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Comparison of the SHRP Profilometers

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Contents

Abstract

This report compares pavement profile data collected by four Profilometers™ used by SHRP's Long Term Pavement Performance Program (LTPP). Three of the Profilometers were identical; the sensors of the fourth were closer together. The purpose of the comparison is to determine if the Profilometers can collect repeatable data with respect to each other as well as individually at a given site, and whether they are collecting accurate data (determined by comparing the International Roughness Index computed from Profilometer data with that computed from Dipstick™ data).

1. INTRODUCTION

The Long Term Pavement Performance Program (LTPP) is one of four major technical research areas of the Strategic Highway Research Program (SHRP). As part of the LTPP study, pavement profile data are being collected at approximately 800 GPS and 100 SPS sites in the United States and Canada (1). The profile data are collected by regional contractors from the four regions: North Central, Western, North Atlantic and Southern. Each region employs its own Profilometer to collect data within the region. The four Profilometers that are being used have been manufactured by K.J. Law Engineers. Three of these Profilometers are identical. They were purchased by SHRP and then released to the regional contractors. The fourth Profilometer which belongs to the FHWA is on loan to SHRP. Although this Profilometer contains the same electro-mechanical equipment as the other Profilometers, the distance between the sensors in this unit is 54 in., while that of the other Profilometers is 66 in.(1). This Profilometer with the shorter distance between the sensors is being used by the North Central region. The Profilometers collect both the left and the right wheelpath profiles. This profile data is used to compute the International Roughness Index (IRI) of each wheelpath. Other statistical summarizes such as RMSVA, slope variance, etc. can also be computed using the profile measurements.

A comparative study between the Profilometers from the four SHRP regions was conducted in Ann Arbor, Michigan from June 3 to 7, 1991. The objectives of this Profilometer comparison are described in the next section.

2. OBJECTIVES

The following were the main objectives of the Profilometer comparison study.

1. Determine if the Profilometers can collect repeatable data with respect to each other.
2. Determine if repeatable data can be obtained by each Profilometer at a given site.
3. Determine if accurate data are being collected by the Profilometers, by comparing the IRI computed from Profilometer data with IRI computed from Dipstick data.

3. DESIGN OF EXPERIMENT

Several factors were identified as having a potential influence on the measurements collected by the Profilometers. Theses factors include: Profilometer used, speed of testing, surface type and level of roughness. The experimental plan selected for this study is shown in Fig. 3.1. In order to evaluate the influence of each factor the IRI index was used to summarize the measured profiles.

As shown in Fig. 3.1 eight pavement sections were used in this study. Four of the pavement sections were asphalt concrete while the other four were portland cement concrete. For each pavement type two levels of roughness were considered. A pavement was categorized as smooth if the IRI was less than 125 in./mile and as medium if the IRI was between 125 and 300 in./mile. Thus, for each pavement type, two of the selected pavements fell into the smooth category while the other two fell into the medium roughness category. At each section, each Profilometer tested at 40 and 50 MPH.

4. SELECTION OF SECTIONS AND DATA COLLECTION

4.1 Selection of Sections

The sections included in the Profilometer comparison study were selected such that they were similar to typical GPS sections. The following guidelines were followed in selecting the test sections (1).

1. The test section should be 500 ft long with similar profile characteristics throughout the 500 ft length as well as immediately before and after the test section.

2. The cross profile in the test section should be as uniform as possible and sites with changing cross profiles, bumps or aberrations should be avoided.

3. The test section should not be located on a horizontal curve greater than 3 degrees or on a vertical grade exceeding 4%.

4. The test section should not include any intersections.

5. The posted speed limit at the location must be at least 50 MPH.

6. The pavement reflectivity should be uniform throughout the test section to avoid lost lock situations.

Information regarding location, surface type and roughness level are presented in Table 4.1 for each section.

Fig. 3.1. Experimental Plan

SPEED	PROFILOMETER	A	B	C	D	E	F	G	H
SURFACE TYPE		ASPHALT				CONCRETE			
ROUGHNESS		SMOOTH		MEDIUM		SMOOTH		MEDIUM	
SECTION		A	B	C	D	E	F	G	H
40	NORTH CENTRAL								
	WESTERN								
	NORTH ATLANTIC								
	SOUTHERN								
50	NORTH CENTRAL								
	WESTERN								
	NORTH ATLANTIC								
	SOUTHERN								

Table 4.1 Sections for Comparative Testing

Section	Route	Direction	Surface Type	Roughness Level
1	M 52	Northbound	Asphalt	Smooth
2	US 12	Eastbound	Asphalt	Medium
3	US 12	Westbound	Asphalt	Medium
4	US 23	Southbound	Asphalt	Smooth
5	M 50	Westbound	Concrete	Medium
6	M 14	Eastbound	Concrete	Medium
7	M 14	Westbound	Concrete	Smooth
8	US 12	Westbound	Concrete	Smooth

4.2 Profilometer Data Collection

Every Profilometer was scheduled to test one asphalt and one concrete section per day. The concrete pavements were tested in the afternoon to minimize the effects of slab curling. The Profilometers were to test the sites according to the schedule shown in Table 4.2. This schedule was set up using a random number generator for the order of the Profilometers and the sites to be tested each day.

The guidelines given in the SHRP-LTPP manual for Profile Measurements (3) were generally followed when collecting profile data. However, for the comparative tests the left wheelpath was marked at each site. The drivers followed this wheelpath so that each Profilometer would collect similar data. The sites were first tested at 50 MPH and thereafter at 40 MPH. Each Profilometer was scheduled to perform six runs at the two speeds for a total of 12 runs per site. Additional runs were made if the operator believed that conditions occurred that would influence the run (i.e. side sway due to passing trucks). Also, additional runs were required if lost lock or saturation was detected during a run. However, the maximum number of runs at section was limited to nine. If situations causing lost lock or saturation could not be altered, the site was retested another day. Due to equipment problems or problems due to saturation spikes, some scheduled tests could not be performed. Any site that could not be tested on a scheduled day was tested on June 7th. The dates on which the Profilometers actually performed testing are shown in Table 4.3. Table 4.4 shows the number of runs performed by each Profilometer at each section at the two test speeds.

4.3 Dipstick Data Collection

Dipstick measurements were made on the left and right wheelpaths at all sections during field layout of the section. The procedure outlined in SHRP-LTPP manual for Dipstick Measurements (4) was followed in collecting the data. In each wheelpath, a forward and a return run was conducted using the Dipstick. The closing error specified in the SHRP manual for the Dipstick for a forward and a return distance of 500 ft (total of 1,000 ft) is 3 in. The closing error was within this allowable value at all sites.

Table 4.2 Schedule for Site Testing

Profilometer	Date							
	June 3		June 4		June 5		June 6	
	AM	PM	AM	PM	AM	PM	AM	PM
	Section							
Southern Region	2	6	3	8	1	7	4	5
Western Region	1	7	4	6	3	5	2	8
N. Atlantic Region	4	8	1	5	2	6	3	7
N. Central Region	3	5	2	7	4	8	1	6

Note: AM – Morning PM – Afternoon

Table 4.3 Dates on which the Sections were Tested

Profilometer	Date							
	June 3		June 4		June 5		June 6	
	AM	PM	AM	PM	AM	PM	AM	PM
	Section							
Southern Region	2	6	3	8	1	7	4	5
Western Region	1	7	4	6	3	5	2	8
N. Atlantic Region	4	8	1	5	2	6	3	7
N. Central Region	3	5	2	7	4	8	1	6

Note: AM – Morning PM – Afternoon

Table 4.4 Number of Runs Performed by Profilometers at Each Section

Section	Number of Profilometer Runs							
	N. Central		Western		N. Atlantic		Southern	
	S40	S50	S40	S50	S40	S50	S40	S50
1	6	6	6	9	9	9	9	9
2	6	6	9	9	7	9	6	9
3	6	6	7	9	8	9	7	6
4	8	7	6	6	6	9	6	6
5	6	6	6	6	9	7	6	9
6	6	7	6	6	6	9	6	6
7	6	6	6	6	9	9	7	6
8	7	8	9	6	7	7	6	7

NOTE: S40 – Testing Speed = 40 mph
S50 – Testing Speed = 50 mph

5. COMPARISON BETWEEN PROFILOMETERS

5.1 Computed IRI

Figure 5.1 shows the experimental plan for the Profilometer comparison experiment with the section numbers that correspond to the different surface types and roughness levels (see Table 4.1). The number of replicates obtained for each cell of the experimental plan shown in Fig. 5.1 corresponds to the number of Profilometer runs shown in Table 4.4. The number of replicates in each cell would therefore vary from 6 to 9. During each run, the Profilometer collects profile data on the left and right wheelpaths. This profile data was input to the Profscan program (5) to obtain IRIs for the left and right wheelpaths. The combined effect of the left and right wheelpaths can be denoted by a both wheelpath IRI, which is the average of the left and right wheelpath IRI. Figure 5.2 shows the variation of left wheelpath IRI of Site 1 for all Profilometer runs for a testing speed of 40 MPH. Graphs showing the variation of left and right wheelpath IRI for all Profilometer runs at all sections are given separately for test speeds of 40 and 50 MPH in Appendix A. These graphs show that at some sites the IRI obtained from the different runs of the same Profilometer are not uniform.

As each Profilometer crew was instructed to obtain six good runs, only six runs in each cell of the experimental plan shown in Fig. 5.1 were selected for analysis. If only six runs were available in a cell, then all the runs were included in the analysis. In cases where more than six runs were available, in many instances the operators had not specifically commented on the runs that were bad. Therefore, the six best runs could not be selected from multiple runs based solely on the operators comments. Therefore, the criteria used to select the six best runs for analysis was to select the six runs that had the least standard deviation. It was noted that runs that were specifically labeled as bad by the operators were rejected when the above criteria was applied.

The left and right wheelpath IRI of all the runs that were selected for analysis are given in Appendix B. The average left wheelpath, right wheelpath and both wheelpath IRI computed from the six Profilometer runs selected for analysis at all sections for both test speeds is shown in Tables 5.1, 5.2 and 5.3 respectively.

Figures 5.3 and 5.4 show the relationship between the left and right wheelpath IRI for the asphalt and concrete pavements respectively. All Profilometer runs selected for analysis at both test speeds (192 runs each for asphalt and concrete pavements) are plotted in each figure. In each figure a cluster of points correspond to a section and the results from 48 Profilometer runs (four Profilometers, six runs each and two test speeds) are

SPEED	PROFILOMETER	SURFACE TYPE	ASPHALT				CONCRETE			
		ROUGHNESS LEVEL	SMOOTH		MED IUM		SMOOTH		MED IUM	
		SECTION	1	4	2	3	7	8	5	6
40	NORTH CENTRAL									
	WESTERN									
	NORTH ATLANTIC									
	SOUTHERN									
50	NORTH CENTRAL									
	WESTERN									
	NORTH ATLANTIC									
	SOUTHERN									

Fig. 5.1 Experimental Plan with Section Numbers

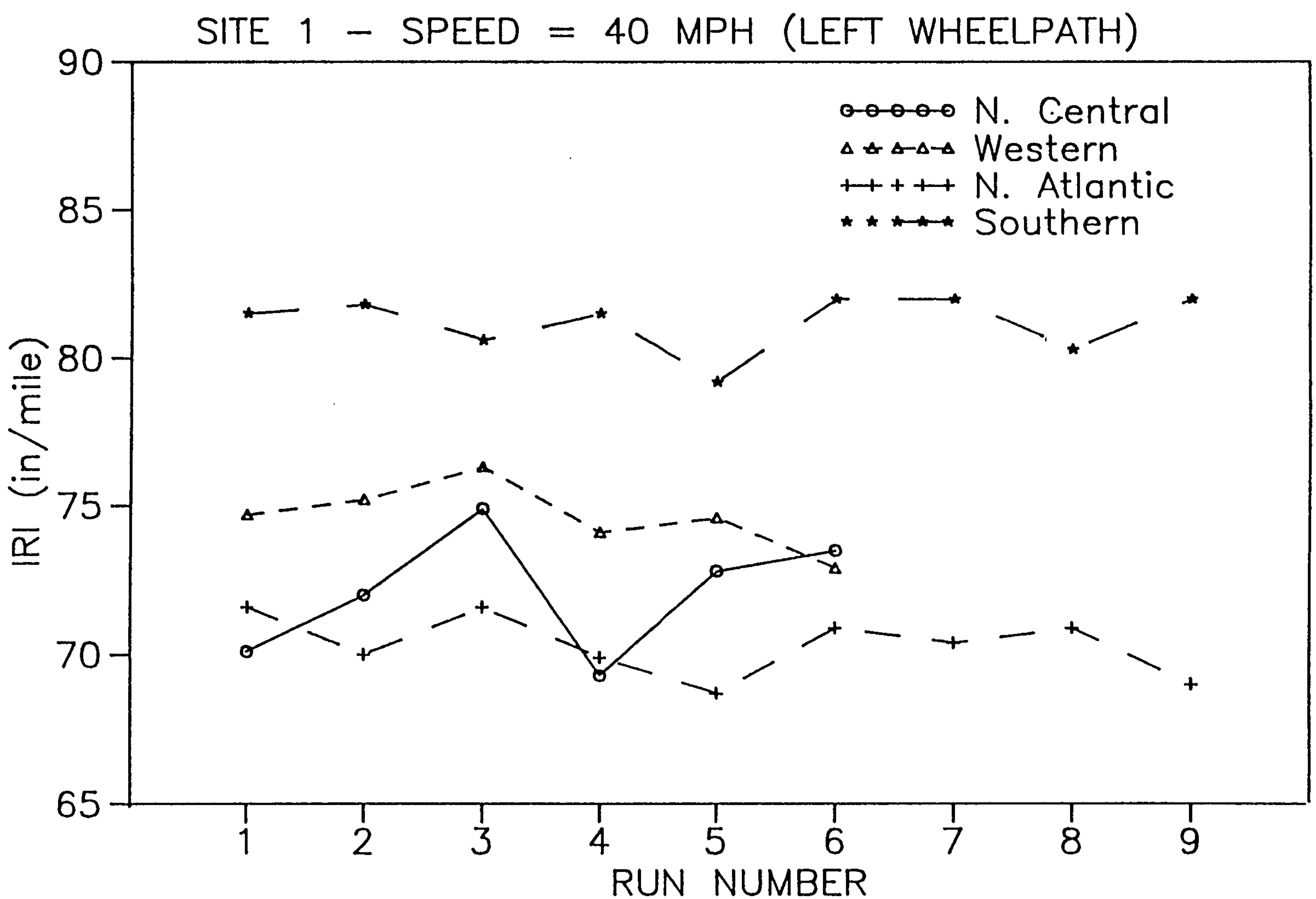


Fig. 5.2 Variation of Left Wheelpath IRI

Fig. 5.3 RIGHT AND LEFT WHEELPATH IRI

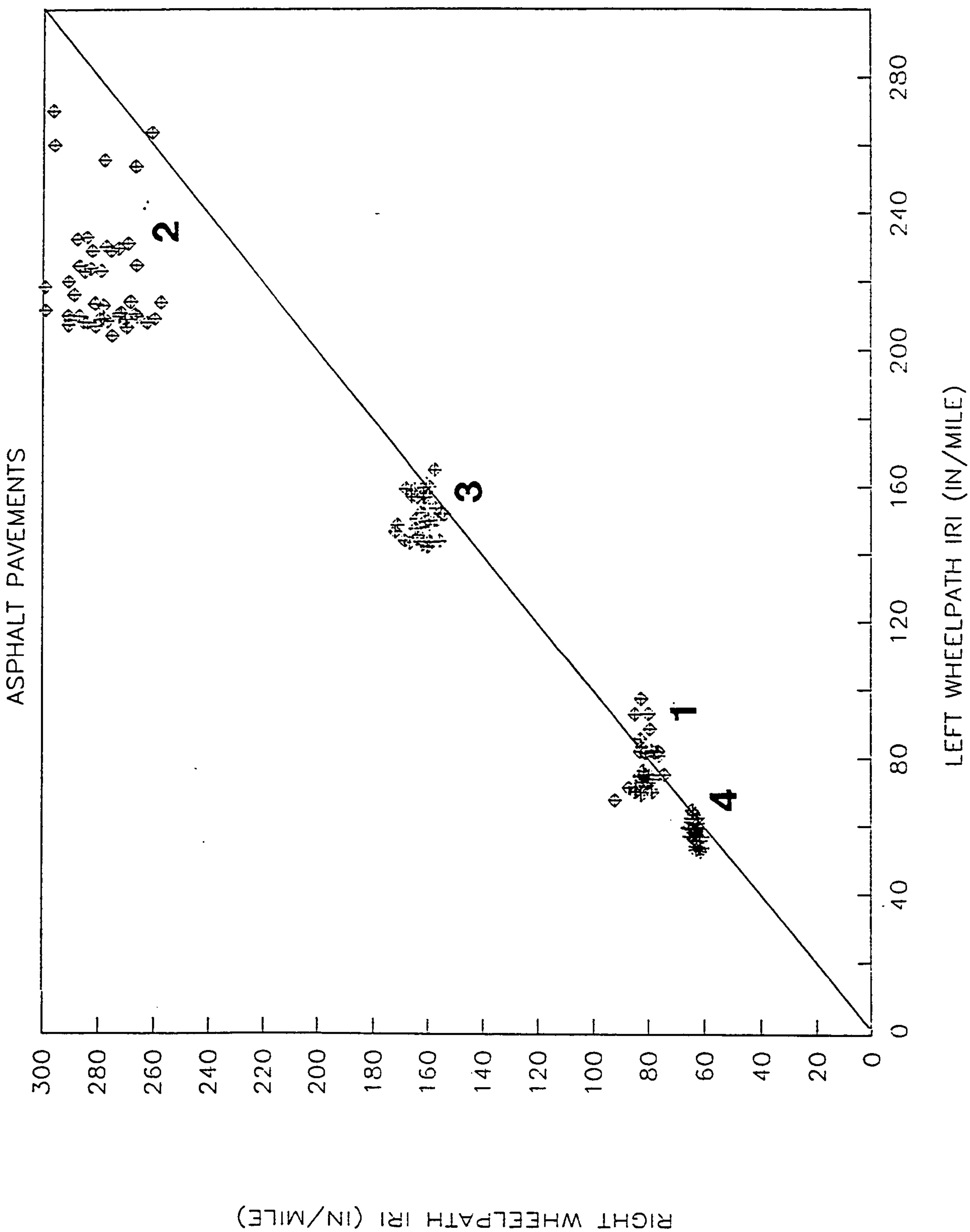


Fig. 5.4 RIGHT AND LEFT WHEELPATH IRI

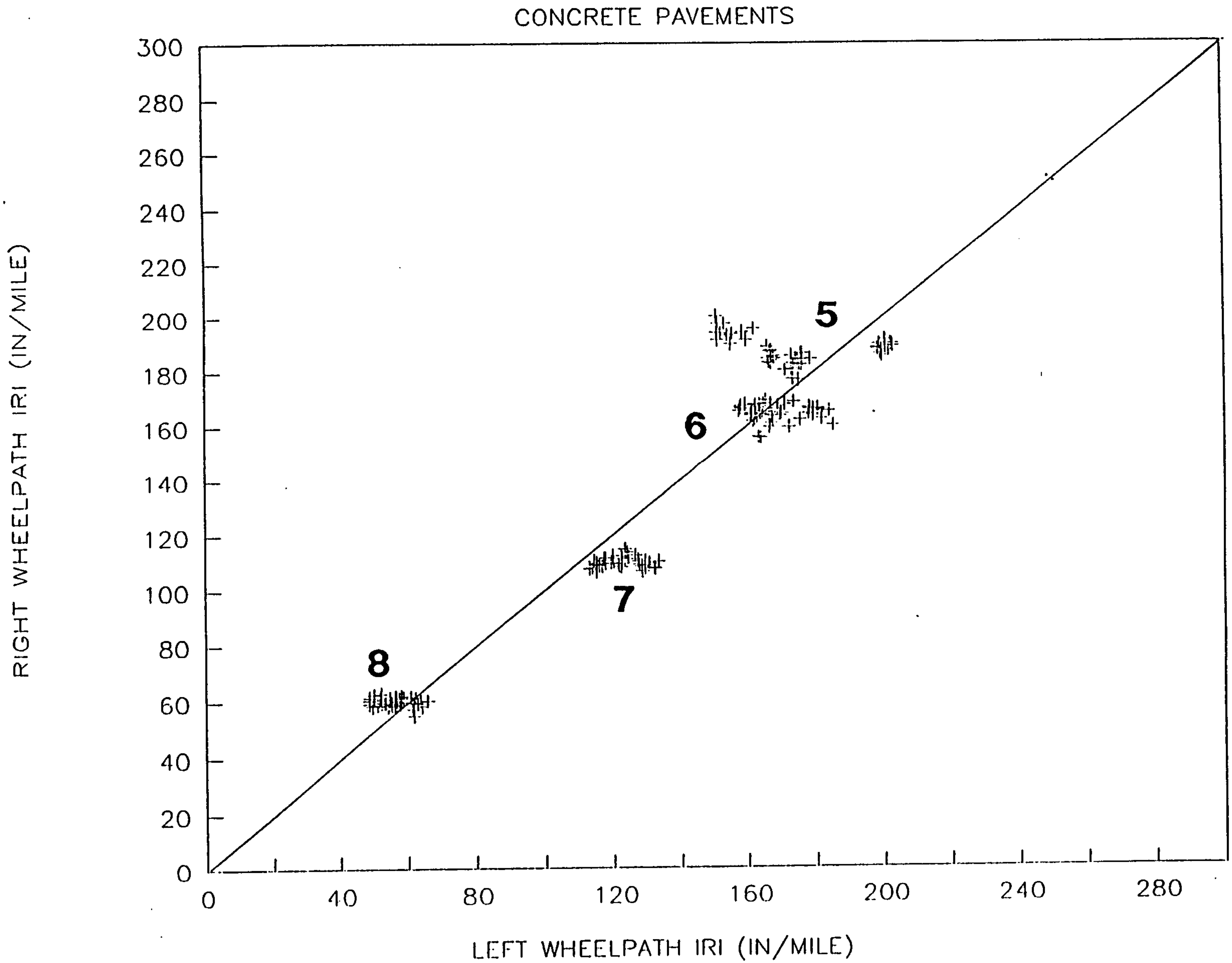


Table 5.1. Average Left Wheelpath IRI (in/mile)

SPEED	PROFILOMETER \ SURFACE TYPE / ROUGHNESS / SECTION	ASPHALT				CONCRETE				AVERAGE
		SMOOTH		MEDIUM		SMOOTH		MEDIUM		
		1	4	2	3	7	8	5	6	
40	NORTH CENTRAL	72	62	207	151	125	56	166	160	125
	WESTERN	75	54	210	144	115	55	175	164	124
	NORTH ATLANTIC	71	58	220	159	115	49	156	161	124
	SOUTHERN	82	57	255	158	128	63	202	179	140
50	NORTH CENTRAL	72	63	211	149	121	58	169	166	126
	WESTERN	75	55	210	144	118	53	174	166	125
	NORTH ATLANTIC	90	58	219	152	123	53	153	168	127
	SOUTHERN	82	59	230	157	130	62	199	180	137
	AVERAGE	78	58	220	152	123	57	177	169	

Table 5.2. Average Right Wheelpath IRI (in/mile)

SPEED	PROFILOMETER \ SURFACE TYPE / ROUGHNESS / SECTION	ASPHALT				CONCRETE				AVERAGE
		SMOOTH		MEDIUM		SMOOTH		MEDIUM		
		1	4	2	3	7	8	5	6	
40	NORTH CENTRAL	82	63	282	157	110	60	186	166	138
	WESTERN	82	62	268	164	109	59	184	160	136
	NORTH ATLANTIC	82	64	290	161	110	60	193	166	141
	SOUTHERN	78	63	277	162	109	60	190	166	138
50	NORTH CENTRAL	85	64	272	161	110	61	183	168	138
	WESTERN	80	62	281	161	111	60	183	163	137
	NORTH ATLANTIC	83	67	294	167	112	61	196	166	143
	SOUTHERN	80	63	277	164	109	58	188	164	138
	AVERAGE	81	63	280	162	110	60	188	165	

Table 5.3. Average Both Wheelpath IRI (in/mile)

SPEED	SURFACE TYPE / ROUGHNESS / SECTION / PROFILOMETER	ASPHALT				CONCRETE				AVERAGE
		SMOOTH		MED IUM		SMOOTH		MED IUM		
		1	4	2	3	7	8	5	6	
40	NORTH CENTRAL	77	62	245	154	117	58	176	163	132
	WESTERN	78	58	239	154	112	57	180	162	130
	NORTH ATLANTIC	76	61	255	160	113	55	175	164	132
	SOUTHERN	80	60	266	160	119	62	196	173	139
50	NORTH CENTRAL	78	63	241	155	116	59	176	167	132
	WESTERN	77	59	246	152	115	57	179	165	131
	NORTH ATLANTIC	86	61	257	159	117	57	174	167	135
	SOUTHERN	81	61	254	161	120	60	193	172	138
	AVERAGE	79	61	250	157	116	58	181	166	

represented at each section. The numbers adjacent to the cluster of points refer to the section numbers associated with each set of points. Figure 5.3 shows that the IRI of right wheelpath at Site 2 is much higher than the left wheelpath.

5.2 Acceptance Criteria

The Profscan program (5) is used to determine if the variance between runs made at a section is acceptable. In order for the runs to be acceptable, the following criteria must be met.

1. The IRI of at least three runs should be within 1% of the mean of all selected runs.
2. The standard deviation of all the selected runs should not exceed 3% of the mean (Coefficient of Variation < =3%).

The user can select the runs to be used with thhe Profscan program out of all available runs. Therefore, if the operator knows that a particular run is bad, it can be omitted when the runs are analyzed with Profscan. Currently Profscan uses the both wheelpath IRI to determine the acceptability of runs.

All six replicate runs selected for analysis for each test situation in Fig. 5.1 were processed with the Profscan program to determine if the criteria were met. Since all Profilometers were aligned with the left wheelpath, an analysis was performed to determine the acceptability of runs at a site applying the criteria to the left wheelpath IRI. The summary statistics for the left wheelpath IRI (mean and standard deviation) for each series of runs by a Profilometer at a site for a specified speed were used to select the acceptable runs. Table 5.4 shows the number of runs for each test situation that met the 1% of the mean criteria which was applied to the left wheelpath IRI. The standard deviation and the 3% of the mean values of the left wheelpath IRI for each test situation are shown in Table 5.5. The analysis of the left wheelpath IRI showed that the 1% of mean criteria was satisfied by 58% of the test situations shown in Fig. 5.1, while the standard deviation criteria was satisfied in 90% of the test situations. This analysis showed that the 1% of the mean criteria in Profscan is more rigid than the standard deviation criteria. In this analysis it was noted that sections which failed the standard deviation criteria also failed the criteria on the mean.

The number of runs meeting the 1% of the mean criteria when the both wheelpath IRI is considered are shown in Table 5.6. When the 1% criteria was applied for the both wheelpath IRI, 73% of the test situations shown in Fig. 5.1 satisfied the criteria.

Table 5.4. Number of Runs that Meet the 1% of the Mean Criteria (Left Wheelpath)

SPEED (MPH)	PROFILOMETER	NO. OF RUNS MEETING CRITERIA SECTION								NO. OF ACCEPTABLE SECTIONS
		1	2	3	4	5	6	7	8	
40	N. CENTRAL	(2)	5	4	(0)	6	(2)	(0)	3	4
	WESTERN	4	3	5	4	4	(2)	4	5	7
	N. ATLANTIC	5	(0)	(2)	(2)	(1)	(2)	3	(1)	2
	SOUTHERN	6	(1)	5	3	6	6	6	(1)	6
50	N. CENTRAL	(2)	5	5	(2)	(1)	(1)	(1)	3	3
	WESTERN	5	5	6	(2)	6	3	(1)	(1)	5
	N. ATLANTIC	(0)	3	(1)	(0)	(1)	3	4	(1)	3
	SOUTHERN	6	5	4	6	6	(1)	3	3	7

Note : Numbers within parantheses are the cases where at least three runs did not fall within 1% of the mean

Table 5.5. Standard Deviations and 3% of the Mean from Profilometer Tests

PROFILOMETER	SECTION	SPEED = 40 MPH STD DEV	SPEED = 40 MPH 3% OF MEAN	SPEED = 50 MPH STD DEV	SPEED = 50 MPH 3% OF MEAN
NORTH CENTRAL	1	1.9	2.2	2.0	2.2
	2	1.4	6.2	1.7	6.3
	3	1.6	4.5	1.9	4.5
	4	1.3	1.8	1.4	1.9
	5	0.6	5.0	2.5	5.1
	6	1.9	4.8	4.2	5.0
	7	*5.7	3.8	2.5	3.6
	8	1.1	1.7	0.8	1.7
WESTERN	1	1.0	2.3	0.6	2.3
	2	2.7	6.3	1.1	6.3
	3	1.5	4.3	0.2	4.3
	4	0.8	1.6	1.5	1.7
	5	1.7	5.3	1.3	5.2
	6	2.2	4.9	3.2	5.0
	7	0.8	3.4	2.6	3.6
	8	0.7	1.7	*1.9	1.6
NORTH ATLANTIC	1	0.6	2.1	*4.8	2.7
	2	*7.1	6.6	4.3	6.6
	3	3.9	4.8	*5.1	4.6
	4	1.3	1.8	1.2	1.7
	5	3.8	4.7	2.9	4.6
	6	3.9	4.8	1.7	5.1
	7	1.4	3.5	0.9	3.7
	8	0.6	1.5	*1.6	1.6
SOUTHERN	1	0.2	2.5	0.2	2.5
	2	*13.9	7.5	1.4	6.9
	3	1.1	4.7	1.1	4.7
	4	0.6	1.7	0.4	1.8
	5	0.9	6.0	0.4	6.0
	6	0.9	5.4	2.9	5.5
	7	0.8	3.9	2.1	3.9
	8	1.1	1.9	0.7	1.9

Note : * denotes cases where the standard deviation was greater than 3% of the mean

Table 5.6. Number of Runs that Meet the 1% of the Mean Criteria (Both Wheelpath)

SPEED (MPH)	PROFILOMETER	NO. OF RUNS MEETING CRITERIA SECTION								NO. OF ACCEPTABLE SECTIONS
		1	2	3	4	5	6	7	8	
40	N. CENTRAL	3	4	6	3	6	5	(0)	3	7
	WESTERN	3	(1)	3	(2)	5	3	6	4	6
	N. ATLANTIC	(2)	(2)	5	3	3	4	3	(2)	5
	SOUTHERN	4	(1)	5	6	6	6	5	3	7
50	N. CENTRAL	3	4	6	3	6	3	(2)	3	7
	WESTERN	(1)	(1)	4	3	3	5	(2)	3	5
	N. ATLANTIC	(1)	4	(1)	(2)	4	5	(2)	(2)	3
	SOUTHERN	4	4	4	6	6	4	6	(1)	7

Note : Numbers within parantheses are the cases where at least three runs did not fall within 1% of the mean

Therefore, using the both wheelpath IRI as opposed to the left wheelpath IRI caused more test situations to meet the 1% criteria.

The percent difference from the mean IRI for each Profilometer run in the experiment was calculated using the following formula.

$$P = \frac{|(Y - R)|}{Y} \times 100$$

where, Y = Average IRI for a given test situation (average IRI of a cell in Fig. 5.1), R = IRI from a run corresponding to that test situation, and P = Percent difference from mean IRI for the run.

As there are six runs in each cell of Fig. 5.1, the percent difference from mean can be calculated for 384 runs. The relationship between the percent difference from the mean and the average IRI for each test situation are shown for the left and both wheelpath IRI in Figs. 5.5 and 5.6 respectively. These figures show that the percent difference from the mean IRI for the both wheelpath has less scatter as compared to the left wheelpath. In addition, these figures show that the percent difference from the mean IRI of a run is not dependent on the magnitude of IRI at that location.

The percentage of runs that fall into the different ranges of percent difference from mean for the left and both wheelpaths are shown in Table 5.7. Table 5.8 shows the percentage of runs that fall below a specified percent difference from the mean (calculated from the data given in Table 5.7). The percentage from mean IRI within which 95% of the runs fell were 4.3% and 2.6% for the left wheelpath and both wheelpaths, respectively.

5.3 Analysis of Variance

The effect of the different levels of the factors Profilometer, speed, roughness and surface type on IRI can be determined by conducting an Analysis of Variance (ANOVA) on the data collected from the experimental plan shown in Fig. 5.1. Only the six best runs selected as described in Section 5.1 were used in ANOVA. The experimental design shown in Fig. 5.1 corresponds to a nested-factorial design (6,7).

A nested design is one in which the level of one factor is similar but not identical for different levels of another factor. If a nested design contains another factor or factors which have the same level across other factors, this mixture of nesting and factorial structure is called a nested factorial design (6,7). For example, in Fig. 5.1 the sections that appear under the roughness level smooth (1 and 4) and the sections that appear under

Fig. 5.5 % DIFFERENCE FROM MEAN VS IRI

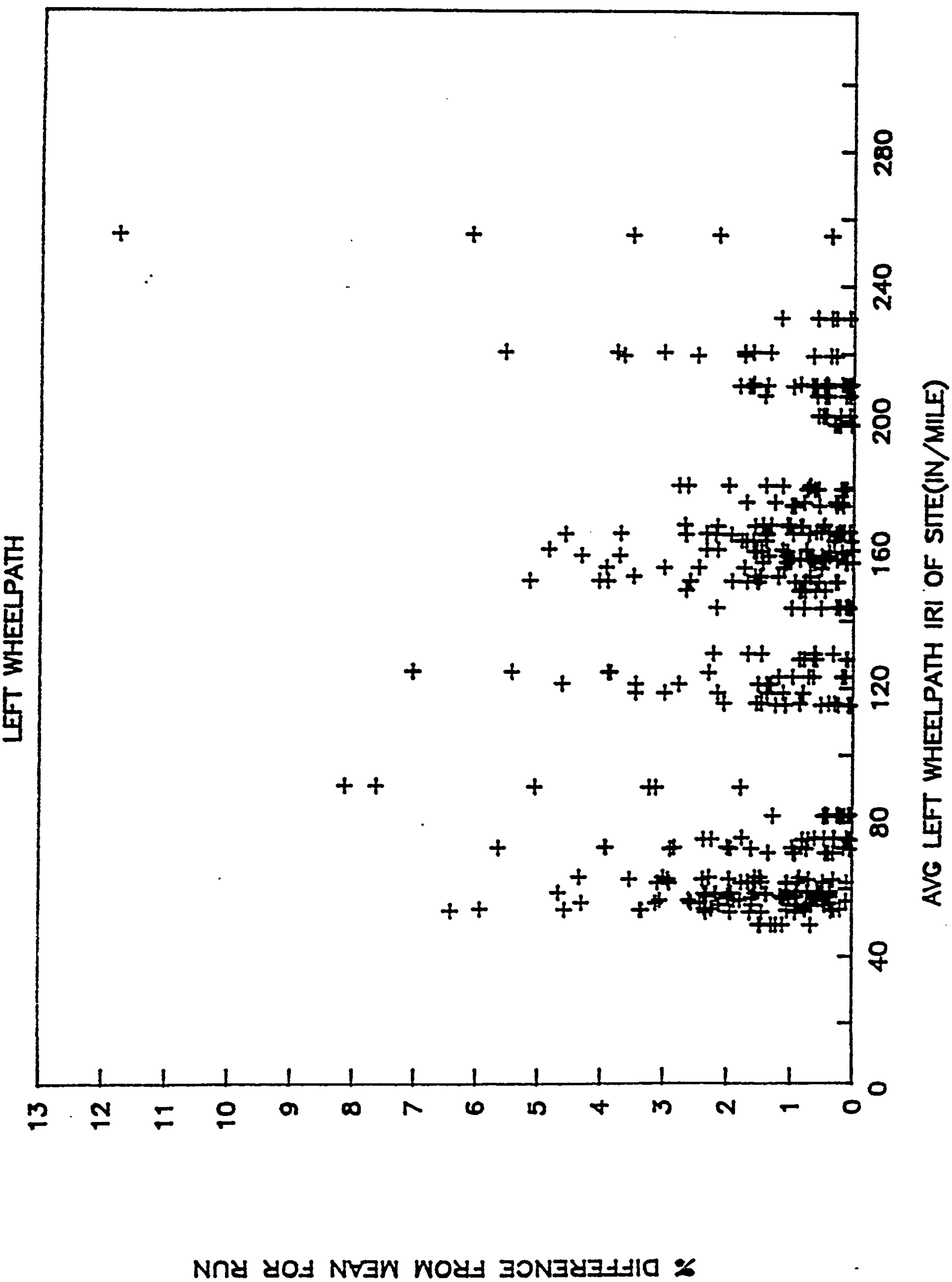


Fig. 5.6

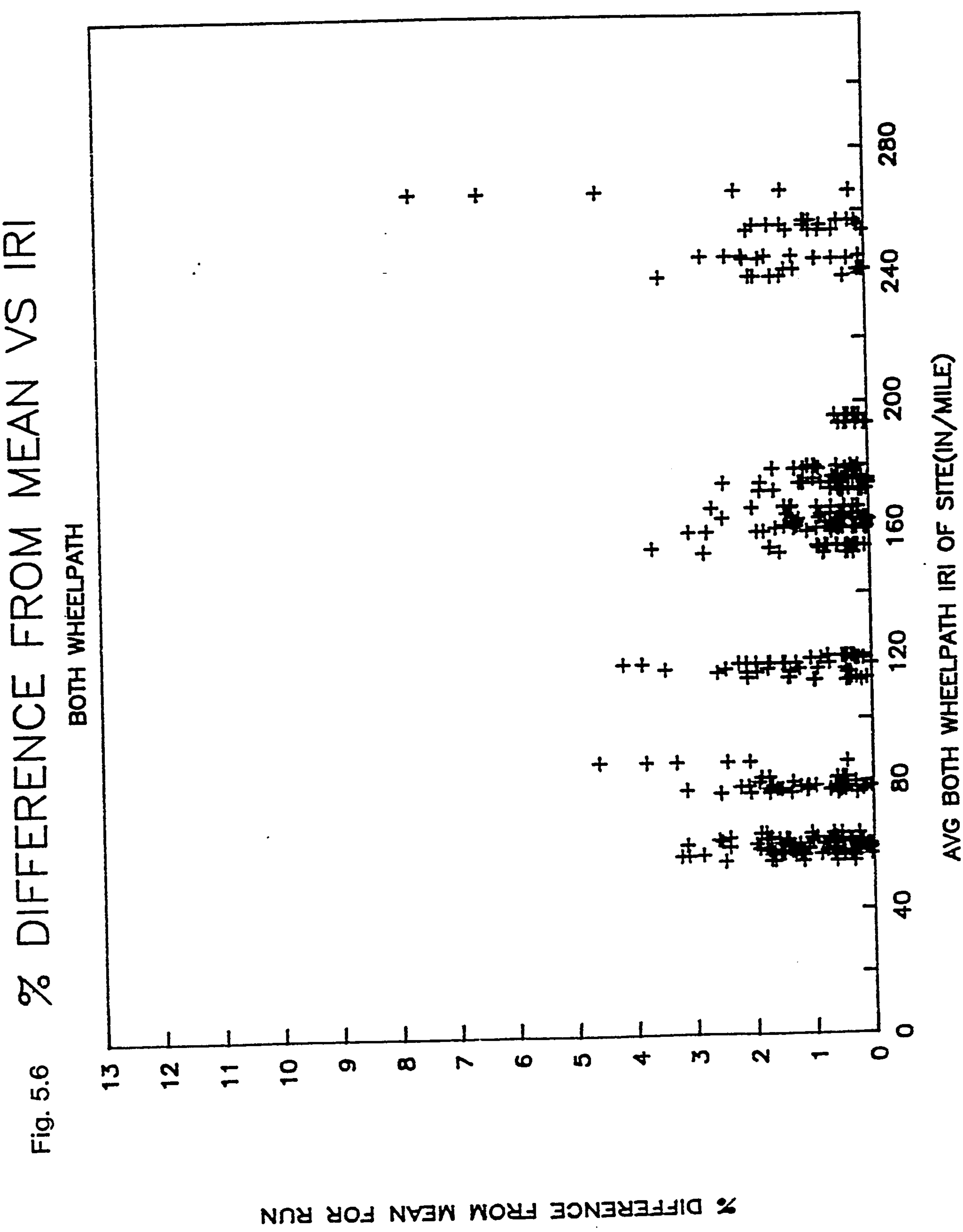

% DIFFERENCE FROM MEAN VS IRI
BOTH WHEELPATH
% DIFFERENCE FROM MEAN FOR RUN
AVG BOTH WHEELPATH IRI OF SITE(IN/MILE)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
0
40
80
120
160
200
240
280

Table 5.7. Percentage of Runs Falling within Different Ranges of Percent Difference from Mean

Range of Percent Difference from Mean	Percent of Runs Falling within Range	
	Left Wheelpath	Both Wheelpath
0 - 1	50.8	58.3
1 - 2	26.3	30.2
2 - 3	10.7	7.3
3 - 4	6.5	2.9
4 - 5	2.3	0.8
5 - 6	1.6	--
6 - 7	0.5	0.3
7 - 8	0.8	0.3
8 - 9	0.3	--
9 - 10	--	--
10 - 11	--	--
11 - 12	0.3	--

Table 5.8. Percentage of Runs Falling below a given Percent of Mean

Percent Difference in Mean	Percentage of Runs Falling Below	
	Left Wheelpath	Both Wheelpath
1	50.8	58.3
2	77.1	88.5
3	87.8	95.8
4	94.3	98.7
5	96.6	99.5
6	98.2	99.7
7	98.7	100
8	99.5	100
9	99.7	100

roughness level medium (2 and 3) are different. Thus, the factor section is nested within the factor roughness. However, for example, all levels of factor speed appear with all levels of factor Profilometer. Therefore, it can be seen that this design contains both nested and factorial factors.

The statistical model used to analyze the experiment and the ANOVA table with the expected mean squares is given in Appendix C. The ANOVA was carried out using the SPSS program (8). The ANOVA was carried out for the Profilometer combinations shown in Table 5.9.

Table 5.9. Profilometer Combinations Used for ANOVA

Case	Profilometer Combination
1	NC WE NA SO
2	NC WE NA
3	NC WE SO
4	NC NA SO
5	WE NA SO

NC - North Central Region WE - Western Region
NA - North Atlantic Region SO - Southern Region

For each Profilometer combination an ANOVA was carried out separately on the left wheelpath, right wheelpath and both wheelpath IRI. An alpha value of 0.05 was used to determine significance in all analyses.

5.3.1 ANOVA - Left Wheelpath IRI

As all Profilometers were aligned to the left wheelpath, the IRI of this wheelpath can be used to compare the Profilometers. Table 5.10 shows the results of ANOVA for the left wheelpath. The computer outputs of the ANOVA are given in Appendix D. The factors that are significant at an alpha value of 0.05 are marked in Table 5.10. The only case where the Profilometers were not significant was when the North Central, Western and North Atlantic Profilometers were grouped together. In all cases where the Southern Profilometer was present, the factor Profilometer was significant. As expected roughness was significant for all cases. Speed of testing was not significant for all cases. The mean IRI of all runs in all sections for both speeds for North Central, Western, North Atlantic and Southern Profilometers are 125.4, 124.2, 125.3 and 138.9 in/mile respectively. These values clearly show that the mean IRI of the Southern Profilometer is higher than the other Profilometers and support the findings of the statistical analysis.

Table 5.10 ANOVA Results for the Left Wheelpath

EFFECTS	PROFILOMETER COMBINATION				
	NC WE NA SO (1)	NC WE NA (2)	NC WE SO (3)	NC NA SO (4)	WE NA SO (5)
PROF	X		X	X	X
SPEED					
ROUGH	X	X	X	X	X
SURTYP					
PROF X ROUGH				X	
PROF X SURTYP					
PROF X SPEED					
ROUGH X SURTYP					
ROUGH X SPEED					
SURTYP X SPEED					
PROF X ROUGH X SURTYP					
ROUGH X SURTYP X SPEED					
PROF X ROUGH X SPEED					
PROF X SURTYP X SPEED					
	X - SIGNIFICANT AT ALPHA = 0.05				

PROF = PROFILOMETER   ROUGH = LEVEL OF ROUGHNESS
SPEED = TEST SPEED   SURTYP = SURFACE TYPE

5.3.2 ANOVA - Right Wheelpath IRI

Table 5.11 shows the results of the ANOVA for the right wheelpath. The computer outputs of the ANOVA are given in Appendix E. As seen in Table 5.11 the factor Profilometer was not significant for three Profilometer combinations. The North Central unit was in all three combinations in which the Profilometers were not significant in spite of it having a different sensor spacing. For the case where the Southern, Western and North Atlantic Profilometers which have the same sensor spacings were grouped together, the factor Profilometer was significant. For the first two Profilometer combinations (see Table 5.11), the speed of testing was significant.

5.3.3 ANOVA for Both Wheelpath IRI

The results of ANOVA for both wheelpath IRI is given in Table 5.12. The computer outputs for the analysis is given in Appendix F. The factor Profilometer was not significant only for the Profilometer combination North Central, Western and North Atlantic. The speed of testing was not significant for any combination. However, as seen from Table 5.12 some interactions were significant.

