INBOUND GULF FREEWAY RAMP CONTROL STUDY II

by

Level of Service Project Staff

Charles Pinnell
Donald R. Drew
William R. McCasland
Joseph A. Wattleworth

Research Report Number 24-13

Level of Service
Research Project Number 2-8-61-24

Sponsored by

The Texas Highway Department
In Cooperation with the
U. S. Department of Commerce, Bureau of Public Roads

July, 1965

TEXAS TRANSPORTATION INSTITUTE
Texas A&M University
College Station, Texas

PREFACE

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

Donald R. Drew - Supervisor of Operations Area. Responsible for data collection and analysis for the evaluation of the experimental ramp signal.

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 overall conduct of the study.

Joseph A. Wattleworth - Supervisor of Systems Area. Responsible for subsystem studies to identify bottleneck locations, development of ramp control plan and the collection and analysis of data for the evaluation of the effects of the controls.

CONTENTS

INTRODUCTION

The level of service on the inbound Gulf Freeway during the morning peak period has been well documented[1,2,3] as a result of research conducted by the Texas Transportation Institute in cooperation with the Texas Highway Department and the U.S. Bureau of Public Roads. In addition to the freeway studies, critical intersections on the arterial streets and freeway frontage road were studied and a capacity improvement was recommended at one very critical location.[4] Several general techniques of studying freeway operations were also developed in order to complete the freeway analyses.[5]

The operational studies on the inbound Gulf Freeway pointed to the need for some form of freeway ramp control. An initial control study[6] was conducted on a moderate scale in August, 1964. The studies reported on herein are an extension of this research effort.

NEED FOR CONTROL

Early operational studies[3] indicated that by controlling the inbound entrance ramps a significant improvement in the inbound freeway level of service could be achieved and the total travel time expended during the morning peak period could be greatly reduced. As a result of this research, a control study was initiated on five inbound freeway entrance ramps between Wayside Drive and Dowling Street.[6] In this study four entrance ramps were closed and one entrance ramp was manually metered at predetermined rates. This study was highly successful but pointed to the need to control additional ramps between Wayside Drive and the Reveille Interchange to further improve freeway operations and to permit greater use of ramp metering and less use of complete ramp closure (by spreading the excess demand over more ramps). The present study was developed to fill this need and to allow the evaluation of a trial ramp control signal installation at the Dumble entrance ramp.

SCOPE OF THE REPORT

This report presents the development of, preparations for, and results of Inbound Gulf Freeway Ramp Control Study II which was conducted between January 26 and March 12, 1965. In addition the traffic operation after the termination of the control study was also studied and these results are presented. Evaluation of the operation during the control period centered mainly on the freeway but also included the inbound frontage roads and the arterial street system.

BEFORE STUDIES

FREEWAY AND FRONTAGE ROADS

Traffic studies were conducted on the inbound Gulf Freeway during 1964 and early 1965 in order to identify the critical bottleneck locations and to determine the duration and amount of excess demand at each of these locations. All studies were conducted during the 6:30 and 8:30 a.m. period between Broadway and Dowling streets.

Closed system input-output studies conducted during January, March, and April, 1964, provide much of the basic volume, density and system travel time data upon which the "before and after" comparisons are based. Table 1 shows the dates of each input-output study which was used for the "before" data in the "before and after" comparisons. These studies have been reported previously[3] and were used in the development of the plans for the Inbound Gulf Freeway Ramp Control Study I[6] which was conducted in August, 1964.

TABLE 1

1964 INPUT-OUTPUT STUDY DATA USED IN "BEFORE AND AFTER" COMPARISONS

System Boundaries	Data Used
Broadway-Griggs	Jan. 28-30, 1964
Griggs - S.HB&T RR	March 16, 17, 20, 1964
S. HB&T RR - Cullen	March 21, April 1, 2, 1964
Cullen - Scott	April 13, 17, 1964
Scott - Dowling	April 20, 23, 24, 1964

While the January, 1964 input-output studies were being conducted, a specially equipped vehicle was used to obtain data on travel times for an individual vehicle. These data are presented in the form of travel time contours and are compared to similar data obtained during the control study reported herein.

Aerial photographs were also used in the collection of data during the ummer of 1964 and during the January-April period of 1965. These data were used o supplement the density and system travel time data obtained from the input-utput studies and to provide data on the operation of the frontage roads and rterial street intersections near the freeway. Such data from early 1965 were ncomplete because the light was insufficient for good photography during the arly part of the 7-8 a.m. peak period which was used in most analyses.

ARTERIAL STREETS

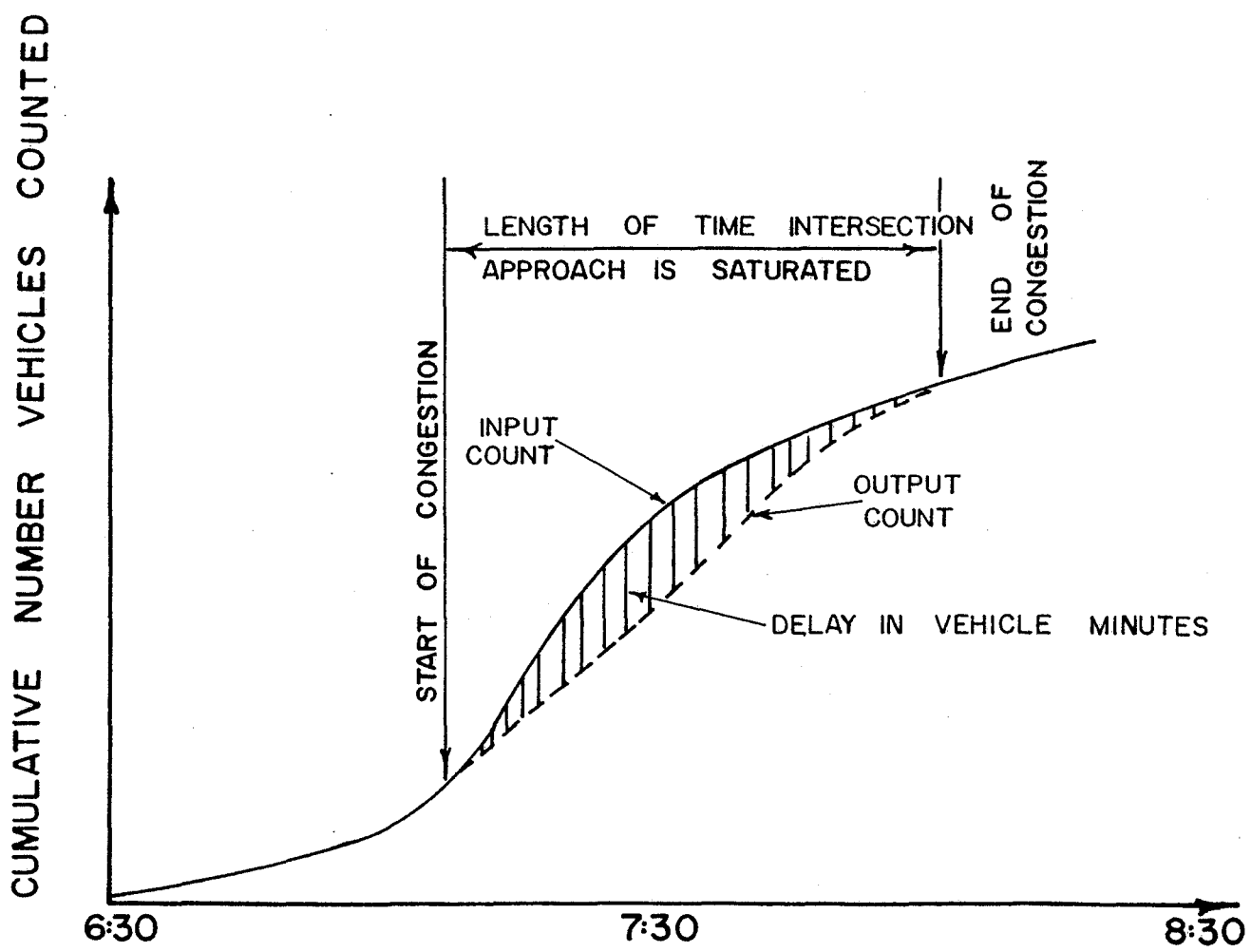
The term "Freeway Control" refers to the control of the input volumes to the freeway at the entrance ramps. Controls of this type increase traffic on the arterial street system, because of diversion from one entrance ramp to another, or to the street system for the entire trip. Also, the control system, if successful, will increase the output of the freeway so that exit ramp volumes may increase for short periods of time. The objective of this phase of the study was to determine the change in travel on the street system and to determine if traffic flow was impaired or penalized by the control system.

To determine the total effect of freeway control over the system of streets and freeways, the studies on all travelled ways had to be compatible, or comparable However, input-output studies that describe so well the conditions on the freeway were not practical on the arterial streets. The numerous entrances and exits to a system of any length on arterial streets would require a very large number of observers. Aerial photography could provide the data if trees, buildings and shadows did not interfere with the line of sight.

A network of arterial streets essentially consist of sections of uncongested roadways and sections of congested roadways, even during peak traffic flows. The congested sections are the approaches to signalized intersections. A certain number of stopped vehicles is to be expected at almost any signalized intersection. Only when an approach becomes saturated, so that some vehicles are delayed for more than one cycle, can we say that the approach is congested. To estimate the effect of ramp closure on the arterial streets, approaches to many intersections on arterial streets considered to be located in the area influenced by the freeway were studied.

The procedure of study involved taking demand counts on the approaches, from 6:30 a.m. to 8:30 a.m. for several days before the control study period. From the demand or input count and the output count on an approach to an intersection, the delay in vehicle minutes could be estimated, where "delay" is defined as the delay to vehicles not clearing the signal during the first green phase after arrival at the signal. This delay, or excess delay, can be illustrated by plotting the cumulative input and output counts as shown in Figure 1.

The shaded area represents the delay to vehicles, as defined above, in vehicle-minutes. The output count during the saturated period represents the capacity of the approach. It is shown as a slightly curved line, implying that the capacity varies slightly over the time period. It is normally assumed that the capacity of an approach is constant, i.e., that this output count is a straight line. It was felt that accepting this as true would introduce only small errors in the estimates of delay. Furthermore, in view of the fact that the difference in delays before and during the study period were of primary interest, this assumption would probably introduce only negligible error into the



CAPACITY DEMAND RELATIONSHIPS

FIGURE 1

estimated difference. The capacity of each approach under study was thus measured by taking output counts during saturated cycles and evaluating the average maximum output (capacity). Then only demand counts were required at the approaches under consideration.

This technique is not well refined and is not considered as a highly accurate estimate of the exact value of the delay, mainly because both the demand and the output are considered as continuous rather than discrete functions. However, any serious effect on the delay on an approach will certainly show up in such an analysis and it was thus considered adequate for the purposes of this study. In addition, travel time runs were made by individual vehicles to provide another means of determining the effect of the freeway control on traffic operations on the surface street system.

The closure of the Griggs Entrance Ramp for a 15- or 20-minute period during the peak hour was of major concern since 170 to 200 vehicles would be diverted to the city street system in an area that had several congested intersections. A license plate Origin-Destination Survey of the ramp traffic was conducted to determine the alternate routes and ramps that this traffic would probably use to enter the freeway. The reassignment of this traffic was used to determine the time the Griggs Ramp should be open and the metering rates for the downstream entrance ramps.

DEVELOPMENT OF CONTROL PLANS

PHILOSOPHY OF THE CONTROLS

The philosophy of Control Study II was essentially the same as that of Control Study I[6], namely that the demand be kept less than or equal to the capacity at each bottleneck. Demand and capacity both represent total directional low rates (three lanes). In Control Study I, the control area was limited to the region between Wayside Drive and Dowling Street, whereas, in Control Study II all inbound entrance ramps between Broadway and Dowling were considered for control.

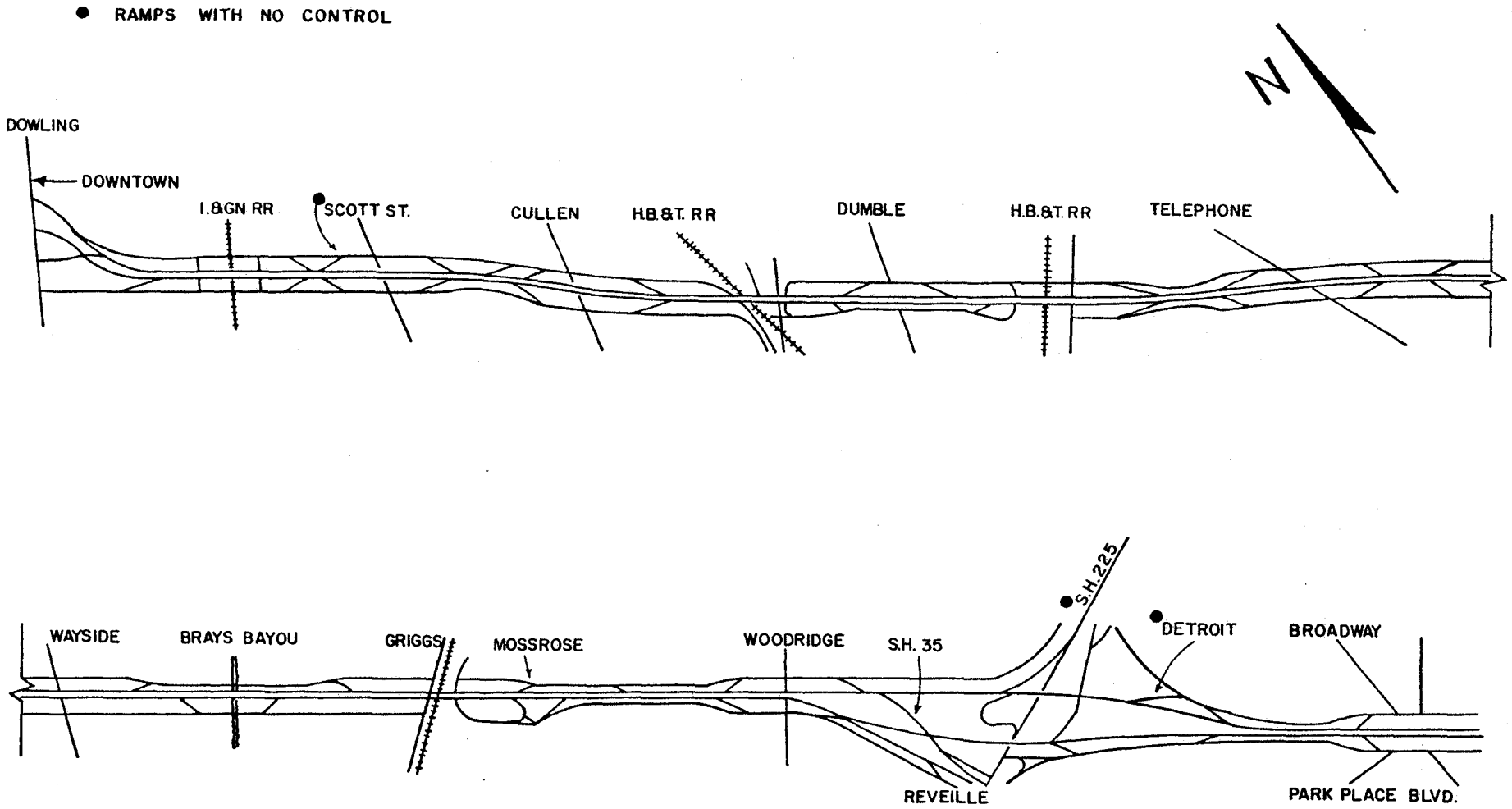
Upstream of each inbound entrance ramp (starting in the Broadway area and proceeding toward Dowling) the five-minute demand rates were estimated.[6,7] For each entrance ramp, the difference between the estimated upstream demand and the estimated capacity provided the basis for metering or closing the ramp.

The capacity flow rates for the critical sections were based on counts obtained from March to August, 1964. These capacities were somewhat higher than would have been obtained from the counts during January and February, 1964, since the January-February, 1964 counts were found to be considerably lower than counts obtained at the same locations in the March-August, 1964 period. The original control plan which was based on these higher capacities was tested during the first four days of the study (January 26-29, 1965). In this period the improvement in the freeway level of service was not as great as was anticipated so the controls were made slightly more restrictive at the beginning of the second week to compensate for the possible overestimation of capacities. Most of the discussions in this report refer to the revised control plan, since this was in effect much longer than the original plan.

LOCATION AND SEVERITY OF CONTROLS

The demand estimates and various other studies showed that no controls were required at the detroit Street entrance ramp or at any entrances upstream of this location. The congestion normally does not back upstream to the Broadway entrance ramp and the demand was found to be less than the capacity at the Detroit entrance ramp throughout the entire peak period. Similar considerations also indicated that control of the Scott entrance ramp was unnecessary.

Control was considered at each entrance ramp from S. H. 225 to Cullen Street as shown in Figure 2, A discussion of the considerations leading to the final control plan at each ramp is presented below.



GULF FREEWAY STUDY SYSTEM

FIGURE 2

. H. 225 ENTRANCE RAMP

This entrance ramp is a directional turning roadway which accommodates ıe right turning vehicles from the southbound S. H. 225 (La Porte Freeway) to the ıbound Gulf Freeway.

Some merging problems were anticipated at this location but the metering of ıis high-volume ramp would probably have created a queue which almost cer- ıinly would have backed onto the La Porte Freeway, blocking one of its two ɔuthbound lanes. Even though the volumes on the La Porte Freeway are less ıan the capacity of one lane, it was decided that the possible benefits to the ulf Freeway traffic of metering this ramp did not outweigh the possible adverse ffects (especially the accident hazards) to the La Porte Freeway traffic.

From a design standpoint the S. H. 225 entrance ramp is one of the best ntrance ramps on the inbound Gulf Freeway. However, under normal operating ɔnditions on the Gulf Freeway, many vehicles by-pass the S. H. 225 entrance ramp nd enter at Woodridge or Mossrose. By doing this, they miss a great deal of eeway congestion but tend to compound the problem by entering downstream at ore critical locations. For this reason, it was deemed advisable to leave the . H. 225 entrance ramp uncontrolled in order to encourage a greater usage of ıe S. H. 225 entrance ramp. Thus for the purposes of Control Study II the . H. 225 ramp was not metered.

. H. 35 Entrance Ramp

The five-minute demand rates upstream of the S. H. 35 entrance ramp were ɜtimated based on count data from the input-output studies (see Table 1). The .lowable metering rate for each five-minute period was calculated as the dif- rence between the merging capacity and the upstream demand. A capacity of '5 vehicles per 5 minutes was used in the derivation of the initial control plan.

The initial control plan was in effect during the first four days (January ɔ-29, 1965) of this study. The metering scheme used at the S. H. 35 entrance mp during this period is shown below:

	Metering Rate	
Time - a.m.	Veh./ 5 min.	1 Veh./ x seconds
6:55-7:00	75	1/4
7:00-7:05	50	1/6
7:05-7:15	75	1/4
7:15-7:30	100	1/3

The metering rates are shown in terms of both the number of vehicles per minutes and the metering headway in seconds. In addition, the personnel operating e metering station were instructed to discontinue the metering if ramp vehicles

had to stop before merging and queued in the merging area past a predetermined point (about 12-15 vehicles in the queue). When the queue cleared to another predetermined point (about 3 or 4 vehicles in the queue) the metering was resumed.

At the beginning of the second week of the control study, a slightly more restrictive control plan was initiated. This plan was in effect until the controls were terminated on March 12, 1965. The revised metering scheme at the S.H. 35 entrance ramp is shown below:

	Metering Rate	
Time - a.m.	Veh./ 5 min.	1 Veh./ x seconds
6:55-7:20	50	1/6
7:20-7:45	75	1/4

The override for stopped vehicles in the merging area was also used in this scheme.

A queue of considerable length was anticipated at this location because of the high demand rate and the metering rates which were used. The storage of the vehicles in the queue was not considered critical because of the length of the ramp and the fact that up to 100 vehicles were queued at this ramp on some days when no controls were in effect.

Woodridge Entrance Ramp

Under normal freeway operating conditions about 45% of the vehicles which enter the freeway at Woodridge did so after bypassing S.H. 225 entrance ramp. Thus, it was assumed that when the Woodridge entrance ramp was metered the vehicles would not bypass the uncontrolled S.H. 225 ramp to wait in the queue at Woodridge. It was anticipated, however, that about 20% of the vehicles which normally enter the freeway at Mossrose would choose to enter at Woodridge. Hence, the expected ramp demand at Woodridge during the control plan was 55% of the normal Woodridge demand plus 20% of the normal Mossrose demand.

The freeway demand was estimated upstream of the Woodridge entrance ramp and a merging capacity of 485 vehicles per 5 minutes was assumed in the calculation of the allowable metering rates. The controls at S.H. 35 were taken into consideration when the freeway demand was estimated. The metering scheme used during the first week of the controls at Woodridge is shown below:

	Metering Rates	
Time - a.m.	Veh./ 5 Min	1 Veh./ x Seconds
6:55 - 7:10	30	1/10
7:10 - 7:20	50	1/6

During the remainder of the control study the rate of 50 vehicles per 5 minutes (1/6 seconds) was extended from 7:20 to 7:45 a.m. Otherwise, the control scheme at this location was unchanged.

An override to the metering, similar to that at the S.H. 35 ramp, was used to clear vehicles from the ramp which had to stop in the merging area to wait for an acceptable gap. When four ramp vehicles were stopped in the merging area the metering was temporarily halted until only one stopped vehicle remained. Then, the metering was resumed. This same override to the metering was used at the Mossrose, Wayside and Telephone entrance ramps.

Mossrose Entrance Ramp

The geometric features of the Mossrose entrance ramp make it one of the most critical merging areas on the inbound Gulf Freeway. The ramp itself is very short and provides a high-angle, direct entry onto the freeway. In addition, the ramp enters the freeway at the foot of the upgrade of the Griggs Road overpass structure on which a difference of elevation of about 30 feet is accomplished in a distance of about 1000 feet. Because of the upgrade, vehicles which have to stop or slow down drastically in the merging area have a severe adverse effect on the freeway traffic. Because of the high ramp volume (approximately 650 vehicles from 7 to 8 a.m.) and the inferior ramp geometrics, a great many ramp vehicles are forced to stop before merging.

