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LTPP Seasonal Monitoring Program

Site Installation and Initial
Data Collection
Section 893015 Trois-Rivieres
Quebec

Report No. FHWA-TS-94-89-01

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Notice

LTPP Seasonal Monitoring Program

Site Installation and Initial Data Collection
Section 893015, Trois-Rivieres Quebec

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15. Supplementary Notes

The report is a cooperative effort between Quebec Ministry of Transportation Pavement Management and Design Division, 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 893015 on Route 40 in Trois-Rivieres Quebec. This portland cement concrete surface pavement test section was instrumented on September 29, 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 30, 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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I. Introduction

The installation of instrumentation on seasonal site 893015 near Trois-Rivieres, Quebec was performed on September 29 - September 30, 1993.

The test section is a GPS-3 experiment, located on the westbound outside lane of Route 40, approximately two kilometers east of exit 220 to Route 359. The nearest major city is Trois-Rivieres which is 30 km west (Figure A-1 in Appendix A). The road consists of two 3.7 m wide lanes in each direction with a gravel outside and inside shoulders.

The pavement structure consists of 208 mm of jointed plain portland cement concrete and 338 mm of crushed stone base over a coarse poorly graded sand on muskeg. 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 24 (jointed plain concrete on coarse subgrade) of the seasonal monitoring program. The annual average frost depth is 1.62 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)	790
Precipitation (mm)	894
No. of Freeze/Thaw Cycles	62
Days Above 32C	2
Days Below 0C	171
Wet Days	145

The road was opened to traffic in 1984. The estimated annual truck volume on the GPS lane is 169755. The estimated annual ESALs on the GPS lane, using vehicle ESALs, is 137 KESALs. These figures are based on 171 days of WIM data in 1992.

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

Marc Ebacher	MEI (Core and Saw Cut Contractor)
Luhl Purhumie	MTQ
Jean-Pierre Leroux	MTQ
Jacques Landry	MTQ
Leon SyRatke	MTQ
Louis Caderre	MTQ
Claude Jusir	MTQ
Jormal Corette	MTQ
John Klemunes	FHWA
Brandt Henderson	Pavement Management Systems (NARO)
Perry Zabaldo	Pavement Management Systems (NARO)
Mike Zawisa	Pavement Management Systems (NARO)
Doug Marshall	Pavement Management Systems (NARO)
Scott Comstock	Pavement Management Systems (NARO)

Table 1. Material Properties

Description	Surface	Base	Subgrade **
Material (Code)	Portland Cement Concrete JPCP (04)	Crushed Stone (303)	Poorly Graded Sand (202)
Thickness (mm)	208	338	
Lab Max Dry Density (kg/m^3)		2190	1765
Lab Opt Moisture Content (%)		6.5	12.0
In-situ Wet Density (kg/m^3) *			
In-situ Dry Density (kg/m^3) *			
In-situ Moisture Content (%) *			
Bulk Specific Gravity			
Max Specific Gravity			
Liquid Limit		0	0
Plastic Limit		0	0
Plasticity Index		NP	NP
% Passing # 200		4.2	2.9

* Note: Not collected for PCC pavements.

** Note: Actually fill material over Muskeg.

II. Instrumentation Installation

Site Inspection and Meeting with MTQ

A site inspection was done on July 21, 1992 in conjunction with the FWD uniformity survey. The review was conducted by Brandt Henderson (NARO) and Guy Bergeron (MTQ). The FWD survey was conducted over two days due to a minor mishap to one of the traffic control operators while adjusting a portable arrow board. An inspection of the pavement surface indicated some moderate to severe longitudinal cracking, mainly in the midlane, and moderate spalling of the transverse joints. The midlane crack appears to be associated with some settling of the fill material which resides on muskeg. The FWD uniformity survey indicated the section to be acceptable from a deflection stand point, although some midlane test locations would not represent the integrity of the total slab due to the midlane crack. There were no plans for rehabilitation of this section in the immediate future. The east end (0+00) of the site was selected for installation of instrumentation as the west end of the site was close to the sign structure announcing the upcoming exit.

This location receives extensive amounts of snowfall and below freezing temperatures which will provide pavement response information on portland cement concrete pavements under extreme environmental conditions.

A preliminary planning meeting was held with MTQ officials on September 10, 1993 at the Ministry of Transportation facility, 200 Dorchester South, Quebec, QE. A list of the attendees at this meeting are shown in Appendix B. A presentation on the installation of seasonal monitoring instrumentation and monitoring requirements were provided by Bill Phang and Brandt Henderson of Pavement Management Systems (LTPP-NARO). This was followed by a review and discussions on the selected seasonal site. Plans for the installation on September 29-30, 1993 were discussed, which covered tasks to be done by MTQ 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 morning of October 12, 1993 at the District 32 maintenance facility office, 800 Rue Houssand, Cap-De-La-Madeleine, Quebec. Plans for the following day were discussed along with a verification check of the equipment to be used for coring the portland cement concrete, augering the instrument hole, cutting the trench to the instrumentation cabinet, cover for the piezometer, and the various supplies necessary to complete the installation and patch the pavement. Information on the permanent bench mark installed near station 2+50 was provided along with the tools required to assess the reference rod. Information on the permanent bench mark is provided in Figure B-1 of Appendix B. Arrangements were made to have traffic control setup for 0800 hours with the sawing and cutting contractor and MTQ drilling crew 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	89AT
CRREL Resistivity Probe	1	89AR
TDR Probes	10	89A01-89A10
Equipment Cabinet		
Campbell Scientific CR10 Datalogger	1	16559
Campbell Scientific PS12 Power Supply	1	5646
Weather Station		
TE525MM Tipping Bucket Rain Gage	1	12096-693
Campbell Scientific 107-L Air Temperature Probe	1	89AAT
Observation Well/Bench Mark	1	N/A
Permanent Bench Mark (Elevation 111.827 m)	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 99 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. The results of these measurements are also shown in Appendix B. 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.

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 28, 1993. The installation was confirmed for 0800 hours. on September 29, 1993. Traffic control for the installation and monitoring was provided by MTQ District 32, Cap-De-La-Madeleine. The pavement surface drilling and sawing of the trench were done by Marc Ebacher of MEI. The augering of the piezometer and instrumentation hole was done by agency equipment and drilling crew under the supervision of Jacques Landry, drilling crew chief. The installation of the measurement equipment, the observation piezometer, weather station pole, and cabinet was performed by PMSL staff. Assistance was provided by John Klemunes, FHWA-LTPP Division, Jean-Pierre Leroux and Michele Lachance, MTQ Pavement Management and Design Division, and local division personnel.

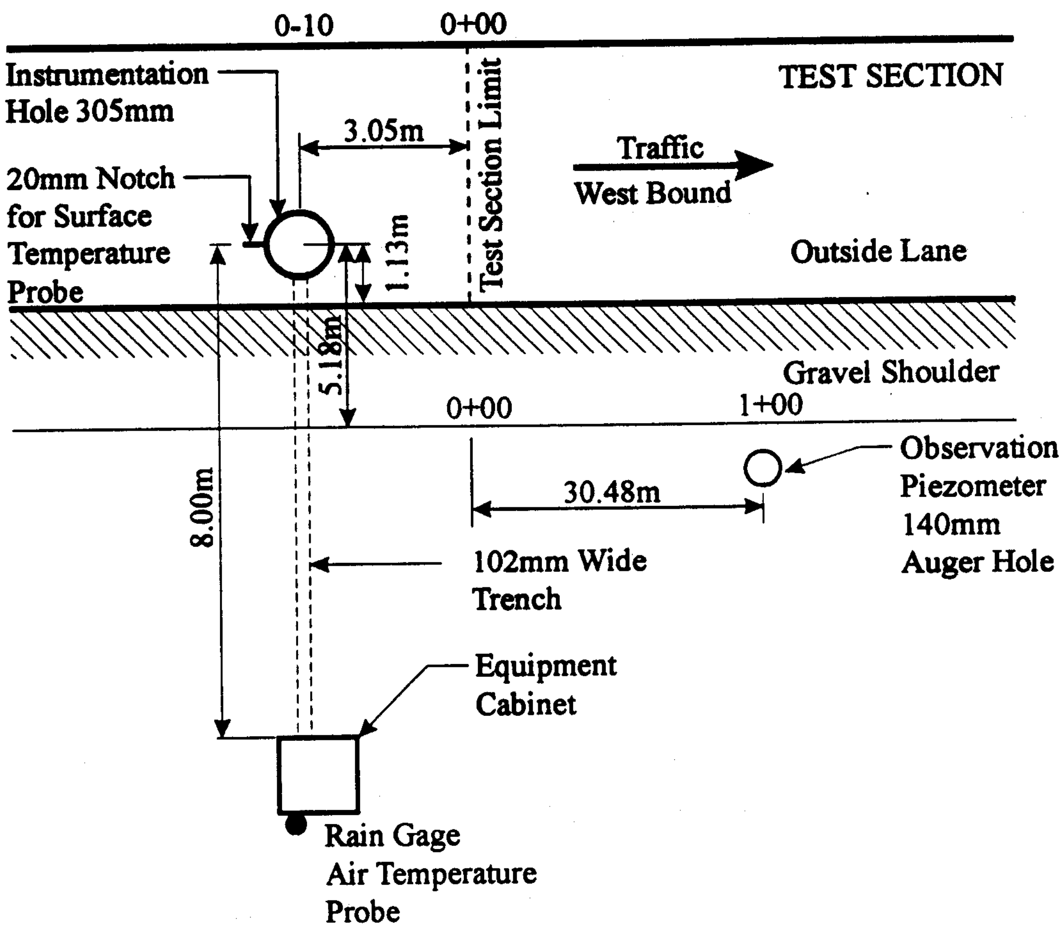
The instrumentation was installed on the east end of GPS 893015, in the outside lane of westbound Route 40 near Trois-Rivieres, Quebec. The combination benchmark/piezometer was placed in the shoulder at station 1+00. The in-pavement instrumentation was installed in the outer wheel path at station 0-10. 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 on the slope of the roadway embankment, 8.0 m from the instrumentation hole. 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 4.06 m from the edge of the pavement at station 1+00 to a depth of 4.29 m using a 152 mm flight auger for drilling the hole. Water was encountered approximately 2 m below the surface where the auger went from the sandy fill material into the underlying muskeg. The material removed from the remainder of the hole was highly organic and wet. A sample of the material was retained from approximately 0.5 to 1.5 m below the surface. The 25.4 mm galvanized pipe was firmly pressed into the hole, followed by 1.9 m of filter sand, a 0.33 m bentonite plug with the remainder of the hole filled with the native material removed. The final elevation for the pipe was 254 mm below the natural ground level at the location of the installation. A water shut off access cover, 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, 1.13 m from the edge of the travel lane at station 0-10, using a portable electric drill and a 305 mm thin wall diamond core barrel. A 102 mm wide by 225 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 east edge of the core hole. The remainder of the material from the trench was removed with a pick and shovel.

A combination of methods were used to excavate the instrumentation hole. The 23 mm minus crushed granular base was scraped out with a hand shovel. The driller used a 251 mm flight auger to loosen the gravely subbase material which contained stones of up to 50 mm. Some of the stones encountered appeared to be crushed but this could have been done by the augering. This material was also removed by hand. The fill material below the granular subbase was removed in three 400 mm lifts to a depth of 2.05 m A black organic material with traces of roots and vegetation was encountered at 1.98 m The water table was also encountered at this level. The findings from the excavation of the instrumentation hole at station 0-10 are presented in Figure 2. The materials and thicknesses appear to be slightly different from those encountered during the drilling and sampling performed in 1989.

All the material excavated from the instrumentation hole was placed and compacted in order of removal. No additional material remained from the instrument hole with some material from the trench area required to top up and level the instrumentation hole. Samples of material placed around the TDR probes were retained 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 at an MTQ laboratory. Material sampled at the location of probe 10 contained some organic and root material for which no moisture determination was done. The excavation of the trench went fairly smooth as the material was generally a clean sand without cobbles or boulders. The wiring of the instrumentation to the equipment cabinet was completed on the same day as installed. The set 45 patching compound used to replace the concrete at the instrumentation hole did not fully set prior to opening the lane to traffic, which resulted in some of the surface material disintegrating due to traffic action.



- Height of Air Temperature Probe (center): 3.43m
- Height of Tipping Bucket Rain Gage (center): 3.35m
- Total Depth of Piezometer: 4.29m
- Distance of Piezometer Below Ground Level: 254mm

Figure 1. Location for Seasonal Monitoring Instrumentation Installed at GPS 893015

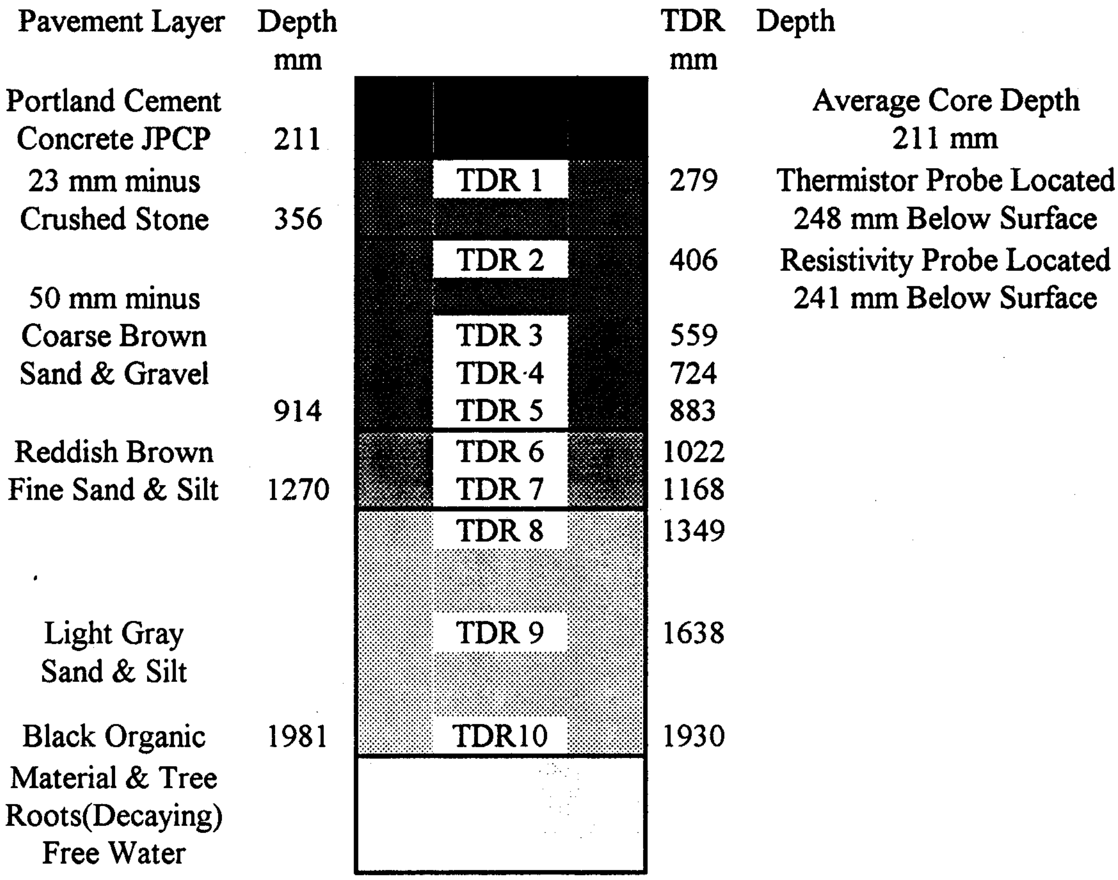


Figure 2. Profile of Pavement Structure and Probe Depths from Surface, Station 0-10

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 0.248 m and the resistivity probe 0.241 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 contents from the TDR traces, field, and laboratory determination, indicated slightly higher moisture content values for the TDR method with the exception of probe number 5, which is near the interface of the subbase and subgrade material. The laboratory moisture contents are also somewhat less than the field moisture contents which may indicate some loss of moisture in the handling process. The moisture profiles from each method indicate similarities in that there is a match between the drier and wetter materials. It should be noted that the calculation of moisture content from TDR method is also 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
89A01	0.279	Base
89A02	0.406	Subbase
89A03	0.559	
89A04	0.724	
89A05	0.883	
89A06	1.022	Subgrade (Fill Material)
89A07	1.168	
89A08	1.349	
89A09	1.638	
89A10	1.930	

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	0.106	
	3	0.186	
2	4	0.262	This unit was installed below the AC layer into the subgrade.
	5	0.339	
	6	0.418	
	7	0.493	
	8	0.569	
	9	0.721	
	10	0.876	
	11	1.028	
	12	1.179	
	13	1.330	
	14	1.483	
	15	1.634	
	16	1.792	
	17	1.940	
	18	2.091	

Table 5. Location of Electrodes of the Resistivity Probe

Connector Pin Number	Electrode Number	Depth from Pavement Surface (m)
36	1	0.272
35	2	0.321
34	3	0.371
33	4	0.421
32	5	0.472
31	6	0.522
30	7	0.575
29	8	0.624
28	9	0.674
27	10	0.726
26	11	0.776
25	12	0.827
24	13	0.876
23	14	0.927
22	15	0.979
21	16	1.030
20	17	1.080
19	18	1.130
18	19	1.181
17	20	1.232
16	21	1.284
15	22	1.334
14	23	1.383
13	24	1.435
12	25	1.487
11	26	1.537
10	27	1.588
9	28	1.638
8	29	1.689
7	30	1.739
6	31	1.789
5	32	1.841
4	33	1.891
3	34	1.942
2	35	1.992
1	36	2.043

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)*
89A01	0.279	Base	9.57%	7.57%	6.40%
89A02	0.406	Subbase	7.89%	6.50%	3.30%
89A03	0.559		5.98%	4.38%	3.10%
89A04	0.724		5.71%	5.68%	5.60%
89A05	0.883		6.25%	8.80%	7.80%
89A06	1.022	Subgrade	10.91%	10.28%	8.208%
89A07	1.168		9.17%	7.16%	6.70%
89A08	1.349		12.32%	9.89%	9.10%
89A09	1.638		13.72%	13.01%	12.70%
89A10	1.930		27.69%	**	**

* Note: Raw data given in Appendix C **..Note: No sample due to interference of roots

Site Repair and Cleanup

The instrumentation hole was repaired using a mixture of set 45 cement and a 19 mm crushed graded gravel. This material was mixed in approximately a 50/50 ratio on the surface of the slab adjacent to the instrument hole from which the hole was filled level with the existing surface. The surface was broomed to add texture and blend with the existing surface. On September 30, 1993 the instrument hole patch was examined and found to have lost approximately a third of the surface material. As all the set 45 cement was used for the initial repair, it was necessary to obtain additional patch material locally. An acrylic based patching material which contained a high concentration of sand was used, but this material failed to setup by the end of the day. Prior to leaving the site, this material was removed and a temporary asphalt patch was used to level the surface. For future installation, it is recommended that the core be reinstalled using a rapid setting bonding agent to ensure consistency and integrity of the surface material.

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. Removal of the concrete trench material were handled by the MTQ district personnel. Traffic control was removed at 1800 hours and the lane reopened to traffic.

Patch/Repair Area Assessment

When the site was visited on December 15, 1993 two and a half months after installation, the instrumentation hole patch was checked and a photo was 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 edge of pavement. 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 30 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. The data collected for September 30, 1993 was not sufficient to show change in temperatures. This was due to the fact that the onsite.dld program, that was downloaded to the datalogger, only records hourly averages (only field 5 data collected). The d_onsite.dld, which stores data every minute, should have been used to collect the data.

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 1 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-1 and D-2 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-3 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, two Fluke 87 digital multimeters, to measure voltage and amperage, and a manual electrode switching board. The measured contact resistance data are plotted in Figure D-4 and in Figure D-5 for the 4-point resistivity. Tables D-1 and D-2 in Appendix D show the raw data for the 2-point and the 4-point resistance respectively.

Comparison between Figure D-3 (contact resistance results from automated mode) and Figure D-4 (contact resistance results from manual mode) indicates that the results are similar with the manual method appearing to be more sensitive. These differences can be expected as the voltages applied through the automated multiplexing circuitry (approximately 2.5 vac) and those applied by the Simpson function generator (5 vac or greater) will result in different contact resistance. Figure D-5 (four point resistance results from manual mode) shows a similar but less variable profile as the energy and contact resistance is over a larger area of material. These results from the automated multiplexing circuitry and the manually collected data using the function generator and multimeters are generally in agreement, which would lead us to believe that both methods are providing reasonable results.

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, ten more measurements have been collected with the FWD, the first on November 3, 1993, then on March 29, April 8, April 28, May 19, June 6, July 14, August 11, September 15, and on October 6, 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 17, 1994), the second in the spring season (April 9, 1994), the third in the summer season (July 19, 1994), and the fourth during the fall season (three surveys on October 19, 1994).

Elevation Surveys

One set of the surface elevation survey was performed on September 30, 1993, the day after the installation, and the results are presented in Appendix D. It was assumed that the elevation at the top of the piezometer pipe was 1.000 meters. The stability of the piezometer pipe as a reference will be periodically checked by reading the permanent bench mark installed by MTQ at station 2+50. Since then, six more sets of the surface elevation surveys have been performed, the first on November 3, 1993, then on February 3, April 8, July 14, August 11, and on October 6, 1994.

Water Depth

During the drilling of the piezometer test hole, water was encountered at approximately 1.5 m below ground level, at the piezometer location. As there was significant disturbance from the drilling and installation, some time will be required before the water level in the piezometer stabilizes with the surrounding conditions. Visually, the muskeg on which the pavement structure resides, is water saturated to surface level. At the instrument hole location, water was encountered at the interface of the sand fill with the underlying organic soil (1.98 m).

IV. Summary

The installation of the seasonal monitoring instrumentation at the GPS site 893015 near Trois-Rivieres, QE was completed on September 29, 1993. A check of the equipment and initial data collection was completed on September 30, 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.
- Permanent bench mark installed by MTQ.

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 westbound Route 40, approximately two kilometers east of interchange 220, exit for Route 359. The section is on a divided road consisting of two 3.7 m wide travel lanes in each direction with gravel shoulders. The median between the east and west bound consists of trees and vegetation which are consistent with the surrounding area. The pavement structure consists of 211 mm of portland cement concrete over 145 mm of crushed gravel base and 558 mm of soil aggregate mixture subbase on a fine poorly graded sand and silt fill material. The embankment slopes to existing ground at about 2 meters below grade at the east end of the site where the instrumentation is installed. The pavement is constructed on muskeg, a kind of bog or marsh containing thick layers of vegetation which for the most part is saturated with water.

All instrumentation was checked prior to installation. 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 Omega hand held temperature gage. The temperature profile for the pavement soils appeared reasonable with no outlying sensors. A check of the tipping bucket indicated it was functioning correctly with tips corresponding to amount of water supplied. Although there were differences between the amount of soil moisture from TDR method and gravimetric moisture content, determined from the samples taken, the results were reasonable based on the methods used.

Although the installation generally went as expected and all instrumentation was in working order at the completion, a few problems were encountered, in particular, with the repair of the instrumentation hole. For this installation we decided to restore the pavement surface with a concrete patch versus reinstalling the concrete core removed. This repair took place at 1630 hours in the afternoon using a mixture of approximately 50/50 set 45 concrete mix and 19 mm minus crushed graded aggregate. The lane was opened to traffic at 1800 hours at which time the concrete appeared to have set but, as we found the next day, had not retained enough strength, especially for the heavy traffic using this lane.

An examination of the patch on September 30, 1993 indicated that approximately 150 mm of surface material had been removed from the patch area by traffic action. A subsequent patch using an acrylic modified patch mix failed to setup and had to be removed. A temporary asphalt surface patch was applied until a permanent solution could be implemented. For future installation, especially on high volume heavy traffic facilities, the pavement core should be replaced and bonded in, using a fast setting high strength bonding agent. It is also suggested that the trench cut be repaired in the same manner.

The ongoing monitoring of this section, except for the problems encountered due to weather and technical difficulties with the FWD, has gone fairly well.

