Report No.CDOT-DTD-R-93-15

Seasonal Monitoring Program
Instrumentation Demonstration
Delta, Colorado

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Final Report
July, 1993

93-15

Prepared in cooperation with the
U.S. Department of Transportation
Federal Highway Administration

Seasonal Monitoring Program
Workshop And Instrumentation Demonstration
Delta, Colorado

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SEASONAL MONITORING PROGRAM
INSTRUMENTATION INSTALLATION AND DATA COLLECTION
TRAINING WORKSHOP

Delta Site, Colorado
June 29, 1993

AGENDA

8:30 - 8:45 a.m.	Welcoming Remarks and Introductions Instructors Participants Purpose of Workshop	(A. Ardani, A. Lopez)
8:45 - 9:30 a.m.	Overview of Seasonal Monitoring Program Objectives Core Experiment and Supplemental Studies Status of Section Selection Process Data Collection Activities Seasonal Instrumentation (Selection and Description)	(G. Rada)
9:30 - 10:00 a.m.	Moisture Measurements Theory - Dielectric Constant TDR Probes and Other Equipment Measurements of Dielectric Constant (TDR Trace) Estimates of Moisture Calibration and Checks	(A. Lopez)
10:00 - 10:30 a.m.	Temperature Measurements Theory - Resistivity Thermistor Probe and Other Equipment Resistivity Measurements Temperature Calculations Calibration and Checks	(B. Henderson)
10:30 - 10:45 a.m.	BREAK	
10:45 - 11:30 a.m.	Frost/Thaw Depth Measurements Theory - Resistivity and Resistance Resistivity Probe and Other Equipment Resistance and Resistivity Measurements Estimates of Frost/Thaw Depth and Other Soil Properties Calibration and Checks	(G. Elkins)

AGENDA (Continued)

11:30 - 12:00 noon	Depth to Ground Water Table Measurements General Background Piezometer Well and Other Equipment Ground Water Table Measurements	(G. Elkins)
12:00 - 1:00 p.m.	LUNCH	
1:00 - 1:30 p.m.	Air Temperature and Precipitation Measurements General Background Air Temperature Probe, Rain Tipping-Bucket, and Other Equipment Air Temperature and Precipitation Measurements Calibration and Checks	(A. Lopez)
1:30 - 3:00 p.m.	Installation of Seasonal Instrumentation General Layout Responsibilities Pre-Installation Activities Colorado Seasonal Site Installation Activities Traffic Control FWD Testing Piezometer Well Thermistor Probe Resistivity Probe, TDR Probes	(G. Rada, G. Elkins)
3:00 - 3:15 p.m.	BREAK	
3:15 - 4:30 p.m.	Installation of Seasonal Instrumentation Installation Activities Air Temperature Probe and Rain Tipping-Bucket Equipment Cabinet and Connections Site Repair and Clean-Up Initial Data Collection Sensor Readings FWD Testing Elevation Surveys Other Surveys Post-Installation Activities	(A. Lopez, B. Henderson, Gary Elkins)

AGENDA (Continued)

4:30 - 5:30 p.m.	Seasonal Data Collection FWD Testing Profile and Elevation Surveys Moisture, Precipitation, Temperature, Depth to Ground Water Table, and Frost/Thaw Depth Measurements Distress Surveys Other Surveys	(G. Rada)
5:30 p.m.	ADJOURN	

Executive Summary

LTPP Seasonal Monitoring Program
Workshop And
Instrumentation Demonstration
Delta, Colorado

During the week of June 28 through July 2, 1993 Colorado Department of Transportation in cooperation with LTPP Division of FHWA and LTPP Western Region Coordination Office sponsored a workshop and a field demonstration in Grand Junction and Delta, Colorado for the Seasonal Monitoring program. The purpose of the workshop and the field demonstration was to train and familiarize The LTPP SHRP Coordinators with the Seasonal Monitoring Program's concept, equipment installation, operation, and data collection.

Altogether there are 64 sites for the seasonal monitoring program across the country which cover four environmental zones (wet-freeze, wet-no freeze; dry freeze, dry no freeze). The matrix that constitute this program also includes pavement type (flexible vs. rigid), thickness, and subgrade type (coarse vs. fine). With all these factors in mind the Colorado site is located in the zone of dry-freeze with fine subgrade and thin flexible pavement surface.

The primary objective of the SHRP's seasonal monitoring program is to evaluate and monitor the impact of seasonal variations in moisture and temperature on pavement response. This program will attempt to establish a relationship between pavement response and deflection measurements taken at different times of the year for a given climatic zone. The ultimate goal of this program is to rationally use the acquired deflection data for evaluation, analysis and design.

The instrumentation consisted of installing the following measurement sensors:

1) TDR (Time Domain Reflectometry) sensors, for moisture
2) Resistivity sensors, to monitor frost penetration
3) Thermistors, to measure temperature of the subgrade
4) Observation well, to monitor depth of ground water
5) Tipping Bucket Rain Gage,. to measure rainfall
6) Ambient Temperature probe, to monitor the air temperature

The equipment was furnished by SHRP and the installation was performed as a cooperative effort between CDOT personnel, FHWA, and the SHRP Western Region contractor.

The SHRP seasonal monitoring site at the Delta site will be tested on a two year cycle; i.e, testing in years 1, 3, 5..etc. The data collected from this site will be entered into the National Information Management System (NIMS), along with data from 63 other sites across the United States and Canada.

Interim results can be expected in 5 years, and final results within the next 10 years.

CDOT

SHRP Seasonal Monitoring Program

June 28 - July 2, 1993

Delta, Colorado

I. <u>Background</u>

Environment or load; which affects the life of the pavement most? Researchers have reasons to believe that some of the main factors in deteriorating pavements are related to environmental factors such as: moisture, temperature, frost penetration, and soil types. Premature distress of pavement on some of Colorado's highways may be due, in part, to the effects of environment.

Many Engineers believe that the environmental factors and load related factors are intertwined; one reinforcing the other in distressing the pavement. However, there is evidence that indicates that the effects of heavy load and environmental factors can be independently evaluated.

SHRP and the FHWA, in cooperation with the participating states, have developed a specialized study (SHRP Seasonal Monitoring Program) to determine how much adverse environmental conditions impact the life of pavement. Of the 800 General Pavement Study (GPS) Sites, 64 have been selected for an extensive study relative to factors such as moisture, temperature, and frost depth, and their effects on pavement strength. These sites will be monitored by the SHRP Western Region team each month and twice during each of the spring break-up months.

Representatives from the CDOT, LTPP Division of FHWA, and all four SHRP Regional offices were present during the equipment installation for the Colorado site in Delta. The following is the summary of the instrument installation and calibration for the SHRP seasonal monitoring site in Delta, Colorado.

II. Objectives

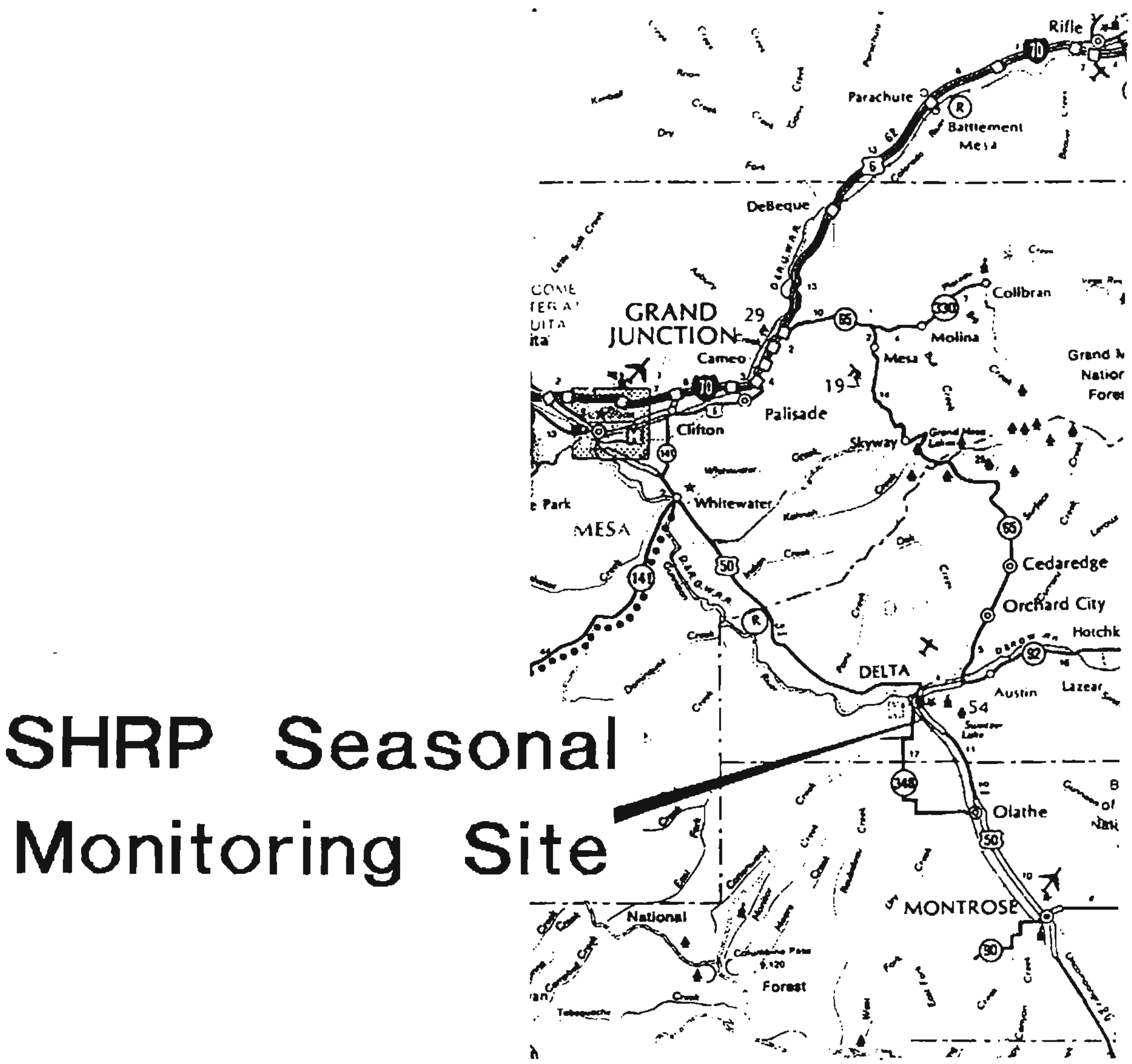
The primary objective of the SHRP's seasonal monitoring program is to evaluate and monitor the impact of seasonal variations in moisture and temperature on pavement response. This program will attempt to establish a relationship between pavement response and deflection measurements taken at different times of the year for a given climatic zone.

