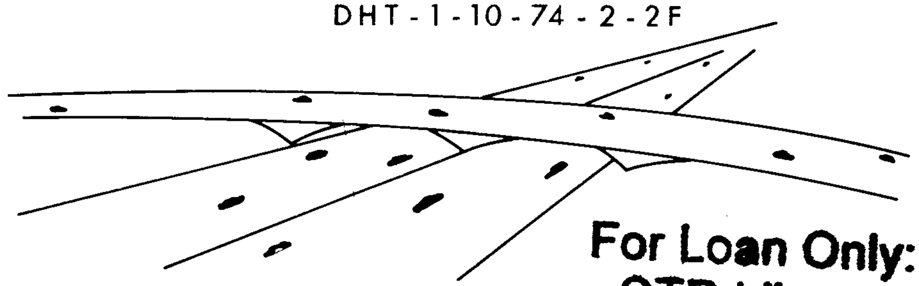
DHT-1-10-74-2-2F



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TECHNICAL REPORT STANDARD TITLE PAGE

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15. Supplementary Notes

Research Study Title "Equipment for the Measurement of Pavement Performance in Texas"
Research done in cooperation with DOT, FHWA

16. Abstract

This is the final report for this project. The report briefly describes the interim report entitled "Equipment for Collecting Pavement Roughness Information," and explains the equipment and data processing techniques available for pavement performance evaluation. Specifically, the report (1) describes the purchase and installation of a modification to the Dynaflect designed to improve its speed of data collection; (2) explains the establishment of a climatological data file and (3) describes the development of a vertical photologger to assist in the collection of pavement distress data on high-volume highways.

17. Key Words	18. Distribution Statement
Skid Resistance, Pavement Roughness, Pavement Deflection, Mays Road Meter, Dynaflect, Vertical Photo-logger, Climatic Data, Pavement Distress	No Restrictions. This document is available to the public through the National Technical Information Service, Springfield, VA 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	38	

Form DOT F 1700.7 (8-69)

Equipment and Methods For Collecting
Pavement Performance Information

by

Kenneth D. Hankins

Research Report 2-2F

Research Study 1-10-74-2
Equipment for the Measurement of Pavement
Performance in Texas

Conducted by

Transportation Planning Division
Research Section
State Department of Highways
and Public Transportation

In Cooperation With the

U.S. Department of Transportation
Federal Highway Administration

October, 1977

The contents of this report reflect the views of the authors who are responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the views or policies of the Federal Highway Administration. This report does not constitute a standard, specification or regulation.

There was no invention or discovery concieved or first actually reduced to practice in the course of or under this contract, including any art, method, process, machine, manufacture, design or composition of matter, or any new and useful improvement thereof, or any variety of plant which is or may be patentable under the patent laws of the United States of America or any foriegn country.

The United States Government and the State Department of Highways and Public Transportation do not endorse products or manufacturers. Trade or manufacturer's names appear herein solely because they are considered essential to the object of this report.

Acknowledgements

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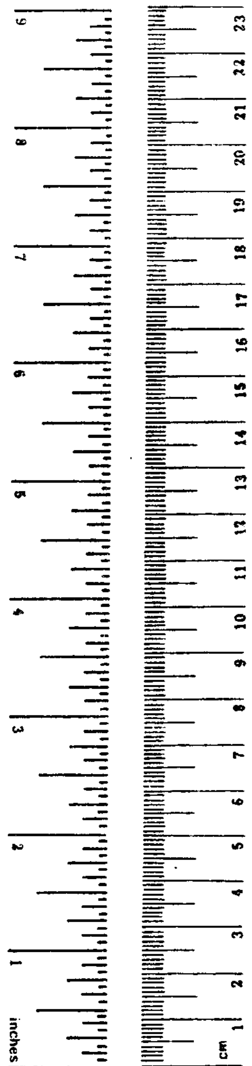
The Division of Automation, particularly Mr. Joel Young, for aid and programming conceived in the preparation and updating the Climatological Data File.

METRIC CONVERSION FACTORS

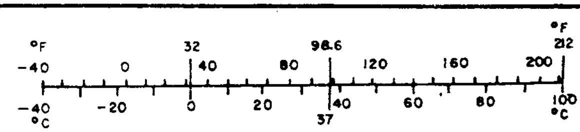
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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Implementation

This project was concieved to develop the equipment and standard methods of data collection, data storage and data retrieval to conduct a pavement evaluation inventory. Implementation has progressed to the extent that:

1. Modifications have been made to the deflection measuring equipment so that data can be collected with greater speed. Two units are available for this inventory. Data processing methods have been used for approximately two years and are being used effectively at this date.

2. The MRM units have been modified to collect data more accurately and rapidly. Six additional trailer units were fabricated. Seven trailer units and four automobile units are available for inventory. Data processing methods have been used approximately two years and are being used effectively at this date.

3. The skid resistance equipment and data processing methods were previously established with four units available for inventory.

4. A Vertical Photologger was fabricated to aid in the data collection and processing of pavement distress data on high volume highways. The data collection and processing methods were established previously. Consideration should be given to data storage and retrieval methods for the pavement condition data. The storage and retrieval methods will probably be developed or suggested by management consultants engaged by the department.

5. A Climatological Data File was established and has received updates on two consecutive years. The file has various uses but implementation should consist of reporting the past 20-year weather history with each report of other pavement evaluation data.

Consideration should be given to consolidating an automated file containing materials and cross-section information. This information will be necessary for a more complete pavement evaluation. This file will probably be developed or suggested by management consultants engaged by the department.

Consideration should be given to revising the deflection and roughness measuring equipment so that data may be collected and processed in an automated manner. The skid resistance equipment presently contains this feature. The present manufacturers of the Dynaflect offer an automated model. The MRM counter equipment developed in this project was fabricated with an "add-on" feature which will permit easy automation when additional or sufficient funds are available. If automated equipment becomes available, additional computer software programs will be needed to process, store and retrieve the data. The extent and cost of the program to process the data will be small since the Division of Automation presently maintains this processing capability. However, the cost of developing data storage and retrieval programs will be large and will depend on the report format desired. The data storage could be accomplished using magnetic tape rather than direct access disc but it will be necessary to at least temporarily hold various types of data so that all the data types can be reported for a given roadway section at a given time.

Summary

This report contains an explanation of equipment and data collection, storage and retrieval methods available for pavement performance evaluation. The data items available are skid resistance, roughness, deflection, pavement distress and weather. The data items of material and cross-section were not completed because of conflict with departmental programs established after the project was initiated. ASTM E 274 type skid test units are available for skid resistance tests. Modified Mays Road Meters are available for roughness measurements. Dynaflect equipment is available for deflection tests. A visual rating is used to obtain pavement distress.

I. INTRODUCTION

For many years the department has been involved in developing a system for monitoring the performance of the pavement structure. In order to monitor pavement performance it is necessary to recoginze the various distress modes, develop equipment to measure the extent of pavement distress, and obtain periodic measurements of the pavement condition. If the pavement condition is monitored until unsatisfactory conditions are found, the rate of failure or service life offers a measure of pavement performance.

Work in determining distress modes and developing equipment to determine the state of distress is not complete, but performance data is badly needed. Thus, an effort is underway to collect performance data using the present state of knowledge. Therefore, the object of this project was to develop or standardize equipment and procedures to obtain and explain pavement performance information.

There are several data items along with methods or equipment which offer a measure of pavement performance that are being considered by the department. These are:

1. Pavement Deflection
2. Skid Resistance
3. Pavement Roughness
4. Distress Index

In addition to the above items, data is needed on cross-section, materials used in construction, and the climatic conditions that have occurred in order to more fully understand the pavement performance.

II. INTERIM REPORTS

Research Report 2-1: "Equipment for Collecting Pavement Roughness Information"

This interim report was concerned with the equipment for obtaining, storing and retrieving pavement roughness information.(1) The report also explained a method of calibrating roughness equipment and of periodically checking to determine if the equipment needed recalibration.

Prior to this study and after several years of research, two types of roughness measuring equipment were selected for use. One type was the Surface Dynamics Profilometer (SDP). The SDP was fabricated by and purchased from the K. J. Law Company. The second type of roughness measuring equipment was the Mays Ride Meter (MRM) available from the Rainhart Company.

The SDP was selected as the standard for roughness evaluation equipment in the State and correlated to the results of several road rating teams. The Serviceability Indes (SI) value was selected as the basis of reporting roughness numbers. The SI concept consists of a number varying from 0 to 5 with 0 being very rough and 5 very smooth. In earlier research the SDP was tested on several sections which were also analyzed by the rating teams and a correlation was established as previously mentioned.

At present several MRM units are used to collect inventory information. Each MRM unit is correlated with the SDP. Therefore each roughness measuring unit is based on values produced by a rating panel with the SDP used as a standard and the MRM units as the inventory equipment.

The major portion of the report is concerned with the development of an electronic counter system used in conjunction with the MRM and a trailer to house the MRM transducer. The counter system provides a roughness count and was developed to improve the speed of data collection. The trailer was developed to reduce the number and extent to which variables such as vehicle weight, tire type, and non-standard suspensions affect MRM values.

An inventory scheme was developed for data collection in which data is recorded (and an SI reported) every 0.2 mile. The data is recorded on code sheets when collected, and is keypunched and processed by a computer program in which data may be input and results obtained via a computer terminal in the user District. Average values along with location data are also stored on a file managed by a central office Division.

As a result of this study, six additional MRM trailer units and counter systems were fabricated. At present there are seven trailer units and five automobile units. A unit is available to each District.

SKID-R Manual

Most of the skid resistance data collection methods and equipment were developed using state funding and were available before the subject project was concieved. No additional work was accomplished in this area on this study. However, in an effort to report the full complement of equipment and information available for pavement evaluation, the SKID-R manual should be consulted for skid resistance information and background.[2] This manual explains the equipment, data collection, data storage and data retrieval available for skid resistance. The equipment consists of four skid test units conforming to ASTM-E27A. Presently, the data is collected on ASR 33 Teletype-punched paper tape and is processed by a computer program. The program accesses stored information related to location, traffic, surface material and prior skid history. The program then combines the accessed information with the skid resistance information on the punched tape and produces a report via computer terminal in the user District. Average skid resistance values are stored in the permanent SKID-R file as skid history. The SKID-R file is available for District access by terminal and a series of six administrative reports are available on call.

III. DEFLECTION

Deflection information is obtained using Dynaflects obtained from Lane Wells, presently an SIE Corporation. There are two Dynaflects in use by the department. The Dynaflect is basically a two-wheeled trailer which houses equipment containing two eccentric cams. In operation, two load wheels are rolled to the pavement surface, the trailer is raised, and the trailer weight is transferred from the "road wheels" to the "load wheels". Simultaneously two eccentric cams being rotated cause a pulsating or cycle load of 8 cycles per second to be produced at the load wheel and pavement surface contact area. The cyclic load is ±500 pounds. The trailer weight produces a load of 1000 pounds on the load wheels when in a static condition. The cyclic load then varies from 500 to 1500 pounds. The deflection transducers are geophones which are fabricated to measure the amplitude of pavement deflection at the 8 cycle per second frequency. Five geophones are spaced along the trailer tongue at one-foot intervals. The first geophone is located at a position midway between the load wheels when measured transversely to the trailer towing direction. The other four geophones are at one-foot intervals longitudinal to the trailer towing direction. In these locations, the deflection is measured between the load wheels and the remaining four geophones produce deflection information, at intervals away from the load wheels, which is used to indicate the deflection basin.

In order to increase the speed of data collection, the original geophone lift assemblies of the Dynaflects were modified. This modification permits the geophones to be lifted to a safe position when the trailer is lowered from the load wheels to the road wheels for traveling between locations. Before the modification, it was necessary to remove the geophones before traveling. Failure to remove the geophones results in the phones being dragged over the surface which damages their fragile internal components.

