

68320

1. Report No.		2. Government Accession No.		3. Recipient's Catalog No.	
4. Title and Subtitle Environmental Factor Determination From In-Place Temperature and Moisture Measurements Under Arizona Pavements				5. Report Date	
				6. Performing Organization Code	
				8. Performing Organization Report No.	
7. Author(s) George B. Way Rowan J. Peters					
9. Performing Organization Name and Address Arizona Department of Transportation Materials Services (Research) 1745 West Madison Street Phoenix, Arizona 85007				10. Work Unit No. (TRAIS)	
				11. Contract or Grant No. <i>Interim Rpt.</i> <i>HPR 1-12(147)</i>	
				13. Type of Report and Period Covered	
12. Sponsoring Agency Name and Address					
				14. Sponsoring Agency Code	
15. Supplementary Notes					
16. Abstract <p>Arizona at present uses the AASHTO Interim Guide equations to determine thickness of structural layers (flexible and rigid) in the highway prism. Inputs to these equations are based on past experience and have been empirically developed. In the future Arizona intends to adopt a systems approach to design of both flexible and rigid pavements.</p> <p>As such several inputs including traffic, environment, construction, structural and maintenance will be needed. The long term (3-5 years) objective of this study is to quantify the environmental inputs and relate them to highway performance. The purpose of this phase of the study was to develop, test and install the sensors and instrumentation to implement a program to monitor moisture and temperature changes in and under the highway.</p> <p>The short term objective was accomplished thru the installation of monitoring equipment at 34 sites stratigically located about the state of Arizona. A schedule for collection of data (temperature, moisture and deflection) was established. Data collection via this schedule will continue into the future.</p> <p>As data is collected it will be analyzed for future incorporation into the design, construction or maintenance operations.</p>					
17. Key Words Pavement Design, Temperature, Moisture, Dynaflect, Monitoring, Environmental Factor			18. Distribution Statement		
19. Security Classif. (of this report)		20. Security Classif. (of this page)		21. No. of Pages	22. Price

## LIST OF FIGURES

### FIGURE

1	Nuclear Probe and Scaler	
2	Nuclear Depth Moisture Monitoring Sites	
3	Typical Access Tube Installation	
4	Typical Nuclear Moisture Measurement	
5	Drive Sampler Operation	
	Detailed Nuclear Site Descriptions as well as Test Results	
6	Sybil Road	I-10
7	Wilmot Road	I-10
8	Marana	I-10
9	Casa Grande	I-10
10	Williams Field	I-10
11	Tonopah	I-10
12	Deer Valley	I-17
13	Lake Pleasant	State Route 74
14	Agua Fria	I-17
15	Sunset Point	I-17
16	Cherry Road	I-17
17	Cienega Creek	State Route 169
18	Sedona	I-17
19	Kachina Blvd.	I-17

LIST OF FIGURES (Continued)

FIGURE

20	Bellemont	I-40
21	Woody Mountain	I-40
22	Winona	I-40
23	Winslow Bypass	I-40
24	Minnetonka	I-40
25	Dead River	I-40
26	Crazy Creek	I-40
27	Timer and Relay Board	
28	Power Supply and Excitation	
29	Location of Recording Sites	
30	Typical Recording Site Installation	
	Detailed Recording Site Descriptions as well as Test Results	
31	Alpine	U.S. 180
32	Ash Fork	I-40
33	Avondale	U.S. 80
34	Benson	I-10
35	Cosnino	I-40
36	Cutter	U.S. 70
37	Flagstaff Airport	I-17
38	Gila Bend	I-8

LIST OF FIGURES (Continued)

FIGURE

39	Lupton	I-40
40	Show Low	U.S. 60
41	Tempe Bridge	U.S. 60
42	Topock	I-40
43	Minnetonka	I-40
44	Typical Temperature Calibration Curve	
45	Typical Moisture Calibration Curve	

## TABLE OF CONTENTS

	PAGE
Introduction	1
Nuclear Moisture Measurement	3
Site Selection	4
Nuclear Depth Moisture Installation	5
Laboratory Testing	8
Monitoring of Nuclear Sites	10
Continuous Monitoring of Moisture and Temperature Recording Sites	12
Equipment Selection	13
Initial Field Installation	15
Laboratory Calibration	17
Final Installation of Equipment	19
General Discussion of Overall Project	21
Future Research	21
Acknowledgements	21
Implementation	22
References	24

## LIST OF TABLES

### TABLE

- |     |  |
|-----|--|
| I   | Nuclear Site General Description                     |
| II  | Dynaflect and Mays Meter<br>Values for Nuclear Sites |
| III | Recording Site General Description                   |
| IV  | Dynaflect and Mays Meter<br>Values for Nuclear Sites |

LIST OF ABBREVIATIONS AND SYMBOLS

ACFC	Asphaltic Concrete Finishing Course
AC	Asphaltic Concrete
BMS*	Bituminous Mixed Surfacing Base materials mixed with asphalt. Mixed and placed with a blade.
BTB*	Bituminous Treated Base Base material mixed with asphalt in a hot plant.
BPM*	Bituminous Plant Mix Mineral aggregate mixed with asphalt. Old term for asphaltic concrete.
BSB*	Bituminous Stabilized Base Base material penetrated with asphalt.
CTB	Cement Treated Base Mineral aggregate or soil mixed with 4 to 5 percent cement.
AB	Aggregate Base Graded aggregate. Graded about the maximum density line.
SM	Select Material Aggregate composing the subbase layer. Not graded as closely as AB.
SGS	Subgrade Seal Generally sand. This material used to seal clay from pumping into subbase or base.
SS	Same as subgrade seal.
BORROW	Material found along alignment used to build embankment.

\*Pre-1960 Terminology

N.G.	Natural Ground
$Q_c$	Centerline of Highway
LL	Liquid Limit from Atterburg Test
PL	Plastic Limit from Atterburg Test
PI	Plasticity Index
C	Cohesion Value from Shear Test
$\phi$	Internal Friction Angle of Soil from Shear Test.
$\sigma$	Overburden Load Calculated from Wet Density of Layers
$\tau$	Shear Strength of Soil

## FINAL REPORT

HPR 1-12 (147)

### Introduction

Arizona at present uses the AASHO Interim Guide (1) equations to determine thickness of structural layers (flexible and rigid) in the highway prism. Inputs to these equations are based on past experience and have been empirically developed. In the future Arizona intends to adopt a systems approach to design of both flexible and rigid pavements. Various systems for design and management have been proposed by Monismith, Hudson and Deacon (2), NCHRP 139 (3) and HRB Special Report 126 (4) to name a few. All of these systems call for several inputs including traffic, environment, construction structural capacity and maintenance schedule. The long term (3-5 years) objective of this study is to quantify the environmental inputs and relate them to structural characteristics. The purpose of this phase of the study was to develop, test and install the sensors and instrumentation to implement a program to monitor moisture and temperature changes occurring in an under the highway.

To perform the above task a general research plan was adopted. This plan involved the use of existing temperature and moisture

measuring devices. A review of the literature indicated a need to distinctly monitor the moisture and temperature changes in the subgrade material, base and surfacing layers. As such, a two part program was adopted. One part of the research would concentrate on the moisture changes of subgrade materials. Past literature (5) indicated that the nuclear depth moisture probe was quite well suited for this purpose. Part two of this research involved the measurement of temperature and moisture in all structural layers down to the top one foot of subgrade. Previous literature (4), (6) had indicated that each structural layer down to subgrade could be greatly influenced by both moisture and temperature. Such influences indeed could even be expected on an hourly basis, therefore warranting a continuous recording type apparatus. A one channel strip chart recorder with a custom made timer and switching unit was selected to perform the continuous recording. Resistivity devices were chosen for measuring moisture and thermistors for temperature. The following text will recount the specific work done to accomplish the installation of the necessary equipment for both the nuclear depth moisture monitoring and daily recording of temperature and moisture in each structural layer down to subgrade.

## Nuclear Moisture Measurement

The nuclear moisture measurement method has been in use for some time. Previous reports (5), (7), have documented the use of available equipment. The Haliburton report (5) in particular was followed quite closely in this study. The purpose of using the nuclear depth moisture equipment would be to study the long term moisture fluctuations of primarily subgrade materials two feet or more below the pavement surface.

Nuclear depth moisture probes were used in this study. Fast neutrons emitted by the radioactive source in the probe are moderated (thermalized) by the hydrogen in the soil moisture. Some of the thermalized neutrons reach the detector tube in the probe and are sensed, thus providing a measurement of in-situ moisture (5), (8). Both probes and scalers (Troxler Model 1255 Nuclear Depth Moisture Systems) (Figure 1) were provided with calibration curves supplied by the manufacturer. Tests by the Arizona Department of Transportation proved these curves to be substantially correct. The nuclear device, however, is subject to errors due to varying materials, density or chemical composition to name a few. Also boundry effects such as being too close to the surface and field installation can cause error.

With these restrictions in mind the nuclear probe appeared best suited for subgrade type deposits.

### Site Selection

Twenty sites across the state were selected as nuclear moisture monitoring locations, Figure II. Sites were selected to represent a cross-section of materials and climate in Arizona. Subgrade materials included cemented sand and gravels, silts, clays and dessicated clays. Air temperatures range from summer highs of 110°F or more in the southern desert to lows of -30°F in the mountains during the winter. Rainfall varies from 4 inches to 25 inches. Both flexible and rigid pavements were selected as well as a few uncovered grade and drain locations. Some sites have irrigation on both sides of the highway. Since nuclear measurements need to be conducted out on the highway by trained personnel, traffic control became a major factor in site selection. All pavement sites are straight (one mile site distance), flat (less than 2% grade) and located on divided interstate highways. Table I gives the site location by the name of the nearest landmark, mile post number, station number and construction project number. Besides this some additional information is given. This includes the elevation in feet (Meters), nearest weather station,

geology (12), topography, vegetation (13), drainage (14) and date built. Following site selection acquisition of materials began.

#### Nuclear Depth Moisture Installation

After purchasing necessary equipment installation began. At each site attempts were made to install four ten foot long, 2 inch outside diameter by 1.90 inch inside diameter class 150 aluminum tubes. Tube type and dimensions were suggested by the manufacturer of the nuclear depth moisture gauge (8). Tubes were to be installed in the shoulder or median, distress, travel and passing lanes at each site. In some cases it was not possible to install 10 foot long tubes in each position across the road. This was due to problems in drilling caused by rocks. Drilling through the pavement and base materials was accomplished by using a 6 inch auger with multi-purpose head driven by a B-30-SH Mobil Drill Rig. Beneath the base layers either a 2 inch or 4 inch auger was used. To determine whether a 2 inch or 4 inch auger should be used an exploratory 6 inch hole was drilled. For damp or wet fine material generally a 2 inch auger could be used. If rock was encountered during the exploratory drilling or the material was very dry a 4 inch Mobile Hex-Core auger with

multi-purpose head was used. As drilling proceeded samples at 2 foot intervals beneath the base course were taken for nuclear gauge calibration. This sampling was accomplished by drilling two feet into subgrade then removing the auger. Sample material was removed off the auger and placed in two clean smooth sided 8 ounce tins. Each tin was marked and sealed with tape for future testing.

After the hole had been drilled to 10 feet or as deep as possible up to 10 feet, an aluminum tube of appropriate length was placed in the hole. Each tube was sealed at the bottom by using a 2 inch cork. The 2 inch auger holes generally gave a neat tight fit for the aluminum tubes. For 4 inch auger holes excess cuttings out of the hole at 2 foot intervals were stored in plastic bags and then poured around the tube and tamped in place. Tamping was accomplished by using a long 1/2 inch steel rod with a flat foot attached to the end. Material was dropped down the hole and tamped in place about the pipe. After tube placement a 4 inch diameter by 12 inch high sewer pipe cleanout was seated around the tube and grouted flush with the pavement. A brass cap neatly covered the hole. Figure 3 shows a diagrammatic representation of a typical access tube installation.

After tubes had been installed and cleanouts were in place, calibration using the nuclear probe began. Nuclear calibration was achieved by first taking a standard count. This generally involved about 20 one minute readings in order to achieve the manufacturers suggested reliability range. After standardization the nuclear probe was dropped down the tube 2 feet into the subgrade and three readings were taken. Readings were taken at 2 foot intervals under the base to the bottom of the tube (Figure 4). The average of the three readings were computed into volume percent moisture using the manufacturers calibration curve. These volume percent moistures were correlated to the sample oven dry moistures later obtained by test. It was assumed that the nuclear percent moisture would be zero at zero percent oven dry moisture. With these two points a straight line with the formula  $\% \text{ moisture by weight} = 0 + \text{slope of line times } \% \text{ moisture by volume}$ . This afforded an easy and accurate means of correlation. In addition, since the nuclear gauge measures percent moisture by volume drive samples were also taken to determine the moisture density relations of the subgrade material to a depth of 4 feet (1.219 meters). Drive sampling was accomplished by using a Dames and Moore Split Ring sampler (Figure 5). This device was driven with a 140 lb. drop hammer to a nominal

depth of 18 inches (.4572 meters). From the samples two five ring (ring one inch high (.0254 meters) by two inch (.0508 meters) diameter) samples were recovered, placed in individual plastic bags and sealed inside fitted aluminum canisters for future laboratory testing.

Because of the flimsy nature of the two inch auger installation of nuclear sites was slower than expected. On numerous occasions the auger was bent or broken. Aluminum tubes needed to be thoroughly cleaned out and checked for dents before transport to a site. When thorough inspections were not made serious problems involving the hanging up of the dummy probe in the tube were encountered. Drive samples could only be taken when the soil was damp and had some cohesion. Dry, cohesionless soils generally fell out of the sampler.

#### Laboratory Testing

Samples taken during site installation were tested to determine moisture as well as various index and strength properties. The two eight ounce tins of soils taken at each two foot depths were oven dried to constant weight at 140°F (60° Celsius). This was done so that soils could be tested for Atterburg limits and grading. Tests performed included Arizona 204, 206, 207 (16)

which are modifications of AASHTO T87, T89, T90 (17) respectively.

Drive samples taken at selected sites were used to determine wet and dry density. In addition where applicable a set of shear tests were run on the one inch high ring samples. Tests were run in a Soil Test constant strain direct shear device, Model D 120. Samples were run at their natural density and moisture. Surcharge loads of 784 Lbs/Ft<sup>2</sup> (37538.12 Pa), 1568 Lbs/Ft<sup>2</sup> (75076.25 Pa) and 2352 Lbs/Ft<sup>2</sup> (112,614.37 Pa) were used to perform the test. A constant shear rate of .099 inch/minute (.00003810 m/s) was applied and strains were measured using Ames dials. Readings were taken at every .010 inch (.00254 m) up to failure or .200 inch (.00580 m) whichever came first.

After testing was completed, data was accumulated and assembled into a final form. Figures 6 thru 26 contain all information derived for each site installation including site number, name and highway locations and date of test. A cross sectional view is shown of each site and thicknesses of each layer are drawn to scale. Cross slopes and tube locations in the cross section are actual locations. Oven dry moistures representing the average of two tests taken at two foot intervals are underlines. Dry densities are shown for each layer. Some

of these densities are assumed, others were actually determined via the drive sample testing and are so marked. From these two values (dry density and moisture) degree of saturation could be determined by assuming an appropriate true specific gravity. As such a true specific gravity of 2.65 was used due to the silicious nature of the soil. In a few of the sites a 2.70 specific gravity was used to reflect the limestone aggregate present. Degree of saturation is shown in parentheses beside each moisture content. Also shown on the figures are results of tests for liquid limit, plastic limit, plasticity index as well as percent passing the 3/8, No. 4, No. 40 and 200 sieves. These values represent the average of three test results except where otherwise noted. Where shear tests were run results are shown as cohesion and friction values (C and  $\phi$ ). Overburden weights were calculated from the thickness and wet density of each layer.

#### Monitoring of Nuclear Sites

After all nuclear sites had been installed a monitoring program began. This program involved the nuclear determination of moisture at two foot depths once every other month. This schedule involves readings in January, March, May, June, August, October and December. In addition to moisture readings, deflect-

ion tests are also performed in the months of January, March, May, August and October.

The schedule of readings is intended to coincide with the climatic conditions generally typical of Arizona. That is:

January	Cold; wet or frozen dependent on location in State.
March	Cold; wet and thawing.
May	Warm; dry.
June	Hot; dry.
August	Hot; middle of monsoon rainy season.
October	Cool; dry.
December	Cool to cold; rain and snow.

Additional readings may be taken depending on the availability of the equipment. Roughness values as measured by the Mays Meter are obtained once a year as a part of Arizona's annual pavement evaluation program (18). Initial values for each site are shown on Table II. Besides these performance tests, samples (cores) of asphaltic concrete (AC) were taken for physical and chemical tests. Typical tests on AC include bulk density, voids analysis, viscosity and Rostler analysis

as per Arizona Report 4 (20). Cores are being tested by the University of Arizona for elastic modulus values (19).

Continuous Monitoring of Moisture and Temperature Recording Sites

Moisture monitoring was intended to reflect the changes in moisture from surfacing to subgrade. Unfortunately changes in surface moisture or base layer moisture cannot be measured with accuracy with the nuclear depth moisture gauge due to geometrical (layer thickness) constraints. In addition to this moisture changes in the upper layers of the highway structure probably change very rapidly with rainfall. Therefore some continuous moisture measurement method was needed for the upper part of the pavement structure. The moisture monitoring system selected for those layers from top of subgrade to surfacing involved the use of sensors compatible with recording equipment. The intended system would involve placement of temperature and moisture sensors in the wheel path of the travel lane at selected locations. Sensors would be connected to suitable timing and recording equipment to allow the recording of each sensor once every four hours. Recorded data would be converted to punch cards for computer conversion into temperature and moisture values.

### Equipment Selection

Before any temperature or moisture sensors were purchased a cursory literature review was performed. This review indicated several sensors were commercially available.

The reviewed literature advised use of either thermocouples or thermistors to measure temperature. Both sensors were tested with available highway department instrumentation. For this study thermistors were selected to measure temperature. Other researchers (9), (10) had indicated good success with thermistors. These devices are economical, durable and easily interfaced with common recording equipment. Thermistors selected for this study were disk type Fenwal Electronics Model JA41J1.

These thermistors were soldered to 25 foot leads. Soldered joints and thermistors were encased in epoxy to protect them from damage as well as shorting.

The literature review (11) advised use of several different sensors including gypsum blocks or fiberglass blocks. Both these devices were tested in this study and later used at actual moisture monitoring sites.

Fiberglass blocks used were from Soil Test #MC-314 and the

Gypsum blocks were as provided by Beckman Instrument, Inc. Both devices work on a resistivity principle; that is the materials specific conductive capacity and its dielectric losses vary with the amount of moisture it contains. Devices come with five foot leads and it was necessary to extend the leads to 25 feet with a soldered joint. Soldered joints were coated with sealer and taped over with electrical tape. The instrumentation finally arrived at involved use of an inexpensive, rugged, accurate one channel strip chart recorder Rustrak Model 288 and a small inexpensive custom made timer and switching unit. The recorder is a model 288, 0-10 millivolt and holds 63 feet of chart paper. The paper is driven at one foot per hour or about 3/8" per each two minute channel.

The timer switching unit is designed to allow 0-6 volt DC excitation for the thermistor. In order to properly excite and read the moisture gauge a square wave signal of one hertz was necessary. Such a signal is generated in the timer. The amplitude is variable and can be set from 0-12 volts peak to peak. Besides the excitation the timer would need to turn on the recorder once every four hours and pole 16 channels (8 DC and 8 AC) for two minutes each. All of these design features were achieved for a nominal price. Total cost of both the

recorder and timer amounted to approximately \$370. Wiring diagrams of the recorder and timer units are shown in Figures 27 and 28.

### Initial Field Installation

While work on the construction of timers continued, recording sites were selected. These sites were selected to represent the different materials and climates in Arizona. In addition an urban curb and gutter and irrigation section were included. Due to the need for power, available traffic counting locations were selected. These locations offered not only power but also hourly traffic counts. Figure 29 shows locations of recording sites in Arizona. Table III gives the site location by name of the nearest landmark or city, milepost number and station number used in construction, noted construction project. Additional information includes elevation, nearest weather station, geology (12), topography, vegetation (13), drainage (14) and date built.

Following site selection work on initial field installation could begin. This initial work was aimed at preparing the site for the future installation of sensors and recording equipment. Sensors and recording equipment would be placed following

moisture sensor calibration performed with material sampled from the recording site.

At each site a traffic control cabinet was mounted on a power pole and electrical outlets installed inside the cabinet. A one foot wide trench was dug from power pole to the roadside. This distance averaged 70 feet. Likewise, a 6 inch trench was cut in the pavement out into the travel lane right wheel path. A two inch PVC conduit with a 23 twisted pair Belden cable was placed in the trench from the cabinet to the roadside. At or near the roadside a concrete pull box was installed to protect the cable connections. From the pull box the two inch PVC conduit was placed in the prepared trench in the highway. No sensors or wires were placed in the conduit at this time. For now the conduit was plugged and covered with AC cold patch which was compacted in place. In some cases two conduits were placed in the highway, this was done to accomodate any additional instrumentation at some future time. Figure 30 shows a typical recording site installation. After all trenches had been filled and compacted an additional three foot square hole was made in the travel lane. This hole or pit was used to perform an in-place density test. A volumeter moisture-density test (Ariz. Test 231a, modification of AASHTO T 205) was performed on each layer

of material under the pavement to a maximum depth of 30 inches. Due to hole size limitation, 30 inches was as deep as was practical. Samples were taken from each layer and tested for grading Atterburg Limits and moisture content (Ariz. Tests 201, 202, 203, 204, 205, 206, 207 tests are modifications of AASHTO T27, T11, T87, T89, T90). Additional sample material from each layer was taken for purposes of moisture sensor calibration. Figures 31 - 43 show site cross section and test results.