The results of an origin-destination study conducted at this ramp[8] showed that about 80% of the vehicles which normally enter at Mossrose bypass either the S.H. 225 or Woodridge entrance ramp or both in an attempt to avoid congestion on the freeway. Thus, only about 20% of the vehicles which normally enter at Mossrose should enter there; the other 80% should enter at S.H. 225 or Woodridge.

In addition to the demand-capacity philosophy used to plan the controls at the other ramps, other considerations were also made. An extremely low metering rate was considered desirable during the early part of the peak period at this ramp for three reasons: (1) a low metering rate would allow most of the ramp vehicles to enter the freeway at high speeds, (2) a low metering rate and its associated high delay would discourage vehicles from bypassing upstream ramps and (3) the low metering rate at Mossrose was expected to produce a higher level of service on the freeway, thereby encourag ing some vehicles to enter the freeway upstream of Mossrose rather than bypassing to Mossrose.

Considerable thought was given to the possibility of closing this ramp instead of metering it. One disadvantage of metering the Mossrose ramp was that the personnel and the various signs involved in the metering would be plainly visible to the motorists on the freeway. Thus, the possibility of the formations of a "gapers

block"* existed. It was decided, however, that it would be better to meter than to close this ramp to avoid causing circuity of travel for approximately 125 vehicles whose trips originate near the ramp and for which the use of the ramp is most natural. The discontinuity in the frontage road at Griggs Road makes the Mossrose ramp especially important for these vehicles. It was reasoned, however, that a higher level of service on the freeway would probably have resulted from the closure of this ramp.

During the first week of the control the following metering scheme was used at the Mossrose entrance ramp:

	Metering Rate	
Time - a.m.	Veh. / 5 Min.	1 Veh./ x Seconds
6:55 - 7:10	20	1/15
7:10 - 7:20	30	1/10
7:20 - 7:30	50	1/6

During the remainder of the control study the metering scheme was changed as follows:

	Metering Rate	
Time a.m.	Veh. / 5 Min.	1 Veh./ x Seconds
6:55 - 7:20	20	1/15
7:20 - 7:45	50	1/6

In order to allow stopped vehicles from the ramp to clear from the merging area, the same override to the metering that was used at Woodridge was employed at Mossrose.

Griggs and Wayside Ramps

Because of the proximity of the Griggs and Wayside entrance ramps and because there are no ramps between them, the controls imposed at one ramp would affect the controls needed at the other ramp. The demand upstream of the Griggs ramp and the capacity downstream of the Wayside ramp determine the allowable entrance volume for the two ramps together. This allowable volume could come from either ramp or a combination but the total volume entering from the two ramps must not

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

exceed the total allowable volume. For this reason control considerations were made at the two ramps simultaneously.

If a large amount of traffic were allowed to enter the freeway from the Griggs ramp, it would have been necessary to impose a low metering rate on the Wayside entrance ramp. The problem of a traffic queue at Wayside, especially the possibility that it might back into the intersection of Wayside Drive and the inbound frontage road, made it unfeasible to have an extremely low metering rate at Wayside. As explained previously, the metering rate could be increased at Wayside only through a corresponding decrease in the metering rate at Griggs. Because of the high volume on the Griggs ramp (about 700 from 7-8 a.m.) a low metering rate there would have created severe queueing problems at this location. Even though the frontage road there could accommodate a large queue without having any intersections blocked, the possibility of a "gapers' block" formation on the freeway was considered to be great.

Since the allowable ramp volume at Griggs (with a high metering rate at Wayside) was so low during part of the peak period the ramp would have been essentially closed. This suggested the possibility of closing the ramp instead of metering it. The advantages of closure are its simplicity and the elimination of a large queue at this ramp. One disadvantage of closure is that the intersection with Wayside Drive is a critical bottleneck on the inbound frontage road[4] and the diversion of a large amount of traffic through this already congested intersection approach would certainly create an extremely bad situation.

It was decided that the frontage road congestion was less critical and the decision was made to close the Griggs entrance ramp. A reassignment of some of the traffic from this ramp indicated that most of this traffic could use more direct routes to other freeway ramps and would not use the frontage road between Griggs and Wayside. Demand-capacity analyses of the alternate routes to be used by most of the traffic diverted by the closure of the Griggs ramp indicated that until about 7:20 a.m. these routes could accommodate the extra traffic. However, after about 7:20 a.m. the additional traffic would be expected to cause severe congestion and excessive delay on many of the alternate routes.

Because of these considerations the decision was made to close the Griggs entrance ramp from 7:05 to 7:20 in spite of the fact that the demand would be close to or slightly over the capacity of the merging area of this ramp for several minutes after the ramp was opened. Were it not for the consideration of the effects on the arterial street system this ramp should desirably have been closed until 7:25 or 7:30 to preserve the high level of service on the freeway.

Demand-Capacity considerations (assumed capacity 490 veh/5min.) at the Wayside entrance ramp including the effects of the closure of the Griggs ramp on freeway and ramp demand led to the establishment of the following metering scheme:

Time - a.m.	Metering Rate: Veh. / 5 Min.	Metering Rate: 1 Veh. / x Seconds
7:00 - 7:05	30	1/10
7:05 - 7:20	50	1/6
7:20 - 7:25	38	1/8
7:25 - 7:30	50	1/6

After the first week of the study the following metering scheme was adopted:

Time - a.m.	Metering Rate: Veh. / 5 Min.	Metering Rate: 1 Veh. / x Seconds
7:00 - 7:25	30	1/10
7:25 - 7:45	50	1/6

The same override to the metering to clear stopped ramp vehicles from the merging area was used at the Wayside, Telephone and Dumble ramps while they were being metered.

Telephone Entrance Ramp

A demand-capacity analysis at the merging area of the Telephone Road entrance ramp provided the basis for the metering plan which was used there. Consideration was made of all controls on upstream entrance ramps and the re-assignment of the vehicles which would be diverted from the Griggs Road ramp during its closure period. About 50% of these were assigned to the Telephone Road entrance ramp and a merging capacity of 490 veh./ 5 min. was assumed. The following metering scheme was developed for the Telephone entrance ramp:

Time - a.m.	Metering Rate: Veh./ 5 Min.	Metering Rate: 1 Veh. / x Seconds
7:00 - 7:15	20	1/15
7:15 - 7:45	40	1/7.5

Dumble Entrance Ramp

The Dumble entrance ramp was selected as the location for testing a traffic signal for metering the ramp traffic. This installation will be discussed more fully in a later section.

A demand-capacity analysis of the merging area of the Dumble entrance ramp was made. It included the effects of upstream controls and the expected diversion of vehicles from their normal routes and assumed a merging capacity of 475 vehicles/ 5 min. This analysis yielded the following metering plan which was in effect during

the first week of the study:

Time - a.m.	Metering Rate - Veh./ 5 Min.
7:05 - 7:10	40
7:10 - 7:15	30
7:15 - 7:20	25
7:20 - 7:25	40
7:25 - 7:30	50

During the second week of the study the rate of 50 veh./ 5 min. was extended until 7:45 a.m.

At the beginning of the third week an automatic timing device was installed at the signal to obviate the necessity of having someone at this location to turn the signal on and off. At this time it was necessary to limit the metering to one rate during the entire period of control. The rate of 40 vehicles per 5 minutes was chosen at this time.

Cullen Entrance Ramps

The demand-capacity analysis at the merging area of the two Cullen entrance ramps indicated that these ramps should be closed from 7:05-7:30 a.m. each day. Because the closure of these ramps on two other occasions[1,6] resulted in few, if any, problems to motorists normally using these ramps, the decision was made to close these two ramps for the twenty-five minute period.

PRELIMINARY PREPARATIONS FOR THE CONTROLS

Advance Publicity

The details of the control plan were announced to the general public through a news release, issued on January 19, 1965. The Appendix contains several articles regarding the controls which appeared in local newspapers. Also on January 19, signs were erected at each of the ramps to be controlled, displaying the date and time of control. A traffic bulletin was issued to each motorist who used the ramps in the study area during the morning peak period on January 25 as a reminder that the study would start the next day and also to indicate the extent of the study area. Figures 3 and 4 show samples of the ramp signs and traffic bulletins.

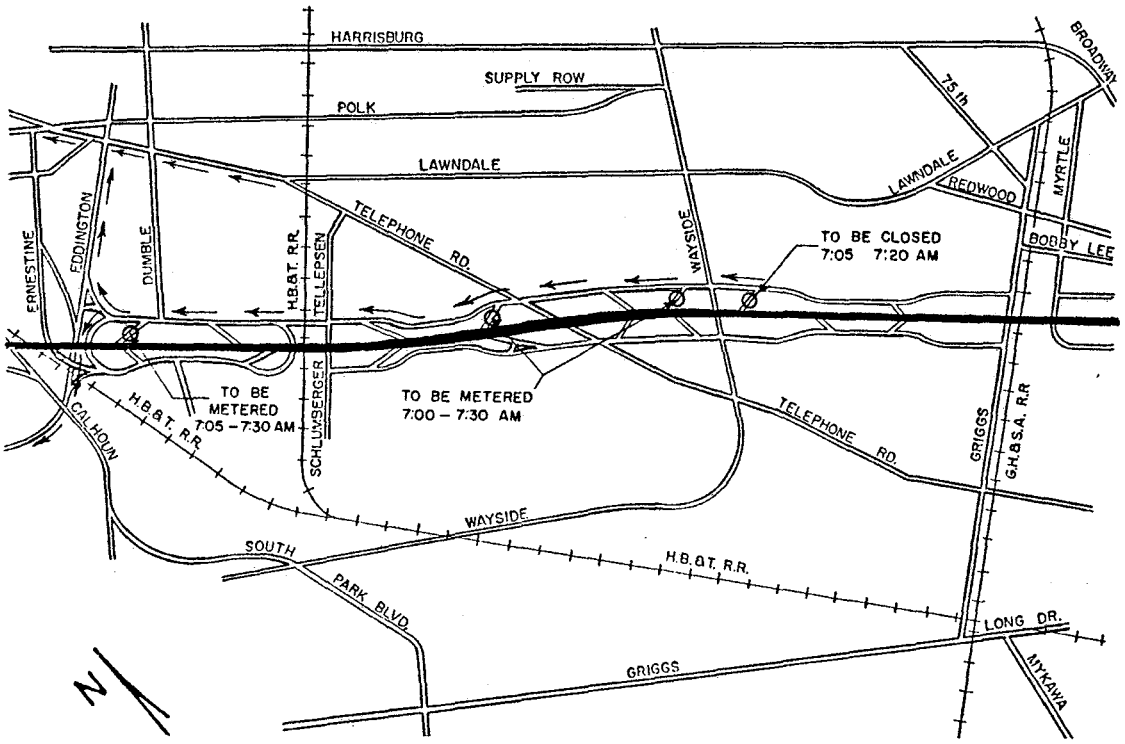
The effectiveness of the advance publicity was evident the first few days of the study by the changes in the pattern of traffic approaching the study area. In many instances the shift in traffic was not expected. Many motorists tried to bypass part of the control area to enter the freeway at downstream ramps.

ADVISORY SIGNS ERECTED AT RAMPS TO BE CONTROLLED

FIGURE 3

FREEWAY SURVEILLANCE AND CONTROL PROJECT

TEXAS TRANSPORTATION INSTITUTE
COOPERATIVE RESEARCH
WITH
TEXAS HIGHWAY DEPARTMENT - CITY OF HOUSTON - BUREAU OF PUBLIC ROADS



As part of an Experimental Freeway Control System to improve traffic operations, the entrance ramps to the Gulf Freeway from State Highway 225 to Downtown will be controlled during the morning peak traffic demand. The traffic using this ramp will be metered by limiting the number of vehicles to enter the Freeway from 7:00 to 7:30 a.m. on weekdays from January 25 to February 5. This will result in some additional delay to ramp traffic during this time period. Motorists who prefer to bypass the control area are advised to take one of the alternate routes shown on the map above.

The map on the reverse side of this traffic bulletin indicates the controls to be placed on the other ramps. It should be noted that traffic diverting to one of the other ramps during the time of control may be delayed several minutes before entering the Freeway.

FIGURE 4

Signing

In addition to the advisory signs erected at the ramps, alternate routing signs such as the one shown in Figure 5, were located at upstream entrance ramps and on the arterial streets at major intersections, and portable "stop" signs and "stop ahead" signs were placed at the ramps.

Signals

The signals at the Dumble Entrance Ramp were installed on Friday, January 22 and operated on flashing amber until the start of the control study January 26. (See Section on Signal Installation at Dumble, page 20.)

Timing Devices

The metering rates were determined on the basis of capacity-demand relationships on the freeway. Timers (Figure 6) that indicated the various metering rates to the ramp control officers were built for the study. They provided a buzz each time a vehicle on the ramp was to be released onto the freeway. The design was crude but effective. A 6 volt motor with a speed of 1rpm, mounted in a 6" x 6" x 4" box, powered a rotary switch. Pins in the lid of the box closed the circuit to a buzzer. The metering rate, represented by the number of pins, was adjusted by changing the lid.

OPERATION OF THE CONTROLS

Manual Metering

Five of the metered ramps were controlled by policemen from the City of Houston, who directed the traffic onto the freeway at specified intervals. The sixth ramp was controlled by a fixed time traffic signal for assigning the right of way to ramp traffic.

The metering stations, controlled by the city policemen, were located at the junction of the entrance ramps and the frontage road as shown in Figure 7. A "stop ahead" sign was placed 200 feet in advance of the metering station. A "stop" sign was placed at the metering station, but it was easily seen by the freeway motorists and tended to cause a "gapers' block". The "stop" signs were removed after the second day on all but one ramp.

The policemen were instructed to direct one vehicle onto the ramp each time the buzzer on the timer sounded. If the vehicles did not move directly into the freeway, but queued up at the merge point, the policemen were instructed to hold all vehicles at the metering station until only one vehicle remained on the ramp. The policemen changed from one metering rate to another at the times specified in the control plan by a simple adjustment of the timer.

exceed the total allowable volume. For this reason control considerations were made at the two ramps simultaneously.

If a large amount of traffic were allowed to enter the freeway from the Griggs ramp, it would have been necessary to impose a low metering rate on the Wayside entrance ramp. The problem of a traffic queue at Wayside, especially the possibility that it might back into the intersection of Wayside Drive and the inbound frontage road, made it unfeasible to have an extremely low metering rate at Wayside. As explained previously, the metering rate could be increased at Wayside only through a corresponding decrease in the metering rate at Griggs. Because of the high volume on the Griggs ramp (about 700 from 7-8 a.m.) a low metering rate there would have created severe queueing problems at this location. Even though the frontage road there could accommodate a large queue without having any intersections blocked, the possibility of a "gapers' block" formation on the freeway was considered to be great.

Since the allowable ramp volume at Griggs (with a high metering rate at Wayside) was so low during part of the peak period the ramp would have been essentially closed. This suggested the possibility of closing the ramp instead of metering it. The advantages of closure are its simplicity and the elimination of a large queue at this ramp. One disadvantage of closure is that the intersection with Wayside Drive is a critical bottleneck on the inbound frontage road[4] and the diversion of a large amount of traffic through this already congested intersection approach would certainly create an extremely bad situation.

It was decided that the frontage road congestion was less critical and the decision was made to close the Griggs entrance ramp. A reassignment of some of the traffic from this ramp indicated that most of this traffic could use more direct routes to other freeway ramps and would not use the frontage road between Griggs and Wayside. Demand-capacity analyses of the alternate routes to be used by most of the traffic diverted by the closure of the Griggs ramp indicated that until about 7:20 a.m. these routes could accommodate the extra traffic. However, after about 7:20 a.m. the additional traffic would be expected to cause severe congestion and excessive delay on many of the alternate routes.

Because of these considerations the decision was made to close the Griggs entrance ramp from 7:05 to 7:20 in spite of the fact that the demand would be close to or slightly over the capacity of the merging area of this ramp for several minutes after the ramp was opened. Were it not for the consideration of the effects on the arterial street system this ramp should desirably have been closed until 7:25 or 7:30 to preserve the high level of service on the freeway.

Demand-Capacity considerations (assumed capacity 490 veh/5min.) at the Wayside entrance ramp, including the effects of the closure of the Griggs ramp on freeway and ramp demand, led to the establishment of the following metering scheme:

	Metering Rate	
Time - a.m.	Veh. / 5 Min.	1 Veh. / x Seconds
7:00 - 7:05	30	1/10
7:05 - 7:20	50	1/6
7:20 - 7:25	38	1/8
7:25 - 7:30	50	1/6

After the first week of the study the following metering scheme was adopted:

	Metering Rate	
Time - a.m.	Veh. / 5 Min.	1 Veh. / x Seconds
7:00 - 7:25	30	1/10
7:25 - 7:45	50	1/6

The same override to the metering to clear stopped ramp vehicles from the merging area was used at the Wayside, Telephone and Dumble ramps while they were being metered.

Telephone Entrance Ramp

A demand-capacity analysis at the merging area of the Telephone Road entrance ramp provided the basis for the metering plan which was used there. Consideration was made of all controls on upstream entrance ramps and the re-assignment of the vehicles which would be diverted from the Griggs Road ramp during its closure period. About 50% of these were assigned to the Telephone Road entrance ramp and a merging capacity of 490 veh./ 5 min. was assumed. The following metering scheme was developed for the Telephone entrance ramp:

	Metering Rate	
Time - a.m.	Veh./ 5 Min.	1 Veh. / x Seconds
7:00 - 7:15	20	1/15
7:15 - 7:45	40	1/7.5

Dumble Entrance Ramp

The Dumble entrance ramp was selected as the location for testing a traffic signal for metering the ramp traffic. This installation will be discussed more fully in a later section.

A demand-capacity analysis of the merging area of the Dumble entrance ramp was made. It included the effects of upstream controls and the expected diversion of vehicles from their normal routes and assumed a merging capacity of 475 vehicles/ 5 min. This analysis yielded the following metering plan which was in effect during

the first week of the study:

Time - a.m.	Metering Rate - Veh./ 5 Min.
7:05 - 7:10	40
7:10 - 7:15	30
7:15 - 7:20	25
7:20 - 7:25	40
7:25 - 7:30	50

During the second week of the study the rate of 50 veh./ 5 min. was extended until 7:45 a.m.

At the beginning of the third week an automatic timing device was installed at the signal to obviate the necessity of having someone at this location to turn the signal on and off. At this time it was necessary to limit the metering to one rate during the entire period of control. The rate of 40 vehicles per 5 minutes was chosen at this time.

Cullen Entrance Ramps

The demand-capacity analysis at the merging area of the two Cullen entrance ramps indicated that these ramps should be closed from 7:05-7:30 a.m. each day. Because the closure of these ramps on two other occasions[1,6] resulted in few, if any, problems to motorists normally using these ramps, the decision was made to close these two ramps for the twenty-five minute period.

PRELIMINARY PREPARATIONS FOR THE CONTROLS

Advance Publicity

The details of the control plan were announced to the general public through a news release, issued on January 19, 1965. The Appendix contains several articles regarding the controls which appeared in local newspapers. Also on January 19, signs were erected at each of the ramps to be controlled, displaying the date and time of control. A traffic bulletin was issued to each motorist who used the ramps in the study area during the morning peak period on January 25 as a reminder that the study would start the next day and also to indicate the extent of the study area. Figures 3 and 4 show samples of the ramp signs and traffic bulletins.

The effectiveness of the advance publicity was evident the first few days of the study by the changes in the pattern of traffic approaching the study area. In many instances the shift in traffic was not expected. Many motorists tried to bypass part of the control area to enter the freeway at downstream ramps.

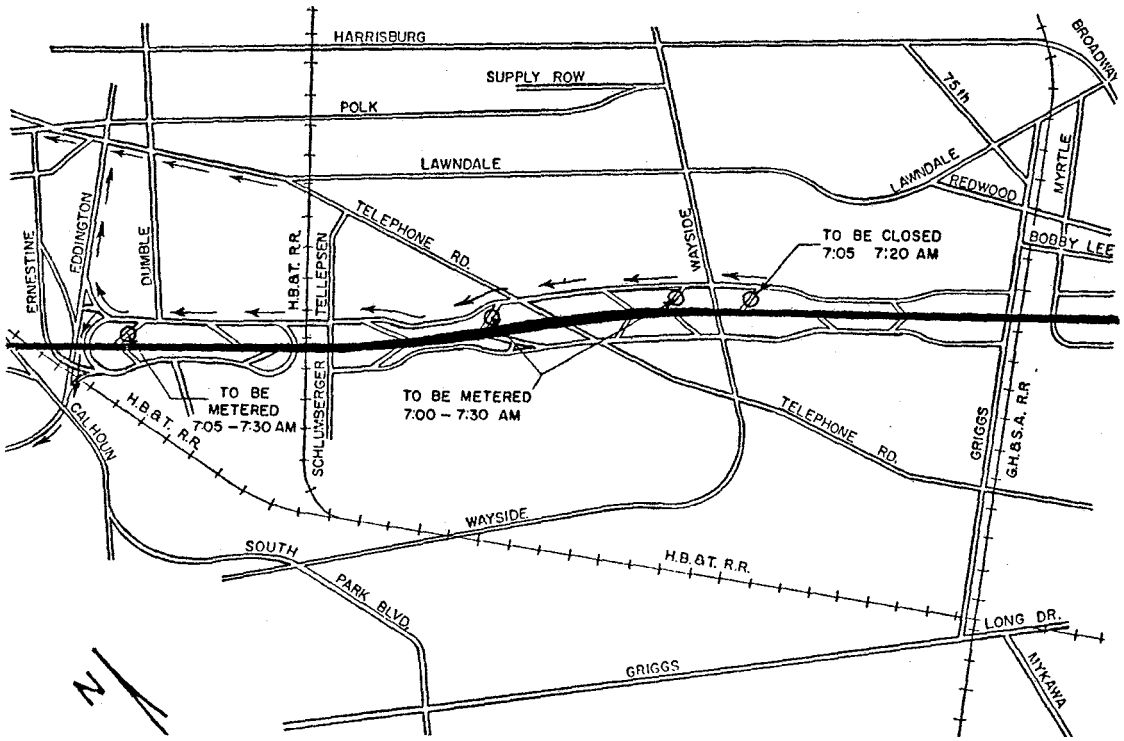
ADVISORY SIGNS ERECTED AT RAMPS TO BE CONTROLLED

FIGURE 3

FREEWAY SURVEILLANCE AND CONTROL PROJECT

TEXAS TRANSPORTATION INSTITUTE
COOPERATIVE RESEARCH
WITH

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



As part of an Experimental Freeway Control System to improve traffic operations, the entrance ramps to the Gulf Freeway from State Highway 225 to Downtown will be controlled during the morning peak traffic demand. The traffic using this ramp will be metered by limiting the number of vehicles to enter the Freeway from 7:00 to 7:30 a.m. on weekdays from January 25 to February 5. This will result in some additional delay to ramp traffic during this time period. Motorists who prefer to bypass the control area are advised to take one of the alternate routes shown on the map above.