The ultimate goal of this program is to rationally use deflection data for evaluation, analysis, and design.

III. SHRP Seasonal Monitoring Program (Delta, Colorado)

A. Site Selection and Description

The site for the SHRP seasonal monitoring program in Colorado is located on a gently-rolling terrain approximately 5 miles south of Delta on westbound US 50 between milepost 75 and 76 (Figure 1). Altogether, there are 64 sites for the seasonal monitoring program across the country which cover four environmental zones (wet-freeze, wet-no freeze, dry freeze, and dry no-freeze). The matrix that constitute this program also includes pavement type (flexible vs. rigid), thickness, and subgrade type (coarse vs. fine). With all these factors in mind the Colorado site is



SHRP Seasonal
Monitoring Site
Rifle
Parachute
Battlement Mesa
DeBeque
GRAND JUNCTION
Cameo
Clifton
Palisade
Collbran
Molina
Mesa
Skyway
Whitewater
MESA
Cedaredge
Orchard City
DELTA
Austin
Lazear
Olathe
MONTROSE
National
Forest

Figure 1

located in the zone of dry-freeze with fine subgrade and thin flexible pavement surface.

The material inventory data obtained during the GPS material sampling indicated a clayey subgrade with high plasticity index (PI > 20). The subbase material consisted of 18 inches of river-bed material (uncrushed) with big boulders (greater than 1/2 foot). The base material consisted of 6 inches of crushed stone.

B. Instrument Description and Installation

The equipment installation for the "SHRP Seasonal Monitoring Program" at the GPS site near Delta was performed during the last week of June, 1993. The instrumentation consisted of installing the following measurement sensors:

1) TDR (Time Domain Reflectometry) sensors, for moisture
2) Resistivity sensors, to monitor frost penetration
3) Thermistors, to measure temperature of the subgrade
4) Observation well, to monitor depth of ground water
5) Tipping Bucket Rain Gage,. to measure rainfall
6) Ambient Temperature probe, to monitor the air temperature

The equipment was furnished by SHRP and the installation was performed with cooperative effort between CDOT personnel, FHWA, and the SHRP Western Region contractor. Representatives from other SHRP Regions were also present to observe this national demonstration.

1) Moisture Content Measurement

Time Domain Reflectometry (TDR) probes were installed for measuring the moisture content of the subgrade, base, and the subbase layers. The TDR sensors were developed and fabricated by the LTPP Division of Federal Highway Administration (FHWA). The TDR equipment was originally developed to detect breaks or shorts in electrical conductors; however, recently it has been used by the agricultural researchers to measure moisture content (1).

The TDR method of acquiring moisture content is primarily based on the dielectric properties of soil. Once the dielectric constant of the soil is measured, the Topp's equation can be used to measure the volumetric moisture content. For more detail on the concept and theory of the TDR, refer to the FHWA publication, "Seasonal Monitoring Instrumentation and Data Collection Guidelines".

The TDR installation began by excavating a 4-inch wide trench in the shoulder and a 18" x 18" pit in the right-wheel-path of the outside lane using a concrete sawing machine (Photo 1 & 2). A drill rig provided by the Region III Geology was used to auger a 10-inch hole through the base and subgrade to a depth of approximately 7 feet below the top of the base. It took approximately 2 hours to auger through the subbase and base material. Big boulders (greater than 12 inches) in the subbase slowed the augering operation (photo 3 & 4). Materials were removed from the auger at 6-inch intervals and placed in 5-gallon plastic buckets as shown in Photo 5.

Prior to placing the TDR sensors, the resistivity probe and the thermistor probes were installed. Photo 6 shows a typical TDR probe with three 8-inch hollow steel prongs. Altogether 10 TDR probes were installed at intervals of 6 inches. The material around the probes was compacted (Photo 7), and moisture content for each layer was determined in the field using a portable gas oven and a scale (Photo 8).

After all 10 TDR probes were installed the wires from the TDR probes, the resistivity probes, and the thermistors probes were placed in a 2-1/2" diameter steel conduit (Photo 9) and buried in a 4" trench leading to the equipment cabinet. The equipment cabinet was located approximately 30 ft. away from the instrument hole (Photo 10). Surface temperature probes were installed in a pre-grooved pavement surface and then sealed with sealant (Photo 11).

All sides of the asphalt block were epoxy coated and the block placed back in its original place and sealed with a self-leveling sealant (Photo 12).

The data acquisition system used for measuring moisture consists of a CR10 data logger, a Textronix 1502B cable tester, and a PC computer (Photo 13). Photo 14 shows a typical TDR signal that was acquired at the site, and Figure 2 shows the plan view of the instrumentation layout in Delta.

2) Frost Depth Measurement

Prior to the installation of the first TDR probe, Resistivity probes were installed. These probes are developed and manufactured by the Army Corps of Engineers' Cold Regions Research and Engineering Laboratory (CRREL). Resistivity probes are composed of 36 circular metal electrodes mounted on a non-conducting rod and spaced at 2-inch intervals (photo 15).

The resistivity of soil depends primarily on its porosity, the degree of pore water saturation, and the resistivity of the pore water. Because the resistivity of ice is much greater than that of unfrozen pore water, the formation of ice in the pore space causes a net decrease in the effective porosity and corresponding increase in the apparent resistivity (1).

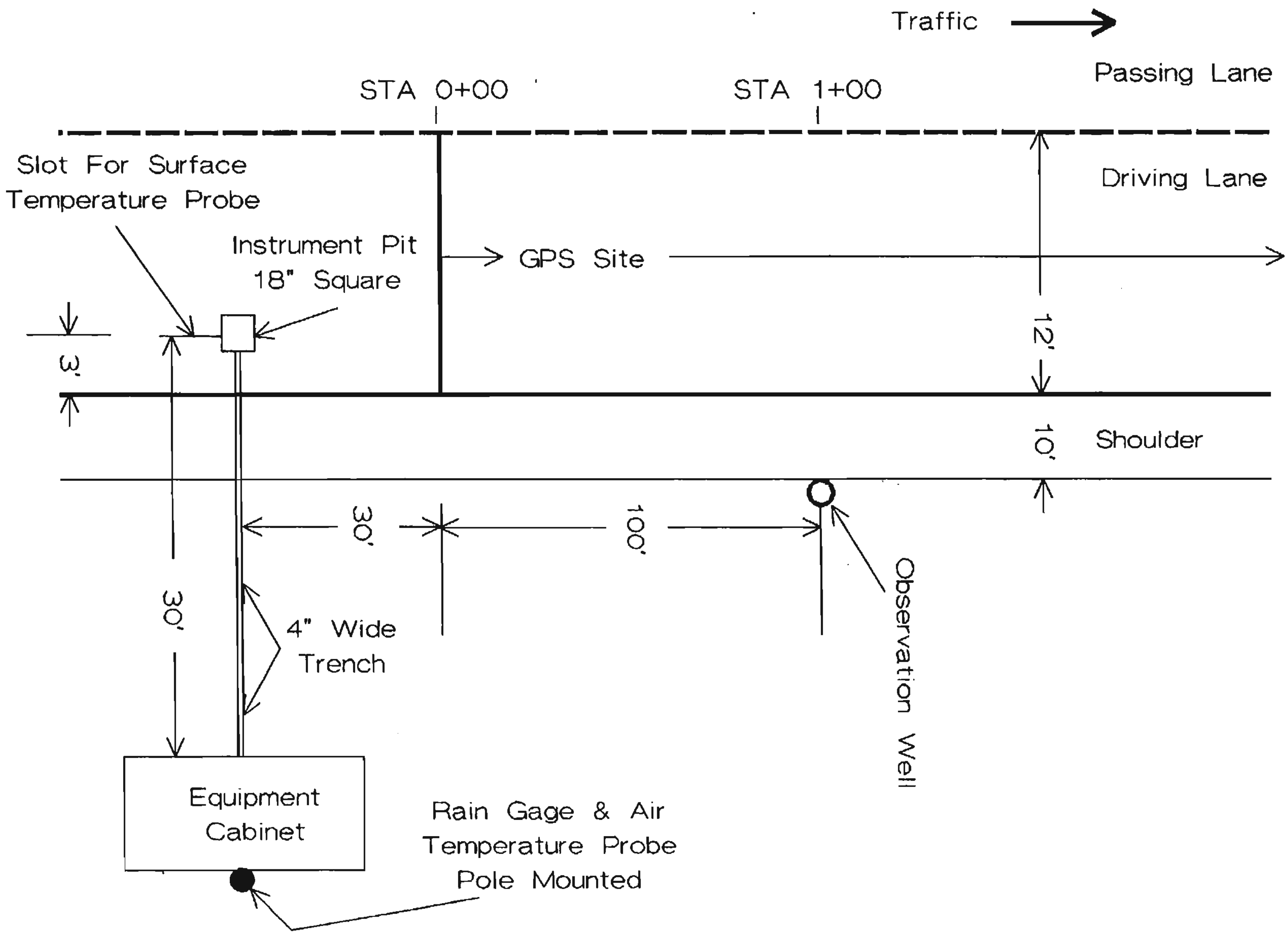


Figure 2. Instrumentation Layout In Delta

Unlike other data, the resistivity data will be taken only during the winter months twice daily during each visit. The resistance is measured by transmitting electrical current through two adjacent electrodes and measuring the current flow and voltage. The location of frost is determined by comparing the resistance for the frozen and unfrozen profile. The frozen areas exhibit large increases in resistance.

