CONDITION OF TEXAS PAVEMENTS

1983-1989 PAVEMENT EVALUATION SYSTEM ANNUAL REPORT

State Department of Highways and Public Transportation

July 1, 1991

EXECUTIVE SUMMARY

This report summarizes the results of the 1989 Pavement Evaluation System (PES) Survey of the Texas highway network and describes statewide pavement condition and rehabilitation needs. Also historical trends over the last seven years (1983-1989) are reported. Analysis of the data has identified the following:

1. *The condition of the Texas highway network has continued to improve each year since 1984, with almost 90 percent of the network in good to very good condition.*

2. *Approximately $540 million is needed for pavement rehabilitation work on 7,092 lane miles. This is about the same funding requirement as needed as in 1988, when $546 million was needed, however the mileage in need of rehabilitation was 8,075 lane miles.*

3. *The expected variability in the PES distress ratings remains at ±15 points. In 1989, District and audit raters agreed within ±15 points on 82.2 percent of the PES audit sections, compared to 72.5 percent in 1988.*

4. *The pavement deflection data analysis indicated that 31.7 percent of the tested mileage could be considered "structurally inferior". The data also indicated that 25 percent of these "inferior" pavements were in very good condition. These "inferior" pavements with very good condition may have been achieved by using seal coats or thin overlays in lieu of reconstruction or rehabilitation because of funding constraints. These "inferior" sections typically experience greater changes in condition (up or down), may require more maintenance, and may not last as long.*

5. *Rutting continues to be a significant problem. Approximately one-third of the sections surveyed had rutting in excess of ½".*

6. *Construction expenditures increased substantially in Fiscal Year (FY) 86 with the introduction of a larger fuel tax. In FY88, construction expenditures peaked (with another fuel tax increase) at more than two billion dollars. Maintenance expenditures have increased each year since FY84, however when inflation is considered, maintenance expenditures peaked in FY88.*

7. *Gains in condition have been directly related to increases in construction and maintenance expenditures. However, if the funding remains at its present level, "inferior" pavements with good and very condition will begin to deteriorate, and a major loss in condition will occur. Such a loss would be more costly to recover than it would be to prevent.*

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CHAPTER 1
INTRODUCTION

The Texas Pavement Evaluation System (PES) is a tool available to the State Department of Highways and Public Transportation (SDHPT) Administration and Districts to determine past and present conditions, to estimate rehabilitation needs, and to compare different geographical areas of the Texas highway network. PES is a combination of field surveys, computer programs, and mainframe database files. The field surveys include surface distress, ride quality, structural strength, and surface friction (optional). These surveys are performed each year on a statistically representative sample of the network. The surface distress and ride quality surveys are conducted between September and January when the pavement is in its most stable state and construction is at a minimum. The structural strength and surface friction surveys are conducted throughout the year due to lengthy data collection procedures. There are seven years of survey results (starting in 1983) stored on mainframe files. PES provides specific reports to aid Department personnel in collecting, storing, and evaluating the data. Following is an overview of PES survey procedures and score interpretations that will be used in this report.

Surface Distress Survey

Each year D-18's Pavement Management section trains approximately 150 District personnel to collect the surface distress data, which is a primary factor in several PES scores. These personnel attend a four day course for beginners and two day refresher course for experienced raters. They then travel in teams of two and record their ratings on separate forms for three major pavement types: Asphaltic Concrete Pavement (ACP), Continuous Reinforced Concrete Pavement (CRCP), and Jointed Concrete Pavement (JCP). The distress types collected for ACP are rutting, patching, failures, block cracking, alligator cracking, longitudinal cracking, and transverse cracking. The distress type for CRCP are spalled cracks, punchouts, asphalt patches, and concrete patches. The distress type for JCP are failed joints and cracks, failures, slabs with longitudinal cracks, shattered slabs, concrete patches. For more information on the PES visual rating survey, contact D-18PM to obtain the "*PES Rater's Manual*".

In 1989, data were collected on 11,417 sections which is 24,123 mainlane miles, or 34.8 percent of the Texas highway network.

Ride Quality Survey

The Department currently maintains 12 automated road roughness measuring units known as SIometers, to collect ride quality data. The SIometer replaced the Mays Ride Meter (MRM), which was previously used to collect ride quality data until 1987. This equipment is operated by trained personnel from the Districts. The SIometer unit consists of an accelerometer mounted in the car's trunk that connects to a processing computer and a data storage computer. Ride quality is reported in terms of a unit called the Serviceability

Index (SI) which varies from 0 for very rough pavements to 5 for very smooth pavements. SIometer calibrations are done in Austin each year to ensure consistency in survey results from year to year. To ensure consistent data during the data collection season, a verification of the equipment is performed throughout the data collection season. Ride Quality data is a factor in two PES scores and can also be used alone in determining needs and trends.

In 1989, data were collected on 11,417 sections which is 24,123 mainlane miles, or 34.8 percent of the Texas highway network. This was the same amount of mileage collected in the surface distress survey.

Structural Strength Survey

The Department currently has 13 automated deflection measuring devices known as Falling Weight Deflectometers (FWD). The FWD is used to collect structural strength data, which was introduced into PES in 1987. The FWD is a non-destructive testing device which measures structural integrity of highway pavements by placing a load on the pavement surface and measuring the resulting deflections. The results are reported in terms of a parameter known as the Structural Strength Index (SSI) which varies from 0 for a weak pavement to 100 for a strong pavement. Deflection data for PES is only collected on flexible pavements, and only about one-third of the statistical sample is tested. SSI is an indicator of a pavement's structural integrity and is a factor in no other PES score at this time.

In 1989, 7,127 sections or 14,036 mainlane miles were tested for structural strength. This is 19 percent of the Texas flexible pavement network, or 18 percent of the entire highway network.

Surface Friction Survey

The Department currently uses a locked-wheel skid trailer and a tow vehicle to measure surface friction (skid). Currently there are four of these units in the field with plans to add three more units. The skid trailer is a two-wheeled trailer which is towed behind a truck at 40 miles per hour (MPH). The left trailer wheel is locked at periodic intervals on a wetted surface and the resulting friction force is measured. This friction force is known as a skid number (SN) and ranges from 0 for a pavement with very low friction *(slick)* to 100 for a pavement with very high friction. This survey is optional for PES and is not used as a factor in any of the PES scores. The skid survey can be used to evaluate effects of aggregate type, asphalt mix design, and pavement construction methods on skid resistance over time.

In 1989, skid resistance data were collected on 2,607 sections or 5,096 mainlane miles. This voluntary survey covered 7.4% of the Texas highway network.

Reporting

PES computes eight different scores to summarize the condition of a pavement section. These scores represent an average condition over two miles of pavement. Each score is a function of one or more variables, as shown in the table below.

SCORES	VARIABLES							
	ADT	ESALS	F CLASS	FRICTION	CLIMATE	DISTRESS	RIDE	DEFLECTION
Serviceability Index (SI)							X	
Structural Strength Index (SSI)		X			X			X
Skid Number (SN)				X				
Unweighted Visual Utility (UVU)						X		
Adjusted Visual Utility (AVU)					X	X		
Weighted Visual Utility (WVU)	X	X			X	X		
Unadjusted Pavement Score (UPS)						X	X	
Pavement Score (PS)	X	X	X		X	X	X	

ADT -- Average Daily Traffic.
ESALS -- Applied loads converted into an equivalent number of single axle loads (18,000 lbs).
F CLASS -- Functional relative importance of pavement section to overall highway network.
CLIMATE -- Average annual rainfall and number of freeze/thaw cycles by county.

This report will address the following scores:

1.	**Unweighted Visual Utility (UVU) - Distress Score**
2.	**Serviceability Index (SI)- Ride Quality Score**
3.	**Unadjusted Pavement Score (UPS) - Condition Score**
4.	**Pavement Score (PS) - Rehab Priority Score**
5.	**Structural Strength Index (SSI)**

All charts and tables have been extrapolated from the random statistical sample that every District is required to rate. **The extrapolated results obtained from the statistical sample and a 100 percent survey indicated little difference in the final value.**

Unweighted Visual Utility (UVU) -- Distress Score

UVU is a function of the surface distresses found on the pavement section (such as rutting, cracking, failures, and spalled cracks, etc.). The values for UVU range from 1 (worst condition -- most distress) to 100 (best condition -- least distress). The following categories are used to describe the Distress score:

UVU	CLASS	DESCRIPTION
90-100	"A"	VERY GOOD -- Little or no distress
80-89	"B"	GOOD -- One or two slight distresses
70-79	"C"	FAIR -- Multiple distress types, or one severe distress
60-69	"D"	POOR -- Multiple distress types with at least one severe distress
1-59	"F"	VERY POOR -- Combination of moderate and severe distresses

A Distress score value below 80 suggests problems. This problem may be caused by multiple distress types (such as rutting and alligator cracking) or by one serious distress (such as deep rutting). This score is used by some Districts to determine maintenance and rehabilitation needs.

Serviceability Index (SI) -- Ride Quality Score

This score is indicative of the travelling public's response to various levels of roughness found on Texas' highways. It is a product of a panel rating performed a number of years ago on a selected set of pavement sections having various levels of roughness. The Ride Quality score ranges from 0 for a very rough pavement to 5 for a very smooth pavement. The table below identifies the classes of ride quality:

SI	CLASS	DESCRIPTION
4.0-5.0	"A"	VERY SMOOTH PAVEMENT
3.0-3.9	"B"	SMOOTH PAVEMENT
2.0-2.9	"C"	MODERATELY ROUGH PAVEMENT
1.0-1.9	"D"	ROUGH PAVEMENT
0-0.9	"F"	VERY ROUGH PAVEMENT

The minimum desirable value for SI in this report is 3.0. Roads may be allowed to have a lower ride depending on other factors. Some Districts use this score to aid in their maintenance and rehabilitation programs.

Unadjusted Pavement Score (UPS) -- Condition Score

UPS is calculated from a section's distress and ride quality. The score values range from 1 (worst condition) to 100 (best condition). The condition score is the average person's "absolute" perception of the pavement's state. This score is not influenced by such factors as the environment, traffic, or functional class. Highways can be classified by pavement condition, as shown below:

UPS	CLASS	DESCRIPTION
90-100	"A"	VERY GOOD
70-89	"B"	GOOD
50-69	"C"	FAIR
35-49	"D"	POOR
1-34	"F"	VERY POOR

A condition score below 50 indicates that major rehab or reconstruction should be done.

Pavement Score (PS)-- Rehab Priority Score

The PS is used to prioritize a section's need for rehabilitation. The Rehab Priority score for a section is a function of the following factors: surface distress, ride quality, environment (average county rainfall and average county freeze/thaw cycles), traffic (ADT and 18-k ESALs), and functional class. This score can help in determine what action should be taken for a pavement, as suggested by the following table:

PS	CLASS	PRIORITY		
		Preventive Maintenance	Routine Maintenance	Rehab/ Reconstruction
90-100	"A"	HIGH	N/A	N/A
70-89	"B"	HIGH	LOW	N/A
50-69	"C"	MODERATE	HIGH	LOW
35-49	"D"	LOW	MODERATE	MODERATE
1-34	"F"	N/A	N/A	HIGH

The values for PS range from 1 (urgent need for rehab) to 100 (no rehab needed). A PS below 50 indicates that some action besides preventive maintenance should be taken. D-18PM and some Districts use PS to determine rehab and maintenance needs.

Structural Strength Index (SSI)

This score is based on deflection data acquired from the FWD. SSI is not factored into any other PES score, but is used as an indicator of a pavement's structural integrity. The values for SSI range from 1 for a very weak pavement to 100 for a very strong pavement. SSI is grouped into the following categories to describe the structural integrity of a pavement:

STRUCTURAL STRENGTH INDEX	CLASS
70-100	STRONG
40-69	MODERATE
1-39	WEAK

A SSI below 70 indicates that the pavement could deteriorate rapidly, even if the pavement surface is in good condition, and must be closely monitored.

Skid Number (SN)

The skid number is calculated from the following equation:

$$SN = 100f$$

Where f is a friction factor obtain from a locked-wheel skid test done which a trailer equipped for wet-skid friction testing with the tire, speed, temperature, water film thickness and other conditions as specified by the American Society of Testing and Materials (ASTM) method E274. The skid resistance measurement does not directly indicate the stopping characteristics of any one vehicle, driver, or environmental condition. However, it is useful in maintenance planning, evaluating various materials and construction methods, and for accident investigation studies. Skid was not analyzed in this report, but the table below is a useful reference on interpreting SN.

SN	CLASS	DESCRIPTION
65-100	EXCELLENT	VERY COARSE CHIP SEAL (seldom attained)
50-64	VERY GOOD	COARSE CHIP SEAL OR HIGH QUALITY SURFACE
35-49	GOOD	TYPICAL ASPHALT OR CONCRETE SURFACE
20-34	FAIR	WORN, POLISHED AND/OR BLEEDING SURFACE
0-19	POOR	HIGHLY POLISHED AND/OR BADLY BLEEDING SURFACE

CHAPTER 2
1983 THROUGH 1989 PES SURVEYS

PES estimates are based on a statistical sample of the state maintained highway system. Samples are used to minimize the amount of time spent collecting data. In 1989, the PES program randomly selected 100 percent of the Interstate (IH) mileage, 50 percent of US and State highway (SH) mileage, and 20 percent of the Farm-to-Market (FM) mileage. This resulted in a sample size of 24,123 mainlane miles in 1989 (for visual and ride).

Table 2.1 lists the total roadway miles of pavement rated from 1983 to 1989, by pavement type (ACP, CRC, and JCP) and by highway system (IH, US, SH, and FM). Table 2.2 lists the percentage of roadway mileage rated from 1983 to 1989, by pavement type and highway system.

TABLE 2.1 -- Total Length of Roadway Mileage Evaluated From 1983-1989.
PES Random Statistical Sample Sections Only.

YEAR	PAVEMENT TYPE	IH	US	SH	FM	TOTAL
1983	ACP	3,208	6,727	6,598	5,554	22,087
	CRC	0	0	0	0	0
	JCP	0	0	0	0	0
	TOTAL	3,208	6,727	6,598	5,554	22,087
1984	ACP	4,051	7,949	8,291	7,145	27,436
	CRC	1,285	516	223	0	2,024
	JCP	273	280	341	18	22,087
	TOTAL	5,609	8,745	8,855	7,163	30,372
1985	ACP	4,190	6,866	7,169	7,591	25,816
	CRC	1,270	28	46	2	1,346
	JCP	199	66	65	22	352
	TOTAL	5,659	6,691	7,280	7,615	27,514
1986	ACP	4,383	8,193	8,707	7,545	28,827
	CRC	1,298	436	204	4	1,942
	JCP	130	256	322	33	741
	TOTAL	5,811	8,885	9,232	7,582	35,510
1987	ACP	4,471	6,836	7,240	7,811	25,706
	CRC	1,087	129	66	2	1,223
	JCP	143	83	97	16	293
	TOTAL	5,701	7,048	7,402	7,657	27,222
1988	ACP	4,459	7,536	8,148	7,413	27,553
	CRC	1,096	370	242	11	1,719
	JCP	168	255	244	0	667
	TOTAL	5,723	8,161	8,634	7,424	29,943
1989	ACP	4,579	4,582	5,955	7,310	22,426
	CRC	1,200	109	46	12	1,367
	JCP	187	51	86	6	330
	TOTAL	5,966	7,742	6,086	7,323	24,123

TABLE 2.2 -- Percentage of Roadway Mileage Evaluated From 1983-1989.
PES Random Statistical Sample Sections Only.

YEAR	PAVEMENT TYPE	IH	US	SH	FM	TOTAL
1983	ACP	87.75%	47.83%	45.08%	14.04%	30.71%
	TOTAL	87.75%	47.83%	45.08%	14.04%	30.71%
1984	ACP	99.73%	56.12%	56.26%	17.90%	37.64%
	CRC	81.23%	89.90%	71.94%	0.00%	81.02%
	JCP	50.65%	57.38%	62.11%	12.00%	52.84%
	TOTAL	90.72%	57.43%	56.78%	17.86%	39.39%
1985	ACP	100.00%	48.73%	48.72%	19.13%	35.52%
	CRC	80.03%	5.62%	14.15%	5.88%	55.07%
	JCP	37.13%	15.28%	11.86%	14.38%	21.09%
	TOTAL	89.64%	46.34%	46.71%	19.10%	35.83%
1986	ACP	101.18%	57.47%	58.60%	18.80%	39.17%
	CRC	87.29%	82.73%	62.20%	11.11%	81.67%
	JCP	25.05%	49.61%	62.28%	21.57%	43.46%
	TOTAL	91.69%	58.08%	58.79%	18.80%	40.57%
1987	ACP	100.22%	48.14%	48.15%	19.40%	35.64%
	CRC	78.83%	26.76%	23.74%	5.41%	59.01%
	JCP	28.89%	17.44%	19.76%	10.53%	21.00%
	TOTAL	89.99%	46.49%	46.83%	19.35%	35.99%
1988	ACP	97.53%	52.92%	53.78%	18.48%	37.20%
	CRC	74.86%	74.60%	67.60%	40.74%	73.30%
	JCP	40.10%	53.68%	48.70%	0.00%	43.12%
	TOTAL	88.66%	53.65%	53.93%	18.42%	38.40%
1989	ACP	101.17%	32.89%	39.42%	18.08%	30.31%
	CRC	81.63%	21.63%	14.84%	34.29%	58.95%
	JCP	50.82%	11.72%	18.30%	4.35%	23.39%
	TOTAL	93.75%	52.06%	38.31%	18.04%	34.89%

NOTE: Percentage may be greater than 100 due to rounding errors. The 1983 percentages do not include rigid pavements.

-Notes-

CHAPTER 3
AUDIT OF PES DATA

In order to verify consistency and accuracy in data collection among the various District rating teams, an audit is performed each year. Each year, District personnel are instructed to rate a small number of randomly selected sections from a neighboring District in addition to rating roads within their own District. These audit sections are used to compare the variability in ratings when two different teams rate the same highway sections.

Audit sections are selected at random from the mandatory PES section list. The audit sample size is kept down to about five percent so that the audit can be completed in a five day period. Each of the three pavement types (ACP, CRC, and JCP) are selected separately so that representative samples of each type are obtained.

Ideally, distress scores computed for a single section using District data and audit data should be identical, since the same area of road is being rated. In reality, the current rating procedure is somewhat subjective and different estimates of distress may be obtained by different rating teams on the same section of road. The precision (or "repeatability") of these scores has a major influence on the reliability of the PES condition estimates.

Reliability of Statewide Distress Scores

Analysis of the 1989 audit data, summarized in Table 3.1, indicates an 82.2 percent probability that distress scores returned by different teams on the same section of road will be within 15 points of each other. This compares with 77.5, 75.0, and 72.5 for 1986, 1987, and 1988, respectively.

The recent improvement in PES precision may be a result of increased rater awareness as a result of audit analysis reports discussed at the annual rater training schools.

TABLE 3.1 -- Precision of PES Distress Scores.

PAVEMENT TYPE	1986	1987	1988	1989
ACP	77.2	74.2	71.7	80.8
CRC	87.2	83.6	89.5	91.2
JCP	60.0	76.9	62.5	80.0
ALL	77.5	75.0	72.5	82.2

Note: Values indicate the probability that distress scores from different rating teams will be within 15 points of each other.

Reliability of Statewide Individual Distress Scores

The PES audit results also enabled an analysis of the reliability of each of the individual distress factors which are combined to determine the overall distress score.

Since some distresses are more detrimental to the pavement's condition than others, the type of distress along with the expected magnitude of error in rating that distress must be considered when assessing the reliability of the distress score. Any error in the distress score will automatically show up in the condition rating.

For example, on asphalt pavements, 10.3 percent of the audit sections showed a disagreement in the ratings for rutting which would have been large enough, by itself, to cause at least a 10-point change in the distress score (e.g., from 80 to 70, or from 45 to 35). Table 3.2 lists similar percentage values for each PES distress type for 1986 through 1989.

TABLE 3.2 -- Precision of PES Distress Ratings.

PAVEMENT TYPE	DISTRESS TYPE	1986	1987	1988	1989
ACP	Rutting	9.2	14.0	13.3	10.3
	Patching	11.0	11.0	10.3	8.8
	Failures	6.3	7.9	6.2	4.0
	Block Cracking	3.8	2.8	3.6	1.5
	Alligator Cracking	16.9	13.3	13.2	8.2
	Longitudinal Cracking	7.2	8.7	7.3	6.9
	Transverse Cracking	8.1	10.2	9.6	5.4
CRC	Spalled Cracks	6.4	0.0	0.0	0.0
	Punchouts	12.8	1.8	0.0	0.0
	Asphalt Patches	8.5	1.8	5.3	2.0
	Concrete Patches	4.2	21.8	8.8	9.8
JCP	Failed Joints/Cracks	33.3	23.1	31.3	13.3
	Failures	33.3	7.7	29.27	20.0
	Shattered Slabs	6.7	0.0	0.0	0.0
	Slabs with Longitudinal Cracks	6.7	0.0	0.0	0.0
	Concrete Patches	6.7	0.0	14.6	0.0

Note: Values indicate the probability that distress ratings from different rating teams will cause at least a 10-point difference in the condition score.

Analysis of the Reliability of Statewide Distress Scores

As shown in Table 3.2, the precision of PES distress ratings is improving on each of the three pavement types rated. The rutting measurements continue to be the least precise distress rating on ACP, but such variability is to be expected when current rutting measurements are done by spot checks using a reference straight-edge and hand-held rulers. D-18PM has begun a research project to automate the collection of rut depth measurements. A prototype device has been constructed and will be tested on a limited basis in the 1991 PES survey.

On JCP, the counting of failed joints/crack and slab failures continues to be a large contributor of inaccuracy, but since the percentage of this pavement type is small, this observed error has minimal impact on the statewide analysis.

Rating on CRC continues to have the best precision which is probably a result of the limited number of distresses found on CRC. Historically, new concrete pavements in Texas tend to show very little distresses early in their life and since recent years have seen a lot of new CRC construction in comparison with the total amount of CRC, the average age of CRC in Texas is relatively low.

Overall, the precision of the PES distress scores shows a 4.7 percent improvement from 77.5 percent in 1986 to the current value of 82.2 percent.

Calibration and Verification of Ride Quality Equipment

The Department currently maintains 12 automated road roughness measuring devices (SIometers) for the collection of PES ride quality data. In 1989, the SIometers were calibrated to nine different sections around the Austin area. These sections measure 0.2 miles in length and varied from very smooth to rough. The roughness of the sections is determined by the Profilometer, which is a non-contact measuring device that provides a profile of two wheelpaths in which a serviceability index (SI) is calculated. Each SIometer was driven over the sections five times. The raw readings collected for each section were averaged and compared to the SIs obtained from the profilometer and a calibration equation was calculated for each SIometer.

Throughout the data collection period, the SIometers were returned to Austin to verify that they were still in calibration. Each SIometer was driven five times over three sections which were in the very smooth, moderately rough, and a rough categories. The SI readings were collected, averaged, and compared to the SI reading of the section. If there was a difference of more than 5 percent the SIometer was considered to be out of calibration and all data collected since the last verification would have to be recollected. In 1989, none of the 12 SIometers were found to be out of calibration.

Calibration and Verification of Deflection (Structural) Equipment

The Department currently operates 13 automated deflection measuring devices (Falling Weight Deflectometers, or FWDs) for the collection of deflection data. A relative calibration is done once a month on the FWD's seven geophones, which is performed on concrete pavement with a deflection of 10-30 mils. The seven geophones are stacked in a specially designed frame to subject all of them to the same pavement deflection simultaneously. Two drops are then made to set the FWD's drop plate, with geophone number one placed at the bottom, five drops are then made. This process is then repeated for each geophone, so that you end up with seven sets of five deflection readings. If any of the geophones are out of agreement by more than 2 percent they are returned to the manufacturer for adjustment.

In 1989, a comparison of all FWD's was made to determine if there was any great difference in the units. This comparison test was made on two rigid and three flexible pavements. The test indicated to D-18PM that an absolute calibration was needed. Research was begun and an absolute and relative calibration will be implemented in September, 1991. Also a calibration verification will be done once a month at the regional centers. If the verification fails, then the FWD will be returned to Austin for re-calibration.

Calibration and Verification of Surface Friction (Skid) Equipment

The Department currently operates four locked-wheel skid units and is building three more units for the collection of surface friction data. A static and dynamic calibration of each skid unit is performed each year before collecting data. The first step is to send one skid unit and the static calibration force plate to the Texas Transportation Institute (TTI) for operation characteristics verification and calibration. Next, when a system is brought on-line, the static calibration is done using the TTI calibrated force plate. Then the TTI calibrated skid unit measures the surface friction of pavement sections around the Austin area for the dynamic calibration of the other units.

Field verification of the static and dynamic calibration are done each day before collecting data. The static calibration is verified by using a torque arm of known weight. The dynamic calibration is checked by skidding a test section setup around locations where data are being collected. If a unit is found to be out of calibration it is returned to Austin for re-calibration.

CHAPTER 4
CONDITION OF TEXAS HIGHWAYS

The general condition of the Texas highway system can be determined through analysis of annual PES survey data. Surface distress and ride quality are primary indicators of condition. For this reason, unadjusted pavement score (UPS) is used as a measure of overall condition.

UPS ratings may be used to compare pavements from different areas, without introducing regional factors to bias the results. Because UPS is not influenced by such factors as traffic, environment, or material properties, it provides an average driver's view of the highway system. All charts in this chapter are derived from the PES random statistical sample sections, and are thus assumed to represent the entire Texas highway system. The condition ratings are divided into five major categories and are defined in Table 4.1.

TABLE 4.1 -- Classes of Condition Rating.

UPS	CLASS	DESCRIPTION
90-100	"A"	VERY GOOD
70-89	"B"	GOOD
50-69	"C"	FAIR
35-49	"D"	POOR
1-34	"F"	VERY POOR

Figure 4.1 depicts the changes in general condition of the Texas highway network from 1983 to 1989. The amount of very good mileage has increased each year since 1984, with 66.2 percent of the 1989 State's mainlane mileage in Class "A". All other categories have decreased, with classes "D" and "F" down, from a combined high of 14.0 percent in 1984 to a low of 5.3 percent in 1989.

One of the reasons for the improvement in condition was ride quality. Ride quality has continued to improve since 1984, with a large increase in very smooth pavements in 1989, as indicated in Figure 4.2. Mainlane mileage with very good and good UVU scores (distress) has also increased each year since 1984, as indicated in Figure 4.3. ACP and JCP improved in overall condition in 1989, while CRC worsen slightly. The decrease in condition for CRC can be attributed to increasing distress. Ride quality and distress will be discussed in more detail later in this chapter.

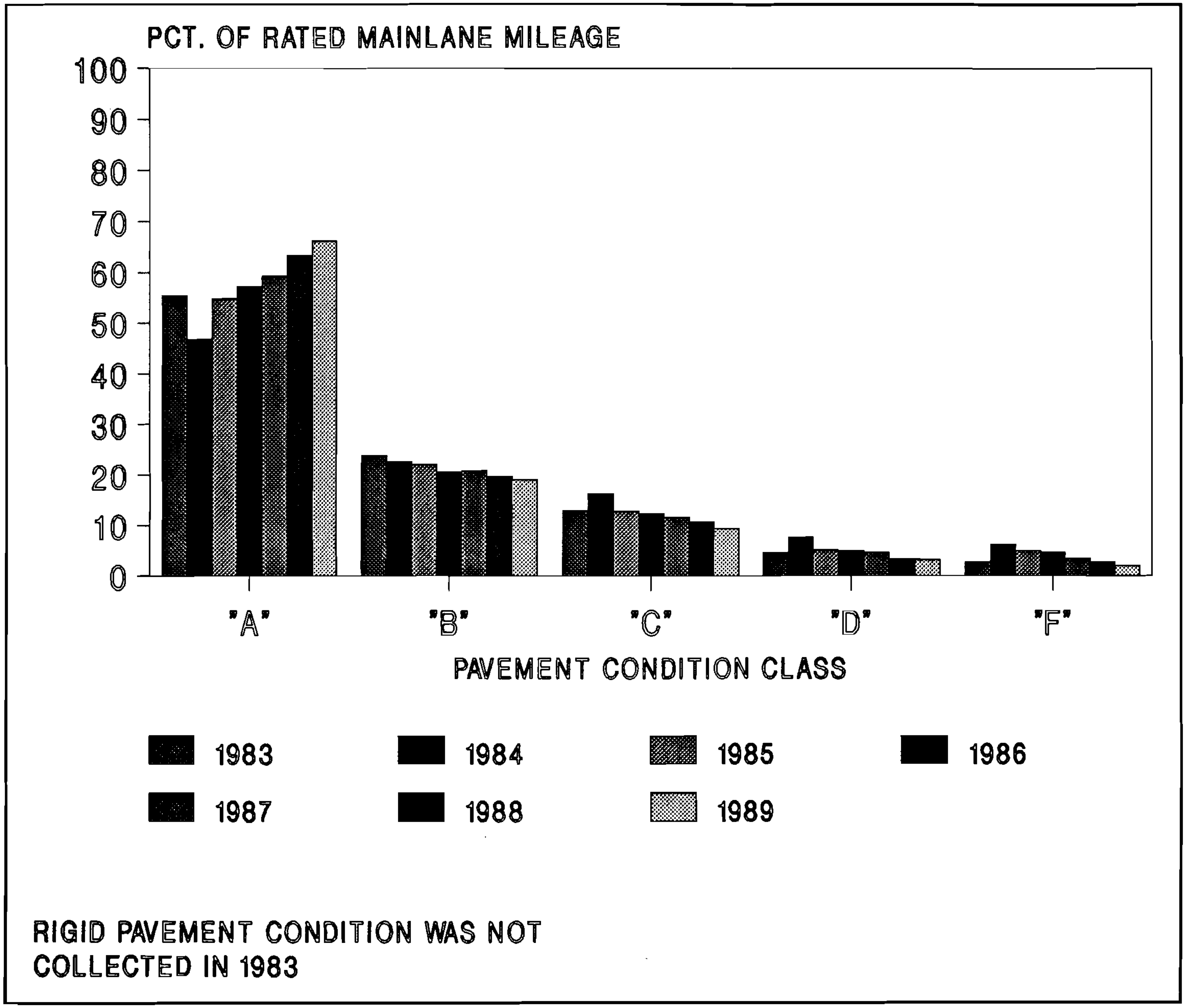

Figure 4.1 -- Condition of Texas Highway Network 1983-1989.
(Frontage roads are not included in this chart.)

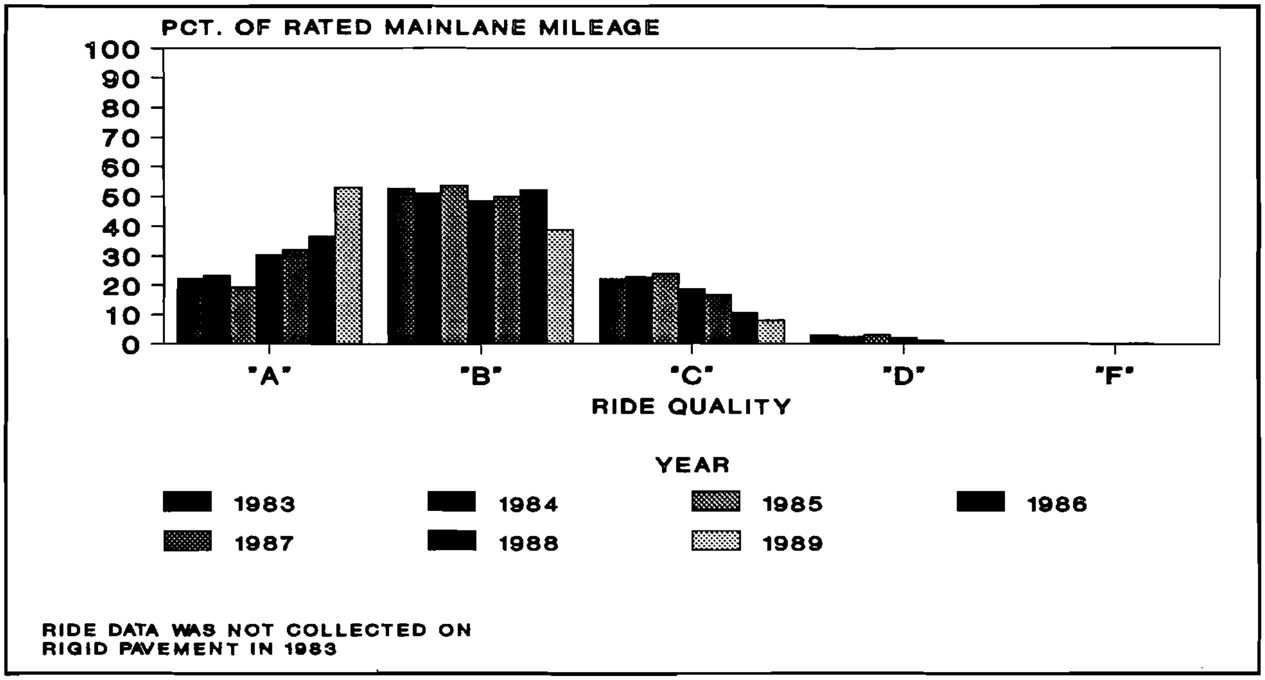

Figure 4.2 -- Ride Quality of Texas Highway Network 1983-1989.

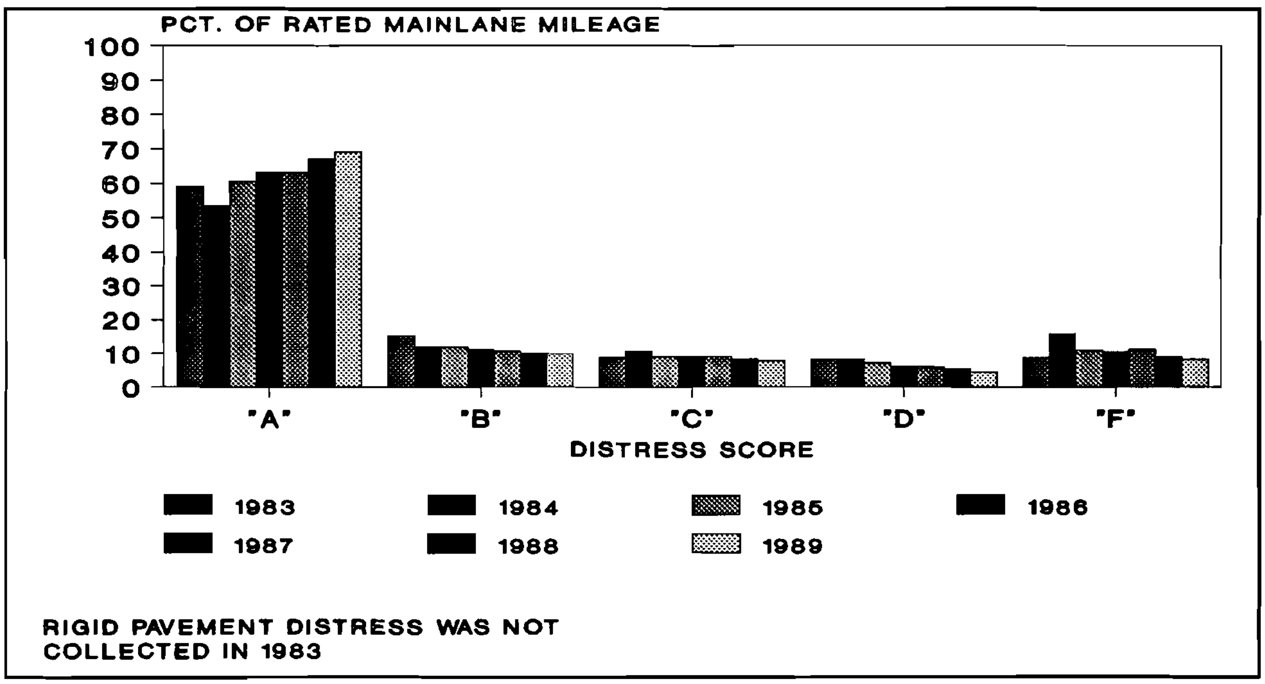

Figure 4.3 -- Pavement Distress of the Texas Highway Network 1983-1989.

