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DEPARTMENT OF
JUN 29 1973

OPERATIVE HIGHWAY RESEARCH PROGRAM
REPORT 70-9

AN ANALYSIS OF TRAFFIC OPERATION ON THE MARK TWAIN EXPRESSWAY AT I-270 IN ST. LOUIS COUNTY.

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DEPARTMENT OF
TRANS
JUN 29 1973

AN ANALYSIS OF TRAFFIC OPERATION ON THE MARK TWAIN EXPRESSWAY AT I-270 in ST. LOUIS COUNTY

STUDY 70-2

Prepared By

Missouri State Highway Department

Division of Planning

December 1970

In Cooperation With

U.S. Department of Transportation

Federal Highway Administration

The opinions, findings, and conclusions expressed in this publication are not necessarily those of the Federal Highway Administration.

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FOREWARD

Traffic operating conditions on the Mark Twain Expressway in St. Louis have been under surveillance for a number of years as a means of anticipating excessive demands on the facility and pinpointing trouble spots before congestion became critical. Surveillance was accomplished by means of aerial photography of the entire route during peak traffic periods, generally at two-year intervals.

Severe congestion was observed during the 1968 study in the westbound lanes in the vicinity of the I-270 interchange. This congestion, which extended back to Natural Bridge Road, appeared to be a result of merging conditions at the I-270 interchange. The initial report of this congestion appeared in Freeway Surveillance Studies, 1969 Annual Report, 70-5, published by the Missouri State Highway Department.

The objective of this study was to determine more precisely the extent of this congestion while simultaneously determining the feasibility of implementing measures to improve operation through the area.

SUMMARY

Preliminary speed and volume measurements were made in order to pinpoint both the time and extent of the congested operation. Speeds in service Levels E and F were found to exist for a period of approximately one hour, beginning in the vicinity of the north to west ramp and extending back to Natural Bridge Road.

The detailed study consisted of aerial surveillance of a section of highway containing the north to west ramp (approximately 1,800 feet). This area was filmed for the twenty-minute period during which traffic conditions were found to deteriorate completely.

The original study plan was aimed at determining the length of acceleration lane necessary to eliminate the merging conflict thought to be the primary factor in the congested operation. The analysis of the film, however, indicated that while the merging movements did indeed have a pronounced effect on operations, especially in the shoulder lane, traffic on the ramp was able to merge as long as traffic moved. The area of substandard operations was found to extend downstream of the study area. A shock wave of start-stop operation in the median lane began somewhere downstream of the study section.

Since the congestion extended beyond the end of the area filmed originally, an additional flight was made to cover the area immediately downstream of the original section. At the same time, speeds and volumes were taken manually at the nose of the north to west ramp.

Operation deteriorated to service Levels E and F over much of the extended section. The drop from Level B to Level F operation took place within a five-minute period. It was during this period that the volume reached its peak five-minute flow rate. At the end of this five-minute

period, a complete breakdown in operations occurred. This took place on a straight section of highway on a slight downgrade built to ideal design specifications.

The reason for the breakdown in operation was determined to be excess demand. Any improvement in operation at the merging points upstream would only have resulted in an increase in volume reaching this point, causing worse congestion than that which already existed.

While the volume appeared to exceed capacity for only a short period of time, the demand, that is, the volume which would exist if congestion did not, exceeded it for about 25 minutes.

In a situation such as this there are two alternatives; either the capacity must be raised or the volume lowered. Since there were no apparent flaws in design, the only means of raising capacity would be through an additional lane. However, this is impossible at present because of the inherent width limitations of the Missouri River Bridge. There is only one other river crossing in this traffic corridor, the Missouri 115 (St. Charles Rock Road) Bridge just north of Interstate Route 70. At present, this bridge is operating at capacity, leaving no possibility for diversion of traffic from I-70. Any plan to reduce volume as opposed to raising capacity would entail delaying traffic at the ramps or other freeway points rather than diverting it.

In order to determine the severity of the problem, travel time studies were conducted. The section of freeway from Lindbergh Boulevard to the first interchange in St. Charles was selected as the critical area. Average travel time per vehicle during the peak period (4-6 pm) increased by one minute over off-peak travel time, from 5.4 to 6.4 minutes. The worst run showed a time loss of only 2.4 minutes. Thus,

the best possible results from any measures designed to increase traffic flow would be minimal, and the only feasible solution (delaying vehicles at the ramps) would appear worse than the problem.

At the present time, it is recommended that no revision of the interchange be made for the purpose of reducing congestion in the area.

With the St. Charles Rock Road Bridge reaching the final stages of its life in the near future, it is imperative that some provisions be made for the increased volume of traffic crossing the Missouri River. At the present time, two locations, the Brown Road and Page Avenue extensions, are being studied. The early completion of a high capacity alternate route within this corridor is essential.

STUDY AREA

The study area appears in Figure 1. Filming was restricted to this area where the congestion appeared to originate although congestion actually backed up to Natural Bridge Road. The numbered points in Figure 1 are the marker locations used as reference points in the aerial photography involved in the study.

PROCEDURE

Field data were collected using time lapse aerial photography, supplemented by speed and volume measurements made on the ground. Two flights, each covering about 2,000 feet of roadway for a twenty-minute period, were made. Markers were placed on the shoulder at 200 foot intervals to provide reference points on the film. Speeds and volumes were measured by means of a twenty-pen recorder, and travel times through the study section were obtained by means of a test vehicle "floating" with the traffic flow.

SPEEDS AND VOLUMES

Prior to and during the course of the study, several measurements of speed and volume were made at locations within the study area. Figure 2 shows one day's data which is typical of conditions found at the nose of the north-west ramp (No. 4 in Figure 1).

Traffic operation deteriorated to the range of Level F from 4:30 to 5:25 pm. This breakdown occurred when the five-minute flow rate reached 3,800. Traffic operated at speeds associated with Levels A and B when the flow rate remained under 3,300.

Average volumes from five days observation at this point are shown in the following table.