#### Laboratory Calibration

Moisture sensor calibration involved use of soil samples taken from each site during conduit placement. Soil samples were oven dried and placed in one gallon cement cans. Distilled water was added to the dried soil, to bring the moisture content to three percent moisture. Moisture sensors were then placed in the wet soil, Figure 42. Wires were run through the lids of the can and sealed. The sensors were allowed 24 hours to equilibrate. After 24 hours the sensors were attached to the timer and recorder. Readings were taken at 2, 4 and 6 volts RMS AC. Moisture was added at two percent increments to the soil. In many cases it was necessary to thoroughly mix the

soil and water in order to achieve uniform distribution. Readings were taken and recorded as before until saturation. Readings were plotted on linear paper with percent moisture versus chart reading. Typically these curves were of a half power shape (Figure 43). For very rocky materials and cinders, curves took on unusual shapes. This was probably due to problems in contact between sensor and soil. That is, if contact could not be achieved the moisture sensor became a humidity device and in so doing lost much of its resolution. The gypsum blocks were tried on several soils and generally found incompatible with the instrumentation. Gypsum blocks acted like sponges when placed in the presence of any free water. Indeed in several soils only 3 percent moisture was necessary to eliminate the resolution of the sensor. Fiberglass sensors generally gave good resolution over a large moisture range. Indeed fiberglass sensors responded so much better than the gypsum that gypsum blocks were placed at very few sites.

Calibration of thermistors involved use of epoxy encased devices attached to 25 foot leads. Leads were attached to the timer and the DC voltage adjusted to 2, 4 or 6 volts. Thermistors were placed in a constant temperature bath Forma Scientific Model #2095 ( $\pm .02^{\circ}\text{C}$ )  $35 - 120^{\circ}\text{F}$ . The bath was set to five

different temperatures and the millivolt output recorded in terms of divisions of chart period. Temperature versus division of chart paper were plotted on log log paper to give a straight line, Figure 44. A computer best fit regression line using a Wang Model 700A was computed. Such regression lines were used to extrapolate lines for in between voltages. In most instances three separate voltages were not needed due to linearity of the devices. After thermistor calibration, devices were logged and set aside for future use in the field.

#### Final Installation of Equipment

After calibration for temperature and moisture was completed work on final installation of recording sites began. This work involved coring a hole in the roadway at the end of the conduit. Moisture and temperature sensors previously calibrated and marked were placed in each layer beneath the pavement. Moisture sensors were stored and placed at a moisture consistent with previous test results on samples taken at each site. By doing this, errors in calibration due to different materials could be reduced. As sensors were placed, soil was carefully backfilled about them and tamped in place. Lead wires were straightened and taped into a braid. The braid was fished through the conduit to a previously installed pull box. Lead wires were paired with the 23 pair

cable and color chart of sensors of timer constructed. Wires were connected with a physical quick connect and coated with a sealer to prevent shorting. In the cabinet all 16 channels were connected to the timer. AC and DC voltages were set at appropriate excitations in order to get maximum resolution. Recordings were checked frequently during the first few days. Generally if problems occurred in timing or recording they occurred very early in operations. Once all devices were functioning properly the recording operation was continued for a three week period.

Three week tapes were brought back from the recording site and coded. Coded information was stored in punch card form for future run through the computer and decoding into temperature and moistures.

Besides measuring temperature and moisture, performance tests are also performed at each site. These tests include Mays Meter (roughness) and Mu-Meter (skid resistance) once a year. In addition dynaflect readings are taken in January, March, May, August and October. Values from these tests are shown in Table VI.

In general installation of recorder sites were slowed by need to design and build a suitable timing device. Actual field

installation was slowed by logistics of each recording site.

### General Discussion of Overall Project

In summary, it should be remembered the purpose of this study was to develop, test and install the sensors and instrumentation to monitor temperature and moisture over a long period of time. This project has substantially accomplished the above task. In all 21 nuclear depth moisture sites and 13 daily recording sites have been built and are functioning.

In addition valuable material characteristic information was obtained from each site.

### Future Research

Monitoring of all sites will continue as per the reported schedule as stated above. Sites will be used in cooperative research aimed at the long term objective. In addition to all this work other physical properties will be monitored on a selected basis. This includes pore pressure, stress and strain at selected sites.

### Acknowledgements

Thanks is given to Marshall Christenson, Walter Chase, of

Materials Services, personnel in all Arizona Districts and many more areas in the Arizona Department of Transportation who cooperated in the completion of this study.

### Implementation

All the work performed and results obtained from this study are part of a larger program aimed at determining the valuable information necessary for the design and rehabilitation of pavements in Arizona. This large program includes testing of cores taken at selected sites. Cores are tested for fatigue and E modulus values. Testing is being performed by Dr. Jimenez as part of his project "Structural Design of Asphalt Pavements" HPR 1-12 (142). Dynaflect readings are also being supplied to Dr. Jimenez as part of this project. Research on AC design will be complimented by future research at selected sites which will involve testing of the highway structure and subgrade materials via use of plate bearing and Mennard pressuremeter. This work will be done through another HPR study. All of this work at selected sites as well as site information is aimed toward utilization in a pavement management system.

The techniques and skills involved in installing and monitoring nuclear and recording sites has in the course of the past year been utilized in other research projects. These

projects included a pre-construction study of use of electro-osmosis, and an HPR electro-osmosis study (HPR 1-11 (142)).

Both these studies utilized the nuclear depth moisture equipment.

In the future recording equipment will provide information on depth of freezing in northern Arizona.

REFERENCES

1. "AASHO Interim Guide for Design of Pavement Structures 1972".
2. "Structural Design of Asphaltic Concrete Pavements to Prevent Fatigue Cracking", Highway Research Board Special Report 140, 1973.
3. "Flexible Pavement Design and Management Systems Formulation", Hudson, W.R. and McCullough, B.F., Materials Research and Development, Inc., NCHRP 139, 1973.
4. "Structural Design of Asphalt Concrete Pavement Systems", Proceedings of a Workshop Held December 7-10, 1970, Austin, Texas, HRB Special Report 126.
5. "Subgrade Moisture Variations", Haliburton, T. Allan, Oklahoma Research Program, Project 64-01-3, August 1970.
6. "Theoretical Evaluation of the Effect of Temperature on the Fatigue Behavior of Bituminous Road-Bases", Nunn, M.E., Transport and Road Research Laboratory Department of the Environment, TRRL Report LR 594.
7. "The Nuclear Method of Soil-Moisture Determination at Depth", Ehlers, Clarence J., et al, Texas University, Austin, Texas, June 1969, PB 194-749.
8. "Instruction Manual Depth Moisture Gauge", Troxler Electronic Laboratories, Inc., Raleigh, North Carolina.

9. "Temperature Instrumentation for Indiana's Thermally Insulated Test Road", Walsh, H.R.J., Highway Research Record Number 429, 1973.
10. "The Response of Asphalt Pavements to Low Temperature Climatic Environments", Christison, J.T. and Anderson, K.O., Third International Conference on the Structural Design of Asphalt Pavements, Volume I, Proceedings 1972.
11. "Instrumentation for Measurement of Moisture", Ballard, L.F., NCHRP 138, 1973.
12. "Arizona Materials Inventory" for each county in Arizona, Arizona Highway Department, Materials Division.
13. "Southwestern Trees, A Guide to the Native Species of New Mexico and Arizona" Agriculture Handbook Number 9, U.S.D.A. Forest Service by Little, Elbert L., Dec. 1950.
14. "Hydrologic Design for Highway Drainage in Arizona", Arizona Highway Department, Bridge Division by Jencsok, Eugene I., March 1969, Page 44a.
15. "Arizona Climate 1931-1972", by Sellers, William D. and Richard H. Hill, The University of Arizona Press, Tucson, Arizona.
16. "Materials Testing Manual", Arizona Department of Transportation
17. "Highway Materials, Part II, Tests", AASHTO.

18. "Proceedings of the Eleventh Paving Conference", The University of New Mexico, Pavement Evaluation in Arizona, by Allen, G.J., January 10-11, 1974.
19. "Structural Design of Asphalt Pavement", by Jimenez, R.A., Arizona Highway Department, AHD-RD-10-142, May 1973.
20. "Asphalt Cement Durability and Aggregate Interaction", Rowan J. Peters, Arizona Highway Department, Research Report 4, April 1973.

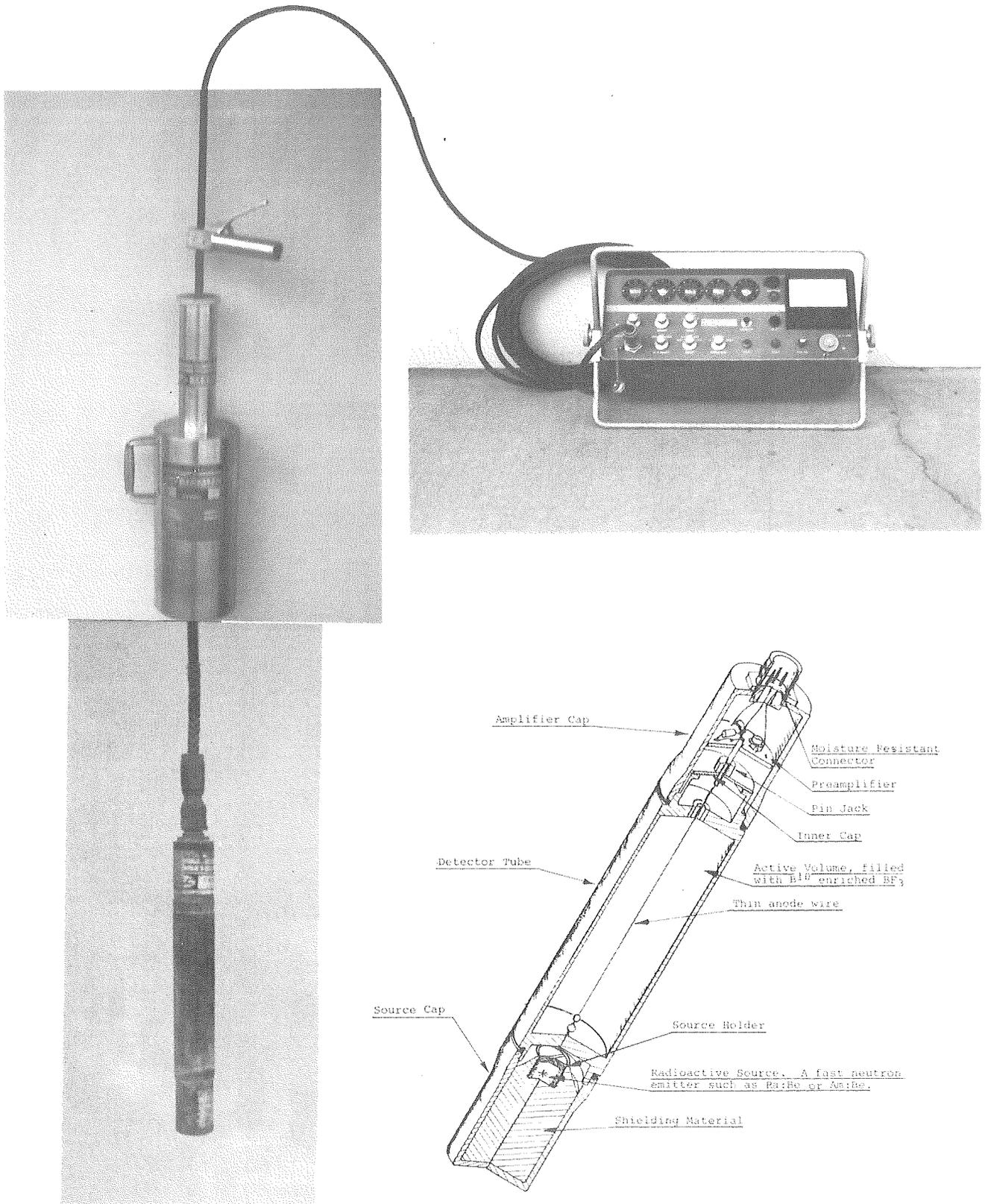


FIGURE 1  
 NUCLEAR PROBE AND SCALER



FIGURE 3

TYPICAL ACCESS TUBE  
INSTALLATION  
CROSS SECTION VIEW

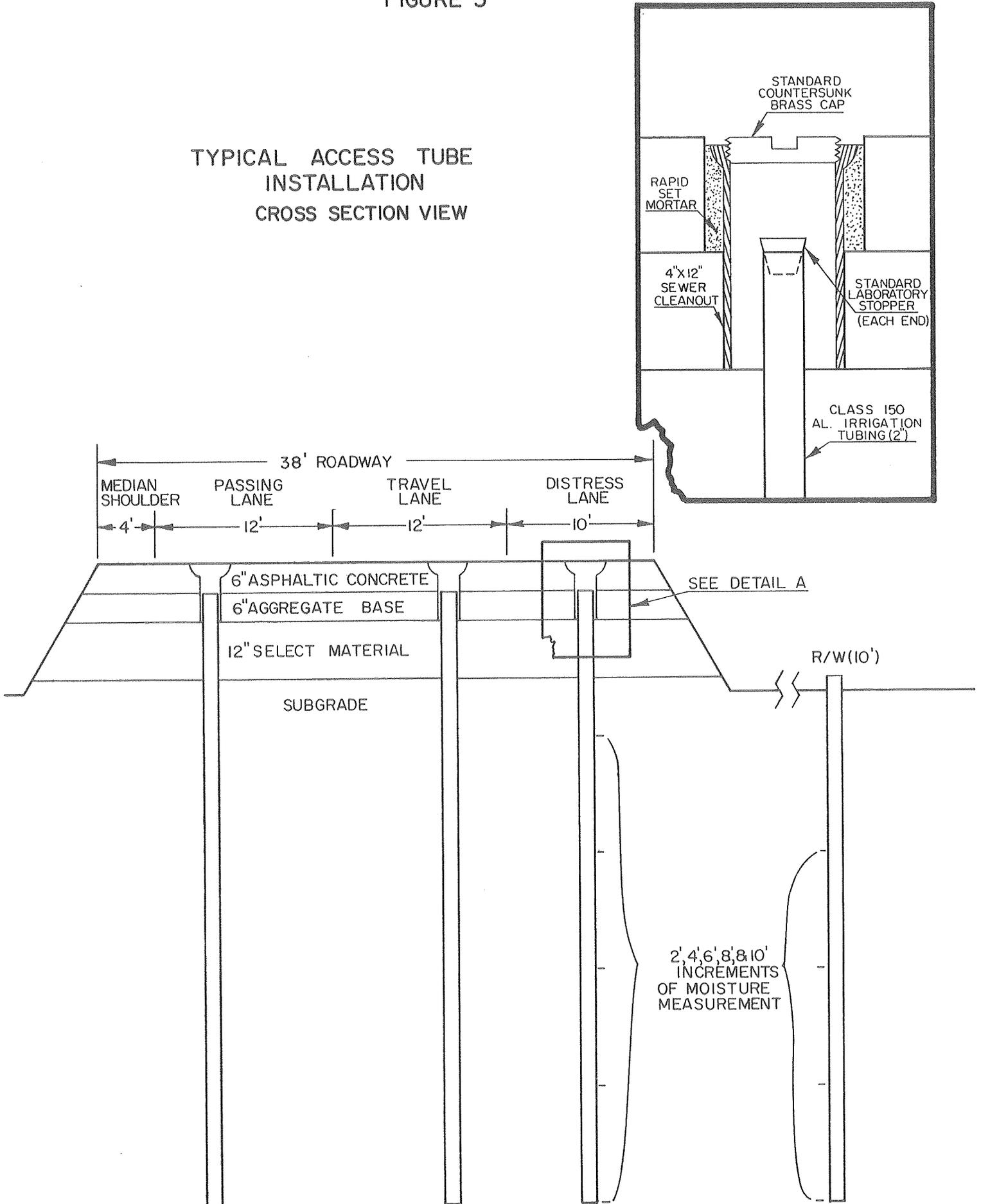


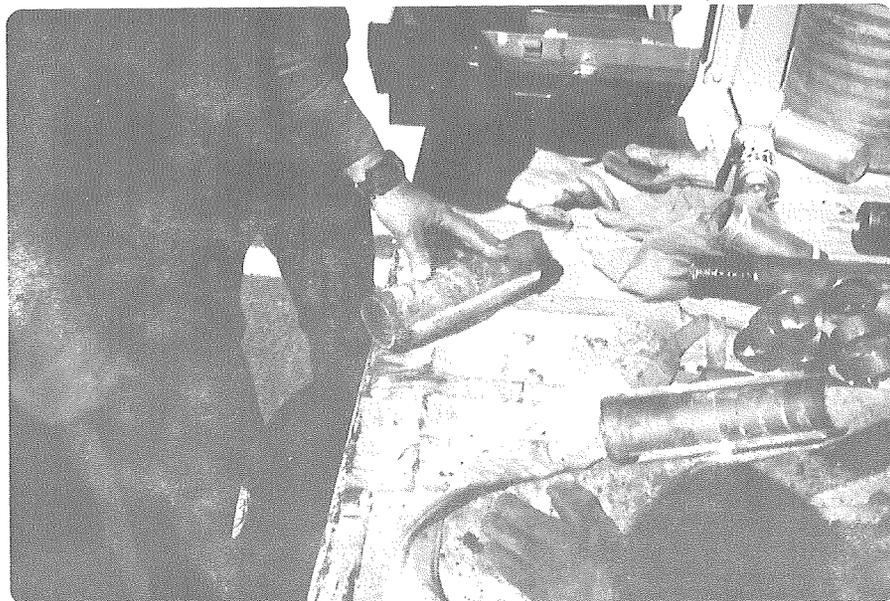
FIGURE 4



TYPICAL NUCLEAR MOISTURE MEASUREMENT

FIGURE 5

DRIVE SAMPLER AND DRILL RIG IN USE



REMOVING IO RINGS FILLED WITH SOIL FROM DRIVE SAMPLER

INDEX PROPERTIES (a)

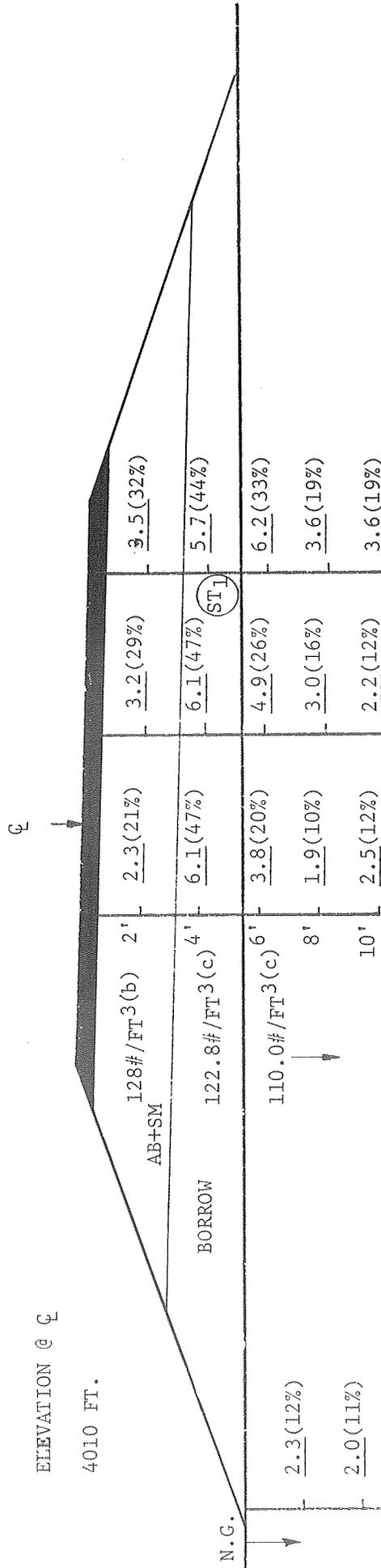
DEPTH	LL	PL	PI	-3/8	-4	-40	-200
2FT	23	22	1	100	90	30	10
4FT	24	15	9	100	95	56	32
6FT	26	17	9	100	95	43	24
8FT	25	17	9	100	94	36	18
10FT	23	19	4	100	94	48	25

FIGURE 6

SITE NUMBER 1  
 SYBIL RD., T.I., I-10, WB, MP 311  
 STA. 283+26  
 12/12/73

LAYER THICKNESS

LAYER	INCH	METER
ACFC	.50	.0127
AC	8.25	.2096
AB	6.00	.1524
SM	24.00	.6096
BORROW	21.25	.5398
TOTAL ABOVE GROUND (N.G.)	60.00	1.8288



NOTE

- UNDERLINED VALUES % MOISTURE BY WEIGHT (VALUES) DEGREE OR PERCENT SATURATION
- (a) INDEX PROPERTIES REPRESENT AVERAGE OF THREE TESTS
- (b) DRY DENSITY BASED ON NEAREST IN PLACE VOLUMETER TEST; BENSON
- (c) DRY DENSITY BY DRIVE SAMPLE
- (d) TEST PERFORMED ON DRIVE SAMPLE @ IN PLACE DENSITY AND MOISTURE

SCALE

HORIZONTAL 1" = 1'  
 VERTICAL .2" = 1'

SHEAR TEST RESULTS (d)

ST	C #/FT2	φ DEGREES	σ #/FT2	τ #/FT2
ST	650	55	600	1505

INDEX PROPERTIES (a)

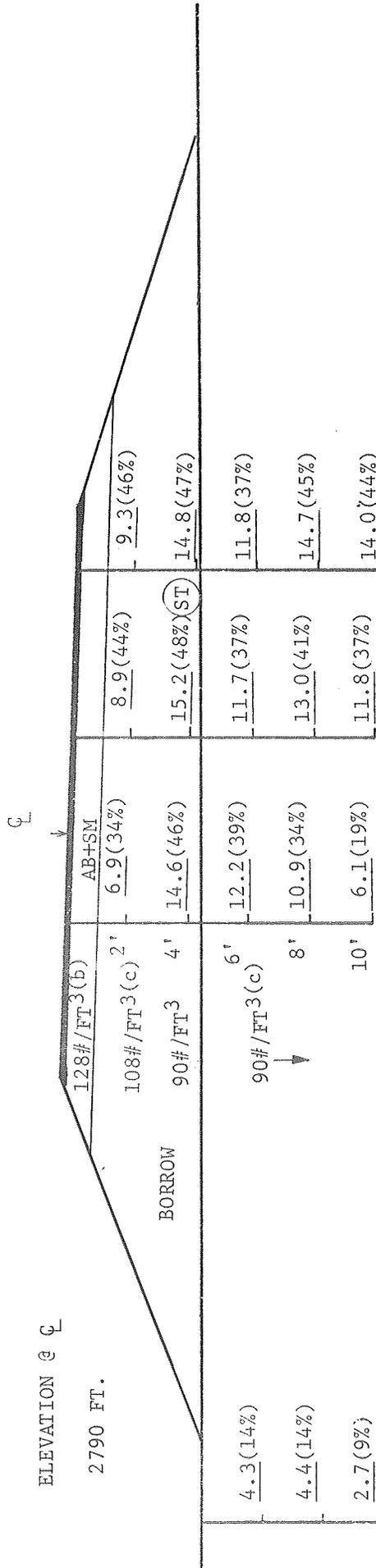
DEPTH	LL	PL	PI	-3/8	-4	-40	-200
2FT	31	17	14	92	84	46	29
4FT	44	17	27	100	99	85	63
6FT	36	17	19	100	98	71	53
8FT	47	18	29	100	99	76	60
10FT	45	20	25	100	94	70	50

