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POROUS PAVEMENT FOR CONTROL OF HIGHWAY RUNOFF

Interim Report

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16. Abstract

A three-lane by 3500 linear feet portion of an urban highway was constructed of porous pavement. This design resulted from a research study of the use of porous pavement to provide highway drainage.

It was determined that after two years of observation, the porous pavement is working as designed. Although the rainfall during the year was slightly less than the typical annual rainfall, there were no storms approaching the ten-year design storms to obtain a full test of the capacity of the system.

Pavement deformation as measured in wheel tracks from a straight edge and from pavement elevations measured at the completion of construction are not severe or abnormal. Slight deformation in control sections of conventional pavement occurred immediately after opening to traffic and have undergone no significant change since then. Deformation in the experimental porous pavement is slightly more and occurred over a somewhat longer period than for the control sections.

Measurements indicate an increase in moisture content of the subgrade at one location in the porous pavement, but little or no change at the other locations monitored. The increase occurred during the first four or five months after the pavement was put into service. The condition of both the control and experimental pavements are excellent at this time.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

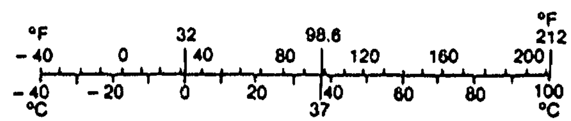
Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimetres	mm
ft	feet	0.305	metres	m
yd	yards	0.914	metres	m
mi	miles	1.61	kilometres	km
		AREA		
in^2	square inches	645.2	millimetres squared	mm^2
ft^2	square feet	0.093	metres squared	m^2
yd^2	square yards	0.836	metres squared	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	kilometres squared	km^2
		VOLUME		
fl oz	fluid ounces	29.57	millilitres	mL
gal	gallons	3.785	litres	L
ft^3	cubic feet	0.028	metres cubed	m^3
yd^3	cubic yards	0.765	metres cubed	m^3

NOTE: Volumes greater than 1000 L shall be shown in m^3.

Symbol	When You Know	Multiply By	To Find	Symbol
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5(F-32)/9	Celcius temperature	°C

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimetres	0.039	inches	in
m	metres	3.28	feet	ft
m	metres	1.09	yards	yd
km	kilometres	0.621	miles	mi
		AREA		
mm^2	millimetres squared	0.0016	square inches	in^2
m^2	metres squared	10.764	square feet	ft^2
ha	hectares	2.47	acres	ac
km^2	kilometres squared	0.386	square miles	mi^2
		VOLUME		
mL	millilitres	0.034	fluid ounces	fl oz
L	litres	0.264	gallons	gal
m^3	metres cubed	35.315	cubic feet	ft^3
m^3	metres cubed	1.308	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.102	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	Celcius temperature	1.8C + 32	Fahrenheit temperature	°F



* SI is the symbol for the International System of Measurement

(Revised April 1989)

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INTRODUCTION

General

Project F045-1 (4), Jct. I-10/Mesa Highway (Knox Road to Baseline Road) consisted of widening and reconstructing 1.47 mi of State Route 87. The work included removing existing asphalt concrete pavement and existing portland cement pavement, constructing new bituminous pavement, curb, gutter and sidewalk, installing new traffic signals at Warner Road, highway lighting and other incidental work. Approximately 0.67 mi of the northbound lanes of the project were paved using an open-graded porous pavement.

Location of Experimental Section

The porous pavement section was located within the northbound lanes of the northern 3,500 ft of the project limits between Station 105+00 and 140+00 on State Route 87. The experimental section has termini approximately 500 ft and 4,000 ft south of Elliot Road.

Instrumentation

Moisture gages were placed in the subgrade at several locations in the conventional and porous pavement sections. A continuous recording rain gage was installed adjacent to the southbound lanes and a wellpoint was installed in the trench section located at Station 130+00.

Field Measurements

Pavement deformation measurements were obtained in the northbound lanes at several locations. Also a visual examination of the porous pavement was performed to determine any pavement distress.

CONSTRUCTION HISTORY

General

The contractor commenced construction on January 10, 1986, and the project was substantially completed in June 1986. The Arizona Department of Transportation (ADOT) accepted this project in July 1986.

Design Changes

During construction, ADOT determined that the southbound lanes of State Route 87 should be constructed of conventional pavement between Station 105+00 and 140+00 Lt. instead of porous pavement as originally planned.

This action was taken because the porous pavement exhibited vertical deformation in excess of 5/8 in. at some locations after 3 weeks of carrying detour traffic, resulting in questions about the performance of the pavement section. It was concluded that the northbound section of the roadway was sufficient to test the porous pavement concept.

Project Construction

Construction of the porous pavement structure commenced with the removal of existing pavement layers and recompacting the soil at the proper subgrade elevation. Following the completion of the subgrade construction, drainage trenches were excavated 2 ft wide and 4 ft deep in front or under curb and gutter. The contractor selected Supac 4WS woven fabric for placement as a filter between the subgrade soil and open-graded subbase material.

The open-graded aggregate subbase material was produced by crushing the existing portland cement concrete pavement removed during the initial construction. This material was placed in the drainage trench and compacted in two lifts of 2 ft each . The subbase was placed in the roadway in an 8-in. compacted layer.

The asphalt treated base was stabilized with 1.8 percent of AC-40 asphalt cement. Specifications required that the 6-in. thick asphalt treated base be placed in two lifts. The open-graded asphalt concrete surface course was placed in two-3 in. thick lifts and compacted with steel wheel rollers. A third lift of approximately 1 in. thickness was placed over a substantial portion of the porous pavement to bring the surface to the established elevation and cross slope.

Porous Pavement Performance and Analysis

On May 10, 1987, traffic was moved onto the northbound lanes of the street where the porous pavement had been placed. Shortly thereafter vertical deformation of the pavement surface was detected and an investigation of the pavement condition commenced on May 29, 1986. Deformation measurements, nuclear density tests and cores were taken along wheel paths in the affected pavement area. After evaluating these data, the decision was made to examine the deformation by opening a trench across a portion of the pavement to observe movements in the separate pavement layers. Following an examination of the exposed pavement layers, it was concluded that the asphalt treated base hauling units decompacted the untreated subbase and subsequent highway traffic recompacted this course causing pavement deformation. Because of the condition of the existing porous pavement, ADOT decided to eliminate the use of porous pavement on the southbound lane of the roadway.

EXPERIMENTAL PROJECT MONITORING

General

Monitoring of the porous pavement section is being conducted over a 3-yr period following completion of construction. In order to obtain rainfall data, a continuous recording rain gage was placed just beyond the west right-of-way line at Station 139+10.

Soil moisture monitoring devices were placed in the subgrade at two locations within the porous pavement and three locations in the control pavement. Six positions can be monitored at each location. Moisture monitoring locations are at Stations 97+40, 138+00, and 143+25 in the southbound lanes and Stations 108+00 and 138+00 in the northbound lanes. Soil cells are placed at depths of 1 and 3 ft below top of subgrade at distances of approximately 5, 10, and 20 ft from the front face of the curb and gutter.

A wellpoint was placed within the drainage trench in the east concrete gutter at Station 130+00. A device installed in the well-point in the middle of February 1987 will record the highest water level reached in the trench. Previous measurements were taken to the water surface at the time of measurement but with no provisions for water level determinations at other times.

Pavement deformations have been monitored over the past year by measuring the vertical distance from a straightedge. Initial readings for deformation were taken from a straightedge on July 7, 1986, in the control section at Station 102, 104, 141, and 143 and within the porous pavement section at 500 ft intervals from Stations 108 to 138.

Actual vertical movements were measured from elevations measured on P-K shiners set into the pavement. The P.K. shiners were set and their elevations determined by use of a level on June 25, 1986. These are located at Station 106, every 500 ft from Station 110 to Station 135 and at Station 139. The reference points are set at 1, 6, 11, 16.5, 22, 28, and 34 ft from the face of the curb and gutter and at locations intermediate between each of these points. Consequently, there are 13 locations at each referenced station.

Visual Pavement Review

The northbound lanes from Station 102 to 143 of State Route 87 were visually reviewed at various times from July, 1986 to June, 1988. These reviews included observing both the conventional and porous pavement sections for cracking, distortion, disintegration, and skid hazards.

A visual review of the pavement was conducted on July 15, 1987. At that time, no visual pavement cracking, distortion, disintegration, or skid hazard was observed. An area 7 x 8 ft in plan dimension had been cut in lane 1 at Station 138+89 to facilitate in the installation of a manhole. Conventional pavement has been used to repair this area. At Station 141+92 within the control section, a 6 x 6 ft area in lanes 1, 2, and 3 has been cut and repaired in the roadway for traffic signal actuation.

The last visual review of the pavement was conducted on June 21, 1988. At that time, no visual pavement cracking, distortion, disintegration, or skid hazard was observed. Two grooves approximately 200 ft long were observed in Lane 3 Northbound between Station 123 to 125. These grooves were apparently caused by an exposed tire rim. Several tire marks were observed in the conventional pavement located at the Palomino Drive intersection.

The surface of both pavements has been observed during rainstorms on October 9, 10, and 11, 1986. It was visually observed that the surface of the porous pavement, although wet, did not have any standing or excess water on its surface. The surface of the conventional pavement section was also wet, but sheets of water could be seen on the surface along with water flowing in the curbs. Slides and video tapes of those conditions were made during a rainstorm on February 24, 1987, by Western Technologies Inc. showing that the porous pavement section was functioning properly. A typical condition of the two pavement surfaces after a rainstorm is presented in Figure 13.

Rainfall Intensity

A continuous recording rain gage was placed on this project just beyond the west right-of-way lane at Station 139+10. On August 11, 1987, at the request of the property owner, the rain gage was moved 385 ft to the west. Continuous rainfall readings were taken from June 29, 1986, to July 11, 1988.

During the first year (June 29, 1986 to July 7, 1987), the greatest amount of rainfall (0.82 in.) over a 24-hr period occurred on February 24, 1987. The total rainfall for this period of time was 7.07 in. The highest estimated rainfall intensity occurred on February 26, 1987. On this date, 0.42 in. of rain fell in an estimated time period of one-half hour giving an estimated rainfall intensity of 0.84 in./hr.

During the second year, continuous rainfall readings were taken from July 8, 1987, to July 11, 1988. Rainfall data are shown in Table 1. A total of 24 days of rainfall occurred between these dates. The greatest amount of rainfall (1.15 in.) over a 24-hour period occurred on December 17, 1987. The highest estimated rainfall intensity occurred on April 15, 1988. On this date, 0.1 in. of rain fell in an estimated time period of one-tenth hour giving an estimated rainfall intensity of 1.0 in./hr. A total rainfall of 6.98 in. was recorded at this site during the period under review.

TABLE 1 - RAIN GAGE DATA AND ESTIMATED RAINFALL INTENSITY

Date	Rainfall (in.)	Time (hr)	Estimated Rainfall Intensity (in./hr)
07-26-87	0.67	1.0	0.67
08-04-87	0.21	0.5	0.42
08-14-87	0.04	0.3	0.12
08-25-87	0.07	0.5	0.14
08-26-87	0.07	0.5	0.14
09-22-87	0.15	2.0	0.08
09-23-87	0.05	0.5	0.10
10-13-87	0.08	1.5	0.05
10-31-87	0.04	1.0	0.04
10-31-87	0.06	1.3	0.04
11-01-87	0.26	0.5	0.52
11-01-87	0.37	2.0	0.18
11-01-87	0.29	0.3	0.87
11-01-87	0.07	0.5	0.14
11-05-87	0.07	0.3	0.21
12-04-87	0.14	0.5	0.28
12-05-87	0.16	0.8	0.21
12-17-87	0.58	5.0	0.12
12-17-87	0.28	2.3	0.12
12-17-87	0.29	2.5	0.12
01-06-88	0.05	0.3	0.15
01-16-88	0.05	2.0	0.02
01-17-88	0.15	1.0	0.15
01-18-88	0.35	4.0	0.09
02-02-88	0.35	3.0	0.12
03-02-88	0.21	0.3	0.63
04-15-88	0.07	0.1	0.70
04-15-88	0.10	0.1	1.00
04-15-88	0.29	3.0	0.10
04-15-88	0.11	5.0	0.02
04-16-88	0.18	0.3	0.60
04-21-88	0.32	1.5	0.21
04-21-88	0.20	0.3	0.67
04-21-88	0.43	1.5	0.29
04-22-88	0.15	2.0	0.08
06-19-88	0.02	0.3	0.06
Total Rainfall	6.98 inches		

Design rainfall intensities for a 10 year, 10 minute storm and a 10 year, 24 hour storm are 5.20 and 0.11 in./hr, respectively. The high estimated maximum rainfall intensity (1.00 in./hr) occurred on April 15, 1988, and is one fifth the amount of a 10 year, 10 minute storm. The greatest measured amount of rainfall over a 24-hour period for a 2 year period was 1.15 in. (0.05 in./hr) recorded on December 17, 1987. This intensity is slightly less than one half of a 10 year, 24-hour storm.

Wellpoint Readings

A wellpoint was placed within the drainage trench located in the east concrete gutter at Station 130. A device installed in the wellpoint in the middle of February 1987 will record the highest water level reached in the trench. The highest water level recorded for the first year in the trench was 3-1/2 in. The highest water level recorded in the trench during the second year was 9 in. as measured from the bottom of the trench on April 25, 1988. Table 2 summarizes the wellpoint data from August 5, 1987, to June 21, 1988.

TABLE 2 - WELLPOINT READINGS

Date	Time	Depth of Water Above Trench Bottom (in.)
08-05-87	10:00 am	2 1/4
08-25-87	4:30 pm	1 1/4
08-26-87	7:15 am	3
09-23-87	7:50 am	1 1/4
11-01-87	2:00 pm	6
11-02-87	6:45 am	3
11-09-87	7:15 am	2 1/2
12-18-87	9:15 am	3 1/2
01-18-88	11:00 am	3 1/4
04-18-88	8:00 am	2 1/2
04-25-88	7:00 am	9 *
04-25-88	7:00 am	2 1/2
06-21-87	8:00 am	1 1/4

* Recorded by maximum water height device

Moisture Monitors

Soil moisture monitoring devices have been placed in two locations within the porous pavement and three locations within the control pavement. Six positions within the subgrade can be monitored at each location. Moisture monitoring locations are Station 97+40, 138+00 and 143+25 in the southbound lanes and Station 108+00 and Station 138+00 in the northbound lanes. Devices are placed at depths of 1 and 3 ft below top of subgrade at distances of approximately 5, 10 and 20 ft from the front face of the curb and gutter (see Figure 1).

