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LTPP Seasonal Monitoring Program

Site Installation and Initial Data Collection Section 871622 Bracebridge, Ontario

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LTPP Seasonal Monitoring Program

Site Installation and Initial Data Collection
Section 871622, Bracebridge, Ontario

Report No. FHWA-TS-94-87-01

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The report is a cooperative effort between Ontario Ministry of Transportation Research and Development Branch, Long Term Pavement Performance (LTPP) Division Federal Highway Administration, and Pavement Management Systems Limited LTPP North Atlantic Region Coordination Office.

16. Abstract

This report provides a description of the installation of seasonal monitoring instrumentation and initial data collection for the seasonal experimental study conducted as part of the Long Term Pavement Performance (LTPP) program at the General Pavement Study (GPS) section 871622 on Highway 11 near Bracebridge, Ontario. This asphalt concrete surface pavement test section was instrumented on September 22, 1993. The instrumentation installed included time domain reflectometry probes for moisture content, electrical resistivity probes for frost location, thermistor probes for temperature, tipping bucket rain gage, piezometer to monitor the ground water table, and an on-site data logger. Initial data collection was performed on September 23, 1993 which consisted of deflection measurements with a Falling Weight Deflectometer, elevation measurements, temperature measurements, TDR measurements, and electrical resistance and resistivity measurements. The report contains a description of the test site and its location, the instruments installed at the site and their locations, characteristics of the installed instruments and probes, problems encountered during installation, specific site circumstances and deviations from the standard guidelines, and a summary of the initial data collection.

17. Key Words	18. Distribution Statement
Instrumentation, Monitoring, Survey, FWD, Profilometer, Time Domain Reflectometry, Thermistor, Piezometer, Electrical Resistance, Electrical Resistivity.	

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ONTARIO SECTION 871622

I. Introduction

The installation of instrumentation on seasonal site 871622 near Bracebridge, Ontario was performed on September 22 - September 23, 1993.

The test section is a GPS-1 experiment, located on northbound Highway 11, approximately five kilometers north of Bracebridge city limits, three kilometers north of Highway 117, and 4.5 kilometers south of Stephenson Road Intersection (Figure A-1 in Appendix A). The highway consists of two 3.7 m wide lanes in each direction with a 3.7 m wide outside and a 1.8 m wide inside gravel shoulders.

The pavement structure consists of 142 mm of asphalt concrete, 168 mm of crushed gravel base and 668 mm of sand subbase over a fine grained sandy silt subgrade. Pavement structure information from the GPS material drilling logs is presented in Figure A-2. Properties determined from the laboratory material tests are shown in Table 1.

Table A-1 in Appendix A summarizes the distress, IRI values from the Profilometer longitudinal profile measurements, and Falling Weight Deflectometer deflection values as monitored since 1989. The uniformity survey results are summarizes in Appendix A, Table A-2 and the deflection values and analysis results from the FWDCHECK are also presented in Appendix A.

The site is in a wet-freeze zone and resides in cell 4 (thin AC on fine subgrade) of the seasonal monitoring program. The annual average frost depth is 1.7 m. Salt is frequently used for ice control at this location. Below is a summary from the LTPP climatic database of the environmental data available from 1989:

Freezing Index (C-Days)	627
Precipitation (mm)	915
No. of Freeze/Thaw Cycles	88
Days Above 32C	0
Days Below 0C	185
Wet Days	196

The road was opened in 1976. The estimated annual average daily traffic (AADT) is 9000 (two way) of which 13% is truck traffic on the GPS lane. The estimated annual kESALs on the GPS lane are 180.

Installation of the instrumentation was a cooperative effort between Ontario Ministry of Transportation and Pavement Management Systems Limited (PMSL) LTPP North Atlantic Region Coordination Office staff.. The following personnel participated in the instrumentation installation:

Jerry Hajek	MTO, Research and Development
Ken Bannerman	MTO, Research and Development
Adam Weremi	MTO, Research and Development
Peter Henderson	MTO, Research and Development
Mike Wakowicz	MTO, Test Facility
Bill Best	MTO, Patrol 7
Bruce Law	MTO, Patrol 7
Pete Kujula	MTO, Patrol 7
James Mellish	James Mellish Drilling and Sawing Co. Ltd.
Dale Brown	Eastern Soils Investigation Ltd.
Andy Carter	Eastern Soils Investigation Ltd.
Sun Jian Hua	Research Institute of Highways, Ministry of Communications, China
Wang Hongzi	Research Institute of Highways, Ministry of Communications, China
Frank Meyer	Pavement Management Systems (NARO)
Brandt Henderson	Pavement Management Systems (NARO)
Perry Zabaldo	Pavement Management Systems (NARO)
Mike Zawisa	Pavement Management Systems (NARO)
Doug Marshall	Pavement Management Systems (NARO)
Randy Plett	Pavement Management Systems (NARO)
Gabe Cimini	Pavement Management Systems (NARO)

Table 1. Material Properties

Description	Surface	Base	Subbase	Subgrade
Material (Code)	Dense Graded HMAC (01)	Crushed Gravel (304)	Sand (306)	Sandy Silt (145)
Thickness (mm)	142	168	668	
Lab Max Dry Density (kg/m^3)		2222	1901	1805
Lab Opt Moisture Content (%)		6.0	10.5	12.5
In-situ Wet Density (kg/m^3) *		2044	2004	2005
In-situ Dry Density (kg/m^3) *		2010	1954	1811
In-situ Moisture Content (%) *		1.73	2.53	10.75
Bulk Specific Gravity	2.371			
Max Specific Gravity	2.526			
Liquid Limit		0		0
Plastic Limit		0		0
Plasticity Index		NP		NP
% Passing # 200		10.15	14.45	48.20

* Note: Test pit @ station 5+60

II. Instrumentation Installation

Site Inspection and Meeting with Highway Agency

The site initially nominated for inclusion in the seasonal monitoring program by Ontario was 871620 on highway 400 at Moonstone. This site was rehabilitated (mill and overlay 08/06/92) prior to the initiation of installations for Seasonal Monitoring Program (SMP). Initial plans were to retain this site in the program, as it filled an experimental cell (4) with a limited number of potential sites, and the agency would incorporate this research effort with studies on experimental test sections adjacent to the GPS site. Prior to finalizing plans for the installation, we were notified by FHWA (June 93) that this site could not be included in the core experiment as it would introduce another factor (rehabilitation) into the experiment.

Based on this response, MTO was approached to include GPS site 871622, near Bracebridge, which also met the requirements for experimental cell 4 of the SMP. There was some concern for traffic control on this site during the winter period, as this site is borderline for chemical (salt) removal of snow and ice. This site was nominated and accepted; with traffic control provided, conditions permitting. As time was limited, a pre survey of this test section was not undertaken, but the FWDCHECK results, on both the GPS and adjacent SPS-3 sites, indicated the pavement structure had relatively uniform response. Plans for the week of installation also included FWD testing, Manual Distress Survey, and coring of treatment layers for the adjacent SPS-3 sites.

A preliminary planning meeting was held at the Ministry of Transportation of Ontario (MTO) Research and Development facility, Downsview, on August 13, 1993. The attendees at the meeting were:

Graham Jones
Gerhard Kennepohl
Jerry Hajek
Adam Weremi
Ken Bannerman
Bill Phang
Brandt Henderson

A presentation on the installation of seasonal monitoring instrumentation and monitoring requirements were provided by Bill Phang and Brandt Henderson. This was followed by a review and discussion on the seasonal site. Plans for the installation on September 22-23, 1993 were discussed; which covered tasks to be done by MTO resources and material requirements. Correspondence from the site inspection and planning meeting are provided in Appendix B.

A pre-installation meeting was held on the afternoon of September 21, 1993 at the District office in Huntsville, Ontario. Attendees at the meeting were:

Jerry Hajek	MTO Research and Development
Dan Doener	MTO District Maintenance
Dan Barrett	MTO District Maintenance

Dave Moore	MTO District Maintenance
Dale Brown	Eastern Soil Investigation
Andy Carter	Eastern Soil Investigation
Brandt Henderson	Pavement Management Systems
Perry Zabaldo	Pavement Management Systems

Plans for the following day were discussed along with a verification check of the equipment to be used for coring the asphalt layer, augering the instrumentation hole, cutting the trench to the instrumentation cabinet and the various supplies necessary to complete the installation and patch the pavement. Arrangements were made to have traffic control setup for 0800 hours with the sawing and cutting contractor and the drilling contractor to be on site by 0830 hours.

Equipment Installed

The equipment installed at the test site included instrumentation for measuring air and subsurface temperature, subsurface moisture content, frost depth, and water table. An equipment cabinet was installed to hold the datalogger, battery pack, and all electrical connections from the instrumentation. The equipment installed are shown in Table 2.

Table 2. Equipment Installed

Equipment	Quantity	Serial Number
Instrumentation Hole		
MRC Thermistor Probe	1	87AT
CRREL Resistivity Probe	1	87AR
TDR Probes	10	87A01-87A10
Equipment Cabinet		
Campbell Scientific CR10 Datalogger	1	16552
Campbell Scientific PS12 Power Supply	1	5622
Weather Station		
TE525MM Tipping Bucket Rain Gage	1	12095-693
Campbell Scientific 107-L Air Temperature Probe	1	87AAT
Observation Well/Bench Mark	1	N/A

Equipment Check/Calibration

Prior to installation, each measurement instrument was checked or calibrated. The tipping bucket rain gauge was connected to the CR10 datalogger for calibration. A plastic container with 473 ml of water was placed in the tipping bucket. The container had a small hole in the bottom, which allowed all the water to be drained out in 45 minutes. For the 473 ml of water, the tipping bucket should measure 100 tips $\pm$ 3 tips. The results showed 100 tips, which was within specification.

The air temperature and thermistor probes were connected to the CR10 datalogger simultaneously. They were checked by placing the probes in ice, room temperature, and boiling water. In order for the probes to pass this check, the temperatures for each probe should correspond to the water temperature. The check indicated that the air temperature and thermistor probes were working properly. A second check was done where the air temperature and thermistor probes were connected to the datalogger and run, in air, for 24 hours. The minimum, maximum, and mean temperature for each sensor were checked. All 18 thermistors were similar in their minimum, maximum, and mean readings respectively, therefore the probes were considered functioning correctly. The results of the air temperature and thermistor probes along with the spacing between the thermistors are presented in Appendix B.

The wiring of the resistivity probe was checked using continuity measurements between each electrode and the corresponding pins on the connector. The distance between each electrode was measured and recorded as shown in Table B-4 in Appendix B. Contact resistance measurements were performed with the probe immersed in a salt water bath. Due to defects in the manufacturing, clear silicon sealant was used to cover exposed wires to the electrodes. The checks on the resistivity probe indicated all electrodes were functioning properly.

The functioning of the TDR probes were checked by performing measurements in air, water, methyl alcohol, and with the prongs shorted at the circuit board and the end of the probe. The traces were taken and the dielectric constant was calculated for the water, air, and methyl alcohol. These values were checked against expected dielectric constants for each medium. The test indicated that all probes were functioning properly. Results of the TDR measurements are presented in Appendix B.

Equipment Installation

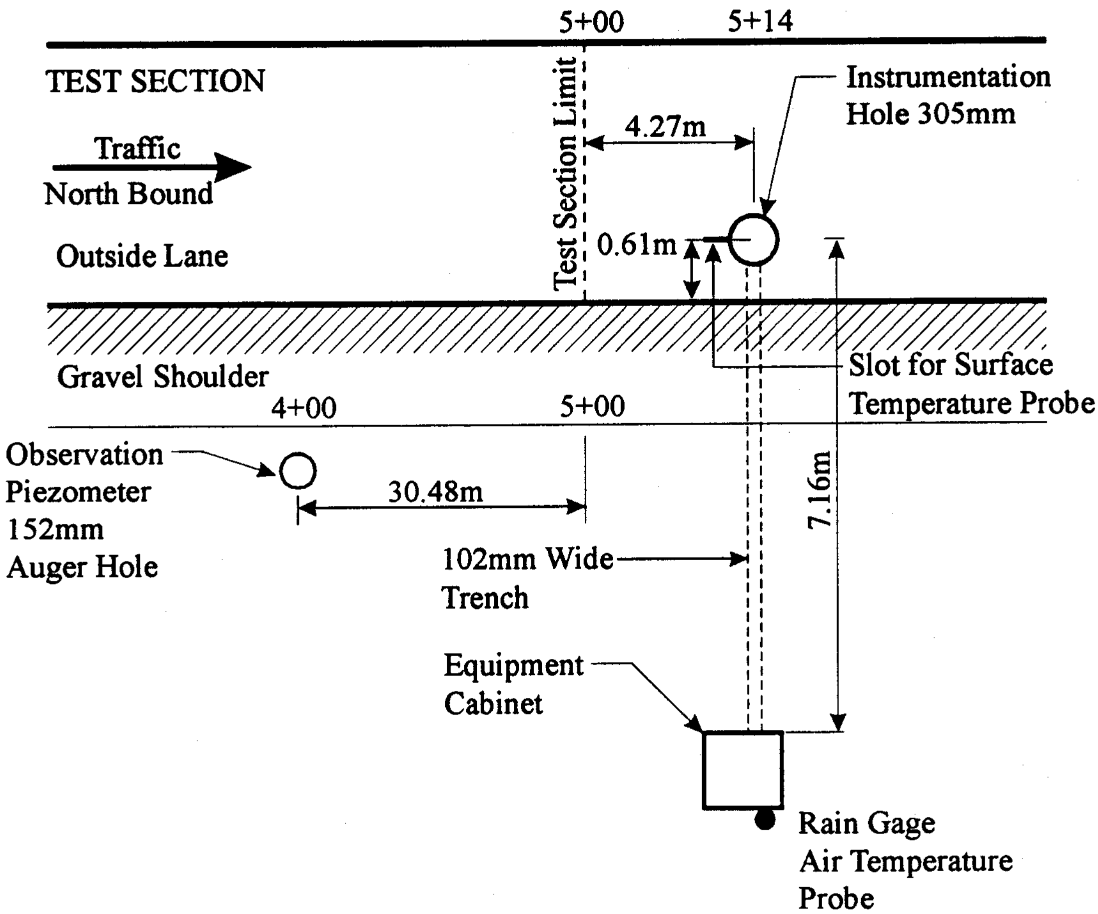
Final details for the installation and initial monitoring were discussed in a meeting on the afternoon of September 21, 1993. The installation was confirmed for 0830 hours on September 22, 1993. Traffic control for the installation and monitoring was provided by patrol 7 from MTO district Maintenance facility in Huntsville, Ontario. The pavement surface drilling and sawing were done by James Mellish, Drilling and Sawing Co. Ltd., Mississauga, Ontario. The augering of the piezometer and instrumentation hole was done by Eastern Soil Investigation Limited, Courtice, Ontario, under the supervision of Michael Bressette. The installation of the measurement equipment, the observation piezometer, weather station pole, and cabinet was performed by PMSL staff with assistance from the MTO research and development group and the local district personnel. Two visiting engineers, Sun Jian Hua and Wang Hongzi from Research Institute of Highways, Ministry of Communication, China, also participated in the installation and monitoring activities.

The instrumentation was installed on the north end of GPS 871622, in the outside northbound lane of highway 11 near Bracebridge, Ontario. The combination benchmark/piezometer was placed in the shoulder at station 4+00. The in-pavement instrumentation was installed in the outer wheel path at station 5+14. The cabling from the instrumentation was placed in a 51 mm flexible conduit and buried in a trench running from the instrument hole to an equipment cabinet installed 7.16 m from the instrumentation hole. To support the cabinet, approximately 0.5 cubic meter of crushed gravel was spread around the cabinet base which resided on the inside slope of the ditch line. This material would only provide a minor restriction to water flow in the ditch. This also provided a level surface for access to the cabinet. The weather pole was installed immediately behind the equipment cabinet. Figure 1 provides the location and distances for the various instrumentation and equipment installed.

The installation generally followed the procedures described in the "LTPP Seasonal Monitoring Program: Instrumentation Installation and Data Collection Guidelines". The combination piezometer/benchmark was installed just off the edge of the paved shoulder to a depth of 4.50 m using a 152 mm flight auger for drilling the hole. A sample of the material was retained from approximately 0.5 to 1.5 m below the surface. The hole was slightly over bored due to material collapsing into the hole. No water was encountered during the drilling exercise. The 25.4 mm galvanized pipe was firmly pressed into the hole, followed by 1.36 m of filter sand, a 0.31 m bentonite plug with the remainder of the hole filled with the native material removed. The final elevation for the pipe was 216 mm below the natural ground level at the location of the installation. A pyramid well cap, held in location by approximately 25 kg of concrete mix, was used to cover and protect the piezometer/benchmark.

A core hole was drilled in the pavement surface, located in the outside wheel path, 0.61 m from the edge of the travel lane at station 5+14, using a portable electric drill and a 305 mm thin wall diamond core barrel. A 102 mm wide by 150 mm deep saw cut was done between the core hole and the edge of the pavement, using a heavy duty pavement cutting machine, to accommodate the instrumentation cabling. The blade of the pavement saw was used to notch a location for the pavement surface temperature probe at the south edge of the core hole.

A combination of methods were used to excavate the instrumentation hole. The crushed granular base was scraped out with a hand shovel. The driller used a 250 mm hollow stem auger with the plug removed to loosen the subbase material, which again was removed by hand. The silty sand, silt and sand subgrade material were removed in 0.3 to 0.4 m lifts. Some material collapsed from the edge of the hole while some problems were encountered in removing all the material with the auger for each attempt. Care was taken to ensure material removed was consistently representative of material at the location from the bore hole. The findings from the excavation of the instrumentation hole at station 5+14 are presented in Figure 2. All the material excavated from the instrument hole was placed and compacted in order of removal. Samples of the material placed around the TDR probes were retrieved to determine the gravimetric moisture at these locations. A field moisture determination was done at the site with sample material retained for laboratory moisture determination by the MTO Materials laboratory. No additional material remained from the instrumentation hole with some material from the trench area required to top up and level the instrumentation hole. The equipment cabinet and pole for the rain gage and air temperature probe were installed as per manual guidelines with the following two exceptions, first the cabinet was installed on the inside ledge of the ditch and a crushed granular fill was used to support the cabinet and provided a platform for access, and second the pole for the rain gage and air temperature probe was installed to a depth of 0.66 m supported in the granular base for the cabinet. The excavation of the trench went fairly smooth as the material was a generally clean sand without cobbles or boulders. The wiring of the instrumentation to the equipment cabinet was completed on the same day as installed.



- Height of Air Temperature Probe (center): 3.40m
- Height of Tipping Bucket Rain Gage (center): 3.40m
- Total Depth of Piezometer: 4.28m
- Distance of Piezometer Below Ground Level: 216mm

Figure 1. Location for Seasonal Monitoring Instrumentation Installed at GPS 871622

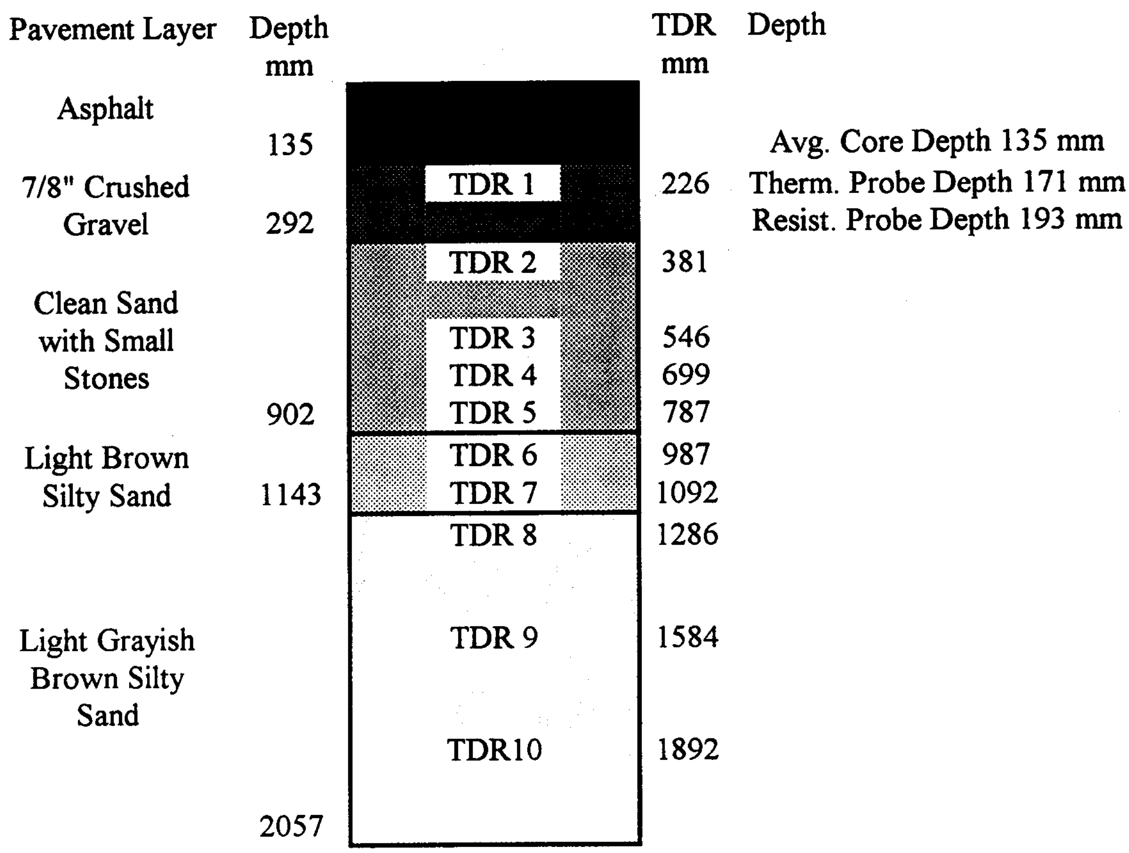


Figure 2. Profile of Pavement Structure and Probe Depths from Surface, Station 5+14

To check for breakage of the TDR probes during installation, each probe was connected to the cable tester and its wave form monitored during compaction of the material around it. The TDR traces are included in Appendix C. By alternating the TDR probes within the instrument hole we were able to keep the cables separate to avoid water from migrating along a bundle of cables attached to the probes placed at various depths. The thermistor and resistivity probes were installed at opposite sides of the instrumentation hole with the thermistor probe 0.171 m and the resistivity probe 0.193 m below the pavement surface. The cables were kept spaced as best as possible until they converged at the opening of the flexible conduit pipe, placed about 50 mm from the edge of the core hole. The cables were then tie wrapped and passed through the conduit to the equipment cabinet. The ends of the conduit were plugged with a mastic pipe sealant.

Tables 3, 4, and 5 present the installed depths of the TDR probes, thermistor sensors, and the resistivity probe respectively. Table 6 gives TDR, field, and laboratory measured moisture content during installation. A comparison of the moisture content from the TDR traces, field, and laboratory determination indicate some discrepancies. The field and laboratory moisture contents generally compare more favorably. The TDR method generally indicates higher moisture content, in particular, for the subbase material but in some instances the moisture content was less. Given the methods under which the material was sampled and the variability in the material, the results can be considered reasonable. It should be noted that the calculation of moisture is dependent on the calibration inputs for the TDR model. Differences of moisture content in the range of 1-2% are not uncommon.

Table 3. Installed Depths of TDR Sensors

Sensor #	Depth from Pavement Surface (m)	Layer
87A01	0.226	Base
87A02	0.381	Subbase
87A03	0.546	
87A04	0.699	
87A05	0.787	
87A06	0.987	Subgrade
87A07	1.092	
87A08	1.286	
87A09	1.584	
87A10	1.892	

Table 4. Installed Location of MRC Thermistor Sensor

Unit	Channel Number	Depth from Pavement Surface (m)	Remarks
1	1	0.025	This unit was installed in the AC layer.
	2	0.068	
	3	0.110	
2	4	0.187	This unit was installed below the AC layer into the subgrade.
	5	0.264	
	6	0.341	
	7	0.418	
	8	0.492	
	9	0.645	
	10	0.797	
	11	0.949	
	12	1.103	
	13	1.256	
	14	1.408	
	15	1.559	
	16	1.711	
	17	1.864	
	18	2.015	

Table 5. Location of Electrodes of the Resistivity Probe

Connector Pin Number	Electrode Number	Depth from Pavement Surface (m)
36	1	0.222
35	2	0.273
34	3	0.323
33	4	0.374
32	5	0.423
31	6	0.474
30	7	0.526
29	8	0.578
28	9	0.628
27	10	0.678
26	11	0.728
25	12	0.779
24	13	0.829
23	14	0.879
22	15	0.930
21	16	0.981
20	17	1.031
19	18	1.083
18	19	1.132
17	20	1.184
16	21	1.234
15	22	1.285
14	23	1.336
13	24	1.387
12	25	1.437
11	26	1.488
10	27	1.539
9	28	1.591
8	29	1.642
7	30	1.693
6	31	1.743
5	32	1.793
4	33	1.844
3	34	1.894
2	35	1.946
1	36	1.997

Table 6. TDR, Field, and Laboratory Moisture Content During Installation

Sensor Number	Sensor Depth (m)	Layer	TDR Moisture Content (by wt)*	Field Moisture Content (by wt)*	Lab Moisture Content (by wt)*
87A01	0.226	Base	4.58%	3.92%	3.40%
87A02	0.381	Subbase	2.06%	2.26%	2.10%
87A03	0.546		4.13%	2.33%	2.00%
87A04	0.699		5.26%	2.91%	2.10%
87A05	0.787		6.44%	3.27%	1.90%
87A06	0.987	Subgrade	10.61%	7.82%	7.30%
87A07	1.092		6.30%	9.31%	7.60%
87A08	1.286		8.92%	8.29%	9.20%
87A09	1.584		9.25%	11.51%	11.80%
87A10	1.892		10.61%	11.78%	11.10%

* Note: Raw data given in Appendix C

Site Repair and Cleanup

The instrumentation hole was repaired by reinstalling the 305 mm asphalt core. Some juggling was required to get the core level with the existing pavement surface. Once the core was leveled it was removed from the hole and the bottom 100 mm was heavily covered with a two part epoxy (PC-7) and reset into the hole forcing the epoxy against the side and up along the wall of the core hole. The weight of the agency dump truck, which slowly moved back and forth over the core, was used to firmly seat the core into the hole.

The trench for the cabling from the instrumentation hole to the edge of pavement was leveled with crushed gravel to the existing bottom of the paved layer and a cold mix was compacted to the level of the existing surface. The remainder of the trench was filled with native material and compacted, followed by a cleanup of loose material from the paved area. Traffic control was removed at 1630 hours and the lane reopened to traffic. During the next day the instrument hole and edge of the trench were sealed using Corning self-leveling 888 crack sealing compound. Removal of the asphalt trench material and other disposable items were handled by the MTO district personnel.

Patch/Repair Area Assessment

When the site was visited on December 13, 1993 two and a half months after installation, the instrumentation hole patch was checked and photos were taken as shown in Appendix E. The pavement core was slightly below the existing pavement and some settlement had taken place along the trench leading from the instrument hole to the pavement edge. Additionally, the sealant failed to bond to the existing pavement and core.

III. Initial Data Collection

The second day activities included initial data collection on the site and checks on functioning of installed equipment. This consisted of examination of the data collected over the day by the onsite datalogger, data collection and check of the mobile CR10 datalogger, deflection testing, and elevation survey.

Air Temperature, Subsurface Temperature, Rain-fall Data

The air temperature, pavement subsurface temperature profile, and rainfall data, collected on September 23 by the CR10 datalogger, were examined. The equipment and datalogger appeared to be functioning properly. The battery voltages were checked and found to be acceptable. Raw data collected at the site are presented in Appendix D. Figure D-1 shows the air temperature data collected from 1445 hours (September 23) through 1455 hours (September 23). Figure D-2 shows the first set of subsurface temperature for the first 5 sensors. Figure D-3 shows the first set of subsurface temperature for all 18 sensors. There was no precipitation that day. All these results indicated that the onsite CR10 datalogger and measurement equipment were working. Only 10 minutes of data were taken to check for the functioning of the sensors, not to be analyzed at a later time.

The tipping bucket rain gauge was checked by determining the number of tips recorded from 473 ml of water discharged into the gauge over a one hour time period. The rain gauge was found to be operating properly.

TDR Measurements

TDR data were collected using the mobile system provided by FHWA. The mobile system contains a CR10 datalogger, battery pack, two TDR multiplexers, and a resistance multiplexer circuit board. Version 1.0 of the MOBILE program was used to collect and record the TDR wave form traced for each sensor. Figures D-4 and D-5 show the initial TDR wave form traces collected with the MOBILE data acquisition system for all 10 sensors. The figures indicate that the multiplexers of the mobile system and TDR sensors were working properly.

Resistance Measurement Data

Resistance data were collected in two modes, automated and manual. The MOBILE data acquisition system automatically performs two point contact resistance measurements and stores the values in terms of millivolts between adjacent electrodes. Figure D-6 shows pavement depth versus measured voltage produced by the MOBILE system.

Manual contact resistance and resistivity measurements were performed using a Simpson Model 420d function generator, Fluke 87 digital multimeters and a manual circuit board. The measured contact resistance data are plotted in Figure D-7 and in Figure D-8 for the

4-point resistivity. Tables D-2 and D-3 in Appendix D show the raw data for the 2-point and the 4-point resistance respectively.

Comparison between Figure D-6 (contact resistance results from automated mode) and Figure D-7 (contact resistance results from manual mode) indicate similar results with the electrodes in the base material indicating differences in resistance from the subbase/subgrade material. Figure D-8 (4-point resistance results from manual mode) indicates that the 4-point test setup has similar results. If the reading equipment is working correctly, all the resistance/resistivity outputs will have similar shapes, although the values will be somewhat different based on the energy applied and distance between sampled electrodes.

Deflection Measurement Data

Deflection measurements followed procedures described in the "LTPP Seasonal Monitoring Program: Instrumentation Installation and Data Collection Guidelines". The analysis results from the FWDCHECK program from the day of installation and the following day are presented in Appendix D. Since then, eleven more measurements have been collected with the FWD, the first on December 13, 1993, then on January 4, March 22, April 6, April 26, May 17, June 14, July 12, August 9, September 13, and the eleventh on October 13, 1994.

Longitudinal Profile Data

According to the guidelines, since this is in a frost area, the survey should be performed on five different occasions; one survey during the middle of each season and one survey during the late winter period (fully frozen condition). Four surveys have already been performed on this site, the first during the fully frozen condition (February 16, 1994), the second in the spring season (April 6, 1994), the third in the summer season (July 14, 1994), and the fourth during the fall season (October 17, 1994).

Elevation Surveys

One set of the surface elevation survey was performed following the guidelines. It was assumed that the elevation at the top of the piezometer pipe was 1.000 meters. The survey was conducted on September 23, 1993, the day after the installation, and the results are presented in Appendix D. Since then, five more sets of the surface elevation surveys have been performed, the first on January 4, the second on April 6,. the third on July 12, the fourth on August 9, and the fifth on October 13, 1994.

Water Depth

A check of the piezometer indicated that there was no water present. Initial indications were that we may encounter the water table within 4 meters from the surface, but at the time of installation no water was present.

IV. Summary

The installation of the seasonal monitoring instrumentation at the GPS site 871622 near Bracebridge, ON was completed on September 22, 1993. A check of the equipment and initial data collection was completed on September 23, 1993. The instrumentation, permanently installed at the site, were:

- Time domain reflectometer probes for moisture measurements
- Electric resistivity probes for frost location
- Thermistor probes for soil gradient temperature measurements
- Air temperature thermistor probe and tipping bucket rain gage to record local climatic conditions, and
- Combination piezometer (well) and bench mark to determine changes in water level and pavement elevations.

The pavement gradient temperature and local climatic data are to have continuous data collection stored in an on-site datalogger. The moisture and electrical resistivity are to be collected during each site visit (14 times per year) using a mobile datalogger system. The water level and elevation data are to be collected manually during site visits.

The test section is on northbound Highway 11, approximately 5 kilometers north of Bracebridge. The section is on a divided highway consisting of two 3.7 m wide travel lanes in each direction with gravel shoulders. The north and south bound lanes are divided by a partially grassed median containing local vegetation and trees. Aside from local commuters and through traffic, this section is used by a number of tourists who frequently visit this area for leisure and recreational activities. The pavement structure consists of 135 mm of asphalt concrete over 157 mm of crushed (19 mm minus) gravel base and 610 mm of clean sand and stone and a sandy silt, silt and sand subgrade. This site is in a cut area that is heavily forested.

