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16. Abstract

An apprpach for operation of frontage road intersections along a major freeway is presented. The strategy considers isolated control, system control, and interface with freeway operation. Initiation of frontage road control is the second major phase in overall corridor control. The first phase, now in operation, is freeway ramp control.

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FRONTAGE CONTROL STRATEGY

FOR

THE NORTH CENTRAL EXPRESSWAY

by

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and
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DALLAS FREEWAY CORRIDOR STUDY

Prepared for
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Texas Transportation Institute
Texas A&M University
Dallas, Texas

September 1974

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DISCLAIMER

1.0 INTRODUCTION

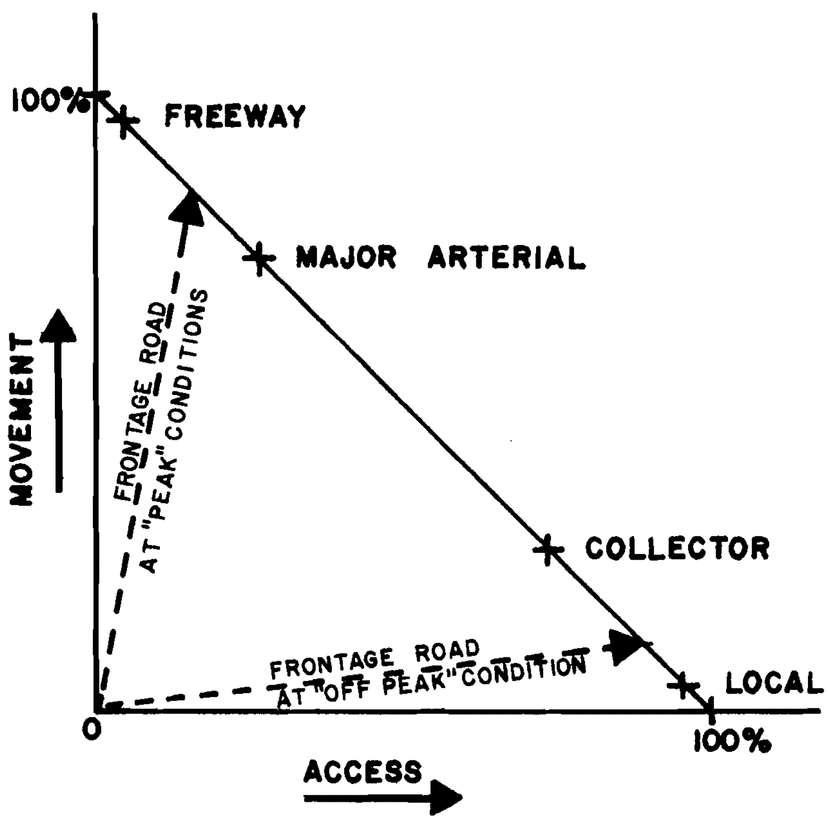
1.1 Frontage Road Functions

The role of a freeway in an overall traffic facility system is primarily the movement of vehicular traffic and the goods and persons associated therewith. The access or service function required by freeway users may be provided by the frontage road. This is generally the situation on freeway facilities that are not yet operating at capacity. However, in many of the urban areas throughout the country, traffic on the major freeways is at or near capacity. When freeway facilities are operating in this range somewhere in level of service E, they are very susceptible to operational breakdown. This breakdown may be caused by an accident, an incident, or changing weather conditions, but the cause does not necessarily have to be as severe a situation as these.

Even with a ramp control system, certain bottlenecks will exist on a freeway. These may be geometric bottlenecks which are present on a daily basis, or they may be operational bottlenecks due to other factors.

Consider a generalized movement versus access curve (Figure 1.1). If the frontage road location were plotted on this curve, it might fall somewhere between local and collector function: i.e., a high level of access as opposed to a low level of traffic movement. This would be a valid classification if the freeway were operating well below capacity with no incident or accident restricting traffic movement. The frontage road would then provide a high degree of service function.

However, when the freeway begins to break down due to overloading or some incident, the frontage road might be used as an alternate route. In this case, the function of the frontage road would more nearly fall between the freeway



MOVEMENT / ACCESS FUNCTIONS

FIGURE 1.1

and major arterial (see Figure 1.1). Since the design of a frontage road is generally high-type design, the geometric considerations for using the frontage road as a major arterial would not be a limiting factor.

In summary, it would seem that a frontage road function might change in response to different situations on the freeway or different times of day. The frontage road could serve as an alternate route to the freeway during peak periods when the freeway is operating at or near capacity. Additionally, during off-peak periods when an incident, accident, or maintenance activities restrict the use of the freeway, the frontage road could be used as an alternate route. If better service could be provided on the frontage road, drivers would more readily divert from the freeway to the frontage road, or may even pick the frontage road as an alternate to the freeway, never entering the freeway facility. This concept would also encourage short-trip drivers not to use the freeway.

1.2 Improving Frontage Road Service

Several methods for improving service on the frontage road are readily evident. Certainly physical design changes on some frontage roads would improve the service provided. Discontinuous frontage roads could be made continuous. The number of lanes on the frontage road could be increased. Frontage road intersections that do not meet high-type design criteria could be redesigned and modified. U-turn bays would keep vehicles desiring to make such a move out of the intersection. Most of these design changes would be fairly expensive in urban built-up areas. However, they may well be cost-effective when analyzing the benefit cost ratio.

Other changes which might be made to improve frontage road level of service would be operational changes. Many frontage roads which were originally designed to be operated as two-way frontage roads have been converted to one-way operation. This change recognizes the need of frontage roads to provide a movement function as well as an access function. Parking has been restricted on frontage roads to insure maximum lane usage. Another operational change would be to upgrade the service provided at the signalized intersections. It is this last mentioned approach which will be addressed in this report.

A typical situation where the freeway has experienced an operational breakdown due to an incident or normal overloading might see average freeway speeds at 15 m.p.h., while average frontage road speeds between intersections might be 30 m.p.h. Travelling a two-mile section on the freeway under these conditions would require eight minutes of a drivers time, while travelling the same distance on the frontage road would require four minutes between intersections. If intersections were spaced at half-mile intervals, the driver on the frontage road would be required to travel through five intersections. Therefore, in order to at least equal the travel time on the freeway, the average delay for each of the five intersections could be no greater than 48 seconds (4 minutes x 60 seconds per minute ÷ 5 intersections).

With peak period multiphase operation at intersections of frontage road and major cross-streets, savings of time in this range would probably not be a common occurrence. Therefore, it would be required that special control measures such as skip-phasing, optimization algorithms, progression algorithms, and penalizing cross-street traffic be employed.

Penalizing another segment of vehicular traffic certainly gets into the realm of political/managerial/engineering determinations. If one agency had responsibility for operation of the freeway/frontage road system (say a state highway department) and another agency had responsibility for operation of the arterial street system (say a municipality), their goals and objectives may not coincide. In this report, an attempt has been made to set certain levels of operation as they relate to favoring one segment of the vehicular traffic so that these decisions could be made and in fact updated in the control program. That is, there would be a wide range of possibilities available for implementation of control. These various ranges could be tested independently and a determination made of the actual penalities experienced by the non-favored segment of the vehicular traffic.

1.3 Facilitating Frontage Road Control

In order to provide flexible and responsive traffic signal control, a flexible responsive traffic control strategy must be available. Such a strategy has been developed on the corridor project and will be outlined in this report.

In order to carry out the control strategy, a flexible responsive hardware control system must be available. The present frontage road control system consists of isolated intersections controlled by stop signs, pretimed controllers, fully actuated controllers, and volume density controllers. Figure 1.2 shows the type of control provided at each intersection. Obviously, any type of system operation would be difficult if not impossible with existing equipment.