APPENDIX A

Test Section Background Information

Appendix A contains the following supporting information:

Figure A-1	Site Location Map
Figure A-2	Profile of Pavement Structure
Table A-1	Site Performance Summary
Table A-2	Uniformity Survey Results
Figure A-3	Deflection Profiles from FWDCHECK (Test Date July 21, 1992)
Table A-3	Volumetric K and Effective Thickness from FWDCHECK (Test Date July 21, 1992)

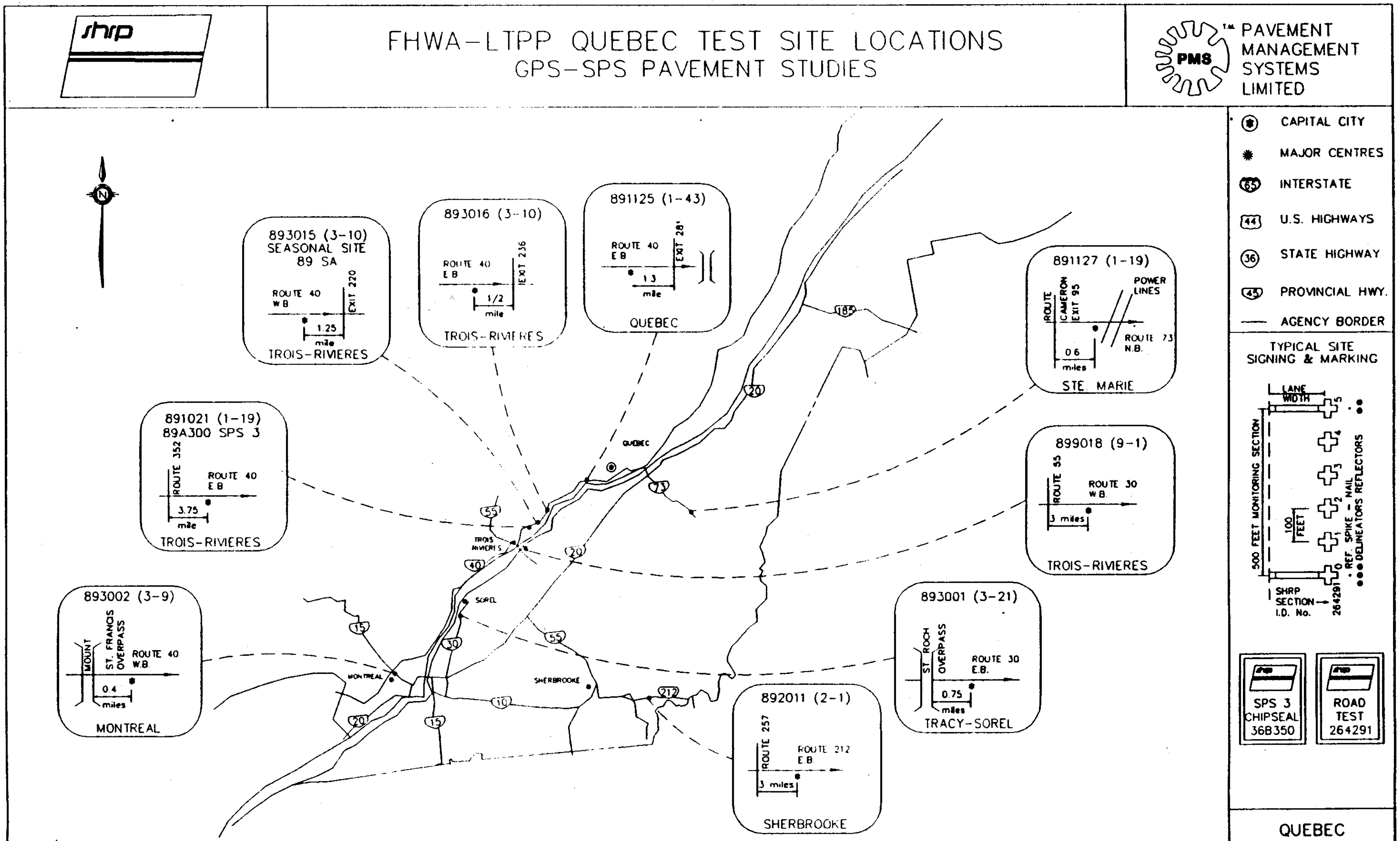


FIGURE A-1 SITE LOCATION MAP - SECTION 893015

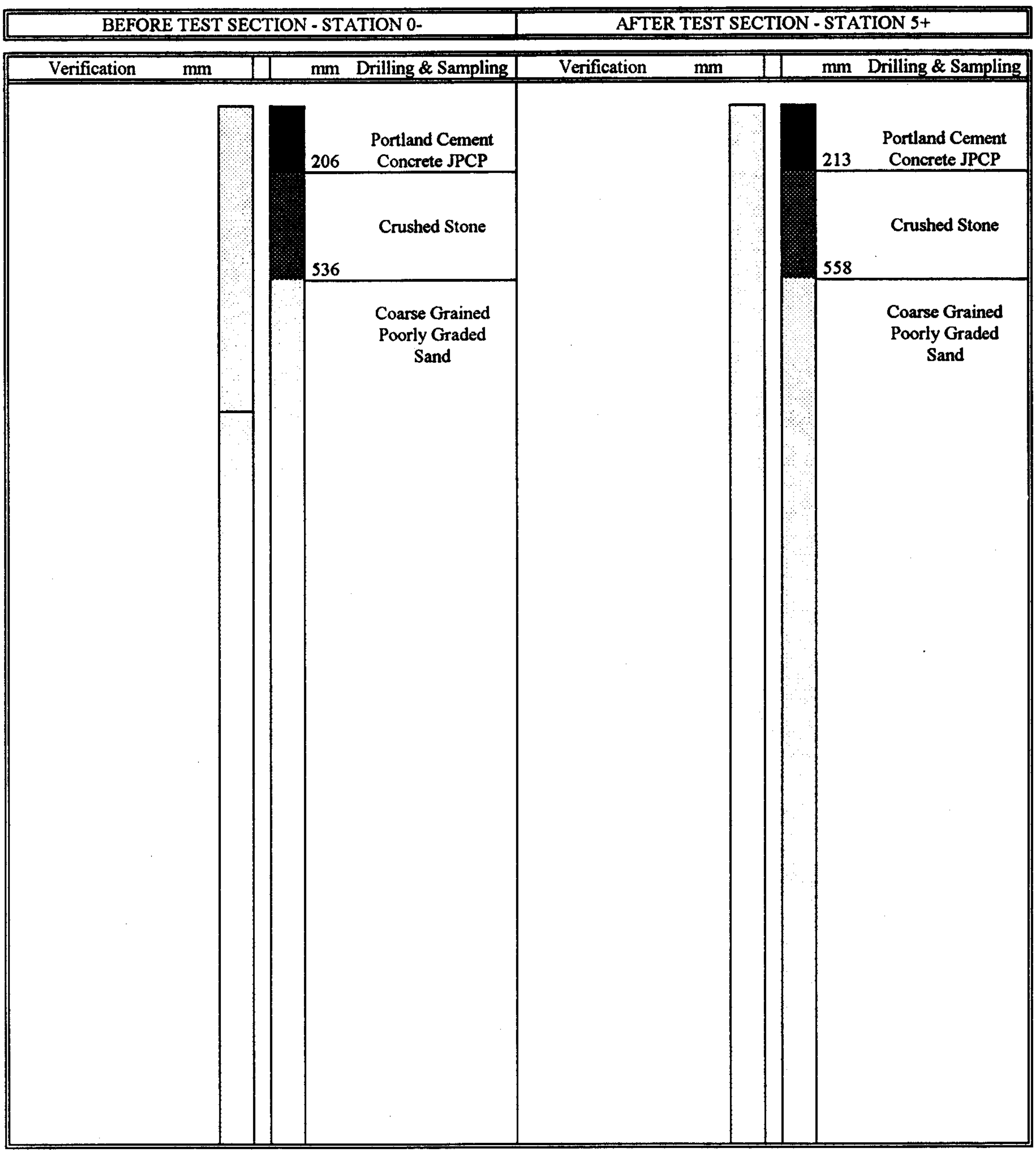


Figure A-2. Profile of Pavement Structure

Table A-1. Site Performance Summary

Distress and Profile Summary		
Distress Summary 1989	Profile Summary	
	Date (mm-dd-yy)	IRI (in/mi)
High Sev. Corner Break - 1	09-23-89	73.80
Mod. Sev. Long. Cracks - 183.99 ft.	06-25-90	94.68
Low Sev. Long. Cracks - 41.35 ft.	07-16-91	95.84
Low Sev. Trans. Cracks - 1 @ 4.13 ft.	08-26-92	106.44
Mod. Sev. Spalled Long. Joints - 1.03 ft.	08-12-93	104.70
Low Sev. Spalled Long. Joints - 2.07 ft.		
Mod. Sev. Spalled Tran. Jts - 3 @ 13.44 ft.		
Low Sev. Spalled Tran. Jts - 9 @ 17.57 ft.		
Mod. Sev. AC Patch - 1 @ 5.17 sq. ft.		
Low Sev. AC Patch - 10 @ 42.38 sq. ft.		

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)
07-10-90	8.80	9.77	2.97	0.41	84	80/92
07-21-92	7.43	1.38	3.30	0.61	85	75/92

	Effective Thickness	Effective Thickness std. dev.	Volumetric K	Volumetric K std. dev.	Test Pit Volum. K	
					1	2
07-10-90	7.39	1.49	157	23	199	222
07-21-92	7.31	0.47	140	23	-	-

Table A-2. Uniformity Survey Results

Seasonal Uniformity Survey Site Number: 893015 Date Surveyed: July 21, 1992	Falling Weight Deflectometer Data Collection and 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	Volum. K	Volum. K std dev	Effective Thick.	Effective Thick. std dev
-100 - 0	7.99	0.19	3.68	0.19	122	5	7.20	0.05
0 - 250	7.54	1.39	3.28	0.65	140	24	7.23	0.46
250 - 500	7.24	1.46	3.33	0.61	140	24	7.44	0.51
500 - 600	8.24	2.39	3.60	0.95	131	37	7.16	0.76

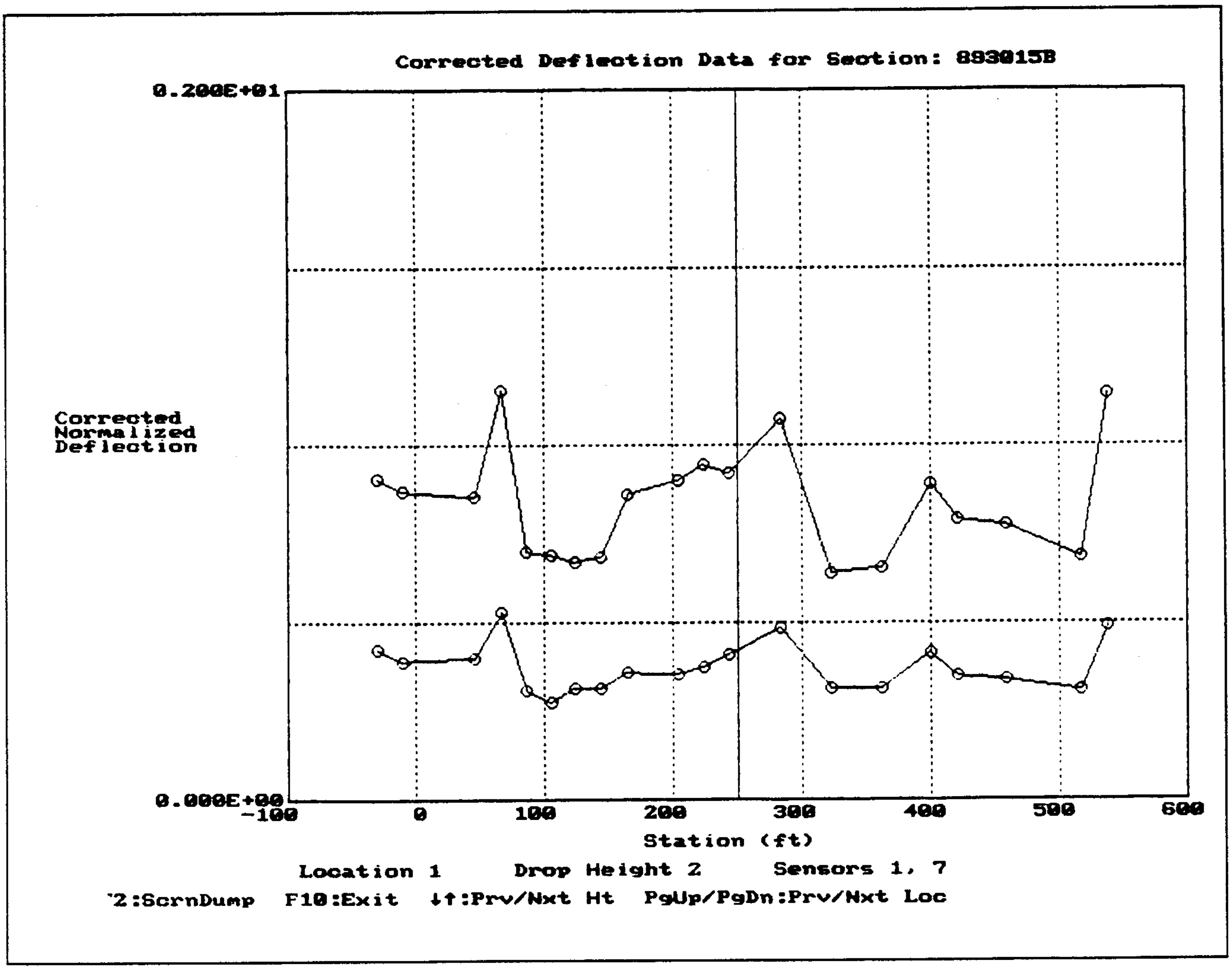


Figure A-3. Deflection Profile from FWDCHECK
(Test Date July 21, 1992)

Table A-3. Volumetric K and Effective Thickness from FWDCHECK
(Test Date July 21, 1992)

Rigid Pavement Thickness Statistics - 893015B - Drop Height 2			
Subsection	Station	Volumetric K	Effective Thickness
1	46	128	7.25
	66	95	6.55
	86	161	7.63
	106	174	7.53
	124	162	7.81
	144	159	7.81
	164	136	7.06
	204	136	6.88
	224	130	6.69
	243	122	7.06
2	283	103	6.69
	323	164	8.00
	362	163	8.00
	400	122	7.16
	421	141	7.44
	459	148	7.34
Subsection 1	Overall Mean	140	7.23
	Standard Deviation	24	0.46
	Coeff. of Variation	16.92%	6.31%
Subsection 2	Overall Mean	140	7.44
	Standard Deviation	24	0.51
	Coeff. of Variation	17.24%	6.81%

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

APPENDIX B

Supporting Site Visit and Installed Instrument Information

Appendix B contains the following supporting information:

BH

PMS™ 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:**	May 07, 1992
		PROJECT:	50450732
		FILE:	6.01
FROM:	Bill Phang *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

PAVEMENT
MANAGEMENT
SYSTEMS

MEMORANDUM

TO: Guy Dore, QE
Dick Haupt, VT
Warren Foster, ME
Alan Rawson,. NH
Charles Dougan, CT

DATE: June 29, 1992

PROJECT: 50450732

FROM: Bill Phang Bill Phang

FILE: 6.01

SUBJECT: Seasonal Testing
Preliminary FWD Investigation

COPIES TO: See Below

One of the findings of the seasonal testing pilot at Syracuse, NY was that the FWD results near the points where the sensors were installed outside of the test section were somewhat different to results within the GPS test section.

It was subsequently decided that for future seasonal testing installations, a preliminary FWD test series would be conducted in the areas adjacent to the test sections. This would help to fix on a location for sensor installation that more closely represents the part of the test section being monitored for seasonal effects.

The FWD has been scheduled to carry out these preliminary tests beginning July 21 at GPS 893015 in Trois Riviere, QE. Other sites are 501683 in Charlotte, VT, on July 24, 237028 in Bethel, ME on July 28, 331001 in Concord, NH on July 29 and 091803 in Groton, CT July 30.

A copy of the FWD schedule is attached. Would you please make necessary arrangements for traffic control. Please call Brandt Henderson of you have any questions.

<u>Distribution to:</u>
I.J. Pecnik
B. Henderson

PMS™ PAVEMENT
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SYSTEMS

ORIGINAL

August 2, 1993
50450925-~~10.01~~ 12.05.2

Mr. Guy Doré
Ministere des Transports
de Quebec
200 Dorchester Sud, 3e Etage
Downsview, Ontario M3M 1J8

RE: **Seasonal Testing - Installation of Instrumentation**

Dear ~~Mr.~~ Guy ~~Dore~~,

The FHWA-LTPP Division plans for establishing seasonal monitoring of selected GPS sites is now at the stage where installation of instrumentation can proceed. The sensor probes, cable connectors, read out devices, data loggers, and equipment cabinets are all acquired and are available for distribution to selected sites. A sample equipment assembly was recently calibrated and put together at the Turner-Fairbanks laboratories and successfully programmed to collect data at specific intervals. Installation and operational manuals are in preparation. A pilot installation in Colorado was completed in June, 1993.

A preliminary planning meeting with the participating agency is needed to familiarize appropriate agency staff with details of the instrumentation, with their roles and responsibilities, with traffic control requirements, with drilling equipment requirements, and with the roles and responsibilities of the FHWA-LTPP Division, Regional Office (NARO) staff, and others involved.

A sample agenda is at attachment A. During or subsequent to this preliminary meeting, tasks, team assignments, contacts, and schedules will be formulated/determined/designated.

Weather permitting, installation is expected to be completed in one full day (8am-4pm). Completion of wiring and collection of the first complete round of monitoring data is planned for the following day (8am-4pm). Traffic control will be needed on both days.

Seasonal Monitoring Program Guidelines describing these installation activities are still in draft form.

The preliminary planning meeting date, the installation meeting on the day prior to installation, and the scheduled day for installation at your site are shown on attachment B, (please note revised dates). Please let me know if you need to change these dates. I will be calling you to finalize arrangements for the planning meeting.

Attachment C consists of extracts from the draft Manual on installation, intended to provide some information of the instrumentation, the installation, and the agency responsibilities. The final Manual is expected to be ready in a few weeks.

Yours Sincerely,
PAVEMENT MANAGEMENT SYSTEMS LIMITED

William A. Phang.

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

BP/tf

c.c. J. P. Leroux
I.J. Pecnik w/attach B
A. Lopez w/attach B
B. Henderson w/attach B

QUEBEC SEASONAL TESTING

NAME	AFFILIATION	TELEPHONE NUMBER
Bertrand Cornier, ing.	M.T.Q.	
Serge Lepage	Stogiaire	
Guy Bergeron, ing.	M.T.Q.	
Nelson Rioux, ing.	M.T.Q.	
Aristide Gobail, Ing.	Chef de service	Office 643-1131 Home 650-2988
* Serge Kirouac, tech.	M.T.Q.	Office 646-2408 Home 682-2687
Alain Levesque, ing.	M.T.Q.	
* Michael Lachance, tech.	M.T.Q.	Office 643-1086 Home 875-3767
Jean-Marie Konrad, ing.	Universite' Loval	
* Jean-Pierre Leroux, ing.	M.T.Q.	Office 646-4068 Home 651-9577

* People who will probably be on the site when the installation is being done.

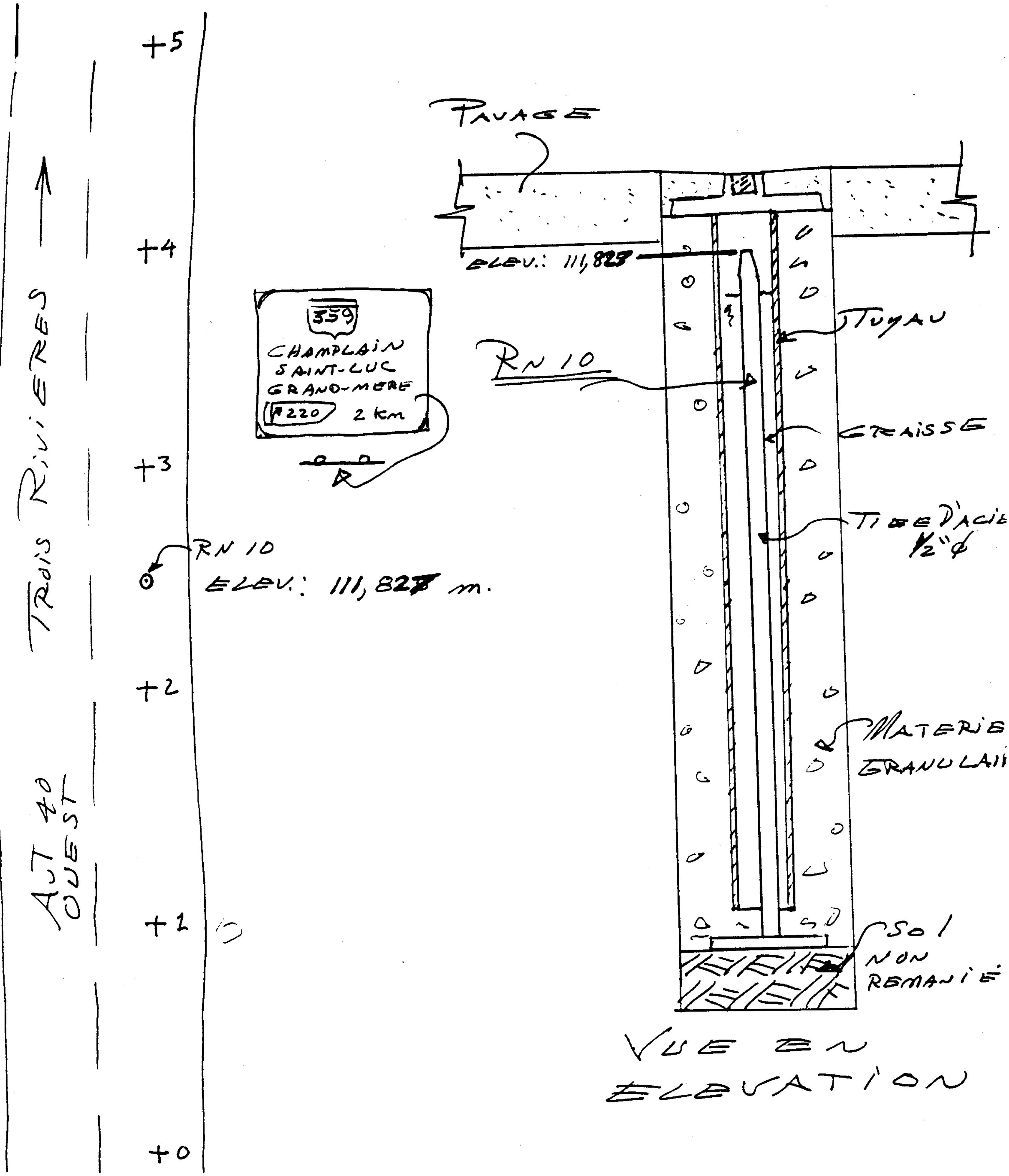


Figure B-1. Bench Mark Location as Prepared by MTQ Staff

Table B-1. Air Temperature Thermistor Calibration

LTPP Seasonal Monitoring Study	State Code	[8 9]
Air Temperature Thermistor Calibration	Test Section Number	[3 0 1 5]

Before Operation Checks	Calibration Date mm-dd-yy	09-28-93
	Probe S/N	89AAT
	Operator	MZ

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
13.10	10.75	22.76	17.30	1452	0.143	1345	43.40	1525	y

Probe Accepted	PZ&MZ	(Initials)

Table B-2. MRC Probe Calibration

LTPP Seasonal Monitoring Study	State Code	[89]
MRC Probe Calibration	Test Section Number	[3015]

Before Operation Checks	Calibration Date mm-dd-yy	09-28-93
	Probe S/N	89AT
	Operator	PZ & MZ

	Mobile Datalogger (24 hour)			Water Room Temp Time 1452	Ice Bath 0 C(+/- 1 C) Time 1345	Hot Water 50 C (+/-) Time 1525	ok
No.	Mean	Min.	Max.	Reading	Reading	Reading	y/n
1	13.8	10.57	27.51	17.2	0.15	44.9	y
2	13.9	10.49	29.54	17.2	0.04	44.8	y
3	13.6	10.37	27.81	17.2	0.15	44.4	y
4	14.3	11.02	36.24	17.4	1.51	38.5	y
5	14.5	11.07	36.41	17.4	0.67	38.7	y
6	14.6	11.05	36.95	17.4	0.48	40.2	y
7	14.5	10.93	36.74	17.4	0.37	40.1	y
8	14.5	10.90	37.08	17.4	0.37	40.6	y
9	14.4	10.87	37.35	17.3	0.26	40.8	y
10	14.4	10.80	38.14	17.2	0.41	41.1	y
11	14.4	10.70	39.33	17.1	0.45	42.2	y
12	14.3	10.57	37.98	17.0	0.56	42.4	y
13	14.2	10.51	37.95	17.0	0.45	42.5	y
14	14.2	10.46	36.47	16.9	0.38	43.3	y
15	14.1	10.37	39.20	16.9	0.38	43.3	y
16	14.2	10.40	40.89	16.9	0.31	43.5	y
17	13.9	10.22	40.57	16.9	0.23	43.1	y
18	13.2	9.57	38.08	16.9	0.34	41.7	y

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

Thermistor distance from top of probe:				(meters)					
4	.014	7	.245	10	.628	13	1.082	16	1.544
5	.091	8	.321	11	.780	14	1.235	17	1.692
6	.170	9	.473	12	.931	15	1.386	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	.014	1.851 m long by 25.4 mm PVC tube installed in the base and subgrade.
	5	.091	
	6	.170	
	7	.245	
	8	.321	
	9	.473	
	10	.628	
	11	.780	
	12	.931	
	13	1.082	
	14	1.235	
	15	1.386	
	16	1.544	
	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)			Dist. from Top (m)
				Line 1	Line 2	Avg.	
36	1	x	Top-1	29	32	30.5	.031
35	2	x	1-2	51	48	49.5	.080
34	3	x	2-3	50	50	50.0	.130
33	4	x	3-4	49	50	49.5	.180
32	5	x	4-5	52	51	51.5	.231
31	6	x	5-6	50	50	50.0	.281
30	7	x	6-7	52	54	53.0	.334
29	8	x	7-8	49	48	48.5	.383
28	9	x	8-9	50	51	50.5	.433
27	10	x	9-10	51	52	51.5	.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	49	50	49.5	.635
23	14	x	13-14	50	52	51.0	.686
22	15	x	14-15	52	51	51.5	.738
21	16	x	15-16	51	51	51.0	.789
20	17	x	16-17	51	50	50.5	.839
19	18	x	17-18	50	50	50.0	.889
18	19	x	18-19	50	51	50.5	.940
17	20	x	19-20	51	52	51.5	.991
16	21	x	20-21	52	51	51.5	1.043
15	22	x	21-22	50	51	50.5	1.093
14	23	x	22-23	49	49	49.0	1.142
13	24	x	23-24	52	51	51.5	1.194
12	25	x	24-25	52	52	52.0	1.246
11	26	x	25-26	50	50	50.0	1.296
10	27	x	26-27	51	51	51.0	1.347
9	28	x	27-28	50	51	50.5	1.397
8	29	x	28-29	51	51	51.0	1.448
7	30	x	29-30	50	50	50.0	1.498
6	31	x	30-31	50	50	50.0	1.548
5	32	x	31-32	52	51	51.5	1.600
4	33	x	32-33	50	51	50.5	1.650
3	34	x	33-34	51	51	51.0	1.701
2	35	x	34-35	50	50	50.0	1.751
1	36	x	35-36	50	51	50.5	1.802
			36-End	27	26	26.5	1.828

