BEST PRACTICES FOR PAVEMENT EDGE MAINTENANCE

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16. Abstract:
The objectives for this research – to identify and to effectively communicate best practices for pavement edge maintenance – were accomplished by capturing over 3700 years of institutional knowledge from maintenance leaders representing all 25 Districts of TxDOT. The research focuses on maintenance practices for naturally-occurring edge drop-offs with an emphasis on low-volume roads. The key factors causing edge drop-offs are narrow road width/ absence of shoulders, traffic volume/type, and adverse environmental conditions. *Tracy's Law*, "If you lose the edge, you lose the road," provides a key perspective on meeting these challenges and emphasizes that good edge maintenance strategy is not only important in achieving good roads, but without good edge maintenance, a District cannot achieve good roads. Edge maintenance practices and procedures fall into three broad categories: awareness, preventive maintenance, and edge repair techniques. Road widening – both in-house using TxDOT forces and by formal contract – emerged as the ultimate practice for long-term treatment of edge problems. Districts use conventional, in-house-modified, and commercially-manufactured equipment specifically dealing with pavement edge maintenance to address the edge drop-off issue. Due to the significant financial resources devoted to pavement edge maintenance, several tools are used to better plan and allocate edge maintenance funds.

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Prepared in cooperation with the Texas Department of Transportation and the U.S. Department of Transportation, Federal Highway Administration.

Implementation Statement

This project identified best practices for pavement edge maintenance by capturing over 3700 years of institutional knowledge from TxDOT maintenance leaders. These best practices for pavement edge maintenance were communicated to over 500 TxDOT maintenance personnel through a series of half-day, regional training workshops covering the entire State. This initial training effort can be implemented more widely and deeply within TxDOT through on-going training and follow-on research efforts.

SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yards	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
NOTE: Volumes greater than 1000 l shall be shown in m^3.				
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5(F-32)/9 or (F-32)/1.8	Celcius temperature	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.71	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	Celcius temperature	1.8C + 32	Fahrenheit temperature	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

* SI is the symbol for the International System of Units. Appropriate

(Revised September 1993)

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CHAPTER 1
INTRODUCTION

1.1 The Research Problem

This research addresses the problem of pavement edge drop-offs as a maintenance, safety and liability issue for the Texas Department of Transportation (TxDOT). With impact to TxDOT's entire roadway system including more than 41,000 centerline miles of Farm-to-Market (FM) highways and millions of dollars in annual maintenance funds, the edge maintenance issue warrants that "best practices" for pavement edge maintenance be defined and implemented.

Multiple perspectives exist on the pavement edge drop-off problem and include construction, design, maintenance, and legal views, among others. Of these, the legal and liability concerns seem to get an inordinate amount of press and discuss topics such as defining pavement edge drop-off severity from a tort liability perspective and establishing threshold pavement edge maintenance standards and requirements. Maintenance and construction publications discuss methods, procedures, equipment and materials for repairing edge drop-offs in varying degrees of detail, both as maintenance activities and as part of pavement reconstruction projects.

One of the challenges of this research has been to explore this many faceted problem but not lose sight of the overall project objective, which has been to define and implement best practices for repair and stabilization of pavement edges. This is clearly a maintenance concern, and while we acknowledge that other perspectives – such as the design, construction, and legal – must be taken into account, we have intentionally focused our research from the *maintenance* perspective.

1.2 Research Approach

The research approach has been to blend theory and practice, academic rigor and common sense in order to identify and communicate best practices for pavement edge maintenance. Given our maintenance focus, we intentionally emphasized the practical, experience-based knowledge areas. The project spanned two calendar years, September 2001 through August 2003, with the first year devoted to identifying best practices for pavement edge maintenance and the second year devoted to training for implementation of the best practices.

The work plan was comprised of seven tasks. In Task 1, we completed a literature review on the subject. Here, the idea was to first develop a comprehensive understanding of the parameters associated with pavement edge repair, and we depended heavily on the literature for external guidance, searching it for examples of similar programs in the public sector throughout the nation. This produced a yardstick by which we evaluated current practice and identified innovative solutions for current edge repair problems. It also allowed us to directly lift others' insights and solutions which have been proved to be successful in their particular environment and saved development work by leveraging past research effort.

Tasks 2 and 3 consisted a survey of each of TxDOT's 25 geographic/ operational districts to capture institutional knowledge and determine current methods, equipment and materials for pavement edge repair projects. In addition to a questionnaire survey, we traveled to each district and interviewed key maintenance personnel, and we observed selected examples of completed edge repair projects, both successful and less than successful. Synthesis of the information we gained from the literature review and the district surveys constitutes the essence of what we present herein as “best practices” for pavement edge maintenance.

In Task 4, we developed of a draft pavement edge repair specification. The draft specification incorporates current repair specifications, both from TxDOT and elsewhere, and contains recommendations for its application with regard to project type, location, environment, traffic volume, etc. The work done in Tasks 1 through 4 was substantially completed in Year 1 of the research project and comprises the bulk of this Research Report.

Tasks 5 and 6, completed in Year 2 of the research project, utilized the information gained in Tasks 1 through 4 and address the implementation and training objectives. Task 5 entailed developing a training package for delivery to maintenance personnel in the TxDOT districts. We prepared training materials for a half-day workshop on best practices for pavement edge maintenance, and this included presentations and a written instruction manual, workbooks for each attendee, on-site classes, statewide conferences, and video tapes. We tested this program by delivering a pilot training session to senior maintenance personnel (subject matter experts) from a sampling of TxDOT districts, and based on their course assessment and evaluation, we finalized the training program. We then provided a series of eight regional training workshops, both face-to-face and by video teleconference, to over 500 maintenance leaders across the State.

Task 7 of the project has consisted of writing the research reports and this was initiated in the first year of the project. As noted, this Research Report summarizes the work done in Tasks 1 through 4 (Year 1) and is the principal document for our findings on best practices for pavement edge maintenance. A companion volume, Product 0-4396-P2, entitled “Best Practices for Pavement Edge Maintenance – District Survey” presents the findings of our surveys for each individual TxDOT district. Readers who desire further detail are referred to that 725-page volume.

1.3 Research Objectives

TxDOT personnel currently use various methods, materials, and equipment to repair roadway edges, but this type of maintenance has typically been done using local (district) forces without the benefit of a broader view of the problem. Although localized perspectives combined with talented and innovative maintenance supervisors have achieved highly-developed insights and repair procedures within a given district, this has also led to a perpetuation of “the way we’ve always done it” method, a situation that we have attempted to improve by helping those personnel involved in TxDOT’s day-to-day maintenance activities become aware of alternatives. We view the “best practices” approach to pavement edge maintenance as a means to take what is best from local practices both within Texas and from across the nation, and share this information with all TxDOT districts, thereby strengthening TxDOT’s entire pavement edge maintenance repair program.

Thus the primary benefit of this research has been a consolidation of institutional knowledge regarding edge repair techniques and the dissemination of those “best practices” across the State of Texas. Stated simply, our research objectives have been (1) to *define* the most effective and efficient practices for repairing and stabilizing edge failures and (2) to *communicate* these “best practices” through practical, clear, and effective training to TxDOT maintenance forces.

CHAPTER 2
RESEARCH METHOD

2.1 Overview

Unlike a "typical" research project where the problem statement attempts to describe the relationship between selected independent and dependent variables; for example, the effect of asphalt content on seal coat aggregate adhesion, here the problem statement is *descriptive* and very open-ended; namely, to define and communicate best practices for pavement edge maintenance. This non-typical problem required a non-typical research method. As briefly stated in the introduction, we approached the problem as one of gathering, synthesizing, and reconstituting a tremendous volume of data. This work was accomplished in seven tasks, four in Year 1 and the remainder in Year 2 of the project. This Research Report presents the findings of the first four tasks and these are described in more detail below.

2.2 Research Tasks

2.2.1 Task 1. Literature Review

We performed a comprehensive review of the literature on pavement edge repair and stabilization to provide a solid theoretical as well as anecdotal context for the assessment of TxDOT pavement edge repair procedures and practices. In addition to previous TxDOT research and academic literature, we reviewed work by other state and federal agencies, for example, selected state Departments of Transportation and federal agencies such as the Federal Highway Administration (FHWA) and the Forest Service. Because of the safety and liability nature of pavement edge drop-offs, we also reviewed much of the significant body of legal documentation on the topic.

The primary focus of the literature review was to identify and characterize pavement edge repair and stabilization strategies in order to meaningfully evaluate TxDOT pavement edge repair practices. This information provided a framework to inventory the maintenance, construction, design, legal and related aspects of the problem. Appendix A of this report contains a list of references cited. Chapter 3 of this report summarizes our findings from the literature review.

2.2.2 Task 2. Evaluate District Edge Repair and Stabilization Procedures, Materials and Equipment

We used the information from Task 1 on edge repair practices, methods, issues and strategies to develop our district edge repair data collection plan. This plan consisted of two primary components: (1) a questionnaire with a standard set of interview questions on district pavement edge maintenance methods, procedures, and practices, and (2) site visits to each of TxDOT's 25 operational/ geographic districts (see Figure 2.1) to discuss pavement edge maintenance and evaluate selected pavement edge repair projects.

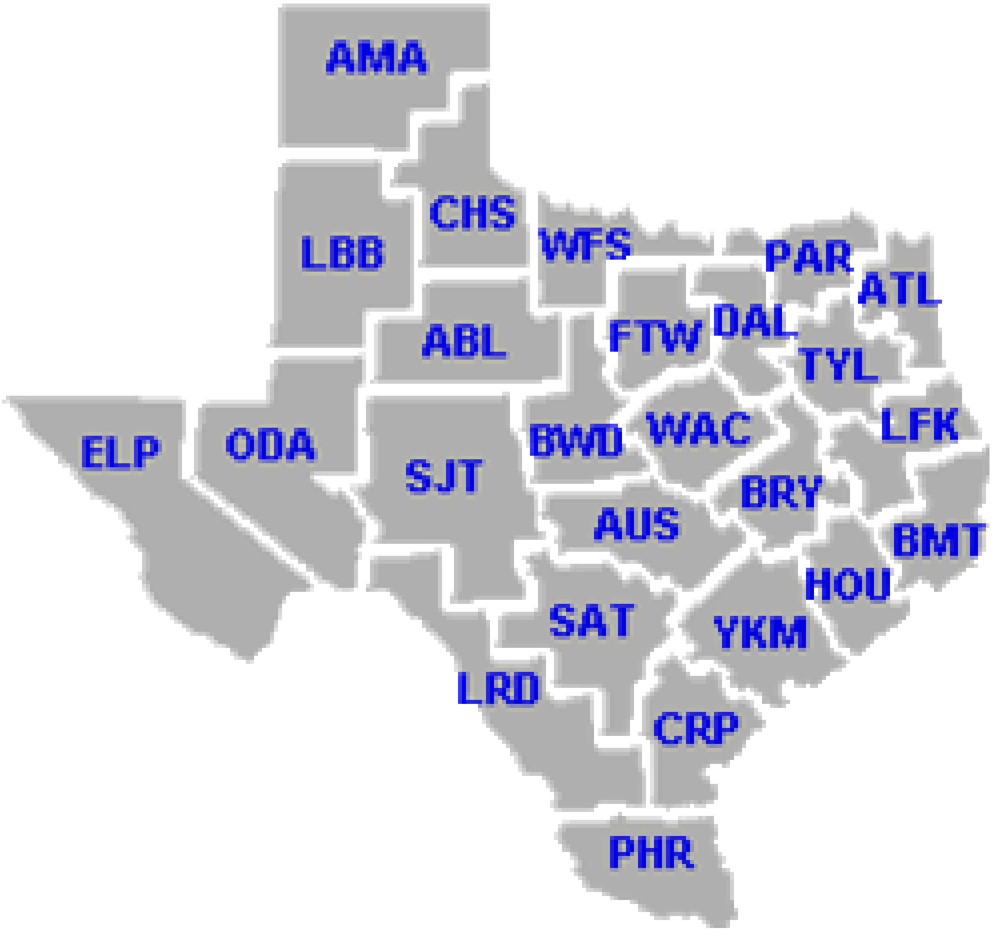


FIG. 2.1 TxDOT Operational/ Geographic Districts (*Source:* TxDOT Expressway 2003)

2.2.2.1 The Interview Questionnaire

Appendix B of this report presents our interview questionnaire. We developed a draft of this questionnaire and submitted it to our TxDOT Project Monitoring Committee for review and comment, and then finalized it for use in the research. We emphasize this is an interview questionnaire, not a survey questionnaire. We provided the questionnaire to district maintenance personnel at least one month in advance of our site visits, the idea being to help district personnel understand the type of information we wanted to talk about in the interview.

The questionnaire contains 57 questions with numerous sub-questions plus two follow-on questionnaire supplements dealing with specific edge drop-off characterization and maintenance issues, for a total of well over 200 questions and sub-questions. On the one hand, this level of detail provided for a very fine-grained and structured conversation about edge maintenance. On the other hand, the questionnaire was simply too voluminous to be taken seriously by district maintenance personnel – only one district completely filled out and answered all the questions.

Most looked at it and decided they would just talk with us about these things when we arrived for the site visit.

For the first few site visits we attempted to dutifully go through the entire questionnaire during our interview, line by line, covering all the questions with the hope of obtaining data specific enough to warrant some type of trend or factor analysis. But this became too cumbersome for both us and the interviewees, and we soon decided that if it were to provide any benefit at all, the interview questionnaire best served as advance notice to district maintenance personnel about the topic for discussion, and as a very loose guide for the conversation once we arrived on site. Therefore, we boiled down our interview questions to a more manageable number – three – that could reasonably be answered by district Maintenance personnel:

1) How are pavement edge drop-offs defined in this district?
2) What are the typical manifestations of pavement edge problems in this district?
3) What practices and procedures does this district use for pavement edge maintenance?

In sum, we felt we had accomplished our research objective if we left the district with an understanding of how edge drop-offs were identified in that particular district, what the typical edge problems were, and how that district addressed those problems from a maintenance perspective.

2.2.2.2 District Site Visits

The key data-gathering aspect of this research was accomplished by making site visits to all 25 of TxDOT's operational/ geographic districts. We scheduled the visits in October-November 2001, and made the site visits from December 2001 through May 2002. The standard procedure for the site visits was as follows:

- Typically two members of the research team visited each TxDOT district to conduct the interview and observe and document selected projects. The typical duration of the visit was one day, with the interview in the morning and field observations in the afternoon. The researchers documented pavement edge repair procedures, materials and equipment by means of notes, photographs, audio recordings, and video recordings, as applicable.
- Each district convened appropriate representatives to communicate their procedures and practices on pavement edge repair and maintenance. Typically, these persons included the Director of Maintenance or Director of Operations, the Maintenance Engineer or Maintenance Manager, and selected Maintenance Supervisors. We were also joined on occasion by Area Engineers, Directors of Construction, and others. The interview typically took place at the district office.
- Prior to the visit, the subject district identified a representative sample of their edge repair projects, as well as any specialized equipment used for edge repair (if applicable). In some cases they arranged for a demonstration of specialized equipment and procedures used in the district. These were observed in the field, with district personnel along to describe the edge maintenance conditions and discuss how they were addressed.

The goal of these site visits was to obtain a shared understanding of district perspectives, practices, and procedures on pavement edge maintenance during the morning interview, and then to physically observe and document illustrative examples of these same conditions and practices in the field in the afternoon. This proved to be a very effective method for gathering information and yielded a large volume of data (over 6 linear feet of shelf space for documentation bound in 3-ring binders).

2.2.3 Task 3: Develop "Best Practices" for Edge Repair and Stabilization

Best practices for pavement edge repair - and by "best practices" we mean those maintenance practices that are the most safe, effective, and efficient – were distilled from the voluminous data obtained from Tasks 1 and 2. Both the literature review and the district interviews and site visits enabled us to identify the types of maintenance that are being done, what does and does not work, why particular approaches work, and under what conditions. Our goal in Task 3 was to synthesize this wealth of information into a manageable number of definable maintenance practices for various traffic, environmental, geotechnical, and related conditions. Chapters 4 through 10 present these findings.

The results of the district surveys, both the interview record and the documentation of selected edge repair practices and procedures, were initially intended to be tabulated and statistically analyzed for trends in the data. However, because of the open-ended nature of the interviews and variation in the discussions, the data were not readily amenable to formal statistical analysis. While broad themes exist which we note and discuss in this report, we did not attempt to characterize potential trends with the language of mathematical rigor nor did we ground our observations with statistical confidence factors.

We emphasize that one of the reasons "best practices" have not existed for pavement edge repair is that this type of maintenance is typically done using local (district) forces without the benefit of a broader view of the problem. We see the best practices as a means to take what is best from local practices and share this information with all the districts, thereby strengthening TxDOT's entire pavement edge maintenance repair program. This dynamic – moving away from many localized pavement edge maintenance perspectives toward a comprehensive "best practices" perspective is the main reason why we visited all 25 of the TxDOT districts as part of our data gathering effort. Only by visiting all the districts could we effectively glean the local expertise from the maintenance staff in those districts. This also helped with implementation, since each district's key maintenance personnel were individually and collectively "bought in" to the process and viewed the project results as something they were a part of, rather than simply an edict from the upper echelons of the agency.

2.2.4 Task 4: Develop Draft Edge Repair Specification for Routine Maintenance Contracts

One unique challenge of this research was to develop a draft specification which could be used for contract pavement edge maintenance work. Although TxDOT does not currently have a statewide pavement edge repair specification, limited Special Specifications exist for certain districts, and project-specific specifications also exist. In Task 4, we developed a draft specification based on review of specifications from other states (obtained through the literature review) as well as existing TxDOT specifications.

Peer review was a critical aspect of our specification development effort. We developed the first draft of the draft specification with awareness of the district evaluation data, the ideal being a statewide specification that could be tailored to produce a successful edge repair project in each district. This determination was submitted to the Project Monitoring Committee and other interested persons for review and comment.

The sequence of events for Task 4 generally consisted of (1) developing the first draft of the "draft" specification, (2) performing an internal peer review within the project team, (3) obtaining review from the Project Monitoring Committee, (4) revising and updating the specification, and (5) issuing the final version of the draft specification. The final product was formally submitted to TxDOT for their own formal review, approval, and implementation. We have included a copy of the draft specification as Appendix C of this report, and we discuss its development in more detail in Chapter 9.

2.2.5 Task 5. Develop Training Program and Materials

Task 5, performed during the second year of the project, consisted of developing a training package for district maintenance, construction, and design personnel on the topic of best practices for pavement edge maintenance. This was accomplished by identifying training objectives based on the issues and needs identified from Tasks 1 through 3, and then designing instructional content around those objectives.

We developed the training materials for a workshop-type setting using both instruction and examples that appropriately illustrated the training objectives. Training materials focus on core content but also cover special or unique technical issues for pavement edge maintenance and repair. The types of media that we used in delivering the training included an instructor's manual, a student workbook, a series of PowerPoint slide presentations and lectures, film clips, and review quizzes. We selected these media and formats in consultation with the TxDOT Project Director in the belief that for the training program to be effective, our instruction must penetrate to the *Maintenance Section level*, and these are the media most appropriate to achieve that goal for this Division of TxDOT.

The sequence of activities for Task 5 consisted of (1) designing the training program, (2) developing the training materials, and (3) obtaining review by the Project Monitoring Committee, and (4) finalizing the materials (during the pilot training workshop in Task 6).

2.2.6 Task 6: Deliver Pavement Edge Maintenance Training

In a very real sense, training and implementation commenced with our program of visiting all 25 TxDOT districts during the evaluation phase (Task 2). These visits were an open invitation to key district maintenance personnel to become aware of and participate in the research process, and helped to sensitize us (as researchers and presenters) to the most effective style and manner by which we should present our findings.

The training effort escalated to include maintenance managers and supervisors with a brief introduction of our research (in progress) through our presentation at the TxDOT Annual Transportation Short Course in October 2002. These events promoted awareness of this research among the senior personnel in TxDOT most closely impacted by it.

Having set the stage for delivery as outlined above, the next step was to present our *complete* research findings through training and instruction at the TxDOT *Maintenance Section level*. This is Task 6 of the proposed research program. As already noted, the training deliverable consisted of a printed workbook with detailed information, presentations, and supporting documentation. We provided a copy of this workbook to each of the 557 TxDOT personnel who attended the training. The training program consisted of the following elements:

- We began with a half-day pilot workshop in January 2003 for maintenance personnel strategically-selected from throughout the state. These personnel critiqued and evaluated the training they received, and we used comments from the pilot workshop to refine and improve the training into final form. This type of assessment was done each time that the training was delivered so as to improve the next session.

- We delivered a "research highlights" presentation to TxDOT maintenance managers and supervisors at the General Session of the TxDOT 2003 Statewide Maintenance Conference.

- We provided half-day regional training workshops for maintenance personnel at eight strategically selected TxDOT districts, from February 2003 through August 2003, using both face-to-face and video-teleconferencing methods. This enabled maintenance personnel from all districts throughout the state to participate in the training program.

- A representative of the TxDOT Audiovisual Production Services group videotaped one of the regional workshops to capture the training for ongoing instructional purposes. This tape was produced and distributed to each maintenance section throughout the State to help facilitate full coverage for all maintenance employees, as well as allow for future training of new maintenance employees.

Thus, the sequence of events for Task 6 consisted of (1) initial training through the pilot workshops, (2) a technical presentation in the General Session of the TxDOT 2003 Statewide Maintenance Conference, and (3) offering a series of eight regional training workshops, with on-going revision and improvement of the training program and materials. This also included production of a video-tape by TxDOT audio-visual personnel.

2.2.7 Task 7: Project Reports

Four reports have been/ are being prepared for this project. The first consisted of the "Best Practices" instruction workbook for maintenance personnel which summarizes the best practices for pavement edge repair and stabilization and included the draft pavement edge repair specification. The second report is this Research Report presenting the findings of Tasks 1 through 4. The third report is the companion to this Research Report and summarizes the findings of our District surveys, discussed below. The fourth report is TxDOT's 4-page Project Summary Report.

2.3 Presentation of Data: The District Profiles

2.3.1 Overview

Product 0-4396-P2 presents what we term the "District Profiles," arranged in order by district number. These profiles summarize the results of the interview and site visits for each of the 25 TxDOT districts and are the data upon which this report is based. The typical district profile consists of a summary of the interview plus one to five exhibits. The interview summary briefly presents, among other things, a district's general demographics, the maintenance personnel's perspective on defining the edge drop-off problem, the typical manifestations of edge problems, and that district's edge maintenance practices and procedures. Following the interview and site visit, we prepared a draft version of this interview summary and submitted it to our point-of-contact for that particular district (usually the Director of Maintenance or Director of Operations) for review and comment. Based on input received, we developed the final version of the profile presented in Product 0-4396-P2. In addition to the interview summary, the first exhibit always consists of selected photographs from the district. Other exhibits, when they are used, include illustrative information such as excerpts from plan sheets, information about unique district procedures for dealing with edge problems, and the like.

2.3.2 District Demographic Summary

Table 2.1 summarizes the district demographics as they relate to our site visits and interviews. Whereas comprehensive TxDOT statistics are available on-line (TxDOT 2003), this table conveniently illustrates the classification of the district, the number of counties and lane miles, and the number of personnel who participated in our interview, along with their years of experience. It is significant to note that 181 TxDOT personnel with a combined total of 3,765 years of maintenance experience participated in this research, offering us the benefit of their knowledge and expertise. The findings we gathered are theirs.

Table 2.1. District Demographics Summary, Pavement Edge Repair Interview

District No./ Designation	District Name	Classification	No. of Counties	No. of Lane Miles	No. of Personnel Interviewed	Years of Maintenance Experience
01/ PAR	Paris	Rural	9	7,126	11	253
02/ FTW	Ft. Worth	Metropolitan	9	8,470	6	132
03/ WFS	Wichita Falls	Rural	9	6,316	6	127
04/ AMA	Amarillo	Rural	17	9,284	8	158
05/ LBB	Lubbock	Urban	17	12,004	9	184
06/ ODA	Odessa	Rural	12	7,928	7	126
07/ SJT	San Angelo	Rural	15	7,113	4	79
08/ ABL	Abilene	Rural	13	8,376	5	123
09/ WAC	Waco	Urban	8	7,705	4	64
10/ TYL	Tyler	Urban	8	8,624	3	57
11/ LFK	Lufkin	Rural	9	6,352	3	62
12/ HOU	Houston	Metropolitan	6	9,683	3	55
13/ YKM	Yoakum	Rural	11	7,904	14	353
14/ AUS	Austin	Metropolitan	11	8,549	14	283
15/ SAT	San Antonio	Metropolitan	12	10,387	8	144
16/ CRP	Corpus Christi	Urban	10	6,936	6	136
17/ BRY	Bryan	Urban	10	6,898	4	95
18/ DAL	Dallas	Metropolitan	7	9,928	21	426
19/ ATL	Atlanta	Rural	9	6,372	3	71
20/ BMT	Beaumont	Urban	8	5,643	8	158
21/ PHR	Pharr	Urban	8	5,613	4	74
22/ LRD	Laredo	Urban	8	4,920	12	260
23/ BWD	Brownwood	Rural	9	5,860	3	60
24/ ELP	El Paso	Urban	6	4,720	9	162
25/ CHS	Childress	Rural	13	5,411	6	123
TOTALS			254	188,122	181	3765

2.3.3 Detailed District Information

The following chapters of this report summarize best practices for pavement edge maintenance as synthesized from the literature review and the district profiles. For detailed information about district conditions and edge maintenance practices and procedures, the reader should refer directly to the district profiles. Here the reader will not only find first-hand information about edge maintenance practices and procedures for a specific region of Texas, but also annotated photographs and helpful contact names and phone numbers for further information (current as of the date they were obtained).

2.4 Research Focus and Limitations

We have already noted that pavement edge drop-offs represent a multi-faceted problem that has been explored from the design, construction, maintenance, legal and other perspectives — but we have intentionally focused our research from the *maintenance* perspective. It is appropriate to identify other boundaries and limitations of this research.

First, it must be emphasized that this report primarily focuses on edge maintenance practices and procedures in Texas, for roads within the TxDOT system. The physiographic make-up of Texas includes mountains, beaches, deserts, high-rainfall areas, grasslands, forests, rural towns, and metropolitan cities, with pavement subgrade ranging from rock to clay. This makes for a highly diverse range of conditions for which the practices and procedures discussed herein will apply. But Texas is obviously located in the southern part of the United States and thus does not experience severe winter weather like northern states do, so the edge maintenance practices and procedures discussed herein do not emphasize freeze-thaw and cold-weather issues.

Second, we acknowledge that pavement edge drop-offs arise from many causes, one highly prominent example being drop-offs that result from highway reconstruction operations. For example, serious vertical edge drop-offs frequently exist on multi-lane highway construction projects where a travel lane is being milled out for replacement, or conversely, when the lanes of a highway are being sequentially overlaid with hot mix asphaltic concrete. These common edge drop-off scenarios on construction projects have been intentionally *excluded* from this research. This is not to say that construction-zone edge drop-offs are not important, but that we have limited our research to “naturally-occurring” edge drop-offs such as would be typically encountered by roadway maintenance personnel. One exception to the above has to do with maintenance/ construction projects where the entire road surface is being overlaid resulting in a higher road surface elevation and thus the potential for extensive edge drop-offs. We do discuss this type of construction because the edge maintenance it engenders often falls within the purview of maintenance forces.

Third, we acknowledge that pavement edge drop-offs are not the only edge defect that maintenance forces deal with. For example, in certain high-rainfall regions of the State it is mostly high edges and not drop-offs that are the problem. While maintenance of pavement edge drop-offs is the dominant concern of this report, we do discuss maintenance of high edges and defects other than just edge drop-offs.

Fourth, we did not limit our research to low-volume, narrow, FM roads. While the most prominent image of pavement edge drop-off problems in Texas probably has to do with Texas’ low-volume FM road system, during the course of our research we encountered comments and perspectives on pavement edge problems for all types of roads, up to and including Interstate highways. Therefore we did not intentionally restrict our attention to the low volume roads, even though they appear most commonly in our discussions simply because they are a major issue.

Fifth, and related to the above, we did not limit our research to roads without shoulders; however, we have intentionally attempted to emphasize maintenance responsibility where edge damage (usually, a drop-off) exists adjacent to a travel lane. We encountered examples of edge drop-offs in just about every type of condition possible, and apart from construction-zone drop-offs we did not purposefully exclude consideration of any of these from this research. We have consciously attempted to point out the potentially heightened severity for edge drop-offs where no shoulder exists adjacent to the travel lane, this as opposed to drop-offs that might exist along a road with a full shoulder.

CHAPTER 3
LITERATURE REVIEW:
PAVEMENT EDGE MAINTENANCE

3.1 Overview

This chapter summarizes the literature on pavement edge drop-offs, including their repair and stabilization. The primary focus of the literature review was to provide a context in which to meaningfully evaluate TxDOT pavement edge maintenance practices and procedures. In addition to previous TxDOT research and academic literature, we reviewed work by other state and federal agencies. Because of the safety and liability nature of pavement edge drop-offs, we reviewed some of the significant body of legal documentation on the topic, and we also reviewed literature on construction, design, maintenance, and related aspects of the problem. Appendix A of this report contains a list of references cited.

3.2 Origin and Significance

The Transportation Research Board (TRB) considers pavement edge drop-offs among the top accident-related disturbances, and a common source of tort claims against highway agencies. As early as 1954, it was recognized that unstabilized shoulders are often subject to erosion resulting in the elevation of shoulders at the pavement edge being several inches lower than the pavement roadway. The repair of deteriorated pavement edges and unpaved shoulders adjacent to pavement edges is a maintenance activity that requires continuous effort by all state and local highway agencies (Zimmer and Ivey 1983).

At a recent FHWA workshop on managing pavement edge drop-offs, Ivey (2004) presented a concise summary of research on pavement edges and highway safety from 1940 to 2004. Ivey's presentation includes a history of research contributions which gives context to the pavement edge drop-off phenomenon.

Glennon (1996) has summarized the issues related to edge drop-offs and his work provides a helpful overview of the subject. Although his focus is highway defects in tort liability, Glennon's summary discusses research findings related to highway safety as well as available construction and maintenance recommendations to deal with edge drop-offs.

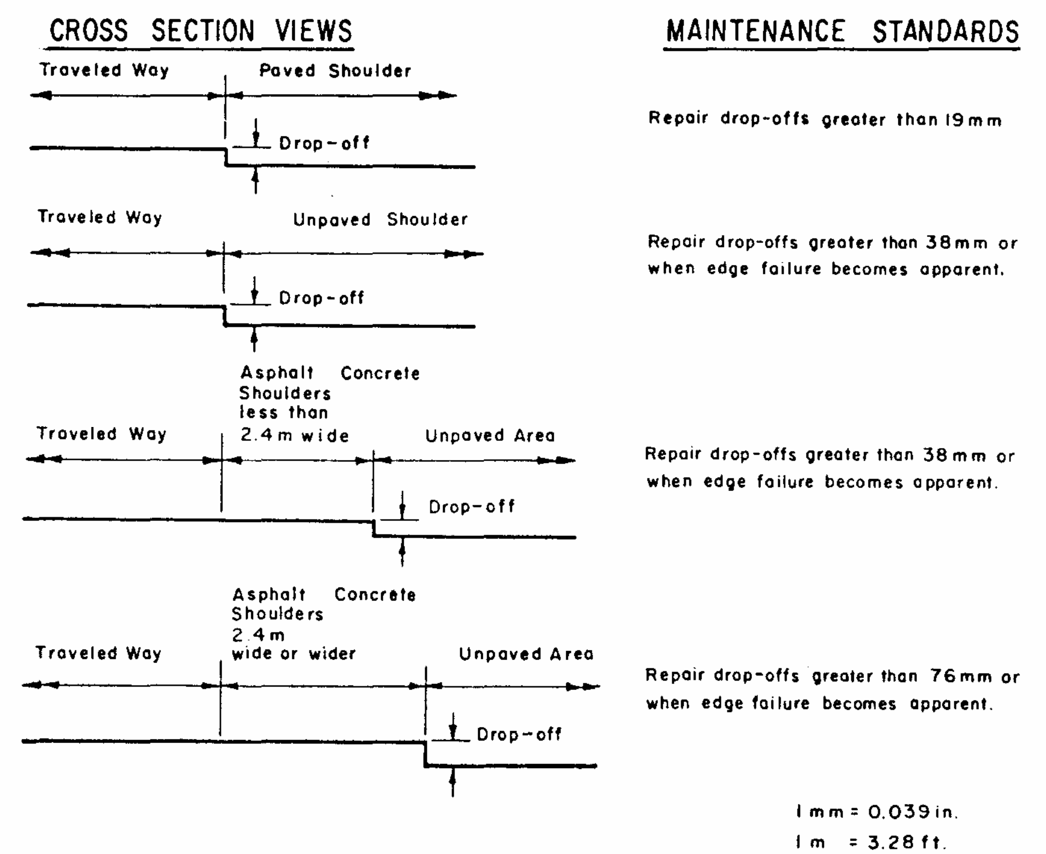
3.3 The Nature and Causes of Edge Drop-offs

ASTM (2001) defines "lane-to-shoulder drop-off" as the difference in elevation between the traveled surface and the shoulder surface. There are also other situations, illustrated by Stoughton, et al. (1979), where a longitudinal edge drop-off exists along a highway when there is a difference in height between two adjacent surfaces, either between:

1. Surfaces of a paved shoulder and the unpaved area alongside it,
2. Surfaces of a paved travel way and an unpaved shoulder,
3. Surfaces of a paved travel way and a paved shoulder, or

4. Two adjacent traveled lanes.

While each of these pavement-edge interfaces is important, as shown in Figure 3.1, the focus of this research has mostly been the second one, that of a paved traveled way and an unpaved shoulder. We consider other cases, but our emphasis is here.



Note: Maintenance Standards refer to the 1974 *CalTrans Maintenance Manual*.

FIG 3.1. Pavement Edge Drop-off Interfaces. *Source:* Stoughton, et al. (1979)

Drop-offs are generally caused by erosion from wind, rain or other environmental conditions and by vehicle tire contact (traffic wear) on an unpaved shoulder (Ivey, et al. 1984). Unpaved shoulders are constructed of untreated materials with inadequate resistance to erosion and abrasion (Ivey, et al. 1984, Kilareski 1996). If the shoulder areas are not compacted properly, they erode easily. When shoulder slopes are too steep, surface runoff water will flow too fast while crossing the shoulder and create significant water erosion (Kilareski 1996).

Edge drop-offs can also happen easily during pavement overlay construction. Paving equipment cannot pave the full width of the traveled way or both the traveled way and shoulder at one time. There is often a delay before all of the existing pavement can be brought up to the grade of the new pavement surface (Stoughton, et al. 1979). In some cases, delays between the time of resurfacing and restoring the adjacent shoulders to bring them up to the resurfaced roadway level are caused by not contracting the full scope of work at one time (Humphreys, et al. 1994).

Kilareski (1996) recommended to The Pennsylvania Local Roads Program that a drop-off of 2 inches or more should be scheduled for maintenance and repaired immediately to ensure highway safety and its structural integrity. Wisconsin DOT (1995) also requires that when there is an edge drop-off of more than 2 inches, the shoulders must be pulled up before the road is opened to through traffic.

Washington State DOT (2001) uses a tool, "Maintenance Accountability Process (MAP)" to measure and communicate the level of service delivered by their departmental maintenance activities. Field inspections of randomly selected sections of highway are made twice a year. The performance of the maintenance effort is measured, recorded and compared to the MAP criteria to determine the level of service delivered. This is used as an effective and strategic tool for planning and budgeting. MAP collects data from right-of-way to right-of-way including pavement surface, shoulder, drainage structures, roadside vegetation, bridges, pavement markings, guideposts, etc. A two-inch drop is used as the threshold value for shoulder edge drop-offs in MAP criteria.

Another problem on shoulders is that of build-up of material along the edge of pavement, or "high" edges. High edges occur for various reasons, a typical one being failure to clean the shoulders after winter operations. Anti-skid material gets shoved to the side of the road by traffic action and catches dust and dirt. Vegetation then grows in this excess material, further slowing the flow of water and holding back more sediment. The water flowing along the edge of the pavement seeps into the pavement base course. Stone base materials composing the base are held together by friction between the stones, but water is an excellent lubricant. When water gets into the stone base, a large portion of the friction force is lost. Thus, the carrying capacity of the pavement decreases and vehicles traveling near the edge cause the surface to break up (Kilareski 1996).

Rogness and Burley (1993) discussed the pavement edge scour problem within the national park system, specifically, the "parkway." Road edge scour damage is the erosion of unpaved shoulders or adjacent roadside surfaces caused by vehicular traffic. Vehicle movements vary from intentional pull-offs to wandering as a driver responds to road conditions. Edge damage is usually associated with older roadways that are experiencing an increased volume of longer, wider, and heavier vehicles. These roads are most frequently those that have not been updated to reflect modern design standards. The edge scour problem represents a conflict between old roadway design standards and modern roadway use. This damage is characterized by destruction of the vegetation cover, rutting of the shoulder, and development of a dike along the pavement edge.

3.4 Edge Drop-offs in Tort Liability Literature

The Transportation Research Board determined that pavement edge drops are a common source of tort claims against roadway agencies. Considerable debate has occurred in courtrooms across the nation not only about what constitutes a hazardous edge drop but also what responsibility roadway agencies have for minimizing hazardous edge drops and/or warning of their existence (Glennon 1996).

Glennon (1996) identifies several possible outcomes of edge drop traversal by a vehicle, ranging from safe recovery to a potential head-on collision or rollover depending on the vehicle's exit angle, the driver's level of surprise, and the driver's steering and/or braking response. Both Glennon (1996) and Chamberlain (1998) claim that researchers have failed to reach a consensus on a safe pavement edge drop height for the naïve driver. Many state roadway agencies have adopted policy which states that edge drops of no more than 3 inches should be permitted. Further, it is desirable that attempts be made to limit edge drops to a value significantly less than 3 inches. On this basis, a 1 ½- to 2-inch criterion is more appropriate for maintenance on 55 to 75 mph roadways (Glennon 1996). Chamberlain (1998) is more conservative and considers a 2-inch drop as safe in a 40 mph zone and a 1-inch drop safe for a freeway speed zone.

Glennon (1996) also found that pavement edge drops at unpaved shoulders are usually a recurring hazard, particularly along narrower two-lane roadways with heavy truck traffic. Trucks not only blow away shoulder material during dry weather, but they commonly disturb shoulder material by running with one wheel of a tandem overhanging the edge, particularly on the inside of roadway curves. Moreover, unstabilized shoulder material is susceptible to rutting by all vehicles during wet weather. Glennon (1996) made the following recommendations to highway agencies to deal with edge drop problems:

- One or more of the following treatments should be employed to either replace or supplement a normal maintenance practice of simply adding more shoulder material when the recurring edge drop exceeds 1½ inches:
  - Place low-shoulder warning signs;
  - Add stabilizing agents to shoulder material that are otherwise susceptible to rutting, or pave the entire shoulder, or pave at least a 2- to 3- foot strip of shoulder adjacent to the travel lane (particularly along the inside of roadway curves with pavements narrower than 22 feet).
- Edge-drops created due to resurfacing should be dealt with using the following practices:
  - There should be no resurfacing contract issued without the provision of placing a stabilized shoulder flush with the pavement surface done at the same time as resurfacing.
  - All resurfacing contracts where the shoulder is unpaved should require a paved 45° or flatter wedge along the pavement edge.
- In order to avoid a possible hazardous situation associated with edge drops in a construction zone, it is recommended that signs, barriers and temporary wedges be used to maintain the traffic.

The Roadway Injury Prevention & Litigation Journal publishes records of court decisions for liability cases involving pavement edge drop-offs. Two examples are a case in Texas (TranSafety 2000a) and a case in Wisconsin (TranSafety 2000b). The primary issues in both of these cases were edge drop-offs and the transportation agency's alledged negligence or failure to provide adequate warning of this condition. The core issue for litigation was the safety of the traveling public.

Research from these court cases indicates that the probability of severe consequences resulting from pavement edge-drop traversals is a function of the speed and path angle of the vehicle and the height and shape of pavement edge drop. If the edge drop-off or difference in elevation reaches a certain level for certain edge shapes, safety can be affected. Extensive research has been performed on the topic of edge drop-offs related to vehicular stability and safety by the researchers including Ivey (1984, 1986, 1988), Zimmer (1983), Stoughton (1979), and Nordlin (1976). They considered pavement edge drop-offs of less than 1 inch to about 6 inches. Edge drop-offs deeper than these constitute more obvious traffic safety problems such as dragging or rollover. In order to understand the safety issues related to pavement edge drop-offs, it is appropriate to illustrate the scenario where a vehicle drives off the road and tries to get back again to the road. Ivey, et al. (1984) describes such a scenario effectively as follows:

1. A vehicle is under control in a traffic lane adjacent to a pavement edge where an unpaved shoulder is lower than the pavement.

2. The driver inadvertently leaves the travel lane and moves into a position with the right wheels on the unpaved shoulder just off the paved surface. The driver gradually steers to the left to bring the right wheel back up onto the traveled lane without reducing speed significantly.

3. The right front wheel encounters the pavement edge at an extremely flat angle and is prevented from moving back onto the pavement. This situation is known as "scrubbing". The driver further increases the steer angle to make the vehicle regain the pavement. However, the vehicle tire continues to scrub the pavement edge and does not respond.

4. The driver over-steers and eventually the right front wheel mounts the paved surface. Suddenly, in less than one wheel revolution, resistance from the pavement edge has disappeared and the front right wheel experiences an increase in available friction on the pavement.