3) Subgrade Temperature Measurement

As mentioned previously, the subgrade temperature probes were installed prior to the installation of the first TDR probe. The temperature probes installed at the Delta site were developed by Measurement Research Corporation (MRC) and are called MRC TP101 thermistor probe. The MRC TP101 thermistor probe consists of three thermistor sensors in a 13" long metal rod and string of 15 thermistor sensors encapsulated in a 1" diameter by 6' long clear plexiglass rod (Photo 16).

The three sensors in the metal rod were installed in an angle into the pavement surface to monitor the temperature at 1" below the surface, mid-depth, and 1" above the bottom of the pavement (Photo 17). The resistance of each thermistor is found by applying a known current and reading the voltage across the thermistor's leads. The resistance reading is then converted to temperature by using a calibration equation (2).

A CR10 Campbell Scientific data logger is used to acquire temperature throughout the subgrade. The average soil temperatures for the first 5 sensors are acquired and recorded on an hourly basis. The average soil temperatures for all 18 sensors are recorded on a daily basis. The maximum and minimum soil temperatures and their corresponding times are also recorded on a daily basis.

4) Ground Water Depth Measurement

To monitor the depth of the ground water table, an observation piezometer was installed outside the edge of the pavement at station 100+00. Figure 3 shows schematic of a typical observation piezometer for seasonal monitoring program.

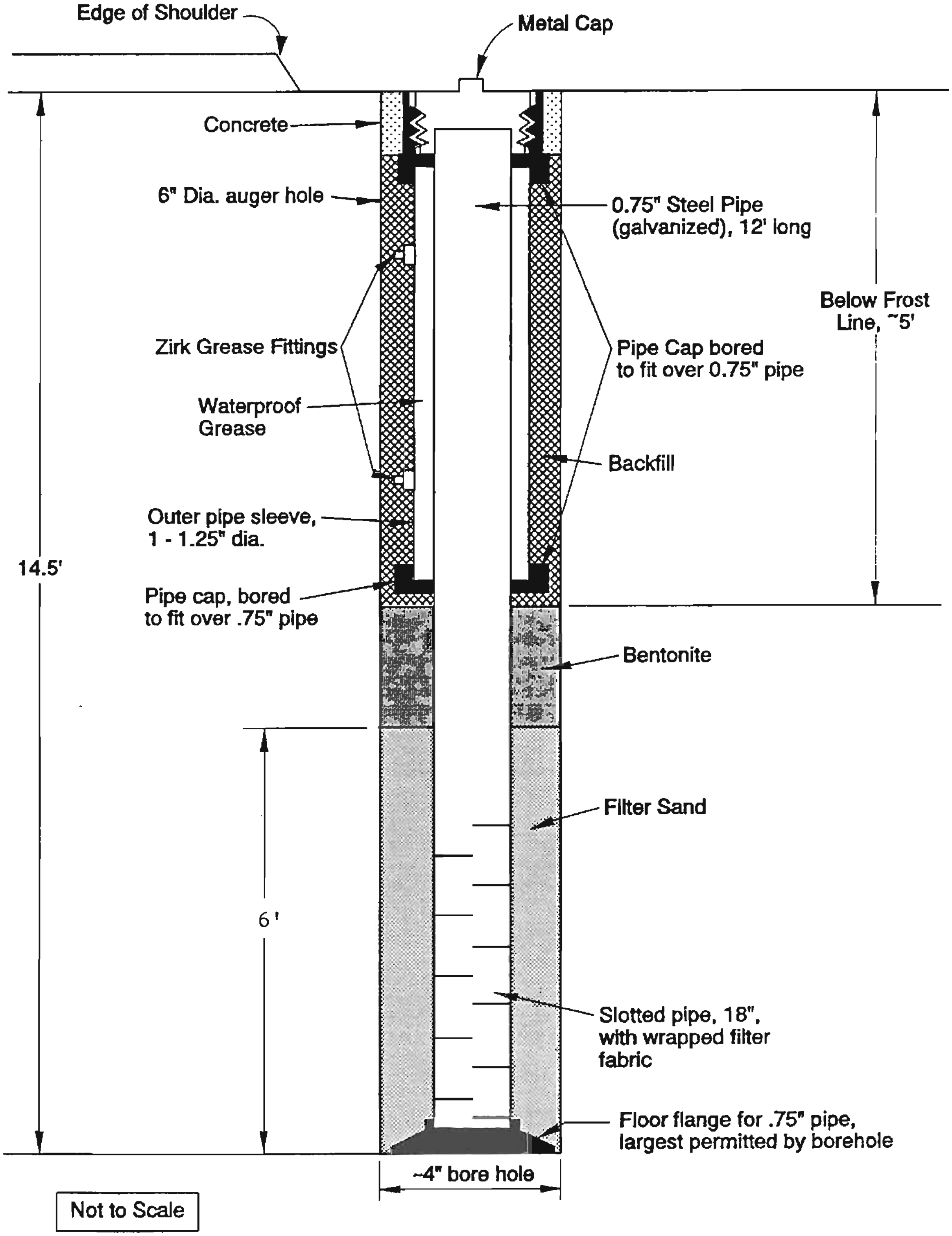
The installation of the observation peizometer began by augering base through the subgrade to a depth of approximately 14.5 feet (Photo 18). The observation piezometer consisted of installing a galvanized steel pipe, 12 feet long with a diameter of 0.75 inches. The bottom 2 feet of the pipe is slotted and wrapped with filter cloth to prevent the migration of fines into the pipe (Photo 19).

To accommodate The frost-heave action, the upper 5 feet of the steel pipe is covered with an outer pipe sleeve of 1.25 inches in diameter. The space between the pipe and the outer sleeve is then filled with grease (Photo 20). After the entire piezometer assembly was placed in the hole, filter sand was placed to a depth of 6.5 feet. Next, a bentonite layer of 1 foot was placed and mixed with water and compacted to stop the penetration of water into the lower level. The rest of the hole was backfilled with local material and then an access cover assembly was placed on the top (Photo 21 and 22).

The piezometer pipe will also serve as a frost and swell-free benchmark for elevation measurements of the pavement surface.

5) Rainfall Measurement

The tipping-bucket rain gage (Model - TE525MM) developed and manufactured by Texas Electronics, was installed to measure the amount of rainfall. Photos 23 through 24 shows a typical



Observation Piezometer for Seasonal Monitoring Program

Figure 3

tipping-bucket rain gage installed at the seasonal monitoring site in Delta. When the rain reaches the calibrated level, the bucket tips activating a switch.

The number of switch-pulses are counted by a data logger installed in the equipment cabinet. Field calibration of the rain gage is verified by applying the equivalent of one inch of rainfall (16.00 oz.) at a control 1" per hour rate. The data logger should record 100 tips.

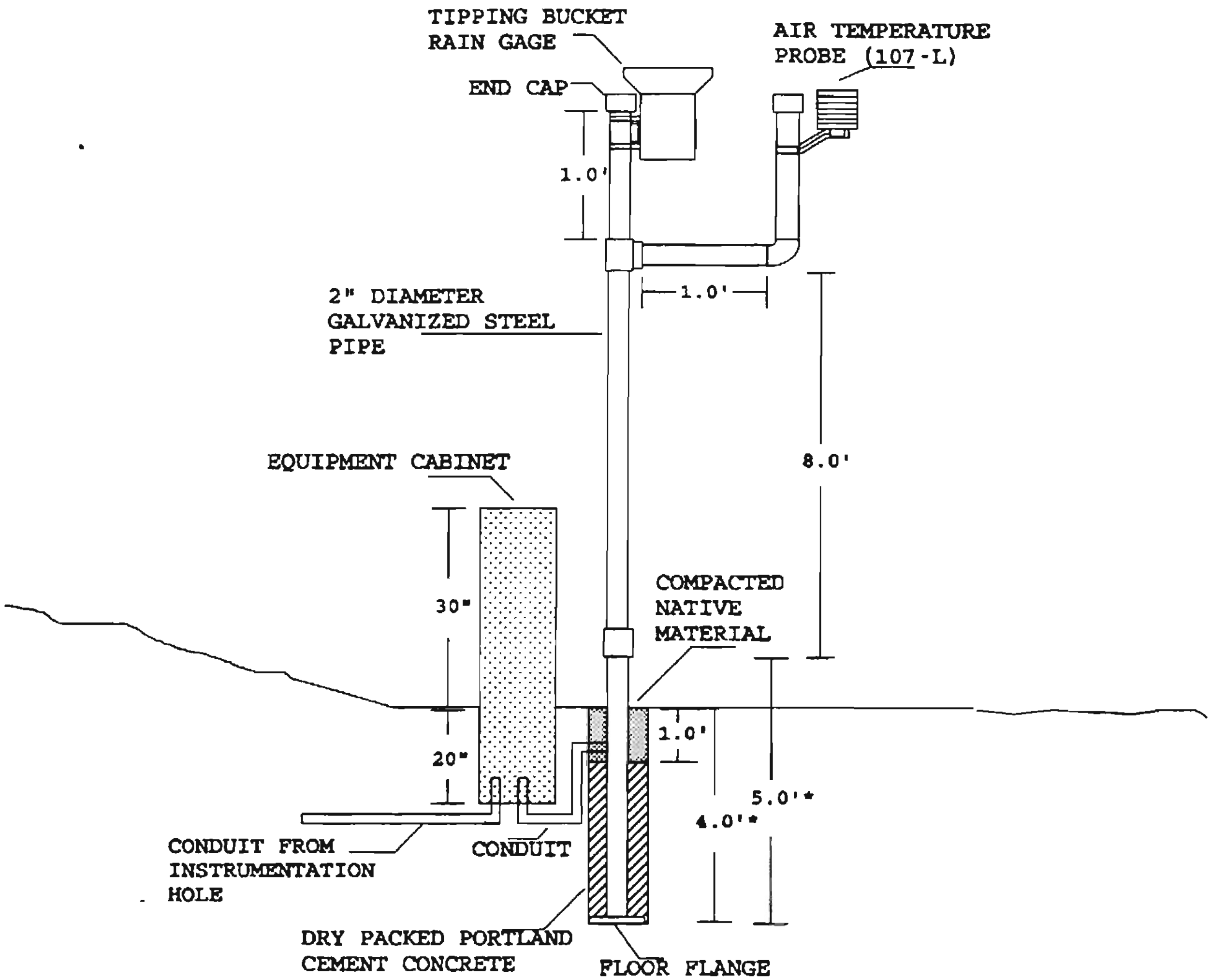
The rain gage is mounted on a pole (3 inch diameter by 10 feet long) and installed approximately 3 feet behind the equipment cabinet (Photo 25 and 26). The rain gage was leveled during the installation.

