TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
TX-83/299-3		

4. Title and Subtitle METHODOLOGY FOR ASSESSING AND PREDICTING THE EFFECTS OF OIL FIELD DEVELOPMENT	5. Report Date July 1983 6. Performing Organization Code
7. Author(s) J. M. Mason, D. Underbrink, B. Stampley, T. Scullion, and N. J. Rowan	8. Performing Organization Report No. Research Report 299-3
9. Performing Organization Name and Address Texas Transportation Institute Texas A&M University College Station, Texas 77843-3135	10. Work Unit No. 11. Contract or Grant No. 2-8-81-299
12. Sponsoring Agency Name and Address Texas State Department of Highways and Public Transportation; Transportation Planning Division	13. Type of Report and Period Covered Research Report - Phase II Sept. 1981 to Mar. 1983 14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

In the last five years, oil field exploration and development has rapidly expanded in Texas. Because of the resulting impact on rural roads, the Texas Department of Highways and Public Transportation wanted to provide a means of predicting the present and future effects of oil field development on rural highways. The main objectives of this research were to develop a method for estimating the amount and type of oil field traffic on a particular roadway and to use the Texas Pavement Distress Equations to assess and predict the reductions in pavement service life from oil field traffic.

An oil field impacted area was studied in Brazos County. There, a light duty surface-treated road, F.M. 2038, was investigated for the effects of oil field traffic on its pavement. Truck traffic was converted to 18-kip equivalent single axle load repetitions which were analyzed for their effect on 6-inch and 10-inch surface-treated pavements. Resulting pavement service lives were compared for various measures of pavement distress. Reductions in service life generally range from 60 to 75 percent. Actual loss of pavement utility varies among the distress types. Raveling and flushing distress produce a 75 percent reduction in service life for both the 6-inch and 10-inch pavements. Since these distresses are traffic associated, the increase in average daily traffic is primarily responsible for this loss of service. Load associated distress (rutting and alligatoring) result in approximately 60 percent loss of life. The thinner 6-inch pavement is, as expected, very sensitive to increased axle loadings.

17. Key Words	18. Distribution Statement
Truck Traffic, Pavement Distress, Oil Field Traffic, Pavement Serviceability, Pavement Design	No Restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	57	

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METHODOLOGY FOR ASSESSING AND PREDICTING THE EFFECTS OF OIL FIELD DEVELOPMENT

by

J. M. Mason, D. Underbrink, B. Stampley, T. Scullion, and N. J. Rowan

Research Report 299-3

Research Project 2-8-81-299

Phase II

Conducted for

The State Department of Highways and Public Transportation

by the

Texas Transportation Institute
The Texas A&M University System
College Station, Texas 77843

July 1983

ACKNOWLEDGEMENT

This phase of the project was sponsored by the Texas State Department of Highways and Public Transportation. John M. Mason served as Principal Investigator, while David M. Underbrink and Bryan E. Stampley served as Graduate Research Assistants. Mr. Gerald B. Peck was the Contact Representative for the State Department of Highways and Public Transportation. The Technical Advisory Committee acted as an integral part of this study; their continuous guidance and support are greatly appreciated.

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ABSTRACT

This study outlines a basic methodology for estimating the amount and type of oil field traffic on a selected roadway. The Texas Pavement Distress Equations are used to predict reductions in pavement service life caused by oil field truck traffic.

The procedure includes a case study example to identify and delineate major oil field activity centers. Truck traffic generated in these centers is converted to 18-kip equivalent single axle load repetitions which are analyzed for their effect on 6-inch and 10-inch surface-treated pavements. Resulting pavement service lives are compared for various measures of pavement distress (pavement serviceability index, rutting, alligatoring, flushing, and raveling). This technique provides a basis for anticipating resurfacing intervals and rehabilitation requirements.

SUMMARY

The principal objectives of this study were to develop a methodology for estimating oil field traffic on a given roadway and to illustrate the use of the Texas Pavement Distress Equations in assessing pavement performance under oil field truck traffic. The study procedure includes an identification of oil field activity centers, the delineation of an area of related influence, and an estimate of rate of oil field development. This information describes the oil field traffic characteristics which are converted to 18-kip equivalent single axle load (18-k ESAL) repetitions and analyzed for their effect on 6-inch and 10-inch surface-treated pavements. Various measures of pavement distress are compared to an intended-use traffic condition, and an estimate of reduced pavement performance is calculated.

Several density maps were developed for the Brazos County case study example. These density maps depict the extent of drilling and production activity in the study area. The primary activity centers were delineated based on the composite of related oil field activity throughout the county. A low-volume, surface-treated farm-to-market road (F.M. 2038) was selected for evaluation. Both 6-inch and 10-inch pavement thicknesses were analyzed, using a computer program that estimates the service life of surface-treated pavement.

The limits of oil field traffic influence were established for F.M. 2038, and an estimate of oil well development was determined for a 4-year time period. Truck traffic generated in the influence area was converted to 18-k ESAL repetitions for use in the pavement distress program. Various levels of distress were examined to determine the effect of the increased truck traffic demand.

Reductions in service life generally range from 60 to 75 percent. Actual loss of pavement utility varies among the distress types. Raveling and flushing distress experience a 75 percent reduction in service life for both the 6-inch and 10-inch pavements. Since these distresses are traffic associated, the increase in average daily traffic is primarily responsible for this loss of service. Load associated distress (rutting and alligatoring) result in approximately 60 percent loss of life. The thinner 6-inch pavement is, as expected, very sensitive to increased axle loadings.

The methodology developed in this study can be used to assess accumulated changes in traffic conditions and to predict the impact of future oil field development. Actual number of wells drilled and producing in a county vary from region to region. However, the magnitude and rate can be estimated from records maintained by the Texas Railroad Commission and through the purchase of current oil field property maps.

This technique can be used to evaluate alternative maintenance strategies or to select pavement thickness commensurate with a truck traffic demand. At the Department level, the procedure can aid in allocating funds to Districts which are in particular need of additional maintenance or reconstruction monies. The versatility of the computer program provides a framework for examining other "special-use" truck traffic conditions.

IMPLEMENTATION STATEMENT

In a previous investigation, site-specific observations identified local oil field traffic and estimated reduced-pavement serviceability. After additional observations were conducted to verify the initial traffic characteristics, a computer program was developed to assess the impact of regional oil field truck traffic.

The results of this analysis provide an overall methodology to be used in evaluating the effects of oil field truck traffic on thin surface-treated pavements, using the Texas Pavement Distress Equations. Oil field density maps must be developed and updated on a regular basis to effectively monitor the activity in oil producing counties of Texas. The benefits of using this procedure can be realized at both the District and Departmental levels. This fundamental framework of analysis can also be applied conceptually to other "special-use" truck traffic situations.

DISCLAIMER

The views, interpretations, analyses, and conclusions expressed or implied in this report are those of the authors. They are not necessarily those of the Texas State Department of Highways and Public Transportation.

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INTRODUCTION

The Problem

The Arab Oil Embargo of 1973 spurred an increase in the amount and intensity of oil field development throughout the nation. In the oil-rich regions of Texas, this increased activity had an adverse impact upon many light-duty rural highways. These highways were intended to service low volumes of passenger cars and light trucks and were not built to withstand the impact of the load-intensive, special-use oil field traffic.

The Texas State Department of Highways and Public Transportation found it necessary to determine the effects of oil field development on rural highways. Phase One of the research (published in Research Report 299-1) identified traffic and vehicle characteristics associated with oil field development and estimated a reduction in pavement service life due to this specialized user (1).

Phase Two of the research involved developing and applying a method of assessing the current effects, and predicting the future effects, of oil field development upon any particular rural highway. The method is in the form of a computer program, "Oil Field Damage Program", and is fully described in Research Report 299-2 (2). Although it was developed as a means of predicting the present and future effects of oil field development, the same basic principle can be used to develop programs for examining the effects of other types of load-intensive, special-use traffic.

The Department can monitor trends in oil field development activity by periodically updating accurate maps of oil field activity centers within local areas. It can then use this information to identify and treat roadways with current oil field development or to allocate future maintenance and reconstruction funds for roadways expected to be impacted by future oil field development.

Phase II Objectives

The goal of the ongoing research is to examine the effects of oil field traffic on Texas highways. In working toward this goal, several phases of study were envisioned. The objectives of this particular phase (Phase II) are as follows:

1. Verify the oil well traffic characteristics found in Phase I.
2. Develop and document a procedure to predict the reduction in pavement life due to oil field truck traffic.
3. Develop a method for estimating the amount and type of oil field traffic on a particular roadway.
4. Use the Texas Pavement Distress Equations to assess the condition of a pavement due to past oil field traffic.
5. Use the Texas Pavement Distress Equations to predict the condition of a pavement under future levels of oil field development.

This report covers objectives 3, 4, and 5 of Phase II. A previous report, Report 299-2, addressed the first two objectives.

STUDY PROCEDURE

In order to estimate and describe oil field traffic on a specific roadway, an "overall picture" of oil field development is necessary. Once the impacted region is delineated, individual roads can be identified within the major producing areas. These affected roadways serve both an intended-use traffic and the special-use oil field traffic. Since the existing roadway must therefore accommodate an increased demand, the anticipated design life is shortened considerably. To better define the resulting change in pavement performance, a methodology for assessing and predicting the effects of oil field development has been prepared.

The study procedure is depicted in Figure 1. Details of each information step are discussed under an appropriate section in this report. In general, the procedure illustrates the need to identify specific activity centers, describe the associated traffic characteristics, and estimate the effect of changes in an intended-use traffic demand on a roadway pavement.

Oil field activity in a region is identified through the following steps:

1. Develop a base map of the study area.
2. Locate (plot) related oil field activity centers.
3. Prepare a composite of the impacted area and delineate areas of influence.

Develop Base Map

The size of the study area influences the detail of the base map. Brazos County was selected as a case study example, because of the recent increase in oil field activity in 1981-1982. A base map was developed for it. The base map (Figure 2) is basically a county map from the State Department of Highways

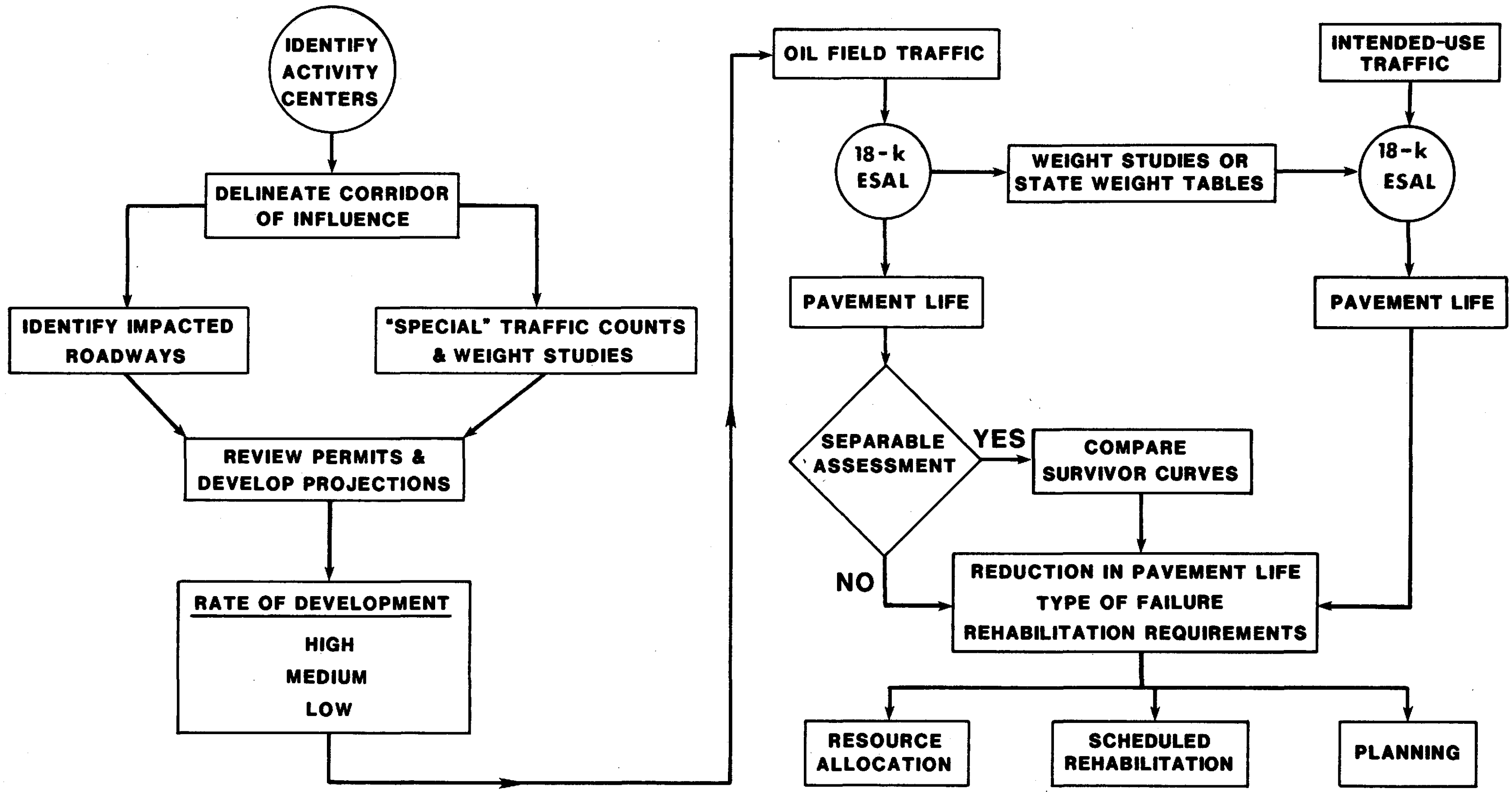


Figure 1. Study Procedure.

