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16. ABSTRACT
Sections of grooved and painted traffic stripes were evaluated for visibility under various conditions at three locations: In a mountainous area elevation at about 6000 feet where heavy snow is prevalent in winter, in a foothill area where no snow is expected, and in the valley also where no snow is expected and where the terrain is very flat.

In the mountainous areas, all paint was removed after the first snow falls due to chain action, snow plowing and sanding operations.

In the foothill and valley areas, under wet nighttime conditions, the groove stripes were generally superior to the regular stripe though not as good as a raised marker line. While the initial cost of a groove and painted stripe is about six times that of a regular painted stripe, the annual cost of a grooved stripe over a 20-year period would be about 60% greater than a plain stripe.

It was concluded that a grooved stripe is not a satisfactory solution to the problem of lane line delineation in snow plow areas, and where no snow is expected, the raised marker type line is best.

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HIGHWAY RESEARCH REPORT

EVALUATION OF GROOVED TRAFFIC STRIPES ON PORTLAND CEMENT CONCRETE HIGHWAYS

FINAL REPORT

STATE OF CALIFORNIA

BUSINESS AND TRANSPORTATION AGENCY

DEPARTMENT OF PUBLIC WORKS

DIVISION OF HIGHWAYS

MATERIALS AND RESEARCH DEPARTMENT

RESEARCH REPORT

CA-HY-MR-5193-1-72-31

Prepared in Cooperation with the U.S. Department of Transportation, Federal Highway Administration September, 197

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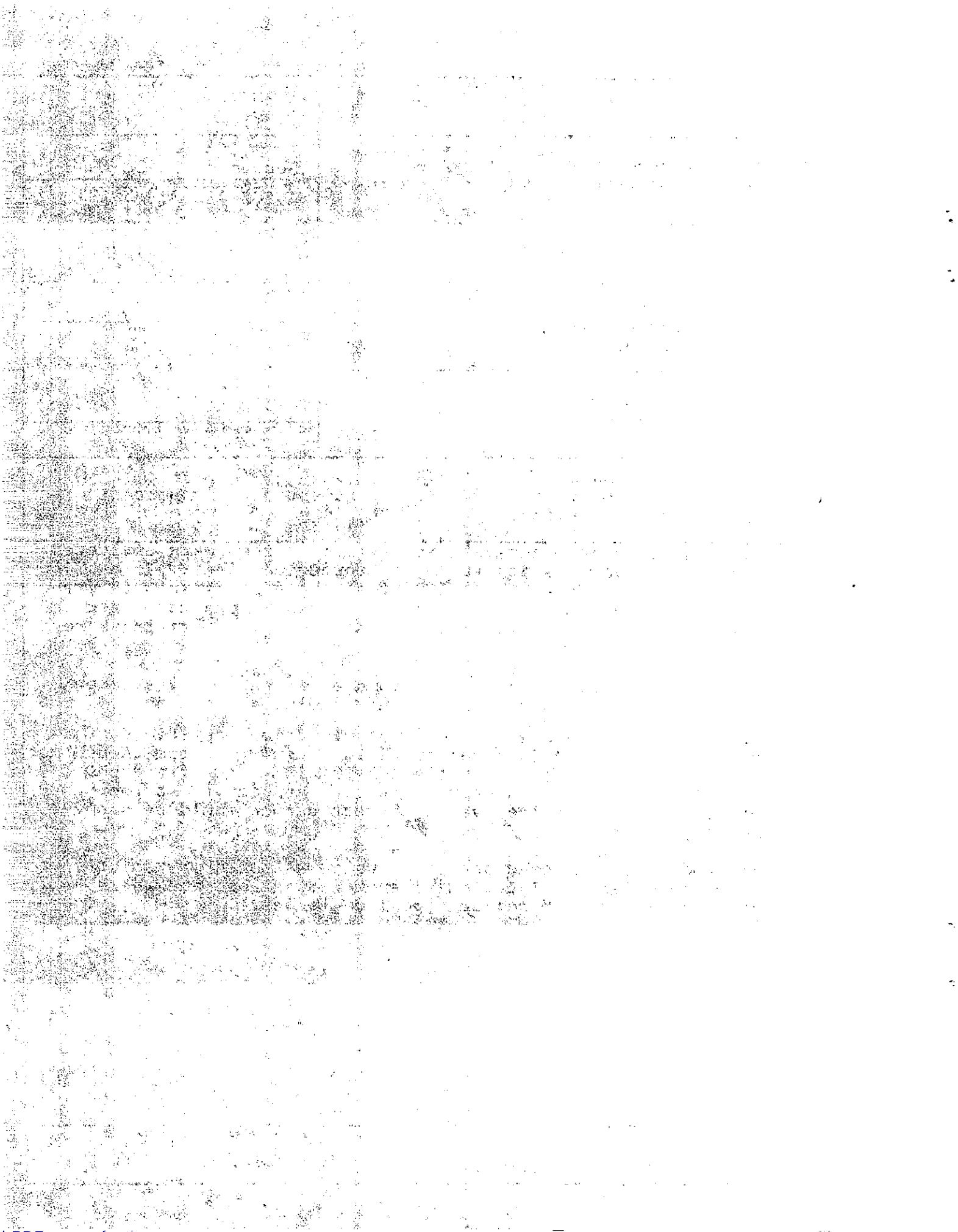


STATE OF CALIFORNIA—BUSINESS AND TRANSPORTATION AGENCY

RONALD REAGAN, Governor

DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS
MATERIALS AND RESEARCH DEPARTMENT
5900 FOLSOM BLVD., SACRAMENTO 95819

September, 1972

Research Report
CA-HY-MR-5193-1-72-31
Fed. No. D-5-34

Mr. R. J. Datel
State Highway Engineer

Dear Sir:

Submitted is a research report titled:

Evaluation of Grooved Traffic Stripes on Portland Cement Concrete Highways

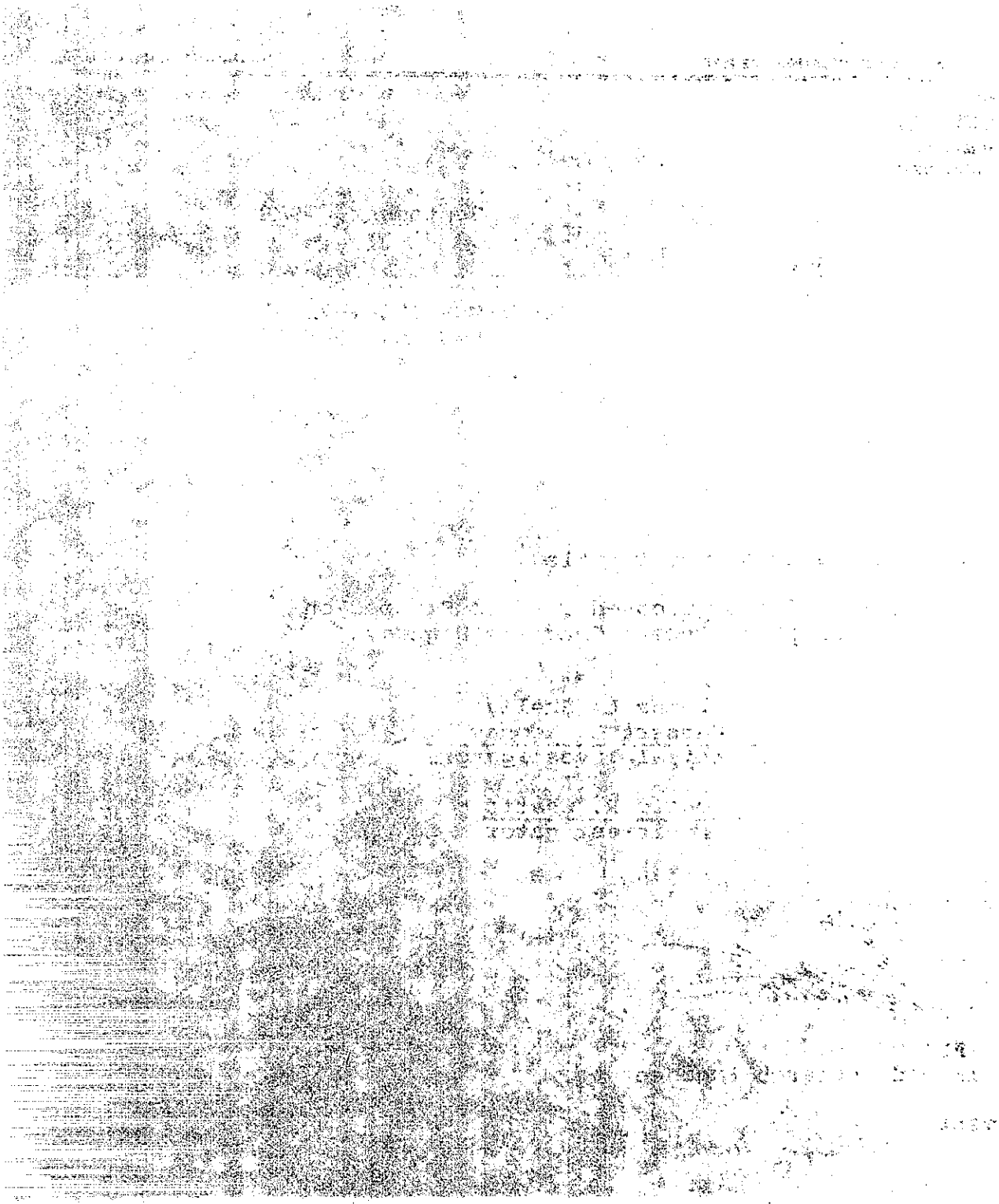
Thomas L. Shelly
Herbert A. Rooney
Principal Investigators

Donald R. Chatto
Co-investigator

Very truly yours,

JOHN L. BEATON
Materials and Research Engineer

Attachment



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

We wish to thank the following for their help in carrying out the work reported herein:

1. Industrial Diamond Services, Inc., 7245 Madison Street, Paramount, California, for cutting grooves under a service contract.