All instrumentation was checked prior to installation at the PMSL facility in Amherst, NY. These initial checks indicated that the instrumentation was within specifications, as required for the seasonal monitoring program. Operational checks during installation and the following day indicated that all instrumentation was functioning properly. The air temperature and gradient temperatures measured in the pavement surface compared favorably with the hand held Omega temperature gage. The temperature profile for the pavement soils appeared reasonable with no outlying sensors. Shortly after the installation and early monitoring of the temperature profiles, the number one temperature sensor (located 25 mm below pavement surface in asphalt concrete) failed. The cause of this failure is not known and as the instrumentation and multiplexing circuitry are buried in the pavement, no efforts have been made to evaluate and repair this sensor. A check of the tipping bucket indicated it was functioning correctly with tips corresponding to amount of water supplied. Moisture content of the soil was determined by TDR method, field moisture determination at time of installation by soil drying and laboratory results provided by Jerry Hajek, MTO research and Development. There were differences between the moisture content determined by the TDR method and gravimetric moisture content determined from the samples taken, although there was nothing that may indicate the TDR probes were not functioning correctly.

The installation generally went as expected with only a few minor problems. The installation was completed and the section opened to traffic by 1700 hours. Aside from the installation and monitoring at the selected seasonal site, the year three data collection on the adjacent SPS-3 maintenance treatment sites were also done in the same week. This consisted of FWD testing, Manual Distress Survey, and coring of the treatment layers for material properties evaluation.

The removal/replacement of the material from the instrumentation hole went very well, with the material being well consolidated around the instrumentation and the core level with the existing pavement surface at completion.

The ongoing monitoring of this section, except for the problems encountered due to weather and technical difficulties with the FWD, has gone fairly well. Aside from the LTPP testing on the GPS site, corresponding testing has been done by MTO using their Benkelman Beam to measure pavement response on adjacent CSHRP test sections, when the LTPP FWD was on site.

APPENDIX A

Test Section Background Information

Appendix A contains the following supporting information:

FHWA-LTPP ONTARIO TEST SITE LOCATIONS
GPS-SPS PAVEMENT STUDIES

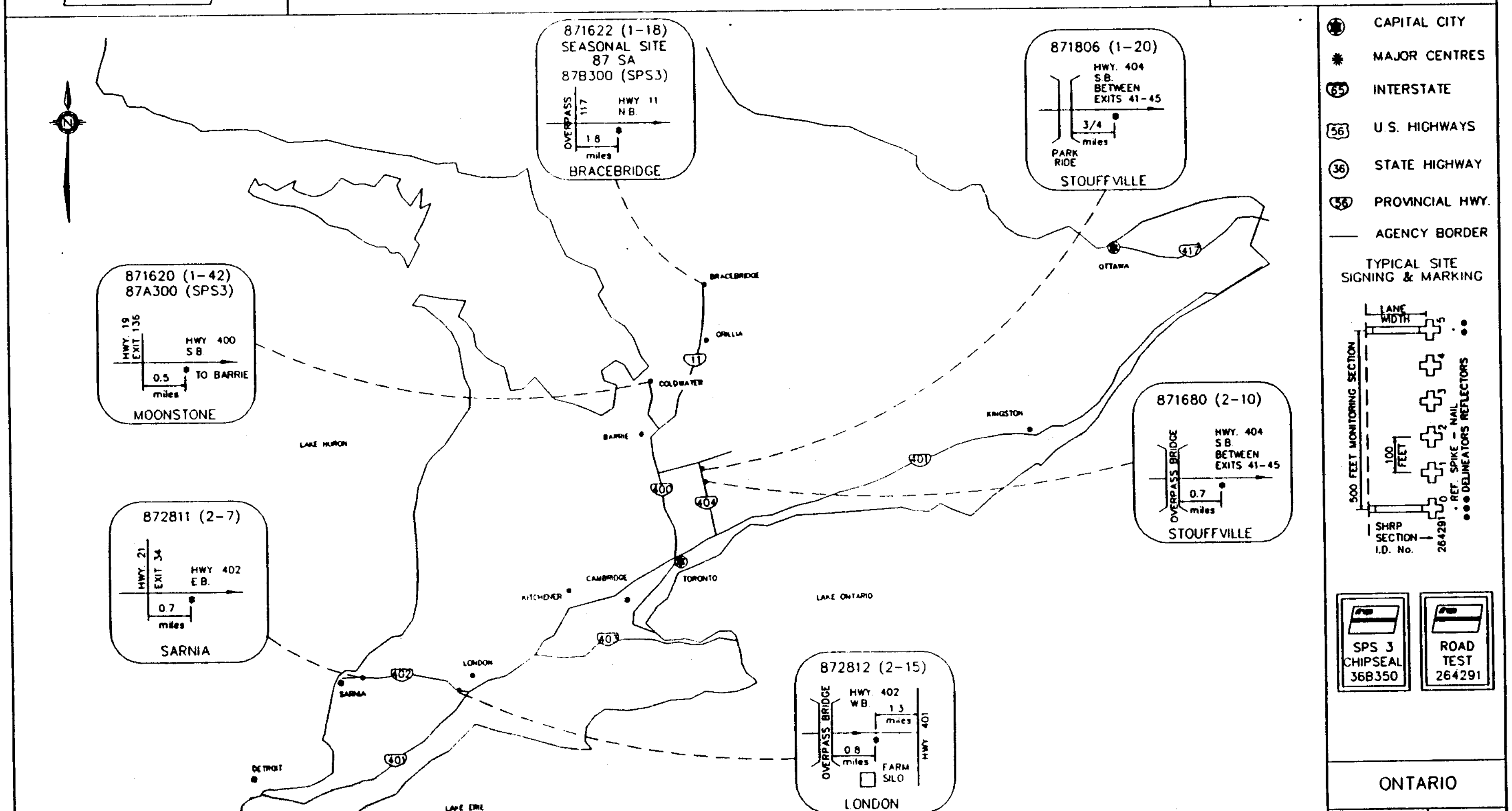


FIGURE A-1 SITE LOCATION MAP - SECTION 871622

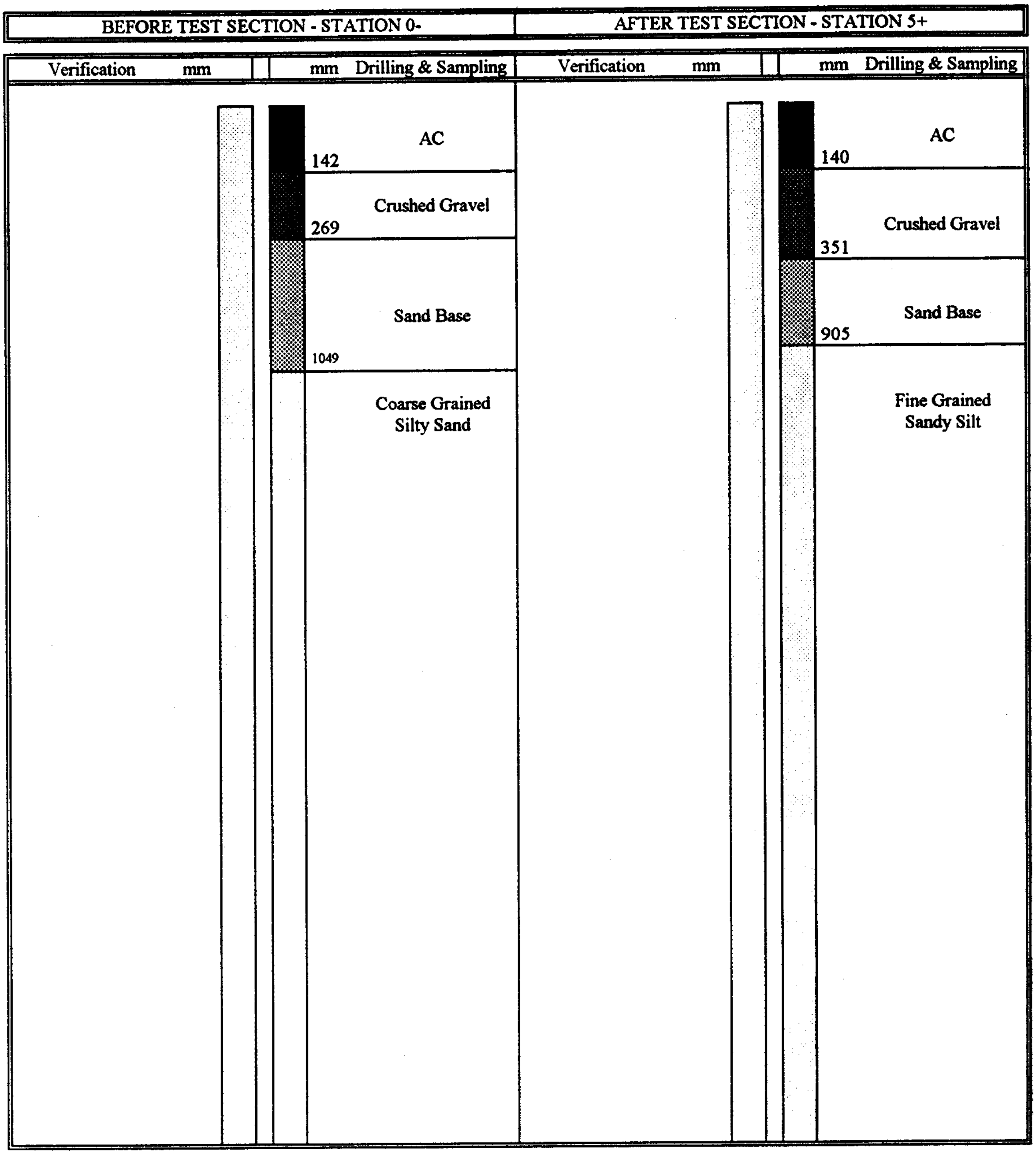


Figure A-2. Profile of Pavement Structure

Table A-1. Site Performance Summary

Distress and Profile Summary		
Distress Summary 1990	**Profile Summary**	
	Date (mm-dd-yy)	**IRI (in/mi)**
Low Sev. Long. Cracks - 487.44 ft.	09-05-89	88.12
Mod. Sev. Trans. Cracks - 1 @ 14.43 ft.	06-18-90	90.66
Low Sev. Trans. Cracks - 26 @ 240.11 ft.	10-19-90	94.15
	04-26-91	97.34
	08-20-92	96.50
	09-08-93	102.24

Falling Weight Deflectometer Data Summary

Date	Mean Value for Drop HT 2 (mils)					
	Sensor 1	Sensor 1 std. dev.	Sensor 7	Sensor 7 std. dev.	MeanTemp D1 (F)	Min/Max TempD1(F)
07-23-90	10.29	0.63	1.08	0.03	79	75/81

	Effective SN	SN std dev	Subgrade Modulus (psi)	Modulus std dev (psi)	Test Pit Mod. (psi) 1	Test Pit Mod. (psi) 2
07-23-90	9.70 10.01 9.58	0.25 0.08 0.09	38357 42157 40600	2705 550 1250	39055	38605
					-	-

Table A-2. Uniformity Survey Results

Seasonal Uniformity Survey	Falling Weight Deflectometer
Site Number: 871622	Data Collection and
Date Surveyed: July 23, 1990	Processing Summary

Section Interval (ft)	Mean Deflection Values for HT 2 (mils) - Corrected							
	Sensor 1	Sensor 1 std dev	Sensor 7	Sensor 7 std dev	Subg modulus (psi)	Subg modulus std dev	Effective SN	SN std dev
-50					39055		9.80	
0 to 310	9.76	0.62	1.09	0.03	38357	2705	9.70	1025
310 to 410	8.85	0.18	1.05	0.01	42157	550	10.01	0.08
410 to 500	10.00	0.23	1.07	0.02	40600	1250	9.58	0.09
564					38605		9.85	

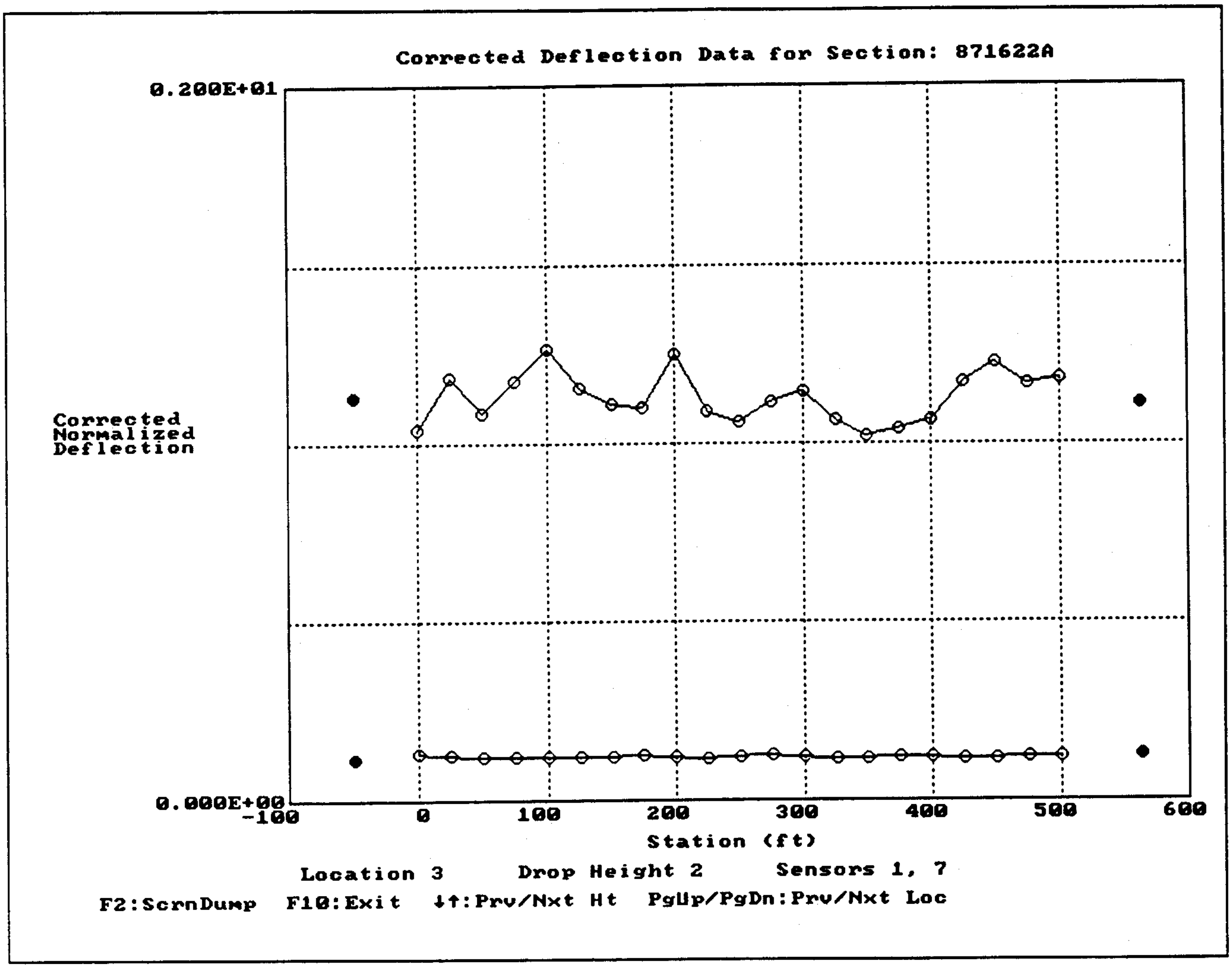


Figure A-3. Deflection Profile from FWDCHECK
(Test Date July 23, 1990)

Table A-3. Subgrade Modulus and Structural Number from FWDCHECK
(Test Date July 23, 1990)

Flexible Pavement Thickness Statistics - 871622A - Drop Height 2			
Subsection	Station	Subgrade Modulus	Effective SN
(TP)	-50	39055	9.80
1	0	36778	10.10
	25	35115	9.60
	50	36983	9.90
	75	40024	9.50
	100	40959	9.20
	125	40948	9.55
	150	34250	9.85
	175	37705	9.80
	200	34417	9.40
	225	42628	9.75
	250	40342	10.00
	275	39466	9.80
	300	39028	9.70
2	325	42956	9.95
	350	42078	10.10
	375	41784	10.05
	400	41809	9.95
3	425	42472	9.60
	450	40014	9.45
	475	40058	9.65
	500	39858	9.60
(TP)	564	38605	9.85
Subsection 1	Overall Mean	38357	9.70
	Standard Deviation	2705	0.25
	Coeff. of Variation	7.05%	2.57%
Subsection 2	Overall Mean	42157	10.01
	Standard Deviation	550	0.08
	Coeff. of Variation	1.30%	0.75%
Subsection 3	Overall Mean	40600	9.58
	Standard Deviation	1250	0.09
	Coeff. of Variation	3.08%	0.90%

APPENDIX B

Supporting Site Visit and Installed Instrument Information

Appendix B contains the following supporting information:

Correspondence from the Site Inspection and Planning Meeting

Table B-1. Air Temperature Thermistor Calibration

Table B-2. MRC Probe Calibration

Table B-3. Description of MRC Thermistor Probe and Sensor Spacing

Table B-4. Resistivity Probe and Sensor Spacing

Table B-5. TDR Probes Calibration

Figure B-1. TDR Traces Obtained During Calibration

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MEMORANDUM

TO:	Graham Jones	**DATE:**	June 26, 1991
FROM:	Bill Phang *Bill Phang*	**PROJECT:**	05-045-07-32
SUBJECT:	FWD Seasonal Monitoring Program	**FILE:**	12.13.1
		COPIES TO:	See Below

Thank you for letting me know that Ontario will participate in the SHRP seasonal FWD testing program at one site, 871620 (Hwy. 400, Moonstone).

As soon as details of instrumentation at a site are finalized, this information will be passed on to you. SHRP will arrange a pilot installation prior to arranging to instrument the Moonstone site. A likely time frame for Moonstone is September/October '91. FWD testing would begin directly thereafter. A schedule will be provided, and a procedure agreed on to deal with delays due to weather, etc.

<u>Distribution to:</u>

C. Richter
G. Rada
J. Hajek
I. Pecnik
B. Henderson

L. ... REC. APR 14 1992
JOB #
FILE #

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Ministry of Transportation
Ministère des Transports
Ontario

Research and Development Branch
3rd Floor, Central Building
1201 Wilson Avenue
Downsview, Ontario
M3M 1J8

Tel: (416) 235-4679
Fax: (416) 235-4872

March 25, 1992

Mr. Bill Phang
Pavement Management Systems Ltd.
3729 Union Road
Buffalo, N.Y. 14225
U.S.A.

Dear Mr. Phang:

Re: SHRP Seasonal Site - Moonstone

871620

With reference to the planned use of the SHRP GPS site on Highway 400 as a seasonal test site, this will confirm our agreement to support the project and to assist with equipment installation around August 1992. Jerry Hajek will act as the coordinator and will arrange for traffic control, district assistance and rehabilitation of the site. I understand that SHRP will want to cut a 12" diameter core in the pavement, together with a number of groves for the instrument cables. The work should take about 2 days with traffic control required during normal working hours, i.e. 8:00 a.m. - 5:00 p.m.

In addition you have requested that we arrange for you to be present when details of the major Highway 400 rehabilitation are discussed with the contractor. Jerry has also agreed to coordinate this meeting. He will be in touch with you later in the year with details of the schedule of rehabilitation.

If I can be of any further help in this or other SHRP related work please feel free to call.

Yours truly,

G.J.F. Jones
Manager
Highway Innovations &
Strategic Research

BH

PAVEMENT MANAGEMENT SYSTEMS

MEMORANDUM

TO:	C. Dougan, CT T. Karasopolous, ME L. Kenison, NH R. Cauley, VT G. Jones, ON G. Dore, QE P. Hughes, MA	**DATE:** **PROJECT:** **FILE:**	May 07, 1992 50450732 6.01
FROM:	Bill Phang		
SUBJECT:	SHRP Seasonal Monitoring Reconfirming Participation	**COPIES TO:**	See Below

Planning for the SHRP Seasonal Monitoring program has now progressed to the stage where preliminary schedules for installation of temperature, moisture, and frost depth penetration need to be determined.

The results of the measurements made at the pilot seasonal testing site at Syracuse, N.Y., and at Boise, ID, are to be examined and recommendations made regarding the instrumentation which will be used at other seasonal testing sites by the end of May 1992. These recommendations will be discussed and the instrumentation finalized by the Instrumentation ETG in June 1992. Acquisition of equipment and plans for installation over the next few months imply that field installation will begin in September 1992.

In the meantime, in order to develop and test the schedules for FWD testing, a trial run of the testing circuit will be made in July. At this juncture the eight (8) first round GPS seasonal testing sites include:

Cell No.	Agency	SHRP ID	SHRP Expt.	Subgrade	AC Thickness	Traffic
4 *	ON **	871620	1	Fine	4.5	High
12	NY **	361011	1	Fine	10.7	Low
12	VT	510002	1	Fine	8.1	Low
16	CT **	091803	1	Coarse	7.0	Low
16	MA	251003	1	Coarse	8.5	High
16	NH	331001	1	Coarse	8.3	High
20	QE	893015	3	Fine	8.5	High
24	ME	233014	3	Coarse	10.0	Low

* To be rehabilitated in May 1992   ** 1992 Confirmation

U.S. Department of Transportation
Federal Highway Administration

COPY

Memorandum

6300 Georgetown Pike
McLean, Virginia 22101-2296

Subject: Seasonal Monitoring Program

Date: JUN 25 1993

From: Aramis Lopez, Jr.
Long-Term Pavement Performance Division

Reply to Attn. of: HNR-40

To: Mr. Brandt Henderson, North Atlantic Regional Contractor

Pursuant to our discussions concerning the suitability of LTPP GPS section number 871620 (Ontario, Canada) for inclusion in the core experiment of the seasonal monitoring program, it is our recommendation that this section not be included. The primary reason for our recommendation is that this section was rehabilitated in 1992 and hence, would introduce an additional factor into the core experiment where we have tried to focus on just a few key parameters. We would also like to recommend that an alternate site be found.

While we do not presently recommend that the section in question be included in the core experiment, it is possible that it could be included at a later time, this section falls into Experimental Cell No. 4 for which we do not presently have any confirmed sections. Although the likelihood of this happening is very low, we feel that as a minimum the section would be an ideal candidate for inclusion in the seasonal supplemental studies.

Should you have any question regarding the above information, please do not hesitate to call me at 703-285-2013.

cc
Ivan Pecnik, Regional Engineer, NARO
File 180.03
A. Lopez

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July 14, 1993
50450910-12.13

Mr. Graham Jones
Highway Innovations and Strategic Research
Ontario Ministry of Transportation
1201 Wilson Avenue
Downsview, Ontario M3M 1J8

RE: Seasonal Monitoring Project in Ontario

Dear Graham ~~Mr. Jones~~,

We were notified by FHWA that the GPS 871620 site on Highway 400 at Moonstone is not to be included in the seasonal monitoring program because it would introduce another factor (rehabilitation) into the experiment. See memo attached.

Could we suggest an alternative location, the GPS 871622 site on Highway 11 NB just north of Highway 117, at Bracebridge? The nomination data, with the subgrade classification amended to Fine as determined by sampling and laboratory testing, shows that this site would just conform to requirements of Cell #4 in the Core Experiment. At this time there is no other GPS that fulfills these requirements.

Should you agree to support this alternative site nomination for seasonal monitoring, it would principally involve traffic control for installation of sensors and instrumentation (2 days), for FWD measurements, level readings etc. for one day per month for a total of 14 times in a year. The observations of weather data, frost penetration, etc. are automated and will be downloaded by the regional office on a monthly basis.

Once the nomination is accepted, we shall be contacting you to schedule a planning meeting and setting a date for the installation of the equipment.

Please let me know whether you will support the nomination. Call if you have any questions.

Yours Sincerely,
PAVEMENT MANAGEMENT SYSTEMS LTD.

William A. Phang

W.A. Phang, D. Eng.
Program Manager, FHWA-LTPP

c.c. I.J. Pecnik
B. Henderson

BP/tf

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July 14, 1993
50450910-12.13

Mr. Jerry Hajek
Highway Innovations and Strategic Research
Ontario Ministry of Transportation
1201 Wilson Avenue
Downsview, Ontario M3M 1J8

RE: Seasonal Monitoring Project in Ontario

Jerry
Dear Mr. ~~Jones~~,

We were notified by FHWA that the GPS 871620 site on Highway 400 at Moonstone is not to be included in the seasonal monitoring program because it would introduce another factor (rehabilitation) into the experiment. See memo attached.

Could we suggest an alternative location, the GPS 871622 site on Highway 11 NB just north of Highway 117, at Bracebridge? The nomination data, with the subgrade classification amended to Fine as determined by sampling and laboratory testing, shows that this site would just conform to requirements of Cell #4 in the Core Experiment. At this time there is no other GPS that fulfills these requirements.

Should you agree to support this alternative site nomination for seasonal monitoring, it would principally involve traffic control for installation of sensors and instrumentation (2 days), for FWD measurements, level readings etc. for one day per month for a total of 14 times in a year. The observations of weather data, frost penetration, etc. are automated and will be downloaded by the regional office on a monthly basis.

Once the nomination is accepted, we shall be contacting you to schedule a planning meeting and setting a date for the installation of the equipment.

Please let me know whether you will support the nomination. Call if you have any questions.

Yours Sincerely,
PAVEMENT MANAGEMENT SYSTEMS LTD.

William A. Phang

W.A. Phang, D. Eng.
Program Manager, FHWA-LTPP

c.c. I.J. Pecnik
B. Henderson

BP/tf

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August 23, 1993
50450910-13.13.3

Dr. Jerry Hajek
Ontario Ministry of Transportation
Research and Development Branch
1201 Wilson Avenue
Downsview, Ontario M3M 1J8

RE: SPS-3 Project 87B300; Bracebridge, Ontario

Dear Jerry,

Further to our plans to install instrumentation for seasonal monitoring at GPS 871622 on September 22, and 23, 1993, it would be appropriate to combine this exercise with the monitoring of the adjacent SPS-3 project 87B300.

For this reason, we are requesting traffic control at this location for September 20, and 21, 1993 in addition to September 22, and 23.

During these first two days of this week, we shall be doing Manual Distress Surveys including transverse dipstick cross section measurements, making deflection measurements with the FWD, and taking 6" core samples of 7 treated test sections and from the GPS control section. During this time the GPS site will be tested and at both ends to determine the best location for installation of seasonal equipment.

As well, we are requesting that core drilling equipment be made available during these two days, September 20, and 21, to acquire from each section the 2-6" OD (or 4-4" OD) cores. Only materials from the top 1/2" of the core will be needed for tests, so the depth of coring will be restricted to about 2 inches.

For the installation of seasonal monitoring instrumentation, a meeting of representatives from all the participating groups, traffic control, sawing crew, drilling crew, maintenance crew (patching), pavement research, NARO, and FHWA, is scheduled for about 1 pm on September 21, at a nearby hotel (to be designated). At this meeting details of tasks will be discussed, and checks made that manpower, equipment, materials and supplies are available to meet the needs.

Please accept thanks for your valuable cooperation.

Yours Sincerely,
PAVEMENT MANAGEMENT SYSTEMS LIMITED

Bill Phang

W.A. Phang, D. Eng.
Program Manager, FHWA-LTPP

BP/tf

c.c. I.J. Pecnik
B. Henderson

Table B-1. Air Temperature Thermistor Calibration

LTPP Seasonal Monitoring Study	State Code	[8 7]
Air Temperature Thermistor Calibration	Test Section Number	[1 6 2 2]

Before Operation Checks	Calibration Date mm-dd-yy	09-09-93
	Probe S/N	87AAT
	Operator	PZ

Mobile Datalogger (24 hour)			Water Room Temperature		Ice Bath 0 C (+/- 1 C)		Hot Water 50 C (+/-)		ok
Mean	Min.	Max.	Reading	Time	Reading	Time	Reading	Time	y/n
17.75	7.15	27.42	18.40	1059	0.419	1011	45.60	1145	y

Probe Accepted	PZ&MZ	(Initials)

Table B-2. MRC Probe Calibration

LTPP Seasonal Monitoring Study	State Code	[87]
MRC Probe Calibration	Test Section Number	[1622]

Before Operation Checks	Calibration Date mm-dd-yy	09-09-93
	Probe S/N	87AT
	Operator	PZ+MZ

	Mobile Datalogger (24 hour)			Water Room Temp Time 1010	Ice Bath 0 C(+/- 1 C) Time 1100	Hot Water 50 C (+/-) Time 1140	ok
No.	Mean	Min.	Max.	Reading	Reading	Reading	y/n
1	17.99	7.62	24.0	19.4	0.61	43.8	y
2	17.9	7.56	24.94	19.1	0.69	43.4	y
3	17.84	7.52	24.97	18.7	0.80	43.4	y
4	17.65	6.21	26.95	19.0	1.71	45.1	y
5	17.79	6.4	27.0	19.0	0.98	33.9	y
6	18.07	6.89	26.36	19.1	1.35	44.9	y
7	18.17	7.21	26.67	19.1	1.53	45.1	y
8	18.12	7.4	27.05	19.1	1.35	45.2	y
9	18.42	7.9	27.84	19.3	1.35	45.5	y
10	18.5	7.94	28.28	19.4	1.42	45.8	y
11	18.5	7.65	29.07	19.9	1.42	46.9	y
12	18.59	7.78	29.58	19.7	1.42	46.6	y
13	18.69	7.78	30.61	20.0	1.53	47.8	y
14	18.72	7.81	32.59	19.7	1.67	48.2	y
15	18.7	7.94	34.58	20.1	1.57	48.4	y
16	18.78	8.94	34.24	20.1	1.64	48.2	y
17	18.75	8.44	33.95	20.2	1.75	47.8	y
18	18.54	8.65	30.71	19.9	1.20	45.0	y

Probe Accepted:	PZ+MZ	(Initials)
Probe Length:	1.851	(meters)

Thermistor distance from top of probe:				(meters)					
4	.016	7	.246	10	.625	13	1.084	16	1.540
5	.092	8	.321	11	.778	14	1.237	17	1.692
6	.170	9	.473	12	.932	15	1.387	18	1.843

Table B-3. Description of MRC Thermistor Probe and Sensor Spacing

Unit	Channel No.	Distance from Top of Unit(m)	Remarks
1	1	.013	0.3302 m long by 63.5 mm stainless steel probe installed in the AC layer
	2	.165	
	3	.318	
2	4	.016	1.851 m long by 25.4 mm PVC tube installed in the base and subgrade.
	5	.092	
	6	.170	
	7	.246	
	8	.321	
	9	.473	
	10	.625	
	11	.778	
	12	.932	
	13	1.084	
	14	1.237	
	15	1.387	
	16	1.540	
	17	1.692	
	18	1.843	

Table B-4. Resistivity Probe and Sensor Spacing

Connector Pin No.	Electrode Number	Continuity x	Measure-ment	Spacing (mm) Line 1	Line 2	Avg.	Dist. from Top (m)
36	1	x	Top-1	29	29	29.0	.029
35	2	x	1-2	51	50	50.5	.080
34	3	x	2-3	50	49	49.5	.130
33	4	x	3-4	51	52	51.5	.181
32	5	x	4-5	49	49	49.0	.230
31	6	x	5-6	51	51	51.0	.281
30	7	x	6-7	52	52	52.0	.333
29	8	x	7-8	52	52	52.0	.385
28	9	x	8-9	50	50	50.0	.435
27	10	x	9-10	50	50	50.0	.485
26	11	x	10-11	50	50	50.0	.535
25	12	x	11-12	51	51	51.0	.586
24	13	x	12-13	50	51	50.5	.636
23	14	x	13-14	50	50	50.0	.686
22	15	x	14-15	51	52	51.5	.737
21	16	x	15-16	51	50	50.5	.788
20	17	x	16-17	50	52	51.0	.838
19	18	x	17-18	52	51	51.5	.890
18	19	x	18-19	49	49	49.0	.939
17	20	x	19-20	52	52	52.0	.991
16	21	x	20-21	50	51	50.5	1.041
15	22	x	21-22	51	50	50.5	1.092
14	23	x	22-23	51	51	51.0	1.143
13	24	x	23-24	51	51	51.0	1.194
12	25	x	24-25	50	50	50.0	1.244
11	26	x	25-26	51	51	51.0	1.295
10	27	x	26-27	51	50	50.5	1.346
9	28	x	27-28	52	52	52.0	1.398
8	29	x	28-29	51	52	51.5	1.449
7	30	x	29-30	51	50	50.5	1.500
6	31	x	30-31	50	50	50.0	1.550
5	32	x	31-32	50	50	50.0	1.600
4	33	x	32-33	51	52	51.5	1.651
3	34	x	33-34	50	50	50.0	1.701
2	35	x	34-35	52	52	52.0	1.753
1	36	x	35-36	51	52	51.5	1.804
			36-End	24	23	23.5	1.828