Prior to this study, Research Study 1-8-69-123 "A System Analysis of Pavement Design and Research Implementation" developed a computer program which produced a deflection report. When used on a flexible pavement, the information from the geophones was used to calculate a "Stiffness Coefficient of the Subgrade" and a "Stiffness Coefficient of the Pavement". A "SCI" or Surface Curvature Index was also calculated. When the Dynaflect was used on rigid pavement, the information from the five geophones was used to calculate an "Elastic Modulus of the Subgrade" and an "Elastic Modulus of the Pavement" along with the SCI. An example of both the flexible and rigid pavement reports are shown in Figures 1A, 1B and 2. This study selected the task of developing a standard code sheet, adapting the computer program for use on the departmental computer system, and developing a method of storing and retrieving the data. The standard code sheets are shown in Figures 3 and 4. Attempts were made to adapt the location information to the methods used in the collection of skid resistance and roughness data.

With the exception of the location and materials information, which should be completed as much as possible prior to data collection, the code sheet is completed in the field during data collection. The code sheets should be keypunched at the District office. Deflection information ob-

TEXAS HIGHWAY DEPARTMENT

DISTRICT 03 -DESIGN SECTION

DYNAFLECT DEFLECTIONS AND CALCULATED STIFFNESS COEFFICIENTS

THIS PROGRAM WAS RUN - 04-01-76

****

PROJECT IDENTIFICATION

DIST.	COUNTY	CONT.	SECT.	PPSN	HIGHWAY	DATE	DYNAFLECT
.03	COOKE	0044	08		U. S. 82	03-17-76	29

REASONS FOR MEASUREMENTS AND COMMENTS	TOTAL PAV DEPTH
DS - WEST BOUND LANE 8FT LT	13.50 INCHES

****

EXISTING PAVEMENT

MATERIAL TYPE	LAYER THICK.(IN)
ASPHALTIC CONCRETE	1.50
LIME TR CR LIMESTONE	12.00
LIME STAB. SUBGRADE	6.00

****

GENERAL LOCATION INFORMATION

DIRECTION OF TRAVEL IS WEST MILEPOINTS
MEASUREMENTS ARE 8 FEET FROM THE RIGHT SIDE OF LANE B

DESCRIPTION OF LOCATION	STATION READING	MILEPOINT
FROM-1 MILE E. OF DRY ELM CR BRIDGE	683+00	13.22
INSCT FM 2739	567+08	9.23
TO-4000 FT E. OF FM 373 AT MUENSTER	472+00	7.46

****

FIGURE 1A: FLEXIBLE PAVEMENT DEFLECTION REPORT

DIST.	COUNTY	CONT.	SECT.	PPSN	HIGHWAY	DATE	DYNAFLECT
03	COOKE	0044	08		U.S. 82	03-17-76	29

DYNAFLECT DATA

ODOMETER	W1	W2	W3	W4	W5	SCI	AS2	AP2	REMARKS	
0.010	0.630	0.470	0.350	0.250	0.156	0.160	0.27	0.61	OVERLAYED	
0.200	0.780	0.430	0.270	0.132	0.090	0.350	0.32	0.43		
0.400	0.900	0.520	0.320	0.186	0.123	0.380	0.30	0.44	FILL	
0.600	0.930	0.560	0.370	0.240	0.162	0.370	0.29	0.45	FILL	
0.800	0.840	0.480	0.310	0.192	0.159	0.360	0.30	0.44	FILL	
1.060	0.430	0.380	0.310	0.240	0.189	0.050	0.25	0.95	FILL-NEAR END 6.R.	
1.200	1.230	0.870	0.580	0.400	0.280	0.360	0.25	0.53		
1.400	0.750	0.500	0.340	0.201	0.135	0.250	0.29	0.51	CUT	
1.600	1.200	0.720	0.350	0.159	0.093	0.480	0.28	0.43		596
1.800	1.020	0.780	0.540	0.380	0.280	0.240	0.24	0.61		585
2.000	0.400	0.350	0.290	0.216	0.180	0.050	0.25	0.92		
2.200	0.930	0.640	0.450	0.300	0.189	0.290	0.27	0.52		565
2.400	0.500	0.410	0.330	0.250	0.165	0.090	0.26	0.75	CUT	
2.450	0.530	0.380	0.270	0.189	0.126	0.150	0.29	0.59	FILL	
2.600	0.340	0.310	0.260	0.183	0.135	0.030	0.25	1.10		
2.810	0.260	0.230	0.183	0.141	0.123	0.030	0.27	0.98	CUT	
3.000	0.650	0.510	0.380	0.270	0.189	0.140	0.26	0.67	CUT	
3.220	0.630	0.460	0.360	0.270	0.201	0.170	0.28	0.59	MILEPOST 10.0	509
3.410	0.580	0.490	0.410	0.340	0.290	0.090	0.25	0.81	CUT-DRIVE	
3.600	0.840	0.630	0.460	0.340	0.270	0.210	0.26	0.60		488
3.800	0.750	0.570	0.450	0.360	0.280	0.180	0.26	0.62		477
4.060	1.530	0.930	0.570	0.380	0.270	0.600	0.26	0.42	W. OF F.M. INT	563
4.200	0.930	0.720	0.500	0.360	0.280	0.210	0.25	0.63		555
4.410	0.530	0.390	0.310	0.240	0.162	0.140	0.29	0.61	FILL	545
4.600	0.450	0.410	0.350	0.280	0.240	0.040	0.23	1.08		
4.800	0.530	0.350	0.204	0.117	0.087	0.180	0.31	0.53	CUT	523
5.010	0.590	0.440	0.310	0.198	0.135	0.150	0.28	0.62		
5.200	0.600	0.450	0.300	0.168	0.120	0.150	0.28	0.62		
5.400	0.370	0.280	0.198	0.153	0.123	0.090	0.30	0.67	FILL	491
5.600	0.204	0.177	0.144	0.120	0.108	0.027	0.29	0.94	FILL	480
5.753	0.480	0.270	0.156	0.084	0.072	0.210	0.34	0.48	CUT	472
AVERAGES	0.688	0.487	0.343	0.237	0.175	0.201	0.27	0.65		
STANDARD DEVIATION						0.141	0.03	0.20		

NUMBER OF POINTS IN AVERAGE = 31

W1-5 DEFLECTIONS AT GEOPHONES 1,2,3,4,&5
SCI SURFACE CURVATURE INDEX (W1 MINUS W2)
AS2 STIFFNESS COEFFICIENT OF THE SUBGRADE
AP2 STIFFNESS COEFFICIENT OF THE PAVEMENT

FIGURE 1B: FLEXIBLE PAVEMENT DEFLECTION REPORT

TEXAS HIGHWAY DEPARTMENT

DISTRICT 13 - DESIGN SECTION

TWO LAYER ELASTIC MODULI
FOR FIVE DEFLECTIONS

THIS PROGRAM WAS RUN - 03-28-78

DIST. COUNTY
13 COLORADO

CONT.	SECT.	JOB	HIGHWAY	DATE	DYNAFLECT
271	01		IH-10 AEB	03-08-76	29

SS PAV. THICK. = 14.00 INCHES

CRCP 8.00 CEM STAB BASE 6.00

SELECT MATL 9.00

LOCATION	W1	W2	W3	W4	W5	SCI	** ES **	** EP **	* RMSE *
427+53	0.620	0.540	0.410	0.340	0.290	0.080	21.5E 03	4.34E 05	0.2034
428+56	0.810	0.720	0.550	0.450	0.340	0.090	16.8E 03	2.98E 05	0.1288
428+76	0.430	0.390	0.320	0.290	0.250	0.040	23.5E 03	1.20E 06	0.1399
431+61	0.600	0.570	0.510	0.460	0.370	0.030	14.3E 03	1.11E 06	0.0731
434+07	0.400	0.360	0.280	0.250	0.200	0.040	29.5E 03	8.90E 05	0.1225
AVERAGES	0.572	0.516	0.414	0.358	0.290	0.056			
STD DEV	0.165	0.146	0.117	0.094	0.068	0.027			
POINTS	5	5	5	5	5	5			
AVERAGES STIFF ON TOP SOLUTIONS							21.12E 03	7.87E 05	
STD DEV							59.42E 02	4.04E 05	
POINTS							5	5	

NO SOFT ON TOP SOLUTIONS

W1-5 DEFLECTION AT GEOPHONES 1,2,3,4, AND 5
SCI SURFACE CURVATURE INDEX (W1 MINUS W2)
ES ELASTIC MODULUS OF THE SUBGRADE FROM W1,W2,W3,W4,& W5
EP ELASTIC MODULUS OF THE PAVEMENT FROM W1,W2,W3,W4,& W5

FIGURE 2: RIGID PAVEMENT DEFLECTION REPORT

TEXAS
STATE DEPARTMENT OF HIGHWAYS
AND PUBLIC TRANSPORTATION
ǂ DYNAFLECT DEFLECTION DATA

CARD NO. 010 – PROJECT IDENTIFICATION

Card No.	Dist.	County	Control	Section	Highway	PPSN	Plot Option
0 1 0							
1 2 3	4 5	6 7 8 9 10 11 12 13 14 15 16 17 18 19	20 21 22 23	24 25	26 27 28 29 30 31 32	33 34 35 36 37 38 39	40 41 42

* Total Pav. Depth	Month	Day	Year	Dynaflect	Reason for Measurement	Comments
43 44 45 46 47	48 49	50 51	52 53	54 55	56 57	58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79

ǂ The cards should be stacked in sequence.

* Total pavement depth must always be coded, it is used to calculate AS2 and AP2.

** CARD NO. 020 – EXISTING PAVEMENT

Card No.	Type of Material	Layer Thick. (in.)
0 2 0 (1 2 3)	4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23	24 25 26 27
	28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47	48 49 50 51
	52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71	72 73 74 75

** Card No. 020 can be coded as many times as needed.

CARD NO. 030 GENERAL LOCATION INFORMATION

Card No.	"W" or "O" Milepoints	Direction of Travel	Lane Position	Lane
0 3 0 (1 2 3)	4	5 6	7 8	9

Location	Physical Description of Location	Milepoint
	FROM–	
	TO–	
10 11 12 13 14 15 16 17	18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54	55 56 57 58 59 60

FIGURE 3 - DEFLECTION CODE SHEET

Form 1112-1 Rev. 5/75

TEXAS
STATE DEPARTMENT OF HIGHWAYS
AND PUBLIC TRANSPORTATION
DYNAFLECT DEFLECTION DATA

CARD NO. 040 - DATA CARDS

Card No.	Cont.	Sect.	Month	Day	Year	PPSN
0 4 0						
1 2 3	4 5 6 7	8 9	10 11	12 13	14 15	16 17 18 19 20 21 22

Location	DYNAFLECT READING										Time	Remarks
	Sc	1	Sc	2	Sc	3	Sc	4	Sc	5		
23 24 25 26 27 28 29 30	31 32	33 34 35	36 37	38 39 40	41 42	43 44 45	46 47	48 49 50	51 52	53 54 55	56 57 58 59 60	61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80

Sheet ___ of ___

Form 1112-2 Rev. 5/75

FIGURE 4 - DEFLECTION CODE SHEET

tained on flexible pavement may be processed through the computer terminal in the District with the report also returned to the terminal. Deflection information collected on rigid pavement must be keypunched at the District and the information forwarded card by card over the terminal to the central computer. When the information is received at the central computer, the data will be manually processed using a source program deck and the report returned via the District computer terminal.