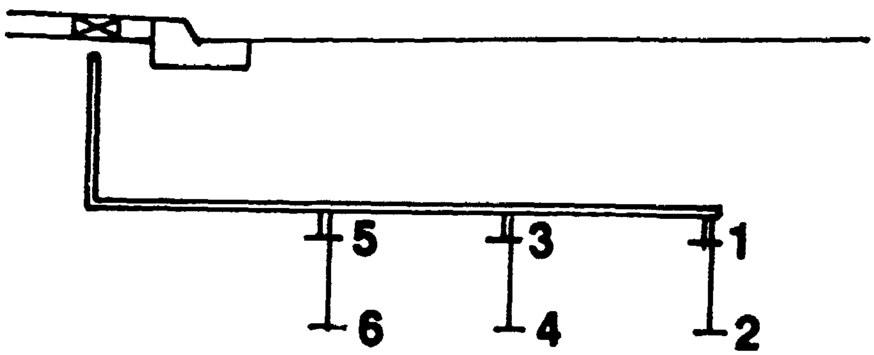

FIGURE 1. TYPICAL MOISTURE MONITOR POSITIONS

All moisture monitors were initially read on June 7, 1986. The majority of the monitors underwent a significant decrease in resistance between then and the next reading on August 11, 1986. A substantial portion of this change is felt to be stabilization of the monitors or moisture contents within the subgrade in the vicinity of the gages. Consequently, changes in subgrade moisture over time were related to the August 11, 1986 readings. Readings were taken several times during the first year. The analysis for moisture change was taken from changes in the electrical resistance of the gages from August 11, 1986 to readings on June 21, 1988. Appendix A gives the moisture monitor readings in ohms.

The moisture readings from monitoring devices located at Station 97+40 Lt and 138+00 Lt remained approximately the same when read on August 11, 1986, July 9, 1987, and June 21, 1988. After the first year, the estimated moisture content of the subgrade at Station 108 Rt increased approximately 2.3 percent. After two years Station 108 Rt had an estimated increase in moisture content of 1.5 percent. The moisture content in the subgrade increased more for gages 5 and 6 which are located nearest to the trench excavation; however, the magnitude of this increase is subject to question. Data recorded from December 8, 1986 to June 21, 1988, indicated little change in the moisture content of the subgrade. This lack of change would indicate that the moisture content of the subgrade has stabilized.

The moisture content of the subgrade over the past year has decreased approximately 1 percent at Station 138+00 Rt. This change was significant at gage 5 where the decrease is estimated to be 4.7 percent. Gage 5 is the upper gage nearest the curb and gutter (see Figure 1). The change in the moisture content at gage 5 may be caused by the stabilization of the subgrade moisture at this location.

Moisture monitor gages located at Station 143+25 Lt indicate a fairly insignificant change in subgrade moisture except for gage 5. During the first year monitoring period, gage 5 indicated a subgrade moisture increase of 9.2 percent. After two years of monitoring, the increase is now 8.7 percent. This small change in moisture content would indicate that the moisture content in this area of the subgrade has stabilized.

At all Stations except for 138+00 Rt some gages read 2000 or infinity. This would indicate that the soil has dried out or that the monitoring gage has malfunctioned.

Before the moisture monitoring devices were placed into the pavement subgrade, four of the monitoring gages were calibrated to 4, 8, 12 and 16 percent soil moisture contents. Three of the gages had similar calibration curves while one gage was significantly different. The results of the three similar gages were used to convert the ohm readings of the gages to moisture content.

TABLE 3 - MOISTURE MONITOR CHANGES

Percent Moisture Change from 8-11-86 to 7-9-87
and from 8-11-86 to 6-21-88

Station	1		2		3		4		5		6	
97+40 Lt	0.0	(0.3)	0.0	(0.7)	0.8	(0.3)	1.2	(0.3)	0.8	(0.8)	**	(0.1)
108+00 Rt	2.8	(2.9)	2.2	(0.9)	2.0	(0.7)	2.3	(+)	12.1	(12.5)	6.1	(6.3)
138+00 Rt	0.0	(0.0)	0.0	(-0.5)	0.4	(-0.5)	0.0	(0.0)	0.0	(-4.7)	0.0	(-1.5)
138+00 Lt	*	(*)	*	(*)	0.5	(*)	0.0	(-0.4)	*	(*)	0.0	(0.8)
143+25 Lt	0.3	(-0.9)	0.4	(0.4)	3.7	(4.1)	-1.8	(-1.8)	9.2	(8.7)	-0.2	(-1.2)

Note: **( ) Percent moisture change from 8-11-86 to 6-21-88**
- Decrease in moisture content
*** No readings**
**** No reading 7/9/87**
+ No reading 6/21/88

Wheel Rut Deformation Measurements (Straightedge)

Wheel rut deformation measurements were made in the northbound lanes at Station 108, 113, 118, 123, 128, 133, and 138 in the porous pavement section and at Station 102, 104, 141, and 143 in the conventional pavement section. Measurement readings were made using a 10 ft straightedge and a scale divided in 1/100 of a foot. A 1/8 in. stepped gage block was used in place of the 1/100-foot scale on July 9, 1987. The revised method of measurement resulted in readings always being rounded downward. To correct this condition, 1/16 in. was milled from the bottom of the stepped gage block. This change in reading method can be seen in the results given in Figure 2. Wheel rut deformation measurement data are given in Appendix B. Table 4 summarizes this data and Figure 2 graphically presents this information.

It was determined that the porous pavement at Station 138 had the largest amount of wheel rut deformation (3/16 in.) for the first monitoring period. Porous pavement Stations 118 and 138 had the largest amount of wheel rut deformation (3/16 in.) after two years.

After the first year, the porous pavement exhibited average wheel rut deformations slightly over 3/16 in., while the conventional pavement measured slightly under 1/8 in. After the second year, the porous pavement exhibited average wheel rut deformations between 1/8 and 3/16 in., while the conventional pavement measured slightly over 1/16 in.

The largest measured wheel rut deformation using the stepped gage block or scale was 1/2 in. This measurement was observed at Station 108 lane 2, Station 113 lane 3, Station 118 lane 3 and Station 138 lane 3. The largest measured wheel rut deformation recorded on January 28, 1988, and June 21, 1988, was 1/4 in.

Figure 3, 4 and 5 illustrate the porous pavement deformations by lane and wheel path. The porous pavement section continued to increase in wheel rut deformations for a short period of time after opening to traffic and then stabilized with little further increase. This early increase in the wheel rut deformations in the porous pavement section is suspected to be caused by the additional recompaction of the untreated subbase by traffic. The conventional pavement underwent some deformation early after completion with little or no subsequent change. The largest wheel rut deformation recorded was 1/4 in. This value was measured in 1986, 1987 and 1988. Wheel track rutting is not severe in either pavement type.

Figures 6, 7 and 8 illustrate the conventional pavement deformations by lane and wheel path. Appendix C and D summarizes the wheel rut deformations by lane and wheel path for both the porous and conventional pavements.

Wheel rut deformation measurements were evaluated by traffic lane and wheel path. It was found for the first monitoring period that lane 3 (next to median) in the porous pavement section had the greatest amount of deformation. After the record monitoring period, lanes 1 and 3 in the porous pavement section have the greatest amount of deformation. Lane 2 had the greatest deformation in the conventional pavement section. The east wheel path in lane 3 of the porous pavement had the most deformation when compared to all other wheel paths. Table 5 summarizes the above information. The deformation location in lane 3 may be the result of the construction sequence for the porous pavement section.

Lanes 1 and 2 were first constructed and opened to traffic for approximately three weeks before lane 3 was placed. Therefore, the open-graded aggregate subbase was most likely recompacted by traffic in these lanes while lane 3 did not benefit from this construction sequence with the recompacting occurring following opening to traffic.

Appendix C and Figures 3, 4 and 5 outline information on each lane and wheel path in the porous pavement section. The average wheel path deformation for the first year monitoring period was slightly over 3/16 in. By the end of the second monitoring period, the deformation was between 1/8 and 3/16 in. Appendix D and Figures 6, 7 and 8 outline information on each lane and wheel path in the conventional section. The average wheel path deformation for the first year monitoring period was slightly under 1/8 in. At the conclusion of the monitoring period, the deformation was slightly over 1/16 in.

TABLE 4 - AVERAGE WHEEL RUT DEFORMATIONS (INCHES)

Porous Pavement Section

Sta	Date 1986						1987			1988		
	7-7	7-16	7-25	8-13	9-8	10-20	2-17	5-22	7-9	1-28	6-21	Avg
138	3/16	3/16	3/16	1/4	1/4	3/16	1/4	3/16	1/8	1/8	1/8	3/16
133	1/8	1/8	1/8	3/16	3/16	1/8	3/16	3/16	1/8	1/8	1/8	1/8
128	1/8	1/8	1/8	3/16	1/8	1/8	1/8	1/8	1/8	1/8	1/16	1/8
123	1/8	1/8	1/8	3/16	3/16	3/16	3/16	1/8	1/8	1/8	1/16	1/8
118	1/8	1/8	3/16	1/4	1/4	3/16	5/16	3/16	1/8	3/16	1/8	3/16
113	1/8	1/8	1/8	3/16	3/16	3/16	1/8	3/16	1/8	1/8	1/8	1/8
108	3/16	3/16	3/16	3/16	3/16	3/16	1/8	3/16	1/8	1/8	1/8	3/16
Avg	1/8	1/8	1/8	3/16	3/16	3/16	1/8	3/16	1/8	1/8	1/8	

Conventional Pavement Section

Sta	7-7	7-16	7-25	8-13	9-8	10-20	2-17	5-22	7-9	1-28	6-21	Avg
143	1/8	1/8	1/8	1/8	1/8	1/8	1/16	1/8	1/16	1/8	1/16	1/8
141	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/8	1/16	1/16	1/16	1/16
104	1/8	1/8	1/8	1/16	1/8	1/8	1/8	1/8	0	1/16	1/16	1/8
102	1/8	1/16	1/16	1/16	1/8	1/8	1/16	1/16	0	1/16	1/16	1/16
Avg	1/8	1/8	1/8	1/16	1/8	1/8	1/16	1/8	1/16	1/16	1/16	

Average Wheel Rut Deformation

	1986-1987	1986-88
Porous Pavement	slightly over 3/16	between 1/8 and 3/16
Conventional Pavement	slightly under 1/8	slightly over 1/16

