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TRAFFIC FLOW IN CONSTRUCTION ZONES

BY

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ABSTRACT

This study of traffic flows in seven work zones where a lane was removed from service concludes that work zone capacities were considerably greater than the 1985 Highway Capacity Manual estimates for temporary work zones. Detailed are the lane transitions, traffic flows and vehicle speeds observed.

A recomendation is made that standard freeway analysis techniques should be used when estimating capacities for similarly designed work zones. Reference is made to similarly high flow rates observed in Toronto, Canada.

TABLE OF CONTENTS

LISTS OF TABLES AND FIGURES

SUMMARY AND CONCLUSIONS

SUMMARY

Data was collected in 7 work zones on Routes I-80 and I-287. Included were measurements of volume & speed as well as observation of queueing. In addition, geometrics were analyzed for impacts on capacity and previous year's volumes were projected as demand for comparison to observed values.

Tables 1 and 2, located in the text, summarize specific work zone designs and some peak flow rates observed, respectively. Figures 1, 2 and 3 present peak period volume results while Figures 4 through 7 illustrate speed and flow rates. Figures 8 and 9 highlight principal geometric characteristics of two work zones commonly employed on Route 80. Figures 10, 11 and 12 present more detailed volume data for those two zones. The figures are located at the end. For consistency, all volumes reported are in terms of Passenger Car Equivalents (PCE's) using a factor of 2 for trucks.

CONCLUSIONS

Lane Transitions

The transition zone where the number of lanes reduced from four to three did not inhibit flows from reaching theoretically lower capacity sections downstream. Transitions needed to split the lanes left and right of a closed lane similarly did not restrict flow.

Flow Rates

Whole one hour volumes consistently exhibited the ability to exceed anticipated maximum average per lane capacities. They far exceeded the reduced rates the HCM suggested as capacities for work zones.

Speed and Delay

Speeds measured during even the most extreme flow rates consistently exceeded 40 mph. Delay was minimal or non-existent since demand was down as much as 25 % and per lane volumes were so high, despite near capacity non-construction demand and the (theoretical) loss of at least 25 % of capacity.

Demand

Substantial reductions in demand were apparent in six of the seven work zones, most likely due to the ongoing mitigation efforts. In spite of relatively minor levels of congestion during early stages, the reductions were among the highest in later stages. While later stages were often more complex, the highest flow rates achieved were within a stage 4 zone. It appears to this researcher that selective demand reduction has occurred. In other words, those that left the road are not representative of the driver population as a whole. If this is true, the more intimidating zones (i.e. split left and right with 0 feet side clearance to barriers) could be expected to have the greatest impact on the less aggressive drivers, especially those who have short trips, reasonable alternate routes or were only using the interstate because it was an easy road too navigate. In any event, flow rates in excess of 1900 vph across more than an hour are not a description of timid drivers.

RECOMMENDATIONS

From the above conclusions it is clear that the relatively well designed work zones observed are capable of substantially higher flows than can be anticipated from Highway Capacity Manual work zone procedures. Thus, lane capacities for lanes remaining open to traffic can be conservatively estimated by assuming non construction zone conditions and evaluating the specific physical features involved with standard freeway procedures. While the reasons for these higher than anticipated flow rates are not fully understood, the fact is that substantial volume reductions have been common. Based on the work zones observed, future estimates of delay and associated mitigation plans should be designed with at least 10 to 20 % demand reductions in mind.

BACKGROUND

Reconstruction on major divided highways in N. J. has become a substantial portion of the Department of Transportation's workload. Constructed as much as 25 years ago, many bridge decks and other key elements have reached the end of their useful life. Reconstruction of bridges may require entire structures to be closed, as in the case of Route I-287. Insofar as shoulders are not usually available for temporary use, substantial capacity reductions to mainline flows will occur even when only one lane is closed for reconstruction at a time, as was the case on Route I-80.

To cope with such potentially traumatic capacity reductions, substantial traffic congestion mitigation plans are a key element in every job and represent significant expenditures of increasingly scarce resources. While avoiding the serious delays which can occur is a major concern, conserving funds is of equal importance. In particular, major costs of the mitigation arise from the often temporary alternate services that are provided, such as park-ride lots and added busses. To aid those in planning such demand oriented portions of the mitigation efforts and so that funds are not overspent in false anticipation of delays, traffic conditions in work zones on Routes I-287 and I-80 have been monitored. Table 1 describes these zones.

While no attempt has been made to segregate the impact of existing mitigation efforts, as that task is the responsibility of others, the reported demands have undoubtedly been affected by those efforts. This study has instead been limited to better understanding the basic flow and capacity characteristics of work zones typical of those that are currently being designed.

RESULTS

Demand

In six of the seven work zones observed the demand was substantially lower than expected. Figure 1 illustrates the roadway volume observed versus the expected peak hour demand in each zone. The differences ranged from 100 to 1000 vehicles per hour (vph) in six of the zones observed volume was below the expected level. In the seventh zone, volume was 300 vph above the expected rate.

TABLE 1 PRINCIPAL GEOMETRIC CHARACTERISTICS

ZONE	CROSS SECTION		LANE TRANSITION	RAMP IN SECTION
I - 80				
I2W	Split	2 Left, 1 Right	4 TO 3	Open
I3W	Simple	Contiguous	4 TO 3	Open
II3W	Simple	Contiguous	4 TO 3	Open
IV4W	Split	2 Left, 1 Right	4 TO 3	Open
IV1E	Simple	Contiguous	4 TO 3	Closed
IV3E	Split	2 Left, 1 Right	4 TO 3	Open
I - 287				
3M	Simple	Across Median	3 TO 2	Open

Figure 2 illustrates that, in terms of demand, volumes dropped as much as 18 % from expected volumes during the peak hour. This suggests trip makers often adjusted the time of their work trip. However, Figure 2 also shows that four hour peak period volumes also dropped substantially, over 20 % in one zone. The zone that had an increase, rose 10 % overall compared to 4 % in the peak hour. Although peak period volumes were unavailable for zone IV3E, it is likely they dropped since this was the trend in other zones where peak hour volume dropped. In only zone II3W was congestion enough on the observed days to have restricted demand and then only in the peak hour. For other zones service volume was synonymous with demand.

