MINNESOTA DEPARTMENT OF TRANSPORTATION

TRAFFIC ENGINEERING

"Improved Transportation Through Research"

EVALUATION OF THE I-694 TRAFFIC MANAGEMENT SYSTEM

MARCH 1985

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16. Abstract

Mn/DOT (Minnesota Department of Transportation) activated a traffic management system on a three mile section of I-694 in August 1980. System elements include vehicle detectors, ramp control signals, a changeable message sign, and monitor and display devices.

Evaluation of this system was complicated by a reconstruction project on I-694. Study results showed that there were improvements in traffic flow and accident experience even though peak period volumes increased substantially. These improvements are attributed to the combined effects of the traffic management system and the reconstruction project.

Despite the improvements, there is a need for additional capacity in the I-694 corridor, and projects intended to accomplish this are briefly described.

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EVALUATION OF THE

I-694 TRAFFIC MANAGEMENT SYSTEM

Report No. MN/TE-85/01

Minnesota Department of Transportation
Office of Traffic Engineering
Traffic Management Center
March 1985

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SUMMARY

This report presents an evaluation of the I-694 Traffic Management System which was activated in August 1980. The system extends along a three mile section of I-694 in Brooklyn Center and Fridley, and includes 100 loop detectors, nine ramp control signals, and one changeable message sign. This system operates remotely via field based microprocessors, but is interconnected to the Traffic Management Center (T.M.C.) via state-owned cable.

Evaluation of this system was complicated by a reconstruction project on I-694 west of the Mississippi River Bridge. Reconstruction was in progress between 1980 and 1982, and resulted in additional capacity for east and westbound traffic west of the bridge. Evaluation items include volumes, speeds, delays, accident experience, and ramp meter violation rates. "Before" data was collected during 1978 and 1979, and "after" data was collected during 1982 and 1983. Following is a summary of the key study results and conclusions for the project.

- Traffic flow improvements included an increase in operating speeds in both directions during A.M. peak periods, and for westbound traffic during P.M. peak periods. Demand continues to exceed capacity for eastbound traffic during P.M. peak periods, resulting in a slight decrease in operating speeds.

- Peak period volumes increased substantially during the study period - as much as 42% at some detector locations.

- There was a 36% reduction in the number of peak period accidents, resulting in a 44% reduction in the peak period accident rate.

- The improvements described above can be attributed to the combined effects of the traffic management system and the capacity increase west of the Mississippi River Bridge.

- Ramp meter queuing created problems at several locations, but geometric and operational revisions made subsequent to the evaluation study have improved this situation. Driver compliance to the ramp control signals is over 97%.

Despite the improvements in traffic flow and accident experience, there is a need for additional capacity in the I-694 corridor. A new river crossing (TH 610) several miles north of I-694 is currently under construction. This project, scheduled for completion in late 1987, will provide a more convenient alternate route than is currently available. Also, a project to add a lane in each direction on I-694, between the river bridge and I-35W, is programmed for an October 1986 letting date.

I. INTRODUCTION

On April 9, 1974, the first computerized Traffic Management System (T.M.S.) in the state of Minnesota was activated, controlling a seventeen mile section of I-35W from downtown Minneapolis to Co. Rd. 42 in Burnsville. Operation of this system has been successful in increasing operating speeds, reducing delays, and improving levels of service throughout the section. A number of reports on the design, operation, and maintenance of this system have been published, and are listed in the Appendix of this report.

The experience gained and the results achieved from the I-35W T.M.S. provided a solid foundation for the planning and implementation of a similar system on a section of I-694 in the Cities of Brooklyn Center and Fridley in Hennepin and Anoka Counties. The I-694 system was activated on August 28, 1980, and has been operated successfully for over four years. The system was intended to optimize traffic flow by regulating access to the freeway with entrance ramp control, improving response to incidents with an incident detection system, and supplying motorist information through the changeable message sign - resulting in stabilized volumes, speeds and travel times, and improved merging operations from the entrance ramps.

This report presents "before" and "after" comparisons of traffic flow characteristics and summarizes the operational experience for the last four years so that system accomplishments and limitations may be better understood. Included is an analysis of volumes, travel times and operating speeds, mainline and ramp delays, violation rates and accidents. System operation and maintenance costs were also analyzed.

Due to geometric changes made on I-694 between 1980 and 1982, direct and meaningful comparisons of certain rebuilt sections of the freeway becomes difficult. In an attempt to alleviate this problem, data is not always presented in a standard format, but rather, with some modifications made to aid the reader in comprehension and comparison. These modifications will be discussed in detail in the body of the report.

II. SITE DESCRIPTION

Interstate Highway 694 comprises the northern and northeastern portions of the beltline loop around the Minneapolis-St. Paul Metropolitan Area. The approximate five mile section studied passes through the Cities of Brooklyn Center, Fridley, and New Brighton, crossing the Mississippi River, and is the major freeway utilized by persons living or working in these suburbs (Figure 1). Alternate routes are possible for short trips within the limits of the section, but are inconvenient at the Mississippi River Bridge since no other river crossings exist within two miles of I-694.

Figures 2 and 3 show the geometry of I-694 as it existed in 1980 and in 1983, respectively. I-694 is primarily a four lane freeway, with auxiliary lanes present at several locations between entrance and exit ramps. Following are problem areas and distinguishing features, as defined for 1980 conditions:

Eastbound

~ The Burlington Northern Railroad (B.N.R.R.) Bridge over I-694, between East River Road and TH 47 (University Avenue) psychologically reduces the capacity of the freeway. This psychological reduction in capacity is a result of reduced shoulder width and massive bridge walls beneath the B.N.R.R. Bridge.

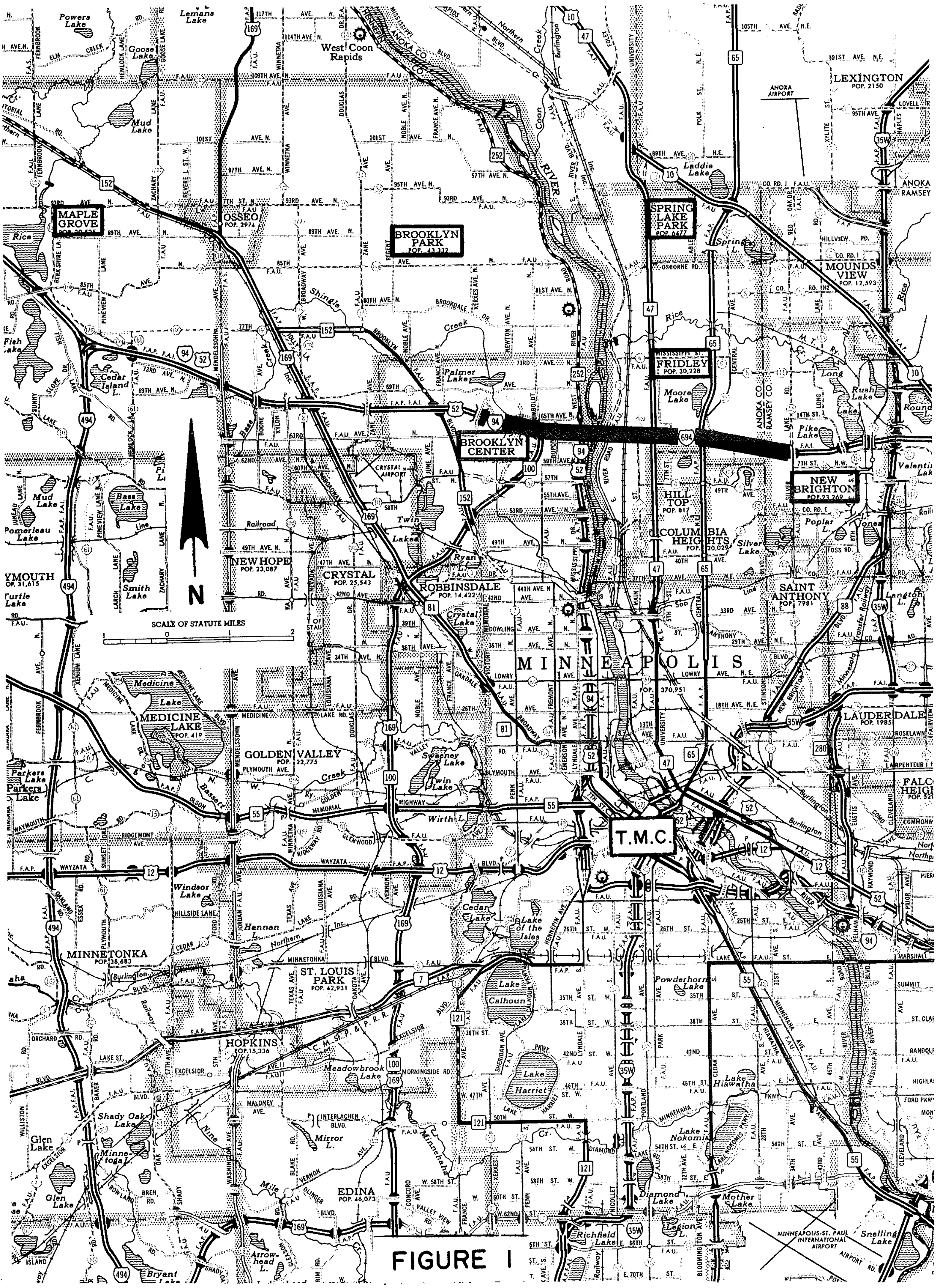
~ The mainline volume, between East River Road and TH 47, reaches capacity during the A.M. Peak Hour.

~ An extremely high percentage of commercial vehicles (16.65%, 1975 data), combined with a very long vertical grade (an average of 2.1% over 8900 feet), substantially reduces the capacity of the freeway. The grade change becomes most significant in the area between TH 65 (Central Avenue) and Silver Lake Road (2-3%).

Westbound

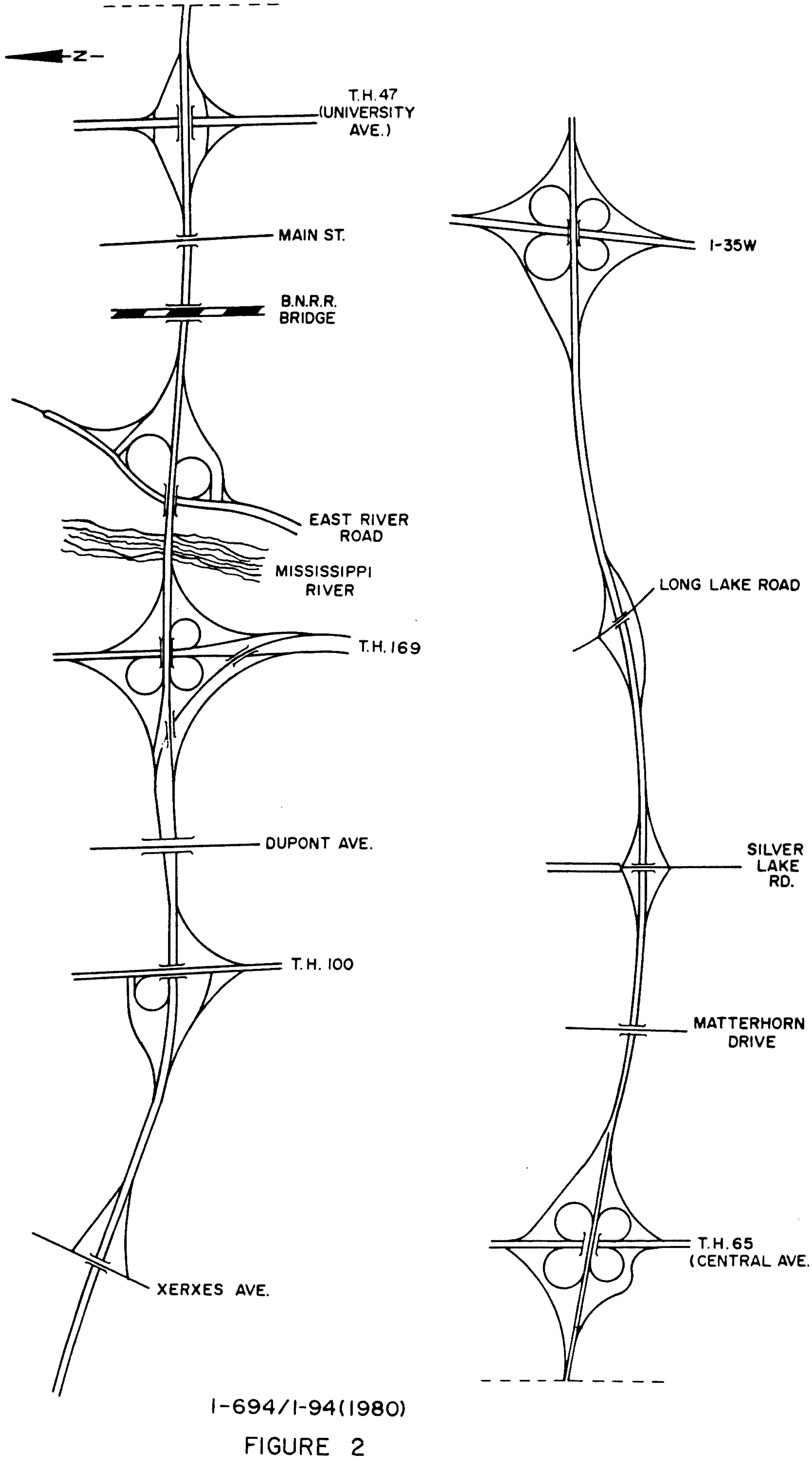
~ Large platoon volumes entering westbound I-694 from TH 47 during the peak periods create a hazardous and sometimes extremely difficult merging situation. This merging problem often results in standing shockwaves on the freeway.

