FIELD EVALUATION OF SELECTED DELINEATION TREATMENTS ON TWO-LANE RURAL HIGHWAYS

FINAL REPORT

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Foreword

This report presents a traffic engineering study that investigated the effects of changes in delineation treatments on traffic operations as indicated by speed and lateral placement measures. A regression analysis was used to correlate delineation-related accident potential to the traffic performance measures. The safety effectiveness of 21 unique delineation systems was then evaluated at eight locations. Recommendations are made for improving the safety effectiveness and/or reducing the cost of conventional delineation treatments now in use.

The report describes the results of a study entitled "Field Evaluation of Selected Delineation Treatments" conducted for the Federal Highway Administration, Office of Research, Washington, D.C. under Contract DOT-FH-11-8834. This final report covers the period of research from June 30, 1975 to October 31, 1977.

Sufficient copies of the report are being distributed to provide a minimum of two copies to each FHWA Regional and Division office. In addition copies of an executive summary are being distributed to both FHWA Regional and Division offices and to State highway agencies.

Charles F. Scheffey
Director, Office of Research
Federal Highway Administration

NOTICE

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16. Abstract The objectives of this research project were to establish relationships between traffic performance and accident probability on two-lane rural highways; to develop an experimental design for field testing the effectiveness of conventional and novel delineation treatments; to evaluate the effect of selected delineation treatments on traffic performance and associated accident probability; and to make recommendations for the design and use of delineation treatments. In the first phase of study, regression analysis was used to correlate delineation-related accident potential to a few systematically derived speed and lateral placement measures. In the second phase of study, additional accident and traffic performance data were collected to test the correlation models and to evaluate the safety effectiveness of 21 unique delineation systems.

Chapters of this Final Technical Report cover the conceptual planning, traffic performance studies, accident analyses, and regression modeling of Phase I, plus the experimental design, field studies, model checking, and treatment effectiveness evaluations of Phase II. The two most sensitive indicators of hazard were found to be off-center driving and longitudinal changes in lateral placement variance. Recommendations are offered with respect to a generalized delineation evaluation methodology, as well as for the immediate implementation on two-lane rural highways of a 10:30 broken centerline pattern, narrower edgelines, and the selective use of raised pavement markers and post delineators.

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Rural Delineation, Novel Delineation Treatments, Accidents, Traffic Performance Measures, Speed, Lateral Placement

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CHAPTER I

EXECUTIVE SUMMARY

INTRODUCTION

Roadway delineation practices have developed over the years primarily as a result of field experience and limited subjective evaluation by engineering and maintenance personnel. Relatively few in-depth studies have been conducted, and most have dealt with limited aspects of specific delineation treatments. For instance, new devices such as raised pavement markers have undergone intensive materials and maintenance testing, but their best use as part of an overall system for roadway delineation has received little attention. Some before-and-after accident studies have been made, but they require lengthy time periods to conduct and have generally addressed either isolated spot-location improvements or such an extensive mileage of diverse highway features so as to cast doubt on true cause-and-effect relationships. Limited diagnostic field tests have been run with teams of engineers, police, and lay drivers, but the results are sometimes difficult to reconcile with serious questions of cost effectiveness.

Also subject to difficulty in interpretation are the findings of studies which have utilized traffic performance measures, such as speed and lateral placement, as the evaluation parameters. A conceptual argument can be posed that certain accident types are due to one or more performance measures exceeding limits dictated by the highway design or adjacent traffic. The potential for this occurence should be reflected in speed and placement samples gathered for a large number of free-flowing vehicles. For instance, the further off-center the average driver operates in his lane, or the more that successive drivers deviate from the average position, the more likely that a sideswipe or run-off-road accident will occur. A serious problem has usually developed, however, in moving from this type of intuitive analysis to the point where intuition is confirmed through an actual mathematical correlation with accident history. Such a correlation, if carefully developed and validated, would permit traffic engineers to evaluate potentially more cost-effective delineation treatments without having to collect before-and-after accident data over a multi-year time period.

OBJECTIVES AND SCOPE OF STUDY

In an effort to develop surrogate safety relationships and demonstrate their usefulness in evaluating delineation treatments, the FHWA in 1975 initiated the two-phase research study reported herein. The basic objectives of the research were:

- To establish relationships between traffic performance and accident probability on two-lane rural highways.

- To develop an experimental design for field testing the effectiveness of conventional and novel delineation treatments.