The peak hour flows observed are illustrated in Figure 3. These volumes are the expansion of four 5 minute counts, one in each quarter of the hour. They were substantially above the capacity estimate (based on HCM procedures) in all but zone I2W. Estimates based on the work zone section of the HCM would be considerably lower (1350 to 1500). Most notable is the peak hour volumes of 2270 pce/hour at zone IV1E and 2090 at zone 3M, 670 and 590 vph respectively above estimated capacities of 1600 and 1500.

Speeds

Figure 4 illustrates the speed data charted against flow rates. Passenger Car Equivalents are based on expanding truck percents by a factor of 2, grades are not in evidence. Obvious is the high proportion of speeds above 40 mph, despite flow rates in excess of 2000 per hour. At the least, this is a testimonial to the well designed work zones.

Figure 5 segregates the data for zones I3W and II3W, the only two zones with any indication of congested flow. Also displayed is a line for the estimated capacities, 1760-1790 vph per lane based strictly on the lateral clearance, lane width and truck factor of 2. The lowest speeds of Figure 4 are generally repeated here. Based on the minor amount of queueing observed coupled with these "reduced" speeds, capacity flows were apparently approached.

Alternatively, Figure 6 shows the data for those zones where no queueing or congestion was apparent. There were few speeds below 50 and fewer flows above 2000 vph these zones, as compared to the zones with queuing.

Figure 7 shows that quite similar results were reported by Messrs. Hurdle and Datta in Transportation Research Record 905 (1). This paper hypothesizes that speeds and flows normally associated with bottlenecks sections are actually speeds in queues caused by some congested area beyond the section of interest. This was derived from comparing the speeds taken with and without congestion present. As with this New Jersey data, the Hurdle data was taken in a highly urban area (Toronto) on a major multilane commuter roadway where neither grades nor curvature is severe. Also like NJ, the sections involved were three lanes wide due to a lane reduction from four lanes.

The comparisons available for this and the Hurdle study illustrate that "unusual" volume and speed combinations have been documented elsewhere. However, limitations of the data collected prevent further comparison or comment on the likelyhood of the exeptionally high (2500 vph) capacities theorized by Hurdle and Datta. Instead, inferences drawn must be limited to assuming non-applicability of the HCM work zone capacity section for similarly well designed work zones.

Detailed Analysis

Zone IV was the only eastbound zone studied. This zone was selected for detailed study because it was expected to be least affected by upstream capacity reductions. Stage 3 was also of concern because it had "split lanes", a configuration with two lanes on the left and one lane on the right of the lane closed for reconstruction. The lane to the right also had an on ramp and the combination of single lane and ramps in the section were expected to provoke capacity constrictions due to merging demands. A second on ramp downstream was beyond the construction zone. Since it also added a lane to the cross section where it came on it was not considered a factor in the study design. Figure 8 includes a diagram of the section in the stage 3 configuration and several design details. The section between the two on-ramps is clearly the most likely to produce a bottleneck, based on estimates of demand and capacity shown in Figure 8. Videotape of traffic in the section was taken from a position between the split lanes to provide info for detailed analysis.

Stage 3

From this taping, rates and hourly volumes in the bottleneck section were determined for individual lanes. Hourly rates were highest on average in the mainline lanes to the left of the split. Rates above 2000 vph were observed in 14 of the 16 5 min periods between 7:10 and 8:30. Rates peaked at 2330 at 7:50 AM. This was the most extreme example of excessive rates noted during the study.

Figures 10 and 11 illustrate the rates observed during individual 5 minute periods. Figure 10 shows the two mainline lanes left of the split. Figure 11 shows the left lanes, right ramp lane and the three lane total. The rates are substantially above the estimated capacity of 4800 for the three lanes. Despite that, there was no evidence of congestion in the section. Flow rates peaked at 7:45 AM in the two left lanes and averaged 2166 vph over a 5 minute period and in the ramp and right lane combined for a rate of 2472 vph at 7:40 AM. Speed data taken during the count period suggests that the two left lanes were near capacity at 7:45. This data is presented in more detail in a later section of this memo.

Table 2 presents a summary of the highest whole hour volumes observed in all three lanes. The extreme rate of over 2160 per hour in the left of two lanes is offset by the right lane which peaked at around 1730 so that the average in that "roadway" peaked at about 1940. While this average is rather high it is less than 2000 vph and such differences between flow rates in adjacent lanes is not unusual.

Stage 3 Summary

The section just downstream of (beyond) the on ramp was selected for analysis because it represented the bottleneck or "critical section". Specifically, the combination of expected demand and reduced capacity were the most extreme. Upstream sections, where the number of lanes reduce from 4 to 3, were monitored to ensure that they did not congest and meter the volumes in the critical section.

Volumes upstream peaked at 7:30 AM when the rate was 6860 vph. An average of 5 minute counts taken at 15 minute intervals between 7 and 8 AM showed 6015 vph in three lanes, about 5% below expected demand. No congestion was evident. Volume downstream of the off ramp (and upstream of the on ramp in the critical section) peaked at 4870, again about 5% below the expected demand. The difference in the volumes is due to the off ramp accessible only from the right lane. The high volume exiting the road via this ramp undoubtedly aided on-ramp vehicles by creating gaps. Due to the split roadway cross section, these gaps were isolated from the remaining traffic and available only to entering vehicles.

TABLE 2 PEAK RATES (Vehicles Per Hour) - ZONE IV3E

SECTION	LANE	VOLUME	TIME
Mainline Left			
- Left	MLLL	2166	7:30 - 8:30 AM
- Right	MLLR	1729	7:05 - 8:05 AM
- Average	MLL	1937	7:20 - 8:20 AM
Right Ramp Lane			
+ Ramp	MLR + RAMP	1892	7:10 - 8:10 AM
ALL LANES	Total	5752	7:10 - 8:10 AM
	Per Lane	1917	

Stage 1

Stage 1, a simple 3 lane section, was observed as well although in less detail. Stage one differed in that the right shoulder was converted for through lane use so that the left two lanes could be closed for center barrier removal. The three lanes open to traffic were contiguous. Figure 9 illustrates the basic configuration. Figures 8 and 9 are typical of work zone designs used elsewhere during the reconstruction.