Table B-5. TDR Probes Calibration

LTPP Seasonal Monitoring Study	State Code		[87]
TDR Probes	Test Section Number		[1622]

Before Operation Checks	M.Z.	Initial	Calibration Date (mm-dd-yy)	09-10-93
			Seasonal Site	87SA

				Probe Shorted		Air	Alcohol	Water
	Probe	Resistance (ohms)		Begin	End	Begin	Begin	Begin
No.	(S/N)	Core	Shield	Length	Length	Length	Length	Length
1	87A01	0.40	0.10	16.130	16.300	16.130	16.160	16.160
2	87A02	0.70	0.70	16.150	16.330	16.150	16.190	16.190
3	87A03	1.60	0.70	16.160	16.340	16.160	16.190	16.190
4	87A04	0.50	0.40	16.660	16.840	16.660	16.690	16.690
5	87A05	0.80	7.00	16.630	16.810	16.630	16.660	16.670
6	87A06	0.70	0.80	16.710	16.890	16.710	16.750	16.740
7	87A07	0.50	0.70	16.660	16.840	16.660	16.690	16.700
8	87A08	0.70	0.50	16.750	16.930	16.750	16.780	16.780
9	87A09	0.70	0.60	16.890	17.070	16.890	16.900	16.910
10	87A10	0.60	0.40	16.700	16.890	16.700	16.740	16.730

NOTE: Record lengths from TDR

Calculation of Dielectric Constant

Probe Length .203 m

V_p Setting .99 V_p

$$\varepsilon = \left[\frac{TDRL}{(PL)\,(V_p)} \right]^2$$

	Air			Alcohol			Water		
No.	TDR Length	Dielectric Constant	In Spec. (?)	TDR Length	Dielectric Constant	In Spec. (?)	TDR Length	Dielectric Constant	In Spec. (?)
1	.19	0.88	y	1.19	34.4	y	1.86	83.1	y
2	.24	1.40	y	1.19	34.4	y	1.85	83.1	y
3	.24	1.40	y	1.20	34.9	y	1.85	83.1	y
4	.22	1.18	y	1.18	33.8	y	1.85	83.1	y
5	.24	1.40	y	1.20	34.9	y	1.85	83.1	y
6	.22	1.18	y	1.17	33.2	y	1.85	83.1	y
7	.21	1.07	y	1.18	33.8	y	1.85	83.1	y
8	.21	1.07	y	1.18	33.8	y	1.86	84.0	y
9	.21	1.07	y	1.18	33.8	y	1.85	83.1	y
10	.21	1.07	y	1.18	33.8	y	1.83	81.3	y

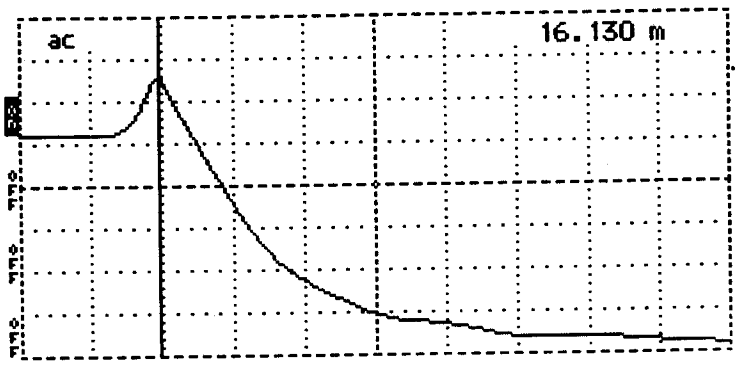
LTPP Seasonal Monitoring Study	State Code	[27]
TDR Probe Calibration	Test Section Number	[1622]

Before Operation Checks - **Calibration Date** 9/10/93
- **Probe S/N** 8741

Probe Number 1

TDR Trace 1 - Beginning Probe Shorted

Cursor .... 16.130 m
Distance/Div..... .25 m/div
Vertical Scale.... 167 mρ/div
Vp 0.99
Noise Filter...... 1 avg
Power........... ac

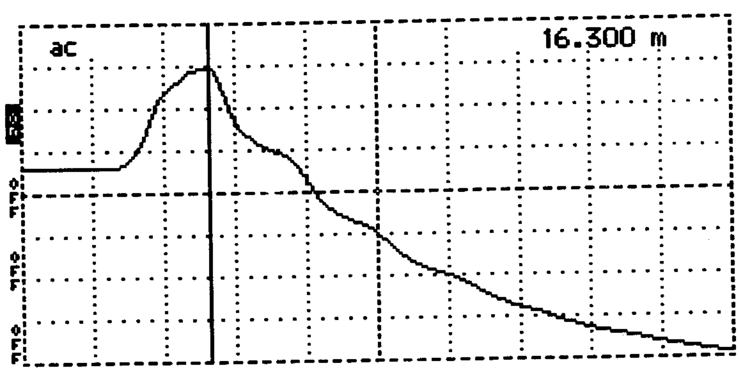


Tektronix 1502B TDR
Date 9/10/93
Cable #1
Notes Shorted @ Cf

Input Trace
Stored Trace
Difference Trace

Trace Number 2 - Ending Probe Shorted

Cursor .... 16.300 m
Distance/Div..... .25 m/div
Vertical Scale.... 167 mρ/div
Vp 0.99
Noise Filter...... 1 avg
Power........... ac



Tektronix 1502B TDR
Date 9/10/93
Cable #1
Notes Shorted @ end

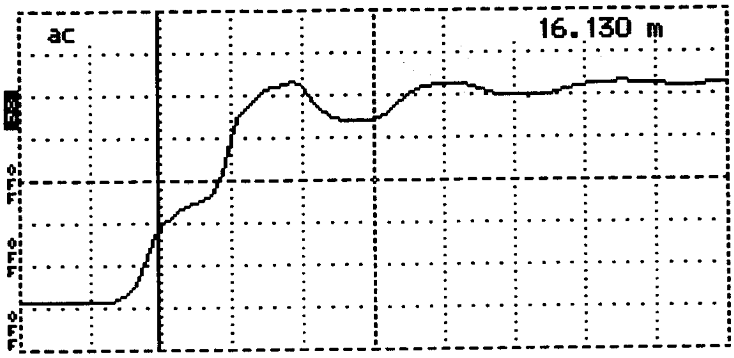
Input Trace
Stored Trace
Difference Trace

Figure B-1. TDR Traces Obtained During Calibration

Probe Number 1 (cont.)

ace Number 3 - Probe in Air

or .... 16.130 m
ance/Div..... .25 m/div
ical Scale.... 167 mρ/div
.... 0.99
e Filter...... 1 avg
er........... ac

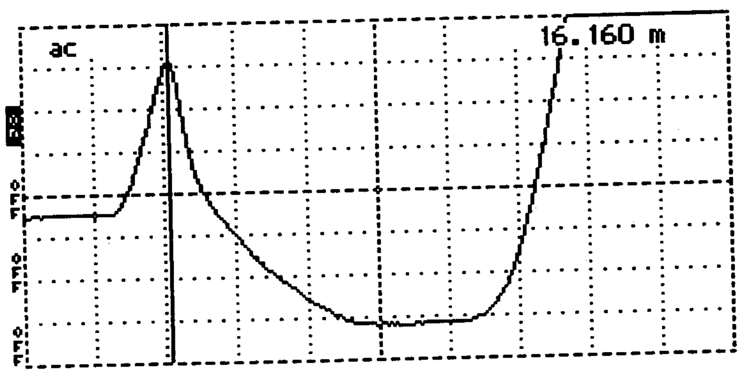


Tektronix 1502B TDR
Date 9/10/93
Cable #1
Notes In Air

Input Trace
Stored Trace
Difference Trace

Trace Number 4 - Probe in Alcohol

Cursor .... 16.160 m
Distance/Div..... .25 m/div
.rtical Scale.... 47.2 mρ/div
Vp 0.99
Noise Filter...... 1 avg
Power........... ac

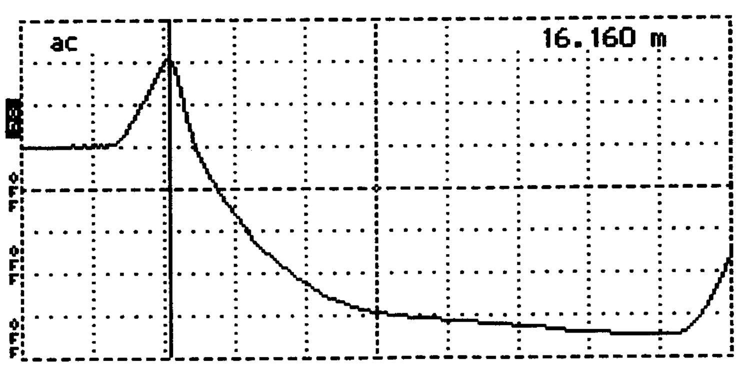


Tektronix 1502B TDR
Date 9/10/93
Cable #1
Notes Alcohol

Input Trace
Stored Trace
Difference Trace

Trace Number 5 - Probe in Water

ursor .... 16.160 m
stance/Div..... .25 m/div
ertical Scale.... 72.7 mρ/div
p 0.99
oise Filter...... 1 avg
ower........... ac



Tektronix 1502B TDR
Date 9/10/93
Cable #1
Notes H_2O

Input Trace
Stored Trace
Difference Trace

Figure B-1(cont.). TDR Traces Obtained During Calibration

LTPP Seasonal Monitoring Study	State Code	[87]
TDR Probe Calibration	Test Section Number	[1622]

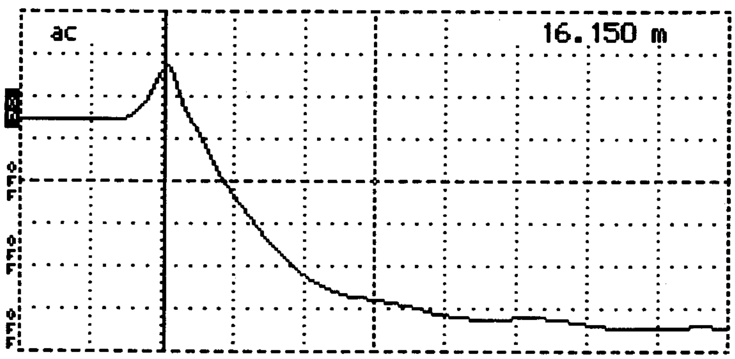
Before Operation Checks

- Calibration Date 9/10/93
- Probe S/N 87A2

Probe Number 2

TDR Trace 1 - Beginning Probe Shorted

ursor .... 16.150 m
istance/Div..... .25 m/div
ertical Scale.... 167 mρ/div
P 0.99
loise Filter...... 1 avg
ower........... ac

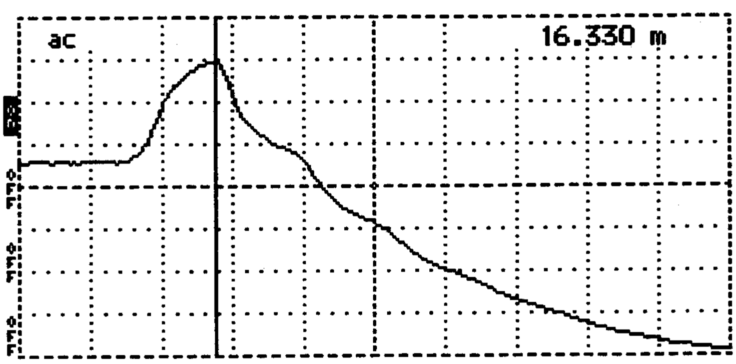


Tektronix 1502B TDR
Date 9/10/93
Cable #2
Notes

Input Trace
Stored Trace
Difference Trace

Trace Number 2 - Ending Probe Shorted

ursor .... 16.330 m
istance/Div..... .25 m/div
ertical Scale.... 167 mρ/div
P 0.99
loise Filter...... 1 avg
ower........... ac



Tektronix 1502B TDR
Date 9/10/93
Cable #2
Notes

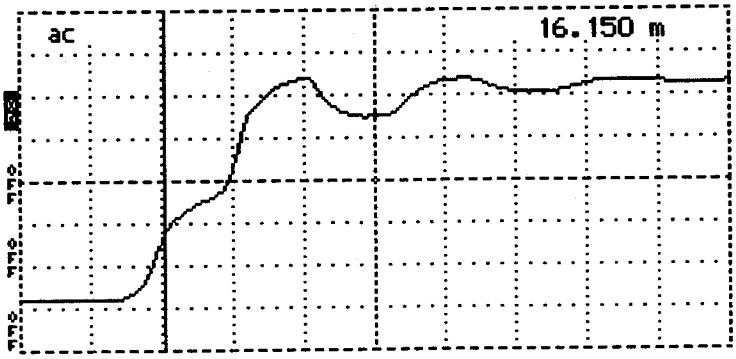
Input Trace
Stored Trace
Difference Trace

Figure B-1(cont.). TDR Traces Obtained During Calibration

Probe Number 2 (cont.)

ce Number 3 - Probe in Air

ursor .... 16.150 m
istance/Div..... .25 m/div
ertical Scale.... 167 mρ/div
P 0.99
oise Filter...... 1 avg
ower.......... ac



Tektronix 1502B TDR
Date 9/10/93
Cable #2
Notes

Input Trace
Stored Trace
Difference Trace

Trace Number 4 - Probe in Alcohol

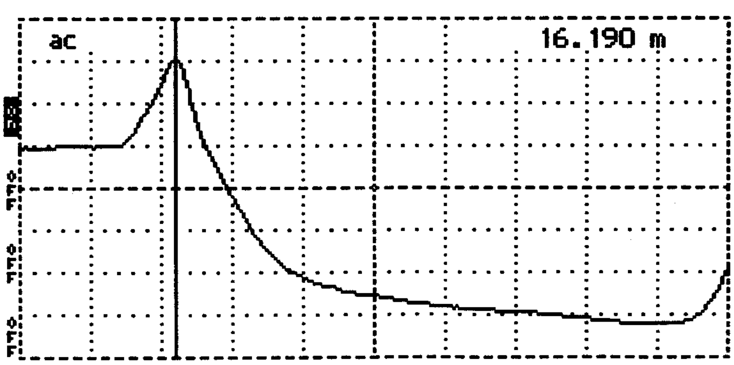
Cursor .... 16.190 m
istance/Div..... .25 m/div
tical Scale.... 47.2 mρ/div
Vp 0.99
Noise Filter...... 1 avg
Power.......... ac

Tektronix 1502B TDR
Date 9/10/93
Cable #2
Notes

Input Trace
Stored Trace
Difference Trace

Trace Number 5 - Probe in Water

Cursor .... 16.190 m
Distance/Div..... .25 m/div
Vertical Scale.... 77.0 mρ/div
Vp 0.99
Noise Filter...... 1 avg
Power.......... ac



Tektronix 1502B TDR
Date 9/10/93
Cable #2
Notes

Input Trace
Stored Trace
Difference Trace

Figure B-1(cont.). TDR Traces Obtained During Calibration

LTPP Seasonal Monitoring Study	State Code	[87]
TDR Probe Calibration	Test Section Number	[1622]

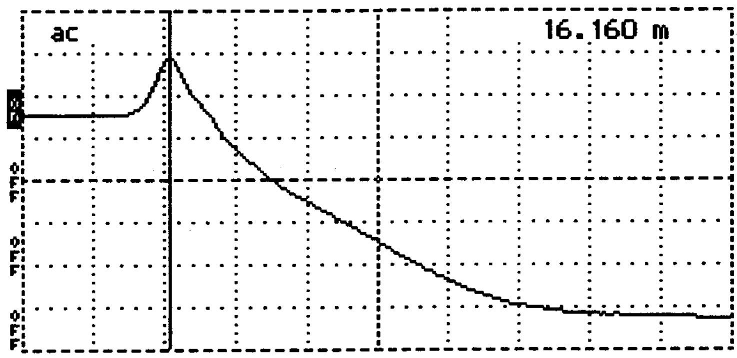
Before Operation Checks

- Calibration Date 9/10/93
- Probe S/N 87A3

Probe Number 3

TDR Trace 1 - Beginning Probe Shorted

ursor .... 16.160 m
stance/Div..... .25 m/div
ertical Scale.... 167 mρ/div
P 0.99
oise Filter...... 1 avg
ower........... ac

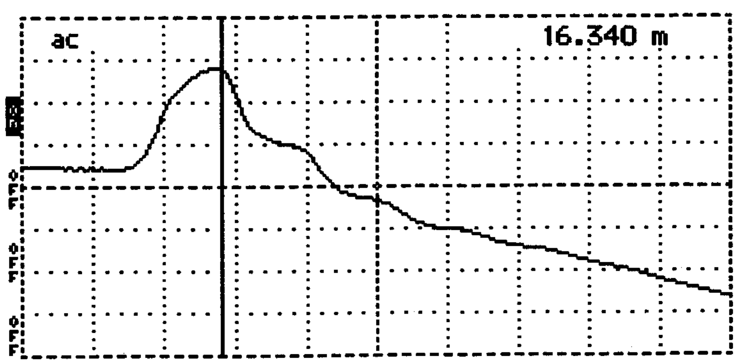


Tektronix 1502B TDR
Date 9/10/93
Cable #3
Notes

Input Trace
Stored Trace
Difference Trace

Trace Number 2 - Ending Probe Shorted

Cursor .... 16.340 m
Distance/Div..... .25 m/div
Vertical Scale.... 167 mρ/div
Vp 0.99
Noise Filter...... 1 avg
Power........... ac



Tektronix 1502B TDR
Date 9/10/93
Cable #3
Notes

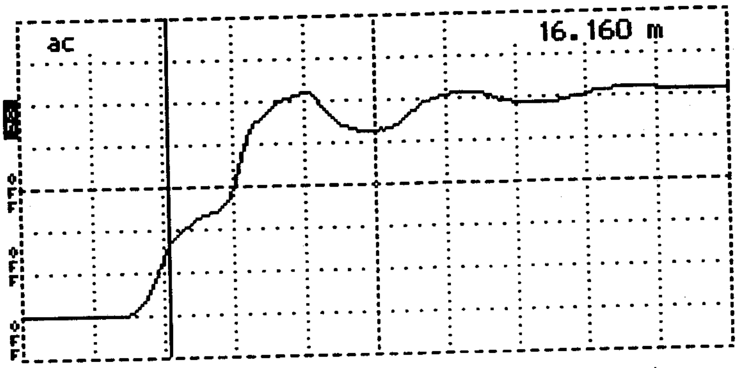
Input Trace
Stored Trace
Difference Trace

Figure B-1(cont.). TDR Traces Obtained During Calibration

Probe Number 3 (cont.)

:e Number 3 - Probe in Air

ursor .... 16.160 m
istance/Div..... .25 m/div
ertical Scale.... 167 mρ/div
P 0.99
oise Filter...... 1 avg
'ower........... ac

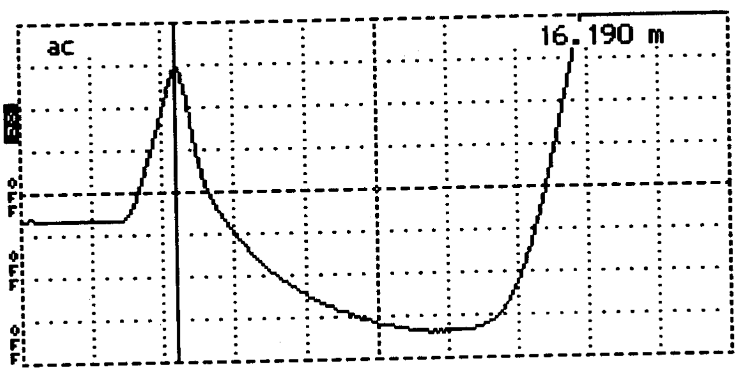


Tektronix 1502B TDR
Date 9/10/93
Cable #3
Notes

Input Trace
Stored Trace
Difference Trace

Trace Number 4 - Probe in Alcohol

ursor .... 16.190 m
ance/Div..... .25 m/div
ical Scale.... 47.2 mρ/div
P 0.99
oise Filter...... 1 avg
ower........... ac

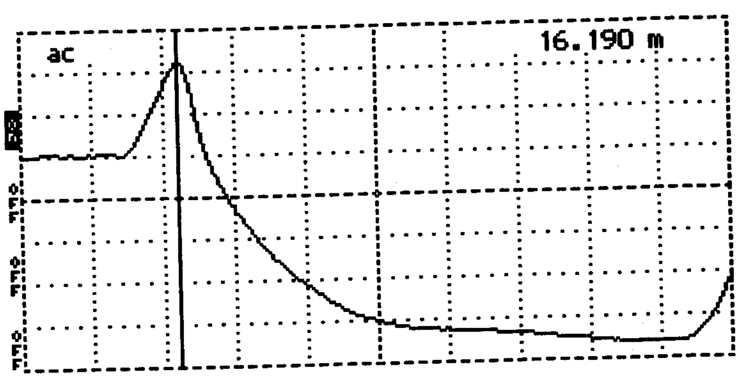


Tektronix 1502B TDR
Date 9/10/93
Cable #3
Notes

Input Trace
Stored Trace
Difference Trace

Trace Number 5 - Probe in Water

Cursor .... 16.190 m
Distance/Div..... .25 m/div
Vertical Scale.... 66.7 mρ/div
Vp 0.99
Noise Filter...... 1 avg
Power........... ac



Tektronix 1502B TDR
Date 9/10/93
Cable #3
Notes

Input Trace
Stored Trace
Difference Trace

Figure B-1(cont.). TDR Traces Obtained During Calibration

LTPP Seasonal Monitoring Study	State Code	[8 7]
TDR Probe Calibration	Test Section Number	[1 6 2 2]

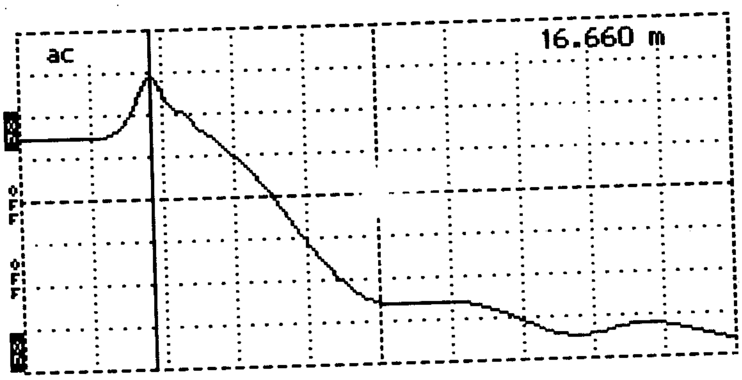
Before Operation Checks - Calibration Date 9/10/93

- Probe S/N 87A4

Probe Number 4

TDR Trace 1 - Beginning Probe Shorted

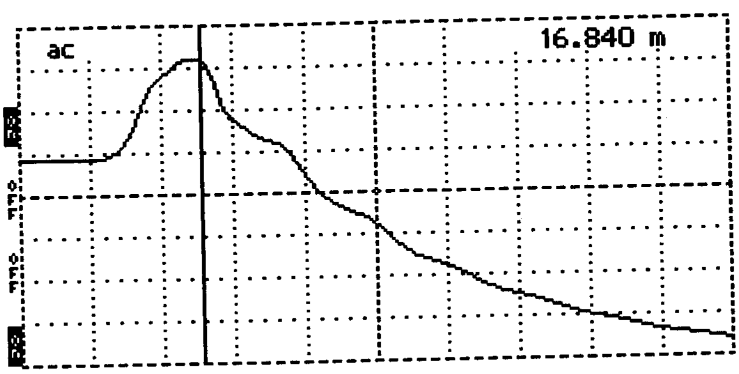
rsor .... 16.660 m
tance/Div..... .25 m/div
rtical Scale.... 167 mρ/div
.... 0.99
ise Filter...... 1 avg
wer.......... ac



Tektronix 1502B TDR
Date 9/10/93
Cable #4
Notes
Input Trace
Stored Trace
Difference Trace

Trace Number 2 - Ending Probe Shorted

Cursor .... 16.840 m
Distance/Div..... .25 m/div
Vertical Scale.... 167 mρ/div
Vp 0.99
Noise Filter...... 1 avg
Power.......... ac



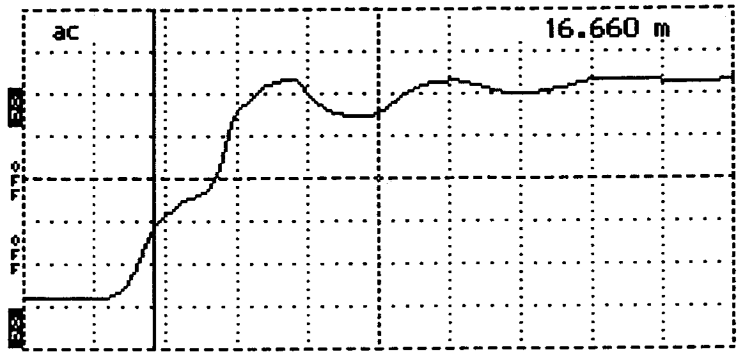
Tektronix 1502B TDR
Date 9/10/93
Cable #4
Notes
Input Trace
Stored Trace
Difference Trace

Figure B-1(cont.). TDR Traces Obtained During Calibration

Probe Number 4 (cont.)

ce Number 3 - Probe in Air

sor .... 16.660 m
tance/Div..... .25 m/div
tical Scale.... 167 mρ/div
.... 0.99
se Filter...... 1 avg
ver........... ac

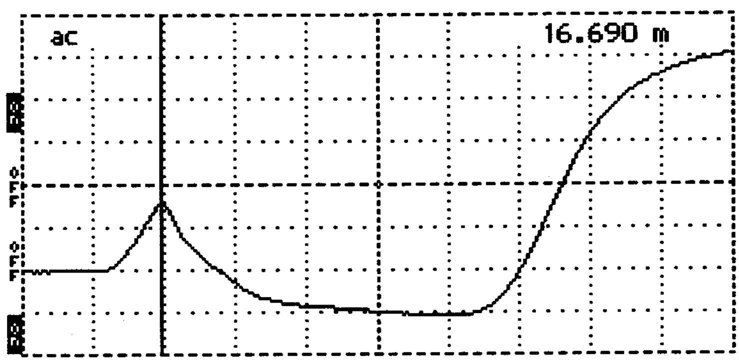


Tektronix 1502B TDR
Date 9/10/93
Cable #4
Notes

Input Trace
Stored Trace
Difference Trace

Trace Number 4 - Probe in Alcohol

sor .... 16.690 m
e/Div..... .25 m/div
tical Scale.... 115 mρ/div
.... 0.99
e Filter...... 1 avg
er........... ac

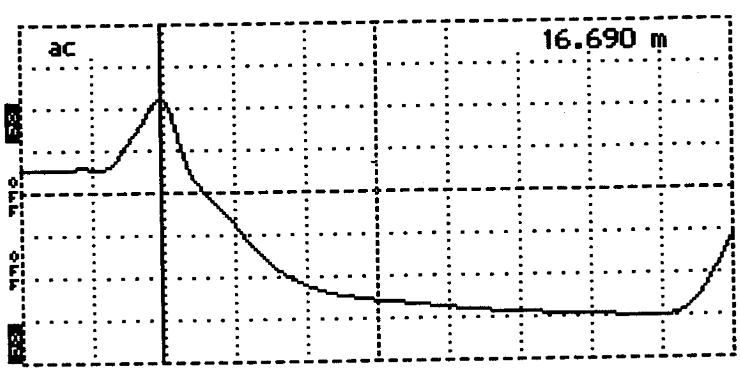


Tektronix 1502B TDR
Date 9/10/93
Cable #4
Notes

Input Trace
Stored Trace
Difference Trace

Trace Number 5 - Probe in Water

ursor .... 16.690 m
stance/Div..... .25 m/div
ertical Scale.... 88.9 mρ/div
.... 0.99
oise Filter...... 1 avg
ower........... ac



Tektronix 1502B TDR
Date 9/10/93
Cable #4
Notes

Input Trace
Stored Trace
Difference Trace

Figure B-1(cont.). TDR Traces Obtained During Calibration

LTPP Seasonal Monitoring Study	State Code	[87]
TDR Probe Calibration	Test Section Number	[1622]

Before Operation Checks - Calibration Date 9/10/93

- Probe S/N 87A5

Probe Number 5

TDR Trace 1 - Beginning Probe Shorted

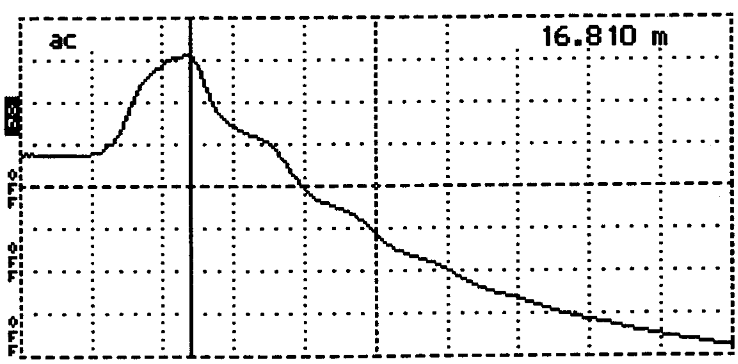
sor .... 16.630 m
tance/Div..... .25 m/div
rtical Scale.... 167 mρ/div
.... 0.99
se Filter...... 1 avg
wer........... ac

Tektronix 1502B TDR
Date 9/10/93
Cable #5
Notes

Input Trace
Stored Trace
Difference Trace

Trace Number 2 - Ending Probe Shorted

sor .... 16.810 m
ance/Div..... .25 m/div
tical Scale.... 167 mρ/div
.... 0.99
se Filter...... 1 avg
er........... ac



Tektronix 1502B TDR
Date 9/10/93
Cable #5
Notes

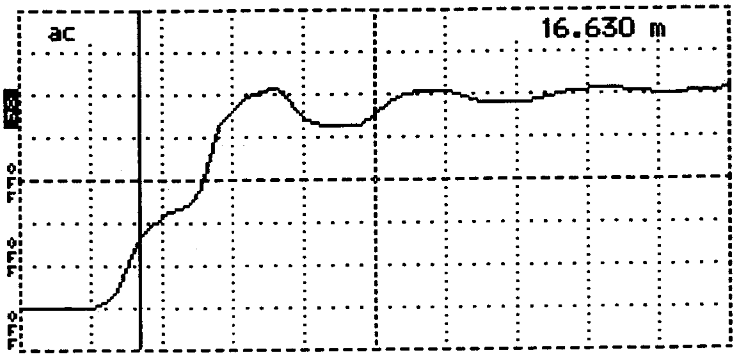
Input Trace
Stored Trace
Difference Trace

Figure B-1(cont.). TDR Traces Obtained During Calibration

Probe Number 5 (cont.)

ce Number 3 - Probe in Air

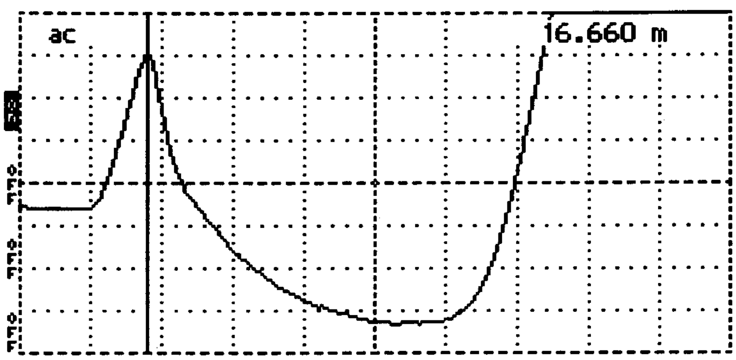
rsor .... 16.630 m
tance/Div..... .25 m/div
rtical Scale.... 167 mρ/div
.... 0.99
se Filter...... 1 avg
ver........... ac



Tektronix 1502B TDR
Date 9/10/93
Cable #5
Notes
Input Trace
Stored Trace
Difference Trace