- To evaluate the effect of selected delineation treatments on traffic performance and associated accident probability.

- To make recommendations for the design and use of delineation treatments.

The research contract was divided into two phases: Phase I addressed the first two objectives, and Phase II addressed the latter two objectives.

Phase I consisted of four major research tasks. The first task covered the entire design and conduct of the field studies necessary to establish an independent-variable data base for accident-probability modeling. Candidate independent variables were sampled at 32 study sites and included basic geometric and traffic volume characteristics as well as speed and lateral placement at critical points on the horizontal alignment. The second task involved the collection and processing of accident data for the sections of highway within which traffic performance was sampled, plus the all-important regression modeling (with accident rate on the left side of the equation and roadway/traffic characteristics on the right side).

The third and fourth tasks required the development of an experimental design for Phase II. Surveys were conducted of State Traffic Engineers, independent researchers, and project staff in order to identify and prioritize several conventional and novel delineation treatments for evaluation. Plans laid for site selection, data collection, and data interpretation took full advantage of the field experiences and analytical findings of Phase I.

Phase II included three research tasks. The first task called for the selection of nine sites according to the criteria established in Phase I, the staged installation of three or four experimental treatments at each site, and collection of traffic performance data during each stage. In the second task, the field data were reduced to the statistics found in Phase I to be indicative of delineation-related driving hazard, and the predicted safety effectiveness of the various novel treatments was compared to that of a conventional centerline and edgeline system. Finally, in the third task, policy recommendations were developed from the effectiveness evaluations, and a generalized field evaluation methodology was suggested.

PHASE I TRAFFIC PERFORMANCE STUDIES

The experimental design for the first phase field studies was based upon a combination of precedents established in related research activities, a review of previously documented relationships between traffic flow characteristics and safety, a conceptualization of the vehicular movements most commonly preceding accidents in various rural highway situations, and certain statistical sample-size requirements.

Speed and lateral placement data for use in accident-probability modeling were collected at 32 study sites in six eastern states. All sites were on two-lane bidirectional roadways in the low to moderate volume range, generally having a tangent, winding, or isolated-curve type of alignment. At each site, a minimum sample of 100 free-flowing observations was obtained during both daylight and darkness in dry weather.

Analysis of the traffic performance data revealed that the mean and variance of speed did not vary significantly along the various types of horizontal alignment, nor between day and night visibility conditions. While motorists were found to maintain a reasonably uniform speed over most sections of level highway, the same tendency did not hold for lateral placement. The amount of change in placement appears to have been most strongly influenced by geometrics, and to some extent, delineation.

A STRATEGY FOR PREDICTING ACCIDENT POTENTIAL

The general hypothesis to be studied was that each of several traffic performance measures and geometric variables could be used to independently predict a portion of the accident potential. The traffic performance measures would indicate the manner in which drivers traverse a given section of roadway, and the geometric variables would in effect define the available factor of safety inherent in the roadway design. Extreme values of traffic performance measures in combination with a limited factor of safety would be expected to result in an above-average accident rate.

In addition to the basic distributional statistics of speed and lateral placement, a number of other traffic performance measures were derived for the accident-probability modeling effort. These were generally arithmetic functions of the mean or variance statistics, normalized by average daily traffic volume, shoulder width, or width of the traveled lane.

Accident data were obtained for each study site for several of the years during which the existing delineation was present. Data were always based on multiples of 12-month periods in order to avoid introducing possible seasonal biases. In determining accident rates for the continuous tangent and winding situations, all accidents occurring over the entire section length (usually 3-5 miles or 4.8-8.1 km) were included. For isolated curves, accidents occuring within 750 feet (229 metres) of the points of curvature were included in the data base.

To improve the likelihood of developing a valid accident-probability model, efforts were focused on that subset of all accidents which occurred under essentially the same operating conditions as those present during the collection of traffic performance data. Specifically, the strongest correlation was expected for delineation-related, non-intersection accidents occurring on dry pavement—stratified by day versus night. Delineation-related accidents consisted of those types whose frequency might be directly affected by the quantity and quality of formal delineation available.

DEVELOPMENT AND EVALUATION OF MODELS

Utilizing stepwise multiple linear regression, attempts to model accident experience for a combined tangent/winding roadway situation proved quite successful for dry nighttime operating conditions. A family of four models (or equations) were developed for subsequent evaluation, ranging in size from two independent variables to five.