Condition of IH Network

In 1989, the overall condition of the IH network decreased slightly, with 71.2 percent of the rated mainlane mileage in class "A" and 4.7 percent in Classes "D" and "F". In 1988, class "A" mileage was at 73.0 percent and only 2.9 percent was in classes "D" and "F". The overall ride quality continued to improve in 1989. Of the three major pavement types, CRC was the only one to have an increase in the amount of distress. Therefore, the slight decrease in the IH network can be attributed to the aging of CRC pavement as will be shown later in this report. Figure 4.4 indicates the condition trends since 1983.

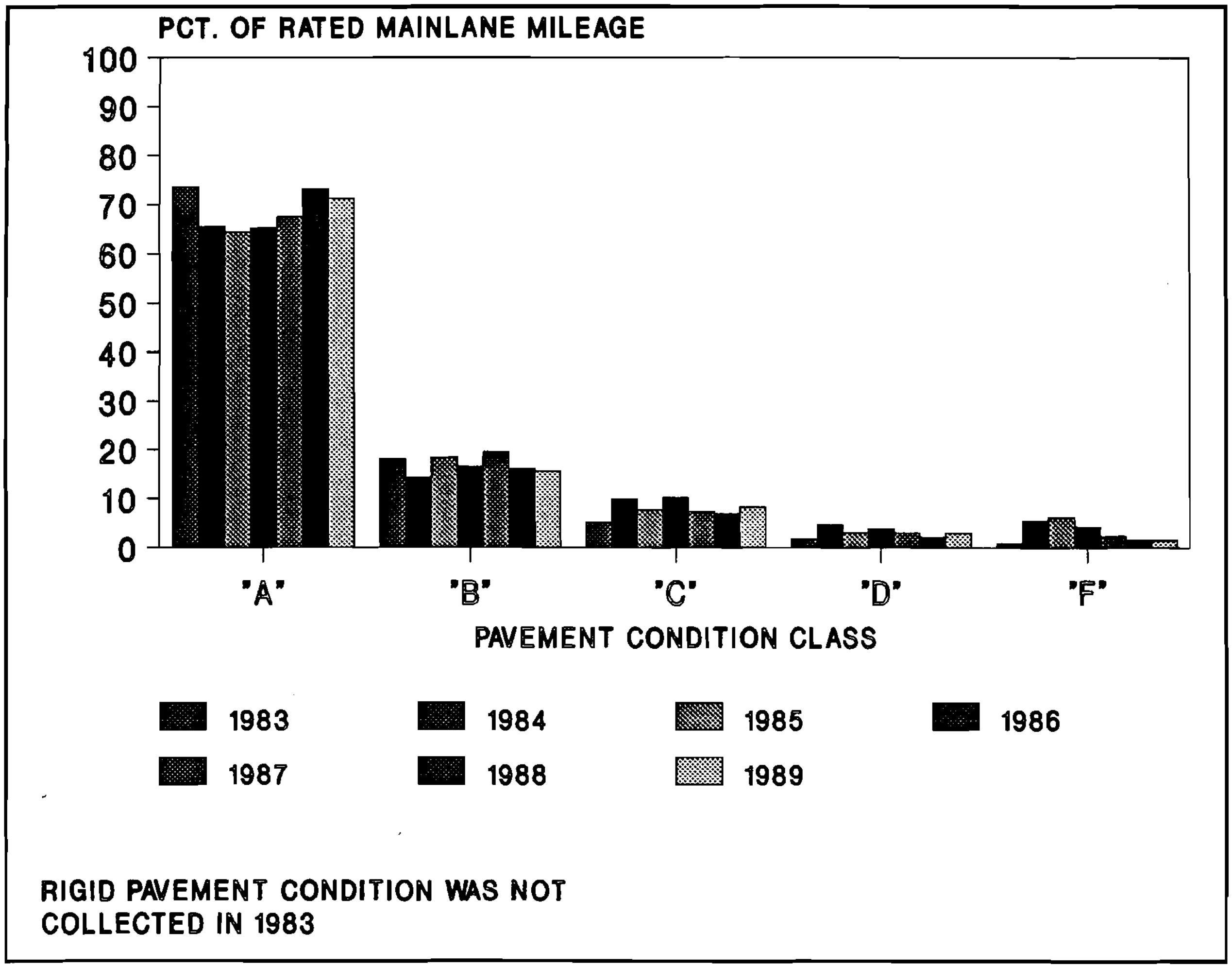

Figure 4.4 -- Condition of IH Network 1983-1989.

Condition of US Network

The US highway network improved overall in 1989, with 68.8 percent of the rated mainlane mileage in class "A". This increase can be attributed to an increase in ride quality and to an overall decrease in distress. The ride quality of the US highways improved greatly with a big shift of class "B" mileage in class "A". The UVU increased on ACP and JCP but declined slightly on CRC. This will be discussed in more detail later in this chapter. Figure 4.5 indicates the condition trends from 1983-1989.

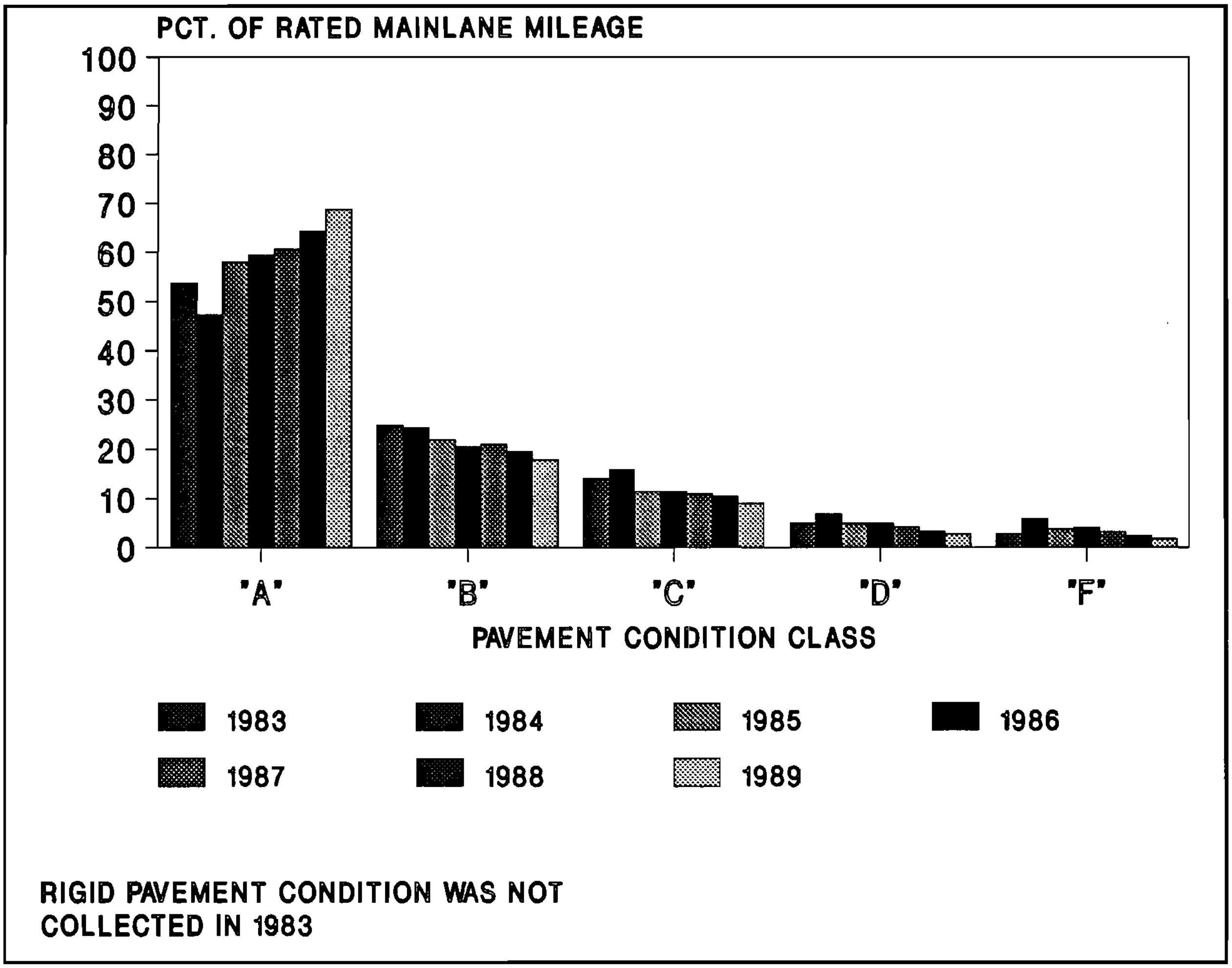

Figure 4.5 -- Condition of US Network 1983-1989.

Condition of SH Network

The State Highway network also improved in 1989, with 67.0 percent of the rated mainlane mileage in very good condition. Again the ride quality improved with a large increase in very smooth mileage. The overall distress score also improved with all pavement types showing a decrease in distress. Therefore the improvement in condition can be attributed to the increase in both ride quality and distress score. Figure 4.6 indicates the condition trends from 1983-1989.

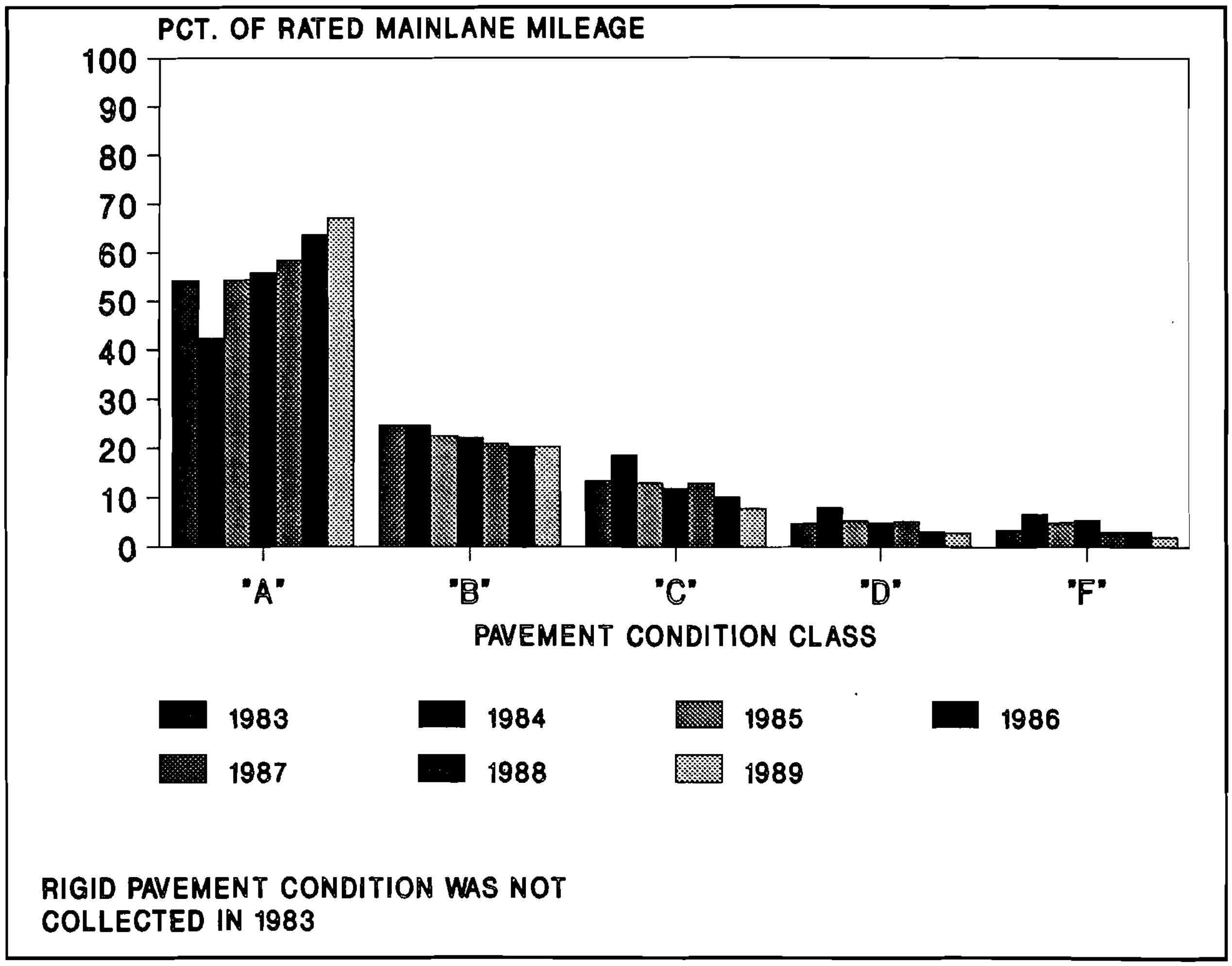

Figure 4.6 -- Condition of SH Network 1983-1989.

Condition of FM Network

The overall condition of the FM highway network continued to improve in 1989, with 60.5 percent of the rated mainlane mileage in class "A". This improvement can be attributed to both ride quality and distress score. The major pavement type for the FM network is ACP which displayed the same amount of class "A" mileage for distress as condition. These findings will be reviewed later in this chapter. Figure 4.7 indicates the trends in condition from 1983-1989.

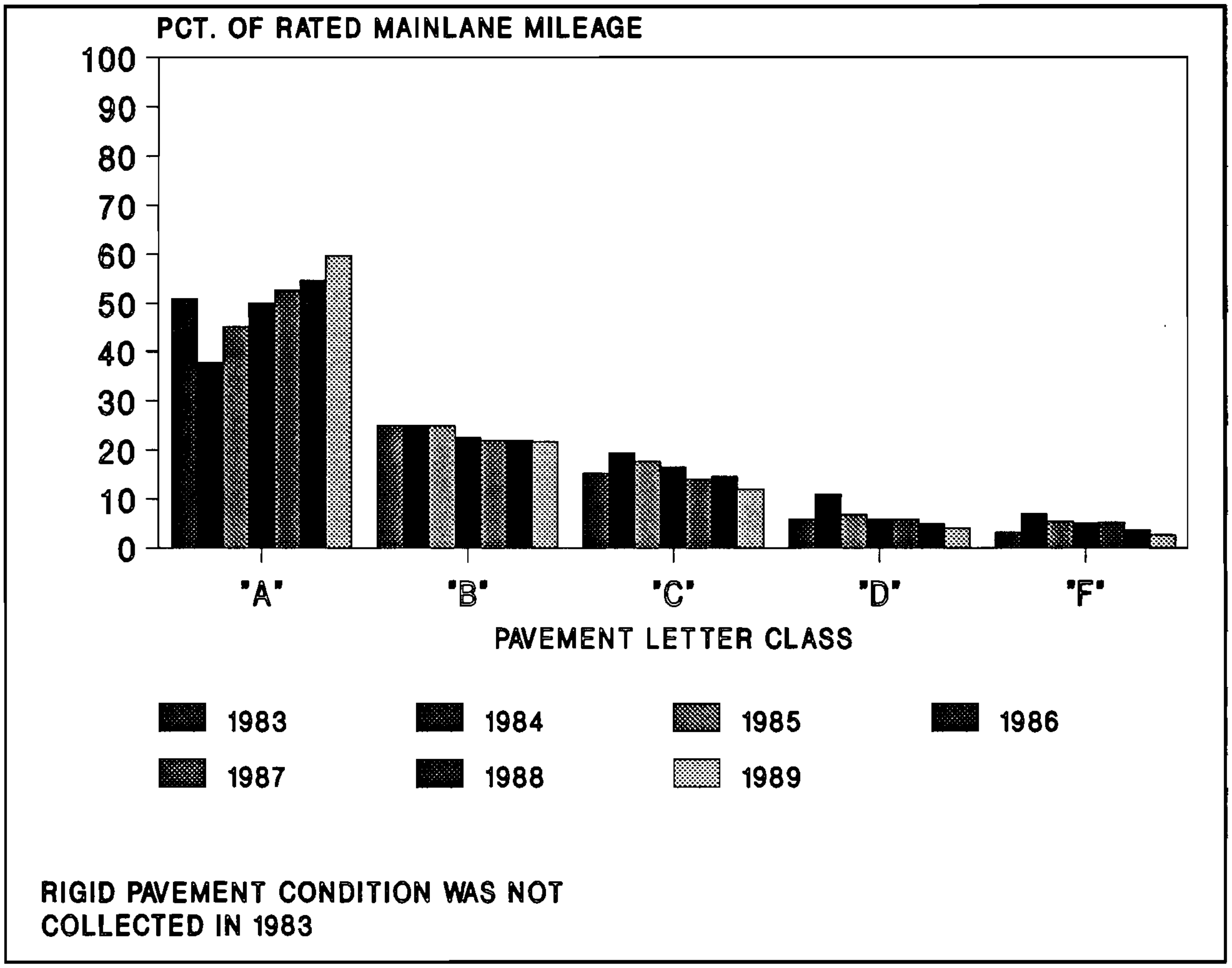

Figure 4.7 -- Condition of FM Network 1983-1989.

Asphalt Pavement (ACP) Condition

In 1989, the overall pavement condition improved for asphalt pavements. This improvement can be attributed to an increase in both ride quality and distress score. The ride quality for all highway systems increased, with large gains made in mileage of very smooth pavement. The distress score for all highway systems also increased in 1989 with rutting being the only distress type to occur more frequently. More information will be given on the distress and ride quality later in this chapter. Figure 4.8 indicates the ACP condition trends since 1983.

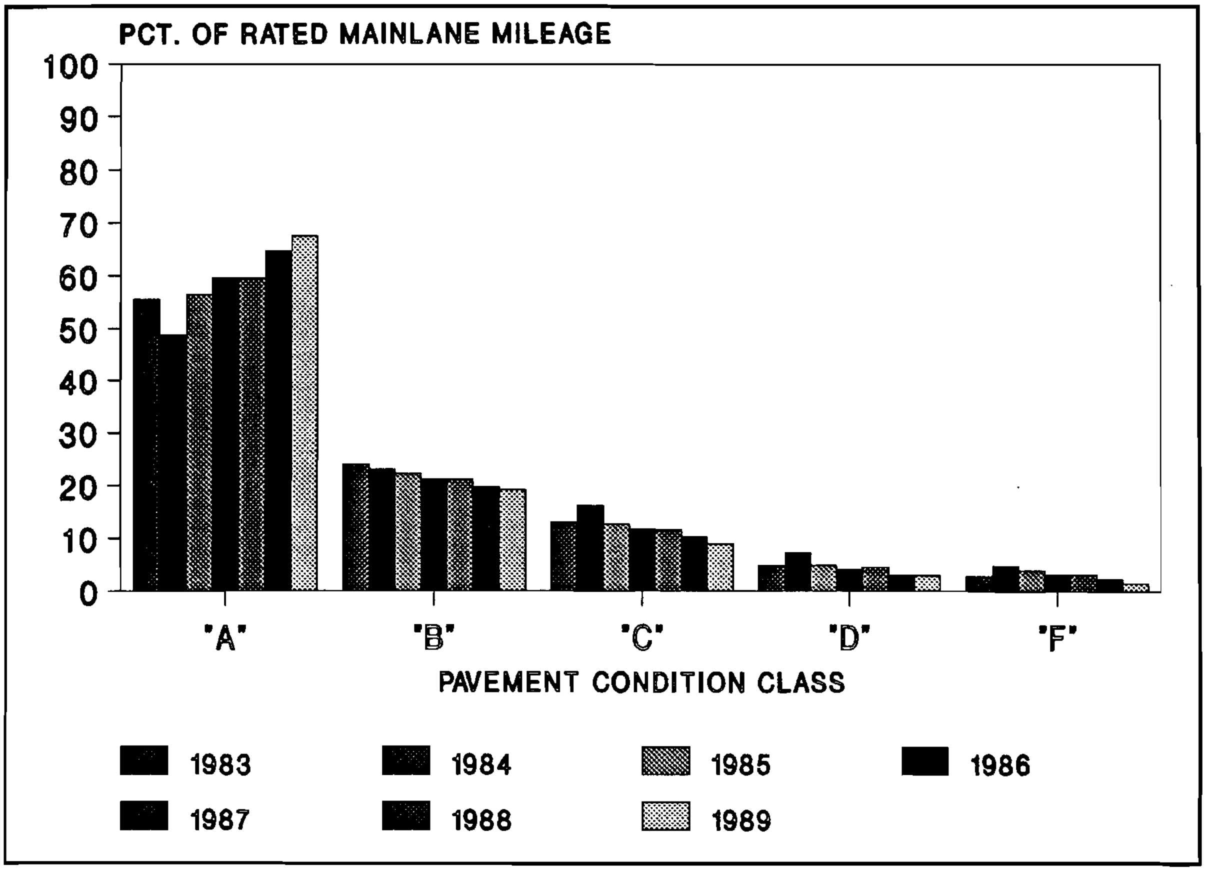

Figure 4.8 -- ACP Condition 1983-1989.

Continuously-Reinforced Concrete (CRC) Condition

CRC decreased in overall condition in 1989, when compared to the 1988 PES survey data. The overall ride quality for the CRC system showed an increase, however the IH and SH networks ride decreased slightly. The UVU score decreased, because the amount and severity of the distress increased, while the percentage of mainlane mileage with distress remained about the same. This indicates that the CRC system is gradually deteriorating as it ages. Figure 4.9 indicates the condition trends from 1984-1989.

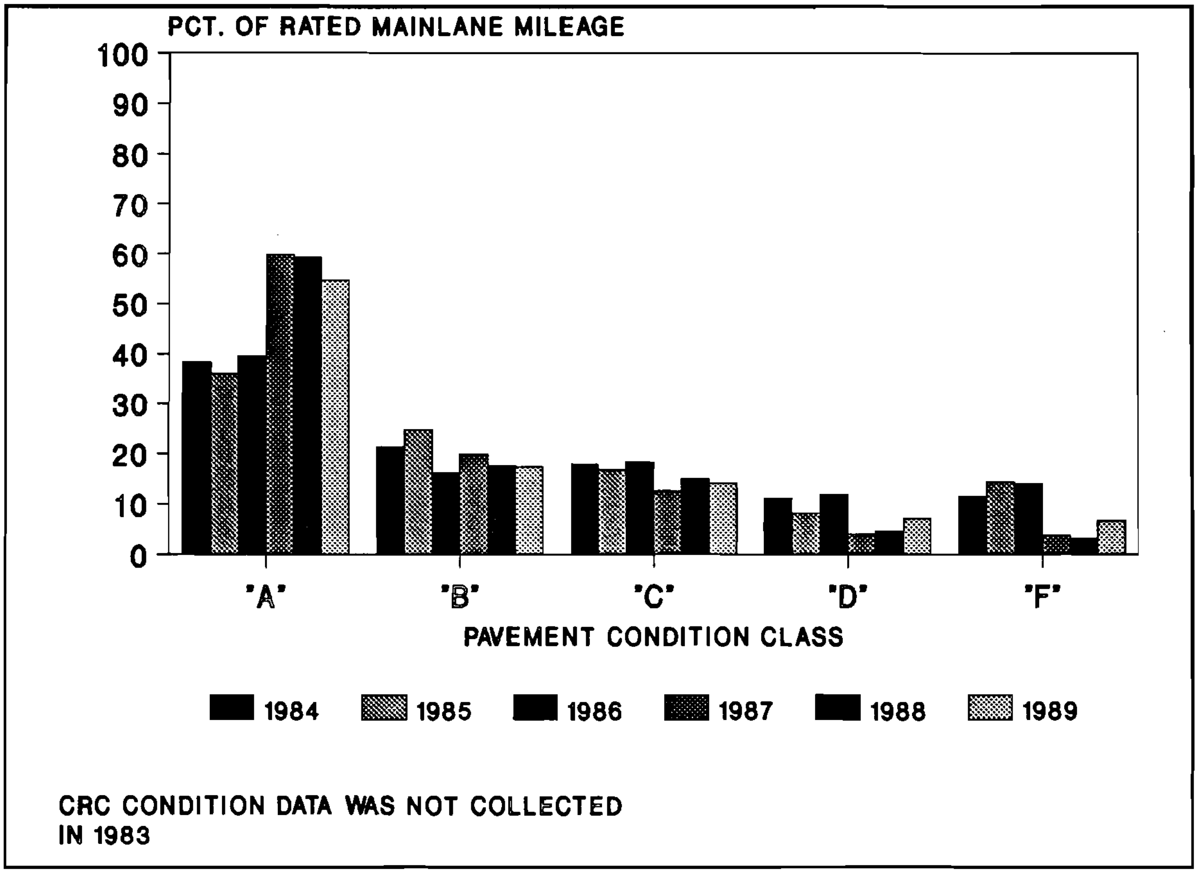

Figure 4.9. -- CRC Condition 1984-1989.

Jointed Concrete Pavement (JCP) Condition

Jointed Concrete Pavement continued to be the pavement type in the worst condition in 1989, but did show an improvement. The ride quality showed a slight improvement, but a large percentage of the mileage still has an SI below 3.0 as Figure 4.18 indicates. The distress score (UVU) also improved in 1989, but due to a small and oscillating sample size little confidence can be placed in this figure. Figure 4.10 displays the condition distribution since 1984.

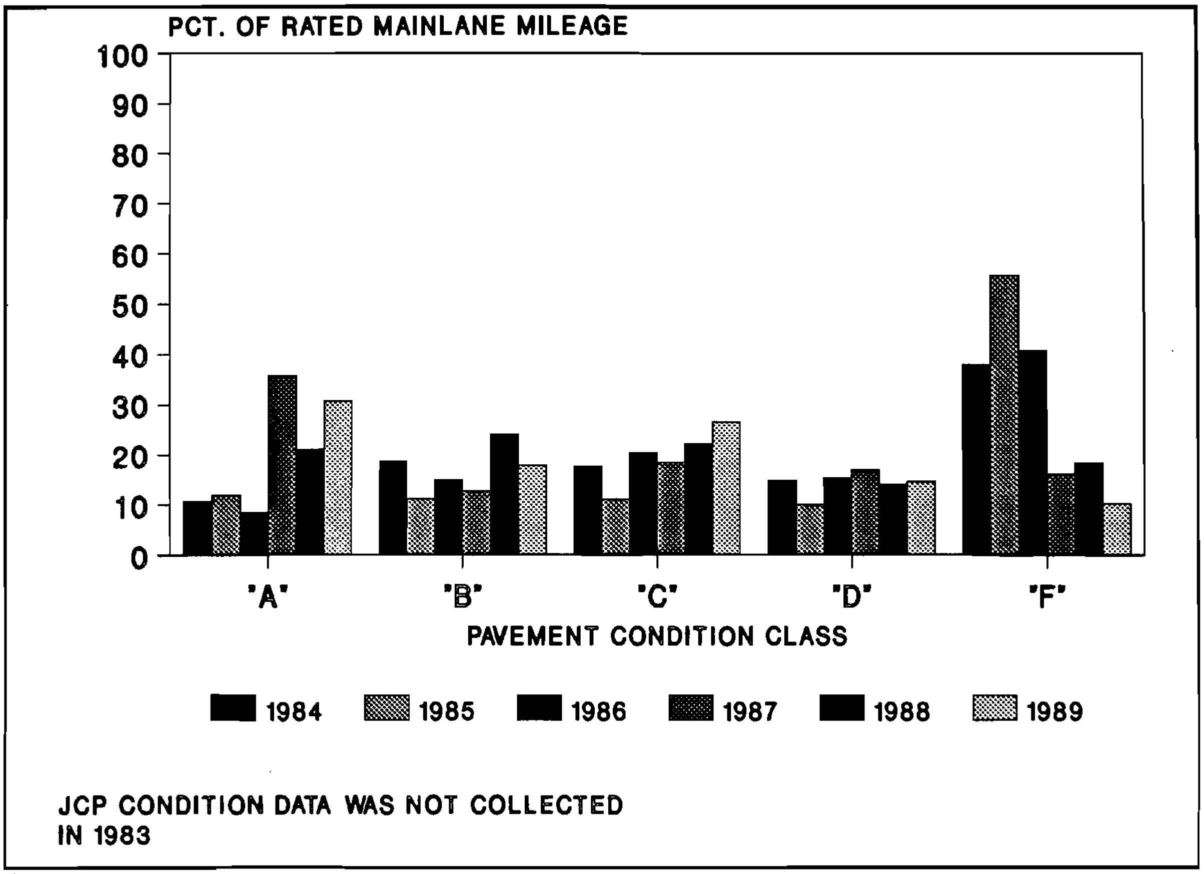

Figure 4.10 -- JCP Condition 1984-1989.

OVERALL RIDE QUALITY OF THE STATEWIDE SYSTEM

The statewide ride quality has continued to improve since 1985, with only 8.4 percent of 1989 Texas highway network having an SI below 3.0. However there was a much larger than expected increase in very good mileage in 1989, which may be attributed to SIometer calibration procedures (Chapter 3). In 1989, all highway systems and pavement types improved in ride quality with the asphalt pavements showing the largest improvement. Table 4.2 list the categories of SI used to describe ride quality. Figure 4.11 indicates the ride quality of the Texas highway network from 1983-1989.

TABLE 4.2 -- Classes of Ride Quality.

SI	CLASS	DESCRIPTION
4.0-5.0	"A"	VERY SMOOTH PAVEMENT
3.0-3.9	"B"	SMOOTH PAVEMENT
2.0-2.9	"C"	MODERATELY ROUGH PAVEMENT
1.0-1.9	"D"	ROUGH PAVEMENT
0-0.9	"F"	VERY ROUGH PAVEMENT

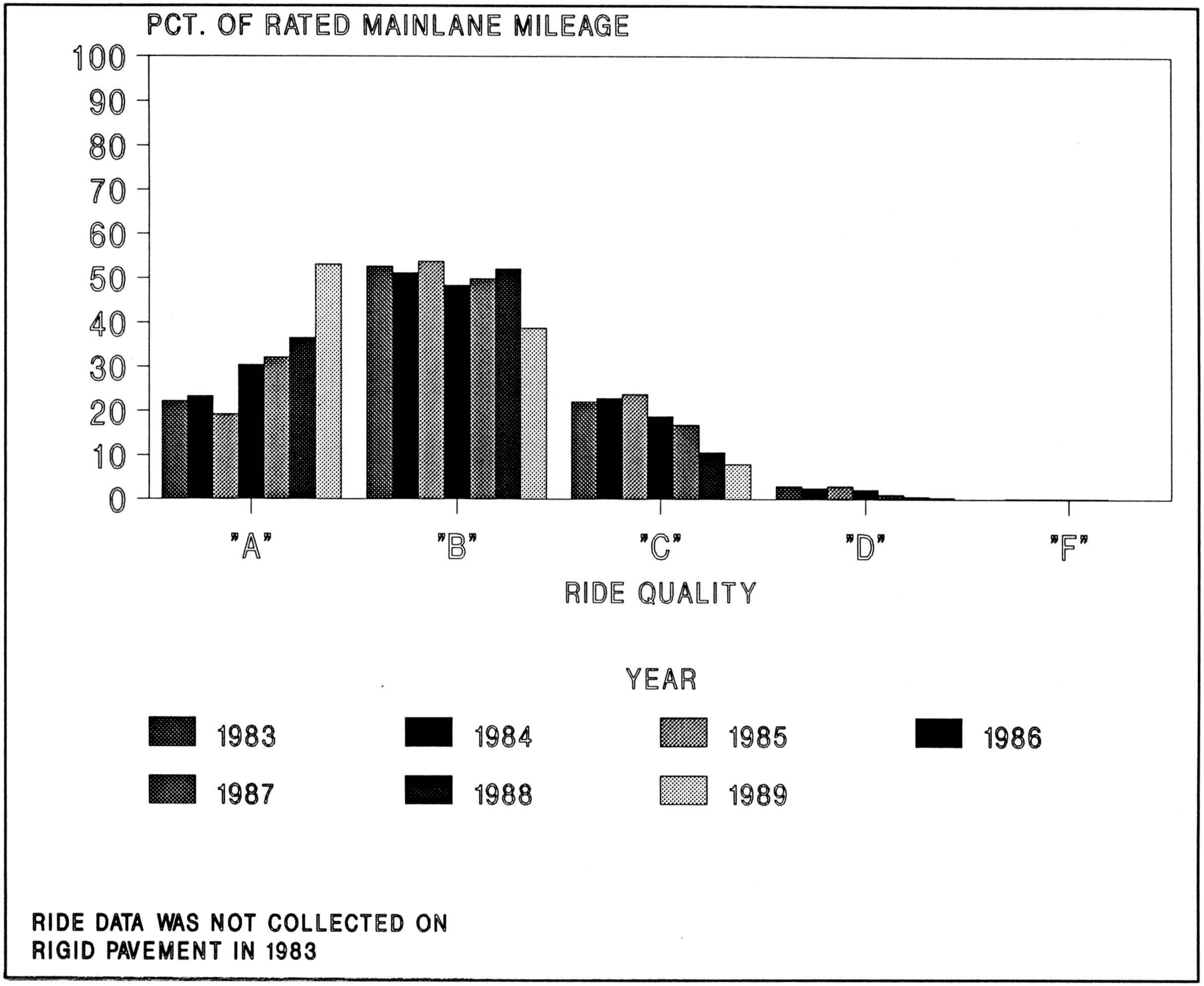

Figure 4.11 -- Ride Quality of Texas Highway Network 1983-1989.

Ride Quality of the Interstate (IH) Network

Only 2.2 percent of the mileage for the IH network had a ride score below 3.0 in 1989. This indicated no change, when compared to 1988 data, however there was an increase in very smooth mileage. This increase is due to a shift of class "B" mileage into class "A". The only IH pavement type that showed a decrease in ride quality was CRC with 4.8 percent of the rated lane mileage with an SI lower than 3.0. Figure 4.12 indicates the ride distribution from 1983-1989.

