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National Cooperative Highway Research Program

NCHRP Synthesis 208

Development and Implementation of Traffic Control Plans for Highway Work Zones

Transportation Research Board
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Synthesis of Highway Practice 208

Development and Implementation of Traffic Control Plans for Highway Work Zones

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PREFACE

A vast storehouse of information exists on nearly every subject of concern to highway administrators and engineers. Much of this information has resulted from both research and the successful application of solutions to the problems faced by practitioners in the daily work. Because previously there has been no systematic means for compiling such useful information and making it available to the entire community, the American Association of State Highway and Transportation Officials has, through the mechanism of the National Cooperative Highway Research Program, authorized the Transportation Research Board to undertake a continuing project to search out and to prepare documented reports on current practices in the subject areas of concern.

This synthesis series reports on various practices, making specific recommendations where appropriate but without the detailed directions usually found in handbooks or design manuals. Nonetheless, these documents can serve similar purposes, for each is a compendium of the best knowledge available on those measures found to be the most successful in resolving specific problems. The extent to which these reports are useful will be tempered by the user's knowledge and experience in the particular problem area.

FOREWORD

By Staff
Transportation Research Board

This synthesis report will be of interest to traffic control plan designers and administrators; highway engineers (traffic, safety, project, and resident construction); highway construction contractor personnel; and consultants, inspectors, and technicians involved with the design, implementation, and revision of highway work zone traffic control plans. Information on the state of the practice in traffic control plan (TCP) management methods is presented. The emphasis of the synthesis is on innovative and efficient methods that lead to safe traffic control in work zones.

Administrators, engineers, and researchers are continually faced with highway problems on which much information exists, either in the form of reports or in terms of undocumented experience and practice. Unfortunately, this information often is scattered and unevaluated and, as a consequence, in seeking solutions, full information on what has been learned about a problem frequently is not assembled. Costly research findings may go unused, valuable experience may be overlooked, and full consideration may not be given to available practices for solving or alleviating the problem. In an effort to correct this situation, a continuing NCHRP project, carried out by the Transportation Research Board as the research agency, has the objective of reporting on common highway problems and synthesizing available information. The synthesis reports from this endeavor constitute an NCHRP publication series in which various forms of relevant information are assembled into single, concise documents pertaining to specific highway problems or sets of closely related problems.

This report of the Transportation Research Board addresses aspects of efficient management of the four stages (predesign planning, design, implementation, and revision) of TCPs for different classes of highways and streets in both rural and urban environments. The synthesis also contains recommendations for an optimal TCP management process, based on the results of a project survey and literature review.

To develop this synthesis in a comprehensive manner and to ensure inclusion of significant knowledge, the Board analyzed available information assembled from numerous sources, including a large number of state highway and transportation departments.

A topic panel of experts in the subject area was established to guide the research in organizing and evaluating the collected data, and to review the final synthesis report.

This synthesis is an immediately useful document that records practices that were acceptable within the limitations of the knowledge available at the time of its preparation. As the processes of advancement continue, new knowledge can be expected to be added to that now at hand.

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The Principal Investigators responsible for the conduct of this synthesis were Sally D. Liff, Manager, Synthesis Studies, and Stephen F. Maher, Senior Program Officer. This synthesis was edited by Kathryn Harrington-Hughes.

Scott A. Sabol, Senior Program Officer, National Cooperative Highway Research Program, assisted the NCHRP 20-5 staff and the topic panel.

Information on current practice was provided by many highway and transportation agencies. Their cooperation and assistance were most helpful.

DEVELOPMENT AND IMPLEMENTATION OF TRAFFIC CONTROL PLANS FOR HIGHWAY WORK ZONES

SUMMARY

Construction and maintenance activities along a highway can disrupt traffic flow and pose safety hazards for motorists, pedestrians, and workers. A traffic control plan (TCP), described by *Federal-Aid Policy Guide* (Part 630J) as a plan for "...handling traffic through a specific highway or street work zone or project," is intended to minimize the effects of traffic disruption and hazard. A TCP may include traffic control strategies, construction staging requirements, specification of traffic control devices and geometric design features, determinations of staffing requirements, and other elements. The *Federal-Aid Policy Guide* (FAPG) specifies that TCPs should be developed for all federal-aid projects.

This synthesis reviews the process and procedures used in developing and implementing work zone TCPs. This planning has evolved over the past 20 years and relies on a wide variety of standards, warrants, and guidelines.

The synthesis is based on an extensive review of literature and two surveys of current state practices. The first survey included visits to six states in 1991. For the second survey, in 1992, the remaining 44 states were contacted by mail, and 36 states responded. Some 60 percent of the responses include specific guidance on TCP preparation in roadway design or other manuals. In most cases this guidance includes explicit policies on speed control and maximum allowable riding surface dropoff. State officials generally view TCP preparation as a multidisciplinary task that must involve expertise in traffic operations, highway design, and construction practices.

In most states, TCPs are prepared by special staff or a committee of agency and contractor personnel. Approximately one-half of the states report that TCP design work is generally done at the central-office level (e.g., state level). About one-third of states report that work is done at the district-office level. Consultants are sometimes employed to prepare the TCP or to supplement agency staff expertise.

Designers who regularly prepare TCPs develop specialized knowledge and skills. Some states specify that TCP designers should become familiar with the project site by making one or more site visits during TCP preparation.

The FAPG requires that a "responsible person" be designated to ensure conformance with safety standards; in most agencies the project engineer or resident engineer is responsible for traffic control. Some states require contractors to designate a responsible person to supervise work zone traffic safety and may require that this person be trained and certified as competent to do so. Most states review TCPs at both the district level and the state level.

State guidance materials for work zone traffic planning generally address four phases of TCP development: (1) predesign planning, (2) design, (3) implementation, and (4) revision. In predesign planning, decisions as to whether a project warrants a site-specific TCP and

which policies will be applied in TCP development (e.g., hours when traffic restriction is permitted, use of detours or temporary structures) are based on factors such as traffic volumes and project scale and likely duration. The design must specify a wide variety of details, such as placement of warning signs, traffic barriers, and traffic channelization devices; temporary pavement markings and pavement marking obliterations; and installation and operation of traffic control devices. Increasing concern over tort liability has heightened the importance of TCP implementation in many states, leading to an emphasis on clear assignments of responsibility and field inspections to ensure TCP compliance. A TCP may need to be revised in light of public complaints, work zone traffic accidents, or other factors that lead responsible staff to determine that change is warranted.

Many states report that TCP design work is performed primarily by relatively junior personnel, and only one-fifth of states require that TCP developers be degreed engineers. Three-quarters of the states report that TCPs are specially developed for at least one-half of their projects, but designers rely on the use of "typicals." Typicals are sets of standard or prototypical designs and specifications from which selections are made and tailored to suit local work zone conditions. The Federal Highway Administration's (FHWA's) 1993 *Manual on Uniform Traffic Control Devices* (MUTCD) includes 44 typicals, classified by work zone duration, location, and highway type. Many states have developed their own sets of typicals.

Some states report that innovative control strategies have been employed in recent TCPs for large reconstruction projects, including provision of alternate transportation modes, advance publicity to alert drivers to changed traffic patterns, and 24-hour project surveillance. Some states use a traffic control or project coordinator to enhance TCP effectiveness when several projects are closely spaced and located in a single corridor (to avoid, for example, contractors placing "End Construction" signs only a short distance from "Road Construction Ahead" signs for the next project). In some projects, permanent roadway features, such as bridge width, have been altered to facilitate traffic operations during construction.

TCP development practices vary from state to state, but the FHWA's 1989 *Work Zone Safety Report* indicates that overall work zone traffic control planning has improved as TCPs have been made more detailed and project specific. Nevertheless, states report that problems with work zone traffic control often stem from inadequate attention to site-related conditions. Over one-half of the states reported relying on memoranda and other interdepartmental communications as their primary means for incorporating into future TCP designs the knowledge gained from in-field TCP implementation. Design and avoidance of pavement edge dropoffs and determination of safe work zone traffic speeds are general problems that continue to receive attention from researchers and FHWA.

CHAPTER ONE

INTRODUCTION

TRAFFIC CONTROL PLAN

Historically, traffic control in work zones has been used to expedite traffic safely through work areas and to protect motorists, workers, and pedestrians. Part VI of the *Manual on Uniform Traffic Control Devices* (MUTCD), published by the Federal Highway Administration (FHWA) in 1993, sets forth basic principles and prescribes standards for work zone traffic control *(1)*. For situations not covered by the MUTCD, highway agencies have developed their own guidelines. Part 630J of the *Federal-Aid Policy Guide* (FAPG) *(2)* was issued to provide additional guidance and to establish procedures for ensuring that adequate consideration is given to safety in situations not addressed in the MUTCD. This guidance also served to provide for better uniformity in highway agency efforts.

The FAPG describes a traffic control plan (TCP) as a plan for "...handling traffic through a specific highway or street work zone or project." The TCP may include traffic control strategies, staging requirements, specific applications of traffic control devices for a particular work zone, and the geometric design of tapers, lane closures, and other work zone features. A TCP may range from a very detailed, specifically tailored set of plans for a certain project to a simple plan referencing standard plans or a section of the MUTCD. According to one expert, the degree of detail incorporated into the TCP depends on the project's complexity, the traffic needs, and the extent of traffic interference with construction activity *(3)*. The traffic control procedures must, however, be consistent with the standards and guidelines provided in the MUTCD.

REQUIREMENTS FOR TRAFFIC CONTROL PLANS

The FAPG requires that a TCP be developed and implemented for all federal-aid construction projects. The TCP is to be included in the plans, specifications, and estimates (PS&E) for each project. The FAPG, the MUTCD, and the *Traffic Control Devices Handbook (4)* further suggest that a TCP be implemented for every construction or maintenance project requiring some form of traffic control.

One of the most important requirements of an effective TCP is that there be someone on the construction project whose foremost concern is traffic control. The FAPG requires that a "responsible person" be appointed to ensure conformance with safety standards. This person's primary duty is to ensure that the TCP and other safety aspects of the contract are adequately executed.

In the past, the importance of safety considerations in temporary traffic control was often overlooked. In both the design phase and the predesign phase, TCP concerns were often overshadowed by concerns over costlier items, such as bridge construction. The benefits of funding traffic control efforts were not always realized. To gain traffic control safety benefits, installation and maintenance of traffic control devices should be included as unit pay items in the PS&E for the project. The FAPG states that "payment for traffic control items as incidental to other items of work should be discouraged." Unit pay items not only force designers to consider specific traffic control requirements, but they also accommodate necessary changes in the number of devices needed and help ensure traffic control is properly maintained throughout the life of the project by providing appropriate compensation to the contractor.

Because contractors have practical experience in the area of traffic control, the FAPG and most states allow contractors to develop their own TCPs. TCPs for federal-aid projects must, however, be approved by the highway agency and FHWA, both of which must agree that the contractor's plans are as good as or better than the plans provided in the PS&E.

The FAPG requires that each highway agency implement a program to review randomly selected projects so as to assess the effectiveness of its procedures on an annual basis. The reviews are to be conducted by a team of appropriate personnel from the highway agency, with an optional representative from FHWA. Accident data are frequently collected and analyzed and then used for evaluating and revising the agency's traffic control policies and plans. However, the FAPG does not provide for standardization of the type of work zone accident data collected, and the data analysis is limited by a lack of information on accident exposure.

OVERVIEW OF MANAGEMENT PROCESS

Surveys concerning the development and implementation of TCPs in states have identified four important elements of TCP management, which are steps or phases that, ideally, ensure efficiency. Not all of these phases are applied in every state, however. The four phases, listed in the order in which they should occur, are as follows:

- Predesign planning
- Design
- Implementation
- Revision.

Predesign Planning

The predesign planning phase addresses the activities that occur prior to actual design and installation of TCPs in the field. A highway agency must decide first on its overall policy concerning TCPs—e.g., when TCPS are warranted, which departments or individuals will do the design, who will be appointed as the responsible person, how typical traffic control drawings will be used in the design, and how TCPs are to be designed for maintenance and utility work zones.

After the policy is set, each project must be assessed to determine if it warrants a specially designed TCP (based on previous policy), if a typical drawing fits the work zone situation, if the project must be given special attention, and so forth. This process is often accomplished through a predesign or scoping meeting of personnel from a variety of departments, thus ensuring that all aspects critical to traffic control are considered.

Design

During the design phase, the TCP is designed by the departments or individuals specified by the highway agency's policy. In this phase, a good TCP designer will collect and collate data for the project. Some states require designers to make at least one site visit during design. The designer will then use the data, along with whatever suggestions or comments that may arise during the predesign phase, to integrate all concerns into a safe, effective TCP for motorists and workers.

The scope of the design task will vary by highway agency. At some highway agencies, much may be done during the predesign phase up to the point of deciding which typical drawings to use and determining how construction staging and other factors will affect the plan. For difficult or unusual projects, many critical aspects of TCP design may be decided in the predesign meetings. Resolving traffic control problems and controlling their impact on other aspects of the work identified during these meetings may go a long way toward producing a usable TCP. At other agencies, a TCP designer may make all decisions such as whether a typical drawing applies and, if not, whether a new design is needed or an old TCP can be revised to accommodate the new situation.

Determining the traffic capacity of the work zone roadway is critical to the design phase. Maintenance and utility operations may be limited to certain hours, based on capacity constraints. Hours that lane closures are permitted may be specified for construction and other long-term projects.

Implementation

The implementation phase addresses the installation of the plan and the procedures that must be followed to ensure the plan's effectiveness. These procedures may include a variety of endeavors, such as a policy of site visits or management of field inspections of TCPs (e.g., how are inspections to be performed, and by whom, and how will the resulting data be gathered, cataloged, and used).

Revision

The revision phase addresses the feedback procedures used to make changes to TCPs, including obtaining data (e.g., data gathered through field inspections conducted in the implementation phase) for revising a TCP currently in use. The revision phase also involves any TCP changes required for safety reasons. TCP management structures must also implement policies for revising the agency's typical traffic control layouts or drawings. Revisions are required when a layout or drawing becomes outdated by new technologies or when an improvement to an existing design is conceived for efficiency or safety reasons. Because typical drawings are used in a large portion of the overall design procedure, a policy evaluating the effectiveness of TCPs designed using those drawings is a vital part of the revision process.

FHWA annually reviews states' efforts in implementing the FAPG. The *FY 1989 Annual Work Zone Traffic Safety Report* is based on information from 49 states and the FHWA division and regional offices *(5)*. According to the report, 39 states conduct training for work zone personnel. Review teams function in 45 states. The number and depth of FHWA and state project inspections have increased. Twenty-eight states have public relations and information campaigns. States' standards, drawings, specifications, and policies regarding, for example, arrow panels and edge dropoffs are being reviewed and improved. Traffic control for utility and maintenance operations was rated poor to fair, leading several states to develop training programs, manuals, and enforcement efforts.

PURPOSE OF SYNTHESIS

The purpose of this synthesis is to describe the state of the practice in TCP management methods. It describes what TCP designers regard as superior TCP design approaches for different classes of highways and streets in both rural and urban environments. Aspects of efficient management of the four stages of TCP development are addressed.

This synthesis reports on the current techniques for designing and implementing TCPs, based on two surveys of state highway agencies. In the first survey, six states—California, Florida, Iowa, New Mexico, Pennsylvania, and Texas—were visited to determine the personnel and procedures involved at each stage of the TCP development process.

In the second survey, state traffic engineers in the remaining 44 states were sent a questionnaire; 36 (82 percent) surveys were returned. The survey form and results are presented in Appendix A. The respondents also furnished manuals, policies, and directives dealing with the development and implementation of TCPs.

In addition, the current literature relating to TCPs was reviewed.

This synthesis reports on how states are currently performing the TCP management process, from predesign planning to revision. Although some policies and procedures do not completely follow the recommendations of federal standards and guidelines, this synthesis emphasizes innovative and efficient methods for safe traffic control in work zones.

The state surveys revealed a wealth of manuals, policies, and guidelines associated with developing and implementing TCPs. The states furnished more data than could be presented in this synthesis, although some policies are quoted verbatim as examples of common practice. The manuals and policy memos referenced in this report are listed in Appendix B.

The surveys revealed that many states use consultants to prepare TCPs. The process that the Michigan Department of Transportation developed for preparing and reviewing TCPs is shown in Appendix C. A maintenance work zone policy from the Wisconsin Department of Transportation is shown in Appendix D. Information from a TCP used by the Arizona Department of Transportation is contained in Appendix E.

The procedures that seem to be the most effective are identified in this synthesis. This synthesis also contains recommendations for an optimal TCP management process, based on results of the project survey and the literature review.

CHAPTER TWO

PREDESIGN PLANNING

There are two important aspects to the presdesign planning phase. First, administrative decisions must be made concerning policies related to TCP development. The policies address what projects will require specific TCPs, who will design the TCP, speed control policies, dropoff policies, inspection schedules, and use of typical plans.

Second, for each project, a determination must be made as to whether a site-specific TCP is warranted, which "typicals" fit the project, and what special measures, such as enforcement patrols or public information campaigns, might be needed. Typicals are prototypical control plans, designs, design details, standards, and operational procedures that may be adapted to a specific work zone.