6) Ambient Air Temperature Measurement

The Cambell Scientific air temperature probe Model 107-L, was installed to monitor the air temperature at seasonal site (Photo 26). The temperature probe was mounted on the same pole that the rain gage was mounted. Figure 4 shows the schematic of a rain gage and a temperature probe.

The temperature probe installed at the Delta site consisted of two parts. The first part is a Model 107-L temperature probe which is capable of sensing temperature between -35 and 50 degrees Celsius. The second part, is a shield that protects the probe from various environmental conditions.

Temperature measurements will be taken automatically at 15 minute intervals; however, only the average hourly temperature and daily statistics such as: mean, minimum, maximum, and their corresponding time will be permanently stored in the data logger. The air temperature, subgrade temperature, and the precipitation



NOTES:

Wire from the Rain Gage and Temperature Probe will be placed through the inside of the pipe.

Wire will be taped around curved sections of the pipe to prevent any shorting of the instrumentation.

Silicon will be placed were the wires from the instrumentation go into the pipe.

* These lengths could be made deeper to extend below expected frost depth.

Figure 4 Rain Gage and Temperature Probe

readings will be taken via the same data logger (Photo 27). Figure 5 shows the schematic of the entire seasonal instrument installation at Delta.

IV. Miscellaneous Activities

A. Deflection Data

In addition to the environmental data, deflection data will also be collected exclusively with the LTPP FWD (Dynatest Falling Weight Deflectometer, Model 8000). Figure 6 illustrates the testing pattern for the flexible pavement at Delta. Deflection data will be acquired in the outer-wheel path and mid-lane in intervals of 25 feet. Three additional locations in the vicinity of the test pit will also be tested; two point along the outer-wheel path and one in the mid-lane as shown in Figure 6.

It will take approximately 1.5 hours to complete one round of deflection testing for flexible pavement. The testing sequence will be repeated a minimum of four times per test day.

As a minimum, the deflection testing and related data collection will be performed on a monthly basis (12 times per year). In frost areas such as the site in Delta, due to the effects of freeze-thaw cycles, the monitoring program will be performed at least twice a month during the Spring break-up.

B. Elevation and Profile Data

To monitor the subgrade volume change (due to frost heave and/or expansive soil) surface elevation, longitudinal and transverse profile will be taken according to the testing pattern in Figure 7. During the first year, the survey profile will be taken 3 to 4 times depending on the temperature regime, but always