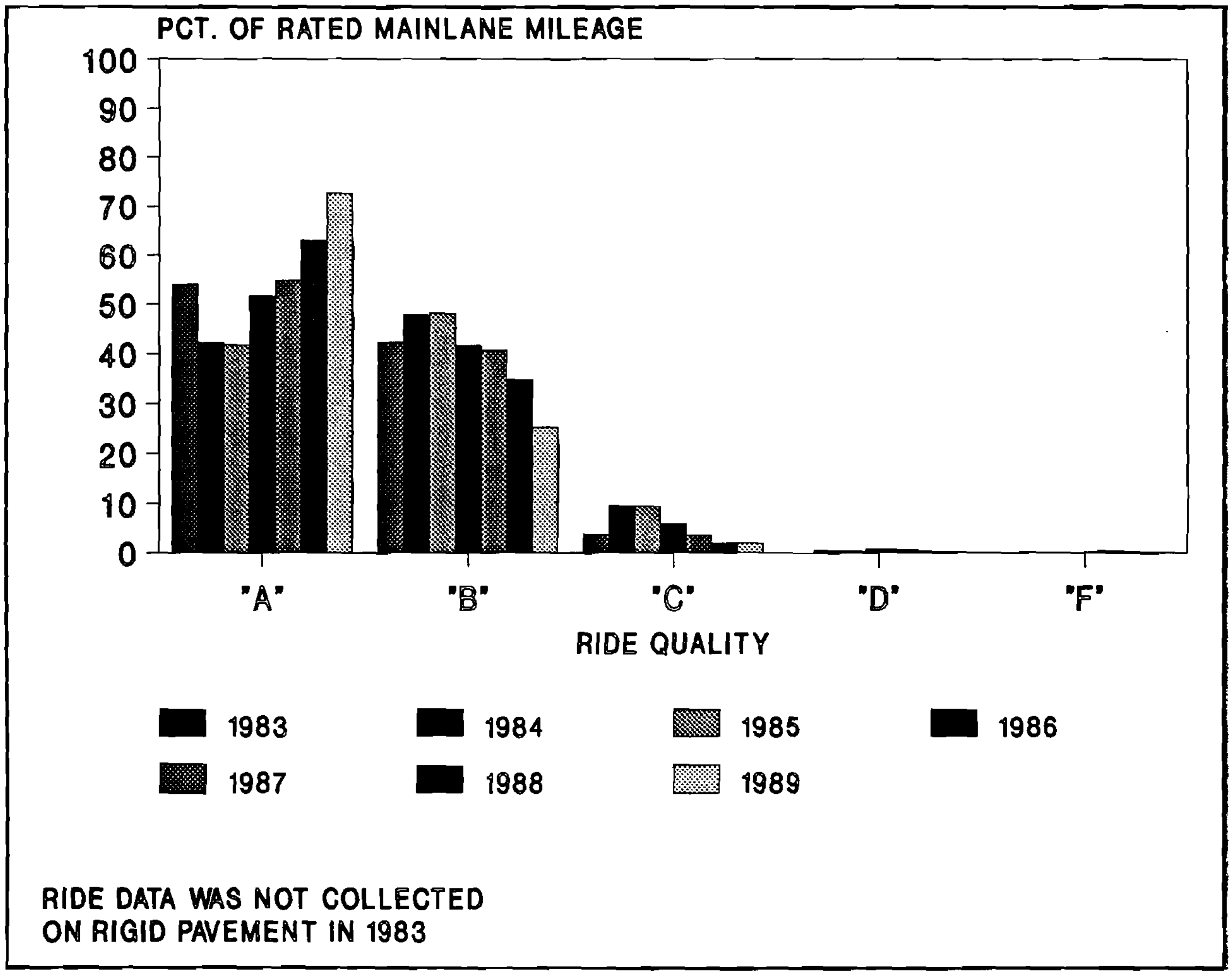

Figure 4.12 -- Ride Quality of IH Network 1983-1989.

Ride Quality of the US Network

The overall ride quality of the US network continued to improve in 1989. All pavement types had an increase in class "A" mileage, however CRC also had an increase in mileage with an SI below 3.0. ACP sections had the biggest improvement in ride quality with a large shift of class "B" mileage into class "A".. Figure 4.13 indicates ride quality from 1983-1989.

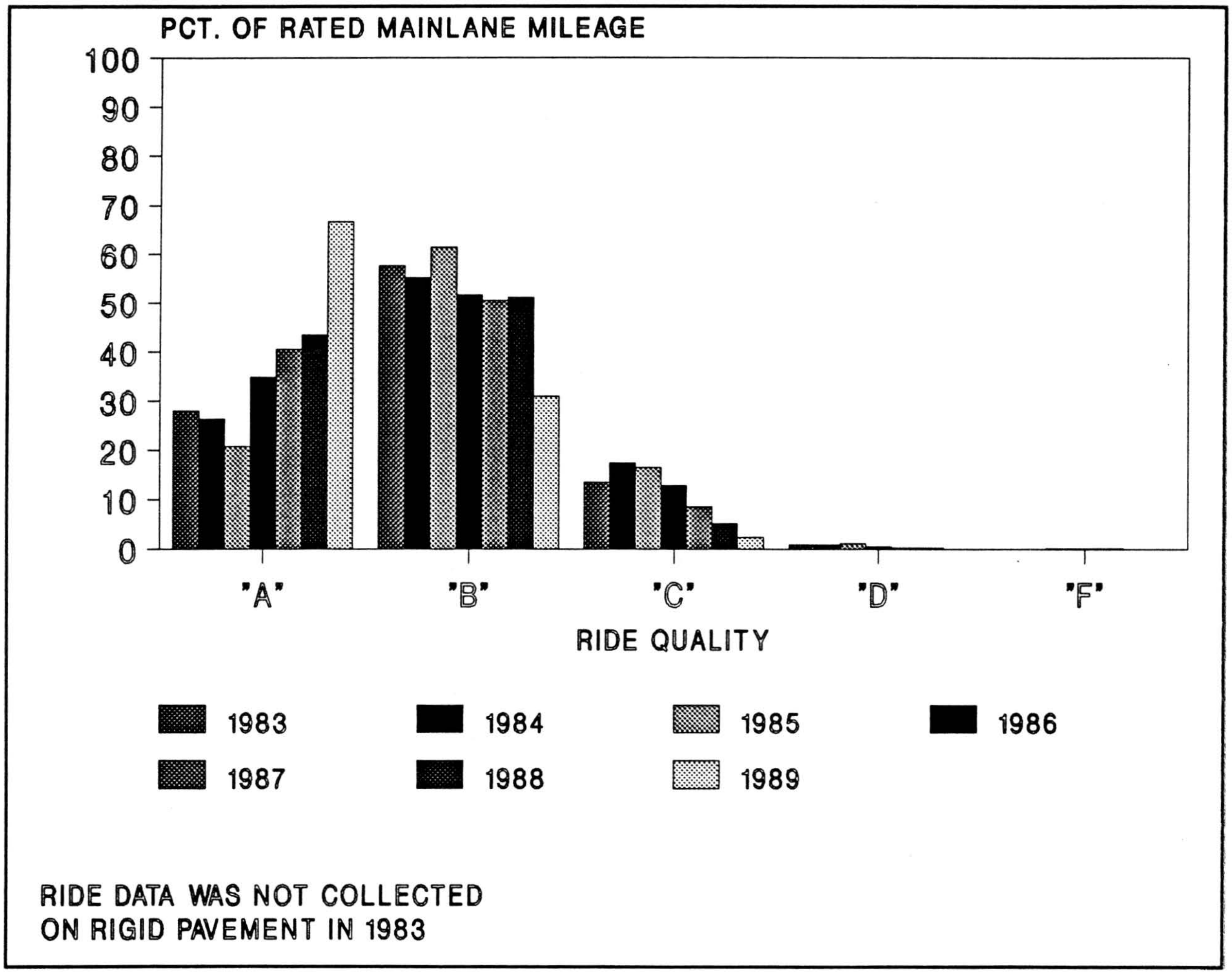

Figure 4.13 -- Ride Quality of US Network 1983-1989.

Ride Quality of the State Highway (SH) Network

The SH system also had an overall improvement in ride quality with only 7.8 percent of the rated mainlane mileage with an SI lower than 3.0. ACP pavement had the largest improvement when compared to 1988 data. The CRC ride quality decreased with 22.1 percent of the rated mainlane mileage having an SI below 3.0, as compared to 14.3 percent in 1988. JCP had the worst ride with 56 percent of its pavement with an SI below 3.0. Figure 4.14 indicates the ride distribution for the SH system from 1983-1989.

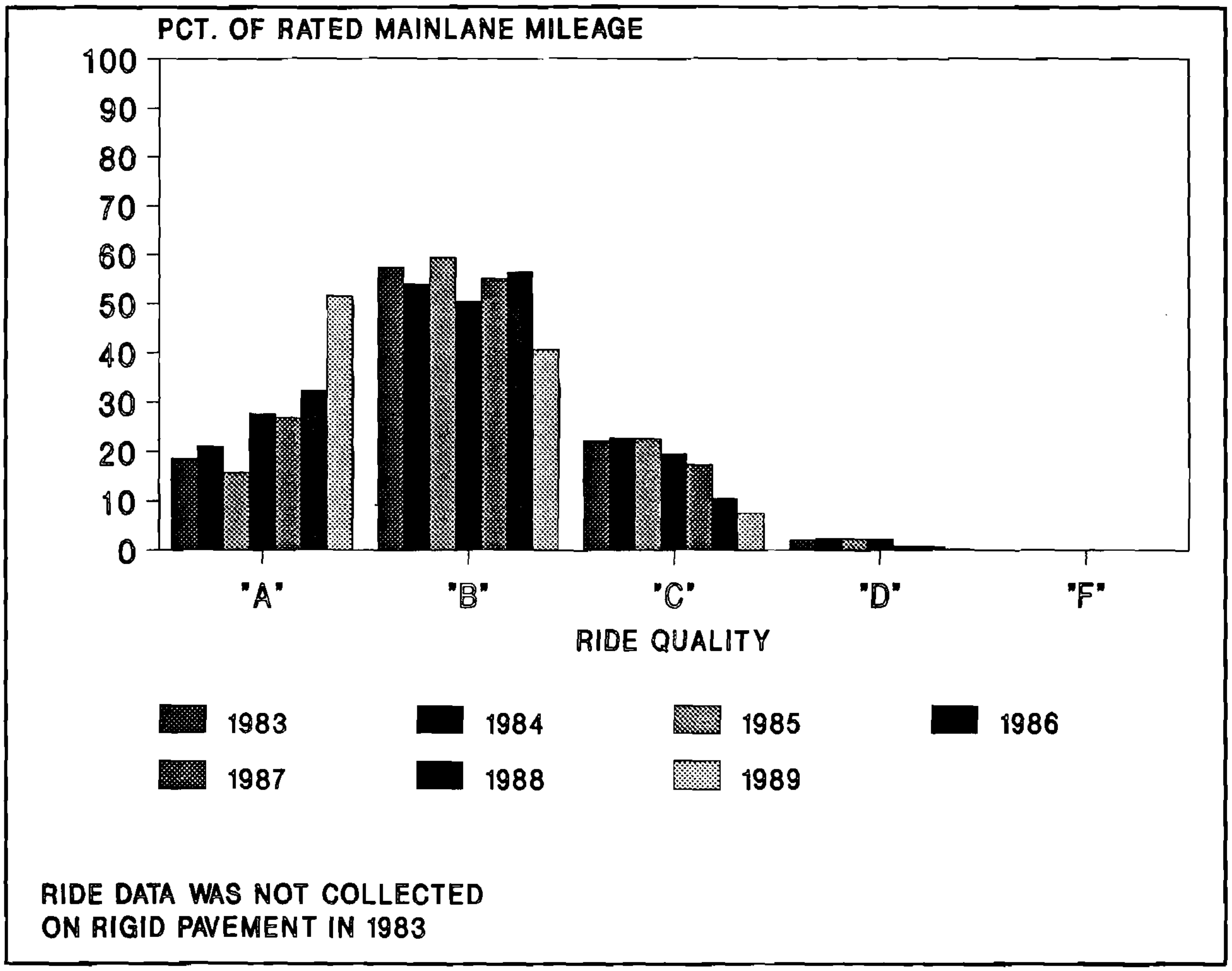

Figure 4.14 -- Ride Quality of SH Network 1983-1989.

Ride Quality of the Farm-to-Market (FM) Network

The FM network's overall ride quality improved in 1989, with 17.2 percent of the rated mainlane mileage having an SI below 3.0. The percentage of class "A" mileage was up, but the majority of the mileage was still in class "B". Figure 4.15 indicates the change in ride quality distribution since 1983.

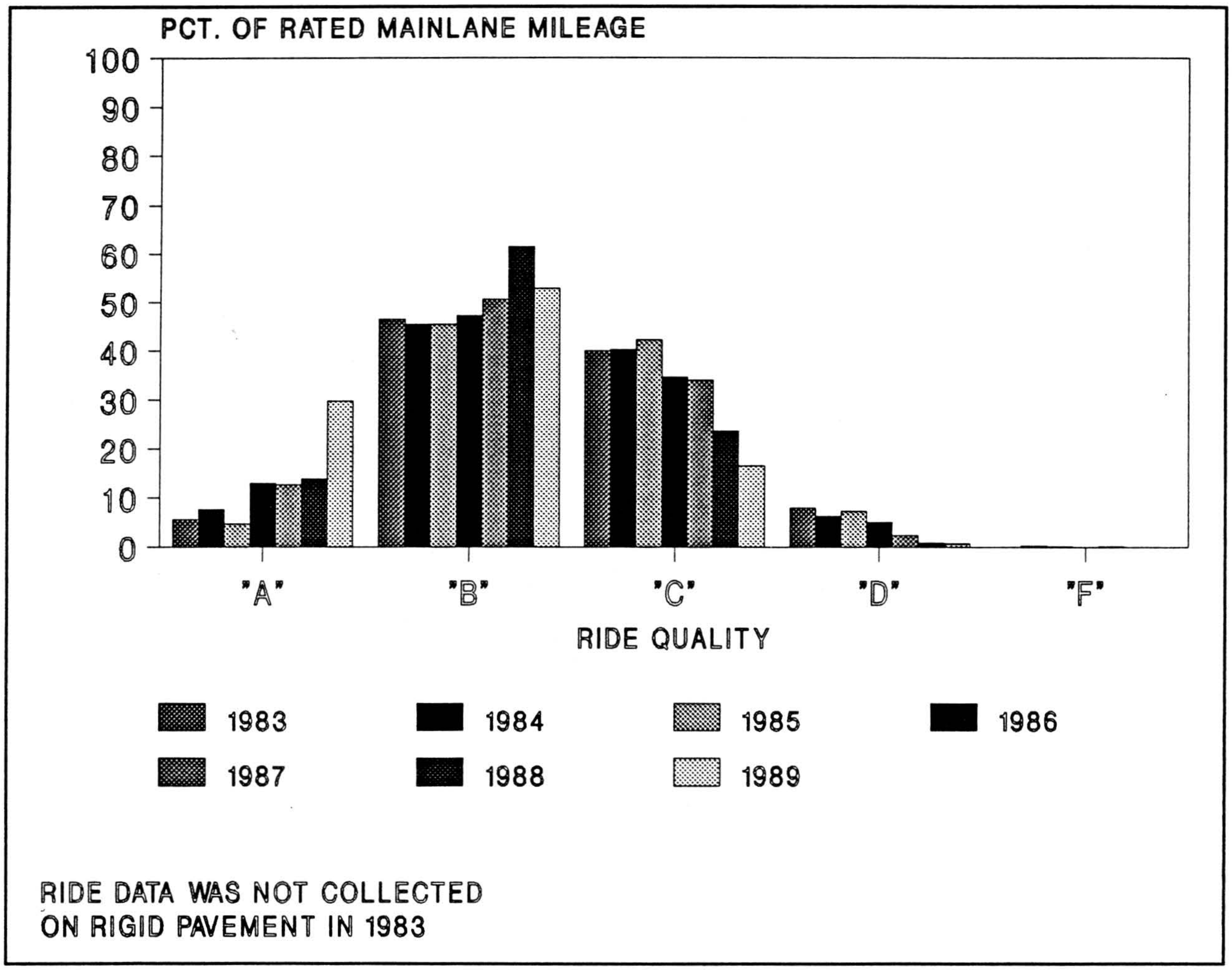

Figure 4.15 -- Ride Quality of FM Network 1983-1989.

ACP Ride Quality

The ACP ride quality improved overall, with a large increase in very good mileage in 1989 (up to 54.7 percent). All highway systems increased in ride quality, with the IH network having the best ride quality and, as expected, the FM network the worst. The largest improvement in ride quality was on the US network. Figure 4.16 indicates the ride quality distribution from 1983-1989.

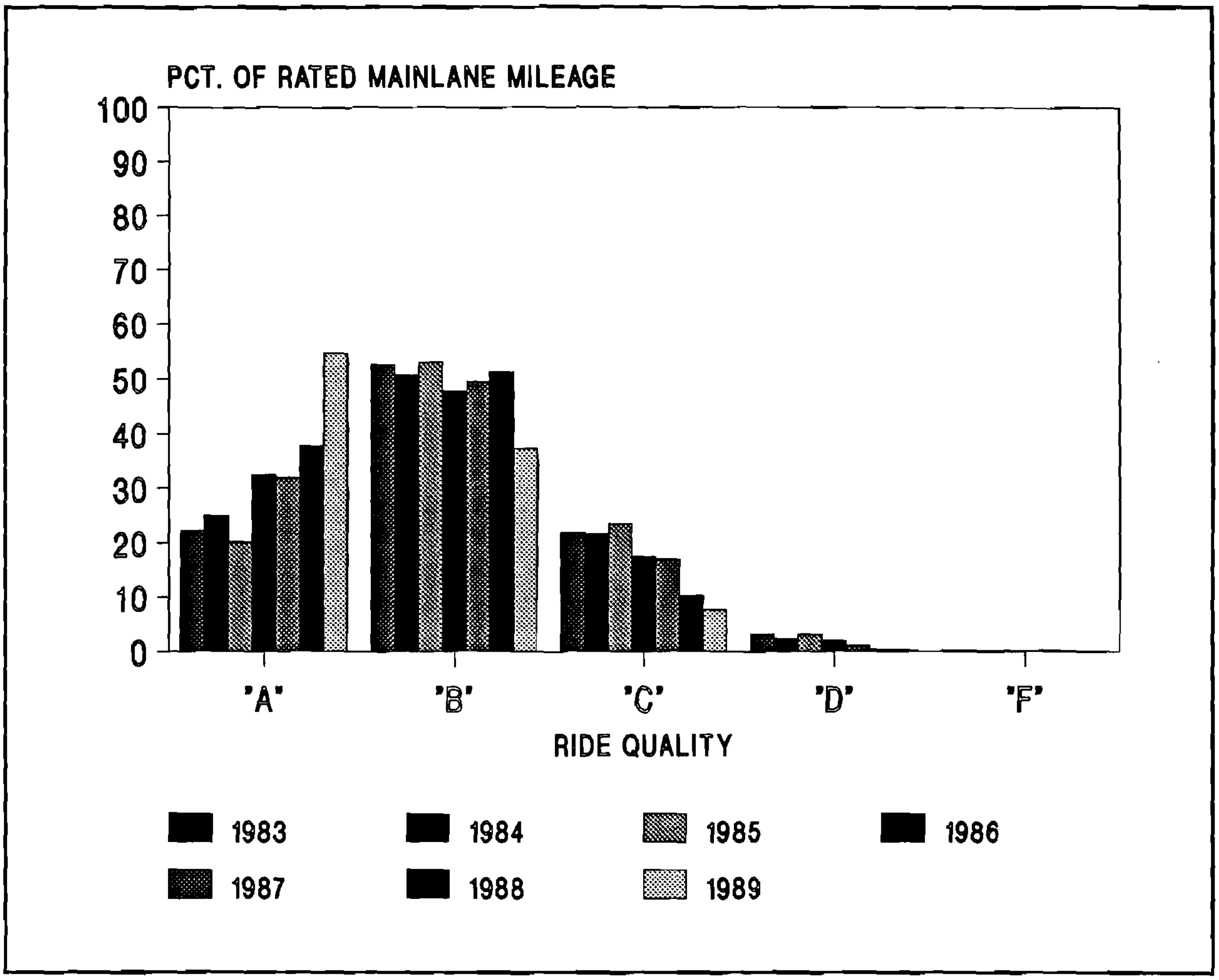

Figure 4.16 -- ACP Ride Quality 1983-1989.

CRC Ride Quality

CRC showed an overall improvement in ride quality in 1989, however the amount of mileage with an SI below 3.0 remained about the same as it was in 1988. The only CRC highway network to improve was the US, while the IH and SH networks decreased slightly. Figure 4.17 indicates the ride quality distribution from 1984-1989.

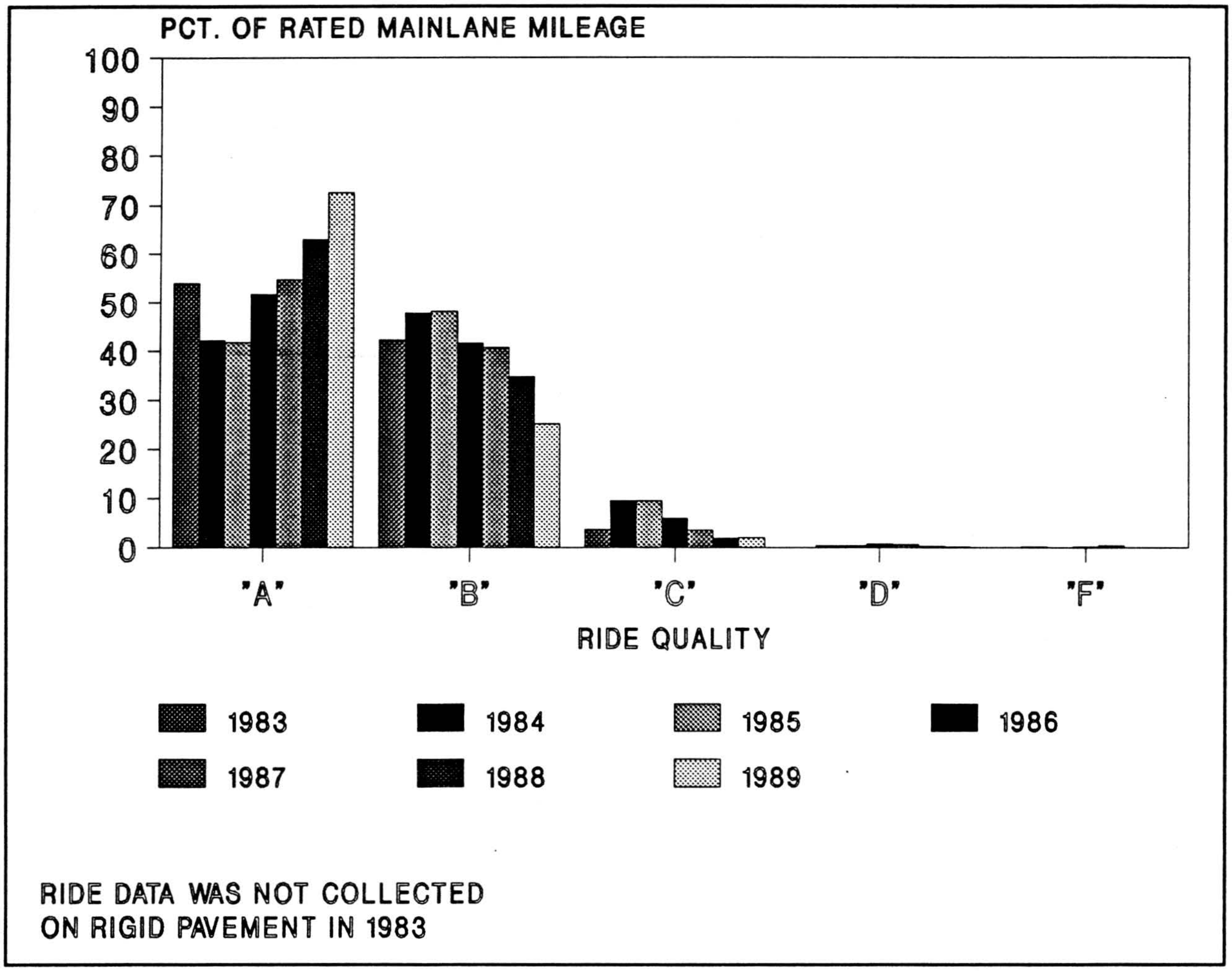

Figure 4.17 -- CRC Ride Quality 1984-1989.

JCP Ride Quality

The 1989 PES survey data indicated that JCP had an increase in very smooth mileage with a slight decrease in mileage with an SI below 3.0. JCP continued to have the worst ride quality with 35.8 percent of the rated mainlane mileage with an SI below 3.0. No trend can be established due to the small and oscillating sample size. Figure 4.18 indicates ride quality distribution since 1984.

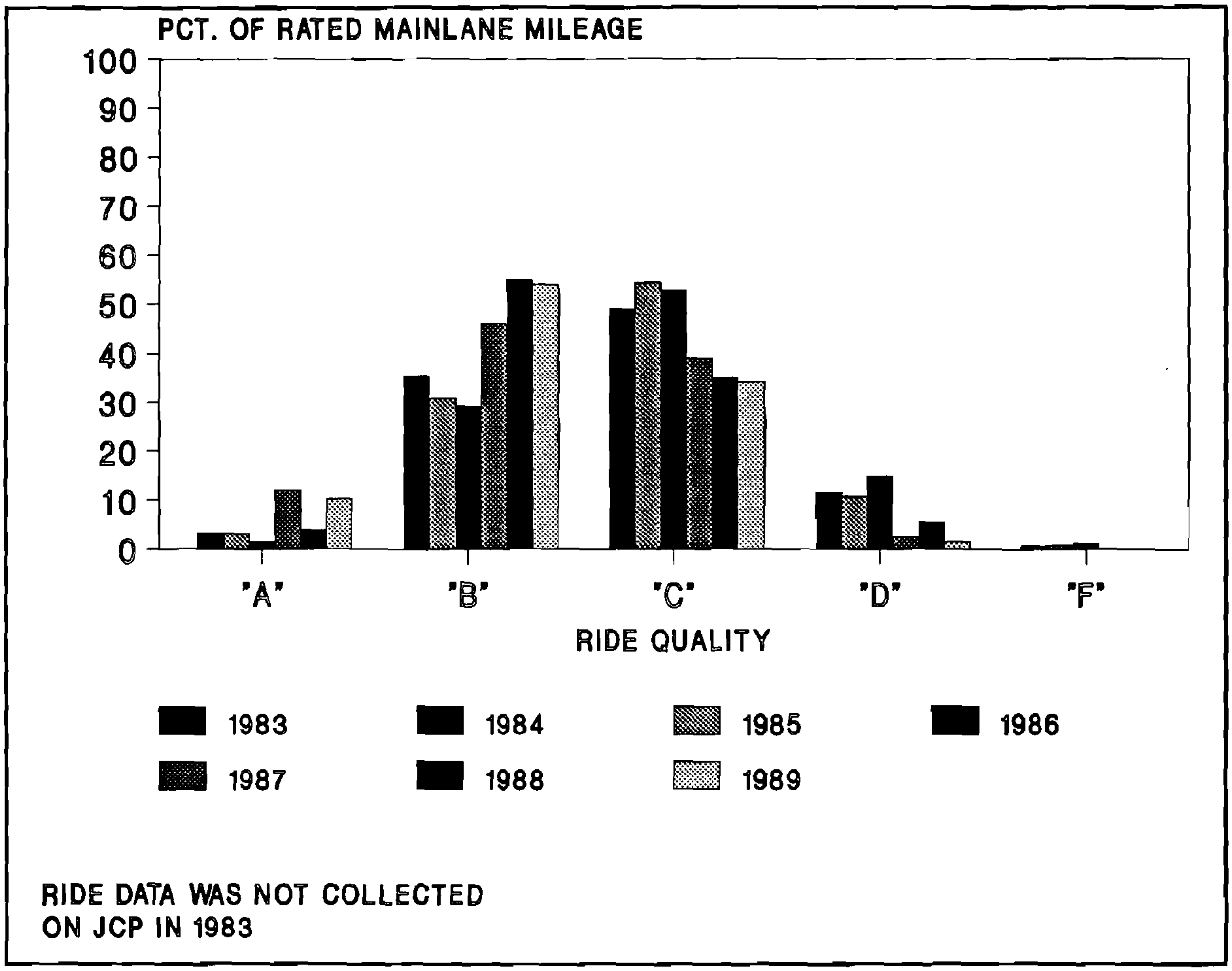

Figure 4.18 -- JCP Ride Quality 1984-1989.

-Notes-

OVERALL PAVEMENT DISTRESS ON THE STATEWIDE SYSTEM

In 1989, the overall pavement distress score on the statewide system continued to improve; with 69 percent of the rated mainlane mileage having little of no distress. The only highway system to show an increase in distress was the IH system. Of the three pavement types, CRC was the only one to have an increase in distress. Table 4.3 list the categories of UVU used to describe the distress score. Figure 4.19 indicates the distress score distribution from 1983-1989.

TABLE 4.3 -- Classes of Distress Score.

UVU	CLASS	DESCRIPTION
90-100	"A"	VERY GOOD -- Little or no distress
80-89	"B"	GOOD -- One or two slight distresses
70-79	"C"	FAIR -- Multiple distress types, or one severe distress
60-69	"D"	POOR -- Multiple distress types with at least one severe distress
1-59	"F"	VERY POOR -- Combination of moderate and severe distresses

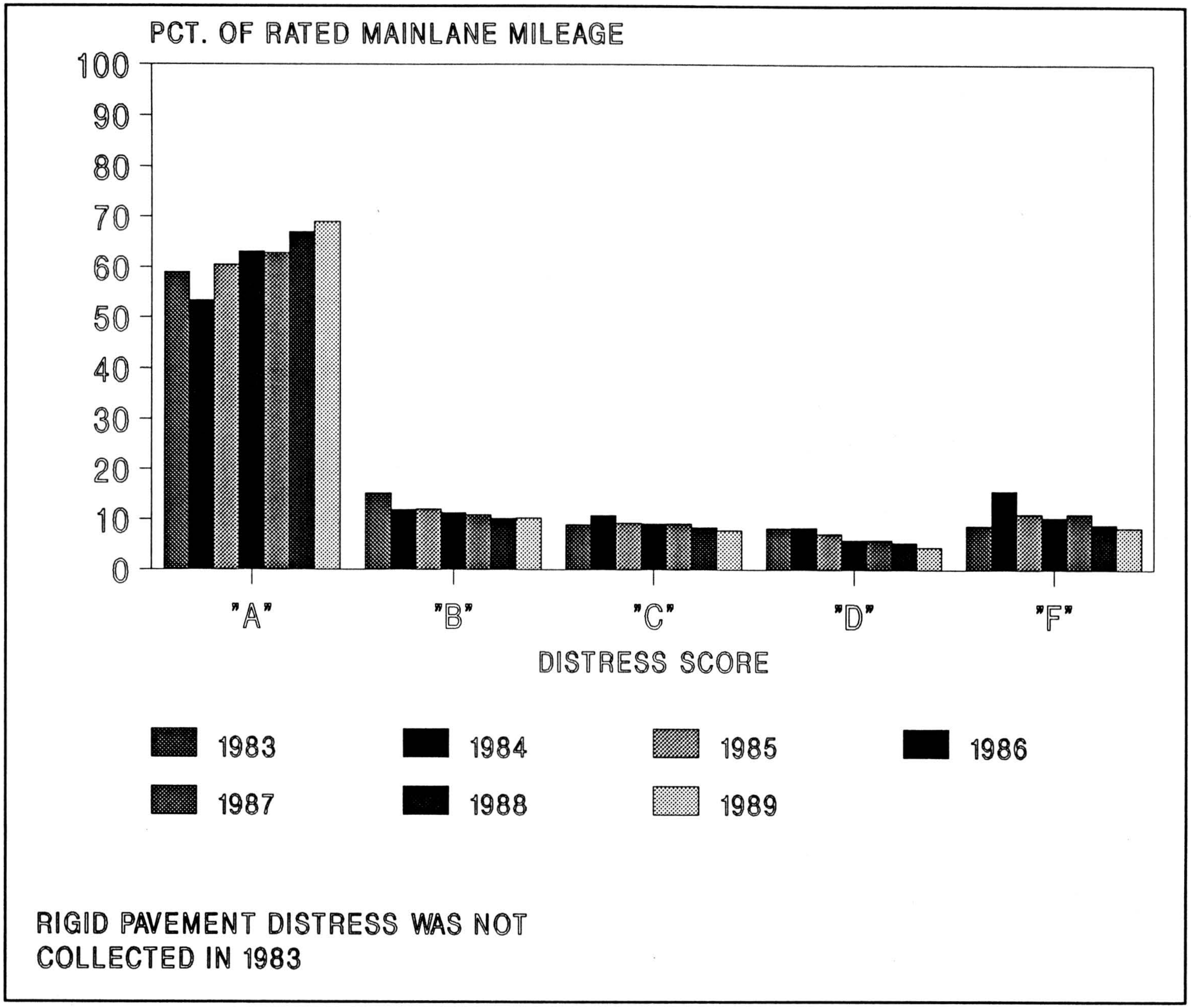

Figure 4.19 -- Pavement Distress of the Texas Highway Network 1983-1989.

Pavement Distress on the IH Network

In 1989, the IH network's pavement distress score worsened slightly with 78.2 percent of the rated mainlane mileage having little or no distress, a drop of 1 percent from 1988. The amount of mileage with a poor to very poor distress score was 8.6 percent in 1989, as compared with 7.1 percent in 1988. This decrease in distress score on the IH network can be attributed to CRC, since it was the only pavement type to increase in distress. Figure 4.20 indicates the distress score distribution from 1983-1989.

