BENEFITS AND SAFETY IMPACT OF NIGHT WORK-ZONE ACTIVITIES

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Virginia Highway & Transportation Research Council
(A Cooperative Organization Sponsored Jointly by the Virginia Department of Highways & Transportation and the University of Virginia)

In Cooperation with the U. S. Department of Transportation
Federal Highway Administration

Charlottesville, Virginia

October 1984
VHTRC 85-R10

1074

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ABSTRACT

Through a literature review and discussions with highway and transportation officials in several states, information was obtained on questions and concerns relating to the planning, safety, and traffic control aspects of night maintenance and construction activities and their advantages and disadvantages. The information obtained was used to develop general guidelines on when and how maintenance and construction work should be performed at night. The report presents case studies illustrating the activities required in different types of night maintenance and construction activities.

Although there are many potential disadvantages of working at night, it is believed that through the experience that has been gained and proper planning and special concern for workmen and motorist safety, the night alternative is feasible for selected work.

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INTRODUCTION

Over the last few years, the emphasis in the highway industry has shifted from building new facilities to maintaining and improving the ones in service.

The rehabilitation and improvement of freeways, especially in urban areas, entail considerable problems where closing traffic lanes for these activities creates heavy congestion on roads already loaded to capacity. The consequences are adverse effects upon the safety of the traveling public and highway workers, and inconvenience and cost to the delayed motorists, all of which can lead to adverse public reaction. To minimize these consequences, many agencies restrict roadway maintenance activities to hours of off-peak traffic, weekends, and nights. While conducting work during off-peak hours, e.g., 9 a.m. to 3 p.m., is feasible in some areas, there are many situations where lanes cannot be closed during the daytime because of high traffic volumes. For example, in recently referring to traffic in a major metropolitan area, a state transportation department official noted that "it was hard to separate the morning rush hour from the evening rush hour." He added that "the traffic is now reaching the physical capacity of the systems inbound and outbound," and that in some areas "the congestion lasts for 12-14 hours a day."(1)

As a means of avoiding some of the problems, in number or degree, encountered in daytime work, nighttime operations have been employed on numerous occasions around the country. In California, it was reported that a concrete paving operation conducted at night was completed in 16 working days, whereas it would have taken at least 35 working days to complete during daylight because of the fewer working hours and more interference from heavy traffic.(2) Further, during the nighttime paving operation traffic moved along the road at near normal speeds.

Although night work is being conducted in numerous areas around the country, and is on the increase, important considerations and questions concerning the safety of the motorist and the worker remain to be dealt with. Visibility is greatly reduced at night, some drivers are less attentive and travel faster than in daylight, and more impaired drivers are reported to be involved in work site incidents and accidents. Also, night work creates problems concerning work forces, work scheduling, material acquisition, quality of work, etc. To examine how a number of highway agencies have handled the concerns and problems inherent in conducting highway operations at night, the research reported here was undertaken.

PURPOSE

This study was conducted to (a) compile information on current practices in conducting highway maintenance and construction operations at night, and (b) to synthesize the information into guidelines for determining when nighttime work should be done and what traffic control devices should be employed.

SCOPE

The information developed for this report was obtained from a survey of available literature on nighttime work zone activities and discussions with personnel in those states and agencies who have developed expertise in night maintenance and construction operations. The discussions were essential to the authors' understanding of the many variables, problems, decisions, and issues involved in nighttime highway rehabilitation, and were accommodated through visits to departments of transportation in the following states:

California (Los Angeles)
Georgia (Atlanta)
Illinois (Chicago)
Maryland (Baltimore)
Michigan (Detroit)
New York (Long Island)
North Carolina (Raleigh)
Pennsylvania (Philadelphia)
Texas (Dallas and Houston)
Virginia (Norfolk)
Washington, D. C.

To illustrate the activities involved in different types of night maintenance and construction operations, and to explain the different strategies and philosophies involved, project plans and specifications were obtained from some of the agencies interviewed and are presented as case studies.

This study includes the primary considerations regarding the procedures and information for deciding if and when night operations should be undertaken. The material is presented under the following major headings:

-- Considerations for Conducting Night Maintenance and Construction Operations

-- Scheduling Lane and Road Closures

-- Cost of Work Zone Operations

-- Safety

-- Public Relations

-- Agency Versus Contracted Work

-- Other Considerations

-- Traffic Control for Night Work Zone Activities

-- Advantages and Disadvantages

-- Case Studies

-- General Guidelines for Night Operations

-- Conclusions

CONSIDERATIONS FOR CONDUCTING NIGHT MAINTENANCE AND CONSTRUCTION OPERATIONS

There are two main reasons for conducting night operations: (1) to allow work over a longer period of light traffic than the off-peak period between the morning and afternoon rushes, and (2) to decrease or eliminate the excessive traffic delays and congestion associated with lane closures during the daytime.

Certain types of road work require more time than is available between the morning and afternoon peaks. For example, a cast-in-place concrete patch in a pavement may require more time for setting than is available between these peak traffic periods.

While the short length of time available for daytime operations dictates that some types of work be done at night, the persons interviewed for this study cited the interference with traffic that results from daytime lane closures as their primary reason for considering night work. How traffic volumes were used in the planning process is a primary consideration and the following discussions will present the associated impacts and analyses available for investigating the alternative of night operations. The basic factors considered in the planning process and their interrelationships are discussed under the following subheads.

Agency Policy

Based on their experience, and in response to public and political pressure, some states have issued policy statements that dictate the traffic control schemes to be used for lane closures on freeways. The following is a list of typical policy statements or instructions from various agencies concerning the handling of traffic.

-- Closures necessitated by work which cannot be done any other way will be scheduled at night or on weekends, but with specific approval.

-- Monitor the vehicular flow on the freeway system and do not schedule work when the traffic volumes are abnormally high.

-- Consider the relief to normal traffic congestion in the freeway environment through the use of work deferred to nights, weekends, use of alternate routes, CB radios, and other media announcements.

-- "When such scheduled activities could have an adverse effect upon motorists, ensure that they are carefully planned to minimize traffic disruptions."

-- "As a general rule, travel delays should not exceed 10 to 20 minutes maximum." This statement automatically requires that other considerations or alternatives such as night operations be contemplated.

-- "The attached map delineates freeway locations and probable degree of congestion and delay that motorists would experience

if a lane closure is made within those limits. The probable amount of congestion and delay is identified on the map by three conditions. Use this map and information as a guide when planning or scheduling freeway closures."

-- One agency has maps showing the portions of high volume roads that should be considered for night or weekend work when lane closures are necessary.

There are policies for planning work zones, and these generally suggest the levels of traffic and other criteria that should be considered when deciding if night operations are warranted.

Traffic Impact

The manner in which traffic volumes are factored into decisions on whether or not to conduct maintenance operations at night varies from state to state and is largely dependent on how much traffic can be allowed to back up, what the motoring public will tolerate, and the characteristics of the roadway. One indication that some states view night operations as a last alternative is that they will allow traffic to back up over long distances to keep from having to work at night, especially if the lane closure can be limited to one or two days. A series of daily lane closures resulting in continuous congestion are usually followed by adverse public and media reactions leading to adoption of the night work alternative.

In view of the above, a determination of traffic volumes is necessary for estimating the congestion that will be created by lane or road closures. Also, knowing the daily variations in traffic volumes is helpful in pinpointing the low volume periods for scheduling work. Although there are some who claim to know, either through experience or judgement, the conditions under which traffic volumes will cause undesirable daytime congestion, there are others who go through a detailed analysis in estimating congestion and must rely on reliable or recent traffic volume counts.

Estimates of traffic volumes are usually available from data taken at permanent traffic count locations; however, care should be taken to ensure that the data are reliable. The data should be current, they should be for time periods similar to those during which it is anticipated the work will be done, and for the vicinity of the work zone, since ramps between the count station and work zone can significantly influence recorded volumes.

The composition of the traffic stream should be noted along with any special events (sports, holidays, etc.) that could influence the expected volume.

The agencies of some jurisdictions, including those in Chicago, Los Angeles, and Detroit, supplement volume data with data from their freeway surveillance system from which real-time traffic flow data are available. All the agencies interviewed noted that existing data are supplemented with special spot counts when necessary as a means of ensuring good volume estimates.

When detours are considered, it is important to have an accurate determination of volumes to ensure that the detour route will handle the volume expected to be placed on it.

Volumes can be influenced by diversion. Prior publicity can induce motorists to take alternate routes. Information from California indicates that a volume diversion of up to 30% was observed for familiar or local traffic when signs were displayed offering information on alternate routes. Also, if work is under way in an area for an extended period of time, motorists sometimes alter their routes to avoid the area. A good example of this was an instance in the Washington, D.C., area where a 10% volume reduction resulted from a prolonged construction project.(3)

Analysis of Congestion

Various states contacted indicated that the decision to work at night was based on the available expertise and the experience that had revealed where and when lane closures would lead to undesirable daytime congestion.

The ability of a lane closure strategy to accommodate traffic is the main determinant of whether operations will be conducted during the day or at night. Any strategy that does not adequately accommodate the traffic demand during the anticipated lane closure must lead to the consideration of alternatives to daytime work, especially if the strategy imposes excessive congestion.

A procedure frequently used to investigate congestion is simply to plot the hourly volumes for the time period during which the work is to take place. For example, Figure 1 shows the volume distribution on a 3-lane freeway during the probable construction period along with estimated capacities for the work area. It is apparent that 2 lanes will handle the demand during the midday period; however, this time period is too limited for the work to be accomplished. Also, the analysis indicates that there is a lengthy period of time each night when 2 lanes can be closed and only 1 lane will be needed to handle the traffic. The times at which the lanes can be closed and reopened to traffic can also be obtained by noting when the traffic demand and capacity are in the same range.

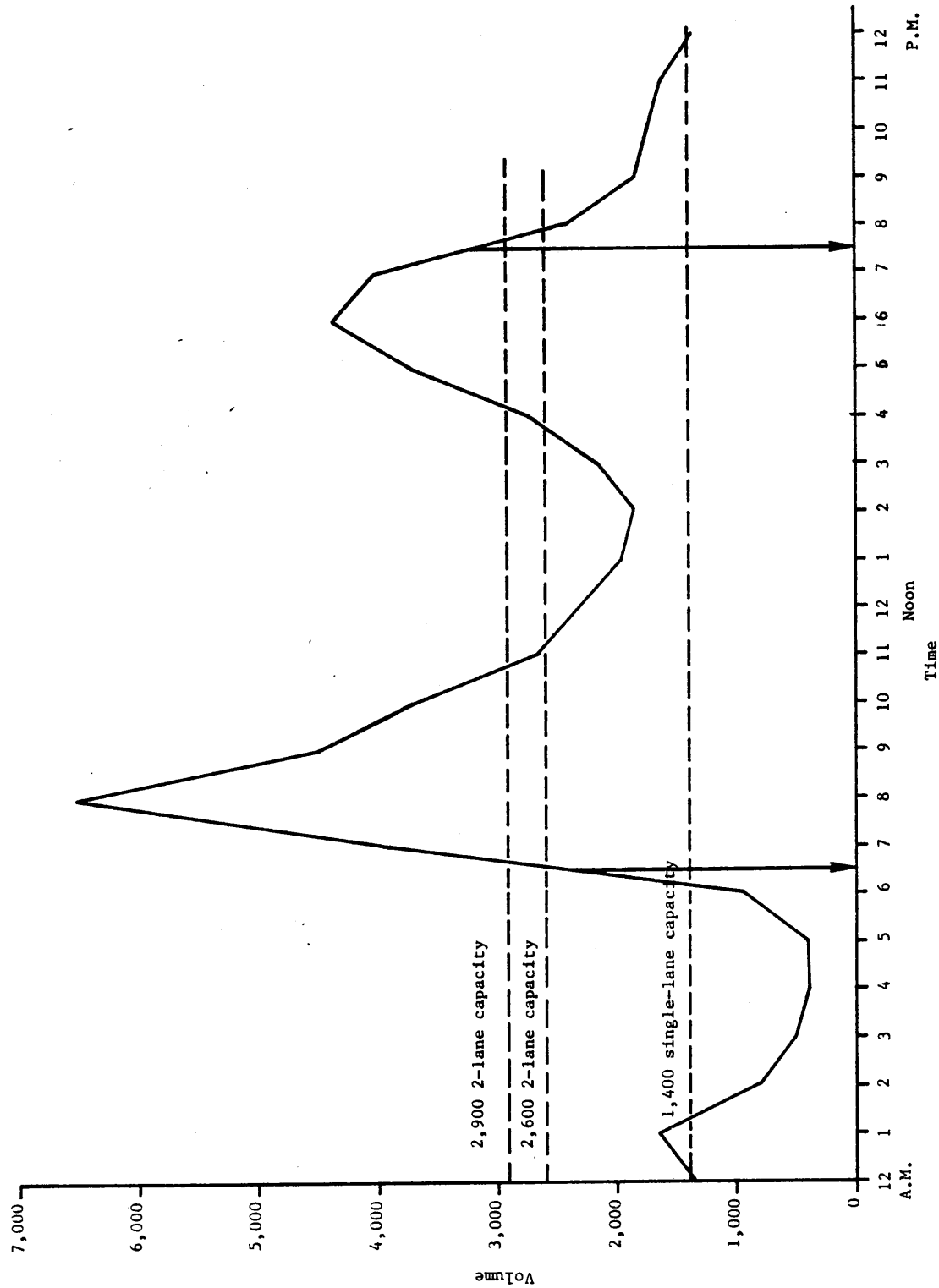


Figure 1. Volume distribution for 3-lane freeway.

From the above it can be seen that an estimate of traffic capacity that can be accommodated through a work zone is an important consideration in the planning process.

Capacity

Capacity Guidelines

Some states and agencies have developed general guidelines for lane capacities based upon their policies and experience, the work area, the type of work to be done, etc. Table 1 summarizes these lane capacities in vehicles per hour per lane (vphpl). These capacities and comments provide a general guide as to the capacity level at which they would start considering night operations. Specific lane capacities for typical operations in California and Texas are shown in Table 2. It is noted that the type of work affects the capacity. Also, Table 3 shows the average capacities for different lane closure situations taken from 37 studies in Texas.

To assist in predicting the risks associated with using these values for a given lane closure, the data shown in Table 3 were plotted in the form of cumulative distributions at observed work zone capacities as shown in Figure 2. For example, the 85th percentile for (3,1), 3 lanes with 1 lane open, is 1,020 vphpl. This means that 85% of the studies conducted on 3-lane freeway sections with 1 lane open through the work zone resulted in capacity flows equal to or greater than 1,020 vphpl. The capacity flow was equal to or greater than 1,330 vphpl in only 20% of the cases studied. Therefore, an assumed capacity of 1,500 vphpl for the (3,1) work zone would likely result in an underestimate of the backups associated with the closure.

Table 1

Lane Capacity

Area	VPH per Lane	Comments
Los Angeles	1,500-1,800	a) 1,500--usually no congestion unless more than one lane is closed. b) Sometimes use 1,800 (with some backups to give contractor more time.
Atlanta	1,200-1,500	a) No daytime closures for Atlanta. Depending on the area, no daytime closures if 2 or more lanes are closed.
Chicago	1,300-1,500	a) Depends on location, number of ramps, etc.
Detroit	1,200-1,500	a) 1,200--volume before backups start. b) 1,500--expect serious backups.
Raleigh	1,300-1,600	a) Depends on area and experience.
Long Island	1,500	a) If closure is 2 or more lanes, have to detour traffic and work at night.
Philadelphia	--	a) Closures based on experience.
Dallas	1,300-1,500	a) In many cases will accept daytime backups rather than work at night.
Houston	1,200-1,500	a) > 1,200--start worrying. b) 1,500--requires a detailed analysis of the situation. c) < 1,500--only with special traffic management.
Norfolk	1,500	a) 1,500 maximum at 35 mi/h (56 km/h) without backups.

Table 2

Summary of Capacities for Typical Operations in California and Texas

Type of Operation	No. Lanes One Dir. 2		No. Lanes One Dir. 3		No. Lanes One Dir. 3 or 4		No. Lanes One Dir. 4	
	No. Open 1		No. Open 1		No. Open 2		No. Open 3	
	Calif.	Texas	Calif.	Texas	Calif.	Texas	Calif.	Texas
Median barrier or guardrail repair or installation	1,500	--	--	--	3,200	2,940	4,800	4,57
Pavement repair	1,400	--	--	1,050	3,000	2,900	4,500	--
Resurfacing, asphalt removal	1,200	1,300	--	1,050	2,600	2,900	4,000	--
Bridge repair	--	1,350	--	1,350	2,200	--	3,600	--

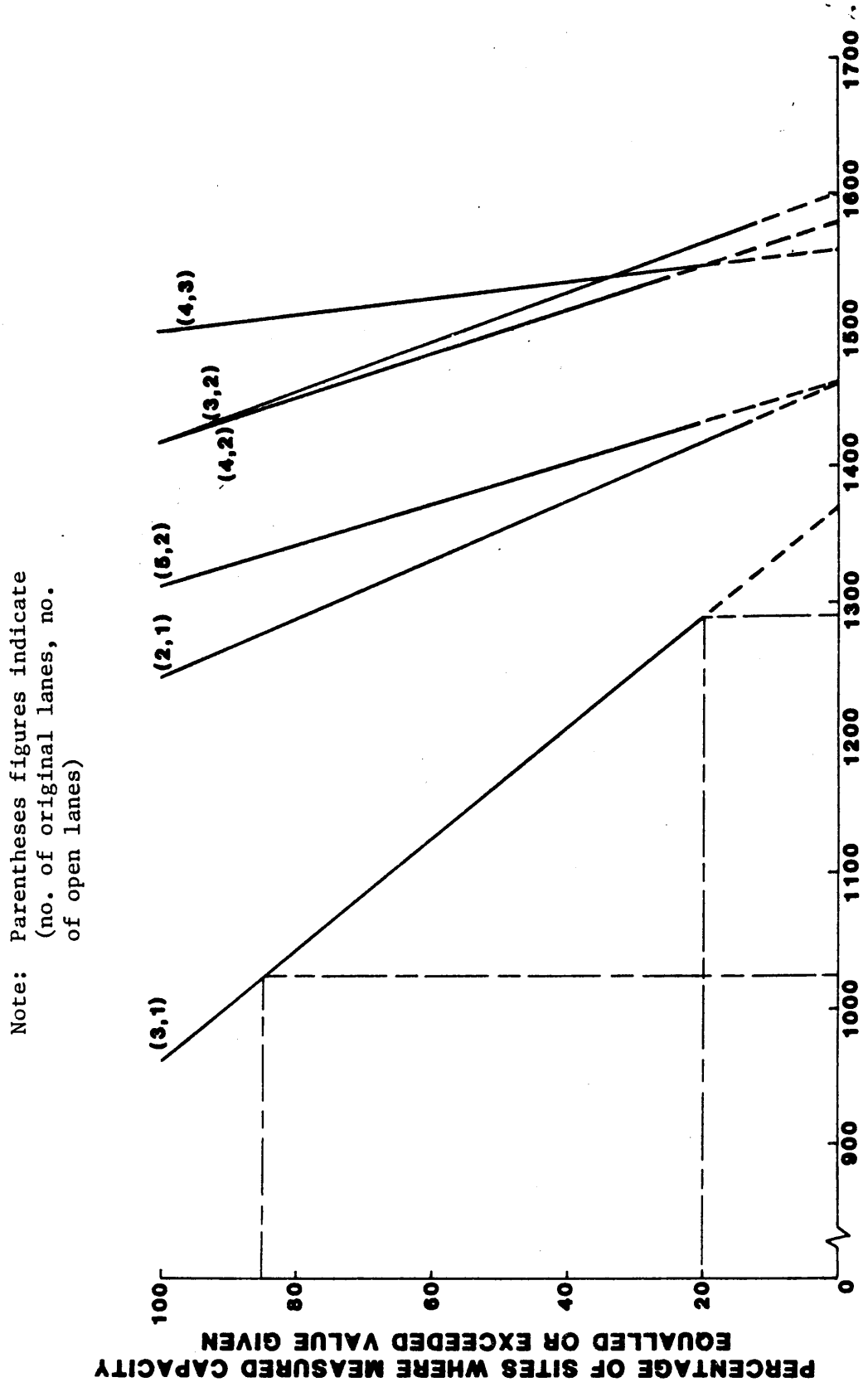
Source: California - Reference 4; Texas - Reference 5

Table 3

Average Capacity for Different Work Zone Closures

No. lanes one direction	No. lanes open one direction	No. Studies	Avg. Capacity vph	Avg. Capacity vphpl
3	1	5	1,130	1,130
2	1	8	1,340	1,340
5	2	8	2,740	1,370
4	2	4	2,960	1,480
3	2	8	3,000	1,500
4	3	4	4,560	1,520

Source: Reference 5



Note: Parentheses figures indicate (no. of original lanes, no. of open lanes)

Figure 2. Cumulative distribution of work zone capacities. (From reference 5.)

Calculated Capacity

Another method for predicting vehicle capacity for work zones uses an equation for calculating the capacity. However, work by Abrams and Wang (6) indicates that the work zone itself has an additional effect on lane capacity beyond that attributed to lane narrowing and other factors included in the Highway Capacity Manual (HCM) (7). The equation developed by Abrams and given in reference (6) is

Freeway Work Zone Capacity =

$$2{,}000 \times TF \times WCF + WZF \text{ (vphpl)}, \quad (1)$$

where

2,000 = passenger cars per hour per lane,

TF = truck adjustment factor as determined from Tables 9.4 and 9.6 of the HCM,

WCF = lane width and lateral clearance adjustment factor as determined from Table 9.2 of the HCM, and

WZF = work zone capacity adjustment factor as determined from Figures 3 or 4 of this report.

The project has 4 lanes reduced to 3 with a 2% grade, 5% trucks and, lane widths of 12 ft (3.6 m).

The following is an example of the capacity for a long-term work zone.

Distance from traffic lane edge to obstruction -- 2 ft.

TF = 0.87 (a passenger car equivalent of 4 from Table 9.4, HCM, gives a truck equivalent factor of 0.87 from Table 9.6, HCM).

WCF = 0.97 (from Table 9.2, HCM, for a 4-lane divided freeway and 2 ft from traffic lane edge to obstruction).

WZF - 280 (from Figure 3 for a truck factor of 0.87).

Work Zone Capacity = 2,000 x 0.87 x 0.97 - 280 = 1,480 vphpl.

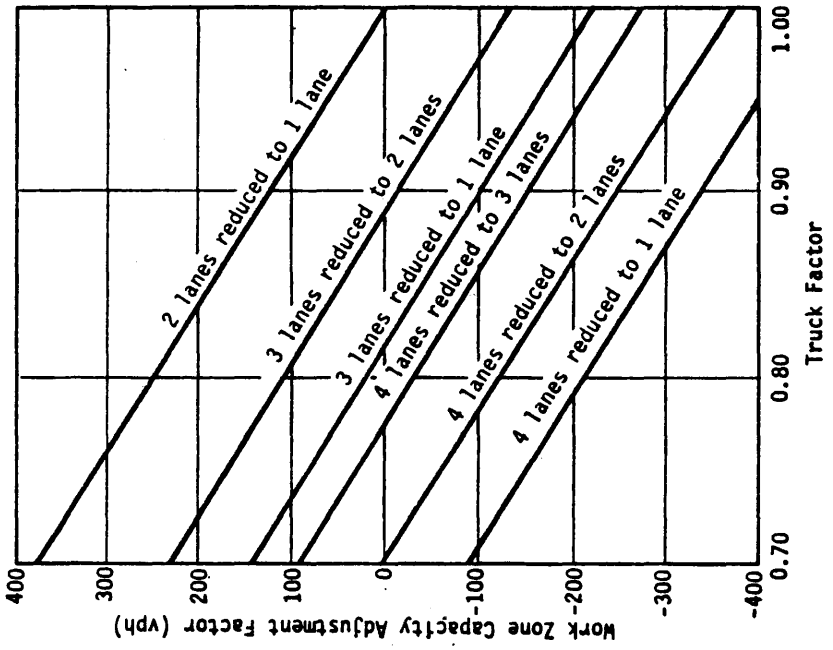


Figure 4. Capacity adjustment factor for short-term work zones. (From reference 6.)

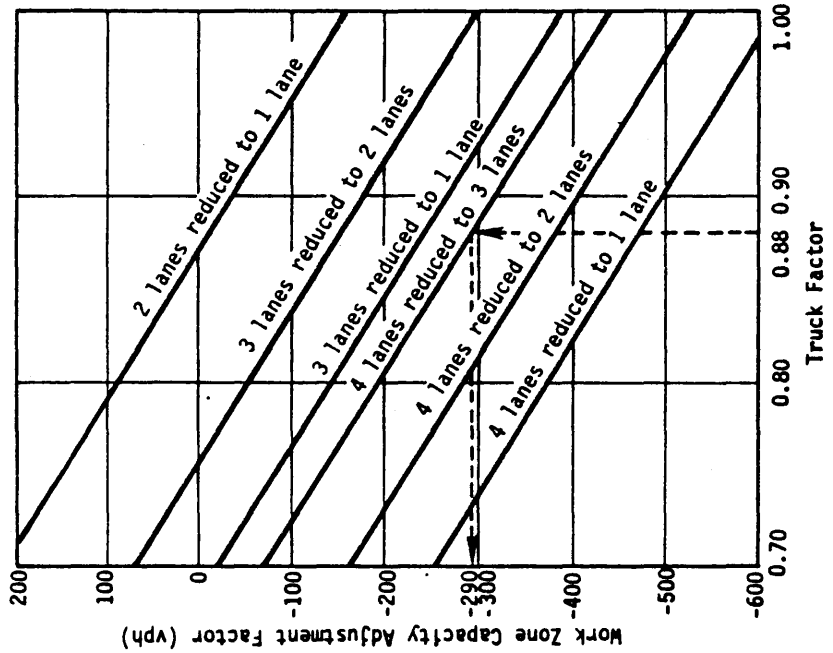


Figure 3. Capacity adjustment factor for long-term work zones. (From reference 6.)

It is noted that because lane capacities associated with lane closures in work areas can be influenced by a number of variables, including the presence of off- and on-ramps, percentage of trucks, grades, alignment, public relations, motorists diversion, some judgement should be used when considering the tables and procedures discussed above. However, these guideline capacities and procedures can be used to develop good estimates of work zone capacities that can be used in decisions concerning the conduct and scheduling of night work. It is felt that the vehicle volumes shown in Tables 2 and 3 are good estimates of vehicle capacity and can be used as a basis for analysis.

Delay

Work zone closures often cause delays in motorists reaching their destinations, with the magnitude of delay depending upon many factors such as the number of lanes closed, approach volume, time of closure, and length of any detours. An estimate of the impacts of vehicle delay is an important part of the analysis of the effects of work zone lane closures. Vehicle delay, for the purposes of this study, can be divided into the following categories:

1. Speed and Distance Change -- delays due to speed changes, increased travel distance (detours), or both.

2. Capacity restriction -- delays due to insufficient capacity causing vehicle queuing.

Speed and Distance Change

The delays caused by reduced speed through work zones and by detours can be estimated from equation 2. Also, the delay caused by an increase in travel distance resulting from a detour or a realignment of the roadway can be estimated by the formula

$$\text{Delay} = \frac{Dw}{Sw} - \frac{D}{S}, \qquad (2)$$

where

Dw = work zone route distance,
Sw = average work zone route speed,
D = normal route distance, and
S = average normal route speed.

Speeds in work zones are usually below the normal speed limit and can be estimated from local data or by judgement. Also, an estimate of speeds may be obtained from the v/c speed curves of the Highway Capacity Manual that are shown in Figure 5.(6)

Capacity Restrictions

A graphical procedure that can be used to estimate queue lengths and delays at work zones is shown in Figure 6. The curved line represents the cumulative demand volume upstream from the work area and is plotted from traffic data. The straight line represents the expected capacity at the work area bottleneck. A queue forms when the slope of the demand volume curve exceeds that of the estimated capacity line. At time t_1, a queue starts building and reaches a maximum at point t_2, where the slope of the volume curve is equal to that of the capacity line. The number of vehicles in the queue at any time, t, is represented by the vertical distance between the curves. At time t_2 there are Q vehicles in the queue. The delay, D, is represented by the horizontal distance between the curves. The vehicle that arrives at time t_2 will be delayed until time t_3. As the volumes decrease relative to the capacity, the queue dissipates and is finally eliminated at time t_4.

The size of the queue can be determined using the equation

$$Q_t = Q_{t-1} + (V_t - C), \tag{3}$$

where

Q_t = queue volume at end of hour t

Q_{t-1} = queue volume at end of hour t-1,

V_t = volume at hour t, and

C = assumed capacity in vph.

The delay of the last vehicle entering for any hour is calculated using the formula

$$D_t = \frac{Q_t}{V_t \times 60} \tag{4}$$

where

D_t = delay in minutes of last vehicle entering at hour t,

Q_t = queue volume at end of hour t, and

V_t = volume at hour t.

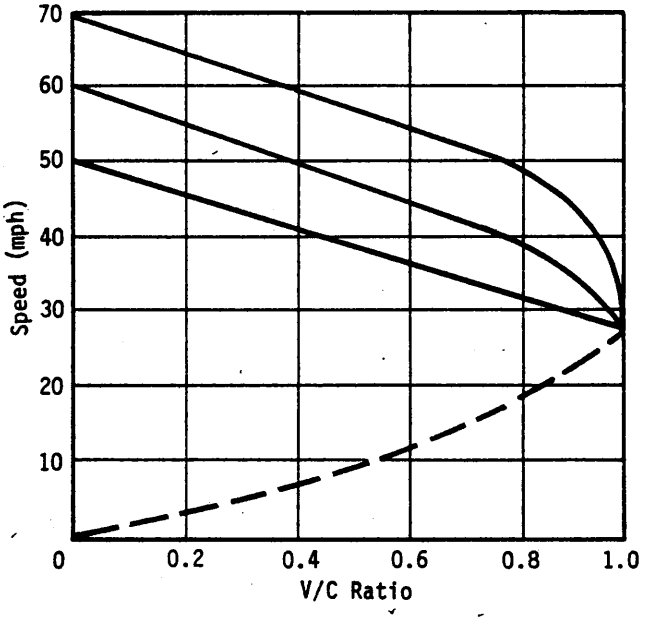


Figure 5. Estimates of vehicle speed. (From reference 6.)

The average delay per vehicle entering is calculated as

$$dt = \frac{(D_{t-1} + D_t)}{2}, \tag{5}$$

where

d_t = average delay in minutes for all vehicles that clear the queue in hour t,

D_t = delay of last vehicle entering in hour t, and

D_{t-1} = delay of vehicle entering in hour t-1.

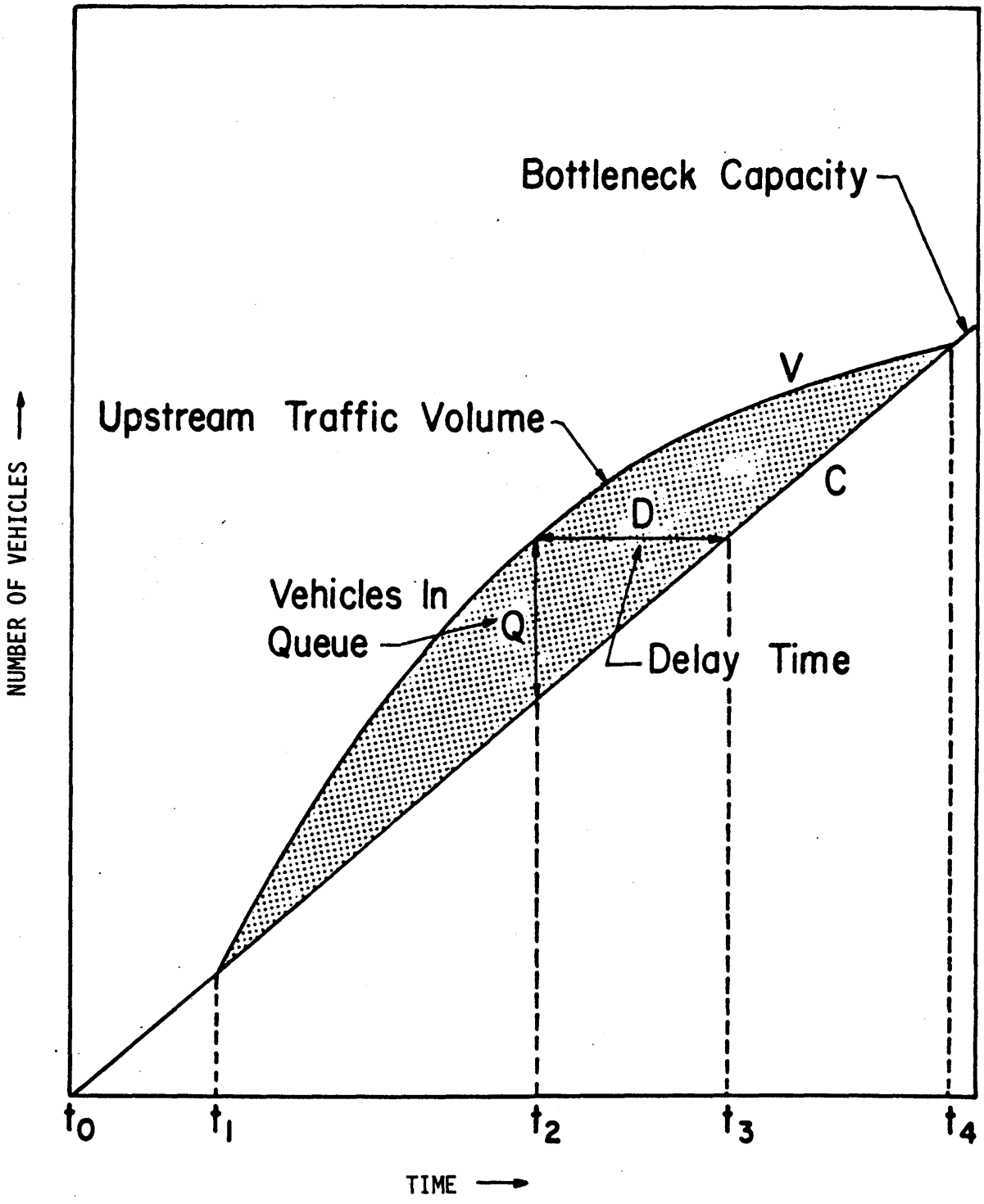


Figure 6. Traffic volume-capacity relationships when queuing occurs. (From reference 8.)

The queue length is calculated as:

$$L_t = Q_t S/N, \quad (6)$$

where

L_t = estimated queue length in ft at time t,

Q_t = estimated queue volume at time t,

S = space occupied by vehicles in queue [use 40 ft (12 m)], and

N = number of lanes upstream from the lane closure.

The length of backup in miles (km) is obtained by dividing L_t by 5,280 ft (1,584 m). The following example demonstrates how this procedure may be used. One lane of a 3-lane freeway is to be closed for resurfacing with an asphalt mix. Table 4 shows the demand volumes from the vicinity of the work area, and Figures 7 and 8 show the cumulative demand curve plotted from the traffic data shown in the table. Figure 7 shows the 8 a.m. to 2 p.m. portion of the curve and Figure 8 shows the 2 p.m. to 8 a.m. portion. An estimate of the capacity under these conditions (3 lanes with 2 lanes open and pavement resurfacing) is obtained from Table 2. It is noted that two capacity estimates are available, one from Texas showing a 2-lane capacity of 2,900 veh/hr and another from California showing 2,600 veh/hr. For this example, 2,900 veh/hr/lane will be used.

Referring to Figure 2, it is seen that the 85th percentile is 2,900 veh/hr,(3,2)), 3 lanes with 2 lanes open, which means that 85% of the time the capacity flows will exceed 2,900 veh/hr.

For a capacity of 2,900 veh/hr, as shown by the straight dashed line in Figures 7 and 8, if the lane is closed at 9:00 a.m., a queue will start forming at 9:00 a.m. and will not dissipate until 12:00 noon. If the lane remains closed, queueing will again start at approximately 3:30 p.m. and continue until 10:30 p.m. If night work is considered, it is noted that work can be started at approximately 7:30 p.m. without any delay and continue to 6:30 a.m. before traffic will start to back up. This allows approximately 11 hours for work without congestion. It is possible to start work before 7:30 p.m., since any queue will soon dissipate because of the decrease in volume demand. It is very important to be sure that the road is open to traffic prior to the morning peak, since a delay in reopening the road will result in excessive backups.

Table 4

Hourly Demand Volume (3 lanes)

Time	Volume
12 - 1 a.m.	1,650
1 - 2	800
2 - 3	510
3 - 4	380
4 - 5	400
5 - 6	930
6 - 7	3,900
7 - 8	6,550
8 - 9	4,500
9 - 10	3,700
10 - 11	2,650
11 - 12	2,300
12 - 1 p.m.	1,950
1 - 2	1,850
2 - 3	2,150
3 - 4	2,700
4 - 5	3,700
5 - 6	4,350
6 - 7	4,000
7 - 8	2,400
8 - 9	1,820
9 - 10	1,720
10 - 11	1,600
11 - 12	1,340

The vehicle delays and queues for any time can be obtained by noting the horizontal and vertical distances, respectively, between the solid and the dashed lines. Table 5 shows the details of vehicle delay and queuing obtained by using equations or Figures 7 and 8 for each hour during the morning peak (assuming that the lane is closed at 9:00 a.m. A capacity of 2,900 veh/hr for the 2 lanes remaining open was assumed, and for comparison an assumed capacity of 2,600 veh/hr is shown in parentheses. Delays and queuing are not calculated for the afternoon peak since it is obvious that these will start at approximately 3:30 p.m. and be quite large.

