INBOUND GULF FREEWAY RAMP CONTROL STUDY I

by

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PREFACE

The research work reported on herein represents a cooperative effort on the part of the authors of the report. Specific areas of responsibilites were as follows:

Donald R. Drew - Supervisor of Operations Area. Responsible for analysis of aerial photo data and the development of freeway flow characteristics and system control parameters.

William R. McCasland - Supervisor of Design Area. Responsible for Origin-Destination Studies, preparation of handouts and other material utilized in the control procedure and conduct of the ramp control operation.

Charles Pinnell - Project Director. Responsible for the coordination of the various research areas and the over-all conduct of the study.

Joseph A. Wattleworth - Supervisor of Systems Area. Responsible for subsystem studies to identify bottleneck locations, development of individual ramp control strategy and data collection and analysis.

CONTENTS

INTRODUCTION

NEED FOR CONTROL

Severe peak-period congestion on the Gulf Freeway in Houston led to the establishment of a "Level of Service" research project which the Texas Transportation Institute is conducting in cooperation with the Texas Highway Department, the City of Houston, and the U. S. Bureau of Public Roads. The study being reported in this research report was conducted as part of the "Level of Service" project.

Past studies (ref. 1, 2, 4) by the Texas Transportation Institute have succeeded in quantifying the problem of congestion on the inbound Gulf Freeway. The duration of congestion was established as well as traffic speeds, densities, etc. The bottlenecks were located and the demand and capacity were estimated for each of these.

It is generally believed that the freeways would operate more efficiently during the peak periods if congestion could be prevented. Congestion develops on a freeway when the demand exceeds the capacity at one or more freeway bottlenecks, and since capacity at any freeway bottleneck cannot generally be increased, it follows that the demand must be altered if congestion is to be prevented. This suggests that some form of control is required to prevent congestion.

SCOPE OF THE REPORT

This report contains the background, development, and results of Ramp Control Study I conducted as part of the "Level of Service" project on the inbound Gulf Freeway. This first study was limited to the entrance ramps on the inbound Gulf Freeway from Wayside Drive to the downtown distribution system during the morning peak period.

The control study was conducted on nine weekdays from August 4 to 14, 1964. The studies from which the control plans were developed were made from January to April, 1964. These and later studies were used to evaluate the effect of the ramp control operation.

The controls which were tested were fixed-time controls, i.e., they were not traffic adjusted. The development of the control plan utilized "historical" data which were collected from January to April, 1964. The approach or philosophy used in the development of this plan was to estimate the demand rate and capacity flow rate at each entrance ramp merging section from Wayside Drive to Scott Street and to control each entrance ramp in this section as severely as needed to keep the demand less than or equal to capacity.

SEVERITY OF CONGESTION BEFORE CONTROL

STUDIES IN SEPTEMBER, 1963

An aerial photographic study was conducted on the Gulf Freeway during the month of September, 1963. On each of six flights over the freeway, time-lapse photographs were taken. Extensive analyses of the data were made, primarily to test several mathematical models of freeway traffic flow.

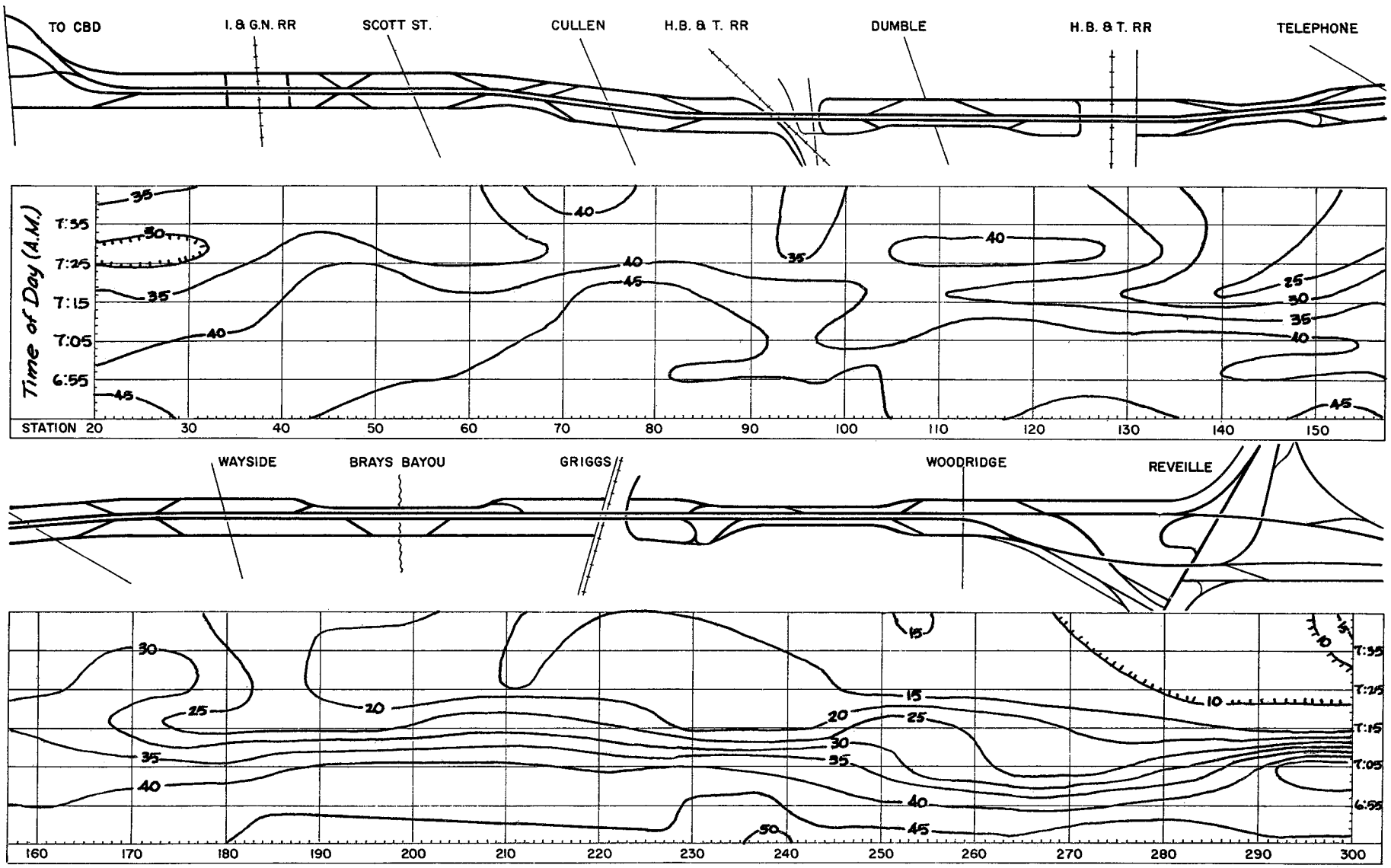
Among the other analyses, speed contours and density contours were plotted and are shown in Figures 1 and 2. The speed contour in Figure 1 shows that the congestion is limited to the region from upstream of the Reveille Interchange to near Telephone Road and the South HB&T Railroad overpass. The most severe congestion occurs in the Reveille Interchange area where the speeds drop to the 10-15 mile per hour range. The density contours verify these findings since the highest densities are found near the Reveille Interchange. Further details of this study are presented in an earlier publication.[1]

STUDIES IN JANUARY - APRIL, 1964

During the four-month period from January through April, 1964, several operational studies were made on the inbound freeway. Among the different types of studies which were conducted during this time period are (1) closed system input-output studies,[2,3] (2) entrance ramp origin-destination studies,[3,4] (3) bottleneck capacity studies,[2,3] and (4) moving vehicle travel time studies.

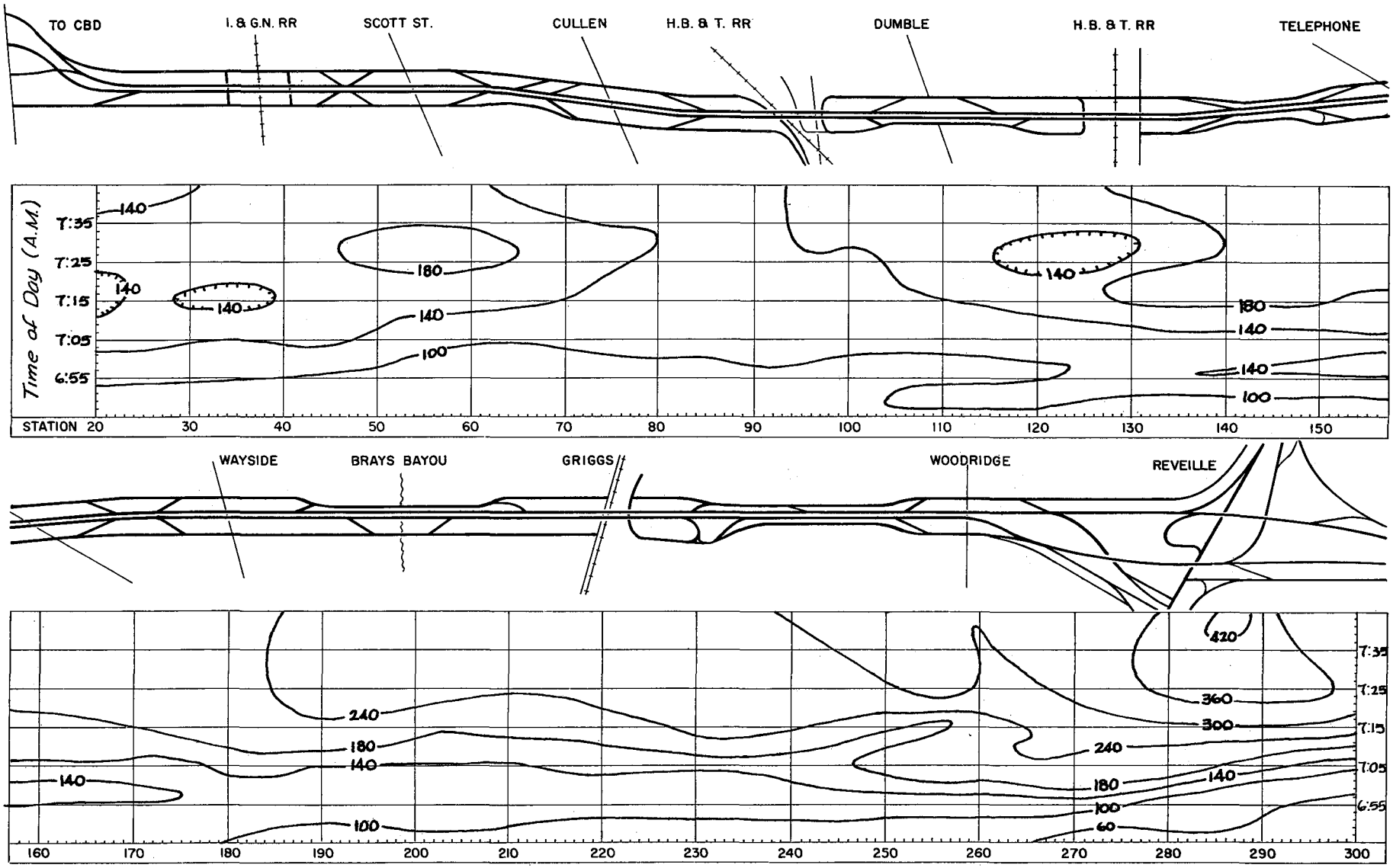
Closed System Input-Output Studies

One of the primary types of studies was that involving the closed system input-output counts. In a study of this type coordinated counts are made on each of the entrances and exits to a section of freeway. From these counts it is possible to determine (1) the total number of vehicles entering the freeway section (freeway subsystem) in any time period, (2) the number of vehicles leaving the freeway subsystem in any time period, (3) the rate of accumulation or discharge of vehicles in the freeway subsystem in any time period, (4) the number of vehicles in the subsystem at any time, and (5) the density in each subsystem at any time. Table 1 contains the five freeway subsystems studied and the dates of the studies. These five subsystems cover the entire inbound Gulf Freeway from Broadway to the Calhoun-Pease distribution system (near the CBD).



SPEED CONTOURS (TOTAL INBOUND TRAFFIC)

FIGURE 1



DENSITY CONTOURS (3 LANE TOTAL)

FIGURE 2

TABLE 1

Study Dates	SUBSYSTEM BOUNDARIES	
	Upstream Boundary	Downstream Boundary
January 27 - 31, 1964	Downstream of Broadway Entrance Ramp	Griggs Road Overpass
March 16 - 20, 1964	Griggs Road Overpass	South HB&T RR Overpass
March 30 - April 3, 1964	South HB&T RR Overpass	Upstream of Cullen Entrance Ramps
April 13 - 17, 1964	Upstream of Cullen Entrance Ramps	Upstream of Scot Entrance Ramp
April 20 - 24, 1964	Upstream of Scott Entrance Ramp	Calhoun-Pease Distribution System

Figure 3 shows the variations of density with time for each of the five subsystems. From these plots it can be seen that severe congestion is prevalent for a long period only between Broadway and the South HB&T Railroad overpass and that congestion is most severe between Broadway and the Griggs Road overpass. Congestion prevails between Broadway and the South HB&T Railroad overpass from about 7 to 8 a.m. This corresponds well with the findings of Drew.[1] (Further details of the closed system studies are given by Wattleworth.[2])

Since the freeway at the Griggs Road overpass is the highest volume output of the most congested subsystem, the traffic characteristics there were carefully examined. Figure 4 shows the flow and speed on the downgrade of the Griggs Road overpass. The flow remains high during the period from 6:50 - 7:05 a.m. During this time the speeds are generally in the 30-40 mph range. From 7:05 - 7:20 a.m. the flows decrease sharply and the speeds average about 20 mph with many minute averages near 15 mph. The decrease in speed and at least part of the decrease in flows can be attributed to queues from downstream bottlenecks reaching the Griggs Road overpass. It is possible that the decrease in flow in the 7:05 - 7:20 a.m. period is caused by the development of congestion on the upgrade side of the overpass (just upstream of the study site). The most sizeable decrease in flow, however, occurring from 7:20 - 7:55 a.m. can be almost entirely attributed to the queues from downstream. (Further details are presented in the literature.[2])

Figure 5 is a volume flow map for the inbound freeway from 7 to 8 a.m. The Reveille Interchange area, which experiences the heaviest congestion, has extremely low hour volumes -- around 3,000 vehicles per hour. This tends to substantiate the finding that the congestion in this area may not be caused by excessive demand, but rather is caused by congestion backing up from downstream bottlenecks. The peak hour volumes in the Wayside-Telephone vicinity are much higher -- around 5,500 - 5,650 vehicles per hour.

It was also shown in these studies that the flow out of a freeway subsystem (with a noncongested subsystem downstream of it) decreases after a period of congested operation. The subsystem extended from Griggs Road to the South HB&T RR overpass. Speeds at the freeway output (South HB&T RR overpass) ranged from 30 to 35 mph during the peak period, indicating that there was no severe congestion at this location.

The output rates of this subsystem and the density within the subsystem are shown in Figure 6. The upper four curves represent four output plots. The lower curve is the freeway output (at the South HB&T RR overpass) only. The second curve is the freeway output plus the output of the next upstream