FIGURE 7

SITE NUMBER 2  
 WILMOT RD. T.I., I-10, EB, MP 270  
 STA. 474+97  
 12/11/73

LAYER THICKNESS

LAYER	INCH	METER
BMS	2.00	.0508
AB	3.00	.0762
SM	9.00	.2286
BORROW	34.00	.8636
TOTAL ABOVE GROUND (N.G.)	48.00	1.2192



NOTE

- UNDERLINED VALUES % MOISTURE BY WEIGHT (VALUES) DEGREE OR PERCENT SATURATION
- a) INDEX PROPERTIES REPRESENT AVERAGE OF THREE TESTS
- b) DRY DENSITY BASED ON NEAREST IN PLACE VOLUMETER TEST; BENSON
- c) DRY DENSITY FROM DRIVE SAMPLE
- d) TEST PERFORM ON DRIVE SAMPLE @ IN PLACE DENSITY & MOISTURE

SCALE  
 HORIZONTAL .1" = 1'  
 VERTICAL .2" = 1'

SHEAR TEST RESULTS (d)

C	$\phi$	$\sigma$	$\tau$
#/FT <sup>2</sup>	DEGREES	#/FT <sup>2</sup>	#/FT <sup>2</sup>
ST 1960	4	493	1994

INDEX PROPERTIES (a)

DEPTH	LL	PL	PI	-3/8	-4	-40	-200
2FT	23	20	3	100	98	77	54
4FT	25	19	6	100	98	77	54
6FT	31	16	15	100	98	88	60
8FT	21	17	4	100	99	88	40
10FT			NP	100	98	70	22

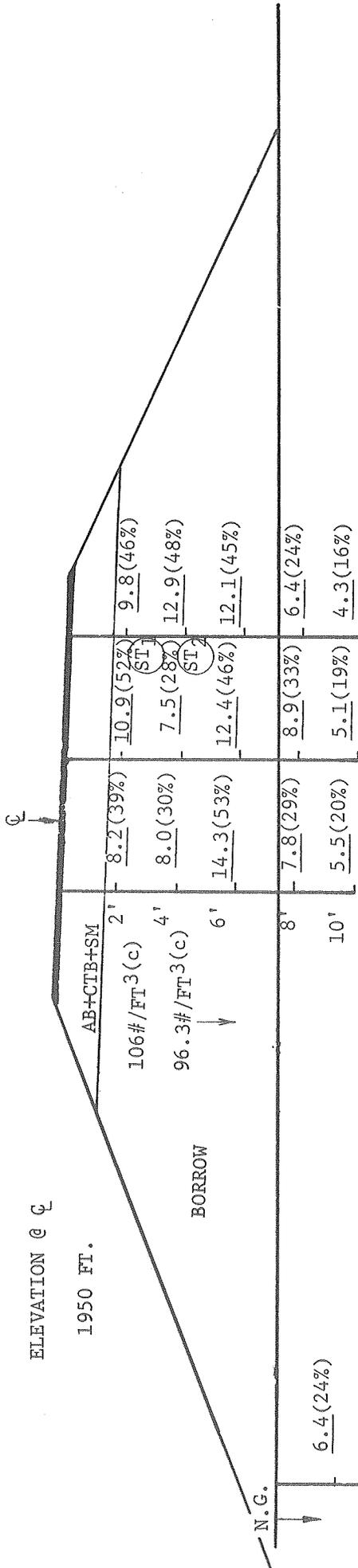
FIGURE 8

SITE NUMBER 3  
 MARANA T. I., I-10, EB, MP 235  
 STA. 4294+85

12/7/73

LAYER THICKNESS

LAYER	INCH	METER
AC	3.00	.0762
AB	4.00	.1016
CTB	6.00	.1524
SM	5.00	.1270
BORROW	66.00	1.6764
TOTAL ABOVE GROUND (N.G.)	84.00	2.1336



NOTE

UNDERLINED VALUES % MOISTURE
( ) DEGREE OR % SATURATION
(a) AVERAGE OF THREE TESTS
(c) DRY DENSITY FROM DRIVE SAMPLE
(d) TEST PERFORMED ON DRIVE SAMPLE @ IN PLACE DENSITY & MOISTURE

SCALE  
 HORIZONTAL .075" = 1'  
 VERTICAL .2" = 1'

SHEAR TEST RESULTS (d)

	C	φ	α	τ
	#/FT <sup>2</sup>	DEGREES	#/FT <sup>2</sup>	#/FT <sup>2</sup>
ST1	550	49	380	987
ST2	1025	29	590	1352

INDEX PROPERTIES (a)

DEPTH	LL	PL	PI	-3/8	-4	-40	-200
2FT			NP	83	70	42	13
4FT	35	17	18	100	100	89	60
6FT	37	19	18	100	100	85	50
8FT	37	19	18	100	100	83	50
10FT	28	17	11	100	100	79	42

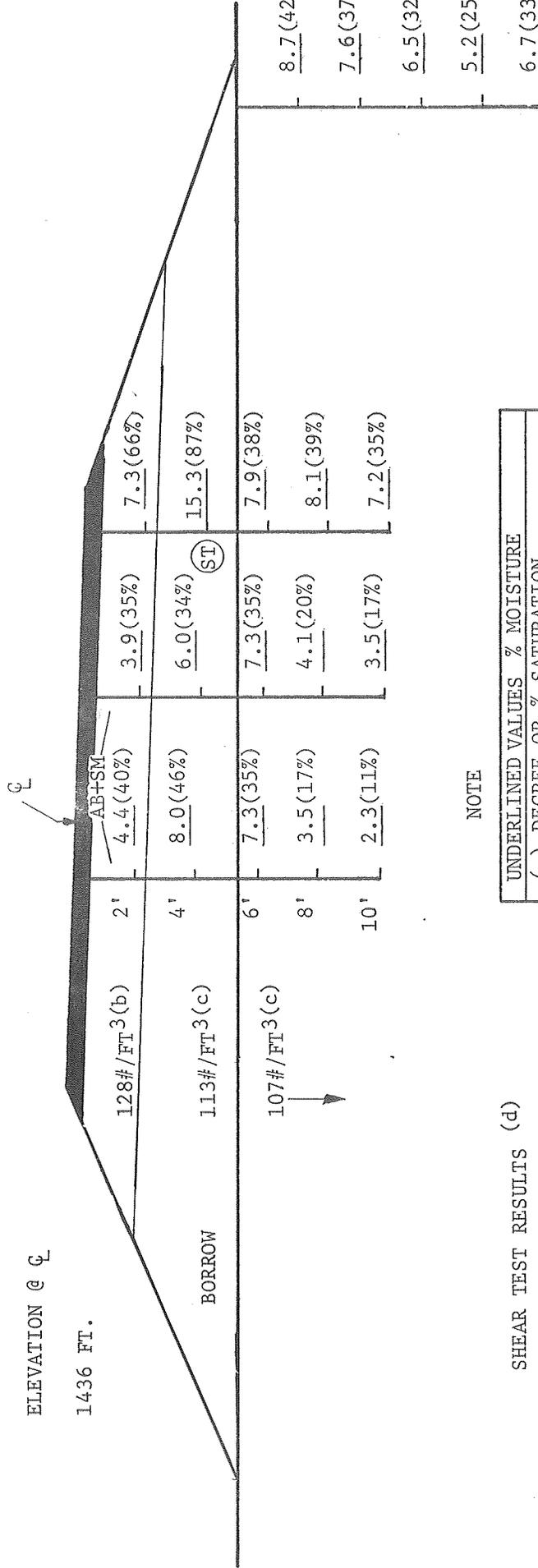
FIGURE 9

SITE NUMBER 4  
 CASA GRANDE I-10, EB, MP 196  
 STA. 2684+08

12/6/73

LAYER THICKNESS

LAYER	INCH	METER
ACFC	.50	.0127
AC	5.50	1.327
AB	4.00	1.016
SM	18.00	4.572
BORROW	26.00	6.604
TOTAL ABOVE		
GROUND (N.G.)	54.00	1.3716



NOTE

UNDERLINED VALUES	% MOISTURE
( )	DEGREE OR % SATURATION
(a)	AVERAGE OF THREE TESTS
(b)	DRY DENSITY BASED ON VOLUMETER TEST PERFORMED AT RECORDING SITES
(c)	DRY DENSITY FROM DRIVE SAMPLE
(d)	TEST PERFORMED @ IN PLACE DENSITY & MOISTURE

SHEAR TEST RESULTS (d)

C	phi	sigma	tau
#/FT2	DEGREES	#/FT2	#/FT2
ST	650	42	587
			1179

SCALE  
 HORIZONTAL .1" = 1'  
 VERTICAL .2" = 1'

INDEX PROPERTIES (a)

DEPTH	LL	PL	PI	-3/8	-4	-40	-200
2FT.	28	18	10	98	92	52	34
4FT.	26	19	7	100	99	69	48
6FT.	31	19	12	100	99	67	45
8FT.	40	20	20	100	100	77	9
10FT.	37	19	18	100	100	67	47

FIGURE 10

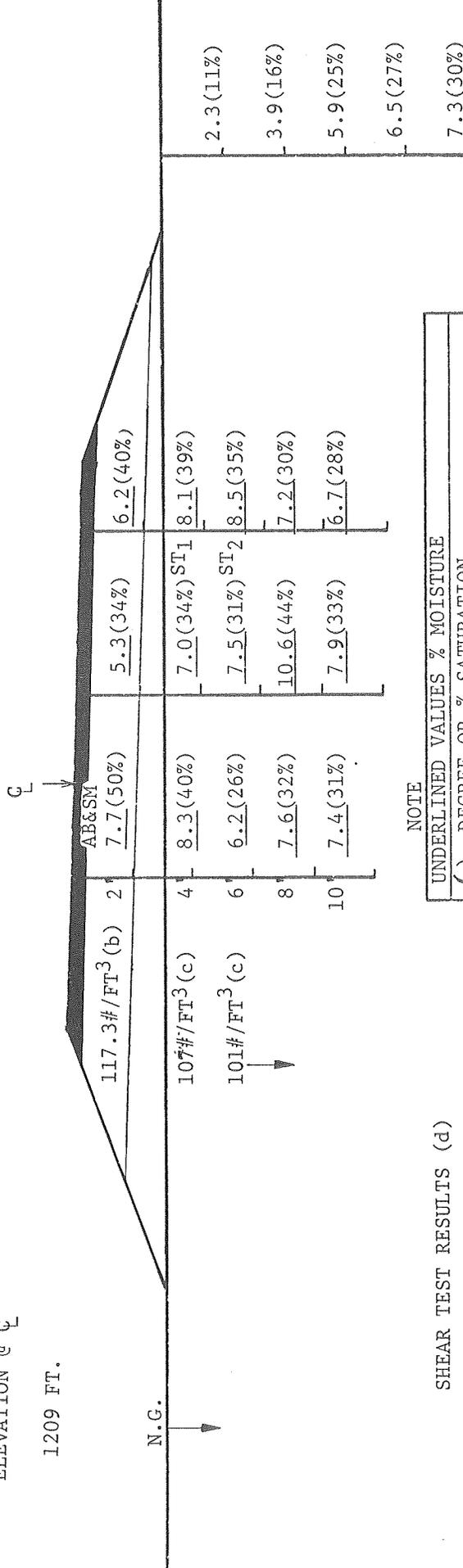
SITE NUMBER 5  
 WILLIAMS FIELD I-10, EB, MP 160  
 STA. 788+27  
 12/5/73

LAYER THICKNESS

LAYER	INCH	METER
ACFC	.50	.0127
AC	3.50	.0889
AB	4.00	.1016
SM	15.00	.3810
BORROW	7.00	.1778
TOTAL ABOVE GROUND (N.G.)	30.00	.7620

ELEVATION @  $\zeta$

1209 FT.



NOTE

UNDERLINED VALUES % MOISTURE
( ) DEGREE OR % SATURATION
a) AVERAGE OF THREE TESTS
b) DRY DENSITY BASED ON NEAREST VOLUMETER
TEST RESULTS, TEMPE+AVONDALE
c) DRY DENSITY FROM DRIVE SAMPLE
d) TEST PERFORMED @ IN PLACE DENSITY & MOISTURE

SHEAR TEST RESULTS (d)

C	$\phi$	$\sigma$	$\tau$
#/FT <sup>2</sup>	DEGREES	#/FT <sup>2</sup>	#/FT <sup>2</sup>
ST1 325	47	466	825
ST2 800	30	608	1151

SCALE  
 HORIZONTAL .1"=1'  
 VERTICAL .2"=1'

INDEX PROPERTIES (a)

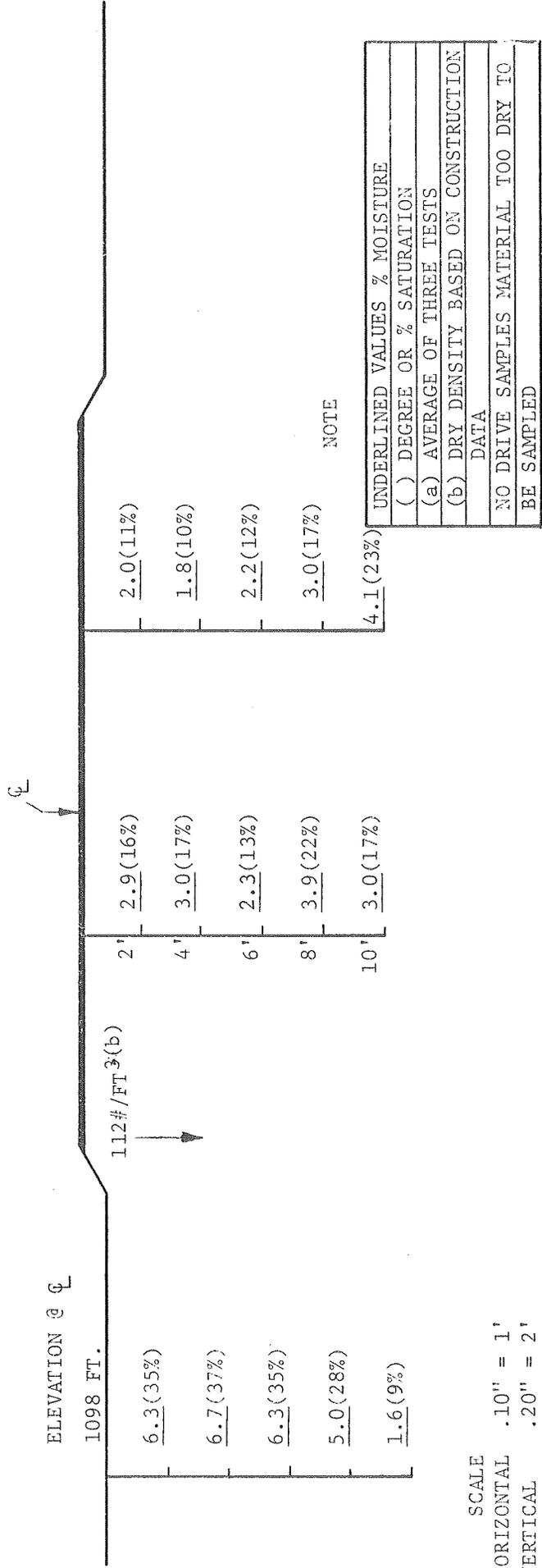
DEPTH	LL	PL	PI	-3/8	-4	-40	-200
2FT	37	22	15	100	100	94	56
4FT	39	22	17	100	96	67	32
6FT	46	23	23	98	94	78	35
8FT	51	23	28	99	97	81	50
10FT	43	22	21	99	96	81	46

FIGURE II

SITE NUMBER 6  
 TONOPAH I-10, EB  
 STA. 5309+60

NO LAYER THICKNESS  
 GRADE AND DRAIN  
 SECTION ON GRADE

4/2/74





# FIGURE I3

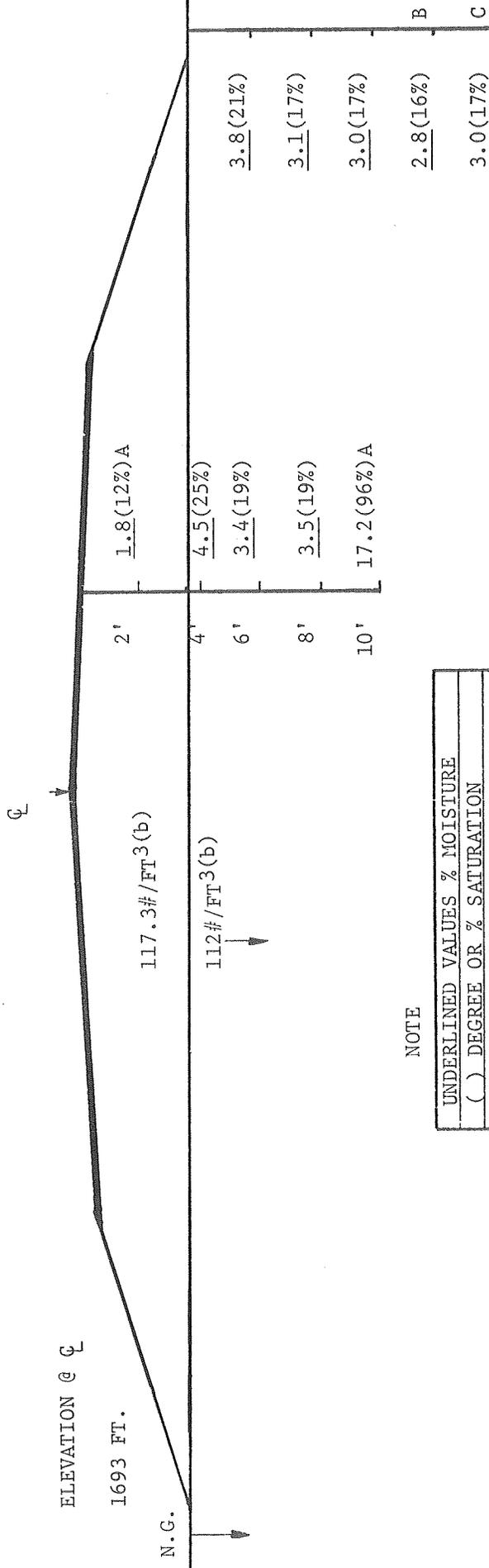
SITE NUMBER 8  
 LAKE PLEASANT  
 HWY. 74, STA. 1238+00  
 4/4/74

## LAYER THICKNESS

LAYER	INCH	METER
BORROW	32.00	.8128
TOTAL ABOVE		
GROUND (N.G.)	32.00	.8128

## INDEX PROPERTIES (a)

DEPTH	LL	PL	PI	-3/8	-4	-40	-200
2FT A	25	19	6	94	75	27	18
4FT	31	23	8	100	99	64	47
6FT	37	28	9	99	89	44	28
8FT	43	33	10	99	96	47	32
10FT A	65	20	45	100	100	94	90
10FT B	35	27	8	100	100	61	35
10FT C	36	28	8	100	98	55	33



## NOTE

- UNDERLINED VALUES % MOISTURE
- ( ) DEGREE OR % SATURATION
- (a) AVERAGE OF TWO TESTS EXCEPT A, B, & C WHICH ARE SINGLE TESTS
- (b) DRY DENSITIES ASSUMED FROM SIMILAR CONSTRUCTION
- NO DRIVE SAMPLES COULD BE TAKEN DUE TO DRY HARD (CALICHE) CONDITIONS.