~ The B.N.R.R. bridge psychologically reduces the capacity of westbound I-694 as described under the eastbound conditions.



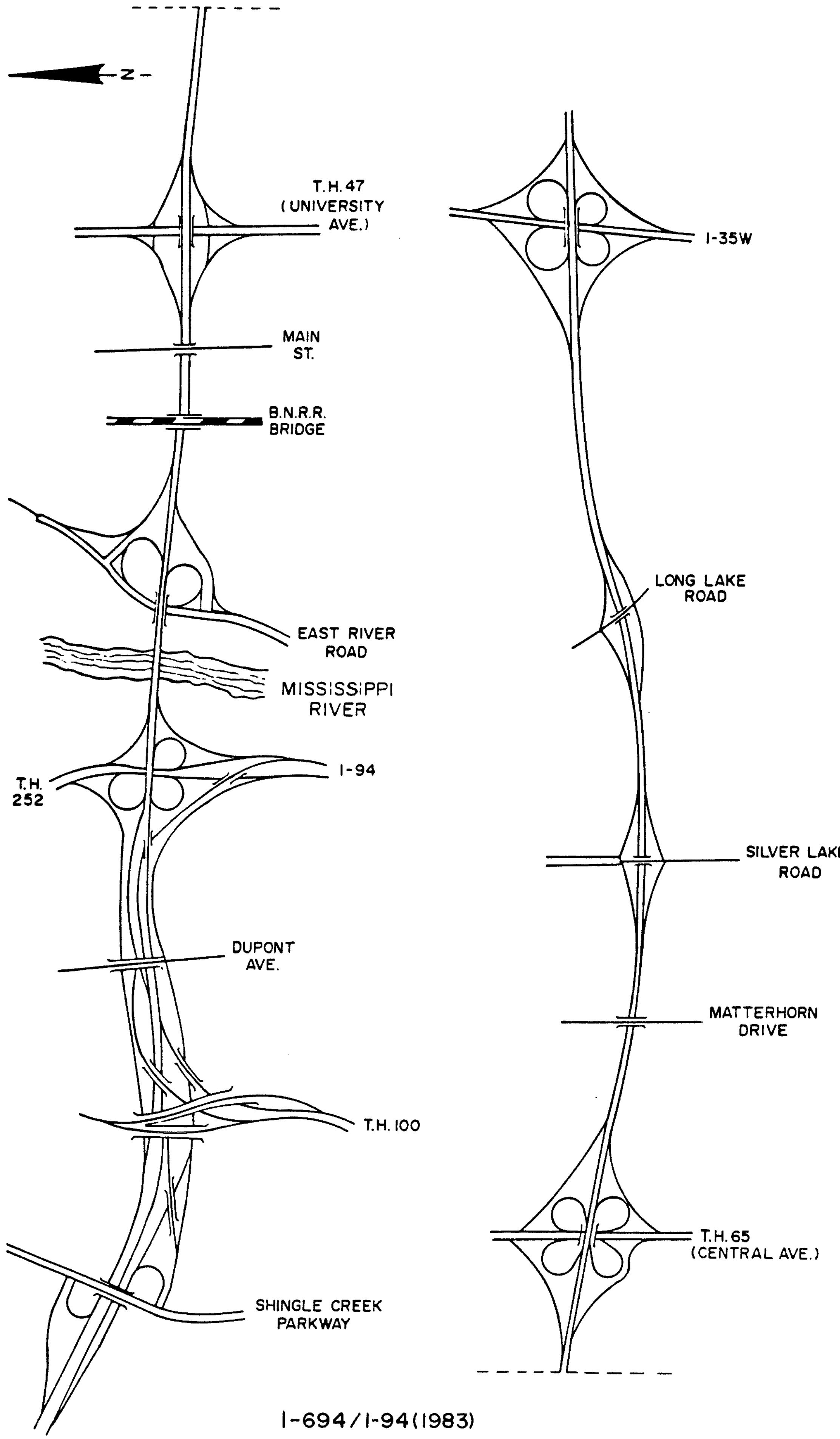
MAPLE GROVE
OSSEO
POP. 2974
BROOKLYN PARK
POP. 43,332
West Coon Rapids
LEXINGTON
POP. 2150
SPRING LAKE PARK
POP. 6477
MOUNDS VIEW
POP. 12,593
FRIDLEY
POP. 30,228
BROOKLYN CENTER
NEW BRIGHTON
NEW HOPE
POP. 23,087
CRYSTAL
POP. 25,543
ROBBINSDALE
POP. 14,422
HILL TOP
POP. 817
COLUMBIA HEIGHTS
SAINT ANTHONY
POP. 7981
MINNEAPOLIS
POP. 370,951
LAUDERDALE
POP. 1985
MEDICINE LAKE
POP. 419
GOLDEN VALLEY
POP. 22,775
T.M.C.
MINNETONKA
POP. 38,683
ST. LOUIS PARK
POP. 42,931
HOPKINS
POP. 15,336
EDINA
POP. 46,073
ANOKA CO.
RAMSEY CO.
ANOKA AIRPORT
CRYSTAL AIRPORT
MINNEAPOLIS-ST. PAUL INTERNATIONAL AIRPORT
N
SCALE OF STATUTE MILES
1 0 1 2

FIGURE I



I-694/I-94(1980)

FIGURE 2



I-694/I-94 (1983)

FIGURE 3

- The mainline volume between TH 47 and East River Road reaches capacity for the majority of the P.M. peak period (3-7 P.M., 1975 data).

- Large volumes entering from East River Road, heavy mainline flow, large exiting volumes at TH 169 and TH 100, and restricted shoulders on the Mississippi River Bridge combine to create a bottleneck from East River Road to TH 100.

It should be noted that 1975 capacity flow (A.M. eastbound, P.M. westbound) gravitates toward I-35W as the focal point of this section of freeway. Prior to 1983, I-35W was the primary access, and the only freeway access into downtown Minneapolis from the northern suburbs. On November 22, 1982, the section of I-94 from downtown Minneapolis to I-694 was completed and opened to traffic. The opening of I-94 has greatly altered traffic patterns on I-694. Because of its capacity and its efficiency, eastbound I-94 has become a more popular inbound route, attracting drivers from as far east as TH 65. However, a large volume of inbound traffic continues to utilize I-35W, creating a "double peak direction" on I-694 in both the A.M. and P.M. peak periods.

Westbound I-94 from downtown runs almost due north and extends to I-694, where they become concurrent. Old TH 169 north of I-694 has become TH 252. The interchange was not reconstructed, but the highway was renumbered. "TH 169" is now being used for the highway previously known as TH 52, and lies to the west of the study section. Although the interchange at TH 169/I-94/TH 252 remains intact, a lane was added on mainline I-694 to increase capacity west of the interchange.

Other significant geometric changes in this area include the closing of the Xerxes Avenue Interchange, the addition of an interchange with Shingle Creek Parkway, the complete revamping of the interchange with TH 100, and eastbound I-94 was separated from eastbound I-694 at a point just east of the Xerxes Avenue Bridge. The addition of this separate road has had a significant impact on volume counts near the I-94/TH 252 interchange. Whereas in 1980, all vehicles exiting to southbound TH 252 were included in volume counts at points prior to the exit, these same vehicles in 1983 have already left the I-694 mainline at the I-94 exit, and are not reflected in 1983 volumes.

III. SYSTEM DESCRIPTION

This T.M.S. encompasses a 3.12 mile section of I-694 and includes changeable message signing, entrance ramp control, and incident detection operating remotely from but tied to the Mn/DOT T.M.C. in Minneapolis via a State owned interconnect cable.

The system operates in a multi-level distributed configuration and uses design and communications techniques appropriate for a total metropolitan T.M.S.

The major objectives of the system are to respond in real time to changes in the traffic stream, implement corrective action by controlling access to the freeway, alert State Patrol personnel to capacity reducing incidents, and provide information to motorists.

Basic principles of the I-35W system common to the I-694 system, and detailed descriptions of T.M.C. facilities can be found in previously published reports listed in the Appendix. Described below are the facilities and procedures unique to the I-694 T.M.S. and the elements of the pre-existing system that are incorporated into the I-694 System.

A. I-694 Subsystem

Included in the I-694 subsystem are 100 loop detectors, nine metered ramps (three westbound and six eastbound), and one westbound changeable message sign. The mainline loop detectors are used for collecting lane volume data, lane occupancy data, vehicle speeds and vehicle classification data. The ramp loop detectors are used for indicating ramp demand, for special turn-on logic, and for measuring traffic input and output to the section of freeway being managed. As shown in Figure 4, the data collection and metering control of the nine entrance ramps are handled by six ramp controllers (devices A-F). Control of the changeable message sign is handled by a sign controller (device S).

SYSTEM BLOCK DIAGRAM

(COMMUNICATIONS MODEMS NOT SHOWN)

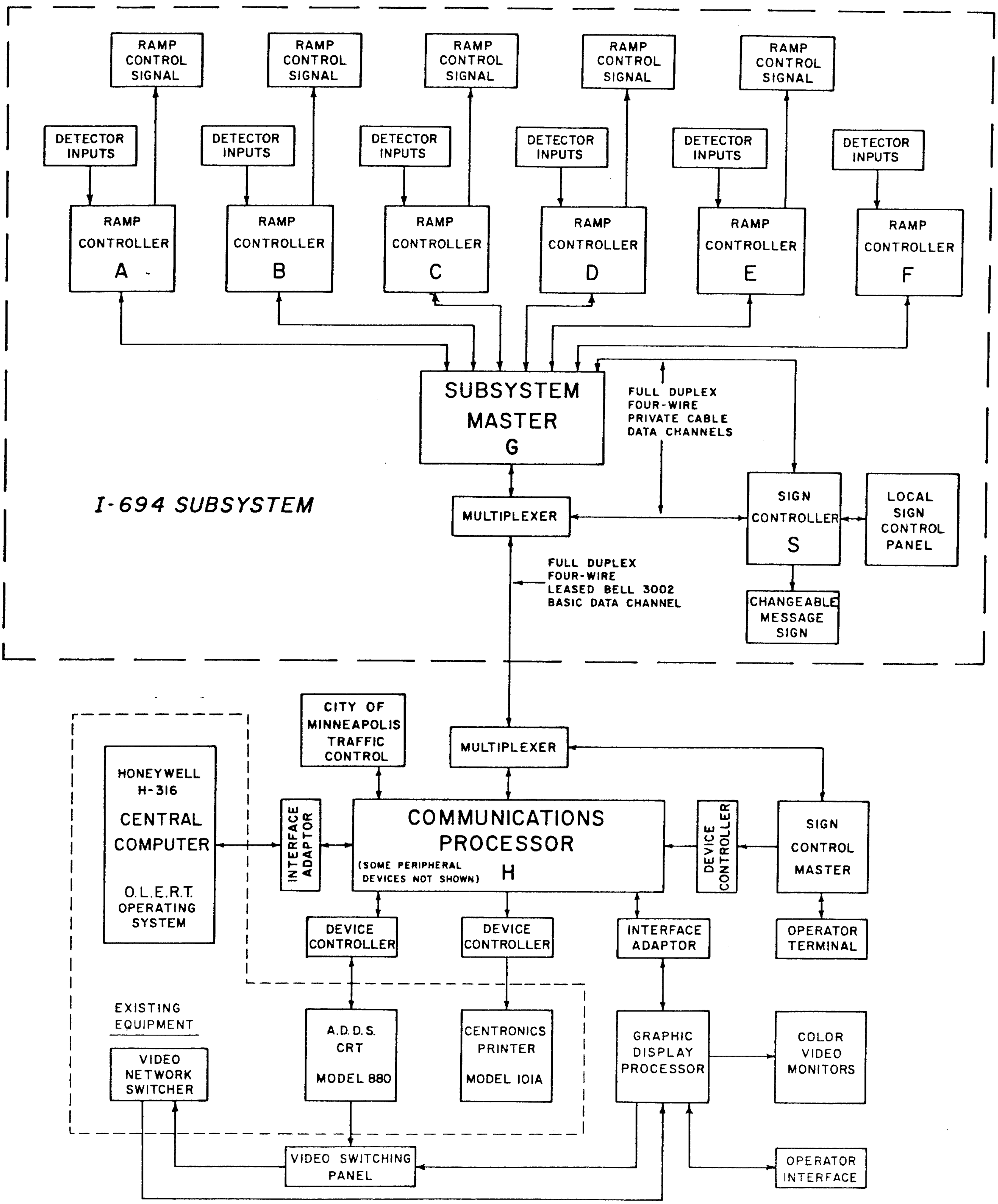


FIGURE 4

B. Operating Overview

Ramp Control

The data collection and metering control of the nine entrance ramps is handled by six ramp controllers. The control of the changeable message sign is handled by a separate sign controller. Each of the ramp controllers is capable of either isolated or supervised operation and simultaneous but independent control of two entrance ramps.

