Report No. CDOT-DTD-96-12

Evaluation of Rumble Treatments on Asphalt Shoulders

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Final Report
December 1996

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

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ACKNOWLEDGEMENTS

Special thanks to the Research Study Panel, who provided input for this study and peer review of this report. The Research Study Panel consisted of Steve Horton (Staff Bridge), Dave Jessup (Staff Traffic), Ken Mauro (Staff Design), and Ken Wood (Region 4 Materials).

REPORT DOCUMENTATION PAGE

FORM APPROVED
OMB NO. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY (Leave Blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	December 1996	4 years

4. TITLE AND SUBTITLE
Evaluation of Rumble Treatments on Asphalt Shoulders

5. FUNDING NUMBERS

6. AUTHORS(S)
David A. Price

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(S)
Colorado Department of Transportation
4201 E. Arkansas Ave.
Denver, Colorado 80222

8. PERFORMING ORGANIZATION REPORT NUMBER
CDOT-DTD-96-12

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(S)
Colorado Department of Transportation
4201 E. Arkansas Ave.
Denver, Colorado 80222

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
CDOT-DTD-96-12

11. SUPPLEMENTARY NOTES
Prepared in Cooperation with the U.S. Department of Transportation, Federal Highway Administration

12a. DISTRIBUTION/AVAILABILITY STATEMENT
No Restrictions: This report is available to the public through the National Technical Information Service. Springfield, VA 22161

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

The chip seal used for shoulder rumble effect produced an effective audible response with a noise difference from the driving lane to the shoulder of 3.8 db. The chip seal also produced a highly visible delineation between the shoulder and the driving lane. This type of treatment has three benefits. Two of the benefits are directly safety related, rumble effect to notify the errant driver that they have entered the shoulder and the visual effect given by the well delineated shoulder. The third benefit is a temporary fix to a badly deteriorating shoulder without the cost of major reconstruction until a later Rumble strips rolled into the shoulder during repaving were very noticeable when leaving the driving lane and appear to be an effective safety item on rural roadways where run-off-road accidents are common. Rumble strips can be placed with little problem during construction if asphalt temperatures are monitored during project startup.

14. SUBJECT TERMS
Rumble Strips
Chip Seal
Rumble Treatments
Run-off-Road Accidents
Asphalt Shoulders

15. NUMBER OF PAGES

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	

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Site Location Map SH-63 Rolled in Rumble Strip A-3

I. INTRODUCTION

Single car runoff the road accidents are one of the most common and severe types of accidents we experience on rural highways. There has been much written as to the effectiveness of shoulder rumble strips to prevent these types of accidents but the Colorado Department of Transportation has no standard details and specifications to implement this safety item on asphalt roadways.

Colorado accident records show that annually between 40 and 45% of all fatal highway crashes are of the single car run-off-road type. This type of accident is responsible for more fatal accidents than any other single type of crash in Colorado. Once a vehicle has left the roadway, there is a very good possibility of some type of serious accident occurring by either rolling, or colliding with some type of roadside obstacle. This problem may greatly be reduced if the shoulder can produce a vibratory and audible trigger to alert the errant driver before he strays off the shoulder.

II. RUMBLE TREATMENTS

FHWA Technical Advisory T5040.29, dated February 2,1990, deals with the recommended practices for the design of paved shoulders. The advisory states the following about textured shoulders. "Shoulder texture treatments that provide an audible/vibrational warning to errant drivers have proven effective in keeping traffic off the shoulder and reducing accidents on long tangent or monotonous highway sections with a history of run-off-the-road accidents."

Treatments include rumble strips either rolled, or cut in the shoulder and the use of chip seal placed on the shoulder. The advisory states that for new pavements, rumble strips should be rolled into the pavement with a steel roller. Typically the indentations are spaced 8 inches apart and 3/4 inch to 1 inch deep. Most States offset this treatment 6 to 12 inches from the edge of the mainline pavement and typical treatment width is 3 feet. Colorado is presently looking at placing a new standard that specifies a typical spacing of 8 to 10 inches, 6 inches from the mainline pavement with a typical width of 1.5 to 2 ft.

The bituminous surface treatment (chip seal) effectiveness is largely dependent upon the gradation of aggregate used. The advisory states that treatments containing 3/4 inch to 1 inch stone have been observed to be very effective as an alerting texture. Figure 1 shows various treatment specifications for asphalt shoulders using a chip seal by states presently using them in there plan specifications.

State	Appl	1-1/2"	1"	3/4"	1/2"	3/8"	#4	#8	#200	#/sy
AZ	1st	—	—	100%	70-90%	—	0-25%	0-5%	0-2%	40-45
	2nd	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
MS	1st	100%	90-100%	20-90%	0-10%	0-5%	—	—	—	50-55
	2nd	—	—	100%	90-100%	40-85%	0-15%	0-5%	—	25-30
NC	1st	—	100%	90-100%	20-55%	0-15%	0-5%	—	—	25-35
	2nd	—	—	100%	95-100%	75-100%	20-45%	0-15%	—	10-12

Figure 1 - Stone Aggregate Gradations (Percent Passing by Weight)

Two types of treatments were tried for the first time in Colorado during the 1991 construction season. They were continuous rumble strips that were placed into the hot asphalt at time of

construction with a specially designed roller, and the other was a chip seal using a maximum 1 inch chip. Both methods appear to be effective at getting the attention of the driver of a vehicle passing over them. However, the continuously rolled rumble strip appears to grab the attention of the driver the most effectively, due to the variation in noise when driving over the strips. Three sites were monitored for construction difficulty, safety, and durability. Rumble strips were rolled into the pavement on two sites, (SH-14 east of SH-71, and SH-63 south of Akron) the third site incorporated the use of a bituminous surface treatment or commonly called chip seal placed on I-76 east of Denver.

The chip seal gave an added benefit to just repairing the poor condition of the shoulder, it also provided an audible/vibrational warning to any driver leaving the roadway and giving the driver a well delineated shoulder when driving from the concrete roadway to the asphalt shoulder.