6. REPEATABILITY OF PROFILOMETERS

The Coefficient of Variation which is the ratio between the standard deviation and the mean of a data set expressed as a percentage can be used to judge variability in data. The Coefficient of Variation of left wheelpath, right wheelpath and both wheelpath IRI computed using the six Profilometer runs selected for analysis for each test condition is given in Tables 6.1 - 6.3. These values are shown graphically in Figs. 6.1 to 6.6. The Profscan program (5) sets a 3% limit on the coefficient of variation through its standard deviation criteria (standard deviation of a set of runs should not exceed 3% of the mean for data acceptability). When the coefficients of variation for the left wheelpath IRI (given in Table 6.1) were analyzed, it was seen that in 90% of the cases the coefficients of variation were within this 3% criteria. A similar analysis of the coefficients of variation of the IRIs of the right wheelpath and the both wheelpath (given in Tables 6.2 and 6.3 respectively) showed that the 3% criteria was satisfied in 90% of the test situations for the right wheelpath and 97% of the test situations for the both wheelpath.

Plots of coefficient of variation with the associated average IRI for the left, right and both wheelpaths are given in Figs. 6.7, 6.8 and 6.9. The coefficients of variation for

Table 5.11. ANOVA Results for the Right Wheelpath

EFFECTS	PROFILOMETER COMBINATION				
	NC WE NA SO (1)	NC WE NA (2)	NC WE SO (3)	NC NA SO (4)	WE NA SO (5)
PROF	X				X
SPEED	X	X			
ROUGH	X	X	X	X	X
SURTYP					
PROF X ROUGH					
PROF X SURTYP					
PROF X SPEED					
ROUGH X SURTYP					
ROUGH X SPEED					
SURTYP X SPEED					
PROF X ROUGH X SURTYP					
ROUGH X SURTYP X SPEED					
PROF X ROUGH X SPEED					
PROF X SURTYP X SPEED					
	X - SIGNIFICANT AT ALPHA = 0.05				

PROF = PROFILOMETER ROUGH = LEVEL OF ROUGHNESS
SPEED = TEST SPEED SURTYP = SURFACE TYPE

Table 5.12. ANOVA Results for Both Wheelpath

EFFECTS	PROFILOMETER COMBINATION				
	NC WE NA SO (1)	NC WE NA (2)	NC WE SO (3)	NC NA SO (4)	WE NA SO (5)
PROF	X		X	X	X
SPEED					
ROUGH	X	X	X	X	X
SURTYP					
PROF X ROUGH	X		X	X	
PROF X SURTYP		X			
PROF X SPEED					
ROUGH X SURTYP					
ROUGH X SPEED					
SURTYP X SPEED					
PROF X ROUGH X SURTYP					
ROUGH X SURTYP X SPEED					
PROF X ROUGH X SPEED					
PROF X SURTYP X SPEED					
	X - SIGNIFICANT AT ALPHA = 0.05				

PROF = PROFILOMETER
SPEED = TEST SPEED
ROUGH = LEVEL OF ROUGHNESS
SURTYP = SURFACE TYPE

Table 6.1. Coefficient of Variation (%) for Left Wheelpath IRI

SURFACE TYPE		ASPHALT				CONCRETE				AVERAGE
ROUGHNESS		SMOOTH		MEDIUM		SMOOTH		MEDIUM		
SECTION		1	4	2	3	7	8	5	6	
SPEED	PROFILOMETER									
40	NORTH CENTRAL	2.7	2.1	0.7	1.0	4.6	2.0	0.4	1.2	1.8
	WESTERN	1.4	1.4	1.3	1.1	0.7	1.2	0.9	1.3	1.2
	NORTH ATLANTIC	0.8	2.2	3.2	2.4	1.2	1.2	2.4	2.4	2.0
	SOUTHERN	0.3	1.1	5.4	0.7	0.6	1.8	0.5	0.5	1.4
50	NORTH CENTRAL	2.8	2.3	0.8	1.3	2.1	1.4	1.5	2.5	1.8
	WESTERN	0.8	2.6	0.5	0.2	2.2	3.6	0.7	1.9	1.6
	NORTH ATLANTIC	5.4	2.0	2.0	3.4	0.7	3.0	1.9	1.0	2.4
	SOUTHERN	0.3	0.6	0.6	0.7	1.6	1.2	0.2	1.6	0.8
AVERAGE		1.8	1.8	1.8	1.4	1.7	1.9	1.1	1.6	

Table 6.2. Coefficient of Variation (%) of Right Wheelpath IRI

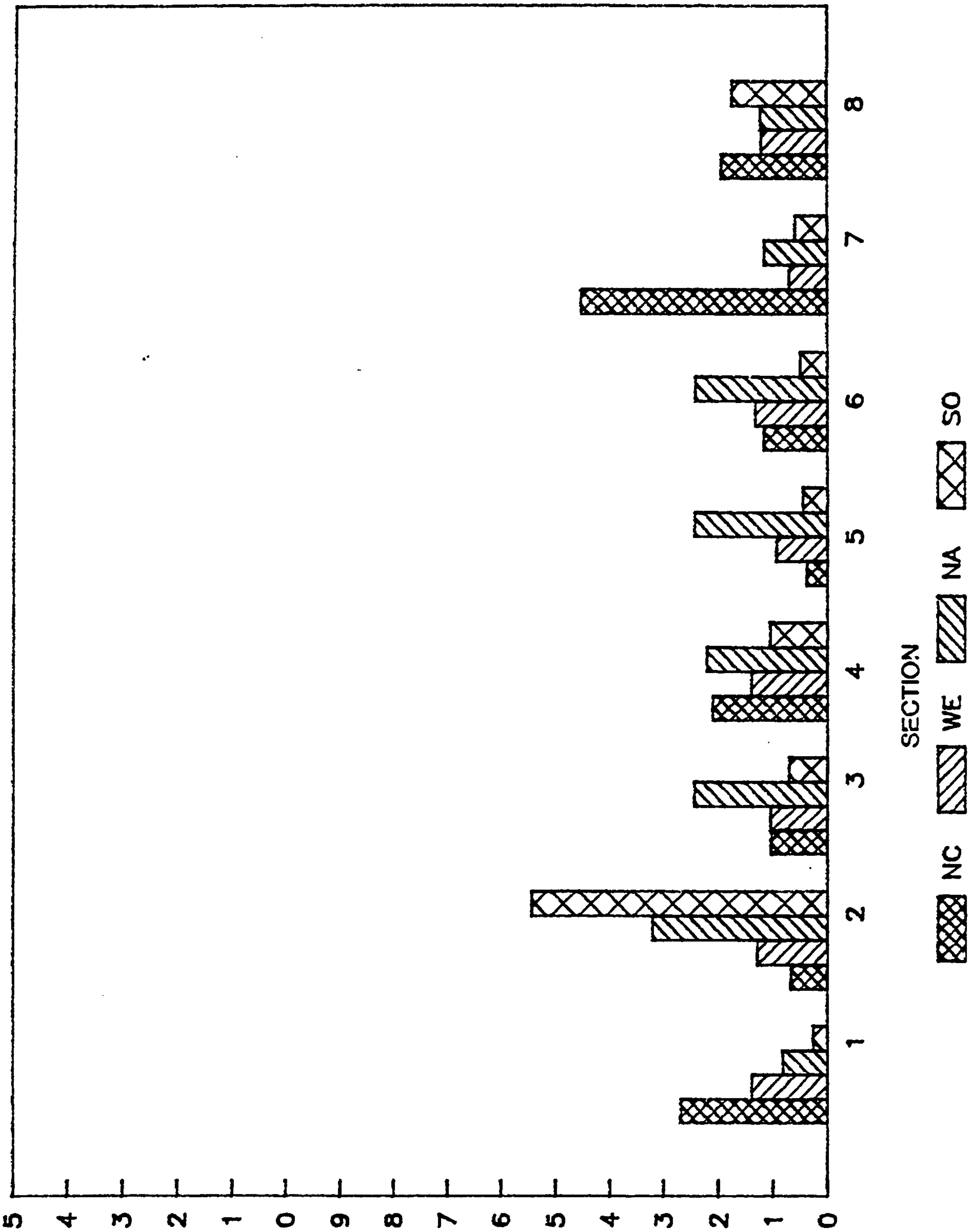
SPEED	PROFILOMETER \ SURFACE TYPE / ROUGHNESS / SECTION	ASPHALT				CONCRETE				AVERAGE
		SMOOTH		MEDIUM		SMOOTH		MEDIUM		
		1	4	2	3	7	8	5	6	
40	NORTH CENTRAL	1.8	0.9	1.9	1.3	0.8	2.0	0.9	1.1	1.3
	WESTERN	1.2	1.3	3.4	2.6	1.1	1.7	0.8	1.9	1.8
	NORTH ATLANTIC	2.9	0.9	3.0	1.0	1.2	2.3	1.4	0.7	1.7
	SOUTHERN	2.0	0.9	5.1	0.8	1.1	1.6	0.6	0.6	1.6
50	NORTH CENTRAL	4.6	0.7	1.5	1.5	1.2	2.0	1.8	0.8	1.7
	WESTERN	3.2	1.3	3.4	2.5	1.3	1.3	1.8	1.1	2.0
	NORTH ATLANTIC	2.3	1.1	2.3	1.6	2.1	1.9	1.3	1.4	1.7
	SOUTHERN	2.3	0.9	1.9	1.2	1.1	3.7	0.7	1.2	1.6
AVERAGE		2.5	1	2.8	1.6	1.2	2.1	1.2	1.1	

Table 6.3. Coefficient of Variation (%) for Both Wheelpath IRI

SPEED	PROFILOMETER \ SURFACE TYPE / ROUGHNESS / SECTION	ASPHALT				CONCRETE				AVERAGE
		SMOOTH		MED IUM		SMOOTH		MED IUM		
		1	4	2	3	7	8	5	6	
40	NORTH CENTRAL	1.0	1.4	1.2	0.5	2.8	1.2	0.4	0.6	1.1
	WESTERN	1.2	1.2	2.0	1.9	0.7	1.0	0.7	1.0	1.2
	NORTH ATLANTIC	1.6	1.3	1.3	0.8	1.2	1.5	1.4	1.2	1.3
	SOUTHERN	1.0	0.4	4.6	0.7	0.6	1.5	0.3	0.4	1.2
50	NORTH CENTRAL	1.3	1.2	0.8	0.5	2.0	1.3	0.5	1.5	1.1
	WESTERN	1.8	1.1	1.9	1.4	1.7	1.9	1.0	0.8	1.4
	NORTH ATLANTIC	3.1	1.3	0.7	2.0	1.3	1.6	0.8	0.8	1.5
	SOUTHERN	1.1	0.3	1.1	0.8	0.5	1.8	0.3	1.0	0.9
	AVERAGE	1.5	1	2.6	1.9	1.1	1.5	2.1	1.8	

Fig. 6.1 COEFFICIENT OF VARIATION (%)

LEFT WHEELPATH IRI. SPEED = 40 MPH



COEFFICIENT OF VARIATION (%)

Fig. 6.2 COEFFICIENT OF VARIATION (%)

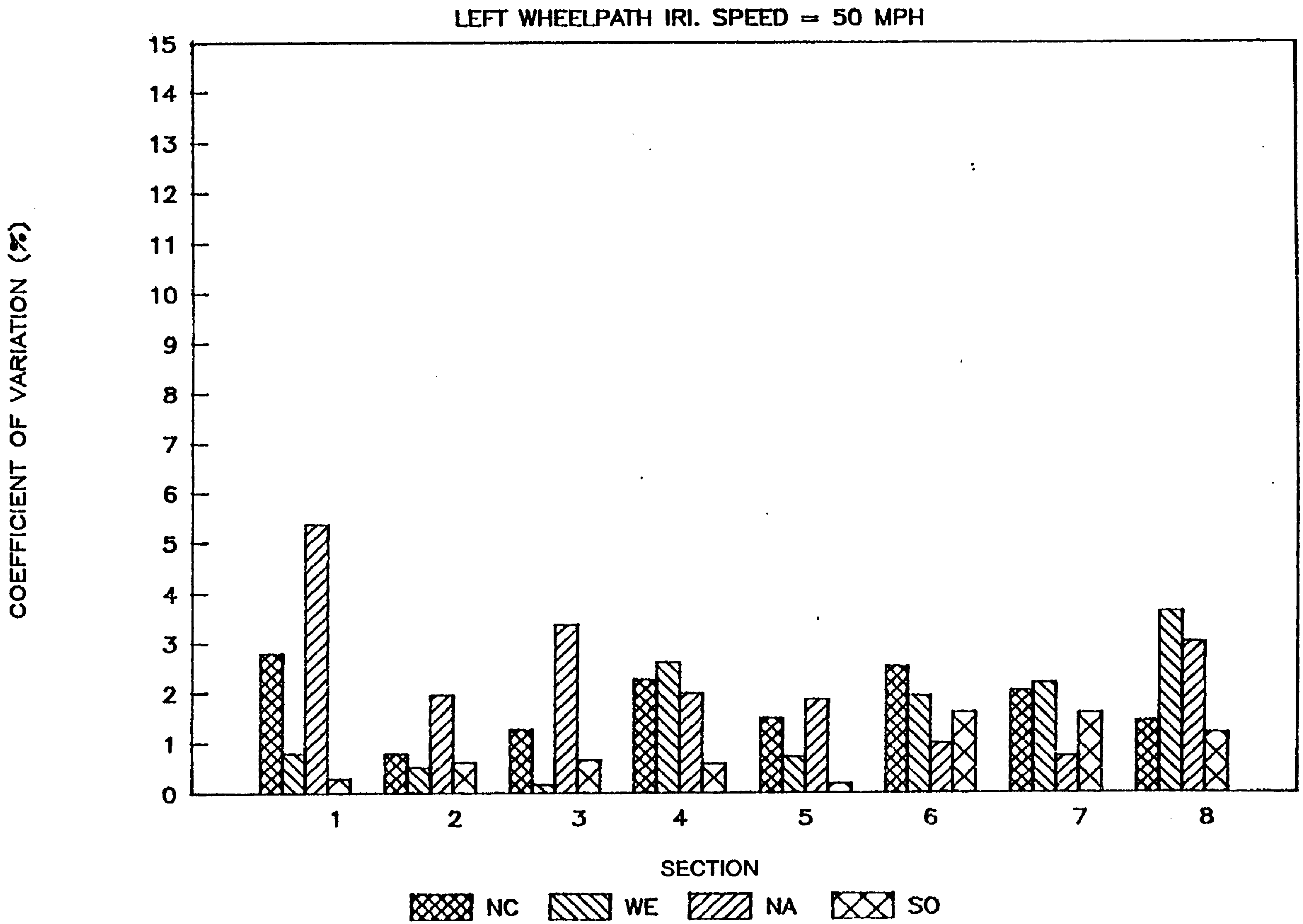


Fig. 6.3 COEFFICIENT OF VARIATION (%)

RIGHT WHEELPATH. SPEED = 40 MPH

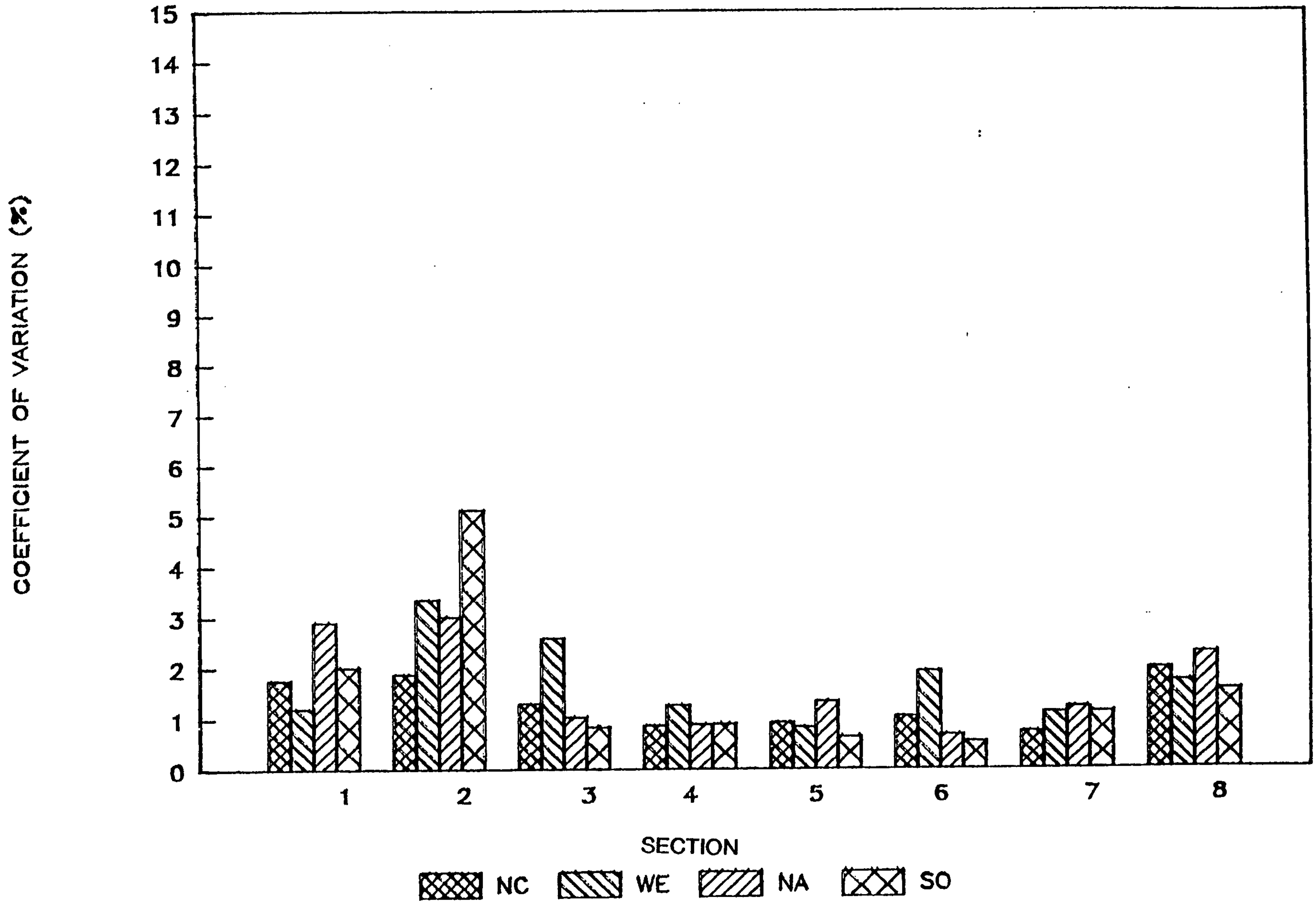


Fig. 6.4 COEFFICIENT OF VARIATION (%)

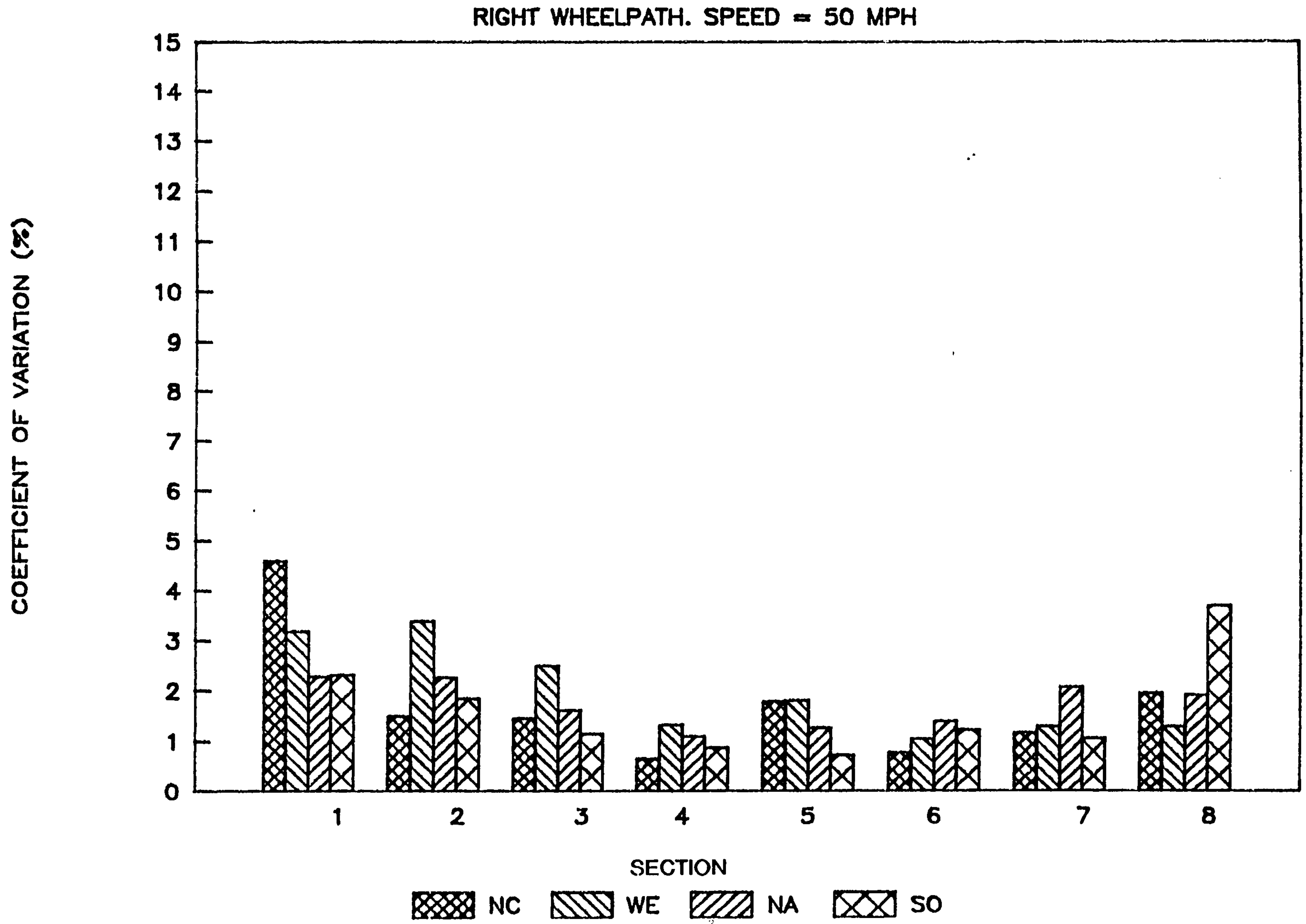


Fig. 6.5 COEFFICIENT OF VARIATION (%)

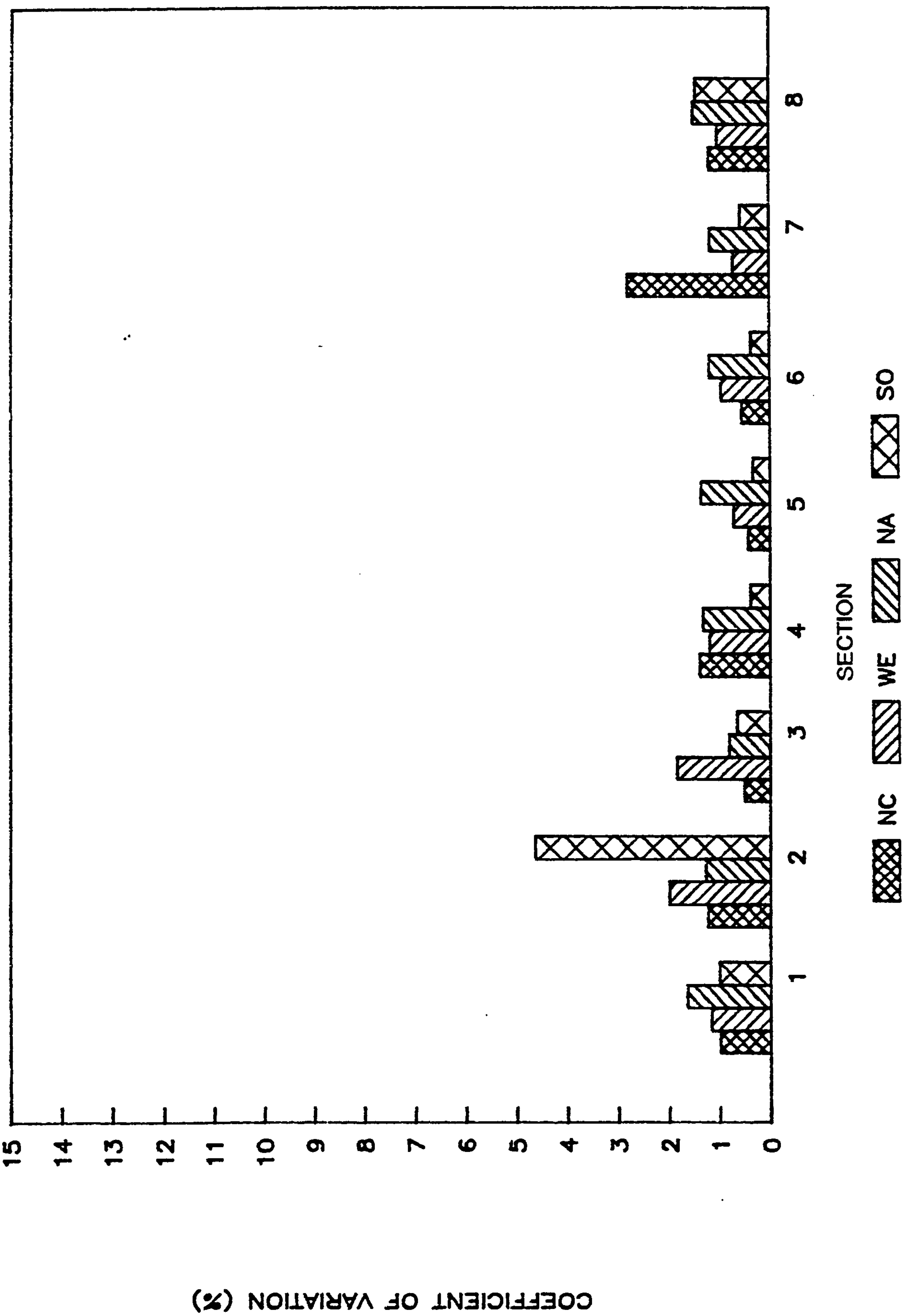


Fig. 6.6

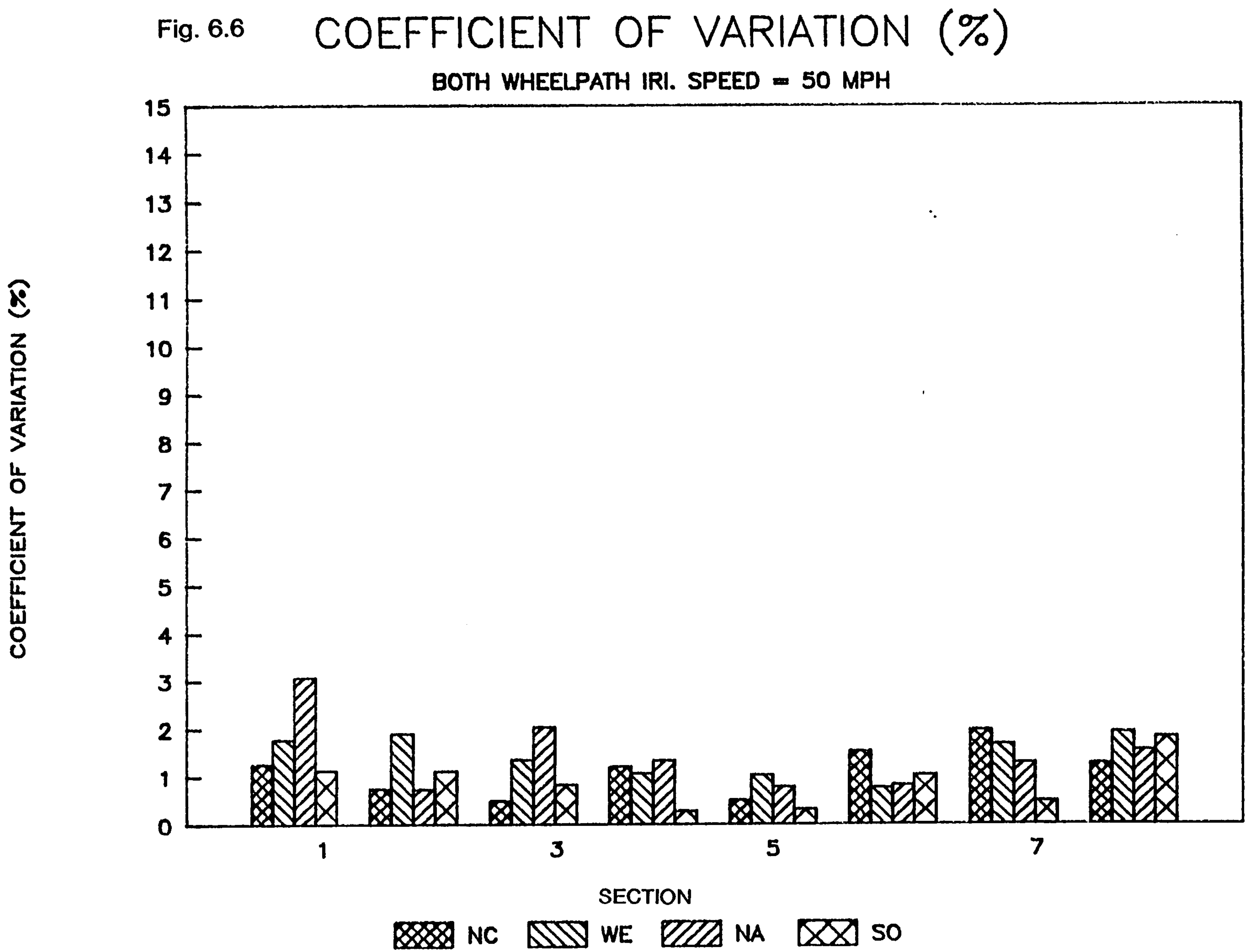
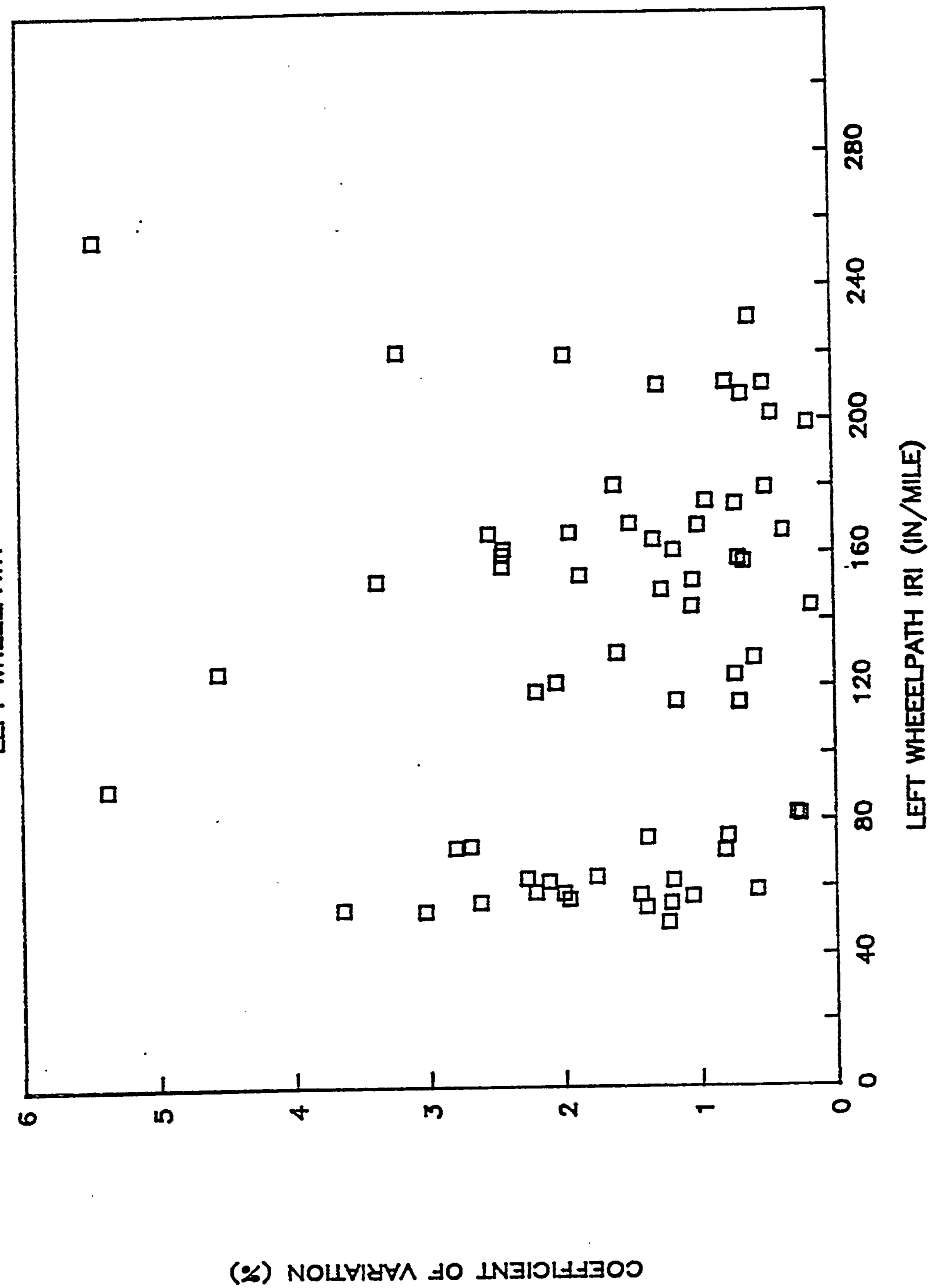

COEFFICIENT OF VARIATION (%)
BOTH WHEELPATH IRI. SPEED = 50 MPH
COEFFICIENT OF VARIATION (%)
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
1
3
5
7
SECTION
NC
WE
NA
SO

FIG. 6.7. COEFF OF VARIATION VS IRI



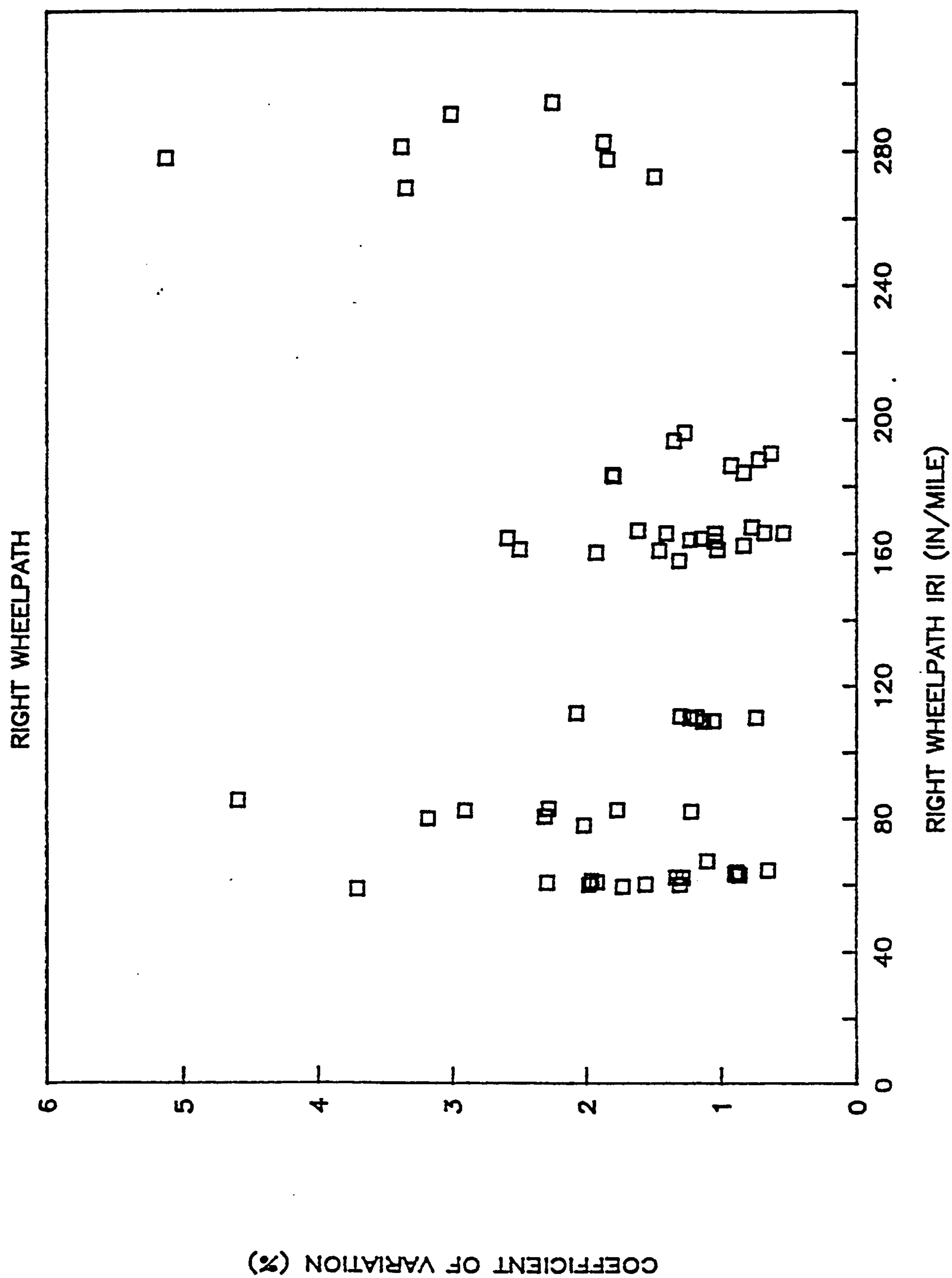


FIG. 6.8 COEFF OF VARIATION VS IRI

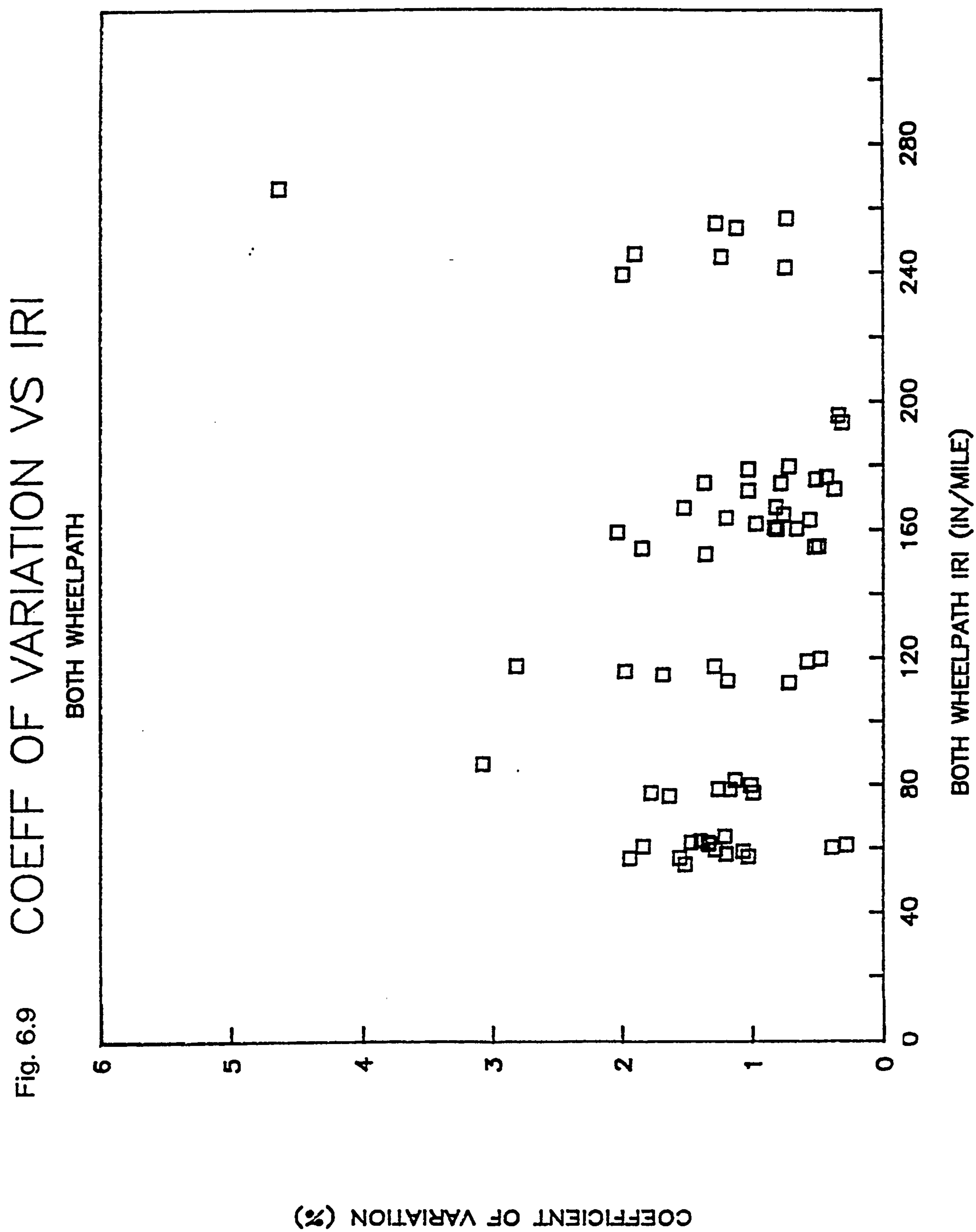


Fig. 6.9
COEFF OF VARIATION VS IRI
BOTH WHEELPATH
COEFFICIENT OF VARIATION (%)
BOTH WHEELPATH IRI (IN/MILE)
0
1
2
3
4
5
6
0
40
80
120
160
200
240
280

the left and right wheelpaths obtained for different test conditions indicate that the repeatability of all Profilometers in the left and right wheelpaths were satisfactory.

Table 6.4 presents the average coefficients of variation of left, right and both wheelpath IRI for the asphalt and concrete pavements. For example, a coefficient of variation given in a cell for asphalt pavements represents the average coefficient of variation of the four asphalt pavements considered in this study. There was no noticeable variation in repeatability of the Profilometers with respect to pavement type (asphalt and concrete) and the two test speeds (40 and 50 MPH) as seen from the coefficients of variation.

7. COMPARISON BETWEEN PROFILOMETER AND DIPSTICK IRI

Dipstick measurements were made on the left and right wheelpaths at all sites. The Dipstick measures the difference in elevation between two points at 12 in. intervals. Figure 7.1 shows the data obtained from the Dipstick over a distance of 100 ft. In this figure the vertical distance between two adjacent points represents the difference in elevation between the two points. A running sum of the Dipstick readings can be used to generate an elevation profile of the site. Figure 7.2 shows the elevation profile obtained from the Dipstick measurements shown in Fig. 7.1.

The computer program given in the World Bank Technical Paper 46 (9) was used to compute the IRI from the Dipstick data. The program that was used is given in Appendix G. The factors and coefficients appropriate for the sampling interval of the Dipstick are used in this program. The Dipstick data is input to the program through a data file. The IRI computed for the forward and return runs of the Dipstick on each wheelpath together with the mean IRI obtained by averaging the forward and return runs are shown in Table 7.1.

The mean IRI for each Profilometer computed from the six runs at 50 MPH, and the mean Dipstick IRI computed from the forward and return runs are shown in Table 7.2. The ratios between the IRI obtained from the Profilometer and Dipstick are shown in Table 7.3. For the left wheelpath, this ratio varies between 0.93-1.19 for North Central, 0.86-1.08 for Western, 0.85-1.19 for North Atlantic and 1.00-1.17 for Southern. The relationship between the IRI computed from the Profilometer data at 50 MPH and Dipstick data for the four Profilometers are shown graphically in Figs. 7.3 to 7.10.

