DEPRESSED TRANSVERSE CRACKS IN ASPHALT PAVEMENTS IN OKLAHOMA: PHASE I

INTERIM REPORT

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16. ABSTRACT

This report describes the results of a preliminary evaluation of the nature and extent of depressed transversed cracking of asphalt pavements in Oklahoma. The primary purpose of the Phase I study was to develop and evaluate procedures for collecting field data on a larger scale in Phase II. Four sites were selected using input from Division Maintenance Engineers for detailed evaluation. Data such as crack occurrence and distribution, crack cross section, pavement cross section, general topography, general soils were collected and evaluated. The results of the Phase I evaluation indicate that:

1. Transverse cracking of asphalt pavements is a prevalent problem in North Central Oklahoma.

2. The depressions associated with transverse cracks occur because of a combination of factors, including, at a minimum; the type of subgrade, the stiffness of the asphalt, and the size and number of vehicles.

3. The field procedures used to collect test section data, although time consuming, worked very well.

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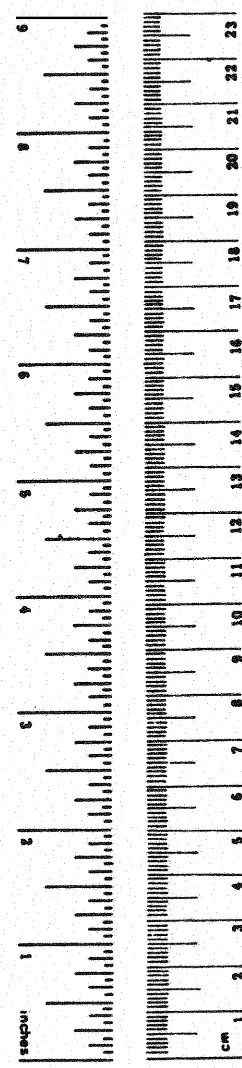
METRIC (SI*) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
	LENGTH			
in	inches	2.54	millimetres	mm
ft	feet	0.3048	metres	m
yd	yards	0.914	metres	m
mi	miles	1.61	kilometres	km
	AREA			
in^2	square inches	645.2	millimetres squared	mm^2
ft^2	square feet	0.0929	metres squared	m^2
yd^2	square yards	0.836	metres squared	m^2
mi^2	square miles	2.59	kilometres squared	km^2
ac	acres	0.395	hectares	ha
	MASS (weight)			
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
	VOLUME			
fl oz	fluid ounces	29.57	millilitres	mL
gal	gallons	3.785	litres	L
ft^3	cubic feet	0.0328	metres cubed	m^3
yd^3	cubic yards	0.0765	metres cubed	m^3

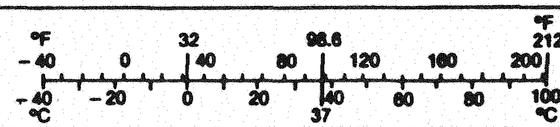
NOTE: Volumes greater than 1000 L shall be shown in m^3.

Symbol	When You Know	Multiply By	To Find	Symbol
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C



APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
	LENGTH			
mm	millimetres	0.039	inches	in
m	metres	3.28	feet	ft
m	metres	1.09	yards	yd
km	kilometres	0.621	miles	mi
	AREA			
mm^2	millimetres squared	0.0016	square inches	in^2
m^2	metres squared	10.764	square feet	ft^2
km^2	kilometres squared	0.39	square miles	mi^2
ha	hectores (10 000 m^2)	2.53	acres	ac
	MASS (weight)			
g	grams	0.0353	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams (1 000 kg)	1.103	short tons	T
	VOLUME			
mL	millilitres	0.034	fluid ounces	fl oz
L	litres	0.264	gallons	gal
m^3	metres cubed	35.315	cubic feet	ft^3
m^3	metres cubed	1.308	cubic yards	yd^3
	TEMPERATURE (exact)			
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



These factors conform to the requirement of FHWA Order 5190.1A.

* SI is the symbol for the International System of Measurements

EXECUTIVE SUMMARY

Because of the diverse climatic conditions in Oklahoma, asphalt pavements are exposed to temperature-induced tensile stress extremes which result in transverse cracking of the pavement structure. The transverse cracks are usually spaced at regular intervals that range from a few feet to several hundred feet, depending on the age of the pavement and the rheological properties of the asphalt mixtures. Other factors such as pavement design and construction methods, materials' characteristics, traffic conditions, and maintenance practices have a less-than-fully-understood influence on the occurrence and distribution of these cracks.

Initially, transverse cracks are not particularly harmful to the pavement, but poor riding quality can result as the cracks become progressively wider and deeper. Open cracks permit surface water to enter the crack as well as other detritus. The water can soften the base and/or subgrade as well as cause stripping of the asphalt-bound materials. When the base and subgrade materials soften, compression of these materials occurs and a depression is formed along the crack which further adversely affects ride quality and the pavement integrity.

The purpose of the research was to assess the influence of the design, construction, materials, maintenance, and climate factors on the occurrence and distribution of depressed transversed cracks in asphalt pavement. This report summarizes the results of Phase I of the research program which involved a review of current literature on the subject of transverse cracking and the development and evaluation of field procedures to collect the pertinent data necessary to evaluate the influence of the above factors.

The results of Phase I confirm the description of the mechanism of transverse cracking (i.e., temperature-induced tensile stresses), but revealed minimal information on the influence of the various factors. Based on the sites evaluated in Phase I, depressed transverse cracking is a prevalent problem in north central Oklahoma. The extent of the problem in other portions of the state will be addressed in Phase II. A set of field procedures, although time-consuming, were developed that work very well for collection of the pertinent data.

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INTRODUCTION

Background

The performance of flexible pavements depends on a variety of design, construction, materials, traffic, maintenance, and climatic factors. Because of its diverse climatic conditions, Oklahoma flexible pavements are exposed to temperature-induced stress extremes which can result in transverse cracking of the pavement structure.

Transverse cracking of flexible pavements is an extensive and costly type of pavement distress in all states that experience relatively cold temperatures during the winter months. These cracks are caused by low-temperature induced tensile stresses that exceed the tensile strength of the pavement materials and result in cracks or fractures. Due to the geometric configuration of the pavement, the principal axis of thermal contraction is in the longitudinal direction and a major portion of these thermal or low-temperature cracks occur transversely.

These transverse pavement cracks are usually spaced at regular intervals that range from a few feet to several hundred feet, depending primarily on the age of the pavement and the rheological properties of the asphalt mixtures. In some cases, these cracks are limited in depth, but others may penetrate through the total pavement structure. Cyclic temperature changes over a period of several years result in a gradual increase in both width and depth of crack opening.

Initially, these cracks are not particularly harmful to the pavement, but poor riding qualities can result as these cracks become progressively wider and deeper. Open cracks permit the ingress of substantial quantities of surface water as well as other detritus. Water, of course, can cause stripping in the asphalt-bound materials as well as softening of the base and/or subgrade. In extreme cases, depressions occur at these cracks due to subgrade softening, the application of heavy axle loads, and possibly pumping of fine materials. Secondary cracks, more or less parallel and on both sides of the primary transverse crack, may occur along with faulting of the intermediate sections of pavement.

Objectives of the Research

It is obvious that this type of progressive pavement distress can drastically reduce the serviceability of a highway and soon become a serious safety hazard for the users. Solutions to the problem are undoubtedly related to the characteristics of the subgrade soil and the paving materials employed, the design of the flexible pavement structure, and the maintenance practices used. From the development of these relationships it should be possible to suggest remedial measures to eliminate or at least mitigate the problems associated with depressed transverse cracks. It is to this end that the major objectives of this research program are directed:

1. Determine the nature and extent or severity of depressed transverse cracking of flexible pavements throughout the Oklahoma highway system;
2. Conduct both field and laboratory investigations of the paving materials and subgrade soils to characterize depression cracks at selected sites and ascertain unique and/or common elements that contribute to the occurrence and distribution of this type of distress;
3. Review Oklahoma Department of Transportation (ODOT) practices and procedures pertaining to structural pavement design, design of surface paving mixtures, construction, and roadway maintenance to establish any correlations with the development of depression cracking in flexible pavements;
4. Based on the results of this study and evaluation, make implementable recommendations, where warranted, regarding
   (a) revisions in paving materials and construction specifications
   (b) structural and mix design procedures

(c) maintenance practices for routine crack sealing

(d) remedial measures used on depression cracks prior to overlaying operations.

CRACKING OF ASPHALT PAVEMENTS
-LITERATURE PRECEDENT

The non-load associated transverse cracking of asphalt pavements is a serious problem which reduces ride quality and shortens the pavements service life. Low-temperature shrinkage cracking of asphalt pavements and the associated reduction in service was first noted in the 1930's, but because of low paved miles combined with small traffic volumes and lighter loads the problems were not as serious. With the authorization and initial construction of the interstate highway system, the problem became more acute by the 1960's, particularly in the northern states. During the past 25 years a great deal of research has been conducted in an effort to find a practical solution to minimize the cracking problem in new pavements and to reduce the harmful effects and restore serviceability in existing pavements (1,2,3,4,5,6,7,8,9,10,11,12,13). These studies concluded that the transverse cracking problem was caused by thermal stresses induced by temperature changes, primarily in the low-temperature range. One of the more significant variables influencing cracking was found to be the consistency characteristics of the surface layer asphalt. In addition, pavement thickness, pavement age, and subgrade type were shown to be significant.

Haas (8) summarized the factors of possible significance in low-temperature cracking of asphalt pavements and categorized them into external and component factors, as shown in Figure 1. These factors do not act independently but are interrelated. For instance, the combination of traffic loads and decreased temperature could create sufficient stress to cause cracking at various stages depending on the magnitudes of load and temperature.

Laboratory investigations conducted on asphalt cement have shown that they lose some of their elasticity at low temperatures and behave essentially in a plastic manner. At the same time, the asphalt layer tends to contract but is partially or wholly restrained. This combination induces tensile stresses in the pavement material. The

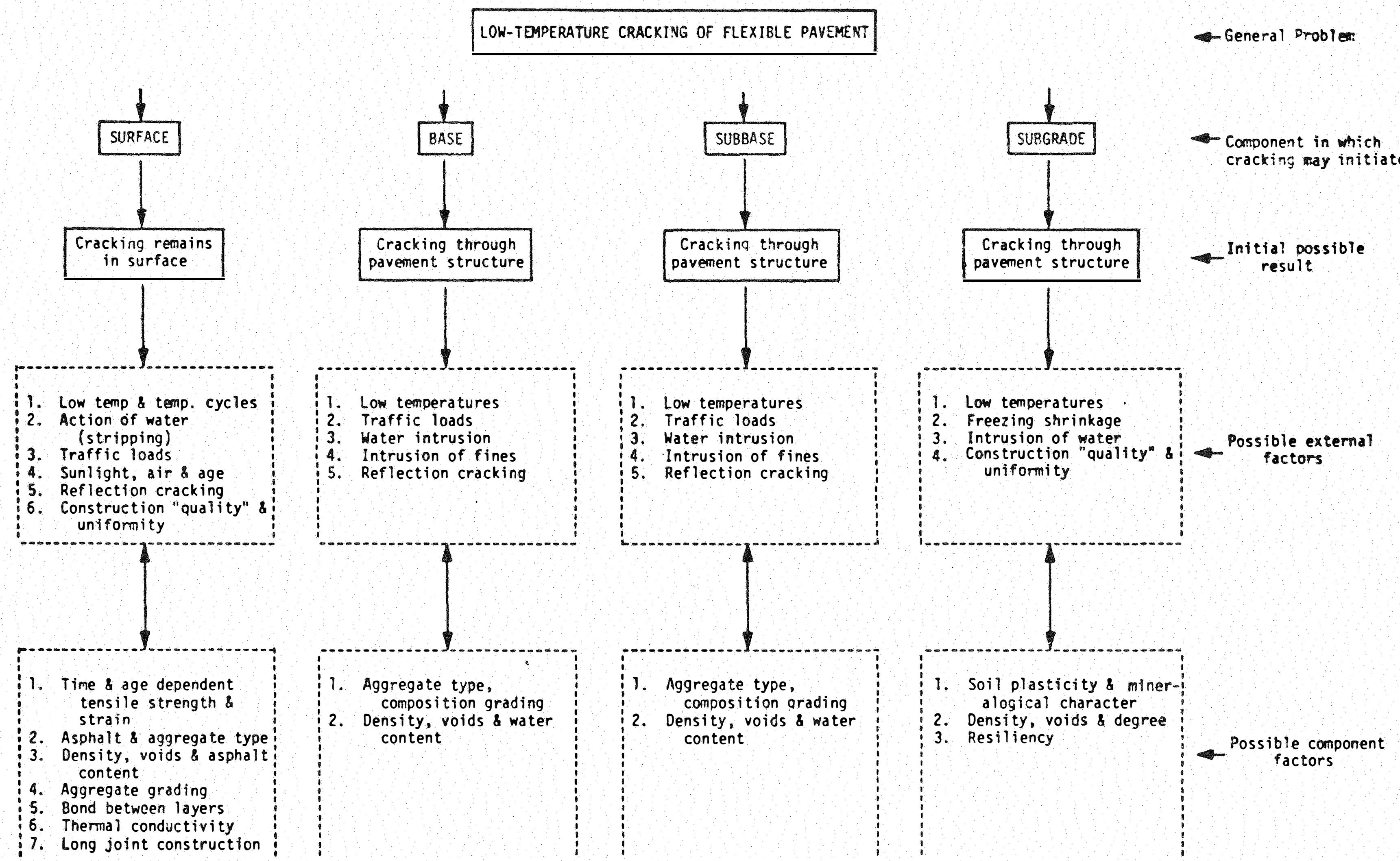


Figure 1. Factors of Possible Significance in Low-Temperature Cracking of Flexible Pavements (8)

appearance of transverse cracks during rapid warming, following a prolonged cold period, indicated to some that fracture was being initiated during and as a result of this warming. However, actual field records indicated that fracture occurred when pavement surface temperatures reached a minimum (14,15,16,17,18). Instrumentation revealed that most transverse cracks started at the surface, but initially progressed to only a limited depth.