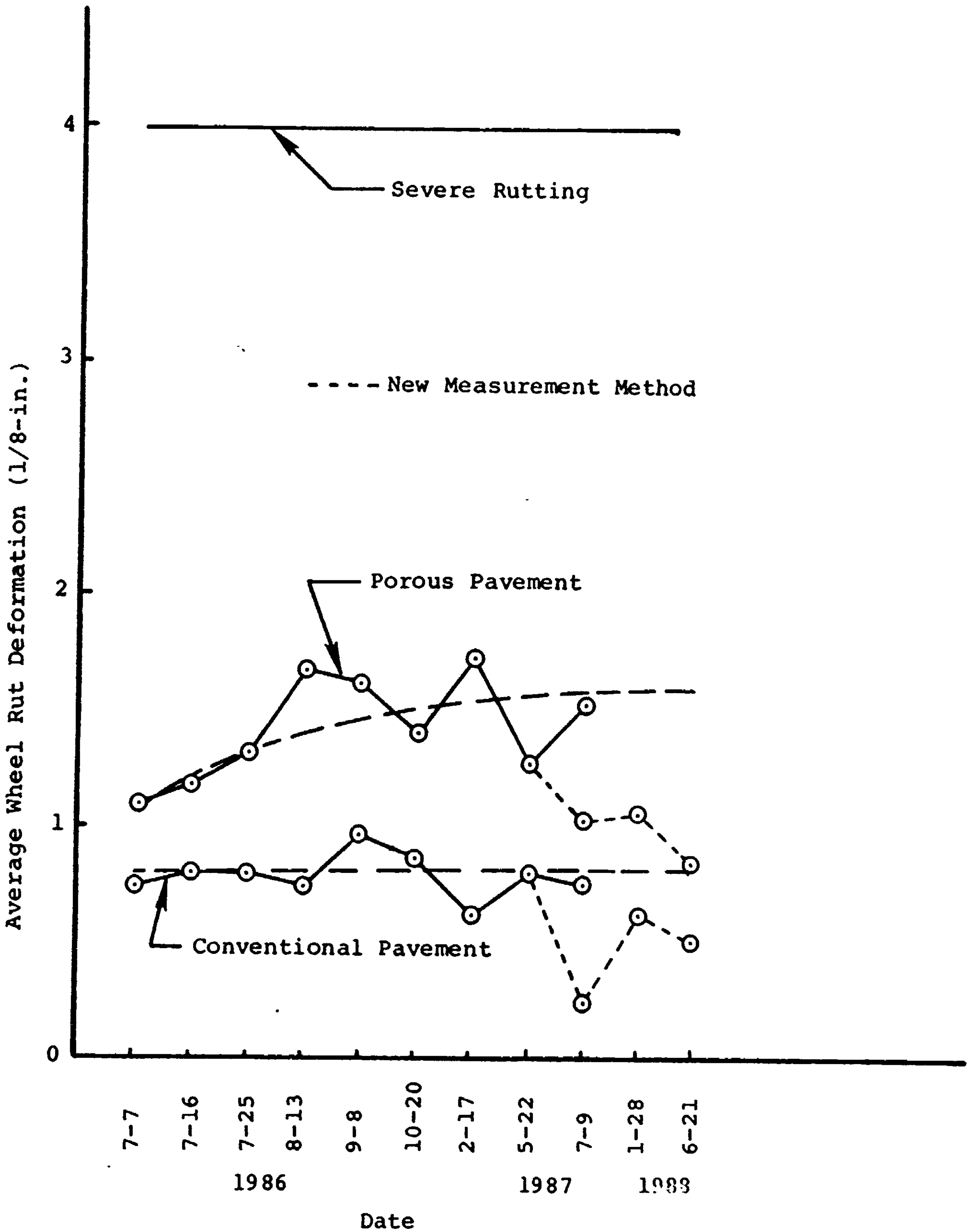

FIGURE 2. AVERAGE WHEEL RUT DEFORMATION

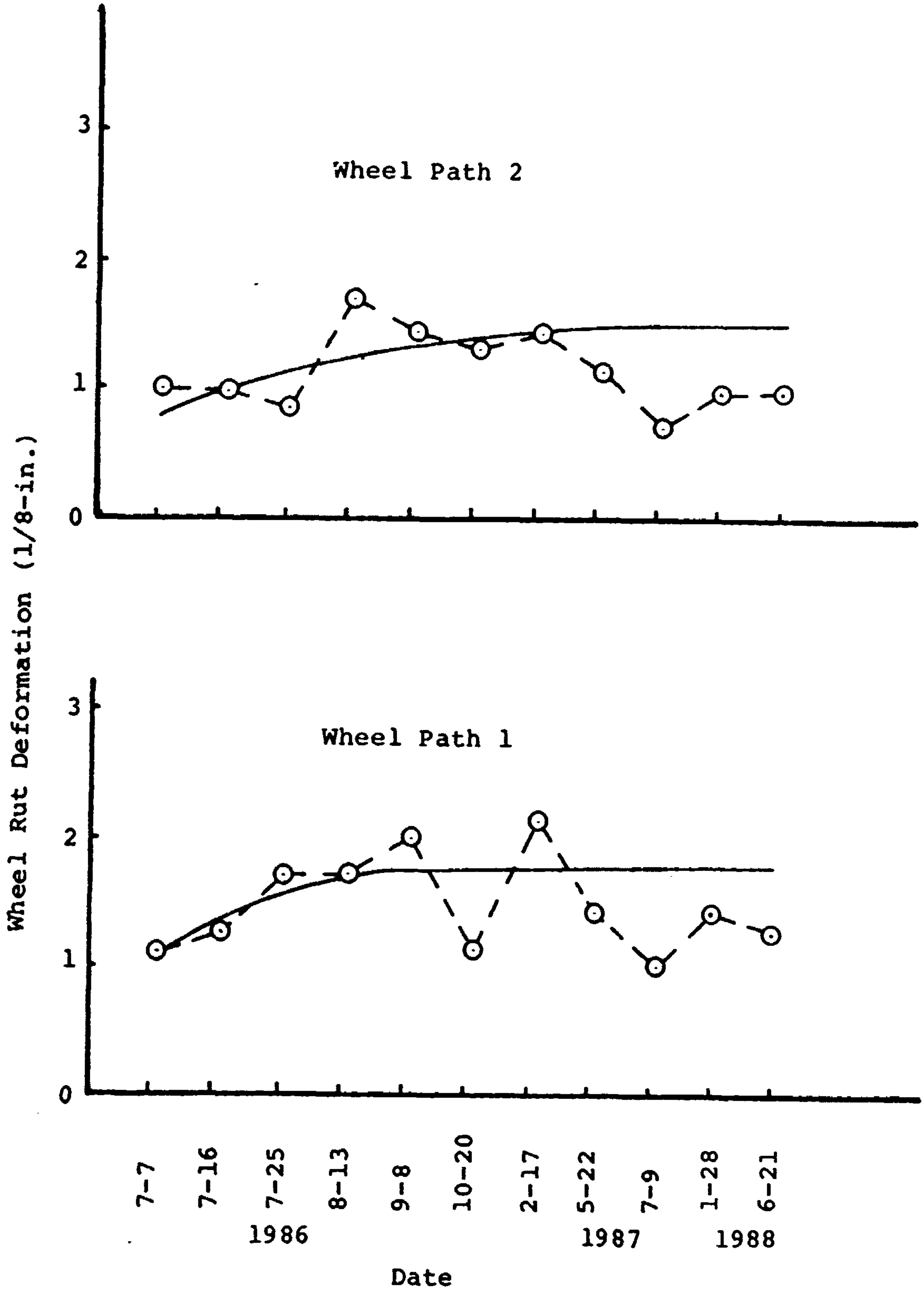

FIGURE 3. WHEEL RUT DEFORMATIONS
POROUS PAVEMENT LANE 1

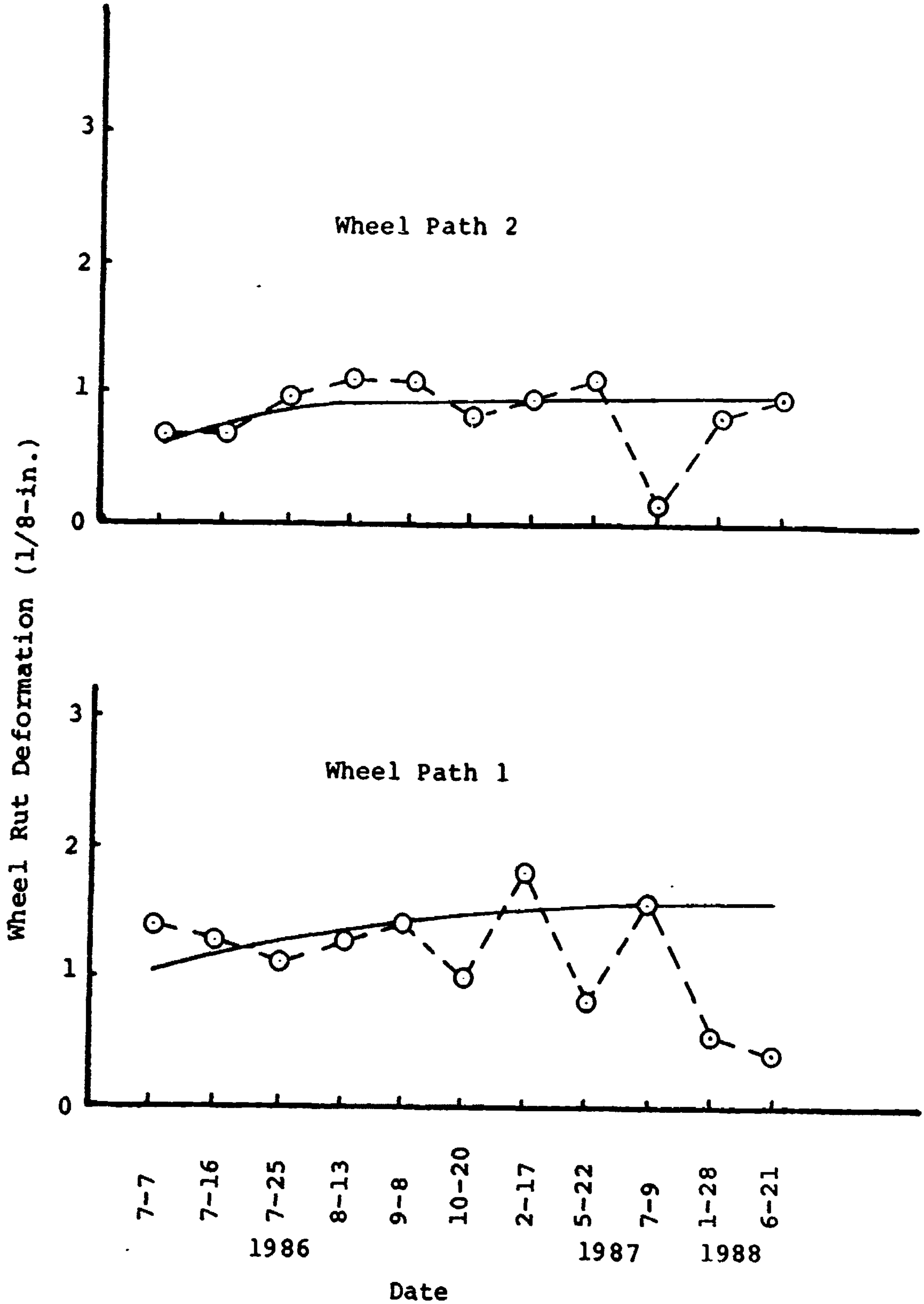

FIGURE 4. WHEEL RUT DEFORMATIONS
POROUS PAVEMENT LANE 2

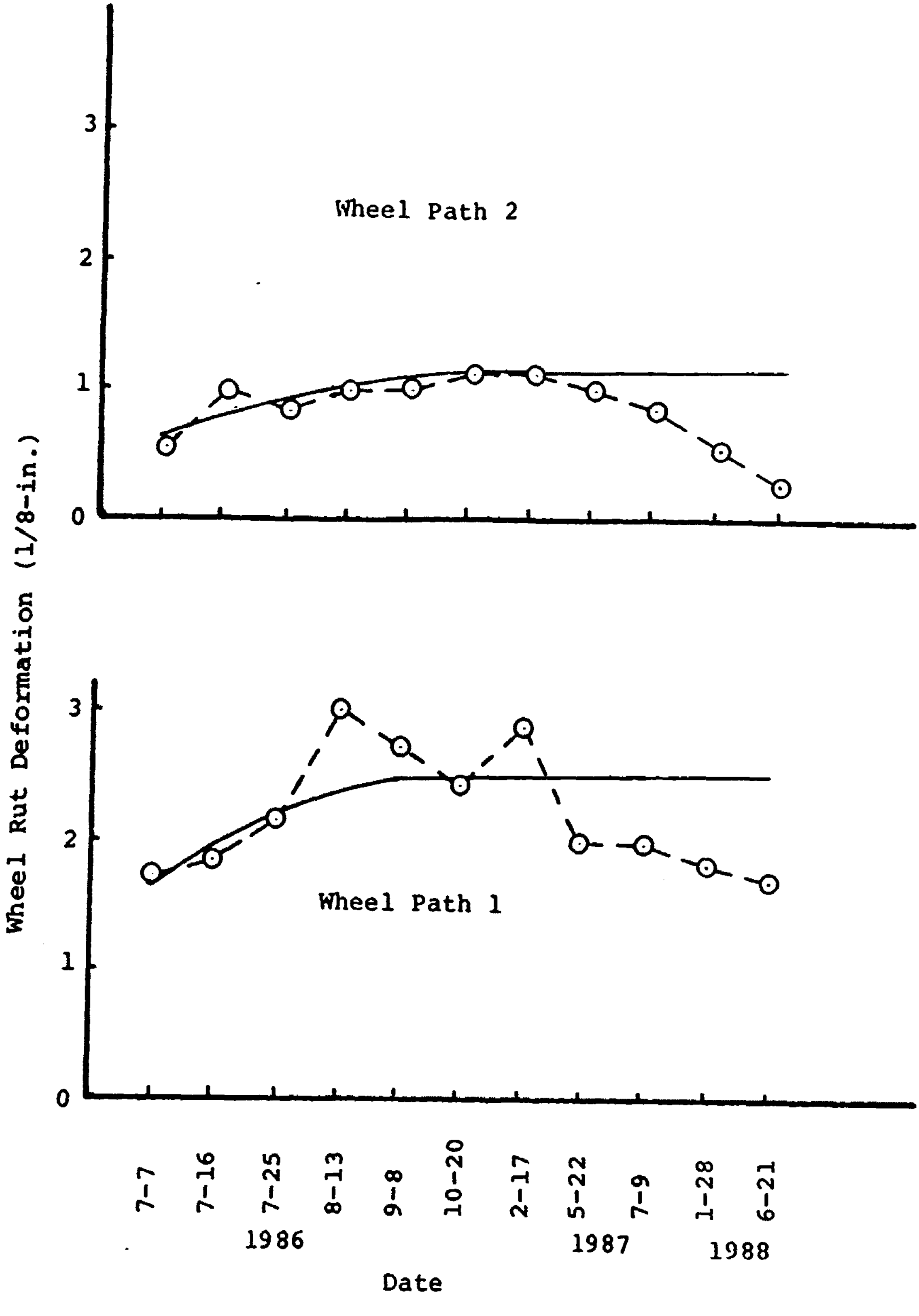

FIGURE 5. WHEEL RUT DEFORMATIONS
POROUS PAVEMENT LANE 3

TABLE 5 - AVERAGE WHEEL RUT DEFORMATION MEASUREMENTS
BY WHEEL PATH (INCHES)

Porous Pavement Section

Lane	3		2		1	
Wheel Path	2	1	2	1	2	1
Station						
138	1/4(1/18)	5/16(1/4)	1/8(1/8)	3/16(0)	1/8(1/8)	1/8(1/16)
133	3/16(1/8)	1/4(1/4)	1/16((1/16)	1/8(0)	1/8(1/8)	3/16(3/16)
128	1/8(1/16)	3/16(1/8)	1/8(1/8)	1/8(0)	1/8(1/8)	1/8(1/8)
123	1/8(0)	1/4(3/16)	1/8(1/8)	1/8(1/16)	1/8(1/8)	3/16(3/16)
118	1/16(1/16)	5/16(1/4)	1/8(1/8)	3/16(1/8)	3/16(1/8)	5/16(1/4)
113	1/16(0)	3/8(1/4)	1/8(1/8)	1/8(1/8)	1/8(1/8)	1/4(3/16)
108	0(0)	5/16(1/4)	1/8(1/8)	5/16(1/8)	3/16(1/8)	1/4(1/8)
Avg	1/8(1/16)	5/16(1/4)	1/8(1/8)	3/16(1/16)	1/8(1/8)	3/16(3/16)

Conventional Pavement

Lane	3		2		1	
Wheel Path	2	1	2	1	2	1
Station						
143	1/16(1/8)	3/16(3/16)	1/8(1/8)	1/8(1/8)	0(0)	1/8(0)
141	1/8(0)	1/16(1/8)	1/16(1/8)	1/16(1/8)	1/16(1/16)	1/16(1/16)
104	1/16(1/8)	1/8(1/8)	1/8(1/8)	3/16(1/8)	1/16(0)	1/16(0)
102	0(0)	1/16(1/8)	1/16(1/8)	1/8(1/16)	1/16(0)	1/16(0)
Avg	1/16(1/16)	1/8(1/8)	1/8(1/8)	1/8(1/8)	1/16(0)	1/16(0)