FIGURE 3 DENSITY VERSUS TIME–ALL SUBSYSTEMS

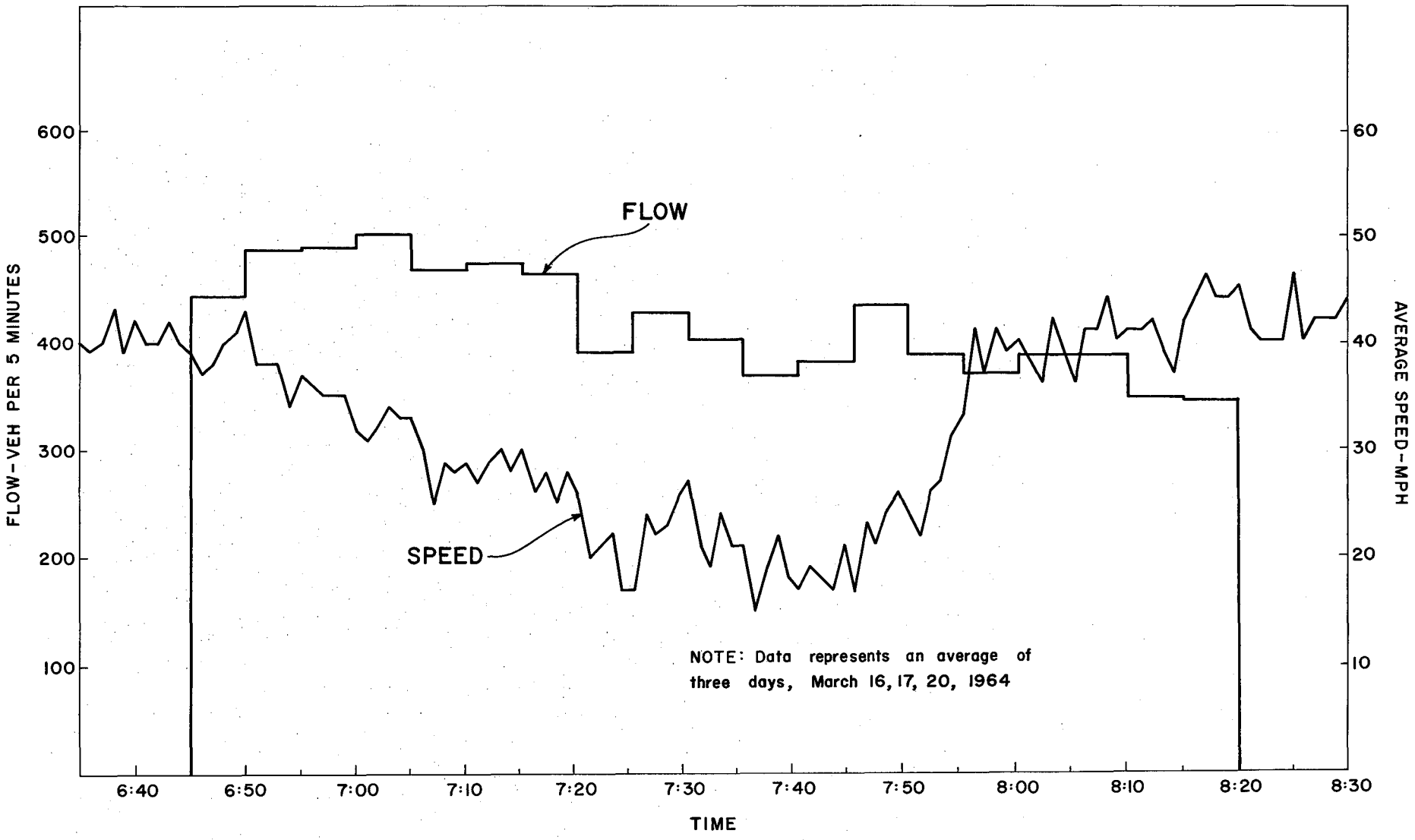


FIGURE 4 FLOW AND SPEED ON FREEWAY AT GRIGGS ROAD

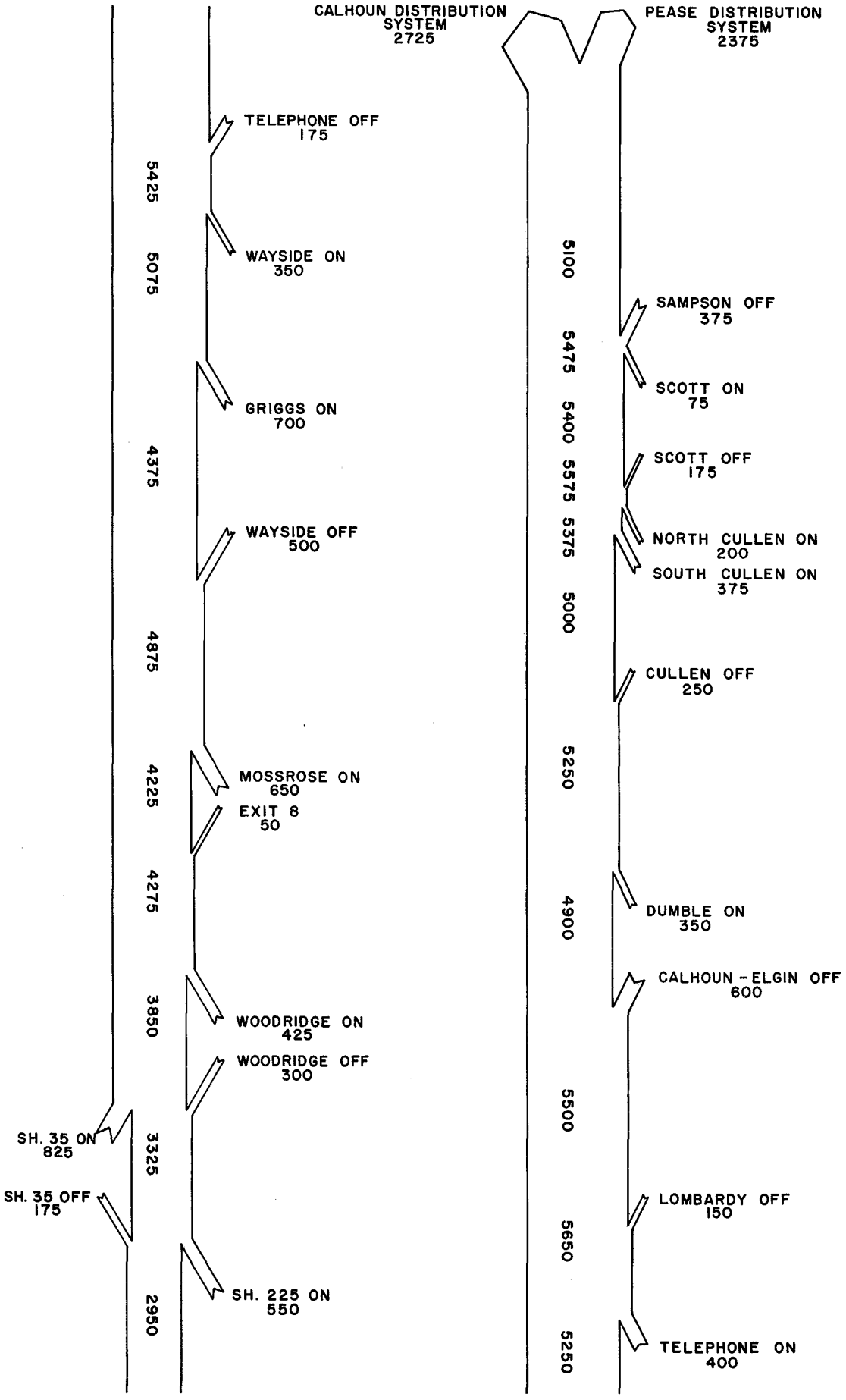


FIGURE 5 — VOLUME FLOW MAP - INBOUND GULF FREEWAY — 7-8 A.M.

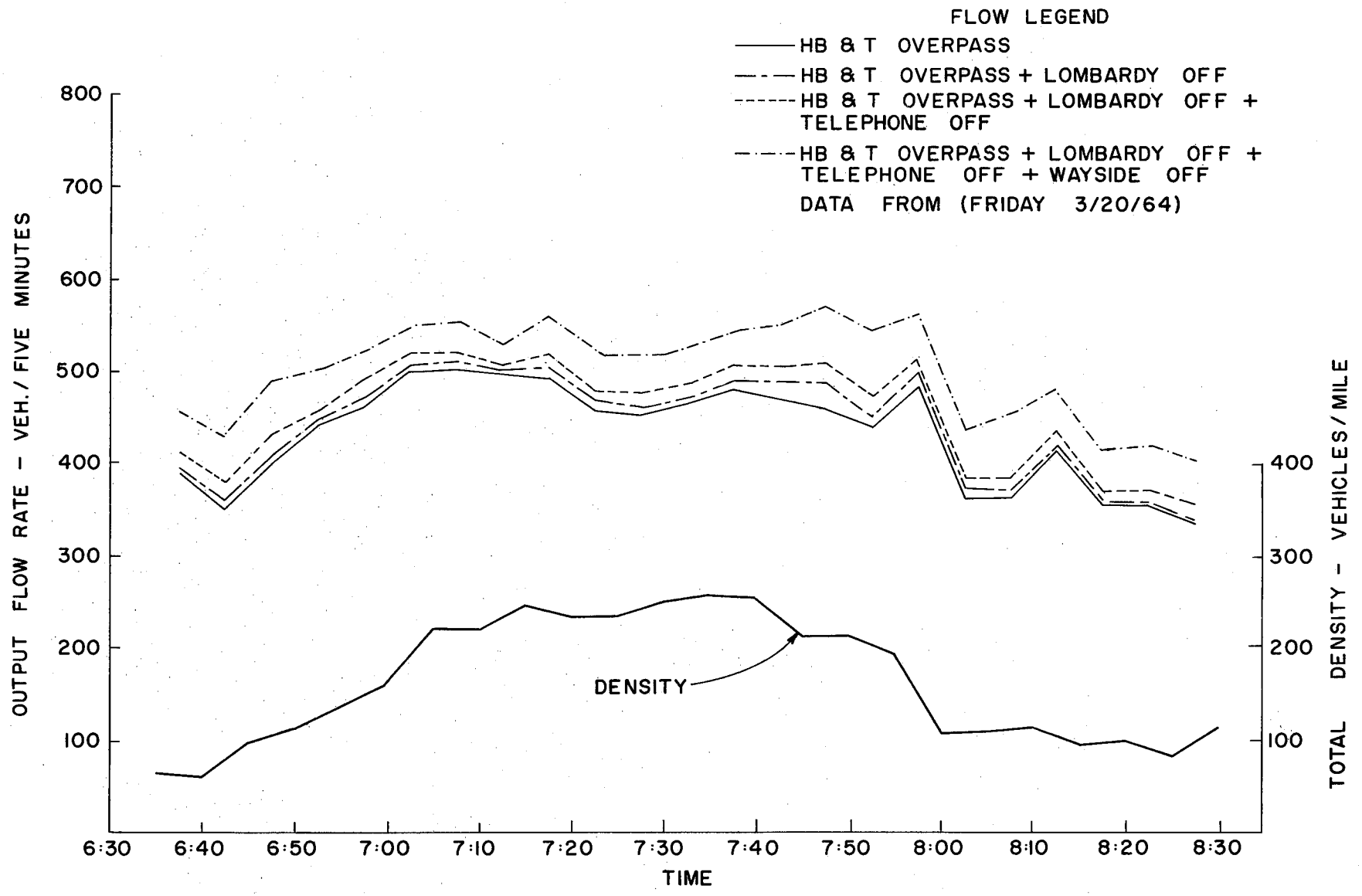


FIGURE 6 OUTPUT FLOW RATES AND TOTAL DENSITY - GRIGGS - SOUTH HB & T RR SUBSYSTEM

exit ramp (Lombardy). The output of the next upstream exit ramp (Telephone Road) is added to produce the third curve and the output of the last exit ramp (Wayside) in the subsystem is added to produce the upper curve. In the 7:15 - 7:40 a.m. period, each of these outputs decreases from the 7:00-7:15 a.m. levels. Thus, the congestion internal to the subsystem apparently decreased the output flow rate of the subsystem.

In summary, it was found that congestion prevailed on the inbound freeway between Broadway and the South HB&T Railroad overpass from about 7 to 8 a.m. Congestion is most severe in the region from Broadway to Griggs Road. Much of the congestion in this region is due to the reduction of the output flow of this area caused by queues on the freeway at Griggs Road originating at downstream bottlenecks. It follows then that a reduction in the queueing at these downstream bottlenecks could reduce the congestion on the freeway between Griggs and Broadway. It was also found that congestion internal to the Griggs-South HB&T RR subsystem decreased the output flow rate of that subsystem as well as the output flow rate of the Broadway-Griggs subsystem.

Entrance Ramp Origin-Destination Studies

Origin-destination questionnaires were distributed to the drivers of vehicles entering the inbound freeway on each of the entrance ramps from the Reveille Interchange to the Calhoun-Pease distribution system. The distribution took place at each ramp on one day from 6:45 to 8:15 a.m. Figure 7 shows a questionnaire of the type used.

From these studies it was possible to determine for each entrance ramp the percentage of vehicles exiting at each downstream exit ramp. It was also found that over 90% of the drivers using the freeway make the same trip five or more times per week.

Further details can be found in the literature.[3,4]

Bottleneck Capacity Studies

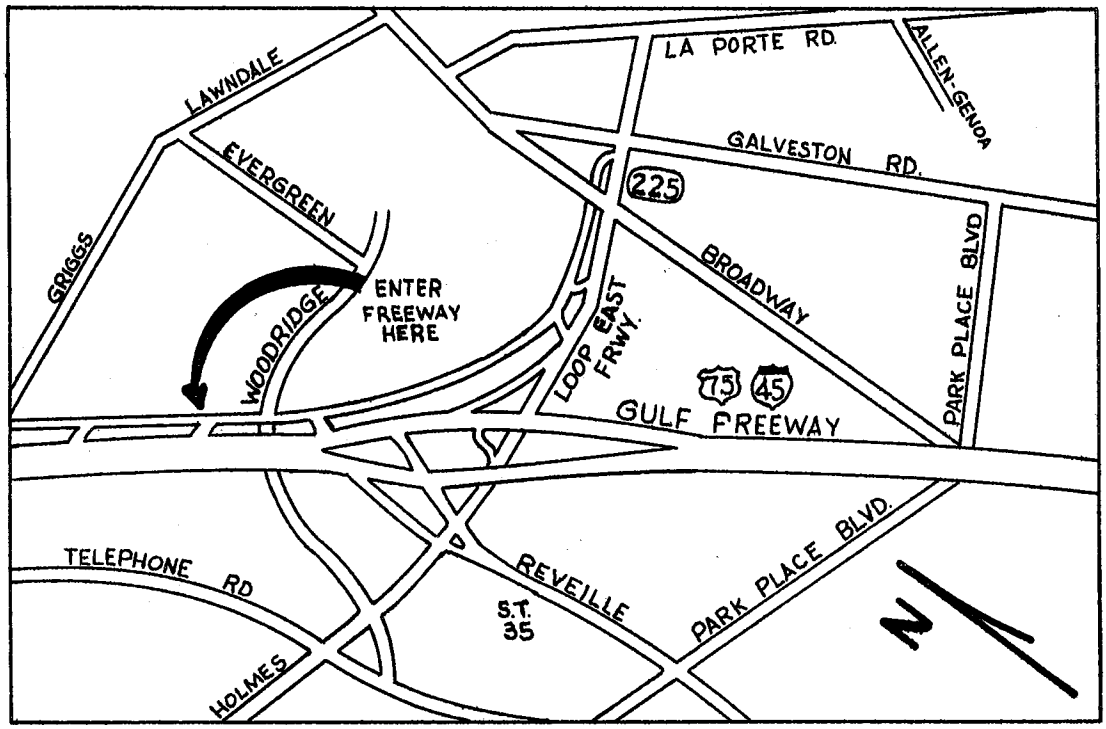
At each bottleneck on the inbound freeway five-minute manual counts and speed samples (each lane, each minute) were collected on several days for the purpose of estimating the capacity flow rates. Further details are presented in the literature.[2]

Moving Vehicle Travel Time Studies

For five days, January 27-31, 1964, a vehicle equipped with a speed-time plotter was operated on the inbound freeway for the purpose of gathering

O-D STUDY - GULF FREEWAY

QUESTIONNAIRE



The following questions concern the trip being made at the time you receive this questionnaire.

1. Please draw a line directly on the above street map showing the route you followed in reaching the indicated entrance ramp. If the origin of the trip is not included in the area shown, extend the route to the border of the map.

2. Where did this trip begin?

_____

Street Address City Time of Day

3. Where did this trip end?

_____

Street Address City Time of Day

4. What exit ramp did you use to leave the freeway? (Check One)

____Exit No. 7-Wayside	____Exit No. 4-Calhoun-Elgin	____Exit No. 1-Sampson
____Exit No. 6-Telephone	____Exit No. 3-Cullen	____Pease Street
____Exit No. 5-Lombardy	____Exit No. 2-Scott	____US 75 North-Calhoun St.

5. How often is this trip made between 6:30 and 8:30 a.m. (Check One)

____Seldom	____Twice per week	____Four times per week
____Once per week	____Three times per week	____Five or more times per week

6. Do you ever use other routes to make this trip? _____yes _____ no.

If yes, what major streets are used?_____

_____

After you have completed this questionnaire, please mail it back to us in the addressed envelope at your earliest convenience to the Texas Highway Department, Research Project, P. O. Box 26656, Houston, Texas 77032.

THANK YOU FOR YOUR COOPERATION

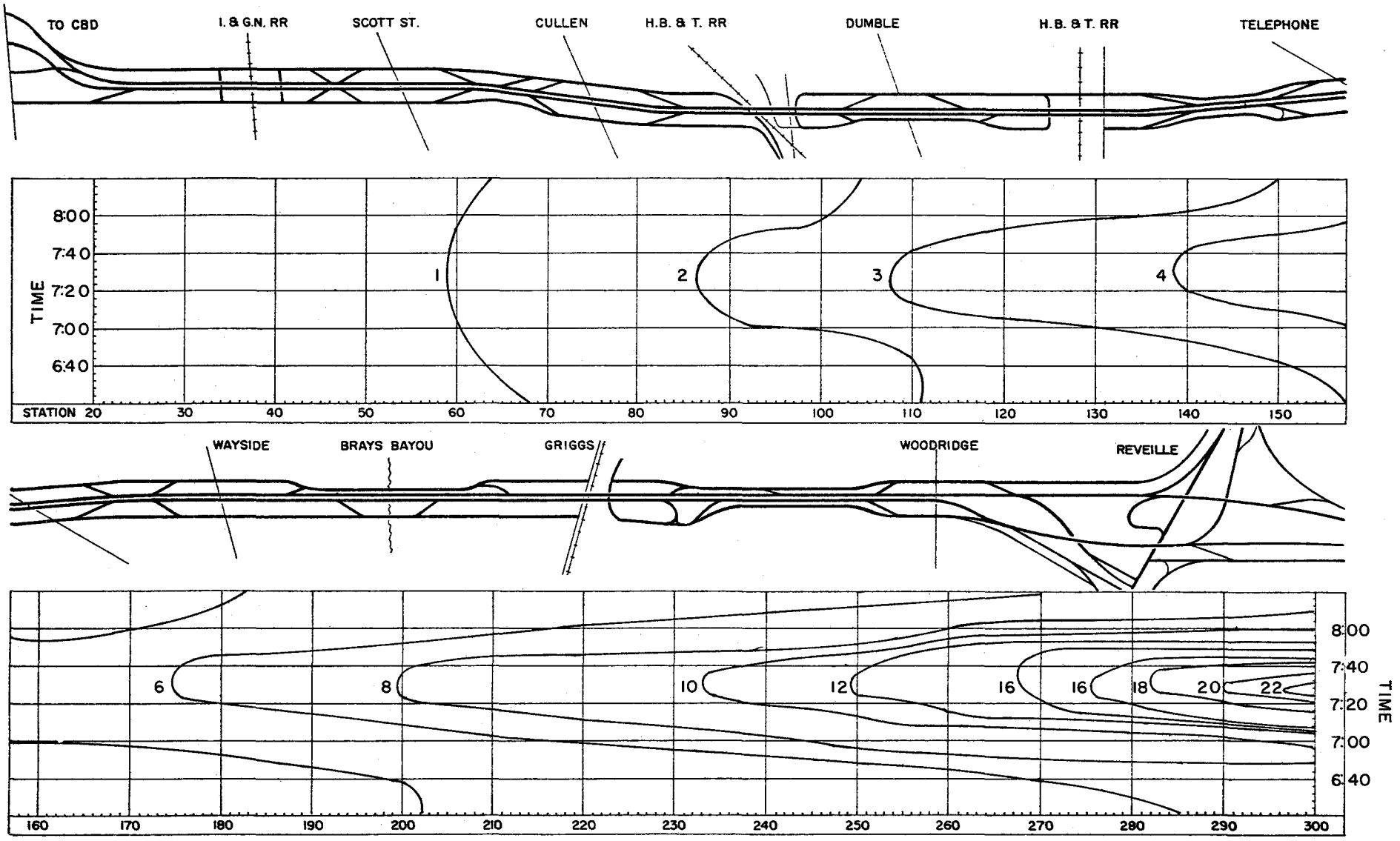
FIGURE 7

data on a fairly new traffic variable, acceleration noise. Because of the way these data were collected, it was also possible to obtain travel times. Figure 8 shows the travel time contour obtained January 28-31, 1964. The highest travel time from the Reveille Interchange to the end of the freeway was found to be more than twenty minutes for the 5.4 mile trip.

STUDIES IN JULY, 1964

Additional airphoto studies were made in July, 1964, to provide a record of traffic conditions just prior to the control study. From these studies it was possible to determine the number of vehicles on any portion of the freeway and/or frontage roads.

Figure 9 shows the variation of density with time on three freeway sub-systems: (1) Broadway to Griggs Road, (2) Griggs Road to the South HB&T RR overpass, and (3) South HB&T RR overpass to the Calhoun-Pease distribution system. From this illustration it can be seen that the density in the Broadway-Griggs subsystem during the 7-8 a.m. period is substantially less than it was during the earlier studies. Thus, the traffic pattern apparently changed during the summer months causing the reduction in congestion. This phenomenon is explained in the next sections of the report.