The previous findings partially substantiated the fracture mechanism hypothesis of Haas and Topper (19). This cracking hypothesis essentially postulated a two-stage phenomenon. At the first stage, a microcrack initiates at the surface of the asphalt layer when the induced thermal stresses exceed the tensile strength due to decreasing temperatures and this crack propagates only to some limited depth. At the second stage, the crack propagates to the full depth of the surface layer after one or more cycles of rapid warming. Because of pavement geometrics, the principal axis of contraction is in the longitudinal direction and, hence, the majority of these cracks are to be expected in the transverse direction.

Field investigations devoted to this problem can be divided into two broad approaches. The first was mainly oriented toward surveying, sampling, and testing the existing cracked pavements in order to document the extent of the problem and attempt to correlate certain factors with the frequency of cracking (4,8). The second approach was primarily concerned with studying the effect of different materials and structural variables on the actual field performance of full-scale pavement sections (16,18). Field testing programs included mapping the different cracking patterns and coring and sampling of base and subgrade materials. Cracking frequency diagrams were prepared to help in selecting specific areas for further detailed examination. This cracking survey also included the number of part, half, full and multiple transverse cracks occurring in each 500 ft interval of the pavement. Figure 2 represents a diagrammatic illustration of the four categories of cracks.

To develop a measure of cracking severity, a Cracking Index (CI) was developed

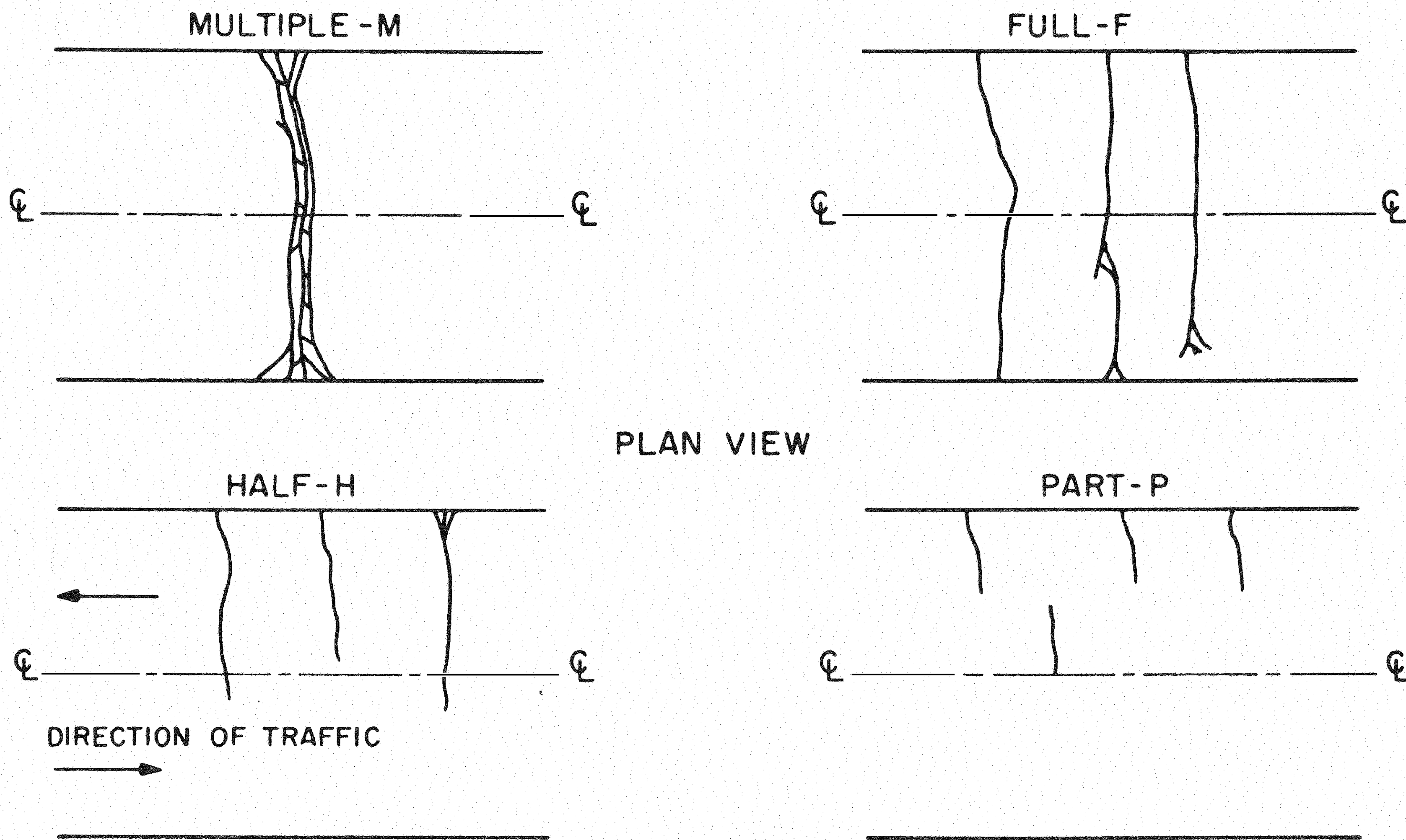


Figure 2. Different Types of Transverse Cracks (11)

(11) and is defined in the following equation:

$$C.I. = N_m + N_f + \tfrac{1}{2}N_h \tag{1}$$

where

C.I. = Cracking Index.

$$\left.\begin{aligned} N_m &= \text{number of multiple cracks} \\ N_f &= \text{number of full cracks} \\ N_h &= \text{number of half cracks} \end{aligned}\right\} \text{ per 500 ft of two-lane pavement}$$

It was felt that smaller transverse cracks usually occur subsequent to the formation of half or full cracks and, therefore, these smaller cracks were disregarded in the calculation of the Cracking Index (11).

Some field studies indicated that variables such as asphalt type, grade and source, as well as age and thickness of pavement, showed a significant correlation with the degree of cracking of pavement sections (2). Consequently, several full-scale experimental sections were constructed in various areas, particularly in Canada, to evaluate the effect of these variables, including asphalt type and grade (17,18,21,22). Air and subsurface temperatures were continuously recorded at these sections. Periodic crack surveys were made to detect crack initiation and to closely follow the propagation and development of these cracks. In addition, the structural capacity of these experimental sections was evaluated by field test procedures (14,15,16,17). The analysis of the performance data on these sections showed a significant correlation between the asphalt source, type and grade, and the observed degree of cracking. However, it was emphasized that low-temperature cracking appeared to be a complex phenomenon with many factors involved and that other variables could be highly important in certain situations (8).

In a detailed study of transverse cracking in Oklahoma asphalt pavement, Noureldin and Manke (23,24) investigated the nature and extent of transverse cracking with primary emphasis on the bituminous components of the pavement. The study combined field observations with a laboratory testing program centered around the tensile properties of the asphalt concrete. The major conclusions derived from the study:

1. Examination of recently developed transverse cracks revealed that, in most cases, the cracks had originated at the pavement surface. Thus, the major cause of these cracks appears to be the cold-temperature contraction of the asphalt concrete surface layer.
2. Temperature had a highly significant effect on the measured tensile properties of the paving mixtures. As temperature decreased, tensile strengths and failure stiffness remarkably increased and tensile strains at failure decreased. This is primarily a result of the increase in stiffness of the asphalt binder.
3. A satisfactory correlation was found between the results of the tensile-splitting tests and the observed degree of cracking. The occurrence of transverse cracking was found to increase as failure strain decreased and failure stiffness increased.
4. A permissible or standard failure strain can be established for a pavement mixture in a given geographic region. Such a value could be used in future mix design procedures in which asphalt viscosity, asphalt content, and aggregate gradation are modified to meet design criteria for failure strain.
5. The stiffness moduli of recovered asphalts, determined at the expected minimum temperature in central Oklahoma, were significantly correlated with the Cracking Indexes of the pavement test sites. The stiffer or harder the asphalt cement in a pavement was, the greater was the degree of transverse cracking.

These conclusions further support the results of research programs conducted in the northern states that the major cause of transverse cracking in asphalt pavements is temperature induced tensile stresses, even in a location without long-duration, extremely cold temperatures.

Although the previously discussed research has significantly increased the understanding of the mechanism of transverse cracking from an asphalt-materials point of view, limited effort has been expended on characterizing the depression problem. It is likely that the extensive loss of ride quality caused by the depressions is related to the properties of the subgrade, which has been treated as an important but secondary contribution to the overall problem.

Equally disturbing is the emphasis on design alternatives for asphalt pavements (25) with minimal effort directed toward remedial options for in-service pavements. Essentially, the options available for post-construction treatment include:

1. fog seals
2. crack filling
3. crack repair, including routing and milling
4. patching, including milling and use of synthetics

All options are obviously expensive and labor intensive and have exhibited varying degrees of success in improving serviceability.

FIELD EVALUATION METHODS FOR DEPRESSED TRANSVERSE CRACKS

In the original proposal, the combined field and laboratory investigation of depressed transverse cracks involved collection of a large amount of data from 20 to 40 sites around the state. There were some concerns over site selection criteria, specifically, how would the sites be characterized in order to objectively select the final group of sites for sampling. In order to minimize potential problems with site selection, with particular emphasis on characterization criteria, the research study was split into two phases. Phase I, which is the subject of this report, included a detailed literature review on the general topic of transverse cracking and the characterization of two to four sites to develop the criteria for final site selection. Phase II will include selection of 20 to 40 sites that will be characterized using procedures developed in Phase I plus a field sampling and laboratory testing program.

The field investigation procedures used in Phase I at a total of four sites included:

1. A walk-over survey of a selected section of roadway exhibiting both depressed and non-depressed transverse cracks. In addition, cross-section features (i.e., cut, fill, transition) were noted along the secton. Typically the section was a minimum of 3 miles in length. The location of all transverse cracks with an indication of being depressed or non-depressed was noted relative to an initial reference point. The location of all the transverse cracks was plotted on plan and profile sheets. From these plots, a 1000-ft section was selected for a second visit. The basis for selection was the occurrence and distribution of depressed and non-depressed cracks, pavement cross-section features and safe site distance.

2. During the second site visit, the exact location of each transverse crack was noted and sketched relative to the beginning of the 1000-ft length. The Crack

Index was defined for the section on a basis of 500-ft lengths. Two depressed and one non-depressed transverse cracks were selected for detailed study. The depth and width of the transverse cracks and the depth and typical cross section of depressions were measured at seven locations across the pavement representing the wheel paths, non-wheel paths, and the shoulders, see Figure 3. A photographic record was made of these cracks at each observtion point as well as the overall section. General drainage and topographic conditions were noted along with a general assessment of the pavement surface condition. The pavement cross section was surveyed at each of the depressed cracks selected for detailed study. Shallow grab-samples of the subgrade material were collected in the shoulder near each of the cracks.

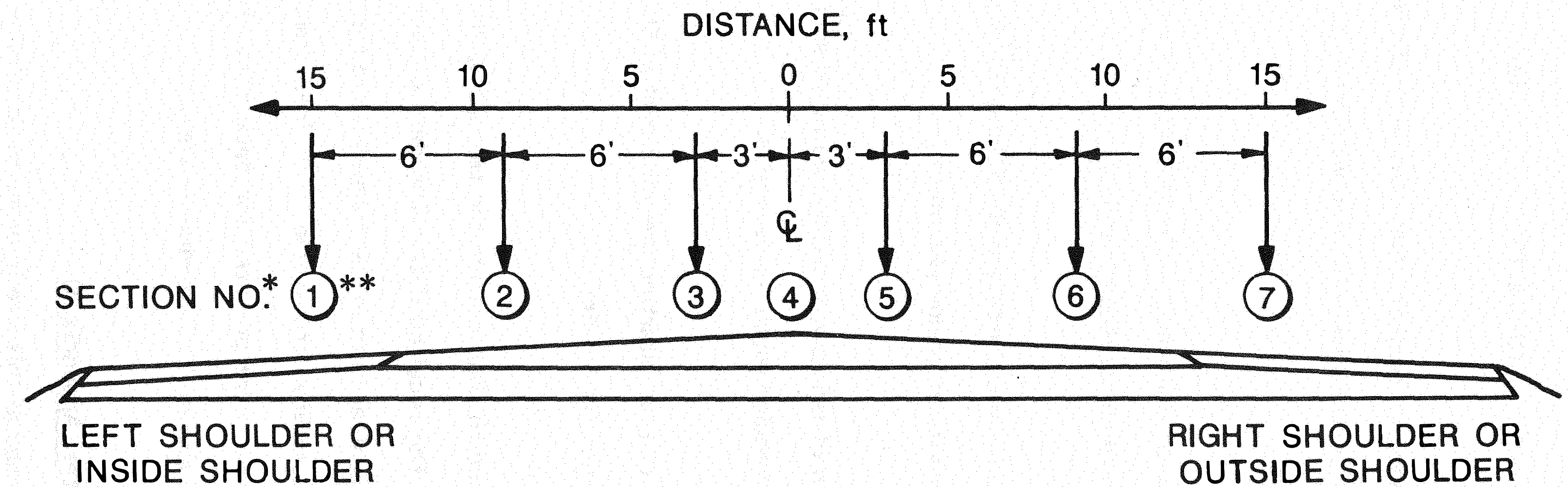
3. Additional information collected for the sites, where available, included design cross section and maintenance history, traffic volumes, PSI, and climatic conditions.

All the data collected during the two site visits were appropriately plotted for evaluation.