Average Wheel Rut Deformations 1986-1987
( )Average Wheel Rut Deformations 1988

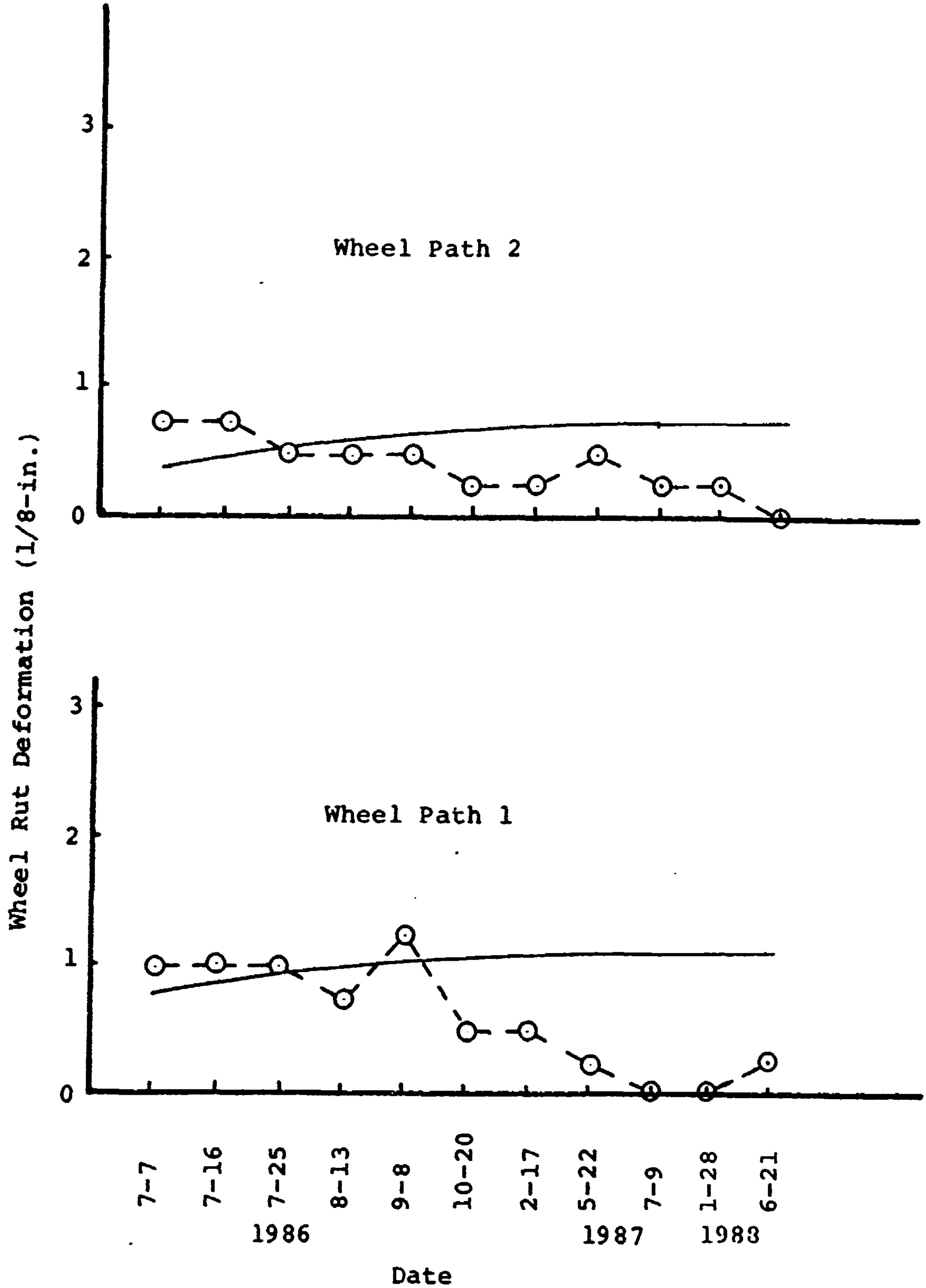

FIGURE 6. WHEEL RUT DEFORMATIONS
CONVENTIONAL PAVEMENT
Lane 1

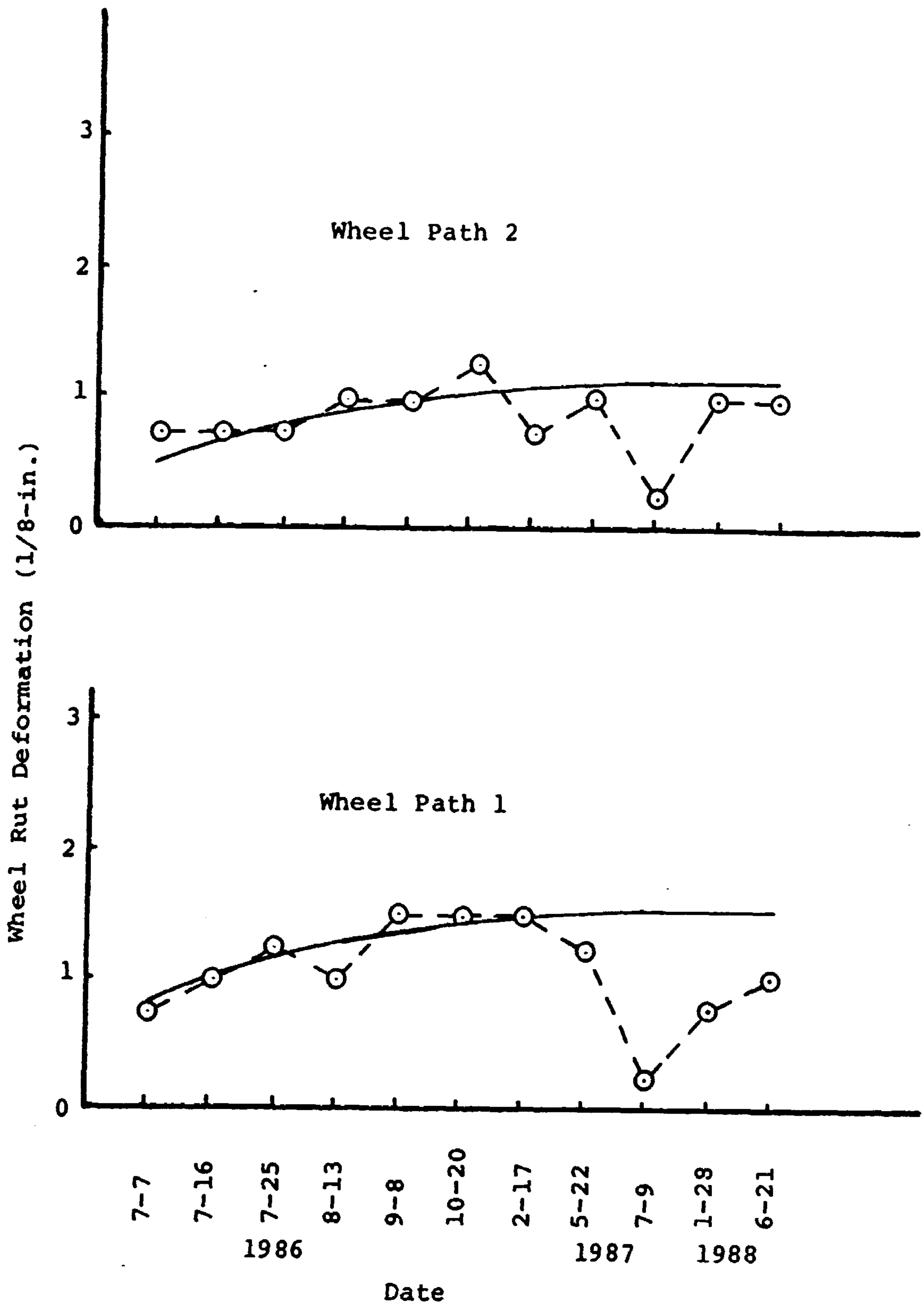

FIGURE 7. WHEEL RUT DEFORMATIONS
CONVENTIONAL PAVEMENT
Lane 2

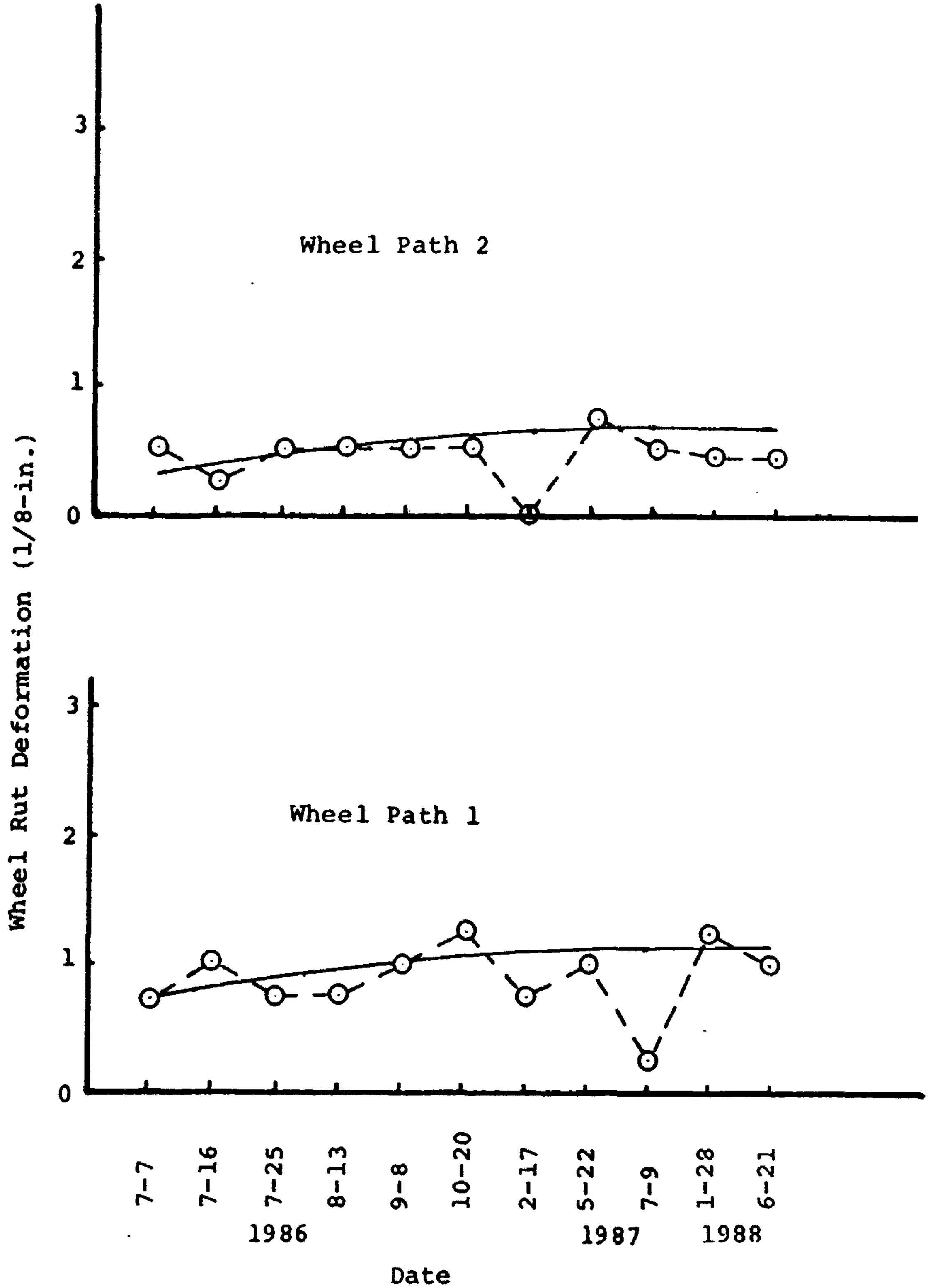

FIGURE 8. WHEEL RUT DEFORMATIONS
CONVENTIONAL PAVEMENT
Lane 3

Vertical Control Measurements (P.K. Shiners)

P.K. Shiners were set at Station 106, every 500 ft. from Station 110 to Station 135 and at Station 139. Reference points are set at 1, 6, 11, 16.5, 22, 28 and 34 ft from the face of the curb and gutter and at locations intermediate between each of these locations. Vertical control data is given in Appendix E. Appendix F summarizes the change in pavement deformations from June 25, 1986 to June 21, 1988. Figures 9, 10, 11 and 12 visually depicts these deformations. In order to graph the vertical changes in deformation readings, an imaginary cross slope was calculated. This was done by obtaining the difference in the pavement elevation at 1 and 34 ft from the edge of the curb and gutter. This difference was then divided by 33 ft to obtain the rate of cross slope elevation change. Vertical deformation readings were then subtracted from the cross slope to determine the vertical changes. This procedure was found necessary because the cross slope varied from location to location to match the roadway to existing curb and gutters.

Between June 25, 1986 and July 22, 1987, Station 110 lane 3 (31 ft from curb and gutter), exhibited a 0.06 ft or 0.72 in. change in vertical deformation which was the largest at the site. The current change at this location is now 0.00 ft. This lack of change may be due to an incorrect reading.

Station 106 lane 1 (8 1/2 ft from curb and gutter), Station 106 lane 3 (31 ft from curb and gutter) and Station 120 lane 2 (11 ft from curb and gutter), exhibited a 0.04 ft or 0.48 in. change in vertical deformation. This deformation was determined by taking the difference in elevation readings from June 25, 1986 and June 21, 1988.

Most vertical deformation graphs exhibited three distinct slopes which would relate to the three passes made by the paving machine. Since the median was constructed after construction of lanes 1 and 2 but before 3, a break in the cross slope often exists at lane 3. Deformation readings taken at Station 135, lane 3, were not used because the P.K. nails were paved over to correct for a cross slope problems. An increase in pavement deformation can be ssen at Station 106, while other stations show relatively no change in the pavement cross section.