5. The vehicle yaws radically to the left, pivoting about the right rear wheel, until that wheel can be dragged onto the pavement surface. The excessive left turn and yaw continues. It is too rapid in its development for the driver to avoid penetrating the oncoming traffic lane.

6. A collision with oncoming vehicles, or spin out and possible vehicle roll, may then occur.

Figure 3.2 provides a graphic which illustrates the scrubbing phenomenon. Unlike static drawings, the online graphic actually shows, in slow motion, vehicle movements during scrubbing.

FIG 3.2. The Scrubbing Phenomenon. *Source:* <www.engineeringarts.com>

The qualitative effect of pavement edge drop-offs has been understood to some degree as early as 1954. Through informal testing at Northwestern University during 1959, it was concluded that a lane-to-shoulder drop off of three inches or more has significance. During the mid-1970s, Ivey and Klein separately reviewed and analyzed accident data from different sources and found that pavement/shoulder drop-offs are a significant contributing factor to accidents (Zimmer, et al. 1983, Glennon 1987). Around the same time, Stoughton, et al. (1979) reported the results of a series of full scale testing conducted by the California Department of Transportation to determine the effects of longitudinal drop-offs along a highway with respect to the stability and controllability of vehicles traveling over the drop-offs at high speeds. The tests included small, medium, and large passenger cars and a pickup truck driven at speeds up to 60 mph. Drop-off heights of 1.5, 3 and 4.5 inches were considered for investigation. Stoughton, et al. (1979) concluded that there was no significant effect of pavement edge drop-offs on vehicle stability and controllability, even at speeds as high as 60 mph. The scrubbing condition, as explained earlier was not tested during all of those studies.

Klein, et al. (1977) studied edge scrubbing conditions extensively and made a major contribution in this area. He successfully defined a control difficulty parameter and related it to a critical speed which ensured that the vehicle would not exceed the opposite lane boundary even after a 4.5-inch climb. He also found the required steering angle to climb a vertical edge drop and developed the general relationship between the steering wheel angle and the edge drop-off (vertical) heights. He concluded that the probability of scrubbing increases dramatically for drop-off heights above 4.5 inches and loss of control was encountered at the higher speed levels, generally more than 30 mph. But he considered only near vertical (90°) edge drop-offs. Zimmer and Ivey (1983) in 1981 conducted a comprehensive study at the Texas Transportation Institute to supplement earlier research in this area. They evaluated the effects of edge shapes based on a variety of drop-off heights, vehicles tires, driver speeds, and positions, and based on this research developed the relationship between edge geometry and safety for scrubbing conditions as shown in the Figure 3.3.

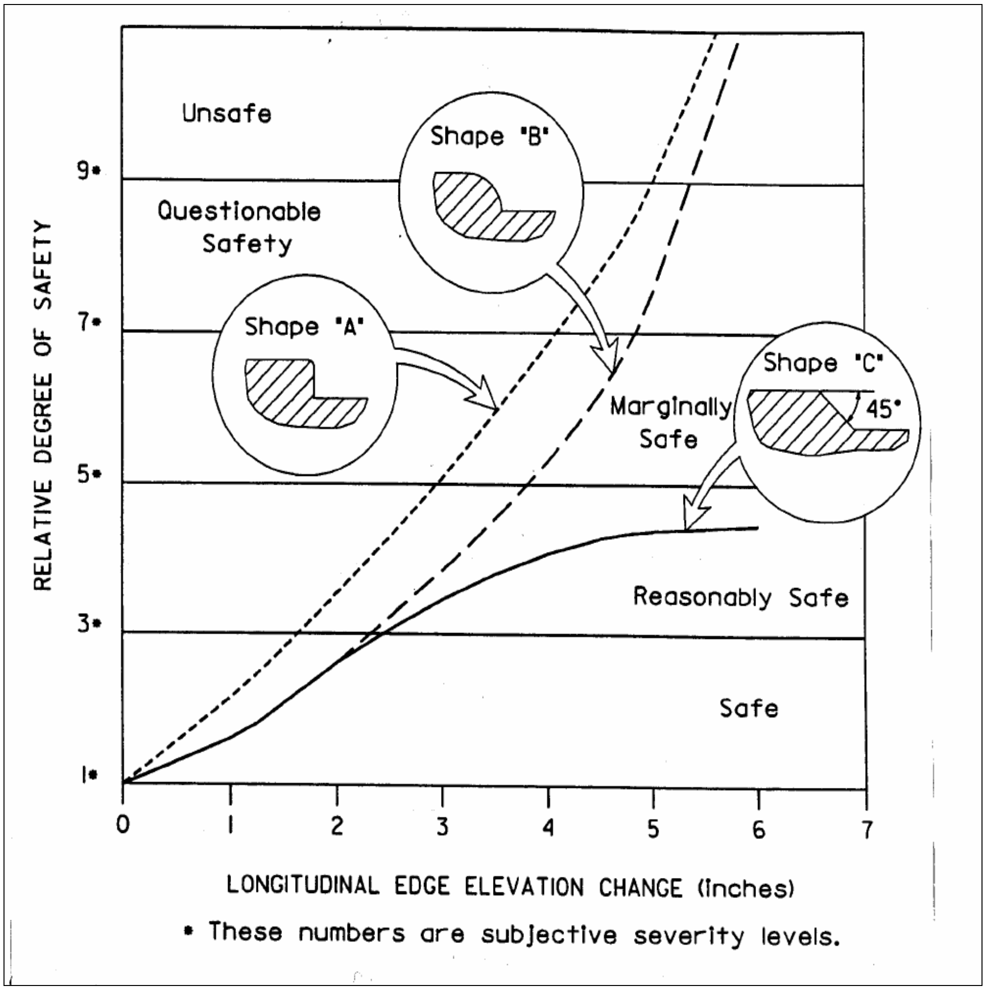


Figure 3.3 Relationship between edge geometry and safety for scrubbing conditions. *Source:* Zimmer and Ivey (1983).

Zimmer and Ivey used a subjective severity rating system and defined five "safety zones" as explained in the Table 3.1. Figure 3.3 suggests that a tapered edge of 45° or flatter would always ensure safety independent of edge drop-off height. When the pavement edge drop-off height does not exceed three inches, the safety problem is minimal (Ellis, et al. 1996). In other words, if the edge drop is steep enough, normally above three inches, the vertical discontinuity can create a potentially hazardous situation for drivers that attempt to steer over it (Chamberlain 1998). A loose or muddy soil shoulder should not increase the edge-climbing difficulty, provided that the overall height is the same (Ivey, et al. 1984). However, similar losses of control can occur even without any drop when an errant vehicle is returned to the higher surface friction of the pavement by over-steering.

A few analytical model studies address safety issues associated with edge drop-offs. Ivey and Sicking (1986) demonstrated how the steer angle prediction by Klein could be combined with a vehicle simulation such as the highway vehicle object simulation model (HVOSM) to predict

Table 3.1 Safety Conditions for Various Drop-off Heights, after Zimmer and Ivey (1983)

Drop-off Height (mm)	Drop-off Height (inches)	Safety Condition	Description
Less than 38.1	Less than 1.5	Safe	No matter how impaired the driver is, the pavement edge condition will not affect vehicle control.
38.1 to 76.2	1.5 to 3.0	Reasonably Safe	A prudent driver of a reasonably maintained vehicle would experience no significant problems.
76.2 to 101.6	3.0 to 4.0	Marginally Safe	A small percentage of drivers would experience a significant control problem.
101.6 to 127.0	4.0 to 5.0	Questionable Safety	A high percentage of drivers would experience a significant control problem.
Greater than 127.0	Greater than 5	Unsafe	Almost all drivers would experience great difficulty.

vehicle movements, stability, and controllability. Some of Klein's findings were partly validated by Graham and Glennon (1987) who also used HVOSM computer simulation techniques to study vertical face drop-offs. They came up with the reentry angle boundaries for successful recovery of the vehicle from a vertical face drop-off. The lower boundary would be the minimum required for a successful non-scrubbing recovery and the upper boundary would be the maximum reentry angle that would allow the vehicle to still recover within the lane. These boundaries are expressed as a function of speed and lane width, as shown in Figures 3.4 and 3.5.

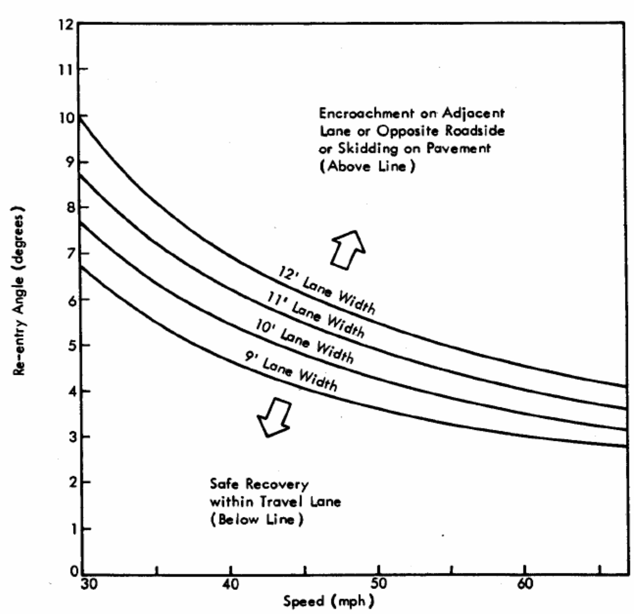


Figure 3.4 Maximum safe reentry angle for shoulder traversal as a function of speed and lane width. *Source:* Graham and Glennon (1984).

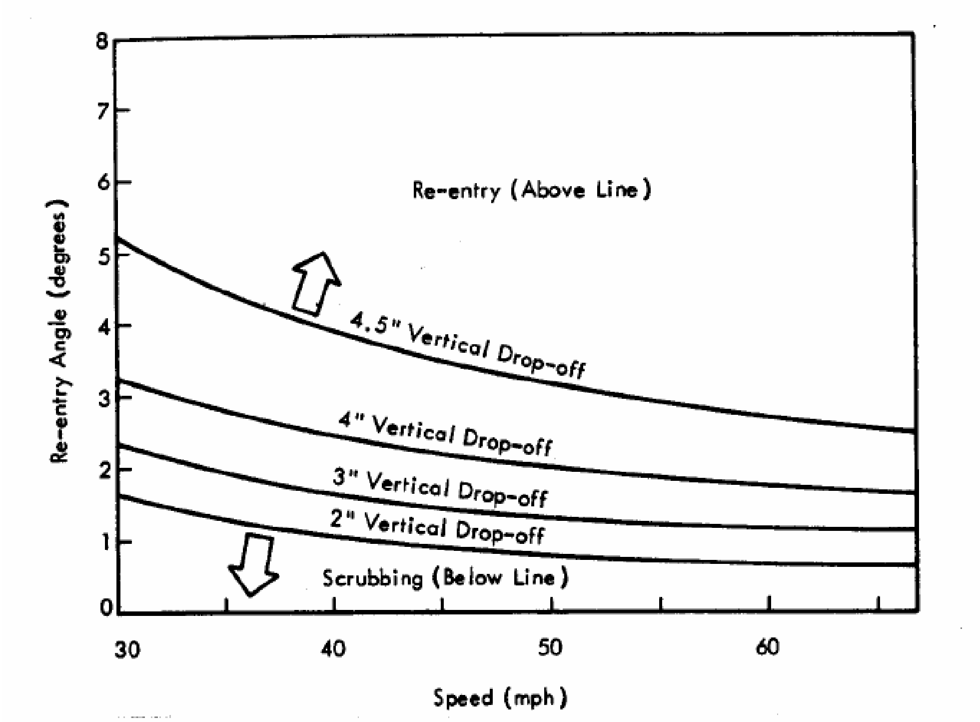


Figure 3.5 Minimum safe reentry angle for traversal of vertical face pavement/shoulder drop-off as a function of speed and drop-off height. *Source:* Graham and Glennon (1984).

Merwin (1988) discussed the issues related to work zone safety. Excessive edge drop-offs are considered to be one of the contributing factors of an unusually high number of accidents in work zones. Positive barriers, improved traffic-control devices and police enforcement of speed limits are a few steps that would enhance work zone safety.

The AAA Foundation for Traffic Safety sponsored research to investigate the techniques to eliminate or mitigate the hazards associated with pavement edge drop-offs during roadway resurfacing. Humphreys and Parham (1994) looked mostly at the drop-offs during construction or resurfacing of the pavement, but the same solutions could be applied to the naturally created edge drop-offs. The study involves synthesis of the opinion or views expressed by the city and county engineers, public works directors, transportation consultants, government legal departments, contractors, and public risk insurance managers. Data for this study was gathered through both personal interviews and questionnaires. Since pavement edge drops are a common source of tort claims against highway agencies, litigation was one of the main focuses of their study. They determined that a vertical drop-off of four or more inches is unsafe because of the possibility of the scrubbing condition experienced by the run-of-the-road drivers during over-steering to get back on the lane.

3.5 Edge Drop-offs in Design Literature

Rowan (1973) of the Texas Transportation Institute conducted a national survey on shoulder design and operation practices among all 50 states. There is a general agreement on the basic need for good shoulders but a substantial disagreement exists in the areas of design guidelines, natural contrast, use of edge lines, most desirable shoulder widths, and structural quality of shoulders as compared to that of main lanes.

AASHTO (2001) *Guidelines for Geometric Design of Very Low-Volume Local Roads* discuss the geometric requirements for low-volume local roads that primarily serve drivers who are familiar with the roadways. Almost 80 percent of the roads in the United States have traffic volumes of less than or equal to 400 vehicles per day. The primary function of these roadways is to provide access to residences, farms, businesses, or other abutting property, rather than to serve through traffic. Motorists using these roadways are local people who are familiar with the roadway condition. Since the primary drivers are familiar with the section, the less restrictive design criteria can be applied on these roads without compromising safety. The AASHTO Guidelines *discourage* widening of lanes and shoulders for those very low volume roads, and also discourage changes in horizontal and vertical alignment, and roadside improvements except in situations where such improvements are likely to provide substantial safety benefits to that specific site. In reviewing the geometric design for sections of existing roadway, the following factors are pertinent:

- 5 to 10 years of crash history data should be considered in investigating and documenting the existence of site-specific safety problems.
- Actual speed on the road compared to the design speed.
- Existence of any skid marks on the surface.
- Presence of any roadside damage.
- Concerns raised by the police or local residents.

The portion of the roadway identified having safety problems associated with the following features should be corrected according to the minimum requirements presented in the Guide:

- Roadway width
- Horizontal alignment
  - Stopping sight distance both at the vertical and horizontal curves
  - Intersection sight distance
  - Clear zone and traffic barrier on the roadside

AASHTO emphasizes that correcting the above features is not generally cost effective and need not be applied unless there is clear evidence of potential benefit or safety improvement. Table 3.2 summarizes the AASHTO recommended minimum roadway width for very low volume local roads in a rural area.

Table 3.2 Guidelines for Total Roadway Width for New Construction of Very Low-Volume Local Roads in Rural Areas, after AASHTO (2001).

Metric						
Design Speed (km/h)	Total roadway width (m) by functional subclass					
	Major Access	Minor Access	Recreational and Scenic	Industrial/ Commercial Access	Resource Recovery	Agricultural Access
20	-	5.4	5.4	6.0	6.0	6.6
30	-	5.4	5.4	6.0	6.0	7.2
40	5.4	5.4	5.4	6.4	6.4	7.2
50	5.4	5.4	5.4	6.8	6.8	7.2
60	5.4	5.4	5.4	6.8	6.8	7.2
70	6.0	6.0	6.0	7.0	-	8.0
80	6.0	6.0	6.0	7.4	-	-
90	6.6	-	6.6	-	-	-
100	6.6	-	-	-	-	-

US Customary						
Design Speed (mph)	Total roadway width (ft) by functional subclass					
	Major Access	Minor Access	Recreational and Scenic	Industrial/ Commercial Access	Resource Recovery	Agricultural Access
15	-	18.0	18.0	20.0	20.0	22.0
20	-	18.0	18.0	20.0	20.0	24.0
25	18.0	18.0	18.0	21.0	21.0	24.0
30	18.0	18.0	18.0	22.5	22.5	24.0
35	18.0	18.0	18.0	22.5	22.5	24.0
40	18.0	18.0	20.0	22.5	-	24.0
45	20.0	20.0	20.0	23.0	-	26.0
50	20.0	20.0	20.0	24.5	-	-
55	22.0	-	22.0	-	-	-
60	22.0	-	-	-	-	-

Note: Total roadway width includes the width of both traveled way and shoulders.

The FHWA (1986) guide for structural design of roadway shoulders discusses the thickness design of roadway shoulders based on mechanistic principles of stress/strain analysis. The geometric design of a shoulder is also discussed in the AASHTO guide for pavement design. This guide covers the structural design of both flexible and rigid pavement shoulders. A NCHRP study shows that shoulders that have structurally adequate design for the expected traffic generally perform satisfactorily, particularly if the pavement-shoulder joint is properly sealed, and/or if adequate drainage is provided. The factors considered in the design include: main lane pavement/shoulder type combination; environmental effects such as temperature, frost, moisture, drainage, etc; soil type; traffic volume, type and use; construction joints; and maintenance issues.

Woods, et al. (1989) studied the benefit of a wide-paved (6 to 10 feet) shoulder on a two-lane rural highway for TxDOT. The study was based on a benefit/cost analysis. The parameters considered for the analysis included the number of accidents, travel time, and the cost of pavement edge and shoulder surface maintenance. This research determined that wide paved shoulders provide an additional travel lane for slow moving vehicles; increase average running speed, thus saving time; facilitate passing maneuvers; accommodate emergency stops; provide primary recovery space for an errant vehicle; and reduce accidents. They also reduce pavement edge damage and thus pavement edge maintenance costs. All these benefits are highly dependent on the traffic demand. The study concluded that wide-paved shoulders (6 to 10 feet wide) are cost beneficial for ADT's above 1,500 vehicles per day.

The Colorado DOT (Price 1990) evaluated a few experimental gravel shoulder sections for maintenance costs, safety, and overall performance. Obviously, the construction cost of a gravel shoulder is much less than a paved shoulder but the maintenance costs may be much higher for the gravel shoulders than the paved shoulder. If the gravel shoulder is not properly maintained, it will show premature pavement edge failure between the gravel shoulder and the roadway. Especially on the higher ADT roadways, maintenance may not be able to keep up with the problems of shoulder rutting and spalling. It was concluded from the study that the gravel shoulders work well and are cost effective for the roadway sections with low ADT but ongoing maintenance is essential to safety. Gravel shoulders were recommended for sections with maximum traffic level of 100 DHV (Design Hourly traffic Volume).

Fitzpatrick, et al. (1999) summarized the findings of an NCHRP study on low-cost safety improvement methods on existing two- and three- lane rural roads. This research suggests that the provision of passing lanes, turning lanes, localized alignment improvements, signs and pavement markings, median treatments, public information and education, increased enforcement, and other relatively low-cost measures can be highly cost-effective in improving both traffic operations and safety on existing two- and three-lane rural roads. These same techniques could easily be applied to prevent some of the potential edge drop-off problems. As illustrated in the Fitzpatrick report, the following are a few techniques successfully used by state DOT's to enhance safety on a two-lane rural road without widening to a full four-lane highway.

- Rumble strips at the centerline – prevent head on collision
- Inverted profile thermoplastic edge line – enhance nighttime visibility, provide an audible and vibratory warning
- Open graded friction course – improve wet weather skid resistance and minimize hydroplaning.
- Left turn lane on high traffic sections
- Left turn channelization by using left turn advisory signs
- Passing lanes in the congested areas
- Climbing lane – prevent lengthy queues of frustrated motorists

- Intelligent transport system to inform drivers about alternate routes – relieve seasonal traffic congestion
- Advanced electronic warning system to educate drivers of potential road hazards

3.6 Edge Drop-offs in Construction Literature with Respect to Safety

Another body of literature addresses construction issues associated with pavement edge drop-offs. Based on an extensive survey of highway officials and contractors, Humphreys and Parham (1994) concluded that it is recommended to resurface both roadway and shoulder at the same time to avoid any construction related drop-off. This national study by the University of Tennessee Transportation Center found that the most effective way of solving the problems associated with pavement edge drop-offs is simply eliminate the issuance of contracts where shoulder work is excluded or not included in the resurfacing contract. The Maryland DOT (2001) requires that all pavement courses exceeding 2-1/2 inches in depth, during overlay operation, shall be matched with the abutting lane or shoulder on the same working day.

For roads with paved shoulders, a simple and cost effective mitigation of construction related edge drop-off problems would be to install a 45-degree angle asphalt fillet along the edge of the roadway as a part of roadway resurfacing (Humphreys, et al. 1994). Adding a 45-degree fillet along the pavement edge ties the existing shoulder into the resurfaced roadway and enables a vehicle to reenter the roadway in a reasonably safe manner without over-steering into the oncoming traffic lane. The cost of such an asphalt fillet is usually minimal in comparison to total amount of the resurfacing contract, and the fillet would save countless dollars in lawsuits, human lives, and property damage. The paving industry uses different types of moulding shoes as attachments to the paving machine to form the asphaltic concrete fillet along the edge as overlays are placed on the roadway surface. This can reduce the amount of hand work required to finish the pavement edge. There are also different types of attachments for compaction of asphalt fillets, for example, one such a device consists of a hydraulically powered wheel that rolls alongside the compactor's drum while simultaneously pinching the edge of the mat towards the drum and providing lateral resistance.

The Indiana DOT (Chamberlain 1998) requires that barricades be placed at 200-foot intervals where drop-offs greater than 3 inches are adjacent to the shoulder until an aggregate (gravel) or earth (dirt) wedge is placed at the edge. The Florida DOT (Ellis, et al. 1996) also has a similar requirement that a barrier should be used to ensure work zone safety if the drop height is more than 3 inches. The Pennsylvania DOT (1994) has a requirement for installation of channelizing devices in the work zone for an edge drop-off greater than 2 inches. Moreover, "Low Shoulder" signs should be installed throughout the drop-off area to supplement the channelizing device, at intervals not exceeding ½-mile. The construction specifications of Maryland DOT (2001) require the contractor provide advance warning (through a traffic control device) of any uneven pavement surfaces during HMA (hot mix asphalt) overlay construction. These requirements are mainly to ensure safety in a construction zone but naturally occurring edge drop-off areas could also benefit from such temporary measures. Glennon (1996) has recommended several practices in Table 3.3 for treating edge drops in traffic-maintained construction zones.

Table 3.3 Traffic Control Needs in Construction Zones with Edge Drop Condition, after Glennon (1996).

Edge Drop Height (inch)	Lateral Position of Edge Drop					
	In Wheel Track	**In Lane**	**On Lane Line**	**At Edge of Pavement**	**At Edge of Shoulder**	**Outside of Shoulder up to 30 ft.**
1 to 1-1/4	Uneven Pavement Sign	Uneven Pavement Sign	Uneven Pavement Sign	Low Shoulder Signs	Do Nothing	Do Nothing
1-3/8 to 2	Disallowed	Disallowed	Channelizing Devices with Steady-Burn Lights	Channelizing Devices with Steady-Burn Lights	Channelizing Devices with Steady-Burn Lights	Do Nothing
2-1/8 to 5-7/8	Disallowed	Disallowed	Channelizing Devices with Steady-Burn Lights	Channelizing Devices with Steady-Burn Lights	Channelizing Devices with Steady-Burn Lights	Channelizing Devices
5 or more	Disallowed	Disallowed	Disallowed	Positive Barrier	Positive Barrier	Channelizing Devices with Steady-Burn Lights

A memorandum issued by FHWA (1997) incorporates the work zone safety program guidance for uneven pavement surfaces and edge drop-offs in a construction zone. Unprotected edge drop-offs may easily arise during the pavement construction or rehabilitation process. Although exposure to such situations should be avoided when possible, it may not always be practical to eliminate such exposure. Therefore, certain measures are recommended to ensure safety. Temporary wedges should be prepared using appropriate materials and compacted so that vehicles can traverse the edge condition safely. Hot or cold asphaltic mixtures are recommended as wedge materials for the drop height of 150 mm (6 inches) or less. On the other hand, granular (unbound) materials are recommended for the wedges over 150 mm (6 inches) in height at the edge (outside travel lane). Without constructing any wedge, the maximum vertical edge drop allowed is 75 mm (3 inches) for a work zone speed limit of less than 30 mph and 50 mm (2 inches) for 30 mph or more. The slope of the wedge and the width of the buffer area depend on the vehicular speed and location of the drop. When the speed limit is more than 30 mph, the slope of the wedge should be 1:1 or flatter.

Price (1989) investigated the problems associated with vertical drop-offs at the shoulder edge as a result of uniform width pavement lifts during construction. The research was conducted on behalf of Colorado DOT. Vertical or near-vertical edges of a pavement often result in severe erosion at the pavement edge resulting in an unsafe pavement edge drop-off. Many areas of eastern Colorado have severe shoulder erosion problems due to the inability of sandy soil to support vegetation. Severe edge drop-offs can be found on almost any highway due the fact that maintenance crews can not keep up with blading all shoulder edges. Constructing a tapered edge (6:1) was suggested as a possible solution. Although there is an initial cost (10% more than just the vertical edge) for building tapered edges during the overlay, the following benefits may justify the cost:

- Reduce shoulder maintenance (blading)
- Better compaction on the shoulder which allows better lateral support
- Improved cold-joint performance
- Safer for run-off-road vehicles. It would be easier for vehicles out of control to regain control.
- Better erosion control – a tapered section can slow down erosion to the point that vegetation can get established, thus preventing severe erosion.

Several research reports (Goodwin 1989, Horta 1991, Fleckenstein, et al. 1993, Deberardino 1995, Fleckenstein, et al. 1996, Horner 1999, Elfino, et al. 2000, Fleckenstein, et al. 2000, Raymond 1999, Whiffin, et al. 1973) are available on the issue of installing edge drainage systems to enhance drainage of water from the pavement structure. These reports primarily deal with the drainage of percolated water through the pavement surface in an effective manner. The issues are improved pavement performance, retention of lateral stability despite the edge drain, use of geosynthetics; and design, construction, and cost/benefit concerns.

3.7 Edge Drop-offs in Maintenance Literature

The portion of pavement under consideration for edge repair and stabilization is the area adjacent to a travel lane. This area may be called a shoulder depending on the definition of shoulder. For low volume roads, these areas may include some stabilized materials or unmodified in-situ materials. Over a period of time such areas get damaged by vehicle tires or eroded due to environmental effects, and this eventually creates an edge drop-off. The techniques to stabilize and repair this problem are of great concern to the highway community irrespective of actual road or shoulder width. For ease of discussion, these areas are considered as shoulders disregarding actual width and material quality. There are few guidelines. Techniques used are mostly based on past experience in addressing such repairs. A brief discussion of such techniques follows.

In 1989, the Louisiana Transportation Research Center and Louisiana DOT jointly developed a "Guide to Common Road and Equipment Maintenance Procedures" for the Rural Technical Assistance Program of FHWA (LDOT 1989). This guide recommended the following two shoulder repair techniques for an edge (pavement to shoulder) drop-off of two inches or more: 1) *reshaping* earth and gravel shoulders, and 2) *replenishing* earth and gravel shoulders. The purpose of both of these techniques is to reestablish the slope and shape of the shoulder to ensure proper water drainage from the surface of the pavement, to level off any edge drop between pavement and shoulder, and to provide side support to the pavement. Reshaping is done when there is very little erosion and when there is enough material in place to allow reestablishing the correct shape. On the other hand, replenishing is also a similar operation but is done when there is more than a two-inch drop-off and when there are not enough materials left on the shoulder to restore it to its original shape and slope. Both of these operations may need additional cleaning and reshaping of the adjacent ditches. Cleaned ditches will ensure a longer lasting repair by helping provide good drainage. Following a correct procedure can make these techniques a long-lasting maintenance repair. The best time to perform these operations is when the surface is moist (wet); otherwise a water truck would be needed to spray just enough water to dampen the surface. A detailed description of the step-by-step procedure is available in the guide. In brief, a reshaping operation on earth and gravel shoulders involves the following steps:

1. Removal of debris from the shoulder and ditch.
2. A motor grader is used to blade the shoulder and spread the material.
3. After achieving proper cross slope, the shoulder surface is compacted with a rubber-tire roller.
4. Water is used as necessary for proper compaction from a water truck.

A replenishing operation, if needed, would start after these operations as follows:

- Additional borrowed material is placed and spread over this compacted surface.
- The surface is compacted again and water is added if necessary for compaction.

Dunbrook (1972), a regional highway maintenance engineer of the New York State Department of Transportation (NYSDOT), described his experience in a 1972 article about shoulder maintenance. Their experience showed the following shoulder re-grading frequency:

1. Sod shoulders – three to four years
2. Gravel shoulders – twice a year
3. Stabilized shoulders – surface treated every three years.

The NYSDOT article states that re-grading the complete shoulder area with a motor grader and not leaving a small berm near the outside which can retain water is an excellent approach. Stabilizing earth or gravel shoulders by compaction helps prolong the service life. Moreover, chemical treatments with calcium chloride or sodium chloride on freshly re-graded material would help resolve dust problems and extend its life. Re-establishing proper ditch drainage during the improvement helps keep the shoulder intact. Many times in low flat areas and dense soil areas the installation of "underdrains" or "french drains" have added to shoulder stability and life span. Chemical treatments and pure surface treatments did not seem to give the desired return in service for the time and money spent. Finally, NYSDOT has a reasonably good measure of success with the "stabilized gravel" approach. This is locally known as "Monkey Mix" or "Dobey Mix" and consists of processed gravel and asphalt cut-back or emulsion. This has given a good shoulder with a relatively longer life at a reasonable cost and it also improved traffic operational quality. The steps involved in this operation are as follows:

1. "Processed Gravel" or "Run-of-Bank" is mixed with asphalt cut-back or emulsion (approximately 15 to 18 gallons of asphalt per cubic yard of gravel). The material can be mixed in a pit or any open space with a motor grader and a front-end loader or a roto-tiller sometimes called a "Seaman Mixer".

2. A trench is cut out at the side of the pavement on the shoulder area.
3. The shoulder trench is then filled with the pre-mix materials. Their experience is that a side plate or shoe at the end of the grader blade will nicely place the material.
4. Once in place, the material is rolled and then allowed to cure. Curing usually takes about 2 to 3 weeks.
5. After the material is cured, a surface treatment (seal coat) is placed on it.

This operation could also be done as “mixed in place”. However, the NYSDOT’s experience with pre-mixing is more favorable. A surface treatment is needed every three years with this process.

The Australian Department of Defense (1997) has recommended the following techniques to repair edge drop-offs on their military aircraft pavements.

- Patch edge with asphalt or cold mix.
- Backfill shoulder with suitable material to existing pavement surface level and reestablish grass cover.
- Carry out shoulder stabilization with bitumen emulsion.
- Any combination of the items above.

The government of South Australia (1998) takes care of edge drop-off problems during their routine shoulder maintenance work, which includes both sealed and unsealed shoulders. Sealed shoulders are usually treated in the same manner as a sealed pavement. The broken edges are repaired to restore the line and level of the original surface. The repair of unsealed shoulders involves in most part, grading to level off the edge drop to ensure proper drainage. When existing material quality is poor, the unsealed shoulders are reconstructed with better quality borrowed materials.

Kilareski (1996) discussed shoulder maintenance to prevent drop-off problems for the Pennsylvania Local Roads Program. A properly constructed shoulder to start with will provide adequate lateral support and prevent edge cracking that can lead to further problems. Shoulder width and cross slope should be designed according to the appropriate design standard. For example, in rural areas, a local road with an ADT of 50 or under requires a minimum shoulder width of 2 feet. Usually the cross-slope of a shoulder is between 2% to 6%. Depending on the traffic volume and functional class of the roadway, shoulder materials can vary from unbound aggregate (gravel) to paved all-weather surfaces. As the function and traffic volume of the roadway increases, the need for a paved shoulder also increases. In order to minimize the future occurrence of edge drop-offs, shoulders must be maintained on a routine basis. Properly shaped and sloped shoulders ensure required drainage and provide adequate lateral support. For unbound gravel shoulders, the reshaping and addition of gravel material along with compaction is required as the minimum amount of maintenance. A stabilized shoulder often requires a seal coat to maintain the surface. Grass/soil shoulders, on the other hand, require cutting and reshaping to remove excess material and keep drainage working. These areas are usually compacted with a roller and swept with a mechanized broom after the cutting/reshaping operation.

The inclusion of hot mix asphalt paved shoulders adjacent to the travel lane was one of the most significant improvements in Maryland highway construction during the 1960s (Maryland 1968). These shoulders consisted of 3- to 4-inch bituminous concrete or sand asphalt over a base and covered by a light colored aggregate surface treatment. These materials substantially enhanced the safety and performance of the highway compared to any other cement stabilized materials, which necessitated constant repair at the edge due to drop-offs. Their view is that a properly designed and constructed asphalt paved shoulder contributes the following features to the roadway:

1. Helps in preventing edge drop-off and ensures vehicular safety.
2. Facilitates emergency vehicle pull over.
3. Provides texture contrast to guide the steering of a vehicle.
4. Provides lateral support to the pavement making it structurally stronger.
5. Ensures adequate seal at the edge of the travel lane and facilitates quick drainage.
6. Significantly reduces maintenance costs and makes snow plowing easier.

Berger and Anderson (1980) discussed an effective roadside management program adopted by Washington DOT. The Washington DOT roadside management plan is intended to reduce highway maintenance costs caused by erosion, slides and snow. It is particularly important to maintain clear shoulders and drainage facilities so that water does not collect and damage the shoulder or pavement edge. Any buildup or encroachment of grass or weeds on the shoulder produces a dike that will trap water on or within the roadway structure.

It is obvious that the vegetation along the roadside is beneficial to the stabilization of pavement edges. For many years, TxDOT and other state highway departments have planted Bermuda grass along the road shoulder to stabilize the edge and provide a visible boundary for drivers. Bermuda grass is hardy, requires little maintenance and is effective in stabilizing road shoulders. But invasive root structure often encroaches into the neighboring asphalt pavement and damages the road structure, and this can result in costly edge repair. The use of herbicides is helpful but it is expensive and raises environmental concerns. Researchers at TTI (1996) found an appealing alternative: buffalo grass, which is just as hardy as Bermuda grass and requires little maintenance. They found buffalo grass to be much better suited for road shoulder stabilization than Bermuda grass. The root structure of buffalo grass is less invasive to asphalt pavement and requires less water to hold soil together which causes little or no deterioration to asphalt pavement, thus reducing the need for expensive and controversial input of chemicals into the environment. Additionally, buffalo grass proved to be very competitive against fast-growing weeds, thus reducing maintenance during growing months.

A field experimental study by Hassan (1971) evaluated the effectiveness of pavement edge marking on narrow rural roads. Two one-mile sections of rural roads in Maryland were selected. One road was 24 feet wide with a 10-foot wide shoulder and the other was 18 feet wide with a 2-

foot shoulder. The factors considered were vehicle speed and placement within a traffic lane. Statistical evaluation of the experiment revealed that edge marking had no significant effect on the placement of daylight traffic, but that nighttime traffic has a tendency to stay closer to the centerline. However, edge lines were shown to have significant effect on vehicle speed. Speed measured "before" edge marking on the narrow 18-foot section was less than that measured "after" edge marking. On the contrary, it was the other way around for a wider 24-foot section and was not significant from a practical stand-point. The higher speed, on a narrow road with an edge line, may indicate that motorists have more confidence and feel safer on roads with edge lines.

Rogness and Burley (1993) discussed the repair of road edge scour for grassed shoulders in a recent TRB publication. Although the roads considered were on the national parkway system, their publication gives some insight into the causes of edge drop-off problems. Numerous corrective measures have been implemented to reduce edge scour. Typical corrective measures include allowing the shoulder turf to recover in the off season, shoulder re-grading, shoulder paving, shoulder and ditch paving, installing turf-concrete matrixes and rolled asphalt curbing. The success of these treatments depends on the specific site condition. In general, these techniques have not been very successful.

FHWA (1986) has developed a general guide to effective and low cost methods of improving and enhancing roadside safety on local roads and streets. Roadside improvements provide the driver with better chances of recovering from an accident and/or in reducing the potential severity of accidents resulting from vehicles "running off the road." These improvements include such work as slope flattening, culvert extensions, tree removal, ditch shaping, installing guardrails, ensuring forgiving roadside (or clear zone), and use of breakaway structures for signs, light poles and mailboxes. Delineation can also be used to warn drivers of hazards. Common locations where good delineation practices would enhance safety include sharp curves, culverts or inlets, narrow roadway sections, narrow bridges, and crush cushions or guardrail terminals.

Duffell (1999) presented a highway maintenance system in the United Kingdom, chiefly with respect to low-volume local roadways. The National Roads Maintenance Condition Survey (NRMCS) was not able to capture and adequately prioritize the maintenance work for local roads. Therefore, a manual survey system was established under the new system to capture the local road condition. A pavement condition index (PCI) was developed based on the relative weightings of each deterioration indicator and warning levels for triggering remedial treatments. The PCI comprises three components: structure, surface, and edge indexes. A table of suggestions for a series of maintenance treatments was developed in relation to overall PCI and each of the structural, surface and edge indexes. These suggestions compared very well with independent engineering judgment for low-volume local roads. However, an effort to correlate a manual survey with a machine survey has shown some promise in terms of only structural index. During this research the chief factors causing different modes of deterioration were also identified. Edge deterioration turned out to be a function of commercial traffic and availability of edge support.

CHAPTER 4
THE NATURE AND OCCURRENCE OF PAVEMENT EDGE DROP-OFFS

4.1 Types of Pavement Edge Problems

4.1.1 Overview

TxDOT maintenance forces have identified several pavement distresses related to the pavement edge, some of which are very specific to the pavement edge and others which contribute to edge damage. Distresses specific to the pavement edge include broken edges, edge scour, and continuous edge drop-offs. Distresses which can contribute to edge damage include inadequate pavement marking, vegetation encroachment, "high" edges (buildup on the edge), quarter-point failures, oxidation and cracking of pavement surface at the edge, raveling and shelling of aggregate at the edge, inadequate drainage, lack of sealing at the edge, unstable subgrade, roadside habitats (e.g., ant dens), and others.

As defined in Chapter 3, for the purposes of this research, an edge drop-off is the difference in vertical elevation between the paved surface and unpaved shoulder surface adjacent to it. Although the focus of this research is the edge drop-off, the other edge distresses are also considered because these are an integral part of the pavement edge problem.

4.1.2 Construction Related Edge Drop-offs

Construction zone edge drop-offs are, for the most part, outside the scope of this research, but our survey revealed that certain types of construction projects often cause significant and unnecessary edge drop-off problems for district maintenance forces, and these special cases should be mentioned. The two most common scenarios, both resulting from improper design, are: 1) failure to replenish or pull up shoulders following a full-width overlay job and, 2) erosion of improperly-specified backfill soil that has been placed along the pavement edge. The first condition, failure to replenish or pull-up shoulders, is an omission that usually occurs because the designer for the overlay project failed to include backfilling pavement edges as a work item in the project specifications. In contrast, the erosion problem appears when the edges are backfilled, but with unsuitable material such as inorganic soil which does not readily establish or support vegetation, or where placement occurs without adequate compaction. These construction problems appear to be a consistent issue across the state. A nationwide survey by Humphreys and Parham (1994) also found this as one of the biggest reasons for pavement edge drop-offs. Such problems are particularly aggravating to maintenance forces, since these conditions require significant, unanticipated maintenance attention to new or rehabilitated roads which were supposed to be maintenance-free for a period of time.

4.1.3 "High" Edge Problems (not Drop-offs)

Build-up of soil along the pavement edge – high edges – is as serious a problem as edge drop-offs in a few districts, especially in east Texas. Due to the high amount of rainfall, conditions in these areas are favorable for aggressive vegetation growth. Windblown material along the pavement edge, such as soil, wood chips from logging trucks, or crop debris, tends to collect and build up against existing vegetation. Over time, this process causes a “high” edge, where the soil and vegetation adjacent to the pavement starts to encroach onto the pavement and is higher in elevation than the pavement surface. This high edge, consequently, prevents rainwater from draining off the road surface, and trapped water tends to flow along the pavement edge, softening and eroding the pavement structure. Oftentimes mowing contractors windrow the mowed grass at the pavement edge but do not remove it afterwards; this can easily create a “high” edge problem also.

4.2 District Practices for Identifying Pavement Edge Problems

4.2.1 Typical Maintenance Practices

TxDOT maintenance personnel identify, or become aware of, pavement edge problems in various ways, but the most common method is a weekly windshield survey of their roads. One designated person (often the maintenance section supervisor himself, his assistant or even the sign man) from each section usually drives all the roads in that maintenance section once a week. Some sections do visual surveys as frequently as twice a week and others do surveys once every two weeks, depending on the roadway classification. The person observing the road takes note (may use a notebook or tape recorder) of any edge damage along the roadway based on his or her windshield observations. The assessment of severity associated with edge damage is subjective, and many conditions of a specific site play a significant role in the assessment. Examples of such conditions are roadway classification and width, presence or absence of a shoulder, volume of traffic, speed limit (posted and actual), location of the distress, percent of truck traffic or unusual types of traffic, and obvious safety hazards, to name a few. Of course, edge drop-offs tend to recur in the same areas, and maintenance supervisors are usually aware of these locations.

4.2.2 Other Practices

TxDOT maintenance forces also learn about pavement edge damage by other methods, including complaints from both the user (traveling public) and other TxDOT employees. However, for most districts, complaints have not been a major issue, with most reports being related to construction zone edge drop-offs, or driveways and mailbox turnouts.