The map on the reverse side of this traffic bulletin indicates the controls to be placed on the other ramps. It should be noted that traffic diverting to one of the other ramps during the time of control may be delayed several minutes before entering the Freeway.

FIGURE 4

Signing

In addition to the advisory signs erected at the ramps, alternate routing signs such as the one shown in Figure 5, were located at upstream entrance ramps and on the arterial streets at major intersections, and portable "stop" signs and "stop ahead" signs were placed at the ramps.

Signals

The signals at the Dumble Entrance Ramp were installed on Friday, January 22 and operated on flashing amber until the start of the control study January 26. (See Section on Signal Installation at Dumble, page 20.)

Timing Devices

The metering rates were determined on the basis of capacity-demand relationships on the freeway. Timers (Figure 6) that indicated the various metering rates to the ramp control officers were built for the study. They provided a buzz each time a vehicle on the ramp was to be released onto the freeway. The design was crude but effective. A 6 volt motor with a speed of 1rpm, mounted in a 6" x 6" x 4" box, powered a rotary switch. Pins in the lid of the box closed the circuit to a buzzer. The metering rate, represented by the number of pins, was adjusted by changing the lid.

OPERATION OF THE CONTROLS

Manual Metering

Five of the metered ramps were controlled by policemen from the City of Houston, who directed the traffic onto the freeway at specified intervals. The sixth ramp was controlled by a fixed time traffic signal for assigning the right of way to ramp traffic.

The metering stations, controlled by the city policemen, were located at the junction of the entrance ramps and the frontage road as shown in Figure 7. A "stop ahead" sign was placed 200 feet in advance of the metering station. A "stop" sign was placed at the metering station, but it was easily seen by the freeway motorists and tended to cause a "gapers' block". The "stop" signs were removed after the second day on all but one ramp.

The policemen were instructed to direct one vehicle onto the ramp each time the buzzer on the timer sounded. If the vehicles did not move directly into the freeway, but queued up at the merge point, the policemen were instructed to hold all vehicles at the metering station until only one vehicle remained on the ramp. The policemen changed from one metering rate to another at the times specified in the control plan by a simple adjustment of the timer.

SIGNS ON ALTERNATE ROUTES

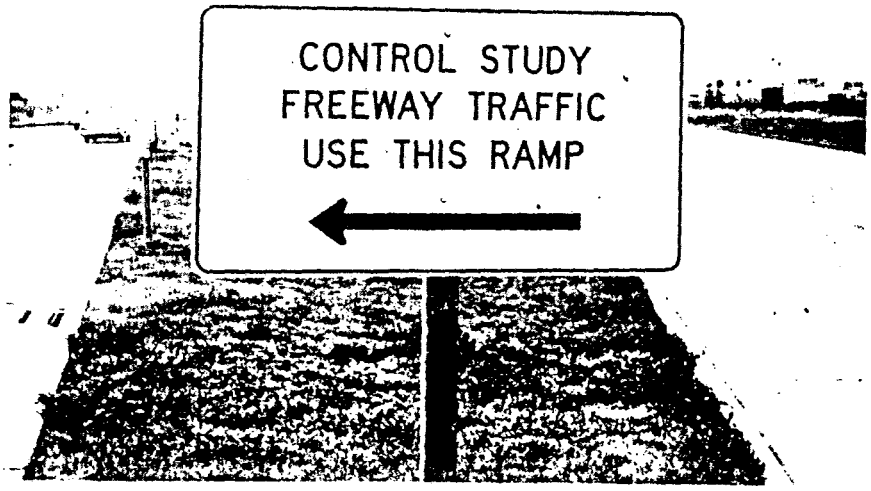
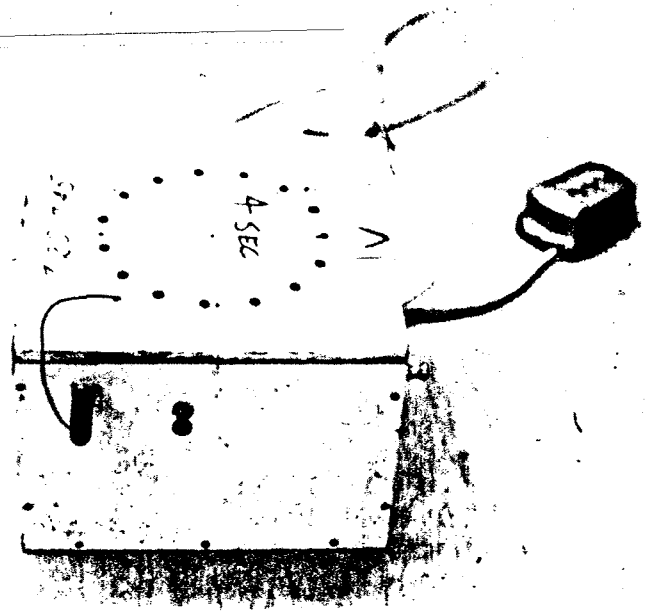


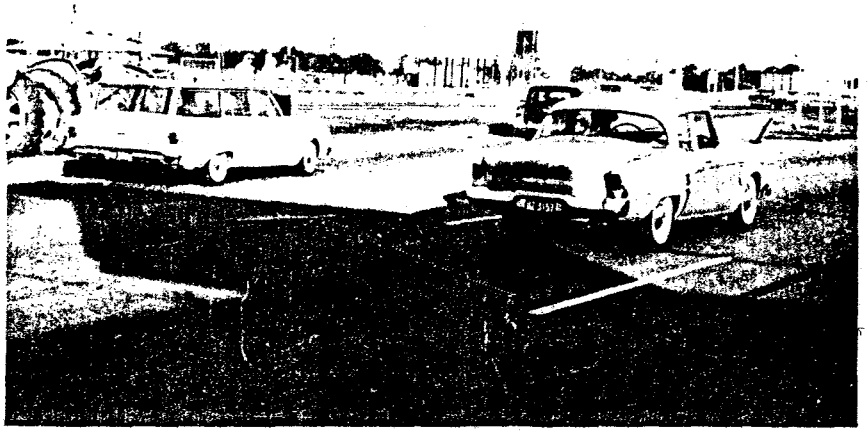
FIGURE 5



TIMER USED FOR RAMP METERING

FIGURE 6

RAMP METERING LOCATION



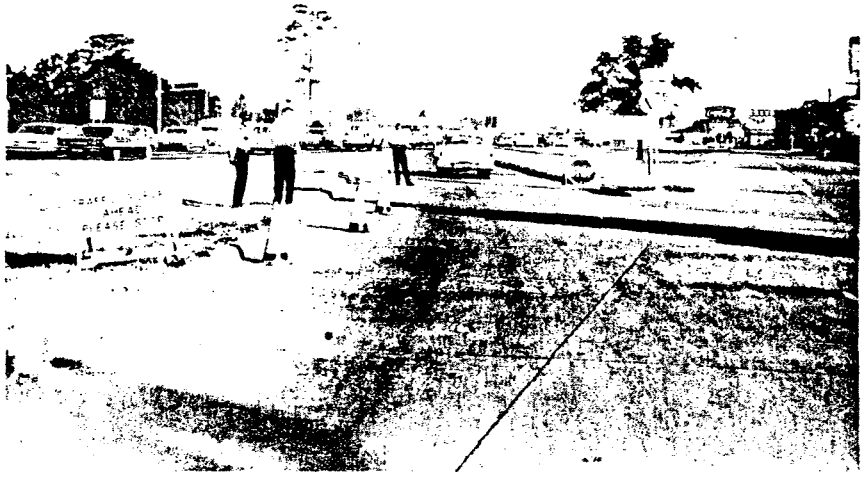


FIGURE 7

Signal Installation at Dumble

One of the most crucial components of a ramp metering system is the type of control devide selected for metering. Since freeway ramp control is an innovation to traffic control techniques commonly encountered by motorists, it is especially necessary that the basic elements of control devices be realized in the development of a ramp control system. The control devices employed must therefore compel the attention of the motorist and must present a message that is clearly understood. Proper location of the control device should allow ample time for the motorist to respond and apply appropriate actions as required by the device.

Ramp metering requires a more sophisticated type of control device than fixed-time ramp closure. It is realized that a metering device must not only be able to meter effectively, but it is envisioned that the device must also operate to completely close a ramp at certain high volume periods on the freeway.

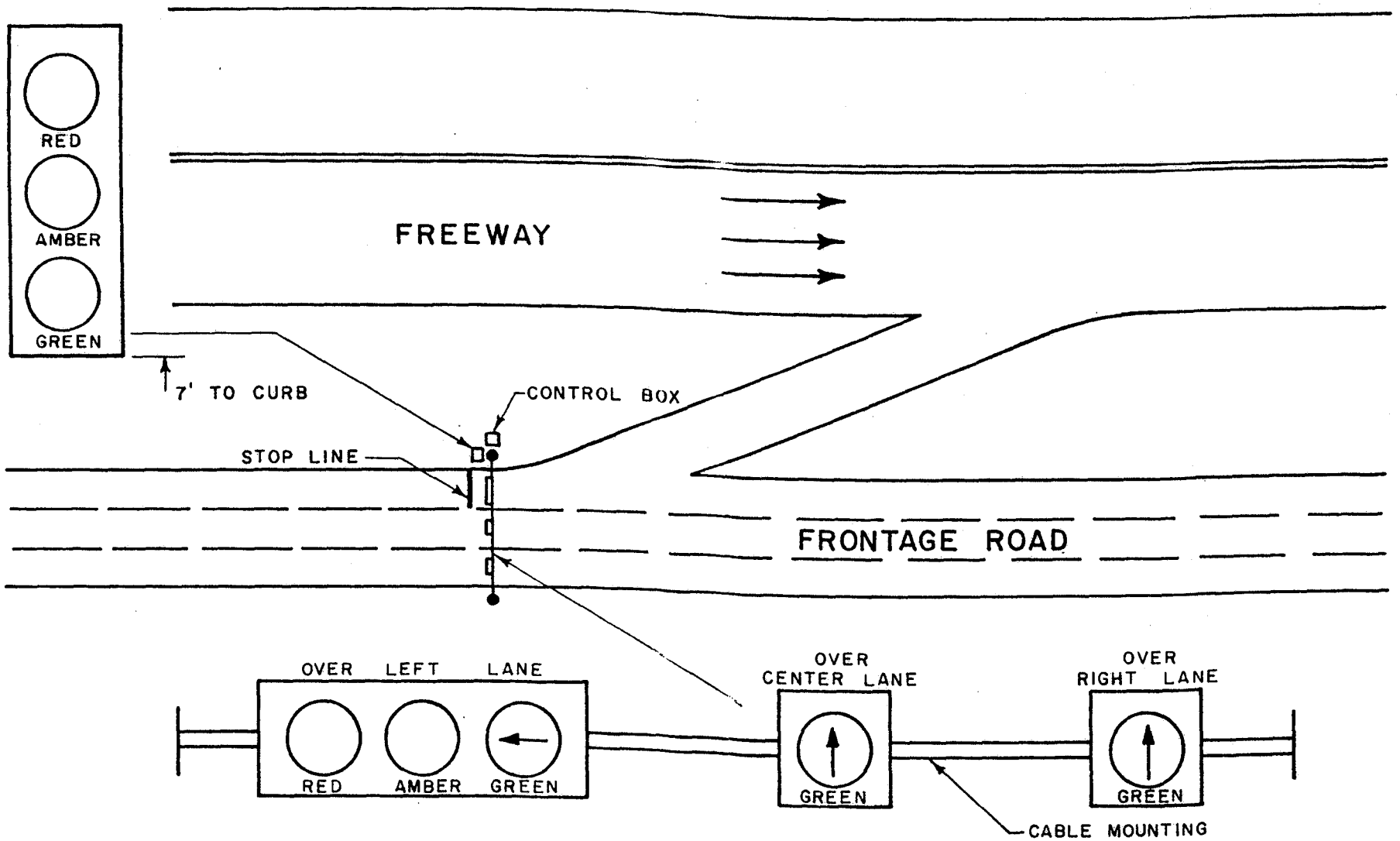
The objective of this phase of the study was to observe some of the characteristics associated with semi-automatic metering in order to determine equipment requirements for future automatic systems. Some aspects of metering considered in the design of the Dumble experiment were the location and type of control signal and the signal phasing.

The selected location of the metering control was on the frontage road as opposed to a location on the ramp. Three advantages were anticipated: (1) a ramp could be closed without trapping a driver on the ramp, (2) signalization of the frontage road-ramp would be similar to operation at a normal intersection and therefore be less of a novelty to the driver, and (3) there is less chance of a metered driver given the green to assume that he has the right of way in the merging situation with the freeway.

The initial study was directed toward determining driver requirements with respect to metering. Since driver responses to a signal using an amber phase following the green were to be evaluated, as against using just the red and green phases, a post-mounted traffic signal with red, amber and green lenses was installed adjacent to the stop line. Overhead signals mounted over each lane of the frontage road were employed to separate the two movements (ramp usage and frontage road usage). Figure 8 shows a diagram of the installation.

The phasing was designed for bulk-service metering. A three-dial pretimed controller was utilized with a constant 30 second cycle length. The three dials were set to give 10 1/2, 8 and 13 1/2 seconds of green with a constant amber of 2 1/2 seconds. Dial #1 was used from 7:05-7:10 and from 7:20-7:25; dial #2 from 7:10-7:20 and dial #3 from 7:25-7:35.

In order to evaluate the proposed metering operation, the plan was (1) to measure starting headways in order to compare actual metering rates with the theoretical rates, (2) to record the number of violations by motorists who either



SCHEMATIC OF SIGNAL INSTALLATION
AT THE DUMBLE ENTRANCE RAMP

FIGURE 8

ignored the signal or did not understand its significance and (3) to measure gap acceptance characteristics of ramp vehicles in the merging area and compare them to characteristics observed during normal operation.

Ramp Closure

Cones and barricades were placed in the outer separation at each of the three ramps that were closed. One city policeman was assigned to each ramp to effect the closure. At the time designated in the control plan, the cones were placed parallel to the frontage road across the entrances to the ramps, and the barricades were placed across the ramp roadway. The policemen were instructed to move away from the ramps and out of the line of sight of the freeway traffic.

At the end of the first two weeks of the control study, a reassignment of personnel was made to extend the study. It was decided at this time that the closure of the ramps did not require a person with police authority. The maintenance department of District 12, Texas Highway Department, which has the responsibility for closing the freeway when the roadway is made impassible by weather, accidents, or maintenance operations, assigned personnel to the project for the remainder of the study. During the final five weeks of the operation, the highway personnel encountered no difficulty in effecting the ramp closures at the specified times.

EVALUATION OF THE IMMEDIATE EFFECTS OF THE CONTROLS

The evaluation of the effects of the controls on freeway operation is divided into two time periods, the first two weeks of the study and the last five weeks, which include the entire seven weeks of the operation of the control study. The results obtained during the first two weeks are classed as immediate results while the results from the next five weeks are classed as long term results.

The evaluation of the effects of the freeway controls on arterial streets is based on studies taken over the seven weeks of operation, but the results will be included in the section on immediate effects of the controls.

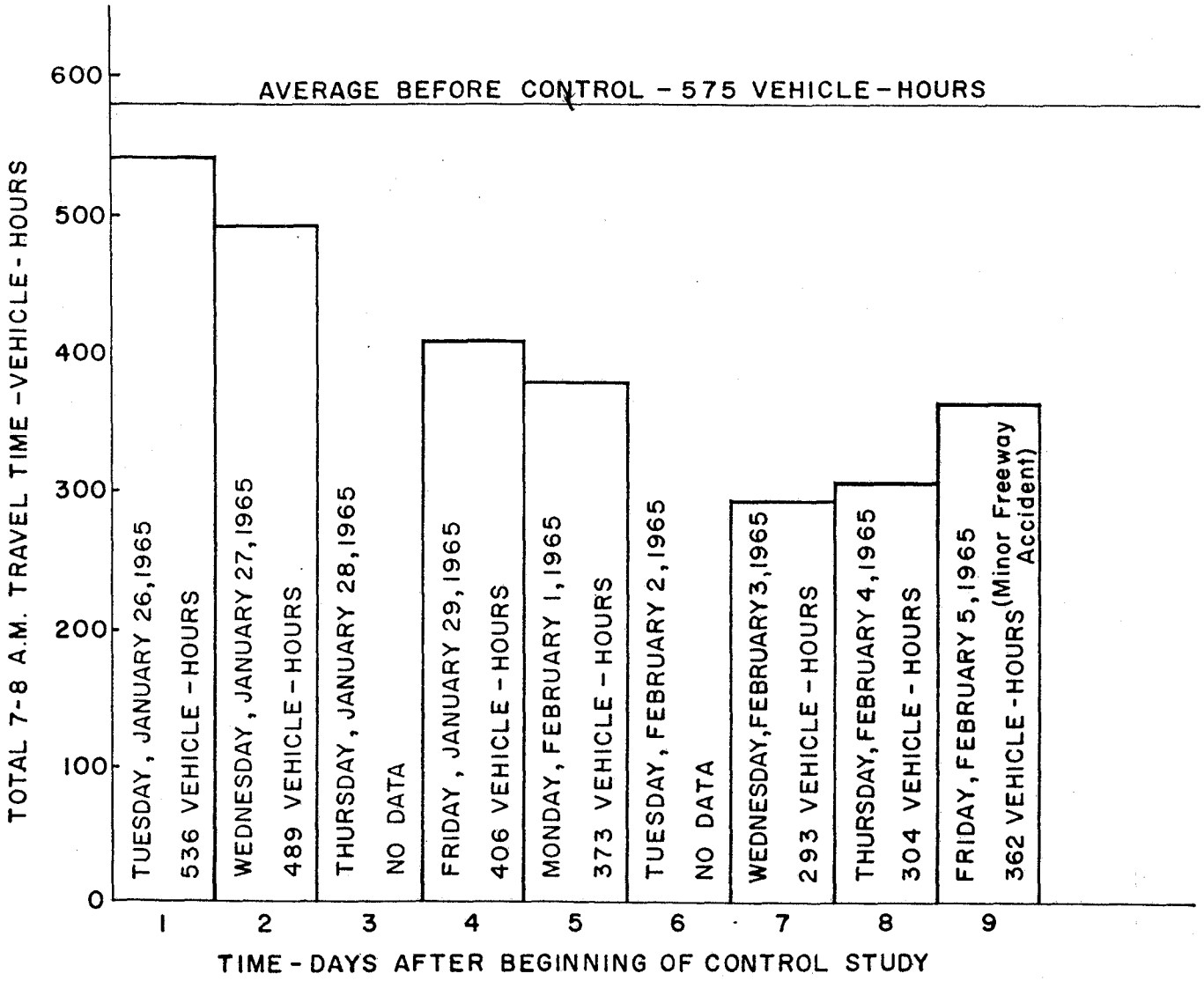
From 1500-2000 motorists were directly affected by the controls. That is, about 1500-2000 motorists normally entered the freeway at the ramps which were controlled during the time that each was controlled. It was anticipated that many motorists would search out new routes to avoid the controls or to enter the freeway at points further upstream because of improved freeway traffic operation. With such a large number of motorists suddenly having their normal travel routine changed, a period of transient system behavior was expected before a steady-state condition was achieved.

Such a transient condition was noted and is the reason for separation of the analysis of the data into two periods. During the first week of the study, the transient effect was especially evident as the freeway level of service consistently improved during successive days of the study. This can be seen in Figure 9. For this reason, only the data from the second week of the study were used in the freeway analyses of the immediate effects of the controls.

The transient effects on the arterial streets were not so noticeable. Therefore, it was decided to concentrate the studies on the freeway system to provide adequate coverage over the two time periods of control, and to continue all arterial street data obtained during control.

FREEWAY AND FRONTAGE ROADS

Three data collection techniques were used during this study - manual counts and speed recordings (most of which were part of the closed system input-output studies), aerial photography and moving vehicle travel time recordings. The aerial photography data were used exclusively in the frontage road studies and in the freeway studies from the South HB&T R.R. overpass to Dowling and were also used to supplement and to check the data from the (manual count) freeway studies. The basic analysis period is 7-8 a.m. but due to insufficient light conditions the aerial photographs did not encompass this entire period on some days. Hence, the frontage road data necessarily represent best estimates based on the photographs available. This same statement holds true for the evaluation of freeway operations from the South HB&T R.R. overpass to Dowling Street.



TRANSIENT BEHAVIOR OF TOTAL 7-8A.M. TRAVEL TIME IN BROADWAY-GRIGGS SUBSYSTEM AT THE BEGINNING OF THE CONTROL STUDY

FIGURE 9

The following table contains the schedule of data used for the "after" portion of the "before and after" studies on the effects of the controls on the freeway and frontage road operation.