2. District 03 maintenance personnel for providing traffic control and painting the grooved and control section.

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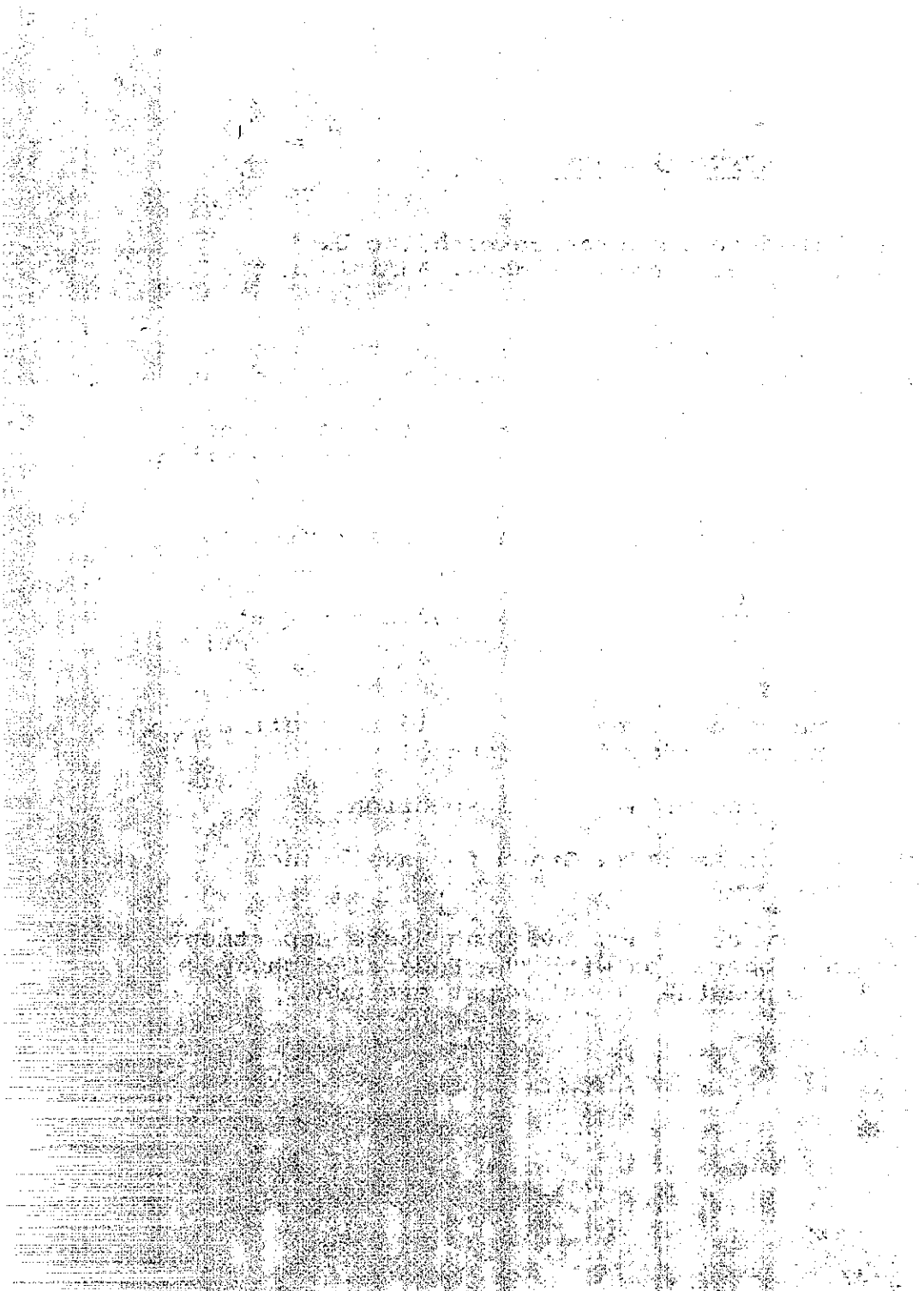

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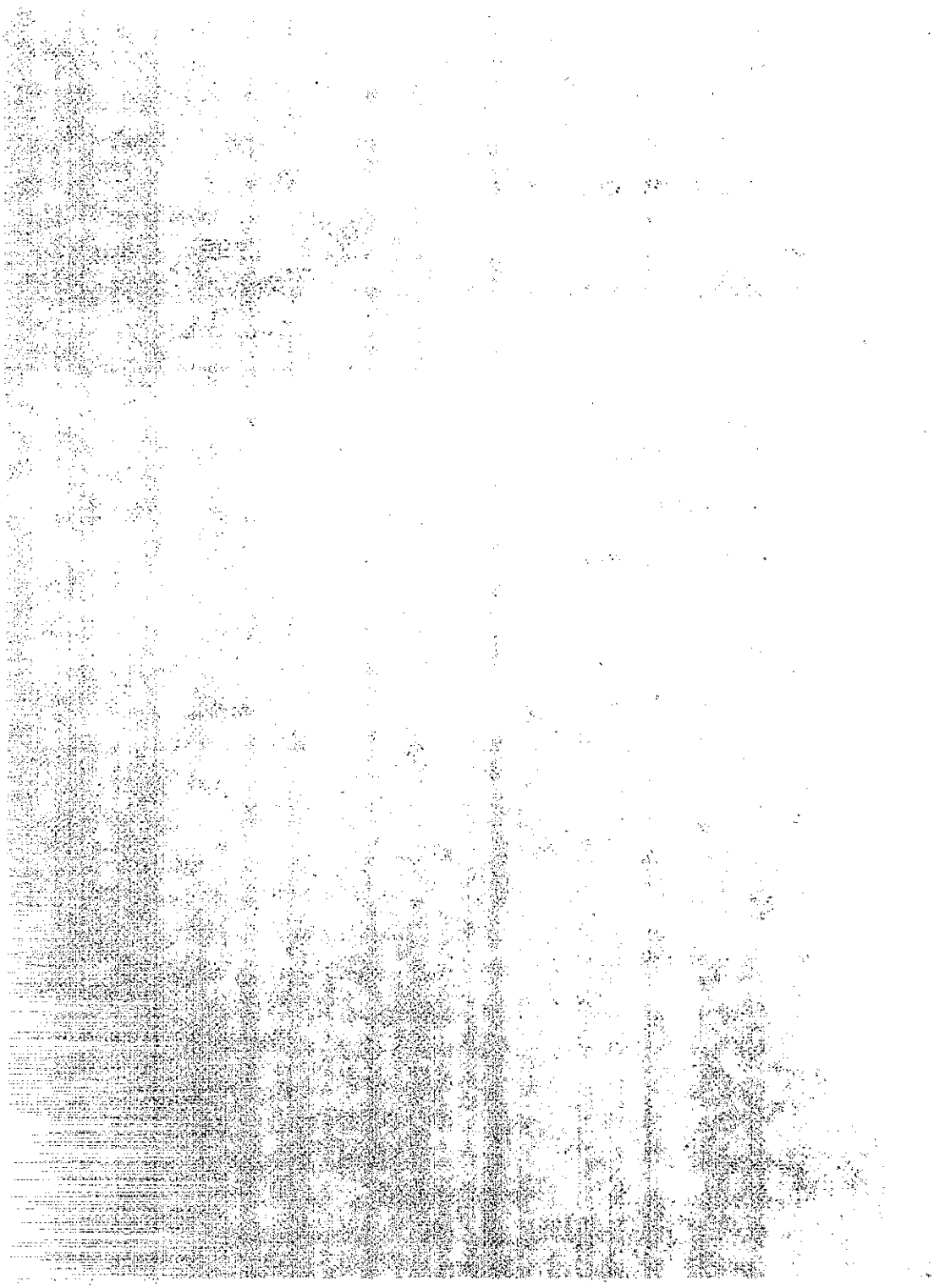


EVALUATION OF GROOVED TRAFFIC STRIPES ON PORTLAND CEMENT CONCRETE HIGHWAYS

Introduction

The service life of the standard beaded traffic paint stripe in California mountain areas is a matter of days when subjected to automobile and truck chain traffic, snow plows, and sanding operations. Since any type of raised pavement marker tested to date will not survive metal snow plow blade action, a recessed type, or grooved type of delineator was thought to be a possible solution. In response to the request from the FHWA to States to try grooved traffic lines three test sections were selected for trial.