A hardware system design has been developed within the corridor project which can accomplish these purposes. Reference is made to previous project reports for details on the hardware system. Briefly, a hierarchical system

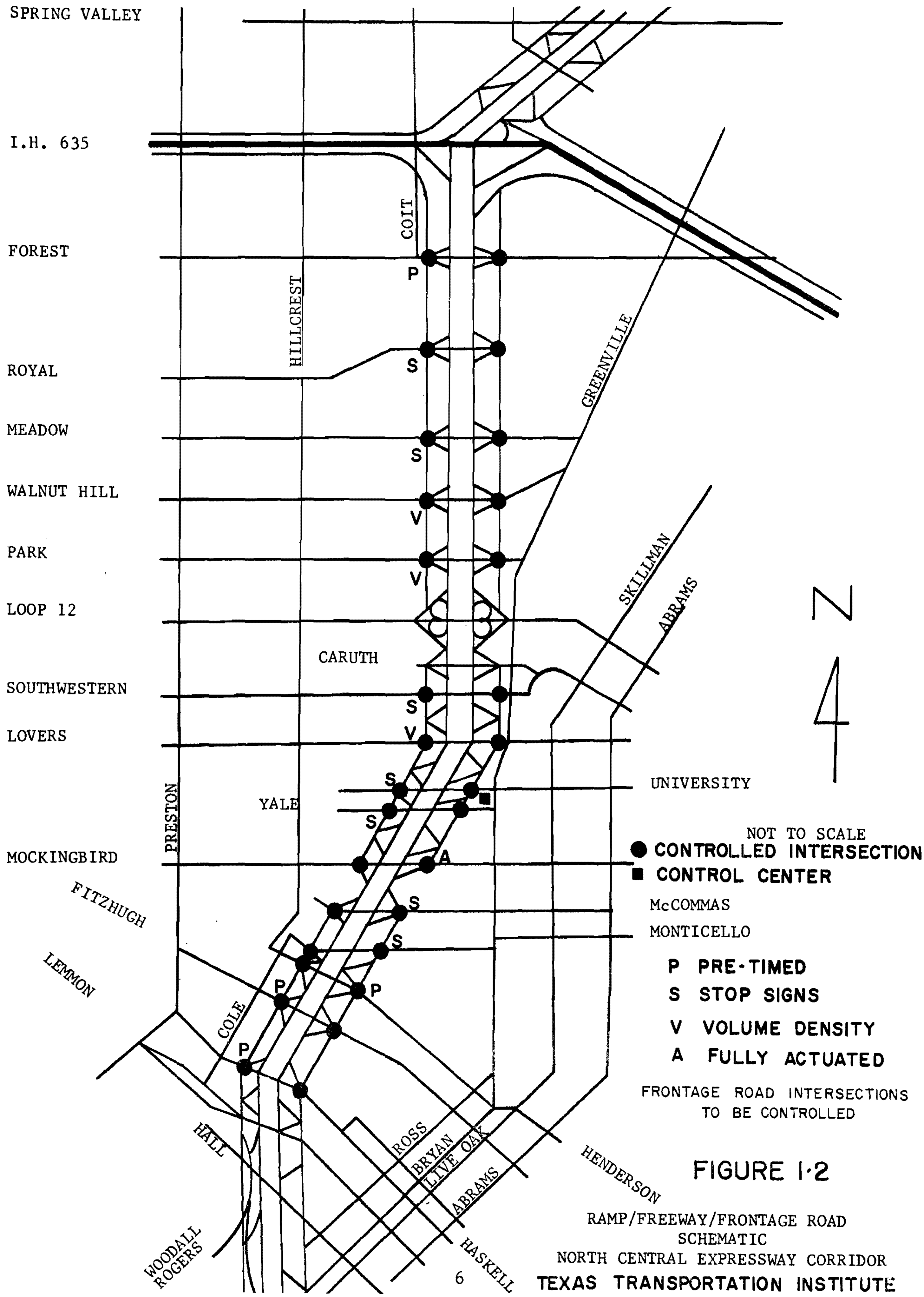


FIGURE 1·2

RAMP/FREEWAY/FRONTAGE ROAD SCHEMATIC
NORTH CENTRAL EXPRESSWAY CORRIDOR
TEXAS TRANSPORTATION INSTITUTE

of minicomputers is being installed to handle the control of fifteen (15) frontage road intersections along the North Central Expressway. Figure 1.2 shows the intersections to be controlled by this system.

Individual intersections will be controlled by a minicomputer at the site. These devices will in turn be linked by telephone lines to supervisory minicomputers which receive field data, act on it according to the control strategy, and provide appropriate information to the field minicomputer (actuator). The hardware system is presently being installed under a TOPICS project.

2.0 GEOMETRIC AND OPERATIONAL CHARACTERISTICS

2.1 General Corridor Characteristics

The study corridor and typical 24-hour volumes are shown in Figure 2.1. The principal traffic facility is the North Central Expressway, a fully access controlled freeway which extends from downtown Dallas generally northward to Richardson, Texas, a distance of approximately 12 miles. The freeway may be described as a depressed freeway with diamond-type interchanges in all interchange locations except two. There is a full cloverleaf interchange at Loop 12 (Northwest Highway) and a directional interchange at IH 635 (LBJ Freeway). The study section extends from Lemmon Avenue to Spring Valley Road.

The freeway has three lanes in each direction from the downtown area to the Mockingbird crossover and two lanes in each direction from that point north. Frontage roads are continuous except at the railroad crossing just south of Mockingbird, the Loop 12 cloverleaf interchange, and the IH 635 interchange.

The freeway's area of influence, or "freeway corridor", has been tentatively established but may be revised as more detailed studies are accomplished. The limits are defined by Skillman-Abrams-Gaston on the east, and Preston-Oak Lawn-Cedar Springs on the west. Major north-south routes in the corridor include those mentioned above; the North Central Expressway, Hillcrest Avenue and Greenville Avenue. Major east-west routes include Spring Valley Road, IH 635 Forest Lane, Royal Lane, Walnut Hill Lane, Lovers Lane and Mockingbird Lane. Major diagonal routes (near the CBD) are McKinney Street, Cole Street, Ross Avenue, Bryan, Live Oak Street and Gaston Avenue. Within the freeway corridor, there are 167 signalized intersections. Of these, 43 are volume density, 26 are traffic actuated, and 98 are fixed-time.

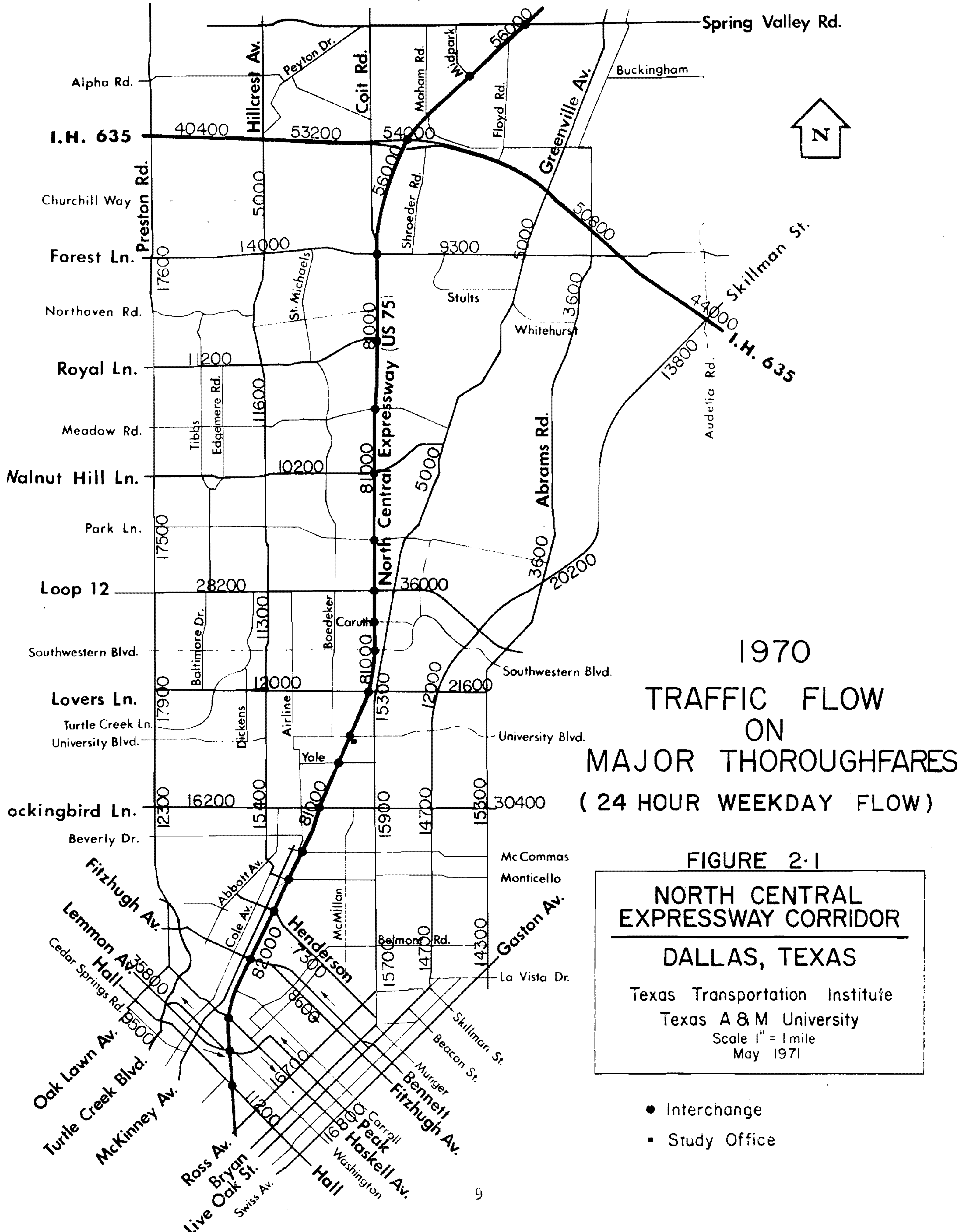


FIGURE 2·1

NORTH CENTRAL EXPRESSWAY CORRIDOR

DALLAS, TEXAS

Texas Transportation Institute
Texas A & M University
Scale 1" = 1 mile
May 1971

The area immediately adjacent to the North Central Expressway is characterized by commercial and office development. Major traffic generators in the corridor are Texas Instruments in the northeast quadrant of the IH 635 - North Central interchange with some 20,000 employees in three shifts; the North Park Shopping Center in the northwest quadrant of the Loop 12 - North Central interchange with parking area to accommodate 6,000 cars; and, Southern Methodist University with 8,000 students enrolled. In addition, apartment complexes are scattered throughout the area. A high concentration of apartments exists around University Avenue between Greenville and Skillman. Several office and apartment complexes are planned or are under construction.