Stage 1 Summary

Section IV, stage 1 was the only work zone studied which experienced increased volumes, previously highlighted by Figures 1 and 2. From count data taken in 5 of each 15 minutes, the peak rate observed for the three lanes was 7250 vph and the peak hour (average in highest 4 contiguous 15 minute periods) was 6820 vph. Figure 12 illustrates the data. Numerous factors undoubtedly contributed to the volumes decrease which occurred during the two months which transpired between this stage and stage 3. Stage 1 was not only the least restrictive type of cross section design it also occurred earlier in time and was not subject to any summer season influences (stage 3 was observed in July). Not only were the more imposing "split" zones employed in stage 2 and 3, drivers also had more time to find alternate routes and take advantage of the substantial mitigation efforts which were ongoing during the entire reconstruction.

(1) V F Hurdle and P K Datta; Speeds and Flows on an Urban Freeway: Some Measurements and a Hypothesis. TRB. TRR 905, 1983, pp 127 - 137.

APPENDIX

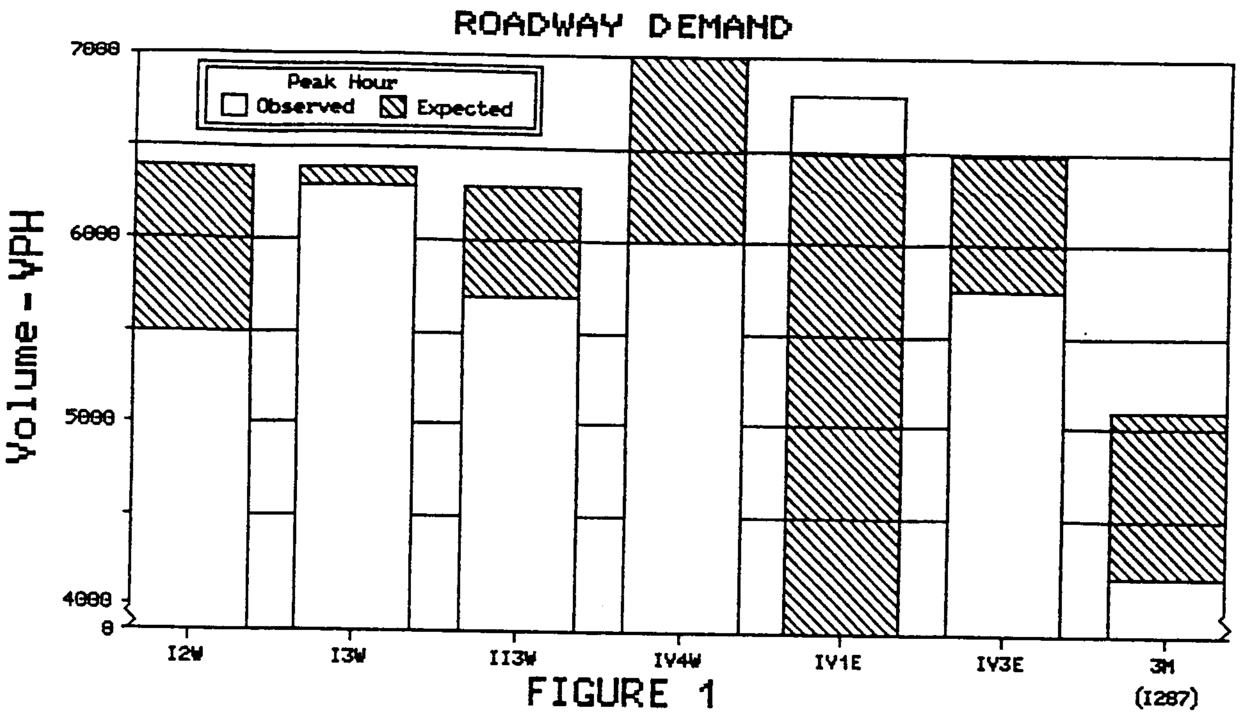


FIGURE 1

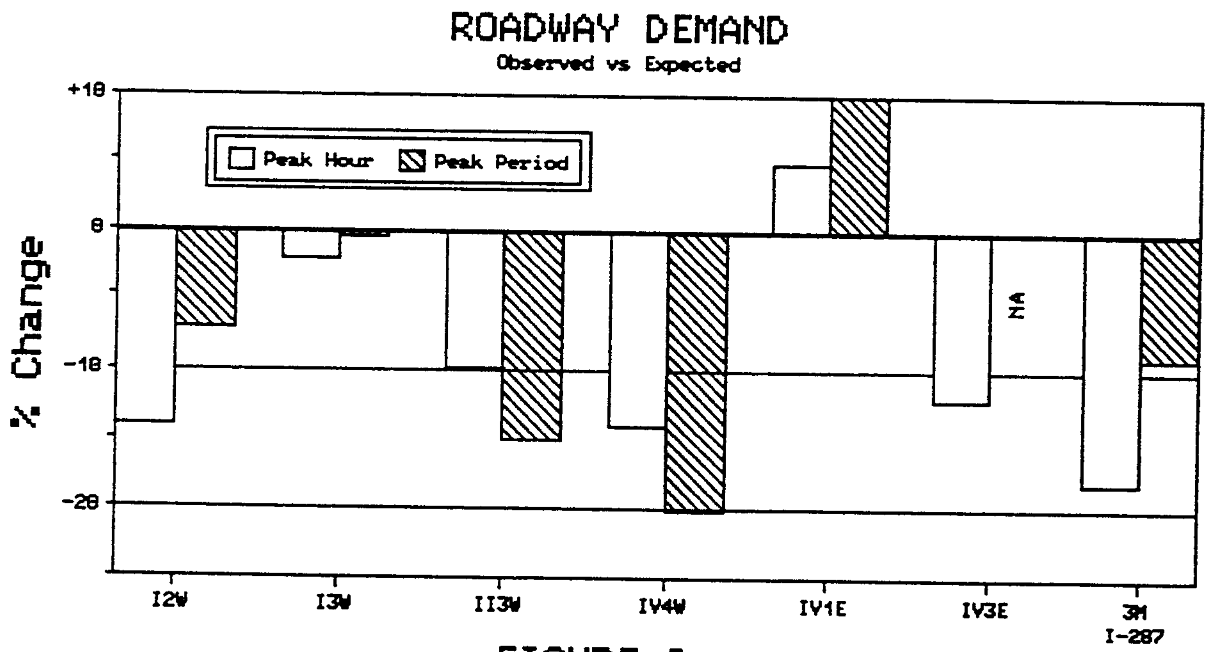
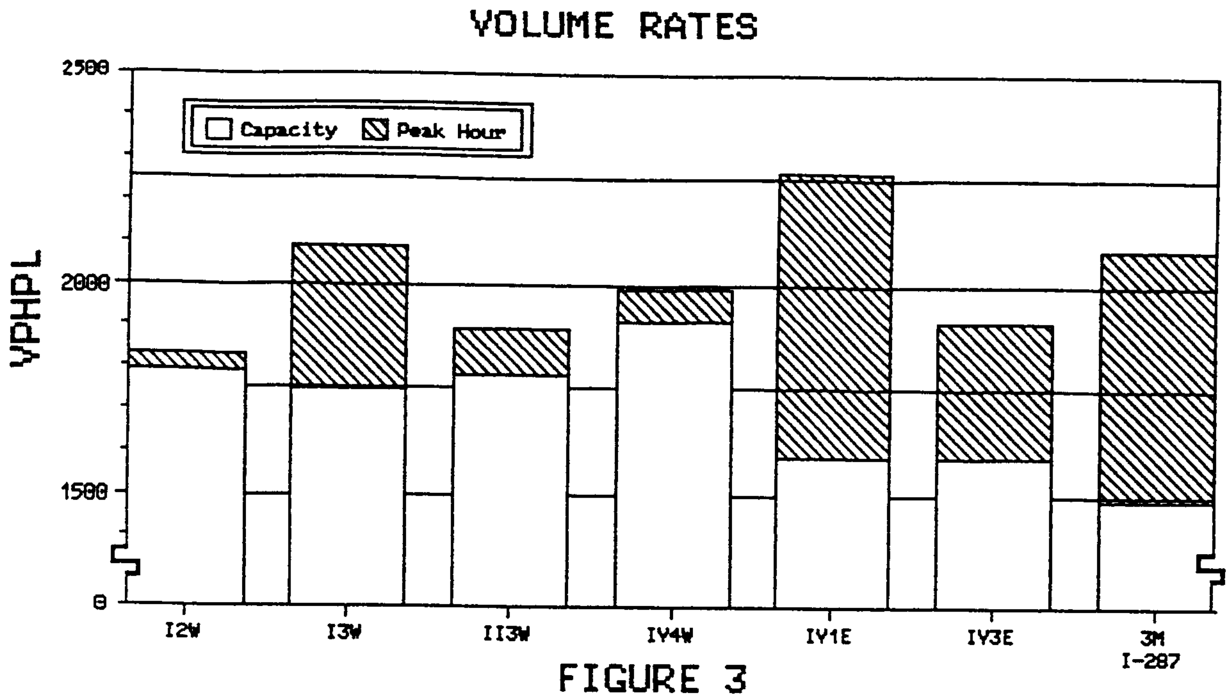


FIGURE 2



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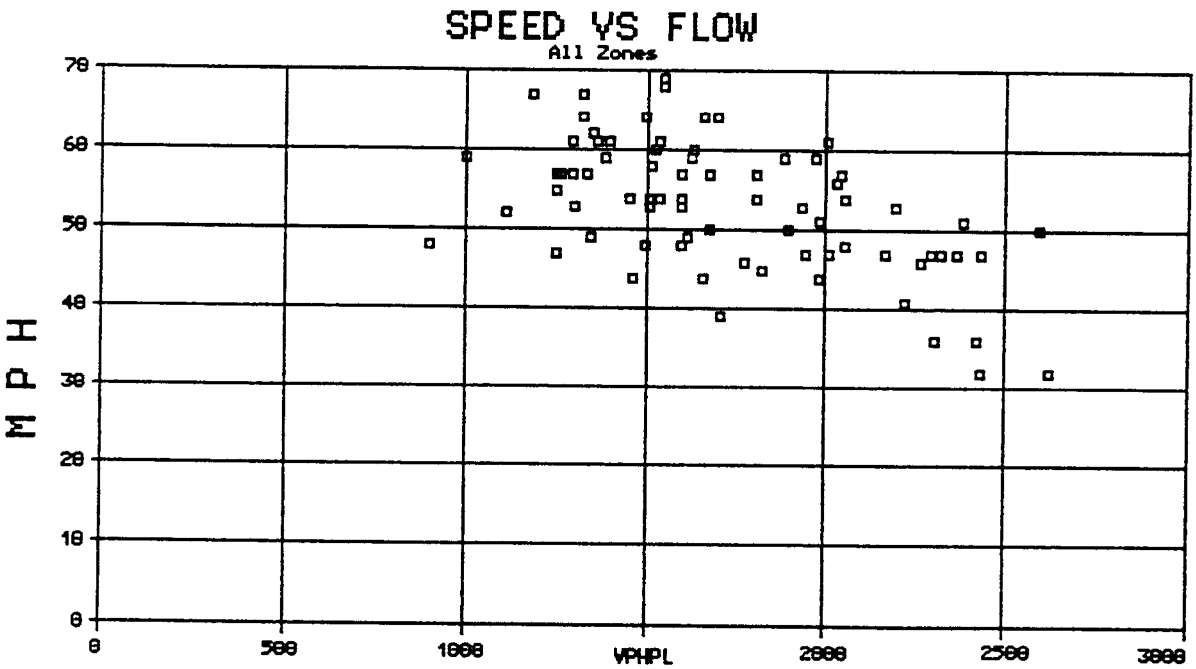