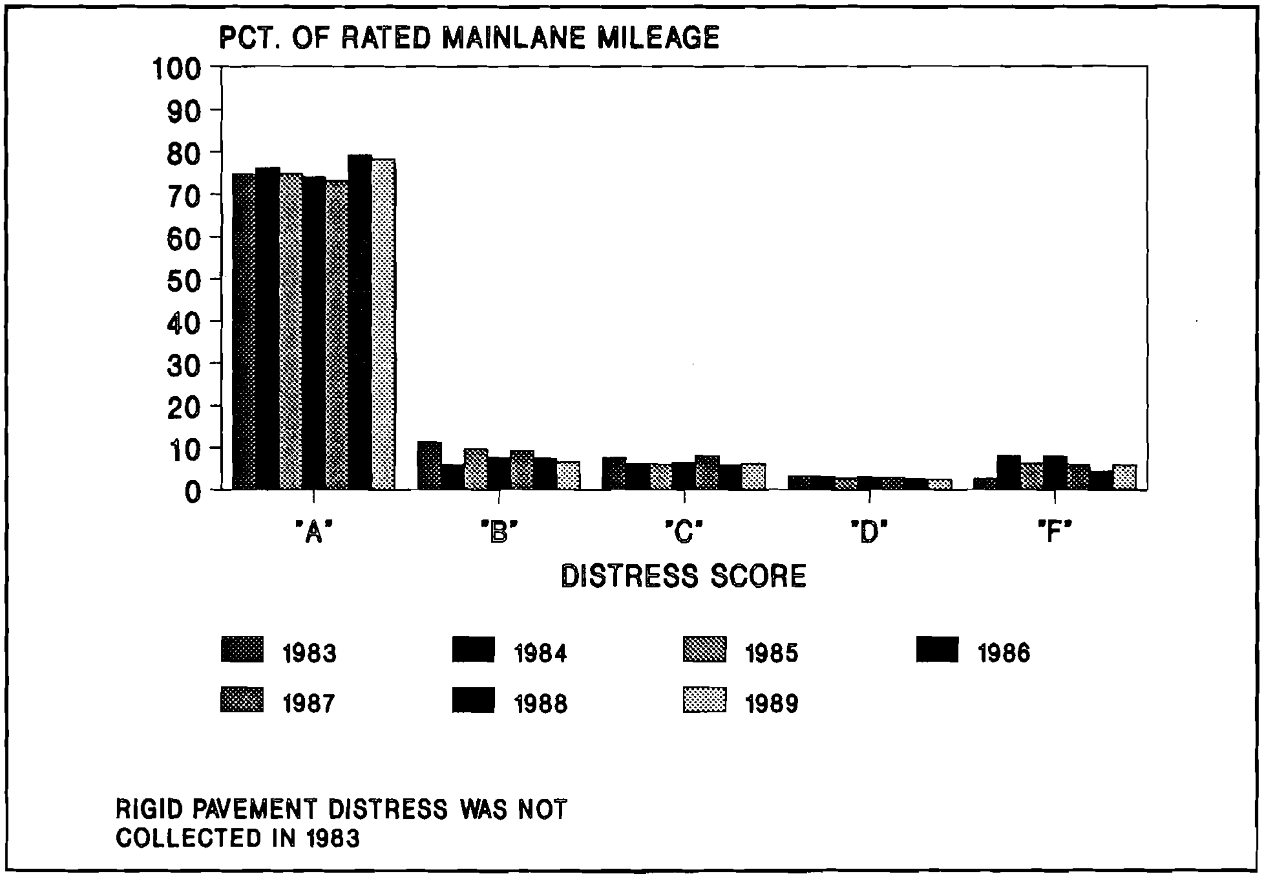

Figure 4.20 – Pavement Distress of the IH Network 1983-1989.

Pavement Distress on the US Network

The US network had less distress in 1989, with 70.3 percent of mileage with little or no distress, as compared to 67.7 percent in 1988. ACP and JCP on the US network had improvement in their distress score, while CRC had a combined increase of 3.8 percent in the poor to very poor pavement distress classes. Figure 4.21 indicates the distress score from 1983-1989.

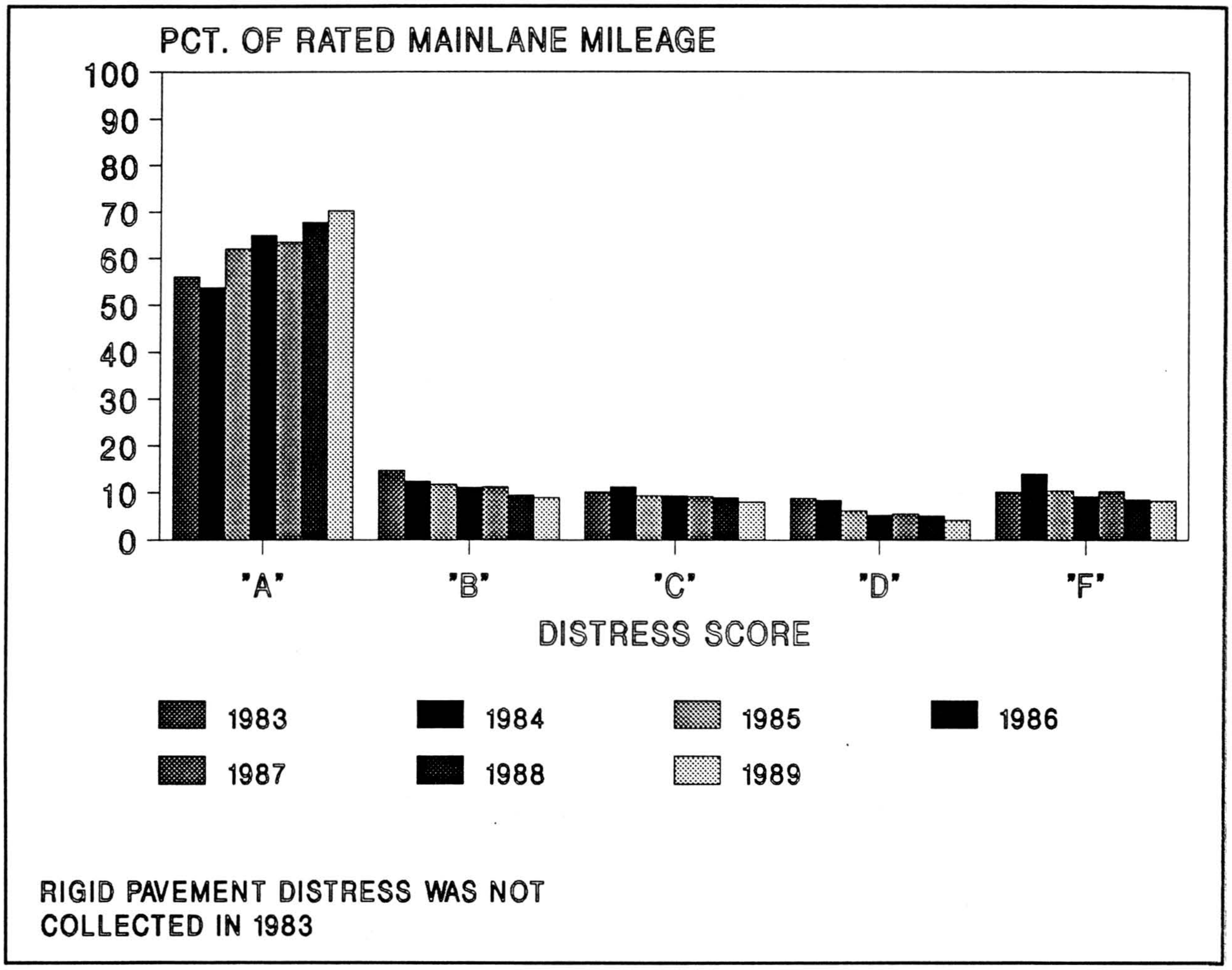

Figure 4.21 -- Pavement Distress of the US Network 1983-1989.

Pavement Distress on the SH Network

The SH network had less distress in 1989, with 69.2 percent of its mileage having a very good distress score. The percentage of mileage with a poor to very poor distress score was 11.1 percent, down 2.1 percent from 1988. All three pavement types also had less distress with JCP having the largest improvement. Figure 4.22 indicates the distress score distribution from 1983-1989.

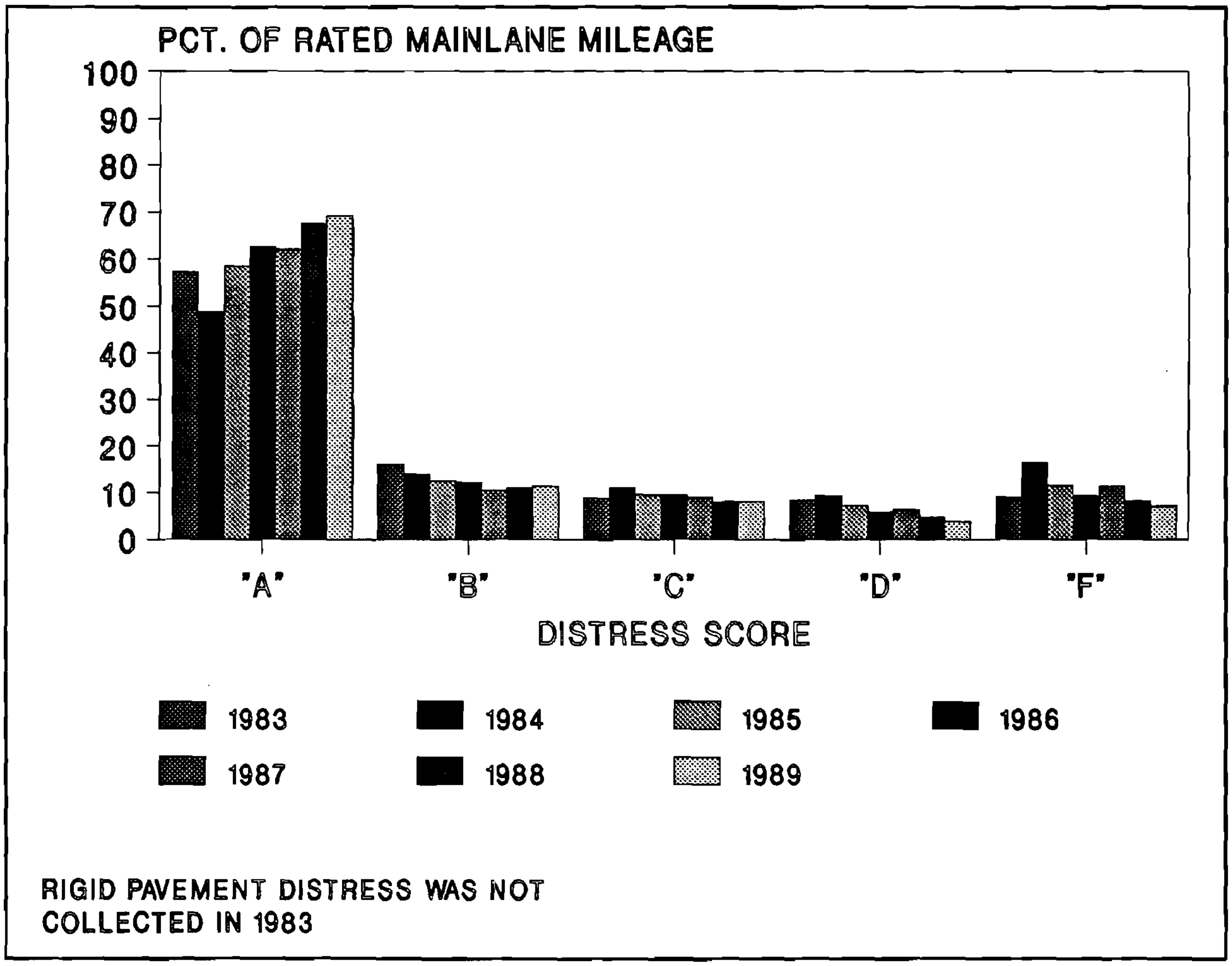

Figure 4.22 -- Pavement Distress of the SH Network 1983-1989.

Pavement Distress on the FM Network

In 1989, the amount of distress on the FM network decreased, with 60.5 percent of the rated lane mileage having a very good distress score. The percentage of mileage with a poor to very poor distress score was 18.0 percent, down 4.2 percent from 1988. The FM network had the most distress of all highway networks. Figure 4.23 indicates the distress score distribution from 1983-1989.

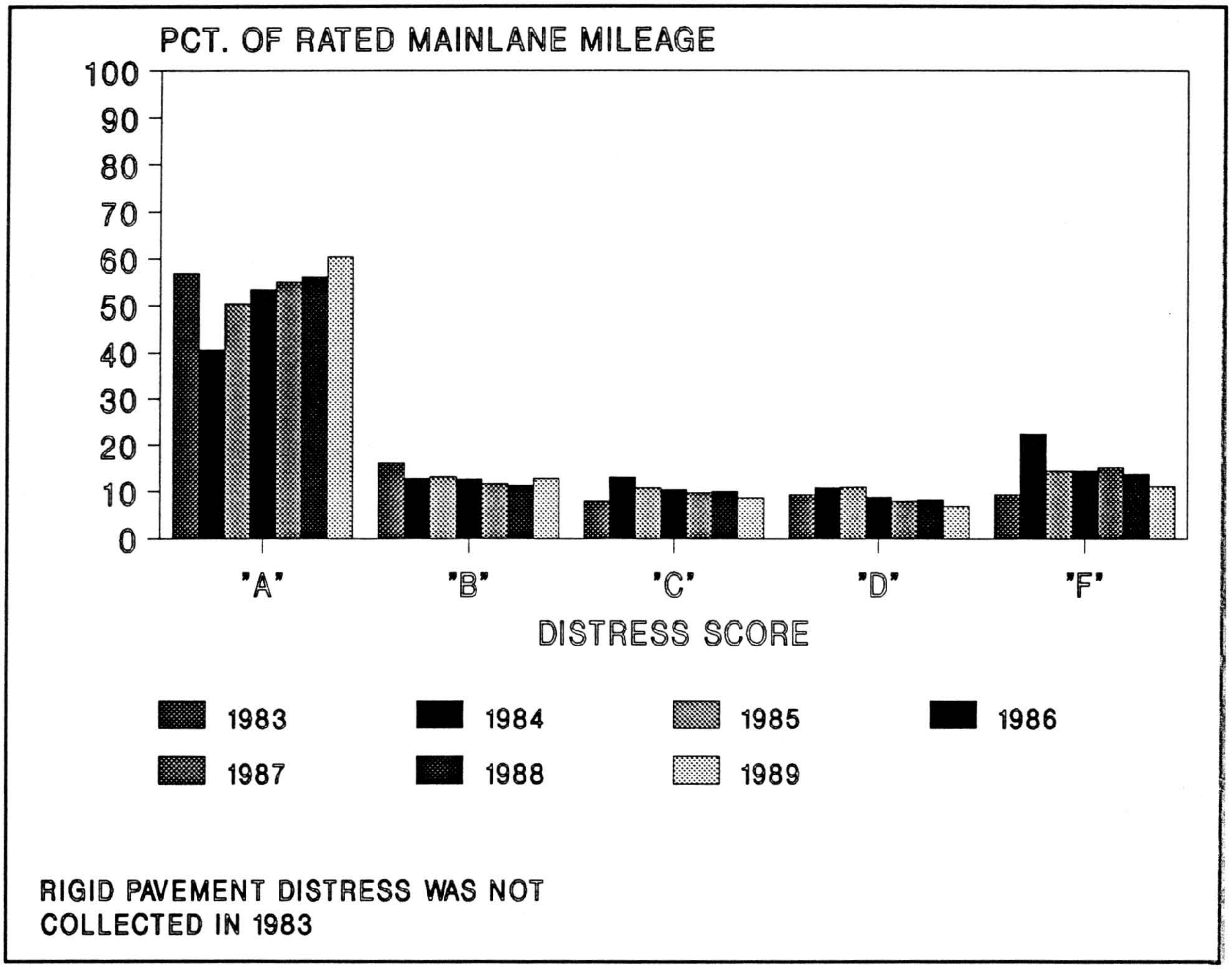

Figure 4.23 -- Pavement Distress of the FM Network 1983-1989.

ACP Pavement Distress Score

In 1989, the distress score for ACP continued to improve, as indicated in Figure 4.24. This improvement was seen on all highway networks, with the largest increase on the FM network. The following pages will describe the individual ACP distresses. Please note, that Figures 4.25 through 4.31 include all sections with the minimum distress requirements needed to be rated, and do not distinguish between amounts or severities.

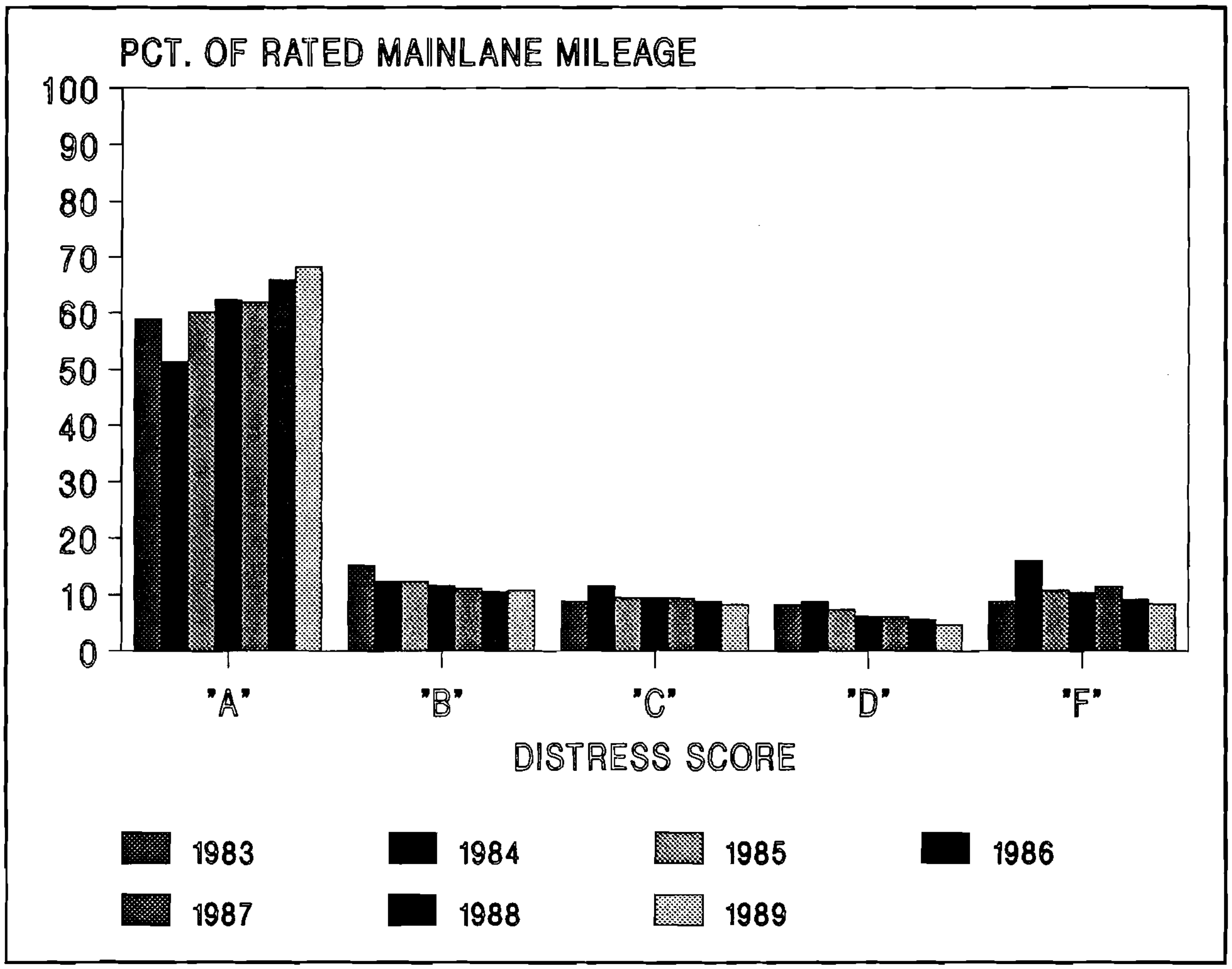

Figure 4.24 -- ACP Pavement Distress 1983-1989.

Rutting

In 1989, rutting was on 30.7 percent of the rated ACP sections, and the only ACP distress to increase in frequency. Rutting was also found on more sections than any other distress. The FM network had the most rated sections with rutting, with 41.3 percent, while the IH network had the least, with only 19.4 percent of rated sections having rutting. Figure 4.25 indicates the percentage of rutting by highway network. The minimum amount of rutting needed to be rated in a typical two mile section is 211 feet of ½ inch or greater rutting.

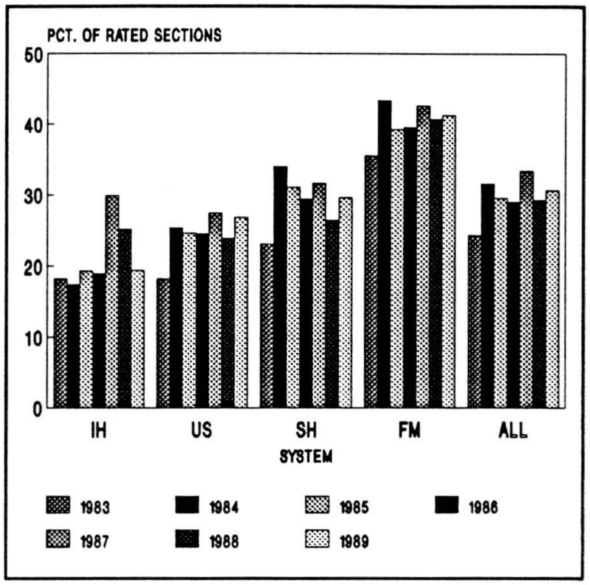

Figure 4.25 -- Rutting, by System, 1983-1989.

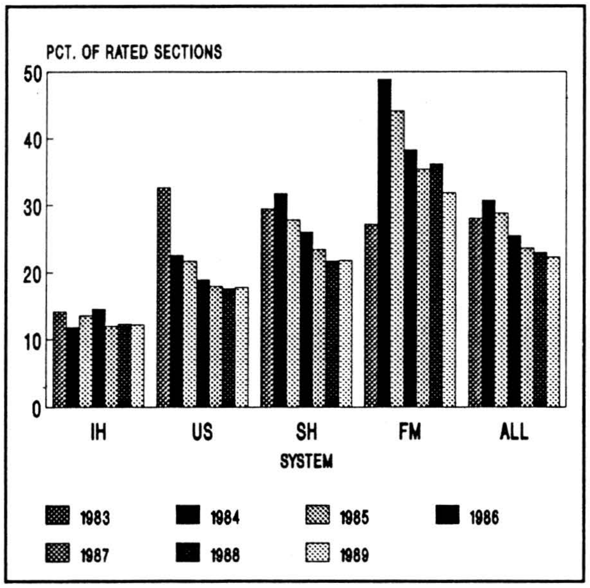

Figure 4.26 -- Patching, by System, 1983-1989.

Patching

In 1989, patching decreased slightly statewide, with 22.3 percent of the rated sections having patching. The FM network still had the largest number of sections with patching, while the IH network had the least. The IH, US, and SH networks had slight increase in patching, while the FM network decreased from 36.2 percent in 1988 to 31.9 percent in 1989. This decrease in patching on the FM network may be due to the increase use of seal coats and thin overlays. Figures 4.26 indicates amount of patching by highway network from 1983-1989. The minimum amount of full lane width patching needed to be rated in a typical two mile section is 106 feet.

Failures

Only 4.0 percent of rated ACP sections had failures in 1989. All highway networks had a decrease in rated sections with failures. The FM network had the highest percentage of sections with failures with 6.9 percent. Failures had the second lowest occurrence among the seven ACP distresses. Figure 4.27 indicates the percentage of rated sections by highway network from 1983-1989. The minimum number of failures needed to be rated in a typical two mile section is two.

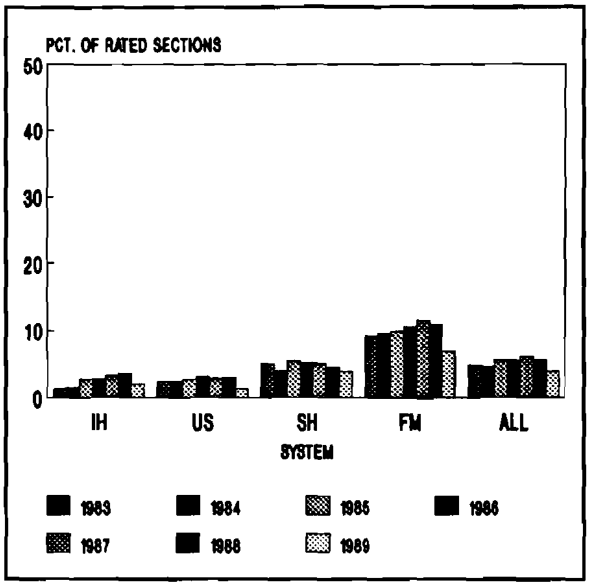

Figure 4.27 -- Failures, by System, 1983-1989.

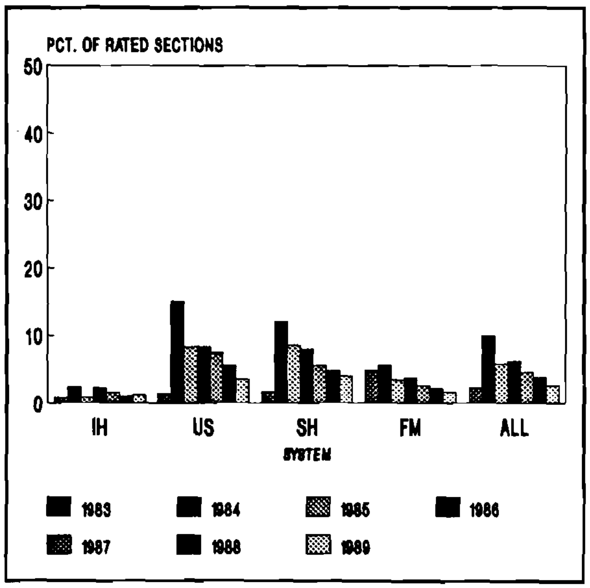

Figure 4.28 -- Block Cracking, by System, 1983-1989.

Block Cracking

In 1989, block cracking was found on 2.7 percent of the rated sections, a slight decrease from 1988. This distress type occurred the least often among all ACP distresses. The SH highway network had the highest percentage with block cracking with 4.1 percent. Figure 4.28 indicates the percentage of rated sections with block cracking by highway network from 1983-1989. The minimum amount of full lane width block cracking needed to be rated in a typical two mile section is 106 feet.

Alligator Cracking

In 1989, alligator cracking was on 8.5 percent of the rated sections, a decrease of 2.2 percent when compared to 1988. The IH network had about the same percentage of sections with alligator cracking, but the other three highway networks exhibited a decrease. The FM network had the highest percentage of section with alligator cracking while the Interstate had the lowest. Figure 4.29 indicates the percentage of rated sections with alligator cracking from 1983-1989. The minimum amount of alligator cracking needed to be rated in a typical two mile section is 211 feet.

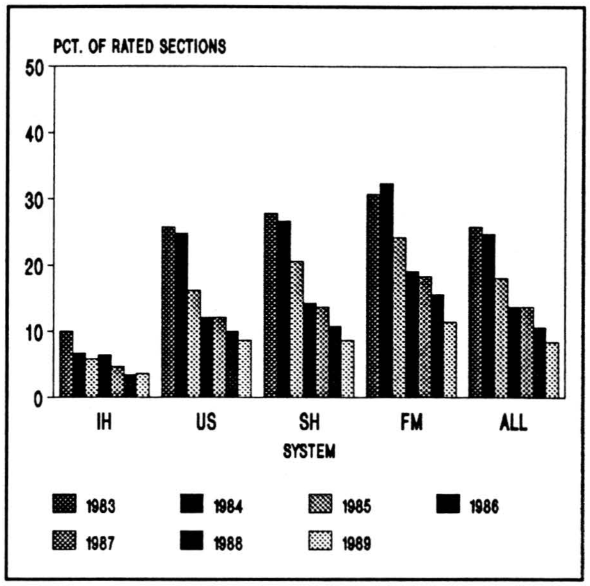

Figure 4.29 -- Alligator Cracking, by System, 1983-1989.

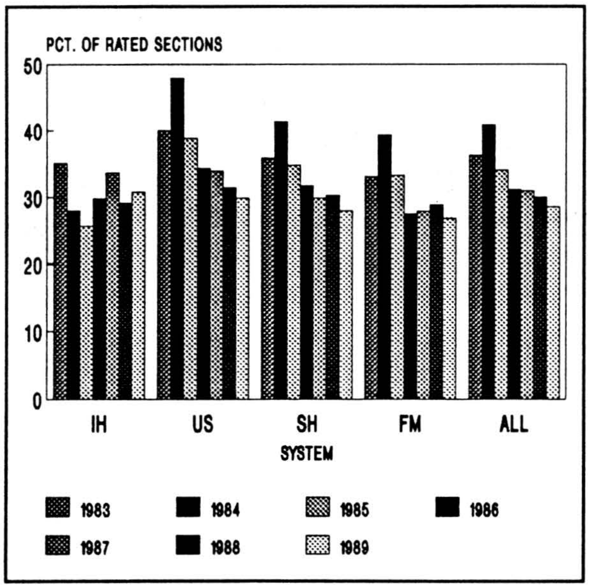

Figure 4.30 -- Longitudinal Cracking, by System, 1983-1989.

Longitudinal Cracking

Longitudinal cracking was on 28.6 percent of the rated sections in 1989, a 1.6 percent decrease from 1988. Longitudinal cracking had the second highest occurrence among all ACP distress in 1989. The IH network had a slight increase in longitudinal cracking while all other highway networks had a slight decrease. The IH network also had the most sections with longitudinal cracking at 30.8 percent, while the FM network had the least at 26.9 percent. Figure 4.30 indicates the percentage of rated sections with longitudinal cracking from 1983-1989. The minimum amount of longitudinal cracking needed to be rated in a typical two mile section is 1056 feet.

Transverse Cracking

In 1989, transverse cracking was rated on 21.1 percent of the rated mainlane sections, a 3.3 percent decrease from 1988. All highway networks exhibited a decrease in occurrence. The highway network with the most transverse cracking was the US network with 30.6 percent, and the one with the least was the FM network with 11.6 percent. The FM network had the lowest percentage of transverse cracking because it has the lowest amount of composite pavements. Figure 4.31 indicates the percentage of rated mainlane sections with transverse cracking from 1983-1989. 106 full lane width transverse cracks are needed to be rated in a typical two mile section.

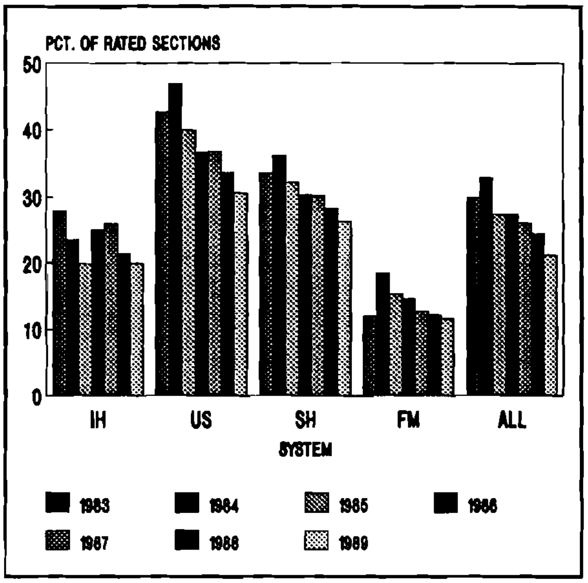

Figure 4.31 -- Transverse Cracking, by System, 1983-1989.

CRC Pavement Distress Score

CRC was the only pavement type to have an increase in pavement distress in 1989, when compared to 1988. This increase can be attributed to the natural aging of CRC. 79.4 percent of the 1989 CRC mileage had a distress score in class "A", a 4.4 percent decline from 1988. The combined mileage in the poor and very poor classes was 13 percent, up 3.4 percent from 1988. Figure 4.32 indicates the distress score distribution from 1984-1989. Figure 4.33 through 4.36 indicate the percentage of sections with a particular distress. Notice that the overall percentage of sections with distress did not increase much in 1989, which indicates that the amount of distress on individual sections increased. The percentage of distressed sections for the FM network are not shown, since CRC is rarely used on FMs. Also notice, that the SH network had a decrease in percentage of punchout, concrete patch, and asphalt patch sections. This indicates that CRC pavement is being taken out of use on the SH network.

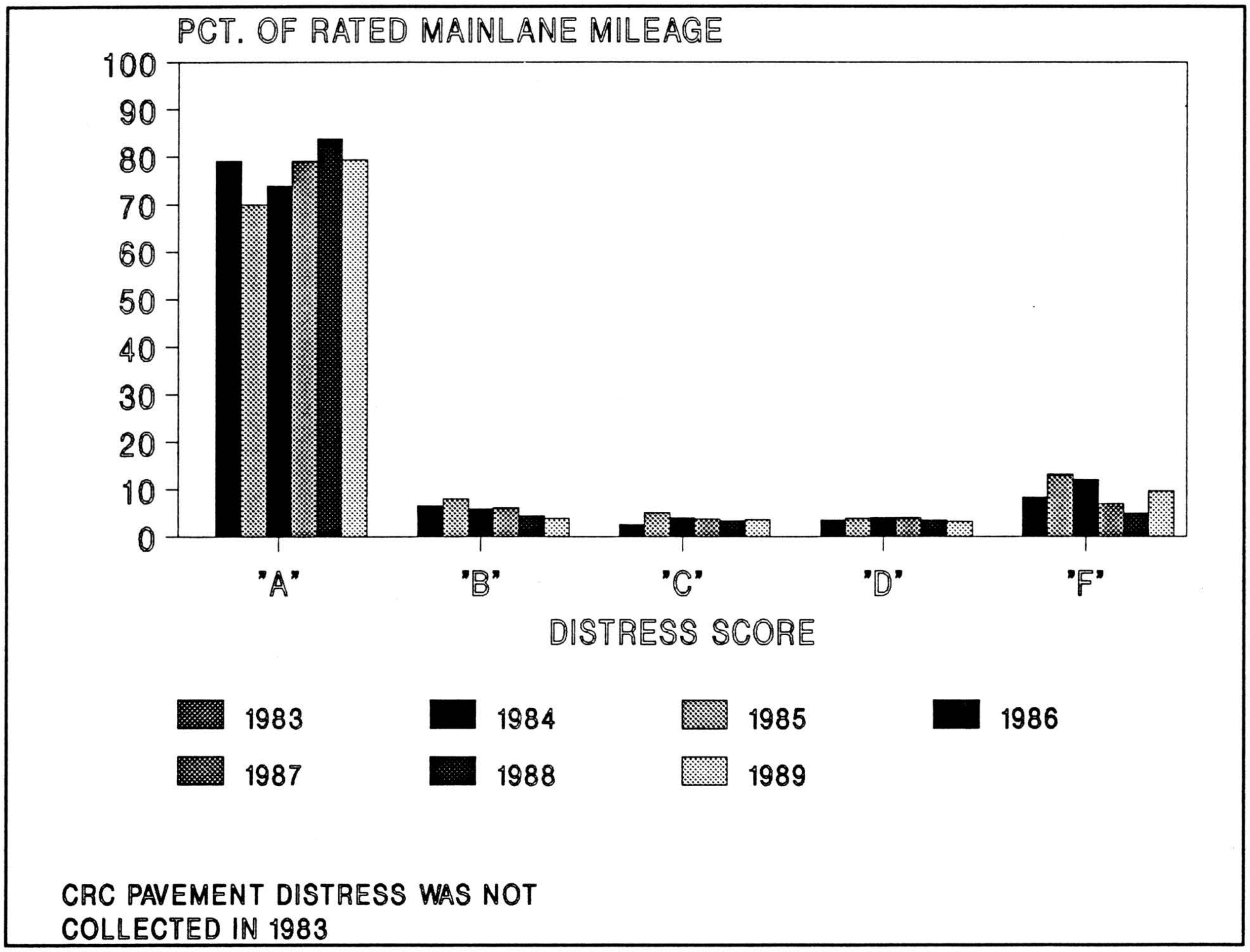

Figure 4.32 -- CRC Pavement Distress 1984-1989.

Spalled Transverse Cracks

In 1989, the percentage of sections with spalled transverse cracks was up slightly, with the three highway networks having CRC increasing. The US network had the highest increase in percentage of spalled crack sections, and also the largest percentage of sections. Spalled transverse cracks occurred the most often of all CRC distresses. Figure 4.33 indicates the percentage of spalled transverse crack sections, by highway network, from 1984-1989.