The North Central Expressway operates at or near possible capacity (Level E) in the peak directions during the hours of 7-9 a.m. and 4-6 p.m. Typical peak hour volumes are shown in Figures 2.2 and 2.3.

Ramp control in peak directions was initiated in June of 1971, and control of both directions during both the peaks was begun in December 1972.

2.1.1 Inbound A.M. Conditions

Freeway speeds are generally in the 50-60 m.p.h. range from Forest to Walnut Hill. A flow is restricted somewhat between Walnut Hill to Caruth causing speeds to drop to below 25 m.p.h. for short intervals. Speeds are in the 25-40 m.p.h. range from that point to Mockingbird. A freeway lane is added at Mockingbird and speeds are generally in the 35-50 m.p.h. range, barring an incident of some type.

2.1.2 Outbound P.M. Conditions

Sufficient capacity exists to handle existing traffic demands in the three-lane section from Lemmon to Mockingbird. However, the dropping of a lane at Mockingbird and the weaving maneuvers in that area severely restrict

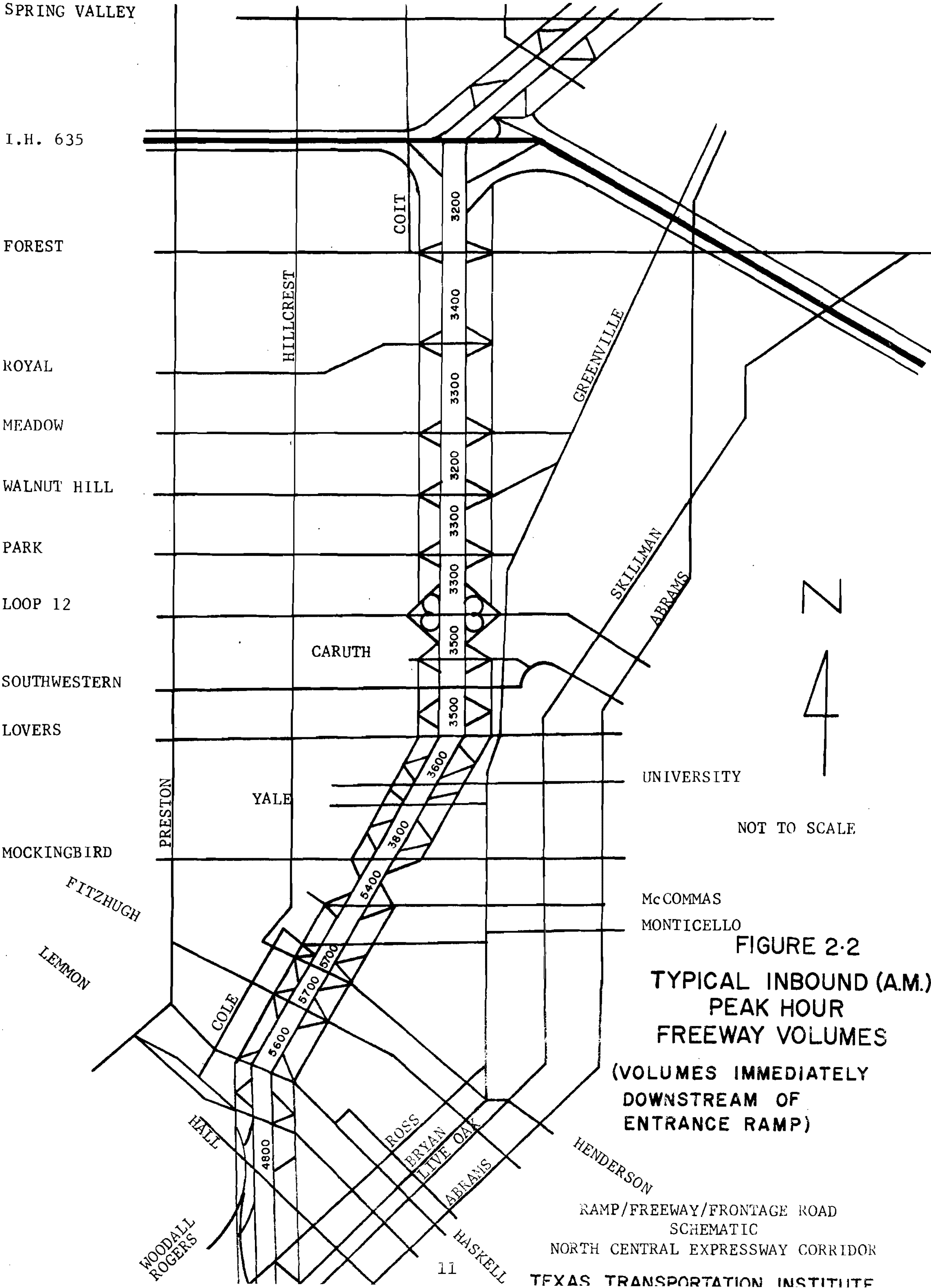


FIGURE 2-2

TYPICAL INBOUND (A.M.) PEAK HOUR FREEWAY VOLUMES

(VOLUMES IMMEDIATELY DOWNSTREAM OF ENTRANCE RAMP)

RAMP/FREEWAY/FRONTAGE ROAD SCHEMATIC
NORTH CENTRAL EXPRESSWAY CORRIDOR

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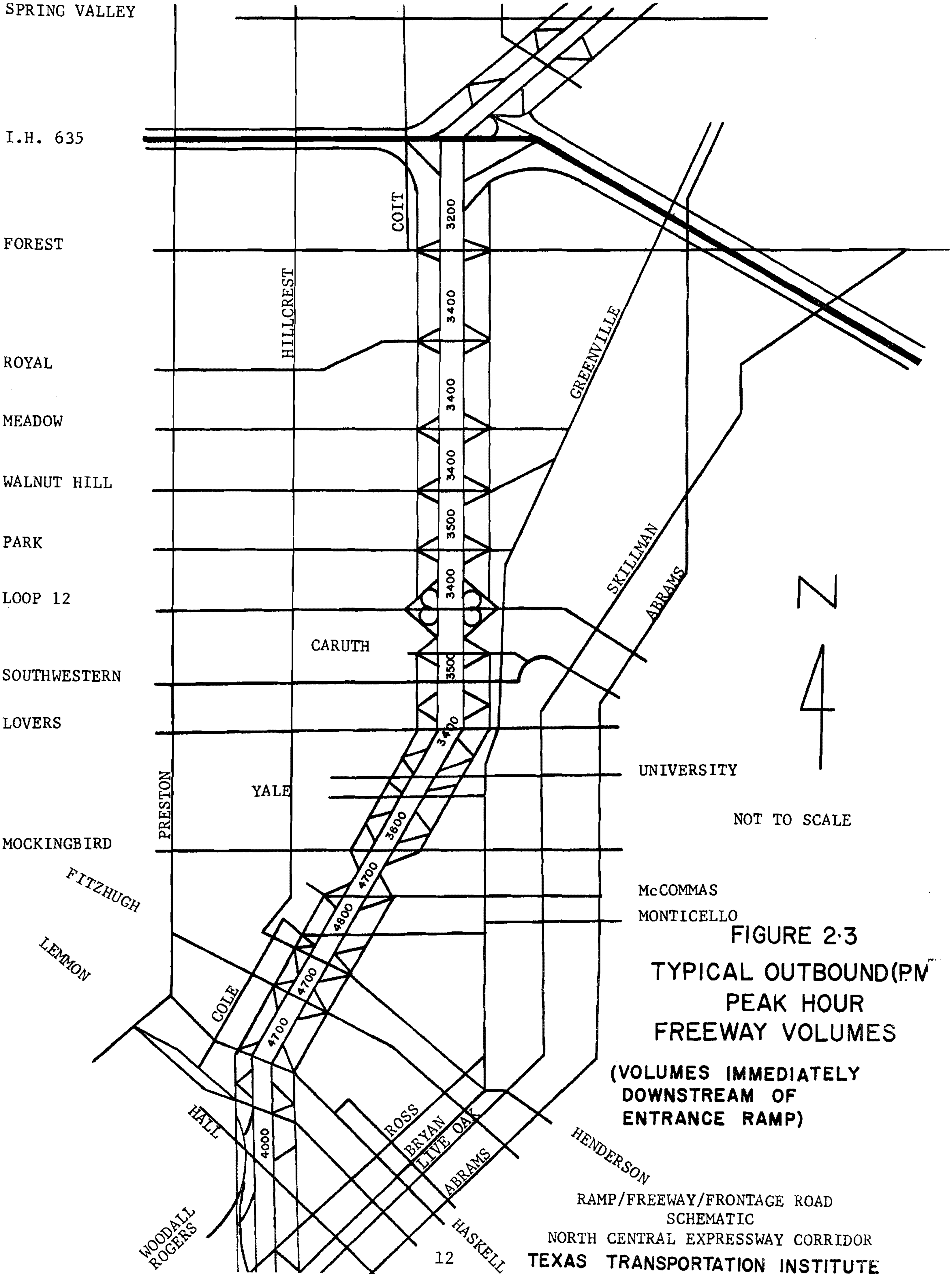