FIGURE 4

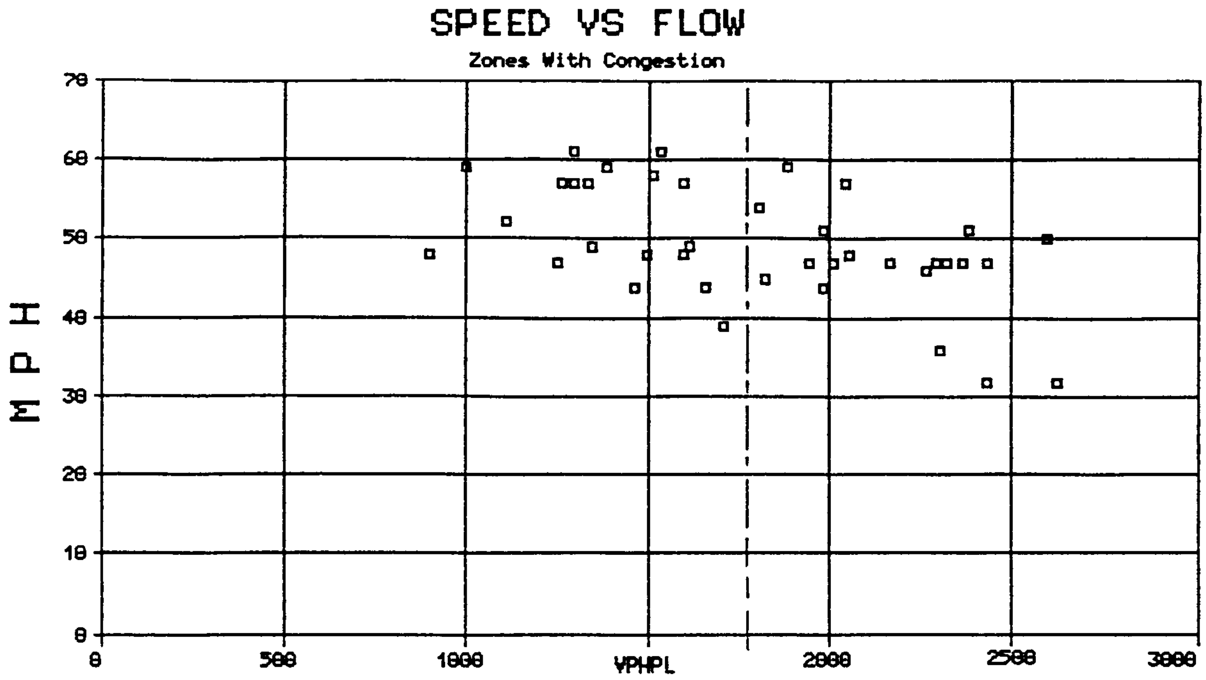
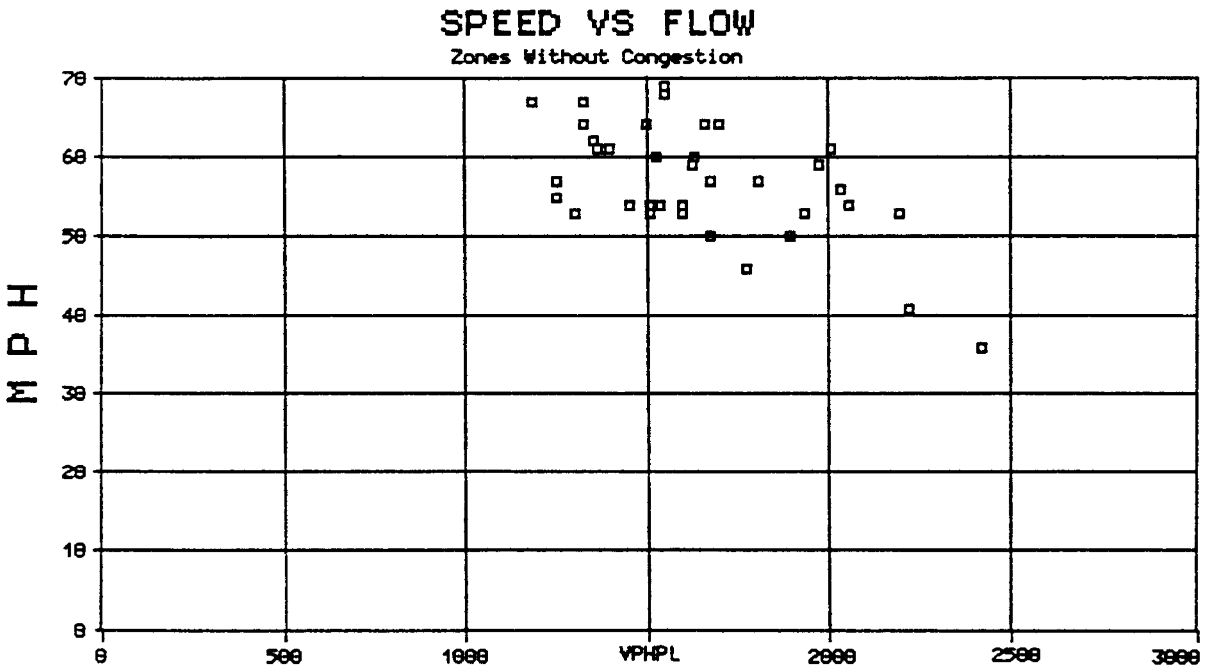