Table B-5. Contact Resistance Calibration

LTPP Seasonal Monitoring Study					State Code		[89]
Data Sheet R1							
Contact Resistance Measurements					Test Section Number		[3015]
1. Date (Month - Day - Year)							[09-28-93]
2. Time Measurements Began (Military)							[1605]
3. Comments							In Salt Water Prior to Installation
Test Position	Connections		Voltage (ACV)		Current (ACA)		Notes
	I V	I V	Range Setting	Reading	Range Setting	Reading	
1	1	2	mV	210.5	uA	134.5	
2	3	2	mV	212.1	uA	130.6	
3	3	4	mV	210.9	uA	132.4	
4	5	4	mV	215.9	uA	124.7	
5	5	6	mV	215.6	uA	125.3	
6	7	6	mV	216.0	uA	124.1	
7	7	8	mV	211.4	uA	130.4	
8	9	8	mV	216.3	uA	123.3	
9	9	10	mV	217.7	uA	121.0	
10	11	10	mV	214.2	uA	125.6	
11	11	12	mV	217.0	uA	121.6	
12	13	12	mV	214.7	uA	124.7	
13	13	14	mV	215.1	uA	123.8	
14	15	14	mV	216.9	uA	120.8	
15	15	16	mV	217.5	uA	119.7	
16	17	16	mV	219.1	uA	117.6	
17	17	18	mV	220.3	uA	115.7	
18	19	18	mV	219.1	uA	117.2	
19	19	20	mV	221.1	uA	113.9	
20	21	20	mV	219.9	uA	115.4	
21	21	22	mV	219.3	uA	116.2	
22	23	22	mV	219.7	uA	115.7	
23	23	24	mV	221.3	uA	113.3	
24	25	24	mV	221.5	uA	112.8	
25	25	26	mV	219.7	uA	115.2	
26	27	26	mV	221.0	uA	113.0	
27	27	28	mV	220.5	uA	113.7	
28	29	28	mV	221.5	uA	112.0	
29	29	30	mV	221.1	uA	112.5	
30	31	30	mV	220.6	uA	113.1	
31	31	32	mV	222.9	uA	109.5	
32	33	32	mV	223.7	uA	108.3	
33	33	34	mV	223.6	uA	108.2	
34	35	34	mV	221.4	uA	111.4	
35	35	36	mV	224.4	uA	106.9	
36	37	38	mV		uA		
37	38	39	mV		uA		
38	39	40	mV		uA		
Preparer :	PZ & MZ				Employer :	PMSL	

Table B-6. TDR Probes Calibration

LTPP Seasonal Monitoring Study	State Code		[89]
TDR Probes	Test Section Number		[3015]

Before Operation Checks	M.Z.	Initial	Calibration Date (mm-dd-yy)	09-12-93
			Seasonal Site	89SA

No.	Probe (S/N)	Resistance (ohms) Core	Resistance (ohms) Shield	Probe Shorted Begin Length	Probe Shorted End Length	Air Begin Length	Alcohol Begin Length	Water Begin Length
1	89A01	0.60	0.70	16.190	16.370	16.190	16.220	16.220
2	89A02	0.70	0.50	16.180	16.370	16.180	16.210	16.210
3	89A03	0.50	0.50	16.700	16.880	16.700	16.730	16.730
4	89A04	0.60	0.70	16.200	16.390	16.200	16.240	16.240
5	89A05	0.60	0.50	16.700	16.880	16.700	16.730	16.730
6	89A06	0.70	0.50	16.180	16.360	16.180	16.210	16.210
7	89A07	0.70	0.50	16.200	16.370	16.200	16.220	16.220
8	89A08	0.50	0.60	16.150	16.330	16.150	16.180	16.180
9	89A09	0.70	0.50	16.720	16.900	16.720	16.760	16.760
10	89A10	2.70	0.70	16.690	16.870	16.690	16.720	16.720

NOTE: Record lengths from TDR

Calculation of Dielectric Constant

Probe Length .203 m

V_p Setting .99 V_p

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

No.	Air TDR Length	Air Dielectric Constant	Air In Spec. (?)	Alcohol TDR Length	Alcohol Dielectric Constant	Alcohol In Spec. (?)	Water TDR Length	Water Dielectric Constant	Water In Spec. (?)
1	.20	0.97	y	1.19	34.4	y	1.84	82.2	y
2	.21	1.07	y	1.18	33.8	y	1.86	84.0	y
3	.20	0.97	y	1.19	34.4	y	1.85	83.1	y
4	.21	1.07	y	1.18	33.8	y	1.85	83.1	y
5	.21	1.07	y	1.19	34.4	y	1.85	83.1	y
6	.20	0.97	y	1.19	34.4	y	1.81	79.5	y
7	.21	1.07	y	1.18	33.8	y	1.83	81.3	y
8	.21	1.07	y	1.20	35.0	y	1.86	84.0	y
9	.21	1.07	y	1.19	34.4	y	1.86	84.0	y
10	.20	0.97	y	1.19	34.4	y	1.86	84.0	y

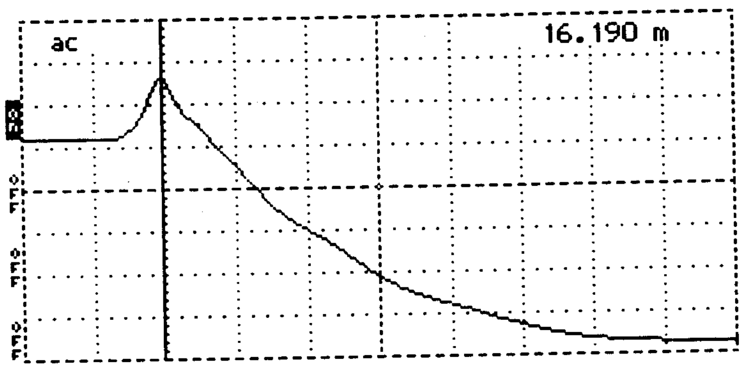
LTPP Seasonal Monitoring Study	State Code	[8 9]
TDR Probe Calibration	Test Section Number	[3 0 1 5]

Before Operation Checks - Calibration Date 9/12/93
- Probe S/N x9 A01

Probe Number 1

TDR Trace 1 - Beginning Probe Shorted

-sor .... 16.190 m
-tance/Div ..... .25 m/div
-tical Scale.... 167 mρ/div
.... 0.99
-ise Filter ...... 1 avg
-wer .... ac

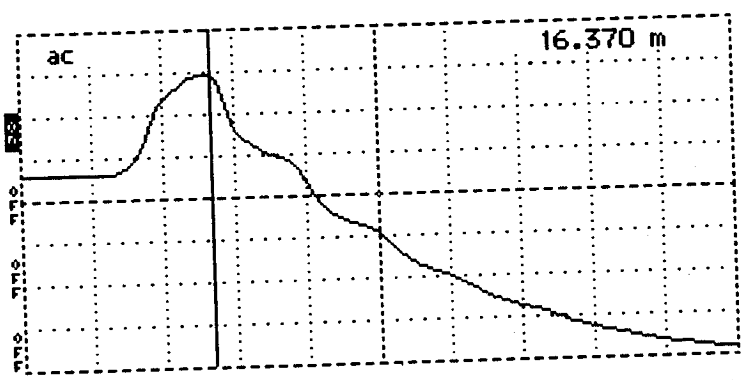


Tektronix 1502B TDR
Date 9/12/93
Cable #1
Notes shorted at CB

Input Trace
Stored Trace
Difference Trace

Trace Number 2 - Ending Probe Shorted

Cursor .... 16.370 m
Distance/Div ..... .25 m/div
Vertical Scale.... 167 mρ/div
VP 0.99
Noise Filter ...... 1 avg
Power .... ac



Tektronix 1502B TDR
Date 9/12/93
Cable #1
Notes Shorted at far end

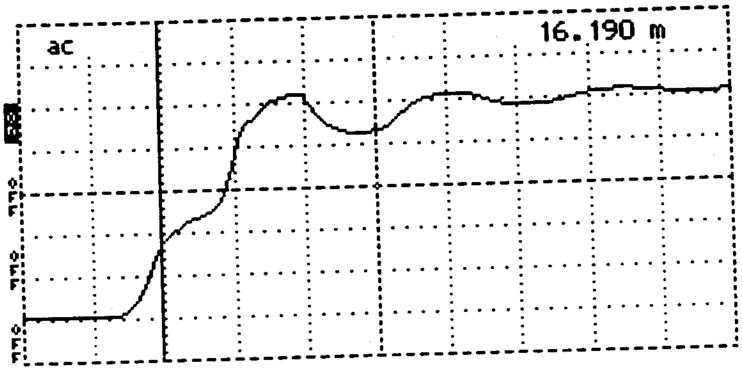
Input Trace
Stored Trace
Difference Trace

Figure B-2. TDR Traces Obtained During Calibration

Probe Number 1 (cont.)

Trace Number 3 - Probe in Air

ursor .... 16.190 m
stance/Div..... .25 m/div
ertical Scale.... 167 mρ/div
P 0.99
oise Filter...... 1 avg
ower........... ac

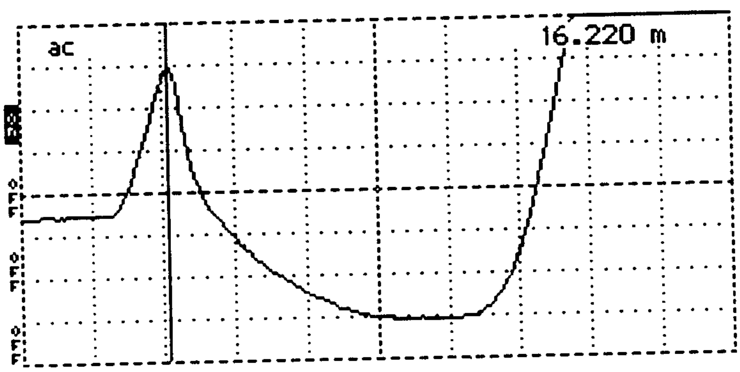


Tektronix 1502B TDR
Date 9/12/93
Cable #1
Notes in air

Input Trace
Stored Trace
Difference Trace

Trace Number 4 - Probe in Alcohol

:or .... 16.220 m
ıstance/Div..... .25 m/div
ertical Scale.... 48.6 mρ/div
P 0.99
oise Filter...... 1 avg
ower........... ac

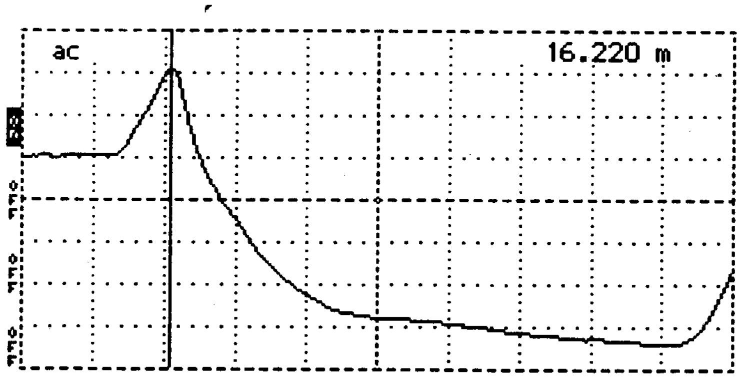


Tektronix 1502B TDR
Date 9/12/93
Cable #1
Notes in methyl alcohol

Input Trace
Stored Trace
Difference Trace

Trace Number 5 - Probe in Water

ursor .... 16.220 m
ıstance/Div..... .25 m/div
ertical Scale.... 72.7 mρ/div
P 0.99
oise Filter...... 1 avg
--wer........... ac



Tektronix 1502B TDR
Date 9/12/93
Cable #1
Notes in Water

Input Trace
Stored Trace
Difference Trace

Figure B-2(cont.). TDR Traces Obtained During Calibration

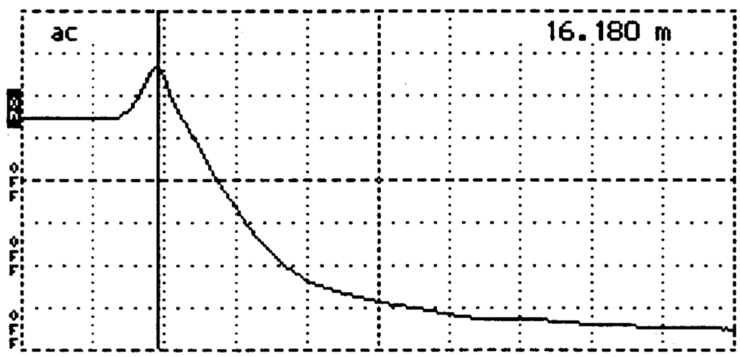
LTPP Seasonal Monitoring Study	State Code	[84]
TDR Probe Calibration	Test Section Number	[3015]

Before Operation Checks - Calibration Date 9/12/93
- Probe S/N X4A'02

Probe Number 2

TDR Trace 1 - Beginning Probe Shorted

sor .... 16.180 m
ance/Div ..... .25 m/div
tical Scale.... 167 mρ/div
.... 0.99
se Filter...... 1 avg
er........... ac

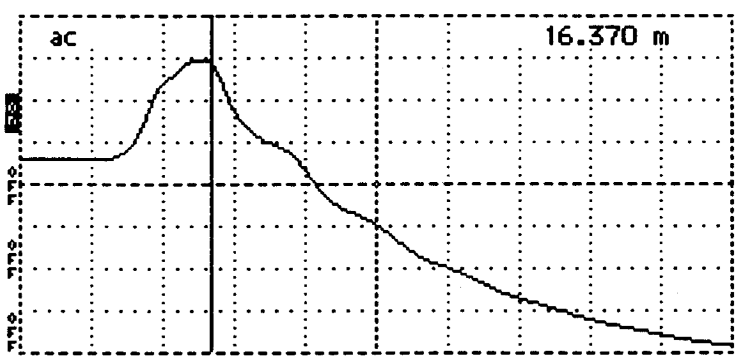


Tektronix 1502B TDR
Date 9/12/93
Cable #2
Notes Shorted at CB

Input Trace
Stored Trace
Difference Trace

Trace Number 2 - Ending Probe Shorted

rsor .... 16.370 m
tance/Div ..... .25 m/div
rtical Scale.... 167 mρ/div
.... 0.99
se Filter...... 1 avg
wer........... ac



Tektronix 1502B TDR
Date 9/12/93
Cable #2
Notes Shorted at end

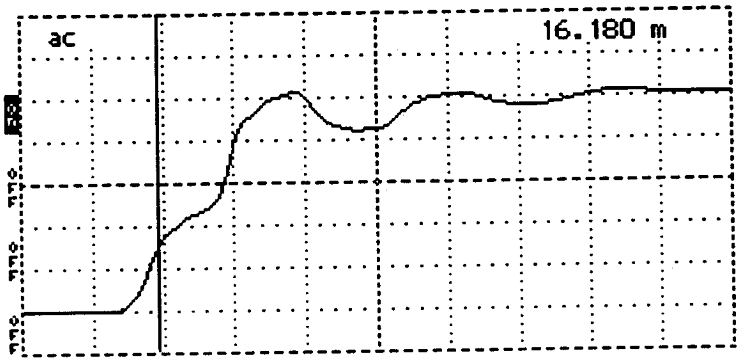
Input Trace
Stored Trace
Difference Trace

Figure B-2(cont.). TDR Traces Obtained During Calibration

Probe Number 2 (cont.)

Trace Number 3 - Probe in Air

sor .... 16.180 m
ance/Div ..... .25 m/div
ical Scale.... 167 mρ/div
.... 0.99
e Filter ...... 1 avg
er .... ac

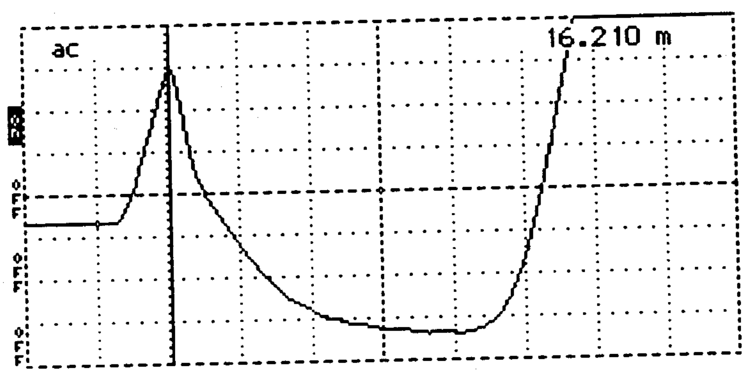


Tektronix 1502B TDR
Date 9/12/93
Cable #2
Notes air

Input Trace
Stored Trace
Difference Trace

Trace Number 4 - Probe in Alcohol

- .... 16.210 m
ance/Div ..... .25 m/div
ical Scale.... 47.2 mρ/div
.... 0.99
e Filter ...... 1 avg
er .... ac

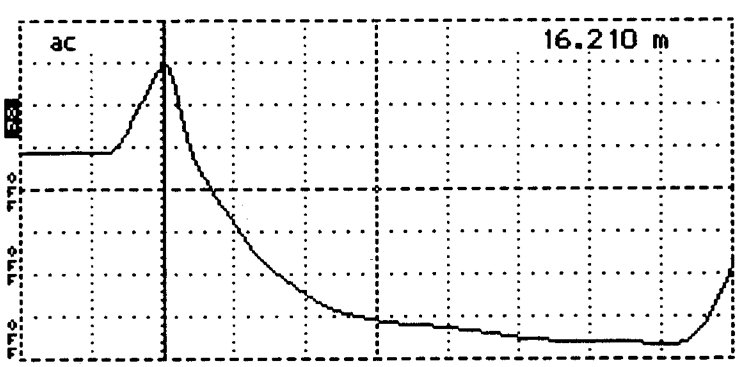


Tektronix 1502B TDR
Date 9/12/93
Cable #2
Notes alchohol

Input Trace
Stored Trace
Difference Trace

Trace Number 5 - Probe in Water

sor .... 16.210 m
ance/Div ..... .25 m/div
ical Scale.... 70.6 mρ/div
.... 0.99
e Filter ...... 1 avg
er .... ac



Tektronix 1502B TDR
Date 9/12/93
Cable #2
Notes water

Input Trace
Stored Trace
Difference Trace

Figure B-2(cont.). TDR Traces Obtained During Calibration

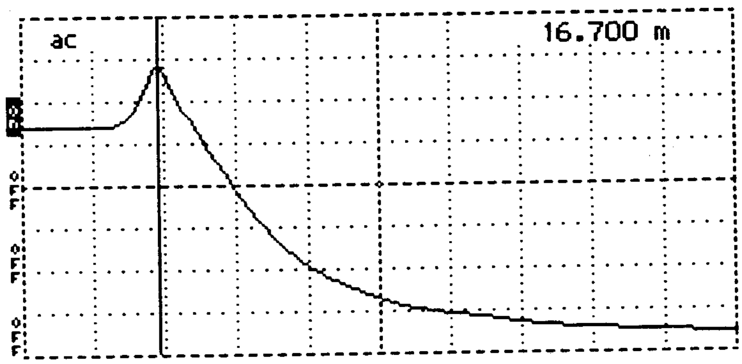
LTPP Seasonal Monitoring Study	State Code	[8 4]
TDR Probe Calibration	Test Section Number	[3 0 1 5]

Before Operation Checks
- Calibration Date 9/12/93
- Probe S/N 86 AC 3

Probe Number 3

TDR Trace 1 - Beginning Probe Shorted

rsor .... 16.700 m
tance/Div..... .25 m/div
rtical Scale.... 167 mρ/div
.... 0.99
se Filter...... 1 avg
wer........... ac

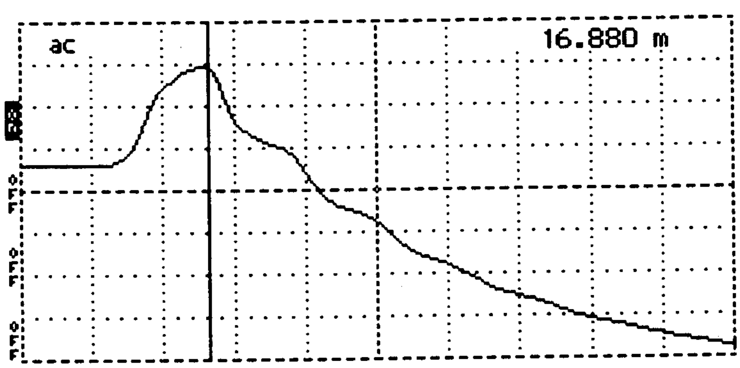


Tektronix 1502B TDR
Date 9/12/93
Cable #3
Notes Shorted @ CB

Input Trace
Stored Trace
Difference Trace

Trace Number 2 - Ending Probe Shorted

ursor .... 16.880 m
istance/Div..... .25 m/div
ertical Scale.... 167 mρ/div
P 0.99
oise Filter...... 1 avg
ower........... ac



Tektronix 1502B TDR
Date 9/12/93
Cable #3
Notes Shorted at end

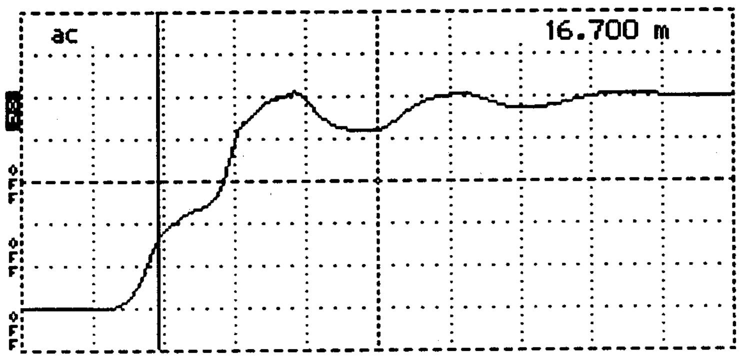
Input Trace
Stored Trace
Difference Trace

Figure B-2(cont.). TDR Traces Obtained During Calibration

Probe Number 3 (cont.)

Trace Number 3 - Probe in Air

rsor .... 16.700 m
tance/Div ..... .25 m/div
rtical Scale.... 167 mρ/div
.... 0.99
se Filter ...... 1 avg
wer .... ac



Tektronix 1502B TDR
Date 9/12/93
Cable #3
Notes Air

Input Trace
Stored Trace
Difference Trace

Trace Number 4 - Probe in Alcohol

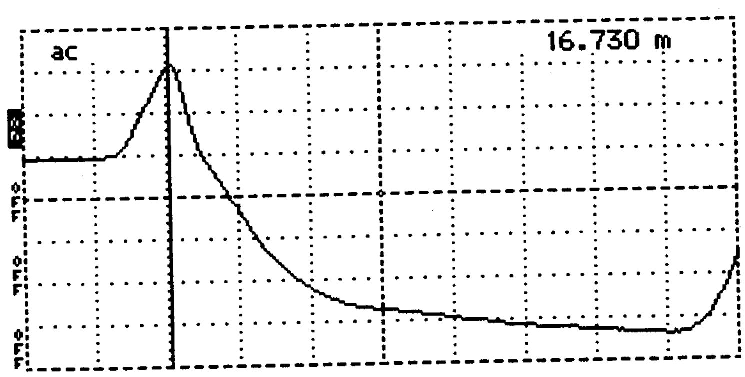
.... 16.730 m
ance/Div ..... .25 m/div
tical Scale.... 44.6 mρ/div
.... 0.99
se Filter ...... 1 avg
er .... ac

Tektronix 1502B TDR
Date 9/12/93
Cable #3
Notes alcohol

Input Trace
Stored Trace
Difference Trace

Trace Number 5 - Probe in Water

rsor .... 16.730 m
stance/Div ..... .25 m/div
rtical Scale.... 70.6 mρ/div
.... 0.99
oise Filter ...... 1 avg
wer .... ac



Tektronix 1502B TDR
Date 9/12/93
Cable #3
Notes Water

Input Trace
Stored Trace
Difference Trace

Figure B-2(cont.). TDR Traces Obtained During Calibration

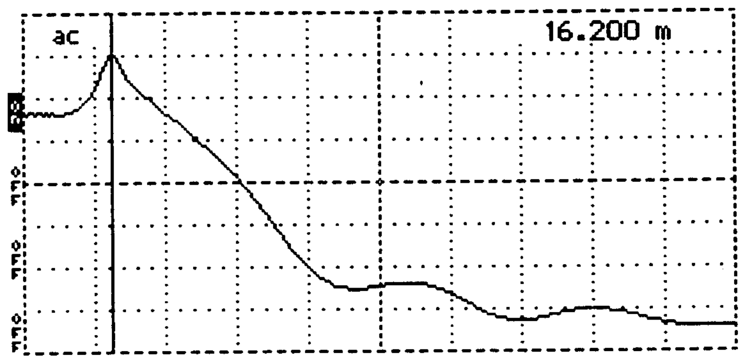
LTPP Seasonal Monitoring Study	State Code	[2 4]
TDR Probe Calibration	Test Section Number	[3 0 1 5]

efore Operation Checks - Calibration Date 9/12/93
- Probe S/N 29 A04

Probe Number 4

DR Trace 1 - Beginning Probe Shorted

rsor .... 16.200 m
stance/Div..... .25 m/div
rtical Scale.... 167 mρ/div
.... 0.99
ise Filter...... 1 avg
wer........... ac

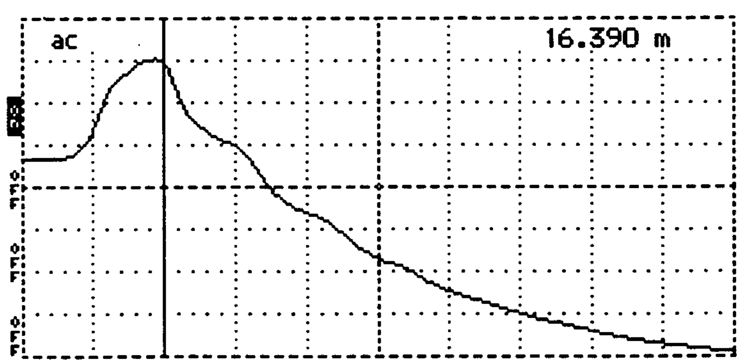


Tektronix 1502B TDR
Date 9/12/93
Cable #4
Notes Shorted @ CB

Input Trace
Stored Trace
Difference Trace

Trace Number 2 - Ending Probe Shorted

ursor .... 16.390 m
stance/Div..... .25 m/div
ertical Scale.... 167 mρ/div
.... 0.99
oise Filter...... 1 avg
ower........... ac