TABLE 2

"AFTER" DATA USED TO DETERMINE IMMEDIATE EFFECTS OF CONTROLS

Manual Counts (Input-Output)	February 2-4, 1965
Aerial Photography	February 2,3, 1965
Moving Vehicle Travel Times	February 2-4, 1965

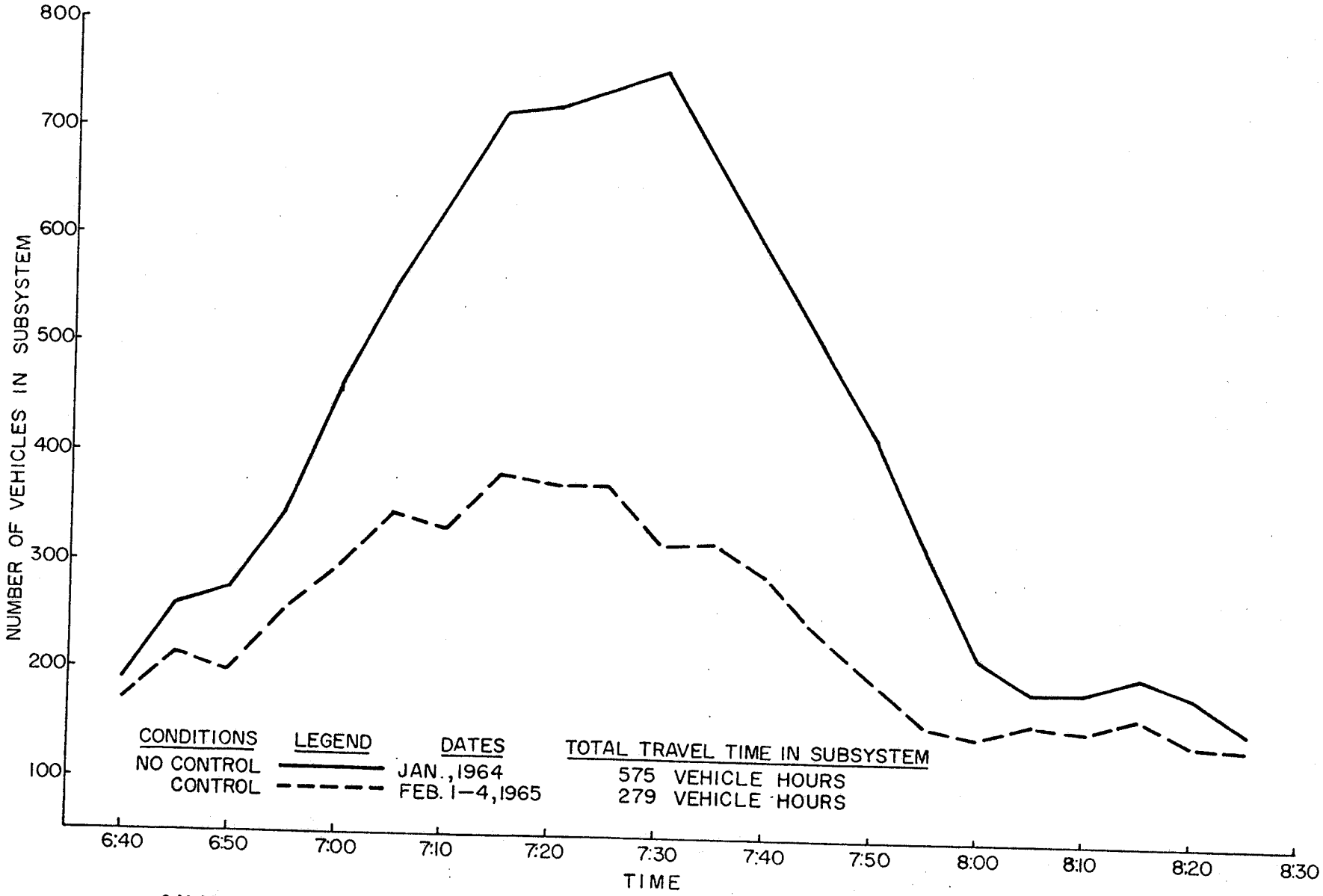
Total System Travel Time

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. The units of this travel time are vehicle-minutes or vehicle-hours. A vehicle-minute represents one vehicle in the system for one minute; a vehicle-hour represents 4 vehicles in the system for 15 minutes each, 5 vehicles in the system for 12 minutes each or some other combination totalling 60 vehicle-minutes.

If the number of vehicles in a given system is a known function of time (such as a graph) the total travel time in the system is the integral of the time function (or the area under the graph) between the times of interest (3). This analysis was made during the 7-8 a.m. peak hour for the Gulf Freeway studies. Thus, for each freeway subsystem and the inbound frontage road the total travel time was calculated for the "before and after" comparisons.

The portion of the freeway on which the greatest operational improvement was anticipated was that between Broadway and Griggs (that is, the Broadway-Griggs subsystem). An improvement in the operations in this subsystem would be reflected by fewer vehicles in the subsystem (lower density). The number of vehicles in the Broadway-Griggs subsystem before and during the controls are shown in Figure 10. The number of vehicles in this subsystem decreased significantly during the control study and the 7-8 a.m. total travel time in this subsystem decreased from 575 vehicle-hours to 297 vehicle-hours representing a 48% reduction.

Table 3 is a summary of the total travel time before and during the control study on the inbound freeway and frontage road. The total travel time on the inbound freeway was 371 vehicle-hours (30%)less than it was before the controls were put into effect. The travel time on the frontage road increased from about 190 to 201 vehicle-hours, a 6% increase. The total effect on the inbound freeway and frontage road travel time was a reduction of 360 vehicle-hours which



NUMBER OF VEHICLES ON BROADWAY-GRIGGS SUBSYSTEM

FIGURE 10

TABLE 3

IMMEDIATE EFFECTS OF CONTROLS

TOTAL SYSTEM TRAVEL TIME FROM 7-8 a.m.

System or Subsystem	Total Travel Time-Vehicle Hours		
	Before Control	During Control	Difference
Inbound Freeway			
Broadway to Griggs	575	297	-278 (-48%)
Griggs to S. HB&T R.R.	367	310	- 57 (-16%)
S. HB&T R.R. to Dowling	302	266*	- 36 (-12%)
Inbound Freeway - Total	1244	873	-371 (-30%)
Inbound Frontage Road	190*	201*	+11 (+ 6%)
Total Inbound Freeway and Frontage Road	1434	1074	-360 (-25%)

* - Based on incomplete data caused by inadequate light conditions which made aerial photography during the early parts of the 7-8 a.m. period impossible.

represents a 30% decrease.

Average 7-8 a.m. Freeway and Ramp Volumes

The initiation of the control plan naturally caused some significant changes in the 7-8 a.m. volumes on the entrances to the freeway. Table 4 contains the average volumes before and during the control study.

TABLE 4

AVERAGE 7-8 a.m. VOLUMES ON ENTRANCES TO THE FREEWAY

Entrance to Freeway System	Before Control January, 1964	During Control February 1-5, 1965	Difference
Freeway near Broadway	2831	3185	+ 354
Detroit on Ramp	218	122	- 96
S. H. 225 on Ramp	559	649	+ 90
*S. H. 35 on Ramp	818	726	- 92
*Woodridge on Ramp	426	398	- 28
*Mossrose on Ramp	643	318	- 325
**Griggs on Ramp	683	496	- 187
*Wayside on Ramp	335	332	- 3
*Telephone on Ramp	413	356	- 57
*Dumble on Ramp	345	294	- 51
**Cullen on Ramps (Combined)	574	348	- 226
Scott on Ramp	63	257	+ 194
Total	7908	7481	(-5.3%) - 427

* - Ramps which were metered
** - Ramps which were closed

As can be seen in Table 4 a large increase in volume took place on the freeway near Broadway. This is attributable to the improved level of service on the freeway and to the controls on the downstream ramps. Some vehicles undoubtedly entered the freeway at or upstream of Broadway instead of entering at their usual ramps farther downstream because (1) the freeway trip was more attractive during the control study because of the reduced freeway congestion and (2) the use of downstream entrance ramps was less attractive because of the ramp controls which produced some delay on entering. Also the overall traffic possibly increased in the year's time between the studies.

The decrease of about 100 vehicles entering at the Detroit entrance ramp does not represent a decrease in freeway traffic but rather is a direct result

of the improved freeway level of service. Normally, during the periods with no ramp control, about 100 vehicles between 7 and 8 a.m. exit at the S.H. 225 (northbound) exit and re-enter at the Detroit ramp to avoid about 1500 feet of freeway congestion. During the control study, congestion did not develop in this region so the exit-reentry maneuver would not save the motorist any time, hence the decrease in the frequency of this maneuver. The number of vehicles exiting at the S.H. 225 northbound exit ramp decreased by 112 during this same time period, further substantiating the explanation of the decrease in the Detroit Street entrance ramp volume.

The increased volume on the S.H. 225 entrance ramp is explained by the fact that it was not controlled while the nearby entrance ramps which are alternate entrances for the La Porte Freeway traffic were controlled. Thus, the 90 vehicle increase represents diversion from other entrance ramps which were controlled.

All of the entrance ramps from S.H. 35 to Cullen had decreases in 7-8 a.m. volume. All of these ramps were controlled and the volume decreases were caused by the expected delays at the metered ramps or by the closure in the cases of the Griggs and Cullen ramps. At some ramps, such as Dumble, the decrease in volume was greater than the expected delay would seem to warrant, indicating a reluctance on the part of some motorists to undergo control. This could be caused either by rebellion or by reluctance to try something which is unknown, but also undoubtedly means that some good alternate routes on arterial streets were available. Otherwise, the rebellion or reluctance would have given way to the desire to reduce travel time.

The increase in volume at the Scott entrance ramp can be entirely attributed to the closure of the Cullen entrance ramps just upstream. Many of the vehicles which normally enter at Cullen during the closure period proceeded down the frontage road and entered at the Scott ramp.

The total decrease in the volume entering the inbound freeway was 427 vehicles (not correcting for the decrease in the frequency of the exit-reentry maneuver at the S.H. 225 exit and Detroit entrance ramps) which represents a 5.3% decrease in traffic entering the freeway. From Broadway to Griggs (after correcting for the decrease in the frequency of the exit-reentry maneuver) the total entering traffic was virtually identical before and during the controls.

Vehicle-Miles of Travel and Average Speed Between Broadway and Griggs

Just as the number of vehicle-hours in a system in a given time period represents the total amount of travel time spent by all vehicles in the system during the time period, the number of vehicle-miles accumulated in the same system in the same time period is the total amount of travel which took place. One vehicle mile is accumulated by one vehicle travelling one mile in the system in the time period of interest. The average speed of all vehicles in the system

during the time period is the total number of vehicle miles of travel divided by the total number of vehicle-hours (the units are miles per hour)

Since changes in the volumes of most of the freeway entrance and exit ramps volumes occurred during the control study, a change in the total amount of travel (vehicle-miles) might have been expected. Also a change in the total travel time was found. Thus, the average speed probably also changed. Table 5 contains a summary of these statistics for the Broadway Griggs subsystem before and during the control study.

TABLE 5

VEHICLE-MILES, VEHICLE-HOURS AND AVERAGE SPEED
OF BROADWAY-GRIGGS SUBSYSTEM FROM 7-8 a.m.

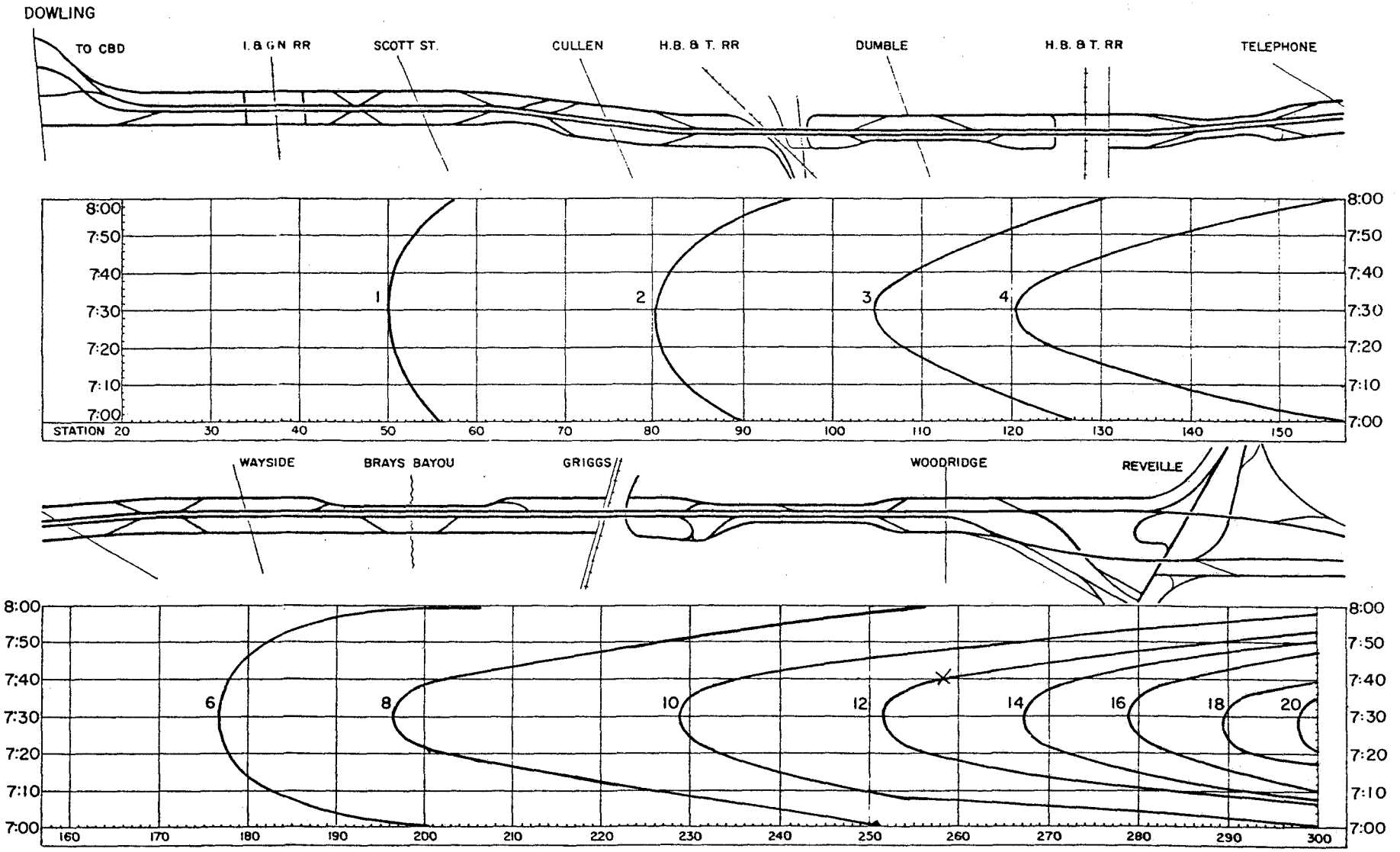
	Before Control January, 1964	During Control February, 1965	Difference
Total Travel - Vehicle-Miles	7990	8865	+ 875 (+11%)
Total Travel Time - Vehicle-Hours	575	297	- 278 (-48%)
Average Speed - Miles/Hour	14	30	+ 16 (+114%)

From this table it can be seen that the total amount of travel between Broadway and Griggs from 7 to 8 a.m. increased 11% from 7990 to 8865 vehicle-miles. This at least partly reflects a more efficient use of the system of streets and freeway caused by clearing the congestion of the freeway, thereby encouraging greater use of the greeway. Meanwhile, the total travel time decreased by 48% from 575 to 297 vehicle-hours. These changes caused the average speed between Broadway and Griggs to increase from 14 to 30 mph between 7 and 8 a.m.

Individual Vehicle Travel Time

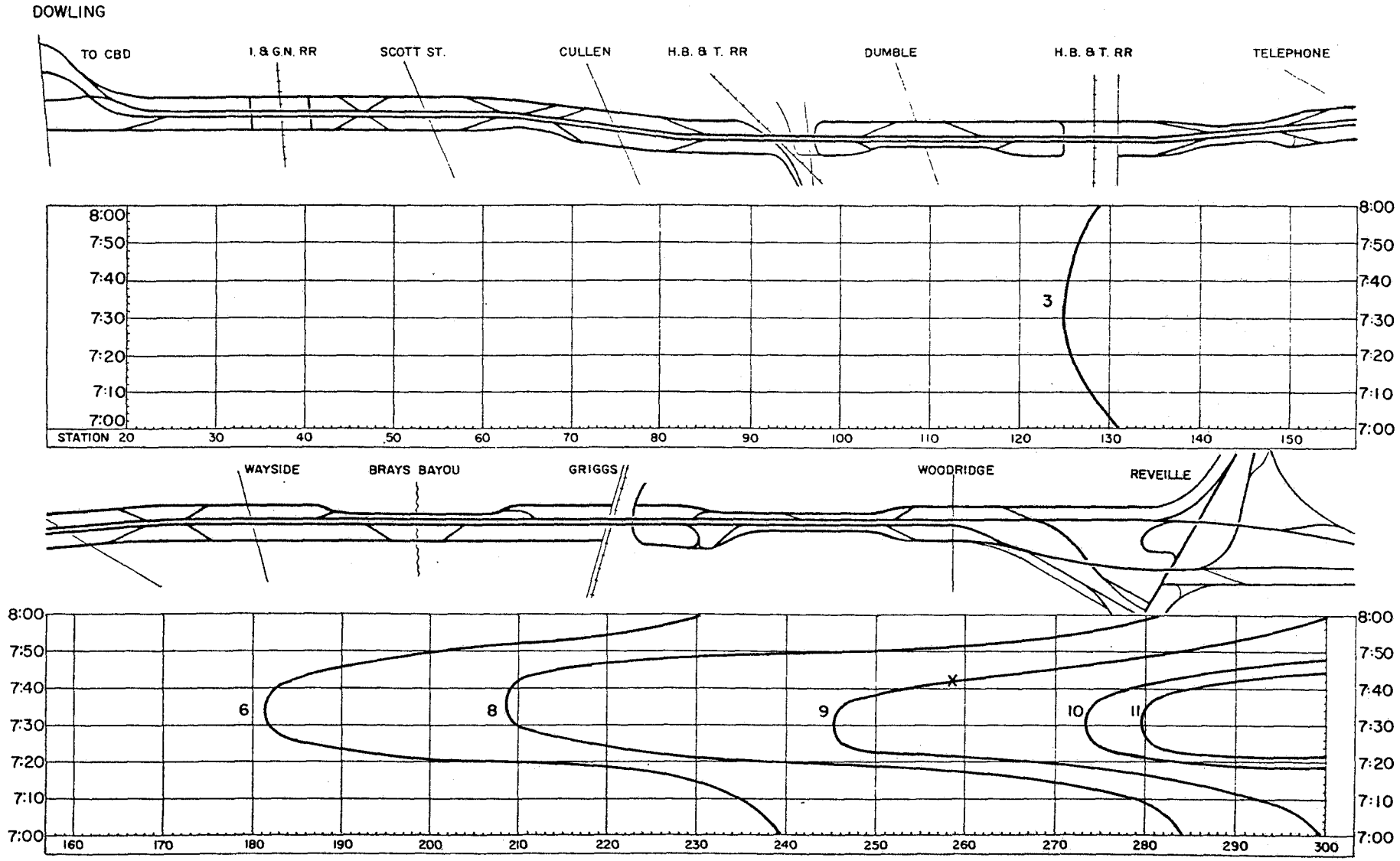
Data on the travel time required for an individual vehicle to travel from various points on the freeway to the end of the freeway near Dowling Street were obtained in January, 1964, before the controls and again from February 1-5, 1965, during the control study. These data are presented in the form of average travel time contours, shown in Figures 11 and 12.

Figure 11 is the average travel time contour map for January, 1964, and Figure 12 is representative of conditions in February, 1965, during the control study. Figure 13 is a contour map of the average savings in travel time for a vehicle travelling from a certain point on the freeway at a certain time to the end of the freeway. A maximum of about 8 minutes was saved on the average by vehicles travelling from the Reveille Interchange area to the end of the freeway at about 7:30 a.m.



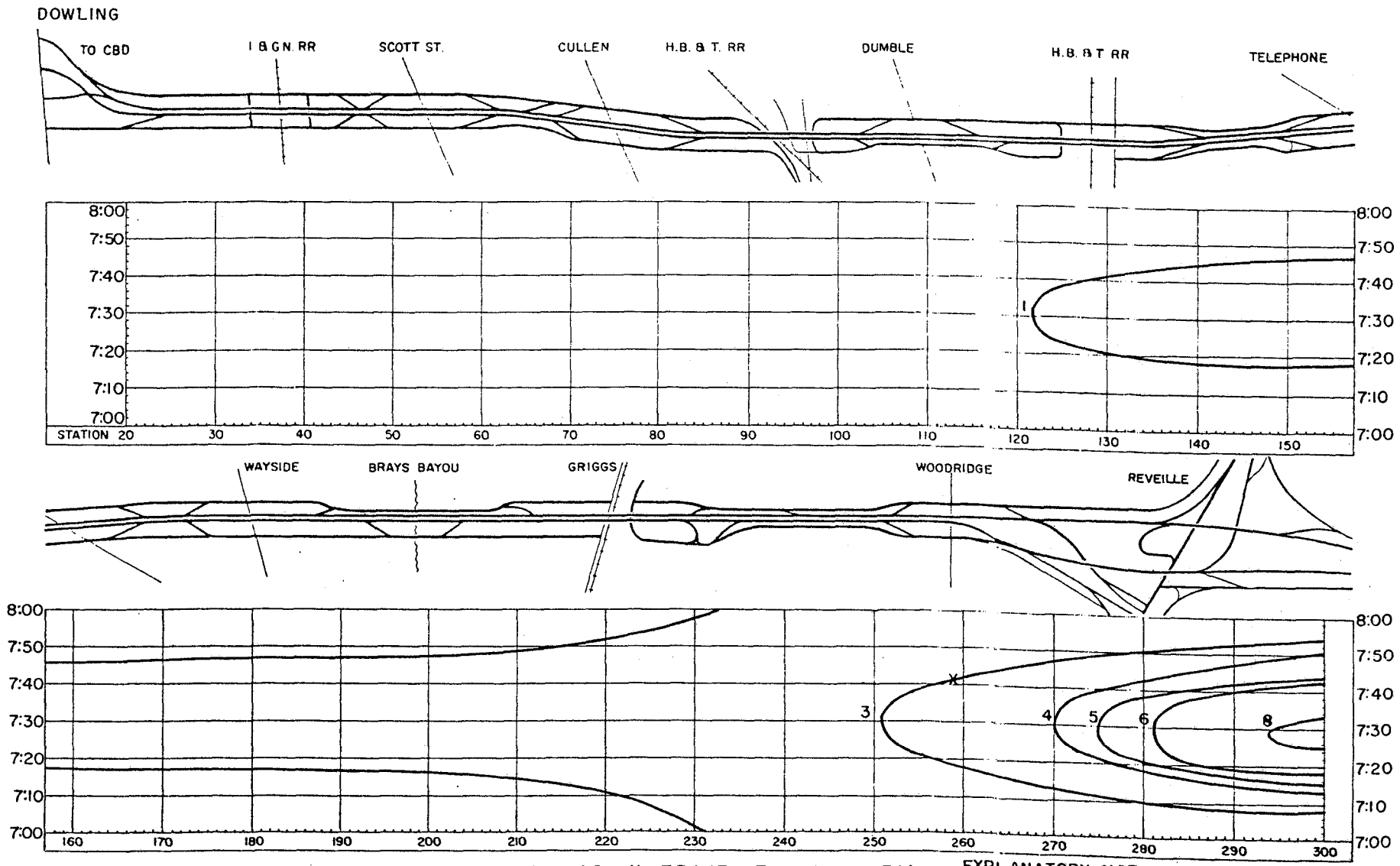
AVERAGE TRAVEL TIME (MINUTES) TO END OF FREEWAY
CONTOUR MAP
BEFORE CONTROL – JANUARY 28-30, 1964
FIGURE 11

EXPLANATORY NOTE: POINT X INDICATES THAT A VEHICLE TRAVELLING ON THE INBOUND GULF FREEWAY AT WOODRIDGE AT 7:42 A.M. WOULD SPEND AN AVERAGE OF 12 MINUTES ON A TRIP TO DOWLING STREET



AVERAGE TRAVEL TIME (MINUTES) TO END OF FREEWAY
CONTOUR MAP
DURING CONTROL—FEBRUARY 2,3,4, 1965
FIGURE 12

EXPLANATORY NOTE: POINT X INDICATES THAT A VEHICLE TRAVELLING ON THE INBOUND GULF FREEWAY AT WOODRIDGE AT 7:42 A.M. WOULD SPEND AN AVERAGE OF 9 MINUTES ON A TRIP TO DOWLING STREET.