## SCALE

HORIZONTAL .10" = 1'  
 VERTICAL .20" = 1'

INDEX PROPERTIES (a)

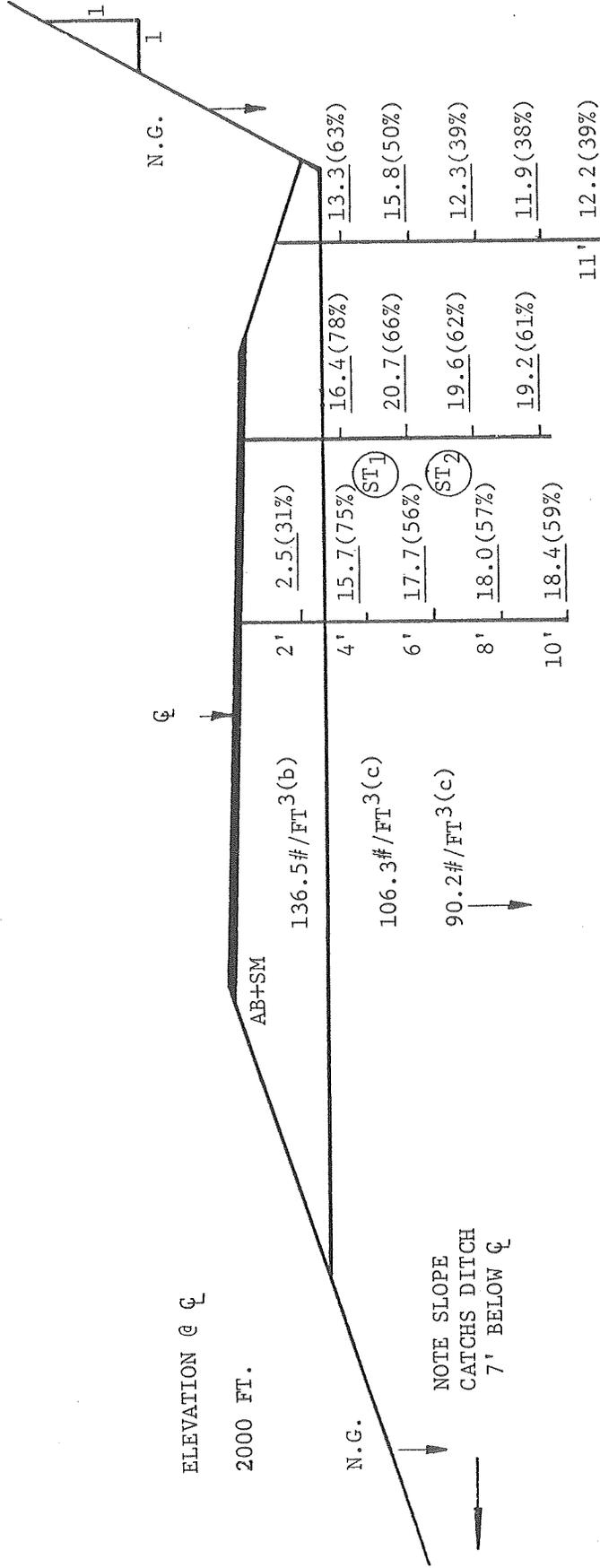
DEPTH	LL	PL	PI	-3/8	-4	-40	-200
2FT	18	15	3	100	97	45	28
4FT	41	29	12	100	99	82	41
6FT	42	29	13	100	98	80	40
8FT	40	30	10	100	99	84	39
10FT	41	29	12	100	99	85	40
11FT	41	29	12	100	99	85	40

FIGURE 14

SITE NUMBER 9  
 AGUA FRIA I-17, NB, MP 243  
 12/4/73

LAYER THICKNESS

LAYER	INCH	METER
ACFC	.50	.0127
AC	2.50	.0635
AB	4.00	.1016
SM	24.00	.6096
TOTAL ABOVE GROUND (N.G.)	31.00	.7874



NOTE

- UNDERLINED VALUES % MOISTURE
- ( ) DEGREE OR % SATURATION
- (a) AVERAGE OF THREE TESTS EXCEPT 11' WHICH IS ONE TEST
- (b) DRY DENSITY FROM VOLUMETER TESTS, TEMPE, AND AVONDALE
- (c) DRY DENSITY FROM DRIVE SAMPLE
- (d) TEST AT IN PLACE DENSITY AND MOISTURE

SHEAR TEST RESULTS

	c	φ	σ	τ
	#/FT <sup>2</sup>	DEGREE	#/FT <sup>2</sup>	#/FT <sup>2</sup>
ST1	2500	5	455	2540
ST2	1310	30	643	1681

SCALE  
 HORIZONTAL .10" = 1'  
 VERTICAL .20" = 1'

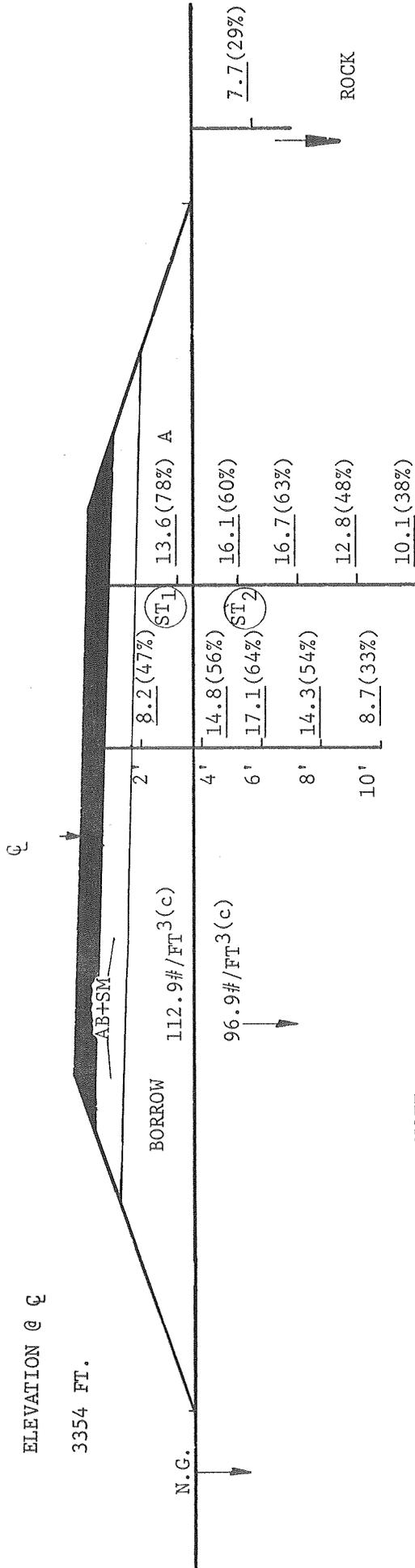
INDEX PROPERTIES (a)

DEPTH	LL	PL	PI	-3/8	-4	-40	-200
2FT	31	19	12	100	70	47	28
2FT A	41	17	24	100	86	73	36
4FT	53	17	36	100	96	85	77
6FT	50	17	33	100	95	86	78
8FT	57	18	39	100	100	90	84
10FT	37	21	16	100	100	82	72

LAYER THICKNESS

LAYER	INCH	METER
ACFC	.50	.0127
AC	3.50	.0889
BTB	3.50	.0889
AB	7.00	.1778
SM	3.00	.0763
BORROW	24.50	.6223
TOTAL ABOVE GROUND (N.G.)	42.00	1.0668

FIGURE 15  
 SITE NUMBER 10  
 SUNSET POINT I-17, NB, MP 251.41  
 STA. 2660+00  
 11/30/73



NOTE

UNDERLINED VALUES	% MOISTURE
( )	DEGREE OR % SATURATION
(a)	AVERAGE OF TWO TESTS EXCEPT 2FT & A
(c)	DRY DENSITY FROM DRIVE SAMPLE
(d)	TEST AT IN PLACE DENSITY AND MOISTURE

SHEAR TEST RESULTS (d)

	C #/FT²	φ DEGREE	σ #/FT²	τ #/FT²
ST1	1725	18	463	1875
ST2	1500	26	574	1779

SCALE  
 HORIZONTAL .1" = 1'  
 VERTICAL .2" = 1'

INDEX PROPERTIES (a)

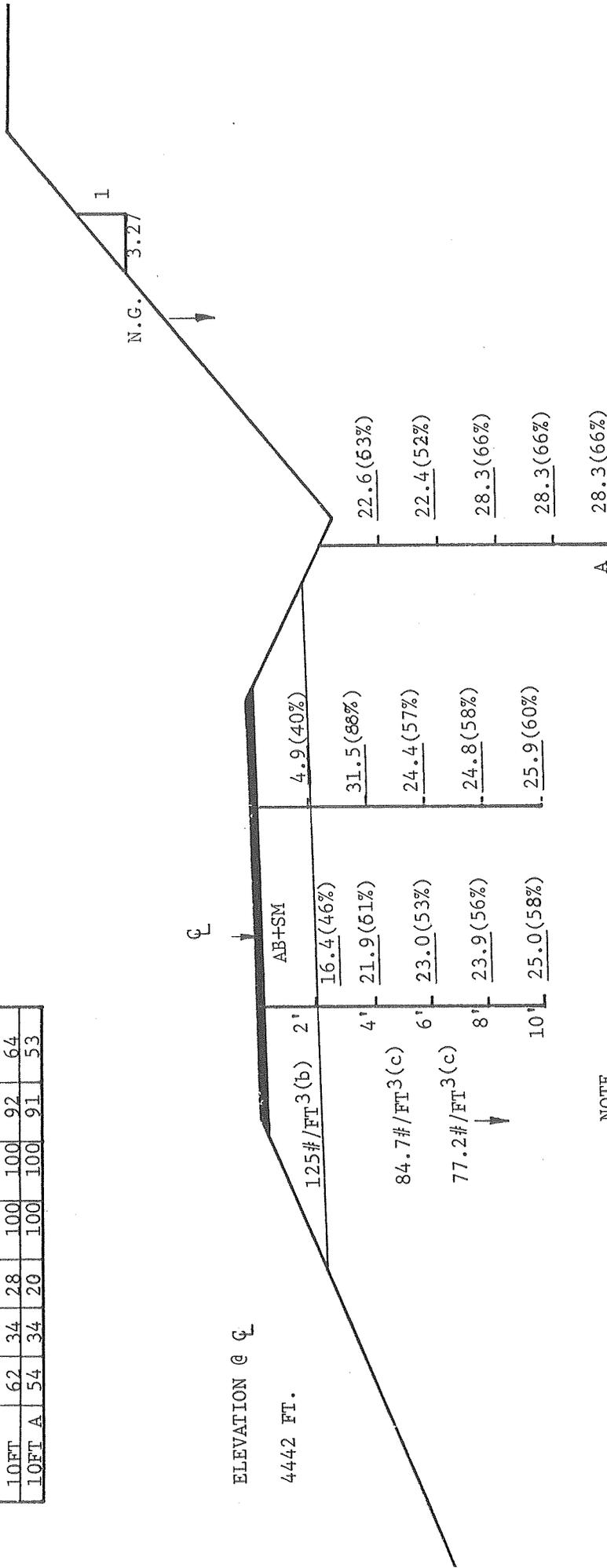
DEPTH	LL	PL	PI	-3/8	-4	-40	-200
2FT	47	23	24	100	95	68	52
2FT A	68	17	51	96	81	52	23
4FT	64	33	31	100	98	87	69
6FT	59	31	28	100	95	84	61
8FT	62	33	29	100	100	86	64
10FT	62	34	28	100	100	92	64
10FT A	54	34	20	100	100	91	53

FIGURE 16

SITE NUMBER 11  
 CHERRY RD., I-17, SB, MP 275  
 STA. 3884+16  
 11/28/73

LAYER THICKNESS

LAYER	INCH	METER
AC	3.00	.0762
AB	3.00	.0762
SM	18.00	.4572
TOTAL ABOVE	24.00	.6096
GROUND (N.G.)		



NOTE

UNDERLINED VALUES % MOISTURE
( ) DEGREE OR % SATURATION
(a) AVERAGE OF THREE TESTS EXCEPT A WHICH IS ONE TEST
(b) ESTIMATED DRY DENSITY
(c) DRY DENSITY FROM DRIVE SAMPLE
(d) TEST AT IN PLACE DENSITY AND MOISTURE

SCALE  
 HORIZONTAL .075" = 1'  
 VERTICAL .20" = 1'

SHEAR TEST RESULTS (d)

ST	C #/FT <sup>2</sup>	φ DEGREE	σ #/FT <sup>2</sup>	τ #/FT <sup>2</sup>
	2450	26°	345	2618

INDEX PROPERTIES (a)

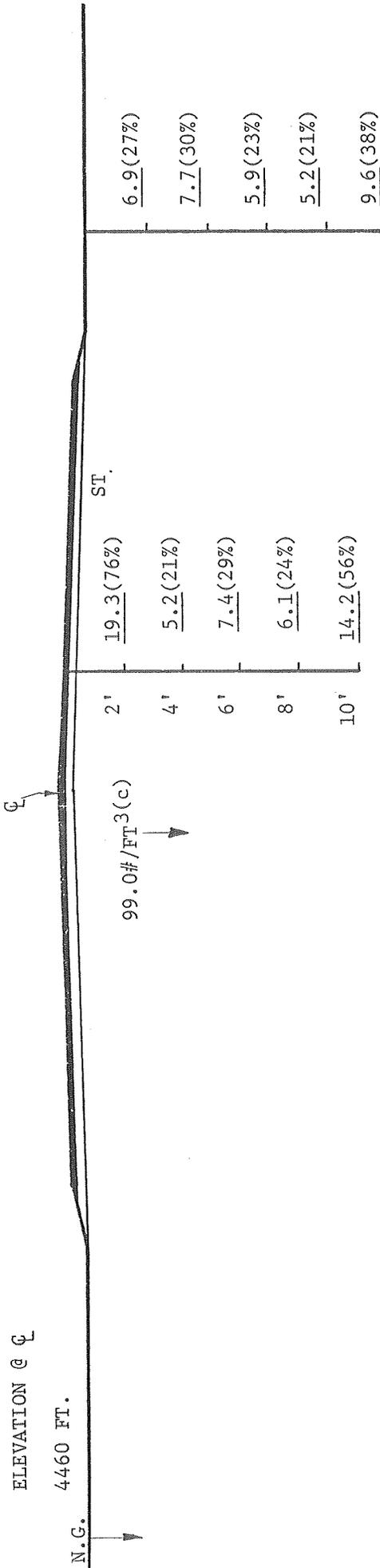
DEPTH	LL	PL	PI	-3/8	-4	-40	-200
2FT.	73	20	53	100	100	92	87
4FT	42	24	18	99	91	57	42
6FT	49	29	20	98	89	59	44
8FT.	48	33	15	99	92	55	40
10FT	52	33	19	100	95	69	46

FIGURE 17  
 SITE NUMBER 12  
 CIENGA CREEK HWY. 169  
 STA. 770+00

4/5/74

LAYER THICKNESS

LAYER	INCH	METER
SS	6.00	.1524
NATURAL GROUND	00	



NOTE

UNDERLINED VALUES % MOISTURE
( ) DEGREE OR % SATURATION
(a) AVERAGE OF TWO TESTS
(c) DRY DENSITY FROM DRIVE SAMPLE
(d) TEST AT IN PLACE DENSITY AND MOISTURE

SCALE  
 HORIZONTAL .10" = 1'  
 VERTICAL .20" = 1'

SHEAR TEST RESULTS (d)

ST	C #/FT <sup>2</sup>	φ DEGREE	σ #/FT <sup>2</sup>	τ #/FT <sup>2</sup>
ST	1500	49°	350	1903

INDEX PROPERTIES (a)

DEPTH	LL	PI	PI	-3/8	-4	-40	-200
2FT A	25	16	9	72	66	54	23
2FT	39	16	23	99	91	70	48
4FT	66	18	48	100	97	87	71
6FT	49	18	31	100	98	82	62
8FT	55	17	38	100	98	85	70
10FT	57	18	39	100	99	87	72
10FT B	78	21	57	100	98	91	82
10FT C	81	26	55	100	98	89	83

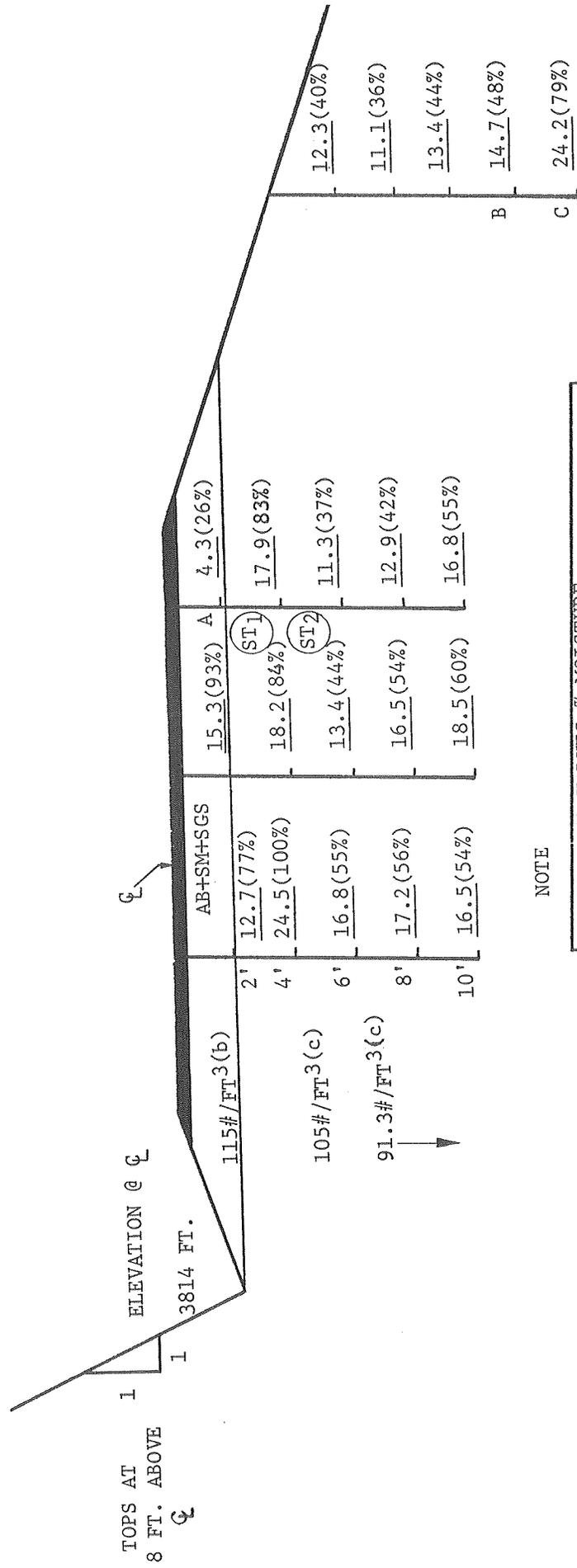
FIGURE 18

SITE NUMBER 13  
 SEDONA T.I., I-17, NB, MP 298±  
 STA. 5171+42

11/29/74

LAYER THICKNESS

LAYER	INCH	METER
AC	4.00	.1016
BTB	3.00	.0762
AB	3.00	.0762
SM	15.00	.3810
SGS	6.00	.1524
TOTAL ABOVE GROUND (N.G.)	31.00	7.874



NOTE

UNDERLINED VALUES % MOISTURE	
( )	DEGREE OR % SATURATION
(a)	AVERAGE OF FOUR TESTS EXCEPT A, B, C ONLY ONE TEST
(b)	ESTIMATED DRY DENSITY
(c)	DRY DENSITY FROM DRIVE SAMPLE
(d)	TEST AT IN PLACE DENSITY AND MOISTURE

SHEAR TEST RESULTS

C	φ	σ	τ
#/FT <sup>2</sup>	DEGREE	#/FT <sup>2</sup>	#/FT <sup>2</sup>
ST1 475	45	467	942
ST2 650	35	677	1124

SCALE  
 HORIZONTAL .1" = 1'  
 VERTICAL .2" = 1'

INDEX PROPERTIES (a)

DEPTH	LL	PL	PI	-3/8	-4	-40	-200
2FT	34	19	15	100	100	80	70
4FT	60	22	38	100	100	90	84
6FT	71	24	47	100	100	100	88
8FT	98	26	62	100	100	100	84
10FT			NP	100	100	100	32

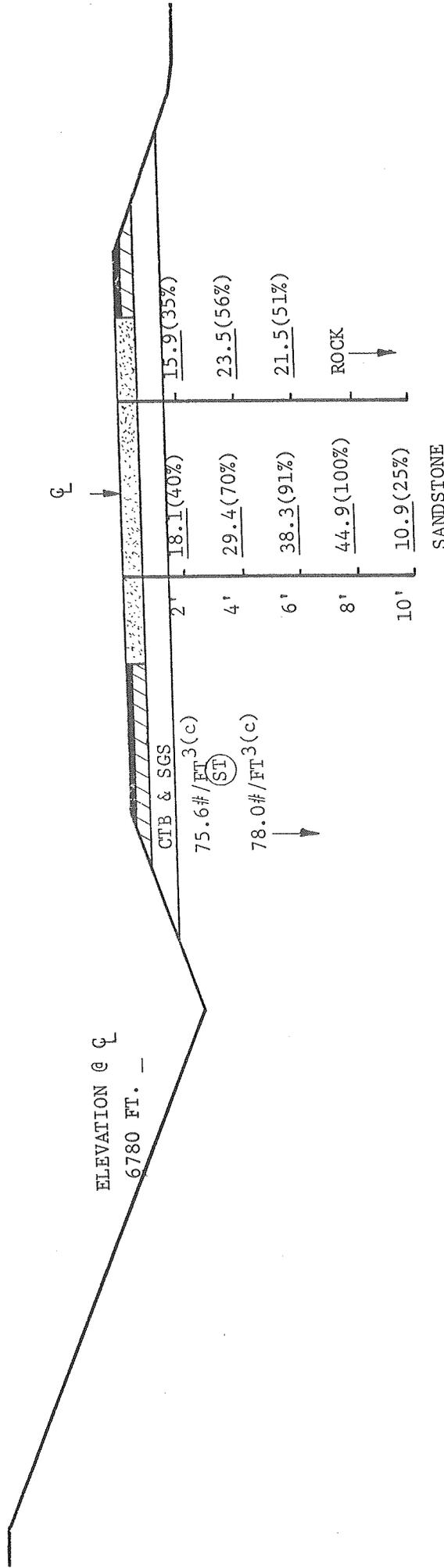
**FIGURE 19**  
 SITE NUMBER 14  
 KACHINA BLVD. I 17, SB  
 STA. 7086+50

10/26/73

LAYER THICKNESS

LAYER	INCH	METER
PCC	8.00	.2032
CTB	6.00	.1524
SGS	6.00	.1524
TOTAL ABOVE		
GROUND (N.G.)	20.00	.5080

3.5" AC + .5" ACFC  
 4" AB



NOTE

UNDERLINED VALUES % MOISTURE
( ) DEGREE OR % SATURATION
(a) AVERAGE OF TWO TESTS EXCEPT 8'+10'
(c) DRY DENSITY FROM DRIVE SAMPLE
(d) TEST AT IN PLACE DENSITY AND MOISTURE

SCALE  
 HORIZONTAL .1" = 1'  
 VERTICAL .2" = 1'

C	$\phi$	$\sigma$	$\tau$
#/FT <sup>2</sup>	DEGREE	#/FT <sup>2</sup>	#/FT <sup>2</sup>
ST 850	16°	334	946

INDEX PROPERTIES (a)

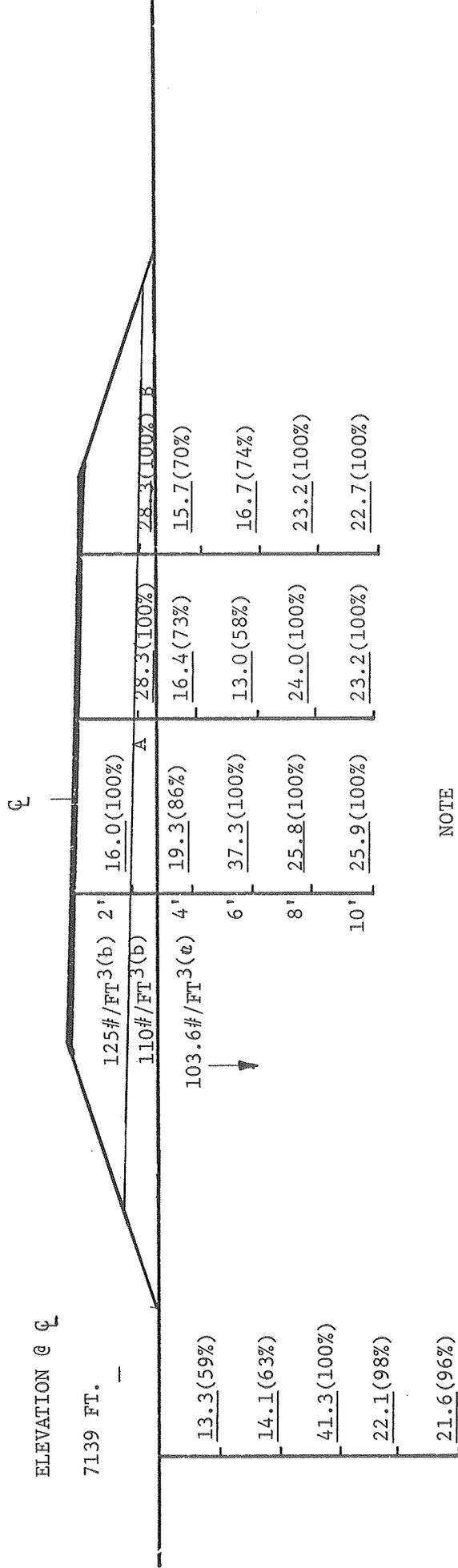
DEPTH	LL	PL	PI	-3/8	-4	-40	-200
2 FT	25	19	6	100	100	67	46
2 FT A&B	34	19	15	100	100	72	59
4 FT	44	21	23	100	100	70	54
6 FT	34	21	13	100	100	69	52
8 FT	36	20	16	100	100	95	70
10 FT	40	20	20	100	100	95	73

FIGURE 20

SITE NUMBER 15  
 BELLEMONT I-40, EB, MP 186.50  
 STA. 1689+30  
 10/24/73

LAYER THICKNESS

LAYER	INCH	METER
BTB	2.00	.0508
AB	4.00	.1016
SM	9.00	.2286
SGS	6.00	.1524
BORROW	9.00	.2286
TOTAL ABOVE	30.00	.7620
GROUND (N.G.)		