FIGURE 2·3
TYPICAL OUTBOUND(P.M.
PEAK HOUR
FREEWAY VOLUMES

(VOLUMES IMMEDIATELY
DOWNSTREAM OF
ENTRANCE RAMP)

RAMP/FREEWAY/FRONTAGE ROAD
SCHEMATIC
NORTH CENTRAL EXPRESSWAY CORRIDOR
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flow at that point, and the resultant shock-wave affects operation from that point to Lemmon. Stop and go operation is not an uncommon occurrence for this reason.

2.2 Frontage Road Characteristics

Table 2.1 shows a summary of frontage road characteristics. The following sections further describe these characteristics.

2.2.1 Geometrics

As mentioned above, frontage roads on North Central are discontinuous at three locations: at the railroad just south of Mockingbird, at the cloverleaf interchange at Loop 12 (Northwest Highway), and at IH 635 (LBJ Freeway). This discontinuity obviously limits the function of the frontage road for long distance trips, but short trips and diversion around incidents can be served.

Frontage roads are thirty (30) feet in width from the southern limit of the study area to Loop 12. Twenty-four feet widths are provided north of Loop 12. U-turn bays are provied at Mockingbird, Yale, University, Lovers, and Southwestern.

Intersection approaches are widened out somewhat as indicated in Table 2.1.

2.2.2 Frontage Road Operation

The existing frontage roads operate as one-way facilities except at two isolated locations. A short (80') two-way section exists between the offset sections of McCommas on the west side of the freeway. A two-way divided section exists on the north approach of Forest Lane. As both of these sections are located near points where frontage roads are discontinuous, they should not greatly influence any diversion plans. However, they do present micro-

TABLE 2.1

FRONTAGE ROAD CHARACTERISTICS
NORTH CENTRAL EXPRESSWAY

CROSS STREET	PEAK PERIOD	APPROACH WIDTH	PEAK HOUR DEMAND	G/C RATIO	SERVICE VOLUME LOS C	SERVICE VOLUME LOS E	EXISTING CONTROL
Haskell	A.M.	32	1045	.26	920	970	Pre-Timed
	P.M.	32	550	.23	935	885	
Fitzhugh	A.M.	34	840	.20	730	770	Pre-Timed
	P.M.	34	1135	.31	1080	1140	
Knox	A.M.	32	500	.24	865	910	Pre-Timed
Henderson	P.M.	32	900	.50	1780	1880	
Monticello	A.M.	32	415	.18	515	545	Stop
	P.M.	32	645	.33*	1080	1140	Signs
McCommas	A.M.	32	335	.14	390	410	Stop
	P.M.	32	900	.33*	1080	1140	Signs
Mockingbird	A.M.	32	235	.22	700	740	Fully
**	P.M.	32	585	.30	755	800	Actuated
Yale	A.M.	32	875	.28*	754	870	Stop
**	P.M.	32	800	.46*	1560	1800	Signs
University	A.M.	35	775	.24*	925	1090	Stop
**	P.M.	32	900	.28*	1015	1170	Signs
Lovers	A.M.	35	710	.16	590	695	Volume
**	P.M.	35	760	.42	1570	1850	Density
Southwestern	A.M.	33	175	.07*	275	320	Stop
**	P.M.	36	490	.21*	870	1015	Signs
Park	A.M.	39	428	.27	1220	1405	Volume
	P.M.	39	343	.27	1190	1255	Density
Walnut Hill	A.M.	42	610	.27	1300	1500	Volume
	P.M.	42	380	.27	1300	1500	Density
Meadow	A.M.	25	275	.25*	700	780	Stop
	P.M.	25	455	.37*	1025	1150	Signs
Royal	A.M.	25	370	.51*	1045	1175	Stop
	P.M.	25	285	.38*	780	875	Signs
Forest	A.M.	34	355	.17	670	760	Pre-Timed
	P.M.	32	860	.27	960	1100	

* ESTIMATED FOR NON-SIGNALIZED INTERSECTIONS
** U-TURN BAYS PROVIDED

scopic operational problems and will require special attention in the signal operation techniques.

Table 2.1 shows the existing intersection control at the frontage road intersections. As can be seen, four (4) intersections have pretimed operation; three (3) have volume density equipment; one (1) has full actuated control; and seven (7) are controlled by stop signs. Signals are not interconnected for progression. Parking is not allowed during peak periods on the three lane frontage roads. Parking is not allowed at any time on the two lane sections.

2.2.3 Demand And Capacity

Typical peak hour demands are indicated in Table 2.1. Practical capacity (LOS C) and possible capacity (LOS E) are also shown. As can be seen, excess capacity is available at most locations. Fully responsive system operation and progression would allow better use of this available capacity.

2.2.4 Floating Vehicle Analysis

One hundred and eight instrumented vehicle studies were made on the frontage road sections from Northwest Highway to Lemmon Avenue. No studies have been made north of Northwest Highway due to construction on both the east and west frontage road. The studies that were made are during both A.M. (7-9 a.m.) and P.M. (4:15 p.m. - 6:15 p.m.) peaks. (See below for table numbers).

Link Description	Link No.	Study Period A.M.	Study Period P.M.
Caruth to Mockingbird	46	2.2	2.3
McCommas to Lemmon	78	2.4	2.5
Lemmon to McCommas	59	2.6	2.7
Mockingbird to Caruth	13	2.8	2.9

The parameters evaluated on each link are as follows:

1. Percent stop-time (70%)
2. Travel time (sec./mile)
3. Velocity (ft./sec.)
4. Mean velocity gradient
5. Greenshields Index
6. Stops (no./mile)
7. Brake applications (no./mile)

Using these parameters, the present operation on the frontage roads can be described as follows:

TABLE 2.2

FRONTAGE ROAD LINK 46
CARUTH TO MOCKINGBIRD
TOTAL DISTANCE - 10,800 FEET
STUDY PERIOD - A.M. PEAK

STUDY NO.	PCT STOP TIME	TRAVEL TIME (SEC./MILE)	VELOCITY (FT./SEC.)	MEAN VELOCITY GRADIENT	GREEN-SHIELDS INDEX	STOPS PER MILE	BRAKE APPLICATIONS PER MILE
1016	20.0	157.0	33.6	0.074	4.50	2.90	3.42
1018	27.0	161.0	32.8	0.079	4.40	2.40	4.40
1020	38.0	197.0	26.9	0.090	2.80	2.90	4.40
1087	28.0	188.0	28.2	0.073	2.70	2.40	4.42
1089	26.0	187.0	28.2	0.080	2.40	2.40	3.45
1091	24.0	175.0	30.4	0.071	3.60	1.90	4.45
1093	26.0	173.0	30.6	0.076	3.30	2.40	2.96
1128	27.0	173.0	30.6	0.094	2.90	2.40	4.39
1130	14.0	137.0	38.5	0.067	6.50	1.90	2.43
1196	37.0	204.0	25.9	0.081	1.70	2.60	2.62
1198	40.0	221.0	24.0	0.085	1.90	2.90	4.41
1200	51.0	243.0	21.8	0.095	1.10	2.90	6.88
MEAN	29.8	184.6	29.2	0.080	3.14	2.49	4.01
NO.	12						

TABLE 2.3

FRONTAGE ROAD LINK 46
CARUTH TO MOCKINGBIRD
TOTAL DISTANCE - 10,800 FEET
STUDY PERIOD - P.M. PEAK

STUDY NO.	PCT STOP TIME	TRAVEL TIME (SEC./MILE)	VELOCITY (FT./SEC.)	MEAN VELOCITY GRADIENT	GREEN-SHIELDS INDEX	STOPS PER MILE	BRAKE APPLICATIONS PER MILE
421	32.0	206.0	25.7	0.083	3.80	2.40	4.38
423	20.0	169.0	31.3	0,078	5.00	2.40	2.93
1095	31.0	172.0	30.7	0.089	3.90	2.40	5.90
1097	33.0	168.0	31.3	0.091	2.80	2.60	3.71
1099	28.0	163.0	32.4	0.084	3.00	2.40	2.46
1102	16.0	157.0	33.6	0.077	6.30	1.90	3.47
1104	40.0	217.0	24.4	0.105	1.90	3.40	5.45
1106	17.0	149.0	35.5	0.075	5.40	1.90	3.96
1203	31.0	182.0	29.1	0.086	2.60	2.40	3.44
1205	34.0	181.0	29.1	0.091	1.90	2.40	2.95
1207	29.0	176.0	30.1	0.078	2.70	2.40	3.94
MEAN	28.2	176.3	30.2	0.085	3.57	2.41	3.87