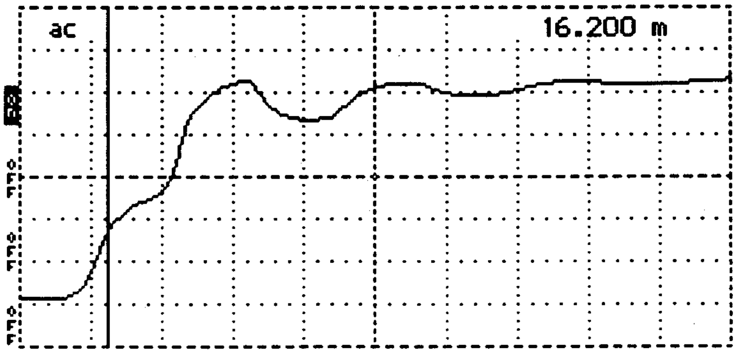
Tektronix 1502B TDR
Date 9/12/93
Cable #4
Notes Shorted @ end

Input Trace
Stored Trace
Difference Trace

Figure B-2(cont.). TDR Traces Obtained During Calibration

Trace Number 3 - Probe in Air

ursor .... 16.200 m
istance/Div ..... .25 m/div
ertical Scale.... 167 mρ/div
P 0.99
oise Filter...... 1 avg
ower.......... ac

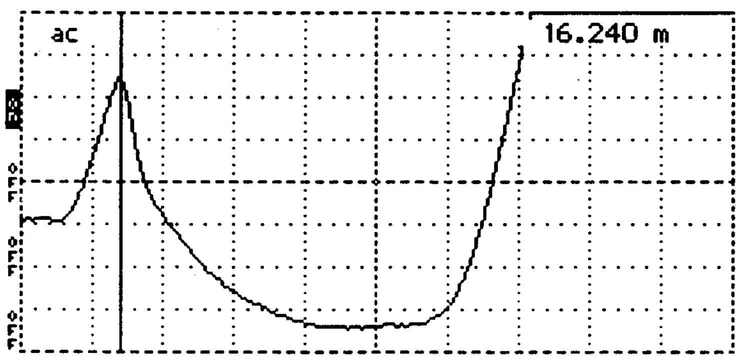


Tektronix 1502B TDR
Date 9/12/93
Cable #4
Notes air

Input Trace
Stored Trace
Difference Trace

Trace Number 4 - Probe in Alcohol

or .... 16.240 m
stance/Div ..... .25 m/div
ertical Scale.... 50.0 mρ/div
P 0.99
oise Filter...... 1 avg
ower.......... ac

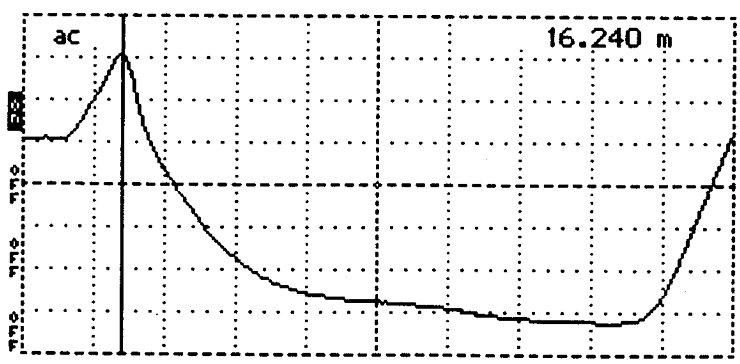


Tektronix 1502B TDR
Date 9/12/93
Cable #4
Notes alcohol

Input Trace
Stored Trace
Difference Trace

Trace Number 5 - Probe in Water

ursor .... 16.240 m
istance/Div ..... .25 m/div
ertical Scale.... 74.8 mρ/div
P 0.99
oise Filter...... 1 avg
er.......... ac



Tektronix 1502B TDR
Date 9/12/93
Cable #4
Notes Water

Input Trace
Stored Trace
Difference Trace

Figure B-2(cont.). TDR Traces Obtained During Calibration

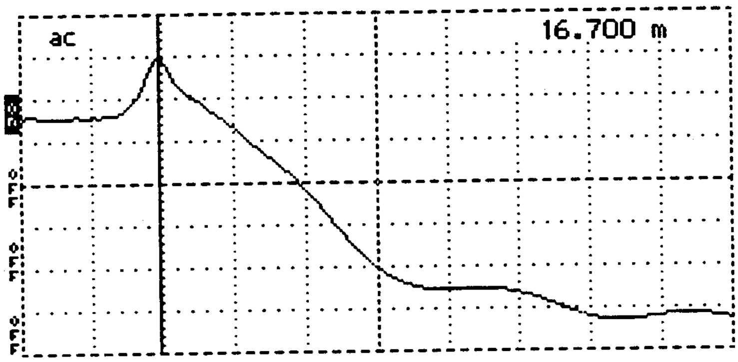
LTPP Seasonal Monitoring Study	State Code	[4 9]
TDR Probe Calibration	Test Section Number	[3 0 1 5]

Before Operation Checks
- Calibration Date 9/12/93
- Probe S/N [illegible]

Probe Number 5

TDR Trace 1 - Beginning Probe Shorted

ursor .... 16.700 m
istance/Div ..... .25 m/div
ertical Scale.... 167 mρ/div
P 0.99
oise Filter ...... 1 avg
ower .... ac

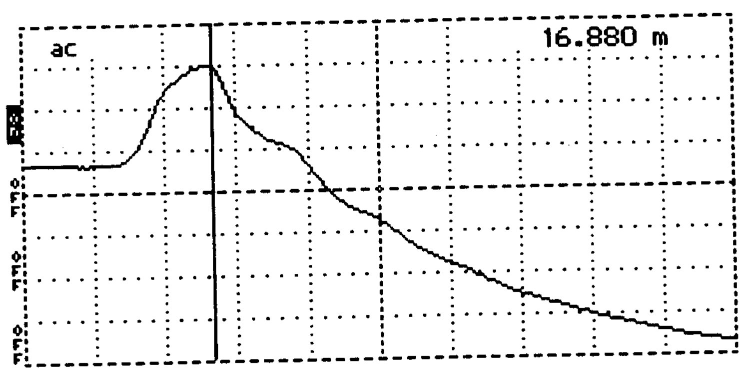


Tektronix 1502B TDR
Date 9/12/93
Cable #5
Notes Shorted @ CB

Input Trace
Stored Trace
Difference Trace

Trace Number 2 - Ending Probe Shorted

ursor .... 16.880 m
istance/Div ..... .25 m/div
ertical Scale.... 167 mρ/div
P 0.99
oise Filter ...... 1 avg
ower .... ac



Tektronix 1502B TDR
Date 9/12/93
Cable #5
Notes Shorted @ end

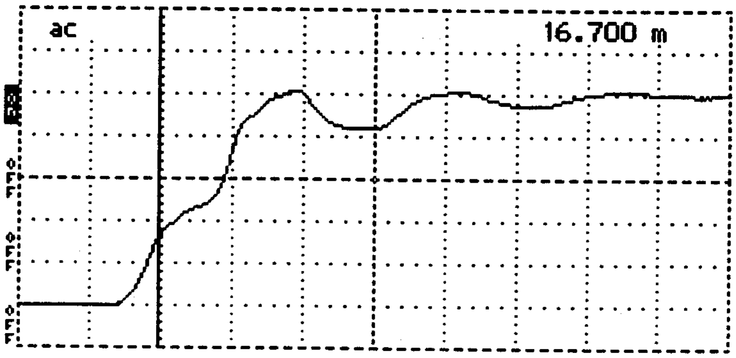
Input Trace
Stored Trace
Difference Trace

Figure B-2(cont.). TDR Traces Obtained During Calibration

Probe Number 5 (cont.)

race Number 3 - Probe in Air

rsor .... 16.700 m
tance/Div ..... .25 m/div
rtical Scale.... 167 mρ/div
.... 0.99
se Filter...... 1 avg
wer........... ac

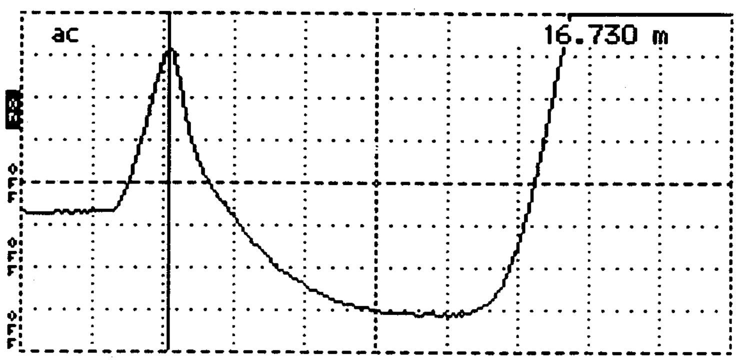


Tektronix 1502B TDR
Date 9/12/93
Cable #5
Notes air

Input Trace
Stored Trace
Difference Trace

race Number 4 - Probe in Alcohol

'sor .... 16.730 m
.tance/Div ..... .25 m/div
rtical Scale.... 44.6 mρ/div
.... 0.99
ise Filter...... 1 avg
wer........... ac

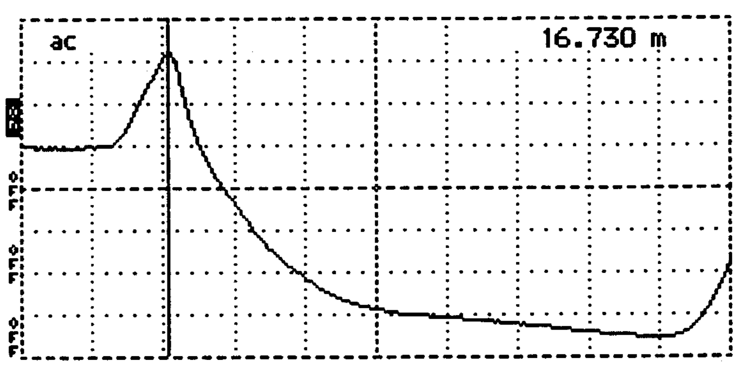


Tektronix 1502B TDR
Date 9/12/93
Cable #5
Notes alcohol

Input Trace
Stored Trace
Difference Trace

Trace Number 5 - Probe in Water

ursor .... 16.730 m
stance/Div ..... .25 m/div
ertical Scale.... 68.6 mρ/div
P 0.99
oise Filter...... 1 avg
'ver........... ac



Tektronix 1502B TDR
Date 9/12/93
Cable #5
Notes Water

Input Trace
Stored Trace
Difference Trace

Figure B-2(cont.). TDR Traces Obtained During Calibration

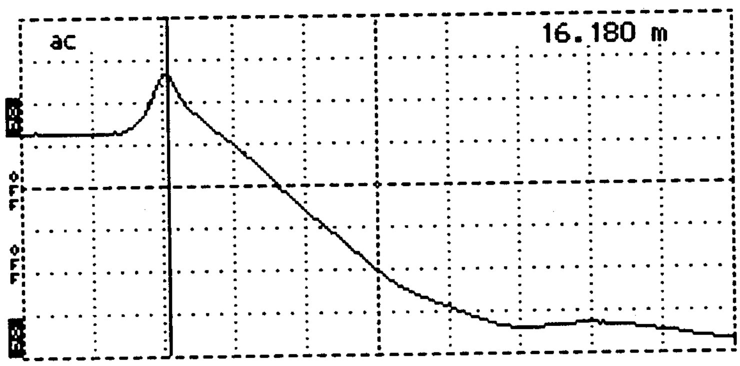
LTPP Seasonal Monitoring Study	State Code	[8 9]
TDR Probe Calibration	Test Section Number	[3 0 1 5]

Before Operation Checks - Calibration Date 9/12/93
- Probe S/N 89 A01

Probe Number 6

TDR Trace 1 - Beginning Probe Shorted

ursor .... 16.180 m
istance/Div ..... .25 m/div
ertical Scale.... 167 mρ/div
P 0.99
oise Filter ...... 1 avg
ower .... ac

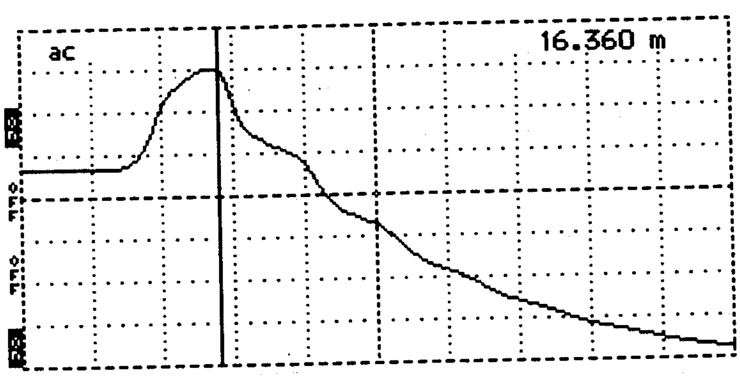


Tektronix 1502B TDR
Date 9/12/93
Cable #6
Notes Shorted @ CB

Input Trace
Stored Trace
Difference Trace

Trace Number 2 - Ending Probe Shorted

Cursor .... 16.360 m
Distance/Div ..... .25 m/div
Vertical Scale.... 167 mρ/div
VP 0.99
Noise Filter ...... 1 avg
Power .... ac



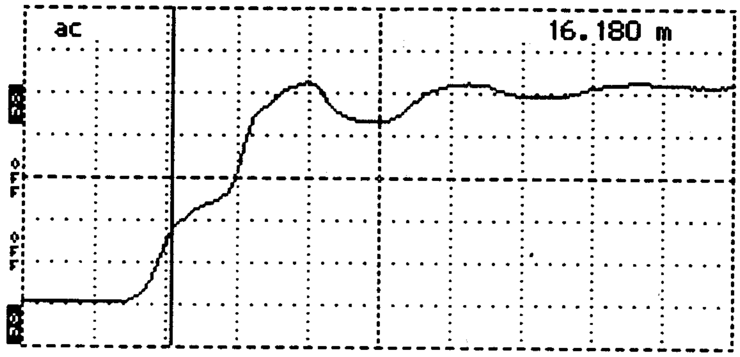
Tektronix 1502B TDR
Date 9/12/93
Cable #6
Notes Shorted @ end

Input Trace
Stored Trace
Difference Trace

Figure B-2(cont.). TDR Traces Obtained During Calibration

Trace Number 3 - Probe in Air

Cursor .... 16.180 m
Distance/Div..... .25 m/div
Vertical Scale.... 167 mρ/div
VP 0.99
Noise Filter...... 1 avg
Power........... ac

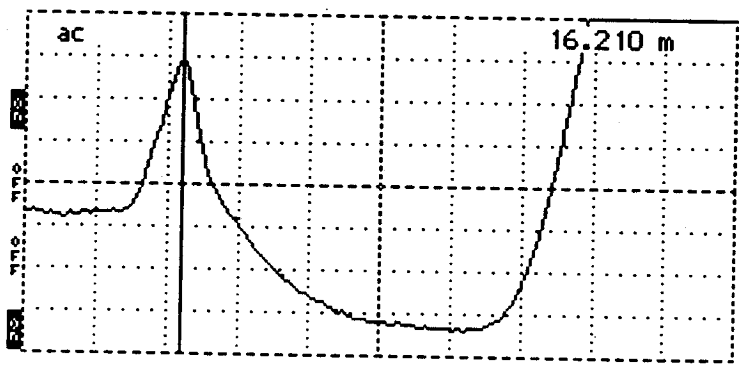


Tektronix 1502B TDR
Date 9/12/93
Cable #6
Notes air

Input Trace
Stored Trace
Difference Trace

Trace Number 4 - Probe in Alcohol

.rsor .... 16.210 m
Distance/Div..... .25 m/div
Vertical Scale.... 47.2 mρ/div
VP 0.99
Noise Filter...... 1 avg
Power........... ac

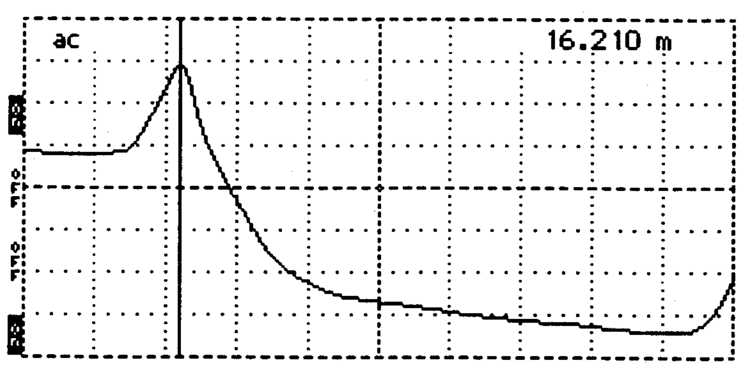


Tektronix 1502B TDR
Date 9/12/93
Cable #6
Notes alcohol

Input Trace
Stored Trace
Difference Trace

Trace Number 5 - Probe in Water

rsor .... 16.210 m
stance/Div..... .25 m/div
rtical Scale.... 77.0 mρ/div
.... 0.99
ise Filter...... 1 avg
r........... ac



Tektronix 1502B TDR
Date 9/12/93
Cable #6
Notes water

Input Trace
Stored Trace
Difference Trace

Figure B-2(cont.). TDR Traces Obtained During Calibration

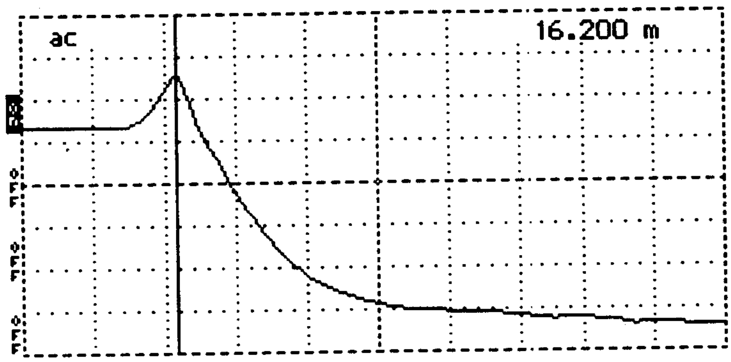
LTPP Seasonal Monitoring Study	State Code	[X 9]
TDR Probe Calibration	Test Section Number	[3 0 1 5]

Before Operation Checks - Calibration Date 9/12/93
- Probe S/N 84407

Probe Number 7

TDR Trace 1 - Beginning Probe Shorted

ursor .... 16.200 m
istance/Div..... .25 m/div
ertical Scale.... 167 mρ/div
P 0.99
oise Filter...... 1 avg
ower...........ac

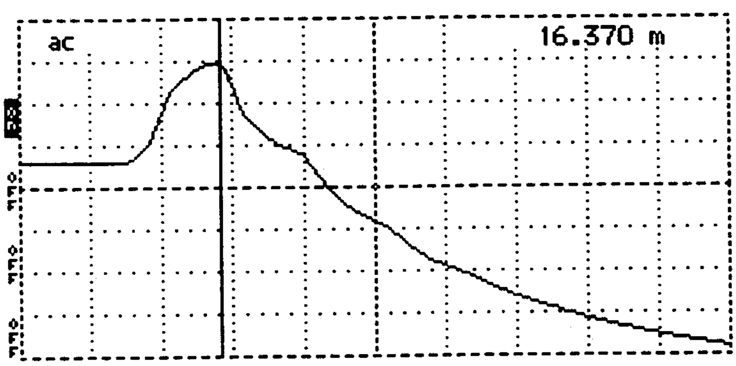


Tektronix 1502B TDR
Date 9/12/93
Cable #7
Notes Shorted @ CB

Input Trace
Stored Trace
Difference Trace

Trace Number 2 - Ending Probe Shorted

ursor .... 16.370 m
istance/Div..... .25 m/div
ertical Scale.... 167 mρ/div
P 0.99
oise Filter...... 1 avg
ower...........ac



Tektronix 1502B TDR
Date 9/12/93
Cable #7
Notes Shorted @ end

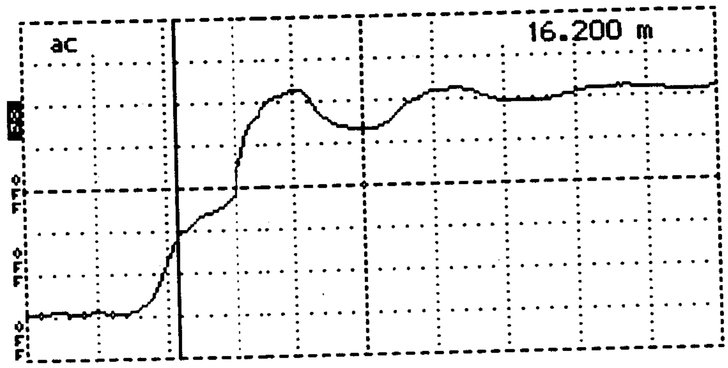
Input Trace
Stored Trace
Difference Trace

Figure B-2(cont.). TDR Traces Obtained During Calibration

Probe Number 7 (cont.)

Trace Number 3 - Probe in Air

rsor .... 16.200 m
tance/Div..... .25 m/div
rtical Scale.... 167 mρ/div
.... 0.99
ise Filter...... 1 avg
wer........... ac

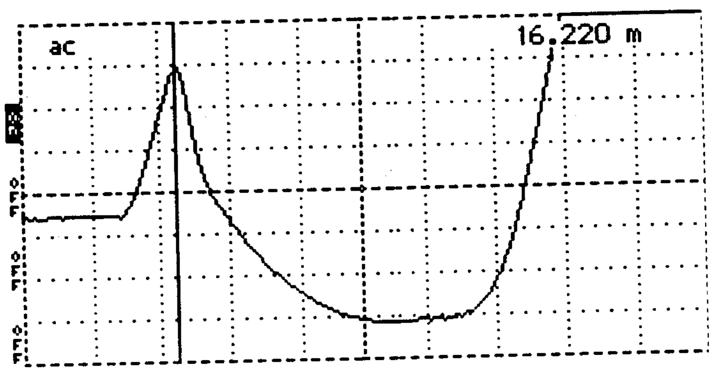


Tektronix 1502B TDR
Date 9/12/93
Cable #7
Notes Air

Input Trace
Stored Trace
Difference Trace

Trace Number 4 - Probe in Alcohol

or .... 16.220 m
stance/Div.... .25 m/div
rtical Scale... 48.6 mρ/div
.... 0.99
ise Filter..... 1 avg
wer......... ac

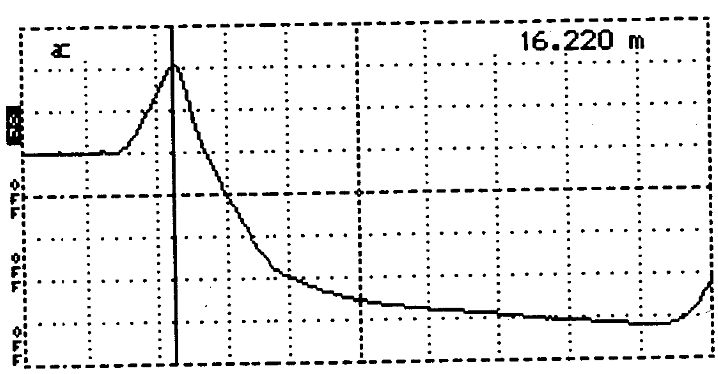


Tektronix 1502B TDR
Date 9/12/93
Cable #7
Notes alcohol

Input Trace
Stored Trace
Difference Trace

Trace Number 5 - Probe in Water

Cursor .... 16.220 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 9/12/93
Cable #7
Notes Water

Input Trace
Stored Trace
Difference Trace

Figure B-2(cont.). TDR Traces Obtained During Calibration

LTPP Seasonal Monitoring Study	State Code	[8 9]
TDR Probe Calibration	Test Section Number	[3 0 _ 5]

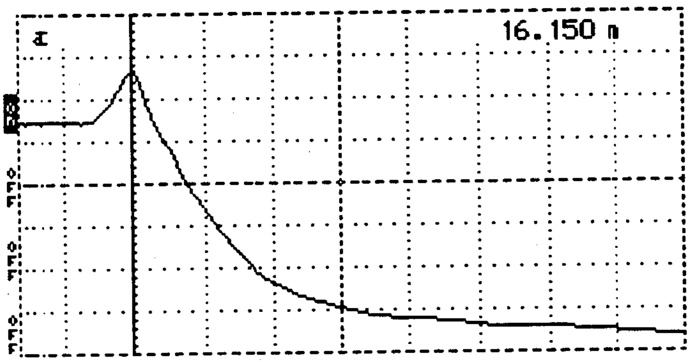
Before Operation Checks

- Calibration Date 9/12/93
- Probe S/N 89 A0K

Probe Number 8

TDR Trace 1 - Beginning Probe Shorted

Cursor .... 16.150 m
Distance/Div ..... .25 m/div
Vertical Scale.... 167 mρ/div
VP 0.99
Noise Filter ...... 1 avg
Power.......... ac

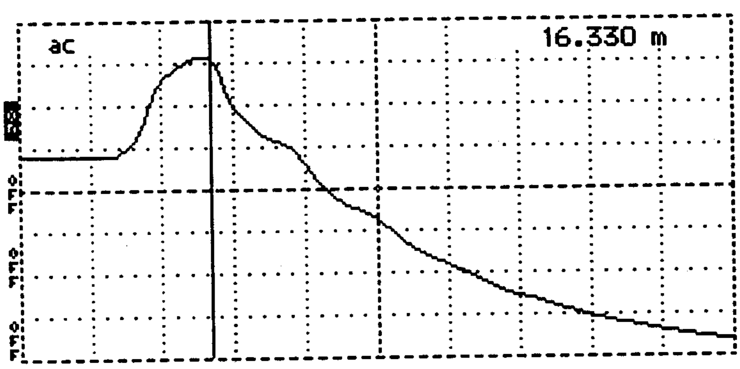


Tektronix 1502B TDR
Date 9/12/93
Cable #8
Notes Shorted @ CB

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



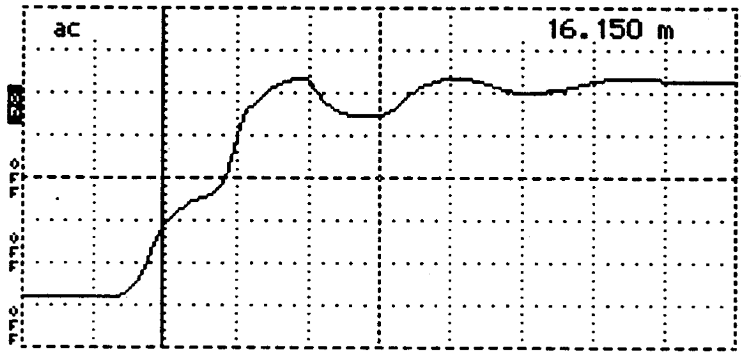
Tektronix 1502B TDR
Date 9/12/93
Cable #8
Notes Shorted @ end