Trace Number 4 - Probe in Alcohol

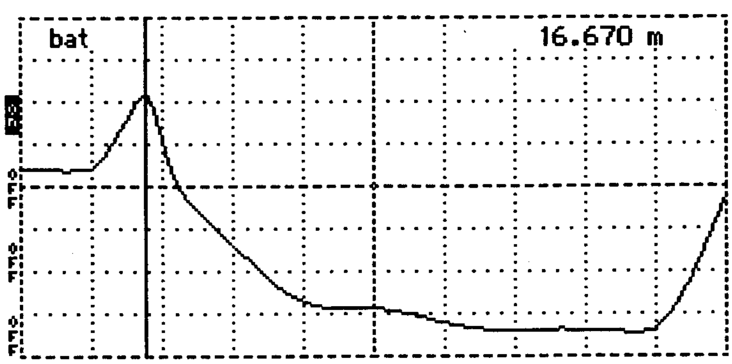
Cursor .... 16.660 m
Distance/Div..... .25 m/div
Vertical Scale.... 45.9 mρ/div
Vp 0.99
Noise Filter...... 1 avg
Power........... ac



Tektronix 1502B TDR
Date 9/10/93
Cable #5
Notes
Input Trace
Stored Trace
Difference Trace

Trace Number 5 - Probe in Water

Cursor .... 16.670 m
Distance/Div..... .25 m/div
Vertical Scale.... 83.9 mρ/div
Vp 0.99
Noise Filter...... 1 avg
Power........... bat/low



Tektronix 1502B TDR
Date
Cable
Notes
Input Trace
Stored Trace
Difference Trace

Figure B-1(cont.). TDR Traces Obtained During Calibration

LTPP Seasonal Monitoring Study	State Code	[37]
TDR Probe Calibration	Test Section Number	[1622]

Before Operation Checks
- Calibration Date 9/10/93
- Probe S/N 87A6

Probe Number 6

TDR Trace 1 - Beginning Probe Shorted

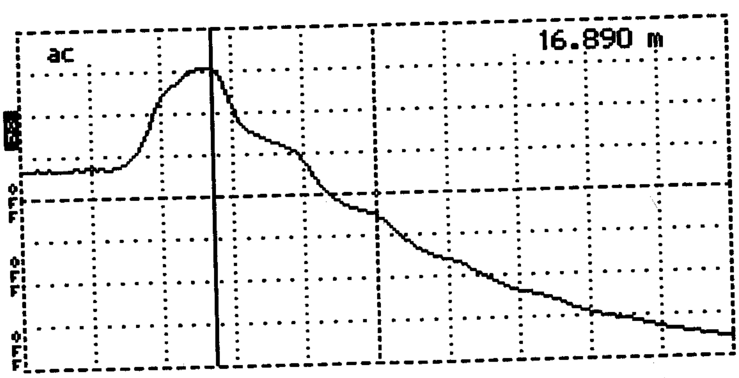
Cursor .... 16.710 m
Distance/Div ..... .25 m/div
Vertical Scale.... 167 mρ/div
Vp 0.99
Noise Filter ...... 1 avg
Power .... ac

Tektronix 1502B TDR
Date 9/10/93
Cable #6
Notes

Input Trace
Stored Trace
Difference Trace

Trace Number 2 - Ending Probe Shorted

Cursor .... 16.890 m
Distance/Div ..... .25 m/div
Vertical Scale.... 167 mρ/div
Vp 0.99
Noise Filter ...... 1 avg
Power .... ac



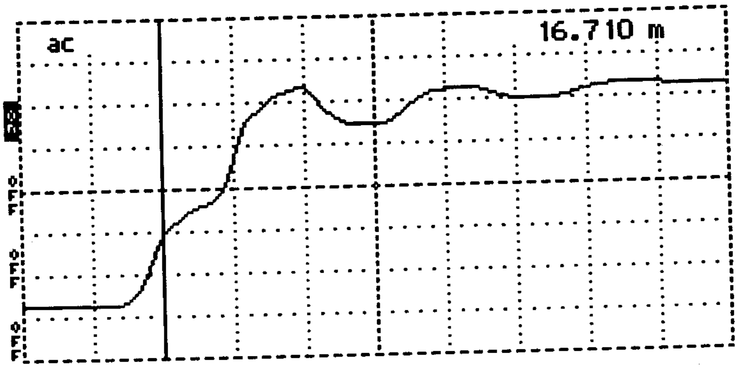
Tektronix 1502B TDR
Date 9/10/93
Cable #6
Notes

Input Trace
Stored Trace
Difference Trace

Figure B-1(cont.). TDR Traces Obtained During Calibration

ce Number 3 - Probe in Air

or .... 16.710 m
ance/Div..... .25 m/div
ical Scale.... 167 mρ/div
.... 0.99
e Filter...... 1 avg
er............ ac

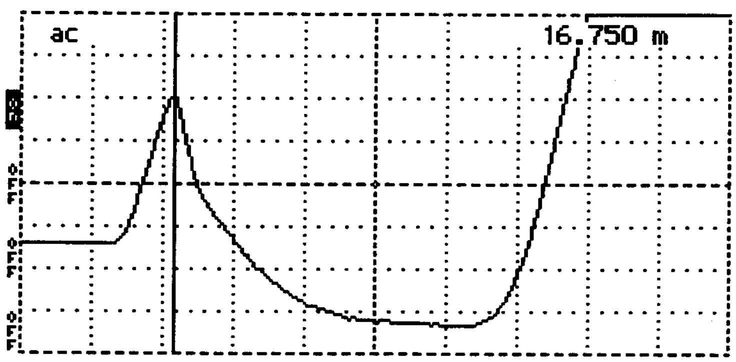


Tektronix 1502B TDR
Date 9/10/93
Cable #6
Notes

Input Trace
Stored Trace
Difference Trace

race Number 4 - Probe in Alcohol

Cursor .... 16.750 m
Distance/Div..... .25 m/div
'ertical Scale.... 53.0 mρ/div
.... 0.99
Noise Filter...... 1 avg
Power............ ac

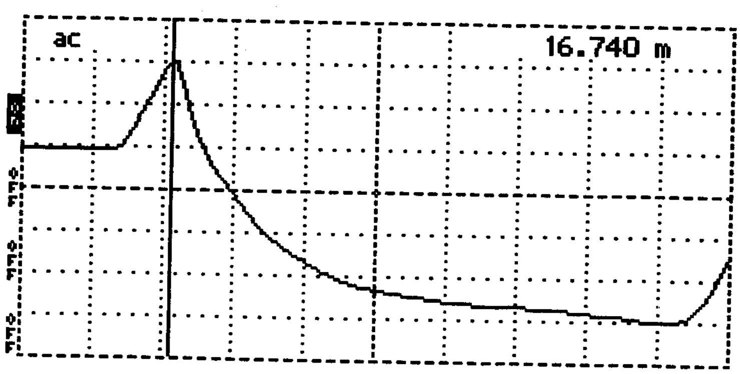


Tektronix 1502B TDR
Date 9/10/93
Cable #6
Notes

Input Trace
Stored Trace
Difference Trace

race Number 5 - Probe in Water

rsor .... 16.740 m
stance/Div..... .25 m/div
rtical Scale.... 77.0 mρ/div
.... 0.99
se Filter...... 1 avg
wer............ ac



Tektronix 1502B TDR
Date 9/10/93
Cable #6
Notes

Input Trace
Stored Trace
Difference Trace

Figure B-1(cont.). TDR Traces Obtained During Calibration

LTPP Seasonal Monitoring Study	State Code	[97]
TDR Probe Calibration	Test Section Number	[L622]

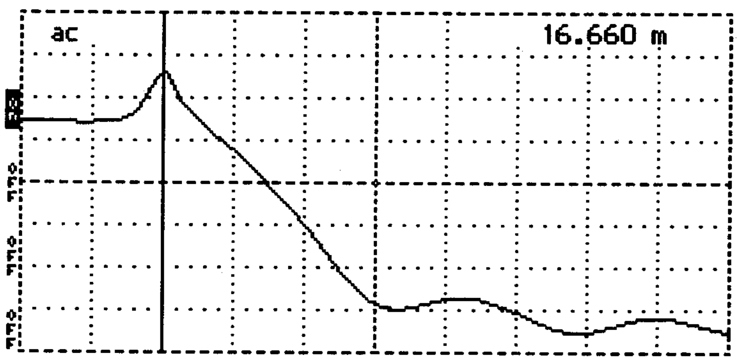
efore Operation Checks - Calibration Date 9/10/93

- Probe S/N 87A7

Probe Number 7

'DR Trace 1 - Beginning Probe Shorted

ursor .... 16.660 m
istance/Div..... .25 m/div
ertical Scale.... 167 mρ/div
P 0.99
oise Filter...... 1 avg
ower............ ac



Tektronix 1502B TDR
Date 9/10/93
Cable #7
Notes

Input Trace
Stored Trace
Difference Trace

race Number 2 - Ending Probe Shorted

ursor .... 16.840 m
istance/Div..... .25 m/div
ertical Scale.... 167 mρ/div
P 0.99
oise Filter...... 1 avg
ower............ ac

Tektronix 1502B TDR
Date 9/10/93
Cable #7
Notes

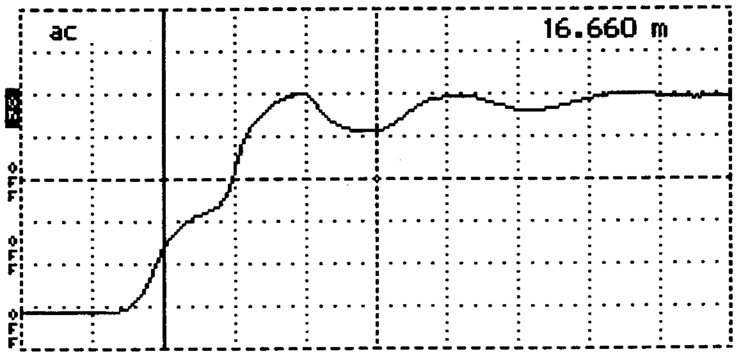
Input Trace
Stored Trace
Difference Trace

Figure B-1(cont.). TDR Traces Obtained During Calibration

Probe Number 7 (cont.)

ace Number 3 - Probe in Air

Cursor .... 16.660 m
Distance/Div..... .25 m/div
Vertical Scale.... 167 mρ/div
Vp 0.99
Noise Filter...... 1 avg
Power........... ac

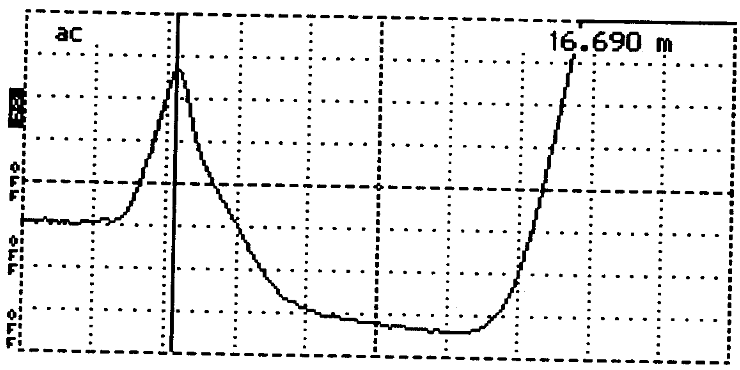


Tektronix 1502B TDR
Date 9/10/93
Cable #7
Notes

Input Trace
Stored Trace
Difference Trace

Trace Number 4 - Probe in Alcohol

Cursor .... 16.690 m
Distance/Div..... .25 m/div
''ertical Scale.... 47.2 mρ/div
ρ 0.99
Noise Filter...... 1 avg
Power........... ac

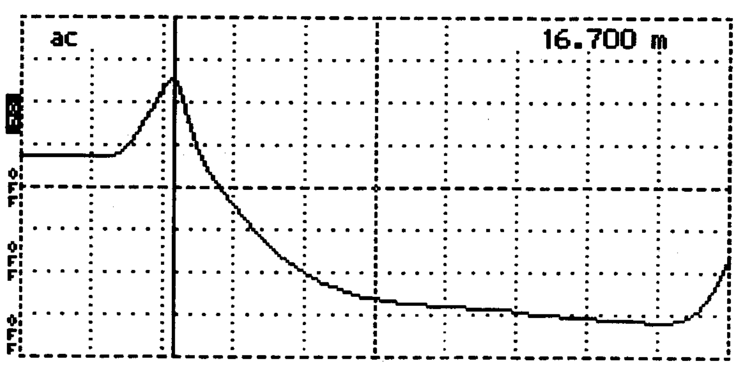


Tektronix 1502B TDR
Date 9/10/93
Cable #7
Notes

Input Trace
Stored Trace
Difference Trace

Trace Number 5 - Probe in Water

Cursor .... 16.700 m
Distance/Div..... .25 m/div
Vertical Scale.... 81.6 mρ/div
Vp 0.99
Noise Filter...... 1 avg
Power........... ac



Tektronix 1502B TDR
Date 9/10/93
Cable #7
Notes

Input Trace
Stored Trace
Difference Trace

Figure B-1(cont.). TDR Traces Obtained During Calibration

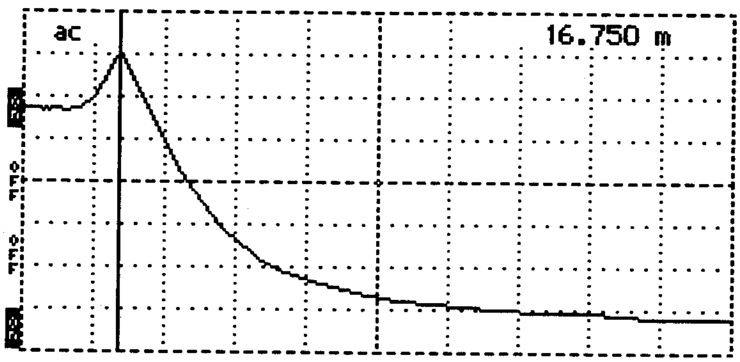
LTPP Seasonal Monitoring Study	State Code	[8 1]
TDR Probe Calibration	Test Section Number	[1 6 2 2]

efore Operation Checks - Calibration Date 9/10/93
- Probe S/N 87A8

Probe Number 8

DR Trace 1 - Beginning Probe Shorted

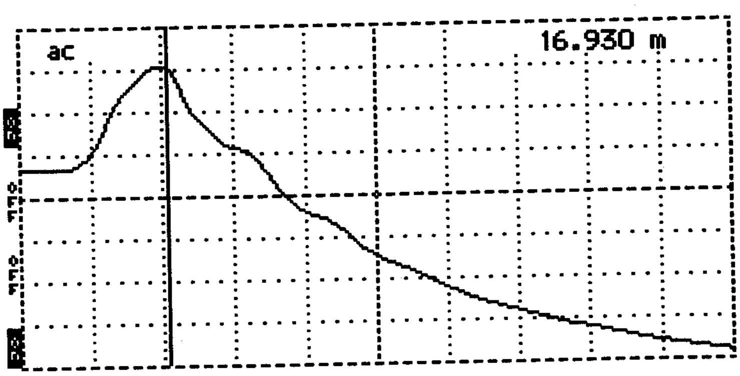
rsor .... 16.750 m
tance/Div..... .25 m/div
rtical Scale.... 167 mρ/div
.... 0.99
se Filter...... 1 avg
wer........... ac



Tektronix 1502B TDR
Date 9/10/93
Cable # 8
Notes
Input Trace
Stored Trace
Difference Trace

race Number 2 - Ending Probe Shorted

sor .... 16.930 m
ance/Div..... .25 m/div
tical Scale.... 167 mρ/div
.... 0.99
e Filter...... 1 avg
er........... ac

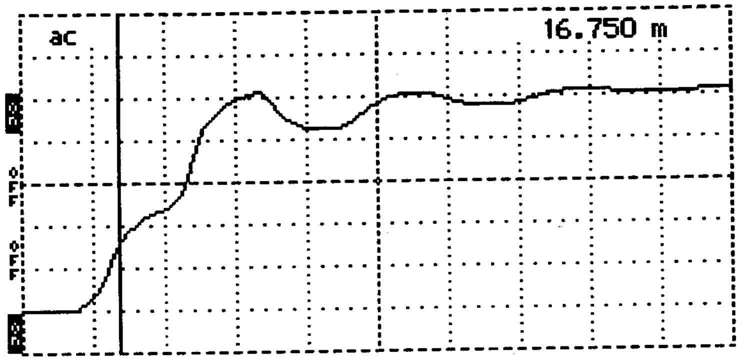


Tektronix 1502B TDR
Date 9/10/93
Cable #8
Notes
Input Trace
Stored Trace
Difference Trace

Figure B-1(cont.). TDR Traces Obtained During Calibration

ce Number 3 - Probe in Air

rsor .... 16.750 m
tance/Div ..... .25 m/div
rtical Scale.... 167 mρ/div
.... 0.99
ise Filter ...... 1 avg
wer .... ac

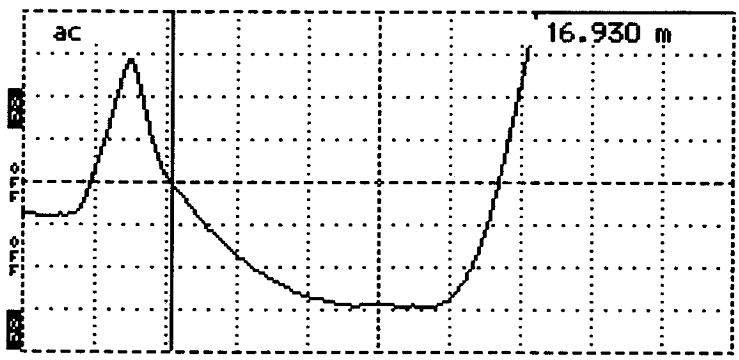


Tektronix 1502B TDR
Date 9/10/93
Cable #8
Notes

Input Trace
Stored Trace
Difference Trace

Trace Number 4 - Probe in Alcohol

Cursor .... 16.930 m
Distance/Div ..... .25 m/div
Vertical Scale.... 48.6 mρ/div
.... 0.99
Noise Filter ...... 1 avg
Power .... ac

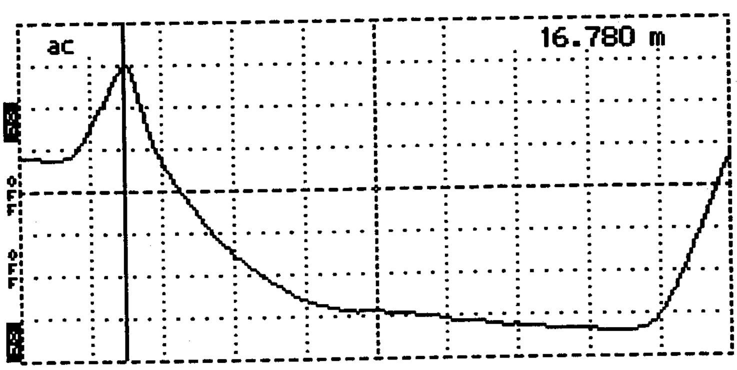


Tektronix 1502B TDR
Date 9/10/93
Cable #8
Notes

Input Trace
Stored Trace
Difference Trace

Trace Number 5 - Probe in Water

Cursor .... 16.780 m
Distance/Div ..... .25 m/div
Vertical Scale.... 70.6 mρ/div
VP 0.99
Noise Filter ...... 1 avg
Power .... ac



Tektronix 1502B TDR
Date 9/10/93
Cable #8
Notes

Input Trace
Stored Trace
Difference Trace

Figure B-1(cont.). TDR Traces Obtained During Calibration

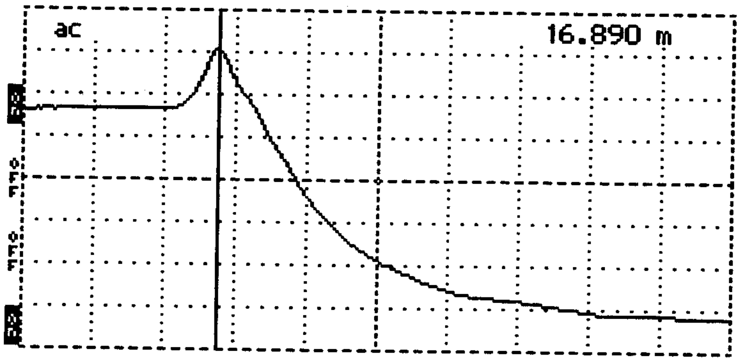
LTPP Seasonal Monitoring Study	State Code	[37]
TDR Probe Calibration	Test Section Number	[1622]

Before Operation Checks - Calibration Date 9/10/93
- Probe S/N 37A9

Probe Number 9

TDR Trace 1 - Beginning Probe Shorted

Cursor .... 16.890 m
Distance/Div..... .25 m/div
Vertical Scale.... 167 mρ/div
VP 0.99
Noise Filter...... 1 avg
Power........... ac

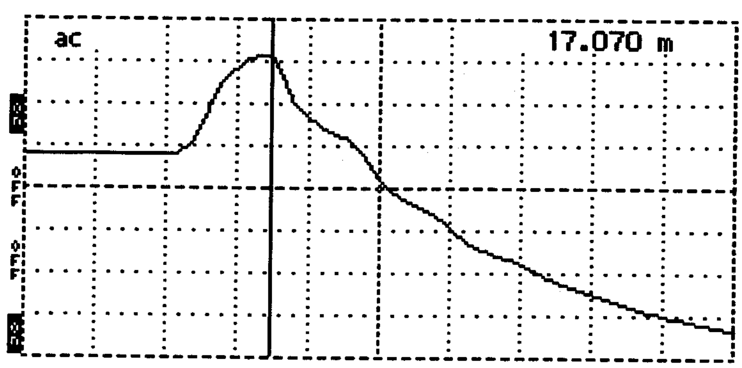


Tektronix 1502B TDR
Date 9/10/93
Cable #9
Notes

Input Trace
Stored Trace
Difference Trace

Trace Number 2 - Ending Probe Shorted

rsor .... 17.070 m
stance/Div..... .25 m/div
rtical Scale.... 167 mρ/div
.... 0.99
ise Filter...... 1 avg
wer........... ac



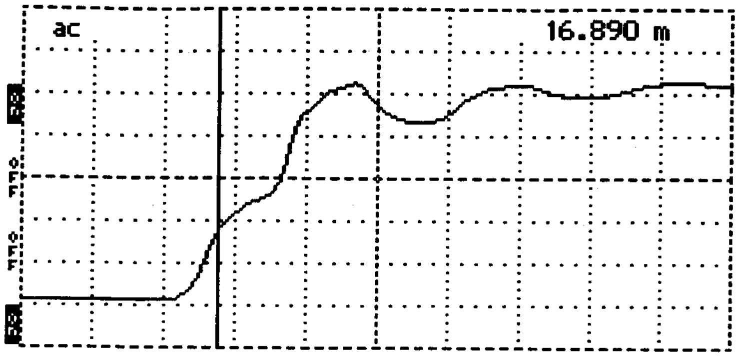
Tektronix 1502B TDR
Date 9/10/93
Cable #9
Notes

Input Trace
Stored Trace
Difference Trace

Figure B-1(cont.). TDR Traces Obtained During Calibration

ce Number 3 - Probe in Air

Cursor .... 16.890 m
Distance/Div..... .25 m/div
Vertical Scale.... 167 mρ/div
Vp 0.99
Noise Filter...... 1 avg
Power.......... ac

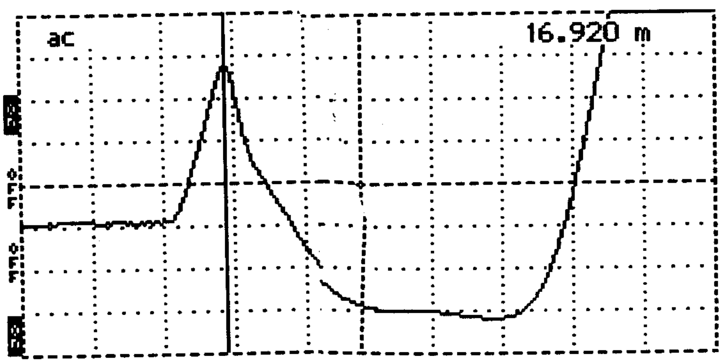


Tektronix 1502B TDR
Date 9/10/93
Cable #9
Notes

Input Trace
Stored Trace
Difference Trace

Trace Number 4 - Probe in Alcohol

sor .... 16.920 m
ance/Div..... .25 m/div
l Scale.... 48.6 mρ/div
.... 0.99
e Filter...... 1 avg
er.......... ac

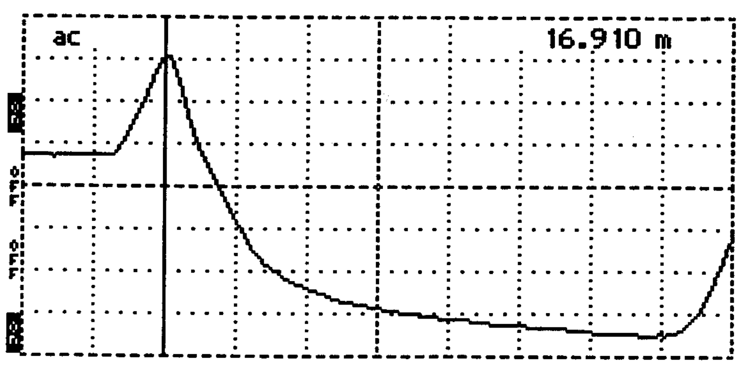


Tektronix 1502B TDR
Date 9/10/93
Cable #9
Notes

Input Trace
Stored Trace
Difference Trace

Trace Number 5 - Probe in Water

Cursor .... 16.910 m
Distance/Div..... .25 m/div
Vertical Scale.... 72.7 mρ/div
Vp 0.99
Noise Filter...... 1 avg
Power.......... ac



Tektronix 1502B TDR
Date 9/10/93
Cable #9
Notes

Input Trace
Stored Trace
Difference Trace

Figure B-1(cont.). TDR Traces Obtained During Calibration

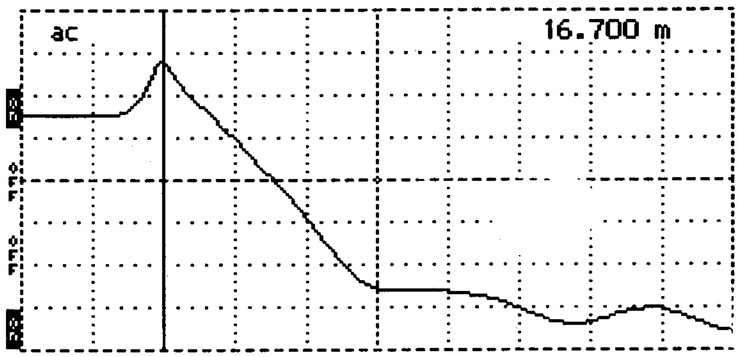
LTPP Seasonal Monitoring Study	State Code	[87]
TDR Probe Calibration	Test Section Number	[1622]

Before Operation Checks - Calibration Date 9/10/93
- Probe S/N 87A10

Probe Number 10

TDR Trace 1 - Beginning Probe Shorted

Cursor .... 16.700 m
Distance/Div..... .25 m/div
Vertical Scale.... 167 mρ/div
VP 0.99
Noise Filter...... 1 avg
Power .... ac

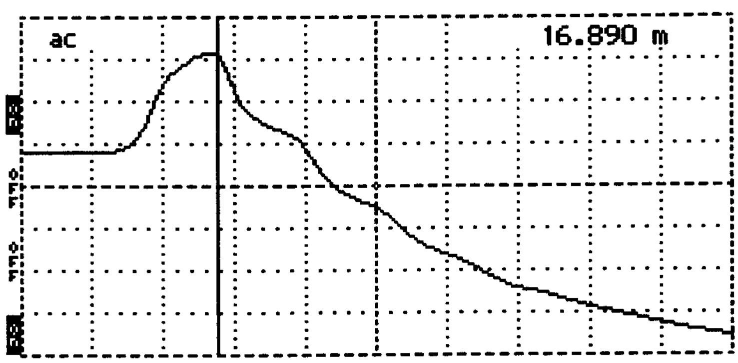


Tektronix 1502B TDR
Date 9/10/93
Cable #10
Notes

Input Trace
d Trace
ence Trace

Trace Number 2 - Ending Probe Shorted

ursor .... 16.890 m
stance/Div..... .25 m/div
ertical Scale.... 167 mρ/div
 .... 0.99
oise Filter...... 1 avg
ower .... ac



Tektronix 1502B TDR
Date 9/10/93
Cable #10
Notes

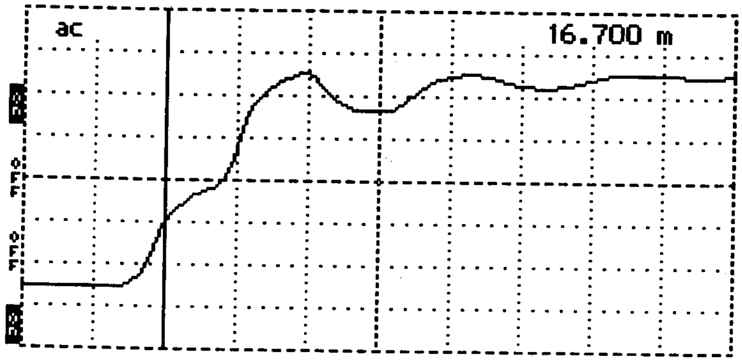
Input Trace
Stored Trace
Difference Trace

Figure B-1(cont.). TDR Traces Obtained During Calibration

Probe Number 10 (cont.)