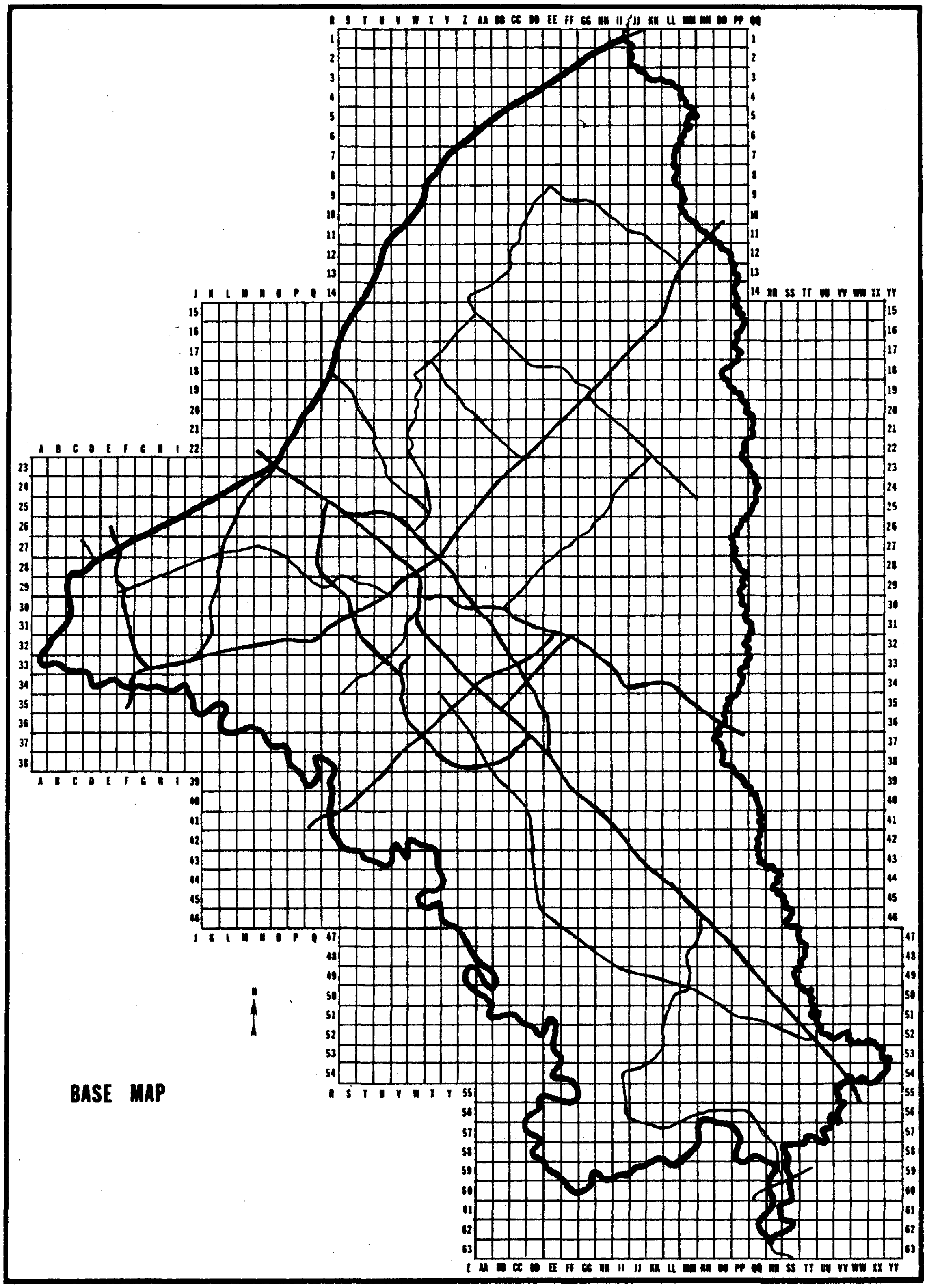


Figure 2. Base Map (Brazos County).

and Public Transportation, (SDHPT) with the county boundaries and pertinent roadways traced on a 24 x 36 in. sheet of Mylar paper at a scale 1 in. = 2 mi. This map size was satisfactory for showing minor roads and streets, creeks, rivers, ponds, and lakes, as well as lines of latitude and longitude. The lines of latitude and longitude orient the base map and serve as an initial "map grid" system.

The size of the map grid system was developed considering state regulations governing oil well density. In Texas, oil field activity is regulated by the Texas Railroad Commission, which typically allows a maximum density of 1 well to each 40 acres (3). In this example, the county map was divided into 51 sectors from east to west and 63 sectors from north to south. Each sector contains 284 acres (approximately 0.67 mi. on a side) and can support 7 oil wells at maximum allowable development.

Optimum production of oil is enforced through spacing requirements for wells. Exceptions to the Commission's Rule 37 (Statewide Spacing Rule) can be filed with proper justification (3). As such, the development of an oil field base map grid system must consider the particular rate of development in a region. The resulting grid size must appropriately depict local activity and be relatively simple to interpret. A "sub-grid" system may be necessary in areas of very dense development.

Locate Oil Field Activity Centers

The map grid system divides the county into sectors. For any given oil field related activity, the number of activity centers is determined for each sector and plotted on separate density maps. The resulting density maps show the extent of a particular activity in the study area.

Oil field activity was segregated into three general types:

1. Service companies
2. Wells drilled
3. Producing wells

Locations of Service Companies. Service companies in Brazos County were located using telephone books from surrounding communities. City maps aided in further locating specific companies. The primary purpose of this effort was to estimate the number of service companies in each sector. To simplify this task, an accounting system was established to tabulate the number of service companies located in each sector, an example of which is shown summarized in Figure 3. The tabulated values are classed according to the legend shown in Figure 4.

Locations of Wells Drilled. The status and location of oil and gas wells throughout the state are available on large-scale maps prepared by several private agencies. A list of current map suppliers is shown in Table 1. Maps can be ordered by county at a cost between $25 and $150 a sheet. Depending on the density of activity, a county may need to be purchased in several sections for full area coverage. Pertinent map information includes property ownership, lease information, and geographical data, such as roads, rivers, and lines of longitude and latitude.

Since Brazos County is mapped in overlapping sections, three sheets were purchased which covered the west, north, and south portions of the county. The base map grid system was appropriately scaled and placed on each map. The amount and status of each well was determined in each sector. An accounting system was again used to tabulate the quantity and status of the wells in each sector. A sample of the accounting system is shown in Figure 5.

Sector		Number of Service Companies
F	36	18
	37	18
K	32	1
L	32	2
	33	2
P	42	8
R	25	2
	28	1
	29	1
	31	1
S	29	1
	30	6
	31	11
	32	3
U	27	2
	31	1
	38	1
V	24	1
	27	3
	32	2
	33	3
	34	1
	35	1
W	26	3
	27	3
	29	4
	30	6
	31	1
X	24	1
	25	1
	27	19
	28	1
	30	3
	32	3
	33	2
	34	1
Y	25	1
	27	19
	28	1
	32	2
Z	24	1
	32	3
	33	2
AA	25	3
	31	3
	32	3
	33	1
	35	3

Sector		Number of Service Companies
BB	30	1
	32	3
	35	2
	36	2
	37	2
CC	22	2
	23	1
	34	3
	36	4
DD	22	6
	34	1
	38	5
EE	33	1
	38	2
FF	38	1
GG	19	9
	20	3
KK	23	1
PP	10	5
QQ	37	1
WW	56	5

Figure 3. Summary Sheet for the Accounting of Service Company Locations.

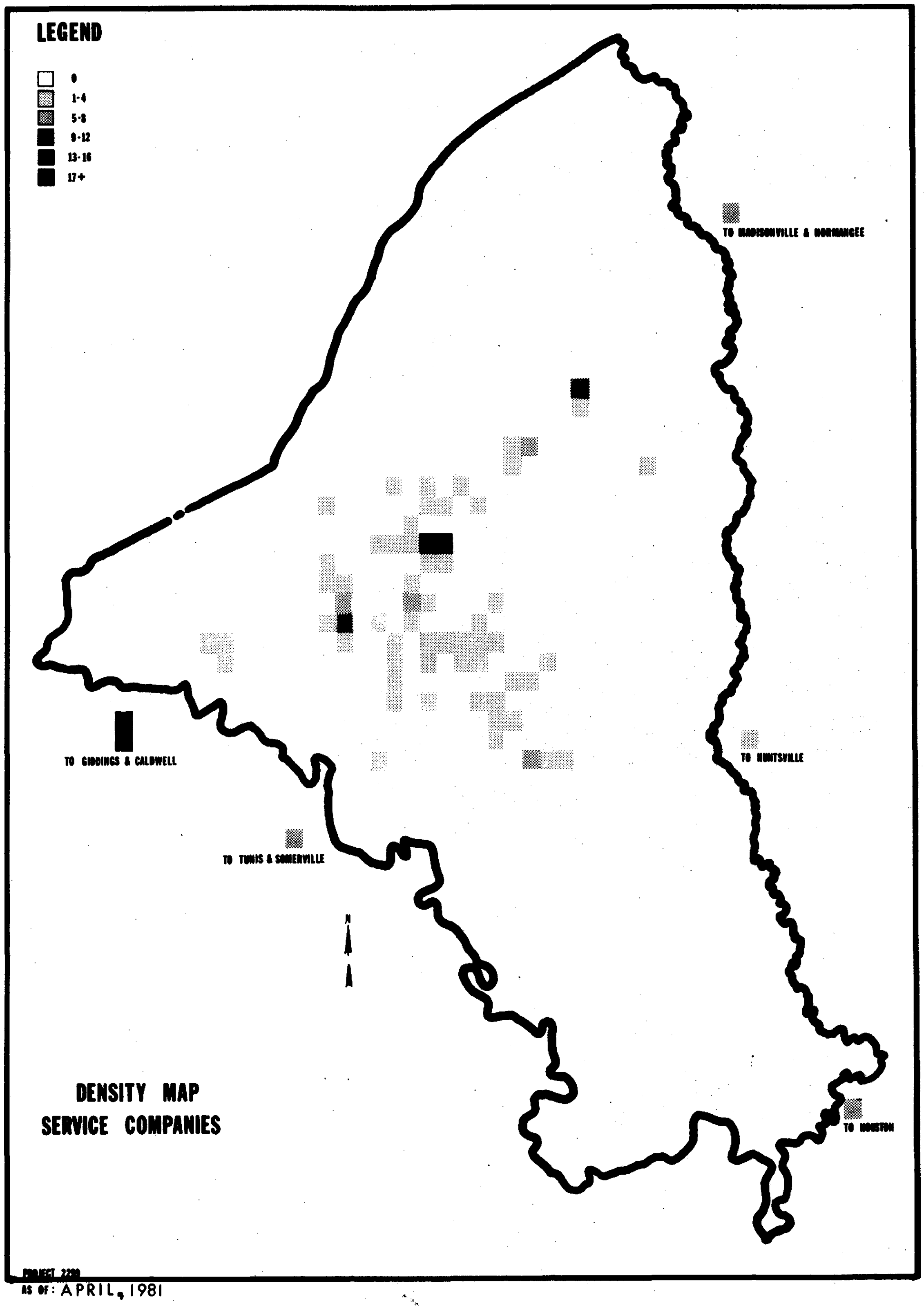


Figure 4. Service Company Density Map.

Table 1. List of Drafting Companies Which Produce Oil Maps.

Acme Map Company 404 W. Elm Tyler, Texas 75702	214/592-0212
Geomap Company Sales Division P. O. Box 30,008 Dallas, Texas 75230	214/424-1511
Midland Map Company P. O. Box 1229 Midland, Texas 79702	915/692-1603
Tobin Map Company P. O. Box 2101 San Antonio, Texas 78297	512/223-6203
South Texas Mapping Service P. O. Box 228 Corpus Christi, Texas 78403	512/882-5679
Zingery Map Company 2405 Norfolk Houston, Texas 77098	713/524-2971
Petroleum Information P. O. Box 34044 San Antonio, Texas 78233	In Texas 800/292-5500

Sector		Oil Wells	Gas Wells	Locations	Dry Holes	Abandoned Locations	Dual Completion	Abandoned Oil Producer	Abandoned Gas Producer	Suspended Operations
A										
B										
C	33				1					
D	33				2					
E										
F	34				1					
G	34				1					
H										
I										
J	30			1						
K										
L										
M	35	1								
	36			1						
N										
O	33	1								
P	34			1						
	37			1						
Q	26	1								
R	18				1					
	22			1						
S										
T										
U	21	1								
	33				1					
V	13				1					
	14				1					
W	13				1					
	41	1								
X	13				1					
Y	11				2					
	22			1						

Figure 5. Summary Sheet for the Accounting of Oil Activity.

The sum of oil wells drilled in each sector was calculated and used to develop the drilling location density map shown in Figure 6.

Locations of Producing Wells. The number of producing wells in each sector was also derived from completed accounting sheets. These sums were used to develop the producing oil well density map shown in Figure 7.

The density maps convey information on the relative levels of activity in the area and the actual magnitude of development. Press-on shading was used to depict the relative density in each sector. Basically, sectors with a low level of activity were lightly shaded, while those having a higher level of activity were increasingly shaded.

To maximize the contrast among each of the various shadings, a high degree of resolution was required. Effective contrast in this example was found to be 0, 10, 20, 40, 70, and 100 percent area shaded for the selective legend. Since drilling and production density vary greatly, an appropriate legend was necessary for each study area.

When the density maps for service companies, wells drilled, and production wells were overlaid one upon another, unique activity centers were delineated. Figure 8 shows that three centers could be outlined in Brazos County. Since these maps were developed for April, 1981, and again updated as of July 1, 1982, the movement and development of new oil wells could be readily depicted. Documenting oil production on a regular basis helps monitor oil field traffic activity in an area. Identifying this additional traffic demand is essential in assessing current pavement conditions and in planning maintenance and rehabilitation strategies.