Input Trace
Stored Trace
Difference Trace

Figure B-2(cont.). TDR Traces Obtained During Calibration

Trace Number 3 - Probe in Air

Cursor .... 16.150 m
Distance/Div..... .25 m/div
Vertical Scale.... 167 mρ/div
Vp 0.99
Noise Filter...... 1 avg
Power........... ac

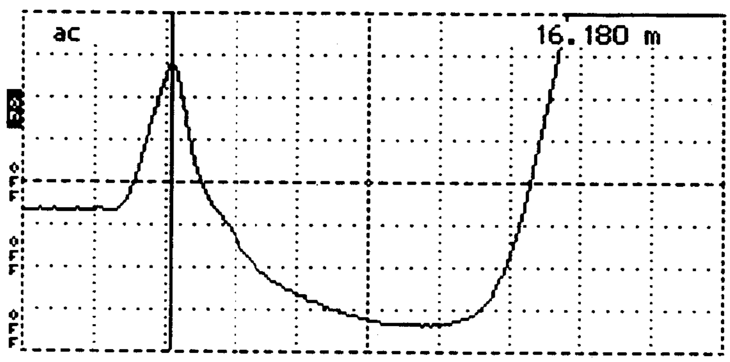


Tektronix 1502B TDR
Date 9/12/93
Cable #8
Notes air

Input Trace
Stored Trace
Difference Trace

Trace Number 4 - Probe in Alcohol

'rsor .... 16.180 m
istance/Div..... .25 m/div
Vertical Scale.... 48.6 mρ/div
Vp 0.99
Noise Filter...... 1 avg
Power........... ac

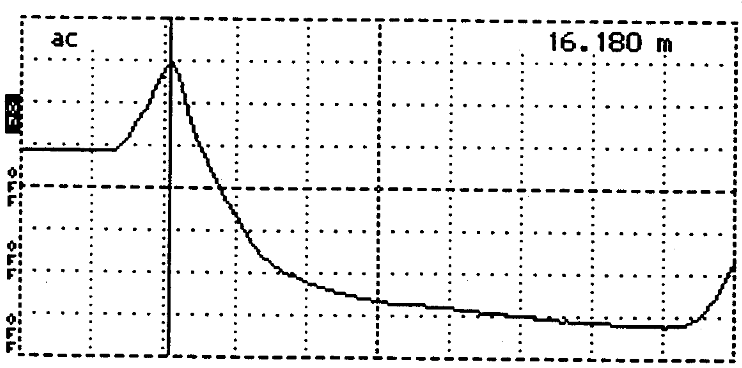


Tektronix 1502B TDR
Date 9/12/93
Cable #8
Notes alcohol

Input Trace
Stored Trace
Difference Trace

Trace Number 5 - Probe in Water

Cur .... 16.180 m
Dice/Div..... .25 m/div
Vetal Scale.... 79.2 mρ/div
Vp............ 0.99
No Filter...... 1 avg
Por........... ac



Tektronix 1502B TDR
Date 9/12/93
Cable #8
Notes water

Input Trace
Stored Trace
Difference Trace

Figure B-2(cont.). TDR Traces Obtained During Calibration

LTPP Seasonal Monitoring Study	State Code	[8 9]
TDR Probe Calibration	Test Section Number	[3 0 1 5]

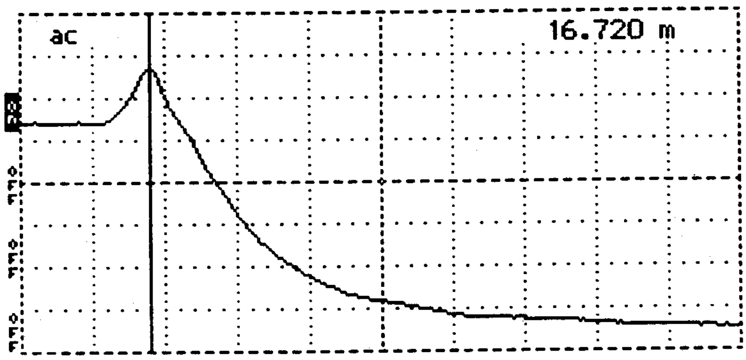
Before Operation Checks - Calibration Date 9/12/93

- Probe S/N 89A09

Probe Number 9

TDR Trace 1 - Beginning Probe Shorted

Cursor .... 16.720 m
Distance/Div..... .25 m/div
Vertical Scale.... 167 mρ/div
Vp 0.99
Noise Filter...... 1 avg
Power........... ac

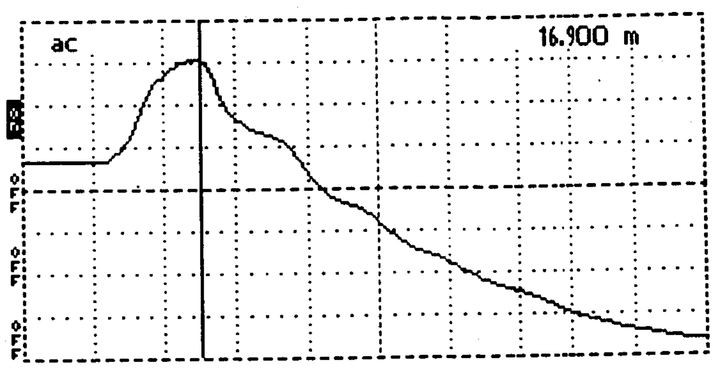


Tektronix 1502B TDR
Date 9/12/93
Cable #9
Notes Shorted @ CB

Input Trace
Stored Trace
Difference Trace

Trace Number 2 - Ending Probe Shorted

Cursor .... 16.900 m
Distance/Div..... .25 m/div
Vertical Scale.... 167 mρ/div
Vp 0.99
Noise Filter...... 1 avg
Power........... ac



Tektronix 1502B TDR
Date 9/12/93
Cable #9
Notes Shorted @ end

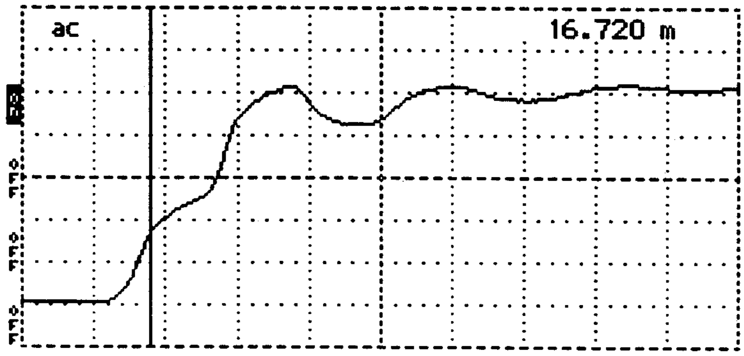
Input Trace
Stored Trace
Difference Trace

Figure B-2(cont.). TDR Traces Obtained During Calibration

Probe Number 9 (cont.)

Trace Number 3 - Probe in Air

Cursor .... 16.720 m
Distance/Div ..... .25 m/div
Vertical Scale.... 167 mρ/div
Vp 0.99
Noise Filter ...... 1 avg
Power .... ac

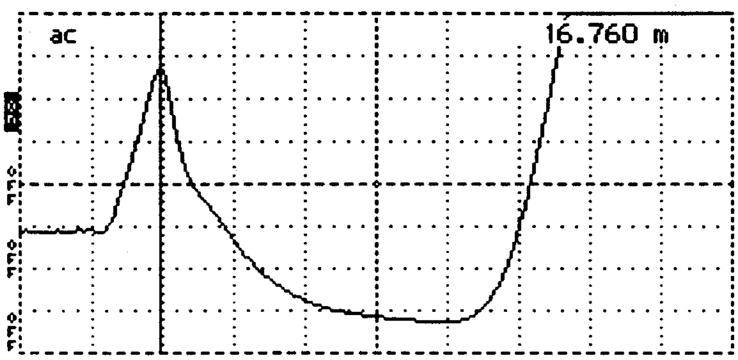


Tektronix 15
Date 9/12/93
Cable #9
Notes air

Input Trace
Stored Trace
Difference Trace

Trace Number 4 - Probe in Alcohol

sor .... 16.760 m
istance/Div ..... .25 m/div
ertical Scale.... 47.2 mρ/div
P 0.99
oise Filter ...... 1 avg
ower .... ac

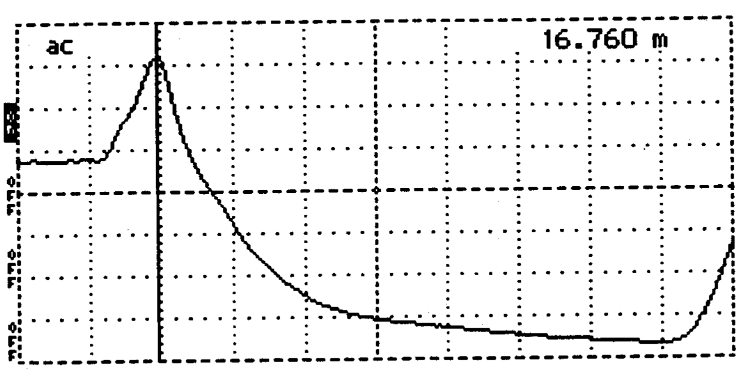


Tektronix 1502B TDR
Date 9/12/93
Cable #9
Notes alcohol

Input Trace
Stored Trace
Difference Trace

Trace Number 5 - Probe in Water

Cursor .... 16.760 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 9/12/93
Cable #9
Notes water

Input Trace
Stored Trace
Difference Trace

Figure B-2(cont.). TDR Traces Obtained During Calibration

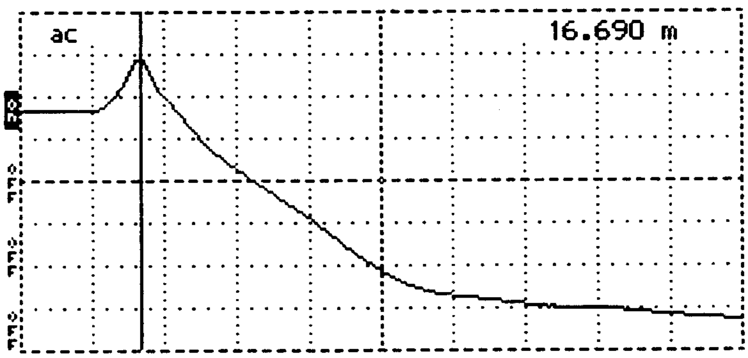
LTPP Seasonal Monitoring Study	State Code	[X 4]
TDR Probe Calibration	Test Section Number	[3 0 1 5]

Before Operation Checks
- Calibration Date 9/12/93
- Probe S/N 29 A 10

Probe Number 10

TDR Trace 1 - Beginning Probe Shorted

Cursor .... 16.690 m
Distance/Div ..... .25 m/div
Vertical Scale .... 167 mρ/div
Vp 0.99
Noise Filter ...... 1 avg
Power .... ac

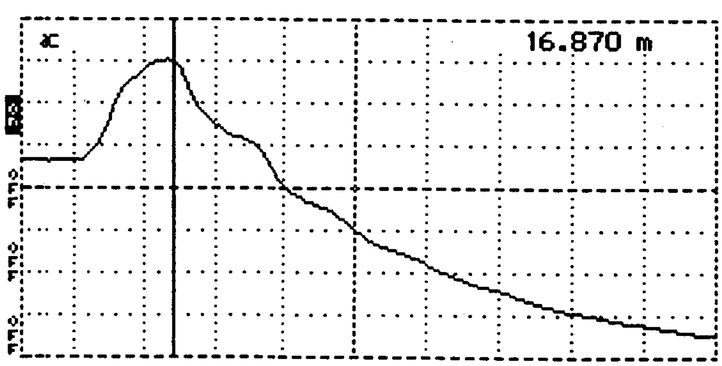


Tektronix 1502B TDR
Date 9/12/93
Cable #10
Notes Shorted @ CB

Input Trace
Stored Trace
Difference Trace

Trace Number 2 - Ending Probe Shorted

Cursor .... 16.870 m
Distance/Div ..... .25 m/div
Vertical Scale .... 167 mρ/div
Vp 0.99
Noise Filter ...... 1 avg
Power .... ac



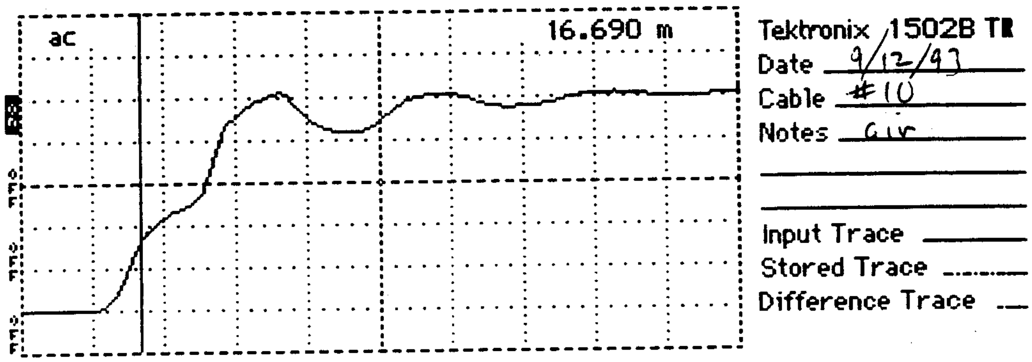
Tektronix 1502B TDR
Date 9/12/93
Cable #10
Notes Shorted @ end

Input Trace
Stored Trace
Difference Trace

Figure B-2(cont.). TDR Traces Obtained During Calibration

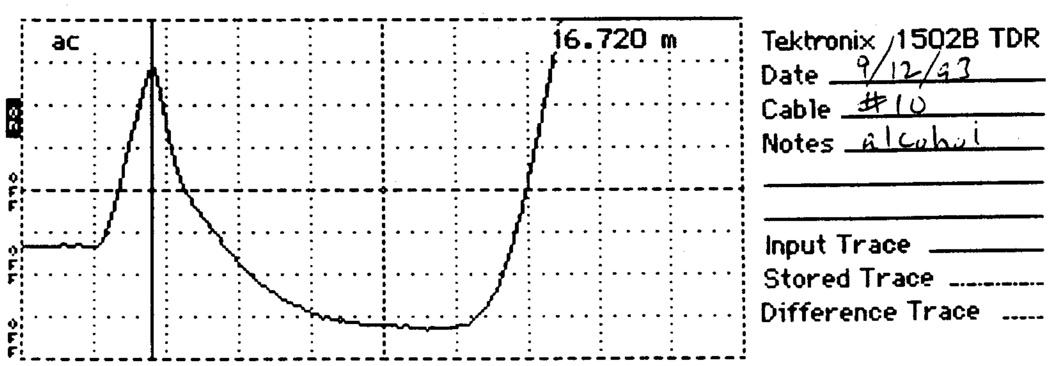
Trace Number 3 - Probe in Air

Cursor .... 16.690 m
Distance/Div..... .25 m/div
Vertical Scale.... 167 mρ/div
Vp 0.99
Noise Filter...... 1 avg
Power........... ac



Trace Number 4 - Probe in Alcohol

Cursor .... 16.720 m
Distance/Div..... .25 m/div
Vertical Scale.... 43.3 mρ/div
Vp 0.99
Noise Filter...... 1 avg
Power........... ac



Trace Number 5 - Probe in Water

Cursor .... 16.720 m
Distance/Div..... .25 m/div
Vertical Scale.... 66.7 mρ/div
Vp 0.99
Noise Filter...... 1 avg
Power........... ac

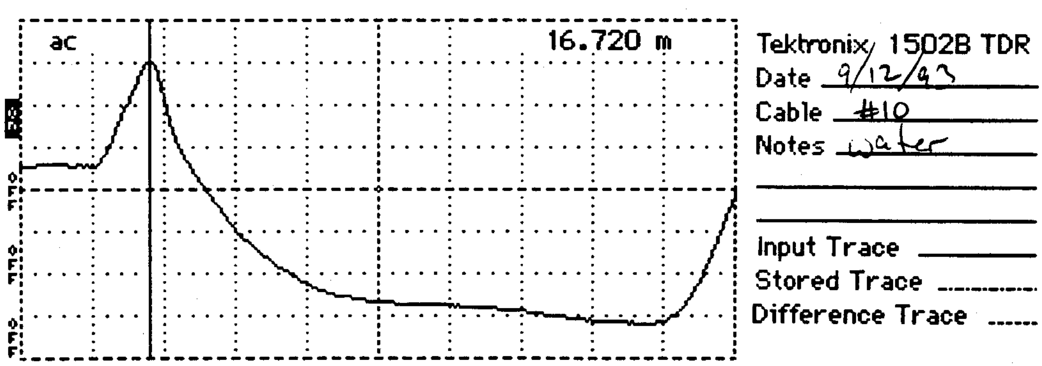


Figure B-2(cont.). TDR Traces Obtained During Calibration

APPENDIX C

Supporting Instrumentation Installation Information

Appendix C contains the following supporting information:

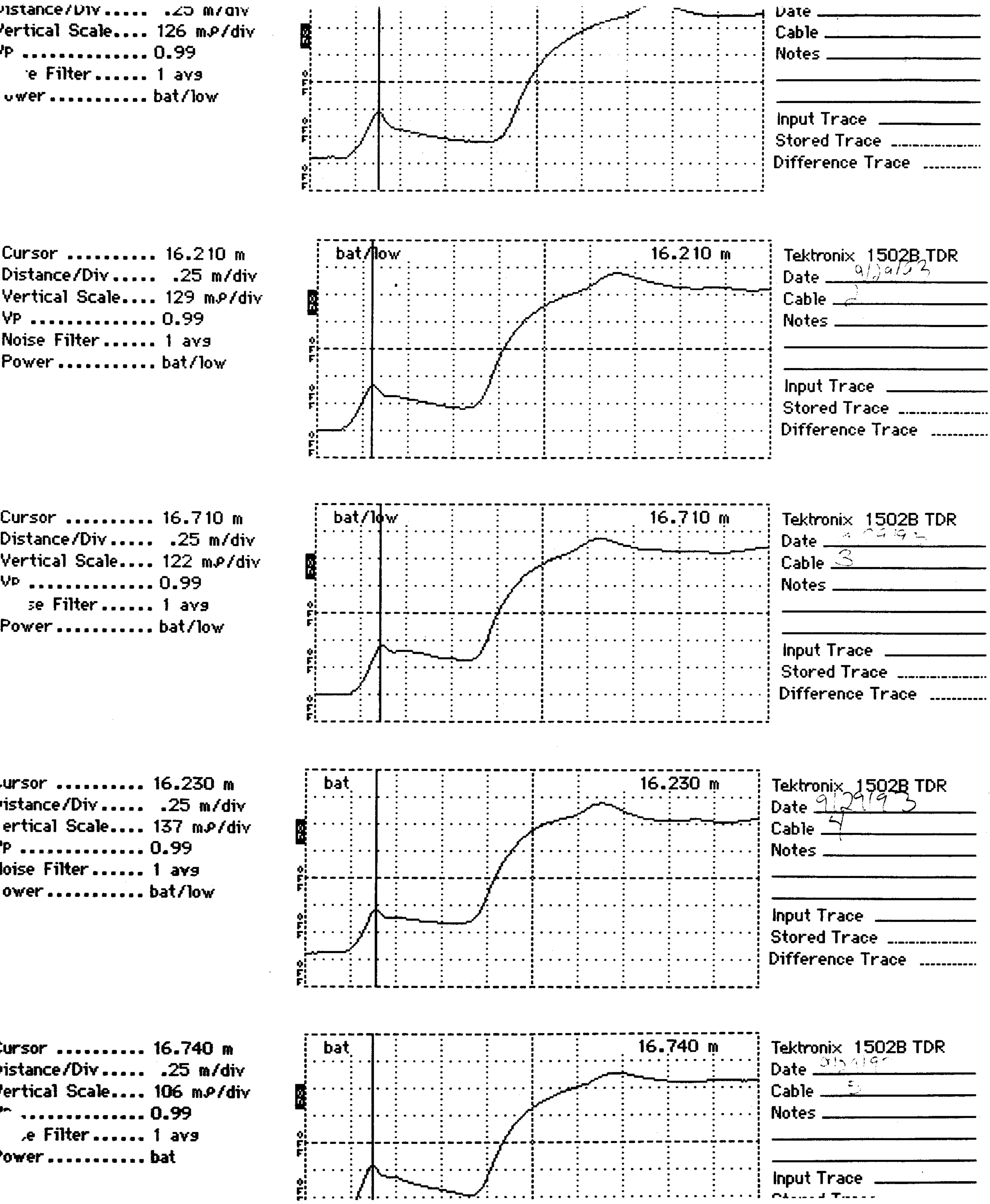
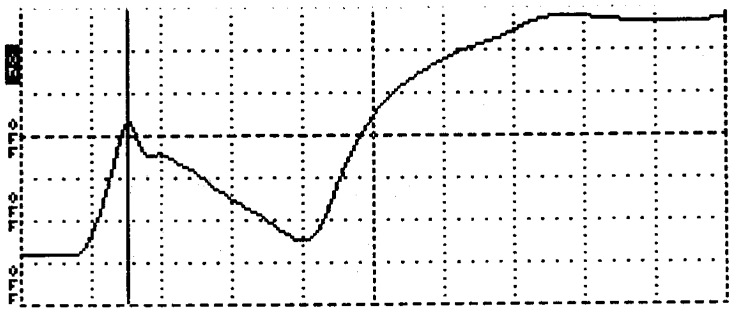


Figure C-1. TDR Traces Measured Manually During Installation

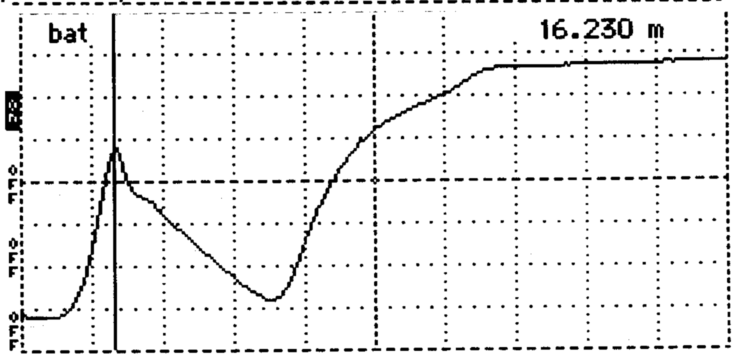
istance/Div..... .25 m/div
ertical Scale.... 68.6 mρ/div
.... 0.99
e Filter...... 1 avg
ower........... bat/low



Date
Cable
Notes

Input Trace
Stored Trace
Difference Trace

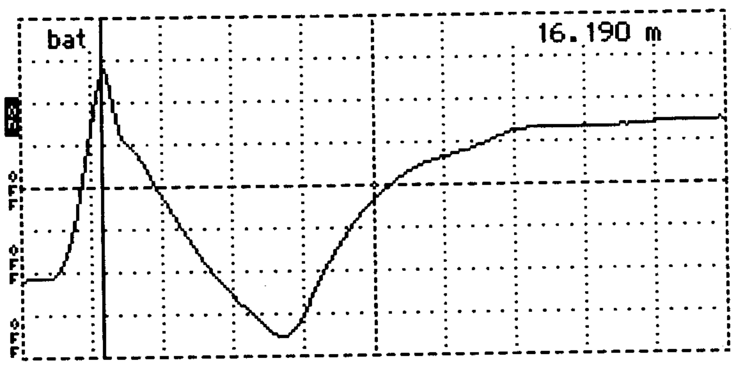
Cursor .... 16.230 m
Distance/Div..... .25 m/div
Vertical Scale.... 56.1 mρ/div
Vp 0.99
Noise Filter...... 1 avg
Power........... bat



Tektronix 1502B TDR
Date
Cable 7
Notes

Input Trace
Stored Trace
Difference Trace

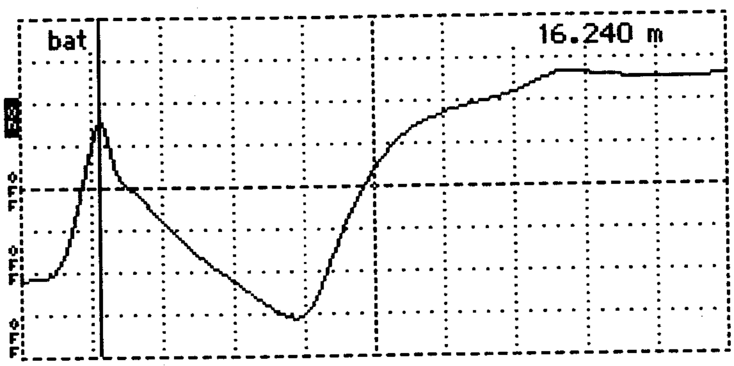
Cursor .... 16.190 m
Distance/Div..... .25 m/div
tical Scale.... 44.6 mρ/div
.... 0.99
Noise Filter...... 1 avg
Power........... bat



Tektronix 1502B TDR
Date
Cable 8
Notes

Input Trace
Stored Trace
Difference Trace

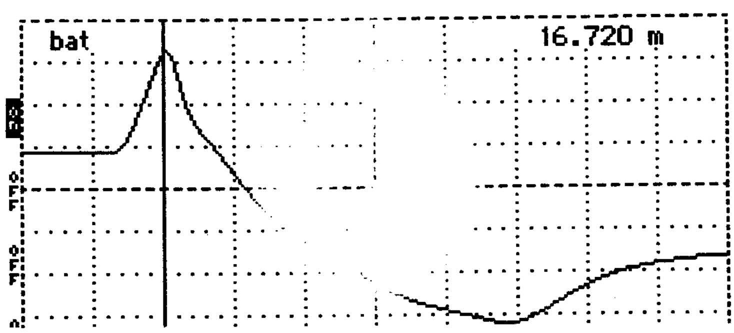
Cursor .... 16.240 m
Distance/Div..... .25 m/div
Vertical Scale.... 57.7 mρ/div
Vp 0.99
Noise Filter...... 1 avg
Power........... bat



Tektronix 1502B TDR
Date
Cable 9
Notes

Input Trace
Stored Trace
Difference Trace

Cursor .... 16.720 m
Distance/Div..... .25 m/div
Vertical Scale.... 81.6 mρ/div
.... 0.99
Noise Filter...... 1 avg
Power........... bat



Tektronix 1502B TDR
Date
Cable
Notes

Input Trace
Stored Trace
Difference Trace

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 (%)
89A01	0.670	11.11	21.06	2.20	9.57
89A02	0.610	9.21	17.36	2.20	7.89
89A03	0.540	7.22	13.15	2.20	5.98
89A04	0.530	6.95	12.56	2.20	5.71
89A05	0.550	7.49	13.74	2.20	6.25
89A06	0.640	10.14	19.21	1.76	10.91
89A07	0.590	8.62	16.14	1.76	9.17
89A08	0.680	11.45	21.68	1.76	12.32
89A09	0.720	12.84	24.16	1.76	13.72
89A10	1.200	35.65	48.74	1.76	27.69

Table C-2. Field Measured Moisture Content During Installation

LTPP Seasonal Monitoring Study	State Code	[89]
In-Situ Moisture Tests	Test Section Number	[3015]

Weight (gm)	Probe 1	Probe 2	Probe 3	Probe 4	Probe 5
Weight of Pan + Wet Soil	354.7	268.2	248.9	250.5	259.9
Weight of Pan + Dry Soil	338.2	259.2	243.5	243.5	248.6
Weight of Pan	120.2	120.8	120.2	120.2	120.2
Weight of Dry Soil	218.0	138.4	123.3	123.3	128.4
Weight of Wet Soil	234.5	147.4	128.7	130.3	139.7
Weight of Moisture	16.5	9.0	5.4	7.0	11.3
Wt of Moisture/Dry Wt x 100	7.57	6.50	4.38	5.68	8.80

Weight (gm)	Probe 6	Probe 7	Probe 8	Probe 9	Probe 10 *
Weight of Pan + Wet Soil	199.4	244.4	263.1	337.4	
Weight of Pan + Dry Soil	192.1	236.1	250.3	312.4	
Weight of Pan	121.1	120.2	120.9	120.3	
Weight of Dry Soil	71.0	115.9	129.4	192.1	
Weight of Wet Soil	78.3	124.2	142.2	217.1	
Weight of Moisture	7.3	8.3	12.8	25.0	
Wt of Moisture/Dry Wt x 100	10.28	7.16	9.89	13.01	

* Note: No sample due to interference of roots

Gouvernement du Québec
Ministère
des Transports

COPY

OCT 27 1993
JOB #
FILE #

Quebec, October 20 1993

Mr Brandt Henderson
Pavement Management System
415, Lawrence Bell Drive
Amherst, N.Y. 14221

Dear Sir,

The samples that were taken at site 893015 on autoroute 40, september 29, were sent to our laboratory for water content analysis. The results are as follows:

Sample no	Water content %
Jar no 1	6.4
Jar no 2	3.3
Jar no 3	3.1
Jar no 4	5.6
Jar no 5	7.8
Jar no 6	8.2
Jar no 7	6.7
Jar no 8	9.1
Jar no 9	12.7

I hope that everything is to your satisfaction.