The actual grooving was performed by a 9-ton concrete planer especially adapted to cut four parallel grooves into the pavement surface. A circular cutting head studded with industrial diamonds was used to cut a longitudinal pattern of four 1/4-inch deep cuts spaced on 1-1/8-inch centers. The grooves had a 3/16-inch radius at the bottom and a 1/4-inch wide flat surface across the crest. In practice this crest width was about 1/2-inch (Figure 1). This configuration allows the raised portion of the groove pattern to drain rapidly in wet weather and prevents the raised portion from being covered with a film of water. This water film is the major cause of poor, wet weather, nighttime visibility of the regular traffic painted line.

On flat grades a short transverse groove is used to facilitate draining of the whole grooved line. The transverse groove consists of a cut, starting at the bottom of the grooved line, at right angles and feathered out to the road surface. The location of the drainage cuts depends on the road cross-slope and grade. (Figure 2.)

The length of the longitudinal grooved and nongrooved "stripe" used in these tests was the same as the California broken paint stripe pattern, that is, 9 feet of groove or stripe with a 15-foot gap between. Total lineal grooving was 2000 feet per highway mile (single stripe) and was done over the existing paint stripe pattern. After the grooving operation, most of the initial painting was done with regular State specification traffic paint applied to the grooved sections at the standard rate of 7 gallons per mile of broken stripe and post beaded at

the rate of 42 pounds of beads per mile. On the Kingvale section, the line was repainted with 3M "Greenlite" paint.

Two depths of grooving were used in these tests to see if there would be any improved durability of the paint in a deeper groove. In the normal depth groove pattern, the clearance between the road surface plane and the top of the crest varies from 0 to 1/32-inch. For deep grooving, the clearance was at least 1/16-inch. Most of the grooves cut were normal depth and deep grooving was used as a comparison on three 1/2-mile sections. (See Figure 1)

Evaluation of this system was based primarily on visibility from the driver's point of view, and an inspection of wear rate as compared to the regular traffic line paint system. All nighttime pictures during rainstorms were taken from inside of a moving sedan with exterior mounted strobe lights.

CONCLUSIONS

1. In mountainous areas, snow plowing, chain traffic, and use of salt and sand results in fast loss of paint. When the paint is intact, sand often fills the grooves and obscures the lines. Grooved stripe performance in these areas is no better than performance of a regular painted line, and is, therefore, of no significant advantage.

2. After two winters of exposure, the grooved lines in the mountain area have been abraded to the point where the original grooved configuration is about one-half its original depth.

3. At lower elevations not subject to snow removal activity, chain traffic, etc., the grooved traffic line is superior to the regular traffic paint line during nighttime wet weather conditions. This is the only advantage of the grooved stripe shown by this study, and the effectiveness in this respect is about equal to nonreflective ceramic markers.

4. The grooved traffic line and regular traffic line are about equal during day and night dry weather conditions, and during daytime wet weather. The grooved line does collect dirt which decreases the white area exposed to the motorist to some extent.

5. Increasing the depth of grooving seems to offer no advantage.

6. The use of high index of refraction beads in the traffic paint does not increase the visibility of the grooved line under any weather conditions.

7. Traffic paint applied to a grooved area does not last significantly longer than the regular traffic line. No economic advantage could be claimed for the grooved line because there was no increase in time between repaintings. Use of a paint which would not flow off the crests might show better durability than a nongrooved section.

COST COMPARISON, TRAFFIC LINE, GROOVED LINE, AND RAISED MARKERS

Grooving costs for this project were $0.30 per lineal foot for normal grooving or about $600 per lane mile including the costs of water and an operator. Deep grooving was $0.35 per lineal foot, or about $700 per lane mile. Painting cost is currently about $120 per lane mile for initial striping, which includes alignment and two coats of paint. Restriping is $50 per lane mile. The total cost of grooving and painting was $720 per lane mile.

Most recent figures show that the cost of the standard pattern of ceramic markers and reflective markers is about $950 per lane mile. The expected life of this system is, however, much greater than that of a painted line. The initial cost of the grooved traffic stripe represents a substantial savings compared to raised markers.

Comparative Costs of Painted Line, Grooved Line, and Raised Markers (Per Mile)

	Initial Cost	20-yr. Cost	Cost per Year
Plain painted line	$120[1]	$1070	$53[2]
Grooved Line	720	1670	83[2,3]
Raised Markers	950	1900	95[3]

(1) Cost of initial striping includes alignment and two coats of paint.

(2) Costs based on one restriping per year.

(3) The life of a grooved stripe is estimated at 20 years. The life of the raised marker system is estimated at 10 years.

TEST SITE DETAILS AND OBSERVATIONS

Kingvale, I-80

Post Miles	Type of Groove	Grade	Length, Miles
Eastbound			
174-174.5	Deep Grooving	Relatively flat	0.5
174.5-175	Normal Grooving	" "	0.5
176-177	" "	+6%	1.0
Westbound			
177-176	Normal Grooving	-6%	1.0
175-174.5	Deep Grooving	Relatively flat	0.5
174.5-174	Normal Grooving	" "	0.5
		Total	4.0

Control Sections
Regular Stripe, No Grooves

EB 175-176

WB 176-175

NOTE:

Grooving started September 30, 1969, and was completed October 3, 1969. About one mile was grooved per day (2000-ft. of grooved stripe), average time to cut a 9-foot length was 40 seconds, but on uphill areas, it took up to 80 seconds. (A typical grooved and painted section is shown in Figure 3.)

The grinding heads are water cooled which resulted in a considerable amount of water-concrete slurry being left in the bottom of the groove. It was necessary to flush the grooves after cutting.

No transverse grooves were necessary for drainage. Paint was State type 691-80-95 and glass beads complying to State Specification 691-80-34. Paint was applied October 21 at a rate of 7 gallons per mile and beads at 42 pounds per mile. There were two storms between the time the grooves were cut and the paint applied. As a result, there was some packed sand and salt in grooves which was not completely removed prior to the first painting.

Rocklin Area, I-80 (Foothills)

Post Miles	Type of Groove	Grade	Length, Miles
Eastbound			
111-111.5	Deep Grooving	Relatively flat	0.5
111.5-112	Normal Grooving	" "	0.5
Westbound			
112-111	Normal Grooving	Relatively flat	1.0
		Total	2.0

Control Sections were 1 mile long at each end of the eastbound and westbound sections.

Grooving operations started October 6, 1969, and were completed October 8, 1969. Time to groove a 9-foot normal groove line was about 40 seconds. For deep grooving, the time was about 70 seconds.

Transverse drainage cuts were made on the eastbound section only from PM 111 to 1/4-mile east. Two cuts were made for each 9-foot grooved line at right angles to the groove and toward the shoulder. Each transverse groove was 2 feet in length and took about 5 seconds to cut (Figure 2).

Regular beaded traffic paint was applied October 20, 1969. The control areas consisted of one mile on each side of the eastbound and westbound grooved areas.

South Sacramento, 99
Northbound only

Post Mile	Type of Groove	Grade	Length, Miles
20-21	Normal Grooving	Very flat	1.0

Grooving started August 24, 1970, and was completed August 25, 1970. Normal depth grooving only was used.

The grade is very flat. Transverse drainage grooves were cut on each end of the grooved lines from PM 20 to 1/2-mile north. The remaining 1/2-mile of grooved stripe has no transverse drainage grooves. (A typical line is shown in Figure 4.)

Regular beaded traffic paint was applied August 28, 1970, from PM 20 to 1/4-mile north and from 3/4-mile north of PM 20 to PM 21. The middle 1/2-mile was striped with high index beads (n = 1.90) at a rate of 70 pounds per mile. This is about the same volume of beads as in the regular beaded stripe because the specific gravity of the H.I. beads is greater.

Inspections

Kingvale

The Kingvale site was inspected and photographed under both day and night conditions on October 30, 1969. No new storms had occurred between then and when it was first painted nine days before. Because of paint draining from the high areas down into the grooves, the paint thickness varied from an estimated 3-4 mils on the rib area to about 10 mils on the bottom of the grooves. As a result, there was some blistering of the thicker coating. (Figure 5.) There was no noticeable difference in delineation between the grooved and control sections.

This site was observed again on December 31, 1969. There had been several rain and snow storms since the October inspection. The paint was almost obliterated in both the grooved and control sections. Due to chain and snow plow action, the crests of the grooved line were already beginning to flatten. (Figure 6.)

By April 1970, all mud and debris had been flushed from the grooves. After the pavement had dried, the lines were all

repainted. No further observations were made until September 1970.

On September 24, 1970, the traffic stripes were repainted with a 3M Greenlite Striper using No. 320 instant dry traffic paint with beads. The paint is very viscous and is heated to about 240°F and sprayed using a pressure of about 2000 psi. The "instant dry" characteristic resulted in a more uniform application of paint with less run off from the crest.

The test site was observed and photographed two weeks later. There was no noticeable difference between either the control, normal, or deep grooved lines during the day or under nighttime conditions.

On October 25, 1970, this section was again inspected. There had been two snowstorms since the September inspection; however, paint was still intact on both the grooved and control section lines (one month after painting).

On December 30, 1970, this test site was inspected again. Up to this time it had been 15 months since the grooves were cut and three months since the last painting. Several storms had occurred and there was no trace of paint left in either the control or grooved lines. The grooves were filled with sand and mud. (See Figure 9 taken after a later repainting.)