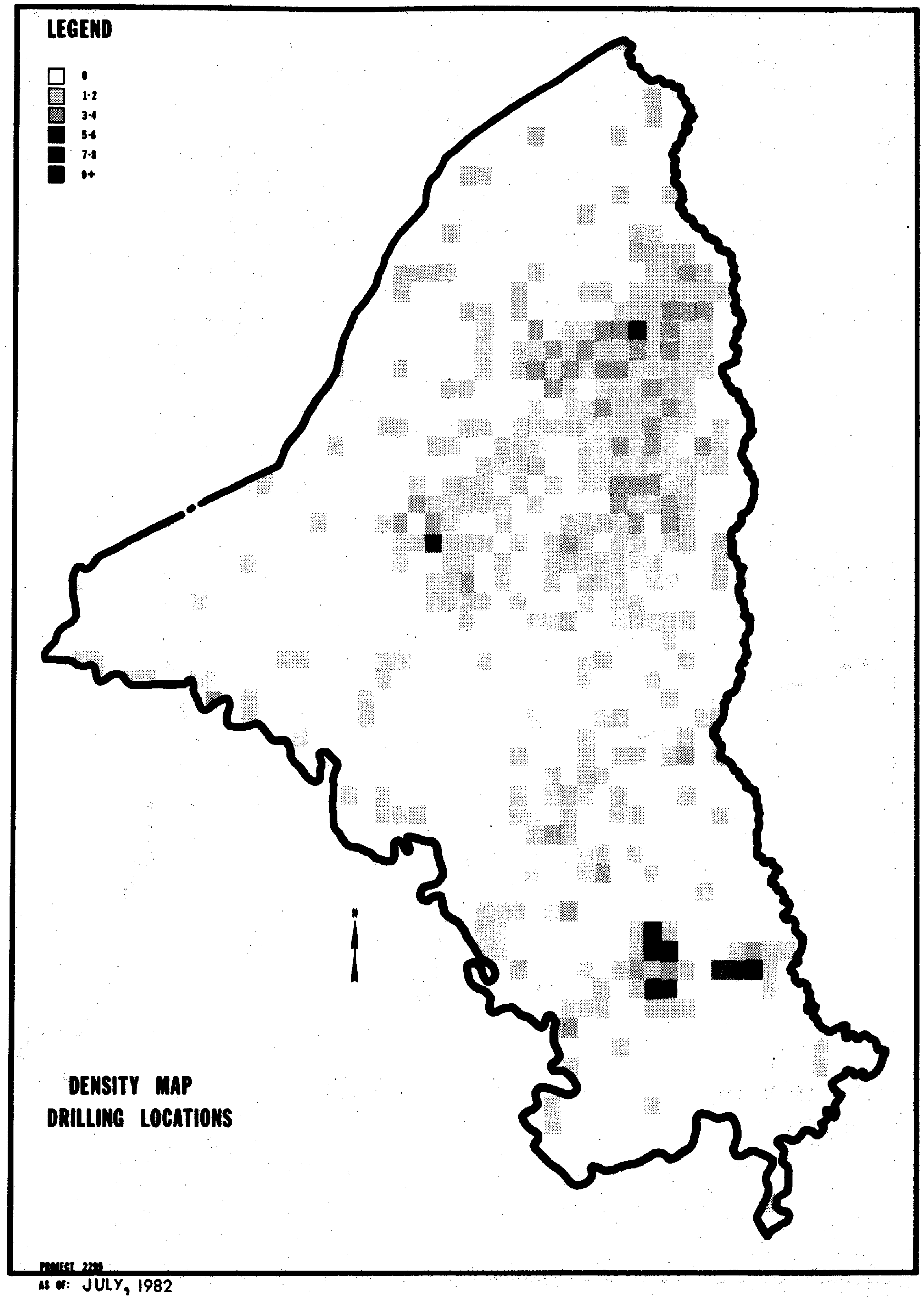


Figure 6. Drilling Location Density Map.

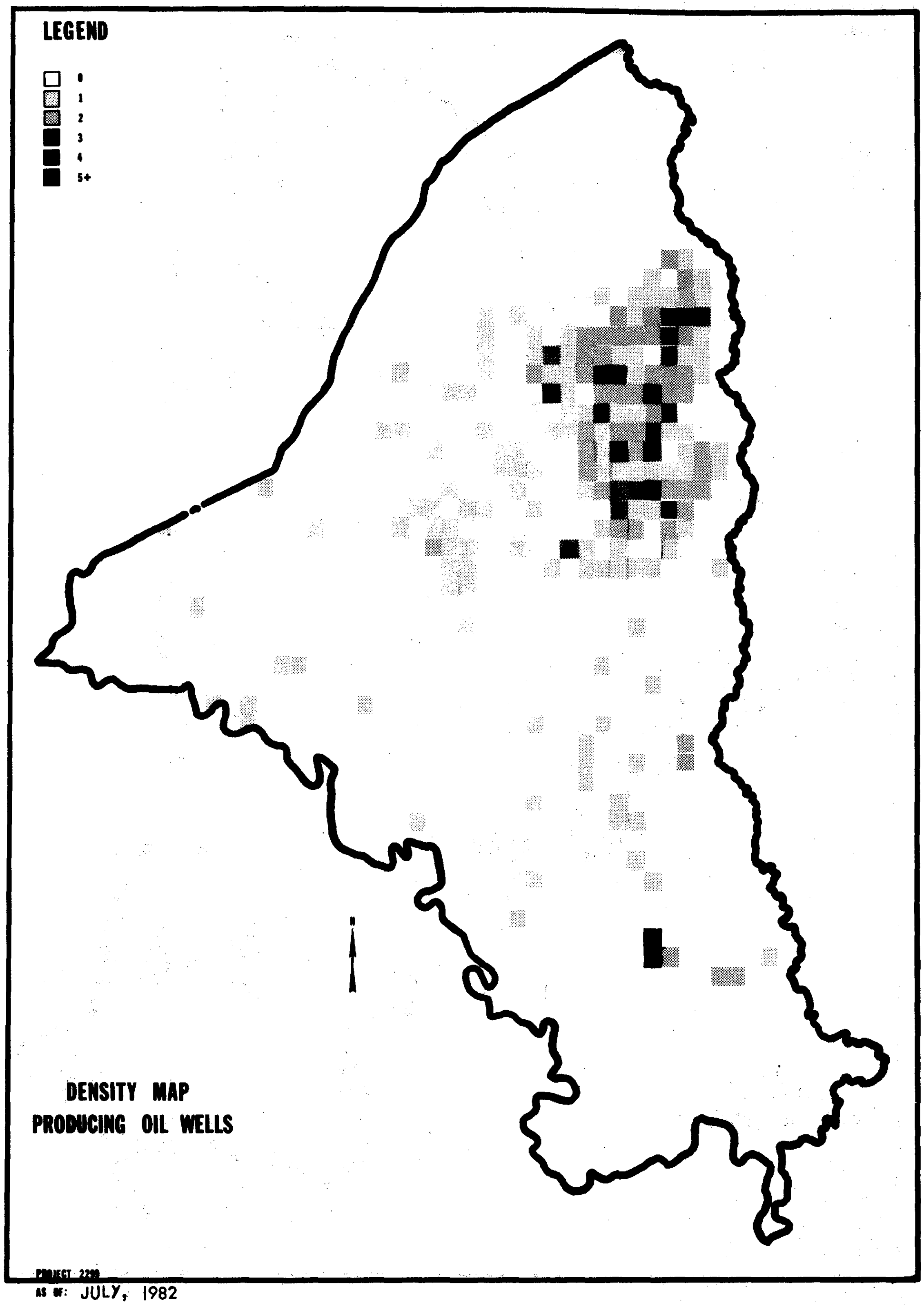


Figure 7. Producing Oil Well Density Map.

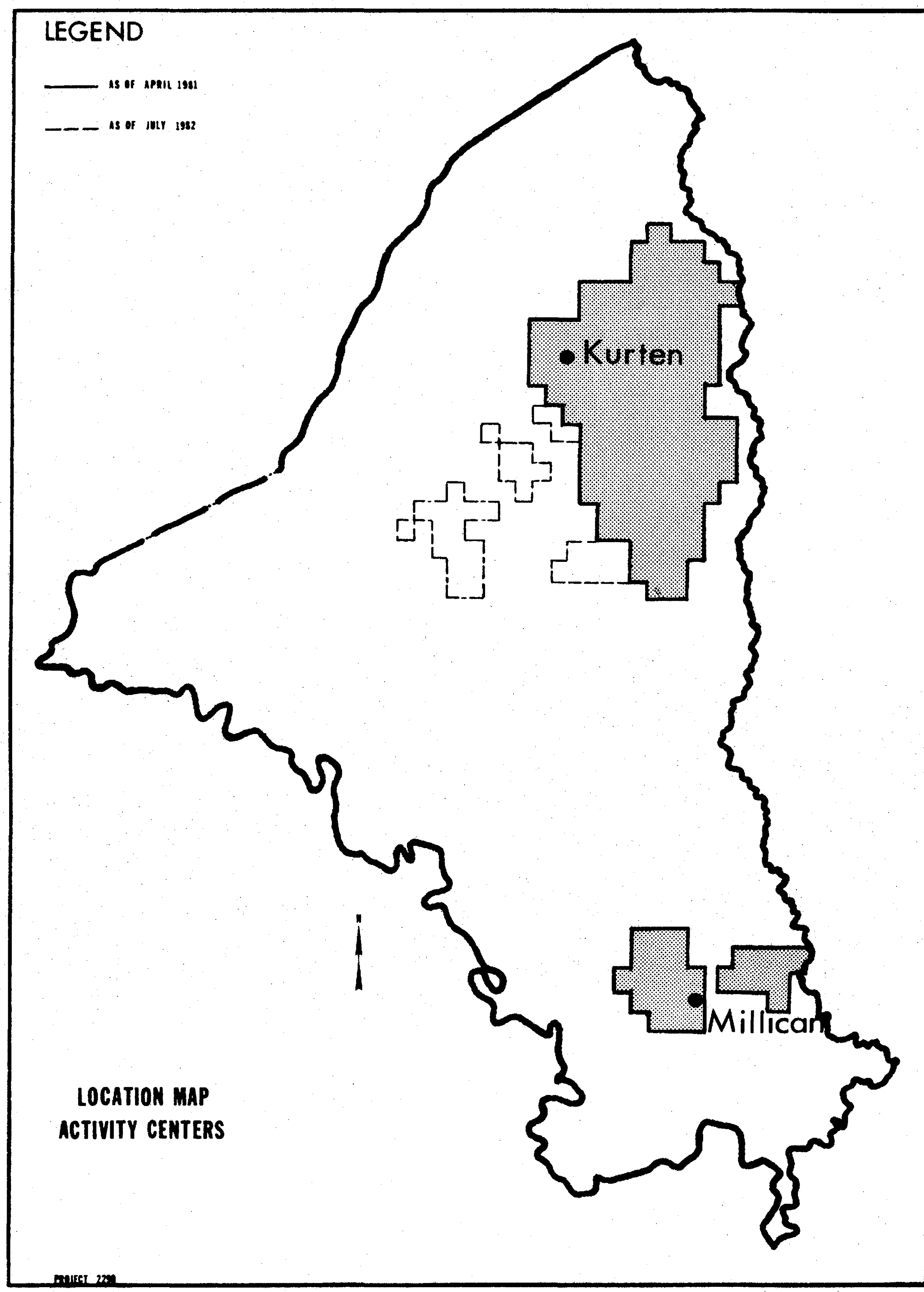


Figure 8. Location of Activity Centers.

CASE STUDY EXAMPLE

The Activity Center Density Map (Figure 8) identified three major centers of oil field activity: one large area around Kurten in the northern third of the county and two smaller areas in the southern third of the county near Millican. Since the Kurten area appeared to be the center of the most activity, it was selected for closer study.

When the final map of activity centers was overlaid on a SDHPT county map, two major routes (S.H. 21 and F.M. 2038) were found to serve the Kurten Field area. The natural boundaries within an activity center were plotted to isolate these two main service routes. Primary features of the area are depicted in Figure 9.

Since light duty, surface-treated pavements were of initial concern in this study, F.M. 2038 was selected as the case study roadway. To estimate the amount of oil field traffic using F.M. 2038, an "influence area" for the road was established, as shown in Figure 10. Basically, all traffic within this "influence area" uses F.M. 2038 when entering and exiting the area. It is helpful to think of the "influence area" as being analagous to a tributary watershed area in hydrology.

Traffic was visualized as "flowing" from the far reaches of the influence area down small "tributary" roads and "emptying" into the "main stream", F.M. 2038, before leaving the area. Vehicles travel in such a manner so as to minimize delay by using the most direct and best roads available, avoiding major natural obstructions. Only the influence area for F.M. 2038 southeast at S.H. 21 was considered in this example.

