSF)

Initial Moisture Content	13.1	%
Dry Density	114.0	
Moisture @ Saturation	15.1	%
Maximum Vertical Strain @ T Max.	(+) 0.006	inches
Shearing Stress T Max.	0.7	KSF

Saturated - Point No. 2 (= ± 1.0 KSF)

Initial Moisture Content	12.8	%
Dry Density	111.5	PCF
Moisture @ Saturation	15.5	%
Maximum Vertical Strain @ T Max.	(+) 0.005	inches
Shearing Stress T Max.	0.8	KSF

Saturated - Point No. 3 (= ± 2.0 KSF)

Initial Moisture Content	12.1	%
Dry Density	110.2	PCF
Moisture @ Saturation	15.5	%
Maximum Vertical Strain @ T Max.	(+) 0.003	inches
Shearing Stress T Max.	1.5	KSF

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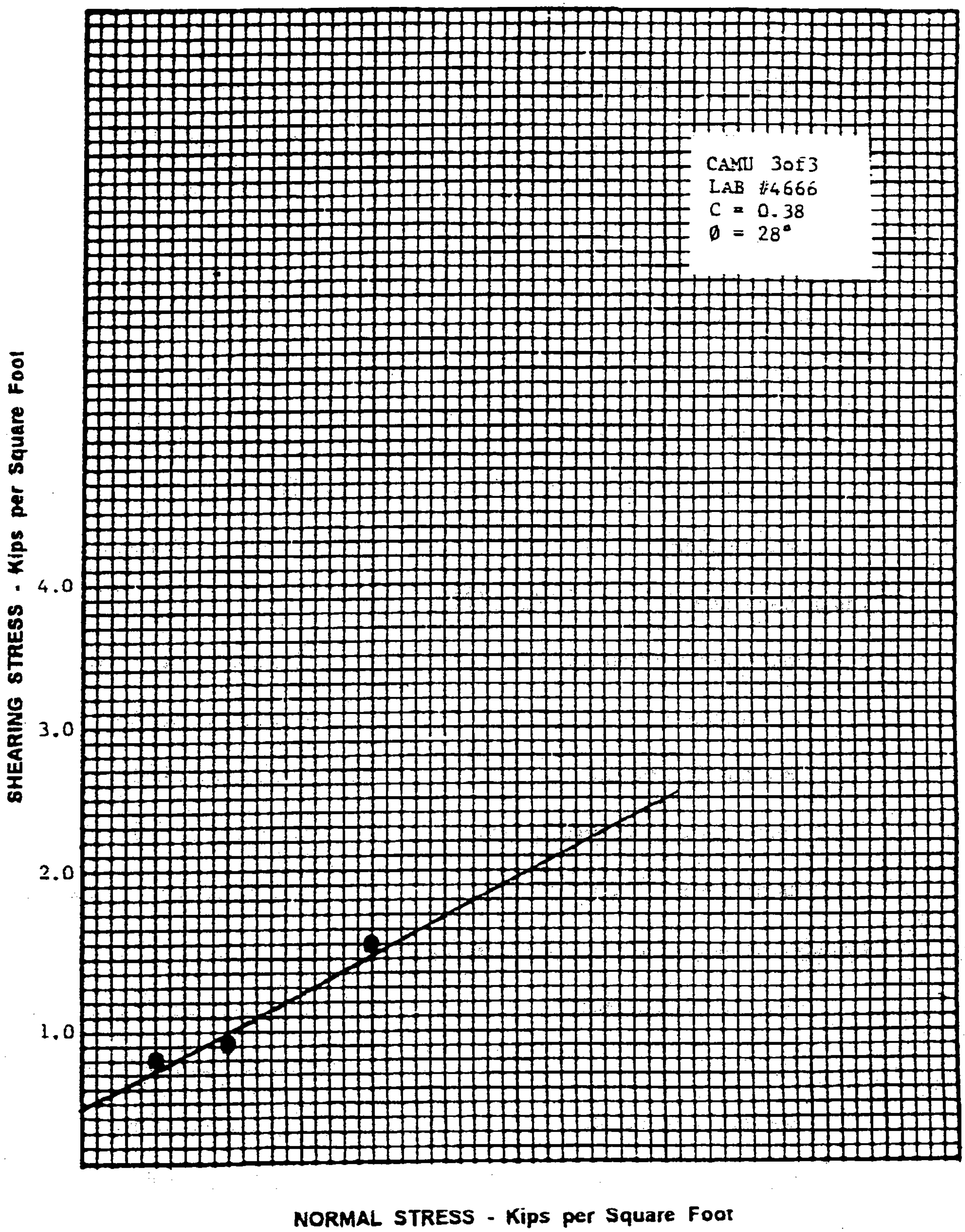
PROJECT MIXED WASTE LANDFILL COVER **JOB NO.** 9-519-001154



SOIL MOISTURE CONDITION

○ – INSITU
● – SUBMERGED

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Project: Mixed Waste Landfill Cover

Date: 06/16/99

Location: Native 1 of 3

Job No: 9-519-001154

Lab No: 4667

Saturated - Point No. 1 (= ± 0.5 KSF)

Initial Moisture Content	10.9	%
Dry Density	106.9	
Moisture @ Saturation	21.0	%
Maximum Vertical Strain @ T Max.	(-) 0.010	inches
Shearing Stress T Max.	0.4	KSF

Saturated - Point No. 2 (= ± 1.0 KSF)

Initial Moisture Content	12.1	%
Dry Density	108.9	PCF
Moisture @ Saturation	18.9	%
Maximum Vertical Strain @ T Max.	(-) 0.002	inches
Shearing Stress T Max.	0.9	KSF

Saturated - Point No. 3 (= ± 2.0 KSF)

Initial Moisture Content	10.2	%
Dry Density	108.3	PCF
Moisture @ Saturation	22.5	%
Maximum Vertical Strain @ T Max.	(-) 0.004	inches
Shearing Stress T Max.	1.4	KSF

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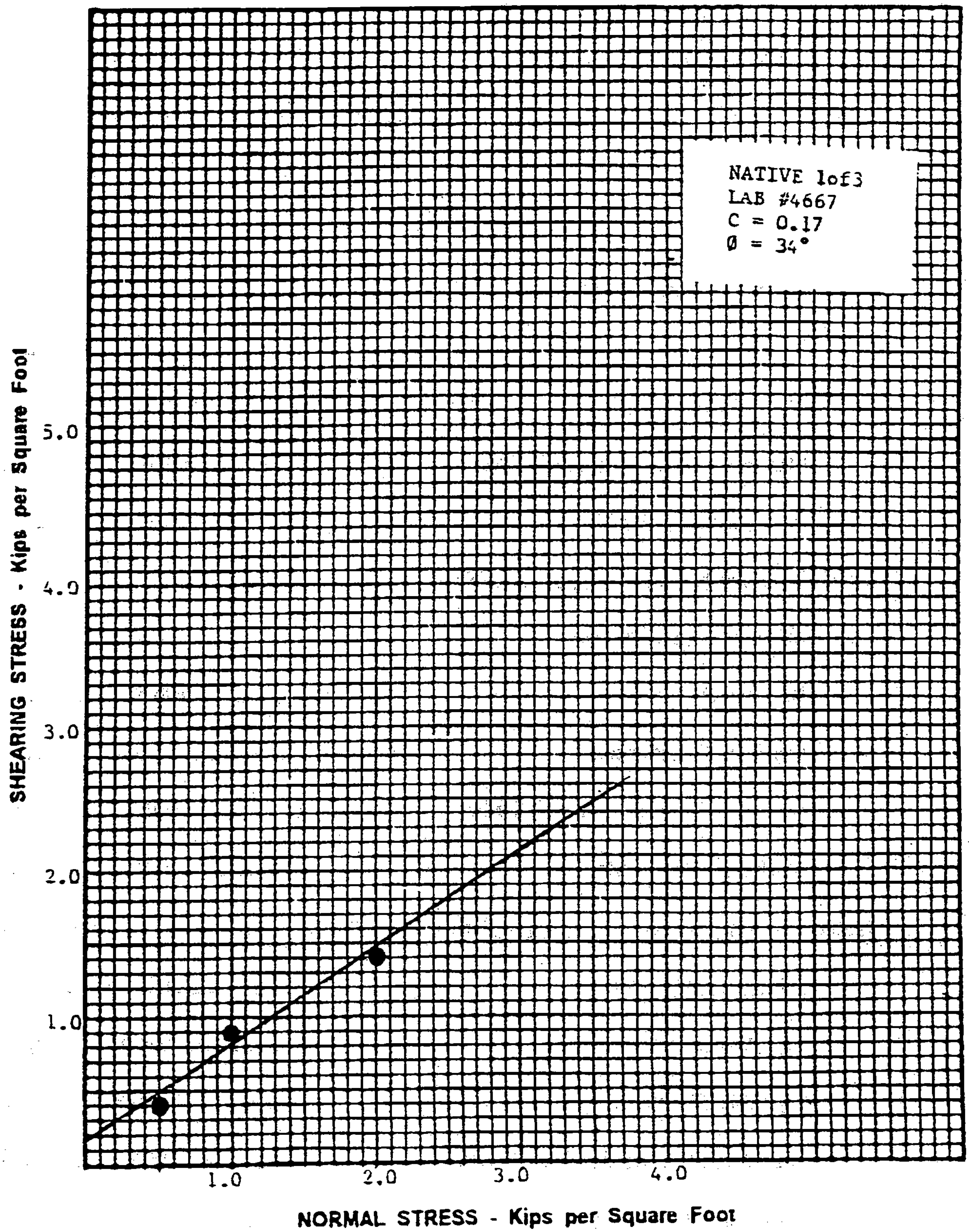
SUMMARY OF DIRECT SHEAR TESTS

PROJECT MIXED WASTE LANDFILL COVER JOB NO. 9-519-001154



SOIL MOISTURE CONDITION

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Date: 06/16/99

Location: Native 2 of 3

Job No: 9-519-001154

Lab No: 4668

Saturated - Point No. 1 (= ± 0.5 KSF)

Initial Moisture Content	14.9	%
Dry Density	105.9	
Moisture @ Saturation	17.7	%
Maximum Vertical Strain @ T Max.	(-) 0.004	inches
Shearing Stress T Max.	0.5	KSF

Saturated - Point No. 2 (= ± 1.0 KSF)

Initial Moisture Content	16.6	%
Dry Density	106.4	PCF
Moisture @ Saturation	20.4	%
Maximum Vertical Strain @ T Max.	(-) 0.002	inches
Shearing Stress T Max.	0.8	KSF

Saturated - Point No. 3 (= ± 2.0 KSF)

Initial Moisture Content	15.1	%
Dry Density	108.9	PCF
Moisture @ Saturation	18.5	%
Maximum Vertical Strain @ T Max.	(-) 0.010	inches
Shearing Stress T Max.	1.3	KSF

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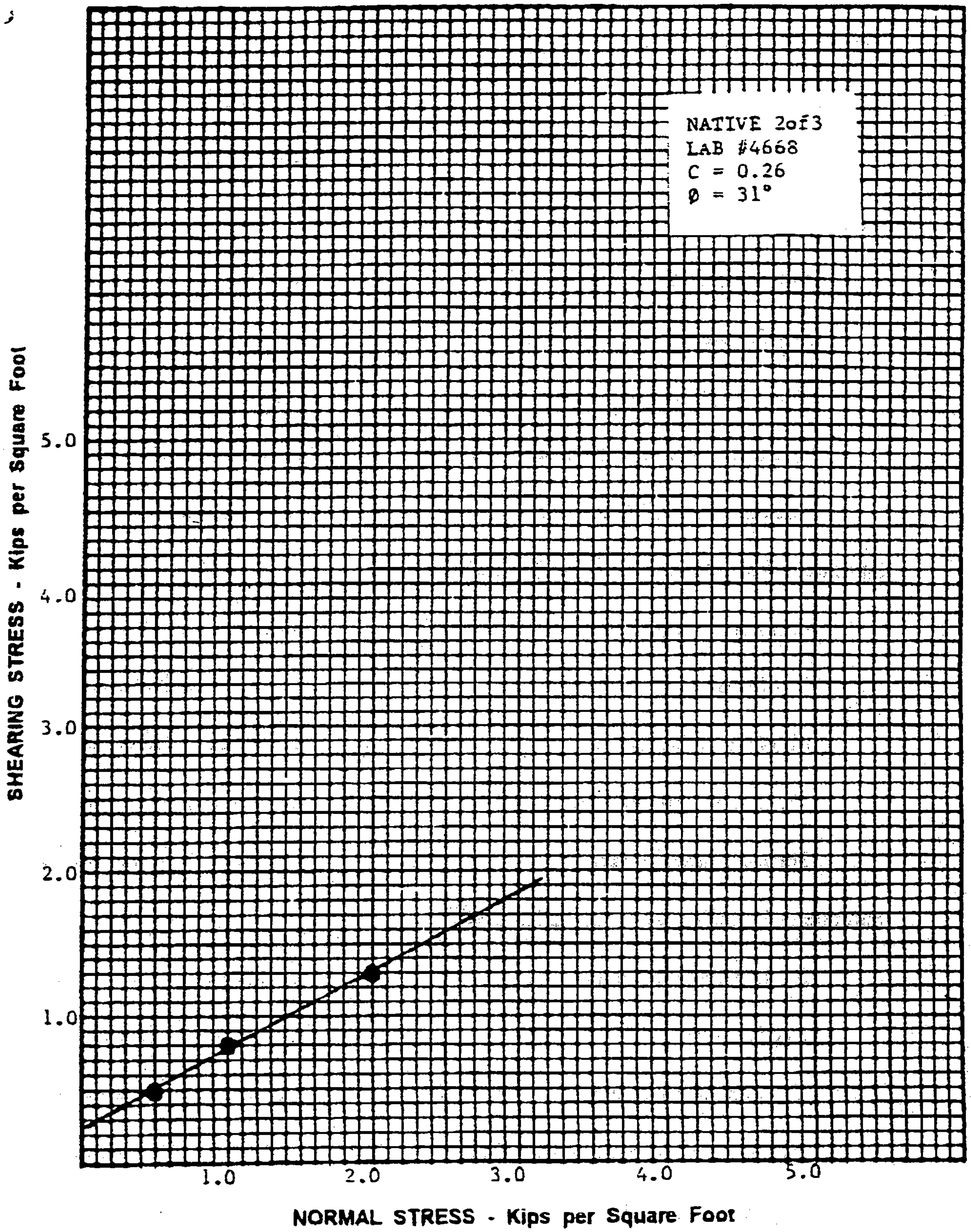
SUMMARY OF DIRECT SHEAR TESTS

PROJECT MIXED WASTE LANDFILL COVER JOB NO. 9-519-001154



SOIL MOISTURE CONDITION

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DIRECT SHEAR TESTS

Project: Mixed Waste Landfill Cover

Date: 06/14/99

Location: Native 3 of 3

Job No: 9-519-001154

Lab No: 4669

Saturated - Point No. 1 (= ± 0.5 KSF)

Initial Moisture Content	12.1	%
Dry Density	108.7	
Moisture @ Saturation	16.1	%
Maximum Vertical Strain @ T Max.	(-) 0.001	inches
Shearing Stress T Max.	0.5	KSF

Saturated - Point No. 2 (= ± 1.0 KSF)

Initial Moisture Content	12.2	%
Dry Density	109.1	PCF
Moisture @ Saturation	17.2	%
Maximum Vertical Strain @ T Max.	(-) 0.008	inches
Shearing Stress T Max.	0.9	KSF

Saturated - Point No. 3 (= ± 2.0 KSF)

Initial Moisture Content	11.2	%
Dry Density	109.2	PCF
Moisture @ Saturation	15.5	%
Maximum Vertical Strain @ T Max.	(-) 0.010	inches
Shearing Stress T Max.	1.5	KSF

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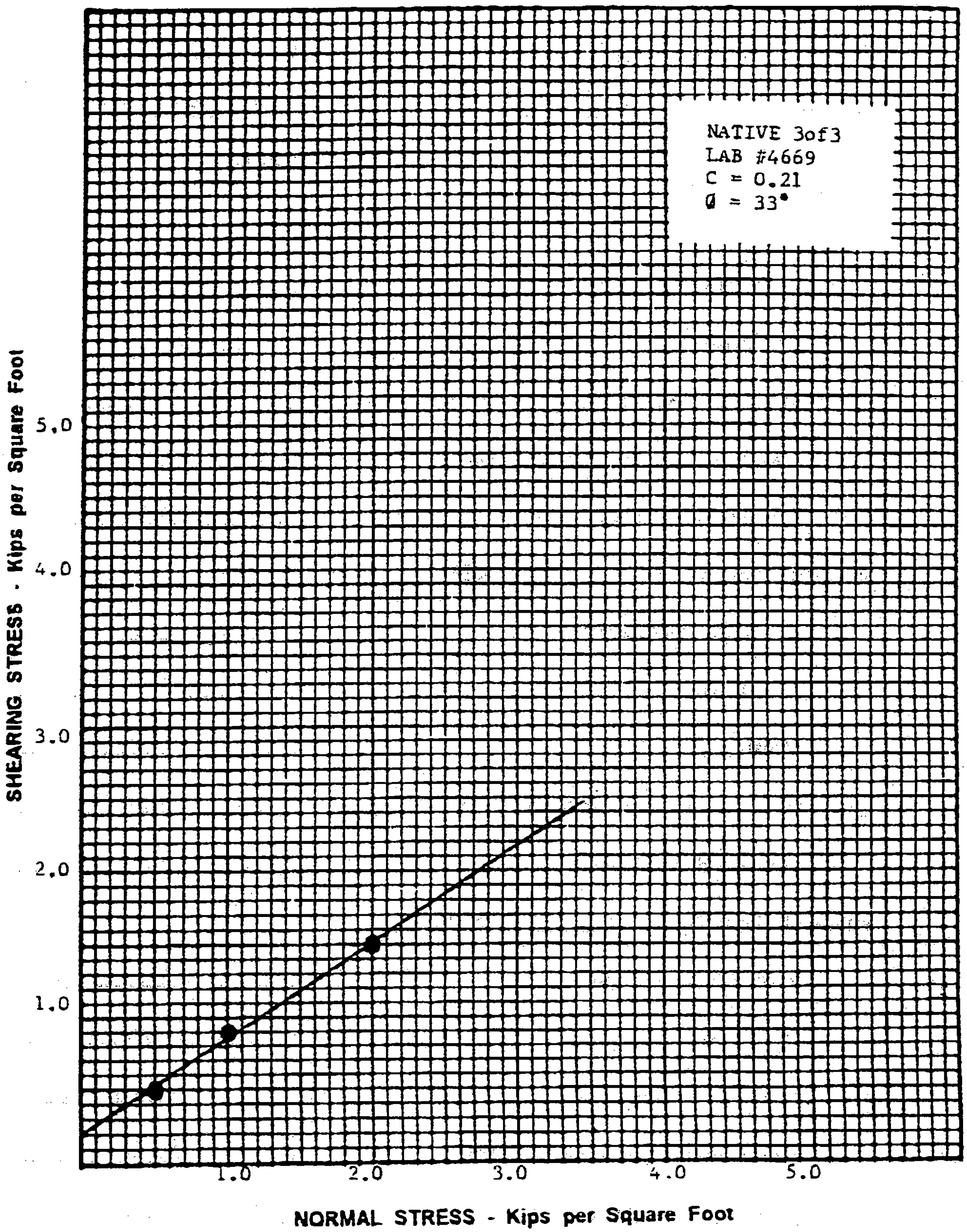
SUMMARY OF DIRECT SHEAR TESTS

PROJECT MIXED WASTE LANDFILL COVER JOB NO. 9-519-001154



SOIL MOISTURE CONDITION

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Project: Mixed Waste Landfill Cover

Date: 06/16/99

Location: Blend P1A 2.0', P1A 2.6' & P1A 3.6'

Job No: 9-519-001154

Lab No: 4670

Saturated - Point No. 1 (= ± 0.5 KSF)

Initial Moisture Content	15.0	%
Dry Density	109.4	
Moisture @ Saturation	17.7	%
Maximum Vertical Strain @ T Max.	(-) 0.0	inches
Shearing Stress T Max.	0.6	KSF

Saturated - Point No. 2 (= ± 1.0 KSF)

Initial Moisture Content	12.4	%
Dry Density	111.2	PCF
Moisture @ Saturation	18.3	%
Maximum Vertical Strain @ T Max.	(-) 0.005	inches
Shearing Stress T Max.	0.8	KSF

Saturated - Point No. 3 (= ± 2.0 KSF)

Initial Moisture Content	13.0	%
Dry Density	111.4	PCF
Moisture @ Saturation	15.3	%
Maximum Vertical Strain @ T Max.	(-) 0.002	inches
Shearing Stress T Max.	1.5	KSF

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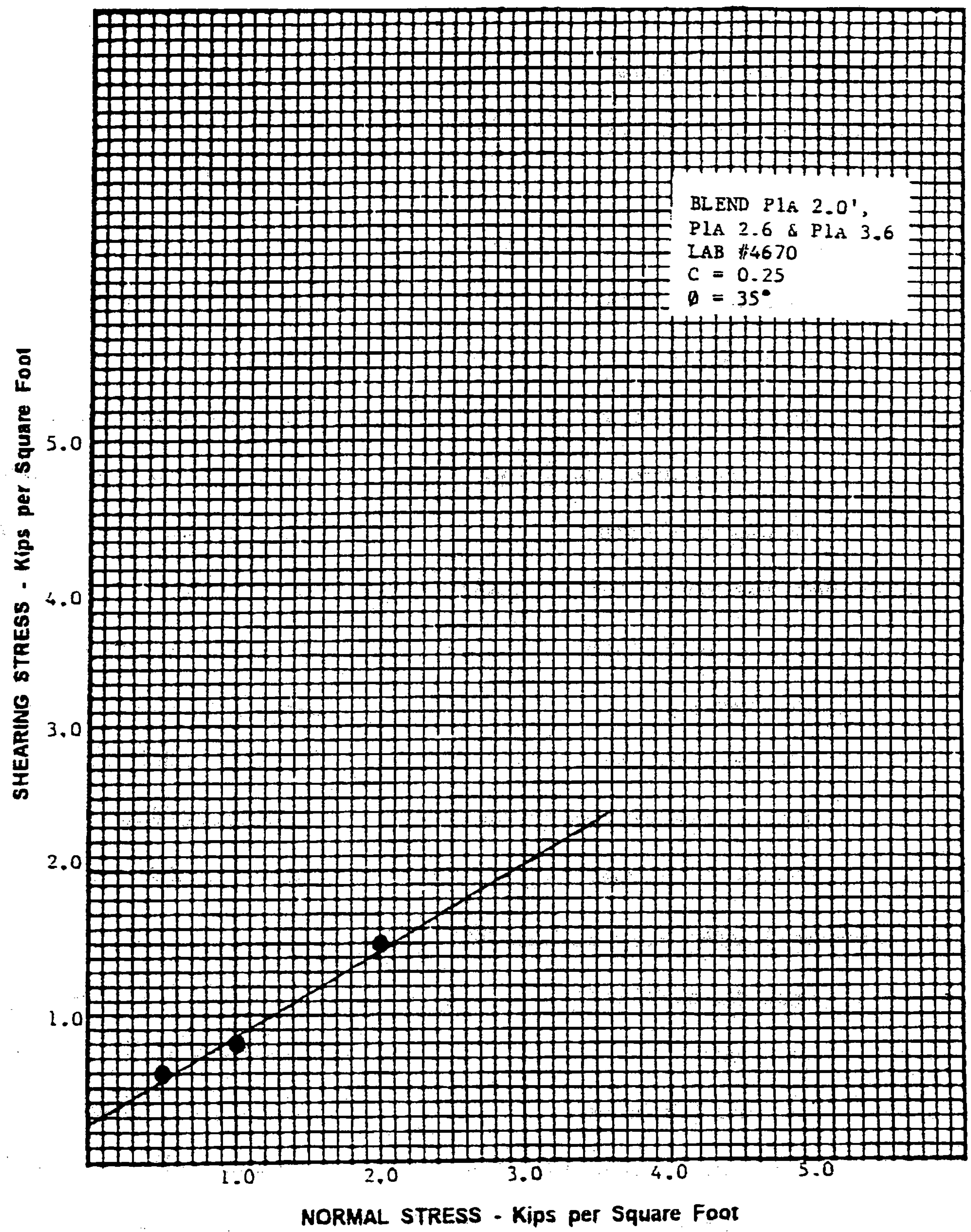
PROJECT MIXED WASTE LANDFILL COVER **JOB NO.** 9-519-001154



SOIL MOISTURE CONDITION

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Project: Mixed Waste Landfill Cover

Location: Blend P2A 1.5', P2A 1.7'

Date: 06/16/99

Job No: 9-519-001154

Lab No: 4671

Saturated - Point No. 1 (= ± 0.5 KSF)

Initial Moisture Content		12.6	%
Dry Density		111.7	
Moisture @ Saturation		15.4	%
Maximum Vertical Strain @ T Max.	(-)	0.004	inches
Shearing Stress T Max.		0.5	KSF

Saturated - Point No. 2 (= ± 1.0 KSF)

Initial Moisture Content		11.4	%
Dry Density		113.3	PCF
Moisture @ Saturation		13.7	%
Maximum Vertical Strain @ T Max.	(-)	0.002	inches
Shearing Stress T Max.		1.1	KSF

Saturated - Point No. 3 (= ± 2.0 KSF)

Initial Moisture Content		11.3	%
Dry Density		113.7	PCF
Moisture @ Saturation		14.3	%
Maximum Vertical Strain @ T Max.	(-)	0.008	inches
Shearing Stress T Max.		1.6	KSF

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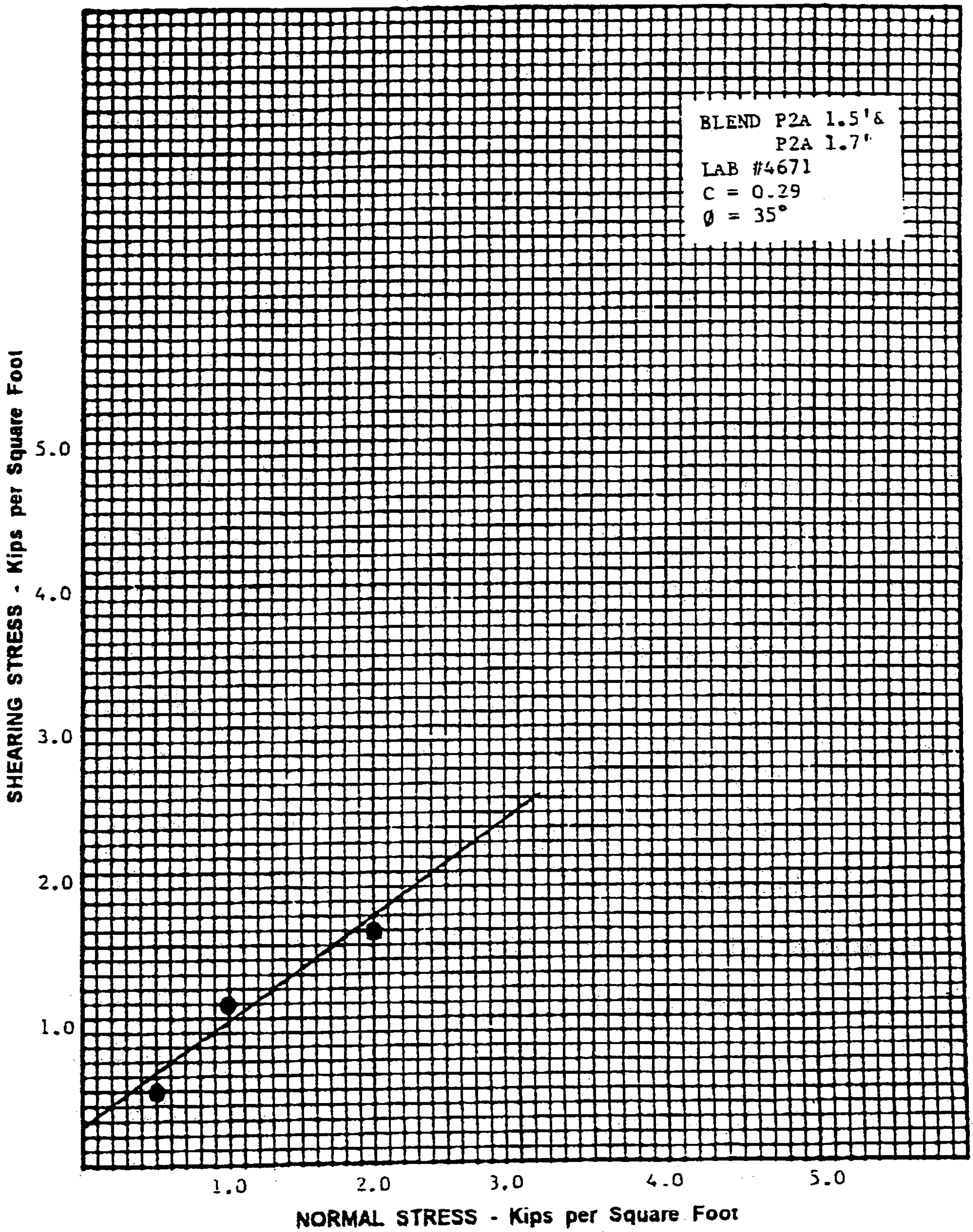
PROJECT MIXED WASTE LANDFILL COVER **JOB NO** 9-519-001154



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APPENDIX B

Erosion and Slope Stability Calculations

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GRAM, Inc. Calculation Sheet

By: M. McVey	Date: 8/31/99	Title: Erosion Potential of the MWL Cover during a 25-year, 24-hour Storm Event
Chkd. By: J. Peace	Date: 9/1/99	

Purpose:

The purpose of this calculation is to estimate the erosion potential of the MWL cover and sideslopes during a 25-year, 24-hour storm event.

Reference:

Geotechnology of Waste Management, 2nd Ed., Issa S. Oweis, Raj P. Khera, February, 1998.

Method of Analysis:

Standard engineering hand calculations using the permissable velocity method, based on the Manning formula.

$$V = \frac{C_1 Q}{d} \text{ (Sheet 10)} \quad \& \quad V_p = C_2 V_u \text{ (Sheet 11)}$$

Where:

V = average calculated velocity

C_1 = flow concentration factor

Q = flow volume

d = flow depth

V_p = permissable velocity

C_2 = depth correction factor

V_u = uncorrected permissable velocity

GRAM, Inc. Calculation Sheet

By: M. McVey	Date: 8/31/99	Title: Erosion Potential of the MWL Cover during a 25-year, 24-hour Storm Event
Chkd. By: J. Peace	Date: 9/1/99	

$Q = CIA$ (see Sheet 12)

where:

C = runoff coefficient

I = rainfall intensity (in./hr)

A = drainage area (acres)

From Sheet 13 ⟹ $C = 0.60$

[C for bare soil – very conservative because cover will initially have straw mulch applied at 2 tons/acre. Cover will never be technically "bare".]

From Sheets 14 and 15 ⟹ $I = 2.5$ inches/hr.

For 2% Cover Slope

$$A = \frac{(327\text{ ft} \times 1\text{ ft})}{43{,}560\text{ ft}^2/\text{Acre}} = 0.0075\text{ Acres}$$

$$Q = (0.60)(2.5\text{ inches/hr.})(0.0075\text{ Acres}) = \underline{\underline{0.0113\text{ cfs}}}$$

For 16.7% Sideslopes

$$A = \frac{(24\text{ ft} \times 1\text{ ft})}{43{,}560\text{ ft}^2/\text{Acre}} = 0.0006\text{ Acres}$$

$$Q = (0.60)(2.5\text{ inches/hr.})(0.0006\text{ Acres}) = \underline{\underline{0.0008\text{ cfs}}}$$

By: M. McVey	Date: 8/31/99	Title: Erosion Potential of the MWL Cover during a 25-year, 24-hour Storm Event
Chkd. By: J. Peace	Date: 9/1/99	

CASE 1: No vegetation yet established; straw mulch applied to cover and sideslopes at 2 tons/acre, crimped into soils with disk.

$$d = \left(C_1 n Q / 1.486 S^{0.5} \right)^{3/5} \quad \text{(Sheet 11)}$$

where:

C_1 = 3.0 (Sheet 10) → differential settlements are minimal and uniform grading is accomplished during construction.

n = 0.06 (Sheet 11 - roughness coefficient for sheet flow)
→ residue cover ≤ 20% represents straw mulch applied to cover and sideslopes at 2 tons/acre.

Q = 1) 0.0113 cfs for 2% cover slope
2) 0.0008 cfs for 16.7% cover sideslopes

S = 1) 0.02 for 2% cover slope
2) 0.17 for 16.7% cover sideslopes

For 2% Cover Slope

$$d = \left(\frac{(3.0)(0.06)(0.0113)}{1.486(0.02)^{0.5}} \right)^{3/5}$$

$$= 0.062 \text{ ft}$$

By: M. McVey	Date: 8/31/99	Title: Erosion Potential of the MWL Cover during a 25-year, 24-hour Storm Event
Chkd. By: J. Peace	Date: 9/1/99	

$$V = C_1 Q/d = \frac{(3.0)(0.0113)}{0.062}$$

$$= \underline{\underline{0.55\ ft/s}}$$

<u>For 16.7% Cover Sideslopes</u>

$$d = \left(\frac{(3.0)(0.06)(0.0008)}{1.486(0.17)^{0.5}}\right)^{3/5}$$

$$= 0.007\ ft$$

$$V = C_1 Q/d = \frac{(3.0)(0.0008)}{0.007}$$

$$= \underline{\underline{0.34\ ft/s}}$$

1) Permissible Velocity for bare topsoil

$$V_p = C_2 V_u$$

where:

$C_2 = 0.5$ (Sheet 16)

→ Sheet flow - depth < 0.25 ft

$V_u = 2.5$ ft/s (Sheet 17)

→ Permissible velocity for sandy loam. There was no permissible velocity for loamy very fine sand. Sandy loam was closest match.