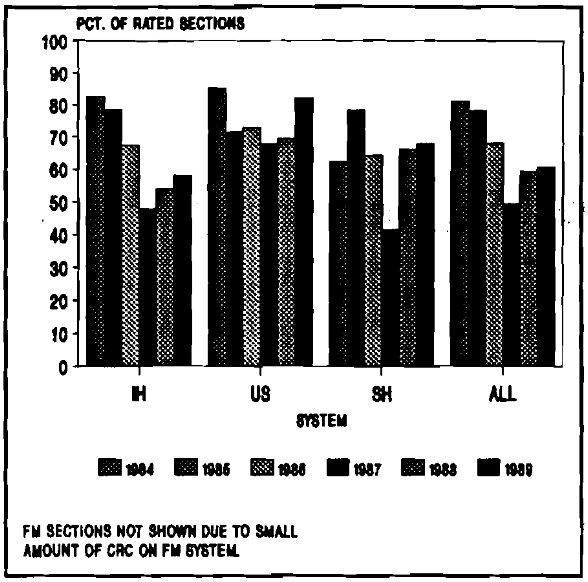

Figure 4.33 -- Spalled Cracks, by System, 1984-1989.

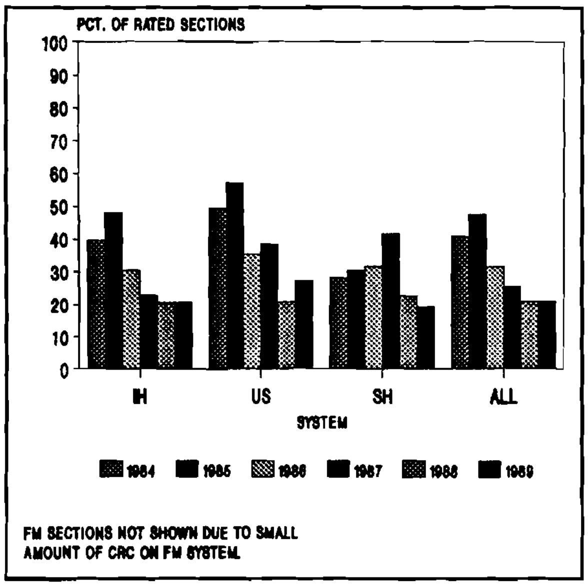

Figure 4.34 -- Punchouts, by System, 1984-1989.

Punchouts

In 1989, the percentage of sections with punchouts remained about the same, at 21.0 percent. The US network was the only network to increase in the percentage of punchout sections, and also had the highest percentage of sections at 27.3 percent. Figure 4.34 indicates the percentage of punchout sections, by highway network, from 1984-1989.

Asphalt Patches

The percentage of asphalt patch sections on the CRC network decreased from 17 percent in 1988 to 11 percent in 1989. This decrease was seen on all highway networks, and is an indication that the appropriate maintenance practices are being used to repair punchouts. The US network had the highest percentage of sections with asphalt patching at 14.55 percent. Figure 4.35 indicates the percentage of asphalt patch sections, by highway network, from 1984-1989.

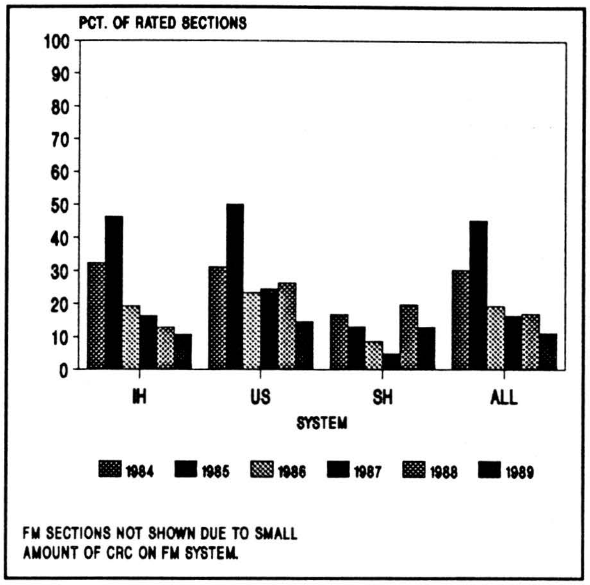

Figure 4.35 -- Asphalt Patches, by System, 1984-1989.

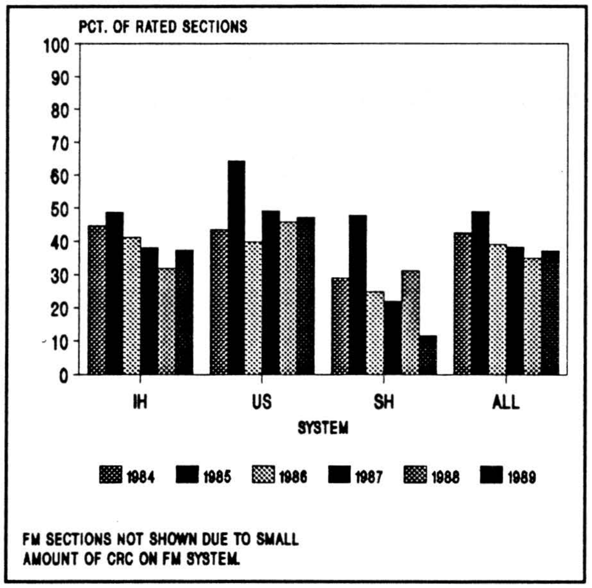

Figure 4.36 -- Concrete Patches, by System, 1984-1989.

Concrete Patches

The percentage of concrete patch sections was up from 34.9 percent in 1988 to 37.0 percent in 1989. The SH highway network was the only highway network to decrease in the percentage of concrete patch sections, while the US network had the highest percentage at 47.3 percent. This increase in the percentage of sections is again an indication that the appropriate maintenance practices are being used to repair punchouts. Figure 4.36 indicates the percentage of concrete patch sections, by highway network, from 1984-1989.

JCP Distress

The 1989 PES survey data indicated that JCP had a dramatic decrease in distress when compared to 1988, as Figure 4.37 indicates. This decrease may not be representative of all JCP mileage due to the small, fluctuating sample size. Because of this small sample size the individual distresses were not analyzed. The problem of representative data for the JCP should be resolved with the implementation of a 100-percent survey starting in September, 1991.

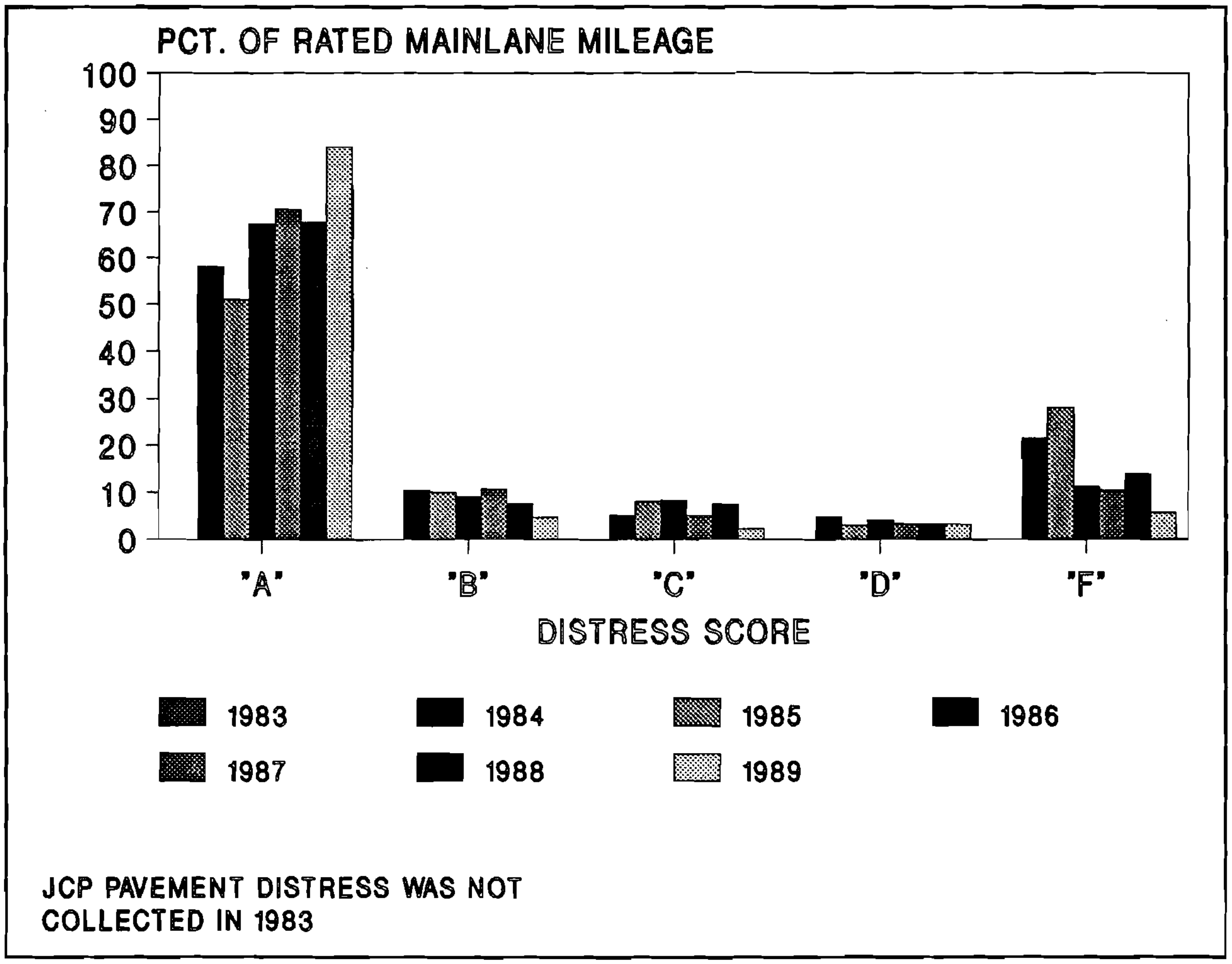

Figure 4.37 -- JCP Pavement Distress 1984-1989.

Summary of Overall Network Pavement Condition

The overall condition of the Texas highway network has improved since 1988, with levels well above those in 1984. Asphalt pavement condition has continued to improve. Continuously-reinforced-concrete condition appears to have peaked, and is on a downward cycle. JCP condition is up this year, but the sample is still too small to make any firm conclusions. All highway networks' condition improved in 1989, excepted for the IH network, which had a slight decrease due to CRC.

The 1989 ride quality shows an overall improvement, with the amount of mileage below 3.0 decreasing for all pavement types and highway networks. The increase in class "A" mileage may be due to a decrease in the number of sections used in calibrating the SIometer in 1989. The amount of mileage for very good ride quality is expected to decrease to 1988 levels in 1990.

The 1989 PES survey data indicated that distress decreased on ACP and JCP, while increasing slightly on CRC. Rutting was the only ACP distress to increase and was found on approximately one-third of rated ACP sections. Spalled transverse cracks and concrete patching increased slightly on CRC, while asphalt patching decreased and punchouts remain the same. The JCP sample was too small to analyze the individual distresses.

This improvement in condition and ride began back in 1985 when the construction budget was nearly doubled and the maintenance budget started to increase. However some of these condition improvements are due to temporary maintenance fixes on roads that need rehab or reconstruction. These temporary fixes are done to sustain the roadway until adequate funding is available for rehabilitation or reconstruction. A complete analysis of construction and maintenance expenditures is in Chapter 8.

CHAPTER 5
STATEWIDE PAVEMENT REHABILITATION NEEDS

Statewide pavement rehabilitation estimates are based on rated lane mileage that is in most urgent need of attention. Chapter 1 describe the Rehab Priority score (pavement score - PS) which ranges from 1 (urgent need for rehab) to 100 (no rehab needed). A pavement section is included in this needs estimate if its rehab priority score is 34 or below.

The rehabilitation model extrapolates the lane mileage in need of immediate rehabilitation from the PES statistical sample of mandatory sections. This is necessary since all state maintained mileage is not rated each year. Highway sections are stratified into the following classes for analysis purposes:

1. District (1-25, except 22)
2. System (IH, US, SH, or FM)
3. Pavement type (ACP, CRC, or JCP)
4. ADT Class (1, 2, or 3)

These four classes partition the Texas highway network into 864 groups (24 x 4 x 3 x 3) of pavement sections each year. Each group is considered independently, with the results being assembled into larger categories for reporting.

Construction sections (which could not be rated) and frontage roads are eliminated from each group before performing the extrapolation. Table 5.1 lists the total assumed inventory of mainlane mileage for each year from 1983-1989, before elimination of construction sections.

The estimated rehab lane mileage is then multiplied by an assumed treatment unit cost. The cost for a typical rehab treatment is based on highway system, pavement type, and ADT class. Table 5.2 indicates the treatment cost used per lane mile. These treatments do not consider effects of inflation, so a year-by-year comparison is possible. These unit costs simulate intensive rehabilitation or reconstruction work, but do not represent all rehabilitation work done in the Districts. Because of the different treatments, funding and mileage estimates do not have a one-to-one correlation.

Table 5.3 lists the statewide lane mileage in need of immediate rehab from 1983-1989 by pavement type and highway system. The lane mileage needing rehabilitation has decreased from a high in 1984 of 16,697 lane miles to only 7,092 lane miles in 1989. This is below the 1983 rehab lane mile estimates, however the rehab funding requirements for 1989 are still above the 1983 level, as Table 5.4 indicates.

TABLE 5.1 -- Assumed Total Statewide Lane Mileage 1983-1989.

YEAR	PAVEMENT TYPE	IH	US	SH	FM	ALL
1983	ACP	7,646	31,919	32,932	80,460	152,957
	CRC	0	0	0	0	0
	JCP	0	0	0	0	0
	TOTAL	7,646	31,919	32,932	80,460	152,957
1984	ACP	8,566	32,245	33,314	81,305	155,430
	CRC	3,799	1,255	776	73	5,903
	JCP	1,497	1,124	1,410	344	4,375
	TOTAL	13,862	34,624	35,500	81,722	165,708
1985	ACP	8,694	32,133	33,267	80,805	154,899
	CRC	3,862	1,104	811	81	5,858
	JCP	1,482	1,017	1,410	350	4,259
	TOTAL	14,038	34,254	35,488	81,236	165,016
1986	ACP	9,180	32,541	33,632	81,918	157,271
	CRC	3,645	1,164	819	84	5,712
	JCP	1,445	1,176	1,340	357	4,318
	TOTAL	14,270	34,881	35,791	82,359	167,301
1987	ACP	9,449	32,450	34,141	82,199	158,239
	CRC	3,431	1,061	685	86	5,263
	JCP	1,407	1,115	1,270	358	4,150
	TOTAL	14,287	34,626	36,096	82,643	167,652
1988	ACP	9,758	32,588	34,439	81,989	158,774
	CRC	3,595	1,091	870	66	5,622
	JCP	1,219	1,111	1,307	369	4,006
	TOTAL	14,572	34,790	36,616	82,424	168,402
1989	ACP	9,696	31,904	34,431	82,674	158,705
	CRC	3,522	1,113	762	82	5,479
	JCP	1,068	1,015	1,221	343	3,647
	TOTAL	14,286	34,032	36,414	83,099	167,831

Notes: Frontage roads are not included in this table since frontage road mileage is not directly available from PES data files. CRC and JCP was not rated in 1983. Since no ratings were available from which to extrapolate rehab needs, estimates of statewide concrete lane mileage were not made for that year. Totals may not be exact due to roundoff error.

TABLE 5.2 -- Assumed 1983-1989 Pavement Rehabilitation Cost (in Dollars per Lane Mile).

PAVEMENT TYPE	IH		US/SH		FM	
	COST	ADT	COST	ADT	COST	ADT
ACP	85,000	23,000	65,000	23,000	25,000	1,500
	143,000	100,000	143,000	100,000	50,000	+1,500
	400,000	100,000+	400,000	+100,000		
CRC	103,000	25,000	103,000	25,000	25,000	1,500
	143,000	100,000	143,000	100,000	50,000	+1,500
	400,000	+100,000	400,000	+100,000		
JCP			65,000	25,000	25,000	1,500
	165,000	100,000	165,000	100,000	50,000	+1,500
	500,000	+100,000	500,000	+100,000		

NOTE: ADT is Average Daily Traffic, in vehicles per day.

TABLE 5.3 -- Total Projected Statewide Lane Mileage in Need of Rehabilitation 1983-1989.

YEAR	PAVEMENT TYPE	IH	US	SH	FM	ALL
1983	ACP	194	2,030	2,021	3,519	7,764
	CRC	0	0	0	0	0
	JCP	0	0	0	0	0
	TOTAL	194	2,030	2,021	3,519	7,764
1984	ACP	531	2,700	2,806	7,840	13,876
	CRC	658	363	134	0	1,155
	JCP	497	462	651	55	1,665
	TOTAL	1,686	3,525	3,591	7,895	16,697
1985	ACP	262	2,023	2,519	5,435	10,239
	CRC	896	134	64	01	1,094
	JCP	591	600	258	101	1,550
	TOTAL	1,749	2,415	3,184	5,536	12,884
1986	ACP	287	1,805	2,083	4,864	9,039
	CRC	768	306	202	2	1,279
	JCP	422	499	611	155	1,688
	TOTAL	1,477	2,610	2,897	5,022	12,005
1987	ACP	490	1,912	1,845	5,396	9,644
	CRC	176	375	3	0	554
	JCP	387	368	281	42	1,078
	TOTAL	1,053	2,655	2,130	5,438	11,276
1988	ACP	294	1,259	1,355	3,828	6,736
	CRC	170	108	35	0	313
	JCP	212	245	456	112	1,025
	TOTAL	676	1,612	1,247	3,940	8,075
1989	ACP	261	1,191	1,096	2,955	5,504
	CRC	470	312	138	0	920
	JCP	130	157	372	9	669
	TOTAL	862	1,660	606	2,964	7,092

Notes: Frontage roads are not included in this table. Concrete (CRC and JCP) pavement was not rated in 1983. Since no ratings were available from which to extrapolate rehab needs, estimates of statewide concrete lane mileage were not made for that year. Totals may not be exact due to roundoff error.

TABLE 5.4 -- Total Projected Statewide Pavement Rehabilitation Funding Requirements 1983-1989.

YEAR	PAVEMENT TYPE	IH	US	SH	FM	ALL
1983	ACP	$22,947,871	$157,928,588	$154,455,489	$118,652,619	$453,984,567
	CRC	$0	$0	$0	$0	$0
	JCP	$0	$0	$0	$0	$0
	TOTAL	$22,947,871	$157,928,588	$154,455,489	$118,652,619	$453,984,567
1984	ACP	$48,336,103	$184,663,712	$202,127,178	$234,087,098	$669,214,091
	CRC	$85,878,801	$54,567,309	$21,823,106	$0	$162,269,216
	JCP	$105,879,384	$45,799,03	$64,249,994	$2,771,099	$218,699,510
	TOTAL	$240,094,288	$285,030,054	$288,200,278	$236,858,197	$1,050,182,817
1985	ACP	$44,185,306	$164,222,405	$198,650,298	$174,534,971	$581,592,980
	CRC	$176,421,089	$44,908,200	$6,606,306	$0	$227,935,595
	JCP	$97,506,091	$26,521,198	$60,391,593	$4,684,083	$189,102,965
	TOTAL	$318,112,486	$235,651,803	$198,650,298	$179,219,054	$931,633,641
1986	ACP	$33,823,036	$155,314,734	$150,542,165	$148,588,597	$488,268,532
	CRC	$159,100,382	$38,741,903	$24,952,287	$112,727	$222,907,299
	JCP	$69,591,633	$68,632,022	$59,773,533	$6,380,561	$204,377,749
	TOTAL	$262,515,051	$262,688,659	$235,267,985	$155,081,885	$915,553,580
1987	ACP	$50,881,209	$136,305,669	$137,620,696	$169,642,351	$494,449,925
	CRC	$23,950,121	$65,204,542	$357,067	$0	$89,511,730
	JCP	$154,613,807	$46,274,000	$18,754,587	$1,474,839	$221,117,233
	TOTAL	$229,445,137	$247,784,211	$156,732,350	$171,117,190	$805,078,888
1988	ACP	$40,374,402	$94,973,859	$102,208,993	$108,168,342	$345,725,596
	CRC	$32,547,304	$11,593,181	$4,469,253	$0	$48,609,738
	JCP	$65,827,298	$36,093,789	$44,790,153	$5,580,000	$152,291,240
	TOTAL	$138,749,004	$142,660,829	$151,468,399	$113,748,342	$546,626,574
1989	ACP	$33,473,321	$89,189,778	$88,531,896	$89,912,439	$301,107,434
	CRC	$99,076,314	$32,822,057	$19,751,333	$0	$151,649,704
	JCP	$27,987,450	$19,424,601	$39,814,383	$470,000	$87,696,434
	TOTAL	$160,537,085	$141,436,436	$148,097,612	$90,382,439	$540,453,572

Notes: Frontage roads are not included in this table. Concrete (CRC and JCP) pavement was not rated in 1983, therefore no estimates of pavement rehabilitation needs could be made. Totals may not be exact due to roundoff error.

Figures 5.1-5.4 indicate the estimated rehabilitation needs from 1983 to 1989, by system

Figures 5.1-5.4 indicate the estimated rehabilitation needs from 1983 to 1989, by system and pavement type. In 1989, the overall mileage in need of rehab was down (Figure 5.1), however rehab mileage on the Interstate and US systems were up slightly. The only pavement type which increased in rehab mileage in 1989 (Figure 5.2) was CRC. Funding needs for 1989 were about the same as 1988, even though the overall rehab mileage needs decreased by approximately 1000 miles. The reason that no major gains were seen in rehab funding needs was that more of the rehab mileage in 1989 had a high rehab cost, because it was on the Interstate system and the pavement type was CRC. Overall , the results indicate that the Texas highway network has stabilized, but if funding is decreased we could see a downward cycle which would cost more in the future. Actual funding for construction and maintenance will be discussed in detail in Chapter 8.

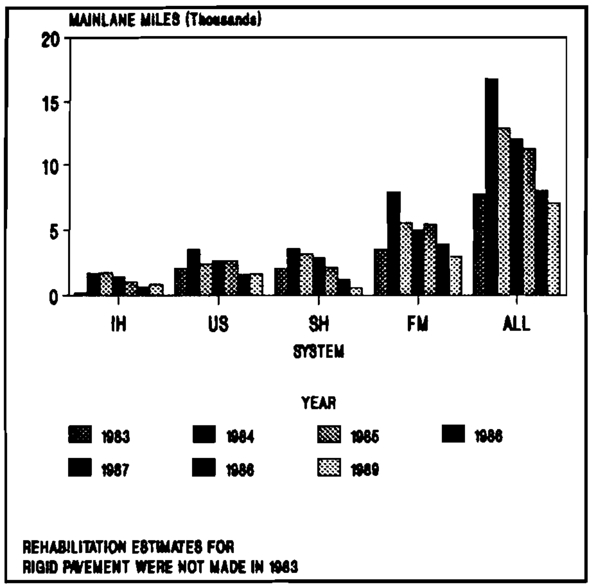

Figure 5.1 -- Estimated Mileage in Need of Rehabilitation, by System, 1983-1989.

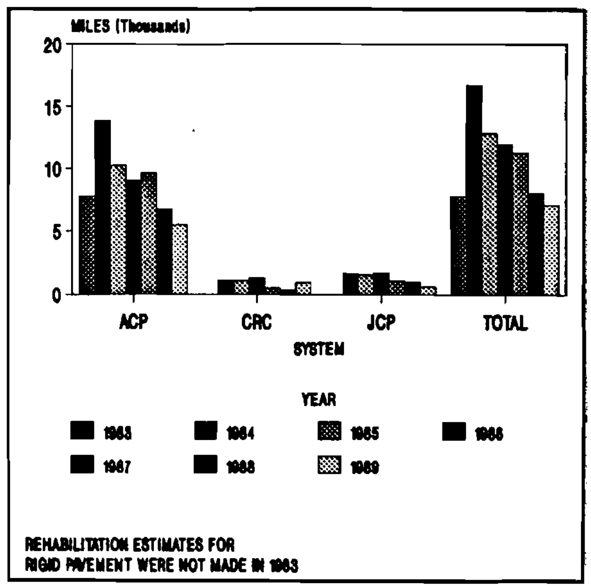

Figure 5.2 -- Estimated Mileage in Need of Rehabilitation, by Pavement Type, 1983-1989.

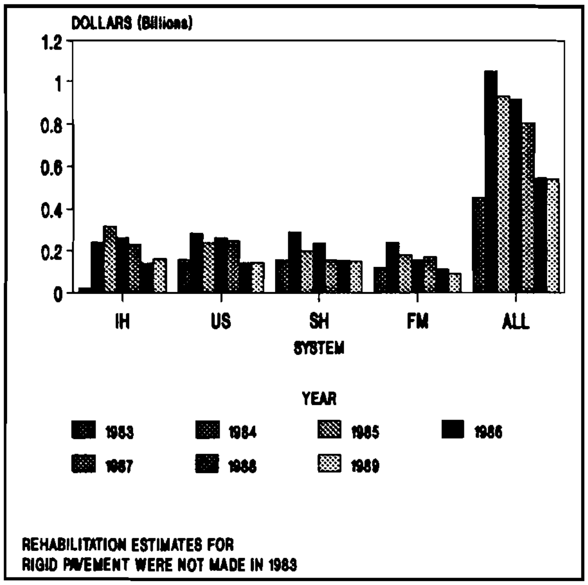

Figure 5.3 -- Estimated Funds Needed for Rehabilitation, by System, 1983-1989.

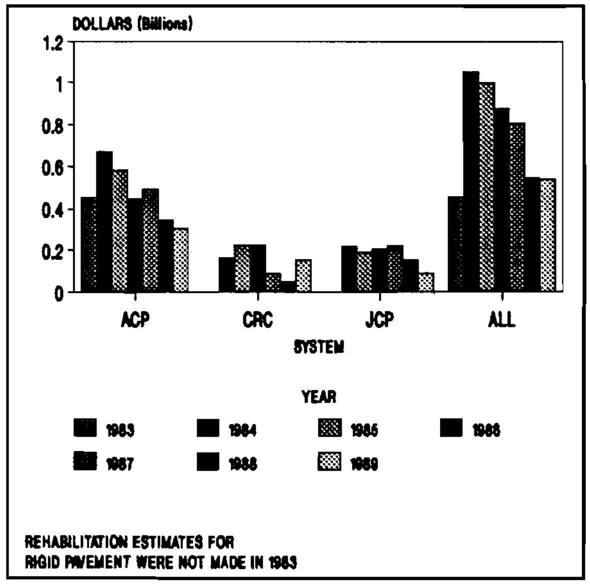

Figure 5.4 -- Estimated Funds Needed for Rehabilitation, by Pavement Type, 1983-1989.

-Notes-

CHAPTER 6
ANALYSIS OF PAVEMENT DEFLECTION DATA

In 1987, pavement deflection testing was introduced into the PES survey. This eliminated a major PES limitation, by providing a means to determine a pavement's strength. Pavement strength is assessed by placing a load at the surface and measuring the resulting deflections at various radial distances from the load. The Department has acquired a number of Falling Weight Deflectometers (FWDs) to accomplish this task. The FWD applies a 9,000-11,000 pound load to the pavement surface and measures pavement deflection at 1-foot intervals from the load, from 0 to 6 feet. As the distance from the load application increases, the line of influence of the load spreads through the layers of the pavement as represented by the conical zone in Figure 6.1, thus the measured deflection at the surface is purely a result of the deformation of the material in the stress zone.

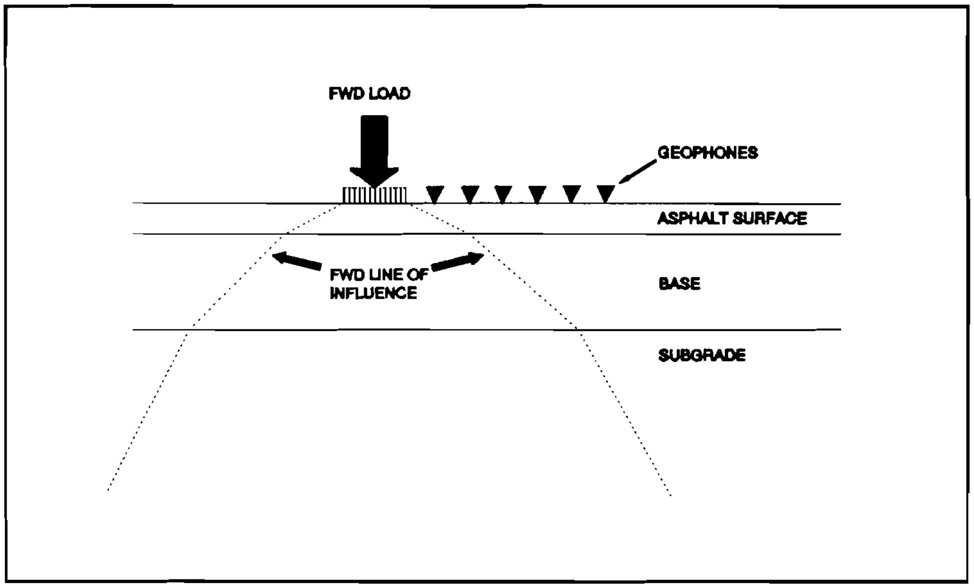

Figure 6.1 -- FWD Line of Influence.

The pavement deflects the most directly under the load, with the deflections decreasing with increasing distance. The result is a "bowl-shaped" basin on the pavement surface often referred to as a deflection basin. The FWD only measures deflections along one bowl radius. A conceptual representation of a deflection basin, as measured by the FWD, is shown on the next page in Figure 6.2.

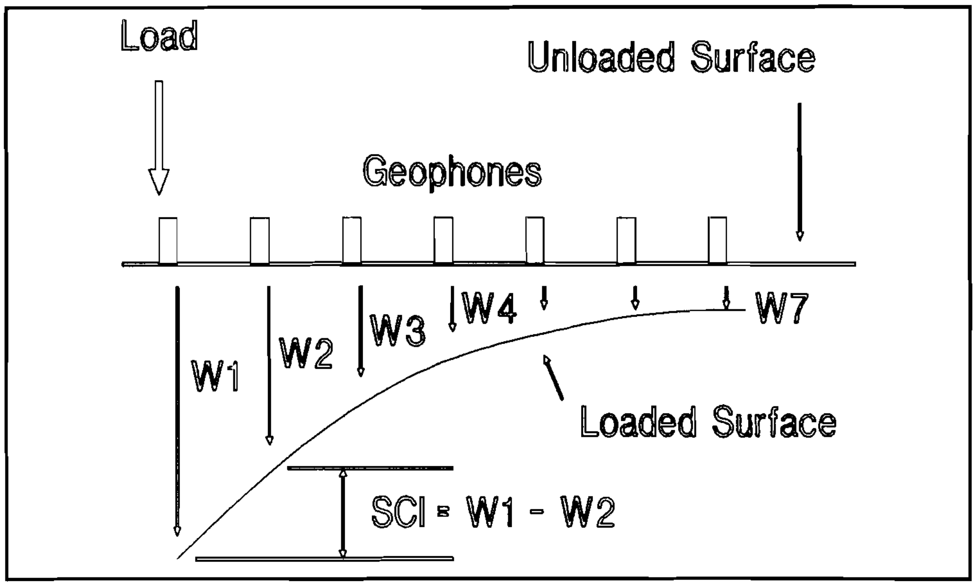

Figure 6.2 -- FWD Deflection Basin.

W1

The deflection measured at geophone one (W1), which is directly under the load, represents the total pavement deflection of all layers. The W1 sensor deflection can be used as an aid in identifying the weaker pavement sections within a highway segment. In this procedure, the statistics μ (the mean or average value) and σ (the standard deviation - a measure of variability) are computed for the W1 sensor deflections. In general, if the W1 sensor deflection at a given test site exceeds the sum of the average W1 sensor deflection plus one standard deviation, we can characterize the pavement at that site as "weak" in comparison to the average strength of other pavements in that area. Using this comparison method, a quick check of deflection data can be made and the location of weak pavement sections identified.

SCI

The deflections measured at geophones one and two (W1) and (W2) are used to compute the Surface Curvature Index (SCI). A large SCI indicates a weak pavement structure and a small SCI indicates a strong pavement.

W7

The deflection at geophone seven (W7), which is 72 inches from the load, is used as an indicator of subgrade stiffness (strength); generally the smaller this deflection is, the stiffer (stronger) the subgrade is.

Based on a field evaluation of in-service pavements, ranges of values for the W7 sensor deflection and SCI have been developed to aid in "diagnosing" the existing pavement and subgrade condition. It was determined that a W7 sensor deflection less than or equal to 1.2 mils (a mil is equal to one-thousandth of an inch) indicates a stiff (strong) subgrade, between 1.3 and 1.9 mils indicates a marginal or medium strength subgrade and equal to or greater than 2.0 mils indicates a weak subgrade. Ranges of values for SCI were also developed and it was determined that an SCI less than or equal to 20 mils indicates a strong pavement, SCI between 20 and 40 indicates a marginal or medium strength pavement and an SCI value greater than 40 indicates a weak pavement. Table 6.1 gives a quick summary of how the W7 sensor deflection and the SCI can be used in determining the existing pavement structural condition:

W7	SCI	PAVEMENT DIAGNOSIS
≤ 1.2	SCI ≤ 20	Good Base, Stiff Subgrade
	20 < SCI < 40	Marginal Base, Stiff Subgrade
	SCI ≥ 40	Thin and/or Soft Base, Stiff Subgrade
1.3 - 1.9	SCI ≤ 20	Good Base, Marginal Subgrade
	20 < SCI < 40	Marginal Base, Marginal Subgrade
	SCI ≥ 40	Thin and/or Soft Base, Marginal Subgrade
≥ 2.0	SCI ≤ 20	Good Base, Soft or Wet Subgrade
	20 < SCI < 40	Marginal Base, Soft or Wet Subgrade
	SCI ≥ 40	Thin and/or Soft Base, Soft or Wet Subgrade

Note: Deflections represented in thousandths of an inch (mils).

-Notes-

Table 6.1 (pages 63 through 69) shows the mean and standard deviation for W1, W7, and SCI by County for the IH and US Highway systems in 1989. Table 6.2 (pages 71 through 79) display the same values for the SH and FM highway systems. These tables provide a useful reference to the Engineer to compare pavement, subgrade, and overall strength of a pavement section using only the deflections collected in the field.

TABLE 6.1 -- FWD Testing Results.