Slightly more than one-half (58 percent) of the states responding to the second survey reported having a section on TCPs in their design guide. An almost equal number (55 percent) of states have a section on TCPs in their construction or maintenance traffic control manual.

According to the survey respondents, the design process usually begins with the design and traffic engineering phases. Twenty-eight of the 35 (80 percent) responding states reported that traffic control is usually considered at the same time as other aspects of the project design. For intermediate-term, short-term, short-duration, and mobile projects, there were two major responses: (1) 11 of 29 (38 percent) responding states said there was no difference based on project duration and (2) 11 states (38 percent) said that typicals are more frequently used for these shorter term projects. Three of the 29 (10 percent) said they begin designing TCPs sooner for complex projects.

Even though typicals are used more for intermediate term and short duration projects, 35 of 36 (97 percent) responding states reported that TCPs are sometimes designed specifically for these projects.

Both parts of the planning phase require committee or group efforts. In Iowa, a traffic safety committee decides which work zone traffic control policies will be used, including design and modification of typical TCPs, called road standard plans. The committee includes the specifications engineer and representatives from the Offices of Construction, Road Design, and Maintenance; the Bureau of Safety; the district; and FHWA. The traffic safety committee develops the layouts, which are then presented to the Specifications Committee for approval. The Specifications Committee consists of all major central office administrators from the highway division of the department of transportation (DOT).

The degree of detail in an Iowa TCP is determined by a preliminary traffic control committee. This committee meets monthly and reviews and recommends special provisions for each upcoming construction project. The committee includes representatives from FHWA, the Iowa State Patrol, and the DOT's construction, road design, and transportation safety divisions.

Most states initiate the planning phase with scoping or planning meetings attended by representatives from several departments. This ensures that diverse interests are represented and that all factors critical to the design of a TCP are considered.

POLICIES

To promote consistency in traffic control efforts, policies should be developed for common work zone situations (e.g., reduced work zone speed limits). The first survey found policies for determining which projects require TCPs and which office is responsible for TCP design, as well as traffic control strategy selection, maintenance work zones, edge dropoffs, speed control, and predesign meetings.

Projects Requiring Traffic Control Plans

Most states now require TCPs for all projects, regardless of whether a project receives federal-aid funds. The following excerpt is from the California Department of Transportation (Caltrans) *Highway Design Manual (6)*:

> TCPs must be developed for all projects to assure that adequate consideration is given to the safety and convenience of motorists, pedestrians, and workers during construction.
>
> Design plans and specifications must be carefully analyzed in conjunction with traffic, construction, and structure personnel (where applicable) to determine in detail the measures required to warn and guide motorists through the project during the various stages of work.

In addition, Caltrans specifies traffic management plans (TMPs) according to the following policy *(7)*:

> A. TMPs shall be required for *all* reconstruction, rehabilitation, and other projects if significant construction delays are anticipated, including projects not funded by the state.
>
> B. When a series of proposed projects are along the same corridor or along corridors of close proximity, a single TMP covering all projects should be used. If circumstances prohibit a single TMP, individual TMPs should be coordinated.

The first survey found that Pennsylvania, Iowa, Texas, Florida, and New Mexico also require TCPs for all projects. In the second survey, 19 of 36 (53 percent) responding states said that TCPs were specifically designed for more than 75 percent of their projects.

The most difficult, but essential, part of the process is identifying those projects that require specifically designed TCPs. Because TCP development is labor intensive, requiring highly trained personnel, designing a new TCP, instead of adopting the format of a previous design, can be very expensive.

The second survey also asked, "What factors most often determine that a TCP will require a large amount of effort?" The factors most frequently cited were traffic volumes and speeds; complexity and impact on traffic; type, location, and duration of work; and type of facility (see Appendix A).

Where Traffic Control Plans Are Designed

An important administrative or policy decision that must be made is at what level of state government should the TCP be designed. In the past, TCPs have been designed in the central office, in the district office, or in the resident engineer's office. Now, however, there is a trend toward designing TCPs by a special staff or committee.

State agencies are finding that TCP development can be a very difficult task, requiring extensive knowledge and expertise. A TCP designer has to consider a number of complicated issues associated with the safe, effective design of a construction project. By calling on the knowledge and expertise of a committee or staff, rather than a lone designer, there is less chance of overlooking an important element in a complex TCP.

When asked in which office TCP designs were done, 27 respondents (47 percent) said "central office," 18 (32 percent) said "district office," 4 (7 percent) said "local office," and 8 (14 percent) said "other." Apparently, TCPs are designed in both central and district offices in some states. The most common "other" response was consultants' offices.

One problem that sometimes arises when TCPs are designed in a central office or by a consultant is that the designers are removed from the work zone they are designing. TCP designers may become detached, uninterested observers of the actual workings of the traffic control strategy being designed. Although designers at the district office are closer to the project and should be more familiar with it, they may still miss critical site-specific points. Review and input by local-level personnel (e.g., the resident engineer) is critical to the design of effective TCPs. After all, local-level personnel will be responsible for implementing the TCP and they must therefore understand and agree with the logic of the plan.

Hands-on involvement of the TCP designer can be accomplished through a policy of mandatory field visits to the site before and during the design phase and shortly after the TCP is installed. Additional post-installation visits will provide the TCP designer with insight into what strategies are effective in particular situations and any problems the TCP may be causing.

Dudek and Richards note that locally prepared TCPs may result in problems with statewide uniformity in traffic control *(8)*. They recommend that a set of typical TCPs be distributed throughout the state. These TCPs must be specific enough for direct implementation at the local level, or they will not be used, and they should address a large variety of reconstruction projects and traffic control situations. In addition, coordination among TCP designers for adjacent or overlapping projects is more difficult to achieve at the local level and provisions must be made to accommodate these situations.

Regardless of where the TCP is developed, a team approach is recommended. The TCP must be designed in accordance with statewide policies, while reflecting local conditions.

Traffic Control Strategy Selection

The TCP designer will normally consider a number of factors in deciding which traffic control strategy to use. These factors usually include cost, disruption to traffic, duration, traffic delay, and ease of construction. The FHWA report *Planning and Scheduling Work Zone Traffic Control* contains a procedure for determining the most beneficial strategy *(9)*.

The TCP designer usually determines the proper traffic control strategy. However, the Pennsylvania DOT *Work Zone Traffic Control Operations Manual* presents guidelines on the use of detours versus maintaining through traffic for bridge construction projects *(10)*. The section on bridge construction reads as follows:

> Because of comments from the public, business community, and the media on not maintaining traffic in the proximity of existing bridges while the bridge is closed for major rehabilitation or replacement, the Department reviewed the maintenance and protection of traffic on bridge construction projects. The review indicated that even though project cost was the major reason for specifying detours, other items such as ADT (average daily traffic) truck traffic, impact on local economy and emergency services, environmental impact, and ease of getting the needed right-of-way for a temporary crossing should be considered prior to specifying detours. The options for maintenance of traffic for bridge projects are to be evaluated during the preliminary studies and/or environmental studies stage. Adequate public coordination should also be performed to minimize adverse impacts.
>
> Additional guidelines for the maintenance and protection of traffic were developed. The guidelines indicate that generally the selection of maintenance and protection of traffic should be based on the following hierarchy of options:
>
> - Detour
> - Half-width construction
> - New bridge adjoining the existing bridge
> - Temporary crossing/bridge and approaches
>
> *Detour*—Consider a detour if any of the following apply:
>
> (i) Emergency conditions require closing of the bridge
>
> (ii) Moderate and tolerable impact on the local economy (emergency services, school bus route, etc.)
>
> (iii) The route is other than a high volume route and detour length is less than approximately ten miles (local conditions may dictate different lengths)
>
> (iv) No major controversy is generated by the detour
>
> (v) Significant environmental impacts (need for extensive archaeological studies, wetland, etc.) and/or right-of-way clearance problems are anticipated if a temporary crossing would be used
>
> (vi) Major river crossings where half-width construction is not possible and the new bridge has to be constructed at the existing location
>
> (vii) The cost of improving and/or maintaining the designated detour is less than the cost of the half-width construction or temporary crossing options
>
> *Half Width Construction* —Consider this option if:
>
> (i) It is compatible with the scope of work and method of construction
>
> (ii) If half-width is selected as a viable option, specify traffic signals to control one-lane traffic on the bridge, if warranted
>
> *New Bridge Adjoining the Existing Bridge*—Consider this option when: The new alignment at least maintains or improves the existing highway geometry and the extension of work limits does not significantly increase the cost of the project.
>
> *Temporary Crossing/Bridge and Approaches*—Generally this is the most costly alternative; however, it can be utilized if:
>
> (i) The new bridge must be located on the same alignment as the existing bridge and half-width construction is not possible, and
>
> (ii) Detouring is not a viable option

If a detour is selected as a viable option and if the project can be completed within one construction season, adjust the project letting date so that the detour will not have to be required over the winter months and, if necessary, specify double shifts or a tight construction schedule with a heavy penalty for delays if the impact on the travelling public and/or affected economic community is severe.

Maintenance Work Zones

The Wisconsin Department of Transportation's (WDOT's) policy on maintenance work zones includes a general policy, a maintenance traffic control policy, traffic control devices, traffic maintenance, sign paddles, hours of work, and suspension of operations *(11)*. The policy, presented in Appendix D, includes the following work zone traffic control typical application diagrams:

- Vehicle off shoulder and work off shoulder—two-lane roadway
- Vehicle on shoulder and work off or on shoulder
- One-lane operation
- Vehicle off shoulder and work off shoulder—divided roadway
- Vehicle off shoulder and work on shoulder—divided roadway
- Lane closure on multilane roadway—divided roadway.

The new Part VI of the MUTCD *(12)* categorizes typicals by work duration, work location, and highway type. The five categories of work duration are as follows:

- Long-term stationary (more than 3 days)
- Intermediate-term stationary (overnight up to 3 days)
- Short-term stationary (daytime, 60 minutes to 12 hours)
- Short duration (up to 60 minutes)
- Mobile (work that moves intermittently or continuously).

TCPs are then further separated by work location, as follows:

- Outside of the shoulder edge—No devices are needed if work is confined to an area 15 feet or more from the edge of the shoulder. A general warning sign like ROAD MACHINERY AHEAD should be used if workers and equipment must occasionally move closer to the highway.
- On or near the shoulder edge—The shoulder should be signed as if work were on the road itself, because it is part of the drivers' recovery area. Advance warning signs are needed. Channelizing devices are used to close the shoulder, direct traffic, and keep the work space visible to the motorist. Portable barriers may be needed to prevent encroachment of errant vehicles into the work space and to protect workers.
- On the median of a divided highway—Work in the median may require traffic control for both directions of traffic through the use of advance warning signs and channelization devices. If the median is narrow, with a significant chance for vehicle intrusion into long-term work sites and/or crossover accidents, portable barriers should be used.
- On the traveled way—Work on the traveled way demands optimum protection for workers and maximum advance warning for drivers. Advance warning must provide a general message that work is taking place, information about specific hazards, and actions the driver must take to drive through the temporary traffic control zone.

The last factor in categorizing typicals is highway type. The following categories are used in the new Part VI of the MUTCD:

- Rural two-lane highways
- Urban arterials
- Other urban streets
- Rural or urban multilane divided and undivided highways
- Intersections
- Freeways.

Such things as how these categories are grouped and the nomenclature for short-duration and mobile operations may vary from state to state, but the essential breakdown by work duration, work location, and highway type remains constant.

Dropoff Policies

FHWA noted problems with pavement edge dropoffs in 1986 work zone safety reviews. A memo was sent to regional administrators on December 1, 1986, giving the following information to be used by states in developing their own dropoff policy *(13)*:

> Any dropoff is considered hazardous, but those greater than 2 inches, left overnight, and immediately adjacent to traffic have a high accident potential. For such situations, one or a combination of the following mitigating measures is recommended:
>
> 1. Specify that the contractor schedule resurfacing or construction operations such that no dropoff is left unprotected overnight, or, as a minimum, limit the length of the dropoff and the period of exposure.
> 2. If feasible, place steel plates to cover an excavation or trench. A wedge of material around the cover may be required in order to assure a smooth transition between the pavement and the plate. Warning signs should be used to alert motorists of the presence of steel plates, particularly when the plates are on the travel lanes.
> 3. Place a wedge of material along the face of the dropoff. The wedge should consist of stable material placed at a 3:1 or flatter slope. Warning signs may be needed in advance and throughout the treatment. Pavement markings or markers are useful in delineating the edge of the travel lane.
> 4. Place channelizing devices along the traffic side of the hazard and maintain a 3-foot wide buffer between the edge of the travel lane and the dropoff. The minimum spacing of the devices in feet should be, at most, twice the speed in miles per hour. Dropoff warning signs should be placed in advance and throughout the dropoff treatment.
> 5. Install portable concrete barriers or other acceptable positive barriers with a 2-foot buffer between the barrier face and the traveled way. An acceptable crashworthy terminal or flared barriers are required at the

upstream end of the section. For nighttime use, the barriers must be supplemented by standard delineation devices, i.e., paint, retroreflective tape, markers, or warning lights.

For dropoffs greater than 6 inches, recommendation 5 is strongly suggested if recommendations 1 or 2 are not feasible. Speed reduction measures need to be considered particularly for recommendations 4 and 5. Although these mitigating measures are directed to nighttime conditions, dropoffs must also be properly addressed during daylight operations.

We recognize that there may be some reluctance by the states to develop a dropoff policy or guidelines. The primary concern that has been stated in the past is that the development of such a policy would increase the potential for tort liability actions. It has, however, also been stated that the existence of properly developed policies and conformance to those policies can in fact provide the state with a good defense against tort liability. More important, however, is that such policies will provide greater protection from accidents and injuries for the motorist.

Most of the surveyed states now have dropoff policies. An example of a dropoff condition and the warning sign alerting motorists of the dropoff is shown in Figure 1.

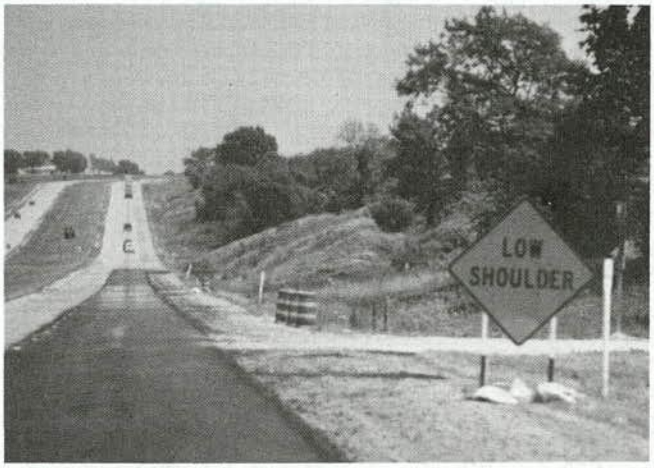

FIGURE 1 *Dropoff and warning sign.*

Speed Control Policies

Work is currently under way on an NCHRP project to develop a national procedure for determining work zone speed limits. Migletz, Graham, and Harwood *(14)* state that there are three basic policies in use for establishing work zone speed limits: (1) policies based on avoiding the need for speed limit reductions whenever possible, (2) policies based on blanket speed limit reductions at all work zone sites, and (3) policies under which the need for a work zone speed limit reduction is based on specific factors.

A survey conducted for the NCHRP project found the following practices:

- Eighteen states avoid reducing the work zone speed limit whenever possible,
- Five states have blanket work zone speed limit reductions—that is, they reduce the work zone speed limit in all or nearly all cases (one of these five states uses a blanket speed limit reduction only in maintenance work zones; speed limits in construction zones are determined on a case-by-case basis), and
- Twenty-nine states follow an established procedure or an established set of factors in deciding whether to use a reduced work zone speed limit (these states typically use reduced work zone speed limits at some sites but not at others).

A summary of the procedure developed during the NCHRP research is shown in Table 1. Analysis of speed and accident data collected for a number of work zones revealed that there are certain work zone activities where a speed limit reduction of up to 10

TABLE 1
WORK ZONE SPEED LIMIT PROCEDURE *(14)*

Condition	*Suggested Amount of Speed Limit Reduction*[a]
Activities that are more than 10 ft from the edge of the pavement	None, unless unusual situations are present
Areas that encroach the area closer than 10 ft, but not closer than 2 ft to the edge of the pavement	10 mph, where Factors 1 or 2 are present
Activities that encroach the area from the edge of the pavement to 2 ft from the edge of the pavement	10 mph, where Factors 1, 2, 3, 4, or 5 are present
Activities that require an intermittent or moving operation on the shoulder	None, unless unusual conditions are present
Activities that encroach the area between the center line and the edge of the pavement (lane closure)	10 mph, where Factors 1, 2, 3, 4, 5, 6, 7, 8, 9, or 10 are present
Activities requiring a temporary detour to be constructed	10 mph, where Factors 5, 6, or 11 are present
Activities that encroach the area on both sides of the center line of a roadway or lane line of a multilane highway	10 mph, where Factors 1, 5, or 12 are present

[a]See Table 2 for Factors

TABLE 2
FACTORS AFFECTING WORK ZONE SPEED LIMITS *(14)*

1	Workers present in traveled way or within 10 ft of traveled way unprotected by barrier
2	Horizontal curvature that might increase vehicle encroachment rate (could include mainline curves, ramps, and turning roadways)
3	Barrier or pavement edge dropoff within 2 ft of traveled way.
4	Design speed for stopping sight distance
5	Unexpected conditions
6	Lane width reduction of 1 ft or more with a resulting lane width less than 11 ft
7	Traffic control devices encroaching on a lane open to traffic or within a closed lane but within 2 ft of the edge of the open lane
8	Design speed of taper length or speed change lane length
9	Design speed of horizontal curve
10	Traffic congestion created by a lane closure
11	Design speed of detour roadway and transitions (radius of curvature, superelevation, and sight distance)
12	Remaining lane plus shoulder width is less than 11 ft because of a restriction due to work in the traveled way

miles per hour is beneficial. Larger speed limit reductions were not found to be safer than no reduction. However, it was determined that where work zone geometrics with reduced design speeds cannot be avoided, the design speed should not be exceeded even if a speed limit reduction greater than 10 miles per hour is required.