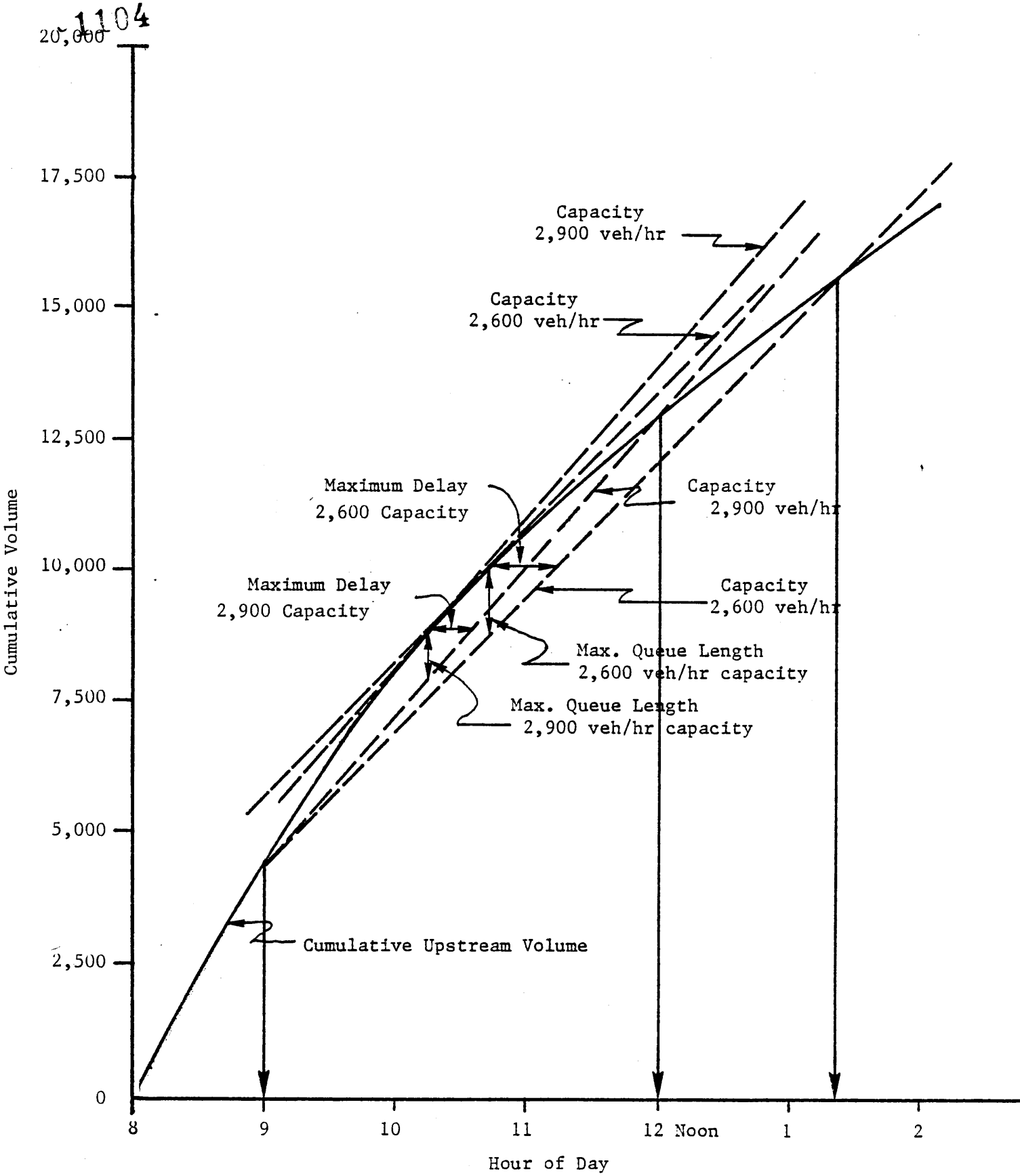


Figure 7. Cumulative demand volume between 8:00 a.m. and 2:00 p.m.

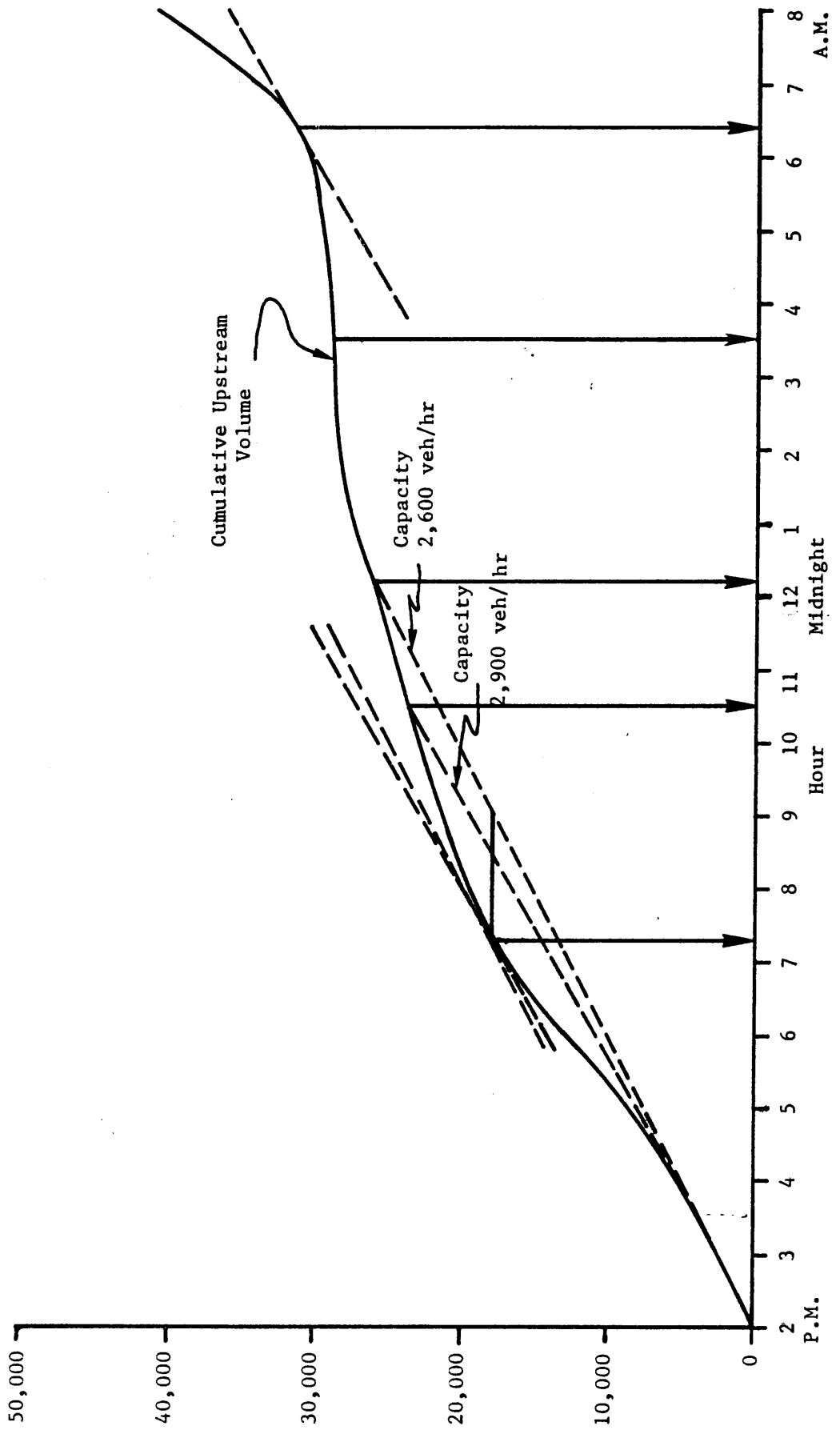


Figure 8. Cumulative demand volume between 2:00 p.m. and 8:00 a.m.

Table 5

Example Computation for Delay
Assumed Capacity of 2,900 veh./hr.

Hour	Volume	Capacity	Queue at end of hour	Queue Length, miles	Delay for last vehicle entering, min.	Average Delay per vehicle clearing, min.
9	3,700	2,900 (2,600)*	800 (1,100)*	3.0 (4.2)*	13.0 (17.8)*	6.5 (8.9)*
10	2,650	2,900 (2,600)	550 (1,150)	2.1 (4.4)	12.5 (26.0)	12.8 (21.9)
11	2,300	2,900 (2,600)	0 (850)	0 (3.2)	0 (22.2)	6.3 (24.1)
12	1,950	2,900 (2,600)	0 (200)	0 (0.8)	0 (6.2)	0 (14.2)
1	1,850	2,900 (2,600)	0 (0)	0 (0)	0 (0)	0 (3.1)

*For 2,600 veh/hr assumed capacity.
1 mi = 1.6 km

Queue Size

$Q_t = Q_{t-1} + (V_t - C)$

$Q_9 = Q_8 + (V_9 - C)$

$Q_9 = 0 + (3,700 - 2,900)$

$Q_9 = 800$ vehicles

Average Delay per Vehicle Clearing

$d_t = (D_{t-1} + D_t)/2$

$d_t = (0 + 13.0)/2$

$d_t = 6.5$ minutes

Queue Length, Miles

$L_t = Q_t s/N \times 5,280$ 40 = vehicle spacing

$L_9 = 800 \times 40/Z \times 5,280$

$L_9 = 3.0$ miles

Delay of Last Vehicle Entering

$D_t = \frac{Q_t}{V_t} \times 60$ $D_t = \frac{800}{3,700} \times 60$ $D_t = 13.0$ minutes

The maximum expected delay is approximately 13 minutes, and the average delays for the hours beginning at 9:00 and 10:00 a.m. are 6.5 and 12.8 minutes, respectively. The maximum backup is approximately 3.3 mi (5.3 km) with backups of 3.0 (4.8) and 2.1 mi (3.4 km) for the end of the hours starting at 10:00 and 11:00 a.m., respectively.

For comparison, the vehicle delay and queue length for an assumed capacity of 2,600 veh/hr is shown in parentheses. Maximum delays of 26 minutes and a maximum backup of 4.4 mi (7.0 km) are expected for this capacity. This is a good example of the importance of having a reliable estimate of the expected capacity at the bottleneck; i.e., an overestimate of capacity of 300 veh/hr (2,900 veh/hr vs. 2,600 veh/hr) equates to an increase in delay of 13 minutes and increase in queue length of 1.1 mi (1.8 km).

The maximum queue length and the extent of congestion that can be tolerated may vary depending on the geometry and location of the road, advance public information, and local policies. Therefore, they must be evaluated on an individual basis. Personnel in California indicated that they try not to exceed a 20-min. delay, whereas Texas uses 15 min. as the cutoff point.

For the above example, (3 lanes with 2 lanes open through the work area and a 2,900 veh/hr capacity) the 6.5 hours between 9:00 a.m. and 3:30 p.m. would be available for work; however, the delays shown will result. The procedure illustrated therefore allows the following questions to be addressed.

-- Is the daytime duration adequate for the proposed work?

-- Are the associated day delays and queues acceptable? Not acceptable? Acceptable for 1 or 2 days? Acceptable for an extended period of time?

-- When can night operations take place with congestion? Without congestion?

-- What are the costs associated with motorist delay during the day? At night?

Detours

When a freeway is completely closed in one direction and traffic is detoured to adjacent routes, the detour route must be capable of handling both the existing and detoured traffic. Also, it is important that the engineer in charge work closely with the local authorities in coordinating signals, signing, adequacy of highway facilities, etc.

Also, consideration must be given to the percentage of trucks using the highway and to whether or not the route is restricted to certain types of vehicles.

Delays in motorists reaching their destinations on detours typically occur because of increased travel distances and reduced speeds, signalized intersections, stop signs, and increased traffic volumes. The delays resulting from reduced speed and increased travel distance and restricted capacity can be calculated using the procedure discussed earlier under the sections "Speed and Distance Change" and "Capacity Restrictions."

Delays resulting from stops at traffic signals and temporary road closures can be estimated using procedures similar to that used for capacity restrictions. A graphical procedure that can be used to estimate queue lengths and delays is shown is Figure 9. At time t_1, all vehicles are stopped as the signal turns red and the queue starts. Vehicle discharge starts at time t_2, when the signal turns green, and the queue dissipates by the time t_3. At time t_4, all vehicles are stopped again and the pattern repeats. The queue length is represented by the vertical distances within the shaded area at any time, t, with the maximum occurring at t_2, the maximum vertical distance in shaded area. The time of delay is represented by the horizontal distance in the shaded area, where the maximum delay occurs for the vehicle entering the section at the start of the stoppage. The total delay is represented by the shaded area and the equation

$$\text{Total Delay} = 1/2 \; Ts \times C \times Td \times n \qquad (7)$$

$$Td = Ts - V/C - V,$$

where

V = vehicular volume,

C = rate of discharge (saturation flow),

n = number of cycles considered,

Ts = duration of stoppage, $t_2 - t_1$, and

Td = time required to discharge the queue, $t_3 - t_2$

It is noted that for detours the delays should be calculated separately for conditions before the work zone is established and during

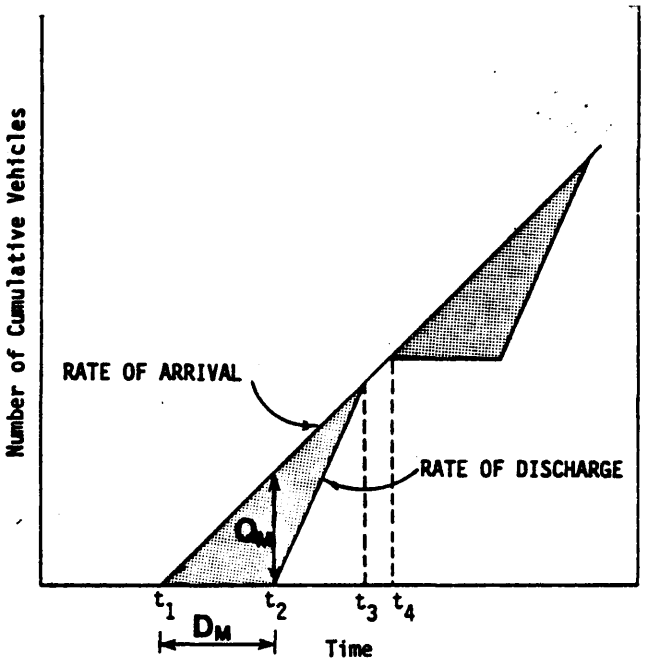


Figure 9. Volume/capacity relationship when traffic stream is temporarily stopped. (From reference 6.)

the time work is under way. The difference represents an estimate of the delay caused by the work zone.

SCHEDULING LANE AND ROAD CLOSURES

Night operations should be scheduled to avoid peak travel periods that may lead to congestion. Also, the schedule should consider peak shopping periods, holidays, and special events.

The scheduling of night operations to avoid or minimize delay requires knowledge of the hourly traffic volumes. For example, looking at Figure 1, which shows the hourly volume distribution for the work area, it is seen that around 7:30 p.m. traffic volumes have diminished to the point that little or no delay would result from a lane closure. Traffic volumes remain low enough throughout the night to allow closures

without congestion until approximately 6:30 a.m., at which time the morning peak starts.

A similar analysis may be made from Figure 8, which shows the cumulative volume demand for the work area. As discussed previously under the section "Capacity Restrictions", it is possible to work between the hours of 7:30 p.m. and 6:30 a.m. without causing traffic congestion and delay.

Adequate time should be given for opening the lanes to traffic in the morning since the traffic volumes increase rapidly during the morning peak and a delay in reopening the lanes could result in sizeable backups.

Also, in an attempt to get a longer work period during the night, consideration may be given to closing the lanes before the capacity meets demand since volumes are decreasing and any congestion should soon dissipate.

The survey of states revealed that closures can start as early as 7:30 p.m. or as late as 11:00 p.m. and usually continue until approximately 6:00 a.m. Recent night maintenance work on two Chicago expressways involved a 4-day, 10-hours a day workweek, with work scheduled from 6:30 p.m. to 5:00 a.m. Monday through Thursday.

Scheduling for those roads that will be completely closed in one direction for night operations and the traffic detoured to alternate routes is not as simple as scheduling for lane closures. Traffic volumes on the alternate routes and the ability of these routes to safely and conveniently accommodate the extra traffic are important. Where the alternate facilities cannot accommodate the detoured traffic, work may have to be scheduled later than usual when volumes are lower. Traffic volumes may not be as critical if collector-distributor roads or alternate freeway facilities are available.

The Michigan Department of Transportation has successfully detoured traffic in the urban Detroit area for night operations on freeways, and work generally starts around 10:00 p.m. and continues until 6:00 a.m. This experience in detouring traffic, coupled with convenient detour routes in the form of service drives and adjacent freeways, has led to a freeway closure plan for Detroit as shown in Table 6. Many of the freeways are routinely closed twice a year for maintenance or construction operations.

Table 6

Proposed 1983 Freeway Closures for Maintenance Operations in Detroit (Night)

Freeway	Limits	*Miles of Closure	Detour Route
EB I-94	Michigan to I-75	7.0	EB Mich. to NB Lodge to NB I-75 to EB I-94
EB I-94	I-75 to Eight Mile Road	11.0	NB to I-75 to EB Eight Mile to EB I-94
WB I-94	Eight Mile to I-75	11.0	WB Eight Mile to SB I-75 to WB I-94
WB I-94	I-75 to Schaefer	8.0	SB I-75 to NB Southfield to WB I-94
SB Lodge	J. L. Hudson Dr. to I-75	12.0	SB Lodge Service Dr. to SB Wyoming to EB I-96 to NB I-75 to SB Lodge
NB Lodge	I-75 to J. L. Hudson Dr.	12.0	WB I-94 to WB I-96 to NB Wyoming to NB Lodge Service Dr. to NB Lodge
SB Southfield	Eight Mile to I-94	14.0	Service Drives
NB Southfield	I-94 to Eight Mile	14.0	Service Drives
SB I-75 (Chrysler) SB I-375	Eight Mile to Lodge I-75 to Jefferson	11.5	WB Eight Mile to SB Lodge to I-75
NB I-75 (Chrysler) NB I-375	Lodge to Eight Mile Jefferson to I-75	11.5	Lodge to I-94 to Eight Mile to I-75
SB I-75 (Fisher)	Livernois to Southfield	6.5	Service Dr. to SB Springwells to SB Fort to NB Southfield to I-75
NB I-75 (Fisher)	Southfield to Clark	7.5	NB Southfield to EB I-94 to I-96 to I-75
WB I-96 (Jeffries)	West Grand Blvd. to Telegraph	11.0	NB Service Dr. to NB Grand River to WB Plymouth to NB Telegraph to WB I-96
EB I-96 (Jeffries)	Telegraph to I-94	11.0	SB Telegraph to EB Plymouth Rd. to SB Grand River to I-94

*1 mi = 1.6 km

COST OF WORK ZONE OPERATIONS

Because of policy decisions or unacceptable daytime traffic delays associated with lane closures, there are many situations where night work must be done regardless of cost; however, cost can be a consideration in the decision as to whether work will be done during the day or at night. The delays, queuing, etc., associated with day and night operations, as previously discussed, can be assigned costs, and these can be combined with the operation and agency costs to obtain an estimate of the total cost of the project.

The costs associated with day or night maintenance or construction work zone operations can be subdivided into the following general categories:

-- Speed and distance change

-- Queuing

-- Vehicle operating cost

-- Accident cost

-- Agency costs

Although many traffic and geometric conditions influence the cost of vehicle delay, those associated with distance and speed changes are relatively insignificant compared to those resulting from queuing and will not be considered here. There may be situations where detours require significantly longer distances and the associated costs should be considered. References containing information required for an in-depth analysis of the costs associated with work sites are included under vehicle operating cost.

Costs Resulting From Queuing

The cost of delays resulting from queuing can be obtained by taking the delays shown in Table 7 and applying a time cost factor from Table 8. The average delays in Table 7 were obtained by using equations 4 and 5 or scaled from the cumulative volume distribution shown in Figures 7 and 8. The cost for each hour is found by multiplying the hourly volume by the cost per vehicle from Table 8, the total daily cost is obtained by totaling the hourly costs, and the total cost incurred over the duration of the project can be obtained by summing the total daily user costs.

Table 7

Cost of Time Delay for Queuing

Hour Beginning	Hourly Volume	Avg. Delay, min.	Cost per Vehicle, $	Total Cost, $
9 a.m.	3,700	6.5	0.050	185
10	2,650	12.8	0.600	1,590
11	2,300	6.3	0.046	106
12	1,950	0	0.0	0
1 p.m.	1,850	0	0.0	0
			Total	$1,881

Vehicle Operating Cost

An estimate of the vehicle operating cost associated with queuing can be obtained by determining the queue length and average speed within the queue. Estimate of the operating costs for different speeds can be obtained from Table 9.

The product of the difference in operating costs with and without a work zone and the vehicle miles in the queue is the operating cost attributable to the work zone. Using the information shown in Table 7, the queue length can be estimated as shown in Table 10.

Table 8

Cost of Time in Dollars per Vehicle

Time Lost or Saved in Minutes	Cost (Value) Per Vehicle in Dollars	Time Lost or Saved, in Minutes	Cost (Value) Per Vehicle, in Dollars
1	0.00	31	3.15
2	0.00	32	3.24
3	0.01	33	3.34
4	0.01	34	3.44
5	0.01	35	3.55
6	0.04	36	3.64
7	0.06	37	3.74
8	0.10	38	3.85
9	0.15	39	3.94
10	0.23	40	4.04
11	0.34	41	4.15
12	0.47	42	4.25
13	0.63	43	4.34
14	0.79	44	4.45
15	0.94	45	4.55
16	1.10	46	4.65
17	1.26	47	4.76
18	1.40	48	4.85
19	1.55	49	4.95
20	1.69	50	5.06
21	1.84	51	5.15
22	1.98	52	5.25
23	2.12	53	5.36
24	2.25	54	5.45
25	2.38	55	5.55
26	2.39	56	5.66
27	2.65	57	5.76
28	2.78	58	5.86
29	2.92	59	5.97
30	3.04	60	6.06

Note: Costs reflect July 1979 estimate based on typical trip purpose distributio composite household income, average car occupancy, and typical mix of passenger c and commercial vehicles.

Source: Reference 6

Table 9

Components of Running Cost at Uniform Speed on Level Tangents for 4,000 Passenger Cars (Consumption Unit per 1,000 vehicle-miles)

Speed (mph)	Running Cost Consumption Item: Fuel (gallons)	Engine Oil (quarts)	Tires (dollars)	Maintenance (dollars)	Depreciation*	Total Dollar Cost
5	157.80	2.08	0.82	10.17	6.84	109.16
10	86.27	1.92	1.50	10.38	6.84	81.28
15	64.39	1.79	2.18	10.72	6.84	73.43
20	54.93	1.68	2.86	11.21	6.84	70.72
25	50.43	1.59	3.42	11.81	6.84	70.00
30	47.97	1.52	3.86	12.47	6.84	70.06
35	47.30	1.46	4.23	13.17	6.84	70.81
40	47.88	1.41	4.52	13.91	6.84	72.03
45	48.90	1.40	4.71	14.69	6.80	73.20
50	50.80	1.43	4.83	15.48	6.70	74.41
55	53.70	1.50	4.87	16.33	6.64	76.23
60	57.55	1.63	4.84	17.26	6.58	78.49
65	61.95	1.83	4.77	18.31	6.57	81.37
70	66.99	2.17	4.69	19.60	6.50	84.57
75	72.65	2.73	4.60	21.26	6.48	88.81
80	79.00	3.61	4.49	23.45	6.41	93.87
Unit 1975 Price ($)	0.40	0.90	32.00	N/A	4,850	N/A

*Dollars per $1,000 new vehicle cost.

N/A = not applicable.

Source: Reference 9.

Note: mi/h x 1.6 = km/h

Table 10

Determination of Queue Length

Hour Beginning, hr	Hourly Volume, vph	Queue at End of Hour, veh	Avg. Queue, veh.	Avg. Queue, 1,000 ft (300 m)	Veh. Miles (1.6 km) In Queue
8	4,500	0	0	0	0
9	3,700	1,100	550	22	1,542
10	2,650	1,150	1,125	45	22,585
11	2,300	850	1,000	40	17,424
12	1,950	200	525	21	7,756
1	1,850	0	100	4	1,402
2	2,150	0	0	0	0
					50,709

Operating Cost:

- 3 lane with one lane closed.
- normal capacity = 5,700
- work zone capacity = 2,600
- normal speed = 55 mi/h (88 km/h)
- v/c = 2,600/5,700 = 0.46
- average speed = 8 mi/h (12.8 km/h)
- operating cost in congested section:
  - for 8 mi/h (12.8 km/h) and Table 9 = $92.43 per 1,000 vehicles
  - for 55 mi/h (88 km/h) and Table 9 = $76.23 per 1,000 vehicles
  - additional operating cost due to work zone: (1 day)
    (92.43 - 76.23) x 50,709 (from Table 10) = $821.00 per 1,000 vehicles

There are several reports that detail user costs of work zone lane closures.

A recent report from the Texas Transportation Institute presents a model called QUEWZ that can be used to estimate the additional user costs resulting from lane closures.(10) The model is designed for freeway conditions and can estimate hourly, as well as daily, user costs, along with queue length when vehicle demand exceeds capacity.

Another report investigates fuel consumption for freeway work zones and presents a procedure for estimating the excess fuel consumption caused by lane closures on 3, 4, and 5 lane freeway sections.(11) Tables, graphs, and an example illustrating the application of the procedure are included.

The costs of delays, fuel consumption, vehicle operation, etc., are presented in a 1981 report which details examples of work zone costs and includes tables and graphs relative to vehicle operating cost and fuel consumption.(6)

Also, a document published by AASHTO entitled "A Manual on User Benefits Analysis of Highway and Bus-Transit Improvement (1977)" is a good source of information concerning user costs for highway improvements.

Accident Costs

It is difficult to estimate a cost for the difference in accidents for night work zone operations as opposed to daytime operations. There is a lack of nighttime accident data and considerable variability in accidents and accident potentials between the types and locations of night work zone projects.

Agency Costs

Costs that can be categorized as agency costs are those for such items as traffic control, traffic control devices, maintenance of devices, and lighting, in addition to the cost of the maintenance or construction work. There are many variables in these costs, and the

expenditures can vary greatly from area to area depending on the location, type of work, and traffic conditions. The following is a partial list of those items that could influence the costs.

-- type and extent of traffic control

-- maintenance of traffic control

-- availability of materials and utilities

-- type and extent of work done

-- equipment necessary for night work along with equipment maintenance and repair

-- worker efficiency and quality of product

-- worker recruitment and possible pay differential

-- traffic characteristics

-- extent and use of lights for illuminating the work area

The literature survey and interviews revealed a lack of available cost information. Also, inconsistencies in the information received were noted; e.g., some projects showed significant cost benefits for night operations, whereas others showed substantial cost increases. The primary reason for this difference is the number of variables involved in night work zone operations.

Information from a recent project in which 2 lanes were closed from 10:00 p.m. to 5:00 a.m. to allow patching of a deck of a bridge on the Dan Ryan Expressway in the Chicago area revealed --

1. a production rate 57% better than that of the standard bridge patching rate, and

2. a cost per yd^2 ($0.81\ m^2$) $10 cheaper than that of the standard bridge patching operation.

Also, because of long pavement lengths and time of closures used on the Eisenhower Expressway in Chicago "the unit costs of pavement patching, even including all the extra rented equipment and lighting, actually turned out to be less than during normal daylight operation." This project involved closing 2 of the 3 lanes in each direction from 6:30 p.m. to 5:00 a.m., Monday-Thursday for bridge deck patching, full-depth pavement patching, and thin overlays or skin patches.

Benefits were also noted for nighttime freeway closures in the Detroit metropolitan area. A July 1982 project on which the entire freeway was closed and traffic detoured produced the comparisons shown in Table 11. Without considering the cost of motorist delay and vehicle operation, approximately 44%, or $138,883, was saved. Closures for which traffic was detoured on the Southfield, John C. Lodge, and Edsel Ford freeways from April to October while work was in progress from 10:00 p.m. to 6:00 a.m., Sunday-Thursday revealed a $351,262 savings. The savings for sweeping the freeway, cleaning catch basins, repairing potholes, cleaning bridges, marking lanes, and replacing pavement sections resulted mainly from reduced cost of traffic control, increased efficiency, and the ability to assign many crews to various maintenance operations simultaneously. The nighttime closures were well accepted by the freeway users.

The success in Detroit is a result of several factors as listed below.

-- Experience in closing freeways and detouring traffic. Substantial benefits were noted for work on the Lodge Expressway in 1968.

-- Prior planning that included a schedule of closing for each year.

-- Efficiency of operation resulting from the ability to do different types of maintenance simultaneously, with little or no concern for traffic.

-- Availability of good detours, including collector-distribution roads and express lanes.

-- Good public relations, which included variable message signs warning of future closures and times.

-- Public acceptance of procedures.

Interviews with personnel in California, Texas, and New York indicated that costs for nighttime operations usually run from 40% to 300% more than those for day operations, with the cost of traffic control being approximately double that for daytime lane closures.

Although the costs of some night work zone operations have been significantly higher, discussions with various states and agencies indicated that under certain conditions (traffic, geometrics, location) and with experience in night work zone procedures, costs may be expected to decrease. It is important to note that night operations present potentially hazardous working conditions and that good planning and traffic control are absolutely necessary, even though the latter may be costly.

Table 11

Cost Comparison (Open vs. Closed Freeways)
September 13 to September 22, 1982

Maintenance Activity	*Sweeping	Cleaning Catch Basin	Mud Jacking	Spot Surface Replacement	Cold Patching	Gore Painting	Bridge Scaling	Total
Actual Costs During Freeway Closures	$ 96,474	$10,788	$11,215	$16,724	$15,909	$7,800	$15,956	$174,866
Estimated Cost During Normal Freeway Traffic (Based on FY 1981 Accomplishments)	138,455	26,036	17,820	46,459	31,046	9,500	44,433	313,749
Savings: (Dollars)	41,981	15,248	6,605	29,735	15,137	1,700	28,477	138,883
(Percentages)	30	59	37	64	49	18	64	44

Note: Costs include all fringe benefits and overhead

*Includes all pre-signing costs ($18,756)

SAFETY

The concern for safety in nighttime maintenance and construction work zones is of utmost importance. The motorist is presented with unique and many times unexpected situations, where a lane, lanes, or entire roadway is closed at night when visibility is limited and relatively more drivers are impaired; i.e., sleepy, under the influence of drugs or alcohol, etc. These conditions, coupled with the higher speeds generally prevailing at night, add a new dimension to safety considerations. It is difficult to compare the safety aspects of night work as opposed to those for day work because of the lack of comparable data. Although night operations are potentially more hazardous, there are several factors that could offset the increased potential for accidents. For example, the reduced volume of traffic at night may be safer and easier to control than daytime traffic with its higher volumes and congestion.

Also, when comparing day versus night accidents the length of time required for the maintenance or construction work should be considered. For example, in a California study it was reported that work done at night was completed in 16 working days, whereas it would have taken at least 35 working days to complete it during daylight hours because of fewer working hours being available and more interference by the public.(2) Therefore, the exposure time for workmen at the work zone was less than half that for a comparable day operation.

Accident Analysis

Although relevant accident data for nighttime operations are limited, some of the data that are available may be of interest. Accident data for the work site conditions reported in this study, i.e., for work zone operations conducted during the night off-peak hours with the roadway being open to traffic during the daytime, may differ from those reported for night operations in general. Worker exposure for the hazardous lane closure operation is increased since traffic control devices have to be erected and taken down each night for the night-only operations, whereas this is done once for long-term day and night work. Also, traffic control devices can differ. For example, concrete barriers are often used for long-term projects. Another factor is that motorists are not as familiar with night-only operations.

The data in Figure 10 for a 1969 California study show that although the lowest number of accidents occurred between 3:00 and 5:00 a.m., the rate was very high. Similar results are shown by 1977 work site data in Virginia, where for all accident categories the lowest number of accidents occurred in the early morning hours.(13)

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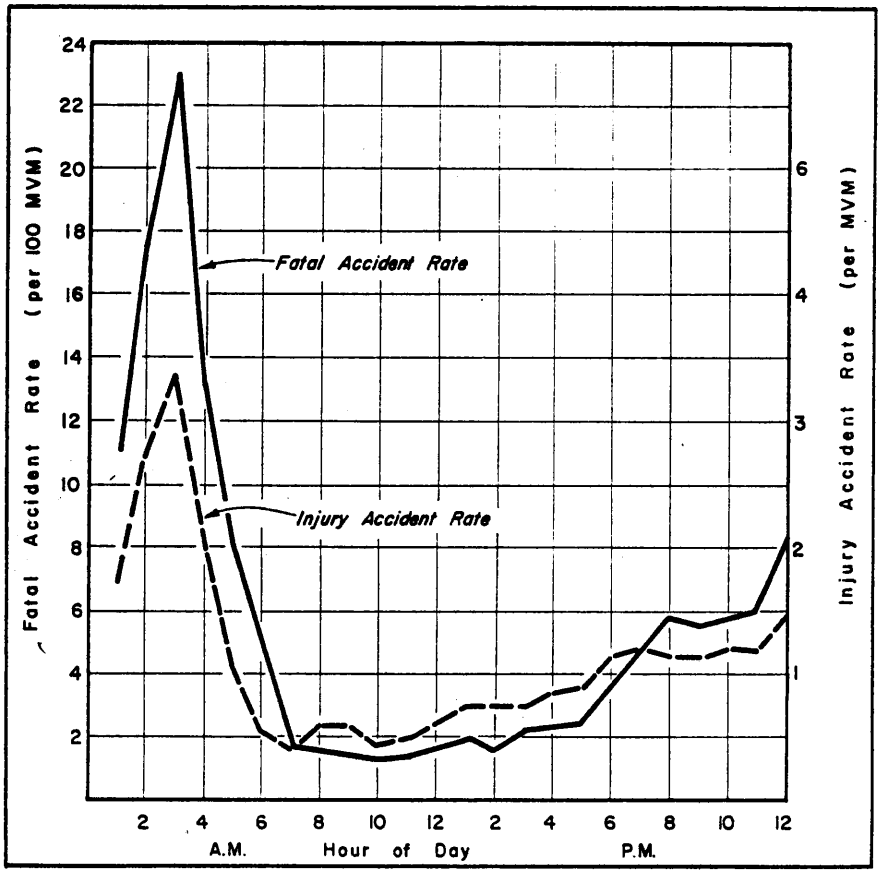


Figure 10. California fatal and injury accident rates expressed as functions of hours of the day. (From reference 12.)

A study by Graham et al. reported that slightly more accidents occurred at nighttime work zones than occurred before the construction began.(14) They presented the following conclusions:

-- Based on detailed analyses of three construction zones with increased accident rates during construction, the increases in accidents were highly related to the construction.

-- Short duration and short length construction projects experience higher accident rates than longer duration or longer distance ones.

-- The proportion of fatal and injury accidents in construction zones is nearly equal to the accident experience before construction, with a slight shift toward less severe accidents during construction.

-- Construction zones with reduced speed limits do not experience lower accident rates than other zones. Field studies indicate that speed zoning does not reduce mean vehicle speed and does increase conflicts in the transition area.

-- Enforcement patrols and lighted sequential arrow panels decrease vehicle speeds near where they are installed, but their speed reduction effect is only effective over a short length of highway.

-- Based on time-trend analyses, the initial period of construction zone traffic control is not more hazardous than later periods.

-- Drivers adjust speed and position based on the environment (geometrics of zone, lateral clearance, and devices) more than on signing.(14)

Agency Discussions

The following are comments and observations relating to safety and accidents for night work zones taken from interviews with states having experience in night maintenance and construction operations.

Texas -- Houston had had a bad experience with work zone accidents and as a result took a serious look at work zone safety. For those situations where night operations are necessary, time, money, and effort are spent to ensure maximum safety, and Texas officials believe that night operations can be accomplished with reasonable safety. An example of the extra effort was the formation of a special crew to manage traffic on high volume freeways. Another urban area in Texas noted that because of the high risk of night operations, they would accept long daytime traffic backups. Daytime maintenance and construction work zone operations and their consequences were thought to be the lesser of two risks.

California -- Although it is sometimes better to delay traffic than to conduct night operations, there is a cutoff point of vehicle

delay beyond which night work is considered. For night operations in the Los Angeles area, traffic was described as "wild" between 2:00 and 3:00 a.m. and was less safe at night for the workmen. When possible, a buffer zone is maintained between traffic and the workmen. Also, it was stated that backups cause accidents, so special efforts are made to ensure that warning signs precede any backups due to work zone operations.

Chicago -- In the scheduling of any maintenance operations in the Chicago area, safety would seem to be the most important of all the factors considered. Accidents were thought to be more severe at night than during the day because of the higher vehicular speeds and more frequent encounters with motorists under the influence of alcohol or drugs. Also, the closing and opening of the lane or lanes was most dangerous. Officials in the Chicago area were sometimes reluctant to consider detours because of the potential safety hazard in some "bad" neighborhoods.

Detroit -- Because of experience and the availability of convenient alternate routes, such as express lanes and service roads, freeways are often closed and traffic detoured for night maintenance operations. The workers prefer a closed freeway since maintenance is easier and safer. For freeway closures the police help by slowing and diverting traffic to the detour ramp. All off-ramps are closed and the ramp area where maintenance trucks enter is monitored to keep motorists out. It was the opinion of officials that there were more accidents for night lane closures because of higher speeds and the larger number of drunken drivers. Also, night accidents were said to be of the "spectacular" type. It was stated that good public relations concerning details of the closures help safety.

New York -- Allowing traffic to travel adjacent to work crews was thought to be dangerous both to the workers and the motorists; therefore, all traffic was detoured for a 1981 repair and resurfacing project on the Long Island Expressway. "In spite of extensive barricade systems, an average of two to three unauthorized vehicles entered and traversed the closed roadway many nights." This obviously led to a hazardous situation for those working on what they assumed was a road free of unauthorized vehicles. In view of these difficulties, more positive measures were taken on other projects and were thought to be more effective. For example, physical barriers to provide vandal-proof closures, additional lights and signs, increased patrol, and a stepped-up public information program were employed. This is a good example of the learning process that some agencies go through in coming to realize the importance of providing nighttime safety and the added cost and emphasis necessary for a safe operation.