A. Chip Seal

The project IR(CX) 76-1(152) is located along both directions (east and west bound lanes) of I-76 between MP 13.87 and MP 16.37. It consisted of planing existing asphalt mat shoulders to a depth of 3/4 inches, followed by the application of a 1 inch maximum size chip seal to provide an audible/vibrational warning to errant drivers. Photos 1 thru 8 show the milling process and chip placement. This project is basically a safety project with the added benefit of partially restoring the deteriorating shoulders until funding can be made available for reconstruction. This stretch of highway is concrete with badly deteriorating asphalt shoulders, and was known to have a high incidence of run-off-the-road accidents.

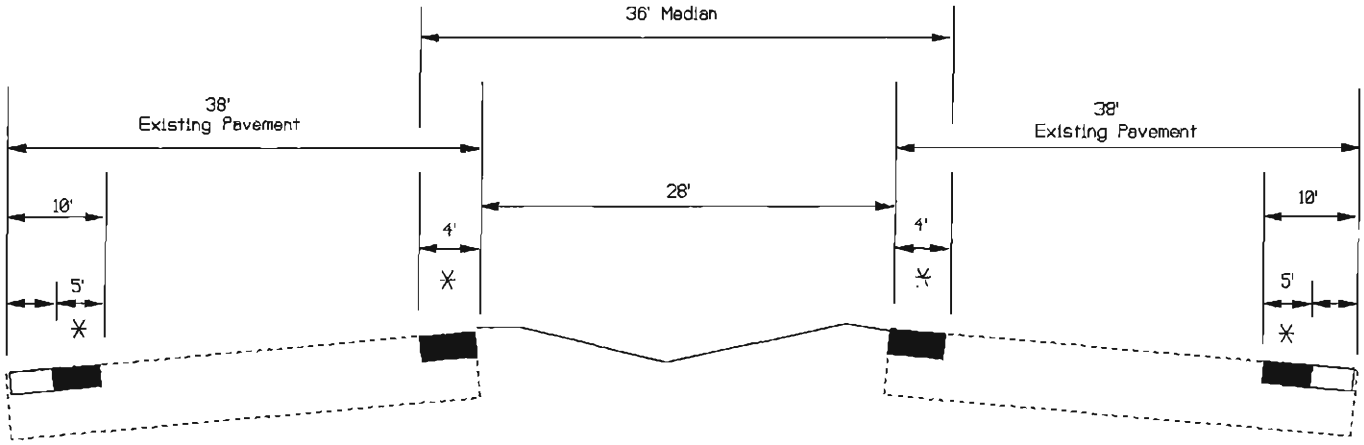
Accident reports taken from January 1,1988 to December 31,1988 show that seven single car

accidents with four injuries occurred within this stretch of highway with six being listed as off roadway accidents. During the same period in 1987, 9 single car accidents occurred and 2 two car accidents. Of these accidents one person was killed and ten were injured. Eight of these accidents were listed as off roadway accidents. The same pattern was seen in 1986 with 10 accidents, seven of which were listed as off roadway accidents. This data demonstrates a problem existed within this area. The use of a chip-seal was felt to be a temporary solution to the problem of the motorist running off the roadway until further funds were available for reconstruction in this area. The original plans for size of the chip-seal came from the February 2,1990 FHWA Technical Advisory (T 5040.29). This advisory showed gradation charts for two states that have placed a chip-seal on their shoulders for safety purposes, North Carolina and South Carolina. The Colorado DOT used the same gradation as South Carolina.

Construction began during the last week of May 1991 with the planing of the shoulder as shown in figure 2. The figure shows that the 10 foot outside shoulder was planed 5 foot wide from the existing concrete driving lane. The purpose behind placing the chip seal for only 5 feet rather than full width was to allow a smooth section for bicycle traffic. The inside shoulder was planed for the full width of 4 feet.

Chip seal gradations are shown below in figure 3 for the eastbound outside and inside shoulders. The westbound outside shoulder used this same gradation, however, during construction of the 4-foot inside shoulder the chip-seal gradation was changed to a 3/4 inch maximum size. This was done, due to safety concerns about the 1" chip being displaced and thrown into traffic.

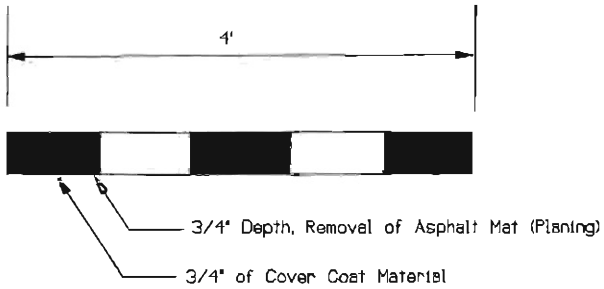
Figure 2
Project IR(CX) 76-1(152)
Typical Section
(Chip Sealed Shoulders)



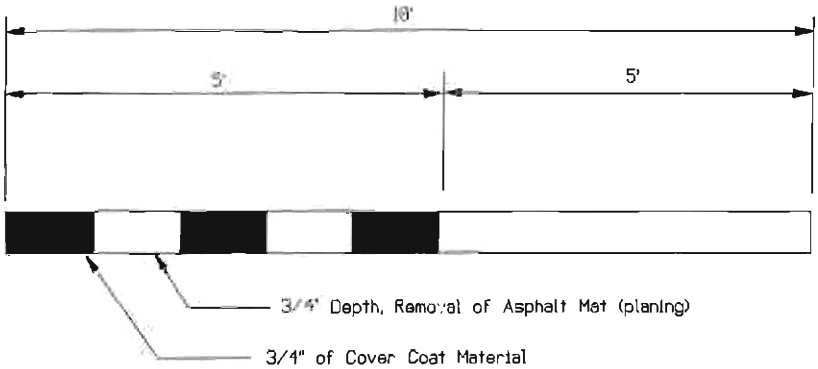
* Shoulder Areas to be Planed and Chip Sealed. (no scale)

Planing and Chip Seal Detail

Detail 4' on Inside Shoulders



Detail 10' on Outside Shoulder



Sieve Size	Percent by Weight Passing
1 inch	90-100
3/4 inch	20-55
1/2 inch	0-10
3/8 inch	0-5
#4	----
#8	----
#16	----
#100	----
#200	0-1.5

Figure 3 - Chip Seal Gradations

Specified application rates of emulsified asphalt and cover coat material were:

Emulsified Asphalt (Rapid-setting) (Polymerized)...@ 0.40 gal./sq.yd.