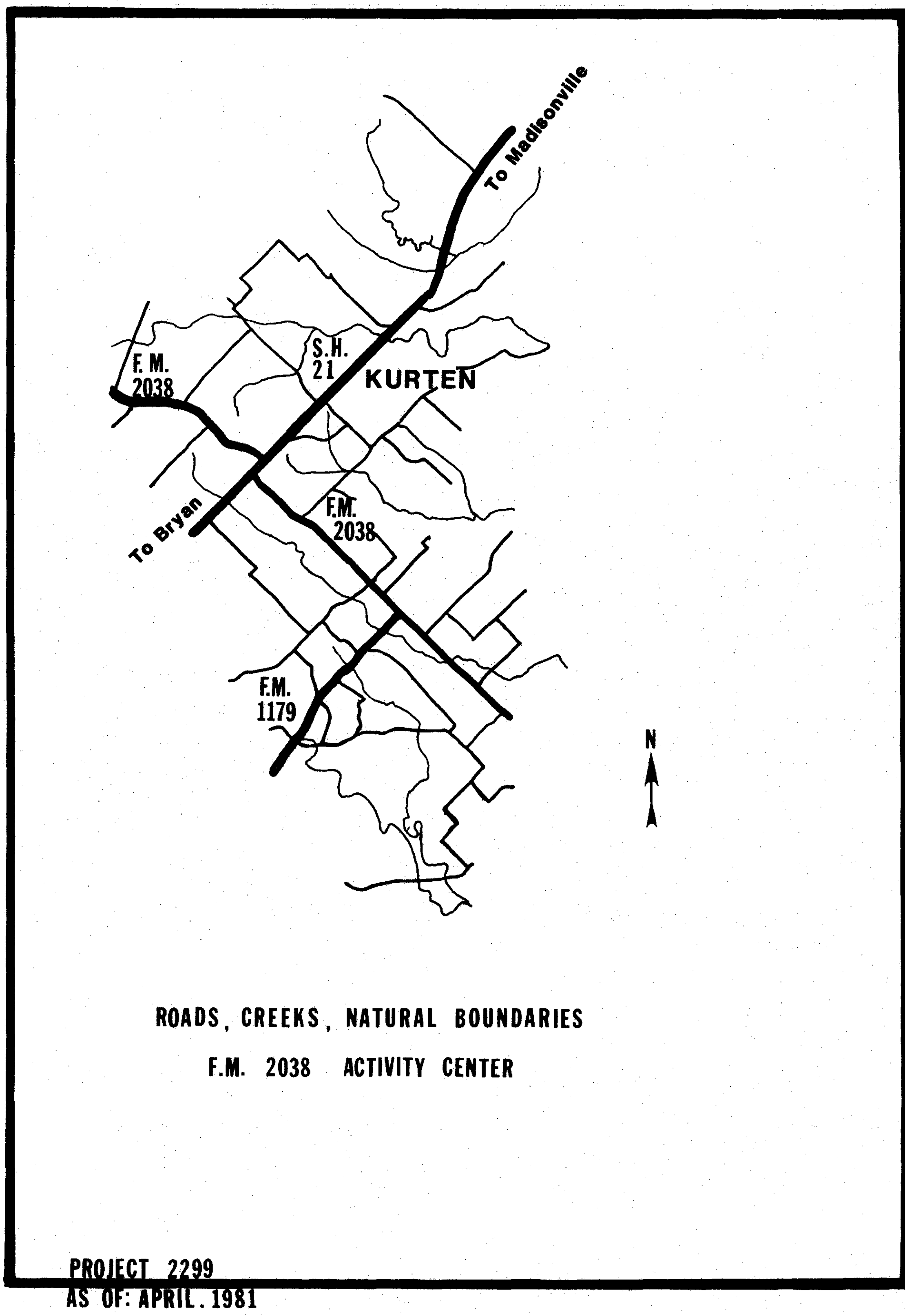
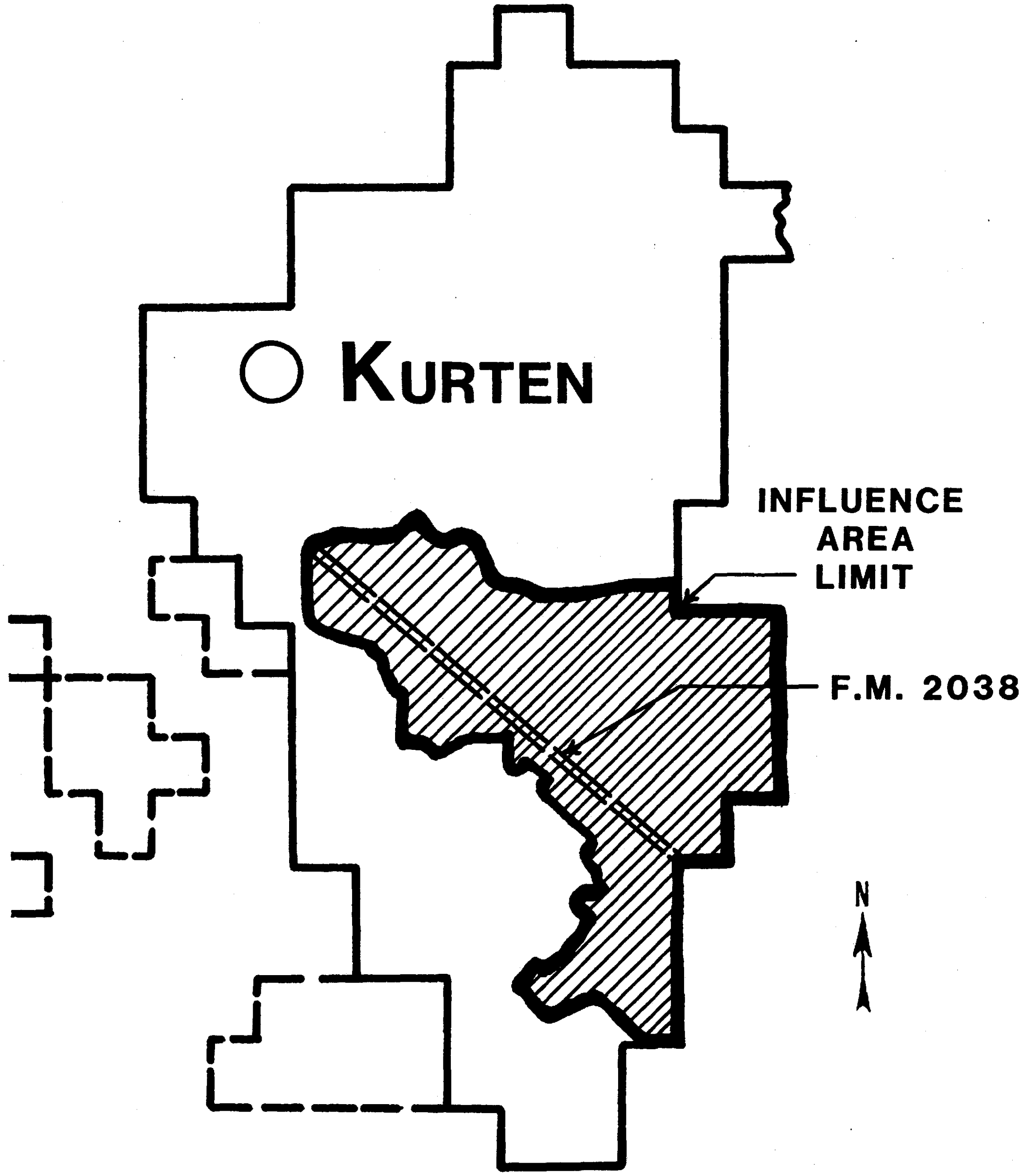


Figure 9. Primary Features of F.M. 2038 Activity Center



PROJECT 2299
AS OF: July, 1982

Figure 10. Limit of F.M. 2038 Influence Study Area.

ASSESSMENT CASE

The fourth objective of Phase II was to use the Texas Pavement Distress Equations (Oil Field Damage Program) to assess the condition of a roadway pavement under oil field traffic. This objective was satisfied by using the prepared density maps to estimate the traffic demand placed on the roadway in a major oil field area. It is anticipated that the Department would develop similar density maps for oil related activity as well as for other special users, such as timber, grain, or gravel trucks. The following analytical procedure can be used to assess pavement damage from each special user.

Study Period

The study period for F.M. 2038 was from July, 1978, to July, 1982. Initially, F.M. 2038 existed as a 6-inch surface-treated pavement. In July, 1978, it was reconstructed using a cement-stabilized subgrade with a 10-inch surface-treated pavement section.

Number of Wells Developed

Oil well ownership maps as of July, 1982, showed a total of 285 producing wells in Brazos County. Drilling permit records for the county from the Texas Railroad Commission showed that 154 oil wells had been drilled between July, 1978, and July, 1982. Therefore, 131 wells were producing oil prior to the July, 1978 reconstruction of F.M. 2038.

To determine the exact number of oil wells developed in the 4-year study period within the F.M. 2038 influence area, "density maps" for that date were necessary. Since such information was not initially available, certain assumptions had to be made:

1. All 154 wells developed in Brazos County (1978-1982) occurred within the three major activity centers.
2. Oil drilling activity was basically uniformly distributed throughout the three major activity centers.
3. The probability of a well being drilled within any influence area is equal to the ratio of the influence area to the total area of the major activity center.

These logical assumptions were necessary due to the lack of a more detailed data base. Monitoring the annual activity will improve the estimate of the site-specific activity.

Wells in Influence Area. Approximately 22 percent of the wells drilled in Brazos County during the 4-year study period occurred within the F.M. 2038 influence area. The percentage is the ratio of the influence area (35 sectors) to the total area of the major activity centers (160 sectors). Therefore, during the 4-year study period, 34 oil wells were assumed to be drilled in the F.M. 2038 influence area.

However, not all wells drilled in the county actually produced crude oil. The drilling density map (Figure 6) indicated that a total of 55 oil wells had been drilled within the F.M. 2038 influence area as of July, 1982. Information from the production density map (Figure 7) showed that 46 of those wells

(83.6 percent) were really producing. Using this 83.6 percent success rate, 28 oil wells were assumed to be actually producing within the F.M. 2038 influence area during the 4-year period.

At the present time, the computer program used to assess pavement condition under oil field traffic does not differentiate between wells drilled and wells producing. In fact, the program takes a conservative approach by considering only the effect of wells drilled and producing oil. For an exact appraisal of pavement conditions, a more detailed data base must be implemented and maintained.

Assessment of Oil Field Development

To illustrate the use of the Texas Pavement Distress Equations as an assessment tool, two computer runs were made for F.M. 2038. The first run assessed the present condition of the 10-inch pavement after 4 years of oil field activity. The second run depicts the condition of a theoretical 6-inch pavement subjected to 4 years of oil field activity. This simulates the effect of the oil field traffic had the 1978 reconstruction been only to restore the pavement to a 6-inch thickness. The effect of a 1978 cement stabilization of the subgrade was considered by changing the subgrade plasticity index of 23 (typical in Brazos County) to 12.

Evaluation. Results obtained from the two computer runs were used to answer the following questions:

1. What is the current condition of F.M. 2038, a 10-inch surface-treatment pavement serving 28 wells?

2. How much additional damage would have been inflicted upon F.M. 2038 if the pavement had been only rehabilitated as a new 6-inch surface-treated pavement?
3. What pavement distresses are expected under intended-use traffic?
4. What pavement distresses are particularly sensitive to oil field truck traffic?

Table 2 summarizes the various distress measures that were calculated using the Texas Pavement Distress Equations. Limiting distress values are tabulated for each distress type. A comparison of the intended-use and oil field-use distress values demonstrates markedly the effects of oil field truck traffic.

Figures 11 through 16 show the performance of a 6-inch and 10-inch pavement under intended-use and oil field traffic. Each figure represents estimated changes in pavement distress levels over time. The initial distress measure assumes a newly reconstructed pavement section. Pertinent limiting values are also shown for each type of distress.

The pavement's performance is rated as either a measure of "severity" or "area" of distress. Selection of the critical rating was based on which rating reached its respective limiting value the earliest (Table 2). Only in the case of "rutting", the actual area of pavement distress approached its critical limit before the severity rating (depth of rutting) exceeded its limit. For all other distress types, the severity rating values reached its critical limit before the respective area rating value was exceeded.

Results.

1. Current Condition of 10-Inch Pavement -- Figure 12 dramatically demonstrates the reduced service life due to the increased traffic demand.

Table 2. Estimated Distress Values - F.M. 2038 (July, 1982)

Distress Type	Distress Measure	Limiting Distress Value	Intended-Use	Oil Field-Use
Ride Quality	P.S.I.	1.5	4.15	3.56
Pavement Score	P.S.	35.0	90.5	29.0
Rutting	Area	50.0	8.0	61.2
	Severity	30.0	3.5	51.0
Alligator Cracking	Area	50.0	0.0	23.8
	Severity	50.0	0.0	47.0
Raveling	Area	80.0	1.7	41.6
	Severity	30.0	3.8	59.2
Flushing	Area	80.0	4.5	61.3
	Severity	30.0	5.2	66.1

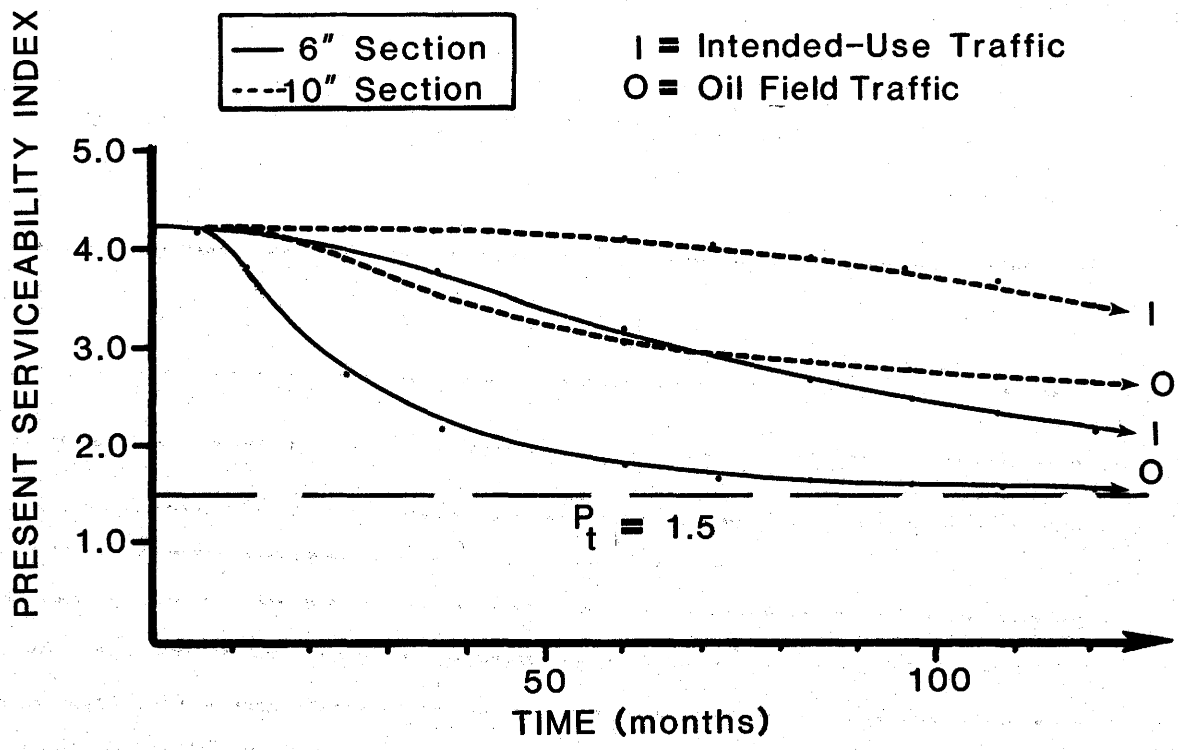


Figure 11. Present Serviceability Index Vs. Time.