ANOVA was used to determine if there was a statistical difference between the left wheelpath IRI computed from the profile data collected by the North Central, Western and

Table 6.4. Comparison of Coefficient of Variation (%) between Asphalt and Concrete Pavements for Different Test Speeds

SPEED	PROFILOMETER \ SURFACE TYPE \ WHEELPATH	COEFFICIENT OF VARIATION					
		LEFT WHEELPATH		RIGHT WHEELPATH		BOTH WHEELPATH	
		AC	PC	AC	PC	AC	PC
40	NORTH CENTRAL	1.6	2.0	1.5	1.2	1.0	1.3
40	WESTERN	1.3	1.1	2.1	1.4	1.6	0.9
40	NORTH ATLANTIC	2.2	1.8	2.0	1.4	1.3	1.3
40	SOUTHERN	1.9	0.8	2.2	1.0	1.7	0.7
50	NORTH CENTRAL	1.8	1.9	2.1	1.4	0.9	1.3
50	WESTERN	1.0	2.1	2.6	1.4	1.5	1.4
50	NORTH ATLANTIC	3.2	1.7	1.8	1.7	1.8	1.1
50	SOUTHERN	0.5	1.2	1.6	1.7	0.8	0.9
	AVERAGE	1.7	1.6	2.0	1.4	1.3	1.1

Fig. 7.1 DIPSTICK DATA

SITE 1. RIGHT WHEELPATH

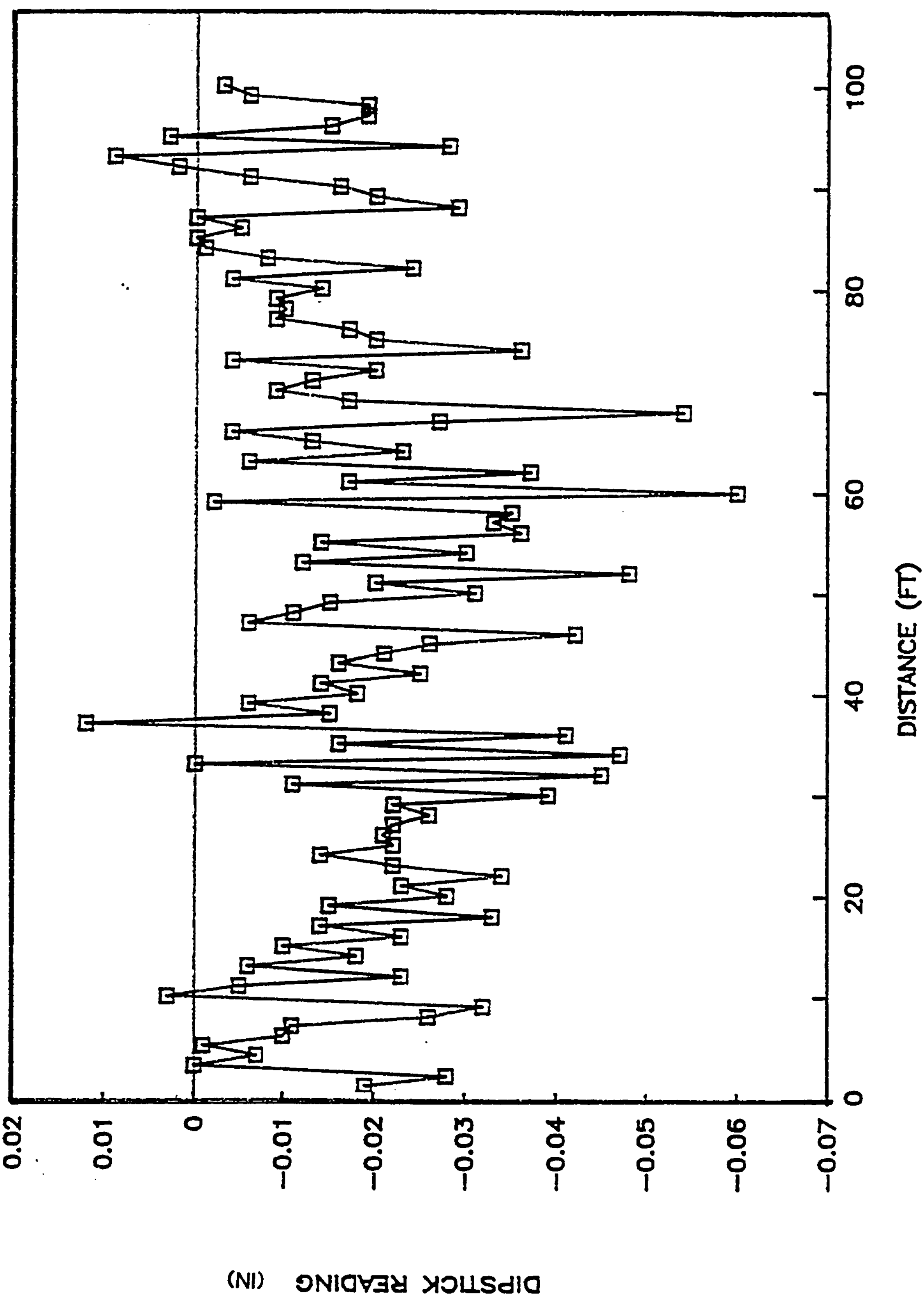


Fig. 7.2 Elevation Profile

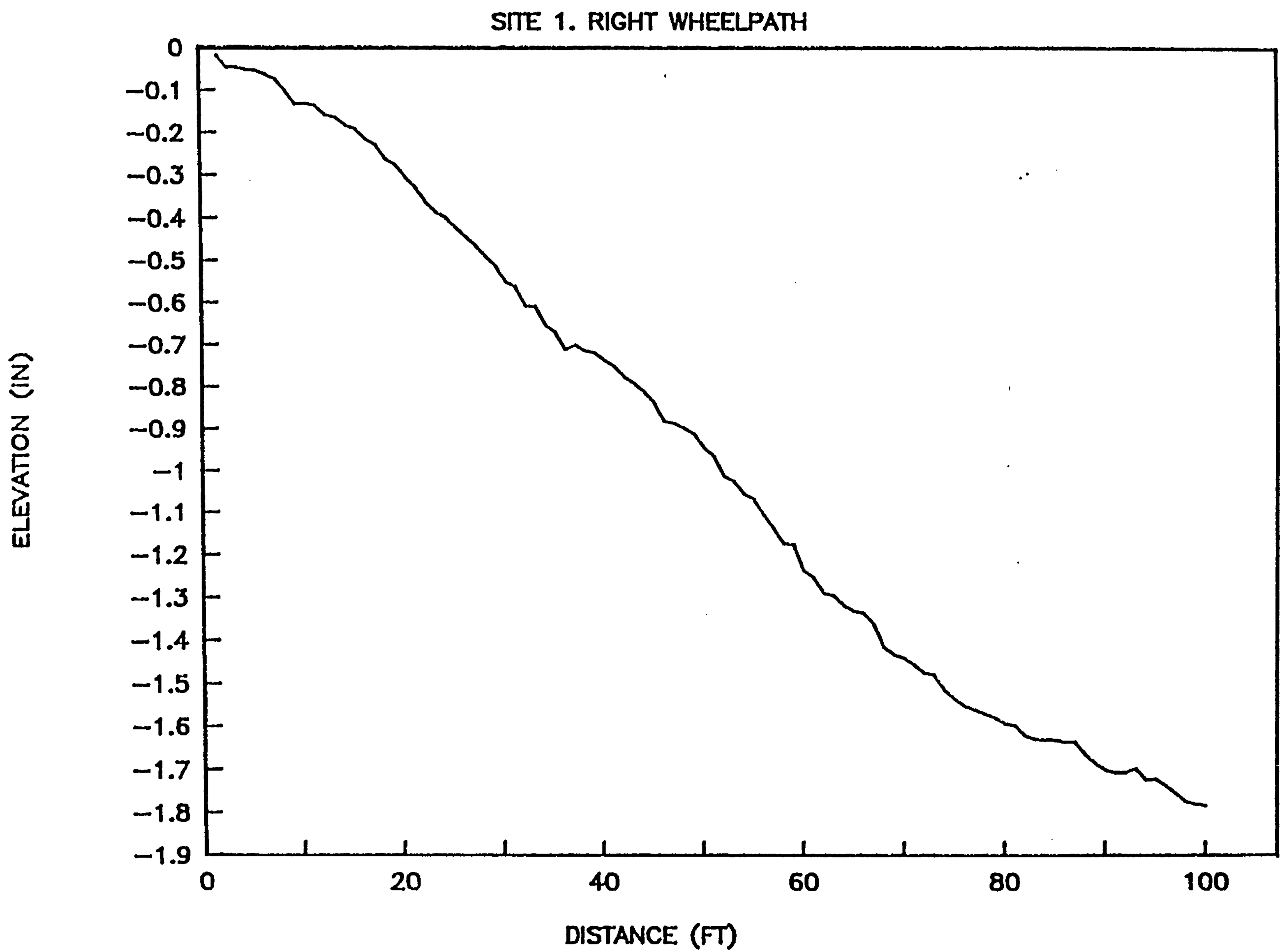


Fig. 7.3

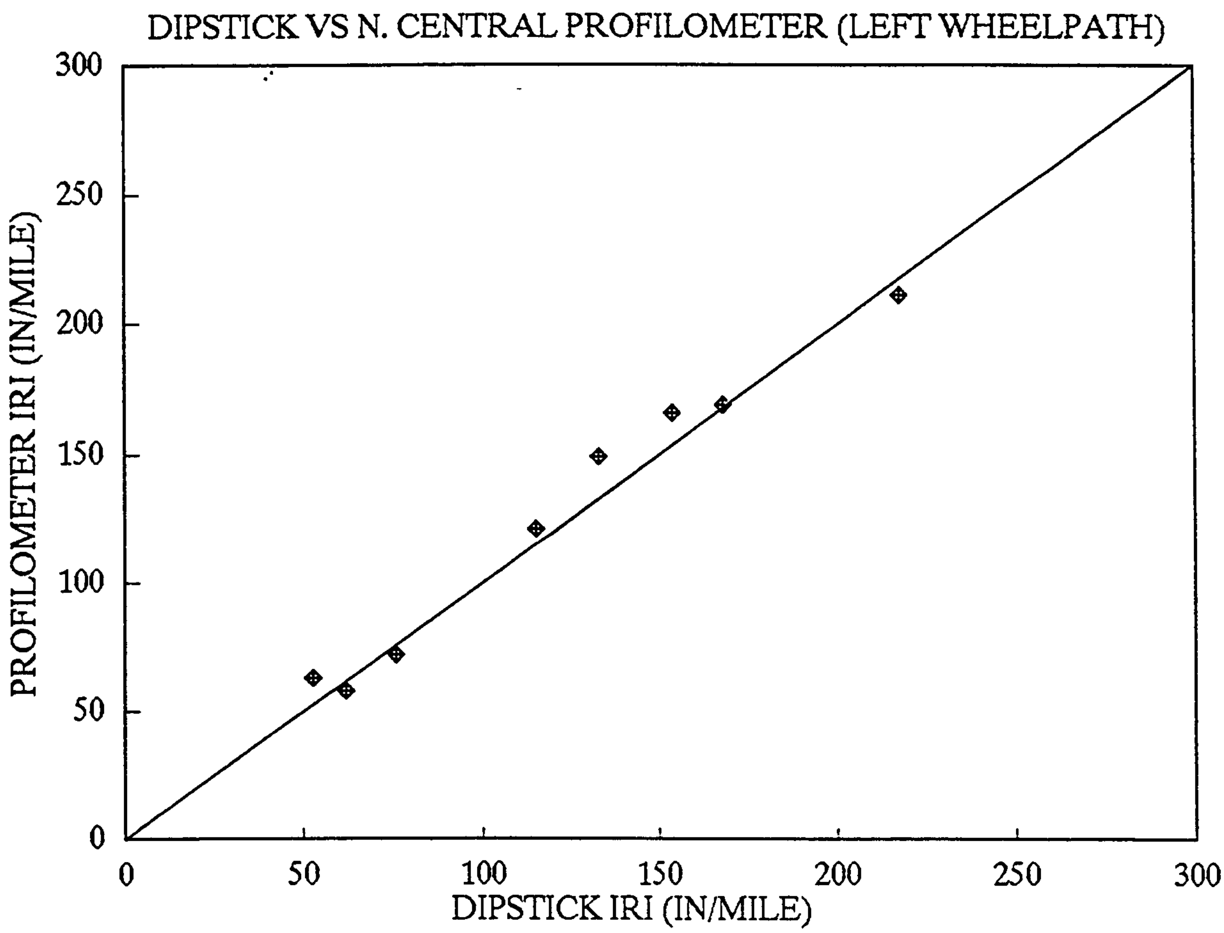

DIPSTICK VS N. CENTRAL PROFILOMETER (LEFT WHEELPATH)
PROFILOMETER IRI (IN/MILE)
DIPSTICK IRI (IN/MILE)
0
50
100
150
200
250
300

Fig. 7.4

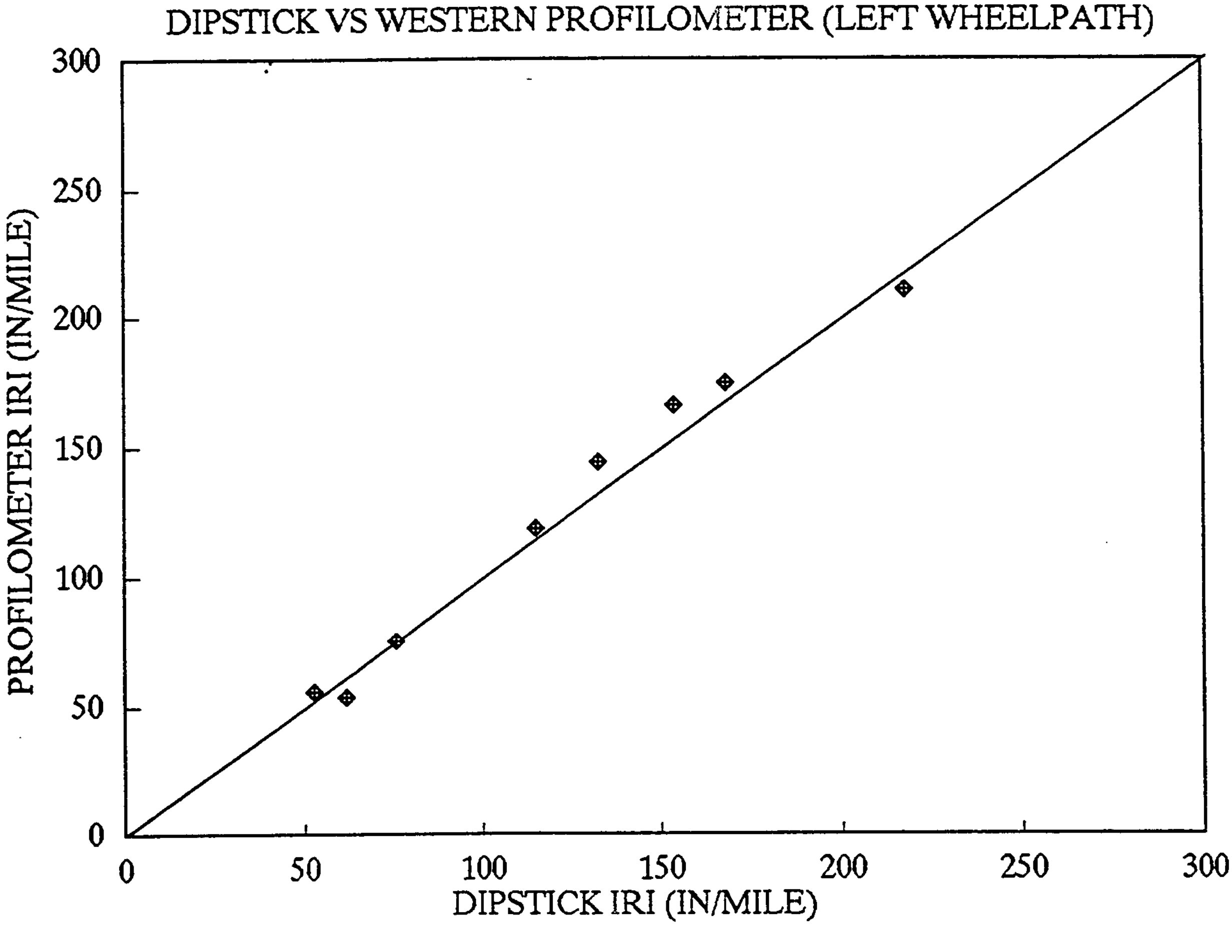

DIPSTICK VS WESTERN PROFILOMETER (LEFT WHEELPATH)
PROFILOMETER IRI (IN/MILE)
0
50
100
150
200
250
300
DIPSTICK IRI (IN/MILE)

Fig. 7.5

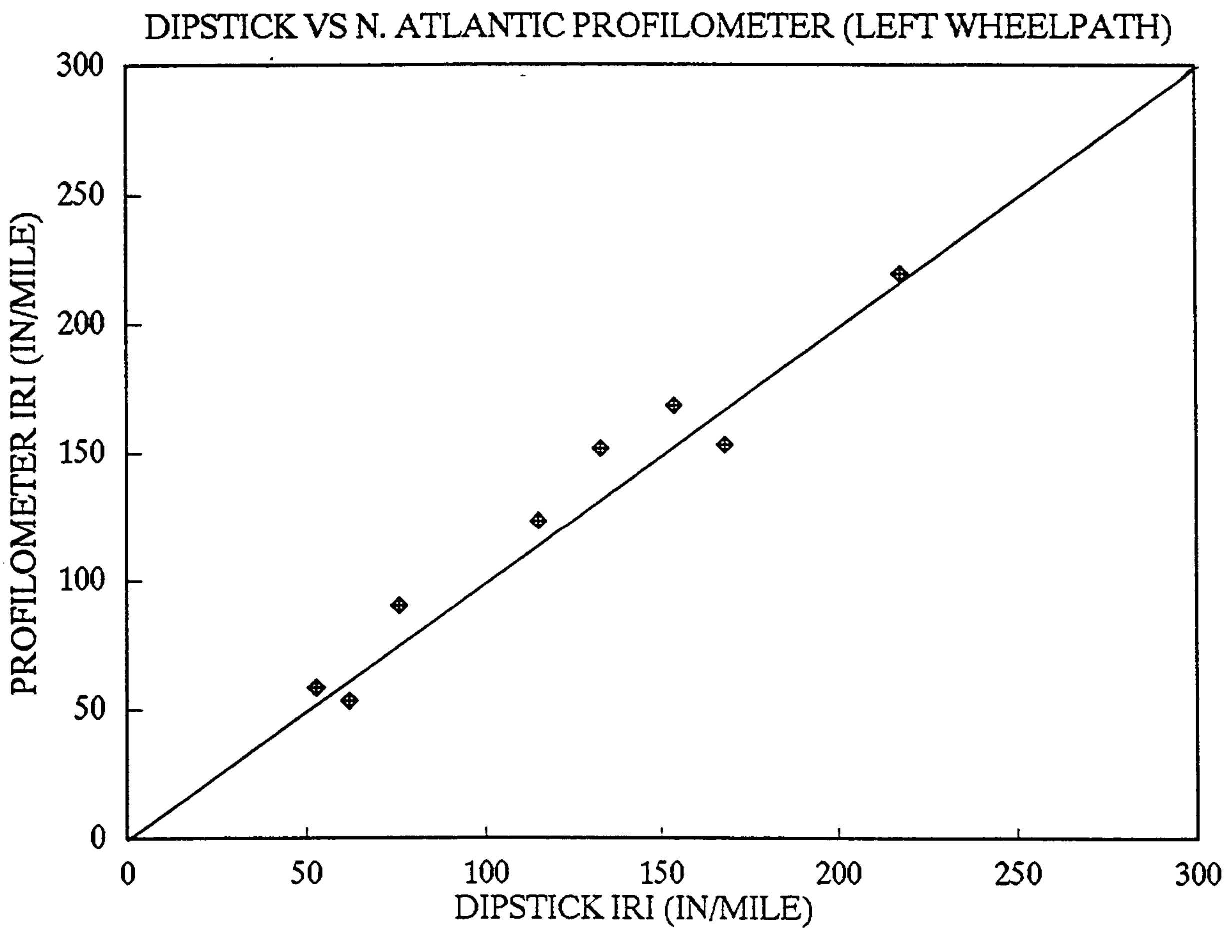

DIPSTICK VS N. ATLANTIC PROFILOMETER (LEFT WHEELPATH)
PROFILOMETER IRI (IN/MILE)
300
250
200
150
100
50
0
0
50
100
150
200
250
300
DIPSTICK IRI (IN/MILE)

Fig. 7.6

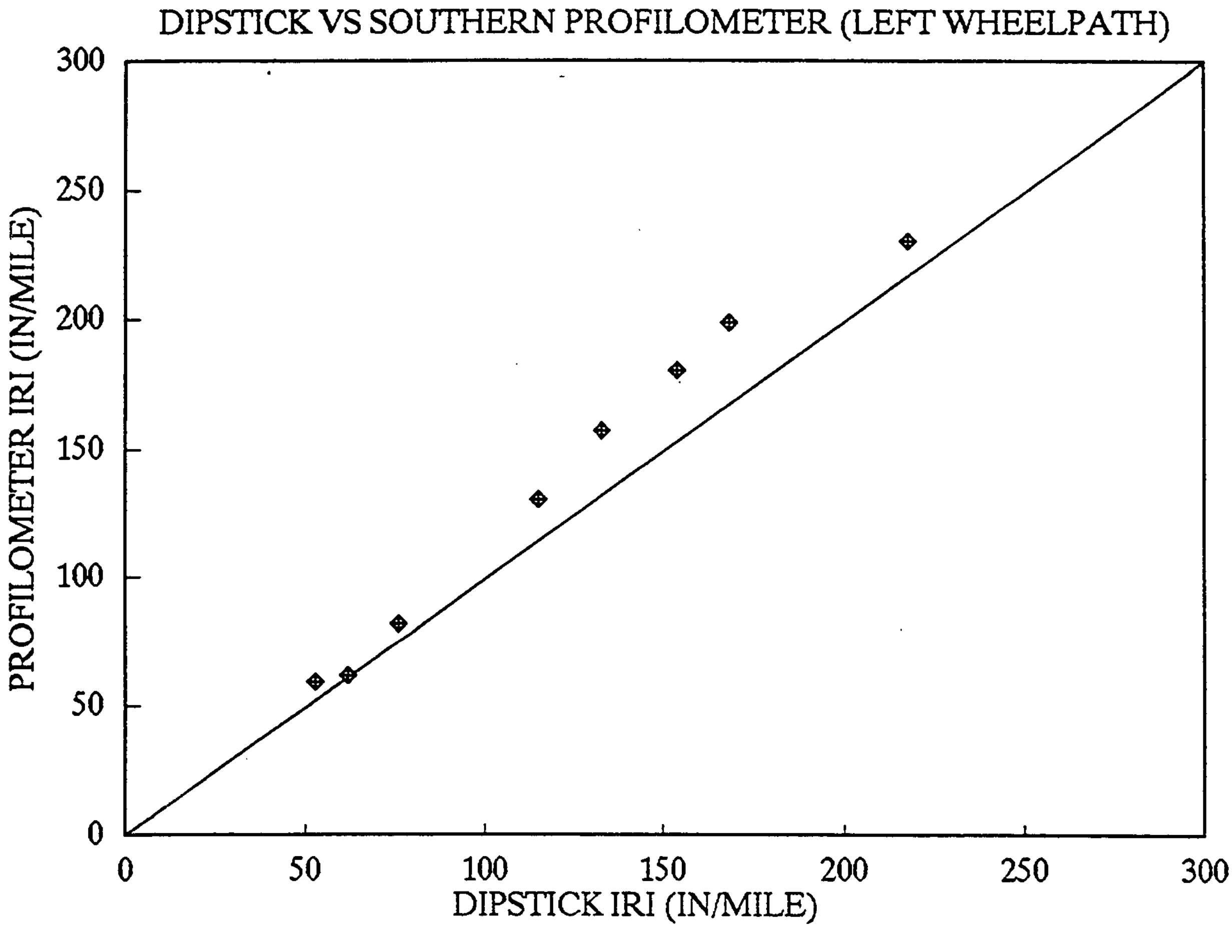

DIPSTICK VS SOUTHERN PROFILOMETER (LEFT WHEELPATH)
PROFILOMETER IRI (IN/MILE)
0
50
100
150
200
250
300
DIPSTICK IRI (IN/MILE)

Fig. 7.7

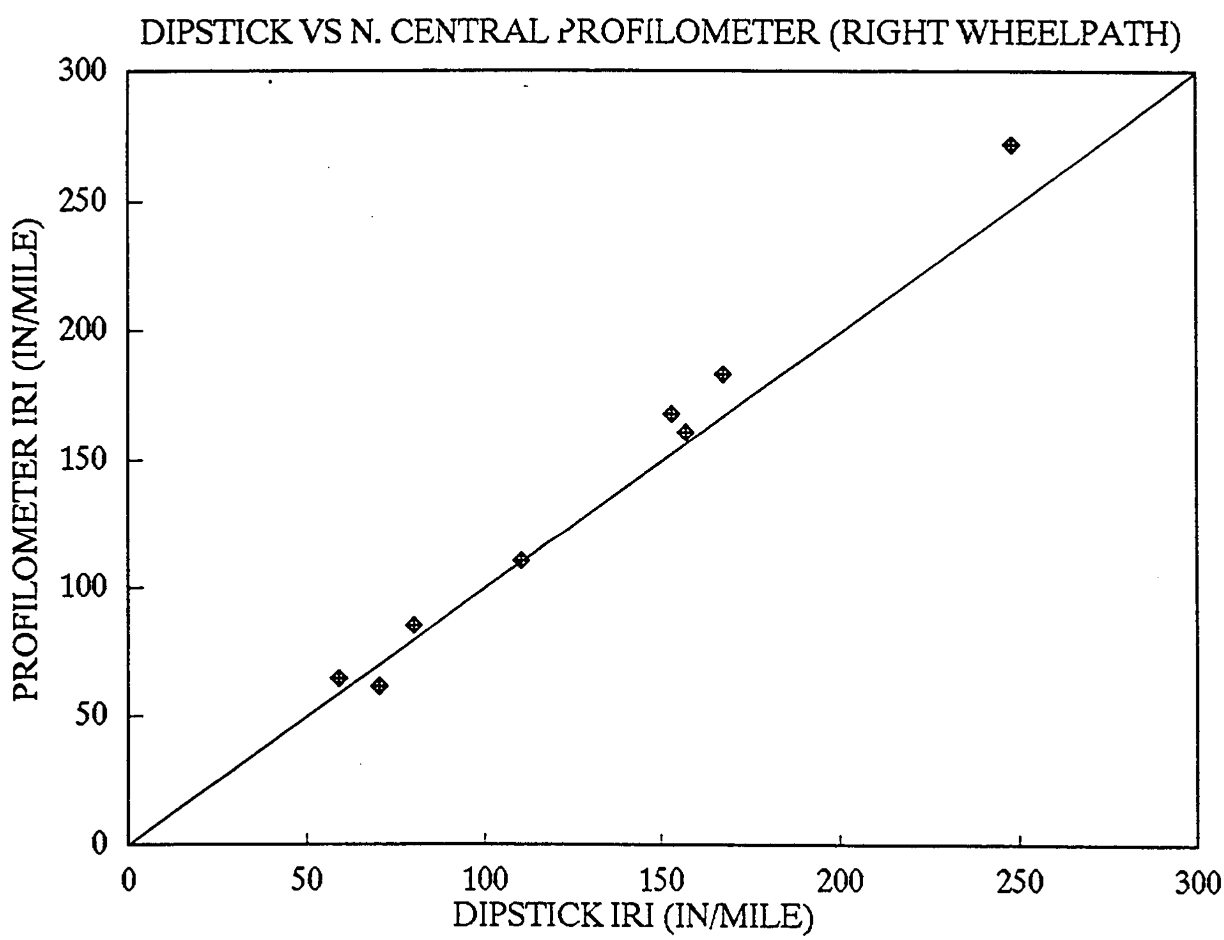

DIPSTICK VS N. CENTRAL PROFILOMETER (RIGHT WHEELPATH)
PROFILOMETER IRI (IN/MILE)
DIPSTICK IRI (IN/MILE)
0
50
100
150
200
250
300

Fig. 7.8

DIPSTICK VS WESTERN PROFILOMETER (RIGHT WHEELPATH)

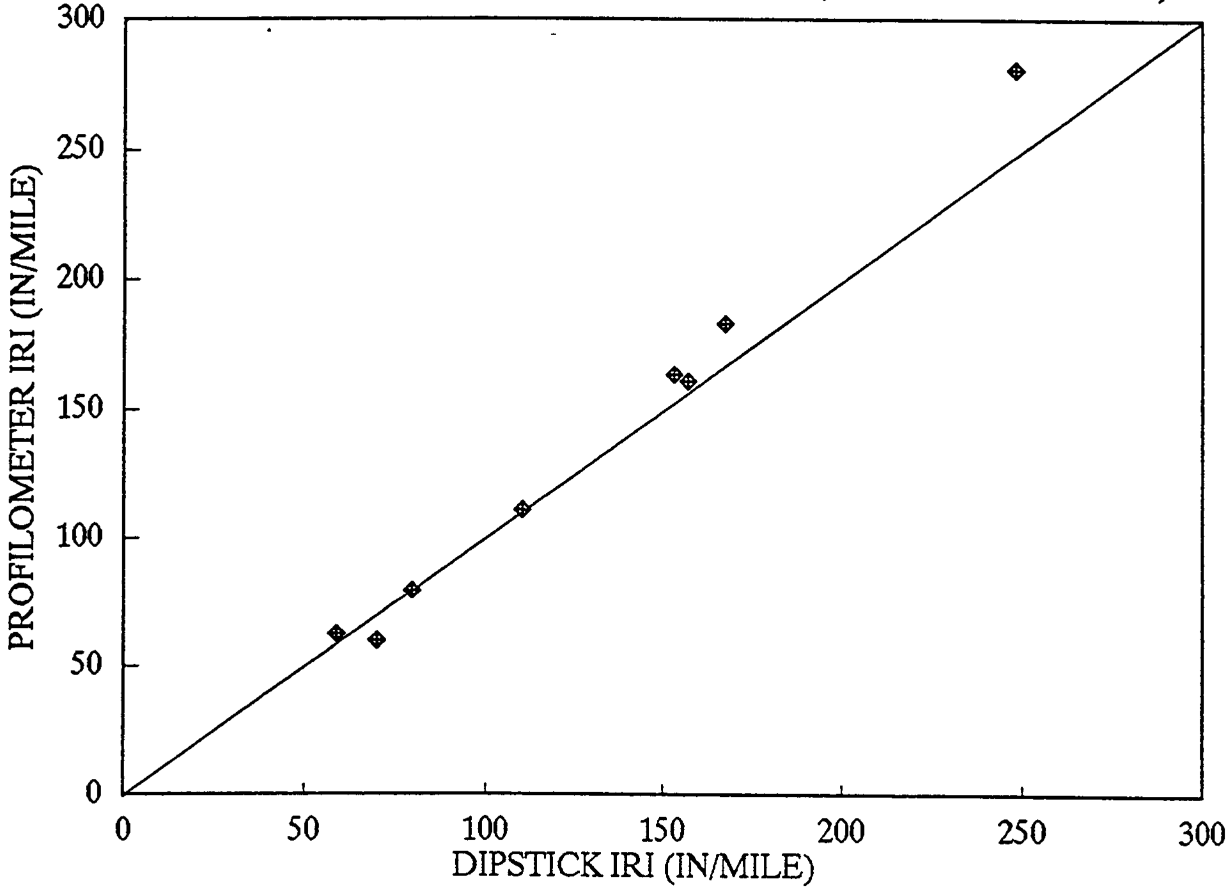
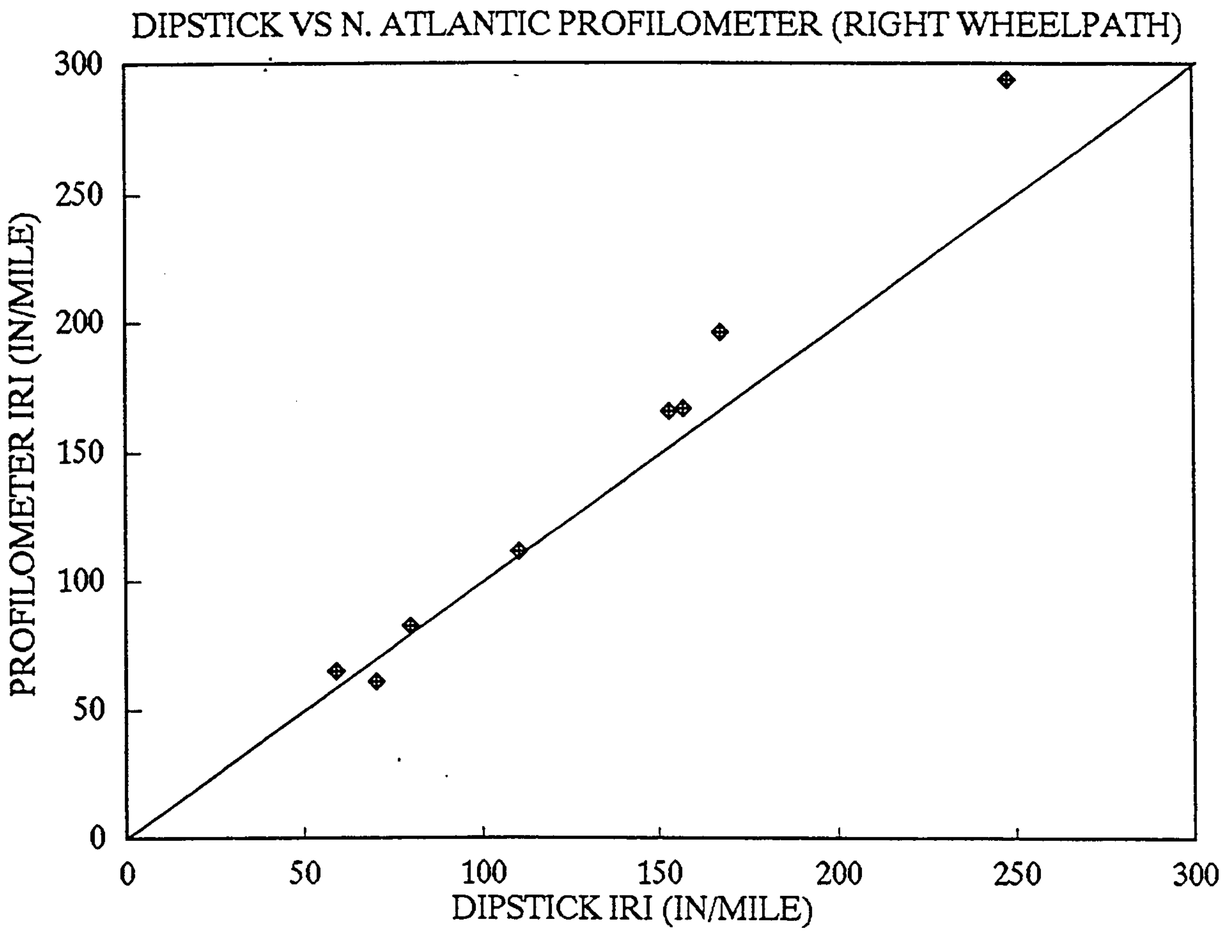


Fig. 7.9



DIPSTICK VS N. ATLANTIC PROFILOMETER (RIGHT WHEELPATH)
PROFILOMETER IRI (IN/MILE)
0
50
100
150
200
250
300
DIPSTICK IRI (IN/MILE)

Fig. 7.10

DIPSTICK VS SOUTHERN PROFILOMETER (RIGHT WHEELPATH)

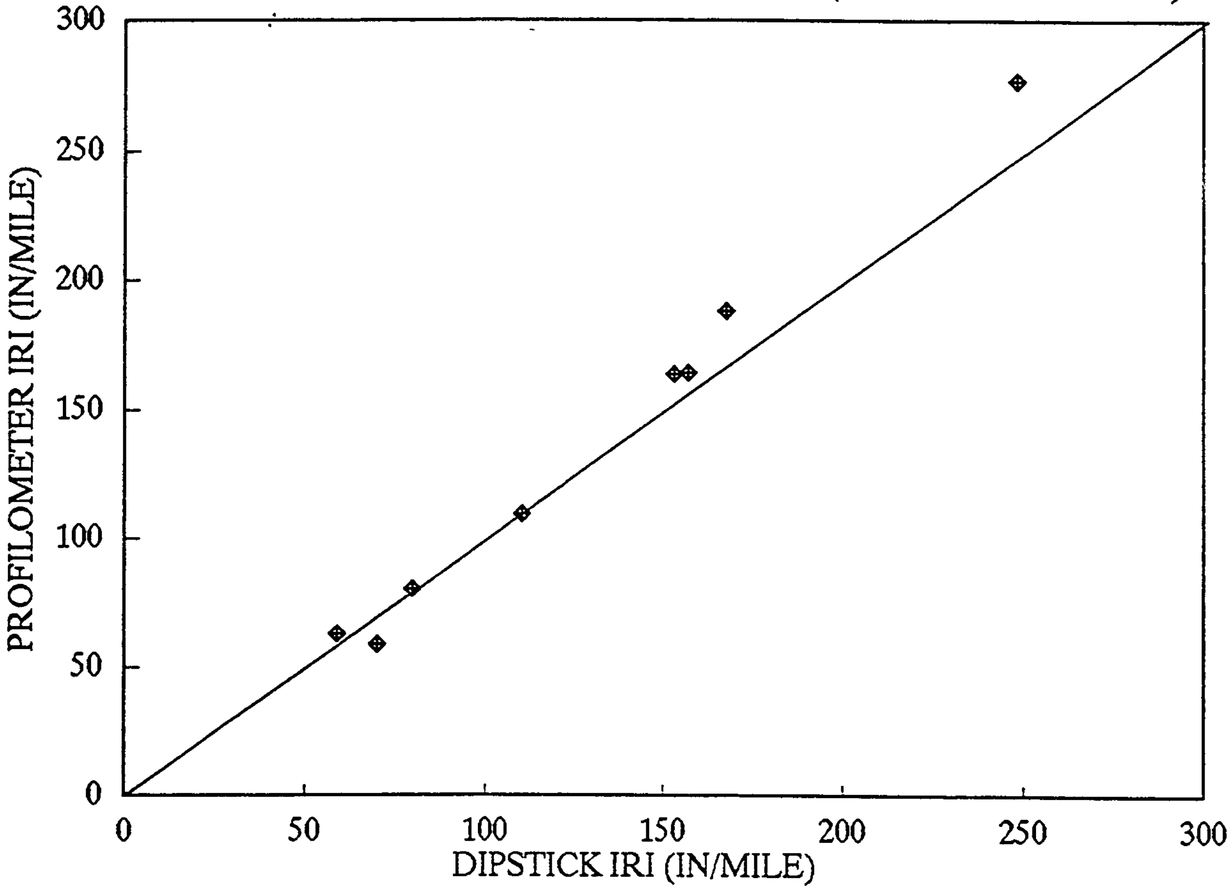


Table 7.1. IRI from Dipstick

SECTION	IRI (IN/MILE)					
	LEFT WHEELPATH			RIGHT WHEELPATH		
	FORWARD RUN	RETURN RUN	AVERAGE	FORWARD RUN	RETURN RUN	AVERAGE
1	75	77	76	78	82	80
2	219	217	218	247	249	248
3	132	134	133	157	157	157
4	54	51	53	58	60	59
5	168	168	168	168	167	168
6	154	154	154	153	154	153
7	116	115	115	110	112	111
8	63	61	62	71	69	70

Table 7.2. Average Profilometer and Dipstick IRI

LEFT WHEELPATH IRI (IN/MILE)

DEVICE	SECTION							
	1	2	3	4	5	6	7	8
N. Central	72	211	149	63	169	166	121	58
Western	75	210	144	55	174	166	118	53
N. Atlantic	90	219	152	58	153	168	123	53
Southern	82	230	157	59	199	180	130	62
Dipstick	76	218	133	53	168	154	115	62

RIGHT WHEELPATH IRI (IN/MILE)

DEVICE	SECTION							
	1	2	3	4	5	6	7	8
N. Central	85	272	161	64	183	168	110	61
Western	80	281	161	62	183	163	111	60
N. Atlantic	82	294	167	65	196	166	112	61
Southern	80	277	164	63	188	164	109	58
Dipstick	80	248	157	59	168	153	111	70

BOTH WHEELPATH IRI (IN/MILE)

DEVICE	SECTION							
	1	2	3	4	5	6	7	8
N. Central	78	241	155	63	176	167	116	59
Western	77	246	152	59	179	165	115	57
N. Atlantic	82	257	159	61	174	167	117	57
Southern	81	254	161	61	193	172	120	60
Dipstick	78	233	145	56	168	154	113	66

Table 7.3. Ratio between Profilometer IRI and Dipstick IRI
(Profilometer IRI/Dipstick IRI)

LEFT WHEELPATH

PROFILOMETER	SECTION							
	1	2	3	4	5	6	7	8
N. Central	0.94	0.97	1.12	1.19	1.00	1.07	1.05	0.93
Western	0.99	0.97	1.08	1.05	1.04	1.08	1.03	0.86
N. Atlantic	1.19	1.01	1.14	1.10	0.91	1.09	1.07	0.85
Southern	1.08	1.06	1.18	1.12	1.18	1.17	1.13	1.00

RIGHT WHEELPATH

PROFILOMETER	SECTION							
	1	2	3	4	5	6	7	8
N. Central	1.07	1.10	1.02	1.09	1.09	1.09	1.00	0.87
Western	1.00	1.13	1.02	1.05	1.09	1.06	1.00	0.85
N. Atlantic	1.03	1.19	1.06	1.10	1.17	1.08	1.01	0.86
Southern	1.01	1.12	1.04	1.06	1.12	1.07	0.99	0.83

BOTH WHEELPATH

PROFILOMETER	SECTION							
	1	2	3	4	5	6	7	8
N. Central	1.01	1.04	1.07	1.13	1.05	1.08	1.02	0.90
Western	0.99	1.05	1.05	1.05	1.06	1.07	1.01	0.86
N. Atlantic	1.06	1.10	1.10	1.10	1.04	1.09	1.04	0.86
Southern	1.04	1.09	1.11	1.09	1.15	1.12	1.06	0.91

North Atlantic Profilometers and the Dipstick. The left wheelpath IRI was selected for comparison as all Profilometers were aligned to this wheelpath. The Southern Profilometer was not included in this analysis as it was seen in Section 5 that the left wheelpath IRI computed from this unit was different than the other three Profilometers. The factors considered for this ANOVA were device (the three Profilometers and the Dipstick) and sections (eight sections given in Table 4.1). As the factor device is a fixed factor and the factor sections is a random factor, a mixed model has to be analyzed. For each section all Profilometers had six replicates (six runs) while the Dipstick had only two replicates (a forward run and a return run). This caused the design to be unbalanced. To avoid complications caused by unbalanced mixed models this problem was analyzed as a balanced factorial design. For each Profilometer two runs were selected out of the six available runs using a random number generator, thus giving a balanced design. The results of the ANOVA showed that the factor device was not significant. The results of the ANOVA are given in Appendix H.

The mean IRIs from the Dipstick and the Southern Profilometer were compared using a paired T-test. Eight data sets corresponding to the eight test sites were available. The mean IRI for the Profilometer was taken as the mean IRI obtained from six runs, while for the Dipstick the mean IRI correspond to the mean of the forward and return runs. At a alpha value of 0.05 the mean values for the left wheelpath IRI were not equal for the two devices.

Table 7.4 gives the results of a regression analysis carried out between the IRI of each Profilometer and the Dipstick for each wheelpath. Though very high coefficients of correlations (R^2) were obtained in all cases, the magnitude of the standard error of estimate should be considered when using these equations.

8. SUBSEQUENT COMPARISON

After the Profilometer comparison study was completed, it was found that there was a malfunction in a computer board related to the left sensor in the Southern Region Profilometer. This could have resulted in erroneous readings for the left sensor during testing. After this problem was corrected, another series of comparative testing at all the eight sections were performed between the Southern and North Central Region Profilometers in September 1991. Unlike the June comparative test, the left wheelpath was not marked at the test sections for this study. Therefore, the Profilometer drivers had to judge the position of the left wheelpath. After the IRIs were computed for all runs, as

Table 7.4. Result of Liner Regression between Profilometer IRI and Dipstick IRI

Wheelpath	Profilometer	R Squared	Equation	SEE
Left	N. Central	0.98	P = 0.984D + 5.43	9.03
	Western	0.98	P = 1.019D - 0.05	8.06
	N. Atlantic	0.96	P = 0.980D + 7.1	12.7
	Southern	0.98	P = 1.125D - 0.25	8.97
Right	N. Central	0.99	P = 1.131D - 9.92	6.53
	Western	0.99	P = 1.183D - 17.2	6.15
	N. Atlantic	0.99	P = 1.248D - 20.51	8.24
	Southern	0.99	P = 1.178D - 16.13	6.47
Both	N. Central	0.99	P = 1.062D - 2.58	5.38
	Western	0.99	P = 1.103D - 8.62	4.43
	N. Atlantic	0.99	P = 1.131D - 8.78	5.90
	Southern	0.99	P = 1.150D - 7.9	5.85
Note :	P = IRI obtained from Profilometer (in/mile) D = IRI obtained from Dipstick (in/mile) SEE = Standard error of estimation			

Table 8.1. Average IRI for North Central and Southern Profilometers from the September Comparison

Left Wheelpath IRI (in/mile)

Section Number	1	5	6	7	8
N. Central Profilometer	68	177	164	120	67
Southern Profilometer	82	208	183	128	80
Difference in IRI (Southern – Noth Central)	14	31	19	8	13

Right Wheelpath IRI (in/mile)

Section Number	1	5	6	7	8
N. Central Profilometer	88	200	172	118	70
Southern Profilometer	76	189	166	109	68
Difference in IRI (Southern – Noth Central)	-8	-11	-6	-9	-2

before the six best runs were selected for analysis based on the standard deviation. The IRI computed for the September testing for North Central and Southern Profilometers is given in Appendix I.