AVERAGE TRAVEL TIME (MINUTES) TO END OF FREEWAY
CONTOUR MAP
BEFORE CONTROL — JANUARY 28 – 31, 1964
FIGURE 8

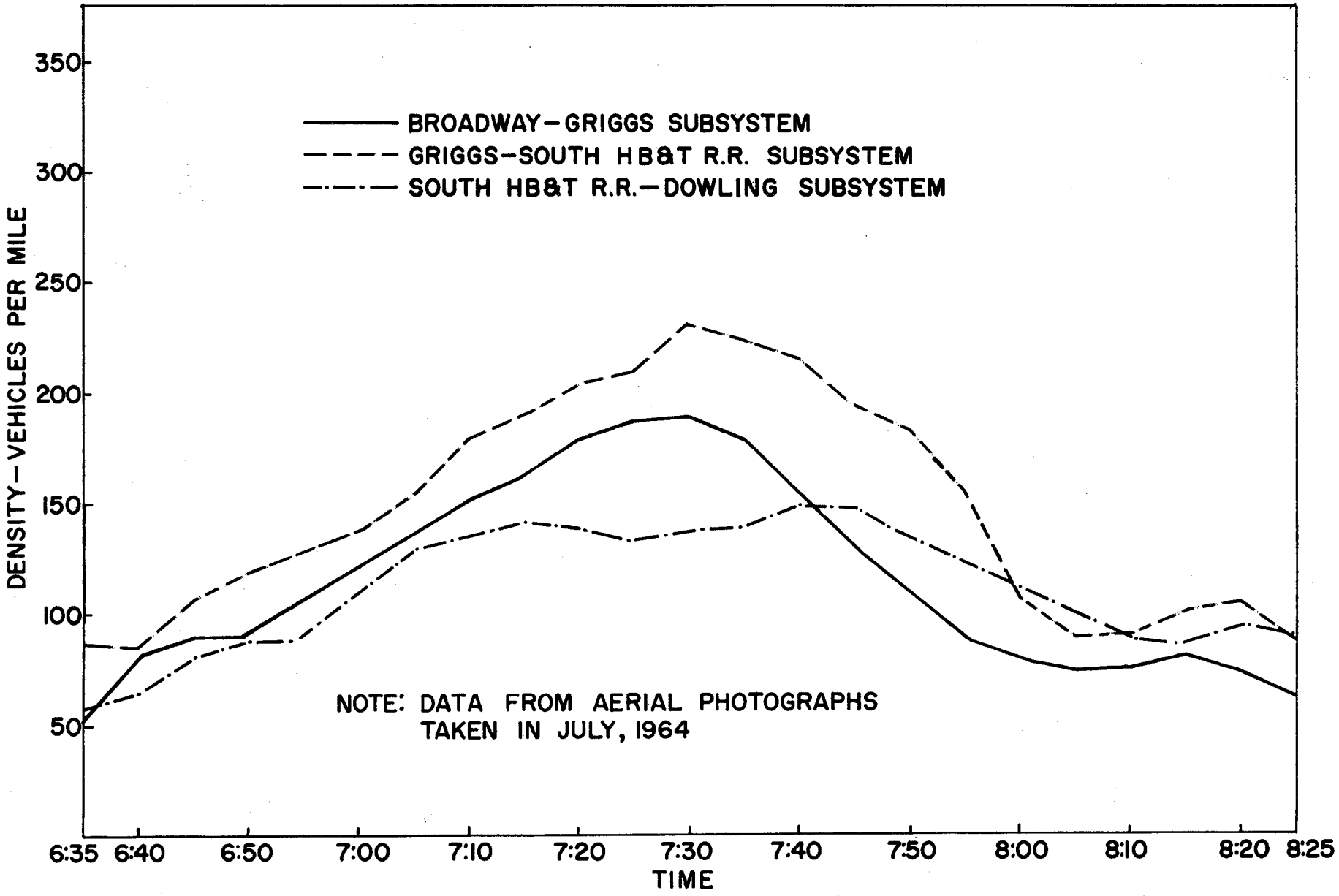


FIGURE 9 – DENSITY VERSUS TIME–FREEWAY SUBSYSTEMS

ESTIMATION OF DEMAND AT FREEWAY BOTTLENECKS

Before the control plans were developed, demand-capacity analyses were made at each bottleneck on the inbound freeway. The purpose of these analyses was to estimate how each bottleneck would operate if it were to operate independently of downstream bottlenecks, i.e., if downstream congestion did not back past the bottleneck. From these analyses it is possible to estimate for each bottleneck (1) the amount by which the demand exceeds the capacity, (2) the time period for which the demand exceeds the capacity, (3) the duration of congestion, and (4) the number of vehicles that would be "stored*" upstream of the bottleneck because the demand exceeds the capacity there. These represent estimates of what would occur at each bottleneck due only to traffic demand at or upstream of the bottleneck.

The technique used to estimate the demand has been reported elsewhere.[2,3,5] Basically the demand at a bottleneck is determined by combining upstream input volumes with origin-destination data for these same inputs and with the capacities of upstream bottlenecks.

As an example, the procedure used in estimating the demand downstream of the S.H. 35 ramp will be outlined. Figure 10 shows the freeway subsystem involved in this estimation. Origin-destination studies [4] indicated that of the vehicles on the freeway at Broadway 7.2% exit at S.H. 225 and 5.7% exit at S.H. 35. This leaves 87.1% of these vehicles which pass through the bottleneck at S.H. 35. Since none of the vehicles from the Detroit, S.H. 225, and S.H. 35 entrance ramps leave the freeway upstream of the S.H. 35 merge, they all must pass through this bottleneck. This means that for each five-minute period the demand downstream of S.H. 35 (the total merging demand) equals 87.1% of the volume on the freeway at Broadway plus 100% of the Detroit entrance ramp volume plus 100% of the S.H. 225 volume plus 100% of the S.H. 35 volume. A graph of the demand at this location is shown in Figure 11. As can be seen from this illustration, the peak occurs at about 7:00 a.m.; it is very short and the demand drops off

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* The term storage of vehicles as used here refers to the cumulative amount of excess demand (which is always positive) and is not the total number of vehicles undergoing congested operation. A storage of 50 vehicles could possibly cause a queue of 500 vehicles upstream of the bottleneck. The storage might be considered to be the excess number of vehicles on the freeway.

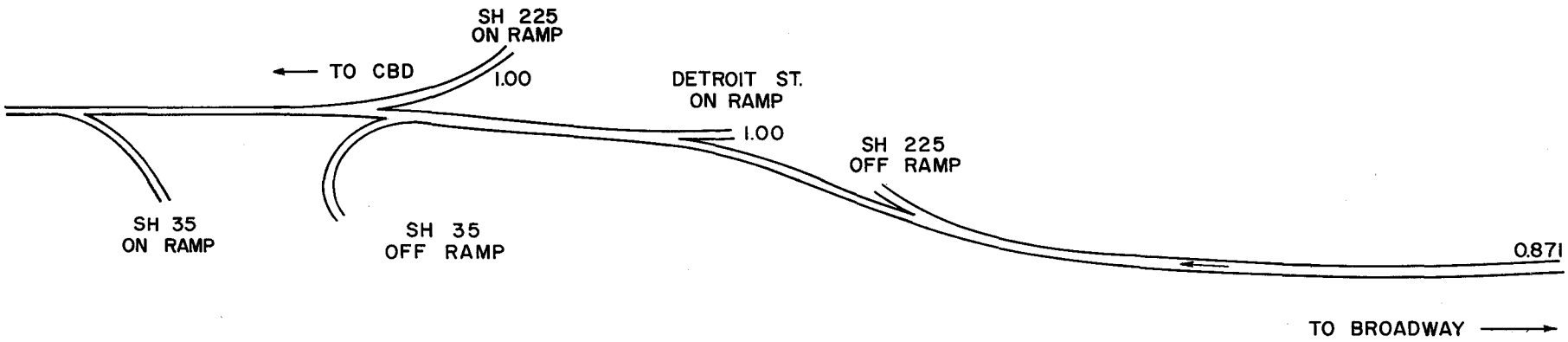

FIGURE 10 FREEWAY SUBSYSTEM UPSTREAM OF S.H. 35 MERGING SECTION

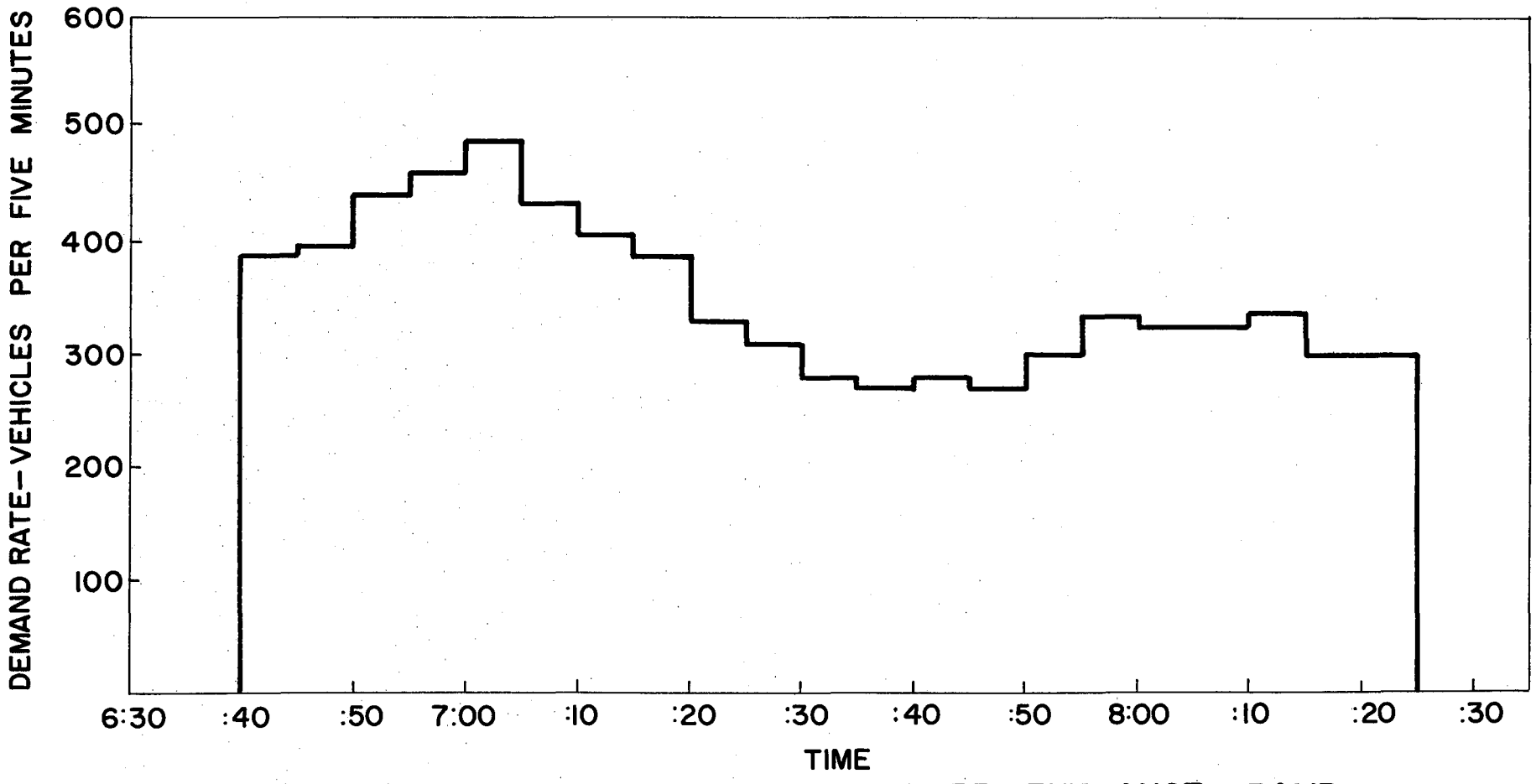

FIGURE 11 DEMAND DOWNSTREAM OF SH 35 ENTRANCE RAMP

very sharply. Without the influence of downstream bottlenecks, the duration of congestion here would be about 15-20 minutes instead of an hour duration which was found to be the case in studies conducted in January.

Figure 12 shows the demand at the bottleneck at the Griggs Road overpass. Again, if it were not for the influence of downstream bottlenecks, the bottleneck at Griggs Road would clear up by about 7:25 a.m. instead of 8:00 a.m. at the present. From these figures it can be seen that the entire subsystem from Griggs to Broadway would be clear at about 7:25 a.m. if controls on downstream ramps prevented the congestion which originates downstream of Griggs Road and backs up to Griggs Road, thereby decreasing the output capacity of the Broadway - Griggs subsystem.

Demand estimates were also made at the other two bottleneck areas on the inbound freeway -- the Wayside Drive merging section and the Telephone Road merging section. The demand was found to exceed the capacity from 7:05 to 7:25 a.m. at the Wayside merging area and from 7:05 to 7:25 a.m. at the Telephone merging area.

From the demand analyses as well as other investigations it could be concluded that congestion develops in the Wayside-Telephone vicinity and is propagated upstream to the Griggs overpass structure. When this queue reaches the Griggs structure, the flow rate there is decreased and this decrease in flow is the cause of most of the congestion in the Broadway-Griggs subsystem*. The demand studies indicated that were it not for the effects of the downstream congestion, the Broadway-Griggs subsystem should be clear of congestion by at least 7:30 a.m., the time when the congestion normally is at its worst. It, then, follows that by proper control of entrance ramps downstream of Griggs Road, the congestion upstream of Griggs Road would be greatly reduced.

A key point in this discussion is that, by preventing queues from downstream from decreasing the flow rate at Griggs Road, the same traffic (or more) could be handled in the Broadway-Griggs subsystem with congestion in this subsystem greatly reduced. This was the major hypothesis which was tested in the August, 1964, control study.

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* It should be remembered that this subsystem was found to experience the most severe congestion on the entire inbound freeway.

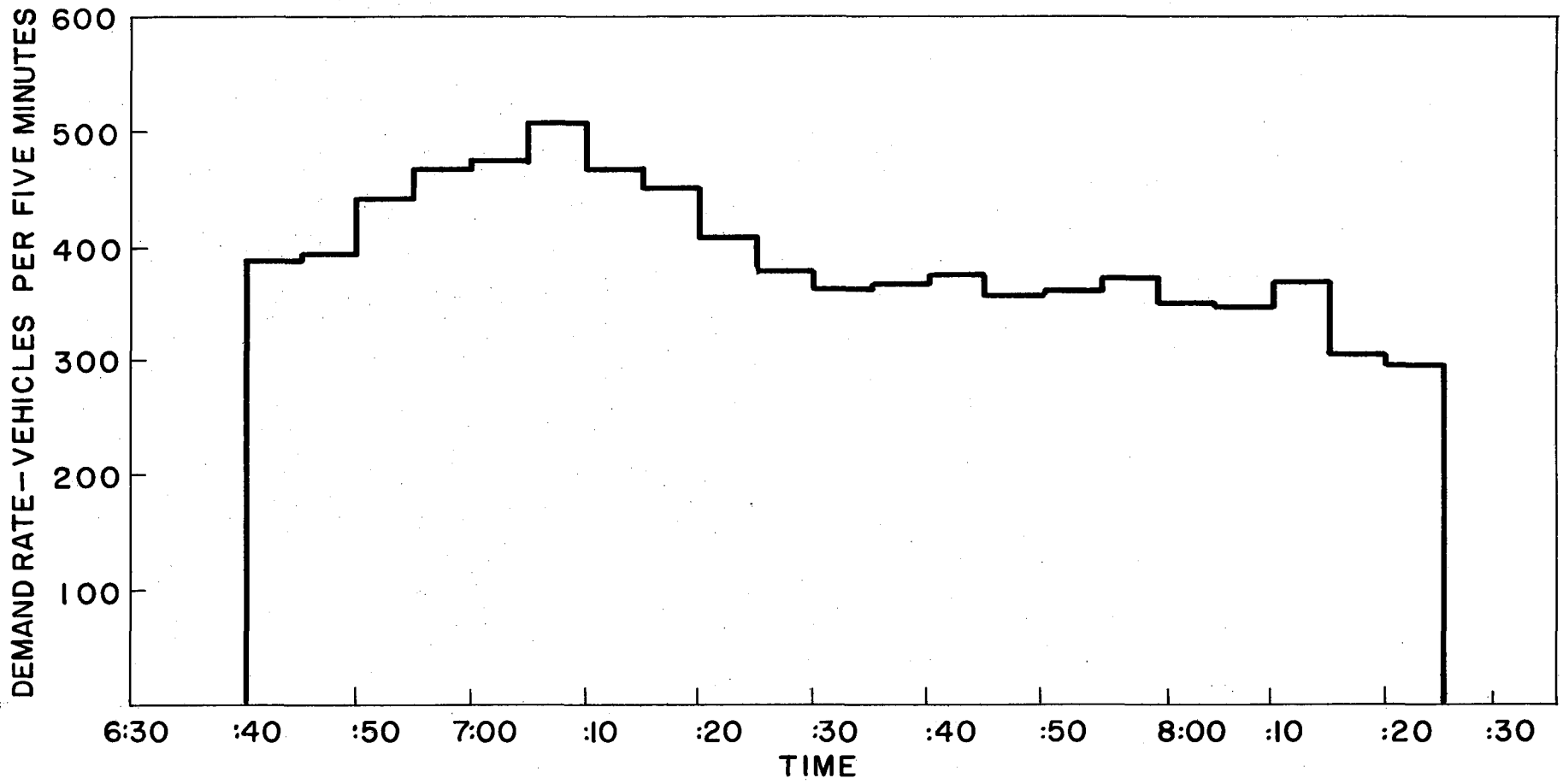

FIGURE 12 DEMAND AT THE GRIGGS OVERPASS

DEVELOPMENT OF CONTROL PLANS

SELECTION OF CONTROL LOCATIONS

Philosophy of the Controls

Because queues which originate downstream of Griggs Road mostly cause the congestion in the Broadway-Griggs subsystem and because the Broadway-Griggs subsystem is the most severely congested area on the inbound freeway, the primary goal of these initial controls was to reduce the congestion downstream of Griggs Road enough to prevent (downstream) reduction in the flow on the freeway at Griggs Road. In this manner, the controls downstream of Griggs Road were intended to alleviate the congestion upstream of Griggs Road and allow the testing of the hypothesis that the same amount of traffic (or more) could use the inbound freeway between Broadway and Griggs with much less congestion (and delay time) in this area.