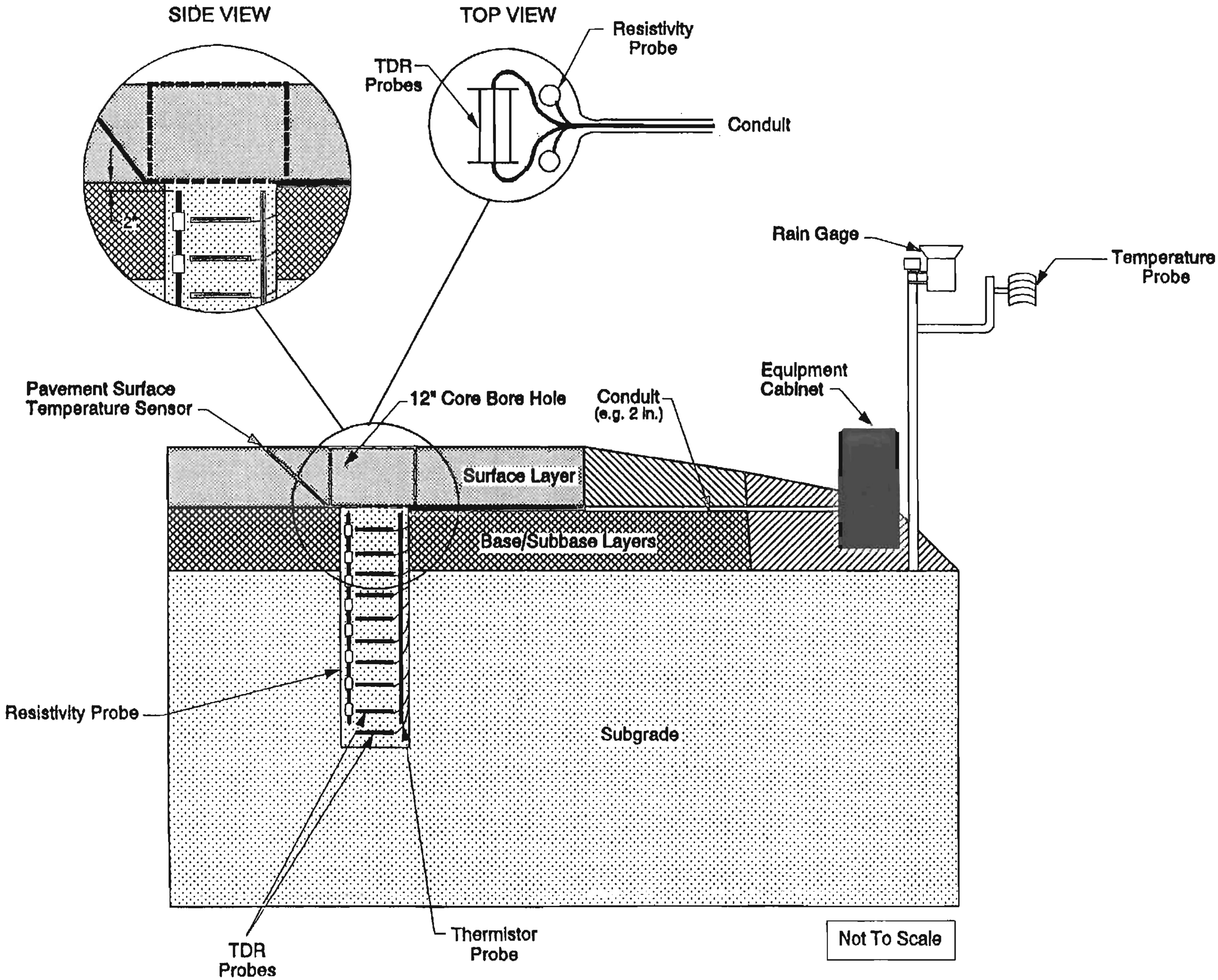
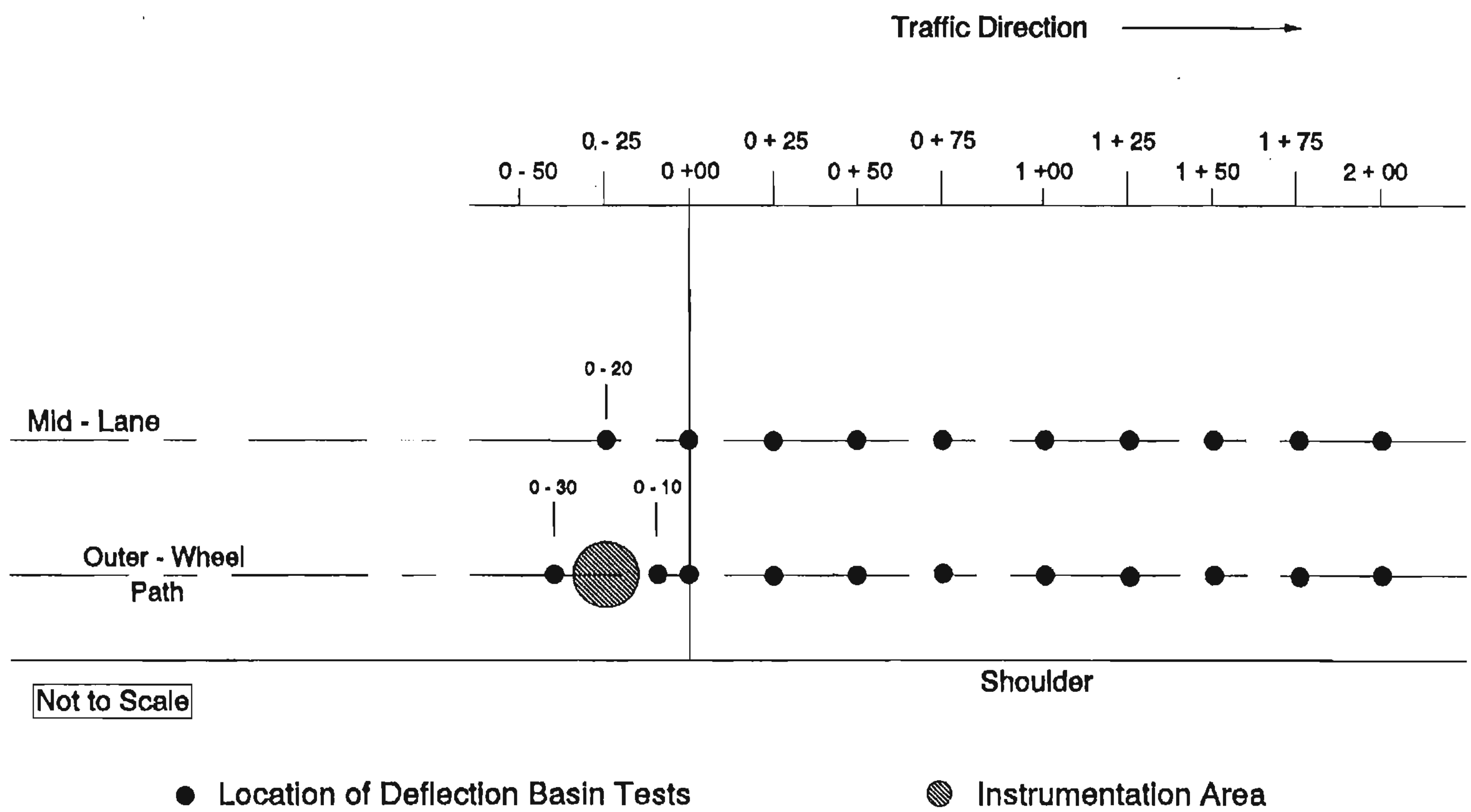
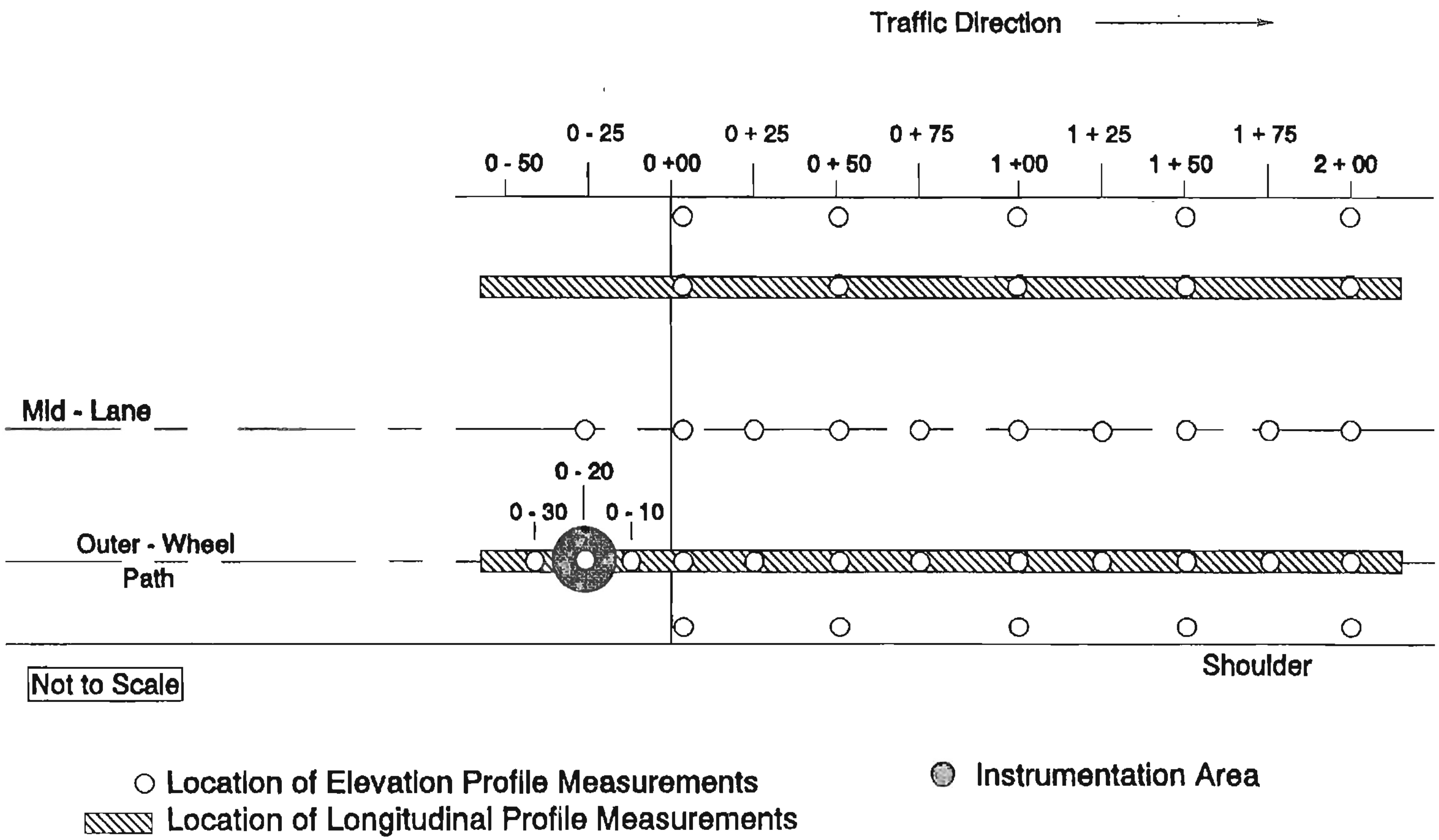


Figure 5 - Illustration of Instrumentation Installation



Notes:
(1) Three additional sets of FWD tests will be performed in the vicinity of the instrumentation.
(2) Avoid installing the instrumentation in the vicinity of the original GPS bulk sampling locations.
(3) End of section can be used instead of beginning portion; e.g., test section between stations 3 + 00 and 5 + 00 and instrumentation at station 5 + 20.

Figure 6 Deflection Data Collection Plan - AC Pavements



Note: End of section can be used instead of beginning portion; e.g., test section between stations 3 + 0 and 5 + 00 and instrumentation at station 5 + 20.

Figure 7 - Elevation and Roughness Data Collection Plan - AC Pavements

concurrently during the FDW testing.

Surface elevation measurements will be taken along the outer-wheel path, mid-lane, and the edge of pavement at 50 feet intervals (5 elevation readings per transverse line a total of 25 measurements). In addition to the surface elevation surveys, longitudinal profile will be obtained using the LTPP Profilometer. As mentioned earlier, the top of the piezometer pipe will be used as a frost-free and swell-free bench mark.

V. Summary

The SHRP seasonal monitoring workshop held in Grand Junction and the instrument installation demonstration in Delta, Colorado was a success. Representatives from CDOT, LTPP Division of FHWA, and all four SHRP Regional offices were present to learn and to participate in this national demonstration.

The SHRP seasonal monitoring site at the Delta site will be tested on a two year cycle; i.e,, testing in years 1, 3, 5..etc. The data collected from this site will be entered into the National Information Management System (NIMS), along with data from 63 other sites across the United States and Canada.

Interim results can be expected in 5 years, and final results within the next 10 years.

VI. References

1- LTPP Seasonal Monitoring Program, "Instrumentation Installation and Data Collection Guidelines", version 1.1 June 1993.

2- LTPP Regional Coordination Office Western Region "Seasonal Instrumentation Installation Montana Section 308129", December 1992.

3- Campbell Scientific Inc., "CR10 Operators's Manual (Measurement and Control Module)", March, 1993.