Table 2 lists factors that should be considered when determining work zone speed limits.

Predesign or Scoping Meeting

In the past, most agencies had no formalized review process in the planning stage. Traffic control was usually ignored until the design phase of the project, when the design engineer was tasked with selecting a traffic control strategy. As a result, TCP design was usually a last-minute task, often conducted with no more forethought than referencing a set of standard plans that were inadequate to the job at hand.

Predesign meetings were held only for major projects. For large budget projects, many state agencies held preliminary design conferences where alternative traffic control strategies were discussed. Final selection was based on a subjective evaluation of the critical factors involved by assigning weights to the various factors on the basis of experience and engineering judgment.

The state survey revealed that 28 of 35 (80 percent) responding states consider traffic control at the same time as other portions of the project design. When asked to comment on how this timing differed for intermediate- or shorter-term projects, 11 states said that there were no differences, and 11 other states said that traffic control for those projects was usually based on typicals.

In New Mexico, a scoping report consists of a general description of the project and existing conditions, such as the typical section, roadside slopes, surface condition, design speed, traffic volume data, safety deficiencies, and capacity analysis. These reports are prepared for all construction projects and ensure early consideration of traffic control concerns and early discussion of the effect of traffic on other areas of project design.

DATA COLLECTION

The TCP designer tailors the TCP to the conditions in a particular work zone, using recent traffic operation and safety data from the site. Accident data are collected before, during, and after the construction project so that the effects of the TCP on traffic can be used as a method of quality control in the TCP design and management process.

Chapter 9 in the Iowa *Road Design Manual (15)* includes a list of the information that should be considered when developing a TCP:

1. Type of work
2. Location
   - (a) Major intersection within 1,000 feet of the work area
   - (b) Access to residences and businesses
   - (c) Other projects in the vicinity
   - (d) Sight distance
3. Traffic
   - (a) Current traffic/peak-hour volumes
   - (b) Special events and recreational traffic
   - (c) Pedestrians/bicyclists
   - (d) Truck traffic
   - (e) Existing speed limit
   - (f) Roadway capacity
4. Existing roadway
   - (a) Number and type of traffic lanes (divided/undivided)
   - (b) Shoulder widths
5. Staging
   - (a) Location of work (on roadway, shoulder, sidewalk)
   - (b) Number of lanes required for work activity
   - (c) Hours during which lane closure is permitted
   - (d) Length of work area
   - (e) Time of exposure to hazards
   - (f) Proximity of traffic to unfinished work

The second survey for this synthesis asked the states, "What data are collected and analyzed prior to designing TCPs?" All 36 responding states indicated traffic volumes were considered, and 30 (83 percent) states also indicated that they analyze speeds. Vehicle mix is considered by 23 (64 percent) states, and accident and pedestrian data are analyzed by 14 (39 percent) and 15 (42 percent) states, respectively. Other data considered include lane widths, lighting conditions, existing traffic control devices, and peak-hour volumes.

All parties interested in the project should review the project plans to ensure that the basic sequence of construction and the strategy selected will accommodate all aspects of the project. Once a consensus has been reached, detailed design of the TCP can begin.

CHAPTER THREE

DESIGN OF TRAFFIC CONTROL PLANS

After the planning stage is completed, the design of the TCP is undertaken. Unlike the planning effort, design is usually done by one person. This chapter discusses the organization of the TCP, the duties and qualifications of TCP designers, the use of typicals, staging/sequencing considerations, good practices in TCP designs, and examples of good TCP designs that were found in the state surveys.

ORGANIZATION OF THE TRAFFIC CONTROL PLAN

Items included in the TCP will usually be covered in one of three parts: plans, notes, and special project-specific provisions. The plans cover most of the items needed in the TCP; notes and special provisions add detail to the plans and give specification information that may be similar for most TCPs.

An an example, a complex TCP obtained from the Texas Department of Transportation (TxDOT) had a total of 60 plan sheets. The sheets were categorized as follows (the number of plan sheets devoted to each category is in parentheses):

- Construction phases (4)
- Temporary ramps (3)
- Continuously reinforced concrete pavement repairs (3)
- Traffic control Phases I-IV (37)
- Barricade and construction standards (7)
- Work zone pavement markings (2)
- Special signs (3)
- Mounting details (1).

According to the Iowa *Road Design Manual (15)*, the TCP should include a set of traffic notes that describe the overall plan, arranged in the following order of importance:

1. Indicate whether through traffic is maintained or traffic is to be detoured off the project.
2. List standard road plans, design detail sheets, and special layouts to be used.
3. Include notes that are unique to a specific project or type of work (e.g., special working hours, special barricade spacing, when to use special layouts).
4. Include standard traffic control notes.

Basic TCP notes used by the Iowa DOT are shown in Figure 2. Special project-specific provisions are used to add detail to the basic TCP notes or to describe site-specific information.

No aspect of work zone traffic control should be overlooked. The California *Highway Design Manual (6)* states that TCPs may include some or all of the following items:

- Signing
- Flagging
- Geometrics of detours

Traffic will be maintained on the project at all times.

Traffic control on this project shall be in accordance with Standard Road Plans..., Detail Sheet..., and special layouts (if any)....For additional complementary information refer to current Supplemental Specifications for Traffic Controls.

(Insert any specific notes which are unique to the project such as to coordinate traffic control, length of time of road closure, restrictions on lane closures, etc....)

All traffic control devices shall be furnished, erected, maintained, and removed by the contractor.

The location for storage of equipment by the contractor during nonworking hours shall be as approved by the engineer in charge of construction.

Parking of private vehicles on interstate right of way will not be allowed.

Parking of unattended equipment within the median or overnight storage of equipment within 50 feet of the edge of pavement will not be allowed.

The engineer may require modifications to the pavement marking details shown. Conflicting permanent edge lines, center lines, or lane lines shall be removed and appropriate temporary lines placed. As applicable, permanent pavement markings shall be in place before the roadway is returned to normal traffic.

The standard specifications series of 1984 and current supplemental specifications shall apply.

Proposed sign spacing may be modified as approved by the engineer to meet existing field restrictions or to prevent obstructions of the motorist's view of permanent signing.

Permanent signs conveying a message contrary to the message of the temporary signs and not applicable to the working conditions shall be covered by the contractor when directed by the engineer.

Proposed changes in the traffic control plan shall be reviewed with the Office of Construction before changes are made....

FIGURE 2 *Basic TCP notes used by Iowa DOT (15).*

- Methods and devices for delineation and channelization
- Application and removal of pavement markings
- Placement and design of barriers and barricades
- Separation of opposing traffic streams (see the FAPG)
- Maximum lengths of lane closures
- Speed limits and enforcement
- Use of pilot cars
- Construction scheduling
- Staging and sequencing
- Length of project under construction at any one time

- Methods of minimizing construction time consonant with safety
- Hours of work
- Storage of equipment and materials
- Removal of construction debris
- Treatment of pavement edge dropoffs
- Roadway lighting
- Movement of construction equipment
- Access for emergency vehicles
- Clear roadside recovery area
- Provision for disabled vehicles
- Surveillance and inspection
- Needed modifications of above items for inclement weather or darkness
- Any other matters appropriate to the safety objective.

TRAFFIC CONTROL PLAN DESIGNERS

The designer is the most critical component of an effective TCP. The people involved in TCP development must have adequate training and background in work zone traffic control and safety. The people involved in creating TCPs should have a broad base of experience in traffic operations, construction engineering, and design; field experience in construction or maintenance is also highly desirable.

In addition, it is helpful if all persons involved in TCP development are well trained and experienced. The Process for Consultants (Appendix C) includes a set of references that should be available to TCP designers. It would be helpful if the state DOT office annually circulated an updated list of the most useful work zone research reports to the TCP designers.

The first survey revealed that, in many instances, TCP designs are done by entry-level engineers or high-level technicians. The second survey revealed that only 8 of 36 (22 percent) responding states require TCP developers to be degreed engineers. In some states, consulting engineering companies are also performing a great deal of the design of TCPs. Consultant plans usually have to be stamped and sealed by a professional engineer in the company; however, the actual design may be done by junior-level personnel.

Regardless of whether TCP design is done at the central, district, or local level in a state highway agency, several designers will usually be involved in the design process. It is very important that clear, written instructions on the correct way to design TCPs be available at the three highway agency levels to facilitate good TCP design.

Each TCP should be thoroughly reviewed by district safety review teams and by central office personnel. It is also important that ample time be allowed for review of a TCP. Both project and resident engineers should have the opportunity to apply their experience and knowledge to TCPs that may involve special or unusual site-specific conditions. The central office should have sufficient time to review and approve TCPs. Local TCP designers should fully utilize the resources and experience available in the central office. Major projects should be formally presented and discussed at a meeting of the district safety review team, and all TCPs should, at some point, be reviewed by the district traffic engineer or staff member.

TYPICALS

TCP designers in many cases rely on "typicals" as a basis for developing traffic controls. Typicals are prototypical control plans, designs, design details, standards, and operational procedures that may be adapted to the specific conditions of a particular work zone. Many state agencies have developed sets of typicals that are included in agency guidelines and reference manuals.

The 1988 MUTCD includes 10 typical TCPs. All of the surveyed states have additional typicals to cover areas such as urban streets, moving operations, ramps, and intersections. The new Part VI of the MUTCD (Revision 3, September 1993) has 44 typicals. (For more information on typicals in Part VI, see Chapter 2.)

Development of a comprehensive set of typicals is important because designers use typicals as a starting point for site-specific TCPs and because simple TCPs may only include typicals. As stated in the Iowa *Road Design Manual (15)*:

> Each traffic control zone differs according to vehicle speed; traffic volumes; and the location of work, pedestrians and intersections. The goal of traffic control is safety, and the key factor in making the TCP work is the application of proper judgment. This section is designed to show how to apply the basic principles discussed previously.
>
> Section RS of the Standard Road Plans and sections 520 and 521 of the Road Design Details show typical applications of various traffic control methods. Since there are endless combinations of geometry, location, and work, it is not possible to have a layout for every conceivable work zone situation. However, these layouts do provide a basis from which other layouts may be derived to fulfill the traffic control needs of a particular work zone situation.
>
> The layouts contained in the Standard Road Plans and the Road Design Details represent minimum requirements for the situation depicted. Factors such as traffic volume, sight distance, and work area location may require modifications to the layouts. In any case, the guidelines contained in this manual and the MUTCD must be satisfied.

An example utility typical designed in Iowa is shown in Figure 3.

The new Part VI of the MUTCD categorizes typicals by work duration, work location, and highway type. Such things as how these categories are grouped and the nomenclature for short duration and mobile operations may vary from state to state, but the essential breakdown by work duration, work location, and highway type remains constant.

For example, the Iowa DOT classifies work zone locations for typical drawings by less or more than 12 feet from the roadway, rather than using the terms "outside of the shoulder edge," "on or near the shoulder edge," or "on the traveled way." However, basic classifications similar to those used in the MUTCD (such as stationary and mobile, short-term and long-term, and classifications based on work location) remain in the categorization process.

The primary goal of categorizing typicals is to fully describe the situations where the typical is to be used.

STAGING/SEQUENCING CONSIDERATIONS

The TxDOT *Design Training Manual* states that choosing a sequence of construction is the first step in the development of a TCP *(16)*. The manual discusses staging/sequencing considerations as follows:

> There are always some trade-offs in the sequence of construction selected. However, the designer strives to balance competing goals such as access to the work zone, minimizing the number of steps,

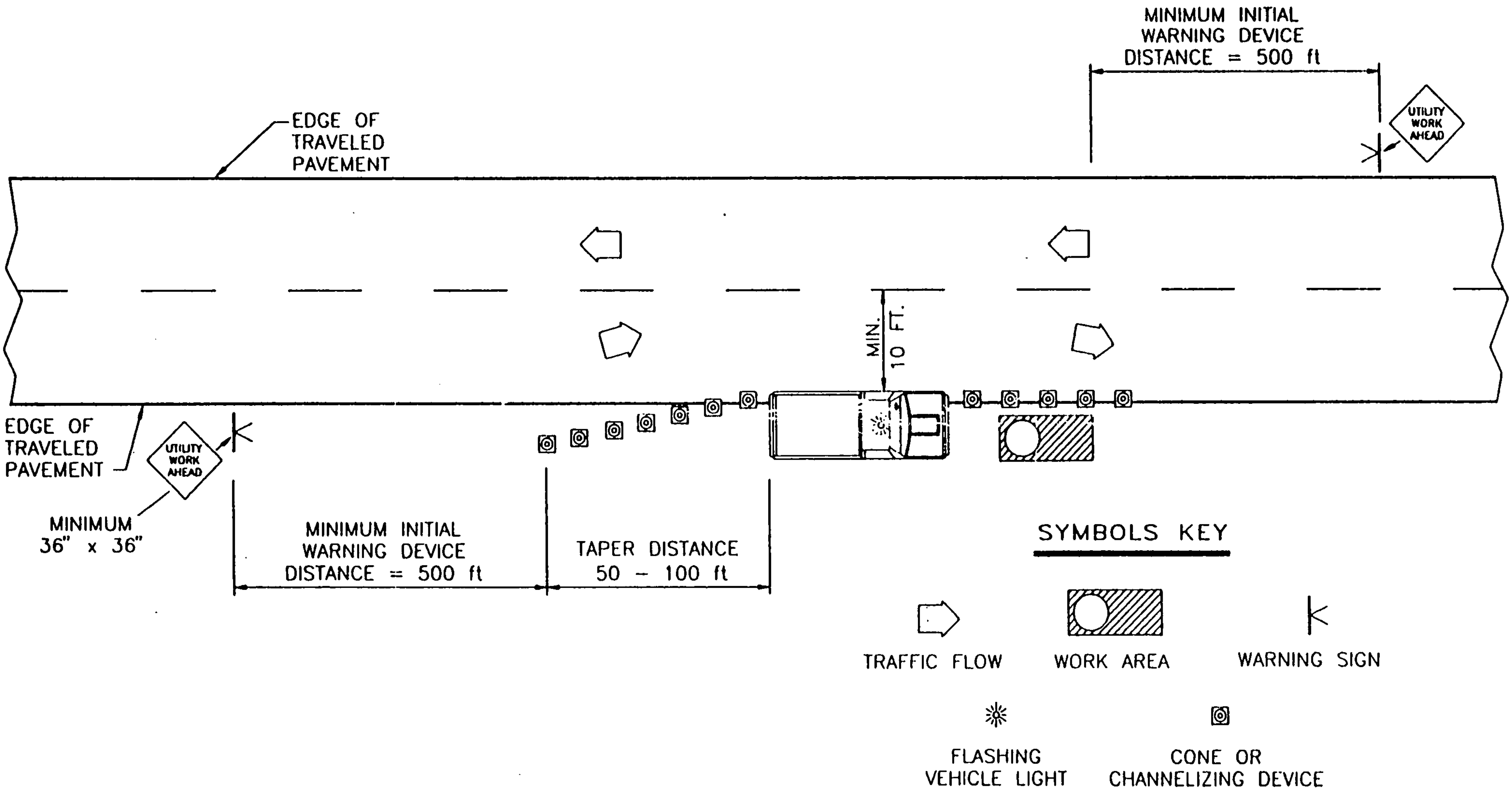

FIGURE 3 *Typical application: minor encroachment with utility work zone on high-volume center-lined two-lane road.*

keeping traffic flowing, maximizing ease of access to properties, and insuring proper pavement joint location for the final pavement. In addition, minimizing construction pavement and striping may also result in cost saving. However, building a little more pavement in order to handle traffic may be necessary based on traffic volumes and available capacity. The contractor may be required to work smaller project lengths to minimize impacts on business or possibly work double shifts to finish the project sooner. The signing, striping, lane width, lane closures, buffer zone and pavement dropoff details of the TCP are all affected by the sequence of construction. A TCP can be developed to accommodate almost any work sequence *but will not improve* a poorly planned sequence of construction. Therefore, planning for a TCP should be addressed very early in PS&E preparation because it will impact many decisions and plans cannot be changed very easily when design work is complete.

Common pitfalls to avoid are improper clearance from the work area, severe roadway transitions and lane closures during hours that exceed capacity. Adequate capacity is the key to success of any TCP.