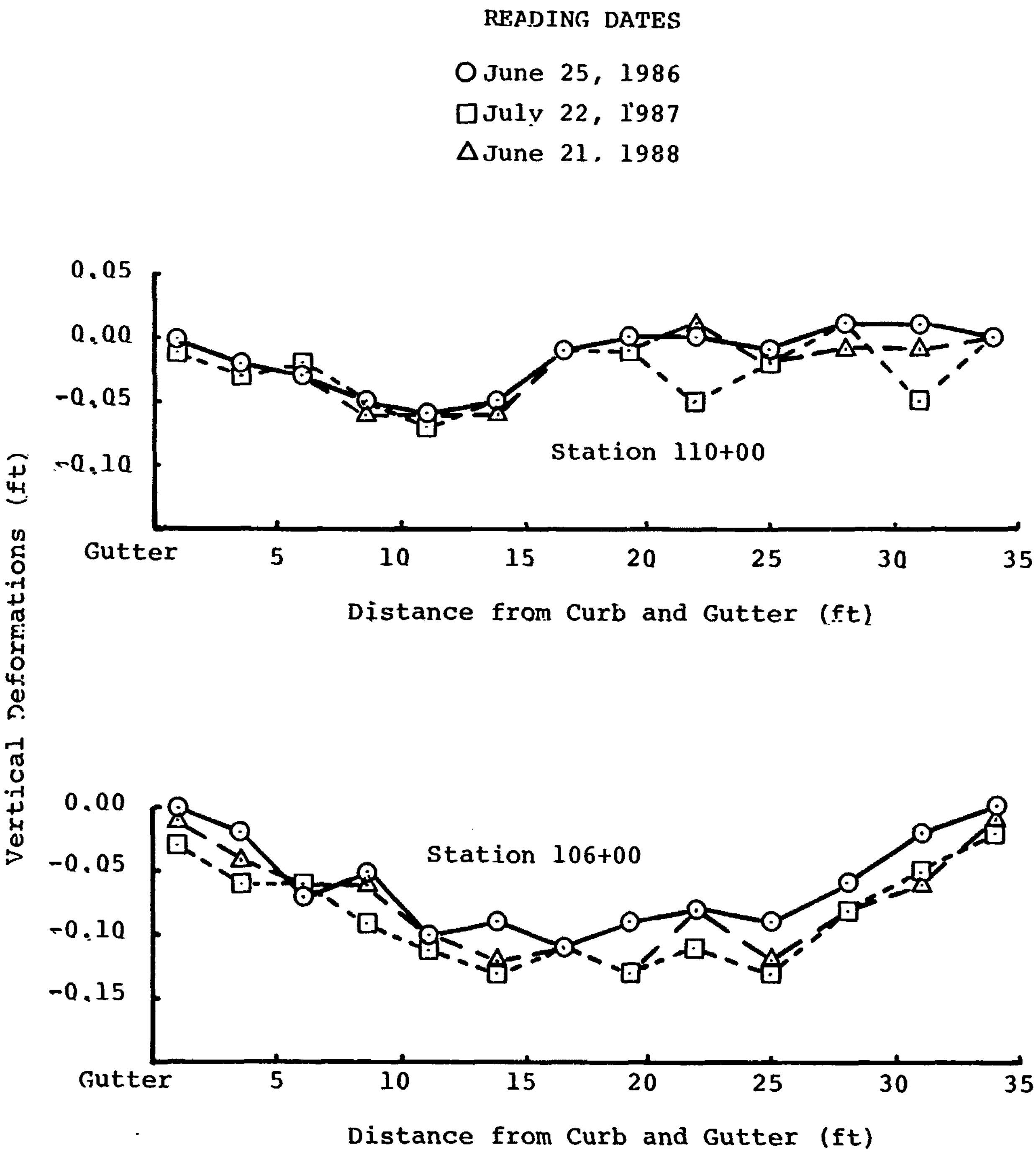

FIGURE 9. VERTICAL DEFORMATIONS
STA 106 AND 110

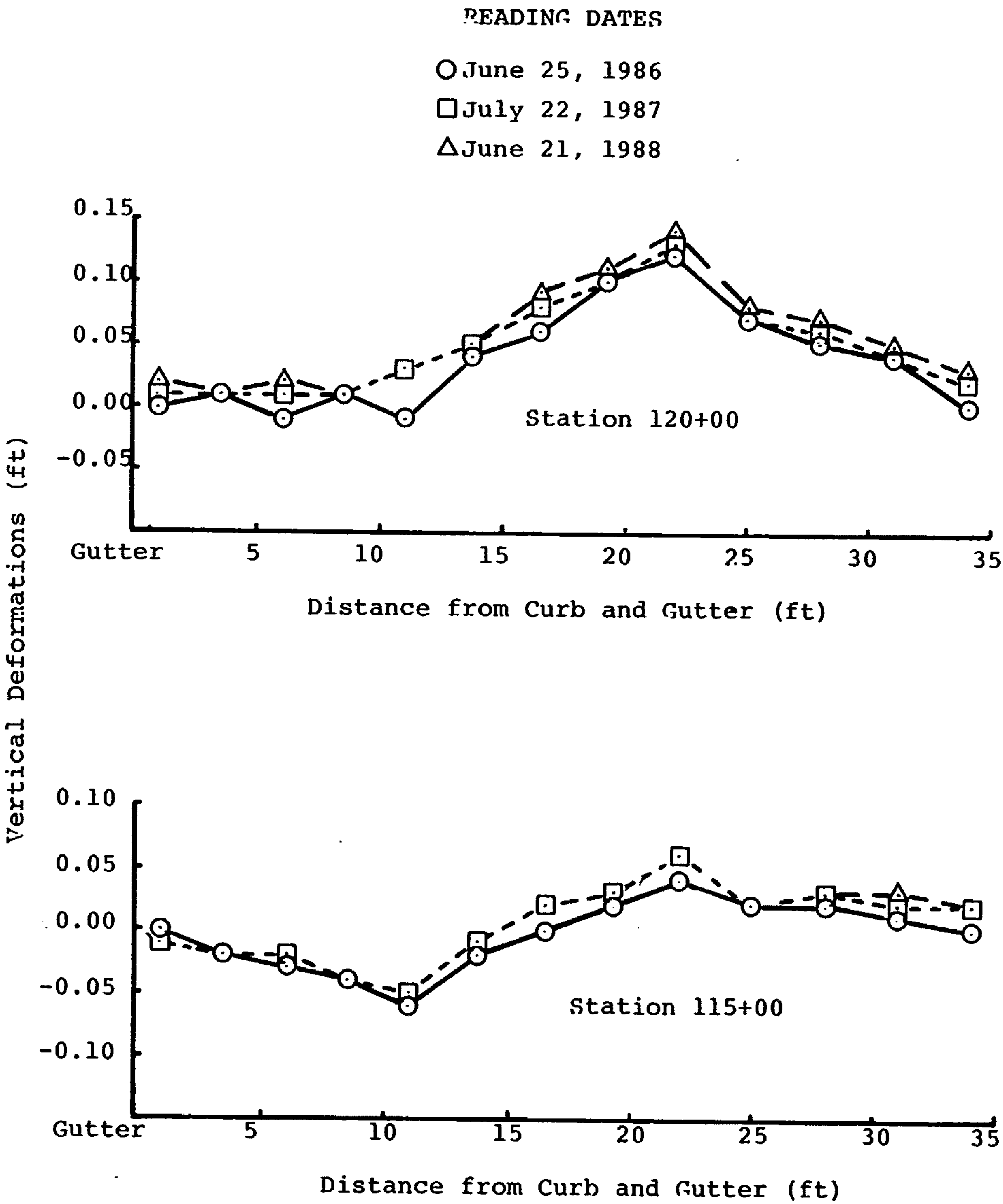

FIGURE 10. VERTICAL DEFORMATIONS
STA 115 AND 120

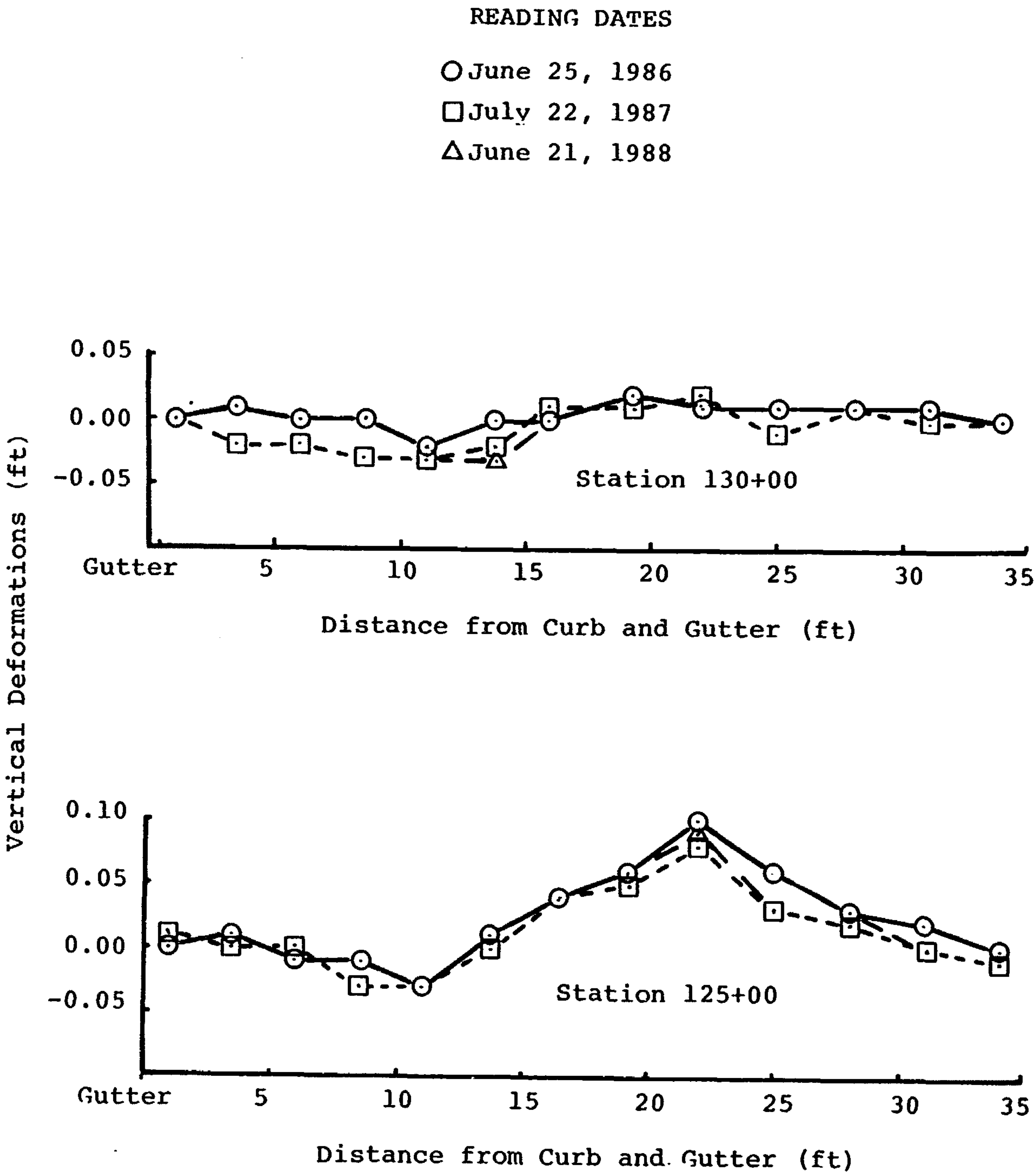

FIGURE 11. VERTICAL DEFORMATIONS
STA 125 and 130

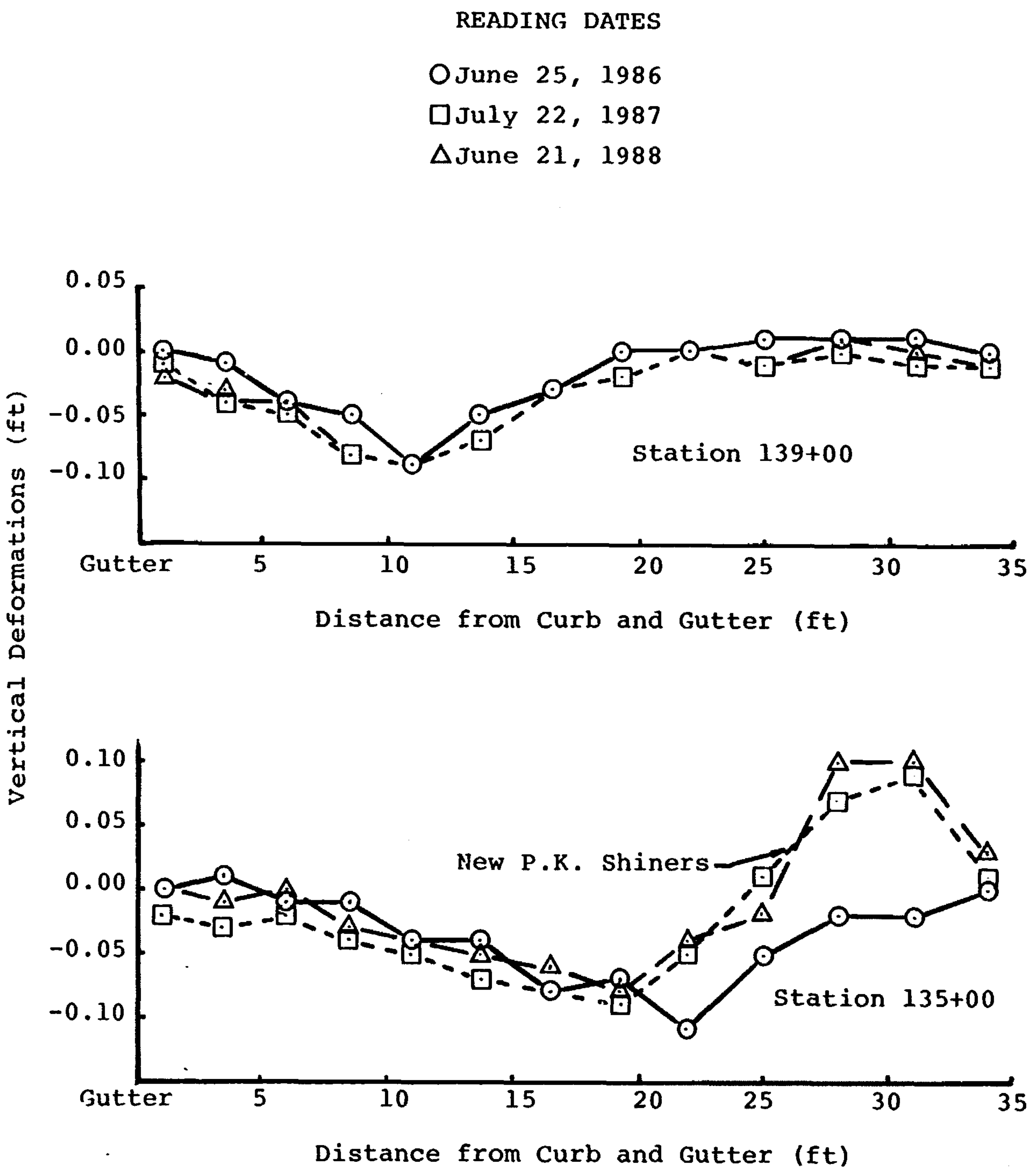

FIGURE 12. VERTICAL DEFORMATIONS
Sta 135 AND 139

TECHNOLOGY TRANSFER

General

The experimental porous pavement section was the subject of several on-site demonstrations for ADOT, County, City and other highway engineers. A video tape was produced by Western Technologies Inc. on December 3, 1986 depicting how the porous pavement performs in a simulated rainfall condition.