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

FIGURE 13

EXPLANATORY NOTE: POINT X INDICATES THAT A VEHICLE TRAVELLING ON THE INBOUND GULF FREEWAY AT WOODRIDGE AT 7:42 A.M. SAVED AN AVERAGE OF 3 MINUTES DURING THE CONTROL STUDY ON A TRIP TO DOWLING STREET

Although not plotted, it was found that the maximum travel time between Broadway and Dowling was decreased from about 23 to 13 minutes during the control study.

Five-Minute Volumes on the Freeway at Griggs Road

Early freeway studies[3], showed that before any controls were initiated the flow rates on the freeway at Griggs Road decreased as the peak period progressed. This decreased in flow was caused largely by the congestion from downstream backing over the Griggs Road overpass and was no doubt caused partly by the congestion forming upstream of this overpass. One objective of the controls which were initiated early in 1965 was to increase the flow rates over the Griggs Road overpass by (1) reducing downstream congestion by ramp controls at the Griggs, Wayside and Telephone entrance ramps and (2) reducing the congestion immediately upstream of the Griggs overpass primarily by strict control at the Mossrose entrance ramp.

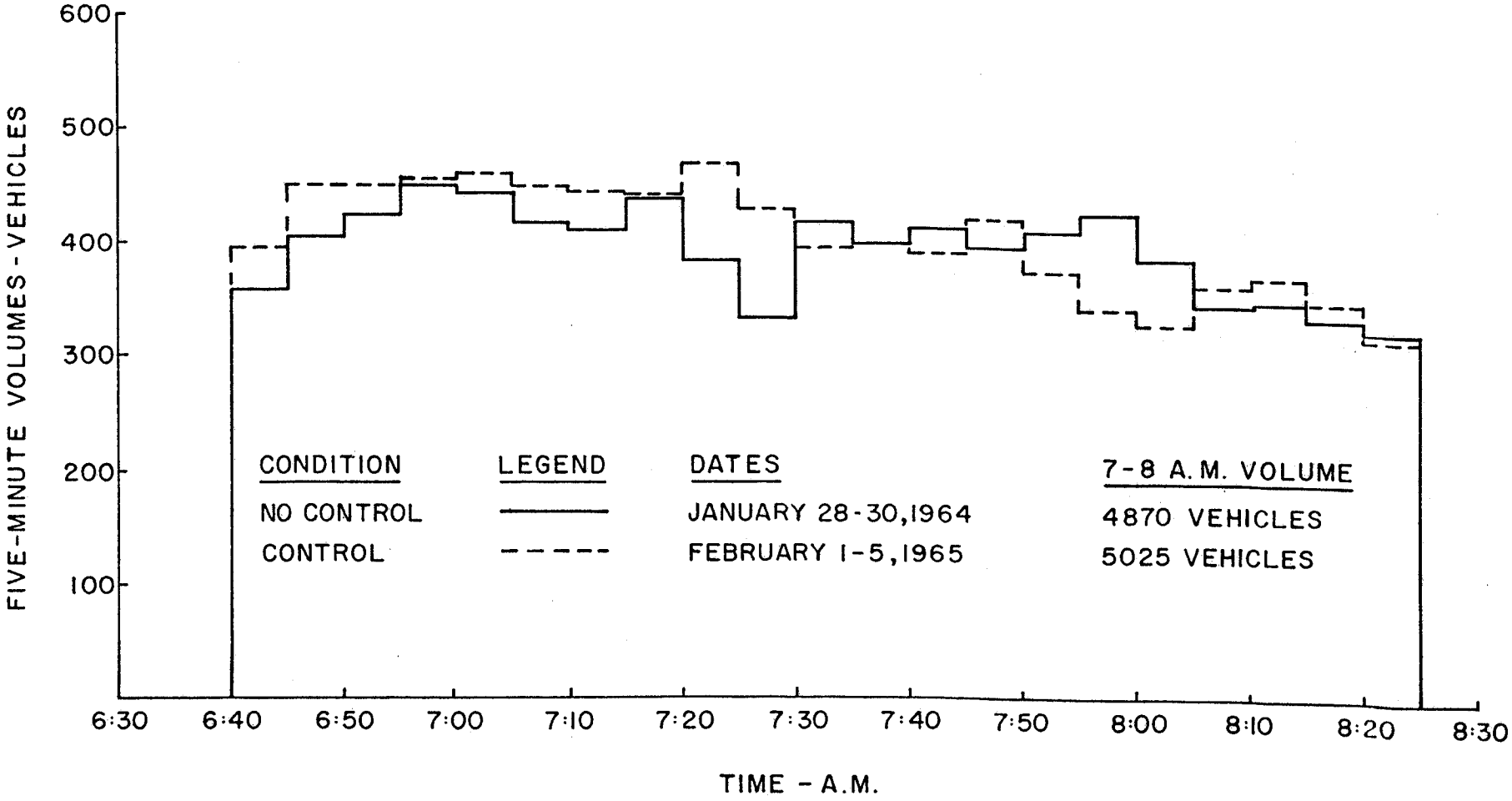
Figure 14 shows the results of these attempts. The average flow rate over the Griggs Road overpass during the control study remained close to 450 vehicles per 5 minutes until about 7:25-7:30 a.m. The Griggs Road entrance ramp (downstream) was reopened at 7:20 a.m. and caused a large part of the volume decrease after this time during the control study. Before the controls the five-minute volumes dropped much sooner and to much lower values than they did during the control study. Thus, the controls did succeed in increasing the flow rate over the Griggs overpass. This was accomplished, not by raising the maximum flow rate (capacity), but by sustaining the maximum flow rate for a longer period of time, i.e., by preventing the large decrease in flow due to downstream congestion. The total inbound freeway volume at the Griggs overpass from 7:00-7:30 a.m. was increased from 2419 to 2699 vehicles during the control study, while the 7:30-8:00 a.m. volume decreased from 2451 to 2326. The total volume from 7-8 a.m. was increased by 155 vehicles.

ARTERIAL STREETS

The street system covered during the control study is shown in Figure 15. This section was selected for study because the traffic diversion expected from the Reveille area and the Griggs Road entrance ramp would have to move through the critical intersections identified on the maps. Traffic diversion from other ramp locations would be accommodated on the frontage roads. Also indicated on the map is the approach volumes for the Griggs Road ramp which was closed for a 15-minute period.

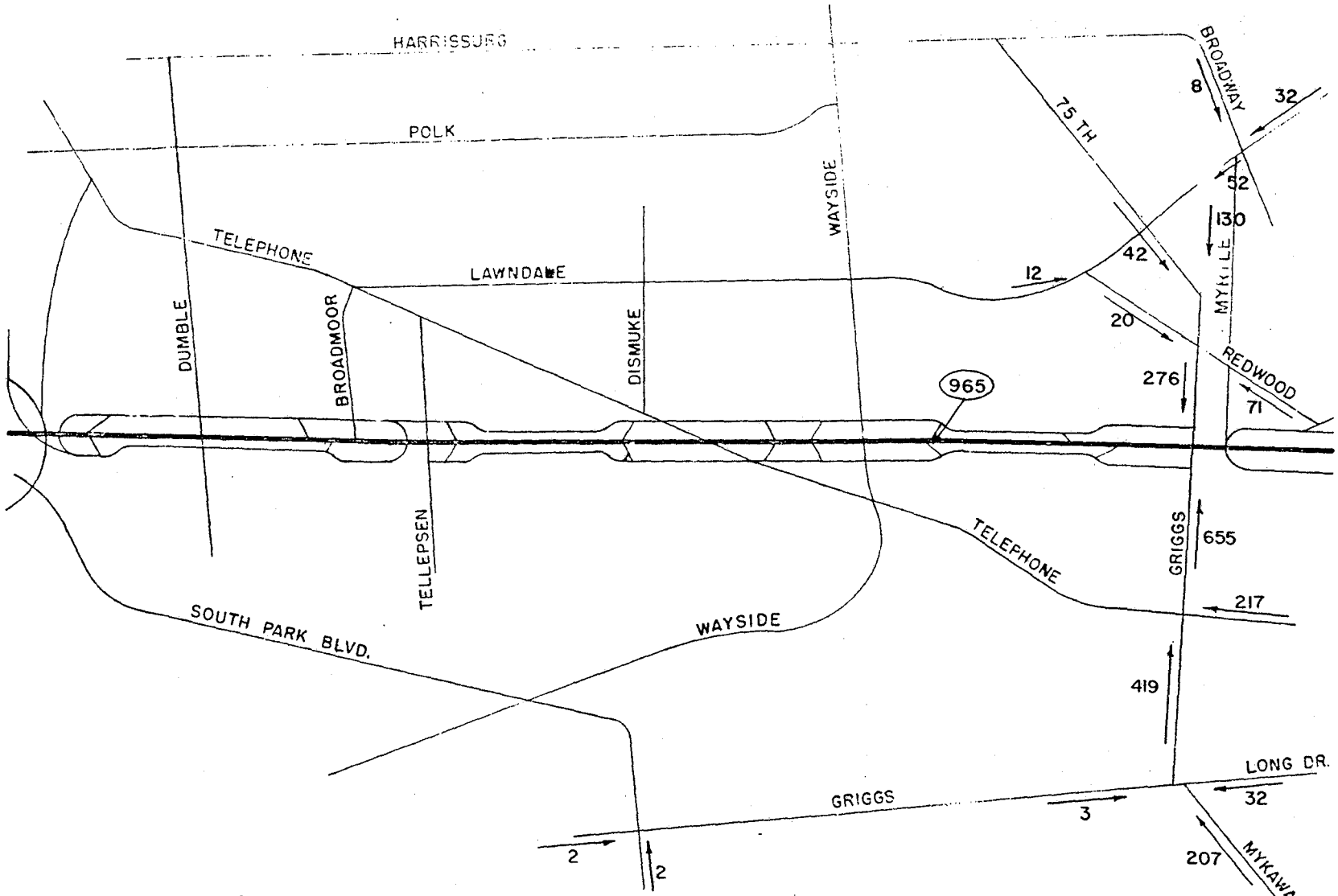
Travel Time Runs

Travel time runs were taken on these alternate routes before, during and after the control study to determine if the shift of traffic from the freeway created any problems on the street system. Only three or four runs were made



FIVE - MINUTE VOLUMES ON GULF FREEWAY AT GRIGGS ROAD

FIGURE 14



ASSIGNMENT OF INTERCHANGE TRAFFIC ENTERING THE GULF FREEWAY AT GRIGGS ENTRANCE RAMP

FIGURE 15

during each time period for each alternate route. The average of these runs which are summarized in Table 6 show no significant difference in travel times, except in the times recorded on Mykawa-Griggs alternate route. The decrease in travel times are due to the small sample and the traffic signals that are not interconnected, and not to the effect of ramp controls. No large increases in travel times were recorded at any time during the study period on the city streets, indicating that the increased travel did not affect traffic operations.

Changes in Volume

The shifting volume pattern on the street system is illustrated in Figure 16. There was a substantial shift in traffic the first week of the study, January 26-29, after which the volumes in most cases dropped back to the normal pattern. At the high volume intersection, the increase in volume came during the time of 7:00-7:30 a.m. when the normal demand on the intersection is low. This accounts for the low travel time runs even though the volumes at the intersection increased.

TABLE 6

SUMMARY OF TRAVEL TIME RUNS ON ARTERIAL STREETS

1. Holmes Road to Gulf Freeway - Via Telephone Road

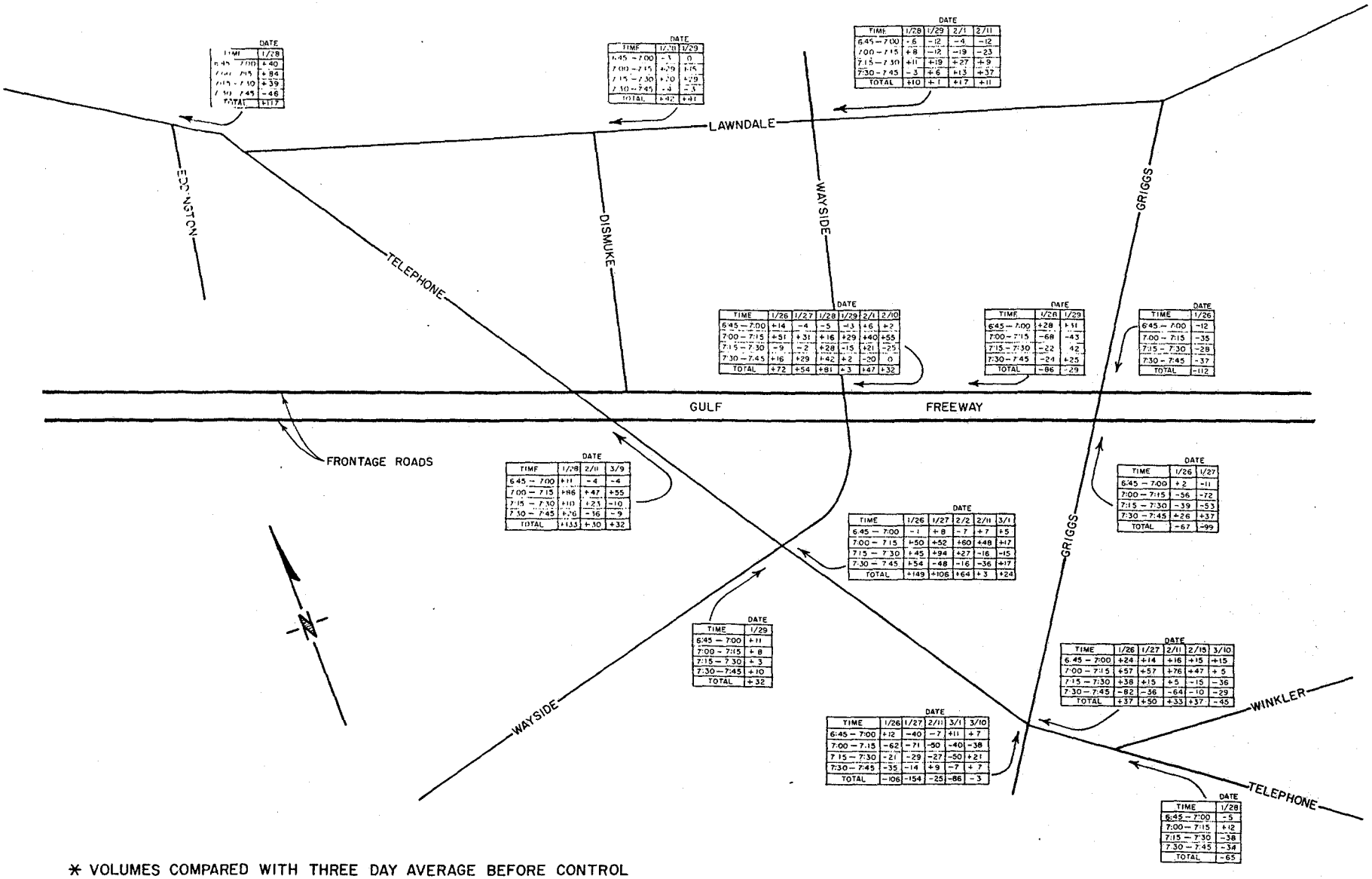
	7:00 - 7:10	7:10 - 7:20	7:20 - 7:30
Before	7 min 0 sec	8 min 0 sec	9 min 0 sec
During	6 min 30 sec	9 min 15 sec	11 min 0 sec
After	6 min 30 sec	7 min 0 sec	9 min 0 sec

2. Mykawa-Griggs to Cullen Blvd. - Via South Park

	6:45 - 7:00	7:00 - 7:15	7:15 - 7:30
Before	7 min 15 sec	11 min 0 sec	15 min 0 sec
During	7 min 0 sec	8 min 0 sec	11 min 0 sec
After	6 min 0 sec	6 min 30 sec	10 min 0 sec

3. Griggs Road to Broadmore - Via Lawndale

	6:45 - 7:00	7:00 - 7:15	7:15 - 7:30
Before	5 min 30 sec	6 min 0 sec	6 min 0 sec
During	5 min 45 sec	6 min 0 sec	7 min 0 sec
After	6 min 0 sec	6 min 15 sec	6 min 15 sec



* VOLUMES COMPARED WITH THREE DAY AVERAGE BEFORE CONTROL

CHANGE IN TRAFFIC VOLUMES DURING FREEWAY CONTROL

FIGURE 16

Traffic Delay

Five major intersections on the alternate routes that operate at or near capacity were studied. The effect of diverting traffic through the intersections was noted by the time congestion began, the length of time the intersection was congested (see Figure 1) and the total travel time for the traffic passing through the intersection. The results in Table 7 indicate congestion started earlier, but lasted about the same length of time as without control. The travel time was slightly increased, but this was primarily due to the increase in volume, rather than an increase in delay.

TABLE 7

EFFECTS OF CONTROL ON MAJOR INTERSECTION APPROACHES

	Start of Congestion	Length of Congestion (Min.)	Total Travel Time (Veh-Min)
South Telephone Approach to Griggs:			
Before Control	7:12 a.m.	50	2123
During Control	7:09 a.m.	47	2265
South Telephone Approach to Wayside:			
Before Control	7:23 a.m.	37	1800
During Control	7:11 a.m.	47	2805
South Telephone Approach to Gulf:			
Before Control	7:18 a.m.	46	1030
During Control	7:10 a.m.	45	1627
West Griggs Approach to Telephone:			
Before Control	7:18 a.m.	25	380
During Control	7:24 a.m.	17	262
East Lawndale Approach to Wayside:			
Before Control	7:17 a.m.	48	1668
During Control	7:14 a.m.	49	1409

EVALUATION OF THE LONG-TERM EFFECTS OF THE CONTROLS

The control study was originally scheduled for a two-week period but was later extended for an additional five-week period. For the original two weeks a field crew of up to twenty men was available for the closed-system, input-output studies and for other counts on the freeway and arterial streets. The field crew consisted of hourly workers who are students from Texas A&M University and the University of Houston and some supervisory personnel from Texas A&M. After the initial two-week period the size of the field crew was reduced to eight because of costs and scheduling difficulties.

After February 5, the field crew was used for freeway and arterial street counts. The aerial photographs were used to obtain the total travel time on the inbound freeway and frontage roads. Moving vehicle studies were conducted to obtain trip time for individual vehicles.

FREEWAY AND FRONTAGE ROADS

Total System Travel Time - 7-8 a.m.

During the remainder of the control study (February 8 - March 12, 1965) aerial photographic data were obtained for the purpose of determining the total 7-8 a.m. travel time in the freeway and frontage road system. However, bad weather forced the cancellation of flights on several days and on each of the days in which aerial photographs were taken the data proved unusable because of freeway accidents or similar traffic disturbance. Since a field crew of sufficient size for the closed system input-output counts was not available, these studies were not made. Hence, no data for total freeway system travel time are available for presentation.

Freeway and Ramp Volumes - 7-8 a.m.

The average 7-8 a.m. volumes on the freeway entrance ramps and the inbound freeway at Broadway during three time periods are shown in Table 8. The average freeway volume during the February 8 to March 12 control period increased by about 90 vehicles over the February 1-5 control period. This probably reflects more motorists finding that the freeway operation had been improved and thereby being attracted to enter the freeway at a point farther upstream than normal.

An increase in volume of about 70 vehicles was observed at the S.H. 225 entrance ramp, again reflecting the improved freeway operation. A 35 vehicle decrease in the volume at Woodridge was found. These vehicles probably normally bypassed the S.H. 225 entrance ramp to enter at Woodridge to reduce the amount of congested freeway driving. However, when the effects of the controls became well known, some of these vehicles probably began entering at S.H. 225 since the freeway congestion was greatly reduced.

TABLE 8

AVERAGE 7-8 a.m. VOLUMES ON ENTRANCES TO THE FREEWAY

Entrance to Freeway System	Before Control January, 1964	During Control Feb. 1-5, 1965	During Control Feb. 8 - Mar 12, 1965
Freeway near Broadway	2831	3185	3274
Detroit on Ramp	218	122	no data
S.H. 225 on Ramp	559	649	707
*S.H. 35 on Ramp	818	726	750
*Woodridge on Ramp	426	398	361
*Mossrose on Ramp	643	318	412
**Griggs on Ramp	683	496	493
*Wayside on Ramp	335	332	315
*Telephone on Ramp	413	356	341
*Dumble on Ramp	345	294	318
**Cullen on Ramps (2)	574	348	296
Scott on Ramp	63	257	no data
Total	7908	7481	7656***

* - Ramps which were metered
** - Ramps which were closed
*** - Assumes Detroit entrance ramp volume = 122 and Scott entrance ramp volume = 257.

The volume at the Mossrose entrance ramp increased by about 100 vehicles in the latter control period. At least two factors may have contributed to this. The first is that the initial diversion from this ramp may have been greater than the delay would have warranted. The notices distributed before the start of the control study warned of very large delays at this ramp. During the first two weeks of the study, some vehicles did find large delays at this ramp but during some portions of the control period there was little or no delay at the ramp. Hence, during the latter control period some vehicles probably tried this ramp and found the delay tolerable. The second factor contributing to the increased ramp volume is the increase in the metering rate by the policeman in charge of metering this ramp. Instead of adhering to the predetermined metering rates, the officer used his judgment as to the proper rates. This usually resulted in an increase in the metering rate and reduced delay, resulting in the higher ramp volume. However, an adverse effect on the freeway operation resulted from this change in metering rates.