The Texas Maintenance Assessment Program (TxMAP), which is TxDOT’s statistical pavement management system, is another source of information regarding the edge drop problem. TxMAP is now in its fourth year (FY 2003), and most districts are beginning to use TxMAP as an indicator of the overall road condition in the district and as a means to compare their performance with other districts. Although TxMAP seems to give a good indication of the overall edge condition in each district, the condition of all the individual roadway sections are not available in the database since it rates only randomly selected sections. Moreover, the condition of those selected sections becomes outdated by the time TxMAP is published. Therefore, the TxDOT maintenance personnel use TxMAP as a long-term planning tool, and rely more on their own real-time survey data gathered through the weekly windshield survey for day-to-day maintenance purposes.

4.3 Defining Pavement Edge Drop-offs – The Different Approaches

4.3.1 Overview

The identification of the pavement edge problem as described in the previous section strongly depends on the definition of an edge drop-off. One of the obvious consequences of edge damage is edge drop-offs. Therefore, it is necessary to define the pavement edge drop-off as a distress that constitutes a problem for the roadway system. There are different approaches to define the edge drop-off problem ranging from physical measure of the drop to the functional adequacy of the roadway system. These approaches are summarized into the following different classifications.

4.3.2 Traditional Research Approach

Transportation literature typically defines an edge drop-off as a vertical discontinuity or difference in elevation between two adjacent road surfaces (Chamberlain 1998, ASTM 2001). As to the magnitude of the edge drop-off, past research has concentrated mainly on safety issues and has demonstrated that the probability of severe consequences resulting from pavement edge-drop traversals is, among other things, a function of edge drop height, edge drop shape, vehicle speed and path angle, and the width of the lane available for recovery (Glennon 1996). While no clear consensus exists, research suggests that a 3-inch edge height is the maximum tolerable for a reasonable level of safety but that a 1-1/2- to 2-inch criterion would be more appropriate for maintenance on 55- to 75-mph roadways (Glennon 1996). Another key element of prior research has been the recognition of different levels of vehicle interaction with the pavement edge. These levels are, in increasing severity: nibbling, scrubbing, drag, and roll (Ivey, et al. 1988). Of the four, prevention of scrubbing represents the key vehicular response threshold from a maintenance perspective. Simple “rules of thumb” derived for the purposes of avoiding tort liability associated with pavement edge maintenance are that: 1) vertical or near-vertical edge drops of 2 inches or more can cause sling-shot accidents even at low speeds, and 2) edge drops of 6 inches or more will cause undercarriage contact often resulting in rollover (Glennon 1996). These vehicular response levels have been scientifically correlated with edge drop height and other factors to produce detailed safety guidelines for maintaining edge drop-offs in construction zones (Ivey, et al. 1988; Glennon 1996).

4.3.3 Simplified Level-of-Service Definition

Transportation researchers customarily identify, isolate and examine the many variables associated with pavement edge drop-offs (e.g., height, shape, bevel angle, rounding, etc.) in order to relate these variables to, say, highway safety considerations. However, roadway maintenance and repair guidelines tend to use a level-of-service approach and define edge drop-offs in simplified terms, often using only one variable, height. For example, in their maintenance manual (2001), TxDOT has established maximum edge drop-off height criteria depending on the level of service required (see Figure 4.1). The “desirable” level is a drop-

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Roadside Maintenance

Component	Desirable Level	Acceptable Level	Tolerable Level
Vegetation	Maintain in accordance with Vegetation Management Manual as follows:	Maintain in accordance with Vegetation Management Manual as follows:	Maintain in accordance with Vegetation Management Manual as follows:
0 - 3,000 ADT	Level 4	Level 4	Level 4
3001 – 10,000 ADT	Level 3	Level 4	Level 4
10,001 & Up ADT	Level 2	Level 2	Level 3
Developed Urban	Level 1	Level 1	Level 1
Litter Control	Maintain as follows:	Maintain as follows:	Maintain as follows:
0 – 3000 ADT	spot pick-up	spot pick-up	Spot pick-up
3001 – 10,000 ADT	<5 CF/AC	<6 CF/AC	<8 CF/AC
10,001 & Up ADT	<4 CF/AC	<5 CF/AC	< 6 CF/AC
Pavement Edges	Maintain < 2" drop off.	Maintain < 3" drop off	Maintain <3" drop off
Drainage	Maintain function with minimum blockage, ponding, or erosion.	Maintain function with some blockage, ponding, or erosion with no damage to highway or private property.	Same as Acceptable level.
Rest Areas	RA-ADT* Hours per day 0-200 8 201-800 16 801 & up 24	RA-ADT * Hours per day 0-400 8 401-1000 16 1001 & up 24	RA-ADT * Hours per day 0-400 8 401-1000 16 1001 & up 24
Picnic Areas	Provide for the safety, comfort, and convenience of the traveling public; clean, inviting appearance	Provide for the safety, comfort, and convenience of the traveling public; Occasional litter, with trash receptacles near capacity; few noticeable appearance defects and minor graffiti.	Provide for the safety, comfort, and convenience of the traveling public; Occasional litter, with trash receptacles near capacity; few noticeable appearance defects and minor graffiti.

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FIG. 4.1 TxDOT Level of Service for Pavement Edges. *Source:* TxDOT Maintenance Manual (2001)

off height less than 2 inches, and the maximum acceptable or "tolerable" level is a drop-off height of 3 inches. Alternatively, TxDOT's statewide maintenance management information system, TxMAP, directs pavement condition raters to score edge drop-offs as "fair" when the edge drop is "greater than 2 inches over a distance of 50 feet or more" (see Figure 4.2). The level-of-service approach to defining edge drop-offs, expressed as a system-wide standard, yields program objectives something like "TxDOT shall maintain 80 percent of the FM road system at the "desirable" level, and 100 percent of the FM road system at the "tolerable" level [this is just an illustration and was not referred to us by TxDOT]. Conceptualizing the edge drop-off problem within the level-of-service framework is attractive in that it offers maintenance directors (those who set budgets) and maintenance supervisors (those who do repairs) a unified and consistent means for characterizing the problem, planning and allocating resources, and measuring progress toward repair.

TxMAP Scoring System

Ratings are based upon the following conditions:

Component	Excellent	Good	Fair	Poor	Failed
Asphalt Pavement	**5**	**4**	**3**	**2**	**1**
Rutting (Do not count FAILURES)	Pavement - like new, no rutting.	Very minor rutting < ¼" Flushing, rock wearing	Minor rutting < ¼" < ½" May be able to feel with vehicle	Moderate Rutting > ½", < 1" May include major rutting at intersections only	Major Rutting > 1"
Cracking (Do not count FAILURES)	No Cracking	Very minor cracking or with few sealed cracks	Minor cracking or minor cracks sealed with some unsealed or moderate cracks all sealed	Moderate quantity of unsealed cracks or major cracks all sealed or some small spots of block or alligator cracking. May have some very minor spot pumping	Major cracking or block or alligator cracking or any cracking that has substantial pumping
Failures	No Failures	One or two patched failures or < three very minor failures	Several patched failures or > three minor failures	Any moderate failures or a few unpatched potholes. Moderate failures will have tight cracking.	Many unpatched potholes, major failures or any failures that are pumping. Major failures will have loose materials.
Ride (Settlement)	Ride very smooth with no humps or depressions	Ride smooth with few minor humps or depressions or all patches are smooth	Ride adequate with several minor humps or depressions or unlevel patches	Ride rough with many humps, depressions, patches, minor or moderate failures, etc.	Ride totally unacceptable, causing a reduction in speed below speed limit to control vehicle
Edges (One foot on and off)	None	Very minor, short lengths < 2"	Minor with a few dropoffs < 50 feet long, < 2" or minor edge raveling	Unacceptable dropoffs > 50 feet in length and 2" to < 4" Many dropoff <50 feet long < 2" or moderate edge raveling	Unacceptable dropoffs > 4" or major edge raveling

FIG. 4.2 TxMAP Scoring System for Pavement Edges, Asphalt Pavement, per TxMAP Manual (2002)

<u>4.3.4 Maintenance Section Supervisor Approach</u>

TxDOT Maintenance Section Supervisors combine elements of both the traditional research conceptualization and the simplified level of service approach when defining edge drop-offs. In the formal sense, maintenance personnel talk about edge drop-offs in risk-based terms with respect to two functional criteria: 1) the impact on safety of the traveling public, and 2) the potential for damage to the road. In both cases, most maintenance supervisors rely primarily on their judgment as opposed to a level-of-service definition, and cite the complexity of the issue when doing so. For example, we asked maintenance supervisors from every TxDOT district to explain how they define edge drop-offs; in particular, the threshold at which an edge drop-off becomes a defect needing repair. A very common response to this seemingly simple "*How do* *you know one when you see it?*" question was to explain that the matter depends on many factors, including the location of the edge drop, its height and length, the roadway width, whether there is encroachment into the travel lane, the configuration of the shoulder face slope, the traffic type and speed, the cause of the defect, and more. Thus on the one hand, maintenance supervisors rely on windshield observations and expressions of edge drop-off parameters which have little precision, while on the other hand, their customary practice is to intuitively conceptualize edge drop-offs for maintenance and repair purposes in a subtle, highly-nuanced manner. This, interestingly, is precisely inverse to the level-of-service approach, which employs a simplified definition but sophisticated measurement tools. When pressed to define pavement edge drop-offs in level-of-service terms (*i.e.*, drop height, or drop height and length), there was a general consensus among the maintenance supervisors that pavement edges showing 2- to 3-inch drop-off heights need to be scheduled for repair, with some supervisors noting repairs could be necessary for 1-inch drops. No consensus existed regarding the nominal length of "run" for which a drop-off needs repair, where responses ranged from "enough to be visible" (say, one foot) to "enough to warrant mobilizing the equipment" (say, a quarter mile). We attempted to press even further, and requested that maintenance supervisors define, in level-of-service terms, the characteristics of a more serious edge drop-off requiring "immediate" repair, as opposed to the case where repair just needs to be scheduled. Supervisors normally responded to the question by stating that level-of-service terms would not be meaningful in such a case, and this more serious threshold could only be evaluated in terms of the specific situation (their own judgment).

4.3.5 Reliance Upon Judgment-Based Definitions, not Written Definitions

While conceptual variation exists, the maintenance literature does indeed provide written definitions of pavement edge drop-offs, in particular, the TxDOT Maintenance Manual and the TxMAP Scoring System cited herein. However, one of the findings of our interviews was that, when we asked maintenance personnel if they were aware of any *written* definitions or standards for pavement edge drop-offs, by far the most common answer across the State was "No." Only in rare instances did the maintenance personnel mention either the Maintenance Manual level-of-service criteria or the TxMAP standard. By far the most common conceptualization was to talk about edge drop-offs in risk-based terms with respect to the impact on safety of the traveling public and the potential for damage to the road. Further, most maintenance supervisors rely primarily on their judgment as opposed to a level-of-service definition, and cite the complexity of the issue when doing so.

4.4 Typical Pavements with Edge Drop-offs

4.4.1 Overview

In the previous sections we discuss the definition and identification of the edge damage (drop-off) problem. In this section, we will highlight the nature and occurrence of the edge damage problem. Edge problems would obviously be at the edge of the pavement but the type of the roadway needs to be identified. The district site visits show that edge damage occurs prominently on low volume roads in Texas, but is not specific to any particular type of roadway; it is present on all different types of roadways such as FM roads, State highways, US highways, and even on some Interstate highways. Therefore it is appropriate to discuss the types of edge problems that exist for each of these road classifications.

4.4.2 Low Volume Roads (State Highways and FM Roads)

Constructed during the 1940s and 1950s under the slogan, “Get the farmer out of the mud,” (Hagan 1991) the Texas Farm-to-Market (FM) system primarily consists of low volume, improved surface roads with ADT values ranging from 250 to 1500 vehicles per day. Although the FM system was adequate for rural communities in the slower, mostly agrarian Texas economy in the decades immediately following World War II, times have changed and Texas now boasts three of the top ten largest US cities (Houston, Dallas, and San Antonio). Thus, while much of the FM system remains essentially the same as it was built 50 to 60 years ago, traffic volume, vehicle size and weight, and vehicle speed have increased, overloading the system both geometrically and structurally. At the same time, as a result of Texas’ population growth, it has been necessary to divert the majority of transportation dollars to congested urban areas, and normal budgetary constraints are such that it is difficult to generate or justify enough funding to widen or significantly rehabilitate these low volume roads. As a consequence, low volume roadways continue to deteriorate and are showing signs of a growing backlog of essential restoration and improvement needs. Moreover, some of these roadways are no longer low volume. For these reasons, low volume roadways appear prominently in our discussion of pavement edge damage.

Although most of the low-volume roads would be FM roads, there are exceptions; traffic volume on a few state highways is low and some FMs may carry a very high volume of traffic. Therefore, our focus in the low-volume category would be predominantly FM roads of low volume having improved surface roads with ADT values ranging from 250 to 1500 vehicles per day. It is important to note that the definition of low volume is subjective; different districts use different ADT values depending on their overall traffic condition. Most of these roadways do not have formal shoulders and 1500 ADT is a tentative cutoff value for shoulder requirement according to TTI research (Woods, et al., 1989). Although some districts like Houston consider less than 5000 ADT low volume, 1500 ADT is a reasonable cut-off maximum value for this research.

4.4.2.1 Typical Low-Volume Roadway Characteristics

4.4.2.1.1 Pavement Age As noted, most of the Texas FM system was constructed during the 1940s and 1950s, and a significant portion of these roads were actually adopted from County roads (see Figure 4.3). Conservatively, the age of most of the FM system is 50 to 60 years, and in many cases these roads no longer satisfy the current standards for modern transportation needs.

4.4.2.1.2 No Shoulders Most of these FM roads do not have a formal shoulder. A formal shoulder would have to be paved and in most cases would be more than 4 feet wide. A shoulder is supposed to provide adequate lateral support and be able to accommodate emergency vehicles on the pavement structure. Some states require that shoulders be of the same quality as the main travel lane and at least 8 to 10 feet wide. In case of the FM system, there may only be 2 to 3 feet of unpaved area beside the paved travel lane, if that. Therefore, these roads may experience a lack of adequate lateral support and consequently show signs of edge damage.

FIG. 4.3. FM Road ROW Marker, Illustrating the Age of the Road (and the System)

4.4.2.1.3 Pavement Structure The structural thickness of these narrow FM roads is typically 8 inches or less, which includes approximately 4-6 inches of base overlaid by multiple one or two-course surface treatments (seal coat / chip seal). Base course type varies among the districts. It could be any of the following: caliche (pit run, Grade 2 or 3), iron ore gravel, crushed limestone (Grade 2 or 3), Type 2 flex base with or without fly ash, cement or asphalt stabilized soil, shell (Grade 2 or 3), pit run gravel, and reclaimed flex base or asphalt pavement (RAP).

4.4.2.1.4 Pavement Width The typical average width of such a road is about 20 feet, with a typical range of 18 to 24 feet (see Figure 4.4). Although not a scientific observation (not measured or validated statistically), the typical roadway widths as reported by maintenance personnel during our site visit interviews are shown in the Figure 4.5. With the exception of Odessa, maintenance personnel indicate that the main reason for edge drop-offs on these roads is insufficient roadway width. Some of these roads are so narrow (18 feet or less) that not only 18-wheel tractor-trailers but also passenger cars run off the edge.

FIG. 4.4. Typical Narrow FM Road in West Texas

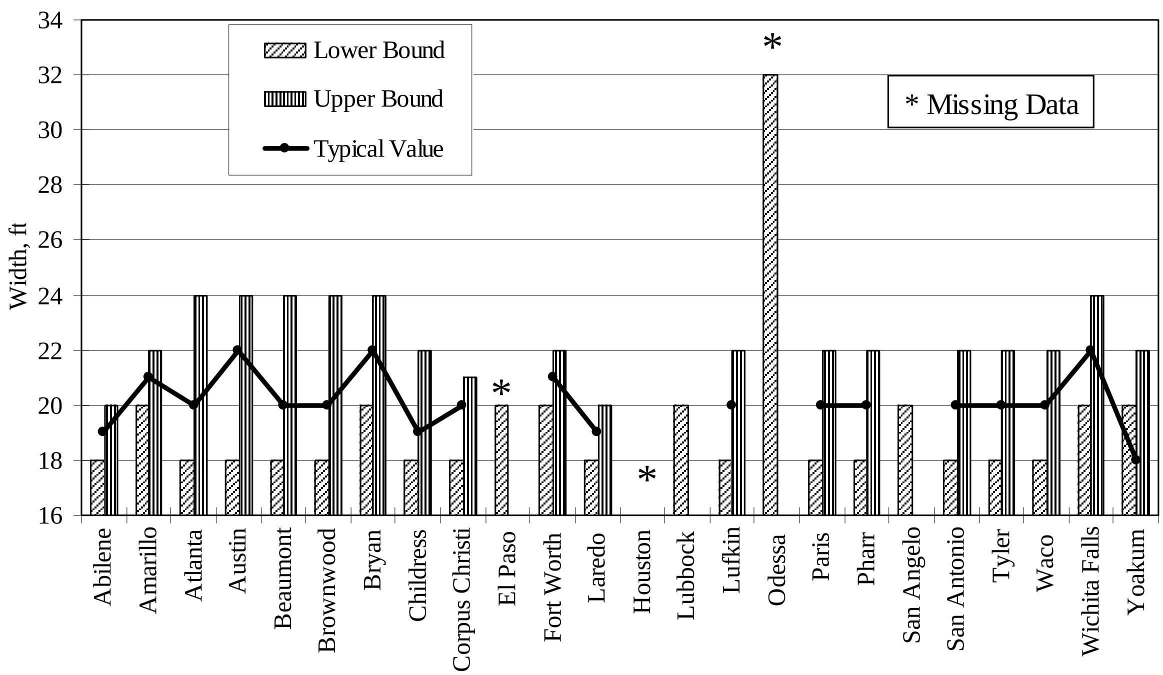

FIG. 4.5. Maintenance Supervisor Subjective Estimate of Typical FM Road Width, by District

4.4.2.1.5 Right-of-Way Width The typical right-of-way (ROW) width for low volume FM roads in most cases would be around 80 feet. The general feeling among the maintenance section supervisors is that ROW width varies from 60 feet to as high as 120 feet depending on the age of the pavement. The older ROWs that are adopted from old county roads are usually on the lower end i.e. about 60 feet, with the most narrow being 50 feet. On the other hand, the newer FM roads would have about 120 feet ROW. The variation in ROW width, as observed from our non-scientific survey among different districts is plotted in Figure 4.6. The narrow right-of-way in a hilly area creates visibility problems due to the presence of trees and bushes on the roadside. In order to accommodate ditches in a narrow right-of-way, the front slopes are usually steep and susceptible to water erosion.

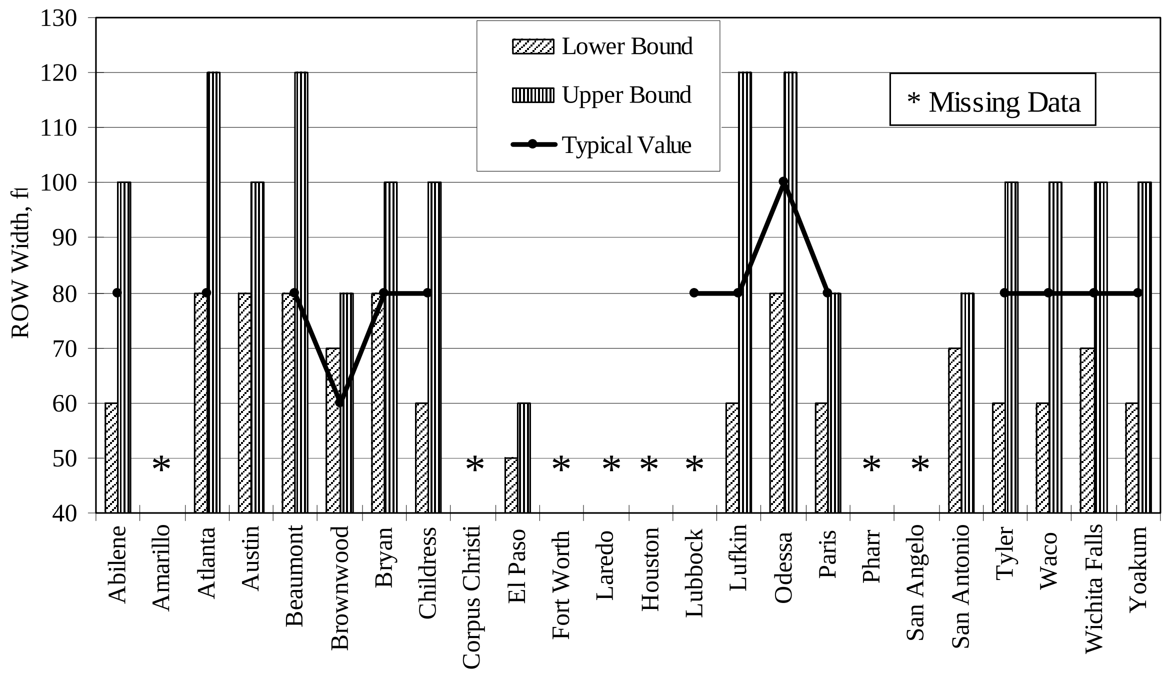

FIG. 4.6. Maintenance Supervisor Subjective Estimate of Typical FM ROW Width, by District

4.4.3 High Volume Roads

Edge drop-off problems occur on narrow state or US highways due to both high traffic volume and high speed. Inadequate width for the volume of traffic is the main contributing factor for edge damage and absence of formal shoulders on many of these roadways aggravates the situation. Traffic has more wander at higher speeds than usual and the outside wheel is prone to running off the edge. In many cases, unauthorized or abusive highway use is the reason for edge damage, this despite adequate roadway geometry. The following are typical cases of edge drop-offs on high volume roads.

4.4.3.1 Narrow 4-Lane US Highways-- "The Poor-Boy 4-Lane"

Several US highways in Texas have relatively narrow right-of-ways and high traffic demand. The typical roadway consists of two 12-foot travel lanes with 10-foot shoulders on each side for a total nominal width of 44 feet. In this case, it is common for motorists to use the shoulder as an unauthorized lane, oftentimes for passing and sometimes for travel. Faced with this situation, district authorities have frequently elected to convert these two-lane roads with full shoulders into four-lane US highways. This they do by seal-coating the entire pavement surface (44 feet width) and re-striping to create four 11-foot travel lanes without shoulders, hence the term "poor-boy" 4-lane. These highways are obviously more vulnerable for edge damage due to high traffic speed and volume, combined with narrow lanes and no shoulders (see Figure 4.7). In fact, the most severe pavement edge drop-offs we observed in the State exist on these types of roads. Again, the key issue is not having a formal shoulder to inhibit higher volumes of traffic that are constantly damaging the pavement edge. Examples of such US highways are US 59, US 82 and US 67 in the Atlanta district along with part of US 290 in Austin.

FIG. 4.7. Edge Drop-off Along a Narrow 4-Lane US Highway ("Poor-Boy" 4-Lane).

4.4.3.2 Narrow High-Volume State Highways and FM Roads

There are plenty of narrow state highways along with farm-to-market roads with high traffic volume. Some of them are in rural areas and others are in urban areas. As mentioned above, the high speed and high volume traffic would also damage the edges on these two-lane highways (see Figure 4.8). Some of the roads in rural areas may also experience edge damage due to “unconventional traffic”, as explained in the low volume roads section (see Figure 4.9). On the other hand, roads in densely-populated urban areas frequently experience edge damage associated with the abusive or unauthorized use of the roadway such as left turn bypass maneuvers, cutting corners, or vehicle pull-offs. These unauthorized or abusive uses of the roadway actually can produce significant edge damage in a short period of time.

FIG. 4.8. Edge Drop-off at Relatively High-Volume, Narrow FM Road (21-foot width, ADT 4,400 vehicles/day).

4.4.3.3 Interstate Highways

Interstate highways and similar controlled-access highways are designed to meet the needs of modern day traffic. Therefore, these highways are usually structurally and geometrically sound. Despite these facts, several districts have experienced edge damage or drop-offs on their interstate highways. Unlike edge drop-offs on narrow, low-volume roads, here the edge damage is mainly due to unauthorized uses such as truck pull-overs, illegal access or exit, and cutting corners, both intentional (illegal) and unintentional (run off the road). Some of these abusive uses occur on the frontage road instead of the main highway (see Figure 4.10). Also, edge damage may result from failure to pull edges after an overlay, or from inadequate backfill due to the limitations in the specification.

FIG. 4.9. Edge Damage due to Unconventional Traffic.

FIG. 4.10. Edge Damage Along Interstate Highway Access Road.

4.5 Causes of Pavement Edge Drop-offs

4.5.1 Narrow Low Volume Roads

Pavement edge damage manifests itself in a systematic pattern on low volume, narrow roads. Some of the damage is related to the geometry of the roadway and some is specific to the traffic demand and type. The more susceptible areas for edge drop-offs on low volume roads are (1) the inside of horizontal curves, (2) at the turning radius of intersections with other paved county roads, ranch crossings, or driveways, and (3) at approaches to uphill or vertical curve areas (see Figures 4.11, 4.12, 4.13). The first and third are associated with limited sight distance where drivers pull over to the right to be safe from opposing traffic.

Other reasons for pavement edge damage on low volume roads include unauthorized use and unconventional traffic. Occasional high volume and high-speed traffic also contribute to edge damage. Mail-box turnouts and school bus stops (see Figure 4.14) are other very common locations for edge drop-offs for low volume roads. Although truck pull-over areas are mainly associated with high volume roadways, similar edge damage can also occur on a narrow FM road, especially near intersections or pull-offs such as roadside vendors or a convenience store. Roadside animal habitats, for example, ant dens or gopher holes, also create localized edge damage. Here, the edge damage frequently exists on the straight portion of the road, with some of the damage being localized and some continuous.

FIG. 4.11. Typical Edge Drop-off at Inside Horizontal Curve on a Low Volume FM Road.

FIG. 4.12. Typical Edge Drop-off at Turning Radius (Maintained by placing RAP).

FIG. 4.13. Typical Edge Drop-off at Approach to Uphill Vertical Curve.

FIG. 4.14. Typical Edge Drop-off at Mail-box Turnout.

4.5.2 Unauthorized (or abusive) Use of the Roadside

Apart from the typical low volume pavement edge problems discussed above, unauthorized or abusive use of the roadside is perhaps the next largest contributing factor for pavement edge damage. Unauthorized use appears to be the dominant cause of edge damage for high-volume roadways. Some of these uses are intentional (illegal) and others are either unintentional (for example, run off the road or emergency response by DPS troopers). Often the illegal maneuvers are repetitive; once they begin, everyone follows the same pattern. The following are brief discussions of a few unauthorized uses directly related to edge drop-off damage.

4.5.2.1 Entrance to Logging Sites, Oilfield Leases, Agricultural Fields, Etc.

We have noted that Texas' FM Road System was created in the 1940s and 1950s under the slogan "Get the farmer out of the mud." Agriculture remains a strong element of Texas' economy and the FM road system remains the primary means by which agricultural and other similar products are transported to processing facilities. In addition to agriculture, similar activities such as dairy and beef cattle production, logging, and oilfield production contribute to the traffic demand on the FM system. This type of traffic tends to be large and heavy – much more so than similar vehicles in the 1940s and 1950s when the FM roads were built – and this traffic is highly abusive to the pavement edge and causes significant pavement edge damage. For example, in South Texas (Rio Grande Valley), fleets of trucks that move sugar cane from the fields to the processing plants produce edge damage because the trucks work off the edge of the pavement. Similar off-road/ on-road traffic occurs with cotton and other types of agricultural products throughout the State (see Figure 4.15). These are seasonal operations but tend to be continuous once the harvest begins. When processing plants start their operation, it is costly to shut down even during adverse weather; therefore, the operations keep running despite weather conditions and this aggravates edge damage significantly. In the case of the oilfield or logging industry, oftentimes trucks create access to these sites by simply driving across the ditch line, creating significant edge damage.

FIG. 4.15. Typical Pavement Edge Damage Associated with Cotton Production in West Texas.

4.5.2.2 Truck Pull-offs

One of the most common abusive uses of the roadside edges consists of trucks pulling over on the side of the road. This is a very common scenario on Interstate highway systems but also happens on other State, US, or FM roads with high traffic volume. The truck drivers often pull over on the shoulder to rest or sleep, check their load, or whatever, especially near an intersection or interchange, and oftentimes underneath an overpass (see Figure 4.16). Sometimes these pullovers are not intentional. For example, in certain stretches of highway and at certain times of the day, trucks are not permitted on the Interstate which forces them to pull over and in a few cases it is due to the fact that the rest areas are completely occupied. This may cause deep edge drop-offs, sometimes as high as 8 to 10 inches.

FIG. 4.16. Pavement Edge Damage Associated with Vehicle Pull-offs Beneath an Overpass.

4.5.2.3 Median Crossing/ Illegal Exit Ramps

For many reasons, motorists often find it convenient to cross the median of highways at locations other than a designated intersection. These illegal maneuvers commonly occur on divided or controlled access highways in both rural and metropolitan areas (see Figure 4.17) and this can cause significant pavement edge damage. Similarly, impatient motorists on freeways in congested urban areas frequently create their own exit ramps by cutting off the pavement across the median to access the service road, and this activity also damages the pavement edge. They may even drive on the shoulder, considering it a part of the lane. These abusive maneuvers create edge drop-offs on both the Interstates and frontage roads. Some vehicles may cut across the ramps or exit the highway if they miss a designated exit or turn. In a few districts where the general terrain is flat (e.g. Odessa), drivers cut across the median or drive over the right-of-way to gain illegal access to the Interstate without hesitation. Garbage trucks and mail carriers often drive on the edge to go from one house to the next, all of which creates substantial edge damage.

FIG. 4.17. Pavement Edge Damage Associated with Illegal Median Crossing. The Inset Shows the Regulation Sign Posted Where the Crossing Continues to Occur

4.5.2.4 Authorized but Non-Designated Use of Right-of-Way

The Border Patrol, Texas Rangers or DPS Troopers often cut across the median of divided highways or drive across the right-of-way instead of turning at a designated interchange (see Figure 4.18). Border Patrol efforts to locate illegal aliens crossing the road sometimes include dragging the ROW to create zones where they can easily spot footprints, and of course, the Highway Patrol often drives on the right-of-way. Although this activity cannot be categorized as unauthorized use, it does significantly damage the pavement edge.

4.5.2.4 Left Turn By-Pass Maneuver

Although left turning is not an unauthorized use, passing off the shoulder area is an illegal maneuver. The road condition and traffic associated with such a maneuver typically involves a two-lane, relatively high-volume road with narrow shoulders. Here, as a vehicle slows to make a left turn to access a housing area or an industrial driveway, due to the high volume of traffic the left-turning vehicle often has to wait a while before it can make a safe turn. Other vehicles behind the left-turning vehicle, rather than waiting, pull around to pass the left-turning vehicle on the right, perhaps leaving one tire on the edge of pavement when a narrow shoulder exists. These maneuvers cause significant damage to the pavement edge (see Figure 4.19). The medium-width shoulder, in this instance, becomes as much an attractive nuisance as a benefit to drivers. Unlike typical low-volume edge damage, here the edge drop-off occurs at the edge of the shoulder.

FIG. 4.18. Border Patrol ROW Activities, Though Legal, Create Significant Pavement Edge Damage

FIG. 4.19. Typical Edge Damage Associated with Illegal Left-Turn Bypass Maneuver.

4.5.2.5 Cutting Corners and Vehicle Pull-offs

Trucks often cut corners to get to a convenience store, to an industrial driveway, or to another road. No matter how wide the radius is, some drivers are going to cut it short (see Figure 4.20). At times traffic may pull off the highway early before reaching the intersection, radius, or a turning lane (both left and right) and drive on the unpaved edges. Using the shoulder for an acceleration or deceleration lane also causes significant damage to the edge.

FIG. 4.20. Edge Damage Caused by Cutting Corners at a Convenience Store Access Drive.

Drivers pulling out of private driveways also tend to cut corners, creating substantial drop-off damage. In 2002, TxDOT changed its policy on maintaining private driveways. Since few metropolitan districts have enough resources to maintain private driveways, districts stopped maintaining private driveways across the State. The rural districts are now spending more of their resources to repair edge drop-offs as a result of this new policy.

4.5.2.6 Roadside Vendors

Vehicles pull over to make illegal access or exit to roadside vendors such as firecracker stands, farmers' produce stands, or shrimp vendors (see Figure 4.21). These types of maneuvers are repetitive in nature and can create significant damage in a short time.

FIG. 4.21. Typical Edge Damage at Location of Roadside Vendor.

4.5.2.7 Snow Plow Activity

Northern parts of Texas, for example, the Amarillo and Lubbock Districts, get appreciable snow most winters. Snow plowing operations cause pavement edge damage both because the operators drive on the edge and because the plowing can score the pavement surface and create raveled and damaged edges (see Figure 4.22).

4.5.2.8 Other Causes

Oftentimes overloaded trucks use narrow FM roads to avoid inspection on state highways and they tend to drive well beyond posted speeds which damages roads considerably. Sometimes construction activity requires that freeway traffic be re-routed onto low volume roads as alternate routes, and again, this increased activity over extended periods of time tends to cause pavement edge damage. Motorists pulling wide trailers (e.g.. boat trailers) may cause damage to the edges, especially near inside curves of hills because of unfamiliarity with the area. When farming tractors turn around or even plow next to the road into the ROW, significant damage is done to the pavement edge. Roadside habitat of rodents, prairie dogs, gophers, “leaf cutter” ants (red ant, town ant) may also cause damage to the edge of the pavement by digging holes underneath the pavement for their den. School buses or city transit buses often damage the pavement edge during loading and unloading.

FIG. 4.22. Typical Edge Damage on a Low Volume Road Caused by Snow Plow Operations.

4.5.3 Traffic Conditions Associated with Edge Drop-offs

As discussed in the previous sections, abusive traffic often has a significant impact on the edge damage and the severity of damage is governed by vehicle speed, volume and type. The following subsections discuss these factors in more detail.

4.5.3.1 Traffic Volume and Speed Ideally, roadways are designed to carry their expected traffic and will have adequate width and structure for this traffic. This is the challenge of transportation infrastructure development, and while Texas roads are a marvelous success, exceptions to the ideal exist at every level. For example, FM Roads, State Highways, US Highways, and some Interstates across Texas carry a higher volume of traffic than their design capacity. In some cases, these roads do not satisfy current standards of roadway design; i.e., they may be too narrow, do not have standard shoulders, or may be structurally inadequate. Sometimes the traffic overload may be due to construction detours, sometimes it is seasonal (harvest season, new construction jobs or industry relocations), sometimes it results from economic policy (e.g., NAFTA), and sometimes it is simply a matter of sustained growth. Also, as a general rule, traffic speed has increased over time. For these reasons it is not hard to see how FM Roads and other roads built 50 to 60 years ago are frequently overloaded both geometrically and structurally, and one of the clear manifestations of this overload is pavement edge damage. In addition, increased traffic creates more of a safety hazard for the maintenance crews who work on these roads, and higher speed compounds this problem.

4.5.3.2 Traffic Type Truck and/ or truck-trailer traffic has gotten larger and heavier over the years, and this increase in vehicle size contributes to the edge drop-off problem. Prominent examples identified by maintenance personnel across the State include oil and gas tanker trucks, agricultural equipment, farm tractors, cattle haulers, dairy operations, aggregate haulers (from a gravel pit or rock quarry), logging trucks, chip trucks, feed lot operations, chicken haulers, sod haulers, module trucks for cotton and peanuts, fleets of trucks for sugar cane plant operations, manure wagons, garbage trucks, construction equipment, water tank trucks, manufactured housing transport, mail carriers, recreational vehicles, boat trailers, and soccer moms in their SUVs (see Figure 4.23). These larger, heavier vehicles – both trucks, tractor-trailers, and unconventional equipment – have more wander than passenger cars at high speed and naturally tend to damage the pavement edge, especially on narrow roads. Larger traffic actually can have a double effect: the outside wheel of a truck or trailer constantly running off the edge will create its own edge damage, but this will also cause oncoming motorists to move over to the other side for their own safety.

FIG. 4.23. An Example of Oversize Traffic Taking Its Half (More than Half) Out of the Middle.

Agricultural vehicles such as sod haulers, cotton module haulers, and sugar cane haulers oftentimes work off the edge of the pavement and routinely drive on and off the road. These agricultural trucks also tend to be heavier than the design load of many low volume roads; there is no weight limit for raw agricultural product trucks and this by itself can cause tremendous pavement damage. Other vehicles, for example, manufactured homes, boat trailers, and farm tractors aggravate the edge damage situation by being wider than conventional traffic. Overloaded trucks coming cross the Mexican border under the NAFTA agreement not only cause edge damage but are prematurely wearing out the roads.

4.5.4 Environmental Conditions Associated with Edge Drop-offs

Up to this point we have discussed several causes of pavement edge damage that maintenance personnel identified during our interviews, including narrow low volume roads, unauthorized or abusive use of the roadside, and traffic growth considerations. Another contributing factor to pavement edge damage has to do with environmental factors; that is, the pavement subgrade, area precipitation, and the like.

4.5.4.1 Pavement Subgrade (Soil) Conditions

The primary focus of this research is best practices for maintenance and repair of "naturally-occurring" pavement edge damage on roads where there is no shoulder; that is, the drop-off occurs adjacent to the travel lane. Subgrade soil is an important factor in this type of edge drop-off problem not only because the soil provides structural support to the road but also because raw subgrade is the predominant material alongside the edge of a pavement. While it is beyond the scope of this report to get into classification and assessment of soil conditions, suffice to say that subgrade soils in the State of Texas cover the gamut from clay to stone and everything in between – see Figure 4.24 (Bureau of Economic Geology 1999).

Clay, in particular the highly-expansive clay for which Texas is known, is a very weak subgrade material and also experiences shrinkage/swell problems with the moisture change. This clay not only provides poor structural support but because of the shrinkage and swelling, it can produce reflective cracks not only at the pavement edge but also across the whole pavement section. With high moisture, this clay gets very soft and would be subject to deep ruts at the pavement edge with as little as one pass of a vehicle wheel, often despite any surface vegetation. Clay soils represent a major pavement subgrade challenge in most areas of the state, with perhaps the most severe problems tending to occur along the IH 35 corridor between San Antonio and Dallas.

Sandy soil, while stronger and more stable than clay, is frequently subject to significant wind and water erosion, in part because it may not support vegetation well. On the one hand, these types of sandy soils can produce significant edge drop-offs by blowing or washing away from the pavement edge. On the other hand, these same soils can create a buildup problem by blowing sand into the pavement from adjacent property. Buildup on the edge can be as big a problem as a drop-off since it prevents water from draining away from the pavement surface.

Rocky or stone subgrade is among the best pavement subgrade materials in the State in that it is both strong and stable. However, even this type of subgrade may have problems. It does not support vegetation well, so localized pockets of fine particles and pavement aggregate may erode away and eventually create edge drop-offs.

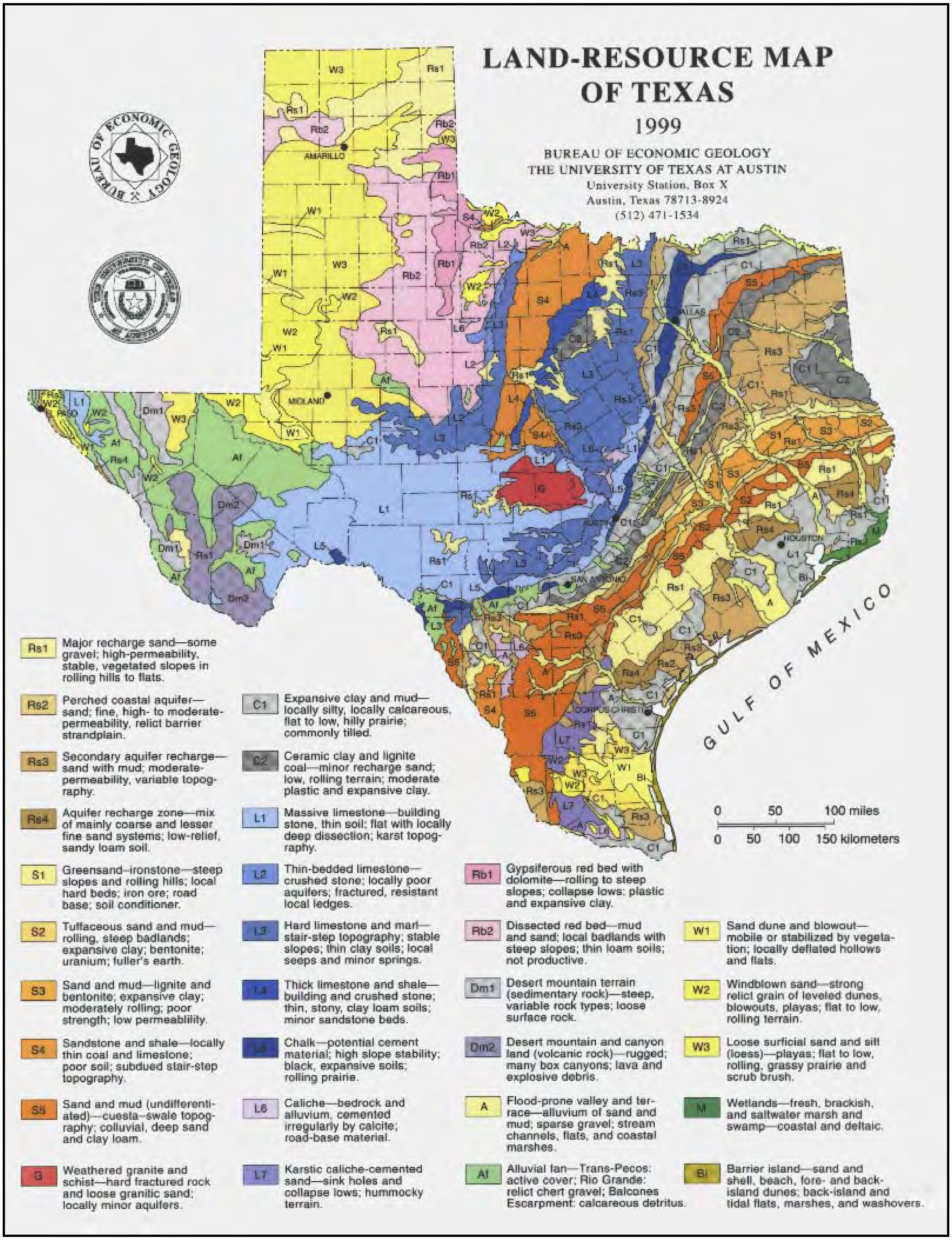

FIG. 4.24. Pavement Subgrade Conditions Across the State of Texas. *Source:* Bureau of Economic Geology (1999).