About April 1971, all lines had been repainted and an inspection was made May 19, 1971. The paint was still visible on both the control and grooved lines, but additional pavement wear was evident. In addition to measurements made of crest width and groove depth, measurements were made of the height of the crests or flat areas below the plane of the adjacent pavement. Results are shown in Table 1.

Table 1

Grooved Line Measurements - Kingvale

Date	Width of Flat Area on Crest	Groove Depth	Distance of Crest Below Pavement Plane	
			Normal Grooving	Deep Grooving
10-1-69	0.50"	0.25"	0.025"-0.045"	0.063"
9-24-70	0.70"	0.20"	0.020"-0.040"	0.043"-0.66"
5-19-71	0.80"	0.10"-0.16"	0.020"-0.040"	0.040"-0.060"

As the pavement wore, the width of the crests increased about 50%. The wear is also shown by a reduction in groove depth which was about one-half as deep after being exposed to traffic for 17 months (two winters). The wear rate of the crest was about equal to the wear rate of the adjacent pavement, though it was believed the crest wear rate might be greater.

Rocklin

The Rocklin I-80 test site was inspected December 18, 1969, at night during a heavy rainstorm, 2 months after painting. While the control line was barely visible, the grooved line provided good delineation in both the normal and deep grooved sections.

On December 23, 1969, the test stripes were photographed at night, again during a moderately heavy rain. The grooved lines (Figure 7) were far superior to the control lines (Figure 8). No significant difference was observed between the grooved stripe area with the transverse drainage cuts and the area with no such cuts.

The test stripes were inspected and photographed again on September 24, 1970, during the daytime. It had been 11 months since they were grooved and painted. Grooves were clean and showed negligible wear. They were, however, in need of re-painting, but both the grooved and control lines were of about equal visibility.

Another inspection was made October 22, 1970, one day after repainting. A considerable amount of paint had run down to the bottom of the grooves. On November 11, 1970, the lines were inspected during daylight in a light rain. There was no significant difference between visibility of the grooved and control lines.

South Sacramento
Route 99

On October 14, 1970, two months after the lines were grooved and painted, a daytime inspection was made. Blistering of paint in the bottom of the grooves was observed due to excess thickness, and the lines photographed. Visibility of all lines was about equal.

On October 23, 1970, the lines were again inspected during daylight, but in a light rain. No difference between the grooved lines with and without transverse drainage cuts was observed.

On the night of November 28, 1970, during a heavy rain, another inspection showed that the grooved lines were excellent, while visibility of the control lines was very poor. The results were similar to those shown at the Rocktlin test site in Figures 7 and 8.

There was no significant difference between the high index bead and regular beaded sections in either of the sections without these cuts. However, all sections having the drainage cuts were significantly better than those without. Considerably more water was standing in the grooves without drainage cuts. This shows the need for cross drainage cuts when the roadway is nearly flat. Just south of the grooved stripe test section there are lines made up of raised markers, both round ceramic type and portland cement markers which were round and wedge shaped. The line formed by these markers was much brighter than the grooved stripe.

Later Observations, and General Comments

Dirt Accumulation in Mountain Areas

It has been noted that the grooved line at Kingvale often filled with dirt so that there was little or no delineation. This condition was photographed in late November 1971 (Figure 9). At this time the paint was about 80% intact.

Daytime Wet Weather Visibility

Observations had indicated that the visibility of the grooved and control sections was about the same during daytime wet weather conditions. This condition was photographed April 5, 1972, on the South Sacramento Freeway during a moderately heavy rain.

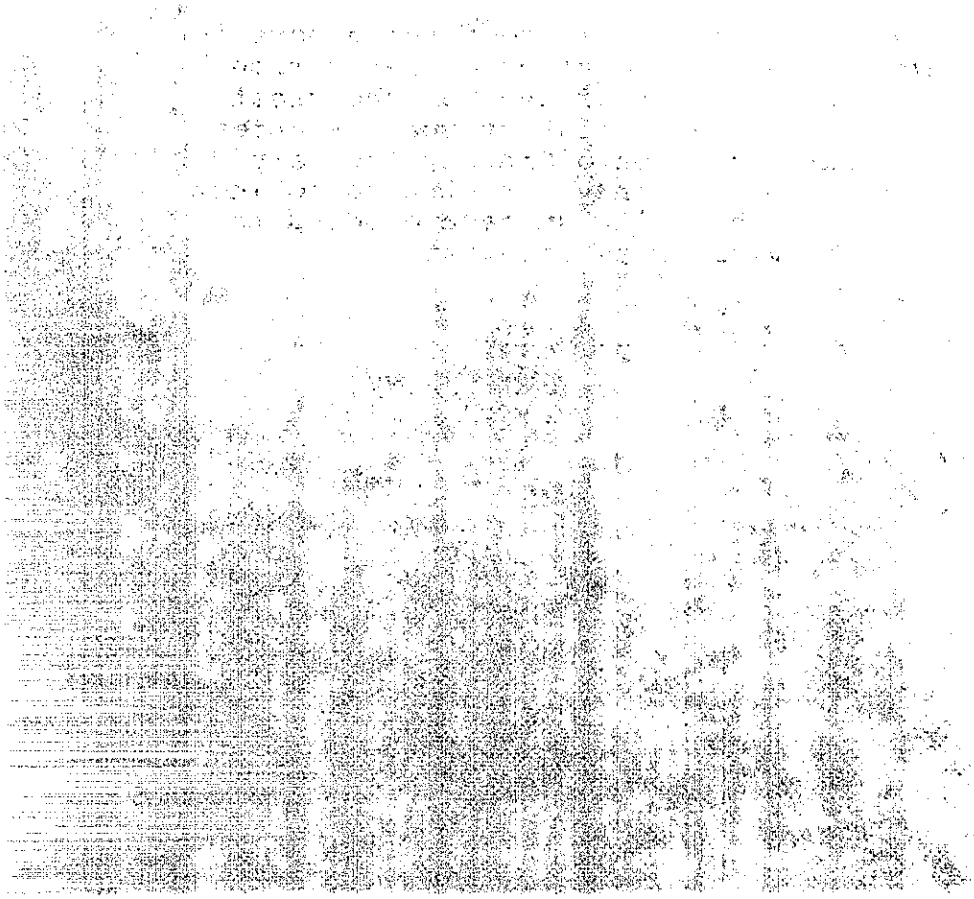
Figure 10 shows the transition from the grooved to the control section. The first stripe in front of the car is grooved and is actually slightly less visible than the next stripe which is a control stripe. The actual visual observations agreed with the photograph since it was very easy to observe the transition from the grooved to control sections. In contrast, Figures 11, taken during dry weather showing the transition from the grooved to the nongrooved section, shows the lines to be equivalent, and it was very difficult to detect the transition point at freeway speed. (This photograph was taken at the Rocklin section.) All photographs taken at the South

Sacramento location missed the transition from grooved to control lines because of the difficulty in seeing the change.

The grooved line is very inferior to ceramic raised markers during wet weather daytime conditions. Photographs taken April 17 on the South Sacramento Freeway in a moderately heavy rain, show a series of raised markers of different types, the whitest of which are ceramic (Figure 12). The grooved section is immediately beyond the last ceramic markers and is completely invisible.

Rate of Wear of Paint on Grooved Stripe and General Daytime Visibility

As mentioned before, the paint on the crest of the groove is about one-half the thickness of the paint on a flat stripe due to runoff of the paint. The rate of wear on the crest is, nevertheless, about the same as a flat stripe. Figures 13 and 14, taken on the South Sacramento Freeway February 8, 1972. Figure 13 also shows the tendency for dirt to collect in the groove which decreases the white surface exposed to the driver and decreases the visibility somewhat.