Phase II of the project will extend the procedures developed in Phase I to a larger number of sites across the state. In addition, samples of the pavement and subgrade materials will be collected adjacent to two selected cracks and at a location away from the transverse cracks. A detailed laboratory investigation is planned to establish a "data-bank" characterizing each site. These data will be used to establish correlations between it and the occurrence and distribution of depressed (or non-depressed) transverse cracks in asphalt pavements.

ODOT - Depressed Transverse Cracking in Asphalt Pavements Project

Location of Sections for Transverse Crack/Depression Surveys



* Section numbers assigned from left to right looking west or north

**Section No. 1 located 13 ft from centerline for pavements with reduced inside (median) shoulder width

Figure 3. Location of Sections for Transverse Crack/Depression Surveys.

RESULTS

During Phase I of the research project, four sites were characterized for inclusion in Phase II. The 1000-ft test sections were located within the surveyed sections at the following locations:

Site 1. On SH 51 west of Stillwater in westbound lanes between Country Club Road and Camp Redlands Road (3 miles)

Site 2. On SH 51 east of Yale, starting at SH 51 and SH 99 junction and extending east to Cimarron River bridge (3.6 miles).

Site 3. On SH 48 north of Bristow, starting two miles south of SH 33 and SH 48 junction and extending south for 3.5 miles.

Site 4. On US 64 east of Enid, starting one mile east of SH 74 and US 64 junction and extending east for 5 miles.

The field procedures used to characterize the test sites, although time consuming, were successful in obtaining the required data. The data collected at the four sites is presented in summary and graphical form in the appendices to this report; specifically, a data summary sheet, crack survey, transverse crack/depression cross sections, and surface elevation cross sections were prepared for each site. The results of the field surveys are discussed by field site in the following paragraphs.

Site 1, SH 51 West of Stillwater (Appendix A)

A 1500-ft section was used at this site in order to determine the appropriate length to balance obtaining the necessary data with minimizing traffic-controlled work time.

The length of the remaining sections was reduced to 1000 ft. For site 1, the Crack Index varied from 2 for the western third of the section to 5 for the middle third. The crack spacing was relatively uniform in the eastern third, but erratic in the remaining two-thirds. The highway cross section varied from cut to fill from east to west with the eastern third predominantly on cut, the middle third on transition from cut to fill and the western third on fill. There were more depressed, transverse cracks in the eastern third (4 of 5) than in the other portions of the test section (2 of 6). The subgrade consisted of sandstone material, which was excavated from the cut sections and used as a fine aggregate base course beneath the asphalt concrete surface. It is not clear whether the increased occurrence of depressed transverse cracks is due to the fact that they occur in a cut section (i.e., subgrade with greater stiffness) or some other combination of factors. The two depressed transverse cracks surveyed (Nos. 2 and 11) both exhibited wider depressions at sections 5 and 6 which corresponds to the wheel paths for the outside lane and supports the influence of traffic on the extent of the depressed behavior. Since completing the detailed survey, SH 51 west of Stillwater has been resurfaced using a latex modified emulsion micro surface. All transverse cracks were individually sealed, then the entire pavement surface was sealed with the slurry.

Site 2, SH 51 East of Yale (Appendix B)

The Crack Index was 6.5 and 7 for the two 500-ft lengths comprising the overall test section. Depressed transverse cracks outnumbered non-depressed cracks by a 10 to 3 margin. The distribution of cracks was relatively uniform over the entire section, even though the cross section varied from fill to cut to fill. Wider depressions were again noted at the sections representing wheel paths. The depth of the depressions was relatively uniform across the pavement.

Site 3, SH 48 North of Bristow (Appendix C)

The Crack Index was 6.5 and 8 for the two 500-ft lengths of the test section.

Depressed transverse cracks outnumbered non-depressed cracks by an 8 to 3 margin. The distribution of cracks was relatively uniform over the entire section. Depressed cracks were more prevalent in the northern portion of the test section in a cut section. A larger number of half-way cracks (7) was noted at this section. In addition, a number of the cracks exhibited offsets at the centerline, which could be the result of a poor longitudinal construction joint. Crack openings for the depressed cracks surveyed were considerably wider at this test section as compared to the other sections.

Site 4, US 64 East of Enid (Appendix D)

The Crack Index was 8.5 and 8 for the two 500-ft lengths of the test section. Depressed transverse cracks outnumbered non-depressed cracks by a 10 to 5 margin. The distribution of the cracks was uniform over the length of test section. Depressed cracks were more prevalent in the eastern portion of the test section which was in a cut section. The width and depth of the depressions were again larger for the wheel path sections.

CONCLUSIONS

Evaluation of the procedures used to obtain the field data and the results of the collected data yielded the following conclusions:

1. Transverse cracking of asphalt pavements is a prevalent problem in the north central portion of Oklahoma. The extent of the problem in other portions of the state will be addressed in Phase II.

2. Transverse cracking of asphalt pavements is primarily caused by temperature-induced stresses, particularly at the low temperature range. The extent to which cracking influences ride quality is primarily affected by maintenance procedures used after the crack has developed and extended through the pavement structure. The depressions associated with transverse cracks occur because of a combination of factors, including, at a minimum: the type of subgrade, the stiffness of the asphalt concrete, and the size and number of vehicles.

3. The field procedures used to collect the test section data, although time consuming, worked very well. During Phase II, additional input from the ODOT Division Offices will be extremely helpful in the site selection process.

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24. Noureldin, M. S., and P. G. Manke. "Study of Transverse Cracking in Flexible Highway Pavements in Oklahoma," Transportation Research Record 695, Transportation Research Board, Washington, D. C., 1978, pp. 28-33.

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APPENDIX A

SCHOOL OF CIVIL ENGINEERING

OKLAHOMA STATE UNIVERSITY

ODOT-DEPRESSED TRANSVERSE CRACKING IN ASPHALT PAVEMENTS PROJECT

TEST SECTION DATA SUMMARY SHEET

LOCATION DATA:

Test Section No. 1 Highway SH 51 County Payne

Control Section No. 51-60-18 Project No. F-198 (45)

Date-Preliminary Survey 5/24/88 Detailed Survey 6/29/88 Sampling ____

Location of Test Section:
Test section located ≈ 3.25 miles west of SH 51 and Western Road intersection between Stations 752 ± 50 (east end) & 737 + 50(west end) in westbound lanes.

PAVEMENT/DESIGN DATA:

Number of Lanes 4 Lane - Divided Date Constructed August, 1975

Pavement: Description 4 1/2 in AC on 8 in Fine Aggregate Base

Width 24 ft Thickness 12 1/2 in @ centerline ____ @ edge

Shoulders: Description ____

Width 10 ft -"0", 3 ft "i" ("o"-outside, "i"-inside, "b"-both)

Thickness ____ @ pavement ____ @ edge

Subgrade: Description Tan and reddish brown sandstone

Original Design/Maintenance History:

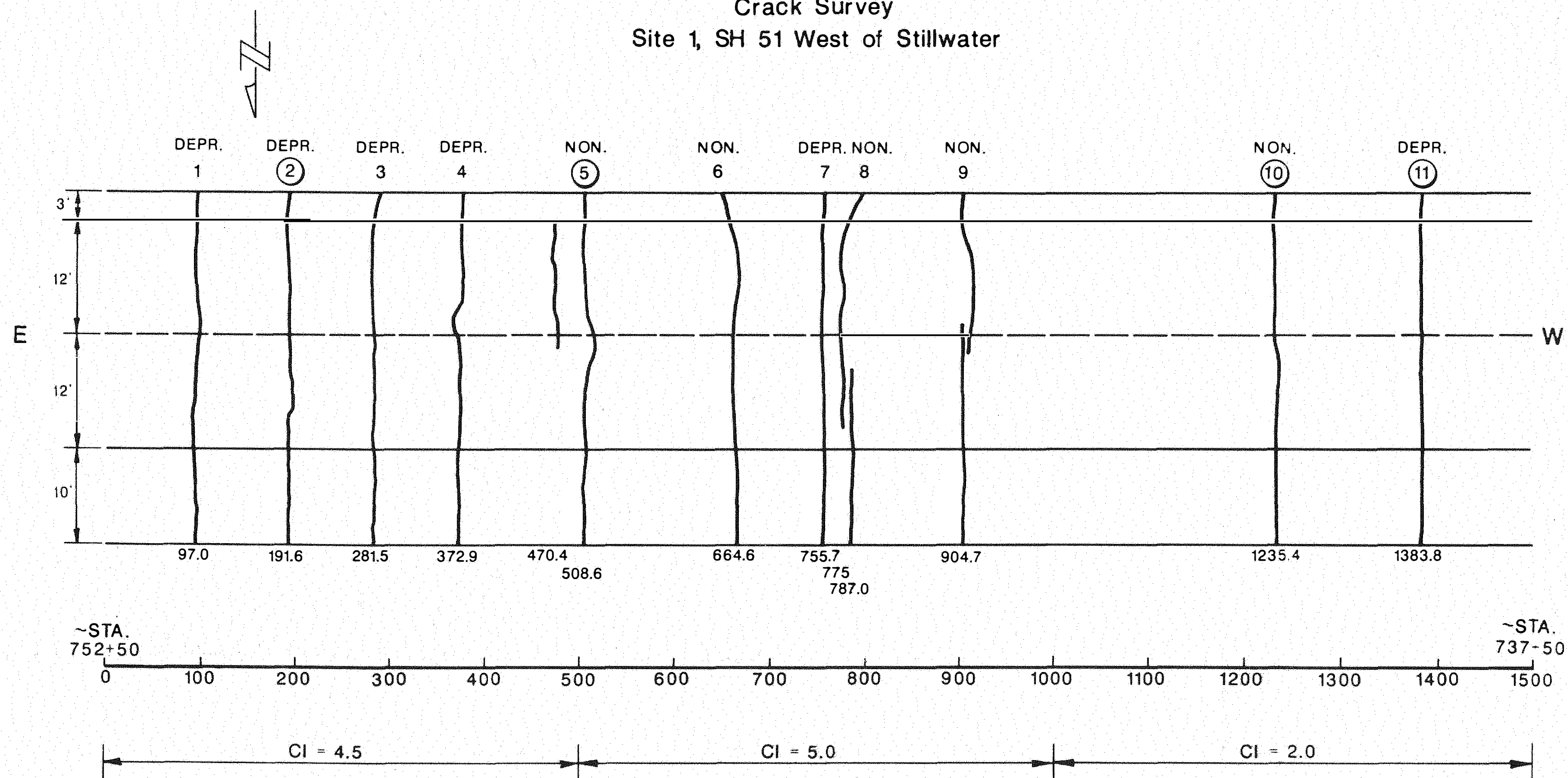
Traffic ____ vpd Heavy Truck Traffic ____ PSI ____

Terrain Upland-rolling Drainage Good- from east to west

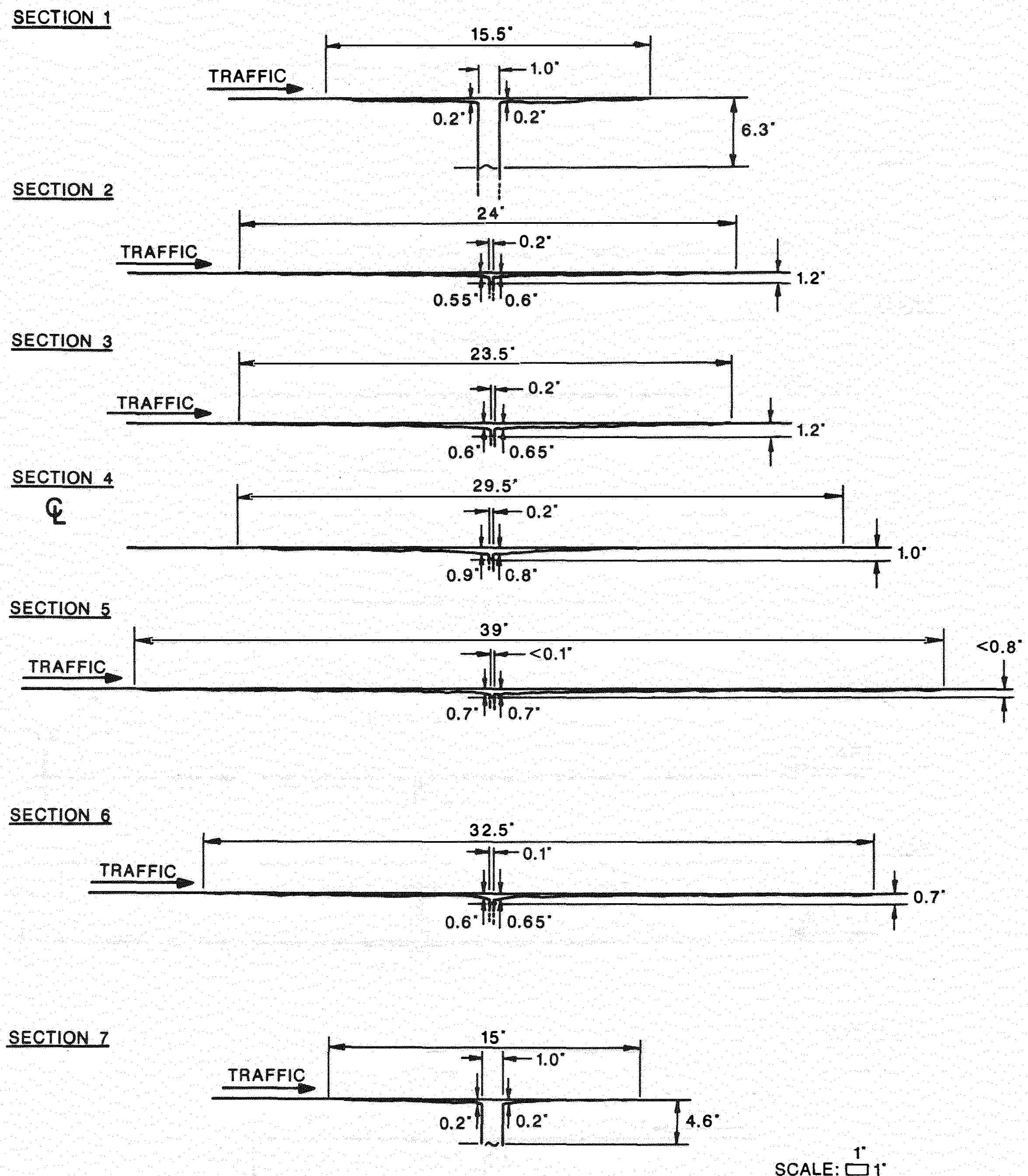
Climate ____

FIELD OBSERVATIONS:

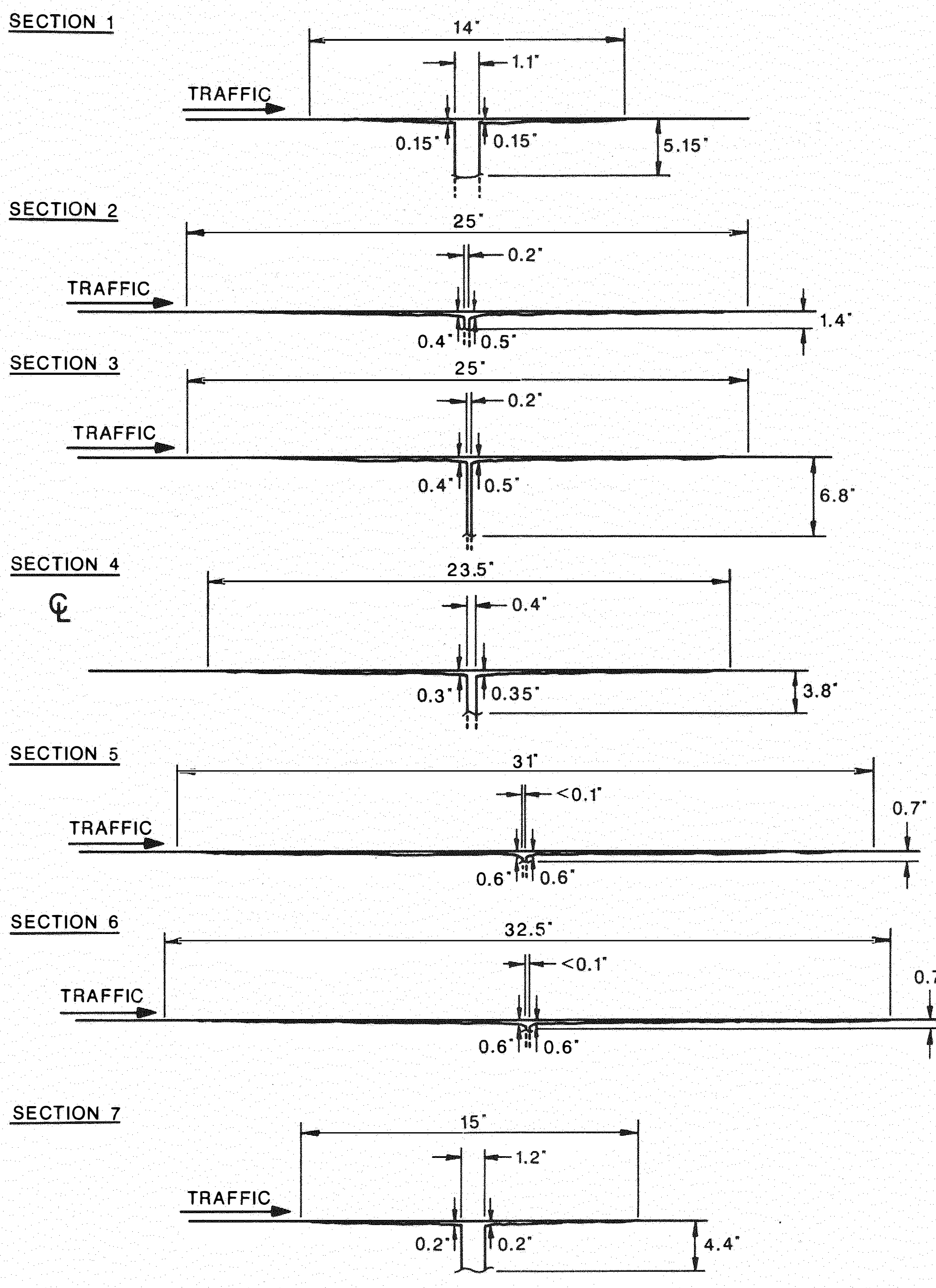
ODOT - Depressed Transverse Cracking in Asphalt Pavements Project
Crack Survey
Site 1, SH 51 West of Stillwater



ODOT - Depressed Transverse Cracking in Asphalt Pavements Project
Transverse Crack/Depression Cross Sections
Site 1, SH 51 West of Stillwater
Crack No. 2

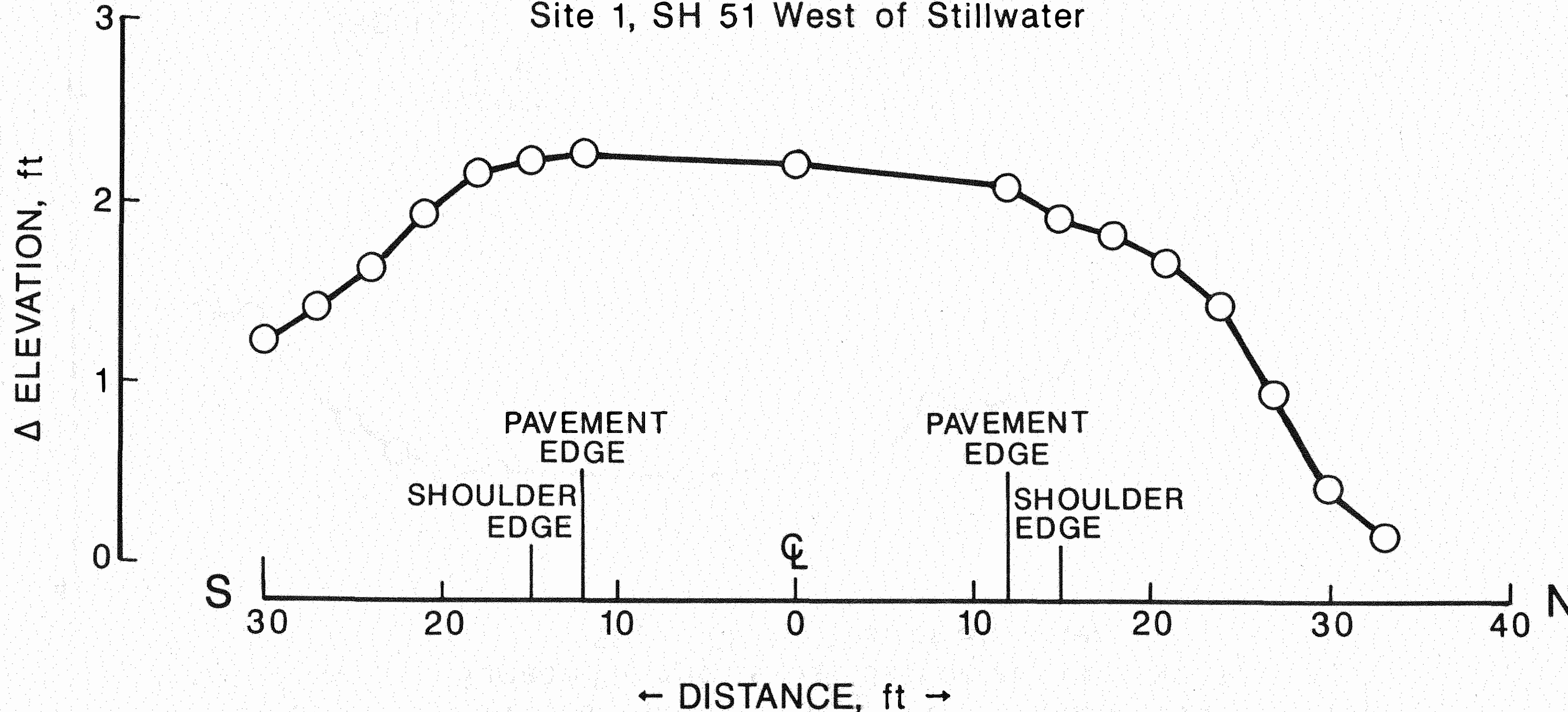


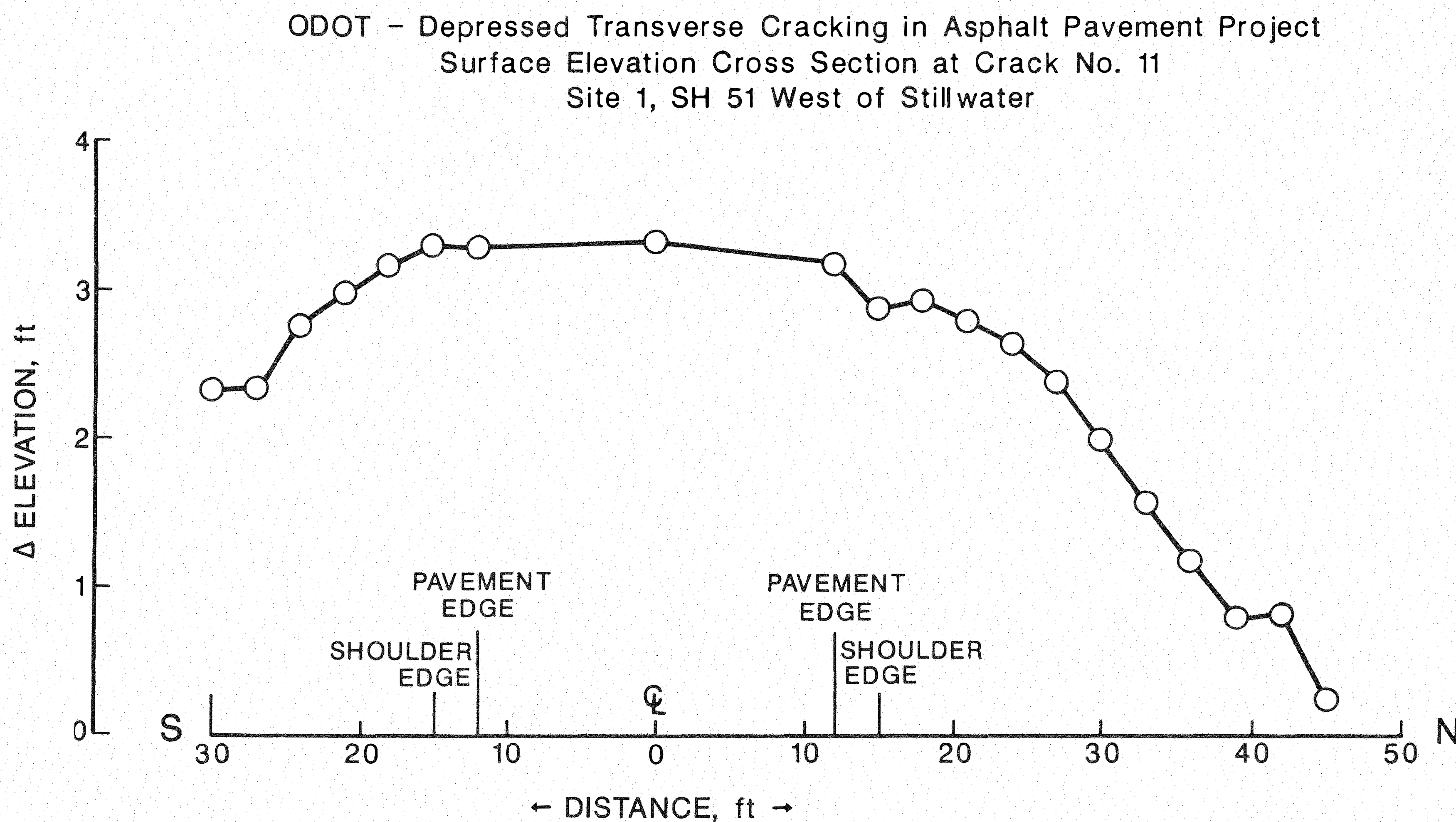
ODOT – Depressed Transverse Cracking in Asphalt Pavements Project
Transverse Crack/Depression Cross Sections
Site 1, SH 51 West of Stillwater
Crack No. 11



SCALE: 1" × 1"

ODOT – Depressed Transverse Cracking in Asphalt Pavements Project
Surface Elevation Cross Section at Crack No. 2
Site 1, SH 51 West of Stillwater




ODOT - Depressed Transverse Cracking in Asphalt Pavement Project
Surface Elevation Cross Section at Crack No. 11
Site 1, SH 51 West of Stillwater
Δ ELEVATION, ft
4
3
2
1
0
PAVEMENT EDGE
SHOULDER EDGE
PAVEMENT EDGE
SHOULDER EDGE
℄
S
N
30
20
10
0
10
20
30
40
50
← DISTANCE, ft →

APPENDIX B

SCHOOL OF CIVIL ENGINEERING

OKLAHOMA STATE UNIVERSITY

ODOT-DEPRESSED TRANSVERSE CRACKING IN ASPHALT PAVEMENTS PROJECT

TEST SECTION DATA SUMMARY SHEET

LOCATION DATA:

Test Section No. 2 Highway SH 51 County Creek

Control Section No. 51-19-38 Project No. F-127 (21)

Date-Preliminary Survey 5/25/88 Detailed Survey 7/13/88 Sampling _____

Location of Test Section:

Test Section located ≈ 1.1 miles east of SH 51 and SH 99 intersection between stations 1489 + 00 (west end) 1499 + 00 (east end).