Appendix A

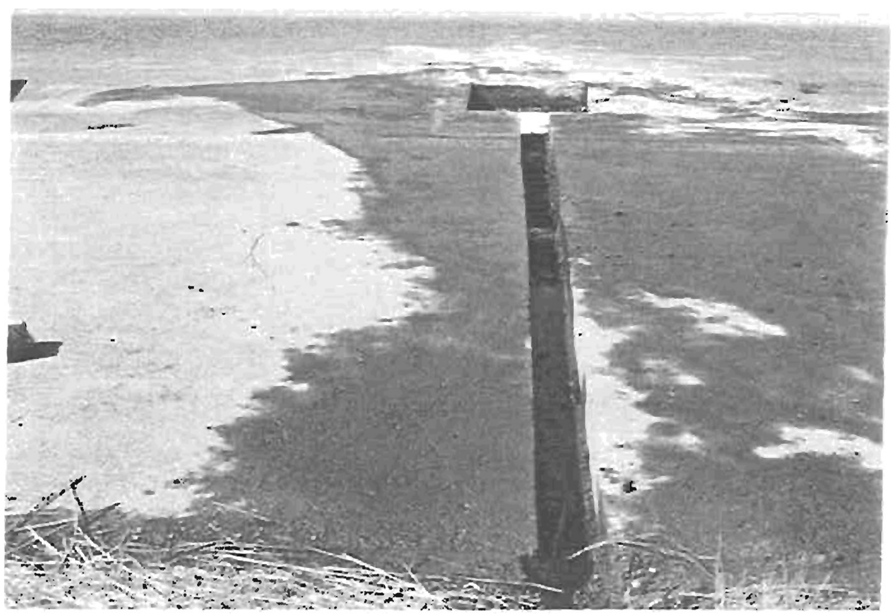


Photo 1 & 2: Instrument pit and trench

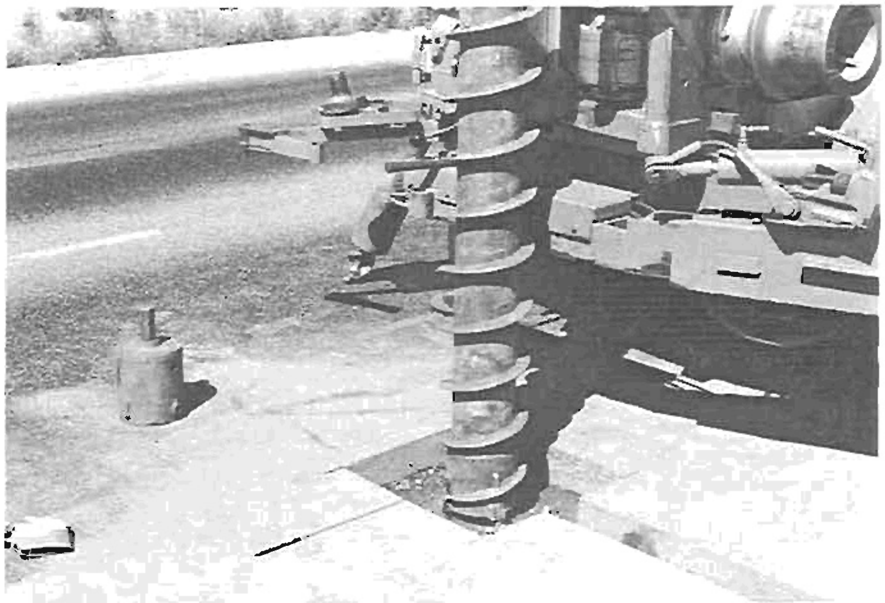


Photo 3: Augering the instrument pit

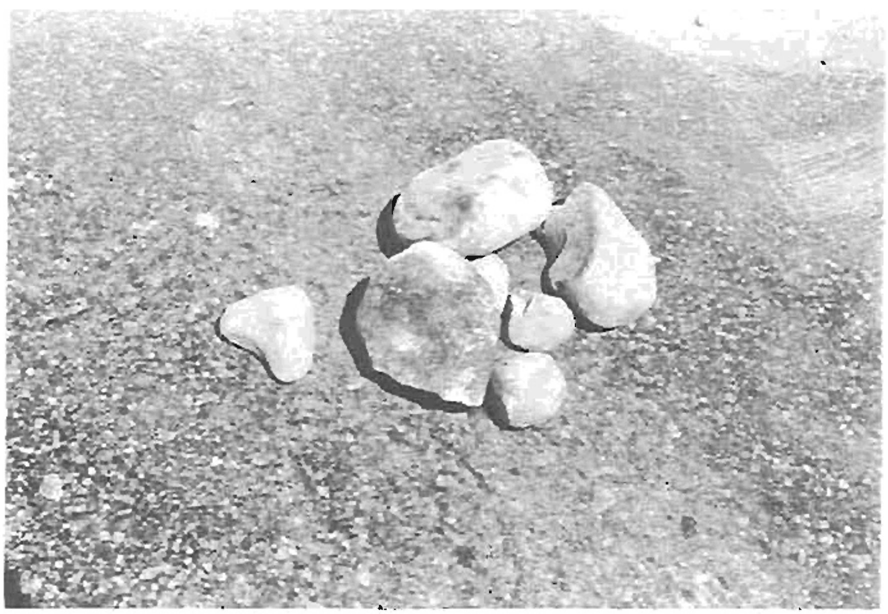


Photo 4: Samples of subbase

Photo 5: Obtaining samples from each layer

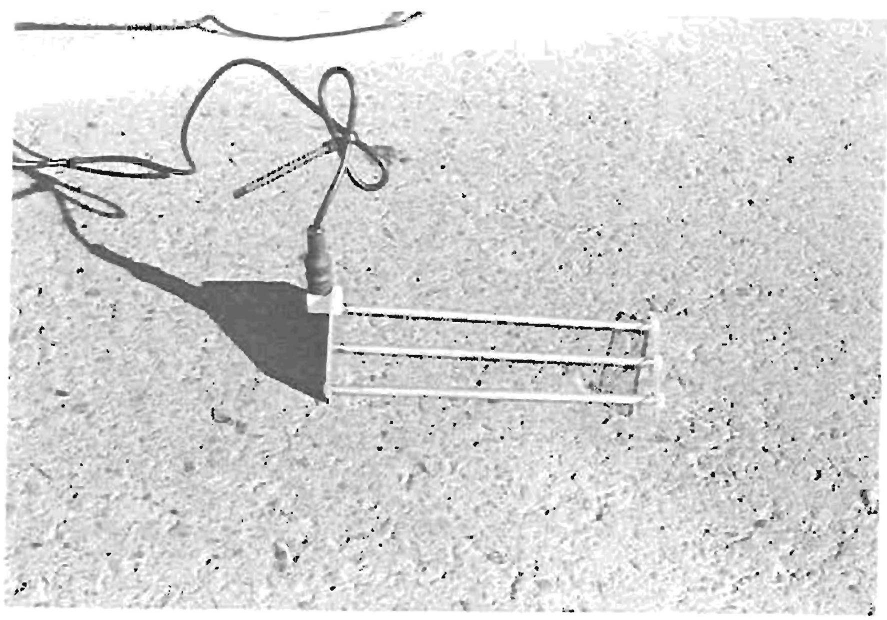


Photo 6: A typical TDR probe

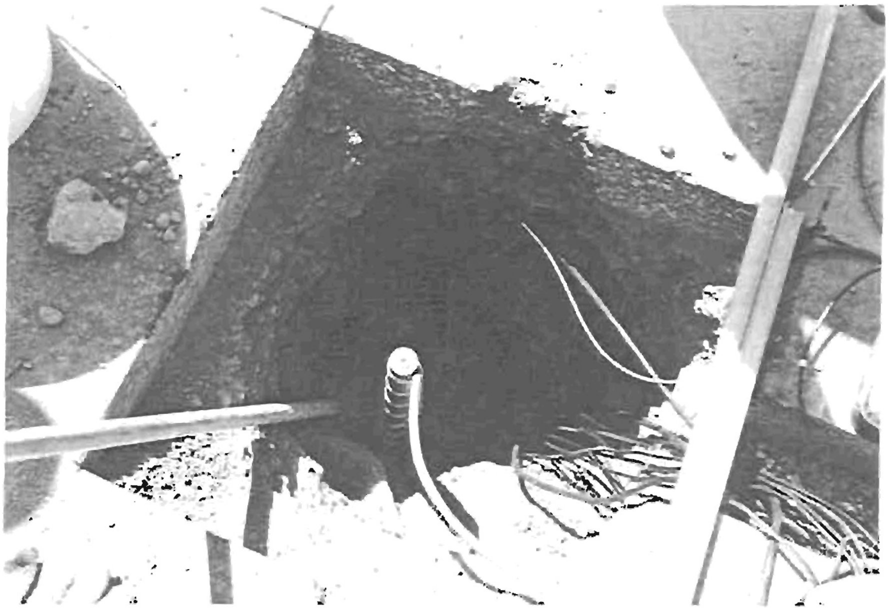


Photo 7: Compaction of the material around the probes

Photo 8: Obtaining moisture content in the field

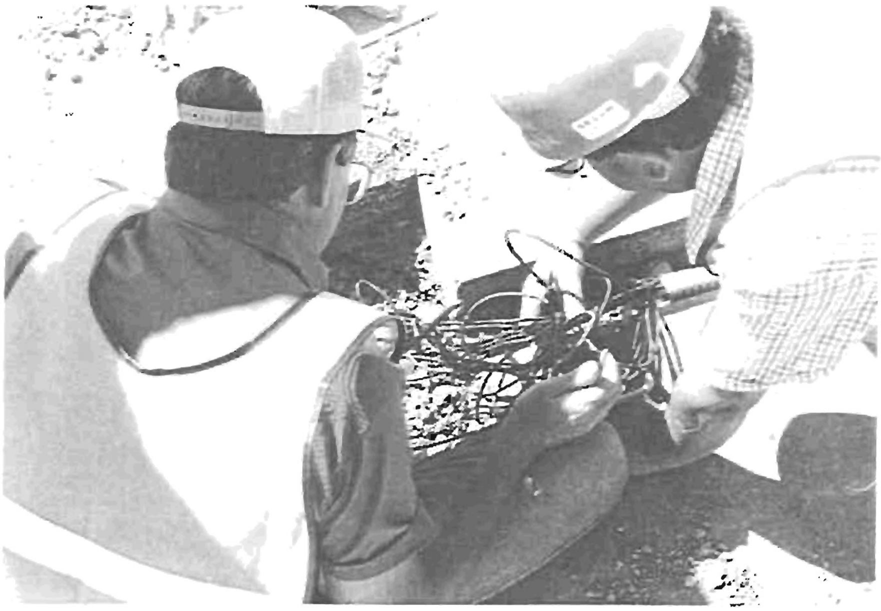


Photo 9: Leading the wires through a conduit to the cabinet