First an ANOVA was conducted using the IRI obtained by the North Central Profilometer in June (during comparative testing) and September to determine if there was a difference in the IRI with respect to time. The design that was used for the ANOVA was the same as that shown in Fig. 5.1 except that the factor Profilometer was replaced by the factor time, which had two levels (June and September). ANOVA was carried out separately for the left wheelpath and right wheelpath IRI. The ANOVA of the left wheelpath IRI indicated that the IRI from the two time periods were not different. However, the analysis of the right wheelpath IRI showed that the IRI for the two time periods were different. As the left wheelpath was not marked during the September test, the path followed by the Profilometer at a section may not be the exact path followed during the June test. The right wheelpath IRI, especially in asphalt pavements may have been affected by such a situation due to transverse variability in pavement profile near the pavement edge. This could have caused the result obtained in the ANOVA for the right wheelpath. The details of the ANOVA are given in Appendix I.

Thereafter, an ANOVA was performed between the IRI obtained from the North Central and Southern Profilometers from the September comparative study. The Southern Profilometer did not test site 4 due to equipment problems. In addition the data obtained for sites 2 and 3 were contaminated by radar spikes and could not be used. Therefore, only five sections were available for this comparison. Due to this reason the earlier design (Fig. 5.1) could not be used and the design shown in Fig. 8.1 was used to conduct the ANOVA. In this design the main factors are Profilometers, speed and sections. The Southern region data used for this analysis is given in Appendix I. The ANOVA for left as well as right wheelpaths showed that the factor Profilometer was significant. The computer outputs for this analysis are given in Appendix I.

The mean IRI of the sections computed from North Central and Southern Profilometer data from the September comparison are given in Table 8.1. The values in this table show that there is a difference in IRI for the left as well as the right wheelpaths for the two Profilometers. However, the difference between the computed IRIs for the two Profilometers in the left wheelpath were much greater than that for the right wheelpath (see Table 8.1). The differences in the left wheelpath IRI are much greater than a difference that is expected due to variation in wheelpath between the two Profilometers. Although ANOVA showed that the IRI of profile data collected by the two Profilometers were different in the right wheelpath, this difference may be due to variations in the

Fig. 8.1. Design used to analyze North Central and Southern Region Profilometer Comparison

		SECTIONS				
		1	5	6	7	8
NORTH CENTRAL	40 mph					
	50 mph					
SOUTHERN	40 mph					
	50 mph					

wheelpaths measured by the two devices. The magnitudes of the differences in the IRI between the two devices in the right wheelpath (see Table 8.1) tends to support this. This comparison showed that the profiles measured by the Southern Profilometer in the left wheelpath were still different from the profiles measured by the North Central Profilometer. The replacement of the computer board in the Southern Profilometers has not corrected the problem with the left sensor.

9. . COMMENTS ON TEST PROGRAM AND ANALYSIS

1. During comparative testing the Profilometer operators used the both wheelpath IRI to determine if a series of Profilometer runs at a site satisfied the Profscan criteria.
2. No adjustments were made to eliminate spikes in the profile data collected by the Profilometers. In the Profscan program a spike threshold value of 0.1 in. was used. When Profscan computes IRI it indicates possible spikes in a run based on this criteria. In most instances where spikes were present in Profilometer runs at a section, the variability of IRI between the runs was small. It is most likely in such cases the spikes were the result of the anomalies in the pavement. However, in a few instances the Profilometer runs at a sections which contained spikes had large variability of IRI between runs. In such cases the spikes were obviously due to some external causes. Such runs were not included in the analysis as they were eliminated when the six runs for the analysis were selected based on the standard deviation criteria.
3. No filtering was performed on the Dipstick data before computing the IRI.
4. The surface type (asphalt or concrete) was used as a factor in ANOVA. In order to determine if there is a difference in readings taken by the Profilometers on an asphalt surface as opposed to a concrete surface, asphalt and concrete sections that have identical IRIs are needed. In this experiment there was no correspondence between the levels of IRIs of the two smooth asphalt sections with the two smooth concrete sections. This also holds true for the sections with medium roughness. Therefore, in the ANOVA the factor surface type merely indicates whether there is a difference in IRI between the asphalt and concrete sections. As the mean IRI of the asphalt and concrete sections used in this experiment are very close to each other, the factor surface type does not become significant.

10. CONCLUSIONS

1. When the IRIs of the left wheelpath were analyzed, the criteria that at least three runs should be within 1% of the mean was met by only 58% of the test situations. However, the criteria that the standard deviation of the runs should be within 3% of the mean was met by over 90% of the test situations. Even in this controlled experiment where the left wheelpath was marked, the 1% criteria on the mean was difficult to achieve in many situations when the left wheelpath IRI was considered. However, when the both wheelpath IRI was considered, the 1% criteria was met by 73% of test situations. It was seen that the acceptance of the 1% of the mean criteria at a site based on the both wheelpath IRI does not automatically ensure that the criteria is met by the individual wheelpath IRIs.
2. When the left wheelpath IRIs were analyzed, 95% of all runs were within 4.3% of the average left wheelpath IRI associated with the runs. When the both wheelpath IRI was considered 95% of all runs were within 2.6% of the both wheelpath IRI associated with the runs. This shows when a set of Profilometer runs are considered, a criteria based on the both wheelpath IRI is easier to achieve than a criteria based on the left wheelpath IRI.
3. The ANOVA of the left wheelpath IRIs shows that the profile data collected by the left sensor of the Southern Region Profilometer was different than that of the other three units. ANOVA showed that the left wheelpath IRI computed from the data collected by the North Central, Western and the North Atlantic Region Profilometers were similar.
4. In the right wheelpath, ANOVA indicated that the profile data collected by the Profilometer combinations of: (a) North Central, Western and North Atlantic (b) North Central, Western and Southern (c) North Central, North Atlantic and Southern were similar. Although the right wheelpath of the North Central Profilometer does not follow the same wheelpath as the other units, all three cases in which the Profilometers were not significant in the ANOVA involved this unit. However, the ANOVA of the right wheelpath showed that at least one Profilometer was different from the others in the Profilometer combination of Western, North Atlantic and Southern Region, though these units have similar sensor spacings.
5. The results from ANOVA of the left wheelpath IRIs showed that the speed of testing was not significant. For the right wheelpath the speed of testing was a

significant factor for two Profilometer combinations out of a total of five combinations that were analyzed.

6. All Profilometers showed excellent repeatability in both wheelpaths, except at a few sections which had spikes in the profile data. It was observed that the repeatability of the Profilometers was not affected by surface type (asphalt vs concrete), the level of roughness (smooth vs medium) or the two speeds selected for testing (40 MPH vs 50 MPH).
7. A statistical analysis indicated that the IRI computed for the left wheelpath from the data collected by the Profilometers of the North Central, Western and North Atlantic regions as well as the Dipstick were similar. This indicates that the three SHRP Profilometers from the North Central, Western and North Atlantic Regions are collecting accurate data in the left wheelpath.

11. RECOMMENDATIONS

1. The criteria used in the Profscan program (that three IRI values should be within 1% of the mean) was found to be difficult to achieve in many situations in this controlled experiment where the wheelpaths were marked. Thus, this criteria would be harder to achieve during routine testing where the wheelpaths are not marked. It is recommended that this criteria be relaxed.
2. ANOVA showed that the left wheelpath IRI of the Southern Profilometer was different from the other three Profilometers. The overall mean of the left wheelpath IRI obtained from all runs performed at all sections were 125.4, 124.2, 125.3 and 138.9 in/mile for North Central, Western, North Atlantic and Southern Profilometers respectively. These numbers as well as the figures in Appendix A show that the left wheelpath IRI of the Southern unit is significantly higher than the other units. However, the Southern Profilometer was as repeatable as the other Profilometers.

   In order to obtain comparable IRIs, the IRIs obtained from the Southern unit need to be adjusted. Appendix J gives the details of a comparison of the mean left wheelpath IRI of the Southern and the North Central units for both the June and September studies. This comparison shows that a relationship between the IRIs of the Southern and North Central units can be developed. Therefore, such a relationship can be used to correct the left wheelpath IRIs of the Southern Profilometer.

ANOVA of the right wheelpath IRI did not indicate that the right wheelpath IRI of the Southern unit was different from the other units. The overall mean IRIs for the right wheelpath were 138, 136.5, 142 and 138 in./mile for North Central, Western, North Atlantic and Southern units. These numbers as well as the figures in Appendix A do not show any evidence that there is a significant difference between the right wheelpath IRIs of the Southern unit and the other units. Therefore, no adjustments are recommended for the right wheelpath IRIs obtained from the Southern Region Profilometer.

It is recommended that a comparative study be performed between the Southern unit and another unit from any region on a series of sections which will encompass the range of roughness encountered during routine testing to develop correction factors (as outlined in Appendix J) for the left wheelpath IRI of the Southern Profilometer.

3. It is recommended that a Profilometer comparison study similar to this study at Ann Arbor be conducted annually. Results of such a study will provide a check on the accuracy of all Profilometers. In future studies it is recommended that testing be performed only at 50 MPH, as this study showed that there was no difference in IRI for test speeds of 40 and 50 MPH.

12. REFERENCES

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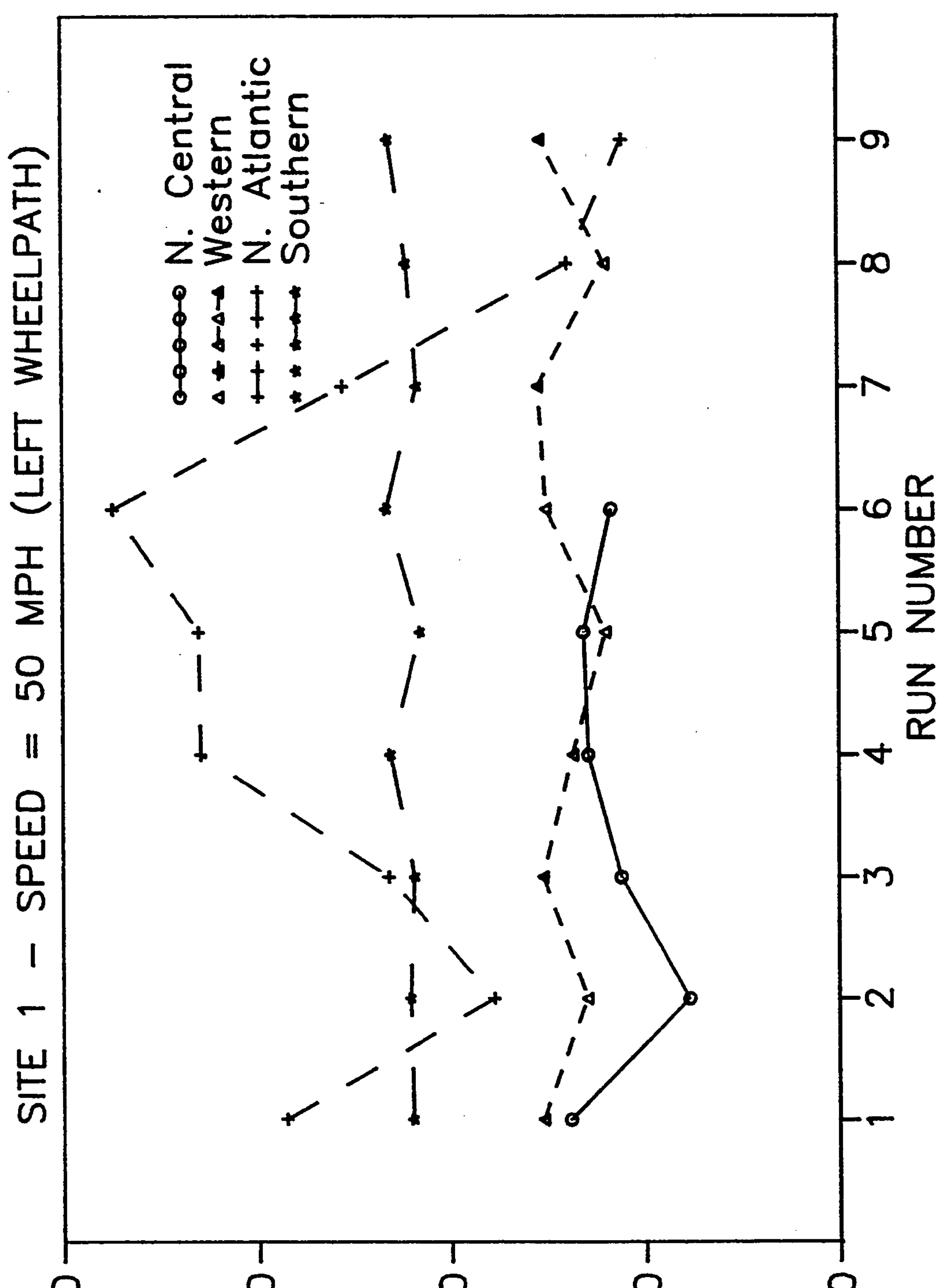
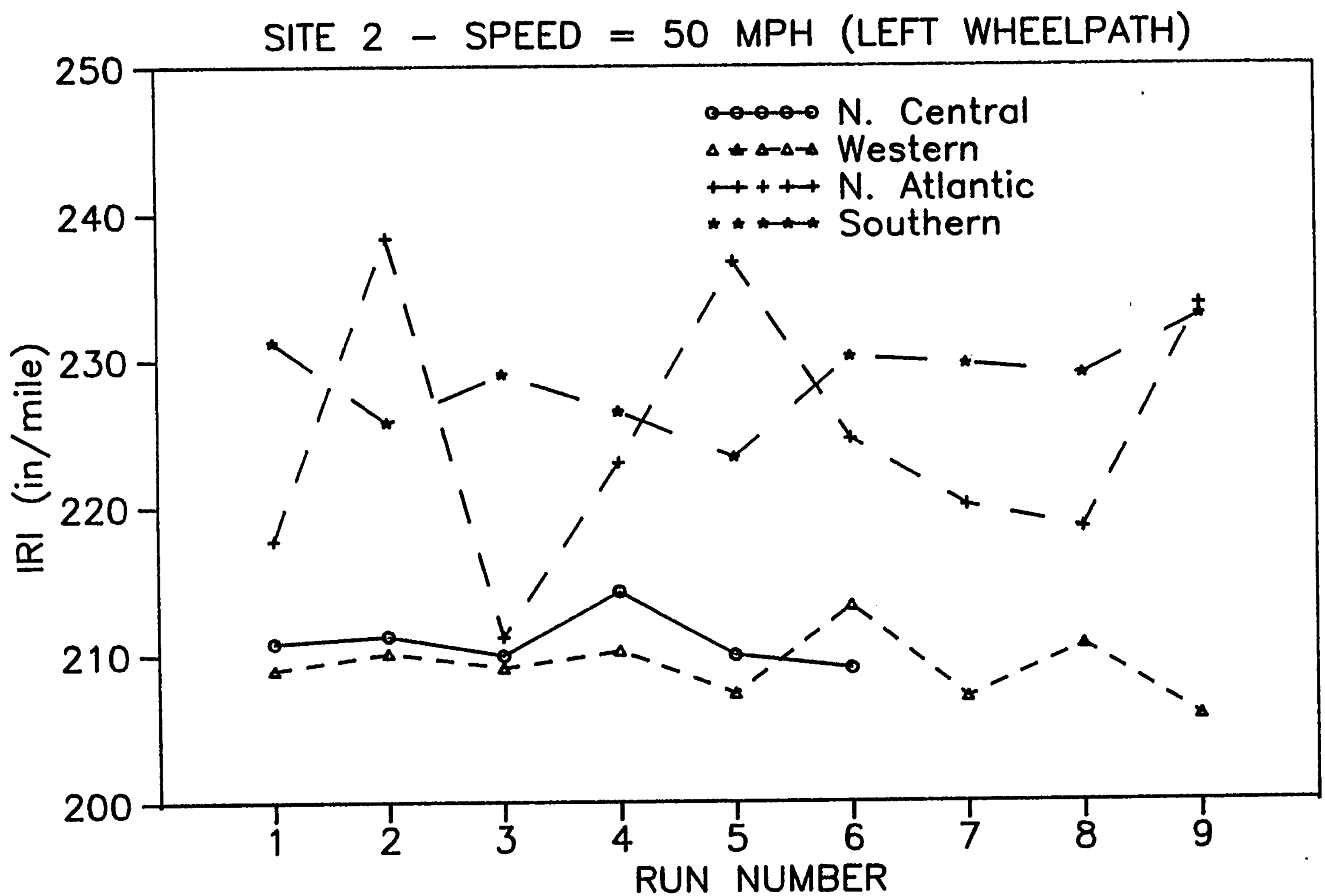
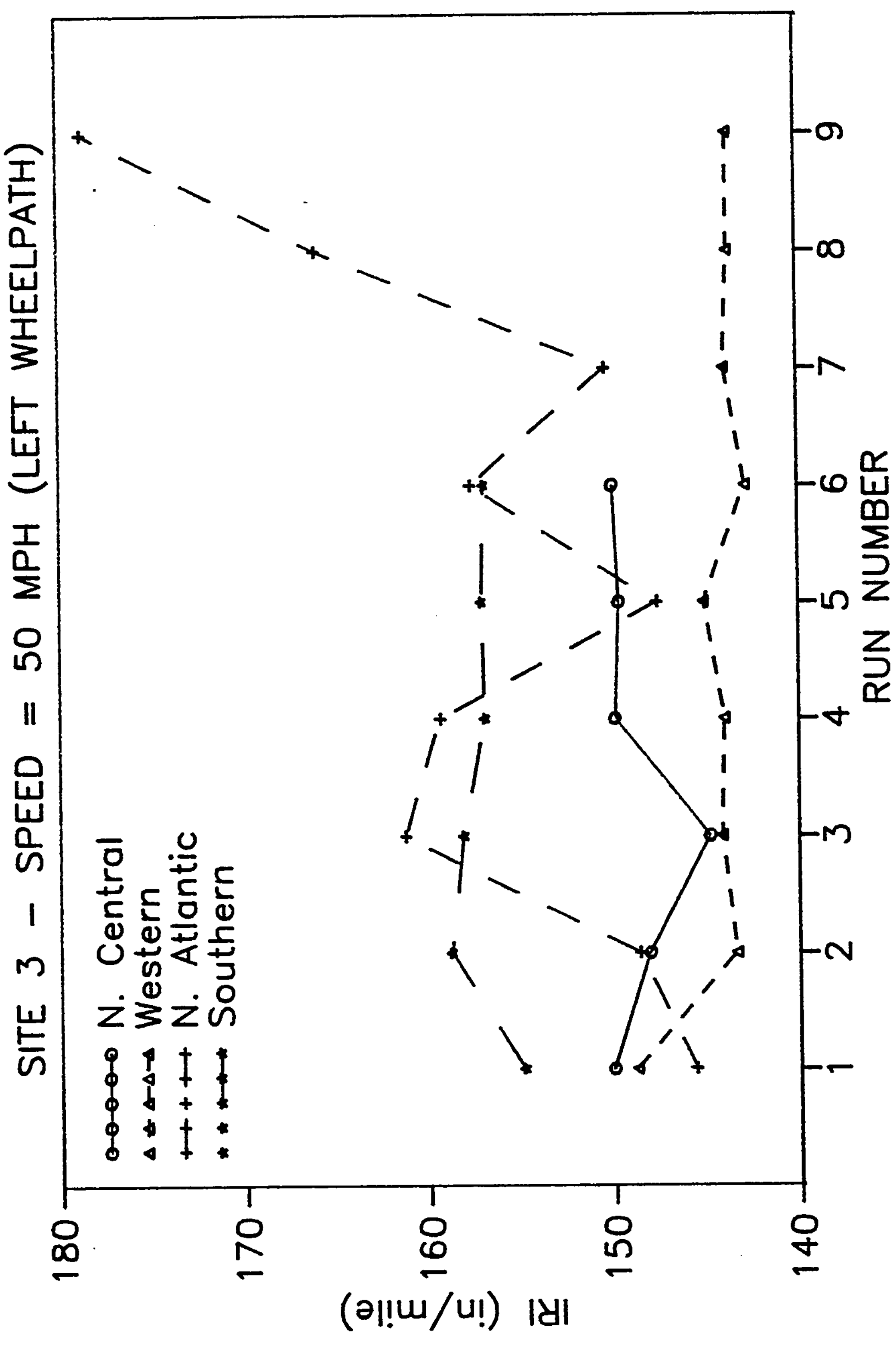
APPENDIX A

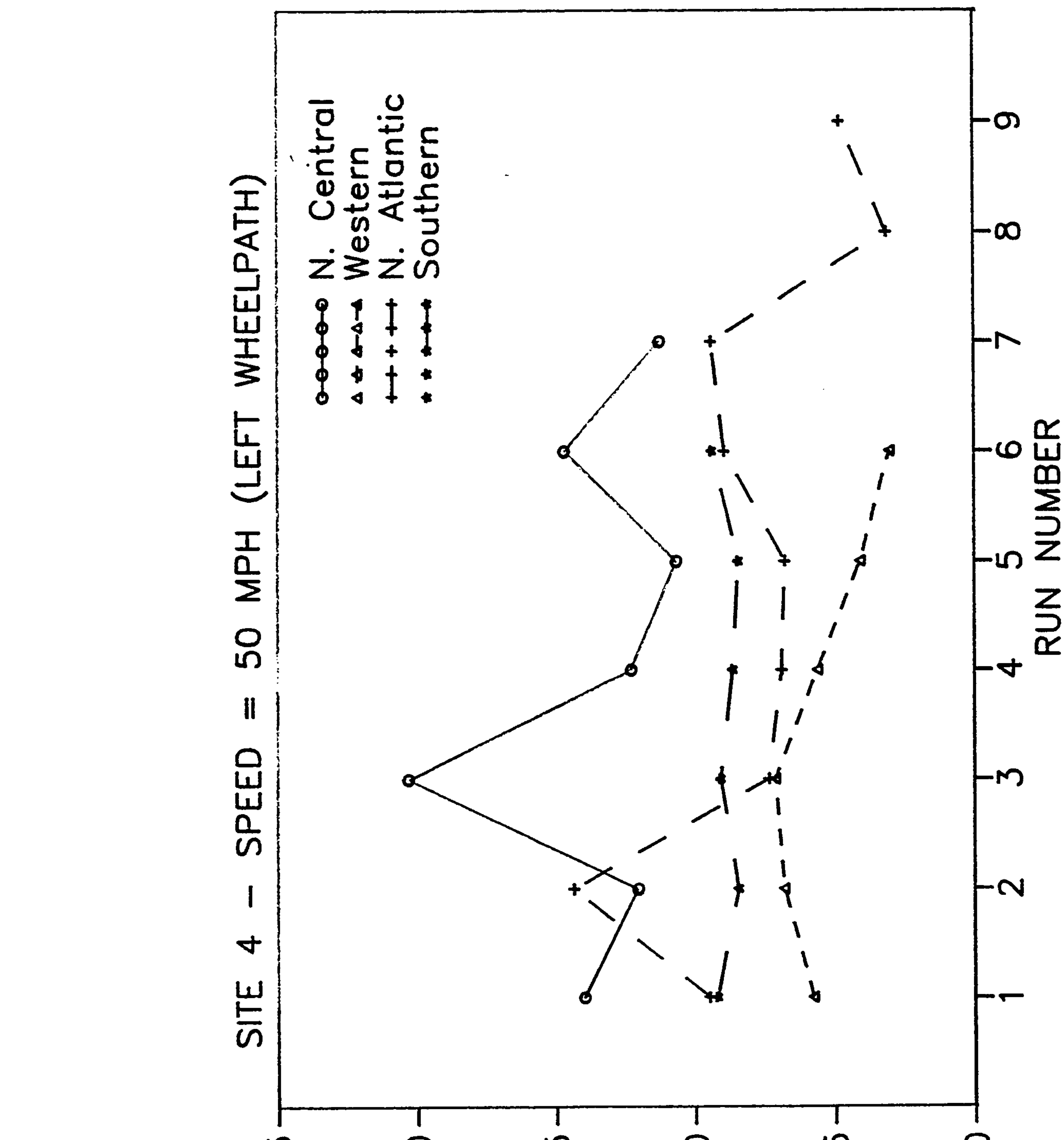
VARIATION OF LEFT AND RIGHT WHEELPATH IRI FOR ALL PROFILOMETER RUNS

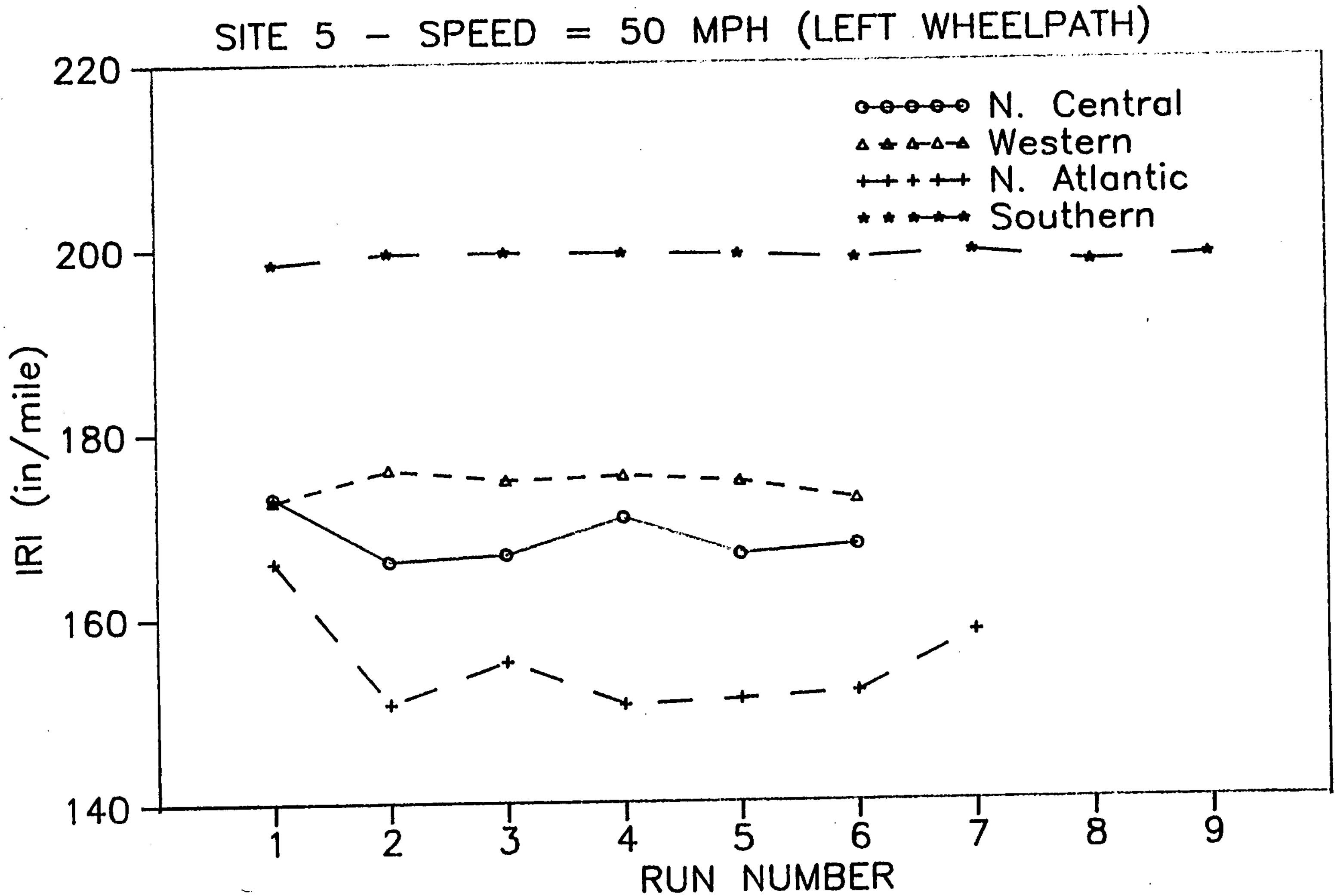


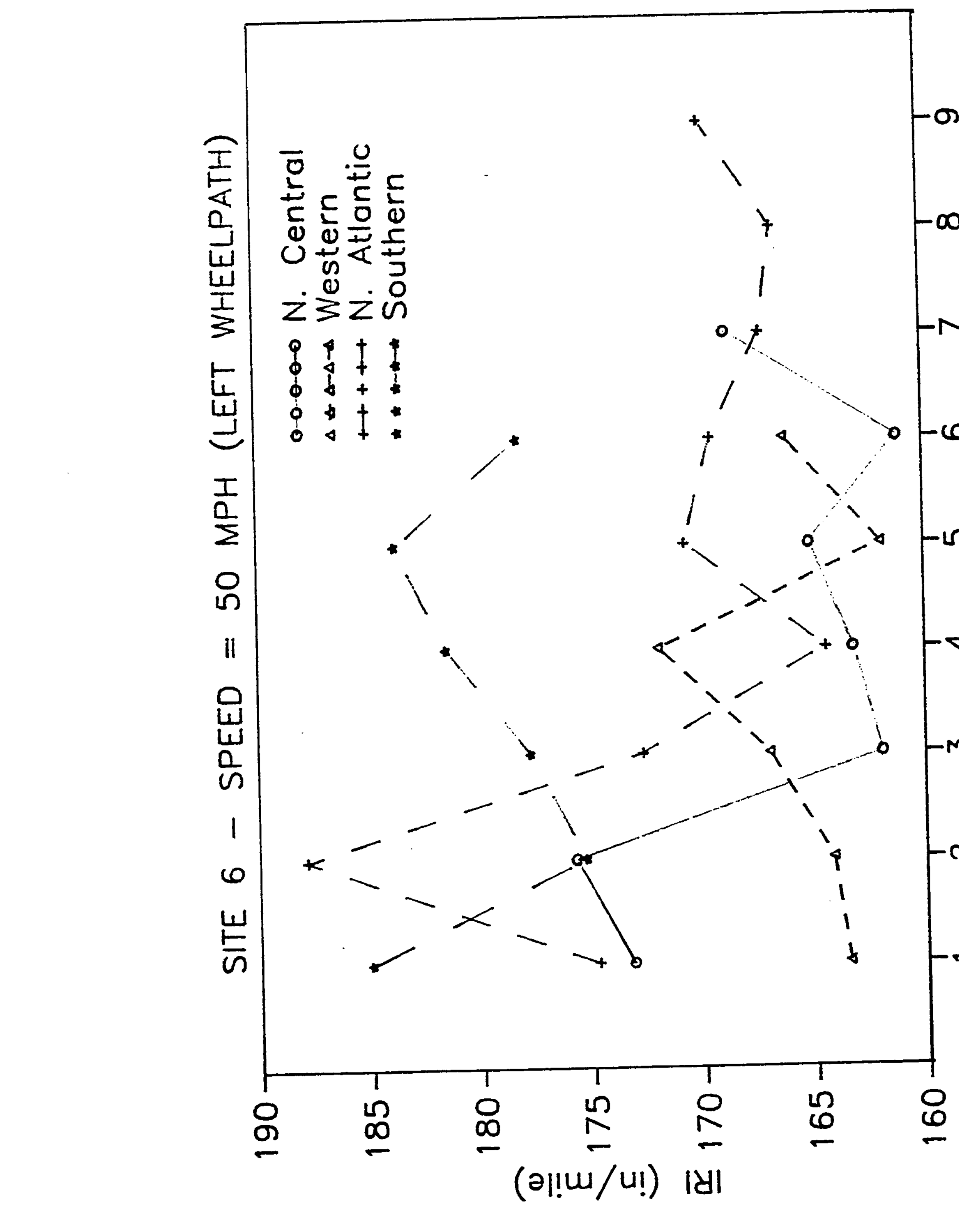
SITE 1 - SPEED = 50 MPH (LEFT WHEELPATH)
IRI (in/mile)
100
90
80
70
60
RUN NUMBER
1
2
3
4
5
6
7
8
9
N. Central
Western
N. Atlantic
Southern

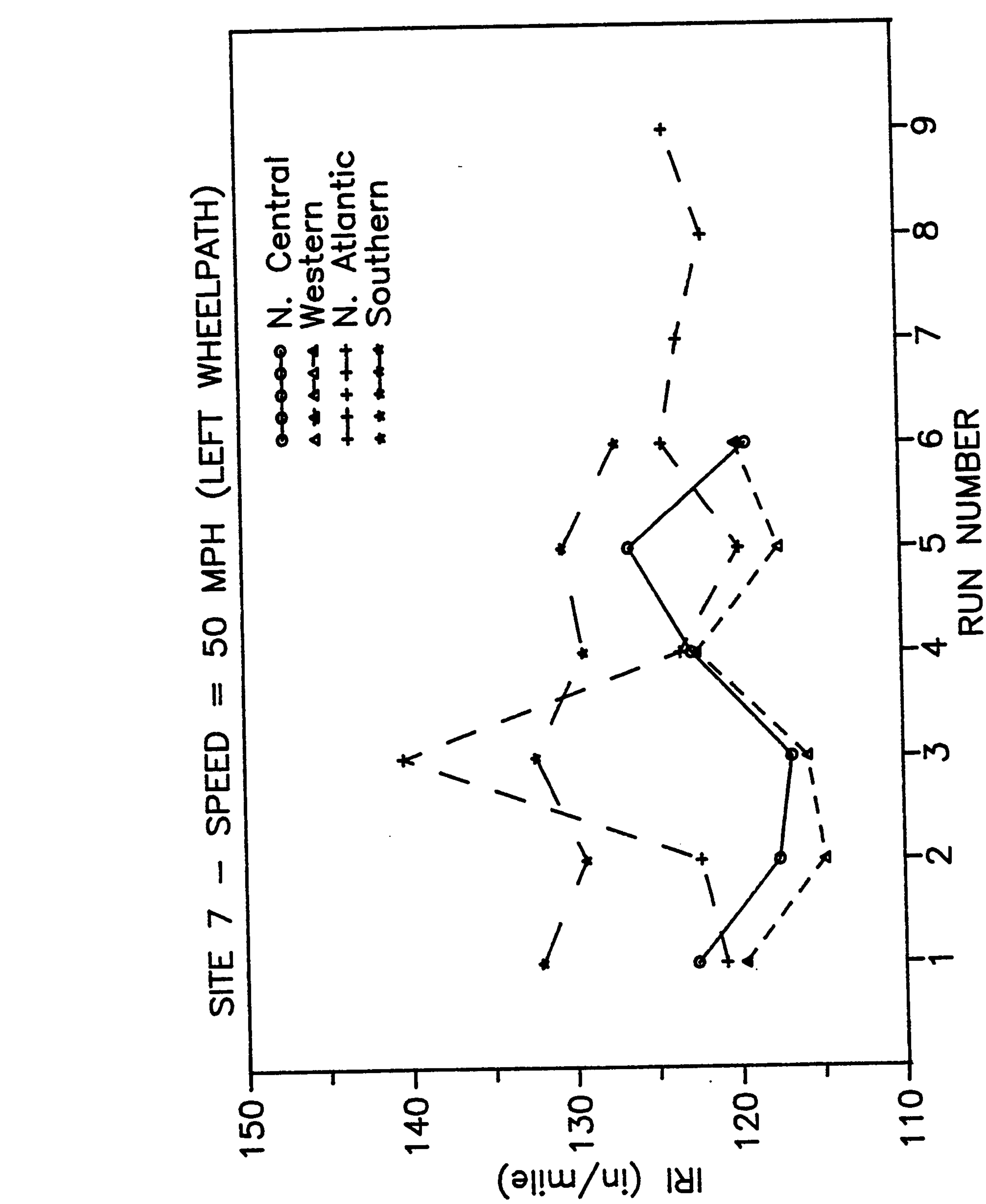

SITE 2 – SPEED = 50 MPH (LEFT WHEELPATH)
N. Central
Western
N. Atlantic
Southern
IRI (in/mile)
250
240
230
220
210
200
RUN NUMBER
1
2
3
4
5
6
7
8
9

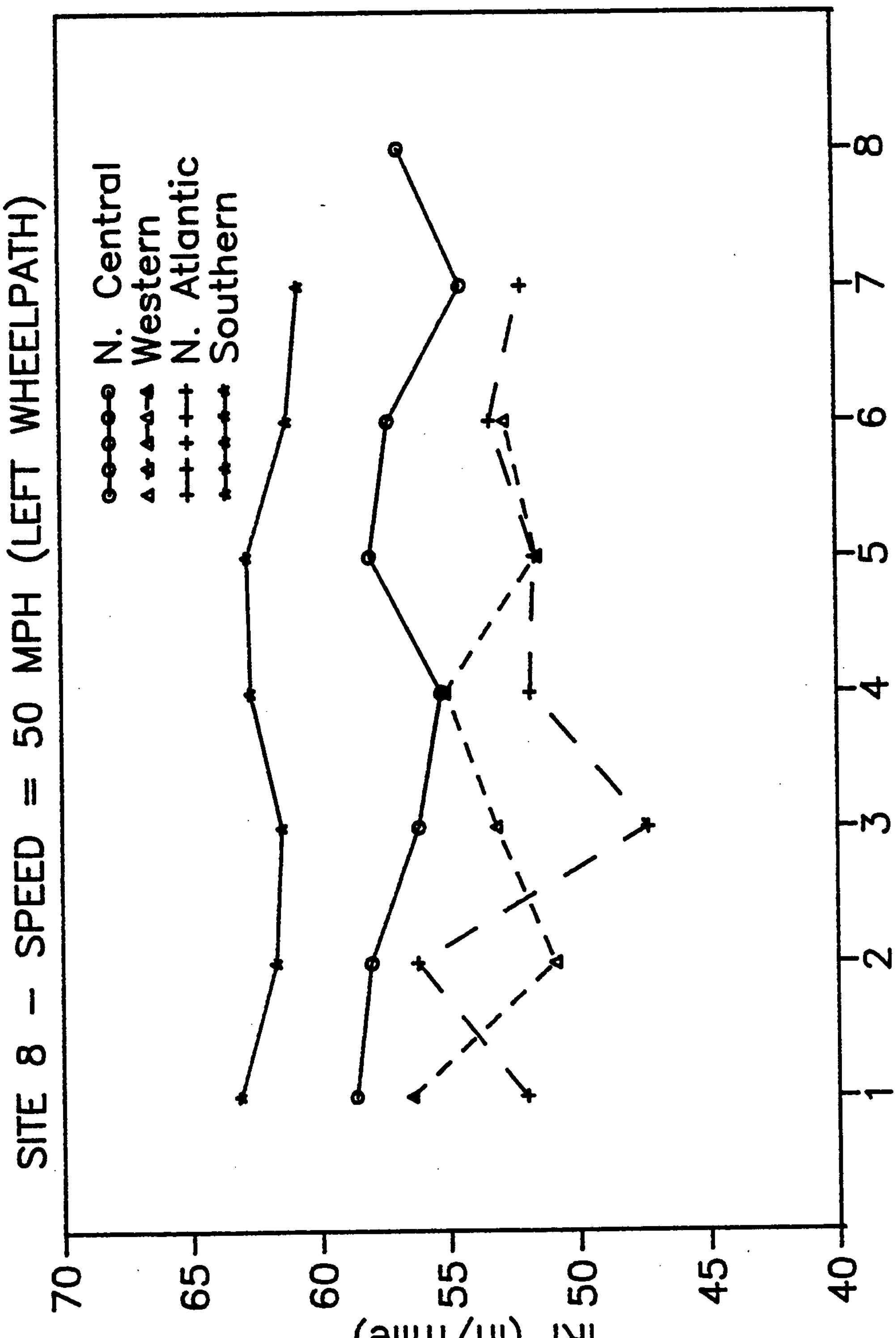

SITE 3 – SPEED = 50 MPH (LEFT WHEELPATH)
N. Central
Western
N. Atlantic
Southern
IRI (in/mile)
180
170
160
150
140
RUN NUMBER
1
2
3
4
5
6
7
8
9

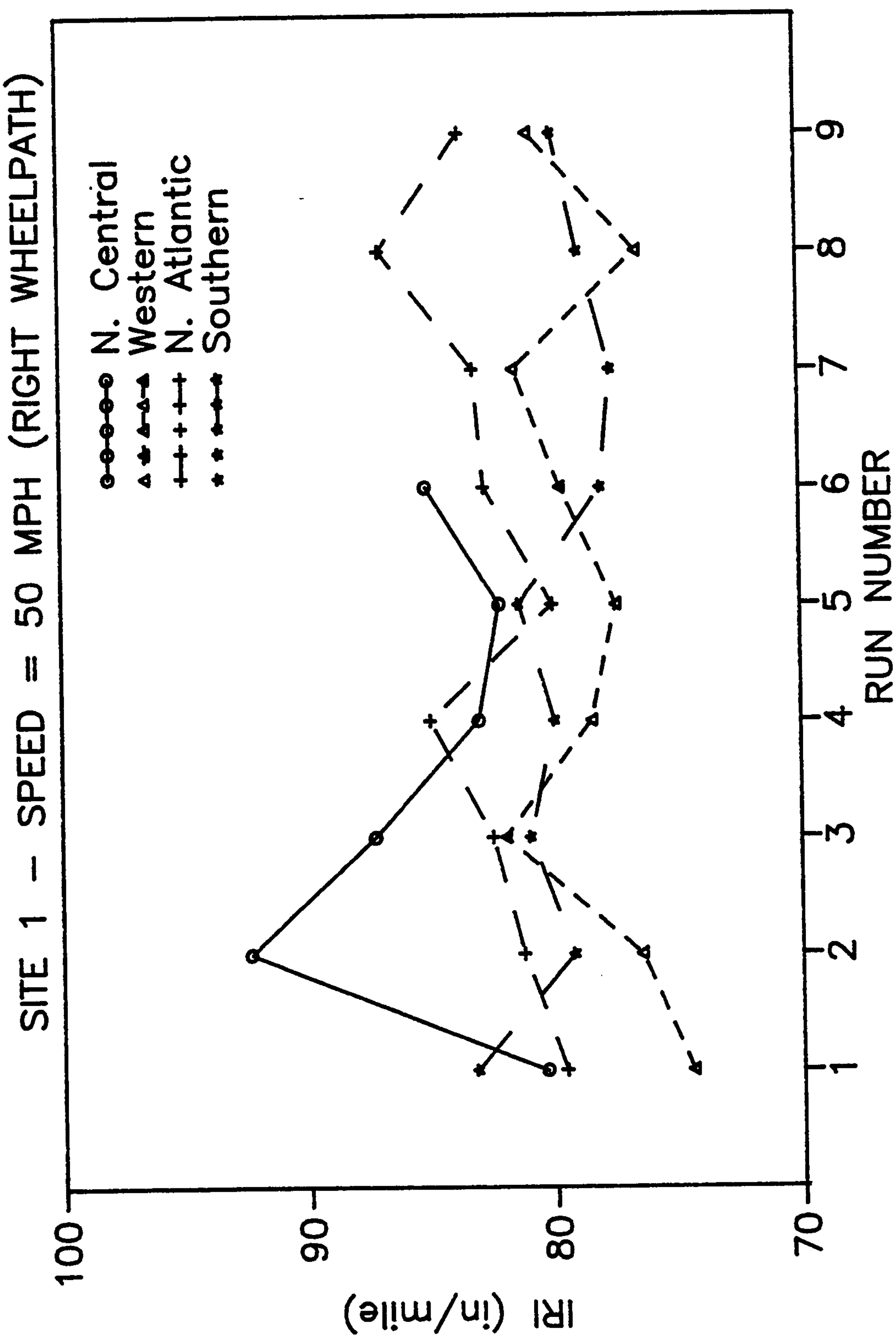

SITE 4 – SPEED = 50 MPH (LEFT WHEELPATH)
N. Central
Western
N. Atlantic
Southern
IRI (in/mile)
75
70
65
60
55
50
1
2
3
4
5
6
7
8
9
RUN NUMBER


SITE 5 - SPEED = 50 MPH (LEFT WHEELPATH)
N. Central
Western
N. Atlantic
Southern
220
200
180
160
140
IRI (in/mile)
1
2
3
4
5
6
7
8
9
RUN NUMBER