The bottlenecks downstream of Griggs Road are located in the merging areas of the Griggs, Wayside, and Telephone entrance ramps. Hence, these ramps were the primary choices for control. Since the control of these ramps would, in all probability, divert some vehicles down the frontage road to the Dumble ramp, this ramp was included for possible control. Good alternate routes also existed to the high-volume pair of entrance ramps at Cullen and the possibility existed for the freeway flow at Cullen to be increased; hence, the control of these entrance ramps was also considered.

One primary philosophy of the controls was to keep them as simple and the least restrictive and yet to try to prevent queues from backing to Griggs Road and decreasing the flow there. The controls which were developed were not intended to eliminate congestion completely but merely to reduce it greatly and to allow some traffic flow theories to be evaluated. The experience gained from this study will allow a more refined control plan to be developed for the Fall or Winter of 1964-65. It was realized that a more restrictive control plan (controlling more ramps, longer control periods, etc.) could improve the operation of the freeway but could also create additional problems on the frontage road and/or arterial streets. Therefore, the simplicity of the controls was also a consideration in this initial control plan.

Griggs Ramp

Control of the Griggs entrance ramp would have caused some diversion

of vehicles through the intersection of Wayside and the inbound frontage road. Since this intersection approach is presently operating over capacity, delay to the motorists would have increased greatly by diversion to this approach. Because of the high volume on the ramp, the metering of the Griggs ramp would probably have caused an extremely large queue at this location. Also the merging demand at this location was not greatly over capacity. For these reasons the control of the Griggs ramp was not considered further. Control of this ramp will be considered in future control plans and will in part depend on the completion of planned capacity improvements at the Wayside frontage road intersection. Figure 13 shows the control area.

TIME AND SEVERITY OF CONTROLS

Wayside Entrance Ramp

The demand upstream of the Wayside entrance ramp was calculated for each five-minute period and the merging capacity was estimated to be 485 vehicles per five minutes. The difference between the merging capacity and the upstream demand is the allowable ramp volume. This quantity was calculated for each five-minute period and represents the number of vehicles which could be allowed to enter the freeway on the ramp without causing congestion. For example, from 7:00 to 7:05 the demand upstream of the Wayside entrance ramp is 41 vehicles which is the allowable ramp volume for the 7:00 to 7:05 a.m. time period. Figure 14 shows the allowable volume on the Wayside entrance ramp for the entire peak period. From 7:05 to 7:25 a.m., it is essentially zero which means that no cars could be allowed to use the ramp without causing congestion.

If the ramp were metered according to these allowable ramp volumes, a queue would be formed. By knowing the rate of arrival of vehicles at the ramp and the metering rate, the length of queue can be estimated. Figure 14 shows a plot of the queue which would be formed at the Wayside entrance ramp if it were metered according to the allowable ramp volume (with a maximum rate of 75 vehicles per five minutes)* and if no diversion took place. A maximum queue of about 100 vehicles would be expected. Because of the excessive queue and the extremely low metering rates, the control plan called for this ramp to be closed from 7:00 to 7:25 a.m.

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* Since each of the vehicles on the entrance ramp is required to stop when the ramp is being metered, a minimum time headway of about 4 seconds fixes the upper limit on the metering rate at about 75 vehicles/5 minutes.

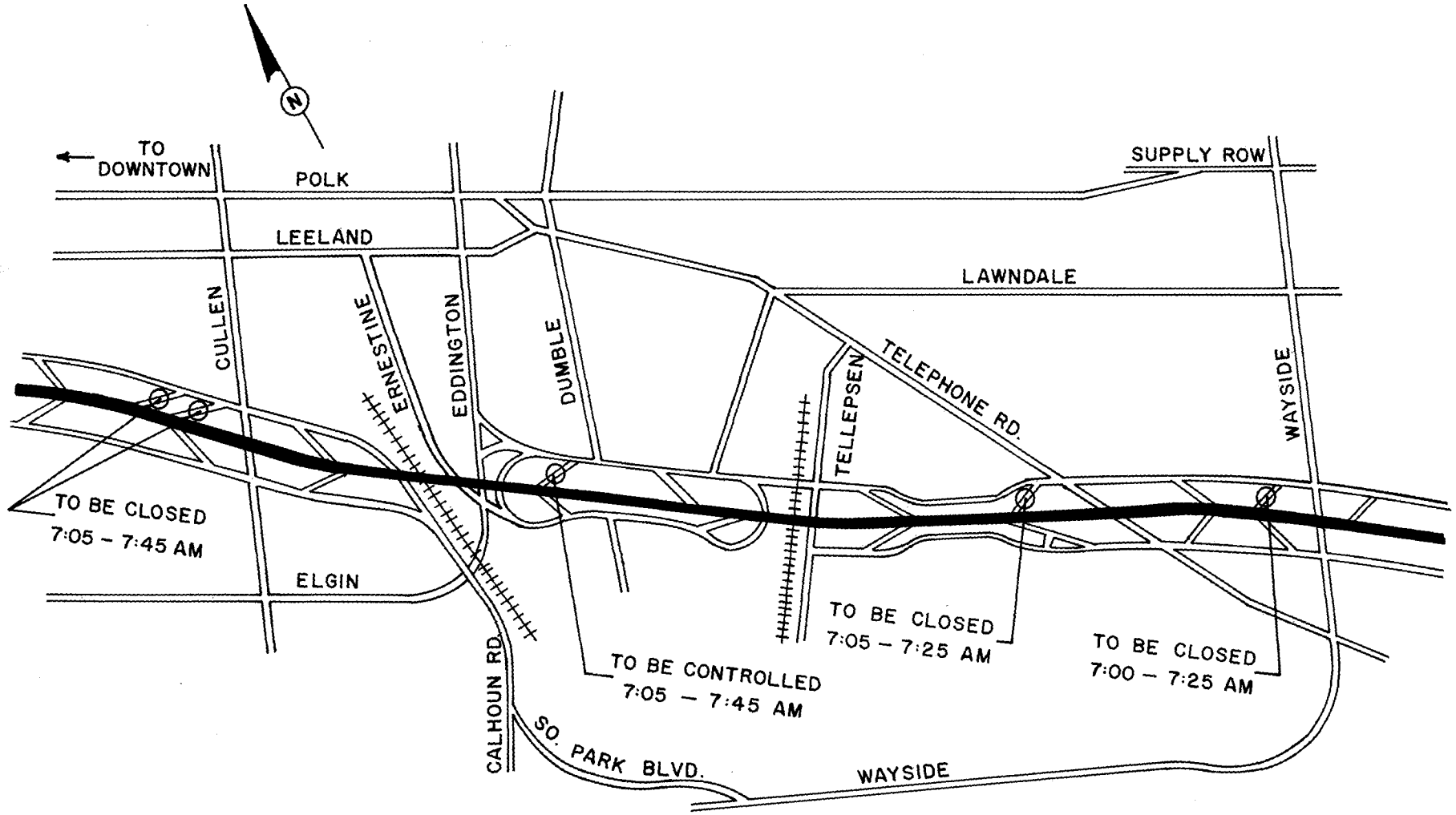
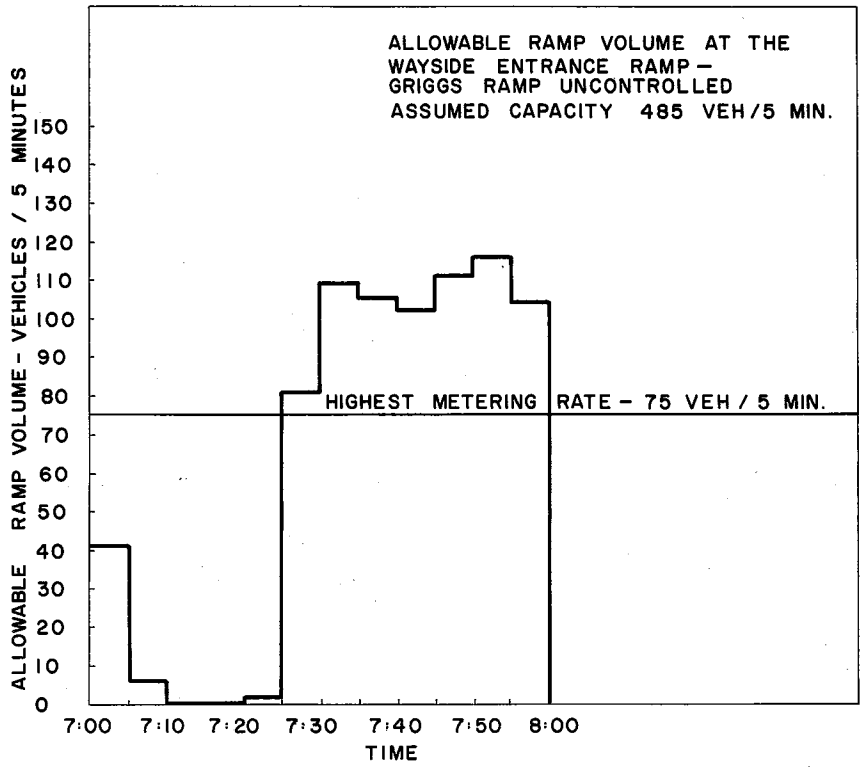
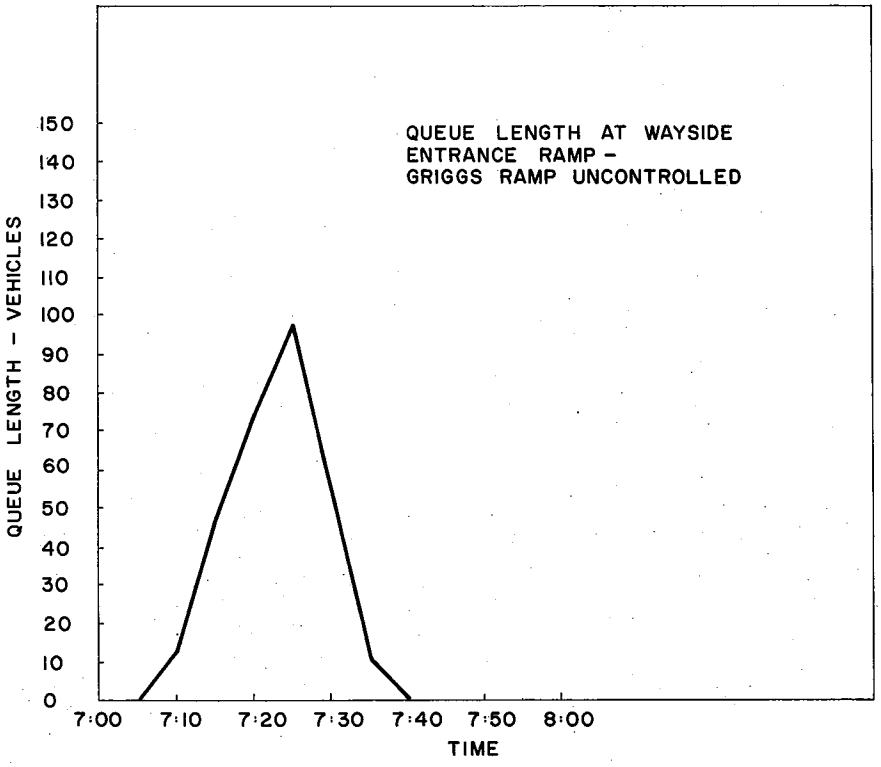


FIGURE 13 CONTROL AREA



a. ALLOWABLE RAMP VOLUME – WAYSIDE ENTRANCE RAMP



b. EXPECTED QUEUE LENGTH AT WAYSIDE ENTRANCE RAMP

FIGURE 14 ALLOWABLE RAMP VOLUME AND EXPECTED QUEUE AT THE WAYSIDE ENTRANCE RAMP

Telephone Entrance Ramp

The same analyses were made for the Telephone Road entrance ramp. The demand upstream of this ramp was calculated assuming that the Wayside entrance ramp was closed from 7:00 to 7:25 a.m. and a capacity of 490 vehicles per five minutes was used. Since metering this ramp would also cause a queue to form, it was assumed that 15% of the normal Wayside ramp traffic and 10% of the normal Telephone ramp traffic would abandon use of the freeway. These are approximately the percentages of vehicles from the respective ramps which leave the freeway at the Telephone, Lombardy, and Calhoun-Elgin exits (short trips) and for which a good alternate route exists on the frontage road. The remaining volume from the two ramps was taken to represent the demand at the Telephone entrance ramp.

Figure 15 shows the allowable volume on the Telephone entrance ramp. Again, from 7:05 to 7:25 a.m. the allowable ramp volume is extremely low. Figure 15 also shows the length of queue expected at this location using the five-minute demands and the allowable ramp volumes as the metering rates (with a 75 vehicles per five-minute maximum). A maximum queue of about 140 vehicles would be expected at this location.

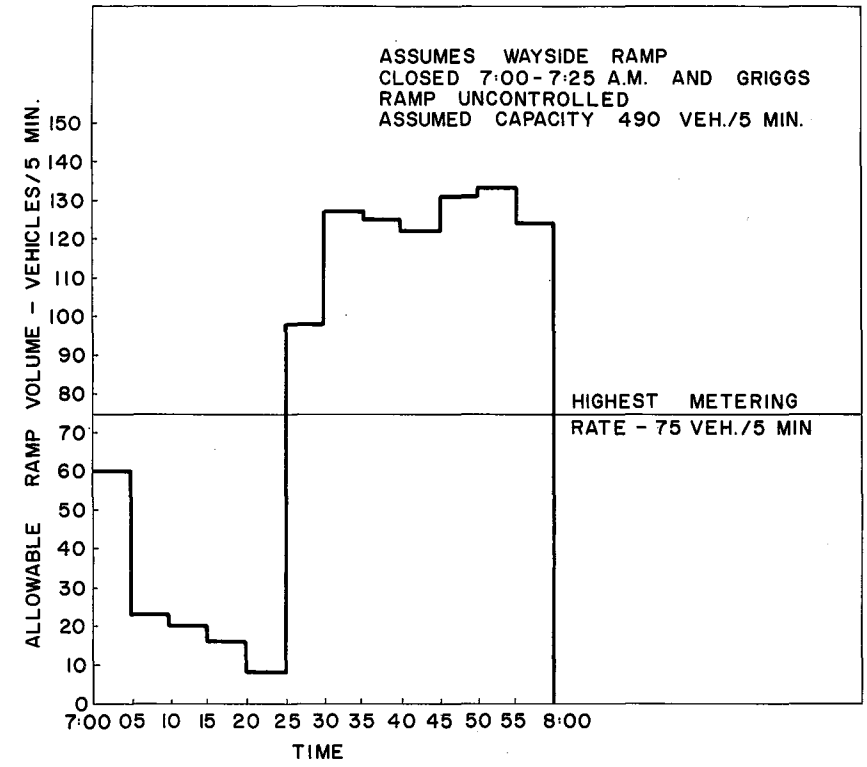
Because of the two considerations of low allowable ramp volumes and the large queue expected, this ramp was closed from 7:05 to 7:25 a.m. under the initial control plan.

Dumble Entrance Ramp

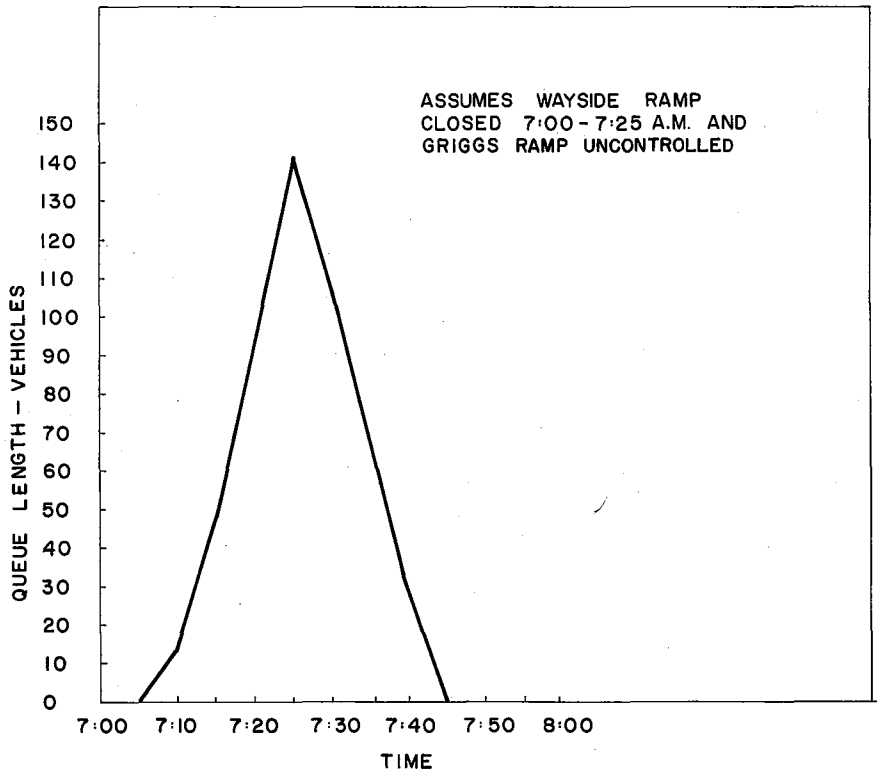
Figure 16 shows the allowable volume on the Dumble entrance ramp and the queue expected at this location with a metering rate of 50 vehicles per five minutes (one vehicle per six seconds) from 7:05 to 7:30 a.m. and a metering rate of 75 vehicles per five minutes from 7:30 until the expected queue clears at about 7:45.

A metering rate of 50 vehicles per five minutes would be very close to the allowable ramp volume. While the expected queue is nearly 100 vehicles, this location is more suited to accommodate a queue than Wayside or Telephone where the queue would block a major intersection. The estimate of queue length was made in a conservative manner and it was considered probable that the diversion would reduce this number.

The initial ramp control plan called for this ramp to be metered from 7:05 until about 7:45 with a rate of one vehicle per six seconds from 7:05 to 7:30 and with the maximum possible rate after 7:30 so as to clear the queue as fast as possible after this time.