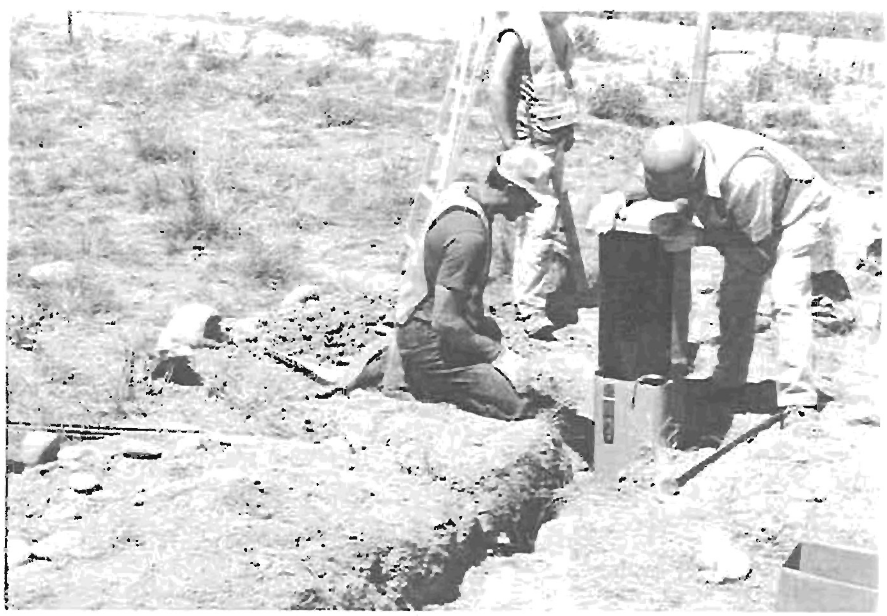


Photo 10: Installation of the equipment cabinet

Photo 11: Placing thermistor probe into the AC layer

Photo 12: Placing the AC block back in its original place

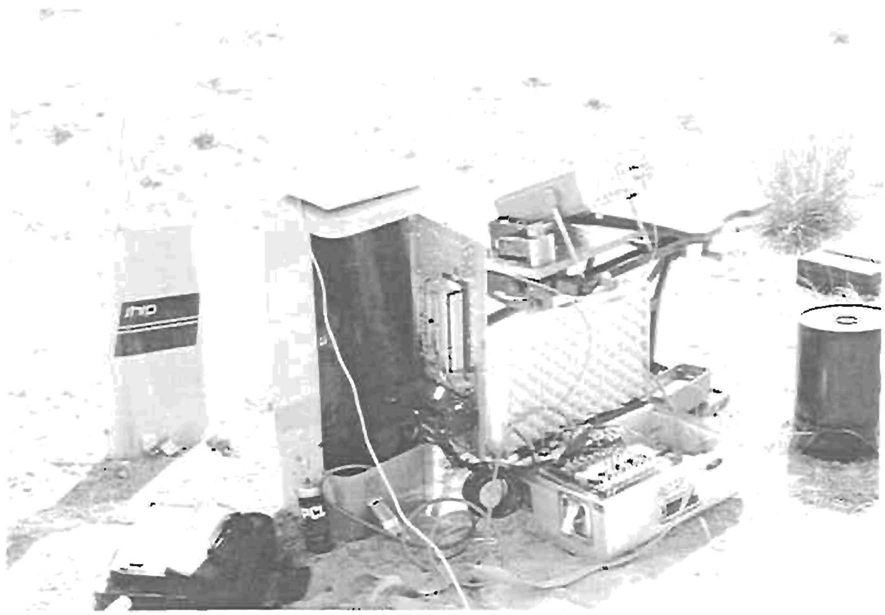


Photo 13: Data acquisition system

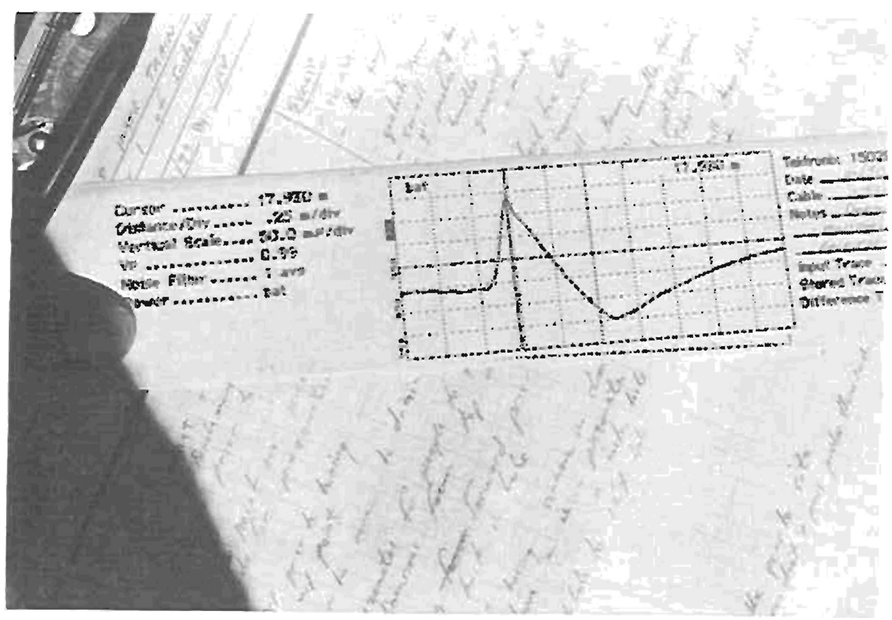


Photo 14: A typical TDR trace

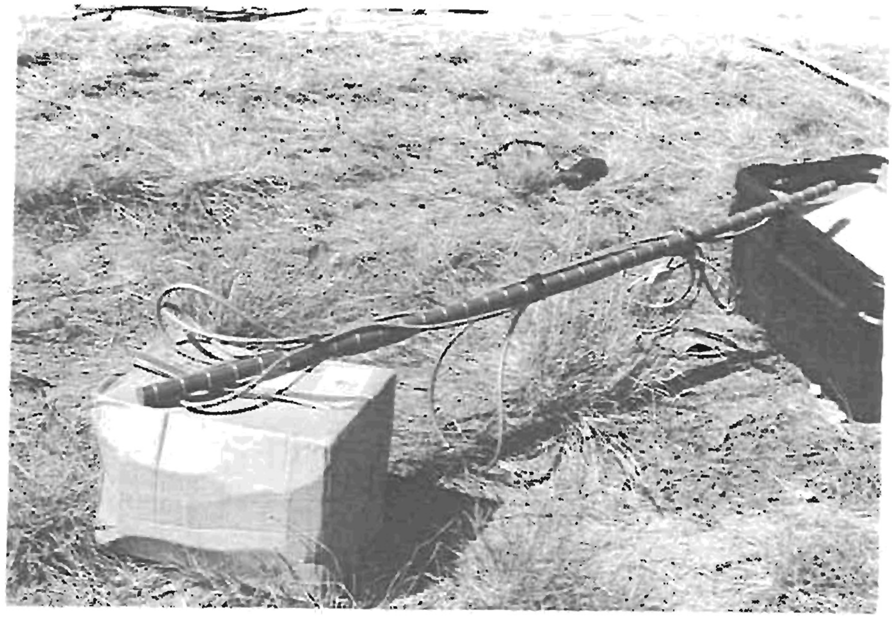


Photo 15: Resistivity probe

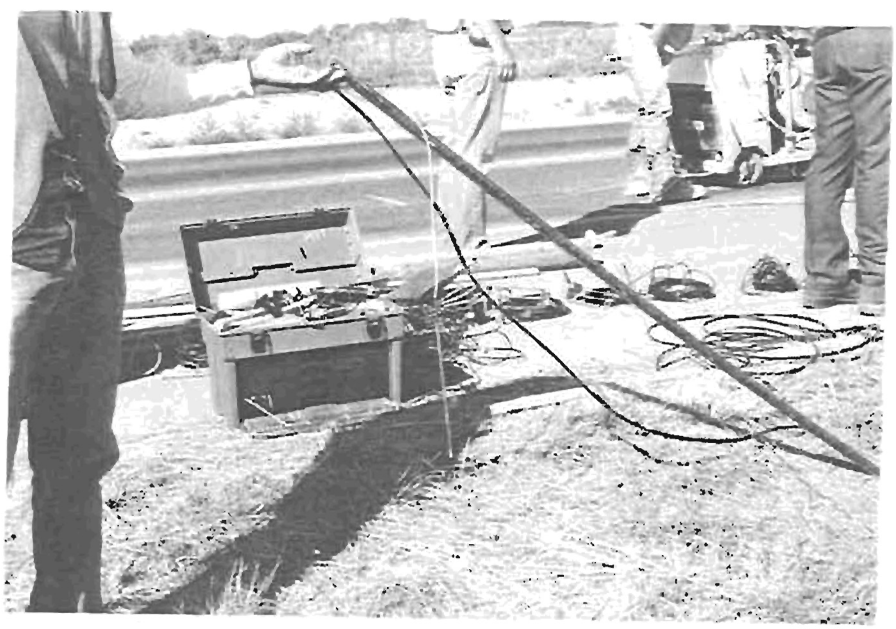


Photo 16: Thermistor probe

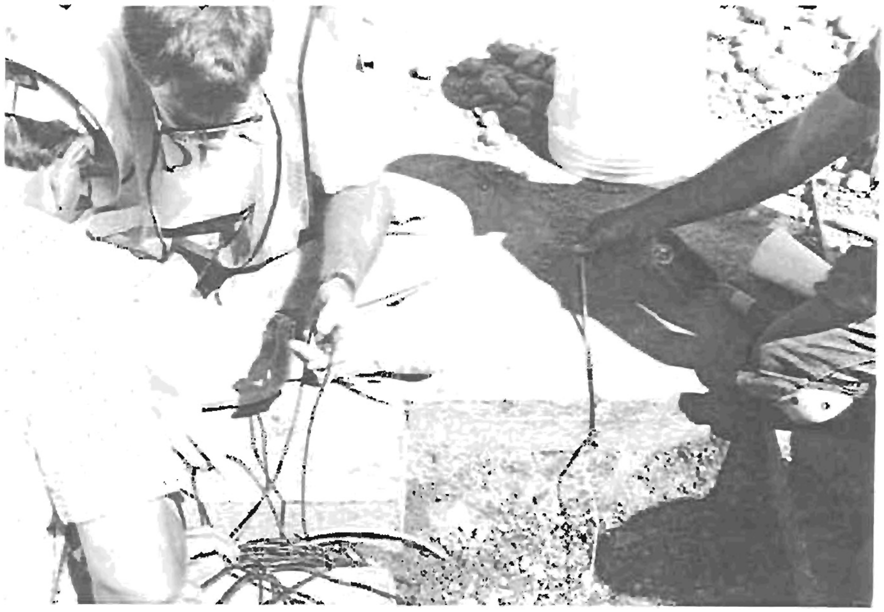


Photo 17: AC thermistor probes were installed last