The state visits conducted for this synthesis revealed that a project's staging was the source of many problems in implementing TCPs. Two problems that resulted in major change orders during the project were (1) use of fill when a temporary roadway was located on the fill area and (2) improper phasing of drainage work, resulting in improper drainage of the traveled way.

Changes to the staging of the job were the most common TCP changes requested by contractors after a job was awarded. These changes were usually requested to save money or improve efficiency of the work rather than to improve safety. The second survey revealed that 31 of 36 (86 percent) states said unexpected changes in staging and sequencing were the most frequent cause of a field change to a TCP.

Capacity considerations are often fundamental to the proper phasing of the project. Harris County, Texas, publishes traffic control maps that specify the number of freeway lanes that may be closed for construction or maintenance operations at any time during the week. Capacities of various work zones, as given in the FHWA training course "Design and Operation of Work Zone Traffic Controls," are shown in Table 3. The *Highway Capacity Manual (17)* includes a section on work zone capacity in its freeway chapter, and computer programs that determine delay times at work zones are available from the Texas Transportation Institute *(18)*. The TRAF-NETSIM software program (available from the Center for Microcomputers in Transportation, Transportation Research Center, University of Florida in Gainesville) may also be used to simulate lane closures on arterials.

TABLE 3

GENERAL GUIDELINES ON VEHICLE CAPACITY THROUGH WORK ZONES

	Basic Capacity (vph)	*Work Zone Capacity (vph)*
Freeway		
4 lanes in each direction	7,600	5,630
3 lanes in each direction	5,700	4,220
2 lanes in each direction	3,800	2,960
1 lane in each direction	--	1,610
Multi-Lane Highway		
3 lanes in each direction	5,700	4,220
2 lanes in each direction	3,800	2,880
1 lane in each direction	--	1,570
Rural 2-Lane Road	1,900	1,670
1-lane road (alternate flow)	--	850
Urban Intersection (2-way street)		
3-lane approach	1,900	1,650
2-lane approach	1,350	1,100
1-lane approach	800	500

Assumptions: 5 percent truck/bus, level terrain. 6 ft shoulder under normal condition and no shoulder under work zone. G/C (green signal time/cycle length) = 0.5, no parking, and 10 percent turning movement at intersections.

PRINCIPLES OF GOOD DESIGN PRACTICE

In the interest of safety and flexibility, a TCP designer involved in a complex project should provide some options in the TCP in the event conditions change after the TCP is installed. The TCP for a complex project should emphasize traffic management, rather than the minute details of traffic control device placement or use.

A TCP should be flexible. It should try to recognize areas that could become problematic and provide for adequate options that would not change the overall management philosophy of the TCP.

Wang and Abrams *(9)* outline the following nine-step process for designing effective TCPs:

1. Assemble data
2. Determine extent of roadway occupancy
3. Identify feasible design alternatives
4. Analyze volume/capacity relationships
5. Analyze capacity improvement techniques
6. Define alternatives
7. Quantify impact
8. Modify procedures
9. Select preferred alternative.

As pointed out earlier, traffic control is usually planned on the basis of subjective evaluations of critical factors. Consequently, much of the related research has been aimed at developing a methodical process for determining the best form of traffic control. This process is usually developed for a generic work site, based on predetermined measures of effectiveness. Controversy can develop over which measures of effectiveness are most relevant and how to accurately measure them.

Nonetheless, because of its potential usefulness, research has been done on finding an acceptable method for quantitative analysis of eight defined measures of effectiveness. An accepted systematic process for TCP design would make information exchange easier and possibly provide a means for finding more specific reasons for a particular TCP's failure to perform effectively. Labor costs could be reduced through a standardized process, and those involved in TCP design would not need to have the benefit of 20 or more years of experience in traffic operations.

The Wang and Abrams report outlines a quantitative, step-by-step process for calculating relative levels of effectiveness for differing methods of work zone traffic control based on the following eight defined work zone evaluation measures:

- Accidents
- Vehicle delay
- Vehicle stops
- Vehicle operating costs
- Fuel consumption
- Air quality

- Traffic control costs
- Business loss.

The report shows how to use these measures in a benefit-cost evaluation for the traffic control management alternatives selected in the first portion of the analysis.

The technique described in the Wang and Abrams report, although comprehensive and effective, may be problematic because of the amount of expensive labor necessary for in-depth quantitative analysis.

An alternative is described in a report by Leonard and Recker *(19)*. As part of a project for Caltrans, they developed and implemented a computer program that assists in the design of work zone traffic control through quantitative analysis of traffic engineering criteria.

The computer program integrates several transportation programs into a package that allows efficient, quantitative analysis of differing strategies for work zone traffic control. The user can design and input the desired alternatives, and the program then calculates the impact of the differing configurations using several standard measures of effectiveness. Effects caused by varying parameters, such as lane constrictions and closures, detour routes, and signal timings can be calculated and judged in a comparative manner. The program was used to make recommendations for an actual work site on Interstate 5 in Orange County, California.

EXAMPLES OF GOOD DESIGNS

Richards, Faulkner, and Dudek point out that freeway reconstruction sites can often pose a variety of traffic control problems *(20)*. These work zones make planning traffic control inherently more difficult because of their heavy traffic volumes, high speeds, close proximity to major traffic generators, and so forth.

They note that steps must be taken to minimize traffic congestion and provide for safety because freeway reconstruction zones account for a large share of work zone accidents. The minimum standards presented in the MUTCD are often insufficient when used alone. Innovative management strategies and control devices are often required.

Richards, Faulkner, and Dudek detail a control strategy they found to be effective on a long-term construction site in Texas. The project involved a 14-mile rural section of Interstate 10 between Houston and Beaumont. The TCP included innovative use of a combination of traffic crossovers on the mainline and parallel frontage roads.

Trucks and buses were controlled with the crossover strategy on the mainline of the four-lane divided freeway, while cars and pickups were diverted to the parallel frontage roads for the length of the work zone. This strategy was combined with an elaborate system of overhead and ground-mounted signs to inform motorists of special traffic conditions and diversion routes around the work zone. Channelization devices and painted markings were installed at the diversion points on both ends of the work zone.

The strategy as implemented was reported to be very effective, and the accident rate actually decreased for the period of time that the work activity occupied the roadway.

Another project reported by Richards, Faulkner, and Dudek investigated the following innovative techniques:

1. Advance notification—An information distribution campaign to the public was implemented well in advance of the actual construction dates.
2. Lane width reduction—This was reported as the only approach that actually was effective in reducing speeds in the work zone. The number of accidents reported did not increase in the areas that used the narrower 10-foot lanes.
3. Ramp closures and traffic diversion—Because the project involved reducing the number of lanes of traffic from five to three, traffic capacity was reduced, and it was necessary to reduce demand on the section by closing some freeway ramps and diverting traffic to detour routes.
4. Load zoning—A sign directed vehicles weighing more than 8,000 pounds to alternate routes. It was reported to be very effective, with the rate of load-zone violations under one per hour.

They also reported that the conventional use of reduced speed zoning in work zones was totally ineffective in the projects they studied.

Another good example of a design solution was developed by the Pennsylvania DOT *(21)*. When a widening project is undertaken along an arterial street lined with strip commercial activity, motorists are often confused about how to gain access to restaurants, motels, and other businesses in the strip. Figure 4 shows an access control typical used in Pennsylvania. To help guide motorists, business names are entered on the panels above the ENTER HERE signs.

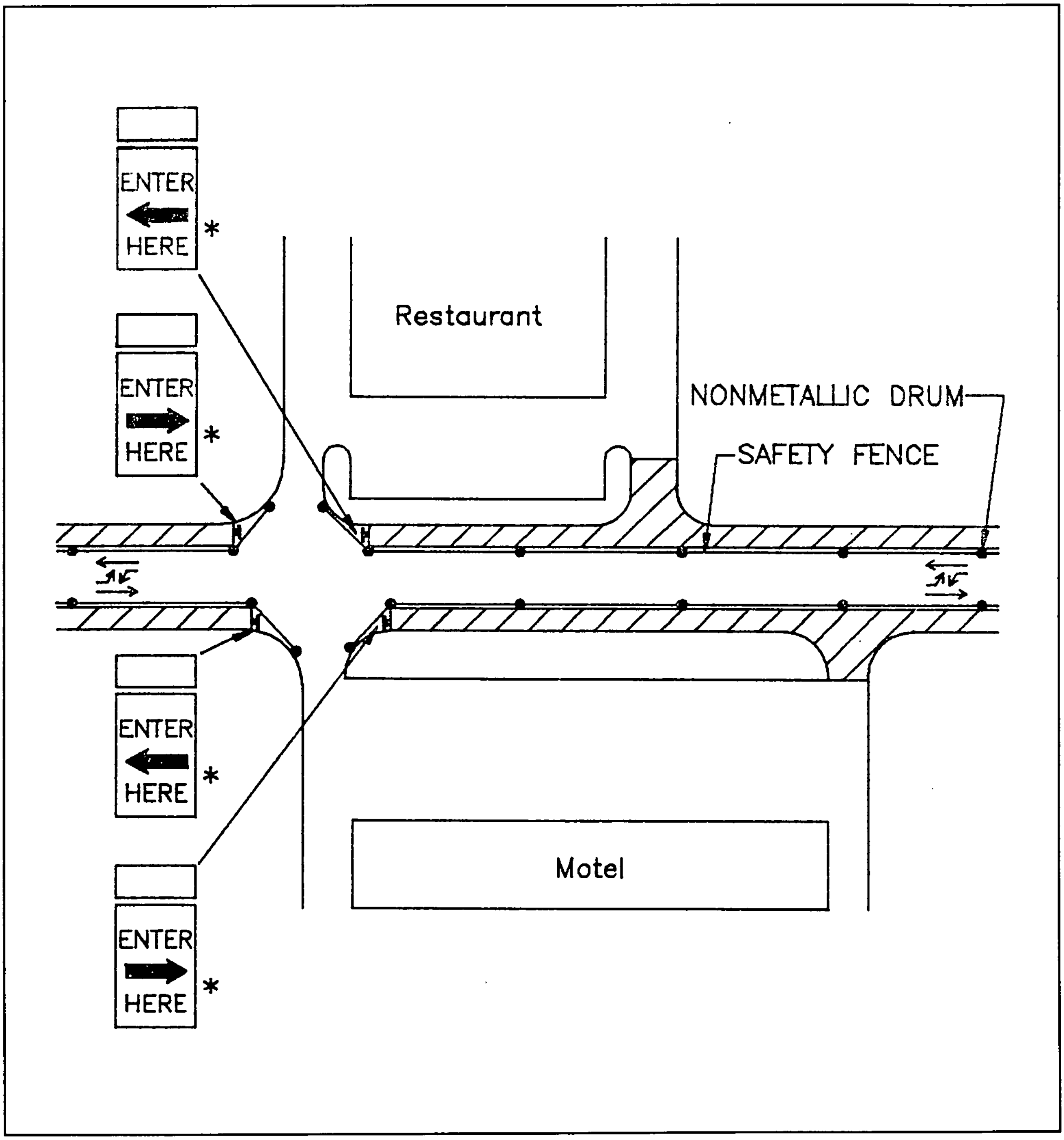

FIGURE 4 *Typical for access control to a business.*

CHAPTER FOUR

IMPLEMENTATION OF TRAFFIC CONTROL PLANS

The implementation phase occurs when the TCP is installed in the field. The FAPG specifies that a highway agency shall designate a qualified person at the project level who will have primary responsibility and sufficient authority to ensure that the TCP and other safety aspects of the contract are efficiently administered. One of the primary duties of the "responsible person" is to conduct inspections of the work zone traffic controls at regular intervals and to make any necessary changes.

Preconstruction meetings can be very useful in establishing inspection schedules prior to traffic controls being installed in the field. The meetings are also good opportunities to make sure everyone understands the TCP. At these meetings the contractor may also submit an alternative TCP. In the second state survey, 30 of 36 (83 percent) responding states said they allowed contractors to develop their own TCPs; only 4 states, however, said that contractors often actually develop TCPs.

RESPONSIBLE PERSON

A "responsible person" is defined as a person involved with the work zone project or incident area whose primary responsibility is traffic control. This person should be trained in work zone traffic control and safety engineering. He or she should be a staff professional with the authority to ensure that directives concerning the implementation of the traffic control strategy are obeyed.

The second state survey found that 20 states assign this duty to the project engineer, 18 assign it to the resident engineer, 13 appoint a subprofessional (e.g., a project inspector) for this duty, and 13 assign it to "other." (Some of the states vary this assignment.)

One of the chronic problems with the development of work zone TCPs relates to the responsible person. Individuals assigned the duties of the responsible person often have other pressing responsibilities. A project or resident engineer typically is so busy with the construction and coordination aspects of managing a work project that traffic control is often relegated to a secondary concern. To counter this, some states assign special TCP inspectors for larger, more complex projects.

If the TCP process is to improve, a project must involve a person whose primary concern is traffic control or else traffic control concerns will continue to be dismissed or given short shrift.

The *FY 1989 Annual Work Zone Traffic Safety Report (5)* states:

> A responsible person is normally assigned to each project. But some have not received training or adequate on-the-job experience. States are requiring certification or training of their responsible persons. Some states require the contractors to designate a person trained or certified in work zone traffic control. Certification and training of project personnel does not guarantee the traffic control will be satisfactory. States should be cautioned that the specification should be written to limit the number of projects a certified person can be responsible for monitoring.

The second state survey revealed that in 24 of the 36 (67 percent) responding states, contractors are required to have a responsible person, but only 7 (19 percent) require that this person be certified or have other special training.

The New Mexico State Highway and Transportation Department *(22)* requirements for contractor's responsible persons are addressed under the following special provision for traffic control management:

> This work shall consist of providing Traffic Control Management in strict compliance with the contract documents and the *Manual on Uniform Traffic Control Devices* (MUTCD), including installation, supervision, inspection, and maintenance of all traffic control devices on the project.
>
> Prior to commencing any work requiring Traffic Control Management, the Contractor shall provide a certification for the designated Traffic Control Supervisor. The Traffic Control Supervisor shall be American Traffic Safety Services Association (ATSSA) certified or certified by an agency approved by the Department.
>
> If certified by an agency approved by the Department, the minimum requirements for certification are as follows:
>
> 1. Successful completion of an approved work zone traffic control course.
> 2. Passing a written examination on the work zone traffic control course.
> 3. A minimum of one (1) year field experience in work zone traffic control.
>
> Duties: The Traffic Control Supervisor shall provide management and supervision services including, but not limited to, the following:
>
> a. Prepares all revisions requested by the Contractor to the Traffic Control Plan established in the Plans and submits the new Traffic Control Plan to the Project Manager for approval by the District Engineer.
>
> b. Direct supervision of project flag and signing personnel.
>
> c. Coordinating all traffic control operations, including those of subcontractors and suppliers.
>
> d. Coordinating project activities with appropriate law enforcement and fire control agencies.
>
> e. Preparing and submitting Statement 5 concerning road closures, delays and other project activities to news media as required.
>
> f. Maintaining a project traffic control diary in a bound book in a format approved by the Project Manager which will become a part of the Department's project records. A copy of the diary shall be submitted to the Project Manager on a bi-weekly basis. The traffic control diary shall be kept current on a daily basis and shall be available for inspection at all times.
>
> g. Inspecting traffic control devices every calendar day that traffic control devices are in use and providing for the repair or replacement of traffic control devices not functioning as required. Traffic control devices shall be inspected during working and non-working hours on a schedule approved in writing by the Project Manager. Inspections shall take place at times in

addition to the beginning and end of the working day. Traffic control devices in use longer than seven days shall be inspected at least once a week during nighttime periods.

h. Overseeing all requirements covered by the contract plans, specifications and special provisions which provide for the convenient, safe and orderly movement of traffic.

Traffic Control Management shall be provided by the Contractor throughout the duration of the project. Traffic control supervision shall be provided by the Contractor on a 24-hour per day basis. The Contractor shall ensure that the Traffic Control Supervisor is available on every calendar day, "on call" at all times, and available upon the Project Manager's request at other than normal working hours. The Contractor shall at all times be able to respond within one (1) hour of notification by the Project Manager.

The Traffic Control Supervisor shall have a set of traffic control plans and an up-to-date copy of the MUTCD available at all times.

Prior to commencing any work requiring Traffic Control Management, the contractor shall, in writing, certify that the Traffic Control Supervisor meets the minimum requirements given above. Along with this certification, the contractor shall submit the certificate verifying successful completion of the course and examination and a summary of the Traffic Control Supervisor's field experience in the operation of work zone traffic control.

At TxDOT, the responsible person's duties are divided into the department responsible person (DRP) and the contractor responsible person (CRP). Their duties and responsibilities are specified in the *Inspectors Training Manual for Traffic Control Through Construction (23).*

The Engineer appoints the Project Manager, and Inspector, or some other Department employee trained in traffic control to serve as the DRP.

DRPs are responsible for at least one daytime and one nighttime inspection per month for each construction project under their supervision.

Note: The DRP must not conduct the formal daytime and nighttime inspections within the same 24-hour period. However, the DRP may make informal inspections at his/her discretion.