Pennsylvania -- Officials interviewed in an urban area noted their reluctance to work at night because of the dangers not normally present during daylight hours; viz., higher speeds, poor visibility, and drunken drivers. However, they were surprised at the few accidents that occurred in the work zone when they conducted nighttime operations. A police escort was recommended for night operations as a patrol car was a deterrent to speeding motorists, drunken drivers, etc., and facilitated communications in emergency situations. Also, it was stated that the news media were less critical of the department since it was not causing daytime congestion in an area that had given it a "black eye" in the past.

General Comments -- During the interviews several statements and observations were heard repeatedly. Following are some of the common thoughts.

-- Nighttime work zone accidents tend to be more severe, primarily because of the influence of alcohol and drugs, drowsiness, higher speeds, and decreased visibility.

-- Experience has been a big factor in understanding the importance of optimizing safety and the procedures necessary to ensure safety.

-- Nighttime operations using lane closures are not as safe for the workers as daytime operations.

-- The assistance of law enforcement personnel is desired to help stabilize traffic flow and to help with road closures when using detours.

-- Overall, most officials feel good about the safety of nighttime operations; however, they noted that they had to be constantly aware of safety and strive to improve the safety features of nighttime work zone operations whenever possible.

-- There was a general belief that an agency should go to whatever means are necessary to protect the workers and motorists.

-- Also, it should try to prevent traffic from queuing past the warning signs whenever possible, and to have a buffer zone between the work area and any open traffic lane.

-- Advance publicity concerning nighttime operations increases safety.

-- Workmen desire slow or queued traffic rather than normal speed traffic next to the work zone.

-- Officials in some urban areas prefer to have daytime traffic congestion rather than create a potentially hazardous nighttime situation.

Summing up the general attitude regarding nighttime work zone operations, safety was held to be the most important consideration and agencies should take whatever means are necessary to ensure the safety of workers and motorists. In other words, the officials believed that they should "pay the price for the manpower, time, cost, etc., to ensure the safety of motorists and workmen in night operations."

PUBLIC RELATIONS

Public relations are an important element in nighttime construction and maintenance activities and can facilitate the success of an operation in terms of reduced congestion, increased safety, and goodwill. In commenting on a pavement resurfacing project, an official noted that "on paper it was thought that traffic would be backed up for miles; however, after a media blitz, no backups occurred." Various means of informing the public about night operations will be discussed below. It is difficult to state how extensive the coverage should be since the size of project, location, traffic volume, experience, availability of techniques, etc., all can have an influence. It is believed that the payoff exceeds the cost in time and money for disseminating information, and all available means of informing the public should be considered. As one state official commented, "we go to extremes to get the word to the public that there will be pavement reconstruction upcoming."

If possible, the motorist should be informed in advance as to what is to be done, why it is necessary, the location and time, and the benefits; however, the extent of coverage will depend on the medium used. Table 12 is a list of available public information techniques and includes the results of a survey showing the extent of their use and how effective they were perceived to be. The results are based on the responses of 211 county, municipal, and state agencies to the question: How effective are the following public information techniques used to reduce traffic impacts at work sites?

It is interesting to note that although releases to newspapers and radio and television stations constituted the most frequently used technique, the respondents thought that special signs, door-to-door personal contact, and personalized letters were the most effective.

Table 12

Public Information Techniques and Reported Effectiveness

Technique	Stationary Work Sites: Use Ranking	Stationary Work Sites: Effectiveness Ranking
Public Hearings		
In Public Buildings	5	13
On Television	11	11
Press Releases		
Newspaper	1	6
Radio	2	4
Television	3	8
Special Mailings		
Agency Newsletter	13	12
Civic Group Publ.	12	14
Incl. in Utility Billing	15	15
Occupant Form Letter/Memo	8	7
Personalized Letter	9	3
Registered Notice	14	9
Telegrams	16	16
Personal Contact		
Special Gathering	6	5
Door-to-Door	4	2
Motorists/Pedestrians	10	10
Special Signs		
None Specified	7	1

Note: There was no significant difference between state, county, and city responses to the question.

Figures represent the rank order of use and effectiveness, e.g., one equals the most used or effective and 16 equals the least used or effective.

Source: Reference 15.

Some states have used elaborate procedures to provide the public with information on upcoming maintenance and construction operations. A good example is the basic comprehensive plans prepared for major freeways in the Chicago area. The plans included descriptions of traffic routing, detailed maps, schedules for work, and an explanation of work to be undertaken. Agency officials met with the local radio, newspaper, and television companies for a special press conference. This special effort led to surprisingly little congestion and generally good public understanding and acceptance of the associated inconvenience. Appendix A gives more details of the public information campaign for this work.

Another example of a comprehensive plan for informing the public is that used for night closing of major freeway sections in the Detroit area. A color map detailing the detour route was distributed along with information on the closure area and time, and other pertinent information. Details of this plan are also given in Appendix A.

One method used in the Detroit area for informing the public of closures involves the use of existing changeable message signs permanently installed along sections of the freeways as part of an areawide traffic surveillance system. The signs are quite useful, since they can provide a highly visible display of details concerning upcoming closures in the vicinity of the work area. Figure 11 shows a sign in the Detroit area giving the location and time of upcoming work. Where

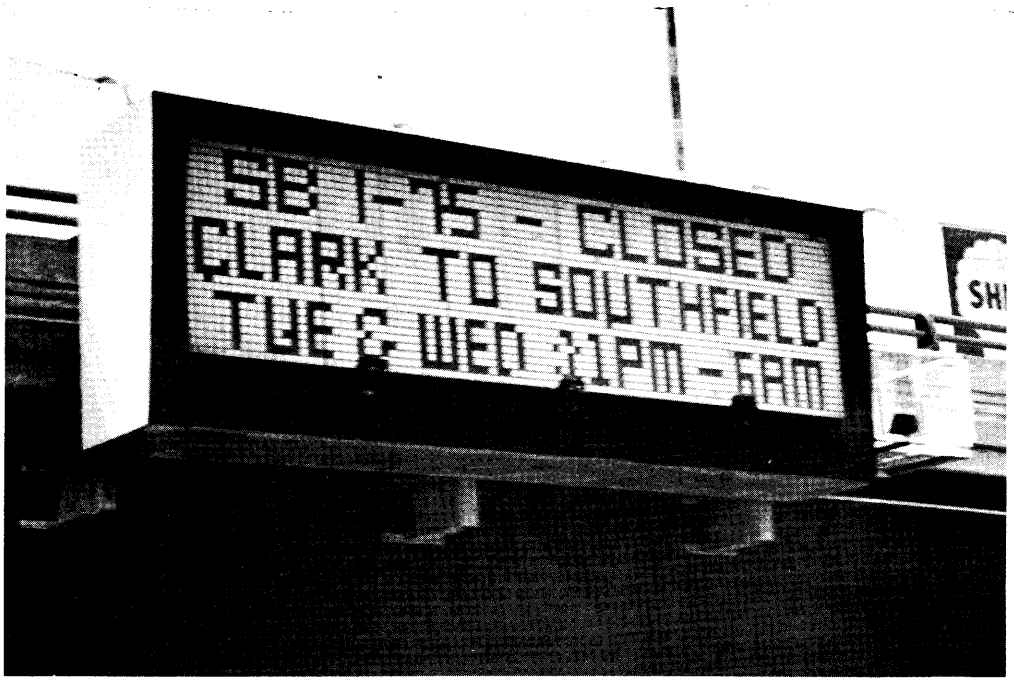


Figure 11. Sign noting upcoming road closure.

variable message signs are either not available in appropriate areas or not available at all in some states, temporary signs (fixed or portable, regular or electronic) can be posted along the route of the proposed work site. Figure 12 shows an electronic, changeable message sign mounted on a pickup, and Figure 13 shows a sign trailer with a message. Such notifications alert motorists and possibly divert some of them to alternate routes or induce them to reschedule their trip itineraries.

Another item that needs to be considered is the timing of the message; i.e., How long before work starts should the message be displayed? Since people tend to forget information given a week in advance, consideration should be given to providing the information the day before work starts, possibly on a Monday or Tuesday. Also, light traffic volumes at midweek are favorable for work on the roadway.

Figure 12. Variable message sign.

-1130

Figure 13. Sign trailer with message relating to future closure.

AGENCY VERSUS CONTRACTED WORK

It is estimated that up to 20% of the total highway maintenance and construction work in urban areas having high traffic volumes is done at night, while in some areas no nighttime work is done. The percentage of the night work done by the agency with its forces varies; however, it is insignificant and usually is limited to light maintenance or emergency repairs. The majority of night work is contracted. The contracted work typically consists of pavement rehabilitation and resurfacing. The contractor usually handles the entire operation, including traffic control; however, there are exceptions. On some nighttime projects in the Chicago area traffic control is let to contract while state forces do the maintenance or construction work. Also, in the Detroit area the state contracts much of the traffic control and road work to the county.

One state agency noted that because of the increase in maintenance and construction work, along with an increase in traffic volumes and a reduction in the state work force, a larger percentage of its work would be contracted in the future.

OTHER CONSIDERATIONS

Other factors that should be considered when contemplating night operations are addressed below. It is emphasized that each construction or maintenance job differs in some respect from others and each should be considered individually.

Supervision and Communication

Some agencies indicated that problems were encountered in administrative functions; however, others noted few problems, citing experience as a primary reason. Planning was noted as being important for night operations and should include furnishing instructions to the crews before dispatching them to the work site. Also, there should be a person on the job who is capable of making decisions or who has contact with the proper authority if information or instruction is needed.

Two problems cited involved lack of supervision and difficulty in contacting supervisory personnel not on duty. Also, difficulties in communications between night and day personnel were cited as a concern; for example, communications between the office and project staff were noted to have been poor when the engineer-in-charge and his personnel were off duty and asleep during normal daylight working hours. Communication between the job site and office, plant, etc., is important and, because of the unavailability of telephones at night (businesses and gas stations closed), two-way radios or other means for effective communication must be available.

Work Force Morale

Many objections to night work were raised by both the supervisory staff and workmen in the field. Since most people's lives revolve around daylight routines, working at night, especially when not initially hired for night work, simply does not fit into their normal schedules. Problems stemming from the general dislike of night work and the resultant low morale were heard repeatedly. One supervisor stated that "strenuous objections to lengthy night shift assignments were voiced by more than 50% of our personnel most qualified for this difficult work." A contractor interviewed noted that the turnover in personnel was significant and that the quality of work suffered as a result. To ameliorate their problems, workers are rotated every 1 to 2 months.

A specific issue was that many employees had second jobs or daytime responsibilities with which night work interfered. Also, the pay

differentials between day and night hours were not sufficient to entice employees to work at night.

Agencies have used different approaches to solving these problems. One agency noted that when dealing with night operations human relations are important, and that unless situations are handled properly, problems result. Suggested solutions included a volunteer night work force with incentives such as a 4-day workweek, significant pay differentials for night work, and rotating shifts. One agency noted that using volunteers for night work was successful mainly because of the short duration of the night projects, and that it would not be successful if night work were continued on a long-term basis. Long-term projects would lead to use of a mandatory rotation system with the concomitant discontent.

The problem may not be as acute for contractors as for state agencies, as they may pay night employees more and include the difference in the contract price.

Although employees voiced a general dislike for night work as noted above, some agencies noted that it was not a big problem, nor a problem that could not be solved with experience, good human relations, and good planning.

Material Acquisition

Problems might be encountered in acquiring materials such as concrete, asphalt, sand, or gravel, when these are needed for night operations, since most suppliers are closed at night. Therefore, the materials have to be stockpiled or the supplier has to remain open at night, which usually leads to higher prices. Many contractors, however, have their own batching plants and can keep them open whenever desirable.

Good planning is quite important, and some agencies note that getting materials is not a problem. Some use stockpiles and storage bins, while others have means of keeping asphalt hot. Where projects are contracted, the contractor is responsible for acquiring the materials and he generally passes on to the agency any additional price attributable to night acquisition.

One interesting comment made by several agencies concerned the delay involved in getting materials and vehicles to the work site for day operations. It was noted that large delays were sometimes encountered in daytime work as vehicles were caught in the congestion resulting from the lane closures, etc. Night work presented few problems of this type.

Labor Unions

Based on information received from the states interviewed, labor unions pose no real problems for night operations. Most differences are negotiated and any stipulations are reflected in the contract bid price. There was a general belief that if night operations were scheduled for long periods or if particular problems in safety arose as a result of night operations, the unions might become more involved.

Parts and Utility Service

If equipment or machinery breaks down, getting parts can be difficult, especially if they have to be obtained from retail establishments. Many agencies plan for this by having spare parts or duplicate equipment available, or they have contingency plans.

Obtaining service from utilities is usually not a problem, especially on freeways where utilities are not so much an integral part of the operation. However, planning is certainly necessary for projects on which utilities are involved.

Noise

Depending on the circumstances, the need to avoid creating noise can be a real problem in night operations, because the ambient background noise level is low and people are trying to sleep. Noises emanating from compressors, loaders, backup alarms, drills, jackhammers, etc., can be quite disturbing and prompt numerous complaints. Many states have ordinances pertaining to noise levels, and at least one prohibits work in residential areas at night. When considering night operations that create noise, agencies should be concerned with such factors as the level of noise made by the equipment to be used, the proximity of the work area to residential areas, and the length of project. The following comments concerning noise and night maintenance were gathered in the interviews.

-- If there is a problem with noise in a residential area, e.g., from jackhammering, work will not be done.

-- Some locations have noise codes that have to be considered.

-- Can usually work with noise if the noise "moves on" and is limited to one night.

-- Do not work in residential areas because of noise.

-- Few problems, since most freeways do not traverse residential areas.

It is also important to consider the increased noise levels for the streets and highways used as detour routes when freeways are closed for night operations.

Lighting

Lighting for night operations is available from existing overhead lights, standard equipment lights, and portable auxiliary floodlights. Some jobs, e.g. sweeping, may require only existing overhead and equipment lights. Where more lighting is needed, as when overlaying or patching a pavement, floodlights can be used.

One agency representative noted that the addition of portable floodlights was one of the most significant improvements to their night operations. Figures 14 and 15 show auxiliary lighting being used on projects in Chicago and New York. Another agency specified the following as part of the contract for a resurfacing project: "In all areas where work is being performed during the hours of dusk or darkness, the contractor shall furnish, place and maintain lighting facilities meeting with the approval of the engineer and capable of providing light of sufficient intensity to permit good workmanship and proper inspection at all times."

It is almost impossible to simulate daylight because the brightness would cause visual problems for workers and motorists. Also, any floodlights should be directed to minimize glare, annoyance, or hazard to workers and motorists.

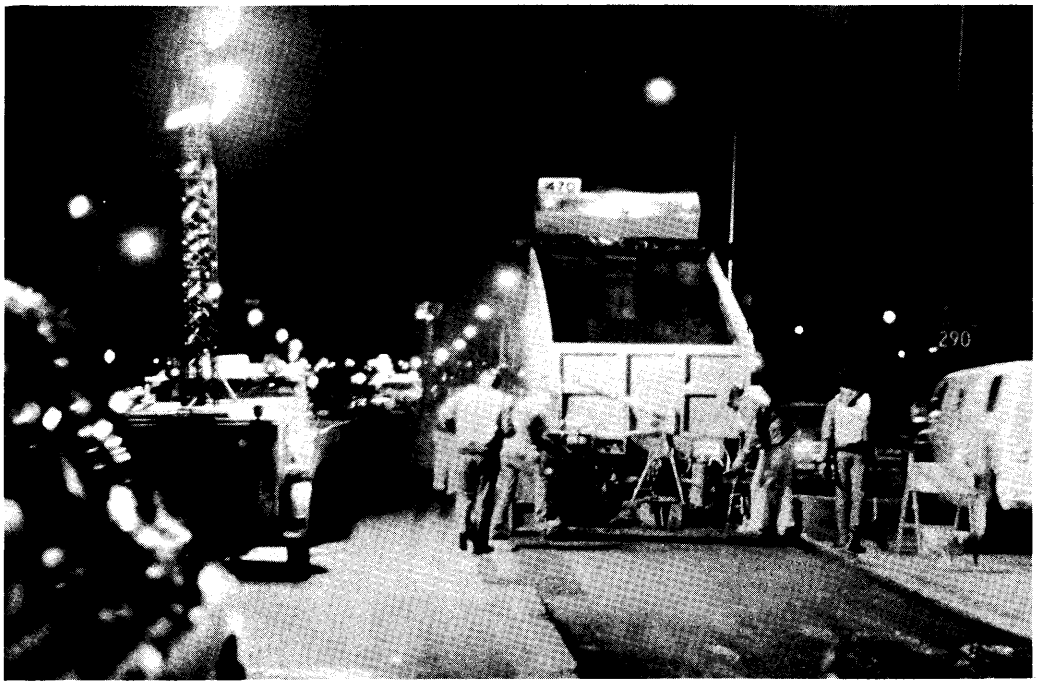


Figure 14. Auxiliary lighting for night operations in Chicago.

Figure 15. Auxiliary lighting for night operations in New York.

Quality of Work

The quality of work on night operations is lower than that on day operations; however, the work is acceptable under the standards and specifications used. The primary reason given for the lower quality was poor lighting. Worker morale, unsafe working conditions, and quality control for materials were also mentioned as reasons for the reduced quality.

Officials of some agencies commented that no problems with quality were observed for contracted work, noting that specifications are included as part of the contract and the contractor is obligated to meet them. One state official noted that quality was better because the conditions under which work was being done, i.e., total road closure, provided a good working environment and an improved product.

When considering the quality of work for night operations, the key word is "acceptable quality." Although in many night operations, quality is suspect, the product is accepted under the applicable plans and specifications.

Efficiency of Operations

The efficiency of night operations is dependent upon such variables as the type of work, conditions under which work is conducted (lane closure, road closure, etc.) experience in conducting night operations, light conditions, and worker morale.

Efficiency can be divided into two categories: efficiency in conducting a specific job, e.g., patching a pothole or sweeping, and efficiency over the total project. For specific jobs, efficiency is impaired by poor working conditions, consisting largely of inadequate lighting, supplemented by possible problems with materials, and worker morale. Efficiency of the total project is mainly dependent upon the type of lane closure and the length of time available for work. For lane closures, the problems noted above coupled with the special effort for traffic control often lead to lowered efficiency in operations at night.

Where the entire road is closed, two main advantages are apparent: a longer period of time is available for work and the entire road is free of traffic. Estimates of savings for these conditions approach twice the time saved. As one state official noted, if a large number of road patches are needed, it would take a much longer time if only one lane could be closed at a time for daylight patching. It was noted that other types of work can be done simultaneously.

Law Enforcement

Normally, it is not specified that law officers be at the project sites; however, police are notified of the proposed activities. Some agencies do specify law enforcement either because of special circumstances or because of added work zone safety. One agency attempts to have officers present all the time, especially during the shut-down phase, because the police vehicle and flashing lights attract attention and enhance motorist cooperation.

Many agencies use police for the closure procedures, especially when the entire road is closed. This is accomplished by the police occupying all lanes of the road approximately 3 miles prior to the proposed closure, and proceeding to the barricades at about 30 mi/h (48 km/h). This slowing of traffic allows a sufficient traffic gap for the road to be closed ahead of the police vehicles. Once the closure is reached, the police lead all traffic off onto the detour route. Police are used in like manner when the road is opened.

Liability

With the increasing emphasis on liability, the potential for lawsuits should not be overlooked. The adverse conditions surrounding night operations certainly provide added incentive to ensure a safe environment for the worker and the motorist. Therefore, every effort should be made to comply with the traffic controls for street and highway construction and maintenance operations set forth in the Manual on Uniform Traffic Control Devices (MUTCD) and other nationally accepted engineering standards and practices. It is noted that all agencies interviewed indicated that the MUTCD was used as a minimum, with additional measures being taken to ensure safe conditions during nighttime work zone operations.

TRAFFIC CONTROL FOR NIGHT WORK ZONE ACTIVITIES

The objectives of traffic control plans are (1) to ensure the smooth and safe movement of vehicles through the work zone, and (2) to provide safety for the workmen and the equipment in the work zone.(16) Traffic is handled by alerting drivers to the hazards presented by the work zone and guiding and directing them safely past the hazards.

A hazardous condition is created by a lane closure on a roadway carrying a high volume of traffic. The importance and cost of controlling the traffic are emphasized by the statement that "The development of traffic handling plans must be given as much comprehensive

professional attention as is required for the physical repairs themselves. Agencies must be prepared in some instances to spend as many or more dollars on the traffic handling requirements of the project as on its basic construction features."(17)

Part VI of the national MUTCD states that night maintenance and construction activities increase the problems associated with delineating the work area and placing warning devices, mainly because of the reduced visibility at night. Consequently, night activities necessitate increased use of warning lights and illumination or reflectivity for work areas and advance warning systems.

The objective of this section of the report is to describe the traffic control plans that are being used in work zones for night activities. The information is presented under four headings: Planning Work Zone Traffic Control, Elements of Work Zone Traffic Control, Traffic Control Layouts, and Summary.

Planning Work Zone Traffic Control

The Federal-Aid Highway Program Manual requires that all highway agencies using federal-aid funds have procedures for assuring traffic safety in highway and street work zones.(18) These procedures include a traffic control plan (TCP) and the designation of a qualified person at the project level to be responsible for assuring the effective administration of the TCP.

The procedures for planning traffic control and the persons responsible for designing, implementing, and maintaining it are generally the same for day, day and night, and night work zone activities. All 11 of the state highway agencies that provided information for this study have TCPs fashioned after the typical traffic control layouts in the state MUTCD or work area protection plan that can be modified to meet the needs of a specific project.

The installation and maintenance of the TCP are provided by contract in 9 of the 11 states. The New York Department of Transportation installs and maintains the TCP. The Texas Department of Highways and Public Transportation installs and maintains the TCP for maintenance only and contracts this service for construction projects.

Since the organizational structures of state DOTs differ, it is not always readily apparent where the responsibility for the TCP rests. Furthermore, the job position of the responsible person differs with the scope, size, and complexity of the project within each state DOT. Because night work zone activities are generally limited to large urban

areas, primary responsibility for the TCP generally is exercised at a district or county level.

Elements of Work Zone Traffic Control

The elements of a traffic control scheme can be categorized under 9 headings:

1. changeable message signs
2. warning signs
3. channelizing devices
4. sight distance
5. arrowboards
6. emergency/enforcement controls (Emergency controls provide assistance for accidents or other vehicle emergencies near the work zone; enforcement controls provide emergency assistance and enforce traffic regulations and control around the work zone.)
7. deterrent controls (Deterrent controls keep unauthorized vehicles out of the work zone and protect the work crew.)
8. special controls (Special controls are any controls applicable for night maintenance but are not included in the above listed controls.)
9. flagging operations and visibility of the worker

The variations in the use of each element by state DOTs, conformance to the MUTCD requirements, differences between routine traffic control and traffic control used only for night work zone activities, and pertinent information from the literature are addressed under the following subheadings.

Changeable Message Signs (CMS)

The CMS can be used to supplement the devices used to warn of freeway lane closures. Hanscom suggested three cost-efficient applications of the CMS in lane closures on high speed freeways: (1) short-term closures characterized by decreased driver expectancy, (2) minimum traffic volumes of 900 vehicles per hour, and (3) limited sight distance

to the closure.(19) Guidelines for the use of the CMS suggest (1) that it be placed approximately 3/4 mi (1.2 km) in advance of the lane closure; (2) that for shoulder placement it be put on the same side of the roadway as the closed lane; (3) that the traffic control arrangement include a two-phase, speed and closure advisory message displaying the wording RIGHT (LEFT) LANE CLOSED AHEAD AND SLOW TO 45 mi/h (72 km/h) and (4) that the CMS format should permit a complete message for each phase to be read at once.(19)

Although the MUTCD does not specify detailed standards for a CMS, it states that it is essential for the CMS to follow the principles established in the Manual to the extent practicable.(16)

Five state DOTs indicated that they make use of the CMS. They place it in advance of the lane closure at the following distances: Texas (Houston) - 0.5 mi (0.8 km); Georgia - 1.5 mi (2.4 km); and Maryland - unspecified. In Detroit, a permanent CMS system called Scandi, which is used primarily for routine traffic control, is used to denote and provide advance notice of detours for night road closures. The CMS is used by California's major incident response team and in the end of queue operation management system as discussed later under emergency/enforcement and special controls, respectively.

Warning Signs

Warning signs alert motorists in advance of any changes in normal traffic flow due to work zone activities. Reflectorization or illumination is required by the MUTCD for all signs used during hours of darkness. Illuminated signs are used only in one of the 11 states surveyed, California. The standard size warning signs, 48 in x 48 in (120 cm x 120 cm) are used by all of the states. Standard warning sign messages and symbols presented in the MUTCD are shown in this report under the section on traffic control layouts. Hostetter et al. have identified words and messages that may be misunderstood by the driver.(20) Drivers may be momentarily uncertain in their response to the words "right" or "left" when these are not supplemented by diagrams. The "KEEP RIGHT" sign could result in driver uncertainty or unnecessary lane changes when used with two or more travel lanes in one direction. Since it is questionable whether all drivers comprehend "construction", it should be replaced by "work".

Georgia, Maryland, and Texas use supplemental speed advisory signs to some extent. Flashing yellow warning lights and orange flags are used to supplement warning signs. Flashing warning lights are effective in attracting the attention of drivers. When used with warning signs, they provide an excellent means of identifying a hazard.(16) Nine state DOTs indicated that they use flashing lights on all warning signs and 1

uses it only for the first two sets of signs. Massachusetts and Texas use high level warning devices consisting of a minimum of three flags with a flashing warning light, and 4 states supplement signs with two flags to some extent. The flags also serve to attract the attention of drivers.

For multilane facilities, warning signs should be placed on both sides of the roadway, unless the sign is appropriate for one side only.

Channelizing Devices

Channelizing devices are used to provide a smooth and gradual transition in moving traffic safely from a closed to an open lane. A variety of channelizing devices are used in tapers, and any devices used at night must be reflectorized or equipped with some kind of lighting.(16)

The taper for channelization is the single most important element in the traffic control system. For speeds of 45 mi/h (72 km/h) or greater, the minimum desirable taper length, L, in feet (0.3 m) is equal to the product of the posted speed or off-peak 85th percentile speed, S, in mi/h (1.6 km/h) and the width of the offset, W, in feet (0.3 m) ($L = S \times W$).(16) The taper length should be adjusted as needed based on road geometrics. The minimum desirable taper length, typically 660 ft (198 m) for urban freeways, is used by eight of the states. Caltrans and the New York DOT employ 1,000 ft (300 m) long tapers while Virginia uses an 800-ft (240-m) taper. Long tapers permit drivers that are trapped at the lane closure taper additional time to change lanes.

The maximum spacing between channelizing devices in a taper should be approximately equal in feet (0.3 m) to the speed limit in mi/h (1.6 km/h). Device spacing in the tangent or straight section where a full lane is closed, in accordance with the work activity, speed limit, and road geometry, should clearly indicate that the roadway is closed. Nine states employ a taper spacing of between 50 and 60 ft (15 and 18 m). Virginia uses 40 ft (12 m) and Massachusetts uses 80 ft (24 m). The tangent spacing varies greatly, with three states using a 100-ft (30-m) spacing, two states each using 50-, 55-, and 120-ft (15, 16.5, and 36- m) spacings, and one state using 80- and 160- ft (24- and 48- m) spacings. Although not shown in the traffic control layouts presented here, channelizing devices are often used to close the shoulder at the beginning of the taper by extending the taper over at least half of the shoulder. Caltrans employs a different strategy, that is a 200 ft (60 m) tangent section with cones spaced at 50 ft (15 m) on the shoulder in front of the taper.

Drums, used by 6 states, were the most frequently used channelizing device, and the plastic type were most commonly used. Pain et al., in their evaluation of channelizing devices, concluded that drums were highly visible and detectable from long distances, both day and night.(21) They recommended that a minimum stripe width of 6 in (15 cm) be used.(21)

Five state DOTs use type II barricades and 2 use type I. Type I barricades in sizes between 12 in (30 cm) x 12 in (30 cm) and 12 in (30 cm) x 36 in (90 cm) are acceptable for work zones during both day and night. Type II barricades are more effective than type I only when smaller sizes such as 8 in (20 cm) x 24 in (60 cm) are used. A minimum stripe width of 6 in (15 cm) was recommended by Pain et al. for the type I and type II.(21)

Cones with reflective sleeves were used by 2 state DOTs. A minimum cone height of 28 in (70 cm) and a preferred height of 36 in (90 cm) should be used with two or three reflective sleeves totaling 150-200 in^2 (14.1 - 25 m^2) (75-100 in^2[3.52 - 6.25 m^2] visible to the driver) and a minimum specific intensity per unit area, SIA = 250.(21) The North Carolina DOT is experimenting with a 13 in (32.5 cm) long sleeve that satisfies the total reflective area requirement. Cones are generally preferred over other devices for short-term operations because of their compactness, portability, durability, and ease of use. However, they do not have the target value of other channelizing devices, get knocked out of place, blow over, and are not as formidable. They may be suitable for short-term jobs.

Translucent cones internally illuminated by a constantly burning, battery-powered bulb are employed in California.

Pain et al. concluded that when designed properly, all channelizing devices (barricades, drums, vertical panels, cones, and tubes) perform adequately both day and night.(21)

Type III barricades are used when closing a road section to traffic. They are generally used alone for ramp and road closures; however, Illinois uses a type II barricade on each side of them in such cases. Caltrans uses a series of type II barricades for road and ramp closures.

Five states have an option on the type of channelizing device to use. For example, in Pennsylvania either type I or type II barricades may be used. The foregoing data represent responses on the use of a single channelizing device in the taper and tangent.

Combinations of two channelizing devices were cited, usually with one type of device in the taper and another in the tangent. The

Illinois DOT uses type I or II barricades in the taper and are experimenting with the use of vertical panels with a plastic support base in the tangent. In Virginia, type II barricades may be used in the taper and cones in the tangent. For maintenance operations in Georgia, type II barricades or drums are used in the taper and cones in the tangent. Probably, cones and vertical panels are used in the tangent because their narrow lateral dimension may provide a wider lane next to the tangent compared to the barricades or drums in the taper. In Dallas, drums and vertical panels that have a higher reflectivity than the drums were alternated in the taper and tangent to improve the visibility during night work. In Massachusetts, drums and cones were alternated in the taper at a 10-ft (3-m) spacing to improve the delineation of the lane closure.

Steady burn yellow warning lights were used on drums or types I or II barricades by 7 states on all the channelizing devices in the taper and tangent and by 1 state on some devices. This type of light provided the longest detection distance when compared to other types of devices and retroreflective materials tested.(21) Consequently, early lane changes were promoted.(21) Furthermore, since they are self-illuminated, steady burn lights do not depend on vehicle headlights and the observation angle as much as does reflective sheeting. It was suggested that steady burn lights be used at night whenever feasible to supplement all channelizing devices in the taper and all devices or alternate devices in the tangent.(21)

Flares have been used during night work to supplement channelizing devices. In Illinois, flares placed between barricades in the taper to improve the delineation of the lane closure were very effective and visible. However, when the flares were located downwind of the work zone fumes from them caused problems for the workers. Flares were also used as a deterrent control in San Antonio, and are discussed later under Deterrent Controls.

A channelizing device (drums or types I and II barricades) supplemented with a steady burn yellow light appears to provide the maximum channelization at night because they combine reflectivity and illumination.

Sight Distance

The sight distance to the lane closure taper is a factor in the safe movement of traffic through the work zone. Although warning signs inform drivers of the lane closure, many drivers do not change lanes until the lane closure is visible.

Richards and Dudek recommended a minimum desirable sight distance of 1,500 ft (450 m) for lane closures for work on urban freeways.(22) They found that (1) more drivers were trapped in the closed lane at the taper area as sight distance to the lane closure decreased, and (2) the sight distance becomes more critical as the volume increases (from 1,000 vph to 3,000 vph or 150 vph/lane to 800 vph/lane). The recommended absolute minimum sight distance to a lane closure was 1,000 ft (300 m). Similar recommendations were made by Cottrell.(23)

McGhee and Knapp recommend that channelizing devices in a taper be visible at night under normal atmospheric conditions from a maximum distance of 900 ft (270 m) when illuminated by low beams of standard automobile headlights.(24) The recommendation is based on the time required for the detection and recognition of a hazard, driver's decision, initiation of response, and completion of a lane change. This figure is basically in agreement with the absolute minimum sight distance recommended by Richards and Dudek, since it is within ±10% of 1,000 ft (300 m).

Arrowboards

Flashing or chevron arrowboards provide additional advance warning and directional information to assist in diverting and controlling traffic around work zones. This supplemental device may be used for day or night closures. The MUTCD requires minimum legibility distances from 1/2 mi (0.8 km) to 1 mi (1.6 km) depending on the size of the arrowboard; minimum of 50% dimming from rated lamp voltage; and minimum flashing rate of 25 flashes per minute.(16)

Graham et al. concluded that (1) arrowboards are effective in promoting early lane changing, (2) the most effective placement of the arrowboard is at or upstream of the beginning of the taper, (3) the largest size arrowboard, 4 ft (1.2 m) x 8 ft (2.4 m), was more effective than the smaller boards, particularly at night and during peak periods, (4) the flashing arrow mode is most effective in conveying its message, and (5) the arrowboard is not generally beneficial in diversions, traffic splits, or shoulder closures, but may prove useful in correcting detected operational problems.(25) Faulkner and Dudek concluded that the arrowboard should be used at the taper for lane closures on urban freeways, with the location (at the beginning, within, or at the end) being dependent upon the sight distance.(26) They also concluded that placing a second arrowboard up to 2,500 ft (750 m) in advance of the taper can be extremely effective in improving the sight distance, if the sight distance to the work zone is less than 1,500 ft (450 m).(26)

Nine state DOTs employ the flashing arrow while 2 employ the chevron arrow. Ten place the arrowboard within the first half of the

taper length and 1 places it 100 ft (30 m) in advance of the taper. An arrowboard is employed as a warning sign 1/2 mi (0.8 km) in advance of the taper in Massachusetts. All of the states use an arrowboard for each lane that is closed.

Emergency/Enforcement Controls

Five state DOTs use some form of emergency or enforcement controls to enforce traffic regulations and control traffic around the work zone, to ensure the safety of the work crew and motoring public, and to alert drivers to the hazards of the work area.

The Illinois DOT has an emergency traffic control unit that assists in installing the traffic control and provides a tow vehicle on-site. Two districts in California have a major incident response team that is available 24 hr/day, 7 days/week to aid the state highway patrol in major incidents such as accidents, road closures, or congestion. A tow vehicle was provided on-site for a project in Maryland.

In Detroit and New York, police assist in slowing and detouring traffic during the installation of traffic controls.

In Maryland, New York, and Texas, police are available on-site to enforce traffic control. In San Antonio, the police vehicle's flashing lights are on and flares are set out at the beginning of the taper, giving the appearance of an accident scene. In Michigan, police are requested to drive through the work area regularly.

Deterrent Controls

Deterrent controls keep unauthorized vehicles out of the work area and provide protection to the work crew. The lowest level of deterrence is the use of channelizing devices placed across the closed lanes. The North Carolina DOT uses 3 drums across the closed lane beginning at the taper and placed every 1,000 ft (300 m). Caltrans uses a minimum of 3 cones every 2,000 ft (600 m), while Virginia employs cones at 200 to 400-ft (60 - 120-m) intervals.

Trucks with flashing or rotating yellow lights are located 50 ft (15 m) in advance of the work area in Virginia. Truck mounted impact attenuators that require a special truck are used in advance of the work area wherever possible in Illinois. Truck mounted and portable impact attenuators are used in Texas, and the latter are used in North Carolina.

In addition to using truck mounted attenuators, Maryland used a screen covering the work area to protect the workers from projectiles. In Massachusetts, a portable barrier fence was located in advance of the work on a bridge project. In Michigan, ramp areas where trucks enter the work area are monitored so that other vehicles will not inadvertently follow the trucks into the work area.

The most extensive deterrence system identified was employed in New York at road and ramp closures to counter serious problems that had occurred in the past. In this system, a type III barricade is backed up by a vehicle-arresting barrier made of a 5 ft (1.5 m) high 11 gauge steel fence with an energy-absorbing anchoring unit that yields when impacted. A uniformed security guard with a 2-way radio is stationed at each closure to warn the work crew if an unauthorized vehicle travels past the vehicle arresting barrier. This system was very effective in that only one vehicle entered past the initial barricade during the routine maintenance project compared to a past experience where 2 to 3 vehicles per night had entered the work area.

Special Controls

Caltrans employs a CMS operation at certain maintenance activity sites where queuing is expected to warn drivers of the queue and therefore reduce rear-end accidents.(19) The truck is constantly repositioned to remain approximately 2,500 ft (750 m) in advance of the queue.

Flagging Operations and Worker Visibility

The MUTCD requires that lights approved by the appropriate highway authority, or reflectorized sign paddles, or reflectorized flags be used to flag traffic at night following the daytime flagging procedures.(16) The sign paddle should be the primary hand-signaling device, and flagger stations should be adequately illuminated at night.

Limited data on this topic were collected from the survey. Caltrans requires high visibility vests for night flaggers and recommends the use of illuminated flagging stations. The placement and number of flaggers vary with the speed, traffic volume, number of travel lanes, and road alignment. In New York, flaggers are used where sight distance is impaired by the road work. In Maryland, flaggers use a flashlight with an orange glow.