Site Demonstrations

During the Fall of 1986, several demonstrations were presented by Western Technologies Inc. for ADOT, County, City and other highway engineers. The seminar commenced with a presentation of the theory used in the development of a porous pavement section. Construction aspects of the project were then discussed. Following this, a demonstration was conducted on both the porous and conventional pavements. To evaluate the porous pavement, 240 gallons of water were applied in 10 minutes over an area 12 ft by 30 ft. This amounts to slightly more than a one-in. rain, or approximately 50 percent greater than a 10-year, 10 minute storm intensity. It was observed that the water was drawn into the porous pavement before it reached the gutter. The same amount of water was released on a conventional pavement section. Sand bags were used to retain the water applied to this pavement section. Because the water had nowhere to drain, it became ponded along the curb line, flooding the entire outer lane.

Videotaping

On December 4, 1986, a videotape entitled "Field Demonstration of Rainfall Absorptive Pavement System" was produced by Western Technologies Inc. depicting how the water from a 10-year, 10-minute storm would behave on the porous and conventional pavement sections. The sequence of events recorded were the same as those given in the Site Demonstration section of this report.

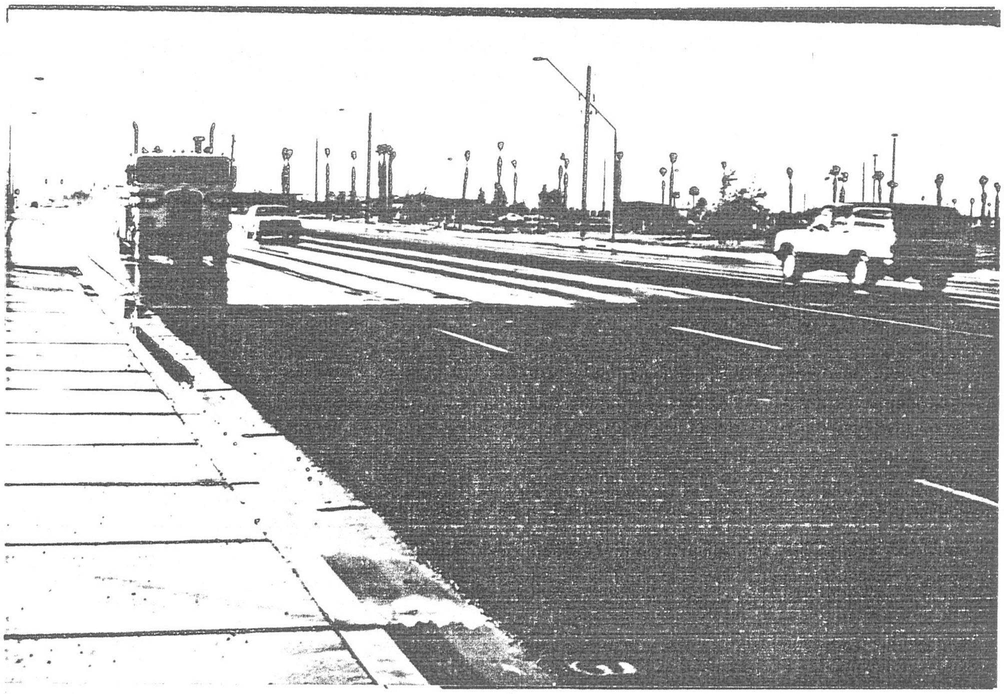

FIGURE 13. CONVENTIONAL AND POROUS PAVEMENT SHORTLY AFTER RAINSTORM

CONCLUSIONS

Conclusions and recommendations resulting from monitoring work carried out to date will be reserved for the final project report. However, some preliminary results are pointed out at this time.

Both the porous and conventional pavement sections showed no visual signs of cracking, distortion, disintegration or skid hazards.

The largest total amount of rainfall was 7.07 in. which occurred between June 29, 1986 to July 7, 1987. The greatest amount of rainfall (1.15 in.) over a 24-hour period (.05 in./hr) occurred on December 17, 1987. The highest estimated rainfall intensity (1.00 in./hr) took place on April 15, 1988. Design rainfall intensities for a 10 year, 10 minute storm and a 10 year 24-hour storm are 5.20 and 0.11 in./hr, respectively.

Soil moisture monitoring devices indicated that the moisture content increased in the porous and conventional pavement subgrades respectively. The moisture content of the subgrade stabilized over the first six months and continues to show little change.

Wheel rut deformations in the porous pavement increased during the first month, and these have stabilized. This condition was not unexpected. During the first year, the porous pavement exhibited an average wheel rut deformation of slightly over 3/16 in. and the conventional pavement had comparable deformation of slightly under 1/8 in. The maximum wheel rut deformation at any location measured was 0.06 ft (0.72 in.), reference Appendix E, Sta 110. After two years of service, the porous pavement exhibited an average wheel rut deformation between 1/8 and 3/16 in. and the conventional pavement had a comparable deformation of slightly under 1/16 in. The maximum wheel rut deformation is now 0.04 ft (0.48 in.), and is located at Stations 106 and 120.

Lane 3 exhibited the largest amount of wheel rut deformation in the porous pavement section. This deformation was felt to be produced by the recompaction of the untreated subbase by traffic.

After two years of service, lanes 1 and 3 in the porous pavement section have the greatest amount of deformation. Wheel truck rutting is not severe in either pavement.

Vertical measurements taken on P.K. Shiners located in the porous pavement section indicate little or no additional pavement settlement the past year.

Visual observations of the porous pavement during several rainstorms revealed the elimination of water spray from car and truck tires. Reducing the amount of water on a pavement surface, will decrease hydroplaning and should reduce skid related accidents. Also, lane striping could be observed on the porous pavement road section. Although the porous pavement was not observed during a rainstorm at night, increase lane recognition should increase driving safety. These conditions were documented by slides and videotapes. The condition of the two pavement surfaces after a rainstorm is presented in Figure 13.

APPENDIX A

MOISTURE MONITOR READINGS (OHMS)

Station	Date	Monitor Number 1	2	3	4	5	6
97 + 40 Lt	06-07-86	5.0	4.6	6.2	6.2	4.3	2.9
	08-11-86	5.5	5.2	8.0	7.0	3.6	2.8
	09-02-86	5.8	5.8	8.6	6.4	0.6	2.7
	10-09-86	7.5	8.0	10.0	9.0	1.1	1.2
	12-08-86	8.3	8.2	10.4	8.5	1.4	1.5
	01-03-87	9.8	9.0	10.0	9.0	1.2	1.6
	02-26-87	8.0	8.0	8.0	6.0	0.7	0.7
	03-24-86	7.0	5.8	5.0	6.0	1.2	1.5
	07-09-87	5.6	5.2	5.0	4.5	0.4	---
	01-28-88	7.0	8.0	---	10.0	1.2	---
	06-21-88	4.6	3.5	7.0	5.6	0.7	2.4
108 + 00 Rt	06-07-86	30.0	11.5	75.0	14.0	150.0	23.0
	08-11-86	12.0	10.0	9.0	11.0	100.0	25.0
	09-02-86	7.0	8.9	8.5	10.0	90.0	23.0
	10-09-86	6.0	10.0	5.0	10.5	20.0	24.0
	12-08-86	0.8	1.3	1.2	1.7	1.2	1.0
	01-30-87	1.0	2.0	1.8	2.1	1.8	1.4
	02-26-87	0.8	1.6	1.4	1.5	2.0	0.7
	03-24-87	1.1	2.0	1.8	2.5	2.4	1.9
	07-09-87	1.2	1.8	1.7	2.4	2.1	2.0
	01-28-88	1.3	1.9	1.8	2.3	2.9	1.8
	06-21-88	1.0	1.6	1.6	---	1.1	1.8
138 + 00 Rt	06-07-86	25.0	8.0	35.0	2.9	16.0	1.8
	08-11-86	0.2	0.6	0.6	0.4	0.2	0.4
	09-02-86	0.2	0.7	0.7	0.6	0.2	0.4
	10-09-86	0.6	1.2	1.4	1.1	0.6	0.8
	12-08-86	0.0	0.8	5.6	0.9	0.2	0.5
	01-30-87	0.4	0.8	3.5	1.2	0.6	0.6
	02-26-87	0.0	0.8	2.7	1.1	0.2	0.4
	03-24-87	0.2	0.8	3.4	1.2	0.7	1.0
	07-09-87	0.5	0.9	2.0	1.0	0.6	0.7
	01-28-88	0.4	1.8	2.5	1.4	8.0	2.3
	06-21-88	0.5	3.5	2.8	1.3	18.0	1.5

Station	Date	Monitor Number					
		1	2	3	4	5	6
138 + 00 Lt	06-07-86	60.0	5.1	19.0	3.0	55.0	38.0
	08-11-86	---	---	9.0	9.0	100.0	10.0
	09-02-86	200.0	200.0	10.0	9.0	100.0	10.0
	10-09-86	2000.0	2000.0	13.0	12.0	100.0	12.0
	12-08-86	300.0	530.0	13.0	11.6	900.0	13.5
	01-30-87	0	0	18.0	14.0	2000.0	16.5
	02-26-87	400.0	0	15.0	14.0	180.0	15.0
	03-24-87	2000.0	2000.0	11.5	11.0	2000.0	12.2
	07-09-87	2000.0	2000.0	7.2	9.2	2000.0	10.0
	01-28-88	---	---	11.0	14.0	---	13.0
	06-21-88	---	---	---	10.5	2000.0	7.0
143 + 25 Lt	06-07-86	40.0	200.0	200.0	150.0	200.0	200.0
	08-11-86	3.0	100.0	200.0	30.0	38.0	1.4
	09-02-86	2.9	150.0	200.0	30.0	40.0	1.7
	10-09-86	3.5	120.0	200.0	40.0	49.0	3.0
	12-08-86	5.0	180.0	250.0	77.0	100.0	2.4
	01-30-87	3.5	200.0	250.0	90.0	70.0	2.0
	02-26-87	3.5	170.0	220.0	60.0	35.0	2.0
	03-24-87	2.6	130.0	190.0	59.0	7.0	1.9
	07-09-87	1.7	90.0	90.0	40.0	0.8	2.3
	01-28-88	2.2	---	---	100.0	2.2	5.0
	06-21-88	1.6	90.0	80.0	40.0	2.4	6.0

--- No reading

APPENDIX B

WHEEL RUT DEFORMATION MEASUREMENTS BY STATION

Lane / Wheel Path / Station	Date	3: 2	3: 1	2: 2	2: 1	1: 2	1: 1
		Lane Readings (1/8 inch)					
102+00	07-07-86	0	1/8	1/8	1/8	1/8	1/8
	07-16-86	0	1/8	1/8	1/8	1/8	1/8
	07-25-86	0	0	0	1/8	1/8	1/8
	08-13-86	0	0	1/8	1/8	1/8	0
	09-08-86	0	1/8	1/8	1/4	1/8	1/4
	10-20-86	0	1/8	1/8	1/4	1/8	1/8
	02-17-87	0	0	0	1/4	0	0
	05-22-87	0	1/8	1/8	1/8	0	0
	07-09-87	0	0	0	0	0	0
	01-28-88	0	1/8	1/8	0	0	0
	06-21-88	0	1/8	1/8	1/8	0	0
104+00	07-07-86	0	1/8	1/8	1/8	1/8	1/8
	07-86-86	0	1/8	1/8	1/4	1/8	1/8
	07-25-86	0	1/8	1/8	1/4	1/8	1/8
	08-13-86	0	1/8	1/8	1/8	0	1/8
	09-08-86	1/8	1/8	1/8	1/4	1/8	1/8
	10-20-86	1/8	1/8	1/8	1/4	0	1/8
	02-17-87	0	1/8	1/8	1/4	1/8	0
	05-22-87	1/8	1/8	1/8	1/4	0	0
	07-09-87	0	0	0	1/8	0	0
	01-28-88	1/8	1/8	1/8	1/8	0	0
	06-21-88	1/8	1/8	1/8	1/8	0	0
108+00	07-07-86	0	1/4	0	1/2	1/8	1/8
	07-16-86	0	3/8	0	3/8	1/8	1/4
	07-25-86	0	1/4	1/4	1/4	1/8	1/4
	08-13-86	0	3/8	1/8	1/8	1/8	1/4
	09-08-86	1/8	3/8	1/8	1/4	1/8	1/4
	10-02-86	0	3/8	1/8	1/4	1/4	1/4
	02-17-87	0	3/8	1/8	3/8	1/4	3/8
	05-22-87	0	1/4	1/8	1/8	1/4	1/4
	07-09-87	0	1/4	0	3/8	1/8	1/8
	01-28-88	0	1/4	1/8	1/8	1/8	1/8
	06-21-88	0	1/4	1/8	1/8	1/8	1/8