GRAM, Inc. Calculation Sheet

By: M. McVey	Date: 8/31/99	Title: Erosion Potential of the MWL Cover during a 25-year, 24-hour Storm Event
Chkd. By: J. Peace	Date: 9/1/99	

$V_p = (0.5)(2.5\ ft/s) = \underline{\underline{1.25\ ft/s}}$

For 2% Cover Slope

$V = 0.55\ ft/s < V_p = 1.25\ ft/s$

OK

For 16.7% Cover Sideslopes

$V = 0.34\ ft/s < V_p = 1.25\ ft/s$

OK

2) Permissible Velocity for topsoil admixed with 25% pea gravel

$V_p = C_2 V_u$

where:

$C_2 = 0.5$ (Sheet 16)

→ Sheet flow-depth < 0.25 ft

$V_u = 5.0$ (Sheet 17)

→ Topsoil admixed with 25% pea gravel

By: M. McVey | Date: 8/31/99
Chkd. By: J. Peace | Date: 9/1/99

Title: Erosion Potential of the MWL Cover during a 25-year, 24-hour Storm Event

$$V_p = (0.5)(5.0\ ft/s) = 2.5\ ft/s$$

For 2% Cover Slope

$$V = 0.55\ ft/s < V_p = 2.5\ ft/s$$

OK

For 16.7% Cover Sideslopes

$$V = 0.34\ ft/s < V_p = 2.5\ ft/s$$

OK

GRAM, Inc. Calculation Sheet

By: M. McVey	Date: 8/31/99	Title: Erosion Potential of the MWL Cover during a 25-year, 24-hour Storm Event
Chkd. By: J. Peace	Date: 9/1/99	

CASE 2: Vegetation is established over cover and sideslopes 12 months after seeding, 1/2 straw mulch remains.

$$d = \left(C_1 n Q / 1.486 S^{0.5}\right)^{3/5} \quad \text{(Sheet 11)}$$

where:

$C_1 = 3.0$ (Sheet 10)

$n = 0.17$ (Sheet 11)

→ residue cover ≥ 20% represents the early stages of growth over cover and sideslopes. n = 0.24 represents fully established dense grasses (see sheet 11).

Q = 1) 0.0113 cfs for 2% cover slope

2) 0.0008 cfs for 16.7% cover sideslopes

S = 1) 0.02 for 2% cover slope

2) 0.17 for 16.7% cover sideslopes

For 2% Cover Slope

$$d = \left(\frac{(3.0)(0.17)(0.0113)}{1.486(0.02)^{0.5}}\right)^{3/5}$$

$= 0.116$ ft

By: M. McVey	Date: 8/31/99	Title: Erosion Potential of the MWL Cover during a 25-year, 24-hour Storm Event
Chkd. By: J. Peace	Date: 9/1/99	

$$V = C_1 Q/d = \frac{(3.0)(0.0113)}{0.116}$$

$$= \underline{\underline{0.29 \text{ ft/s}}}$$

For 16.7% Cover Sideslopes

$$d = \left(\frac{(3.0)(0.17)(0.0008)}{1.486(0.17)^{0.5}}\right)^{3/5}$$

$$= 0.012 \text{ ft}$$

$$V = C_1 Q/d = \frac{(3.0)(0.0008)}{0.012}$$

$$= \underline{\underline{0.2 \text{ ft/s}}}$$

1) Permissible velocity for bare topsoil

$V_p = 1.25$ ft/s (see sheets 4 and 5)

For 2% Cover Slope

$V = 0.29$ ft/s $<$ $V_p = 1.25$ ft/s

OK

By: M. McVey	Date: 8/31/99	Title: Erosion Potential of the MWL Cover during a 25-year, 24-hour Storm Event
Chkd. By: J. Peace	Date: 9/1/99	

For 16.7% Cover Sideslopes

$V = 0.2 \text{ ft/s} < V_p = 1.25 \text{ ft/s}$

OK

2) Permissible velocity for topsoil admixed with 25% pea gravel

$V_p = 2.5 \text{ ft/s}$ (see sheets 5 and 6)

For 2% Cover Slope

$V = 0.29 \text{ ft/s} < V_p = 2.5 \text{ ft/s}$

OK

For 16.7% Cover Sideslopes

$V = 0.2 \text{ ft/s} < V_p = 2.5 \text{ ft/s}$

OK

Sheet 10 of 17

months old. Thus,

$A = 15.8 \times 0.4 = 6.32$ tn/acre/yr for areas with seedings 0–60 days,

$A = 15.8 \times 0.05 = 0.79$ for areas with seedings 2–12 months old, and

$A = 15.8 \times 0.01 = 0.16$ tn/acre/yr for seedings over 12 months old

Assuming that runoff from the plateau is collected, we calculate the soil loss for the side slope as

$A = 200(0.1)(15.73)(VM) = 315(VM)$

$= 315 \times 0.4 = 126$ tn/acre/yr for recently planted areas (<2 months old)

$= 315 \times 0.05 = 15.75$ tn/acre/yr for areas with seedings 2–12 months old

$= 315 \times 0.01 = 3.15$ tn/acre/yr for mature grass cover 12 months and older.

The above estimates for the side slopes are higher than the usually accepted criterion of 2 tn/acre/yr.

12.6 EROSION ANALYSIS (PERMISSIBLE VELOCITY)

The velocity of sheet flow over a landfill slope can be estimated by solving the Manning formula expressed as

$$V = 1.486R^{2/3}s^{1/2}/n \tag{12.22}$$

where V is the average velocity of a specified cross section, R is the hydraulic radius (=area/wetted perimeter), s is the slope of the channel bottom (length/length), and n is the surface roughness coefficient. Typical values of n for landfill covers are 0.02 or 0.025. Table 12.10 (SCS, 1986) may be used for sheet flow.

Eq. 12.22 accounts for the average velocity in an open channel. Velocity reaches a maximum near the free surface and decreases with depth. In cap design, the depth of flow is usually a few inches and the base flow velocity tending to erode the slope is nearly equal to the maximum velocity. For a strip a unit length wide, the velocity, V, is

$$\boxed{V = C_1Q/d} \tag{12.23}$$

where d is the depth of flow, Q is the flow volume computed by the methods of Section 12.8, and C_1 is the flow concentration factor. A value of 3 for C_1 may be used if differential settlements are minimal and uniform grading is accomplished during construction. Limited data are available on flow concentration; engineers must use their judgment based on local conditions.

Sheet 11 of 17

Table 12.10 Roughness coefficients (Manning's n) for sheet flow

Surface description	n[a]
Smooth surfaces (concrete, asphalt, gravel, or bare soil)	0.011
Fallow (no residue)	0.05
Cultivated soils	
Residue cover $\leq 20\%$	0.06
Residue cover $> 20\%$	0.17
Grass	
Short grass prairie	0.15
Dense grasses[b]	0.24
Bermuda grass	0.41
Range (natural)	0.13
Woods[c]	
Light underbrush	0.40
Dense underbrush	0.80

[a] The n values are a composite of information compiled by Engman (1986).
[b] Includes species such as weeping lovegrass, bluegrass, buffalo grass, blue grama grass, and native grass mixtures.
[c] When selecting n, consider cover to a height of about 0.1 ft. This is the only part of the plant cover that will obstruct sheet flow.
Source: SCS, 1986

For shallow flow over the landfill slope, the hydraulic radius (area/wetted perimeter) is close to flow depth d. Eqs. 12.22 and 12.23 can be solved for d as

$$d = (C_1 n Q / 1.486 S^{0.5})^{3/5} \tag{12.24}$$

Based on the computed depth of flow in Eq. 12.24, the velocity is calculated from Eq. 12.23. The computed velocity is compared to the permissible velocity, V_p, which is estimated as

$$V_p = C_2 V_u \tag{12.25}$$

where V_u is the uncorrected permissible velocity (Tables 12.3 to 12.6) and C_2 is the depth correction factor (Table 12.7). If the calculated actual flow velocity is larger than the permissible velocity, either a cover protection or a design for lesser velocities (by fattening slopes and/or intermediate collection swales) is needed.

Example 12.4

Consider a landfill cover with a maximum flow distance to a collection swale of 300 ft along a $4H$ on $1V$ slope. The flow quantity per unit width (from the methods in Section 12.8) is 0.1 cubic ft/s (cfs). The upper 2 ft of the landfill is sandy silt. Determine the flow velocity and analyze the potential for erosion.

detail, and completeness of the hydrologic records, which may be either precipitation or stream flow. An example of the variation of detail in the final result may be found in the determination of flood runoff. Several methods yield only peak discharge; others give the complete hydrograph. Accuracy is limited by cost and assumptions made in the development of a method.

The methods that follow are a convenient means for solving typical runoff problems encountered in water engineering. One method pertains to minor hydraulic structures, the second to major hydraulic structures. A minor structure is one of low cost and of relatively minor importance and presents small downstream damage potential. Typical examples are small highway and railroad culverts and low-capacity storm drains. Major hydraulic structures are characterized by their high cost, great importance, and large downstream damage potential. Typical examples of major hydraulic structures are large reservoirs, deep culverts under vital highways and railways, and high-capacity storm drains and flood-control channels.

Method for Determining Runoff for Minor Hydraulic Structures ▪ The most common means for determining runoff for minor hydraulic structures is the **rational formula**

$$Q = CIA \qquad (21\text{-}127)$$

where Q = peak discharge, ft³/s

C = runoff coefficient = percentage of rain that appears as direct runoff

I = rainfall intensity, in/h

A = drainage area, acres

The assumptions inherent in the rational formula are:

1. The maximum rate of runoff for a particular rainfall intensity occurs if the duration of rainfall is equal to or greater than the time of concentration. The time of concentration is commonly defined as the time required for water to flow from the most distant point of a drainage basin to the point of flow measurement.
2. The maximum rate of runoff from a specific rainfall intensity whose duration is equal to or greater than the time of concentration is directly proportional to the rainfall intensity.
3. The frequency of occurrence of the peak discharge is the same as that of the rainfall intensity from which it was calculated.
4. The peak discharge per unit area decreases as the drainage area increases, and the intensity of rainfall decreases as its duration increases.
5. The coefficient of runoff remains constant for all storms on a given watershed.

Since these assumptions apply reasonably well for urbanized areas with drainage facilities of fixed dimensions and hydraulic characteristics, the rational formula has gained widespread use in the design of drainage systems for these areas. Its simplicity and ease of application have resulted in its being used in rural areas where the assumptions are not so applicable.

The rational formula is criticized for expressing runoff as a fraction of rainfall rather than as rainfall minus losses and for combining all the complex factors that affect runoff into a single coefficient. Although these and similar criticisms are valid, use of a more complicated formula is not justified because the time and money spent to obtain the necessary data would not be warranted for minor hydraulic structures.

Numerous refinements have been developed for the runoff coefficient. As an example, the Los Angeles County Flood Control District gives runoff coefficients as a function of the soil and area type and of the rainfall intensity for the time of concentration. Other similar refinements are possible if the resources are available. Careful selection of the runoff coefficient C will give values of peak runoff consistent with project significance. The values of C in Table 21-16 for urban areas are commonly recommended design values (V. T. Chow, "Hydrologic Determina-

DRAINAGE — RUNOFF — 2

Q=Aci RATIONAL FORMULA (Logical approach).

Q = RUNOFF = Peak discharge of watershed in cubic feet per second (c.f.s.) due to maximum storm assumed. See Figs. A to F, Pg. 18-01 (Usually 10 - 25 years).
A = Area of watershed in acres.
C = Coefficient of runoff, Table B below (Measure of losses due to infiltration, etc.).
i = Intensity of rainfall in inches per hour based on concentration time. See Pg. 18
Concentration time = time required for rain falling at most remote point to reach discharge point. Concentration time may include Overland flow time, Fig. H, Pg. 18-01, and Channel flow time, Pg. 18-05, 18-06, 18-69 and 18-71.

TABLE A-COMPUTATION FORM FOR RATIONAL FORMULA.

LOCATION			A			TIME OF FLOW-MIN.					DESIGN					PROFILE				
STREET	FROM	TO	INCREMENT	TOTAL	C	TO INLET	IN CHANNEL	TIME OF CONC	i *	Q c.f.s.	CHANNEL OR PIPE SIZE	SLOPE ft. per ft.	n	CAPACITY FULL c.f.s.	V ft. per Sec.	LENGTH ft.	FALL ft.	OTHER LOSSES ft. †	INV. ELEV. UPPER END	INV ELEV LOWER END
FIRST ST.	A	B	1.8	1.8	.44	16.5	0.3	16.5	3.8	3.0	15"	.008	.015	4.6	3.9	60	0.48	0	82.00	81.5
MAIN RD.	B	C	1.9	3.7	.50		2.5	16.8	3.7	6.8	D-2	.011	.030	12.0	2.8	420	4.62	0	81.52	76.9
" "	C	D	2.0	5.7	.50		1.8	19.3	3.5	10.0	21"	.007	.015	11.1	4.5	480	3.36	2.20	74.70	70.3

*Note that the sequence of design as in example, Fig. J, Pg. 18-01 involves trial assumptions in determining i.
† Fall in manhole.

TABLE B - VALUES OF C = RUNOFF / RAINFALL

SURFACES			VALUE PROPOSED MIN.	VALUE PROPOSED MAX.	VALUE BY OTHER AUTHORITY MIN.	VALUE BY OTHER AUTHORITY MAX.
ROOFS, slag to metal.			0.90	1.00	0.70	0.95
PAVEMENTS	Concrete or Asphalt.		0.90	1.00	0.95	1.00
	Bituminous Macadam, open and closed type.		0.70	0.90	0.70	0.90
	Gravel, from clean and loose to clayey and compact.		0.25	0.70	0.15	0.30
R.R. YARDS			0.10	0.30	0.10	0.30
EARTH SURFACES	SAND, from uniform grain size, no fines, to well graded, some clay or silt.	Bare	0.15	0.50	0.01	0.55
		Light Vegetation	0.10	0.40	0.01	0.55
		Dense Vegetation	0.05	0.30	0.01	0.55
	LOAM, from sandy or gravelly to clayey.	Bare	0.20	0.60		
		Light Vegetation	0.10	0.25		
		Dense Vegetation	0.05	0.35		
	GRAVEL, from clean gravel and gravel sand mixtures, no silt or clay to high clay or silt content.	Bare	0.25	0.65		
		Light Vegetation	0.15	0.50		
		Dense Vegetation	0.10	0.40		
	CLAY, from coarse sandy or silty to pure colloidal clays.	Bare	0.30	0.75	0.10	0.70
		Light Vegetation	0.20	0.60	0.10	0.70
		Dense Vegetation	0.15	0.50	0.10	0.70
COMPOSITE AREAS	City, business areas.		0.60	0.75	0.60	0.95
	City, dense residential areas, vary as to soil and vegetation.		0.50	0.65	0.30	0.60
	Suburban residential areas, " " "		0.35	0.55	0.25	0.40
	Rural Districts, " " "		0.10	0.25	0.10	0.25
	Parks, Golf Courses, etc., " " "		0.10	0.35	0.05	0.25

NOTE: Values of "C" for earth surfaces are further varied by degree of saturation, compaction, surface irregularity and slope, by character of subsoil, and by presence of frost or glazed snow or ice.

① Bryant & Kuichling, Report, Back Bay Sewerage District, Boston, 1909.
② Metcalf and Eddy, American Sewerage Practice, 1928. McGraw-Hill.
③ Used by City of Boston, reported by Metcalf & Eddy.
④ Used by City of Detroit, reported by Metcalf & Eddy.
⑤ L.C. Urquhart, Civil Engineering Handbook, 1940. McGraw-Hill.

Therefore, there is little opportunity for a liquid waste leak to occur. Together, the design features and the operational practices will greatly minimize the possibility of leaks from the proposed containment cell to the vadose zone and, subsequently, to groundwater.

The LCRS incorporated into the design for the bottom liner component of the proposed containment cell liner system will be used to routinely monitor and withdraw leachate from the containment cell during the operational period and during the post-closure care period. The LCRS will be used to detect, collect, and remove leachate that accumulates above the HDPE geomembranes. The HDPE geomembranes provide the first barrier to prevent migration from the containment cell.

The LCRS design capacity is based on the amount of precipitation from a 25-year, 24-hour storm event that could occur during the operational period of the proposed containment cell. For the Albuquerque area, the rainfall amount during a 25-year, 24-hour storm event is 2.5 inches (City of Albuquerque, 1993); this value was used to calculate the maximum volume of leachate that could potentially be generated during the operating period of the proposed containment cell. Based on an open containment cell, the maximum leachate volume generated during the design storm event is estimated to be 7,128 cubic feet per day. Upon closure of the containment cell, the volume of leachate that could potentially be generated will, of course, be greatly diminished because the final cover system will be in place.

The GCL component of the containment cell provides the second barrier to prevent migration from the containment cell. It will underlie the HDPE geomembranes and will function as a leachate barrier layer in the event that the HDPE geomembranes fail. The 1/4-inch-thick GCL will have a maximum hydraulic conductivity of 2.8×10^{-6} feet per day (1×10^{-9} centimeters per second). This value is two orders of magnitude less than the maximum hydraulic conductivity of 2.8×10^{-4} feet per day (1×10^{-7} centimeters per second) typically required for 3-foot-thick compacted soil material.

The VZMS beneath the bottom liner system of the proposed containment cell will be capable of early detection of any potential leak from the cell. In addition, the VZMS will be capable of detecting a leak that is orders of magnitude less in volume than one required for detection

8.0 References

AEE, see AGRA Earth & Environmental, Inc.

AGRA Earth & Environmental, Inc. (AEE), 1996. "Geotechnical Investigation, Environmental Restoration Area, Technical Area III," Sandia National Laboratories. Albuquerque, New Mexico.

Anderholm, S.K., 1988. "Ground-Water Geochemistry of the Albuquerque-Belen Basin. Central New Mexico," U.S. Geological Survey Water-Resources Investigations Report 86-4094, 110 pp.

Bjorklund, L.J. and B.W. Maxwell, 1961. "Availability of Groundwater in the Albuquerque Area, Bernalillo and Sandoval Counties," New Mexico State Engineer Report 21.

City of Albuquerque, 1993. *Development Process Manual*, Volume 2, Design Criteria for the City of Albuquerque, New Mexico.

COE, see U.S. Army Corps of Engineers.

Davis, S.N., and R.J.M. DeWiest, 1966. *Hydrogeology*, John Wiley and Sons, New York, New York.

EPA, see U.S. Environmental Protection Agency.

Grant, P.R., 1981. "Geothermal Potential on Kirtland Air Force Base Lands, Bernalillo County, New Mexico," SAND81-7141, Sandia National Laboratories, Albuquerque, New Mexico.

Hacker, L.W., 1977. "Soil Survey of Bernalillo County and Parts of Sandoval and Valencia Counties, New Mexico," U.S. Department of Agriculture, Soil Conservation Service, Albuquerque, NM.

Hawley, J.W., and C.S. Haase (editors), 1992. "Hydrogeologic Framework of the Northern Albuquerque Basin," New Mexico Bureau of Mines and Mineral Resources, Open-File Report 387, Socorro, NM.

Kelley, V.C., 1977. "Geology of the Albuquerque Basin, New Mexico," New Mexico Bureau of Mines and Mineral Resources, Memoir 33.

Kues, G.E., 1987. "Groundwater Level Data for Albuquerque-Belen Basin, New Mexico, Through Water Year 1985," U.S. Geological Survey Open File Report 87-116, pp. 51.

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Table 12.7
Correction factors for permissible velocity

Depth of flow (ft)	Correction factor
≥3	1.0
1.9	0.9
1.0	0.8
0.65	0.7
0.4	0.6
→ ≤0.25	0.5

Source: USNRC, 1990

where A is the loss per unit area per year (tn/acre/yr) and R is the rainfall factor. The rainfall factor (Lutton et al., 1979) is

$$EI/100$$

where E is the total kinetic energy of a given storm ($E = 916 + 331 \log i$) (ft-tn/acre-in.), i is the rainfall intensity (in./hr), and I is the maximum 30-min rainfall intensity (in./hr). The E for an individual storm can be obtained by dividing the storm into individual increments with uniform intensity and summing the incremental Es.

The rainfall factor R for specific areas of the United States can be obtained from the local Soil Conservation Service (SCS) office. For average annual soil loss, R can be estimated from Figure 12.7 (Lutten et al., 1979). The topographic factor, LS, is

$$LS = (L/72.6)^m(65s^2 + 450s + 650)/(s^2 + 10{,}000) \qquad \textbf{(12.21)}$$

where

L = slope length (ft),
s = slope steepness (%)
m = exponent
= 0.2 for $s < 1$
= 0.3 for $1 < s < 3$
= 0.4 for $3 < s < 5$
= 0.5 for $5 < s < 10$
= 0.6 for $s > 10$

The erosion control factor, VM, accounts for erosion control measures at a particular site and may vary from 1.0 to 0.01, as explained in Table 12.8 (Nelson et al., 1986). The soil erodibility factor, K, depends on the soil composition. Table 12.9 (Lutton et al., 1979) shows approximate values of K for USDA textural soil classification (see Chapter 2).

K is the average soil loss in tn/acre per unit of R for a given soil on a "unit plot." A unit plot is 72.6 ft long with a 9% slope, has continuous fallow, and is tilled parallel to the land slope. Nomograph empirical solutions of K are available (NAVFAC DM-7.1). Such solutions require grain size data, the permeability classification of the soil and organic matter, and the soil structure classification.

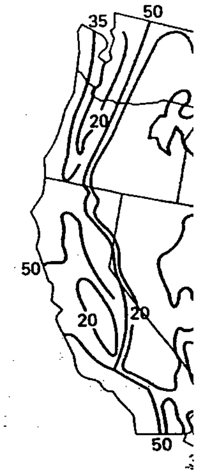

Figure 12.7 Average

Table 12.8
Typical VM factor values

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Table 12.3
Maximum permissible velocities in erodible channels

Channel material	Water transporting colloidal silts, v (ft/s)
Fine sand, colloidal	2.50
Sandy loam, noncolloidal	2.50
Silty loam, noncolloidal	3.00
Alluvial silts, noncolloidal	3.50
Firm loam	3.50
Volcanic ash	3.50
Stiff clay, colloidal	5.00
Alluvial silts, colloidal	5.00
Shales and hardpans	6.00
Fine gravel	5.00
Graded loam to cobbles, noncolloidal	5.00
Graded silts to cobble, colloidal	5.50
Coarse gravel, noncolloidal	6.00
Cobbles and shingles	5.50

Source: Lane, 1955

Table 12.4
Maximum allowable velocities in sand-based material

Material	Velocity (ft/s)
Very light sand of quicksand character	0.75 to 1.00
Very light loose sand	1.00 to 1.50
Coarse sand to light sandy soil	1.50 to 2.00
Sandy soil	2.00 to 2.50
Sandy loam	2.50 to 2.75
Average loam, alluvial soil, volcanic ash	2.75 to 3.00
Firm loam, clay loam	3.00 to 3.75
Stiff clay soil, gravel soil	4.00 to 5.00
Coarse gravel, cobbles, and shingles	5.00 to 6.00
Conglomerate, cemented gravel, soft slate, tough hardpan, soft sedimentary rock	6.00 to 8.00

Source: Lane, 1955

Table 12.5
Limiting velocities in cohesive materials

	COMPACTNESS OF BED			
Principal cohesive material	Loose velocity (ft/s)	Fairly compact velocity (ft/s)	Compact velocity (ft/s)	Very compact velocity (ft/s)
Sandy clay	1.48	2.95	4.26	5.90
Heavy clayey soils	1.31	2.79	4.10	5.58
Clays	1.15	2.62	3.94	5.41
Lean clayey soils	1.05	2.30	3.44	4.43

Source: Lane, 1955

Table 12.6
Maximum permissi[ble]
velocities in feet pe[r]
second (fps) for
channels lined
with uniform stand[s]
of various well-
maintained grass
covers

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GRAM, Inc. **Calculation Sheet**

By: M. McVey	**Date:** 8/19/99	**Title:** Potential Soil Loss from the MWL Cover by Overland Runoff
Chkd. By: J. Peace	**Date:** 8/20/99	

Purpose:

Determine the soil loss due to sheet and rill erosion for the Mixed Waste Landfill alternative cover. The soil loss will be calculated by the Modified Universal Soil Loss Equation (MUSLE). This calculation only presents potential loss.

References:

1. Geotechnology of Waste Management, 2nd Ed., Issa S. Oweis, Raj P. KHera, February, 1998.
2. AGRA, Mixed Waste Landfill Cover, Tabulation of Test Results performed by AGRA Earth & Environmental on May 17, 1999.

Soil Loss Calculations

Modified Universal Soil Loss Equation (MUSLE):

$$A = RK(LS)(VM)$$

Where:

A = Average annual soil loss (Tons/Acre/yr.)

R = Rainfall factor

K = Soil erodibility factor

LS = Topographic factor

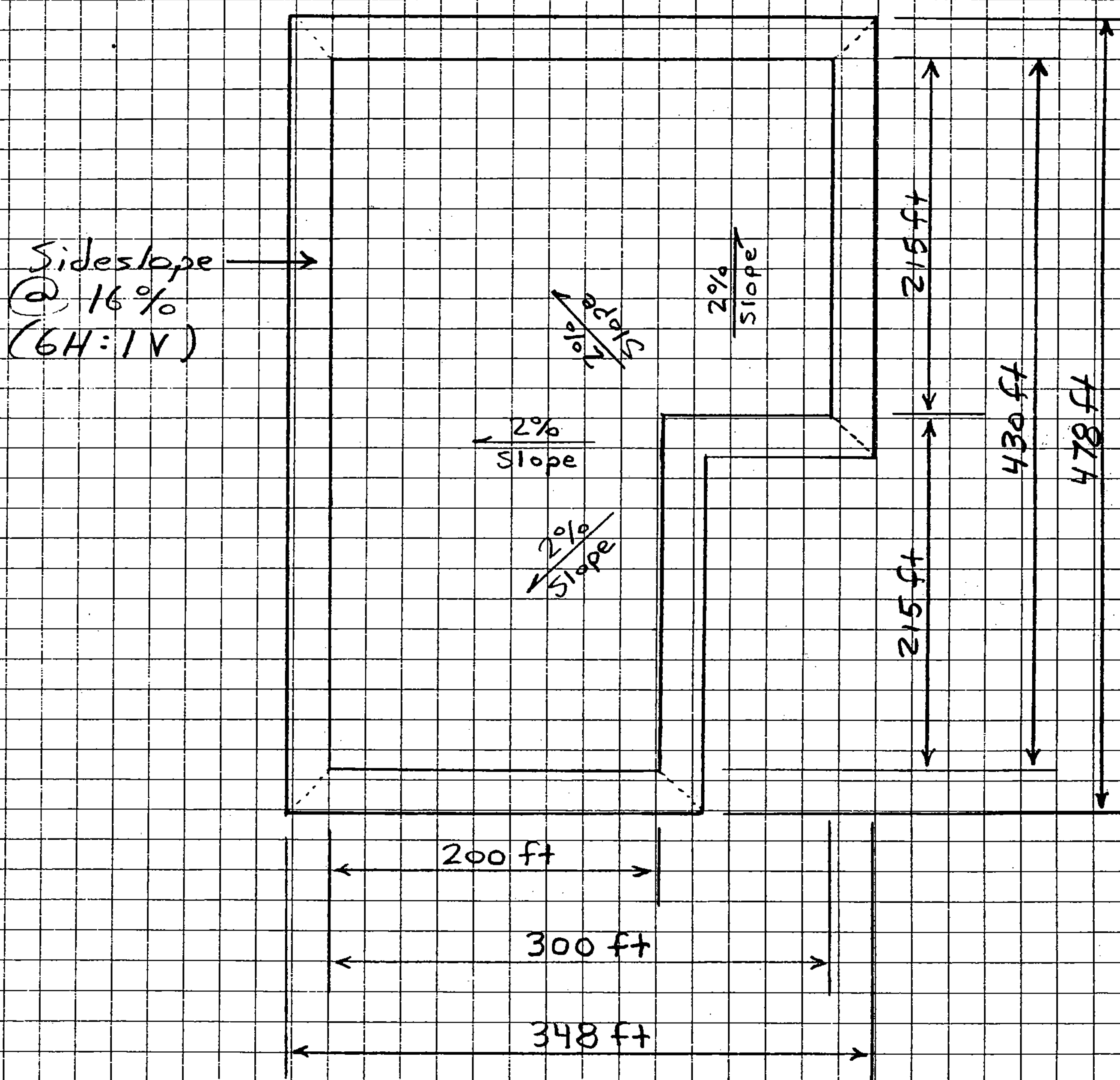
VM = Erosion control factor

GRAM, Inc.

Calculation Sheet | **Sheet** 2 **of** 15

By: M. McVey	**Date:** 8/19/99	**Title:** Potential Soil Loss from the MWL Cover by Overland Runoff
Chkd. By: J. Peace	**Date:** 8/20/99	

Plan View Cover



By: M. McVey	Date: 8/19/99	Title: Potential Soil Loss from the MWL Cover by Overland Runoff
Chkd. By: J. Peace	Date: 8/20/99	

Area of Cover

$$A_c = (200\,ft \times 215\,ft) + (200\,ft \times 215\,ft) + (100\,ft \times 215\,ft)$$
$$= 107{,}500\,ft^2$$
$$= 107{,}500\,ft^2 / 43{,}560\,ft^2/Acre$$
$$= \underline{\underline{2.47\ Acres}}$$

Area of Sideslopes

$$A_{SS} = (24\,ft \times 478\,ft) + (24\,ft \times 200\,ft) + (24\,ft \times 239\,ft) + (24\,ft \times 100\,ft) + (24\,ft \times 215\,ft) + (24\,ft \times 324\,ft)$$
$$= 37{,}344\,ft^2 / 43{,}560\,ft^2/Acre$$
$$= \underline{\underline{0.86\ Acres}}$$

Total Area of Cover and Sideslopes

$$A_{TOT} = A_c + A_{SS}$$
$$= 2.47\ Acres + 0.86\ Acres$$
$$= \underline{\underline{3.33\ Acres}}$$

GRAM, Inc. **Calculation Sheet**

By: M. McVey	Date: 8/19/99	Title: Potential Soil Loss from the MWL Cover by Overland Runoff
Chkd. By: J. Peace	Date: 8/20/99	

1) Determine rainfall factor, R:
   From Figure 1 (Sheet 9)

   ⇒ R = 35

2) Determine soil erodibility factor, K:
   - From Tabulation of AGRA Test Results, Table 1 (Sheet 10), USCS Classifation = SM

   - USDA classification for SM with sand fraction > 70% is loamy sand, Figure 2 (Sheet 11).
   - Percent passing #170 sieve indicates that sand fraction is predominantly fine to very fine.

   ⇒ Loamy very fine sand

   From Table 2 (Sheet 12), K for a loamy very fine sand with organic content < 0.5%
   = 0.44

   K = 0.44

By: M. McVey	Date: 8/19/99	Title: Potential Soil Loss from the MWL Cover by Overland Runoff
Chkd. By: J. Peace	Date: 8/20/99	

3) Determine topographic factor, LS:

$$LS = \frac{(L/72.6)^m (65S^2 + 450S + 650)}{(S^2 + 10{,}000)}$$

where:

L = Slope length (See sheet 13)

S = Slope steepness (%)

m = exponent

0.20 for S < 1

0.30 for 1 < S < 3

0.40 for 3 < S < 5

0.50 for 5 < S < 10

0.60 for S > 10

$$LS_{(2\%)\ \text{Cover}} = \frac{(327/72.6)^{0.3} (65(2)^2 + 450(2) + 650)}{(2)^2 + 10{,}000}$$

$$= \underline{\underline{0.28}}$$

for:

L = 327 ft

S = 2%

m = 0.30

By: M. McVey	Date: 8/19/99	Title: Potential Soil Loss from the MWL Cover by Overland Runoff
Chkd. By: J. Peace	Date: 8/20/99	

$$LS_{(16.7\%)\ \text{Sideslopes}} = \frac{(24/72.6)^{0.6}\left(65(16.7)^2 + 450(16.7) + 650\right)}{(16.7)^2 + 10{,}000}$$

$$= \underline{\underline{1.32}}$$

for:

$L = 24$ ft (See sheet 13)

$S = 16.7\%$

$m = 0.60$

MUSLE:

$$A = RK(LS)(VM)$$

$$A_{(2\%\ \text{Cover})} = 35(0.44)(0.28)(VM)$$

$$= \underline{4.31(VM)}$$

$$A_{(16.7\%\ \text{Sideslopes})} = 35(0.44)(1.32)(VM)$$

$$= \underline{20.33(VM)}$$

GRAM, Inc. Calculation Sheet

By: M. McVey	Date: 8/19/99	Title: Potential Soil Loss from the MWL Cover by Overland Runoff
Chkd. By: J. Peace	Date: 8/20/99	

4) Determine erosion control factor, VM:

Case 1 : No vegetation yet established, straw mulch applied to cover and sideslopes at 2 tons/acre, crimpted into soils with disk.

From Table 3 (Sheet 14)

$\Longrightarrow VM_{(2\%\ Cover)} = 0.06$

$\Longrightarrow VM_{(16.7\%\ Sideslopes)} = 0.11$

For 2% Cover Slope

$A = 4.31(0.06) = 0.26$ Tons/acre/yr.

For 16.7% Sideslopes

$A = 20.33(0.11) = 2.24$ Tons/acre/yr.

$$\text{Total Soil Loss} = \frac{(0.26\ Tn/Ac/Yr)(2.47\ Ac) + (2.24\ Tn/Ac/Yr)(0.86\ Ac)}{2.47\ Ac + 0.86\ Ac}$$

$= 0.77$ Tons/Acre/yr. $<$ 2 Tons/Acre/yr.

OK

By: M. McVey	Date: 8/19/99	Title: Potential Soil Loss from the MWL Cover by Overland Runoff
Chkd. By: J. Peace	Date: 8/20/99	

Case 2: Vegetation is established over cover and sideslopes 12 months after seeding; 1/2 straw mulch remains.

From Table 4 (Sheet 15)

$\Rightarrow VM = 0.01$

For 2% Cover Slope

$A = 4.31(0.01) = 0.04$ Tons/Acre/yr.

For 16.7% Sideslopes

$A = 20.33(0.01) = 0.2$ Tons/Acre/yr.

$$\text{Total Soil Loss} = \frac{(0.04\ \text{Tn/Ac/yr.})(2.47\ \text{Ac}) + (0.2\ \text{Tn/Ac/yr.})(0.86\ \text{Ac})}{2.47\ \text{Ac} + 0.86\ \text{Ac}}$$

$= 0.08$ Tons/Acre/yr. < 2 Tons/Acre/yr.