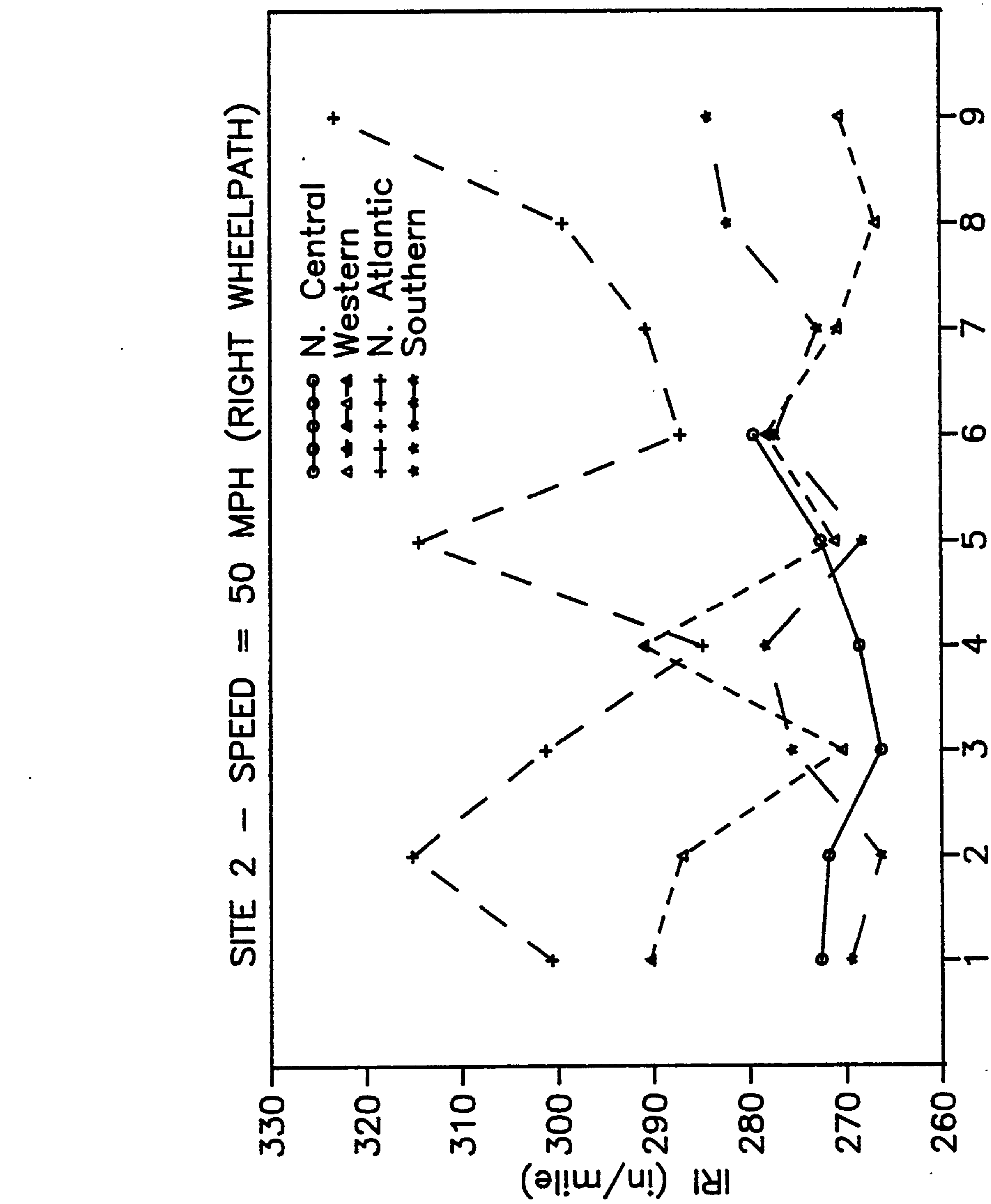

SITE 6 — SPEED = 50 MPH (LEFT WHEELPATH)
N. Central
Western
N. Atlantic
Southern
IRI (in/mile)
190
185
180
175
170
165
160
RUN NUMBER
1
2
3
4
5
6
7
8
9

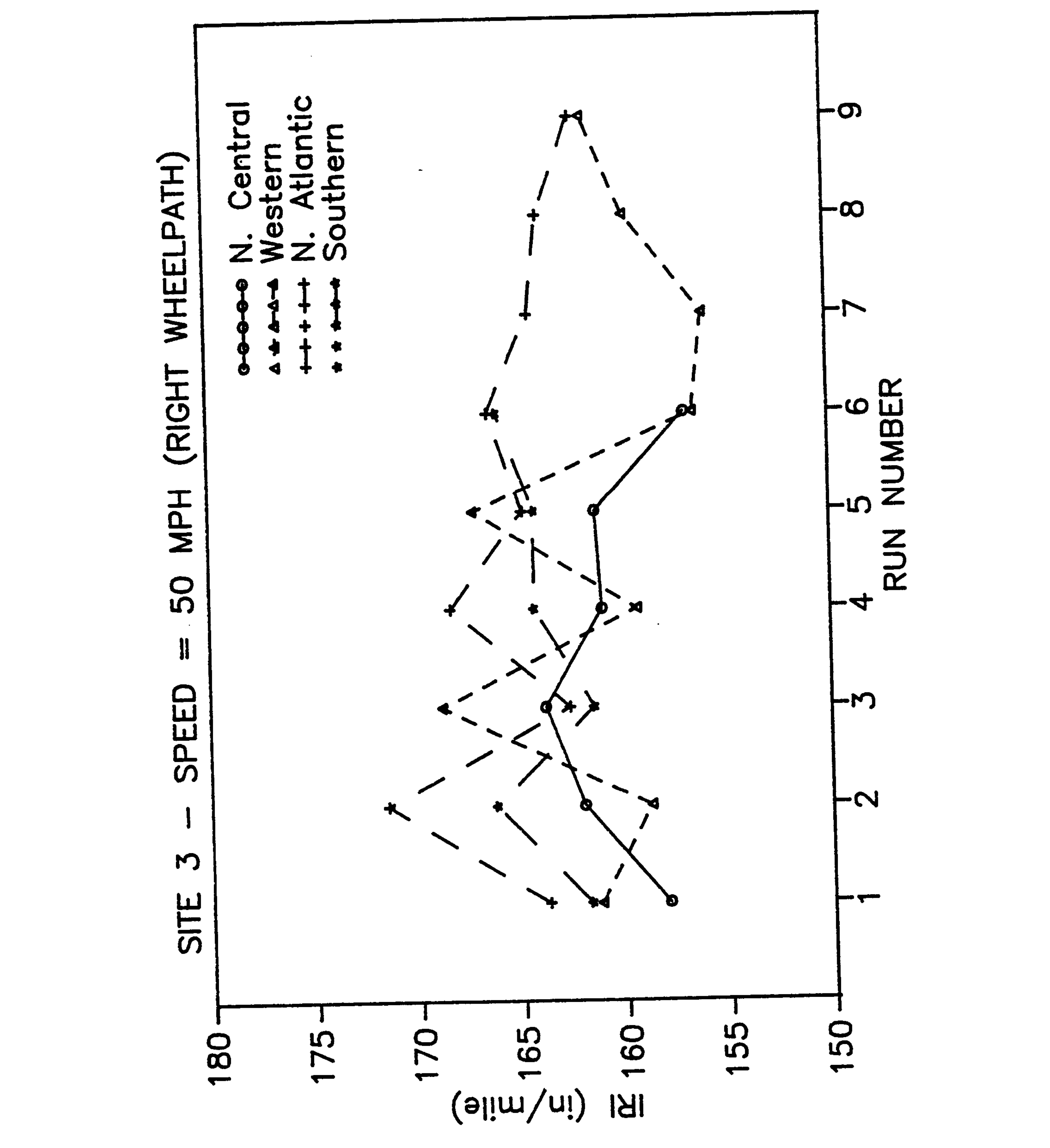

SITE 7 – SPEED = 50 MPH (LEFT WHEELPATH)
N. Central
Western
N. Atlantic
Southern
IRI (in/mile)
150
140
130
120
110
RUN NUMBER
1
2
3
4
5
6
7
8
9


SITE 8 – SPEED = 50 MPH (LEFT WHEELPATH)
N. Central
Western
N. Atlantic
Southern
IRI (in/mile)
70
65
60
55
50
45
40
RUN NUMBER
1
2
3
4
5
6
7
8

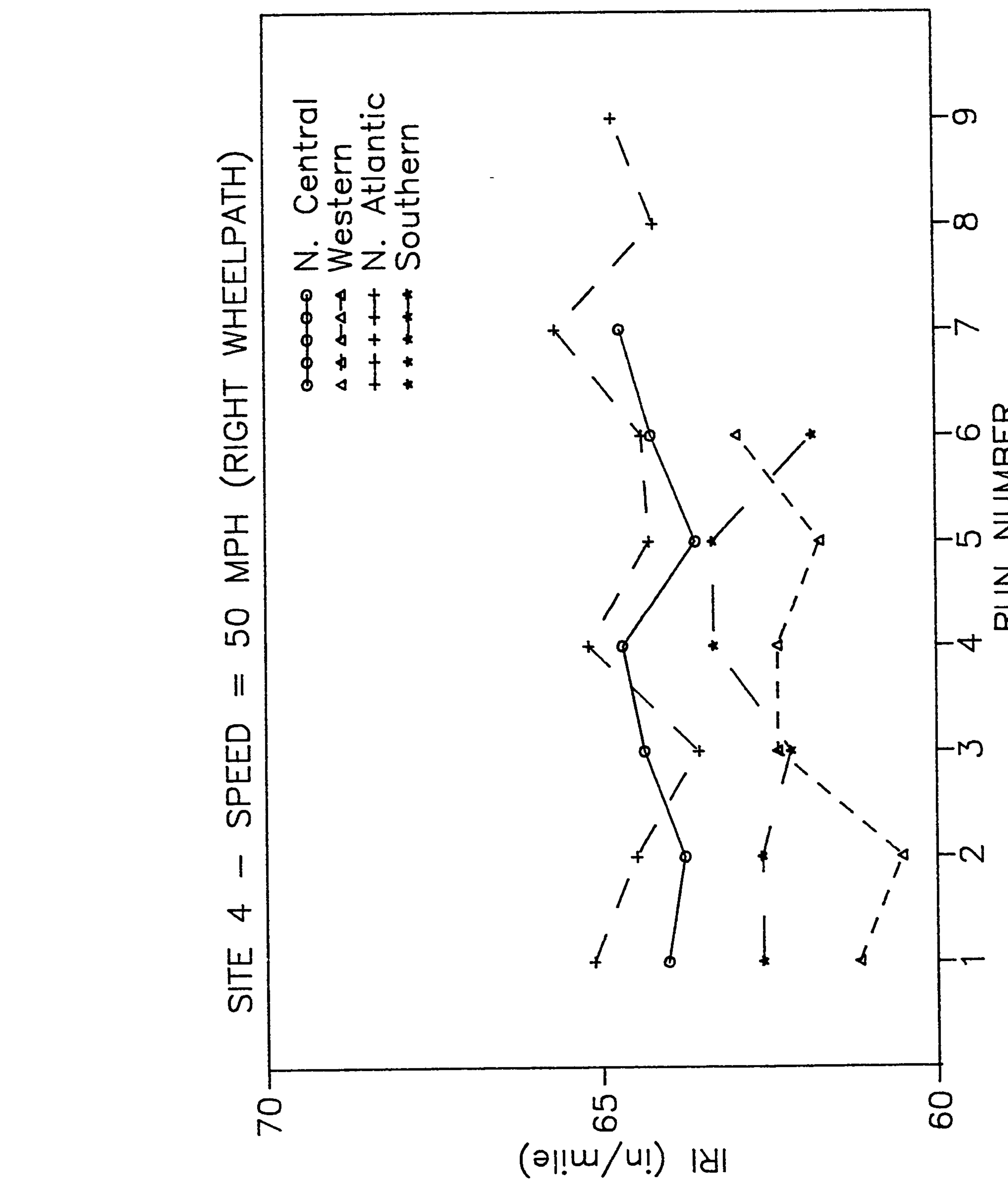


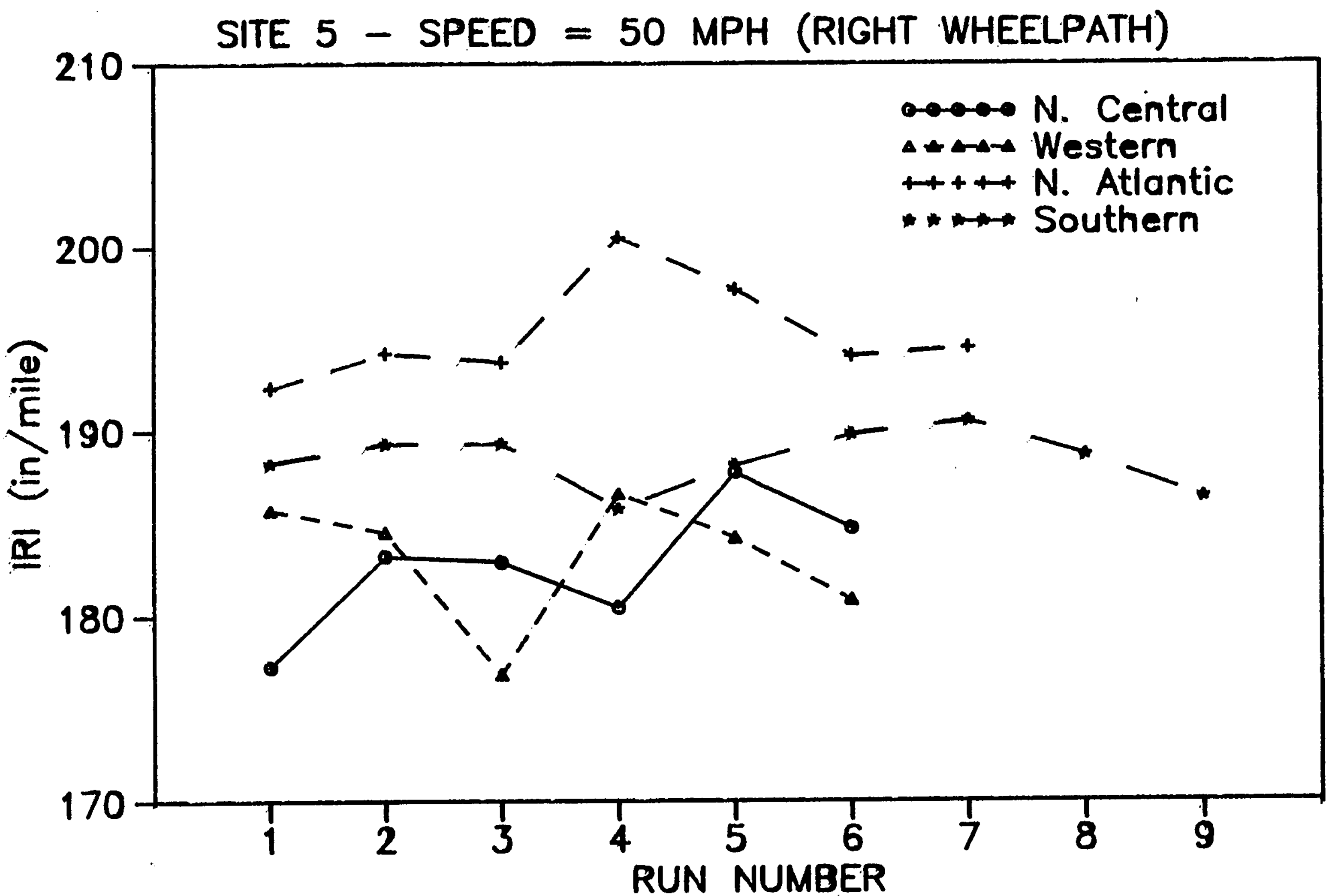
SITE 1 — SPEED = 50 MPH (RIGHT WHEELPATH)
N. Central
Western
N. Atlantic
Southern
IRI (in/mile)
100
90
80
70
RUN NUMBER
1
2
3
4
5
6
7
8
9

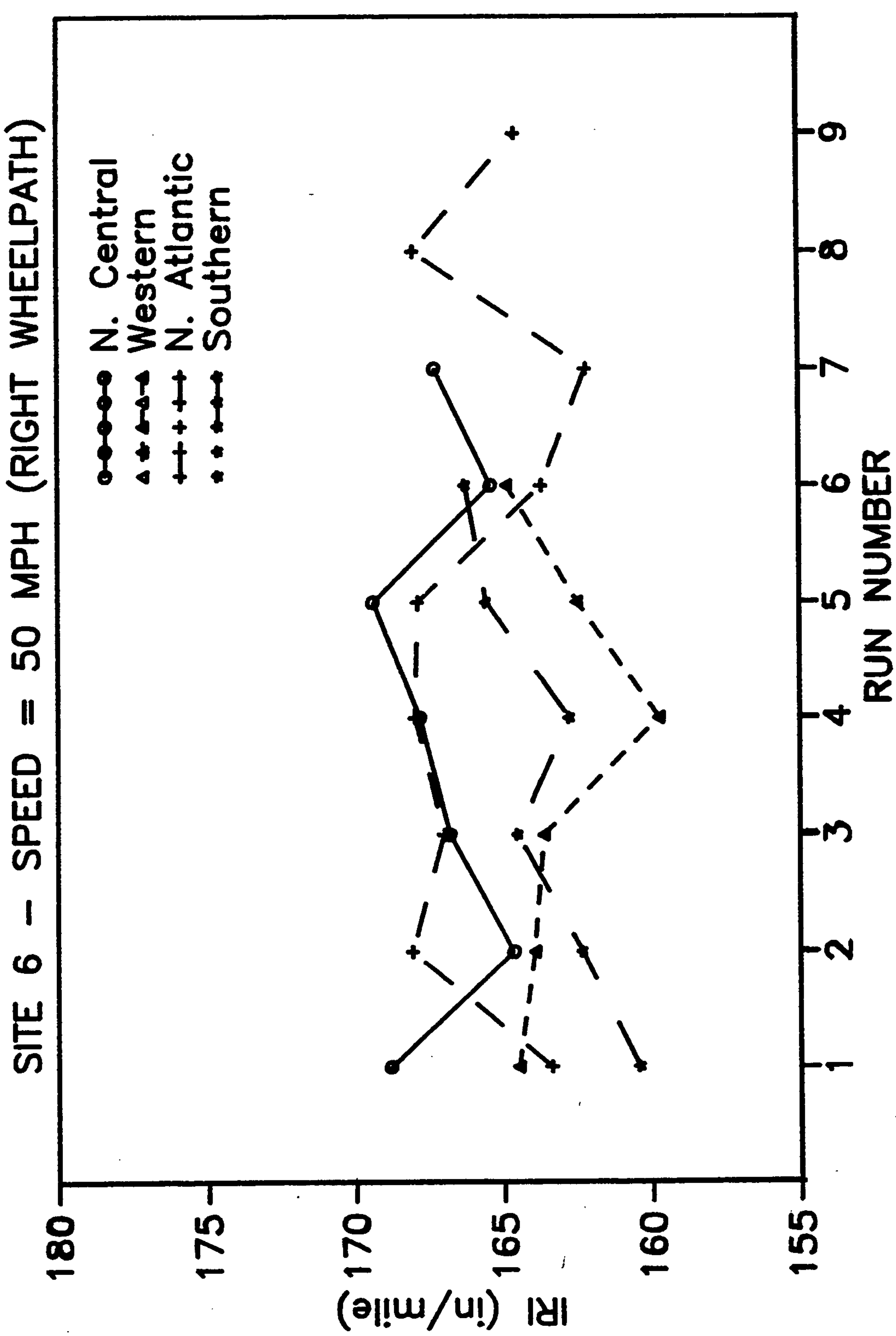

SITE 2 — SPEED = 50 MPH (RIGHT WHEELPATH)
N. Central
Western
N. Atlantic
Southern
IRI (in/mile)
330
320
310
300
290
280
270
260
RUN NUMBER
1
2
3
4
5
6
7
8
9

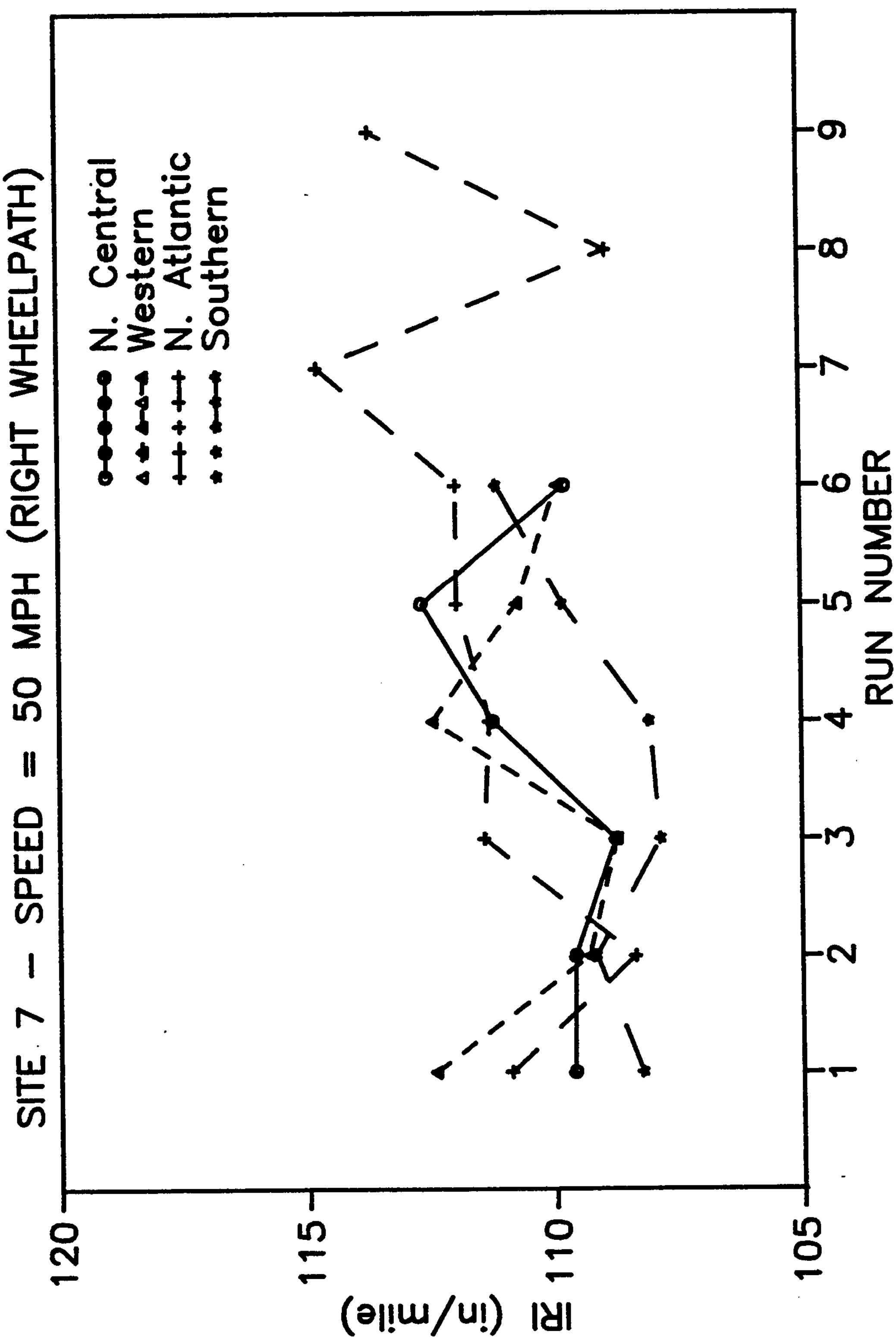


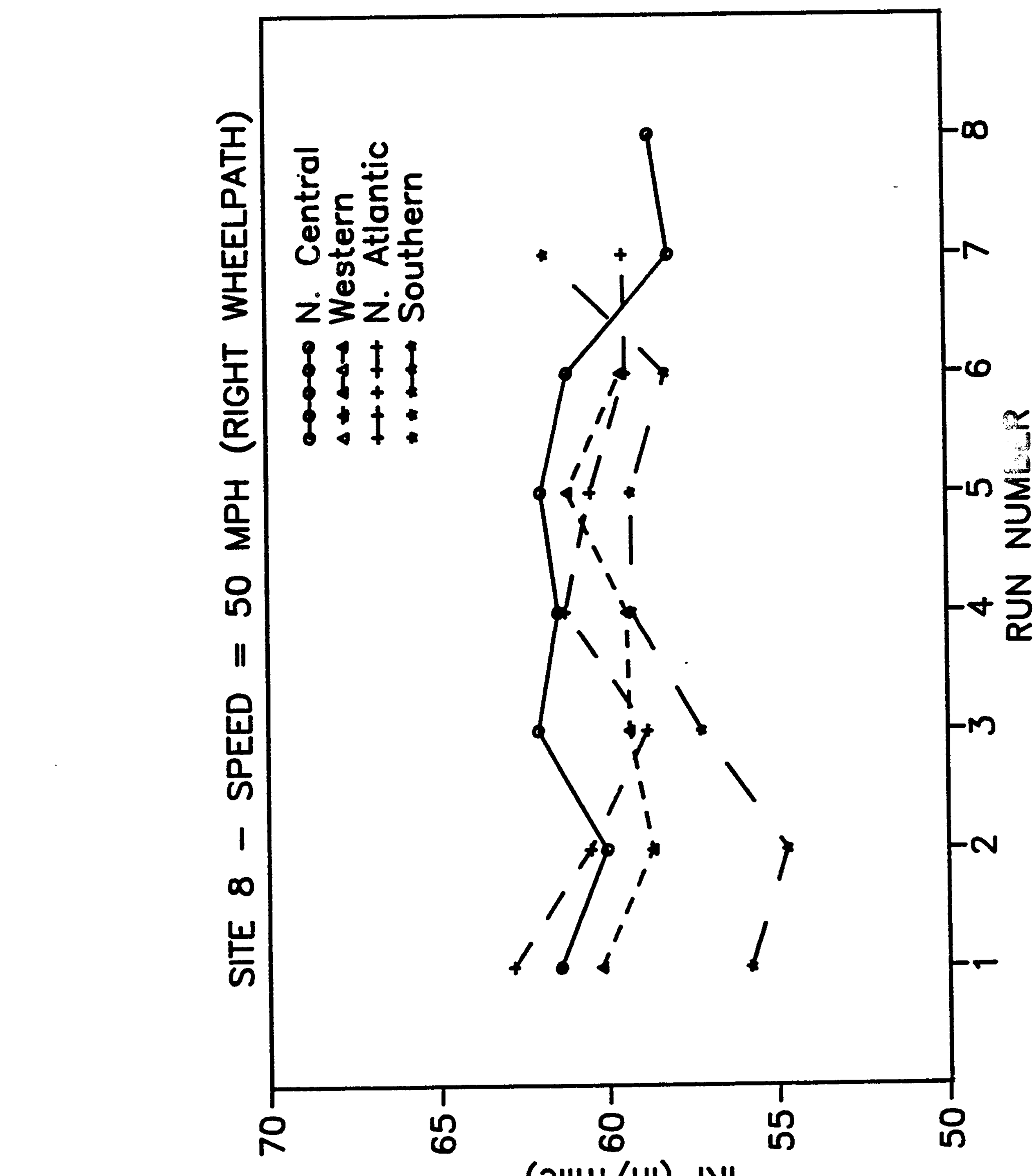
SITE 3 – SPEED = 50 MPH (RIGHT WHEELPATH)
N. Central
Western
N. Atlantic
Southern
IRI (in/mile)
180
175
170
165
160
155
150
RUN NUMBER
1
2
3
4
5
6
7
8
9


SITE 4 – SPEED = 50 MPH (RIGHT WHEELPATH)
N. Central
Western
N. Atlantic
Southern
IRI (in/mile)
70
65
60
RUN NUMBER
1
2
3
4
5
6
7
8
9

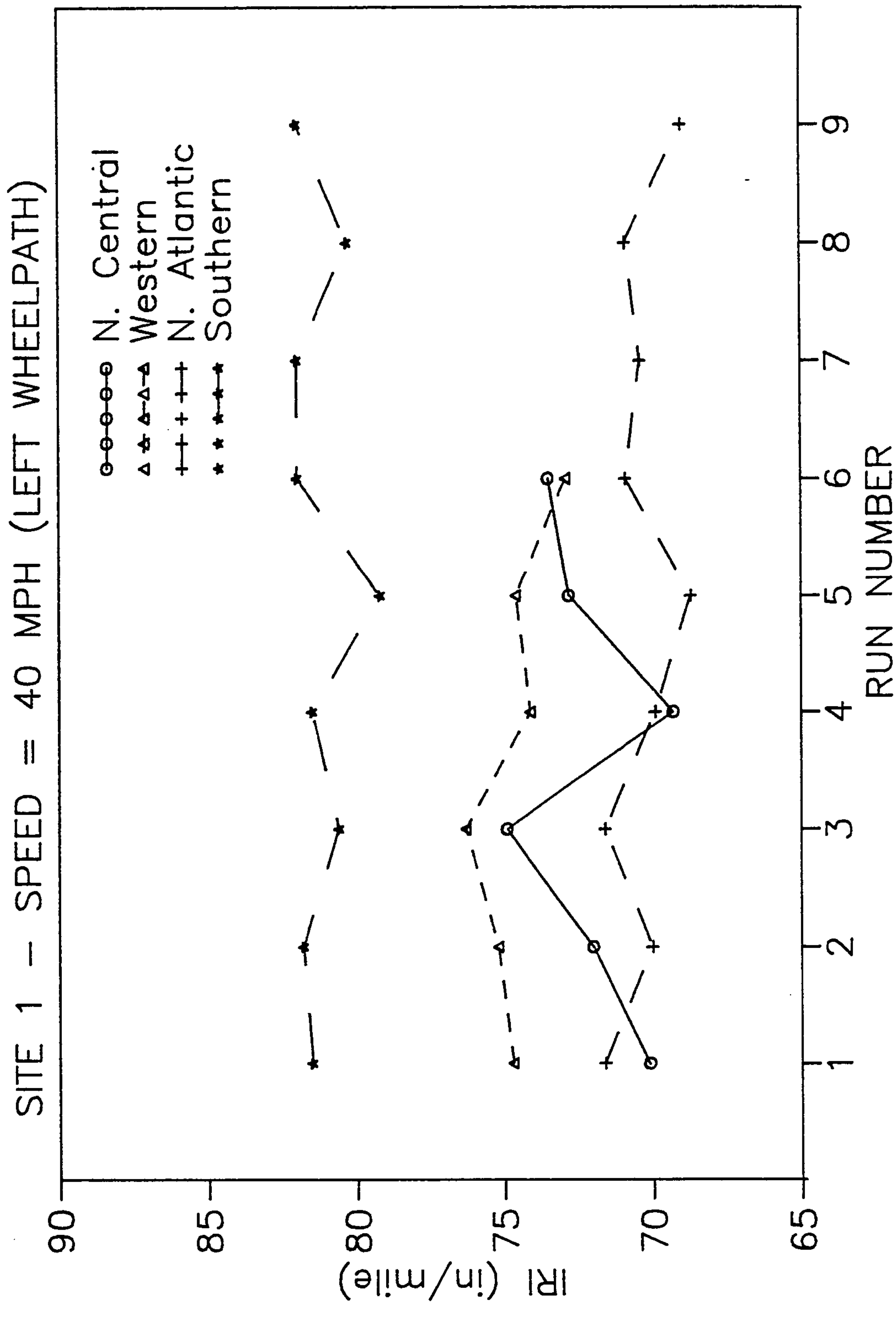

SITE 5 – SPEED = 50 MPH (RIGHT WHEELPATH)
N. Central
Western
N. Atlantic
Southern
IRI (in/mile)
210
200
190
180
170
1
2
3
4
5
6
7
8
9
RUN NUMBER

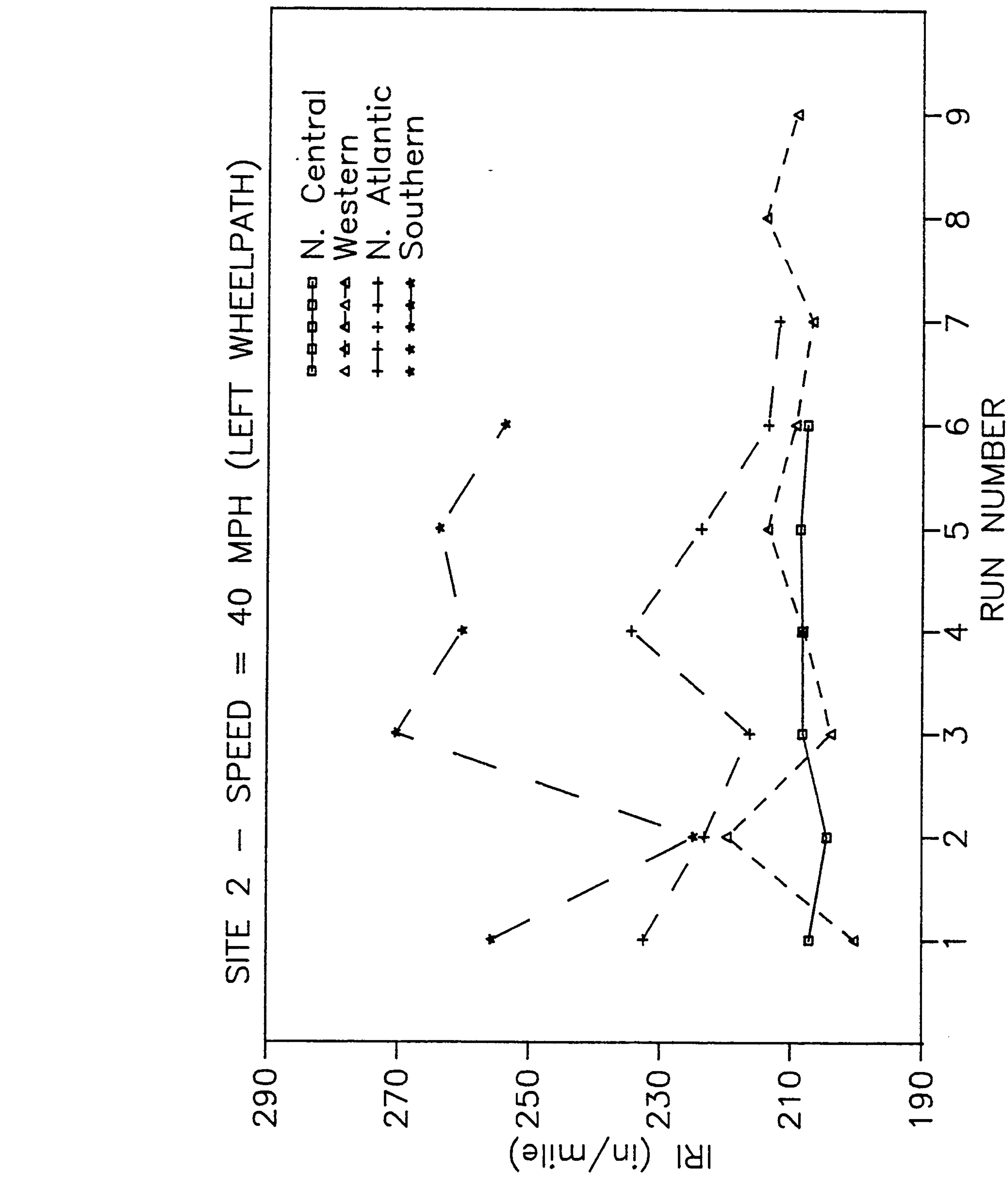

SITE 6 - SPEED = 50 MPH (RIGHT WHEELPATH)
N. Central
Western
N. Atlantic
Southern
IRI (in/mile)
180
175
170
165
160
155
RUN NUMBER
1
2
3
4
5
6
7
8
9


SITE 7 - SPEED = 50 MPH (RIGHT WHEELPATH)
N. Central
Western
N. Atlantic
Southern
IRI (in/mile)
RUN NUMBER
120
115
110
105
1
2
3
4
5
6
7
8
9

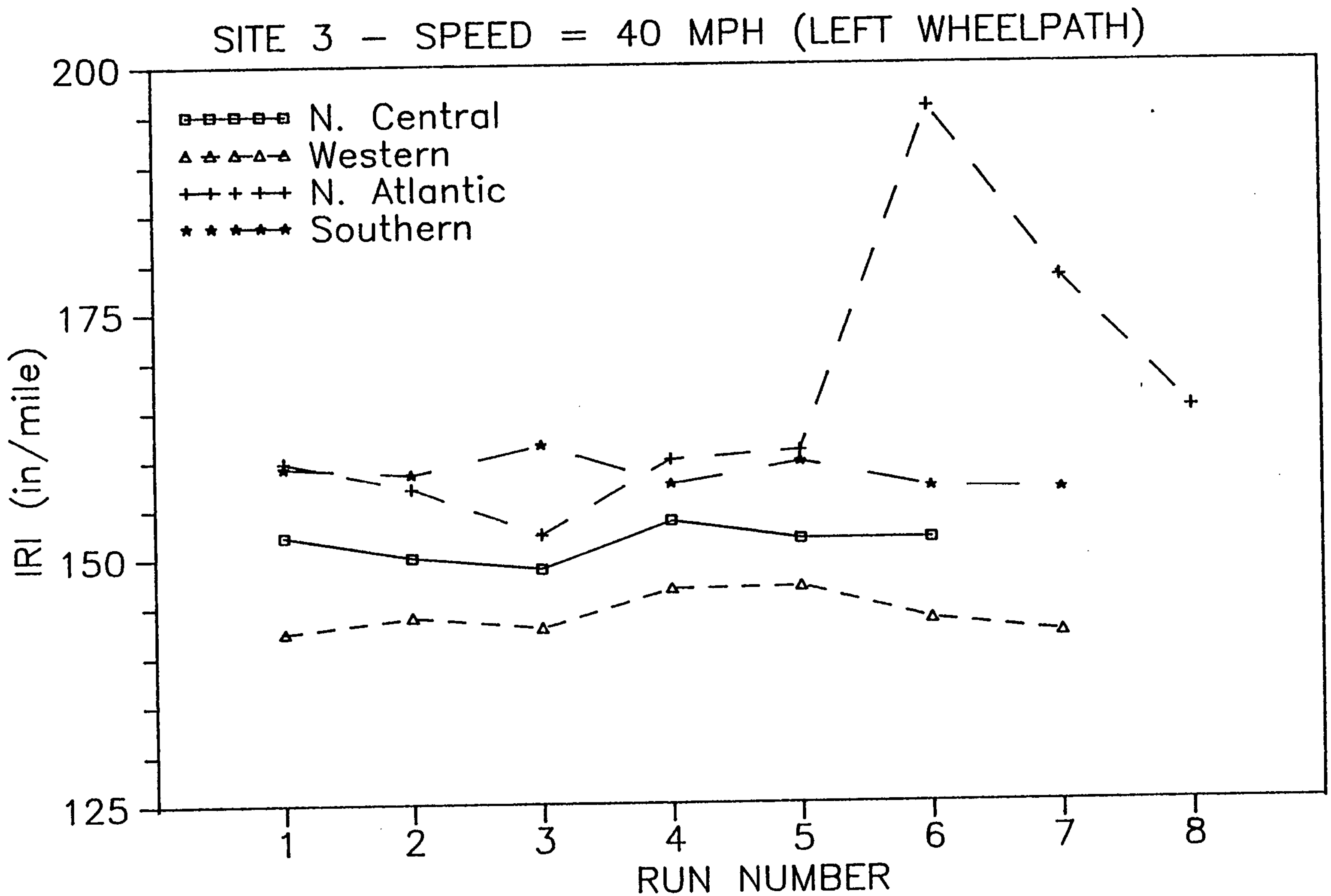


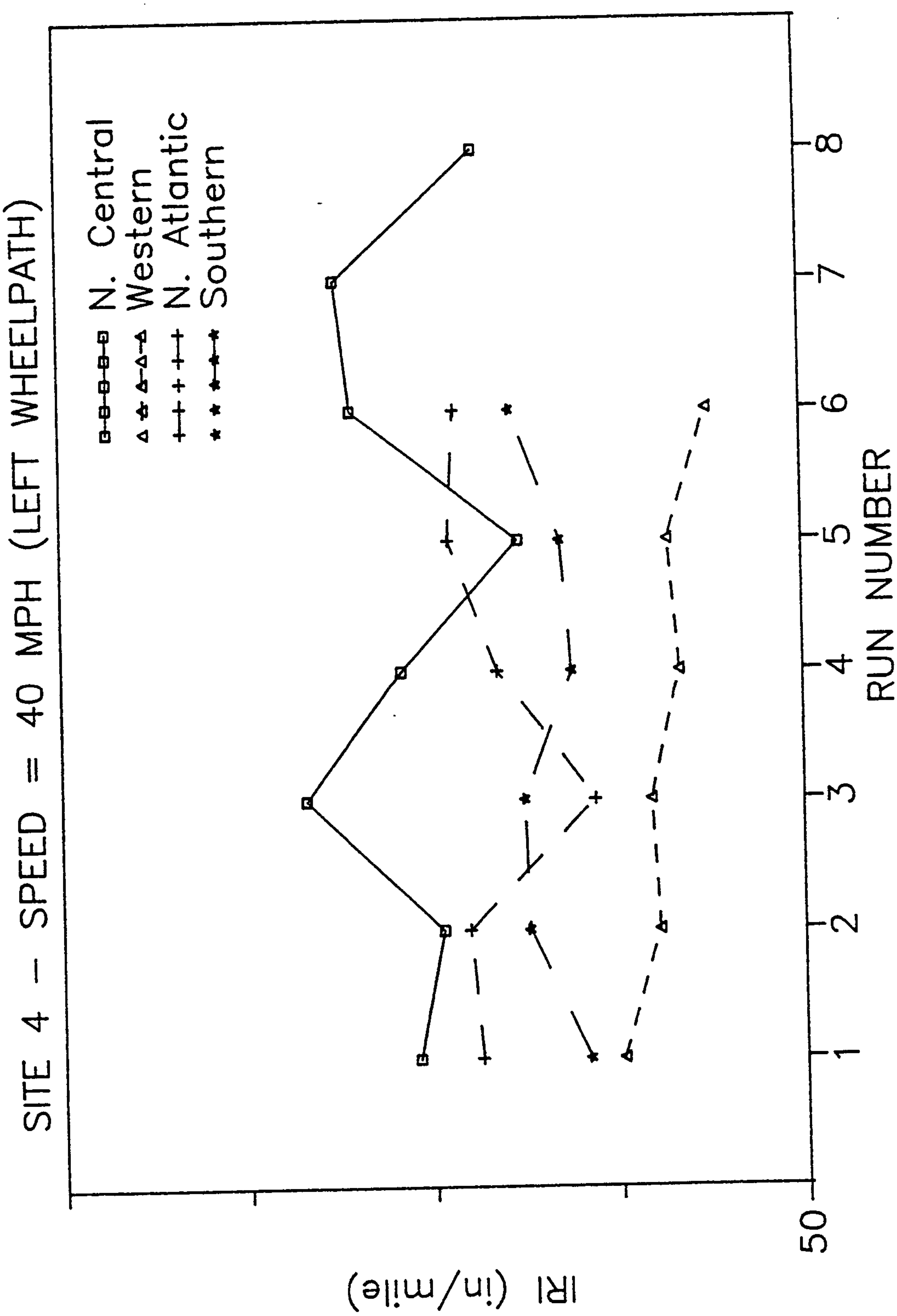
SITE 8 – SPEED = 50 MPH (RIGHT WHEELPATH)
N. Central
Western
N. Atlantic
Southern
IRI (in/mile)
70
65
60
55
50
1
2
3
4
5
6
7
8
RUN NUMBER

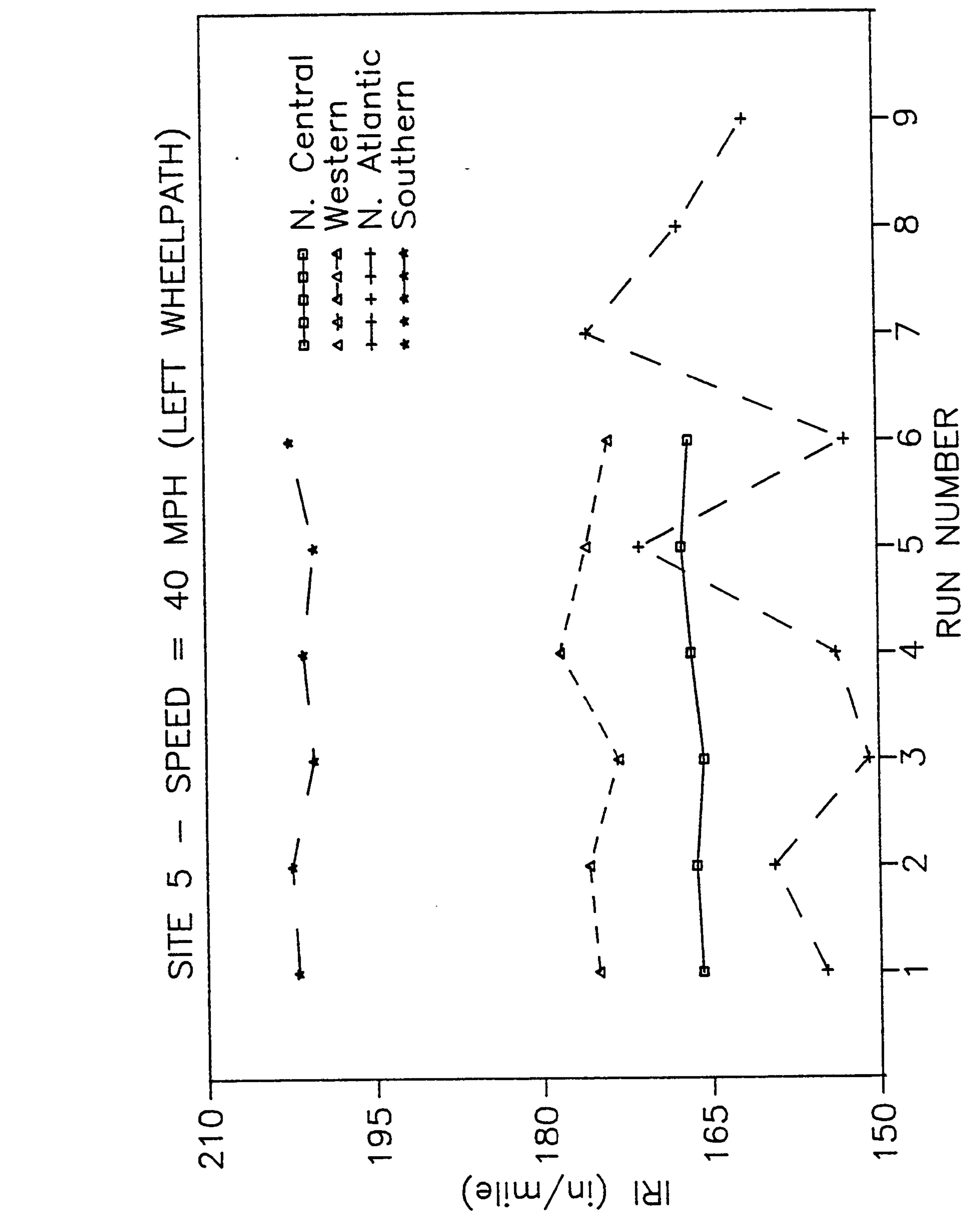

SITE 1 — SPEED = 40 MPH (LEFT WHEELPATH)
N. Central
Western
N. Atlantic
Southern
IRI (in/mile)
90
85
80
75
70
65
RUN NUMBER
1
2
3
4
5
6
7
8
9