IV. CLIMATIC DATA

It is postulated that the climate affects pavement performance significantly, yet there is little known about these effects. Presently, some knowledge is being gained about climate and pavement performance through the study of soil suction, thermal cracking and shrinkage cracking occurring in the pavement structure. There is also some knowledge available from the study of vehicluar accidents related to skidding in inclement weather. Based on this information a Climatological Data File (CDF) was developed.

A large portion of the CDF was developed from Carpenter,et.al. in Research Report 18-1 and from McCullough in Research Report 123-14.[3, 4] However, input concerning the file was also obtained from several Divisions. A search indicated that several state agencies in Texas have need of climatic data. As a result the Texas Water Development Board maintains several types of climatic data files which are available for all state agencies. Contact was made with the Texas Water Development Board (TWDB) and this agency graciously assisted the project by forwarding the initial data, indicating that yearly data would be available upon request. Much of the TWDB data was originally obtained from the National Weather Service and several data items are available. Three data items were selected for the CDF. These items are maximum temperature (AT), minimum temperature (IT) and precipitation (P). Daily records were selected and the latest 20 years of data were obtained for the file. The amount of data in the file will be constant. Only 20 years will be maintained with the current data added each year and the oldest (the 21-year-old data) removed from the file. The data will consist of daily records of maximum temperature, minimum temperature and precipitation.

There are many weather reporting stations in Texas. Generally, there is at least one station in each county. However, there are some counties without a station and many stations maintain only a minimum number of data items. For example, most stations measure P but not all measure AT and IT. Also the amount of data collected at a station varies (probably because the station keeper is away from the station). Also some stations close during the year and new stations are opened. Therefore, it was decided to maintain a file of the data from one station in each county as the primary county station with one additional station in the county as a secondary station where at least two stations were available in the county. There are 254 counties in Texas and the original CDF was established with approximately 254 primary stations and 182 secondary stations for a total of 436 stations. Where a station was not available in a county, a station in a nearby county was selected to represent that county. In other words, departmental personnel can request CDF data for any county and receive the best information available. A current list of stations are shown in Appendix A.

The file format was as follows:

a.	District	2 Columns
b.	County	3 Columns
c.	Reporting Station Number	4 Columns
d.	Year of Data	2 Columns
e.	Month of Data	2 Columns
f.	Day of Data	2 Columns
g.	Calculated Default (Concerned with data reporting variation)	1 Column
h.	Maximum Temperature	3 Columns
1.	Calculated Default	1 Column
j.	Minimum Temperature	3 Columns
k.	Precipitation	4 Columns

The file resides on magnetic tape. The approximate size of the file is:

436	Stations
29	Daily file format
365	Days
20	Years
92,301,200	Bytes

In addition to the establishment of the CDF, a computer program was developed to produce a yearly climatic report for each county. An example of the yearly report for one county is shown in Figure 5. Initially a report was prepared for each county and for each of the 20 years involved (1955 to 1974). The program was established to not only process and file the new data incoming from TWDB each year but to produce the report for each county at that time. The basic format of the report was obtained from Research Report 18-1 by Carpenter,et.al.. The upper table was used by Carpenter to show the manual calculations involved in producing a yearly Thornthwaite Moisture Index which is explained in Carpenter's report. Since these calculations show monthly precipitation, evapotranspiration, estimated water deficits in the soil, estimated storage, and estimated water surpluses, it was decided to also indicate these values in the report. The Thornthwaite Moisture Index is believed to be an indicator of shrinkage cracking occurring in subgrade and base and may be used in the future to improve pavement performance by applying the Index to the various soils and roadway conditions found in a given region. The number of freeze-thaw cycles combined with the precipitation and temperature information was believed to be related to pavement surface and base distress. The precipitation, number of days with precipitation, and number of days with continuous precipitation were believed to be of interest to highway safety engineers in the study and prevention of accidents.

It should be stated that the calculations of the Thornthwaite Moisture Index use only the minimum amount of climatic data available from the CDF and therefore should be considered as estimated values. A better explanation may be found in Research Report 18-1. As stated previously, the data from TWDB contained gaps or missing information on some days. On occasion, daily information would be missing for a month

STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION 08/17/77 PAGE 67
PROGRAM P260697C (TWDBRPRT)
1976 CLIMATOLOGICAL DATA FROM STATION 5890
SUMMARY FOR DISTRICT 06, COUNTY 165 - MIDLAND

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
POTENTIAL EVAPOTRANS . .	C.44	1.62	1.75	2.97	3.71	5.91	5.27	6.12	4.36	1.96	0.68	0.47
PRECIPITATION.	0.03	0.18	0.30	2.02	1.08	2.14	3.56	0.84	1.25	1.84	0.26	0.08
MOISTURE CHANGE.	-0.41	-0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	C.00	0.00	0.00
WATER STORAGE.	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ACTUAL EVAPOTRANS. . . .	C.44	0.35	0.30	2.02	1.08	2.14	3.56	0.84	1.25	1.84	0.26	0.08
WATER DEFICIT.	0.00	1.27	1.45	0.95	2.63	3.77	1.71	5.28	3.11	0.12	0.42	0.39
WATER SURPLUS.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

THORNTHWAITE MOISTURE INDEX = ((100 * ACCUM. SURPLUS) - (60 * ACCUM. DEFICIT)) / ACCUM. POTENTIAL EVAPOTRANS = -35.90

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
FREEZE-THAW CYCLES . . .	15	4	2	0	0	0	0	0	0	0	6	20
WET FREEZE-THAW CYCLES .	2	0	0	0	0	0	0	0	0	0	1	0
DAYS WITH PRECIPITATION.	2	1	3	6	6	6	11	3	8	7	2	1
MAX. DAYS CONT. PRECIP..	1	1	2	1	1	4	5	2	4	3	2	1
MEAN MAX. TEMPERATURE. .	59	73	72	79	82	91	86	93	83	72	59	60
AVERAGE TEMPERATURE. . .	44	56	57	65	68	78	76	79	72	58	47	44

NOTE1 - SUMMARY FOR A MONTH NOT REPORTED IN FULL (SEE STARRED COLUMNS) IF
A. 4 OR MORE PRECIPITATION READINGS FOR THAT MONTH ARE NOT AVAILABLE OR
B. 11 OR MORE COMBINED MAXIMUM AND MINIMUM TEMPERATURE READINGS FOR THAT MONTH ARE NOT AVAILABLE.
NOTE2 - STORAGE (FOR CARRYFORWARD TO MONTH + 1) FOR A 'NO REPORT' MONTH IS
A. AN EXPANSION OF PRECIPITATION BASED UPON ATLEAST 7 READINGS MINUS MOISTURE CHANGE OR
B. IF FEWER THAN 7 READINGS, A DIRECT FORWARD SHIFT OF STORAGE FROM MONTH - 1.
NOTE3 - THORNTHWAITE NOT CALCULATED IF 'NO REPORT' MONTHS GREATER THAN 2.
NOTE4 - CLIMATOLOGICAL SUMMARY NOT PRINTED IF 'NO REPORT' MONTHS GREATER THAN 10.
NOTE5 - FREEZE-THAW CYCLE COUNTED IN MONTH BEGUN. PRECIPITATION CUT AT END OF MONTH.
NOTE6 - TEMPERATURE FIGURES REPORTED IN DEGREES FAHRENHEIT. PRECIPITATION FIGURES REPORTED IN INCHES.
NOTE7 - FROM MOE & GRIFFITHS' ''A SIMPLE EVAPORATION FORMULA FOR TEXAS'', SLOPE = 0.16 AND Y-INTERCEPT = -6.5.
NOTE8 - STATION 5890 USED FOR 12/75 STORAGE CARRYFORWARD OF 0.58.

FIGURE 5: CLIMATOLOGICAL DATA YEARLY REPORT

or more. TWDB furnished information as to the continuity of the data for the stations available in Texas. Before the stations were selected, this data was studied and the stations with the longest and most productive history of data collection recieved priority consideration. However, it became necessary to establish a technique of data processing for the stations selected. This technique was as follows (with respect to data gaps):

1. Information for a given month was not shown on the Climatological Summary report if

   a. Greater than 10 days of information was missing for the AT or IT. The information was not considered if one or both of the temperatures were missing on a given day.

   b. Greater than 3 days of P information was missing.

2. The Thornthwaite Index was not calculated for a given year if data was missing for more than two months.

3. In years where at least 2 months of data was available, the data was given in the Climatological Summary report. If there were less than 2 months of data available, the report was not developed for that year.

Based upon the information above, a value of 29°F rather than 32°F was selected as the point of determining freeze-thaw data. This value stems from the fact that at a given depth pavements do not freeze at an ambient air temperature of 32°F but at a lower temperature which is basically dependent on the depth in the pavement structure at which it is desired to determine the freezing point. Basically, Texas is not subjected to long periods where the temperature is below freezing and ice lenses form. Rather, most of the pavement structural damage results from the freeze-thaw cycles of which there may be several. Therefore, a depth of one inch was selected as the depth for calculations. In other words, the ambient air temperature was determined when the pavement was freezing at a one inch depth. The method of obtaining this temperature value was selected from Research Report 123-14 by McCullough.

The CDF has been updated on two occasions, with 1975 and 1976 data, since initiation. The file is available for District use and for state research agencies. At present the Center for Highway Research and Texas Transportation Institute have requested and recieved copies of the file. Detailed information of the program and file is available in the Texas Weather Data Collection and Retrieval System Manual published by the Division of Automation (D-19).[5]

V. CROSS SECTION AND MATERIALS DATA

As originally conceived, this project would study the available sources for cross-section and materials data and develop methods for collecting the data where needed. An automated method of data collection, storage and retrieval was needed. Cross-section data would include both horizontal and vertical locations of each of the pavement structural layers. In this manner, thickness and depths of the structural layers would be available to personnel studying pavement performance. The location or deletion of various layers after reconstruction or rehabilitation was needed. Materials information would include such items as:

1. Pavement type (for example, continuously reinforced concrete paving, dense graded asphaltic concrete, etc.)
2. Material type of the various structural layers (Example - crushed limestone base)
3. Binder type and content of the various structural layers. (Example - 4 percent cement stabilized)
4. Material type and features of the subgrade (for example, clay, triaxial class 5.2)

The materials information should be correlated with the cross section information.

The researchers were aware of an existing study which had developed a method whereby the materials and cross-section information could be stored and retrieved in an automated manner. This was study 2-8-75-207 entitled "Flexible Pavement Evaluation and Rehabilitation." The subject study visualized implementation of the method developed by study number 2-8-75-207. Implementation would have included some revisions to the method; establishment of a file; suggestion and promotion of revised code sheets and procedures for obtaining information from the final construction plans (and manual files); and would have begun the task of obtaining, coding and storing information of existing roadways. Problems with implementation arose from the fact that several items of the materials and cross section data are available in existing Road Inventory and Road Life files and duplication of data would exist.

During the course of the study, the Department secured the services of a group of consulting engineers to develop a plan entitled "Management Information System". This plan included a subprogram in which pavement evaluation was included. A major thrust of the "Management Information System" was toward combining several files and eliminating duplicate data. It was believed this portion of the project should not be continued because of the conflict with the "Management Information System" study.

VI. VISUAL RATING

During the course of Research Project 2-18-71-151 "Maintenance Quality, Methods and Rating" a procedure for collecting visual rating information was developed.(7) The procedure was adapted from the "Washington State" procedure and included several modifications. Code sheets for data collection are shown in Figures 6 & 7. The procedure was quickly adopted and several districts began inventory work on a regular basis. A series of reports were prepared by the project staff and an example is found in Figure 8. With these reports and the urging of study personnel and personnel from the Maintenance Operations Division, the Districts began using the information in various ways.