COUNTY	IH						US					
	W1		W7		SCI		W1		W7		SCI	
	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD
1	0	0	0	0	0	0	24.5	8.3	1.1	0.5	13.8	5.8
2	0	0	0	0	0	0	26.6	5.6	1.2	0.2	11.7	2.4
3	0	0	0	0	0	0	8.5	7.5	1.7	0.6	2.3	3.4
4	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	6.4	2.9	1.5	0.3	0.8	0.8
6	0	0	0	0	0	0	11.4	6.6	1.2	0.3	3.9	3.4
7	12.5	7.1	1.4	0.5	4	2.8	15.3	15.9	1	0.3	8.5	13
8	2.8	0.7	1	0.3	0.3	0.3	5.5	1	1.1	0.1	0.3	0.1
9	0	0	0	0	0	0	33.9	13.7	1.2	0.3	20.2	7.4
10	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	23.9	10.8	1.7	0.9	9.2	5.1
12	0	0	0	0	0	0	11.7	5.9	1.4	0.5	3.3	2.8
13	0	0	0	0	0	0	20.5	15.7	1.1	0.6	9.3	8.7
14	7.1	3.5	0.7	0.5	2.6	1.5	0	0	0	0	0	0
15	8	7.8	1.1	0.5	3.6	7.4	9	3.2	1	0.6	3.9	2.7
16	0	0	0	0	0	0	15.7	8.3	0.5	0.4	8.5	5
17	0	0	0	0	0	0	18.2	11.1	1.5	0.3	8.7	7.4
18	0	0	0	0	0	0	0	0	0	0	0	0
19	4.9	10.8	1.2	0.4	1.9	10.5	19	13.5	1.4	0.5	8.8	8.2
20	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	5.3	2.3	1.6	0.4	0.7	0.6
22	0	0	0	0	0	0	24.5	19	1.1	0.7	12.9	10
23	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	11.2	10.5	1.6	0.3	3.3	4.1
25	0	0	0	0	0	0	9.3	4.9	0.9	0.3	4.3	2.6
27	0	0	0	0	0	0	10.9	2.7	0.3	0.2	5.8	1.8
28	0	0	0	0	0	0	12.9	7.1	1.5	0.5	5.3	4.1
29	0	0	0	0	0	0	8.2	3.1	2.3	0.4	1.7	1.1
30	4.3	1.7	0.8	0.4	0.9	0.6	28.2	10.9	1.4	0.6	13.6	6.5

COUNTY	IH						US					
	W1		W7		SCI		W1		W7		SCI	
	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD
31	0	0	0	0	0	0	19.9	13.4	2.7	0.3	7.6	7.7
32	0	0	0	0	0	0	20	6.5	0.8	0.2	8.5	3
33	7	1.6	1.9	0.7	1.2	0.8	23.5	9.5	1.9	0.5	11.6	6
34	0	0	0	0	0	0	13.8	5.4	0.9	0.5	5.3	2.8
35	0	0	0	0	0	0	17.2	4.4	1.1	0.3	8.6	2.7
36	5.7	4.1	1.4	0.3	1.3	1.5	0	0	0	0	0	0
37	0	0	0	0	0	0	22.1	8.3	0.9	0.3	12.2	5.6
38	0	0	0	0	0	0	15.3	11.8	1.6	0.4	5.8	6.3
39	0	0	0	0	0	0	5.5	2.3	1.1	0.3	1.3	0.9
40	0	0	0	0	0	0	0	0	0	0	0	0
41	0	0	0	0	0	0	19.8	11.4	1.1	0.5	10	5.8
42	0	0	0	0	0	0	12.9	7.6	0.9	0.4	6.7	4.4
43	0	0	0	0	0	0	0	0	0	0	0	0
44	0	0	0	0	0	0	23	11.2	1.2	0.5	14.2	7.7
45	3.4	0.9	0.9	0.3	0.4	0.3	13.3	7	1.3	0.5	3	2.5
46	0	0	0	0	0	0	13.2	4.1	0.6	0.2	6.1	2.2
47	0	0	0	0	0	0	12.7	6.6	1.1	0.2	6.2	3.2
48	0	0	0	0	0	0	17.5	11	0.8	0.4	9.7	6.9
49	2.2	0.9	0.7	0.2	0.5	0.3	14.8	5.5	0.9	0.4	6.6	3.2
50	0	0	0	0	0	0	15.9	5.6	0.9	0.5	7	2.8
51	0	0	0	0	0	0	15.4	9.3	1.4	0.6	7.1	6.2
52	0	0	0	0	0	0	10.3	4.1	1	0.3	4.2	1.6
53	5.9	2.1	0.4	0.3	3.3	1.2	30.6	17.4	1.4	1	17.9	9.6
54	0	0	0	0	0	0	29.4	10.6	1.5	0.4	13.6	6.3
55	3.2	1	0.9	0.4	0.3	0.2	11.3	7.5	0.9	0.6	3.4	2.7
56	0	0	0	0	0	0	31	9.6	1.2	0.3	18.4	5.8
57	4.9	2.4	1.4	0.5	1.2	1.2	5.5	3	1.1	0.7	1.2	1.2
58	0	0	0	0	0	0	28.3	8	1.3	0.3	14.9	3.9
59	0	0	0	0	0	0	20.9	8.7	1.2	0.2	9.5	6.5
60	0	0	0	0	0	0	0	0	0	0	0	0
61	3.7	1.1	1.4	0.4	0.5	0.6	14.5	6.9	1	0.4	6	3.8
62	0	0	0	0	0	0	19.1	10.5	1.3	0.5	8.7	6.4
63	0	0	0	0	0	0	16.8	6.3	1.2	0.4	7.9	2.6
64	0	0	0	0	0	0	37.9	15.6	1.6	0.7	22.6	9.6
65	7.6	3.1	1.4	0.2	1.8	1.7	18.3	4.6	1.4	0.3	9.8	2.8
66	0	0	0	0	0	0	14.9	10.4	1.4	0.3	5.9	4.1
67	0	0	0	0	0	0	24.9	11.2	1.6	0.6	12.2	5.7
68	5.4	2.8	0.7	0.3	2.2	1.5	16.7	8	0.9	0.3	8.4	3.9
69	4.9	2.5	0.6	0.2	1.5	1.2	22.7	12.2	1.1	0.4	11.1	6.4
70	0	0	0	0	0	0	13.2	5.6	0.4	0.3	8.8	4.1

COUNTY	IH						US					
	W1		W7		SCI		W1		W7		SCI	
	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD
71	5.5	13.7	1.3	0.3	2.6	13.6	8.1	3.8	1.3	0.9	2.6	1.7
72	8.1	8.7	1.4	0.7	1.8	7.9	20	8.7	1.3	0.4	7.2	3.8
73	0	0	0	0	0	0	11.1	7	1.1	0.8	3.7	3.4
74	0	0	0	0	0	0	19.5	9.3	1.5	0.4	8.4	4.7
75	0	0	0	0	0	0	18.7	6.7	1.1	0.5	8.2	3.9
76	3.6	1.2	0.9	0.3	0.4	0.2	23.5	18.7	1.6	0.8	5.5	6
77	0	0	0	0	0	0	21.8	7.7	1.3	0.5	11	4
78	0	0	0	0	0	0	26.7	15	1.7	0.5	13.3	8
79	0	0	0	0	0	0	17.8	10.5	1.3	0.5	9.5	7
80	0	0	0	0	0	0	6.2	3.7	1.6	0.2	2.3	2.6
81	7.8	1.4	1.4	0.2	4.2	1.5	6.8	0.9	2.2	0.4	0.8	0.5
82	4	1.8	1.5	0.8	0.4	0.2	26	13.6	1.5	0.4	11.5	7.5
83	7.6	3.7	1	0.4	3.1	1.9	21.8	8.7	1.2	0.5	10.9	5.3
84	0	0	0	0	0	0	30.4	11.4	1	0.2	16	6.4
85	0	0	0	0	0	0	0	0	0	0	0	0
86	0	0	0	0	0	0	21.7	18.9	1.3	0.5	11	12.1
87	6.4	1.8	0.1	0.1	3.3	0.7	18.7	9.3	0.6	0.5	9.5	4
88	0	0	0	0	0	0	20.7	5.4	1.5	0.3	8.8	2.9
89	0	0	0	0	0	0	15.7	10.3	1.1	0.4	7	6.2
90	0	0	0	0	0	0	14.6	14.7	1.3	0.5	6.8	13.7
91	8.5	2.1	1.4	0.3	2.2	0.8	23.7	7.7	1.7	0.5	13	5.3
92	0	0	0	0	0	0	18.9	14.2	0.9	0.4	9.2	7.5
93	3.5	1	1.1	0.4	0.5	0.2	19.3	13.9	1.3	0.3	8.4	7.4
94	0	0	0	0	0	0	0	0	0	0	0	0
95	6.6	3.2	1.1	0.3	2.6	1.6	11.2	5	1.7	1.4	4.7	2.9
96	0	0	0	0	0	0	10.2	4.9	2	0.6	2.1	2
97	0	0	0	0	0	0	16.8	12.6	1.8	0.4	6.6	7.7
98	0	0	0	0	0	0	19.2	7.7	0.9	0.5	10.1	4.4
99	0	0	0	0	0	0	0	0	0	0	0	0
100	0	0	0	0	0	0	11.2	5.6	1.3	0.3	4.4	3.2
101	0	0	0	0	0	0	20.5	9	1.2	0.6	9.5	5.3
102	3.5	1.4	1.3	0.2	0.8	0.7	3.9	1.1	1.4	0.4	0.9	0.6
103	3.9	1.1	1.2	0.4	0.6	0.3	14.1	11.6	0.8	0.4	6.3	7
104	0	0	0	0	0	0	22.5	4.7	1.3	0.3	11	2.7
105	0	0	0	0	0	0	16.8	6.3	1.3	0.4	8.2	3.8
106	6.6	3	0.5	0.3	2.6	1.4	12.9	3.3	0.1	0.1	7.1	1.9
107	0	0	0	0	0	0	19.9	10.2	1.4	0.4	9.4	7
108	0	0	0	0	0	0	14.6	11.9	1.8	1	4.7	5.9
109	0	0	0	0	0	0	19.4	9.7	1.7	0.6	7.1	5.2
110	5.7	2.3	0.9	0.4	2	1.1	7.9	5.1	0.6	0.6	2.8	2.2

COUNTY	IH						US					
	W1		W7		SCI		W1		W7		SCI	
	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD
111	0	0	0	0	0	0	35.8	10.5	1.2	0.2	21.6	7
112	0	0	0	0	0	0	6	1.8	0.8	0.3	2.3	1.4
113	6.4	1.1	1.5	0.3	2.6	0.9	8.6	7.1	2.1	0.6	1.6	1.9
114	0	0	0	0	0	0	27.3	8.2	1.6	0.7	12.4	5.9
115	7.8	3.7	1	0.3	3	2.2	21.9	8.7	1	0.3	13.4	6
116	5.5	7.3	1	0.4	1.3	6.5	13.2	4.6	1	0.3	6.4	2.4
117	4	0.9	1.5	0.3	1.1	0.7	18	8.8	1.8	0.3	7.6	5.5
118	0	0	0	0	0	0	0	0	0	0	0	0
119	0	0	0	0	0	0	33.7	6.4	1.7	0.3	13.2	4.1
120	0	0	0	0	0	0	21.4	7.6	0.9	0.3	11	4
121	0	0	0	0	0	0	3.6	0.7	1.3	0.3	0.3	0.1
122	0	0	0	0	0	0	17.1	8.7	1.3	0.5	6.8	4.4
123	2.1	0.5	0.9	0.3	0.2	0.1	21.4	7.4	1.8	0.6	8.8	4.3
124	4.2	0.8	1.6	0.3	0.7	0.2	3.9	1.6	1.6	0.3	0.9	1.1
125	0	0	0	0	0	0	0	0	0	0	0	0
126	0	0	0	0	0	0	0	0	0	0	0	0
127	6	2.4	1.2	0.2	1.5	0.8	13.6	5.2	1.3	0.3	4.5	2.1
128	0	0	0	0	0	0	18.5	9	1.4	0.4	9.5	4.6
129	0	0	0	0	0	0	34.3	16.7	2.1	0.7	14	7.7
130	0	0	0	0	0	0	12.3	10.3	1.5	0.6	3.8	3.4
131	5.9	2.3	0.3	0.2	3.2	1.4	11.9	3.7	0.5	0.3	7	1.4
132	0	0	0	0	0	0	20.8	5.2	1.5	0.4	10.6	3
133	6	2.4	0.3	0.2	3.3	1.4	16.1	5	0.4	0.3	9.4	2.5
134	4.4	1.6	0.3	0.2	2.1	1	19.6	14	0.9	0.4	11.3	9.3
135	0	0	0	0	0	0	24.6	8.7	1.3	0.3	14.9	6.5
136	0	0	0	0	0	0	19.5	4.5	1.3	0.5	9	2.5
137	0	0	0	0	0	0	13.3	7.2	2.1	0.3	3.2	2.7
138	0	0	0	0	0	0	10.8	7	1.6	0.3	3.4	3.3
139	0	0	0	0	0	0	10.2	6.9	1.6	0.2	3.5	3.8
140	0	0	0	0	0	0	27.6	8.1	1.3	0.3	15	4.4
141	0	0	0	0	0	0	8.8	5.9	0.6	0.4	4.7	2.8
142	17.5	9.1	1.4	0.6	7.4	5.1	0	0	0	0	0	0
143	0	0	0	0	0	0	18.9	8.6	1.3	0.4	4.3	2.4
144	0	0	0	0	0	0	26.8	5.5	1.2	0.4	12.9	2.9
145	3.9	1.5	1.3	0.6	0.4	0.2	16.3	7.7	1.4	0.5	6.6	5.1
146	0	0	0	0	0	0	7.6	1	1.8	0.3	2.8	0.6
147	0	0	0	0	0	0	12.3	2.8	1.8	0.3	3.3	1.3
148	0	0	0	0	0	0	15.3	6.4	1.1	0.7	6.2	3.9
149	6.9	3.4	1.4	0.6	1.6	1.2	26.8	18	1.8	0.9	12.6	8.9
150	0	0	0	0	0	0	0	0	0	0	0	0

COUNTY	IH						US					
	W1		W7		SCI		W1		W7		SCI	
	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD
151	0	0	0	0	0	0	0	0	0	0	0	0
152	0	0	0	0	0	0	20.6	11.4	1.2	0.4	9.8	6.4
153	0	0	0	0	0	0	28	13.1	1.4	0.3	15.1	9.2
154	4.3	1	1.4	0.3	0.6	0.2	9.6	6.9	1.7	0.3	1.8	2.9
155	0	0	0	0	0	0	10.8	3.1	0.7	0.6	3.1	0.8
156	4.9	1.2	0.8	0.2	1	0.4	27.3	14.8	1.5	0.5	13	11
157	0	0	0	0	0	0	35.9	12.1	0.4	0.2	19.2	8.1
158	0	0	0	0	0	0	0	0	0	0	0	0
159	0	0	0	0	0	0	35.3	18.4	1.5	0.7	20.2	10.4
160	0	0	0	0	0	0	15.4	9.9	1	0.5	7.5	4.8
161	4.2	1.8	1.1	0.6	0.9	0.8	19.2	4.8	1.5	0.5	9.5	4.2
162	0	0	0	0	0	0	48.5	7.9	1.6	0.4	30	5
163	4.5	1.3	1.1	0.5	0.7	0.3	15.3	6.8	1.5	0.5	6.2	4
164	0	0	0	0	0	0	27.8	12.4	0.9	0.4	14.7	7
165	7	2.5	0.8	0.3	1.8	1.2	19.5	6.7	1.2	0.3	10.4	4
166	0	0	0	0	0	0	14.6	9.3	1.3	0.5	3.4	2.9
167	0	0	0	0	0	0	11.9	4.3	0.7	0.3	6.1	2.1
168	5.5	2.4	1.3	0.4	1.4	1	0	0	0	0	0	0
169	0	0	0	0	0	0	8.2	2.6	1	0.6	2.7	1.1
170	2.7	0.6	0.9	0.2	0.6	0.2	0	0	0	0	0	0
171	0	0	0	0	0	0	18.6	5.8	1.1	0.4	8.3	3.1
172	3.7	0.8	1.2	0.4	0.7	0.3	31.5	17.6	1.1	0.8	16.2	10.1
173	0	0	0	0	0	0	21.7	7.5	1.2	0.4	10.9	4.1
174	0	0	0	0	0	0	6.7	2.6	1.1	0.3	1.8	1.2
175	0	0	0	0	0	0	5.6	1.1	1.5	0.3	1.1	0.3
176	0	0	0	0	0	0	38	15.3	0.7	0.5	24.9	9.1
177	5	2.1	1.1	0.4	1.3	0.8	14.9	2.9	1.5	0.3	5.6	1.8
178	13.3	8.4	2	0.7	3.5	3.1	0	0	0	0	0	0
179	0	0	0	0	0	0	32.6	6.4	1.3	0.5	18.8	4
180	10.4	4.2	1.4	0.2	3.5	2.2	15.5	9.5	1.1	0.4	7.5	5.1
181	14.6	5.4	1.4	0.3	6.1	2.5	0	0	0	0	0	0
182	0	0	0	0	0	0	11.5	4.6	0.9	0.3	3.9	2.4
183	0	0	0	0	0	0	19.5	13	1.3	0.3	9.5	7.9
184	0	0	0	0	0	0	11.1	7.6	1.3	0.4	3.6	2.8
185	0	0	0	0	0	0	18	6.6	1.2	0.2	7.9	4.1
186	5.4	3.2	0.6	0.3	2.4	1.7	30.1	18.4	1.3	0.5	16.4	11.4
187	0	0	0	0	0	0	12.3	10.8	1.3	0.7	4.4	5.6
188	6.2	1.4	1.8	0.4	1.8	1	17.9	3.3	1.1	0.2	8.8	2.2
189	0	0	0	0	0	0	15.5	8.3	1.4	0.6	6	5.7
190	0	0	0	0	0	0	19.3	9.3	1.4	0.1	9	5.7

COUNTY	IH						US					
	W1		W7		SCI		W1		W7		SCI	
	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD
191	6	2	1.9	0.5	1.1	0.6	13.9	2.3	1.3	0.2	4.5	1.6
192	0	0	0	0	0	0	32	12.1	1.4	0.6	17.6	6.4
193	0	0	0	0	0	0	17.1	4.2	0.5	0.3	10.3	3.1
194	0	0	0	0	0	0	11.1	7.3	1.6	0.4	4.5	3.6
195	6.5	3.9	0.7	0.4	2.7	2.2	17.9	7.9	1.1	0.5	8.2	3.5
196	0	0	0	0	0	0	8.3	5.4	1.4	0.5	2.3	2
197	0	0	0	0	0	0	21.1	6.4	2.5	0.4	8.7	3.7
199	8.2	2	1.5	0.5	1.7	0.6	0	0	0	0	0	0
200	0	0	0	0	0	0	16.6	6.2	1.1	0.3	8.3	4
201	0	0	0	0	0	0	27.5	15.1	0.9	0.4	16.3	10.3
202	0	0	0	0	0	0	15.7	10.2	1.7	0.4	7.3	8.1
203	0	0	0	0	0	0	21.9	2.7	0.8	0.3	11.8	3.5
204	0	0	0	0	0	0	4.4	1.6	1.3	0.4	1	0.5
205	11.1	6.4	1.7	0.5	3.6	3.4	14.1	5.5	1.4	0.3	5.8	2.6
206	0	0	0	0	0	0	29.6	13.8	1.8	0.7	15	6.5
207	0	0	0	0	0	0	18.4	8.8	1.1	0.8	8.8	4.2
208	0	0	0	0	0	0	11.7	8.8	1.1	0.4	5	6.1
209	0	0	0	0	0	0	16	6.6	1.1	0.5	7	3.7
210	0	0	0	0	0	0	18.3	13	1.3	0.5	8.1	7.9
211	0	0	0	0	0	0	38.8	7.2	1.6	0.4	18.3	3.7
212	3.2	0.6	1	0.3	0.5	0.2	17.2	8.6	1.1	0.4	8.3	5.6
213	0	0	0	0	0	0	25.5	4.8	1.4	0.4	12.4	2.9
214	0	0	0	0	0	0	25.7	6.6	2.3	0.6	9.8	3
215	0	0	0	0	0	0	17.7	5.8	1	0.4	9	2.6
216	0	0	0	0	0	0	21.2	8.7	1.2	0.4	11.5	5
217	0	0	0	0	0	0	23.5	12.2	1.3	0.4	11.6	6.8
218	4.2	1.6	0.3	0.2	2.1	1.1	20.8	6.2	0.6	0.1	9.8	2.3
219	0	0	0	0	0	0	28.3	13.1	1.7	0.4	14.1	8.4
220	3.8	1.5	1.1	0.5	0.5	0.3	7.6	3.9	0.9	0.4	2.8	2.3
221	5.8	2.3	1	0.4	1.3	0.7	13.3	7	1	0.5	5.9	4.4
222	0	0	0	0	0	0	15.5	6.4	0.6	0.4	9.1	3.8
223	0	0	0	0	0	0	23.6	13.7	1	0.3	13.9	8.8
224	0	0	0	0	0	0	21.2	15.4	1.5	0.5	9.8	9.8
225	3.9	1.1	1.3	0.4	0.7	0.2	6.4	1.6	1.2	0.2	1.7	0.7
226	0	0	0	0	0	0	13.9	9.3	1	0.6	6.3	4.5
227	3.4	1.5	0.4	0.2	1.3	0.8	0	0	0	0	0	0
228	0	0	0	0	0	0	22.8	13.6	1.4	0.4	9.6	8.1
229	0	0	0	0	0	0	20	9.6	0.9	0.5	9.7	4.7
230	0	0	0	0	0	0	19.8	10.4	1	0.3	9	5.7
231	0	0	0	0	0	0	23.2	9.7	1.2	0.5	10.5	5.5

COUNTY	IH						US					
	W1		W7		SCI		W1		W7		SCI	
	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD
232	0	0	0	0	0	0	22.6	14.4	1.2	0.8	12.9	12.6
233	0	0	0	0	0	0	14.8	6	0.5	0.4	8.9	3.7
234	3.7	0.9	1.3	0.4	0.5	0.2	14.9	12.9	2.1	1	5.7	8.1
235	0	0	0	0	0	0	6.6	5.6	1.4	0.5	1.7	2.6
236	4.4	2.5	1.3	0.4	0.4	0.4	8.8	3.9	1.6	0.5	1.8	3.4
237	3.9	1.1	1.6	0.3	0.9	0.7	5.6	1.3	1.3	0.2	1.7	0.8
238	5.3	2.4	0.7	0.2	1.3	0.9	30.5	9.5	0.7	0	17.5	8.6
239	0	0	0	0	0	0	5.7	4.9	1	0.4	0.9	1.1
240	7.5	3.1	1.5	0.5	1.4	0.9	24.1	9.7	1.5	0.6	11.9	4.7
241	0	0	0	0	0	0	5.2	2.4	1.4	0.3	0.8	0.5
242	0	0	0	0	0	0	9.2	6.4	1.4	0.3	3.3	4.9
243	0	0	0	0	0	0	17	6.3	1.1	0.7	4.3	2.3
244	0	0	0	0	0	0	15.7	19.8	1.4	0.5	5.4	9
245	0	0	0	0	0	0	23	10.7	1.9	0.7	8.9	3.8
246	4.8	2.1	0.4	0.3	2.1	0.8	11	5.9	0.5	0.4	5.7	2.9
247	0	0	0	0	0	0	21	10.3	1.6	0.6	9.9	5.3
248	0	0	0	0	0	0	0	0	0	0	0	0
249	0	0	0	0	0	0	0	0	0	0	0	0
250	0	0	0	0	0	0	21.1	8.7	1.4	0.4	9.8	5
251	0	0	0	0	0	0	28.7	8.9	1	0.4	18.1	7
252	0	0	0	0	0	0	33.8	8.8	1.6	0.5	15.4	4.6
253	0	0	0	0	0	0	28.8	8.9	1.6	0.4	13.4	4.2
254	0	0	0	0	0	0	17.2	5.7	1.4	0.4	9.7	3.8
ALL	6.1	5.1	1	0.6	2	3.6	18.9	12.6	1.2	0.6	9.1	7.7

The preceding table can be used to compare the results of deflection testing on Interstates (IH) and US Highways. For example, if test results on a given Interstate in Williamson County (246) exceeded 6.9 mils (4.8 + 2.1), then this site could be considered weak in comparision with other typical sections in the county.

-Notes-

Table 6.2 (pages 71 through 79) shows the mean and standard deviation for W1, W7, and SCI by County for for the SH and FM Highway systems in 1989. Table 6.1 (pages 63 through 69) display the same values for the IH and US highway systems. These tables provide a useful reference to the Engineer to compare pavement, subgrade, and overall strength of a pavement section using only the deflections collected in the field.

TABLE 6.2 -- FWD Testing Results.

COUNTY	SH						FM					
	W1		W7		SCI		W1		W7		SCI	
	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD
1	28.9	7.9	1.1	0.5	16	4.6	33.8	12.1	1.2	0.5	20.8	8.7
2	24.3	9.7	0.9	0.3	12.4	4.8	25.2	11	0.9	0.2	14.9	7.2
3	20.3	14.4	1.5	0.6	9.3	9.3	36.2	17.6	1.6	0.6	19.5	12.7
4	28	11.7	1.7	0.3	14.8	8.3	42.8	22	2.1	0.9	21.6	11.9
5	24.6	21.6	1.7	0.6	10.1	16.5	40.1	15.4	1.7	0.6	19.9	10.5
6	50	12.9	1.5	0.3	33	14.6	62.7	17.5	2	0.5	40.2	12.7
7	19.7	12.2	1.5	0.6	9.4	7.2	32.5	17.2	1.6	0.7	17.5	10.3
8	9.7	5.6	1.5	0.3	1.8	1.7	26.8	9.6	1.4	0.5	7.7	3.7
9	49	12.2	1.7	0.6	25.2	5.6	39.4	11.8	1.4	0.3	24.1	6.6
10	22.7	10.8	0.9	0.5	13	7.3	34.7	19.2	0.9	0.6	22.8	12.3
11	24	15.3	1.1	0.6	11.2	7.9	31.7	12.8	1.7	0.7	15.5	6.8
12	12.6	5.4	1.5	0.5	3.1	2.6	30.9	14.5	1.7	0.4	14.6	9
13	21.1	9.3	1.6	0.6	9.6	4.8	45.6	18.7	1.6	0.8	27.9	12.2
14	18.8	8.8	1.4	0.7	7.7	4	23.1	12.9	1.3	0.8	11.2	7.3
15	8.9	6	1.7	1.1	3.1	4.3	25.5	17.8	1.6	0.9	12.9	10
16	9.7	3.7	0.2	0.1	6.9	2.7	30.2	13.5	0.8	0.5	18.9	9
17	0	0	0	0	0	0	39.6	16.5	1.5	0.6	22.7	10.6
18	25.2	16.6	1	0.6	13.4	9.4	31.6	16.6	0.9	0.5	19.8	11.6
19	16.2	10.8	1	0.3	7.3	6.5	34.6	14.5	1.3	0.5	19.8	9.7
20	9.5	12.1	1.9	0.5	3.5	7.6	20.5	15.4	2	0.5	9	8.6
21	13.1	9.7	1.6	0.5	3.5	4.4	29.2	17.8	1.7	0.5	9.4	7.5
22	0	0	0	0	0	0	27	14.3	1	0.7	14.9	6.9
23	51.7	20.6	1.7	0.8	31.6	13.2	60.2	17.3	1.7	0.5	42	12.1
24	27.9	11	1.1	0.3	18.1	7.1	46.5	22.1	1.3	0.5	28.8	14
25	27	9.3	1.1	0.4	13.6	4	31.4	18.4	1.2	0.6	18.4	11.5
27	12.1	4.2	0.3	0.2	5.2	2.2	24	13.2	0.4	0.4	14.9	8.5
28	28.2	12.1	1.8	0.8	13.5	6.2	41.2	15.8	1.8	0.6	23.5	10.5
29	20.7	19.1	2	0.6	8.9	11	37.7	21.2	2.2	0.6	19.7	13.6
30	16.1	9.3	1	0.3	8	7.2	29.1	16.7	1.1	0.4	17.1	12.1
31	16	15.5	2.3	0.8	5.9	8.6	39.2	28.3	2.6	0.9	19	16.7
32	36.1	13.6	1	0.3	20.4	7.3	36	11.2	1	0.2	22	8
33	22.4	9.3	1.5	0.4	10.5	5.9	51.9	19.3	1.8	0.4	32.5	14.3
34	25.7	15.2	1	0.5	14.2	9.4	33.1	12.1	1.1	0.5	20.2	7.9

COUNTY	SH						FM					
	W1		W7		SCI		W1		W7		SCI	
	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD
35	23.9	15	1.3	0.4	11.8	6.9	48.2	19.9	1.6	0.4	31.6	14.3
36	51.3	12.4	2.5	0.5	28.6	7.1	51	21.3	2.4	0.6	29.7	12.7
37	32.6	9.9	1	0.4	18.5	6.3	34.5	12.2	1	0.5	21.9	8.8
38	30.3	27	1.4	0.5	15.2	16.9	52.1	18.6	1.9	0.4	31.6	12
39	40.7	15.6	1.2	0.5	20.6	9.8	48.8	15.5	1.3	0.5	28	10.4
40	40.2	11.2	1.2	0.2	26.2	8	38.1	10.5	1.2	0.2	24.9	7.3
41	20	8	1.1	0.3	11.2	4.7	28	10.8	1.1	0.3	16.3	6.5
42	18	6.8	1.3	0.4	7.9	4.3	34.3	20.5	1.3	0.7	21	14.1
43	12.5	10	1.6	0.8	4.5	5.7	29	12.8	1.8	0.6	14.4	10.8
44	33.5	8.3	1.5	0.3	19.1	4.5	42.8	15.8	1.6	0.4	26.9	10.7
45	9.8	6.7	1.7	0.6	1.4	1.9	28.9	14.5	1.4	0.6	9	5.8
46	10.1	4.1	0.4	0.2	5.5	2.4	20.7	14.6	0.8	0.7	12.1	9
47	14.4	7.7	1	0.4	6.8	3.6	31.3	18.5	1.3	0.5	19.1	12.5
48	0	0	0	0	0	0	38.7	12.5	1.4	0.6	23.5	7.7
49	0	0	0	0	0	0	33.6	14.3	1	0.5	19	9.8
50	16.1	5.9	1	0.6	7.9	3.5	27.5	15.3	0.9	0.5	16.6	10
51	0	0	0	0	0	0	37.8	17.4	1.7	0.7	21.2	11.6
52	29.7	4.5	0.9	0.3	18.3	3.5	27	6.3	1.2	0.4	14.9	4
53	25.6	13.1	1.3	0.7	13.3	7.2	44.8	22.2	1.3	0.9	26.2	14.3
54	43.1	11.4	1.6	0.5	24.1	6.2	44.5	15.7	1.5	0.4	26.8	9.2
55	34	18.9	1.4	0.8	18	10.2	28.3	15.4	1	0.8	16.5	10.2
56	43.3	22.1	1.7	0.8	25.7	16.5	47.8	12.9	1.6	0.6	30.9	8.6
57	4.3	1.9	1.1	0.6	0.6	0.4	7.3	2.8	1	0.5	1.5	0.9
58	40.8	7.7	1.5	0.4	22.5	5.1	45.4	13.1	1.4	0.3	29	8.8
59	64.2	18	1.9	0.6	38.6	10.4	44	19.3	1.6	0.5	27.3	12.7
60	18.3	8.6	2.1	0.5	8.3	4.5	48.1	17.7	2.6	0.8	25.3	10.2
61	20.2	17.9	1.2	0.2	11.1	11.4	20.4	12.2	1.4	0.5	9.3	7.4
62	27.1	13.9	1.4	0.5	13.1	8.1	30.7	17.1	1.2	0.6	17.2	10.6
63	28.6	9.4	1	0.3	17.9	6.6	42	14.4	1.6	0.4	25.6	9.4
64	28	14.2	1.2	0.6	17.5	8.4	46.2	19.6	1.6	0.8	29.9	13.8
65	32.5	10.1	1.4	0.4	19.7	6.7	38.4	11	1.4	0.2	25.5	8.2
66	0	0	0	0	0	0	0	0	0	0	0	0
67	41.6	15.4	1.9	0.9	22.7	8.1	33.9	13.6	1.2	0.6	21.8	8.4
68	16.3	7.4	1	0.3	8.3	4.6	30.5	14.4	1.1	0.4	17.8	9.5
69	21	11.2	0.9	0.5	10.5	5	16.5	10.4	0.9	0.5	7.8	5
70	15	7.9	0.5	0.3	8.5	4.1	23.8	14	0.5	0.2	17.2	10.5
71	8.1	7.2	1.5	0.4	2.4	4.1	26.3	14.4	1.6	0.7	11.7	8.5
72	20.2	19.2	2.3	1.1	7.3	14.1	19.1	14.7	1.7	1	7.4	7.1
73	28.2	10.6	1	0.4	13.7	6.1	29.7	13.5	0.8	0.4	16.8	8.6
74	13.9	6.7	1.9	0.5	5.1	4.3	42.6	15.4	2.1	0.7	23.9	10.3

COUNTY	SH						FM					
	W1		W7		SCI		W1		W7		SCI	
	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD
75	30.4	14.5	1.6	0.6	15.7	8.7	50	22.2	1.6	0.8	29.4	15.9
76	20.7	14.7	1.2	0.6	5.8	4.5	35.5	20.1	1.6	0.6	11.5	8.7
77	28	17.3	1.7	0.5	13.5	11	41.2	14.7	1.6	0.5	23.7	8.9
78	42.8	11.3	1.6	0.5	26.1	7.6	40.7	13	1.5	0.4	25.3	9.2
79	28.4	8.8	1.7	0.6	12.9	4.8	53.6	20.5	1.8	0.7	32.7	13.4
80	9.5	6.6	1.8	0.2	2.7	2.8	20.3	14.2	1.8	0.5	8.3	7.4
81	34.5	15.8	1.4	0.5	16.6	8.5	44.2	18.7	1.7	0.5	25	12.2
82	10.8	9	2	0.6	4.1	5.9	41.7	17.4	1.7	0.6	23	11.7
83	35.3	17	1.3	0.5	23	11.7	30.2	15.8	1.2	0.5	18.3	10.1
84	27.3	11.7	0.9	0.3	17.1	7.9	33.1	11.9	0.9	0.3	22.3	8.4
85	15.3	9.7	2.1	0.5	5.1	3.7	22.2	15.7	2.1	0.6	9.5	8.2
86	38.7	17.8	1.6	0.6	19.9	9.1	48	19.6	1.7	0.6	28.4	12.1
87	22.8	10.4	0.5	0.4	13.5	6.1	36.9	13.6	0.7	0.5	23.8	9.1
88	26	12.3	1.2	0.4	15	7.1	61.3	15.3	1.8	0.5	34.8	8.1
89	34.9	16.5	1.4	0.4	18.5	11.9	38.3	18.3	1.4	0.6	22.8	11.8
90	36.4	25.5	1.7	0.7	17.6	18	36.8	17.2	1.5	0.6	18.2	9.9
91	31.6	10.9	1.6	0.5	17	7	37.8	11	1.6	0.5	23.4	7.6
92	16.6	10.4	1.4	0.7	7.7	6.3	31.3	24.8	1.3	0.6	16.9	16.1
93	22.1	8.4	1	0.4	12	6.3	33	9.6	1.1	0.4	18.9	6
94	11.4	9	1.4	0.6	2.5	3.2	42.2	19.1	1.7	0.6	18.3	11
95	14.4	8.2	1.4	1	5.7	3.8	32.8	21.7	1.6	0.7	18.6	14.5
96	27.2	15.3	1.6	0.6	13.3	10.3	39.3	12.8	1.4	0.4	25	8.3
97	33.6	17.8	2	0.7	18.1	12.1	45.6	17.8	1.8	0.6	27.8	11.7
98	16.8	8.9	0.8	0.4	9	5.4	41.6	17.2	1.1	0.5	26.9	12.4
99	40.9	14.6	1.7	0.5	25.5	8.8	52.9	15.5	1.8	0.4	34	11
100	20.1	9.4	1.5	0.7	9.5	6.8	41.3	19.4	1.7	0.6	24.7	12.9
101	20.6	20.2	2.4	1	10.2	17.7	37.4	16.9	1.6	0.8	19.3	10.1
102	7.1	6.4	1.3	0.4	2.3	3.2	15.1	10.5	1.6	0.5	5.5	4.8
103	31.3	14.3	1.1	0.5	16.7	8.7	39.2	14.6	1.3	0.5	24	11
104	43.5	6.5	1.6	0.3	25.7	2.4	41.9	12.8	1.5	0.3	26.8	8.9
105	30.1	29.8	1.4	0.7	18	19.4	40.6	18.2	1.6	0.7	24.3	11.9
106	26.4	14.3	0.5	0.3	14.8	8.4	26.7	12.5	0.4	0.5	16.2	8.1
107	34.6	9.8	1.4	0.4	19.5	5	30	8.4	1.2	0.3	19	6
108	26.7	20.9	1.6	0.6	14.7	18.1	36.2	16.7	1.5	0.6	23.4	13.8
109	26.2	19.6	2.6	1.2	10.7	10.2	40.4	20.8	2.5	0.7	20.2	12.8
110	17.8	9.4	1.5	0.5	7.6	5.3	31.3	13.8	1.7	0.7	16.5	9.4
111	26.1	19.6	1.1	0.3	14.9	10.8	40.1	11.6	1.3	0.3	26.2	8
112	11.3	8.6	1.6	0.2	3.3	3.8	23.6	10.7	1	0.4	13.7	7
113	24.6	8.1	1.6	0.4	11.5	4.6	48.9	19	2.1	0.5	26.4	12.9
114	26.9	14.9	1.5	0.6	13.7	10.8	39.1	15.2	1.5	0.6	23.7	10.3