4.5.4.2 Climate and Rainfall

It is beyond the scope of this report to get into classification and assessment of climate and rainfall, but like pavement subgrade, the climate in Texas covers the gamut from arid to subtropical-humid, and normal annual rainfall in this State ranges from 8 inches to 56 inches – see Figure 4.25 (Texas Department of Water Resources 1984).

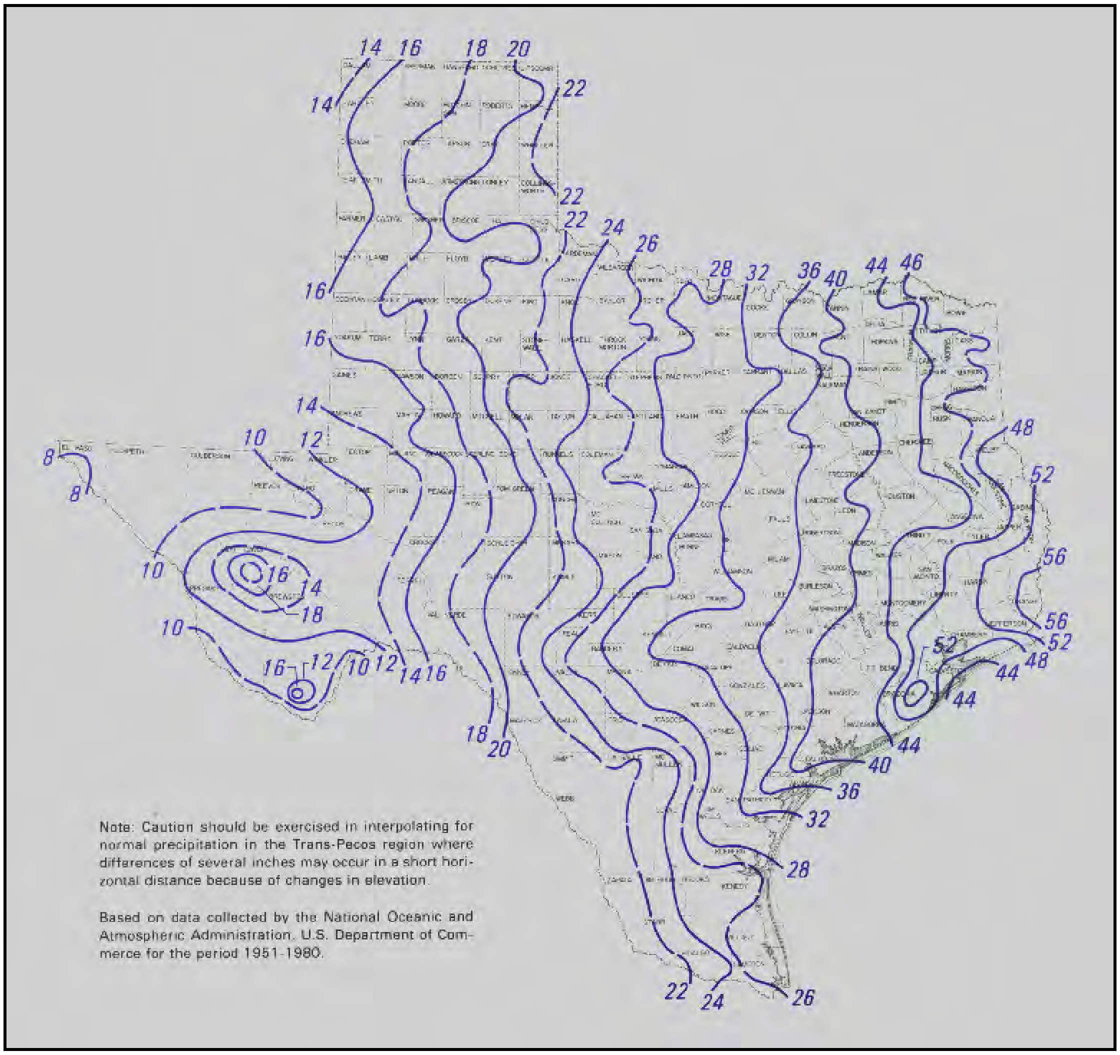

FIG. 4.25. Normal Annual Precipitation for the State of Texas. *Source:* Texas Department of Water Resources (1984).

One obvious issue is that rain can create erosion-induced drop-offs along the edge of the pavement, this being a function of, among other things, the amount and intensity of rainfall and the stability of the subgrade soil. This is especially significant for roads with very narrow right-of-ways and steep face slopes on the bar ditches. In contrast to these sloped areas, in flat terrain water will tend to remain on the ground near the pavement edge for longer periods and keep it wet and soft. Here, a few or even one pass of the wheel of an overweight/ oversized truck or even a car can produce a large drop-off along the pavement edge (see Figure 4.26).

FIG. 4.26. Edge Drop-off Associated with Wet Subgrade Along the Edge of Pavement

In addition, precipitation dramatically affects construction operations and access for maintenance, to name a few. For example, after a hot mix overlay operation, pavement edges are usually backfilled. But one or two events of heavy rain could wash the soil away before vegetation is established, and this will produce an edge drop-off. Inadequate compaction or improper fill material selection may also contribute to this problem.

Precipitation and climate also directly impact growth of vegetation, and this warrants special mention since roadside vegetation figures prominently both in supporting pavement edges and in controlling erosion. On the one hand, high rainfall usually means lush vegetation and this requires extensive maintenance to avoid both drop-offs and high edges. On the other hand, it is hard to establish vegetation in a region where there is little precipitation.

4.5.4.3 Snowfall and Freeze/Thaw

Limited to the northwestern region of the state, especially the Panhandle area, snowfall and freeze-thaw are significant contributing factors to the edge drop problem. In the Amarillo district, annual snowfall would be around 15 inches to a maximum of about 48 inches. Snow and freeze/thaw conditions may damage the pavement edge in several ways:

- Once the ground and pavement are covered with snow, it is hard to distinguish the pavement edges. The plowing operation for snow removal can easily peel off the pavement edge, as well as the grass and destroy the vegetation if the freezing has not done enough damage to it already (see Figure 4.22).

- When snow starts melting or during frozen ground thaws, this introduces moisture into the ground for a longer time and makes the ground very soft. One or two passes of a tire along the pavement edge can easily create a deep rut.
- It is necessary to remove snow from the pavement edges as well as the from road surface. Snowplow operators try to pile the snow on the right-of-way, as far away as possible from the pavement edge. This is because snow drifts near the pavement edge tend to hold moisture and this moisture eventually seeps into the pavement structure, weakening it.
- Deicing salt can aggravate the situation by creating a buildup at the pavement edge and preventing snowmelt from draining off the pavement.

Winter snow and freeze/thaw conditions are frequent in the Amarillo District but also regularly affect other districts including Lubbock, Abilene, Childress, Wichita Falls, Fort Worth, Dallas and even Paris .

4.6 Summary

In summary, our interviews with TxDOT maintenance personnel, together with our observations and literature research show that a correlation exists between the occurrence and severity of edge drop-offs and several factors, many of which are identified in Figure 4.27. Our research method did not attempt to scientifically quantify these correlations, this is simply what we observed. Put another way, it appears that pavement edge drop-offs will be more pervasive and more severe when more of these factors exist, and when these factors exist in greater degree.

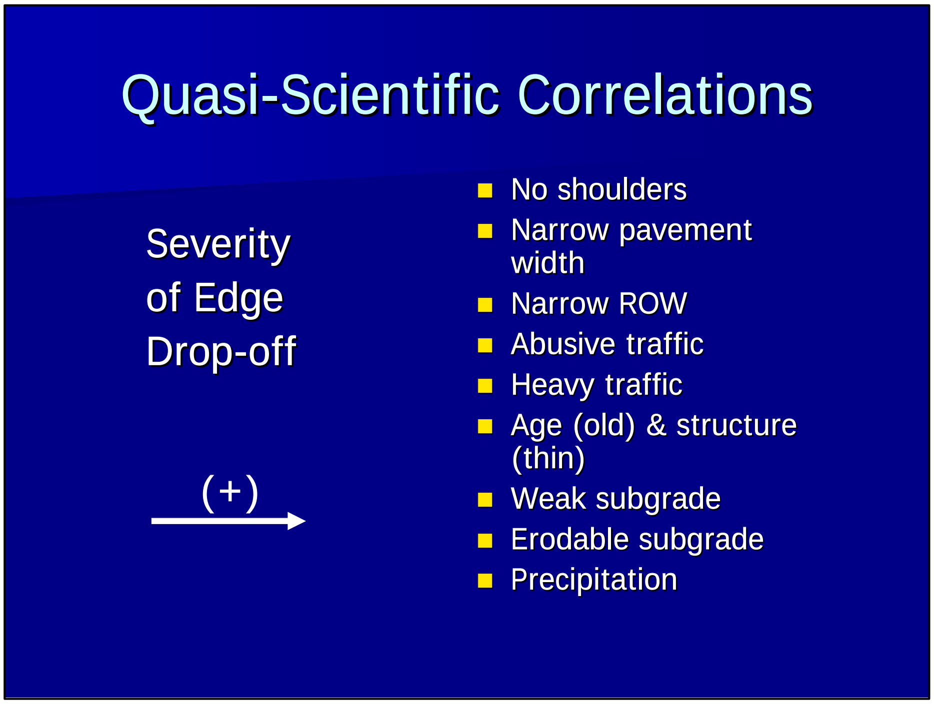

FIG. 4.27. Correlation Between the Severity of Edge Drop-off and Selected Pavement Factors

It is appropriate to note that some TxDOT districts are more fortunate than others in that they have fewer of these factors to contend with. For example, a district may have narrow roads but at least they have good-quality soils, or low traffic. It is when all, or several, of these factors go bad at once that the most severe pavement edge problems occur.

CHAPTER 5
EDGE MAINTENANCE PRACTICES AND PROCEDURES

5.1 Perspective on Edge Maintenance

5.1.1 Overview of Pavement Edge Maintenance Practices and Procedures

This chapter presents pavement edge maintenance practices and procedures gleaned from our district interviews, field observations, and literature search. We begin in this section with a recommended perspective on pavement edge maintenance. We then get into the practices and procedures themselves, starting with a discussion of edge maintenance awareness, followed by, in increasing maintenance effort, preventive edge maintenance, edge maintenance and repair techniques, and a brief comment on road widening as the ultimate solution for pavement edge maintenance (Chapter 6 is devoted to the topic of road widening). We close out this chapter by discussing the costs of pavement edge maintenance, both what they may seem and what they really are.

5.1.2 *Tracy's Law* – A Key Perspective on Pavement Edge Maintenance

The TxDOT Maintenance Manual, Section 2, discusses Level of Service and among other things identifies four major areas of maintenance, and these are (1) pavement maintenance, (2) roadside maintenance, (3) operations and (4) bridge maintenance (TxDOT 2001). Within these four major areas exists several conditions or components for which maintenance forces are responsible. For example, in the area of pavement maintenance, TxDOT forces are responsible for maintaining the pavement in the areas of longitudinal rutting, alligator cracking, and ride quality. In the area of roadside maintenance, TxDOT forces are responsible for vegetation, litter control, pavement edges, rest areas, and picnic areas. Operations maintenance components include safety appurtenances, illumination, traffic signals, signs, mailbox supports and delineators, and pavement markings. Bridge maintenance components include bridges, channels, culverts, approaches, deck, superstructure, and substructure. All this to say, maintenance covers many different aspects of TxDOT's transportation system with pavement edges being just one component of only one major maintenance area (roadside).

Recognizing the many demands and responsibilities of maintenance personnel, not to mention competition for scarce financial resources, district maintenance forces commonly reminded us during our interviews that "Edge maintenance is just one of many things we do." Thus it is appropriate to ask the question, "Why all the focus on edge maintenance?" While this question could be answered many ways, one very compelling answer came during our site visit to the Lubbock District from our Project Director, Mr. Tracy Cumby. When we were discussing this issue, Mr. Cumby, formerly a Maintenance Supervisor in Hockley County, pointed out what he and others have observed over the years; namely, that the key to good roads is good pavement edge maintenance strategy. More specifically, Mr. Cumby stated – and he credited this quote to others – "If you lose the edge, you lose the road." We have come to refer to this as *Tracy's Law* (Figure 5.1), and we believe that *Tracy's Law* is a profound statement that provides the key perspective as to why pavement edge maintenance is such an important part of overall maintenance success.

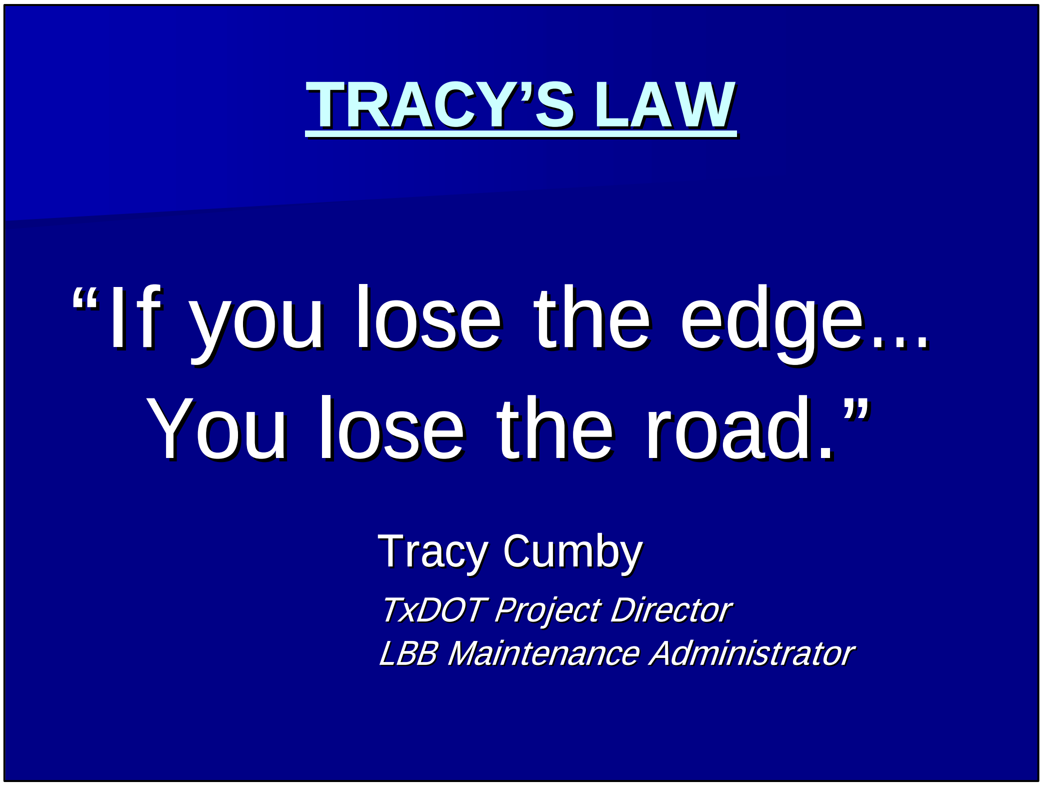

FIG. 5.1 *Tracy's Law*

5.1.3 TxMAP Edge Condition Assessment

While Tracy's Law was mentioned simply as an adage from an experienced maintenance supervisor, it has support from statistical observation, specifically, in the TxMAP data which TxDOT has collected for the past three years. Figures 5.2, 5.3 and 5.4 present "Non-Interstate Assessment, District Overall Summary" data for pavement edges and overall categories for each district for the years 2000, 2001, and 2002, respectively (TxMAP 2000, TxMAP 2001, TxMAP 2002). These data represent a composite of the rankings for US Highways, State Highways, and FM Roads; they do not include Interstate Highways. Table 5.1 summarizes the "overall" and "edge" district rankings for these years.

Table 5.1. TxMAP District Rankings for "Overall" and "Edge" Categories, Non-Interstate Assessment, District Overall Summary, for the Years 2000, 2001, and 2002

Ranking	2000		2001		2002	
	Overall	**Edges**	**Overall**	**Edges**	**Overall**	**Edges**
1	06/ ODA	06/ ODA	23/ BWD	24/ ELP	06/ ODA	06/ ODA
2	24/ ELP	24/ ELP	06/ ODA	06/ ODA	07/ SJT	05/ LBB
3	25/ CHS	09/ WAC	07/ SJT	25/ CHS	23/ BWD	07/ SJT
4	23/ BWD	07/ SJT	14/ AUS	08/ ABL	08/ ABL	24/ ELP
5	01/ PAR	25/ CHS	04/ AMA	05/ LBB	21/ PHR	08/ ABL
6	07/ SJT	13/ YKM	09/ WAC	14/ AUS	24/ ELP	21/ PHR
7	05/ LBB	04/ AMA	19/ ATL	23/ BWD	01/ PAR	04/ AMA
8	04/ AMA	23/ BWD	08/ ABL	19/ ATL	04/ AMA	25/ CHS
9	17/ BRY	05/ LBB	21/ PHR	07/ SJT	05/ LBB	23/ BWD
10	21/ PHR	01/ PAR	24/ ELP	21/ PHR	09/ WAC	19/ ATL
11	22/ LRD	20/ BMT	20/ BMT	15/ SAT	12/ HOU	20/ BMT
12	20/ BMT	12/ HOU	05/ LBB	09/ WAC	19/ ATL	01/ PAR
13	19/ ATL	11/ LFK	11/ LFK	10/ TYL	02/ FTW	13/ YKM
14	09/ WAC	03/ WFS	15/ SAT	04/ AMA	20/ BMT	11/ LFK
15	10/ TYL	16/ CRP	25/ CHS	01/ PAR	14/ AUS	09/ WAC
16	03/ WFS	21/ PHR	17/ BRY	20/ BMT	25/ CHS	12/ HOU
17	12/ HOU	19/ ATL	02/ FTW	17/ BRY	13/ YKM	15/ SAT
18	11/ LFK	22/ LRD	22/ LRD	02/ FTW	17/ BRY	18/ DAL
19	02/ FTW	17/ BRY	13/ YKM	12/ HOU	15/ SAT	02/ FTW
20	08/ ABL	10/ TYL	01/ PAR	11/ LFK	22/ LRD	22/ LRD
21	16/ CRP	18/ DAL	10/ TYL	13/ YKM	18/ DAL	17/ BRY
22	18/ DAL	02/ FTW	12/ HOU	18/ DAL	11/ LFK	14/ AUS
23	13/ YKM	08/ ABL	16/ CRP	22/ LRD	16/ CRP	16/ CRP
24	14/ AUS	14/ AUS	03/ WFS	16/ CRP	10/ TYL	03/ WFS
25	15/ SAT	15/ SAT	18/ DAL	03/ WFS	03/ WFS	10/ TYL

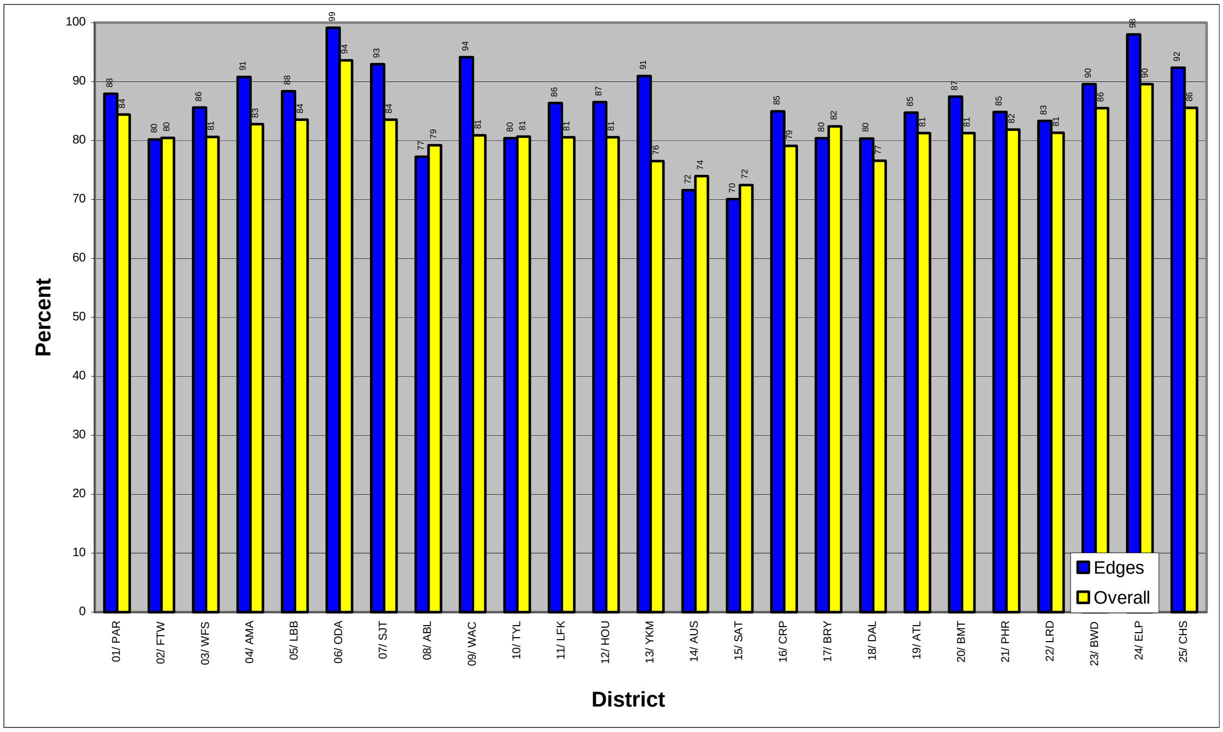

FIG 5.2 TxMAP 2000 Non-Interstate Assessment, District Summary, after TxMAP (2000)

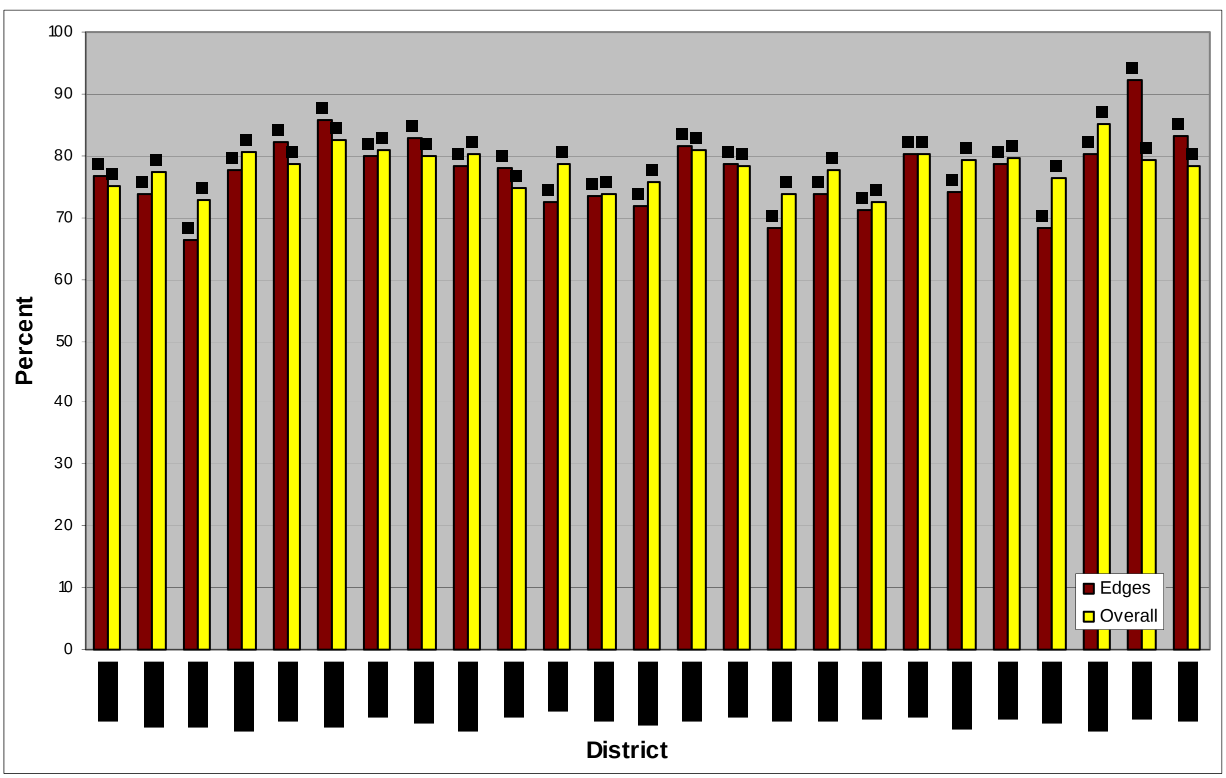

FIG 5.3 TxMAP 2001 Non-Interstate Assessment, District Summary, after TxMAP (2001)

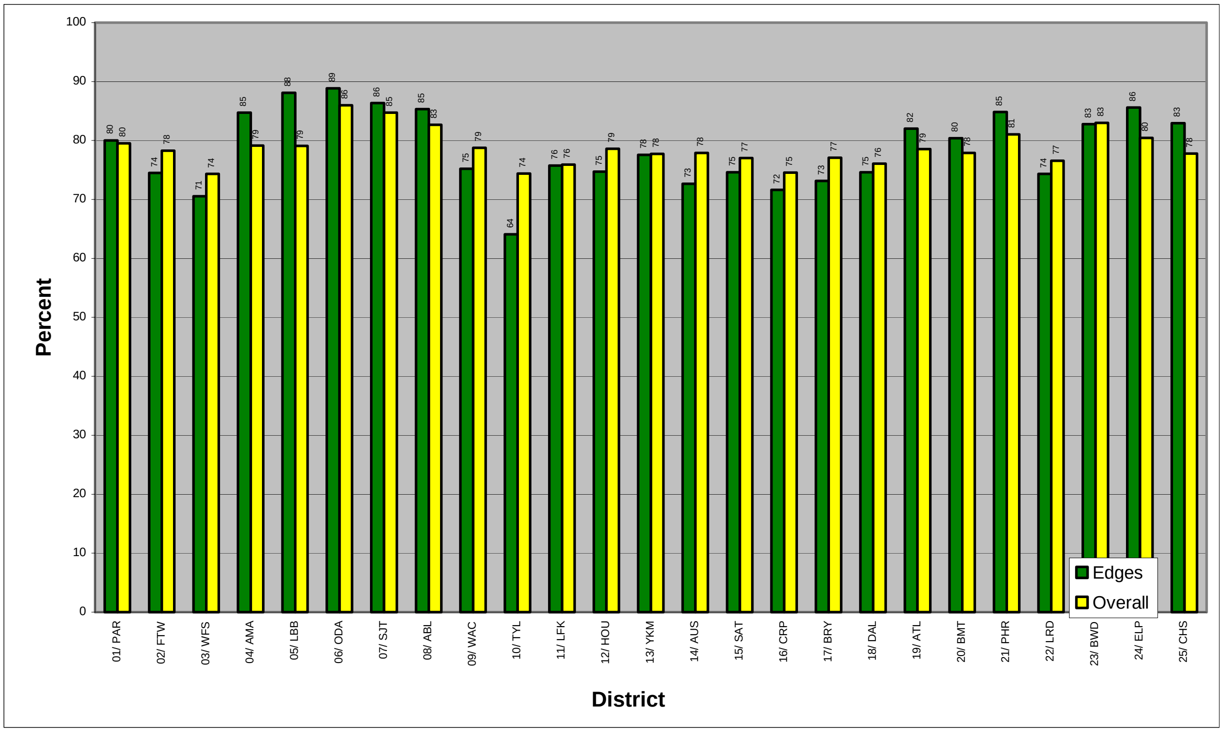

FIG 5.4 TxMAP 2002 Non-Interstate Assessment, District Summary, after TxMAP (2002)

Review of these TxMAP data show a remarkable amount of correlation between edge condition and overall performance at the top, and more particularly, the bottom, of the rankings. Let us assume that an important goal for TxDOT personnel would be to achieve a district overall ranking at or near the top of the overall rankings for the State. The TxMAP data in Table 5.1, for the year 2000, show the top 3 districts overall were within the top 5 districts for edges. This can be interpreted to say that in order for a district to rank as one of the top 3 districts in the State overall for non-interstate assessment, it was necessary to rank in the top 5 in the State on edge maintenance. Similar correlations exist for the year 2001 (to be in the top 3 overall a district had to score in the top 9 on edges) and the year 2002 (to be in the top 3 overall a district had to score in the top 9 on edges). This correlation suggests that good edge maintenance strategy is necessary for good roads.

But the correlation is even stronger at the bottom of the list. With the exception of one anomaly in 2000 (the first year the rankings were done), for all three years data have been collected, those districts that ranked in the bottom 3 of the State overall fell within the bottom 4 on edges. Stated another way, if a district ranked at the bottom of the list on edges, it *was* the bottom of the list overall. This very strong correlation at the low end demonstrates that good roads can not be achieved without good edge maintenance strategy.

The TxMAP data appear to suggest that good edge maintenance strategy is not only important in achieving good roads, but without good edge maintenance a district cannot achieve good roads. While more rigorous analysis can be done, on the face of it, TxMAP data appear to support *Tracy's Law*, "If you lose the edge, you lose the road." It is on this basis we contend that good pavement edge maintenance strategy is the key element of a successful highway maintenance program.

5.2 Edge Maintenance Awareness and Emphasis

While synthesizing the data from our site visits and interviews, it became apparent that some maintenance personnel are more aware of pavement edge issues than others, *Tracy's Law* being one illustration. This section of the report discusses maintenance practices and procedures that can best be categorized under the heading of "awareness." We identify them as best practices because to be aware of the issues associated with pavement edge maintenance is the first step toward addressing them.

5.2.1 Design Details & Construction Phase Awareness

Several times during our interviews, maintenance personnel identified maintenance problems they had to deal with on a recurring basis that could have been readily solved during the design phase and built into the construction contract.

For example, personnel in several districts mentioned how construction contracts for full-width overlays often do not include a bid item for pulling up the edges. Whereas prior to construction the road might have edge drop-offs of no more than an inch or two in height and be well within the desirable level of service, after an overlay this same stretch of road may have continuous drop-offs of more than 3 inches. Failure to include pulling up the edges in the Contractor's scope of work for this type of project places a significant maintenance burden directly on district forces. This is particularly aggravating since in their annual planning, maintenance forces view construction and rehabilitation projects as jobs where the work is done correctly and will not require heavy maintenance as soon as the contractor leaves the site.

Another example has to do with maintenance-friendly design details. The Fort Worth district cited an example where construction bid documents for a full-width overlay project included a tapered edge that helped to minimize pavement edge drop-offs (see Figure 5.6).

The Wichita Falls District cited an example where construction bid documents for a full-width overlay project did include a bid item for pulling up edges following the overlay, and since this project was for a divided US Highway, the main functional requirement for the edge backfill soil was that it be able to support vegetation. However the backfill specification only addressed gradation and plasticity and did not mention the vegetation requirement, and although the contractor did satisfy the material specifications for the project, the soil did not contain any organics and at the first rainfall much of it washed away (see Figure 5.5).

5.2.2 The Safety Edge

Maintenance friendly and driver safe edge design details were being used in some districts, this in awareness of the importance of design details and construction phase implementation. The Fort Worth District cited an example where construction bid documents for a full-width overlay project specified a tapered edge that helped to minimize pavement edge drop-offs (see Figure 5.6). Known as the "Safety Edge" or "edge wedge" (FHWA 2004), this detail applies Zimmer and Ivey's research (1983) which establishes a relationship between pavement edge slope and roadway safety (see Figure 3.3). Whereas the tapered edge in Figure 5.6 was accomplished by a home-made screed attachment, development work is in process by TransTech Systems (TransTech 2004) to develop a patented device to address the pavement shoulder edge drop-off problem. FWHA continues to perform research on the safety aspects of the pavement edge wedge (Delaigue 2004). We did not see the "safety edge" prominently mentioned in TxDOT districts, probably because so much of TxDOT's pavement maintenance involves seal coats rather than full pavement width hot mix overlays. However, where overlays are being done, the safety edge is an appropriate detail to use.

FIG 5.5 Tapered Edge Detail to Reduce Edge Drop-offs Following a Full-Width Overlay, Fort Worth District (see Fort Worth District Profile, Photo 8)

FIG 5.6 Soil Erosion of Pavement Edge Backfill due to Improper Specification, Wichita Falls District (see Wichita Falls District Profile, Photo 7)

Yet another example was cited by the Dallas District (see Figure 5.7). Here, an effective edge construction detail had been used in the past, but for whatever reason was not continued on later construction contracts. Failure to incorporate the detail created an almost un-maintainable edge condition for district forces.

FIG 5.7 Tapered Edge Detail, Dallas District (see Dallas District Profile, Photo 6)

In each of these examples, awareness of the edge maintenance issues at all levels, in particular by design and construction personnel, would have gone a long way toward avoiding the problem and saved TxDOT significant money and effort in the long run. This suggests that it is important for maintenance, design and construction personnel to regularly discuss projects in the design phase so that potential maintenance issues can be given proper attention.

5.2 3 Risk Management to Reduce Tort Liability

We noted in Chapter 3 in our review of the legal literature that a significant aspect of the edge drop-off problem is risk of harm to the traveling public and the liability this risk engenders. Maintenance personnel in the Brownwood District are working to better understand the risk aspects of their jobs by attending the TxDOT course, "Risk Management to Reduce Tort Liabililty" (see Figure 5.8). These personnel pointed out that much – even *most* – of a maintenance supervisor's daily work has to do with unplanned emergency situations, and properly understanding and assessing the risks associated with those situations is key to properly dealing with them. Every maintenance section supervisor in the Brownwood District had taken this course and they all found it very helpful.

FIG 5.8 Risk Management to Reduce Tort Liability (see Brownwood District Profile)

5.2.4 Maintenance Leadership Focus

Another best practice for pavement edge maintenance has to do with leadership focus on the edge maintenance issue. Maintenance leaders at all levels of the TxDOT agency have taken the opportunity to make a difference here. First, the Maintenance Division is responsible to emphasize pavement edge maintenance by establishing policy and by continually holding up edge maintenance as a key element of TxDOT's maintenance program. This they do by, among other things, establishing a level of service requirement for edge maintenance as published in the Maintenance Manual, by incorporating measurement of edge conditions in the TxMAP assessment rankings, and by regular emphasis of pavement edge maintenance considerations in public meetings such as the Statewide Maintenance Conference and Transportation Short Course.

At the district level, in one district (Tyler), the District Engineer (DE) issued a memo that emphasized the importance of pavement edge maintenance and gave priority to it, the idea being, if edge maintenance is a priority for the DE, it should also be a priority for everyone else in the district. Maintenance Directors, Maintenance Engineers and Administrators, and Maintenance Section Supervisors also demonstrated concern and awareness of pavement edge maintenance issues. We view leadership focus as a best practice for pavement edge maintenance because when the leaders of the agency demonstrate through their words and actions that edge maintenance is important, it is not hard to convince those persons responsible for day-to-day maintenance activities that they should also view the issue as important.

5.3 Preventive Edge Maintenance

Preventive edge maintenance is that group of activities performed to protect the pavement and decrease the rate of deterioration of the pavement edge. The following are brief descriptions of the preventive maintenance practices most commonly used by the different TxDOT districts.

5.3.1 Raw Edging

Sealing hairline cracks to enliven surfaces at the edge of the pavement is known as "Raw Edging". This is usually performed by TxDOT in-house maintenance forces and oftentimes charged to maintenance function code 233 (Fog Seal). Applying a fog seal along the edge of the pavement is one of the common preventive maintenance practices against edge damage. Several TxDOT districts use raw edging with varied levels of success: Amarillo, Childress, Laredo (very limited case), Lubbock, Lufkin, Odessa, Paris, Pharr, San Angelo, Tyler, and Wichita Falls.

Proponents claim that raw edging keeps the pavement edges "alive" and slows down the propagation of hairline cracks at the worn out edge of the pavement. It tends to rejuvenate the oxidized asphalt and retards the raveling of aggregates from weathered, disintegrated edges. Sometimes raw edging is used as an erosion control measure over the soil at the edge of the pavement. It is considered to be a routine maintenance operation in most districts mentioned above. In some cases it may be done annually or on a three-year-cycle.

Raw edging involves shooting (spraying) liquid asphalt along the pavement edge to cover one or two feet of the edge (see Figure 5.9). Sometimes the coverage may be 50% on the paved surface and 50% on the unpaved soil area adjacent to the pavement. The most common type of liquid asphalt used is some type of emulsion (e.g. MS-2 with 50/50 water); a few districts like cutback asphalt (e.g. RC 250). Due to environmental regulations, use of RC-250 (or any cutback) is very limited. Some districts spread a thin layer of fine-grained soils (e.g. blow sand) over sprayed edges with a motor grader to eliminate stickiness, especially in case of excessive asphalt. This becomes more of a strip seal, and care must be used to not create buildup along the pavement edge that would trap water in the wheel path of the travel lane.

Raw edging is commonly done after "Edge Repair" or "Pulling Shoulders" as a preventive measure. It offers some degree of stabilization against wind or light rain erosion. The emulsion also helps seal the pavement to retard moisture infiltration. Some district personnel said that this activity is one way to use up their left-over stock of liquid asphalt (at the end of a budget year) and therefore alleviates a potential storage problem. District personnel often pointed out that the emulsion acts as a fertilizer, actually helping to grow vegetation along

FIG 5.9 Raw Edging, Amarillo District (see Amarillo District Profile, Photo 9)

the side of the road, and this can sometimes create problems of encroachment of vegetation onto the pavement.

TxDOT Specification Item 134 (backfilling) has the provision of using emulsion for the same reasons as explained here. However, the cost-benefit ratio of this activity has never been established with any degree of rigor. Perhaps the main drawback expressed to us by TxDOT maintenance personnel was that raw edging covers up the edge lines (on those roads which have edge lines). However, others have noted that the color contrast provided by the "black" raw edge against the lighter-color oxidized pavement surface serves as a type of "negative" edge stripe, and this keeps motorists off the edge.

In sum, the prevailing view from our research is that raw edging helps keep the pavement edge "alive", controls raveling, seals cracks, and generally helps extend the life of the pavement. While this is viewed as a beneficial preventive maintenance activity, not everyone agrees on just how beneficial it is, even though it is commonly done.

5.3.2 Edge Seal/ Strip Seal (seal coat/chip seal)

Application of an edge seal or strip seal is another common preventive edge maintenance operation used by different districts of TxDOT. The edge/strip seal involves the spray-application of a single layer of asphalt (asphalt cement or emulsified asphalt) followed immediately by application of a thin aggregate cover (one stone thick) which is rolled as soon as possible. Although the operation is similar to a seal coat, the edge seal is typically done for a one- to two-foot strip at the edge of the pavement instead of full width. The strip seal is a formal maintenance operation with a TxDOT maintenance function code designation 232 (see Figure 5.10).

FIG 5.10 Edge Seal, Childress District (see Childress District Profile, Photo 5)

The edge/strip seal serves some of the same purposes as “raw edging” such as sealing hairline cracks on the surface and rejuvenating oxidized asphalt. This technique is used quite often to help hold together cracked or broken edges. Sometimes it is used before the formal seal coat operation or in between seal coats. Some of the districts that use strip seals to prevent edge damage are Atlanta, Austin, Childress, Paris, Pharr, San Angelo, Waco, Wichita Falls and Yoakum. The Pharr district considers the edge/strip seal to be particularly beneficial for narrow FM roads. In Wichita Falls, it is a part of their 3-year routine maintenance plan.

Both emulsion and hot asphalt can be used as liquid asphalt. Cutback asphalts are not used due to environmental concerns. Although any specified aggregate could be used, most districts use a grade 5 aggregate (fine aggregate, Item 302 in TxDOT specification book) to establish a cover and restore or enhance skid resistance at the edge.

Like raw edging, this operation is commonly done after “edge repair” or “pulling shoulders” as a preventive measure; some districts report that edge sealing helps these other repairs last longer. One concern about placing an edge seal is creating a build-up of fine aggregate at the pavement edge. Repeated application of a seal coat/ strip seal at the edge can create a “hump” which prevents water from draining off of the outside wheel path.