NO. 11

TABLE 2.4

FRONTAGE ROAD LINK 78
MCCOMMAS TO LEMMON
TOTAL DISTANCE - 11,070 FEET
STUDY PERIOD - A.M. PEAK

STUDY NO.	PCT STOP TIME	TRAVEL TIME (SEC./MILE)	VELOCITY (FT./SEC.)	MEAN VELOCITY GRADIENT	GREEN-SHIELDS INDEX	STOPS PER MILE	BRAKE APPLICATIONS PER MILE
867	26.0	158.0	33.4	0.103	2.80	2.30	3.74
869	21.0	149.0	35.5	0.105	3.00	2.30	4.68
871	28.0	162.0	32.6	0.109	2.70	2.30	2.35
873	32.0	175.0	30.2	0.121	2.50	1.90	3.32
981	9.0	116.0	45.4	0.061	8.40	1.30	1.38
984	26.0	157.0	33.7	0.076	5.50	1.80	2.77
986	22.0	160.0	33.1	0.082	3.80	2.30	3.69
1030	37.0	212.0	25.0	0.110	2.30	2.70	4.62
1032	16.0	144.0	36.7	0.079	5.50	2.30	2.30
1040	14.0	154.0	34.3	0.059	6.50	1.80	
1042	25.0	182.0	29.1	0.070	4.20	2.30	
1044	16.0	157.0	33.6	0.071	5.50	1.80	
1108	34.0	187.0	28.3	0.080	2.00	2.30	2.77
1110	9.0	146.0	36.2	0.059	7.30	1.30	2.31
1112	20.0	149.0	35.5	0.072	6.40	1.30	4.61
MEAN	22.3	160.5	33.5	0.083	4.55	1.99	3.20
NO.	15						

TABLE 2.5

FRONTAGE ROAD LINK 78
MCCOMMAS TO LEMMON
TOTAL DISTANCE - 11,070 FEET
STUDY PERIOD - P.M. PEAK

STUDY NO.	PCT STOP TIME	TRAVEL TIME (SEC./MILE)	VELOCITY (FT./SEC.)	MEAN VELOCITY GRADIENT	GREEN-SHIELDS INDEX	STOPS PER MILE	BRAKE APPLICATIONS PER MILE
875	43.0	231.0	22.9	0.137	1.60	3.70	5.62
877	33.0	178.0	29.8	0.101	3.40	2.30	3.69
997	38.0	194.0	27.3	0.096	2.10	2.30	4.16
999	29.0	182.0	29.1	0.085	3.60	2.30	3.69
1001	39.0	229.0	23.1	0.112	1.70	3.70	
1064	19.0	165.0	32.2	0.071	5.90	1.80	2.31
1066	44.0	243.0	21.8	0.104	1.50	3.60	5.07
1068	33.0	196.0	27.0	0.083	3.80	2.30	3.69
1116	18.0	160.0	33.1	0.077	4.80	2.30	3.23
1118	24.0	171.0	31.0	0.077	4.40	1.80	2.77
1120	40.0	232.0	22.9	0.092	2.40	2.70	5.54
1122	33.0	203.0	26.1	0.078	2.30	2.30	4.62
MEAN	32.7	198.6	27.1	0.092	3.12	2.59	3.69
NO.	12						

TABLE 2.6

FRONTAGE ROAD LINK 59
LEMMON TO MCCOMMAS
TOTAL DISTANCE - 11,405 FEET
STUDY PERIOD - A.M. PEAK

STUDY NO.	PCT STOP TIME	TRAVEL TIME (SEC./MILE)	VELOCITY (FT./SEC.)	MEAN VELOCITY GRADIENT	GREEN-SHIELDS INDEX	STOPS PER MILE	BRAKE APPLICATIONS PER MILE
868	26.0	156.0	33.9	0.095	3.10	1.90	4.28
870	28.0	171.0	30.9	0.111	2.30	2.30	3.82
872	42.0	204.0	25.9	0.115	1.30	2.80	3.33
982	18.0	154.0	34.4	0.072	5.00	2.30	4.29
983	46.0	215.0	24.6	0.119	1.60	3.20	4.22
985	22.0	164.0	32.3	0.084	3.90	2.30	3.81
1031	30.0	193.0	27.5	0.085	2.80	1.90	4.29
1039	25.0	174.0	30.3	0.074	4.00	1.90	
1041	24.0	178.0	29.7	0.070	3.70	2.30	
1043	20.0	169.0	31.3	0.071	4.10	1.40	
1109	32.0	208.0	25.5	0.073	1.70	1.90	4.76
1111	30.0	200.0	26.5	0.086	3.10	2.80	4.29
1113	29.0	196.0	27.1	0.086	2.60	2.80	5.23
MEAN	28.6	183.2	29.2	0.087	3.01	2.29	4.22
NO.	13						

TABLE 2.7

FRONTAGE ROAD LINK 59
LEMMON TO MCCOMMAS
TOTAL DISTANCE - 11,405 FEET
STUDY PERIOD - P.M. PEAK

STUDY NO.	PCT STOP TIME	TRAVEL TIME (SEC./MILE)	VELOCITY (FT./SEC.)	MEAN VELOCITY GRADIENT	GREEN-SHIELDS INDEX	STOPS PER MILE	BRAKE APPLICATIONS PER MILE
874	28.0	188.0	28.1	0.087	3.30	2.30	3.33
876	14.0	144.0	36.8	0.090	4.60	1.90	2.85
975	43.0	207.0	25.5	0.105	3.40	2.40	3.85
998	25.0	175.0	30.2	0.084	2.90	2.30	4.76
1000	20.0	155.0	34.1	0.074	3.60	1.90	3.80
1002	40.0	222.0	23.9	0.092	2.00	1.90	
1045	26.0	161.0	33.0	0.083	5.40	1.90	2.85
1063	10.0	144.0	36.8	0.066	6.40	1.90	2.85
1065	31.0	183.0	28.9	0.084	3.20	2.30	2.85
1067	35.0	202.0	26.2	0.082	3.40	2.30	3.33
1117	30.0	187.0	28.3	0.085	3.10	1.90	4.75
1119	35.0	197.0	26.9	0.078	2.20	1.40	3.81
1121	32.0	186.0	28.5	0.085	2.20	2.30	3.33
MEAN	28.3	180.8	29.7	0.084	3.51	2.05	3.52
NO.	13						

TABLE 2.8

FRONTAGE ROAD LINK 13
MOCKINGBIRD TO CARUTH
TOTAL DISTANCE - 10,770 FEET
STUDY PERIOD - A.M. PEAK

STUDY NO.	PCT STOP TIME	TRAVEL TIME (SEC./MILE)	VELOCITY (FT./SEC.)	MEAN VELOCITY GRADIENT	GREEN-SHIELDS INDEX	STOPS PER MILE	BRAKE APPLICATIONS PER MILE
201	19.0	167.0	31.5	0.077	3.50	2.40	2.94
202	24.0	182.0	29.1	0.080	2.90	2.40	3.43
203	19.0	176.0	30.1	0.076	3.50	2.40	2.95
204	18.0	176.0	30.1	0.068	3.80	2.40	2.47
212	15.0	141.0	37.4	0.067	4.80	1.90	1.95
1017	17.0	154.0	34.3	0.068	4.10	1.90	3.41
1019	30.0	185.0	28.7	0.076	3.00	2.40	2.44
1021	11.0	132.0	40.0	0.070	5.50	1.40	2.92
1088	16.0	162.0	32.7	0.069	5.60	2.90	3.42
1090	6.0	148.0	35.6	0.066	6.00	1.90	4.41
1092	22.0	172.0	30.7	0.073	4.20	1.90	2.94
1129	26.0	161.0	32.9	0.080	4.40	2.40	3.42
1131	25.0	145.0	36.5	0.079	3.40	1.90	2.92
1133	9.0	124.0	42.4	0.072	6.80	1.90	4.90
1197	24.0	166.0	31.9	0.076	2.80	2.40	2.93
1199	7.0	138.0	38.4	0.056	7.00	1.40	3.42
1201	9.0	129.0	40.8	0.075	6.30	1.40	3.43
MEAN	17.4	156.3	34.2	0.072	4.56	2.07	3.19
NO.	17						