I-70 ST. LOUIS

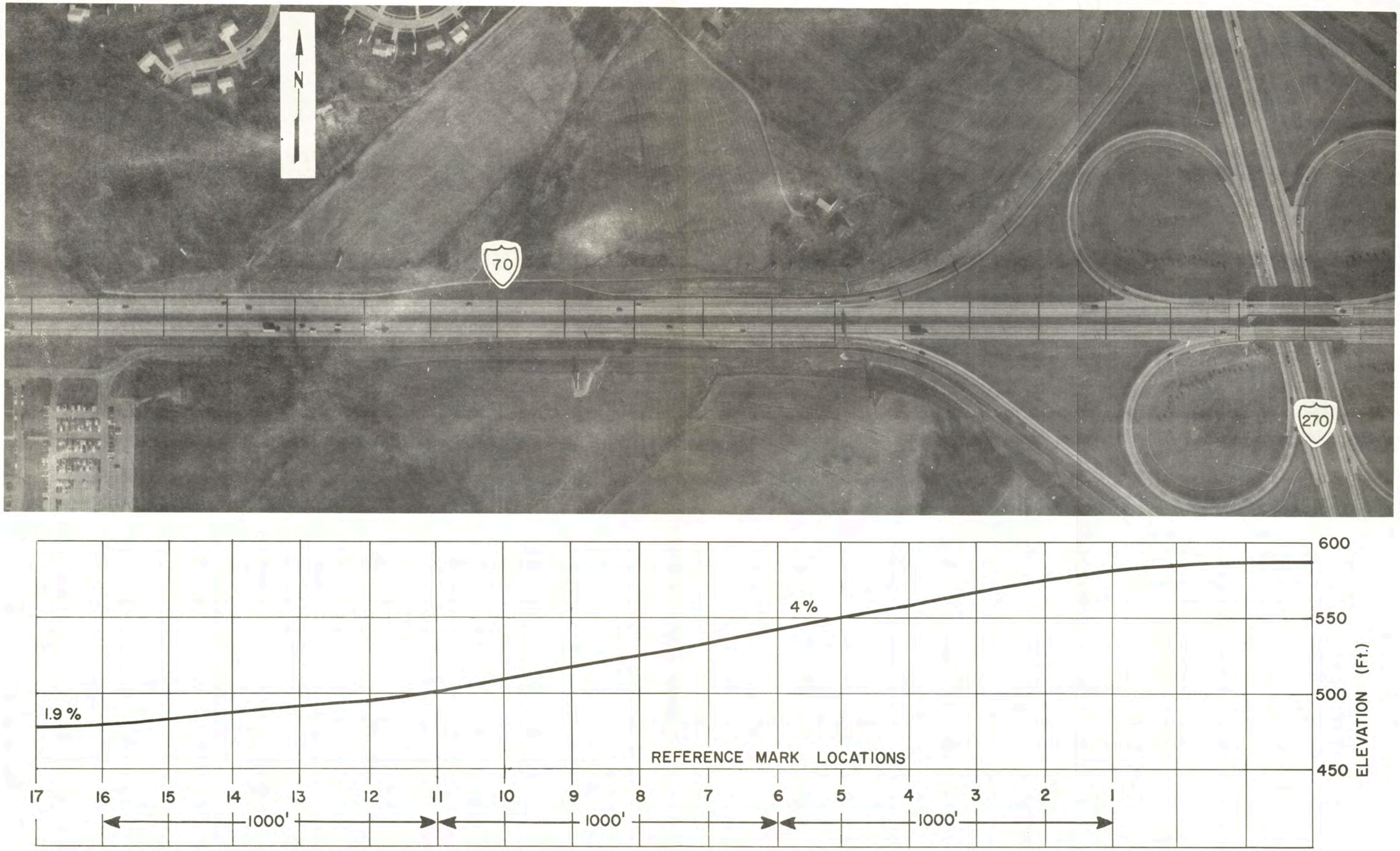

FIGURE 1 STUDY AREA

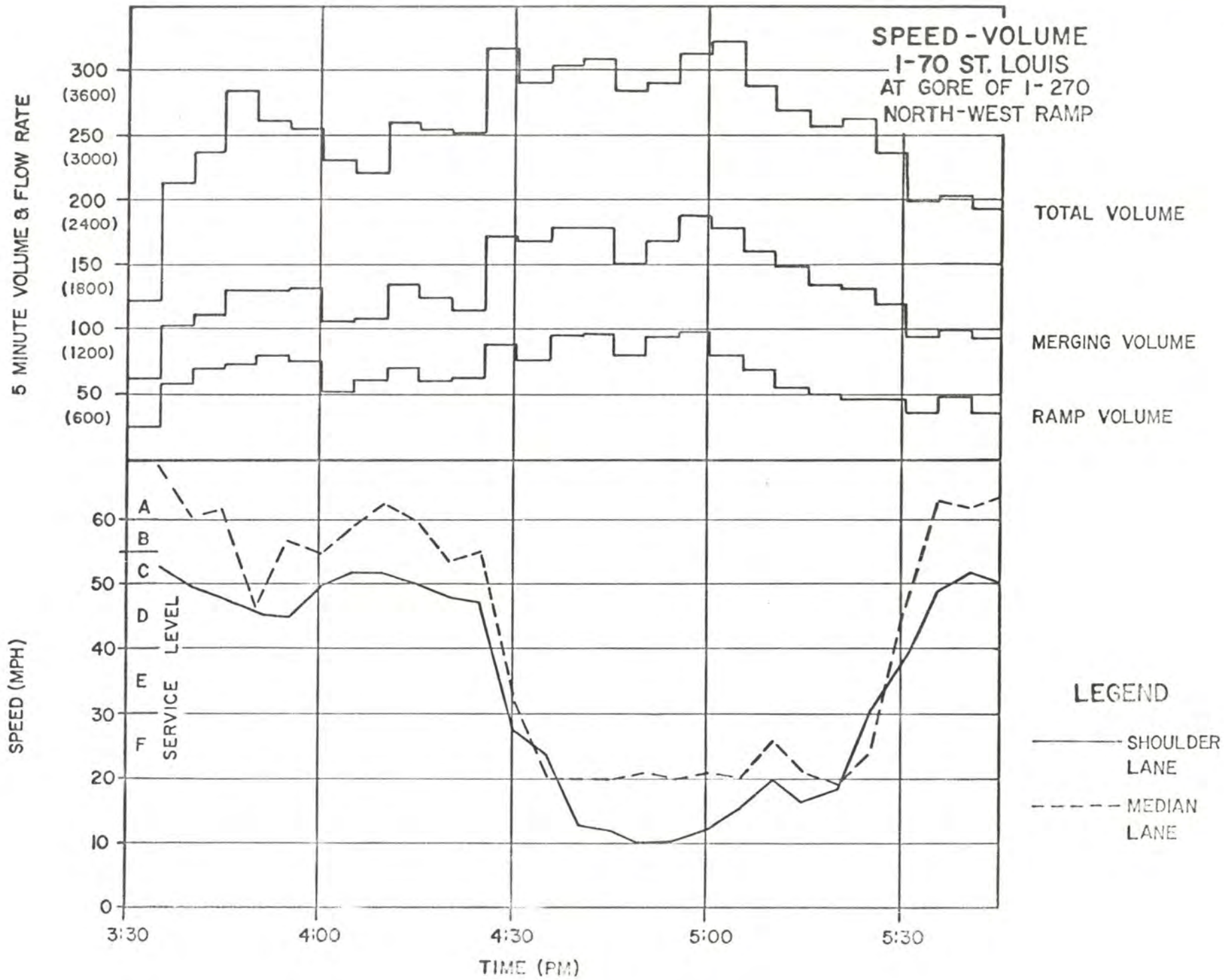
SPEED - VOLUME
I-70 ST. LOUIS
AT GORE OF I-270
NORTH-WEST RAMP
5 MINUTE VOLUME & FLOW RATE
300
(3600)
250
(3000)
200
(2400)
150
(1800)
100
(1200)
50
(600)
TOTAL VOLUME
MERGING VOLUME
RAMP VOLUME
SPEED (MPH)
60
50
40
30
20
10
0
A
B
C
D
E
F
SERVICE LEVEL
3:30
4:00
4:30
5:00
5:30
TIME (PM)
LEGEND
SHOULDER LANE
MEDIAN LANE