A slight increase in volume was observed at the S.H. 35 entrance ramp. The volume at the Griggs ramp was virtually unchanged from the first control period to the second.

Small decreases in volume were observed at the Wayside and Telephone ramps and a slight increase was found at the Dumble ramp indicating a slight change in the travel patterns in this area. At the Cullen ramps a decrease of about 50 in the 7 - 8 a.m. volume was found. One possible explanation is that some drivers found that use of the frontage road instead of the freeway between Cullen and Dowling Streets results in little increase in travel time.

No data were collected at the Detroit and Scott entrance ramps since anticipat volume changes at these ramps were slight.

Individual Vehicle Travel Time

A contour map of travel time on the freeway to Dowling Street is shown in Figure 17. The contours can be seen to be quite similar to those obtained during the February 1-5, 1965 control period. Thus, the data obtained during the February 1-5 period probably represented steady-state or equilibrium conditions.

Five Minute Volumes on the Freeway at Griggs Road

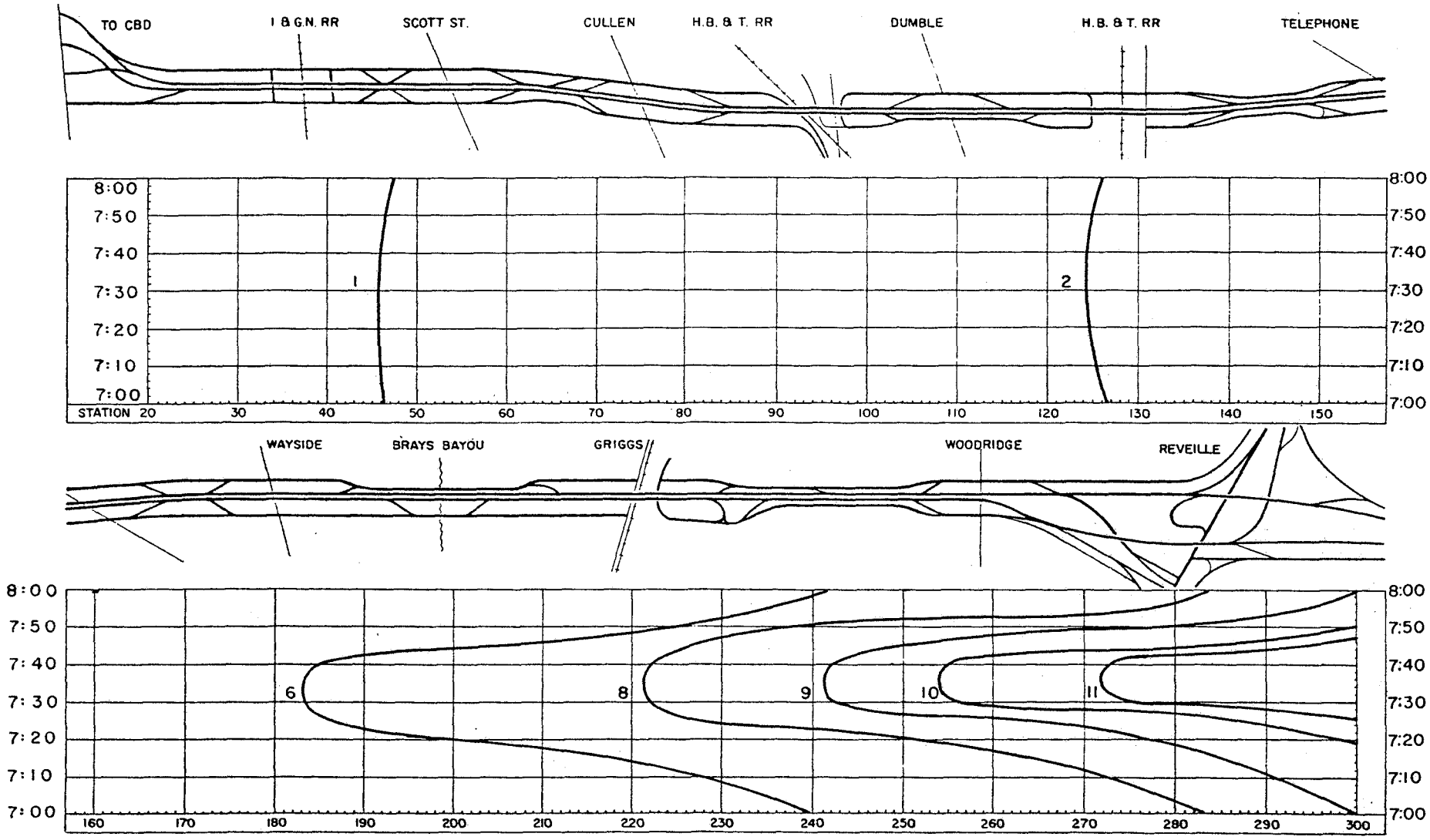
Figure 18 shows the five-minute volumes on the freeway at the Griggs Road overpass. The solid graph represents the data from January, 1964, and the dashed line represents the data obtained during the last five weeks of the control study.

It can be seen that the five-minute volumes during the control study are consistently higher than the corresponding volumes obtained in the "before" study up to about 7:30 a.m. and are approximately the same after 7:30 a.m. This means that during the control study more vehicles were able to get out of the congested Broadway-Griggs subsystem during the early period, leaving less storage to be cleared in the latter period.

The average 7:00-7:30 a.m. volume was 2703 vehicles during this period compared to 2414 vehicles before the control study. This represents a 12% increase in volume during this time period.

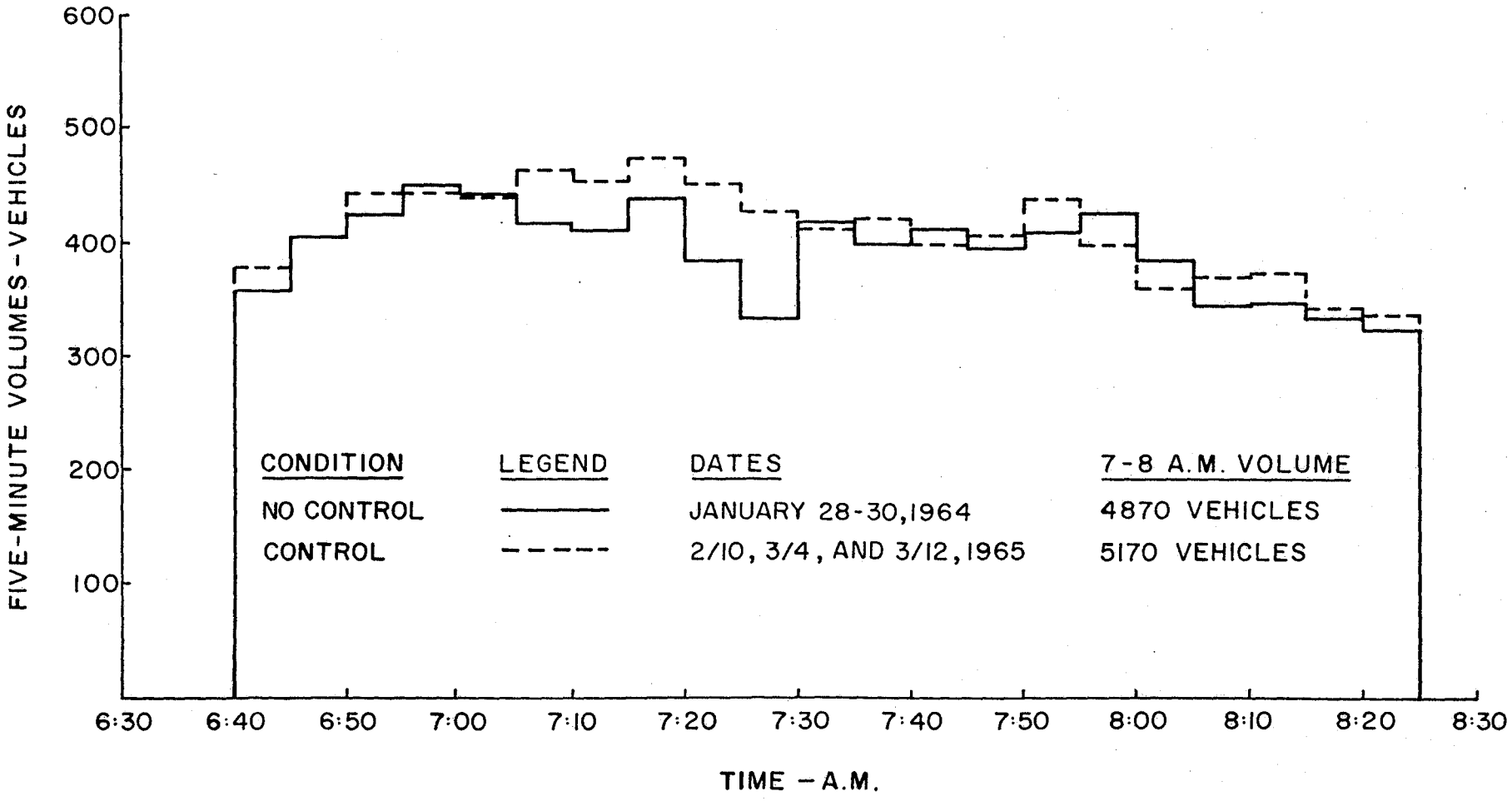
ARTERIAL STREETS

The results of the freeway controls on arterial streets were not divided into 'immediate' and 'long term' effects. However, the shift in traffic volume during the control period can be seen in Figure 16. After the first two days of control, the traffic pattern on the arterial streets did not appear to differ significantly from the conditions that prevailed before the controls were initiated.



AVERAGE TRAVEL TIME (MINUTES) TO END OF FREEWAY
CONTOUR MAP
DURING CONTROL—FEBRUARY 8—MARCH 12, 1965

FIGURE 17



FIVE - MINUTE VOLUMES ON GULF FREEWAY AT GRIGGS ROAD

FIGURE 18

OPERATION AFTER THE TERMINATION OF THE CONTROLS

The last day that the controls were in effect was March 12, 1965. Hence on Monday, March 15 the freeway returned to an uncontrolled state. This section contains the results of studies during the period of time from March 15 to April 30, 1965.

Total System Travel Time - 7-8 a.m.

Several attempts were made to take aerial photographs for the purpose of determing the total system travel time from 7-8 a.m. after the controls had been removed. Adverse weather or unusual traffic conditions (due to accidents or other reduced-capacity situations) reduced the number of good days of data to one - April 28, 1965. This was approximately a month and a half after termination of the control study.

Table 9 shows the total 7-8 a.m. travel time on the inbound freeway and frontage roads on April 28, 1965 as well as comparable figure before the control study and during the second week of the control study. The data in this table indicate that, as far as the total travel time is concerned, the freeway conditions after the termination of the controls returned approximately to the conditions which existed before the beginning of the control study. However, it should be borne in mind that only one day of data was used in "the after" analysis.

TABLE 9

TOTAL SYSTEM TRAVEL TIME FROM 7-8 a.m.
BEFORE, DURING AND AFTER THE CONTROL STUDY

System or Subsystem	Total System Travel Time - Vehicle Hours		
	Before Control	During Control	After Control
Inbound Freeway			
Broadway to Griggs	575	297	578
Griggs to S. HB&T R.R.	367	310	386
S. HB&T R.R. to Dowling	302	266*	260
Inbound Freeway - Total	1244	873	1224
Inbound Frontage Road	190*	201*	214
Total Inbound Freeway and Frontage Road	1434	1074	1438

* - Based on incomplete data caused by inadequate light conditions which made aerial photography during the early part of the 7-8 a.m. period impossible.

Freeway and Ramp Volumes - 7-8 a.m.

Several counts were made at entrance to the freeway during the period March 15 - April 30, 1965, after the termination of the controls. Table 10 contains the average 7-8 a.m. volumes at the entrances to the freeway before, during and after the control study.

It would seem that the traffic pattern would return to that which prevailed before the controls were initiated. Indeed, the total volume entering the freeway returned almost to the level of January, 1964. Also the S.H. 225, Telephone and Scott on ramp volumes returned to the volumes obtained before the control study. However, the volumes at other location did not return to the volume level of January, 1964.

The 7-8 a.m. volume on the freeway at Broadway remained about 475 vehicles greater than the volumes obtained before the controls. There was a decrease in volume on each of the S.H. 35, Woodridge and Mossrose entrance ramps with a total decrease of about 200 vehicles after the controls relative to the volumes in January of 1964. Thus, a net increase in volume of about 275 vehicles was found between Broadway and Griggs Road.

The volume on the Griggs, Wayside, Dumble and Cullen ramps were also considerably lower (a total of about 215 vehicles) after the controls terminated than they had been before the start of controls. The volume on the Dumble entrance ramp remained virtually unchanged from the last 5 weeks of the control study after the termination of the controls. This seems to suggest that many motorists who normally used the Dumble entrance ramps and who diverted during the control study found alternate routes which they liked as well as their old freeway routes.

Individual Vehicle Travel Time

The contour map of average travel time to the end of the freeway after the termination of the controls is shown in Figure 19. It can be seen that these conditions were somewhere between those before the controls and those found during the control study. In other words conditions were better after the termination of the controls than they were before the control study but worse than they were during the control study. Figure 20, which is a plot of the average travel time from the S.H. 225 entrance ramp to Dowling Street before, during and after the controls clearly shows this. The line of average travel time from the S.H. 225 entrance ramp versus time after the controls falls between similar lines obtained from data taken before the controls and during the controls.

Five-Minute Volumes on the Freeway at Griggs Road

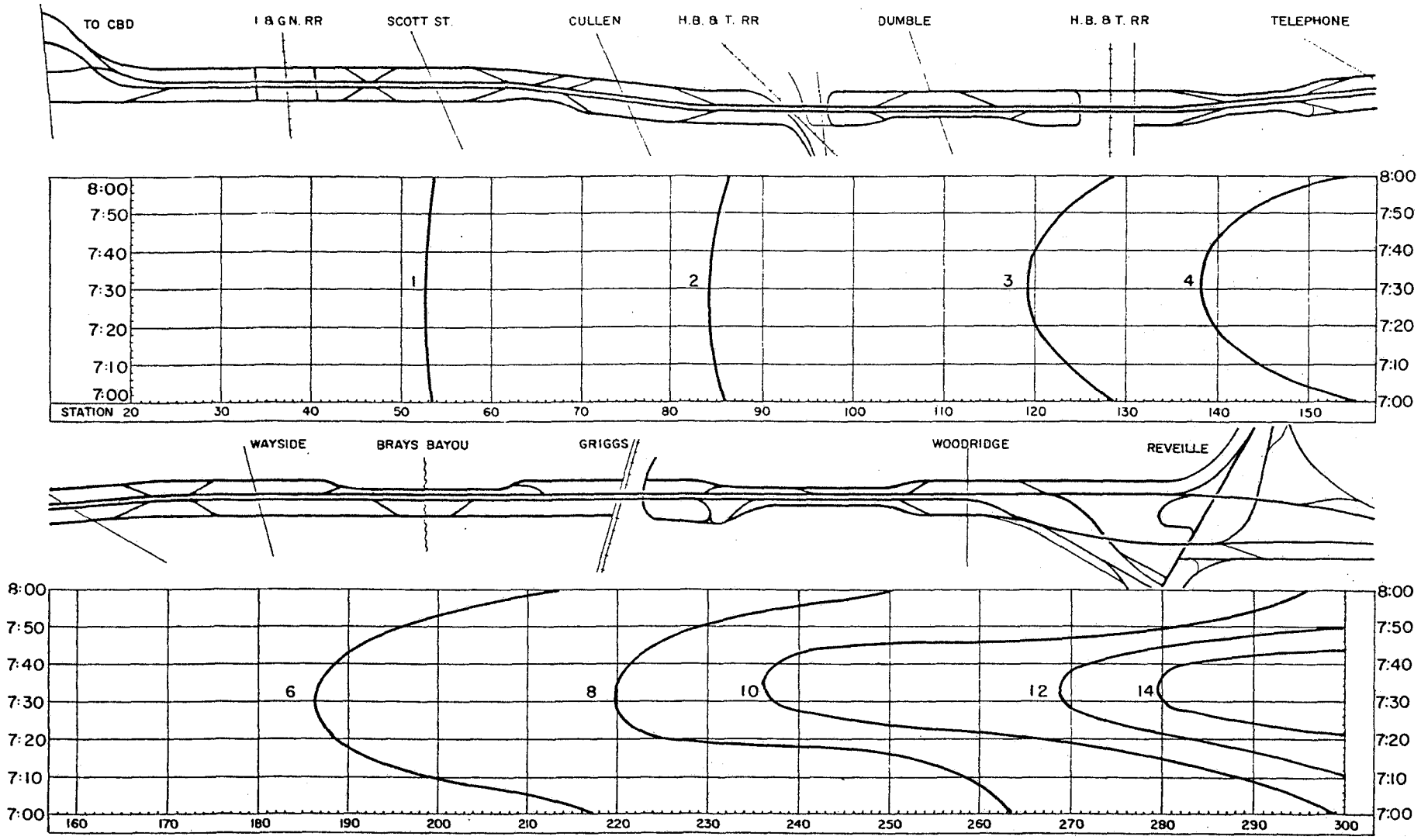
Figure 21 shows the five-minute volumes on the freeway at Griggs Road before

TABLE 10

AVERAGE 7-8 a.m. VOLUMES ON ENTRANCES TO THE FREEWAY
BEFORE, DURING AND AFTER THE CONTROLS

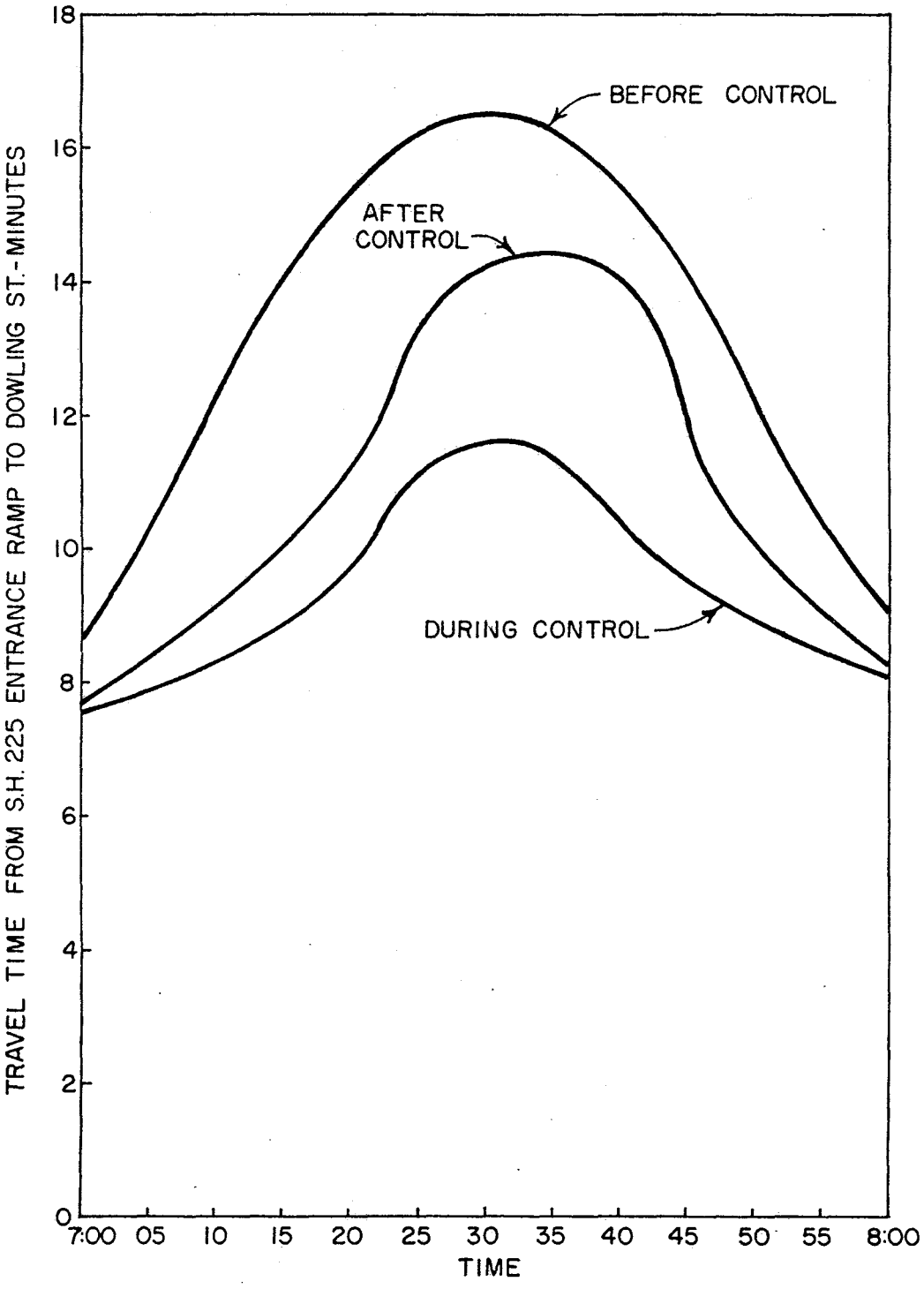
Entrance to Freeway System	Before Control	1st 2 Weeks	Last 5 Weeks	After Control
Freeway at Broadway	2831	3185	3274	3306
Detroit on Ramp	218	122	-	-
S.H. 225 on Ramp	559	649	707	549
*S.H. 35 on Ramp	818	726	750	777
*Woodridge on Ramp	426	398	361	343
*Mossrose on Ramp	643	318	412	558
**Griggs on Ramp	683	496	493	637
*Wayside on Ramp	335	332	315	257
*Telephone on Ramp	413	356	341	401
*Dumble on Ramp	345	294	318	317
**Cullen on Ramps (2)	574	348	296	509
Scott on Ramp	63	257	-	71
Total	7908	7481	7646***	7847****

* - Ramps which were metered
** - Ramps which were closed
*** - Assumes Detroit entrance ramp volume = 122 and Scott entrance ramp volume = 257.
**** - Assumes Detroit entrance ramp volume = 122.