5.3.3 Approach Apron or Turning/ Acceleration Lane

We have noted that vehicles tend to cut corners at intersections and this has been identified as a significant contributing factor for pavement edge drop-offs. Not having a turning lane makes the situation worse, especially for narrow roads. San Angelo District maintenance forces have addressed this issue by building what we call an "approach apron" or "turning or acceleration lane" as a preventive feature to help protect pavement edges at the intersections of their low volume roads (see Figure 5.11). Typical locations for these types of approach aprons include a ranch/farm-to-market road (RM or FM) intersecting a major highway, and a ranch/farm access road intersecting an RM or FM road.

FIG 5.11 Intersection Approach Apron, San Angelo District (see San Angelo District Profile, Photo 5)

The San Angelo District approach apron usually consists of widening a 600 to1000-foot stretch of road at the intersection by adding a 3-foot "shoulder" on each side. Widening consists of blading out 4-8 inches of subgrade material next to existing pavement and filling this trench with pre-mix to create a paved shoulder. Maintenance forces perform this work under Function Code 245 which is widening the pavement (2 to 4 feet) to correct a maintenance problem.

The widened pavement section provides more room for motorists to turn onto or off of the road without having to encroach onto the pavement edge. The 600 to 1000-foot stretch of widened pavement also enables motorists to get lined up and traveling on the paved surface. The restricted distance for widening is justified by the low traffic volume.

5.3.4 Vegetation Practices

5.3.4.1 Promoting Growth of Desirable Vegetation

Maintenance personnel from just about every district across the State hold that vegetation along the roadside is beneficial, both for erosion control purposes and because a well-developed root mass next to the pavement helps buttress and stabilize the pavement edge. This represents a change in maintenance philosophy from 15 to 20 years ago. Until the late 1980s, it was common practice to intentionally establish a clear zone along the roadside, 6 feet or more wide and with no vegetation of any kind. However, maintenance personnel noticed that this practice left the pavement roadside highly susceptible to erosion and actually caused them to have to maintain the edges continuously for drop-off problems. Eventually they realized that vegetation at the pavement edge protects the edges from wind, rain, and traffic erosion and thus solves more problems than it causes.

Vegetation practices are directly affected by a district's amount of annual rainfall. Neither the weather nor soil conditions in the western part of the State are favorable to vegetation growth; it is difficult to establish vegetation because of sandy soil and low rainfall. In contrast, the eastern part of Texas has mostly favorable soil and abundant rainfall for vegetation, and here the issue is more controlling vegetation growth than getting it established. Roadside vegetation is maintained mostly by natural rainfall, but some districts may water at certain critical times and places if needed. Some districts such as Fort Worth and Atlanta have successfully used mulch and compost as backfill cover (about 4 inch cover) to promote vegetation. The compost consisted of wood chips and seeds mixed together. The wood chips prevent rain-drops from washing soil away until the vegetation gets established (see Figure 5.12).

District maintenance forces in most parts of the State try to promote vegetation during their shoulder maintenance or reshaping operations. They rely mostly on existing native seeds or roots but occasionally they sow seed or place sod. Although most districts prefer native grass, some districts, like Amarillo, seed for Buffalo grass and other districts use Bermuda grass. It is usually easier to establish Bermuda grass but encroachment into farmers' fields can be a big concern.

Establishment of vegetation is frequently a part of construction contracts for road rehabilitation or new road projects. The contractor is required to cover the base crown with top soil and establish vegetation at the pavement edge during the backfilling operation. EPA regulations for storm water pollution prevention plans (SW3P) require roadside vegetation to re-grow at least 70% before the contractor is relieved of responsibilities from roadside

FIG 5.12 Composting to Promote Vegetation Growth, Fort Worth District (see Fort Worth District Profile, Photo 48)

construction and in very dry climates this is a major challenge. Contractors usually seed or place sod during their shoulder backfilling operations. Watering during construction in the dry season does not necessarily help in establishing the vegetation. It may only cause the grass to germinate but this grass will not sustain itself without continuous irrigation, and this is a concern for maintenance forces.

Contract edge backfilling operations are sometimes not done properly and erosion occurs (see Figure 5.13); in those cases, TxDOT maintenance forces must pull topsoil over the exposed base crown and establish vegetation. Similarly, topsoil may also be used as a cover in places where in-situ soil does not support vegetation, but this cover soil is very susceptible to rain erosion. Occasionally, emulsion is sprayed on top of backfilled areas, both to seal the pavement edge and prevent moisture and dirt loss at the pavement edge. The emulsion promotes vegetation growth by acting as a fertilizer (see Figure 5.14).

5.3.4.2 Controlling Undesirable Vegetation

Grass in and on the pavement surface is not desirable for many reasons. For example, grass in the asphalt promotes moisture intrusion, weakens the pavement structure, and results in cracking and deterioration of the pavement edges (see Figure 5.15). Therefore, most districts have a herbicide program to kill vegetation on the pavement; typically they use commercial herbicides such as Roundup. They also use herbicide to kill weeds (ragweed, tumble weed, Bahia grass and Johnson grass) from the roadside so that Bermuda grass or any desirable vegetation can grow more easily.

FIG 5.13 Erosion-induced Edge Drop-off Following an Overlay, Atlanta District (see Atlanta District Profile, Photo 11)

FIG 5.14 Edge Seal to Promote Vegetation Growth, Yoakum District (see Yoakum District Profile, Photo 7)

FIG 5.15 Encroachment of Vegetation onto the Pavement Edge, Lubbock District (see Lubbock District Profile, Photo 16)

As already noted, several years ago it was common practice for district maintenance forces to blade or kill all vegetation from the roadside for a certain distance, perhaps as much as six feet or more. But this made the roadside highly susceptible to erosion, and current practice is to establish vegetation next to the pavement. The problem is that even desirable vegetation starts to encroach onto the road surface. Some districts; for example, Austin and Brownwood, over-spray herbicide as much as 2-6 inches off the edge to kill vegetation in order to prevent immediate encroachment of vegetation into the pavement structure and also to eliminate a build-up problem. Other districts; for example, Corpus Christi, San Antonio and Yoakum, prefer to kill vegetation about one foot off the pavement edge.

5.3.5 Delineation

Most districts surveyed indicated that delineation is an effective method of preventive maintenance for pavement edge drop-offs. Districts use a range of delineation techniques, some common and some unusual, to achieve this function.

5.3.5.1 *Conventional Delineators*

Many districts use delineators to control traffic and help keep vehicles off the pavement edge. For example, the Houston District uses delineator posts quite often to restrict traffic in situations where vehicles pull over illegally, say, to access a convenience store, or in locations where vehicles are prone to make unauthorized exits from freeways. Conventional delineators are effective in combination with a traffic citation by the DPS officer, since the officer can write a ticket for breaking off the delineator posts. Post and cable is another common technique to restrict unauthorized traffic which causes pavement edge damage. However, determined motorists do not necessarily comply (see Figure 5.16).

FIG 5.16 Post and Cable Median Barrier, San Antonio District (see San Antonio District Profile, Photo 15)

The Waco District has used 6-inch domes successfully at intersections to keep drivers from cutting corners. Edges at the radius are lined up with the 6–inch domes. Although delineators are effective to some degree, the presence of delineators creates maintenance difficulties in terms of mowing, spraying herbicide, or blading around them.

5.3.5.2 Signage

Use of advisory signage to identify edge drop-off problems is not a very common practice for areas with naturally-occurring edge drop-offs. Regulatory signs such as “Shoulder Drop-off” usually appear only in construction zones (see Figure 5.17).

FIG 5.17 Shoulder Drop-off Sign, Construction Project, Paris District (see Paris District Profile, Photo 34)

5.3.5.3 Striping

Striping is the most common form of delineation used to address the edge drop-off problem. The majority view in most TxDOT districts is that a white edge line is beneficial in keeping traffic off the pavement edge because (1) it signifies the road is actually wide enough for an edge line, (2) it clearly delineates the edge of pavement, and (3) the edge line is a type of psychological barrier. In fact, any sharp contrast; for example, a fog seal or an edge seal, tends to help keep traffic off the edge and reduces the edge drop-off problem.

It is the policy of most TxDOT districts to put a centerline stripe on all the roads irrespective of their width. The narrow roads, even the 18 or 16-foot wide ones, get centerline stripes. Because the centerline stripe separates opposing travel lanes, some maintenance personnel have commented that a center-line stripe on a narrow road actually pushes the traffic onto the edge and creates more edge damage than not having the stripe. We encountered minor variation in District practices with respect to use of the centerline stripe; many supervisors commented that not having a centerline stripe on very narrow roads would not be a problem since these roads usually have very low ADT (often less than 300 vehicles per day).

Most districts are in the process of installing or have already installed raised pavement markings (RPM) along the centerline of all the roads. Although RPMs increase the nighttime visibility, they tend to separate opposing vehicles further, pushing them toward the edge of the pavement. Some configurations of centerline striping and RPMs can take up as much as 20 inches of roadway surface, leaving very narrow travel lanes on already-narrow roads.

It is TxDOT policy to place an edge line on all undivided highways with a minimum traveled way width of 20 feet (see Figure 5.18). This means that the practical minimum roadway width for placing edge lines is about 22 feet, this to provide enough room for the centerline stripe, the minimum-width travel lanes, and 6 inches of pavement outside the edge lines. Persistent occurrence of broken edges makes it difficult to place and maintain edge lines precisely at pavement edge, especially on narrow roads. For narrower roads, further restriction of the travel lane is problematic, and the edge lines are often not effective - they just add another item to the maintenance list.

FIG 5.18 Typical Striping, Low-Volume FM Road, Fort Worth District (see Fort Worth District Profile, Photo 6)

While variation exists in district interpretations of the edge line policy, most maintenance personnel in our interviews (15 of the 25 districts represented) agreed that an edge line is beneficial for roads that are at least 22 feet wide or wider. They say edge lines are a good thing, not only for reducing pavement edge maintenance but they also cite improved safety because of increased visibility and definition of the pavement edge, especially at night or during heavy rain.

Some districts expressed concern about recent TxDOT policy requiring the use of thermoplastic paint for all striping. Although thermoplastic paints are long lasting and offer better visibility, they are four times more expensive than water-based paints. The observation of some maintenance supervisors we talked with is that water based paints are probably appropriate for placing edge lines on low volume roads.

5.3.5.4 Special Delineation Techniques

The Atlanta District is experimenting with some special delineation technology. They have tried two types of high-visibility RPMs with photo-electric cells: one RPM starts flashing when it is dark and another flashes when it is wet, as in during a rainstorm (Figure 5.19).

FIG 5.19 Experimental High-Visibility RPM with Photoelectric Cell that Lights up During Rainfall Events, Atlanta District (see Atlanta District Profile, Photo 31)

Another type of delineation with direct application to preventing edge damage is “inverted profile pavement marking” – refer to Special Specification 7322 Inverted Profile Pavement Marking, or Special Specification 7323 Inverted Profile Pavement Marking (High Contrast). This is a textured, thick (at least 0.14 inch) thermoplastic paint stripe that is grooved at intervals of 1 inch. The grooves are 3/32- to 5/16-inch wide and the paint at the grooves is 0.025 to 0.05-inch thick. These grooved markings allow rapid drain of water from the highway surface and keep the markings highly reflective in heavy rain (Figure 5.20, 5.21).

This inverted profile is very effective on smooth surfaces like hot mix asphalt, creating a type of mini-rumble strip with a noticeable, high-pitched whine. These have been used experimentally on rough pavement surfaces like seal coat where the reflectivity remains high but the rumble strip effect is diminished. The cost for this type of pavement marking is expensive, about $1.25 per linear foot, so it is being used selectively to delineate certain stretches of road based on Department accident data.

FIG 5.20 Inverted Profile Pavement Marking, Atlanta District (see Atlanta District Profile, Photo 27)

FIG 5.21 Inverted Profile Pavement Marking, Close-up View, Atlanta District (see Atlanta District Profile, Photo 26)

5.4 Edge Repair Techniques

Having reviewed edge maintenance awareness and preventive maintenance techniques, we will now cover the typical edge repair practices and procedures identified during our district interviews and field observations. These are the types of activities that normally come to mind in a discussion of pavement edge maintenance. Standard repair techniques include repair of broken pavement edges (fishmouths), reshaping (pulling up) the shoulder, cutting high edges, and replenishing the shoulder with select borrow materials.

5.4.1 Hand-Patching Localized Broken Pavement Edges (Fishmouths or Ducknests)

Among the most simple of edge repair techniques is hand-patching. This technique remains the standard for localized edge damage such as fishmouths or ducknest-type failures (see Figure 5.22). The operation is similar to pothole repair and the equipment consists of a #2 scoop and a patching crew. Different types of repair materials are used including premix (cold mix) such as winterized mix, universal patch mix, instant road repair, Class 1 containerized road repair, or even Limestone Rock Asphalt (LRA). The procedure is as follows:

1) The potholes or edge drops are cleaned and swept with a broom.

2) The exposed surface may be tacked with liquid asphalt.

3) Asphalt mix is placed over the tack to fill the drop.

4) Laid down mixes are compacted as necessary by the tire of the vehicle that is carrying the patch material.

FIG 5.22 Fishmouth-type Edge Failure, San Antonio District (see San Antonio District Profile, Photo 12)

If constructed properly, this type of repair may last for as long as 2 to 3 years. When the repair area is more than 100-200 feet long, it is considered too big for a patching crew but may not be long enough for full scale repair operation. Some districts use a Grade-All in such cases.

5.4.2 Reshaping (Pulling) Shoulders with On-Site Material

Known by names such as "pulling shoulders," "pulling edges," "shouldering up," "lifting edges," and "pulling up and kicking off," the academic term for this most common of edge repair techniques is *reshaping* existing soil materials along the pavement edge. This is in contrast to *replenishing* which involves adding new material to the pavement edge – to be discussed later. The TxDOT *Maintenance Manual* identifies reshaping shoulders as an accepted method for repairing edge drop-offs (Chapter 8, Part 2, Section 2, Routine Pavement Maintenance, page 90).

This method consists of reshaping the soil along the pavement edges (shoulder) by using a motor grader (maintainer) to pull the on-site materials, including whatever soils may have washed away in the ditch or down the slope, back up to the pavement edge. The pulled-up soil is usually rolled to achieve ordinary compaction with the motor grader tires; in some cases a pneumatic tire roller is used. If the operation includes borrowed materials in addition to on-site materials, the hauler or dump truck tire may also be used for compaction. Excess materials are feathered out (bladed off) with the motor grader to match the existing or design face slope of the bar ditch, and any loose materials are swept off the pavement surface with a broom (see Figure 5.23).

FIG 5.23 Reshaping (Pulling) Shoulders, Childress District (see Childress District Profile, Photo 15)

Reshaping usually involves a one-man crew with a motor grader. Some districts use two motor graders; one pulls up the edge materials and the other kicks them off the pavement just behind the first one. In rare cases, dropped edges are cut a little deeper to establish a defined edge before pulling up any soil.

District maintenance personnel (those in drier climates) commonly say that the best time to perform this operation is after a rain or when the soil is damp; otherwise a water truck may be needed for moisture adjustment before compaction. A typical time for this type of work is during the colder months (November to April). Winter is a slower time of the year for other types of maintenance work, and vegetation is dormant plus the ground tends to holds more moisture for proper compaction. In very dry climates, water may have to be sprayed over the repair area even before pulling any soil. Of course, use of water and a water truck adds considerable expense to the operation.

Districts make a special effort to reestablish vegetation at the repaired pavement edge. Some do this by seeding or laying grass sod or pulling vegetation from the ditch, since one or two incidences of heavy rain can wash away bare soil if vegetation does not become established. Most districts rely on the existing seeds or roots in the soil. It is not a usual practice to disturb the existing vegetation: the topsoil with vegetation is usually bladed off first and stored for later use and it is pulled back after the repair. If the existing soil is not good for vegetation, borrowed topsoil may be hauled to the site. As a preventive measure against wind or rain erosion, some districts apply a fog seal (emulsion – say, at the rate of 0.1 gallon per square yard). The fog seal helps retard moisture loss and aids in growing vegetation since emulsion acts as a fertilizer.

Reshaping – pulling shoulders – is a common practice in most districts of TxDOT because it is a very quick and inexpensive way to repair edge drop-offs. The downside is that it may not last too long. Depending on the specific situation – soil and traffic – a pulled-up shoulder may perform only a week, or it may last as long as 6 months to a year. If maintenance supervisors have to pull shoulders more frequently than every winter, they usually look for more permanent solutions. First, they will try to achieve better compaction by adjusting the moisture content in the soil. This can enhance the life of the repair as much as three times, depending on the traffic and environment. If this is not effective, they will then look into using borrowed materials.

Several districts expressed their concerns about this operation because of environmental regulations and requirements about re-vegetation. If the vegetation in the ditches is disturbed during the shouldering operation, it can be difficult to satisfy the EPA's SW3P (Storm Water Pollution Prevention Plan) requirements regarding the reestablishment of seventy percent vegetation before project completion.

Different districts use different maintenance function codes for this operation. The most frequently used are Function Code (FC) 270 (Edge Repair), FC 455 (Reshaping Unpaved Shoulder) and FC 561/562 (Ditch Maintenance/ Reshaping Ditches). Usually materials are pulled up or hauled from the ditches; therefore, this operation is often incidental to ditch maintenance operations. Usually TxDOT in-house maintenance forces perform this operation; such work is rarely contracted out. Edge backfilling after overlay construction (Specification Item 134) is a similar operation that *is* contracted out but uses predominantly borrowed materials.

5.4.3 Cutting High Edges

While reshaping shoulders is the most common edge repair technique, it is not the only one. This is because a few districts – the high-rainfall areas of East Texas – have as much of a problem with high edges as with edge drop-offs (see Figure 5.24). When grass next to the pavement gets long, wind-blown materials such as silt, dirt and debris (for example, wood chips from logging trucks) start to build up at the pavement edge, and this creates a dike situation and drainage problems. Where the road is flat, trapped water ponds on the pavement surface, but where road grades allow, the trapped water actually flows along the pavement edge and erodes it. These are the significant maintenance issues associated with high edges.

FIG 5.24 Cutting High Edges, Lufkin District (see Lufkin District Profile, Photo 14)

Accumulated debris, excess materials and high vegetation along the edge of the pavement must be bladed off periodically to facilitate proper surface drainage. Shaved-off materials from the high edges are frequently used to fill low spots elsewhere. When vegetation is very dense and thick, blading to reshape the pavement edge may become difficult because of clumping. In extreme cases, district forces use a Kuhn Tiller (see Figure 5.25) or Bomag crusher (MPH-50 Reclaimer) to pulverize/fluff and blend the soil and vegetation for a 5-foot wide strip along the edge of the pavement. The Bomag works best for this kind of operation when it is available, but requires a special kind of tooth; a spoon blade as opposed to a button blade. When vegetation is more than 2 feet tall, it has to be mowed before any reshaping operation can be performed.

When tilling, district forces usually disc up 4 to 6 inches of soil and then shape the soil with a motor grader. Exposed soils are susceptible to rain erosion; therefore, cutting high edges is often scheduled during the Spring growing season to avoid heavy rainfall eroding soil from the edges where there is no vegetation. District maintenance forces commonly roll the reshaped soil using the motor grader tires to achieve ordinary compaction, but in some cases a pneumatic roller may be used. Vegetation usually grows back quickly which helps to reduce the problem with weeds overtaking the natural grasses. Occasionally, district forces erect a “Soft Shoulder” sign after this type of reshaping operation. This type of repair typically lasts from 6 months to two years.

FIG 5.25 Kuhn Tiller, Tyler District (see Tyler District Profile, Photo 16)

5.4.4 Replenishing the Pavement Edge with Select Borrow Materials

Reshaping for edge drop-offs and cutting for high edges are similar edge repair techniques in that both procedures use existing soil material along the roadside to achieve the final outcome. However, in the case of edge drop-offs, a common scenario is that insufficient or improper soil material exists along the pavement edge and thus reshaping is not a viable option. In these cases, *replenishing* the edge with borrowed materials such as Reclaimed Asphalt Pavement (RAP), flex base, LRA (Lime Rock Asphalt), black base and others, is considered (the next section of this report discusses edge repair materials). In fact, our statewide interviews and site visits show that for narrow FM roads, common practice in most districts is to replenish with borrowed materials instead of reshaping with on-site materials. Mostly FC 270 (edge repair) is used for such an operation, the TxDOT *Maintenance Manual* identifies replenishing shoulders as an accepted method for repairing edge drop-offs (Chapter 8, Part 2, Section 2, Routine Pavement Maintenance, page 90).

5.4.4.1 Procedure

Replenishing pavement edges with select borrowed materials is an operation similar to pulling the shoulder with on-site materials with a few additional steps, as described below. While district practices vary in the details, the typical replenishing procedure uses the following steps:

1. Surface preparation
2. Delivering/spreading borrowed materials
3. Compaction
4. Surface sealing

We present a brief summary of the variations in each of these steps in the following sections.

5.4.4.1.1 Surface preparation: Surface preparation presumably enhances the bonding of new repair materials with the existing surface and also gives better stability. District practices for surface preparation vary depending on the height of the edge drop, the type of material used, and other factors. For example, some districts use no surface preparation, especially where the edge drop-off is deep. Intermediate preparation would involve brooming loose materials away from the pavement edge with a rotary broom.

Yet another level of surface preparation involves cutting a wedge-shaped “notch” along the pavement edge with the motor grader. This is to provide a uniform, stable area for placement of sufficient repair material. Typically the notch is at least 4 inches deep, but usually not more than 8 inches, and forms a wedge from the pavement edge to the face slope of the bar ditch. District maintenance personnel stated that they will often cut such a wedge where the edge drop is no more than 2 inches, since the replenished material tends to shell out with such a shallow drop.

More extensive surface preparation is a usual practice in reoccurring edge problem areas like the inside of horizontal curves or poor subgrade areas. About 1.5 to 2 feet of soil is bladed out from the pavement edge using a motor grader, often with a shoe attachment, to create a 6-8 inch deep trench along the pavement edge. We observed some districts go as far as 3 feet wide and 20 inches deep (see Figure 5.26). Such dressing provides a more defined edge to facilitate better bonding and enough space for more materials to achieve stability.

In addition to the above steps, maintenance forces sometimes apply a prime coat over the prepared surface before any overlay to enhance bonding (this is done when asphaltic materials are used to fill the trench). Both cutback and emulsified asphalt (e.g., MC-800, MS-2) are used for such coatings. Some districts spray only water to help in compaction and facilitate bonding, but asphalt materials are preferred in high traffic and recurring problem areas. Due to environmental regulations, emulsions are preferred over cutbacks.

5.4.1.1.2. Delivery/ Spreading of Borrowed Materials: After surface preparation, the next step in the replenishing operation is to deliver the repair materials to the pavement edge. Again, district maintenance forces do this in several ways, ranging from conventional construction practices to extensive involvement of specialized equipment.

FIG. 5.26 Replenishing Repair at the Inside Horizontal Curve of an FM Road, Paris District (see Paris District Profile, Photo 23)

A simple way to deliver the repair material to the roadside edge is to dump the borrowed materials on the road with a dump truck and blade them off to the pavement edge with a motor grader. Some districts use a drag box behind the dump truck to ensure a uniform windrow of material which they then blade to the pavement edge (prepared trench). The motor grader then blades up and spreads the material to achieve proper slope. This method can deliver a lot of material to the pavement edge, very quickly, and we observed this method used very effectively in the El Paso District. This is beneficial for inexpensive repair materials such as RAP, but the tendency to over-supply is less than desirable when material costs are high.

Specialized types of equipment, both homemade and the commercially-manufactured variety, have been developed for the specific purpose of delivering repair material to the pavement edge. Chapter 7 of this report provides details on edge repair equipment, but it is appropriate to note that we observed maintenance forces using all different types in their replenishing operations. These include homemade tailgate discharge chutes, the Swenson Tailgate Cross Conveyor (also known as the “Swenson Spreader” – see Figure 5.27), center-chute and side-discharge drag boxes, modified V-box side discharge spreaders, the Moon Paver, and more.

Some districts add water as an aid to the compaction process for soil, flex base or even RAP materials (most do this as necessary, noting that it definitely helps). Maintenance personnel in the El Paso District found that it is essential to use a steel wheel roller to smooth out the final prepared surface; their experience is that without a few final passes of the steel wheel roller, RAP or flex base materials start to ravel out. Personnel in other districts, however, noted that compaction must first be accomplished with a pneumatic tire roller; the steel wheel roller will bridge from the edge of pavement to the face slope of the ditch and not compact the soil in between.

FIG. 5.27 Delivering Flex Base to the Pavement Edge Using a Swenson Tailgate Cross Conveyor (a.k.a. "Swenson Spreader"), Brownwood District (see Brownwood District Profile, Photo 13)

5.4.1.1.3. Compaction: District maintenance forces agree that compaction is necessary for an effective repair, but the compaction requirements are usually not specified for this type of repair. Most districts roll the materials with the tire of the motor grader, dump/hauler truck, or water truck (whatever they have on site) to achieve ordinary compaction to the satisfaction of the operator; there is no set density requirement (see Figure 5.28).

Maintenance forces in some districts use a pneumatic tire roller for compaction. Usually the higher the compaction, the better the stability. But a few maintenance section supervisors expressed their concern about the problem of vegetation growth in case of too much compaction for certain types of soil.

FIG. 5.28 District Forces Use Dump Truck Tires to Achieve Ordinary Compaction for Edge Repair, Amarillo District

5.4.1.1.4. Surface Sealing: District maintenance forces generally agree that sealing the final compacted surface makes it last longer, even though it costs more money. Maintenance forces sometimes add a top layer of type CC mix or a simple seal coat as a surface seal (see Figure 5.30); sometimes they spray raw asphalt (e.g. MC-30 or any emulsion) over the compacted surface. In cases where unbound materials are used for the repair, some districts try to establish vegetation on the surface and may place a layer of top soil for this purpose. We observed that some districts (mainly in wetter climates) sow seeds or pull sod on top of unbound materials to establish vegetation – even on RAP.

5.4.4.2 Basis, Applicability and Expected Performance

Replenishing with select borrow materials is typically done when on-site materials are not available or the soil is in poor condition. Also, borrowed materials of better quality than on-site materials are strategically used to repair edges in recurring problem areas such as the inside of horizontal curves on narrow roads, turning radii at intersections, erosion-prone areas, and locations of repeated abusive maneuvers such as truck pull-offs.

FIG. 5.29 Strip Seal Coat on a Contract Replenishing Project Using Flex Base, Austin District (see Austin District Profile, Photograph 4)

Replenishing typically requires a crew of 8 or more persons which includes a motor grader operator, drivers for the haul trucks, a person operating/overseeing discharge of material to the pavement edge, a water truck operator, a pneumatic tire/steel wheel roller operator, and traffic control personnel. Minor jobs can be done with fewer persons, but when the longitudinal run of a repair is more than a quarter of a mile, most maintenance sections feel it is worthwhile to mobilize a full crew and equipment. The rate of production depends on several factors but ranges from a ½ mile/day to as much as 6 miles per day.

Unlike reshaping, replenishing is viewed as a relatively long-term edge procedure, its effectiveness and durability being a function of effort, workmanship and quality of materials. Depending on the steps followed and specific site conditions, road edges repaired in this manner have performed satisfactorily from one to several years.

5.4.5 Edge Repair Materials

The select borrow materials used to repair pavement edges vary from untreated subgrade soil to the best quality hot mix asphalt. Although availability and cost are the main factors considered in the material selection process, material strength and stability also play an important role. An obvious question is, "Which materials do districts use most for pavement edge repair?" From this research, the best answer to this question appears to be "They use what they have." The following discussion identifies several different types of materials used for edge repair by the different districts of TxDOT.

5.4.5.1 Reclaimed Asphalt Pavement (RAP)

Reclaimed Asphalt Pavement (RAP) is perhaps the most common and widely-used borrow material for edge repair, primarily because it is cheap and most districts have large quantities of it. Under current practices, TxDOT retains the ownership of RAP in any contracted milling operation. Since TxDOT considers RAP as waste material, it does not cost TxDOT anything and use of RAP for edge repair satisfies both recycling objectives and problems of storage and disposal. Some districts produce a significant amount of RAP and others do not. Obviously, those districts with plenty of RAP make an effort to use it efficiently.

5.4.5.1.1 The RAP Literature

TxDOT, in cooperation with FHWA (Federal Highway Administration), sponsored a five-year (1987 to 1992) research study to determine the most economical and effective routine maintenance use for asphalt pavement millings (commonly known as RAP). The following is a brief summary of these research findings (Estakhri and Button 1992).

The research surveyed all 25 districts of TxDOT as well as all other state DOTs, and also included laboratory and field evaluation of RAP. According to the study, TxDOT predominantly uses RAP for constructing driveways, building mailbox turnouts, and shoulder repair (or edge repair). Other state DOTs use as much as 70% RAP in their Hot Recycled mixtures mostly on the main travel lane; use of up to 10% does not require any formal design. TxDOT uses both treated and untreated RAP. Among the different rejuvenators used by TxDOT, AES-300RP (about 1 to 2%) was found to be the most efficient recycling emulsion for RAP. Blending RAP with conventional maintenance mixes such as lime rock asphalt (LRA) and hot mix cold laid (HMCL) mixes was also found to be effective. As much as 40% raw RAP and 50% treated RAP mixed with LRA or HMCL mixes performed reasonably in the field.

The research found that most RAP produced in most districts in Texas does not have particles larger than 1½ inches, therefore further processing is not usually needed before recycling, but the study recommended using the RAP within a year of production to avoid setting up. Also, the rejuvenated RAP could be stockpiled for a maximum of one year without setting up. Minimizing the handling and hauling of RAP also helps keeps the cost of RAP usage low. The study identified some concerns about the ownership of RAP. The Texas legislature requires that TxDOT retain the ownership of RAP whereas most other DOTs give it to the contractor. TXDOT ownership of RAP may be an economic burden because of the hidden costs associated with bookkeeping, administration, land use for storage, stockpile maintenance, and hauling. Making good use of RAP might offset some of these expenses.

Laboratory investigations indicated some degradation of aggregate during the milling process. Hveem stability was found to be the best laboratory property indicative of expected field performance of RAP. RAP mixed with LRA or HMCL mix showed better laboratory performance than RAP mix alone. The mixes with RAP showed more susceptibility to moisture damage in laboratory testing.

The Estakhri and Button research project also involved evaluation of field performance and construction process. A total of fourteen projects were evaluated in the study. These projects included several overlay projects, one shoulder repair and a few base repairs involving full depth recycling. A blend of RAP and conventional maintenance mixes was used for overlay and shoulder repair projects. RAP was also used as a base material in the following different ways:

- Untreated (raw) RAP was used to repair base failures;
- RAP was pulverized and blended-in-place with existing base materials; and stabilized with asphalt cement.
- RAP was cement-stabilized at the stockpile and used for parking lot construction.

The RAP was treated with rejuvenator emulsion in two different ways for the field trial sections: pugmill mixing and blade/pulver mixing. Apart from economy-of-scale considerations, both processes yielded a uniform blend and the costs were also comparable. All these trial sections reported to be performing well at the time of the report publication (1992). This time period would be a maximum of two years.

5.4.5.1.2 District Practices for Using RAP for Edge Repair

This research project identified several ways RAP is currently being used in the districts for edge repair. Following are the most common techniques used by different districts:

a. Plain, untreated, unblended, unmodified RAP with no additives is by far the most commonly-used RAP material for edge repair (see Figure 5.30). Maintenance supervisors' experiences suggest that the RAP is more workable when it is fresh, of a smaller size (100% passing 1½-inch sieve), and not contaminated with other materials. Untreated, un-rejuvenated RAP provides some bonding and stability and works better during hot summer days. Some districts moisture-condition the RAP with plain water to enhance compaction during placement, the same as they might do with flex base. Others spray emulsion on top of the completed project in the belief that a final coating of emulsion holds the RAP together and makes it more durable.

b. RAP may be rejuvenated with asphaltic materials, especially when it has been stockpiled for an extended period of time and has become dry or set up. In such cases, the San Antonio District mixes MC 800 with RAP in the stockpile before hauling it to the site. Other types of emulsions or cutbacks could also be used to rejuvenate the RAP. If necessary, the RAP can be crushed before mixing with the rejuvenating agent. Maintenance supervisors in the Wichita Falls District stated that rejuvenating the RAP can actually create a mess during the mixing operation, and that the rejuvenated RAP is prone to getting pulled up with the truck tires. For thicker fills, RAP may be laid down in more than one lift and if so, an asphalt tack coat can be applied between lifts.

FIG. 5.30 Untreated, High-Quality RAP, Beaumont District, (see Beaumont District Profile, Photograph 6)

c. A few districts have successfully used different additives to enhance the binding property of the RAP. A good bond essentially produces a stable material. For example, the San Antonio District has mixed RAP with Portland cement and water. They use one sack of cement per 1.5 cubic yards of RAP, blended with enough water to make the mixture moist so that it binds together. This is done in the stockpile, and the district has had good results with this process, noting that it finishes out nicely. In addition to cement, the Lufkin District has mixed sand with RAP. On an experimental basis, the Tyler District used foamed RAP that is similar to cement-treated RAP, but is a pug-milled mixture of performance grade asphalt 64-22, cement, water, and RAP particles passing a 2-inch sieve.

   Another promising RAP additive is magnesium chloride. The El Paso District uses this type of treated RAP for main lane construction on low volume traffic sections, for parking lots, and for edge repair. They also report that the City of El Paso, the New Mexico State Highway and Transportation Department, and other agencies treat their RAP with magnesium chloride. Magnesium chloride is typically used for dust control and a de-icing agent. But it also appears to work as an excellent lubricant and binder in the RAP, such that the RAP compacts and holds together well, much like hot mix. In fact, we observed sections of pavement where one could not really tell the difference between a hot-mix surface and a pavement surface of magnesium-chloride-stabilized RAP (see Figure 5.31). The supplier for this magnesium chloride solution is Texas Soil Control, Inc. (refer to El Paso District Profile).

FIG. 5.31 US Customs Truck Parking Lot, RAP Treated with Magnesium Chloride, El Paso District, (see El Paso District Profile, Photograph 23)

d. A few districts have blended RAP with virgin or salvaged base or subgrade soil and have been successful in achieving some stability at the repaired edge. They have tried as much as a 50-50 blend. Where sandy subgrade soils exist, RAP has been windrowed along the pavement edge and mixed and blended directly into the soil using a Bomag machine.

e. A few districts seek to establish vegetation on top of RAP, the view being that vegetation will help hold the RAP in place. Maintenance supervisors have mixed feelings about the benefit of vegetation on the RAP.

5.4.5.2 Base-Type Materials

Several districts use flexible base materials, as specified in the TxDOT Specification Manual, for edge repair purposes. Most districts use the easily available materials in their area which includes crushed limestone, iron ore, sandstone, caliche or gravel (see Figure 5.32). Some districts reuse salvaged base materials from road rehabilitation projects. For example, the Corpus Christi District has had good success with salvaged caliche base stabilized at the stockpile with 4% cement.

FIG. 5.32 Flex Base for Pavement Edge Repair, Brownwood District, (see Brownwood District Profile, Photograph 15)

5.4.5.2 Asphalt Type Materials

Different types of asphaltic materials have successfully been used for edge repair by different districts. These include both hot and cold mix materials. Limestone Rock Asphalt (LRA) from Uvalde, TX is one of the most popular asphaltic materials for edge repair (see Figure 5.33). It is a naturally occurring asphalt impregnated rock (5 to 9% asphalt by weight) and gives sufficient stability without any addition of asphalt. Other types of mix such as black base, hot mix cold laid, premix, winterized mix, universal patch mix, instant road repair, and Class 1 containerized road repair have also been used. Hot mix asphalt (HMA) (hot laid) is also used by some districts but mostly in extensive repair operations such as road widening.

5.4.6 Rebuilding the Pavement Edge on the Existing Base Crown

The previously-discussed edge repair techniques – hand patching, pulling shoulders, cutting high edges, and replenishing the edge with select material – show an increasing progression of effort, expense, and – hopefully – durability in the constructed project. It is also appropriate to note that each of these techniques is a faithful application of *Tracy's Law*. One other edge repair technique should also be mentioned, that of rebuilding eroded or damaged edges where the damage is to the pavement itself and not the base and subgrade layers; therefore, the repair is accomplished on the existing base crown.

FIG. 5.33 Limestone Rock Asphalt (LRA) for Pavement Edge Repair, Pharr District, (see Pharr District Profile, Photograph 7)

Various districts do this in different ways. For example, the Waco District outlined a procedure for addressing their roads where the edges are raveled and broken, and the road width is 19-20 feet while the base crown is more than 22 feet wide. Figure 5.34 shows a series of slide photographs that detail the process. These are from a video submitted by Mr. Phil Murphy, Assistant Maintenance Supervisor, Bosque County.

The Abilene District has used a somewhat similar procedure for edge repair, but in their case, the problem was rutting and low edges. Figure 5.35 shows a series of slide photographs that detail the process. These are from a video submitted by Mr. Dale Tollett, Area Maintenance Supervisor, Hamlin, Texas.

Figures 5.34 and 5.35 outline repairs that were done within the limits of the existing base crown. In both examples, the project not only involved the specified edge repair to restore the pavement edge and original width of pavement, but also pulling up the edges to address drop-offs.

FIG. 5.34 FM 182 Pavement Edge Repair, Bosque County, Texas, Waco District

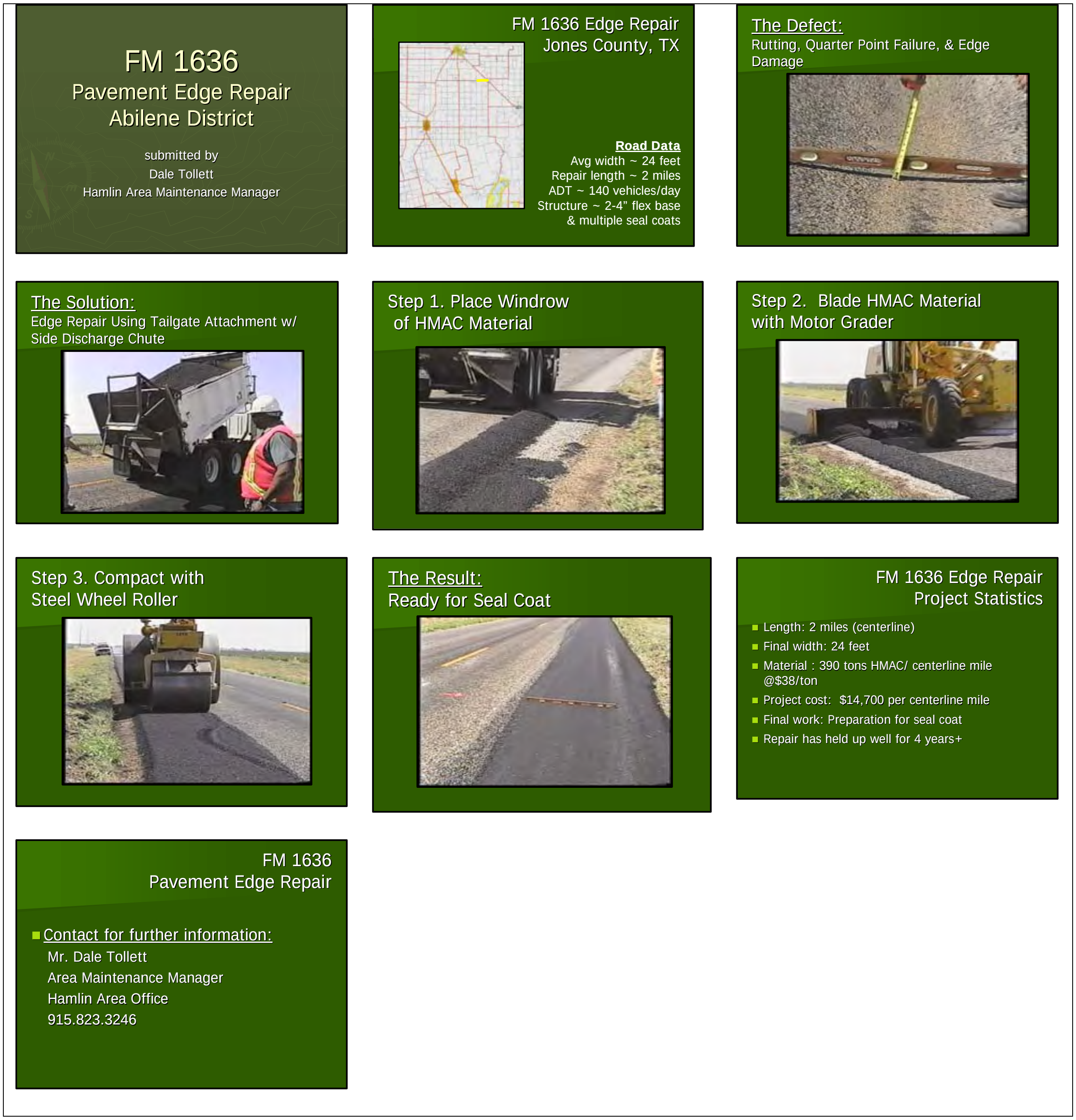

FIG. 5.35 FM 1636 Pavement Edge Repair, Jones County, Texas, Abilene District

5.5 Road Widening as the Ultimate Solution to Pavement Edge Maintenance Problems

We have noted that most district maintenance and engineering personnel identify narrow roads/no shoulders as perhaps the major factor causing pavement edge drop-offs. The edge repair techniques discussed up to this point directly impact this issue. In particular, replenishing in some cases becomes a limited operation in widening the road. On this basis and for the sake of completeness in our discussion of edge repair techniques, we submit that widening narrow roads would be the ultimate solution to the pavement edge maintenance problem. Chapter 6 of this report develops this idea and discusses road widening in detail.