Under normal operating conditions all of the controllers are monitored by a separate controller, the subsystem master, which makes system-wide decisions and sends metering rate override commands to the ramp controllers when appropriate. Using the system-wide data from the ramp controllers, the subsystem master also selects an appropriate message to be displayed on the changeable message sign. This determination is sent to the sign controller which drives the sign. Finally, the subsystem master acts in a data-switching capacity, sending all traffic data back to the T.M.C. to be routed to the appropriate device. The system does, however, continue to function independently upon loss of the T.M.C. data channel.

Changeable Message Sign Control

The changeable message sign, located at Matterhorn Drive, is capable of providing up to three lines of message to the westbound motorists with advance information on traffic flow conditions, roadway incidents, and construction and maintenance activities which allows motorists sufficient time to respond or avoid the situation. A typical sequence of messages might include something as follows: "CONGESTION", "AT UNIVERSITY", "PREPARE TO STOP".

The message lines consist of 16 individual disk-matrix modules capable of displaying alphanumeric characters readable from a minimum distance of 800 feet. The messages are capable of a flashing operation which alerts the driver well in advance of the 800 foot minimum viewing distance. Control of the changeable message sign may originate from local, subsystem or central levels.

Graphic Display

The graphic map display is a tool to give the operator at the T.M.C. a visual picture of freeway traffic flow conditions. The primary function of this equipment is to receive data and commands from the communications processor and generate map displays which show status of the freeway with colored segments representative of traffic conditions.

The map displays consist of two color video monitors, either of which is capable of displaying any of 6 maps with detector, lane control signal, and sign status as selected by the operator. The data base used to update the monitors is made up of the data from the I-694 subsystem and data from subsystems controlled from the T.M.C. The monitors are updated with real-time information every 30 seconds.

In addition to the traffic status on the I-694 display, alphanumeric information about the current metering rates, traffic volume and occupancy, sign status, and equipment malfunctions on the I-694 subsystem are displayed to the operator. Using keyboard entries on a CRT terminal, the operator is able to exercise central control of the I-694 subsystem ramp and sign activities by inputting an override. The command is then transmitted to the subsystem master via the communications processor and communications cable and used by the appropriate controller.

C. Incorporated Elements

Traffic Management Center

The T.M.C. was constructed in 1972 as the central control facility for the I-35W and I-94 traffic management systems, with space available for ultimate expansion of traffic management to the entire urban freeway network. The I-694 T.M.S. represents a portion of this expanded control network.

The T.M.C. is located at 1101 4th Avenue South, on the southeast edge of the Minneapolis Central Business District. It is a two story building with approximately 5,000 square feet of space on each level. Housed on the upper level are the central computer facility, operations room, and staff for system administration and operation. The lower level houses staff support facilities including utilities, communications room, an electronic repair shop, and work space for supervisory and design staff.

Cathode Ray Terminal (CRT)

A system CRT is located in the Operations Room. It is used by traffic control operators to communicate with the computer to gain detailed information on traffic flow conditions, and to input commands to the I-694, I-94 and I-35W systems.

Radio Scanner

A radio scanner with the capability to scan State Patrol, City Police and Mn/DOT construction and maintenance radio frequencies is located in the control room.

T.M.C. Maintenance Radio

All T.M.C. vehicles are equipped with radios with capability to communicate with the T.M.C. control room operators at an assigned frequency. If any incident is observed by the staff it is relayed to the operator for proper response.

State Patrol & City Police

The control room is connected to the State Patrol dispatcher via a two way leased "hot line", while conventional telephone is used to communicate with various city police departments. Serious incidents and possible safety problems detected by the T.M.C. are relayed to the State Patrol dispatcher, who may also contact the control room to either notify or verify independently reported incidents.

Commercial Radio

The T.M.C. provides traffic information to several metropolitan area radio stations via a direct phone line hookup to station news rooms. Routine reports on traffic flow conditions, including the traffic condition "grades", are given at periodic intervals, and severe incidents are reported as soon as they are detected.

IV. EVALUATION OF SYSTEM OPERATION

System evaluation results have been developed utilizing "before" and "after" comparison of traffic flow conditions on I-694 in 1980 and 1983. To summarize the operational experience of the system over the past four years, peak period data were gathered for the following evaluation items:

- Mainline & Ramp Volumes
- Freeway Travel Times and Operating Speeds
- Spot Speeds
- Mainline and Ramp Delays
- Accidents
- Violations

In addition, system operation and maintenance costs were analyzed.

A. Volumes

Volume data was collected in August of both 1980 and 1983 by means of computer linked loop detectors which record the volume counts on every five minute interval. The 1980 counts were taken before the ramp control system was in operation. Data was recorded in the A.M. from 6:00-9:00, peak hour being 7:00-8:00 A.M., and in the P.M. from 3:00-6:00, peak hour being 4:00-5:00 P.M. Data from approximately five different days, (with the exclusion of Monday mornings and Friday afternoons because of their atypical volume patterns) was averaged to find a mean volume at each location.

The bar graphs of Figures 5 and 6 show the mainline volumes and percentage change in volume for seven areas along I-694. In the four year study period, volumes have increased everywhere with the exception of both eastbound and westbound A.M. volumes in the TH 100 - eastbound I-94 (252) link. The volume reduction in this particular link can be attributed to the fact that many cars counted in previous years currently bypass this link due to the opening of the westbound I-694 to eastbound I-94 interchange, the separation of I-694 and I-94 west of the counting stations, and the closing of the eastbound Xerxes Avenue entrance as discussed earlier in the site description. The general volume growth along I-694 is a direct consequence of the ex-

% CHANGE IN VOLUME(1980-83)

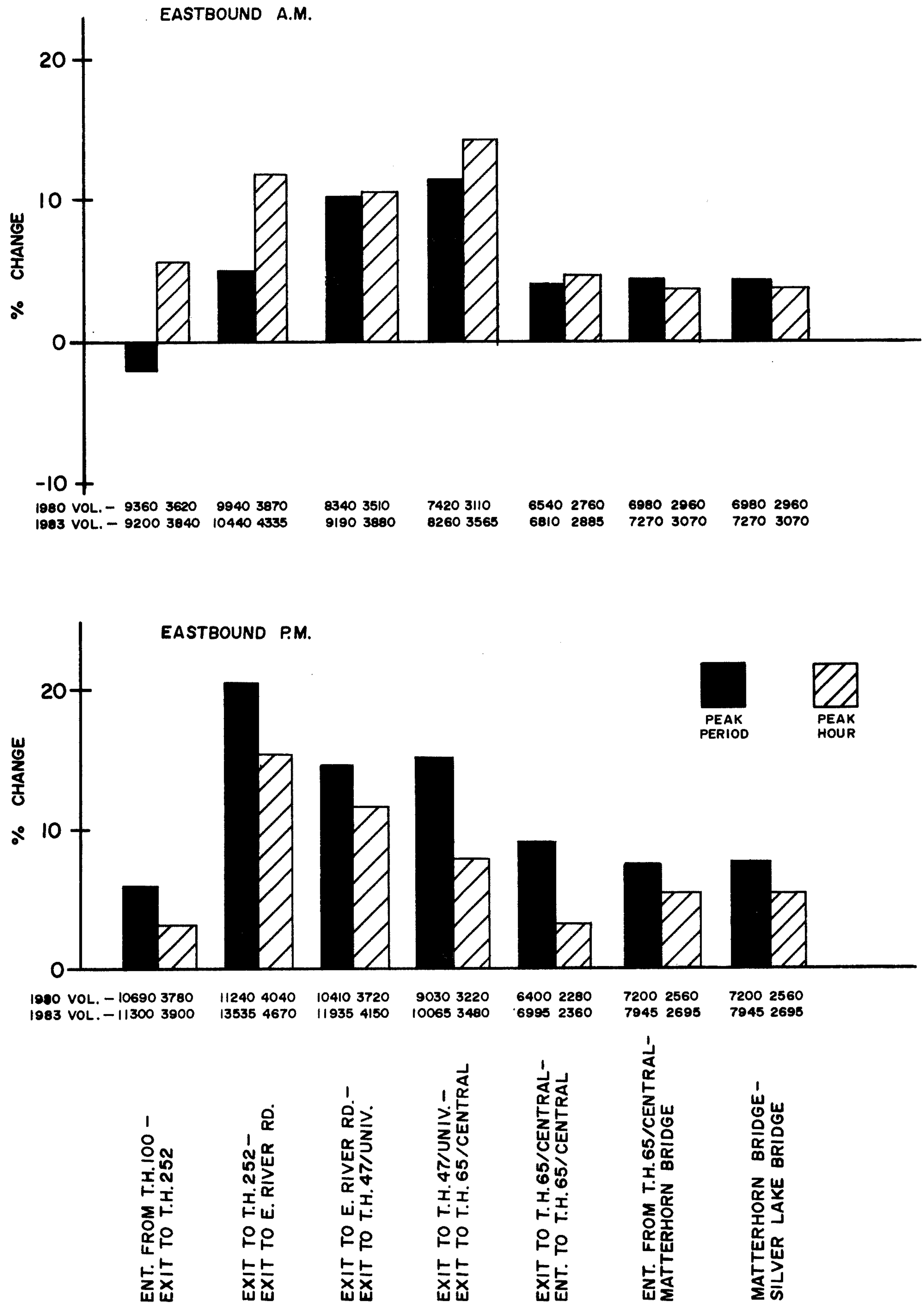


FIGURE 5

% CHANGE IN VOLUME(1980-83)

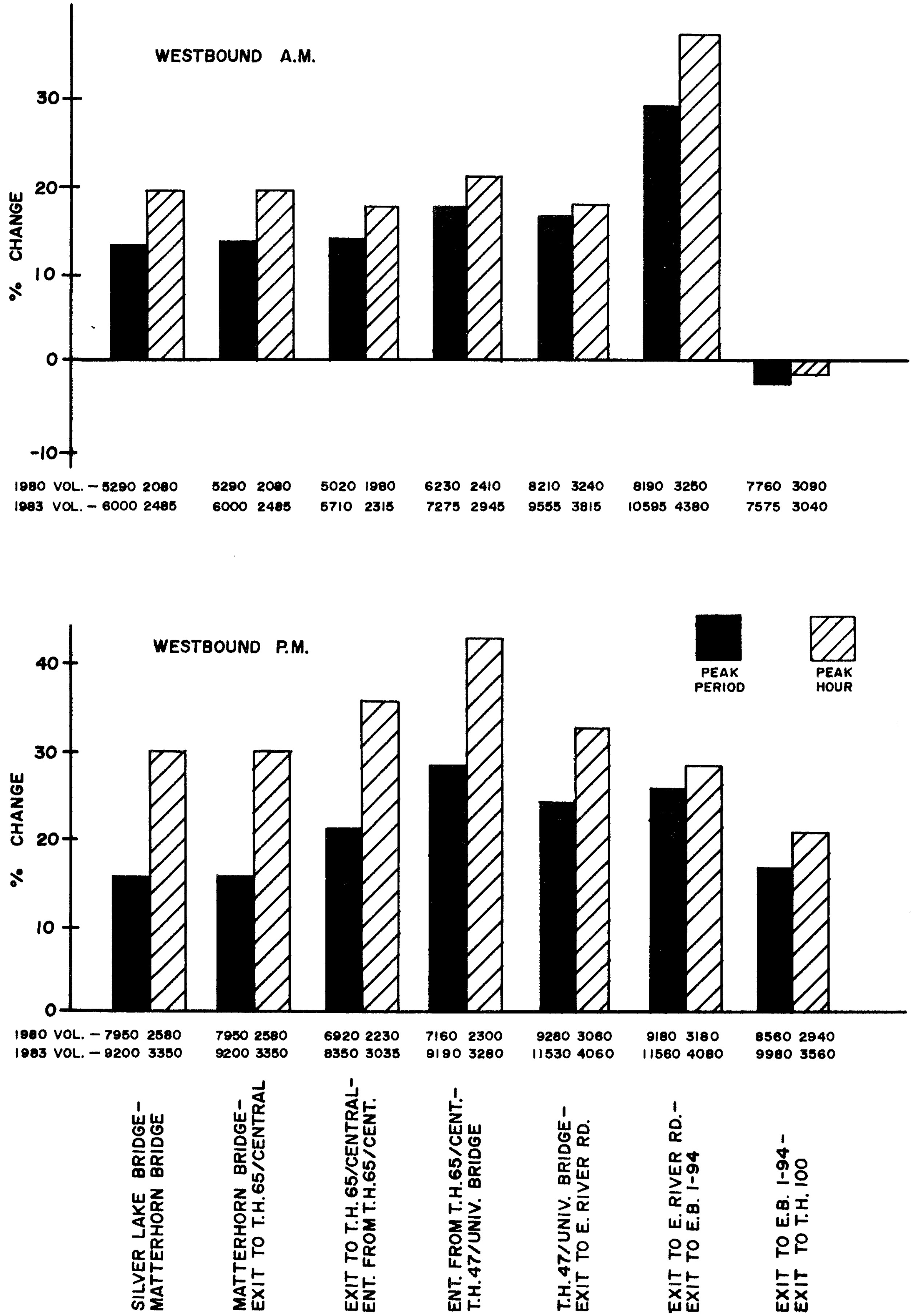


FIGURE 6

panding population of the Northwestern suburbs. Brooklyn Park and Maple Grove in particular have experienced rapid population growth in recent years. The largest volume growth has come about because of the attractiveness of the I-94 route in and out of Minneapolis. Rather than travel on arterials such as Central or University Avenues, or take the longer I-35W route, drivers prefer to take I-94. The westbound direction shows the greatest percentage volume increase, ranging from 13-42% and averaging 21%, while the eastbound direction increases in the range of 4-20%, and averages a 9% increase.