OK

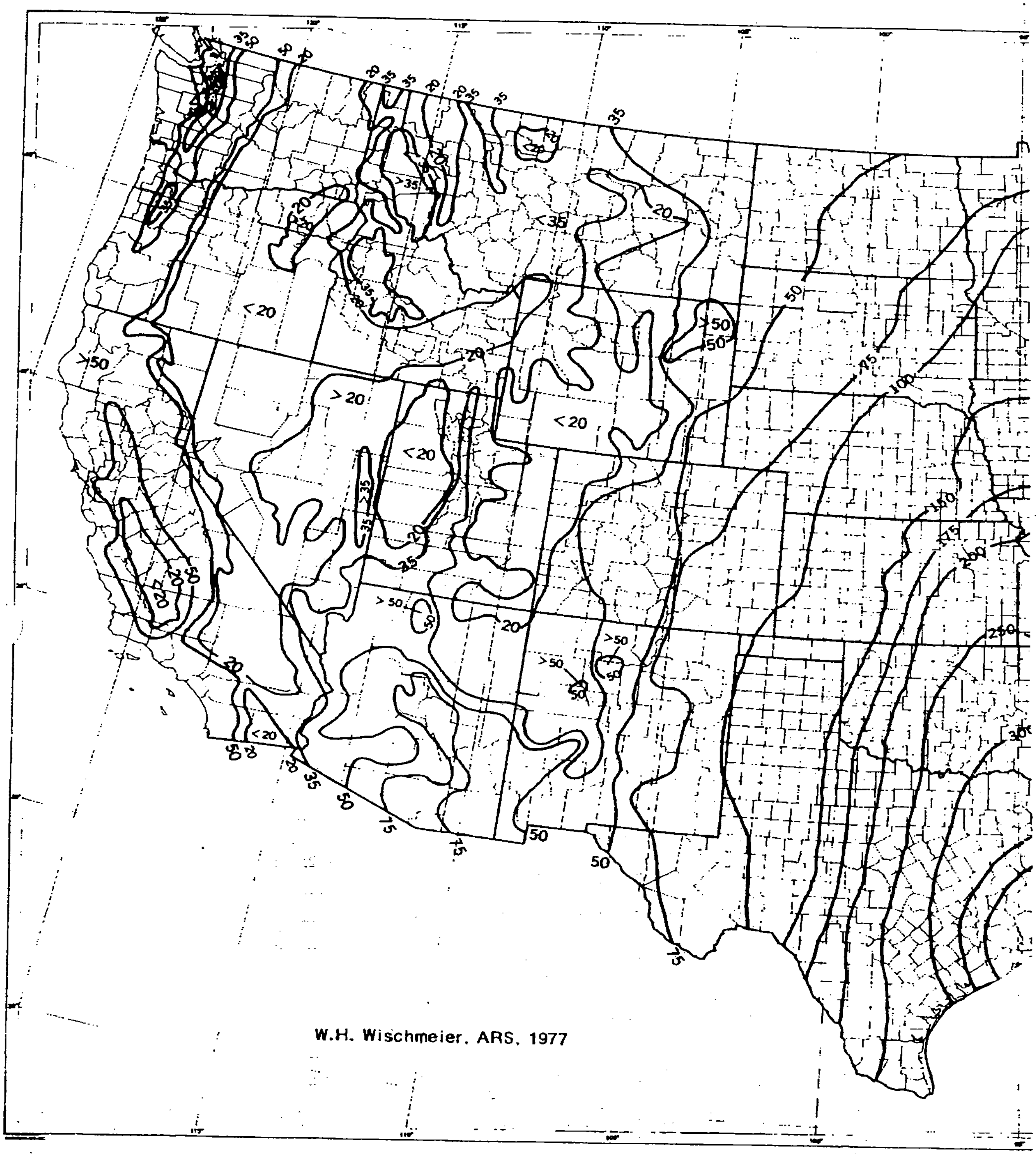


Figure 1 —Iso-erodent map illustrating average annual values of the rainfall factor, R.

Table 1.

TABULATION OF TEST RESULTS

JOB NO. 9-519-001154

PROJECT: Mixed Waste Landfill Cover

DATE: 05/17/99

SOURCE: SNL

LOCATION	DEPTH (ft.)	UNIFIED CLASS	LL	PI	SIEVE ANALYSIS - ACCUM. % PASSING 200	170	100	80	70	40	10	4	3/8	1/2	3/4	MOIST.	LAB NO.
Composite MWL-A1	0'-2'	ML	NV	NP	58	64	82	85	87	89	95	98	99	100		4.5	4557
Composite MWL-1B	2'	SM	NV	NP	25	35	56	73	79	87	95	99	100			4.3	4560
Native Soil	1 of 3	SM	NV	NP	24	35	68	74	78	83	90	94	97	100		4.8	4565
Native Soil	2 of 3	SM-SC	22	6	31	42	70	75	78	84	91	96	98	100		6.2	4566
Native Soil	3 of 3	SM	NV	NP	28	38	60	66	70	77	87	92	97	100		6.5	4567
Subgrade Soil	1 of 3	SM	NV	NP	29	40	69	75	78	82	91	96	99	100		8.4	4568
Subgrade Soil	2 of 3	SM	NV	NP	25	36	67	73	76	81	91	96	99	100		6.6	4569
Subgrade Soil	3 of 3	SM	NV	NP	27	38	69	75	78	83	91	95	100			7.3	4570
P2A	0.6'	SM	NV	NP	43	43	73	82	88	96	99	100				13.1	4571
P2A	1.5'	SM	NV	NP	28	36	63	73	81	92	96	99	100			7.1	4572
P2A	1.7'	SM	NV	NP	25	33	61	72	82	94	98	100				7.3	4573
P2D	0.6'	SM-SC	23	7	37	45	70	80	88	97	100					12.0	4574
P2E	1.0'	ML	NV	NP	62	67	83	88	92	97	99	100				5.9	4575

SM => Silty Sand (USCS)
Loamy Very Fine Sand (USDA)

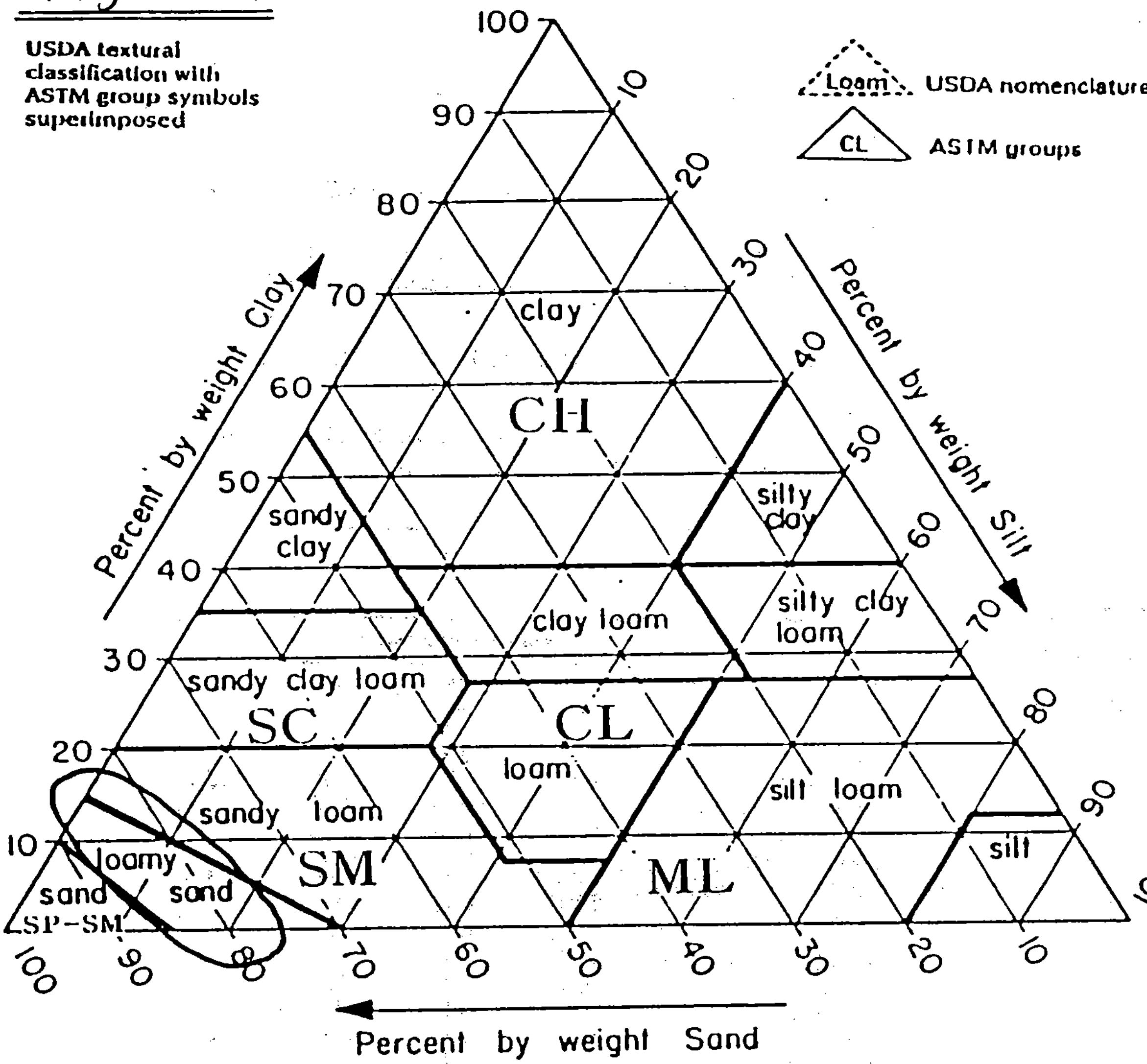
Sheet 11 of 15

Table 2.6
Soil symbols used in USDA

USDA soil type or state	USDA symbol
Gravel	G
Sand	S
Silt	Si
Clay	C
Loam (sand, silt, clay, and humus mixture)	L
Coarse	Co
Fine	F

Figure 2.

USDA textural classification with ASTM group symbols superimposed



Sheet 12 of 15

Example 12.3

A landfill in south New Jersey is designed to have a cover with a slope of 5% of a top plateau extending from a central ridge (high point) for a distance of 300 ft. Beyond this distance, the cover slopes down to the toe at a grade of $1V$ on $4H$. The upper cover component is loamy sand with 2% organic content. Grass is the only means of erosion control. Determine the expected soil loss from sheet flow.

Solution: From Figure 12.7, $R = 200$. From Table 12.9, $K = 0.1$. From Eq. 12.21:

LS (top plateau), $m = 0.4$

$LS = (300/72.6)^{0.4}(65 \times 25 + 450 \times 5 + 650)/(25 + 10{,}000) = 0.794$

LS (side slope), $m = 0.6$

$LS = (500/72.6)^{0.6}(65 \times 625 + 450 \times 25 + 650)/(625 + 10{,}000) = 15.73$

To determine the soil loss, we begin by using Eq. 12.20 for the top plateau:

$$A = 200(0.1)(0.79)(VM) = 15.8(VM)$$

From Table 12.8, the VM factors are 0.4, for grass seedings less than 2 months old, 0.05 for those 2 to 12 months old, and 0.01 for those over 12

12.6

Table 2.

Approximate values of factor K for USDA textural classification

Texture class	Organic matter content <0.5% K	2% K	4% K
Sand	0.05	0.03	0.02
Fine sand	0.16	0.14	0.10
Very fine sand	0.42	0.36	0.28
Loamy sand	0.12	0.10	0.08
Loamy fine sand	0.24	0.20	0.16
→ Loamy very fine sand	0.44	0.38	0.30
Sandy loam	0.27	0.24	0.19
Fine sandy loam	0.35	0.30	0.24
Very fine sandy loam	0.47	0.41	0.33
Loam	0.38	0.34	0.29
Silt loam	0.48	0.42	0.33
Silt	0.60	0.52	0.42
Sandy clay loam	0.27	0.25	0.21
Clay loam	0.28	0.25	0.21
Silty clay loam	0.37	0.32	0.26
Sandy clay	0.14	0.13	0.12
Silty clay	0.25	0.23	0.19
Clay		0.13–0.29	

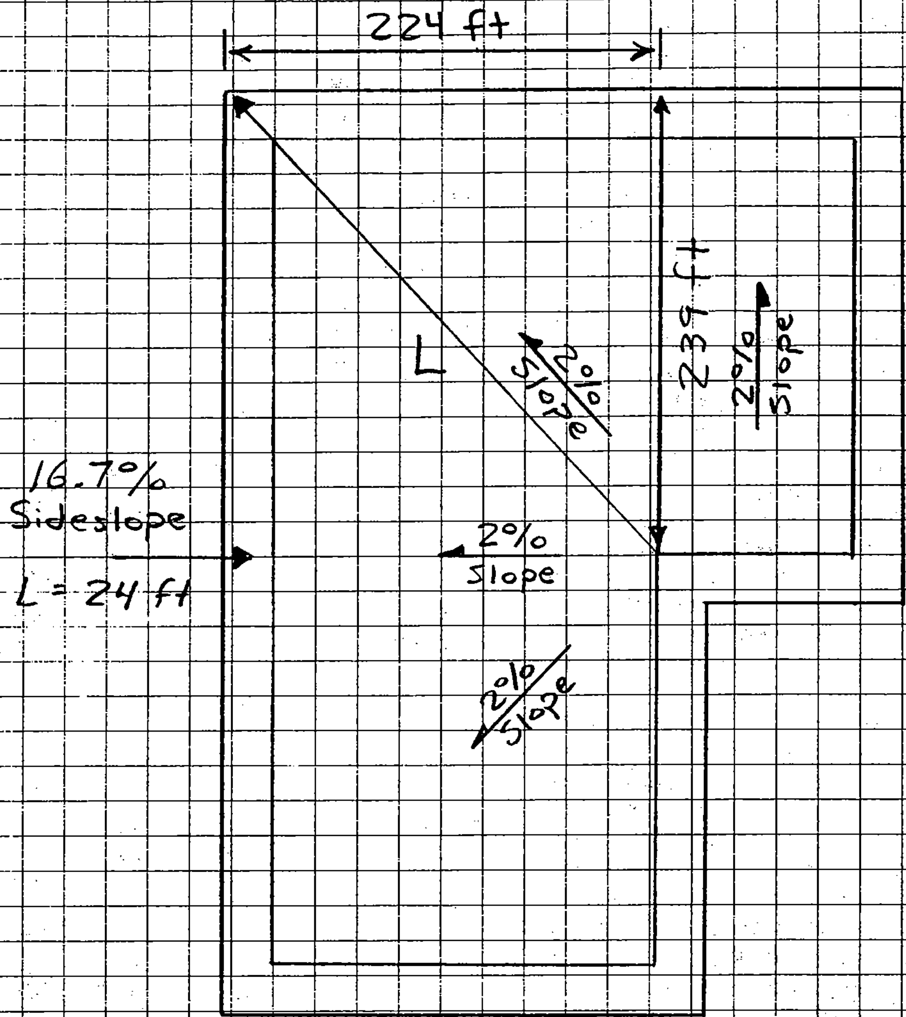
The values shown are estimated averages of broad ranges of specific-soil values. When a texture is near the borderline of two texture classes, use the average of the two K values.

Source: Lutten et al., 1979

GRAM, Inc.

Calculation Sheet

By: M. McVey	Date: 8/19/99	Title: Potential Soil Loss from the MWL Cover by Overland Runoff
Chkd. By: J. Peace	Date: 8/20/99	



For 2% Cover Slope

L = 327 ft

For 16.7% Sideslopes

L = 24 ft

Straw or hay mulches applied to steep construction slopes and not tied to the soil by anchoring and tacking equipment may be less effective than equivalent mulch rates on cropland. In Indiana, tests on a 20% slope of scalped subsoil, a 2.3-t rate of unanchored straw mulch allowed soil losses of 12 t/A when 5 in. of simulated rain was applied at 2.5 in./hr on a 35-ft plot (Wischmeier and Meyer, 1973). There was evidence of erosion from flow beneath the straw. Mulches of crushed stone at 135 or more t/A, or wood chips at 7 or more t/A, were more effective.

Table IV presents approximate C values for straw, crushed stone, and woodchip mulches on construction slopes where no canopy cover exists, and also shows the maximum slope lengths on which these values may be assumed to be applicable.

Soil loss ratios for many conditions on SLB, construction, and developmental areas can be obtained from Table IV if good judgment is exercised in comparing the surface conditions with those of specified agricultural conditions. Time intervals analogous to cropstage periods will be defined to begin and end with successive construction or management activities that appreciably change the surface conditions.

The observed soil loss ratios for given conditions often varied substantially from year to year because of influence of unpredictable random variables and experimental error. The percentages listed for Table V are the best available averages for a wide variety of specified agricultural conditions, only a few of which might be applicable to SLB systems. To make the table inclusive enough for general field use, expected ratios had to be computed for cover, residue, and management combinations that were not directly represented in the plot data. This was done by using empirical relationships of soil losses to the subfactors and interactions discussed in the preceding subsection. The user should recognize that the tabulated percentages are subject to appreciable experimental error and could be improved through additional research. However, because of the large volume of data considered in developing the table, the listed values should be near enough to the true averages to provide highly valuable planning and monitoring guidelines. A ratio derived locally from 1-year rainfall simulator tests on a few plots would not necessarily more accurately represent the true average for that locality. Small samples are more subject to bias by random variables and experimental error than are larger samples.

Table 3.

MULCH FACTORS AND LENGTH LIMITS FOR CONSTRUCTION SLOPES[a]

Type of Mulch	Mulch Rate (Tons/Acre)	Land Slope (%)	Factor C	Length Limit[b] (ft)
None	0	all	1.0	—
Straw or hay,	1.0	1-5	0.20	200
tied down by	1.0	6-10	0.20	100
anchoring and				
tacking	1.5	1-5	0.12	300
equipment[c]	1.5	6-10	0.12	150
2% Cover Slope →	2.0	1-5	0.06	400
	2.0	6-10	0.06	200
	2.0	11-15	0.07	150
16.7% Sideslopes →	2.0	16-20	0.11	100
	2.0	21-25	0.14	75
	2.0	26-33	0.17	50
	2.0	34-50	0.20	35
Crushed stone, ¼ to 1½ in	135	<16	0.05	200
	135	16-20	0.05	[illegible]
	135	21-33	0.05	[illegible]
	135	34-50	[illegible]	75
	240	<21	0.02	300
	240	21-33	0.02	200
	240	34-50	0.02	150
Wood chips	7	<16	0.08	75
	7	16-20	0.08	50
	12	<16	0.05	150
	12	16-20	0.05	100
	12	21-33	0.05	75
	25	<16	0.02	200
	25	16-20	0.02	150
	25	21-33	0.02	100
	25	34-50	0.02	75

[a]From Meyer and Ports (1976). Developed by an interagency workshop group on the basis of field experience and limited research data.

[b]Maximum slope length for which the specified mulch rate is considered effective. When this limit is exceeded, either a higher application rate or mechanical shortening of the effective slope length is required.

[c]When the straw or hay mulch is not anchored to the soil, C values on moderate or steep slopes of soils having K values greater than 0.30 should be taken at double the values given in this table.

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Table 12.8
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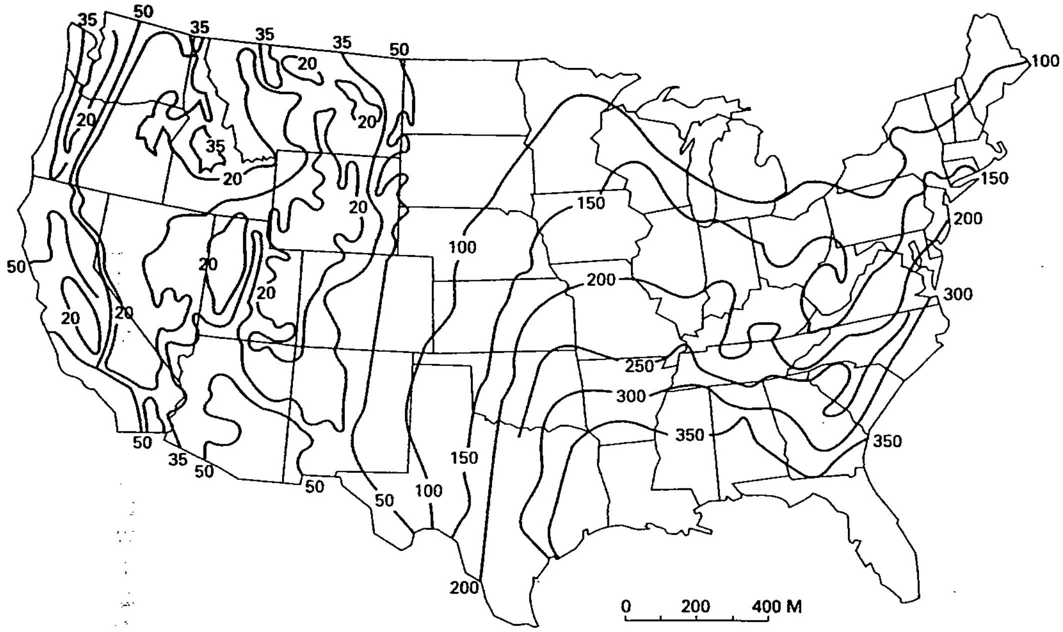

Figure 12.7 Average annual rainfall — erosivity factor R

Table 4.

Typical VM factor values

Condition	VM factor
Bare soil condition	
Freshly disked, 6–8 in.	1.0
After one rain	0.89
Loose, 12 in. thick	
Smooth	0.9
Rough	0.8
Compacted bulldozer scraped up and down	1.3
Same except roots raked	1.2
Compacted bulldozer scraped across slope	1.2
Rough irregular tracked in all directions	0.9
Seed and fertilize fresh	0.9
Same after 6 months	0.54
Compacted fill	1.24–1.71
Saw dust, 2 in. deep disked in	0.61
Dust binder	
605 gal/acre	1.05
1210 gal/acre	0.29–0.78
Hydromulch (wood fiber slurry), fresh	
1000 lb/acre	0.05
1400 lb/acre	0.01–0.02
Seedings	
Temporary, 0–60 days	0.4
After 60 days	0.05
Permanent, 0–60 days	0.4
2–12 months	0.05
After 12 months	0.01
Excelsior blanket with plastic net	0.04–0.1

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By: M. McVey	Date: 8/24/99	Title: Potential Soil Loss from the MWL Cover by Wind Erosion
Chkd. By: J. Peace	Date: 8/25/99	

Purpose:

Determine the soil loss due to wind erosion for the Mixed Waste Landfill alternative cover. The soil loss will be calculated by the Wind Erosion Equation (WEQ). This calculation only presents potential loss.

References:

Natural Resources Conservation Service (NRCS) National Agronomy Manual, 190-V-NAM, 2nd Ed., Part 502, March 1988.

N.P. Woodruff and F.H. Siddaway, 1965. "A Wind Erosion Equation," Soil Science Society of America Proceedings, Vol. 29, No. 5, pages 602-608.

Method of Analysis:

Standard engineering hand calculations using the Wind Erosion Equation (WEQ).

$$E = f[(IKC)LV]$$

Where:

- E = estimated average annual soil loss (Tons/Acre/yr.)
- I = soil erodibility index
- K = ridge roughness factor
- C = climatic factor
- L = unsheltered distance
- V = vegetative factor

By: M. McVey	Date: 8/24/99	Title: Potential Soil Loss from the MWL Cover by Wind Erosion
Chkd. By: J. Peace	Date: 8/25/99	

1) Determine soil erodibility index, I:
- From Tabulation of AGRA Test Results, Table 1 (Sheet 9), USCS Classification is SM.
- USDA classification for SM with sand fraction > 70% is loamy sand (Sheet 10).
- Percent passing #170 sieve indicates that the sand fraction is predominantly fine to very fine.

Soil classification ⟹ Loamy very fine sand

From Table 2 (Sheet 11) for a loamy very fine sand ⟹ I = 134 Tons/Acre/yr.

For 2% Cover Slope

I = 134 Tons/Acre/yr.

- Knoll erodibility adjustment: Adjustments of the "I" factor for knolls is used where windward facing slopes are less than 500 ft long and the increase in slope gradient from the adjacent upwind landscape is 3% or greater.

Since the windward facing slopes are > 500 ft long and < 3%, no adjustment to the soil erodibility index, I, is warranted for the 2% cover slope.

I = 134 Tons/Acre/yr.

By: M. McVey	Date: 8/24/99	Title: Potential Soil Loss from the MWL Cover by Wind Erosion
Chkd. By: J. Peace	Date: 8/25/99	

For the 16.7% Sideslopes

$I = 134$ Tons/Acre/yr.

Knoll erodibility adjustment: Since the 6:1 (16.7%) sideslopes are < 500 ft long and the windward facing slopes are > 3%, the knoll erodibility adjustment is warranted.

Max slope change = 16.7% (6:1)

From Table 3 (Sheet 12):

Adjustment to I = 1.4 multiplier

Therefore: $I = 134(1.4) = 188$

$I = 188$ Tons/Acre/yr.

2) Determine the total surface roughness, K:

$K = K_{rd}$ (ridge roughness) x K_{rr} (random roughness)

K_{rd}

Because the cover is man-made, it is assumed that the cover and sideslopes will be smooth and without ridges.

From Figure 2 (Sheet 13): $K_r = 0$

Since $K_r = 0 \Longrightarrow K_{rd} = 1.0$

By: M. McVey	Date: 8/24/99	Title: Potential Soil Loss from the MWL Cover by Wind Erosion
Chkd. By: J. Peace	Date: 8/25/99	

K_{rr}

Random roughness (rr) is the nonoriented surface roughness that is sometimes referred to as cloddiness. Cloddiness is usually created by the action of tillage implements.

From Table 4 (Sheet 14):

For drill, double disk ⇒ rr = 0.4 inches

For 2% Cover Slope

rr = 0.4 inches

I = 134

From Figure 3 (Sheet 14) ⟹ $K_{rr} = 1.0$

For 16.7% Sideslopes

rr = 0.4 inches

I = 188

From Figure 3 (Sheet 14) ⟹ $K_{rr} = 1.0$

Total Surface Roughness for the 2% Cover Slope and the 16.7% Sideslopes

$$K = K_{rd} \times K_{rr} = (1.0)(1.0)$$

$K = 1.0$

GRAM, Inc. Calculation Sheet

By: M. McVey	Date: 8/24/99	Title: Potential Soil Loss from the MWL Cover by Wind Erosion
Chkd. By: J. Peace	Date: 8/25/99	

3) Determine the climatic factor, C:

The climatic factor is an index of the relative erosivity by geographic location.

From Figure 4 (Sheet 15) ⟹ C = 120

4) Determine the unsheltered distance, L:

The unsheltered distance is the field length along the prevailing wind direction.

For 2% Cover Slope

From Figure 5 (Sheet 16) ⟹ L = 524 ft

For 16.7% Sideslopes

From Figure 6 (Sheet 17) ⟹ L = 25 ft

5) Determine the vegetative cover factor, V:

The effect of vegetative cover in the WEQ is expressed by relating the kind, amount, and orientation of vegetative material to its equivalent in pounds per acre of small grain residue in reference condition (small grain equivalent - Sge).

Case 1: No vegetation yet established, straw mulch applied to cover and sideslopes at 2 tons/acre, crimped into soil with disk.

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Chkd. By: J. Peace	Date: 8/25/99	

2 Tons/Acre (straw mulch) = 4,000 lbs./Acre (Small grain residue)

From Figure 7, using the flat winter wheat residue 10" long randomly distributed reference line (because straw mulch will be lying flat on landfill cover surface)

⟹ V = 4,500 Sge (small grain equivalent)

Case 2: Vegetation is established over cover and sideslopes 12 months after seeding; 1/2 straw mulch remains.

1 Ton/Acre (1/2 straw mulch remains) = 2,000 lbs./Acre (Small grain residue)

From Figure 7: 2,000 lbs/Acre small grain residue

⟹ V = 2,800 Sge (small grain equivalent)

12 months after seeding, 400 Sge* of native grass is established on the cover and sideslopes.

* 400 Sge is a conservative estimate from New Mexico state Agronomist, Mike Sporcic. The estimate is based upon a two year decomposition routine contained in a revised USLE equation for grain straw decomposition in contact with soil.

⟹ V = 2,800 Sge + 400 Sge = 3,200 Sge

GRAM, Inc. Calculation Sheet

By: M. McVey	Date: 8/24/99	Title: Potential Soil Loss from the MWL Cover by Wind Erosion
Chkd. By: J. Peace	Date: 8/25/99	

6) Determine the average annual soil loss, E:

For 2% Cover Slope

From Table 5 (Sheet 19)

for: C = 120

I = 134

K = 1.0

L = 524 ft

Case 1:

V = 4,500 Sge

⟹ E = 0 Tons/Acre/yr.

Case 2:

V = 3,200 Sge

⟹ E = 0 Tons/Acre/yr.

GRAM, Inc.

Calculation Sheet

By: M. McVey	Date: 8/24/99	Title: Potential Soil Loss from the MWL Cover by Wind Erosion
Chkd. By: J. Peace	Date: 8/25/99	

For 16.7% Sideslopes

From Table 6 (Sheet 20)

for: C = 120

I = 188

K = 1.0

L = 25 ft

Case 1:

V = 4,500 Sge

⟹ E = 0 Tons/Acre/yr.

Case 2:

V = 3,200 Sge

⟹ E = 0 Tons/Acre/yr.

Table 1.

TABULATION OF TEST RESULTS

JOB NO. 9-519-001154

PROJECT: Mixed Waste Landfill Cover

DATE: 05/17/99

SOURCE: SNL

LOCATION	DEPTH (ft.)	UNIFIED CLASS	LL	PI	SIEVE ANALYSIS - ACCUM. % PASSING 200	170	100	80	70	40	10	4	3/8	1/2	3/4	MOIST.	LAB NO.
Composite MWL-A1	0'-2'	ML	NV	NP	58	64	82	85	87	89	95	98	99	100		4.5	4557
Composite MWL-1B	2'	SM	NV	NP	25	35	56	73	79	87	95	99	100			4.3	4560
Native Soil	1 of 3	SM	NV	NP	24	35	68	74	78	83	90	94	97	100		4.8	4565
Native Soil	2 of 3	SM-SC	22	6	31	42	70	75	78	84	91	96	98	100		6.2	4566
Native Soil	3 of 3	SM	NV	NP	28	38	60	66	70	77	87	92	97	100		6.5	4567
Subgrade Soil	1 of 3	SM	NV	NP	29	40	69	75	78	82	91	96	99	100		8.4	4568
Subgrade Soil	2 of 3	SM	NV	NP	25	36	67	73	76	81	91	96	99	100		6.6	4569
Subgrade Soil	3 of 3	SM	NV	NP	27	38	69	75	78	83	91	95	100			7.3	4570
P2A	0.6'	SM	NV	NP	43	43	73	82	88	96	99	100				13.1	4571
P2A	1.5'	SM	NV	NP	28	36	63	73	81	92	96	99	100			7.1	4572
P2A	1.7'	SM	NV	NP	25	33	61	72	82	94	98	100				7.3	4573
P2D	0.6'	SM-SC	23	7	37	45	70	80	88	97	100					12.0	4574
P2E	1.0'	ML	NV	NP	62	67	83	88	92	97	99	100				5.9	4575

SM => Silty Sand (USCS)
Loamy Very Fine Sand (USDA)

Table 2.6
Soil symbols used in USDA

USDA soil type or state	USDA symbol
Gravel	G
Sand	S
Silt	Si
Clay	C
Loam (sand, silt, clay, and humus mixture)	L
Coarse	Co
Fine	F

Figure 1.

USDA textural classification with ASTM group symbols superimposed

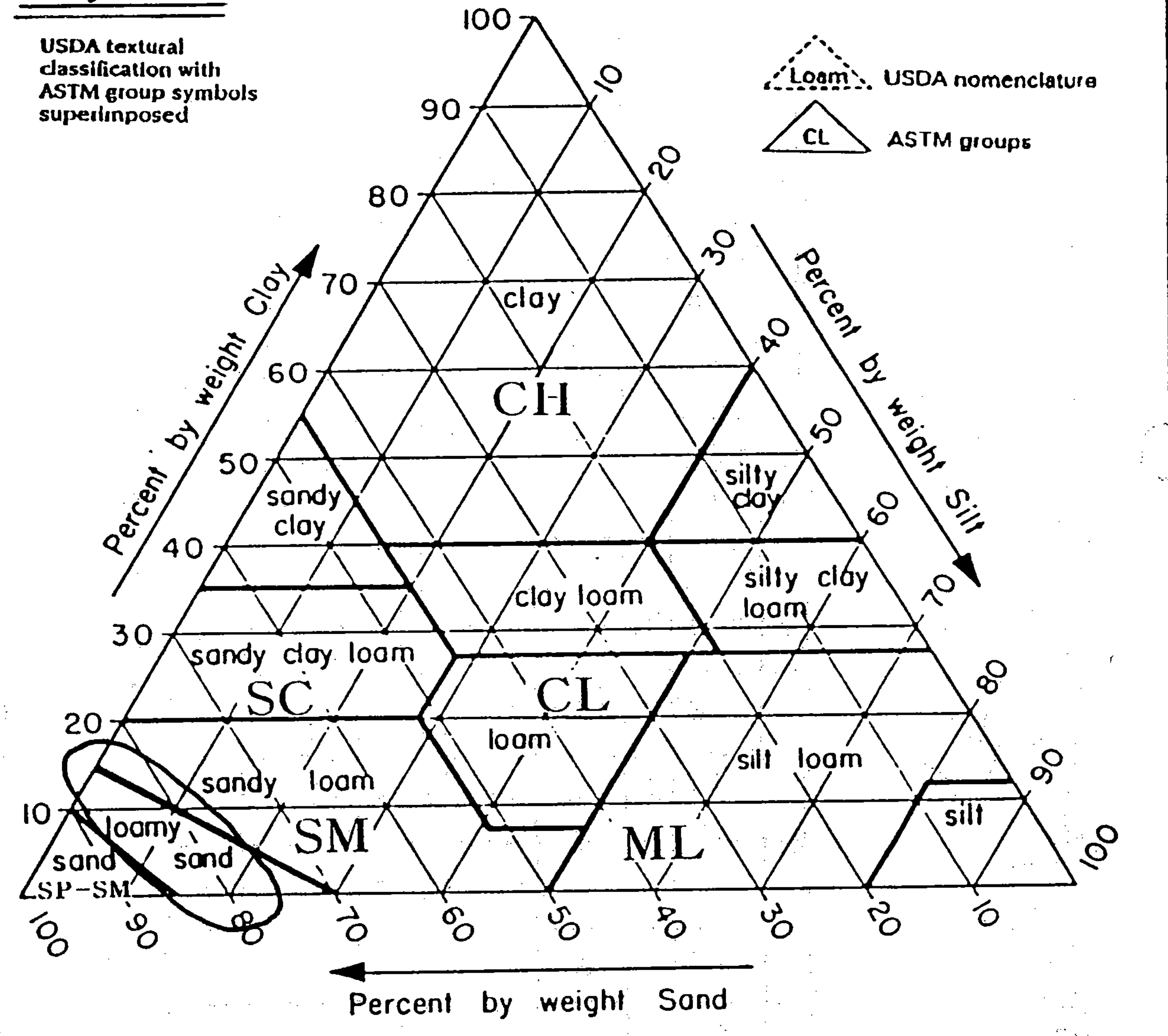


TABLE 2.