TABLE 2.9

FRONTAGE ROAD LINK 13
MOCKINGBIRD TO CARUTH
TOTAL DISTANCE - 10,770 FEET
STUDY PERIOD - P.M. PEAK

STUDY NO.	PCT STOP TIME	TRAVEL TIME (SEC./MILE)	VELOCITY (FT./SEC.)	MEAN VELOCITY GRADIENT	GREEN-SHIELDS INDEX	STOPS PER MILE	BRAKE APPLICATIONS PER MILE
191	25.0	176.0	30.1	0.088	3.80	2.40	2.96
192	16.0	178.0	29.6	0.079	4.00	2.90	4.91
193	26.0	188.0	28.1	0.077	2.40	2.40	3.43
194	22.0	173.0	30.5	0.071	4.40	1.90	2.94
1094	24.0	163.0	32.5	0.090	3.50	2.40	6.88
1096	20.0	157.0	33.6	0.089	3.20	2.40	3.92
1098	35.0	208.0	25.5	0.099	2.40	2.40	6.90
1100	46.0	209.0	25.4	0.105	1.40	2.40	7.84
1101	24.0	173.0	30.6	0.073	4.20	2.40	2.46
1103	32.0	190.0	27.9	0.094	2.90	2.90	5.43
1105	30.0	192.0	27.5	0.104	3.10	2.90	5.44
1107	53.0	265.0	20.0	0.134	1.10	3.40	11.83
1202	25.0	160.0	33.1	0.081	3.80	2.40	3.91
1206	37.0	193.0	27.4	0.100	3.00	2.90	7.84
1208	40.0	211.0	25.1	0.090	1.50	2.40	5.88
MEAN	30.3	189.0	28.4	0.091	2.97	2.56	5.50
NO.	15						

A.M. operation

- 21.3 m.p.h. in both directions
- a relative poor quality of flow as reflected by Greenshields Index and mean velocity gradient
- 2.21 stops per mile

P.M. operation

- 19.6 m.p.h. in both directions
- poor quality of flow
- 2.5 stops per mile

Each table gives the present conditions on one link for A.M. or P.M. operation.

3.0 CONTROL STRATEGIES

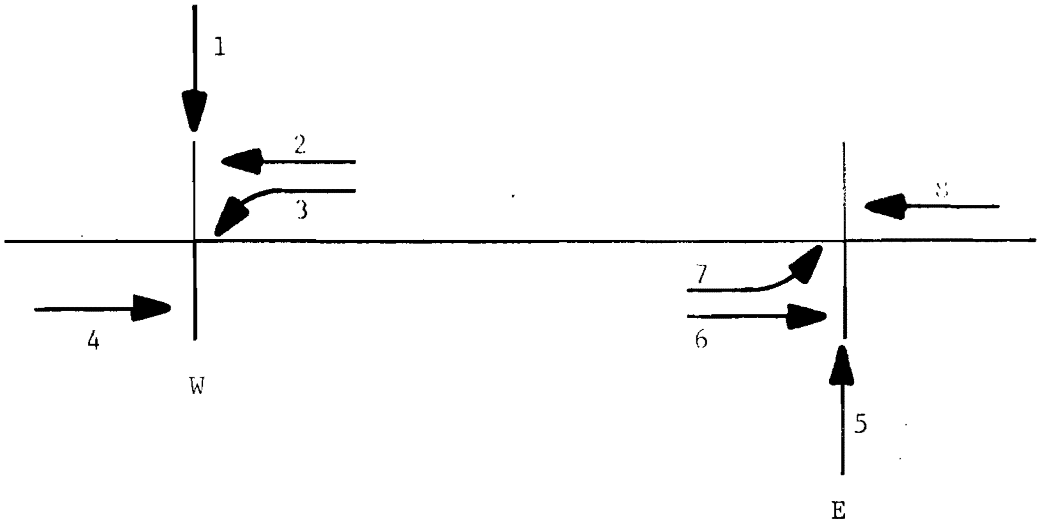
3.1 Isolated Control

For isolated operation, the diamond interchanges are thought of as two three-phase intersections located a short distance apart with a predetermined offset between them. The signal phasing that will be used is the common four-phase with overlaps. This phasing is particularly applicable where u-turn bays are present and usually results in no standing on the crossover.

The phasing configuration will be as shown in Figure 3.1. The length of the offset, ϕ, for both directions will be constant for each particular intersection. Conditions to consider in establishing the offset are (1) travel time from one frontage road to another, (2) amount of traffic turning left off the bridge or underpass, and (3) observed operation.

One stage of isolated control is operation of the "back-up controller." This controller must necessarily be simple so that it can be self-contained within the actuator at the intersection. The phasing will be as shown in Figure 3.1 with a set of minimums and maximums assigned to each movement. Movements 1, 4, 5 and 8 will be used to extend the phases associated with each movement. Phase 2 and 5 will be constant to account for the offset. With the back-up controller in use, only the stopline detectors for movements 1, 4, 5 and 8 will be used. A short extension related to the detector location will provide sharp movement cutoff. As there will be no interconnect when using the backup, each intersection will be allowed to float with the current traffic conditions.

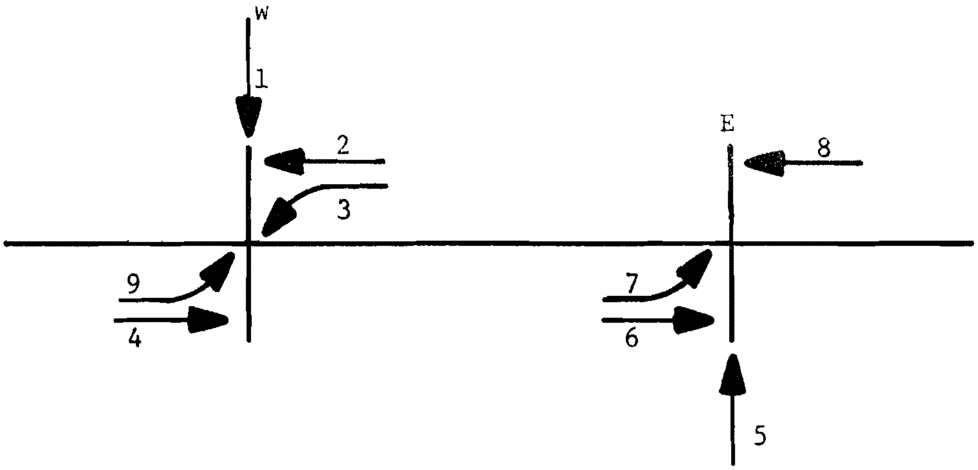
There is one special condition at Forest and Central. The movements for the Forest interchange are shown in Figure 3.2 along with the phasing. The conditions at Royal Lane will be handled much like a standard frontage road inter-



TIME

WEST SIDE (w) PHASING	INTERVAL LENGTHS	EAST SIDE (e) PHASING	PHASE NO.
4, 2	ϕ_4	5	2
2, 3	$g_{e5} - \phi_4$	5	1
2, 3	$g_{e8} - \phi_8$	6, 8	6
1	ϕ_8	6, 8	5
1	$g_{w1} - \phi_8$	7, 6	4
4, 2	$g_{w4} - \phi_4$	7, 6	3