Best regards,

Jean-Pierre Leroux ing.

Jean-Pierre Leroux, ing.
Service des Chaussées
Ministère des Transports
200 Dorchester Sud, 4e étage
Québec (Canada) G1K 5Z1

JPL/hg

APPENDIX D

Initial Data Collection

Appendix D contains the following supporting information:

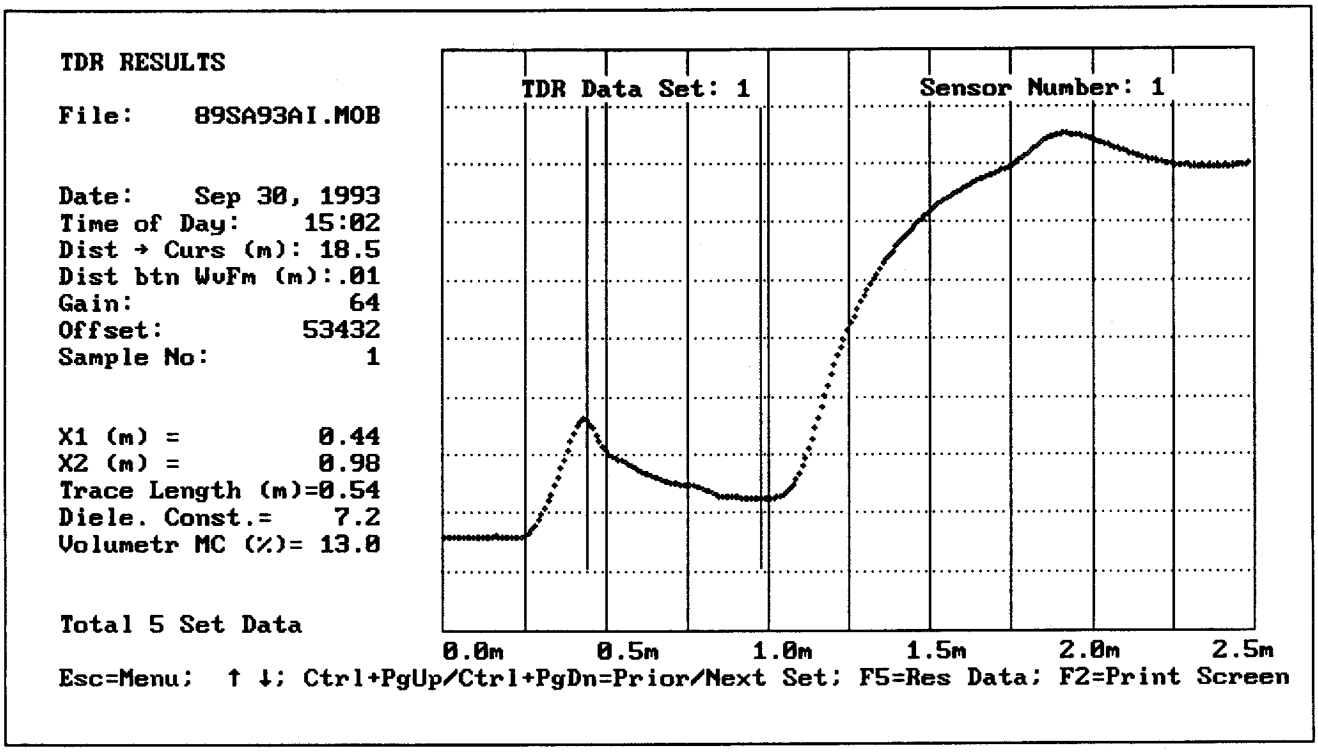


Figure D-1. Initial First Set of TDR Traces Measured with the Mobile Unit

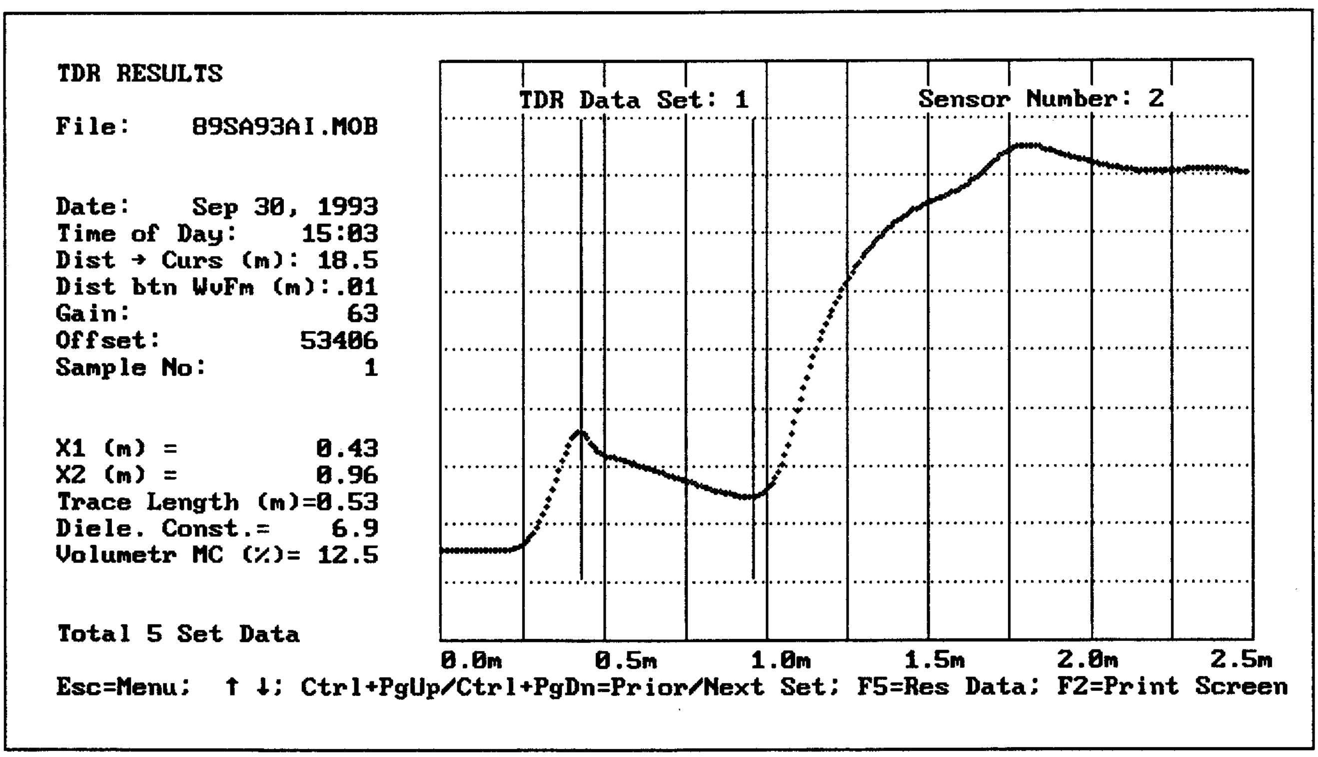


Figure D-1(cont.). Initial First Set of TDR Traces Measured with the Mobile Unit

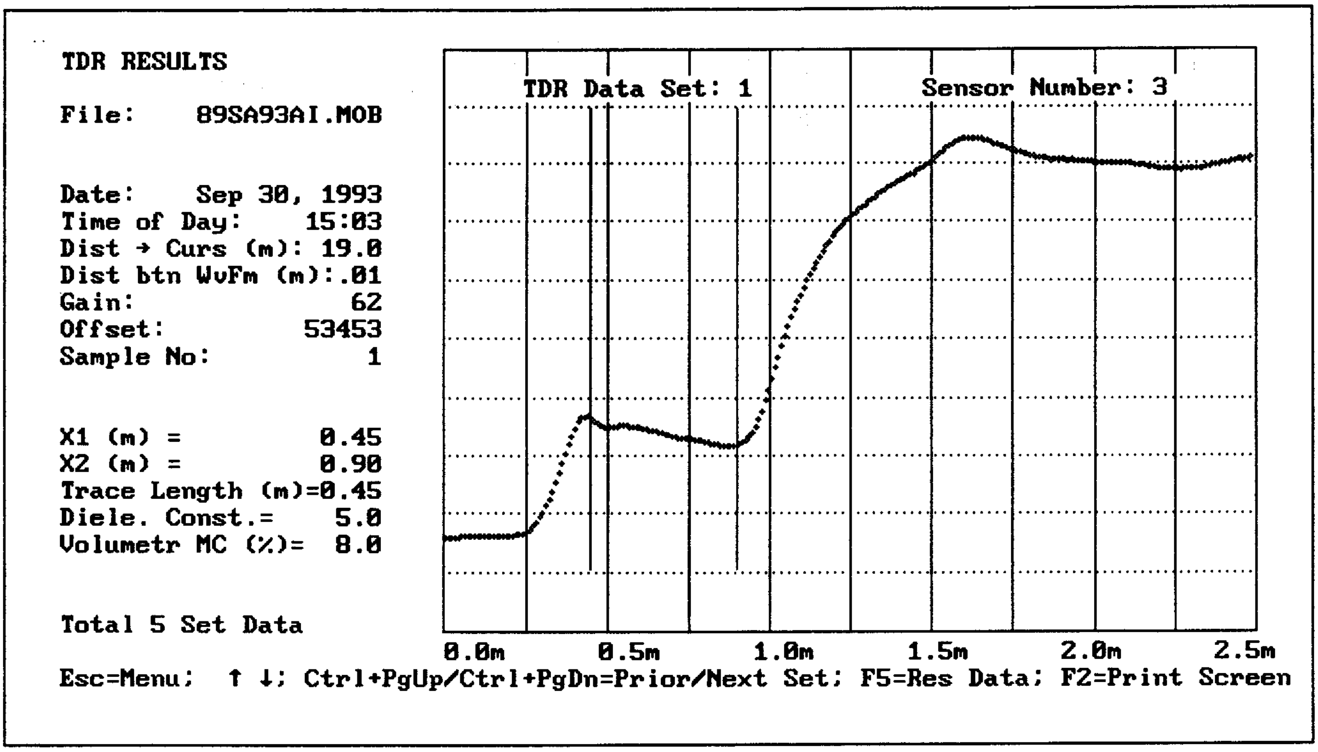


Figure D-1(cont.). Initial First Set of TDR Traces Measured with the Mobile Unit

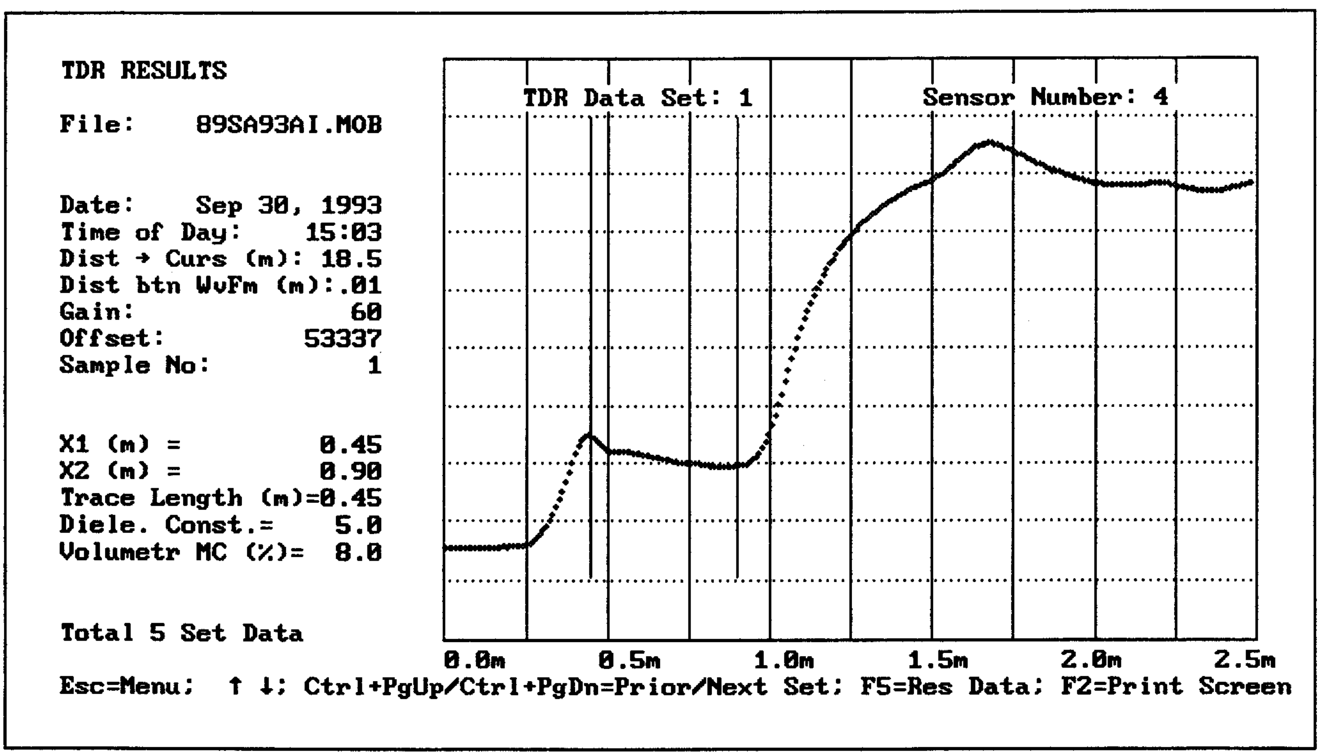


Figure D-1(cont.). Initial First Set of TDR Traces Measured with the Mobile Unit

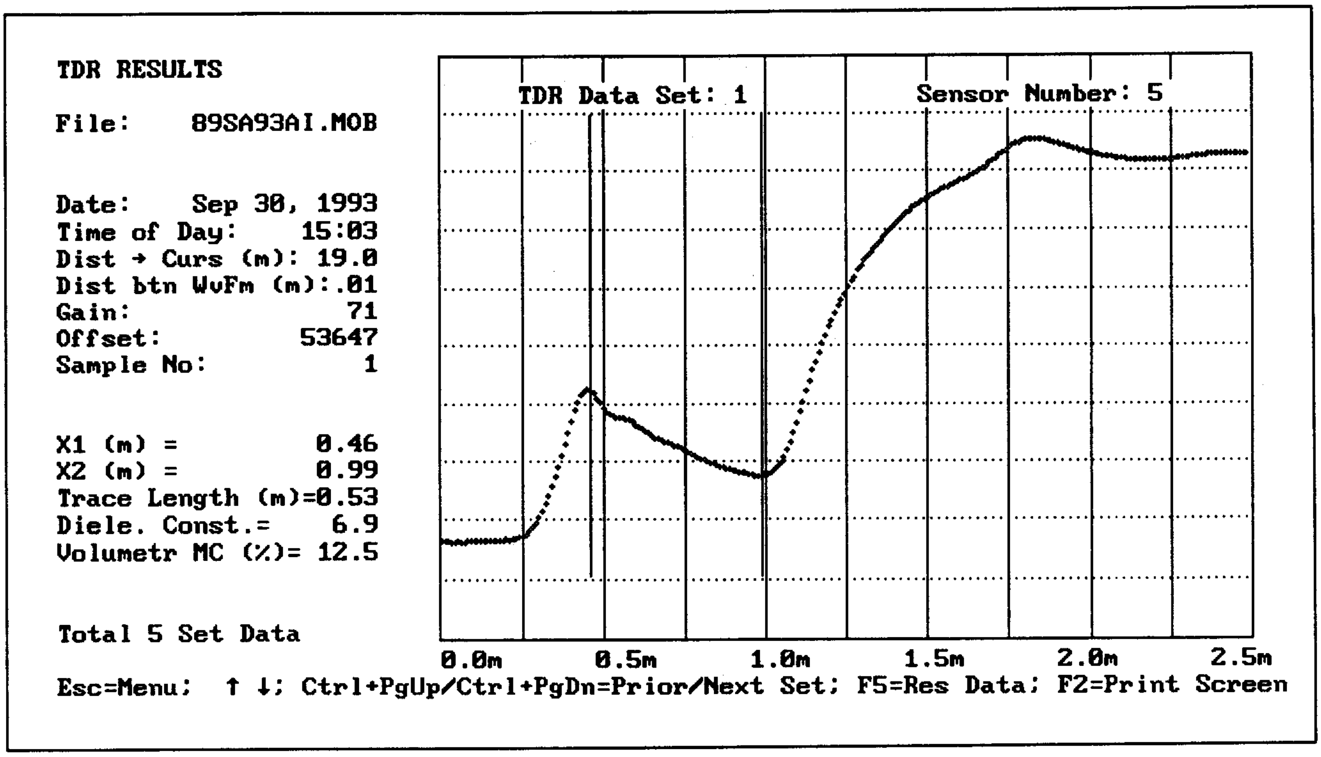


Figure D-1(cont.). Initial First Set of TDR Traces Measured with the Mobile Unit

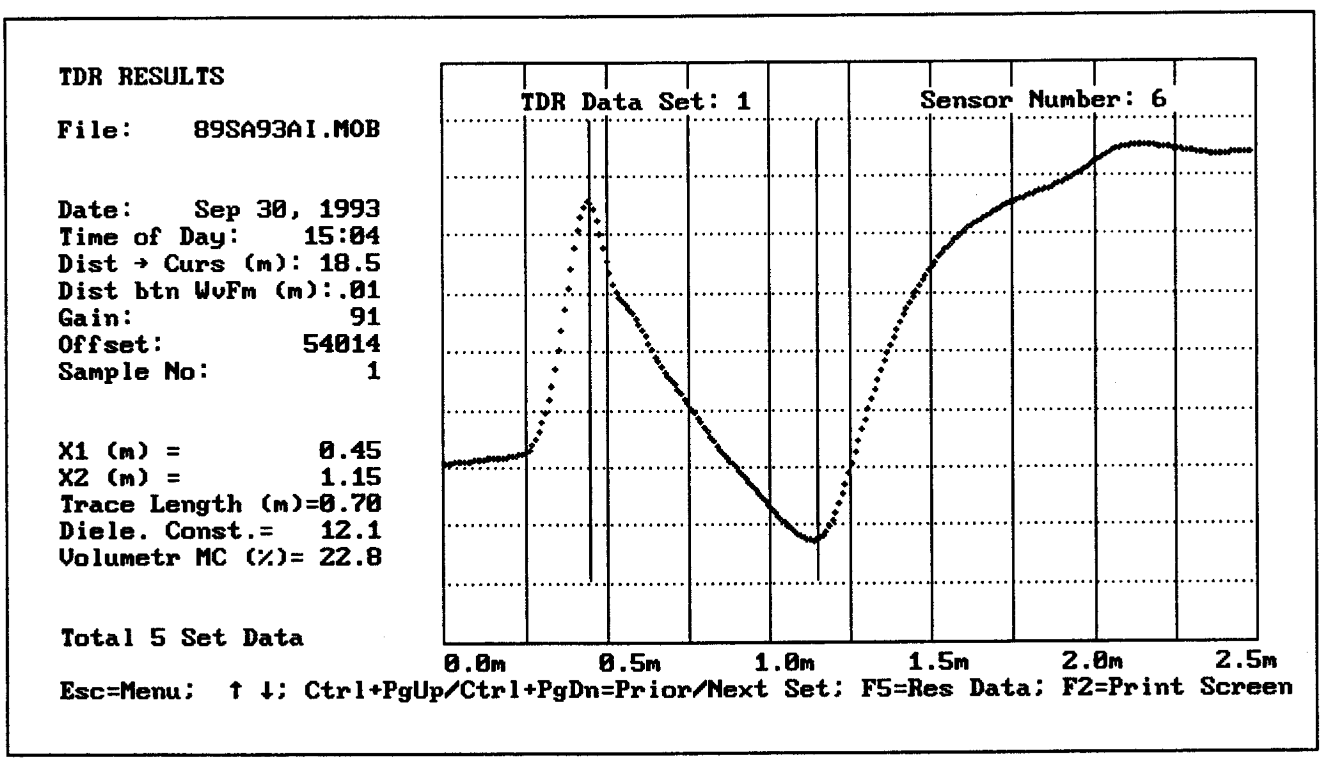


Figure D-1(cont.). Initial First Set of TDR Traces Measured with the Mobile Unit

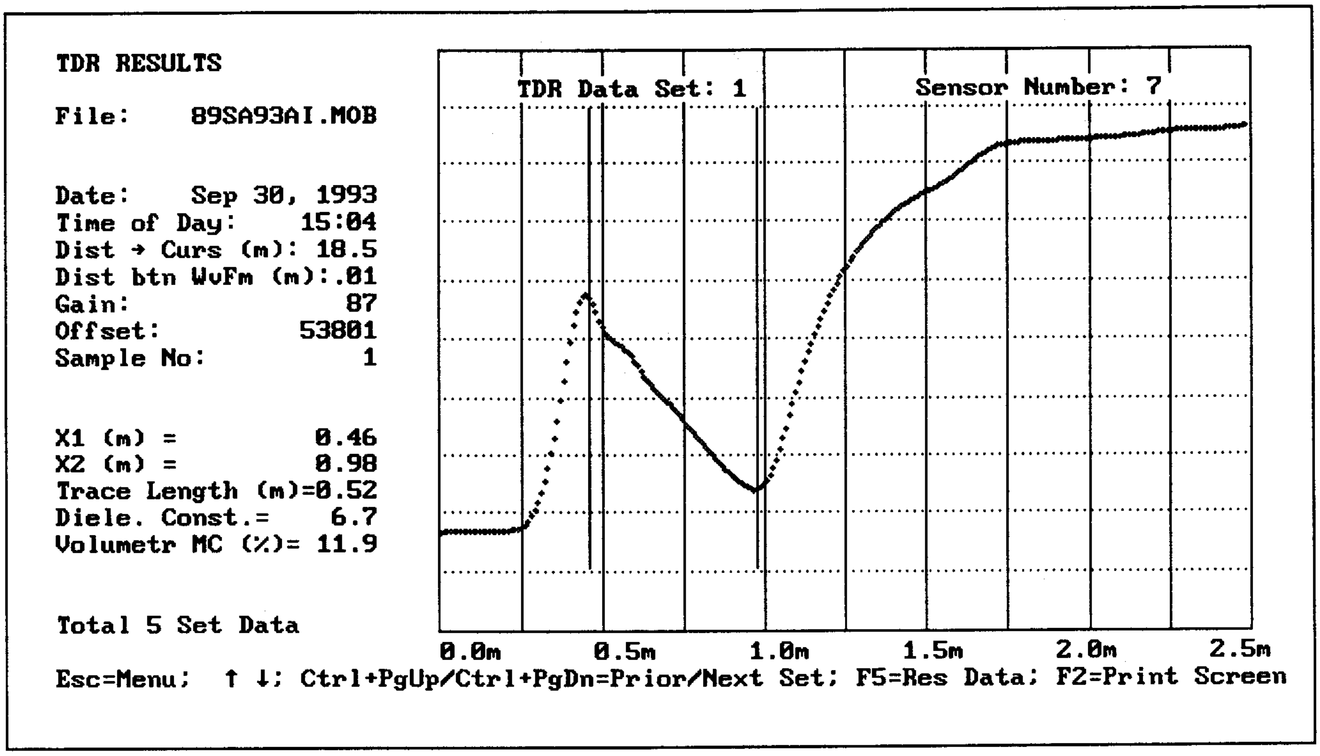


Figure D-1(cont.). Initial First Set of TDR Traces Measured with the Mobile Unit

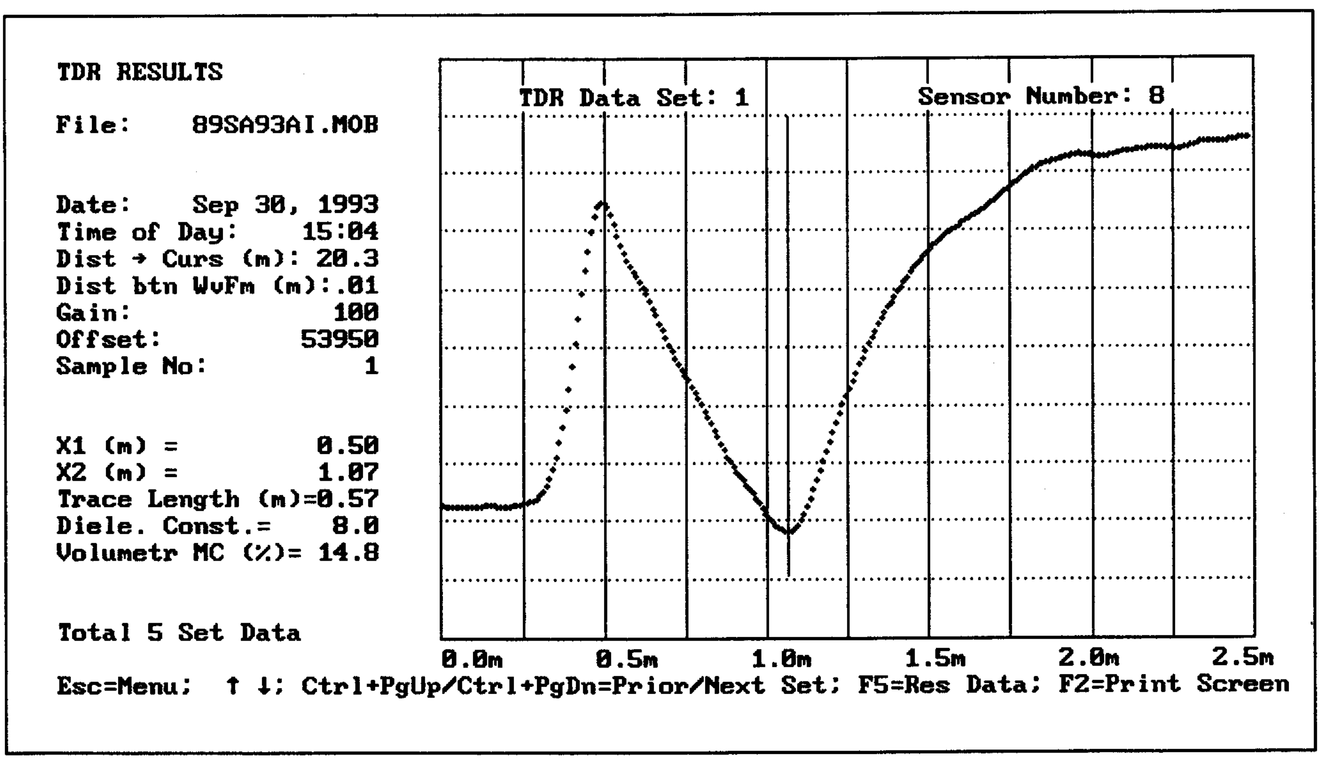


Figure D-1(cont.). Initial First Set of TDR Traces Measured with the Mobile Unit

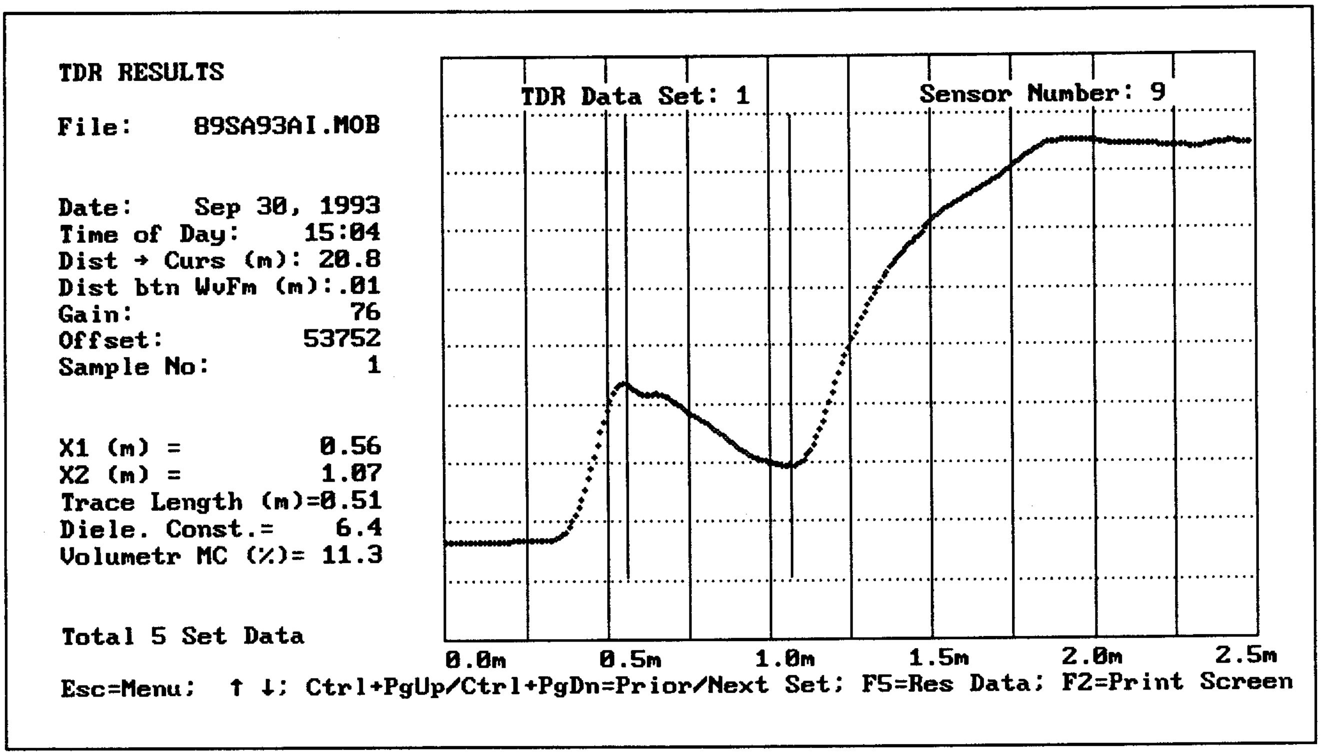


Figure D-1(cont.). Initial First Set of TDR Traces Measured with the Mobile Unit

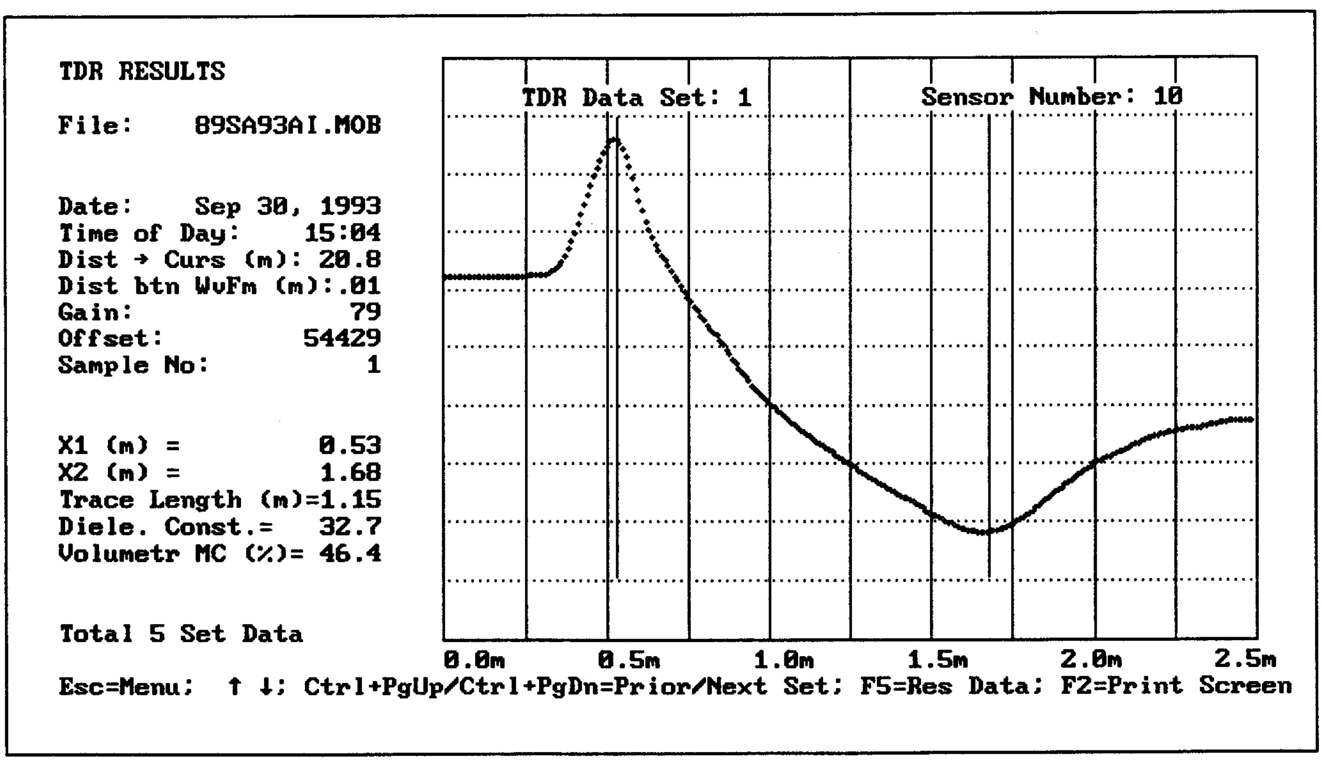


Figure D-1(cont.). Initial First Set of TDR Traces Measured with the Mobile Unit

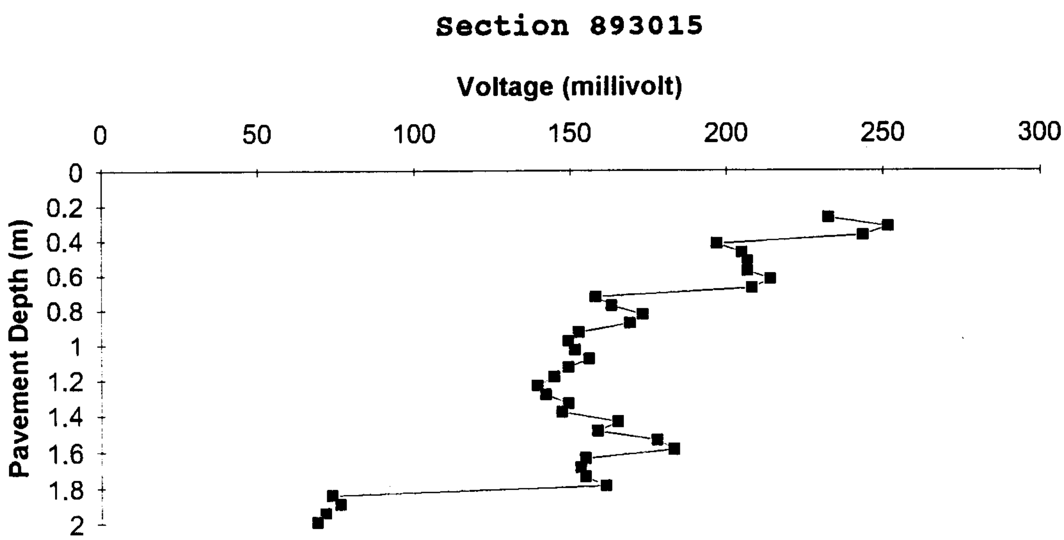


Figure D-2. Voltages Measured Using the Mobile System
During Initial Data Collection, September 30, 1993

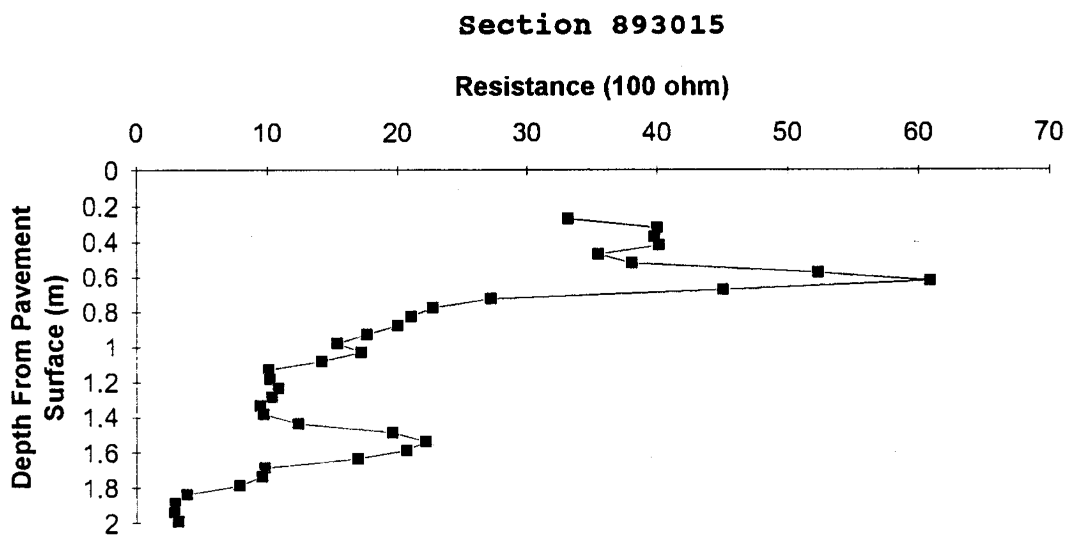


Figure D-3. Manually Collected Contact Resistance
During Initial Data Collection, September 30, 1993

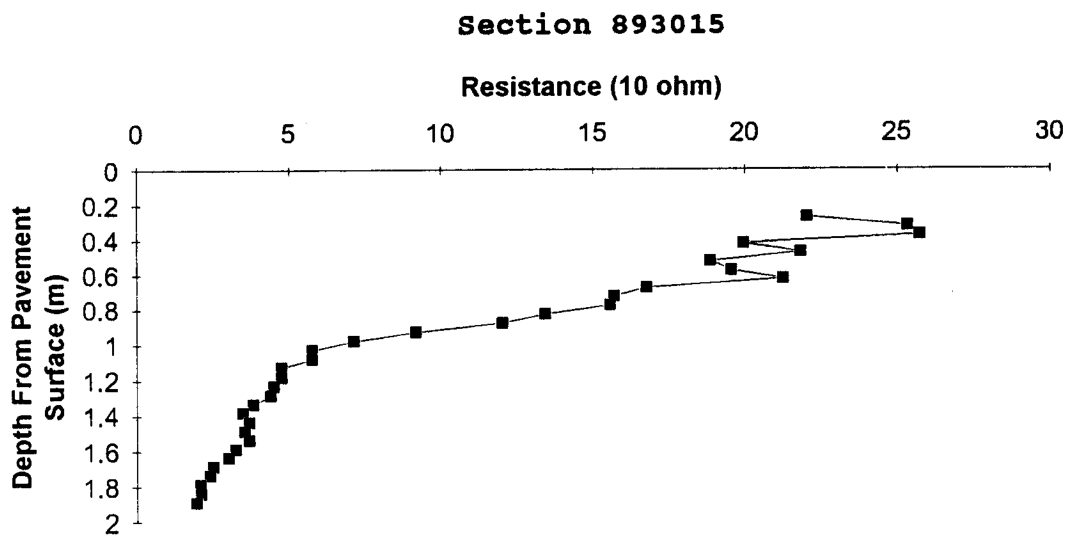


Figure D-4. Manually Collected Four Point Resistivity During Initial Data Collection, September 30, 1993

Table D-1. Contact Resistance After Installation

LTPP Seasonal Monitoring Study	State Code	[89]
Data Sheet R1		
Contact Resistance Measurements	Test Section Number	[3015]

1. Date (Month-Day-Year)		[09-30-93]
2. Time Measurements Began (Military)		[1340]
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	225.3	uA	68.0	
2	3	2	mV	231.4	uA	57.9	
3	3	4	mV	230.8	uA	58.0	
4	5	4	mV	230.8	uA	57.5	
5	5	6	mV	225.7	uA	63.7	
6	7	6	mV	228.1	uA	59.9	
7	7	8	mV	237.6	uA	45.4	
8	9	8	mV	241.2	uA	39.6	
9	9	10	mV	232.8	uA	51.7	
10	11	10	mV	214.3	uA	78.9	
11	11	12	mV	206.1	uA	90.8	
12	13	12	mV	202.3	uA	96.2	
13	13	14	mV	199.6	uA	99.8	
14	15	14	mV	192.9	uA	109.5	
15	15	16	mV	185.3	uA	120.7	
16	17	16	mV	191.4	uA	111.4	
17	17	18	mV	180.4	uA	127.3	
18	19	18	mV	159.5	uA	158.0	
19	19	20	mV	159.8	uA	156.8	
20	21	20	mV	163.6	uA	150.6	
21	21	22	mV	160.8	uA	154.9	
22	23	22	mV	155.4	uA	164.1	