WIND ERODIBILITY GROUPS and SOIL ERODIBILITY INDEX

Predominant Soil Texture Class of Surface Layer	Wind Erodibility Group (WEG)	Soil Erodibility Index (I) (Tons/Acre/Year)[1]
Very fine sand, fine sand, sand, or coarse sand	1	310[2] 250 220 180 160
Loamy very fine sand, loamy fine sand, loamy sand, loamy coarse sand, or sapric organic soil materials	2	134
Very fine sandy loam, fine sandy loam, sandy loam, or coarse sandy loam	3	86
Clay, silty clay, noncalcareaous clay loam, or silty clay loam with more than 35 % clay	4	86
Calcareous loam and silt loam, or calcareous clay loam and silty clay loam	4L	86
Noncalcareous loam and silt loam with less than 20% clay, or sandy clay loam, sandy clay, and hemic organic soil materials	5	56
Noncalcareous loam and silt loam with more than 20% clay, or non-calcareous clay loam with less than 35% clay	6	48
Silt, non-calcareous silty clay loam with less than 35% clay, and fibric organic soil material	7	38
Soils not susceptible to wind erosion due to coarse surface fragments or wetness	8	---

[1] The soil erodibility index is based on the relationship of dry soil aggregates greater then .84 mm to potential soil erosion.

[2] The "I" factors for WEG 1 vary from 160 for coarse sands to 310 for very fine sands. Use an I of 220 as an average figure. For coarse sand with gravel, use a low figure. For no gravel and very fine sand, use a higher figure.

TABLE 3. KNOLL ERODIBILITY ADJUSTMENT FACTOR FOR I

Slope Change in Prevailing Wind Erosion Direction	A Knoll Adjustment to I	B Increase at Crest Area Where Erosion Is Most Severe
3	1.3	1.5
4	1.6	1.9
5	1.9	2.5
6	2.3	3.2
8	3.0	4.8
10	3.6	6.8
10 - 15*	2.0	--
16.7% * 15 - 20	1.4	--
20 +	1.0	--

*Factors above 10% slope change based on NRCS judgment. No research data available.

To adjust the "I" factor for knoll erodibility the "I" factor for the soil on the windward facing part of the knoll is multiplied by the factor shown in Column A of Table 3. Column B in the same table shows the increased erodibility near the crest (upper 1/3 of the slope), where the effect is most severe. This adjustment applies only to that portion of the knoll exposed to the prevailing wind erosion direction.

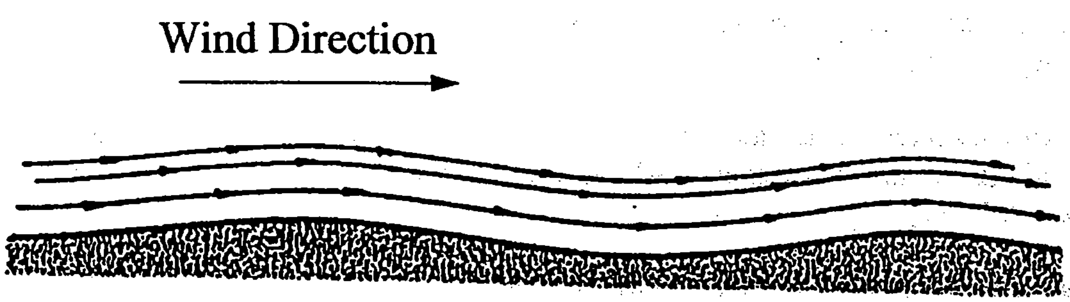
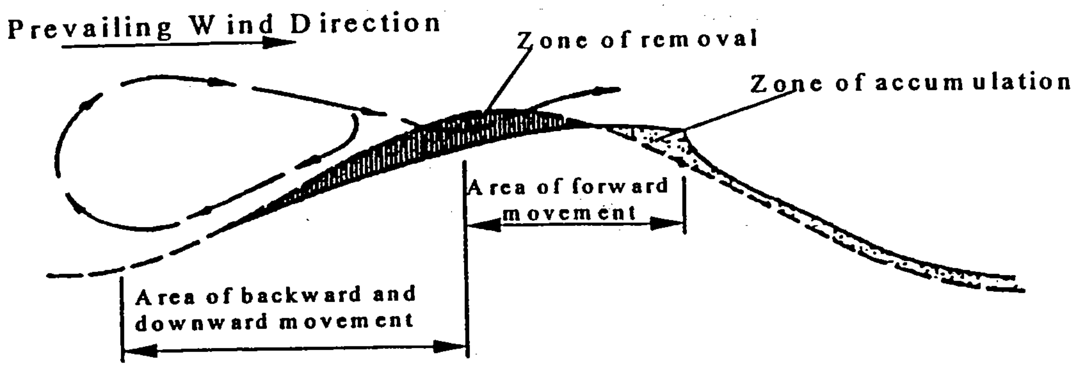


Figure 4. Wind Flow Pattern over Level to Rolling Terrain

On level fields or on rolling terrain where slopes are longer and slope changes are less than those used to describe a knoll, the wind flow pattern tends to conform to the surface and do not exhibit the flow constriction typical of knolls, as illustrated in Figure 4.



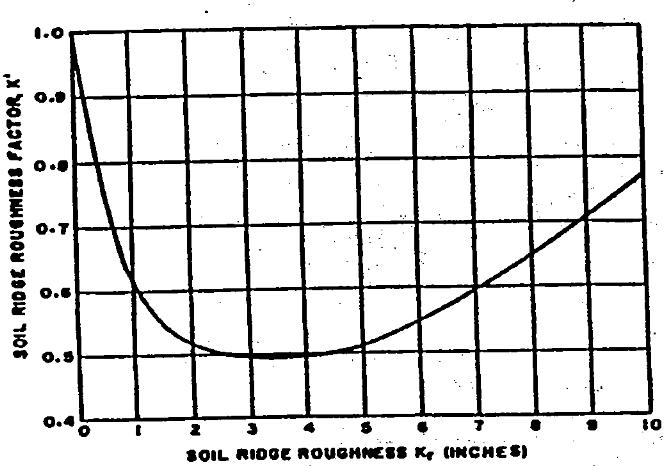
Soil Movement on Ridges

<u>Information Needed to Determine the "K" Factor for Ridge Roughness</u>

- Angle of Deviation
  - Prevailing wind erosion direction
  - Ridge-furrow direction
- Ridge Height
- Ridge Spacing

The "K" factor is based on a standard ridge height to ridge spacing ratio of 1:4. Calibrations of wind tunnel studies led to the development of this curve that relates ridge-furrow roughness to the "K" factor.

This curve is the basis for the "K" factor tables found in Exhibit 502.62 in the National Agronomy Manual and in the Field Office Technical Guide.



$$K_r = \frac{4h^2}{s}$$

where:
h = ridge height in inches
s = ridge spacing (inches) measured in the wind erosion direction

Figure 2. Graph to determine soil ridge roughness factor K from soil ridge roughness Kr.

Table 4. Random Roughness Values for "Core" Field Operations[1]

Field Operations	Random Roughness (in)	Field Operations	Random Roughness (in)
Chisel, sweeps	1.2[2]	Fertilizer applicator, anhydrous knife	0.6
Chisel, straight points	1.5	Harrow, spike	0.4
Chisel, twisted shovels	1.9	Harrow, tine	0.4
Cultivator, field	0.7	Lister	0.8
Cultivator, row	0.7	Manure injector	1.5
Cultivator, ridge till	0.7	Moldboard plow	1.9
Disk, one way	1.2	Mulch treader	0.4
Disk, heavy plowing	1.9	Planter, no-till	0.4
Disk, tandem	0.8	Planter, row	0.4
Drill, double disk	0.4	Rodweeder	0.4
Drill, deep furrow	0.5	Rotary hoe	0.4
Drill, no-till	0.4	Vee ripper	1.2
Drill, no-till into sod	0.3		

[1] These values are typical and representative for operations in medium textured soils tilled at optimum moisture conditions. Many of the machines may vary by cropping region, farming practice, soil texture, or other conditions.

[2] These values may be used in WEQ for random roughness. However, the use of the random roughness photos in Agriculture Handbook 703 is preferable.

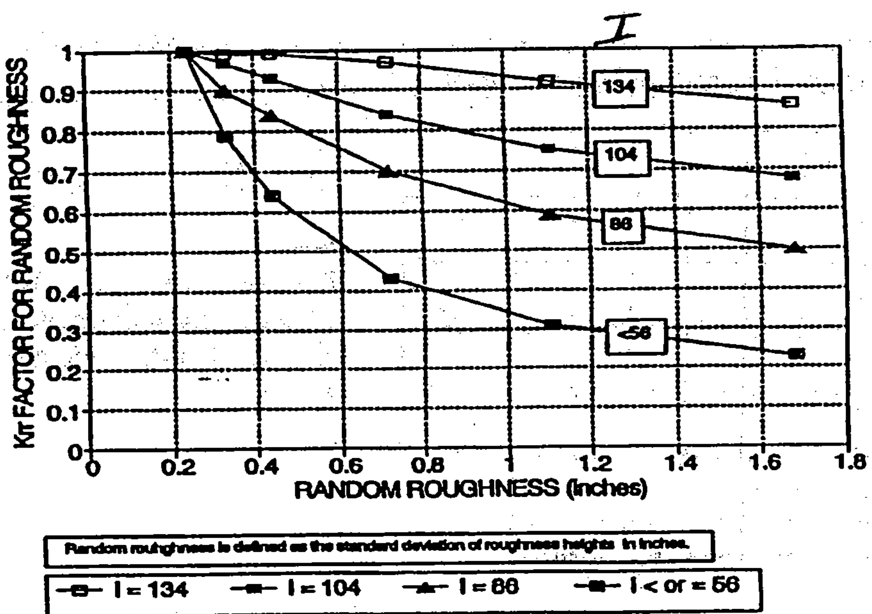


Figure 3. Graph to Determine K_{rr} from Random Roughness and "I" Factor Values

Annual "C" Values
Of The Wind Erosion Equation
New Mexico

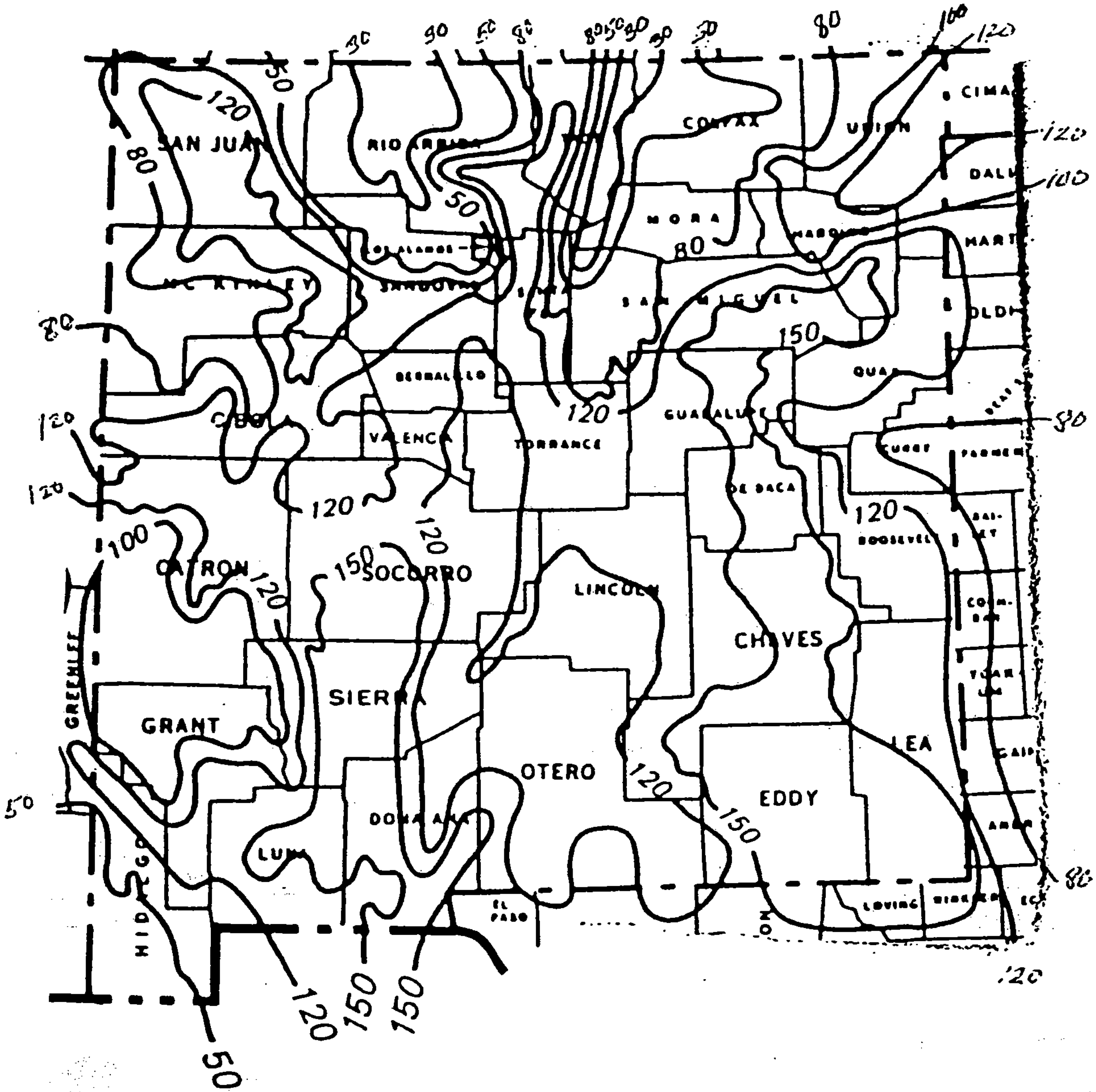


Figure 4.

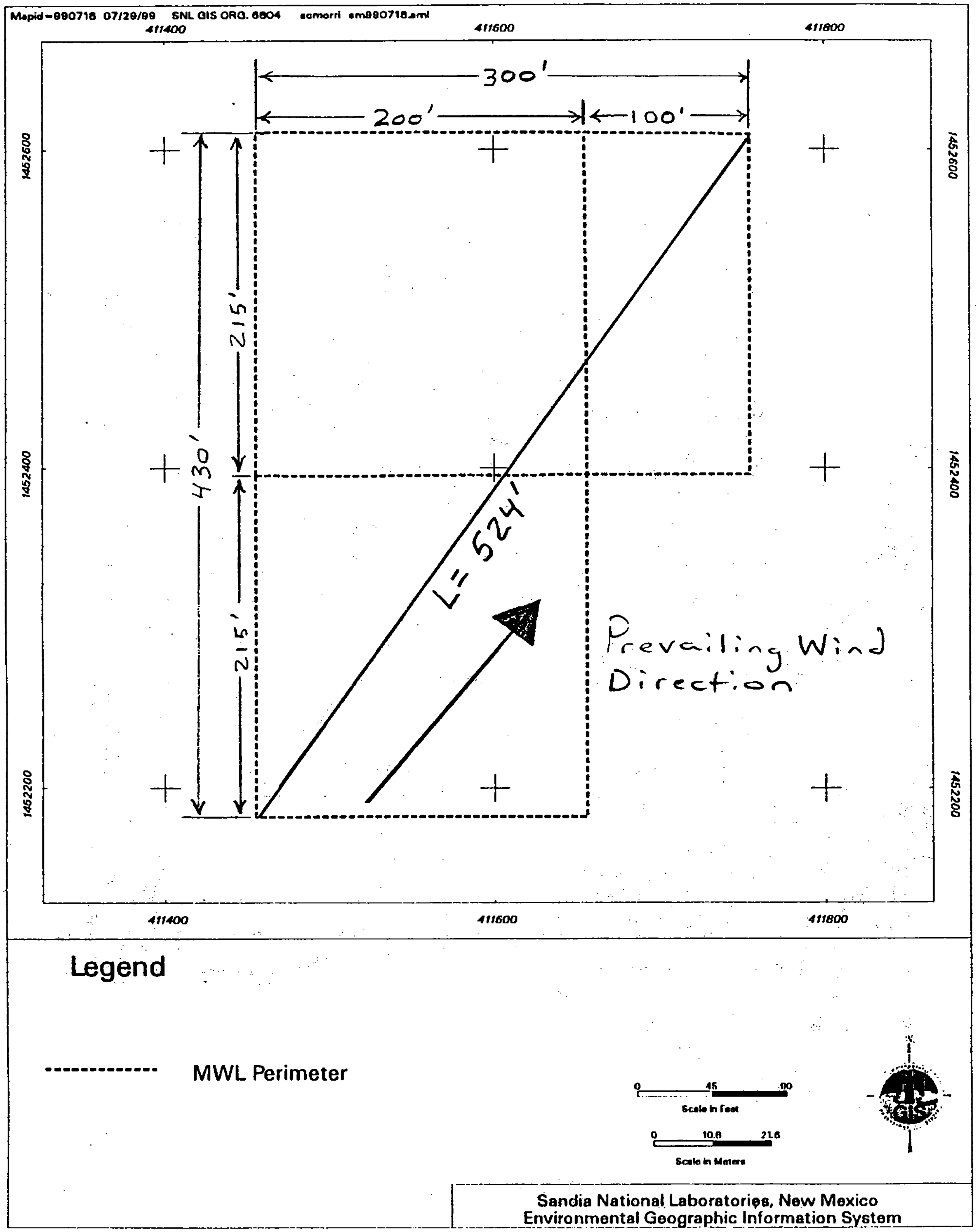


Figure 5. Unsheltered distance, L, for the 2% Cover Slope

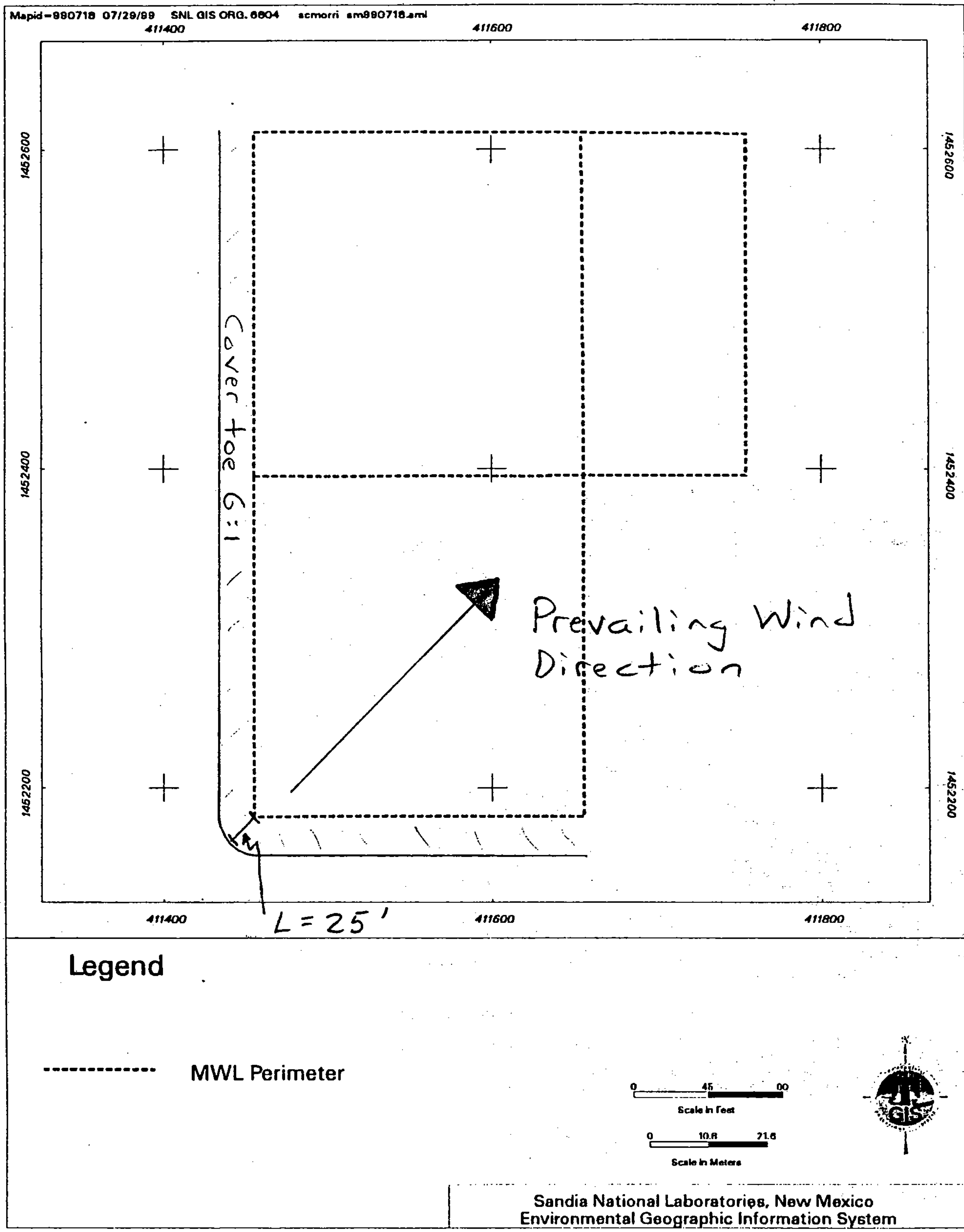


Figure 6. Unsheltered distance, L, for the 16.7% Sideslopes

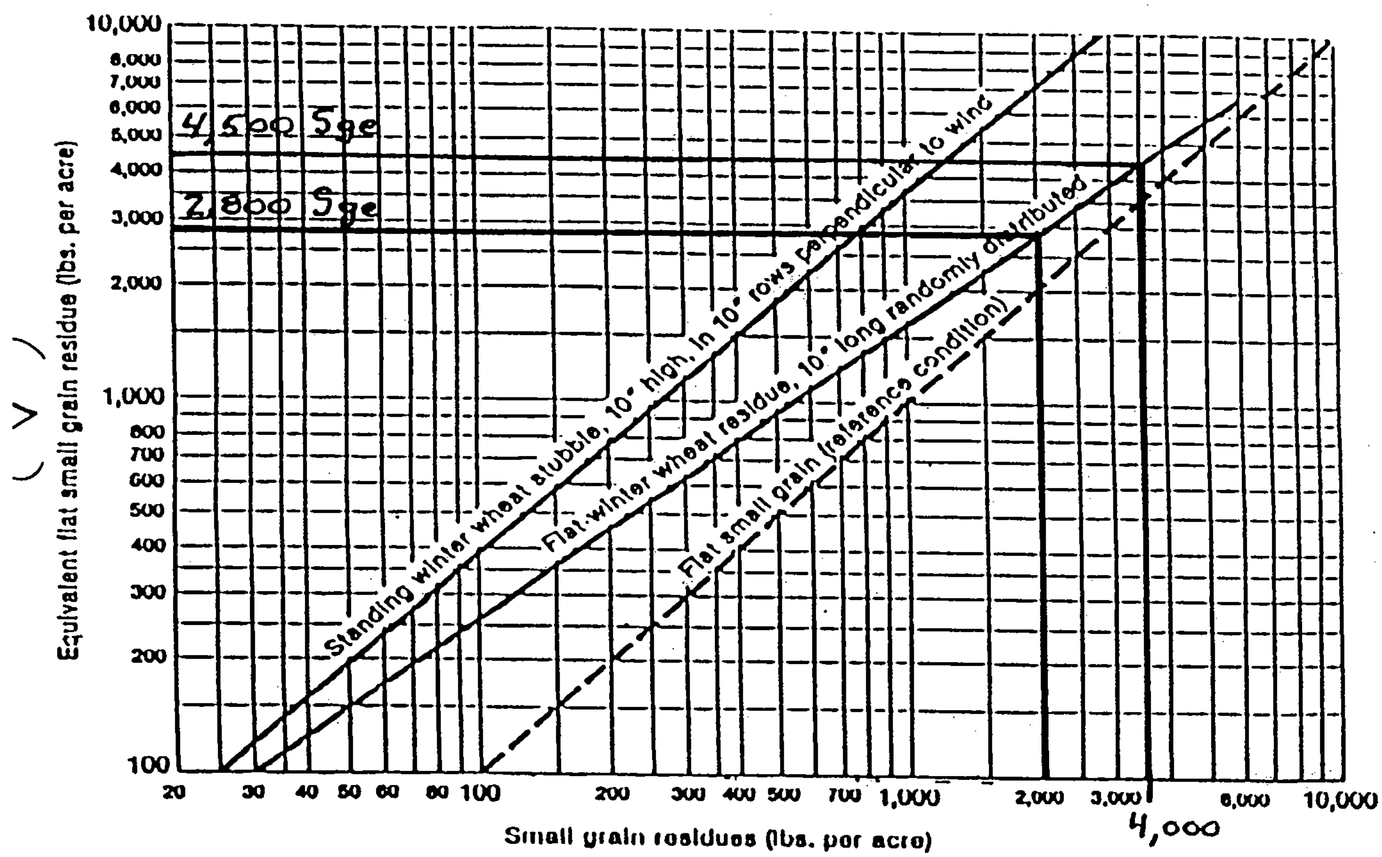
ETATIVE COVER "V"

Erosion Equation E = ƒ[(IKC)LV]

<u>ative Cover Factor "V"</u>

ffect of vegetative cover in the Wind Erosion Equation is expressed by relating the . amount, and orientation of vegetative material to its equivalent in pounds per acre of grain residue in reference condition (SGe).

Flat Small Grain Equivalents of Small Grain Residues
(Use for wheat, barley, rye and oats)



Reference condition - dry small grain stalks 10" long, lying flat on the soil surface in 10" rows, rows perpendicular to wind direction, stalks oriented to wind direction.
Source: Lyles and Allison—Trans. ASAE 1981, 24 (2): 405-406.
Residues are washed, air dried, and placed as described for wind tunnel tests.

<u>Figure 7.</u>

<u>Reference Condition</u>

erm Flat Small Grain Equivalent (SGe) is based on a reference condition (dotted line gure 6) developed from wind tunnel research. It is defined as:

10-inch stalks of small grain lying parallel to the wind arranged in rows

Table 5. C=120, I=134, k=1.0

WIND EROSION EQUATION "C" FACTORS

NEW MEXICO

(E)* SOIL LOSS FROM WIND EROSION IN TONS PER ACRE PER YEAR

JANUARY, 1998
C - 120
I - 134

SURFACE - K =1.00

(V)** - FLAT SMALL GRAIN RESIDUE IN POUNDS PER ACRE

(L) UNSHELTERED DISTANCE IN FEET	0	250	500	750	1000	1250	1500	1750	2000	2250	2500	2750	3000
10000	160.8	144.5	122.7	101.4	70.1	49.4	30.1	19.0	12.2	6.6	3.7	0.8	0.4
8000	160.8	144.5	122.7	101.4	70.1	49.4	30.1	19.0	12.2	6.6	3.7	0.8	0.4
6000	160.8	144.5	122.7	101.4	70.1	49.4	30.1	19.0	12.2	6.6	3.7	0.8	0.4
4000	160.8	144.5	122.7	101.4	70.1	49.4	30.1	19.0	12.2	6.6	3.7	0.8	0.4
3000	160.8	144.5	122.7	101.4	70.1	49.4	30.1	19.0	12.2	6.6	3.7	0.8	0.4
2000	160.8	144.5	122.7	101.4	70.1	49.4	30.1	19.0	12.2	6.6	3.7	0.8	0.4
1000	153.2	137.4	116.2	95.5	65.4	45.4	27.4	17.1	10.8	5.8	3.2	0.7	0.4
800	151.0	135.3	114.3	93.7	64.0	44.3	26.6	16.5	10.5	5.5	3.0	0.6	0.3
600	144.7	129.5	109.0	88.9	60.2	41.2	24.5	15.0	9.4	4.9	2.6	0.2	0.0
524' > 400	137.4	122.7	102.8	83.3	55.9	37.6	22.1	13.3	8.3	4.2	2.2	0.2	↓
300	131.6	117.2	97.9	78.9	52.5	34.9	20.3	12.1	7.4	3.7	1.9	0.2	
200	120.2	106.7	88.5	70.5	46.1	29.9	17.0	9.8	5.9	2.8	1.4	0.1	
150	111.5	98.7	81.3	64.2	41.4	26.3	14.6	8.3	4.9	2.3	1.1	0.1	
100	104.4	92.1	75.5	59.1	37.6	23.4	12.8	7.1	4.1	1.9	0.9	0.1	
80	98.5	86.7	70.7	54.9	34.6	21.2	11.4	6.3	3.6	1.6	0.7	0.1	
60	88.7	77.7	62.8	48.2	29.7	17.7	9.3	4.9	2.8	1.2	0.4	0.0	
50	82.8	72.4	58.2	44.2	26.9	15.7	8.1	4.2	2.3	1.0	0.3	↓	
40	77.5	67.5	54.0	40.7	24.5	14.0	7.1	3.6	2.0	0.7	0.0		
30	69.3	60.1	47.7	35.4	20.9	11.6	5.7	2.8	1.5	0.5	↓		
20	57.9	49.8	38.9	28.3	16.1	8.5	4.0	1.9	0.9	0.0			
10	43.2	36.8	28.1	19.7	10.6	5.1	2.3	1.0	0.3	↓	↓	↓	↓

(E)* SOIL LOSS FROM WIND EROSION IN TONS PER ACRE PER YEAR

JANUARY, 1998
C - 120
I - 134

SURFACE - K =0.90

(V)** - FLAT SMALL GRAIN RESIDUE IN POUNDS PER ACRE

(L) UNSHELTERED DISTANCE IN FEET	0	250	500	750	1000	1250	1500	1750	2000	2250	2500	2750	3000
10000	144.7	129.5	109.0	88.9	60.2	41.2	24.5	15.0	9.1	4.9	2.6	0.2	
8000	144.7	129.5	109.0	88.9	60.2	41.2	24.5	15.0	9.4	4.9	2.6	0.2	
6000	144.7	129.5	109.0	88.9	60.2	41.2	24.5	15.0	9.4	4.9	2.6	0.2	
4000	144.7	129.5	109.0	88.9	60.2	41.2	24.5	15.0	9.4	4.9	2.6	0.2	
3000	144.7	129.5	109.0	88.9	60.2	41.2	24.5	15.0	9.4	4.9	2.6	0.2	
2000	143.2	128.0	107.6	87.7	59.3	40.4	23.9	14.6	9.1	4.7	2.5	0.2	
1000	137.3	122.6	102.7	83.3	55.8	37.6	22.1	13.3	8.2	4.2	2.2	0.2	
800	132.5	118.1	98.7	79.7	53.1	35.4	20.6	12.3	7.5	3.8	2.0	0.2	
600	126.6	112.7	93.8	75.2	49.7	32.7	18.8	11.1	6.7	3.3	1.7	0.1	
400	118.1	104.8	86.7	69.0	44.9	29.0	16.4	9.5	5.6	2.7	1.3	0.1	
300	112.0	99.1	81.7	64.5	41.6	26.4	14.8	8.4	4.9	2.3	1.1	0.1	
200	104.1	91.9	75.3	58.9	37.5	23.3	12.8	7.1	4.1	1.9	0.9	0.1	
150	96.6	85.0	69.2	53.7	33.6	20.5	11.0	6.0	3.4	1.5	0.7	0.1	
100	88.7	77.8	62.9	48.2	29.7	17.7	9.3	4.9	2.8	1.2	0.4		
80	83.1	72.6	58.4	44.4	27.1	15.8	8.2	4.3	2.3	1.0	0.3		
60	74.3	64.7	51.6	38.7	23.1	13.0	6.6	3.3	1.8	0.7			
50	69.8	60.6	48.0	35.7	21.1	11.7	5.8	2.9	1.5	0.6			
40	64.8	56.1	44.2	32.6	18.9	10.3	5.0	2.4	1.3				
30	57.2	49.3	38.4	27.9	15.8	8.3	3.9	1.8	0.9				
20	48.8	41.8	32.1	22.9	12.6	6.3	2.9	1.3	0.4				
10	35.4	29.9	22.4	15.3	8.0	3.6	1.5	0.5					

* NOTE: SOIL LOSS FOR VALUES WHERE 'E' IS LESS THAN 0.1 OR GREATER THAN 440.0 ARE NOT SHOWN; OTHER VALUES NOT SHOWN ARE INVALID

** NOTE: VALUES SHOWN ARE FLAT SMALL GRAIN EQUIVALENT, NOT 'V'

Sheet 19 of 20

Table 6.　C = 120, I = 188, k = 1.0

WIND EROSION EQUATION "C" FACTORS

NEW MEXICO

(E)* SOIL LOSS FROM WIND EROSION IN TONS PER ACRE PER YEAR　JANUARY, 1998
C = 120
I = 180

SURFACE - K =1.00
(V)** - FLAT SMALL GRAIN RESIDUE IN POUNDS PER ACRE

(L) UNSHELTERED DISTANCE IN FEET	0	250	500	750	1000	1250	1500	1750	2000	2250	2500	2750	3000
10000	216.0	196.6	171.0	146.7	107.5	82.3	54.0	37.2	25.7	15.7	9.8	2.4	1.6
8000	216.0	196.6	171.0	146.7	107.5	82.3	54.0	37.2	25.7	15.7	9.8	2.4	1.6
6000	216.0	196.6	171.0	146.7	107.5	82.3	54.0	37.2	25.7	15.7	9.8	2.4	1.6
4000	216.0	196.6	171.0	146.7	107.5	82.3	54.0	37.2	25.7	15.7	9.8	2.4	1.6
3000	216.0	196.6	171.0	146.7	107.5	82.3	54.0	37.2	25.7	15.7	9.8	2.4	1.6
2000	216.0	196.6	171.0	146.7	107.5	82.3	54.0	37.2	25.7	15.7	9.8	2.4	1.6
1000	214.0	194.7	169.2	145.0	106.1	81.0	53.0	36.5	25.1	15.3	9.5	2.4	1.6
800	211.0	191.8	166.5	142.5	103.9	79.1	51.5	35.3	24.2	14.7	9.1	2.2	1.5
600	206.0	187.1	162.1	138.2	100.4	75.8	49.1	33.4	22.8	13.7	8.4	2.0	1.3
400	196.7	178.3	153.8	130.5	93.9	70.0	44.8	30.1	20.3	12.0	7.2	1.7	1.1
300	190.0	172.0	148.0	124.9	89.3	65.9	41.9	27.8	18.6	10.8	6.4	1.5	1.0
200	179.0	161.6	138.4	116.0	81.9	59.5	37.3	24.3	16.0	9.1	5.3	1.2	0.6
150	167.2	150.5	128.2	106.5	74.2	52.8	32.5	20.8	13.5	7.4	4.2	0.9	0.5
100	156.0	140.0	118.6	97.6	67.1	46.9	28.4	17.8	11.4	6.1	3.4	0.7	0.4
80	147.3	131.9	111.2	90.9	61.8	42.5	25.4	15.6	9.8	5.1	2.8	0.6	0.0
60	135.7	121.1	101.4	82.0	54.9	36.8	21.6	13.0	8.0	4.0	2.1	0.2	↓
50	127.8	113.7	94.7	76.1	50.3	33.2	19.1	11.3	6.9	3.4	1.7	0.1	
40	119.7	106.2	88.0	70.1	45.8	29.6	16.8	9.7	5.8	2.8	1.4	0.1	
25' > 30	109.5	96.8	79.6	62.7	40.3	25.4	14.1	8.0	4.7	2.2	1.0	0.1	
20	94.6	83.1	67.6	52.2	32.6	19.7	10.6	5.7	3.2	1.4	0.4	0.0	
10	72.7	63.2	50.3	37.6	22.4	12.6	6.3	3.2	1.7	0.6	0.0	↓	

(E)* SOIL LOSS FROM WIND EROSION IN TONS PER ACRE PER YEAR　JANUARY, 1998
C = 120
I = 180

SURFACE - K =0.90
(V)** - FLAT SMALL GRAIN RESIDUE IN POUNDS PER ACRE

(L) UNSHELTERED DISTANCE IN FEET	0	250	500	750	1000	1250	1500	1750	2000	2250	2500	2750	3000
10000	194.4	176.1	151.9	128.6	92.3	68.6	43.8	29.3	19.7	11.6	6.9	1.6	1.1
8000	194.4	176.1	151.9	128.6	92.3	68.6	43.8	29.3	19.7	11.6	6.9	1.6	1.1
6000	194.4	176.1	151.9	128.6	92.3	68.6	43.8	29.3	19.7	11.6	6.9	1.6	1.1
4000	194.4	176.1	151.9	128.6	92.3	68.6	43.8	29.3	19.7	11.6	6.9	1.6	1.1
3000	194.4	176.1	151.9	128.6	92.3	68.6	43.8	29.3	19.7	11.6	6.9	1.6	1.1
2000	194.4	176.1	151.9	128.6	92.3	68.6	43.8	29.3	19.7	11.6	6.9	1.6	1.1
1000	189.6	171.6	147.6	124.6	89.0	65.7	41.7	27.7	18.5	10.7	6.4	1.5	1.0
800	186.4	168.5	144.8	122.0	86.8	63.8	40.3	26.6	17.7	10.2	6.0	1.4	0.7
600	182.7	165.1	141.6	119.0	84.4	61.6	38.8	25.5	16.9	9.6	5.7	1.3	0.7
400	174.1	156.9	134.1	112.0	78.7	56.6	35.2	22.8	14.9	8.4	4.8	1.1	0.6
300	167.3	150.6	128.3	106.6	74.3	52.9	32.6	20.8	13.5	7.5	4.2	0.9	0.5
200	153.1	137.3	116.1	95.4	65.3	45.3	27.3	17.0	10.8	5.7	3.2	0.7	0.4
150	143.3	128.1	107.7	87.8	59.4	40.5	24.0	14.7	9.2	4.7	2.5	0.2	
100	134.1	119.6	100.0	80.8	54.0	36.1	21.1	12.6	7.8	3.9	2.0	0.2	
80	126.3	112.3	93.5	75.0	49.5	32.5	18.7	11.0	6.7	3.3	1.7	0.1	
60	114.9	101.8	84.1	66.6	43.2	27.6	15.5	8.9	5.3	2.5	1.2	0.1	
50	108.3	95.8	78.7	61.9	39.7	25.0	13.8	7.8	4.5	2.1	1.0	0.1	
40	102.8	90.7	74.2	58.0	36.8	22.8	12.5	6.9	4.0	1.8	0.9	0.1	
30	94.5	83.1	67.5	52.2	32.6	19.7	10.6	5.7	3.2	1.4	0.4		
20	79.5	69.4	55.6	42.1	25.4	14.6	7.5	3.9	2.1	0.8			
10	60.1	51.8	40.6	29.7	17.0	9.0	4.3	2.0	1.0				

* NOTE: SOIL LOSS FOR VALUES WHERE 'E' IS LESS THAN 0.1 OR GREATER THAN 440.0 ARE NOT SHOWN; OTHER VALUES NOT SHOWN ARE INVALID

** NOTE: VALUES SHOWN ARE FLAT SMALL GRAIN EQUIVALENT, NOT 'V'

Sheet 20 of 20

PLACE COLOR DIVIDER HERE

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GRAM, Inc.