FIGURE 2

Table 1
Volume at Northwest Ramp

	5-Minute Rate	Peak Hour
Ramp	1152	851
Shoulder Lane	1080	951
Total Merging	2232	1802
Median Lane	1860	1618
Total	4092	3434

DETAILED FILM ANALYSIS

The area encompassing points 1-11 was filmed during the time period when breakdown occurred. Speeds and volumes were taken from this film by counting and timing vehicles as they passed between points 4 and 5. These were plotted (Figure 3) in order to provide a comparison between the volumes (especially the ramp and merging volumes) and the level of operation as indicated by the speed. It was found that speeds on the ramp closely matched those on the shoulder lane, indicating good merging conditions.

All volumes increased rapidly at 4:34 p.m., at which time speed in the two through lanes dropped to Level D. At this time, the flow rate (based on one-minute volumes) ranged between 3,600 and 4,600. This condition was of about fifteen minutes duration while operation dropped through Level E to Level F. At this time, as is typical of Level F operation, the volume passing through the section dropped. The flow rate during this period of unstable operation averaged 4,000.

At this point a significant difference in speeds between the median and the shoulder lanes existed, with the extreme drop in shoulder lane speeds probably due to the merging traffic.

Speeds and volumes (shown in Figure 4) were measured at the downstream end of the study area (point 10) where it was felt that the traffic would