Tables 1 and 2 give the upstream mainline volumes, the volume of each subsequent entrance and exit ramp, and the downstream mainline volumes.

They are also divided into A.M. and P.M. peak hour and peak periods, and show the percentage change from 1980-1983. The tables show that many of the ramps have undergone significant volume changes. However, it must again be taken into account that when the I-94 to I-694 link was completed, drastic changes in travel patterns occurred in both directions. In general, eastbound entrance ramp volumes fell due to fewer cars taking SB I-35W into downtown Minneapolis, and westbound entrance ramp volumes rose as more drivers opted for the eastbound I-94 route.

Because of the geometric changes which have taken place, it is impossible to determine the percentage of volume changes and route alterations which can be attributed solely to the implementation of ramp metering.

EASTBOUND VOLUMES I-694

Location		AM 1980	AM 1983	AM % Change	PM 1980	PM 1983	PM % Change
Upstream Mainline	PH	2770	3300	+ 19.1	3320	3480	+ 4.8
	PP	7540	7800	+ 3.4	9520	10100	+ 6.1
Entrance from SB 252*	PH	850	540	- 36.5	460	420	- 8.7
	PP	1850	1400	- 24.3	1170	1200	+ 2.6
Exit to NB 252	PH	20	45	+125.0	80	130	+ 62.5
	PP	70	45	+ 57.1	280	390	+ 39.3
Entrance from WB I-94*	PH	270	540	+100.0	340	900	+164.7
	PP	620	1350	+117.7	830	2625	+216.3
Exit to East River Rd.	PH	670	700	+ 4.5	790	960	+ 21.5
	PP	2280	1820	- 20.2	2180	2750	+ 26.1
Entrance from East River Rd.*	PH	310	245	- 21.0	470	440	- 6.4
	PP	680	570	- 16.2	1350	1150	- 14.8
Exit to 47/ University Ave.	PH	680	600	- 9.1	920	1050	+ 14.1
	PP	1600	1630	+ 1.9	2540	3020	+ 18.0
Entrance from 47/University Ave.*	PH	280	285	+ 1.8	420	380	- 9.5
	PP	680	700	+ 2.9	1160	1150	- 1.0
Exit to SB 65/Central	PH	220	280	+ 27.3	260	330	+ 26.9
	PP	510	600	+ 17.6	880	1000	+ 13.6
Entrance from SB 65/Central*	PH	280	250	- 10.7	170	160	- 5.9
	PP	640	600	- 6.3	530	520	- 1.9
Exit to NB 65/Central	PH	410	650	+ 58.5	850	950	+ 11.8
	PP	1010	1450	+ 43.6	2280	2590	+ 13.6
Entrance from NB 65/Central*	PH	180	185	+ 2.8	280	335	+ 19.6
	PP	440	460	+ 4.5	800	950	+ 18.8
Downstream Mainline	PH	2960	3070	+ 3.7	2560	2695	+ 5.3
	PP	6980	7270	+ 4.2	7200	7945	+ 10.3

* = metered ramps
PP = peak period
PH = peak hour

Table 1

WESTBOUND VOLUMES I-694

Location		AM 1980	AM 1983	AM % Change	PM 1980	PM 1983	PM % Change
Upstream Mainline	PH	2080	2485	+ 19.5	2580	3350	+ 29.8
	PP	5290	6000	+ 10.2	7950	9200	+ 15.7
Exit to NB 65/Central	PH	130	160	+ 23.1	310	320	+ 3.2
	PP	330	385	+ 16.7	850	890	+ 4.7
Entrance from NB 65/Central*	PH	170	230	+ 35.3	290	325	+ 12.1
	PP	450	570	+ 26.7	830	320	- 3.0
Exit to SB 65/Central	PH	140	240	+ 71.4	330	320	- 3.0
	PP	390	475	+ 21.8	1010	910	- 9.9
Entrance from SB 65/Central*	PH	800	870	+ 12.5	470	605	+ 28.7
	PP	2050	2320	+ 13.2	1280	1860	+ 45.3
Exit to 47/ University Ave.	PH	340	270	- 20.6	400	360	- 10.0
	PP	840	755	- 10.1	1040	1020	- 1.9
Entrance from 47/University Ave.*	PH	800	870	+ 8.8	760	780	+ 2.6
	PP	840	755	- 15.2	2120	2340	+ 10.4
Exit to East River Road	PH	350	295	- 15.7	430	200	- 57.5
	PP	990	880	- 11.1	1040	670	- 35.6
Entrance from East River Road	PH	820	1060	+ 29.3	1400	920	- 34.3
	PP	2140	2440	+ 14.0	2790	2550	- 8.6
Exit to NB 252	PH	460	200	- 56.5	850	700	- 17.6
	PP	1170	520	- 55.6	1850	1850	0.0
Exit to EB I-94	PH	160	1340	+737.5	240	520	+116.7
	PP	430	3020	+602.3	620	1580	+154.8
Downstream Mainline	PH	3090	3040	- 1.6	2940	3560	+ 21.1
	PP	7760	7575	- 2.4	8560	9980	+ 16.2

* = metered ramps
PP = peak period
PH = peak hour

Table 2

B. Operating Speeds

Operating speed is a key measure of effectiveness for the traffic performance along a freeway. Elapsed travel times were noted at pre-established points on I-694 by observers in vehicles using the "floating car" method. These travel time runs were made in both the A.M. and P.M. peak periods, and in both the eastbound and westbound directions as there is no clear "primary direction" for this section of freeway. The data was collected in August of 1980, and in July of 1983, and was computer tabulated using previously developed software. Operating speeds are presented in Tables 3 through 6. Results are tabulated by year and by time period, showing both peak hour and peak period totals. A "percent capacity" comparison of 1980 and 1983 volumes is presented in Figures 7 and 8 to benefit the reader in the interpretation of travel times and operating speed results.

The number and selection of points at the west end of the study section differ slightly from 1980 to 1983, due to geometric changes since construction, as discussed earlier. All points east of, and including East River Road are consistent from year to year. These points were then combined into "zones", the limits of which were determined by changes in traffic flow patterns. It should be noted that the differences in zones west of East River Road from 1980 to 1983 must be considered when making any comparisons. Following is a separate analysis for each direction and peak period.

Eastbound - A.M. Peak Period:

In the first two eastbound zones, both peak hour and peak period operating speeds increased greatly from 1980 to 1983 (Table 3). Peak hour data shows an increase from 36 to 49 mph in the first zone, and from 40 to 46 mph in the second zone. Throughout the peak period, average operating speeds increased from 41 to 53 mph in the first zone, and from 43 to 50 mph in the second zone. These improvements in operating speeds can be attributed primarily to the increase in capacity due to construction.

Operating speeds for all zones beyond the exit to East River Road show a slight decrease. Although the positive implications of these results are not immediately obvious, they become more apparent upon viewing Figure 7. The increase in mainline volumes throughout the system from 1980 to 1983 demonstrates the fact that the system was running closer to capacity in 1983 than in 1980. Therefore, even though there is a slight decrease in speeds, this decrease is small when considering the additional volume of traffic now using the freeway. If the freeway was to run at capacity throughout the system, average operating speeds would de-

I-694 EB AM OPERATING SPEEDS

ZONE #	SECTION OF I-694	Dist. (mi)	MEAN SPEED (mph) Peak Hour (0700-0800) 1980	1983	Peak Period (0630-0900) 1980	1983
1	Ent from TH 100 - Exit Leg to TH 169 (1980)	0.351	36		41	
	Ent from TH 100 - Exit to TH 252 (1983)	0.494		49		53
2	Exit Leg to TH 169 - Exit Loop to E Riv Rd (1980)	0.591	40		43	
	Exit to TH 252 - Exit Loop to E Riv Rd (1983)	0.340		46		50
3	Exit Loop to E River Rd - Exit Leg to TH 47/Univ	0.539	50	49	52	51
4	Exit Leg to TH 47/Univ - Exit Leg to TH 65/Cent	0.742	55	51	56	53
5	Exit Leg to TH 65/Cent - Ent Leg from TH 65/Cent	0.430	54	50	55	52
6	Ent Leg from TH 65/Cent - Matterhorn Drive Bridge	0.314	55	53	56	54
7	Matterhorn Drive Bridge - Silver Lake Road Bridge	0.929	59	57	60	59
	Ent from TH 100 - Silver Lake Road Bridge		50	52	52	54

Table 3

EASTBOUND % CAPACITY

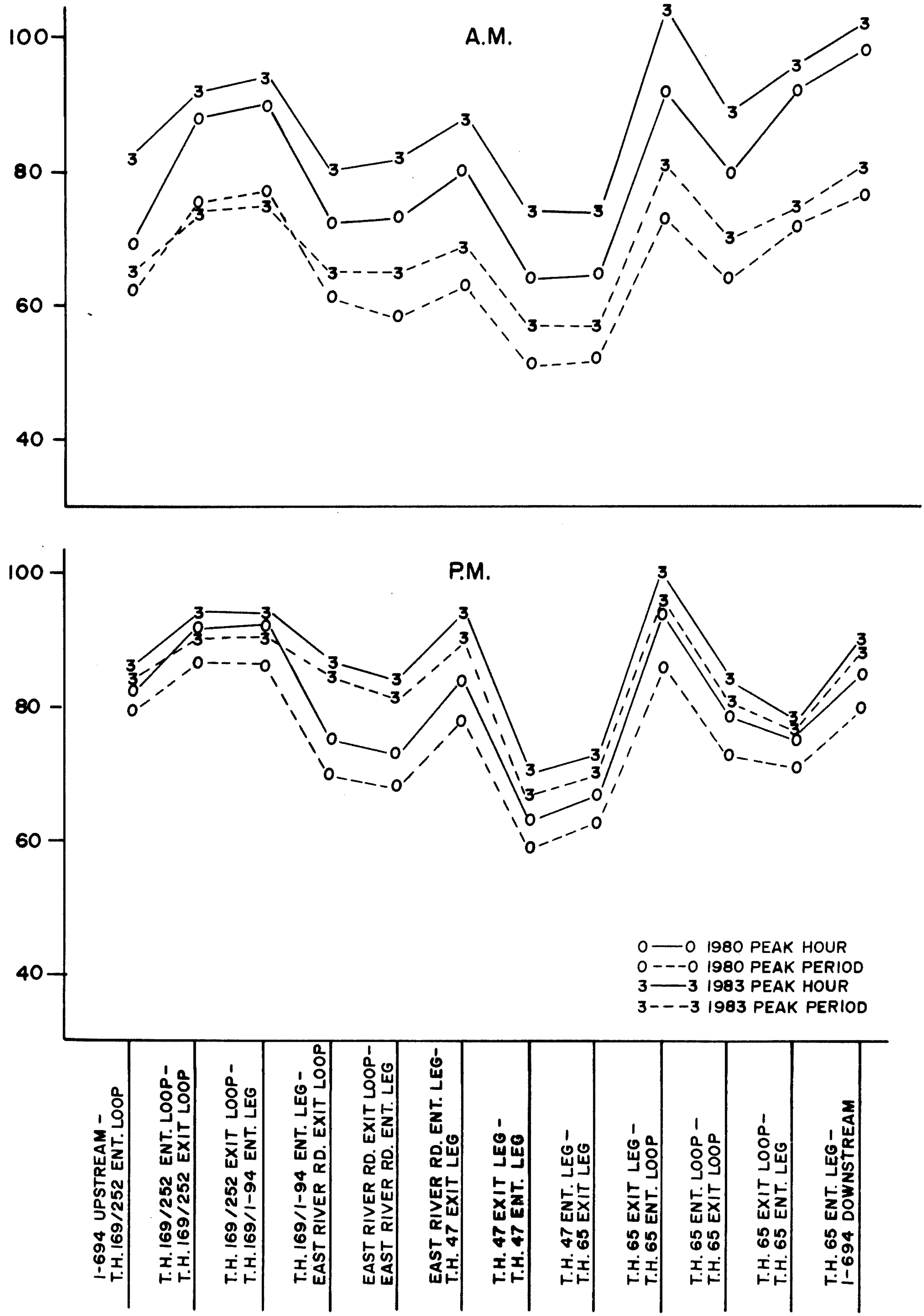


FIGURE 7

crease even further, to approximately 45 mph. The individual driver experiences a modest increase in travel time through these eastern zones of the section. However, the net positive effect on the system must be considered to be of primary importance.

Eastbound - P.M. Peak Period:

The result of the P.M. operating speed study differed markedly from the A.M. result in the first two eastbound links (Table 4). Zone 1 exhibits a mean speed of 31 mph in both the peak hour and peak period in 1983 and Zone 2 shows a mean speed of 39 mph during the peak hour and 41 mph during the peak period. These speeds are considerably slower (as much as 24.4%) than in 1980. For all zones east of the exit to East River Road, trends similar to A.M. patterns were followed, and the same factors (increased volumes, close to capacity) account for these trends. Explaining the dramatic decrease in 1983 operating speeds in the first two zones, however, is more complicated. It is believed that it resulted from a combination of factors and not from the exclusive effect of one element.