FIGURE 5



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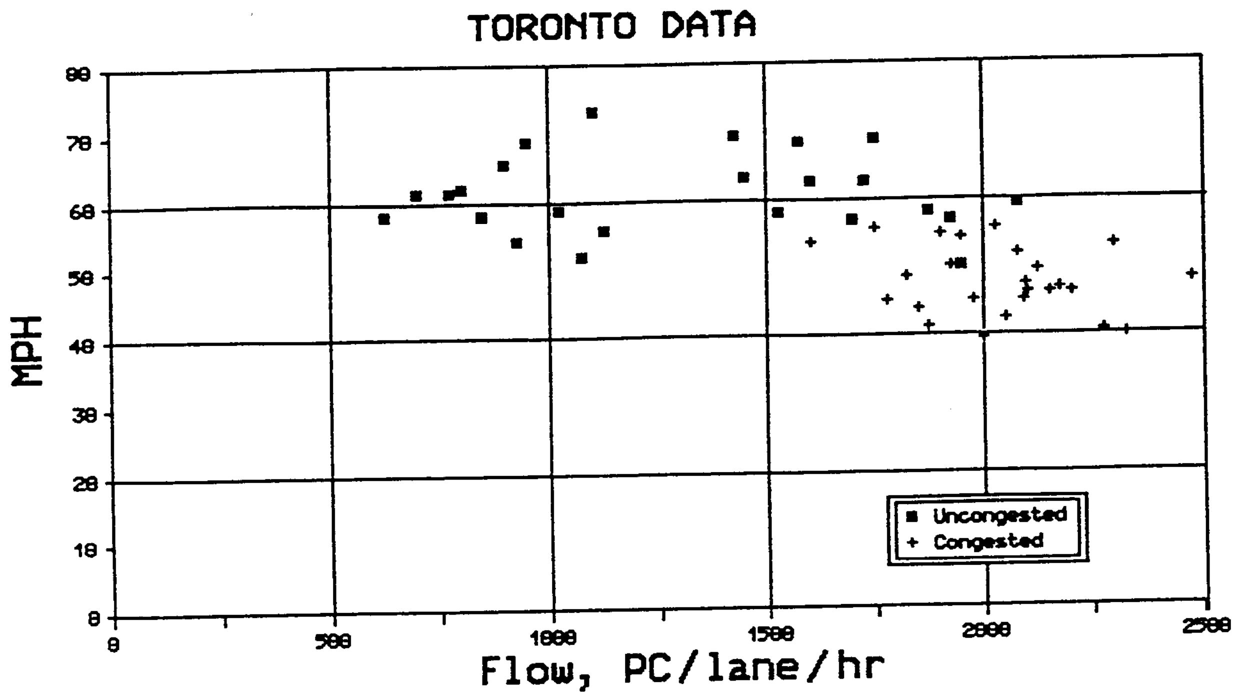
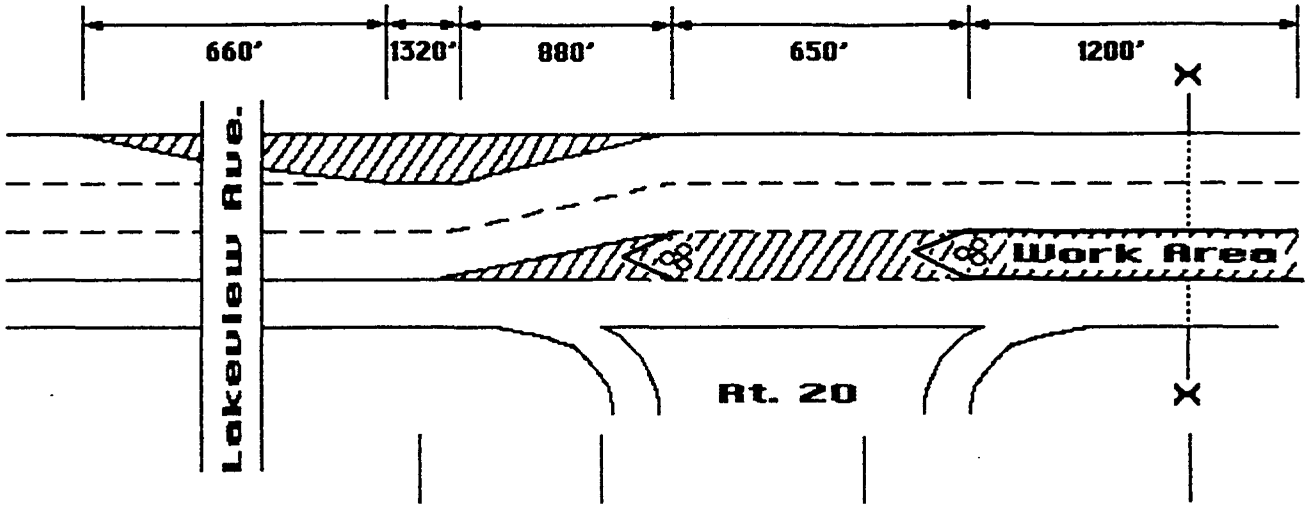

TORONTO DATA
MPH
80
70
60
50
40
30
20
10
0
0
500
1000
1500
2000
2500
Flow, PC/lane/hr
Uncongested
Congested