- Cover Coat Material (Special)(3/4 inch thick).....@ 45 lbs./sq.yd.

Due to the large size of the cover coat material emulsified asphalt quantities had to be increased so the chip-seal would remain in place. Emulsified asphalt was increased to 0.90 gal./sq.yd. Emulsified asphalt was also shot over the top of the chip-seal at a quantity of 0.25 gal./sq.yd. to help hold the chips in place. This gave a total of 1.15 gal./sq.yd for the project.

1. Noise Meter Testing on Chip Seal

A Noise meter built by Quest Electronics model M-28 was used for obtaining noise data. The comparison was performed between the adjacent highway driving lane and the chip-sealed shoulder. Vibration is also a very important part to the effectiveness of rumble strips in waking an errant driver to the condition. However, at this point we have no instruments within the department that can measure the magnitude of vibrations, so only noise readings were taken. The noise meter was placed on a tripod above the transmission hump of a 1989 Dodge Aries K wagon. The noise meters microphone was than placed at a height that would be in the general area of the drivers ear. Tests were taken at a highway speed of 55 mph for a duration of one tenth of a mile. Results are shown in Table A. Figure 4 shows the overall results of the testing by lane and shoulder.

The readings are in decibels. Decibels are a measure on a logarithmic scale. For this purpose direct comparisons are difficult. If two identical sound sources were to be placed side by side the increase in the sound level would be 3 db.

Looking at the westbound driving lane and outside shoulder in figure 4 it can be seen that there is an increase of 3.8 db at 55 mph between the two which is a noticeable difference. The passing lane or inside lane was consistently quieter than the driving lane. This was due to the

there is an increase of 3.8 db at 55 mph between the two which is a noticeable difference. The passing lane or inside lane was consistently quieter than the driving lane. This was due to the fact that the driving lane is much more deteriorated and rougher than the passing lane. The westbound inside shoulder was chip-sealed with a smaller gradation of maximum size 3/4 inches. The sound levels were lower in this area however, the overall change in sound levels was 5.9 db which was again a noticeable difference.

One thing that was noticed in this area compared to standard rumble stripes is that the sound caused by the chips is heard at first and noticeable, however, it is a constant noise level. If the motorist does not recognize the sound when he or she first enters the shoulder the sound does not vary, but just becomes normal road noise. Rumble strips vary the sound level back and forth allowing the decibel variation to become more of a factor. The chip-seal also gives the added benefit of a visible delineation between the white concrete driving lanes and the shoulder that should help the motorist.

Louisiana is one state that is presently using a coarse aggregate chip seal in its standard design for rumble effect at intersections and shoulders.

Table A
RUMBLE TREATMENTS ON ASPHALT SHOULDERS
Chip Seal for Rumble Effect
Project IR(CX) 076-1(152)
6/9/91
Noise Meter Results

Eastbound Lanes - Inside Driving Lane (CONCRETE)

	Run 1	Run 2	Run 3	Logarithmic Avg.
LEQ	75.00	80.50	75.80	77.83
PEAK	109.50	106.80	106.80	107.90
MAX	78.00	84.00	79.80	81.35

Eastbound Lanes - Inside Shoulder (CHIP-SEAL)
1" MAX CHIP SIZE

	Run 1	Run 2	Run 3	Logarithmic Avg.
LEQ	80.90	80.50	82.40	81.35
PEAK	107.60	108.30	112.80	110.22
MAX	84.00	85.80	85.50	85.17

Eastbound Lanes - Outside Driving Lane (CONCRETE)

	Run 1			
LEQ	82.30			
PEAK	108.70			
MAX	84.70			

Eastbound Lanes - Outside Shoulder (CHIP-SEAL)
1" MAX CHIP SIZE

	Run 1			
LEQ	87.10			
PEAK	109.50			
MAX	91.50			

Westbound - Inside Shoulder (CHIP-SEAL)
3/4" MAX. CHIP SIZE

	Run 1	Run 2	Run 3	Logarithmic Avg.
LEQ	81.00	81.00	79.20	80.48
PEAK	110.60	108.00	108.00	109.05
MAX	82.80	82.10	81.70	82.22

Westbound - Inside Passing Lane (CONCRETE)

	Run 1	Run 2	Run 3	Logarithmic Avg.
LEQ	72.90	72.20	77.10	74.64
PEAK	109.80	103.80	102.00	106.54
MAX	76.10	79.50	80.60	79.11

Westbound Outside Shoulder (CHIP-SEAL)

1" MAX CHIP SIZE

	Run 1	Run 2	Run 3	Logarithmic Avg.
LEQ	83.30	80.90	81.30	81.97
PEAK	108.70	106.50	110.60	108.91
MAX	87.00	82.50	85.80	85.48

Westbond Outside Driving Lane (CONCRETE)

	Run 1	Run 2	Run 3	Logarithmic Avg.
LEQ	75.20	81.10	75.30	78.15
PEAK	103.50	110.20	105.70	107.38
MAX	79.10	85.10	78.70	82.03

Logarithmic average calculated using formula from
FHWA Noise Prediction Model.
10*LOG((ALOG(0.1*(run1))+ALOG(0.1*(run2))+ALOG(0.1*(run3)))/3)