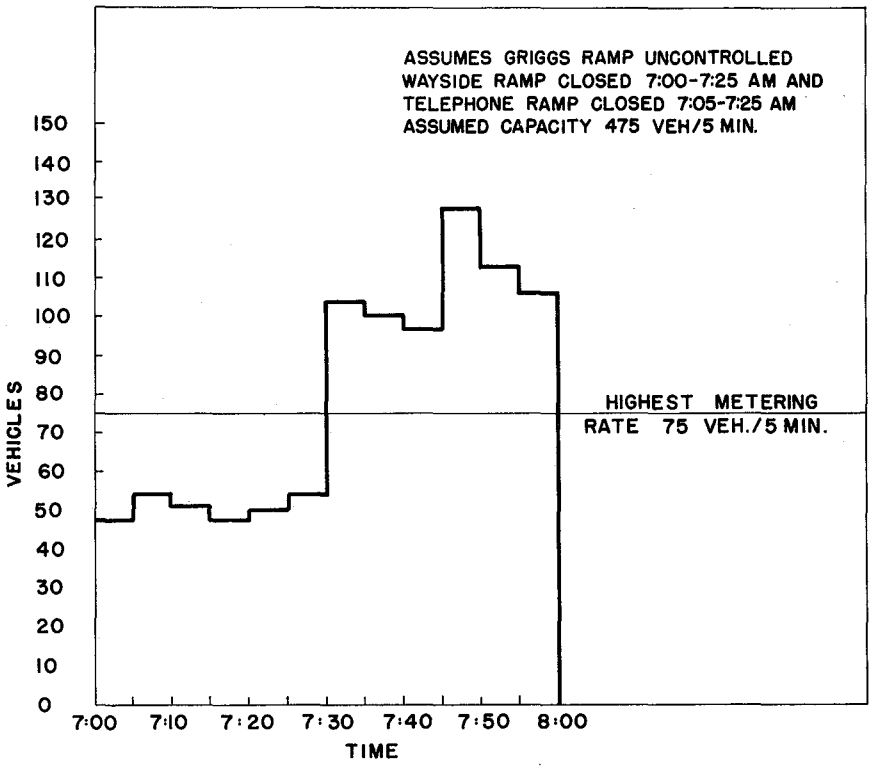


a. ALLOWABLE RAMP VOLUME - TELEPHONE ENTRANCE RAMP

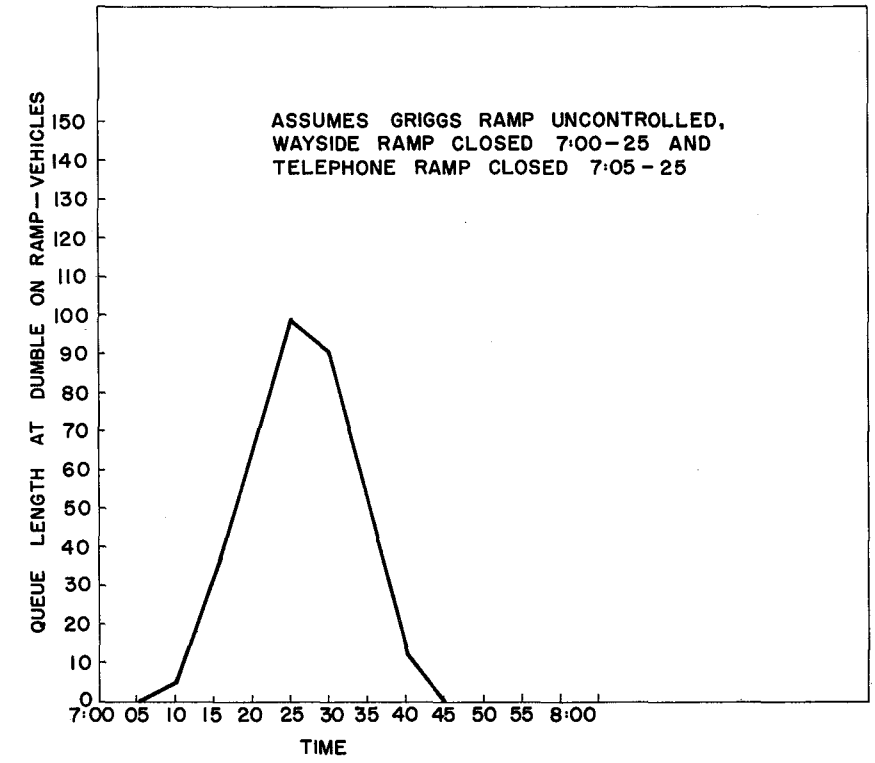


b. EXPECTED QUEUE LENGTH AT TELEPHONE ENTRANCE RAMP

FIGURE 15 ALLOWABLE RAMP VOLUME AND EXPECTED QUEUE AT THE TELEPHONE ENTRANCE RAMP



a. ALLOWABLE RAMP VOLUME – DUMBLE ENTRANCE RAMP



b. EXPECTED QUEUE LENGTH AT DUMBLE ENTRANCE RAMP

FIGURE 16 ALLOWABLE RAMP VOLUME AND EXPECTED QUEUE AT THE DUMBLE ENTRANCE RAMP

Cullen Entrance Ramps

Five-minute estimates of demand upstream of and downstream of the two Cullen entrance ramps indicated that the merging section at this location would be operating at or near capacity from 7:05 to 7:45 a.m. Since a continuous frontage road from Cullen to the end of the freeway provides a good alternate route and since earlier studies by the Texas Transportation Institute revealed that the closure of the Cullen entrance ramps produced little adverse effect on the ramp traffic, the control plan called for these two ramps to be closed during the 7:05 to 7:45 a.m. period.

SUMMARY OF CONTROL PLANS

1. Wayside entrance ramp closed from 7:00 to 7:25 a.m.

2. Telephone entrance ramp closed from 7:05 to 7:25 a.m.

3. Dumble entrance ramp metered from 7:05 to 7:45 a.m.

   a. Metering rate of 1 vehicle/6 seconds from 7:05 to 7:30 a.m.

   b. Metering rate of 1 vehicle/4 seconds from 7:30 to 7:45 a.m.

4. Cullen entrance ramp closed from 7:05 to 7:45 a.m.

5. Dates of control: August 4-7, 10-14, 1964.

EVALUATION OF THE EFFECTS OF THE CONTROLS

Data for the evaluation of the effects of the controls were collected during three periods -- two before the control study and one during the study. In January - April, 1964 period, input-output studies on the closed freeway subsystems and floating vehicle travel time studies were made. In July only aerial photographic data were obtained. During the control study in August all three of these types of studies were made. In the "before and after" comparisons, only data which were obtained on days in which the traffic flow was unaffected by accidents, stalled vehicles or inclement weather were used.

TOTAL SYSTEM TRAVEL TIME

The total amount of travel time expended by all vehicles using a particular facility during the peak period is one good measure of its operational efficiency. In each of the three study periods, the number of vehicles on the freeway was determined as a function of time from the closed subsystem study data and the aerial photographic data. This function was integrated from 7:00 to 8:00 a.m. to yield the total travel time on the inbound freeway during this time period. From the airphotos it was also possible to determine the total travel time on the inbound frontage road in the 7:00 to 8:00 a.m. period.

Figure 17 shows the number of vehicles in the inbound freeway subsystem between Broadway and Griggs plotted against time. This illustration shows that during the peak period there was a considerably greater number of vehicles in this subsystem in January "before" study than during either of the two later studies. Also shown in this illustration is the total travel time expended in the inbound Broadway-Griggs subsystem between 7:00 and 8:00 a.m. for each of the three studies. The total travel time in this subsystem was found to be 575 vehicle hours in the January "before" period, 330 venicle hours in the July "before" period, and 305 vehicle hours during the ramp control study in August. These travel times equal the area under the respective curves of number of vehicles in the subsystem versus time between 7:00 and 8:00 a.m.

Table 2 contains a summary of the total travel time data obtained by this technique. These data are divided into three freeway subsystems and the inbound frontage roads as well as the inbound freeway subtotal and the total inbound system. For the entire inbound freeway the travel time decreased from 1244 vehicle hours in the January-April period to 939 vehicle hours in the July and further decreased to 829 vehicle hours during the ramp

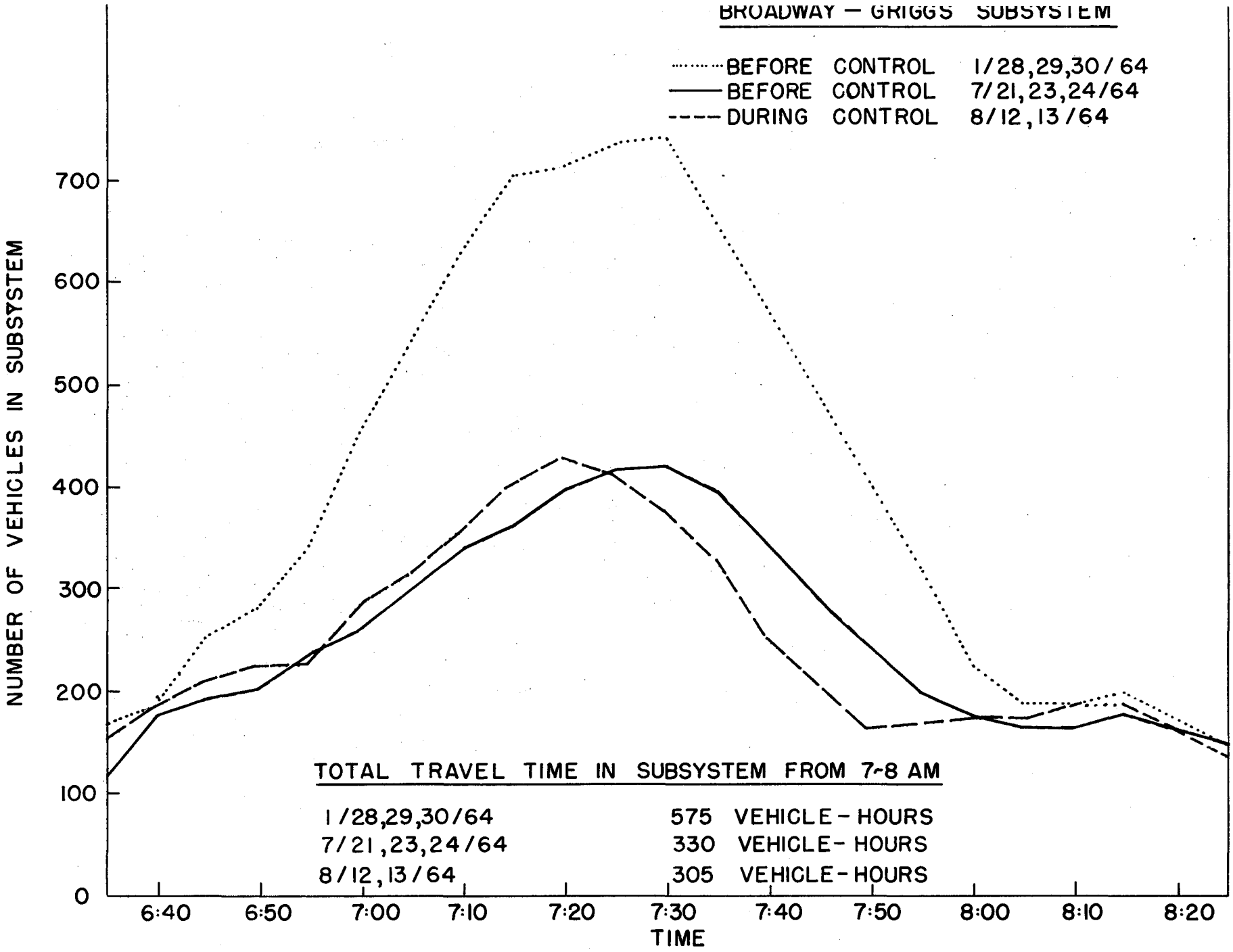


FIGURE 17 — NUMBER OF VEHICLES ON INBOUND FREEWAY SUBSYSTEM

TABLE 2

TOTAL SYSTEM TRAVEL TIME FROM 7-8:00 A.M.

SYSTEM OR SUBSYSTEM	TRAVEL TIME — VEHICLE HOURS		
	JANUARY-APRIL, 1964	JULY, 1964	AUGUST, 1964 DURING CONTROL
INBOUND FREEWAY			
Broadway - Griggs	575	330	305
Griggs - S. HB&T R. R.	367	329	277
S. HB&T R.R. - Calhoun - Pease Distribution System	302	280	247
INBOUND FREEWAY TOTAL	1,244	939	829
INBOUND FRONTAGE ROAD	NO DATA	205	238
TOTAL INBOUND FREEWAY AND FRONTAGE ROAD	1,449*	1,144	1,067

* - Uses the frontage road travel time from July, 1964

control period. The travel time on the inbound frontage road increased from 205 vehicle hours in July to 238 vehicle hours during the control study due to the diversion of some vehicles from the freeway to the frontage road.

The total travel time for the inbound freeway and frontage road was found to be 1449, 1144, and 1067 vehicle hours in the January-April, July, and August periods, respectively. The reduction in travel time from the January-April "before" period to the control period was 26% while the reduction was 7% relative to the July "before" period.

TRAVEL TIME FOR AN INDIVIDUAL VEHICLE

During the control study two vehicles were used to obtain speed and travel time data. Figure 18 shows the travel time contour map obtained during the control period (August 6, 7, 12, 13). The longest trip during that period was 12 minutes compared with more than 20 minutes in the January period.

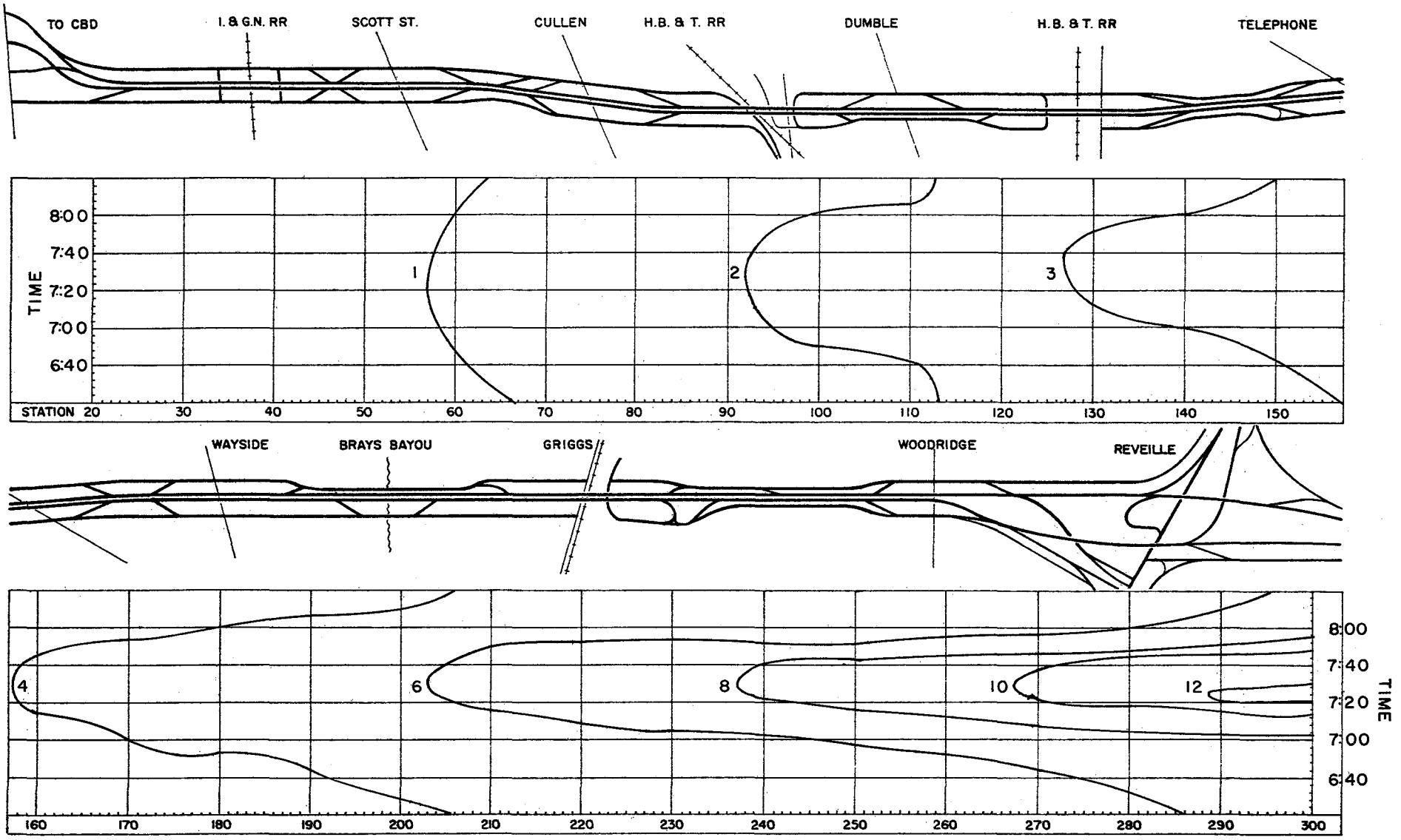
Figure 19 is the contour map of savings in travel time to the end of the freeway. From this it can be seen that a maximum of about 8-10 minutes was saved for a trip between the Reveille interchange and the end of the freeway. A maximum of 2-3 minutes was saved between Griggs Road and the end of the freeway, meaning that most of the travel time was saved between the Reveille interchange and Griggs Road.

CHANGE IN TRAVEL PATTERNS

7:00 to 8:00 a.m. Volumes

The controls naturally caused some significant changes in volumes on some of the entrances to the freeway. Table 3 contains the 7:00 to 8:00 a.m. volumes before the controls and during the control period at each entrance to the freeway system and the change between the periods. The table indicates that large changes in volume took place on most of the freeway entrances -- both those that were controlled and those that were not controlled. A net reduction of 592 vehicles entering the freeway was observed between 7:00 and 8:00 a.m. during the control study.