NOTE

UNDERLINED VALUES % MOISTURE
( ) DEGREE OR PERCENT SATURATION
(a) AVERAGE OF THREE TESTS
(b) ESTIMATED DENSITY
(c) DRY DENISY FROM DRIVE SAMPLE
NO SHEAR TEST

SCALE  
 HORIZONTAL .1" = 1'  
 VERTICAL .2" = 1'

INDEX PROPERTIES (a)

DEPTH	LL	PL	PI	-3/8	-4	-40	-200
2FT	34	21	13	100	100	86	65
4FT	50	22	38	100	100	88	74
6FT	38	26	12	100	100	80	60
8FT	38	25	13	100	100	82	62
10FT	39	27	12	100	100	77	56

LAYER THICKNESS

LAYER	INCH	METER
PCC	8.00	.2032
CTB	6.00	.1524
SGS	6.00	.1524
BORROW	40.00	1.0160
TOTAL ABOVE		
GROUND (N.G.)	60.00	1.5240

FIGURE 21

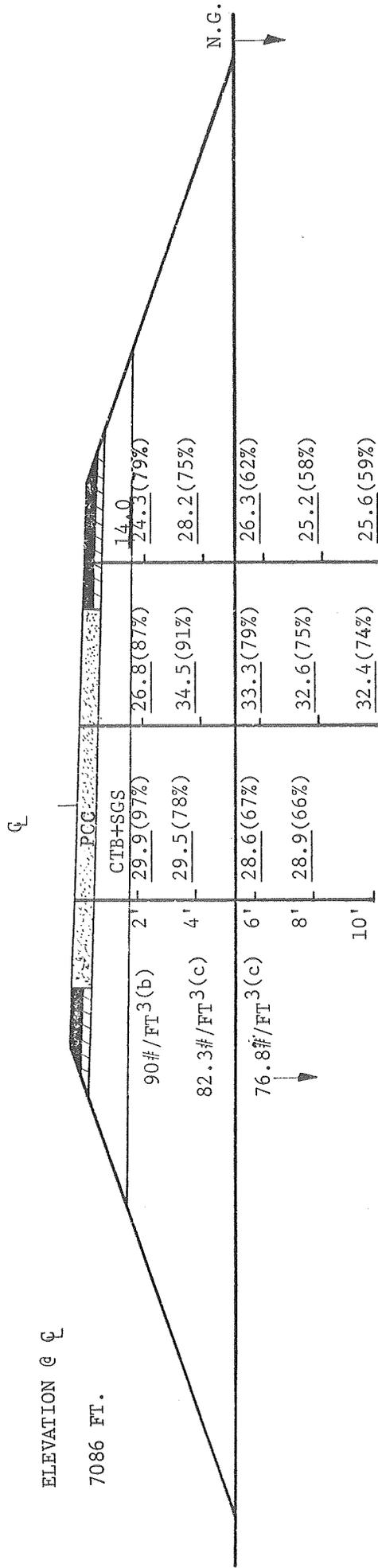
SITE NUMBER 16

WOODY MTN. T.I., I-40, EB, MP 192.85

STA. 2032+00

10/23/73

3.5" AC + .5" ACFC  
4" AB



NOTE

UNDERLINED VALUES % MOISTURE
( ) DEGREE OR PERCENT SATURATION
(a) AVERAGE OF THREE TESTS
(b) ESTIMATED DENSITY
(c) DRY DENSITY FROM DRIVE SAMPLE
NO SHEAR TEST

SCALE

HORIZONTAL .1" = 1'

VERTICAL .2" = 1'

INDEX PROPERTIES. (a)

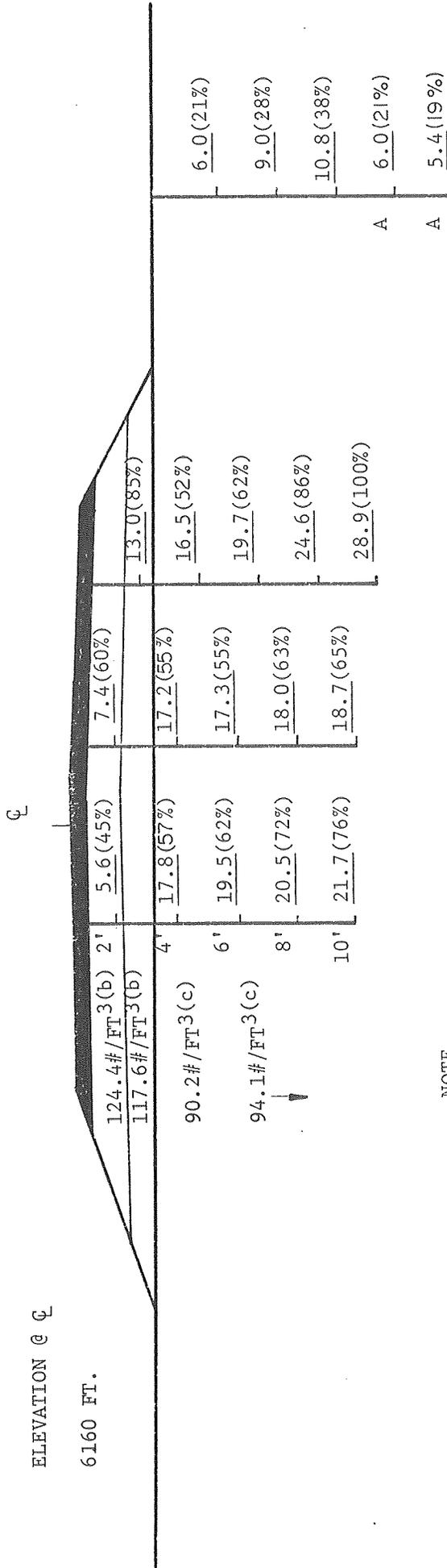
DEPTH	LL	PL	PI	-3/8	-4	-40	-200
2FT	-	-	NP	100	100	45	20
4FT	29	21	8	100	100	74	50
6FT	25	22	3	100	100	68	42
8FT	28	23	5	100	100	76	48
10FT	29	24	5	100	100	76	50
10FT A	18	17	1	100	100	89	51

LAYER THICKNESS

LAYER	INCH	METER
ACFC	.75	.0191
AC	3.00	.0762
BPM	4.00	.1016
AB	3.00	.0762
SM	9.00	.2286
BORROW	10.25	.2731
TOTAL ABOVE GROUND (N.G.)	30.00	.7620

FIGURE 22

SITE NUMBER 17  
 WINONA T.I., I-40, WB, MP 212.60  
 STA. 821+15  
 10/25/73



NOTE

UNDERLINED VALUES % MOISTURE
( ) DEGREE OR PERCENT SATURATION
(a) AVERAGE OF TWO OR MORE TEST EXCEPT A, ONE TEST
(b) DRY DENSITIES FROM VOLUMETER TEST AT COSMINO AND ASHFORK
(c) DRY DENSITY BY DRIVE SAMPLE NO SHEAR TEST

SCALE  
 HORIZONTAL .1" = 1'  
 VERTICAL .2" = 1'

INDEX PROPERTIES (a)

DEPTH	LL	PL	PI	-3/8	-4	-40	-200
2FT	31	16	15	100	100	93	73
4FT	53	21	32	100	98	93	88
6FT	52	21	31	100	99	93	87
8FT	44	21	23	100	100	96	90
10FT			NP	100	100	96	36

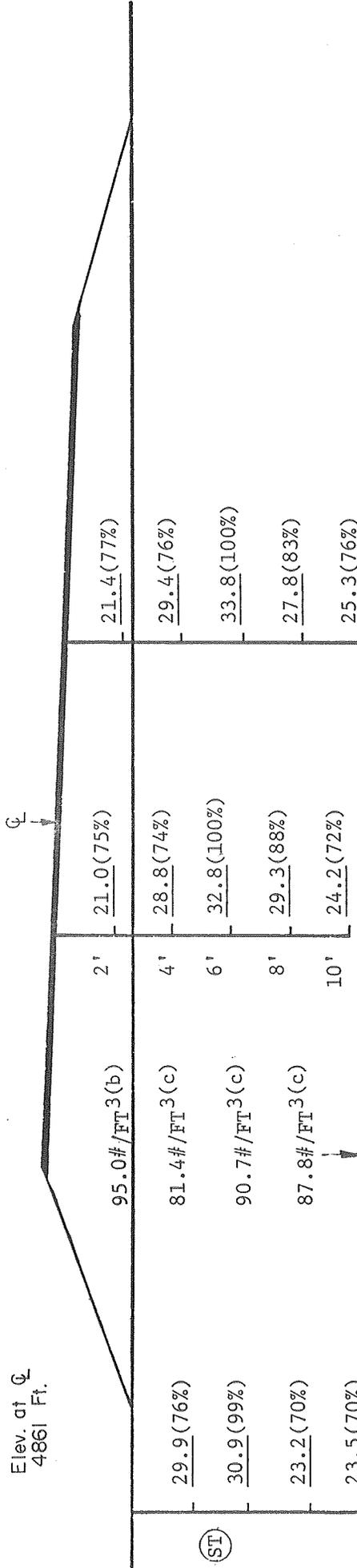
LAYER THICKNESS

LAYER	INCH	METER
BORROW	31.00	.7874

FIGURE 23

SITE NUMBER 18  
 WINSLOW BYPASS I-40, EB  
 STA. 3215+00

4/10/74



NOTE

UNDERLINED VALUES % MOISTURE	
( )	DEGREE OR PERCENT SATURATION
(a)	AVERAGE OF THREE VALUES
(b)	ESTIMATED
(c)	DRY DENSITY FROM DRIVE SAMPLE
(d)	TEST RUN AT IN PLACE DENSITY & MOISTURE

SCALE  
 HORIZONTAL .1" = 1'  
 VERTICAL .2" = 1'

SHEAR TEST RESULTS (d)

ST	C #/FT <sup>2</sup>	$\phi$ DEGREE	$\sigma$ #/FT <sup>2</sup>	$\tau$ #/FT <sup>2</sup>
ST	375	18°	657	588

INDEX PROPERTIES (a)

DEPTH	LL	PL	PI	-3/8	-4	-40	-200
2FT	64	21	43	100	100	99	88
4FT	66	23	43	100	100	99	88
6FT	38	19	19	100	100	99	89
8FT	35	20	15	100	100	99	91

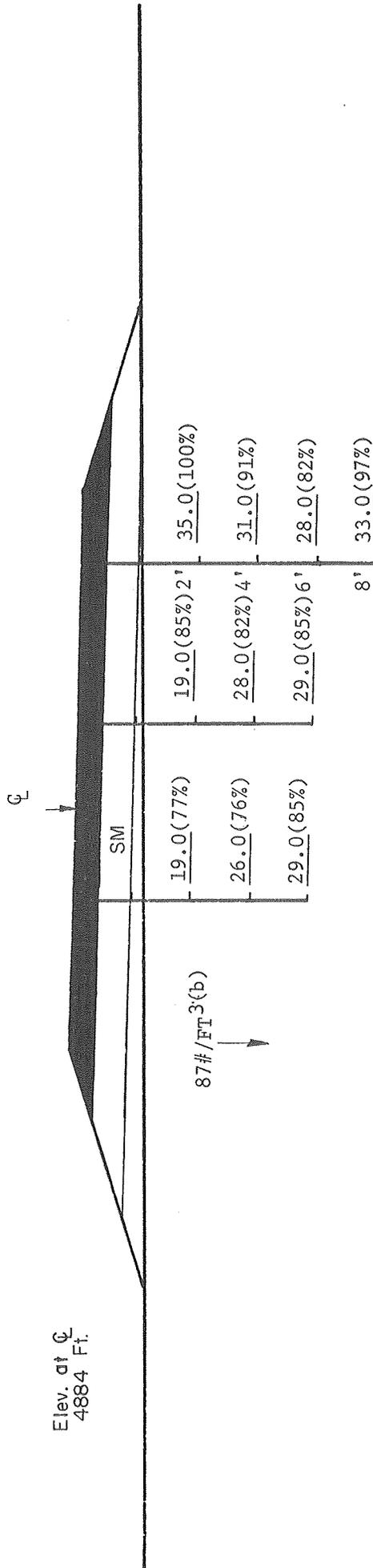
FIGURE 24

SITE NUMBER 19  
MINNETONKA I-40, EB, MP 261.78  
STA. 369+00

4/10/74

LAYER THICKNESS

LAYER	INCH	METER
ACFC	.50	.0127
NEW AC	1.25	.0318
OLD AC	3.50	.0889
BSB	3.00	.0762
SM	15.00	.3810
BORROW	3.00	.0762
TOTAL ABOVE	26.25	.6668
GROUND (N.G.)		



Elev. at CL  
4884 Ft.

NOTE

UNDERLINED VALUES % MOISTURE
( ) DEGREE OR PERCENT SATURATION
(a) SINGLE TEST RESULT
(b) ESTIMATED
NO DRIVE SAMPLES

SCALE

HORIZONTAL .1" = 1'  
VERTICAL .2" = 1'

INDEX PROPERTIES (a)

DEPTH	LL	PL	PI	-3/8	-4	-40	-200
2'	21	16	5	100	100	96	39
4'	21	16	5	100	100	94	34
6'	25	16	9	100	100	97	42
8'	26	15	11	100	100	96	45
10'	23	14	9	100	100	94	40
10'*	39	15	24	100	100	94	64

LAYER THICKNESS

LAYER	INCH	METER
ACFC	.50	.0127
NEW AC	4.00	.1016
OLD AC	4.00	.1016
CTB	6.00	.1524
SM	4.00	.1016
BORROW	22.00	.5588
TOTAL ABOVE GROUND (N.G.)	40.50	1.0287

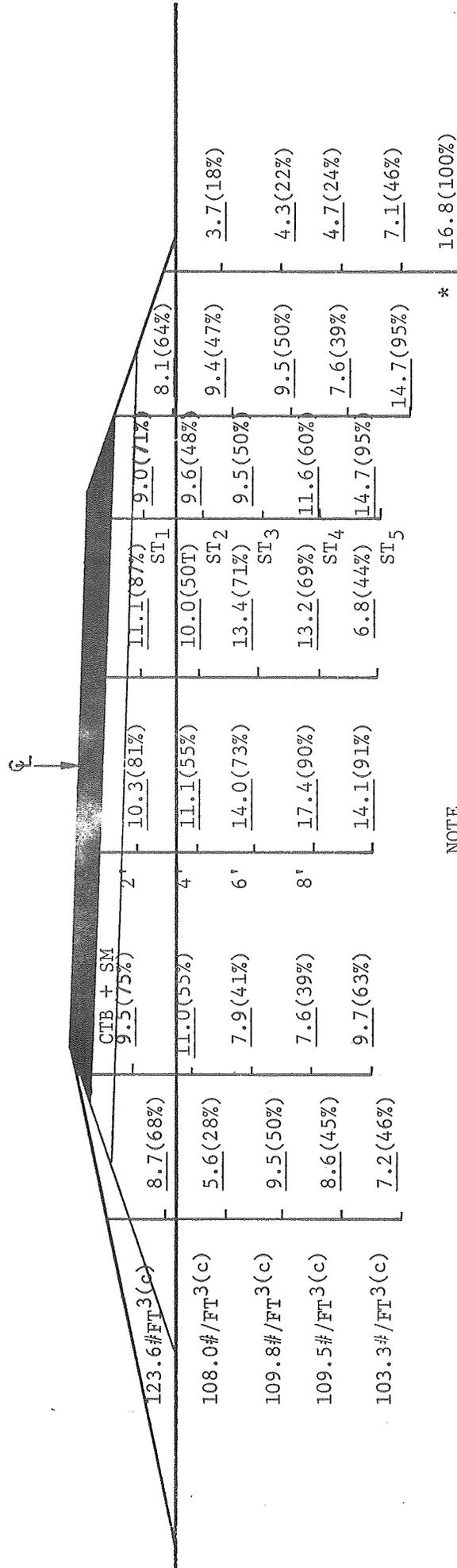
FIGURE 25

SITE NUMBER 20

DEAD RIVER

I-40, EB, MP 316.68, STA. 500

8/5/74



NOTE

UNDERLINED VALUES % MOISTURE	
( )	DEGREE OR PERCENT SATURATION
(a)	AVERAGE OF SIX
(c)	DRY DENSITY FROM DRIVE SAMPLE
(d)	TEST RUN AT IN PLACE DENSITY & MOISTURE.