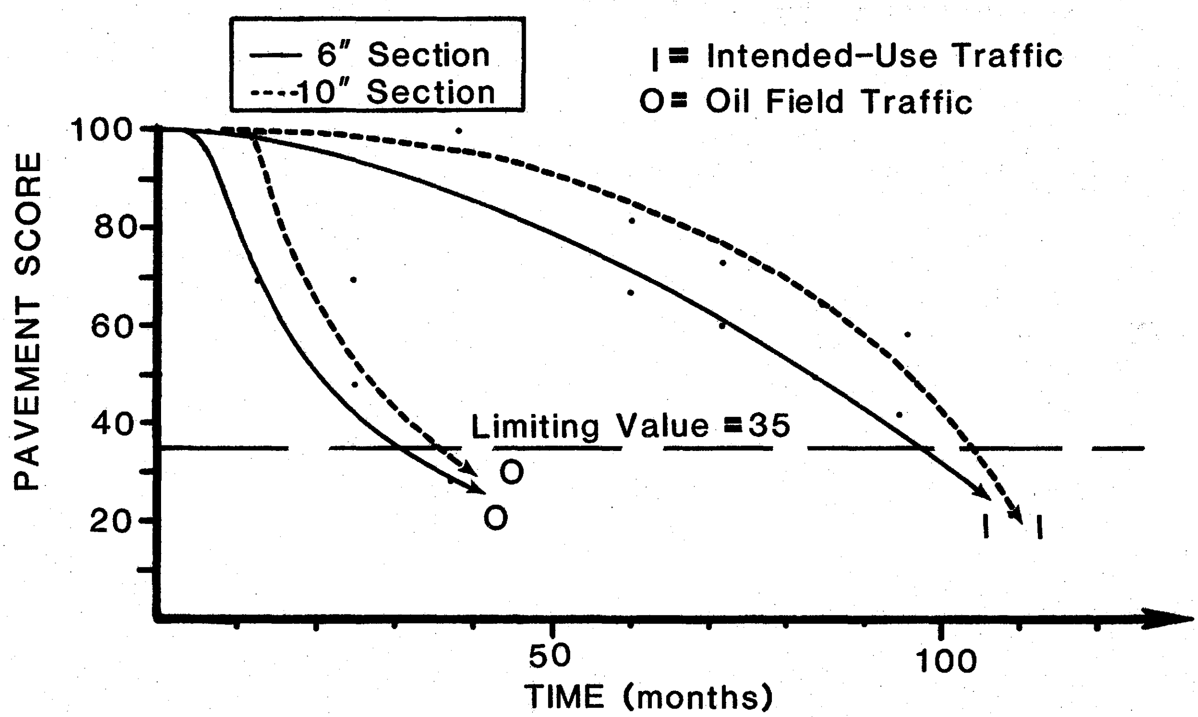


Figure 12. Pavement Score Vs. Time.

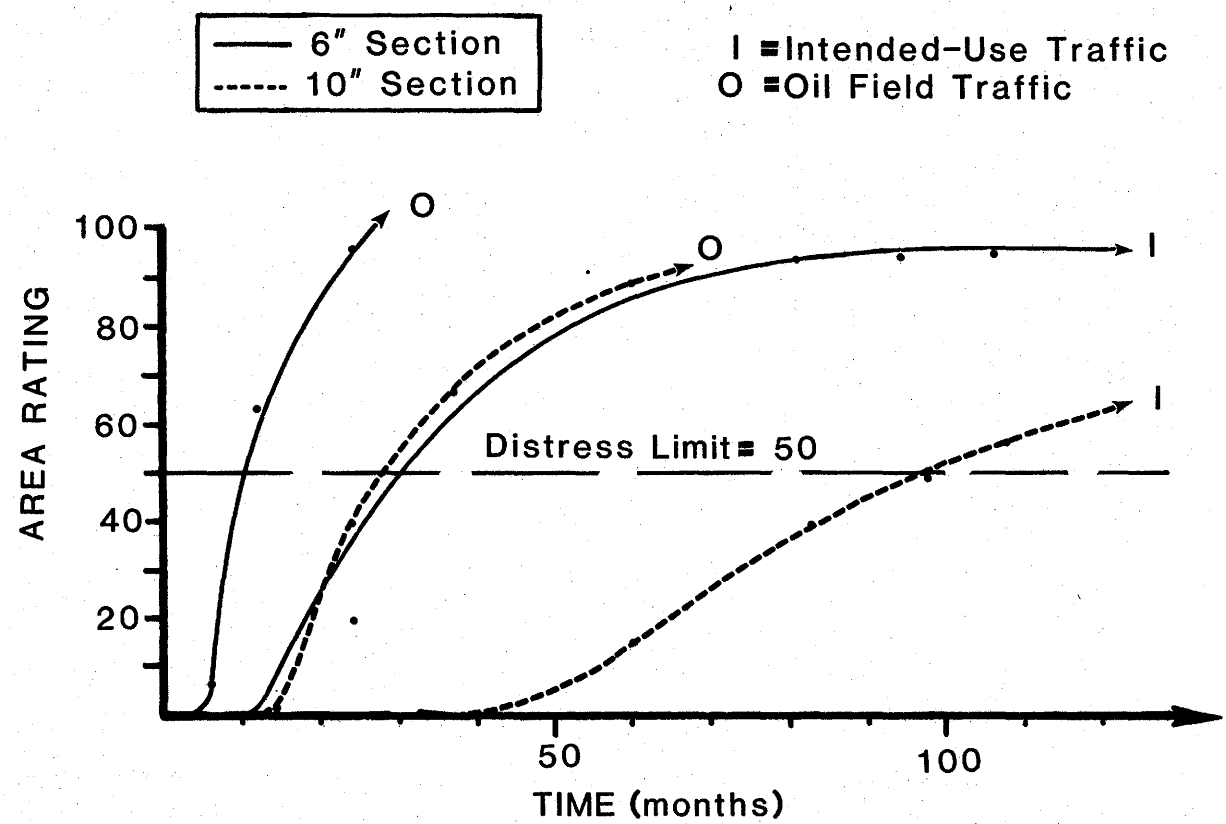


Figure 13. Rutting Area Vs. Time.

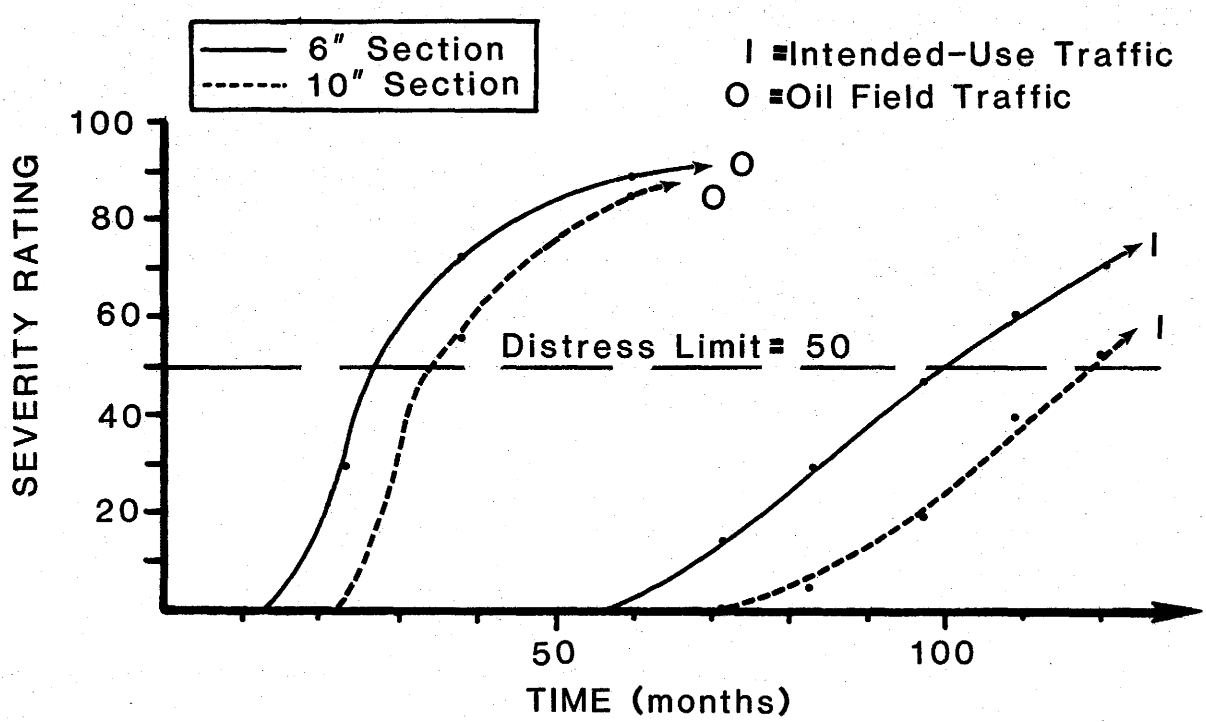


Figure 14. Alligatoring Severity Vs. Time.

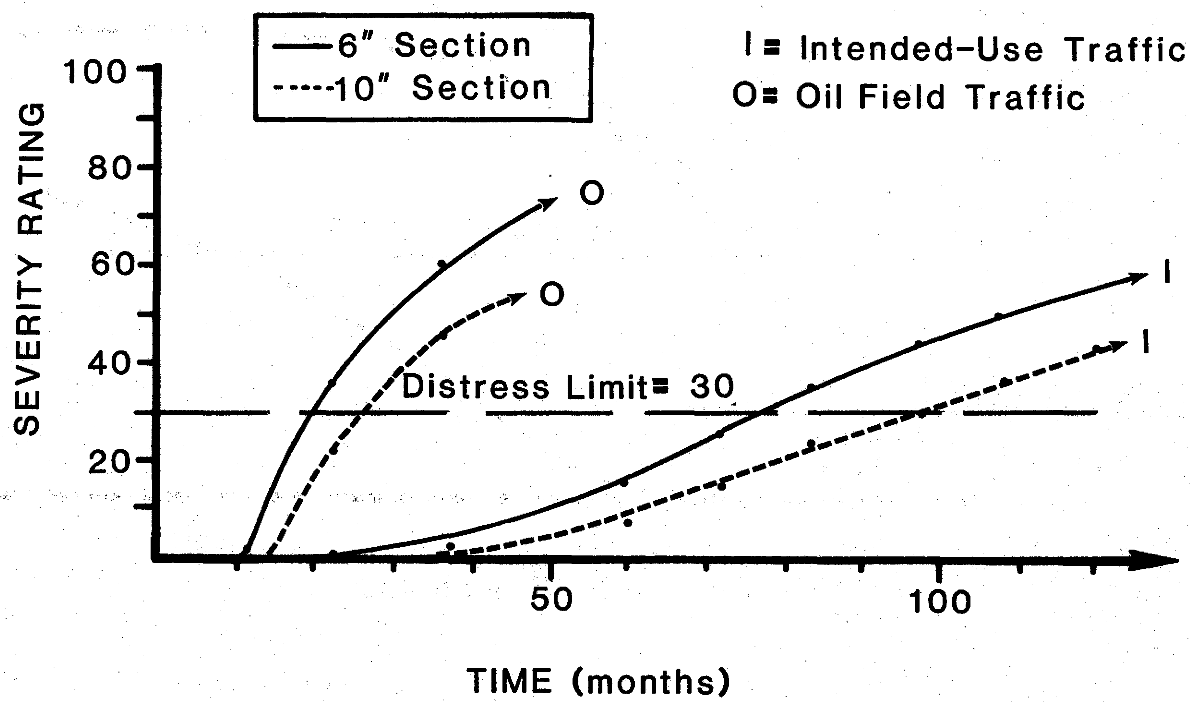


Figure 15. Raveling Severity Vs. Time.

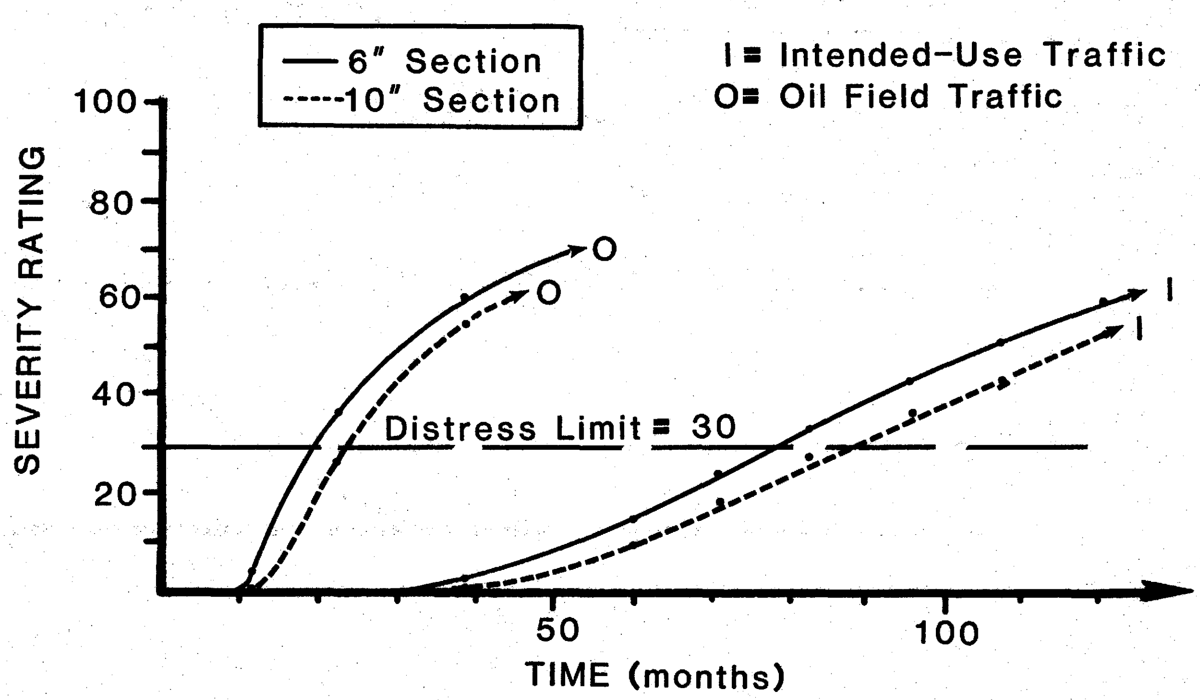


Figure 16. Flushing Severity Vs. Time.