The two most explanatory variables (i.e., the first two to enter the regression and the ones forming the so-called two-variable model) are defined as follows:

- Centrality Index — Describing the degree to which the average driver operates off-center in the delineated lane, this measure accounts for lane width and vehicle types sampled as well as mean lateral placement.

- Difference in Placement Variances — This measure is the arithmetic difference between the lateral placement variances sampled independently at two critical points on a roadway's horizontal alignment, normalized (or divided) by lane width.

Three-, four-, and five-variable models were created with the stepwise addition of independent variables representing the skewness of the speed distribution, the roadway width, and the shoulder width, respectively.

The two-variable model and the five-variable model were selected for closer scrutiny. While the latter model was able to explain about 80 percent of the accident rate variance in the sample at a 95 percent confidence level (i.e., $R^2 = 0.80$), the much simpler two-variable model provided a Phase I data fit nearly as good by explaining 66 percent of the sample variance ($R^2 = 0.66$). The respective standard errors of the estimate were 1.33 and 1.61 accidents per million vehicle-miles.

It is important to note that the models deal only with the expected level of delineation-related, non-intersection accidents occurring during hours of darkness and on dry pavements. Thus, none of the models should be considered a "black box" capable of accurately predicting the overall accident rate for any particular section of rural highway. Instead, their more relevant value is that they add credibility to the traffic performance measures previously studied solely on the basis of intuition and judgment.

A limited statistical check of the Phase I accident-probability models was made using a portion of the independent Phase II data base. This check required the collection and analysis of both accident data and traffic performance data associated with the "base condition" delineation system historically present. The predictive power of each of the models was evaluated by inputting the appropriate traffic performance statistics and comparing predicted accident rate to actual accident rate. It was found that for a rather minimal sacrifice in Phase I data fit (i.e., $R^2 = 0.66$ versus $R^2 = 0.80$), the two-variable model produced much better agreement with the selected Phase II data than did the more complex five-variable model. Hence, the two-variable model was adopted as one of several tools for evaluating the balance of the second phase field data for the tangent and winding sites.

A statistically significant accident-probability model was not developed for isolated horizontal curves, daylight operation, nor adverse weather conditions. However, it would appear reasonable to assume that the same types of traffic performance measures could be considered as before-and-after effectiveness indicators under other geometrically similar test conditions. Those experimental delineation treatments resulting in statistically significant and intuitively beneficial changes in these indicators could be judged more conducive to traffic safety than the base treatments to which they are compared.

PHASE II FIELD STUDIES

A literature search and a survey of professional traffic engineers generated a list of 38 delineation treatments for possible inclusion in the Phase II experimental design. Each treatment was supposed to offer likely improvements in traffic performance and safety at approximately the same costs as current techniques, or current levels of traffic performance and safety at reduced costs. A systematic ranking by the project staff, together with the preferences expressed by the state and Federal-level traffic engineers surveyed, lead to the selection of 12 treatments for evaluation in Phase II of the project. As shown in Table 1, these treatments encompassed pavement markings (reduced stripe-to-gap centerline, narrower striping, selected use of edgelines, etc.), raised pavement markers (as a supplement to or replacement for paint striping), and post-mounted delineators (optional spacing).

The 12 experimental treatments were then combined to form total systems achievable by logical delineation augmentations. A tradeoff was developed between the analytical advantages of minimizing the number of study sites and the concurrent need for efficiently scheduling treatment installation, driver acclimation periods, and data collection. In the Phase II experimental design process, plans were developed for evaluating traffic performance for three or four different delineation levels at each of nine field study sites. By general type of horizontal alignment, these sites included five tangent sections, two winding sections, and two isolated curves.

Table 1. Conceptual treatment comparisons selected for phase II testing.

Experimental Delineation Treatment[1]	Base Delineation Treatment [1]	Research Priority Ranking[2]
Reduced stripe-to-gap ratio for centerlines and lanelines	Standard stripe-to-gap ratio of 3:5	1½
Single solid stripe as centerline where passing is prohibited	Double striping	1½
RPM's as *replacement* for painted centerline or lanelines	Paint stripes only	3½
Substantially variant spacing of PMD's (i.e., greater than 500 ft.)	Traditional close spacing of about 200 ft.	3½
Narrower striping for some centerlines, lanelines, and edgelines	Standard 4- to 6-inch wide striping	5
Continuous edgelines on *narrow* roads (< 22 ft.)	Centerline only	6
RPM's as *supplement* to painted centerline or lanelines	Paint stripes only	7
PMD's just on curved sections of roadway	Centerline only	9½
PMD's just on curved sections of roadway	Centerline with continuous edgelines	12
RPM's just on curved sections of roadway	Standard paint striping only	13
RPM's as *supplement* to painted edgeline	Standard painted edgeline	14
Continuous PMD's as *supplement* to edgelines	Standard continuous edgelines	20½

[1] RPM = raised pavement marker and PMD = post-mounted delineator; 1 ft. = 0.305 m. and 1 in. = 2.54 cm.