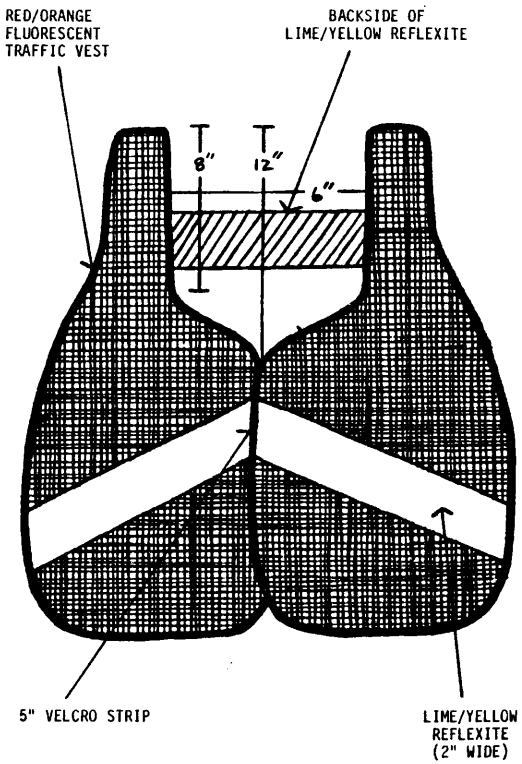
In Illinois, the workers were required to wear high visibility vests, but it was concluded that these were too hot and their visibility was inferior to that of the standard vest.

Three vest designs were developed in an attempt to improve the vest by having it outline the body. Brackett and Stuart recommend a design of an upward pointing chevron made of 2 in (5 cm) wide strips of lime-yellow reflective material stitched onto the front and back and a strip of the material stitched horizontally across the back to connect the 2 shoulder straps (Figure 16).(27) Reflective arm, leg, and helmet bands should be used to supplement the vest. Gordon recommends a minimum design using 1 in (2.5 cm) white reflective tape to outline the edges of the vest with the vertical lines slanting inward at the bottom (Figure 16).(28) A study conducted by the Michigan DOT developed a pattern of 2 chevrons with the points touching in the middle and the top chevron pointing downward and the bottom one pointing upward (Figure 16).(28)

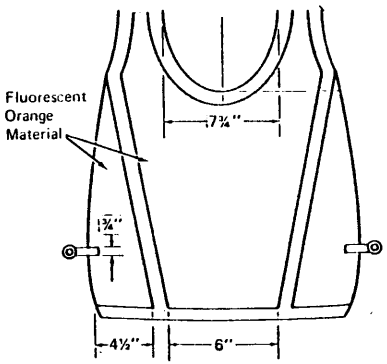
Traffic Control Layouts

Traffic control layouts display the traffic control system for a typical road closure. The MUTCD states that the advance warning distance should be 1/2 mi (0.8 km) or more for expressway and limited access facilities. The traffic control layouts discussed below are for (1) a 1-lane closure, (2) a 2-lane closure, (3) a center lane closure, (4) the use of the shoulder as a travel lane, (5) a road closure, (6) ramp control, and (7) ramp closures. Since information on the effectiveness of various traffic control layouts is not available, the layouts presented will be based on (1) compliance with the MUTCD, (2) frequently used elements and their placement, and (3) a subjective analysis emphasizing uniformity and consistency.

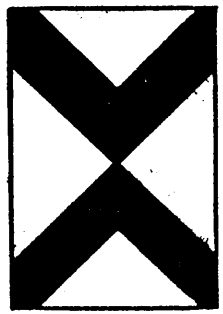
For lane or road closures, the use of advance warning signs such as "Road Work Ahead" should be considered in advance of the expected or identified queue when lengthy delays causing backups of more than 1 mi (1.6 km) from the closure are expected.



a. Brackett and Stuart's proposed design. (From reference 27)



b. Gordon's proposed design. (From reference 28)



c. Michigan DOT selected vest design. (From reference 28)

Figure 16. Worker vest designs.

One-Lane Closure

The variations in sign layout with respect to the message and location are summarized in Table 13. From this information, a composite of the most commonly used traffic control layout at night was developed as shown in Figure 17. "Work" is preferred over "construction" since (1) the lane closure is of short duration, and (2) construction may be misunderstood.

Table 13

Summary of Traffic Control for One-Lane Closure
Used by Ten State DOTs

1st Sign	Location:	2 mi - 1; 1.5 mi - 1; 1 mi - 6; 1/2 mi - 2
	Message :	Road Work X Mile - 3
		Road Construction X Mile - 4
		Road Construction Ahead - 1
		Right Lane Closed Ahead - 1
2nd Sign	Location:	1 mi - 2; 3/4 mi - 1; 1/2 mi - 6
	Message :	Right Lane Closed X Mile - 7
		Right Lane Closed Ahead - 2
3rd Sign	Location:	1/2 mi - 3; 1,500 ft - 1; ,1000 ft - 4; 750 ft - 1
	Message :	Right Lane Closed X ft. (or mile) - 4
		Right Lane Closure Symbol - 2
		Right Lane Closed Ahead - 1
		Form y Line(s) Left - 1 (where y equals the number of open lanes)
		Lane Ends Merge Left - 1
4th Sign	Location:	1,500 ft - 2; 1,000 ft - 1; 500 ft - 4
	Message :	Right Lane Closure Symbol - 4
		Right Lane Closed X Ft. - 2
		Right Lane Closed Ahead - 1
5th Sign	Location:	500 ft - 3
	Message :	Right Lane Closure Symbol - 3
6th Sign	Location:	beginning of the taper
	Message :	Keep Left

Table 13 continued

Final Sign	Location:	generally unspecified, MUTCD - 500 ft past lane channelizing device
	Message :	End Road Work - 4 End Construction - 4

Note: Right and Left are interchanged for a left lane closure. The composite location and message are underlined.

1 ft = 0.3 m
1 mi = 1.6 km

The composite differs from the MUTCD typical layout by the addition of the third sign at 1,000 ft (300 m) and the lane change symbol is shifted from 1,000 ft (300 m) in the MUTCD to 500 ft (150 m) in the composite. The additional warning sign supplements the lane closure taper, which should be visible from a minimum of 1,000 ft (300 m).

Two-Lane Closure

The advance warning sign layout for a two-lane closure is similar to that for a one-lane closure. All signs with "Right Lane" are changed to "2 Right Lanes." An additional sign is added in the tangent section of the first lane closure. Five state DOTs and the MUTCD place a lane closure symbol within the first half of the tangent section, and Caltrans adds a "Lane Closed" sign. The Pennsylvania DOT includes both a "Right (or Left) Lane Closed Ahead" sign and a lane closure symbol sign within the tangent sections and a "Keep Left" sign at the beginning of the second taper.

Three state DOTs utilize a single taper over both lanes, while 3 use two tapers separated by a tangent section. The tangent sections for 2 of these states are at least twice the length of the taper and that for the other state is 1,000 ft. (300 m). It is noted that the use of one taper requires that a driver change lanes twice within almost half the distance permitted by two tapers. Consequently, it is recommended that two tapers be used.

A typical two-lane-closure layout is shown in Figure 18. Additional lanes would be closed by extending the preceding tangent section to 2L and adding a taper and tangent section for each lane.

KEY:

■■ Channelizing devices with steady burn warning lights

◀ Arrowboard

Flashing warning lights

NOTES:

1. Taper Formula:

   L = SXW for speeds of 45 or more.

   $L = \frac{WS^2}{60}$ for speeds of 40 or less.

   Where:

   L = Minimum length of taper.
   S = Numerical value of posted speed limit prior to work or 85 percentile speed.
   W = Width of offset.

2. The maximum spacing between channelizing devices in a taper should be approximately equal in feet to the speed limit.

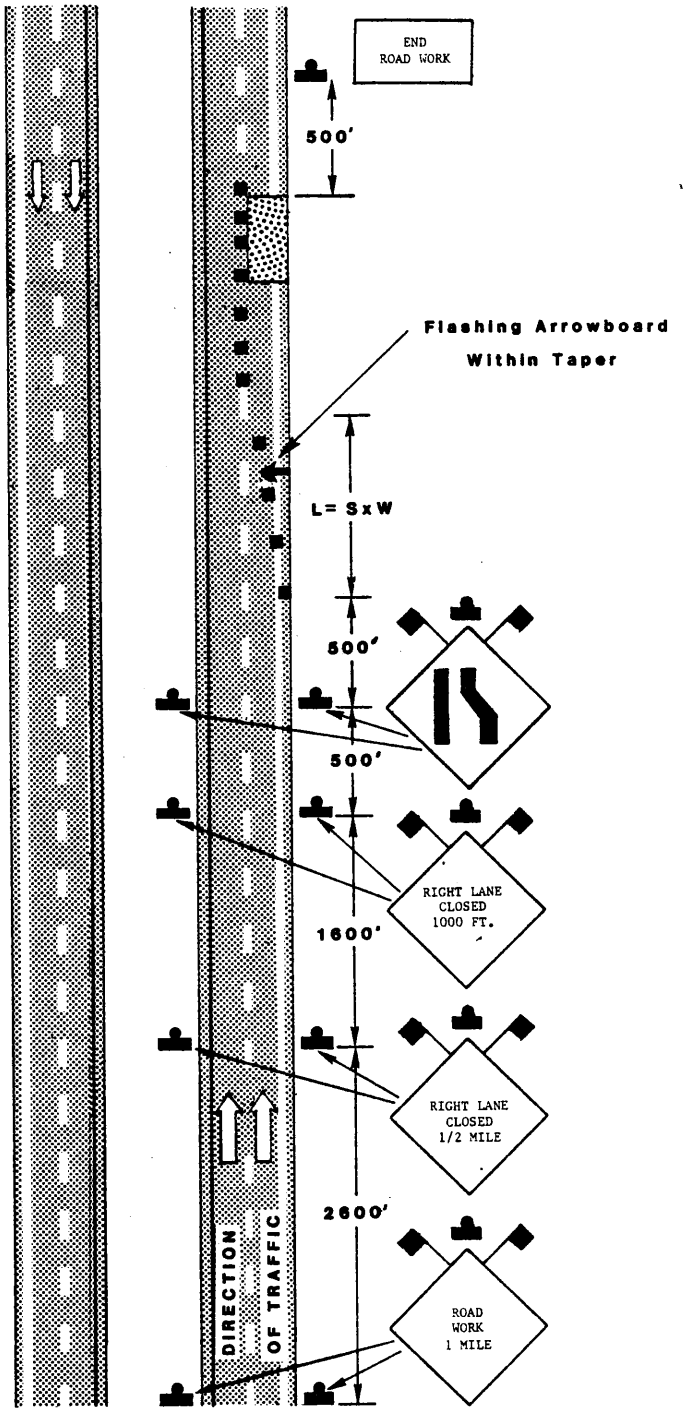


Figure 17. Typical layout for a single-lane closure.

KEY:

■■ Channelizing devices

Arrowboard

Flashing Warning Light

NOTES:

1. Taper Formula:

   L = SXW for speeds of 45 or more.

   $L = \frac{WS^2}{60}$ for speeds of 40 or less.

   Where:

   L = Minimum length of taper.
   S = Numerical value of posted speed limit prior to work or 85 percentile speed.
   W = Width of offset.

2. The maximum spacing between channelizing devices in a taper should be approximately equal in feet to the speed limit.

3. Flashing warning lights and/or flags may be used to call attention to the early warning signs.

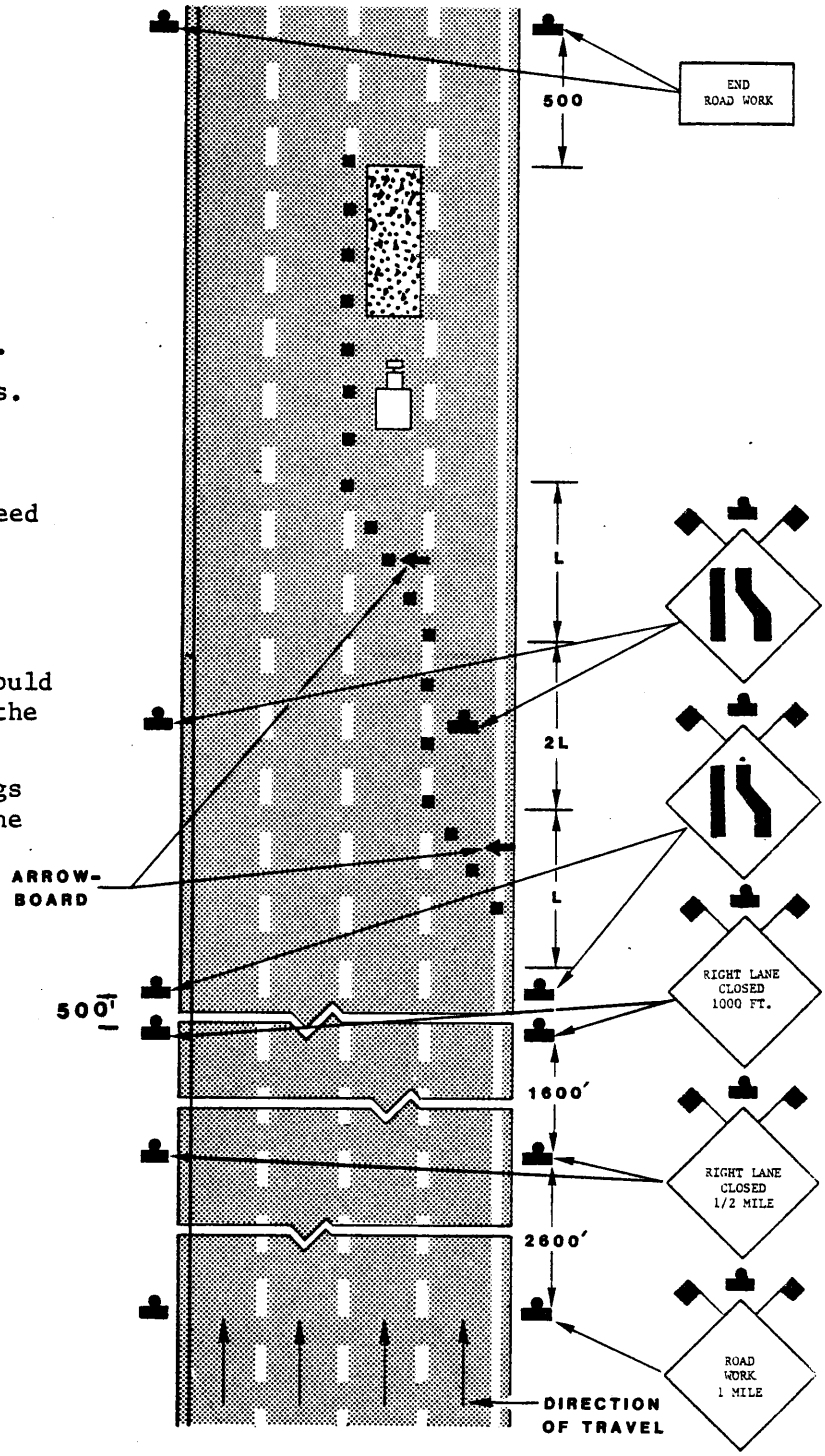


Figure 18. Typical layout for closing two (or more) lanes of a multilane highway.

The Los Angeles District in California prefers to close an additional lane for use as a buffer zone when working within 6 ft (1.8 m) of a travel lane (2 ft [0.6 m] for grooving). The Texas district around Houston closes additional lanes to provide a buffer zone and to slow down vehicles.

Center Lane Closure

The MUTCD and California and Virginia close at least two lanes, a shoulder lane and a center lane, for center lane work. The Pennsylvania DOT splits the traffic and closes only the work activity lane, while the Maryland DOT permits the option of closing two lanes or splitting traffic. The procedures for the remaining states were not given. The absence of a traffic control layout for splitting traffic is taken to imply that a two-lane closure is used.

The primary reason for splitting traffic as opposed to closing two lanes is to increase capacity. On the other hand, splitting traffic may result in driver confusion and increased erratic lane changing maneuvers because there are two options for traversing the lane closure area. The potential hazard of splitting traffic is demonstrated by the fact that in Virginia this strategy is avoided more than any other traffic control strategy. A typical layout for splitting traffic with a center lane closure is shown in Figure 19. The critical function of the layout is to channel the traffic from the center lane and into the left lane in a convenient, well-defined path.

In a field study in the Houston district of Texas where traffic on a roadway without shoulders was split, Dudek and Richards concluded that (1) the strategy appeared to provide an adequate level of safety to both motorists and the work crew, and (2) the strategy should be used for only short sections and should not be used immediately upstream of high-volume exit ramps.(29)

A center lane closure that splits traffic is discouraged. The use of shoulders as travel lanes is a preferred alternative to splitting traffic. However, the use of shoulders as a travel lane should be used with much caution. The consideration of splitting traffic or using the shoulders as travel lanes should be preceded by a capacity analysis.

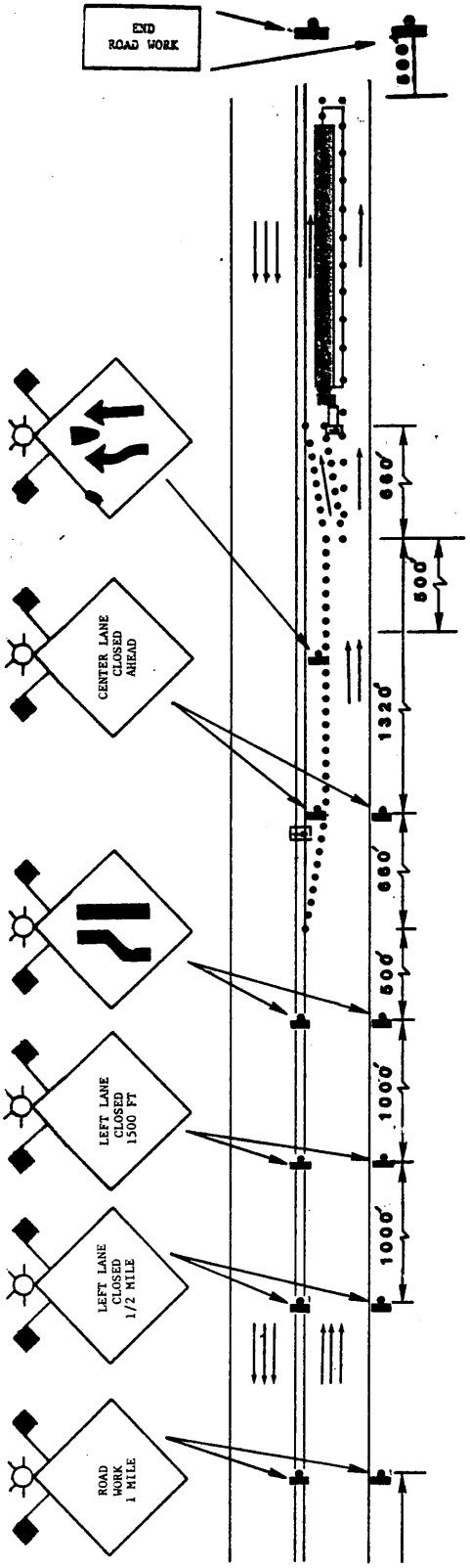


Figure 19. Typical layout for center-lane closure with split traffic.

Use of Shoulders as Travel Lanes

The use of shoulders as travel lanes is sometimes permitted to increase the capacity at a work zone. Dudek and Richards found that drivers will begin using shoulders when some degree of congestion develops on the main line and that shoulder usage increases with increased volume and congestion on the main lines.(29) Although the warning sign "Cars May Use Shoulder 500 ft (150 m) Ahead," which implies that only passenger cars should use the shoulder, was used, 25% of all trucks used the shoulder when the volume was 2,400 vph.(29)

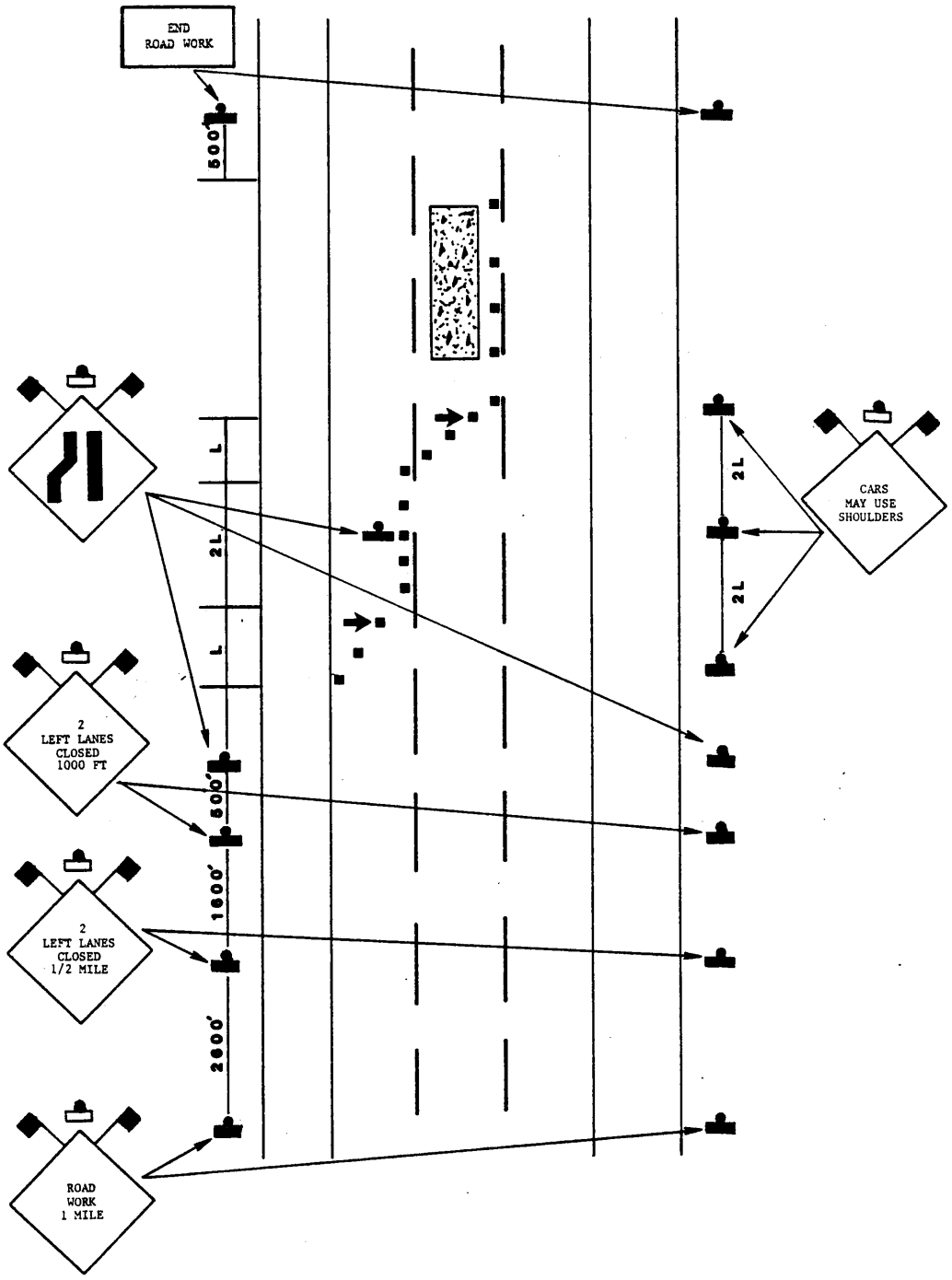
The Massachusetts DOT and Virginia Department of Highways and Transportation use the signs "Use of Breakdown Lane Permitted in Work Area," and "Cars May Use Shoulder," respectively. The Massachusetts DOT installed its sign at (1) the beginning of the taper, (2) the beginning of the tangent, and (3) the midpoint of the tangent for a single-lane closure. For two-lane closures, the third sign is placed at the beginning of the second tangent section. In Virginia, shoulders are used rarely as a travel lane and only in the situation where two of three lanes are closed for 1 mi (1.6 km) or less for center lane road work and substantial congestion is anticipated with one travel lane. The warning sign is placed in advance of the "Road Work 1 Mile" sign. Experience in Virginia has shown that the shoulder is not used much. In most cases, the use of shoulders works well if the road section is away from ramps. It is noted that there must be an understanding between the highway agency and the police on the intent and legality of traveling on the shoulder.

A composite layout for use of shoulders is shown in Figure 20.

Road Closures

California, Michigan, New York, and Texas use full-road closures for night work. This provides the maximum safety at work zones since the work area and motorists are separated completely. The applications of full-road closures are limited because adequate alternate routes, such as service roads, are essential.

A road closure is essentially a series of lane closures that end in the traffic exiting the freeway. Therefore, the advance signing and channelization taper should be similar to that for a multilane closure.



KEY:

■■ Channelizing devices

Arrowboard

Flashing Warning Light

Notes: See Figure 18.

Figure 20. Typical layout for use of shoulders.

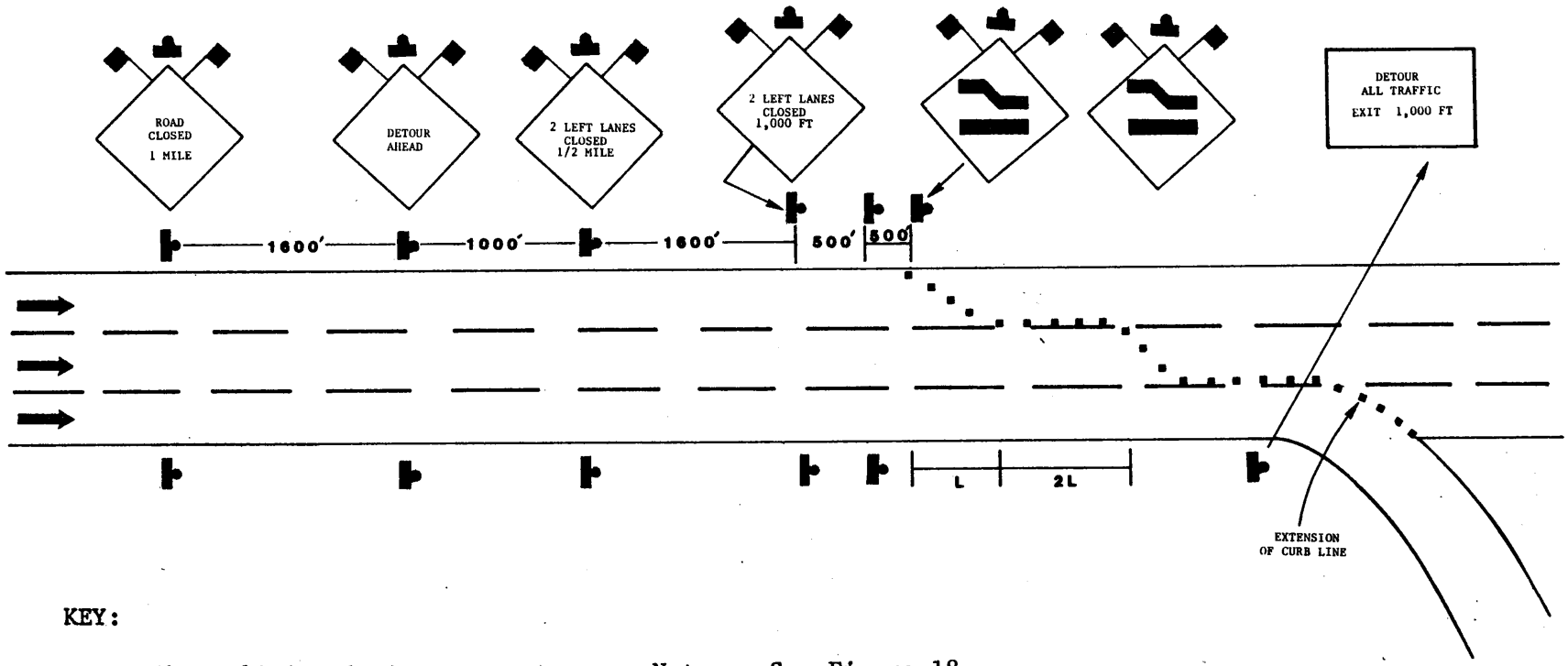
A composite layout, based on layouts of three state DOTs and the typical application of a multilane closure, is shown in Figure 21. The individual state DOT layouts differed from the composite in the following: (1) 2 layouts signed for 1 instead of 2 left lanes closed; (2) 1 layout used 2 sets of signs stating "Freeway Closed Ahead" in lieu of the "Left Lane Closed" signs; (3) along the tangents, 1 layout used 2 signs, "Single Lane xxx ft." with a supplemental arrow, while 1 layout used signs stating "Lanes Closed" in lieu of the lane closure symbol sign; (4) 1 layout used a detour arrow while another used a right curve symbol near the entrance ramp in lieu of the detour sign; and (5) 1 layout used a continuous taper.

Ramp Control

Ramp control strategies are needed when the lane adjacent to the ramp is closed. Traffic may be channeled through the closed lane into the travel lanes or ramps.

A composite layout based on layouts from 4 state DOTs is shown in Figure 22 for entrance ramp control. All of the layouts include a merge symbol sign for the freeway main line traffic. A "Warning No Acceleration Lane" sign, which is used in Virginia instead of the "Right Lane Closed" sign, does impart a clear message and should be considered as an additional sign when an acceleration lane is closed. The Massachusetts DOT uses a "Work Area Be Prepared to Stop" sign in lieu of the yield sign. The taper channelizing the ramp traffic on the right side is at a length of approximately 600 ft (180 m) in Caltrans' layout. An acceleration taper, with a minimum length of 600 ft (180 m) and a maximum length equal to the acceleration lane if one is present, should be considered if the taper does not extend into the work area. The acceleration taper would reduce the speed differential between the entering and main line vehicles, and thereby provide a smoother traffic flow and increased safety. If there is no acceleration lane, then the taper should be aligned as an extension of the ramp lane line.

California, Massachusetts, and Michigan use the typical exit ramp treatment displayed in Figure 23. A deceleration taper is provided that is approximately equal to the deceleration lane length. A temporary exit sign is the only sign used.



KEY:

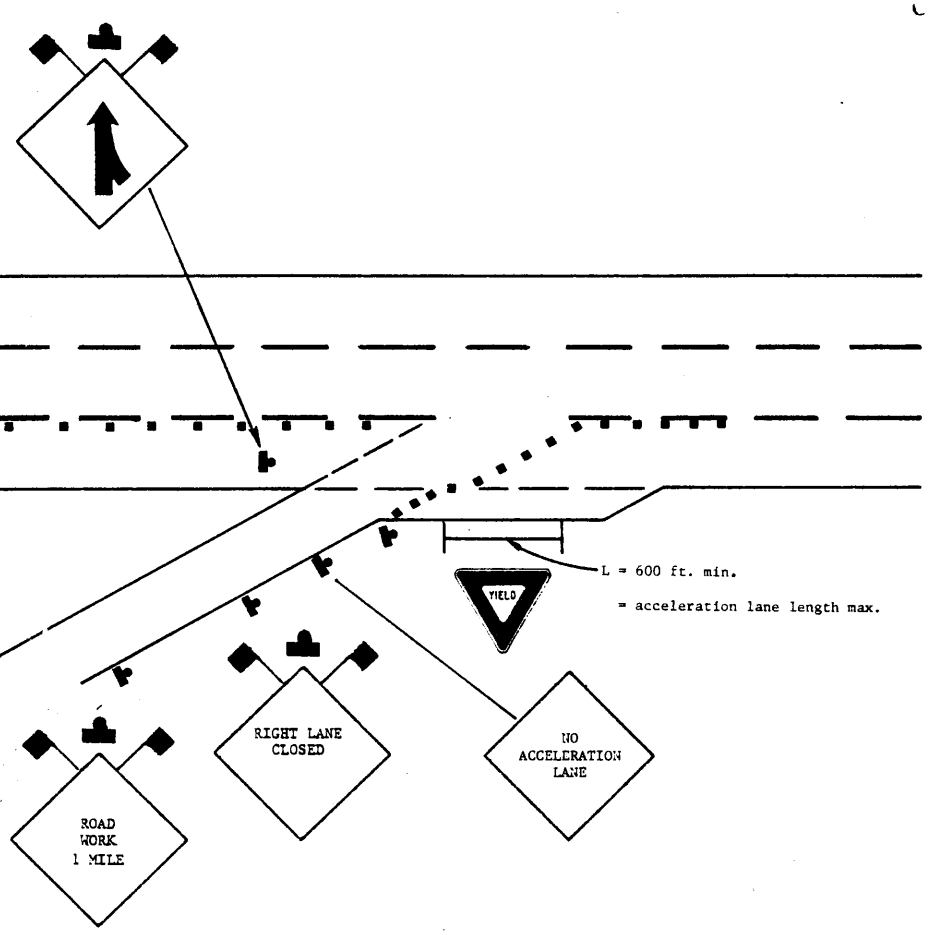
■ ■ Channelizing devices with steady burn warning lights

Arrowboard

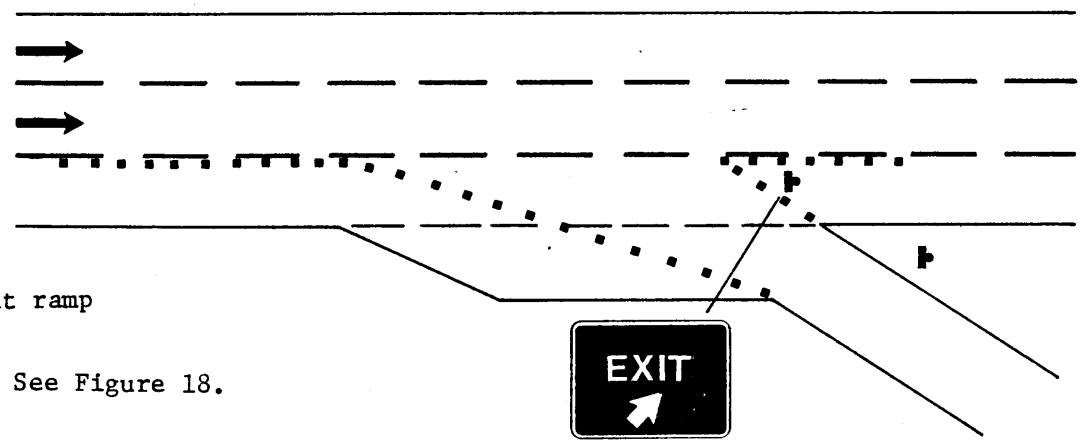
Flashing warning lights

Notes: See Figure 18.

Figure 21. Typical layout for a road closure.



a. entrance ramp



b. exit ramp

cover existing exit sign

(exit # optional)

Notes: See Figure 18.

KEY:

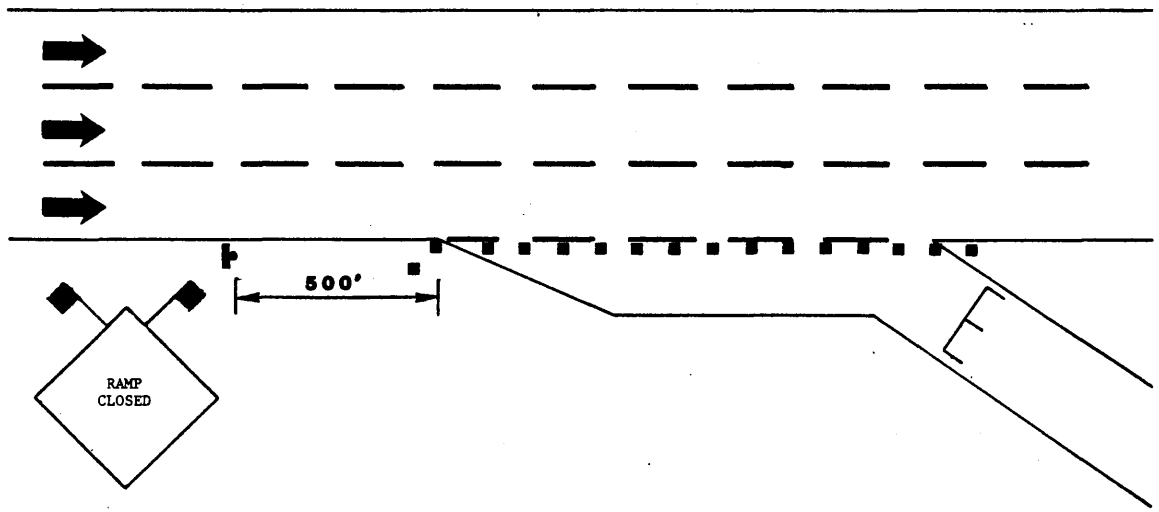
■■ Channelizing devices

Arrowboard

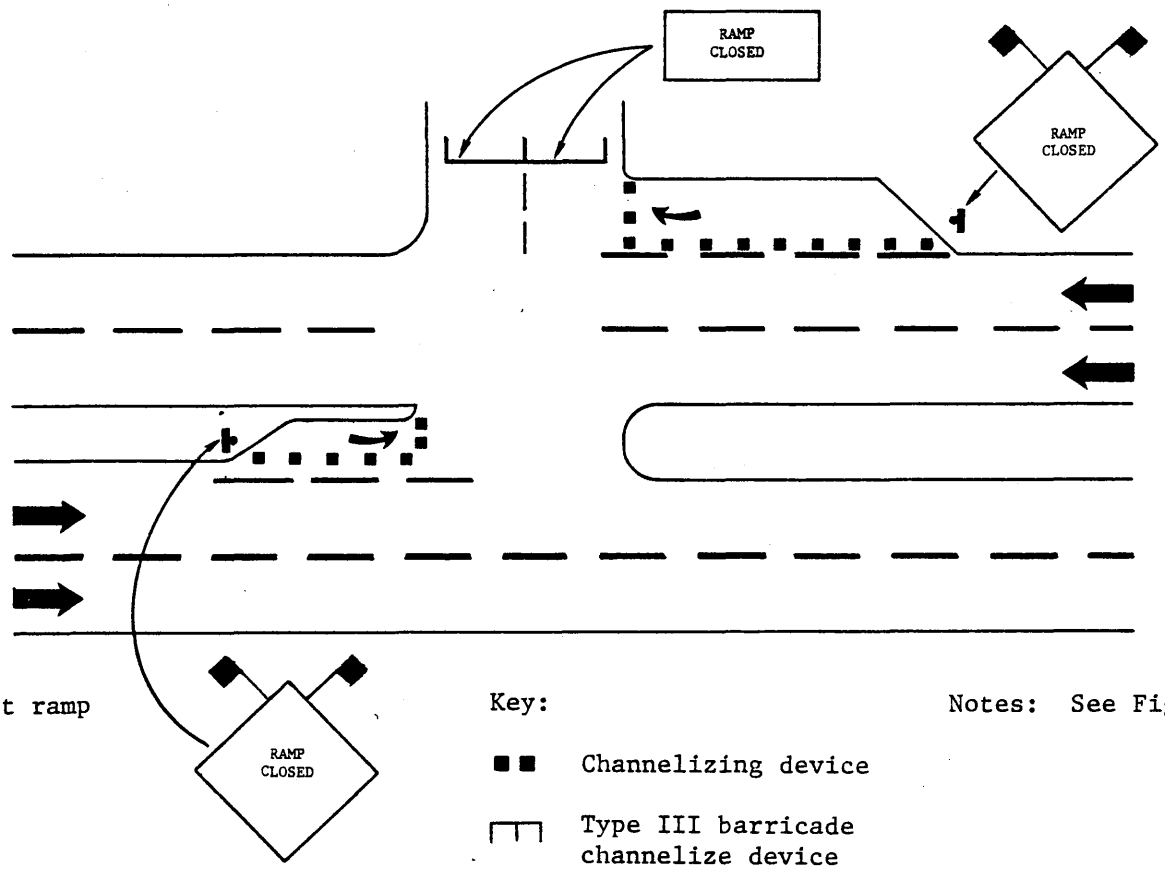
Flashing Warning Light

If there are no deceleration/acceleration lanes, the deceleration/acceleration taper should be extended from the ramp curbline to the tangent.