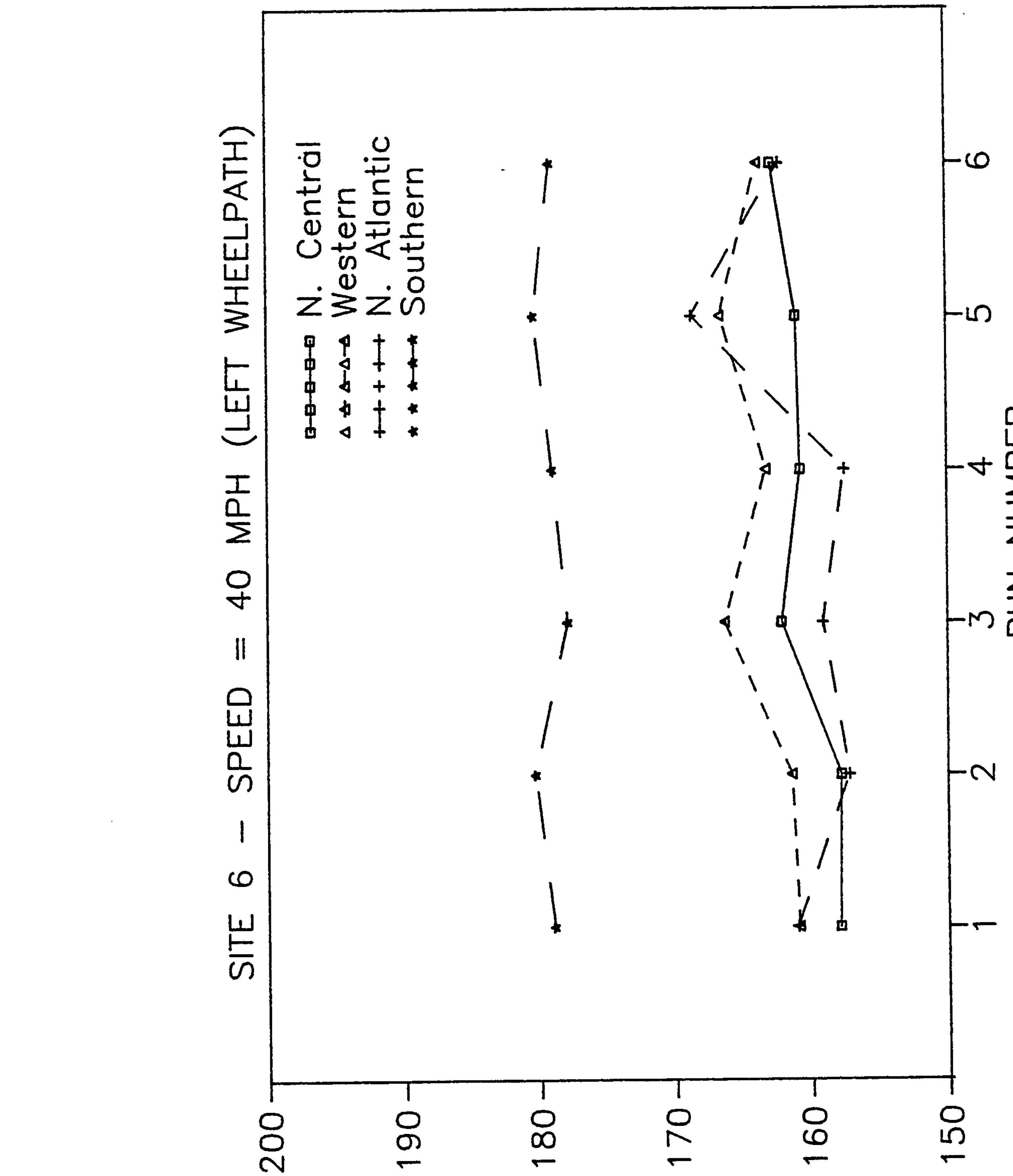


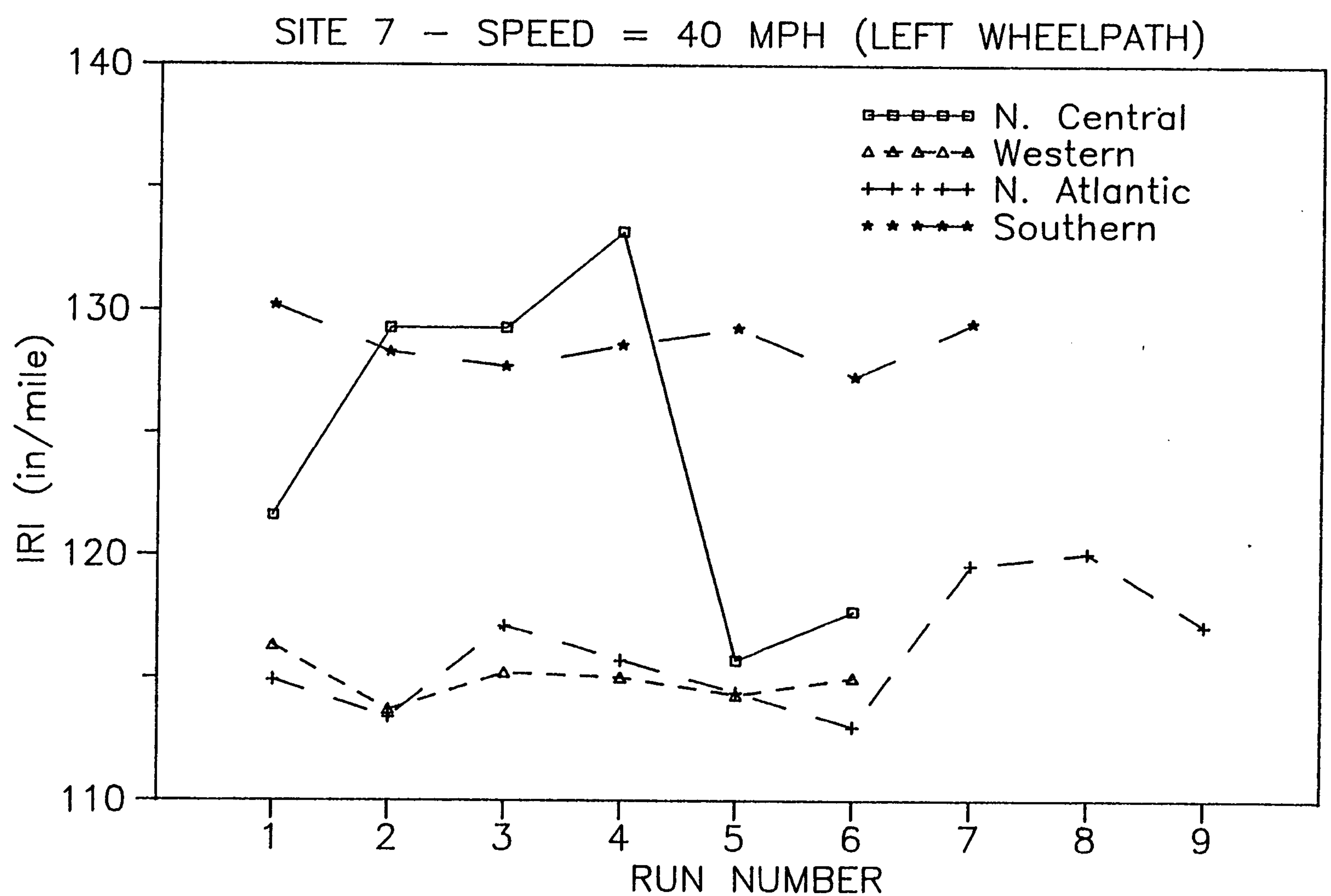
SITE 2 – SPEED = 40 MPH (LEFT WHEELPATH)
N. Central
Western
N. Atlantic
Southern
IRI (in/mile)
290
270
250
230
210
190
RUN NUMBER
1
2
3
4
5
6
7
8
9

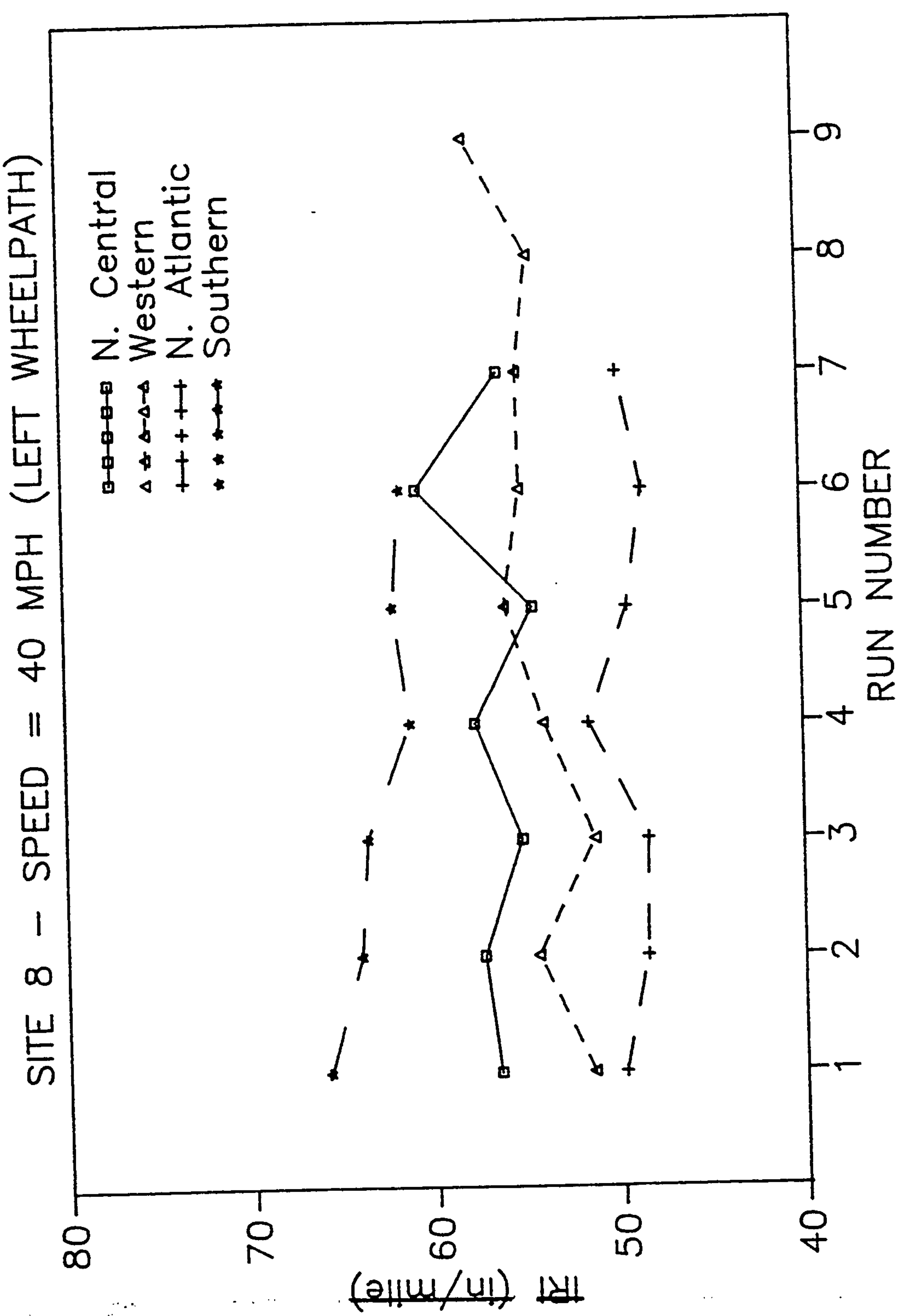

SITE 3 – SPEED = 40 MPH (LEFT WHEELPATH)
N. Central
Western
N. Atlantic
Southern
200
175
150
125
IRI (in/mile)
1
2
3
4
5
6
7
8
RUN NUMBER

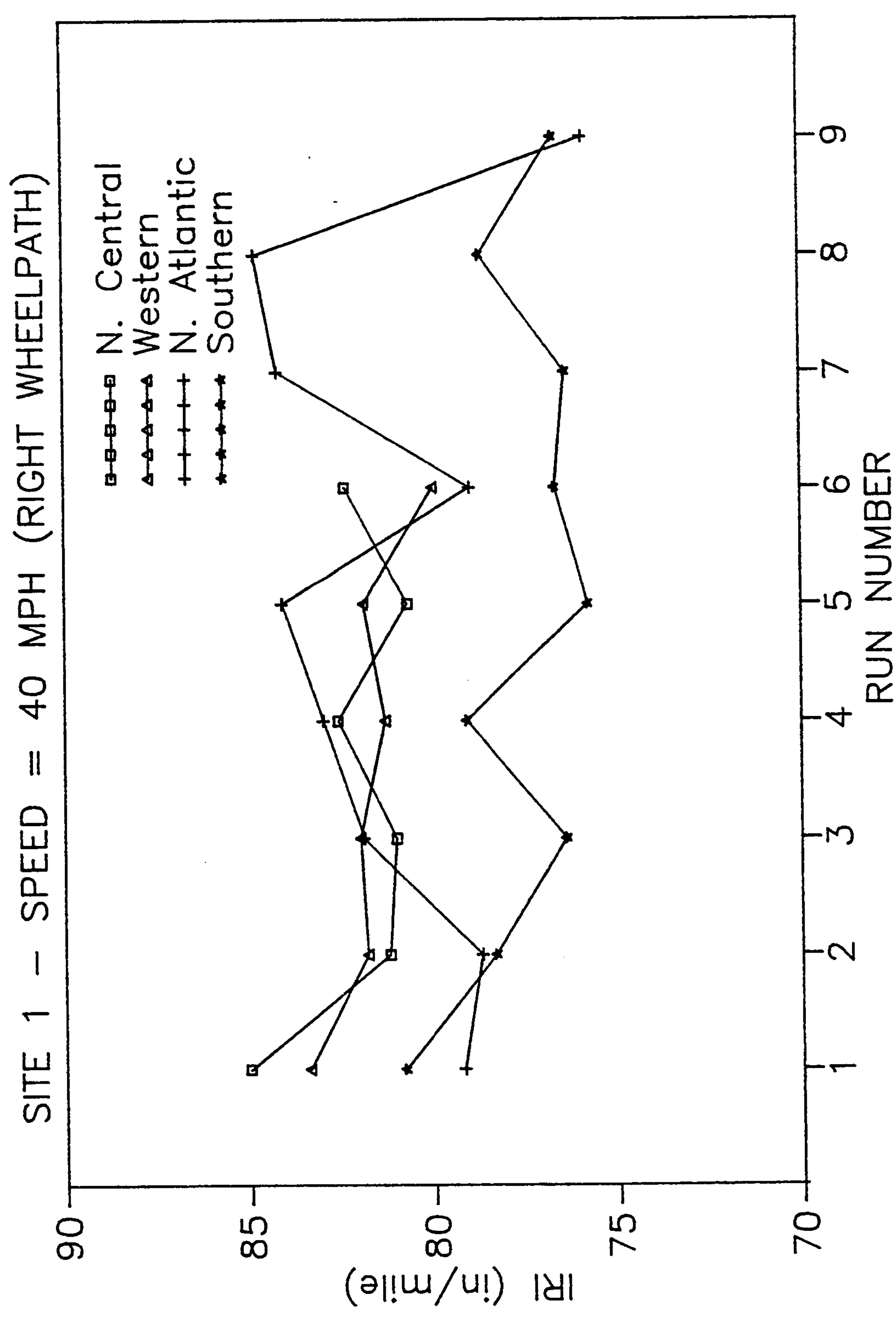

SITE 4 - SPEED = 40 MPH (LEFT WHEELPATH)
N. Central
Western
N. Atlantic
Southern
IRI (in/mile)
50
1
2
3
4
5
6
7
8
RUN NUMBER

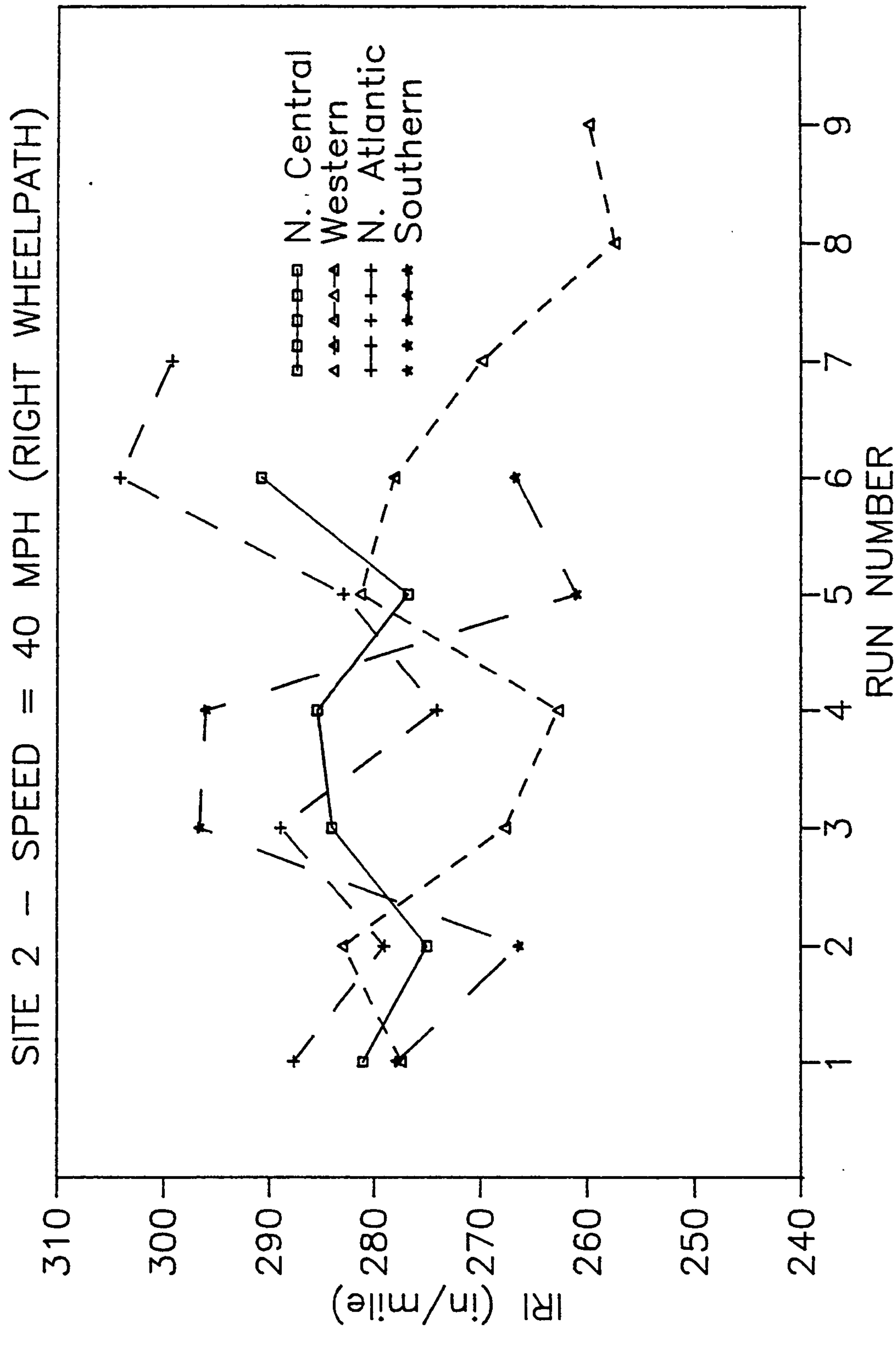

SITE 5 - SPEED = 40 MPH (LEFT WHEELPATH)
N. Central
Western
N. Atlantic
Southern
IRI (in/mile)
210
195
180
165
150
RUN NUMBER
1
2
3
4
5
6
7
8
9

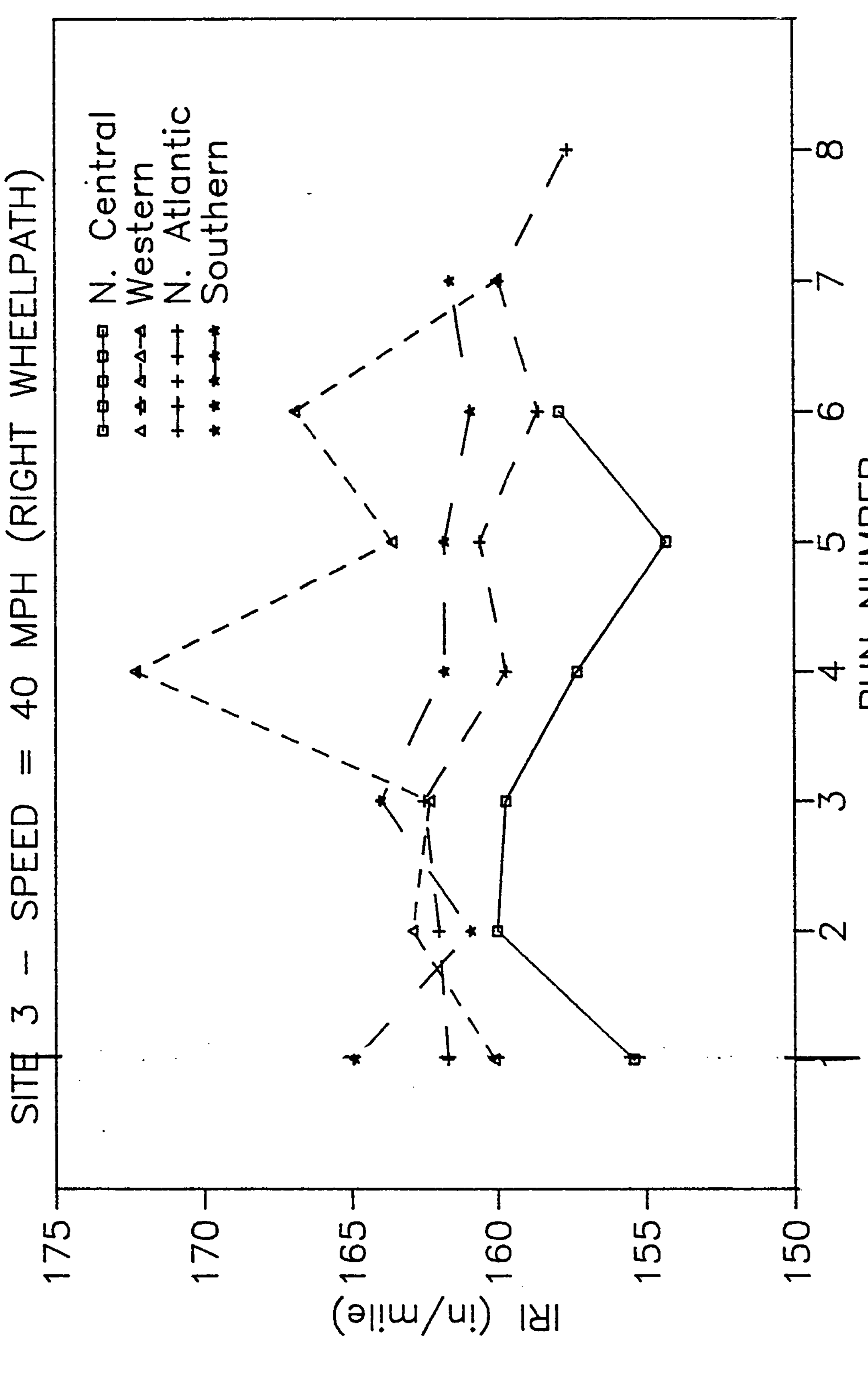

SITE 6 — SPEED = 40 MPH (LEFT WHEELPATH)
N. Central
Western
N. Atlantic
Southern
IRI (in/mile)
200
190
180
170
160
150
RUN NUMBER
1
2
3
4
5
6

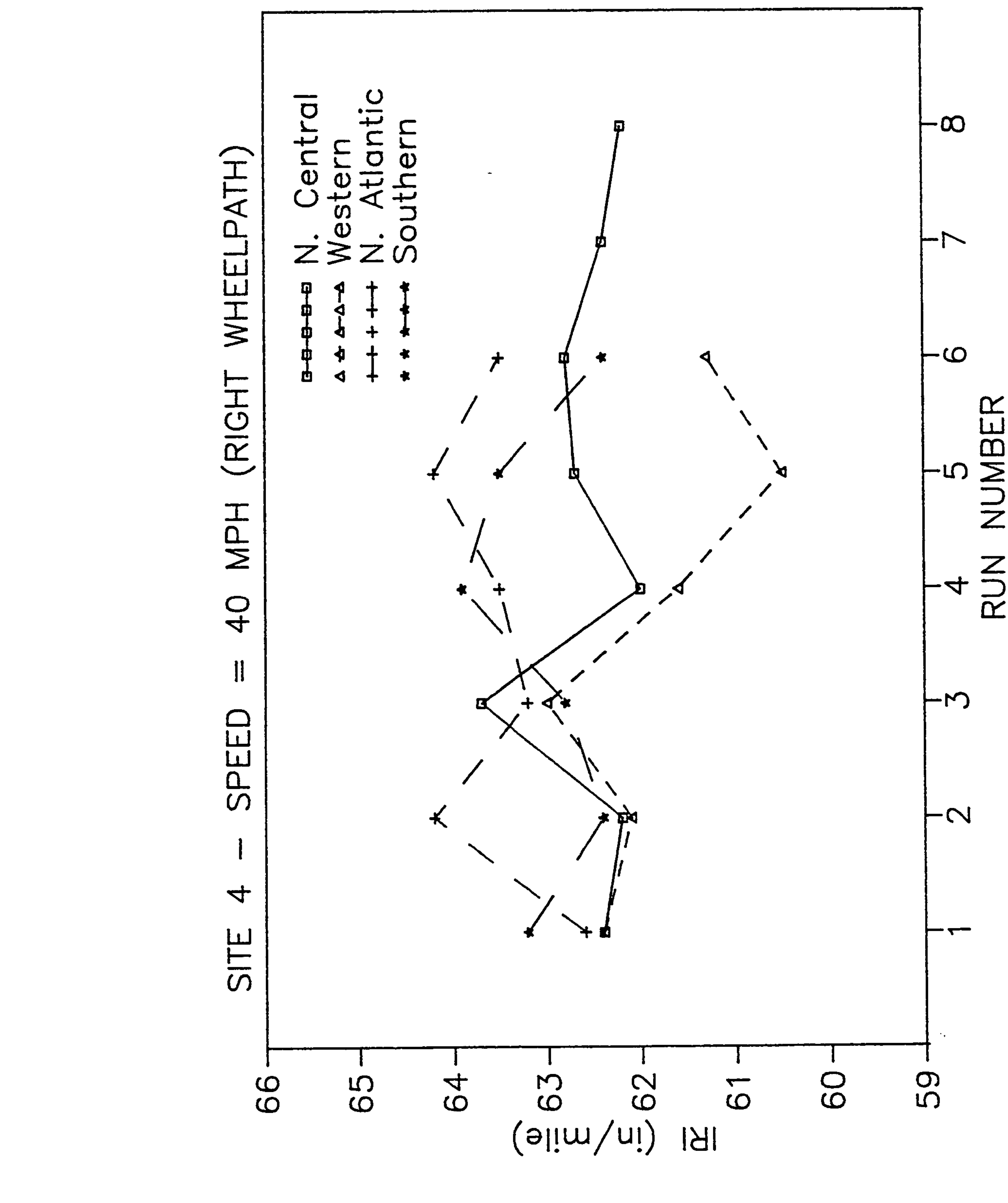

SITE 7 – SPEED = 40 MPH (LEFT WHEELPATH)
N. Central
Western
N. Atlantic
Southern
IRI (in/mile)
140
130
120
110
1
2
3
4
5
6
7
8
9
RUN NUMBER

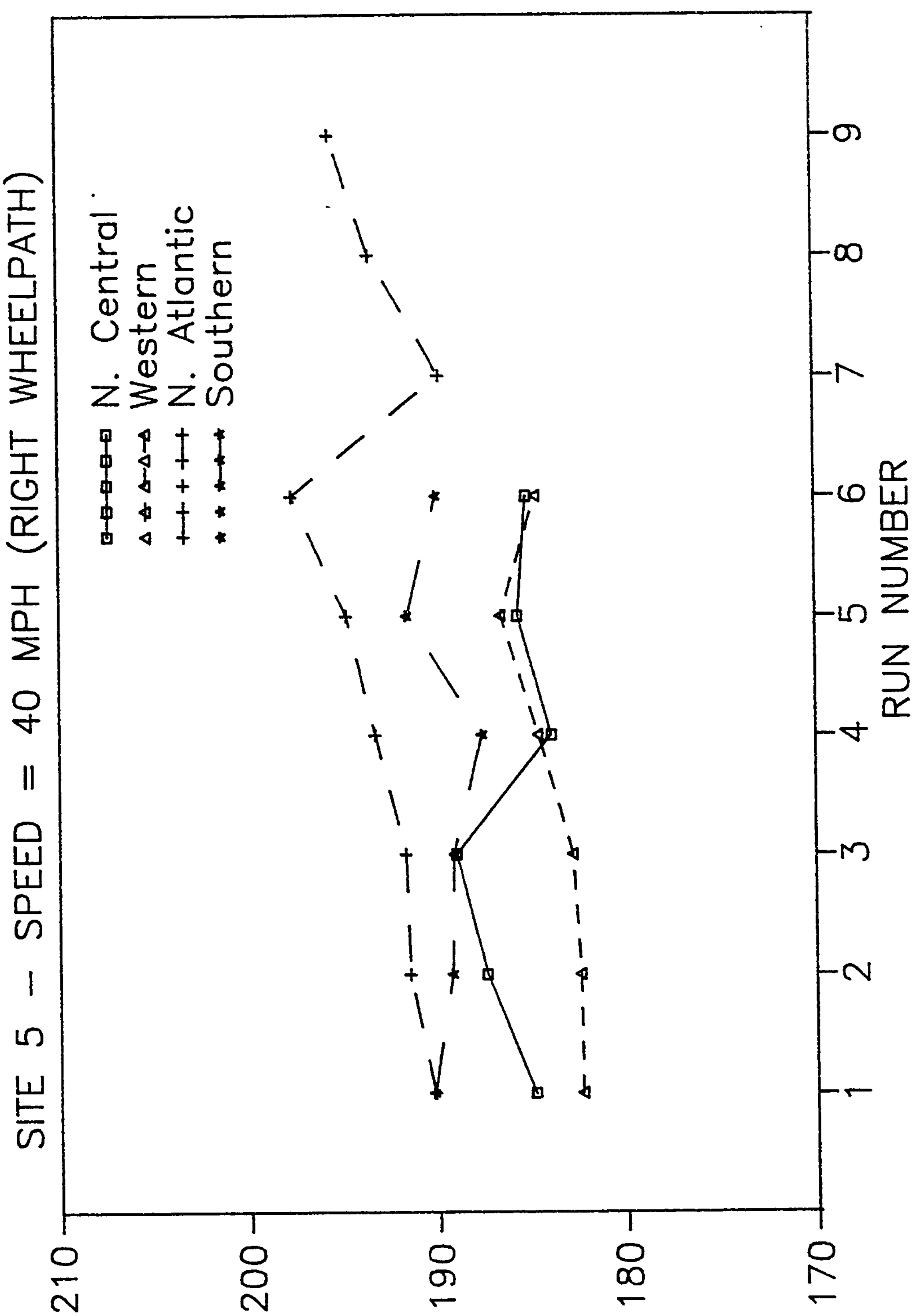

SITE 8 – SPEED = 40 MPH (LEFT WHEELPATH)
N. Central
Western
N. Atlantic
Southern
IRI (in/mile)
80
70
60
50
40
1
2
3
4
5
6
7
8
9
RUN NUMBER

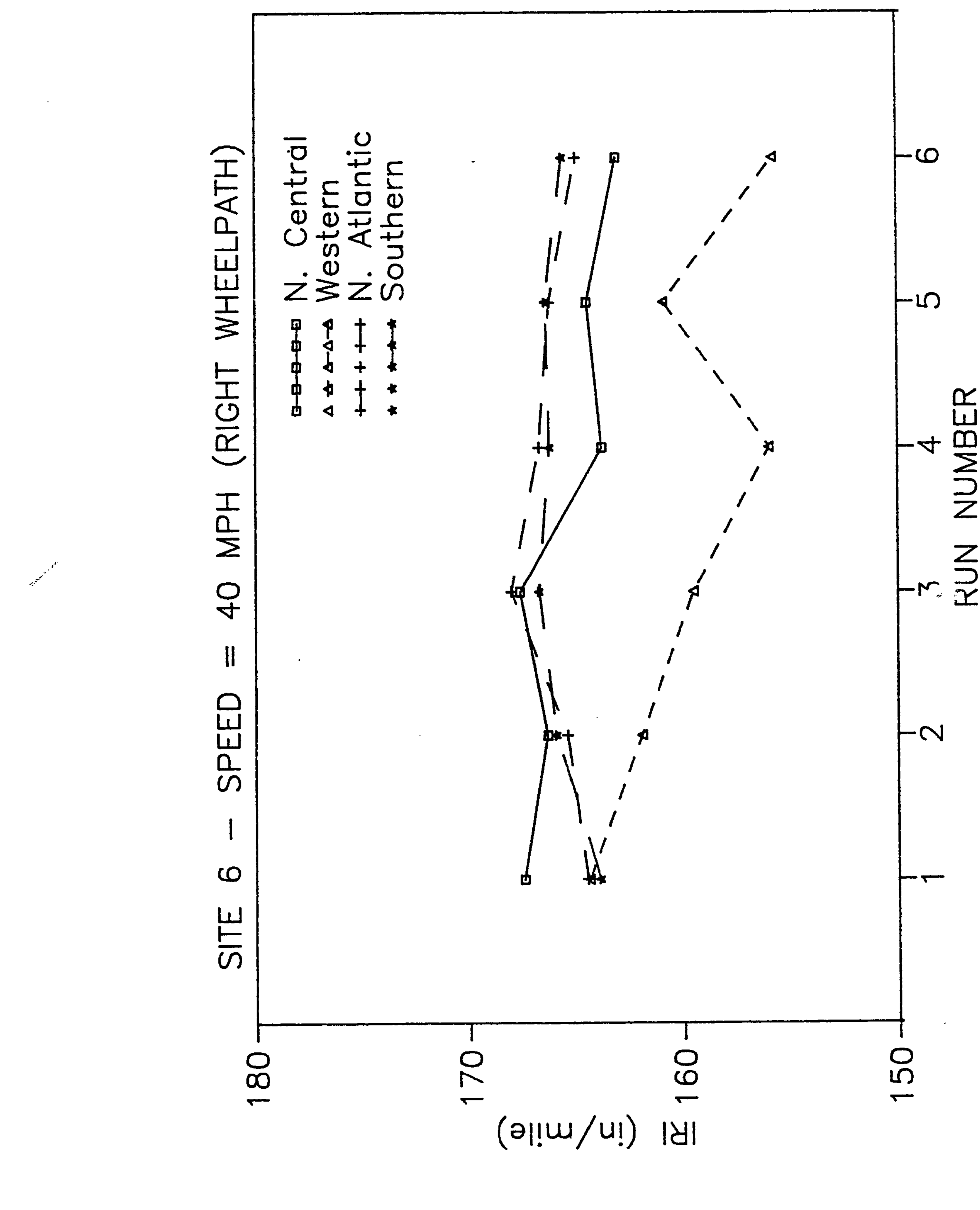

SITE 1 – SPEED = 40 MPH (RIGHT WHEELPATH)
N. Central
Western
N. Atlantic
Southern
IRI (in/mile)
90
85
80
75
70
RUN NUMBER
1
2
3
4
5
6
7
8
9


SITE 2 - SPEED = 40 MPH (RIGHT WHEELPATH)
N. Central
Western
N. Atlantic
Southern
IRI (in/mile)
310
300
290
280
270
260
250
240
RUN NUMBER
1
2
3
4
5
6
7
8
9

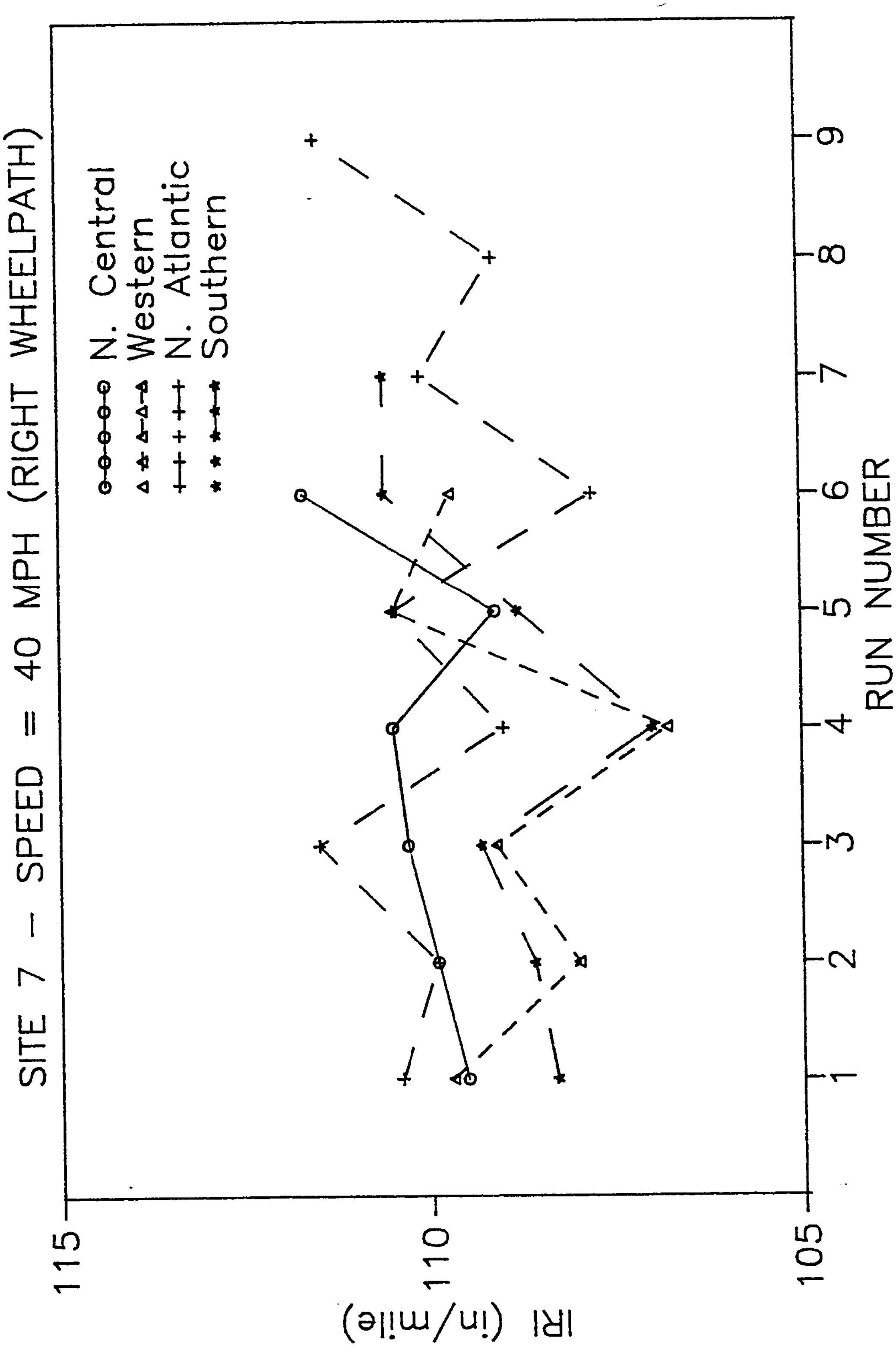

SITE 3 - SPEED = 40 MPH (RIGHT WHEELPATH)
N. Central
Western
N. Atlantic
Southern
IRI (in/mile)
175
170
165
160
155
150
RUN NUMBER
1
2
3
4
5
6
7
8

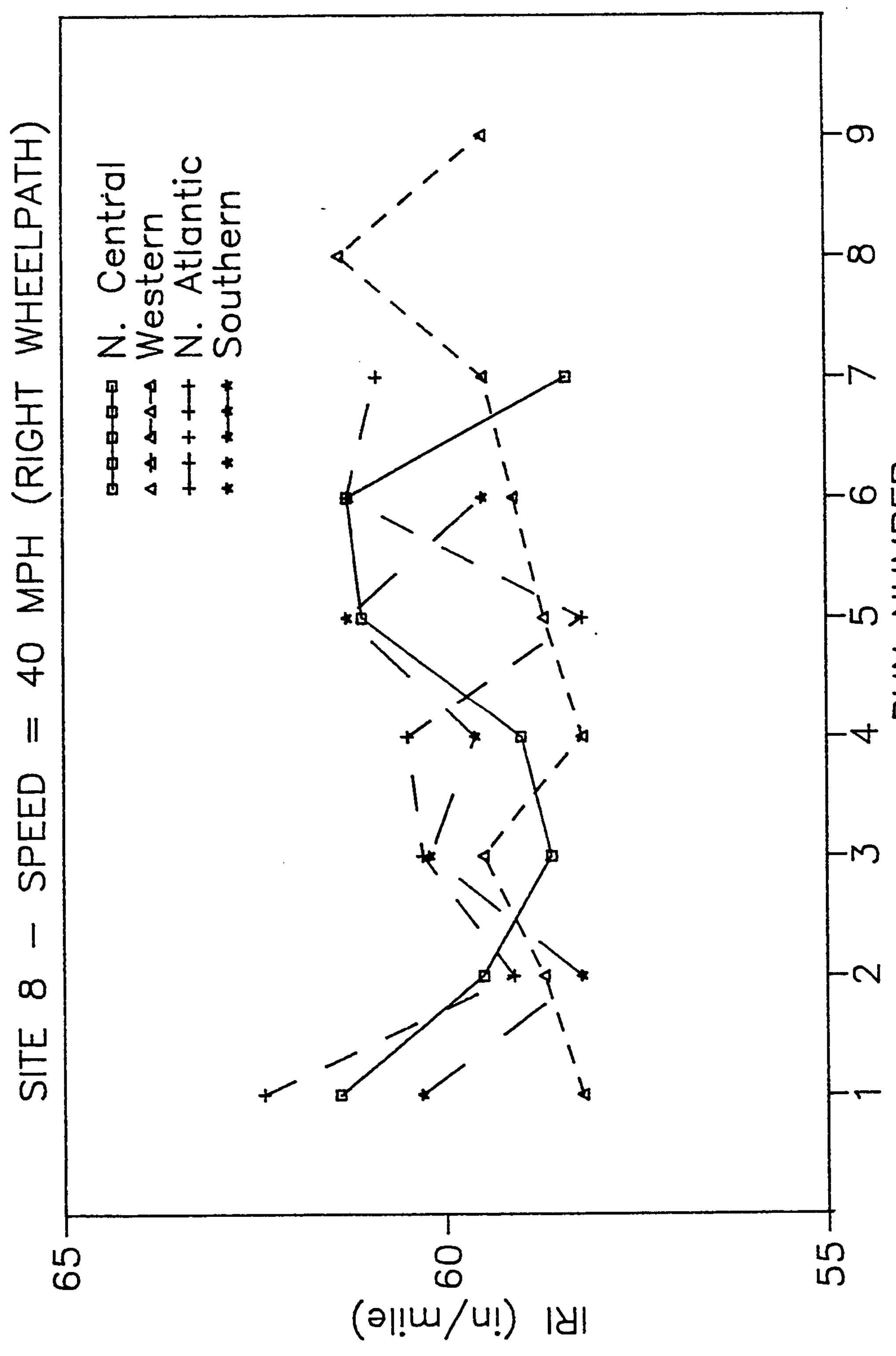

SITE 4 – SPEED = 40 MPH (RIGHT WHEELPATH)
N. Central
Western
N. Atlantic
Southern
IRI (in/mile)
RUN NUMBER
66
65
64
63
62
61
60
59
1
2
3
4
5
6
7
8


SITE 5 – SPEED = 40 MPH (RIGHT WHEELPATH)
N. Central
Western
N. Atlantic
Southern
IRI (in/mile)
210
200
190
180
170
RUN NUMBER
1
2
3
4
5
6
7
8
9



SITE 6 - SPEED = 40 MPH (RIGHT WHEELPATH)
N. Central
Western
N. Atlantic
Southern
180
170
160
150
IRI (in/mile)
1
2
3
4
5
6
RUN NUMBER


SITE 7 - SPEED = 40 MPH (RIGHT WHEELPATH)
N. Central
Western
N. Atlantic
Southern
IRI (in/mile)
115
110
105
RUN NUMBER
1
2
3
4
5
6
7
8
9



SITE 8 — SPEED = 40 MPH (RIGHT WHEELPATH)
N. Central
Western
N. Atlantic
Southern
IRI (in/mile)
65
60
55
RUN NUMBER
1
2
3
4
5
6
7
8
9

APPENDIX B

LEFT AND RIGHT WHEELPATH IRI OF ALL RUNS SELECTED FOR ANALYSIS

The data obtained from the profilometer comparative study is given in tabular form in this appendix. A description of each column of this table is given below.