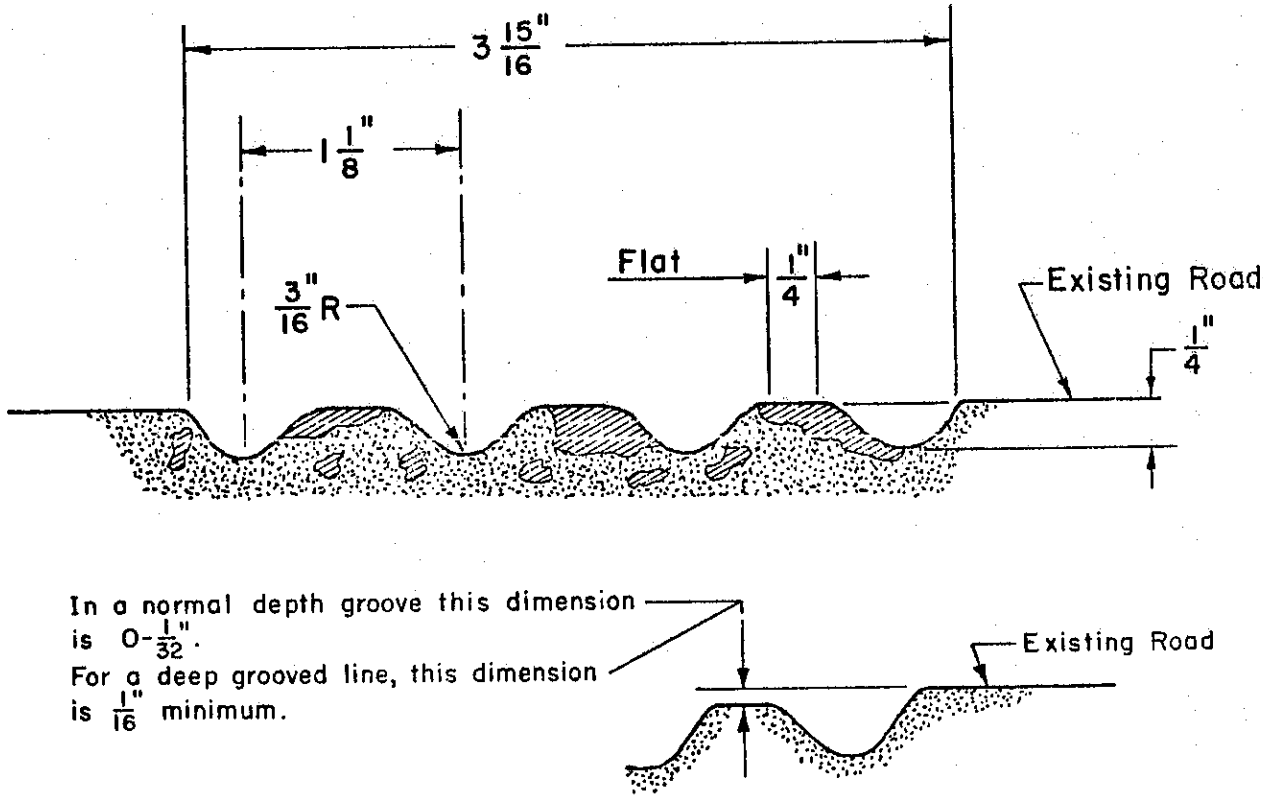


Figure 1

Grooved Traffic Line Cross Section

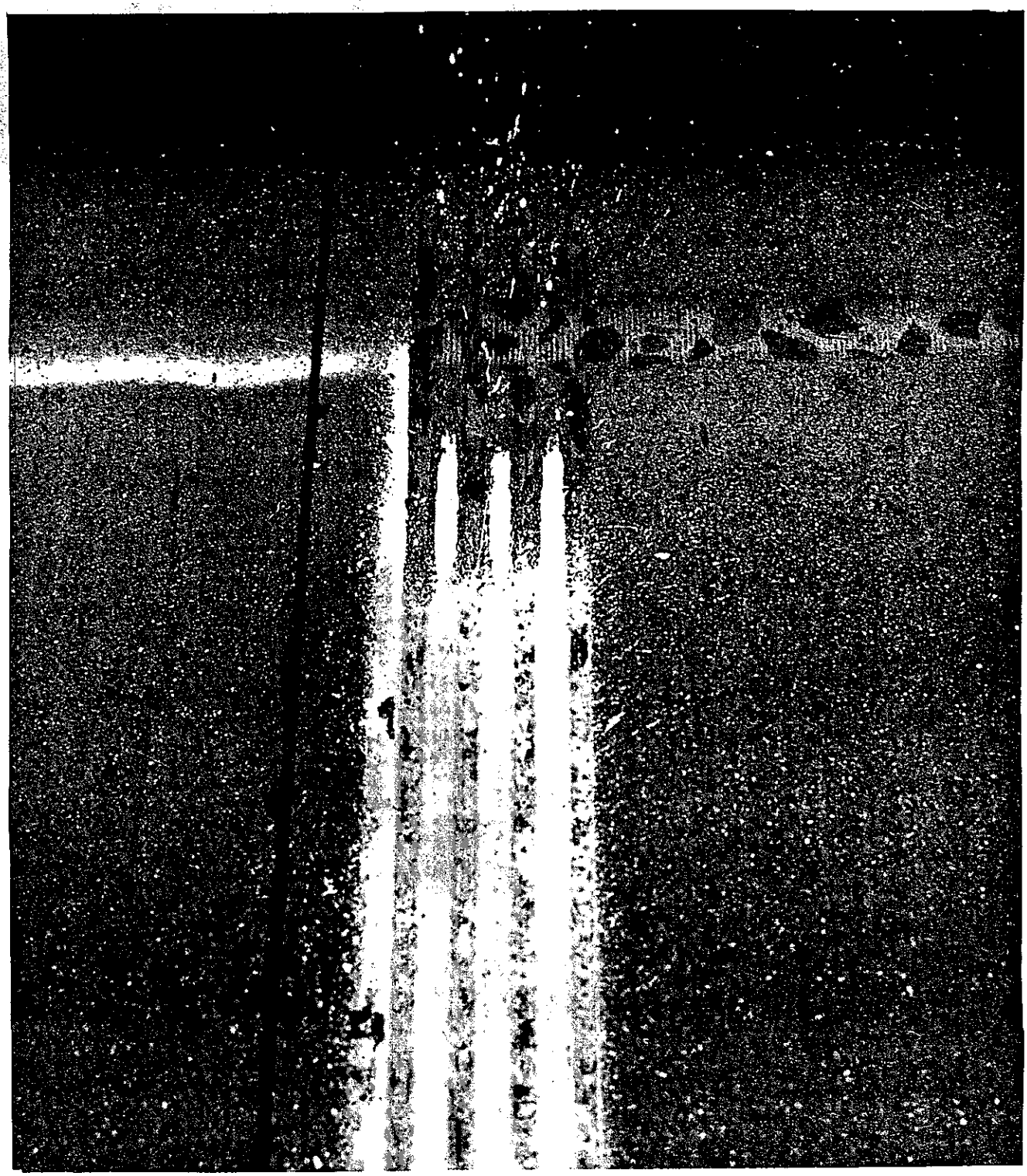


Figure 2

Grooved Traffic Line Showing Transverse Cut

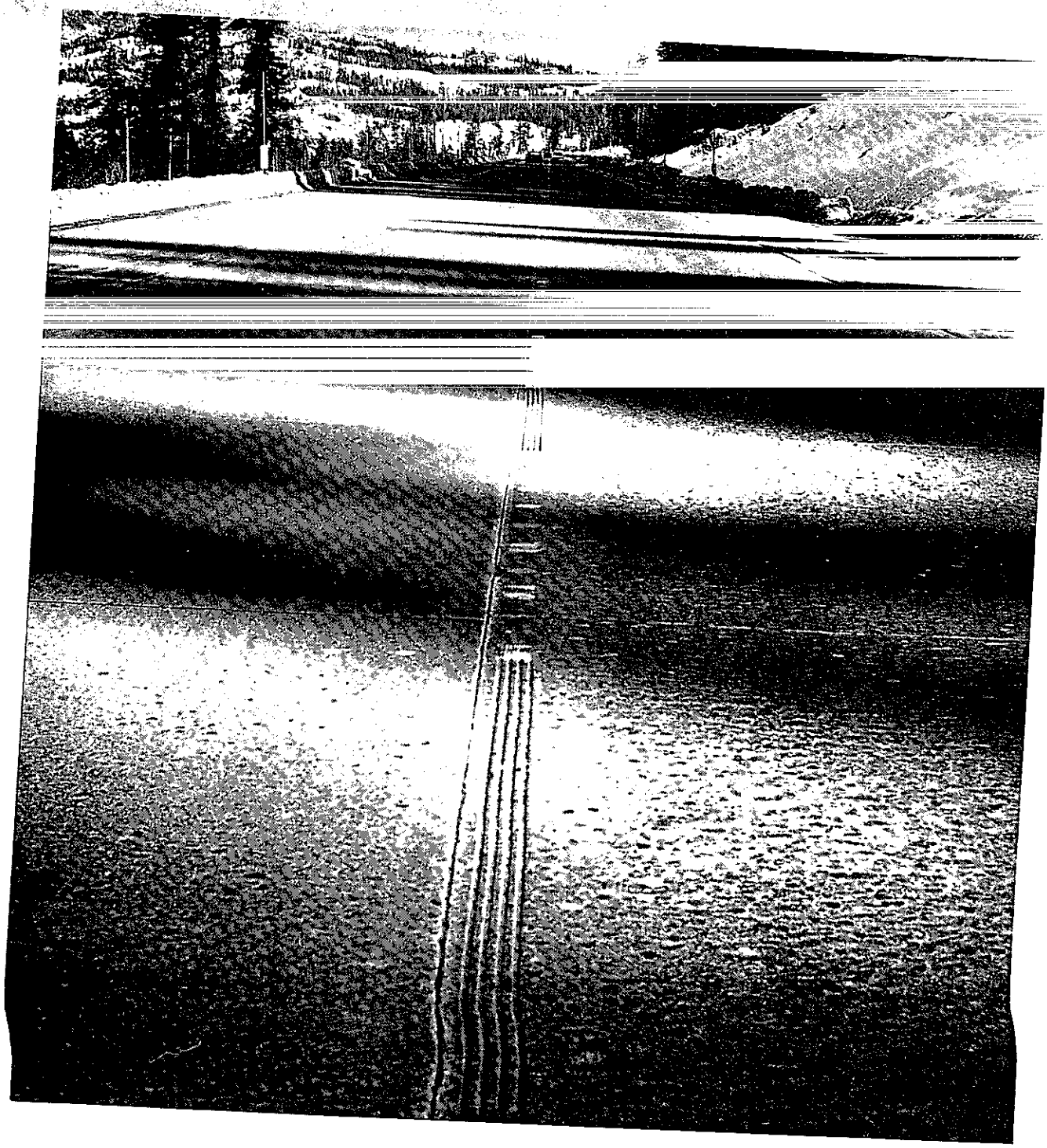


Figure 6