One use was in developing budget information concerned with maintenance improvements of "worse condition" roadways. The extent and amount of damaged roadway suggested the type and quantity of maintenance needed. Materials, manpower and equipment could be estimated along with associated costs. Maintenance engineers and foremen would receive aid because "worst condition" sections could be treated with a limited budget. However, two problems exist and both are related to future needs.

First if long range budgets are needed it will be necessary to determine the deterioration of roadway performance. How long can a pavement with various degrees of minor damage last before major maintenance is needed? Second, what life can be expected of various maintenance techniques? To answer these questions it will be necessary to maintain a history of periodic pavement distress measurements. Therefore, it was the intent of this study to develop a method of automated storage and retrieval of the pavement distress data.

One report developed by the Project 2-18-71-151 staff consisted of a straight line map of the present pavement evaluation data which was produced by the computer. (See example Figure 9) The report included skid resistance, roughness and deflection data. The subject project obtained the program from the Project 2-18-71-151 staff of Texas Transportation Institute and assisted in preparing the program and code sheets for use in the departmental computer system. Assistance was also offered to Districts in explaining the data input and in obtaining data. During the course of the study, a group of consulting engineers were engaged by the Department to develop the mentioned earlier plan entitled "Management Information System". A portion of this program was directed toward a "Roadway Maintenance System". The "Roadway Maintenance System" subprogram included pavement evaluation and the reports necessary for maintenance management. The development of further reports and information related to distress was found to be in conflict with this part of the subject study. At the request of the administration, further efforts to develop pavement distress reports were stopped.

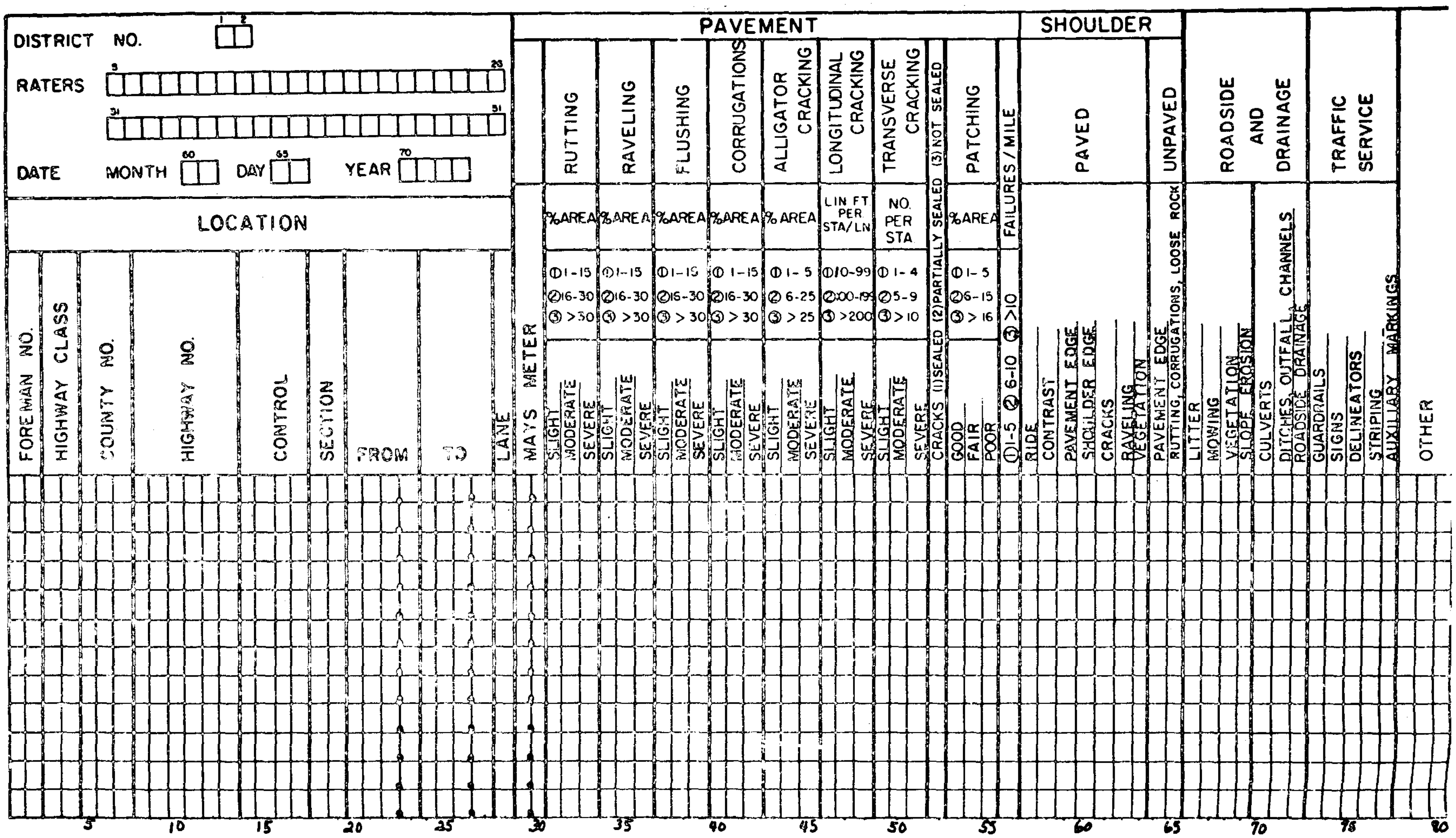

FIGURE 6: MAINTENANCE RATING FORM FOR FLEXIBLE PAVEMENTS

(AFTER EPPS ET AL, RESEARCH REPORT 151-2)