The river bridge has already been identified in this report as a bottleneck section for both directions. This appears to be the only eastbound problem area in the morning. During the evening peak period, however, the merge area from northbound TH 100 also becomes critical. In the A.M., ramp volumes are low, and queues are infrequent, allowing mainline traffic to pass through this section unimpeded. P.M. ramp volumes are observed to be much higher (due to the closing of the Xerxes Avenue ramp, traffic patterns, and higher system volumes in general), generating a continual queue, and creating a constant conflict in the merge area.

Because volume figures in the first eastbound zone do not reflect true volume increases as discussed earlier, volume data from the second zone is used for comparison purposes. Volumes are higher in 1983 than in 1980, and are also higher in the P.M. than in the A.M. In the zone from the TH 169/I-94 entrance to the exit to East River Road, the freeway is running at 87% capacity in the P.M. peak hour, as compared with 80% capacity in the 1983 A.M. and only 75% capacity in the 1980 P.M. (see Figure 7).

I-694 EB PM OPERATING SPEEDS

ZONE #	SECTION OF I-694		Dist. (mi)	MEAN SPEED (mph) Peak Hour (1600-1700) 1980	1983	Peak Period (1530-1800) 1980	1983
1	Ent from TH 100 - Exit Leg to TH 169	1980	0.531	38		41	
	Ent from TH 100 - Exit to TH 252	1983	0.494		31		31
2	Exit Leg to TH 169 - Exit Loop to E Riv Rd	1980	0.591	42		43	
	Exit to TH 252 - Exit Loop E Riv Rd	1983	0.340		39		41
3	Exit Loop to E Riv Rd - Exit Leg to TH 65/Cent		0.539	48	46	47	47
4	Exit Leg to TH 47/Univ - Exit Leg to TH 65/Cent		0.742	54	52	55	53
5	Exit Leg to TH 65/Cent - Ent Leg from TH 65/Cent		0.430	55	53	54	52
6	Ent Leg from TH 65/Cent - Matterhorn Drive Bridge		0.314	56	54	56	54
7	Matterhorn Drive Bridge - Silver Lake Road Bridge		0.929	59	60	60	59
	Ent from TH 100 - Silver Lake Road Bridge			50	47	51	48

Table 4

Figure 5 shows that although A.M. peak hour volumes in this same zone increased 12% from 1980 to 1983, A.M. peak period volumes increased only 5%. P.M. volumes, on the other hand, showed an increase of 15% in the peak hour, and an even larger increase of 20% over the peak period, indicating a much larger demand over a longer period of time. Volume and speed data demonstrate that demand exceeds capacity for a longer portion of the P.M. peak period, resulting in reduced quality of flow.

A combination of these factors contribute to a premature breakdown of traffic flow in this area. Because of the high demand associated with this section, traffic flow is slow to recover, resulting in the especially low mean speeds achieved.

<u>Westbound - A.M. Peak Period</u>

In the A.M. peak period, volumes were not high enough to cause a breakdown of traffic flow in 1980. As shown in Table 5, however, drivers did experience a slight slowdown (to speeds of 49 mph in the peak hour and 50 mph in the peak period) in Zone 7. These were improved in 1983 to speeds of 56 and 59 mph (peak hour and peak period, respectively). For all sections relatively unaffected by the capacity increase (in this case, all zones upstream of the exit to East River Road), the improvements can be attributed to the T.M.S. Table 5 shows operating speeds between Silver Lake Road and TH 100 virtually unchanged from 1980 to 1983. Since volumes have greatly increased throughout the system, an appreciable reduction in speeds could be expected. The system was running very near capacity in some locations in 1983 (e.g. 88% capacity in the TH 47 entrance - East River Road exit section), yet operating speeds never dropped below 54 mph throughout the system.

Traffic flow in both westbound peak periods was dependent upon one primary factor - the river area bottleneck. An increase in capacity beyond the exit to eastbound I-94 in 1983 has vastly reduced the bottleneck effects on traffic flow through this section and upstream of it. It can be seen from Figure 8 that although mainline volumes decreased beyond the TH 169/I-94 exit, percent capacity now decreases with volume.

I-694 WB AM OPERATING SPEEDS

ZONE #	SECTION OF I-694	Dist. (mi)	MEAN SPEED (MPH) Peak Hour (0700-0800) 1980	1983	Peak Period (0630-0900) 1980	1983
1	Silver Lake Road Bridge - Matterhorn Drive Bridge	0.929	58	58	59	59
2	Matterhorn Drive Bridge - Exit Leg to TH 65/Cent	0.314	58	58	59	59
3	Exit Leg to TH 65/Cent - Ent Leg from TH 65/Cent	0.430	58	58	59	58
4	Ent Leg from TH 65/Cent - TH 47/Univ Bridge	0.559	58	56	58	55
5	TH 47/Univ. Bridge - Exit to E River Rd	0.539	57	56	57	58
6	Exit to E River Rd - Exit Loop to TH 169 (1980) Exit to EB I-94 (1983)	0.642	52	54	52	55
7	Exit Loop to TH 169 - Exit Loop to TH 100 (1980)	0.609	49		50	
	Exit to EB I-94 - Exit to TH 100 (1983)	0.353		56		59
	Silver Lake Road Bridge - Exit to TH 100		55	56	56	58

Table 5

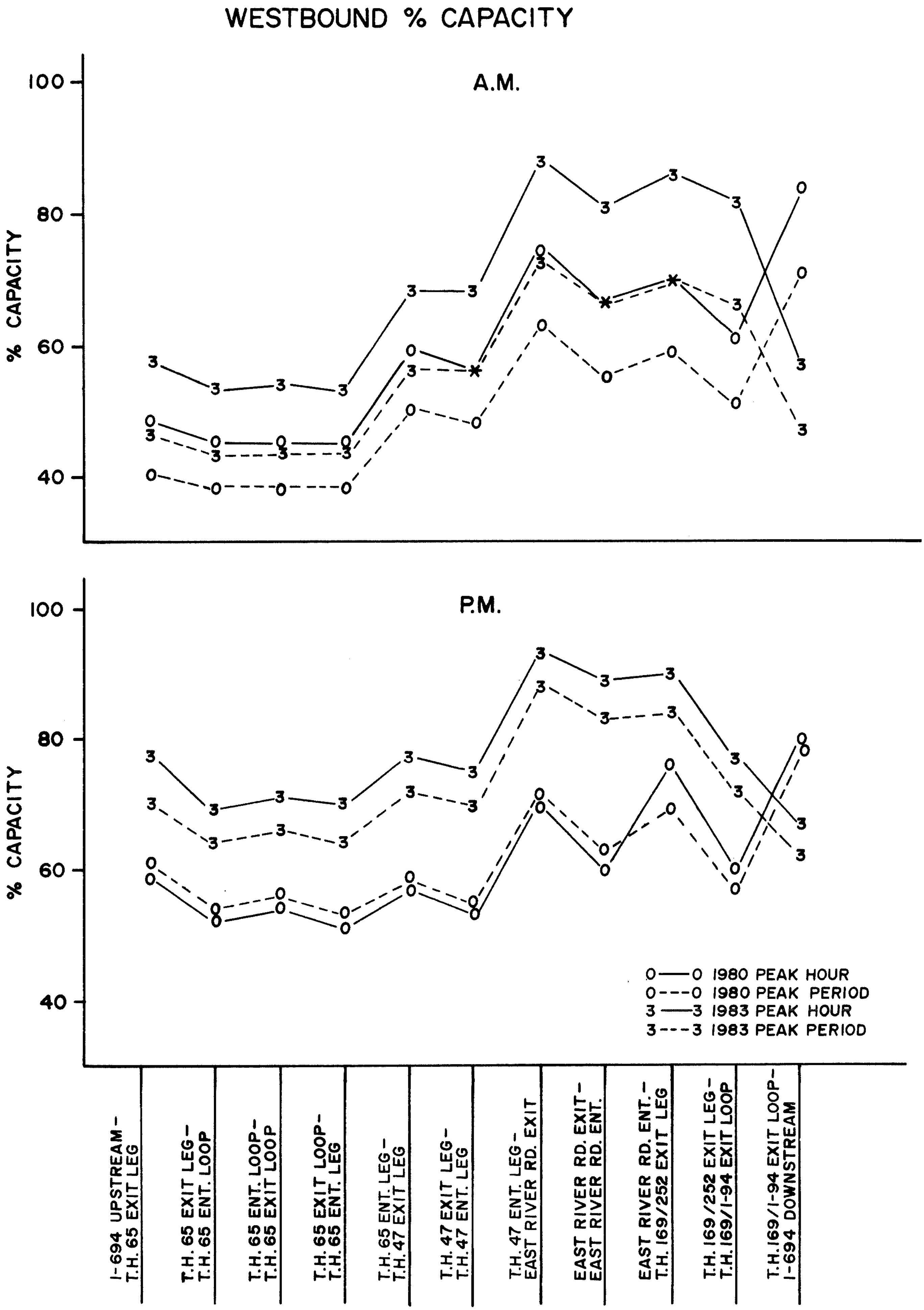

WESTBOUND % CAPACITY
A.M.
P.M.
% CAPACITY
100
80
60
40
0——0 1980 PEAK HOUR
0---0 1980 PEAK PERIOD
3——3 1983 PEAK HOUR
3---3 1983 PEAK PERIOD
I-694 UPSTREAM-T.H. 65 EXIT LEG
T.H. 65 EXIT LEG-T.H. 65 ENT. LOOP
T.H. 65 ENT. LOOP-T.H. 65 EXIT LOOP
T.H. 65 EXIT LOOP-T.H. 65 ENT. LEG
T.H. 65 ENT. LEG-T.H. 47 EXIT LEG
T.H. 47 EXIT LEG-T.H. 47 ENT. LEG
T.H. 47 ENT. LEG-EAST RIVER RD. EXIT
EAST RIVER RD. EXIT-EAST RIVER RD. ENT.
EAST RIVER RD. ENT.-T.H. 169/252 EXIT LEG
T.H. 169/252 EXIT LEG-T.H. 169/I-94 EXIT LOOP
T.H. 169/I-94 EXIT LOOP-I-694 DOWNSTREAM

FIGURE 8

Westbound - P.M. Peak Period

P.M. peak period volumes were sufficient to precipitate a severe breakdown of traffic flow in 1980. Table 6 shows 1980 operating speeds resulting from the river area bottleneck, the shockwave it produced, and its effects on traffic upstream of it. Peak hour speeds fell as low as 30 mph in Zone 5, a speed which was improved to 51 mph in 1983. Operating speeds in the unaffected zones showed a negligible reduction from 1980 to 1983, though volumes once again show a significant increase, as much as 42% (see Figure 8). Mean speeds for the overall system were improved from 46 to 53 mph in the peak hour and from 50 to 54 mph in the peak period.

Analysis of Results

Both the I-694 T.M.S. and the reconstruction efforts at the west end of the study section contributed to the overall improvement of traffic flow in this area. The focal point of this section of freeway was, and remains, the bridge over the Mississippi River. An increase in capacity in the area west of the river bridge sufficiently resolved traffic problems for all but the Eastbound P.M. peak period. In this time period, geometric changes were not enough to overcome substantial increases in volume, and demand continued to exceed capacity in 1983. The ramp metering system also aided in the improvement of traffic flow near the river, particularly at the westbound I-94 to eastbound I-694 ramp.

In the zones removed from the effects of the river area bottleneck, operating speeds showed no change, or a minimal decrease, despite sizeable volume increases throughout the system. A much larger volume combined with only a slight decrease in operating speed resulted in a greater throughput of vehicles during the peak hours, and a more efficient flow of traffic throughout the system.

C. Freeway Time Mean Speeds

Concurrent with the travel time studies, instantaneous speeds at pre-established points were noted and recorded. These instantaneous speeds were used to determine the time mean speeds (spot speeds) for these locations. Time mean speed is simply the average of all the instantaneous speeds for each location, and is not averaged over distance. Spot speed studies are used primarily to identify any erratic movement in traffic flow. "Before" and "after" comparisons of the time mean speeds by direction and time period are

I-694 WB PM OPERATING SPEEDS

ZONE #	SECTION OF I-694	Dist. (mi)	MEAN SPEED (MPH) Peak Hour (1600-1700) 1980	1983	Peak Period (1530-1800) 1980	1983
1	Silver Lake Road Bridge - Matterhorn Drive Bridge	0.929	57	55	57	56
2	Matterhorn Drive Bridge - Exit Leg to TH 65/Cent	0.314	58	56	57	57
3	Exit Leg to TH 65/Cent - Ent Leg from TH 65/Cent	0.430	57	54	57	55
4	Ent Leg from TH 65/Cent - TH 47/Univ Bridge	0.559	57	51	57	54
5	TH 47/Univ Bridge - Exit to E River Rd	0.539	30	51	40	53
6	Exit to E River Rd - Exit Loop to TH 169 (1980) Exit to EB I-94 (1983)	0.642	39	50	42	52
7	Exit Loop to TH 169 - Exit Loop to TH 100 (1980)	0.609	45		47	
	Exit to EB I-94 - Exit to TH 100 (1983)	0.353		56		57
	Silver Lake Road Bridge - Exit to TH 100		46	53	50	54

Table 6

shown in Figures 9 through 12. Again, the different points at the west end of the section should be compared with due consideration. Also, it should be remembered that the figures are not actually "graphs". Points from like sets of data are connected merely for legibility purposes, and do not imply that intermediate speeds between points can be interpolated from the figures.