FIGURE 3.1 PHASING AND PHASE LENGTH



FOREST AND NORTH CENTRAL

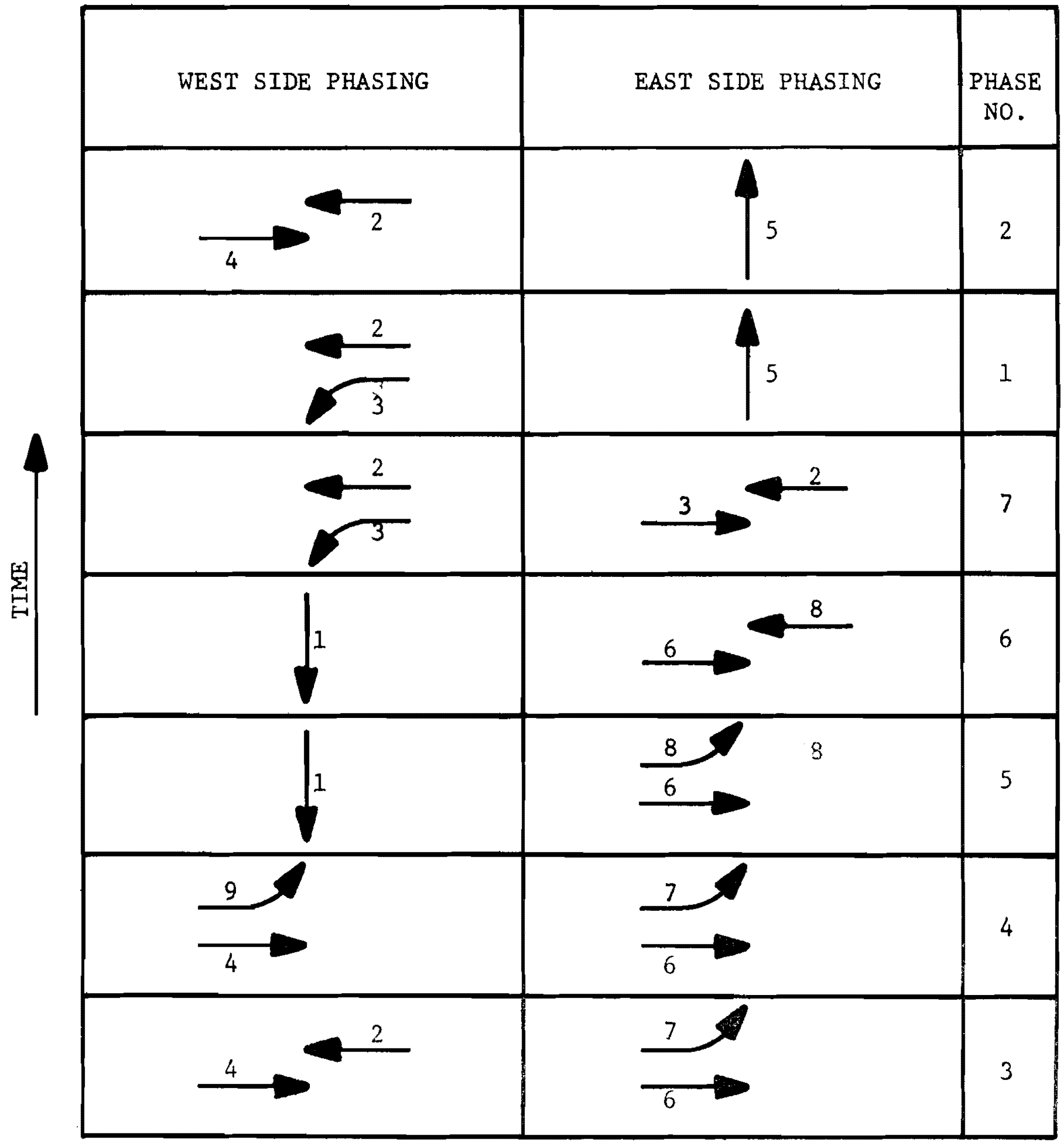


FIGURE 3.2 PHASING FOR FOREST
AND CENTRAL

section. However, movements 1, 4 and 5 will be used to extend the green with movement 8 given a fixed minimum. (See Figure 3.1).

The second stage of isolated control will use the approach volume detectors. As discussed in this report, the frontage road is on the edge between being classed as principally for movement or principally for access. A major function of the approach volume detection will be to optimize the operation between that of movement and/or access.

At present, even without driver information signing on the freeway, diversion takes place from the freeway to the frontage road when a stoppage occurs. Under these conditions, the frontage road should act as a system from the location of the stoppage to some point upstream.

An automatic freeway stoppage detection system is being tested now. The procedure locates rapidly changing flow rates and low speeds.

The volume detection on the service road will be used to manage this diversion by changing the frontage road from isolated operation to system operation.

3.2 System Operation

While operating as part of a system, the cycle length at each intersection must be held constant or varied the same throughout the system under consideration. To maintain a cycle with offsets, ϕ_4, ϕ_8, the following green movement requirements must be satisfied:

(1) $g_{w3} + g_{e7} = c - \phi_4 - \phi_8$

(2) $g_{w3} + g_{w4} + g_{w1} = c$

(3) $g_{e7} + g_{e8} + g_{e5} = c$

where the subscripts 'w' and 'e' of the green movements refer to the west and east side intersections, c is the cycle length, and ϕ_4 and ϕ_8 are the eastbound and westbound offsets respectively. As mentioned above, ϕ_4 and ϕ_8 are fixed for any one intersection which will also fix the sum of the two left turns in equation (1). The latter two requirements are such that at each intersection the sum of the three non-conflicting movements must add to the cycle length (See Figure 3.1).

The control objective is then to provide progression down one side of the frontage road or the other and at the same time compute the phase lengths such that progression through the intersection will be attained in both the east and west directions. To accomplish progression through the intersection, the cycle length is determined from the approach detection for movements 1, 4, 5 and 8, and then left turns are computed to satisfy equation (1) above. The east side left turn movement green, g_{e7}, is computed from

$$g_{e7} = \frac{S_{w4} + S_{w1}}{S_{w4} + S_{w1} + S_{e8} + S_{e5}}$$

where S_{w4} is the demand/capacity ratio of the west movement 4, etc. This left turn green time must fall within the following bounds

$$g_{w4\ min} + g_{w1\ min} - \phi_8 - \phi_4 \leq g_{e7} \leq$$
$$c - g_{e8\ min} - g_{e5\ min}$$

to insure adequate time for the remaining movements at the two intersections after the left turn at each intersection is computed.

When providing progression along one frontage road, the demands in that direction will be larger in proportion to the opposite side demands. In the case of larger west side demands, the east side left turn, g_{e7}, will be correspondently larger. As a consequence, from equation (1), it is apparent that the west side left turn will be small permitting a relatively larger west side frontage road time, g_{w1}. After the left turns are computed, the cycle is proportioned to the other movements as needed.

The offsets and system cycle lengths will be determined with the progression program developed on the Mockingbird Pilot Study. That program is presented in the report "Arterial Progression Control As Developed On The Mockingbird Pilot Study." Extensive redesign of the program's organization will be required to convert it from a research tool to an operational system; however, the decision making procedure will remain the same.

3.3 Response To Freeway Conditions

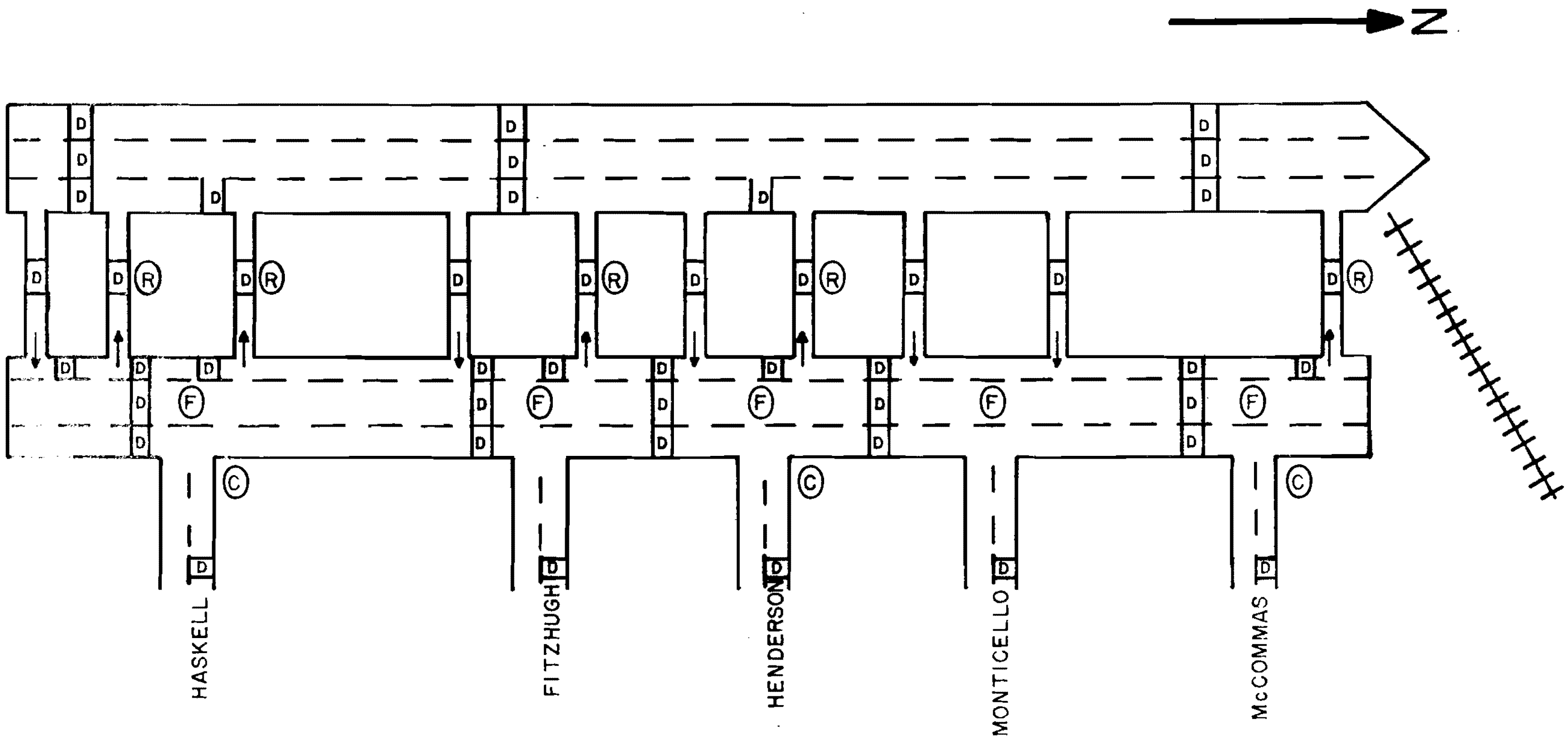
Thus far, control objectives in the Dallas North Central Expressway Corridor have been restricted to what could, or could not be done, with traffic as it entered the freeway. After the traffic was on the freeway, or if the traffic left the freeway for any reason, the control engineer's "hands were tied." However, with Phase II frontage road control, one can in a real sense start planning to manage traffic in much the same way one would manage a pipeline system where reserve capacity and/or bypass capacity is available when needed.