23	23	24	mV	156.9	uA	161.6	
24	25	24	mV	171.5	uA	138.8	
25	25	26	mV	196.8	uA	100.3	
26	27	26	mV	202.9	uA	91.5	
27	27	28	mV	199.7	uA	96.5	
28	29	28	mV	160.5	uA	94.7	
29	29	30	mV	135.8	uA	138.3	
30	31	30	mV	135.9	uA	141.3	
31	31	32	mV	126.1	uA	159.6	
32	33	32	mV	85.6	uA	222.7	
33	33	34	mV	73.2	uA	243.8	
34	35	34	mV	72.9	uA	247.8	
35	35	36	mV	77.9	uA	243.2	
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 9]
Data Sheet R2		
Four-Point Resistivity Measurements	Test Section Number	[3 0 1 5]

1. Date (Month-Day-Year)	[09-30-93]
2. Time measurements Began (Military)	[1600]
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	11.8	uA	53.5	
2	2	3	4	5	mV	11.5	uA	45.4	
3	3	4	5	6	mV	12.9	uA	50.1	
4	4	5	6	7	mV	8.7	uA	43.6	
5	5	6	7	8	mV	8.3	uA	38.0	
6	6	7	8	9	mV	7.7	uA	40.8	
7	7	8	9	10	mV	9.8	uA	50.1	
8	8	9	10	11	mV	9.1	uA	42.8	
9	9	10	11	12	mV	7.7	uA	45.9	
10	10	11	12	13	mV	10.4	uA	66.2	
11	11	12	13	14	mV	11.5	uA	73.8	
12	12	13	14	15	mV	11.6	uA	86.3	
13	13	14	15	16	mV	10.7	uA	88.9	
14	14	15	16	17	mV	7.7	uA	83.8	
15	15	16	17	18	mV	8.3	uA	116.3	
16	16	17	18	19	mV	6.5	uA	112.6	
17	17	18	19	20	mV	6.1	uA	105.6	
18	18	19	20	21	mV	6.1	uA	128.4	
19	19	20	21	22	mV	6.5	uA	136.9	
20	20	21	22	23	mV	6.1	uA	135.6	
21	21	22	23	24	mV	5.7	uA	129.8	
22	22	23	24	25	mV	4.6	uA	120.2	
23	23	24	25	26	mV	3.2	uA	91.5	
24	24	25	26	27	mV	3.7	uA	100.1	
25	25	26	27	28	mV	3.1	uA	87.3	
26	26	27	28	29	mV	3.2	uA	86.6	
27	27	28	29	30	mV	3.5	uA	107.5	
28	28	29	30	31	mV	2.8	uA	92.7	
29	29	30	31	32	mV	3.7	uA	146.7	
30	30	31	32	33	mV	4.3	uA	177.3	
31	31	32	33	34	mV	3.3	uA	157.9	
32	32	33	34	35	mV	4.4	uA	207.0	
33	33	34	35	36	mV	4.3	uA	217.6	

Preparer	MZ & PZ	Employer	PMSL

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

Seasonal Uniformity Survey	Falling Weight Deflectometer
Site Number: 893015	Data Collection and
Date Surveyed: September 29-September 30, 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	Volum. K	Volum. K std dev	Effective Thick.	Effective Thick. std dev	
-10 to 169 **Sept 29** @ 0956	6.37	1.19	2.84	0.49	164	28	7.69	0.51	*
-10 to 169 **Sept 30** @ 0852	5.74	2.27	3.02	1.10	169	48	8.56	1.72	40.8
-10 to 169 **Sept 30** @ 1131	6.25	1.01	2.74	0.35	166	22	7.68	0.47	53.5
-10 to 169 **Sept 30** @ 1358	6.46	0.84	2.80	0.45	162	23	7.59	0.34	60.4

* Note: No temperature taken on September 29, 1993

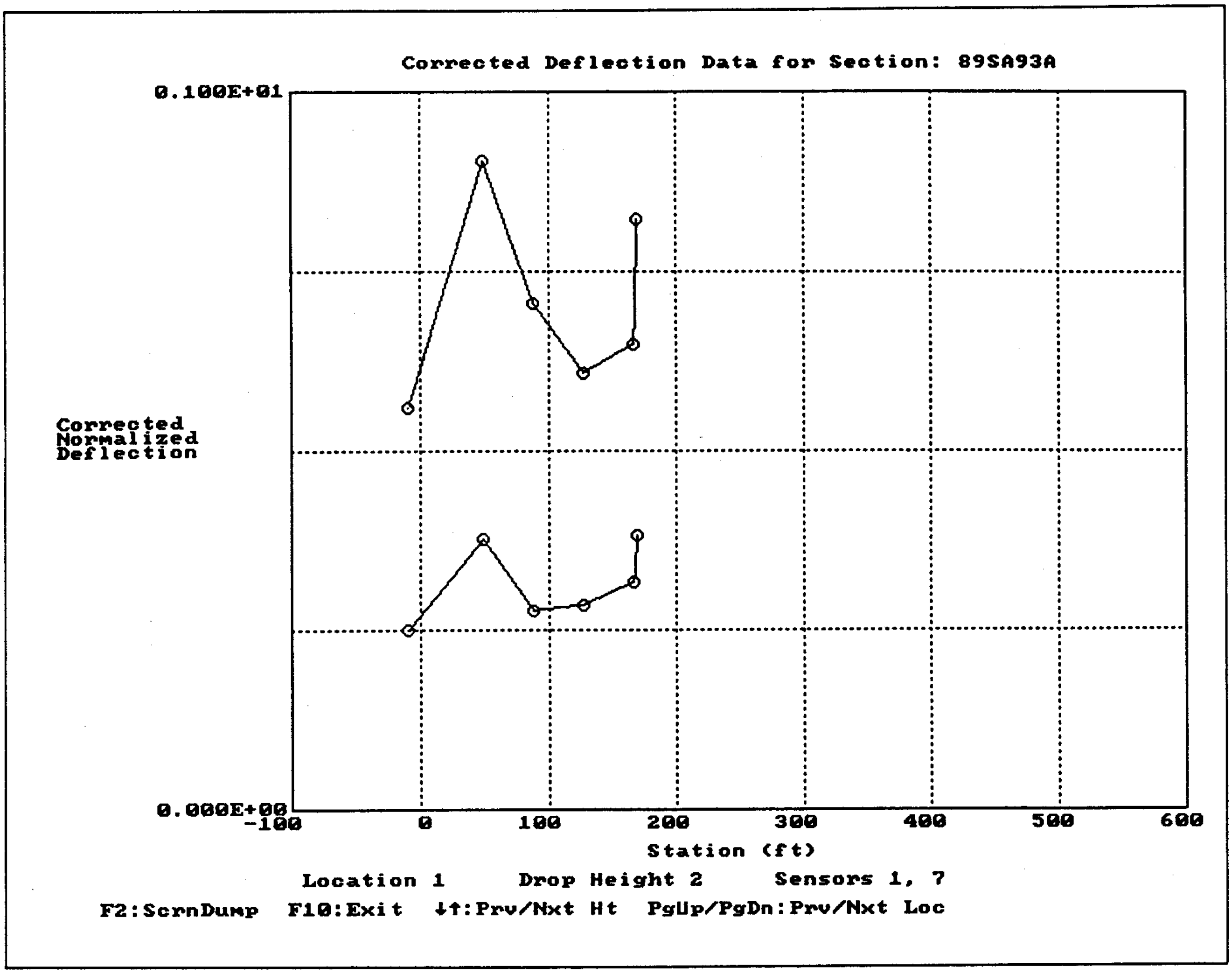


Figure D-5. Deflection Profiles from FWDCHECK
(Test Date and Time September 29, 1993 @ 0956)

Table D-4. Volumetric K and Effective Thickness from FWDCHECK
(Test Date and Time September 29, 1993 @ 0956)

Rigid Pavement Thickness Statistics - 89SA93A - Drop Height 2			
Subsection	Station	Volumetric K	Effective Thickness
1	-10	200	8.19
	50	129	6.97
	89	178	7.44
	129	179	8.19
	166	163	8.00
	168	131	7.34
Subsection 1	Overall Mean	164	7.69
	Standard Deviation	28	0.51
	Coeff of Variation	17.24%	6.62%