PAVEMENT/DESIGN DATA:

Number of Lanes 2 Lane Date Constructed May, 1975

Pavement: Description 4 1/2 in AC on 8 in Fine Aggregate Base

Width 24 ft Thickness 12 1/2 in @ centerline _____ @ edge

Shoulders: Description _____

Width 10 ft - "b" ("o"-outside, "i"-inside, "b"-both)

Thickness _____ @ pavement _____ @ edge

Subgrade: Description Brown silty sand

Original Design/Maintenance History:

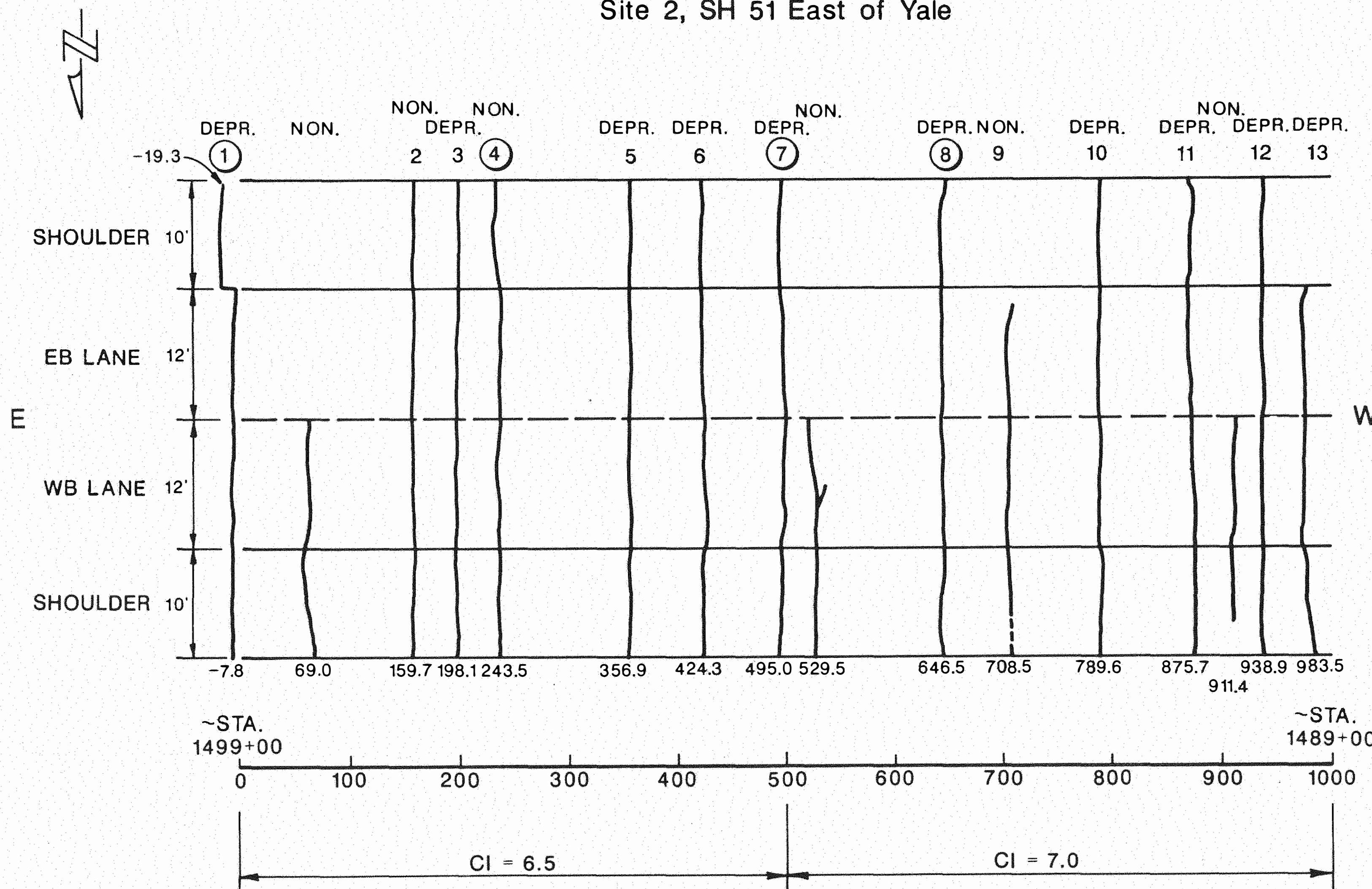
Traffic _____ vpd Heavy Truck Traffic _____ PSI _____

Terrain Upland - rolling Drainage Good - from east to west

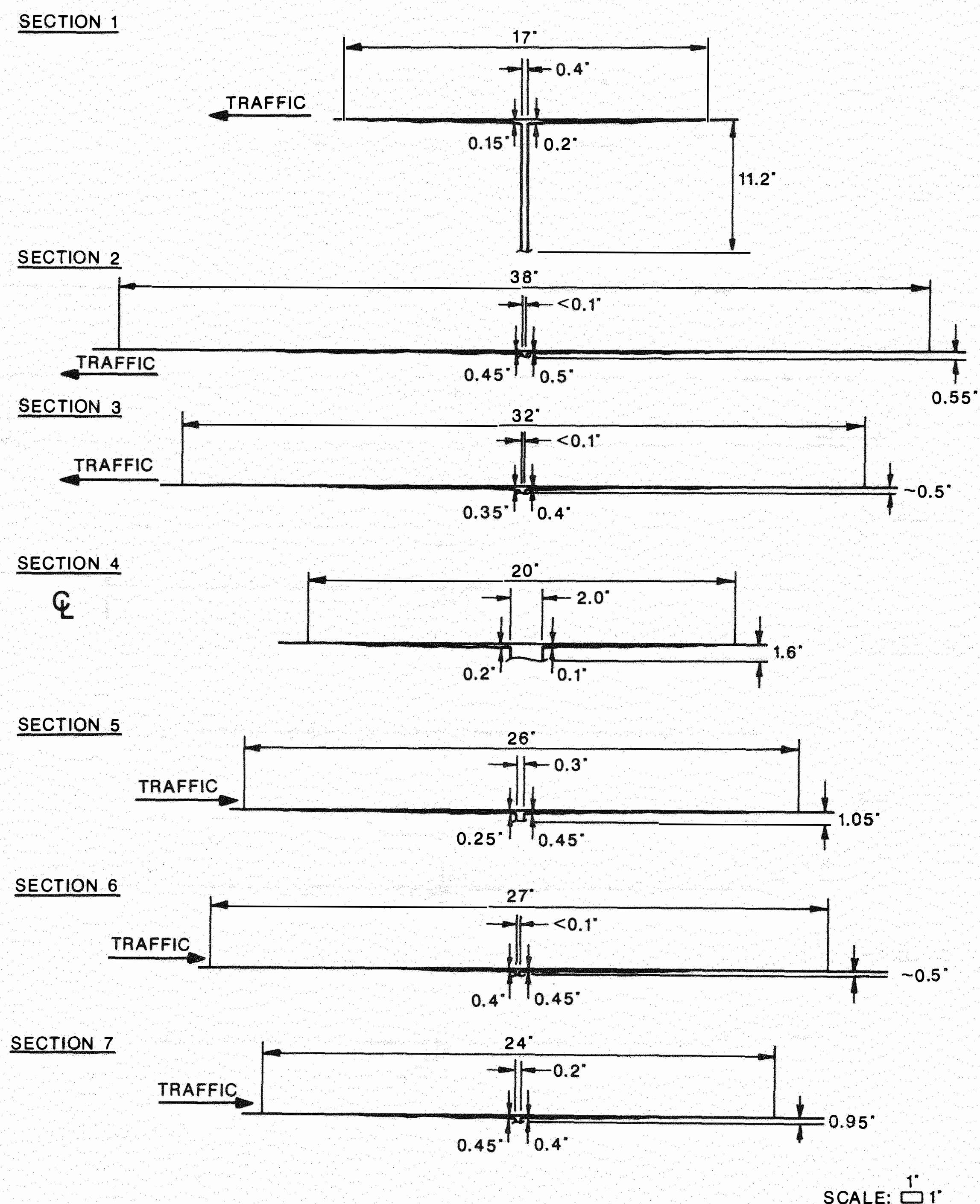
Climate _____

FIELD OBSERVATIONS:

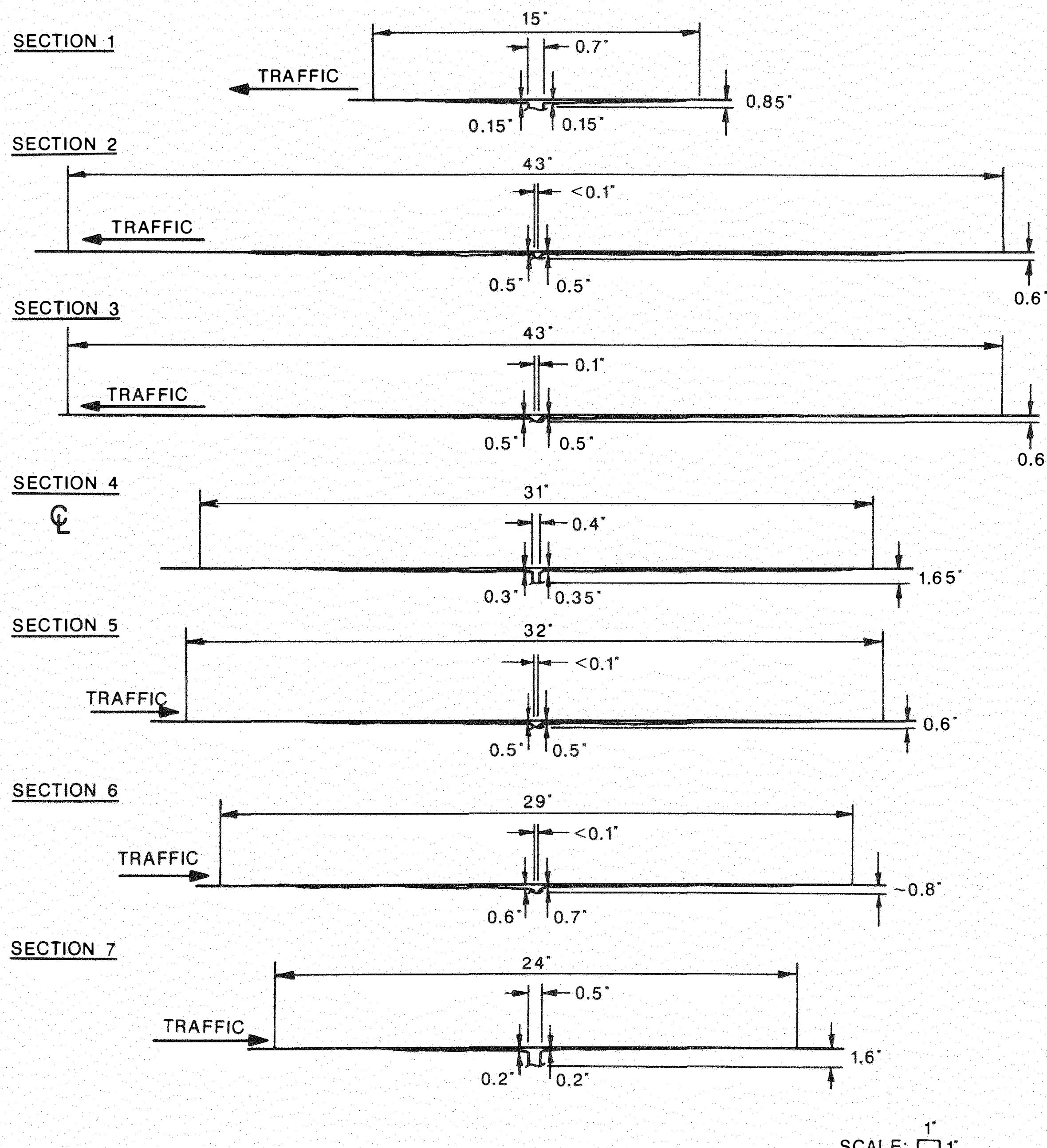
ODOT - Depressed Transverse Cracking in Asphalt Pavements Project
Crack Survey
Site 2, SH 51 East of Yale