COUNTY	SH						FM					
	W1		W7		SCI		W1		W7		SCI	
	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD
115	10.9	1.6	1.2	0.3	3.2	1.5	38.1	19.5	1.4	0.6	23.5	12.8
116	10.2	6.4	2.2	1	2.5	4	41	18.5	1.3	0.6	24.5	11.1
117	25.4	18.3	1.9	0.4	11.8	10.6	53.6	20.8	2.6	0.7	29.5	13.4
118	36.6	12.4	1.7	0.3	21.6	8.7	33.6	12	1.4	0.3	19.8	7.8
119	39.1	14.6	1.2	0.6	21.4	9	43.5	19.8	1	0.5	26.4	12.5
120	10.6	4.3	0.7	0.3	4.4	2.3	23.9	11.1	1	0.5	11	6.6
121	11.1	8.9	1.7	0.3	3.8	5	45	18.4	1.9	0.6	26	13
122	31.6	11.2	1	0.5	17.4	7.2	41.1	15.3	1.5	0.6	23.3	10.9
123	30.8	20.6	1.2	0.7	17.2	12.3	49.2	23.7	2	1	27.9	14
124	24.1	13.4	2.7	1.1	10.7	7.8	32.1	24.9	2.3	0.7	18	21
125	34.9	14.2	1.3	0.5	22.9	12.3	22.4	11.2	1.2	0.6	12.7	8.2
126	17.6	7.3	1.9	0.6	7	4	50.2	22.1	2.2	0.9	28.1	13.3
127	15.9	7.3	1.3	0.6	7.5	5.1	25.2	12.2	1.3	0.7	12.6	7.5
128	7.5	2.5	1.1	0.2	1.6	1	35.3	15.5	1.6	0.6	20.1	10
129	26.5	9.8	1.7	0.5	12.4	6.3	48	20.1	2.2	1	24.6	12
130	16.5	17.3	1.9	0.7	6.9	11	31.8	17.9	1.8	0.5	14.7	11
131	14.4	7.1	0.7	0.6	7.2	2.3	33.7	19.2	0.9	0.4	21.5	12.8
132	30.5	8.6	1.5	0.4	16.6	4.8	31.3	11	1.5	0.5	18.4	7.4
133	22.2	14.6	0.6	0.6	13.4	9.6	26.8	12.8	0.8	0.3	17.1	8.7
134	19.7	12.8	0.5	0.3	12.2	8	34.3	15.2	1.1	0.7	20.9	9.5
135	41.6	10.5	1.8	0.9	22.4	6.2	38.2	13.2	1.7	0.4	21.9	6.5
136	32.8	12.2	1.4	0.4	17.5	6.8	40.1	23.1	1.4	1.2	24.7	12.5
137	15.2	6	1.9	0.8	4.9	2.3	56.7	26.1	2.4	0.8	31.1	17
138	27.2	11.5	1.6	0.4	13.3	7.9	37.2	15.1	1.7	0.6	20	9.1
139	30	16.5	2	0.4	14.1	9.6	45.2	23	2.3	0.7	23.3	15.3
140	30.2	13.4	1.6	0.6	16.8	7.4	37.4	11.6	1.3	0.3	24.1	8.2
141	0	0	0	0	0	0	29.1	14.8	1	0.6	17.8	9.8
142	39.1	15.6	1.8	0.6	23.6	11.1	31	17.3	1.5	0.6	17.7	11.2
143	14.5	7.9	1.8	0.7	4.7	4.6	44.3	20.6	1.6	0.7	15.9	7.9
144	0	0	0	0	0	0	35.1	12.7	1.5	0.5	17.6	7.6
145	12.5	9	1.5	0.6	5	5.4	34.9	14.3	1.5	0.5	19.6	11.2
146	28	18.7	1.9	0.6	14.3	11.9	34.6	16.1	1.8	0.6	18.5	9.9
147	22.3	7.9	1.7	0.5	10.3	4.7	35	15.8	2.1	0.6	17.8	10.1
148	31.1	10.6	1.4	0.5	18.7	6.6	43.4	14	1.4	0.4	28.5	10.2
149	36.8	15.9	1.7	0.3	15	7.8	47.3	21.2	2	0.9	27.4	12.6
150	27.8	10.9	0.4	0.3	15.6	5.5	38.3	11.5	0.4	0.2	25.6	9.2
151	17.9	8.5	0.8	0.3	9.7	5.2	21.4	8.8	0.9	0.2	12.8	6.4
152	21	10.3	1.1	0.3	11.1	6.8	39.8	13.9	1.3	0.4	25.1	8.2
153	32.5	10.7	1.4	0.3	19.1	7.9	44.9	16	-1.5	0.5	28.8	10.6
154	31.9	19.7	2.1	0.7	12.5	9.8	44.7	18.3	1.8	0.5	18.6	10.9

COUNTY	SH						FM					
	W1		W7		SCI		W1		W7		SCI	
	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD
155	34.8	11.8	1	0.3	19.3	7.8	29.1	10.3	0.9	0.4	17.8	7.8
156	19.7	7.6	1.1	0.4	9.2	5.3	29.9	11.1	1.3	0.4	16.3	5.7
157	22.2	7	0.4	0.3	13.1	3.4	32.9	10.5	0.4	0.2	20.7	7.5
158	5.9	1.6	1.6	0.2	1.3	0.9	16.5	15.9	1.8	0.6	6.8	9.5
159	54.9	14.6	2.7	0.9	30	7.8	45.1	22.4	1.8	0.9	26.5	13
160	16.5	6.9	0.6	0.1	9.9	4.2	34.5	17.8	1.3	0.8	21.3	11.9
161	17.6	10.3	1.3	0.5	7.9	5.7	26.5	12.4	1.2	0.7	14.4	7.4
162	34	16.3	1.7	0.5	19.9	11	49.2	18.8	2.1	0.8	29.9	12.6
163	14.2	8.8	0.7	0.5	8	4.2	25.4	13.5	1.4	0.6	13.5	8.4
164	18.2	8.9	0.8	0.6	10.6	3.5	27.3	13.3	0.9	0.5	15.9	8.2
165	13.8	5.4	0.8	0.3	7	2.7	29.3	12.1	1.1	0.4	15.5	6.2
166	6.6	1.1	1.5	0.4	0.7	0.3	38.5	17.5	1.7	0.7	16.2	9.6
167	21.1	6.5	0.8	0.3	14.3	5.2	30.6	13.4	0.9	0.5	19.7	10.3
168	34.7	20.5	1.3	0.6	18.8	12.9	46.6	20.2	1.6	0.5	29.2	13.6
169	16.4	8.8	0.8	0.4	6.5	4.2	42.5	16.3	1.1	0.4	24.6	9.4
170	9.8	6.9	1.1	0.4	3.3	3.4	14.9	6.8	1.1	0.5	5.4	3.4
171	43.7	12.2	1.5	0.3	25.3	7.3	32.5	14	1.4	0.4	18.9	8.9
172	34	7.1	0.9	0.4	20.6	3.7	30	9.2	1	0.3	17.2	5
173	18.5	3.8	1.2	0.4	9.9	2.1	42.9	21.1	1.9	0.6	23.9	13
174	24.4	10.4	1.2	0.4	12.6	6.9	34.7	13.9	1.3	0.5	20.7	10.2
175	11	10.5	1.6	0.4	3.3	5.1	36.1	17	2	0.5	18.1	10.9
176	31.3	17.2	1.4	0.7	16.9	9.8	37.7	17.5	1.3	0.9	21.7	10.5
177	25.3	16.4	1.3	0.5	13.2	9.1	36.4	15.4	1.3	0.7	22.1	10.5
178	30.4	23.1	2.4	0.8	15.1	19.6	50.6	23.1	2.5	1.2	26.2	13.3
179	45.2	9.2	1.7	0.4	28.2	6	49.1	15.8	1.8	0.4	31.6	10.9
180	61.4	20.9	2.1	0.5	36.1	13	27.3	15	1.7	0.6	13.9	11.1
181	9	9	1.7	0.6	2.5	3.1	40.1	21.7	2.1	0.8	20.6	12.8
182	19.4	8.6	0.8	0.5	9.3	5.1	26.3	12.2	1	0.5	12.8	6.9
183	21.9	14.2	1.4	0.5	11	8	45.1	17.5	1.5	0.6	27	11.1
184	17	6.8	1.1	0.5	7.5	2.4	23.7	9.8	1.1	0.4	11.8	5.9
185	32.2	16.1	1.3	0.3	19.7	10.9	45.5	12.9	1.6	0.6	29.2	8.6
186	24.5	12.4	1.1	0.4	12.6	7.5	32.7	16.7	1.5	0.7	17	9.2
187	8.2	4.4	1.7	0.4	1.9	2.2	36.1	16.9	1.5	0.8	19.8	11.7
188	22.9	8.8	1.4	0.4	10.8	5.6	39.7	12	1.5	0.5	23.9	6.9
189	71.4	14.7	2.2	0.4	39.6	9.2	38.6	18.1	1.5	0.5	21.5	12
190	28.5	4.5	1.2	0.2	14.1	2.6	53.7	18.7	2	0.6	31	13
191	29.7	11.1	1.4	0.4	16.1	6.5	50.8	16.4	1.6	0.5	32.7	10.9
192	46	16.1	1.4	0.5	28	10.9	49.7	17.5	1.2	0.5	31	11.1
193	17.5	5.7	1	0.4	8.9	3.4	31.6	15.6	0.9	0.6	19	8.9
194	19.3	9.9	1.5	0.4	9.9	6.1	40.7	17.5	2	0.7	19.9	11.4

COUNTY	SH						FM					
	W1		W7		SCI		W1		W7		SCI	
	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD
195	27.8	12.6	1.2	0.4	13.5	5.8	25.1	12.2	1.3	0.6	12.9	5.9
196	17.8	11.7	1.9	0.5	6.9	6.3	38.6	12	2.4	0.5	18.4	7.3
197	40	17.9	1.5	0.4	23.4	16.6	48.5	17.9	1.9	0.6	29.7	11
199	15.9	10.1	2.3	0.3	6.3	6.5	49	20.4	2.2	0.7	26.3	15.1
200	22.3	11.1	0.9	0.2	13.2	7.6	34	17.2	1.4	0.7	20.7	10.5
201	23.7	13	1.3	0.7	12.8	9.9	40	14.5	1.2	0.6	24.6	9.6
202	43	14.7	1.2	0.5	26.7	9.2	48.3	15.2	1.4	0.6	31.8	12.5
203	37.3	12.8	1.4	0.6	21.5	7.3	45.4	16.4	1.3	0.6	28.9	11.7
204	20.7	10.4	1.4	1	8.5	5.2	31	9.8	1.2	0.7	17.7	6.7
205	23	11.4	2	0.6	9.6	5.7	45.7	25.9	2.8	1.1	23.7	14.8
206	28.6	16.1	1.3	0.6	15.6	9.8	32.2	16.9	1.2	0.6	19.5	11.3
207	0	0	0	0	0	0	35	15.9	1	0.9	19.4	9.7
208	22.4	9.5	1.2	0.4	11.3	4.8	38.1	19	1.5	0.6	22.7	12
209	19.7	6.8	0.9	0.5	10.4	3.8	30.3	20.4	1.4	0.6	17.1	15.5
210	36.6	20.3	1.5	0.7	19	12	53.5	20.2	1.6	0.7	33.5	15.2
211	34.8	6.2	1.4	0.4	22.2	3.9	49.6	15	1.7	0.4	32.5	11.2
212	25.4	10.6	1	0.4	14.4	7.2	37.8	12.2	1.2	0.5	23.8	9.4
213	15.7	3.1	1.2	0.3	5.6	1.1	28.6	13.5	1	0.4	16	8.4
214	0	0	0	0	0	0	37.9	17.1	1.7	0.7	21.2	9.3
215	17.4	7.3	1	0.5	8.5	3.5	28.2	14.6	1.1	0.5	15.1	9.1
216	38.7	23.9	1.6	0.8	21.8	13.6	27.1	10.7	1.1	0.3	17.2	7
217	53.6	24	1.9	0.9	30.8	15.4	37.7	16.9	1.4	0.3	22.8	12.2
218	17.6	6.3	0.5	0.2	8.5	4.3	39.4	16	1	0.7	22.7	9.4
219	42.9	17.5	1.6	0.5	26.5	10.3	45.6	13.1	1.7	0.5	29.5	9.4
220	7.4	5	1.1	0.5	2	2.2	16.1	10.6	1	0.4	7.2	6.1
221	10.9	7.9	1.3	0.4	3.4	4	30.7	16.9	1.2	0.5	18.5	11.8
222	23.4	12.4	0.6	0.3	14.1	7.3	33.6	14.4	1.2	0.6	18.3	7.1
223	38.6	6.4	1.2	0.2	24.3	4	40.6	9.9	1.2	0.2	27.6	6.8
224	26.8	17.8	1.4	0.5	11.9	12.4	37.3	17.7	1.5	0.7	21.1	12.3
225	23.6	8.3	1.4	0.5	11	6.9	41	16.1	1.5	0.6	23.3	10.1
226	22.3	7.9	1.1	0.4	11.4	3.9	34.1	13.7	1.4	0.6	19.6	8.5
227	8.7	4.4	0.6	0.5	4.3	2.1	19.6	12	1	0.8	10.3	6.3
228	21.8	11.6	1.7	0.7	9	6.7	40.9	14.7	1.7	0.6	23.3	11.2
229	0	0	0	0	0	0	34.9	9.4	1.1	0.6	21	6.4
230	27	9.9	1.1	0.3	13.6	5.9	33.6	9.9	1	0.4	19.9	6.4
231	20	9.8	1.1	0.6	10	4.4	36.8	15.6	1.2	0.4	19.7	10
232	26.4	13.5	1.2	0.6	15.3	7.4	36.9	23.2	1.5	0.9	23.2	15.6
233	33	20.6	0.8	0.4	21.5	13	36	21.2	0.8	0.5	23.6	12.8
234	22.2	15.9	1.5	0.5	11.1	9.4	39.5	14.9	1.8	0.6	23.8	10.6
235	18.3	9.4	1.9	0.5	6	4.2	28.7	16.5	1.8	0.8	14	9.1

COUNTY	SH						FM					
	W1		W7		SCI		W1		W7		SCI	
	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD	MEAN	STD
236	7.5	2.5	1.5	0.6	1.1	1	35.6	15.5	1.5	0.5	12.8	7.6
237	5.6	3	1.1	0.4	1.6	1	27.5	14.2	1.4	0.6	12.9	8.4
238	13.3	6.5	0.8	0.2	7.4	4.2	22.7	12.7	0.9	0.5	12.6	6.7
239	18	10.6	1.6	0.6	4	3.2	35	16.2	1.6	0.7	13	7.9
240	32.1	28.2	2.2	1.4	16.6	16.8	37.9	19.2	1.5	0.8	22	9.8
241	10.5	7.1	1.9	0.3	2.3	2.6	39.6	18.2	1.9	0.6	18.5	12.4
242	23.9	3.9	1.2	0.4	12.8	1.7	33.6	12.5	1.5	0.4	19.6	7.3
243	26.2	17.9	1.6	0.5	11.5	10.9	44.6	17.2	1.4	0.4	26.1	12.5
244	64.6	21.3	1.8	0.7	36	12.2	39.8	13.8	1.4	0.4	22.1	8.4
245	20.5	7.4	1.6	0.3	8.7	3.5	56.9	22.6	2.8	0.7	30.3	14.8
246	19.2	9.5	0.7	0.6	9	5.1	29.3	14	1.1	0.7	15.2	8.3
247	25.5	17.1	1.4	0.5	16	12.7	40	18.4	1.6	0.6	25.2	12.8
248	27.9	8.1	1	0.3	14.1	4.5	24.1	3.5	1.1	0.3	13.8	2.3
249	9.5	7	0.9	0.4	3.6	4	26.4	10.1	1	0.4	13.2	7
250	34.9	12.3	1.5	0.4	20.2	9.4	37.1	15.1	1.4	0.6	22.5	10
251	32.2	16.8	1	0.3	21	11.8	46.6	11.1	1.2	0.3	29.2	7.2
252	17.7	9.5	1.2	0.5	7.5	5.9	33.8	18.8	1.1	0.5	18.4	12.9
253	48.1	33.9	2.4	1.1	25.7	20.6	25.3	13.5	1.3	0.5	14.3	8.7
254	0	0	0	0	0	0	36.2	17.4	1.8	0.7	21.5	10.8
ALL	25.2	16.9	1.4	0.7	13.1	10.9	36.5	18.3	1.5	0.7	20.7	12.1

The preceding table can be used to compare the results of deflection testing on State Highways (SH) and Farm-to-Market (FM) roads. For example, if test results on a given State Highway in Young County (252) exceeded 27.2 mils (17.7 + 9.5), then this site could be considered weak in comparision with other typical sections in the county.

Structural Strength Index

Structural Strength Index (SSI) is a function of W7 and SCI. SSI is used by PES to identify areas of poor subgrade and potentially weak base/surface layers. The higher the value of W7 and SCI, the lower the SSI score. SSI is further adjusted downward for increasing amounts of rainfall and truck traffic. Thus for two pavements having similar deflections, the pavement with higher rainfall and traffic will have the lower SSI. PES does not incorportate SSI into any pavement scores at this time. SSI values may be divided into three categories of pavement structural strength, as shown in Table 6.3:

TABLE 6.3 -- SSI Categories.

STRUCTURAL STRENGTH INDEX	CLASS
70-100	STRONG
40-69	MODERATE
1-39	WEAK

The 1989 PES structural survey indicated that 31.7 percent of the tested mainlane mileage had an SSI below 70, as indicated in Figure 6.3. These pavements which fall into the moderate and weak catagories are considered "structurally inferior." Such "inferior" pavements may be in good to very good condition, but they can rapidly deteriorate unless frequently monitored.

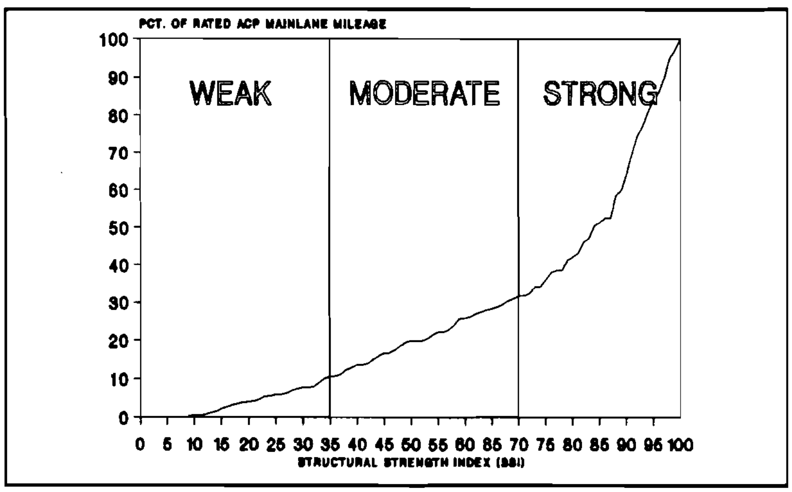

Figure 6.3 -- Statewide Distribution of Structural Strength Index Values 1989 PES.

Figures 6.4 through 6.8 indicate the SSI distribution for each pavement condition class in 1989. As illustrated in these figures, the good pavements are predominantly stronger than the poorer condition pavements, which tend to exhibit weaker structural strengths. This is expected, as the ability of a pavement to remain in good condition is directly influenced by its structural integrity. In 1989, the estimated ACP lane mileage was 158,705 miles, of which 103,665 miles were estimated to be in very good condition. However, 25 percent (26,900 miles) of these very good pavements were "structurally inferior". This is an indication that we are covering up distress with seal coats and thin overlays, and doing little to improve the structural strength of these pavements. This is also reflected by the decreasing occurrence of all distresses except for rutting.

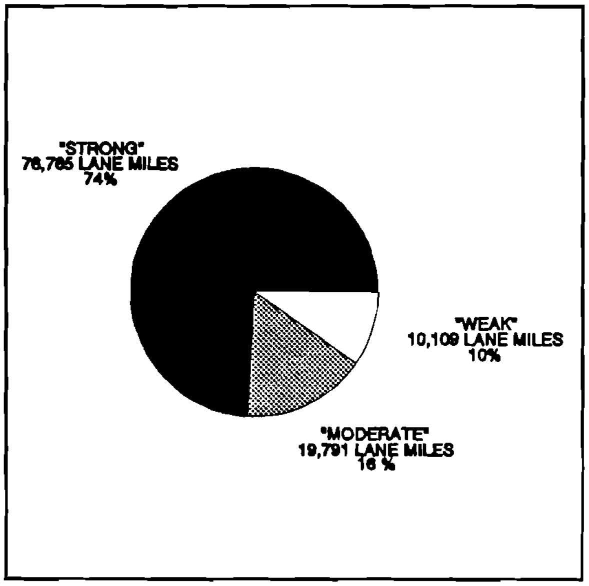

Figure 6.4 -- SSI Distribution for Condition Class "A" (Very Good) in 1989.

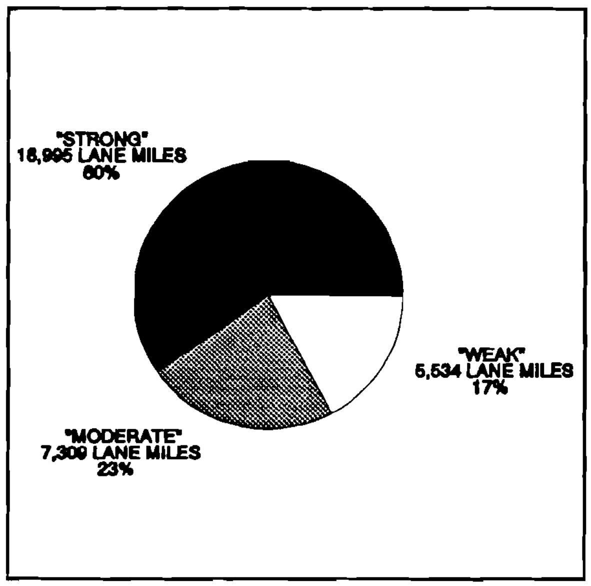

Figure 6.5 -- SSI Distribution for Condition Class "B" (Good) in 1989.

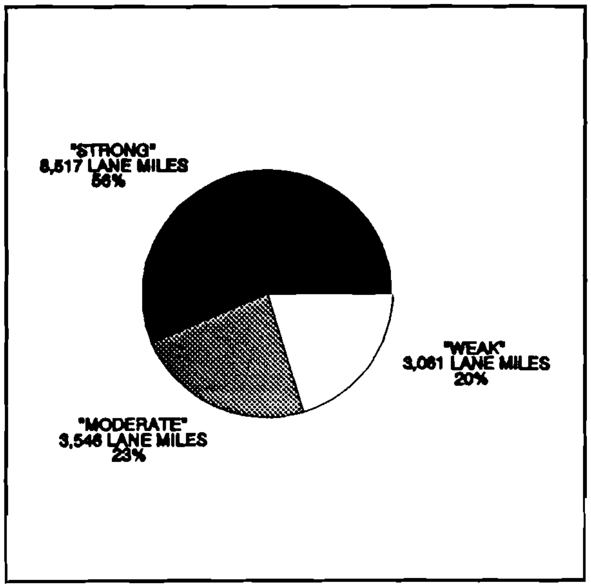

Figure 6.6 -- SSI Distribution for Condition Class "C" (Fair) in 1989.

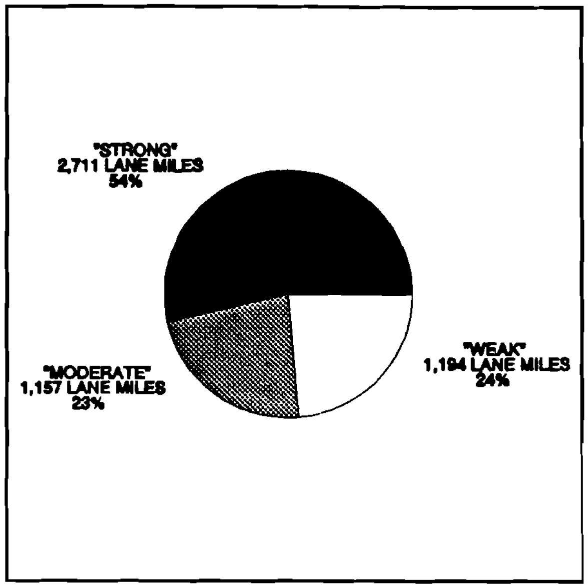

Figure 6.7 -- SSI Distribution for Condition Class "D" (Poor) in 1989.

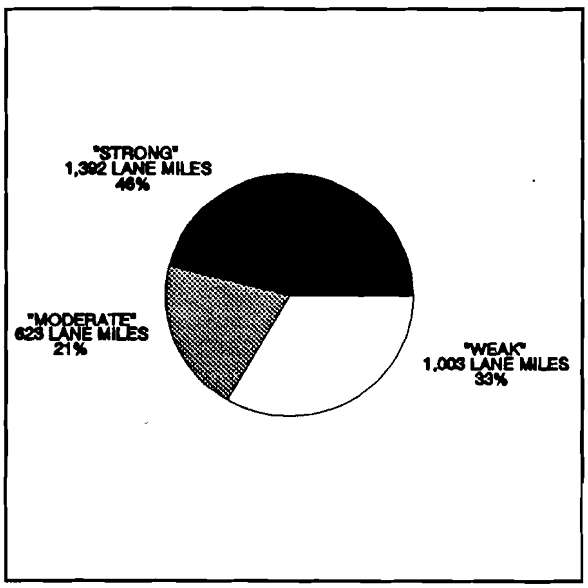

Figure 6.8 -- SSI Distribution for Condition Class "F" (Very Poor) in 1989.

Effect of Subgrade Support and Base/Surface Stiffness on Pavement Condition

The first step in building long-lasting roads is to establish a good subgrade support. The following maps (Figures 6.9 through 6.11) show the ranges found throughout the state.

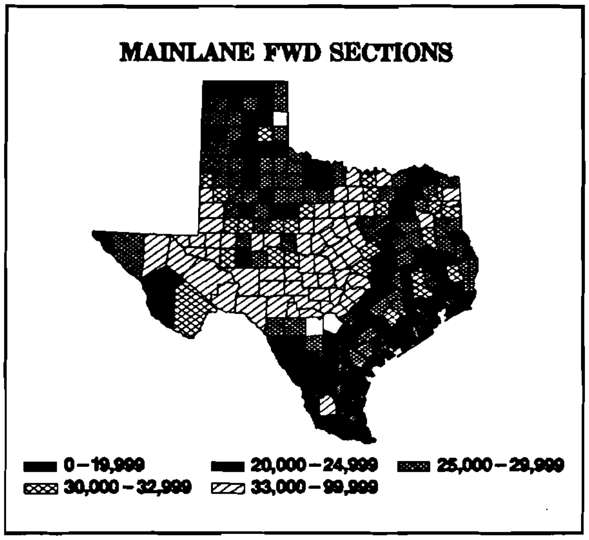

Figure 6.9 -- Subgrade Support 1987 PES.

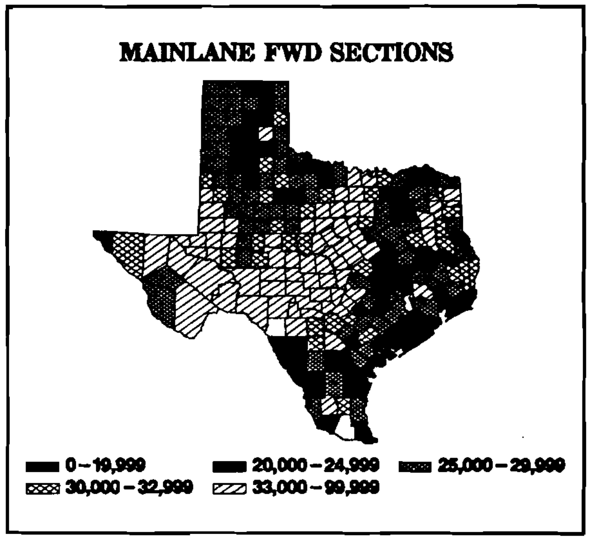

Figure 6.10 -- Subgrade Support 1988 PES.

Major geologic features are readily apparent, especially the single-striped counties around the Balcones Escarpment, Llano Uplift, and Edwards Plateau regions of central Texas (the white regions indicate counties where deflection data were not available).

Also note that, although individual counties may change, the overall distribution of subgrade remains about the same. This is to be expected, because subgrade is a relatively natural material.

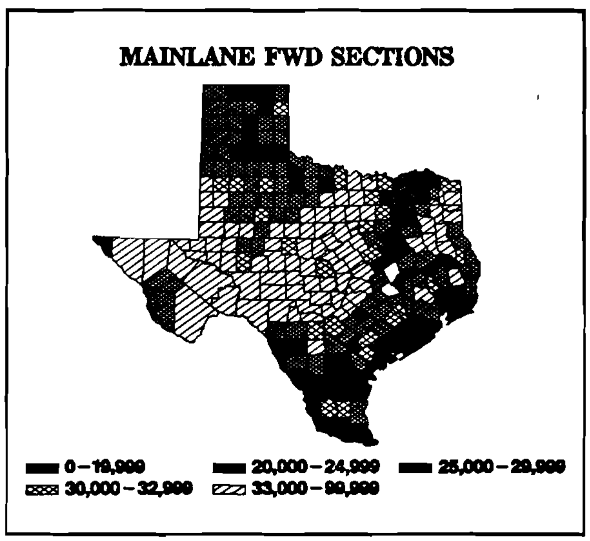

Figure 6.11 -- Subgrade Support 1989 PES.

The next step is to provide a strong base/surface. Figures 6.12 through 6.14 display the average surface curvature index (SCI) -- a measure of base and surface stiffness -- for each county since 1987.

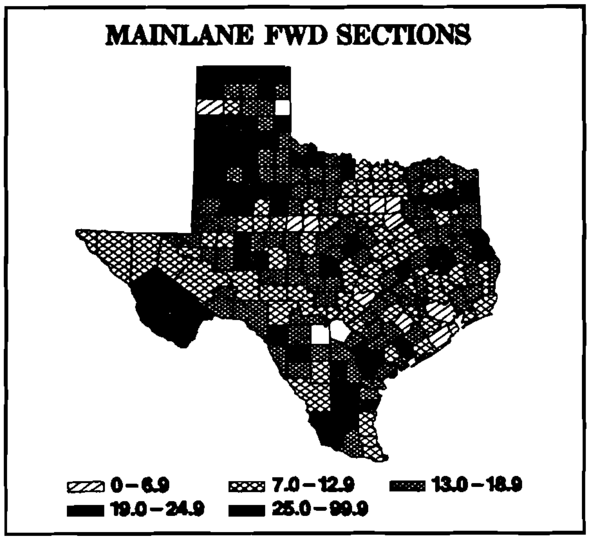

Figure 6.12 -- Surface Curvature Index 1987 PES.

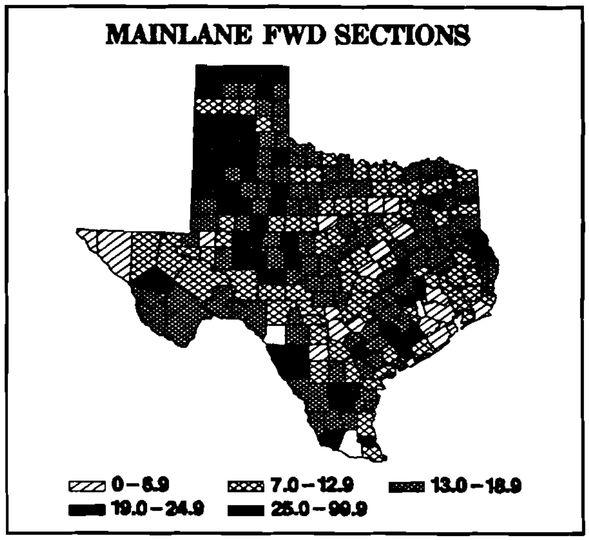

Figure 6.13 -- Surface Curvature Index 1988 PES.

The SCI values indicate the relative quality of the "man-made" roadbed material, as opposed to the "natural" subgrade materials. Figures 6.12 through 6.14 display some of the same general trends as Figures 6.9 through 6.11, identifying areas where local (subgrade) material is being used in the pavement construction. However, predominant use of seal coats in some rural counties will worsen the average stiffness, since the light-duty seal coat surface has little or no stiffness. "Very Good" values for the major urban counties (Harris, Dallas, Travis, Tarrant, and Jefferson) indicate the use of better materials or thicker sections in construction. This practice has become more prevalent, given the infeasibility of frequent maintenance in urban areas, however it places a greater burden on District design/construction personnel because more money and effort are at risk if an isolated section fails prematurely.