Column 1 - NO: Data set Number.

Column 2 - DEVICE: Profilometer. NC - North Central Region Profilometer, WE - Western Region Profilometer, NA - North Atlantic Region Profilometer, SO - Southern Region Profilometer.

Column 3 - ROUG: Roughness Level. 1 corresponds to a smooth pavement (IRI < 125 in/mile) while 2 corresponds to a pavement with medium roughness (IRI between 125 and 300 in/mile).

Column 4 - SURTYP: Surface Type. Surface type 1 is asphalt while surface type 2 is concrete.

Column 5 - SECNO: Section Number. Eight sections were used for the study.

Column 6 - SPEED: Speed of testing (either 40 or 50 mph).

Column 7 - RUN: Run Number (1 through 6).

Column 8 - LIRI: IRI (in/mile) of the left wheelpath obtained from PROFSCAN.

Column 9 - RIRI: IRI (in/mile) of the right wheelpath obtained from PROFSCAN.

Column 10 - BIRI: Both wheelpath IRI (in/mile). This is the average of the left and right wheelpath IRI's.

Column 11 - DISP: Displacement (mm/mile).

NO (1)	REGION (2)	ROUGH (3)	SYRTYP (4)	SECNO (5)	SPEED (6)	RUN (7)	LIRI (8)	RIRI (9)	IRI (10)	DISP. (11)
1	NC	1	1	1	40	1	70	85	78	186
2	NC	1	1	1	40	2	72	81	77	184
3	NC	1	1	1	40	3	75	81	78	187
4	NC	1	1	1	40	4	69	83	76	182
5	NC	1	1	1	40	5	73	81	77	184
6	NC	1	1	1	40	6	74	82	78	187
7	NC	2	1	2	40	1	207	281	244	586
8	NC	2	1	2	40	2	204	275	240	576
9	NC	2	1	2	40	3	208	284	246	591
10	NC	2	1	2	40	4	208	285	247	593
11	NC	2	1	2	40	5	209	277	243	583
12	NC	2	1	2	40	6	207	291	249	599
13	NC	2	1	3	40	1	152	155	154	370
14	NC	2	1	3	40	2	150	160	155	372
15	NC	2	1	3	40	3	149	160	154	371
16	NC	2	1	3	40	4	154	157	155	374
17	NC	2	1	3	40	5	152	154	153	368
18	NC	2	1	3	40	6	152	158	155	372
19	NC	1	1	4	40	1	60	62	61	147
20	NC	1	1	4	40	2	60	62	61	146
21	NC	1	1	4	40	3	63	64	64	153
22	NC	1	1	4	40	4	61	62	61	148
23	NC	1	1	4	40	5	62	63	62	150
24	NC	1	1	4	40	6	62	62	62	150
25	NC	2	2	5	40	1	166	185	175	421
26	NC	2	2	5	40	2	166	187	177	425
27	NC	2	2	5	40	3	166	189	177	426
28	NC	2	2	5	40	4	167	184	175	421
29	NC	2	2	5	40	5	167	186	177	424
30	NC	2	2	5	40	6	167	185	176	423
31	NC	2	2	6	40	1	158	167	163	391
32	NC	2	2	6	40	2	158	166	162	389
33	NC	2	2	6	40	3	162	168	165	396
34	NC	2	2	6	40	4	161	164	162	390
35	NC	2	2	6	40	5	161	164	163	391
36	NC	2	2	6	40	6	163	163	163	392
37	NC	1	2	7	40	1	122	110	116	278
38	NC	1	2	7	40	2	129	110	120	287
39	NC	1	2	7	40	3	129	110	120	288
40	NC	1	2	7	40	4	133	110	122	293
41	NC	1	2	7	40	5	116	109	112	270
42	NC	1	2	7	40	6	118	112	115	276
43	NC	1	2	8	40	1	56	61	59	142
44	NC	1	2	8	40	2	57	60	58	140
45	NC	1	2	8	40	3	55	59	57	137
46	NC	1	2	8	40	4	58	59	58	140

NO (1)	REGION (2)	ROUGH (3)	SYRTYP (4)	SECNO (5)	SPEED (6)	RUN (7)	LIRI (8)	RIRI (9)	IRI (10)	DISP. (11)
47	NC	1	2	8	40	5	54	61	58	139
48	NC	1	2	8	40	6	56	58	57	138
49	NC	1	1	1	50	1	74	80	77	185
50	NC	1	1	1	50	2	68	92	80	192
51	NC	1	1	1	50	3	71	87	79	190
52	NC	1	1	1	50	4	73	83	78	187
53	NC	1	1	1	50	5	73	82	78	187
54	NC	1	1	1	50	6	72	85	78	188
55	NC	2	1	2	50	1	211	273	242	581
56	NC	2	1	2	50	2	211	272	242	580
57	NC	2	1	2	50	3	210	266	238	572
58	NC	2	1	2	50	4	214	269	241	580
59	NC	2	1	2	50	5	210	273	241	580
60	NC	2	1	2	50	6	209	280	244	587
61	NC	2	1	3	50	1	150	158	154	370
62	NC	2	1	3	50	2	148	162	155	372
63	NC	2	1	3	50	3	145	164	154	371
64	NC	2	1	3	50	4	150	161	155	373
65	NC	2	1	3	50	5	150	161	155	374
66	NC	2	1	3	50	6	150	157	153	369
67	NC	1	1	4	50	1	64	64	64	154
68	NC	1	1	4	50	2	62	64	63	151
69	NC	1	1	4	50	3	62	65	63	153
70	NC	1	1	4	50	4	61	64	62	149
71	NC	1	1	4	50	5	65	64	64	155
72	NC	1	1	4	50	6	61	65	63	151
73	NC	2	2	5	50	1	173	177	175	421
74	NC	2	2	5	50	2	166	183	175	420
75	NC	2	2	5	50	3	167	183	175	420
76	NC	2	2	5	50	4	171	180	176	422
77	NC	2	2	5	50	5	167	188	177	426
78	NC	2	2	5	50	6	168	185	176	423
79	NC	2	2	6	50	1	173	169	171	411
80	NC	2	2	6	50	2	162	167	164	395
81	NC	2	2	6	50	3	163	168	166	398
82	NC	2	2	6	50	4	165	169	167	402
83	NC	2	2	6	50	5	161	165	163	392
84	NC	2	2	6	50	6	169	167	168	404
85	NC	1	2	7	50	1	123	110	116	279
86	NC	1	2	7	50	2	118	110	114	273
87	NC	1	2	7	50	3	117	109	113	271
88	NC	1	2	7	50	4	123	111	117	281
89	NC	1	2	7	50	5	126	113	120	287
90	NC	1	2	7	50	6	119	110	115	275
91	NC	1	2	8	50	1	59	61	60	144
92	NC	1	2	8	50	2	58	60	59	142

NO (1)	REGION (2)	ROUGH (3)	SYRTYP (4)	SECNO (5)	SPEED (6)	RUN (7)	LIRI (8)	RIRI (9)	IRI (10)	DISP. (11)
93	NC	1	2	8	50	3	56	62	59	142
94	NC	1	2	8	50	4	58	62	60	144
95	NC	1	2	8	50	5	57	61	59	142
96	NC	1	2	8	50	6	57	59	58	139
97	WE	1	1	1	40	1	75	83	79	190
98	WE	1	1	1	40	2	75	82	79	189
99	WE	1	1	1	40	3	76	82	79	191
100	WE	1	1	1	40	4	74	81	78	187
101	WE	1	1	1	40	5	75	82	78	188
102	WE	1	1	1	40	6	73	80	76	184
103	WE	2	1	2	40	1	208	263	235	567
104	WE	2	1	2	40	2	214	281	247	596
105	WE	2	1	2	40	3	209	278	244	587
106	WE	2	1	2	40	4	207	270	238	574
107	WE	2	1	2	40	5	214	258	236	568
108	WE	2	1	2	40	6	209	260	235	565
109	WE	2	1	3	40	1	142	160	151	364
110	WE	2	1	3	40	2	144	163	153	369
111	WE	2	1	3	40	3	143	162	153	367
112	WE	2	1	3	40	4	147	172	159	384
113	WE	2	1	3	40	5	143	167	155	374
114	WE	2	1	3	40	6	142	160	151	364
115	WE	1	1	4	40	1	55	62	59	141
116	WE	1	1	4	40	2	54	62	58	140
117	WE	1	1	4	40	3	54	63	59	141
118	WE	1	1	4	40	4	53	62	57	138
119	WE	1	1	4	40	5	54	61	57	137
120	WE	1	1	4	40	6	52	61	57	137
121	WE	2	2	5	40	1	175	182	179	430
122	WE	2	2	5	40	2	176	182	179	431
123	WE	2	2	5	40	3	173	183	178	428
124	WE	2	2	5	40	4	178	185	181	437
125	WE	2	2	5	40	5	176	187	181	436
126	WE	2	2	5	40	6	174	185	179	432
127	WE	2	2	6	40	1	161	164	163	392
128	WE	2	2	6	40	2	161	162	162	389
129	WE	2	2	6	40	3	166	160	163	392
130	WE	2	2	6	40	4	163	156	160	384
131	WE	2	2	6	40	5	167	161	164	394
132	WE	2	2	6	40	6	164	156	160	385
133	WE	1	2	7	40	1	116	110	113	272
134	WE	1	2	7	40	2	114	108	111	267
135	WE	1	2	7	40	3	115	109	112	270
136	WE	1	2	7	40	4	115	107	111	267
137	WE	1	2	7	40	5	114	110	112	271
138	WE	1	2	7	40	6	115	110	112	270

NO (1)	REGION (2)	ROUGH (3)	SYRTYP (4)	SECNO (5)	SPEED (6)	RUN (7)	LIRI (8)	RIRI (9)	IRI (10)	DISP. (11)
139	WE	1	2	8	40	1	54	59	57	136
140	WE	1	2	8	40	2	54	58	56	135
141	WE	1	2	8	40	3	56	59	57	138
142	WE	1	2	8	40	4	55	59	57	137
143	WE	1	2	8	40	5	55	59	57	138
144	WE	1	2	8	40	6	54	61	58	139
145	WE	1	1	1	50	1	75	74	75	180
146	WE	1	1	1	50	2	75	82	79	189
147	WE	1	1	1	50	3	74	78	76	183
148	WE	1	1	1	50	4	75	80	77	186
149	WE	1	1	1	50	5	75	82	78	189
150	WE	1	1	1	50	6	75	81	78	188
151	WE	2	1	2	50	1	209	290	250	601
152	WE	2	1	2	50	2	210	287	249	598
153	WE	2	1	2	50	3	209	270	240	577
154	WE	2	1	2	50	4	210	291	251	603
155	WE	2	1	2	50	5	213	278	246	592
156	WE	2	1	2	50	6	211	267	239	575
157	WE	2	1	3	50	1	143	159	151	364
158	WE	2	1	3	50	2	144	169	156	377
159	WE	2	1	3	50	3	144	159	152	365
160	WE	2	1	3	50	4	144	156	150	361
161	WE	2	1	3	50	5	144	160	152	365
162	WE	2	1	3	50	6	144	162	153	368
163	WE	1	1	4	50	1	56	61	58	141
164	WE	1	1	4	50	2	57	61	59	141
165	WE	1	1	4	50	3	57	62	60	144
166	WE	1	1	4	50	4	56	62	59	142
167	WE	1	1	4	50	5	54	62	58	139
168	WE	1	1	4	50	6	53	63	58	140
169	WE	2	2	5	50	1	173	186	179	431
170	WE	2	2	5	50	2	176	184	180	434
171	WE	2	2	5	50	3	175	177	176	423
172	WE	2	2	5	50	4	175	187	181	436
173	WE	2	2	5	50	5	175	184	179	432
174	WE	2	2	5	50	6	173	181	177	426
175	WE	2	2	6	50	1	163	164	164	395
176	WE	2	2	6	50	2	164	164	164	395
177	WE	2	2	6	50	3	167	164	165	398
178	WE	2	2	6	50	4	172	160	166	399
179	WE	2	2	6	50	5	162	162	162	391
180	WE	2	2	6	50	6	166	165	166	399
181	WE	1	2	7	50	1	120	112	116	279
182	WE	1	2	7	50	2	115	109	112	270
183	WE	1	2	7	50	3	116	109	112	270
184	WE	1	2	7	50	4	122	112	117	283

NO (1)	REGION (2)	ROUGH (3)	SYRTYP (4)	SECNO (5)	SPEED (6)	RUN (7)	LIRI (8)	RIRI (9)	IRI (10)	DISP. (11)
185	WE	1	2	7	50	5	117	111	114	275
186	WE	1	2	7	50	6	120	110	115	277
187	WE	1	2	8	50	1	56	60	58	140
188	WE	1	2	8	50	2	51	59	55	132
189	WE	1	2	8	50	3	53	59	56	135
190	WE	1	2	8	50	4	55	59	57	138
191	WE	1	2	8	50	5	52	61	56	136
192	WE	1	2	8	50	6	53	60	56	135
193	NA	1	1	1	40	1	70	79	74	179
194	NA	1	1	1	40	2	72	82	77	184
195	NA	1	1	1	40	3	70	83	76	184
196	NA	1	1	1	40	4	71	79	75	180
197	NA	1	1	1	40	5	70	84	77	186
198	NA	1	1	1	40	6	71	85	78	187
199	NA	2	1	2	40	1	232	288	260	625
200	NA	2	1	2	40	2	223	279	251	603
201	NA	2	1	2	40	3	216	289	253	607
202	NA	2	1	2	40	4	224	283	253	609
203	NA	2	1	2	40	5	214	304	259	622
204	NA	2	1	2	40	6	212	299	256	614
205	NA	2	1	3	40	1	160	162	161	386
206	NA	2	1	3	40	2	157	162	159	383
207	NA	2	1	3	40	3	152	163	157	378
208	NA	2	1	3	40	4	160	160	160	384
209	NA	2	1	3	40	5	161	161	161	386
210	NA	2	1	3	40	6	165	158	161	388
211	NA	1	1	4	40	1	59	63	61	146
212	NA	1	1	4	40	2	59	64	62	148
213	NA	1	1	4	40	3	56	63	59	143
214	NA	1	1	4	40	4	58	64	61	146
215	NA	1	1	4	40	5	59	64	62	149
216	NA	1	1	4	40	6	59	64	61	148
217	NA	2	2	5	40	1	155	190	173	415
218	NA	2	2	5	40	2	159	191	175	422
219	NA	2	2	5	40	3	151	192	171	412
220	NA	2	2	5	40	4	154	193	174	417
221	NA	2	2	5	40	5	153	198	175	421
222	NA	2	2	5	40	6	162	196	179	429
223	NA	2	2	6	40	1	161	165	163	391
224	NA	2	2	6	40	2	157	165	161	388
225	NA	2	2	6	40	3	159	168	164	393
226	NA	2	2	6	40	4	157	167	162	389
227	NA	2	2	6	40	5	169	166	167	402
228	NA	2	2	6	40	6	162	165	164	393
229	NA	1	2	7	40	1	115	110	113	271
230	NA	1	2	7	40	2	117	111	114	275

NO (1)	REGION (2)	ROUGH (3)	SYRTYP (4)	SECNO (5)	SPEED (6)	RUN (7)	LIRI (8)	RIRI (9)	IRI (10)	DISP. (11)
231	NA	1	2	7	40	3	116	109	112	270
232	NA	1	2	7	40	4	114	111	112	270
233	NA	1	2	7	40	5	113	108	110	265
234	NA	1	2	7	40	6	117	112	114	275
235	NA	1	2	8	40	1	50	62	56	135
236	NA	1	2	8	40	2	48	59	54	129
237	NA	1	2	8	40	3	48	60	54	131
238	NA	1	2	8	40	4	49	58	54	129
239	NA	1	2	8	40	5	49	61	55	132
240	NA	1	2	8	40	6	50	61	55	133
241	NA	1	1	1	50	1	89	80	84	202
242	NA	1	1	1	50	2	83	82	83	199
243	NA	1	1	1	50	3	93	85	89	214
244	NA	1	1	1	50	4	93	80	87	208
245	NA	1	1	1	50	5	97	83	90	217
246	NA	1	1	1	50	6	86	83	84	203
247	NA	2	1	2	50	1	218	301	259	623
248	NA	2	1	2	50	2	211	301	256	616
249	NA	2	1	2	50	3	223	285	254	610
250	NA	2	1	2	50	4	225	287	256	615
251	NA	2	1	2	50	5	220	291	255	614
252	NA	2	1	2	50	6	219	299	259	622
253	NA	2	1	3	50	1	146	164	155	372
254	NA	2	1	3	50	2	149	171	160	385
255	NA	2	1	3	50	3	159	168	164	394
256	NA	2	1	3	50	4	148	165	156	375
257	NA	2	1	3	50	5	158	166	162	389
258	NA	2	1	3	50	6	150	164	157	378
259	NA	1	1	4	50	1	59	65	62	150
260	NA	1	1	4	50	2	57	64	60	145
261	NA	1	1	4	50	3	57	65	61	147
262	NA	1	1	4	50	4	57	64	61	145
263	NA	1	1	4	50	5	59	64	62	148
264	NA	1	1	4	50	6	59	66	63	150
265	NA	2	2	5	50	1	151	194	172	414
266	NA	2	2	5	50	2	155	194	174	419
267	NA	2	2	5	50	3	151	201	176	422
268	NA	2	2	5	50	4	151	198	174	419
269	NA	2	2	5	50	5	152	194	173	416
270	NA	2	2	5	50	6	158	195	176	424
271	NA	2	2	6	50	1	164	168	166	399
272	NA	2	2	6	50	2	171	168	169	407
273	NA	2	2	6	50	3	169	164	167	400
274	NA	2	2	6	50	4	167	162	165	396
275	NA	2	2	6	50	5	167	168	167	402
276	NA	2	2	6	50	6	170	165	167	402

NO (1)	REGION (2)	ROUGH (3)	SYRTYP (4)	SECNO (5)	SPEED (6)	RUN (7)	LIRI (8)	RIRI (9)	IRI (10)	DISP. (11)
277	NA	1	2	7	50	1	122	108	115	277
278	NA	1	2	7	50	2	123	111	117	282
279	NA	1	2	7	50	3	124	112	118	284
280	NA	1	2	7	50	4	123	115	119	286
281	NA	1	2	7	50	5	122	109	115	277
282	NA	1	2	7	50	6	124	114	119	286
283	NA	1	2	8	50	1	52	63	57	138
284	NA	1	2	8	50	2	56	60	58	140
285	NA	1	2	8	50	3	52	61	57	136
286	NA	1	2	8	50	4	52	60	56	135
287	NA	1	2	8	50	5	53	59	56	135
288	NA	1	2	8	50	6	52	59	56	134
289	SO	1	1	1	40	1	81	81	81	195
290	SO	1	1	1	40	2	82	78	80	192
291	SO	1	1	1	40	3	81	76	79	189
292	SO	1	1	1	40	4	82	77	79	191
293	SO	1	1	1	40	5	82	76	79	190
294	SO	1	1	1	40	6	82	77	79	191
295	SO	2	1	2	40	1	256	278	267	641
296	SO	2	1	2	40	2	225	266	246	590
297	SO	2	1	2	40	3	270	297	283	681
298	SO	2	1	2	40	4	260	296	278	668
299	SO	2	1	2	40	5	264	261	262	630
300	SO	2	1	2	40	6	254	267	260	625
301	SO	2	1	3	40	1	159	165	162	389
302	SO	2	1	3	40	2	159	161	160	384
303	SO	2	1	3	40	3	157	162	160	383
304	SO	2	1	3	40	4	160	162	161	386
305	SO	2	1	3	40	5	157	161	159	382
306	SO	2	1	3	40	6	157	162	159	382
307	SO	1	1	4	40	1	56	63	59	143
308	SO	1	1	4	40	2	57	62	60	144
309	SO	1	1	4	40	3	57	63	60	145
310	SO	1	1	4	40	4	56	64	60	144
311	SO	1	1	4	40	5	57	64	60	144
312	SO	1	1	4	40	6	58	62	60	144
313	SO	2	2	5	40	1	202	190	196	471
314	SO	2	2	5	40	2	202	189	196	471
315	SO	2	2	5	40	3	200	189	195	468
316	SO	2	2	5	40	4	201	188	194	467
317	SO	2	2	5	40	5	200	192	196	471
318	SO	2	2	5	40	6	202	190	196	471
319	SO	2	2	6	40	1	179	164	171	412
320	SO	2	2	6	40	2	180	166	173	416
321	SO	2	2	6	40	3	178	167	172	414
322	SO	2	2	6	40	4	179	166	173	415

NO (1)	REGION (2)	ROUGH (3)	SYRTYP (4)	SECNO (5)	SPEED (6)	RUN (7)	LIRI (8)	RIRI (9)	IRI (10)	DISP. (11)
323	SO	2	2	6	40	5	180	166	173	417
324	SO	2	2	6	40	6	179	166	172	414
325	SO	1	2	7	40	1	128	109	118	285
326	SO	1	2	7	40	2	128	109	118	285
327	SO	1	2	7	40	3	129	107	118	283
328	SO	1	2	7	40	4	129	109	119	286
329	SO	1	2	7	40	5	127	111	119	286
330	SO	1	2	7	40	6	129	111	120	288
331	SO	1	2	8	40	1	66	60	63	152
332	SO	1	2	8	40	2	64	58	61	147
333	SO	1	2	8	40	3	64	60	62	147
334	SO	1	2	8	40	4	61	60	60	145
335	SO	1	2	8	40	5	62	61	62	148
336	SO	1	2	8	40	6	62	60	61	146
337	SO	1	1	1	50	1	82	83	83	198
338	SO	1	1	1	50	2	82	79	81	194
339	SO	1	1	1	50	3	82	81	81	196
340	SO	1	1	1	50	4	82	81	81	196
341	SO	1	1	1	50	5	82	78	80	191
342	SO	1	1	1	50	6	82	79	81	194
343	SO	2	1	2	50	1	231	269	250	601
344	SO	2	1	2	50	2	229	276	252	606
345	SO	2	1	2	50	3	230	277	254	610
346	SO	2	1	2	50	4	230	273	251	604
347	SO	2	1	2	50	5	229	282	256	614
348	SO	2	1	2	50	6	233	284	259	622
349	SO	2	1	3	50	1	155	162	158	380
350	SO	2	1	3	50	2	159	166	162	390
351	SO	2	1	3	50	3	158	161	160	384
352	SO	2	1	3	50	4	157	164	161	386
353	SO	2	1	3	50	5	157	164	161	386
354	SO	2	1	3	50	6	157	166	161	388
355	SO	1	1	4	50	1	59	63	61	146
356	SO	1	1	4	50	2	58	63	61	145
357	SO	1	1	4	50	3	59	62	61	146
358	SO	1	1	4	50	4	59	63	61	147
359	SO	1	1	4	50	5	58	63	61	146
360	SO	1	1	4	50	6	59	62	61	146
361	SO	2	2	5	50	1	198	188	193	464
362	SO	2	2	5	50	2	199	186	193	463
363	SO	2	2	5	50	3	199	188	194	465
364	SO	2	2	5	50	4	199	190	194	467
365	SO	2	2	5	50	5	198	189	193	465
366	SO	2	2	5	50	6	199	186	193	463
367	SO	2	2	6	50	1	185	160	173	415
368	SO	2	2	6	50	2	175	162	169	406

NO (1)	REGION (2)	ROUGH (3)	SYRTYP (4)	SECNO (5)	SPEED (6)	RUN (7)	LIRI (8)	RIRI (9)	IRI (10)	DISP. (11)
369	SO	2	2	6	50	3	178	165	171	411
370	SO	2	2	6	50	4	182	163	172	414
371	SO	2	2	6	50	5	184	166	175	420
372	SO	2	2	6	50	6	178	166	172	414
373	SO	1	2	7	50	1	132	108	120	289
374	SO	1	2	7	50	2	129	109	119	287
375	SO	1	2	7	50	3	132	108	120	289
376	SO	1	2	7	50	4	129	108	119	285
377	SO	1	2	7	50	5	131	110	120	289
378	SO	1	2	7	50	6	127	111	119	286
379	SO	1	2	8	50	1	62	55	58	140
380	SO	1	2	8	50	2	61	57	59	143
381	SO	1	2	8	50	3	63	59	61	146
382	SO	1	2	8	50	4	63	59	61	147
383	SO	1	2	8	50	5	61	58	60	143
384	SO	1	2	8	50	6	61	62	61	147

APPENDIX C

STATISTICAL MODEL AND ANOVA TABLE

The factors considered in this experiment together with the levels employed are given below.

FACTOR	LEVELS	EFFECT
SURFACE TYPE	Two 1. Asphalt Concrete 2. Portland Cement	Fixed
ROUGHNESS	Two 1. Smooth 2. Medium	Fixed
PROFILOMETER	Four 1. North Central Region 2. Western Region 3. North Atlantic Region 4. Southern Region	Fixed
SPEED	Two 1. 40 mph 2. 50 mph	Fixed
SECTIONS	Eight	Random

The statistical model employed for this study is described by the following equation :

$$Y_{ijklm} = PROF_i + ROUGH_j + SURTYP_k + SEC(ROUGH,SURTYP)_{l(jk)} +$$

$$SPEED_m + ROUGH*SURTP_{jk} + PROF*SURTYP_{ik} + SURTYP*SPEED_{km} +$$

$$PROF*ROUGH_{ij} + ROUGH*SPEED_{jm} + PROF*SEC(ROUGH,SURTYP)_{il(jk)}$$

$$+ SEC*SPEED(ROUGH,SUYRTYP)_{lm(jk)} + PROF*SPEED_{im} +$$

$$PROF*ROUGH*SURTYP_{ijk} + ROUGH*SURTYP*SPEED_{jkm} +$$

$$PROF*SURTYP*SPEED_{ikm} + PROF*ROUGH*SPEED_{ijm}$$

$$+PROF*SEC*SPEED(ROUGH,SURTP)_{ilm(jk)} +$$

$$PROF*ROUGH*SURTYP*SPEED_{ijkm} + ERROR$$

where,
PROF = Profilometer
ROUGH = Level of Roughness
SURTYP = Surface Type
SEC = Sections nested within surface type and roughness
SPEED = Speed of Testing

The Analysis of Variance (ANOVA) table for this model together with the expected mean squares is shown below.

FACTOR	MEAN SQUARES
PROF	$bcdfeF(P) + ef\sigma^2_{P,S} + \sigma^2$
ROUGH	$acdefF(R) + aef\sigma^2_{S} + \sigma^2$
SURTYP	$abdefF(T) + aef\sigma^2_{S} + \sigma^2$
SEC(ROUGH,SURTYP)	$aef\sigma^2_{S} + \sigma^2$
SPEED	$abcdefF(SP) + af\sigma^2_{S.SP}$
ROUGH*SURTYP	$adefF(R,T) + aef\sigma^2_{S} + \sigma^2$
PROF*SURTYP	$bdefF(P,T) + ef\sigma^2_{P,S} + \sigma^2$
SURTYP*SPEED	$abdfF(T,SP) + af\sigma^2_{S,SP} + \sigma^2$
PROF*ROUGH	$cdefF(P,R) + ef\sigma^2_{P,S} + \sigma^2$
ROUGH*SPEED	$acdfF(R,SP) + af\sigma^2_{S,SP} + \sigma^2$
SEC*PROF(ROUGH,SURTYP)	$ef\sigma^2_{P,S} + \sigma^2$
SEC*SPEED(ROUGH,SURTYP)	$af\sigma^2_{S,SP} + \sigma^2$
PROF*SPEED	$bcdfF(P,SP) + f\sigma^2_{P,S,SP} + \sigma^2$
PROF*ROUGH*SURTYP	$defF(P,R,T) + ef\sigma^2_{P,S} + \sigma^2$
ROUGH*SURTYP*SPEED	$adfF(R,T,SP) + af\sigma^2_{S,SP} + \sigma^2$
PROF*SURTYP*SPEED	$bdfF(P,T,SP) + f\sigma^2_{P,S,SP} + \sigma^2$
PROF*ROUGH*SPEED	$cdfF(P,R,SP) + f\sigma^2_{P,S,SP} + \sigma^2$
PROF*SEC*SPEED (ROUGH,SURTYP)	$f\sigma^2_{P,S,SP} + \sigma^2$
SURTYP*ROUGH*PROF*SPEED	$dfF(P,R,T,SP) + \sigma^2$

Note :

P = Profilometer
R = Roughness
T = Surface Type
S = Sections
SP= Speed

a = Levels for profilometers
b = Levels for roughness
c = Levels for surface type
d = Levels for sections
e = Levels for speed

APPENDIX D

ANOVA FOR LEFT WHEELPATH

CASE 1 (LEFT WHEELPATH)

PROFILOMETERS : NOTH CENTRAL, WESTERN, NORTH ATLANTIC AND SOUTHERN

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	3441.60	320	10.75		
SEC WITHIN ROUGH W ITHIN SURTYP (ERROR 2)	227235.50	4	56808.87	5282.09	.000
PROF BY SEC WITHIN ROUGH WITHIN SURTYP (ERROR 1)	6038.57	12	503.21	46.79	.000
SPEED BY SEC WITHI N ROUGH WITHIN SURTY P (ERROR 3)	296.42	4	74.10	6.89	.000
PROF BY SPEED BY SEC WITHIN ROUGH WITH IN SURTYP (ERROR 4)	1548.96	12	129.08	12.00	.000
PROF BY ROUGH BY SUR TYP BY SPEED	141.82	3	47.27	4.40	.005

Source of Variation	SS	DF	MS	F	Sig of F
Error 1	6038.57	12	503.21		
PROF	14087.80	3	4695.93	9.33	.002
PROF BY ROUGH	4805.19	3	1601.73	3.18	.063
PROF BY SURTYP	2971.32	3	990.44	1.97	.173
PROF BY ROUGH BY SUR TYP	782.53	3	260.84	.52	.678

Source of Variation	SS	DF	MS	F	Sig of F
Error 2	227235.50	4	56808.87		
ROUGH	963816.79	1	963816.79	16.97	.015
SURTYP	972.54	1	972.54	.00	.000
ROUGH BY SURTYP	31585.55	1	31585.55	.56	.497

Source of Variation	SS	DF	MS	F	Sig of F
Error 3	296.42	4	74.10		
SPEED	18.50	1	18.50	.25	.644
ROUGH BY SPEED	309.73	1	309.73	4.18	.110
SURTYP BY SPEED	90.28	1	90.28	1.22	.332
ROUGH BY SURTYP BY S PEED	299.40	1	299.40	4.04	.115

Source of Variation	SS	DF	MS	F	Sig of F
Error 4	1548.96	12	129.08		
PROF BY SPEED	499.70	3	166.57	1.29	.322
PROF BY ROUGH BY SPEED	522.48	3	174.16	1.35	.305
PROF BY SURTYP BY SP	102.64	3	34.21	.27	.849

CASE 2 (LEFT WHEELPATH)

PROFILOMETERS : NORTH CENTRAL, WESTERN AND NORTH ATLANTIC

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	2030.41	240	8.46		
SEC WITHIN ROUGH W ITHIN SURTYP (ERROR 2)	155077.43	4	38769.36	4582.64	.000
PROF BY SEC12 WITHIN ROUGH WITHIN SURTYP (ERROR 1)	2125.20	8	265.65	31.40	.000
SPEED BY SEC WITHI N ROUGH WITHIN SURTY P (ERROR 3)	362.53	4	90.63	10.71	.000
PROF BY SPEED BY SEC WITHIN ROUGH WITH IN SURTYP (ERROR 4)	621.48	8	77.69	9.18	.000
PROF BY ROUGH BY SUR TYP BY SPEED	75.53	2	37.77	4.46	.012

Source of Variation	SS	DF	MS	F	Sig of F
Error 1	2125.20	8	265.65		
PROF	84.58	2	42.29	.16	.855
PROF BY ROUGH	225.34	2	112.67	.42	.668
PROF BY SURTYP	2248.99	2	1124.49	4.23	.056
PROF BY ROUGH BY SURTYP	782.37	2	391.18	1.47	.285

Source of Variation	SS	DF	MS	F	Sig of F
Error 2	155077.43	4	38769.36		
ROUGH	666469.75	1	666469.75	17.19	.014
SURTYP	184.13	1	184.13	.00	.948
ROUGH BY SURTYP	23750.37	1	23750.37	.61	.478

Source of Variation	SS	DF	MS	F	Sig of F
Error 3	362.53	4	90.63		
SPEED	185.57	1	185.57	2.05	.226
ROUGH BY SPEED	95.80	1	95.80	1.06	.362
SURTYP BY SPEED	10.71	1	10.71	.12	.748
ROUGH BY SURTYP BY SPEED	119.12	1	119.12	1.31	.316

Source of Variation	SS	DF	MS	F	Sig of F
Error 4	621.48	8	77.69		
PROF BY SPEED	107.87	2	53.94	.69	.527
PROF BY ROUGH BY SPEED	403.50	2	201.75	2.60	.135
PROF BY SURTYP BY SPEED	4.40	2	2.20	.03	.972

CASE 3 (LEFT WHEELPATH)

PROFILOMETERS : NORTH CENTRAL, WESTERN AND SOUTHERN

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	2330.56	240	9.71		
SEC WITHIN ROUGH WITHIN SURTYP (ERROR 2)	173235.82	4	43308.96	4459.94	.000
PROF BY SEC WITHIN ROUGH WITHIN SURTYP (ERROR 1)	3605.52	8	450.69	46.41	.000
SPEED BY SEC WITHIN ROUGH WITHIN SURTYP (ERROR 3)	213.62	4	53.40	5.50	.000
PROF BY SPEED BY SEC WITHIN ROUGH WITHIN SURTYP (ERROR 4)	811.75	8	101.47	10.45	.000
PROF BY ROUGH BY SURTYP BY SPEED	119.49	2	59.75	6.15	.002

Source of Variation	SS	DF	MS	F	Sig of F
Error 1	3605.52	8	450.69		
PROF	12836.61	2	6418.31	14.24	.002
PROF BY ROUGH	4300.03	2	2150.01	4.77	.043
PROF BY SURTYP	172.08	2	86.04	.19	.830
PROF BY ROUGH BY SURTYP	311.50	2	155.75	.35	.718

Source of Variation	SS	DF	MS	F	Sig of F
Error 2	173235.82	4	43308.96		
ROUGH	742098.00	1	742098.00	17.13	.014
SURTYP	2858.12	1	2858.12	.07	.810
ROUGH BY SURTYP	20466.52	1	20466.52	.47	.530

Source of Variation	SS	DF	MS	F	Sig of F
Error 3	213.62	4	53.40		
SPEED	19.94	1	19.94	.37	.574
ROUGH BY SPEED	62.69	1	62.69	1.17	.340
SURTYP BY SPEED	82.51	1	82.51	1.54	.282
ROUGH BY SURTYP BY SPEED	159.33	1	159.33	2.98	.159

Source of Variation	SS	DF	MS	F	Sig of F
Error 4	811.75	8	101.47		
PROF BY SPEED	231.32	2	115.66	1.14	.367
PROF BY ROUGH BY SPEED	307.95	2	153.97	1.52	.276
PROF BY SURTYP BY SPEED	99.72	2	49.86	.49	.629

CASE 4 (LEFT WHEELPATH)
PROFILOMETERS : NORTH CENTRAL, NORTH ATLANTIC AND SOUTHERN

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	3158.79	240	13.16		
SEC WITHIN ROUGH W ITHIN SURTYP (ERROR 2)	174352.87	4	43588.22	3311.77	.000
PROF BY SEC WITHIN ROUGH WITHIN SURTYP (ERROR 1)	5776.68	8	722.08	54.86	.000
SPEED BY SEC12 WITHI N ROUGH WITHIN SURTY P (ERROR 3)	336.66	4	84.17	6.39	.000
PROF BY SPEED BY SEC WITHIN ROUGH WITH IN SURTYP (ERROR 4)	1454.16	8	181.77	13.81	.000
PROF BY ROUGH BY SUR TYP BY SPEED	53.29	2	26.64	2.02	.134

Source of Variation	SS	DF	MS	F	Sig of F
Error 1	5776.68	8	722.08		
PROF	11773.17	2	5886.58	8.15	.012
PROF BY ROUGH	4698.21	2	2349.10	3.25	.092
PROF BY SURTYP	2565.89	2	1282.95	1.78	.230
PROF BY ROUGH BY SURTYP	216.52	2	108.26	.15	.863

Source of Variation	SS	DF	MS	F	Sig of F
Error 2	174352.87	4	43588.22		
ROUGH	731683.01	1	731683.01	16.79	.015
SURTYP	286.96	1	286.96	.01	.939
ROUGH BY SURTYP	27492.39	1	27492.39	.63	.472

Source of Variation	SS	DF	MS	F	Sig of F
Error 3	336.66	4	84.17		
SPEED	9.27	1	9.27	.11	.757
ROUGH BY SPEED	379.87	1	379.87	4.51	.101
SURTYP BY SPEED	116.33	1	116.33	1.38	.305
ROUGH BY SURTYP BY S PEED	387.67	1	387.67	4.61	.098

Source of Variation	SS	DF	MS	F	Sig of F
Error 4	1454.16	8	181.77		
PROF BY SPEED	497.84	2	248.92	1.37	.308
PROF BY ROUGH BY SPEED	450.26	2	225.13	1.24	.340
PROF BY SURTYP BY SPEED	76.48	2	38.24	.21	.815

CASE 5 (LEFT WHEELPATH)
PROFILOMETERS WESTERN, NORTH ATLANTIC AND SOUTHERN

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	2805.04	240	11.69		
SEC WITHIN ROUGH WITHIN SURTYP (ERROR 2)	181053.23	4	45263.31	3872.74	.000
PROF BY SEC WITHIN ROUGH WITHIN SURTYP (ERROR 1)	4595.45	8	574.43	49.15	.000
SPEED BY SEC WITHIN ROUGH WITHIN SURTYP (ERROR 3)	492.77	4	123.19	10.54	.000
PROF BY SPEED BY SEC WITHIN ROUGH WITHIN SURTYP (ERROR 4)	1243.17	8	155.40	13.30	.000
PROF BY ROUGH BY SURTYP BY SPEED	129.86	2	64.93	5.56	.004

Source of Variation	SS	DF	MS	F	Sig of F
Error 1	4595.45	8	574.43		
PROF	12873.11	2	6436.56	11.21	.005
PROF BY ROUGH	3590.25	2	1795.12	3.13	.099
PROF BY SURTYP	2936.55	2	1468.28	2.56	.139
PROF BY ROUGH BY SURTYP	776.35	2	388.18	.68	.536

Source of Variation	SS	DF	MS	F	Sig of F
Error 2	181053.23	4	45263.31		
ROUGH	752801.32	1	752801.32	16.63	.015
SURTYP	578.85	1	578.85	.01	.915
ROUGH BY SURTYP	23308.20	1	23308.20	.51	.513

Source of Variation	SS	DF	MS	F	Sig of F
Error 3	492.77	4	123.19		
SPEED	7.29	1	7.29	.06	.820
ROUGH BY SPEED	564.98	1	564.98	4.59	.099
SURTYP BY SPEED	95.50	1	95.50	.78	.428
ROUGH BY SURTYP BY SPEED	279.35	1	279.35	2.27	.207

Source of Variation	SS	DF	MS	F	Sig of F
Error 4	1243.17	8	155.40		
PROF BY SPEED	495.49	2	247.75	1.59	.261
PROF BY ROUGH BY SPEED	231.56	2	115.78	.75	.505
PROF BY SURTYP BY SPEED	93.11	2	46.55	.30	.749

APPENDIX E

ANOVA FOR RIGHT WHEELPATH

CASE 1 (RIGHT WHEELPATH)

PROFILOMETERS NORTH CENTRAL, WESTERN, NORTH ATLANTIC AND SOUTHERN

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	4629.77	320	14.47		
SEC WITHIN ROUGH WITHIN SURTYP (ERROR 2)	416491.41	4	104122.85	7196.75	.000
PROF BY SEC WITHIN ROUGH WITHIN SURTYP (ERROR 1)	1392.42	12	116.03	8.02	.000
SPEED BY SEC WITHIN ROUGH WITHIN SURTYP (ERROR 3)	20.87	4	5.22	.36	.837
PROF BY SPEED BY SEC WITHIN ROUGH WITHIN SURTYP (ERROR 4)	754.87	12	62.91	4.35	.000
PROF BY ROUGH BY SURTYP BY SPEED	86.71	3	28.90	2.00	.114

Source of Variation	SS	DF	MS	F	Sig of F
Error 1	1392.42	12	116.03		
PROF	1347.43	3	449.14	3.87	.038
PROF BY ROUGH	858.90	3	286.30	2.47	.112
PROF BY SURTYP	89.39	3	29.80	.26	.855
PROF BY ROUGH BY SURTYP	130.53	3	43.51	.37	.773

Source of Variation	SS	DF	MS	F	Sig of F
Error 2	416491.41	4	104122.85		
ROUGH	1385100.11	1	1385100.1	13.30	.022
SURTYP	24766.61	1	24766.61	.24	.651
ROUGH BY SURTYP	79677.23	1	79677.23	.77	.431

Source of Variation	SS	DF	MS	F	Sig of F
Error 3	20.87	4	5.22		
SPEED	44.70	1	44.70	8.57	.043
ROUGH BY SPEED	.76	1	.76	.15	.721
SURTYP BY SPEED	22.35	1	22.35	4.28	.107
ROUGH BY SURTYP BY SPEED	10.23	1	10.23	1.96	.234

Source of Variation	SS	DF	MS	F	Sig of F
Error 4	754.87	12	62.91		
PROF BY SPEED	90.42	3	30.14	.48	.703
PROF BY ROUGH BY SPEED	157.08	3	52.36	.83	.501
PROF BY SURTYP BY SPEED	33.04	3	11.01	.18	.911

CASE 2 (RIGHT WHEELPATH)
PROFILOMETERS NORTH CENTRAL, WESTERN AND NORTH ATLANTIC

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	3082.98	240	12.85		
SEC WITHIN ROUGH WITHIN SURTYP (ERROR 2)	318429.26	4	79607.32	6197.16	.000
PROF BY SEC WITHIN ROUGH WITHIN SURTYP (ERROR 1)	1219.14	8	152.39	11.86	.000
SPEED BY SEC WITHIN ROUGH WITHIN SURTYP (ERROR 3)	27.02	4	6.75	.53	.717
PROF BY SPEED BY SEC WITHIN ROUGH WITHIN SURTYP (ERROR 4)	722.63	8	90.33	7.03	.000
PROF BY ROUGH BY SURTYP BY SPEED	86.22	2	43.11	3.36	.037

Source of Variation	SS	DF	MS	F	Sig of F
Error 1	1219.14	8	152.39		
PROF	1293.49	2	646.74	4.24	.055
PROF BY ROUGH	838.37	2	419.19	2.75	.123
PROF BY SURTYP	56.44	2	28.22	.19	.834
PROF BY ROUGH BY SURTYP	122.26	2	61.13	.40	.682

Source of Variation	SS	DF	MS	F	Sig of F
Error 2	318429.26	4	79607.32		
ROUGH	1034212.01	1	1034212.0	12.99	.023
SURTYP	19365.45	1	19365.45	.24	.648
ROUGH BY SURTYP	60462.72	1	60462.72	.76	.433

Source of Variation	SS	DF	MS	F	Sig of F
Error 3	27.02	4	6.75		
SPEED	69.56	1	69.56	10.30	.033
ROUGH BY SPEED	4.46	1	4.46	.66	.462
SURTYP BY SPEED	4.82	1	4.82	.71	.446
ROUGH BY SURTYP BY SPEED	9.73	1	9.73	1.44	.296

Source of Variation	SS	DF	MS	F	Sig of F
Error 4	722.63	8	90.33		
PROF BY SPEED	64.40	2	32.20	.36	.711
PROF BY ROUGH BY SPEED	149.74	2	74.87	.83	.471
PROF BY SURTYP BY SPEED	18.59	2	9.30	.10	.903

CASE 3 (RIGHT WHEELPATH)
PROFILOMETERS NORTH CENTRAL. WESTERN AND SOUTHERN

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	3602.37	240	15.01		
SEC WITHIN ROUGH W ITHIN SURTYP (ERROR 2)	296395.41	4	74098.85	4936.67	.000
PROF BY SEC WITHIN ROUGH WITHIN SURTYP (ERROR 1)	288.19	8	36.02	2.40	.017
SPEED BY SEC WITHI N ROUGH WITHIN SURTY P (ERROR 3)	46.28	4	11.57	.77	.545
PROF BY SPEED BY SEC WITHIN ROUGH WITH IN SURTYP (ERROR 4)	708.36	8	88.54	5.90	.000
PROF BY ROUGH BY SUR TYP BY SPEED	74.30	2	37.15	2.47	.086