I-76 SHOULDER CHIP SEAL

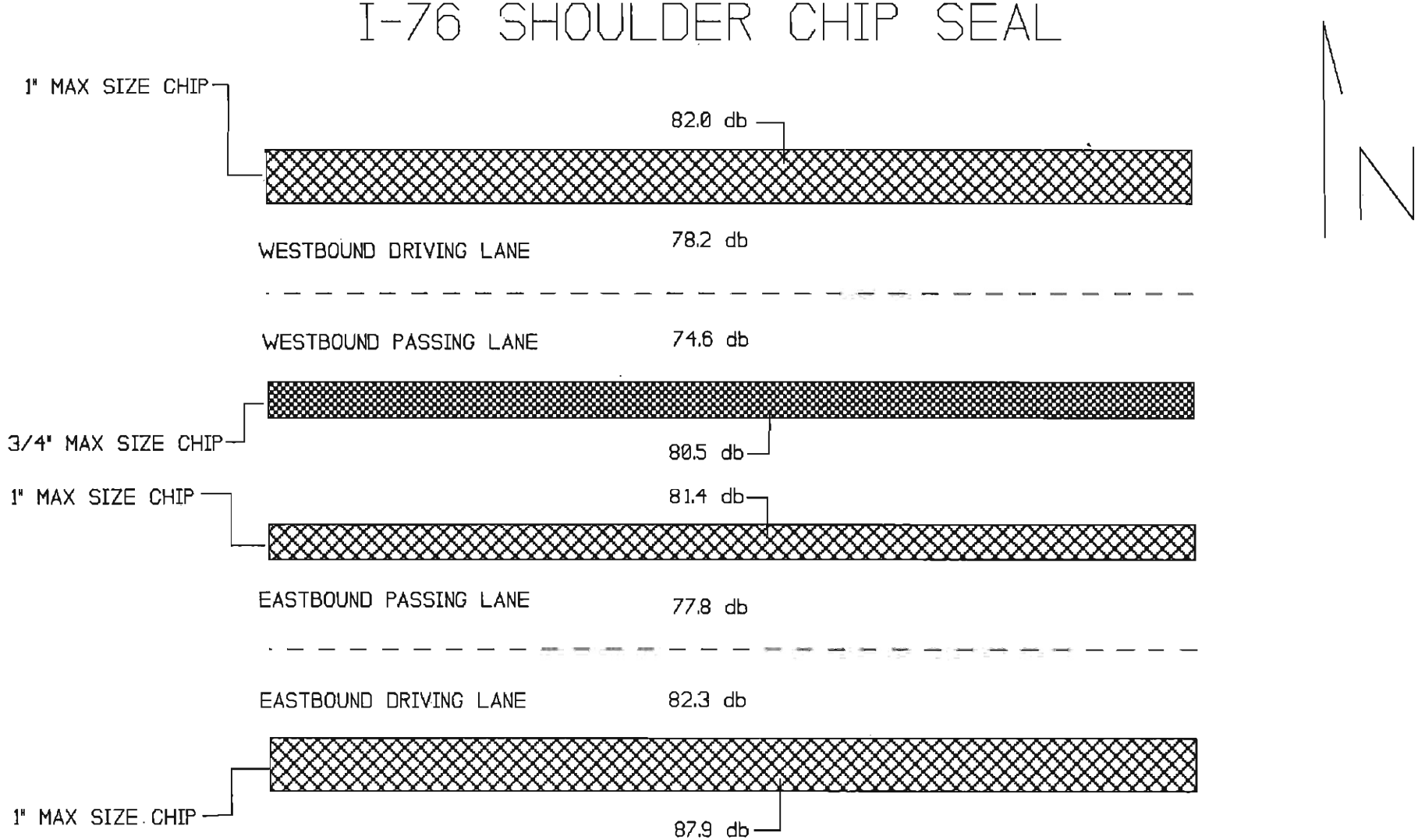


Figure 4

Photo 1 - Eastbound lanes I-76 between MP 13.87 and MP 16.37. Five foot of the outside shoulder was planned 3/4 of an inch and four foot of the inside shoulder was planned.

Photo 2 - Planning was performed to a depth of 3/4 of an inch.

Photo 3 - Emulsified asphalt was rapid-setting, polymerized placed at 0.9 gallons per square yard. Original plans called for 0.4 gallons per square yard.

Photo 4 - Placement of the aggregate for the chip seal.

Photo 5 - The cover coat material was placed at 45 lbs./sq.yd.

Photo 6 - Five feet of the outside shoulder was left uncovered by the chip seal for bike traffic.

Photo 7 - The chips were rolled into the emulsified asphalt first by a rubber tired roller and then followed by a lite weight steel roller.

Photo 8 - Same as above.

B. Rumble Strips

During the 1991 construction season several projects in Colorado incorporated rumble strips that were rolled into the shoulder during overlay construction. The detail for construction on SH-14 (figure 5) shows the rumble strip to be placed 12 inches from the lane edge strip, 18 inches long, 8 to 9 inches apart and 1-1/4 inches deep.

Construction began on SH-14 just east of SH-71 in July of 1991. Photos 8 and 9 show the roller that the contractor manufactured to place the rumble strips into the new mat. The contractor cut 2-1/2 inch steel pipe in half and welded them to a steel drum. This drum was than mounted onto the roller using a hydraulic arm to lift it up and place it into position. Water was sprayed onto the fabricated drum to reduce the amount of asphalt sticking to it. The cost to place this strip amounted to the cost of one extra roller operator.

These strips were placed behind the breakdown roller with the pavement at a temperature of 225 degrees F. The mat was a 1-1/2 inch Colorado spec grading F, (a gradation that 85% passes a #8 screen). The ideal temperature for rolling in rumble strips will vary depending on the thickness of the mat and the gradation of the asphalt being placed. The rumble strips placed on SH-14 were placed with little problem and are very noticeable when driven over. The ease in which the strips were placed may be partly due to the small aggregate size of the mat. All costs for rumble strips on this project were included in the bid price for the H.B.P (Gr. F). The finished product is shown in photos 10 and 11. Figure 5 shows the rumble strip detail and the site location can be seen in appendix A.