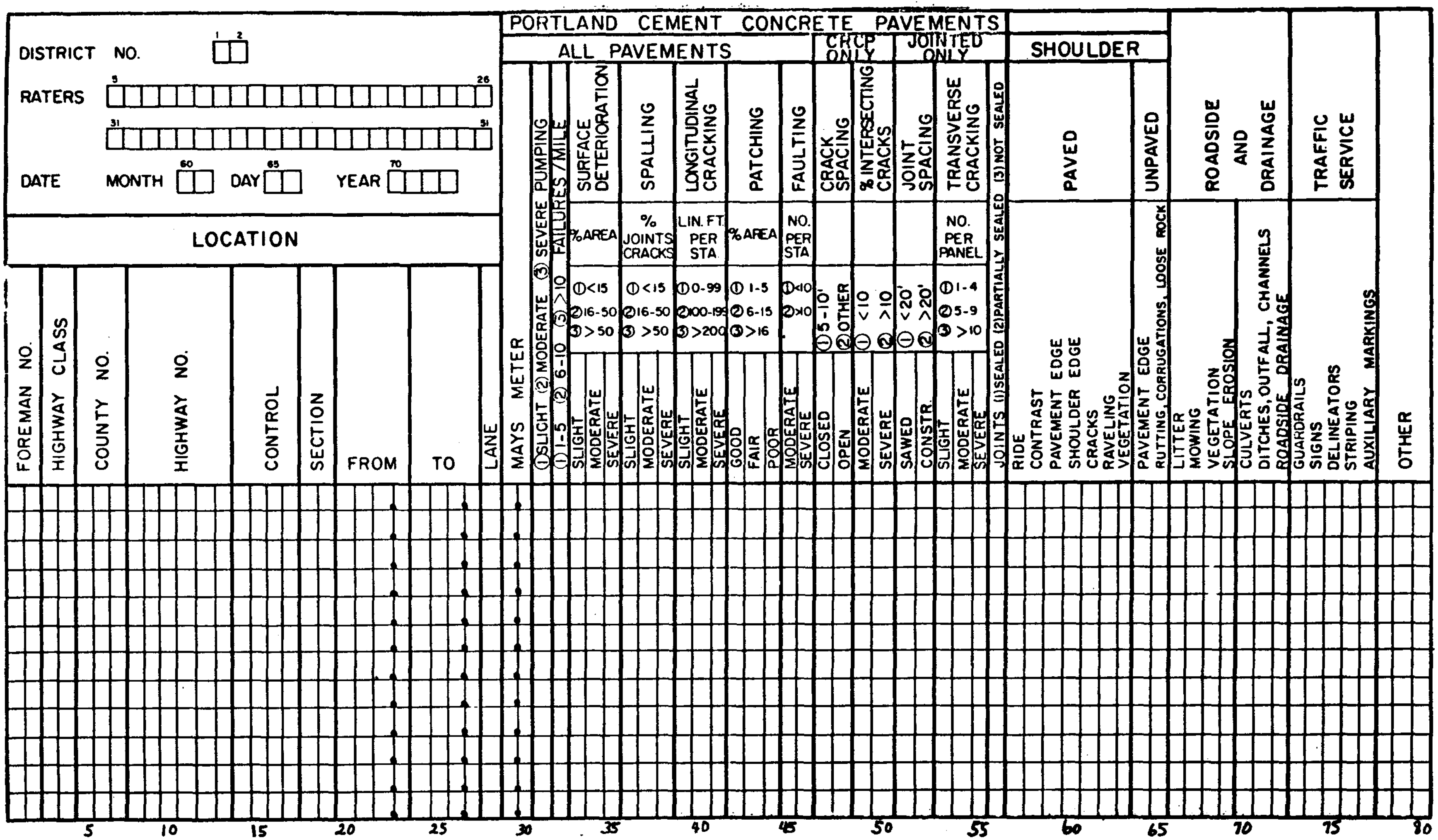

FIGURE 7: MAINTENANCE RATING FORM FOR RIGID PAVEMENTS

AFTER EPPS ET AL
RESEARCH REPORT 151-2

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*DISTRICT NO.  3 --SORT BY COUNTY*
                                                                                                              **********
                                                                                                              *ROADSIDE*******
                                                               ***********************************************   AND  *TRAFC*
                                                               *                 PAVEMENT                 * SHOULDER *DRAINAGE*SERVS*
                                                               ***********************************************************************
                                                               *    *    *    * C *    * L *    *     * * * PAVED *UP*     *    *      *    *
                                                               *    *    *    * O *    * O *    *     * * ************     *    *      *    *
                                                               *    *    *    * R *    * N * T *     * * *         * R*     *    *      *    *
                                                               *    *    *    * R * A * G * R *     * * *         * U*     *    *    A*    *
                                                               *    * R * F * U * LC* IC* AC*     * *F*         * T*     * DR*    U*    *
                                                               * R * A * L * G * LR* TR* NR*     * *A*         * T*     * IO*    X*    *
                                                               * U * V * U * A * IA* UA* SA*     * *I*         * I*     * TA*    I*    *
*************************************************************** T * E * S * T * GC* DC* VC*     * *L*         * N*     * .O*    L*    *
*  * H*   *       *    *  *      *     * **********  RATING ****** T * L * H * I * AK* IK* EK* P *C*U*  PS    *PG*   S*  S*    I*    *
*  * I*   *       *    *  *      *     * **********  SCORES ****** I * I * I * O * TI* NI* RI* A *R*R*  AH    *A *   L* OI*    A*    *
*  * G*   *       *    *  *      *     * ************************* N * N * N * N * ON* AN* SN* T *A*E*  VO    *VC*   O* TD*  D R*    *
* F* H*   *   H   *    *  *      *     * **M**   *   *   *   * T * G * G * G * S * RG* LG* EG* C *C*S*  EU   V*EO*  VP* FE*G E Y*    *
* O* W* C *   I   *    *  *      *     * **A**   *   *   *   * R *   *   *   *   *   *   *   * H *K* *  ML   E*MR*  EE* A *U L  *    *
* R* A* O *   G   *    *  *      *     * **Y** P * S * R * D * A * M * M * M * M * M * M * M * I * *P* CED RG*ER*  G *CLD*A ISM*    *
* E* Y* U *   H   * C * S*  F   *     * **S** A * H * O * R * F * O * O * O * O * O * O * O * N *S*E* DNE AE*NU*  EE*U.R*R NTA*    *
* M*  * N *   W   * O * E*  R   *     * ** ** V * O * A * A * . *SDS*SDS*SDS*SDS*SDS*SDS*SDS* G *E*R* NTRCVT*TG*LMTR*L A*D ERR*    *
* A* C* T *   A   * N * C*  O   *  T  * **M** E * U * D * I *   *LEE*LEE*LEE*LEE*LEE*LEE*LEE*   *A* * T  REA* A*IOAO*VCI*RSAIK* O *
* N* L* Y *   Y   * T * T*  M   *  O  *L**E** M * L * S * N * S *IRV*IRV*IRV*IRV*IRV*IRV*IRV*GFP*L*M*RREEALT*ET*TWTS*EHN*AITPI* T *
*  * A*   *       * R * I*      *     *A**T** E * D * I * A * E *GAE*GAE*GAE*GAE*GAE*GAE*GAE*OAO*I*I*IADDCII*DI*TIII*RAA*IGOIN* H *
* N* S* N *   N   * O * O*  M   *  M  *N**E** N * E * D * G * R *HTR*HTR*HTR*HTR*HTR*HTR*HTR*OIO*N*L*DSGGKNO*GD*ENOO*TNG*LNRNG* E *
* O* S* O *   O   * L * N*  P   *  P  *E**R** T * R * E * E * . *TEE*TEE*TEE*TEE*TEE*TEE*TEE*DRR*G*E*ETEESGN*EN*RGNN*S.E*SSSGS* R *
*************************************************************************************************************************************
* 5* 3*252*IH  35*  22* 1*  5.2*  9.0*S*3.9* 86* 84* 87* 90*100*1  *2  *   *   *   *   *1  *   *2* *2113121*  *2111*111*      *  B*
* 5* 3*252*IH  35*  22* 1*  5.2*  9.0*R*3.9* 89* 86* 77* 87* 84*3  *   *   *   *   *   *1  *   *2* *2111131*  *2223*121*3212 *  B*
* 5* 3*252*IH  35*  22* 1*  5.2*  9.0*M*4.0* 89* 83* 87* 90*100*1  *1  *   *   *   *   *1  *   *2* *211313 *  *2111*111*      *  B*
* 5* 3*252*IH  35*  22* 1*  5.2*  9.0*L*4.0* 89* 84* 82* 87* 88*3  *   *   *   *   *   *1  *   *2* *3111131*  *2113*121*2112 *  B*
* 5* 3*252*IH  35*  22* 1*  5.2*  9.0*X*3.8* 86* 79* 85* 90* 86*   *3  *   *   *   *   *   *   * * *2422122*  *2211*111*-2212*  B*
* 5* 3*252*IH  35*  22* 1*  5.2*  9.0*A*3.7* 86* 74* 80* 90* 86*   *3  *   *   *   *   *   *1  * * *1343223*  *2222*111* 2212*  B*
* 5*12*252*US 283*  89* 1*  0.0*  5.2*S*4.0* 80*100*100*100*100*   *   *1  *   *   *1  *2  *   *3* *        *  *    *    *    *  A*
* 5*12*252*US 283*  89* 1*  0.0*  5.2*R*3.9* 65* 71* 75* 80* 60*2  *   *2  *   *2  *1  *2  *   *3* *3526211*  *4411*222*14546*  A*
* 5*12*252*US 283*  89* 1*  0.0*  5.2*M*3.8* 79*100*100*100*100*   *   *1  *   *   *1  *2  *   *3* *        *  *    *    *    *  A*
* 5*12*252*US 283*  89* 1*  0.0*  5.2*L*3.5* 71* 80* 75* 80* 60*2  *   *1  *   *1  *1  *2  *   *3* *3223211*  *4411*222*14546*  A*
* 5* 1*252*FM 578*1031* 7*  0.0*  4.6*R*3.2* 55* 70* 85* 83* 84*   *2  *   *   *1  *2  *  1*1  *2* *       *33*2211*212* 233 *  A*
* 5* 1*252*FM 578*1031* 6*  4.6*  8.2*R*3.0* 42* 70* 87* 87* 84*   * 3 *   *   *1  *1  *  1*   *2* *       *42*1121*112* 233 *  A*
*************************************************************************************************************************************
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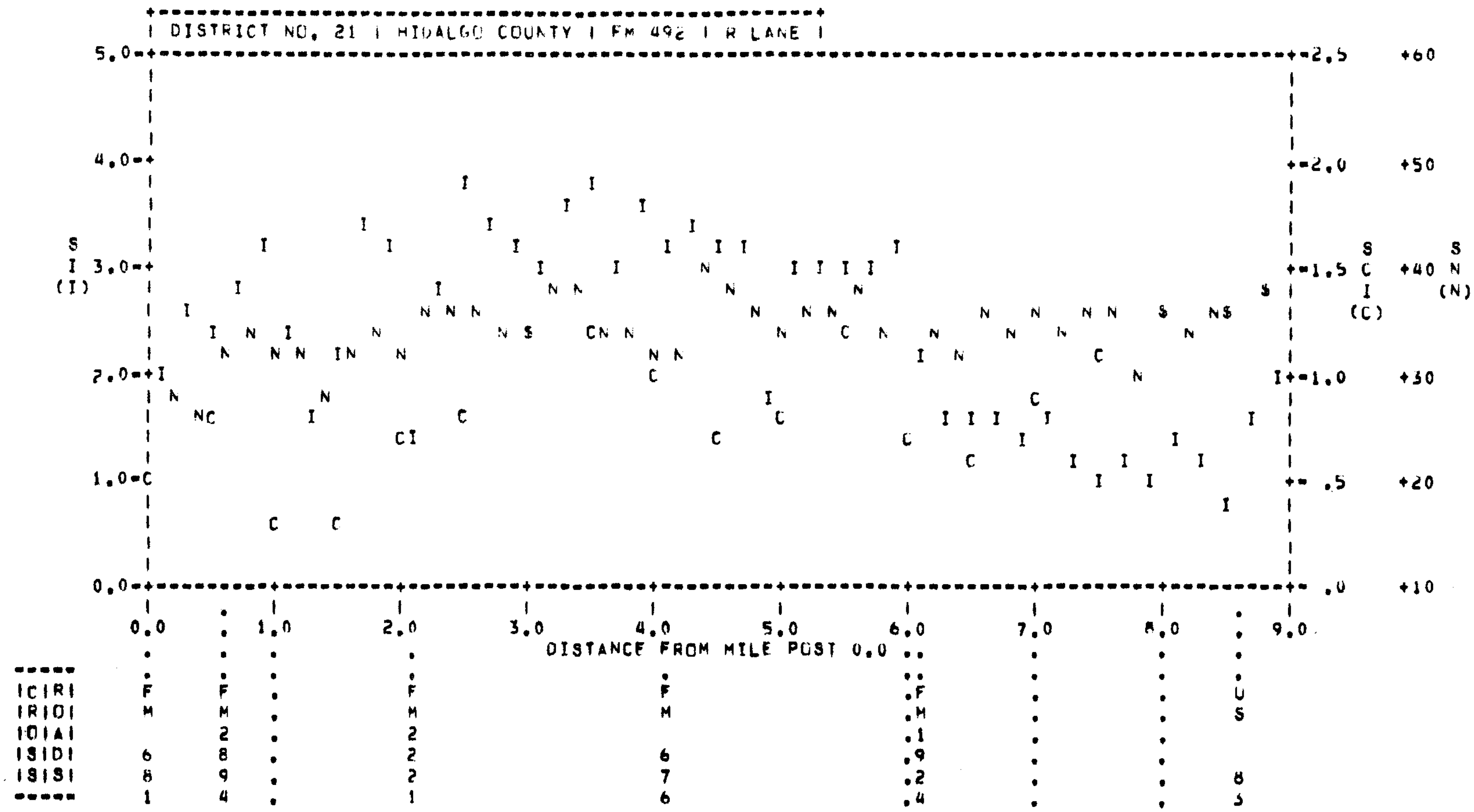
FIGURE 8: EXAMPLE OF A VISUAL RATING REPORT

PAGE 1 OF 2



AVERAGE DAILY TRAFFIC	510	710	1060	1200
18 KIP EQUIV. AXLES	0.19	0.183	0.215	0.214

CONTROL-SECTION	862-1	
SURFACE TYPE	SC	
DATE OF LAST SURFACE	8/74	11/68
DOLLAR COST/MILE	1024	
COST/BENIFIT RATIO	14.222	15.515
FOREMAN NO.	6	
PAVEMENT RATING	85	65
SHOULDER RATING	60	60
ROADSIDE RATING	70	67
DRAINAGE RATING	67	60
TRAFFIC SERV. RATING	80	78

FIGURE 9: MAINTENANCE RATING PLOT

VII. VERTICAL PHOTOLOGGER

Part of the pavement distress information explained previously will be collected on high volume facilities. To collect the data it is necessary to walk on the travel lanes, closely observing the pavement surface. This can be dangerous for both the visual rating team and traffic operating on the highway. Therefore, it was desired to develop equipment which could obtain pavement distress information without the necessity of a collection crew walking on the pavement surface. The result was a Vertical Photologger.

The word "vertical" was used in the nomenclature to distinguish the equipment from photologgers which obtain photos through the windshield of a moving vehicle in a near-horizontal manner. It was desired to obtain photographs from a moving vehicle at a speed close to that of the surrounding traffic using relatively simple, low-cost data collection and processing equipment. Considerable aid was received from Center for Highway Research Personnel who had obtained vertical photographs from a moving vehicle while involved in research project 3-8-75-177 "Development and Implementation of Design, Construction and Rehabilitation of Rigid Pavements."

The equipment developed consisted of a boom mounted on the rear of an MRM trailer (See Figure 10). A 35 mm camera was mounted at the top of the boom at a height of eight feet. The camera was controlled from the towing vehicle.

In studies conducted before the purchase and fabrication of the equipment, a continuous strip camera, a movie camera and a television system were considered and discarded. The continuous strip camera proved too costly for the project budget. The movie camera and televison camera were not available with sufficient shutter speeds to prevent "speed blurr" when installed in a rapidly moving vehicle. When the camera is mounted vertically at a relatively low height, the film should be exposed a very short period of time. Long periods of film exposure allow the pavement surface to move relative to the camera resulting in a blurred photograph. Experiments with a leased camera indicated that the shutter speed should be some what less than 1/1000 second at 40 mph with an eight foot height and with the desired "F stops".

Therefore a 35 mm camera with the following features was called for:

1. To have a variety of shutter speeds but with one speed being less than 1/1000-second.

2. To be equipped with a large film magazine.

3. To have a motorized film advance.

4. To have the capability of obtaining exposures rapidly, possibly on a timed interval.

The low bidder made available a Nikon F25 system with a frame back equipped with a 250 frame magazine. The camera with accessories is shown in Figure 11. The camera has a motorized film advance and shutter speeds of

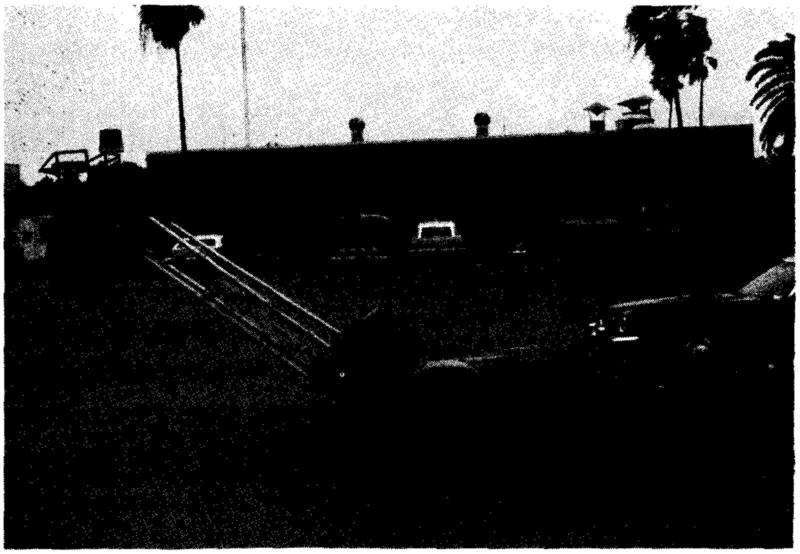


Figure 10
Vertical Photologger

Figure 11
Camera System

one second to 1/2000-second. The motorized film advance allows exposures at a rate up to 5 frames per second along with manual activation of a single frame if desired.