5.6 "True" Costs for Pavement Edge Maintenance

While it may be obvious that a significant portion of TxDOT's annual maintenance budget is spent on edge repair, the actual cost of pavement edge maintenance is difficult to fully estimate. One reason is that despite the detailed function code (FC) data available in TxDOT's Maintenance Management Information System (MMIS), our interviews show that district practices for coding the costs and effort for various maintenance procedures vary. For example, a function code exists for edge repair (FC 270) but not all districts use this function code, or they use it for different edge-related tasks. Another reason costs are difficult to capture is that edge repair is not always done by itself but is frequently incidental to other types of repair, such as seal coating (FC 231), ditch maintenance (FC 561), and reshaping ditches (FC 562), to name a few. Yet another reason is that edge problems are often associated with repair of major defects such as quarter point failures, and are sometimes a driving force behind contract road rehabilitation projects, and these types of edge repair costs are not directly captured in the MMIS data. All this to say, in order to understand the "true" costs for pavement edge maintenance, it becomes necessary to explain the possible items of expenditure that may be related to edge maintenance. We will illustrate this using FY 2001 cost figures, the most recent year for which we have data readily available.

5.6.1 Pavement Edge Maintenance Function Codes and Cost Data

We have noted that FC 270 is explicitly identified as being used for edge repair. However, from our interviews, it is clear that at least six function codes are commonly used for edge repair procedures (FC 232, 233, 245, 270, 455, 541 and 562). Further, TxDOT personnel identified a total of 22 different function codes associated with edge repair procedures. Table 5.2 shows each of these 22 possible function codes, along with their description and the total annual FY 2001 expenditures for each. The seven most commonly-used edge repair function codes are in bold print.

In reviewing Table 5.2, it is appropriate to note that TxDOT's total FY 2001 budget (TxDOT Pocket Facts 2001) was $5,117 million, of which $453 million, $230 million, and $285 million were allocated to routine, preventive and contracted maintenance, respectively.

5.6.2 Lower-bound Estimate for Pavement Edge Maintenance

The absolute lower bound expenditure for pavement edge maintenance certainly is the cost registered against FC 270 (edge repair). Function code 270 deals with the repair of raveled, low or damaged pavement edges, but this does not necessarily mean that all the maintenance section supervisors charge their edge repair expenses against FC 270. As noted above, other function codes such as 232, 233, 245, 455, 541 and 562 are used extensively for edge repair. Considering only FC 270, TxDOT spent about $11.4 million in FY 2001 statewide. At the same time, costs associated with FC 232, 233, 245, 455, 541 and 562 total $40 million. Therefore, the lower bound expenditure for edge maintenance costs probably lies somewhere between $11.4 million to $40 million for FY 2001. Such expenditure represents about 1.2 to 4.1 percent of the total maintenance budget, and about 2.5 to 8.8 percent of the FY 2001 routine maintenance budget.

Table 5.2 Maintenance Function Codes Associated with Pavement Edge Maintenance, Including FY2001 Annual Costs. *Source: TxDOT Annual Report (2001*)

Function Code	Description	FY 2001 Total Expenditure (Millions of Dollars)
FC 110	Base Removal/Replacement	$ 17.6
FC 120	Base in Place Repair	$ 18.4
FC 212	Leveling/ Overlay with Blade	$ 60.4
FC 213	Leveling by Hand	$ 6.1
FC 232	**Aggregate Strip/ Spot Seal**	**$ 8.3**
FC 233	**Fog Seal**	**$ 3.4**
FC 241	Potholes Semi-permanent Repair	$ 10.1
FC 242	Potholes Permanent Repair	$ 1.1
FC 245	**Adding/Widening Pavement**	**$ 2.6**
FC 270	**Edge Repair**	**$ 11.5**
FC 325	Cleaning/ Sealing Joints and Cracks	$ 1.0
FC 455	**Reshaping Unpaved Shoulders**	**$ 4.3**
FC 480	Side Road Approaches/ Crossover/ Turnouts	$ 3.5
FC 541	**Chemical Vegetation Control Edges**	**$ 6.5**
FC 542	Chemical Vegetation Control Overspray	$ 5.5
FC 548	Seeding/ Sodding/ Hydromulching	$ 0.5
FC 561	Ditch Maintenance	$ 7.9
FC 562	**Reshaping Ditches**	**$ 3.4**
FC 710	Spot Paint and Bead Striping	$ 1.6
FC 711	Paint and Bead Striping	$ 7.6
FC 712	Thermoplastic Striping	$ 26.4
FC 721	Delineators/ Delineator Posts	$ 5.3
	TOTALS	**$ 213**

5.6.3 "High-ball" Estimate for Edge Maintenance

The upper bound estimate for FY 2001 edge maintenance expenditures includes all the possible function codes where edge maintenance might be incidental to the work, possibly as much as $213 million. As noted, the maintenance functions listed in Table 5.2 are the ones identified to us where edge maintenance is at least incidental to the work. But edge maintenance may be a very small fraction of the work performed under some of these function codes, and it is not possible to accurately break out the edge portion. Another complication is that TxDOT has invested significant dollars in edge maintenance that are not included in this table, for example, construction or pavement rehabilitation projects where edge damage was a significant contributing factor for doing the project.

5.6.4 The Realistic Cost of Pavement Edge Maintenance

It is difficult if not impossible to definitively establish the total cost of TxDOT's annual pavement edge maintenance operations, even as a percentage of the annual routine maintenance budget. However, the preceding discussion makes it clear that edge maintenance involves much, much more than simply edge repair FC 270 (2.5 percent of the annual routine maintenance budget), even though it does not include all costs posted to the 22 function codes identified in Table 5.2 (47 percent of the annual routine maintenance budget). Somewhere in between is probably reasonable, conservatively, 10 percent of the annual routine maintenance budget, on the order of $45 million/ year. The point is that TxDOT's edge maintenance effort is a substantial financial investment, much more than one might think.

This analysis is complicated by the fact that TxDOT invests significant construction dollars for pavement rehabilitation projects where road widening is a part and actually solves edge maintenance issues permanently. The expenses related to pavement rehabilitation mostly come from construction budgets which could easily add another few hundred million dollars per year.

CHAPTER 6
ROAD WIDENING

6.1 Roads with Shoulders… The Way Things Ought to Be

6.1.1 Edge Maintenance Practices and Procedures as a Continuum

It is helpful to think of the pavement edge maintenance practices and procedures discussed thus far as loosely falling along a continuum, illustrated in Figure 6.1. Each of these practices and procedures implements *Tracy's Law* to some degree, and it can also be noted that the effort associated with implementation generally increases from left to right. For example, edge repair techniques are generally more rigorous than edge maintenance awareness practices, and within the edge repair techniques category, rebuilding pavement edges is a more rigorous process than hand patching.

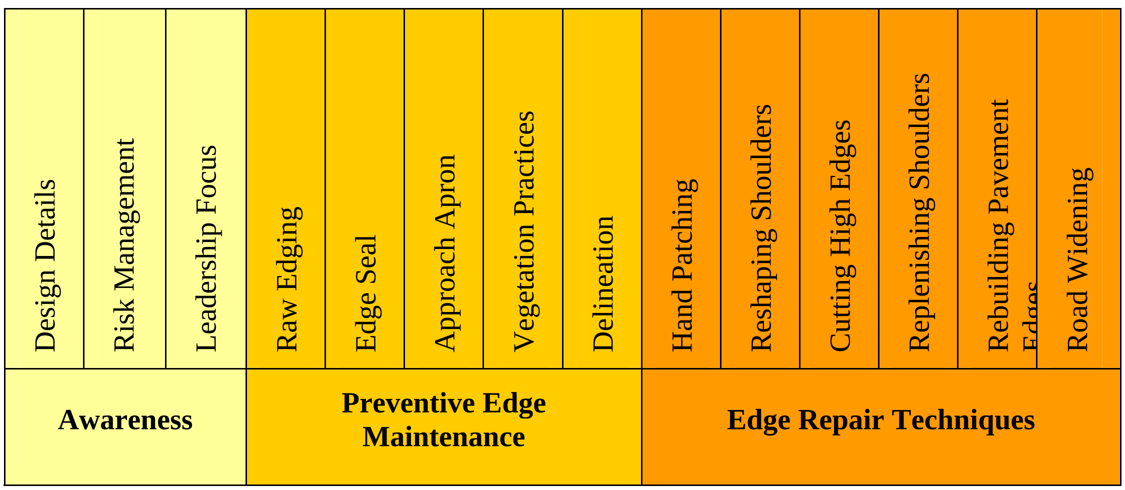

FIG. 6.1 The Continuum of Pavement Edge Maintenance Practices and Procedures

The main things to note from Figure 6.1 for the purposes of this research are, first, pavement edge maintenance is not a monolithic process but involves many aspects of TxDOT's overall maintenance program. The person who thinks about edge maintenance primarily in terms of pulling shoulders is taking too limited a view. Second, given the financial, manpower and other constraints associated with maintaining Texas' transportation system, each of these practices and procedures can realistically be considered as a "best practice" for pavement edge maintenance. This is because not only do edge problems differ, but the districts and maintenance Sections are at different levels of maturity in their operations. One district might dramatically improve their pavement edges at the preventive maintenance level; whereas, another district might be considering more rigorous edge repair techniques. Therefore, "best practices" does not have to mean "the *best* practice" in the ultimate sense of the term.

In this chapter, we consider road widening which we are suggesting is the high end of the continuum, the ideal solution for pavement edge maintenance. Our visits with maintenance personnel across the State revealed that some districts are tempted to dismiss road widening as a viable solution due to, among other things, lack of funds, physical constraints, policy considerations, design challenges, and other issues. However, other districts embrace the idea that widening their roads is good maintenance strategy, and they plan for it and actually widen significant sections of their narrow roads each year.

6.1.2 Road Widening as the Ideal Edge Repair Solution

The logical and empirical basis for our claim that road widening is the ideal solution for pavement edge repair derives from our observations, presented in Chapter 4, that narrow roads without shoulders, in combination with abusive traffic and environmental factors, are the primary causes of pavement edge drop-offs. Widening the road directly and positively impacts two of these three key factors. This can be illustrated at both the state and national levels.

Recall the discussion of typical road widths for the FM road system. Figure 4.5 illustrates that the typical FM road width ranges from 18 feet to 24 feet, average 20 feet, for all districts in Texas except one – Odessa. The typical width for FM roads in Odessa is 32 feet; that is, two 12-foot travel lanes with 4-foot shoulders. Fewer than 10 roads in the entire Odessa District do not have shoulders, and these are mostly access roads for divided highways. Also, recall our discussion of district rankings for TxMAP, both for edges and overall, as per Table 5.1 and Figures 5.2 through 5.4. For the three years TxMAP data are available, for non-interstate roads Odessa ranked first among all the districts in 2000 and 2002, and second in 2001, for both the edges and overall categories. This suggests a strong link between wider roads, the presence of shoulders and good edge performance.

Another Texas illustration is the Houston District. Review of the Houston District Profile (Volume 2 of this report) will reveal that about 7 years ago, maintenance leaders in Houston made the strategic decision to add narrow shoulders to their FM roads, this to more permanently and effectively address roadside maintenance issues. The reason is that the very high traffic, the wet climate, and the soft soils in Houston are such that it is not safe for crews to be out doing shoulder maintenance on a routine basis. So in the Houston District, for many years edge maintenance has consisted primarily of road widening. The result is that most of the FM roads in the Houston District now have narrow (at least 2-foot) shoulders. Further, most of the edge drop-off problems in Houston are now related to deliberate/illegal activity, such as cutting corners at intersections, making unauthorized exits off the freeway, etc.

Similar experiences exist at the national level. Part of our literature review involved contacting a sample of the State DOTs and discussing their edge maintenance practices.

The Chief of the Pennsylvania Department of Transporation (PennDOT) Maintenance Division, Mr. Don Wise (Wise 2002) stated that the Pennsylvania roadway system includes everything from dirt roads to Interstates. Further, PennDOT instituted a formal plan about 3 years ago to widen their narrow roads 2 to 4 feet on each side, this as a function of budget and manpower, focusing on the higher volume roads first. They link this plan to their pavement management information system which video logs their entire roadway system, ROW to ROW, each year.

The State Maintenance Engineer for the Georgia Department of Transportation (GDOT), Mr. Buddy Gratton, P.E. (Gratton 2002), has more experience with road widening than most. Under

Mr. Gratton's tenure, GDOT instituted a program some 20 years ago to add 2-foot shoulders to all their roads. They have done 3 to 4 percent of their system each year, phase by phase, ranking roads as a function of speed, width and volume. First they did the high volume, high speed roads, then the low volume, high speed roads, and so on, and have continued with this program until now they are basically done. Mr. Gratton stated that this has been very expensive, but he is very pleased with the outcome. When asked if, would he do anything differently if he had it to do over again, Mr. Gratton replied, "Yes, I would add 4-foot shoulders instead of 2-foot shoulders."

These illustrations support the contention that road widening is the ultimate solution for pavement edge maintenance, and offer compelling evidence that road widening is a sound maintenance investment. We now turn our attention to the details of road widening, and begin by attempting to address some of the questions and concerns of district maintenance personnel about Maintenance Division policy and design issues.

6.2 Maintenance Division Policy on Road Widening

During our district interviews, some maintenance personnel expressed concern that work to widen a narrow road would somehow force or require the entire road to be upgraded to meet current standards for new wider roads for both geometric and structural design. Roads not widened in this "proper" manner might (1) mislead and somehow harm the traveling public, and (2) expose TxDOT to liability. Further, all road widening plans and designs would need to be approved through the District Design Office, and TxDOT's database of road widths would need to be upgraded as widening was performed. In view of these time-consuming and costly requirements, the perceived view of these maintenance personnel was that road widening is best done under construction contract based on engineered plans and specifications, and road widening is really not a maintenance function.

To address this concern, we met with senior TxDOT Maintenance Division personnel Kenneth Boehme, P.E. and Joe Graff, P.E. (Minutes 2002) to discuss Maintenance Division policy on road widening. The summary points from this discussion are:

- The Maintenance Manual allows for road widening to a width of 26 feet to correct a maintenance problem (see Figure 6.2).

- TxDOT's MMIS includes a maintenance function code for road widening (FC 245).

- District maintenance personnel should do this type of work (road widening); the Maintenance Manual is written with flexibility to allow districts the freedom to do what needs to be done to address local maintenance issues.

- Candidate projects should be assessed to make sure that road widening jobs under a maintenance function are not turned into what ought to be construction projects.

Shoulder and Side Approaches

Routine Maintenance	Preventive Maintenance	Major Maintenance
All shoulder work to restore to its originally constructed condition including: recondition, rebuild, level-up and overlay. This work would also encompass installation and maintenance of public access drives crossovers, turn lanes, and mailbox turnouts.	All shoulder work to prevent major deterioration of the pavement including: milling or bituminous level-ups to restore cross section, light overlays (overlays not to exceed total average depth of 2") seal coats, crack sealing and microsurfacing. Shoulder repair and widening not to exceed 26' full roadway width.	All shoulder work to restore to its originally constructed condition and/or to strengthen the pavement structure for the current and projected future traffic usage, including but not limited to: recondition and/or stabilize base and subgrade, add base, level up, light overlays (overlays not to exceed total average depth of 2") and seal coats. Adding shoulders, if done to correct a maintenance problem, (maximum width of 4' total for both sides) can be considered major maintenance.

FIG. 6.2 TxDOT Maintenance Manual Guidance on Road Widening. *Source: Maintenance Manual* (2001), Chapter 1, Section 2, Item 1.201, Part 1-3

6.3 Road Widening Design Issues and Considerations

It is beyond the scope of this report to provide detailed guidance on design standards and procedures for widening roads. Based on our conversation with Maintenance Division personnel, the key points about minimum design requirements for road widening are:

- Design issues associated with road widening/adding shoulders are discussed in the TxDOT *Roadway Design Manual* (2002).
- As a minimum, road widening projects must satisfy non-freeway resurfacing or restoration (2R) design guidelines as per the *Roadway Design Manual*.
- The definition of 2R projects states that "…the addition of … shoulders are acceptable as restoration work as long as the existing through lane and shoulder widths are maintained as a minimum."
- More involved road widening projects where the goal is to preserve and extend the service life and enhance safety may need to satisfy resurfacing, restoration, or rehabilitation (3R) design guidelines as per the *Roadway Design Manual*.
- Per the Texas Engineering Practice Act (TBPE 2003), engineered plans and specifications ***are required*** where the construction cost exceeds $20,000 (*reference:* Texas Occupations Code, Title 6, Subtitle A, Chapter 1001, Subchapter B, §1001.053)

- Inquiry on these and related design issues should be directed to the TxDOT Design Division.

In addition to the above points, most Maintenance Supervisors we interviewed stated that they routinely get input and discuss potential road widening candidate projects with their district engineering personnel including the Director of Maintenance, the Maintenance Engineer, the Area Engineer, the District Design Engineer, and others. Also, as regards updating the TxDOT database of roadway widths, the District Director of Transportation Planning and Programming is the individual designated to make these types of changes, and the database should be updated locally (in the district) any time district forces widen a particular section of road.

6.4 Contract Road Rehabilitation

Narrow FM roads are sometimes rebuilt, or rehabilitated, as part of a major construction project, and when these types of upgrades are done it is usually customary to widen the roadway to 26 feet, minimum. Thus, road widening as part of a larger rehabilitation effort can be considered the most formal expression of pavement edge maintenance practice, even though it is done under a construction contract.

Candidate roads for pavement rehabilitation not only are narrower but typically have higher ADT, and are also worn out as evidenced by age, ride deterioration, insufficient pavement structure, quarter point failures, base failures, and various types of edge damage. These roads frequently have structure restrictions, and sometimes widening may be necessary due to safety concerns.

Notice that for rehabilitation, the focus is on the road being *worn out* as opposed to just narrow. Here, widening the road is incidental to the rehabilitation work, even though it is recognized that widening will help address edge drop-off problems in a significant way.

The design process for rehabilitation projects involves full scale planning, engineered drawings, and specifications to satisfy the current 3R design standards, including proper geometrics and upgrading of fixed structures and signs. These projects are typically built under a construction contract with dedicated program funding (“program money”). Figure 6.3 summarizes the issues associated with road widening for pavement rehabilitation projects.

We observed several cases of road rehabilitation projects where the road was widened as part of a larger rehabilitation effort. For example, FM 933 in the Waco District (ADT 2700; 23-foot wide) had significant distress and this road was fully rehabilitated using phased construction to a final 40-foot wide section (12-foot travel lanes and 8-foot shoulders – see Figure 6.4). The Waco District Profile (Volume 2 of this report) includes an engineered drawing showing the widened cross-section. Another illustration is Old San Antonio Road in the Bryan District where the aged, narrow road was pulverized using a Bomag and resurfaced with hot mix asphalt to achieve limited widening of the pavement section (see Figure 6.5).

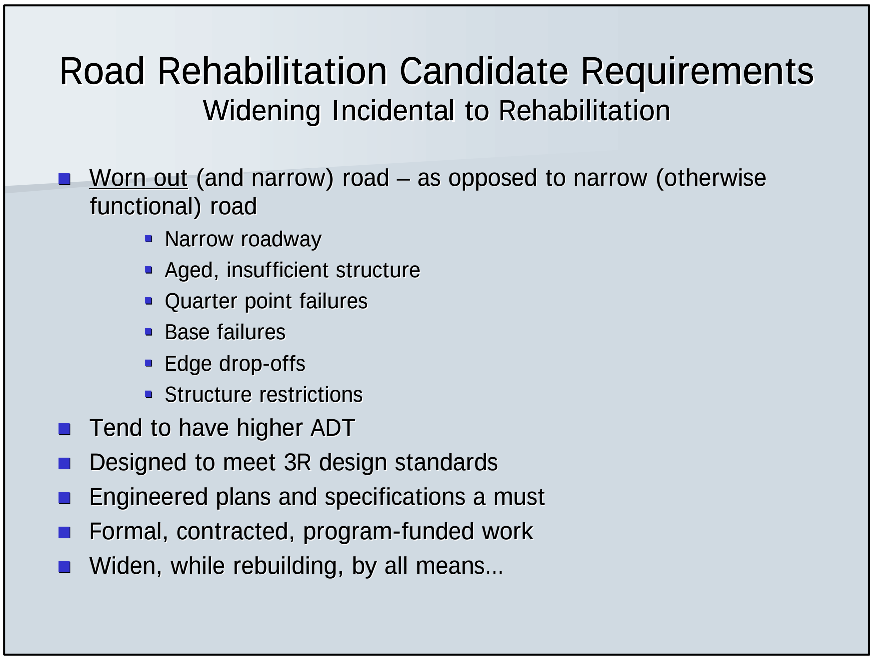

FIG. 6.3 Road Rehabilitation Candidate Requirements

FIG. 6.4 FM 933 Road Rehabilitation, Waco District (see Waco District Profile, Photo 16)

FIG. 6.5 Old San Antonio Road (OSR) Road Rehabilitation, Bryan District (see Bryan District Profile, Photo 8)

6.5 Contract Road Widening (Add Narrow Shoulders)

Some districts add narrow shoulders or widen the road in order to solve recurring edge damage problems, and as we have noted, within the proper context this is sound maintenance strategy and is fully in accordance with TxDOT maintenance policy. Here the focus is on widening narrow roads, this as opposed to the previous discussion on rehabilitating worn out roads where widening was incidental to the process.

Candidate projects for road *widening*, then, are narrow but otherwise functional roads. This means that the combination of traffic, pavement structure, alignment, and ROW width are generally sufficient and that the existing pavement is in good enough condition to be added on to. *Narrow* is the central issue. The engineered design must satisfy 2R or possibly 3R standards and must consider not only the roadway but also associated widening or upgrading of fixed structures – such as culverts, narrow bridges, signs, etc. – and these types of improvements can make such projects very expensive.

Such work has been performed under both construction and maintenance contracts. Because of the expense involved, most districts who do this work seem to use construction contracts as opposed to maintenance contracts.

We observed several cases of contract road widening projects. For example, FM 1736 in the Houston District (ADT 980; 22-foot wide) was widened under a maintenance contract to achieve a final 26-foot wide section (11-foot travel lanes and 2-foot shoulders – see Figure 6.6). This involved building new 2.5-foot shoulders on each side of the road using a 10-inch section of black base, and reworking the entire road surface. The Houston District Profile (Volume 2 of this report) includes an engineered drawing showing the widened cross-section.

FIG. 6.6   FM 1736 Contract Road Widening, Houston District (see Houston District Profile, Photo 10)

Another contract widening illustration is FM 843 in the Lufkin District where this 20-foot wide road was widened to a minimum of 24 feet at a cost of about $260,000 per mile (see Figure 6.7), and paid for in part using “Safety Money.” The high cost was due to the roadway section plus the frequent driveways, mailbox turn-outs, and culverts that had to be addressed; the Lufkin District Profile includes an engineered drawing showing the widened cross-section. Other examples include FM 670 in the Abilene District (see Figure 6.8) and FM 194 in the Paris District (see Figure 6.9).

FIG. 6.7 FM 843 Contract Road Widening, Lufkin District (see Lufkin District Profile, Photo 3)

FIG. 6.8 FM 670 Contract Road Widening, Abilene District (see Abilene District Profile, Photo 7)

FIG. 6.9 FM 194 Contract Road Widening, Paris District (see Paris District Profile, Photo 30)

6.6 In-house (TxDOT) Road Widening

6.6.1 Policy and Considerations for In-house Widening

Maintenance forces in several TxDOT districts are actively involved in road widening and adding shoulders to their narrow roads. Like the contract road widening projects just discussed, the candidate projects for in-house widening are narrow but otherwise functional roads; however, the decision to widen in-house turns on several other factors. First, in-house candidate widening projects usually are reserved for the very low ADT roads which will never qualify for any type of program money. Second, while such projects tend to have recurring edge problems, ideally they will likely *not* have the same fixed structure concerns –culverts, narrow bridges, signs, etc. – which can make contract road widening projects very expensive. Third, district maintenance forces must have the staff, equipment and funds to do the project. This includes the idea of opportunity, and a perspective voiced to us that this type of rigorous maintenance effort provides maintenance personnel with a welcome opportunity to use their skills to accomplish a challenging yet rewarding long term maintenance objective. Figure 6.10 summarizes the considerations for road widening with TxDOT maintenance forces.

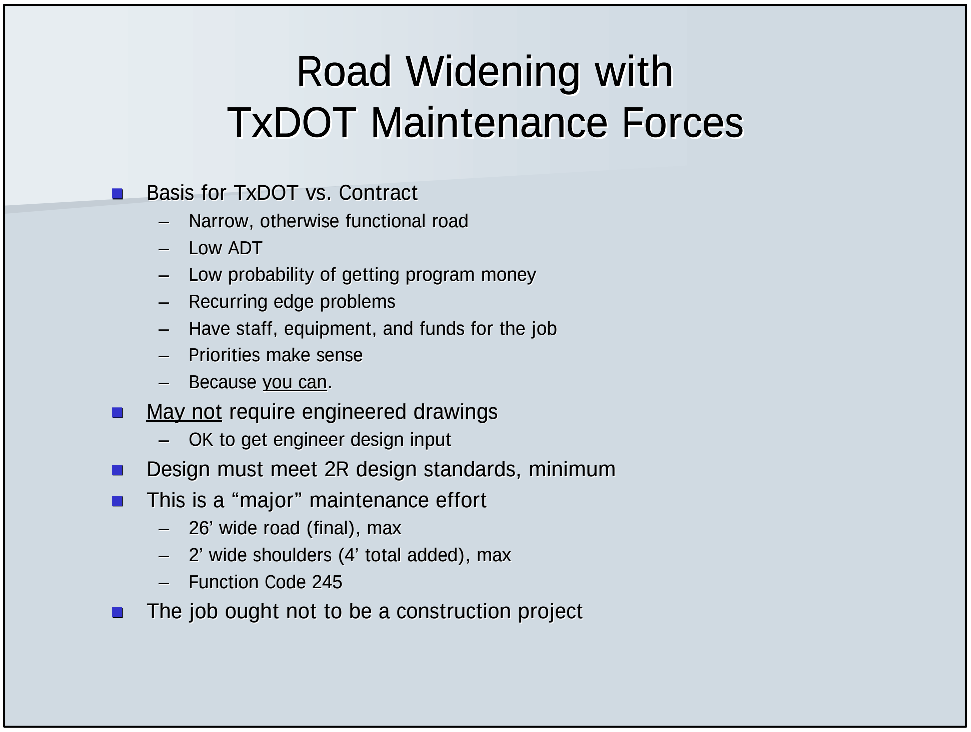

FIG. 6.10 TxDOT (In-house) Road Widening Candidate Requirements

Unlike the rehabilitation and contract road widening projects discussed previously, in-house road widening projects do not necessarily require engineered drawings. As long as the estimated construction cost is $20,000 or less (per the Texas Engineering Practice Act), formal drawings are not required, even though it is fully appropriate to obtain engineer input. These projects must satisfy 2R design standards and be done as per Maintenance Division policy. The Maintenance Manual stipulates that road widening/adding shoulders is "major maintenance," the final road width must not exceed 26 feet, and the added shoulder width must not exceed 2 feet (4 feet total for both sides).

Most district maintenance personnel tend to think of road widening as a preventive maintenance operation where they are restoring lost pavement section or adding lateral support to correct a maintenance problem. This type of repair directly falls under MMIS FC 245. The typical road widening construction sequence is similar to an enhanced version of the "replenishing" repair discussed in Chapter 5; therefore, maintenance personnel in some districts consider this as edge repair with borrowed material and charge it to FC 270. Although district forces do not typically widen drainage structures, they do upgrade (move) signs if necessary and most will stripe the edge if at least a 24-foot roadway width is available after repair.

6.6.2 In-house Road Widening Examples

We observed several examples of in-house road widening across the State. Districts which are doing this type of operation include Abilene, Atlanta, Childress, Dallas, El Paso, Fort Worth, Houston, Laredo, Lufkin, Odessa, Pharr, Waco, Wichita Falls and others.

Various districts do this in different ways. For example, the Fort Worth District outlined what can be considered a typical procedure for widening narrow roads using in-house forces. Figure 6.11 shows a series of slide photographs that detail the process. These are from a video submitted by Mr. Allan Donaldson, Maintenance Supervisor, Parker County. Depending on variations in the materials and equipment used, the typical cost ranges from $7,800 per edge mile to $11,650 per edge mile.

The Amarillo District has used a somewhat similar procedure for road widening, but in their case, the solution is much less expensive – on the order of $1000 per edge mile – because they used RAP as the repair material and used conventional road-building equipment with home-made attachments. Figure 6.12 shows a series of slide photographs that detail the process. These are from a video submitted by Mr. Parker Stewart, Maintenance Supervisor, Armstrong County.

Other examples of in-house road widening include:

- **RM 2059 –** San Angelo District, ADT 70, widened to 27 feet with premix (Figure 6.13)

- **FM 239 –** Yoakum District, ADT 180, widened to 20 feet with premix (Figure 6.14)

- **FM 1151 –** Amarillo District, ADT 390, widened to 24 feet with RAP (Figure 6.15)

- **FM 1005 –** Beaumont District, ADT 700, widened to 28 feet with blended RAP (Figure 6.16)

- **FM 1585 –** Lubbock District, ADT 920, widened to 24 feet with RAP (Figure 6.17)

- **FM 113 –** Fort Worth District, ADT 1500, widened to 24 feet with hot mix asphalt (Figure 6.18)

- **FM 2661 –** Tyler District, ADT 2800, widened to 26 feet with “foamed RAP” (Figure 6.19)

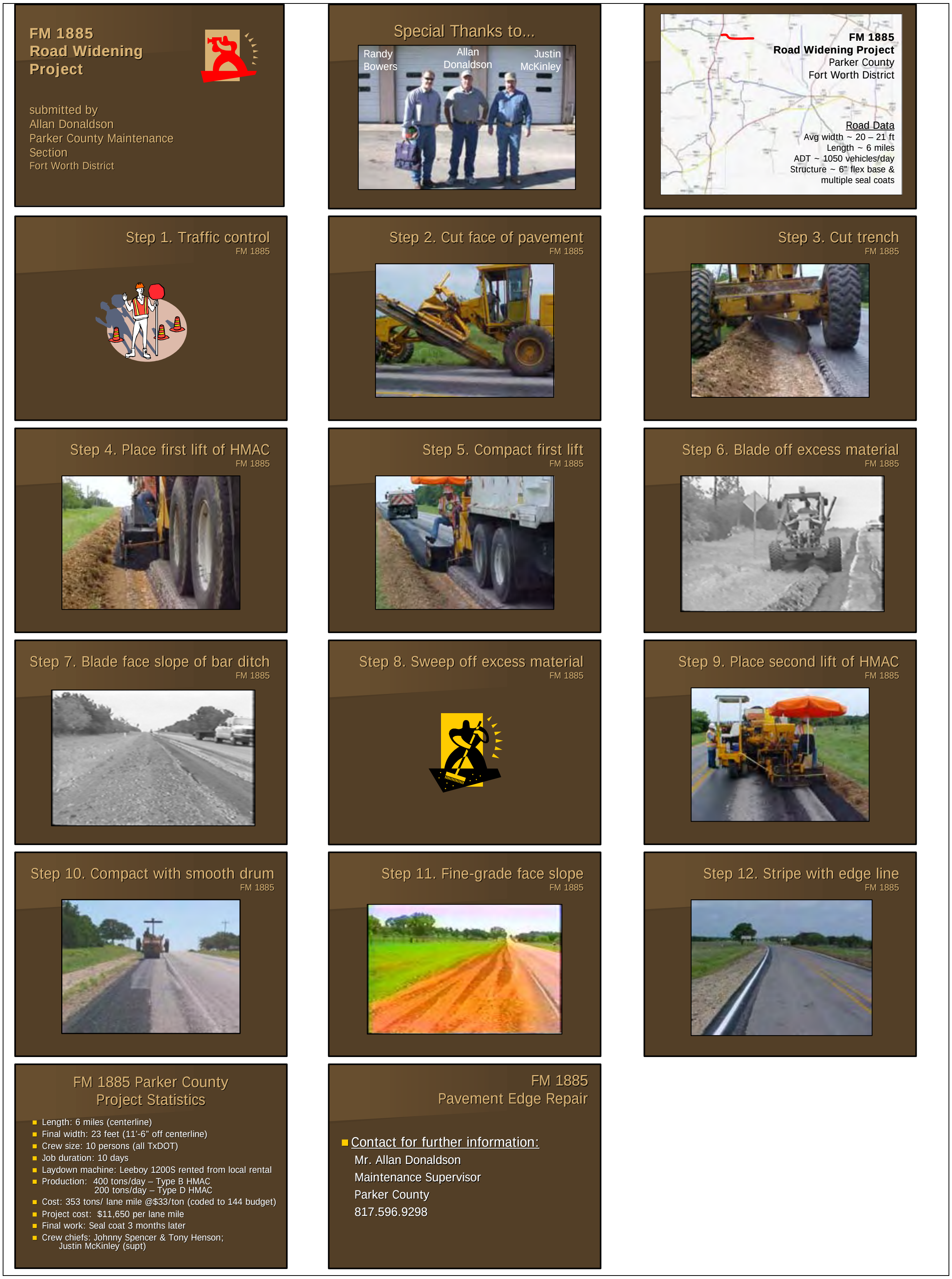

FIG. 6.11. FM 1885 Road Widening, Parker County Texas, Fort Worth District

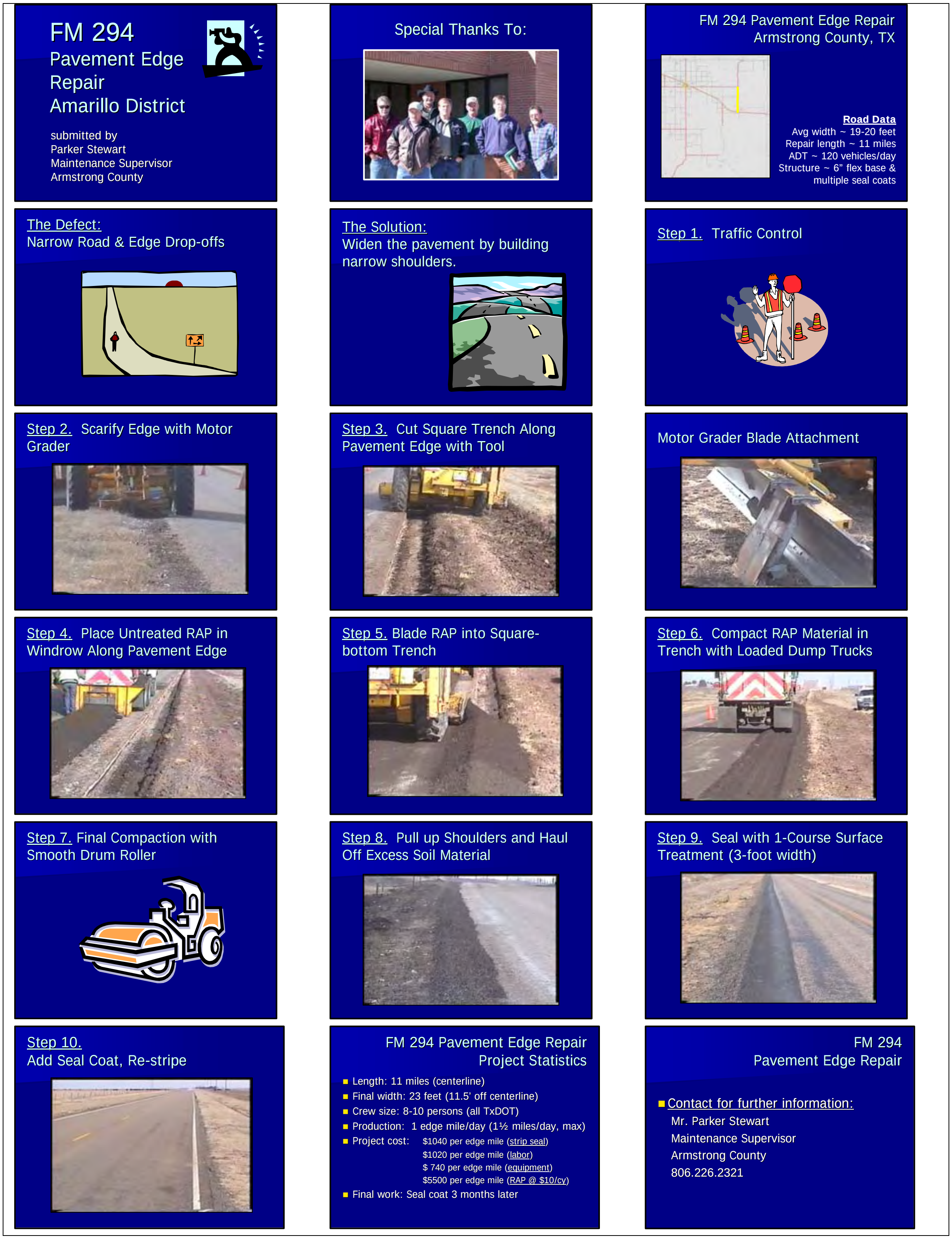

FIG. 6.12. FM 294 Road Widening, Armstrong County Texas, Amarillo District

FIG. 6.13. RM 2059 Road Widening, Coke County Texas, San Angelo District (see San Angelo District Profile, Photo 14)

FIG. 6.14. FM 239 Road Widening, DeWitt County Texas, Yoakum District (see Yoakum District Profile, Photo14).

FIG. 6.15. FM 1151 Road Widening, Armstrong County Texas, Amarillo District (see Amarillo District Profile, Photo 29)

FIG. 6.16. FM 1005 Road Widening, Jasper County Texas, Beaumont District (see Beaumont District Profile, Photo 3)

FIG. 6.17. FM 1585 Road Widening, Lubbock County Texas, Lubbock District (see Lubbock District Profile, Photo 13)

FIG. 6.18. FM 113 Road Widening, Parker County Texas, Fort Worth District (see Fort Worth District Profile, Photo 23)

FIG. 6.19. FM 2661 Road Widening, Smith County Texas, Tyler District (see Tyler District Profile, Photo 8)

6.7 Recommended Decision-Making Approach for Road Widening

Our research suggests that road widening is the ultimate long-term solution for pavement edge maintenance, especially for those narrow roads with recurring edge maintenance problems. The basic decision-making process is to first establish whether the issue is primarily a narrow road, or if it is more serious – a worn-out, narrow road. The latter case must not only be widened but also fully *rehabilitated*. However, where the road is narrow but otherwise functional, road *widening* is a viable option since there is something to build to. The lower-volume, less-complex widening projects can be considered for in-house maintenance forces. Contract widening can be used for the more significant projects. In all cases, road widening projects must satisfy Maintenance Division policy and, at a minimum, 2R and possibly 3R design standards.

CHAPTER 7
EDGE MAINTENANCE EQUIPMENT

7.1 Perspectives on Edge Maintenance Equipment

7.1.1 Equipment for Edge Maintenance Awareness and Preventive Maintenance

It is customary, albeit too narrow, to conceptualize pavement edge maintenance solely in terms of physical repair to the pavement edge, and nowhere is this more prevalent than when thinking about edge maintenance equipment. In contrast to this monolithic view, the edge maintenance practices and procedures discussed in Chapter 5 engage pavement edge maintenance at many different levels – awareness, preventive maintenance, and edge repair practices and procedures – so it is appropriate to discuss edge maintenance equipment in the same manner.

We have suggested that edge maintenance *awareness* may be just as important and possibly even more effective than the most rigorous pavement widening procedures. Therefore, in an effort to broaden the restrictive view that pavement edge maintenance is just about repairing physical damage to the pavement edge, we submit that certain non-conventional yet key pieces of edge maintenance "equipment" exist which are easily overlooked. These include: (1) computers with drafting programs by which edge-maintenance design details can be incorporated into construction drawings, (2) risk management training which helps maintenance supervisors make more effective decisions about maintenance activities, (3) clear policy from the Maintenance Division that encourages operational implementation of sound edge maintenance strategy, and (4) communication of priorities from district maintenance leaders which both motivates action and introduces accountability into the process. These non-conventional awareness "tools" hold the potential to accomplish as much edge repair, more effectively and at lower cost, as any physical attachment to a dump truck or motor grader.

Likewise, we have suggested that *preventive maintenance* practices can be highly effective at controlling edge damage and thus avoiding the need for physical repair – an ounce of prevention being worth a pound of cure. Preventive practices include, among other things, delineation, vegetation practices, and placement of strip seals and fog seals. The equipment associated with accomplishing these and other types of preventive maintenance, as well as the awareness tools discussed previously, offer high cost-benefit ratios and are certainly the place to start investing in pavement edge maintenance.

7.1.2 Equipment for Edge Repair Practices and Procedures

Of course pavement edge damage does exist in the physical realm, this damage must be repaired, and it is appropriate to accomplish the repair in the most efficient, effective, and inexpensive manner. The remainder of this chapter discusses the different types of equipment which maintenance forces use to repair physical damage to the pavement edge. This equipment broadly falls into the categories of (1) standard roadway maintenance equipment, (2) modified or home-made equipment for edge repair, and (3) commercially-manufactured equipment for edge repair.

7.1.3 Necessity is the Mother of Invention

With some regularity during our interviews, maintenance section supervisors observed that the driving idea behind development of new pavement edge maintenance equipment was to get away from the labor-intensive practice of doing edge repair by shoveling hot mix out of the back of a 6 CY dump truck with a No. 2 asphalt scoop (see Figure 7.1). After a day or so of this physically-demanding work, they were highly-motivated to come up with better ways to do the job. This theme of "necessity being the Mother of invention" is remarkably strong in the discussions of different types of pavement edge maintenance equipment.