The DRP has the authority to:

- oversee the setup and maintenance of the TCP,
- instruct the Contractor to correct hazards and deficiencies,
- ensure that Contractors correct hazards and deficiencies at the time of inspection if possible,
- halt work if necessary until the Contractor makes the needed corrections, and
- make minor or emergency changes to the TCP, documenting the changes according to the district's documentation procedures.

Note: Some districts may require the Engineer's approval for *any* TCP change.

The Contractor must designate one person to be responsible for traffic control on the project.

The CRP may be the Contractor's project superintendent, an engineer, or a safety specialist.

The CRP has authority to:

- implement and maintain traffic control devices as the contract specifies,
- take corrective measures or direct the Contractor's other employees to correct deficiencies as soon as possible after their discovery, and
- halt work until the Contractor's employees make the necessary changes.

The CRP:

- makes daily traffic control inspections, reporting any deficiencies to the DRP;
- reports corrections of any TCP deficiencies to the DRP;
- accompanies the DRP on formal bi-monthly inspection; and
- makes other inspections at his/her discretion or at the Department's request.

FIELD INSPECTIONS OF TRAFFIC CONTROL PLANS

Highway tort liability has become increasingly important in recent years as the number of lawsuits against highway agencies has increased. For this reason, Dudek and Richards point out, good inspection practices have become an integral part of the TCP management process *(8)*. They recommend daily inspections of traffic control and written records of these inspections, kept in the project diary or on a separate report form.

In many of the surveyed states there is a hierarchy of inspections and inspectors. In New Mexico, the responsible person conducts daily inspections and at least one nighttime inspection each week. In Texas, the CRP is responsible for daily traffic control inspections; the DRP must make at least one daytime and one nighttime inspection per month. In TxDOT's Houston District, a district traffic control coordinator reviews the inspections of the DRP and also reviews and inspects traffic control with the resident engineer on a quarterly basis. The overall schedule for inspection is shown in Table 4.

Inspections in Texas are documented on Form 599, which provides a record of the discovery and correction of traffic control deficiencies. Both the DRP and CRP must sign Form 599 in case a liability claimant uses the form as evidence.

The DRP uses Form 599 for the following tasks:

- Document deficiencies he or she discovers during traffic control inspections
- Recommend corrections
- Record the dates and times the contractor makes the corrections.

District and residency policies for distribution of Form 599 vary. Typically, the DRP completes Form 599 during official DRP

TABLE 4

TEXAS TCP INSPECTION SCHEDULE

Responsible Person(s)	*Frequency*	*Comments*
Project	Daily	Inspectors may also make any number of inspections.
DRP	At least twice monthly (one in daytime, one at night) and after major TCP changes	The two inspections may not be within the same 24-hour period. The CRP accompanies the DRP.
CRP	Daily	The CRP accompanies the DRP's inspections and makes additional night inspections at his or her own discretion and the Department's request.
District Safety Review Team	Occasional, if at all	The team announces its reviews in advance.

inspections and sends the original to the residency. A completed Form 599 from the Texas *Inspectors Training Manual for Traffic Control Through Construction* is shown in Figure 5.

The Texas *Inspectors Training Manual* also documents how to inspect each aspect of the TCP. For example, the steps in inspecting arrowboards are as follows *(23)*:

Step 1—Review the plans for arrow board requirements in your inspection area, including:

- Number,
- Locations,
- Flashing modes,
- Types of mountings, and
- Size.

Step 2 —Inspect arrowboards to ensure that they meet the standards in this manual, and the plan requirements for:

- Purpose and location,
- Mounting height,
- When to use each flashing mode, and
- Size.

Step 3—Inspect the operation of the lamps to ensure that:

- All lamps are operating;
- The flashing rate is 25 to 40 flashes per minute;
- Lamps are on at least 50 percent of the time for flashing modes, and
- Automatic dimming switches are working and, contractors dim the lamps at night

Step 4—Drive through lane closure tapers, observing to ensure that:

- Contractors use exactly one arrowboard per lane closure; and
- Arrowboards do not cause driver confusion near ramps, median crossovers, and intersections.

SDHPT
Form 599—6-86

Traffic Control Devices Inspection Report

Proj. No. ME 611-12
Contractor ABC
Inspection Date 5-20-89
Night X Day ____ Time 9:30

Section I Review Items

Advance Signs & Barricades
In Conformance to Plans

Signs Within Project
Standard Color
Standard Size
Standard Position
Adequate Reflectivity

Barricades Within Project
Standard Color
Standard Position
Properly Lighted
Adequate Reflectivity

Pavement Markings
Standard Color
Visible at Night

Warning Lights
In Conformance to Standards

Delineation of Transitions and Detours
In Conformance to Plans

Section II List of Deficiencies

Type of Device: Sign	Barricade	Warning Lights	Pavement Marking	Delineation	Barrier	Other	Reason for Deficiency: Non-Reflective	Non-Standard Color	Non-Standard Size	Improperly Used or Located	Missing	Dirty	Other	Location: Approximate Location or Station	Action: Recommended Corrective Action	Date & Time Contractor Made Correction	Verified by (Initials)
X								X				X		10+00	replace and clean	2:00PM 5-22-89	JS
		X											X	11+10	replace battery	2:00PM 5-22-89	JS
	X									X		X		11+30	do not place parallel to traffic	10:00AM 5-21-89	JS
			X							X				12+50	remove at lane closure at bridge constr.	9:00AM 5-22-89	JS
X							X							13+00	replace	9:00AM 5-22-89	JS

Section III Actions

Contractor Notified of Deficiencies
Date 5-21-89
Contractor Completed Correcting Noted Deficiencies
Date 5-22-89

Section IV Comments

Attach Additional Pages for Comments
☐ Yes ☒ No

Inspection made by John Smith
Accompanied by Al Cole
Signature: John Smith (Inspector)
Signature: Al Cole (Contractor)

FIGURE 5 *Example Form 599. Note the information each of the four sections requires.*

CHAPTER FIVE

REVISION OF TRAFFIC CONTROL PLANS

Inspections and reviews of TCPs are needed to ensure that the TCP is performing as expected and that needed changes are identified. The TCP management process must include reviews and reports to management to identify changes needed in policies, typicals, or administrative procedures. TCPs used for maintenance and utility operations, which are often typicals, should also be reviewed and changed as necessary.

SAFETY REVIEWS

One of the FAPG requirements for TCP development is safety review of TCP designs. These reviews can be performed in a number of different ways, but the FAPG requires they be performed at least once a year and that appropriate personnel with a wide variety of backgrounds be present. Current or recent projects may be reviewed for safety, and all roadway aspects of the TCPs should be examined.

The *FY 1990 Annual Work Zone Traffic Safety Report (24)* states:

> In all regions except one, the regional staff participated in several division/state reviews, and most of the divisions participated in state reviews. Regional reports emphasized these reviews often included night activities to determine the quality and maintenance of retroreflective devices. Regional summaries also indicated a growing trend in the use of statewide review teams which include an FHWA participant.

The Iowa DOT publishes a report that details the results of its yearly review *(25)*. In April 1985, eight different projects were studied and, in most cases, the review team consisted of the state traffic engineer, a safety review engineer, the project resident construction engineer or city/county engineer, an Office of Road Design section engineer or secondary urban engineer, an Office of Construction engineer, an FHWA engineer, and an "at-large" member. The review teams were headed by the state traffic engineer. The bulk of the report describes the proceedings of the actual review meetings: what was discussed, problems found with specific devices or strategies, and how their solutions were implemented. All aspects of the TCP, general traffic handling, and safety were covered by these team reviews.

As part of the yearly review process, resident engineers are required to report within 2 weeks any corrective actions taken as a result of a team review. A copy of this report is submitted with the draft copy of the review report to team members. When the final report of team reviews is completed, a summary is included that points out deficiencies and positive findings. The state traffic engineer reviews pertinent items with the Traffic Safety Committee. The items of interest to field personnel are discussed the following winter at training seminars and district meetings.

An important aspect of the Iowa review procedure is review by the design section. TCP designers should get feedback on how well their TCPs performed in the field. The second state survey revealed that 31 of 36 (86 percent) responding states said there was such a feedback procedure.

PROCEDURES FOR CHANGES TO TRAFFIC CONTROL PLANS

Dudek and Richards report several problems with the procedures for changes to TCPs in Texas *(8)*. In all of the interviews conducted concerning TCPs, district personnel felt that the project engineer needs to be given more flexibility to implement field changes to TCPs. It was reported to take an average of 3 to 6 months for approval of field changes submitted through "proper channels." The policy is also vague as to what emergency situations merit immediate authorization of a change by a department's responsible person. There is ambiguity concerning how minor a change must be before it can be made without formal approval.

The Texas *Inspectors Training Manual (23)* gives the following guidance for changes to the TCP:

> The Project Engineer must approve all major changes in TCPs.
>
> The DRP can make minor and emergency changes.
>
> These circumstances may require TCP changes:
>
> - Any evidence of driver confusion,
> - Accidents within the project limits,
> - Severe storms,
> - Major nearby fires, or
> - Other disasters such as chemical spills.
>
> The Department authorized Inspectors to:
>
> - Recommend TCP changes if it fails to provide a smooth, safe traffic flow, and
> - Change the TCP in emergencies.
>
> The Contractor has authority to:
>
> - Request Departmental approval of TCP changes, and
> - Change the TCP with Departmental approval in emergencies.

Procedures for changing the TCP are summarized in Figure 6.

The second state survey revealed that in 15 of the responding states, project engineers can authorize changes to TCPs. In other states, the responsibility may rest with someone higher in the DOT organization.

ACCIDENT REPORTING PROCEDURES

The FAPG requires that accidents occurring in work zones be analyzed in both short-term and long-term time periods. Although most of the states have policies about obtaining accident reports, the analysis of accident data to make TCP changes is evident only for large construction projects in major urban areas. Because of inconsistency in accident data from year to year and state to state, the requirement to submit accident data to FHWA was discontinued in 1989 *(26)*. States with good accident data systems were encouraged to continue review of work zone accidents.

If the TCP...	*Then the inspector should...*
Needs minor changes	1. Instruct the contractor to make changes
	2. Document and date the changes
Causes accidents or hazards	1. Instruct the contractor to immediately correct faulty conditions
Will need future field changes	1. Instruct the contractor to immediately correct faulty conditions
	2. Form specific ideas for field changes that will solve the problems
	3. Ask the resident engineer for analysis, advice, and approval of your proposed field changes

FIGURE 6 *Procedure for changing the TCP (22).*

Graham and Migletz *(27)* suggest that an annual work zone accident report be prepared by the state traffic engineer and contain the following items:

- The percentage of work zone accidents to total accidents, broken down by severity and roadway type;
- The percentage of change in accident rates from the before-construction to during-construction time periods, broken down by the construction roadway types;
- The number of various types of work zone accidents, including flagger involved, rear-end collision, construction-object collision, etc.;
- A summary of the short-term corrective actions that were made statewide;
- A summary of suggestions from districts for needed policy and procedural changes;
- For a selected sample of construction projects, a comparison of the number of reports coded as work zone accidents versus the number of accidents found when a request was made by location and date; and
- For a selected sample of construction projects, a determination of the number of accidents that were related to work activity.

States often collect accident data for use in liability suits. The Iowa policy on accident reporting follows *(28)*:

A. General

1. Prior to commencement of construction, the Resident Construction Engineer (RCE) for the Iowa DOT will notify in writing the appropriate Iowa State Patrol Post with a copy to the Department of Public Safety Communications Office serving that area. This correspondence will identify the location, construction dates, and other pertinent data. This data includes the names and phone numbers of responsible persons, both contractor and DOT, to be contacted in case of accident or other problems within the construction zone.

2. It is anticipated that the Iowa State Patrol, upon investigation of a construction site accident, finding immediate repairs by the Iowa DOT are necessary, will contact the nearest Department of Public Safety communication base station. They will in turn notify the local maintenance area supervisor. The area supervisor will assess the nature of any damage to DOT facilities and take necessary action. In the case of construction zone damage to traffic control devices or other items, the area supervisor will contact the RCE or designated representative. The RCE or representative will take whatever steps are necessary to contact the contractor's representative to take needed corrective action.

When the construction zone accident does not require immediate corrective action by DOT or contractor representatives, the investigating officers are to report the accident to the RCE within 12 hours.

B. Procedure

1. To meet the needs of the General Counsel Division in anticipation of litigation, when an accident occurs within a construction zone involving vehicles traveling through or across the project, the Resident Construction Engineer will complete Form No. 181300 Report of Investigation - Vehicle Accident. The report should include pictures, diagrams, weather conditions, and other pertinent information as appropriate. The report will be submitted to the Claims Manager, Bureau of Transportation Safety, within seven days from the date of the accident. If there are any other accident reports by other agencies such as the Highway Patrol, County Sheriff's Office, or City Police Department, a copy should be attached to Form 181300.

2. When the investigation has been completed by the Resident Construction Engineer's Office, the entire file shall be forwarded to the Central Office Transportation Safety Bureau.

CHAPTER SIX

FINDINGS AND CONCLUSIONS

The literature review and surveys of state agency practices provide a basis for identifying several trends in work zone traffic control. Although the TCP itself remains the central focus of this practice, accumulated experience demonstrates that opportunities for improvement are to be found in all four stages of the work zone traffic control management process: predesign planning, design, implementation, and revision.

PREDESIGN PLANNING

- Consistency in traffic control is enhanced when agencies define policies for TCP development in commonly encountered work zone situations.
- A team approach is most effective for TCP planning, bringing together personnel with the disciplinary expertise and local knowledge needed to ensure that traffic control strategy, sequence of construction, and other essential aspects of the project are adequately considered. Traffic control planning is a distinct area of practice that complements the range of design, construction, and operational experience that many agencies seek to provide their professional staff.
- Effective data collection prior to undertaking TCP design encompasses location information, work sequences, and current traffic statistics. The checklist developed for the Iowa *Road Design Manual* (included in Chapter 2 of this report) is a particularly useful guide to the types of data that should be available for TCP development.
- A standard set of references, instructions, and other background information on work zone traffic control contributes to TCP effectiveness. The California *Highway Design Manual* includes a useful list of items to consider in TCP development (see Chapter 3 of this report).
- A comprehensive set of "typicals"—i.e., prototypical designs and standards that may be adapted to specific project conditions—is an important resource and starting point for TCP development. Typicals are generally classified by work duration, work location, and highway type. State agencies have developed typicals that supplement the range now included in the MUTCD.
- Effective policies concerning pavement edge dropoffs consider traffic volumes, lateral distance from travel lane to edge of dropoff, duration of hazardous condition, and shape of the edge or slope of the dropoff.
- Recent research has identified factors that significantly influence safe work zone speed limits.

DESIGN

- TCP design typically is assigned to entry-level professional staff or experienced technicians.
- Site visits by TCP designers are a valuable means for improving TCP effectiveness. Such visits are useful not only during design, but also immediately after initial TCP implementation, after the TCP has been in effect for 1 to 2 weeks, and following introduction of substantial changes in the TCP.
- Major factors that shape the TCP include construction sequence and maintenance of traffic flow and highway capacity. The most generally effective TCPs are those designed to be flexible and focused on traffic management rather than focused on details of traffic control device placement or use.
- TCPs are typically reviewed by local, district, and central office personnel, including project and resident engineers, central office traffic and design engineers, district safety review teams, and district traffic engineers.

IMPLEMENTATION

- The project or resident engineer is most frequently designated the "responsible person" for work zone traffic and safety control. For large and complex construction projects, some states assign this role to a person concerned solely with traffic control. Some states specify that the construction contractor will designate a counterpart responsible person.
- Although most states will permit construction contractors to develop their own work zone traffic control management plans, few contractors typically choose to do so.
- Regular work zone inspections are generally required to ensure that the traffic controls have been implemented as detailed in the TCP. The Texas Inspectors Training Manual includes good examples of inspection scheduling guidelines, inspector guidance, and inspection reporting forms (see Chapter 4 of this report).

REVISION

- Changes in project design or construction sequencing, obvious safety deficiencies, and work zone traffic congestion are the most frequently cited causes for TCP revision. Most agencies authorize the project, resident, or construction engineer to make field changes. The Texas *Inspectors Training Manual* includes useful guidance on factors that may warrant changing the TCP (see Chapter 4 of this report).
- Some agencies use annual safety reviews to identify needs for change in TCP development practices. Internal memoranda, training seminars, and district meetings are the most frequently used means for communicating review results within the agency.
- Accident investigations and reports are used both to make immediate corrections on the project where an accident has occurred and to supplement data used for statewide analysis of TCP effectiveness.

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APPENDIX A

State Survey Questionnaire

Two surveys were conducted to determine current practice in development and implementation of TCPs. First, visits were made to six states to determine the people and procedures involved at each stage of the TCP development process. The six states visited were California, Florida, Iowa, New Mexico, Pennsylvania, and Texas. Results of these visits are reported throughout the body of this synthesis.

To obtain a wider representation of state practices, a second survey was mailed to the remaining 44 states. The survey was sent to 44 state traffic engineers; 36 (82 percent) surveys were returned. The survey form and results of the survey are shown in this appendix. States responding to the survey are shown in Table A-1. Summaries of written responses to questions 4, 14, 19, and 20 are given in Tables A-2 through A-5.