	#/FT <sup>2</sup>	Ø	σ #/FT <sup>2</sup>	τ #/FT <sup>2</sup>
ST1	2545	19	280	2641
ST2	875	28	480	1130
ST3	160	36	680	654
ST4	60	41	880	825
ST5	800	28	1080	1374

SCALE  
HORIZONTAL .10 = 1"  
VERTICAL .20 = 1"

INDEX PROPERTIES (a)

DEPTH	LL	PL	PI	-3/8	-4	-40	-200
2'			NP	100	100	84	31
4'	19	16	3	100	100	80	43
6'	36	14	22	100	100	95	72
8'	49	17	32	100	99	92	81
10'	86	20	66	100	100	98	92
12'	63	18	45	100	100	100	91

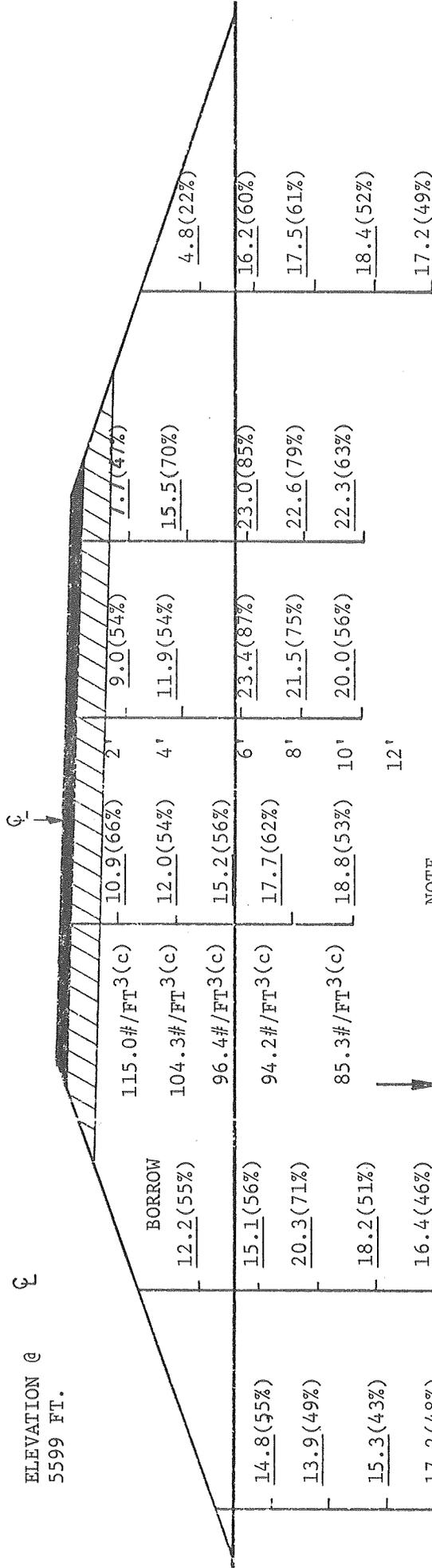
LAYER THICKNESS

	INCH	METER
AC	4.00	.1016
CTB	6.00	.1524
SM	6.00	.1524
BORROW	50.00	1.2700
TOTAL ABOVE		
GROUND (N.G.)	66.00	1.6760

FIGURE 26

SITE NUMBER 21  
 CRAZY CREEK  
 I-40, EB, MP 322.72  
 STA. 819+50

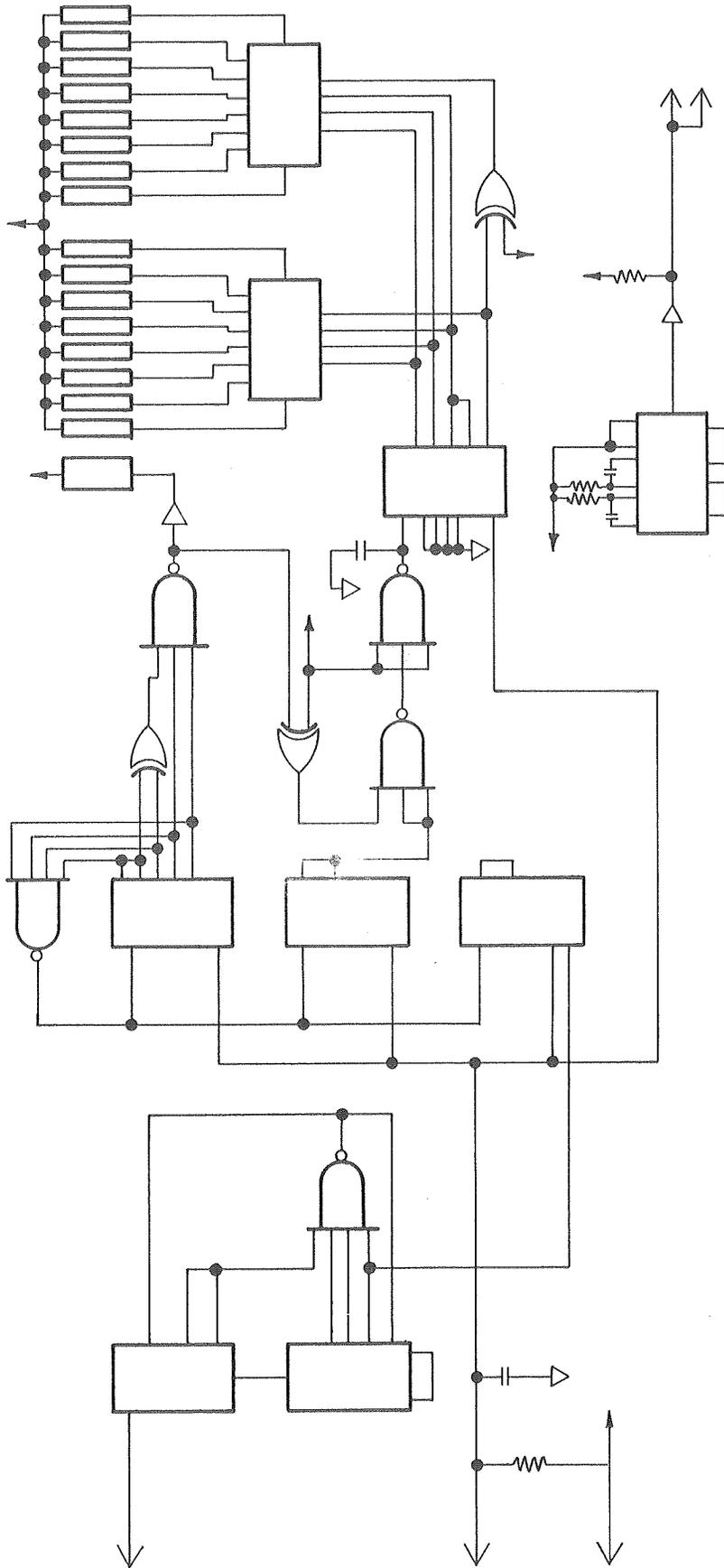
5/30/74



NOTE

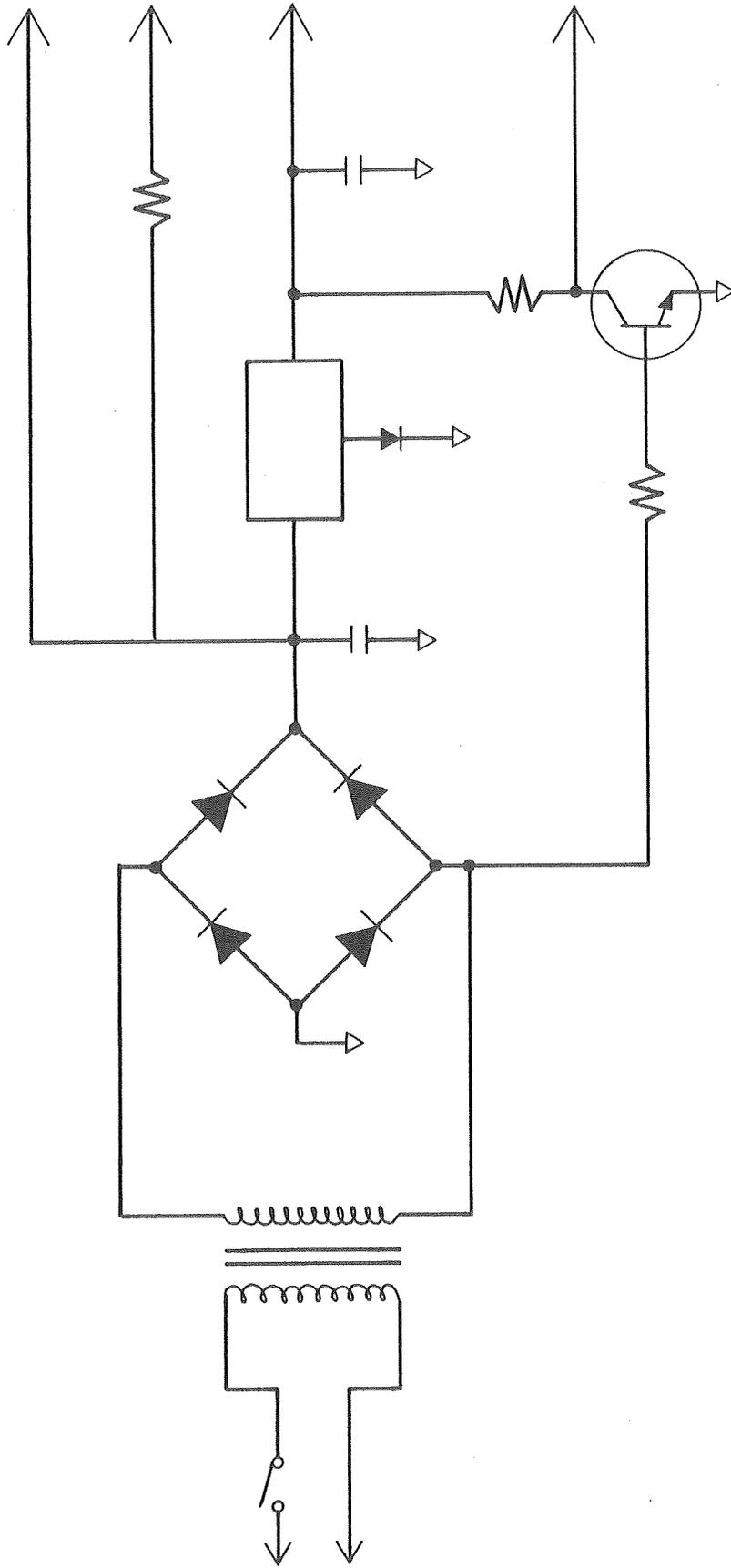
UNDERLINED VALUES % MOISTURE
( ) DEGREE OR % SATURATION
(a) AVERAGE OF THREE TESTS
(c) DRY DENSITY FROM DRIVE SAMPLE

SCALE  
 HORIZONTAL .10" = 1'  
 VERTICAL .20" = 1'



TIMER AND RELAY BOARD

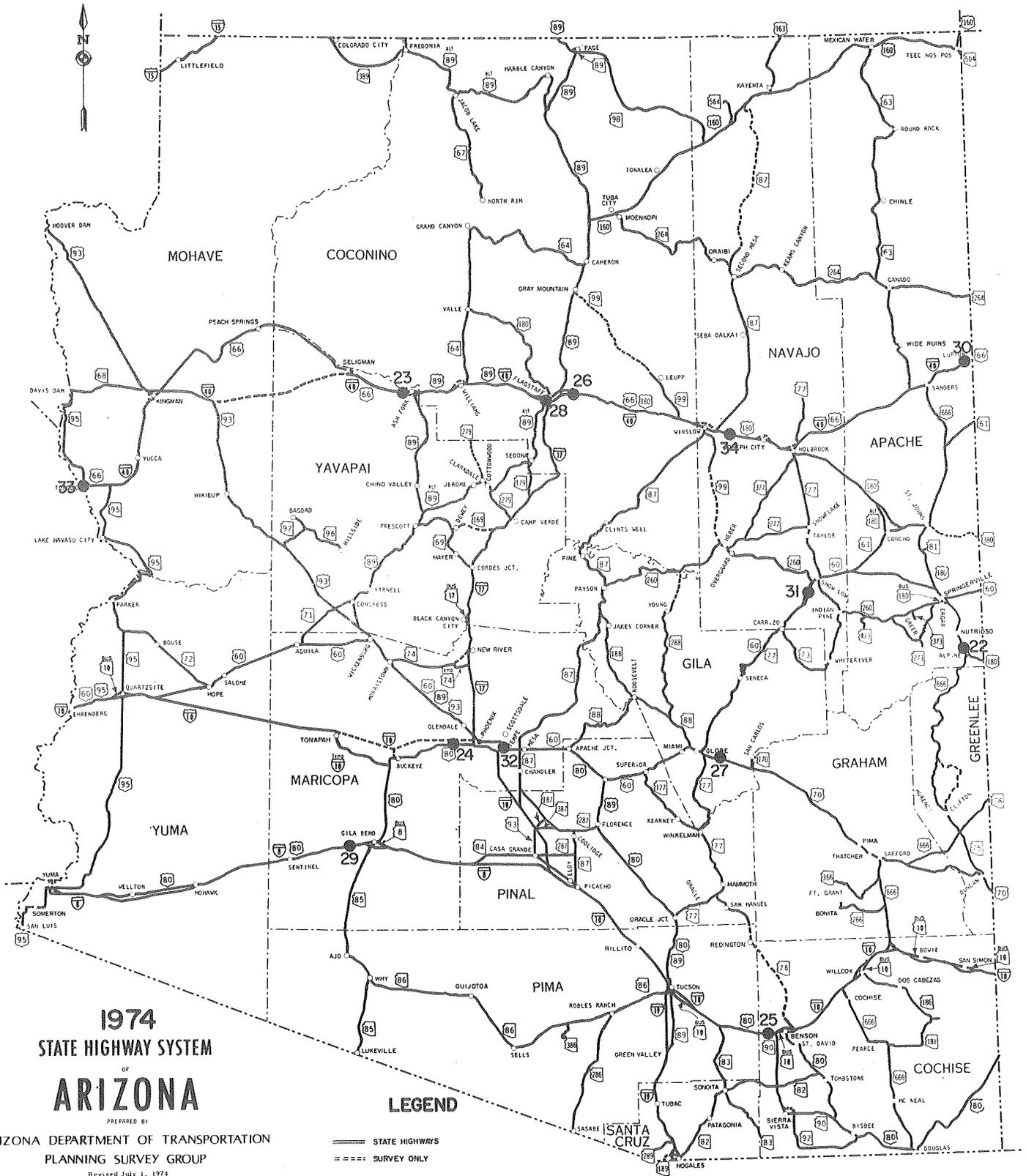
FIGURE 27



POWER SUPPLY AND EXCITATION FOR  
TIMER AND RELAY BOARD

FIGURE 28

FIGURE 29  
LOCATIONS OF MOISTURE  
RECORDING SITES



1974  
STATE HIGHWAY SYSTEM  
OF  
**ARIZONA**

PREPARED BY  
ARIZONA DEPARTMENT OF TRANSPORTATION  
PLANNING SURVEY GROUP

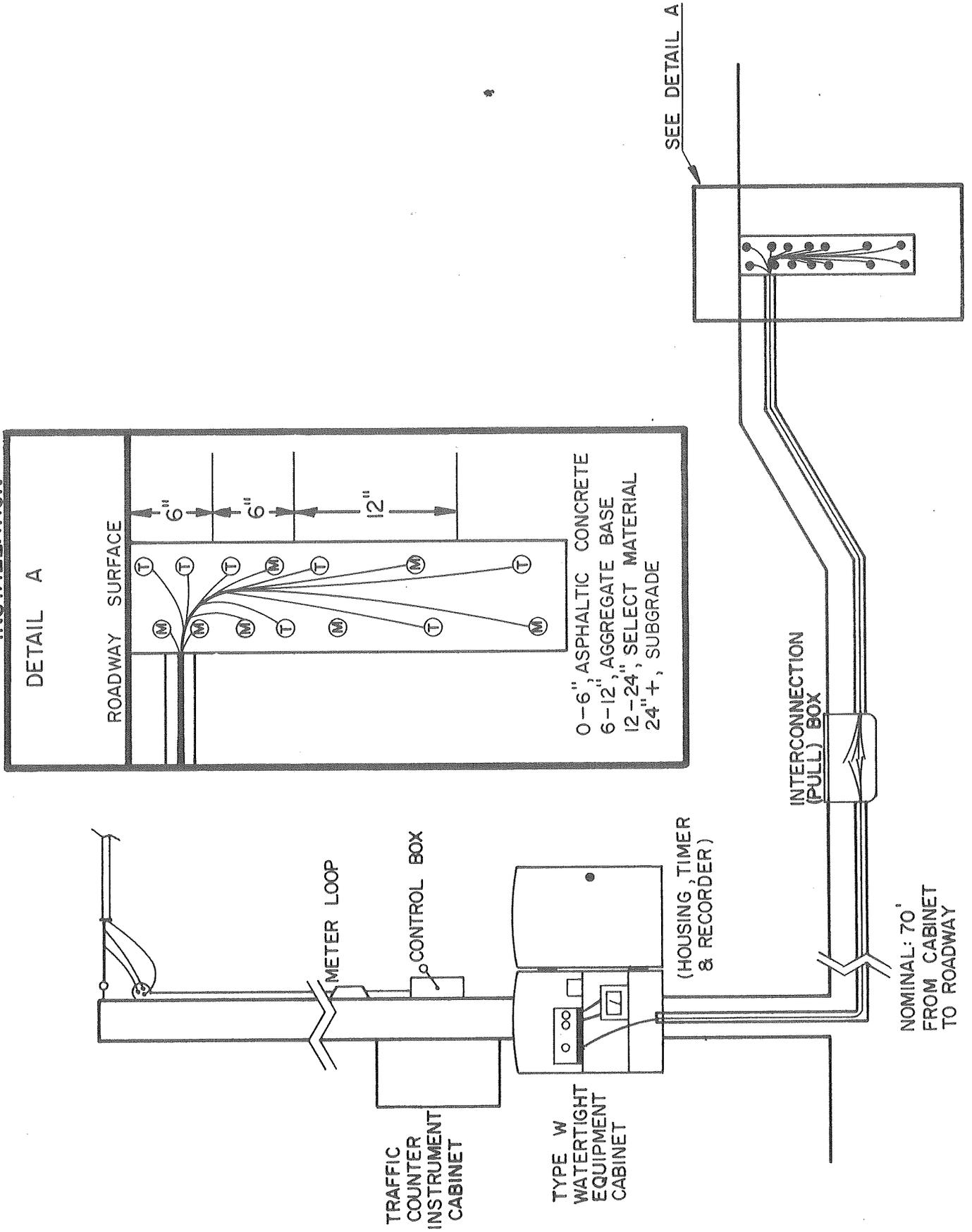
Revised July 1, 1974

SCALE - MILES  
0 10 20 30

**LEGEND**

- STATE HIGHWAYS
- - - - SURVEY ONLY

**FIGURE 30  
TYPICAL RECORDING SITE  
INSTALLATION**



INDEX PROPERTIES

DEPTH	LL	PL	PI	-3/8	-4	-40	-200
10"	31	27	4	59	39	20	10
18"	19	18	1	100	99	93	22

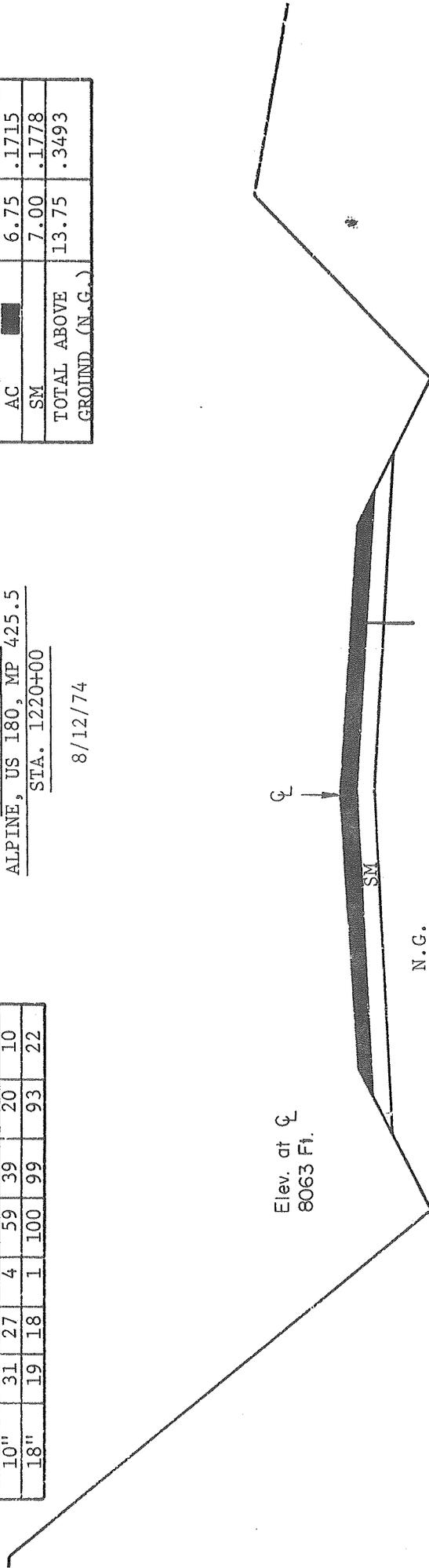
FIGURE 31

SITE NUMBER 22  
ALPINE, US 180, MP 425.5  
STA. 1220+00

8/12/74

LAYER THICKNESS

LAYER	INCH	METER
AC	6.75	.1715
SM	7.00	.1778
TOTAL ABOVE GROUND (N.G.)	13.75	.3493



DENSITY RESULTS

DEPTH	DRY DENSITY	% MOISTURE	DEGREE SATURATION
10"	103.5	16.9	75%
18"	115.8	11.2	69%

SCALE  
HORIZONTAL .066 = 1'  
VERTICAL .2" = 1'

SENSOR DEPTH

DEPTH	TEMPERATURE	MOISTURE
1/4"	T	
3.5"	T	M
7.0"	T	M
10.0"	T	M
24.0"	T	M
30.0"	T	M
AIR	T	
TEMP.		

INDEX PROPERTIES (a)

DEPTH	LL	PL	PI	-3/8	-4	-40	-200
7"AB			NP	78	52	10	5
14"SM			NP	57	39	11	6
26"SG	35	28	7	81	67	40	22

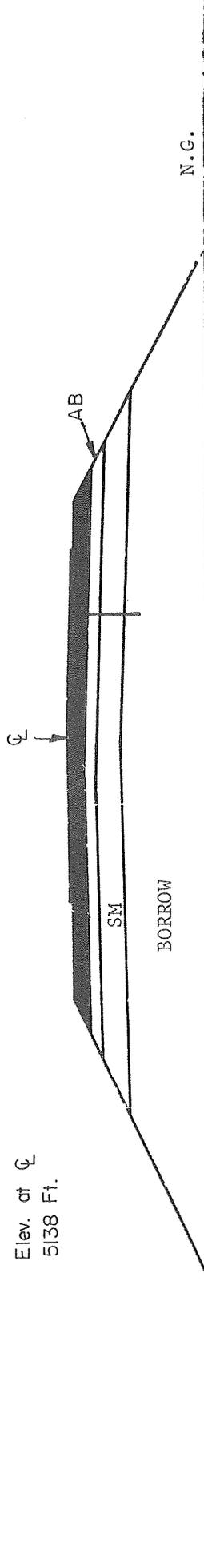
FIGURE 32

SITE NUMBER 23  
 ASH FORK, I-40, WB, MP 144.54  
 STA. 190+43

1/30/74

LAYER THICKNESS

LAYER	INCH	METER
ACFC	.50	.0127
AC	4.50	.1143
AB	4.00	.1016
SM	11.00	.2794
BORROW	33.00	.8382
TOTAL ABOVE		
GROUND (N.G.)		



DENSITY RESULTS

DEPTH	DRY DENSITY	% MOISTURE	DEGREE SATURATION
7"	102.6	11.7	51%
12"	103.9	12.3	55%
24"	117.6	18.3	100%

SCALE  
 HORIZONTAL .1" = 1'  
 VERTICAL .2" = 1'

SENSOR DEPTH

DEPTH	TEMPERATURE	MOISTURE
1/4"	T	
2.5"		M
5"	T	M
11"	T	M
16"	T	M
24"	T	M
30"	T	M
AIR TEMP.		

INDEX PROPERTIES

DEPTH	LL	PL	PI	-3/8	-4	-40	-200
4"			NP	73	65	42	14
10"			NP	60	54	28	8
19"	30	17	13	95	93	81	62

LAYER THICKNESS

LAYER	INCH	METER
AC	2.00	.0508
AB	4.00	.1016
SM	8.00	.2032
BORROW	10.00	.2540
PCC	8.00	.2032

FIGURE 33

SITE NUMBER 24

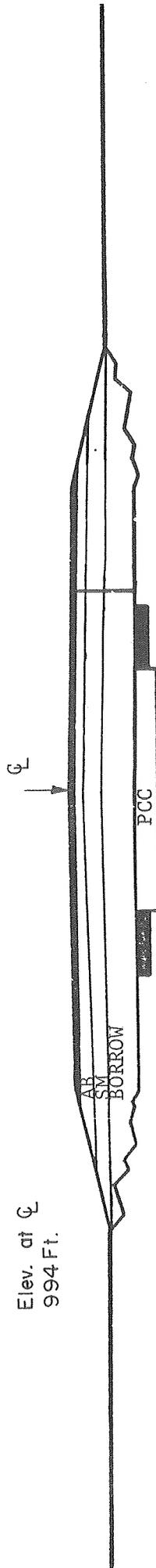
AVONDALE

BUCKEYE-91ST. AVE.