Lane Wheel Path Station	Date	3 2	3 1	2 2	2 1	1 2	1 1
		Lane Readings (1/8 inch)					
113+00	07-07-86	0	1/4	1/8	0	1/8	1/4
	07-16-86	1/8	1/4	1/8	0	1/8	1/4
	07-25-86	0	1/4	1/8	1/8	1/8	1/4
	08-13-86	1/8	1/2	1/8	1/8	1/8	1/4
	09-08-86	1/8	1/2	1/8	1/8	1/8	1/4
	10-20-86	1/8	3/8	1/8	1/8	1/8	1/4
	02-17-87	1/8	1/2	1/8	1/4	1/8	3/8
	05-22-87	1/8	1/4	1/8	1/8	1/8	1/4
	07-09-87	0	3/8	1/8	1/8	1/8	1/8
	01-28-88	0	1/4	1/8	1/8	1/8	1/8
	06-21-88	0	1/4	1/8	1/8	1/8	1/4
118+00	07-07-86	0	1/4	1/8	1/8	0	1/8
	07-16-86	0	1/4	1/8	1/8	1/8	1/8
	07-25-86	0	3/8	1/8	1/8	1/8	3/8
	08-13-86	0	3/8	1/8	3/8	3/8	3/8
	09-08-86	0	3/8	1/8	3/8	1/8	3/8
	10-20-86	0	3/8	1/8	1/8	1/4	1/4
	02-17-87	1/8	3/8	1/8	3/8	1/4	1/2
	05-22-87	1/8	1/4	1/4	1/8	1/8	1/4
	07-09-87	1/8	1/4	0	1/8	1/8	1/4
	01-28-88	1/8	1/4	1/8	1/8	1/8	1/4
	06-21-88	0	1/4	1/8	1/8	1/8	1/4
123+00	07-07-86	1/8	1/8	1/8	1/8	1/8	1/8
	07-16-86	1/8	1/8	1/8	1/8	1/8	1/8
	07-25-86	1/8	1/4	1/8	1/8	0	1/4
	08-13-86	1/8	3/8	1/8	0	1/4	1/4
	09-08-86	1/8	3/8	1/8	1/8	1/4	1/4
	10-20-86	1/8	1/4	1/8	1/8	1/8	1/4
	02-17-87	1/8	3/8	1/8	1/8	1/4	1/8
	05-22-87	0	1/4	1/8	1/8	1/8	1/8
	07-09-87	0	1/4	0	1/8	1/8	1/8
	01-28-88	0	1/4	1/8	1/8	1/8	1/4
	06-21-88	0	1/8	1/8	0	1/8	1/8

Lane		3		2		1	
Wheel Path		2	1	2	1	2	1
Station	Date	Lane Readings (1/8 inch)					
128+00	07-07-86	1/8	1/8	1/8	1/8	1/8	1/8
	07-16-86	1/8	1/8	1/8	1/8	1/8	1/8
	07-25-86	1/8	1/8	1/8	1/8	1/8	1/8
	08-13-86	1/8	1/4	1/8	1/8	1/4	1/8
	09-08-86	1/8	1/8	1/8	1/8	1/8	1/8
	10-20-86	1/4	1/4	1/8	0	1/8	1/8
	02-17-87	1/8	1/8	1/8	1/8	1/8	1/8
	05-22-87	1/8	1/4	1/8	0	1/8	1/8
	07-09-87	1/4	1/8	0	1/4	1/8	1/8
	01-28-88	1/8	1/8	1/8	0	1/8	1/8
	06-21-88	0	1/8	1/8	0	1/8	1/8
133+00	07-07-86	0	1/4	0	1/8	1/8	1/8
	07-16-86	1/8	1/4	0	1/8	1/8	1/8
	07-25-86	1/8	1/4	0	1/8	1/8	1/4
	08-13-86	1/4	1/4	1/8	1/4	1/8	1/4
	09-08-86	1/8	1/4	1/8	1/8	1/4	1/4
	10-20-86	1/4	1/4	0	1/8	1/8	1/8
	02-17-87	1/4	1/4	0	1/8	1/8	1/4
	05-11-87	1/4	1/4	1/8	1/8	1/8	1/8
	07-09-87	1/8	1/4	0	1/8	0	1/8
	01-28-88	1/8	1/4	0	0	1/8	1/4
	06-21-88	1/8	1/4	1/8	0	1/8	1/8
138+00	07-07-86	1/4	1/4	1/8	1/4	1/4	1/8
	07-10-86	3/8	1/4	1/8	1/4	1/8	1/8
	07-25-86	3/8	3/8	1/8	1/8	1/8	1/8
	08-13-86	1/4	1/2	1/4	1/8	1/4	1/8
	09-08-86	1/4	3/8	1/4	1/8	1/4	1/4
	10-20-86	1/4	1/4	1/8	1/8	1/8	1/8
	02-17-87	1/4	1/2	1/4	1/4	1/8	1/8
	05-22-87	1/4	1/4	1/8	1/8	1/8	1/8
	07-09-87	1/4	1/4	0	1/4	0	0
	01-28-88	1/8	1/4	1/8	0	1/8	1/8
	06-21-88	1/8	1/4	1/8	0	1/8	0

Lane Wheel Path Station	Date	3 2	3 1	2 2	2 1	1 2	1 1
		Lane Readings (1/8 inch)					
141+00	07-07-86	1/8	0	0	0	1/8	1/8
	07-16-86	1/8	0	0	0	1/8	1/8
	07-25-86	1/8	0	0	1/8	0	1/8
	08-13-86	1/8	0	1/8	1/8	0	1/8
	09-08-86	1/8	0	1/8	1/8	0	1/8
	10-20-86	1/8	1/8	1/8	1/8	0	0
	02-07-87	0	1/8	1/8	1/8	0	1/8
	05-22-87	1/8	1/8	1/8	1/8	1/8	0
	07-09-87	1/8	0	0	0	1/8	0
	01-28-88	0	1/8	1/8	1/8	1/8	0
	06-21-88	0	1/8	1/8	1/8	0	1/8
143+00	07-07-86	1/8	1/8	1/8	1/8	0	1/8
	07-16-86	0	1/4	1/8	1/8	0	1/8
	07-25-86	1/8	1/4	1/4	1/8	0	1/8
	08-13-86	1/8	1/4	1/8	1/8	1/8	1/8
	09-08-86	0	1/4	1/8	1/8	0	1/8
	10-20-86	0	1/4	1/4	1/8	0	0
	02-17-87	0	1/8	1/8	1/8	0	1/8
	05-22-87	1/8	1/8	1/8	1/8	1/8	1/8
	07-09-87	1/8	1/8	1/8	0	0	0
	01-28-88	1/8	1/4	1/8	1/8	0	0
	06-21-88	1/8	1/8	1/8	1/8	0	0

APPENDIX C

WHEEL PATH RUT DEFORMATION MEASUREMENTS (INCHES)

POROUS PAVEMENT SECTION

Lane 1 Wheel Path 1

Date	1986						1987			1988	
Sta.	7-7	7-16	7-25	8-13	9-8	10-20	2-17	5-22	7-9	1-28	6-21
138	1/8	1/8	1/8	1/8	1/4	1/8	1/8	1/8	0	1/8	0
133	1/8	1/8	1/4	1/4	1/4	1/8	1/4	1/8	1/8	1/4	1/8
128	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/8
123	1/8	1/8	1/4	1/4	1/4	1/4	1/8	1/8	1/8	1/4	1/8
118	1/8	1/8	3/8	3/8	3/8	1/4	1/2	1/4	1/4	1/4	1/4
113	1/4	1/4	1/4	1/4	1/4	1/4	3/8	1/4	1/8	1/8	1/4
108	1/8	1/4	1/4	1/4	1/4	1/4	3/8	1/4	1/8	1/8	1/8
Avg	1/8	3/16	1/4	1/4	1/4	3/16	1/4	3/16	1/8	3/16	1/8

Lane 1 Wheel Path 2

Date	1986						1987			1988	
Sta.	7-7	7-16	7-25	8-13	9-8	10-20	2-17	5-22	7-9	1-28	6-21
138	1/4	1/8	1/8	1/4	1/4	1/8	1/8	1/8	0	1/8	1/8
133	1/8	1/8	1/8	1/8	1/4	1/8	1/8	1/8	0	1/8	1/8
128	1/8	1/8	1/8	1/4	1/8	1/8	1/8	1/8	1/8	1/8	1/8
123	1/8	1/8	0	1/4	1/4	1/8	1/4	1/8	1/8	1/8	1/8
118	0	1/8	1/8	3/8	1/8	1/4	1/4	1/8	1/8	1/8	1/8
113	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/8
108	1/8	1/8	1/8	1/8	1/8	1/4	1/4	1/4	1/8	1/8	1/8
Avg	1/8	1/8	1/8	3/8	3/16	3/16	3/16	1/8	1/8	1/8	1/8

Lane 2 Wheel Path 1

Date Sta.	1986 7-7	1986 7-16	1986 7-25	1986 8-13	1986 9-8	1986 10-20	1987 2-17	1987 5-22	1987 7-9	1988 1-28	1988 6-21
138	1/4	1/4	1/8	1/8	1/8	1/8	1/4	1/8	1/4	0	0
133	1/8	1/8	1/8	1/4	1/8	1/8	1/8	1/8	1/8	0	0
128	1/8	1/8	1/8	1/8	1/8	0	1/8	0	1/4	0	0
123	1/8	1/8	1/8	0	1/8	1/8	1/8	1/8	1/8	1/8	0
118	1/8	1/8	1/8	3/8	3/8	1/8	3/8	1/8	1/8	1/8	1/8
113	0	0	1/8	1/8	1/8	1/8	1/4	1/8	1/8	1/8	1/8
108	1/2	3/8	1/4	1/8	1/4	1/4	3/8	1/8	3/8	1/8	1/8
Avg	3/16	3/16	1/8	3/16	3/16	1/8	1/4	1/8	3/16	1/16	1/16

Lane 2 Wheel Path 2

Date Sta.	1986 7-7	1986 7-16	1986 7-25	1986 8-13	1986 9-8	1986 10-20	1987 2-17	1987 5-22	1987 7-9	1988 1-28	1988 6-21
138	1/8	1/8	1/8	1/4	1/4	1/8	1/4	1/8	0	1/8	1/8
133	0	0	0	1/8	1/8	0	0	1/8	0	0	1/8
128	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/8	0	1/8	1/8
123	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/8	0	1/8	1/8
118	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/4	0	1/8	1/8
113	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/8
108	0	0	1/4	1/8	1/8	1/8	1/8	1/8	0	1/8	1/8
Avg	1/16	1/16	1/8	1/8	1/8	1/8	1/8	1/8	0	1/8	1/8

Lane 3 Wheel Path 1

Date	1986						1987			1988	
Sta.	7-7	7-16	7-25	8-13	9-8	10-20	2-17	5-22	7-9	1-28	6-21
138	1/4	1/4	3/8	1/2	3/8	1/4	1/2	1/4	1/4	1/4	1/4
133	1/4	1/4	1/4	1/4	1/4	1/4	1/4	1/4	1/4	1/4	1/4
128	1/8	1/8	1/8	1/4	1/8	1/4	1/8	1/4	1/8	1/8	1/8
123	1/8	1/8	1/4	3/8	3/8	1/4	3/8	1/4	1/4	1/4	1/8
118	1/4	1/4	3/8	3/8	3/8	3/8	3/8	1/4	1/4	1/4	1/4
113	1/4	1/4	1/4	1/2	1/2	3/8	1/2	1/4	3/8	1/4	1/4
108	1/4	3/8	1/4	3/8	3/8	3/8	3/8	1/4	1/4	1/4	1/4
Avg	3/16	1/4	1/4	3/8	5/16	5/16	3/8	1/4	1/4	1/4	3/16

Lane 3 Wheel Path 2

Date	1986						1987			1988	
Sta.	7-7	7-16	7-25	8-13	9-8	10-20	2-17	5-22	7-9	1-28	6-21
138	1/4	3/8	3/8	1/4	1/4	1/4	1/4	1/4	1/4	1/8	1/8
133	0	1/8	1/8	1/4	1/8	1/4	1/4	1/4	1/8	1/8	1/8
128	1/8	1/8	1/8	1/8	1/8	1/4	1/8	1/8	1/4	1/8	0
123	1/8	1/8	1/8	1/8	1/8	1/8	1/8	0	0	0	0
118	0	0	0	0	0	0	1/8	1/8	1/8	1/8	0
113	0	1/8	0	1/8	1/8	1/8	1/8	1/8	0	0	0
108	0	0	0	0	1/8	0	0	0	0	0	0
Avg	1/16	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/16	1/16

APPENDIX D

WHEEL PATH RUT DEFORMATION MEASUREMENTS (INCHES)

CONVENTIONAL PAVEMENT SECTION

Lane 1 Wheel Path 1

Date	1986						1987			1988	
Sta.	7-7	7-16	7-25	8-13	9-8	10-20	2-17	5-22	7-9	1-28	6-21
143	1/8	1/8	1/8	1/8	1/8	0	1/8	1/8	0	0	0
141	1/8	1/8	1/8	1/8	1/8	0	1/8	0	0	0	1/8
104	1/8	1/8	1/8	1/8	1/8	1/8	0	0	0	0	0
102	1/8	1/8	1/8	0	1/4	1/8	0	0	0	0	0
Avg	1/8	1/8	1/8	1/8	1/8	1/16	1/16	0	0	0	0

Lane 1 Wheel Path 2

Date	1986						1987			1988	
Sta.	7-7	7-16	7-25	8-13	9-8	10-20	2-17	5-22	7-9	1-28	6-21
143	0	0	0	1/8	0	0	0	1/8	0	0	0
141	1/8	1/8	0	0	0	0	0	1/8	1/8	1/8	0
104	1/8	1/8	1/8	0	1/8	0	1/8	0	0	0	0
102	1/8	1/8	1/8	1/8	1/8	1/8	0	0	0	0	0
Avg	1/8	1/8	1/16	1/16	1/16	0	0	1/16	0	0	0