Kingvale Area after Several Rain and Snow Storms

Figure 4

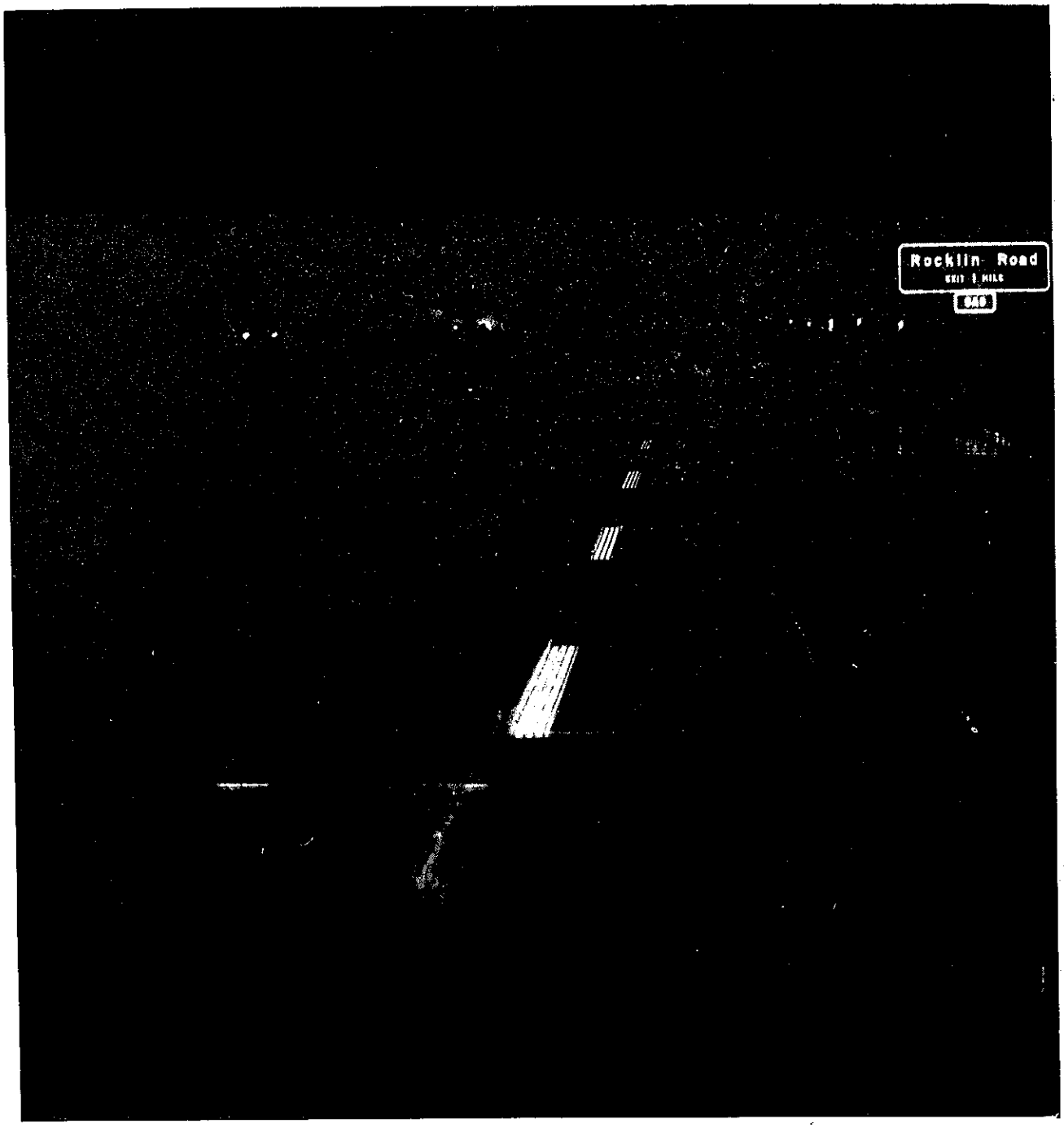


Figure 7

Rocklin Area Grooved Section. Night photograph during rain.

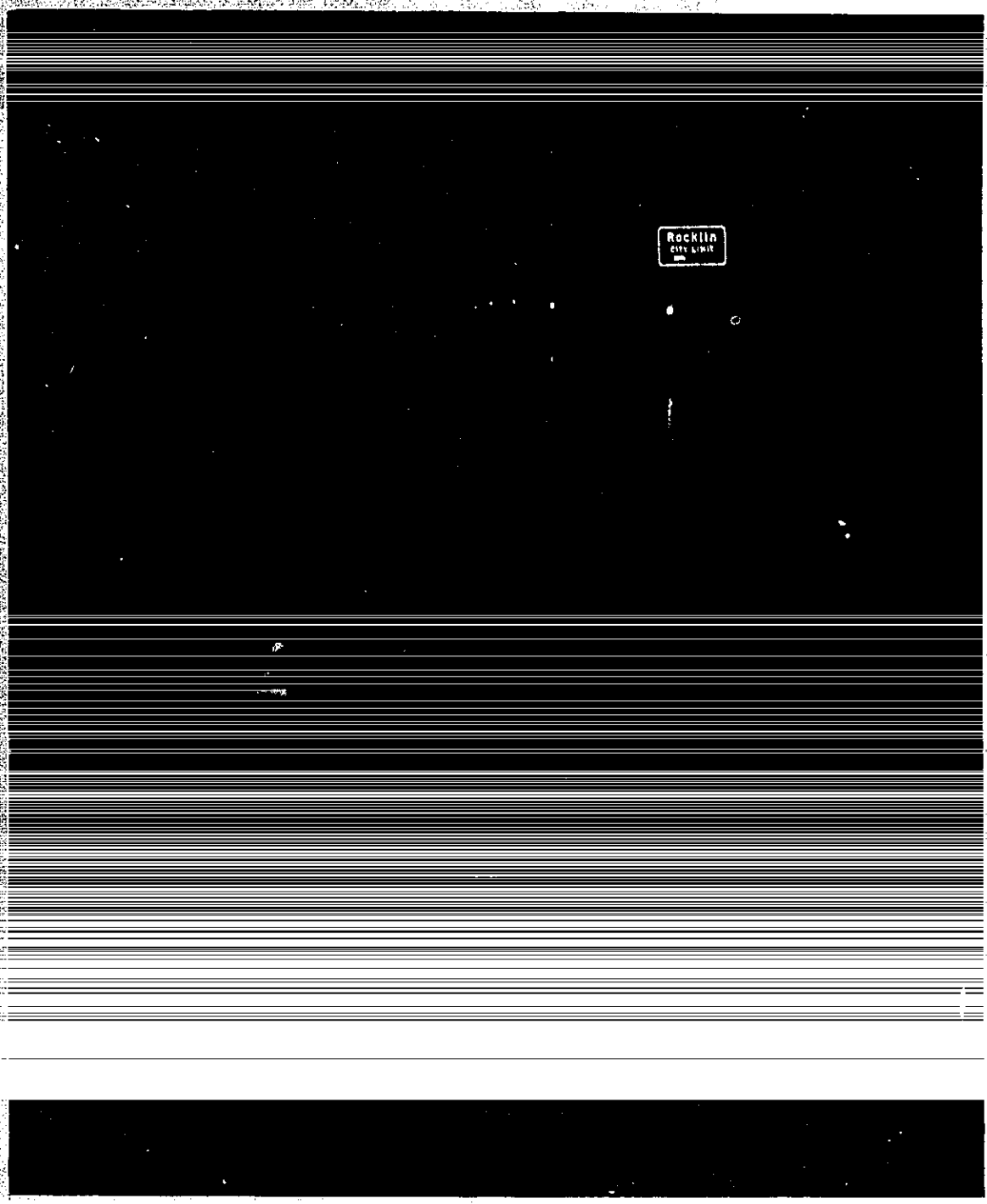
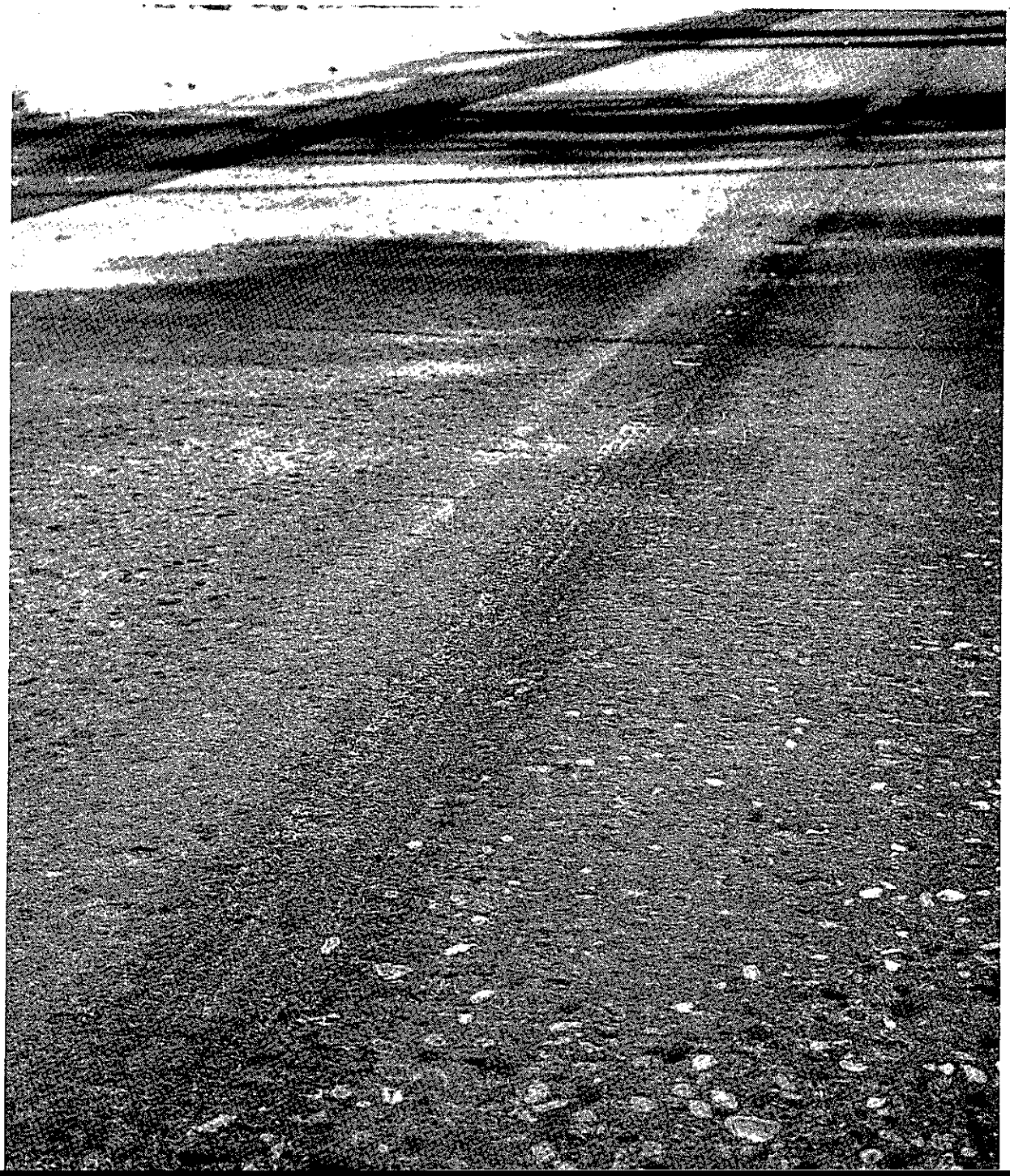