FIG. 7.1 Basic Edge Maintenance Equipment – The No. 2 Asphalt Scoop

7.2 Standard Roadway Maintenance Equipment

TxDOT maintenance forces have used, and continue to use, standard construction equipment for pavement edge maintenance purposes. Ranging from hand tools (*e.g.*, No. 2 scoop) to mechanized roadway construction vehicles (*e.g.*, motor grader, dump truck, pneumatic roller and the like), maintenance supervisors have ready access to this standard equipment and consider it an essential and fundamental component of their edge maintenance effort. For example, when doing replenishing, El Paso District maintenance forces actually prefer to use conventional equipment (see Figure 7.2). They use RAP for this type of repair because it is plentiful, and since they are not worried about the cost of the material, the key issue for their operation is speed. Conventional equipment enables them to place more material more quickly and thus achieve higher production rates, even though they tend to use more material than is strictly necessary. In contrast, specialized equipment – *e.g.*, side discharge spreaders with their tendency to restrict the flow of material – is viewed as being too slow.

The El Paso District's experience, while valid for their context, is not the prevailing view across the State. External factors such as an increased focus on the maintenance and repair of edge drop-offs, pressure to increase production while reducing maintenance labor and material costs, as well as a desire for innovation, have resulted in development of several types of equipment specifically for pavement edge maintenance. This specialized equipment, both home-made and commercially-manufactured, supplements rather than replaces a maintenance section's reliance upon standard construction equipment for pavement edge repair.

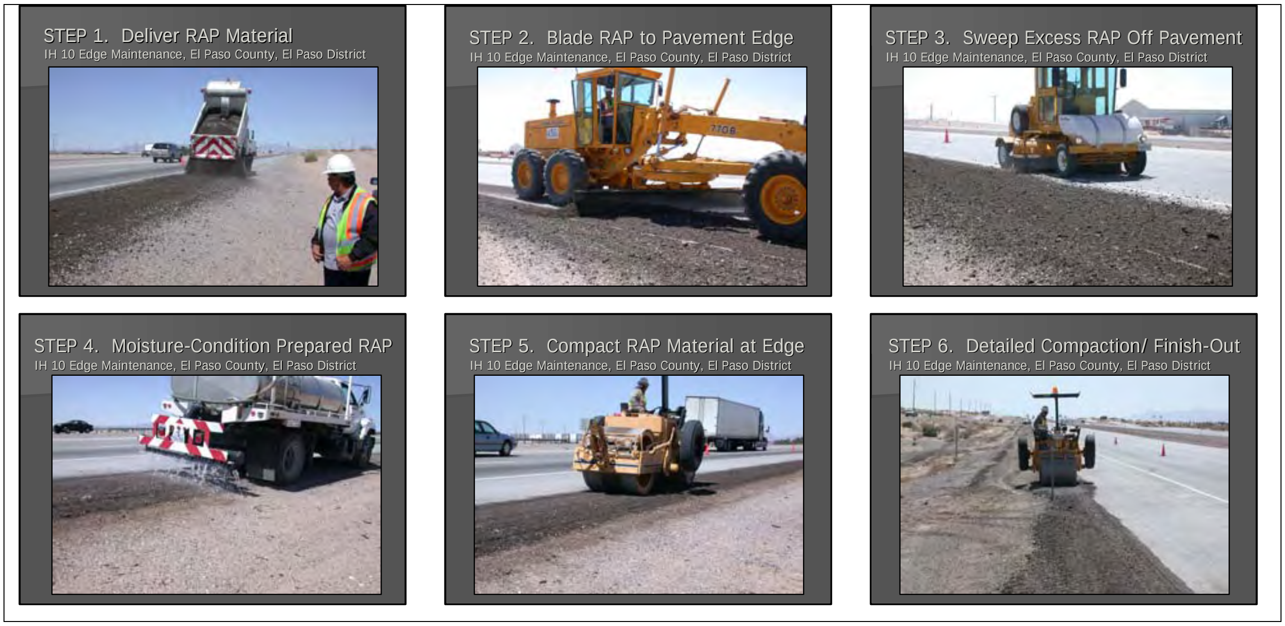

FIG. 7.2 Using Standard Roadway Maintenance Equipment to Replenish the Edge of IH 10 with RAP, El Paso District (see El Paso District Profile, Photos 9 through 17)

7.3 Modified or Home-Made Equipment for Pavement Edge Repair

The following discussion identifies different types of home-made tools or pieces of equipment that we encountered during our district interviews and site visits. We provide a brief discussion of each type of equipment, its applicability and use, and direct the reader to the district profiles for contact information.

7.3.1 Motor Grader Blade Attachments and Other Edging "Shoes"

Perhaps the simplest home-made tools for pavement edge maintenance consist of different types of steel attachments, commonly called "shoes," designed and built by TxDOT maintenance forces for various edge repair applications.

Figure 7.3 shows a steel shoe which can be bolted to the motor grader blade when the motor grader is used for pulling up pavement edges. This shoe prevents "pulled" soil from flowing off the back of the motor grader blade and onto the pavement travel lane surface, and thus allows the edging operation to be accomplished with only one pass of the motor grader, rather than two.

FIG. 7.3 Motor Grader Blade Shoe for Pulling Shoulders, Corpus Christi District (see Corpus Christi District Profile, Photo 9)

Figure 7.4 shows a steel attachment to the motor grader blade which is used for road widening. This inexpensive shoe, made from scrap – two pieces of bridge rail and a length of old motor grader blade – is used to cut a square-bottom ditch along the pavement edge (for more information about this road widening process, refer to Figure 6.12).

Figure 7.5 shows a curved shoe attachment for the Midland Machinery Road Widener, discussed later in this chapter. This shoe helps control the flow of material and keeps the material on the pavement edge.

Figure 7.6 shows an attachment to the motor grader blade which is used for rebuilding the pavement edge on the existing base crown. This shoe cuts and strips away deteriorated asphalt along the pavement edge (for more information about this edge rebuilding process, refer to Figure 5.34). District forces initially built this shoe to have a hard corner as shown in the photograph, but during use the corner wears down to the rounded shape shown in the photograph.

Figure 7.7 is another simple steel shoe which can be bolted to the motor grader blade and is used for shaping material along the pavement edge. This shoe helps provide for a uniform width of shaped material. For more information about this edge rebuilding process, refer to Figure 5.35. The edge repair process in Figure 5.34 also uses a similar shoe.

FIG. 7.4 Motor Grader Blade Shoe for Road Widening, Amarillo District

FIG. 7.5 Curved Shoe for Midland Machinery Road Widener, Fort Worth District (see Fort Worth District Profile, Photo 29)

FIG. 7.6 Motor Grader Blade Extension for Reshaping Pavement Edges, Waco District (refer to Waco District for detailed fabrication plans)

FIG. 7.7 Motor Grader Blade Shoe for Reshaping Shoulders, Waco District

7.3.2 Drag Boxes

Maintenance forces have, for years, utilized home-made drag boxes, which as the name implies, are open-top, trailer-like containers that attach behind a dump truck, their purpose being to efficiently discharge road-building material to a specific location in a uniform lift. A production-enhancing tool, some of these drag boxes incorporate side discharge gates which deliver the road-building material directly to the pavement edge, as opposed to the surface of the road. These drag boxes are appropriate for longer segments of road maintenance where it is necessary to replenish the pavement edge with borrow material, rather than pulling up the edge with on-site soil.

Figure 7.8 shows a drag-box intended to be pulled behind a dump truck and which has center, right-side, and left-side discharge gates which can be opened and adjusted to deliver an appropriate windrow of material along the pavement edge.

Figure 7.9 shows a different style drag box, specifically intended to deliver a uniform windrow of material on the pavement surface. In the application shown, the material will be bladed from the pavement surface over into the ditch along the pavement edge in order to widen the road.

Figure 7.10 shows a newer style drag box used for repair of edge rutting. This drag box can help simplify the type of repair depicted in Figure 5.35.

7.3.3 Dump Truck Tailgate Side-Discharge and Center-Discharge Chutes

Dump trucks have been modified in various ways to selectively and uniformly discharge road-building material from the truck directly to the pavement edge. One simple approach replaces the standard truck tailgate with a home-made, center-discharge tailgate chute and drag box, but this requires that the dump truck straddle the pavement edge, rather than drive on the roadway surface and discharge material along the pavement edge (see Figure 7.11).

An improved version has been to replace the standard truck tailgate with a home-made tailgate extension that includes a side discharge chute (see Figure 7.12). The effectiveness is enhanced when district forces insert a diversion barrier (heavy plywood, suitably braced) diagonally across the rear of the truck bed, which directs material to the side of the truck for discharge (see Figure 7.13).

Some of these modified tailgates incorporate an adjustable chute gate with a manually-operated lever to control the flow of material, and some incorporate an operator platform for the worker who operates the chute (see Figure 7.14). While the basic idea is good, these dump truck tailgate devices rely on the free and uniform flow of material toward the discharge opening (which does not always happen) and the designs do not acknowledge customary human factors and safety standards.

Figures 7.15 and 7.16 show a simple side discharge chute and drag "*bar*" for pavement edge maintenance. Built and used in the Wichita Falls District, this drag bar spreads and shapes repair material that has been windrowed along the pavement edge.

FIG. 7.8 Drag Box; Tow-Behind, Used for Delivering Material to the Left, Center, or Right Side of Pavement, Waco District (see Waco District Profile, Photo 8)

FIG. 7.9 Drag Box; Tow-Behind, Used for Delivering Windrow of Material to the Center of Pavement, Amarillo District

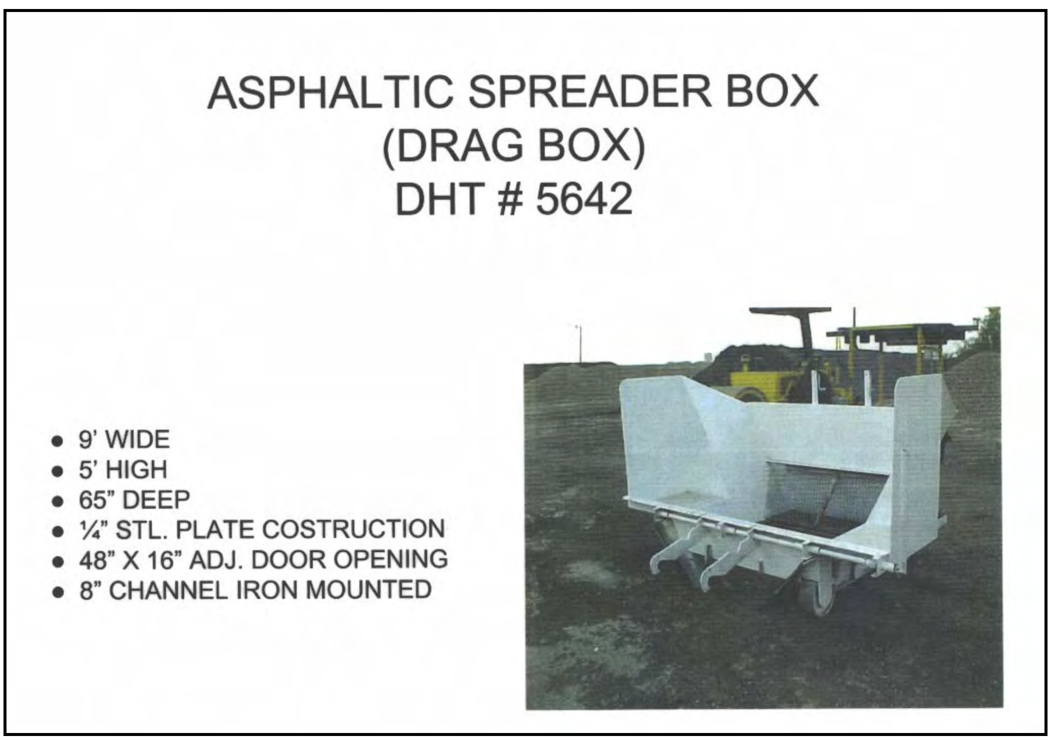

FIG. 7.10 Drag Box; Tow-Behind, Used for Delivering Windrow of Material to the Center of Pavement, Pharr District

FIG. 7.11 Center-Discharge Tailgate Chute with Drag Box, Pharr District (see Pharr Profile, Photos 3 through 5)

FIG. 7.12 Side-Discharge Tailgate Chute, Waco District (see Waco District Profile, Photo 7)

FIG. 7.13 Plywood Insert in Dump Truck Bed to Direct Flow of Material to Side-Discharge Chute, Abilene District (*Photo courtesy of Jones County Maintenance*)

FIG. 7.14 Side Discharge Chute with Operator Platform and Material Flow Regulation Lever, Abilene District (*Photo courtesy of Jones County Maintenance*)

FIG. 7.15 Photo Series: Side Discharge Chute and Tow-Behind Drag Bar for Edge Repair, Wichita Falls District

FIG. 7.16 Close-up View, Side Discharge Chute and Tow-Behind Drag Bar for Edge Repair, Wichita Falls District

7.3.4 Modified V-box Side Discharge Spreader

Many TxDOT maintenance sections do seal coat work, so they have V-box conveyor inserts for their dump trucks that are specifically designed to deliver and spread seal coat aggregate. Some have modified these V-box spreaders by replacing the seal coat aggregate spreader wheel with a removable side discharge chute (see Figure 7.17). This is a temporary and reversible modification, used during those months when seal coat work is not being done. The chute directs material from the V-box conveyor to the pavement edge, allowing the truck to stay on the pavement surface as material is discharged (see Figure 7.18). The goal is to increase production by more quickly and efficiently delivering the material to the pavement edge.

One drawback is that unlike seal coat aggregate, certain edge repair materials; for example, pre-mix and RAP, will “clump” and tend to bridge over the center V-box conveyor belt (see Figure 7.19). This effectively halts delivery of material, and the rodding necessary to cause these materials to flow toward the discharge chute is highly labor intensive (but not as labor-intensive as unloading the material from the bed of the truck, by hand, with a No. 2 scoop, which was the previous method).

FIG. 7.17 Modified V-Box Side Discharge Spreader: End View, San Angelo District (see San Angelo District Profile, Photo 16)

FIG. 7.18 Modified V-Box Side Discharge Spreader: Side View, San Angelo District (see San Angelo District Profile, Photo 17)

FIG. 7.19 Modified V-Box Side Discharge Spreader: Front View, San Angelo District (see San Angelo District Profile, Photo 19)

7.3.5 Ergonomics and Worker Safety

It was beyond the scope of this project to evaluate the ergonomic design and worker safety aspects of home-made edge repair equipment. However, maintenance forces in one district stated that, as part of a routine safety inspection, Division safety personnel cited a home-made center-discharge dump truck tailgate attachment as being unsafe for worker use. The specific issues had to do with improper design which might cause worker back strain, and probable pinch points (high probability of smashed fingers). We did not investigate the worker safety issue.

However, as a general practice, it is appropriate for district maintenance personnel to evaluate their home-made edge maintenance equipment to ensure it is properly designed and can be operated safely.

7.4 Commercially-Manufactured Pavement Edge Maintenance Equipment

A market exists for commercially-manufactured equipment which safely and effectively helps accomplish pavement edge maintenance. Tools, attachments, specialized equipment, and even entire edge repair systems exist in the marketplace for the express purpose of maintaining pavement edges. This equipment presumably incorporates appropriate ergonomic and worker safety design.

The following paragraphs discuss several types of commercially-manufactured edge maintenance equipment, some of which we learned about from our literature review, and most we observed during our district site visits. We provide a brief discussion of each type of equipment, its applicability and use, and direct the reader to manufacturer's websites, sales representatives, and in some cases, district maintenance personnel, for more information.

7.4.1 Side Discharge Conveyors

7.4.1.1 Swenson Tailgate Cross Conveyor (STCC)

Perhaps the most commonly-used piece of commercially-available pavement edge maintenance equipment at TxDOT is the Swenson Tailgate Cross Conveyor (STCC), commonly referred to as the "Swenson Spreader." This hydraulically-operated, side-discharge conveyor attaches to the back of a standard 6 CY or 10 CY dump truck (see Figure 7.20). This device basically achieves the functionality of all of the home-made dump truck tailgate discharge chutes previously discussed, and represents an improvement over most of them since the conveyor system spans the full width of the truck (thus it is not as prone to clogging), it can be operated from inside the truck cab by the driver (it is less labor intensive), and has been designed to meet recognized safety standards. While some maintenance supervisors observe that, under certain circumstances, they can achieve greater production using standard construction equipment (unmodified dump truck and a motor grader), those who must buy their replenishing material (as opposed to using "free" materials such as RAP) claim that the Swenson Spreader, which can be purchased within the TxDOT system for $2,976 per unit, quickly pays for itself in both labor and material costs (see Figure 7.20).

Some maintenance supervisors voiced problems with their Swenson spreaders, claiming that they either did not function as well as desired or they lacked features which would make them easier to use. In an attempt to investigate these concerns, we contacted the manufacturer and learned several helpful things. First, STCCs which are purchased within the TxDOT purchasing system are delivered under a single TxDOT purchase specification. One visible aspect of this is that STCC's delivered to TxDOT are painted off-white; whereas, everywhere else in the US they are construction orange. Further, the specification does not vary across the State and does not take into account such things as variation in the hydraulic pumps, flow valves, and fluid delivery systems that probably exist in TxDOT's dump truck fleet. This means that, if an operator is having difficulty with the STCC, a high probability exists that the hydraulics on the truck – the pump, the flow valves, or the lines – are not adequate for the unit, and this should be investigated on a case-by-case basis with the manufacturer (see Figure 7.21 for contact information). Another point is that Swenson sells several attachments which can be purchased to enhance the STCC's functionality; however, these attachments are not included in the TxDOT purchasing specification and would have to be purchased separately.

FIG. 7.20 Swenson Tailgate Cross Conveyor (STCC), Corpus Christi District (see Corpus Christi District Profile, Photo 7)

FIG. 7.21 Swenson Tailgate Cross Conveyor (STCC) Product Information

7.4.1.2 Hydraulic Truck Conveyor

Other side discharge conveyors exist on the market and are used within TxDOT, although unlike the Swenson STCC, no other side discharge conveyor manufacturer has negotiated a statewide purchasing specification with TxDOT. One of the competitor conveyor systems is the Hydraulic Truck Conveyor (HTC) Model 1800 side discharge conveyor. Figure 7.22 briefly summarizes information about this product. Representatives from HTC proudly claim that they are the *original* developer of the side discharge conveyor (Swenson and others came after) and that their product is superior in that it is roller driven, not chain driven.

FIG. 7.22 Hydraulic Truck Conveyor (HTC) Model 1800 Side Discharge Conveyor Product Information

7.4.1.3 Hi-Way TGC-18 Reversible Tailgate Conveyor

Another side discharge conveyor on the market which we identified in our literature search but did not see within TxDOT is the Hi-Way TGC-18 Reversible Tailgate Cross Conveyor. Like the STCC it is chain driven, and like both the Swenson and HTC products it comes with several attachments which can be added to enhance functionality. Figure 7.23 briefly summarizes information about the Hi-Way TGC-18 product.

FIG. 7.23 Hi-Way TGC-18 Reversible Tailgate Cross Conveyor Product Information

7.4.2 Moon Paver

The Moon Paver, manufactured by Moon Paver, Inc., is a light-weight, screed-type device which attaches to the Swenson Spreader or any of the other side discharge conveyors (see Figure 7.24). Used in tandem with a side discharge conveyor, the Moon Paver delivers a uniform, well-defined, narrow lift of replenishing material along the pavement edge, thus eliminating the need for a motor grader to place and spread a wind row of material (Figure 7.25). Maintenance forces use the Moon Paver selectively, primarily for localized edge maintenance and repair jobs, where fill quantities are small and mobilization distances are such that it is preferable not to mobilize both a dump truck and a motor grader. The Moon Paver comes with a swing-away attachment to enable the operator to more quickly deploy or stow the device. Figure 7.26 briefly summarizes information about the Moon Paver product.

7.4.3 Pro Patch Pothole Repair Truck

The Pro-Patch TCM 415-60 pothole repair truck, manufactured by H.D. Industries, Inc. is, as the name implies, a fully self-contained asphalt patching machine (Figure 7.27). With hot mix asphalt laydown capabilities, the Pro-Patch truck has been effectively used for isolated pavement edge maintenance applications such as repair of broken pavement edges, fish-mouths, and replenishing localized edge drop-offs. Inherently specialized in its application, the Pro-Patch is available at a cost of about $85,000 per unit (including the truck). Most maintenance sections that have a device of this type use it for edge repair because it is available, but they did not purchase it specifically for edge maintenance purposes. Figure 7.28 briefly summarizes information about the Pro-Patch TCM 415-60 pothole repair truck.

FIG. 7.24 Moon Paver, Corpus Christi District (see Corpus Christi District Profile, Photo 4)

FIG. 7.25 Moon Paver: Close-up View, Corpus Christi District (see Corpus Christi District Profile, Photo 5)

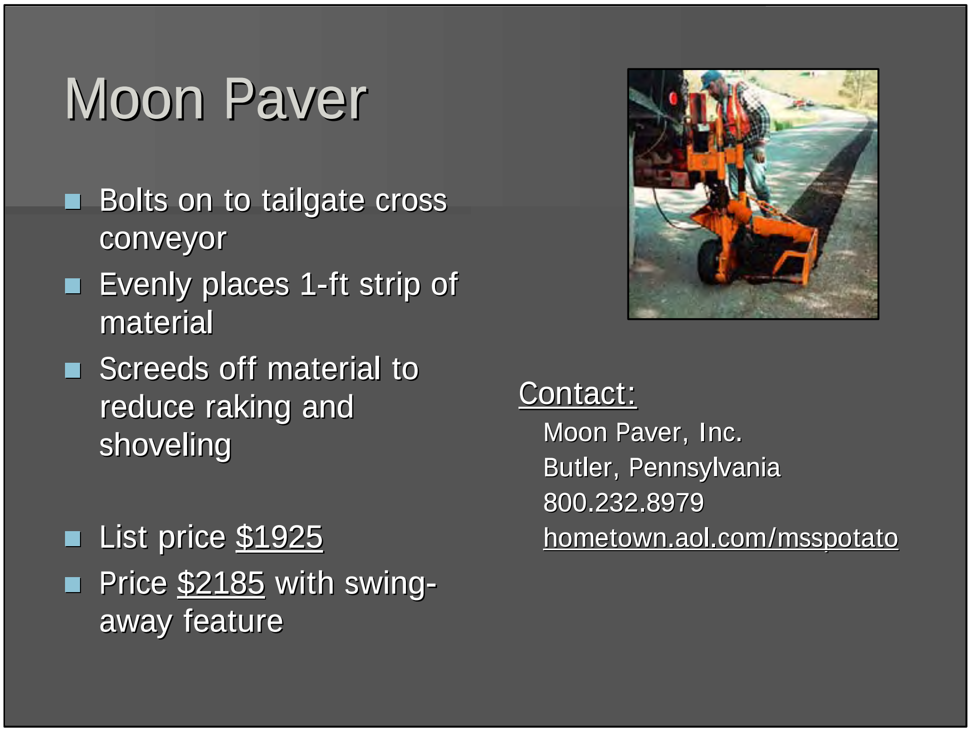

FIG. 7.26 Moon Paver Product Information

FIG. 7.27 Pro-Patch TCM 415-60 Pothole Repair Truck, Tyler District (see Tyler District Profile, Photo 15)

FIG. 7.28 Pro-Patch TCM 415-60 Pothole Repair Truck Product Information

7.4.4 Tools for Maintaining "High" Edges

7.4.4.1 Kuhn Mixer

Although this research has focused on pavement edge drops, it is appropriate to note that build-up of soil and vegetation along the pavement edge is also disadvantageous, since a "high" edge can trap water on the pavement surface and accelerate deterioration of the pavement structure. Maintenance forces in those physiographic regions where rainfall and vegetation are such that edge build-up is a problem – East Texas, mostly – typically use a pulver-mixer type device, like the Kuhn mixer, to address the problem (see Figure 7.29). Manufactured by Kuhn Farm Machinery, Inc., this roto-tiller-like device is towed behind a tractor and operates off of the power take off. Pulverizing a swath of soil and vegetation adjacent to the pavement edge allows for reshaping and reallocating this material to restore the proper edge slope and drainage. Figure 7.30 briefly summarizes information about the Kuhn mixer.

FIG. 7.29 Kuhn Mixer, Lufkin District (see Lufkin District Profile, Photo 7)

FIG. 7.30 Kuhn Mixer Product Information

7.4.4.2 Other Pulverizer/Mixers

While pulver-mixers are commonly used to recycle pavements; *e.g*., BOMAG Recycler/ Stabilizer, they are also effective for the purpose of treating high edges. However, such heavy equipment is usually not available for pavement edge maintenance, since it is more cost-effective to use this type of equipment for its intended function, pavement recycling. When used for edge maintenance, the pulver-mixer must be fitted with a spoon-type bit.

7.4.4.3 Tiger Claw Shoulder Maintenance Tool

The Tiger Corporation markets their Tiger Claw Shoulder Maintenance Tool for pavement edge maintenance. Similar in its application to the Kuhn mixer, the Tiger Claw Shoulder Maintenance Tool consists of a heavy-duty disk plow designed to break down (pulverize) soil and vegetation accumulated along the pavement edge. No TxDOT forces we talked to are using this tool, but they expressed interest in learning more about its application.

The manufacturer indicates that the Tiger Claw Shoulder Maintenance Tool is primarily used in sod shoulder applications where buildup and high edges are a problem. Operators take care to only blade the top few inches of the soil so as to not disturb the root mass and destroy vegetation next to the road. Figure 7.31 briefly summarizes information about the Tiger Claw Shoulder Maintenance Tool.

7.4.5 Road Wideners

Maintenance forces in some maintenance sections use specialized equipment to widen their roads by building narrow shoulders. While this equipment certainly helps accomplish the road-widening objective, the specialized function, high cost, and limited use of road widening equipment are such that maintenance personnel tend to lease the equipment, with an operator, for the short term rather than purchase the equipment outright. The economics of purchasing a road widener would probably not work for an individual maintenance section, but might work satisfactorily for districts where they have a lot of road widening to do and thus can achieve appropriate equipment utilization.

7.4.5.1 LeeBoy 1200S Asphalt Maintainer

The LeeBoy 1200S Asphalt Maintainer, manufactured by Lee-Boy, is a highly-specialized edge maintenance tool (see Figure 7.32). Developed for repairing utility cuts in pavement, the LeeBoy 1200S is actually a small asphalt lay-down machine capable of placing a narrow, uniform lift of hot mix asphalt. As regards pavement edge maintenance, the LeeBoy 1200S can be used for paving narrow (1-1/2 to 3 feet wide) shoulders; however, maintenance forces who use this machine have noted that while it is multi-purpose it is not production oriented, and while it does a good job and achieves an excellent surface finish, there are quicker ways to build a narrow shoulder. Figure 7.33 briefly summarizes information about the LeeBoy 1200S Asphalt Maintainer; refer to Figure 6.11 for a series of photographs showing road widening with this machine.

FIG. 7.31 Tiger Claw Shoulder Maintenance Tool Product Information

FIG. 7.32 LeeBoy 1200S Asphalt Maintainer for Edge Repair, Fort Worth District

FIG. 7.33 LeeBoy 1200S Asphalt Maintainer Product Information

7.4.5.2 Midland Machinery Road Widener

A related piece of equipment suitable for widening roads by building narrow shoulders is the Road Widener. Manufactured by Midland Machinery Company, Inc., this device also delivers a narrow lift of asphalt, but without the careful screed control of the LeeBoy 1200S. Hence, the Road Widener achieves greater production, but not the same high degree of finished surface as the LeeBoy 1200S. Figure 7.34 briefly summarizes information about the Midland Machinery Road Widener; Figure 7.35 shows a completed road widening project completed with this machine.

7.4.7 Other Pavement Edge Maintenance Equipment

We have noted that much of the home-made and commercially-manufactured edge maintenance equipment was developed by people who, having experienced the physically-demanding aspects of edge repair, were highly-motivated to come up with better ways to do the job. Therefore, it is reasonable to think that new and better home-made and commercially-manufactured equipment and tools have entered the market since we completed our research data-gathering in 2002.

FIG. 7.34 Midland Machinery Road Widener Product Information

FIG. 7.35 Completed Edge Repair Project Using Midland Machinery Road Widener, Fort Worth District (see Fort Worth District Profile Photo 43)

CHAPTER 8
EDGE MAINTENANCE PLANNING TOOLS

8.1 Overview

8.1.1 Fiscal Responsibility – The Context for Edge Maintenance Planning

While just about all maintenance supervisors we interviewed commented that they had more lane miles of road than they had the resources to maintain the way they would like to, it is also true that TxDOT's maintenance investment is substantial. Recall from Section 5.6 of this report that TxDOT's total FY 2001 budget (Pocket Facts 2001) was $5,117 million, of which $453 million, $230 million, and $285 million were allocated to routine, preventive and contracted maintenance, respectively. Of this amount, depending on which function codes are included in the totals, somewhere between $11.4 million to $213 million or more was spent on edge maintenance, and such expenditure represents somewhere between 2.5 percent to 47 percent of the FY 2001 routine maintenance budget. Thus, TxDOT invests a significant portion of its annual maintenance budget on edge repair, and stewardship of public dollars is a fundamental reason for maintenance planning in general and edge maintenance planning in particular.

We also observed that it is not uncommon for the day-to-day activity of maintenance supervisors to be an exercise in crisis management – they seem to always be "putting out fires." But not every day is unscheduled or controlled by unforeseen circumstances, and since "chance favors the prepared mind" (Pasteur 1854), those maintenance supervisors who have a sound plan that incorporates good edge maintenance strategy are the ones most likely to achieve significant headway in their edge maintenance efforts.

Therefore, stewardship of significant financial resources coupled with a desire to manage the maintenance process are the context for edge maintenance planning.

8.1.2 Assessment and Planning

Edge maintenance planning is a reflexive process that involves assessment of pavement edge conditions on the one hand, followed by prioritization of edge maintenance activities on the other. Comments about detailed and specific procedures for edge condition assessment, together with a host of "standard" maintenance planning tools, surfaced with some regularity during our interviews. The assessment and planning tools discussed in this chapter are the systematic approaches used by the different districts of TxDOT to address their edge drop-off problems. Given the strong competition for limited maintenance resources, it is only reasonable that planning and assessment be given a prominent place among the best practices for pavement edge maintenance.

8.2 Edge Maintenance Assessment

8.2.1 Real-Time Condition Assessment Practices

TxDOT's maintenance section supervisors do edge condition assessment in real-time as part of their job – typically through their weekly windshield survey. Here, a representative of the maintenance section drives each road in the Section, identifies and records any damage to the pavement edge (or other aspects of the roadway), and reports this information for maintenance attention. As discussed in Section 4.2 of this report, the weekly windshield surveys help identify problem spots as they develop, and recurring problem areas become apparent over time. This short term assessment of edge conditions allows Maintenance Section Supervisors to know where their edge problems are and direct their maintenance effort accordingly. This also provides a basis for validating the long-term assessment procedures commonly used in annual maintenance planning.

8.2.2 TxMAP for Assessment of Pavement Edges

Prominent among the long-term condition assessment tools is TxMAP, the TxDOT Maintenance Division's "Texas Maintenance Assessment Program," now in its fourth year. TxMAP evaluates 21 elements of highway infrastructure divided into three main components: pavements, traffic operations, and roadsides. Among other things, the pavement component includes edges and shoulders as discussed in Sections 4.2 and 4.3 of this report. These elements are rated on a scale of one to five for randomly selected one-mile sections of road. Each element is ultimately assigned a score in percentsge points (100 percent being excellent condition), this after several steps of weighting.

TxMAP relies on a statistical sample of roads; the Maintenance Division, with the assistance of district maintenance personnel, evaluates approximately 10 percent of the Interstate system and 5 percent of the non-Interstate system (U.S. highways, State highways and FM system) each year. Although TxMAP is not intended to identify any particular roadway section for day-to-day maintenance needs, the data are useful for overall planning and budgeting of the maintenance operations at the District level, and at the Section level (Schorlemmer 2003). In particular, TxMAP allows for meaningful comparison of performance among the different Sections within a district, and among the different districts within the State.

Maintenance section supervisors interviewed typically say that they are beginning to use TxMAP data to help with their prioritization and annual maintenance planning. Also, some use preprinted TxMAP assessment forms to record observations from their weekly windshield survey, this to introduce a mindset of measurement and accountability as they go about their daily task.

8.2.3 Performance Evaluation Efficiency Report (PEERs) Assessment

The Bryan District uses a formal condition assessment tool called "PEERs" (Performance Evaluation Efficiency Report) to assess the performance of roads in the district. It is our understanding that PEERs is actually a precursor to TxMAP, it was used previously in other districts throughout the State and has been used in the Bryan District since 1994.

The PEERs condition assessment is done in addition to the statewide TxMAP and PMIS (Pavement Management Information System) assessments and focuses on the roadside, not the travel lanes. Unlike PMIS or TxMAP, it does not use a statistical sample; rather, it rates 100% of the roads in the district. Edge drop-offs are a significant part of the PEERs program and roads are classified according to three levels of service:

Class A: No edge drop-offs greater than 2 inches in depth and/or edge buildup that will restrict drainage and cause minor ponding on pavement.

Class B: Spotty areas of drop-offs greater than 2 inches in depth and/or edge buildups that will restrict drainage and cause minor ponding on pavement.

Class C: Large areas of drop-offs greater than 2 inches in depth, with some drop-offs at a depth that could become a hazard and/or large areas of buildups that are restricting drainage and could cause major ponding on pavement.

The assessment approach is similar to that used by most TxDOT Maintenance Section Supervisors across the State and represents a formal way of collecting and organizing data from the windshield survey. However, unlike other assessment tools, two persons conduct the survey for the whole district, collecting data during the months of February through May each year. They drive 100% of the roadway sections for visual evaluation through the windshield of their car and record observations on pre-formatted data entry screens directly into a Microsoft Access database on a laptop computer. Figure 8.1 shows a typical data entry screen.

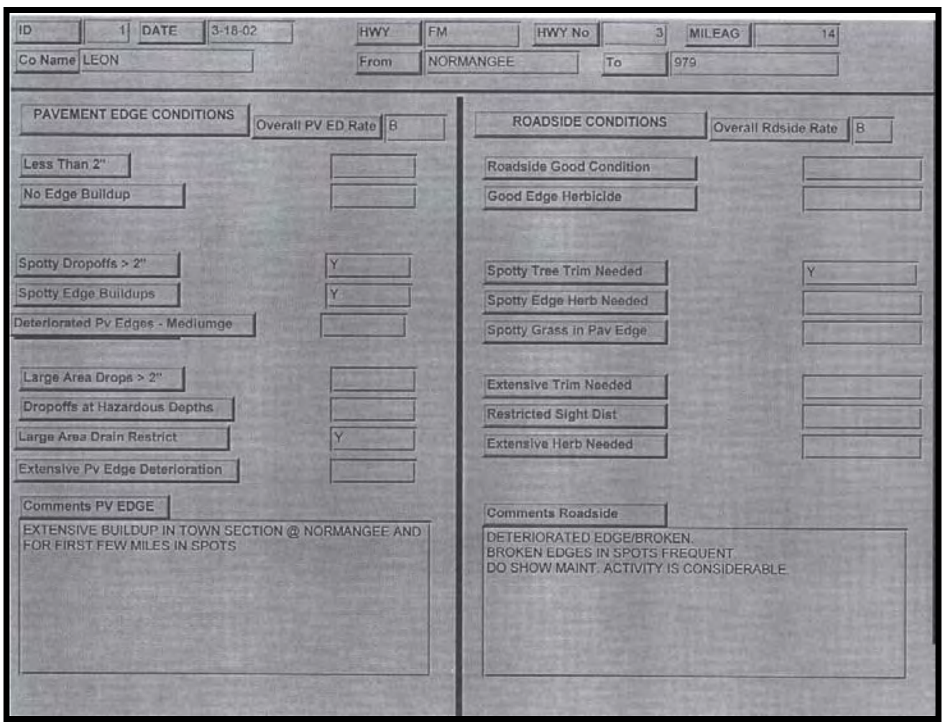

FIG. 8.1 PEERs Edge Condition Assessment, Data Input Screen for Microsoft Access Database, Bryan District

As noted above, PEERs uses a 2-inch edge drop as the threshold value for pavement edge condition assessment. Upon completion of the data gathering, the District Maintenance Engineer prepares a color-coded map that identifies each section of road with its assigned grade/class, and they use these maps for maintenance planning purposes. District maintenance personnel view

PEERs data as giving their Maintenance Section Supervisors a broader look at the roadside and pavement edge conditions, the "forest" as opposed to the "trees." Further, since the condition assessment maps are based on full evaluation of all the roads, there is little quibbling over the findings. The Bryan District Profile includes further details about PEERs.

The key features of PEERs in contrast with other condition assessment tools like TxMAP and PMIS are, first, the PEERs program does not use a statistical sample of roads but grades 100% of the roadways. While this gives the actual condition of all the roads and is not subject to statistical sampling error; obviously, such rating is very labor intensive and requires at least two persons' travel time for four months to assess just one district. Second, the PEERs program focuses only on the roadside, not the traveled way. The PEERs rating elements are "improved shoulder," "pavement edges," and "roadside." Third, PEERs provides information for comparison among different Sections within a district, but only with the three levels (classes A, B and C) of severity for edge drop, not a weighted numerical score. Ultimately the decision to use PEERs turns on the value that district maintenance personnel ascribe to the more comprehensive data it provides in comparison to, say, TxMAP.

8.3 Planning Tools for Pavement Edge Maintenance

8.3.1 Overview

The goal of condition assessment programs is to provide information that can help maintenance personnel in the districts identify and strategically prioritize their maintenance challenges. That is one part of the task of planning. The other part – which we will now discuss – is to *apply* the assessment data to solve pavement maintenance problems, and we have suggested that because of *Tracy's Law*, edge maintenance should have high priority. Some districts use systematic, formal approaches for their maintenance planning, and others are guided by standard maintenance planning tools or informal approaches. As noted in Chapter 6, most districts realize the ultimate solution to pavement edge problems is to widen their roads, and this type of evaluation requires planning specific to the task. As with any type of planning, the goal is to address maintenance problems, but funds are not always available, and in some cases, the maintenance budget is barely enough to meet emergency needs. Always, the district maintenance forces must use their experience and judgment, the focus being to safely, effectively, and efficiently alleviate their edge problems.

8.3.2 Annual Maintenance Work Plan

The *TxDOT Maintenance Manual* (TxDOT 2001) requires that every Maintenance Section develop an annual Maintenance Plan (Section 3, Part 1-6). Here, each Maintenance Section Supervisor plans his or her work for that Section for the coming fiscal year. Among other things, the Maintenance Plan should reflect the long range maintenance strategies for the district, and should demonstrate how those strategies will be implemented. The annual Maintenance Plan identifies, by maintenance function, the particular sections of road that will be improved within each county/ maintenance section, and also ought to address special priority items such as, in our case, edge maintenance. This represents an estimated or projected amount of repair work, and the annual Maintenance Plan for a district is the accumulation of each of the Maintenance Section plans.

Two districts – San Angelo and Pharr – made specific mention of their annual Maintenance Plan in relation to edge repair during our interview. In the San Angelo District, the Maintenance Plan identifies different maintenance functions associated with pavement edge maintenance, such as fog seal, repair of broken edges, elimination of edge drop-offs, and emulsion edge seal. Maintenance Section Supervisors in San Angelo identify a certain number of lane miles for each of these functions to be performed in the coming fiscal year, and the District Director of Operations manages them against this plan (see Figure 8.2).

FY 2001 MAINTENANCE WORK PLAN

September 2000 - May 2001 Report

Pavement Maintenance	FY 2001 Plan	6 Month 28-Feb	9 Month 31-May	12 Month 31-Aug	
Full depth rehab to:	83	38	85	69.5	lane miles
Levelup/overlay to:	198	50	97.64	164.38	lane miles
Levelup at:	97	42	55	49.5	bridge approaches
Crackseal to:	677	763	1039.06	858.06	lane miles
Sealcoat/Strip Seal to:	241	28	288.69	90.69	lane miles
Fog Seal to:	64	78	81.39	24.39	lane miles
Repair broken edges to:	412	121	255.421	235.101	lane miles
Eliminate edge drop-off to:	315	102	179.35	190.12	lane miles
Emulsion edge seal to:	506	263	335	290	lane miles
Sweep urban curb and gutter roadways:	95	41	76.7	42	cycles
Sweep bridge decks after ice control activities:	28	13	14.7	13.7	cycles
Roadside Maintenance					
Upgrade nonstandard MBGF to current standards to:	20,200	17,915	22,515	18,665	linear feet
Restore ditch section for drainage to:	224	44	126.06	98.12	lane miles
Herbicide for noxious vegetation control to:	4,980	596	2964	3569	lane miles
Herbicide for mesquite control to:	241	103	200	221	lane miles
Strip mow all rural highways:	2	0	1.62	11.10	cycles per Section
Full width mow all rural highways:	2	0	1.67	17.00	cycles per Section
Full width mow all urban highways:	3	0	2.00	15.00	cycles per Section
Safety mow intersections:	7	2	8.17	47.00	each per Section
Tree/brush trimming to:	320	44	83.55	114.05	lane miles
Inspect driveway & SET installation at:	177	86	142	142	locations

FIG. 8.2. Annual Maintenance Plan, Excerpt Showing Edge Maintenance Functions, San Angelo District

In the Pharr District, the Director of Maintenance works closely with the Maintenance Section Supervisors to develop the Maintenance Plans for each Maintenance Section, and in fact does the actual writing, the goal being to lessen the paperwork burden on the Maintenance Section personnel. The Pharr District plans address various edge repair functions, and recently have started to include a specific amount of road widening each year.