For three years following construction no distress was observed in the area of the rumble

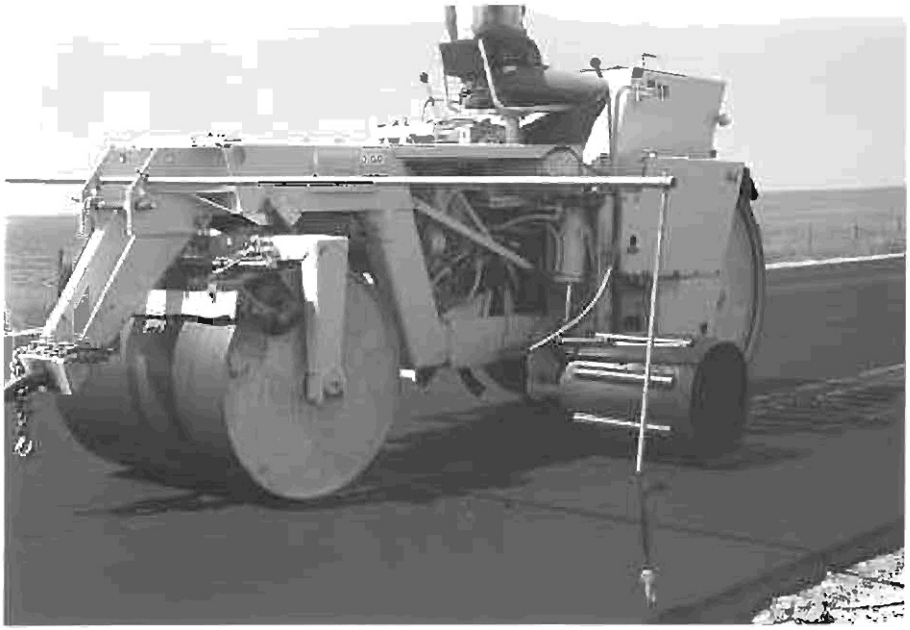


Photo 9 Rumble strips rolled into shoulder with modified hydraulic roller attachment during repaving.

Photo 10 · Same as photo 9.

Photo 11- Finished rumble srip on SH-14.

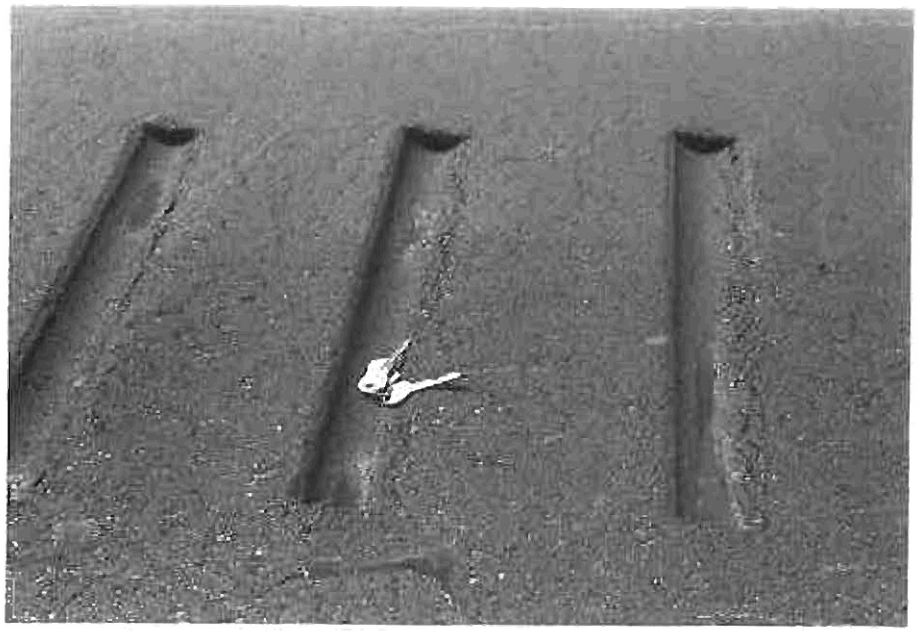
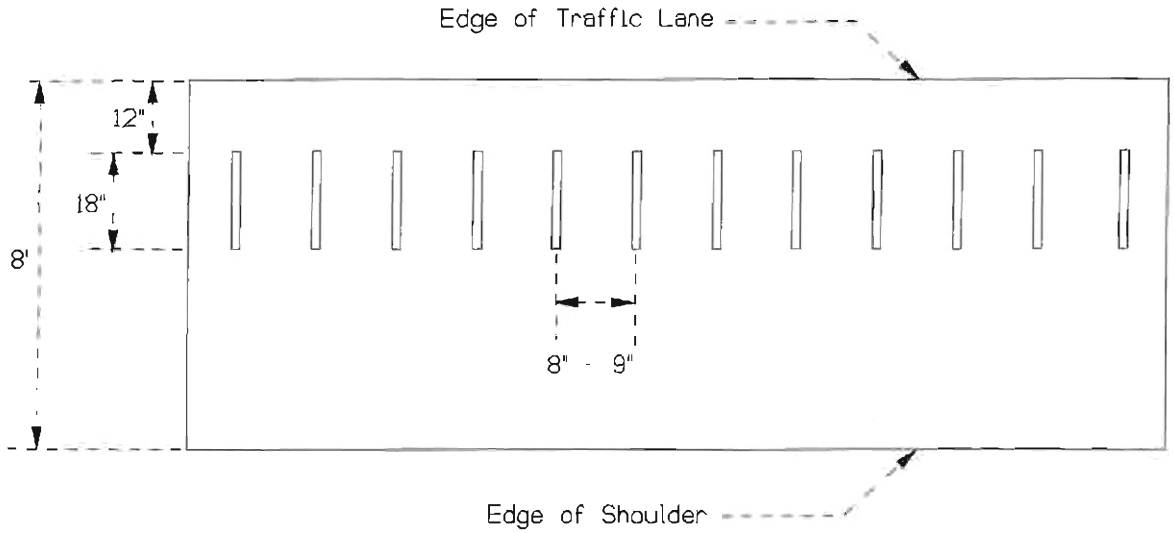


Photo 12 - Photo shows good penetration by modified roller into shoulder overlay producing a a well defined rumble strip.