The limiting pavement score of 35 was to be attained after approximately 102 months (8.5 years). Instead, it was reached after only 41 months (3.4 years), a 60-percent reduction in its normal life. Severe rutting and alligator cracking had been predicted, as well as excessive flushing and raveling.

A visual site inspection made in October, 1982, generally confirmed the severe flushing and raveling predictions. Localized rutting was observed along the roadway length; alligator cracking was minimal. The cement stabilized subgrade may be responsible for the indications of favorable strength. The visual inspections were based on standardized identifications of distress types described in the Highway Pavement Distress Identification Manual (4).

2. Expected Damage to 6-Inch Pavement -- The results indicate, as would be expected, the thinner pavement reaches its limiting value in less time. However, one pertinent observation from each diagram (Figures 11-16) is that relative percent reduction in service life appears constant for each distress type for both the 6-inch and 10-inch pavements. Table 3 summarizes the loss of service time and categorically demonstrates the similarities in actual overall percent reduction.

3. Expected Intended-Use Pavement Distress -- The pavement distress program can be used to predict service life under normal traffic conditions and to assist in selecting a desired pavement thickness. Table 4 summarizes the approximate time to road failure, given the assumptions of this analysis.

   The distress limits for rutting area and flushing and raveling severity are reached in a 7- to 8-year time period. The 6-inch

Table 3. Reduction In Pavement Service Life Comparison.

Distress Type	10-Inch Pavement		6-Inch Pavement	
	Loss of Time (Months)★	% Reduction	Loss of Time (Months)★	% Reduction
Pavement Score	104 - 41 = 63	61	97 - 31 = 66	68
Rutting	88 - 35 = 53	60	32 - 14 = 18	56
Alligatoring	116 - 50 = 66	57	99 - 35 = 64	65
Raveling	96 - 23 = 73	76	80 - 21 = 59	74
Flushing	88 - 22 = 66	75	80 - 20 = 60	75

★(Time to failure under intended-use traffic)-(Time to failure under intended-use plus oil field traffic) = Loss of pavement service time.

Table 4. Time to Failure Under Intended-Use Traffic.

Approximate Time to Failure (Months)	
6" Section	10" Section
Rutting: 32	Rutting: 88
Flushing: 80	Flushing: 88
Raveling: 80	Raveling: 96
Pavement Score: 97	Pavement Score: 104
Alligator Cracking: 99	Alligator Cracking: 116

Table 5. Time to Failure Under Intended-Use + Oil Field Traffic.

Approximate Time to Failure (Months)	
6" Section	10" Section
Rutting: 14	Rutting: 22
Flushing: 20	Flushing: 23
Raveling: 21	Raveling: 35
Pavement Score: 31	Pavement Score: 41
Alligator Cracking: 35	Alligator Cracking: 50

ment appears susceptible to severe rutting, reaching its critical limit in 32 months.

4. Pavement Distresses Sensitive to Oil Field Truck Traffic -- Oil field truck traffic induces rapid acceleration in the development of pavement distress. The reductions are illustrated in Figures 11-16 and summarized in Table 3. Estimated time to failure under the assumed oil field truck traffic condition is presented in Table 5. The distress types are listed in increasing time to failure. Traffic associated failures, such as flushing and raveling, are non-load associated failures. Whereas, rutting and alligatoring on the thin 6-inch pavement shows sensitivity to repeated increases of axle loads.

PLANNING SCENARIO

The fifth objective of Phase II was to demonstrate the use of the Texas Distress Equations to predict the condition of a pavement under future levels of oil field development. Projections of future pavement condition are imperative in anticipating needed financial resources and in distributing allocated funds. This study's estimates of pavement service life provide a basis to assess the impact of future oil field activity on roadways.

Study Period

Future oil field development along F.M. 2038 was selected as the case study example for the planning scenarios. A 5-year planning horizon was used to demonstrate the use of the pavement distress program. The study period begins at the conclusion of the previous assessment case study problem, July, 1982, and will continue until July, 1987.

Rate of Oil Field Development

Since the rate of oil field development fluctuates in an area, three general activity rates were defined: low, medium, and high. The actual number of wells drilled, as well as the rate of drilling, varies among the counties. However, both the magnitude and the rate can be estimated based on records maintained by the Railroad Commission (R.R.C.) of Texas.

As of July, 1977, the R.R.C. maintains on computer files: the number of wells drilled in each county, permit date, "spud-in" date (start of drilling), and "completion" date (date of production). The computer tapes containing the above information can be purchased and updated quarterly through the R.R.C. Printouts pertaining to the study region were given to TTI by the R.R.C. for this initial case study example. The computer tapes can be accessed to strip pertinent data for any county.

A frequency histogram depicting spud-in activity in Brazos County from July, 1977, to July, 1982, is shown in Figure 17. The rate of development, the number of wells drilled per month, is shown as a relative frequency histogram in Figure 18. From this probability distribution, a cumulative frequency distribution was developed, as shown in Figure 19. The 15th and 85th percentile points conveniently segregate the drilling rates in the case study. Table 6 summarizes the three levels of drilling activity developed for Brazos County.

Low activity was defined as at least 1 well drilled per month, medium as 3.5 wells per month, and high drilling rate as more than 5 wells per month (actually 6 wells were used in further analysis). These activity rates represent drilling activity for the entire county.

The three levels of development translate into drilling rates of 12, 42, and 72 wells per year. Applying the influence area ratio of 22 percent and a success rate of production of 83.6 percent, 2, 6, and 12 wells per year were calculated for the influence area rate of development. Table 7 summarizes the rate of oil well activity and presents the resulting 18-kip ESAL repetitions for the 5-year analysis period. These values represent the total annual wells drilled and consider actual production for each rate of development.

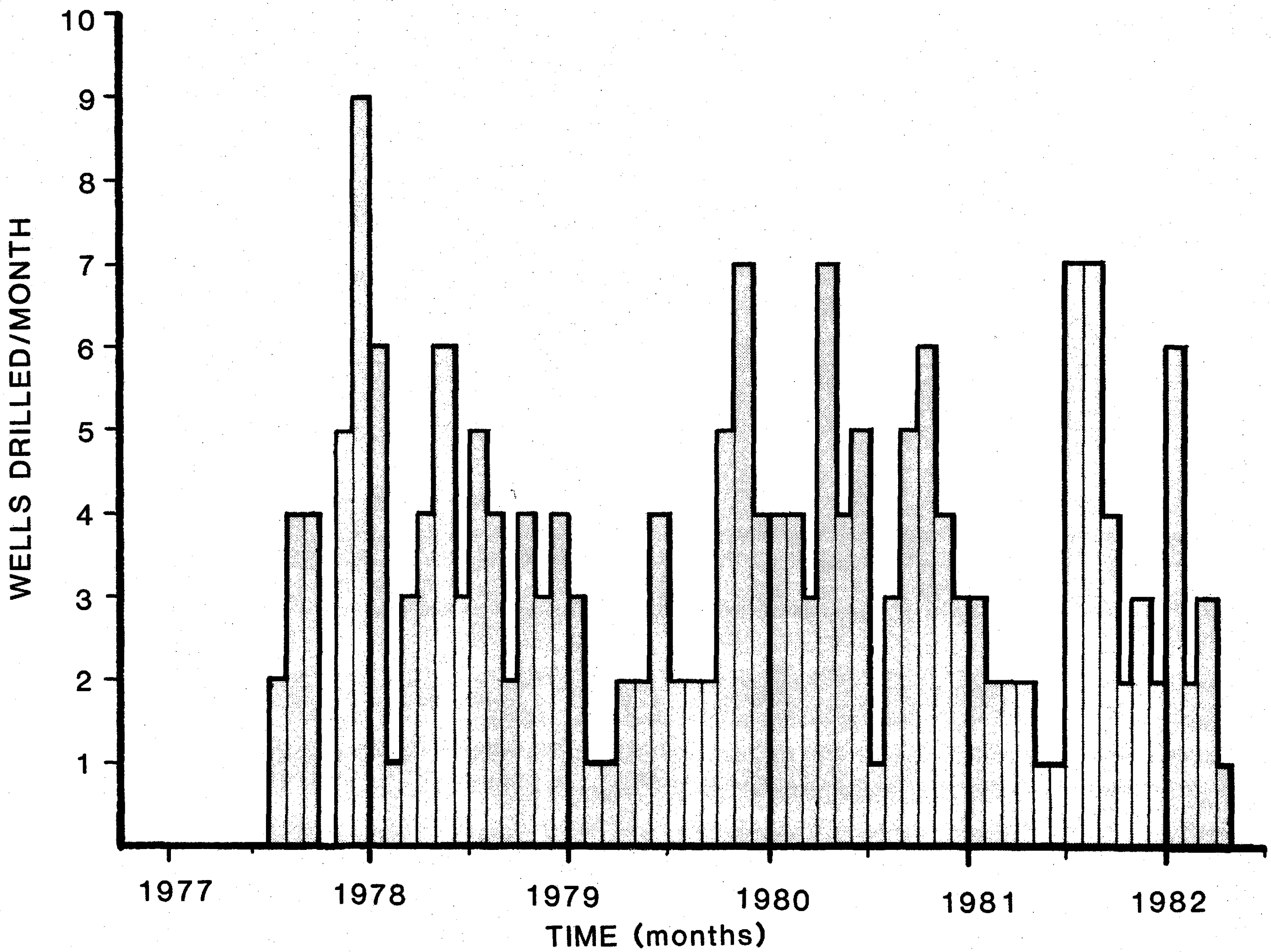


Figure 17. Spud-In Activity - Brazos County (July, 1977 - July, 1982).

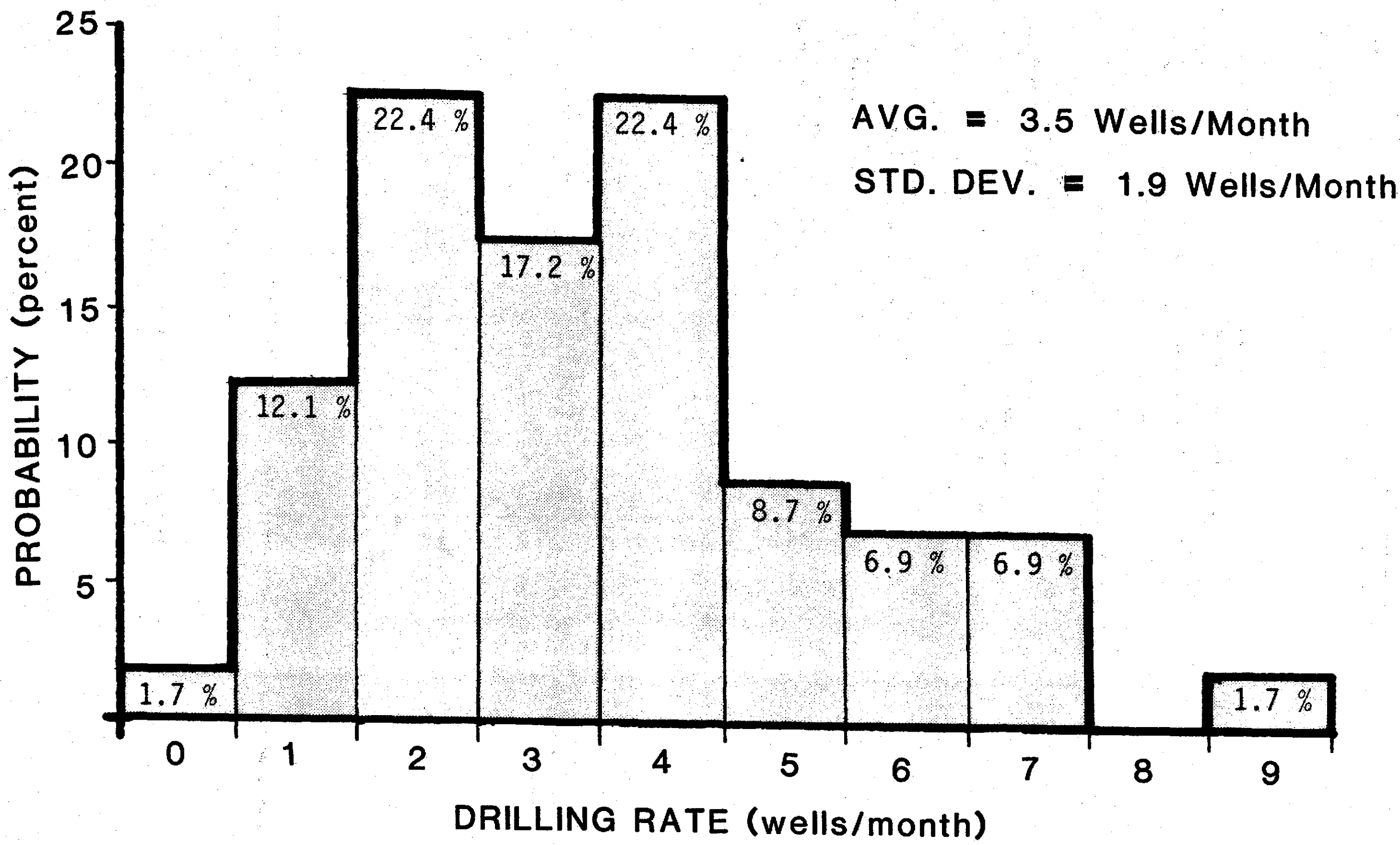


Figure 18. Relative Frequency Histogram of Oil Well Development.