Most of this reduction naturally occurred on the ramps which were controlled. For the four entrance ramps which were closed at various times during the peak period (see summary of control plans, page 28), the 7:00 - 8:00 a.m. volumes decreased by a total of 731 vehicles. The total volume which had used these ramps during each ramp's respective closure period was 709 vehicles and, except for some expected diversion in time, the 709 vehicles represented the anticipated decrease in volume

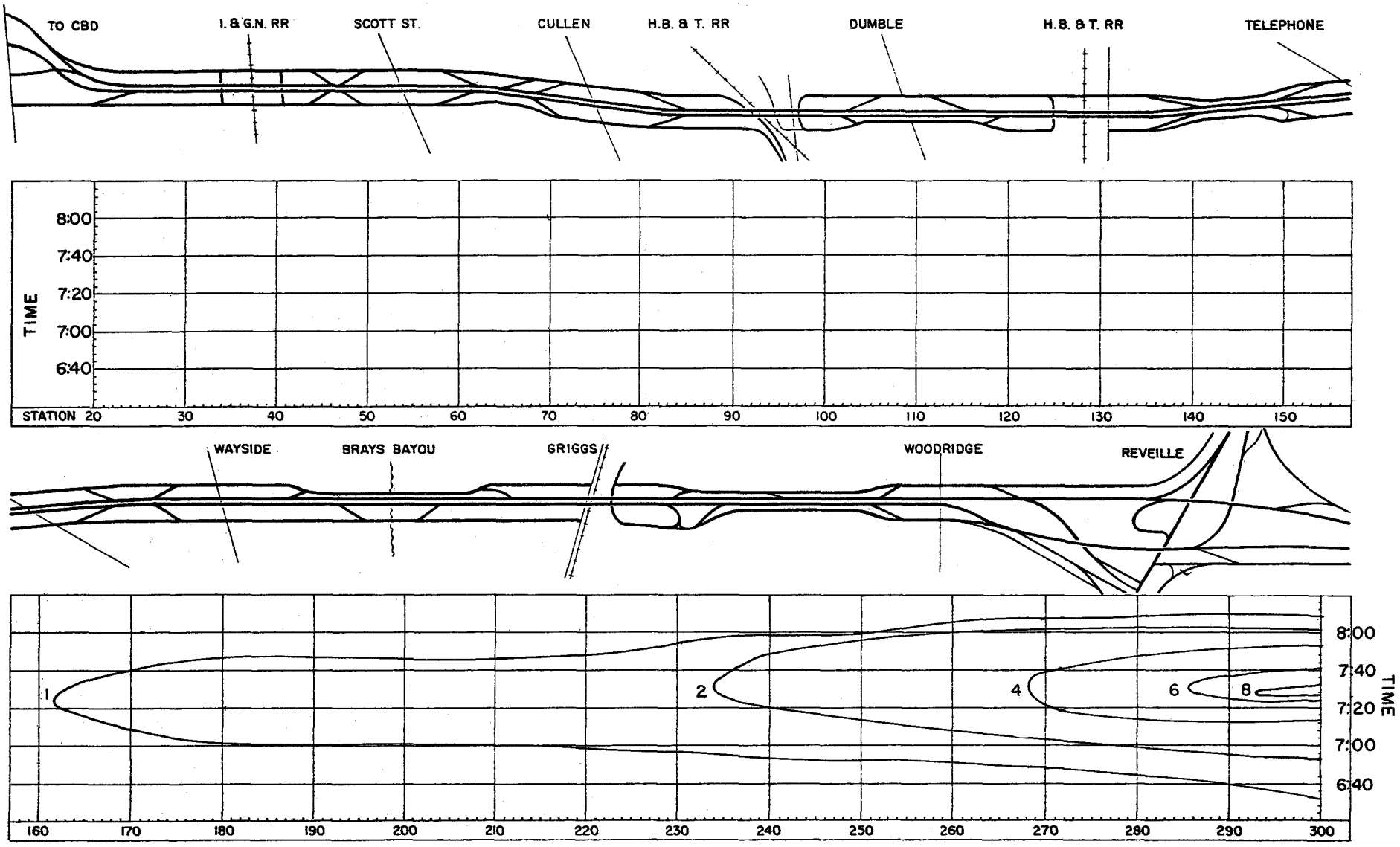


AVERAGE TRAVEL TIME (MINUTES) TO END OF FREEWAY

CONTOUR MAP

DURING CONTROL — AUGUST 6, 7, 12, 13, 1964

FIGURE 18



SAVINGS IN TRAVEL TIME (MINUTES)
TO END OF FREEWAY
CONTOUR MAP
FIGURE 19

TABLE 3
7–8 AM VOLUMES ON ENTRANCES TO THE FREEWAY

ENTRANCE TO FREEWAY SYSTEM	7–8 AM VOLUME–VEHICLES BEFORE CONTROL	DURING CONTROL	DIFFERENCE
FREEWAY NEAR BROADWAY	2861	3154	+293
DETROIT ON RAMP	218	105	−113
S.H. 225 ON RAMP	559	667	+108
S.H. 35 ON RAMP	818	910	+92
WOODRIDGE ON RAMP	426	294	−132
MOSSROSE ON RAMP	643	435	−208
GRIGGS ON RAMP	683	716	+33
WAYSIDE ON RAMP ✳	335	149	−186
TELEPHONE ON RAMP ✳	413	217	−196
DUMBLE ON RAMP ✳✳	345	267	−78
CULLEN ON RAMPS (COMBINED) ✳	574	188	−376
SCOTT ON RAMP	63	240	+177
		NET CHANGE	−586

✳ RAMPS WHICH WERE CLOSED

✳✳ RAMP WHICH WAS METERED

at the four closed ramps. The actual decrease was only slightly more than this number (731 vehicles).

A large increase in traffic at the Dumble entrance ramp had been expected because of the closure of the two entrance ramps immediately upstream. During the control study, the Dumble entrance ramp volume decreased by 104 vehicles in the 7:00 to 8:00 a.m. period.

The total decrease in volume on the five controlled ramps was 835 vehicles for the 7:00 to 8:00 a.m. period. This was approximately 350 vehicles larger than the anticipated decrease. The unexpectedly large diversion was probably caused by a combination of the following four factors.

1. In spite of the advance signing and the reminders* which were distributed to the users of the controlled ramps, it appeared that some drivers were not sure of the exact control times and some apparently diverted when the ramps were not being controlled.

2. Similarly, it appeared that many drivers were not sure that the Dumble ramp was open to traffic and bypassed it instead of joining the queue there.

3. The fact that many of the drivers selected alternate routes without making much of an effort to learn the exact control times and the exact nature of the controls suggested that the use of these alternate routes did not greatly inconvenience the motorists. If the use of the alternates would have caused these motorists to incur large increases in travel time or distance, they would have tended to have continued to use the freeway.

4. Studies in July indicated that the severity of congestion had decreased from the winter and spring months, especially in the Broadway-Griggs area. This suggested that a seasonal shift in travel patterns had taken place, apparently reducing some of the entrance ramp volumes.

For the freeway inputs between Broadway and Griggs, the number of vehicles entering the freeway between 7:00 and 8:00 a.m. was 52 higher during the control period than in the January studies. In addition the 7:00 to 8:00 a.m. volume on the S. H. 225 exit ramp decreased by 119 vehicles. During the January studies the congestion on the freeway backed past the S.H. 35 exit ramp and vehicles were observed leaving the freeway at the S. H. 225 exit and re-entering on the Detroit St. entrance ramp. By making

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* See Appendix for a description of the preparation for controls.

this maneuver, they avoided about 1500 feet of freeway congestion. Since the severity of congestion was much less in this region during the control study, the motivation for making the exit-entrance maneuver would also be decreased. During the control study the 7:00 - 8:00 a.m. volume on the S. H. 225 exit ramp decreased by 119 vehicles while the corresponding Detroit St. entrance ramp volume decreased by 92 vehicles. It thus appeared that about 100 of the exit-re-entry maneuvers were eliminated during the control study. Therefore, the total increase in traffic in the Broadway-Griggs subsystem from 7:00 to 8:00 a.m. equalled about 150 vehicles -- about a 50-vehicle increase in input volume and about a 100-vehicle decrease in the number of vehicles leaving and re-entering the freeway.

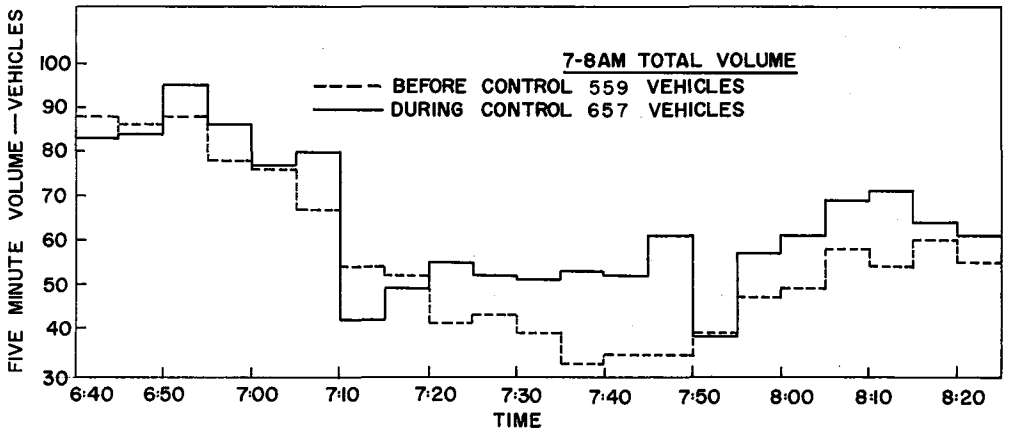
The 7:00 to 8:00 a.m. volume on the Griggs entrance ramp increased slightly (by 21 vehicles) during the August control study. This was probably due to the diversion of some vehicles from the controlled ramps. At the Scott entrance ramp, the 7:00 to 8:00 a.m. volume increased from 67 to 237 vehicles, presumably due to the control of the upstream entrance ramps -- particularly the closure of the two Cullen ramps.

Five-Minute Entrance Ramp Volumes

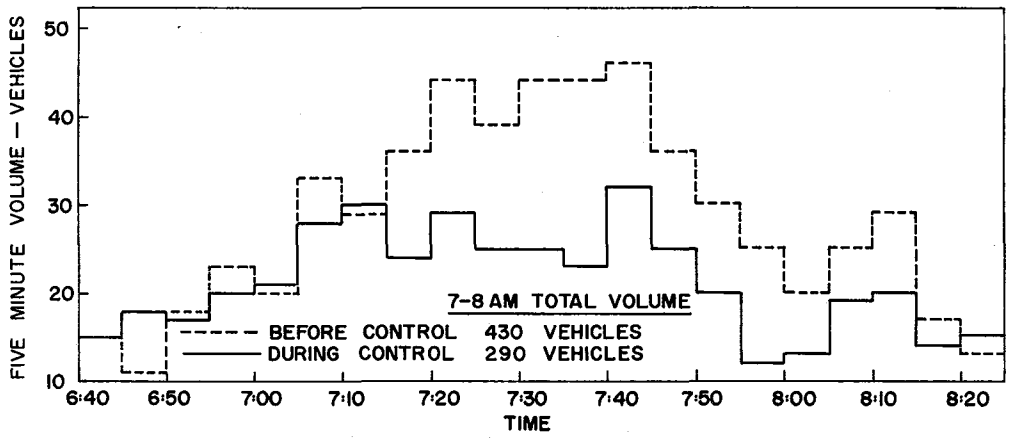
While the 7:00 - 8:00 a.m. volumes are useful in determining over-all changes in the traffic patterns, the five-minute volumes on the freeway and ramps allow a much more detailed analysis of these shifts in both time and space.

The five-minute volumes on the S.H. 225, Woodridge, and Mossrose entrance ramps are shown in Figure 20a, 20b, and 20c, respectively. Between 7:00 and 8:00 a.m., the S.H. 225 entrance volume increased during the August control study in 9 of the 12 five-minute periods. The similar volumes at the Woodridge and Mossrose entrance ramps decreased in 10 of 12 five-minute periods.

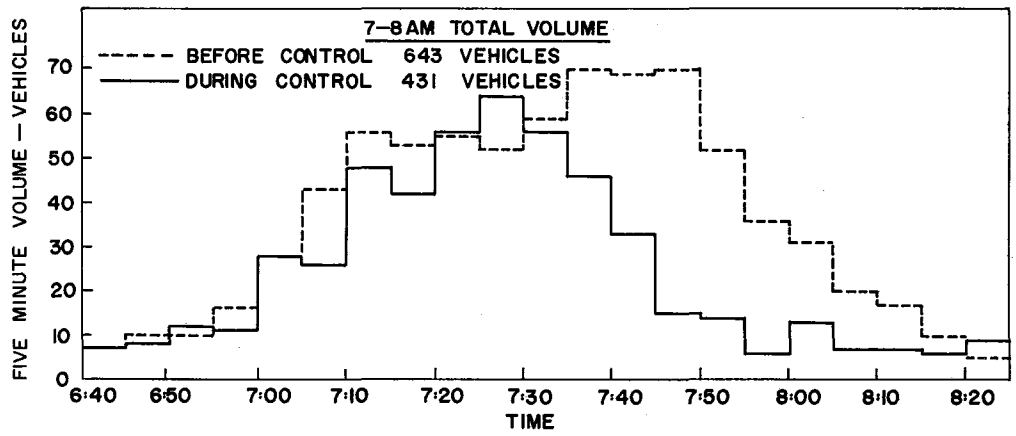
The frontage road between these ramps is continuous but is discontinuous just downstream of the Mossrose entrance ramp (because of a railroad line). Before the controls were applied, many vehicles would enter the freeway at Woodridge or Mossrose after bypassing opportunities to enter at upstream ramps. In this way they reduced the amount of driving on the congested freeway. In particular, many vehicles approaching the freeway on S.H. 225 do this as they can observe the traffic conditions on the freeway as they approach it and can exit to the frontage road if the freeway is congested. They then proceed down the frontage road and enter the freeway at Woodridge or Mossrose.



a. FIVE MINUTE VOLUMES ON THE S.H. 225 ENTRANCE RAMP



b. FIVE MINUTE VOLUMES ON THE WOODRIDGE ENTRANCE RAMP



c. FIVE MINUTE VOLUMES ON THE MOSSROSE ENTRANCE RAMP

FIGURE 20 - FIVE MINUTE VOLUMES ON THE S.H. 225, WOODRIDGE AND MOSSROSE ENTRANCE RAMPS BEFORE AND DURING THE CONTROL STUDY

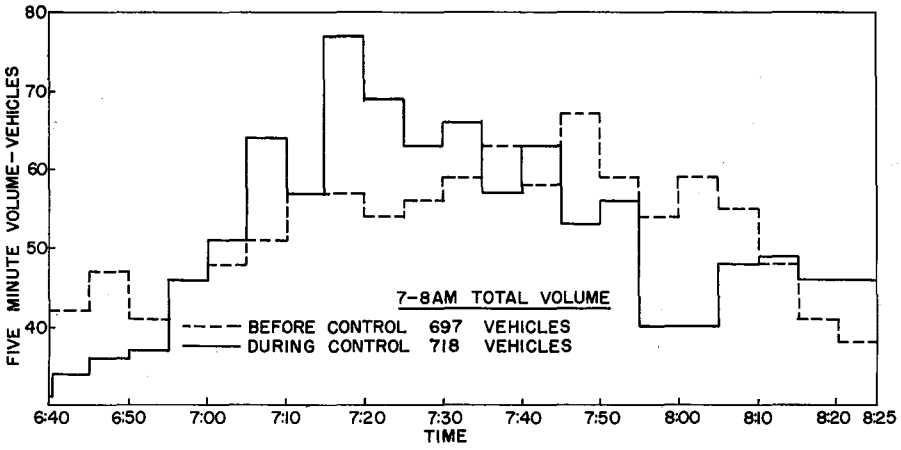
During the control study, when the freeway congestion in this area was greatly reduced, this type of action would not produce the same time savings and, as a result, the 7:00 - 8:00 a.m. volumes on the Woodridge and Mossrose ramp decreased and the S.H. 225 volume increased during the control study.

The five-minute volumes on the Griggs and Wayside entrance ramps are shown in Figures 21a and 21b, respectively. At the Griggs ramp, the five-minute volumes were higher during the control study from 7:00 to 7:35 a.m. This is probably due to two factors. The first is the diversion of some vehicles from the controlled ramps. The second factor is the reduction of the queue which normally formed at this ramp. In the normal operation the congestion on the freeway limited the ramp volume and, as a result, when the demand exceeded this limited volume, a queue formed. With the reduced freeway congestion during the control study, a higher ramp volume was possible. From 7:45 until after 8:00 a.m. the volumes during the control study were less than in the normal operation, because under normal conditions the queue would be clearing during this period.

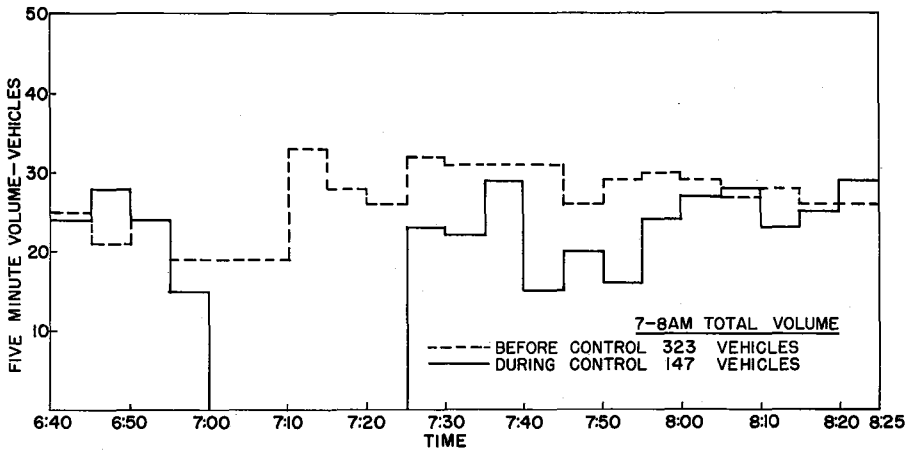
Figure 21b, the five-minute volumes at the Wayside entrance ramp, provides some insight into the psychology of the driver regarding the controls. It was anticipated that many drivers would divert in time rather than in space to avoid the control period, that is, they would either leave earlier than normal or later than normal but would follow their normal routes. Thus, the expectation was that part of the decrease in volume at each closed ramp during the actual control times would be compensated for by increases in volume just before and after the control times.

At the Wayside entrance ramp in the ten-minute period before the controls period began, a slight decrease in volume was observed, while a slight increase occurred in the five-minute period preceding this. This seemed to indicate that drivers who did leave early did not try to arrive at the ramp just before it was closed, but rather they allowed themselves plenty of leeway.

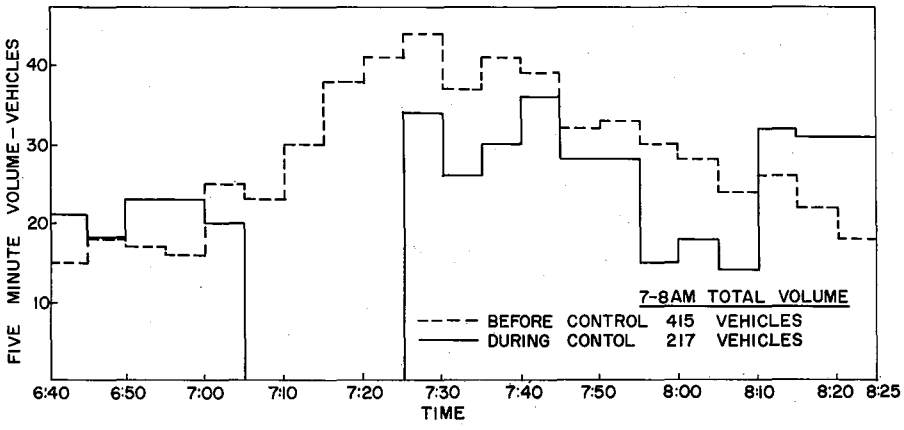
In the time period from 7:25 until 8:00 a.m. after the ramp was opened, the volumes during the control study were lower than those in corresponding periods before the control study. This seems to indicate that few drivers attempted to miss the controls by delaying their trips. This is probably due to the fact that most people who are travelling at these relatively early hours have fairly inflexible schedules. The decrease in volume in the 7:25 to 8:00 a.m. period also seems to indicate that some drivers were uncertain about the control times and probably diverted unnecessarily to alternate routes. This again points up the fact that the use of the alternate routes caused



a. FIVE MINUTE VOLUMES ON THE GRIGGS ENTRANCE RAMP



b. FIVE MINUTE VOLUME ON THE WAYSIDE ENTRANCE RAMP



c. FIVE MINUTE VOLUMES ON THE TELEPHONE ENTRANCE RAMP

FIGURE 21 - FIVE MINUTE VOLUMES ON THE GRIGGS, WAYSIDE AND TELEPHONE RAMPS BEFORE AND DURING THE CONTROL STUDY

little, if any, additional travel time or distance for most of the drivers. Otherwise such diversion would have been less frequent.