Figure 22. Typical layouts for ramp control.



a. entrance ramp



b. exit ramp

Key:

■■ Channelizing device

Type III barricade channelize device spacing = 40 ft.

Notes: See Figure 18.

Figure 23. Typical layouts for ramp closures.

Ramp Closures

California, Illinois, Michigan, and New York have typical ramp closures. Two of the state DOTs use type III barricades (one uses a type II barricade on each side of the type III barricade) to close the ramp and a regulatory sign attached to the barricades stating "Ramp Closed" or "Road Closed XX PM to XX AM Mon. thru Fri." Illinois installs advance information signs on the ramps to notify motorists of the date and time of the ramp closures. California employs a series of advance warning signs: "Road Construction Ahead," "Ramp Closed Ahead," and a regulatory sign, "Ramp Closed (detour arrow)," for exit ramps. Also, turn lanes leading to an entrance ramp are closed with channelizing devices and a warning sign "Ramp Closed".

In Michigan, when an entrance ramp from a service road is closed, the corresponding exit ramp is also closed to prevent motorists from entering by way of the exit ramp.

Typical ramp closures are shown in Figure 23. Marking alternate or detour routes should be considered for high volume ramps, especially those likely to be used by drivers who are unfamiliar with the local road system.

Summary

The major findings of each section are summarized below.

Planning Work Zone Traffic Control

Traffic control planning is performed in the same way for day, day and night, and night work zone installations.

Elements of Work Zone Traffic Control

In general, the traffic control for night work zone activities is similar to routine traffic control for day and night roadway closures. There is an emphasis on providing increased illumination and reflectivity to increase the visibility of traffic control devices. The following traffic control devices are effective.

1. Advance warning by changeable message signs.
2. 48 in x 48 in (120 cm x 120 cm) warning signs with flashing yellow lights and two orange flags.

3. Drums, types I and II barricades with steady burn yellow warning lights spaced at approximately 55 ft (16.5 m) in the taper.

4. Desirable and absolute minimum sight distances to the lane closure of 1,500 and 1,000 ft (450 and 300 m), respectively.

5. A flashing arrowboard located within the taper for each lane that is closed.

6. A physical deterrent, such as a truck or impact attenuator, should be located in advance of the work area for lane closures.

7. Emergency/enforcement controls, special controls, and flagging operations should be used as needed and at the discretion of the engineer responsible for the TCP.

Traffic Control Layouts

There is substantial variation in the traffic control layouts used by state DOTs. Consequently, composite layouts representing typical applications were developed (1) to provide uniformity and consistency among the layouts, (2) to identify what appeared to be the superior traffic control elements for each layout in terms of safety, clarity, and effectiveness, and (3) to identify commonly used traffic control elements. The traffic control elements and layouts discussed are in conformance with those in the MUTCD.

ADVANTAGES AND DISADVANTAGES OF NIGHT OPERATIONS

It should be realized that because of the many variables associated with night work zone operations, and that no two jobs are exactly alike, some of the advantages and disadvantages cited below may not apply to every project. It is believed, however, that they do reflect the overall attitude toward night operations.

Advantages

The major advantages of working at night as compared to working during daytime are as follows:

For Partial and Complete Roadway Closures

1. The avoidance of traffic congestion and motorist delay -- the primary benefit.
2. Opportunity to enlarge work areas and to concurrently conduct multiple work functions.
3. Longer and more productive working hours.
4. Improved working conditions with less traffic interference and less heat.
5. Use of the full capacity of the production plant.
6. Better public relations and fewer motorist complaints.
7. More efficient hauling because of less congestion.

For Complete Roadway Closure

1. Increased worker safety.
2. Higher efficiency in work performance.
3. Safer movement of vehicles.
4. Shorter setup time.

Disadvantages

The possible disadvantages of night work zone activities as compared to daytime operations are as follows:

For Partial and Complete Roadway Closures

1. More prevalent driver drowsiness, inattentiveness, and intoxication (alcohol and drugs).

2. Greater potential for more severe accidents because of the higher accident rate at night coupled with higher speeds.

3. Unexpected conditions with restricted visibility.

4. Lessened visibility, even with supplemental lighting, especially for tasks requiring accurate depth perception.

5. Adverse public reaction to noise in residential areas and restrictive noise ordinances.

6. Impaired communications between work site personnel and main offices, media, police, etc.

7. Low worker morale and difficulty in recruiting personnel, even with pay incentives.

8. More employees working two jobs.

9. Difficulty with crew becoming accustomed to night work.

10. Problems in obtaining materials since some plants do not remain open.

11. Problems with quality control.

12. Difficulty in repairing equipment breakdowns.

13. Lower quality workmanship.

14. Difficulty in obtaining service from utilities.

15. Pressure to ensure completion of job or to have road open prior to morning rush period.

16. Higher cost for some operations because of pay differentials, increased traffic control, material acquisition, etc.

17. Less advance notice of pending poor weather.

For Complete Roadway Closure

1. For detours, problems with communication and coordination with local officials.

2. Additional traffic control, noise, environmental considerations.

3. Concern for capacity on detour routes.

4. Public resentment of detours and associated consequences.

5. Increased project costs if there is a need to improve the detour route.

6. Degradation in safety.

Although there are numerous potential disadvantages of working at night, it is believed that through planning, including prior consideration of these items, along with experience and a coordinated effort between all concerned, the night alternative is feasible for selected work.

CASE STUDIES

Case studies drawn from information supplied by California, Illinois, Maryland, Michigan, New York, Texas, and Virginia are presented in Appendix B. All of the case studies are recent and representative of the different types of night work conducted by the states, and they include both lane closures and total roadway closures. They provide a good opportunity to review specifications and special provisions for various types of night operations around the country. Items covered are traffic control, safety, planning, scheduling, lighting, and special considerations and restrictions.

GENERAL GUIDELINES FOR NIGHT OPERATIONS

The following general guidelines are offered as an aid in decisions concerning night construction and maintenance operations on highly trafficked freeways. Included are factors and general criteria that should be used in deciding if night operations are feasible, along with suggestions for traffic control.

Guidelines for Deciding on Night Operations

A. Evaluate proposed project

1. Location of work

2. Type of work being done

3. Duties and time requirements for each duty

4. Required closure conditions

   -- One lane
   -- Two lane
   -- Lane location (right, left, center)
   -- Total road closure
   -- Two-lane, two-way operations

B. Examine relevant traffic data

1. Hourly traffic volumes for a 24-hour period or one week

2. Traffic characteristics (percentage trucks, directional splits, local vs. foreign traffic, etc.)

3. Special counts, if necessary

4. Possible diversions

5. Special events, holidays, etc.

C. Estimate roadway capacity for proposed project

1. From experience (Table 1)

2. Estimate using Tables 2 and 3

3. Estimate using Highway Capacity Manual equations

D. Determine potential daytime vehicle delay using above input

1. Analyze potential delay (lane closure) by comparing the work area capacity with the volume distribution (Figure 1), and/or

2. Use graphic procedures with cumulative demand volumes (Figures 7 and 8)

E. Analyze feasibility of night work

1. Determine if delays associated with potential daytime closures (step D) will be excessive

2. Determine if cost is a factor

   - Possible extra costs of night work
   - Special traffic control
   - Maintenance of devices
   - Availability of materials, etc.
   - Lower worker efficiency and quality of product
   - Supplemental lighting
   - Wage differentials
   - Cost of detour

   - Possible extra costs of day work

     - More congestion and delay
     - Longer time to complete work (manpower, equipment, safety)

   - Possible cost savings

     - Reduction in traffic delay
     - Expansion of work space
     - Extended work hours

3. Determine if adequate time is available during night for work (refer to the section entitled "Scheduling Lane and Road Closures")

4. Decide if possible secondary considerations are significant

   - Safety -- hazard potential, poor visibility, high speeds, impaired drivers, etc.

   - Noise -- noise ordinances and proximity to residential areas, hospitals, etc.

   - Quality of Work -- possible lower quality

F. Analyze feasibility of closing entire roadway

1. Determine if alternate detour routes are available

2. Determine if alternate routes have available capacity for extra volume

3. Determine if traffic control, i.e., signs, signals, etc., is adequate for traffic (cars, trucks, etc.)

4. Identify potential problems in coordinating and communicating with local officials

5. Define detour characteristics, i.e., length of detour, neighborhood characteristics, etc.

G. Decide on night operations

1. Review experience with project type, location, conditions, etc.

2. Note agency policy relating to night operations

3. Using estimated delay --

   note specific delay criteria limiting closures, consider if daytime delay is excessive, and if night work will alleviate delay

4. Note other considerations

H. After deciding to conduct night operation

1. Perform advance planning, considering

   -- administrative and manpower coordination
   -- provision of manpower
   -- procurement of materials
   -- service from utilities
   -- consequences of noise
   -- equipment repair
   -- involvement of law enforcement officials
   -- need for detours

2. Ensure adequate advance public information

3. Emphasize safety through traffic control (note special conditions required for night operations and see following guidelines for traffic control)

4. Schedule times for closing and opening roadway (see "Scheduling Lane and Road Closures") keeping in mind that work has to be completed and road has to be open to traffic in time to carry the morning peak traffic

5. Continue to monitor project for possible improvements

Guidelines for Traffic Control

A. Develop a TCP using the standard procedure for the agency with emphasis on increased illumination and reflectivity to increase the visibility of traffic control devices.

B. Use the following elements of work zone traffic control in the TCP. (These are recommended for use.)

   1. 48 in x 48 in (120 cm x 120 cm) or larger reflective warning signs with flashing yellow warning lights and orange flags

   2. Drums, type I or type II barricades with steady burn yellow warning lights spaced in conformance with the MUTCD or agency standard (in most cases, this will be approximately 55 ft (16.5 m) in the taper)

   3. Desirable and absolute minimum sight distances of 1,500 and 1,000 ft (450 and 300 m), respectively to the lane closure

   4. A flashing arrowboard located within the taper for each lane that is closed

   5. A physical deterrent, such as a truck or impact attenuator, immediately in advance of the work area

C. Consider using the following elements of work zone traffic control in the TCP. (These are optional.)

   1. Advance warning by changeable message signs

   2. Additional advance warning signs in advance of the end of the queue when lengthy delays causing backup of more than 1 mi (1.6 km) from the closure is expected

   3. Emergency/enforcement controls, special controls, and flagging operations as needed and at the discretion of the person responsible for the TCP

D. Use the typical traffic control layouts presented earlier in this report as the basis for the TCP.

E. Monitor the effectiveness of the TCP to identify and then correct any problems. This requires that a person responsible for traffic control be on-site for the duration of the work activities.

CONCLUSIONS

The question of whether to conduct construction or maintenance operations at night is difficult to answer because of the numerous considerations involved. The key consideration is the degree of congestion or vehicle delay caused by daytime lane closures. Although some agencies accept long delays as being a part of daytime road work, others do not and opt for night work, even though working at night is usually considered the least attractive alternative. Because of the increased emphasis on maintenance and reconstruction of existing facilities, coupled with the high traffic volumes in urban areas, there is reason to believe that more night operations will have to be scheduled.

Because night operations are conducted under reduced visibility, and there are more impaired drivers traveling at higher speeds than during the day, every effort has to be made to ensure the safety of workmen and motorists. In addition to increased attention to safety, consideration must be given to informing the public in advance of the work scheduled, and cost, coordination of the work force, noise, quality of work, and the acquisition of materials become the object of more than usual concern.

Although there are many potential disadvantages of working at night, it is believed that through the experience that has been gained and proper planning, the night alternative is feasible for selected work.

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APPENDIX A

PUBLIC INFORMATION PROCEDURES

Chicago

The following steps were followed by the Illinois Department of Transportation for a $16 million daytime project in the Chicago area in which a 15-mi (24 km) major expressway system was resurfaced. For daytime operations, the large anticipated delays require elaborate public information and public relations programs as listed below. Although night operations do not create such delays, these programs should also be considered for night work.

1. A task force composed of design, construction, maintenance, and traffic personnel prepared project contracts and traffic phasing and controls.

2. A meeting was held with other highway agencies and interested public and private transportation organizations to discuss the proposed work and identify possible conflicting work areas.

3. Before the project was let to bids, a meeting was held with contractors to discuss the project work and phasing, as well as the importance of the required traffic controls.

4. Formal briefings were held with the communications center dispatchers, the expressway emergency patrol supervisory staff, expressway surveillance personnel, and maintenance yard supervisors. In addition, individual briefings were given to radio traffic reporters from the major municipal radio stations to review the details of traffic phasing, the recommended alternate routes, and other modes of travel available.

5. A formal press conference was held by the secretary of transportation to discuss justification for the pavement repairs because of expected public interest. Film clips were distributed showing the problem areas of roadway to be replaced.

6. Private companies responsible for large changeable message advertising signs adjacent to the expressways were requested to publicize the starting date of the project.

7. A formal press conference was held by the secretary of transportation to announce the project approximately one week in advance of the start of work. A public information officer of the department provided liaison between news media and project

personnel. Field trips were arranged after the conference to permit the media representatives to photograph the project site.

8. Cross-street, bridge-mounted signs were displayed on the day of the press conference indicating "expressway repairs begin on (date) -- only two lanes open." Also, advisory signs indicating the work planned and alternate routes available were erected on approaching interstate highways.

9. On the day the work started, traffic engineers accompanied the helicopter traffic reporters to explain the traffic control. Up-to-date traffic reports were provided through the regional communications center. The office staff was augmented to handle citizen telephone inquiries about alternate routes, closed ramps, and access to high traffic generators.

10. Weekly work status reports were issued throughout the project. Special project features were highlighted and field trips were arranged for the news media throughout the project to discuss activities with the traffic engineers, construction engineers, and contractors.

11. Signs thanking the motorists for their cooperation were erected at the conclusion of the project. Press releases were issued announcing completion of the project ahead of schedule, as well as the bonuses earned by the contractor for early completion.

12. The secretary of transportation arranged a luncheon for project engineers and news media personnel where they were individually recognized for their contributions to the success of the project.

Several comments concerning the public information program in the Chicago area are listed below.

-- "An essential element in any effective public information program is the development of a continuous relationship with the news. A two-way relationship is a necessity if a level of trust and understanding is to be developed between the agency and the media."

-- "The driving public is directly affected and therefore vitally interested in the variety of traffic problems they encounter daily on the urban interstate facilities."

-- "With the growth in interstate usage, the rush periods have been lengthening and the public criticism for even nonrush period lane closures for any type of work is increasing."

-- "We purposely hold the press conference within a week of the start of the project and attempt to hold all project information so that maximum attention is assured at the time of the formal announcement.... we attempt to aim all of our efforts for maximum publicity regarding the work start. We feel the details of the traffic controls such as which lanes will be closed, where the median crossovers are arranged, and what special traffic provisions we made for high traffic generators are very important."

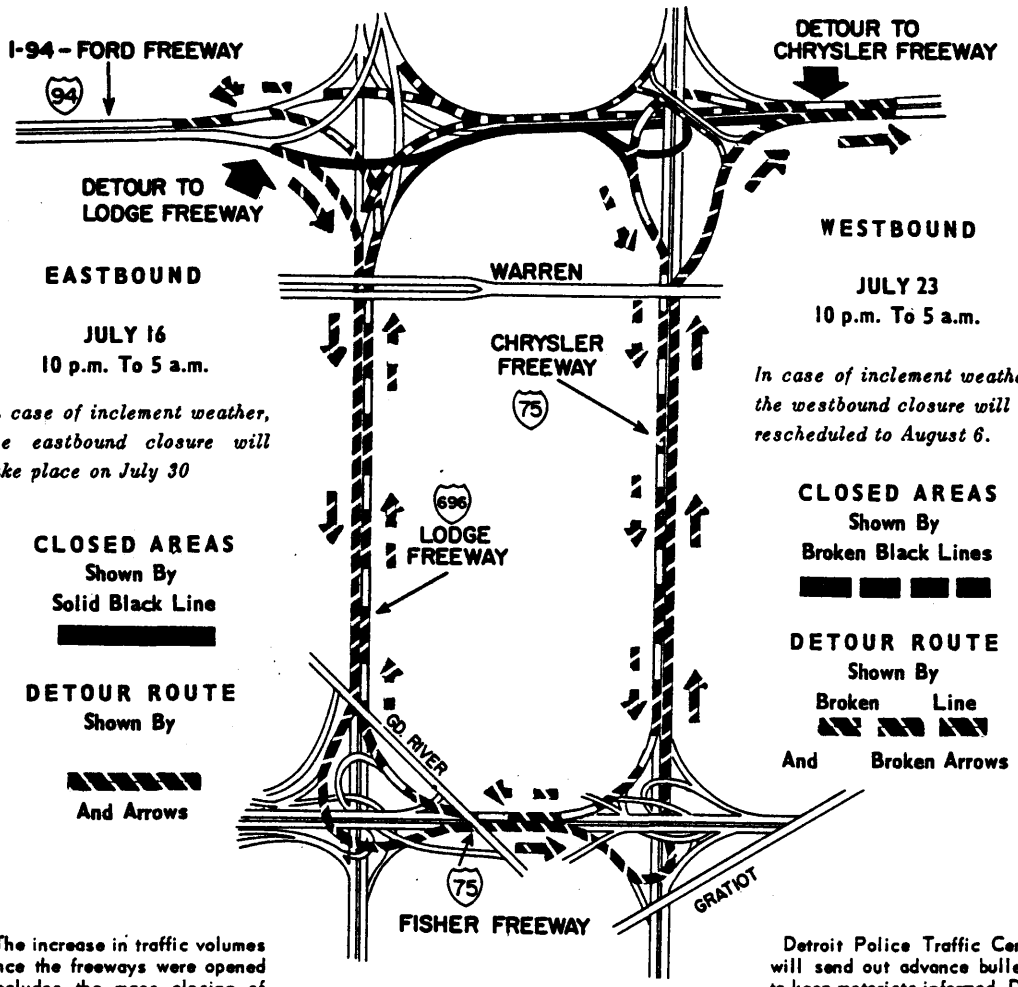
-- "Another consideration which affects the public information effort on the large projects is which day you begin the lane closures and start work. The motorist is more likely to remember the radio messages regarding the project start if he hears them the day before. Usually our midweek days are also lighter in volume so we avoid the heavy Monday and Friday traffic conflicts when the first barricades are placed."

Detroit

Urban freeways in the Detroit area have been successfully closed and traffic diverted to alternate routes. As a part of this program, bulletins giving information concerning the closure and the detour routes were distributed to motorists at strategic points. The information sheet on page 96 was printed in two colors for added emphasis.

-1180

I-94-FORD FREEWAY CLOSINGS - JULY 16, JULY 23



The increase in traffic volumes since the freeways were opened precludes the mass closing of entire freeways and the current system of working one or two lanes at a time during restricted hours is slow, costly, hazardous and often temporary.

These closures are designed to permit efficient and safe repair operations with sufficient alternate routes to handle traffic volumes safely during the time required for the maintenance work.

The eastbound Edsel Ford Freeway (I-94) will be closed to traffic between the Lodge-Ford Interchange and the Ford-Walter P. Chrysler Freeway (I-75) Interchange from 10:00 p.m. to 5:00 a.m. Thursday, July 16.

The following week the westbound Ford Freeway will be closed from 10:00 p.m. to 5:00 a.m. Thursday, July 23.

Traffic for both closures will be detoured via Lodge, Fisher and Chrysler freeways (see map above). Motorists are urged to pay attention to advanced signs and warnings.

Detroit Police Traffic Central will send out advance bulletins to keep motorists informed. Drivers in the area are urged to stay tuned to one of the following radio stations for up-to-the-minute advisories and bulletins on the ramp closings:

WCAR • WCHB • WDEE
WIID • WJR • WKNR
WWJ • WXYZ • CKLW

Urban freeway detour information sheet (Detroit).
Two-color printing provided emphasis on the original.

APPENDIX B

CASE STUDY SUMMARIES

This Appendix includes summaries of case studies for California, Illinois, Maryland, Michigan, New York, Texas, and Virginia. The summaries were compiled from information available from job proposals and special provisions, announcement memoranda, plans, and project reports. It is noted that portions of this information have been omitted. For the most part the original language has been retained and drawings have been modified and reduced. Below are given the metric conversion factors for the English units used.

Conversion of English to Metric Units

1 in	=	2.5 cm
1 ft	=	0.3 m
1 yd	=	0.9 m
1 mi	=	1.6 km
1 yd^2	=	0.8 m^2
1 yd^3	=	0.8 m^3
1 mi/h	=	1.61 cm/h
1 lb/in^2	=	6.89 kPa

CALIFORNIA

Reasons for Performing Work at Night

Daytime traffic volume results in excessive congestion and delay if lanes are closed.

Description of Project

Highway Type: 4 Div. Freeway

ADT: 66,000-70,000

Type of Work: Pavement Resurfacing

Project Length: 5 miles

Project Duration: 250 working days

Cost: Bid $6,530,552

DESCRIPTION OF WORK

The work to be done consists, in general, of constructing a freeway by grading and paving with portland cement concrete over lean concrete base and on existing surfacing; and constructing ramps by grading and surfacing with asphalt concrete over aggregate base and on the grading plane as shown on the typical cross sections.

Clearing and grubbing are to be performed; existing highway facilities are to be abandoned, removed, adjusted, modified, or capped; drainage facilities are to be constructed or installed; sound walls, miscellaneous concrete construction, fences, guardrails and concrete barriers are to be constructed; traffic stripes are to be painted; pavement markers are to be placed; and such other items or details, not mentioned above, that are required by the plans, Standard Specifications, or these special provisions shall be performed, placed, constructed or installed.

CONSTRUCTION DETAILS

General

ORDER OF WORK -- Order of work shall conform to the provisions in "Order of Work," of the Standard Specifications and these special provisions.

Attention is directed to "Maintaining Traffic" of these special provisions and to the "Traffic Handling" sheets of the plans.

The work shall be performed in conformance with the stages of construction shown on the plans. Nonconflicting work in subsequent stages may proceed concurrently with work in preceding stages, provided satisfactory progress is maintained in said preceding stages of construction.

In each stage, after completion of the preceding stage, the first order of work shall be the removal of existing pavement delineation as directed by the engineer. Pavement delineation removal shall be coordinated with new delineation so that lane lines are provided at all times on traveled ways open to public traffic.

Wherever the Contractor's operations obliterate pavement delineation (lane lines, either pavement markers or painted lane lines or both), such pavement delineation shall be replaced by either permanent or temporary delineation before opening the traveled way to public traffic. Temporary delineation shall consist of reflective traffic line tape applied in pieces not less than 4" long nor less than 4" wide spaced not more than 10' apart on curve nor more than 20' apart on tangents. Reflective traffic line tape shall be applied in accordance with the manufacturer's instructions. Temporary delineation shall be the same color as the permanent delineation. Full compensation for temporary delineation shall be considered as included in the prices paid for the contract items of work that obliterated the existing delineation and no separate payment will be made therefore.

The sound walls shall be constructed as a first order of work.

Work between Rose Avenue and Vineyard Avenue shall not be performed between the hours of 8:00 p.m. and 6:00 a.m. except for removal and painting of traffic stripe and pavement markings until the sound walls are completed.

OBSTRUCTIONS -- Attention is directed to Sections 8-1.10, "Utility and Non-Highway Facilities," and 15, "Existing Highway Facilities," of the Standard Specifications and these special provisions.

The Contractor's attention is directed to the existence of certain underground facilities that may require special precautions be taken by the Contractor to protect the health, safety and welfare of workmen and of the public. Facilities requiring special precautions include, but are not limited to: conductors of petroleum products, oxygen, chlorine, and toxic or flammable gases; natural gas in pipelines greater than 6" in diameter or pipelines operating at pressures greater than 60 psi (gage); underground electric supply system conductors or cables either directly buried or in duct or conduit which do not have concentric neutral conductors or other effectively grounded metal shields or sheaths; and underground electrical conductors with potential to ground of more than 300 volts. The Contractor shall notify the engineer at least 24 hours prior to performing any work in the vicinity of such facilities.

The General Telephone Company will be placing telephone ducts across the freeway at approximate Station 145+10 in coordination with the various stages of construction.

CONSTRUCTION AREA SIGNS -- The term "Construction Area Signs" shall include all temporary signs required for the direction of public traffic through or around the work during construction. Such signs are shown in or referred to in the current MANUAL OF TRAFFIC CONTROLS - Warning Signs, Lights, and Devices for Use in Performance of Work Upon Highways, published by the Department, hereinafter referred to as MANUAL OF TRAFFIC CONTROLS.

The Contractor shall furnish all sign panels, posts and hardware, and shall erect, maintain, and remove all construction area signs shown on the plans as provided in these special provisions.

The fifteenth paragraph in Section 7-1.09, "Public Safety," of the Standard Specifications is amended to read:

> The payment for furnishing, erecting, maintaining, and removing construction area signs, as provided in the special provisions, shall in no wise relieve the Contractor from his responsibility as provided in this Section 7-1.09.

All construction area signs shall conform to the dimensions, color, legend and reflectorization or lighting requirements of the plans, the current MANUAL OF TRAFFIC CONTROLS and these special provisions. All sign panels shall be the product of a commercial sign manufacturer, but need not be new. Used sign panels, in good repair as determined by the engineer, may be furnished.

Sign panels for portable signs may be of materials described below for stationary mounted signs or may be cotton drill fabric, flexible

industrial nylon fabric or other approved fabric. Size, color and legend requirements for fabric signs shall be as described for stationary mounted signs.

Sign panels for stationary mounted signs shall consist of high quality reflective sheeting applied to a base of aluminum or plywood in conformance with the following:

Base material shall be exterior grade plywood not less than 3/8" thick, or sheet aluminum not less than 0.063" thick for widths of up to 42" and not less than 0.080" thick for widths of 48" or greater.

Reflective sheeting shall be of the same quality as the products manufactured to meet the Department's Specifications for Reflective Sheeting Aluminum Signs. Copies of the Department's Specifications for Reflective Sheeting Aluminum Signs and Framing Details for Sheet Aluminum Signs may be obtained from the Department's Office of Business Management, Material Operations Branch, 6002 Folsom Blvd., Sacramento, CA 95819. The high quality reflective sheetings presently being manufactured or marketed by 3M Company, American Decal, and Mitsubishi Corporation have been evaluated by the Department and found to comply with these specifications. Used signs shall be considered satisfactory if (1) the sheetings have not deteriorated due to natural causes, (2) the sign is effective for its intended purpose when viewed from a vehicle during daylight and at night under low beam headlamp illumination, and (3) the colors conform to the requirements of the current MANUAL OF TRAFFIC CONTROLS. A significant difference between day and nighttime reflective color shall be grounds for rejecting signs.

Legend and border may be applied by a screening process or by use of pressure sensitive cut-out sheeting. Size and spacing of letters and symbols shall be as depicted on the sign specification sheets published by the Department. Copies of the sign specification sheets may be purchased from the Department's Central Publication Distribution Unit also located at 6002 Folsom Blvd., Sacramento, CA.

All rectangular sheet aluminum signs over 55 inches measured along the horizontal axis, and all diamond-shaped sheet aluminum signs 60 inches and larger shall be framed unless otherwise specified. Frames shall be constructed in accordance with "Framing Details for Sheet Aluminum Signs," Sheets 1 through 4 and Table 1 on Sheet 5, as published by the Department.

Construction area signs shall not be used until they are needed and when no longer needed they shall become the property of the Contractor and shall be removed from the site of the work. The Contractor may be required to cover certain signs during the progress of the work. Covers for construction area signs shall be of sufficient size and density to completely block out the message so that it is not visible either during the day or at night. Covers shall be fastened securely to prevent movement caused by wind section.

Except as otherwise shown on the plans, construction area signs shall be stationary signs or portable signs. Construction area signs shall be erected at the locations shown on the plans as directed by the Engineer. Stationary signs shall be erected on wood posts in the same manner specified for roadside signs. Posts shall be new or good sound used posts, suitable for the purpose. If the post size is not shown on the plans, the post shall be not less than 4" x 4" nominal size. Portable signs shall conform to the provisions in Section 12-3.06, "Portable Signs," of the Standard Specifications except that the second paragraph in said Section 12-3.06 shall not apply and the sign standard or framework shall be capable of supporting the size of sign specified.

The Contractor shall clean all construction area sign panels at the time of installation and as often thereafter as the Engineer determines to be necessary, but at least once every 4 months.

Signs damaged by any cause shall be repaired or, if determined by the Engineer to be irreparable, replaced by the Contractor at his expense.

To properly provide for changing traffic conditions and damage caused by public traffic or otherwise, the Contractor shall be prepared to furnish on short notice additional construction area sign panels, posts and mounting hardware or portable sign mounts. The Contractor shall maintain an inventory of the commonly required items at the job site or shall make arrangements with a supplier who is able, on a daily basis, to furnish such items on short notice.

The second sentence in the first paragraph in Section 12-2.02, "Flagging Costs," of the Standard Specifications is amended to read:

> The cost of providing stands or towers for use of flagmen shall be considered as part of the cost of furnishing flagmen.

Construction area signs shown on the plans, except those signs required for traffic control system for lane closure, will be paid for on a lump sum basis, which lump sum price shall include full compensation for furnishing all labor, materials, tools, equipment, and incidentals, and for doing all the work involved in furnishing

construction area signs required for the direction of public traffic through or around the work and for erecting or placing, maintaining (including covering and uncovering as needed) and, when no longer required, removing construction area signs at locations shown on the plans.

Full compensation for furnishing, erecting, maintaining and removing any additional construction area signs the Contractor may deem necessary will be considered as included in the lump sum price paid for construction area signs and no additional compensation will be allowed therefore.

Furnishing, erecting, maintaining, moving, and removing any additional construction area signs ordered by the Engineer will be paid for as extra work as provided in Section 4-1.03D of the Standard Specifications, except that full compensation for furnishing additional sign panels ordered by the Engineer, other than special message sign panels, shall be considered as included in the contract lump sum price paid for construction area signs and no additional compensation will be allowed therefore.

Attention is directed to section entitled "Traffic Control System for Lane Closure" elsewhere in these special provisions regarding compensation for construction area signs shown on the plans for traffic control system for lane closure.

MAINTAINING TRAFFIC -- Attention is directed to Sections7-1.08, "Public Convenience," 7-1.09, "Public Safety," and 12, "Construction Area Traffic Control Devices," of the Standard Specifications and to the Section entitled "Public Safety" elsewhere in these special provisions, and these special provisions. Nothing in these special provisions shall be construed as relieving the Contractor from his responsibility as provided in said Section 7-1.09.

Section 12-3.04, "Portable Delineators," of the Standard Specifications is amended by deleting the words "either" and "or yellow" and the table of dry reflectance values for yellow reflective sheeting from the fifth paragraph. Reflective bands for portable delineators shall be silver white.

Lane closures shall conform to the provisions in the section of these special provisions entitled "Traffic Control System for Lane Closure".

Personal vehicles of the Contractor's employees shall not be parked within the freeway right of way.

Whenever vehicles or equipment are parked or work is performed on the shoulder within 2 feet of a traffic lane, the shoulder area shall be closed as shown on the plans.

Except as otherwise provided in these special provisions Freeway lanes shall be closed only during the hours shown on Tables A and B included in this section "Maintaining Traffic." Except work required under said Sections 7-1.08 and 7-1.09, work that interferes with public traffic shall be performed only during the hours shown for lane closures.

Freeway lanes shall not be closed during the period beginning 7 days before and ending 7 days after Christmas day, and during Friday and the weekend following Thanksgiving.

Southbound lanes shall not be closed until after midnight for the duration of time that the 1984 Olympic Games or the Ventura County Fair are in progress.

Temporary railing (Type K) shall be in place between opposing traffic lanes, as shown on the plans, or as designated by the Engineer, before routing traffic onto the temporary roadway.

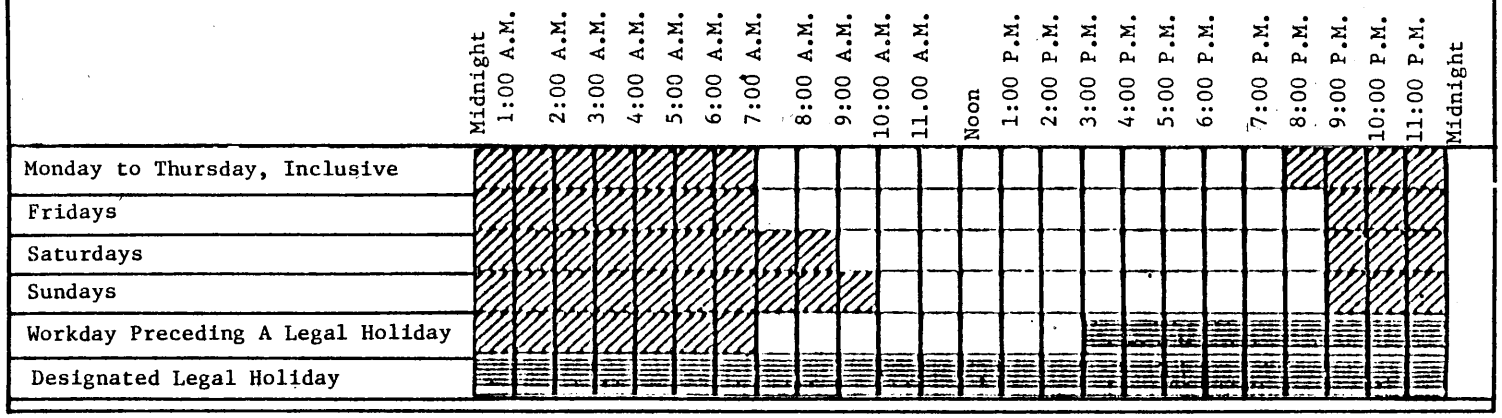
At locations where barriers are to be constructed or railing (Type K) is to be placed a temporary crash cushion shall be placed to protect the exposed end of barrier or railing.

At the end of each working day if a difference in excess of 0.25-foot exists between the elevation of the existing pavement and the elevation of any excavation within 8 feet of the traveled way, material shall be placed and compacted against the vertical cuts adjacent to the traveled way. During excavation operations, native material may be used for this purpose; however, once the placing of the structural section commences, structural material shall be used. The material shall be placed to the level of the elevation of the top of existing pavement and tapered at a slope of 4:1 or flatter to the bottom of the excavation. Full compensation for placing the material on a 4:1 slope, regardless of the number of times it is required, and subsequent removing or reshaping of the material to the lines and grades shown on the plans shall be considered as included in the contract price paid for the materials involved and no additional compensation will be allowed therefore. No payment will be made for material placed in excess of that required for the structural section.

The full width of the ramp traveled way shall be open for use by public traffic on Saturdays, Sundays and designated legal holidays, after 3:00 p.m. on Fridays and the working day preceding designated legal holidays, and when construction operations are not actively in progress.

Table A Direction North No. Lanes 2 Location CENTRAL AVE. TO SHERWIN AVE.

LANE REQUIREMENTS AND HOURS OF WORK



Provide at least one freeway lane in direction of travel.

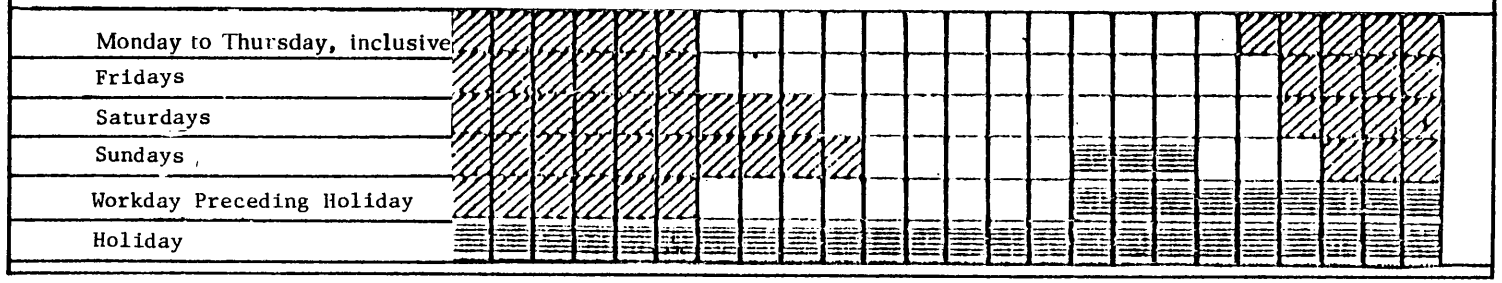
No freeway lane closure permitted; work permitted anywhere that does not require freeway lane closure.