Calculation Sheet

By: M. McVey	Date: 8/26/99	Title: Stability Analysis for the MWL Cover Sideslopes (6:1)
Chkd. By: J. Peace	Date: 8/27/99	

Purpose:

The purpose of this calculation is to estimate the stability of the 6:1 MWL cover sideslopes against a rotational type failure. There are no weak layers of soil present.

References:

1. NAVFAC DM-7, "Soil Mechanics, Foundations, and Earth Structures," Naval Facilities Engineering Command, Washington D.C., 1971.
2. AGRA, Mixed Waste Landfill Cover Direct Shear Test Results, 6-14-99 and 6-16-99.

Assumptions:

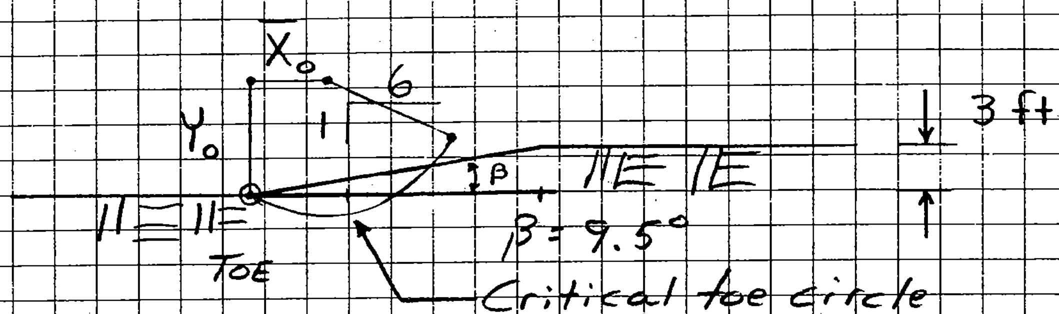
1. Material is homogeneous
2. Groundwater is below failure surface.

Method of Analysis:

Standard engineering hand calculations using NAVFAC DM-7 design aid (see sheet 4).

By: M. McVey	Date: 8/26/99	Title: Stability Analysis for the MWL Cover Sideslopes (6:1)
Chkd. By: J. Peace	Date: 8/27/99	

Figure 1.



From AGRA Earth & Environmental Direct Shear Tests and Summary of Direct Shear Tests (see Sheets 5 and 6).

$c = 0.17$ KSF or 170 psf

$\phi = 34°$

$\gamma_T = \gamma_d + H_2O = 108.9 \times 1.121 = 122$ psf

$H = 3$ ft, $\beta = 9.5°$

$$\lambda_{c\phi} = \frac{\gamma H \tan\phi}{c} = \frac{122\,psf\,(3.0\,ft)(0.6745)}{170\,psf}$$

$= 1.45$ or 1.5

$N_{cf} = 14.7$, see sheet 7

$Y_o = 2.4$, see sheet 7

$X_o = 1.9$, see sheet 7

GRAM, Inc. Calculation Sheet

By: M. McVey	Date: 8/26/99	Title: Stability Analysis for the MWL Cover Sideslopes (6:1)
Chkd. By: J. Peace	Date: 8/27/99	

$$\text{Factor of Safety} = F.S. = \frac{N_{cf}\,C}{\gamma H}$$

$$F.S. = \frac{14.7(170\ psf)}{122\ psf(3\ ft)}$$

$$= \underline{\underline{6.8 >> 1.5}}$$ (See sheet 8)

$$Y_o = y_o H = (2.4)(3\ ft) = 7.2\ ft$$

$$\bar{X}_o = x_o H = (1.9)(3\ ft) = 5.7\ ft$$

<u>Conclusion:</u>

The 6:1 MWL cover sideslopes are very stable.

Section 3. ANALYSIS METHODS

1. **EFFECTIVE STRESS METHOD.** Utilize strength parameters c′ and Φ′ determined from effective stress test envelope or c and Φ from CU tests. Estimate pore pressures resulting from seepage and consolidation and apply these as boundary pressures normal to potential failure surface. Use effective stress analysis in the following situations:

(1) For long-term stability and drawdown in pervious, incompressible, coarse grained soils, use Φ′, usually neglecting c′. Apply pore pressures from ground water or seepage only.

(2) For dense, moderately compressible soil, such as an earth dam embankment, use c′ and Φ′. Apply only seepage or drawdown, or consolidation pore pressures if piezometers are installed to confirm pore pressures assumed in design.

(3) For compressible soils where some drainage occurs during load application, use c and Φ from CU tests. Apply ground water plus consolidation pore pressures, including an allowance for dissipation of hydrostatic excess pressures.

2. **TOTAL STRESS METHOD.** Use shear strength determined from undrained laboratory tests or from vane shear tests. Take Φ equal to zero. These strengths represent initial conditions without considering drainage of pore water during stress changes. Use total stress analysis for the following applications:

(1) Failures in slopes of normally consolidated or slightly preconsolidated clays, where little dissipation of hydrostatic excess pore pressures occurs prior to critical stability conditions.

(2) Analysis of embankment or structure load applied rapidly on a clay stratum where no provision is made to drain pore water.

3. **PROCEDURES.** See Table 7-1 for analysis methods and failure characteristics in natural slopes. See Table 7-2 for analysis methods and failure characteristics where time-conditioned changes in strength occur.

a. Rotational Failure, General Method. For details of slip circle analysis with movement on a surface approximated by a circular arc, use procedures described in Terzaghi and Peck, *Theoretical Soil Mechanics*.

b. Rotational Failure (Φ = 0). For slopes in cohesive soils having approximately constant strength with depth, use Figure 7-1 to determine the safety factor. Utilize shear strength from U or UU tests, ignoring pore pressures, as follows:

(1) For slope in cohesive soils with strata of different strengths, determine centers of possible critical circles from Figure 7-2. Circles are tangent to interface between strata. Analyze these possible circles, applying the appropriate shear strength on sections of the arc in each stratum.

(2) With surcharge, tension cracks, or submergence of slope, apply corrections of Figure 7-3 to determine safety factor.

*

c. Rotational Failure (Φ and c strengths). For homogeneous material, use Figure 7-4 to compute safety factor with ground water below toe of slope. If ground water is near top of bank, compute approximate safety factor by using one-half the ordinary friction angle in the analysis, as follows:

(1) For materials where insignificant pore pressures are developed during shear, apply c′ and Φ′ from effective stress envelope.

(2) Where significant pore pressures are built up in shear, utilize c and Φ from CU tests.

(3) See Figure 7-3 for corrections for surcharge tension cracks, or submergence of slope.

d. Translation Failure. Where failure location is controlled by a relatively thin and weak layer, analyze stability of a translating mass with active and passive wedges by the method of Figure 7-5. See Figure 7-6 for an example of wedge analysis. To determine the overall safety factor of the entire mass,

AGRA EARTH & ENVIRONMENTAL, INC.
DIRECT SHEAR TESTS

Project: Mixed Waste Landfill Cover

Date: 06/16/99

Location: Native 1 of 3

Job No: 9-519-001154

Lab No: 4667

Saturated - Point No. 1 (= ± 0.5 KSF)

Initial Moisture Content	10.9	%
Dry Density	106.9	
Moisture @ Saturation	21.0	%
Maximum Vertical Strain @ T Max.	(-) 0.010	inches
Shearing Stress T Max.	0.4	KSF

Saturated - Point No. 2 (= ± 1.0 KSF)

Initial Moisture Content	12.1	%
Dry Density	108.9	PCF
Moisture @ Saturation	18.9	%
Maximum Vertical Strain @ T Max.	(-) 0.002	inches
Shearing Stress T Max.	0.9	KSF

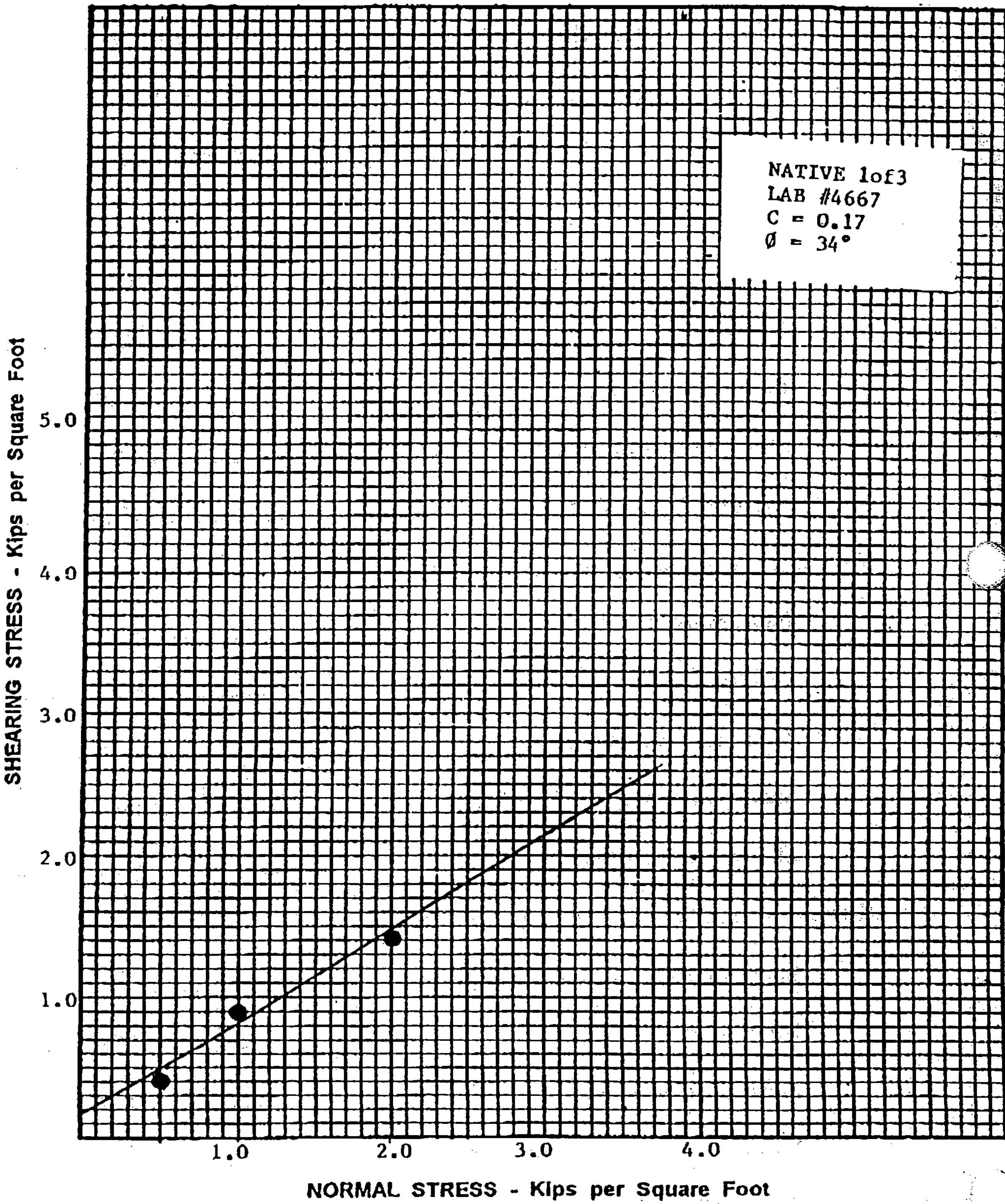
Saturated - Point No. 3 (= ± 2.0 KSF)

Initial Moisture Content	10.2	%
Dry Density	108.3	PCF
Moisture @ Saturation	22.5	%
Maximum Vertical Strain @ T Max.	(-) 0.004	inches
Shearing Stress T Max.	1.4	KSF

AGRA ENGINEERING GLOBAL SOLUTIONS

SUMMARY OF DIRECT SHEAR TESTS

PROJECT MIXED WASTE LANDFILL COVER JOB NO. 9-519-0011!



SOIL MOISTURE CONDITION

○ – INSITU
● – SUBMERGED

AGRA
Earth & Environmental, Inc.
4700 Lincoln NE
Albuquerque, NM 87109

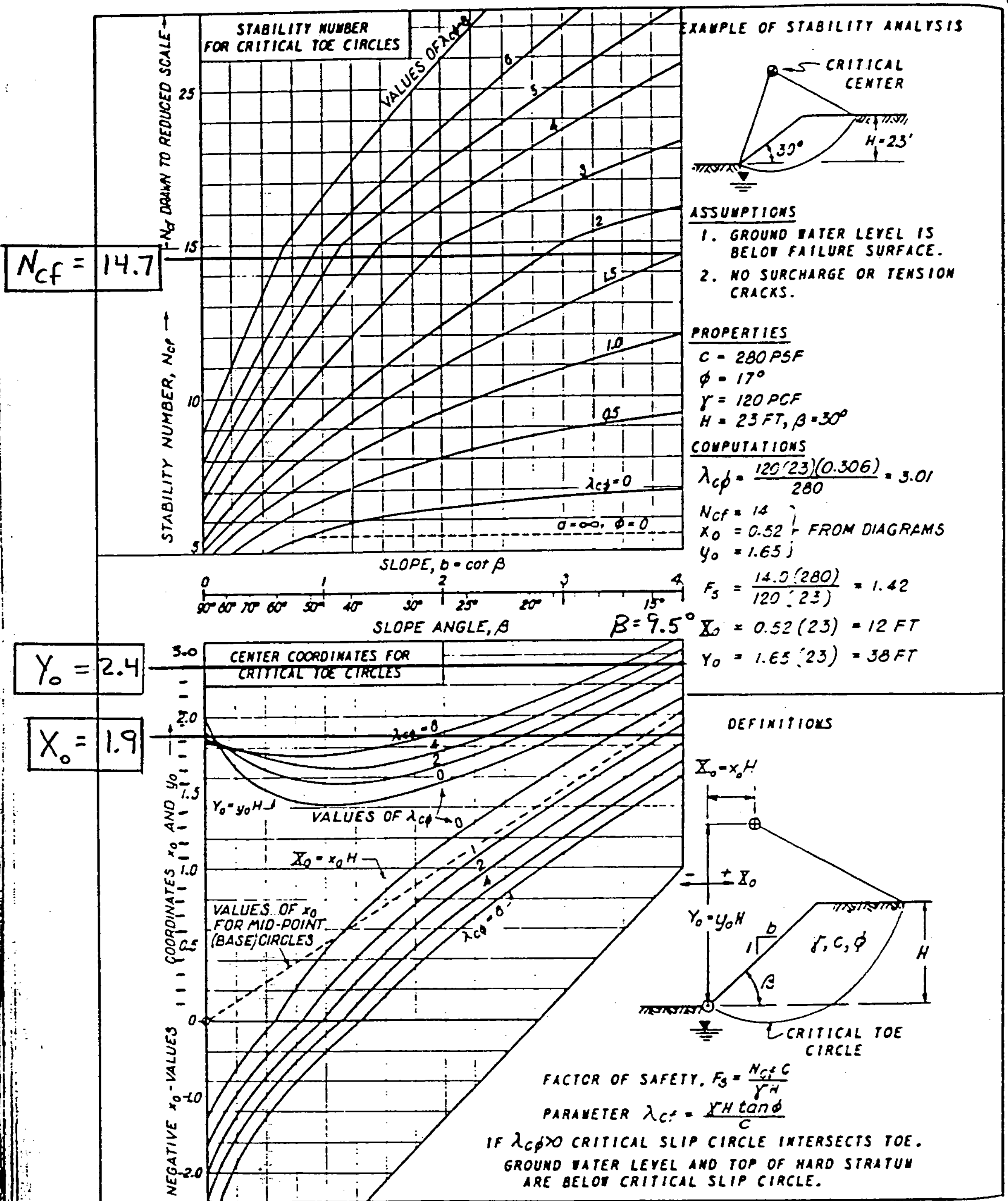


FIGURE 7-4

Stability Analysis for Slopes With ϕ and c.

combine forces as shown in the vector diagrams. To determine the ratio of available strength in the critical stratum to strength required for stability, summarize the resultant active and passive forces as shown in the bottom panel of Figure 7-5.

e. **Embankments on Soft Clay.** See Figure 7-7 for approximate analysis of embankment with stabilizing berms on foundations of constant strength. Determine the probable form of failure from relationship of berm and embankment widths and foundation thickness in top left panel of Figure 7-7.

f. **Structure Foundation on Clay.** For approximate analysis of a structure foundation on thick stratum, use bearing capacity method of Figure 11-1. For approximate analysis with an upper clay layer of finite thickness, see Figure 11-5. For detailed study, check safety factor on trial surfaces with active and passive wedges and translating block.

g. **Required Safety Factor.** The following values should be provided for reasonable assurance of stability:

* (1) Safety factor no less than 1.5 for permanent or sustained loading conditions.

(2) For foundations of structures, a safety factor exceeding 2.0 is desirable to limit movements necessary for strength mobilization or local plastic strains at foundation edge. See Chapter 11 for detailed requirements for safety factors in bearing capacity analysis.

(3) For temporary loading conditions or where stability reaches a minimum during construction, safety factors may be reduced to 1.3 or 1.25 if controls are maintained on load application.

(4) For transient loads, such as earthquake, safety factors as low as 1.2 or 1.15 may be tolerated.

Section 4. PORE PRESSURE ANALYSIS

1. **PROCEDURES.** See Table 7-3 for pore water pressures that may be present in various situations before start of failure. In materials where no pore pressures are developed during shear, or where buildup of pore pressures is observed and controlled in the field, evaluate pore pressures as shown in Table 7-3 and apply them in effective stress analysis with C' and Φ' strengths. Where additional pore pressures are developed during shear of compressible impervious materials, utilize pore pressures of Table 7-3 in effective stress analysis with strengths C and Φ from CU tests.

a. **Seepage Pressures.** Predict boundary pore pressures from flow net construction, or in case of rapid drawdown, by approximation of the pattern of equipotential lines. See Panels (3) and (4) of Table 7-3.

b. **Construction Pore Pressures.** In compressible fill materials placed at or above optimum moisture, construction pore pressures may develop during fill placement. Assume maximum pore pressures in the center of an impervious section of the embankment equal to the full theoretical value given by formula in Panel (2) of Table 7-3. Using judgment or examples of field observations, allow for dissipation of pore pressures on the periphery of the impervious section from drainage to pervious shells or foundation.

c. **Consolidation Pore Pressures in Foundation.** Where loading rate is rapid and no drainage relief is provided, consolidation pore pressures at the center of an impervious foundation may equal applied stresses at this level. Horizontal drainage in varved or lensed strata reduces pore pressures beneathe embankment centerline but may simultaneously increase pore pressures outside the toe. Where rate of construction is controlled or drainage is accelerated by vertical sand drains, estimate pore pressure dissipation by theory of consolidation. Apply reduced consolidation pore pressures plus ground water pressures in effective stress analysis using C and Φ from CU tests. When drainage allowance is included in design, provide piezometers for field observations to confirm pore pressure assumptions.

APPENDIX C

Construction Specifications

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MIXED WASTE LANDFILL ALTERNATIVE COVER
CONSTRUCTION SPECIFICATIONS
REVISION 1
06/12/01

SPECIFICATION NUMBER	TITLE
01001	Definitions
01563	Temporary Diversion and Control of Water during Construction
02110	Clearing and Grubbing
02200	Earthwork
02210	Grades, Lines, and Levels
02221	Trenching, Backfilling, and Compaction
02445	Administrative Control Fences and Gates
02670	Monitoring Well Extension, Neutron Probe Access Hole Construction, and Fiber Optics Cable Installation
02930	Reclamation Seeding and Mulching

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SECTION 01001

DEFINITIONS

General Conditions	General Terms and Conditions for Construction Contractors at Sandia National Laboratories, New Mexico.
Operator	Sandia National Laboratories, New Mexico
Construction Contractor	Hereinafter referred to as the "Contractor." Operates separately from the Operator and the Construction Quality Assurance Engineer. Responsible for constructing the Mixed Waste Landfill (MWL) alternative cover in strict accordance with the design criteria, specifications, design drawings, and Construction Quality Assurance (CQA) plan using the necessary construction procedures and techniques.
Construction Quality Assurance Engineer	Hereinafter referred to as the CQA Engineer. Operates separately from the Operator and the Contractor. Responsible for activities specified in the CQA plan (e.g., inspection, sampling, and documentation).

END OF SECTION

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SECTION 01563

TEMPORARY DIVERSION AND CONTROL OF WATER DURING CONSTRUCTION

PART 1 GENERAL

1.1 SCOPE OF WORK

1.1.1 Work Included

The Contractor shall furnish all materials, labor, tools and equipment for controlling surface water and dewatering work areas prior to and throughout construction operations. Control measures implemented may include berms, swales, ditches, temporary pipes/hoses, portable pumps, silt fences, sediment traps, or any other measure approved by the Operator in accordance with this specification.

1.1.2 Related Work Specified Elsewhere

1) Clearing and Grubbing shall be in accordance with Section 02110 of these specifications.

2) Earthwork shall be in accordance with Section 02200 of these specifications.

3) Reclamation Seeding and Mulching shall be in accordance with Section 02930 of these specifications.

1.1.3 Work to be performed by the Operator and/or the CQA Engineer:

1) Review and approve data submittals as required by this specification,

2) Inspect work for compliance with requirements of this specification, in addition to inspection by the Contractor and with the design drawings.

3) Review pre-placement conditions, placement of controls, and other job conditions during performance of the work.

4) Perform final inspection and acceptance of water diversion and control work.

1.2 SUBMITTALS

Within 8 working days after notice to proceed, the Contractor shall submit proposed methods, materials, and proposed locations of each control measure to be implemented.

PART 2 PRODUCTS

2.1 EQUIPMENT AND MATERIAL REQUIREMENTS

2.1.1 Equipment

1) All equipment and tools shall conform to the safety requirements of the MWL Health and Safety Plan.

2) All equipment and tools used by the Contractor to perform the work shall be subject to inspection by the Operator before the work is started and maintained in satisfactory working condition at all times.

3) The Contractor's equipment shall be adequate and capable of controlling water prior to and throughout construction as required by this specification.

2.1.2 Materials

1) All materials shall be furnished by the Contractor and shall be subject to approval by the Operator.

2) Maintenance, repairs, and replacement of materials damaged by the Contractor shall be the responsibility of the Contractor.

PART 3 EXECUTION

3.1 GENERAL

3.1.1 Standing water outside the construction boundary may be allowed to infiltrate.

3.1.2 The Contractor shall manage stormwater such that all construction areas shall be free of standing water. Suitable water control measures shall be constructed at all locations where construction work may be affected by surface water at the time of the work.

3.1.3 The Contractor shall divert surface water around the periphery of the construction area by constructing temporary ditches, berms, or other means of control.

3.1.4 The Contractor shall be solely responsible for the protection of work against damage, delay, or environmental impacts from water flow.

3.1.5 The Contractor shall direct and control surface water in a manner that protects adjacent structures and facilities.

3.2 WORK IN EXTREME WEATHER

3.2.1 In the event of extreme storm activity, the Contractor shall provide protective measures to prevent damage to the construction area and maintain control of runoff and run-on. During such extreme storm events, the Contractor shall protect slopes by methods approved by the Operator. The Contractor shall inspect erosion protection structures within 24 hours after extreme storm events to verify that erosion protection structures are in place and functional. To maintain the integrity of erosion prevention structures, the Contractor shall clean out, as necessary, all temporary control structures of debris and sediment buildup, and repair or replace any damaged areas either in the temporary control structures or in permanent work areas as identified by the Operator. The Contractor shall inspect erosion protection structures within 24 hours after extreme storm events to verify that erosion protection structures are in place and functional.

3.3 INSPECTIONS AND REPAIRS

1) The Contractor shall inspect temporary water control structures and materials on a regular basis and shall record inspection findings in the Daily Field Report. The inspection records shall be submitted weekly to the Operator.

2) The Contractor shall remove debris and sediment build-up from the temporary control structures as required to maintain the intended flow path.

3) Should an overflow or breach condition be encountered or any other damage observed at the temporary water control structures, repair and/or replacement of the damaged area shall be completed by the Contractor.

4) Acceptance criteria for repaired and/or replaced temporary water control structures shall be in accordance with the requirements of this section.

3.4 REMOVAL OF TEMPORARY CONTROL MEASURES

Temporary storm water control measures shall be removed once the work has been completed and as approved by the Operator. The materials removed shall be properly disposed of by the Contractor, at locations designated by the Operator. All areas where temporary control structures are removed shall be regraded and revegetated in accordance with Sections 02200 and 02930 of these specifications.

3.5 ACCEPTANCE

The Contractor shall submit a description of any repair or replacement work required to the Operator prior to implementation. Acceptance criteria for repaired or replaced water control measures shall be in accordance with the requirements of this specification.

END OF SECTION

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SECTION 02110

CLEARING AND GRUBBING

PART 1 GENERAL

1.1 SCOPE OF WORK

1.1.1 Work Included

The Contractor shall furnish all materials, labor, tools, and equipment, and shall perform clearing and grubbing during construction activities in accordance with this specification and as shown on the design drawings.

1.1.2 Related Work Specified Elsewhere

1) Temporary Diversion and Control of Water during Construction shall be in accordance with Section 01563 of these specifications.

2) Trenching, Backfilling, and Compaction shall be in accordance with Section 02221 of these specifications.

3) Reclamation Seeding and Mulching shall be in accordance with Section 02930 of these specifications.

1.1.3 Work to be performed by the Operator and/or the CQA Engineer:

1) Review and approve submittals as required for this specification,

2) Designate items that require salvage, storage, reuse, and/or relocation,

3) Perform final inspection and confirm acceptance of clearing and grubbing,

4) In addition to inspection by the Contractor, the Operator and/or the CQA Engineer may inspect work for compliance with the requirements of this specification.

1.2 SUBMITTALS

1.2.1 Procedures

The Contractor shall submit a description of materials and/or methods of clearing and grubbing in accordance with the requirements of this specification to the Operator for approval within 8 work days after notice to proceed.

1.2.2 Certifications

The Contractor shall submit a letter to the Operator verifying conformance to the requirements identified in this specification within 4 work days after completion of the work specified herein.

1.2.3 Records

1) The Contractor shall submit records of inspections to the Operator within 4 work days after completion of the inspection.

2) The Contractor shall submit all field notes from surveying and layout activities to the Operator for information. These notes shall be submitted within 4 work days after the completion of surveying.

PART 2 PRODUCTS

2.1 EQUIPMENT AND MATERIAL REQUIREMENTS

All equipment and tools used by the Contractor to perform the work shall be subject to inspection by the Operator before the work is started and shall be maintained in satisfactory working condition by the Contractor at all times.

The Contractor's equipment shall have the capability to perform the indicated clearing and grubbing specified herein.

The Contractor shall ensure that all equipment used for clearing and grubbing work is fitted with appropriate safety devices that comply with all applicable Federal laws and the MWL Health and Safety Plan, and that will adequately protect equipment operators and minimize exposure of site workers and others.

2.2 ITEMS SALVAGED FOR REUSE, STORAGE, OR RELOCATION

The Operator will designate items that require reuse, storage, or relocation.

PART 3 EXECUTION

3.1 GENERAL

3.1.1 Site Inspection

The Contractor shall inspect the site to determine the nature, location, size, and extent of vegetative material, debris, and obstructions to be removed or preserved, as specified herein.

3.1.2 Traffic

The Contractor shall conduct clearing and grubbing operations to ensure minimum interference with roads, walks, and adjacent facilities. The Contractor shall not close or obstruct roads, walks, or adjacent operational facilities without written permission from the Operator.

3.1.3 Protection of Existing Structures and Facilities

The Contractor shall provide protection necessary to prevent damage to the existing structures and facilities which are to remain in place. The Contractor shall restore or replace damaged property to original condition, or to the satisfaction of the Operator. Items damaged in removal shall be repaired and refinished, or replaced by the Contractor with new matching items as required by the Operator.

3.1.4 Salvageable Items

Items damaged in removal shall be repaired, refinished, or replaced by the Contractor with new matching items as required by the Operator. The Contractor shall save and protect from construction damage all vegetative materials (trees, shrubs, grass, and other vegetation) beyond the limits of the required clearing and grubbing. The Contractor shall restore or replace damaged vegetative materials to the conditions as required by the Operator, in accordance with Section 02930 of these specifications.

3.1.5 Protection of Monuments and Other Permanent Surface Features

The Contractor shall locate and mark existing monuments, monitoring wells, stanchions, and markers before construction operations commence and shall protect such items during construction. The Contractor shall restore or replace damaged items to original condition as required by the Operator.

3.2 CLEARING AND GRUBBING

3.2.1 Clearing and Grubbing

The Contractor shall clear the site of shrubs, vegetation, rocks and debris as required by the limits of the landfill cover, laydown areas, and borrow areas west of the MWL. Roots exceeding 1 inch in diameter, rocks and other debris exceeding 2 inches in diameter in the top 3 inches of the existing site grade shall be removed by hand or mechanical means. Removal methods shall minimize the disturbance of soils below 3 inches in depth.

3.2.2 Reclamation Seeding and Mulching

The Contractor shall seed and mulch disturbed areas in accordance with Section 02930 of these specifications.

3.3 DISPOSAL OF WASTE AND DEBRIS MATERIALS

3.3.1 Organic Material

Organic materials, including grass, shrubs, stumps, roots, and other organic debris removed due to clearing activities, shall be transported by the Contractor to a stockpile/disposal site designated by the Operator. The stockpile/disposal site shall be located within ¼ mile of the project area. Organic material shall be stockpiled or disposed of as directed by the Operator.

3.3.2 Disposal

The Contractor shall remove all materials not designated for relocation, reuse, or salvage. These materials shall be disposed of or stockpiled as directed by the Operator.

3.4 DAMAGED AREAS

The Contractor shall confine clearing and grubbing operations to within those areas required for cover construction or as directed by the Operator. Any areas outside the designated areas that are damaged or disturbed by the Contractor's operations shall be reclaimed by the Contractor. Reclamation shall be in accordance with Section 02930 of these specifications.