Photo 13 - Rumble strips being placed on SH-63 south of Akron.

Photo 14 - Rumble strip without proper depth due to low asphalt temperature during placement.

DETAIL OF RUMBLE STRIP



STEEL DRUM DETAIL

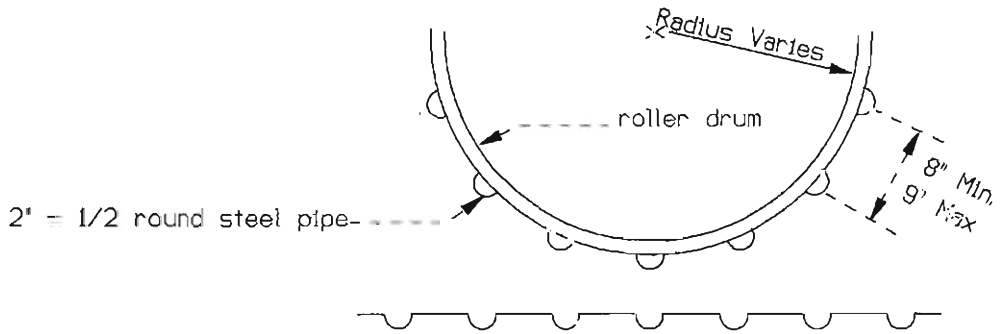


Figure 5

strip placement however, the asphalt in the area of the rumble strip is less compacted providing a lower density at that point than the rest of the pavement and may become a problem in the future. Another concern with rumble strips is the accumulation of gravel within the rumble strip grooves. However, the test locations did not show this to be a problem. Gravel was blown out of the grooves by traffic and appeared to be in good structural condition.

II. ACCIDENT DATA

Accident data was collected on the rolled rumble strip shoulder for a period of four years before placement in 1991 to four years after in 1995. The two sites investigated for rumble strips combined to a total of seven miles of rural highway. The data collected did not show enough accident activity for a true statistical analysis however, the data may show some trends.

SH-14 during the period for four years before the placement of the rumble strips showed three off-road-accidents occurring. The road was icy in one of these accidents. For four years after the rumble strip placement two accidents occurred with both happening during icy road conditions. The rumble strips do nothing during icy conditions, so the possibility of the rumble strip helping in this area may be significant even with limited data. The four miles on SH-63 four years before the placement of rumble strips showed zero accidents as well as zero accidents for four years after placement of the rumble strip. This site does not show any decrease in accidents due to the placement of rumble strips however, it also does not show any increase due to there placement.

The chip sealed section was overlayed six months after being placed due to unexpected reconstruction funds for this area. This section did have a high run-off-road accident history however, there was an insufficient amount of time after the chip seal placement to evaluate the

safety side of this type of construction.

Previous studies performed by various states have proved that rumble strips are an effective way to reduce run-off-road accidents. A study completed by the Louisiana Transportation Research Center stated the following about safety aspects on exposed aggregate rumble strips: A comparison of accident report statistics indicates that, after installation of coarse, exposed aggregate rumble strips, there is a slight reduction in both the quantity and severity of accidents. Accident reports that covered a four-year period, two-years before and two-years after installation, demonstrated that 58.6% of all accidents occurred prior to installation. Louisiana Transportation Center also showed an analysis of the time-of -day in which accidents were most likely to occur demonstrated that two-thirds of all accidents were during daylight hours. Daylight accidents within the rumble strip sections dropped 4.7% from the period before placement of the rumble and nighttime accidents dropped 50%

III. CONCLUSIONS

The chip seal used for shoulder rumble effect produced an effective audible response with a noise difference from the driving lane to the shoulder of 3.8 db. The chip seal also produced a highly visible delineation between the shoulder and the driving lane. This type of rumble treatment has three benefits. Two of the benefits are directly safety related, rumble effect to notify the errant driver that they have entered the shoulder and the visual effect given by the well delineated shoulder from the driving lane where the driving lane is concrete. The third benefit of the chip seal is a temporary fix to a badly deteriorating shoulder without the cost of major reconstruction until a later date.

Rumble strips rolled into the shoulder during construction were very noticeable when leaving the driving lane and appear to be an effective safety item on rural roadways where run-off-road accidents are common. The rumble strips can be placed with little problem during construction if asphalt temperatures are monitored during project startup for ideal rumble strip placement. This temperature will vary depending on the mix type and the depth of the mix used on the project. The primary cost of this type of rumble strip placement is the cost of one extra roller operator and the modification of an existing roller to place the strips.

Rumble strips have been proven to be effective for safety in hazardous run-off-road locations and with the use of the rolled in rumble strip during construction the safety can be improved on rural highways. CDOT is presently developing a standard for asphalt rumble strips that specifies a typical spacing of 8 to 10 inches apart and 6 inches from the edge of mainline pavement with a typical width of 1.5 to 2 inches.

IV. IMPLEMENTATION

Chip seals have the added benefit of being an efficient way to prolong the life of a badly deteriorated shoulder as well as at the same time place an audible rumble effect that can increase safety by deterring the errant driver from leaving the driving lanes.

Both continuous rolled rumble strips and chip seals should be considered during overlay construction.