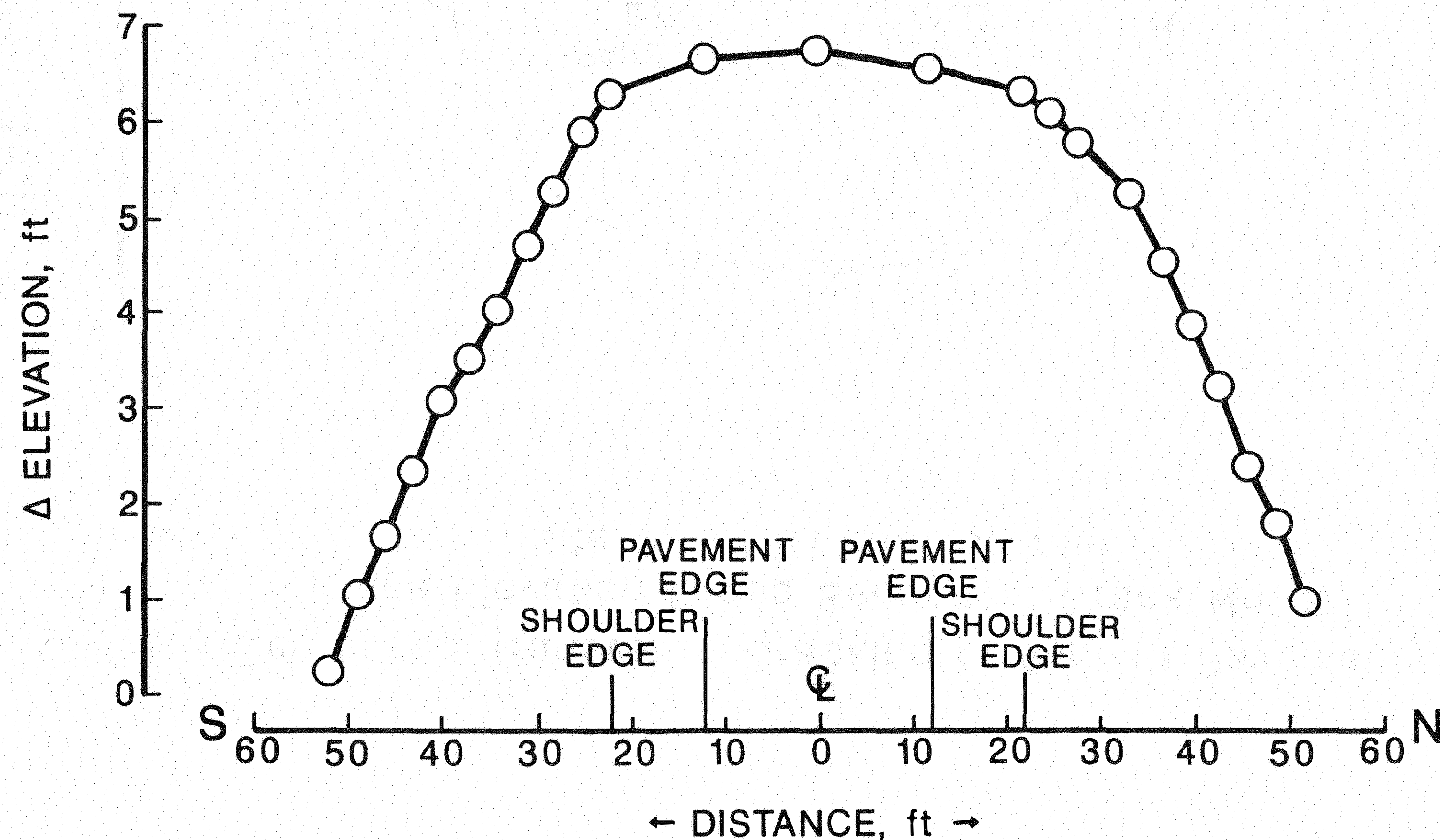
ODOT - Depressed Transverse Cracking in Asphalt Pavements Project
Transverse Crack/Depression Cross Sections
Site 2, SH 51 East of Yale
Crack No. 1



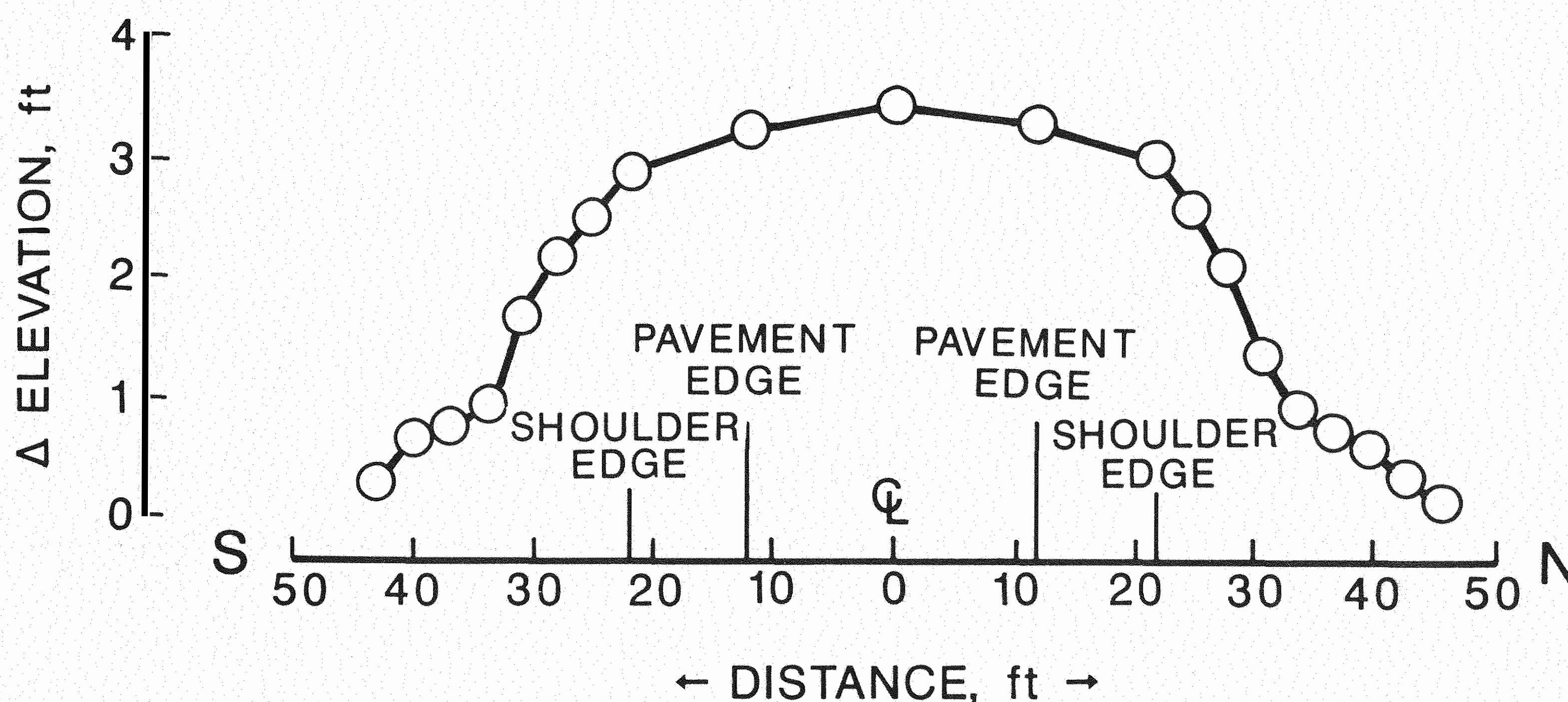
ODOT - Depressed Transverse Cracking in Asphalt Pavements Project
Transverse Crack/Depression Cross Sections
Site 2, SH 51 East of Yale
Crack No. 8



ODOT - Depressed Transverse Cracking in Asphalt Pavements Project
Surface Elevation Cross Section at Crack No. 1
Site 2, SH 51 East of Yale



ODOT - Depressed Transverse Cracking in Asphalt Pavements Project
Surface Elevation Cross Section at Crack No. 8
Site 2, SH 51 East of Yale



APPENDIX C

SCHOOL OF CIVIL ENGINEERING

OKLAHOMA STATE UNIVERSITY

ODOT-DEPRESSED TRANSVERSE CRACKING IN ASPHALT PAVEMENTS PROJECT

TEST SECTION DATA SUMMARY SHEET

LOCATION DATA:

Test Section No. 3 Highway SH 48 County Creek

Control Section No. 48-19-3 Project No. S-806(5)S & (6)S

Date-Preliminary Survey 5/25/88 Detailed Survey 7/12/88 Sampling ____

Location of Test Section:
Test section located ≈ 3.1 miles south of SH 48 and SH 33 intersection between stations 503+00 (north end) and 493 + 00 (south end).

PAVEMENT/DESIGN DATA:

Number of Lanes 2 Lane Date Constructed March 1968

Pavement: Description 2 in AC on 10 in Hot Sand Asphalt Base

Width 24 ft Thickness 12 in @ centerline ____ @ edge

Shoulders: Description ____

Width 6 ft - "b" ("o"-outside, "i"-inside, "b"-both)

Thickness ____ @ pavement ____ @ edge

Subgrade: Description Dark brown clayey silt

Original Design/Maintenance History:

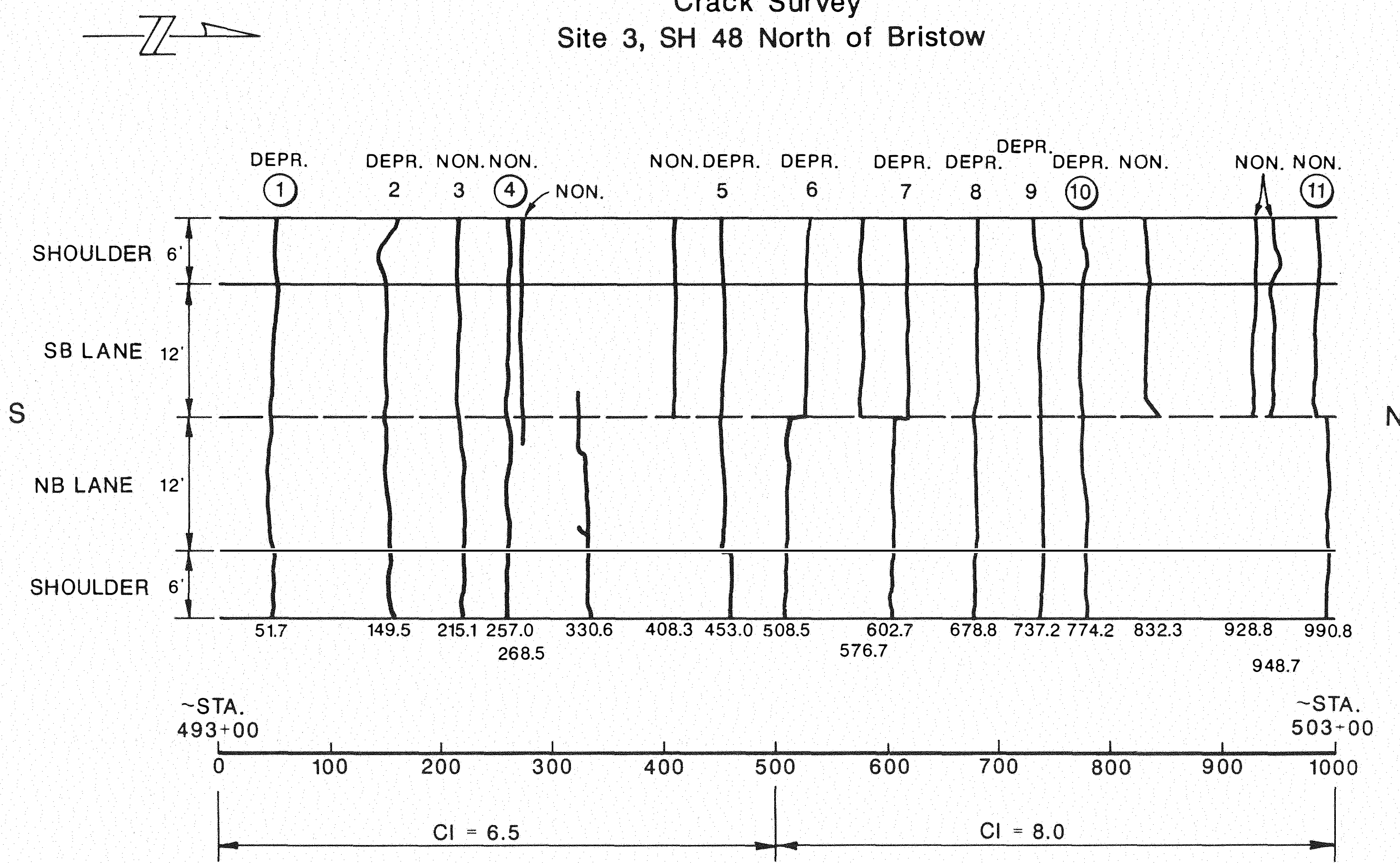
Traffic ____ vpd Heavy Truck Traffic ____ PSI ____

Terrain Rolling - alluvial valley Drainage Good - south to north

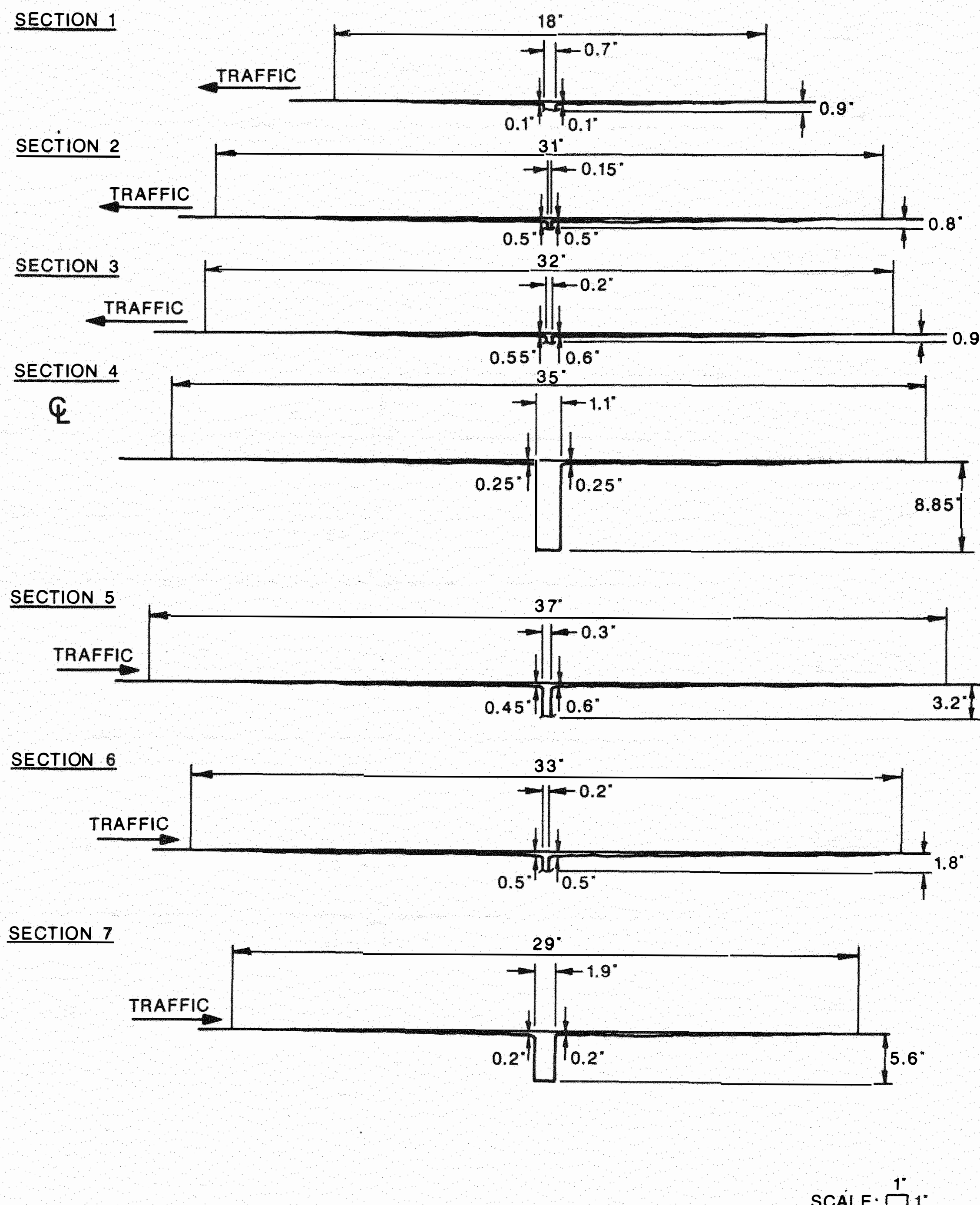
Climate ____

FIELD OBSERVATIONS:

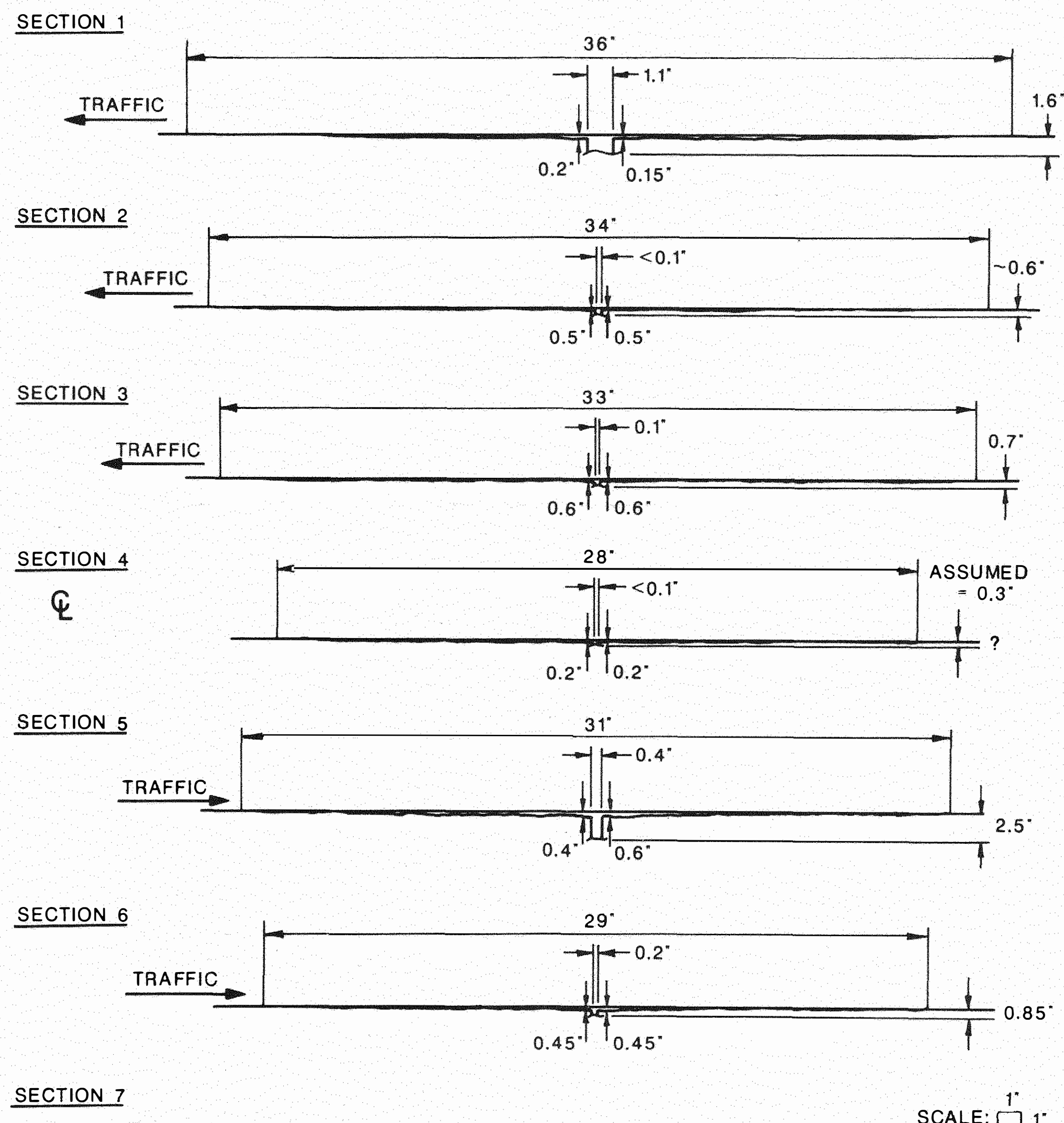
ODOT – Depressed Transverse Cracking in Asphalt Pavements Project
Crack Survey
Site 3, SH 48 North of Bristow



ODOT - Depressed Transverse Cracking in Asphalt Pavements Project
Transverse Crack/Depression Cross Sections
Site 3, SH 48 North of Bristow
Crack No. 1

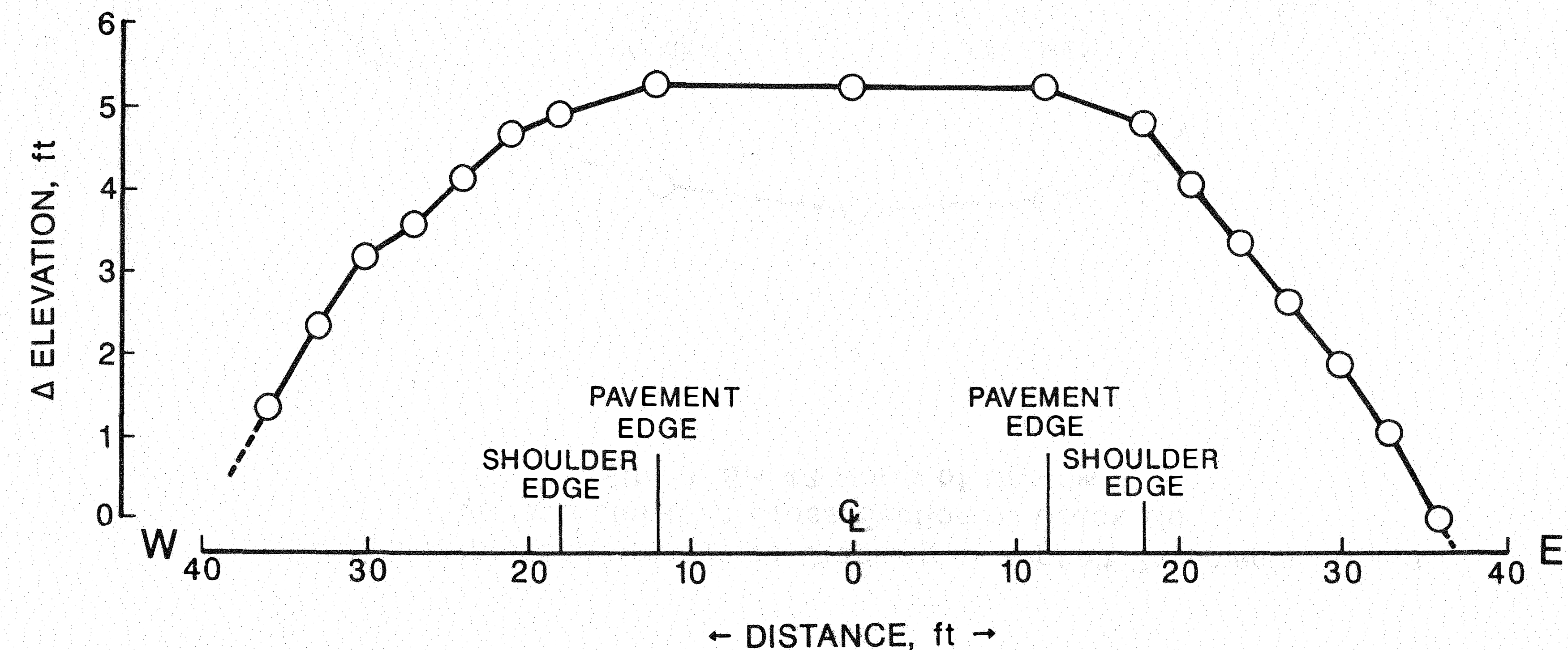


ODOT - Depressed Transverse Cracking in Asphalt Pavements Project
Transverse Crack/Depression Cross Sections
Site 3, SH 48 North of Bristow
Crack No. 10

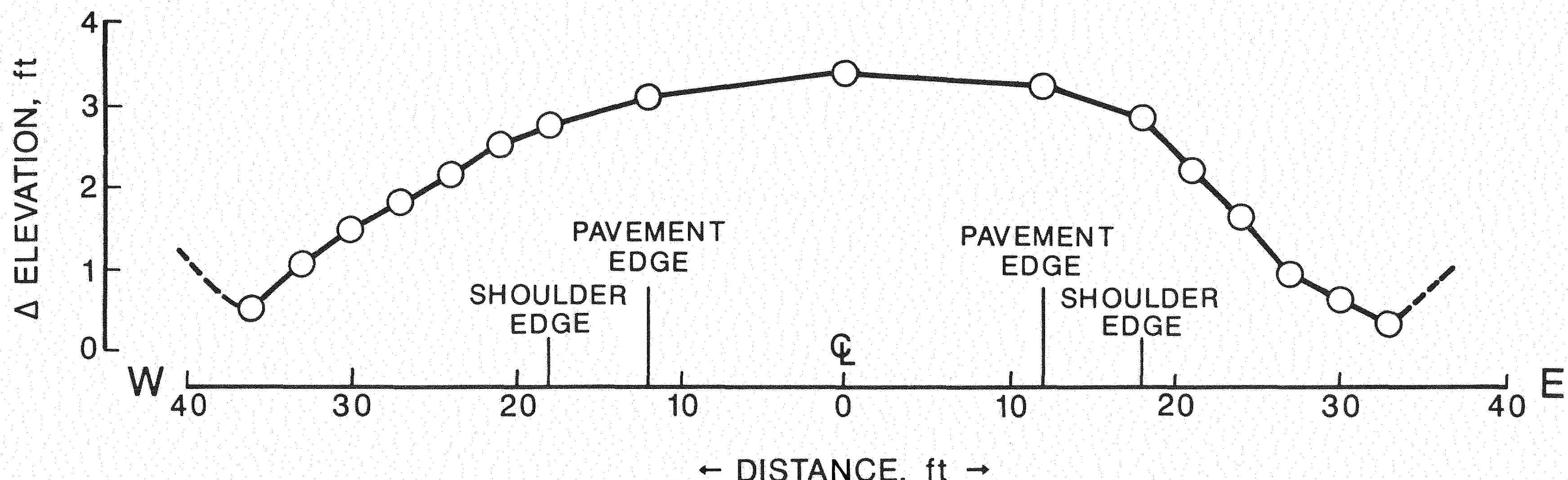


NO CRACK IN SHOULDER

ODOT - Depressed Transverse Cracking in Asphalt Pavement Project
Surface Elevation Cross Section at Crack No. 1
Site 3, SH 48 North of Bristow



ODOT - Depressed Transverse Cracking in Asphalt Pavements Project
Surface Elevation Cross Section at Crack No. 10
Site 3, SH 48 North of Bristow



APPENDIX D

SCHOOL OF CIVIL ENGINEERING

OKLAHOMA STATE UNIVERSITY

ODOT-DEPRESSED TRANSVERSE CRACKING IN ASPHALT PAVEMENTS PROJECT

TEST SECTION DATA SUMMARY SHEET

LOCATION DATA:

Test Section No. 4 Highway US 64 County Garfield

Control Section No. 64-24-31 Project No. F-396 (75)

Date-Preliminary Survey 5/24/88 Detailed Survey 7/14/88 Sampling ______

Location of Test Section:

Test section located ≈ 2.71 miles east of US 64 and SH 74 intersection between stations 1040 + 00 (west end) and 1050 + 00 (east end).