I-70 ST. LOUIS
SPEED — VOLUME
AT GORE OF I-270 NORTH-WEST RAMP
7-29-69

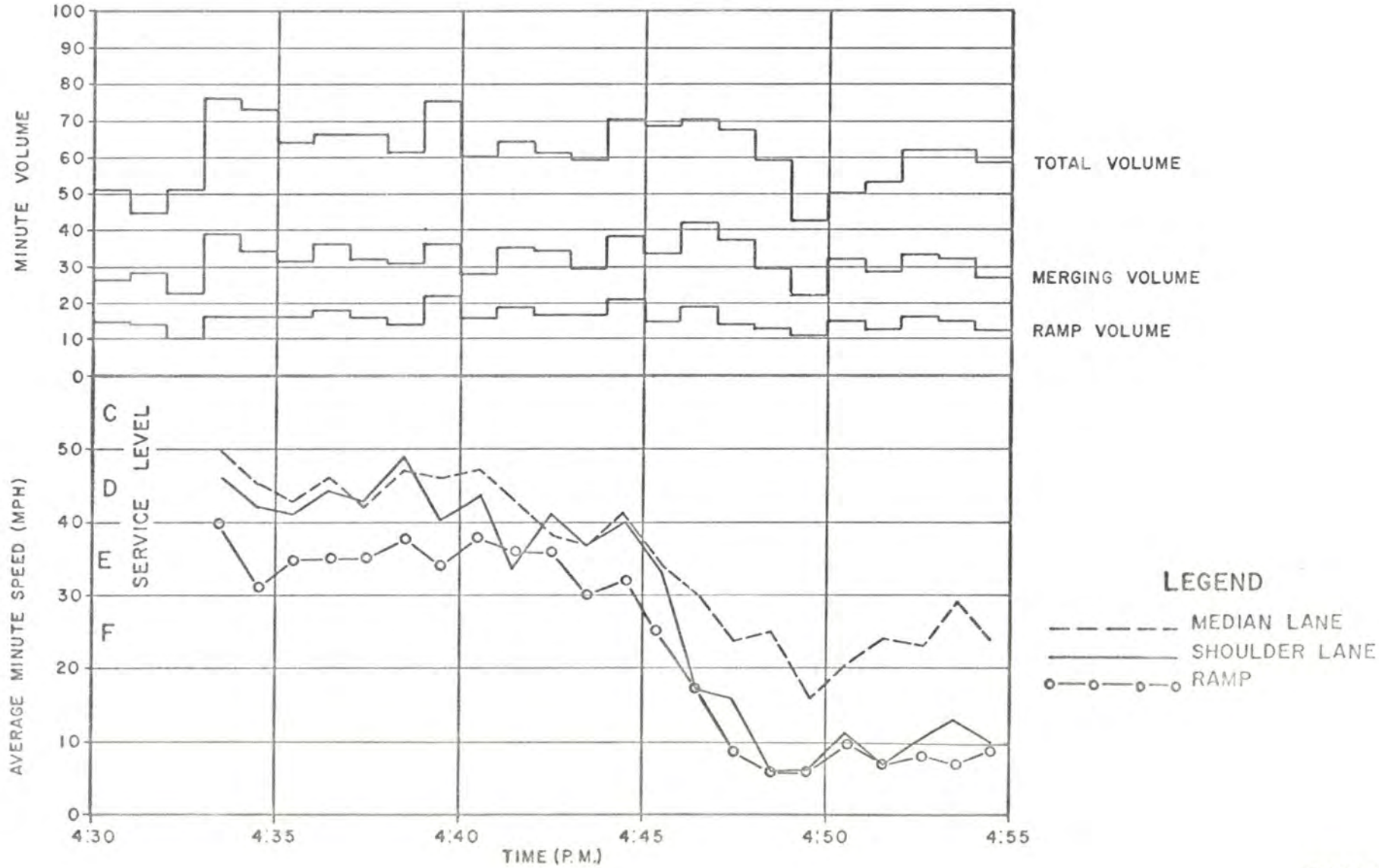

FIGURE 3

SPEED-VOLUME
I-70 ST. LOUIS
400 FEET WEST OF I-270 NORTH-WEST RAMP ACCELERATION LANE
7-29-69

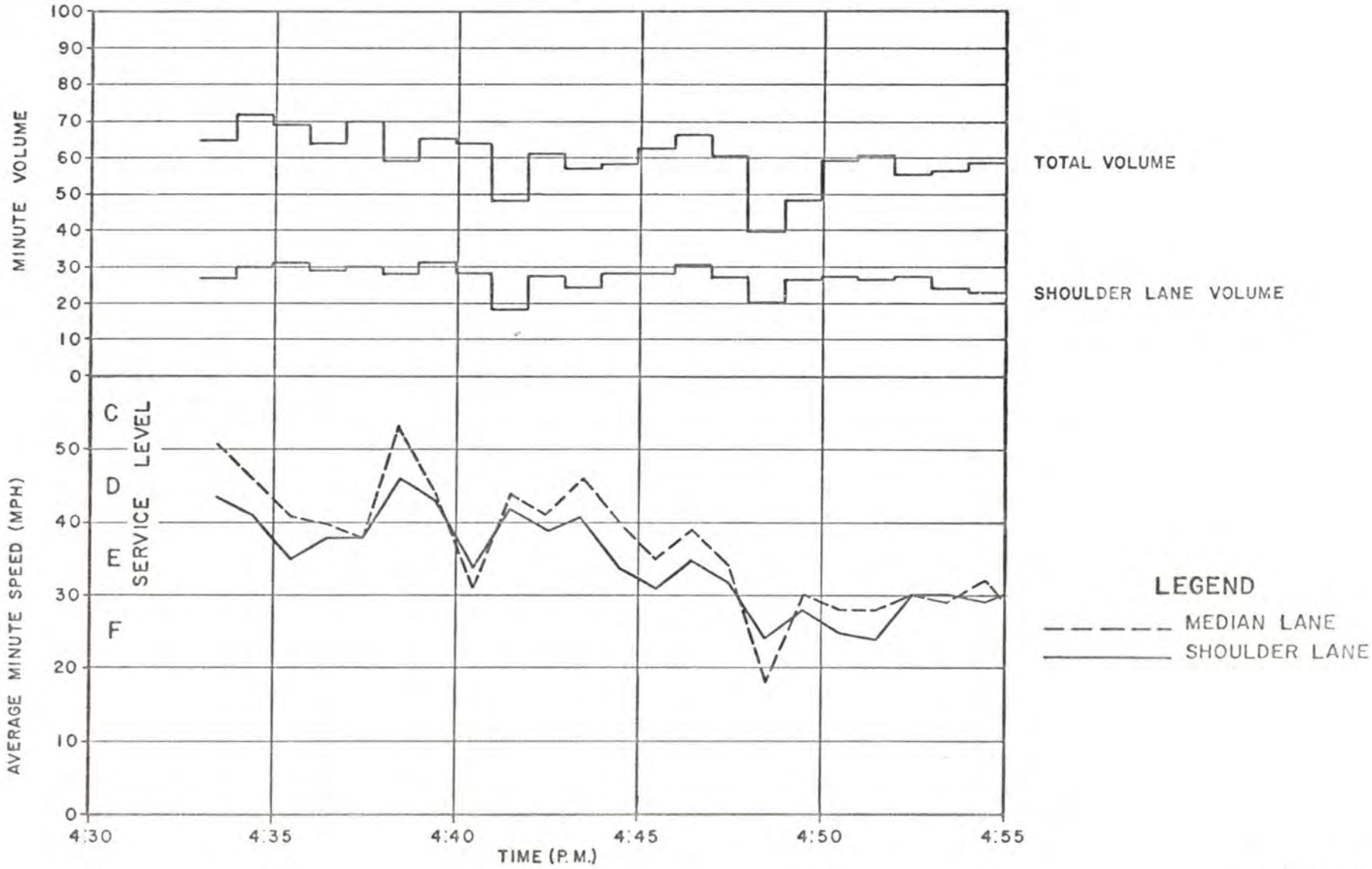

FIGURE 4

have recovered from the effect of merging traffic. The speeds in the median lane, however, were unchanged from the upstream location. Neither lane showed the conditions usually found downstream of a bottleneck location. One other noteworthy fact is the sudden drop in operating speed and volume occurring in the median lane at 4:48 in Figure 4 and at 4:49 in Figure 3.

Individual vehicles were traced through the study area during the period when operation dropped to its lowest level, from 4:42 to 4:50. This provided detailed coverage of operation over the entire study section during the period of breakdown. Every tenth vehicle was traced until a definite deterioration in operation, at which time every fifth vehicle was traced. Figure 5, the shoulder lane, clearly shows the effect of the merging volume.