There are several characteristics that are common to all the graphs. For instance, the sharp rises and drops of the curves at the east end of the section reflect the prominent grade changes present here. Also, the minimum speeds in both directions occur between the river bridge and the railroad bridge inclusive. This is due to the bottleneck characteristics that are peculiar to this section, as discussed previously. Finally, the increased speeds after the bottleneck section can be explained by a limited volume being able to pass through the bottleneck section. A driver who is slowed by the bottleneck finds, upon clearing it, a roadway of higher capacity ahead allowing for rapid acceleration.

Figure 9, (eastbound A.M.), shows a breakdown of traffic flow in 1980 before reaching the river where breakdown is normally expected. This problem has been alleviated in the 1983 curve, showing only a breakdown precipitated by the bottleneck section. Also significant here is the smaller range in speeds in 1983 as opposed to 1980. The 1980 peak hour curve ranges from a minimum of 44 mph to a maximum of 61 mph, whereas the 1983 peak hour curve ranges from a minimum of 46 mph, to a maximum of 58 mph. indicating smoother traffic flow.

Eastbound P.M. curves, shown in Figure 10, indicate 1983 spot speeds consistently slower throughout the system. This was caused by consistently higher volumes, forcing the system to operate at or near capacity, thus restricting operating speeds. This fact is also apparent in westbound peak periods (Figures 11 and 12) where volumes have increased as much as 45% from 1980 to 1983 in the area between Central Avenue (TH 65) and University Avenue (TH 47) in the P.M. peak hour (see Table 2).

The most significant aspect of the westbound P.M. graph (Figure 12) is the reduction in severity of the breakdown near the bottleneck from 1980 to 1983. Although a slowdown does occur in 1983, the minimum speed occurring in the peak hour is still 49 mph at the entrance from University Avenue, and the deceleration to this speed is gradual. Conversely,

EASTBOUND A.M. SPOT SPEEDS
PEAK PERIOD (0630-0900) AND PEAK HOUR (0700-0800)

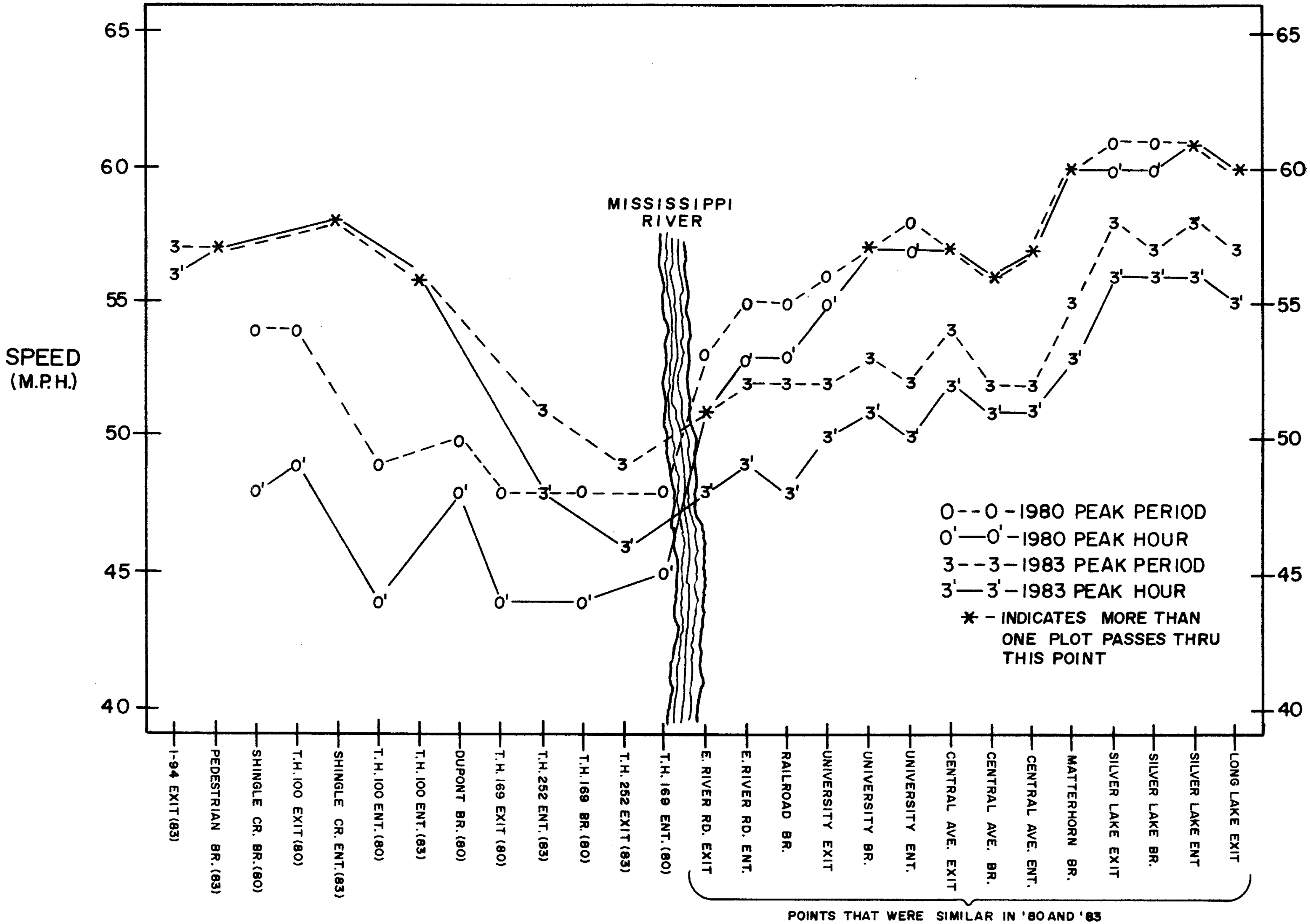


FIGURE 9

EASTBOUND P.M. SPOT SPEEDS

PEAK PERIOD (1530-1800) AND PEAK HOUR (1600-1700)