[2] Among 38 candidate comparisons

Using an improved "Z-trap" method of roadway instrumentation, speed and lateral placement were monitored for 32 combinations of study site and delineation system. In each case, 100-150 vehicles were observed under both day and night visibility conditions, and for most of the raised-pavement-marker and post-delineator treatments at two Maine Facility tangent sites, wet-weather data were also obtained. Two relative durations of driver acclimation were examined at the Maine Facility and for post-delineator treatments at two isolated horizontal curves located elsewhere.

The traffic performance data were processed with computer software developed in Phase I of the project. Additionally, a new post-processor program was written to summarize the more important measures and test for statistically significant differences between various treatments and operating conditions.

RECOMMENDED DELINEATION DEPLOYMENT PRACTICES

The objectivity and comprehensiveness of the delineation evaluations performed in this research project allow recommended revisions to practice to be stated with a fair degree of confidence. This section reviews current estimates of relative installation costs; reveals which delineation systems provided a better overall performance than existing standard systems; and lastly, recommends the immediate implementation, further research, or cessation of research of the treatments evaluated herein.

Each of the delineation systems tested in Phase II was broken into its several component treatments, and estimates were made of the 1976 initial installation costs. Most of the unit cost data, as discussed in Chapter XII, were extracted from a recent implementation study performed for the FHWA. The following assumptions were made by AMV as to individual treatment costs for a two-lane rural highway:

- A broken yellow centerline with a standard stripe-to-gap ratio of 3:5 costs $75/mile ($47/km), 45 percent of which is attributable to the paint itself.

- A single solid yellow stripe, 4 inches (10 cm) wide, costs $100/mile ($62/km) to install.

- A pair of standard 4-inch (10-cm)-wide white edgelines costs $180/mile ($112/km); the paint itself costs $55 or 30 percent of the total.

- The installation cost (materials plus labor) for non-snow-plowable raised pavement markers averages $3.00 for each reflective marker and $1.50 for each non-reflective marker.

- Post-mounted delineators cost $10 each to install.

Practices for the General Roadway Situation

Table 2 summarizes the most pertinent study findings as to the costs and effects of continuous tangent/winding delineation systems. The 18 systems evaluated are listed by general category of the component treatments, i.e., striping only, striping plus raised pavement markers, striping plus post-mounted delineators, and raised pavement markers only. The systems, numbered G—1 through G—18, are compared in every case to a base condition of standard MUTCD centerline with edgelines. Statistically insignificant changes are indicated with a dash (—).

Systems for Immediate Implementation — Several less paint-intensive delineation systems performed as well or better than the more expensive base condition. With emphasis on Systems G—3 through G—8 in Table 2, the following recommendations are made:

(1) Beginning with the next repainting cycle, System G—8 (with no-passing barrier striping as appropriate) should be applied to all rural two-lane highways. At two sites where this system was studied, the predicted delineation-related hazard on a dry night was found to be either unchanged or substantially reduced. An immediate cost savings of about 4 percent should also result.

(2) Where the quality control associated with the painting equipment will allow, the 10:30 centerline on new or newly resurfaced highways should be accompanied by edgelines 2-3 inches (5-8 cm) wide (System G—7). No adverse safety effects were predicted at the two locations where narrower edgelines were tested in combination with a reduced centerline stripe-to-gap ratio. In comparing System G—7 to System G—8, an additional 12 percent in striping costs would be saved.

(3) Systems G—3 and G—5 could be applied in a controlled fashion over long sections of tangent-type highway. In the vicinity of no-passing zones, however, it would be advisable to revert to System G—7 or G—8.