The five-minute volumes on the Telephone Road entrance ramp, shown in Figure 21c, bring out these same points.

The five-minute volumes at the Dumble ramp, which was metered, are shown in Figure 22a. Until 7:25 a.m. these volumes were about the same before and during the control study. From 7:25 until 8:00 a.m. the volumes were much lower during the control study. At 7:25 a.m. the Wayside and Telephone entrance ramps were reopened, so after this time the decrease in ramp volume at Dumble during the control study reflects the propensity of many of the regular Dumble ramp users to divert rather than to use the controlled ramp.

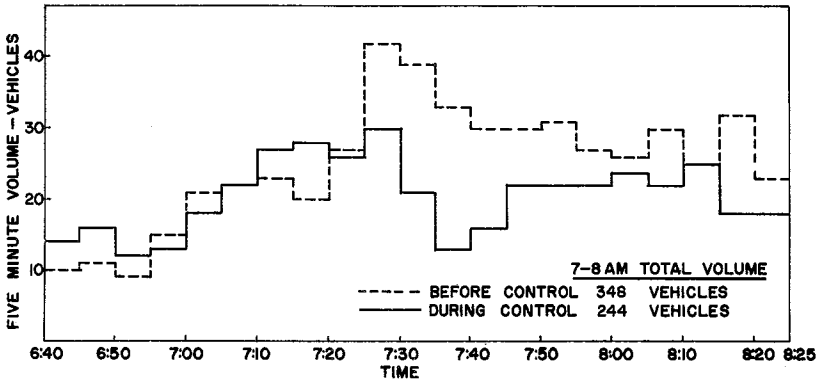
The same general comments can be made for the five-minute volumes on the two Cullen entrance ramps, Figure 22b, as were made of the Wayside and Telephone ramps.

The volume pattern of the Scott entrance ramp, Figure 22c, shows a large increase in volume during the control study from 7:05 to 7:45 a.m. This is the closure period for the two Cullen ramps which are immediately upstream so most of this increase undoubtably consisted of vehicles which normally enter at Cullen.

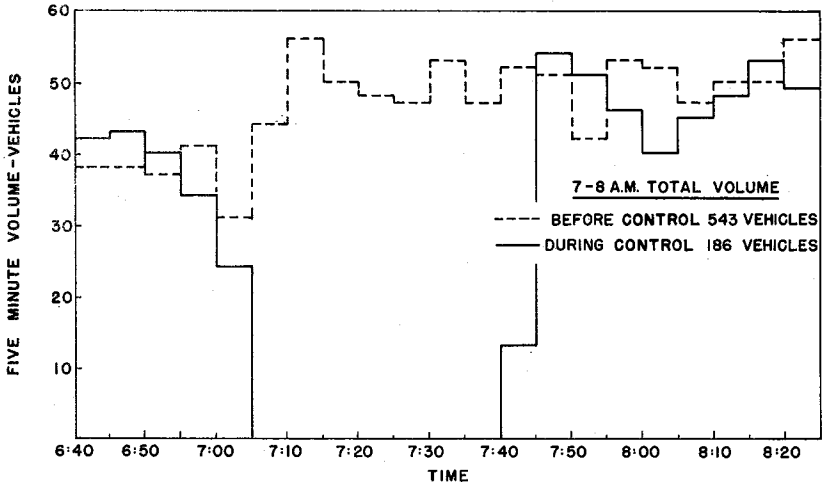
Five-Minute Freeway Volumes

Figure 23a shows the five-minute volumes on the freeway near Broadway. Most of these volumes were higher during the control study than in the normal operation. This increase in volume could be attributed to three sources: (1) reduced freeway congestion encouraged drivers to enter the freeway farther upstream than they normally would, (2) normal seasonal variations in travel patterns, and (3) some diversion from the controlled ramps. The last source is probably of minor importance.

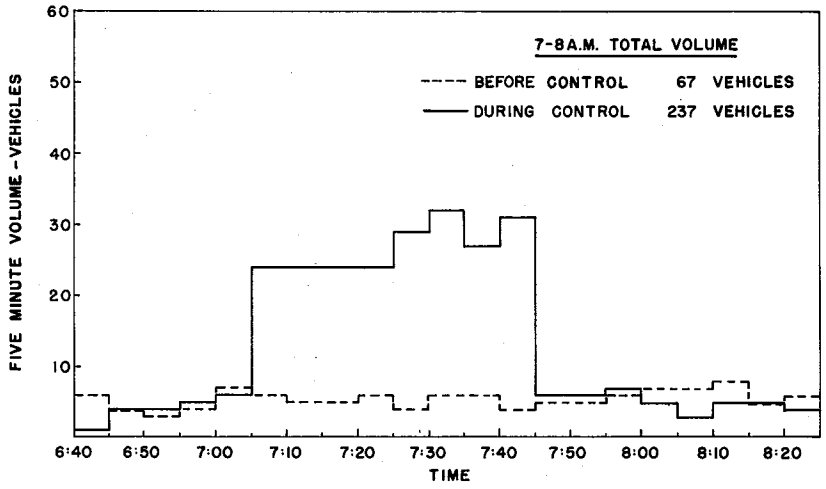
The five-minute volumes on the freeway at Griggs Road show some of the effects of the control. From 7:00 until 7:45 a.m. these volumes were higher during the control study while from 7:45 until 8:05 a.m. they were lower during the control study. This reflects the fact that during the control study there was less influence from queues originating downstream of this location and the volumes there were not reduced as much by these queues. Thus, the demand upstream of Griggs was satisfied earlier during the control study.



a. FIVE MINUTE VOLUMES ON THE DUMBLE ENTRANCE RAMP

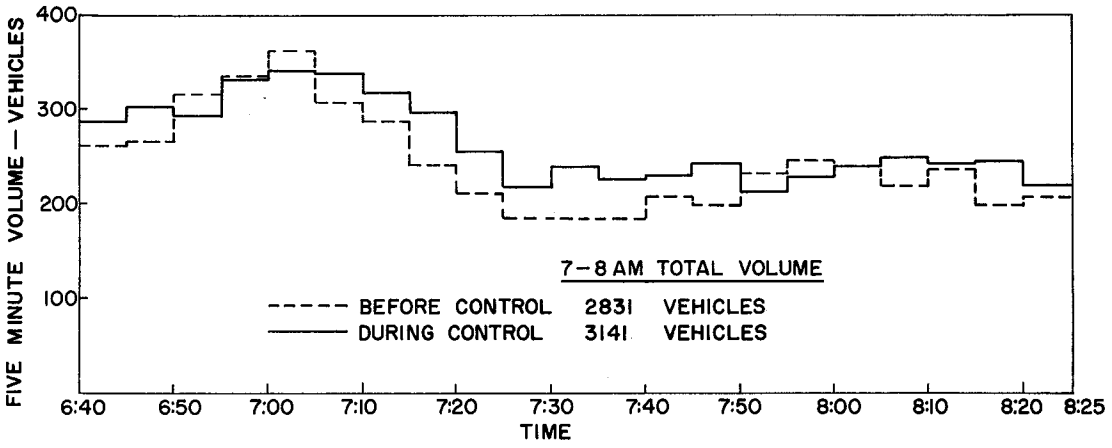


b. FIVE MINUTE VOLUMES ON THE TWO CULLEN ENTRANCE RAMPS

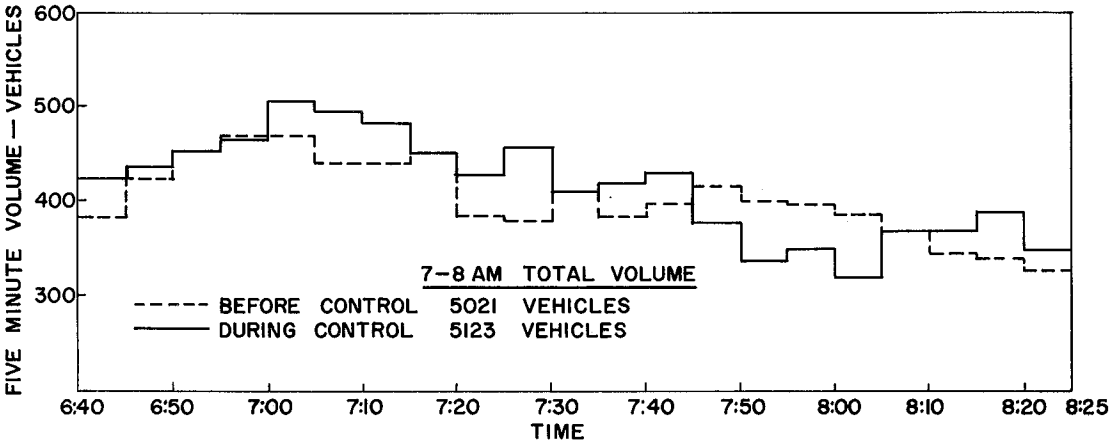


c. FIVE MINUTE VOLUMES ON THE SCOTT ENTRANCE RAMP

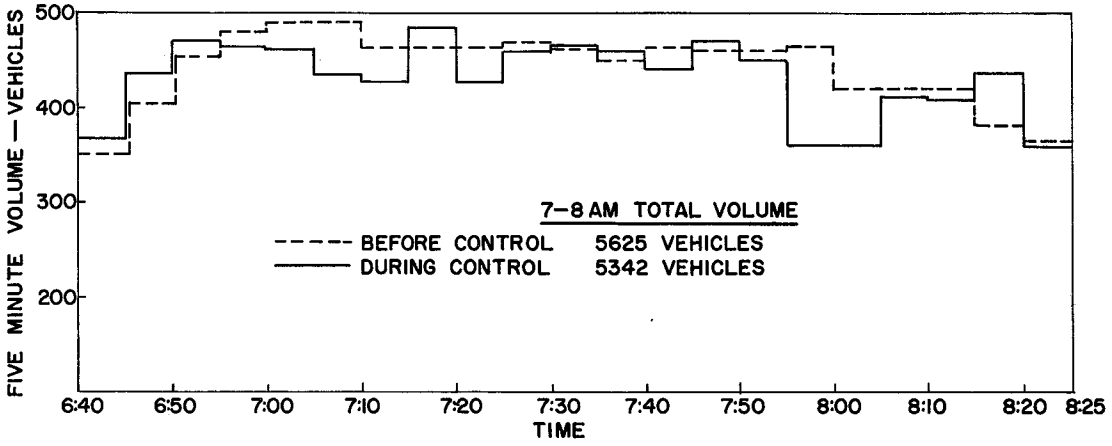
FIGURE 22 - FIVE MINUTE VOLUMES ON THE DUMBLE, CULLEN AND SCOTT ENTRANCE RAMPS BEFORE AND DURING THE CONTROL STUDY



a. FIVE MINUTE VOLUMES ON THE GULF FREEWAY NEAR BROADWAY



b. FIVE MINUTE VOLUMES ON THE GULF FREEWAY AT GRIGGS ROAD



c. FIVE MINUTE VOLUMES ON THE GULF FREEWAY AT THE SOUTH H.B.&T. RAILROAD OVERPASS

FIGURE - 23 - FIVE MINUTE VOLUMES AT THREE LOCATIONS ON THE GULF FREEWAY BEFORE AND DURING THE CONTROL STUDY

At the south HB&T Railroad overpass, the freeway volumes (Figure 23c) were mostly lower during the entire peak period, reflecting the lower volumes on the controlled ramps.

Five-Minute Input and Output Volumes - Broadway to Griggs

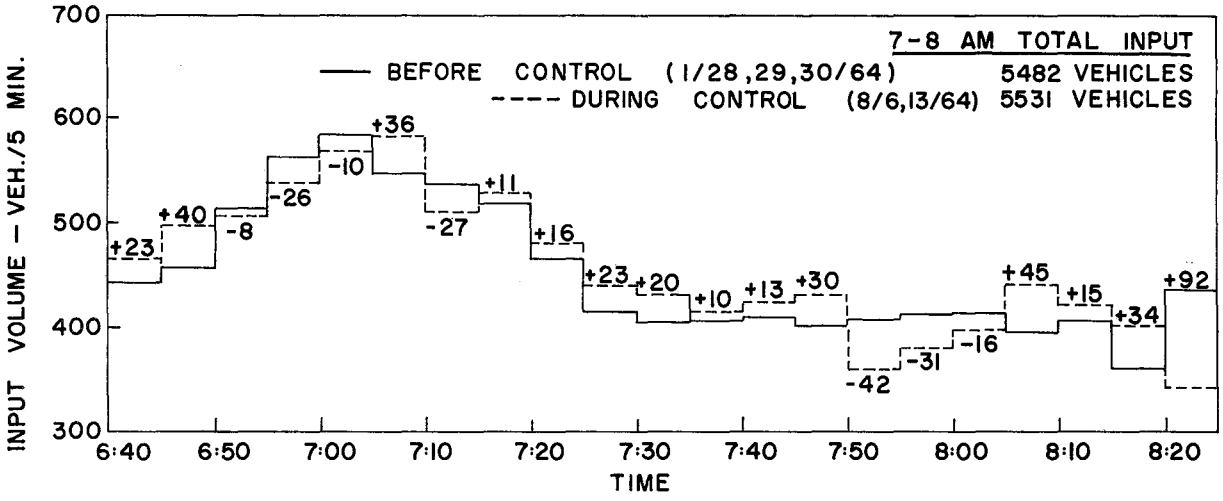
Figure 24a shows the total input to the freeway subsystem between Broadway and Griggs, i. e. for each time period it is the sum of the freeway volume at Broadway plus the volumes on all of the entrance ramps between Broadway and Griggs. This is essentially the demand on the Broadway-Griggs freeway subsystem.

Between 7:00 and 8:00 a.m. the demand during the control study was higher than it was before the control study in 8 of the 12 five-minute time periods. For each five-minute period from 7:15 until 7:50 a.m., the demand during the control study was higher than during the normal operation.

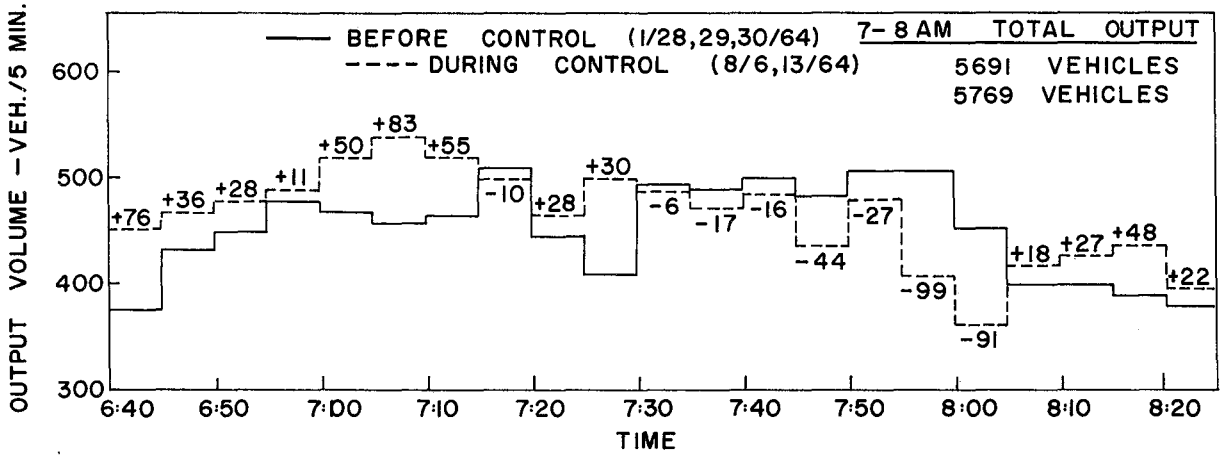
During the control study, the five-minute output volumes (freeway volume at Griggs plus all exit ramp volumes) for this same subsystem were higher from 7:00 to 7:30 a.m. (except for one period) and were lower from 7:30 to 8:05 a.m. (see Figure 24b). This indicates that fewer vehicles were stored in this system from 7:00 to 7:30 a.m., so fewer vehicles had to be cleared from 7:30 to 8:05 a.m. Vehicles were able to leave the system earlier during the control study. The output from 7:00 to 8:00 a.m. was lowered by about 119 vehicles because of the decrease in the number of vehicles exiting at S.H. 225 and re-entering at the Detroit entrance ramp. Were it not for this somewhat artificial lowering of one subsystem output volume, the total output volume would have been found to have increased even more during the control study.

Arterial Street Operation

Before initiation of the controls, travel time studies, and intersection capacity studies were made on the inbound frontage road and arterial streets which might be used by some of the diverted traffic as alternate routes while the controls were in effect. Very little congestion was found on any of these routes and sufficient excess capacity was available at each intersection to accommodate the expected diverted traffic. On several days when the controls were in effect, personnel of the City of Houston drove throughout the system of arterial streets and frontage roads primarily making visual observations about the traffic conditions on these routes. They reported that no congestion or other serious problems developed on any of these alternate routes. On the arterial streets, the travel time for an individual vehicle was probably about the same before and during the control study.



a. INPUT VOLUME FOR FREEWAY SUBSYSTEM FROM BROADWAY TO GRIGGS



b. OUTPUT VOLUME FOR FREEWAY SUBSYSTEM FROM BROADWAY TO GRIGGS

FIGURE 24 - FIVE MINUTE INPUT AND OUTPUT VOLUMES FOR THE FREEWAY SUBSYSTEM FROM BROADWAY TO GRIGGS

Public Opinion

Public reaction to the study was slight and the little reaction that was seen was generally favorable. Coverage in the news media ranged from neutral to slightly favorable. Phone calls received by City of Houston and Texas Highway Department officials were primarily from motorists who were pleased with the effects of the control study. No serious critical reactions from the motorists were observed.