APPENDIX A

SITE LOCATIONS

NO REVISIONS REVISED VOID

STATE DEPARTMENT OF HIGHWAYS

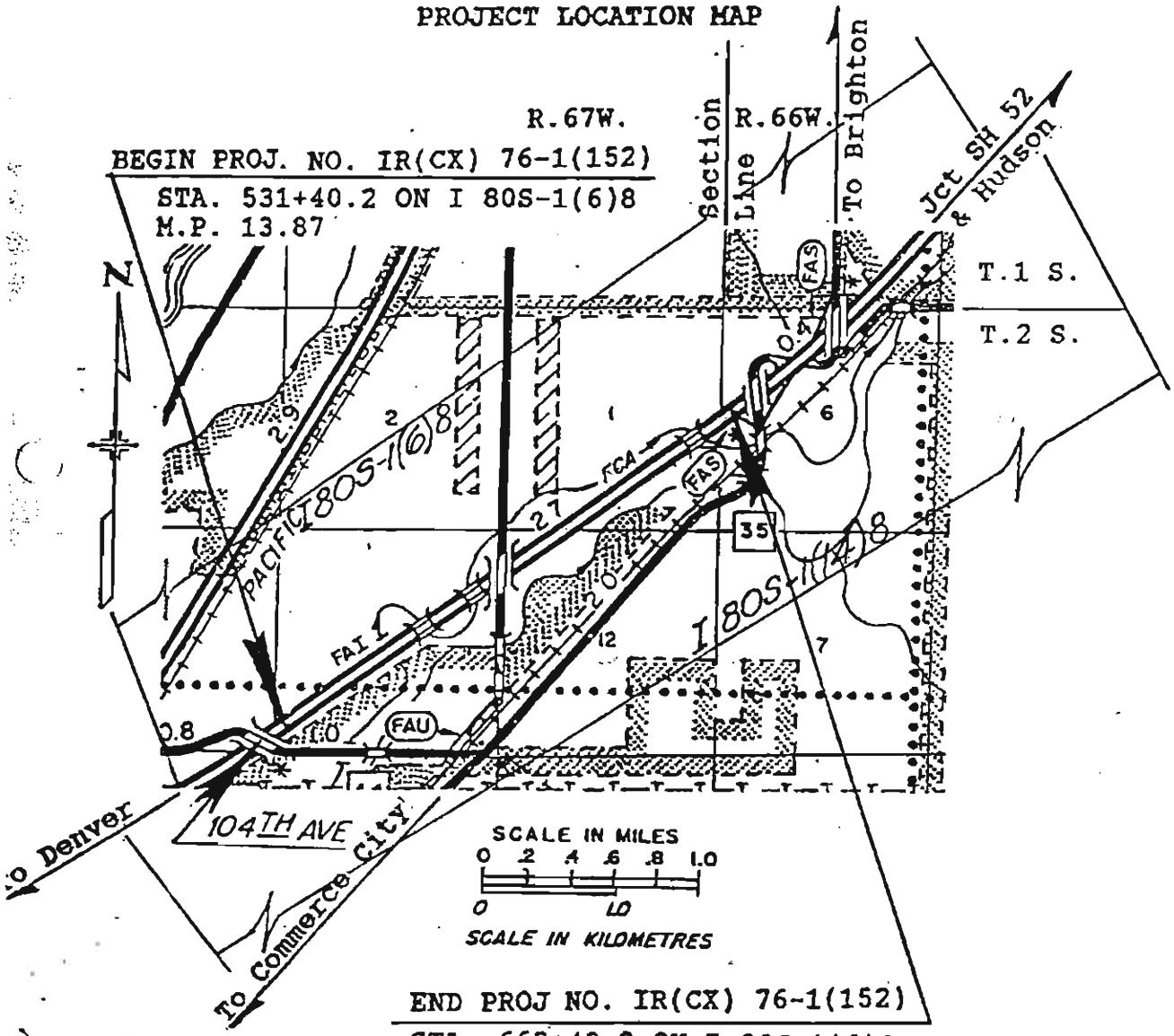
DIVISION OF HIGHWAYS—STATE OF COLORADO

FEDERAL AID PROJECT NO. IR(CX) 76-1(152)

STATE HIGHWAY NO. 76

ADAMS COUNTY

PROJECT LOCATION MAP



BEGIN PROJ. NO. IR(CX) 76-1(152)
STA. 531+40.2 ON I 80S-1(6)8
M.P. 13.87

END PROJ NO. IR(CX) 76-1(152)
STA. 663+40.2 ON I 80S-1(6)8
M.P.16.37

AS CONSTRUCTED INFORMATION

P.E., R.O.W. & UTILITIES
UNDER PROJ. FR014-2(18)