Source of Variation	SS	DF	MS	F	Sig of F
Error 1	288.19	8	36.02		
PROF	109.59	2	54.80	1.52	.276
PROF BY ROUGH	194.19	2	97.10	2.70	.127
PROF BY SURTYP	18.71	2	9.35	.26	.778
PROF BY ROUGH BY SUR TYP	75.98	2	37.99	1.05	.392

Source of Variation	SS	DF	MS	F	Sig of F
Error 2	296395.41	4	74098.85		
ROUGH	1012713.52	1	1012713.5	13.67	.021
SURTYP	17446.81	1	17446.81	.24	.653
ROUGH BY SURTYP	57966.16	1	57966.16	.78	.426

Source of Variation	SS	DF	MS	F	Sig of F
Error 3	46.28	4	11.57		
SPEED	6.17	1	6.17	.53	.506
ROUGH BY SPEED	4.12	1	4.12	.36	.583
SURTYP BY SPEED	8.69	1	8.69	.75	.435
ROUGH BY SURTYP BY S PEED	1.02	1	1.02	.09	.782

Source of Variation	SS	DF	MS	F	Sig of F
Error 4	708.36	8	88.54		
PROF BY SPEED	46.71	2	23.36	.26	.775
PROF BY ROUGH BY SPEED	126.03	2	63.01	.71	.519
PROF BY SURTYP BY SPEED	27.78	2	13.89	.16	.857

CASE 4 (RIGHT WHEELPATH)
PROFILOMETERS NORTH CENTRAL, NORTH ATLANTIC AND SOUTHERN

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	3155.81	240	13.15		
SEC WITHIN ROUGH WITHIN SURTYP (ERROR 2)	321355.23	4	80338.81	6109.78	.000
PROF BY SEC WITHIN ROUGH WITHIN SURTYP (ERROR 1)	1071.51	8	133.94	10.19	.000
SPEED BY SEC WITHIN ROUGH WITHIN SURTYP (ERROR 3)	170.50	4	42.63	3.24	.013
PROF BY SPEED BY SEC WITHIN ROUGH WITHIN SURTYP (ERROR 4)	190.97	8	23.87	1.82	.075
PROF BY ROUGH BY SURTYP BY SPEED	55.21	2	27.60	2.10	.125

Source of Variation	SS	DF	MS	F	Sig of F
Error 1	1071.51	8	133.94		
PROF	881.84	2	440.92	3.29	.091
PROF BY ROUGH	644.37	2	322.19	2.41	.152
PROF BY SURTYP	88.14	2	44.07	.33	.729
PROF BY ROUGH BY SURTYP	106.98	2	53.49	.40	.683

Source of Variation	SS	DF	MS	F	Sig of F
Error 2	321355.23	4	80338.81		
ROUGH	1053807.18	1	1053807.2	13.12	.022
SURTYP	18423.20	1	18423.20	.23	.657
ROUGH BY SURTYP	58577.52	1	58577.52	.73	.441

Source of Variation	SS	DF	MS	F	Sig of F
Error 3	170.50	4	42.63		
SPEED	13.51	1	13.51	.32	.604
ROUGH BY SPEED	9.58	1	9.58	.22	.660
SURTYP BY SPEED	22.72	1	22.72	.53	.506
ROUGH BY SURTYP BY SPEED	.00	1	.00	.00	.996

Source of Variation	SS	DF	MS	F	Sig of F
Error 4	190.97	8	23.87		
PROF BY SPEED	72.53	2	36.27	1.52	.276
PROF BY ROUGH BY SPEED	97.72	2	48.86	2.05	.191
PROF BY SURTYP BY SPEED	31.23	2	15.62	.65	.546

CASE 5 (RIGHT WHEELPATH)
PROFILOMETERS : WESTERN, NORTH ATLANTIC AND SOUTHERN

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	4048.14	240	16.87		
SEC WITHIN ROUGH W ITHIN SURTYP (ERROR 2)	313758.47	4	78439.62	4650.41	.000
PROF BY SEC WITHIN ROUGH WITHIN SURTYP (ERROR 1)	1134.27	8	141.78	8.41	.000
SPEED BY SEC WITHI N ROUGH WITHIN SURTY P (ERROR 3)	70.44	4	17.61	1.04	.385
PROF BY SPEED BY SEC WITHIN ROUGH WITHIN SURTYP (ERROR 4)	391.03	8	48.88	2.90	.004
PROF BY ROUGH BY SUR TYP BY SPEED	15.50	2	7.75	.46	.632

Source of Variation	SS	DF	MS	F	Sig of F
Error 1	1134.27	8	141.78		
PROF	1308.24	2	654.12	4.61	.047
PROF BY ROUGH	613.47	2	306.74	2.16	.177
PROF BY SURTYP	75.07	2	37.54	.26	.774
PROF BY ROUGH BY SUR TYP	42.85	2	21.42	.15	.862

Source of Variation	SS	DF	MS	F	Sig of F
Error 2	313758.47	4	78439.62		
ROUGH	1054853.90	1	1054853.9	13.45	.021
SURTYP	19094.16	1	19094.16	.24	.648
ROUGH BY SURTYP	62068.80	1	62068.80	.79	.424

Source of Variation	SS	DF	MS	F	Sig of F
Error 3	70.44	4	17.61		
SPEED	74.99	1	74.99	4.26	.108
ROUGH BY SPEED	36.49	1	36.49	2.07	.223
SURTYP BY SPEED	41.85	1	41.85	2.38	.198
ROUGH BY SURTYP BY S PEED	48.86	1	48.86	2.77	.171

Source of Variation	SS	DF	MS	F	Sig of F
Error 4	391.03	8	48.88		
PROF BY SPEED	57.47	2	28.74	.59	.578
PROF BY ROUGH BY SPEED	45.40	2	22.70	.46	.644
PROF BY SURTYP BY SPEED	10.49	2	5.24	.11	.900

APPENDIX F

ANOVA FOR BOTH WHEELPATH

CASE 1 (BOTH WHEELPATH)

PROFILOMETERS NORTH CENTRAL, WESTERN, NORTH ATLANTIC AND SOUTHERN

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	2075.64	320	6.49		
SEC WITHIN ROUGH WITHIN SURTYP (ERROR 2)	303954.03	4	75988.51	11715.10	.000
PROF BY SEC WITHIN ROUGH WITHIN SURTYP (ERROR 1)	1257.47	12	104.79	16.16	.000
SPEED BY SEC WITHIN ROUGH WITHIN SURTYP (ERROR 3)	114.34	4	28.58	4.41	.002
PROF BY SPEED BY SEC WITHIN ROUGH WITHIN SURTYP (ERROR 4)	511.15	12	42.60	6.57	.000
PROF BY ROUGH BY SURTYP BY SPEED	61.90	3	20.63	3.18	.024

Source of Variation	SS	DF	MS	F	Sig of F
Error 1	1257.47	12	104.79		
PROF	3537.55	3	1179.18	11.25	.001
PROF BY ROUGH	1575.51	3	525.17	5.01	.018
PROF BY SURTYP	989.92	3	329.97	3.15	.065
PROF BY ROUGH BY SURTYP	236.62	3	78.87	.75	.542

Source of Variation	SS	DF	MS	F	Sig of F
Error 2	303954.03	4	75988.51		
ROUGH	1164930.99	1	1164931.0	15.33	.017
SURTYP	3981.34	1	3981.34	.05	.830
ROUGH BY SURTYP	52896.69	1	52896.69	.70	.451

Source of Variation	SS	DF	MS	F	Sig of F
Error 3	114.34	4	28.58		
SPEED	30.17	1	30.17	1.06	.362
ROUGH BY SPEED	69.96	1	69.96	2.45	.193
SURTYP BY SPEED	5.70	1	5.70	.20	.678
ROUGH BY SURTYP BY SPEED	49.77	1	49.77	1.74	.257

Source of Variation	SS	DF	MS	F	Sig of F
Error 4	511.15	12	42.60		
PROF BY SPEED	223.77	3	74.59	1.75	.210
PROF BY ROUGH BY SPEED	107.32	3	35.77	.84	.498
PROF BY SURTYP BY SPEED	13.20	3	4.40	.10	.957

CASE 2 (BOTH WHEELPATH)
PROFILOMETERS NORTH CENTRAL, WESTERN AND NORTH ATLANTIC

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	1042.49	240	4.34		
SEC WITHIN ROUGH WITHIN SURTYP (ERROR 2)	219395.74	4	54848.94	12627.19	.000
PROF BY SEC WITHIN ROUGH WITHIN SURTYP (ERROR 1)	490.62	8	61.33	14.12	.000
SPEED BY SEC WITHIN ROUGH WITHIN SURTYP (ERROR 3)	119.37	4	29.84	6.87	.000
PROF BY SPEED BY SEC WITHIN ROUGH WITHIN SURTYP (ERROR 4)	242.32	8	30.29	6.97	.000
PROF BY ROUGH BY SURTYP BY SPEED	42.33	2	21.16	4.87	.008

Source of Variation	SS	DF	MS	F	Sig of F
Error 1	490.62	8	61.33		
PROF	457.60	2	228.80	3.73	.072
PROF BY ROUGH	271.82	2	135.91	2.22	.171
PROF BY SURTYP	723.91	2	361.95	5.90	.027
PROF BY ROUGH BY SURTYP	233.93	2	116.96	1.91	.210

Source of Variation	SS	DF	MS	F	Sig of F
Error 2	219395.74	4	54848.94		
ROUGH	840274.63	1	840274.63	15.32	.017
SURTYP	3943.76	1	3943.76	.07	.802
ROUGH BY SURTYP	39999.70	1	39999.70	.73	.441

Source of Variation	SS	DF	MS	F	Sig of F
Error 3	119.37	4	29.84		
SPEED	120.59	1	120.59	4.04	.115
ROUGH BY SPEED	14.74	1	14.74	.49	.521
SURTYP BY SPEED	.29	1	.29	.01	.926
ROUGH BY SURTYP BY SPEED	15.19	1	15.19	.51	.515

Source of Variation	SS	DF	MS	F	Sig of F
Error 4	242.32	8	30.29		
PROF BY SPEED	68.80	2	34.40	1.14	.368
PROF BY ROUGH BY SPEED ED	60.97	2	30.49	1.01	.407
PROF BY SURTYP BY SPEED	3.85	2	1.93	.06	.939

CASE 3 (bOTH WHEELPATH)
PROFILOMETERS NORTH CENTRAL, WESTERN AND SOUTHERN

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	1743.40	240	7.26		
SEC WITHIN ROUGH W ITHIN SURTYP (ERROR 2)	224444.29	4	56111.07	7724.37	.000
PROF BY SEC WITHIN ROUGH WITHIN SURTYP (ERROR 1)	922.22	8	115.28	15.87	.000
SPEED BY SEC WITHI N ROUGH WITHIN SURTY P (ERROR 3)	86.52	4	21.63	2.98	.020
PROF BY SPEED BY SEC WITHIN ROUGH WITH IN SURTYP (ERROR 4)	369.84	8	46.23	6.36	.000
PROF BY ROUGH BY SUR TYP BY SPEED	61.54	2	30.77	4.24	.016

Source of Variation	SS	DF	MS	F	Sig of F
Error 1	922.22	8	115.28		
PROF	3537.54	2	1768.77	15.34	.002
PROF BY ROUGH	1572.79	2	786.39	6.82	.019
PROF BY SURTYP	49.91	2	24.96	.22	.810
PROF BY ROUGH BY SUR TYP	25.19	2	12.60	.11	.898

Source of Variation	SS	DF	MS	F	Sig of F
Error 2	224444.29	4	56111.07		
ROUGH	872156.17	1	872156.17	15.54	.017
SURTYP	1545.63	1	1545.63	.03	.876
ROUGH BY SURTYP	36829.21	1	36829.21	.66	.463

Source of Variation	SS	DF	MS	F	Sig of F
Error 3	86.52	4	21.63		
SPEED	.98	1	.98	.05	.842
ROUGH BY SPEED	24.74	1	24.74	1.14	.345
SURTYP BY SPEED	9.41	1	9.41	.44	.545
ROUGH BY SURTYP BY S PEED	33.76	1	33.76	1.56	.280

Source of Variation	SS	DF	MS	F	Sig of F
Error 4	369.84	8	46.23		
PROF BY SPEED	91.57	2	45.79	.99	.413
PROF BY ROUGH BY SPEED	86.72	2	43.36	.94	.431
PROF BY SURTYP BY SPEED	9.20	2	4.60	.10	.906

CASE 4 (BOTH WHEELPATH)
PROFILOMETERS NORTH CENTRAL, NORTH ATLANTIC AND SOUTHERN

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	1620.67	240	6.75		
SEC WITHIN ROUGH W ITHIN SURTYP (ERROR 2)	233366.44	4	58341.61	8639.65	.000
PROF BY SEC WITHIN ROUGH WITHIN SURTYP (ERROR 1)	1075.89	8	134.49	19.92	.000
SPEED BY SEC WITHI N ROUGH WITHIN SURTY P (ERROR 3)	199.13	4	49.78	7.37	.000
PROF BY SPEED BY SEC WITHIN ROUGH WITH IN SURTYP (ERROR 4)	293.44	8	36.68	5.43	.000
PROF BY ROUGH BY SUR TYP BY SPEED	5.49	2	2.75	.41	.666

Source of Variation	SS	DF	MS	F	Sig of F
Error 1	1075.89	8	134.49		
PROF	2323.45	2	1161.73	8.64	.010
PROF BY ROUGH	1419.35	2	709.68	5.28	.035
PROF BY SURTYP	899.46	2	449.73	3.34	.088
PROF BY ROUGH BY SUR TYP	147.06	2	73.53	.55	.599

Source of Variation	SS	DF	MS	F	Sig of F
Error 2	233366.44	4	58341.61		
ROUGH	885417.85	1	885417.85	15.18	.018
SURTYP	3528.35	1	3528.35	.06	.818
ROUGH BY SURTYP	41579.83	1	41579.83	.71	.446

Source of Variation	SS	DF	MS	F	Sig of F
Error 3	199.13	4	49.78		
SPEED	11.29	1	11.29	.23	.659
ROUGH BY SPEED	127.53	1	127.53	2.56	.185
SURTYP BY SPEED	9.06	1	9.06	.18	.692
ROUGH BY SURTYP BY S PEED	97.31	1	97.31	1.95	.235

Source of Variation	SS	DF	MS	F	Sig of F
Error 4	293.44	8	36.68		
PROF BY SPEED	215.97	[illegible]	107.98	2.94	.110
PROF BY ROUGH BY SPEED	41.72	[illegible]	20.86	.57	.588
PROF BY SURTYP BY SPEED	9.64	2	4.82	.13	.879

CASE 5 (BOTH WHEELPATH)
PROFILOMETERS WESTERN, NORTH ATLANTIC AND SOUTHERN

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	1820.36	240	7.58		
SEC WITHIN ROUGH W ITHIN SURTYP (ERROR 2)	235074.77	4	58768.69	7748.19	.000
PROF BY SEC WITHIN ROUGH WITHIN SURTYP (ERROR 1)	864.53	8	108.07	14.25	.000
SPEED BY SEC WITHI N ROUGH WITHIN SURTY P (ERROR 3)	108.37	4	27.09	3.57	.008
PROF BY SPEED BY SEC WITHIN ROUGH WITH IN SURTYP (ERROR 4)	457.45	8	57.18	7.54	.000
PROF BY ROUGH BY SUR TYP BY SPEED	55.71	2	27.85	3.67	.027

Source of Variation	SS	DF	MS	F	Sig of F
Error 1	864.53	8	108.07		
PROF	3114.87	2	1557.43	14.41	.002
PROF BY ROUGH	937.40	2	468.70	4.34	.053
PROF BY SURTYP	966.51	2	483.26	4.47	.050
PROF BY ROUGH BY SUR TYP	224.80	2	112.40	1.04	.397

Source of Variation	SS	DF	MS	F	Sig of F
Error 2	235074.77	4	58768.69		
ROUGH	897469.50	1	897469.50	15.27	.017
SURTYP	3256.25	1	3256.25	.06	.825
ROUGH BY SURTYP	40360.19	1	40360.19	.69	.454

Source of Variation	SS	DF	MS	F	Sig of F
Error 3	108.37	4	27.09		
SPEED	32.24	1	32.24	1.19	.337
ROUGH BY SPEED	78.63	1	78.63	2.90	.164
SURTYP BY SPEED	2.73	1	2.73	.10	.767
ROUGH BY SURTYP BY S PEED	23.67	1	23.67	.87	.403

Source of Variation	SS	DF	MS	F	Sig of F
Error 4	457.45	8	57.18		
PROF BY SPEED	220.37	2	110.19	1.93	.207
PROF BY ROUGH BY SPEED	96.77	2	48.39	.85	.464
PROF BY SURTYP BY SPEED	12.51	2	6.26	.11	.898

APPENDIX G

COMPUTER PROGRAM USED TO COMPUTE DIPSTICK IRI

```
REM THIS PROGRAM WAS OBTAINED FROM GUIDELINES FOR CONDUCTING
REM AND CALIBRATING ROAD ROUGHNESS MEASUREMENTS, TECHNICAL
REM PAPER 46, WORLD REM BANK BY MICHAEL W. SAYERS,
REM THOMAS D. GILLESPIE AND WILLIAM D.O. REM PATERSON
REM THIS PROGRAM IS VALID ONLY FOR COMPUTING IRI FROM
REM DIPSTICK DATA
REM
REM --------------------------------Initialize constants
DIM Y(26), Z(4), Z1(4), ST(4, 4), PR(4)
READ DX
K = 2
BL = DX
FOR I = 1 TO 4
    FOR J = 1 TO 4
        READ ST(I, J)
    NEXT J
    READ PR(I)
    NEXT I
REM ----------------------------------Initialize variables
    OPEN "C:\elevat\t.PRN" FOR INPUT AS #1
    OPEN "C:\elevat\t.out" FOR OUTPUT AS #2
REM INPUT PROFILE ELEVATION 36 FT FROM START
    INPUT #1, Y(K)
REM INPUT X=0. ELEVATION
    INPUT #1, Y(1)
    Z1(1) = (Y(K) - Y(1)) / 36
    Z1(2) = 0
    Z1(3) = Z1(1)
    Z1(4) = 0
    RS = O
    IX = 1
    I = 0
    IK = 0
REM ------- LOOP TO INPUT PROFILE AND CALCULATE ROUGHNESS
    DO WHILE NOT EOF(1)
    I = I + 1
    IK = IK + 1
    IX = IX + 1
    INPUT #1, Y(K)
REM ----------------------------- COMPUTE SLOPE INPUT
    YP = (Y(K) - Y(1)) / BL
    FOR J = 2 TO K
        Y(J - 1) = Y(J)
    NEXT J
REM ------------------------------SIMULATE VEHICLE RESPONSE
    FOR J = 1 TO 4
        Z(J) = PR(J) * YP
        FOR JJ = 1 TO 4
            Z(J) = Z(J) + ST(J, JJ) * Z1(JJ)
        NEXT JJ
    NEXT J
    FOR J = 1 TO 4
        Z1(J) = Z(J)
    NEXT J
```

```
RS = RS + ABS(Z(1) - Z(3))
XX = DX * IK
XY = RS * DX
XZ = (RS / I) * 5280
WRITE #2, XX, XY, XZ
LOOP
END
DATA 1.0
DATA .9951219, .01323022, -.004721649, .00045164,
.009599989
DATA -.6468806, .9338062, -1.319262, .05659404, 1.966143
DATA .03018876, .003010939, .6487856, .009129263,
.3210257.
DATA 3.661957, .3772937, -43.40468, .3016807, 39.74273
```

APPENDIX H

ANOVA BETWEEN PROFILOMETRS AND DIPSTICK

ANOVA BETWEEN DIPSTICK AND PROFILOMETERS

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	203.68	32	6.36		
SECNO	186469.10	7	26638.44	4185.17	.000
DEVICE BY SECNO (ERROR 1)	1762.16	21	83.91	13.18	.000

* * ANALYSIS OF VARIANCE -- DESIGN 1 * *

Tests of Significance for LIRI using UNIQUE sums of squares

Source of Variation	SS	DF	MS	F	Sig of F
Error 1	1762.16	21	83.91		
DEVICE	204.64	3	68.21	.81	.501

APPENDIX I

COMPARATIVE STUDY BETWEEN NORTH CENTRAL AND SOUTHERN REGION PROFILOMETERS IN SEPTEMBER

NORTH CENTRAL REGION PROFILOMETER DATA

See Appendix B for a description of the column headings.

NO (1)	REGION (2)	ROUGH (3)	SURTYP (4)	SECNO (5)	SPEED (6)	RUN (7)	LIRI (8)	RIRI (9)	IRI (10)
1	NC	1	1	1	50	1	73	84	79
2	NC	1	1	1	50	2	71	87	79
3	NC	1	1	1	50	3	65	98	81
4	NC	1	1	1	50	4	70	83	76
5	NC	1	1	1	50	5	65	90	77
6	NC	1	1	1	50	6	67	83	75
7	NC	1	1	1	40	1	67	85	76
8	NC	1	1	1	40	2	67	83	75
9	NC	1	1	1	40	3	67	84	76
10	NC	1	1	1	40	4	64	99	81
11	NC	1	1	1	40	5	66	87	76
12	NC	1	1	1	40	6	65	85	75
13	NC	2	1	2	50	1	212	270	241
14	NC	2	1	2	50	2	219	265	242
15	NC	2	1	2	50	3	218	259	238
16	NC	2	1	2	50	4	217	267	242
17	NC	2	1	2	50	5	217	249	233
18	NC	2	1	2	50	6	214	294	254
19	NC	2	1	2	40	1	208	275	242
20	NC	2	1	2	40	2	209	287	248
21	NC	2	1	2	40	3	210	259	235
22	NC	2	1	2	40	4	211	287	249
23	NC	2	1	2	40	5	214	316	265
24	NC	2	1	2	40	6	220	324	272
25	NC	2	1	3	50	1	165	164	165
26	NC	2	1	3	50	2	164	161	163
27	NC	2	1	3	50	3	164	162	163
28	NC	2	1	3	50	4	166	168	167
29	NC	2	1	3	50	5	167	169	168
30	NC	2	1	3	50	6	165	165	165
31	NC	2	1	3	40	1	165	164	165
32	NC	2	1	3	40	2	165	176	171
33	NC	2	1	3	40	3	165	166	166
34	NC	2	1	3	40	4	160	162	161
35	NC	2	1	3	40	5	162	162	162
36	NC	2	1	3	40	6	162	160	161
37	NC	1	1	4	50	1	73	66	70
38	NC	1	1	4	50	2	74	76	75
39	NC	1	1	4	50	3	72	64	68
40	NC	1	1	4	50	4	74	66	70

NO (1)	REGION (2)	ROUGH (3)	SURTYP (4)	SECNO (5)	SPEED (6)	RUN (7)	LIRI (8)	RIRI (9)	IRI (10)
41	NC	1	1	4	50	5	73	66	69
42	NC	1	1	4	50	6	72	65	69
43	NC	1	1	4	40	1	74	66	70
44	NC	1	1	4	40	2	71	64	68
45	NC	1	1	4	40	3	70	63	67
46	NC	1	1	4	40	4	72	64	68
47	NC	1	1	4	40	5	70	64	67
48	NC	1	1	4	40	6	71	63	67
49	NC	2	2	5	50	1	177	207	192
50	NC	2	2	5	50	2	177	202	190
51	NC	2	2	5	50	3	180	196	188
52	NC	2	2	5	50	4	177	198	187
53	NC	2	2	5	50	5	175	198	186
54	NC	2	2	5	50	6	177	202	189
55	NC	2	2	5	40	1	176	196	186
56	NC	2	2	5	40	2	178	196	187
57	NC	2	2	5	40	3	175	198	187
58	NC	2	2	5	40	4	177	199	188
59	NC	2	2	5	40	5	176	195	186
60	NC	2	2	5	40	6	175	196	185
61	NC	2	2	6	50	1	162	172	167
62	NC	2	2	6	50	2	162	172	167
63	NC	2	2	6	50	3	166	174	170
64	NC	2	2	6	50	4	165	173	169
65	NC	2	2	6	50	5	166	172	169
66	NC	2	2	6	50	6	164	172	168
67	NC	2	2	6	40	1	166	177	172
68	NC	2	2	6	40	2	163	171	167
69	NC	2	2	6	40	3	163	172	168
70	NC	2	2	6	40	4	165	171	168
71	NC	2	2	6	40	5	164	179	171
72	NC	2	2	6	40	6	164	175	169
73	NC	1	2	7	50	1	120	118	119
74	NC	1	2	7	50	2	119	122	120
75	NC	1	2	7	50	3	121	117	119
76	NC	1	2	7	50	4	124	115	119
77	NC	1	2	7	50	5	117	119	118
78	NC	1	2	7	50	6	120	118	119
79	NC	1	2	7	40	1	114	119	116
80	NC	1	2	7	40	2	119	117	118
81	NC	1	2	7	40	3	118	121	119
82	NC	1	2	7	40	4	118	119	119
83	NC	1	2	7	40	5	118	117	118
84	NC	1	2	7	40	6	118	119	118
85	NC	1	2	8	50	1	70	72	71
86	NC	1	2	8	50	2	70	68	69

NO	REGION	ROUGH	SURTYP	SECNO	SPEED	RUN	LIRI	RIRI	IRI
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
87	NC	1	2	8	50	3	65	70	67
88	NC	1	2	8	50	4	63	74	69
89	NC	1	2	8	50	5	67	71	69
90	NC	1	2	8	50	6	67	66	67
91	NC	1	2	8	40	1	68	69	69
92	NC	1	2	8	40	2	68	68	68
93	NC	1	2	8	40	3	68	70	69
94	NC	1	2	8	40	4	68	70	69
95	NC	1	2	8	40	5	64	75	69
96	NC	1	2	8	40	6	69	68	68

ANOVA BETWEEN JUNE AND SEPTEMBER DATA FOR NORTH CENTRAL PROFILOMETER.
LEFT WHEELPATH

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	1019.76	160	6.37		
SEC12 WITHIN ROUGH W ITHIN SURTYP (ERROR 2)	78027.60	4	19506.90	3060.61	.000
TIME BY SEC12 WITHIN ROUGH WITHIN SURTYP (ERROR 1)	1702.23	4	425.56	66.77	.000
SPEED BY SEC12 WITHI N ROUGH WITHIN SURTY P (ERROR 3)	63.22	4	15.81	2.48	.046
TIME BY SPEED BY SEC 12 WITHIN ROUGH WITH IN SURTYP (ERROR 4)	68.39	4	17.10	2.68	.033
TIME BY ROUGH BY SUR TYP BY SPEED	27.99	1	27.99	4.39	.038

Error 1	1702.23	4	425.56		
TIME	1287.70	1	1287.70	3.03	.157
TIME BY ROUGH	229.45	1	229.45	.54	.503
TIME BY SURTYP	48.83	1	48.83	.11	.752
TIME BY ROUGH BY SUR TYP	73.42	1	73.42	.17	.699

Source of Variation	SS	DF	MS	F	Sig of F
Error 2	78027.60	4	19506.90		
ROUGH	444427.66	1	444427.66	22.78	.009
SURTYP	496.62	1	496.62	.03	.881
ROUGH BY SURTYP	18846.24	1	18846.24	.97	.381

Source of Variation	SS	DF	MS	F	Sig of F
Error 3	63.22	4	15.81		
SPEED	71.63	1	71.63	4.53	.100
ROUGH BY SPEED	20.89	1	20.89	1.32	.314
SURTYP BY SPEED	1.96	1	1.96	.12	.743
ROUGH BY SURTYP BY S PEED	7.34	1	7.34	.46	.533

Source of Variation	SS	DF	MS	F	Sig of F
Error 4	68.39	4	17.10		
TIME BY SPEED	8.47	1	8.47	.50	.520
TIME BY ROUGH BY SPEED	15.01	1	15.01	.88	.402
TIME BY SURTYP BY SPEED	18.81	1	18.81	1.10	.353

ANOVA BETWEEN JUNE AND SEPTEMBER DATA FOR NORTH CENTRAL PROFILOMETER.
RIGHT WHEELPATH

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	5586.53	160	34.92		
SEC12 WITHIN ROUGH W ITHIN SURTYP (ERROR 2)	201607.67	4	50401.92	1443.53	.000
TIME BY SEC12 WITHIN ROUGH WITHIN SURTYP (ERROR 1)	222.72	4	55.68	1.59	.178
SPEED BY SEC12 WITHI N ROUGH WITHIN SURTY P (ERROR 3)	1040.18	4	260.04	7.45	.000
TIME BY SPEED BY SEC 12 WITHIN ROUGH WITH IN SURTYP (ERROR 4)	180.91	4	45.23	1.30	.274
TIME BY ROUGH BY SUR TYP BY SPEED	83.12	1	83.12	2.38	.125

Source of Variation	SS	DF	MS	F	Sig of F
Error 1	222.72	4	55.68		
TIME	2136.47	1	2136.47	38.37	.003
TIME BY ROUGH	22.58	1	22.58	.41	.559
TIME BY SURTYP	462.24	1	462.24	8.30	.045
TIME BY ROUGH BY SUR TYP	.08	1	.08	.00	.972

Source of Variation	SS	DF	MS	F	Sig of F
Error 2	201607.67	4	50401.92		
ROUGH	668733.20	1	668733.20	13.27	.022
SURTYP	7249.99	1	7249.99	.14	.724
ROUGH BY SURTYP	35287.73	1	35287.73	.70	.450

Source of Variation	SS	DF	MS	F	Sig of F
Error 3	1040.18	4	260.04		
SPEED	91.12	1	91.12	.35	.586
ROUGH BY SPEED	304.24	1	304.24	1.17	.340
SURTYP BY SPEED	122.38	1	122.38	.47	.530
ROUGH BY SURTYP BY S PEED	295.49	1	295.49	1.14	.346

Source of Variation	SS	DF	MS	F	Sig of F
Error 4	180.91	4	45.23		
TIME BY SPEED	52.47	1	52.47	1.16	.342
TIME BY ROUGH BY SPEED	26.19	1	26.19	.58	.489
TIME BY SURTYP BY SPEED	73.79	1	73.79	1.63	.271

SOUTHERN REGION PROFILOMETER DATA - SEPTEMBER

See Appendix B for a description of the column headings.

NO (1)	PROF (2)	ROUGH (3)	SURTYP (4)	SECNO (5)	SPEED (6)	RUN (7)	LIRI (8)	RIRI (9)	IRI (10)
1	SO	1	1	1	50	1	82	82	82
2	SO	1	1	1	50	2	81	73	77
3	SO	1	1	1	50	3	82	78	80
4	SO	1	1	1	50	4	82	76	79
5	SO	1	1	1	50	5	82	70	76
6	SO	1	1	1	50	6	82	79	81
7	SO	1	1	1	40	1	80	80	80
8	SO	1	1	1	40	2	80	78	79
9	SO	1	1	1	40	3	79	81	80
10	SO	1	1	1	40	4	79	79	79
11	SO	1	1	1	40	5	79	75	77
12	SO	1	1	1	40	6	80	81	81
13	SO	2	2	5	50	1	209	187	198
14	SO	2	2	5	50	2	209	185	197
15	SO	2	2	5	50	3	208	192	200
16	SO	2	2	5	50	4	209	190	199
17	SO	2	2	5	50	5	210	192	201
18	SO	2	2	5	50	6	208	190	199
19	SO	2	2	5	40	1	210	191	200
20	SO	2	2	5	40	2	209	191	200
21	SO	2	2	5	40	3	211	189	200
22	SO	2	2	5	40	4	209	187	198
23	SO	2	2	5	40	5	210	187	198
24	SO	2	2	5	40	6	211	189	200
25	SO	2	2	6	50	1	181	167	174
26	SO	2	2	6	50	2	183	166	175
27	SO	2	2	6	50	3	184	166	175
28	SO	2	2	6	50	4	185	166	176
29	SO	2	2	6	50	5	182	165	174
30	SO	2	2	6	50	6	181	167	174
31	SO	2	2	6	40	1	182	163	173
32	SO	2	2	6	40	2	181	164	173
33	SO	2	2	6	40	3	180	166	173
34	SO	2	2	6	40	4	181	164	173
35	SO	2	2	6	40	5	183	165	174
36	SO	2	2	6	40	6	179	165	172
37	SO	1	2	7	50	1	127	111	119
38	SO	1	2	7	50	2	130	109	119
39	SO	1	2	7	50	3	127	108	118
40	SO	1	2	7	50	4	127	111	119
41	SO	1	2	7	50	5	129	108	119

NO (1)	PROF (2)	ROUGH (3)	SURTYP (4)	SECNO (5)	SPEED (6)	RUN (7)	LIRI (8)	RIRI (9)	IRI (10)
42	SO	1	2	7	50	6	129	110	120
43	SO	1	2	7	40	1	132	108	120
44	SO	1	2	7	40	2	132	111	121
45	SO	1	2	7	40	3	132	109	120
46	SO	1	2	7	40	4	130	109	120
47	SO	1	2	7	40	5	131	113	122
48	SO	1	2	7	40	6	129	110	119
49	SO	1	2	8	50	1	81	67	74
50	SO	1	2	8	50	2	80	68	74
51	SO	1	2	8	50	3	80	69	75
52	SO	1	2	8	50	4	80	68	74
53	SO	1	2	8	50	5	80	66	73
54	SO	1	2	8	50	6	78	69	74
55	SO	1	2	8	40	1	87	72	80
56	SO	1	2	8	40	2	87	76	81
57	SO	1	2	8	40	3	86	75	80
58	SO	1	2	8	40	4	87	72	80
59	SO	1	2	8	40	5	87	72	79
60	SO	1	2	8	40	6	86	74	80

COMPARISON BETWEEN NORTH CENTRAL AND SOUTHERN PROFILOMETRS USING SEPTEMBER DATA

LEFT WHEELPATH

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	269.49	100	2.69		
SECNO	286847.71	4	71711.93	26609.90	.000
SECNO BY PROF (ERROR 1)	1756.73	4	439.18	162.97	.000
SECNO BY SPEED (ERROR 2)	111.88	4	27.97	10.38	.000
PROF BY SPEED BY SECNO (ERROR 3)	71.54	4	17.88	6.64	.000

Source of Variation	SS	DF	MS	F	Sig of F
Error 1	1756.73	4	439.18		
PROF	9902.65	1	9902.65	22.55	.009

Source of Variation	SS	DF	MS	F	Sig of F
Error 2	111.88	4	27.97		
SPEED	.39	1	.39	.01	.912

Source of Variation	SS	DF	MS	F	Sig of F
Error 3	71.54	4	17.88		
PROF BY SPEED	44.95	1	44.95	2.51	.188

COMPARISON BETWEEN NORTH CENTRAL AND SOUTHERN PROFILOMETRS USING SEPTEMBER DATA.

RIGHT WHEELPATH

Source of Variation	SS	DF	MS	F	Sig of F
WITHIN CELLS	814.87	100	8.15		
SECNO	278557.40	4	69639.35	8546.03	.000
SECNO BY PROF (ERROR 1)	427.14	4	106.79	13.10	.000
SECNO BY SPEED (ERROR 2)	67.35	4	16.84	2.07	.091
PROF BY SPEED BY SECNO (ERROR 3)	73.14	4	18.28	2.24	.070

Source of Variation	SS	DF	MS	F	Sig of F
Error 1	427.14	4	106.79		
PROF	1486.07	1	1486.07	13.92	.020

Source of Variation	SS	DF	MS	F	Sig of F
Error 2	67.35	4	16.84		
SPEED	6.76	1	6.76	.40	.561

Source of Variation	SS	DF	MS	F	Sig of F
Error 3	73.14	4	18.28		
PROF BY SPEED	26.48	1	26.48	1.45	.295

APPENDIX J

CORRECTION FACTORS FOR IRI OF SOUTHERN REGION PROFILOMETER

ANOVA indicated that the left wheelpath IRI of the Southern profilometer was different from the other three profilometers. A comparison was performed between the left wheelpath IRI of the Southern and North Central profilometers to see if there was a relationship between the IRI's. The mean IRI (in/mile) obtained for each site from the two profilometers from the June comparison study are given below.

Section	1	2	3	4	5	6	7	8
N. Central	72	211	149	63	169	166	121	58
Southern	82	230	157	59	199	180	130	62

In the comparative study performed in September, all sections could not be tested by the Southern profilometer. The table below gives the IRI's of the tested sections.

Section	1	5	6	7	8
N. Central	68	177	164	120	67
Southern	82	208	183	128	80

Figures J1 and J2 show the relationship between the left wheelpath IRI's from the Southern and North Central profilometers for the June and September comparisons respectively. These figures show that the IRI's from the Southern unit are higher than those from the North Central

Fig. J1 MEAN LEFT WHEELPATH IRI FOR SOUTHERN AND N. CENTRAL PROFILOMETERS – JUNE COMPARISON

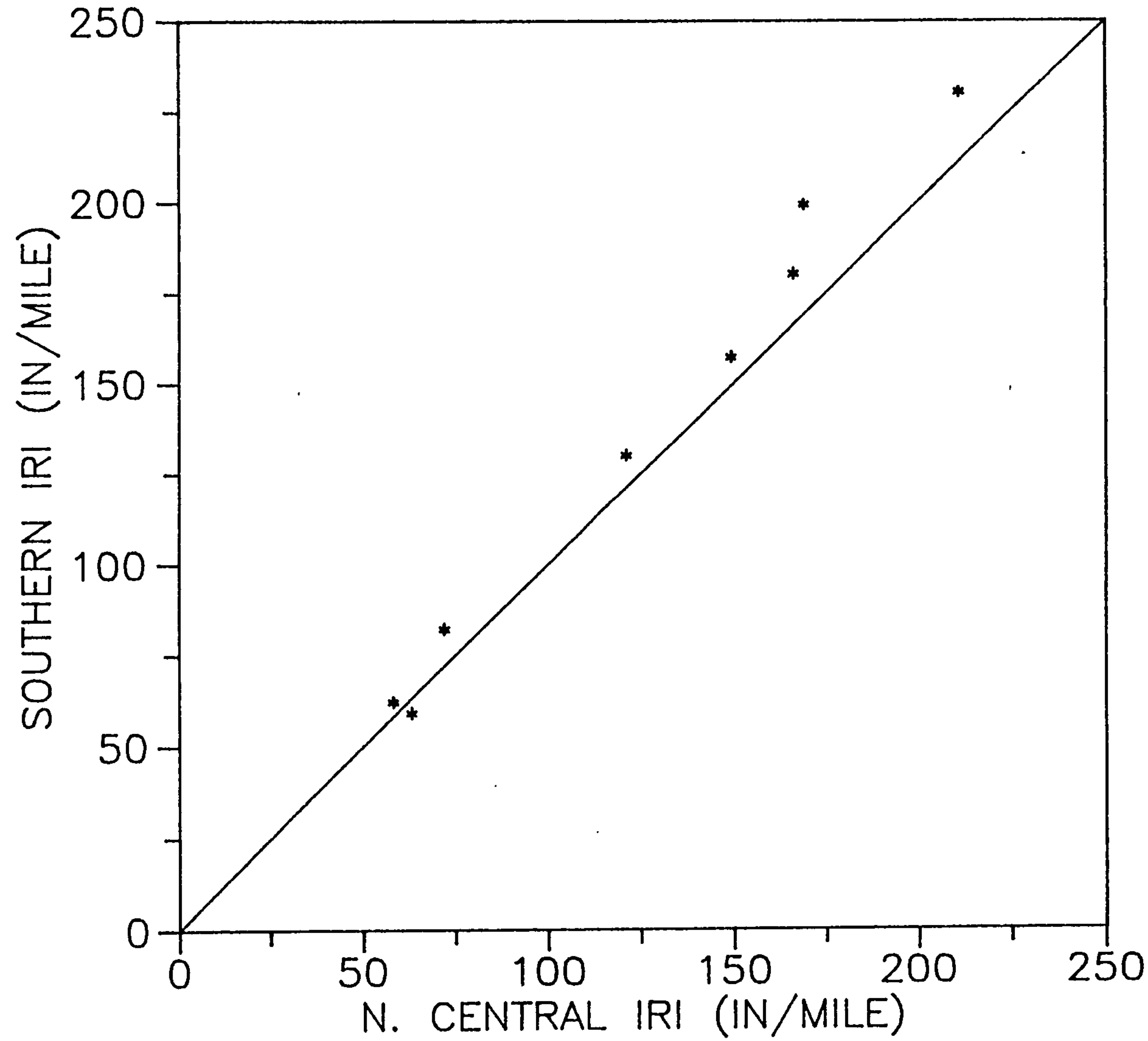
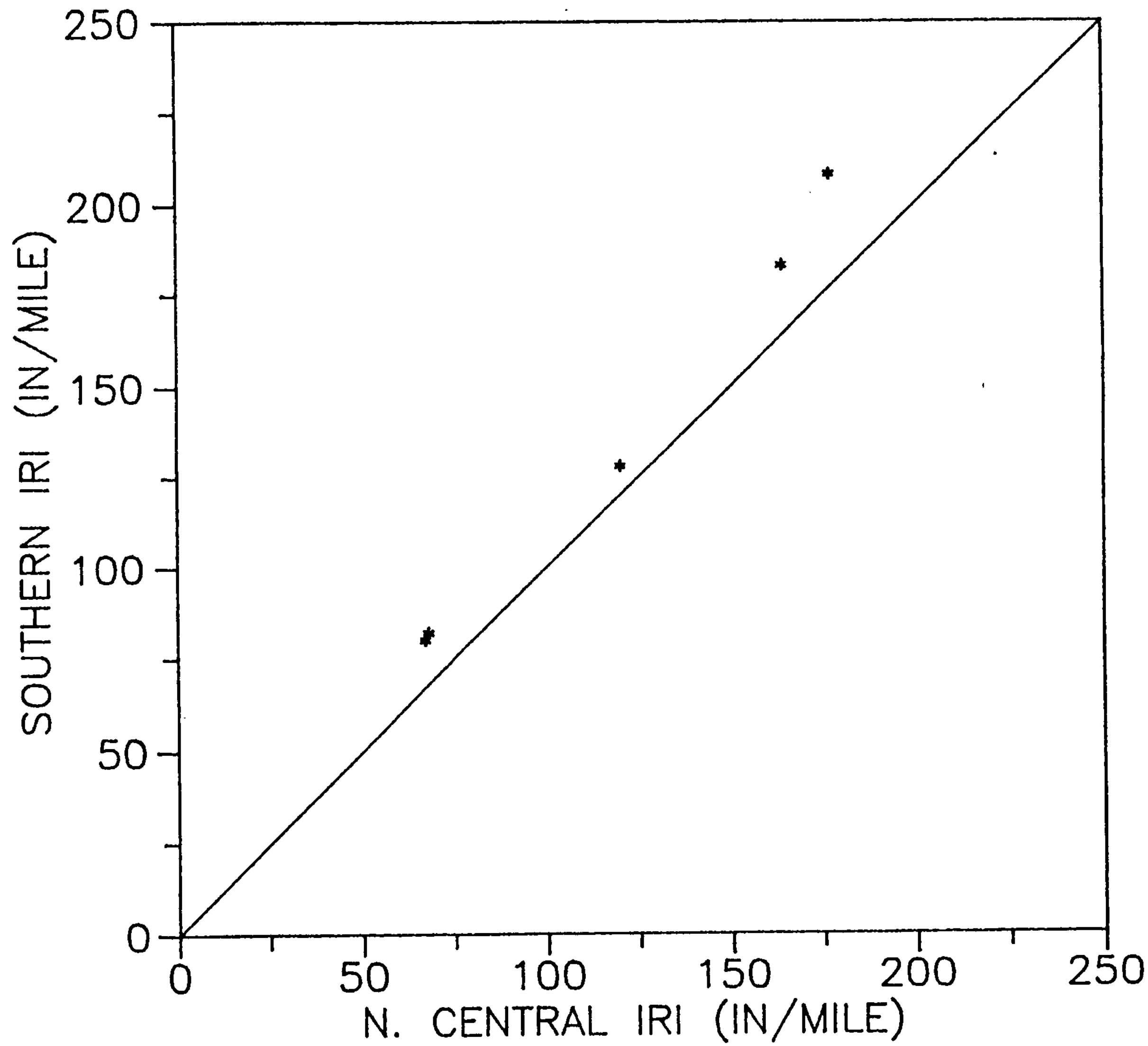


Fig. J2 MEAN LEFT WHEELPATH IRI FOR SOUTHERN AND N. CENTRAL PROFILOMETERS – SEPTEMBER COMPARISON



unit. The only exception occurred during the June testing at a site that had a very low IRI.

The mean left wheelpath IRI's obtained form the June and September study were used to develop a regression equation relating the North Central and Southern profilometers. The results obtained are given next.

RESULTS FROM REGRESSION ANALYSIS

Study	Regression Equation	R^2	SEE
June	Y = 0.873X + 6.22	0.99	6.38
September	Y = 0.885X - 1.27	0.99	6.48

Note :
1. Y = Left wheelpath IRI of N. Central unit, X = Left wheelpath IRI of Southern unit
2. R^2 - Coefficient of determination
3. SEE = Standard error of estimate

It should be noted that eight data sets were used for the equation developed from the June study, while only five data sets were available for the equation developed from the September study. A regression equation of the above form developed by a comparison study between the Southern unit and a profilometer from any of the other three regions can be used to correct the IRI's of the left wheelpath obtained from the Southern unit.