Figure 8

Rocklin Area Control Section. Night photograph during rain.



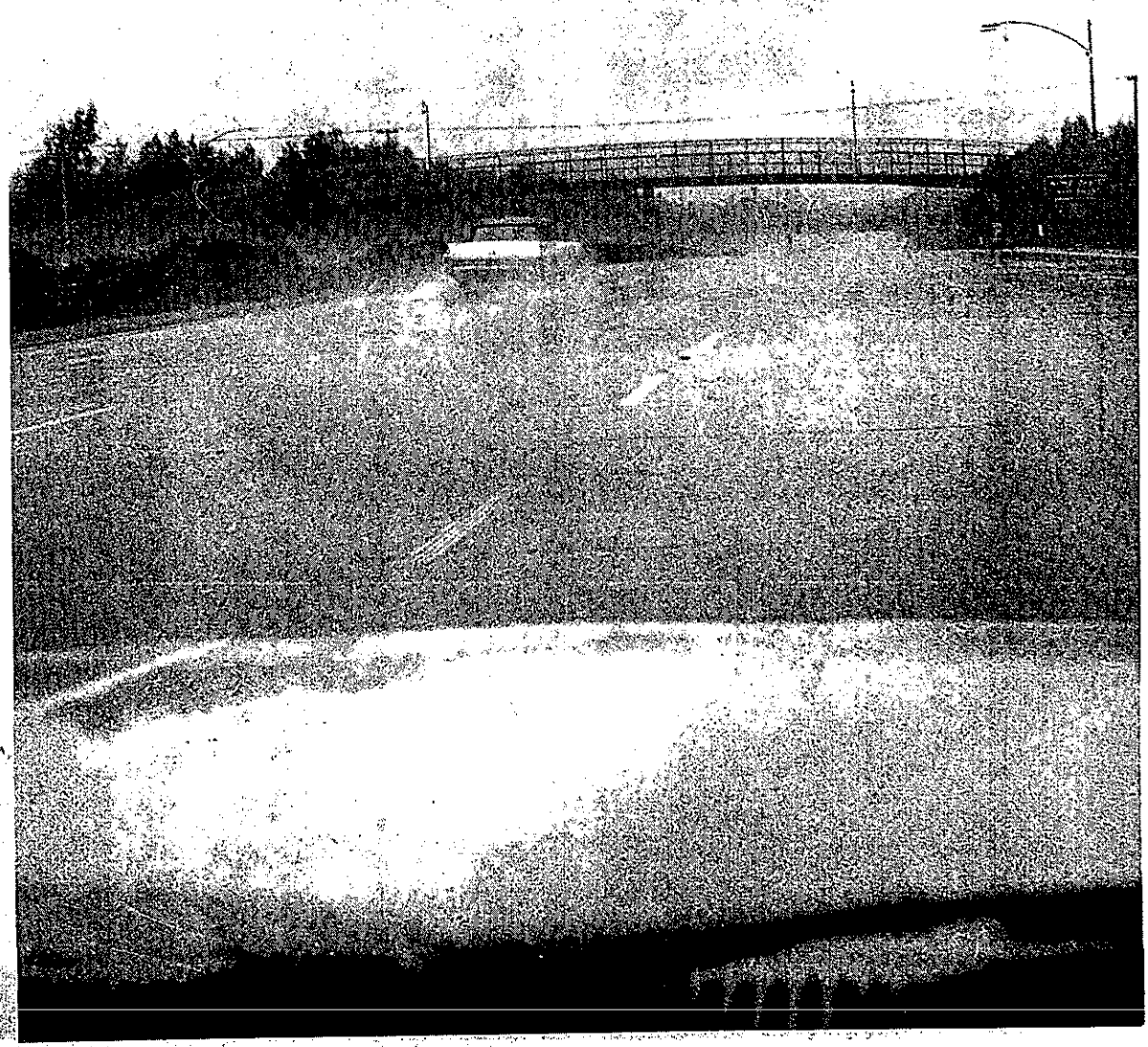


Figure 10.

South Sacramento Area During Moderate Rain. Grooved stripe in front of car is slightly less visible than the next control stripe.

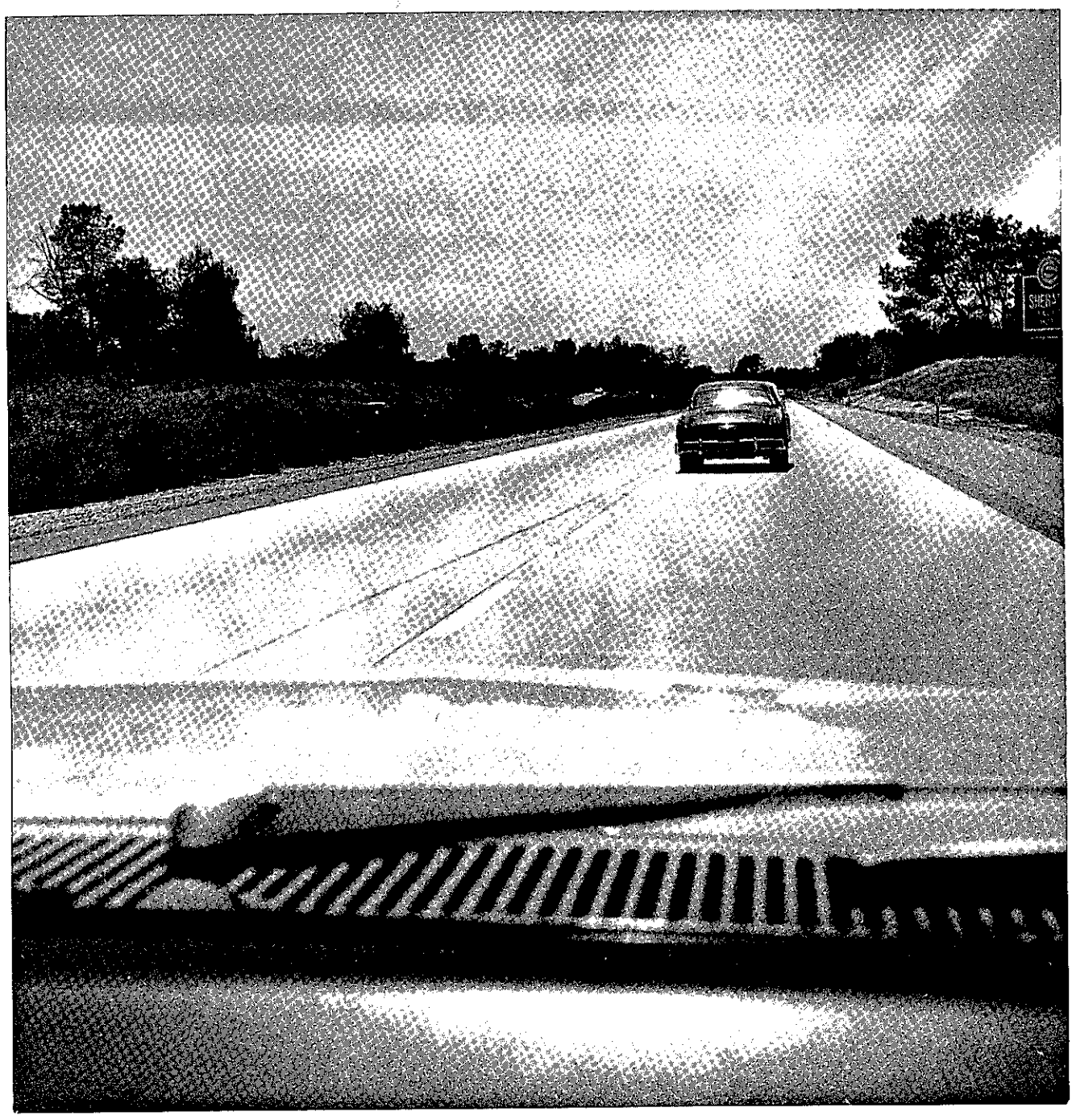


Figure 11

Rocklin Area During Dry Weather. Grooved stripe in front of car is scarcely distinguishable from next control stripe.