STATE DEPARTMENT OF HIGHWAYS
DIVISION OF HIGHWAYS—STATE OF COLORADO

PLAN AND PROFILE OF PROPOSED
FEDERAL AID PROJECT NO. FR(CX)014-2(23)
STATE HIGHWAY NO. 14
WELD & LOGAN COUNTIES

SCALES OF ORIGINAL DRAWINGS
ON PLAN, 1 IN. = 100 FT.
ON PROFILE { 1 IN. = 100 FT. HORIZONTAL
1 IN. = 10 FT. VERTICAL

STA 2040+00 BEGIN FR(CX)014-2(23)
STA 2040+00 END FR014-2(19)
STA 2040+00 ON S0024(11)
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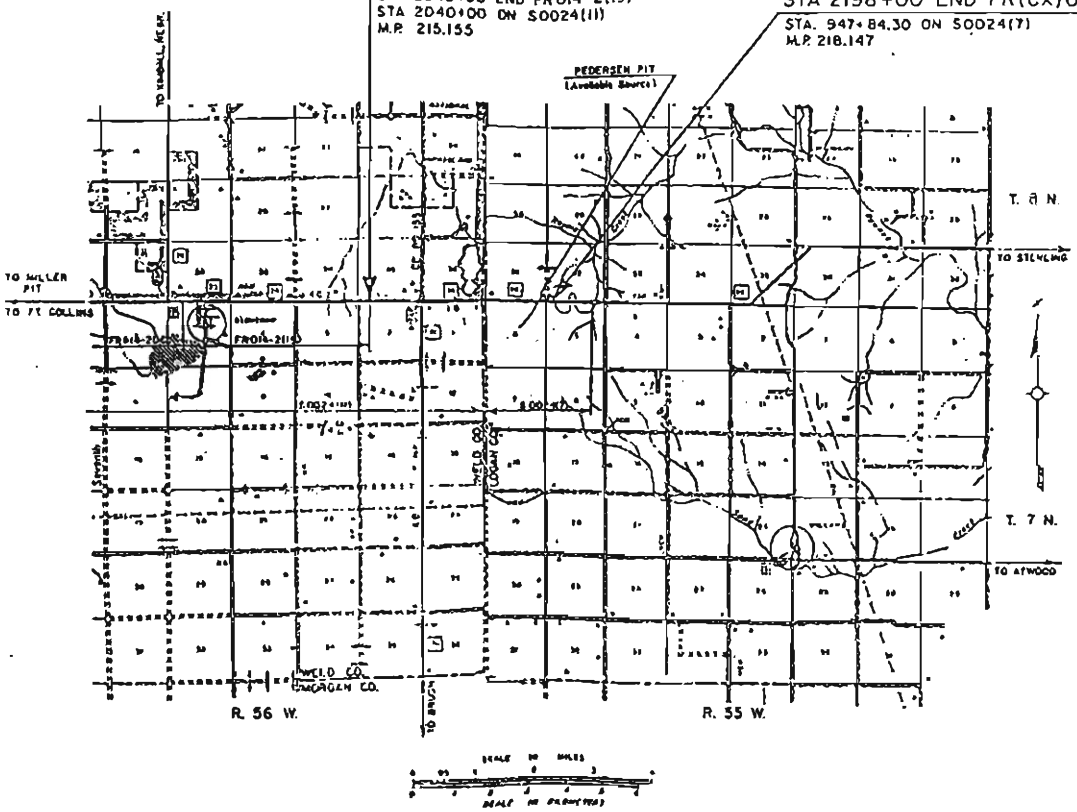
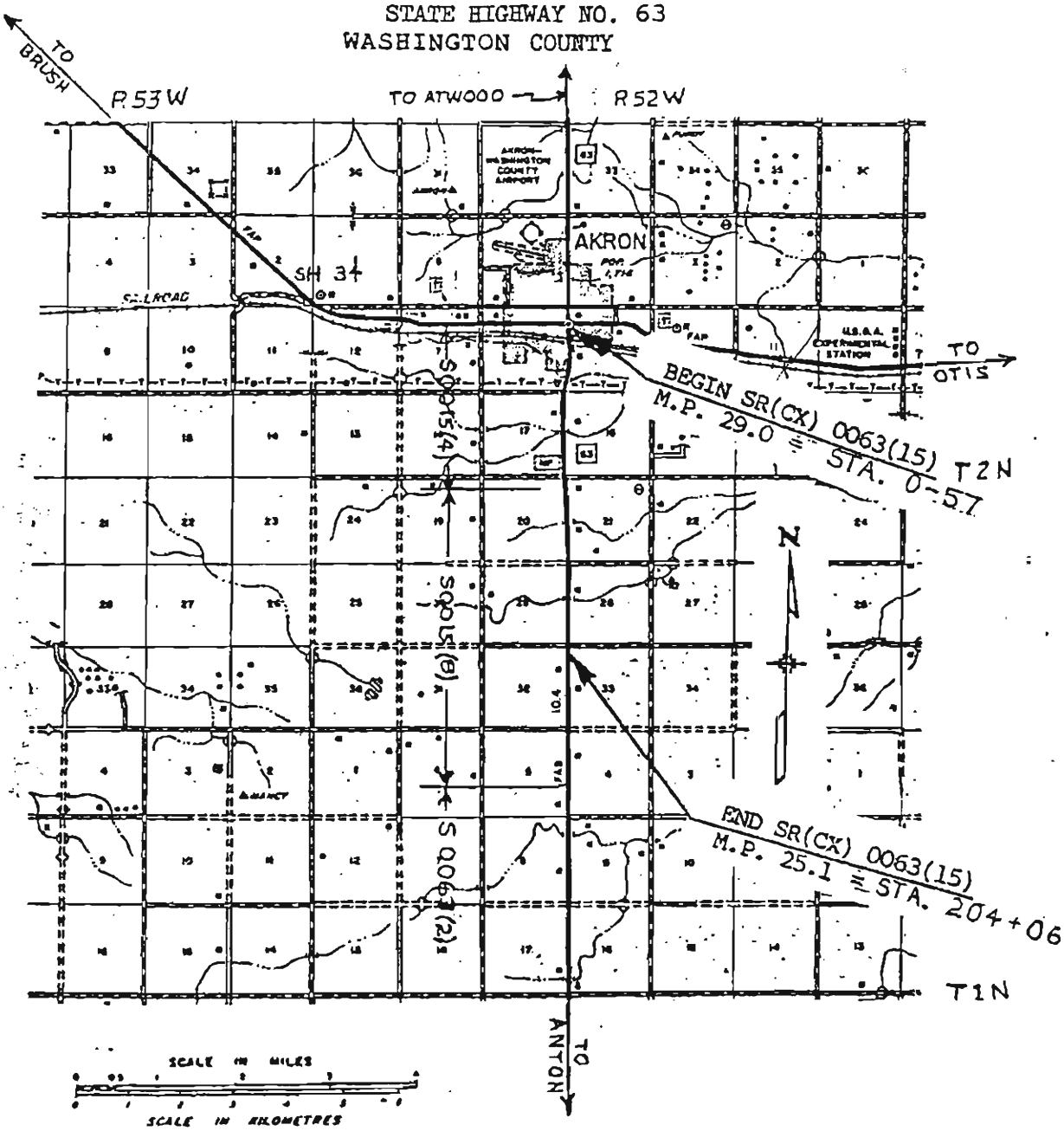
STA. 947+84.30 ON S0024(7)
M.P. 218.147



STATE DEPARTMENT OF HIGHWAYS
DIVISION OF HIGHWAYS - STATE OF COLORADO
COLORADO PROJECT NO. SR(CX) 0063(15)
STATE HIGHWAY NO. 63
WASHINGTON COUNTY