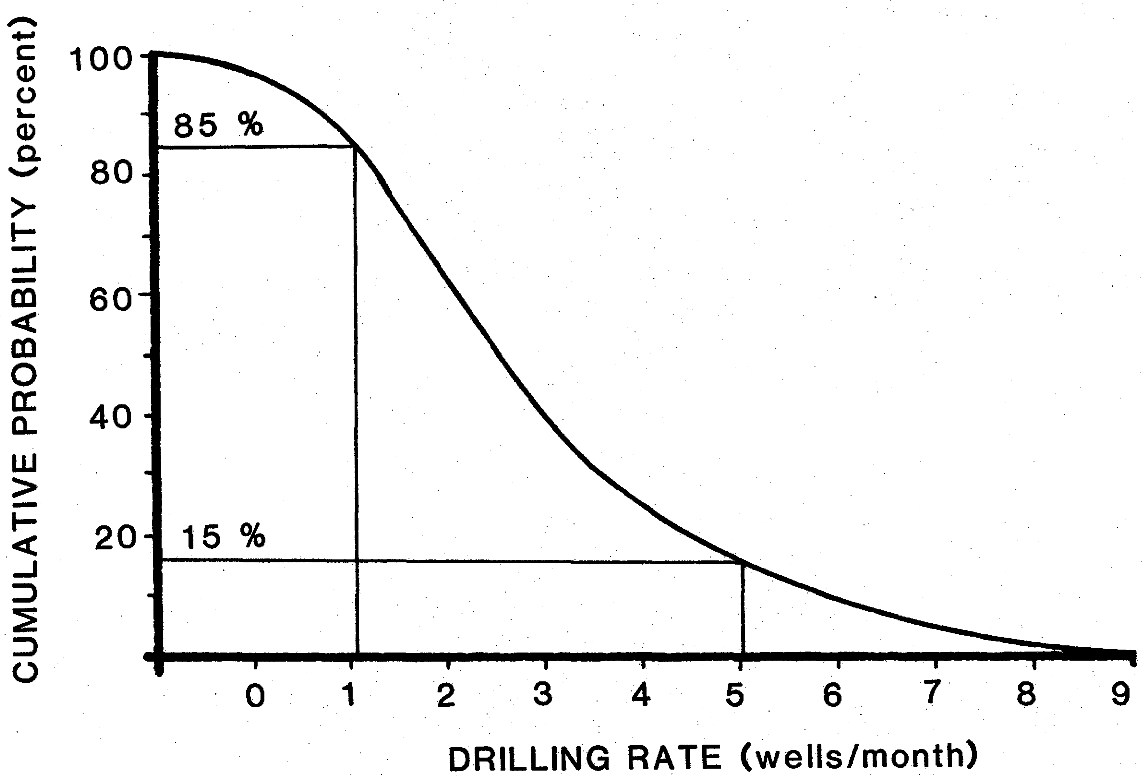


Figure 19. Cumulative Frequency Distribution of Oil Well Development.

Table 6. Summary of Drilling Rates for Brazos County.

# of wells per year / or / wells per month	Drilling Rates for Brazos County: LOW	MEDIUM	HIGH
# of wells per year	12	42	72
wells per month	1	3.5	6

Table 7. Summary of Drilling Rates for F.M. 2038 Influence Area.

		Drilling Rates for Influence Area: LOW	MEDIUM	HIGH
# of wells per year		2	6	12
or 1 well per ...		6 months	2 months	1 month
Traffic Conditions (18-k ESAL Repetitions)	Intended-Use	25,600	25,600	25,600
	Oil Field	15,683	49,166	99,383
	Intended-Use + Oil Field	41,283	74,766	124,988

Since oil field activity in Brazos County does not represent development in every region of the state, site-specific development rates need to be defined using local data. However, the general procedure discussed in this section is a rational approach to predicting future oil field traffic anywhere in the state.

Prediction of Effects of Development

To illustrate the prediction capabilities of the Texas Pavement Distress Equations, several computer runs were made on a reconstructed, 10-inch surface-treated pavement section. The program was run for an intended-use traffic condition and at low, medium, and high rates for the future development cases.

Evaluations. Results obtained demonstrate the capability of anticipating pavement performance under varying rates of oil field development. Figures 20 through 25 portray the performance of a 10-inch pavement under the three rates of development. The expected intended-use condition is also shown. Since the results of the previous assessment case indicated that F.M. 2038 would require reconstruction, the planning example assumed a rehabilitated pavement section. The pertinent limiting values for each type of distress are shown for the critical measures of performance rating.

The primary purpose of including these results in this report was to demonstrate the potential of using the overall methodology as a planning tool. Although the rate of oil field development varies among regions and fluctuates over time, general trends can be documented in site-specific areas. Currently (1981-1982) oil production in Texas is stabilizing and approaching what oil

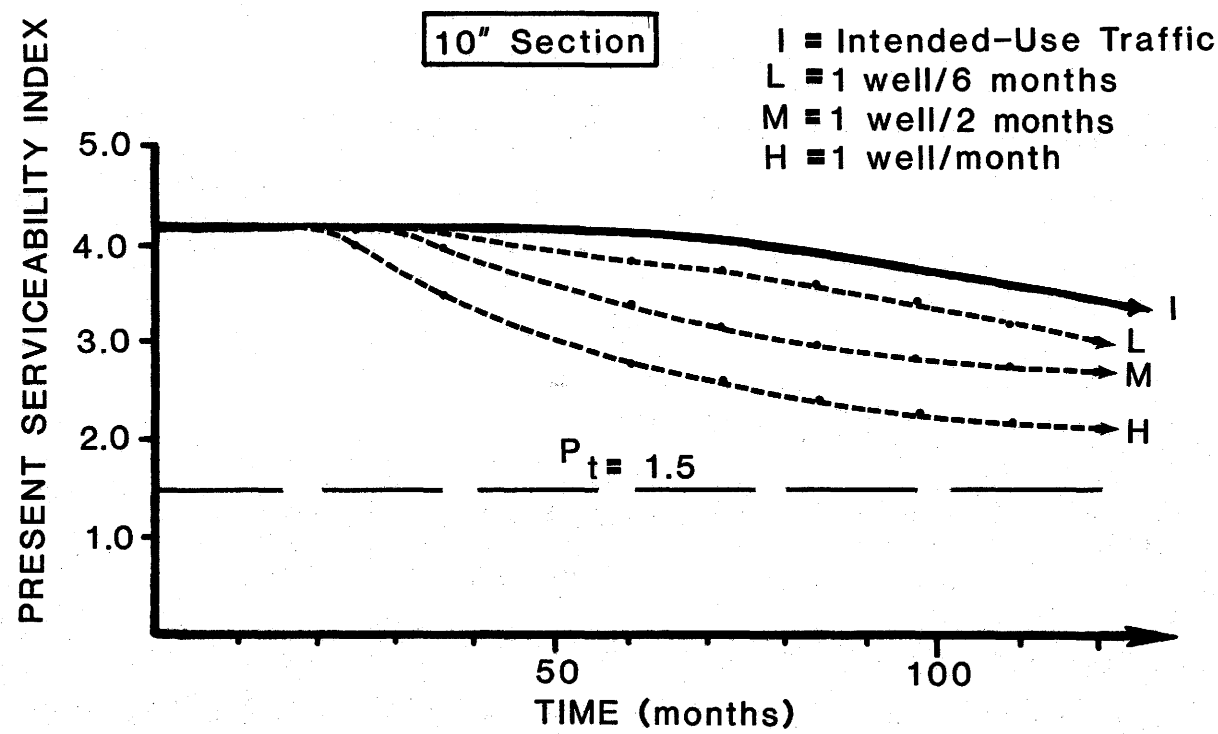


Figure 20. Present Serviceability Index Vs. Time.

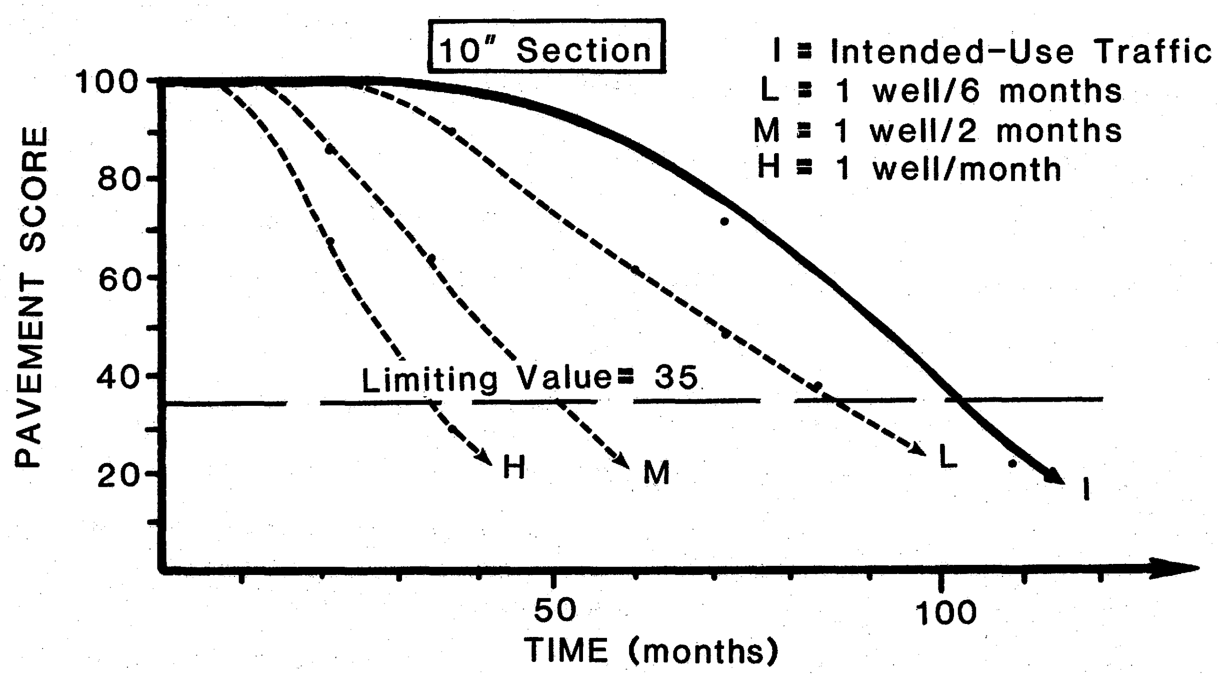


Figure 21. Pavement Score Vs. Time.

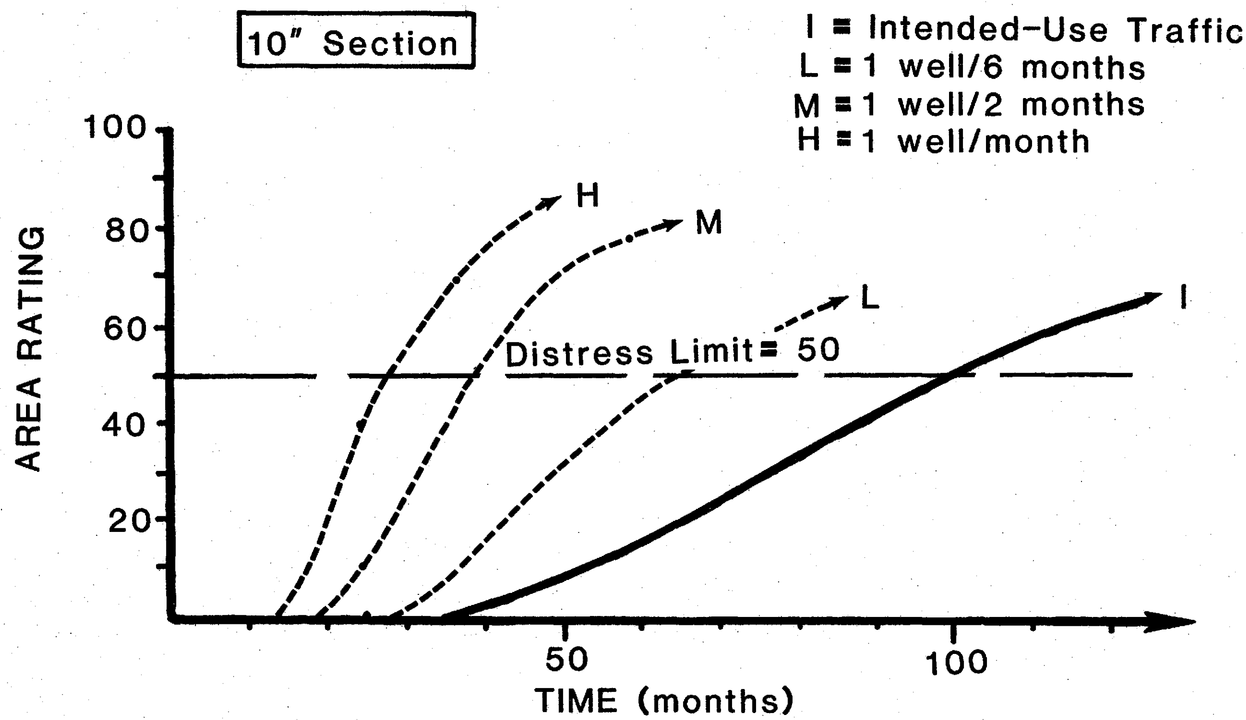


Figure 22. Rutting Area Vs. Time.