PAVEMENT/DESIGN DATA:

Number of Lanes 2 Lane Date Constructed May, 1971

Pavement: Description 4 1/2 on AC on 8 in Black Base

Width 24 ft Thickness 12 1/2in @ centerline ______ @ edge

Shoulders: Description ______

Width 10 ft - "b" ("o"-outside, "i"-inside, "b"-both)

Thickness ______ @ pavement ______ @ edge

Subgrade: Description ______

Original Design/Maintenance History:

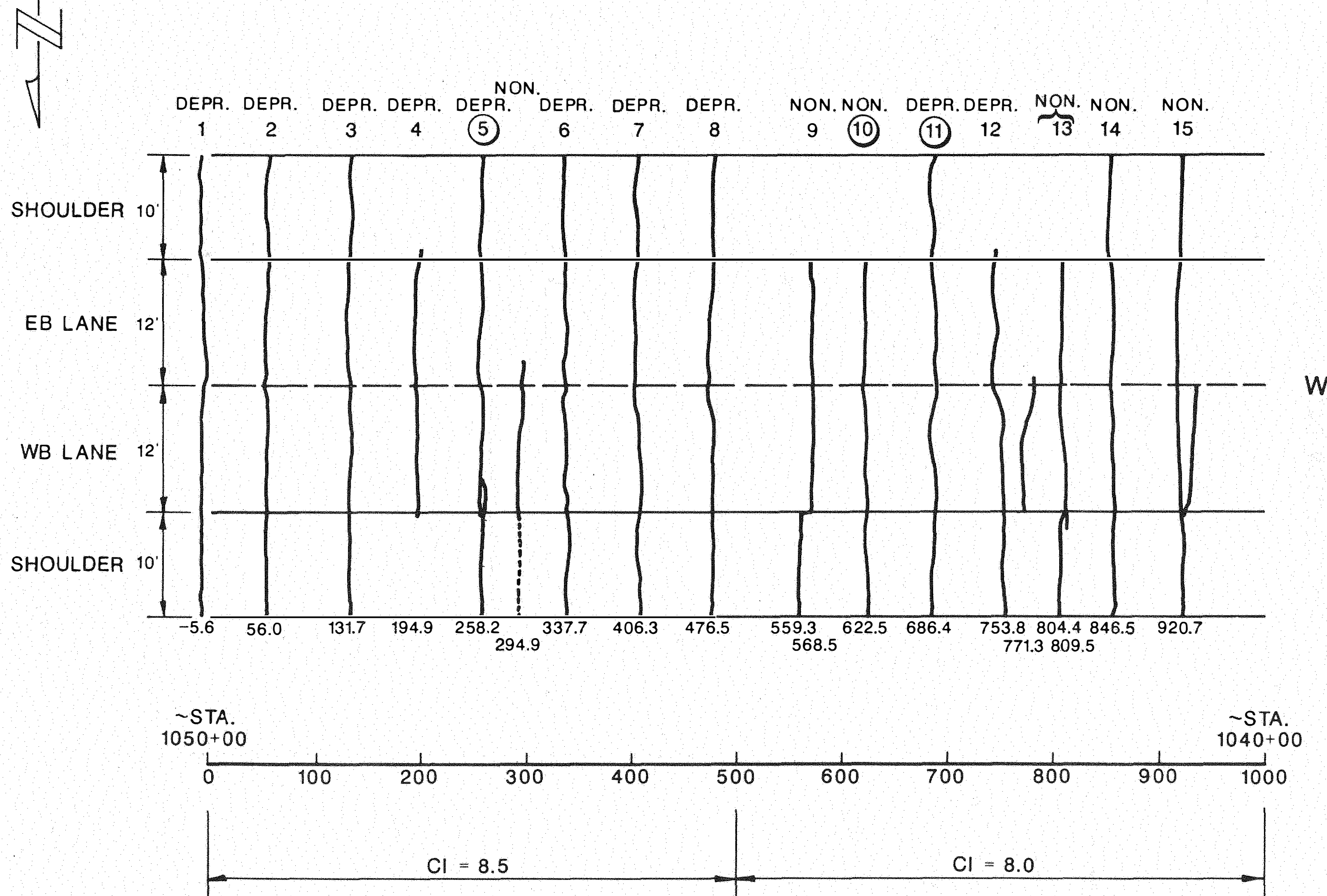
Traffic ______ vpd Heavy Truck Traffic ______ PSI ______

Terrain Upgrade - gently rolling Drainage Good - east to west

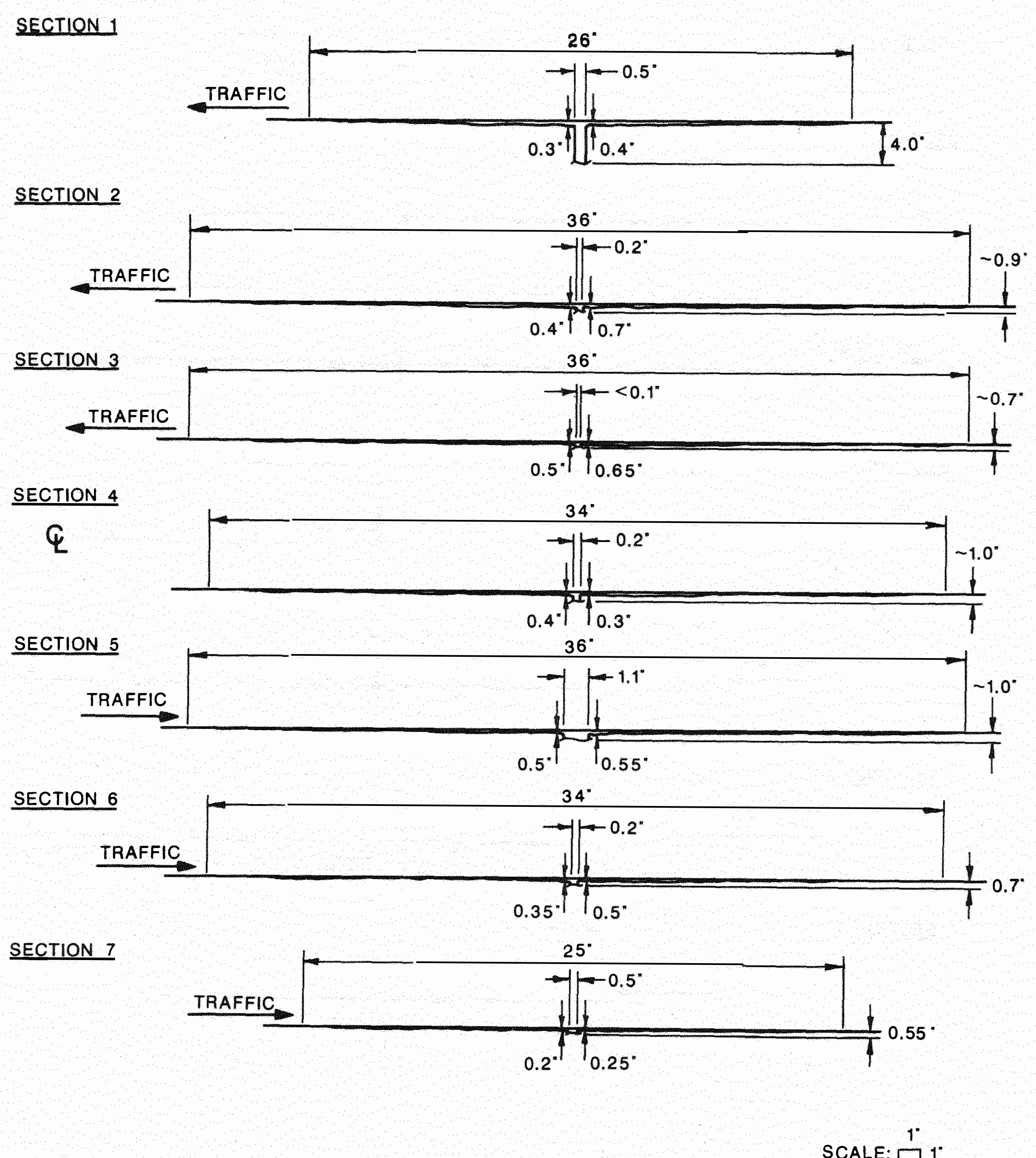
Climate ______

FIELD OBSERVATIONS:

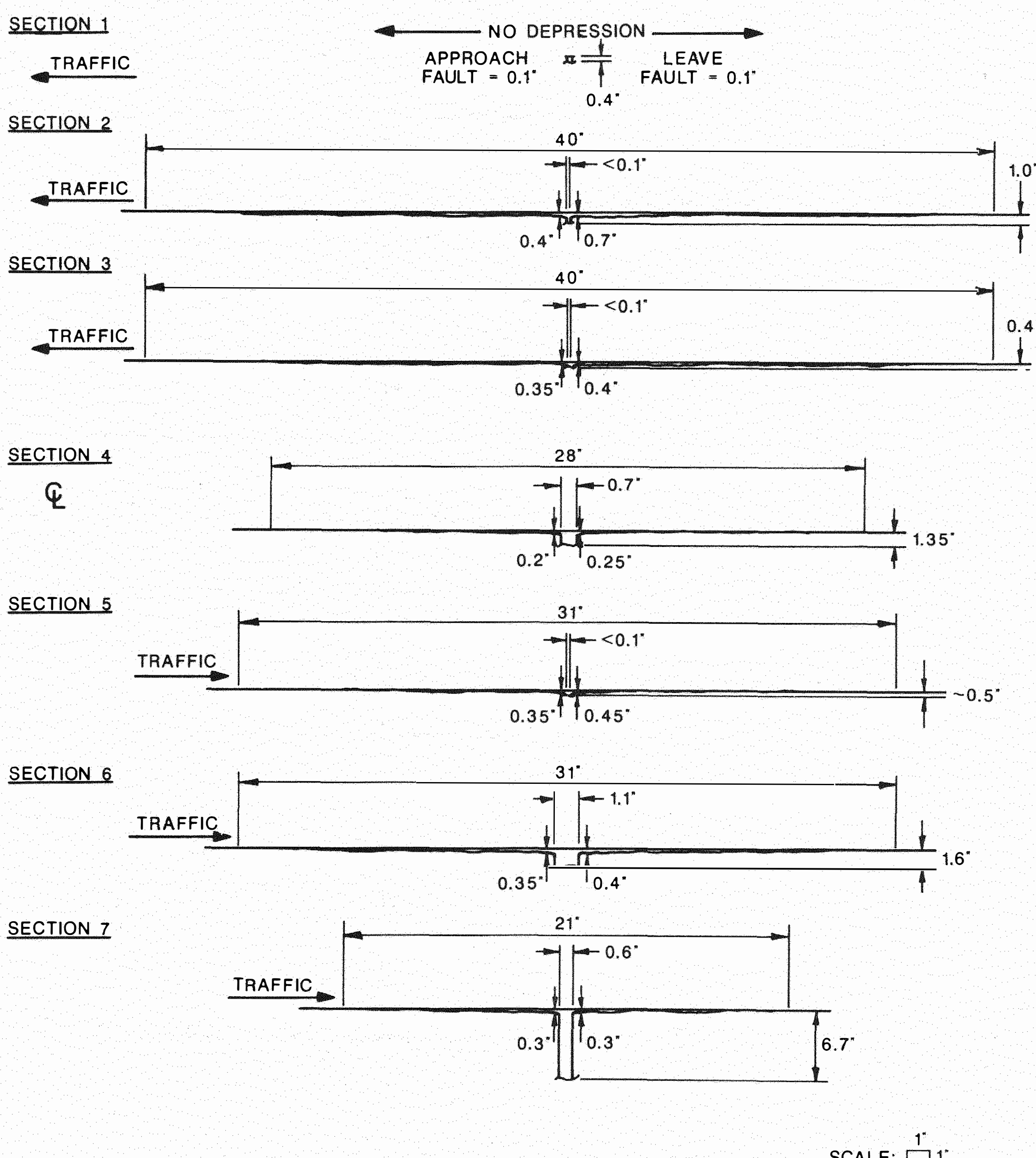
ODOT – Depressed Transverse Cracking in Asphalt Pavements Project
Crack Survey
Site 4, US 64 East of Enid



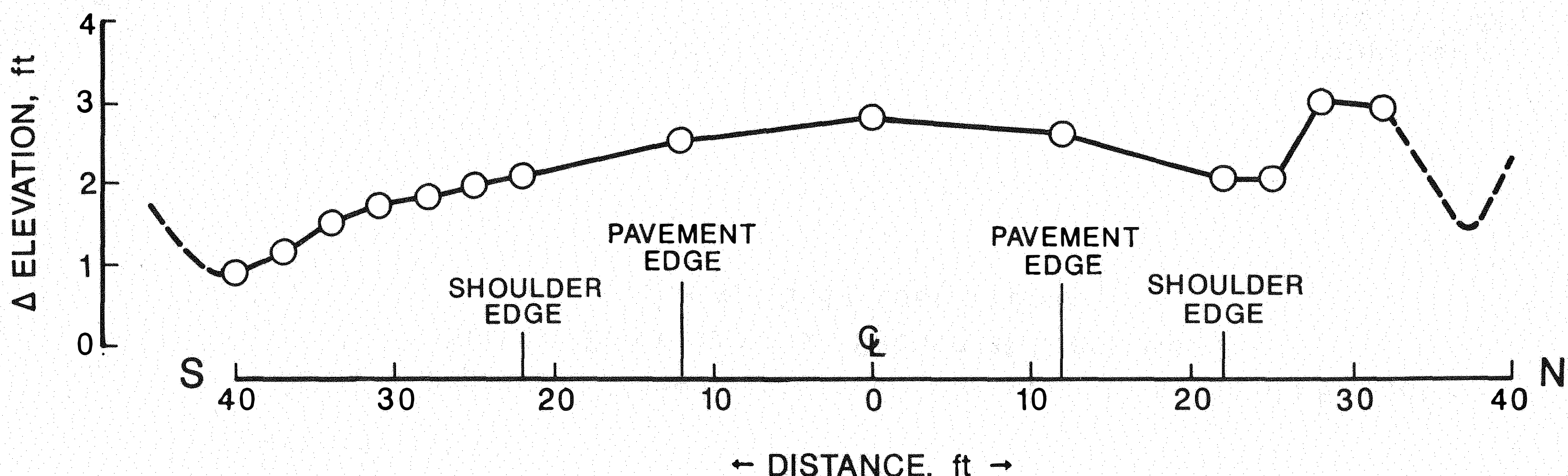
ODOT - Depressed Transverse Cracking in Asphalt Pavement Project
Transverse Crack/Depression Cross Sections
Site 4, US 64 East of Enid
Crack No. 5



ODOT - Depressed Transverse Cracking in Asphalt Pavements Project
Transverse Crack/Depression Cross Sections
Site 4, US 64 East of Enid
Crack No. 11



ODOT - Depressed Transverse Cracking in Asphalt Pavements Project
Surface Elevation Cross Section at Crack No. 5
Site 4, US 64 East of Enid



ODOT - Depressed Transverse Cracking in Asphalt Pavements Project
Surface Elevation Cross Section at Crack No. 11
Site 4, US 64 East of Enid