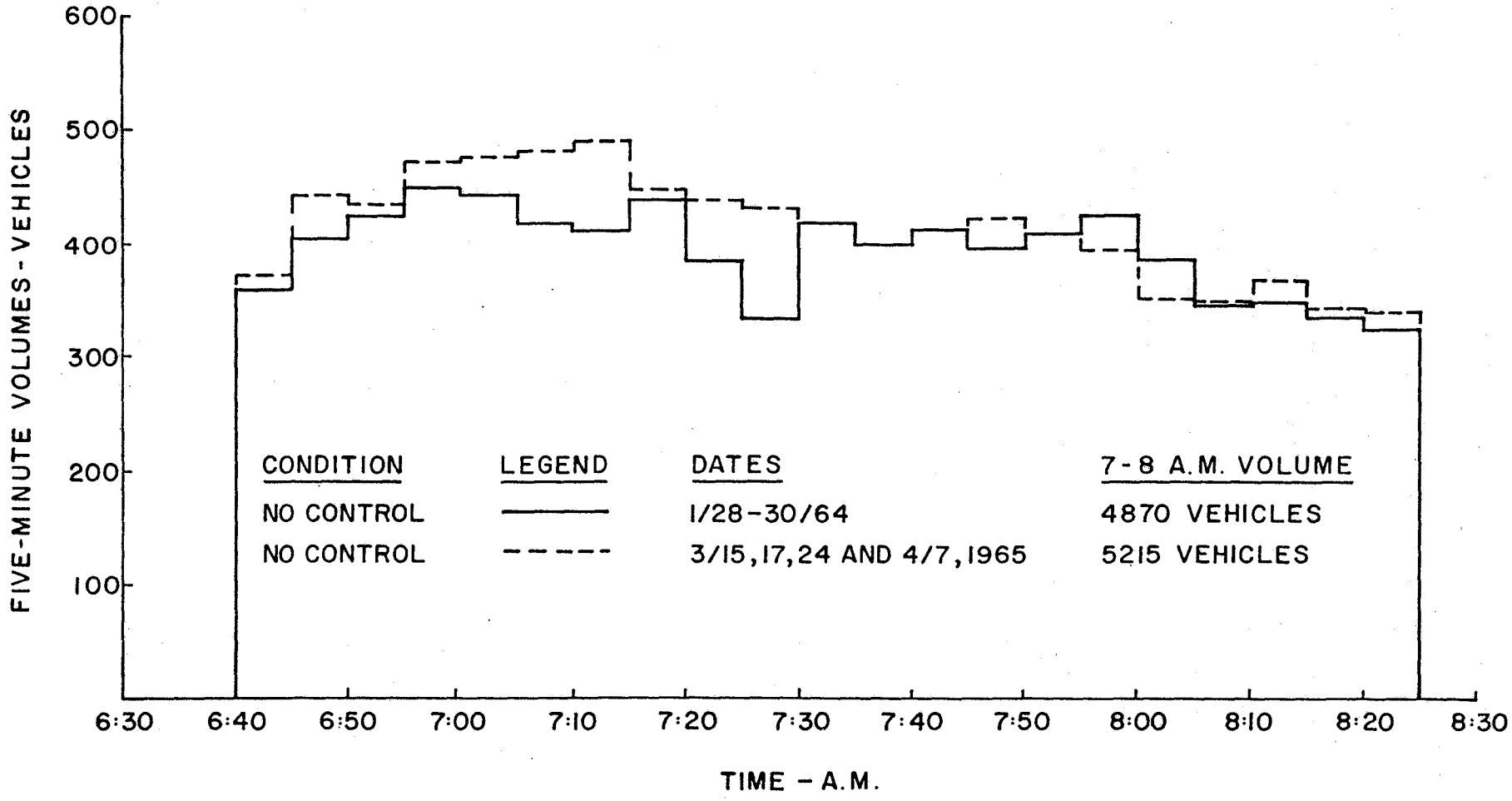
AVERAGE TRAVEL TIME (MINUTES) TO END OF FREEWAY
CONTOUR MAP
AFTER CONTROLS — MARCH 15 — APRIL 30, 1965

FIGURE 19



AVERAGE TRAVEL TIME FROM S.H. 225 ENTRANCE RAMP TO DOWLING ST. BEFORE, DURING AND AFTER CONTROL STUDY

FIGURE 20



FIVE - MINUTE VOLUMES ON GULF FREEWAY AT GRIGGS ROAD

FIGURE 21

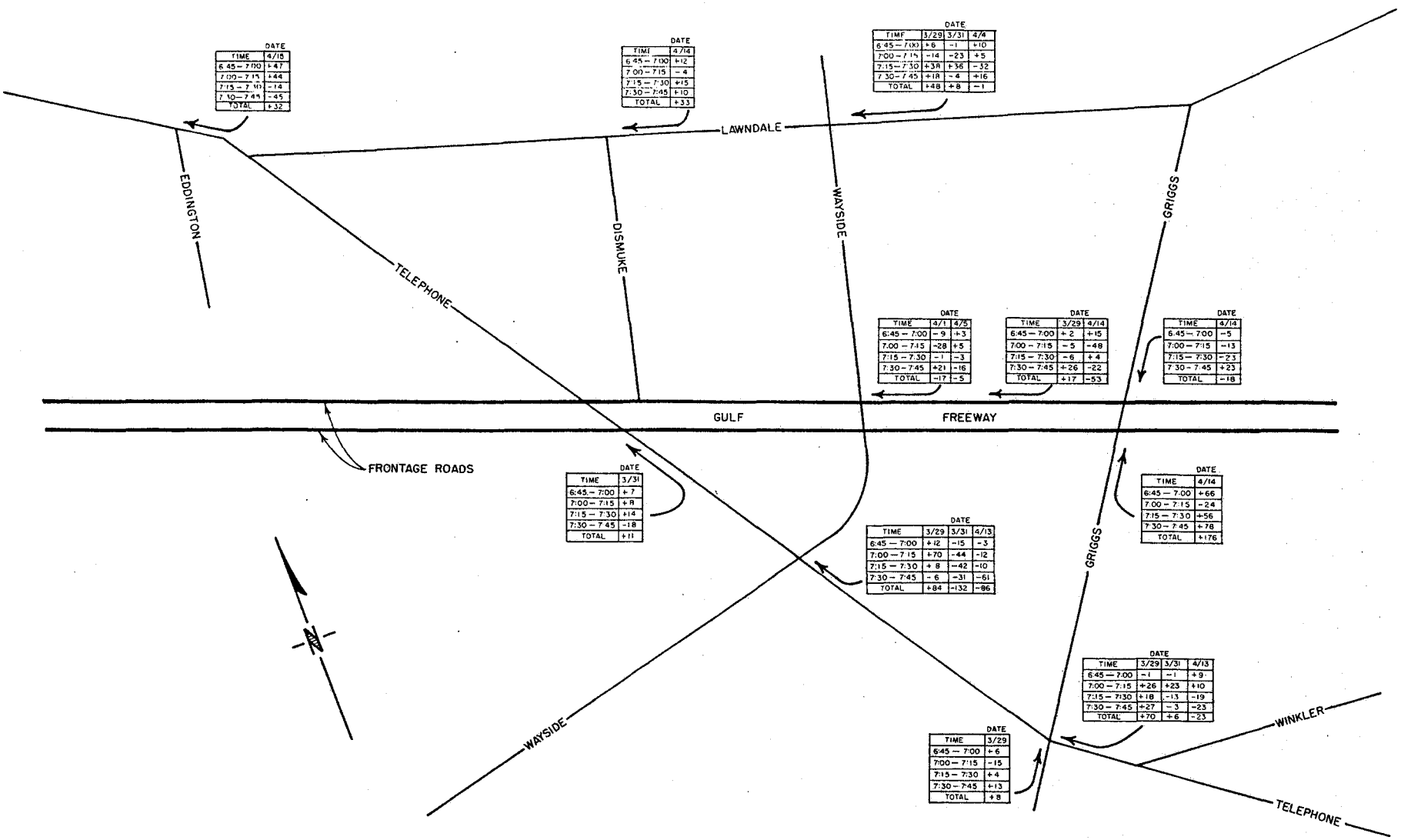
the controls were initiated and after they were terminated. As can be seen, a substantial change occurred between the two time periods. Until 7:30 a.m. the volumes after the controls were terminated were higher than those of January, 1964 and after 7:30 a.m. they were both about the same. The total 7-8 a.m. volume was about 350 vehicles greater in the latter period. The increased volume (after the controls ended) up to about 7:30 seems to come from two sources. The first is that a higher flow rate was maintained from 6:55-7:15 a.m., suggesting a higher capacity (probably due to the better light conditions in the latter period). The second is the decreased severity of the volume decrease caused by downstream congestion.

Arterial Streets

Several counts were made on the arterial streets during the period, March 15 to April 15, 1965, after the termination of the controls. Figure 22 shows the change in volume from 6:45 to 7:45 a.m. when compared to volumes before control.

It would seem that the total hourly volumes have in most cases returned to the level of before control. There is still shifting of traffic away from the Griggs Entrance Ramp approaches during the 7:00 to 7:15 time period when the ramp was closed.

There was no significant change in travel times on the alternate routes after the controls were removed (Table 6).



* VOLUMES COMPARED WITH THREE DAY AVERAGE BEFORE CONTROL

CHANGE IN TRAFFIC VOLUMES AFTER FREEWAY CONTROL

FIGURE 22

PUBLIC OPINION

The objective of the numerous traffic counts, travel time runs, and aerial surveys was to determine the effect of the freeway control plan on the peak period traffic. The changes that are brought about in travel time or the length and severity of congestion may be readily evident to the researcher or the traffic engineer, but not to the individual motorist. Since public acceptance of a control system will be so vital to its successful operation, special attention was given to a study of this aspect. It was desired to obtain as much data as possible to evaluate the reaction of individual motorists to the operation of the controls.

NEWS MEDIA

The newspapers and radio-television stations were given the details of the control plan in a news release on January 19 which is shown in Appendix A. No special effort was made to encourage support of the plan by the news media. Routine news articles were published and reported on radio and television one day before the control study began. No editorial comments or special news features were observed in the news media during the study.

Public opinion as expressed through the news media was represented by one comment, contained in a news article. A City of Houston Councilman stated that the control plan was denying City of Houston tax payers access to a public facility. No official complaints were received from the Councilman's office.

QUESTIONNAIRE STUDY

The experience of the first control study conducted in August, 1964, was that although significant improvements in traffic characteristics were made, the public did not express its opinion, one way or another. Except for a few phone calls to the Highway Department or City Hall, no criticism or praise of the control plan was received. Therefore, a questionnaire survey was conducted as part of the control plan of January, 1965, in an attempt to determine the consensus of opinion of the motoring public involved in the study.

The survey was made of those persons who enter the freeway by one of the inbound entrance ramps from S.H. 225 to Dumble. It did not include traffic that entered the study area via the freeway lanes from upstream of the Reveille Interchange area.

Addresses of many of the motorists who entered the freeway by the ramps in the control area were obtained from origin-destination surveys[8] conducted during the past 18 months. A questionnaire (Figure 23) with an attached letter of explanation was mailed to these addresses on February 3, two days before the end

FREEWAY CONTROL QUESTIONNAIRE

All questions below pertain to travel from 6:45 - 8:00 a.m. during the period, January 26 to February 5.

1. Did the freeway ramp controls affect your trip? Yes_____ No_____

2. Did you avoid using the Gulf Freeway due to the controls? Yes_____ No_____

3. If you traveled on the Gulf Freeway, did you use a different entrance ramp than the one you would normally use? Yes_____ No_____ Name of Ramp_____

4. Did you change the starting time of your peak hour trip (left earlier or later) to avoid the freeway controls? Yes_____ No_____

5. If you entered the freeway, please indicate your impression of the delay encountered at the entrance ramp by checking one of the following:

   No Delay_____ Slight Delay_____ Long Delay_____

6. Was the overall travel time of your peak trip reduced_____, increased_____, about the same as normal_____.

7. Do you feel that the control plan greatly improved traffic operation_____, produced no noticeable change_____, made conditions worse_____.

8. Do you feel that the control plan should be continued_____, discontinued_____, no opinion_____.

9. Please comment on the control plan giving any suggestions or criticisms you feel pertinent.

   COMMENTS:_____

of the first two week period. The forms were to be completed and returned by mail.

The distribution by mail had certain disadvantages such as (1) occupants had moved or changed their trip, (2) addresses were incomplete or (3) addresses were copied down wrong. However distiribution at the ramps would have disrupted traffic while other field studies were being made to determine the effectiveness of freeway control.

Results of Questionnaire Survey

The results of the questionnaire survey are summarized in Tables 11 and 12. Because of the different volumes on the ramps and the different percent returns, the number of motorists responding to the questions are not earily compared. Table 12 presents the data in terms of the percent of total returned by each ramp.

As each question is summarized by entrance ramps, it is important to consider the 3000 vehicles that enter the study area upstream of State Highway 225. These motorists receive the maximum benefit of any control system that improves the flow on the freeway lanes, and suffer none of the disadvantages such as added delay at entry or diversion to other ramps. Yet it was impossible to contact these motorists since they had never participated in an origin-destination survey.

1. Percent Return

The number of forms distributed and returned are indicated by ramp at the top of Tables 11 and 12. The total return of 28.4% is considered good for a mailed survey. The percent return by individual ramps was close to the average with the exception of the following three ramps:

S. H. 225 - The 16.5% return could be attributed to the fact that this ramp was not controlled.

S. H. 35 - The high return from this ramp of 38.6% can be attributed to two things. The metering control changed the operation of this ramp from a two-lane type to a one-lane type and thereby improved merging conditions. The motorists are very interested in methods for improving overall travel conditions. A very high return was received from this ramp for the origin and destination survey conconducted in 1963.

Wayside - The low return of 18.4% can be attributed to the fact that this ramp had the smallest number of

TABLE 11

SUMMARY OF FREEWAY CONTROL QUESTIONNAIRE SURVEY

NUMBER OF RETURNS

	S.H. 225	S.H. 35	Woodridge	Mossrose	Griggs	Wayside	Telephone	Dumble	Total
NUMBER DISTRIBUTED	355	560	324	442	360	195	251	213	2700
NUMBER RETURNED	60	217	107	110	113	37	76	51	771
PERCENT RETURN	16.5	38.6	33.0	24.7	31.4	18.4	30.3	24.0	28.4
1. Did the Freeway ramp controls affect your trip?									
YES	37	153	75	84	75	20	42	31	517
NO	19	52	28	24	31	17	29	15	215
NO ANSWER	4	12	4	2	7	0	5	5	39
2. Did you avoid using the Gulf Freeway due to the controls?									
YES	1	16	3	3	14	4	7	12	60
NO	56	190	102	104	93	33	62	35	675
NO ANSWER	3	11	2	3	6	0	7	4	36
3. Did you use a different entrance ramp than the one you would normally use?									
YES	7	15	9	23	31	5	14	4	108
NO	48	182	94	80	70	31	52	41	598
NO ANSWER	5	20	4	7	12	1	10	6	65
4. Did you change the starting time of your peak hour trip to avoid the freeway controls?									
YES	4	29	11	14	31	8	14	14	125
NO	51	175	93	94	75	29	54	33	604
NO ANSWER	5	13	3	2	7	0	8	4	42

	S.H. 225	S.H. 35	Woodridge	Mossrose	Griggs	Wayside	Telephone	Dumble	Total
5. Indicate your impression of the delay encountered at the entrance ramp.									
NO DELAY	28	95	65	31	41	15	23	19	317
SLIGHT DELAY	24	86	34	62	46	16	29	20	317
LONG DELAY	2	7	3	5	9	1	5	3	35
NO ANSWER	6	29	5	12	17	5	19	9	102
6. What effect did the freeway control have on the overall travel time?									
REDUCED	39	129	70	67	48	17	25	11	406
INCREASED	5	20	17	10	26	3	11	12	104
NO CHANGE	13	53	17	30	32	14	31	23	213
NO ANSWER	3	15	3	3	7	3	9	5	48
7. What effect do you feel the freeway control had on traffic operation?									
IMPROVED OPERATION	45	158	88	83	59	20	32	21	506
NO CHANGE	10	31	10	21	23	12	28	17	152
MADE CONDITIONS WORSE	2	9	5	2	22	2	5	6	53
NO ANSWER	3	19	4	4	9	3	11	7	60
8. Do you feel that the control plan should be continued?									
YES	48	166	87	82	54	22	29	17	505
NO	2	8	3	14	32	9	18	12	98
NO OPINION	8	21	13	12	16	4	21	17	112
NO ANSWER	2	22	4	2	11	2	8	5	56

TABLE 12

SUMMARY OF FREEWAY CONTROL QUESTIONNAIRE SURVEY

PERCENT OF RETURNS

	S.H. 225	S.H. 35	Woodridge	Mossrose	Griggs	Wayside	Telephone	Dumble	Total
NUMBER DISTRIBUTED	355	560	324	442	360	195	251	213	2700
NUMBER RETURNED	60	217	107	110	113	37	76	51	771
PERCENT RETURN	16.5	38.6	33.0	24.7	31.4	18.4	30.3	24.0	28.4
1. Did the Freeway ramp controls affect your trip?									
YES	61.6	70.5	70.1	76.4	66.4	54.1	55.3	60.8	67.1
NO	31.7	23.9	26.2	21.8	27.4	45.9	38.2	29.4	27.8
NO ANSWER	6.7	5.6	3.7	1.8	6.2	0.0	6.5	9.8	5.1
2. Did you avoid using the Gulf Freeway due to the controls?									
YES	1.7	7.4	2.8	2.7	12.4	10.8	9.2	23.5	7.8
NO	93.3	87.6	95.3	94.6	82.1	89.2	81.6	68.6	87.5
NO ANSWER	5.0	5.0	1.9	2.7	5.5	0.0	9.2	7.9	4.7
3. Did you use a different entrance ramp than the one you would normally use?									
YES	11.7	6.9	8.4	20.9	27.4	13.5	18.4	7.9	14.0
NO	80.0	83.9	87.9	72.7	62.0	83.8	68.4	80.4	77.6
NO ANSWER	8.3	9.2	3.7	6.4	10.6	2.7	13.2	11.7	8.4
4. Did you change the starting time of your peak hour trip to avoid the freeway controls?									
YES	6.7	13.4	10.3	12.7	27.4	21.6	18.4	27.4	16.2
NO	85.0	80.6	86.9	85.5	66.4	78.4	71.1	64.7	78.3
NO ANSWER	8.3	6.0	2.8	1.8	6.2	0.0	10.5	7.9	5.5

	S.H. 225	S.H. 35	Woodridge	Mossrose	Griggs	Wayside	Telephone	Dumble	Total
5. Indicate your impression of the delay encountered at the entrance ramp.									
NO DELAY	46.7	43.8	60.7	28.2	36.3	40.5	30.3	37.3	41.1
SLIGHT DELAY	40.0	39.7	31.8	56.4	40.7	43.2	38.1	39.2	41.1
LONG DELAY	3.3	3.2	2.8	4.5	8.0	2.7	6.6	5.9	4.6
NO ANSWER	10.0	13.3	4.7	10.9	15.0	13.6	25.0	17.6	13.2
6. What effect did the freeway control have on the overall travel time?									
REDUCED	65.0	59.4	65.4	61.0	42.5	45.9	32.9	21.6	52.7
INCREASED	8.3	9.2	15.9	9.1	23.0	8.1	14.5	23.5	13.5
NO CHANGE	21.7	24.4	15.9	27.2	28.3	37.9	40.8	45.1	27.6
NO ANSWER	5.0	7.0	2.8	2.7	6.2	8.1	11.8	9.8	6.2
7. What effect do you feel the freeway control had on traffic operation?									
IMPROVED OPERATION	75.0	72.8	82.2	75.4	52.2	54.1	42.1	41.1	65.6
NO CHANGE	16.7	14.3	9.3	19.1	20.4	32.4	36.8	33.3	19.7
MADE CONDITIONS WORSE	3.3	4.1	4.7	1.8	19.5	5.4	6.6	11.8	6.9
NO ANSWER	5.0	8.8	3.8	3.7	7.9	8.1	14.5	13.8	7.8
8. Do you feel that the control plan should be continued?									
YES	80.0	76.5	81.3	74.5	47.8	59.5	38.2	33.3	65.5
NO	3.3	3.9	2.8	12.7	28.3	24.3	23.7	23.5	12.7
NO OPINION	13.4	9.5	12.2	11.0	14.2	10.8	27.6	33.3	14.5
NO ANSWER	3.3	10.1	3.7	1.8	9.7	5.4	10.5	9.9	7.3

forms distributed. A larger percent of forms were sent to motorists who during the origin and destination survey, used the ramp during a time not affected by the controls.

2. Returns on Each of Eight Questions

Question #1 - Did the freeway ramp control affect your trip?

The forms were distributed to persons who had used the ramp during the peak hour. Some of these persons had changed their trip or had entered the freeway when the controls were not in effect. Those returns that answered Yes (527 of 771) to question No. 1 were analyzed separately with the following results:

		Percent of Return
*Diversion	Used City Streets	9.5%
	Used Different Ramp	18.5%
	Changed Time of Trip	20.0%
*Delay at Ramp	No Delay	42.0%
	Slight Delay	43.0%
	Long Delay	6.0%
*Travel Time	Reduced	63.0%
	Increased	18.0%
	Same	17.0%
*Traffic Conditions	Improved	76.0%
	Made Worse	10.0%
	No Change	11.0%
*Study Plan	Continue	76.0%
	Discontinue	15.0%
	No Opinion	9.0%

Question #2 - Did you avoid using the Gulf Freeway due to the controls?

The traffic conditions on the city street system must be considered in the design of freeway control. The survey indicated that 7.8% of the traffic diverted to the arterial streets. Volume counts made several days after the O & D survey was mailed indicated that this percentage decreased as the control study continued.

Question # 3 - Did you use a different entrance ramp during the control study?

Where continuous frontage roads and alternate routes on the arterial street system are available, the traffic moves from one ramp to another, depending on the condition of the freeway operation. 14% of the traffic used a different ramp during the control study. Most of this ramp changing was anticipated in the design of the control plan.

Question # 4 - Did you change the starting time of your trip?

To spread the traffic demand at the ramps, it was suggested that the motorists could avoid unusual delays at the ramps if the time of arrival was changed to miss the control period. The survey indicated that 16.2% of the traffic changed the time of their trip.

Question # 5 - Indicate your impression of the delay encountered at the entrance ramp.