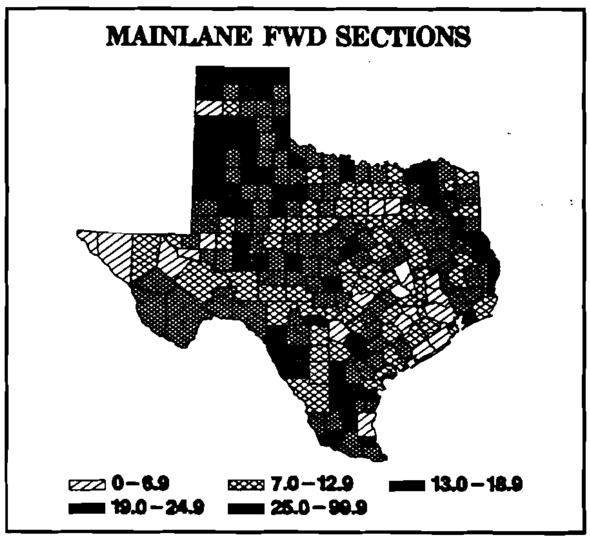

Figure 6.14 -- Surface Curvature Index 1989 PES.

The combination of the subgrade support and base/surface data should directly yield an overall picture of county pavement condition. However, the following maps (Figures 6.15 through 6.17) demonstrate that pavement condition (at least surface condition, as measured by PES) is dependent on other factors as well.

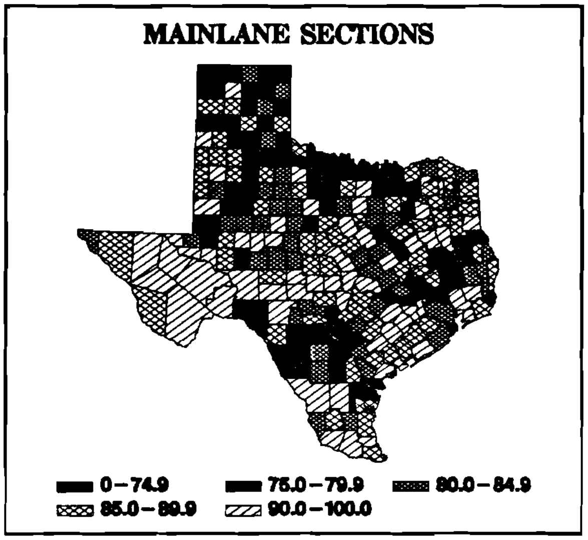

Figure 6.15 -- Pavement Condition 1987 PES.

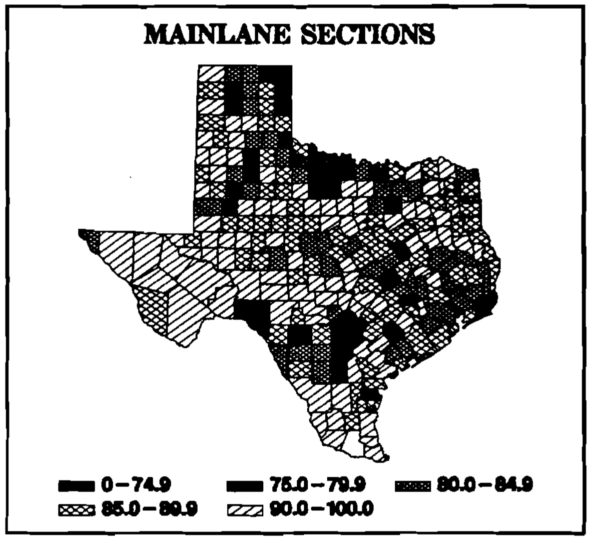

Figure 6.16 -- Pavement Condtion 1988 PES.

"Good" and "Very Good" pavement condition exists in many counties throughout the state, even in those regions with "Poor" or "Very Poor" subgrade support. The most striking example is the entire coastal region, where subgrade support is poor and base/surface stiffness is generally fair, at best, with a scattering of better values.

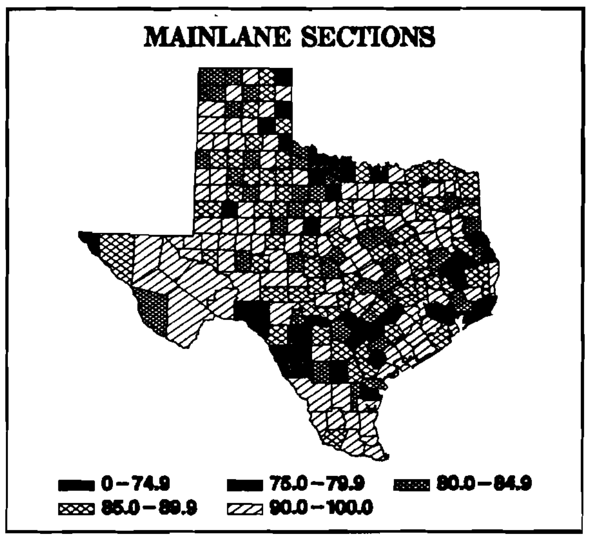

Figure 6.17 -- Pavement Condition 1989 PES.

This prevalence of "Good" and "Very Good" pavement condition suggests several interesting causes:

1. Unusually long-lasting maintenance/design practices, which are capable of providing quality pavement, even in adverse conditions.

2. Higher-level (even "overdesigned") treatments, applied at the same frequency as normally-adequate "lesser" treatments.

3. Unusually frequent maintenance/rehabilitation practices (e.g., seal coats applied every three years, when once every seven years would be normally expected). This is a particularly worrisome cause, since it suggests that work is being misapplied and is not lasting.

4. Errors in the PES computations of pavement condition or subgrade support.

In the past, there were some regions (the Panhandle in 1987) which had poorer condition and poorer subgrade. A review of treatment and funding allocations was recommended in the 1987 report and now the pavement condition in this region has improved significantly.

CHAPTER 7
GENERAL STATEWIDE RUTTING TRENDS

Approximately one-third of the mainlane PES flexible pavement sections have measurable amounts of rutting (i.e., ruts at least ½" deep). Shallow rutting is typically only a problem during wet weather conditions when water buildup within the ruts contributes to hydroplaning whereby the tires of vehicles are actually separating from contact with the road surface. Deeper rutting amplifies the potential for hydroplaning and induces steering instabilities due to the forces associated with displacing the pooled water. Considering that the Western Association of State Highway and Transportation Officials (WASHTO) has suggested that any pavement with a rut depth of ½" or more has reached the end of its design life, the PES rutting values represent a sizable problem. Figure 7.1 shows that the number of sections containing any amount of rutting greater than ½" deep continues to fluctuate about an average of 30%.

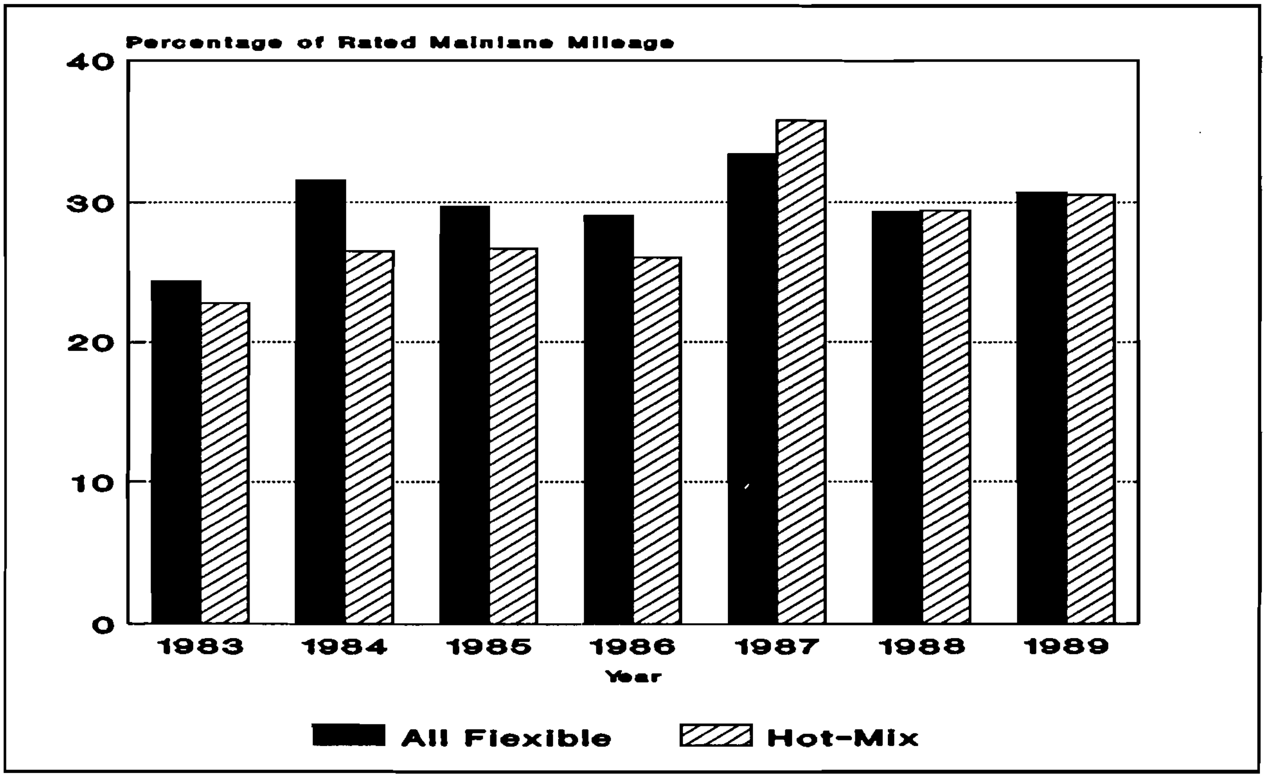

Figure 7.1 -- Flexible Vs. Hot-Mix PES Sections, Rutting on Texas Highways 1983-1989.

The flexible sections depicted in this figure are made up of all PES asphaltic pavements (types 4-10) while the hot-mix sections are made up of only PES pavement types 4-6, 9 typical of thicker asphaltic pavements (exclusive of asphalt/concrete combinations).

High rutting values would normally be expected only on the thin-surface seal coat pavements, however hot-mix pavements also show a substantial amount of rutting. In 1987, rutting on hot-mix pavement increased rapidly, surpassing the frequency observed on flexible pavements as a whole for the first time in five years. More frequent rutting on the hot-mix sections is troubling because hot-mix pavements are supposed to be more carefully designed and constructed than the other asphaltic pavements. Deficiencies (especially premature ones) observed in such a pavement, no matter how unavoidable they may be technically, could undermine the public's confidence in the highway department. Apparently the quality control on hot-mix sections was improved upon in 1988 and 1989, after publication of the 1987 PES Annual Report.

Even though the percentage of rutting on hot-mix sections appears to be improving when compared to all flexible sections inclusive, there still appears to be a trend toward increased rutting throughout the highway system. Comparison of the PES pavement distress ratings and deflection data indicates that, although structurally weak subgrade and base/surface layers are no doubt contributing to the increased rutting, enough rutting is still occurring on "strong" sub-surface layers to warrant closer examination of pavement material selection, mix design, paving practices, etc...

It must be mentioned that audits of PES distress rating data indicate that rutting is one of the more difficult distresses to rate consistently. Even when asked to rate rutting into three categories (<½", ½" to 1", and >1" deep), independent rating teams typically agreed only about 74 percent of the time and this was primarily due to general consensus on sections having little or no rutting.

TABLE 7.1 -- Percent agreement on types of rutting.

RUT CLASS	PERCENT AGREEMENT			
	1986	1987	1988	1989
<½	83.66	79.79	81.92	85.65
½" to 1"	50.36	39.20	41.94	45.22
>1"	37.56	27.77	31.58	17.39
ALL	74.25	65.61	72.51	72.71

NOTE: Ruts 3" or deeper are measured along their length and rated as failures. Failures in excess of 40 feet are rated as multiple failures as determined by dividing the total number of feet by 40.

As stated previously in Chapter 3, D-18PM plans to automate the collection of rut depth measurements. These automated methods will allow more accurate measurements of rutting to be obtained, particularly in sections where rutting may not be readily apparent to visual raters.

Figures 7.2 through 7.8 depict the percentage of rutting in excess of ½" for each County in the State. The black shaded areas indicate areas of worst rutting. Totally white Counties are shown where no rut data was collected.

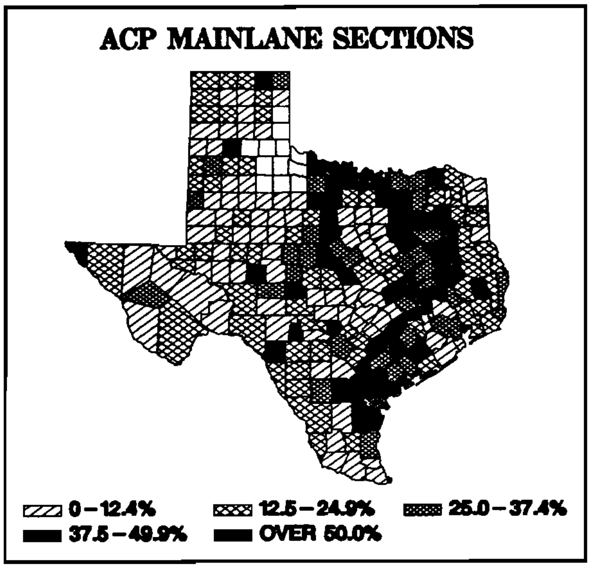

Figure 7.2 -- Rutting on Texas Highways 1983 PES.

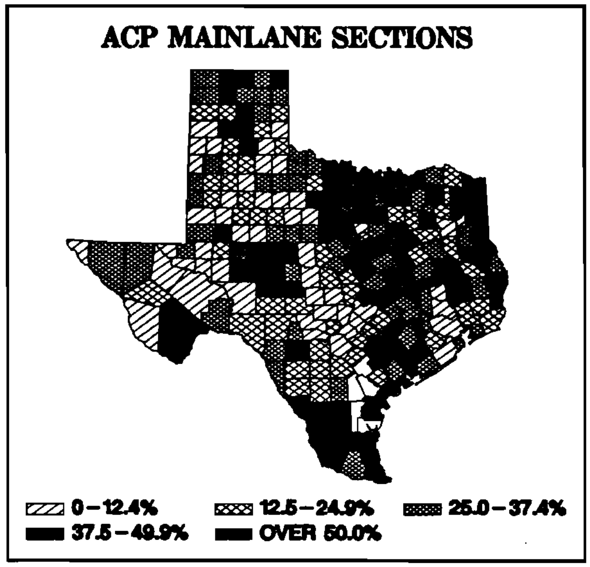

Figure 7.3 -- Rutting on Texas Highways 1984 PES.

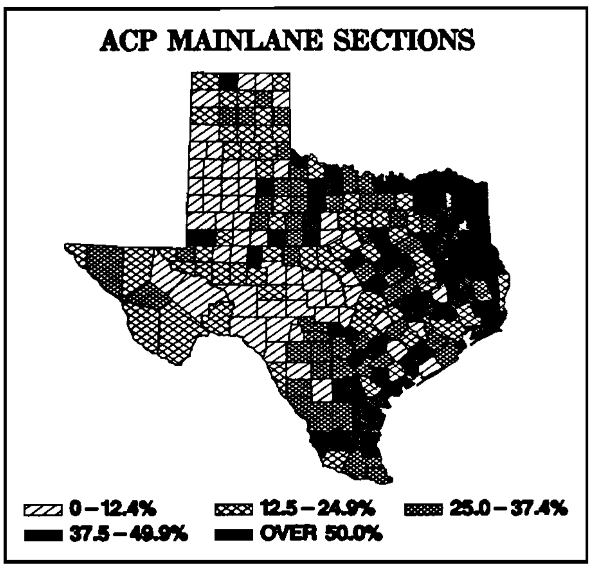

Figure 7.4 -- Rutting on Texas Highways 1985 PES.

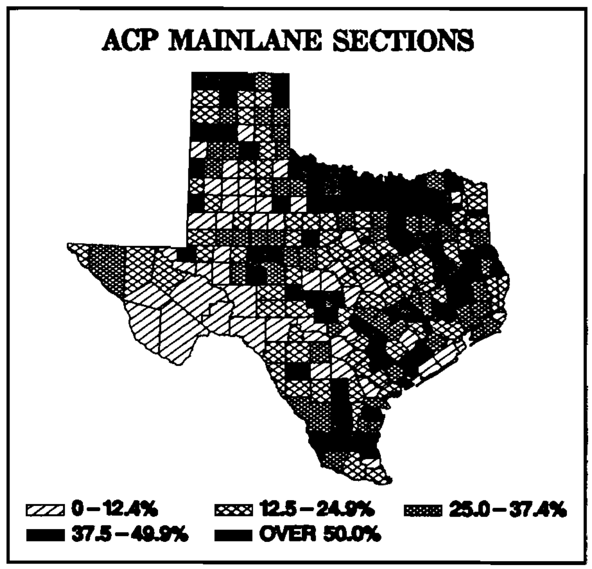

Figure 7.5 -- Rutting on Texas Highways 1986 PES.

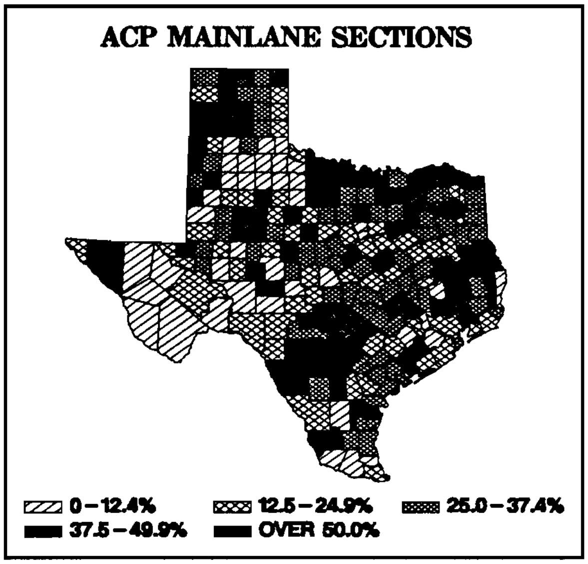

Figure 7.6 -- Rutting on Texas Highways 1987 PES.

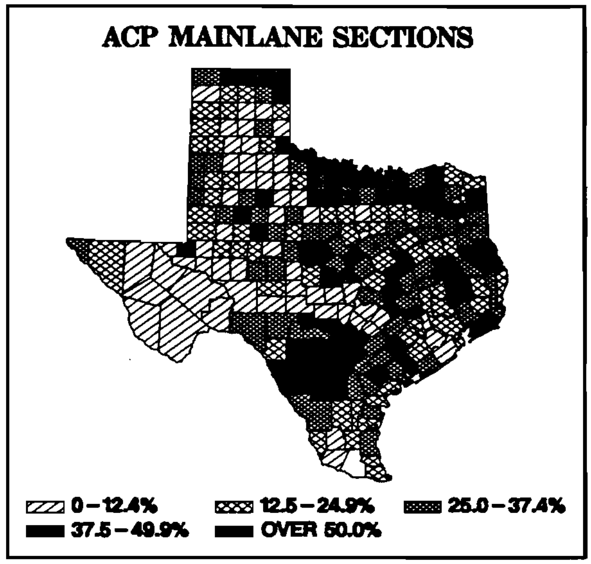

Figure 7.7 -- Rutting on Texas Highways 1988 PES.

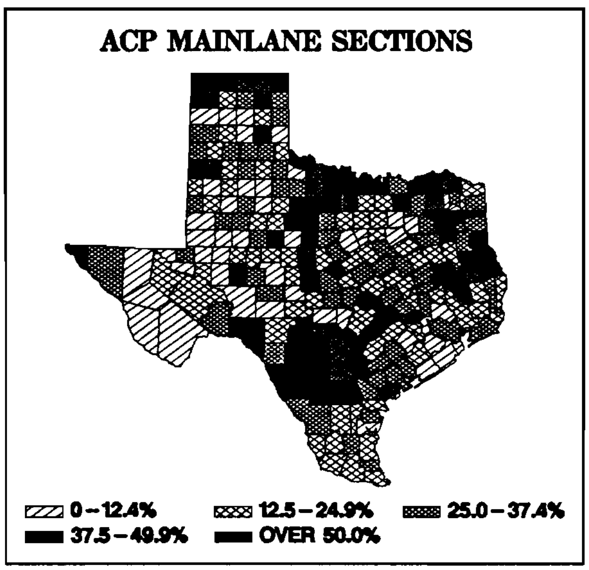

Figure 7.8 -- Rutting on Texas Highways 1989 PES.

Evidence of the hard freeze in 1983 that extended into the southern portions of the State is reflected in the map of 1984. During this freeze, the pavements in the south experienced freeze-thaw cycles that they were not designed for and henceforth, developed a large number of porous cracks which let water through to the subgrade and consequently undermined subgrade support with the result being increased rutting. Since funding was also reduced in 1984, these areas were unable to make a quick recovery from the freeze damage.

Some Districts continue to have major rutting problems as evidenced by certain areas of localized rutting throughout the years. A review of the funding and paving techniques in these Districts may be warranted.

-Notes-

CHAPTER 8
CONSTRUCTION AND MAINTENANCE FUNDING

One of the most important factors in maintaining a highway network in good condition is sufficient funding. The Texas highway network had deteriorated to a poor level in 1984, with a large percentage of the system mainlane mileage in fair to very poor condition, as seen in Figure 8.1. Fuel tax increases were implemented in 1985 and again in 1987 to provide sufficient funding for the Texas highway network. As a result, the Texas highway network was in its best condition in 1989. This chapter will examine the construction and maintenance expenditures from Fiscal Year (FY) 84-90 and their relationship to the overall condition of the Texas highway network.

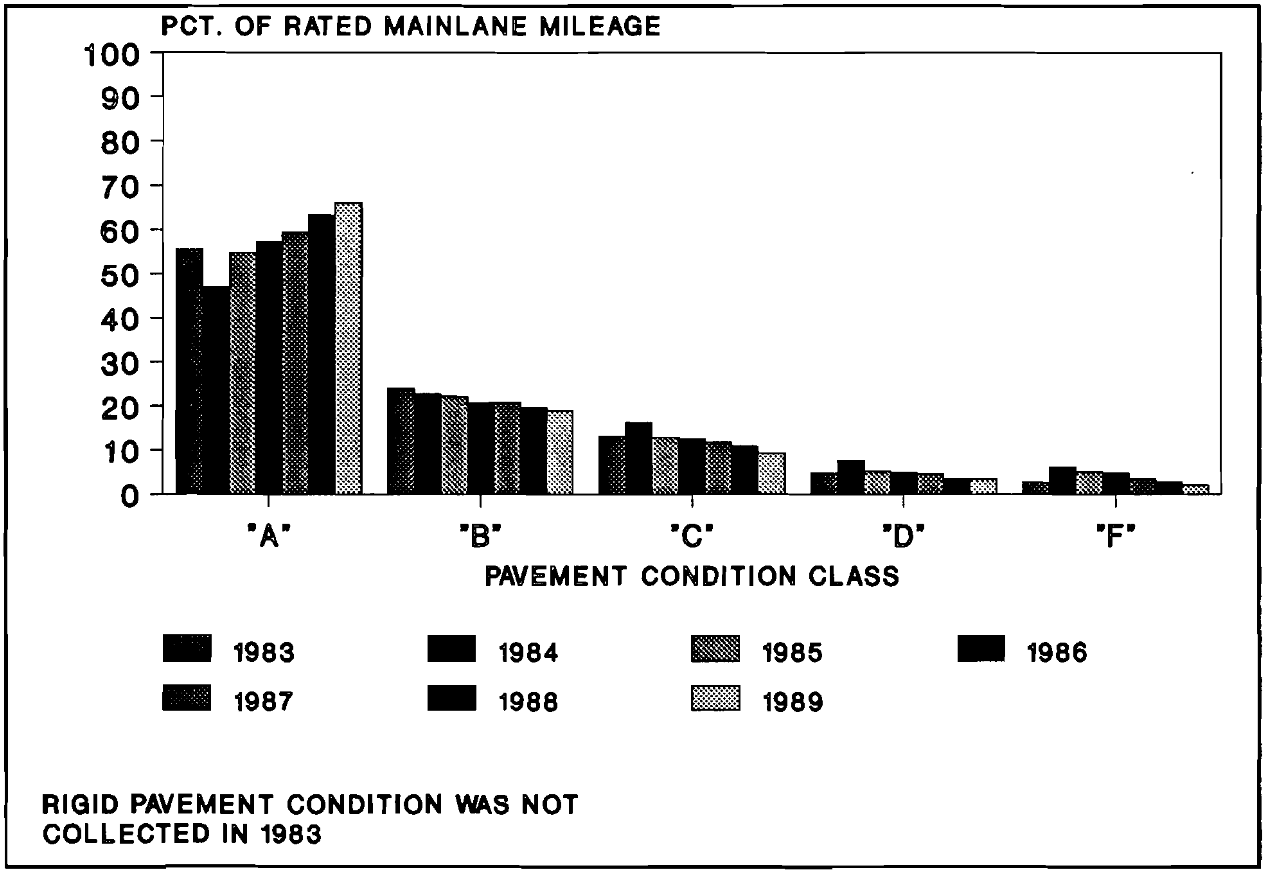

Figure 8.1 -- Condition of Texas' Highway Network 1983-1989.

Construction Expenditures

Figure 8.2 indicates construction expenditures from FY84 through FY90 in "Actual" dollars and FY84 "Constant" dollars. The FY84 "Constant" dollars were calculated using the Kiplinger Consumer Price Index. As mention earlier, a fuel tax increase was implemented in 1985, which accounts for the construction budget nearly doubling in FY 86. With this increase, the condition of the Texas highway network started improving. The construction budget peaked in FY88, with more than two billion dollars being spent. With most construction projects taking approximately two years to complete, the Texas highway network was in its best condition in 1989. However, when inflation is considered, the construction budget has never topped FY86 levels. If these funding trends continue, pavement condition of Texas highways will start a downward slide, and more funds will have to be spent to return it to its present level.

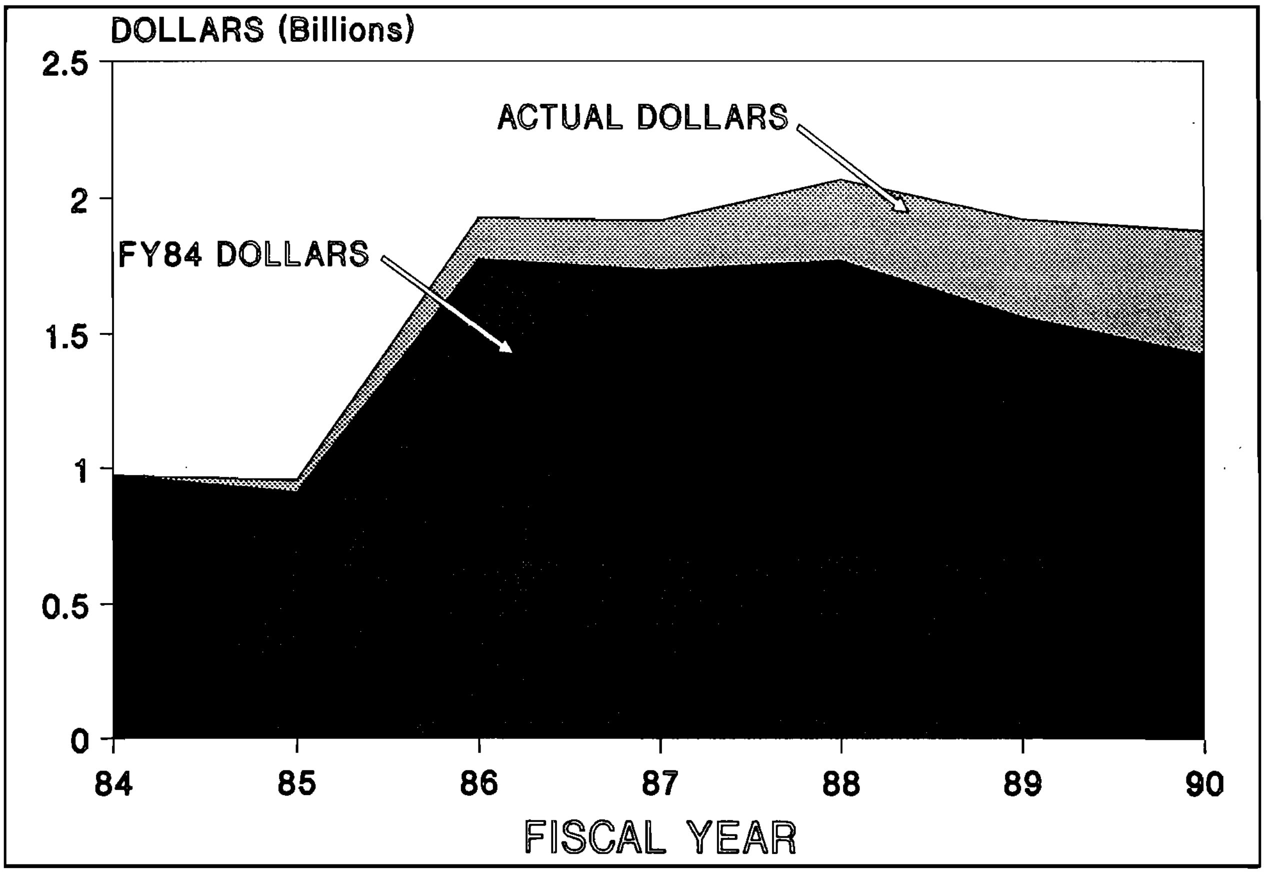

Figure 8.2 -- Construction Expenditures in Actual and FY84 Dollars FY84-FY90.

Maintenance Expenditures

Figure 8.3 indicates the maintenance expenditures from FY84-FY90 in "Actual" dollars and FY84 "Constant" dollars. In "Constant" dollars, the maintenance expenditures increased from $363 million to $451 million between FY84 and FY90. In FY88, maintenance expenditures were at their greatest, with $477 million FY84 dollars being spent. This increase in maintenance funding is another reason that the condition of the Texas highway network has improved to its current level. Maintenance treatments are often used in lieu of rehabilitation or reconstruction due to funding restrictions. These maintenance treatments (e.g. seal coats and thin-overlays) improve the roadway's surface condition, but do nothing for the structural strength. When these treatments are used, pavement condition is improved, but must be monitored closely, or rapid deterioration will occur.

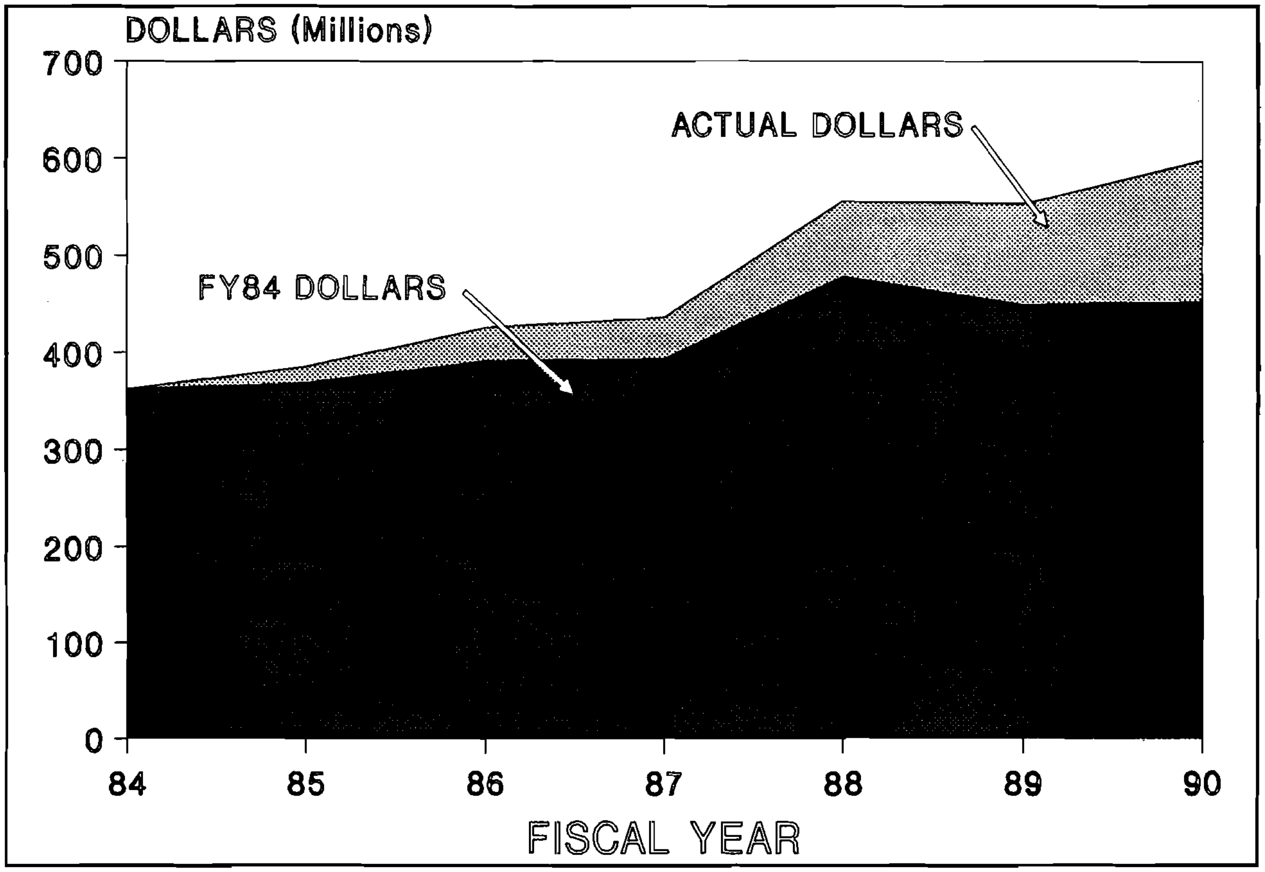

Figure 8.3 -- Maintenance Expenditures in Actual and FY84 Dollars FY84-FY90.

-Notes-

CHAPTER 9
CONCLUSIONS

Analysis of the PES condition data indicates that the Texas highway network has continued to improve in pavement condition since 1984. The gains in condition made in 1987, 1988, and 1989 are slight compared to 1985 and 1986. Almost 90 percent of the network is in good to very good condition, however areas of poor subgrade and possible weak base/subgrade layers have been identified by structural strength testing. The decreasing occurrence of all distresses except for rutting provides additional evidence to support this conclusion. Pavements with good condition but "inferior" structure may be due to the use of seal coats or thin overlays in lieu of reconstruction or rehabilitation because of funding constraints. Pavement condition gained by the use of these treatments could be lost rapidly, if not diligently monitored and maintained.

Rehabilitation needs decreased only slightly in 1989, when compared to 1988. This slight decline could be an indication that the network's condition has peaked and is about to begin a downward cycle, especially if funding is reduced substantially.

The precision of the PES visual distress ratings was 82.2 percent ± 15 points in 1989. This was better than previous years and may be the result of increased rater awareness due to audit analysis reports being discussed at the annual rater training course. Implementation of more automated data collection equipment is expected to improve precision. Starting in the fall of 1991, implementation will begin on an automated rut measuring device attached to the SIometer. Research is also underway to automate the other visual distress ratings.