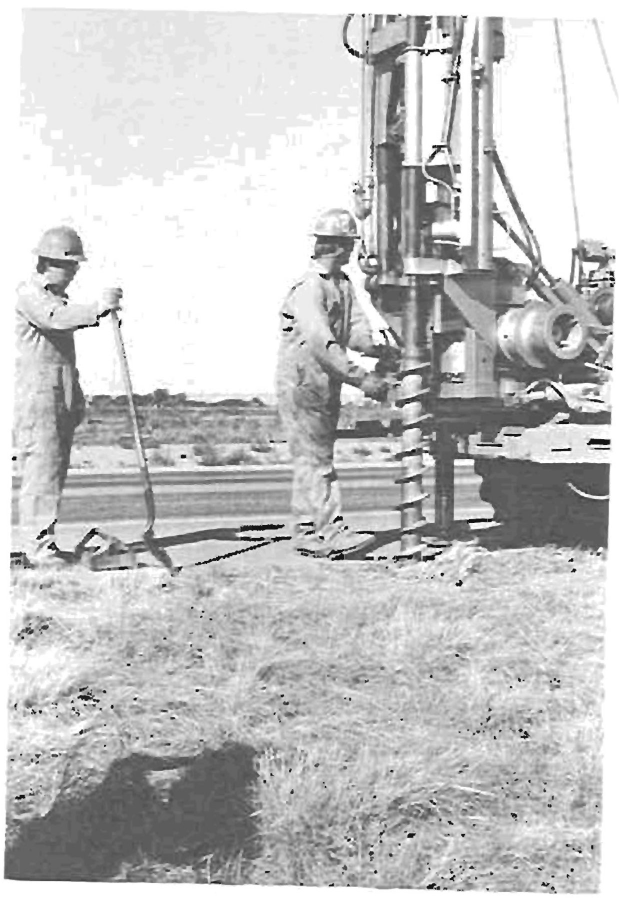


Photo 18: Augering the piezometer hole

Photo 19: Fabric wrap around bottom of the piezometer pipe

Photo 20: Greasing the sleeve

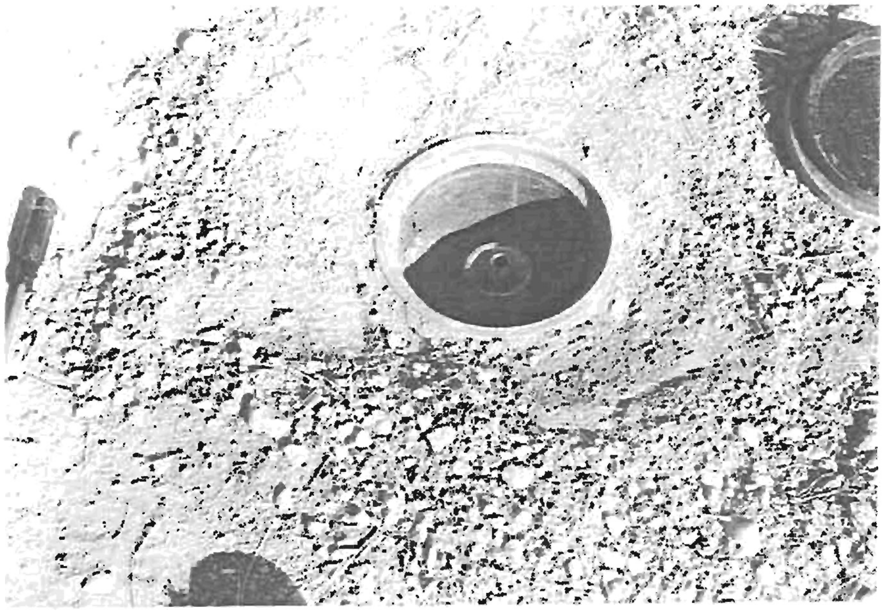


Photo 21 & 22: View of the completed piezometer well

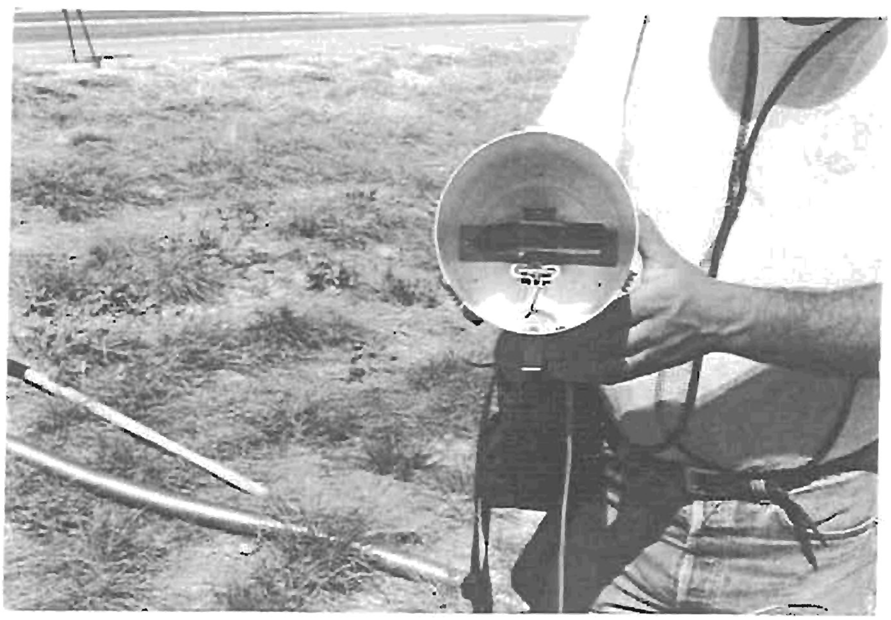


Photo 23 & 24: Tipping bucket rain gage

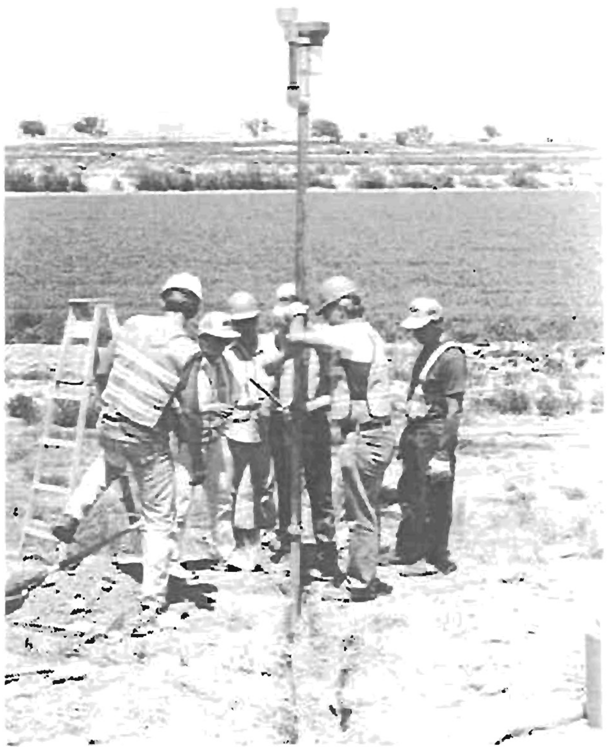


Photo 25 & 26: Rain gage installation and the data acquisition system

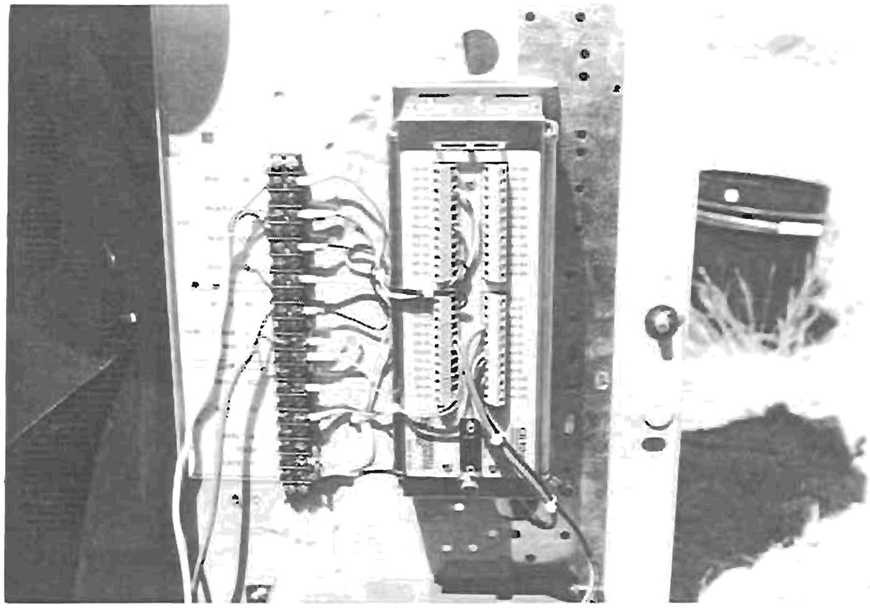


Photo 27: Data logger for air temperature, subgrade temperature, and rainfall

Photo 28: Air temperature probe