Trace Number 3 - Probe in Air

sor .... 16.700 m
tance/Div..... .25 m/div
tical Scale.... 167 mρ/div
.... 0.99
se Filter...... 1 avg
ver........... ac

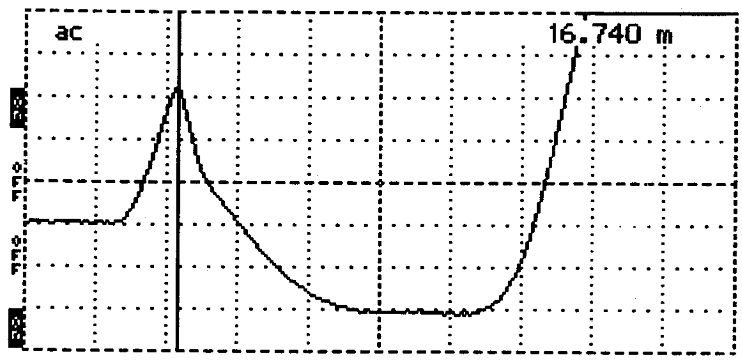


Tektronix 1502B TDR
Date 9/10/93
Cable #10
Notes

Input Trace
Stored Trace
Difference Trace

Trace Number 4 - Probe in Alcohol

r .... 16.740 m
ance/Div..... .25 m/div
rtical Scale.... 53.0 mρ/div
.... 0.99
ise Filter...... 1 avg
wer........... ac

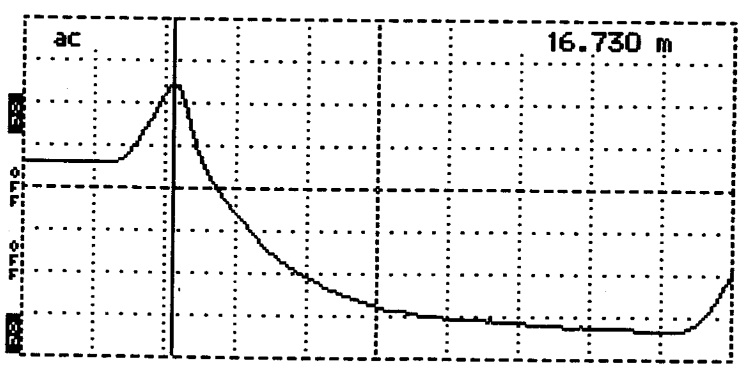


Tektronix 1502B TDR
Date 9/10/93
Cable #10
Notes

Input Trace
Stored Trace
Difference Trace

Trace Number 5 - Probe in Water

or .... 16.730 m
ance/Div..... .25 m/div
ical Scale.... 79.2 mρ/div
.... 0.99
e Filter...... 1 avg
er........... ac



Tektronix 1502B TDR
Date 9/10/93
Cable #10
Notes

Input Trace
Stored Trace
Difference Trace

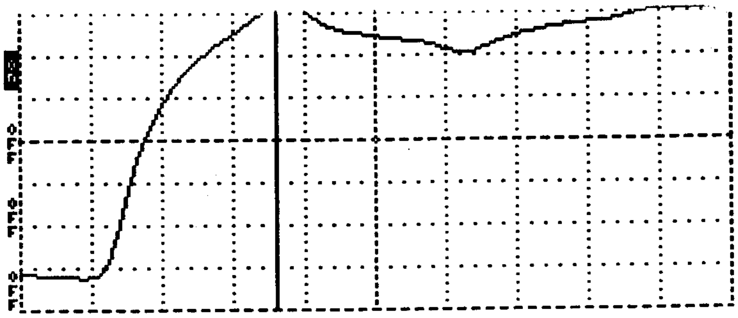
Figure B-1(cont.). TDR Traces Obtained During Calibration

APPENDIX C

Supporting Instrumentation Installation Information

Appendix C contains the following supporting information:

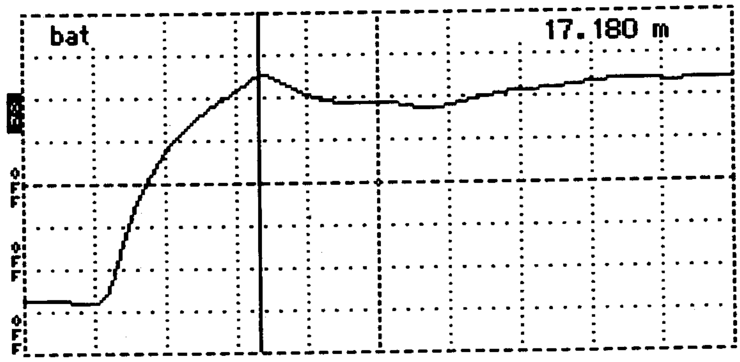
istance/Div..... .25 m/div
ertical Scale.... 100 mρ/div
.... 0.99
oise Filter...... 1 avg
ower........... bat



Date
Cable
Notes

Input Trace
Stored Trace
Difference Trace

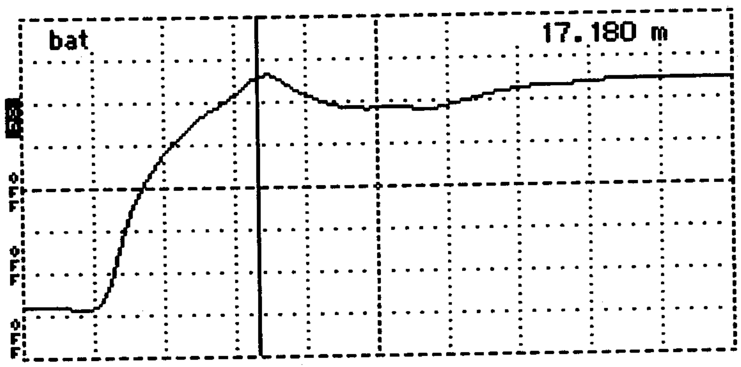
Cursor .... 17.180 m
Distance/Div..... .25 m/div
Vertical Scale.... 100 mρ/div
VP 0.99
Noise Filter...... 1 avg
Power........... bat



Tektronix 1502B TDR
Date
Cable
Notes

Input Trace
Stored Trace
Difference Trace

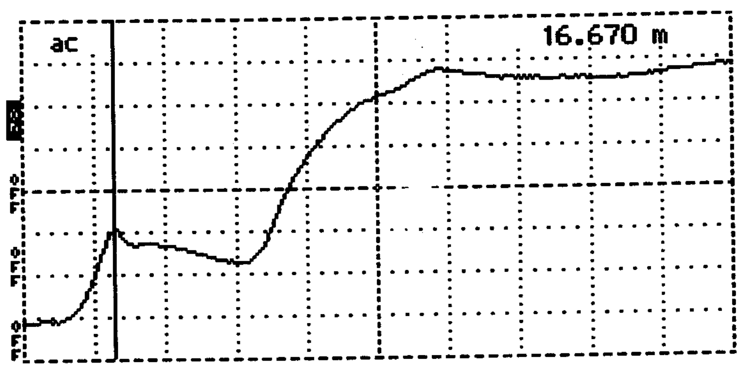
ursor .... 17.180 m
istance/Div..... .25 m/div
rtical Scale.... 100 mρ/div
.... 0.99
e Filter...... 1 avg
wer........... bat



Tektronix 1502B TDR
Date 4/22/93
Cable 3
Notes

Input Trace
Stored Trace
Difference Trace

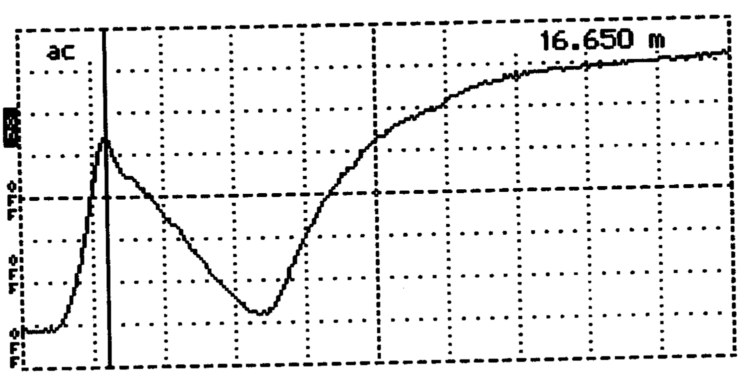
Cursor .... 16.670 m
Distance/Div..... .25 m/div
Vertical Scale.... 100 mρ/div
VP 0.99
Noise Filter...... 1 avg
Power........... ac



Tektronix 1502B TDR
Date
Cable
Notes

Input Trace
Stored Trace
Difference Trace

Cursor .... 16.650 m
Distance/Div..... .25 m/div
Vertical Scale.... 47.2 mρ/div
VP 0.99
Noise Filter...... 1 avg
ver........... ac

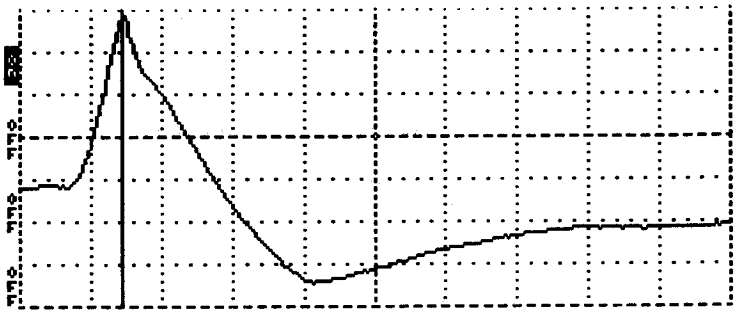


Tektronix 1502B TDR
Date
Cable
Notes

Input Trace
Stored Trace
Difference Trace

Figure C-1. TDR Traces Measured Manually During Installation

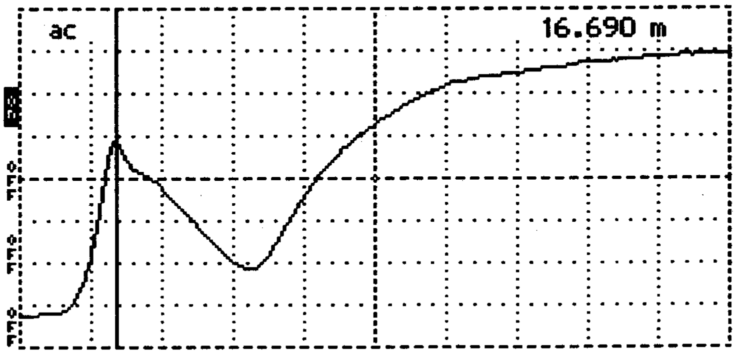
stance/Div..... .25 m/div
rtical Scale.... 51.5 mρ/div
.... 0.99
:e Filter...... 1 avg
wer........... ac



Date
Cable
Notes

Input Trace
Stored Trace
Difference Trace

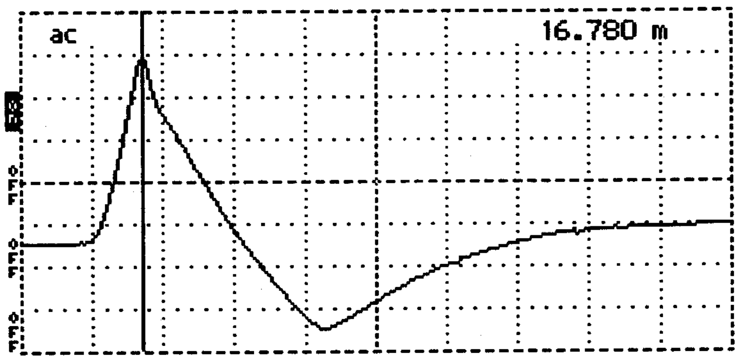
rsor .... 16.690 m
stance/Div..... .25 m/div
rtical Scale.... 51.5 mρ/div
.... 0.99
ise Filter...... 1 avg
wer........... ac



Tektronix 1502B TDR
Date 9/22/93
Cable 7
Notes

Input Trace
Stored Trace
Difference Trace

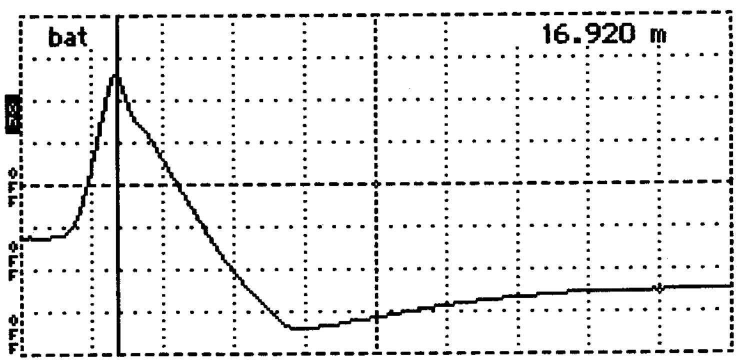
rsor .... 16.780 m
stance/Div..... .25 m/div
rtical Scale.... 45.9 mρ/div
.... 0.99
ise Filter...... 1 avg
r........... ac



Tektronix 1502B TDR
Date 9/22/93
Cable #8
Notes

Input Trace
Stored Trace
Difference Trace

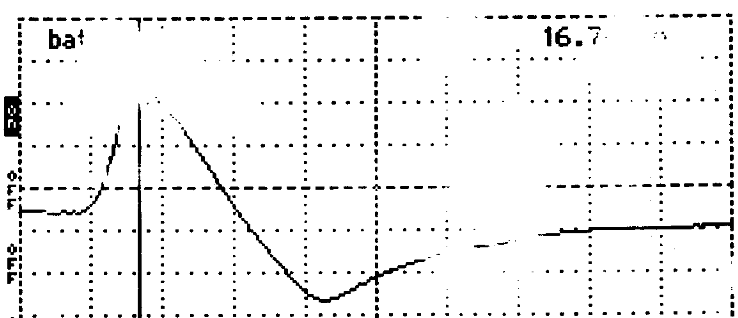
rsor .... 16.920 m
stance/Div..... .25 m/div
rtical Scale.... 54.5 mρ/div
.... 0.99
ise Filter...... 1 avg
wer........... bat/low



Tektronix 1502B TDR
Date 9/22/93
Cable #9
Notes

Input Trace
Stored Trace
Difference Trace

rsor .... 16.740 m
tance/Div..... .25 m/div
rtical Scale.... 50.0 mρ/div
.... 0.99
ilter...... 1 avg
.... bat/low



Tektronix 1502
Date 9/22/93
Cable #10
Not

Input
Store
Diffe

Figure C-1(cont.). TDR Traces Measured Manually During Installation

Table C-1. TDR Moisture Content During Installation

TDR No.	TDR Length (m)	Dielectric Constant	Volumetric Moisture Content (%)	In-Situ Dry Density	Gravimetric Moisture Content (%)
87A01	0.470	5.47	9.15	2.00	4.58
87A02	0.370	3.39	4.02	1.95	2.06
87A03	0.450	5.01	8.06	1.95	4.13
87A04	0.490	5.94	10.26	1.95	5.26
87A05	0.530	6.95	12.56	1.95	6.44
87A06	0.640	10.14	19.21	1.81	10.61
87A07	0.510	6.44	11.40	1.81	6.30
87A08	0.590	8.62	16.14	1.81	8.92
87A09	0.600	8.91	16.75	1.81	9.25
87A10	0.640	10.14	19.21	1.81	10.61

Table C-2. Field Measured Moisture Content During Installation

LTPP Seasonal Monitoring Study	State Code	[87]
In-Situ Moisture Tests	Test Section Number	[1622]

Weight (gm)	Probe 1	Probe 2	Probe 3	Probe 4	Probe 5
Weight of Pan + Wet Soil	425.4	273.8	265.8	265.1	250.4
Weight of Pan + Dry Soil	413.9	270.4	262.5	261.0	246.3
Weight of Pan	120.9	120.2	120.9	120.2	120.9
Weight of Dry Soil	293.0	150.2	141.6	140.8	125.4
Weight of Wet Soil	304.5	153.6	144.9	144.9	129.5
Weight of Moisture	11.5	3.4	3.3	4.1	4.1
Wt of Moisture/Dry Wt x 100	3.92	2.26	2.33	2.91	3.27

Weight (gm)	Probe 6	Probe 7	Probe 8	Probe 9	Probe 10
Weight of Pan + Wet Soil	218.1	232.4	212.9	280.8	217.0
Weight of Pan + Dry Soil	211.0	222.9	205.8	264.3	206.8
Weight of Pan	120.2	120.9	120.2	120.9	120.2
Weight of Dry Soil	90.8	102.0	85.6	143.4	86.6
Weight of Wet Soil	97.9	111.5	92.7	159.9	96.8
Weight of Moisture	7.1	9.5	7.1	16.5	10.2
Wt of Moisture/Dry Wt x 100	7.82	9.31	8.29	11.51	11.78

RESULTS TO - STEVE SENIOR (1)

Ministry of Transportation Ontario

93-B **MOISTURE CONTENT TEST** 45,000 S

Soils and Aggregates Section

45109

Project		SHRP SEASONAL STRENGTH VARIATION				
B.H. No.		HWY 11 BRACEBRIDGE SITE				
Sample No.						
Lab. No.	45109-1	45109-2	45109-3	45109-4	45109-5	45109-6
Tin No.						
Tin + Wet Soil	641.5	808.4	441.9	479.1	765.5	587.7
Tin + Dry Soil	625.2	794.6	436.1	472.4	754.3	557.9
Moisture Loss	16.3	13.8	5.8	6.7	11.2	29.8
Tare	139.3	135.1	142.4	150.4	165.1	150.5
Dry Soil Mass	485.9	659.5	293.7	322.0	589.2	407.4
Moisture Content	3.4	2.1	2.0	2.1	1.9	7.3

jlp/93 02 16

RESULTS TO - STEVE SENIOR (2)

Ministry of Transportation Ontario

93-B **MOISTURE CONTENT TEST** 45,000'S

Soils and Aggregates Section

45109

Project						
B.H. No.						
Sample No.						
Lab. No.	45109-7	45109-8	45109-9	45109-10		
Tin No.						
Tin + Wet Soil	416.0	340.1	432.5	561.3		
Tin + Dry Soil	396.6	323.2	401.1	520.9		
Moisture Loss	19.4	16.9	31.4	40.4		
Tare	141.2	139.5	135.2	157.8		
Dry Soil Mass	255.4	183.7	265.9	363.1		
Moisture Content	7.6	9.2	11.8	11.1		

APPENDIX D

Initial Data Collection

Appendix D contains the following supporting information:

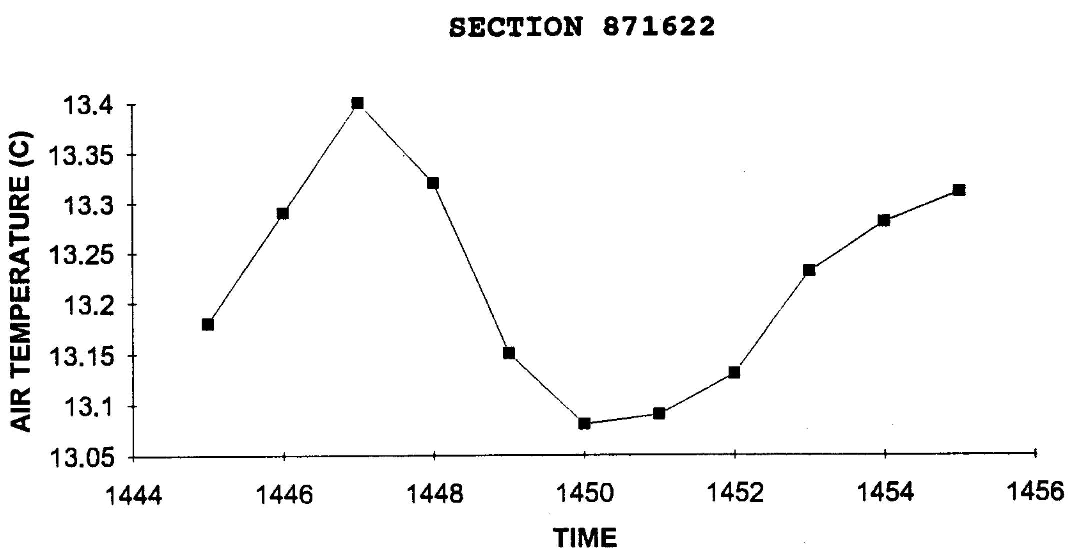


Figure D-1. Measured Air Temperature
During Initial Data Collection, September 23, 1993

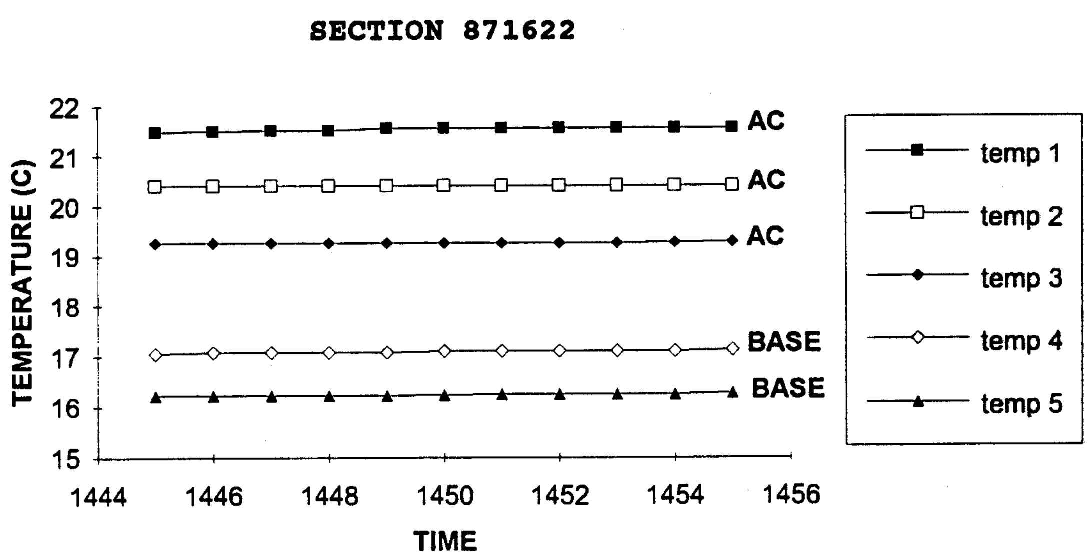


Figure D-2. Measured Subsurface Temperature for the First 5 Sensors
During Initial Data Collection, September 23, 1993

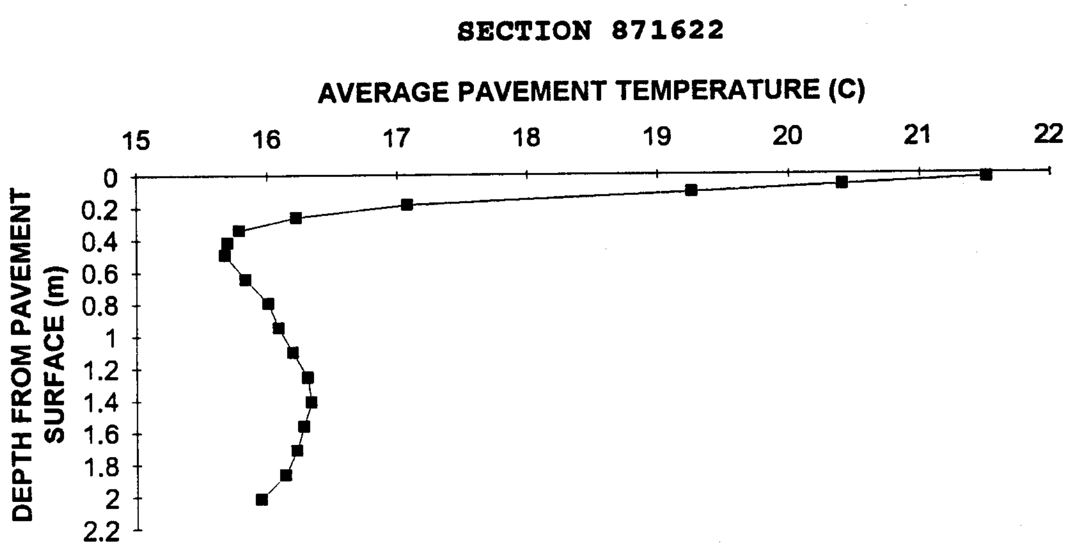


Figure D-3. Measured Subsurface Temperature for All 18 Sensors During Initial Data Collection, September 23, 1993