In Figure 6, the median lane, the most significant occurrence is the complete breakdown for a brief period when a shock wave of start-stop operations backs up from downstream. This indicates that some condition downstream of the study area, in this case it turned out to be demand in access of capacity, is causing considerable trouble.

Since the congestion extended beyond the end of the area filmed originally, an additional flight was made. This flight covered the area immediately downstream of the first section.

Operating conditions on this section of the route were found to be similar to those on the first section. Figure 7 shows conditions during breakdown at a point 800 feet beyond the end of the acceleration lane (point 12). Operation drops from Level A to Level F, the flow rate increases from around 3,000 to around 4,000, and density immediately

TIME-DISTANCE VEHICLE TRACES
I-70 ST. LOUIS
W OF I-270
SHOULDER LANE
7-29-69

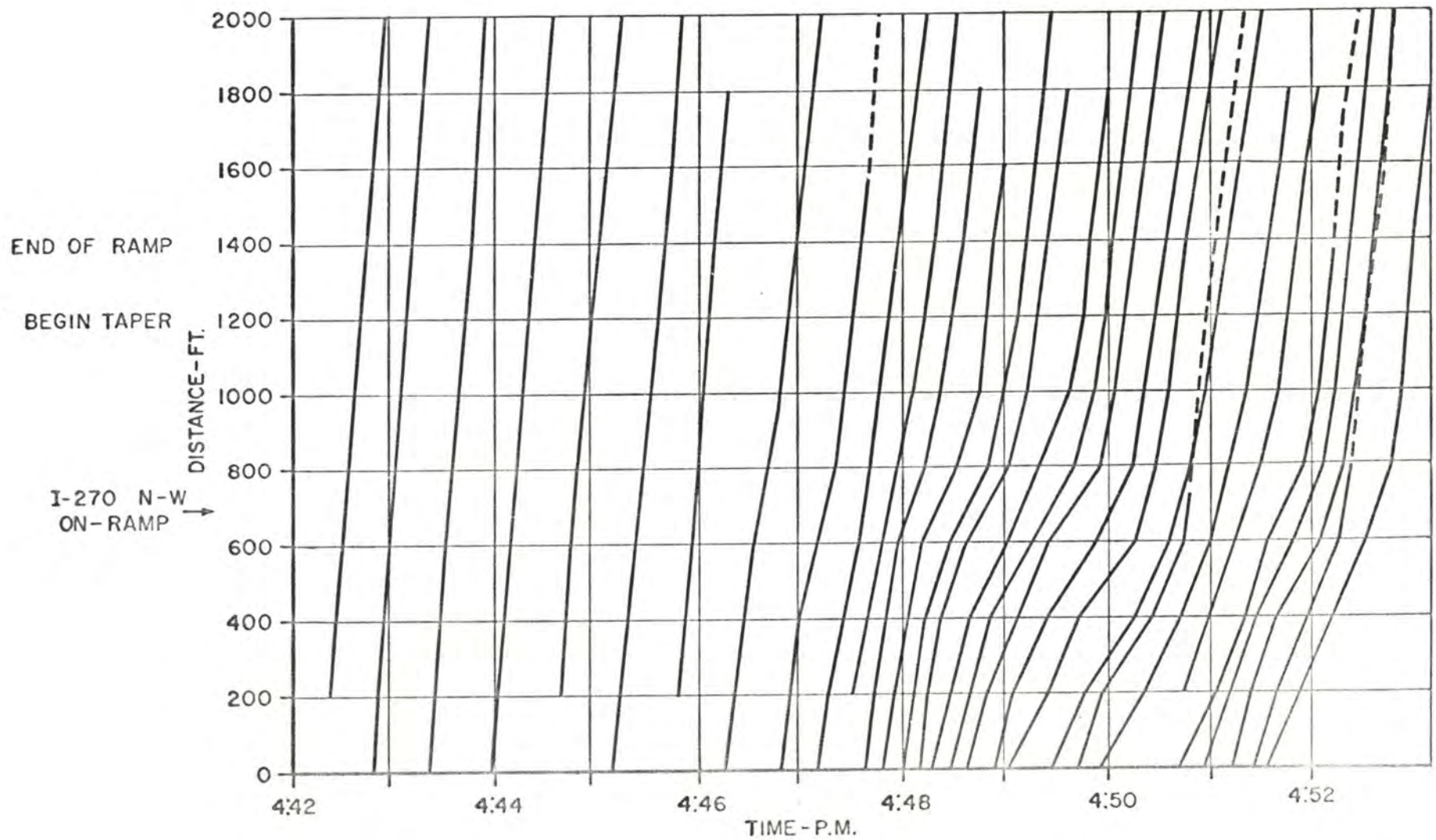

FIGURE 5

TIME-DISTANCE VEHICLE TRACES
I-70 ST. LOUIS
W OF I-270
MEDIAN LANE
7-29-69

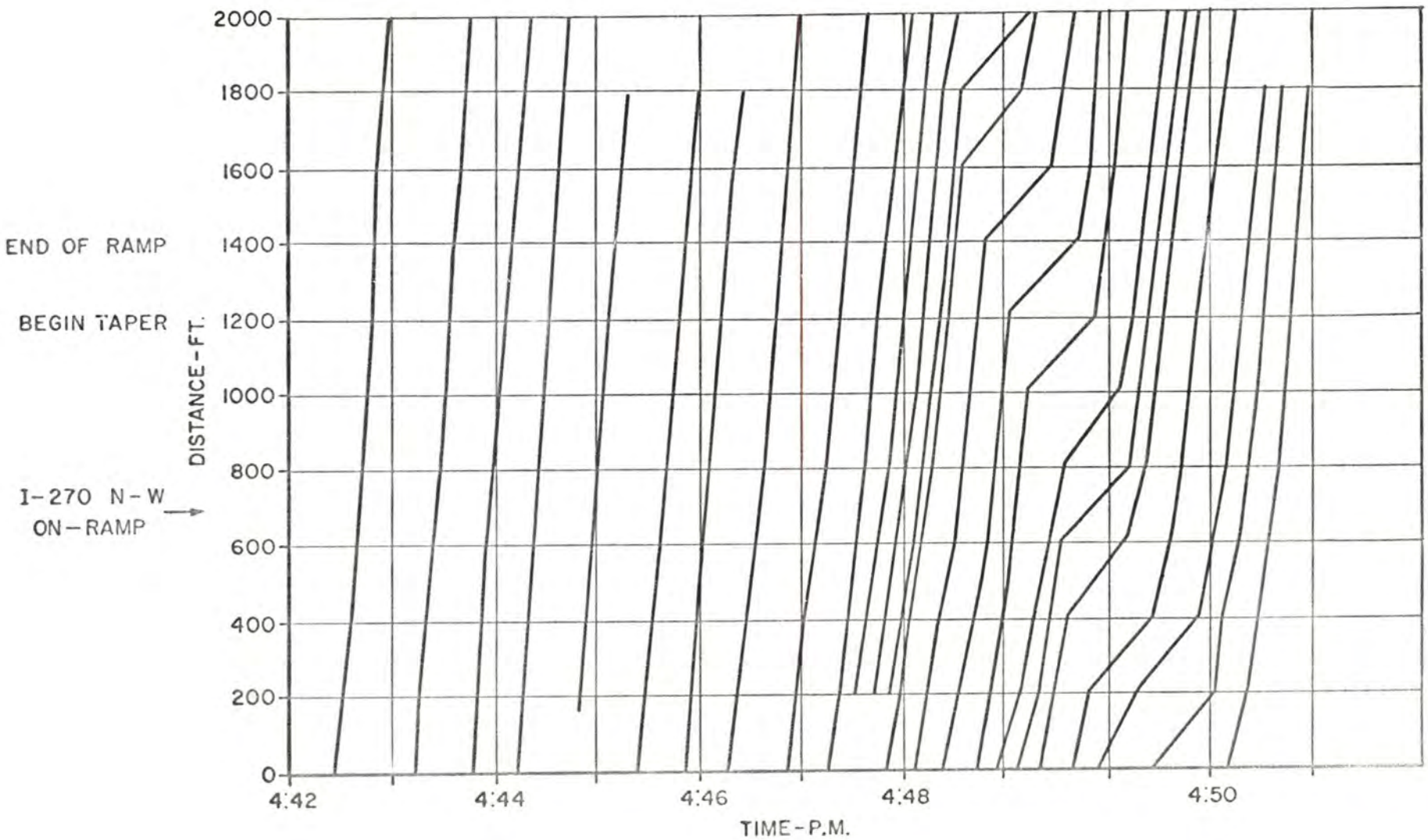

FIGURE 6

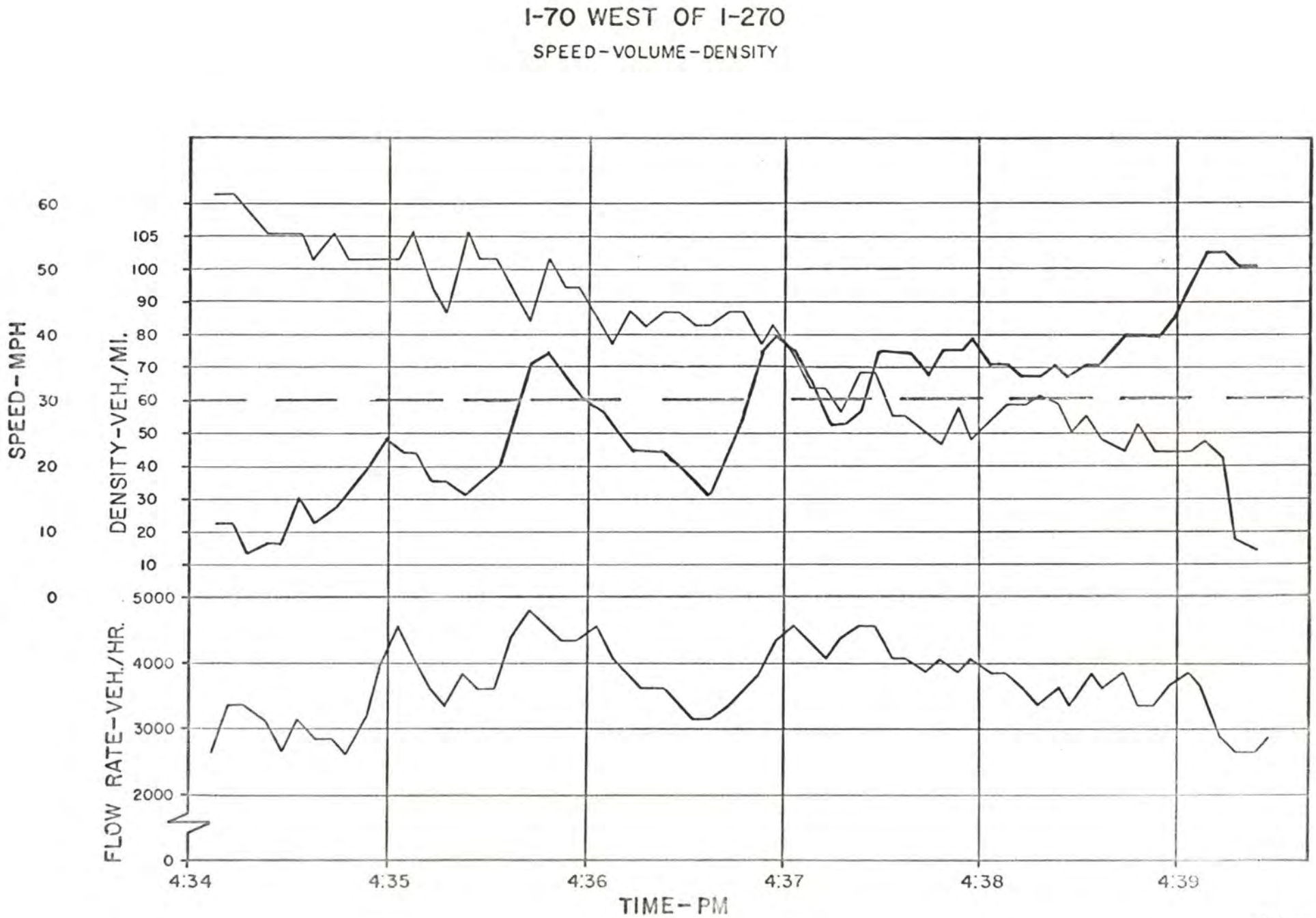
I-70 WEST OF I-270
SPEED-VOLUME-DENSITY
SPEED-MPH
60
50
40
30
20
10
0
DENSITY-VEH./MI.
105
100
90
80
70
60
50
40
30
20
10
FLOW RATE-VEH./HR.
5000
4000
3000
2000
0
4:34
4:35
4:36
4:37
4:38
4:39
TIME-PM

FIGURE 7

begins to build while speeds drop. At the end of the five-minute period, operation completely breaks down.