Figures 3.3 and 3.4 depict two of the six freeway-frontage road subsystems in the North Central Expressway Corridor. It is within these reticulations that effective traffic management is possible. Points of control are shown with either a Ⓡ for ramp signls or Ⓕ for frontage road signals. Points of detection are shown with a [D] . CCTV, © , will be useful in observing operation and verifying traffic flow characteristics displayed by the control system.

The northbound subsystem in Figure 3.3 is characterized by a freeway off-ramp in each block of the frontage road. This will allow diversion from the freeway at any point from Haskell to McCommas. The southbound subsystem in figure 3.4 has similar geometric characteristics except between McCommas and Monticello. This will create a heavy load on the off-ramp before McCommas in the event of freeway stoppage upstream of Henderson.

There are two types of diversion that can take place from the freeway to the frontage road. The diversion can be driver response from an observed condition or driver response from a driver information device such as road side radio. The first type of diversion requires that the control engineer be aware

SCHEMATIC OF HASKELL-McCOMMAS NORTHBOUND FREEWAY-FRONTAGE ROAD SUBSYSTEM



D DETECTOR

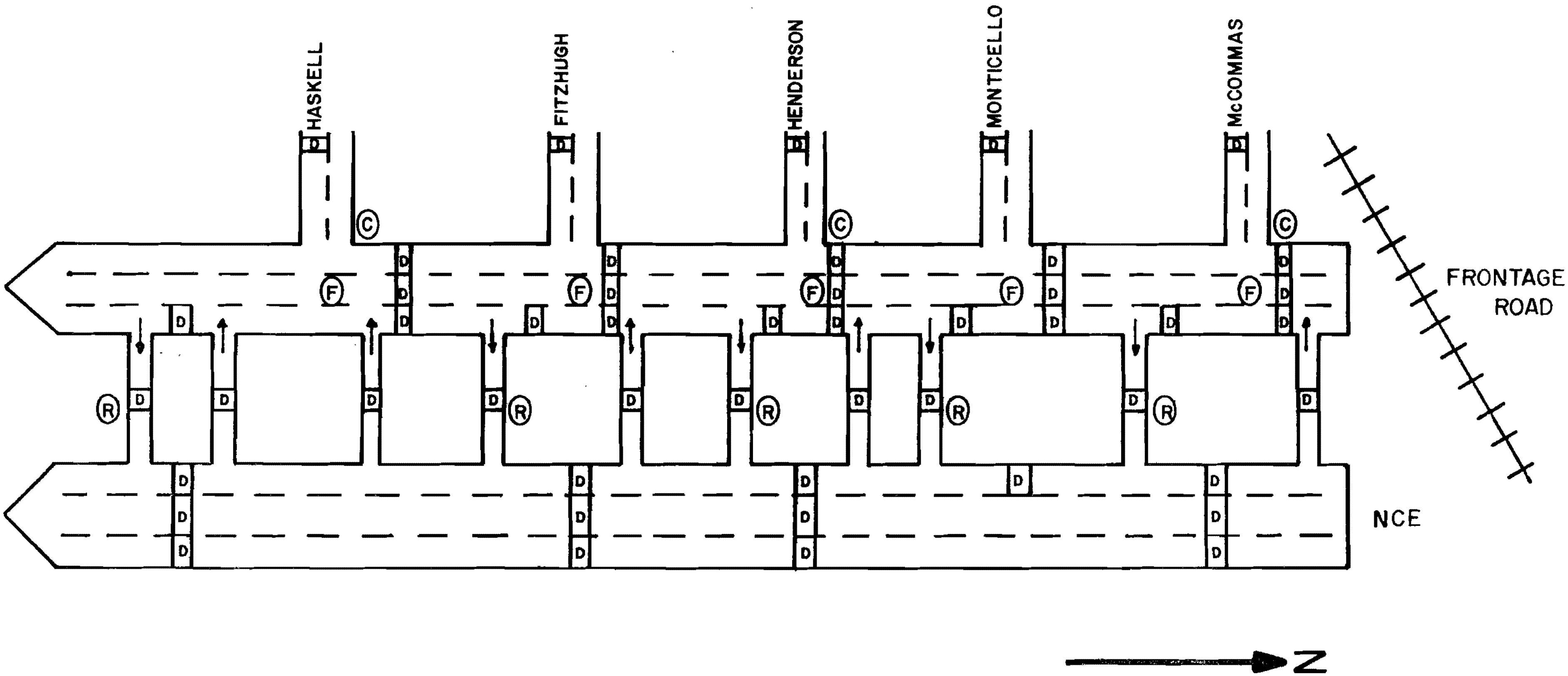
R RAMP SIGNAL

F CONTROLLED FRONTAGE ROAD SIGNAL

C CCTV

FIGURE 3.3

SCHEMATIC OF McCOMMAS-HASKELL SOUTHBOUND FREEWAY-FRONTAGE ROAD SUBSYSTEM



D DETECTOR

R RAMP SIGNAL

F CONTROLLED FRONTAGE ROAD SIGNAL

C CCTV

FIGURE 3.4

of a stoppage on the freeway and the subsequent diversion. There is no control in this case over the amount of diversion. The second type assumes that the stoppage is known and that some action is being taken. In this case, a limited amount of control over the extent and location of the diversion is possible. Either through direct (driver information devices) or indirect (frontage road signal timing) controls, the frontage road will be operated as standby capacity, not just three more lanes of freeway.

Table 3.1 presents several levels of operation for the freeway. The management policy will be to direct or take care of diversion in such a way as to balance the level of service on the freeway and the frontage road. In-other-words, if the frontage road's capacity is not needed, cross street operation will be optimized. However, if there is a stoppage on the freeway that can be helped by the frontage road, the level of service on both the freeway and frontage road will be balanced to optimize all trips through that subsystem.

3.4 Response To Special Vehicles

In addition to control techniques described above, certain considerations may be given to special vehicles, i.e.: transit vehicles. The concept of favoring buses over private vehicular traffic has been expanded in various technical reports. The rationale for this concept is to move people as opposed to vehicles during the peak periods. The average private vehicle occupancy in the North Central Corridor is 1.2 persons per vehicle. The occupancy of buses is considerably higher and with improved operation and service, this form of transportation could become more attractive to the travelling public.

TABLE 3.1

FREEWAY LEVELS OF OPERATION

SPEEDS (MPH)	1 MINUTE FLOW RATES 2-LANE	3-LANE	L.O.S.
0-20	72≤	105≤	Level F2
21-29	67-71	100-104	Level F1
30-34	63-66	95-99	Level E2
35-39	60-62	90-94	Level E1
40-44	55-59	85-89	Level D2
45-49	50-54	80-84	Level D1
50-54	34-49	60-79	Level C
55-59	24-33	40-59	Level B
≥60	0-23	0-39	Level A

In conjunction with the corridor project, a demonstration project is planned to provide priority treatment of buses at urban intersections. Under this project, selective vehicle detectors will be installed on intersection approaches to detect the presence of a bus. Based on this information, the phase will be extended for a period of time to allow the bus to pass through the intersection. Should the cycle be in cross street green, the phase will be terminated early to allow an advance green to the bus approach.

4.0 EVALUATION PLAN

A detailed evaluation plan for the frontage road system will be developed at a later date. Basically, this evaluation will consider the areas listed below.

4.1 Isolated Intersection

Microscopic evaluation of key individual intersections will be performed. Analyses may include input/output studies; delay studies; and accident studies.

4.2 System Operation

Macroscopic evaluation will be accomplished primarily with moving vehicle analyses. Quality of flow indications will be determined for travel through the system. Factors to be considered may include: travel time; Greenshields Index; stopped time; progression efficiency; number of brake applications; and/or acceleration noise.

4.3 Response To Freeway Conditions

Freeway flow and volume data will be routinely logged and analyzed where diversion to the frontage road is encouraged. Relative levels of service provided by the two facilities will be determined for normal and incident influenced days.

5.0 SUMMARY

The preceding chapters have presented a strategy for control of fifteen (15) frontage road intersections along North Central Expressway in Dallas, Texas. Strategies for isolated operation; system operation; and response to freeway conditions have been presented.

The computing, detection and communication equipment are being installed to accomplish these objectives. Software is under development.

Prior to initiating control, an evaluation of existing traffic operational conditions will be accomplished. During control, additional studies will be carried out to evaluate the effectiveness of various control policies.