NCHRP Project 20-5 Topic 21-08

Development and Implementation of Traffic Control Plans for Highway Work Zones

Graham-Migletz Enterprises, Inc. (GME) is preparing a synthesis report for the National Cooperative Highway Research Program (NCHRP) on the above topic. The purpose of this project is to get an overview of current work zone traffic management processes. A major feature of work zone traffic control management is in the area of development and implementation of traffic control plans (TCPs).

We are surveying state traffic engineers to identify and report the wide range of practices being used today. We are requesting your help by asking that you or your representative complete the attached survey form comprised of yes/no, multiple choice, and fill-in-the-blank questions. It should take less than ten minutes to complete. Your consideration is greatly appreciated.

We want to learn how management strategies vary for different categories of work zones. An example would be the differences in traffic control for work zones of different duration. That is, how do the traffic controls for long-term, fixed-site construction zones differ from moving, and short-term, etc., operations such as maintenance or utility work? Five categories of work duration are presented below.

CATEGORIES OF WORK ZONE DURATION

1. Long-term stationary—work that occupies a location more than three days.
2. Intermediate-term stationary—work that occupies a location from overnight to three days.
3. Short-term stationary—daytime work that occupies a location from one to twelve hours.
4. Short duration—work that occupies a location up to one hour.
5. Mobile—work that moves along the roadway intermittently or continuously.

In addition, we want to know how your state uses on-site data to design, implement, and revise TCPs. Examples include constructability and phasing of the project and use of traffic engineering data such as volume, vehicle mix, pedestrians, accident experience, speeds, congestion, capacity, etc.

TABLE A-1

STATES RESPONDING TO SURVEY

Alabama	Kansas	New Hampshire	South Carolina
Arizona	Maine	New Jersey	South Dakota
Arkansas	Maryland	New York	Tennessee
Colorado	Massachusetts	North Carolina	Utah
Connecticut	Michigan	North Dakota	Vermont
Delaware	Mississippi	Ohio	Virginia
Georgia	Missouri	Oklahoma	West Virginia
Idaho	Nebraska	Oregon	Wisconsin
Illinois	Nevada	Rhode Island	Wyoming

TABLE A-2

RESPONSES ON WHEN TRAFFIC CONTROL IS CONSIDERED AND HOW THIS DIFFERS FOR SHORT-TERM PROJECTS

	Response	*Number of States*	*Percentage of Responses*
1.	There is no difference based on project duration	11	37.9
2.	Typicals or MUTCD standards are used for short-term projects	11	37.9
3.	Traffic control may be a large part of short-term project design	1	3.5
4.	Short-term project design is related to the time of day work is performed	1	3.5
5.	On short-term projects, traffic control is done after project design	2	6.9
6.	Traffic control design starts sooner for complex projects	3	10.3
	Total	29	100.0

TABLE A-3

FACTORS CONSIDERED IN DETERMINING LEVEL OF DETAIL NEEDED IN A TRAFFIC CONTROL PLAN

	Factor	*Number of Times Mentioned*
1.	Volumes and speeds	21
2.	Complexity—stage construction—impact on traffic	16
3.	Type, location, of duration of work	1
4.	Type of facility, functional classifications	8
5.	Capacity problems or constraints	4
6.	Detours involved	4
7.	Effect on business, schools, or political entity	3
8.	Grades or interchange spacing	3
9.	When typicals are not sufficient	3
10.	Safety concerns	2
11.	Traffic engineer's judgment	1
12.	Trucks	1

TABLE A-4

RESPONSES ON HOW INFORMATION ABOUT FIELD CHANGES ARE INCORPORATED INTO FUTURE TRAFFIC CONTROL PLAN DESIGNS

	Response	*Number of States*	*Percentage of Responses*
1.	Through memos and interdepartmental communications	20	57.1
2.	By formal team reviews	9	25.7
3.	Little feedback	4	11.5
4.	By review of old plans and plan changes	2	5.7
	Total	35	100.0

TABLE A-5

RESPONSES ON HOW TRAFFIC CONTROL PLAN MANAGEMENT DIFFERS FOR PROJECTS OF DIFFERENT DURATION

	Response	*Number of States*	*Percentage of Responses*
1.	No differences based on project duration	13	39.4
2.	Short-term projects are more often handled with typicals	7	21.2
3.	Traffic engineers more involved on long-term projects. Foremen handle short-term traffic control	6	18.2
4.	More devices are required for long-term, short-term receives less emphasis	4	12.1
5.	Typicals are designed to account for duration	3	9.1
	Total	33	100.0

NCHRP PROJECT 20-5
Topic 21-08
Development and Implementation of Traffic Control Plans for Highway Work Zones

Survey Form

State 36 State Responses: Table A-1 Person Responding ________

Telephone Number ________

Check all answers that apply, or fill in the blanks, as appropriate.

1. Is there a section in your state's design guide or design manual that deals specifically with design of traffic control plans?

 _21_ Yes _15_ No

2. Is there a section in your state's construction or maintenance traffic control manual that deals specifically with design of traffic control plans?

 _20_ Yes _16_ No

3. In what department do initial designs of TCPs usually begin?

 _1_ Planning _19_ Design _2_ Construction
 _16_ Other (specify) 13/16 Traffic Engineering;IL,NJ-Planning and Design; WY-Input from Field Construction

4. At what point in project design is traffic control considered?

 _2_ Before other aspects such as staging and sequencing.
 _28_ At the same time as other portions.
 _5_ After other aspects of project design have been completed.

 How does this differ for short-term projects?

 30 Comments: Table A-2

5. What data is collected and analyzed prior to designing TCPs?

 _36_ Traffic volumes _14_ Accident data _30_ Speeds
 _23_ Vehicle mix _15_ Pedestrian use
 _5_ Police experience in the area near the construction or maintenance project.
 _15_ Other (specify) ________

6. Are TCPs designed:

 _27_ At the central office? _18_ At the district offices? _4_ By the local offices?
 _8_ Other

 If other, please specify: ________

7. Are contractors allowed to develop their own TCPs for a project?

 _30_ Yes _6_ No

8. Do contractors who develop their own TCPs do so after the contract is let to bid?

 _31_ Yes _5_ No ____ Varies

9. If they are allowed, how often do contractors actually develop TCPs?

 _2_ Never
 _15_ Rarely
 _15_ Occasionally
 _4_ Often

10. Who prepares the plan for the contractor?

 _11_ Contractor's Engineer
 _18_ Contractor's Responsible Person
 _7_ Traffic Control Subcontractor
 _10_ Other________

11. Within the highway agency, who is normally assigned to be a "Responsible Person"(as defined by the MUTCD)?

 20 Project Engineer
 18 Resident Engineer
 13 Specially assigned TCP inspectors
 13 Other (specify) ________

12. Is the contractor also required to hire a specific person to inspect and maintain traffic control?

 24 Yes 12 No

13. Is certification or other special training required for the contractor's responsible person?

 7 Yes 29 No

14. How do you decide the level of detail for a TCP? In other words, what factors most often determine that a TCP will require a large amount of effort?

 36 Comments: Table A-3

15. Are TCPs ever designed especially for an intermediate-term, short-term,short duration or mobile project?

 35 Yes 1 No

16. Do TCP designers learn of problems that may occur in the field with the TCPs that they have designed?

 31 Yes 5 No

17. Who can authorize field changes to TCPs?

 15 Project Engineer 12 District Traffic Engineer 17 Resident Engineer
 19 Construction Engineer
Any Others? 13

18. What is usually the cause of a field change to a TCP?

 13 Public complaints 19 Congestion in work zone
 19 Obviously deficient safety concerns
 31 Unexpected changes in design factors such as staging and sequencing, layout, etc.
Any others? 9

19. How is information about field changes incorporated into future TCP designs?

 35 Comments: See Table A-4

20. How does TCP management differ from projects of different duration (long-term, short-term, etc) operations?

 33 Comments: See Table A-5

21. What percentage of projects have specifically-designed TCPs?

 4 <25% 5 25-50% 8 50-75% 19 >75%

22. Are TCP developers in your state required to be degreed engineers?

 8 Yes 28 No

We also ask that you please furnish copies of any manuals (or chapters from manuals), policies, directives, etc. from your state that refer to design of traffic control plans.

Once again, we thank you for your help in completing this project.

Please mail completed form to:
Graham-Migletz Enterprises, Inc.
Topic 21-08
P.O. Box 348
Independence, Missouri 64050

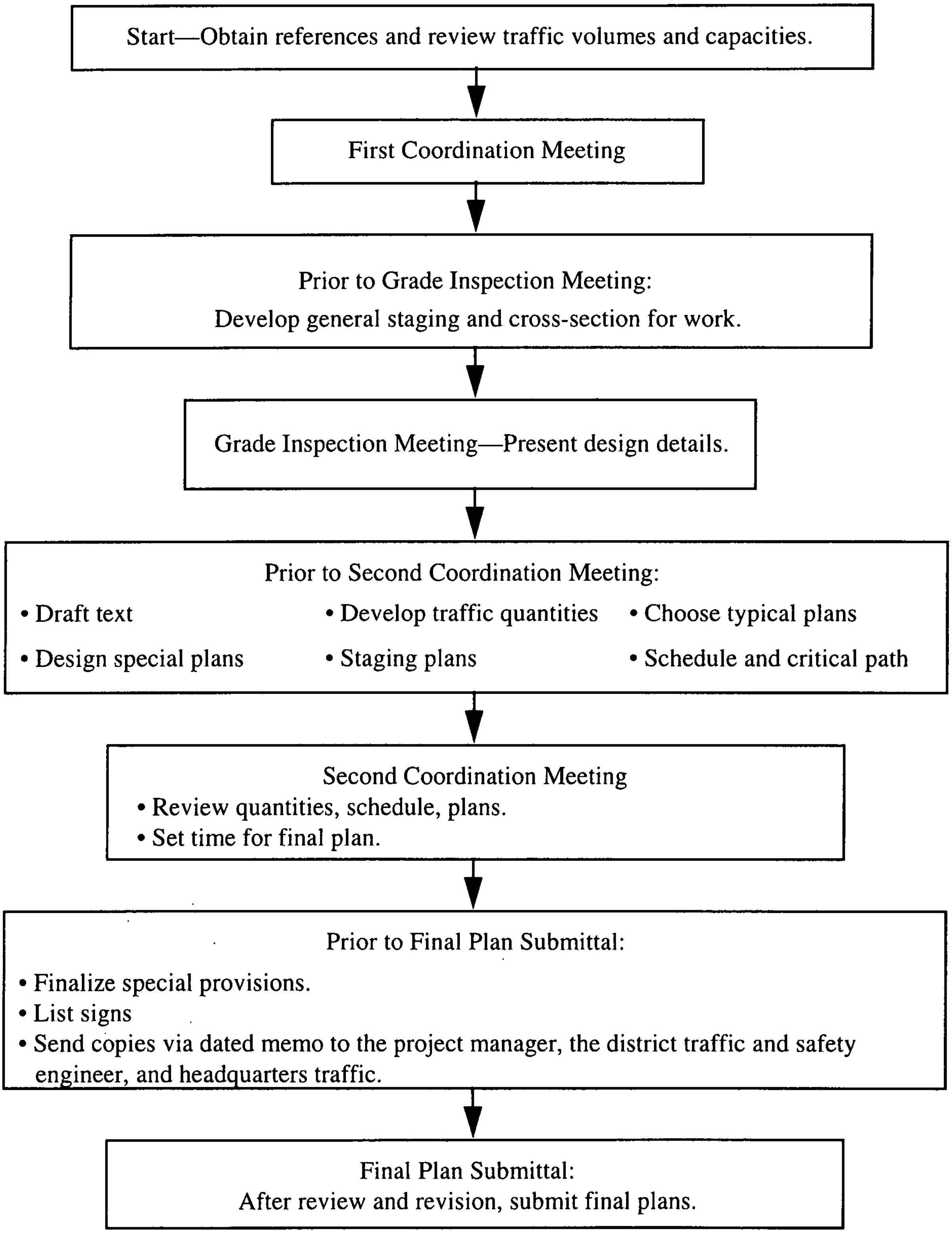
APPENDIX B

MANUALS AND POLICIES RELATED TO TCP DEVELOPMENT OTHER THAN MUTCD

State	Manual	Policy
California	Construction Manual	Section 2-30—Traffic, Guideline for Traffic Control Plans
	Highway Design Manual	Section 110.6—Traffic Control
Florida	Roadway Plans Preparation Manual	Chapter 10—Work Zone Traffic Control
Iowa	Road Design Manual	Chapter 12—Traffic Control
	Construction Manual	Section 5.10—Traffic Safety in Construction Zones
New Mexico	Construction Manual	Division 700—Traffic Control Devices
Pennsylvania	Operations Manual	Pub. 54—Work Zone Traffic Control
		Pub. 203—Work Zone Traffic Control
Texas	Design Training Manual	X. Traffic Design
	Inspectors Training Manual	

APPENDIX C

Michigan Department of Transportation
Process for Consultants Preparing Traffic Control Plans



Appendix D

Wisconsin Department of Transportation Maintenance Work Zone Policy

State Highway Maintenance Manual:	<u>P O L I C Y</u> 51.20
Effective: January 1, 1991	50.00 GENERAL OPERATIONS 51.00 TRAFFIC SAFETY 51.20 MAINTENANCE WORK ZONES
Supersedes: Initial Issue	
By: State Maintenance Engineer for Highways	

A. <u>General Policy</u>

All highway maintenance and other related operations on or adjacent to roadways open to traffic shall be performed in accordance with the provisions of this document.

B. <u>Maintenance Traffic Control Policy</u>

1. All stationary daytime maintenance operations shall have the following advanced signing:

   a. One traffic warning sign for work areas beyond the roadbed (vehicle off shoulder and work off shoulder).

   b. Two traffic warning signs for work areas on the shoulder (vehicle on shoulder and work off or on shoulder).

   c. Three traffic warning signs for work areas on the pavement (one-lane operations).

2. The accompanying standard details for "Typical Daytime Stationary Maintenance Work Zone Traffic Control" (numbered 1 thru 6) shall also be consulted.

3. Deviations from the above policy for traffic control shall be done in accordance with the latest revision of Part IV, Traffic Controls for Construction and Maintenance Operations, of the Wisconsin Manual of Uniform Traffic Control Devices. Such deviations shall be recorded in a journal or other written documents available upon request.

C. <u>Traffic Control Devices</u>

All arrow boards, barricades, drums, lights, signs, cones and other traffic control equipment shall conform in all ways to section 643 of the current Standard Specifications for Road and Bridge Construction. This equipment shall also be clean, in good working condition and properly reflective.

D. <u>Maintaining Traffic</u>

The portions of the roadway used by automobiles shall be maintained in such a way as to allow for reasonable traffic flow. Temporary approaches, crossings and intersections with roads and driveways shall be maintained in safe and usable condition.

E. <u>Sign Paddle</u>

The sign paddle shall be the primary hand-signalling device. Flags shall be used in emergency situations only.

F. <u>Hours of Work</u>

Except in emergency situations, all maintenance work or other operations shall be performed so that traffic control devices are set up and removed during daylight hours and preferably during non-peak traffic hours.