Figure 12

Sacramento Area During Moderate Rain. Series of raised markers followed by the grooved section shows the superiority of raised markers.

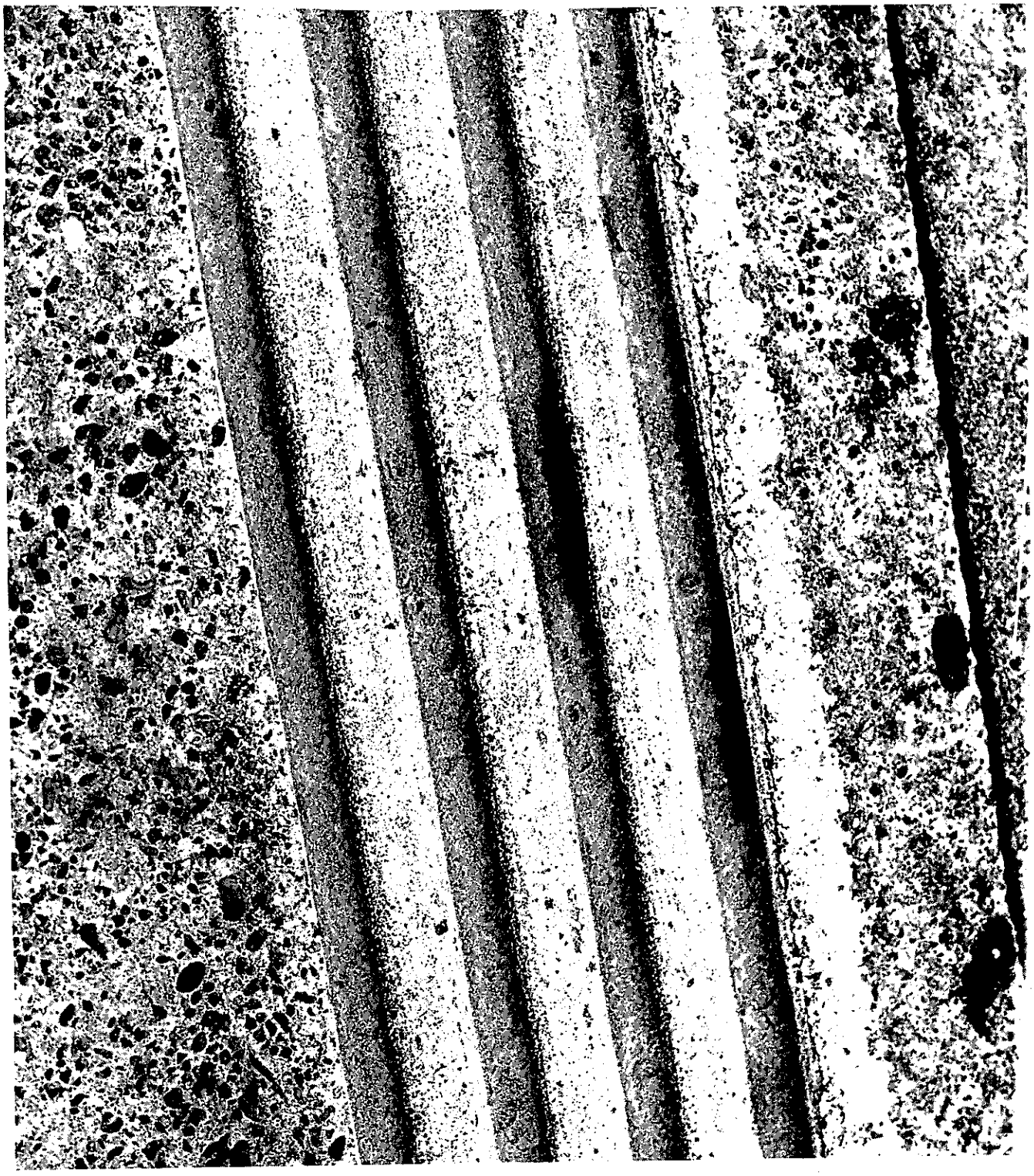


Figure 13

Painted Grooved Traffic Stripe in Sacramento Area. The accumulation of dirt in the trough decreases the visibility somewhat. The wear on the crests is about equal to the adjacent control section (Fig. 14).

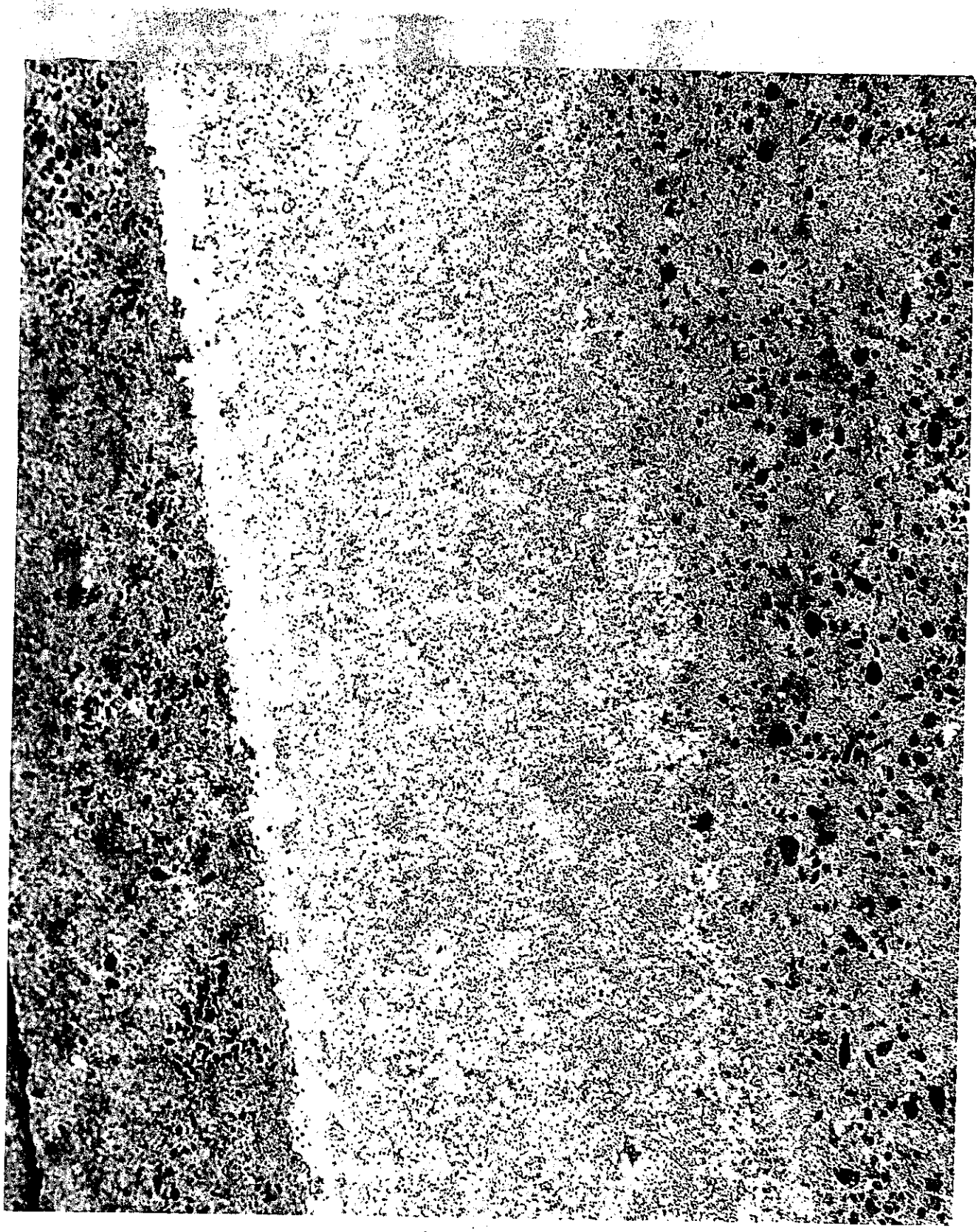


Figure 14

Painted Control Traffic Stripe in South Sacramento Area.