A 24 mm, F2.8 wide angle lense was selected to obtain a 35 mm slide covering an approximate 8 X 12 - foot surface area from the eight foot height. A small amount of distortion may be noted at the edges of the slide, but this distortion was not believed to be important because of the type and accuracy of the data needed from the photograph.

The film advance was modified so that the film was advanced on the basis of a length pulse rather than a timed advance. This modification uses a Distance Measuring Instrument system obtained from Numetrics, Inc. The modification allows shutter activation and film advance of various towing vehicle speeds even during acceleration. There is a maximum speed at which the vehicle can be driven since the camera has a maximum speed at which the film will advance and the shutter will activate. When the camera is mounted with a 12 foot transverse width and a 8-foot longitudianl length, consecutive, end-to-end photographs may be obtained at 20 mph. The photographs will have a 6-inch overlap on each end. When the camera is mounted with an 8-foot transverse and a 12-foot longitudinal coverage area, a speed of 30 mph can be used, producing photographs with the characteristics of those mentioned above.

The processed film is returned in roll form which contains up to 250 frames. This film could be cut and mounted to form 250 slides. However, it was more convenient to maintain, analyze and store the film in roll form. The projector purchased handles the film in roll form however, the only projectors available were those which projected only one-half of the frame or slide and it was necessary to advance the film in the projector to view the remaining half. The projector was therefore modified so that full frames could be viewed.

For analysis, the film was projected on a standard screen, the pavement surface studied visually and the pavement distress information coded directly on a data form as previously shown in Figures 6 and 7. Not all of this visual rating information can be obtained from the film produced by the Vertical Photologger. In the flexible pavement data sheets it may be noted that shoulder, roadside, drainage and traffic service information are also obtained. It is difficult to obtain rutting and corrugation information from the film. Therefore, a second pass of the vehicle or a trip by the rating team will be necessary to obtain shoulder, roadside, drainage, traffic service, rutting and corrugation information. This information can be obtained while in a vehicle parked or traveling slowly along the shoulder. Flushing, raveling, alligator cracking, longitudinal cracking, transverse cracking, patching, sealing and failure information may be collected from the film.

For rigid pavements, pumping, failures, surface deterioration, spalling, longitudinal cracking, patching, crack spacing, crack intersection, joint spacing, transverse cracking and crack sealing information can be obtained from the film. Shoulder, roadside, drainage and traffic service information should be obtained from the vehicle parked or traveling slowly along the shoulder.

The photographic method of collecting pavement rating information was checked for accuracy by analyzing both the photographs and the usual roadway methods. The Vertical Photologger was used to obtain information over a preselected section of pavement and the same section was analyzed by visual observation while walking along the pavement surface. The processed film was than analyzed. Ten sections of pavement with varying surface distress were selected for study. Five men were used in analyzing the photographic material and three men collected information from the roadway. Each analysis was performed independently with no consultation between men until after the work was completed. Two of the men analyzed both the roadways and the photographic material. Only the cracking information was tested. The results are shown in Table I. The values recorded in Table A are based on information developed for Research Report 151-2 and shown in Figures 6 and 7. The information shown in these figures shows a code number to be used for extent of damage. This number is to be shown in a certain column which indicates the severity of damage when considering the major heading "pavement". The code numbers are:

1. Used for the smaller % areas, lineal feet, or number

2. Used for medium extent of damage

3. Used for the larger extents of damage

The severities are:

Slight
Moderate
Severe

Therefore refering to Table I, a "1 sli" under Alligator would be a pavement which has alligator cracking over 1 to 5 percent of the surface area. The cracks are slight with very small widths and no spalling or pumping around the crack. As a future example, if Table I contained a 3 Sev under "Long" the pavement would have greater than 200 lineal feet of longitudinal cracking per station per lane. The cracking would be relatively wide with spalling or pumping possibly associated with the cracking. A 2M under "Trans" would indicate 5 to 9 transverse cracks per station with a moderate crack width and a small amount of spalling or pumping at the crack.

Note that the data on Sections 3, 4 and 6 shown in the Table A indicate minor cracking. These sections were selected because of the minor cracking and also because the cracks had very small widths. In fact, in the visual observations on the roadway it was necessary for the eye to be close to the surface before the cracks could be detected. There was concern that the film might not show the cracks with the lens and camera height which was used whereas the cracks could be found in usual observations of the roadway. This concern proved to be partially well founded

TABLE I
COMPARISON OF PHOTOGRAPHIC AND ROADWAY ANALYSES

		Photo Determination			Roadway Determination		
Sect.	Indiv.	Alligator	Long.	Trans.	Alligator	Long.	Trans.
1	a.	1 Sli	2 M	1 Sli			
	b					1 M	1 M
	c.		1 M	2 M	1 Sli	1 M	
	d.		2 M	2 M		2 M	2 Sev
	e.		2 M	2 M			
	f.		3 M	3 M			
2	a.		1 M	3 M			
	b.					1 M	2 M
	c.		2 M	2 M		1 M	2 M
	d.		1 M	2 M	———	———	———
	e.		1 M	3 M			
	f.		1 M	2 M			
3	a.		1 M				
	b.					0	
	c.		1 S		1 Sli		
	d.	2 Sli			1 Sli		
	e.		0				
	f.		0				
4	a.	1 Sli		1 Sli			
	b.				1 M		
	c.			1 Sli	1 Sli		
	d.	2 Sli					1 Sli
	e.		0				
	f.		0				
5	a.	1 Sli	1 Sev				
	b.				2 M	2 Ser	
	c.		2 M		2 M	2 M	
	d.	2 Sli	2 Sev		———	———	———
	e.		2 M				
	f.		3 Sev				
6	a.		0				
	b.					1 M	1 Sli
	c.		1 Sli	1 Sli		1 M	1 Sli
	d.		0			1 Sli	1 Sli
	e.		0				
	f.		0				

TABLE I CONTINUED

Sect.	Indiv.	Photo Determination Alligator	Long.	Trans.	Roadway Determination Alligator	Long.	Trans.
7	a.	2 M					
	b.				2 M	1 Sli	
	c.	2 M			2 M		
	d.	3 M			2 Sli	1 Sli	
	e.	1 M					
	f.	2 M					
8	a.	2 M					
	b.				2 M		
	c.	2 M			2 M		
	d.	3 M			2 Sli		
	e.	2 Sev					
	f.	3 M					
9	a.	3 M					
	b.				2 M		
	c.	3 Sev			3 M		
	d.	3 Sev			3 Sli		
	e.	3 Sev					
	f.	3 Sev					
10	a.	1 Sli					
	b.				2 Sli		
	c.	1 Sev			2 M		
	d.	2 S			2 Sli	1 Sli	
	e.	1 M					
	f.	2 Sev					

since the observers labeled "e and f" could not find cracking on these sections from the film. However, the observer labeled "b" did not find cracking in the film but did note cracking on the roadway. Therefore the determination of very small cracks from film could be a problem. However, this problem might be reduced since the roadway to be measured carries heavy traffic volumes and surface distress would be very evident. Also, it would be difficult to perform minor maintenance because of the traffic, therefore, only major maintenance or rehabilitation would probably be involved.

Table I shows considerable variation between observers. Some of this variation probably stems from the difficulty of rating between crack types. For example there were differences of opinion as to whether a pavement has alligator cracked or has a series of closely spaced transverse and longitudinal cracks. In almost every section there was also a difference of opinion between observers concerning the extent and the severity of distress. However, there were also differences of opinion when comparing photographic determinations with roadway determinations.

Epps et al, in Research Report 151-2, also offered a method of arriving at a numerical value representing the pavement condition which was called the "Pavement Rating Score". This method proposed a value of 100 to represent an excellent pavement condition and used certain values to deduct from this value for the various extents and severities of the distress. The deduct values which were proposed in Research Report 151-2 are found in Table II and III. These values were used in conjunction with Table I to form the information shown in Table IV. It may be noted that the deduct values are shown as having been calculated from the rating of each observer. Again Table IV indicates some variation between observers and between data collection methods. It would appear the overall differences between observers and collection methods are similar.

It was postulated that the best method of determining if the equipment produced acceptable results was to compare the variation or differences in deduct values between the data collection methods (photo verses roadway) with the variation in deduct values found between observers. If the variation between data collection methods was greater than the variation between observers, some doubt would exist as to whether the equipment was adequate. However, if the variation between observers proved greater than the variation between collection methods the equipment could be used since more error could be found due to individual opinion.

In order to obtain a more error-free analysis of the equipment, the data from observer "c" and "d" was used since they analyzed both the photographic material and the roadway. Table V shows the data and results of this analysis. The data was obtained directly from Table IV. Table V indicates the differences in deduct values found between the photo determinations and roadway determinations for each observer. The table also indicates the differences in deducted values found between individuals for both photo and roadway determinations. The differences appear to:

1. Be random from section to section.

Type of Distress	Degrees of Distress	Extent or Amount of Distress (1)	(2)	(3)
Rutting	Slight	0	2	5
	Moderate	5	7	10
	Severe	10	12	15
Raveling	Slight	5	8	10
	Moderate	10	12	15
	Severe	15	18	20
Flushing	Slight	5	8	10
	Moderate	10	12	15
	Severe	15	18	20
Corrugations	Slight	5	8	10
	Moderate	10	12	15
	Severe	15	18	20
Alligator Cracking	Slight	5	10	15
	Moderate	10	15	20
	Severe	15	20	25
Patching	Good	0	2	5
	Fair	5	7	10
	Poor	7	15	20

Deduct Points for Cracking

Longitudinal Cracking

	Sealed (1)	(2)	(3)	Partially Sealed (1)	(2)	(3)	Not Sealed (1)	(2)	(3)
Slight	2	5	8	3	7	12	5	10	15
Moderate	5	8	10	7	12	15	10	15	20
Severe	8	10	15	12	15	20	15	20	25

Transverse Cracking

	Sealed (1)	(2)	(3)	Partially Sealed (1)	(2)	(3)	Not Sealed (1)	(2)	(3)
Slight	2	5	8	3	7	10	3	7	12
Moderate	5	8	10	7	10	15	7	12	15
Severe	8	10	15	10	15	20	12	15	20

Failures		20	30	40

Mays Meter								
	Deduct Points	50	40	30	20	10	5	0
	SI	2.4	2.7	2.9	3.1	3.3	3.5	4.7