FIGURE 7

Rt. 80

Rt. 20 Interchange
Zone III 3E

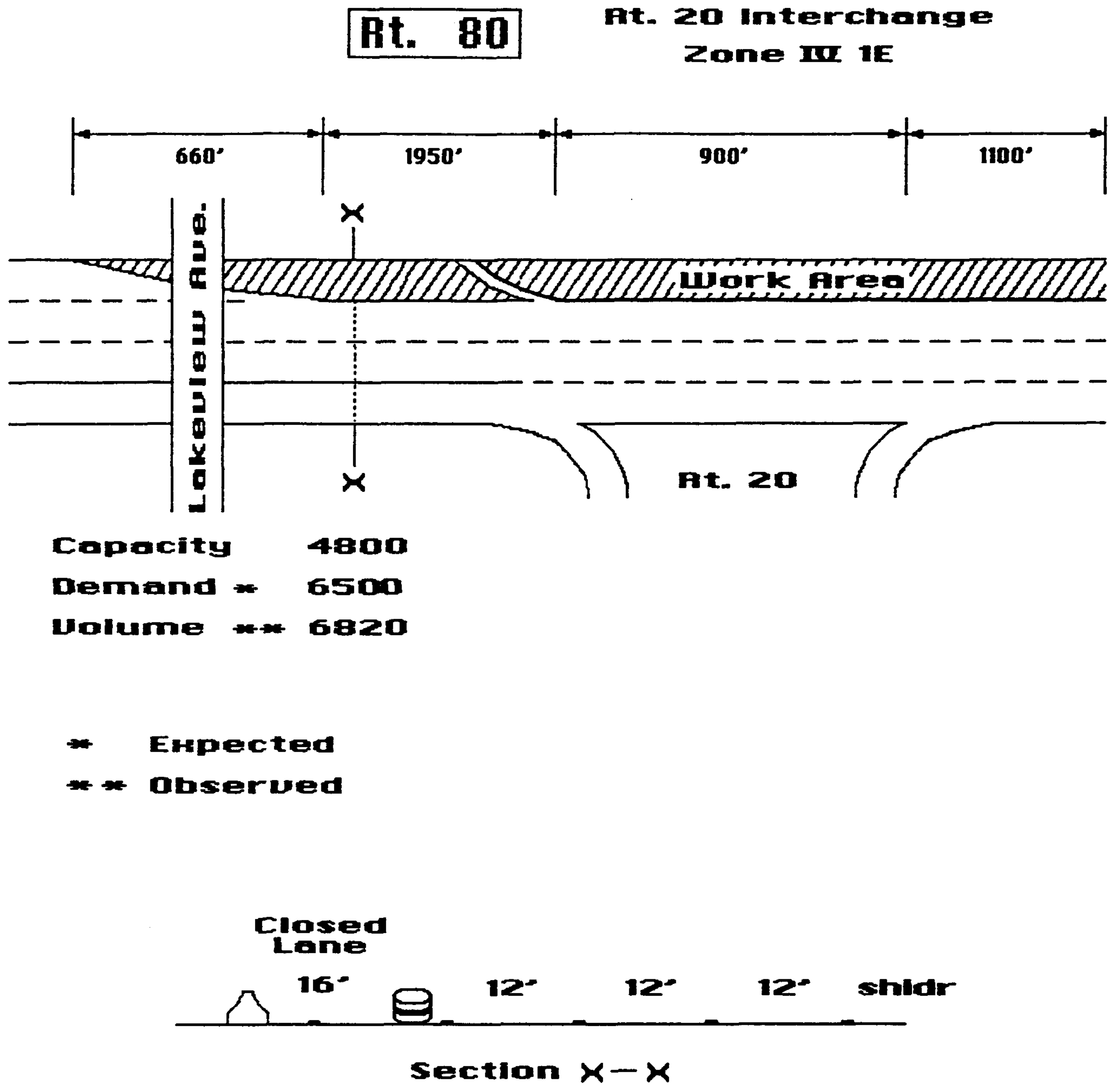


Capacity	5460	4800	4800	4800
Demand *	6500	6500	5100	6200
Volume **	6015	6015	4870	5750

* Expected
** Observed

Section X–X

FIGURE 8



Rt. 80
Rt. 20 Interchange
Zone IV 1E
660'
1950'
900'
1100'
Lakeview Ave.
Work Area
Rt. 20
Capacity 4800
Demand * 6500
Volume ** 6820
* Expected
** Observed
Closed Lane
16'
12'
12'
12'
shldr
Section X—X