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

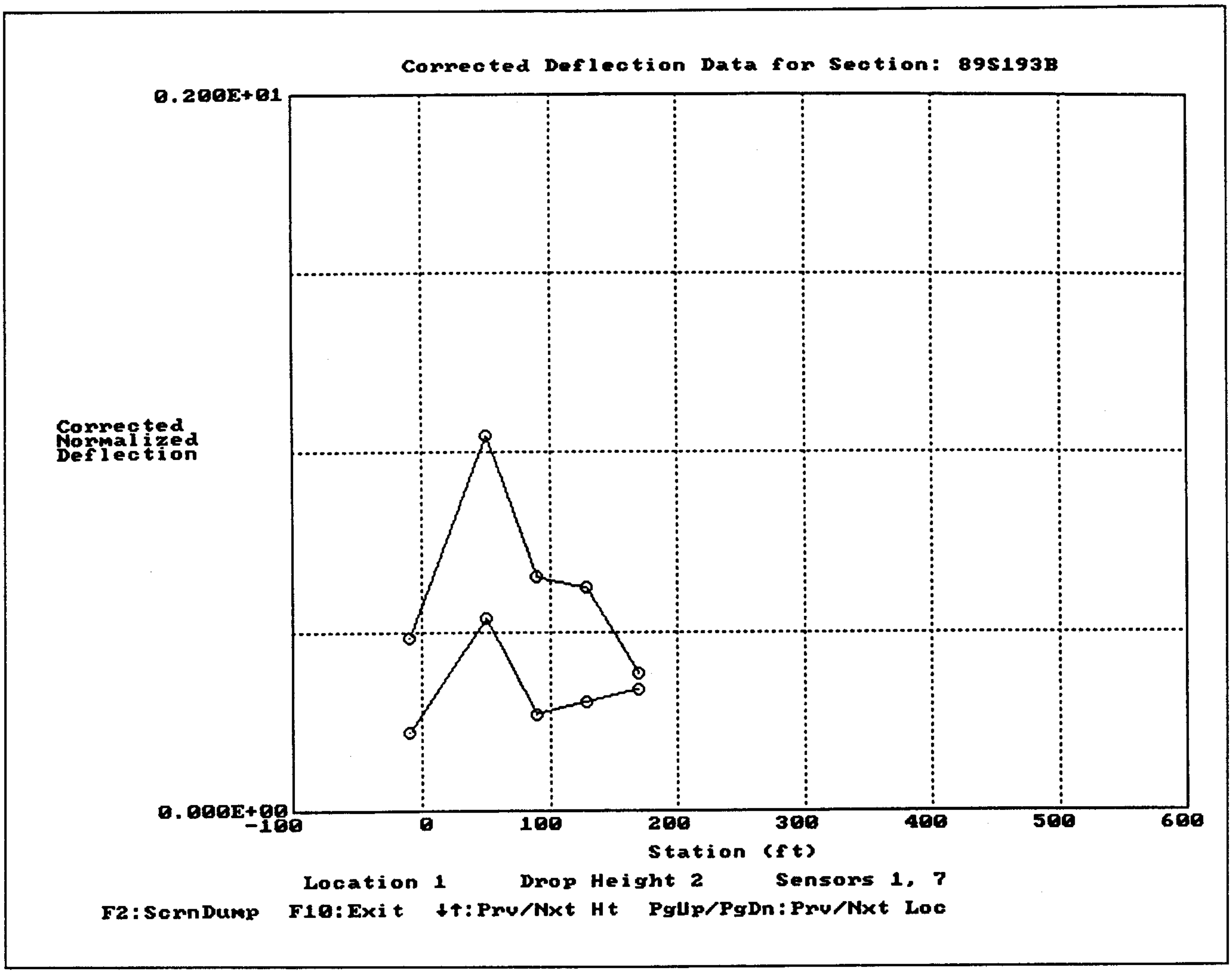


Figure D-6. Deflection Profiles from FWDCHECK
(Test Date and Time September 30, 1993 @ 0852)

Table D-5. Volumetric K and Effective Thickness from FWDCHECK
(Test Date and Time September 30, 1993 @ 0852)

Rigid Pavement Thickness Statistics - 89S193B - Drop Height 2			
Subsection	Station	Volumetric K	Effective Thickness
1	-10	231	8.75
	50	99	6.88
	89	184	7.63
	129	170	8.19
	166 *		
	168	160	11.38
Subsection 1	Overall Mean	169	8.56
	Standard Deviation	48	1.72
	Coeff of Variation	28.32%	20.07%

Note: No test pit data found. therefore no results exist...
* Note: Station 166 not tested

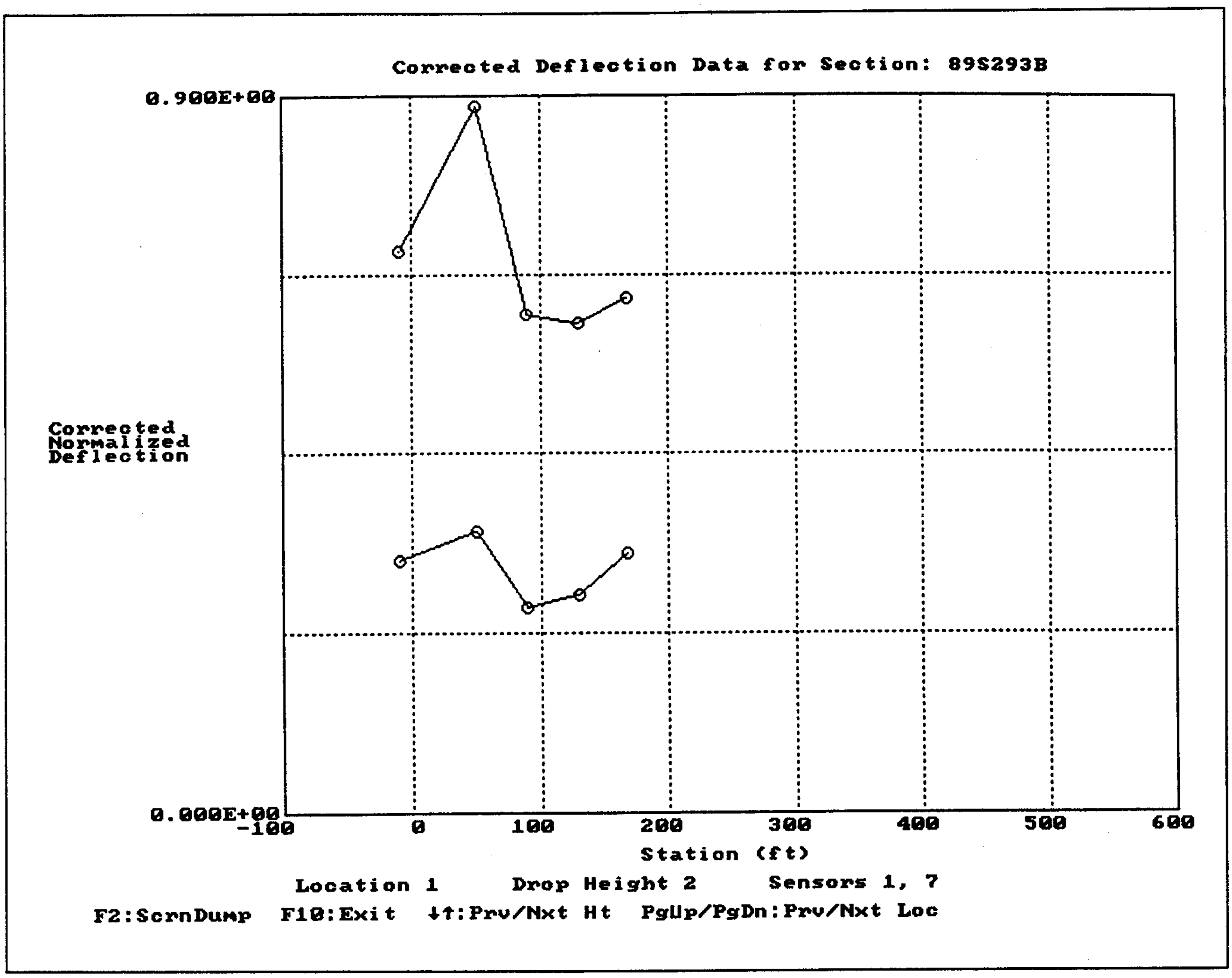


Figure D-7. Deflection Profiles from FWDCHECK
(Test Date and Time September 30, 1993 @ 1131)

Table D-6. Volumetric K and Effective Thickness from FWDCHECK
(Test Date and Time September 30, 1993 @ 1131)

Rigid Pavement Thickness Statistics - 89S293B - Drop Height 2			
Subsection	Station	Volumetric K	Effective Thickness
1	-10	156	7.72
	50	136	6.88
	89	191	7.81
	129	184	8.00
	166 *		
	168	162	8.00
Subsection 1	Overall Mean	166	7.68
	Standard Deviation	22	0.47
	Coeff of Variation	13.25%	6.08%

Note: No test pit data found, therefore no results exist...
* Note: Station 166 not tested

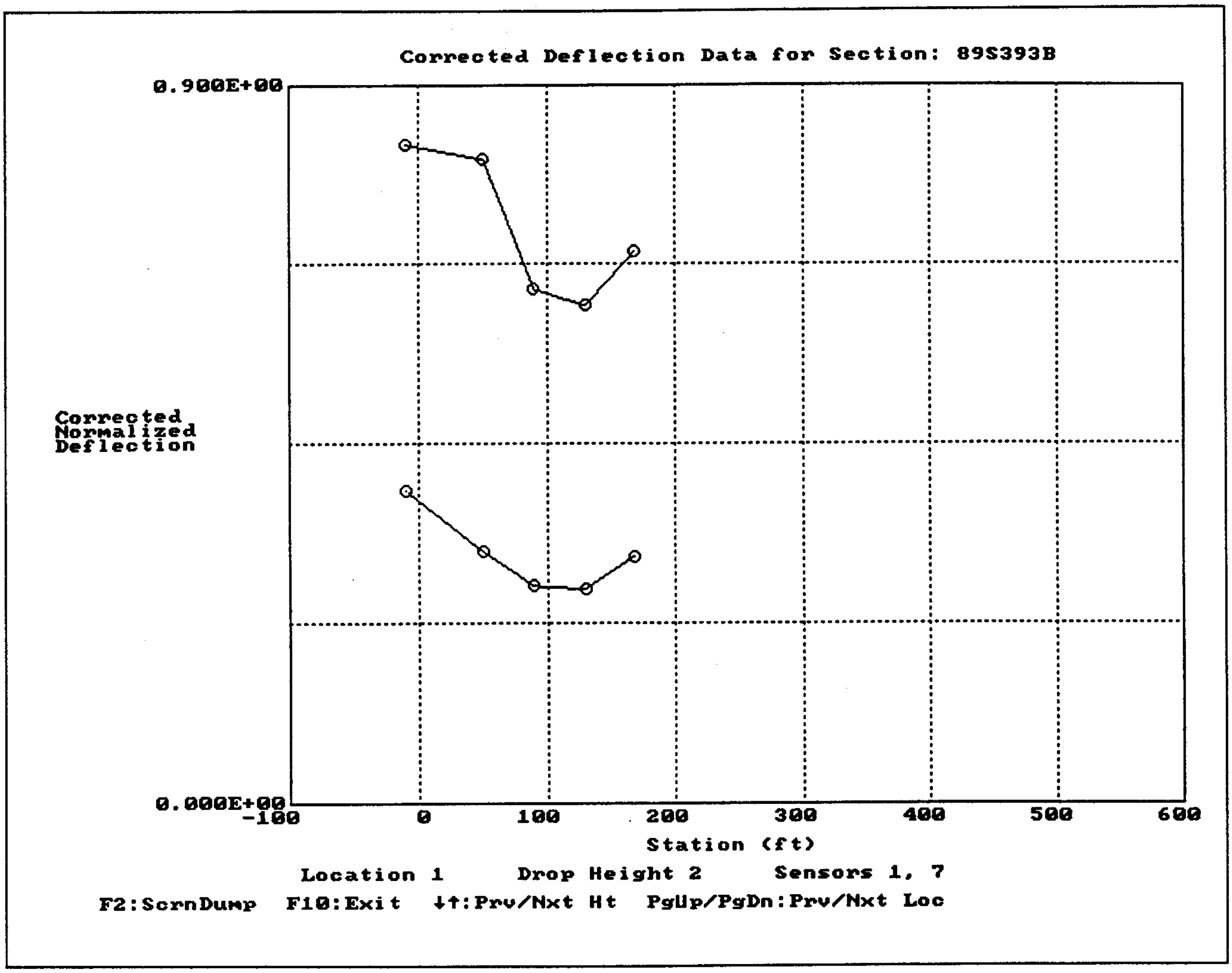


Figure D-8. Deflection Profiles from FWDCHECK
(Test Date and Time September 30, 1993 @ 1358)

Table D-7. Volumetric K and Effective Thickness from FWDCHECK
(Test Date and Time September 30, 1993 @ 1358)

Rigid Pavement Thickness Statistics - 89S393B - Drop Height 2			
Subsection	Station	Volumetric K	Effective Thickness
1	-10	129	7.44
	50	151	7.06
	89	182	7.81
	129	185	7.91
	166 *		
	168	162	7.72
Subsection 1	Overall Mean	162	7.59
	Standard Deviation	23	0.34
	Coeff of Variation	14.32%	4.51%

Note: No test pit data found, therefore no results exist...
* Note: Station 166 not tested

Table D-8. Surface Elevation Measurements

LTPP Seasonal Monitoring Study	State Code	[89]
Surface Elevation Measurements	Test Section Number	[3015]

Survey Date	September 30, 1993
Surveyed By	MZ & PZ
Surface Type	Portland Cement Concrete JPCP
Benchmark	Observation Piezometer - 1.000 meters - assumed

STATION		OSE m offset 0.08 m	MS m offset 1.98m	ISE m offset 3.56m
0-20	3+20	1.424	1.466	1.494
0-10	3+30	1.427	1.469	1.497
0+00	3+40	1.430	1.475	1.503
0+38	3+60	1.457	1.500	1.533
0+48	3+70	1.466	1.506	1.536
0+58	3+80	1.463	1.500	1.536
0+78	4+00	1.472	1.515	1.543
0+88	4+10	1.485	1.521	1.552
0+98	4+20	1.488	1.521	1.552
1+17	4+40	1.494	1.533	1.567
1+27	4+50	1.497	1.539	1.573
1+37	4+60	1.509	1.552	1.582
1+57	5+00	1.521	1.552	1.604
1+67	5+10	1.530	1.567	1.600
1+77	5+20	1.533	1.573	1.613

OSE	Outer Slab Edge
MS	Mid Slab
ISE	Inner Slab Edge

APPENDIX E

Photographs

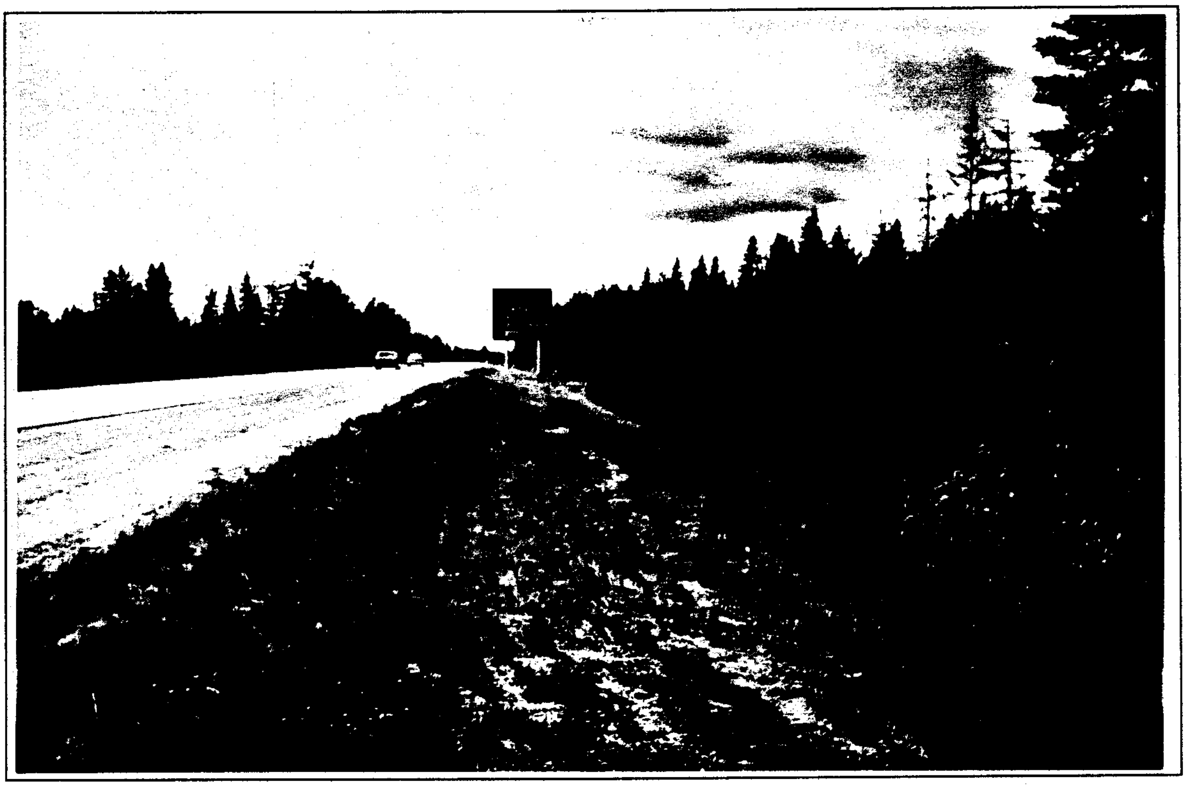


Figure E-1. Site Overview - Preliminary Visit

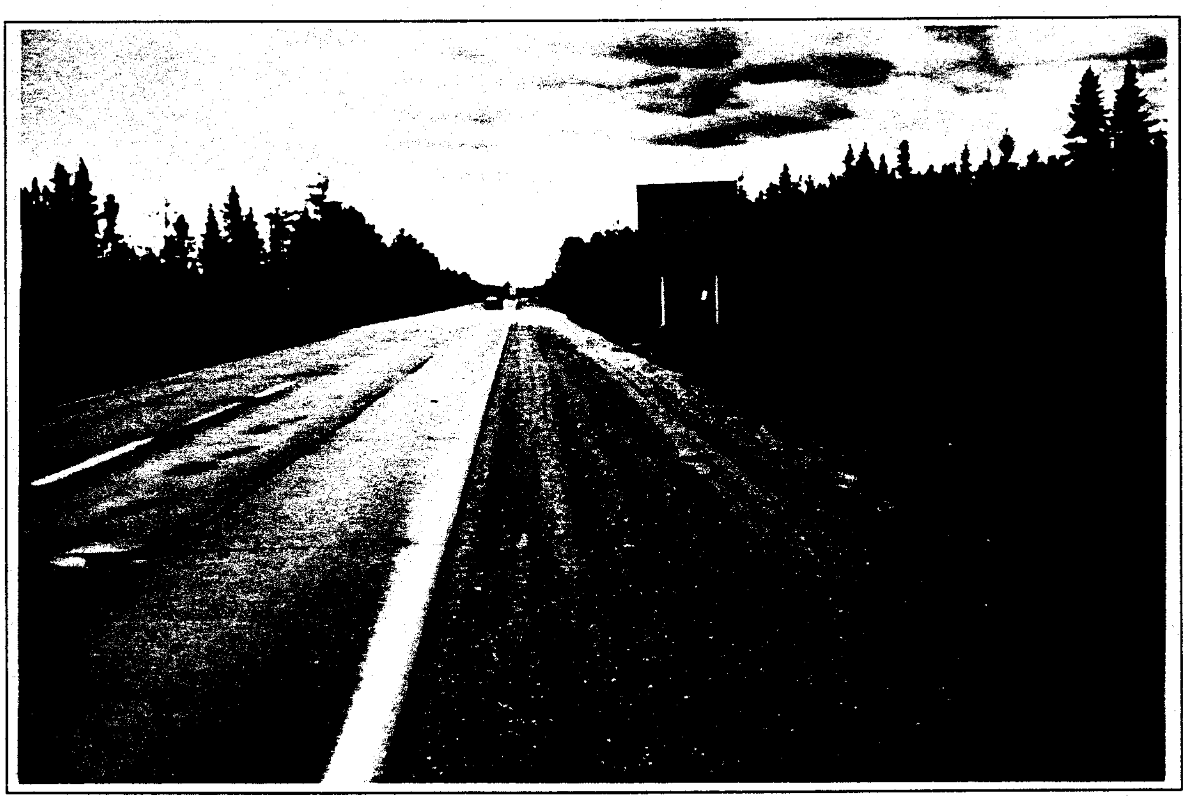


Figure E-2. Site Overview - Preliminary Visit

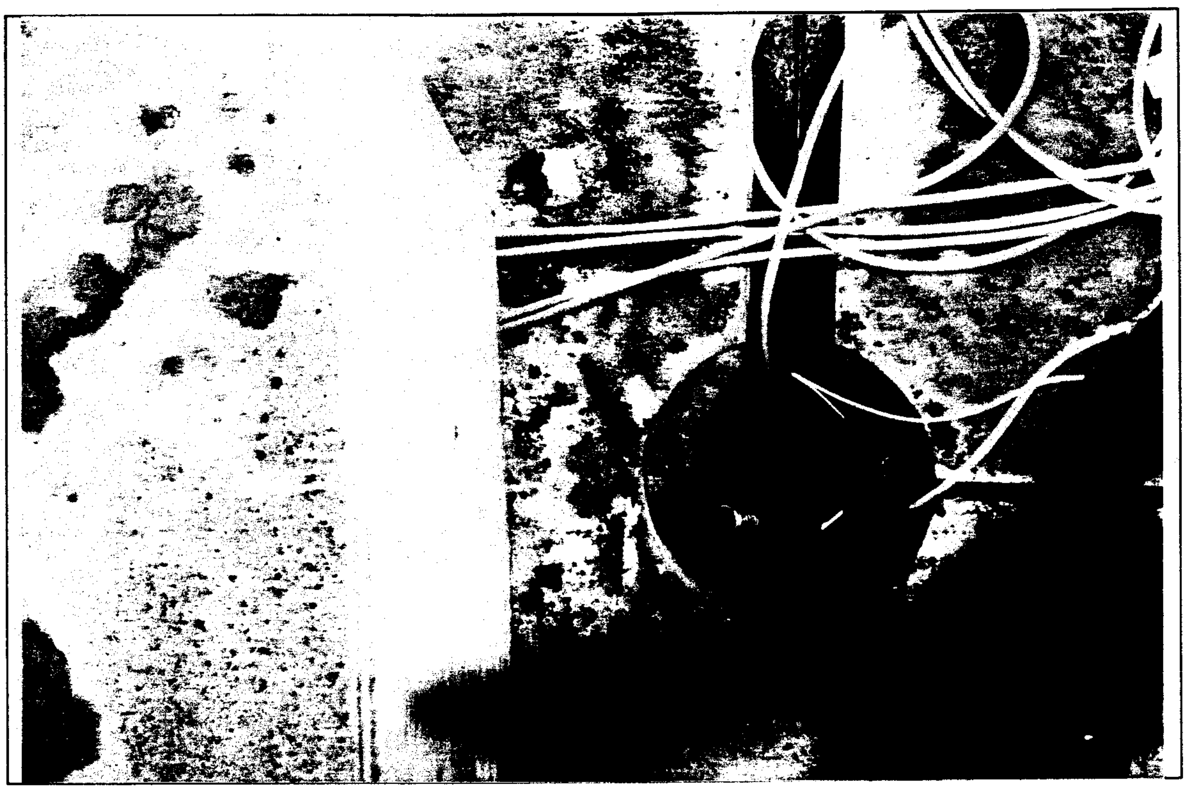


Figure E-3. Instrumentation Hole and Trench

Figure E-4. Trench from Instrumentation Hole to Equipment Cabinet

Figure E-5. Observation Well During Installation

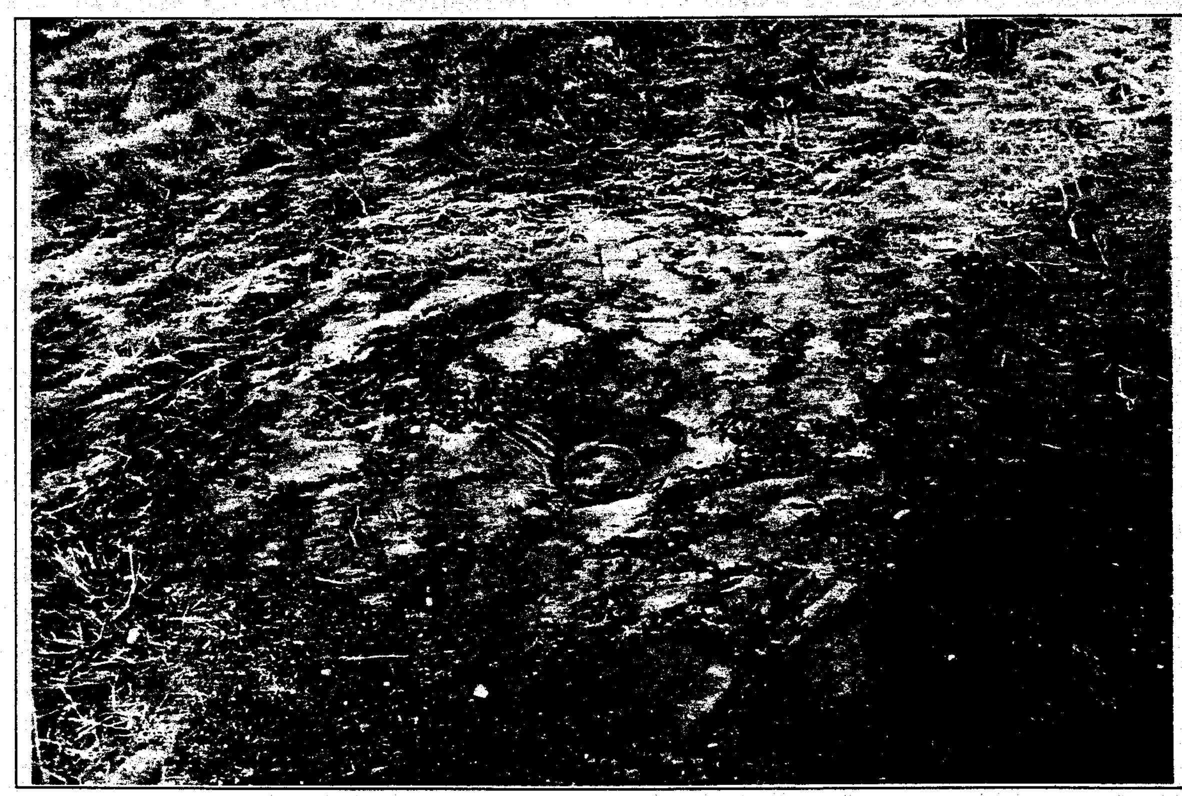


Figure E-6. Observation Well After Installation

Figure E-7. Patch Area, Two and a Half Months After Installation