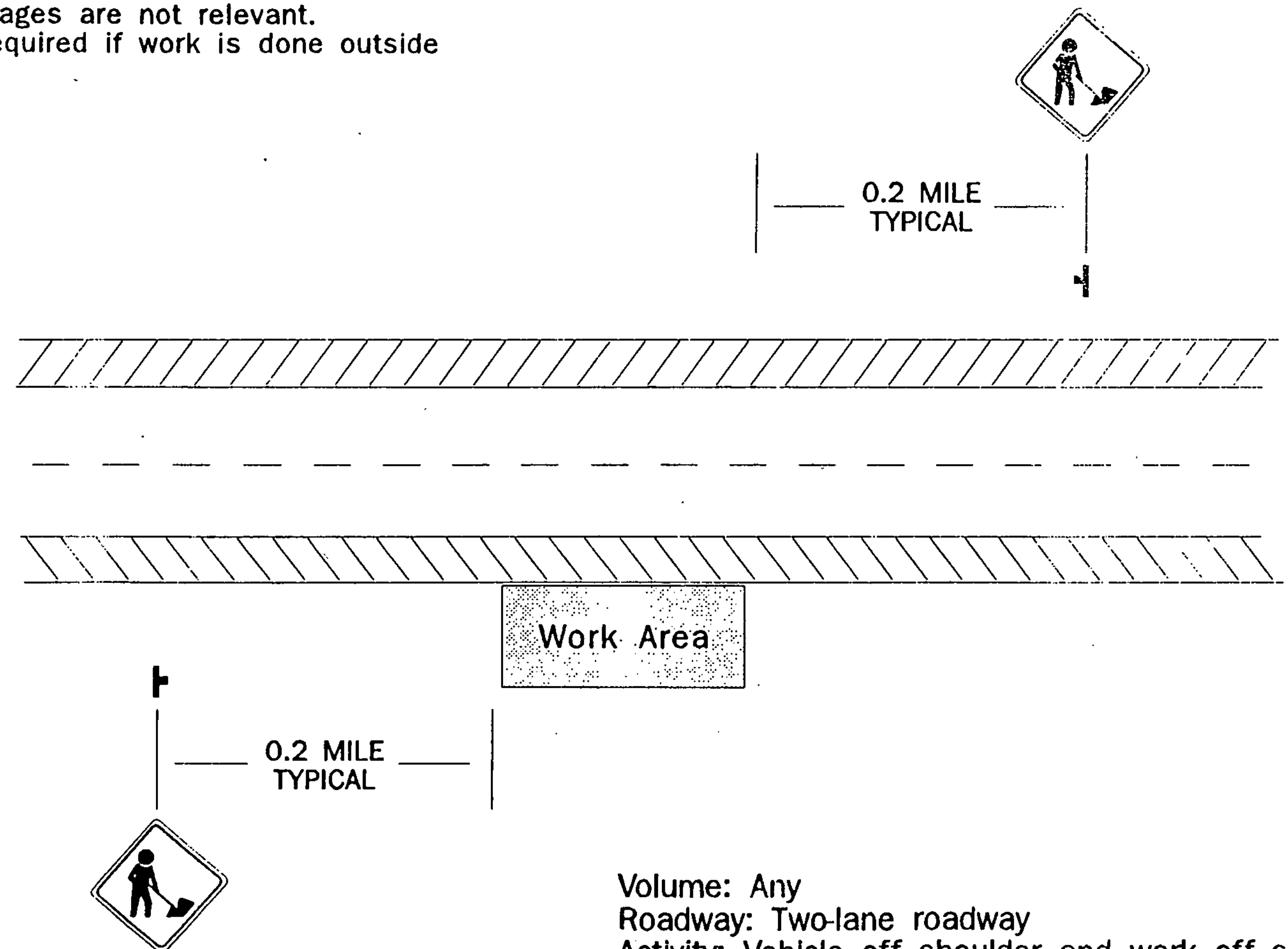
G. <u>Suspension of Operations</u>

The Area Maintenance Supervisor shall have the authority to suspend all work and remove all traffic control devices if operations are not being performed in accordance with this policy.

GENERAL NOTES

1. Flashers on vehicles shall be activated at all times.
2. All signs shall be 48"X48".
3. If the sight distance or terrain suggest a more logical placement of signs to warn motorists, variation in placement is allowed.
4. All signs shall be removed or covered when workers or workers' vehicles are not at the location or when the signs' messages are not relevant.
5. Signing is not required if work is done outside the clear zone.

TYPICAL DAYTIME STATIONARY MAINTENANCE
WORK ZONE TRAFFIC CONTROL
SHEET 1 OF 6



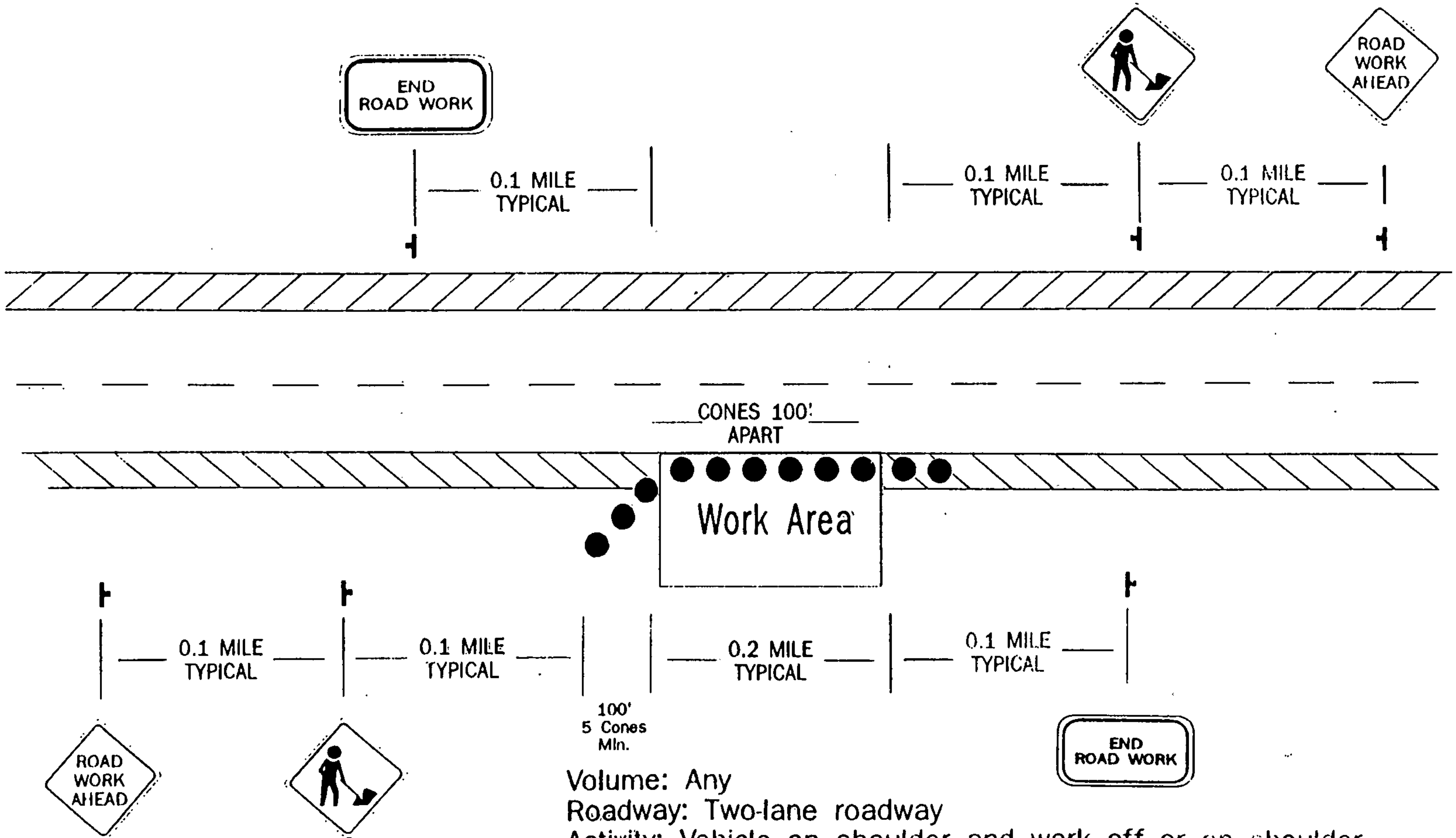
Volume: Any
Roadway: Two-lane roadway
Activity: Vehicle off shoulder and work off shoulder

FIGURE D-1 *Two-lane roadway, vehicle and work off shoulder.*

GENERAL NOTES

1. Flashers on vehicles shall be activated at all times.
2. All signs shall be 48"X48".
3. If the sight distance or terrain suggest a more logical placement of signs to warn motorists, variation in placement is allowed.
4. All signs shall be removed or covered when workers or workers' vehicles are not at the location or when the signs' messages are not relevant.

TYPICAL DAYTIME STATIONARY MAINTENANCE WORK ZONE TRAFFIC CONTROL
SHEET 2 OF 6



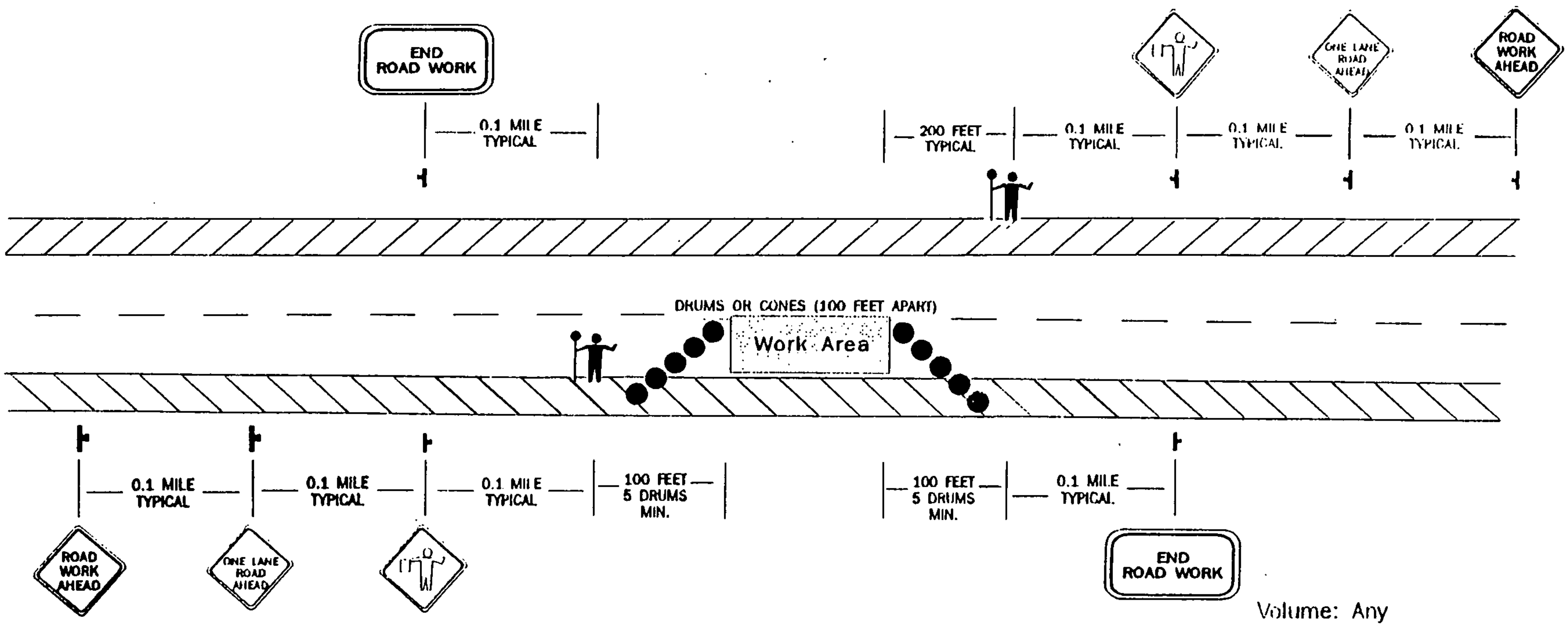
Volume: Any
Roadway: Two-lane roadway
Activity: Vehicle on shoulder and work off or on shoulder

FIGURE D-2 *Two-lane roadway, vehicle on shoulder, work off or on shoulder.*

GENERAL NOTES

1. Flashers on vehicles shall be activated at all times.
2. All signs shall be 48"X48".
3. If the sight distance or terrain suggest a more logical placement of signs to warn motorists, variation in placement is allowed.
4. The taper should extend across the shoulder unless doing so would greatly conflict with operations.
5. All signs shall be removed or covered when workers or workers' vehicles are not at the location or when the signs' messages are not relevant.
6. A STOP/SLOW paddle is to be used instead of a flag.

TYPICAL DAYTIME STATIONARY MAINTENANCE WORK ZONE TRAFFIC CONTROL
SHEET 3 OF 6



Volume: Any
Roadway: Two-lane roadway
Activity: One-lane operation

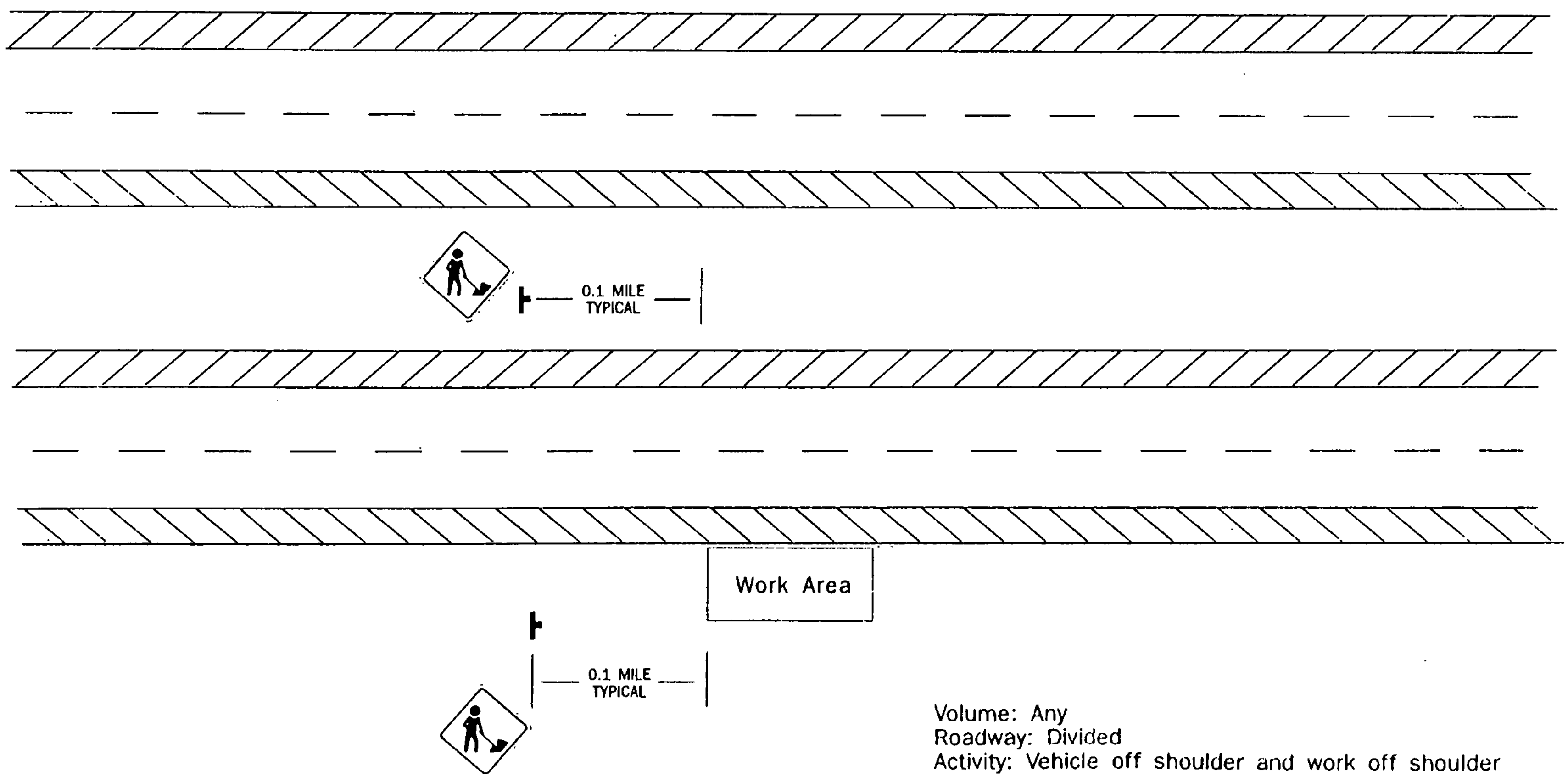
Flag Person

FIGURE D-3 *Two-lane roadway, one-lane operation.*

GENERAL NOTES

1. Flashers on vehicles shall be activated at all times.
2. All signs shall be 48"X48".
3. If the sight distance or terrain suggest a more logical placement of signs to warn motorists, variation in placement is allowed.
4. All signs shall be removed or covered when workers or workers' vehicles are not at the location or when the signs' messages are not relevant.
5. When the work area is in the median, signs must be on both roadways.
6. Signing is not required if the work area is outside the clear zone.