No freeway lane closure permitted; no work permitted on north roadway.

Table B Direction South No. Lanes 2 Location CENTRAL AVE. TO SHERWIN AVE.

LANE REQUIREMENTS AND HOURS OF WORK

Monday to Thursday, inclusive



Provide at least one freeway lane in direction of travel.

No freeway lane closure permitted; work permitted anywhere that does not require freeway lane closure.

No freeway lane closure permitted; no work permitted on south roadway.

Designated legal holidays are: January 1st, the third Monday in February, the last monday in May, July 4th, the first Monday in September, November 11th, Thanksgiving Day, and December 25th. When a designated legal holiday falls on a Sunday, the following Monday shall be a designated legal holiday. When November 11th falls on a Saturday, the preceding Friday shall be a designated legal holiday.

Minor deviations from the requirements of this section concerning hours of work which do not significantly change the cost of the work may be permitted upon the written request of the Contractor if in the opinion of the Engineer public traffic will be better served and the work expedited. Such deviations shall not be adopted until the Engineer has indicated his written approval. All other modifications will be made by contract change order.

On- and off-ramps at Almond Drive and Santa Clara-Rice Avenue may be closed for a period not to exceed 5 working days, starting on Monday.

The westbound off-ramp at Rose Avenue and the ramps at Vineyard Avenue shall remain open to public traffic.

The westbound on-ramp and the eastbound on- and off-ramp at Rose Avenue may be closed for periods not to exceed 10 consecutive calendar days. The westbound on-ramp shall be closed only during the WB stage and the eastbound on-ramp shall be closed only during the EB stage as shown on the "Stage Construction" plans. The eastbound off-ramp shall be closed for both the EB and WB stages. The 10 consecutive calendar days shall start only on a Monday, Tuesday or Wednesday.

The westbound on- and off-ramps to Wagon Wheel Road may be closed only in conjunction with lane closure for work in the immediate area.

Two consecutive on-ramps or off-ramps in the same direction of travel shall not be closed at the same time. Ramps shall not be closed on designated holidays nor during the period beginning one week before Thanksgiving through New Years Day.

At Almond Drive or Santa Clara-Rice Avenue, when westbound ramps are closed the eastbound ramps shall remain open. When eastbound ramps are closed the westbound ramps shall remain open.

TRAFFIC CONTROL SYSTEM FOR LANE CLOSURE.--A traffic control system shall consist of closing traffic lanes in accordance with the details shown on the plans, the provisions of Section 12, "Construction Area Traffic Control Devices," of the Standard Specifications, the provisions under "Maintaining Traffic" elsewhere in these special provisions, and these special provisions.

Signs for traffic control system shall conform to the provisions under "Construction Area Signs" elsewhere in these special provisions, except for payment.

The provisions in this section will not relieve the Contractor from his responsibility to provide such additional devices or take such measures as may be necessary to comply with the provisions in Section 7-1.09, "Public Safety," of the Standard Specifications.

Each vehicle used to place, maintain, and remove components of a traffic control system on multilane highways shall be equipped with a Type II flashing arrow sign which shall be in operation when removing said components. The sign shall be controllable by the operator of the vehicle while the vehicle is in motion. The flashing arrow sign shown on the plans shall not be used on the vehicles which are doing the placing, maintaining, and removing, and shall be in place before a lane closure requiring its use is completed.

If any component in the traffic control system is damaged, displaced, or ceases to operate or function as specified, from any cause, during the progress of the work, the Contractor shall immediately repair said component to its original condition or replace said component and shall restore the component to its original location.

When lane closures are made for work periods only, at the end of each work period, all components of the traffic control system, except portable delineators placed along open trenches or excavation adjacent to the traveled way, shall be removed from the traveled way, shoulder and auxiliary lanes. If the Contractor so elects, said components may be stored at selected central locations, approved by the Engineer, within the limits of the highway right of way.

Upon completion of the work requiring lane closure, all components of the traffic control system shall be removed from the site of the work and shall become the property of the Contractor.

The contract lump sum price paid for traffic control system shall include full compensation for furnishing all labor, materials (including signs), tools, equipment and incidentals, and for doing all the work involved in placing, removing, storing, maintaining, moving to new locations, replacing, and disposing of the components of the traffic control system as shown on the plans, as specified in the Standard Specifications and these special provisions, and as directed by the Engineer.

The adjustment provisions in Section 4-1.03, "Changes," of the Standard Specifications, shall not apply to the item of traffic control system. Adjustments in compensation for traffic control system will be made only for increased or decreased traffic control system required by

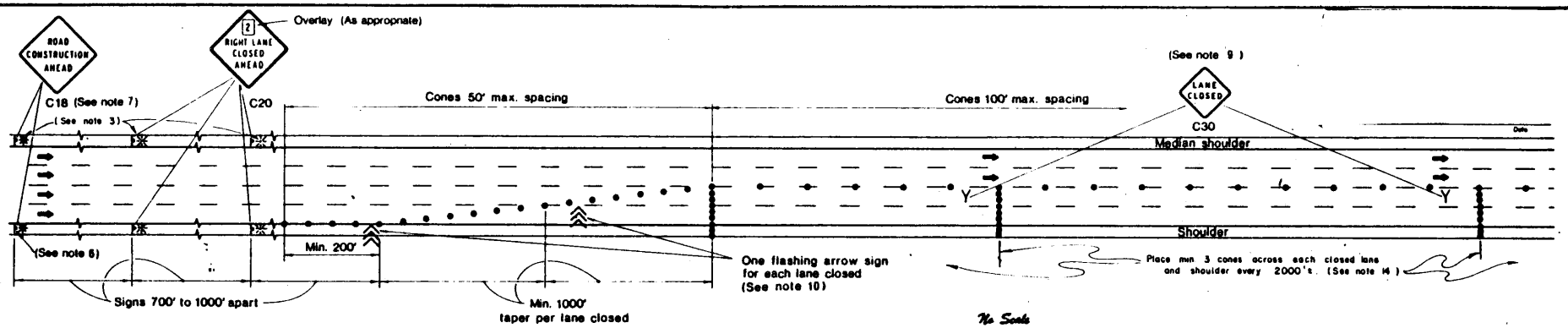
changes ordered by the Engineer and will be made on the basis of the cost of the increased or decreased traffic control necessary. Such adjustment will be made on a force account basis as provided in Section 9-1.03, "Force Account Payment," of the Standard Specifications for increased work, and estimated on the same basis in the case of decreased work.

Traffic control system required by work which is classed as extra work, as provided in Section 4-1.03D of the Standard Specifications, will be paid for as a part of said extra work.

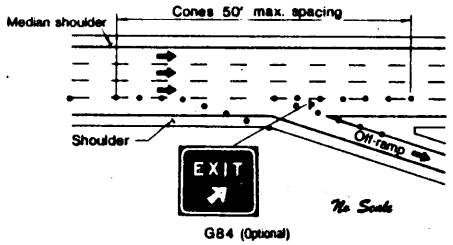
CONSTRUCTION AREA LIGHTING -- All working areas utilized by the Contractor to perform work during the hours of darkness shall be lighted to conform to the minimum illumination intensities established by the California Division of Occupational Safety and Health Construction Safety Orders.

All lighting fixtures shall be mounted and directed in a manner precluding glare to approaching traffic.

Full compensation for conforming to the requirements of this section shall be considered as included in the contract prices paid for the various items of work involved and no separate payment will be made therefore.

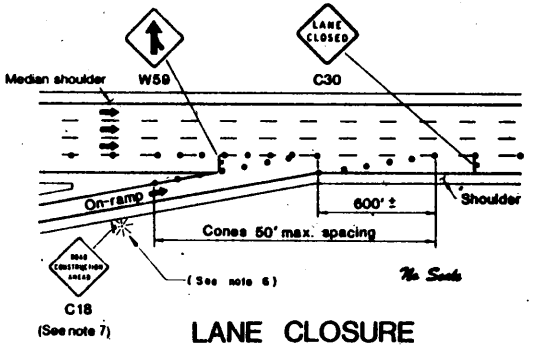


LANE CLOSURE



G84 (Optional)

LANE CLOSURE AT OFF-RAMP



C18 (See note 7)

LANE CLOSURE AT ON-RAMP

NOTES

1. Median lane closures shall conform to details for outside lane closures except that a "LEFT" overlay shall be placed over "RIGHT" on the signs.
2. Full time maintenance shall be provided for traffic control devices on all night lane closures, or daytime closures exceeding 1 mile in length including the taper.
3. Duplicate advance warning sign installations on opposite shoulders are not required for daytime operations if at least one-half of the available lanes remain open to traffic. Duplicate signs in median not required where width of shoulder is less than 8' and closure is on right side.
4. All advance signs for work during hours of darkness shall be illuminated. Other signs shall be either illuminated or reflectorized.
5. All advance warning signs for closures shall be 48" x 48" minimum or larger unless otherwise specified in the Special Provisions.
6. All advance warning sign installations shall be equipped with flags for daytime closures or flashing beacons during hours of darkness.
7. A C23 "ROAD WORK AHEAD" sign may be used in lieu of the C18 when approved by the Engineer.
8. A C13 "END CONSTRUCTION" or C14 "END ROAD WORK" sign, as appropriate, shall be placed at the end of the project.
9. Place C30 sign on flag tree every 2,000' throughout length of lane closure.
10. The first flashing arrow sign shall be Type I. All others may be either Type I or Type II unless otherwise specified in the Special Provisions.
11. A minimum 1,500' of sight distance shall be provided, where possible, for vehicles approaching the first flashing arrow sign. Lane closures shall not where possible begin at top of crest vertical or on horizontal curves.
12. All cones shall be 28" min. height. During hours of darkness they shall be internally illuminated and fitted with reflective sleeves.
13. If portable delineators, as described in Section 12-3.04 of the Standard Specifications, are used in lieu of cones the spacing shown on this plan shall be reduced by one-half.
14. When approved by the Engineer, gaps and/or a flagman may be provided at the transversely placed cones or barricades in the lane closure for continual equipment access.

LEGEND

- Cone
- Sign
- Flagtree
- Flashing arrow sign
- Portable flashing yellow beacon

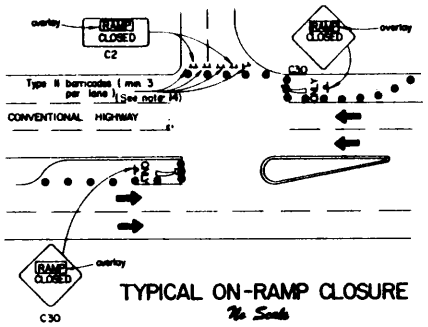
REDUCED PLAN USE SCALE BELOW

TRAFFIC CONTROL SYSTEM FOR LANE CLOSURE ON FREEWAYS AND EXPRESSWAYS

MISCELLANEOUS DETAILS

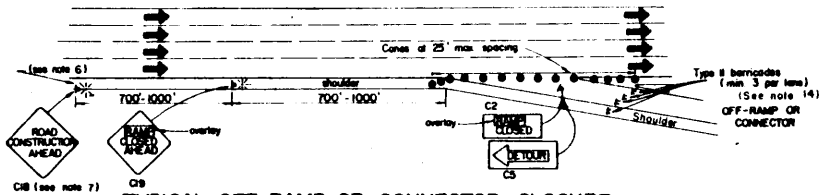
07 229 - 472601

MODIFIED T-10



TYPICAL ON-RAMP CLOSURE

No Scale

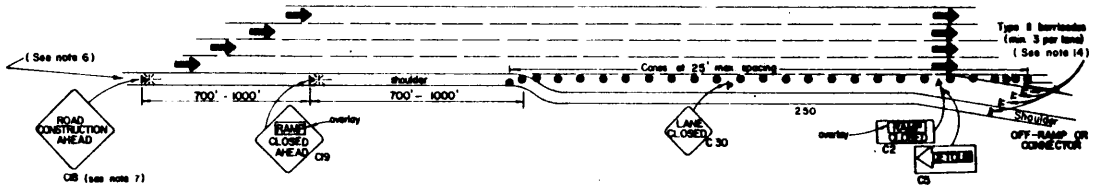


TYPICAL OFF-RAMP OR CONNECTOR CLOSURE

No Scale

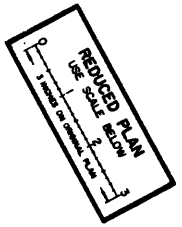
NOTES A Type II barricades shall conform to details shown in current edition of "Manual of Traffic Controls," published by the State of California, Department of Transportation.

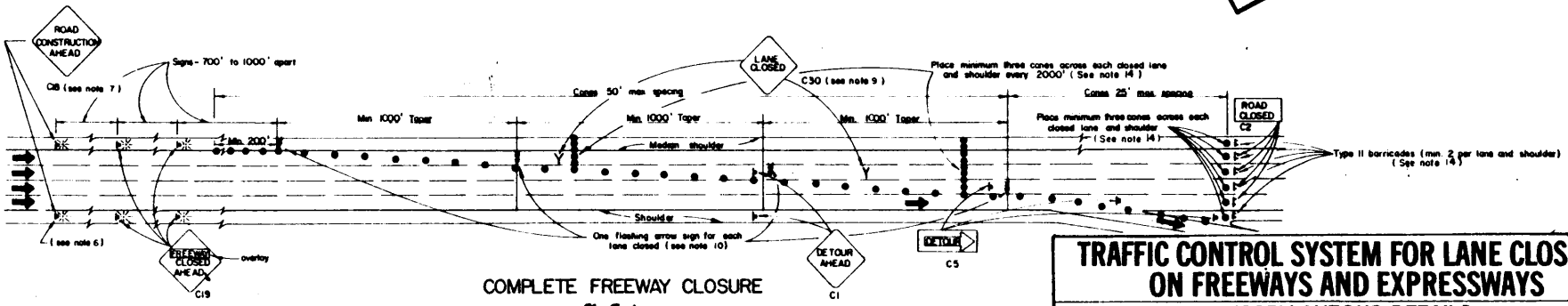
B. Refer to Modified Std Plan T-10 for applicable numbered notes and legend descriptions.



TYPICAL CLOSURE FOR OFF-RAMPS OR CONNECTORS WITH AUXILIARY LANES

No Scale





COMPLETE FREEWAY CLOSURE

No Scale

TRAFFIC CONTROL SYSTEM FOR LANE CLOSURE ON FREEWAYS AND EXPRESSWAYS

MISCELLANEOUS DETAILS

07 229 - 472601 | MODIFIED T-10A

-1136

ILLINOIS (CHICAGO)

Reasons for Performing Work at Night

To reduce daytime traffic congestion.

Description of Project

Highway Type: Expressway

ADT: 226,300

Type of Work: Patching of bridge deck

Project Length: 5.05 centerline miles (24.66 lane miles)

Project Duration: 3 weeks

Cost: $33,800

TO : I.D.O.T. Communications Center

SUBJECT: Rt. 1 (E) I-90/94 Dan Ryan Expressway
28th Street to Taylor Street

DATE : June 11, 1982

The Illinois Department of Transportation announced today that in an effort to reduce daytime congestion on the Dan Ryan Bridge between 28th Street and Taylor Street during maintenance activities, State crews will be working on the bridge at night between 10:00 p.m. and 5:00 a.m. beginning Monday night, June 14, 1982. These two lane closures will be restricted to Monday through Thursday nights and will occur for the next three weeks at various locations in both directions on the bridge.

Motorists are urged to drive with care through the construction zone and use alternate routes if possible.

Dan Ryan Bridge Deck Patching Project

Location — North- and southbound Dan Ryan, involving all four lanes between 14th Street and 28th Street, consisting of work zones requiring two-lane closures.

Date and Time — Beginning Monday, June 14, 1982, at 9:00 p.m. and ending Friday, July 2, 1982, at 6:00 a.m. Involving four 9-hour work shifts each week for three weeks.

Scope of Work — Patching of ± 1,200 sq. yds. of bridge deck surface.

Traffic Control — Warning lights to provide lighted barricades, signs and two arrowboards plus maintenance. EPV to provide truck and driver. Bureau of Traffic to provide detour marking plus overview of traffic control. Billing will be on a per day basis and approved bills submitted to the District Office for payment.

Material — Central Blacktop to provide up to 30 tons per night to be picked up about midnight in two loads at McCook Plant on Joliet Road. _____ will be on duty at the plant and dispense the material to our trucks as requested. Each lead worker will write their own Material Order for the specific quantity they need and one lump sum billing for special heating and storage will be submitted to the District Office for payment at the end of the project. Dan Ryan and Stevenson to provide one truck and driver each to haul material. Each yard to dispose of their own cut out material and any hot overage. Each yard should also have a stockpile of cold mix available should it be necessary.

Equipment — Dan Ryan and Stevenson to provide all necessary equipment and hand tools to be self sufficient. Dan Ryan mechanic will handle emergency repairs for both team sections. Back up equipment should be available at each team section. Each team section shall provide steel plates for emergencies.

Procedure — _____ will paint mark the patches to be repaired allowing for production beyond daily estimate of 110 square yards. Each Lead Worker will be responsible for the conduct of their crew, the quality and quantity of work accomplished. Alternate bad weather work assignments of cleaning under the Dan Ryan Bridge between 16th and 22nd and Stewart and Wentworth. Also on the Stevenson from Dan Ryan east to Martin Luther King Drive and west to Damen. Equipment maintenance where necessary can also be completed. Each team section should establish additional alternate work assignments as necessary. Any full depth holes through

the deck should be reported to the Bridge Crew for repair scheduling and be plated that evening.

Administrative

Time cards should be used for four-day work week. The start-stop time should reflect the 9 p.m. to 6 a.m. hours and ten hours should be credited in the hours worked column. Absences will be charged as ten hours should absences occur; however, all personnel have indicated their intention to work the periods indicated without absence. With the two Lead Workers, one Mechanic and eighteen HCEOs and HMs it should not be necessary to substitute for absentees. OPBS accomplishments should be turned into respective team sections, subsection numbers will be provided to the Lead Worker. Communication channels should be established between the project Lead Workers and their respective team sections to correct problems and/or convey messages. During the White Sox home games on June 21, 22, and 23, 1982, only southbound work will be allowed. A tentative schedule has been developed and is attached indicating work areas for each workday. _____ should be given a copy of schedule.

_____ will initiate any cancellations by calling the representative from Central Blacktop. Mr._____ plant number 485-1051, office number 482-0660 before 3:00 p.m., and to confirm our operation and availability of material for that evening. For traffic control, Mr. _____ telephone number 628-2650, should be advised of any known cancellations to eliminate charges for that day. State forces will work the full period on alternate assignments if necessary and no cancellations will affect their work schedule.

Emergencies that arise on the Dan Ryan or Stevenson during this period will be handled by other than the project work crew during the hours they are working on the project.

TRAFFIC CONTROL PLAN Traffic Control shall be in accordance with the applicable sections of the "Standard Specifications," the "Illinois Manual on Uniform Traffic Control Devices for Streets and Highways," these special provisions, any special details and Highway Standards contained herein and in the plans, and the "Standard Specifications for Traffic Control Items."

Special attention is called to Articles 107.09 and 107.14 of the Standard Specifications and the following Highway Standards, Details and

Supplemental Specifications and Mimeographed Special Provisions contained herein, relating to traffic control.

The Contractor shall contact the District One Bureau of Traffic at least 72 hours in advance of beginning work.

SPECIAL PROVISIONS

At the preconstruction meeting the Contractor shall furnish the name of the individual in his direct employ who is to be responsible for the installation and maintenance of the traffic control for this project. If the actual installation and maintenance are to be accomplished by a subcontractor, consent shall be requested of the Engineer at the time of the preconstruction meeting in accordance with Article 108.01 of the Standard Specifications. This shall not relieve the Contractor of the foregoing requirement for a responsible individual in his direct employ to supervise this work. The Department will provide the Contractor the name of its representative who will be responsible for the administration of the Traffic Control Plan.

TRAFFIC CONTROL AND PROTECTION This item of work shall include furnishing, installing, maintaining, relocating and removing all traffic control devices used for the purpose of regulating, warning or directing traffic during the construction or maintenance of this improvement.

Traffic Control and Protection shall be provided as called for in the plans, these special provisions, applicable Highway Standards, applicable sections of the Standard Specifications, or as directed by the Engineer.

The following traffic control requirements are of special importance. Conformance to these requirements, however, shall not relieve the Contractor from conforming to all other applicable requirements of the Standard Specifications for Road and Bridge Construction.

The governing factor in the execution and staging of work for this project is to provide the motoring public with the safest possible travel conditions along the roadway through this construction zone. The Contractor shall so arrange his operations as to keep the closing of any lane of the roadway to a minimum.

All traffic control devices used on this project shall conform to the plans, special provisions, traffic control standards, "Standard Specifications for Traffic Control Devices" and the "Illinois Manual on Uniform Traffic Control Devices for Streets and Highways." No

modification of these requirements will be allowed without prior written approval of the Engineer.

Traffic control devices include: signs and their supports, signals, pavement markings, barricades with sand bags, channelizing devices, warning lights, arrowboards, flaggers, or any other device used for the purpose of regulating, warning or guiding traffic through the construction zone.

The Contractor shall be responsible for the proper location, installation, and arrangement of all traffic control devices. Special attention shall be given to advance warning signs during construction operations in order to keep lane assignment consistent with barricade placement at all times. The Contractor shall cover all traffic control devices which are inconsistent with detour or lane assignment patterns during the transition from one construction stage to another.

Construction signs referring to daytime lane closures during working hours shall be removed or covered during non-working hours.

The Contractor shall coordinate all traffic control work on this project with adjoining or overlapping projects, including barricade placement necessary to provide a uniform traffic detour pattern. When directed by the Engineer, the Contractor shall remove all traffic control devices which were furnished, installed and maintained by him under this contract, and such devices shall remain the property of the Contractor. All traffic control devices shall remain in place until specific authorization for relocation or removal is received from the Engineer.

The Contractor shall ensure that all traffic control devices installed by him are operational 24 hours a day, including Sundays and holidays.

The Contractor shall provide a manned telephone on a continuous 24-hour-a-day basis to receive notification of any deficiencies regarding traffic control and protection and shall dispatch men, materials and equipment to correct any such deficiencies. The Contractor shall respond to any call from the Department concerning any request for improving or correcting traffic control devices and begin making the requested repairs within two hours from the time of notification.

When traveling in lanes open to public traffic, the Contractor's vehicles shall always move with and not against or across the flow of traffic. These vehicles shall enter or leave work areas in a manner which will not be hazardous to, or interfere with, traffic and shall not park or stop except within designated work areas. Personal vehicles

shall not park within the right of way except in specific areas designated by the Engineer.

Any drop-off greater than 3" but less than 6" within 8' of the pavement edge shall be protected by Type I or II barricades equipped with mono-directional steady burn lights at 100' center to center spacing. If the drop-off within 8' of the pavement edge exceeds 6", the barricades mentioned above shall be placed at 50' center to center spacing. Barricades that must be placed in excavated areas shall have leg extensions installed such that the top of the barricade is in compliance with the height requirements of Standard 2299. Vertical panels or other delineating devices may be substituted for Type I or II barricades with the approval of the Engineer.

Check barricades shall be placed in work areas perpendicular to traffic every 1,000', one (1) per lane and shoulder, to prevent motorists from using work areas as a traveled way. Additional check barricades shall be placed in advance of any hazard in the work area which would endanger a motorist. Check barricades shall be Type I or II and equipped with a flashing light.

Placement of all signs and barricades shall proceed in the direction of flow of traffic. Removal of all signs and barricades shall start at the end of the construction areas and proceed toward oncoming traffic unless otherwise directed by the Engineer.

Delays to the Contractor caused by complying with these requirements will be considered incidental to the item for Traffic Control and Protection, and no additional compensation will be allowed.

METHOD OF MEASUREMENT This item of work will be measured on a lump sum basis for furnishing, installing, maintaining, relocating and removing the traffic control devices required in the plans and these special provisions, excluding Existing Pavement Marking Removal and Temporary Pavement Marking, which will be paid for separately.

BASIS OF PAYMENT This work will be paid for at the contract lump sum price for TRAFFIC CONTROL AND PROTECTION, which price shall be payment in full for all labor, materials, transportation, handling and incidentals necessary to furnish, install, maintain, and remove all traffic control devices indicated in the plans and specifications. The salvage value of the materials removed shall be reflected in the bid price for this item.

The Engineer may require additional traffic control or traffic control to be installed in accordance with standards and/or designs other than those included in the plans. In such cases, the standards and/or designs will be made available to the Contractor at least one week in advance of the change in traffic control. Payment for any

additional traffic control required will be in accordance with Article 109.04 of the Standard Specifications.

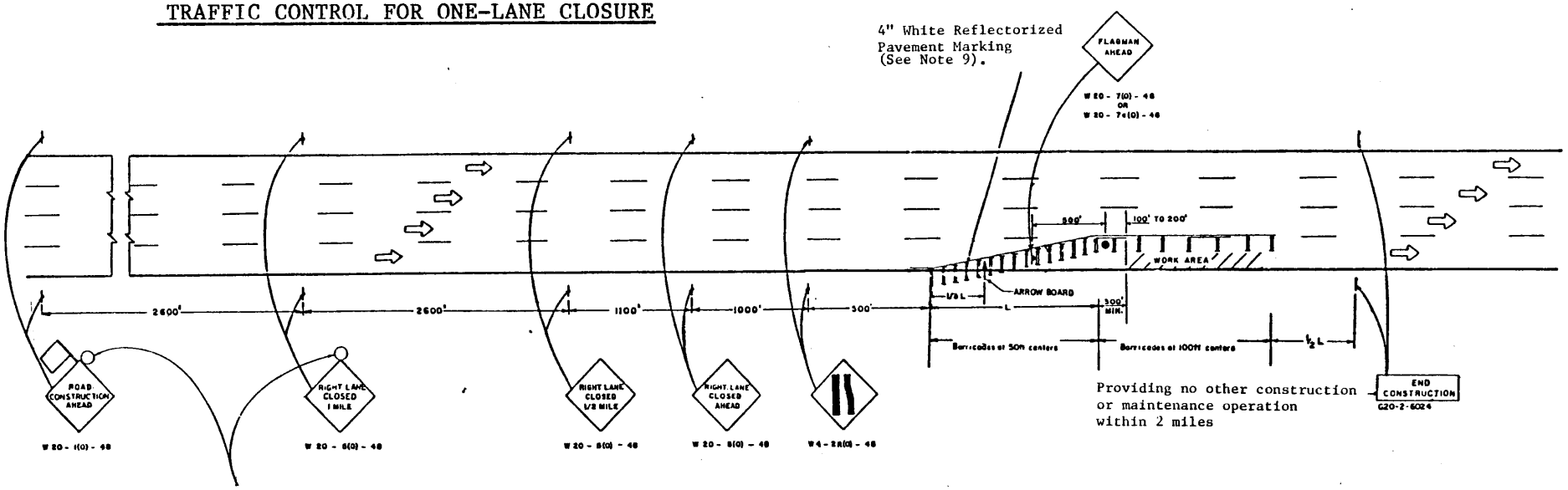
Revisions in the phasing of construction or maintenance operations requested by the Contractor may require traffic control to be installed in accordance with standards and/or designs other than those included in the plans. Revisions or modifications to the traffic control shown in the contract shall be submitted by the Contractor for approval by the Engineer.

TEMPORARY PAVEMENT MARKING This work shall consist of furnishing, installing, maintaining, and removing all temporary pavement markings in construction zones in accordance with the plan detail sheets, traffic control standards, the Standard Specifications and these special provisions.

Temporary pavement markings shall be required on paved, primed and milled surfaces.

PROTECTION AND RESTORATION OF TRAFFIC SIGNS Prior to the beginning of construction operations, the Contractor will be provided a sign log of all existing signs within the limits of the construction zone. The Contractor is responsible for verifying the accuracy of the sign log. Throughout the duration of this project, all existing traffic signs shall be maintained by the Contractor. All provisions of Article 107.22 of the Standard Specifications shall apply except the last paragraph shall be revised to read: The Contractor shall maintain, furnish and replace at his own expense, any traffic sign or post which has been damaged or lost by the Contractor or a third party. The Contractor will not be held liable for third party damage to large freeway guide signs.

TRAFFIC CONTROL FOR ONE-LANE CLOSURE



Providing no other construction or maintenance operation within 2 miles

High intensity flashing lights

SYMBOLS

- BARRICADES WITH MONO-DIRECTIONAL STEADY BURNING LIGHTS
- WORK AREA
- SIGN WITH 18" BY 18" (MINIMUM) ORANGE FLAG ATTACHED
- SIGN ON PORTABLE OR PERMANENT SUPPORT
- FLAGGER WITH TRAFFIC CONTROL SIGN
- ARROWBOARD

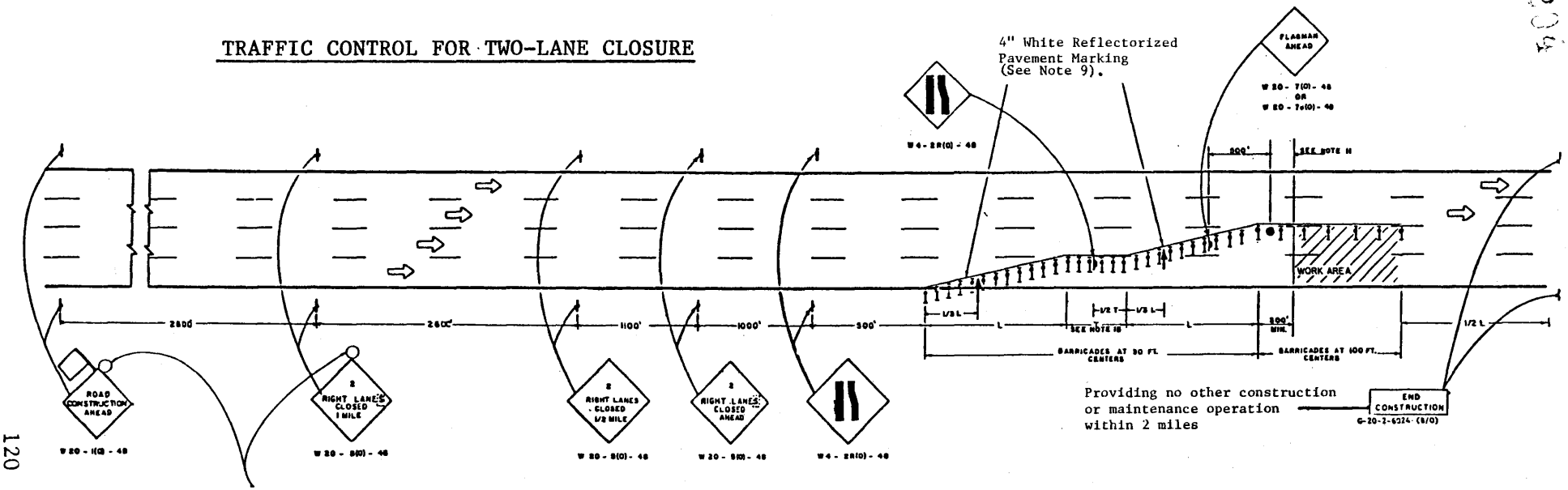
NOTES

1. THE "L" DISTANCE EQUALS THE LANE WIDTH TIMES THE TAPER RATIO.

NORMAL POSTED SPEED (M.P.H.)	TAPER RATIO (FT./FT.)
55	55/1
50	50/1
45 OR LESS	45/1

2. WHEN THERE IS NO WORK BEING PERFORMED THE FLAGGER SIGN(S) WILL NOT BE REQUIRED.
3. THIS CASE ALSO APPLIES WHEN WORK IS BEING PERFORMED IN THE LEFT LANE. UNDER THESE CONDITIONS LEFT LANE CLOSED SIGNS SHALL BE SUBSTITUTED FOR RIGHT LANE CLOSED SIGNS.
4. CONES MAY BE SUBSTITUTED FOR BARRICADES AT HALF THE SPACING DURING DAY OPERATIONS. CONES SHALL BE A MINIMUM OF 28" IN HEIGHT.
5. STEADY BURNING LIGHTS WILL NOT BE REQUIRED FOR DAY OPERATIONS.
6. THE ENGINEER MAY REQUIRE STEEL DRUMS, EITHER 55 GALLON OR 30 GALLON, TO BE USED TO SUPPLEMENT THE BARRICADES IF THE CLOSURE TIME EXCEEDS FOUR DAYS.
7. ALL SIGNS SHALL BE POST MOUNTED IF THE CLOSURE TIME EXCEEDS FOUR DAYS.
8. HIGH INTENSITY FLASHING LIGHTS SHALL BE USED DURING THE HOURS OF DARKNESS AND SHALL BE INSTALLED ABOVE THE FIRST TWO SETS OF SIGNS.
9. REFLECTORIZED TEMPORARY PAVEMENT MARKING TAPE SHALL BE PLACED THROUGHOUT THE TAPER AND FOR 300' ALONG SIDE THE WORK AREA WHERE THE CLOSURE TIME IS GREATER THAN FOURTEEN DAYS. THE EDGELINE SHALL BE YELLOW FOR LEFT LANE CLOSURES.
10. WHEN A RAMP INTERSECTS THE HIGHWAY WORK AREA, ADDITIONAL TRAFFIC CONTROL DEVICES SHALL BE ERECTED AS DIRECTED BY THE ENGINEER.
11. LONGITUDINAL DIMENSIONS MAY BE ADJUSTED SLIGHTLY TO FIT FIELD CONDITIONS. THE INTERNAL PLACEMENT OF THE FLAGMEN MAY BE VARIED FROM THAT SHOWN. THE FLAGMEN SHALL BE STATIONED APPROXIMATELY 100' TO 200' IN ADVANCE OF EACH WORK PARTY.
12. ALL VEHICLES, EQUIPMENT, MEN AND THEIR ACTIVITIES ARE RESTRICTED AT ALL TIMES TO ONE SIDE OF THE PAVEMENT UNLESS OTHERWISE AUTHORIZED BY THE ENGINEER.
13. FOR DAYTIME LANE CLOSURES, LASTING 6 HOURS OR LESS, THE CONTRACTOR MAY ELIMINATE THE "ROAD CONSTRUCTION AHEAD" SIGNS.
14. AUTHORIZATION FROM THE DISTRICT'S BUREAU OF TRAFFIC IS REQUIRED FOR ALL FREEWAY LANE CLOSURES.

TRAFFIC CONTROL FOR TWO-LANE CLOSURE



High intensity flashing lights

SYMBOLS

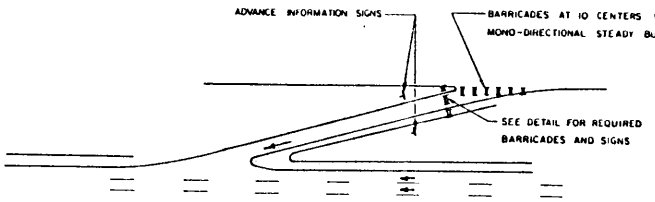
- BARRICADES WITH MONO-DIRECTIONAL STEADY BURNING LIGHTS
- WORK AREA
- SIGN WITH 18" BY 18" (MINIMUM) ORANGE FLAG ATTACHED
- SIGN ON PORTABLE OR PERMANENT SUPPORT
- FLAGGER WITH TRAFFIC CONTROL SIGN
- ARROWBOARD

NOTES

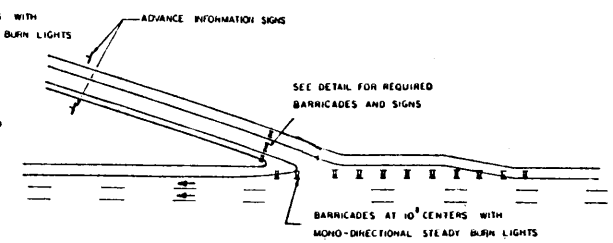
1. THE "L" DISTANCE EQUALS THE LANE WIDTH TIMES THE TAPER RATIO.