Lane 2 Wheel Path 1

Date Sta.	1986 7-7	1986 7-16	1986 7-25	1986 8-13	1986 9-8	1986 10-20	1987 2-17	1987 5-22	1987 7-9	1988 1-28	1988 6-21
143	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/8	0	1/8	1/8
141	0	0	1/8	1/8	1/8	1/8	1/8	1/8	0	1/8	1/8
104	1/8	1/4	1/4	1/8	1/4	1/4	1/4	1/4	1/8	1/8	1/8
102	1/8	1/8	1/8	1/8	1/4	1/4	1/4	1/8	0	0	1/8
Avg	1/8	1/8	1/8	1/8	3/16	3/16	3/16	1/8	0	1/8	1/8

Lane 2 Wheel Path 2

Date Sta.	1986 7-7	1986 7-16	1986 7-25	1986 8-13	1986 9-8	1986 10-20	1987 2-17	1987 5-22	1987 7-9	1988 1-28	1988 6-21
143	1/8	1/8	1/4	1/8	1/8	1/4	1/8	1/8	1/8	1/8	1/8
141	0	0	0	1/8	1/8	1/8	1/8	1/8	0	1/8	1/8
104	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/8	0	1/8	1/8
102	1/8	1/8	0	1/8	1/8	1/8	0	1/8	0	1/8	1/8
Avg	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/8	0	1/8	1/8

Lane 3 Wheel Path 1

Date	1986						1987			1988	
Sta.	7-7	7-16	7-25	8-13	9-8	10-20	2-17	5-22	7-9	1-28	6-21
143	1/8	1/4	1/4	1/4	1/4	1/4	1/8	1/8	1/8	1/4	1/8
141	0	0	0	0	0	1/8	1/8	1/8	0	1/8	1/8
104	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/8	0	1/8	1/8
102	1/8	1/8	0	0	1/8	1/8	0	1/8	0	1/8	1/8
Avg	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/8	0	1/8	1/8

Lane 3 Wheel Path 2

Date	1986						1987			1988	
Sta.	7-7	7-16	7-25	8-13	9-8	10-20	2-17	5-22	7-9	1-28	6-21
143	1/8	0	1/8	1/8	0	0	0	1/8	1/8	1/8	1/8
141	1/8	1/8	1/8	1/8	1/8	1/8	0	1/8	1/8	0	0
104	0	0	0	0	1/8	1/8	0	1/8	0	1/8	1/8
102	0	0	0	0	0	0	0	0	0	0	0
Avg	1/16	0	1/16	1/16	1/16	1/16	0	1/8	1/16	1/16	1/16

APPENDIX E

VERTICAL CONTROL MEASUREMENTS (FEET)

Distance from Curb and Gutter (feet)

Sta.	Date	1		6		11		16.5		22		28		34
106	6/25/86	9.95	10.00	10.02	10.10	10.12	10.21	10.26	10.36	10.40	10.51	10.63	10.75	10.85
	7/22/87	9.92	9.96	10.03	10.06	10.11	10.17	10.26	10.32	10.37	10.47	10.61	10.72	10.83
	6/21/88	9.94	9.98	10.03	10.06	10.12	10.18	10.27	10.33	10.41	10.48	10.61	10.71	10.84
110	6/25/86	9.89	9.93	9.97	10.01	10.06	10.14	10.23	10.30	10.37	10.43	10.51	10.58	10.64
	7/22/87	9.88	9.92	9.98	10.01	10.05	10.14	10.23	10.29	10.32	10.42	10.51	10.52	10.64
	6/21/88	9.88	9.92	9.97	10.00	10.06	10.13	10.23	10.29	10.38	10.42	10.51	10.58	10.64
115	6/25/86	9.63	9.67	9.71	9.76	9.80	9.90	9.98	10.06	10.15	10.20	10.26	10.32	10.38
	7/22/87	9.62	9.67	9.72	9.76	9.81	9.91	10.00	10.07	10.17	10.20	10.27	10.33	10.40
	6/21/88	9.63	9.67	9.72	9.76	9.81	9.91	10.00	10.07	10.17	10.20	10.27	10.33	10.40
120	6/25/86	9.64	9.69	9.72	9.79	9.81	9.91	9.98	10.07	10.14	10.15	10.18	10.22	10.24
	7/22/87	9.65	9.69	9.74	9.79	9.85	9.92	10.00	10.07	10.15	10.15	10.19	10.22	10.26
	6/21/88	9.66	9.69	9.75	9.79	9.85	9.92	10.01	10.08	10.16	10.16	10.20	10.23	10.26
125	6/25/86	9.72	9.78	9.81	9.86	9.90	9.99	10.08	10.16	10.25	10.27	10.31	10.36	10.40
	7/22/87	9.73	9.77	9.82	9.84	9.90	9.98	10.08	10.15	10.23	10.24	10.30	10.34	10.39
	6/21/88	9.73	9.77	9.82	9.84	9.90	9.98	10.08	10.16	10.24	10.24	10.31	10.34	10.39
130	6/25/86	9.69	9.75	9.79	9.84	9.87	9.95	10.00	10.08	10.13	10.19	10.25	10.31	10.36
	7/22/87	9.69	9.72	9.77	9.81	9.86	9.93	10.01	10.07	10.14	10.17	10.25	10.30	10.36
	6/21/88	9.69	9.72	9.77	9.81	9.86	9.92	10.01	10.07	10.14	10.17	10.25	10.30	10.36
135	6/25/86	9.16	9.25	9.30	9.38	9.43	9.51	9.56	9.65	9.70	9.85	9.97	10.07	10.18
	7/22/87	9.14	9.21	9.29	9.35	9.42	9.48	9.56	9.63	9.76*	9.91*	10.06*	10.18*	10.19
	6/21/88	9.16	9.23	9.31	9.36	9.43	9.50	9.58	9.64	9.77	9.92	10.09	10.19	10.21
139	6/25/86	9.69	9.73	9.75	9.80	9.81	9.91	9.98	10.07	10.13	10.20	10.26	10.32	10.38
	7/22/87	9.68	9.70	9.74	9.77	9.81	9.89	9.98	10.05	10.13	10.18	10.25	10.30	10.37
	6/21/88	9.67	9.70	9.75	9.77	9.81	9.89	9.98	10.05	10.13	10.18	10.26	10.31	10.37

* New PK nails

APPENDIX F

VERTICAL CHANGE IN PAVEMENT DEFORMATION
FROM JUNE 25, 1986 TO JUNE 21, 1988

STATION 106

Distance from Curb & Gutter	Readings 6/25/86	*	Vertical Change 6/25/86	7/22/87	6/21/88
1	9.95	9.95	0.00	0.03	0.01
3.50	10.00	10.02	0.02	0.06	0.04
6	10.02	10.09	0.07	0.06	0.06
8.50	10.10	10.15	0.05	0.09	0.06
11	10.12	10.22	0.10	0.11	0.10
13.75	10.21	10.30	0.09	0.13	0.12
16.50	10.26	10.37	0.11	0.11	0.10
19.25	10.36	10.45	0.09	0.13	0.12
22	10.40	10.48	0.08	0.11	0.07
25	10.51	10.60	0.09	0.13	0.12
28	10.63	10.69	0.06	0.08	0.08
31	10.75	10.77	0.02	0.05	0.06
34	10.85	10.85	0.00	0.02	0.01

STATION 110

Distance from Curb & Gutter	Readings 6/25/86	*	Vertical Change 6/25/86	7/22/87	6/21/88
1	9.89	9.89	0.00	0.01	0.01
3.50	9.93	9.95	0.02	0.03	0.03
6	9.97	10.00	0.03	0.02	0.03
8.50	10.01	10.06	0.05	0.05	0.06
11	10.06	10.12	0.06	0.07	0.06
13.75	10.14	10.19	0.05	0.05	0.06
16.50	10.23	10.24	0.01	0.01	0.01
19.25	10.30	10.30	0.00	0.01	0.01
22	10.37	10.37	0.00	0.05	+0.01
25	10.43	10.44	0.01	0.02	0.02
28	10.51	10.50	+0.01	+0.01	+0.01
31	10.58	10.57	+0.01	0.05	+0.01
34	10.64	10.64	0.00	0.00	0.00

* Elevations of a straight line taken from a distance 1 ft to 34 ft from the curb and gutter.

All readings in feet.

STATION 115

Distance from Curb & Gutter	Readings 6/25/86	*	Vertical Change 6/25/86	Vertical Change 7/22/87	Vertical Change 6/21/88
1	9.63	9.63	0.00	0.01	0.00
3.50	9.67	9.69	0.02	0.02	0.02
6	9.71	9.74	0.03	0.02	0.02
8.50	9.76	9.80	0.04	0.04	0.04
11	9.80	9.86	0.06	0.05	0.05
13.75	9.90	9.92	0.02	0.01	0.01
16.50	9.98	9.98	0.00	+0.02	+0.02
19.25	10.06	10.04	+0.02	+0.03	+0.03
22	10.15	10.11	+0.04	+0.06	+0.06
25	10.20	10.18	+0.02	+0.02	+0.02
28	10.26	10.24	+0.02	+0.03	+0.03
31	10.32	10.31	+0.01	+0.02	+0.03
34	10.38	10.38	0.00	+0.02	+0.02

STATION 120

Distance from Curb & Gutter	Readings 6/25/86	*	Vertical Change 6/25/86	Vertical Change 7/22/87	Vertical Change 6/21/88
1	9.64	9.64	0.00	+0.01	+0.02
3.50	9.69	9.68	+0.01	+0.01	+0.01
6	9.72	9.73	0.01	+0.01	+0.02
8.50	9.79	9.78	+0.01	+0.01	+0.01
11	9.81	9.82	0.01	+0.03	+0.03
13.75	9.91	9.87	+0.04	+0.05	+0.05
16.50	9.98	9.92	+0.06	+0.08	+0.09
19.25	10.07	9.97	+0.10	+0.10	+0.11
22	10.14	10.02	+0.12	+0.13	+0.14
25	10.15	10.08	+0.07	+0.07	+0.08
28	10.18	10.13	+0.05	+0.06	+0.07
31	10.22	10.18	+0.04	+0.04	+0.05
34	10.24	10.24	0.00	+0.02	+0.02

* Elevations of a straight line taken from a distance 1 ft to 34 ft from the curb and gutter.

All readings in feet.

STATION 125

Distance from Curb & Gutter	Readings 6/25/86	*	Vertical Change 6/25/86	7/22/87	6/21/88
1	9.72	9.72	0.00	+0.01	+0.01
3.50	9.78	9.77	+0.01	0.00	0.00
6	9.81	9.82	0.01	0.00	0.00
8.50	9.86	9.87	0.01	0.03	0.03
11	9.90	9.93	0.03	0.03	0.03
13.75	9.99	9.98	+0.01	0.00	0.00
16.50	10.08	10.04	+0.04	+0.04	+0.04
19.25	10.16	10.10	+0.06	+0.05	+0.06
22	10.25	10.15	+0.10	+0.08	+0.09
25	10.27	10.21	+0.06	+0.03	+0.03
28	10.31	10.28	+0.03	+0.02	+0.03
31	10.36	10.34	+0.02	0.00	0.00
34	10.40	10.40	0.00	0.01	0.01

STATION 130

1	9.69	9.69	0.00	0.00	0.00
3.50	9.75	9.74	+0.01	0.02	0.02
6	9.79	9.79	0.00	0.02	0.02
8.50	9.84	9.84	0.00	0.03	0.03
11	9.87	9.89	0.02	0.03	0.03
13.75	9.95	9.95	0.00	0.02	0.03
16.50	10.00	10.00	0.00	+0.01	+0.01
19.25	10.08	10.06	+0.02	+0.01	+0.01
22	10.13	10.12	+0.01	+0.02	+0.02
25	10.19	10.18	+0.01	0.01	0.01
28	10.25	10.24	+0.01	+0.01	+0.01
31	10.31	10.30	+0.01	0.00	0.00
34	10.36	10.36	0.00	0.00	0.00

* Elevations of a straight line taken from a distance 1 ft to 34 ft from the curb and gutter.

All readings in feet.

STATION 135

Distance from Curb & Gutter	Readings 6/25/86	*	Vertical Change 6/25/86	7/22/87	6/21/88
1	9.16	9.16	0.00	0.02	0.00
3.50	9.25	9.24	+0.01	0.03	0.01
6	9.30	9.31	0.01	0.02	0.00
8.50	9.38	9.39	0.01	0.04	0.03
11	9.43	9.47	0.04	0.05	0.04
13.75	9.51	9.55	0.04	0.07	0.05
16.50	9.56	9.64	0.08	0.08	0.06
19.25	9.65	9.72	0.07	0.09	0.08
22	9.70	9.81	0.11	0.05	0.04
25	9.85	9.90	0.05	+0.01	+0.02
28	9.97	9.99	0.02	+0.07	+0.10
31	10.07	10.09	0.02	+0.09	+0.10
34	10.18	10.18	0.00	+0.01	+0.03

STATION 139

Distance from Curb & Gutter	Readings 6/25/86	*	Vertical Change 6/25/86	7/22/87	6/21/88
1	9.69	9.69	0.00	0.01	0.02
3.50	9.73	9.74	0.01	0.04	0.04
6	9.75	9.79	0.04	0.05	0.04
8.50	9.80	9.85	0.05	0.08	0.08
11	9.81	9.90	0.09	0.09	0.09
13.75	9.91	9.96	0.05	0.07	0.07
16.50	9.98	10.01	0.03	0.03	0.03
19.25	10.07	10.07	0.00	0.02	0.02
22	10.13	10.13	0.00	0.00	0.00
25	10.20	10.19	+0.01	0.01	0.01
28	10.26	10.25	+0.01	0.00	0.01
31	10.32	10.31	+0.01	0.01	0.00
34	10.38	10.38	0.00	0.01	0.01

- P.K. nails paved over, new P.K. nails installed

* Elevations of a straight line taken from a distance 1 ft to 34 ft from the curb and gutter.

All readings in feet.