US 80 MP 183.75

STA. 1235+00

1/15/74



Elev. at C  
994 Ft.

SENSOR DEPTH

DEPTH	TEMPERATURE	MOISTURE
1/4"	T	
2"	T	M
5"	T	M
12"	T	M
16"	T	M
24"	T	M
AIR TEMP		

DENSITY RESULTS

DEPTH	DRY DENSITY	% MOISTURE	DEGREE SATURATION
4"	134.4	3.8	44%
10"	134.5	2.2	25%
19"	115.7	12.6	78%

SCALE  
HORIZONTAL .1" = 1'  
VERTICAL .2" = 1'

INDEX PROPERTIES

DEPTH	LL	PL	PI	-3/8	-4	-40	-200
7"			NP	72	57	24	7
16"			NP	65	56	25	7
25"			NP	97	91	34	11

FIGURE 34

SITE NUMBER 25  
 BENSON I-10, WB, MP 300.07  
 STA. 2159

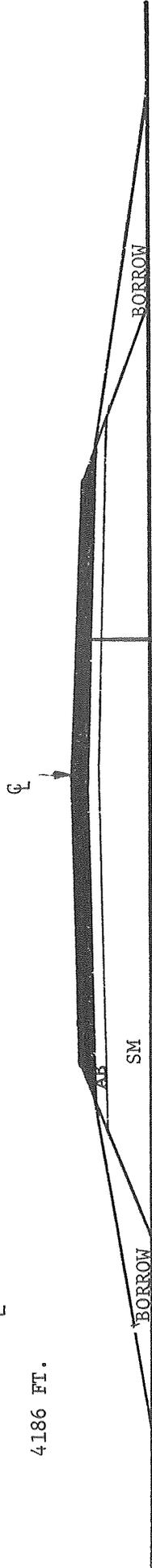
2/5/74

LAYER THICKNESS

LAYER	INCH	METER
ACFC	.50	.0127
NEW AC	2.50	.0635
OLD AC	2.00	.0508
AB	4.00	.1016
SM	15.00	.3810
TOTAL ABOVE	24.00	.6096
NATURAL GROUND		

ELEVATION @  $\phi$

4186 FT.



DENSITY RESULTS

DEPTH	DRY DENSITY	% MOISTURE	DEGREE SATURATION
7"	131.9#/FT <sup>3</sup>	5.7	60
16"	123.2	6.4	50
25"	129.1	4.6	43

SENSOR DEPTH

DEPTH	TEMPERATURE	MOISTURE
1/4"	T	
3"	T	M
6"		M
10"	T	M
20"	T	M
27"	T	M
AIR TEMP.	T	

SCALE

HORIZONTAL .1" = 1'

VERTICAL .2" = 1'

INDEX PROPERTIES

DEPTH	LL	PL	PI	-3/8	-4	-40	-200
6" AB			NP	68	49	23	13
11" CTB			NP	88	72	40	24
16" SGS			NP	93	82	48	44
24"	21	17	4	59	57	45	31

FIGURE 35

SITE NUMBER 26

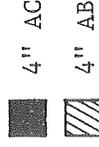
COSNINO, I-40, EB, MP 206.42

STA. 494+76

3/5/74

LAYER THICKNESS

LAYER	INCH	METER
PCC	8.00	.2032
CTB	6.00	.1524
SGS	5.00	.1270
BORROW	29.00	.7366
TOTAL ABOVE GROUND (N.G.)	48.00	



Elev. at  $\mathcal{C}$

6496 Ft.



DENSITY RESULTS

DEPTH	DRY DENSITY	% MOISTURE	DEGREE SATURATION
6"	124.4	9.3	75%
11"	136.8	10.2	100%
16"	132.3	10.5	100%
24"	138.6	11.0	100%

SCALE

HORIZONTAL .1" = 1'

VERTICAL .2" = 1'

SENSOR DEPTH

DEPTH	TEMPERATURE	MOISTURE
1/4"	T	
4"		M
9"	T	M
17"	T	M
24"	T	
30"	T	M
AIR TEMP		

INDEX PROPERTIES

DEPTH	LL	PL	PI	-3/8	-4	-40	-200
4"			NP	83	74	17	5
13"			NP	80	72	23	6
24"	23	19	4	96	86	43	21

FIGURE 36

SITE NUMBER 27  
 CUTTER, US 70, MP 258.65  
 STA. 84+72

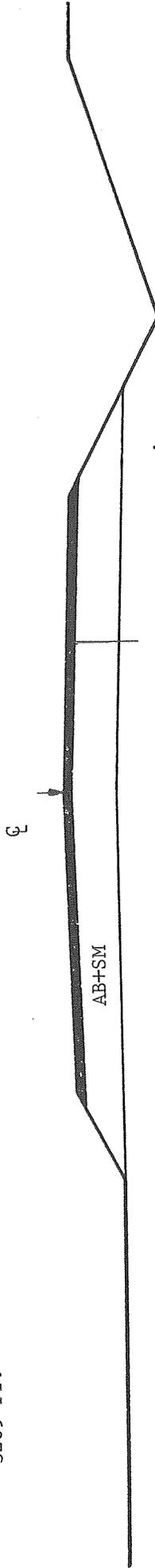
1/21/74

LAYER THICKNESS

LAYER	INCH	METER
ACFC	.50	.0127
AC	2.50	.0635
AB	2.00	.0508
SM	16.00	.4064

ELEVATION @  $\mathcal{L}$

3209 FT.



DENSITY RESULTS

DEPTH	DRY DENSITY	% MOISTURE	DEGREE SATURATION
4"	134.4	3.3	38%
13"	138.9	3.4	47%
24"	121.8	8.1	85%

SCALE  
 HORIZONTAL .1" = 1'  
 VERTICAL .2" = 1'

SENSOR DEPTH

DEPTH	TEMPERATURE	MOISTURE
1/4"	T	
1.5"	T	M
4"	T	M
11"		M
17"	T	M
24"	T	M
30"	T	M
AIR TEMP		

INDEX PROPERTIES

DEPTH	LL	PL	PI	-3/8	-4	-40	-200
6" AB			NP	82	63	21	16
11" CTB			NP	84	77	51	23
17" SGS			NP	88	83	57	38
24"	18	16	2	100	100	74	46

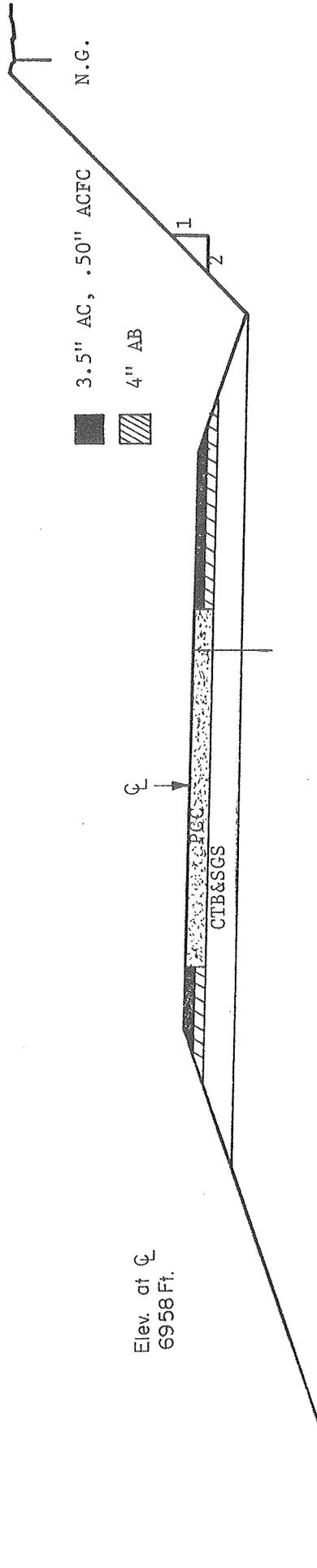
FIGURE 37

SITE NUMBER 28  
 FLAGSTAFF AIRPORT I-17, SB  
 STA. 7215+80

3/6/75

LAYER THICKNESS

LAYER	INCH	METER
PCC	8.00	.2032
CTB	6.00	.1524
SGS	6.00	.1524
TOTAL ABOVE GROUND (N.G.)	20.00	.5080



DENSITY RESULTS

DEPTH	DRY DENSITY	% MOISTURE	DEGREE SATURATION
6"	122.8	8.2	63%
11"	124.5	13.8	100%
17"	130.0	16.4	100%
24"	132.0	10.6	100%

SCALE  
 HORIZONTAL .1" = 1'  
 VERTICAL .2" = 1'

SENSOR DEPTHS

DEPTH	TEMPERATURE	MOISTURE
1 1/4"	T	
4"		M
8"	T	M
12"	T	M
17"	T	M
24"	T	M
30"	T	M
AIR TEMP	T	

INDEX PROPERTIES

DEPTH	LL	PL	PI	PI	-3/8	-4	-40	-200
10"			NP	79	66	31	13	
16"			NP	81	65	26	11	
24"	31	22	9	81	68	37	22	

FIGURE 38

SITE NUMBER 29

GILA BEND, I-8, EB, MP 112.80

STA. 4896+70

1/17/74

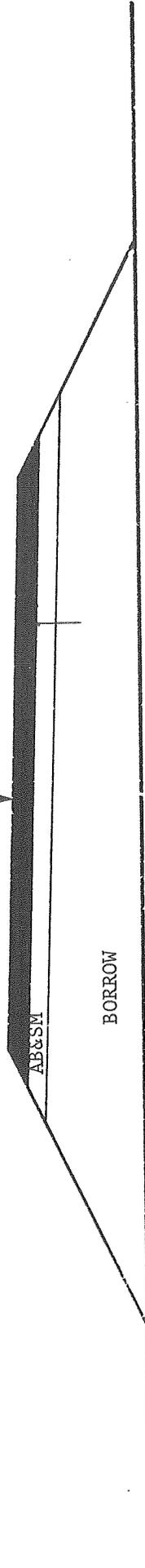
LAYER THICKNESS

LAYER	INCH	METER
ACFC	.75	.0191
AC	7.25	.1842
AB	4.00	.1016
SM	4.00	.1016
BORROW	32.00	.8128
TOTAL ABOVE	48.00	1.2192
GROUND (N.G.)		

ELEVATION @  $\zeta$

730 FT.

$\zeta$



DENSITY RESULTS

DEPTH	DRY DENSITY	% MOISTURE	DEGREE SATURATION
10"	127.2	4.4	39%
16"	127.1	5.0	44%
24"	125.0	4.4	36%

SCALE  
 HORIZONTAL .1" = 1'  
 VERTICAL .2" = 1'

SENSOR DEPTH

DEPTH	TEMPERATURE	MOISTURE
1/4"	T	
4"	T	M
8"	T	M
13"	T	M
17"	T	M
24"	T	M
AIR TEMP.	T	

INDEX PROPERTIES

DEPTH	LL	PL	PI	-3/8	-4	-40	-200
7"							
15"			NP	100	100	82	26
26"			NP	100	100	85	40

FIGURE 39

SITE NUMBER 30  
 LUPTON, I-40, WB, MP 359  
 STA. 2871+50

3/12/74

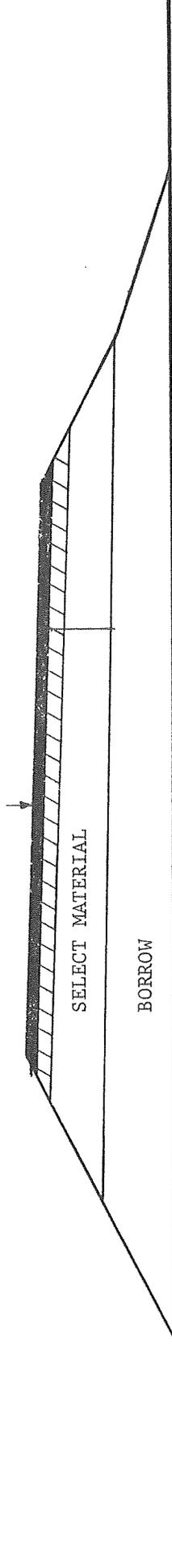
LAYER THICKNESS

LAYER	INCH	METER
AC	4.00	.1016
CTB	6.00	.1524
SM	21.00	.5334
BORROW	24.00	.6096
TOTAL ABOVE		
GROUND (N.C.)	55.00	1.3970

ELEVATION @  $\phi$

6184 FT.

$\phi$



DENSITY RESULTS

DEPTH	DRY DENSITY	% MOISTURE	DEGREE SATURATION
7"		14.8	
15"	115.9	6.2	39%
26"	112.0	6.9	38%

SENSOR DEPTH

DEPTH	TEMPERATURE	MOISTURE
1/4"	T	
2"		M
4"	T	
7"	T	M
20	T	M
30	T	M
36	T	M
AIR TEMP.	T	

SCALE  
 HORIZONTAL .1" = 1'  
 VERTICAL .2" = 1'

INDEX PROPERTIES

DEPTH	LL	PL	PI	-3/8	-4	-40	-200
6"			NP	73	36	11	4
14"			NP	55	29	12	6
26"	25	22	3	61	47	40	15

FIGURE 40

SITE NUMBER 31  
 SHOW LOW, U.S. 60, MP 337.74  
 STA. 21+50

1/23/74

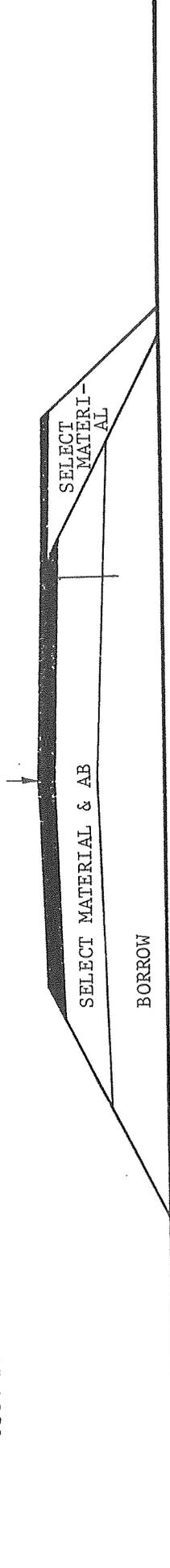
LAYER THICKNESS

LAYER	INCH	METER
ACFC	.50	.0127
AC	2.00	.0508
BTB	2.00	.0508
AB	4.00	.1016
SELECT	15.50	.3937
BORROW	24.00	.6096
TOTAL ABOVE GROUND (N.G.)	48.00	1.2192

ELEVATION @  $\zeta$

6384 FT.

$\zeta$



DENSITY RESULTS

DEPTH	DRY DENSITY	% MOISTURE	DEGREE SATURATION
6"	105.1	13.8	64%
14"	126.0	8.6	73%
26"	122.5	16.1	100%

SCALE  
 HORIZONTAL .1" = 1'  
 VERTICAL .2" = 1'

SENSOR DEPTH

DEPTH	TEMPERATURE	MOISTURE
1/4"	T	
4"	T	M
6"	T	M
14"	T	M
24"	T	M
30"	T	M
AIR TEMP.	T	

INDEX PROPERTIES

DEPTH	LL	PL	PI	-3/8	-4	-40	-200
5"			NP	76	58	14	0
11"			NP	48	39	11	0
20"			NP	62	46	16	7

FIGURE 41

SITE NUMBER 32  
 TEMPE BRIDGE, U.S. 60, MP  
 STA. 37+00

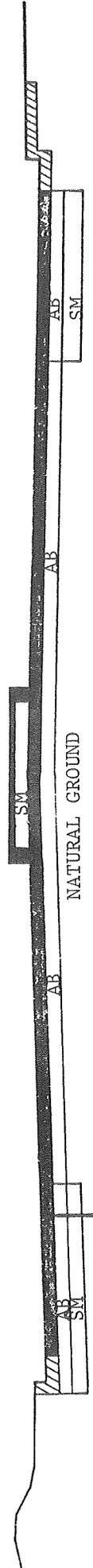
1/4/74

LAYER THICKNESS

LAYER	INCH	METER
ACFC	.50	.0127
AC	2.50	.0635
AB	6.00	.1524
SM	6.00	.1524
TOTAL ABOVE GROUND (N.G.)	15.00	.3810

ELEVATION @ C

1188 FT.



DENSITY RESULTS

DEPTH	DRY DENSITY	% MOISTURE	DEGREE SATURATION
5"	135.8	3.7	45%
11"	141.2	4.0	62%
20"	118.1	9.5	63%

SCALE  
 HORIZONTAL .1" = 1'  
 VERTICAL .2" = 1'

SENSOR DEPTH

DEPTH	TEMPERATURE	MOISTURE
1/4"	T	
2"	T	M
5"	T	M
13"	T	M
17"	T	M
20"	T	M
AIR TEMP.	T	

INDEX PROPERTIES

DEPTH	LL	PL	PI	-3/8	-4	-40	-200
6"			NP	83	72	34	8
11"			NP	78	66	33	7
20"			NP	77	70	38	6

FIGURE 42

SITE NUMBER 33  
 TOPOCK, I-40, MP.42, WB  
 STA. 23+85

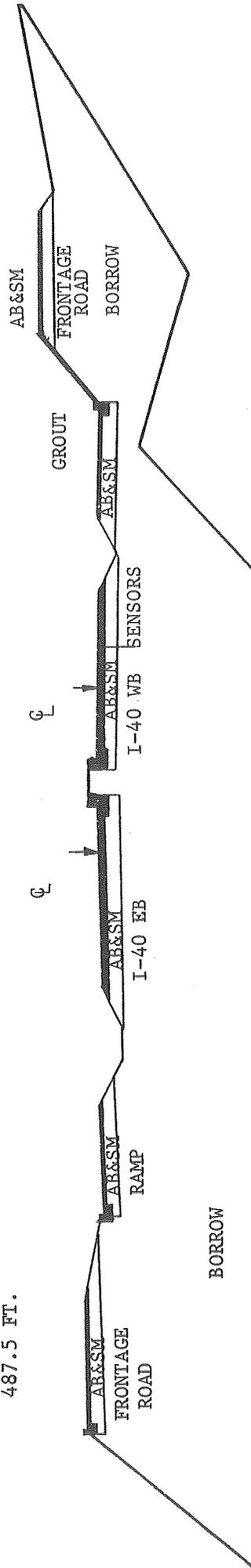
1/29/74

LAYER THICKNESS

LAYER	INCH	METER
ACFC	.50	.0127
AC	3.50	.0889
AB	4.00	.1016
SELECT	9.00	.2286
BORROW	216.00	5.4864
TOTAL ABOVE GROUND (N.G.)	233.00	5.9182

ELEVATION @  $\phi$

I-40 WB  
 487.5 FT.



DENSITY RESULTS

DEPTH	DRY DENSITY	% MOISTURE	DEGREE SATURATION
6"	128.3	2.6	24%
11"	132.9	2.6	28%
20"	123.2	3.0	23%

SLOPES TO  
 COLORADO RIVER

N.G.

SCALE  
 HORIZONTAL .033" = 1'  
 VERTICAL .1" = 1'

SENSOR DEPTH

DEPTH	TEMPERATURE	MOISTURE
1/4"	T	
2.5"		M
5"	T	M
12"	T	M
17"	T	M
24"	T	M
30"	T	M
AIR TEMP.	T	

INDEX PROPERTIES

DEPTH	LL	PL	PI	-3/8	-4	-40	-200
10"			NP	98	96	68	10
17"	64	21	43	100	100	99	88
24"	66	23	43	100	100	99	89

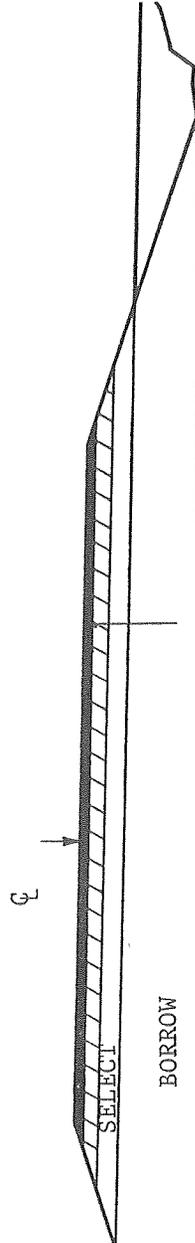
Elev. of  $\zeta$   
4897 Ft.

FIGURE 43

SITE NUMBER 34  
MINNETONKA, I-40, EB, MP  
STA. 286+00

LAYER THICKNESS

LAYER	INCH	METER
ACFC	.50	.0127
NEW AC	1.25	.0318
OLD AC	6.50	.1651
SELECT	6.00	.1524
BORROW	36.00	.9144
TOTAL ABOVE GROUND (N.G.)	50.25	1.2764



MEDIAN  
DITCH

N.G.