NORMAL POSTED SPEED (M.P.H.)	TAPER RATIO (FT./FT.)
55	55/1
50	50/1
45 OR LESS	45/1

2. WHEN THERE IS NO WORK BEING PERFORMED THE FLAGGER SIGN(S) WILL NOT BE REQUIRED.
3. THIS CASE ALSO APPLIES WHEN WORK IS BEING PERFORMED IN THE LEFT LANE. UNDER THESE CONDITIONS LEFT LANE CLOSED SIGNS SHALL BE SUBSTITUTED FOR RIGHT LANE CLOSED SIGNS.
4. CONES MAY BE SUBSTITUTED FOR BARRICADES AT HALF THE SPACING DURING DAY OPERATIONS. CONES SHALL BE A MINIMUM OF 28" IN HEIGHT.
5. STEADY BURNING LIGHTS WILL NOT BE REQUIRED FOR DAY OPERATIONS.
6. THE ENGINEER MAY REQUIRE STEEL DRUMS, EITHER 55 GALLON OR 30 GALLON, TO BE USED TO SUPPLEMENT THE BARRICADES IF THE CLOSURE TIME EXCEEDS FOUR DAYS.
7. ALL SIGNS SHALL BE POST MOUNTED IF THE CLOSURE TIME EXCEEDS FOUR DAYS.
8. HIGH INTENSITY FLASHING LIGHTS SHALL BE USED DURING THE HOURS OF DARKNESS AND SHALL BE INSTALLED ABOVE THE FIRST TWO SETS OF SIGNS.
9. REFLECTORIZED TEMPORARY PAVEMENT MARKING TAPE SHALL BE PLACED THROUGHOUT THE TAPER AND FOR 300' ALONG SIDE THE WORK AREA WHERE THE CLOSURE TIME IS GREATER THAN FOURTEEN DAYS. THE EDGELINE SHALL BE YELLOW FOR LEFT LANE CLOSURES.
10. WHEN A RAMP INTERSECTS THE HIGHWAY WORK AREA, ADDITIONAL TRAFFIC CONTROL DEVICES SHALL BE ERECTED AS DIRECTED BY THE ENGINEER.
11. LONGITUDINAL DIMENSIONS MAY BE ADJUSTED SLIGHTLY TO FIT FIELD CONDITIONS. THE INTERNAL PLACEMENT OF THE FLAGMEN MAY BE VARIED FROM THAT SHOWN. THE FLAGMEN SHALL BE STATIONED APPROXIMATELY 100' TO 200' IN ADVANCE OF EACH WORK PARTY.
12. ALL VEHICLES, EQUIPMENT, MEN AND THEIR ACTIVITIES ARE RESTRICTED AT ALL TIMES TO ONE SIDE OF THE PAVEMENT UNLESS OTHERWISE AUTHORIZED BY THE ENGINEER.
13. FOR DAYTIME LANE CLOSURES, LASTING 6 HOURS OR LESS, THE CONTRACTOR MAY ELIMINATE THE "ROAD CONSTRUCTION AHEAD" SIGNS.
14. AUTHORIZATION FROM THE DISTRICT'S BUREAU OF TRAFFIC IS REQUIRED FOR ALL FREEWAY LANE CLOSURES.
15. THE TANGENT SECTION SHALL BE OMITTED WHEN CLOSURE TIME IS 4 DAYS OR LESS. TANGENT LENGTH "T" SHALL BE EQUAL TO "L" FOR CLOSURE TIMES GREATER THAN 4 DAYS BUT LESS THAN 14 DAYS. TANGENT LENGTH "T" SHALL BE EQUAL TO "2L" FOR CLOSURE TIMES OF 14 DAYS OR GREATER.



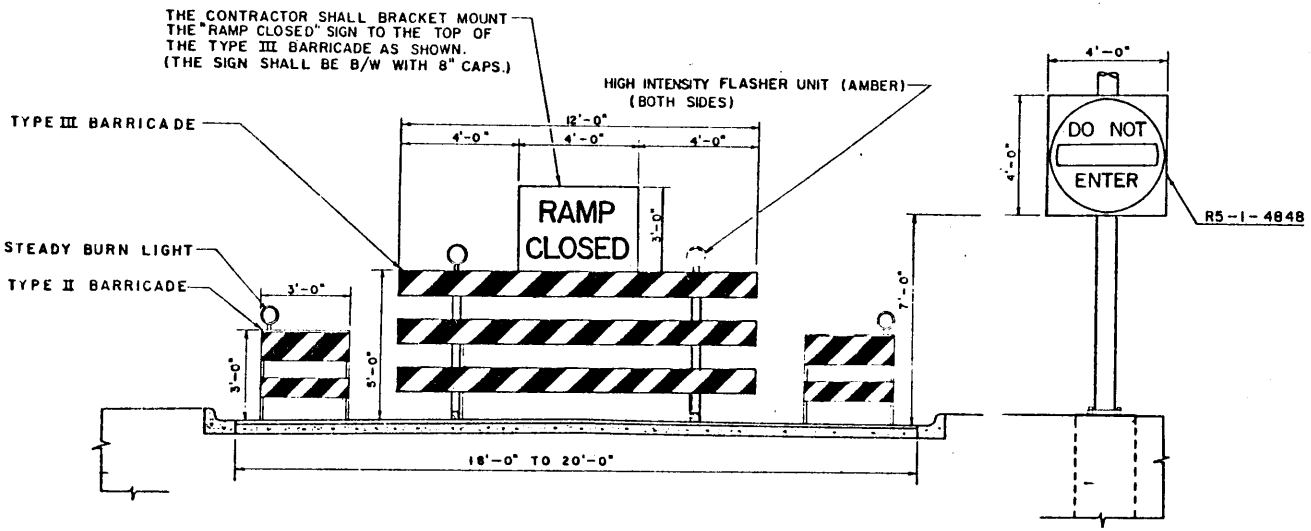
ENTRANCE RAMP CLOSURE



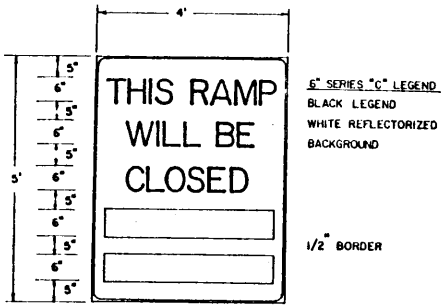
EXIT RAMP CLOSURE

NOTES:

1. CONES MAY BE SUBSTITUTED FOR TYPE I AND TYPE II BARRICADES DURING DAY OPERATIONS. CONES SHALL BE A MINIMUM OF 28" IN HEIGHT.
2. STEADY BURN LIGHTS WILL NOT BE REQUIRED FOR DAY OPERATIONS.
3. THE RAMP CLOSURE ADVANCE INFORMATION SIGNS SHALL BE ERECTED IF THE CLOSURE TIME EXCEEDS TWENTY-FOUR (24) HOURS.
4. ADDITIONAL ADVANCE WARNING SIGNS ON EXIT GUIDE SIGNING WILL BE REQUIRED FOR EXIT RAMP CLOSURES THAT EXCEED TWENTY FOUR (24) HOURS IN LENGTH.



DETAIL FOR REQUIRED BARRICADES & SIGNS



RAMP CLOSURE ADVANCE INFORMATION SIGN

THE VARIABLE MESSAGE WITH DATES FOR THE BOTTOM TWO LINES SHALL BE DETERMINED BY THE ENGINEER AND GIVEN TO THE CONTRACTOR BEFORE THE REQUIRED FIELD ERECTION DATE.
THIS SIGN SHOULD BE FABRICATED AND ERECTED BY THE CONTRACTOR ON BOTH SIDES OF THE RAMP 48 HOURS IN ADVANCE OF THE CLOSURE.

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MARYLAND/VIRGINIA - WOODROW WILSON MEMORIAL BRIDGE

Reasons for Performing Work at Night

The inability of the Woodrow Wilson Memorial Bridge to handle traffic during the morning and afternoon peaks when lanes are closed for deck replacement.

Description of Project

Highway Type:	6-lane divided bridge
ADT:	105,700
Type of Work:	Widening and Replacement of Concrete Deck
Project Length:	5,689 ft.
Project Duration:	Traffic detoured at night from December 1982 to September 1983.
Cost:	$25,000,000 (total project)

DESCRIPTION

These Special Provisions and the Specifications named elsewhere herein are for the complete construction necessary for the widening and concrete deck replacement of the Woodrow Wilson Memorial Bridge, and all incidental work pertinent thereto, all as indicated on the Plans, outlined in these Special Provisions, the Specifications, the Supplement to Specifications, and/or as may be directed by the Engineer.

The work covered by these Special Provisions consists of:

1. Widening and replacement of the existing concrete deck on the Virginia approach structure from the west abutment to the bascule span including New Jersey type barriers, for a total length of approximately 2,326 feet.

2. Widening and replacement of the existing concrete deck on the Maryland approach structure from the east abutment to the bascule span including New Jersey type barriers, for a total length of approximately 3,363 feet.

3. Modifications to the existing metal median barrier and parapets on the bascule spans to provide a wider roadway.

4. Relocation of existing concrete median barriers.

5. Removal and replacement of roadway lighting on the bridge.

6. Repairs to the channel fender system.

7. Repairs to the bascule span nose locks.

8. Rebalancing bascule leaves.

9. The safe and continuous maintenance of vehicular traffic on I-95 (Capital Beltway) during the life of the Contract.

Contractor's attention is directed to the fact that vehicular traffic over the existing bridge must be maintained during the life of this Contract as covered elsewhere herein and/or as directed by the Engineer.

The Contractor must completely finish one roadway (one-half the bridge from abutment to abutment) before he can begin work on the other roadway.

This Project is located on I-95 (Capital Beltway) over the Potomac River between the states of Maryland and Virginia and the District of Columbia.

SPECIFICATIONS

All work on this Project shall be done in accordance with the requirements of the State Roads Commission/State Highway Administration's Standard Specifications entitled "Specifications for Materials, Highways, Bridges, and Incidental Structures" dated March 1968 and the "Supplement to Specifications" dated August 1980, revisions thereof, or additions thereto, included in this Proposal and the Special Provisions.

MAINTENANCE OF TRAFFIC

Included:

The Contractor will be required to adhere to these Special Provisions, the Supplement to the Specifications and applicable Interim Specification Addenda, and the Manual on Uniform Traffic Control Devices (MUTCD) except as otherwise specified in these Special Provisions.

Construction Methods:

A prime requisite of this Contract is the safe and continuous maintenance of vehicular traffic at all times during the life of the Contract. No storage of equipment, material, or traffic control devices will be allowed on the bridge when all lanes are open to traffic.

The traveled way on the approach roadway and the bridge proper shall generally conform to the details within the Plans and the MUTCD as to signing, general layout and delineation, and other maintenance of traffic control devices except as modified herein.

Existing guide signing for all interchange ramps on both the Maryland and Virginia approaches shall be maintained and functioning at all times.

For protective shields to protect the river and roadway under the bridge from falling debris, see article elsewhere herein titled "Removal of Portions of Existing Bridge."

No work shall be commenced on any stage of construction until the signs, barriers and barricades for that stage, indicated on the Plans, are complete in place. The Contractor will be solely responsible for all accidents and/or damages to person and/or persons and/or property resulting from his operations. Compliance with prescribed precautions contained herein, or in the Specifications, etc., shall not relieve the Contractor of his primary responsibility to take all necessary measures to protect and safeguard the work, nor relieve him of any responsibilities prescribed by Section 107 and GP Section 7 of the General Provisions.

The Contractor will be required to demonstrate to the Engineer two consecutive nights of satisfactory Traffic Condition III lane closures prior to initiating the deck removal and replacement work.

Traffic Control:

The State Highway Administration has prepared a Traffic Control Plan (TCP) upon which are shown all necessary traffic control devices to include channelizing devices, barricades by type, signs, and so forth. The TCP prepared by the State Highway Administration is not mandatory, the Contractor may develop his own, however, it must be submitted for review and approval by the Federal Highway Administration, Maryland State Highway Administration, Virginia Department of Highways and Transportation and the District of Columbia Department of Transportation. Details for the TCP prepared by the State Highway Administration may be modified by the Contractor and must be approved by the Engineer. Any approved changes in the details of the TCP must be

forwarded to the Division of Bridge Development so that contract documents can be revised.

The TCP shall conform to Article 35.11A of the Supplement to Specifications and the following:

The Traffic Control Plan (TCP) has been developed as a series of LANE CLOSURE PLANS. These plans are described as THREE LANE CLOSURE, TWO LANE CLOSURE, MEDIAN LANE CLOSURE, CENTER LANE CLOSURE, RIGHT LANE CLOSURE, and NO LANE CLOSURE. The Contractor shall implement the lane closure Traffic Control Plans in accordance with the following table and provisions, and the table listing holiday dates when no work will be permitted which would affect traffic.

WORK HOUR RESTRICTIONS

Traffic Condition	TRAFFIC CONDITION I	II	III
Monday thru Thursday	6:00 AM - 9:00 AM 3:30 PM - 8:00 PM	9:00 AM - 3:30 PM	12:00 PM - 6:00 AM 8:00 PM - 12:00 PM
Friday	6:00 AM - 9:00 AM 3:00 PM - 9:30 PM	9:00 AM - 3:00 PM	12:00 PM - 6:00 AM 9:30 PM - 12:00 PM
Saturday	--	7:30 AM - 8:00 PM	12:00 PM - 7:30 AM 8:00 PM - 12:00 PM
Sunday	--	10:30 AM - 10:00 PM* 10:30 AM - 8:00 PM**	12:00 PM - 10:30 AM 10:00 PM - 12:00 PM* 8:00 PM - 12:00 PM**

Traffic Condition I - No lane closures permitted, all lanes open to traffic.

Traffic Condition II - Single lane closure (median, center, right) permitted.

Traffic Condition III - Three, two or one lane closure permitted.

*After Easter weekend through second Sunday in September.

**Third Sunday in September through weekend before Easter.

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HOLIDAY SCHEDULE

	1982	1983	1984
New Year's Day		12/30/82 thru 1/02/83	12/30/83 thru 1/02/84
Washington's B'day		2/18/83 thru 2/21/83	2/17/84 thru 2/20/84
Easter (Good Friday)		4/01/83 thru 4/03/83	4/19/84 thru 4/22/84
Memorial Day		5/27/83 thru 5/30/83	5/25/84 thru 5/28/84
Independence Day		7/01/83 thru 7/04/83	7/03/84 thru 7/04/84
Labor Day	9/03/82 thru 9/06/82	9/02/83 thru 9/05/83	
Veterans Day	11/10/82 thru 11/11/82	11/10/83 thru 11/14/83	
Thanksgiving Day	11/24/82 thru 11/28/82	11/23/83 thru 11/27/83	
Christmas Day	12/23/82 thru 12/26/82	12/23/83 thru 12/26/83	

No work will be permitted during the Traffic Condition III periods noted on the plans and in these Special Provisions on the above dates.

If the contract extends beyond July 1984, the restriction will still apply to those holidays listed.

During Traffic Condition III, the Contractor will be required to have a tow vehicle on site for use in case of emergency. The tow vehicle shall be of a size capable of towing tractor trailers.

All construction tasks shall be completed on one roadway before undertaking any such tasks on the other roadway.

At any one time, the Contractor shall implement only one THREE or TWO LANE CLOSURE and at any one time the Contractor shall implement only one SINGLE LANE CLOSURE on either or both the eastbound and westbound roadways.

The Contractor shall have in place and operating all traffic control devices prior to the commencement of construction activities associated with the appropriate TRAFFIC CONTROL PLAN.

The Contractor will not be allowed to perform any work until the appropriate Lane Closure TCP is in place and operating satisfactorily. All work on the bridge including the installation and subsequent removal or covering of all signs, markers, beacons, channelizing devices, arrow boards and shadow vehicles shall be completed within the respective times specified in the work hour restrictions table.

All Contractor activities are subject to the final approval of the Engineer.

The Contractor shall follow the recommended sequence of operations relating to the specific LANE CLOSURE TRAFFIC CONTROL PLAN as shown on the plans.

Prior to starting any work on the bridge, the construction warning signs shall be in place and remain for the duration of the construction. These are "Road Construction 2 Miles," "Road Construction 1 Mile," and "End Construction" as shown for the "NO LANE CLOSURE" TCP. The Contractor's attention is directed to the need to cover certain of these signs during the several other lane closures in order to avoid confusion.

Prior to establishing a THREE LANE CLOSURE, relocate the "Jersey Type" median barrier adjacent to the raised median curb throughout the entire length. In the event that all such work cannot be accomplished in one day, the Contractor shall align two removed barrier sections and locate them diagonally between relocated and existing sections to prevent exposure of barrier ends to the traffic flow. The Contractor shall remove and repave the 6-inch existing raised median barrier. Removal shall start from the Virginia end in a progressive manner toward the Maryland end.

The bridge roadways and approaches shall be restriped after relocation of the barrier.

Prior to initial establishment of a THREE LANE CLOSURE, median openings for crossovers shall be made by removing median barrier sections where indicated on the plans.

All removed median barrier sections shall be reconstructed subsequent to final usage of the THREE LANE CLOSURE Traffic Control Plan.

During the periods between the time the median barrier is removed and replaced and other than the time that the THREE LANE CLOSURE Traffic Control Plan is in operation, the median barrier terminal shall be protected with impact attenuators and the remaining openings shall be closed with channelizing devices to be used for the THREE LANE CLOSURE.

In the performance of the work, the Contractor shall undertake various construction tasks such as, but not limited to, median removal, relocation and replacement, redecking and wearing surface placement, which will require the closing of one, two or three lanes on one of the two bridge roadways.

The Contractor shall use each Plan to establish placement of traffic control devices routing traffic around a work zone. These devices include construction warning signs, arrow boards, channelizing devices, barrier trucks, impact attenuators, truck mounted attenuators, truck mounted signs and flagmen.

Channelizing Devices and Temporary Barriers:

The Contractor shall provide, maintain in good condition, replace and move when necessary or directed all traffic control devices and temporary barriers used for channelizing and protection of vehicles.

Reference is made to the latest edition of the MUTCD, wherein all such items are fully described with regard to use, application, warrants, size, color, placement, etc., and wherein typical traffic control device layouts are shown, as all such devices and techniques planned for use on this project shall strictly conform to the Manual's requirement except as noted on the Plans.

Channelizing devices shall be as shown on the Plans or equal as approved. They shall be orange and white striped and reflectorized with a tape that has a smooth, sealed outer surface which will display the same approximate size, shape and color day and night.

The channelizing devices shall be mounted with the top a minimum of 36" above the roadway. Four-inch stripes shall be used. Striping shall conform to MUTCD. The devices shall have a square ballasted bottom for stability, be of one piece construction of UV Resistant Polyethylene with a minimum barrel diameter of 18", weigh after ballasting approximately 14 lb., have molded handholes and contain a pocket to accommodate a warning beacon, and be fully nestable.

The channelizing devices shall be placed as indicated on the Plans or as directed by the Engineer.

The temporary Thrie Beam barrier for Maintenance of Traffic used on the bascule leaves shall be located as shown on the Plans. This barrier shall be attached to the deck as indicated on the Plans. Guardrail components need not be new, but must be in good condition and acceptable to the Engineer. The method of attachment to the deck must be approved by the Engineer and all work for installation, and relocation thereof shall be incidental to the Maintenance of Traffic item.

The existing precast concrete median barriers shall be utilized for maintenance of traffic and shall be located as shown on the Plans. Refer to Article titled "Removing, Relocating and Resetting Existing Concrete Median Barrier" elsewhere in these Special Provisions.

The existing concrete median barrier at the approach roadways shall be removed for the maintenance of traffic crossover as shown on the Traffic Control Plans. Refer to article titled "Removal of Existing Concrete Median Barrier on Approaches."

Temporary concrete barriers will be placed at the approach roadway crossovers as shown on the TCP. At the completion of work each night, and before roadway is open to traffic the following morning, the Contractor shall relocate the temporary concrete barriers to close the median area and remove any additional temporary barrier section from the roadway. The temporary barriers shall be reset as shown on the Plans or as directed by the Engineer prior to implementing the Traffic Control Plan for commencing deck replacement work.

No traffic regulations, to include speed zones and no passing zones, may be imposed without authorization by the State Highway Administration.

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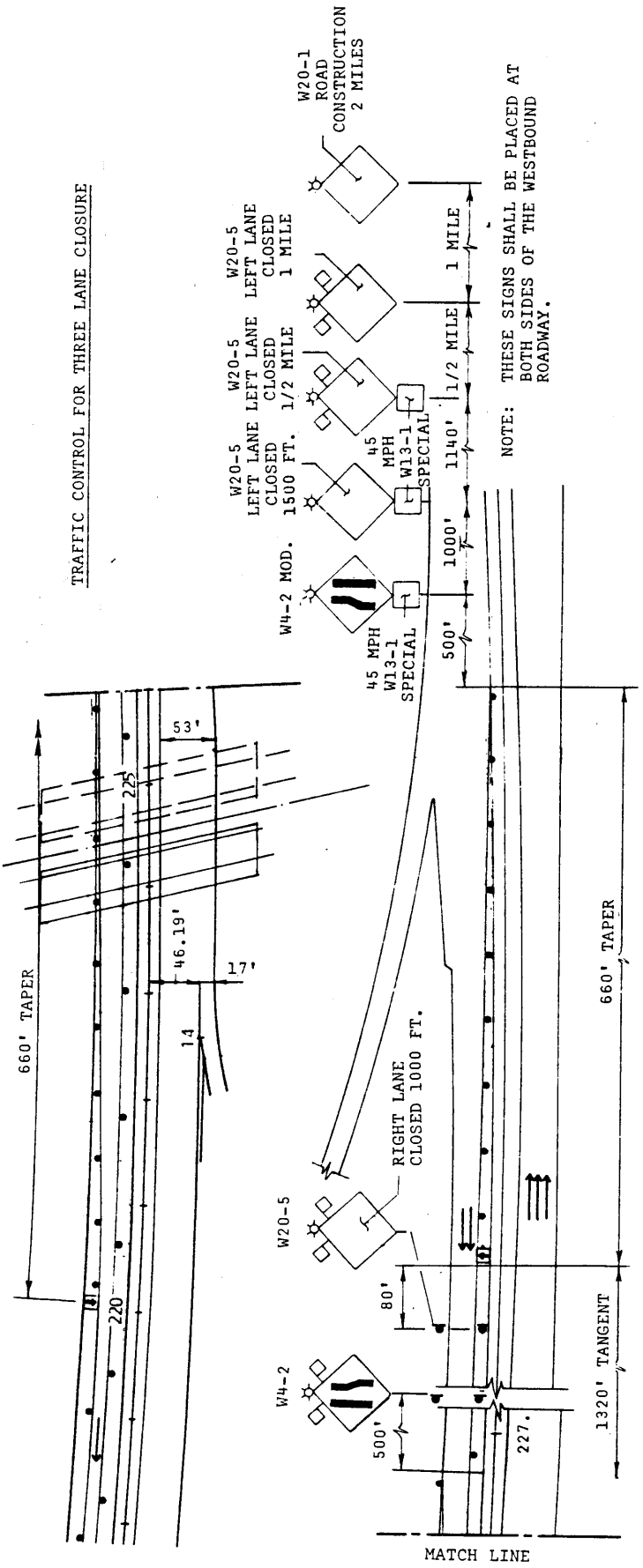
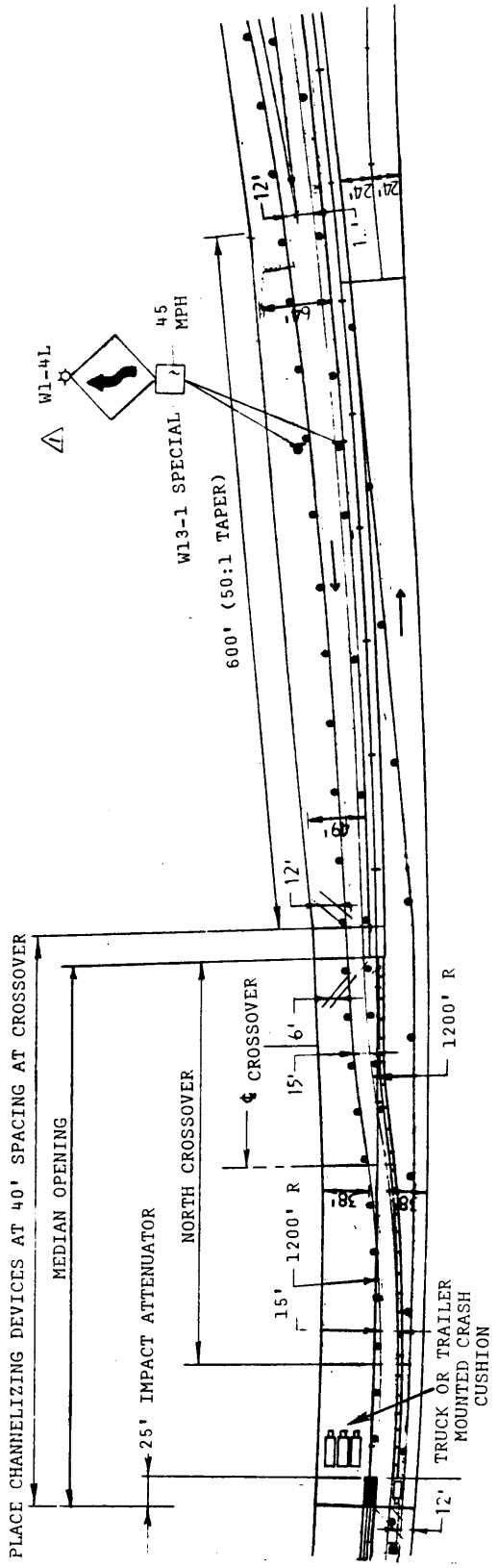
TRAFFIC CONTROL FOR THREE LANE CLOSURE



EASTBOUND CROSSOVER



MICHIGAN (DETROIT)

Reasons for Performing Work at Night

High traffic volumes cause daytime congestion and long delays. Also, the scope of work results in lower cost since the work can be done more efficiently.

Description of Project

Highway Type: 6-lane divided, limited access

ADT: 75,000-115,000

Type of Work: Concrete median barriers safety upgrading, lighting and signing and concrete joint repair, and concrete shoulders and sign maintenance

Project Length: 6.28 miles

Project Duration: Two seasons; however, most freeway closures confined to one season.

Cost: $3,868,831

SPECIAL PROVISIONS FOR MAINTAINING TRAFFIC

General

Traffic shall be maintained in accordance with Sections 1.04.05 and 6.31 of the 1976 Standard Specifications as herein specified.

Construction Influence Area (CIA)

The CIA shall include the right of way of M-39 and Southfield Road, including ramps, from three miles south of the P.O.B. to three miles north of the P.O.E. Also, the limits shall extend east and west of M-39 along I-96 and US-10 to include the signing as shown on the plans.

Traffic Restrictions

1. Median Barrier - Lane adjacent to the median may be closed in each direction in 12,000' increments for removing existing median, paving, and constructing the concrete barrier and glare screen. Only one increment may be closed at any time. No other lane closure shall be permitted while an increment of the median is under construction. At no time shall the clear opening between the end of the poured barrier and the end of existing guardrail exceed 10,000'.

2. Outside Shoulder Work - No outside shoulder work shall be started until the median work, including the lighting, is completed. During shoulder construction, one lane may be closed in either or both directions from 9:00 a.m. to 3:00 p.m., and 8:00 p.m. to 6:00 a.m. No two consecutive on or off ramps can be closed at the same time.

3. Freeway Closure for Joints or Pavement Repair - The freeway may be closed in one direction only from P.O.B. to P.O.E. between 8:00 p.m. Friday to 6:00 a.m. Monday. The contractor shall give the project engineer a minimum of three days' notice of plans to close the freeway.

4. Work Adjacent to Service Roads - One lane may be closed on service roads in the vicinity of the work area except during the time the service road is being used to detour traffic when the freeway is closed.

5. Drainage Correction Left of Station 459+ - It is anticipated that the southbound service drive will have to be closed to construct the 12" interceptor sewer and restore the area to its original condition. It will be required that this work be accomplished within one weekend from 8:00 p.m. Friday to 6:00 a.m. Monday. The contractor shall give the project engineer a minimum of three days' notice of plans to begin construction.

Traffic Control Devices

The contractor shall place all signs as indicated in the plans and proposal. In addition, when closing the freeway for joint and pavement repair, the contractor shall uncover those signs indicated in the plans and cover them when reopening the freeway. Covering and uncovering shall be included in Minor Traffic Devices.

Lighted Arrow Type A shall be used when closing traffic lanes and as directed by the engineer elsewhere. Barricades shall be Type II Lighted except where noted otherwise. Barricade spacing shall be 50' on

tapers and 100' on tangents. Spacing may be modified by the engineer to ensure proper traffic control.

All warning signs shall be 48" x 48" unless otherwise noted. All signs shall be portably mounted at 5' minimum bottom height unless noted otherwise in the plans or directed by the engineer.

All warning signs shall be equipped with two Type A warning lights and one orange flag.

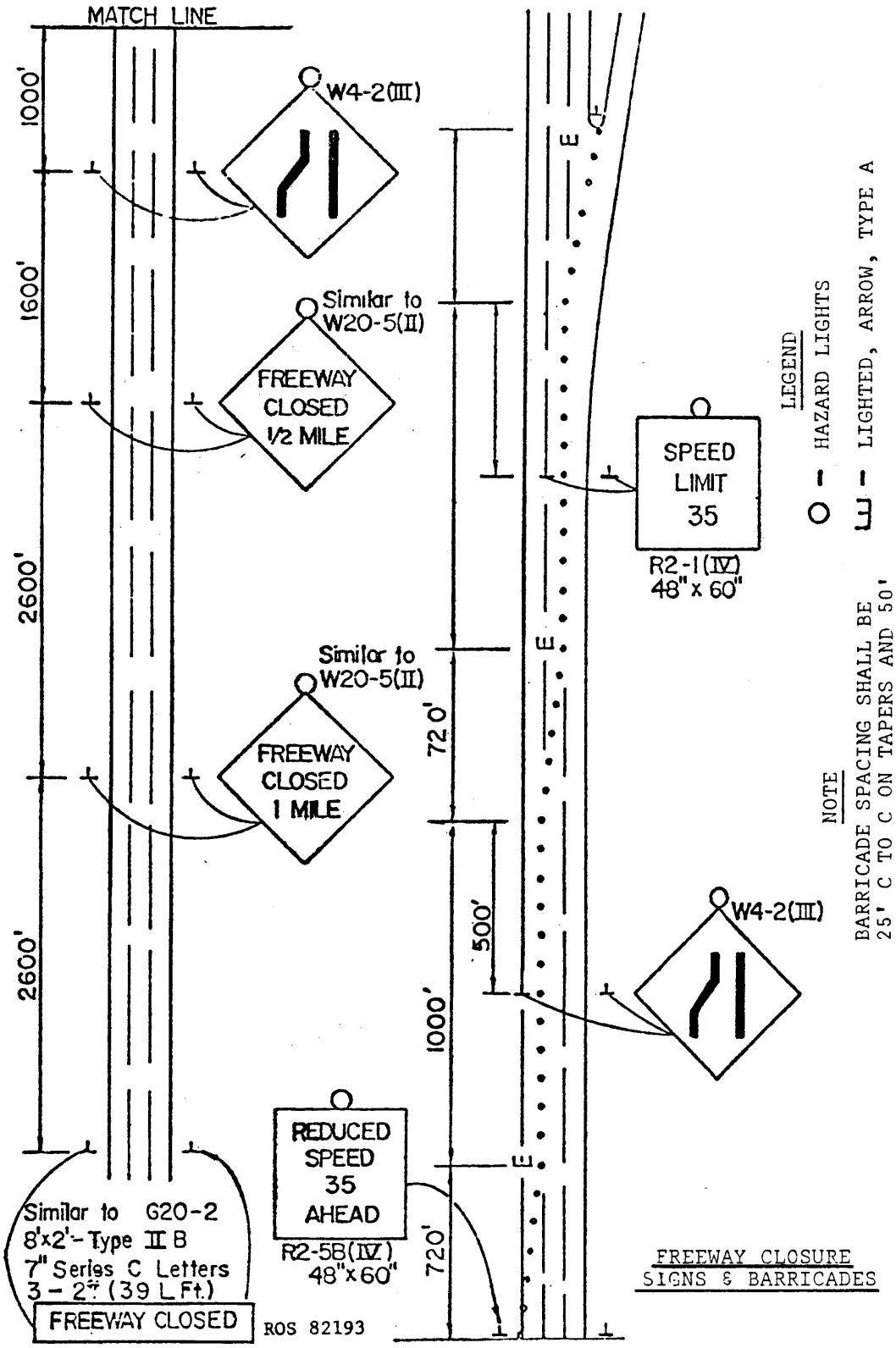
The contractor shall maintain all signing within the CIA.

The above special provisions are subject to change as directed by the engineer.

The contractor shall coordinate lane closures on this project with those on adjacent projects so that a minimum of two miles is kept between lane closures regardless of which project they are on.

The number of units for the bid items of Barricade Type II Lighted - Furnished, Barricade Type II Lighted - Operated and Barricade Type III have been increased over those shown on the plans. Plan quantities are estimated to be:

	Job No. 11231A	Job No. 11392A	Total
Barricade Type II Lighted - Furnished	925	175	1100 Each
Barricade Type II Lighted - Operated	590	110	700 Each
Barricade Type III		23	23 Each



FREEWAY CLOSURE
SIGNS & BARRICADES

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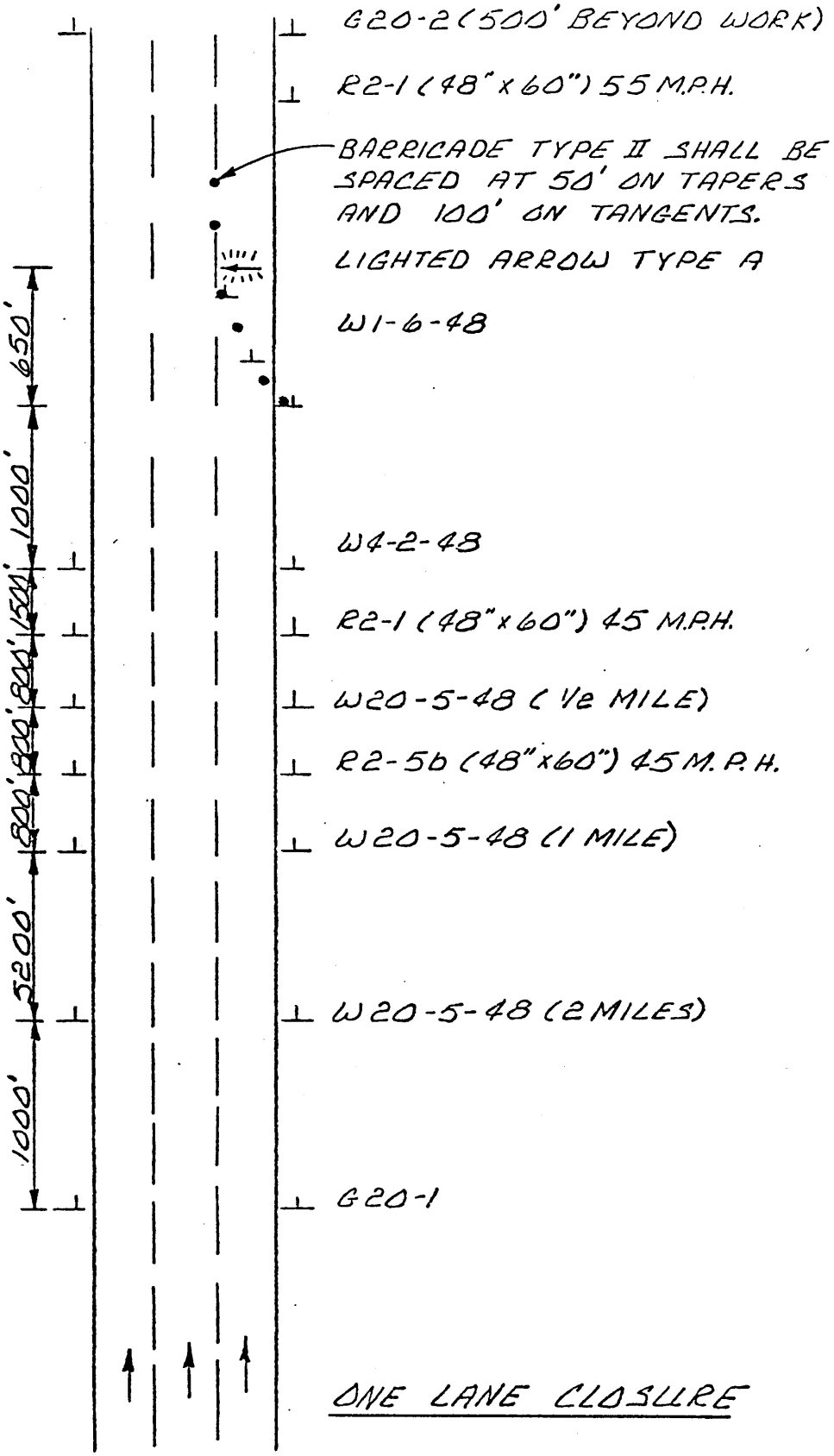

G20-2 (500' BEYOND WORK)
R2-1 (48"x60") 55 M.P.H.
BARRICADE TYPE II SHALL BE SPACED AT 50' ON TAPERS AND 100' ON TANGENTS.
LIGHTED ARROW TYPE A
W1-6-48
650'
1000'
W4-2-48
R2-1 (48"x60") 45 M.P.H.
W20-5-48 (1/2 MILE)
R2-5b (48"x60") 45 M.P.H.
W20-5-48 (1 MILE)
5200'
1000'
W20-5-48 (2 MILES)
G20-1
ONE LANE CLOSURE

NEW YORK

Reasons for Performing Work at Night

High daytime traffic volumes and the resulting delay and congestion when a lane or lanes are closed.

Description of Project

Highway Type: 6-lane, divided (limited access)

ADT: 150,000

Type of Work: Shoulder work, joint sealing, and repaving

Project Length: 9.26 miles

Project Duration: 4 months

Cost: Not available

GENERAL NOTES

1. The major portion of this contract is to be constructed at night during closure of the expressway. Refer to maintenance and protection of traffic details and notes, and the proposal for information.

2. Street and sign lighting shall be energized prior to opening ramp 'C' to traffic.

MAINTENANCE AND PROTECTION OF TRAFFIC NOTES

1. The expressway main line will be closed and work shall be performed during nighttime hours in accordance with the special note in the proposal.

2. Maintenance and protection of traffic schemes are to be in accordance with the plans, the New York State Manual of Uniform Traffic Control Devices, and figures of Appendix 7 as ordered by the engineer.

3. The contractor may submit revisions to the maintenance and protection of traffic plan for approval, but any change that alters the basic concepts of the plan must be approved by the regional director or his designee.

4. Where signs are shown in both diamond and rectangular shapes, only diamond shapes will be permitted despite other indications in the MUTCD.

5. All signs used on the expressway shall be the largest size available in accordance with the MUTCD.

6. Advance lane closing signs shall be located as ordered by the engineer in advance of any potential back-up that may occur as a result of closures.

7. Any existing signs which in the opinion of the engineer would cause confusion to motorists shall be covered with an opaque material.

8. In addition to the devices shown in various schemes, a truck is to be parked at the beginning of the work area for all schemes involving lane closures during daytime operations. The truck is to be positioned to offer workmen added protection in the event of vehicle penetration of the advance signs, cones, etc. The cost of this work is to be included under Item 619-91.