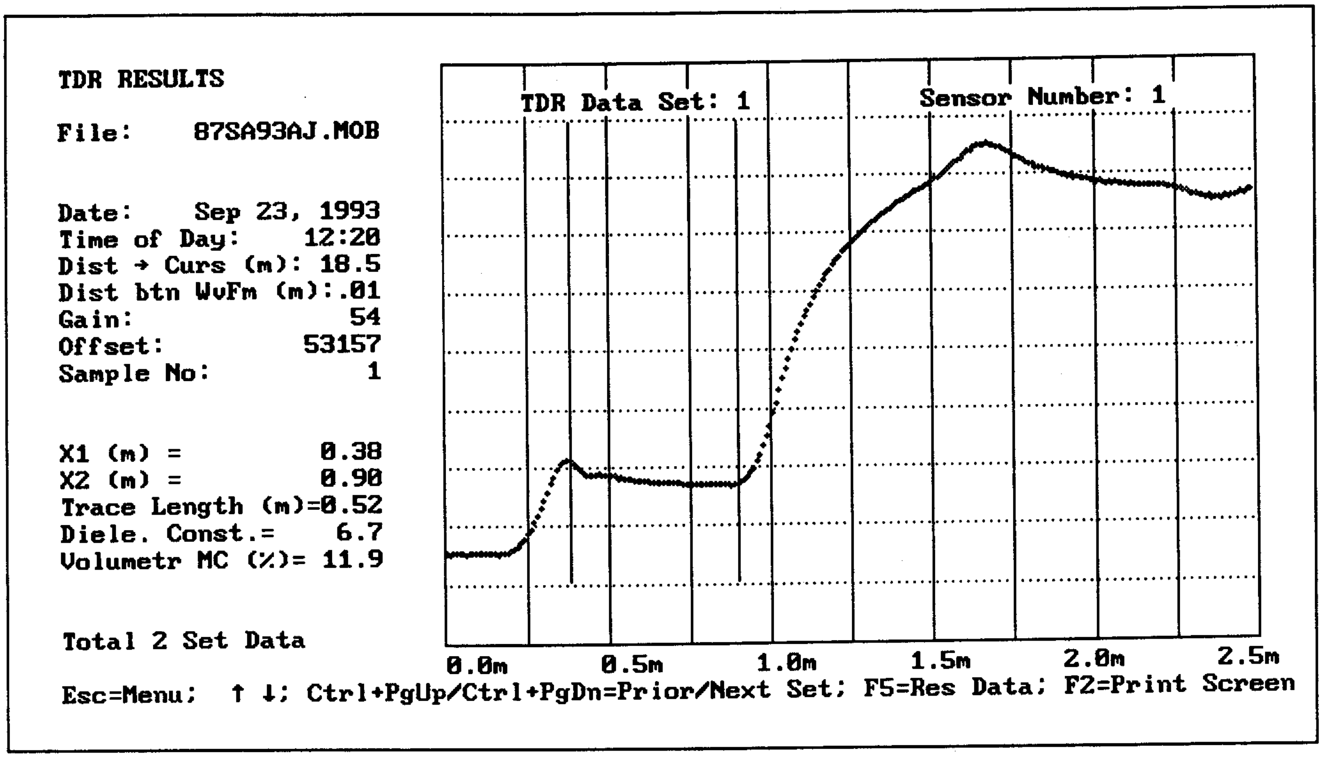


Figure D-4. Initial First Set of TDR Traces Measured with the Mobile Unit

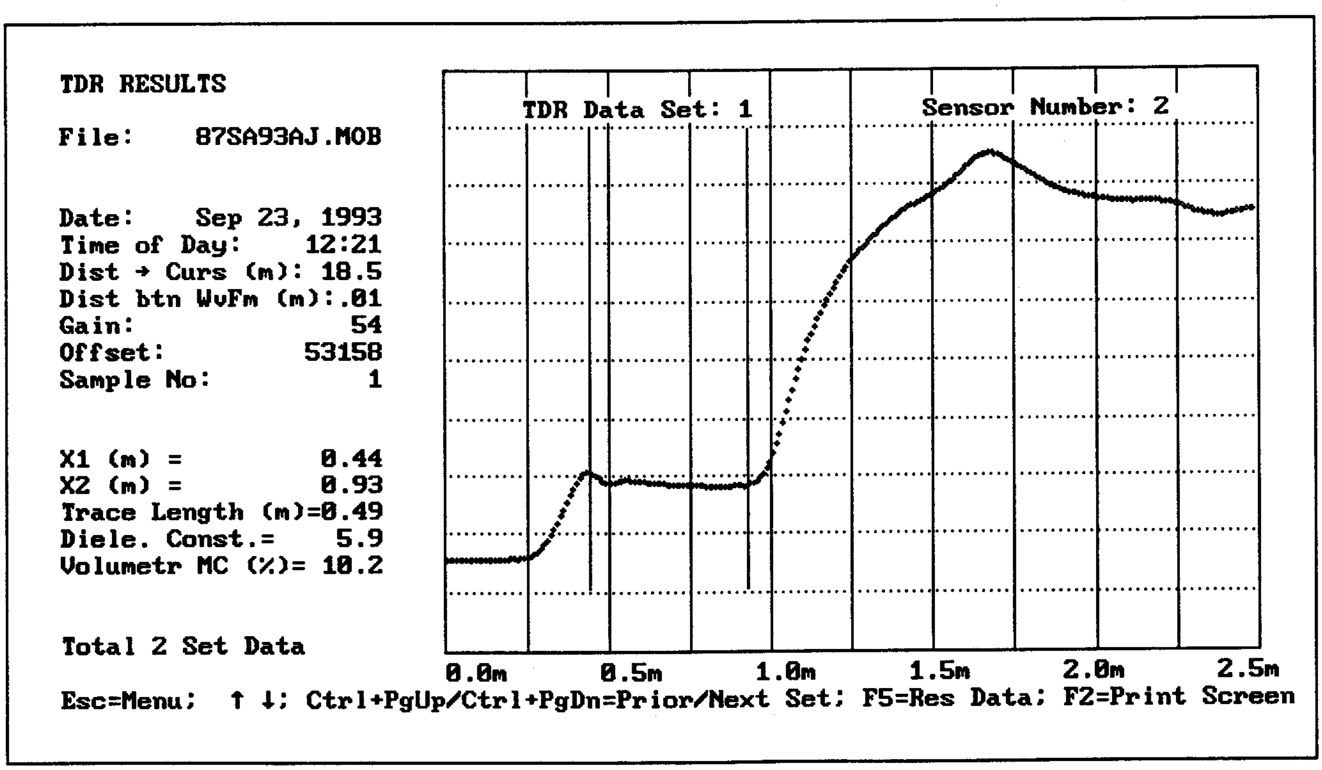


Figure D-4(cont.). Initial First Set of TDR Traces Measured with the Mobile Unit

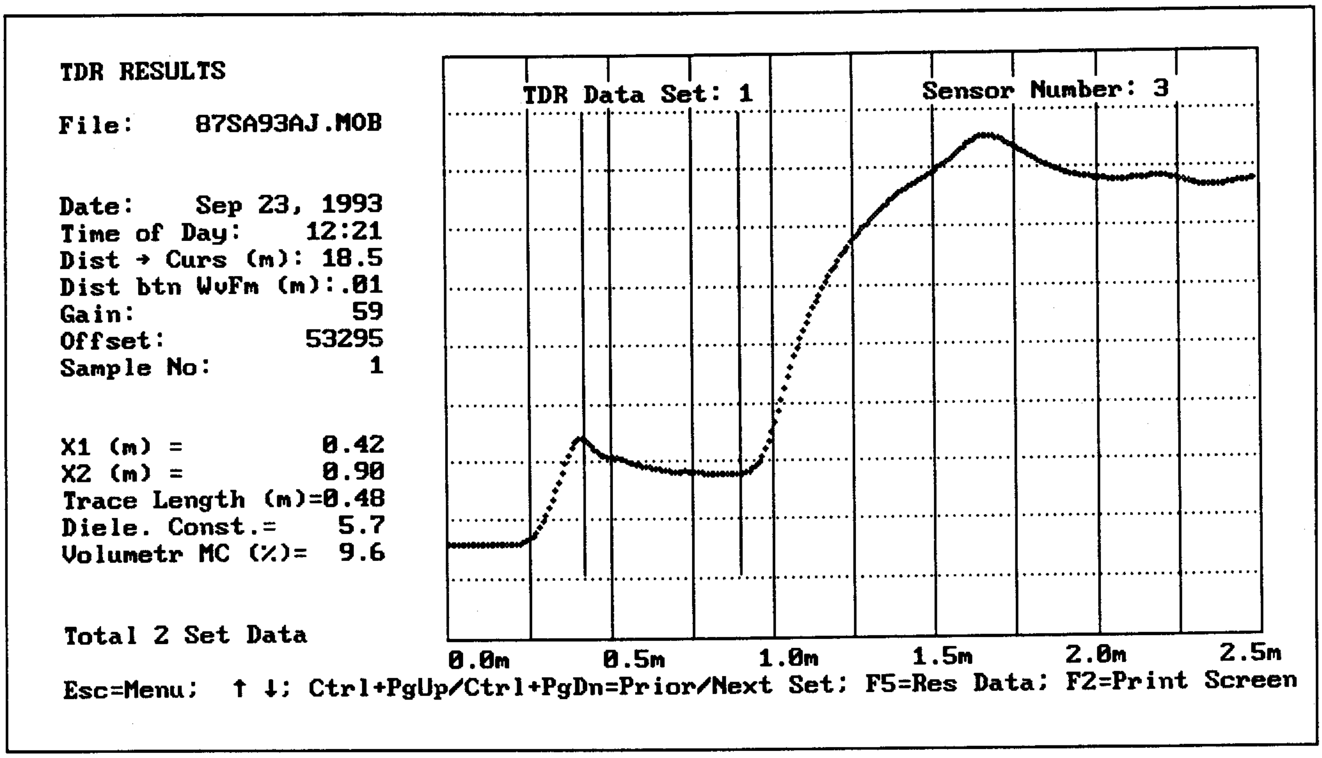


Figure D-4(cont.). Initial First Set of TDR Traces Measured with the Mobile Unit

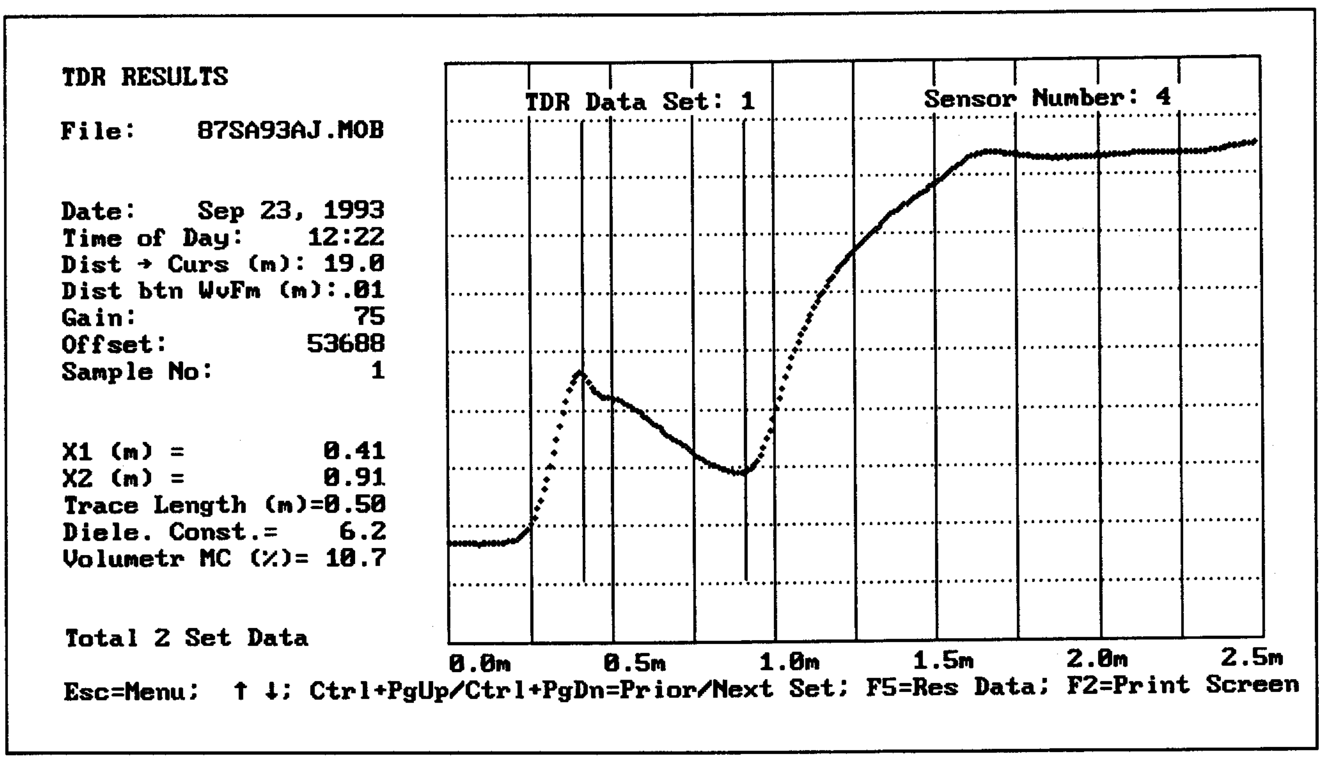


Figure D-4(cont.). Initial First Set of TDR Traces Measured with the Mobile Unit

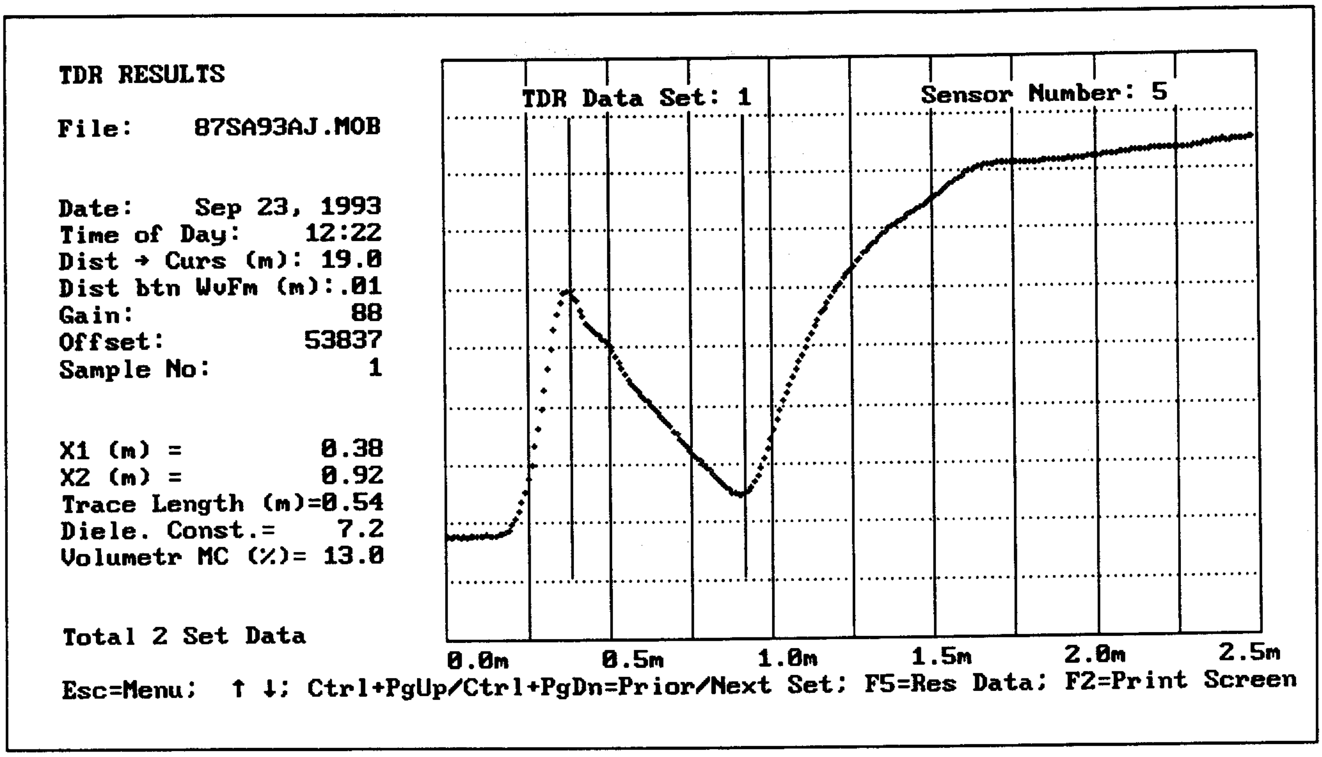


Figure D-4(cont.). Initial First Set of TDR Traces Measured with the Mobile Unit

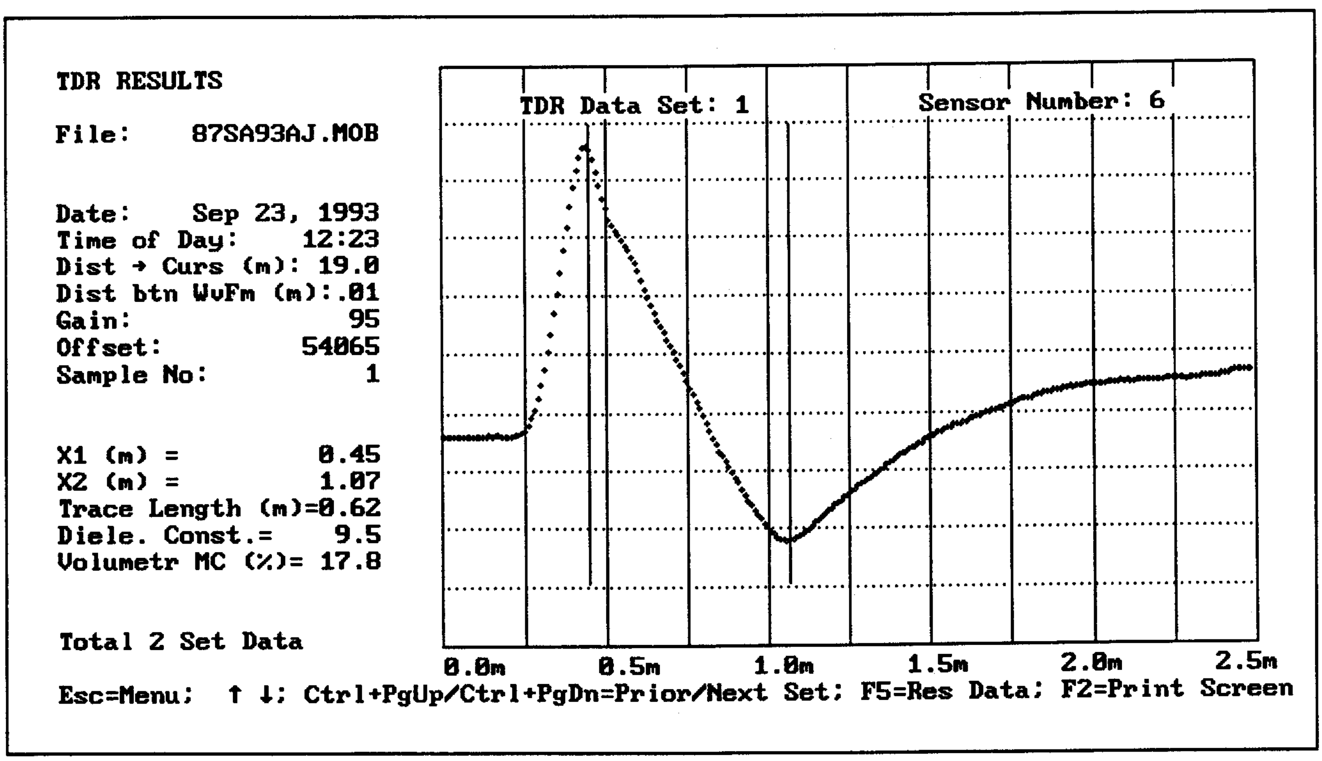


Figure D-4(cont.). Initial First Set of TDR Traces Measured with the Mobile Unit

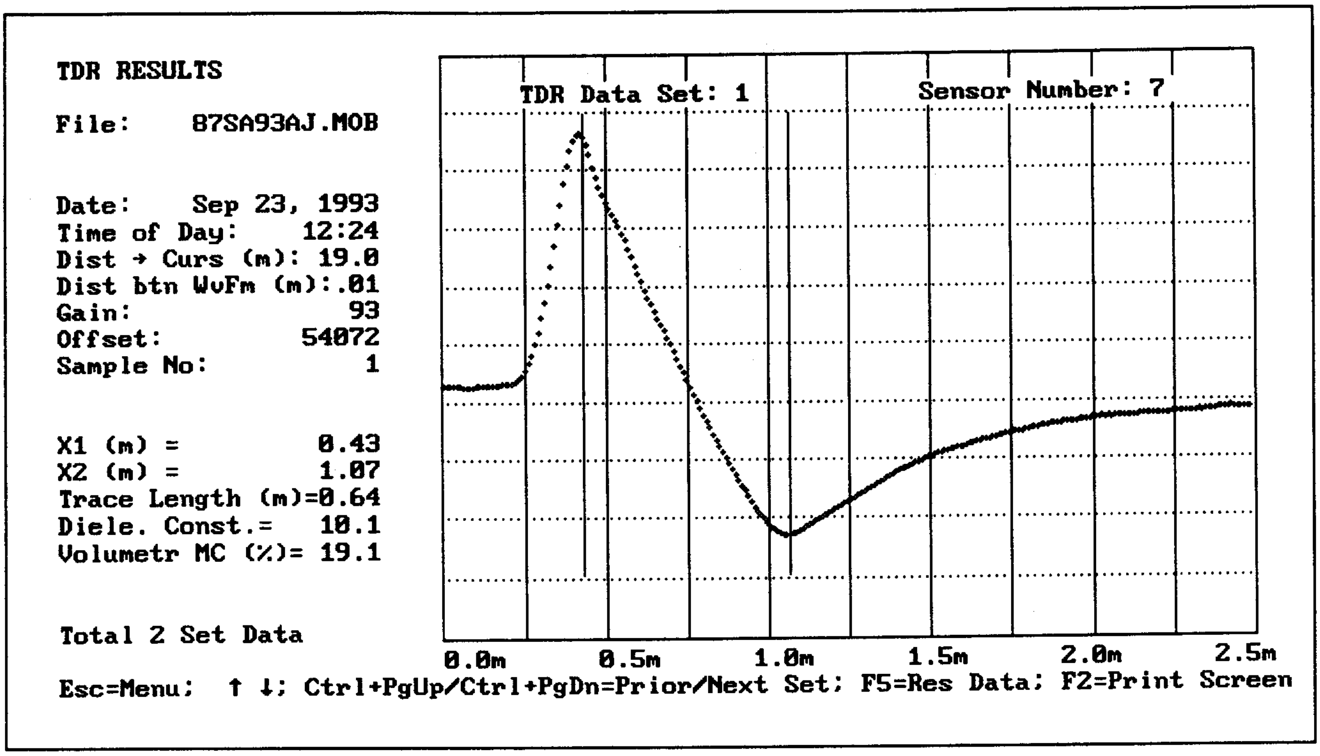


Figure D-4(cont.). Initial First Set of TDR Traces Measured with the Mobile Unit

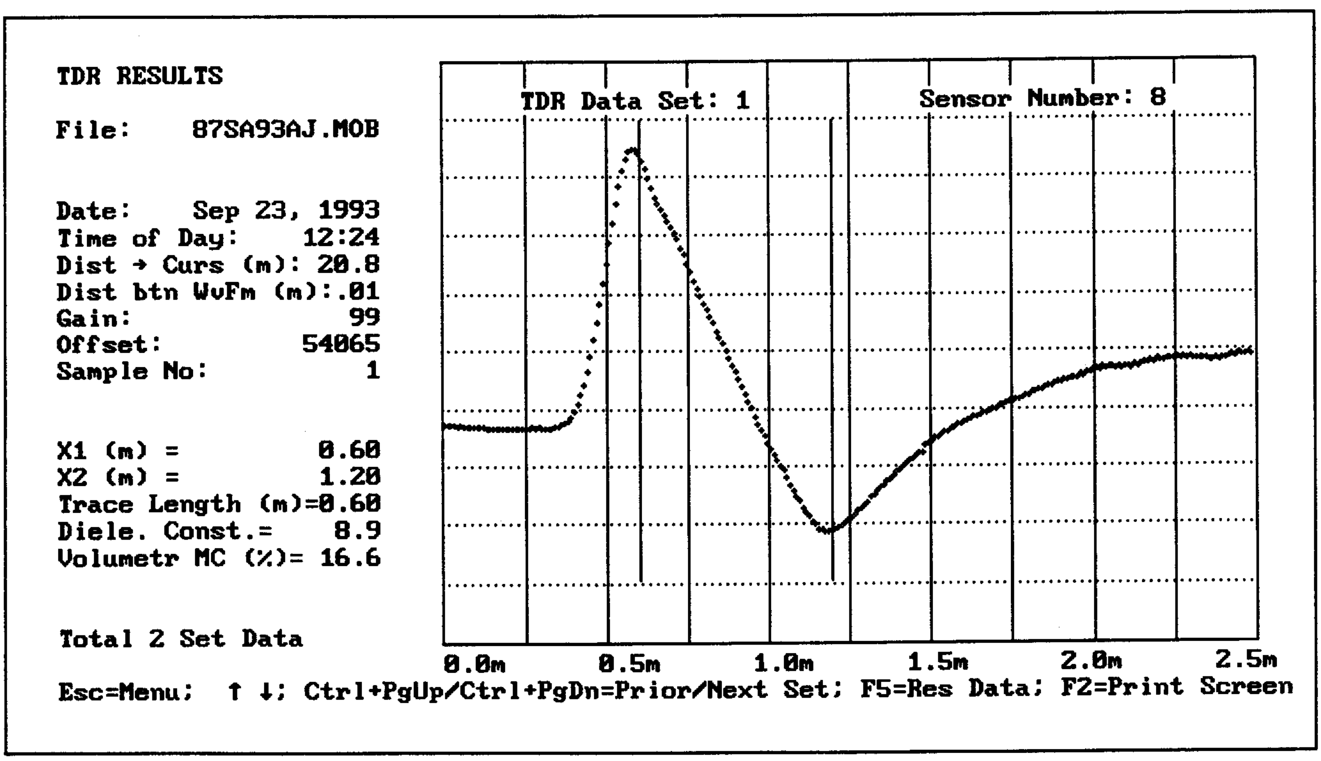


Figure D-4(cont.). Initial First Set of TDR Traces Measured with the Mobile Unit

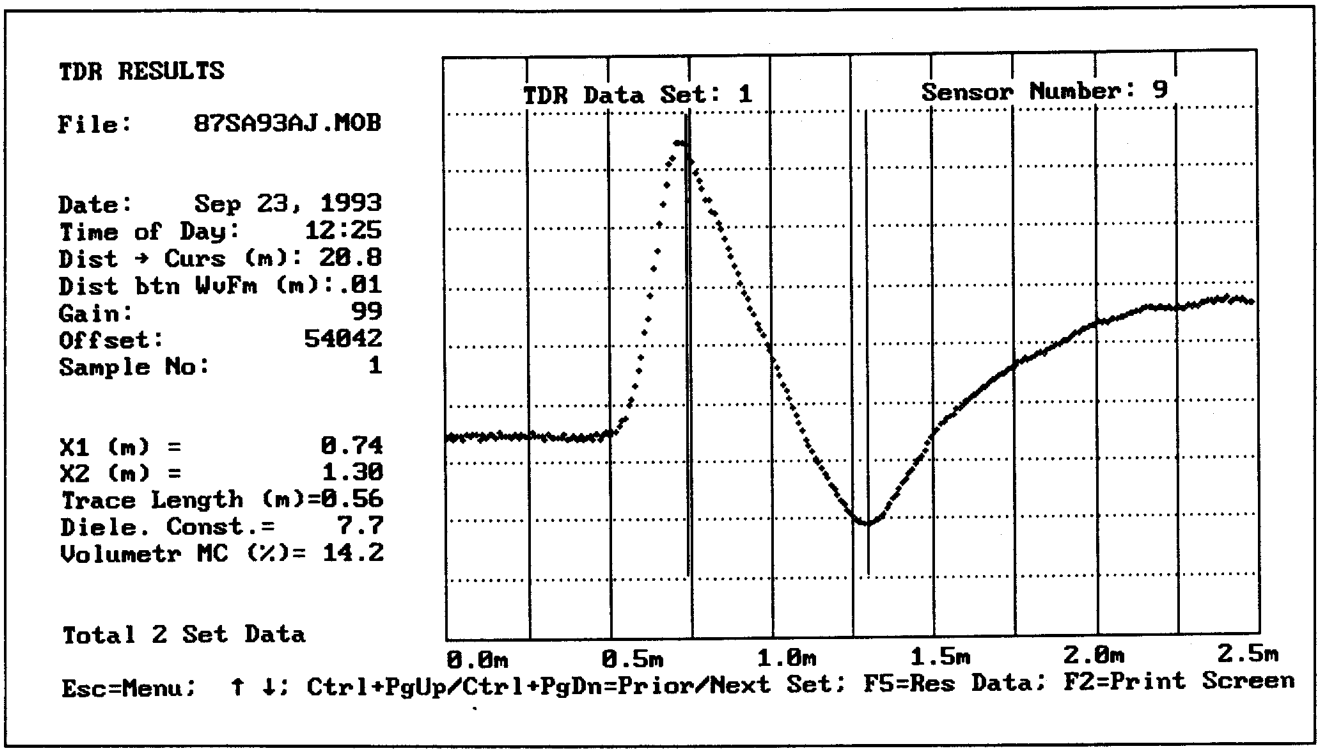


Figure D-4(cont.). Initial First Set of TDR Traces Measured with the Mobile Unit

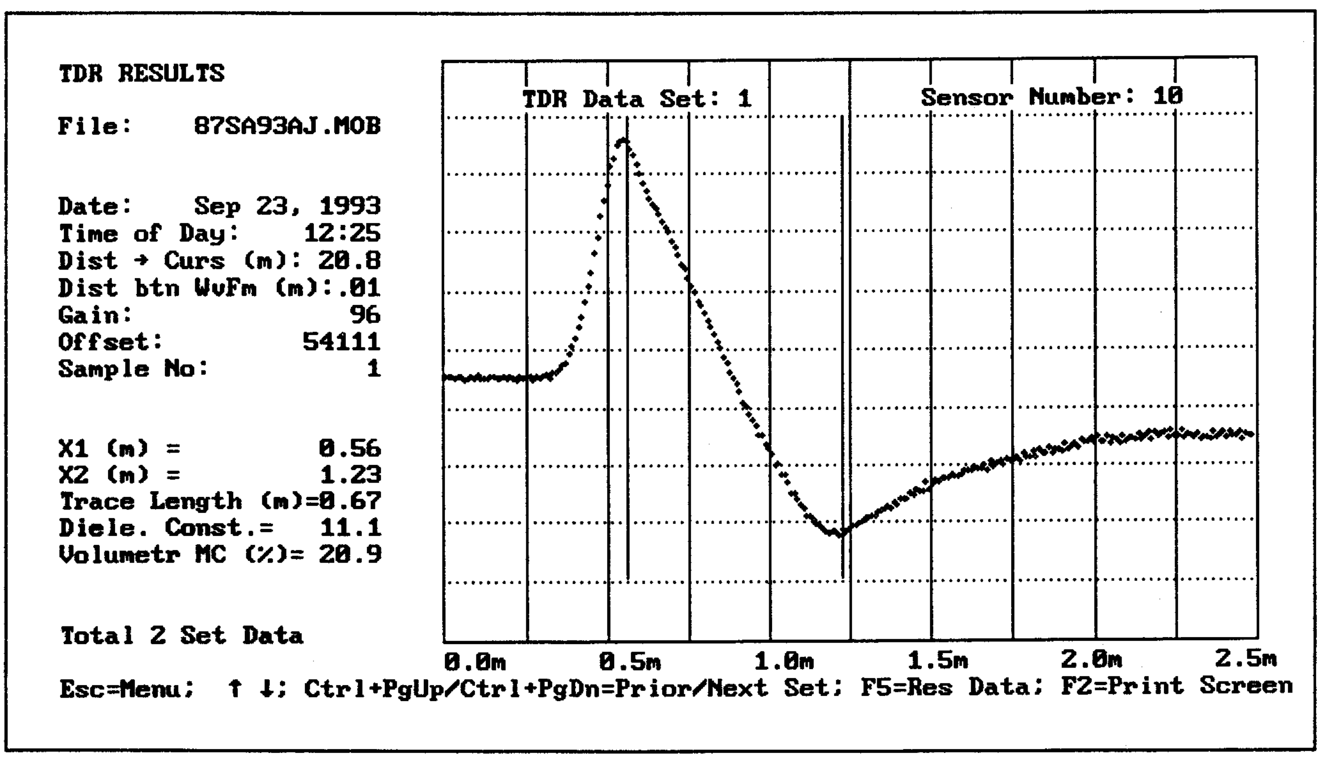


Figure D-4(cont.). Initial First Set of TDR Traces Measured with the Mobile Unit

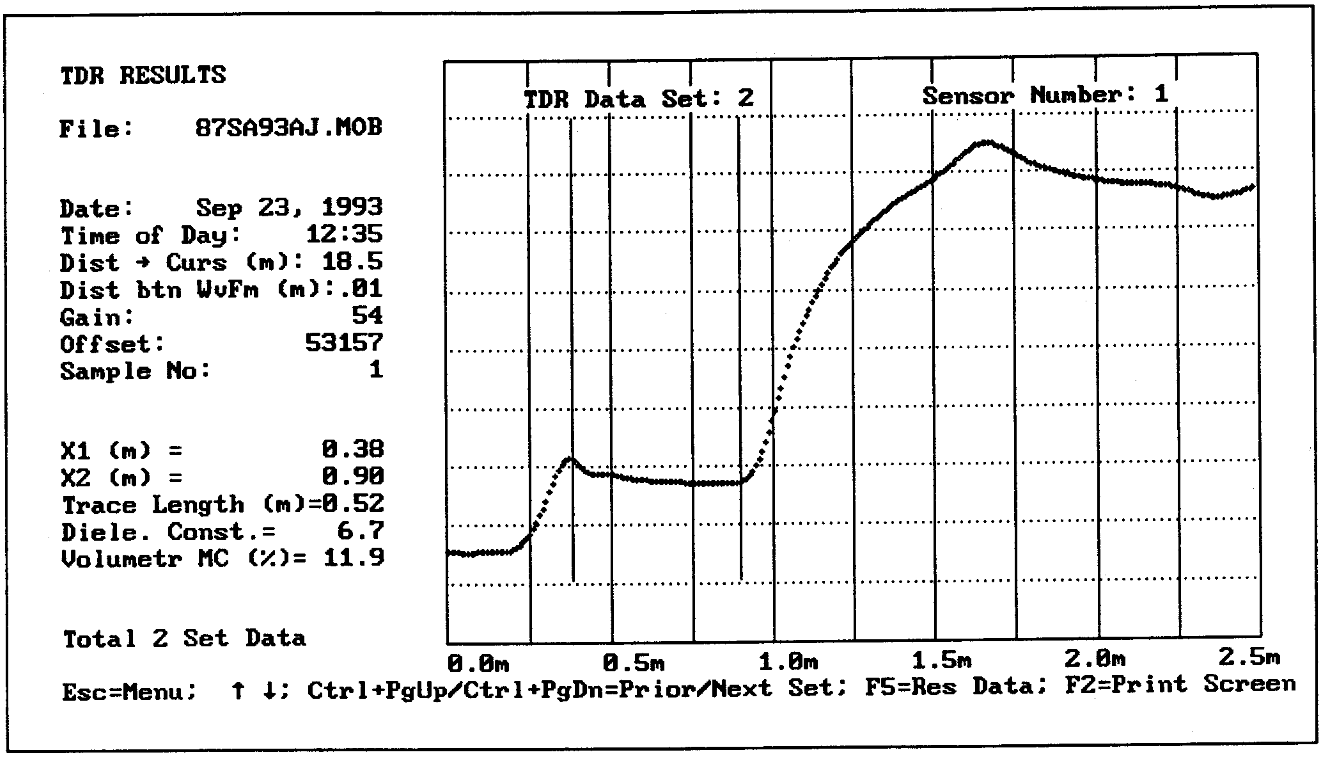


Figure D-5. Initial Second Set of TDR Traces Measured with the Mobile Unit

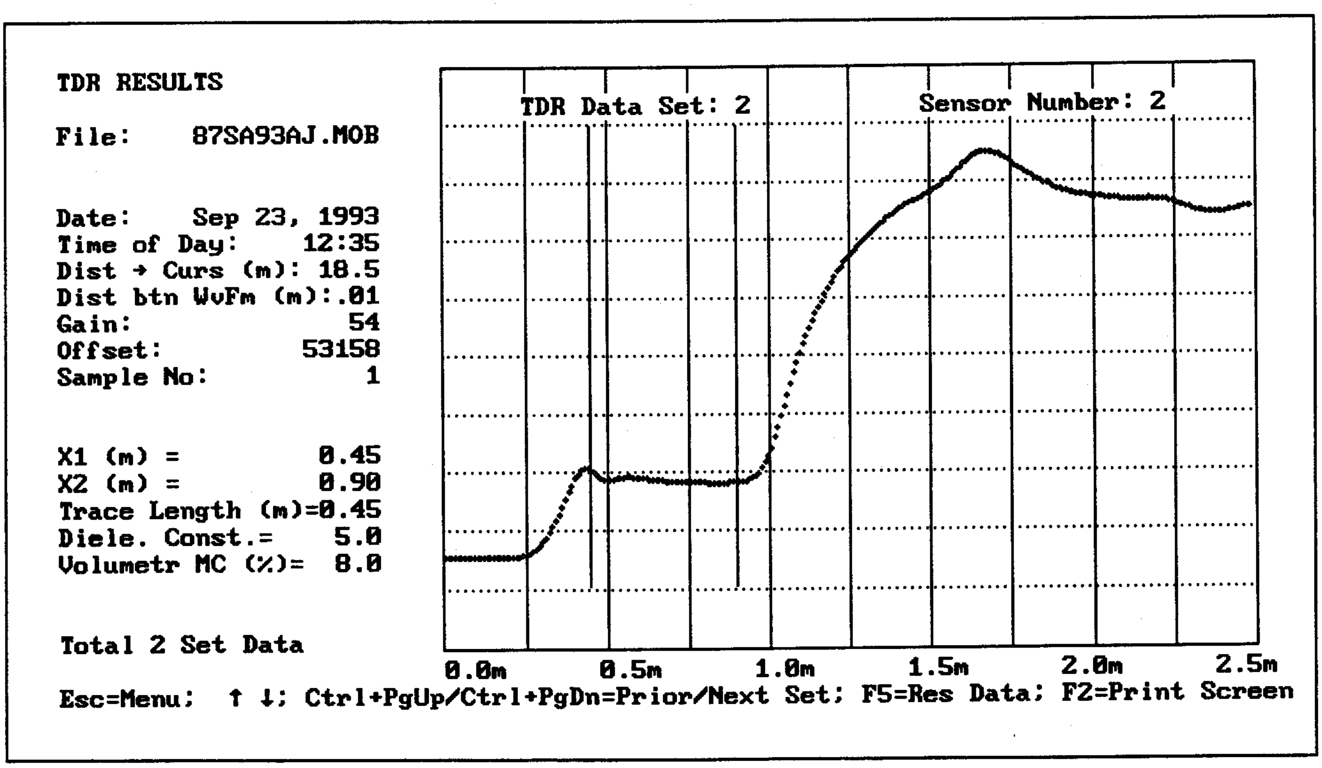


Figure D-5(cont.). Initial Second Set of TDR Traces Measured with the Mobile Unit

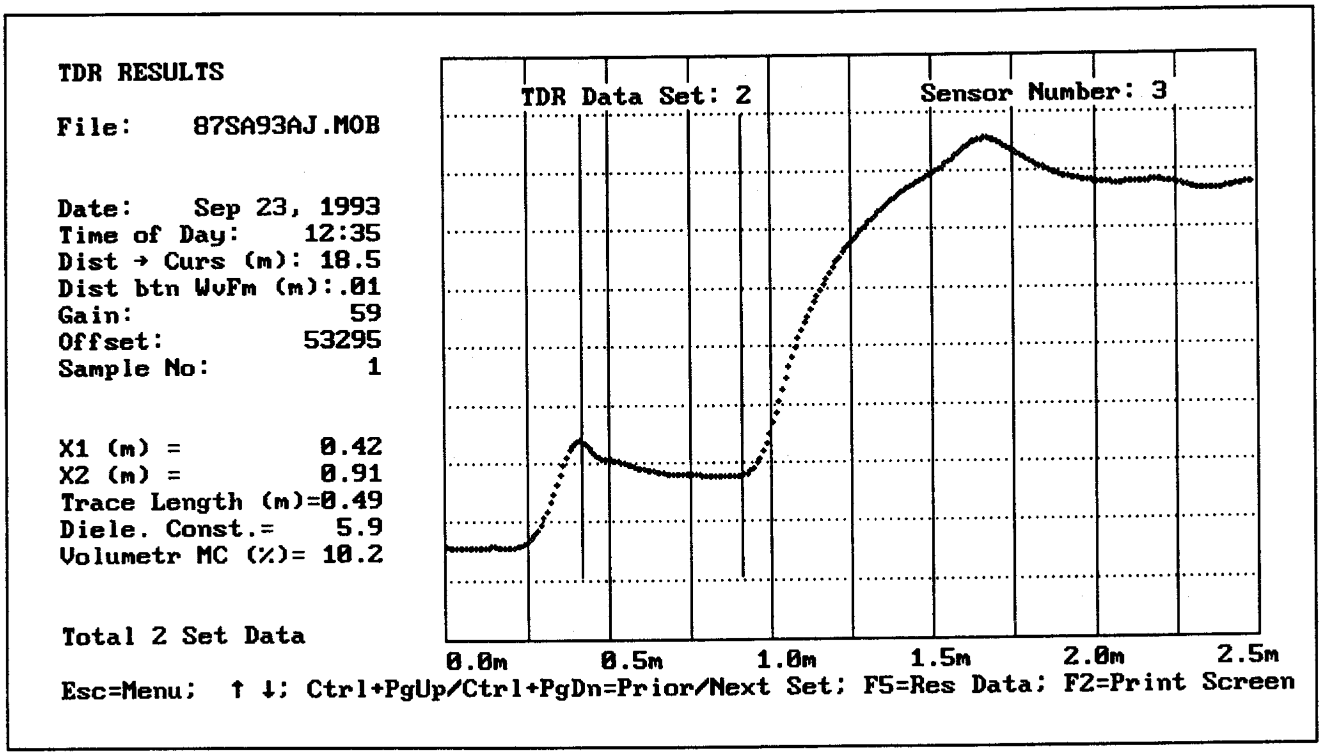


Figure D-5(cont.). Initial Second Set of TDR Traces Measured with the Mobile Unit