TABLE II: DEDUCT VALUES FOR FLEXIBLE PAVEMENT

Type of Distress	Degrees of Distress	Extent or Amount of Distress (1)	(2)	(3)
Pumping		20	40	60
Failures/Mile		20	30	40
Surface Deterioration	Slight	5	10	20
	Moderate	10	20	30
	Severe	20	40	60
Spalling	Slight	5	10	15
	Moderate	10	15	20
	Severe	20	40	60
Longitudinal Cracking	Slight	5	10	15
	Moderate	10	15	20
	Severe	15	20	25
Patching	Good	0	2	5
	Fair	5	7	10
	Poor	7	15	20
Faulting	Moderate	5	15	
	Severe	15	40	
Crack Spacing	Closed	0	10	
	Open	15	40	
% Intersecting Cracks	Moderate	5	15	
	Severe	15	40	
Joint Spacing	Information Only			
Transverse Cracking If Joint Spacing is less than 20 feet.				
	Slight	5	10	20
	Moderate	10	20	30
	Severe	15	30	40
If Joint Spacing is greater than 20 feet.				
	Slight	0	5	10
	Moderate	5	10	20
	Severe	10	15	30
Joints		0	10	20
Failures		20	30	40

Mays Meter	Deduct Points	50	40	30	20	10	5	0
	SI	2.4	2.7	2.9	3.1	3.3	3.5	4.7

TABLE III: DEDUCT VALVES FOR RIGID PAVEMENT

TABLE IV
DEDUCT VALUES FOR PHOTO AND ROADWAY

Sect.	Indiv.	Photo Determin.	Roadway Determin.	Sect.	Indiv.	Photo Determin.	Roadway Determin.
1	a.	20		6	a.	0	
	b.		17		b.		13
	c.	17	15		c.	8	13
	d.	27	27		d.	0	8
	e.	22			e.	0	
	f.	30			f.	0	
2	a.	15		7	a.	15	
	b.		13		b.		20
	c.	16	13		c.	15	15
	d.	13			d.	20	15
	e.	15			e.	10	
	f.	17			f.	15	
3	a.	5		8	a.	15	
	b.		0		b.		15
	c.	2	5		c.	15	15
	d.	10	5		d.	20	10
	e.	0			e.	20	
	f.	0			f.	20	
4	a.	8		9	a.	20	
	b.		10		b.		15
	c.	5	5		c.	25	20
	d.	10	3		d.	25	15
	e.	0			e.	25	
	f.	0			f.	25	
5	a.	20		10	a.	5	
	b.		35		a.		10
	c.	15	27		c.	15	15
	d.	25			d.	10	15
	e.	15			e.	10	
	f.	25			f.	20	

TABLE V
COMPARISON OF DATA COLLECTION METHODS AND OBSERVERS

Sect.	Observer	Photo Determin.	Roadway Determin.	Diff. Photo: Road For C	Diff. Photo: Road For D	Diff. Between Observers Photo	Diff. Between Observers Road
1	c	17	15				
	d	27	27	+2	0	-10	-12
2	c	16	13				
	d	13	-	+2	---	+ 3	---
3	c	2	5				
	d	10	5	-3	+5	- 8	0
4	c	5	5				
	d	10	3	0	+7	- 5	+ 2
5	c	15	27				
	d	25	—	-12	---	-10	---
6	c	8	13				
	d	0	8	5	-8	+ 8	+ 5
7	c	15	15				
	d	20	15	0	+5	- 5	0
8	c	15	15				
	d	20	10	0	+10	- 5	+ 5
9	c	25	20				
	d	25	15	+5	+10	0	+ 5
10	c	15	15				
	d	10	15	+5	0	+ 5	0
		Average		3.5	4.5	5.9	3.6

Note the "---" indicates the section had been sealed before "d" could observe the section. A "-" indicates the roadway or observer "d" had a greater value.

2. Show little overall variation between observers and collection methods. The average difference between observers (discounting sign) was found to be 3.5 for observer "d". The average difference between the collection methods was found to be 5.9 for the "Photo" and 3.6 for the "Roadway".

Therefore, it is recommended that the Vertical Photologger be used to obtain pavement distress information on high speed, high volume facilities to reduce danger to rating crews and traffic. The cost of the equipment is estimated to be $10.35 per mile. Approximately 50 to 75 miles may be inventoried per day. The estimate is based on sampling the pavement every mile similar to that suggested in the roadway rating. The sample would be continuous, end-to-end frames for a 200-foot distance every mile, with photos also obtained in areas noted from the moving vehicle as being heavily distressed. Twenty-five frames would be obtained every mile. Using a 250-frame magazine, approximately 7 miles could be inventoried before a magazine change. About 15 minutes are needed for a magazine change and about 45 minutes are needed per mile including the magazine change, down time, etc. The cost is approximately $0.05 per frame for the film and approximately $0.05 per frame for processing. Therefore, the cost was estimated as follows:

Film - $0.10/Frame @ 35 Frames	= 3.50
Personnel - 2 Men @ $100/Day @ 60 miles/Day	= 3.35
Equipment - Vertical Photologger @ $0.30/Mi	= .30
Traffic Control Personnel - 2 Men @ $90/Day @ 60 miles/Day	= 3.00
Traffic Control Equipment - @ $0.20/Mi	= .20
Total	$ 10.35

The analysis of photographic material indicates one person can analyze ten 200-foot sections in about two hours. Each of the ten sections was on a separate roll of film and the time included inserting and removing the film. With this experience as information, one person could analyze the equipment of 40 miles of roadway per day.

REFERENCES

1. Curtis L. Goss, Kenneth D. Hankins, Allan B. Hubbard; "Equipment for Collecting Pavement Roughness Information"; State Department of Highways and Public Transportation; Research Report 2-1; December 1976.

2. "System SKIDR: Manual for the Automated Skid Resistance Survey"; Texas State Department of Highways and Public Transportation; Transportation Planning Division.

3. Samuel H. Carpenter, Robert L. Lytton, Jon A. Epps; "Environmental Factors Relevant to Pavement Cracking in West Texas"; Texas Transportation Institute; Research Report No. 18-1; January 1974.

4. Momahed Y. Shahin, B. Frank McCullough; "Prediction of Low Temperature and Thermal-Fatigue Cracking in Flexible Pavements"; Center for Highway Research, Research Report 123-14; August 1972.

5. Texas Weather Data Collection and Retrieval System Manual; Division of Automation, Texas Department of Highways and Public Transportation; September 1976.

6. Robert L. Lytton, Personal Correspondence, November 8, 1976.

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APPENDIX A

CURRENT LIST OF CLIMATOLOGICAL STATIONS

LIST OF CLIMATOLOGICAL STATIONS

Co. No.	County Name	Dist. No.	Primary Location	Location Number	Secondary Location	Location Number
1	Anderson	10	Palestine	6757		
2	Andrews	6	Andrews	0248		
3	Angelina	11	Lufkin FAA-AP	5424		
4	Aransas	16	Rockport	7704	Aransas Wildlife Refuge	0305
5	Archer	3	Archer City	0313	Dundee 6NNW	2633
6	Armstrong	4	Claude	1778	Wayside	9527
7	Atascosa	15	Charlotte 5NNW	1663	Jourdanton	4647
8	Austin	12	Columbus in Co. No. 45	1911		
9	Bailey	5	Muleshoe 1	6135	Muleshoe 2 (3NW)	6136
10	Bandera	15	Tarpley	8845	Medina	5742
11	Bastrop	14	Red Rock	7497	Elgin	2828
12	Baylor	3	Seymour	8221	Red Springs 2 ESE	7499
13	Bee	16	Beeville 5 NE	0639		
14	Bell	9	Killeen	4791	Stillhouse Hollow Dm.	
15	Bexar	15	San Antonio WB AP	7945	Randolph Field	7422
16	Blanco	14	Johnson City	4605	Blanco	0832
17	Borden	8	Gail	3411	Knapp 6 SW(Co.No. 208)	4841
18	Bosque	9	Whitney Dam	9715	Iredell	4476
19	Bowie	19	Texarkana	8942	DeKalb	2352
20	Brazoria	12	Angleton 2 W	0257	Freeport 2 NW	3340
21	Brazos	17	College Sta. FAA-AP	1889		
22	Brewster	24	Panther Junction	6792	Chisos Basin	1715
23	Briscoe	25	Silverton	8323	Quitague	7361
24	Brooks	21	Falfurrias	3063		
25	Brown	23	Brownwood	1138		
26	Burleson	17	Sommerville Dam	8446	Caldwell	1314
27	Burnet	14	Burnet	1250	Bertram 3 ENE	0738
28	Caldwell	14	Luling	5429	Lockhart	5284
29	Calhoun	13	Port Lavaca 2	7182	Port O'Conner	7186
30	Callahan	8	Putnam	7327	Cross Plains	2128
31	Cameron	21	Harlingen	3943	Brownsville WSO-AP	1136
32	Camp	19	Pittsburg 5 S	7066		
33	Carson	4	Panhandle	6785		
34	Cass	19	Linden	5229	Atlanta	0408
35	Castro	5	Dimmitt 2 N	2464	Dimmitt 6 E	2463
36	Chambers	20	Anahuac TBCD	0235		
37	Cherokee	10	Rusk	7841	Jacksonville	4525
38	Childress	25	Childress FAA-AP	1698	Childress 13 NW	1697
39	Clay	3	Henrietta	4093	New Port	6331
40	Cochran	5	Morton 1 WNW	6074		
41	Coke	7	Robert Lee	7669	Water Valley IONNE	9501
42	Coleman	23	Hords Creek Dam	4278	Coleman	1875
43	Collin	18	Lavon Dam	5094	McKinney 3 S	5766
44	Collingsworth	25	Wellington 2	9570		
45	Colorado	13	Columbus	1911	Eagle Lake	2675
46	Comal	15	New Braunfels	6276	Canyon Dam	1429
47	Comanche	23	Proctor Res.	7300	Comanche	1914
48	Concho	7	Eden 1	2741	Eden 2	2744
49	Cooke	3	Gainesville	3415	Muenster	6130
50	Coryell	9	Gatesville	3485	Coryell City	2024
51	Cottle	25	Paducah	6740		
52	Crane	6	Crane	2082		
53	Crockett	7	Ozona	6734	Ozona 8 WSW	6736
54	Crosby	5	Crosbyton	2121	Lorenzo	5363
55	Culberson	24	Van Horn	9295	Salt Flat IOENE	7921
56	Dallam	4	Dalhart FAA-AP	2240	Conlen	1946
57	Dallas	18	Dallas FAA-AP	2244	Dal-Ft.W Reg WSMO AP	2242
58	Dawson	5	Lamesa 1 SSE	5013	Ackerly	0034
59	Deaf Smith	4	Hereford	4098		
60	Delta	1	Cooper	1970		