3.5 ACCEPTANCE

Clearing and grubbing not in accordance with the requirements of this specification shall be repaired and/or replaced by the Contractor at the Contractor's expense. The Contractor shall submit a description of the repair and/or replacement methods to the Operator for approval before use. Acceptance criteria for repaired and/or replaced clearing and grubbing shall be in accordance with the requirements of this specification.

END OF SECTION

SECTION 02200

EARTHWORK

PART 1 <u>GENERAL</u>

1.1 SCOPE OF WORK

1.1.1 <u>Work Included</u>

The Contractor shall furnish all materials, labor, tools, and equipment for all types of earthwork to be performed during the construction activities in accordance with this specification and as shown in the design drawings. Earthwork includes grading and placement of all earthen cover materials, disposal of unsuitable materials, and reclamation of areas designated by the Operator.

1.1.2 <u>Related Work Specified Elsewhere</u>

1) Temporary Diversion and Control of Water during Construction shall be in accordance with Section 01563 of these specifications.

2) Clearing and Grubbing shall be in accordance with Section 02110 of these specifications.

3) Grades, Lines, and Levels shall be in accordance with Section 02210 of these specifications.

4) Trenching, Backfilling, and Compaction shall be in accordance with Section 02221 of these specifications.

5) Reclamation Seeding and Mulching shall be in accordance with Section 02930 of these specifications.

1.1.3 <u>Work to be performed by the Operator and/or the CQA Engineer:</u>

1) Review and approve submittals as required by this specification,

2) Review and approve results of quality assurance tests and surveying performed for compliance with this specification,

3) Document and monitor corrective actions,

4) Identify the acceptable borrow areas and soil stockpiles,

5) Have the option to approve all compaction equipment prior to use,

6) Have the option to inspect and approve surface conditions prior to placement of fill,

7) Have the option to inspect and approve all fill prior to placement, and

8) Have the option to perform final inspection and confirm acceptance of earthwork.

1.2 SUBMITTALS

1.2.1 Test Reports

The Contractor shall submit test reports at the following frequencies:

1) Borrow Source Testing - within 4 work days after the performance of the test, as per Specification 02200 (3.4.2).

2) Field Placement Tests - Field tests requiring offsite laboratory tests shall be reported to the Operator within 4 work days after the performance of the test, as per Specification 02200 (3.4.3). Field tests that provide immediate results shall be recorded on the Daily Field Report and presented to the Operator on request or by the end of the day, whichever comes first.

3) Field Quality Control Tests - Field tests requiring offsite laboratory tests shall be reported to the Operator within 4 work days after the performance of the test. Field tests that provide immediate results shall be recorded on the Daily Field Report and presented to Operator on request or by the end of the day, whichever comes first.

1.2.2 Procedures

The Contractor shall submit a work plan describing the equipment, materials, and methods for earthwork to be employed to meet the requirements of this specification to the Operator for approval within 8 work days after notice to proceed. The work plan shall be formatted in accordance with the requirements outlined in the contract special condition titled Construction Work Plan.

1.2.3 Certifications

The Contractor shall submit a letter to the Operator verifying conformance to the requirements identified in this specification within 4 work days after completion of the work specified herein.

1.2.4 Records

The Contractor shall submit to the Operator for information all field and laboratory records resulting from surveying, layout, laboratory, and field inspection activities within 4 work days after completion of these activities.

1.3 QUALITY ASSURANCE

The Contractor shall prepare, maintain, and use a written QA/QC Manual for the work performed. The QA/QC Manual shall be submitted within 8 work days after notice to proceed and shall include requirements to ensure the application of the latest design documents and the incorporation of approved changes. As a minimum, the Contractor shall record and maintain appropriate data that verify the quality of materials, the application of approved procedures, and performance of tests and inspections. The Contractor shall maintain appropriate written approval signatures for acceptance of work performed.

PART 2 PRODUCTS

2.1 EQUIPMENT AND MATERIALS

2.1.1 Equipment

All equipment and tools shall comply with the safety requirements of the MWL Health and Safety Plan.

All equipment and tools used by the Contractor to perform the work shall be subject to inspection by the Operator before the work is started and shall be maintained in satisfactory working condition at all times. All compaction equipment shall be inspected for acceptance by the Operator prior to the start of construction.

The Contractor's equipment shall be adequate for and have the capability to produce the requirements specified herein. Compaction equipment shall be appropriate to compact the fill as specified by the manufacturer.

2.1.2 Fill

Fill shall be from an Operator-designated, soil stockpile or borrow area and shall be free of plants, rubble, litter, insect infestation, and other deleterious matter and be free of rocks larger than 2-inches in diameter.

1) Subgrade fill shall be obtained from the CAMU soil stockpile approximately 1.5 miles south of the MWL and be classified by the Unified Soil Classification System (USCS) as SM, SC as determined in accordance with ASTM D4318 and ASTM D2487. The Contractor shall screen Subgrade fill to conform to the following gradation:

Sieve Designation	Percent Passing
#10	80 - 100
#40	70 - 100
#200	20 - 40

2) Native Soil Layer fill shall be obtained from the CAMU soil stockpile approximately 1.5 miles south of the MWL and be classified by the Unified Soil Classification System (USCS) as SM, SC as determined in accordance with ASTM D4318 and ASTM D2487. The Contractor shall screen Native Soil Layer fill to conform to the following gradation:

Sieve Designation	Percent Passing
#10	80 – 100
#40	70 – 100
#200	20 – 40

3) Topsoil Layer soil shall be obtained from borrow areas directly west of the MWL and be classified by the Unified Soil Classification System (USCS) as SM, SC in accordance with ASTM D4318 and ASTM D2487. The Contractor shall screen Topsoil Layer fill to conform to the following gradation:

Sieve Designation	Percent Passing
#10	90 - 100
#40	85 - 100
#200	20 - 45

The Topsoil Layer fill shall be admixed with 3/8-inch, crushed gravel, ASTM size #8, 25 percent by volume, before placing and grading. The gravel is to be clean with no more than 5 percent passing the #4 sieve.

4) Pre-acceptance QC testing of fill soils shall be in accordance with Section 3.4 of this specification. Acceptance of materials with variations from this classification will be evaluated by the CQA Engineer and the Operator.

PART 3 EXECUTION

3.1 PROTECTION AND SAFETY

The Contractor shall keep all operational areas adjacent to or part of this project usable at all times. The Contractor shall provide all necessary measures for the protection of the workers and the public, as per the standards established by the Operator or the Occupational Safety and Health Administration (OSHA).

3.1.1 The Contractor shall provide protection necessary to prevent damage to existing structures indicated in the design drawings or indicated by the Operator to remain in place. The Contractor shall restore damaged property to original condition, and obtain written approval of repairs from the Operator.

3.1.2 The Contractor shall clearly mark all laydown areas.

3.1.3 The Contractor shall mark or otherwise indicate the location of existing monuments and markers, and protect these structures before construction operations commence. The Contractor shall be responsible for the marking and/or protection of all necessary objects.

3.1.4 During earthwork operations, a representative of the Contractor shall be present at all times to observe work and notify the CQA Engineer and Operator immediately upon the discovery of any deviations from this specification.

3.2 EXISTING UTILITIES

3.2.1 There may be existing utilities within the limits of the construction or borrow areas. Known utilities shall be identified by the Operator and the utilities protected by the Contractor. The Operator shall be immediately notified of utilities not shown on the design drawings. The Contractor shall follow the guidelines for protection of utilities in accordance with Section 02221 of these specifications.

3.3 INSTALLATION OF COVER MATERIALS

3.3.1 General Requirements

1) The Contractor shall ensure that the stockpiling and handling of fill is confined within the limits of the designated work area. Stockpiling of clean imported material shall be confined to the Contractor's laydown and storage area as approved by the Operator. Stockpiled materials shall have stable slopes and be evenly graded and self-draining. Materials shall be stockpiled in such a way that any storm water can be controlled to prevent escape of excessive fill from the stockpile area.

2) The Contractor shall place all materials to the lines, grades, and elevations as shown in the design drawings and as specified in Section 02210 of these specifications.

3) The Contractor shall not begin placement of fill until after acceptance by the CQA Engineer and the Operator of the existing landfill surface or layer and placement conditions for all underlying layers.

4) The Contractor shall not place fill on frozen surfaces, in standing water, or when fill contains snow or ice.

5) The Contractor shall operate compaction equipment so that structures or underlying instrumentation are not damaged or overstressed during placement operations. The Contractor shall use hand-operated mechanical tampers for compaction of fill adjacent to wells or instrumentation wherever rolling compaction equipment is impractical for use.

6) The Contractor shall use placement methods which ensure the integrity of the underlying fill.

7) The Contractor shall slope temporary grades to direct water away from the construction area to reduce the potential for ponding of water. The Contractor shall provide erosion protection as specified in Section 01563 of these specifications.

8) Previously approved compacted subgrade, lifts, or layers disturbed by subsequent construction operations by the Contractor or adverse weather shall be reworked to the required placement conditions specified herein or to the satisfaction of the CQA Engineer and Operator.

9) Application of water for dust suppression activities shall comply with Section 01563 of these specifications. Standing water will be minimized during dust suppression operations.

10) The Contractor shall ensure that unsuitable materials shall not enter the construction area.

3.3.2 <u>Fill</u>

1) The borrow area directly west of the MWL shall be cleared and grubbed in accordance with Section 02110 of these specifications to remove surface vegetation.

2) The Contractor shall perform field-testing of the compacted materials in accordance with Section 3.4 of this specification. The Contractor shall submit results of the testing to the CQA Engineer and Operator for approval prior to placement of subsequent lifts.

5) The Contractor shall take care to avoid disturbance of the underlying lifts, layers, and instrumentation.

6) The Contractor shall reclaim borrow areas in accordance with Section 02930 of these specifications. Borrow areas shall be regraded to minimize erosion and sustain vegetation.

3.3.3 Existing Landfill Surface

1) The existing grade shall be prepared as required in Sections 02110 of these specifications.

2) The existing grade shall be scarified to a depth not to exceed 3 inches.

3) The contractor shall remove all rock and debris greater than 2 inches in diameter in preparation for compaction.

4) The contractor shall compact the existing landfill surface to not less than 90 percent of maximum dry density at -2 to +2 percentage points of optimum moisture content, as determined by ASTM D698 (Standard Proctor testing).

3.3.4 Subgrade

1) The CAMU soil stockpile, located approximately 1.5 miles south of the MWL, shall be used to obtain fill.

2) Subgrade fill may be stockpiled at an Operator-approved location at the MWL.

3) The Contractor shall remove all rock and debris greater than 2 inches in diameter from the fill.

4) The Contractor shall place the fill in maximum 8-inch loose lifts to attain maximum 6-inch compacted lift thickness.

5) The Contractor shall compact fill to not less than 90 percent of maximum dry density at -2 to + 2 percentage points of optimum moisture content, as determined by ASTM D698 (Standard Proctor testing).

6) The Contractor shall perform field-testing of the compacted fill in accordance with Section 3.4 of this specification. The Contractor shall submit test results to the CQA Engineer and Operator for approval prior to placement of subsequent lifts.

7) The Contractor shall take care to minimize disturbance to underlying lifts.

8) Lifts not compacted to the density and moisture content specifications or not meeting the requirements of this specification shall be reworked to the full

depth of the lift and recompacted until the specifications are attained or the Operator accepts the placement conditions.

3.3.5 Native Soil Layer

1) The CAMU soil stockpile, located approximately 1.5 miles south of the MWL, shall be used to obtain Native Soil Layer fill.

2) Native Soil Layer fill may be stockpiled at an Operator-approved location at the MWL.

3) The contractor shall remove all rock and debris greater than 2 inches in diameter from the fill.

4) The Contractor shall place the fill in maximum 8-inch loose lifts to attain maximum 6-inch compacted lift thickness.

5) The Contractor shall compact fill to not less than 90 percent of maximum dry density at -2 to + 2 percentage points of optimum moisture content, as determined by ASTM D698 (Standard Proctor testing).

6) The Contractor shall perform field-testing of the compacted fill in accordance with Section 3.4 of this specification. The Contractor shall submit test results to the CQA Engineer and Operator for approval prior to initiation of placement of subsequent lifts.

7) Lifts not compacted to the density and moisture content specifications or not meeting the requirements of this specification shall be reworked to the full depth of the lift and recompacted until the specifications are attained or the Operator accepts the placement conditions.

3.3.5 Topsoil Layer

1) The borrow area directly west of the MWL shall be used to obtain topsoil. The borrow area shall be cleared and grubbed in accordance with Section 02110 of these specifications to remove surface vegetation.

2) Topsoil may be stockpiled at an Operator-approved location at the MWL.

3) The Contractor shall place topsoil in a minimum 8-inch loose lift.

4) The Contractor shall compact topsoil to not less than 80 percent and not greater than 85 percent of maximum dry density at -2 to + 2 percentage points of optimum moisture content, as determined by ASTM D698 (Standard Proctor testing) to provide a uniform, prepared surface for seeding. Topsoil shall be minimally compacted to facilitate root development.

5) The Contractor shall perform field-testing of the topsoil in accordance with Section 3.4 of this specification. The Contractor shall submit test results to the CQA Engineer and Operator for approval prior to reclamation seeding.

6) The Contractor shall take care to minimize disturbance to the underlying layer.

7) The Contractor shall reclaim the borrow area west of the MWL as directed by the Operator. The borrow area shall be regraded to minimize erosion and sustain vegetation. Reclamation seeding and mulching of the borrow area shall be in accordance with Section 02930 of these specifications.

3.4 TESTING

3.4.1 General

The Contractor shall be responsible for the performance of all pre-acceptance and placement quality control testing. The Contractor shall submit results of laboratory and field testing within 4 work days after completion to the CQA Engineer and Operator. Test results shall be provided from an approved independent soils testing laboratory.

3.4.2 Fill Testing

The Contractor shall submit results for the following tests conducted during construction:

1) Subgrade: Standard Proctor (ASTM D698), Gradation (ASTM D422), Classification (ASTM D2487)

2) Native Soil Layer: Standard Proctor (ASTM D698), Gradation (ASTM D422), Classification (ASTM D2487)

3) Topsoil Layer: Standard Proctor (ASTM D698), Gradation (ASTM D422), Classification (ASTM D2487)

The CQA Engineer and Operator shall review and accept submittals pertaining to testing prior to the transportation and placement of fill.

3.4.3 Field Placement Testing

The Contractor shall be responsible for the performance of all field testing and for confirmation of placement conditions. The Contractor shall submit all field test data for review and approval by the CQA Engineer and Operator. Table 3.1 outlines the material type, test methods, and test frequency for field placement activities.

3.5 INSPECTION

3.5.1 The Contractor shall be responsible for pre-operation, operation, and post-operation inspection during the performance of all work.

3.5.2 The Operator reserves the right to inspect all work for compliance with this specification.

3.6 ACCEPTANCE

The Contractor shall be responsible for documenting all test results and the number of compaction passes completed per lift. Placed materials not in accordance with the requirements of this specification shall be repaired and/or replaced by the Contractor. The Contractor shall submit a description of repair and/or replacement methods to the Operator for written approval before use. Acceptance criteria for repaired and/or replaced materials shall be in accordance with the requirements of this specification.

Areas that do not conform with the compaction specifications will be first investigated by the Contractor for the extent of the non-conformance. Areas that are of a different material type or that have failed the specifications after efforts to recompact the fill shall undergo additional testing regardless of the testing frequency guidelines. The Operator will determine when additional testing is required. Additional testing may include Standard Proctor, Atterberg Limits, and Gradation tests. Results of additional testing shall be submitted to the Operator for review. Following review of the testing results, the Operator shall determine whether a new moisture-density relationship curve shall be developed or if the Contractor shall continue to rework the non-conforming areas to meet specifications. If a new moisture-density relationship curve is produced for a change in soil type, all tests outlined in Table 3.1 shall be conducted for the new material type.

Final acceptance shall be explicitly detailed by survey location, layer description, material type, and lift number. A final report shall be submitted by the Contractor within 30 calendar days after final acceptance of the cover, detailing all field survey and quality control information performed during construction operations.

TABLE 3.1
Testing Methods and Frequencies for Borrow and Fill Areas

Fill	Test Method	Frequency
Existing landfill surface	Field Density and Moisture Testing (ASTM D-2922 and ASTM D-3017)	5/acre[a,b]
Borrow Area Testing:		
Subgrade	Gradation (ASTM D-422)	1/500 cubic yards
	Classification (ASTM D-2487)	1/500 cubic yards
	Standard Proctor (ASTM D-698)	1/500 cubic yards

Fill Area Testing:		
Subgrade	Field Density and Moisture Testing (ASTM D-2922 and ASTM D-3017)	5/acre/lift[a,b]
Borrow Area Testing:		
Native Soil Layer	Gradation (ASTM D-422)	1/500 cubic yards
	Classification (ASTM D-2487)	1/500 cubic yards
	Standard Proctor (ASTM D-698)	1/500 cubic yards
Fill Area Testing:		
Native Soil Layer	K_{sat} (saturated hydraulic conductivity)	1/acre/lift
	Field Density and Moisture Testing (ASTM D-2922 and ASTM D-3017)	5/acre/lift[a,b]
Borrow Area Testing:		
Topsoil Layer	Gradation (ASTM D-422)	1/500 cubic yards
	Classification (ASTM D-2487)	1/500 cubic yards
	Standard Proctor (ASTM D-698)	1/500 cubic yards
Fill Area Testing:		
Topsoil Layer	Field Density and Moisture Testing (ASTM D-2922 and ASTM D-3017)	5/acre[a,b]

a) Quality Control checks for density shall be conducted for at least 1 of every 20 Nuclear Methods by the Sand Cone Method (ASTM D1556).
b) Quality Control checks for moisture content shall be conducted for at least 1 of every 20 Nuclear Methods (shallow depth) by Direct Water Content Measurements (ASTM D2216).

END OF SECTION

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SECTION 02210

GRADES, LINES, AND LEVELS

PART 1 GENERAL

1.1 SCOPE OF WORK

1.1.1 Work Included

The Contractor shall furnish all materials, labor, tools and equipment to perform surveying. The Contractor shall perform surveying to ensure that the proper grades, lines, and levels are established as set forth in these specifications and as shown in the design drawings. The Operator may procure an independent survey, provided by an independent firm registered in the State of New Mexico, to verify construction surveys. Construction surveys may be completed by the Contractor or an independent firm provided the work is completed under the supervision of a Registered Land Surveyor in the State of New Mexico.

1.1.2 Related Work Specified Elsewhere

1) Clearing and Grubbing shall be performed in accordance with Section 02110 of these specifications.

2) Earthwork shall be performed in accordance with Section 02200 of these specifications.

3) Trenching, Backfilling, and Compaction shall be performed in accordance with Section 02221 of these specifications.

4) Monitoring Well Extension, Neutron Probe Access Hole Construction, and Fiber Optics Cable Installation shall be performed in accordance with Section 02670 of these specifications.

1.1.3 Work to be performed by the Operator and/or CQA Engineer:

1) Review and approve submittals as required for this specification,

2) Provide Contractor with SNL/NM survey grid information,

3) Provide two benchmarks near the landfill, as shown in the design drawings,

4) Inspect work for compliance with the requirements of this specification in addition to inspection by the Contractor,

5) Perform final inspection and confirm acceptance of surveying work.

1.2 REFERENCE DOCUMENTS

SNL/NM topographic grid and MWL design drawings.

1.3 SUBMITTALS

1.3.1 Procedures

1) The Contractor shall submit within 8 days after notice to proceed a plan for the work, including descriptions of survey equipment, procedures used to establish temporary or permanent benchmarks or measurements, field notes, calculations, reductions, closures, and documentation for any benchmarks or monuments to the Operator for approval.

2) Data shall be reduced and plotted by the Contractor in a form acceptable to the Operator. Legible notes, drawings, and reproducible documentation shall be submitted to the Operator for approval. The Contractor shall supply the following survey data to the Operator for approval within 4 work days after completion of the survey:

   A) Topography plat of final grade of each of the intermediate layers of the cover (Subgrade, Native Soil Layer) with a contour interval of 0.5 feet and the location, as appropriate, of monitoring wells and instrumentation.

   B) Topography plat of the final grade of the cover with a contour interval of 0.5 feet and the location, as appropriate, of monitoring wells and instrumentation.

3) All topography plats and all project benchmarks shall be based upon the SNL/NM grid. In addition to the above noted submittals, all plats shall also be submitted in electronic microstation format.

4) The Contractor shall not proceed with placement of an overlying layer or with subsequent work phases until the surveyor has completed the survey of the existing layer measurements and the data have been reviewed and accepted by the Operator.

1.3.2 Certifications

The Contractor shall submit a letter to the Operator within 4 work days after completion of the work specified herein, verifying conformance to the requirements identified in this specification. The letter shall be prepared and executed by a Professional Land Surveyor registered in the State of New Mexico.

1.3.3 Records

The Contractor shall submit to the Operator for information, all field notes from surveying and layout activities within 4 work days after completion of these activities.

1.4 QUALITY ASSURANCE

The Contractor shall be responsible for protecting and maintaining all horizontal and vertical control points during construction.

1.4.1 Accuracy

Optical survey, tape measurement, and electronic measurement shall have a minimum accuracy of ± 0.1 feet in horizontal locations and ± 0.01 feet in elevations, or as superseded by criteria set forth in other sections of these specifications.

1.4.2 Tolerances

The Contractor shall survey all finished layers within the tolerances specified below:

Description	**Tolerances**
Subgrade:	-0.00 to +0.25 feet
Native Soil Layer	-0.00 to +0.25 feet
Topsoil Layer	-0.00 to +0.25 feet
Reclaimed Borrow Areas	-0.00 to +0.25 feet

The Contractor shall ensure that no low points capable of retaining water are present in the final cover surface. If any low points are identified, the Contractor shall repair such locations.

PART 2 PRODUCTS

None.

PART 3 EXECUTION

3.1 GENERAL

3.1.1 All surveying shall be recorded in the New Mexico State plane central zone NAD 27.

3.1.2 The Contractor shall check and verify that as-built thickness and elevations match those shown in the design drawings based on site benchmarks, and prepare as-built drawings of the cover.

3.1.3 The Contractor shall be responsible for controlling lift thickness and individual layer thickness such that overall cover thickness conforms to the specified tolerances. The Contractor shall be responsible for establishing, recording, protecting, and maintaining all permanent and temporary horizontal and vertical control benchmarks.

3.2 SURVEY MEASUREMENTS

3.2.1 Prior to commencement of construction work, the Contractor shall establish survey control at the construction area.

3.2.2 Survey control points shall be established so that any point within the construction area can be accurately re-established and elevations can be obtained to the required tolerances at any time during the course of construction. The Contractor shall verify all baselines, and horizontal and vertical control benchmarks stipulated in the information provided by the Operator.

3.3 ACCEPTANCE

1) Surveying work not in accordance with the requirements of this specification shall be repaired and/or replaced by the Contractor. The Contractor shall submit a description of the corrective action methods to the Operator for approval before use. Acceptance criteria for corrected actions shall be in accordance with the requirements of this specification.

2) In the event of a survey discrepancy, the area in question shall be re-surveyed and verified at no cost to the Operator.

END OF SECTION

SECTION 02221

TRENCHING, BACKFILLING, AND COMPACTING

PART 1 GENERAL

1.1 SCOPE OF WORK

1.1.1 Work Included

The Contractor shall furnish all materials, labor, tools, and equipment to complete trenching, backfilling, and compacting necessary during construction activities for installing drainage swales and fiber optic cables.

1.1.2 Related Work Specified Elsewhere

1) Temporary Diversion and Control of Water during Construction shall be in accordance with Section 01563 of these specifications.

2) Clearing and Grubbing shall be in accordance with Section 02110 of these specifications.

3) Earthwork shall be in accordance with Section 02200 of these specifications.

4) Grades, Lines, and Levels shall be in accordance with Section 02210 of these specifications.

5) Reclamation Seeding and Mulching shall be in accordance with Section 02930 of these specifications.

1.1.3 Work to be performed by the Operator and/or CQA Engineer:

1) Review and approve data submittals required by this specification,

2) Have the option to perform final inspection and acceptance of trenching, backfilling, and compacting.

1.2.3 Records

The Contractor shall submit to the Operator for information all field notes from surveying and layout activities within 4 work days after completion of these activities.

PART 2 GENERAL REQUIREMENTS

2.1 The Contractor shall be responsible for trenching, backfilling, and compacting.

2.2 The Contractor shall contain trenching, backfilling, and compacting operations within the designated areas, layers, and lifts as indicated in the design drawings. If conditions encountered warrant modification to the designated limits, the Operator shall be notified prior to proceeding.

2.3 The Contractor shall perform trenching, backfilling, and compacting operations in a manner that maintains drainage and control at all times, in accordance with Section 01563, Temporary Diversion and Control of Water during Construction.

PART 3 FIBER OPTICS CABLE TRENCHING

3.1 The fiber optics cable shall be installed in trenches excavated to the required depth in the finished subgrade surface and in the third compacted native soil lift as shown in the design drawings.

3.2 The Contractor shall not backfill trenches until trenches have been approved by the Operator.

3.3 The Contractor shall place and compact fill carefully around fiber optics cable to avoid damage to the cable.

PART 4 DRAINAGE SWALE EXCAVATION

4.1 The Contractor shall excavate the drainage swale to the required cross-section and grade shown in the design drawings.

4.2 The Contractor shall take care to avoid excavating the drainage swale below the grade indicated except where unsuitable materials are encountered as defined by the Operator. Areas where existing grade is less than that required in the design drawings shall be backfilled to grade.

4.3 The Contractor shall ensure positive drainage of the drainage swale.

4.4 The drainage swale shall be revegetated in accordance with Section 02930.

4.5 The drainage swale shall be maintained by the Contractor until final acceptance of the work.

PART 5 INSPECTION

5.1 The Contractor shall be responsible for in-process inspection during performance of all work.

5.2 In addition to inspection by the Contractor, the CQA Engineer and/or Operator shall inspect all work for compliance with the requirements of this specification.

PART 6 ACCEPTANCE

Trenching, backfilling, and compacting not in accordance with the requirements of this specification shall be repaired or replaced by the Contractor. The Contractor shall submit a description of the repair and/or replacement methods for work not in compliance with this specification to the Operator for written approval before use. Acceptance criteria for repaired and/or replaced trenching, backfilling, and compacting shall be in accordance with the requirements of this specification.

END OF SECTION

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SECTION 02445

ADMINISTRATIVE CONTROL FENCES AND GATES

PART 1 GENERAL

1.1 SCOPE OF WORK

1.1.1 Work Included

The Contractor shall furnish all materials, labor, tools, and equipment to construct administrative control fences and gates in accordance with this specification and as shown in the design drawings. Fence material shall be produced and installed by methods recognized as good commercial practices.

1.1.2 Work to be performed by the Operator and/or CQA Engineer:

1) Review and approve data submittals required by this specification;

2) Have the option to inspect work for compliance with the requirements of this specification, in addition to inspection by the Contractor;

3) Have the option to review pre-installation conditions, installation, and other job conditions during performance of the work, and;

4) Have the option to perform final inspection and confirm acceptance of administrative control fences and gates.

1.2 REFERENCE DOCUMENTS

None.

1.3 SUBMITTALS

1.3.1 Data

The Contractor shall submit the proposed administrative control fence, gate, and sign materials to the Operator for written approval 8 work days prior to procurement.

1.3.2 Test Reports

None.

1.3.3 Procedures

The Contractor shall submit a description of methods for repair and/or replacement of administrative control fences and gates that are not in accordance with the requirements of this specification to the Operator for written approval before use.

1.3.4 Certifications

The Contractor shall submit a letter to the Operator within 4 work days after completion verifying conformance to the requirements identified in this specification and as shown in the design drawings.

1.3.5 Records

1) The Contractor shall submit records of inspection to the Operator within 4 work days after completion of the inspection. Inspection records shall include on-site inspection records of the administrative control fences and gates.

2) The Contractor shall submit to the Operator for information all field notes from surveying and layout activities within 4 work days after completion of these activities.

PART 2 PRODUCTS

2.1 EQUIPMENT AND MATERIAL REQUIREMENTS

2.1.1 General

1) Administrative control fences shall be strand barbed wire with tee posts driven into the ground and steel corner posts set in concrete.

2) All fence materials shall be galvanized in accordance with ASTM A123, A384, and A385.

3) All fence items shall be the product of an established fence manufacturer.

2.2.2 Barbed Wire

1) Barbed wire shall conform to ASTM A121 with a Class 1 coating.

2) Fence shall consist of 3 horizontal runs of barbed wire spaced as shown in the design drawings.

3) Barbed wire shall be No. 12-1/2 gauge, 2-strand, copper-bearing, hot-galvanized steel wire with large, four-point-pattern, hard-tempered, round barbs spaced 5 inches apart.

4) Tie wires for fastening barbed wire to steel posts shall be No. 12 gauge copper-bearing steel wire. Tie wires shall be heavily galvanized by the hot-dip process.

5) Stays shall be No. 9 gauge copper-bearing steel wire conforming to the requirements of ASTM A116. Stays shall be 42 inches long.

2.2.3 Posts

1) End and corner posts shall be nominal 2-1/2-inch diameter standard galvanized pipe per ASTM A53, Type S, Grade B, or Operator approved equivalent.

2) Tee posts shall be fabricated from rail, billet, or commercial grade steel which conforms to the requirements of ASTM A702.

2.2.4 Gates

1) All gates, hardware, and accessories for installation of the gates shall be furnished and installed by the Contractor.

2) Hinges shall be pivot-type, galvanized and industry standard size to suit gate size as shown in the design drawings. Hinges shall be non-lift-off type and offset to permit 180-degree gate opening. Each gate leaf shall be provided with 2 hinges.

3) Gates shall be galvanized high carbon-welded, 2-inch diameter, tubular steel 40 inches high, or Operator approved equal, with internal bracing. Gate fabric shall be No. 14 gauge copper-bearing open-hearth steel wire, woven in a 2-inch by 4-inch mesh, and heavily galvanized by the hot-dip process after weaving.

4) Gate posts shall be nominal 2-1/2-inch diameter standard galvanized steel pipe.

2.2.5 Bracing

All end and corner posts shall be braced by means of diagonal trusses. Trusses shall be hot-galvanized 3/8-inch steel rod complete with turnbuckles.

PART 3 EXECUTION

3.1 FOOTINGS

3.1.1 General

1) All corner and end posts shall be set and centered in a concrete encasement to the diameters and depths shown in the design drawings.

2) Concrete footings shall be neatly domed off at the finish grade line to shed water from the posts.

3) Concrete shall have a minimum 28-day strength of 3000 psi.

3.2 ERECTION OF FENCING

3.2.1 General

1) The Contractor shall assemble and erect fences and gates as specified herein and in the design drawings, and in accordance with detailed instructions furnished by the fence manufacturer.

2) Where necessary, the Contractor shall adjust the grade of the fence to fit the contour of the ground. The Operator shall be notified prior to any grading of surface soils.

3.3 ACCEPTANCE

Installation of fences and gates not in accordance with the materials and method requirements of this specification shall be repaired and/or replaced by the Contractor. The Contractor shall submit the repair and/or replacement methods to the Operator for written approval before use. Acceptance criteria for repaired fences and gates shall be in accordance with the requirements of this specification.

END OF SECTION

SECTION 02670

MONITORING WELL EXTENSION, NEUTRON PROBE ACCESS HOLE CONSTRUCTION, AND FIBER OPTICS CABLE INSTALLATION

PART 1 <u>GENERAL</u>

1.1 SCOPE OF WORK

1.1.1 <u>Work Included</u>

The MWL alternative cover shall incorporate an infiltration monitoring system that shall include both neutron probe access holes and fiber optics cable. The Contractor shall furnish all labor, tools, and equipment necessary to extend monitoring well MW-4, construct neutron probe access holes, and install fiber optics cable in accordance with this specification and as shown in the design drawings. The Operator shall provide the Contractor with the materials necessary for extension of monitoring well MW-4, construction of neutron probe access holes, and installation of fiber optics cable.

1.1.2 <u>Related Work Specified Elsewhere</u>

Trenching, Backfilling, and Compaction shall be performed in accordance with Section 02221 of these specifications.

1.1.3 <u>Work to be performed by the Operator and/or CQA Engineer:</u>

1) Review and approve submittals as required by this specification,

2) Inspect and approve existing conditions prior to extension of monitoring well MW-4, construction of neutron probe access holes, and installation of fiber optics cable.

3) Perform final inspection and confirm acceptance of monitoring well MW-4 extension, construction of neutron probe access holes, and installation of fiber optics cable.

PART 2 <u>PRODUCTS</u>

2.1 EQUIPMENT AND MATERIAL REQUIREMENTS

2.1.1 <u>General</u>

The components, materials, and configuration required for monitoring well extension, neutron probe access hole construction, and fiber optics cable installation are shown in the design drawings.

PART 3 EXECUTION

3.1 Monitoring Well MW-4 Extension

1) The Contractor shall remove the existing MW-4 concrete pad, stanchions, protective casing, and locking top cap prior to initiation of construction activities.

2) The Contractor shall complete the well extension utilizing acceptable PVC construction techniques before or during cover construction, whichever is most convenient.

3) Existing MW-4 Schedule 80 PVC well casing shall be extended such that the top of the PVC well casing is located a minimum of 2' - 6" above the final grade of the constructed cover.

4) Only hand-operated compaction equipment shall be used to compact soils around the extended well casing as each lift is placed during cover construction.

5) The concrete pad, protective casing, and locking top cap shall be refitted to its original configuration, consisting of steel cover, locking top cap, and concrete pad. Soil directly below the concrete pad shall be compacted to 90 percent of maximum dry density at -2 to +2 percent of optimum moisture content as determined by ASTM D698 (Standard Proctor testing). Protective stanchions shall not be required.

6) The final location and elevation of the top of the new PVC well casing and four corners of the concrete pad shall be surveyed. The results of the survey shall be retained for future use to prepare as-built drawings.

3.2 Neutron Probe Access Hole Construction

1) The Contractor shall locate neutron probe access hole collars to within 0' - 6" of the locations shown in the design drawings. The Contractor shall verify that neutron probe access holes do not intercept or damage underlying fiber optic cable.

2) The Contractor shall install neutron probe access holes by augering 2.5-inch diameter boreholes through the constructed cover. Each borehole shall extend 2' - 0" into the original landfill surface.

3) Borehole casing shall be constructed of 6061-T6 aluminum fitted with a perforated, tapered drive-tip. Aluminum casing shall be driven to proper depth and shall extend 1' - 0" above the final grade of the cover.