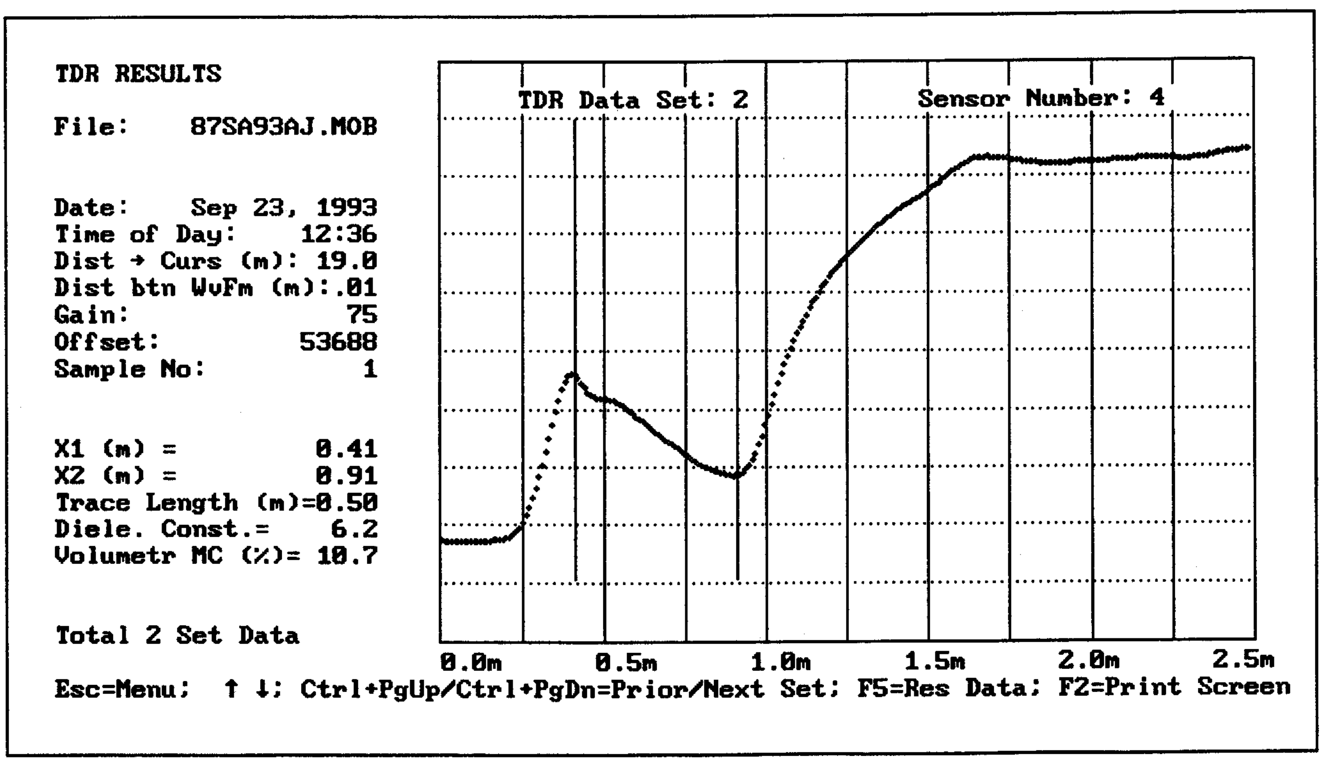


Figure D-5(cont.). Initial Second Set of TDR Traces Measured with the Mobile Unit

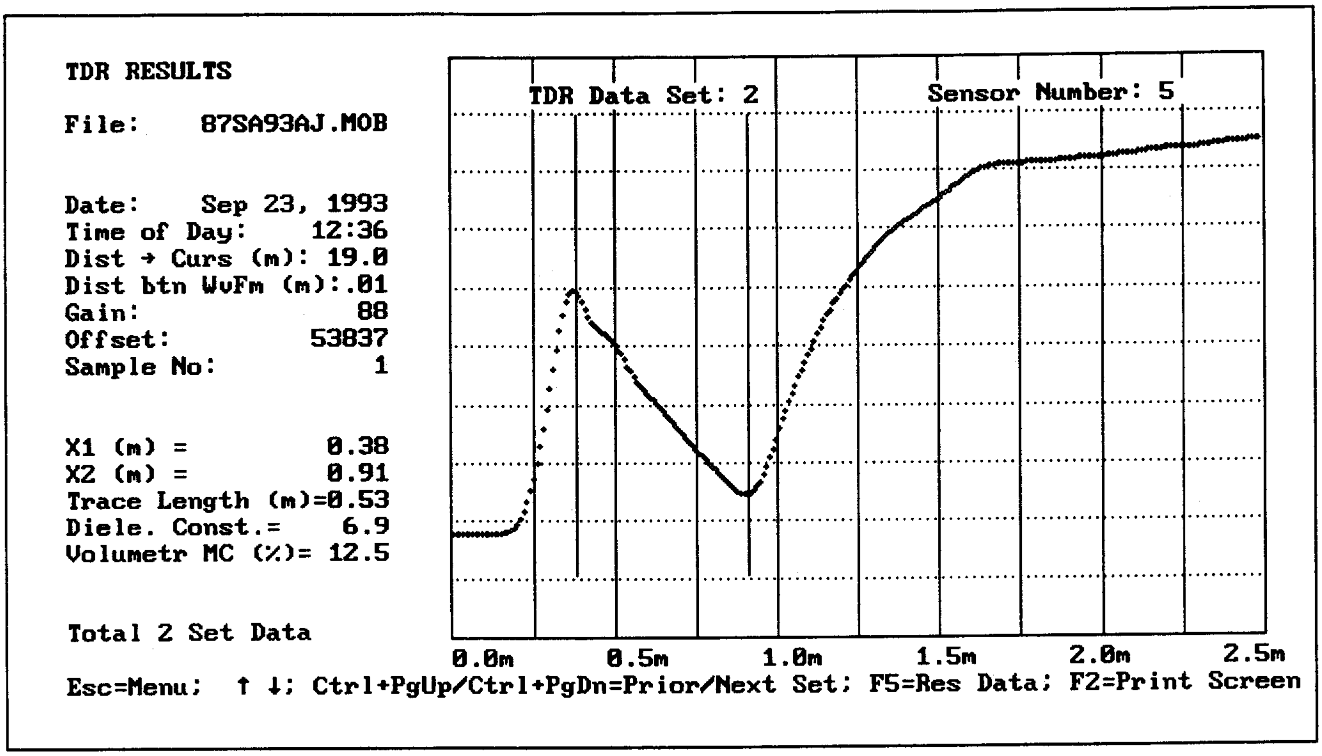


Figure D-5(cont.). Initial Second Set of TDR Traces Measured with the Mobile Unit

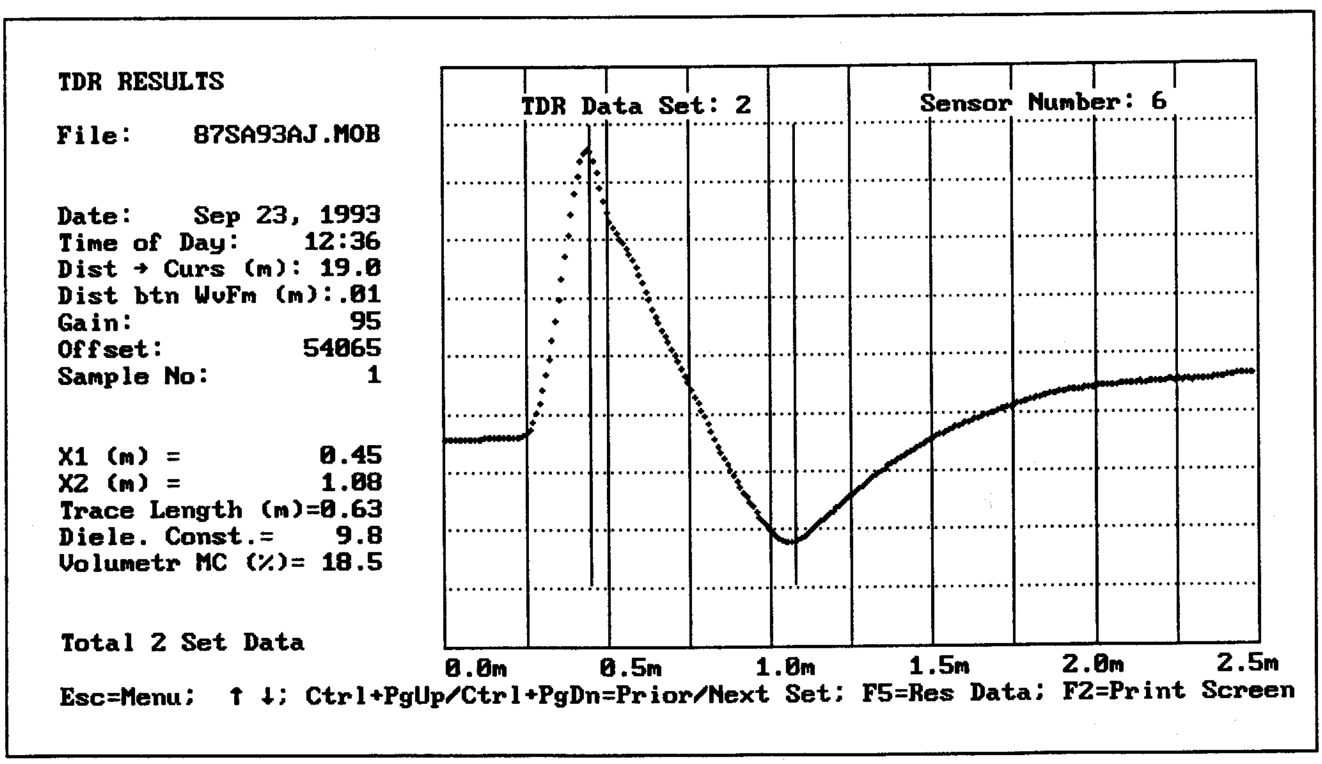


Figure D-5(cont.). Initial Second Set of TDR Traces Measured with the Mobile Unit

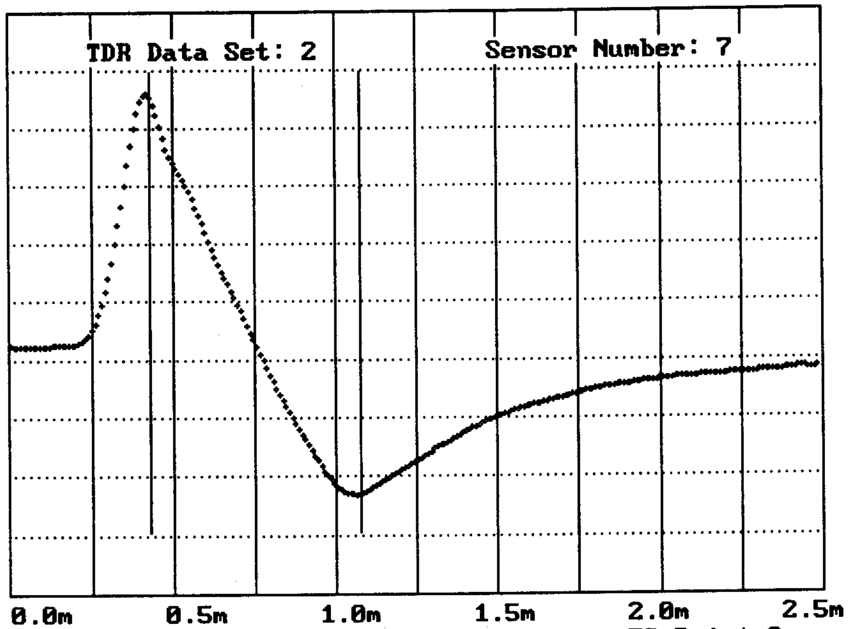
TDR RESULTS

File: 87SA93AJ.MOB

Date: Sep 23, 1993
Time of Day: 12:36
Dist → Curs (m): 19.0
Dist btn WvFm (m):.01
Gain: 93
Offset: 54072
Sample No: 1

X1 (m) = 0.43
X2 (m) = 1.08
Trace Length (m)=0.65
Diele. Const.= 10.4
Volumetr MC (%)= 19.7

Total 2 Set Data



Esc=Menu; ↑ ↓; Ctrl+PgUp/Ctrl+PgDn=Prior/Next Set; F5=Res Data; F2=Print Screen

Figure D-5(cont.). Initial Second Set of TDR Traces Measured with the Mobile Unit

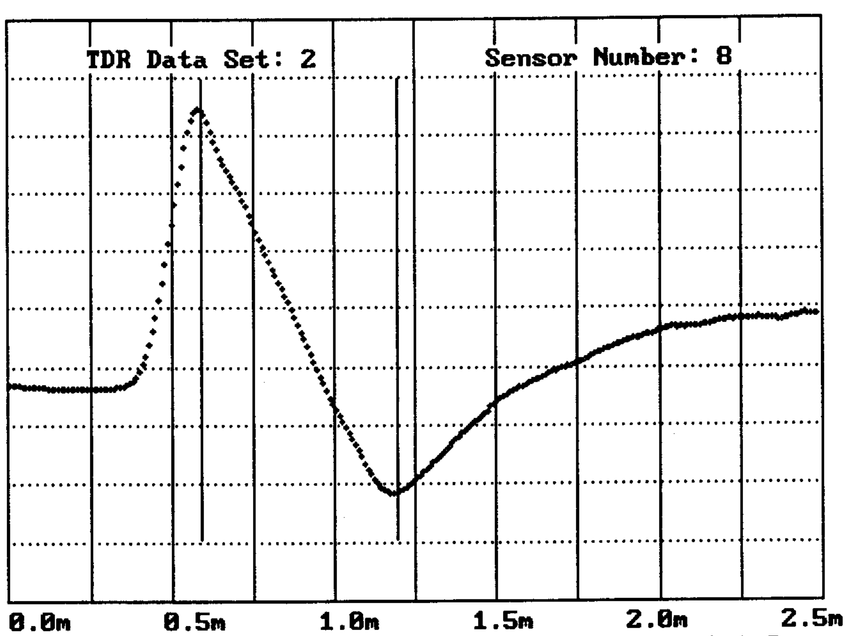
TDR RESULTS

File: 87SA93AJ.MOB

Date: Sep 23, 1993
Time of Day: 12:36
Dist → Curs (m): 20.8
Dist btn WvFm (m):.01
Gain: 99
Offset: 54065
Sample No: 1

X1 (m) = 0.59
X2 (m) = 1.20
Trace Length (m)=0.61
Diele. Const.= 9.2
Volumetr MC (%)= 17.2

Total 2 Set Data



Esc=Menu; ↑ ↓; Ctrl+PgUp/Ctrl+PgDn=Prior/Next Set; F5=Res Data; F2=Print Screen

Figure D-5(cont.). Initial Second Set of TDR Traces Measured with the Mobile Unit

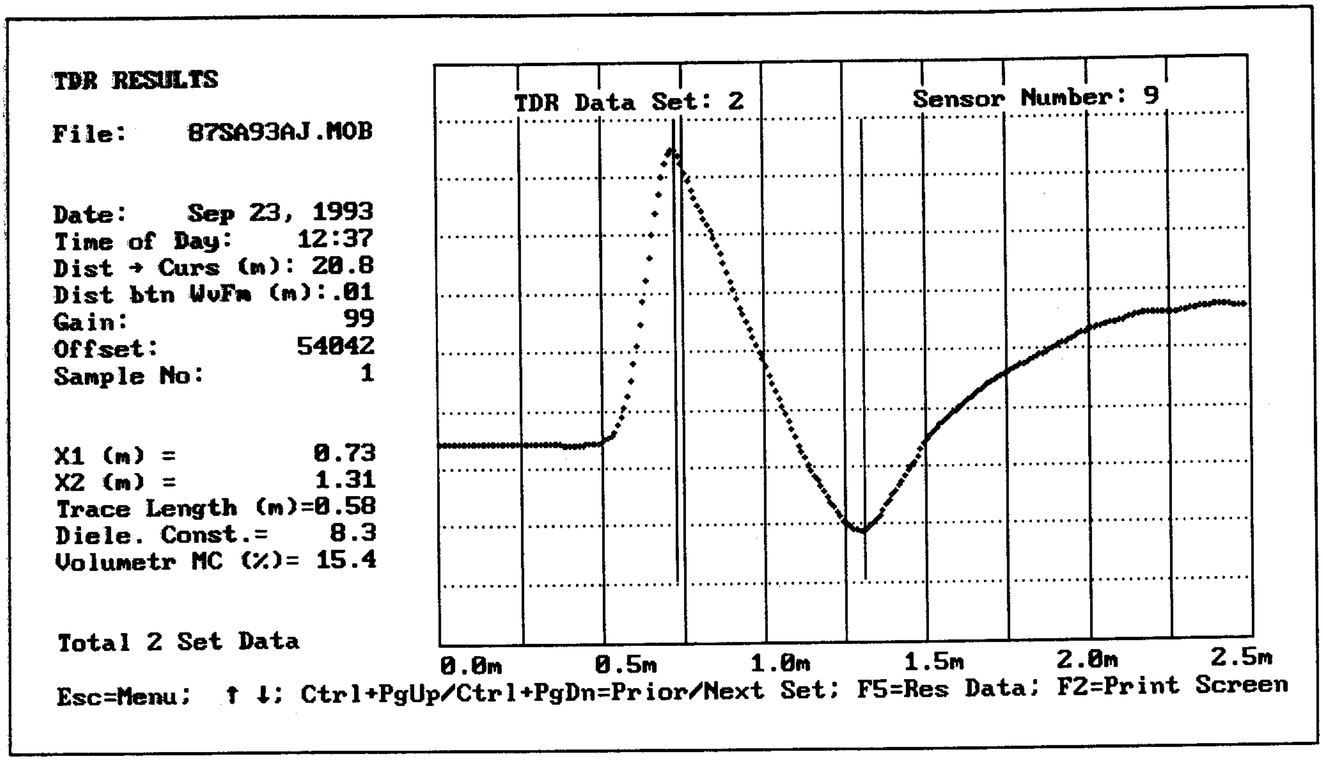


Figure D-5(cont.). Initial Second Set of TDR Traces Measured with the Mobile Unit

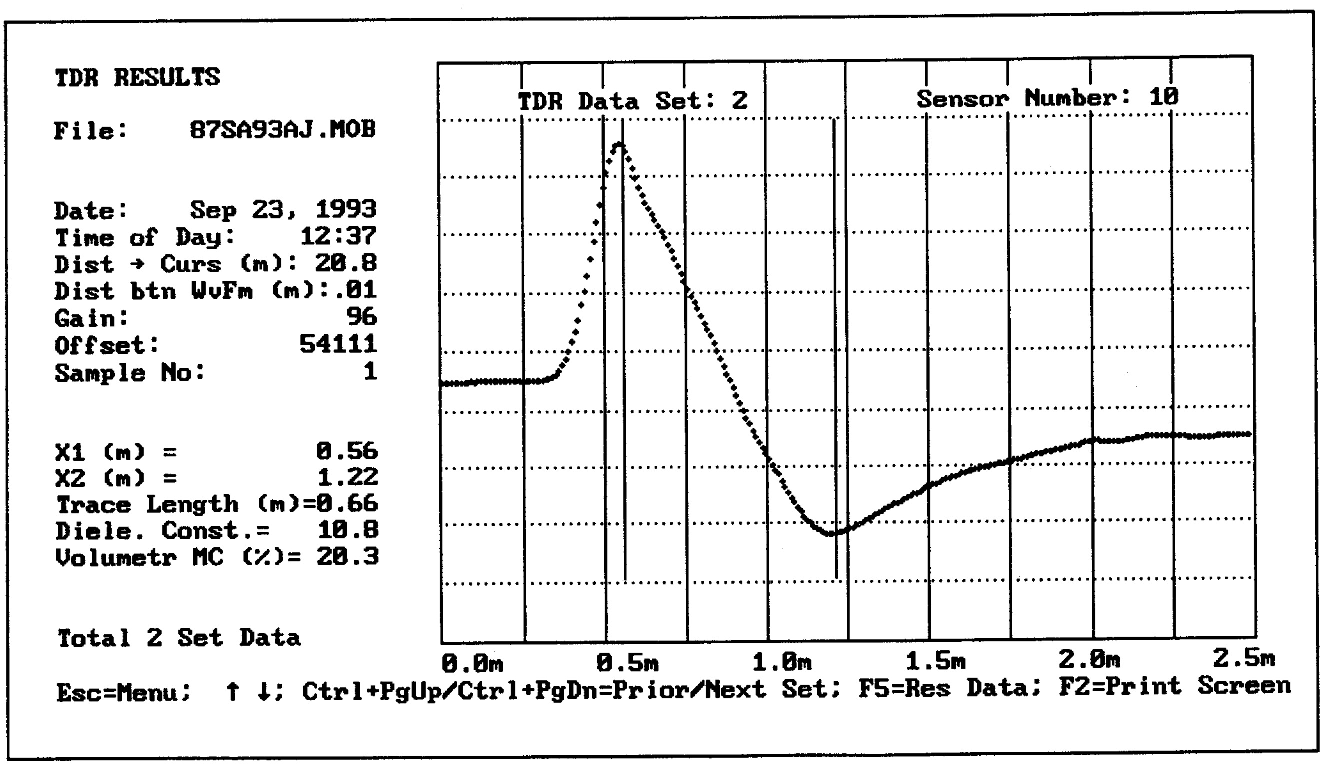


Figure D-5(cont.). Initial Second Set of TDR Traces Measured with the Mobile Unit

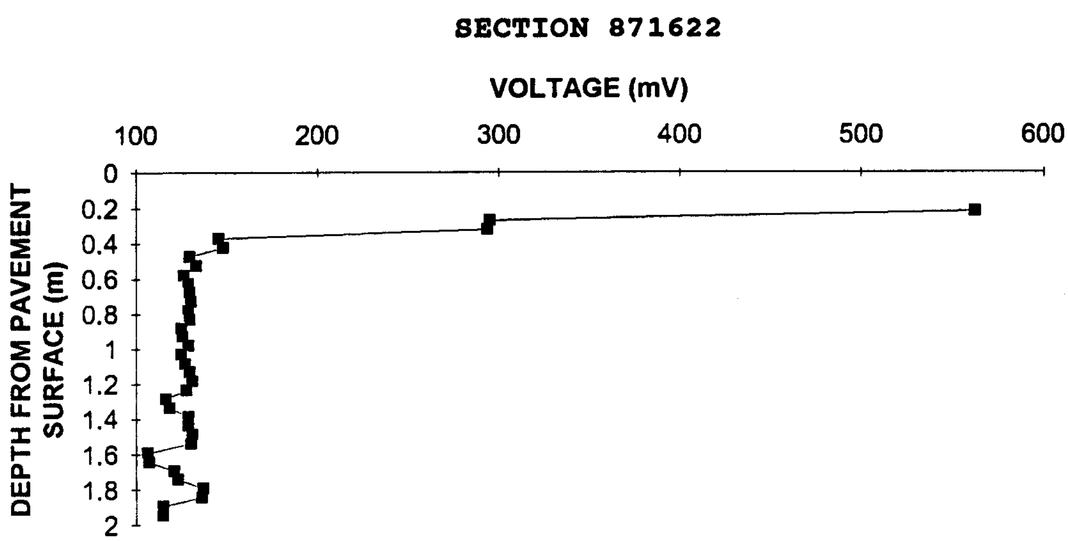


Figure D-6. Voltages Measured Using the Mobile System During Initial Data Collection, September 23, 1993

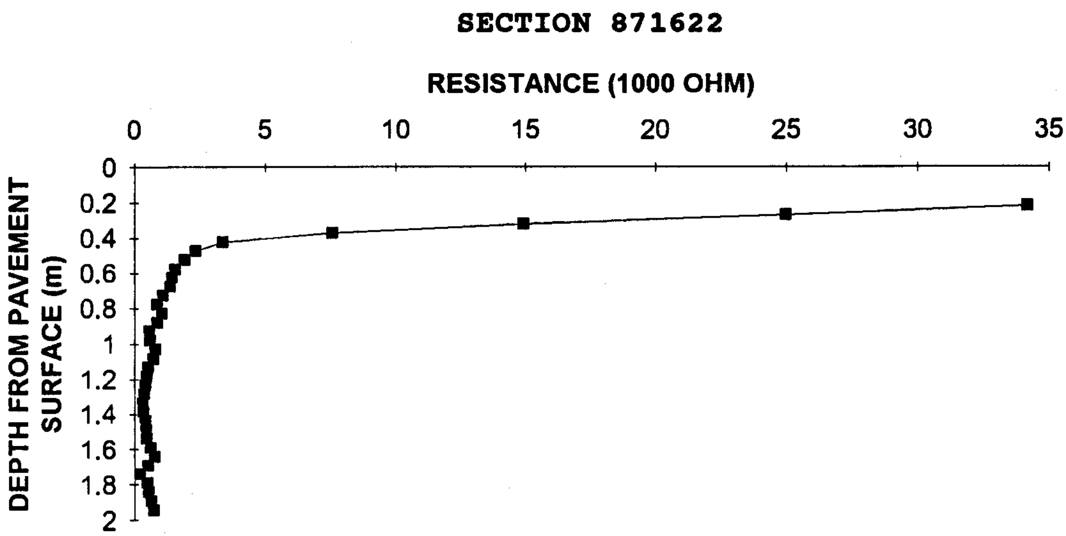


Figure D-7. Manually Collected Contact Resistance
During Initial Data Collection, September 23, 1993

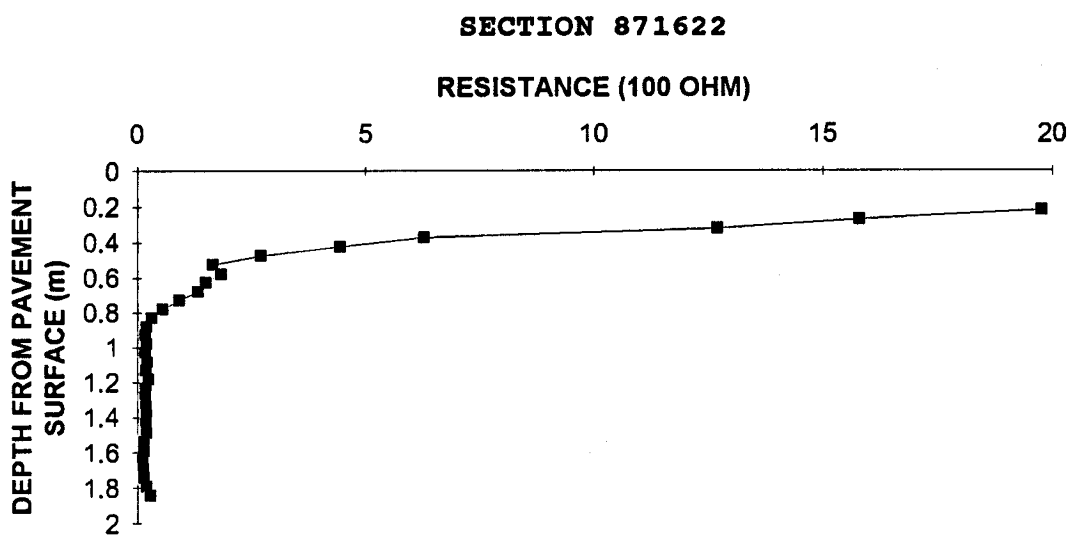


Figure D-8. Manually Collected Four Point Resistivity
During Initial Data Collection, September 23, 1993

Table D-1. Contact Resistance After Installation

LTPP Seasonal Monitoring Study	State Code	[87]
Data Sheet R1		
Contact Resistance Measurements	Test Section Number	[1622]

1. Date (Month-Day-Year)	[09-23-93]
2. Time Measurements Began (Military)	[1320]
3. Comments	After Installation * Note: Known Resistors

Test Position	Connections		Voltage (ACV)		Current (ACA)		notes
	I V	I V	Range Setting	Reading	Range Setting	Reading	
1	1	2	mV	239.2	uA	7.0	
2	3	2	mV	237.3	uA	9.5	
3	3	4	mV	232.9	uA	15.6	
4	5	4	mV	223.4	uA	29.4	
5	5	6	mV	202.9	uA	59.8	
6	7	6	mV	188.9	uA	80.2	
7	7	8	mV	180.2	uA	93.0	
8	9	8	mV	169.7	uA	108.9	
9	9	10	mV	165.4	uA	115.2	
10	11	10	mV	163.3	uA	118.5	
11	11	12	mV	150.7	uA	137.3	
12	13	12	mV	137. 8	uA	157.4	
13	13	14	mV	149.1	uA	141.5	
14	15	14	mV	137.5	uA	159.0	
15	15	16	mV	112.6	uA	197.0	
16	17	16	mV	116.8	uA	191.5	
17	17	18	mV	133.1	uA	167.2	
18	19	18	mV	127.8	uA	174.8	
19	19	20	mV	107.8	uA	204.6	
20	21	20	mV	101.9	uA	212.9	
21	21	22	mV	93.9	uA	223.2	
22	23	22	mV	90.0	uA	229.6	
23	23	24	mV	82.2	uA	241.9	
24	25	24	mV	85.8	uA	236.1	
25	25	26	mV	94.0	uA	224.6	
26	27	26	mV	98.2	uA	219.2	
27	27	28	mV	101.4	uA	214.4	
28	29	28	mV	118.8	uA	190.7	
29	29	30	mV	132.6	uA	172.3	
30	31	30	mV	109.9	uA	204.5	
31	31	32	mV	53.7	uA	229.9	
32	33	32	mV	103.7	uA	208.5	
33	33	34	mV	110.2	uA	199.4	
34	35	34	mV	119.7	uA	184.4	
35	35	36	mV	127.6	uA	171.1	
36 *	37	38	mV		uA		
37 *	38	39	mV		uA		
38 *	39	40	mV		uA		

Preparer:	Michael Zawisa	Employer:	PMSL

Table D-2. Four-Point Resistivity After Installation

LTPP Seasonal Monitoring Study	State Code		[8 7]
Data Sheet R2			
Four-Point Resistivity Measurements	Test Section Number		[1 6 2 2]

1. Date (Month-Day-Year)	[09-23-93]
2. Time measurements Began (Military)	[1300]
3. Comments	After Installation

Test Position	Connections				Voltage (ACV)		Current (ACA)		Notes
	I_1	V_1	V_2	I_2	Range Setting	Reading	Range Setting	Reading	
1	1	2	3	4	mV	16.8	uA	8.5	
2	2	3	4	5	mV	18.5	uA	11.7	
3	3	4	5	6	mV	23.5	uA	18.5	
4	4	5	6	7	mV	19.5	uA	31.0	
5	5	6	7	8	mV	25.8	uA	58.0	
6	6	7	8	9	mV	22.1	uA	81.7	
7	7	8	9	10	mV	15.3	uA	92.6	
8	8	9	10	11	mV	18.8	uA	102.2	
9	9	10	11	12	mV	18.7	uA	124.5	
10	10	11	12	13	mV	16.6	uA	125.2	
11	11	12	13	14	mV	11.1	uA	120.4	
12	12	13	14	15	mV	9.7	uA	173.0	
13	13	14	15	16	mV	5.4	uA	170.5	
14	14	15	16	17	mV	3.2	uA	156.9	
15	15	16	17	18	mV	3.1	uA	172.8	
16	16	17	18	19	mV	4.2	uA	201.3	
17	17	18	19	20	mV	3.4	uA	196.6	
18	18	19	20	21	mV	3.9	uA	180.0	
19	19	20	21	22	mV	4.1	uA	213.9	
20	20	21	22	23	mV	5.4	uA	215.7	
21	21	22	23	24	mV	4.5	uA	233.3	
22	22	23	24	25	mV	4.0	uA	222.2	
23	23	24	25	26	mV	4.2	uA	227.9	
24	24	25	26	27	mV	4.5	uA	227.9	
25	25	26	27	28	mV	4.0	uA	219.1	
26	26	27	28	29	mV	4.0	uA	192.6	
27	27	28	29	30	mV	2.9	uA	190.6	
28	28	29	30	31	mV	3.3	uA	229.5	
29	29	30	31	32	mV	2.2	uA	191.3	
30	30	31	32	33	mV	2.6	uA	186.6	
31	31	32	33	34	mV	3.3	uA	217.5	
32	32	33	34	35	mV	3.9	uA	190.5	
33	33	34	35	36	mV	5.1	uA	181.0	

Preparer	MZ & PZ	Employer	PMSL

Table D-3. Uniformity Survey Results Before and After Installation

Seasonal Uniformity Survey	Falling Weight Deflectometer
Site Number: 871622	Data Collection and
Date Surveyed: September 22-September 23, 1993	Processing Summary

Section Interval (ft)	Mean Deflection Values for HT 2 (mils) Corrected								Mean Temp D1 (F)
	Sensor 1	Sensor 1 std dev	Sensor 7	Sensor 7 std dev	Subg modulus (psi)	Subg modulus std dev	Effective SN	SN std dev	
300 to 520 **Sept 22** @ 0918	9.30	0.46	1.25	0.05	27692	1060	8.79	0.17	45.7
0 to 300 **Sept 23** @ 1226	10.18	0.59	1.21	0.05	28550	1064	8.44	0.22	75.2
300 to 525 **Sept 23** @ 1226	9.68	0.66	1.16	0.04	29563	987	8.60	0.24	75.2

Note: On September 23, 1993 the whole GPS section was surveyed with the FWD to confirm the uniformity of the section. The section was split to two subsections to have a closer look at the last 200 feet, for comparison reasons, being the part that is surveyed on a monthly basis.