DENSITY RESULTS

DEPTH	DRY DENSITY	% MOISTURE	DEGREE SATURATION
10"	115.1	9.5	58%
17"	92.4	25.1	84%
24"	91.0	28.3	92%

SCALE  
HORIZONTAL .1" = 1'  
VERTICAL .2" = 1'

SENSOR DEPTH

DEPTH	TEMPERATURE	MOISTURE
1/4"	T	
5"	T	M
10"	T	M
17"	T	M
23"	T	M
30"	T	M
AIR TEMP.	T	

# FIGURE 44

TYPICAL TEMPERATURE CALIBRATION CURVE  
NOTE TEMPERATURES CODED BY +40°F

N=7  
CORRELATION COEFF.=.99783  
LOG Y=1.28222+.40657 (LOG X)

VALVES  
COMPUTER FITTED

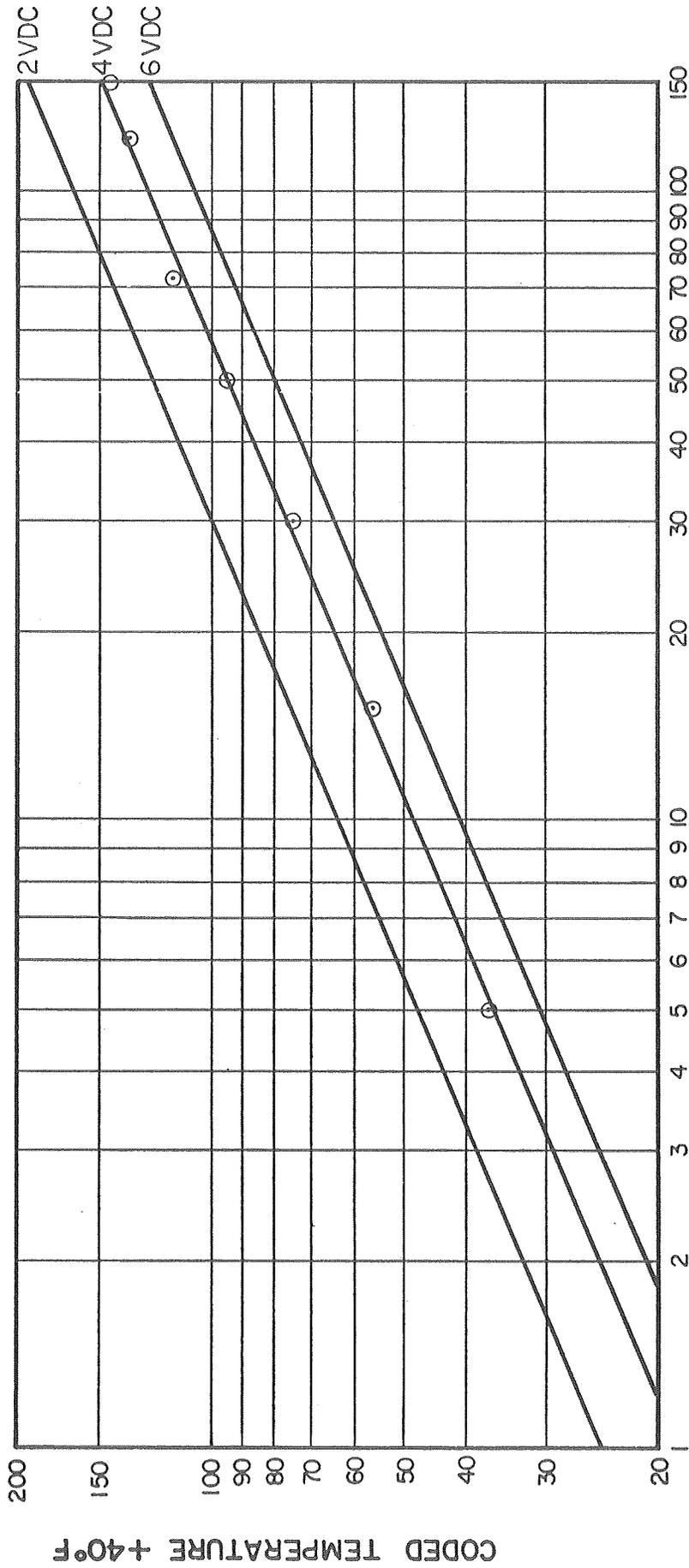


CHART PAPER READING  
160 CHART DIVISIONS = FULL SCALE 10 MILLI-VOLT

FIGURE 45  
 TYPICAL MOISTURE CALIBRATION CURVE  
 FITTED BY HAND

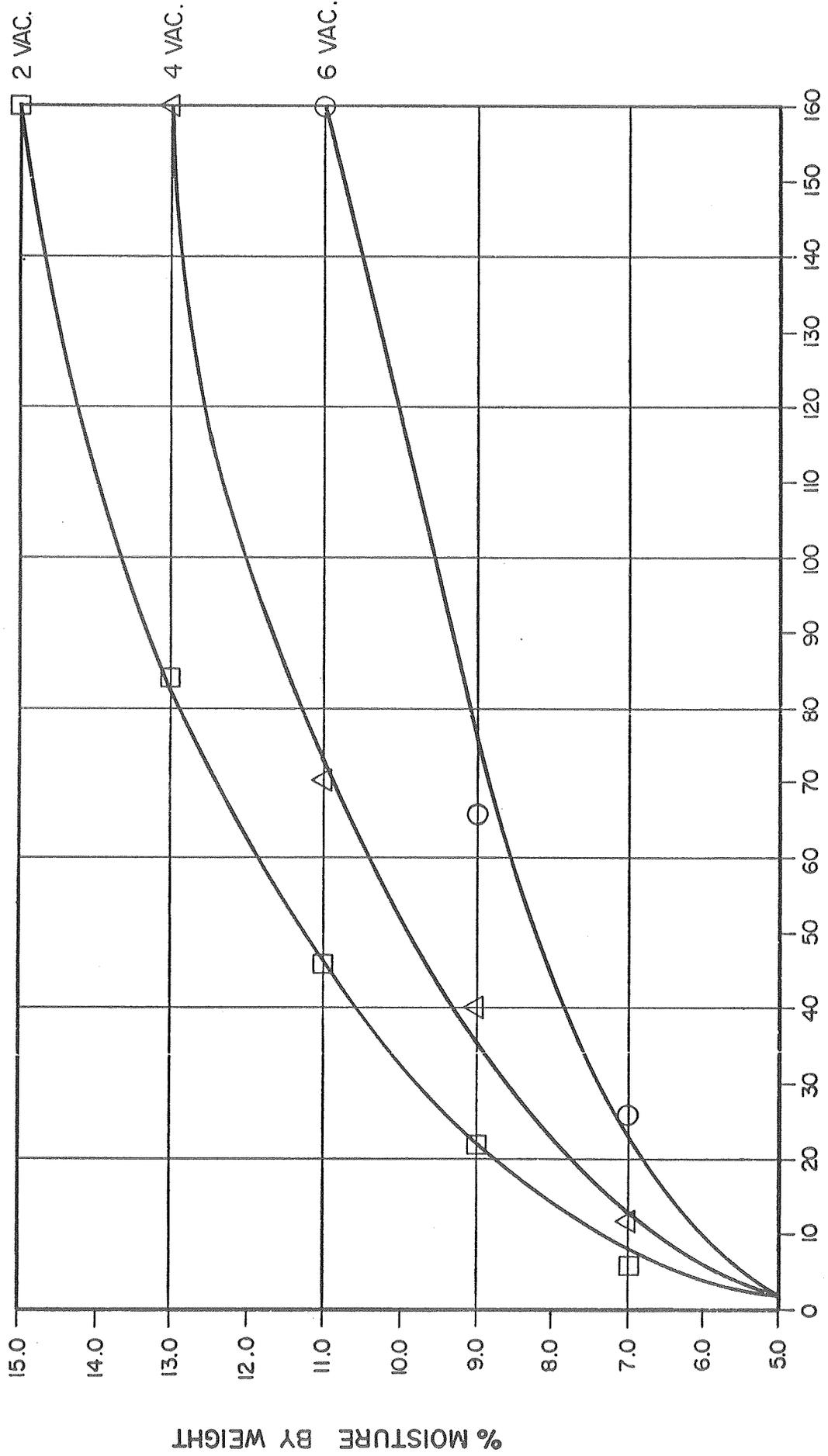


CHART PAPER READING  
 160 CHART DIVISIONS = FULL SCALE 10 MILLI-VOLT

TABLE I

NUCLEAR SITE  
GENERAL DESCRIPTION

SITE NUMBER AND NAME EXACT LOCATION AND PROJECT NUMBER	ELEV. FT. (METERS)	NEAREST WEATHER STATION	GEOLOGY	TOPOGRAPHY VEGETATION DRAINAGE	DATE BUILT
1. Sybil Rd. T.I. I 10 WB, MP 311 Sta. 283+26 - I 10-6 (9)	4010 (1222)	Benson	Qts Old Valley Fill Deposit	Rolling Hills Desert Grass Slow Infiltration	7/1960
2. Willmot Rd. T.I. I 10 EB, MP 270 Sta. 474+97 - I 10-5 (12)	2790 (850)	Tucson	Qw Younger Alluvial Deposit Intermittent Stream Channel	Flat Valley Floor Desert-Creosote and Salt Bush Very Slow Infiltration	4/1960
3. Marana T.I. I 10 EB, MP 235 Sta. 429+85 - I 10-4 (27)	1950 (594)	Red Rock	Qs Younger Alluvial Deposit Surficial Valley Fill. Undifferentiated	Flat Valley Floor Irrigated Land Slow Infiltration	7/1968
4. Casa Grande T.I. I 10 EB, MP 196 Sta. 268+08 - I 10-3 (59)	1436 (438)	Casa Grande	Qs Younger Alluvial Deposit. Surficial Valley Fill. Undifferentiated	Flat Valley Floor Irrigated Land Slow Infiltration	7/1968
5. Williams Field T.I. I 10 EB, MP 160 Sta. 788+27 - I 10-3 (56)	1209 (367)	Chandler	Qfp Alluvial Fan and Rock Sediment	Flat Valley Floor Irrigated Land Slow Infiltration	4/1967
5. Tonopah I 10 EB, MP 100.67 Sta. 5309+06 - I 10-2 (13)	1098 (335)	Tonopah	Qfp Alluvial Fan and Rock Sediment	Flat Valley Floor Desert Creosote & Salt Brush Slow Infiltration	Grade and Drain 1971

TABLE I (Continued)

NUCLEAR SITE  
GENERAL DESCRIPTION

SITE NUMBER AND NAME EXACT LOCATION AND PROJECT NUMBER	ELEV. FT. (METERS)	NEAREST WEATHER STATION	GEOLOGY	TOPOGRAPHY VEGETATION DRAINAGE	DATE BUILT
7. Upper Deer Valley I 17 NB, MP 223 Sta. 1170+47 - I 17-1 (56)	1639 (500)	Cave Creek	Qp Younger Alluvial Deposit. Flood Plain and Playas	Flat Valley Floor. Desert Creosote & Salt Bush Very Slow Infiltration	10/1964
8. Lake Pleasant SR 74, MP 23.44 Sta. 1238+00 - S 434 (3)	1693 (516)	Cave Creek	Qfp Alluvial Fan and Rock Sediment Caliche	Rolling Hills. Desert Creosote and Salt Bush Very Slow Infiltration	1973 Grade and Drain
9. Agua Fria River I 17 NB, MP 243 Sta. 2215+77 - I 17-1 (59)	2000 (610)	Cave Creek	QTs Older Valley Fill	Foothills. Leading to Plateau Desert Palo Verde & Cacti - Slow Infiltration	10/1964
10. Sunset Point I 17 NB, MP 251.41 Sta. 2660 - I 17-1 (55)	3354 (1022)	Cordes	QTb Basic Volcanic and Intrusive Rocks.	Flat Plateau Chaparral Very Slow Infiltration	9/1967
11. Cherry Rd. T.I. I 17 NB, MP 275 Sta. 3884+16 - I 17-2 (62)	4442 (1354)	Cordes	QTb Basic Volcanic and Intrusive Rocks	Rolling Hills Chaparral Very Slow Infiltration	5/1970
12. Cienga Creek SR 169 MP 14.58 Sta. 770+00 - S 447 (2)	4460 (1359)	Cordes	QTb Basalt	Plateau Cut by Washes. Oak and Charral Very Slow Infiltration	8/1971 Grade and Drain

TABLE I (Continued)

NUCLEAR SITE  
GENERAL DESCRIPTION

SITE NUMBER AND NAME EXACT LOCATION AND PROJECT NUMBER	ELEV. FT. (METERS)	NEAREST WEATHER STATION	GEOLOGY	TOPOGRAPHY VEGETATION DRAINAGE	DATE BUILT
13. Sedona T.I. I 17 NB MP 298.54 Sta. 5171+42 - I 17-2 (20)	3814 (1163)	Sedona	Qtz Older Valley Fill	Foothills to Mogollon Rim. Pinyon Juniper Very Slow Infiltration	3/1961
14. Kachina Blvd. I 17 SB MP 334.57 Sta. 7086+50 - I 17-2 (35)	6780 (2067)	Flagstaff	Pk Kaibab Limestone	Rolling Mogollon Rim Ponderosa Pine. Slow Infiltration	8/1974
15. Bellemont I 40 EB, MP 186.5 Sta. 1689+30 - I 40-3 (22)	7139 (2176)	Flagstaff	Qtz Basalt, Cinders and Clay Mixed	Rolling. Ponderosa Pine Slow Infiltration	12/1965
16. Woody Mtn. T. I. I 40 EB MP 192.85 Sta. 2032 - I 40-3 (32)	7086 (2160)	Flagstaff	Qb Basalt, Cinders and Clay Mixed	Rolling. Ponderosa Pine Slow Infiltration	5/1969
17. Winona I 40 WB, MP 212.60 Sta. 821+15 - I 40-4 (69)	6160 (1876)	Flagstaff	Qb Basalt, Cinders and Silt Mixed.	Foot Hills Pinyon Juniper Slow Infiltration	1/1970
18. Winslow Bypass I 40 EB, MP 257.78 Sta. 3215+00 - I 40-4 (61)	4861 (1482)	Winslow	Qs River Sand	Flat Upper Plateau Short Grass Slow Infiltration	1974

TABLE I (Continued)

NUCLEAR SITE  
GENERAL DESCRIPTION

SITE NUMBER AND NAME EXACT LOCATION AND PROJECT NUMBER	ELEV. FT. (METERS)	NEAREST WEATHER STATION	GEOLOGY	TOPOGRAPHY VEGETATION DRAINAGE	DATE BUILT
19. Minnetonka I 40 EB, MP 261.78 Sta. 369+00 - I 40-4 (90)	4884 (1489)	Winslow	Qs Sand and Clay Very wet.	Flat Upper Plateau Short Grass Slow Infiltration	7/1972
20. Navajo Co. Line to Pinta I 40 EB, MP 316.68 Sta. 500+00 - I 40-5 (38)	5568 (1697)	Navajo	Tr C Desiccated Clay Shales of Chinle Formation Very Expansive	Flat Upper Plateau Short Grass Slow Infiltration	6/1974
21. Crazy Creek I 40 EB, MP 322.72 Sta. 819+50 - I 40-5 (14)	5599 (1707)	Navajo	TR C Desiccated Clay Shales of Chinle Formation Very Expansive	Flat Upper Plateau Short Grass Slow Infiltration	6/1962

TABLE II  
DYNAFLECT AND MAY METER VALUES FOR NUCLEAR SITES  
MAY 1974

SITE NUMBER NAME AND LOCATION				DEFLECTION 1ST SENSOR (D.), MILS SURFACE CURVATURE INDEX (SCI) * (RI) **		
				D.	SCI	RI
1. Sybil Rd. T. I.	I - 10	WB	MP 311	1.131	.065	3.73
2. Wilmot Rd. T.	I - 10	EB	MP 270	1.370	.101	3.11
3. Marana T. I.	I - 10	EB	MP 235	.879	.101	3.10
4. Casa Grande T. I.	I - 10	EB	MP 196	.876	.194	3.91
5. Williams Field T. I.	I - 10	EB	MP 160	.866	.319	3.83
6. Tonopah	I - 10	EB	MP 100.67	1.666	.886	----
7. Deer Valley T. I.	I - 17	NB	MP 223	2.067	.794	3.27
8. Lake Pleasant	SR 74	EB	MP 23.44	.739	.350	----
9. Agua Fria River	I - 17	NB	MP 243	.792	.421	3.71
10. Sunset Point	I - 17	NB	MP 251.41	1.463	.605	3.85
11. Cherry Rd. T. I.	I - 17	SB	MP 275	.937	.404	3.87
12. Cienga Creek	SR 169	EB	MP 14.58	2.315	1.095	----
13. Sedona T. I.	I - 17	NB	MP 298.54	1.225	.498	3.62
14. Kachina Blvd.	I - 17	SB	MP 334.57	.342	.040	----
15. Bellemont	I - 40	EB	MP 186.5	2.514	1.500	2.82
16. Woody Mtn. T. I.	I - 40	EB	MP 192.85	1.095	.111	3.34
17. Winona	I - 40	WB	MP 212.60	2.407	.829	3.67
18. Winslow Bypass	I - 40	EB	MP 257.78	2.387	.651	----
19. Minnetonka	I - 40	EB	MP 261.78	2.139	.542	3.68
20. Navajo Co. Line-Pinta	I - 40	EB	MP 316.68	1.356	.227	2.36
21. Crazy Creek	I - 40	EB	MP 322.72	1.114	.235	2.89

\* SCI = (SENSOR 1 - SENSOR 2)

\*\* RIDEABILITY INDEX FROM 1-5; 5 is smooth and 1 very rough. 2.5 taken as break between smooth and rough.

TABLE III

RECORDING SITE  
GENERAL DESCRIPTION

SITE NUMBER AND NAME EXACT LOCATION AND PROJECT NUMBER	ELEV. FT. (METERS)	NEAREST WEATHER STATION	GEOLOGY	TOPOGRAPHY VEGETATION DRAINAGE	DATE BUILT
22. Alpine US 180, MP 425.5 STA 1220+00 EDA F051-2 (9)	8061 (2458)	Alpine	Ts Sandstone Silt & Gravel	Mountainous Ponderosa Pine Slow Infiltration	11/1974
23. Ash Fork I 40 WB, MP 144.54 ING 80 (18) STA 190+43	5139 (1567)	Ash Fork	QTb Basalt & Andesite Clay Cap with Rock beneath	Flat Short grass Slow Infiltration	1955
24. Avondale Buckeye - 91st Ave. I 40 EB, MP 183.75 STA 1235+00 S 371 (1)	994 (303)	Litchfield Park	Qs Alluvial Sediments with some caliche	Flat Irrigated land on both sides of road; no curb slow infiltration	1956
25. Benson I 10 WB, MP 300.07 STA 2159 I 10-5 (27)	4186 (1276)	Benson	Qs Alluvial Sediments with some caliche	Flat Desert Grass Slow Infiltration	1966
26. Cosmino I 40 EB, MP 206.42 STA 494+76 I 40-4 (69)	6496 (1980)	Flagstaff	Pk Kaibab Limestone	Rolling Hills Ponderosa Pine & Juniper Slow Infiltration	1970

TABLE III

RECORDING SITE  
GENERAL DESCRIPTION

SITE NUMBER AND NAME EXACT LOCATION AND PROJECT NUMBER	ELEV. FT. (METERS)	NEAREST WEATHER STATION	GEOLOGY	TOPOGRAPHY VEGETATION DRAINAGE	DATE BUILT
27. Cutter US 70, MP 258.65 STA 84+72 FLH 13A-1	3209 (978)	Globe	Qs Alluvial sediments	Flat Desert Saltbush Creosotebush Slow Infiltration	1941
28. Flagstaff Airport T.I. I 17 SB, MP 337 STA 7215+80 I 17-2 (35)	6958 (2121)	Flagstaff	Pk Kaibab Limestone	Rolling Hills Ponderosa Pine Slow Infiltration	9/1974
29. Gila Bend I 8 EB, MP 112.8 STA 4896+70 I 8-2 (18)	730 (223)	Gila Bend	Qfp Alluvial sediment some caliche	Flat Desert Saltbush Creosotebush Slow Infiltration	1960
30. Lupton I 40 WB, MP 359 STA 2871+50 I 40-5 (29)	6184 (1885)	Lupton	Jsr Sandstone	Mountains Rushing up out of flat plateau Pinyon & Juniper High Infiltration	1964
31. Show Low US 60, MP 337.74 STA 21+50 FH 30 A-3	6384 (1946)	Show Low	Ks Limestone shale & Limestone	Rolling Hills Ponderosa Pine Slow Infiltration	1946

TABLE III

RECORDING SITE  
GENERAL DESCRIPTION

SITE NUMBER AND NAME EXACT LOCATION AND PROJECT NUMBER	ELEV. FT. (METERS)	NEAREST WEATHER STATION	GEOLOGY	TOPOGRAPHY VEGETATION DRAINAGE	DATE BUILT
32. Tempe US 60, MP 172 STA 37+00 Non F 022-3 (61)C	1188 (362)	Tempe	TKs sedimentary conglomerate	Curb & gutter, park with Eucalyptus trees on one side Slow Infiltration	1960
33. Topock I 40 WB, MP .42 STA 23+85 I 40-1 (8)	487.5 (149)	Yucca	gm Granite Gneiss	Rolling Hills Desert Saltbush Creosotebush Slow Infiltration	1966
34. Winslow I 40 EB, MP 260.21 STA 286 I 40-4 (90)	4897 (1493)	Winslow	Qs Alluvial sediment	Flat, one mile from little Colorado river; short grass Slow Infiltration	1973

TABLE IV  
 DYNAFLECT AND MAYS METER VALUES FOR RECORDING SITES  
 MAY 1974

	SITE NUMBER NAME AND LOCATION				DEFLECTION 1ST SENSOR (D.), MILS SURFACE CURVATURE INDEX (SCI) * (RI) **		
					D.	SCI	RI
22.	Alpine	US 180	EB	MP 425.5	.651	.254	Const.
23.	Ash Fork	I - 40	WB	MP 144.54	3.862	1.723	3.03
24.	Avondale, Buckeye-91st	US 80	WB	MP 183.75	1.306	.419	3.36
25.	Benson	I - 10	WB	MP 300.07	1.044	.416	3.83
26.	Cosnino	I - 40	EB	MP 206.42	.719	.483	3.40
27.	Cutter	US 70	WB	MP 258.65	2.092	.781	3.05
28.	Flagstaff Airport T. I.	I - 17	SB	MP 337.0	.389	.038	Const.
29.	Gila Bend	I - 8	EB	MP 112.80	.625	.187	3.93
30.	Lupton	I - 40	WB	MP 359	.882	.097	2.35
31.	Show Low	US 60	WB	MP 337.74	1.823	.805	2.68
32.	Tempe Bridge	US 60	EB	MP 172	.673	.181	City
33.	Topock	I - 40	WB	MP .42	.852	.253	4.02
34.	Winslow, Minnetonka	I - 40	EB	MP 260.21	1.413	.421	3.68

\* SCI = (SENSOR 1 - SENSOR 2)

\*\* RIDEABILITY INDEX FROM 1-5; 5 is smooth and 1 very rough. 2.5 taken as break between smooth and rough.