A distinction between slight and long delays can not be made in terms of time since the normal delay at one ramp may be 3 minutes and at another ramp, only 1 minute. Those that encountered long delays (4.6%) were in most cases expressing their dissatisfaction with the control plan. For example, one-fourth of this group normally use the Griggs Ramp which was closed.

Forty-one percent of the motorists indicated a slight delay at the entrance. This was anticipated in the design of the plan. However, only 7% (of the 41% delayed) also noted that the total travel time was increased.

Question # 6 - What effect did the control system have on the overall travel time of your trip?

The results indicated that 13.5% (average for all controlled ramps) of the traffic entering the freeway by one of the controlled ramps had longer travel times. Half of this group, however, did not want the control study to be discontinued.

It should be noted again that traffic entering the study area on the freeway lanes are affected by the control study. If a survey had been made of this traffic, it should have approximated the results received from State Highway 35, except there would be no additional delays caused by metering the traffic.

Question # 7 - How do you feel that the control plan affected traffic operation?

Only 7% of the returns indicated that the control system made conditions worse. One-half of this group used the arterial street system during the control; the other half experienced long delays at the ramps and increased travel times.

Many persons who indicated no change or increased travel times also noted an improvement in the traffic conditions. Comments received on these returns were of improved merging operations and a smoother, more uniform flow of traffic on the freeway lanes.

Question # 8 - Do you feel the control plan should be continued?

The returns indicate that 12.7% of the motorists are in favor of discontinuing

the study. The ramps that benefit the most from the control plan are S.H. 225, S.H. 35, Woodridge and Mossrose. Only 6% of this traffic is in favor of discontinuing the controls, as compared to 25% of the traffic downstream of Griggs Road.

The belief that the ramps in the Reveille area are favored over those downstream of Griggs Road is reason for the opposition to the plan. The closure of Griggs Entrance Ramp for fifteen minutes is the major cause of the opposition.

Questionnaire Conclusions

Based on the results of the mailed questionnaire, the following conclusions are made concerning the freeway control plan:

1. A majority of the motorists indicated that the controls were effective in reducing travel time. Some additional delay was encountered at the entrance ramps but overall travel time was reduced.

2. The traffic operation on the freeway was improved.

3. The motorists are prepared to accept a freeway control system on a regular basis. Special emphasis should be given informing motorists on ramps to be closed of the possible alternatives.

4. The returns from ramps S.H. 35, S.H. 225, Woodridge and Mossrose are more favorable toward the control plan.

DISCUSSION

GENERAL CONTROL PLAN

The control plan as developed and later amended worked very well as an examination of the total system travel times will reveal. The estimates of demand and capacity were at least fairly accurate and the freeway level of service was greatly improved. The capacities at bottleneck locations were probably overestimated slightly (5% or so) for the January-February portion of the control study since the freeway volumes during these months (especially January) are lower than they are during the later (summer) months. This is probably due to the earlier sun rise and during the later months the entire peak period fell during good light conditions. In the January studies darkness prevailed until about 7:15-7:30 a.m., well into the peak period. Except for this minor difficulty, the demand-capacity approach provided a rational means of developing a control plan for a freeway system.

When the demands and capacities are estimated for a control plan, an inherent assumption is that these values will not be changed. However, accidents, adverse weather, etc. can change both the demands and capacities at several locations on the freeway. Because of the fixed-time nature of the control system, it was not flexible enough to handle these unusual situations. Such situations will undoubtedly tax the capabilities of the most sophisticated, traffic-adjusted control system that will be developed. However, the more sophisticated control systems will undoubtedly be much better able to cope with the reduced-capacity occurrences.

The opening time of the Griggs entrance ramp at 7:20 a.m. was probably somewhat early since the ramp vehicles normally precipitated congestion on the freeway there shortly after the ramp was opened. The opening time of 7:20 a.m. was actually a compromise in order to avoid diversion to the street system during its peak period. Perhaps this ramp should have been closed longer or metered for a period after 7:20 a.m.

OPERATION OF THE CONTROLS

Two problems did arise with the manual metering operation. One was that the officers were visible from the freeway and the freeway traffic tended to slow down slightly in the vicinity of the metering point. The second was the tendency on the part of some of the policemen to change the metering rates according to their subjective evaluation of the freeway and merging traffic conditions. The

tendency which was noted was an attempt to reduce the length of the queue at the metering point when, in some cases, one object of the control may have been to develop a long queue (to discourage the use of that ramp). In some instances the officer's judgment may have been superior to the fixed-time plan (especially in the case of upstream accidents) but their changes in the controls conflicted somewhat with the research objective of evaluating the operation under a particular control plan.

Signal Installation at Dumble

The starting headways for metered vehicles at the Dumble signal installation is summarized in Table 13. These values are about 10% higher than starting headways at typical signalized intersections which may be attributed, in part, to the conservative reaction of drivers in an unfamiliar situation.

Table 14 is a comparison of the observed metering rates at Dumble with the desired theoretical rates established by the master freeway control plan. The observed rates are seen to be slightly lower due to the comparative sluggishness in the starting headways as explained above.

Two police officers were stationed at the signal to enforce metering on all but one day. On that day metering was accomplished by the signal alone and out of 123 vehicles metered, only 5 violations were observed. There was no significant difference in the starting headways or the number of violations with or without the policemen.

The effect of the bulk-service technique of ramp metering on the critical gap for merging ramp vehicles is illustrated in Figure 24. The critical gap for bulk service metering is seen to be 3.1 seconds compared to 2.5 seconds for normal operation. The reason for this is not clear, but it is suspected that (1) metered vehicles have a greater relative speed and (2) metered drivers are more conscious of the merging maneuver and are therefore more cautious.

The general conclusions of those observing the operation were that if metering is to be accomplished on the frontage road, the amber phase is a necessity. However, the inclusion of an amber phase in each cycle limits the maximum metering rate. In order to obtain higher metering rates using the bulk service technique, the cycle length must be increased allowing several vehicles to arrive at the freeway merging area at one time. This creates a platoon of ramp vehicles and raises the critical acceptance gap which for a given ramp and freeway volume will result in a lower merging level of service than that obtained during normal operation or during single-vehicle metering. For these reasons, it is suggested that in the future the metering station be located on the ramp, and that vehicles be metered one at a time using just the red and green phases.

TABLE 13

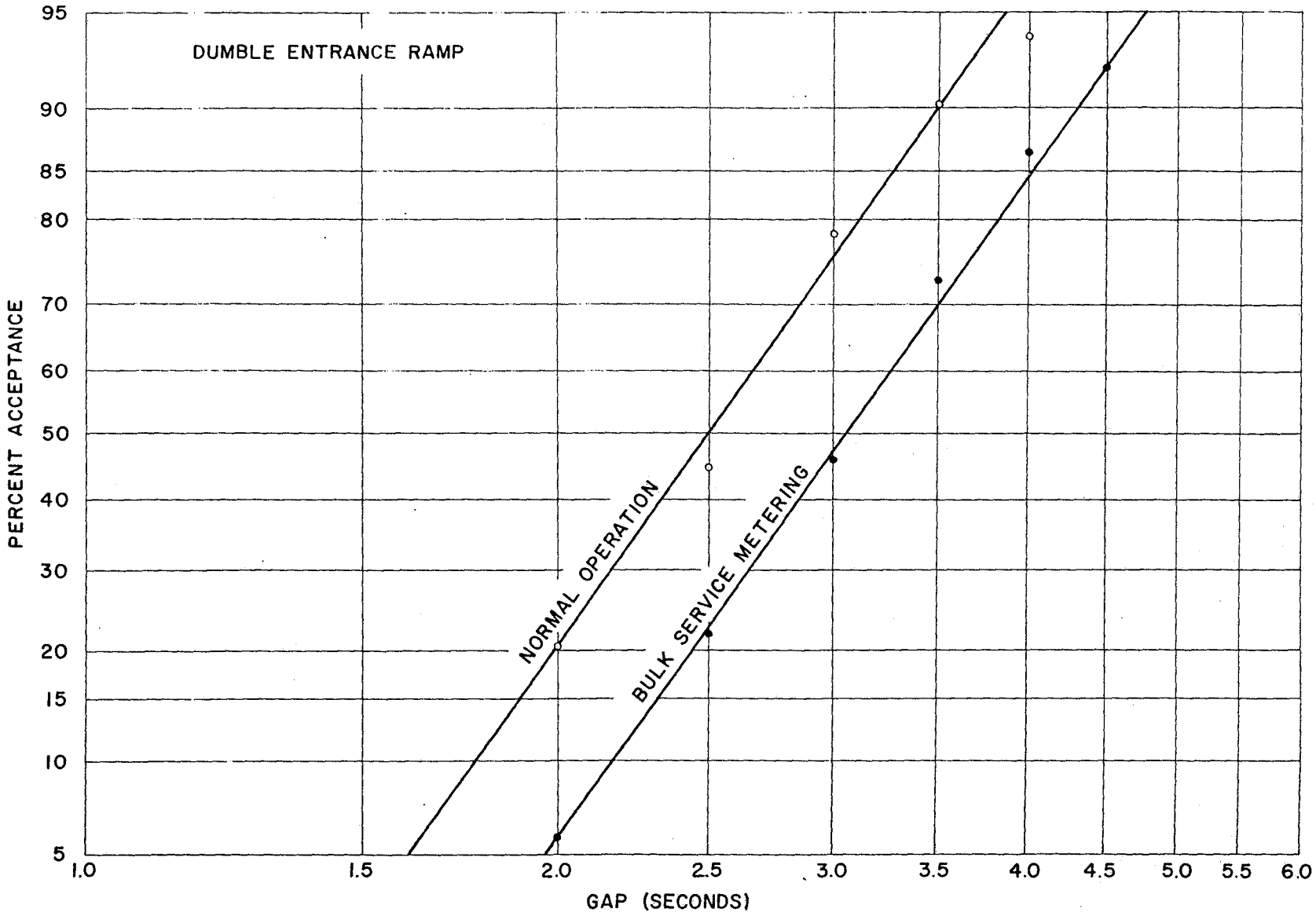
Time Intervals Between Successive Vehicles

Vehicles	No. Observ.	Interval (Sec.)
0-1	147	3.3
1-2	93	2.7
2-3	51	2.4
3-4	5	2.2

TABLE 14

Comparison of Theoreticatical and Observed Metering Rates

Time	Theoret. 5-min. Rate	Observ. 5-min. Rate
7:05-7:10	40	35
7:10-7:20	25	24
7:20-7:25	40	35
7:25-7:35	50	49



COMPARISON OF PERCENT ACCEPTANCE FOR MOVING MERGING VEHICLES DURING NORMAL AND CONTROLLED OPERATION

FIGURE 24

Ramp Closure

The personnel responsible for closing and reopening the three entrance ramps (with barricades) were very dependable and the actual closure times were very close to the desired closure times each day. This ramp closure technique, while somewhat crude, worked extremely well, and created no special problems.

OVERALL EFFECTS OF THE CONTROLS

The overall effect of the controls was a sizeable improvement in the traffic operation on the inbound Gulf Freeway during the morning peak period. The total travel time on the inbound freeway and frontage roads was reduced by about 360 vehicle hours, roughly a 25% reduction, while a 48% reduction in travel time was accomplished on the freeway between Broadway and Griggs. Most of the additional travel time on the arterial streets naturally appear in the form of delay at the critical intersections. Delays at five critical intersections were studied and a total 23 vehicle-hour increase in delay was found at these intersections. Thus, the overall decrease in travel time was about 320-330 vehicle-hours which, assuming an average vehicle occupancy of 1.5 persons per vehicle, represents a savings of about 475-500 man hours per day.

The observed changes in the travel patterns were not unexpected. Generally the volumes decreased on entrance ramps that were controlled and increased on uncontrolled ramps and the freeway near Broadway. The total volume using the freeway from 7-8 a.m. decreased about 5% although between Broadway and Griggs the total 7-8 a.m. volume using the freeway was virtually unchanged.

Individual vehicles saved a substantial amount of time on inbound freeway trips in the 7-8 a.m. period, especially between Broadway and Dumble Streets. Travel time savings on a trip between Broadway and Dowling were as much as 10 minutes.

The additional delay occurring at the critical arterial street intersections was slight. Thus, a considerable system travel time reduction was produced by the controls.

The questionnaire sent to the ramp motorists revealed that about 70% of the ramp motorists felt that the freeway traffic operations were improved by the controls and that the controls should be continued. This indicates the readiness of the motorists for some type of freeway ramp controls.

DIRECTION OF FUTURE RAMP CONTROL WORK

The two control plans which have been evaluated to date have both been

of the fixed-time type. Time alone determined the type and degree of controls which were in effect at each ramp. Historic traffic data obtained from previous studies were used to estimate the demands at the various locations. While this type of demand-capacity analysis provides a rational basis for a control system and was an excellent first step in developing a control system, it is not at all flexible and cannot respond to reduced-capacity occurrences nor even normal fluctuations in demand or daily variations in demand. This fairly simple type of control system was necessary to determine the order of magnitude of the benefits to the peak-period traffic and to determine the responses or reactions of the motorists to these controls.

Thus the study indicates one of the next steps should be research studies of a control system which will respond to traffic conditions on the freeway. This type of control system can base the individual ramp controls on what the freeway traffic conditions are at the particular instant of time rather than what they were at that time on a typical day several months ago.

This can best be accomplished by an immediate installation of ramp control signals at each of the inbound entrance ramps. This will permit studies to determine the best type of ramp signal and the best operation of the signals. The first signal installation should be capable of manual operation and should also have several fixed time settings available. With the signals, the problem of subjective decisions of the police officers will be solved and the freeway traffic slowdowns due to the presence of metering personnel at the ramps will be greatly reduced. The differences in freeway level of service under one-at-a-time or two-at-a-time metering can be tested.

Such a signal system could be operated at one or two locations according to traffic conditions on the freeway as detected manually. Thus the proper variables (gaps, 3 lane volume, one lane volume, density, etc.) to be detected and the proper detector location can be determined. This determination is, of course, necessary before a fully automatic control system can be developed.

The final step in an automatic control system is the interconnection of all control locations so that they can truly be operated as a system. Some form of computer or real time control system may be required to accomplish this.

CONCLUSIONS

1. The control plan which was tested was quite successful at reducing the Gulf Freeway congestion during the morning peak period. Over-all freeway travel time was reduced about 25%.

2. The control plan tested produced little adverse effect on the arterial street system near the Gulf Freeway.

3. The total 7-8 a.m. volume using the inbound Gulf Freeway decreased about 5% during the control study.

4. Individual vehicles saved as much as 10 minutes in travelling between Broadway and Dowling during the control study.

5. The demand-capacity technique provides a good method for determining a fixed-time control plan.

6. A fixed-time control plan lacks the flexibility to deal with reduced-capacity situations such as accidents and adverse weather.

7. The motorists complied extremely well to the police-operated metering controls.

8. It is desirable that ramp metering signals release vehicles onto the freeway one at a time rather than allowing multiple entries.

9. Public acceptance of the controls was good and the study indicates that the motorists are prepared to accept a freeway control system on a continuing basis.

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APPENDIX

A news release (Figure A-1) was issued to the Newspapers and the radio and television stations on January 19 by the Texas Highway Department. This release described the control study and listed the times and dates of control for the two week study. The news articles that appeared in the two Houston newspapers are shown in Figures A-2 and A-3.

At the end of the first week of operation, it was apparent that a longer study period was required to reach a steady state condition in traffic patterns. The news agencies were informed by phone of the extension of the control study. The resulting news article (Figure A-4 and A-5)did not contain specific times on the controls.

The statement by the City Councilman in that article was the only published criticism of the study.

FIGURE A-1 OFFICIAL NEWS RELEASE

The second in a series of freeway control studies, conducted by the Texas Highway Department, City of Houston, and the Texas Transportation Institute of Texas A&M University under the sponsorship of the U. S. Bureau of Public Roads, will be placed in effect on the Gulf Freeway during the morning peak periods from January 26 to February 6, 1965.

The controls will consist of closing three ramps and metering, or limiting the number of vehicles that enter the freeway at the other ramps from State Highway 225 to Dowling Street. The following control plan for the time and type of controls to be placed on each ramp was developed from the results of numerous studies completed during the last twelve months:

Ramp	Type of Control	Time Control Is In Effect
State Highway 35	Meter	6:55 - 7:30 a.m.
Woodridge	Meter	6:55 - 7:30 a.m.
Mossrose	Meter	6:55 - 7:30 a.m.
Griggs	Close	7:05 - 7:20 a.m.
Wayside	Meter	7:00 - 7:30 a.m.
Telephone	Meter	7:00 - 7:30 a.m.
Dumble	Meter	7:05 - 7:30 a.m.
Cullen (South)	Close	7:05 - 7:30 a.m.
Cullen (North)	Close	7:05 - 7:30 a.m.

Previous studies in Houston and other cities have proven the need for some type of traffic control during the periods of peak traffic demand to maintain a high level of efficiency on urban freeways. The objectives of these studies are to provide the information necessary to develop an automatic freeway control system.

The results of the first control study conducted last August and limited to a short section of the Gulf Freeway substantiated the claim that traffic flow can be improved by controlling the critical entrance ramps during the time of peak loading. That study also indicated that the small number of motorists who are diverted from the freeway during the control period can be accommodated on the city street system. The second control system which will include all ramps in the congested area of the Gulf Freeway is expected to produce similar improvements but over a longer section of roadway and for a greater number of motorists.

THE HOUSTON CHRONICLE

Friday, December 11, 1964

More Gulf Freeway Ramps Into City May Be Closed

For 10 days during August traffic experts sealed off with road blocks the inbound ramps on the Gulf Freeway from Broadway to Dowling.

During that period, traffic moved 25 percent faster on the most congested expressway in the city.

Now the experts are considering closing all the inbound and a number of outbound ramps between Broadway and Dowling during peak traffic.

To the August experiment there was "a little public resentment," the experts said.

Another conclusion from the study:

"Limited ramp control indicates . . . it can be used successfully to reduce peak periods of freeway congestion."

The study was financed by the United States Bureau of Roads.

A more thorough study of Gulf Freeway traffic is planned with the use of closed circuit television.

Bids will be asked soon on such a TV system from Reveille to Dowling. The traffic would be monitored from a vantage point on Wayside.

FIGURE A - 2

THE HOUSTON CHRONICLE

Tuesday, January 19, 1965

Jan. 26 Until Feb. 6

Close Few Gulf Freeway Ramps

Some ramps for inbound traffic on the Gulf Freeway will be either closed or the amount of traffic regulated by the State Highway Department beginning Jan. 26 and continuing until Feb. 6.

The ramps admitting traffic on the freeway from Reveille, Woodridge and Mossrose will meter traffic from 6:55 a.m. to 7:30 a.m.; the Griggs Rd. ramp will be closed from 7:05 to 7:20 a.m.; the Wayside and Telephone ramps will meter traffic to the freeway from 7 a.m. to 7:30 a.m.; the Dumble ramp will meter traffic from 7:05 to 7:30 a.m., and the Cullen ramp will be closed from 7:05 a.m. to 7:30 a.m.

"Metering" is a process whereby traffic will be allowed on the freeway by state highway engineers as gaps appear in freeway traffic.

Traffic will have the option at those ramps of either waiting or taking alternate routes into the downtown area.

Traffic must use alternate routes where ramps are closed.

District Highway Engineer W. E. Carmichael said that beginning Wednesday, signs will be put up at the inbound ramps affected, giving directions to motorists.

Last August a similar study was made between Wayside and Dowling. Carmichael said this is an expanded study.

FIGURE A - 3

THE HOUSTON POST
WEDNESDAY, JANUARY 20, 1965

Gulf Freeway Ramps Will Be Closed in Another Test

Nine ramps on the Gulf Freeway will be closed or curtailed during morning rush periods from next Tuesday through Feb 6.

This is the second in a series of tests aimed at relieving rush-hour hardening of the traffic artery.

THE NEW TEST, more extensive than the first, will close or limit traffic on all ramps between Gulfgate Shopping City and Dowling Street downtown.

Motorists who normally use these near-downtown ramps will be diverted to other routes leading downtown. The idea is that everybody will get to town faster if the short-trip freeway drivers are eliminated.

This appeared to be the result in the first freeway closing test last August.

The Texas Highway Department reported recently that freeway traffic got to town 25 per cent faster during the first test, even though the freeway was carrying more traffic.

THESE RAMPS and times are involved in the new test:

State Highway 35, Woodridge and Mossrose—limited traffic from 6:55 to 7:30 AM.

Griggs—closed from 7:05 to 7:20 AM.

Wayside and Telephone—limited traffic from 7 to 7:30 AM.

Dumble—limited traffic from 7:05 to 7:30 AM.

Cullen—both ramps closed from 7:05 to 7:30 AM.

FIGURE A - 4

THE HOUSTON CHRONICLE

Saturday, February 6, 1965

3 Freeway Ramps To Close an Hour

The State Highway Dept. will close three Gulf Freeway ramps on an "indefinite" basis to facilitate the free flow of downtown traffic between 7 and 8 a.m.

State Dist. Highway Engr. Wiley Carmichael said the ramp at Griggs Rd. and two ramps at Cullen will be closed during the peak periods.

Six other ramps, at Reveille, Woodridge, Moss Rose, Wayside, Telephone and Dumble, will be regulated by traffic patrolmen during the morning rush period. The officers will permit traffic to enter these ramps only when it will not interfere with through traffic.

These ramps were closed in August on a test basis. The test was so successful, said Carmichael, that the ramps will now remain closed on an "indefinite" basis.

City Councilman Bill Elliott protested that city drivers, who pay the bulk of the taxes, are being penalized for the benefit of rural dwellers who work in Houston.

FIGURE A - 5

PUBLICATIONS

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

1. Research Report 24-1, "Theoretical Approaches to the Study and Control 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.

10. Research Report 24-10, "Inbound Gulf Freeway Ramp Control Study I" by Charles Pinnell, Donald R. Drew, William R. McCasland, and Joseph A. Wattleworth.

11. Research Report 24-11, "Investigation of an Internal Energy Model for Evaluating Freeway Level of Service" by Donald R. Drew and Conrad L. Dudek.

12. Research Report 24-12, "Gap Acceptance Characteristics for Ramp-Freeway Surveillance and Control" by Donald R. Drew.

13. Research Report 24-13, "Inbound Gulf Freeway Ramp Control Study II" by Charles Pinnell, Donald R. Drew, William R. McCasland, and Joseph A. Wattleworth.