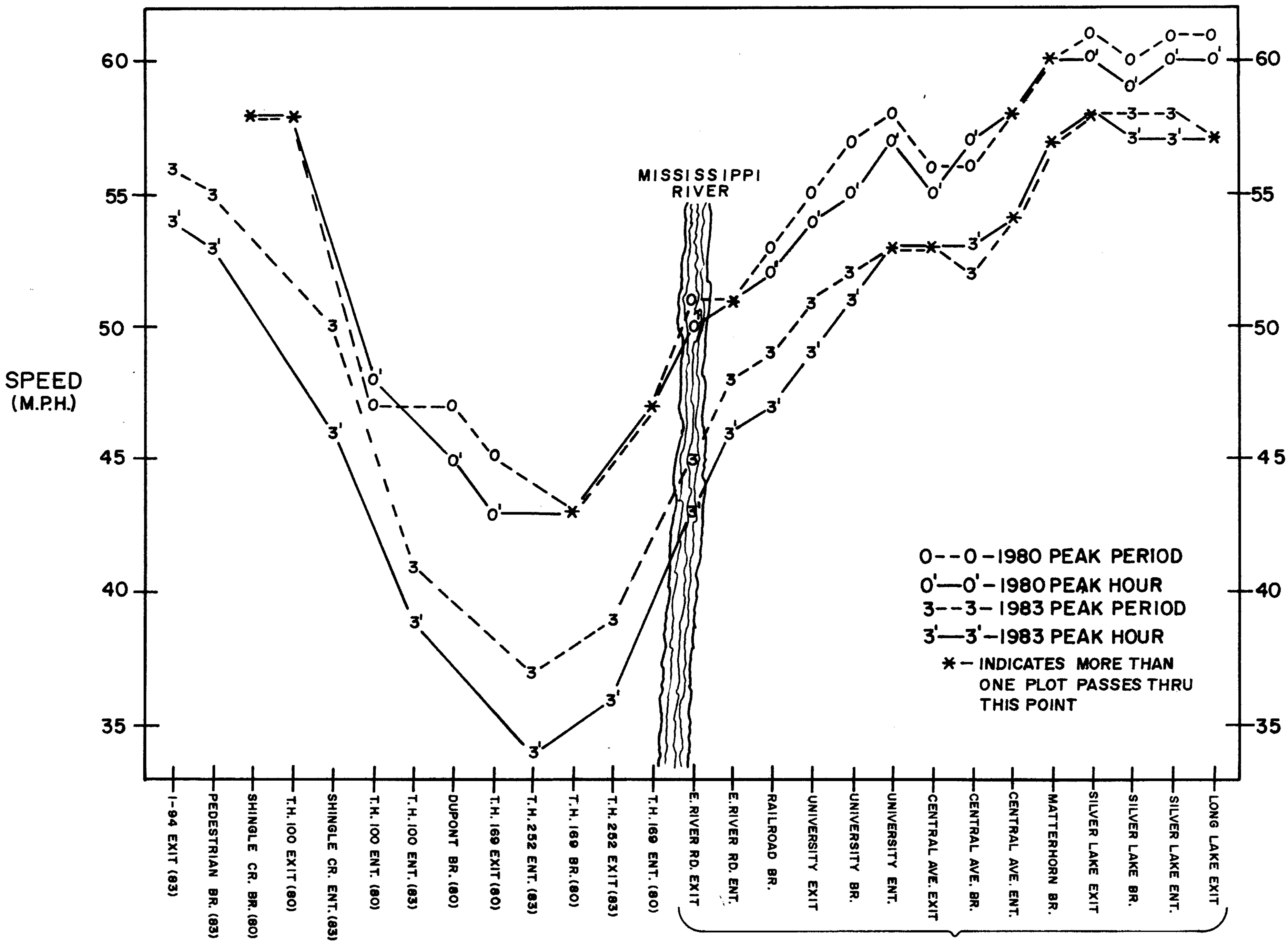


FIGURE 10

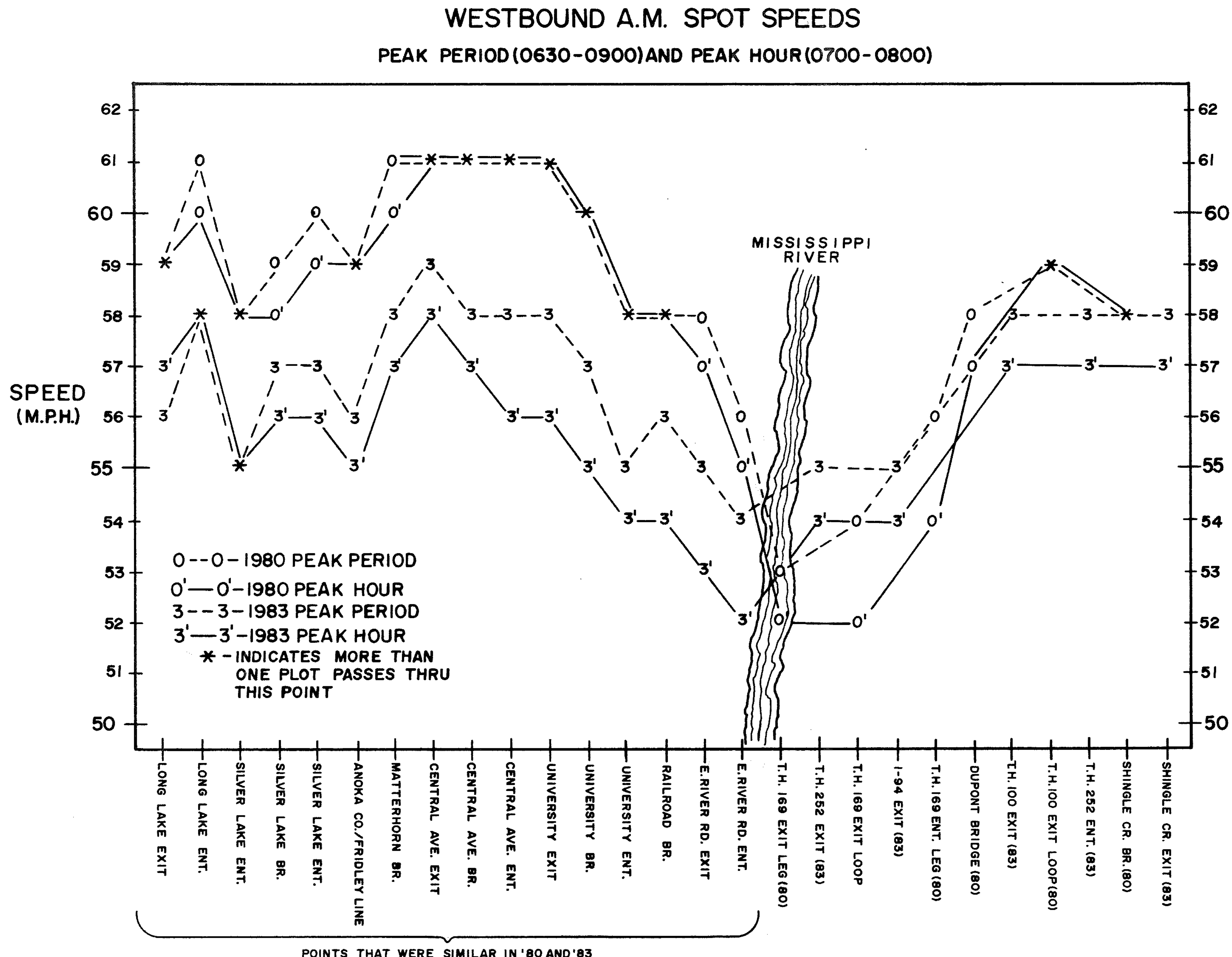

WESTBOUND A.M. SPOT SPEEDS
PEAK PERIOD (0630-0900) AND PEAK HOUR (0700-0800)
SPEED (M.P.H.)
MISSISSIPPI RIVER
0--0-1980 PEAK PERIOD
0'—0'-1980 PEAK HOUR
3--3-1983 PEAK PERIOD
3'—3'-1983 PEAK HOUR
✱ -INDICATES MORE THAN ONE PLOT PASSES THRU THIS POINT
LONG LAKE EXIT
LONG LAKE ENT.
SILVER LAKE ENT.
SILVER LAKE BR.
SILVER LAKE ENT.
ANOKA CO./FRIDLEY LINE
MATTERHORN BR.
CENTRAL AVE. EXIT
CENTRAL AVE. BR.
CENTRAL AVE. ENT.
UNIVERSITY EXIT
UNIVERSITY BR.
UNIVERSITY ENT.
RAILROAD BR.
E. RIVER RD. EXIT
E. RIVER RD. ENT.
T.H. 169 EXIT LEG (80)
T.H. 252 EXIT (83)
T.H. 169 EXIT LOOP
I-94 EXIT (83)
T.H. 169 ENT. LEG (80)
DUPONT BRIDGE (80)
T.H. 100 EXIT (83)
T.H. 100 EXIT LOOP (80)
T.H. 252 ENT. (83)
SHINGLE CR. BR. (80)
SHINGLE CR. EXIT (83)
POINTS THAT WERE SIMILAR IN '80 AND '83

FIGURE 11

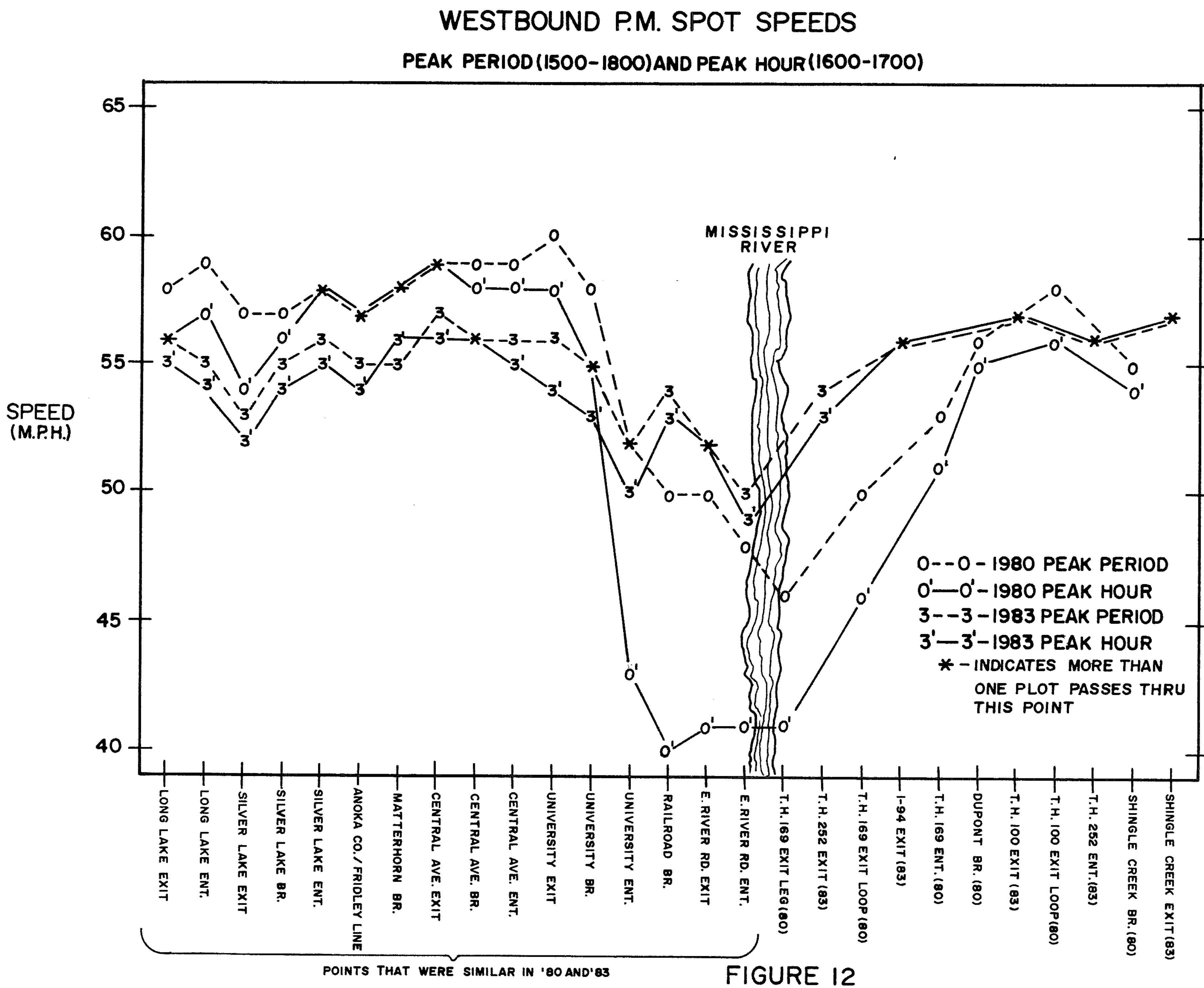

WESTBOUND P.M. SPOT SPEEDS
PEAK PERIOD (1500-1800) AND PEAK HOUR (1600-1700)
SPEED (M.P.H.)
65
60
55
50
45
40
MISSISSIPPI RIVER
0--0 - 1980 PEAK PERIOD
0'—0' - 1980 PEAK HOUR
3--3 - 1983 PEAK PERIOD
3'—3' - 1983 PEAK HOUR
* - INDICATES MORE THAN ONE PLOT PASSES THRU THIS POINT
LONG LAKE EXIT
LONG LAKE ENT.
SILVER LAKE EXIT
SILVER LAKE BR.
SILVER LAKE ENT.
ANOKA CO./FRIDLEY LINE
MATTERHORN BR.
CENTRAL AVE. EXIT
CENTRAL AVE. BR.
CENTRAL AVE. ENT.
UNIVERSITY EXIT
UNIVERSITY BR.
UNIVERSITY ENT.
RAILROAD BR.
E. RIVER RD. EXIT
E. RIVER RD. ENT.
T.H. 169 EXIT LEG (80)
T.H. 252 EXIT (83)
T.H. 169 EXIT LOOP (80)
I-94 EXIT (83)
T.H. 169 ENT. (80)
DUPONT BR. (80)
T.H. 100 EXIT (83)
T.H. 100 EXIT LOOP (80)
T.H. 252 ENT. (83)
SHINGLE CREEK BR. (80)
SHINGLE CREEK EXIT (83)
POINTS THAT WERE SIMILAR IN '80 AND '83

FIGURE 12

the 1980 peak hour graph drops sharply from a speed of 58 mph at the exit to University Avenue, to a minimum of 40 mph at the Railroad Bridge. This sudden braking (an 18 mph decrease in speed over .519 miles) is indicative of turbulent traffic flow and suggests conditions highly susceptible to accidents.

D. Mainline Delay

Mainline delay has been calculated utilizing statistical methods. In order that this could be done the assumption was made that driving speeds follow an approximate normal curve. In the range of practical speeds, this assumption is reasonable.

Delay for a vehicle was defined as occurring when a driver's mean speed fell below 50 mph. Mainline delay then, is the excess time a vehicle traveling under 50 mph spent on one of the seven sections of roadway. To compute the delay, travel times were standardized by placing the mean travel time for each link at the 50th percentile on a normal curve. The 50 mph travel time was also placed on the normal curve and from its placement the percentage of cars traveling 50 mph or slower was found. This percentage multiplied by the total volume gave the number of cars experiencing delay. The median travel time of these delayed vehicles was also determined utilizing the normal curve. Delay per delayed vehicle then is the difference between the 50 mph travel time, and the median travel time of the delayed vehicles. Total delay is computed by multiplying the delay per delayed vehicle by the number of vehicles delayed.

Table 7 shows eastbound and westbound mainline delay in both peak periods. In both directions the major portion of vehicle delay time materialized surrounding the river crossing. Eastbound P.M. is the only direction which exhibits an increase in delay from 1980 to 1983. (As discussed in the volume section, due to the reconstruction of the eastbound I-94/Shingle Creek Parkway and Xerxes Avenue exits, the number of cars passing through that section has seen a greater increase). This increased mainline volume, combined with the large volumes which now merge from TH 100 and westbound I-94 in the P.M., create a standing shockwave leading to the increased delay in 1983. By contrast, the eastbound A.M. traffic in this same area has actually experienced reduction in delay. This is explained by smaller mainline volumes than in the P.M., and a lesser volume demand from the TH 100 and westbound I-94 entrances.

MAINLINE DELAY

T.H. 100 to Silver Lake Road Bridge					
		Volumes		Delay	
Direction	Year	Total	% Speed < 50	Per delayed Veh. (min.)	Total (Hours)
Eastbound A.M.	1980 1983	7870 8221	33.27 33.80	1.07 0.25	46.74 11.59
Eastbound P.M.	1980 1983	8832 9038	39.27 49.11	1.04 1.48	60.25 109.77
Westbound A.M.	1980 1983	6620 7586	17.26 3.62	0.27 0.10	5.11 0.46
Westbound P.M.	1980 1983	8197 9910	34.41 22.85	2.35 0.33	110.67 12.34
Total Delay 1980 222.77 hrs. 1983 134.16 hrs.					

Table 7

The westbound improvements in delay can be attributed to the greater capacity now existing between I-94 and TH 100, and to the smoother merge area created by the ramp control signal at the University Avenue entrance. Westbound A.M. delay has been reduced from over five hours to less than 0.46 hours and P.M. delay has been reduced from as much as 110.67 hours to as little as 12.34 hours in these areas.

Eastbound delay is generally a bit higher than westbound delay because heavy vehicles are slowed by the uphill grades from Central Avenue to Matterhorn Drive. The weave areas near exit and entrance ramps also cause some delay in both directions.

E. Entrance Ramp Delay

Ramp delay was calculated from the queue length data collected at metered ramps during July and August of 1983. Peak hour volumes are from 7:00-8:00 A.M. and 4:00-5:00 P.M., and peak period volumes are for the time periods that metering was in operation (6:30-8:30 A.M. and 3:30-6:00 P.M.). Queue length data was collected by manually counting the number of cars waiting at the meter at thirty second intervals. An average queue length, total delay and average delay per vehicle was calculated from this information. These results are shown in Tables 8 and 9.

The data shows that average delays and queue lengths are at acceptable levels with four exceptions as follow:

1. The most serious queuing problem existed at the ramp from westbound I-94 to eastbound I-694 during P.M. peak periods. This ramp experienced average delays of 3.6 minutes, a maximum delay of 17.8 minutes, and a maximum queue length of 89 vehicles. Subsequent to the evaluation study, this ramp was reconstructed to provide an additional lane of storage, with two-lane alternate release metering being implemented in November 1984. Further improvements should be experienced at this ramp in July 1985 when new ramp meters become operational at the entrances to eastbound I-694 from TH 100 and Shingle Creek Parkway.

2. At the ramp entering westbound I-694 from southbound Central Avenue (TH 65) the average delays were quite short (0.1 to 0.4 minutes), but the queue from this meter often extended through the signalized intersection of TH 65 and Moore Lake Drive. This caused operational problems, especially for southbound and westbound traffic entering the intersection. Subsequent to the evaluation study, this ramp was also widened to provide for two-lane alternate release operation.

ENTRANCE RAMP VOLUME AND DELAY - PEAK PERIOD

(6:30-8:30 A.M. and 3:30-6:00 P.M.)