The downstream front of the congestion was near the end of the study area. Beyond this point, operation rapidly returned to the Level C range of operation.

The freeway at this point has two twelve-foot lanes with a full shoulder and no horizontal curvature, and is on a slight downgrade. With respect to capacity, this represents ideal conditions.

DEMAND-CAPACITY

Demand volumes for the study area were obtained by counting traffic on the free flowing portion upstream of the congestion and adding and subtracting ramp volumes. Demand and volume at the nose of the north-west ramp (Point 4) are shown in Figure 8.

Service volumes and corresponding five-minute flow rates for various service levels were computed using the Highway Capacity Manual and field measurements. The observed service levels are based on speed only. These are shown in the following table.

Table 2

Theoretical and Observed Capacities

		Capacity Manual		Observed	
Service Level	Avg. Speed (mph)	Service Volume	5-Minute Flow Rate	Hour	5-Minute Flow Rate
A	60 (or greater)	1358	-	-	1500
B	55-60	1940	-	-	2400
C	50-55	2444	2910	-	3100
D	40-50	2933	3492	-	3400
E	30-40	3880	3880	-	3800
F	30 (or less)	-	-	3434	3800 (or less)

Peak Hour Factor: .84

The theoretical volumes correspond with the actual flow rates except

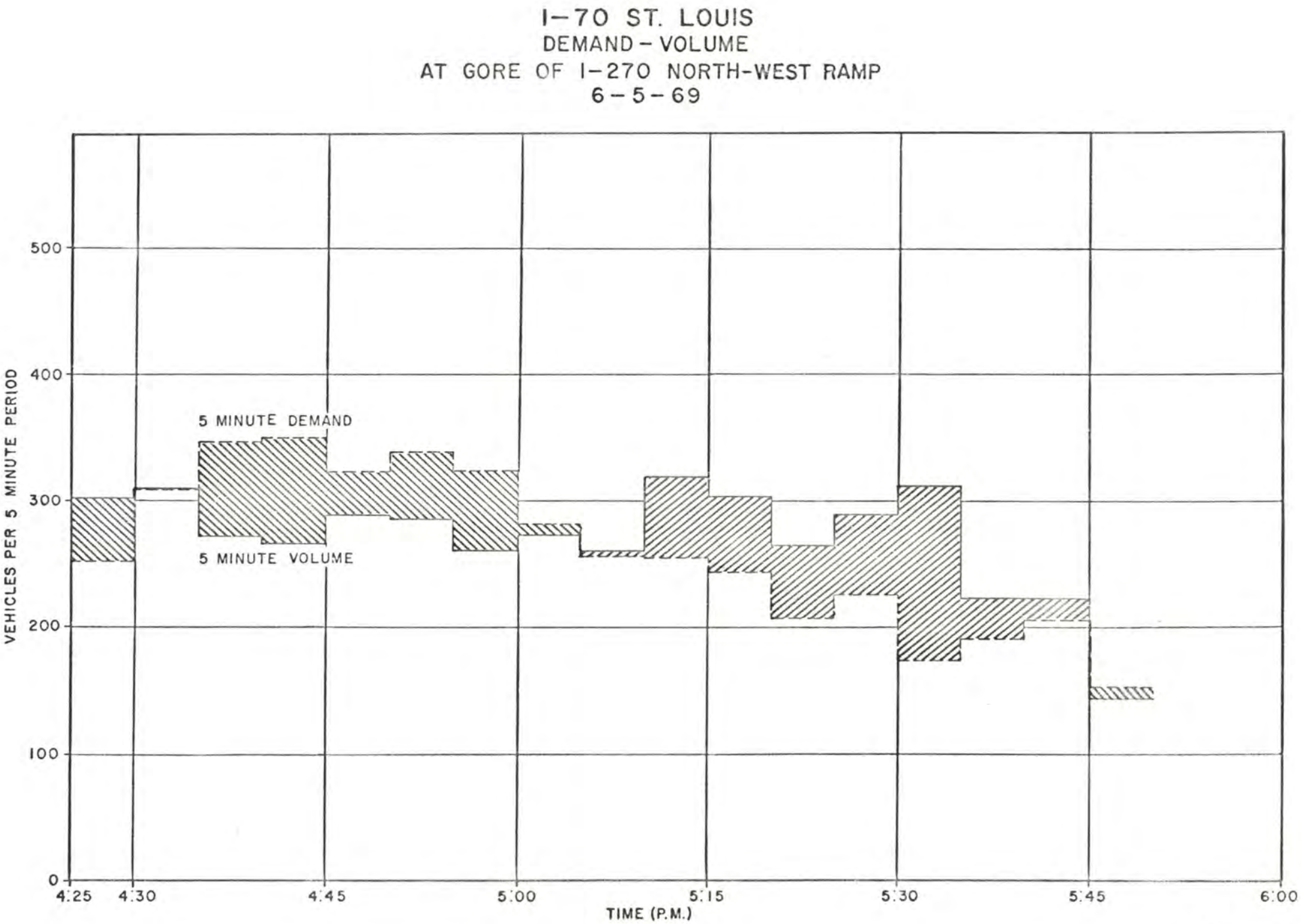
I-70 ST. LOUIS
DEMAND - VOLUME
AT GORE OF I-270 NORTH-WEST RAMP
6-5-69
5 MINUTE DEMAND
5 MINUTE VOLUME
VEHICLES PER 5 MINUTE PERIOD
0
100
200
300
400
500
4:25
4:30
4:45
5:00
5:15
5:30
5:45
6:00
TIME (P.M.)