4) Surface completion shall consist of a 1' - 0" by 1' - 0" concrete pad placed around each casing collar to prevent preferential flow down the annulus. Concrete shall be 3000 psi concrete and shall be sloped away from the casing to allow for free drainage away from the hole.

5) Soil directly below concrete pads shall be compacted to 90 percent of maximum dry density at -2 to +2 percent of optimum moisture content, as determined by ASTM D698 (Standard Proctor testing).

3.3 Fiber Optics Cable Installation

1) The Contractor shall locate fiber optics cable trenches to within 0' - 6" of the locations shown in the design drawings.

2) The Contractor shall install trenches to a uniform depth of 6 inches in the finished subgrade surface and in the third compacted native soil lift 1' - 6" above the subgrade surface. The fiber optics cable installed in the native soil lift shall be transposed 90 degrees from the fiber optics cable installed in the subgrade surface.

3) The Contractor shall remove all loose soil from trenches prior to placement of the fiber optics cable. The fiber optics cable shall be hand-laid on the bottom of the trench.

4) The Contractor shall carefully replace fill around the fiber optics cable and compact with hand-operated compaction equipment to avoid damage to the cable.

5) The Contractor shall allow for a minimum of one day for the Operator to test and verify the optical integrity of the fiber optics cable after installation.

3.2 INSPECTION

3.2.1 The CQA Engineer and Operator shall be responsible for in-process inspection during performance of all work.

3.2.2 Monitoring well extension, neutron probe access hole construction, and fiber optics cable installation not in accordance with the requirements of this specification shall be repaired or replaced by the Contractor. The Contractor shall submit a description of the repair and/or replacement methods for work not in compliance with this specification to the Operator for written approval before use. Acceptance criteria for repaired and/or replaced monitoring well extension, neutron probe access hole, and fiber optics cable shall be in accordance with the requirements of this specification.

END OF SECTION

SECTION 02930

RECLAMATION SEEDING AND MULCHING

PART 1 <u>GENERAL</u>

1.1 SCOPE OF WORK

1.1.1 <u>Work Included</u>

The Contractor shall furnish all labor, materials, tools and equipment, and shall place seed and mulch in accordance with this specification and as indicated in the design drawings. This section describes the Contractor's requirements to provide a final vegetated surface in those areas designated herein. These designated areas shall be seeded and mulched as set forth in this section.

1.1.2 <u>Work to be performed by the Operator and/or CQA Engineer:</u>

1) Review and approve submittals as required by this specification,

2) Have the option to inspect equipment, work, and materials for compliance with the requirements of this specification, in addition to inspection by the Contractor,

3) Have the option to review pre-seeding conditions and other related job conditions during performance of the work, and,

4) Have the option to perform inspection and acceptance of the final vegetated surfaces.

1.2 REFERENCE DOCUMENTS

City of Albuquerque, Specification 1012, Native Grass Seeding

Biological Assessment for the Sandia National Laboratories Coyote Canyon Test Complex, Kirtland Air Force Base, Albuquerque, New Mexico, July 1992

1.3 SUBMITTALS

1.3.1 <u>Procedures</u>

The Contractor shall submit a Seeding and Mulching Plan to the Operator for written approval within 8 work days after notice to proceed. The plan shall describe the methods of placement and the equipment to be used during operations.

1.3.2 Certification

1) The Contractor shall submit 8 work days prior to use, the seed vendor's certified statement for the seed mixture required, stating scientific and common names, percentages by weight, and percentages by purity and germination. The Contractor shall submit a signed statement certifying that the seed is from a lot that has been tested by a recognized laboratory for seed testing within 6 months prior to the date of delivery to the construction site.

2) The Contractor shall submit a letter to the Operator verifying conformance to the requirements identified in this specification within 4 work days after completion of the work specified herein.

1.3.3 Records

The Contractor shall submit records of inspection to the Operator within 4 work days after completion of the inspection.

PART 2 PRODUCTS

2.1 GENERAL

Seed, fertilizer, mulch, and equipment shall be inspected upon arrival at the job site by the Operator and/or CQA Engineer for the conformity to type and quality in accordance with these requirements. Unacceptable materials shall be removed from the job site by the Contractor.

2.2 EQUIPMENT AND MATERIAL REQUIREMENTS

2.2.1 Seed Mix for Cover and Reclaimed Areas

Seed shall be labeled in accordance with USDA rules and regulations under the Federal Seed Act. Seed shall be furnished in sealed bags or containers clearly labeled to show the name and address of the supplier, the seed name, the lot number, net weight, origin, the percentage of weed seed content, the guaranteed percentage of purity and germination, pounds of live seed of each seed species, the total pounds of pure live seed in the container, and the date of the last germination test which shall be within a period of 6 months prior to commencement of planting operations. Seed shall be from a current or previous year's crop.

The following seed mixture shall be used:

Species	(lb/acre pure live seed)
Galleta grass	4.0
Black grama	3.0
Sand dropseed	1.5
Crested wheat grass	5.0
Alkali sacaton	1.5
Total rate:	20 lb/acre

2.2.2 Fertilizer

A starter fertilizer containing nitrogen, phosphorous, potassium, and sulfur shall be used. A 20-20-0-22 shall be acceptable.

2.2.3 Mulch

The Contractor shall furnish all labor, materials, tools and equipment to place a grain straw (wheat, oats, or barley) mulch on the reclaimed areas. The straw mulch shall be applied at the rate of 2 tons/acre. The straw mulch shall be clean, free of seed, and free of noxious weeds.

2.2.4 Equipment

The Contractor shall provide appropriate types of equipment for the performance of drill seeding and mulch spreading. Seeding of the grass species shall be performed with a rangeland grass drill equipped with multiple seed bins, depth bands, and press wheels. Drills shall have agitators to prevent the seed from segregating and lodging in the seed box. The depth bands should be suitable for placing the seed at a depth that does not exceed 1/2 inch.

Mulch crimping equipment shall properly crimp the straw without cutting the straw. Discing equipment shall not be used.

2.3 PRODUCT DELIVERY, STORAGE, AND HANDLING

2.3.1 Delivery

The Contractor shall deliver seed to the site in the original, unopened containers bearing the container labels or tags stating the producer's guaranteed statement of analysis.

2.3.2 Storage

Materials shall be stored in areas designated by the Operator. Seed shall be stored in cool, dry locations away from contaminants and in accordance with manufacturer's recommendations. Storage times shall not exceed manufacturer's recommendations.

2.3.3 Handling

Except for bulk deliveries, the Contractor shall not drop or dump materials from vehicles.

PART 3 EXECUTION

3.1 APPLICATION PROCEDURES

3.1.1 Topsoil Preparation

Prior to seeding, the Contractor shall till the top 3 inches of the surface into an even and loose seed bed, free of clods in excess of 4 inches in diameter, and bring the tilled surface to the desired line and grade. The area to be seeded shall be free of erosion rills and gullies.

3.1.2 Seeding

1) The Contractor shall seed the constructed cover, laydown and borrow areas, drainage swale, and other locations impacted by construction activities. The CAMU soil stockpile area shall not be seeded.

2) The Contractor shall apply the seed mix uniformly to the prepared surface by means of drill seeding at not less than the minimum rate specified in Part 2.2.1 of this specification.

3) Seed shall be uniformly drilled to a maximum depth of 1/2 inch using equipment specified in Part 2.2.4 of this specification.

4) The Contractor shall seed in a pattern perpendicular to the slope, working from the top of the slope down and using row markers to indicate seeded areas.

5) The Contractor shall seed the grass mixture in either the spring or fall. Spring seeding shall be performed after the chances of freezing temperatures have passed. Fall seeding shall be performed before the ground is frozen and covered with snow and after the time temperatures would cause germination.

6) The stand of grass resulting from the seeding shall not be considered satisfactory until accepted by the Operator. The Contractor shall provide a one-year warranty to assure the stand of grass from the seeding. If areas are

determined to be unacceptable, the unacceptable areas shall be reseeded in accordance with these specifications.

3.1.3 Fertilizer

Fertilizer shall be placed at a spreading volume of 10 lb/acre unless otherwise specified by the Operator.

3.1.4 Mulch

Mulch shall be straw spread uniformly at a rate of 2 tons/acre immediately following seeding. Mulch shall be anchored into the soil to a depth of at least 2 inches with no more than one pass of the crimping equipment. The crimping operation shall proceed perpendicular to the slope so as not to encourage the formation of rivulets down slope. Mulching shall not be performed when wind interferes with placement.

3.2 MAINTENANCE

3.2.1 General

1) Maintenance of the constructed cover, laydown and borrow areas, drainage swale, and other locations impacted by construction activities during seeding shall be provided by the Contractor.

2) Areas damaged by the Contractor during seeding shall be repaired and reseeded by the Contractor at the Contractor's expense.

3.2.2 Inspections

1) The Contractor shall perform daily inspections of all seeded areas during the performance of reclamation activities. The inspection records shall be submitted weekly to the Operator.

2) All inspection findings shall be submitted to the Operator in writing including, but not limited to, conditions observed, repairs recommended, and materials recommended. The Contractor is required to submit a repair report documenting the repairs made and materials used.

3.2.3 Warranty

The warranty period shall be for a period of one year. Areas of erosion shall be immediately repaired and reseeded by the Contractor throughout the warranty period.

3.3 ACCEPTANCE

Seeding and mulching not in accordance with the requirements of this specification shall be repaired and/or replaced by the Contractor. The Contractor shall submit a description of the repair and/or replacement methods to the Operator for written approval before use. Acceptance criteria for repaired and/or replaced seeding or mulching shall be in accordance with the requirements of this specification.

END OF SECTION

APPENDIX D

Construction Quality Assurance Plan

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1.0 Introduction

A construction quality assurance (CQA) plan is essential for determining, with a reasonable degree of certainty, whether a completed final cover system meets or exceeds all design criteria, plans, and specifications. This document presents the various controls established by the CQA plan for construction of the Mixed Waste Landfill (MWL) alternative cover at Sandia National Laboratories (SNL)/New Mexico (NM). It should be recognized that the management of construction quality involves using scientific and engineering principles and practices to verify that the alternative cover to be constructed meets or exceeds design criteria, plans, and specifications. This management activity begins prior to construction, continues throughout construction, and ends when the alternative cover is accepted by the New Mexico Environment Department (NMED).

1.1 Concept and Objectives of the CQA Plan

The governing purpose for the CQA plan is to verify that the MWL alternative cover is constructed as specified in the design. To verify proper construction, the following objectives must be met:

- Guidelines and requirements in design drawings and construction specifications are followed
- Inspection and verification testing throughout construction to verify that design features are implemented as intended
- Evaluation of variances to the design and their effects upon system performance
- Complete documentation demonstrating that the design has been implemented and that performance requirements have been met.

In meeting these objectives, the following are defined as part of the CQA plan:

- Quality-related qualifications, responsibilities, and authorities of personnel
- Controls for the procurement of services and materials
- Direction for necessary inspections and verification testing during construction so that execution of the design documents can be confirmed. Acceptance criteria for the inspections and testing are also included

- Provision for continuity throughout construction so that the work progresses as an organized, planned sequence of events which allows revision and change
- Direction for the preparation and maintenance of records so that it can be demonstrated that the construction was performed in accordance with design requirements.

An audit system will be established to provide evaluation of the implementation of the design drawings and construction specifications, the CQA program, and work areas and activities including materials and workmanship.

1.2 Basis of the CQA Plan

The following sources have been used as guidance in the preparation of the CQA plan:

- U.S. Environmental Protection Agency (U.S. EPA), Technical Guidance Document, "Quality Assurance and Quality Control for Waste Containment Facilities," Report No. EPA/600/R-93/182, September 1993
- U.S. Environmental Protection Agency (U.S. EPA), Design and Construction of RCRA/CERCLA Final Covers, EPA/625/4-91/025, May 1991
- New Mexico Administrative Code Title 20, Chapter 4, Part 1, Subpart V
- Manufacturer supplied installation guidelines (where applicable).

1.3 Presentation of the CQA Plan

The CQA plan contains general direction for the control of construction activities, such as the definition of organizational responsibilities and authorities, CQA personnel qualifications, and specific technical information, such as execution guidance and verification tests to be performed throughout construction.

Inspection checklists have been developed for use by CQA personnel to document the inspection and verification requirements in the CQA plan. These checklists will be completed and signed by CQA Inspectors and will be reviewed by the CQA Engineer. The checklists will become part of the final construction report, documenting the CQA process throughout construction. Examples of these checklists are included in Attachment A of this plan.

Whenever possible, nationally recognized test methods such as those published by the American Society for Testing and Materials (ASTM) will be utilized. In general, recognized standards will be cited only by reference and not included verbatim. If a test method is not a nationally recognized standard, the test method will be defined, including criteria for acceptability.

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2.0 Responsibility and Authority

The principal organizations involved in construction of the SNL/NM MWL alternative cover include:

- New Mexico Environment Department (NMED) (Lead Regulatory Agency)
- U.S. Department of Energy (DOE) (Owner)
- SNL/NM (Operator)
- Construction Quality Assurance (CQA) Contractor
- Construction Contractor.

The areas of responsibility and lines of authority are delineated in the following sections such that the lines of communication are established to effectively implement the CQA plan. An organizational chart for the project during cover construction is shown in Figure 2-1.

2.1 Review/Permitting Agency

The NMED, the lead regulatory agency, has the authority to review the MWL alternative cover design and approve construction of the cover. It is the responsibility of the NMED to review the Operator's site-specific CQA plan for compliance with the agency's regulatory requirements, and to review all CQA documentation during and/or after construction of the cover to confirm that the CQA plan was followed and that the cover was constructed as specified.

2.2 Owner/Operator

Representing the DOE, SNL/NM will have overall responsibility for construction of the MWL alternative cover. As the Owner's representative, SNL/NM has responsibility for compliance with the regulatory requirements of the NMED in order to obtain approval of the MWL alternative cover design and assure the NMED, by the submission of CQA documentation, that the cover was constructed as specified in the approved design. SNL/NM has the authority to select and dismiss the organizations responsible for the CQA and construction activities. The DOE also has the authority to accept or reject design drawings and construction specifications, the CQA plan, reports and recommendations of the CQA Engineer, and the materials and workmanship of the Construction Contractor. In addition, the DOE will have a Construction Representative (Sandia Construction Representative [SCR]) on site to coordinate and oversee all construction-related activities.

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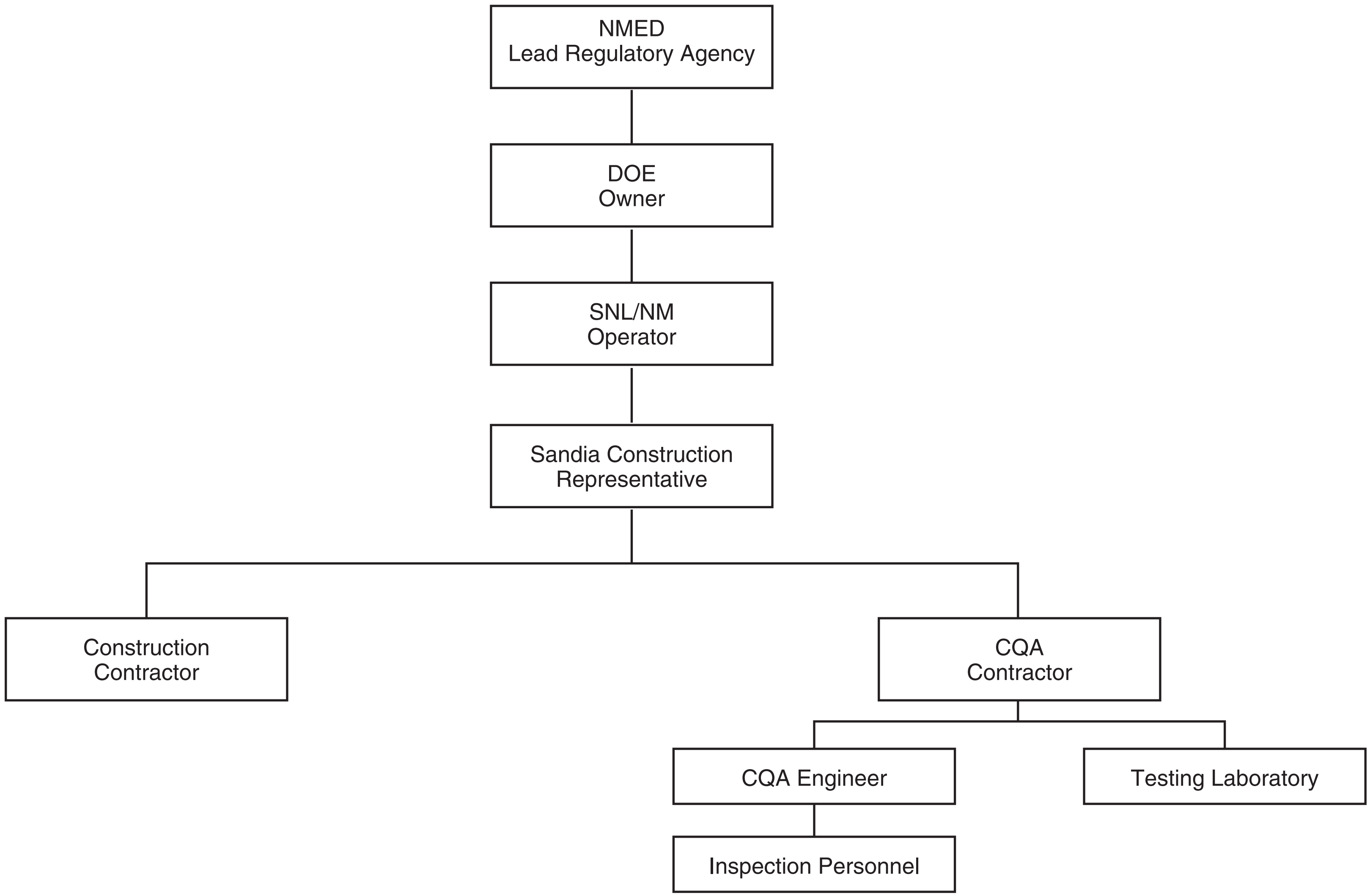

Figure 2-1
Organizational Chart, SNL/NM Mixed Waste Landfill Alternative Cover

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2.2.1 Sandia Construction Representative (SCR) (Owner's Representative)

The SCR will report directly to SNL/NM and has the following responsibilities:

- Overall coordination of construction activities
- Oversee implementation of the CQA plan
- Notify the CQA Contractor, and the Construction Contractor of any nonconformances observed
- Approve changes and notify other personnel, as appropriate, for the changes
- Ensure that inspections and verification tests performed by the CQA Contractor are conducted at required intervals and in accordance with the CQA plan
- Review as-built drawings, results of inspections, and field and laboratory data from verification testing
- Prepare audits and surveillance reports for submission to the Operator
- Stop work if conditions adverse to quality are persistent, and ensure that conditions are corrected before proceeding
- Maintain construction documents and records after transfer from the CQA Contractor.

2.3 SNL/NM (Operator)

The Operator's primary responsibility is to design and specify an alternative cover that fulfills the closure needs of the Owner and the regulatory requirements of the NMED. Design activities may not end until the cover is completed. Revisions to the design may be required if unexpected site conditions are encountered or changes in construction methodology occur that could adversely affect cover performance. The CQA program provides assurance that these unexpected changes or conditions will be detected, documented, and addressed during construction.

Additional responsibilities and authority of the Operator include formulating and implementing the CQA plan, periodic review of CQA documentation, modifying construction site activity, and specifying corrective measures in cases where deviation from the approved design or failure to meet design criteria, plans, and specifications is identified by CQA personnel.

2.4 Construction Contractor

It is the responsibility of the Construction Contractor to construct the MWL alternative cover in strict accordance with the design criteria and drawings, construction specifications, and CQA plan using the necessary construction procedures and techniques.

2.5 CQA Contractor

The overall responsibility of the CQA Contractor is to perform those activities specified in the CQA plan (e.g., inspection, sampling, and documentation). At a minimum, the CQA Contractor will include a CQA Engineer and the necessary supporting CQA inspection personnel. Specific responsibilities and authority of the CQA Contractor's personnel are defined clearly below and in the associated contractual agreements with the Owner.

2.5.1 CQA Engineer

Specific responsibilities of the CQA Engineer include, but are not limited to, the following:

- Review of design criteria and drawings, and construction specifications for clarity and completeness so that the CQA plan can be implemented
- Educate CQA inspection personnel on CQA requirements and procedures
- Schedule and coordinate CQA inspection activities
- Direct and support the CQA Inspectors in performing observations and tests by:
  - Confirming that regular calibration of testing equipment is properly conducted and recorded
  - Confirming that the testing equipment (e.g., nuclear density gauge), personnel, and procedures do not change over time or making sure that changes do not adversely impact the inspection process
  - Confirming that the test data are accurately recorded and maintained (This may involve selecting reported results and backtracking them to the original observation and test data sheets.)
  - Verifying that the raw data are properly recorded, validated, reduced, summarized, and interpreted
  - Ensuring that construction CQA testing is conducted at a frequency of at least 5% of that done by the Construction Contractor.
- Maintain CQA-related documents, including but not limited to the CQA plan, field notes, meeting notes, test results, and miscellaneous reports

- Provide the SCR with recommendations and reports on the inspection results including:
  - Review and interpretation of data sheets, as-built drawings, and reports
  - Identification of work that will be accepted, rejected, or uncovered for observation, or that may require special testing, inspection, or approval
  - Verification that corrective measures are implemented.
- Report nonconformances to the SCR
- Report to the SCR activities that are adverse to overall quality
- Document nonconformances.

2.5.2 CQA Inspection Personnel

The CQA Inspectors will provide day-to-day inspections and field verification tests. Their role is critical to successful demonstration of construction procedures and required documentation. Their major responsibilities include:

- Performing independent on-site inspection of the work in progress to assess compliance with cover design criteria and drawings, and construction specifications
- Inspect delivery tickets and manufacturers quality control (QC) reports to verify that materials meet construction specifications
- Verifying that the equipment used in testing meets the test requirements and that the tests are conducted in accordance with standardized procedures defined by the CQA plan
- Collecting samples in the field for subsequent verification testing by off-site laboratories. CQA testing will be conducted at a frequency of at least 5% of that done by the Construction Contractor
- Reporting to the CQA Engineer results of all inspections including work that is not of acceptable quality or that fails to meet the specified design criteria
- Reporting of nonconformances, as appropriate, to the construction foremen, superintendents, or manager if correction can be made during the normal course of work
- Reporting of nonconformances to the CQA Engineer if correction cannot be readily achieved to the satisfaction of the CQA Inspector, so that resolution can be accomplished by the CQA Engineer

- Reporting to the CQA Engineer any activities which are adverse to overall quality and any nonconformances which are recurring
- Documenting nonconformances
- Reporting to the CQA Engineer any changes in the design drawings and/or construction specifications
- Documenting inspection and verification testing activities through the completion of specified forms and daily logs.

2.5.3 CQA Certifying Engineer

The CQA Certifying Engineer is responsible for certifying to the Owner and the NMED that, in his or her opinion, the cover has been constructed in accordance with all plans and specifications, and that the CQA document has been approved by the NMED. The certification statement is normally accompanied by a final CQA report that contains all the appropriate documentation, including daily observation reports, sampling locations, test results, drawings of record or sketches, and other relevant data. The CQA Certifying Engineer may be the CQA Engineer or someone else in the CQA Engineer's organization that is a registered professional engineer (PE) with experience and competency in certifying like installations.

2.6 Testing Laboratory

Commercial laboratories perform many CQA tests. The testing laboratory will have its own internal QC plan to verify that the laboratory procedures conform to the appropriate ASTM standards or other applicable testing standards. The testing laboratory is responsible for ensuring that tests are performed in accordance with applicable methods and standards, internal QC procedures are followed, sample chain-of-custody records are maintained, and data are effectively and accurately reported. The testing laboratory must be willing to allow the Operator, CQA Engineer, or the NMED to observe the sample preparation, testing procedures, or record-keeping procedures, if they so desire. The Operator, CQA Engineer, or the NMED may request that they be allowed to observe some or all tests on a particular job at any time, either announced or unannounced. The testing laboratory personnel must be willing to accommodate such a request, but the observer will not interfere with the testing or slow the testing process.

3.0 Personnel Qualifications

The key individuals involved in CQA and their minimum recommended qualifications are listed in Table 3.1.

Table 3-1
Recommended Personnel Qualifications

Individual	Minimum Recommended Qualifications
Sandia Construction Representative	The specific individual designated by the Owner with knowledge of the project, its plans, specifications and QA/QC documents.
CQA Engineer	Employed by an organization that operates separately from the Construction Contractor and Owner/Operator; registered Professional Engineer and approved by the NMED.
CQA Inspectors	Employed by an organization that operates separately from the Construction Contractor and the Owner/Operator; experienced in performing the appropriate field tests and making observations during construction activities.
CQA Certifying Engineer	Employed by an organization that operates separately from the Construction Contractor and Owner/Operator; registered Professional Engineer in the state of New Mexico and approved by the NMED.

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4.0 Project Communications

Communication between CQA program participants is crucial. Required reporting to program participants is necessary so that activities can be reviewed and work can proceed. Communications in the form of construction documents, inspection reports, audit reports, verification test results, and daily logs must be timely so that reviews and evaluations can take place.

Throughout this plan, required report preparation and the individuals responsible for distribution, review, and approval are cited.

4.1 Meetings

Meetings will be held throughout the course of construction. Following are discussions of three specific meeting formats.

4.1.1 Preconstruction Meeting

Prior to the start of construction of the MWL alternative cover, a Preconstruction Meeting will be held to review and acquaint personnel with the requirements of the CQA Program, design drawings, and construction specifications. The Preconstruction Meeting will include a tour of the MWL, borrow areas, and access routes. The meeting will be led by the SCR and the CQA Engineer. Attendance at the meeting should include: the Operator's field engineer, CQA Inspectors, Construction Contractor(s), including but not limited to, the surveyor, construction manager, superintendents, and foreman. Meeting notes will be prepared by the CQA personnel and will be maintained in the on-site records system. Subcontractor personnel will attend the meeting as applicable to their scope of work. If any subcontractors arrive on site after construction begins and the preconstruction meeting has been held, the SCR and CQA Engineer will meet with those subcontractors to review appropriate activities of their work. These meetings will be documented as well.

The preconstruction meeting should present the following:

- Schedule
- MWL Health & Safety Plan
- Documents pertinent to each group's activities during construction

- Construction organization
- Review requirements of the design drawings and construction specifications
- Responsibilities and authority of specific personnel such as the CQA Inspectors and the SCR
- Review requirements of the CQA Program
- Inspection and verification testing methods, frequencies, and acceptance criteria
- A review of required documentation and operation of the on-site records system
- A discussion of the procedure for resolution of nonconformances and the responsibility of all personnel to bring attention to nonconformances
- A discussion of the procedure for change to design drawings and construction specifications and the means for review and approval.

4.1.2 Progress Meetings

Progress meetings will be held at the request of the SCR and should include, as appropriate, members of the of the Construction Contractor(s) personnel (including subcontractors), and the CQA personnel. Progress meetings will be documented in the form of meeting notes prepared by the CQA personnel. These notes will be maintained in the on-site construction and/or CQA records system.

The purpose of the progress meeting is to:

- Review activities and accomplishments
- Review the work location and activities for the week
- Identify the Construction Contractor's personnel and equipment assignments for the week
- Discuss any potential construction problems.

This meeting will be documented by a member of the CQA personnel.

4.1.3 Quality Resolution Meetings

Special meetings may be called by Owner, the Operator, the SCR, or the CQA Engineer to discuss activities adverse to construction quality and to define resolution. It is intended that these meetings be called to discuss quality problems that cannot be readily resolved, or those that continue to be ongoing or recurring.

The purpose of this meeting is to:

- Define and discuss the quality-related problems
- Review appropriate solutions
- Implement a plan to resolve any quality-related problems that have been defined.

Resolution of quality-related problems will be approved by the Operator and/or the SCR, as appropriate. A member of the CQA personnel will prepare meeting notes.

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5.0 Cover Infiltration Monitoring System

The MWL alternative cover will incorporate a redundant infiltration monitoring system that will include both baseline, neutron probe access holes and advanced, distributed fiber optics. Shallow vadose zone neutron probe access holes will be installed using Resonant Sonic drilling under separate contract.

In order to verify proper CQA, inspection checklists will be developed for use by CQA personnel. The checklists will be completed and signed by CQA Inspectors and will be reviewed by the CQA Engineer to ensure that construction was according to design drawings and construction specifications. The checklists will become part of the final construction report, documenting the CQA process throughout construction. Examples of the inspection checklists for installation of the fiber optics and neutron probe access holes are included in Attachment A of this plan. Attachment A inspection sheets may be modified as needed to enhance CQA.

5.1 Fiber Optics Cable Installation

The fiber optics cable will be installed in trenches excavated to a depth of 3 inches in the finished subgrade surface and in the third compacted native soil lift 1.5 feet above the subgrade surface as shown in the design drawings. The fiber optics cable will be hand-laid on the bottom of the excavated trench. The trench will be backfilled with excavated soil and campacted with hand-operated compaction equipment. The uppermost fiber optics cable will be transposed 90 degrees from the lower cable as shown in the design drawings.

5.1.1 Acceptance

Upon delivery of the fiber optics cable and associated materials to the site, the CQA Engineer will:

- Inspect delivery tickets to verify that the fiber optics cable meets construction specifications and that the measurements are consistent with those specifications
- Ensure that the fiber optics cable and all associated materials are not damaged in any way that would preclude their use for construction, including testing the optical integrity of the cable using a hand-held diode laser.

5.1.2 Observations and Inspections

CQA personnel will continuously perform the following observations and inspections during deployment:

- Inspect the trenches in which the fiber optics cable will be placed. Ensure that trenches are excavated in the appropriate layer or lift and in the appropriate configuration according to design drawings and construction specifications

- Inspect the prepared trenches for appropriate depth as detailed in construction specifications

- Observe that the trenches are free of deleterious material prior to placement of the fiber optics cable

- Inspect placement of the fiber optics cable in each trench. Ensure that the cable is not damaged and that it is deployed according to construction specifications

- Verify that trenches are backfilled with excavated soils and in such a manner as to prevent damage to the underlying fiber optics cable. Only hand-operated compaction equipment will be used to recompact soils in the trenches.

5.1.3 Laboratory Tests

No laboratory tests of the fiber optics trench backfill will be performed.

5.1.4 Field Tests

The optical integrity of the fiber optics cable will be tested by means of a hand-held diode laser upon placement in each layer and lift, and after compaction of excavated soils.

5.2 Neutron Probe Access Hole Construction

The cover will contain six vertical neutron probe access holes, two in each of the original disposal areas. Each access hole will extend through the cover and an additional two feet into original landfill soils. Access hole casing construction will be 2-inch-inside-diameter 6061-T6 aluminum. Aluminum casings will extend one foot above the final grade of the cover.

Access hole casings will be installed once cover construction is completed by hand-augering 2.5-inch-outside-diameter boreholes through the cover and driving the aluminum casing to proper depth. Each casing will be fitted with a tapered, perforated drive-tip. A 1-ft by 1-foot concrete pad will be placed at the surface around each casing collar to prevent preferential flow down the annulus.

5.2.1 Acceptance

Upon delivery of the aluminum neutron probe access casing to the site, the CQA Engineer will:

- Inspect delivery tickets to verify that the casing meets construction specifications and that the measurements are consistent with those specifications
- Ensure that the casing is not damaged in any way that would preclude its use for construction.

5.2.2 Observations and Inspections

CQA personnel will continuously perform the following observations and inspections during installation of the aluminum casings:

- Ensure that the neutron probe access holes are located according to construction specifications and will not intersect or damage underlying fiber optics cable
- Observe hand-augering of neutron probe access holes to ensure that the boreholes are drilled to the proper depth according to construction specifications
- Observe installation of the aluminum casing to ensure that installation is according to construction specifications
- Ensure that augered soils are returned to grade and compacted by hand-operated compaction equipment once the aluminum casing is installed
- Ensure that construction of the concrete pads and the locking top-caps for each of the neutron probe access holes are completed according to construction specifications
- Observe that the final locations and elevations of the neutron probe access holes are surveyed. The results of the survey will be retained for future use to prepare as-built drawings.

5.2.3 Laboratory Tests

No laboratory tests will be performed during construction of the neutron probe access holes.

5.2.4 Field Tests

To determine whether construction performance meets project requirements, field testing of soils directly below the concrete pad will be performed. Densities and/or moisture contents not conforming to the construction specifications will be removed and replaced or reworked to conform to those specifications.

The field tests include the following:

- Determination of the soil in-place density and moisture content by nuclear methods performed in accordance with ASTM D-2922 and ASTM D-3017. All holes resulting from nuclear gauge testing will be backfilled and hand-tamped.

6.0 Alternative Cover—Observations, Inspection Activities, and Tests

The alternative cover design for the MWL includes up to 40 inches of compacted subgrade; 2.5 feet of compacted native soil fill; and a maximum 8-inch, minimally compacted topsoil layer containing 25% by volume 3/8-inch crushed gravel. A fiber optics cable will be installed in the finished subgrade surface. A second fiber optics cable will be installed transverse to the lower cable in the third compacted native soil lift, 1.5 feet above the subgrade surface. The final cover will be seeded with native grasses, mulched and crimped. The layers of the alternative cover in descending order are as follows:

- A maximum 8-inch, minimally compacted topsoil layer containing 25% by volume 3/8-inch crushed gravel (ASTM Size #8)
- 2.5 feet of compacted native soil
- Up to 40 inches of compacted subgrade.

6.1 Earthwork

This section specifies the observations, inspections and tests necessary to control, verify, and document that the earthwork for the MWL alternative cover conforms to the design drawings and construction specifications.

Earthwork activities include:

- Clearing, grubbing, and compaction of existing MWL surface and perimeter
- Placement and compaction of subgrade fill
- Placement of fiber optics cable
- Placement and compaction of native soil layer fill
- Placement and minimal compaction of topsoil layer.

In order to verify proper CQA, inspection checklists have been developed for use by CQA personnel. The checklists will be completed and signed by CQA Inspectors and will be reviewed by the CQA Engineer to ensure that construction of the cover was according to design drawings and construction specifications. The checklists will become part of the final construction report, documenting the CQA process throughout construction. Examples of the inspection checklists for each phase of cover construction are included in Attachment A of this plan. Attachment A inspection sheets may be modified as needed to enhance CQA.