9. In addition to the signing required in the Manual of Uniform Traffic Control Devices, the contractor shall use a flashing arrowboard, for all main line travel lane closings and shall position it at the head of the work area.

10. The contractor shall provide a flagman where sight distances are impaired by his operation or as ordered by the engineer.

11. The contractor shall use Type B high intensity yellow flashing beacons conforming to the New York State Manual of Uniform Traffic Control Devices, as amended by authorization 74-6. Unless otherwise indicated on the plans, each beacon shall be mounted on an approved tripod assembly so as to be displayed at a height of 8' above the pavement surface.

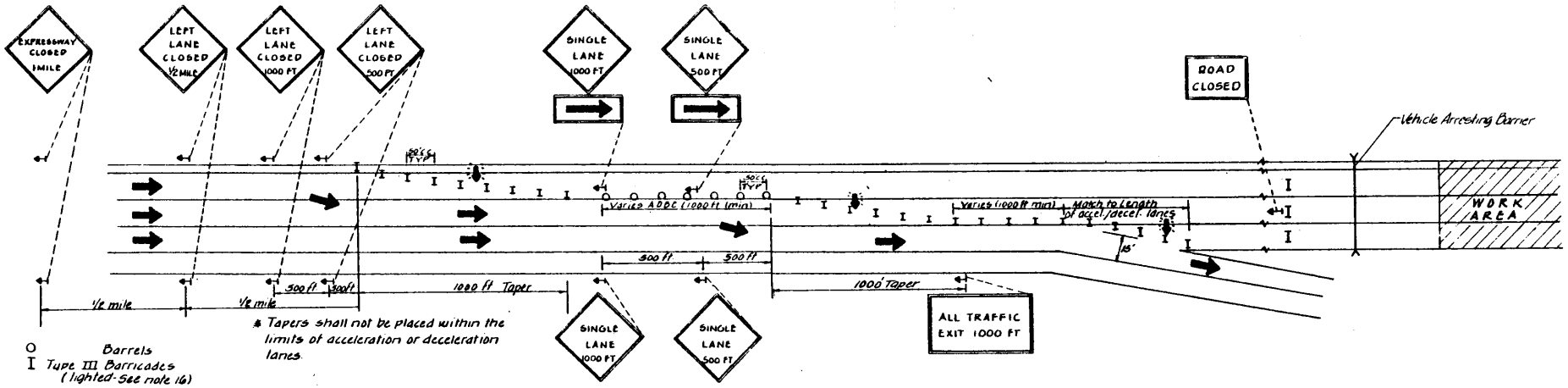
12. The lighting to be installed and operated in the contract shall be Type C - Steady Burn Barricade Warning Lights in conformance with the Institute of Transportation Engineers' "Standard for Flashing and Steady Burn Barricade Warning Lights" (1971), except as specified in the New York State Manual of Uniform Traffic Control Devices. The electric power shall be supplied by batteries, portable generators, or commercial power.

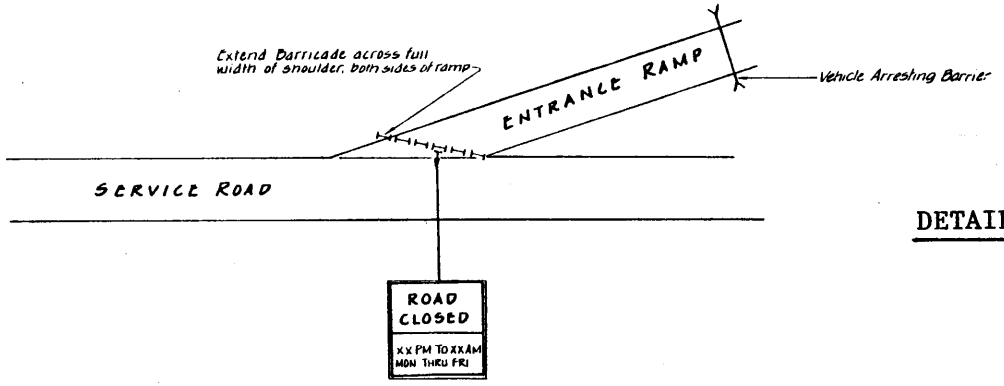
13. When the expressway is closed at night, vehicle arresting barriers shall be installed at each end of the work area in each direction and across all entering ramps within the work area. A uniformed security guard equipped with a two-way radio shall attend each vehicle arresting barrier for the entire period it is in place.

The engineer in charge and each of the contractor's and subcontractor's work crews shall be equipped with radios having sufficient range to reach all points in the closed section of the expressway and they shall be used to warn the work crews if any unauthorized vehicle enters the closed section of the expressway. No work may proceed until the vehicle arresting barriers and uniformed security guards are in place.

14. The contractor shall be required to continuously patrol all detour routes when in use to ensure that all signs, barricades, delineators, markers, signals, and other traffic control devices are erected in position and in good working condition and that the traveled way is in a safe and reasonable condition. All corrective work necessary shall be performed as soon as the need arises.

DETAIL OF MAIN LINE CLOSURE





DETAIL OF RAMP CLOSURE

TEXAS

Reasons for Performing Work at Night

Excessive delay and congestion if lanes closed during the daytime.

Description of Project

Highway Type:	4-lane divided freeway
ADT:	142,000 - 176,000 (1983)
Type of Work:	Removal and replacement of concrete pavement
Project Length:	13.8 miles
Project Duration:	February 1, 1983 - May 22, 1984
Cost:	Approximately $3,000,000 (bid)

DESCRIPTION OF PROJECT, SCOPE OF CONTRACT AND SEQUENCE OF WORK

DESCRIPTION OF PROJECT

The work to be performed on this contract consists of repairing damaged portland cement concrete pavement on I-610, removing and replacing faulted roadway concrete pavement at the bridge ends of four structures on I-610, removing asphalt overlay on the four structures, planing and texturing the surface of the I-610 (South Loop) bridge over SH 288, removing and replacing a section of asphalt overlay on I-610 (South Loop), and placing a thin concrete overlay test section on I-610 (South Loop).

SCOPE OF CONTRACT

General

Damage to the concrete pavement on I-610 (South Loop) and I-610 (West Loop) consists of cracks, spalls, punchouts, blow-ups,

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longitudinal lane joint separations and longitudinal lane-shoulder joint separations. Damage to concrete bridge decks consists primarily of spalling at joints. Longitudinal pavement cracks shall be repaired by routing out the cracks and filling with polymer concrete and/or silicone joint seal. Spalled areas shall be repaired by cleaning and filling with quick setting concrete and polymer concrete. Blow-ups and punchouts shall be repaired by removing unsound concrete and reinforcing steel and placing new reinforcing steel and polymer concrete or quick setting concretes. Lane separations shall be repaired by cleaning the joint and filling with polymer concrete. Lane-shoulder separations will be repaired by saw cutting and cleaning the joint and filling with polymer concrete and rapid cure asphalt.

The roadway pavement at the bridge ends of the Fournace, Evergreen, Green Willow, and Crestmont structures shall be removed and replaced with portland cement concrete pavement. It is the intent of this contract that this work be done during the weekend. Two lanes of traffic will be maintained during the work period.

The I-610 (South Loop) bridge over SH 288 and a small section of roadway pavement on I-610 (South Loop) have been overlaid with asphaltic concrete. The profile of the bridge deck and roadway pavement shall be smoothed by milling or planing the surface. The asphaltic concrete on the Fournace, Evergreen, Green Willow, and Crestmont structures may be removed by other methods as approved by the Engineer.

Traveling Public

The safety and convenience of the traveling public passing through the project is an important function of this contract and shall be so regarded by the Contractor. All the work on this contract is along an existing freeway carrying large volumes of traffic and most of the work to be performed will require that certain lanes of traffic be closed in order to perform the work. Subject to the approval of the Engineer, freeway lanes serving traffic in opposing directions may be closed at the same time. The limits of freeway sections in which lane closings are to be accomplished shall be selected judiciously so as to minimize interference to traffic.

Unless otherwise directed by the Engineer, the Contractor will be required to perform the work during th times and at the locations outlined in the following schedules. The Engineer may direct that the schedules be adjusted as traffic conditions warrant. Also, the Engineer may direct that the schedules be adjusted if in his opinion events at the Astrodome and work by the Contractor pose a safety or traffic hazard or too much inconvenience to the traveling public. However, if emergency work or a major accident necessitates closing of freeway lanes in or adjacent to sections occupied by the Contractor, the Engineer may direct the Contractor to cease operations and remove his men, materials and equipment from the freeway until such emergency work is completed or the accident is cleared.

The Contractor's attention is directed to the plan sheet showing construction sequences and construction phases. These sheets show in detail such measures as are deemed necessary to handle traffic during the construction of this project. At least 7 days prior to closing sections of IH 610 and entrance ramps thereto, the Contractor shall post signs showing the date such facilities are to be closed. Signs shall be erected at those locations indicated in the plans, or as directed by the Engineer.

SCHEDULES SHOWING INTERVALS DURING WHICH CERTAIN FREEWAY LANES MAY BE CLOSED*

LOCATION: I-610 NOTE: Basis used was 1500 VPH per lane.

BETWEEN	LANE CLOSURE	DAY OF WEEK MON-THUR	FRIDAY	SATURDAY	SUNDAY
Richmond to Bissonnet (S.B.) Sta. 222+93 - Sta. 742+00	1	12PM-6 AM 8 PM-12M	12PM-6 AM 9 PM-12M	12M-6 PM 9 PM-12M	All Day
	2	12M-6 AM 8 PM-12M	12M-6 AM 9 PM-12M	12M-9 AM 10PM-12M	12M-11 AM 7 PM-12M
Bissonnet to N. Braeswood (S.B.) Sta. 742+00 - Sta. 652+00	1	12M-6 AM 10AM-4PM 7 PM-12M	12M-6 AM 7 PM-12M	All Day	All Day
	2	12M-6 AM 8 PM-12M	12M-6 AM 9 PM-12M	12M-10AM 9 PM-12M	12M-12N 5 PM-12N
Willow Water Bayou to Buffalo Speedway (E.B.) Sta. 415+00 - Sta. 517+00	1	12M-6 AM 10AM-5PM 7 PM-12M	12M-6 AM 7 PM-12M	All Day	All Day
	2	12M-6 AM 8 PM-12M	12M-6 AM 9 PM-12M	12M-10AM 9 PM-12M	12M-12N 5 PM-12N
Buffalo Speedway to SH 288 (E.B.) Sta. 517+00 - Sta. 640+00	1	12M-6 AM 8 PM-12M	12M-6 AM 9 PM-12M	12M-6 AM 9 PM-12M	All Day
	2	12M-6 AM 8 PM-12M	12M-6 AM 9 PM-12M	12M-9 AM 10PM-12M	12M-11AM 7 PM-12M

*Partial Schedule

Complete freeway closure in one direction within the limits described below will be permitted from 12 Midnight to 6 AM Monday through Friday and from 4 AM to 12 Midnight Sunday.

@ Fournace (S.B.)
Sta. 780+00 - Sta. 765+00

Bellaire to Beechnut (S.B.)
Sta. 742+00 - Sta. 682+00

Stella Link (E.B.)
Sta. 450+)) - Sta. 474+00

Stella Link - Buffalo Speedway (E.B.)
Sta. 474+00 - Sta. 518+00

Buffalo Speedway to Astroworld Bridge (E.B.)
Sta. 518+00 - Sta. 569+00

@ Fannin (E.B.)
Sta. 569+00 - Sta. 586+00

Cullen to Calais (E.B.)
Sta. 720+00 - Sta. 818+00

Calais to Crestmont (E.B.)
Sta. 760+00 - Sta. 818+00

End job to Telephone (W.B.)
Sta. 941+00 - Sta. 908+00

Crestmont to Calais (W.B.)
Sta. 818+00 - Sta. 744+00

Fannin to Kirby (W.B.)
Sta. 586+00 - Sta. 540+00

On Sundays, the Contractor will be permitted to close two freeway main lanes in one direction all day for removing and replacing concrete pavement at bridge ends when complete freeway closure is not permitted.

Sequence of Work

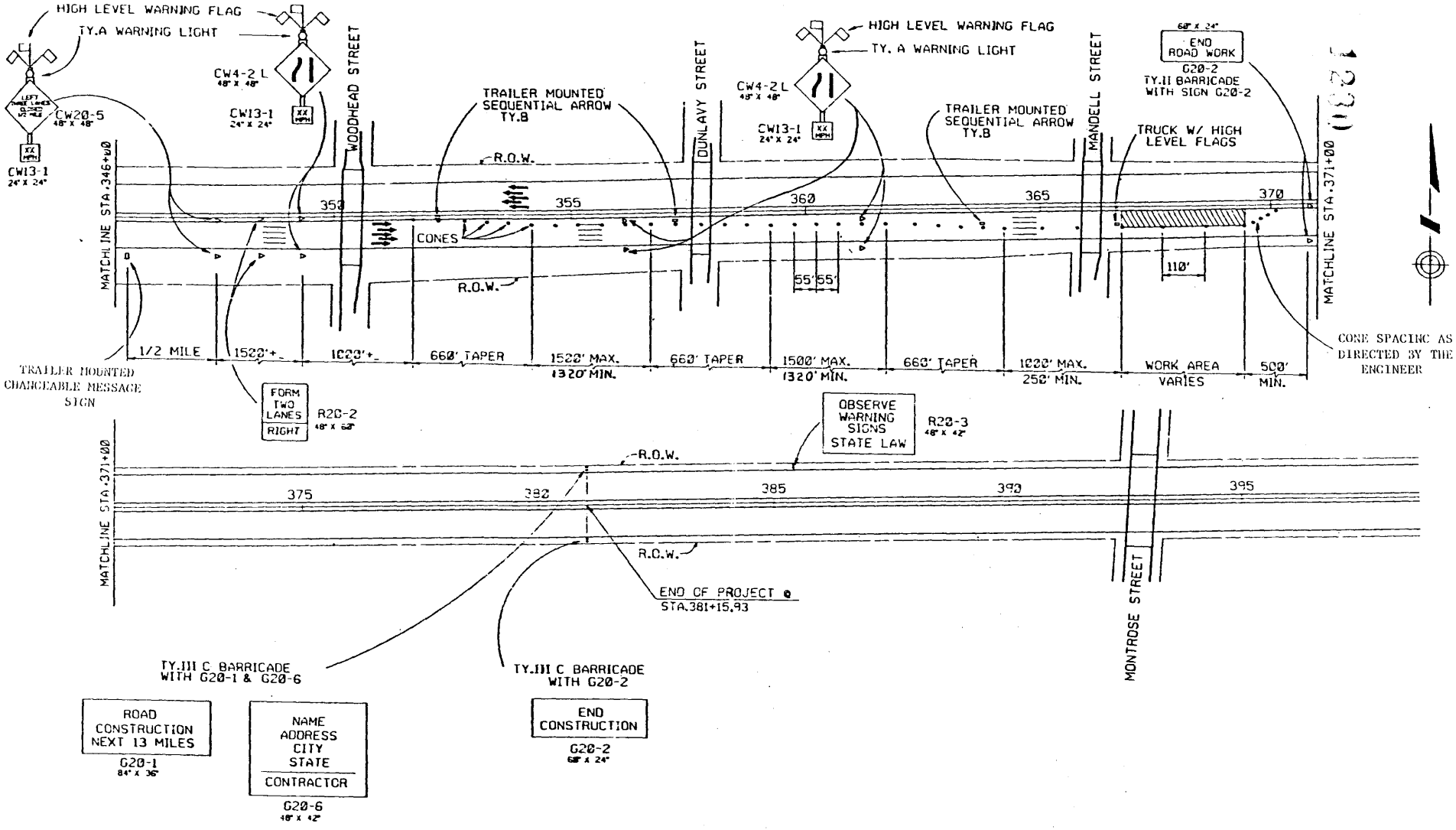
Immediately upon issuance of the work order by the State on the project, the Contractor shall submit to the Engineer, subject to the foregoing requirements, a proposed sequence of construction of the entire project. Upon approval of the Engineer, such sequence shall constitute the construction procedure of this project. No change will be permitted in the approved sequence except as approved by the Engineer in writing.

LEGAL RELATIONS AND RESPONSIBILITIES TO THE PUBLIC

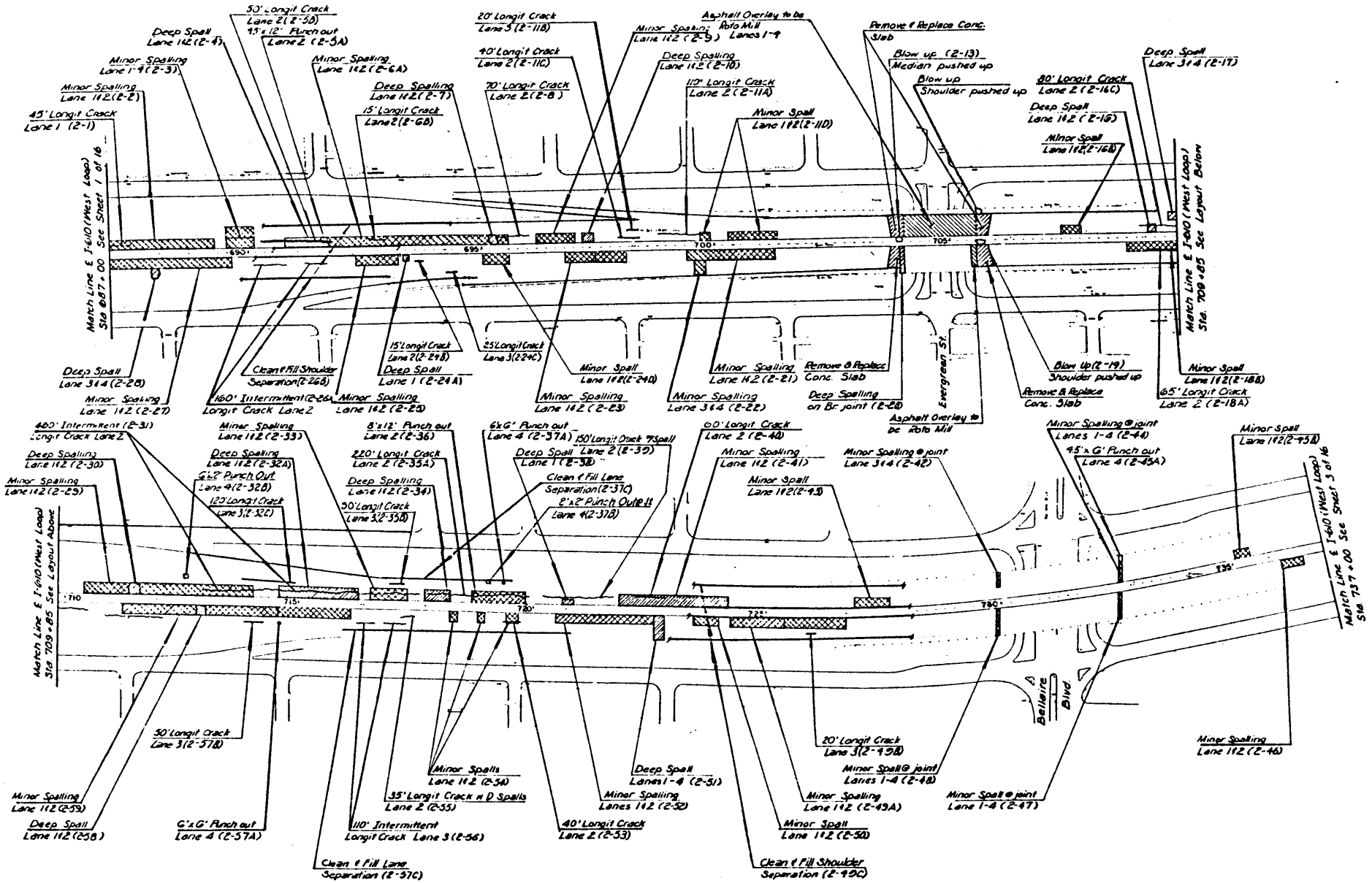
Barricades, Warning Signs and Other Traffic Control Devices for Construction Areas.

The Contractor shall provide, install, move, replace and maintain in a clean and good condition all barricades, signs, barriers, cones, lights, signals, and other such type devices as may be required by the item, "Barricades, Signs and Traffic Handling". Upon completion of the work, all barricades, signs, barriers, etc., and evidences thereof shall be removed by the Contractor.

Materials furnished and work performed under these provisions shall be measured and paid for in accordance with the pertinent bid items.



TRAFFIC CONTROL PLAN—THREE LANE CLOSURE ON MAIN LINE



SAMPLE OF PROPOSED ROAD REPAIRS

VIRGINIA

Reasons for Performing Work at Night

Traffic congestion and delay caused by daytime lane closures.

Description of Project

Highway Type:	Multilane Toll Road
ADT:	67,500
Type of Work:	Concrete pavement repairs
Project Length:	2.34 miles
Project Duration:	160 calendar days
Cost:	$422,000

PROPOSED CONCRETE REPAIR PROJECT
SUFFOLK DISTRICT
PR-5-83

ROUTE:	44 - Virginia Beach-Norfolk Expressway
FROM:	Independence Boulevard MP 3.48
TO:	Rosemont Road MP 5.82
LENGTH:	2.34 mi EBL & WBL (Including Ramps)
WIDTH:	36 ft. & VAR.
CITY:	Virginia Beach

1233

ITEMS	QUANTITIES	UNIT
Patching Cement Concrete Pavements (Type I)	2,481	yd^2
Pressure Relief Joint	1,072	lin ft
Clean and Reseal Longitudinal Joint	28,659	lin ft
Clean and Reseal Transverse Joint	11,572	lin ft
Shoulder Joint Seal	61,105	lin ft
1½" Preformed Joint Sealer	36	lin ft
1-5/8" Preformed Joint Sealer	418	lin ft
2" Preformed Joint Sealer	716	lin ft
3" Preformed Joint Sealer	156	lin ft
3½" Preformed Joint Sealer	24	lin ft
Modified Underdrain	100	lin ft
Bit. Conc. Type S-5	50	Ton
Maint. of Traffic Control Devices	3,000	HR.
Electronic Arrow	4,000	H.R.
Field Office Type II		L.S.
Mobilization		L.S.
Barricade Group 2	4,000	Day
Bit. Conc. Heat Stabilization	50	Unit
Warning Lights	4,000	Day

All work is to be performed within the existing right-of-way.

1234

VIRGINIA DEPARTMENT OF HIGHWAYS AND TRANSPORTATION
SPECIAL PROVISION FOR
PATCHING PORTLAND CEMENT CONCRETE PAVEMENT

August 2, 1983

Description

This work shall consist of removing designated areas of defective concrete pavement and unstable subbase material, replacing subbase material where required, and replacing pavement with high early strength portland cement concrete in accordance with this specification and in reasonably close conformity with the original lines and grades or as established by the Engineer.

Materials

Concrete for patching portland cement concrete pavement shall conform to Section 219 for Class A-3 paving concrete, except that the minimum compressive strength shall be at least 3,000 psi within 24 hours. The accelerated strength gain shall be accomplished by using 800 lb $\pm$ 50 lb/yd^3 of Type 111 cement conforming to AASHTO M-85 and approved air entraining, accelerating, and water reducing admixtures conforming to Section 217 of the Specifications. In the event calcium chloride is permitted as an accelerating admixture, it shall be limited to 2%. The air content shall be 6, $\pm$ 2%. The water/cement ratio shall not exceed 0.42 by weight.

The use of water reducing and accelerating admixtures which have not been tested for compatibility with the brand, type, source and quantity of cement proposed for use will not be permitted until such compatibility has been confirmed.

The Contractor shall submit mix design(s) prior to commencement of work. The Contractor shall also prepare sufficient trial batches in the presence of the Engineer to verify the strength and workability of the mix design. The continued adequacy of the mix design and minimum compressive strength will be verified monthly by the Engineer. All costs incurred due to adjustments of the concrete mix design and for trial batches shall be borne by the Contractor and no additional compensation will be made or allowed.

Subbase material shall conform to Section 209 of the Specifications.

Preformed bituminous joint filler shall conform to Section 213 of the Specifications.

Curing material shall conform to Section 223 of the Specifications.

Type S-5 bituminous concrete shall conform to Section 212 of the Specifications, except that material may be accepted by certification and visually inspected at the job site.

The Contractor shall be responsible for the quality of the concrete placed in any weather or atmospheric condition. Should a concrete mobile mixer be used for the production of concrete, the Contractor shall assume responsibility for the initial determination and all necessary subsequent adjustments in proportioning of materials used to produce the specified concrete. The Contractor shall arrange for Department personnel to be briefed on the mobile mixer design and concrete producing capabilities. Instructions shall be provided by a knowledgeable manufacturer's representative of the mobile mixer. The concrete mobile mixer shall be calibrated by the Contractor and approved by the Engineer prior to commencement of work.

SPECIAL PROVISION FOR
LIMITATIONS OF OPERATIONS AND MAINTENANCE OF TRAFFIC
PR-5-83

July 26, 1983

The Contractor shall conduct repair operations in such a manner that all lanes are open to traffic on Friday afternoons, Saturdays, Sundays, holidays and the day preceding holidays in accordance with the time period specified herein. Traffic shall not be restricted on the westbound lane between the hours of 5:00 A.M. and 10:00 A.M. or on the eastbound lane between the hours of 3:00 P.M. and 7:00 P.M. The Contractor shall maintain two (2) main line lanes of traffic open in either direction at all other times except when work is performed in the center lane, when it will be allowable as approved by the Engineer to close the center and left main line lanes between the hours of 7:00 P.M. and 5:00 A.M., and at least three (3) Toll Collection Lanes in each direction shall remain open during these times to accommodate traffic unless otherwise approved by the Engineer. Ramp traffic shall be maintained at all times. All restrictions to traffic shall be removed by 3:00 P.M. the day before holiday(s) and shall not be restricted again until the day after holiday(s). When a holiday falls on Monday, restrictions shall be removed by 3:00 P.M. the preceding Friday. When a holiday falls on a Friday, restrictions shall not be placed until the following Monday.

Work sites for this contract shall not exceed 1½ miles in length. The limits of the work area may be extended upon request by the Contractor provided the Contractor's operations do not adversely affect

traffic conditions as determined by the Engineer. The Contractor shall place and remove all traffic control signs, barricades, and channelizing devices as work progresses from one work site to another.

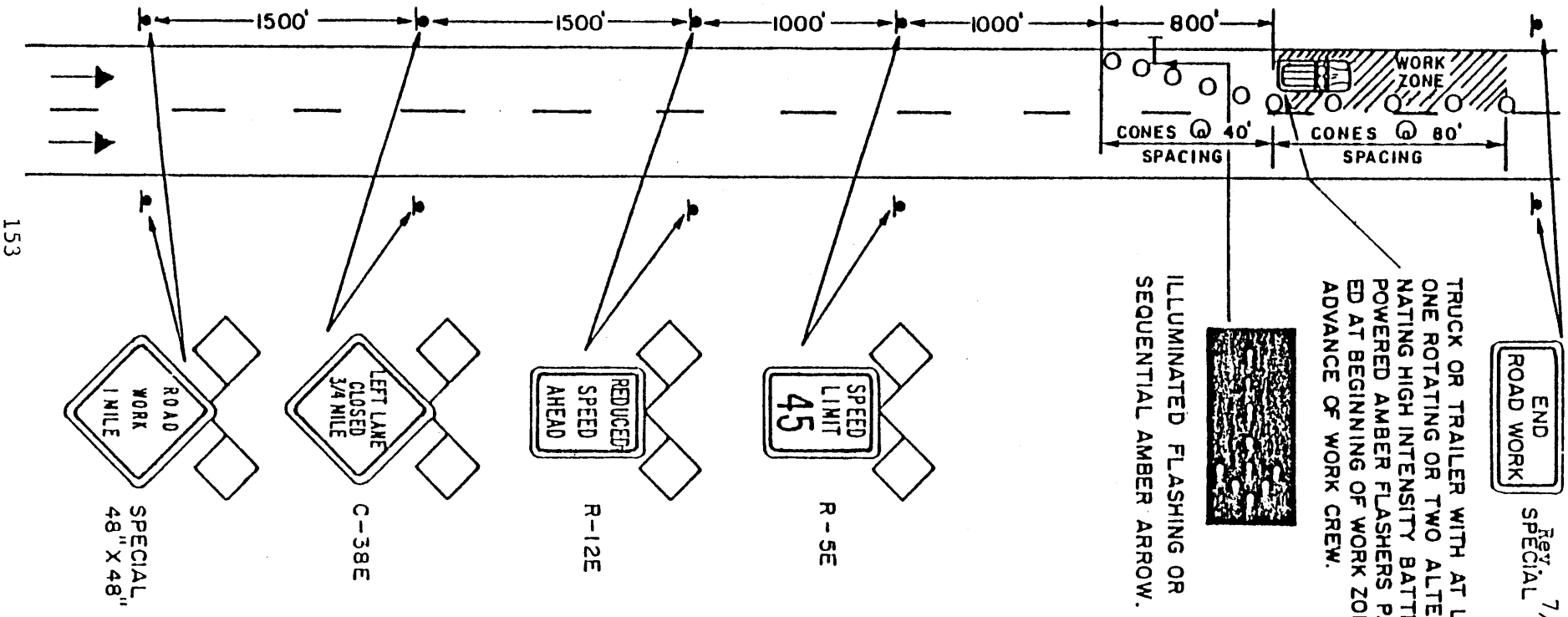
When night work is in progress, the Contractor shall provide sufficient lighting of the work site(s) to enable the satisfactory completion of the work. Lighting shall be arranged so as not to interfere with or impede traffic approaching the work site(s) from either direction. Lighting arrangements at the work site(s) shall provide a minimum of 50 foot candles of light for areas of approximately 15 feet by 15 feet with a minimum of 5 foot candles in the corners of the area. Lighting shall be from a minimum of 2 fixtures with back-up fixtures and power source readily available.

The Contractor shall provide a person whose primary responsibility shall be to continually inspect and maintain signs, barricades, other channelizing devices, and lights during the time that traffic is restricted due to construction operations. The Contractor shall provide a pickup truck or other suitable vehicle and all necessary cleaning equipment and replacement items. Maintenance of traffic control devices shall include keeping signs and lights clean and legible at all times.

Maintenance of traffic control devices will be measured in units of man hours for the actual time the Contractor is engaged in such work as required or approved by the Engineer.

Maintenance of traffic control devices will be paid for at the contract unit price per hour, which price shall be full compensation for furnishing necessary personnel, equipment and transportation, and for all materials, labor, tools, equipment and incidentals necessary to complete the work.

TYPICAL TRAFFIC CONTROL FOR REPAIRS TO PAVEMENT ON LIMITED ACCESS HIGHWAYS (WORKING IN INSIDE LANE)

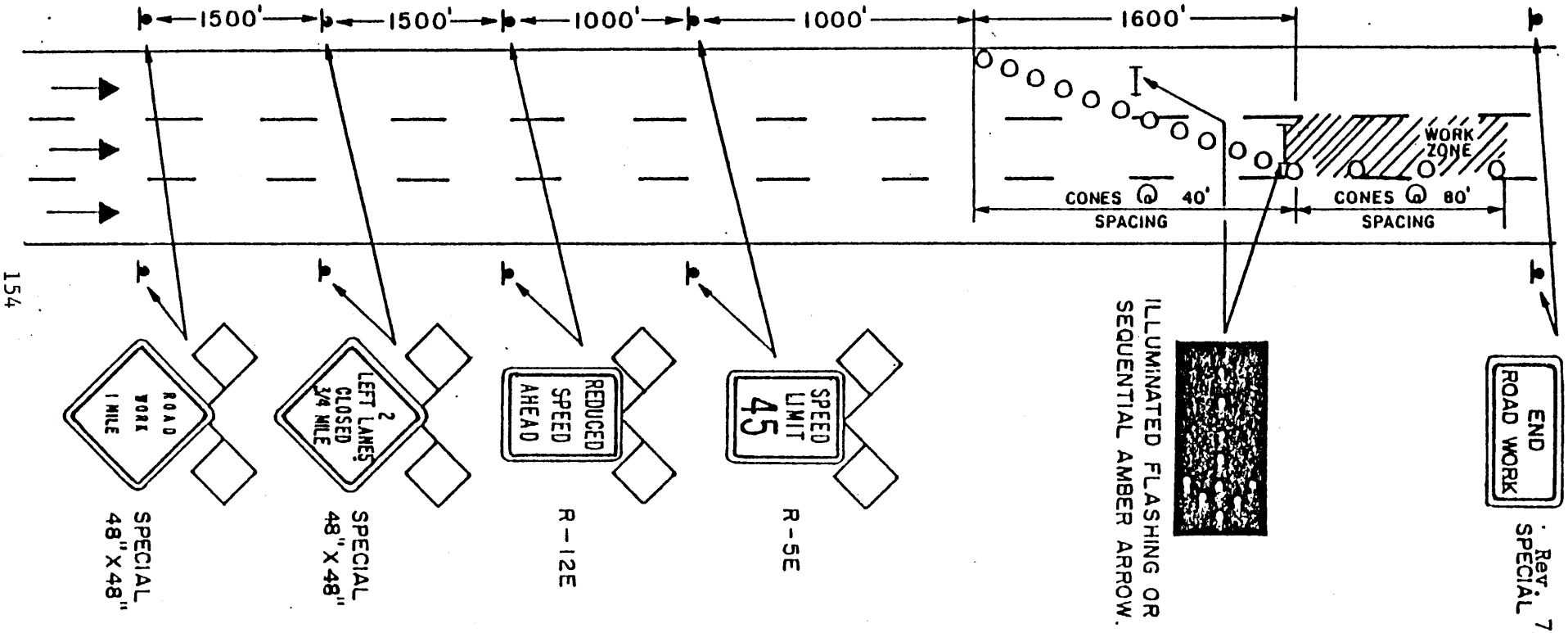


NOTES:

1. During hours of darkness, Type II Barricades with lights shall be used in the transition area.
2. During hours of darkness, warning lights will be required on State furnished signs.

Rev. 7/26/83

TYPICAL TRAFFIC CONTROL
FOR REPAIRS TO PAVEMENT
ON LIMITED ACCESS HIGHWAYS
(WORKING IN CENTER LANE)



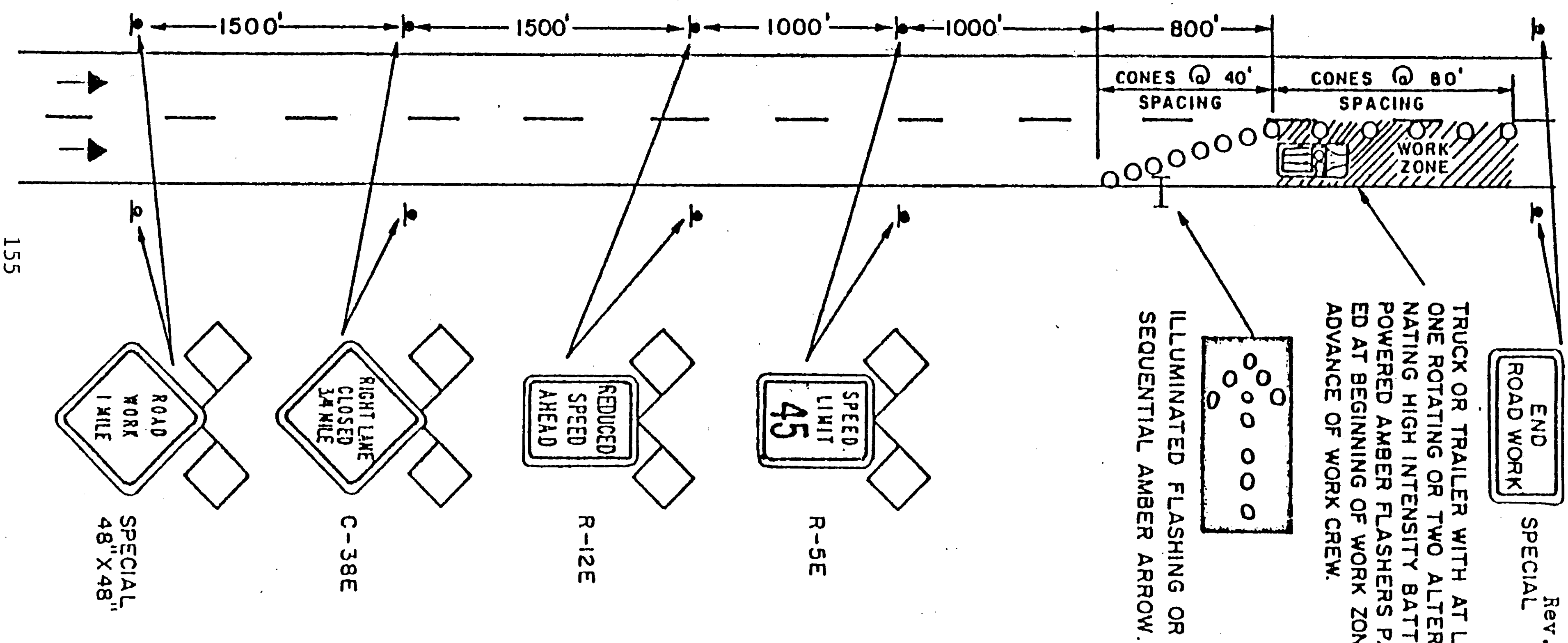
NOTES:

1. During hours of darkness, Type II Barricades with lights shall be used in the transition area.
2. During hours of darkness, warning lights will be required on State furnished signs.

Rev. 7/26/83

Rev. 7/26/83

TYPICAL TRAFFIC CONTROL FOR REPAIRS TO PAVEMENT ON LIMITED ACCESS HIGHWAYS (WORKING IN OUTSIDE LANE)



NOTES:

1. During hours of darkness, Type II Barricades with lights shall be used in the transition area.
2. During hours of darkness, warning lights will be required on State furnished signs.