FIGURE 8

that speeds in the higher service levels are obtained with slightly higher volumes.

Operation remains in the Level C or better range as long as the flow rate remains below 3,000. Level D was found when flow rates remained below 3,400.

The peak hour volume of 3,434 is much less than the capacity figure of 3,880. This figure cannot be obtained due to the high five-minute flow rate which causes the drop to Level F operation where the flow rate varies around the 3,300 level.

The peak hour demand is about the same as the peak hour volume (3,400); however, the peak five-minute demand rate is 4,188. The demand equals or exceeds capacity for twenty-five minutes during the peak hour.

The excess demand could be taken care of by an additional lane from east of I-270 to the first or second interchange in St. Charles. The four-lane bridge over the river, however, appears to prevent this, at least for the present. The addition of a lane ending just short of the bridge, on the other hand, would only aggravate the problem. One alternate solution would be to meter traffic on ramps feeding the study section in order to keep the total through volume at or below the critical level.

The critical (Level E) flow rate appears to be about 3,800. If the surges of traffic could be held to a number below this, operating speeds should remain above 30 mph, and most of the backup would be reduced or eliminated. A flow rate of 3,600, the midpoint of the Level E range, appears the most desirable.

The demand and output volume just downstream of the acceleration lane are shown in Table 3. In addition, Table 3 shows the present vehicle accumulation and the accumulation at a theoretical output rate of 300 for a five-minute demand period.

Table 3

Five Minute Demand - Volumes

Time Ending	Demand	Acc. at 300 Output	Output Volume	Present Acc.
4:30	251	-	301	-
4:35	308	8	309	-
4:40	346	54	213	73
4:45	349	103	266	156
4:50	323	126	289	190
4:55	337	163	286	241
5:00	324	187	259	306
5:05	281	168	272	315
5:10	256	124	260	311
5:15	255	79	319	247
5:20	243	22	304	186
5:25	207	-	264	129
5:30	225	-	288	66
5:35	173	-	311	-
5:40	192	-	222	-
5:45	205	-	222	-
5:50	152	-	144	-
5:55	174	-	164	-

Ramps to be metered would include those on I-270 and I-244 as well as those on I-70. This would help the weaving and merging problem at the I-270 interchange. Since volumes for the entire peak hour are less than capacity, the metering would be for a period of less than one hour.

Table 4 is a sample metering plan based on fifteen-minute machine counts. The details of this plan would need to be determined by more current observations. More ramps could be included in order to minimize the delay to individual vehicles. The total delay to all vehicles using the metered ramps would be 84.1 hours, or an average of 2.29 minutes per vehicle.

TRAVEL TIME

A travel time study using the floating car method was made during peak and off-peak periods as a means of providing a measure of the severity of congestion in comparative terms. Results of this travel time are as follows:

Table 5

Travel Time Summary

Lindbergh Boulevard to 5th Street Exit (St. Charles)

Time Period	Average Speed (mph)	Travel Time (Minutes)	Excess Time (Minutes)
Off-peak	64.0	5.37	-
4-5 pm	54.4	6.34	.97
5-6 pm	52.6	6.54	1.17
4-6 pm	53.5	6.44	1.07
mid peak	44.2	7.78	2.41

Section length: 5.74 miles
Volume, 4-6 pm: 6190

Table 4

Sample Metering Plan

Loc.	15 Min. Ending	Volume	Allowed	Excess	Acc. Excess	Veh. Per Min.	Headway Sec Veh.
Mo. 115	4:45	205	174	31	31	11.6	5.2
to	5:00	130	110	20	51	7.3	8.2
I-270	5:15	160	190	-30	21	12.7	4.7
	5:30	119	183	-64	-	12.2	4.9
Mo. 180	4:45	132	112	20	20	7.5	8.0
to	5:00	94	80	14	34	5.3	11.3
I-70	5:15	104	124	-20	14	8.3	7.3
	5:30	88	135	-47	-	9.0	6.7
Lindbergh	4:45	61	52	9	9	3.5	17.3
S-W	5:00	60	51	9	18	3.4	17.6
	5:15	40	48	-8	10	3.2	18.8
	5:30	33	51	-18	-	3.4	17.6
Lindbergh	4:45	161	137	24	24	9.1	6.6
N-W	5:00	179	152	27	51	10.1	5.9
	5:15	139	165	-26	25	11.0	5.5
	5:30	95	146	-51	-	9.7	6.2
Airport	4:45	113	96	17	17	6.4	9.4
to I-70	5:00	83	71	12	29	4.7	12.7
	5:15	126	150	-24	5	10.0	6.0
	5:30	82	126	-44	-	8.4	7.1

The travel time study covers the section of freeway between Lindbergh Boulevard and the first interchange in St. Charles and includes all the freeway found to be affected by the congestion.

As is typical of most travel time studies, neither the loss in speed nor the loss in travel time was as great as the average motorist would assume. The average loss in travel time per vehicle during the two-hour peak period was only 1.07 minutes During the worst test run it was only 2.41 minutes. Based on a 4-6 pm volume of 6,190, the total lost time would be 110.4 vehicle hours daily.

If the congestion were to be completely eliminated, the best results would yield a decrease in travel time of 2.4 minutes while the average results would be far less. For the motorist who was delayed at the ramps as much as 2 or 3 minutes, the delay would far outweigh the gain in the motorist's mind, even though there was a net gain for all cars.

CONCLUSIONS

Traffic from the I-270 north to west ramp combined with traffic in the shoulder lane has a considerable effect on operation in the shoulder lane; however, the merging movement is not the cause of the congestion on Interstate 70.

The total volume passing through the study area exceeds the capacity of the two lanes downstream of the study section.

Lengthening the acceleration lane would not improve operation overall, and would probably only move the congestion front downstream. Any additional lanes would need to be carried to the first intersection in St. Charles.

The actual time loss to the motorist is not yet severe enough to justify the only immediate solution, the metering or diversion of traffic at the on-ramps serving this section.

RECOMMENDATIONS

It is recommended that no revision of the interchange be made for the purpose of improving flow through the intersection until the pressure on the downstream lanes is relieved.

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