Two observations can be made. First, our interviews clearly show that, as a general rule, Maintenance Section Supervisors are no lovers of paperwork, so the typical Maintenance Section Supervisor holds no affection for a paper-intensive task like the annual Maintenance Plan. In this vein, the Pharr District's approach may be very beneficial. Second, however, since the annual Maintenance Plan is expressly *required* by the *TxDOT Maintenance Manual,* no good reason exists not to use it to help identify and prioritize edge maintenance work. Since it must be done anyway, the Maintenance Plan might as well be of benefit, and in fact this plan can become an effective tool in implementing pavement edge maintenance strategy.

8.3.3 Childress Narrow Road Widening Plan

Whereas the annual Maintenance Plan addresses all maintenance functions and should be viewed as a district's basic guide for implementation of their maintenance strategy, planning associated with the specific task of road widening has been given particular attention. For example, the Childress District has developed an excellent planning tool to select and prioritize their narrow roads for upgrading to 26-foot width.

Developed in 2000 by the Childress District 26' Roadway Task Force, the Childress Narrow Road Widening Plan is built around a composite roadway ranking which derives from an 8-criteria scoring system that reflects the various issues which are important for road widening. The Task Force selected the 8 criteria after several rounds of discussion among themselves, and a general consensus among members established the relative weights and assigned numerical values to each criterion.

Table 8.1 identifies the 8 criteria, and more detail is available in the Childress District Profile in Volume 2 of this report. In order to put more emphasis on State Highways, the Childress Plan considers highway classification as one of the important factors. Traffic volume (ADT) has the highest maximum score, potentially accounting for 25 out of a total of 85 points. The Task Force discussed assigning 'percentage of truck traffic' as a separate criterion, but they did not do this because of concerns about having an overload of information for implementation. Presence on the Official Travel Map is considered another important factor because of a greater chance of exposure to out-of-state travelers. The next criterion is functional classification of the roadway; connectors and generators are given preference over dead end sections. Other criteria include current road width, whether the road is a wide load route, compatibility of proposed width with neighboring district sections, and finally, the current PMIS score. There are no separate weighting factors; all are included into the numerical values assigned to each criterion, and the higher the total score, the higher the preference for road widening.

Use of this ranking system involves the following steps:

1) All roads narrower than 26 feet in the district are identified. These include State Highways, Farm-to-Market roads and Loops. In the case of Childress, this amounted to a combined total of 1421 centerline miles of roadway.

Table 8.1 Childress Narrow Road Widening Plan; Criteria for Establishing the Composite Ranking of Roadways.

No.	Selective Criteria	Basis	Numerical Score *
1.	Classification of Highway	State Highway	15
		Farm-to-Market	10
2.	Annual Average Daily Traffic (ADT)	0 to 200	5
		201 to 400	10
		401 to 600	15
		601 to 800	20
		801 to 1000	25
		More than 1000	30
3.	Location on TxDOT Official Travel Map	Yes	10
		No	0
4.	Connector, Dead-End or Traffic Generator	Connector	10
		Generator	5
		Dead-End	0
		Connector and Generator	15
5.	Roadway Width	18.0 to 20.0 feet	5
		20.1 to 22.9 feet	4
		23.0 to 24.9 feet	3
		25.0 to 26.0 feet	2
6.	Wide Load Routes	Yes	5
		No	0
7.	Neighboring District Section	Narrower	5
		Same or Wider	0
8.	PMIS Scores	1 to 59	5
		60 to 69	4
		70 to 79	3
		80 to 89	2
		90 to 100	1

*NOTE: Maximum possible score is 85.

2) The Task Force determines the composite score for each section of roadway based on the 8 criteria.
3) The sections are ranked in order based on the composite score, highest to lowest.
4) With prioritization established, maintenance plans are developed to upgrade the road with the highest score first, followed by the second, then the third, and so on, subject to availability of maintenance funds.

The Childress Narrow Road Widening Plan strongly illustrates how planning is a necessary first step toward accomplishing strategic maintenance objectives. Further, it points out how seemingly insurmountable funding obstacles can be overcome. Recognizing that road widening projects can get very expensive when they include upgrades to fixed roadside structures such as bridges, culverts, signs, and the like, the Childress Plan allows for incremental progress with limited resources. Rather than say "Widening roads is too expensive" and do nothing, Childress will say, "We can justify widening an XX mile section of FM YYY this year," and they have a rational basis for allocating their funds in accordance with the overall district maintenance strategy. At current funding levels, the Childress District estimates that full implementation of their plan will take about 20 years, and they have started.

8.3.4 Pharr Road Widening Plan

While their plan is not as elaborate as Childress', the Pharr District has also given considerable thought to setting priorities for widening their roads. Maintenance personnel in Pharr have identified all the roads in their district narrower than 24 feet and listed them in their "Upgrade Pavements Less than 24' Program." This is a spreadsheet with 24 fields including, among other things, roadway identification data, traffic volume, the design standard, existing and proposed pavement widths, a rehabilitation cost estimate, PMIS scores, and accident data. Most significantly, the spreadsheet is sorted based on rehabilitation cost per vehicle mile, which is another way of saying "biggest bang for your maintenance buck." The Pharr District Profile, Volume 2 of this report, contains an example of the Pharr Road Widening Plan.

High traffic volume roads get preference and these typically are prioritized for road widening under construction contract using "2R money." Where ROW is sufficient, the district's plan is to widen these sections of the road to 28 feet. On the other end of the spectrum, the lower volume roads are scheduled into the District Maintenance Plan for widening using in-house maintenance forces.

8.3.5 Houston Road Widening Contract Expertise

While not a formal plan, *per se,* the Houston District has, for the past seven years, approached pavement edge maintenance almost solely in terms of widening their roads by either construction or maintenance contract. This shift in edge maintenance strategy resulted from a convergence of several factors including the high traffic volume, a shrinking maintenance force, and environmental considerations (poor soils and relatively high rainfall) that limit the window for performing what most districts consider routine edge maintenance. In contrast to most areas of the State – especially the rural areas – in Houston, any type of maintenance activity adversely impacts traffic patterns, and because of the high traffic volume and high speeds, they run a higher risk of getting maintenance personnel hurt. Further, during the extended wet seasons, it would be practically impossible to keep up with edge maintenance. All this to say, district maintenance leaders made the decision to widen their roads and thus eliminate most of their (non-intentional) edge drop-off damage. This represents a fundamental shift in edge maintenance strategy; rather than do routine edge maintenance; for example, pulling shoulders, the goal in Houston has expressly been to build roads that do not require this type of attention.

To implement their approach, Houston District maintenance personnel strategically developed expertise in maintenance contracting to widen roads. They quickly learned it was in their interest to not only prioritize their roads but also do the engineering ahead of time. Thus, they have plans and specifications available, sitting on shelves, ready to be contracted out as soon as money became available. This state of readiness enabled Houston to capture maintenance rehabilitation funds that other districts could not. Thus, good edge maintenance practice in Houston actually has centered around the ability to get a road widening or rehabilitation project under contract, as opposed to the more traditional view of performing a particular maintenance function. While in some ways unique to Houston, this is a perspective that probably has merit in other metropolitan districts of the State with similar traffic challenges.

8.3.6 Other, Less Formal Road Widening and Edge Maintenance Plans

Several districts have taken the view that widening their roads is a worthwhile preventive measure against edge drop-off problems. Some, like Childress and Pharr, have formal road widening plans, but most rely on less formal procedures or incorporate road widening into other maintenance strategies that they hold primary, such as the 7-year seal coat cycle. The following discussion briefly summarizes these other, informal approaches we encountered during our interviews.

Abilene: The Abilene District has an informal, long-term goal in each Maintenance Section to gradually widen all of their narrow roads to at least 24 to 26 feet, either through contract or by in-house maintenance forces.

Atlanta: Like many districts, Atlanta contracts out road rehabilitation work under both maintenance and construction contracts where traffic justifies and as funding is available. In these cases, road widening is typically incidental to more comprehensive pavement rehabilitation which is being done because a road is worn out rather than just narrow. The district planning committee recognizes that there are a few 18-foot road sections and they have plans to widen and rehabilitate these roads over time.

Fort Worth: The Fort Worth District has taken a long-term approach to edge maintenance by widening their narrow roads as the money becomes available. High-volume roads get preference and the district has already identified and prioritized their higher-volume roads for widening under construction contract (2R or 3R money). Besides contract widening, TxDOT in-house forces routinely build two-foot shoulders on narrow FM roads to widen a 20- foot road to a 24-foot section, just enough for an edge line. Several counties in this district have a systematic plan to upgrade/ widen one section of FM road per year, usually about ten miles or so. Since in-house crews do the work, the widening cost consists of only materials and equipment rental. The selected candidates are typically widened 6 months to a couple of years in advance of when they are scheduled to receive a seal coat.

Lufkin: The Lufkin District typically does not widen roads with their in-house forces; they do this work under a construction contract with a set of formal drawings. The District Engineer or Area Engineers usually propose a section of road for widening and then 4 or 5 different people travel through that section and make a decision, using care to widen between "logical termini." Ultimately, the district plans to widen and rehabilitate a few sections of road per year and they realize this can dramatically improve the ride on their roads. With upgrading and repairing roadside structures, widening becomes very expensive; consequently, sections of road with the least upgrading work needed are usually selected first.

Odessa: In past years, the Odessa district added shoulders to their narrow FM roads such that today, the typical width for FM roads in Odessa is 32 feet; that is, two 12-foot travel lanes with 4-foot shoulders. Fewer than 10 roads in the entire Odessa District do not have shoulders, and these are mostly access roads for divided highways.

Waco: The Waco District has taken a long-term approach to edge maintenance by widening or rehabilitating their narrow roads as the money becomes available. They allocate about $2 million a year for widening low volume roads, typically under construction contract. Priority candidates for widening are those roads with sufficient ROW and limited fixed structures to make widening financially feasible. Widening roads with many fixed structures such as bridges and culverts gets very expensive, and narrow ROW makes ditch slopes very steep, perhaps unacceptably so. The Waco District has already widened most of their narrow roads where they have enough right-of-way to create a 28-foot section consisting of 12-foot travel lanes and 2-foot shoulders. Roads with insufficient ROW or structures to achieve the 28-foot width fall within the secondary goal of widening to a minimum of 25 feet.

Wichita Falls: Wichita Falls has a three-year routine maintenance plan and under that program they fog seal and/or strip seal the edges on a regular basis as a preventive measure against edge raveling. Although there is no formal plan to widen roads, a portion of the edge repair work in Wichita Falls involves widening their roads by adding narrow shoulders.

8.4 Pavement Rehabilitation Budgeting Tools

Each district develops their annual Maintenance Plan within the context of that year's maintenance budget, so TxDOT maintenance personnel have a good idea of what their maintenance costs are. Unit price cost data are also available from contract jobs. In addition to these customary sources for cost information, we learned of a budgeting program, developed by TxDOT, which can be used to conveniently estimate costs for various pavement rehabilitation strategies, and this program may prove to be a useful planning tool in the area of pavement edge maintenance.

Previewed at the 2002 Statewide Maintenance Conference by Ken Fults (Fults 2002), the PMIS budgeting program was developed to address the Texas Transportation Commission's 10-year goal of improving PMIS ride scores for the TxDOT system to where 90 percent of the roads have a good or better rating. The PMIS budgeting program uses built-in, universal cost data to calculate costs for quick and simple "what-if" rehabilitation scenarios and to evaluate the impact of these strategies on ride. While not specifically developed for edge maintenance purposes, this budgeting tool could also be used to chart out options for edge maintenance.

CHAPTER 9
PAVEMENT EDGE REPAIR SPECIFICATION

9.1 Overview

A requirement of this research project was to develop a draft specification which could be used for contract pavement edge maintenance work. Although TxDOT does not currently have a statewide pavement edge repair specification, limited Special Specifications exist for certain districts, and project-specific specifications also exist. This chapter describes the extant edge repair specifications we identified during this project, discusses TxDOT experience in contracting out edge repair work, summarizes how we developed the draft edge repair specification based on review of existing TxDOT specifications as well as specifications from other states, and presents the draft edge repair specification developed for this project.

9.2 Extant Edge Repair Specifications

9.2.1 Specifications from Other State DOTs

Our literature review included contacting a sample of DOTs across the United States. Two of the states sampled, CalTrans (California) and NYSDOT (New York State) responded with their written policy and/or specifications for pavement edge maintenance, and we have included these responses as Appendix D of this Report.

The NYSDOT shoulder maintenance guidelines do not include an edge repair specification; rather, they describe the logical basis for shoulder maintenance and present a chart from research by Zimmer and Ivey (1982) to determine the need for shoulder maintenance.

CalTrans did provide an edge repair specification; their Item 10-1.14, “Shoulder Backing,” which is a specification for constructing shoulder backing adjacent to the edge of new pavement surfacing. CalTrans maintenance personnel also provided a very detailed and helpful response to questions regarding their standard maintenance policy and procedures for dealing with edge drop-off issues.

9.2.2 TxDOT Special Specifications for Edge Repair

The first reported TxDOT edge repair specification of which we are aware was published by TxDOT in their Routine Maintenance Specification book (TxDOT 1990) as Item Number 9452, “Maintenance Specification for Replacing Pavement on Broken Pavement Edges and Shape Base Slope.” As the title indicates, this specification was used to restore pavement loss with a serviceable well-compacted asphalt-wearing surface after first restoring the eroded flexible base. A copy of this specification was made available by the Tyler District and appears in the Tyler District Profile, Volume 2 of this report. This is a method type specification describing the steps involved in the pavement restoration process.

The subsequent modification to this specification was published as a special specification in 1995 by TxDOT. Item 7079, “Repair of Broken Pavement Edges and Overlay of Access

Drives," was used for the preparation and overlay of broken pavement edges and overlay of access drives along designated roadways that were to be seal coated by State forces.

The Tyler District adapted special specification Item 7079 with very minor modification and published it as their special specification Item 7093 (for a copy, refer to the San Antonio District Profile, Volume 2 of this report). Although Item 7093 still appears in TxDOT's online database of special specifications, the Tyler District no longer uses this specification. The main reason is that they developed it for a particular application – a relatively small project which involved repair of scattered broken pavement edges prior to seal coat work – and the specification is not readily transferable to other contexts.

9.2.3 TxDOT's Standard Edge Backfill Specification and Accompanying General Notes

TxDOT's 1993 standard specification (Blue Book) Item 134, Backfilling Pavement Edges, was mentioned most frequently during our interviews as the specification districts currently use for contract edge repair, typically as part of a hot mix overlay contract but sometimes as a separate project. However, Item 134 does not specify the edge repair materials, nor does it describe construction methods in adequate detail to serve as a stand-alone specification; therefore, it is used with accompanying general notes details.

For example, the general notes on plans provided by the Odessa District for specification Item 134 (see the Odessa District Profile, Volume 2 of this report) identify the desired slope of the backfill and provide detailed guidance on the sequence of the backfilling operation. These notes include the type and gradation of the materials to be used and also mention cutting a "notch" along the pavement edge before backfilling in certain situations.

Similar notes from plans provided by the Austin District (see the Austin District Profile, Volume 2 of this report) describe edge repair which consisted of placing a 6-inch thick flex layer, tapering off to a four-foot width, and covering 2 feet of the base with a seal coat, plus brooming and cleaning the pavement and protecting the existing driving surface.

The Huntsville Area Office of Bryan District uses Item 134 for backfilling operations but with notes for three different methods (A, B or C) of construction (see the Bryan District Profile, Volume 2 of this report). Method A, the least preferred but most inexpensive, is used on almost every preventive maintenance overlay project in the area and it requires only RAP (supplied by TxDOT) as backfill material. A flat wheel roller or other equipment approved by the engineer is used to compact backfill edges until the RAP is uniformly compacted by "ordinary compaction." Although the payment is based on Item 134, compaction and sprinkling are performed in accordance with Items 210 (rolling) and 204 (sprinkling), respectively. Method B is exactly the same as Method A except that the RAP is mixed in-place with the existing material before compaction. In all cases, it is recommended to blade to construct a 6:1 taper section if possible. Method C, the preferred but most expensive method, is essentially specification Item 134 with the following requirements: (a) Type A backfill materials should be crushed stone with a specified Master Grading, (b) MC-80 should be used for sealing backfilled surfaces, and (c) compaction and taper requirements are the same as Methods A and B.

In contrast to these structural applications where the backfill material is subject to traffic load, notes from plans submitted by the Wichita Falls District (see the Wichita Falls District Profile, Volume 2 of this report) describe a mostly non-structural application where the goal was to backfill the pavement edge but to establish vegetation on this backfill for erosion control purposes. In addition to Item 134, the contract identified specification Items 166 (Fertilizer) and 168 (Vegetative Watering). Many districts use this non-structural type of specification when backfilling low edges along the shoulders of their divided highways, as was the case here.

9.3 TxDOT's Experience in Contracting Edge Repair

9.3.1 Item 134 Backfilling Pavement Edges

TxDOT specification Item 134, Backfilling Pavement Edges, was mentioned most frequently during our interviews as the tool districts currently use to contract out edge repair work. However, only about a third of the districts explicitly mentioned contracting out their edge repair, with most districts preferring to do this type of work in-house using TxDOT Maintenance forces. Among those districts that do contract out edge repair work, the prevailing view is that good quality control monitoring is the key to a successful project.

9.3.2 TxDOT's Total Maintenance Contract

Selected TxDOT districts including Waco, Dallas, and Fort Worth either have plans to use or are using a "Total Maintenance Contract" to maintain portions of the Interstate Highway system. In a Total Maintenance Contract, all the maintenance functions for a defined section of highway are contracted to an outside vendor for a specified time frame. The performance standard incorporates TxDOT's maintenance specifications, the goal being that contract maintenance ought to be the same as if TxDOT were doing the work. For edge repair, the explicit standard is that any drop-off greater than 2 inches and more than 50 feet in length is not acceptable on both flexible and rigid pavements.

However, for a number of reasons, the district personnel we interviewed were generally unsatisfied with the quality of the contracted maintenance work. Largely because of a different perspective (short-term vendor rather than long-term owner), even though the specifications are the same, the contract maintenance effort is susceptible to being more surface level and does not reflect the care and effort necessary to meet TxDOT maintenance supervisors' standards.

It is our understanding that the Total Maintenance Contract specifications are still evolving and different contract language, focusing on specific maintenance strategies that can be effectively defined and monitored, is being used.

9.3.3 Challenges Associated with Contracting Out Edge Repair Work

TxDOT's experience with the Total Maintenance Contract and the vagueness of specification Item 134 illustrate some of the challenges associated with contracting out edge repair work. First, despite a basic understanding of the maintenance function, the details of edge repair are usually not well defined. Wide variations exist in the actual practices and procedures employed in the edge repair process. For example, surface preparation can be used (or not); different quality backfill materials can be selected, and the backfill materials can be moisture conditioned (or not), just to name a few. Second, even when these details are explicitly defined, edge repair is still accomplished using a method specification; quality control testing is not typically done. Effective practices are "handed down," the execution of which is something of an art. One illustration is that compaction, a key element of the process, will be subject to the judgment and integrity of the person doing the repair. Full-time monitoring by experienced personnel becomes necessary but is often impractical, leaving projects largely to be taken at face value. Finally, and perhaps most fundamentally, vagueness exists about the level of performance that can be reasonably expected from the edge repair process. Such vagueness derives from environmental factors and traffic loads on the one hand, and the edge repair materials and procedures on the other. This creates a situation where it becomes difficult to cleanly and clearly establish objective performance standards for edge repair.

9.4 Development of a New Edge Repair Specification

9.4.1 The Implied Meaning of Edge Repair

This report discusses numerous practices and procedures for maintaining the pavement edge, ranging from simple preventive measures (fog seal) to widening the road by adding narrow shoulders. In contrast to this diverse concept of edge maintenance, from the discussion thus far, it should be apparent that the implied meaning of edge repair for the purpose of developing a specification is "replenishing the pavement edge with select borrow material" as discussed in Section 5.4.4 of this report. Edge repair involves much more than replenishing the pavement edge, but this is the procedure intended in the specification.

9.4.2 Approximating the Ideal

The specification has been developed around several themes, or ideals. One is awareness of existing specifications, both those in-use and those no longer in service, and the realization that a method specification is probably the most appropriate way to approach the issue. Another ideal is diversity. Replenishing the pavement edge with select borrow materials can involve a wide selection of materials, equipment, practices and procedures, and a successful specification would allow for this. A third ideal is that the specification should be appropriate for use statewide, and not limited to one particular geographic area. Yet another ideal is convenience; one of the needs in specifying edge repair by replenishing is to include all the necessary information in one convenient document, but at the same time, allow the person using the specification the freedom to select the aspects of the procedure appropriate for a particular application.

In addition to these ideals, one of the realities of replenishing is that the desired outcome dramatically affects the process. Perhaps the most basic point of divergence has to do with edge repair applications that will see traffic (material placed next to the travel lane), versus edge repair along shoulders where the material is not intended to support any traffic but instead is to grow vegetation for erosion control. These specifications would be quite different, and here, we made

the decision to address only the traffic-bearing, or structural, application. The non-structural, vegetation application will require a separate specification.
Another reality is that materials of construction and the equipment used also significantly affect the specification details. Within the structural category, materials can range from unbound, granular materials to hot mix asphalt. They might also include stabilized materials, blended materials, or combinations, some of which may require moisture-conditioning, some a prime-coat, and others, something else. This level of diversity within the material category is such that all materials and processes cannot reasonably be included. The specification of construction equipment follows a similar challenge, and our attempt to provide detailed guidance on equipment necessarily involves selection of one mutually exclusive approach. For these reasons, the specification cannot include all the materials available for construction, or all the equipment that could (or should) be used.

Given these and other challenges, the specification attempts to strike a balance between the many ideals and realities of the edge repair process. As a draft specification, it is written to describe a robust or "high end" replenishing procedure intended to support some traffic load (it is not a pavement) and which is adaptable to many edge repair contexts. As has been noted, the specification includes certain materials and equipment at the expense of others.

9.4.3 The DRAFT Edge Repair Specification

Appendix C of this report includes a copy of an annotated version of the Draft Specification for Pavement Edge Drop-off Repair. The annotations provide background information and commentary explaining certain aspects of the specification, decision points and the like. These annotations are intended to assist reviewers in finalizing the specification.

The specification description makes it clear that the intended application is for repair of drop-offs along existing sections of roadway, and that the specification is not a stand-alone document. Its use requires, among other things, a plan sheet defining the limits of the project, general notes, and possibly a repair cross-section drawing.

The specification describes several options for edge repair materials and references these to TxDOT standard specifications where applicable. The specification also requires certain types of equipment necessary for the process.

As noted, the construction methods define a high-end replenishing process. If the user elects not to require all the steps, this could be explained in accompanying general notes. The specification also provides direction on measurement and payment.

9.4.4 The Specification Review Process

For the purposes of this research, the objective has been to write the "draft" specification, and this is complete. We performed an internal peer review based on input from the project team and the Project Monitoring Committee, and ultimately, issued the draft specification as the annotated version included in Appendix C, herein. The final product is now in the hands of TxDOT for their own formal review, approval, and implementation.

CHAPTER 10
RECOMMENDATIONS FOR ADDITIONAL RESEARCH

10.1 On-going Implementation Training

A highly beneficial aspect of this research is that it not only called for identifying the best practices for pavement edge maintenance (the subject of this report) but has also included a series of regional training workshops to implement these findings, statewide, at the maintenance section level. This regional training effort is complete, and the final report for this research project describes the training and implementation aspects in detail.

Since completion of the training, we have had repeated comments about its effectiveness and appropriateness for a wide audience, not only for maintenance personnel but also for engineering, construction, design and planning. Therefore, it is reasonable to recommend that the training program be continued as an ongoing implementation project in order to communicate best practices for pavement edge maintenance to all appropriate audiences within TxDOT, maintenance and otherwise.

10.2 Edge Repair Materials – Stabilizing RAP with Magnesium Chloride

In our site visits, we noted that District maintenance personnel use a wide variety of edge repair materials, and while different maintenance section supervisors have varying impressions about what works, there seems to be no systematic, structured understanding of their edge repair performance characteristics, cost/benefits, etc. This is particularly the case for variations on how to best use RAP.

One particularly intriguing practice we observed is that RAP is being effectively stabilized with the addition of magnesium chloride. The El Paso District of TxDOT, as well as the City of El Paso and the New Mexico State Highway and Transportation Department each have been utilizing RAP treated with magnesium chloride for both pavement edge maintenance and as a pavement surface course, akin to hot mix asphaltic concrete. Their applications appear to be working very well. However, it is not at all clear whether the success of the stabilized RAP is due to the gradation or asphalt content of the RAP, the environmental conditions (hot weather) under which the material is placed, the traffic load, the stabilization process, or of course, some stabilizing effect of the magnesium chloride.

This idea has generated a lot of interest around the State at our regional training workshops, so we feel that quality research into stabilizing RAP with magnesium chloride is worth doing.

10.3 Edge Repair Planning Tools

A key finding of this research has been that districts employ a variety of planning tools to help them accomplish pavement edge maintenance, especially the more extensive projects such as widening the road. Given the central importance of planning as a means to accomplish sound pavement maintenance strategy, we think it would be beneficial to synthesize the planning tools discussed herein and take a deeper, more systematic look into edge maintenance planning process. Such research may offer tremendous benefit to District Maintenance Section Supervisors, Engineers, and Directors of Operations as they seek to address edge drop-offs as a preventive maintenance issue.

10.4 FM Road System Upgrade Analysis

One of the most profound insights of this research has been that narrow roads, worn-out roads, and ubiquitous edge drop-offs across the State serve as a potent indicator that the FM Road System is over-extended beyond the purposes for which it was originally designed and built in the 1940s and 1950s. Our research clearly suggests that the edge drop-off problem is not just a maintenance issue but is more properly seen as evidence of a progressive systemic failure – a system-wide infrastructure concern.

Research into the current state of the FM System could provide insight to meaningfully inform transportation policy for years to come. Of course, this type of policy is addressed at the Transportation Commission level, but when the issue is pavement edge drop-offs, the policy concern is nevertheless valid. In the same way that the Commission embarked on an initiative some 50-60 years ago to “get the farmer out of the mud,” and this resulted in our current FM Road System, this edge repair research suggests too narrow roads, too much traffic, and too heavy traffic on the FM System today calls for political influence and a policy focus to ensure “the safe, effective and efficient movement of people and goods.” Research and analysis to define this matter within its proper socio-economic context seems in order.

APPENDIX A

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APPENDIX B

INTERVIEW QUESTIONNAIRE
TxDOT 0-4396: Improving Edge Repair and Stabilization

District: ____________________

DISTRICT MAINTENANCE PERSONNEL

No.	Name	Title	Yrs. Exp.	Contact No.
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				

DISTRICT MAINTENANCE DEMOGRAPHICS

11. Rural/ Metropolitan (% lane miles) ?______
12. Population served? ____________________
13. Total number of highway-lane miles?
    ____
14. Number of highway-lane miles without a shoulder? ___________________________
15. (a) % Low-volume (e.g., Rural FM, Rural State – ADT < _______?)
    ____
15. (b) %Low Vol. Rigid/Flexible ___________
16. (a) No. of District maintenance personnel?
    ____
16. (b) No. of Counties & Sections in District ?
    ____

17. ***District* Maintenance *Budget***
    a. 2001 ________________________
    b. 2000 ________________________
    c. 1999 ________________________

18. District Maintenance *Edge Repair* Budget
    d. 2001 ________________________
    e. 2000 ________________________
    f. 1999 ________________________

19. Other ______________________________
    ____

DEFINITION OF PAVEMENT EDGE DROP-OFF

20. Describe your District's procedure for identifying and documenting the edge drop-off problem; *i.e.*, how do you recognize that the edge drop-off problem exists?
    a. External (consumer) reports and complaints
    b. Lawsuits
    c. Random observation by TxDOT personnel
    d. Systematic/ statistical observation
    e. Routine (recurring) pavement condition assessment (TxMAP)
    f. Other
    g. Other

21. When do you consider edge drop-offs as a defect?
    a. Height of drop (& method of measurement & tolerance)
    b. Length of drop (& method of measurement & tolerance)
    c. Drop-off Angle (& method of measurement & tolerance)
    d. Other

22. Written (unwritten) standards you use to define this problem.
    a. TxDOT Standards
    b. FHWA Standards
    c. Other Standards

23. Do you rate the severity of individual edge drop-off defects? If so, how do you differentiate?

24. No. of lane miles for which the edge-drop-off condition exists in your District (frequency%)

CHARACTERIZATION OF TYPICAL PAVEMENT W/ EDGE DROP-OFF

Identify the three (3) most common roadway/pavement situations for which edge drop-offs occur in your District, and estimate the relative percentage of time edge drop-offs occur for each type. Use ***Questionnaire Supplement No. 1*** to provide detailed information for each example.

25. Example A (e.g., "FM Road w/ unpaved shoulder, especially at sharp turns")

a. Brief Description

____

b. Percentage of Edge Drop-off Cases

____

27. Example B.

c. Brief Description

____

d. Percentage of Edge Drop-off Cases

____

27. Example C.

e. Brief Description

____

f. Percentage of Edge Drop-off Cases

____

4 EDGE DROP-OFF MAINTENANCE REPAIR TECHNIQUES

For *your* District, please identify (i) the frequency of use and (ii) the expected life for the following edge drop-off maintenance techniques (District-wide). Please identify any additional techniques you use but are not listed below. Regarding frequency of use, rate these as [1-almost never, 2-occasionally, 3-often, 4 -very often]. Regarding the expected life of the repair, note this in *years*.

Frequency/Use	*Expected Life*	
______	______	28. Replenishing (on-site material) and compaction
______	______	29. Use of borrow materials (RAP, gravel etc.)
______	______	30. Use of chemical or other soil stabilizers
______	______	31. Pavement edge spray seal
______	______	32. Pavement marking
______	______	33. Temporary "fillet" edge patch
______	______	34. Correcting cross slope at outer edge of drive lane
______	______	35. Protective vegetation management
______	______	36. Erosion control features
______	______	37. Use of geosynthetic reinforcement
______	______	38. Retrofitting of drainage
______	______	39. Paved shoulder construction
______	______	40. Temporary warning signs
______	______	41. Other
______	______	42. Other

5 EDGE DROP-OFF MAINTENANCE REPAIR PROCEDURES and EQUIPMENT

43. What actions initiate an edge repair maintenance activity?
    a. Routine maintenance ___________________________
    b. Availability of funds ___________________________
    c. Condition survey and assessment ___________________________
    d. Visual ___________________________
    e. FWD or other means ___________________________
    f. Lawsuit ___________________________
    g. Other ___________________________
44. What percentage of edge repair work is done with in-house crews?
    ____
45. Basis for going with in-house vs. contract?
    ____
46. What is the range for the length of a typical edge repair job (in lane miles)?
    ____
47. What type of repair specification is used (a) in house? (b) for contract job? --- any examples available ?
    ____
    ____
48. Any design involved in producing the repair?
    a. Design Criteria ___________________________
    b. Materials ___________________________
    c. Structural ___________________________
    d. Who does it? ___________________________
    e. Consideration of fixed objects? ___________________________
    f. Any formal cost/benefit analysis among alternatives? ___________________________
    g. General notes on drawings/ specifications? ___________________________
49. What is the typical repair season for edge drop-offs?
    a. Preventative maintenance cycle? ___________________________
    b. Seasonal recurrence? ___________________________
    c. Non-repair season? ___________________________
50. Edge drop-off repair performance evaluation
    a. Life expectancy? ___________________________
    b. How to evaluate performance? ___________________________
    c. Indicators of premature failure? ___________________________
    d. In-house vs. contract ___________________________
    e. Any job control or quality control provision enforced? ___________________________
    f. Example QC/QA document?___________________________
51. Any specialized equipment used in your district? Please describe.
    ____
    ____
    ____
52. Any specialized innovations used in your District? Please describe.
    ____
    ____
    ____

53. Other

EDGE REPAIR TECHNIQUES – DETAILED DESCRIPTION

Identify the three (3) most common procedures used to repair edge drop-offs occur in your District, and estimate the relative percentage of time edge drop-offs occur for each type.

See ***Questionnaire Supplement No. 2*** to provide details of the most common procedures used in your District for each example.

54. Example A.

g. Brief Description

h. Percentage of Edge Drop-off Cases

55. Example B.

i. Brief Description

j. Percentage of Edge Drop-off Cases

56. Example C.

k. Brief Description

l. Percentage of Edge Drop-off Cases

57. Other information about edge drop-off maintenance in your District that we have not covered?

Questionnaire Supplement No. 1

TxDOT 0-4396: Improving Edge Repair and Stabilization

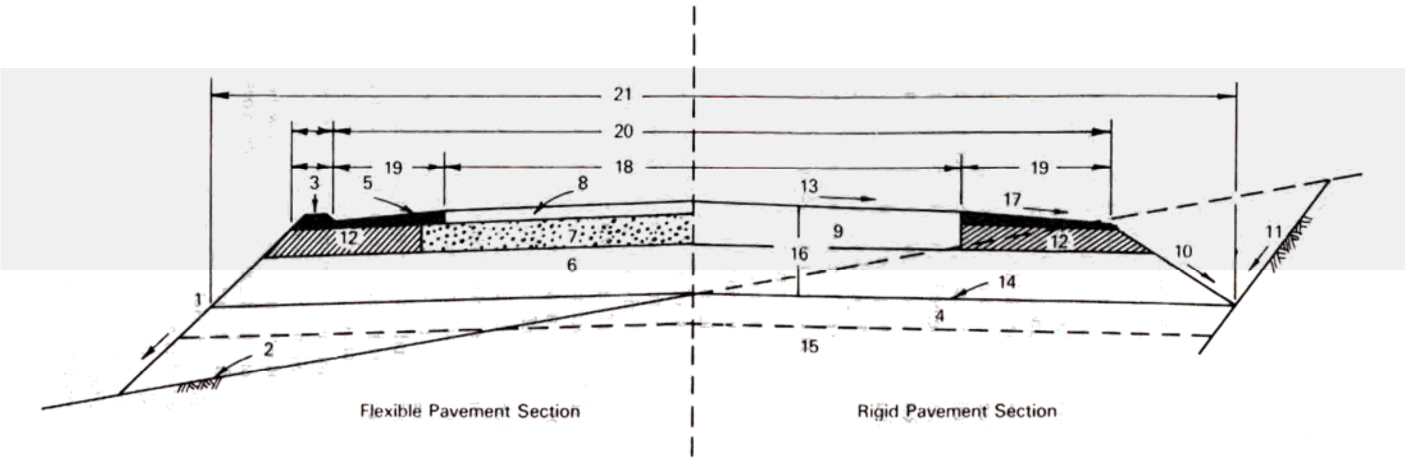
District: ____________________

CHARACTERIZATION OF TYPICAL PAVEMENT W/ EDGE DROP-OFF

A. BASIC DESCRIPTION: ____________________

B. EXAMPLES: ____________________

C. PERCENTAGE EDGE DROP-OFF CASES: ____________________



D. PAVEMENT STRUCTURE & CROSS SECTION (*refer to sketch*)

1. Fill slope ____________________
2. Original ground ____________________
3. Dike ____________________
4. Prepared roadbed ____________________
5. Shoulder surfacing ____________________
6. Subbase ____________________
7. Base course ____________________
8. Surface course ____________________
9. Pavement slab (rigid) ____________________
10. Ditch slope ____________________
11. Cut slope ____________________
12. Shoulder base ____________________
13. Crown slope ____________________
14. Subgrade ____________________
15. Roadbed soil ____________________
16. Pavement structure thickness ____________________
17. Shoulder slope ____________________
18. Travel lane(s) width ____________________
19. Shoulder width ____________________
20. Roadway width ____________________
21. Roadbed width ____________________

E. ROADWAY GEOMETRY

22. Horizontal Curvature
    a. None (straight) ______________
    b. Minor ______________________
    c. Sharp _______________________
    d. Limited sight distance? ________
23. Vertical Curvature
    a. None (flat) _________________
    b. Minor ______________________
    c. Steep _______________________
    d. Limited sight distance? ________
24. Fixed Objects Close to the outside edge of the travel lane (safety concern)
    a. None _______________________
    b. .____________________________

F. ENVIRONMENTAL CONDITIONS

25. Seasonal rainfall ___________________
26. Temperature variation _______________
27. Snowfall __________________________
28. General terrain (hilly or plain) _________
29. Water table _______________________
30. Primary soil type (fine or coarse-grained) ________________________
31. Problem soils (e.g., expansive clay) ____ ___________________________________
32. Other (e.g., dusting?) ________________

F. TRAFFIC

33. Average Annual Daily Traffic _________
34. Percent trucks ______________________
35. Percent oversize vehicles ____________
36. Type oversize? ______________________
37. Abusive Road shoulder use ___________

G. PAVEMENT MARKING

38. Lane marking @ outer edge? _________
39. Distinction between travel lane & shoulder (type, color, etc.) ____________ ___________________________________
40. Min^{m} lane width ____________________
41. Signage ___________________________
42. Condition of markings _______________

H. ROADSIDE VEGETATION & DRAINAGE

43. Roadside vegetation description ___________________________________
44. Condition of vegetation______________
45. Drainage type (sheet flow, bar ditch, subsurface edge drain, etc.) ___________________________________
46. Condition __________________________
47. Other ______________________________

I. PAVEMENT CONDITION WHEN EDGE DROP-OFFS OCCUR

48. Age ________________________________
49. Drive lane condition ________________
50. Shoulder condition ___________________________________
51. Potholes? __________________________
52. Scour? _____________________________
53. Break-offs __________________________
54. Pumping/soft subbase, subgrade _______
55. Any other condition detrimental to edge drop-off maintenance _______________ ___________________________________ ___________________________________

Questionnaire Supplement No. 2
TxDOT 0-4396: Improving Edge Repair and Stabilization

District: ____________________

TYPICAL EDGE REPAIR MAINTENANCE (DETAILED DESCRIPTION)

A. GENERAL

1. Brief description

   ____

2. What is the sequence of events in selecting this technique?

   ____

   ___

3. Does it depend on level of traffic? What level?

   ____

4. Is it a cyclic event? What is the cycle length?

   ____

5. Usually done with in-house crews or contract?

   ____

   a. Basis for choice?

      ____

   b. Difference in performance and design?

      ____

6. What existing pavement conditions are considered appropriate for this technique?

   ____

   ___

B. DESIGN

7. Do you do a "design", formal or otherwise?

   ____

8. Who performs the design?

   ____

9. What is the design procedure and what are the design criteria used?

   ____

   ___

10. Subgrade strength analysis?

    ____

11. What materials and thickness?

    ____

12. Drainage design

    ____

13. Cross slope and width

    ____

14. Use of any geosynthetic reinforcement

    ____

15. Other design considerations?

    ____

16. What general notes do you include?

    ____

C. CONTRACT

17. Who are the contractors that bid on such projects?

    ____

18. Does it go together with main lane repair contract?

    ____

19. How do you handle "measurement and payment"?____

    ____

    ___

D. MATERIALS

20. On site materials

    ____

21. Borrow materials

    ____

    a. Soil

       ____

    b. Coarse aggregate (such as gravel or crushed stone)

       ____

    c. RAP (reclaimed asphalt pavement)

       ____

22. Any chemical stabilizer (on site or borrow?)

    ____

    a. Dosage

       ____

    b. Curing time & methods

       ____

    c. Rejuvenator?

       ____

    d. Selection criteria

       ____

E. EQUIPMENT:

23. What equipment is used for this technique?

    ____

24. Any special cleaning equipment?

    ____

25. Any special compaction equipment

    ____

26. Other?

    ____

F. CONSTRUCTION:

27. What is the typical season and time for such repair?

    ____

28. Typical job duration

    ____

29. Construction sequence

    ____

a. Cleaning – use of broom ____________________

b. Hauling borrow materials ____________________

c. Grading ____________________

d. Edge sealing ____________________

e. Compaction – how much? ____________________

f. Pavement markings? ____________________

g. Installation of drainage facility ____________________

h. Installation of any protective vegetation ____________________

i. Cleaning ditches ____________________

30. Traffic control (before, during, and after construction) ____________________

 a. Use of signage ____________________

 b. Any diversion devices ____________________

G. SPECIFICATIONS AND JOB CONTROL:

31. Is there any written manual, procedure or specification for in-house or contract job? ________
32. If it is project by project basis – any example available? ____________________
33. Is there any QC/QA option? ____________________

 a. What properties are being checked and what are the tolerances? ____________________

 b. Any special tests or tools used to control quality? ____________________

 c. Is there any penalty for non-compliance? How do you resolve it? ____________________

34. Who does the job control inspection? ____________________
35. Who keeps the records and in what form? ____________________

H. PERFORMANCE

36. How do you evaluate performance? ____________________
37. What are the distresses considered? ____________________

38. What is the typical life span of an edge repair job? (age or traffic load)

____

I. CONTINUOUS MAINTENANCE

39. Is there any continuous repair of roadside potholes or ditches?

____

40. Regular maintenance of roadside markings?

____

41. Introduction of warning signs or pavement marks to indicate most vulnerable spots along the roadway

____

42. Any other pertinent information?

____

____

______

APPENDIX C

APPENDIX D