Ramp Location	Volume		Delay for Avg. Veh. (Minutes)		Total Delay (Hours)		Maximum Queue Length		Maximum Delay Per Veh. (Minutes)	
	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM
SB TH 252 To EB I-694	1000	970	.6	.4	9.5	6.1	22	13	3.7	1.7
WB I-94 (NB TH 252) To EB I-694	990	2240	.1	3.6	2.3	134.5	7	89	1.4	17.8
East River Road To EB I-694	430	960	.2	1.1	1.4	18.3	9	52	2.3	13.0
TH 47/University Ave. To EB I-694	520	970	.2	.2	1.6	3.8	6	8	1.2	1.6
SB TH 65/Central To EB I-694	450	430	.2	.2	1.1	.9	7	5	2.3	1.7
NB TH 65/Central To EB I-694	350	780	.2	.2	1.1	3.0	3	7	.4	1.9
NB TH 65/Central To WB I-694	430	800	.2	.5	1.1	7.0	5	16	1.7	4.3
SB TH 65/Central To WB I-694	1760	1580	.1	.4	3.0	10.7	20	35	4.0	7.0
TH 47/University Ave. To WB I-694	1610	1990	.9	1.0	27.0	31.7	44	36	5.9	3.6

Table 8

ENTRANCE RAMP VOLUME AND DELAY - PEAK HOUR

(7:00-8:00 A.M. and 4:00-5:00 P.M.)

Ramp Location	Volume AM	Volume PM	Delay for Vehicle Average (Minutes) AM	Delay for Vehicle Average (Minutes) PM	Total Delay (Hours) AM	Total Delay (Hours) PM
SB TH 252 To EB I-694	540	420	.8	.5	7.3	3.8
WB I-94 (NB TH 252) To EB I-694	540	900	.2	4.1	1.6	61.8
East River Road To EB I-694	245	440	.2	.2	.8	1.3
TH 47/Univ. Ave. To EB I-694	285	380	.2	.2	1.1	1.5
SB TH 65/Central To EB I-694	250	160	.2	.1	.8	1.3
NB TH 65/Central To EB I-694	185	335	.2	.2	.5	1.2
NB TH 65/Central To WB I-694	230	325	.2	.7	.6	4.0
SB TH 65/Central To WB I-694	900	605	.3	.2	4.7	1.6
TH 47/Univ. Ave. To WB I-694	870	780	1.0	1.0	14.0	12.5

Table 9

3. The ramp entering westbound I-694 from University Avenue (TH 47) experiences operational problems, especially during A.M. peak periods. At times the southbound queue extends through the signalized intersection of TH 47 and 57th Avenue Northeast, blocking the right lane of TH 47. Adding to the problems at this location is a bus stop for southbound buses, just south of the intersection. Buses often have to wait in the queue in order to pick up or discharge passengers.

4. The ramp from East River Road to eastbound I-694 experiences operational problems during P.M. peak periods. While the average delay is at an acceptable level of just over one minute, heavy surges of traffic from the industrial area to the south result in a maximum delay of 13 minutes and a maximum queue length of over 50 vehicles.

F. Accidents

Accident experience was studied for two years prior to system activation, 1978 and 1979, and for two years with the system in operation, 1982 and 1983. The years 1980 and 1981 were omitted because the system was activated in 1980 and freeway reconstruction was still in progress in 1981. Data was collected for the section of I-694 between Matterhorn Drive and Shingle Creek Parkway.

Study results are presented in Tables 10 and 11. The data in Table 10 shows that peak period accidents were reduced during A.M. and P.M. peak periods for both eastbound and westbound traffic. Total peak period accidents were reduced from 125 to 80 per year (36%). The largest percentage reduction was for westbound traffic during A.M. peak periods (54.8%), and the smallest reduction was for eastbound traffic during P.M. peak periods (23.4%). Since peak period volumes increased substantially during the study period, the percentage reduction in accident rates was greater than the percentage reduction in the number of accidents. Overall, the peak period accident rate was reduced from 4.22 to 2.35 accidents per million vehicle miles traveled (44.3%).

TABLE 10

PEAK PERIOD* ACCIDENTS

Average Number of Accidents Per Year

	1978-79	1982-83	Percent Reduction
Eastbound A.M.	16.0	10.0	37.5
Eastbound P.M.	32.0	24.5	23.4
Eastbound A.M. & P.M.	48.0	34.5	28.1
Westbound A.M.	36.5	16.5	54.8
Westbound P.M.	40.5	29.0	28.4
Westbound A.M. & P.M.	77.0	45.5	40.9
Eastbound & Westbound A.M. & P.M. Totals	125.0	80.0	36.0

PEAK PERIOD* ACCIDENT RATES

Accidents/MVM**

	1978-79	1982-83	Percent Reduction
Eastbound A.M.	2.52	1.37	45.6
Eastbound P.M.	3.52	2.33	33.8
Eastbound A.M. & P.M.	3.10	1.94	37.4
Westbound A.M.	6.74	2.66	60.5
Westbound P.M.	4.63	2.87	38.0
Westbound A.M. & P.M.	5.44	2.79	48.7
Eastbound & Westbound A.M. & P.M. Totals	4.22	2.35	44.3

* A.M. Peak Period (6:00-9:00) and P.M. Peak Period (15:00-19:00)
**Million Vehicle Miles

Table 11 presents information on accident types. Rear end type accidents experienced the largest numerical reduction (35), while ramp/merge type accidents experienced the largest percentage reduction (60.0%). The only accident type that experienced an increase was ran off the road accidents, increasing from 12.5 to 15.0 per year (20.0%).

TABLE 11

ACCIDENT TYPES

Accident Type	Average Number of Peak Period Accidents Per Year 1978-79	1982-83	% Change
Rear end	85.0	50.0	-41.2
Side swipe	17.5	11.0	-37.1
Ran off road	12.5	15.0	+20.0
Ramp/merge	10.0	4.0	-60.0
Totals	125.0	80.0	-36.0

G. Violation Rates

A metered ramp violation occurs when a vehicle fails to wait for a green light before proceeding along the ramp. The southbound TH 65 to westbound I-694 and the westbound I-94 to eastbound I-694 ramps allow two cars per green due to their large volumes and lack of vehicle storage space. A violation will occur at these ramps if more than two cars proceed per green. Violation data was manually collected by inconspicuously observing each metered ramp during the A.M. and P.M. metering periods, 6:30-8:30 and 3:30-6:00 respectively.

Violations occur as random events, making it very difficult to draw any clear cut conclusions about when a driver is likely to violate. The majority of drivers will not come to a complete stop for the meter if there are no other vehicles present on the ramp. These occurances were not included in the violations count because the absence of any queues indicates there is space available on the mainline for smooth merging. Violations were no more or less common during the peak hour as compared to the metering period, nor did ramp volumes seem to have any prescribed effect upon violation rates.

Table 12 shows the violation rates of each metered ramp along I-694. The A.M. violation rates are consistently lower than P.M., except at East River Road. This may be due to the fact that A.M. volumes consist mainly of commuters who are work bound and are familiar with the ramp metering system, whereas P.M. trips include those made for personal reasons and have a greater percentage of inexperienced drivers.

An average violation rate of less than 1% was found on I-35W, in comparison to 2.6% on I-694. However, this 2.6% still does not represent a serious violation problem. Over 97% of the motorists comply with the ramp metering system.

METER VIOLATION RATES

Ramp Location	VIOLATION RATE* A.M. (6:00-9:00)	VIOLATION RATE* P.M. (3:30-6:00)
SB TH 252 Ent Loop-EB I-694	1.1	1.4
WB I-94 Ent Leg-EB I-694	2.1	3.4
East River Road Ent-EB I-694	2.7	2.6
TH 47/University Ave. Ent-EB I-694	3.0	3.8
SB TH 65/Central Ave. Ent Loop-EB I-694	2.1	3.9
NB TH 65/Central Ave. Ent Loop-WB I-694	3.2	4.0
SB TH 65/Central Ave. Ent Leg-WB I-694	2.8	3.2
TH 47/University Ave. Ent-WB I-694	.8	2.5
Average	1.9	3.1
System Average = 2.6		

$$*\text{RATE} = \frac{\text{number of meter violations}}{\text{ramp volume}}$$

Table 12

H. System Costs

Information on the cost of operating and maintaining the I-694 system was gathered for the fiscal year 1983 utilizing records kept by the T.M.C. Staff. This information is presented in Table 13.

Four areas of expenditures are examined: maintenance, operation, building and computer costs. Maintenance represents work being done to maintain the system in working condition. It has been further subdivided to show labor, supplies and vehicle use costs. The system operations labor costs reflect the fact that the I-694 system is controlled from the T.M.C. The labor cost of the operator was based on an estimate of 5% of his/her total time in the Operations Room being spent dealing with I-694. The electricity and telephone costs shown under operations are incurred by the system's computer usage. The I-694 system was also assessed 20% of the total building expenses, such as electricity costs and general building costs, including janitorial services, telephone, water, and various miscellaneous expenses. The figure given for computer maintenance is based on a yearly third party contract held with Honeywell Inc., who has the responsibility for repairing and maintaining the Level 6 computer. Computer programming costs for I-694 were computed as 15% of overall programming expenditures. Annual capital costs are based on a bid price of $960,400, 6% interest, and a pay off period of ten years.

It is fairly simple to demonstrate the costs incurred per year by the I-694 system. A much larger task would be to try and evaluate the value of the benefits being received. It is not always possible to put dollar values on concepts such as "improved operating speeds" or "smoother traffic flow". The purpose of this report is to analyze a variety of traffic conditions before and after system installation on I-694 and to pinpoint the various improvements or benefits which would not have been received without the system. In addition, it is impossible to completely separate the benefits from the ramp metering system from those due to the geometrical changes. For these reasons, a benefit analysis was not completed.

ANNUAL SYSTEM COSTS
Fiscal Year 1983

System Maintenance Costs	
Labor*	$ 8,252
Supplies	$ 3,520
Vehicle Use	$ 1,125
Total	$ 12,898
System Operations Costs	
Labor*	$ 7,746
Electricity	$ 1,910
Telephone	$ 1,526
Vehicle Use	$ 831
Total	$ 12,013
Building Maintenance Costs	
Electricity	$ 2,151
General	$ 5,100
Total	$ 7,251
Computer Costs	
Maintenance	$ 7,000
Programming	$ 10,800
Total	$ 17,800
Annual Capital Cost	= $130,500
Total Annual Cost	= $180,462

Table 13

*Includes labor additives

V. CONCLUSIONS

Analysis of the data, and experience with the I-694 T.M.S. operation and maintenance leads to the following conclusions:

- Average operating speeds have increased during the study period for both directions in the A.M. peak period, and for the westbound direction in the P.M. peak period. These increases can be attributed to the combined effects of the traffic management system and the capacity increase west of the Mississippi River Bridge.

- These increases in operating speeds have been achieved even though peak period volumes have increased as much as 42% during the years studied.

- The increase in capacity has not been sufficient to overcome the substantial volume increases in the eastbound P.M. peak period. For this case, demand continues to exceed capacity, and average operating speeds have shown a slight decrease over the study period. However, without the influence of the ramp control system, much larger decreases in operating speeds could be expected.

- The general increase in operating speeds combined with an increase in volumes throughout the system results in a greater throughput of vehicles, vastly improving freeway efficiency.

- The improved operating conditions on the freeway resulted in a 36% reduction in total peak period accidents, and a 44% reduction in the peak period accident rate.

- Although queuing is a problem at several metered ramps, the driver compliance rate to the meters is over 97%.

- Despite the improvements described above, there is a need for additional capacity in the I-694 corridor. A new river crossing (TH 610) several miles north of I-694 is currently under construction. This project, scheduled for completion in late 1987, will provide a more convenient alternate route than is currently available. Also, a project to add a lane in each direction on I-694, between the river bridge and I-35W, is programmed for an October 1986 letting date.

- Further research and development activities should be directed toward accomodating the capacity increases expected for the I-694 system, integrating the I-694 system with the system currently under construction on I-94 between I-694 and downtown Minneapolis, and evaluating the incident management program on I-694.

APPENDIX
I-35W REFERENCES

1. "I-35W Ramp Metering" Report No. 07-118, January 1971, Office of Traffic Engineering, Minnesota Highway Department.

2. "Final Report, Planning for I-35W Urban Corridor Demonstration Project - Bus-on-Metered Freeway System" September 1971, Minnesota Highway Department, Metropolitan Transit Commission, Bather-Ringrose-Wolsfeld Inc.

3. "MHD Traffic Management Center - Design & Function" Report No. 07-043-04, May 1973, Office of Traffic Engineering, Minnesota Highway Department.

4. "I-35W Urban Corridor Demonstration Project" Final Report, August 1975, Minnesota Highway Department, Bather-Ringrose-Wolsfeld et al, for the Urban Mass Transportation Administration, U.S. Department of Transportation.

5. "I-35W Surveillance and Control System Operational Software" December 1975, Office of Traffic Engineering, Minnesota Highway Department.

6. "Ramp Meter Bypass for Carpools" Report No. FHWA-PD-76-189, October 1976, Office of Traffic Engineering, Minnesota Department of Transportation.

7. "Evaluation of Highway Advisory Radio in the I-35W Traffic Management Network" Report No. FHWA-RD-79-33, March 1979, Traffic Engineering Section, Minnesota Department of Transportation.

8. "I-35W Traffic Management System - Summary of Operating Experience 1974-1978" November 1979, Office of Traffic Engineering, Minnesota Department of Transportation.

9. "The Use of C.B. Radio in Traffic Management" February 1980, Office of Traffic Engineering, Minnesota Department of Transportation.

10. "I-35W Incident Management and Impact of Incidents on Freeway Operations" January 1982, Office of Traffic Engineering, Minnesota Department of Transportation.

11. "Maintenance of the Traffic Management System 1974-1981" August 1982, Office of Traffic Engineering, Minnesota Department of Transportation.