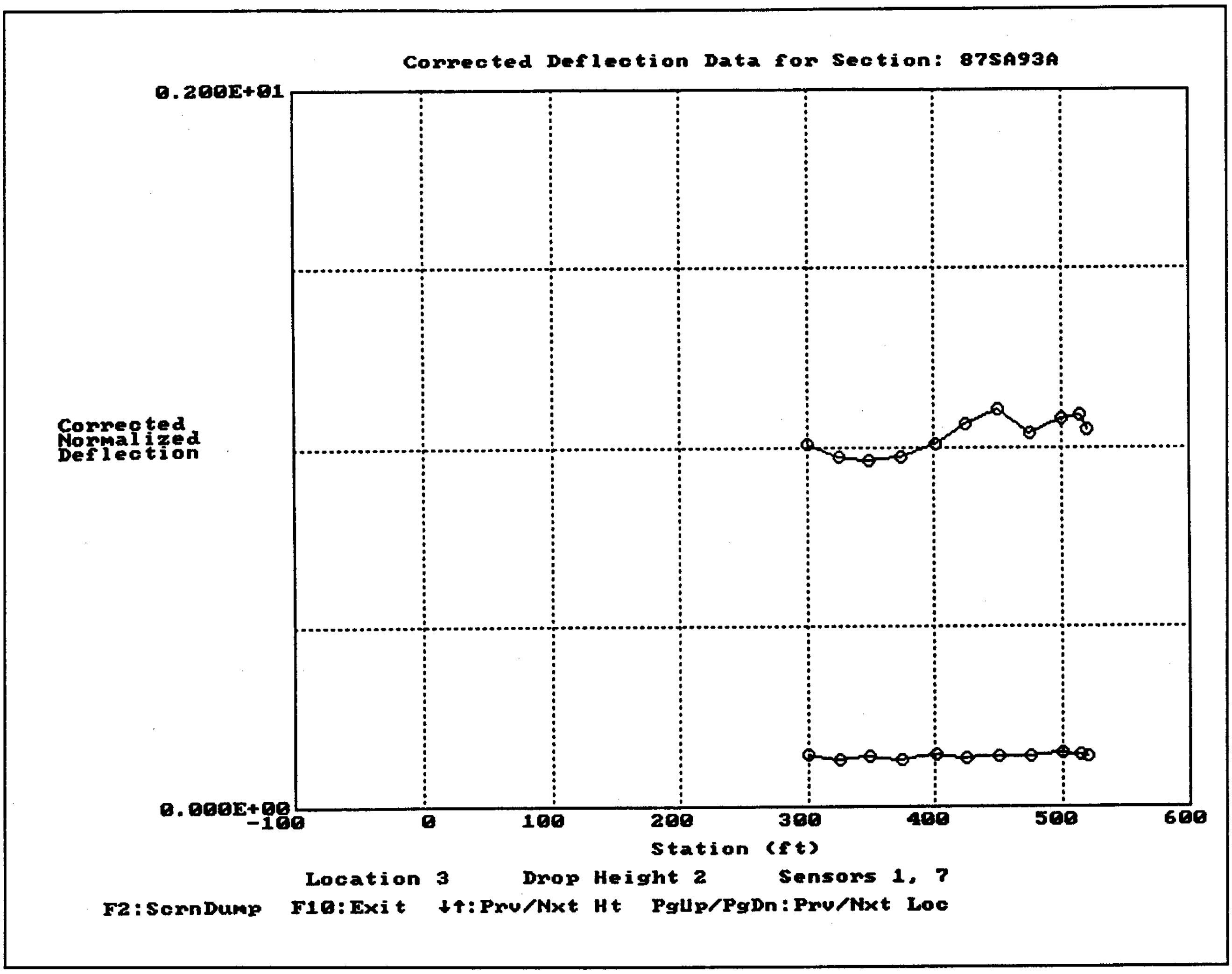


Figure D-9. Deflection Profiles from FWDCHECK
(Test Date and Time September 22, 1993 @ 09:18)

Table D-4. Subgrade Modulus and Structural Number from FWDCHECK
(Test Date and Time September 22, 1993 @ 0918)

Flexible Pavement Thickness Statistics - 87SA93A - Drop Height 2			
Subsection	Station	Subgrade Modulus	Effective SN
1	300	26803	8.90
	325	29464	8.95
	350	27717	9.05
	375	29476	8.95
	400	27020	8.90
	425	28379	8.65
	450	27438	8.55
	475	27891	8.75
	500	26150	8.65
	514	26908	8.60
	520	27371	8.75
Subsection 1	Overall Mean	27692	8.79
	Standard Deviation	1060	0.17
	Coeff. of Variation	3.83%	1.90%

Note: No test pit data found, therefore no results exist...

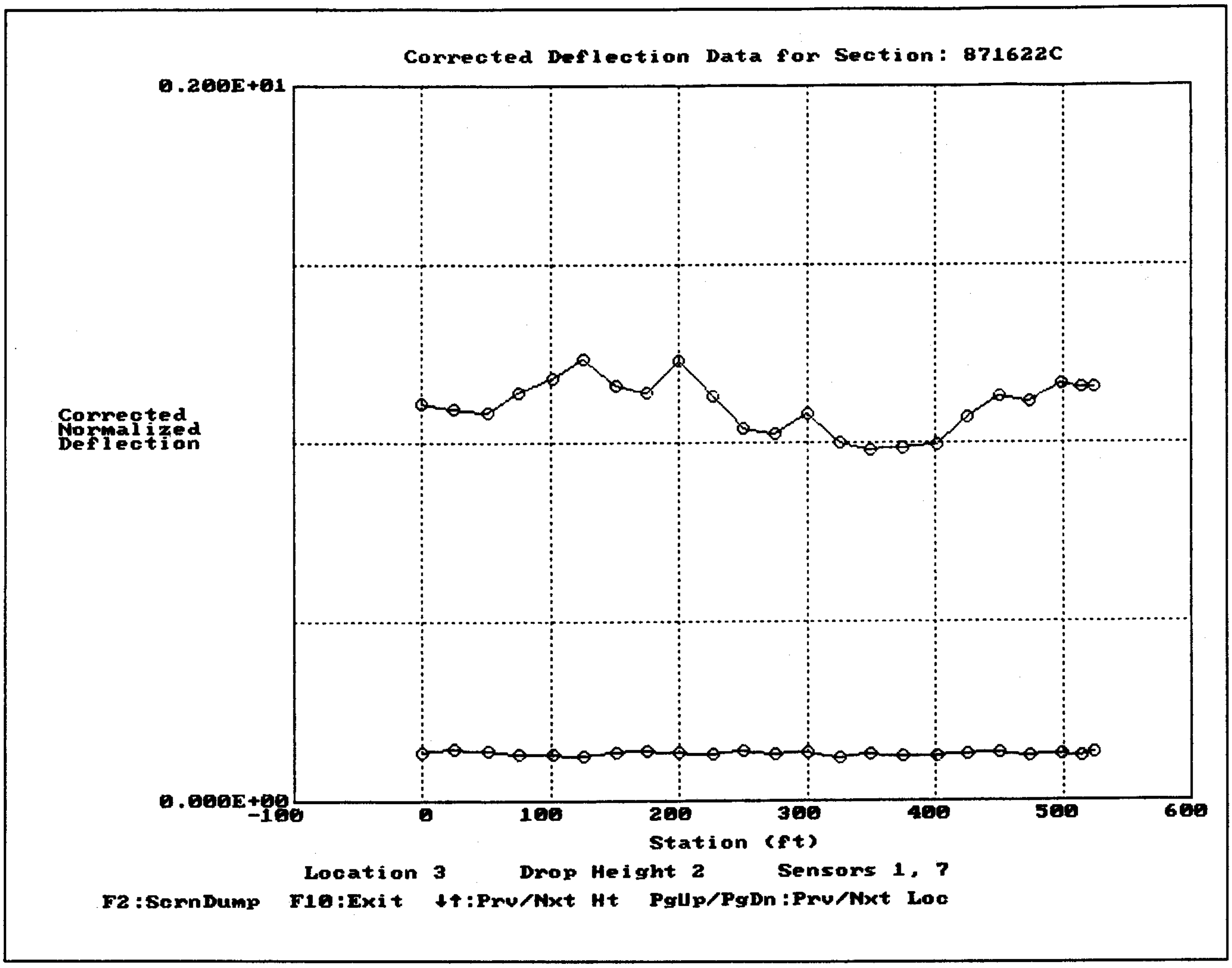


Figure D-10. Deflection Profiles from FWDCHECK
(Test Date and Time September 23, 1993 @ 1226)

Table D-5. Subgrade Modulus and Structural Number from FWDCHECK
(Test Date and Time September 23, 1993 @ 1226)

Flexible Pavement Thickness Statistics - 871622C - Drop Height 2			
Subsection	Station	Subgrade Modulus	Effective SN
1	0	28041	8.50
	25	26608	8.60
	51	27867	8.60
	75	29814	8.35
	101	29583	8.25
	125	29873	8.10
	150	28342	8.35
	175	27283	8.45
	200	28824	8.15
	226	29460	8.40
	250	27757	8.75
	275	29151	8.80
2	300	28719	8.60
	325	31902	8.80
	350	29286	8.95
	375	29958	8.90
	401	29960	8.85
	425	29032	8.60
	450	28309	8.45
	474	29911	8.45
	499	29574	8.30
	514	29991	8.35
	525	28557	8.35
Subsection 1	Overall Mean	28550	8.44
	Standard Deviation	1064	0.22
	Coeff. of Variation	3.73%	2.61%
Subsection 2	Overall Mean	29563	8.60
	Standard Deviation	987	0.24
	Coeff. of Variation	3.34%	2.79%

Note: No test pit data found, therefore no results exist...

Table D-6. Surface Elevation Measurements

LTPP Seasonal Monitoring Study	State Code	[87]
Surface Elevation Measurements	Test Section Number	[1622]

Survey Date	September 23, 1993
Surveyed By	MZ & PZ
Surface Type	A/C
Benchmark	Observation Piezometer - 1.000 meters - assumed

STATION		PE m offset 0.08m	OWP m offset 0.79m	ML m offset 1.75m	IWP m offset 2.74m	ILE m offset 3.56m
0-50	3+00	1.655	1.664	1.695	1.704	1.722
0-40	3+25	1.607	1.616	1.646	1.649	1.677
0-30	3+50	1.555	1.564	1.591	1.604	1.625
0-20	3+75	1.506	1.515	1.539	1.552	1.625
0-10	4+00	1.466	1.472	1.494	1.506	1.527
0+00	4+25	1.421	1.430	1.454	1.463	1.488
0+25	4+50	1.378	1.387	1.415	1.427	1.451
0+50	4+75	1.338	1.347	1.375	1.384	1.408
0+75	5+00	1.293	1.299	1.329	1.338	1.360
1+00	5+14.5	1.265	1.274	1.302	1.311	1.338
1+25	5+20	1.253	1.262	1.293	1.305	1.329
1+50	5+25.5	1.247	1.256	1.283	1.296	1.320
1+75	5+30	1.244	1.247	1.274	1.287	1.311
2+00	5+40	1.226	1.232	1.262	1.271	1.296

PE	Pavement Edge
OWP	Outer Wheel Path
ML	Mid Lane
IWP	Inner Wheel Path
ILE	Inner Lane Edge

APPENDIX E

Photographs

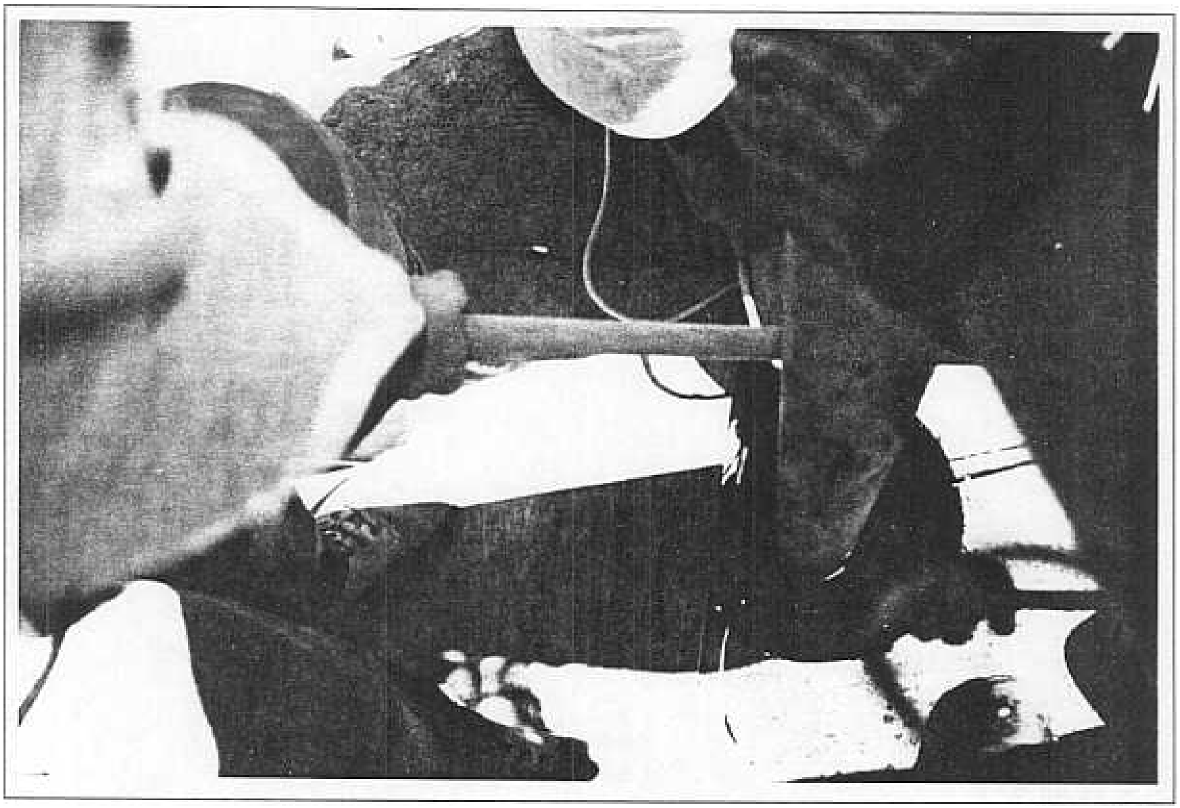


Figure E-1 Instrumentation Hole

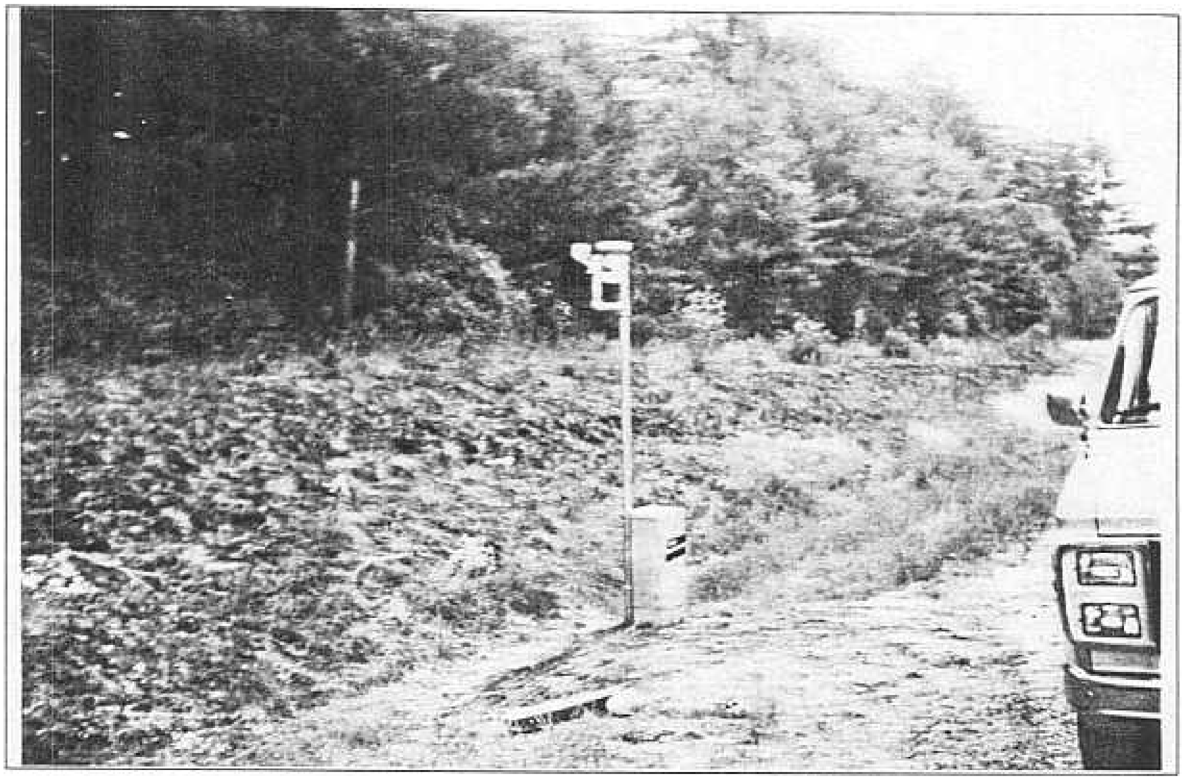


Figure E-2. Equipment Cabinet, Air Temperature Probe, and Rain Gage

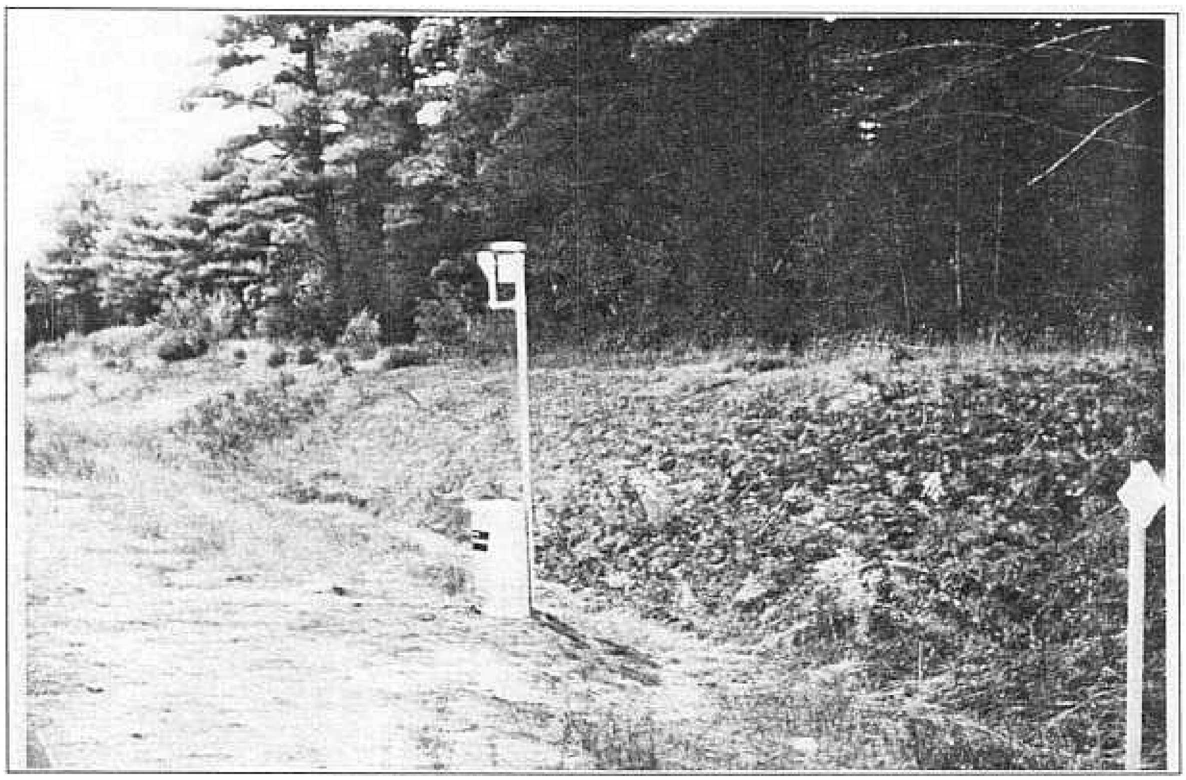


Figure E-3. Equipment Cabinet, Air Temperature Probe, and Rain Gage

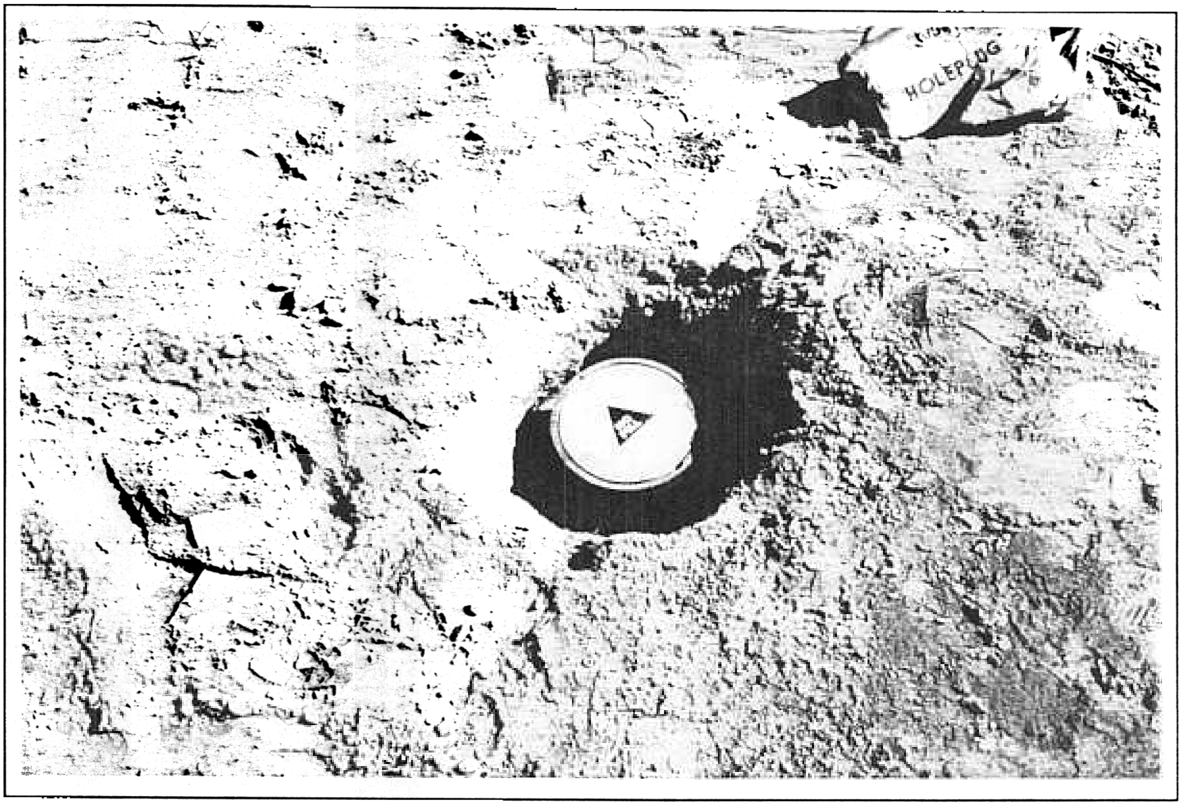


Figure E-4. Observation Well

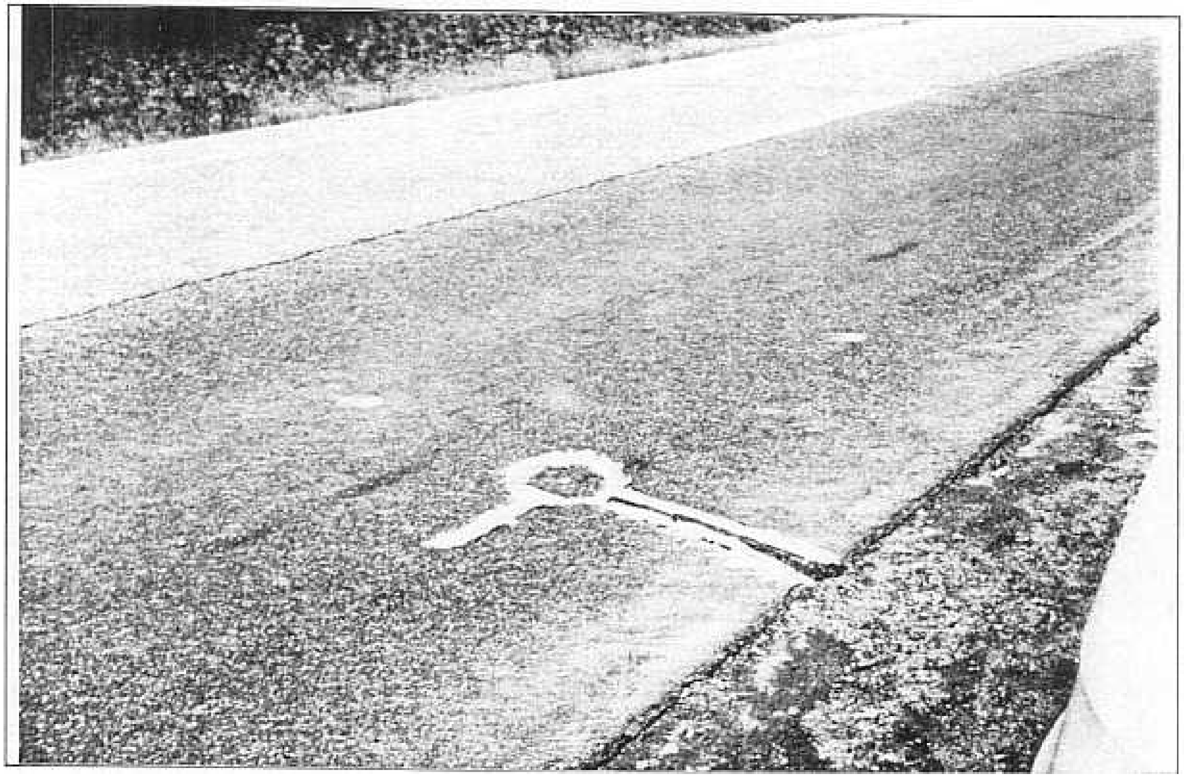


Figure Patch Area, :I Day After ıstall

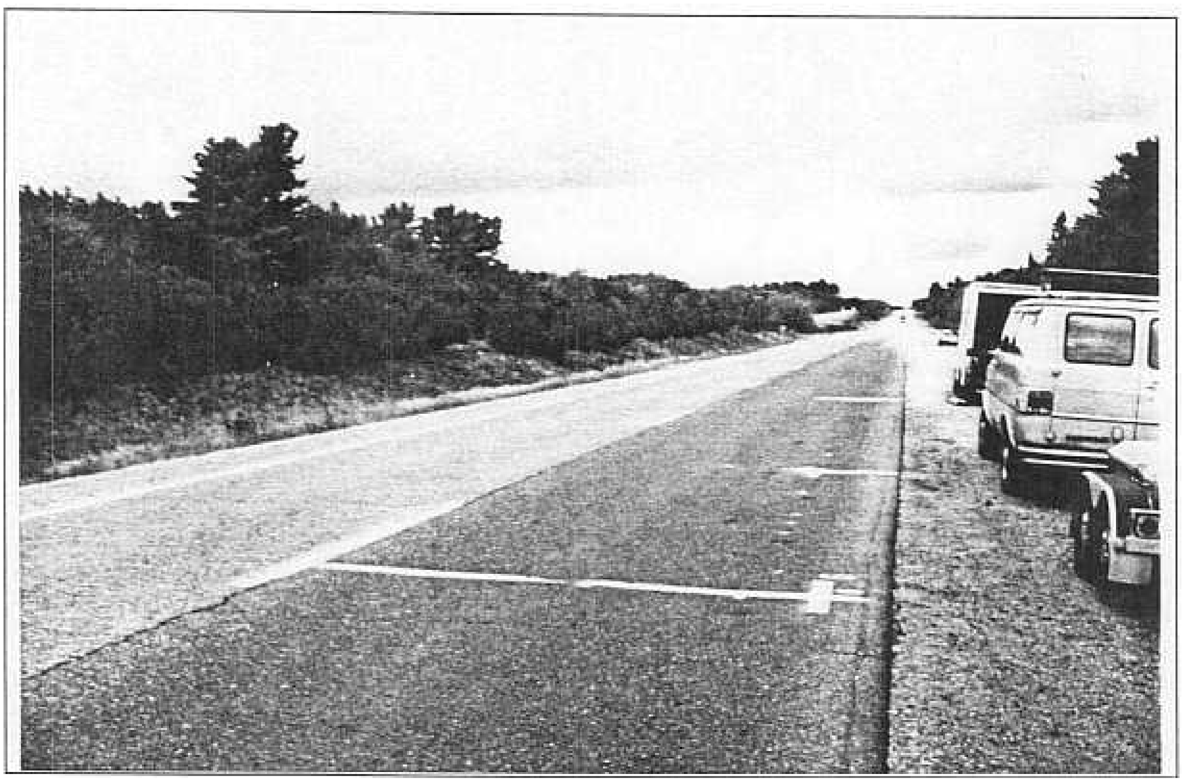


Figure :-6. Patch Area, :he Day After ıstall

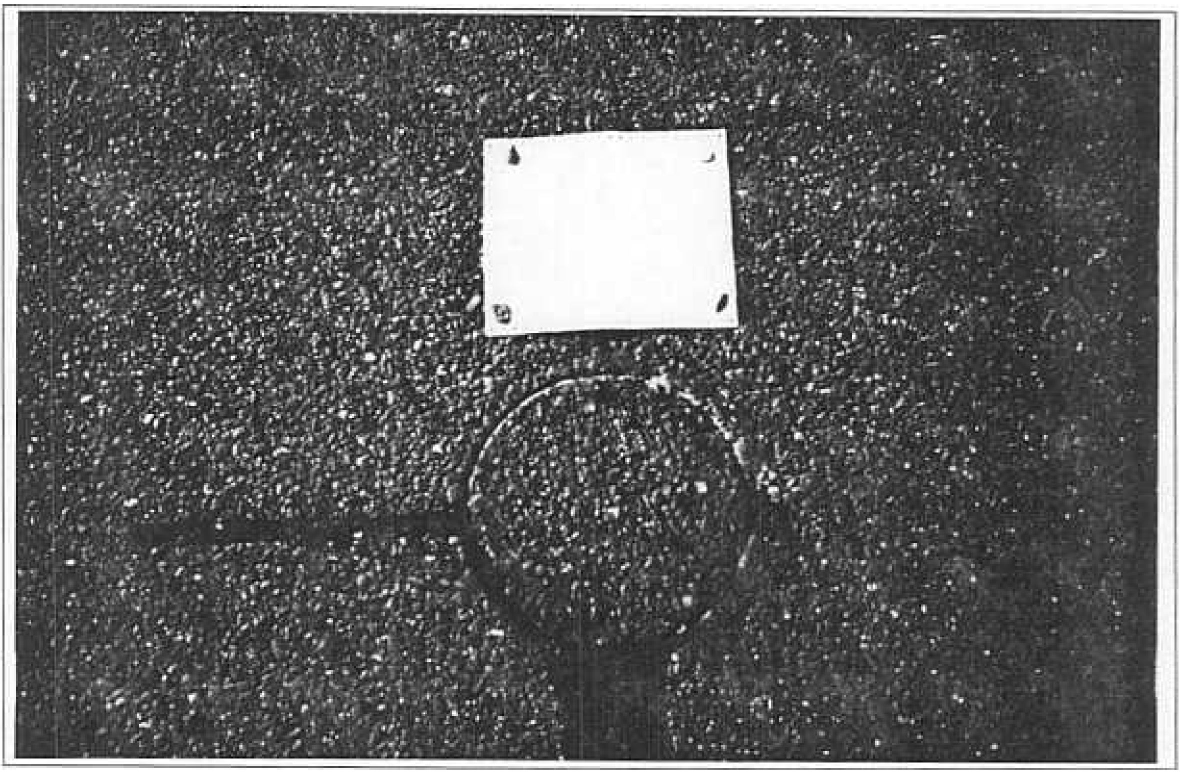


Figure E-7. Patch Area 'wo to Three Months After Installation

Figure E-8 Patch Area, 'wo to Three Months After Installation