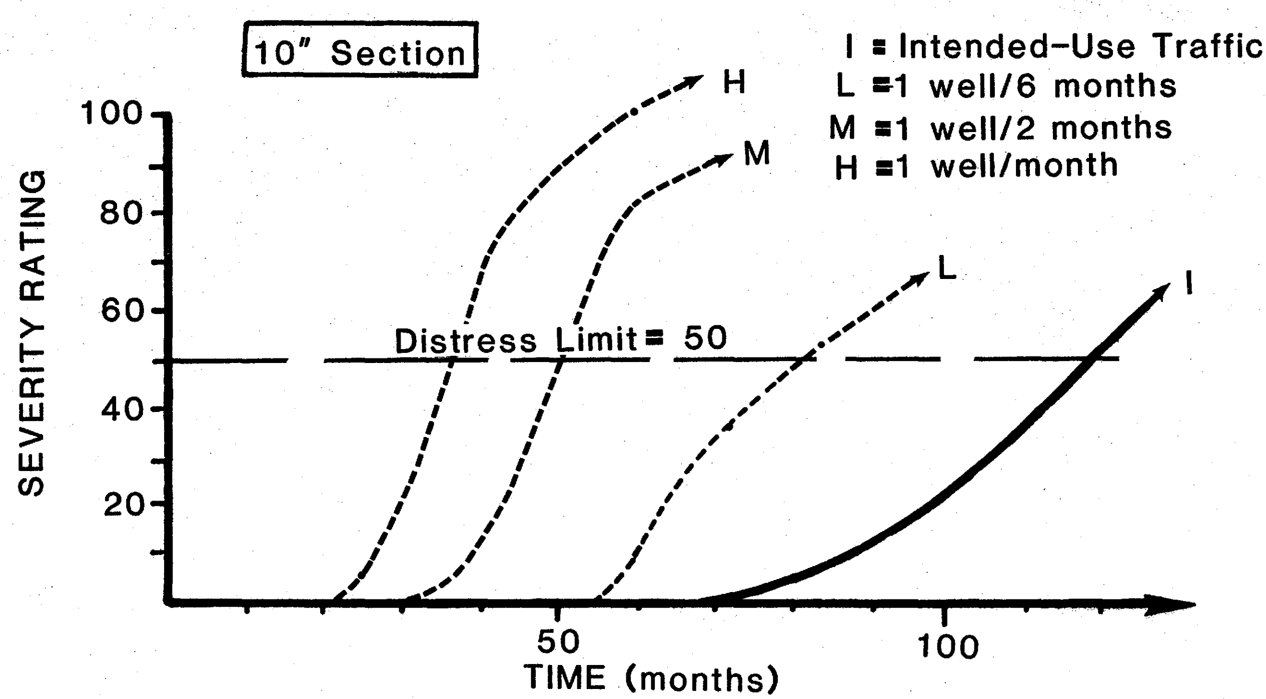


Figure 23. Alligatoring Severity Vs. Time.

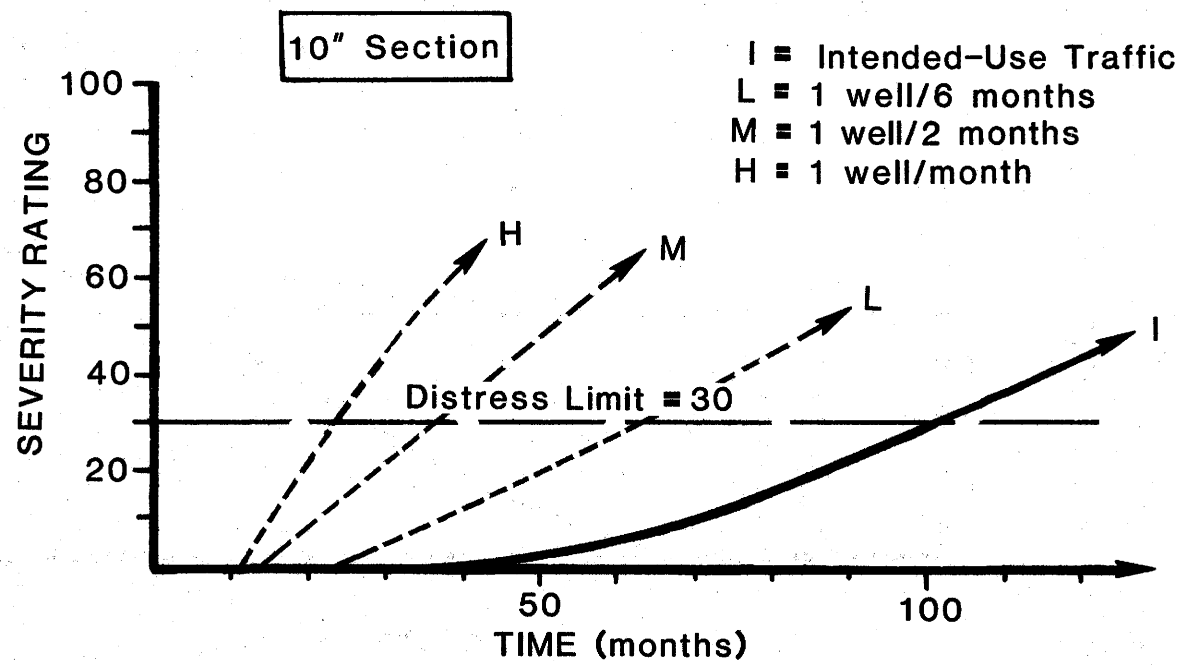


Figure 24. Raveling Severity Vs. Time.

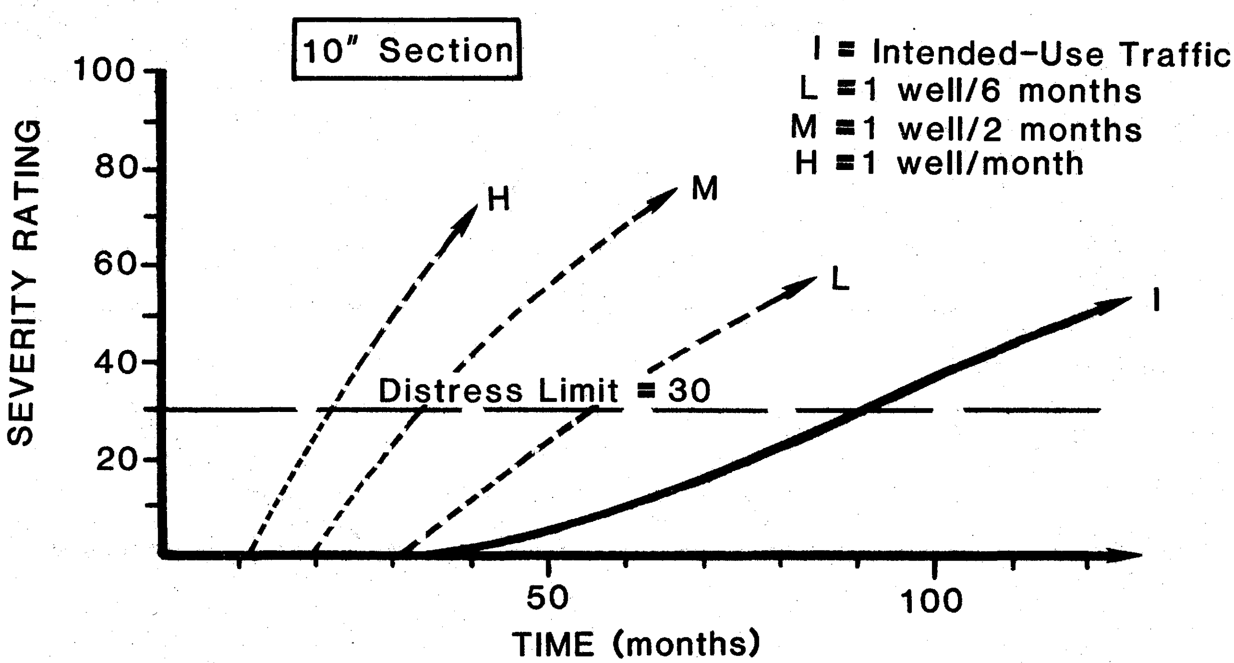


Figure 25. Flushing Severity Vs. Time.

drillers term "back to normality". This does not mean the problem of intense, heavy axle loads in oil-producing areas is "going away", but that the rate of development should be lower than in the immediate past (1977-1981).

The results of the planning scenarios indicate that even under low rates of development (2 wells drilled per year in a known area of crude deposits), service life can be reduced on a 10-inch pavement section. A review of the pavement score diagram (Figure 21) shows an overall potential loss of 16 months under a low oil field development rate. While this loss of service life is not as dramatic as higher activity rates or as consequential as may occur in thinner pavements, Figures 22 through 25 demonstrate the specific distress problems that need to be anticipated.

Load associated distresses, such as rutting and alligatoring, result in approximately two years of expected service. Traffic related measures of performance, such as raveling and flushing, cause about three years of reduced utility. Again, these reductions are based on the conservative low rates of oil field development.

Basically, this technique of examining future conditions can aid in the planning of appropriate maintenance as well as the selection of adequate and economic pavement thicknesses. A reduction in pavement life is inevitable on any roadway. However, the effects of increased site-specific axle load repetition cannot be ignored. Identifying and quantifying future levels of expected reduced service life can assist the Districts and Department in justifiably requesting additional maintenance and rehabilitation funds.

CONCLUSIONS AND RECOMMENDATIONS

The presence of oil field traffic on a roadway causes a substantial reduction in expected pavement life. A 60 to 75 percent loss of predicted service life is possible on thin surface-treated pavements. The actual magnitude of increased pavement distress is a function of pavement thickness, ADT, percentage of trucks, several environmental factors, and subgrade characteristics. In order to evaluate the effects of oil field traffic under various conditions, a methodology has been developed for assessing and predicting site-specific and regional impacts.

The procedure illustrates the techniques used to identify major activity centers and delineate an area of influence for oil field traffic. Intended-use traffic and the oil field related traffic are converted to 18-kip equivalent single axle load repetitions. Using the Texas Pavement Distress Equations, a series of survivor curves is established for several types of pavement distress measures. The resulting pavement service lives are compared and used to assess the effects of accumulating axle loads or to predict the impact of future oil field developments. A review of each measure of pavement performance provides a basis for anticipating resurfacing intervals and other rehabilitation requirements.

Recommendations for Implementation

The methodology described in this report necessitates the development and periodic updating of oil well location maps. The Department or a District should purchase the maps on a regular basis and assemble the pertinent information as previously described in the overall methodology. The Texas Railroad Commission can supply additional data on permitting, drilling, and production rates.

It is recommended that the primary use of this research be at the District level. It is at the local level where the site-specific activity is first observed. If the District maintains density maps that reflect current activity, the engineer can readily identify the impacted roadways. The influence area should be delineated and monitored to anticipate future serious pavement failures.

The Texas Pavement Distress Equations for surface-treated pavements can be used to evaluate the current condition of an existing roadway or to predict its distress levels under future traffic conditions. Several rehabilitation strategies can then be examined. In the future, alternative pavement thicknesses can be analyzed to determine long-range maintenance and reconstruction needs.

On a state level, the total methodology for assessing the effects of oil field traffic can be used to help the Department allocate funds by locating roads which are in need or soon will be in need of maintenance or reconstruction monies. The versatility of the program not only allows the highway agency to predict where work will be needed but also to indicate the type of work required and when it may be required.

Phase III Considerations

The purposes of Phase II were to develop a program analyzing the effects of axle loads on thin pavements and to develop a method of evaluating oil field activity. This report, in conjunction with Report 299-2 (Estimating Service Life of Surface-Treated Pavements in Oil Field Areas), satisfies these objectives.

The methodology for predicting and assessing the effects of oil field development is suitable for district use but has limitations for state use in its present form. Not only has the field information been site-specific, but density maps have to be developed by manual manipulating and drafting of oil field related plans. However, to improve the comprehensiveness of the overall methodology for statewide use, the Technical Advisory Committee has recommended the following objectives be considered in Phase III of this study:

1. Develop additional information to describe the variability of drilling activity throughout the state.
2. Investigate the use of Texas Railroad Commission computer files to create density maps directly from their permit and drilling records.
3. Identify other "special-use" activities that impact the Texas highway system beyond its original "intended-use".

Interpretation

The interpretation of these results must consider the assumptions described in this report. Because the data used in this analysis are site-specific, the findings should not be interpreted as being representative of all situations. The examples presented in this discussion were used to illustrate the potential uses for the overall analysis procedure.

Recommendations for Future Research

Once additional information is developed that describes the variability of oil field drilling activity throughout Texas, statewide influences can be evaluated. Future research needs relative to the investigation undertaken in this study are extensions of the Phase III objectives:

1. Create density maps directly from R.R.C. files.
2. Identify and analyze other "special-use" activities.

Density Maps. Since the Texas Railroad Commission currently keeps an exhaustive file of well permits issued, wells drilled, and wells producing, it is in the best interest of the Department to pursue automated plotting of density maps directly from R.R.C. computer records. A selection of pertinent highway survey monument ties is also necessary to guarantee the useful coordination of final density maps with existing Department plans.

Special-Use Activities. The traffic characteristics and axle loads of trucks used by the timber, grain, and gravel industries are atypical. Their isolated demands differ from those of vehicles associated with normal operating situations. To make the most effective use of existing planning strategies, site-specific data needs to be collected and analyzed for these unique truck demands.

REFERENCES

1. Mason, J. M., Metyko, M. J., and Rowan, N. J., "The Effects of Oil Field Development on Rural Highways -- Phase II -- Identification of Traffic Characteristics, Pavement Serviceability and Annual Cost Comparison," Research Report 299-1, Texas Transportation Institute, Texas A&M University, College Station, Texas, February 1982.

2. Mason, J. M., Scullion, T., and Stampley, B., "Estimating Service Life of Surface-Treated Pavements in Oil Field Areas," Research Report 299-2, Texas Transportation Institute, Texas A&M University, College Station, Texas, March 1983.

3. "Rules and Regulations of the Texas Railroad Commission," R. W. Byran and Co., Vol. I, Austin, Texas, April 1976.

4. Smith, R. E., Herrin, S. M., and Darter, M. I., "Highway Pavement Distress Identification Manual," Federal Highway Administration, U.S. Department of Transportation, Interim Report, 1977-79.