General Observations at the Dumble Ramp

Several general observations were made of the operation of the Dumble entrance ramp area during the metering there. First, the queue which formed at the metering location was not nearly as long as that which had been planned for in organization of the study. The maximum length was generally about 20 - 30 vehicles and during much of the time no queue at all existed there. The diversion of some vehicles to arterial streets was the apparent reason that the queue did not reach the maximum of about 100 vehicles which had been conservatively estimated for the purpose of providing adequate preparation for the worst situation possible.

In the development of the control plans the possibility existed that a "gapers' block"* would be formed on the freeway near the Dumble entrance ramp by the drivers being distracted by the metering operation. In order to minimize this possibility, three Texas Highway Department mowers were parked on the outer separation near the metering location. The metering operation was fairly well hidden from the view of the freeway motorists. This seemed to work well because the "gapers' block" developed only a few times and when it did form it was usually caused by too many vehicles attempting to merge at the on ramp. The slowdown would then be extended by drivers observing the metering operation. This would seem to suggest that drivers of vehicles travelling at high speeds are less likely to be distracted by unusual events than they would be if they were to pass the site at low speeds.

At times a vehicle released from the metering point was forced to stop before finding an acceptable gap. Normally, other vehicles queued up be-

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* A "gapers' block" is a traffic slowdown caused by drivers looking at an accident, disabled vehicle or other distraction which is not actually blocking their paths.

hind the first stopped vehicle. Usually the gap accepted by the first stopped vehicle was sufficiently large to allow one or two other vehicles to enter the freeway following the first one. This suggests (as is commonly believed) that a stopped vehicle requires a larger acceptable gap than a moving vehicle. It also seems to indicate that capacity would be wasted at this location if the metering were operated in such a way as not to release a vehicle until the preceding vehicle had successfully merged onto the freeway.

DISCUSSION

The "before" studies of January-April, 1964, indicated that the most severe congestion on the inbound freeway occurred between Broadway and Griggs. They also indicated that much of the congestion in this area can be attributed to queues which form at downstream bottlenecks and which are propagated across the Griggs overpass, reducing the output flow at this location. The demand studies indicated that congestion in the Broadway-Griggs subsystem would clear up much sooner if this queueing could be prevented. Thus the primary goal of the controls was to prevent the development of these queues at the Wayside and Telephone entrance ramps.

In the July "before" study a slight shift in travel patterns in the Wayside-Telephone area apparently partially accomplished this purpose before the controls were initiated. Since the input to the Broadway-Griggs subsystem was about the same in the January-April "before" studies and in the August control studies and since the controls probably caused little diversion of traffic to the freeway entrances between Broadway and Griggs, it is probable that about the same input or demand conditions prevailed in this area during the two "before" periods (one in January-April and the second in July). It then follows that the changes which caused the sharp reduction in travel time in this area between January and July had to be caused by some changes in conditions downstream of Griggs.

Indeed, the fact that more demand was handled in the control period in the Broadway - Griggs subsystem than during the January "before" period and that it was handled at about half the total travel time (305 vehicle hours during control and 575 vehicle hours before control) shows that freeway control offers great promise in reducing freeway congestion. The fact that a great reduction in the congestion in this area occurred before the controls were initiated indicates that the amount of congestion is a very sensitive function of the number of vehicles attempting to use the freeway.

CONCLUSIONS

1. The control study verified the fact that much of the freeway congestion between Broadway and Griggs Road was caused by congestion from downstream. Ramp control only downstream of Griggs Road greatly reduced the congestion upstream of Griggs Road.

2. During the control study, more traffic used the freeway between Broadway and Griggs in the 7:00 to 8:00 a.m. period than under normal operation and this traffic was handled with about a 45% reduction in total travel time.

3. During the control study the travel time for an individual vehicle travelling between the Reveille interchange and the end of the freeway was about 8 to 9 minutes lower than in the "before" studies.

4. Some changes in travel patterns during the summer resulted in reduced congestion on the freeway. This indicates that, once a freeway is congested, the total amount and duration of congestion is extremely sensitive to changes in the demand on the freeway.

5. The diversion of vehicles from the controlled ramps during times when the controls were not in effect seemed to indicate that use of the alternate routes did not cause great increases in travel time or travel distance.

6. Based on the public sentiment which was expressed to the City of Houston and Texas Highway Department officials, the motorists affected by the controls were mildly in favor of the study. No strong opposition to the controls study was expressed by the public.

7. The control philosophy of keeping the demand at each bottleneck less than or equal to the capacity there provides a rational basis for the development of control plans.

POSSIBLE EXTENSIONS OF FREEWAY RAMP CONTROL

In the first control plan the decision was made to limit the controls to the inbound freeway between Wayside and the downtown distribution couplet. Even working within these constraints, the control study was extremely successful and no serious problems were encountered in the mechanics of control.

However, in order to achieve an even further reduction in congestion on the inbound freeway it is necessary to develop a control plan in which the control of each inbound entrance ramp can be considered. In this way the demand can be kept less than the capacity of all of the bottlenecks on the inbound freeway and not just those downstream of Wayside Drive. By distributing the required control over more ramps, a less severe control will probably be required at each ramp. A greater use of metering and less use of complete closure may be possible.

Since control of the Griggs entrance ramp will be an integral part of this next control plan, many vehicles which normally use this ramp will probably be diverted through the intersection of the frontage road and Wayside Drive. Thus, the completion of the planned capacity improvements at this intersection would contribute in no small part to the success of this larger control plan. At present the inbound frontage road at Wayside is badly overcapacitated and the diversion of many additional vehicles through this intersection would greatly increase the delay there.

Plans for an initial control for the outbound freeway in the afternoon peak period are being developed. At this time the exact nature of these controls are unknown but they will probably be similar in concept to those tested on the inbound freeway.

REFERENCES

1. Drew, D. R., "A Study of Freeway Traffic Congestion," Doctoral Dissertation, Texas A&M University, 1964.

2. Wattleworth, J. A., "System Demand - Capacity Analysis on the Inbound Gulf Freeway," Texas Transportation Institute Research Report 24-8, 1964.

3. Wattleworth, J. A. and McCasland, W. R., "Study Techniques for Planning Freeway Surveillance and Control," presented to the 44th Annual Meeting of the Highway Research Board, 1965.

4. McCasland, W. R., "Traffic Characteristics of the Westbound Freeway Interchange Traffic on the Gulf Freeway," Texas Transportation Institute Research Report 24-7, 1964.

5. Wattleworth, J. A., "The Estimation of Demand at a Freeway Bottleneck," Traffic Engineering, Vol. 35, No. 5, 1965.

APPENDIX

PREPARATION FOR CONTROL

Advanced Publicity

A concerted effort was made to inform those motorists directly involved in the control procedures of the control schedules and the alternatives available to them. One week before the start of the control study, signs stating the time and dates of control were erected at the ramps to be controlled (Figure 1A). At the same time traffic bulletins were issued to the motorists using the ramps during the morning peak period (Figure 2A). The bulletins listed the times and dates of control for all ramps in the study area. Alternate routes along the arterial streets were listed and indicated on a map. The same bulletins were issued a second time one day before the start of the control study.

The general public was informed of the control plans through a news release issued one week prior to the start of the control study. The maps showing times and dates of the ramp controls and the alternate routes on the street system were furnished in the news release. All of the newspapers and television stations used the information for news stories during the week before the study.

Alternate Route Signs

To remind the motorists of the control study while they are still on the approaches to the freeway, alternate routing signs of the type shown in Figure 3A were placed at major intersections of arterial streets and at upstream entrance ramps to the freeway. The signs, attached to portable stands, were turned away from traffic after the control period each morning of the study.

Metering Station

Traffic at the Dumble Ramp was directed into the freeway one vehicle at a time by policemen of the City of Houston. A member of the research project assisted him in maintaining predetermined rates of flow by use of a portable timer. The field setup was similar to those used for distributing handouts (Figure 4A).

The activity on the ramp would have been clearly visible and distracting to the freeway traffic. To minimize the distraction to freeway traffic, three Texas Highway Department mowers were parked in the outer separation near the metering location (Figure 5A). The freeway motorists were familiar with this equipment and the placement of it near the freeway was not unusual. The mowers were placed in positions that did not reduce the effective sight distance of the traffic entering the freeway on the Dumble Ramp, but which shielded the metering location from the view of the motorists on the freeway.

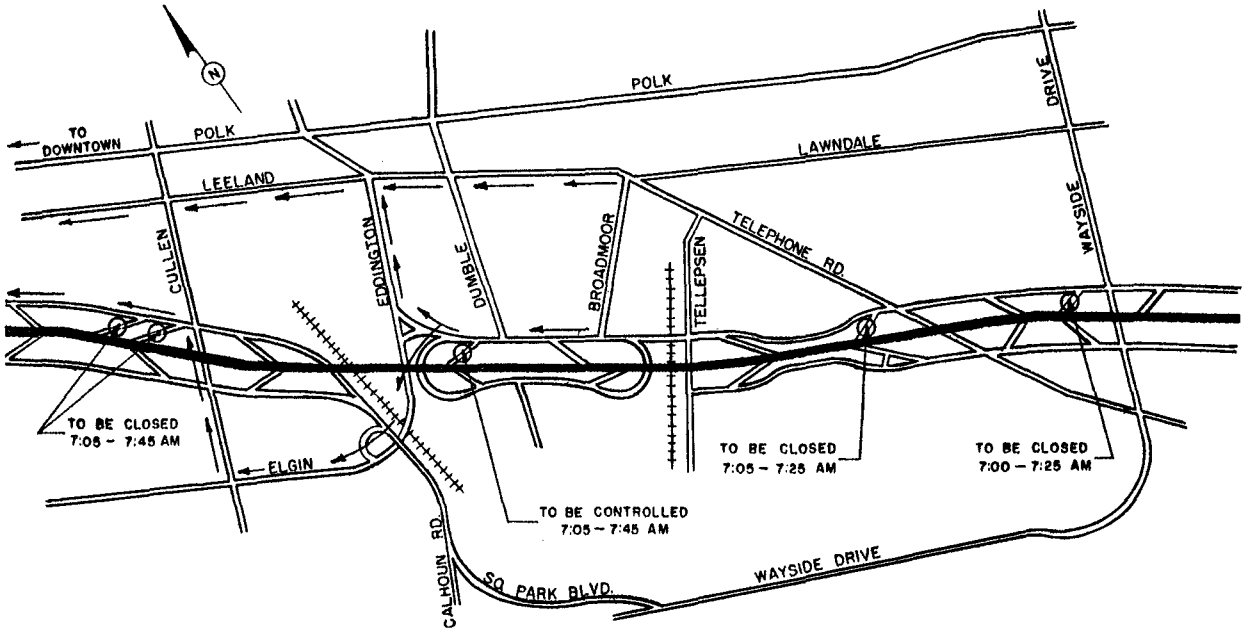
FREEWAY CONTROL SIGNS AT ENTRANCE RAMPS

FIGURE 1 A

FREEWAY SURVEILLANCE AND CONTROL PROJECT

TEXAS TRANSPORTATION INSTITUTE
COOPERATIVE RESEARCH
WITH

TEXAS HIGHWAY DEPARTMENT – CITY OF HOUSTON – BUREAU OF PUBLIC ROADS



As a part of an Experimental Freeway Control System, this ramp will be regulated during the peak traffic demand on the Freeway from 7:05 to 7:45 a.m. on weekdays from Aug 4 to Aug 14. The number of cars that will be permitted to enter the freeway during this period will be limited. This will result in some delay to the traffic approaching the ramp during this control period. Alternate routes which will bypass the control area that can be used by traffic approaching this ramp are noted on the map:

1. Vehicles approaching the Freeway from the South should consider the Elgin-Cullen route or the Eddington-Leeland Street route.

2. Vehicles approaching the Freeway from the east should consider the route on Leeland to Dowling Street.

If the time of arrival can be adjusted to miss the control period, no additional delay will be encountered at the ramp.

FREEWAY TRAFFIC CONTROL BULLETIN

FIGURE 2A

ADVISORY SIGNS ON ALTERNATE ROUTES

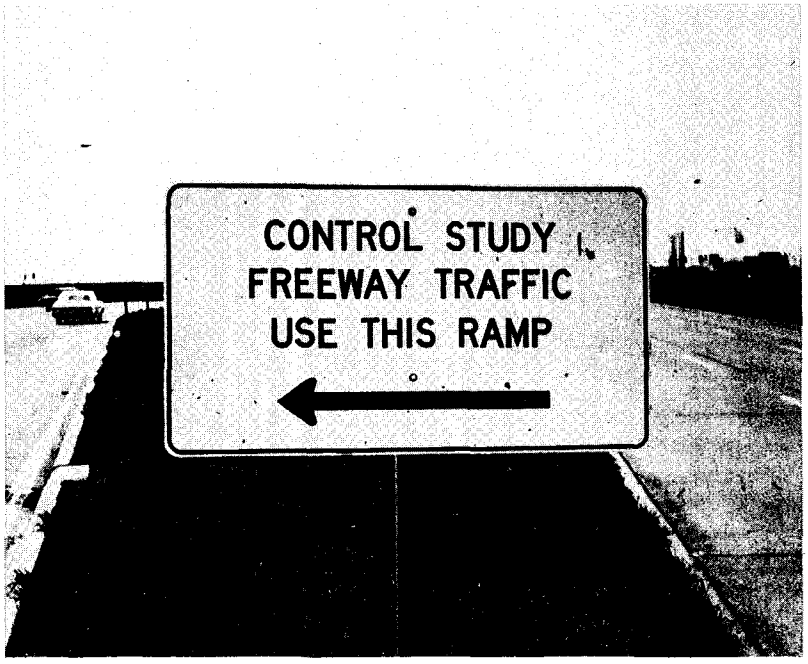


FIGURE 3A

FIELD SETUP FOR DISTRIBUTING FORMS

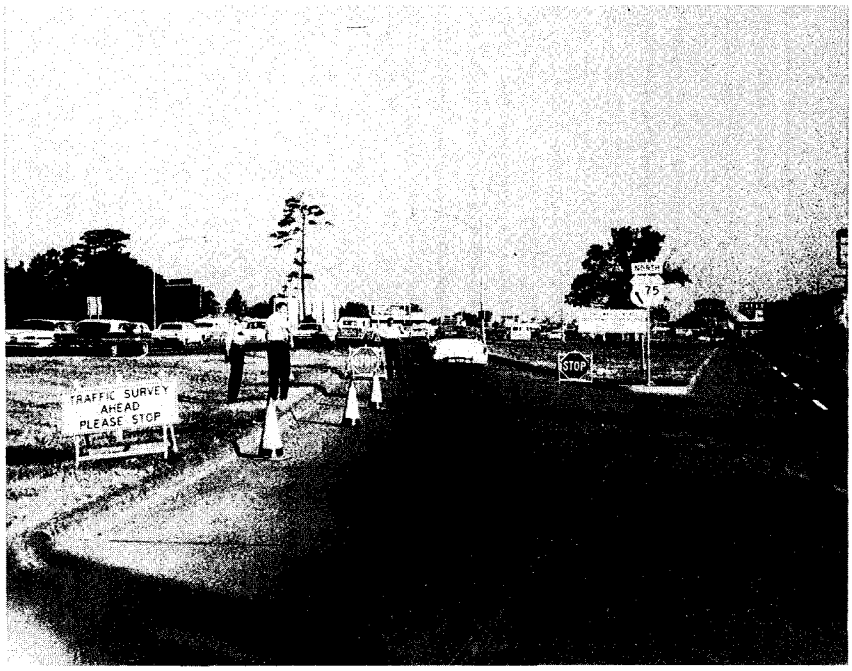


FIGURE 4A

FIELD SETUP FOR METERING RAMP TRAFFIC USING MOWING EQUIPMENT FOR SHIELD

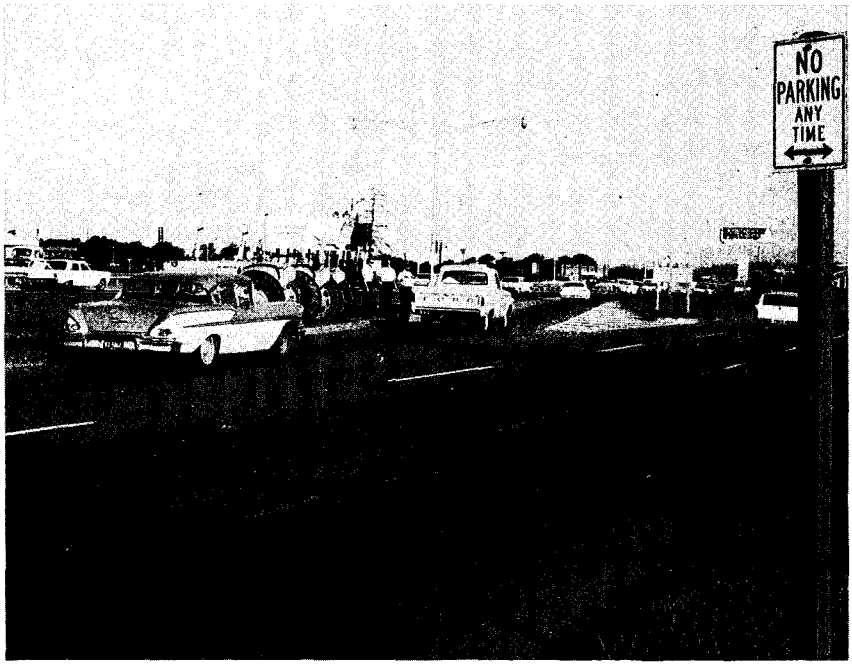


FIGURE 5A

PUBLICATIONS

Project 2-8-61-24
Freeway Surveillance and Control

1. Research Report 24-1, "Theoretical Approaches to the Study and of Freeway Congestion" by Donald R. Drew.

2. Research Report 24-2, "Optimum Distribution of Traffic Over a Capacitated Street Network" by Charles Pinnell.

3. Research Report 24-3, "Freeway Level of Service as Influenced by Volume Capacity Characteristics" by Donald R. Drew and Charles J. Keese.

4. Research Report 24-4, "Deterministic Aspects of Freeway Operations and Control" by Donald R. Drew.

5. Research Report 24-5, "Stochastic Considerations in Freeway Operations and Control" by Donald R. Drew.

6. Research Report 24-6, "Some Considerations of Vehicular Density on Urban Freeways" by John J. Haynes.

7. Research Report 24-7, "Traffic Characteristics of the Westbound Freeway Interchange Traffic of the Gulf Freeway" by William R. McCasland.

8. Research Report 24-8, "System Demand-Capacity Analysis on the Inbound Gulf Freeway" by Joseph A. Wattleworth.

9. Research Report 24-9, "Capacity - Demand Analysis of the Wayside Interchange on the Gulf Freeway" by William R. McCasland.