TYPICAL DAYTIME STATIONARY MAINTENANCE
WORK ZONE TRAFFIC CONTROL
SHEET 4 OF 6



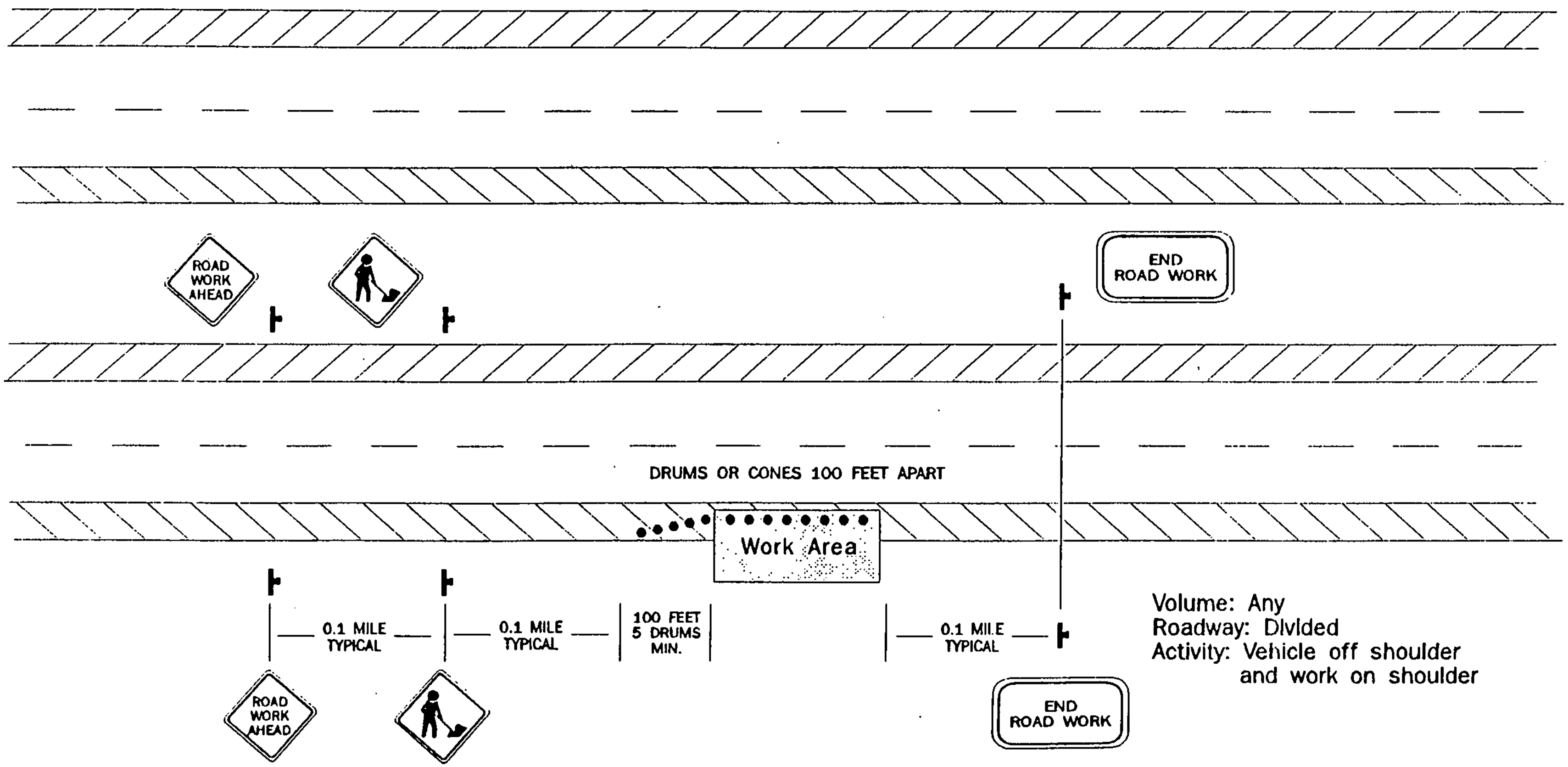
Volume: Any
Roadway: Divided
Activity: Vehicle off shoulder and work off shoulder

FIGURE D-4 *Divided roadway, vehicle and work off shoulder.*

GENERAL NOTES

1. Flashers on vehicles shall be activated at all times.
2. All signs shall be 48"X48".
3. If the sight distance or terrain suggest a more logical placement of signs to warn motorists, variation in placement is allowed.
4. All signs shall be removed or covered when workers or workers' vehicles are not at the location or when the signs' messages are not relevant.
5. Cones shall be spaced 100 feet adjacnet to an open traffic lane and shall not project into that lane.
6. When the work area is in the median, signs must be placed on both roadways.

TYPICAL DAYTIME STATIONARY MAINTENANCE WORK ZONE TRAFFIC CONTROL
SHEET 5 OF 6



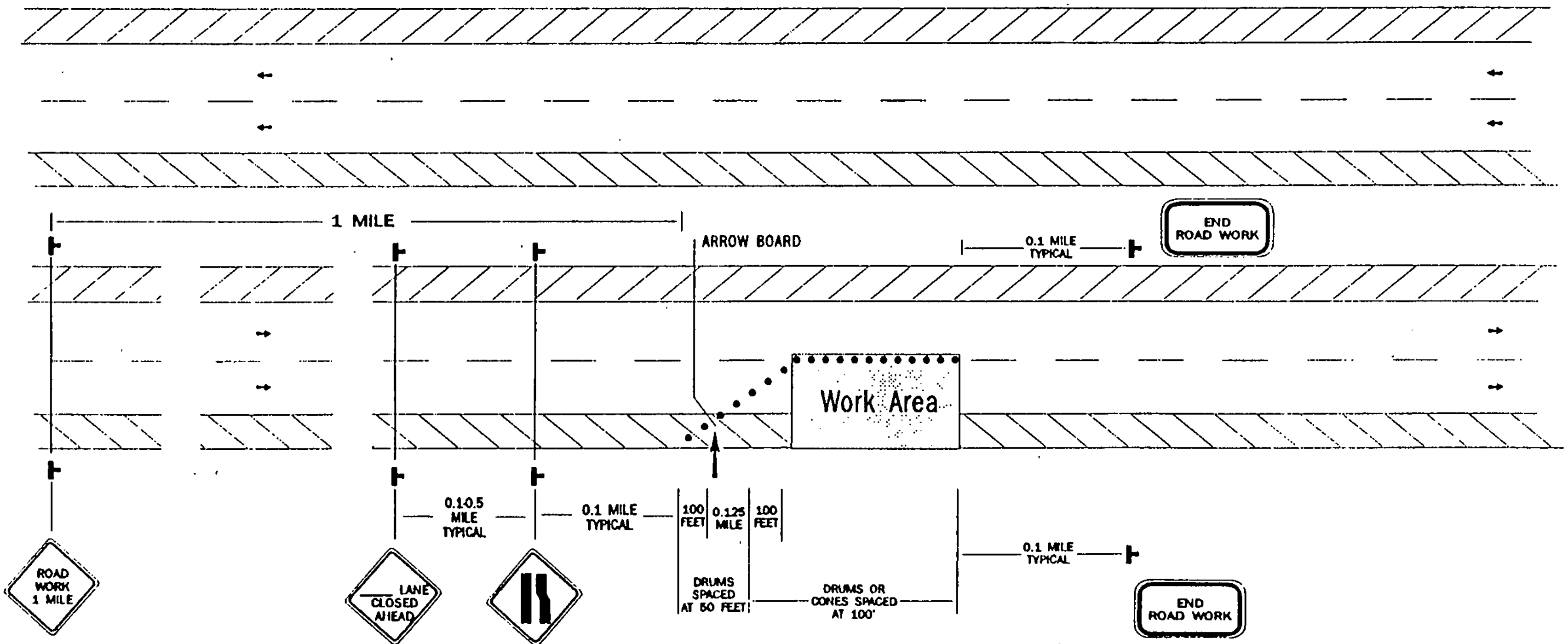
Volume: Any
Roadway: Divided
Activity: Vehicle off shoulder and work on shoulder

FIGURE D-5 *Divided roadway, vehicle off shoulder, work on shoulder.*

GENERAL NOTES

1. Flashers on vehicles shall be activated at all times.
2. All signs shall be 48"X48".
3. If the sight distance or terrain suggest a more logical placement of signs to warn motorists, variation in placement is allowed.
4. Channeling devices placed adjacent to the work area shall be pulled back from the travel lane when work is not in progress.
5. All lane closure signs shall be removed or covered and all arrowboards and devices removed beyond the shoulder when the work is not in progress and the lane is restored to a safe operating condition.
6. Channelizing devices shall be spaced at 100 feet adjacent to an open traffic lane and should not project into that lane.

TYPICAL DAYTIME STATIONARY MAINTENANCE
WORK ZONE TRAFFIC CONTROL
SHEET 6 OF 6

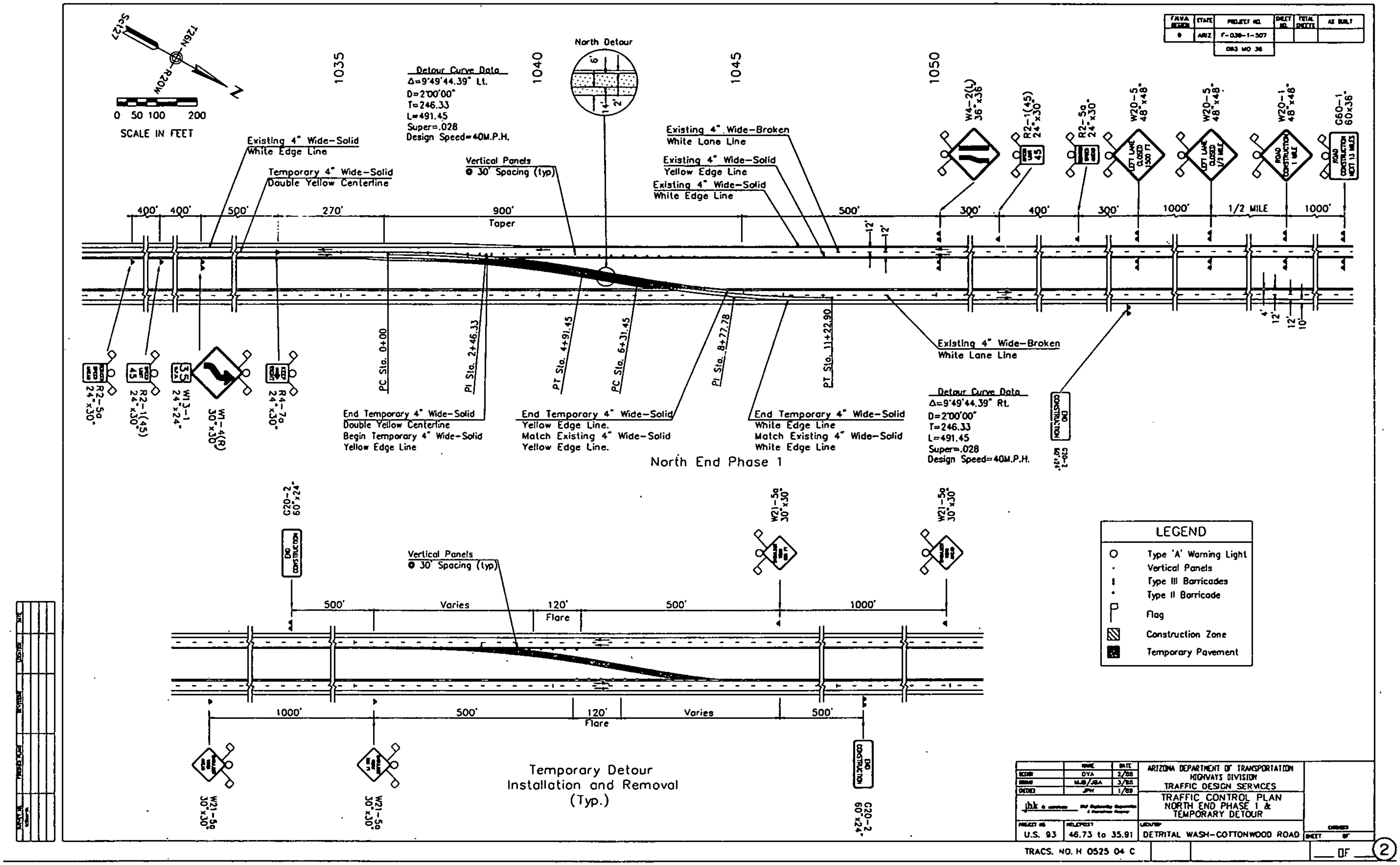


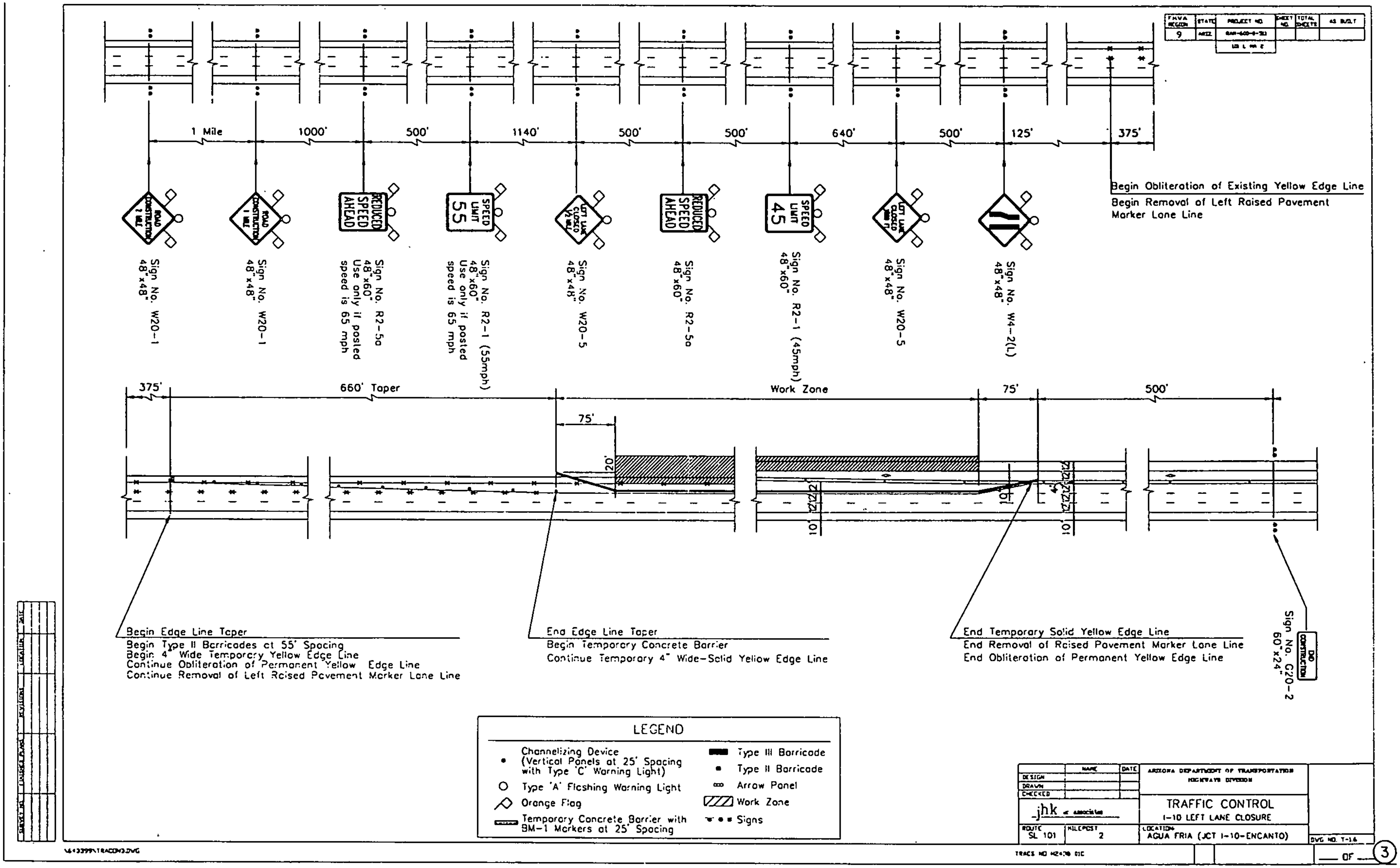
Volume: Any
Roadway: Divided
Activity: Lane closure on multi-lane highway

FIGURE D-6 *Divided roadway, lane closure on multilane highway.*

Appendix E

Traffic Control Plan Used by Arizona Department of Transportation





FHWA REGION 9
STATE ARIZ
1 Mile
1000'
500'
1140'
500'
500'
640'
500'
125'
375'
Begin Obliteration of Existing Yellow Edge Line
Begin Removal of Left Raised Pavement Marker Lane Line
ROAD CONSTRUCTION 1 MILE
REDUCED SPEED AHEAD
SPEED LIMIT 55
SPEED LIMIT 45
Sign No. W20-1 48"x48"
Sign No. W20-1 48"x48"
Sign No. R2-5a 48"x60" Use only if posted speed is 65 mph
Sign No. R2-1 (55mph) 48"x60" Use only if posted speed is 65 mph
Sign No. W20-5 48"x48"
Sign No. R2-5a 48"x60"
Sign No. R2-1 (45mph) 48"x60"
Sign No. W20-5 48"x48"
Sign No. W4-2(L) 48"x48"
375'
660' Taper
Work Zone
75'
500'
75'
20'
10'
Begin Edge Line Taper
Begin Type II Barricades at 55' Spacing
Begin 4" Wide Temporary Yellow Edge Line
Continue Obliteration of Permanent Yellow Edge Line
Continue Removal of Left Raised Pavement Marker Lane Line
End Edge Line Taper
Begin Temporary Concrete Barrier
Continue Temporary 4" Wide-Solid Yellow Edge Line
End Temporary Solid Yellow Edge Line
End Removal of Raised Pavement Marker Lane Line
End Obliteration of Permanent Yellow Edge Line
END CONSTRUCTION
Sign No. G20-2 60"x24"
LEGEND
Channelizing Device (Vertical Panels at 25' Spacing with Type 'C' Warning Light)
Type 'A' Flashing Warning Light
Orange Flag
Temporary Concrete Barrier with BM-1 Markers at 25' Spacing
Type III Barricade
Type II Barricade
Arrow Panel
Work Zone
Signs
DESIGN
DRAWN
CHECKED
NAME
DATE
ARIZONA DEPARTMENT OF TRANSPORTATION HIGHWAYS DIVISION
jhk & associates
TRAFFIC CONTROL
I-10 LEFT LANE CLOSURE
ROUTE SL 101
MILEPOST 2
LOCATION AGUA FRIA (JCT I-10-ENCANTO)
DWG NO. T-16
OF 3

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