FIGURE 9

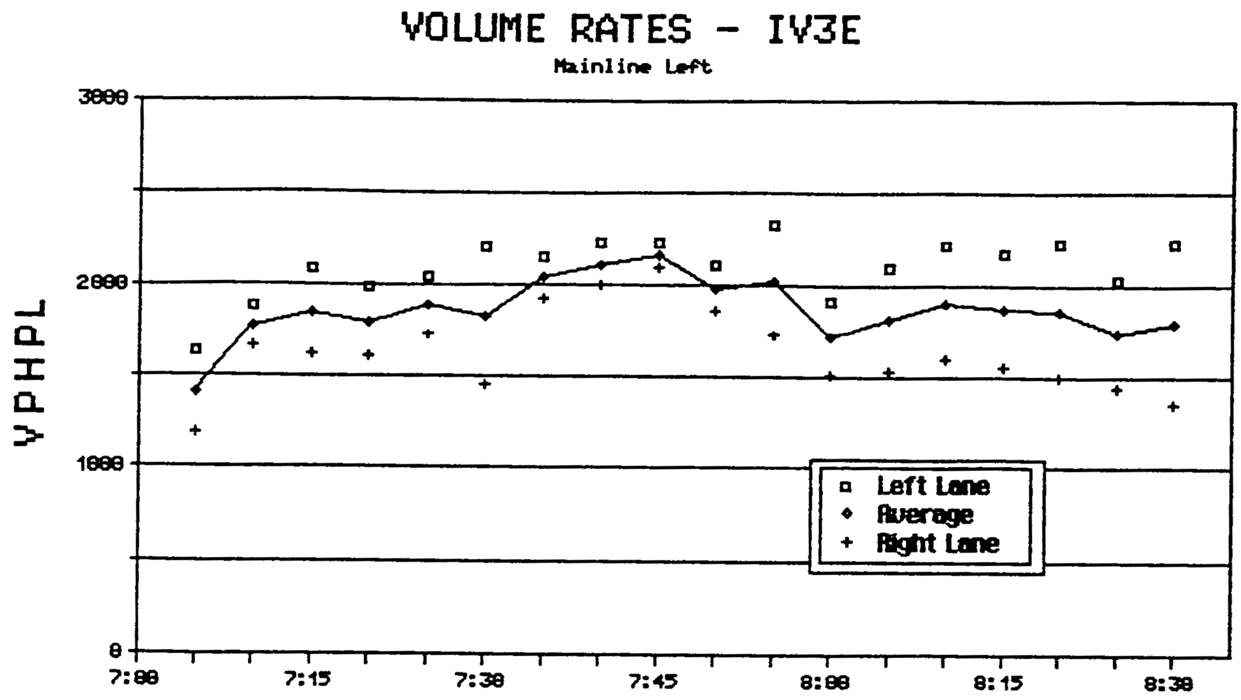


FIGURE 10

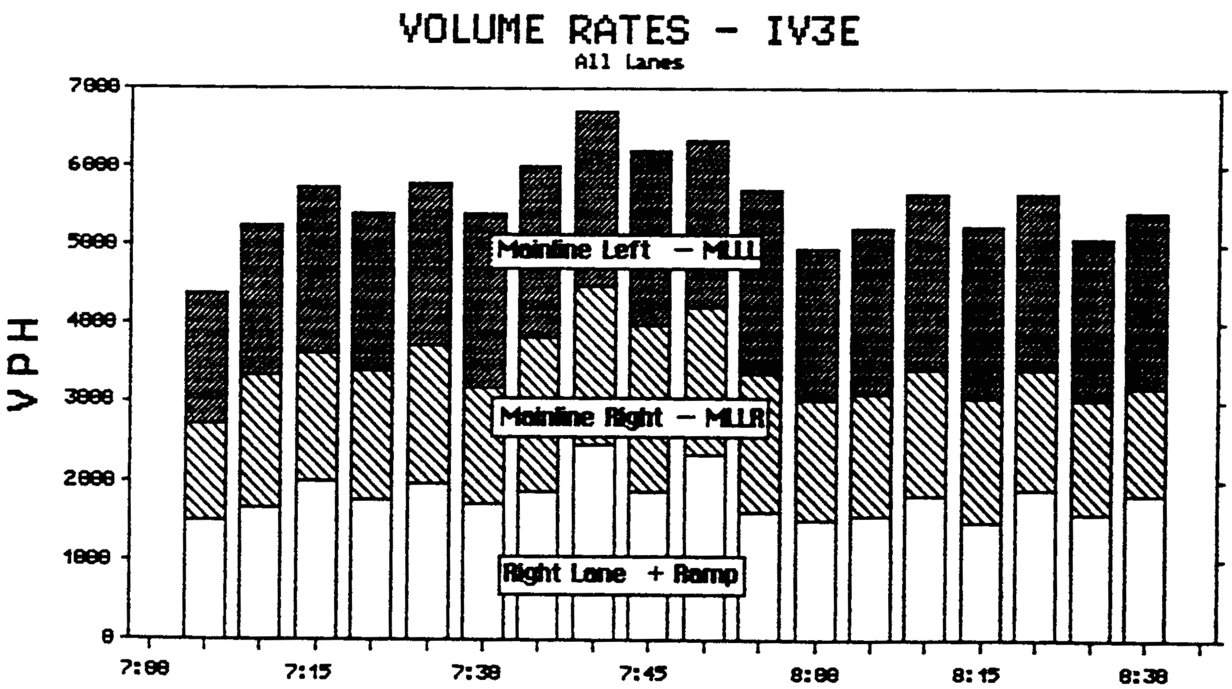


FIGURE 11

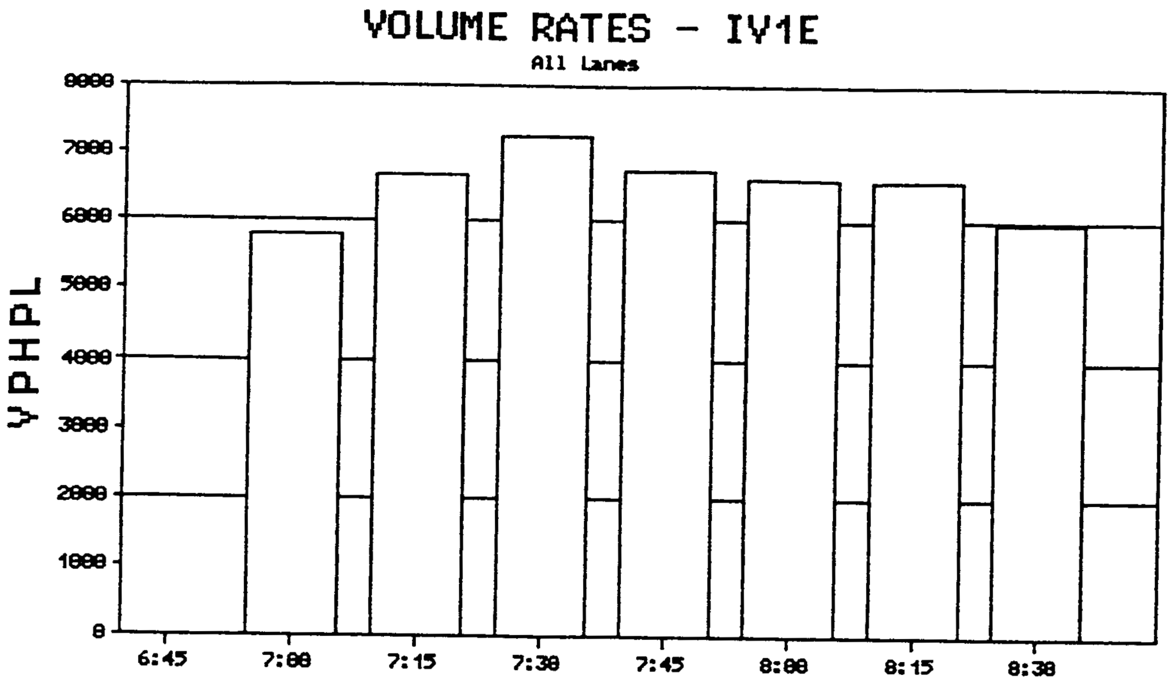

VOLUME RATES - IV1E
All Lanes
VPHPL
8000
7000
6000
5000
4000
3000
2000
1000
0
6:45
7:00
7:15
7:30
7:45
8:00
8:15
8:30

FIGURE 12