Co. No.	County Name	Dist. No.	Primary Location	Location Number	Secondary Location	Location Number
61	Denton	18	Denton 2 SE	2404	Justin	4679
62	DeWitt	13	Cuero	2173	Yorktown	9953
63	Dickens	25	Dickens	2448		
64	Dimmit	22	Catarina	1528	Carizzo Springs	1486
65	Donley	25	Clarendon	1761		
67	Duval	21	Benavides 2	0690	Freer	3341
68	Eastland	23	Eastland	2715	Gorman	3646
69	Ector	6	Penwell	6932	Odessa	6502
70	Edwards	22	Rocksprings	7706	Carta Valley	1492
71	Ellis	18	Waxahachie	9522	Bardwell Dam	0518
72	El Paso	24	Fabens	3033	Ysleta	9966
73	Erath	2	Stephenville WSMO	8623	Dublin	2598
74	Falls	9	Marlin 3 NE	5611		
75	Fannin	1	Bonham	0923	Honey Grove	4257
76	Fayette	13	LaGrange	4903	Flatonia 2W	3183
77	Fisher	8	Rotan	7782		
78	Floyd	5	Floydada	3214	Floydada 9 SE	3215
79	Foard	25	Crowell	2142		
80	Fort Bend	12	Thompson 3 WSW	8996	Richmond	7594
81	Franklin	1	Mount Vernon	6119	Hagansport	3846
82	Freestone	17	Fairfield	3047	Longlake 5 SW	5327
83	Frio	15	Pearsall	6879	Dilley	2458
84	Gaines	5	Seminole	8201	Loop	5351
85	Galveston	12	Galveston WSOCI	3430		
86	Garza	5	Post	7206		
87	Gillespie	14	Fredericksburg	3329	Gold	3605
88	Glasscock	7	Garden City 1 E	3445		
89	Goliad	16	Goliad	3618	Goliad 1 SE	3620
90	Gonzales	13	Gonzales	3622	Nixon	6368
91	Gray	4	Pampa No. 2	6776	McLean 3 E	5770
92	Grayson	1	Denison Dam	2394	Sherman Pump Sta.	8274
93	Gregg	10	Longview	5341	Gladewater 3 WSW	3565
94	Grimes	17	Bedias	0635	Richards	7586
95	Guadalupe	15	New Braunfels	6276	Canyon Dam	1429
96	Hale	5	Plainview	7079	Abernathy	0012
97	Hall	25	Memphis	5821	Turkey 2 WSW	9191
98	Hamilton	9	Hamilton 2 SSE	3884	Indian Gap	4440
99	Hansford	4	Gruver	3787	Spearman	8523
100	Hardeman	25	Quanah 5 SE	7336		
101	Hardin	20	Kountze 3 SE	4878		
102	Harris	12	Houston WSMO AP	4300	Houston FAA AP	4307
103	Harrison	19	Marshall	5618	Karnack	4693
104	Hartley	4	Channing	1646	Hartley	3981
105	Haskell	8	Haskell	3992		
106	Hays	14	San Marcos	7983		
107	Hemphill	4	Canadian 1 ENE	1412	Gageby	3410
108	Henderson	10	Athens 3 SSE	0404	Trinidad Powr. Plt.	9137
109	Hidalgo	21	McAllen FAA-AP	5702	McAllen	5701
110	Hill	9	Hillsboro	4182	Kopperl 5 NNE	4866
111	Hockley	5	Levelland	5183	Pep	6935
112	Hood	2	Lipan	5243	Cresson	2096
113	Hopkins	1	Sulphur Springs	8743		
114	Houston	11	Lovelady	5398	Crockett	2114
115	Howard	8	Big Spring	0786	Big Spring Field Sta.	0784
116	Hudspeth	24	Sierra Blanca	8305	Cornudas Service Sta.	2012
117	Hunt	1	Greenville 7 NW	3734	Commerce	1921
118	Hutchinson	4	Borger 3 W	0958	Stinnett	8647
119	Irion	7	Mertzon	5859	Funk Ranch	3401
120	Jack	2	Jacksboro	4517	Antelope	0271

Co. No.	County Name	Dist. No.	Primary Location	Location Number	Secondary Location	Location Number
121	Jackson	13	Edna	2768		
122	Jasper	20	Jasper	4563	Horger	4280
123	Jeff Davis	24	Mt. Locke	6104	Valentine	9270
124	Jefferson	20	Port Arthur WSO AP	7174	Port Arthur City	7172
125	Jim Hogg	21	Hebbronville	4058		
126	Jim Wells	16	Alice	0144		
127	Johnson	2	Cleburne	1800	Burleson 2 SSW	1245
128	Jones	8	Anson	0268	Stamford 2	8584
129	Karnes	16	Kenedy 1E	4752	Runge	7836
130	Kaufman	18	Kaufman 3SE	4,05	Terrell	8929
131	Kendall	15	Boerne	0902	Bankersmith	0509
66	Kenedy	21	Armstrong	0342	Sarita 7E	8081
132	Kent	8	Jayton	4570		
133	Kerr	15	Kerrville	4780	Kerrville 3 NNE	4782
134	Kimble	7	Junction	4670	London	5312
135	King	25	Guthrie	3828		
136	Kinney	22	Brackettville	1007		
137	Kleberg	16	Kingsville	4810		
138	Knox	25	Truscott	9163	Munday	6146
139	Lamar	1	Paris	6794	Deport	2415
140	Lamb	5	Littlefield #2	5265	Olton	6644
141	Lampasas	23	Adamsville	0050	Moline	5996
142	LaSalle	15	Cotulla FAA AP	2050	Cotulla	2048
143	Lavaca	13	Hallettsville	3873	Yoakum	9952
144	Lee	14	Lexington	5193	Fedor	3112
145	Leon	17	Centerville	1596	Jewett	4591
146	Liberty	20	Liberty	5196	Cleveland	1810
147	Limestone	9	Mexia	5869	Thornton	9004
148	Lipscomb	4	Lipscomb	5247	Follett	3225
149	Live Oak	16	George West	3508	Three Rivers	9009
150	Llano	14	Llano	5272	Castell	1521
151	Loving	6	Red Bluff Dam	7481		
152	Lubbock	5	Lubbock WSFO AP	5411	Lubbock 9N	
153	Lynn	5	Tahoka	8818	Slaton 5 SE	8373
154	Madison	17	Madisonville	5477		
155	Marion	19	Jefferson	4577		
156	Martin	6	Lenorah	5158		
157	Mason	14	Mason 4 W	5650	James Riv. Reh.	4538
158	Matagorda	12	Matagorda 2	5659	Bay City Waterwks	0569
159	Maverick	22	Eagle Pass	2679		
160	McCulloch	23	Brady	1017	Doole 6 NNE	2527
161	McLennan	9	Waco WSO AP	9419	Waco Dam	9417
162	McMullen	15	Tilden	9031		
163	Medina	15	Hondo WSMO AP	4256	Natalia	6205
164	Menard	7	Menard	5822		
165	Midland	6	Midland/Odessa WSO AP	5890	Midland 4 ENE	5891
166	Milam	17	Cameron	1348	Rockdale	7685
167	Mills	23	Goldwaite 1 WSW	3614	Center City	1580
168	Mitchell	8	Lake Colorado City	4974	Colorado City	1903
169	Montague	3	Bowie	0984	Bonita	0926
170	Montgomery	12	Conroe	1956	New Caney 4 NW	6280
171	Moore	4	Sunray 4 SW	8761	Dumas	2617
172	Morris	19	Daingerfield 9 S	2225	Naples 1 SW	6190
173	Motley	25	Matador	5658	Matador #2	5656
174	Nacogdoches	11	Nacogdoches 2 ENE	6177		
175	Navarro	18	Corsicana	2019	Navarro-Mills Dam	6210
176	Newton	20	Kirbyville 5 ESE	4819	Bon Wier	0917
177	Nolan	8	Roscoe	7743		
178	Nueces	16	Corpus Christi WSO AP	2015	Robstown	7677
179	Ochiltree	4	Notla 3 SE	6477	Buler 4 NNW	1203
180	Oldham	4	Vega	9330	Tascosa	8852
181	Orange	20	Orange 4 NW	6664		
182	Palo Pinto	2	Mineral Wells FAA	5958	Mineral Wells 1 SSW	5957
183	Panola	19	Carthage	1500		
184	Parker	2	Weatherford	9532	Reno	7556
185	Parmer	5	Friona	3368		
186	Pecos	6	Ft. Stockton KFST Radio	3280	Bakersfield	0482
187	Polk	11	Livingston 2 NNE	5271		
188	Potter	4	Amarillo WSO AP	0211		

Co. No.	County Name	Dist. No.	Primary Location	Location Number	Secondary Location	Location Number
189	Presidio	24	Marfa #2	5596	Presidio	7262
190	Rains	1	Emory	2902		
191	Randall	4	Canyon	1430	Umbarger	9224
192	Reagan	7	Big Lake 2	0779	Big Lake - LCRA 140	0776
193	Real	22	Prade Ranch	7232	Leakey	5113
194	Red River	1	Clarksville 2 NE	1773	Clarksville 1W	1773
195	Reeves	6	Pecos	6892	Pecos 12 SSW	6893
196	Refugio	16	Refugio	7529		
197	Roberts	4	Miami	5875		
198	Robertson	17	Franklin	3321	Bremond	1045
199	Rockwall	18	Dallas FAA AP	2244	Dal-Ft.W. Reg. WSMO AP	2242
200	Runnels	7	Ballinger 1 SW	0493	Winters 1 NNE	9847
201	Rusk	10	Henderson	4081	Overton	6722
202	Sabine	11	Hemphill	4076	Bronson	1094
203	San Augustine	11	Jackson Hill GS	4523	San Augustine	7951
204	San Jacinto	11	Cold Spring 5 SSW	1870		
205	San Patricio	16	Sinton	8354	Mathis	5661
206	San Saba	23	San Saba	7992	Richland Spr.	7593
207	Schleicher	7	Eldorado 11 NW	2812	Eldorado 1 N	2811
208	Scurry	8	Snyder	8433	Knapp 6 SW	4841
209	Shackelford	8	Albany	0120		
210	Shelby	11	Center	1578		
211	Sherman	4	Stratford	8692		
212	Smith	10	Tyler 5 NE	9214	Swan 4 NW	8778
213	Somervell	2	Glen Rose 2W	3591		
214	Starr	21	Falcon Dam	3060	Rio Grande City 3 W	7622
215	Stephens	23	Brackenridge	1042		
216	Sterling	7	Sterling City	8630	Sterling City 8 NE	8631
217	Stonewall	8	Aspermont 2 SSW	0394		
218	Sutton	7	Sonora	8449	Humble Pump Sta. 5 WNW	4363
219	Swisher	5	Tulia	9175	Kress	4880
220	Tarrant	2	Ft. Worth WSO AP	3284	Ft. Worth Federal Bldg	3285
221	Taylor	8	Abilene WSO AP	0016	Lake Abilene	4960
222	Terrell	6	Sanderson	8022	Dryden	2590
223	Terry	5	Brownfield #2	1128		
224	Throckmorton	3	Throckmorton 2 W	9014	Woodson 5 NNE	9893
225	Titus	19	Mt. Pleasant	6108		
226	Tom Green	7	San Angelo Dam	7940	San Angelo WSO AP	7943
227	Travis	14	Austin WSO AP	0428		
228	Trinity	11	Groveton	3778		
229	Tyler	20	Warren	9480		
230	Upshur	19	Gilmer 2W	3546		
231	Upton	6	Rankin	7431	McCamey	5707
232	Uvalde	22	Uvalde	9265	Sabinal 1 WSW	7873
233	Val Verde	22	Langtry	5048	Del Rio WSO AP	2360
234	Van Zandt	10	Wills Point	9800	Canton	1425
235	Victoria	13	Victoria WSO AP	9364		
236	Walker	17	Huntsville	4382		
237	Waller	12	Hempstead	4080	Waller 3 SSW	9448
238	Ward	6	Monahans	5999	Grandfalls 3 SSE	3680
239	Washington	17	Brenham	1048	Washington St. Park	9491
240	Webb	21	Laredo #2	5060	Encinal 3 NW	2906
241	Wharton	13	Pierce 1E	7020	New Gulf	6286
242	Wheeler	25	Shamrock Radio KBYP	8236	Shamrock	8235
243	Wichita	3	Wichita Falls WSO AP	9729	Electra	2818
244	Wilbarger	3	Vernon	9346		
245	Willacy	21	Raymondville	7458	Port Mansfield	7184
246	Williamson	14	Georgetown	3506	Taylor	8861
247	Wilson	15	Floresville	3201		
248	Winkler	6	Wink FAA AP	9830	Wink	9829
249	Wise	2	Bridgeport	1063	Lake Bridgeport Dam	4972
250	Wood	10	Mineola 8 ENE	5956	Quitman 2S	7363
251	Yoakum	5	Plains	7074		
252	Young	3	Graham	3668	Olney	6636
253	Zapata	21	Zapata	9976		
254	Zavala	22	Crystal City	2160	Batesville	0560