6.1.1 Existing Landfill Surface

The alternative cover will extend beyond the MWL fenced perimeter as shown in the design drawings. Appropriately, the existing surface and perimeter of the MWL will be cleared, grubbed, and compacted to provide a stable surface for the final cover and side slopes.

6.1.1.1 Observations and Inspections

CQA personnel will perform the following observations and inspections during the preparation of the MWL surface and perimeter:

- Ensure that the MWL surface and perimeter has been cleared of all vegetation, organic matter, rubble, trash, and deleterious material. Rocks larger than 2 inches will be removed
- Ensure that any loose or soft zones have been appropriately compacted.

6.1.1.2 Laboratory Tests

The Operator will provide archived laboratory data for use in preparation of the existing MWL surface and perimeter. The MWL is designated as a Radioactive Materials Management Area (RMMA) and a Soils Contamination Area (SCA). Soil samples from the existing landfill surface shall not be taken off-site.

6.1.1.3 Field Tests

In addition to performing the required observations and inspections, CQA personnel will perform the following field tests as required by the earthwork specifications:

- Determination of the soil in-place density and moisture content by nuclear methods performed in accordance with ASTM D-2922 and ASTM D-3017. Testing shall be performed at a minimum frequency of 5% of that done by the Construction Contractor. Plot and check all field density test locations and elevations. All holes resulting from nuclear gauge testing will be backfilled and hand-tamped.

6.1.2 Subgrade Fill

Subgrade fill will be obtained from the CAMU soil stockpile. Subgrade fill will bring the entire landfill surface to a uniform 2% grade. Subgrade fill will be placed in maximum 8-inch loose lifts to attain maximum 6-inch compacted lift thickness. Fill will be compacted to not less than 90% of maximum dry density at -2 to + 2 percentage points of optimum moisture content, as determined by ASTM D-698 (Standard Proctor testing). The subgrade will tie to the existing landscape to achieve a stable and functional slope.

6.1.2.1 Observations and Inspections

CQA personnel will continuously perform the following observations and inspections during construction of the subgrade:

- Inspect the fill to be used for construction of the subgrade. Fill will be obtained from the CAMU soil stockpile. Visual inspections of fill will be made by CQA personnel to detect the presence of organic matter, rubble, trash, and deleterious material. Any such material will be removed prior to use for construction. In addition, irreducible material in excess of 2 inches in diameter will be removed from subgrade fill

- Observe coverage and number of passes made by compaction equipment

- Verify that only hand-operated compaction equipment is used around monitoring wells and fiber optics trenches

- Inspect individual and final lift thickness

- Verify lines and grades of the completed subgrade.

6.1.2.2 Laboratory Tests

Laboratory tests of subgrade fill will be performed to document the engineering properties and to verify the acceptability of the fill for use in construction.

The laboratory tests will include the following:

- Standard Proctor moisture-density relation as determined by ASTM D-698 for each 500 cubic yards of fill, or more often if there is a change of material

- Gradation as determined by ASTM D-422, performed on each sample subjected to the Standard Proctor Test (one per 500 cubic yards), or when CQA personnel notice a change in material

- Classification as determined by ASTM D-2487, performed on each sample subjected to the Standard Proctor Test (one per 500 cubic yards), or when CQA personnel notice a change in material.

6.1.2.3 Field Tests

To determine whether construction performance meets project requirements, field testing of in-situ portions of the subgrade fill will be performed. Fill placed at densities and/or moisture contents not conforming to the construction specifications will be removed and replaced or reworked to conform to those specifications.

The field tests include the following:

- Determination of the soil in-place density and moisture content by nuclear methods performed in accordance with ASTM D-2922 and ASTM D-3017. Testing shall be performed at a minimum frequency of 5% of that done by the Construction Contractor. Plot and check all field density test locations and elevations. All holes resulting from nuclear gauge testing will be backfilled and hand-tamped.

6.1.3 Native Soil Layer

A 30-inch layer of native fill will be placed and compacted between the subgrade fill and the topsoil layer. Native fill will be placed in successive 8-inch loose lifts to attain maximum 6-inch compacted lift thickness. Fill will be compacted to not less than 90% of the maximum dry density at -2 to + 2 percentage points of optimum moisture content, as determined by ASTM D-698 (Standard Proctor testing).

6.1.3.1 Observations and Inspections

CQA personnel will continuously perform the following observations and inspections during construction:

- Inspect the fill to be used for construction of the native soil layer. Fill will be obtained from CAMU soil stockpile. Visual inspections of fill will be made by CQA personnel to detect the presence of organic matter, rubble, trash, and deleterious material. Any such material will be removed prior to use for construction. In addition, irreducible material in excess of 2 inches in diameter shall be removed from native soil layer fill

- Observe coverage and number of passes made by compaction equipment

- Verify that only hand-operated compaction equipment is used around monitoring wells and fiber optics trenches
- Inspect individual and final lift thickness
- Verify lines and grades of the completed native soil layer.

6.1.3.2 Laboratory Tests

Laboratory tests of the compacted native soil fill will be performed to document the engineering properties and to verify the acceptability of the fill for use in construction.

The laboratory tests will include the following:

- Standard Proctor moisture-density relation as determined by ASTM D-698 for each 500 cubic yards of fill, or more often if there is a change of material
- Gradation as determined by ASTM D-422 performed on each sample subjected to the Standard Proctor Test (one per 500 cubic yards), or when CQA personnel notice a change in material
- Classification as determined by ASTM D-2487 performed on each sample subjected to the Standard Proctor Test (one per 500 cubic yards), or when CQA personnel notice a change in material.

6.1.3.3 Field Tests

To determine whether construction performance meets project requirements, field testing of in-situ portions of the compacted native soil fill will be performed. Fill placed at densities and/or moisture contents not conforming to the constructions specifications will be removed and replaced or reworked to conform to those specifications.

The field tests include the following:

- Determination of the soil in-place density and moisture content by nuclear methods performed in accordance with ASTM D-2922 and ASTM D-3017. Testing shall be performed at a minimum frequency of 5% of that done by the Construction Contractor. Plot and check all field density test locations and elevations. All holes resulting from nuclear gauge testing will be backfilled and hand-tamped.

6.1.4 Topsoil Layer

A maximum 8-inch topsoil layer containing 25% by volume 3/8-inch crushed gravel will be placed on top of the native soil layer. Topsoil will be compacted to not less than 80 percent and not greater than 85 percent of maximum dry density at -2 to + 2 percentage points of optimum moisture content, as determined by ASTM D698 (Standard Proctor testing). Topsoil will be minimally compacted to provide a uniform, prepared surface for seeding and to facilitate root development.

6.1.4.1 Observations and Inspections

CQA personnel will continuously perform the following observations and inspections during construction:

- Inspect the topsoil to be used for construction of the topsoil layer. Topsoil will be obtained from borrow areas directly west of the MWL. Visual inspections of topsoil will be made by CQA personnel to detect the presence of organic matter, rubble, trash, and deleterious material. Any such material will be removed prior to use for construction. In addition, irreducible material in excess of 2 inches in diameter will be removed from topsoil
- Observe coverage and number of passes made by compaction equipment
- Verify that only hand-operated compaction equipment is used around monitoring wells
- Inspect final thickness
- Verify lines and grades of the completed topsoil layer.

6.1.4.2 Laboratory Tests

Laboratory tests of the topsoil layer will be performed to document the engineering properties and to verify the acceptability of the topsoil for use in construction.

The laboratory tests will include the following:

- Standard Proctor moisture-density relation as determined by ASTM D-698 for each 500 cubic yards of fill, or more often if there is a change of material
- Gradation as determined by ASTM D-422 performed on each sample subjected to the Standard Proctor Test (one per 500 cubic yards), or when CQA personnel notice a change in material

- Classification as determined by ASTM D-2487 performed on each sample subjected to the Standard Proctor Test (one per 500 cubic yards), or when CQA personnel notice a change in material.

6.1.4.3 Field Tests

To determine whether construction performance meets project requirements, field testing of in-situ portions of the topsoil layer will be performed. Topsoil placed at densities and/or moisture contents not conforming to the constructions specifications will be removed and replaced or reworked to conform to those specifications.

The field tests include the following:

- Determination of the soil in-place density and moisture content by nuclear methods performed in accordance with ASTM D-2922 and ASTM D-3017. Testing shall be performed at a minimum frequency of 5% of that done by the Construction Contractor. Plot and check all field density test locations and elevations. All holes resulting from nuclear gauge testing will be backfilled and hand-tamped.

6.1.5 Reclamation Seeding and Mulching

The topsoil layer will be seeded with native grasses in accordance with the construction specifications.

6.1.5.1 Acceptance of Seed

Following the delivery of the seed mix, the CQA Engineer will:

- Inspect the delivery ticket to verify that the quantity and type of seed supplied by the manufacturer is consistent with construction specifications.

6.1.5.2 Storage and Handling

CQA personnel will verify the following storage conditions:

- All seed will be stored in a cool area, free of moisture and water.

6.1.5.3 Observations and Inspections

CQA personnel will perform the following observations and inspections during seeding of the topsoil layer:

- Inspect the seed to ensure that it has been stored appropriately and has not rotted

- Verify that seeding takes place during favorable weather conditions (i.e., low winds)
- Verify that the appropriate application method is used
- Observe and verify that the application rate of soil additives and seed are in accordance with the construction specifications
- Survey lines and grades of the completed cover.

7.0 Monitoring Well MW-4 Extension

Monitoring well MW-4 will be extended such that the top of the PVC casing is located a minimum of 30 inches above the final grade of the constructed cover. MW-4 will be refitted to its original configuration, consisting of steel protective cover, locking top cap, and concrete pad. Protective stanchions will not be required.

7.1 Observations and Inspections

CQA personnel will continuously perform the following observations and inspections during construction:

- Ensure that the existing MW-4 concrete pad, protective steel stanchions, protective steel well casing cover and locking top cap are removed prior to cover construction
- Observe extension of the existing MW-4 PVC well casing. The well casing will be extended before cover construction commences
- Ensure that only hand-operated compaction equipment is used to recompact fill around the extended well casing as each lift is placed during cover construction
- Observe completion of the new concrete pad, protective steel well casing cover and locking top cap to ensure that construction is performed in accordance with construction specifications
- Observe that the final location and elevation of the top of the new PVC well casing and four corners of the concrete pad are surveyed. The results of the survey will be retained for future use to prepare as-built drawings.

7.2 Laboratory Tests

No laboratory tests will be performed during extension of monitoring well MW-4.

7.3 Field Tests

To determine whether construction performance meets project requirements, field testing of soils directly below the concrete pad will be performed. Densities and/or moisture contents not conforming to the construction specifications will be removed and replaced or reworked to conform to those specifications.

The field tests include the following:

- Determination of the soil in-place density and moisture content by nuclear methods performed in accordance with ASTM D-2922 and ASTM D-3017. All holes resulting from nuclear gauge testing will be backfilled and hand-tamped.

8.0 Nonconformance

Nonconforming items and activities are those which do not meet the design drawings, construction specifications, procurement document criteria, approved work procedures, or the CQA program.

Nonconformances may be detected and identified by:

- CQA personnel—during construction operations by field inspections and/or verification testing
- Laboratory personnel—during the preparation for and performance of laboratory testing and/or during calibration of equipment
- SCR—during the performance of audits, surveillances, and/or other CQA-related activities.

Each nonconformance affecting quality will be documented by the personnel identifying or originating nonconformance. For this purpose, the results of calibration and laboratory analysis quality control tests, audit reports, inspection reports, or an internal memorandum or letter can be used as appropriate. This documentation will be compiled by the CQA Engineer and documented in a Nonconformance and Corrective Action Report and submitted to the SCR.

This report will, when necessary, include:

- Description of nonconformance
- Identification of individual(s) identifying or originating the nonconformance
- Method(s) for completing corrective action and corrective action taken
- Schedule for completing corrective action and corrective action taken
- Responsible individuals for correcting the nonconformance and verifying satisfactory resolution.

Documentation will be available to the Owner, SCR, Construction Contractor, CQA Contractor, and/or subcontractor(s), as necessary. It is the responsibility of the CQA personnel to notify the appropriate personnel of the nonconformance. In addition, the SCR should be notified as soon as practical of nonconformances which could impact the results of the work.

CQA personnel, as part of future activities, should verify completion of corrective actions for nonconformances.

Any recurring nonconformance should be evaluated by the SCR, CQA Contractor, and/or testing laboratory to determine its cause and the appropriate changes instituted to prevent future recurrence. When such an evaluation is performed, the results will be documented.

9.0 Documentation

Compliance with the requirements of the construction specifications for the MWL cover will be documented throughout all phases of construction. Documentation will consist of records prepared by CQA personnel, the independent testing laboratory, the Construction Contractor, and any subcontractors.

9.1 Daily Summary Report

Whenever there is any construction activity, a daily summary report will be prepared. Other records required will depend on the specific work being performed that day.

The daily summary report will be prepared by the CQA Engineer, or under the direct supervision of the CQA Engineer. It will contain the following:

- The date
- A summary of the weather conditions
- A summary of locations where construction is occurring
- A list of personnel on the project
- A summary of any meetings held and attendees
- A description of all materials used and references or results of testing and documentation
- The certificates for calibration and recalibration of test equipment
- The daily inspection checklists from each CQA Inspector.

9.2 Inspection Checklists

Inspection checklists (Attachment A of this plan) will be reviewed by the CQA Engineer, and submitted to the SCR. The purpose of the checklists is to document all inspections performed by CQA personnel during construction activities.

At a minimum, each inspection checklist will contain the following information:

- The date and time of inspection
- The location
- Weather conditions
- The type of inspection
- The procedure used (e.g., ASTM method)
- Test data
- The results of the activity
- Personnel involved in the inspection and sampling activities
- The signature of the inspector.

9.3 Nonconformance and Corrective Action Reports

Whenever any material or workmanship does not meet the requirements of the construction specifications or has an obvious defect, the appropriate personnel will be notified and a Nonconformance and Corrective Action Report will be completed by the CQA Engineer. Additional information on nonconformance, corrective action, and the documentation thereof is presented in Section 7.0 of this Plan.

9.4 Field and Laboratory Test Reporting

Reports of all field and laboratory tests will be submitted to the CQA Engineer and SCR.

9.4.1 Field Test Data

The soil testing technicians will submit reports of all field tests and retests to the CQA Engineer and SCR as soon as possible upon completion of the required tests.

The reports may include, but are not limited to, the following:

- Date of the test and date submitted
- Location of test
- Weather
- Test method (ASTM or approved)
- Wet weight, moisture content, and dry weight of field sample (if required)
- Description of soil

- Ratio of field dry density to maximum lab dry density expressed as a percent (if required)
- Comments concerning the field density passing or failing the specified compaction
- Comments about results.

CQA Inspectors will record field test data on the appropriate inspection checklists or approved forms.

9.4.2 Laboratory Test Data

The independent testing laboratory will submit data reports of all laboratory tests to the CQA Engineer as soon as possible upon completion of the tests. The reports will include, but not be limited to, the following:

- Date of the test and date submitted
- Identification and description of sample tested
- Test method (ASTM or approved)
- Results of test.

9.4.3 Data Reports

Data reports from laboratory testing of soils will be reported by the independent testing laboratory using its customary reporting format and forms. Field test data will be reported on daily inspection checklists approved by the CQA Engineer.

9.5 Photographic Reporting

Any photographs used to document the progress and acceptability of the alternative cover construction may be incorporated into the daily summary report and the acceptance report.

Each photo will be identified individually as well as in a photograph log that contains the following information:

- The date, time, location, and direction of the photograph
- The name of the photographer.

9.6 As-Built Drawings

All records prepared by the CQA Contractor will be retained in the on-site records system to provide documentation of the cover construction. Final as-built drawings will be prepared by the

CQA Contractor utilizing this information and will be retained by the Owner as a permanent record of the final configuration and dimensions of the cover features (e.g., subgrade, fiber optics cable, neutron probe access holes, and final cover system). As-built drawings must be reviewed and approved by the CQA Engineer and the SCR.

9.7 Acceptance of Completed Components

Upon completion of the construction of the alternative cover, the CQA Engineer will prepare an acceptance report to submit to the Operator.

The acceptance report will contain the following:

- A certification by the CQA Engineer that the cover system has been constructed in accordance with the construction specifications
- As-built drawings
- All daily summary reports.

9.8 Final Documentation

When construction of the MWL alternative cover has been completed and the final inspection/punch list shows that all items have been resolved, a final report will be prepared for submittal to the NMED.

The final report will be certified as correct by the CQA Engineer and will contain the following:

- Daily summary reports
- Daily inspection checklists
- Nonconformance and corrective action reports
- Field test results
- Laboratory test results
- Photographs
- As-built drawings
- Internal CQA memoranda or reports with data interpretation or analyses
- Design changes.

9.9 Document Control

During construction of the MWL alternative cover, this CQA plan will be maintained by the SNL/NM ER Records Center under a document control procedure to provide for convenient replacement of pages. The revision status will be indicated on each page. A control scheme will be designed and implemented to organize and index all CQA documents so a reviewer can identify and retrieve original inspection reports or data sheets for any completed work.

9.10 Storage of Records

During construction of the MWL alternative cover, the CQA Engineer will be responsible for storage of all CQA documents such as:

- Design drawings
- Construction specifications
- CQA plan
- Inspection checklists (originals)
- Field test data reports (originals)
- Laboratory test data reports (originals).

Duplicate copies will be kept at another location as a safeguard in case the originals are damaged or lost. Once construction is complete, the originals will be transferred to a permanent records storage location.

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ATTACHMENT A
INSPECTION CHECKLISTS

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The inspection checklists contained in this attachment are provided for use by CQA personnel during construction of the MWL alternative cover. The format of the inspection checklists may be modified by the CQA Engineer; however, the revised inspection checklist must include all checks and information contained in the original form and meet the approval of the Operator. The inspection checklists will be completed and signed by CQA Inspectors and reviewed by the CQA Engineer. These checklists will become part of the final cover construction report documenting the CQA process throughout construction.

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List of Forms

Title	Form No.
RECEIVING INSPECTION	
Fiber Optics Cable	RI-01
Neutron Probe Access Hole Aluminum Casing	RI-02
Seed/Fertilizer/Mulch	RI-03
TESTING INSPECTION	
Existing Landfill Surface and Perimeter Field Test Form	TI-01
Subgrade Fill Field Test Form	TI-02
Native Soil Layer Fill Field Test Form	TI-03
Topsoil Layer Field Test Form	TI-04
Subgrade Fill Laboratory Test Verification Form	TI-05
Native Soil Layer Laboratory Test Verification Form	TI-06
Topsoil Layer Laboratory Test Verification Form	TI-07
Moisture/Density Field Test Results Form	TI-08
CONSTRUCTION INSPECTION	
Existing Landfill Surface and Perimeter Clear and Grub Field Form	CI-01
Subgrade Fill Field Form	CI-02
Native Soil Layer Fill Field Form	CI-03
Topsoil Layer Field Form	CI-04
Reclamation Seeding and Mulching Field Form	CI-05
Fiber Optics Cable Installation Field Form	CI-06
Neutron Probe Access Holes Construction Field Form	CI-07

CI-07
CONSTRUCTION INSPECTION FORM
NEUTRON PROBE ACCESS HOLE CONSTRUCTION FIELD FORM

Project Name ______________________________ Date ______________________________

Weather ______________________________ Inspected by ______________________________

Neutron Probe Access Hole ____

Compaction Equipment ____

(Provide explanatory notes if the answer to any of the following questions is "no." Include any remedial steps required.)

	YES/NO	NOTE NO.
Has the neutron probe access hole location been surveyed to verify that it will not intersect or damage fiber optics cable?	_______	_________
Has the neutron probe access borehole been augered to the proper depth?		
Is the correct aluminum casing being used for this neutron probe access hole?	_______	_________
Has the aluminum casing been driven to the proper depth?	_______	_________
Has the concrete pad and underlying soils been constructed to conform to construction specifications?	_______	_________

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RI-01
RECEIVING INSPECTION FORM
FIBER OPTICS CABLE

Project Name ________________________________

Date ________________________________
Received by ____________________________
Inspected by ____________________________

Type of Cable ____________________________
Transporter/Supplier ______________________
Linear Feet/Rolls Delivered ________________

Storage Location ________________________

	SPECIFICATION	MATERIAL RECEIVED	NOTE NO.
Manufacturer	____________	__________	_________
Manufacturer's designation	____________	__________	_________
Cable Length/Diameter	____________	__________	_________

(Provide explanatory notes if the answers to any of the following questions is "no." Include any remedial steps required.)

	YES/NO	NOTE NO.
Checks before unloading:		
Have delivery tickets been provided for all cables/rolls received?	_______	_________
Does the cable description match the construction specifications?	_______	_________
Does the cable diameter and length meet specifications?	_______	_________
Is the cable free of damage?	_______	_________
Has the optical integrity been checked?	_______	_________
Checks after unloading:		
Is the cable free of damage?	_______	_________
Is the cable properly stored?	_______	_________
Has the optical integrity been checked?	_______	_________
Is the storage area free of water and/or moisture?	_______	_________

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RI-02
RECEIVING INSPECTION FORM
NEUTRON PROBE ACCESS HOLE ALUMINUM CASING

Project Name ______________________

Date ______________________
Received by ______________________
Inspected by ______________________

Type/Number of Casings ______________________
Transporter/Supplier ______________________
Linear Feet Delivered ______________________

Storage Location ______________________

	SPECIFICATION	MATERIAL RECEIVED	NOTE NO.
Manufacturer	________	________	________
Manufacturer's designation	________	________	________
Casing Length/Diameter	________	________	________

(Provide explanatory notes if the answers to any of the following questions is "no." Include any remedial steps required.)

	YES/NO	NOTE NO.
Checks before unloading:		
Have delivery tickets been provided for all casing received?	______	________
Does the casing description match the construction specifications?	______	________
Does the casing diameter and length meet specifications?	______	________
Is the casing free of damage?	______	________
Checks after unloading:		
Is the casing free of damage?	______	________
Is the casing properly stored?	______	________

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RI-03
RECEIVING INSPECTION FORM
<u>SEED/FERTILIZER/MULCH</u>

Project Name ______________________	Date ______________________
	Received by ______________________
	Inspected by ______________________
Type of Material ______________________	Delivery Shipment No. ______________________
Transporter/Supplier ______________________	Storage Location ______________________
Number of Bags/Bales ______________________	

	SPECIFICATION	MATERIAL RECEIVED	NOTE NO.
Supplier	________	________	________
Supplier designation	________	________	________
Material	________	________	________

(Provide explanatory notes if the answers to any of the following questions is "no." Include any remedial steps required.)

	YES/NO	NOTE NO.
Checks before unloading:		
Have delivery tickets and QC certificates been provided for seed/fertilizer/mulch received?	______	______
Does the material description match the construction specifications?	______	______
Is the material free of damage?	______	______
Is the material acceptable for use?	______	______
Checks after unloading:		
Is the material free of damage?	______	______
Is the material properly stored?	______	______
Is the storage area free of water and/or moisture?	______	______

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TI-01
TESTING INSPECTION FORM
EXISTING LANDFILL SURFACE AND PERIMETER FIELD TEST FORM

Project Name ______________________ Date ______________________

Inspected by ______________________ Weather ______________________

Compaction Equipment ____

Surface area and location covered during shift ______________________________
____
____

(Provide explanatory notes if the answer to any of the following questions is "no." Include any remedial steps required.)

	YES/NO	NOTE NO.
Have in situ soil nuclear density and moisture content tests been performed?	_______	_________
Have field density test locations and elevations been plotted and checked?	_______	_________
Have the results of the in situ density and moisture content tests been performed in accordance with ASTM D-2922 and ASTM D-3017, and recorded on Form TI-08 "Moisture/Density Field Test Results Form?"	_______	_________
Have all holes from the soil nuclear density tests been backfilled with like material and hand-tamped?	_______	_________

NOTES:

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TI-02
TESTING INSPECTION FORM
SUBGRADE FILL FIELD TEST FORM

Project Name ______________________________ Date ___________________________________

Lift Number ______________________________ Inspected by ______________________________

Borrow Area ______________________________ Weather __________________________________

Compaction Equipment ____

Soil Description ____

____

____

Volume and location of soil placed during shift ____________________________________

____

____

Surface area and location covered during shift _____________________________________

____

____

(Provide explanatory notes if the answer to any of the following questions is "no." Include any remedial steps required.)

	YES/NO	NOTE NO.
Have in situ soil nuclear density and moisture content tests been performed?	_______	_________
Have field density test locations and elevations been plotted and checked?	_______	_________
Have the results of the the in situ density and moisture content tests been performed in accordance with ASTM D-2922 and ASTM D-3017, and recorded on Form TI-08 "Moisture/Density Field Test Results Form?"	_______	_________
Have all holes from the soil nuclear density tests been backfilled with like material and hand-tamped?	_______	_________

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TI-03
TESTING INSPECTION FORM
NATIVE SOIL LAYER FILL FIELD TEST FORM

Project Name ______________________ Date ______________________

Lift Number ______________________ Inspected by ______________________

Borrow Area ______________________ Weather ______________________

Compaction Equipment ______________________

Soil Description ______________________

____

____

Volume and location of soil placed during shift ______________________

____

____

Surface area and location covered during shift ______________________

____

____

(Provide explanatory notes if the answer to any of the following questions is "no." Include any remedial steps required.)

	YES/NO	NOTE NO.
Have in situ soil nuclear density and moisture content tests been performed?	_______	_________
Have field density test locations and elevations been plotted and checked?	_______	_________
Have the results of the the in situ density and moisture content tests been performed in accordance with ASTM D-2922 and ASTM D-3017, and recorded on Form TI-08 "Moisture/Density Field Test Results Form?"	_______	_________
Have all holes from the soil nuclear density tests been backfilled with like material and hand-tamped?	_______	_________
Have the saturated hydraulic conductivity tests been done at the specified frequency?	_______	_________

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TI-04
TESTING INSPECTION FORM
TOPSOIL LAYER FIELD TEST FORM

Project Name ________________________________ Date ______________________________________

Inspected by ________________________________ Weather ____________________________________

Borrow Area ________________________________

Compaction Equipment ____

Soil Description ____

____

____

Volume and location of soil placed during shift ____

____

____

Surface area and location covered during shift ____

____

____

(Provide explanatory notes if the answer to any of the following questions is "no." Include any remedial steps required.)

	YES/NO	NOTE NO.
Have in situ soil nuclear density and moisture content tests been performed?	_______	_________
Have field density test locations and elevations been plotted and checked?	_______	_________
Have the results of the the in situ density and moisture content tests been performed in accordance with ASTM D-2922 and ASTM D-3017, and recorded on Form TI-08 "Moisture/Density Field Test Results Form?"	_______	_________
Have all holes from the soil nuclear density tests been backfilled with like material and hand-tamped?	_______	_________

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TI-05
TESTING INSPECTION FORM
SUBGRADE FILL LABORATORY TEST VERIFICATION FORM

Project Name ______________________________ Date ______________________________

Inspected by ______________________________

Weather ______________________________

(Provide explanatory notes if the answer to any of the following questions is “no.” Include any remedial steps required.)

	YES/NO	NOTE NO.
Has the relationship between moisture content and density been analyzed by the Standard Proctor test in accordance with ASTM D698?	_______	_________
Has gradation been performed in accordance with ASTM D422?	_______	_________
Has classification been performed in accordance with ASTM D2487?	_______	_________

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TI-06
TESTING INSPECTION FORM
NATIVE SOIL LAYER LABORATORY TEST VERIFICATION FORM

Project Name ________________________________ Date ______________________________________

Inspected by ________________________________

Weather ______________________________________

(Provide explanatory notes if the answer to any of the following questions is "no." Include any remedial steps required.)

	YES/NO	NOTE NO.
Has the relationship between moisture content and density been analyzed by the Standard Proctor test in accordance with ASTM D698?	_______	_________
Has gradation been performed in accordance with ASTM D422?	_______	_________
Has classification been performed in accordance with ASTM D2487?	_______	_________

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TI-07
TESTING INSPECTION FORM
TOPSOIL LAYER LABORATORY TEST VERIFICATION FORM

Project Name ______________________________ Date ____________________________________

Inspected by ______________________________

Weather ____________________________________

(Provide explanatory notes if the answer to any of the following questions is "no." Include any remedial steps required.)

	YES/NO	NOTE NO.
Has the relationship between moisture content and density been analyzed by the Standard Proctor test in accordance with ASTM D698?	_______	_________
Has gradation been performed in accordance with ASTM D422?	_______	_________
Has classification been performed in accordance with ASTM D2487?	_______	_________

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TI-08
TESTING INSPECTION FORM
MOISTURE/DENSITY FIELD TEST RESULTS FORM

LOCATION SKETCH

Project Name:
Stockpile Area:
Borrow Area:
Type of Construction:
(landfill surface and perimeter, subgrade, native soil layer, topsoil layer)
Maximum Dry Density (pcf):
Optimum Moisture:

Test Number	Approximate Location			In Situ Dry Density (pcf)	Percent Compaction	In Situ Water Content (WC %)	Percent Water Content Variation	Soil Description
	North	East	Elevation					

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CI-01
CONSTRUCTION INSPECTION FORM
EXISTING LANDFILL SURFACE AND PERIMETER CLEAR AND GRUB FIELD FORM

ONE FORM PER SHIFT WHEN THIS WORK IS BEING DONE

Project Name ______________________________________ Date ____

Weather ____ Inspected by _________________________________

Compaction Equipment ____

Surface area and location covered during shift ____
____
____

(Provide explanatory notes if the answer to any of the following questions is "no." Include any remedial steps required.)

	YES/NO	NOTE NO.
Have all shrubs, grass, roots, and other vegetation been completely cleared and grubbed from the landfill surface and perimeter?	_______	_________
Has the landfill surface and perimeter been inspected to ensure that all loose or soft zones have been properly compacted?	_______	_________
Has the landfill surface and perimeter been inspected to ensure that it is free of all rocks greater than 2 inches in diameter?	_______	_________
Has the number of passes and the coverage of the compaction equipment been documented?	_______	_________

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CI-02
CONSTRUCTION INSPECTION FORM
SUBGRADE FILL FIELD FORM

ONE FORM PER SHIFT WHEN THIS WORK IS BEING DONE

Project Name ______________________________

Borrow Area ______________________________
Weather ______________________________

Date ______________________________
Inspected by ______________________________
Max Dry Density (pcf) ______________________________
Optimum Moisture (%) ______________________________

Compaction Equipment ______________________________

Fill Description ______________________________
____
____

Volume and location of soil placed during shift ______________________________
____
____

Surface area and location covered during shift ______________________________
____
____

(Provide explanatory notes if the answer to any of the following questions is "no." Include any remedial steps required.)

	YES/NO	NOTE NO.
Has all organic matter, rubble, trash, and deleterious material been removed from subgrade fill prior to use?	_______	_______
Has the prepared subgrade been surveyed for final grades to verify that it conforms to the construction drawings?	_______	_______
Have CAMU soils been determined to be suitable for subgrade fill?	_______	_______
Has approved fill been used during subgrade construction?	_______	_______
Has the subgrade been inspected to ensure that it is free of all rocks greater than 2 inches in diameter?	_______	_______
Has the number of passes and the coverage of the compaction equipment been documented?	_______	_______

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CI-03
CONSTRUCTION INSPECTION FORM
NATIVE SOIL LAYER FILL FIELD FORM

ONE FORM PER SHIFT WHEN THIS WORK IS BEING DONE

Project Name ________________________________ Date ________________________________
Lift Number ________________________________ Inspected by ________________________________
Borrow Area ________________________________ Max Dry Density (pcf) ____________________
Weather ________________________________ Optimum Moisture (%) ____________________

Compaction Equipment ____

Fill Description ____
____
____

Volume and location of soil placed during shift ____
____
____

Surface area and location covered during shift ____
____
____

(Provide explanatory notes if the answer to any of the following questions is "no." Include any remedial steps required.)

	YES/NO	NOTE NO.
Has the previous lift been surveyed for final grades to verify that it conforms to the construction specifications?	_______	_________
Have CAMU soils been determined to be suitable for native soil lifts?	_______	_________
Has approved fill been used during lift construction?	_______	_________
Has the lift been inspected to ensure that it is free of all rocks greater than 2 inches in diameter?	_______	_________
Has the number of passes and the coverage of the compaction equipment been documented?	_______	_________

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CI-04
CONSTRUCTION INSPECTION FORM
TOPSOIL LAYER FIELD FORM

ONE FORM PER SHIFT WHEN THIS WORK IS BEING DONE

Project Name ____

Date ____

Inspected by ________________________________

Borrow Area ____

Weather ____

Topsoil Description ____

____

____

Volume and location of topsoil placed during shift ____

____

____

Surface area and location covered during shift ____

____

____

(Provide explanatory notes if the answer to any of the following questions is “no.” Include any remedial steps required.)

	YES/NO	NOTE NO.
Has the previous lift been surveyed for final grade to verify that it conforms to the construction specifications?	_______	_________
Has the borrow topsoil been determined to be suitable for the topsoil layer?	_______	_________
Has the topsoil been admixed with 25% by volume 3/8-inch crushed gravel?	_______	_________
Has approved topsoil been used for topsoil layer?	_______	_________
Has the topsoil layer been inspected to ensure that it is free of all rocks greater than 2 inches in diameter?	_______	_________

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CI-05
CONSTRUCTION INSPECTION FORM
RECLAMATION SEEDING AND MULCHING FIELD FORM

ONE FORM PER SHIFT WHEN THIS WORK IS BEING DONE

Project Name ________________________________ Date ________________________________

Weather ________________________________ Inspected by ________________________________

Surface area and location covered during shift ________________________________
____
____

(Provide explanatory notes if the answer to any of the following questions is "no." Include any remedial steps required.)

	YES/NO	NOTE NO.
Has the cover surface been surveyed for final grade prior to placement of seed?	_______	_________
Has approved seed been used for seeding?	_______	_________
Has the cover surface been mulched and crimped after seeding?	_______	_________

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CI-06
CONSTRUCTION INSPECTION FORM
<u>FIBER OPTICS CABLE INSTALLATION FIELD FORM</u>

Project Name ______________________________ Date ______________________________

Weather ______________________________ Inspected by ______________________________

(Provide explanatory notes if the answer to any of the following questions is "no." Include any remedial steps required.)

	YES/NO	NOTE NO.
Has the lift surface been surveyed for final grade to verify that it conforms to the construction specifications?	_______	_________
Does trench depth conform to the construction specifications?	_______	_________
Does the trench grid conform to the construction specifications?	_______	_________
Has the fiber optics cable been placed in the trench to conform to the construction specifications?	_______	_________
Has the trench been compacted with hand-operated compaction equipment in accordance with construction specifications?	_______	_________

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