(4) To overcome possible target-value problems for System G—3 under adverse visibility conditions (e.g., fog and nighttime rain), serious consideration should be given where practical to the supplemental centerline use of reflective raised pavement markers (RPM's). A combination of one- and two-way amber markers is suggested: wherever passing is allowed for a given direction of travel, the driver would see reflective elements at 80-foot (24.4-m) intervals, and where passing is prohibited for the same direction, he would see the reflectors at 40-foot (12.2-m) intervals. As shown on Table 2, delineation-related driving hazard on a dry night alone might be reduced by 30-80 percent. See Figure 1 for an indication of initial cost versus predicted safety effectiveness for System G—9.

Table 2. Evaluation of costs and effects of continuous delineation systems.

Delineation Category	Experimental Delineation System		Study Site No.	% Changes to Base Characteristics[2]			
	Description[1]	No.		Initial Cost to Install	Night Variances[3] Speed	Night Variances[3] Placement	Predicted Dry-Night Hazard[4]
Striping Only	Single solid centerline						
	• w/o edgelines	G-1	6	↓74	↓60	↓30	-
	• w/4-in. edgelines	G-2	6	↓26	-	↓30	↑71
	4-in., 5:35 centerline						
	• w/4-in. edgelines	G-3	3	↓8	↓25	↑30	↓82
	2-in., 10:30 centerline						
	• w/o edgelines	G-4	4A	↓78	-	-	-
	• w/2-in. edgelines	G-5	4A	↓20	↓40	-	↓31
	4-in., 10:30 centerline						
	• w/o edgelines	G-6	4B	↓75	-	-	↑+ +
	• w/2-in. edgelines	G-7	4B	↓16	-	-	-
	• w/4-in. edgelines	G-8	4B	↓4	-	-	-
			4A	↓4	-	-	↓49
Striping and RPM's	4-in., 5:35 centerline						
	• Ctr. RPM's @ 80 ft. (w/4-in. edgelines)	G-9	3	↑71	↓35	-	↓27
	4-in., 10:30 centerline						
	• Ctr. RPM's @ 80 ft. (w/4-in. edgelines)	G-10	3	↑75	↓35	-	↑96
	4-in., 15:25 centerline						
	• Ctr. RPM's @ 80 ft. (w/4-in. edgelines)	G-11	2	↑78	-	↓25	↓41

Table 2. Evaluation of costs and effects of continuous delineation systems. (continued)

Delineation Category	Experimental Delineation System		Study Site No.	% Changes to Base Characteristics[2]			
	Description[1]	No.		Initial Cost to Install	Night Variances[3]		Predicted Dry-Night Hazard[4]
					Speed	Placement	
Striping and RPM's (cont'd)	4-in., 15:25 centerline • RPM's on both sides of lane @ 80 ft. (w/4-in. edgelines)	G-12	2	235 ↑	-	30 ↓	45 ↓
	4-in., 15:25 centerline • RPM's on both sides of lane @40 ft. (w/4-in. edgelines)	G-13	2	471 ↑	60 ↑	-	48 ↓
	Centerline of reflective & non-reflective RPM's • w/4-in. edgelines	G-14	5	783 ↑	-	-	3 ↑
	• w/4-in. edgelines supplemented by RPM's @ 40 ft.	G-15	5	888 ↑	-	-	68 ↓
Striping and PMD's	4-in., 15:25 centerline • w/PMD's @ 528 ft. (w/4-in. edgelines)	G-16	1	78 ↑	-	30 ↓	21 ↓
	4-in., 15:25 centerline • w/PMD's @ 264ft. (w/4-in. edgelines)	G-17	1	157 ↑	30 ↓	25 ↓	32 ↓
RPM's Only	Centerline of reflective & non-reflective RPM's • w/o edgelines	G-18	5	736 ↑	50 ↑	-	12 ↑

[1] 1in. = 2.54 cm and 1 ft. = 0.305m.; RPM = raised pavement marker and PMD = post-mounted delineator.

[2] Base-condition delineation system consisted of edgelines with double solid centerline at sites 5 and 6 and 15:25 centerline at other sites; all striping 4 inches (10 cm) wide.
(↑ means a statistically significant increase of percentage shown),
(↓ means a statistically significant decrease of percentage shown),
(–means any change was statistically insignificant).

[3] Dry-night values for upstream trap at tangent sites (Nos. 1, 2, 3, 4A, and 4B) and midpoint-of-inside-curve trap at winding sites (Nos. 5 and 6).

[4] From two-variable accident-probability model based on centrality within the lane and longitudinal change in placement variance.

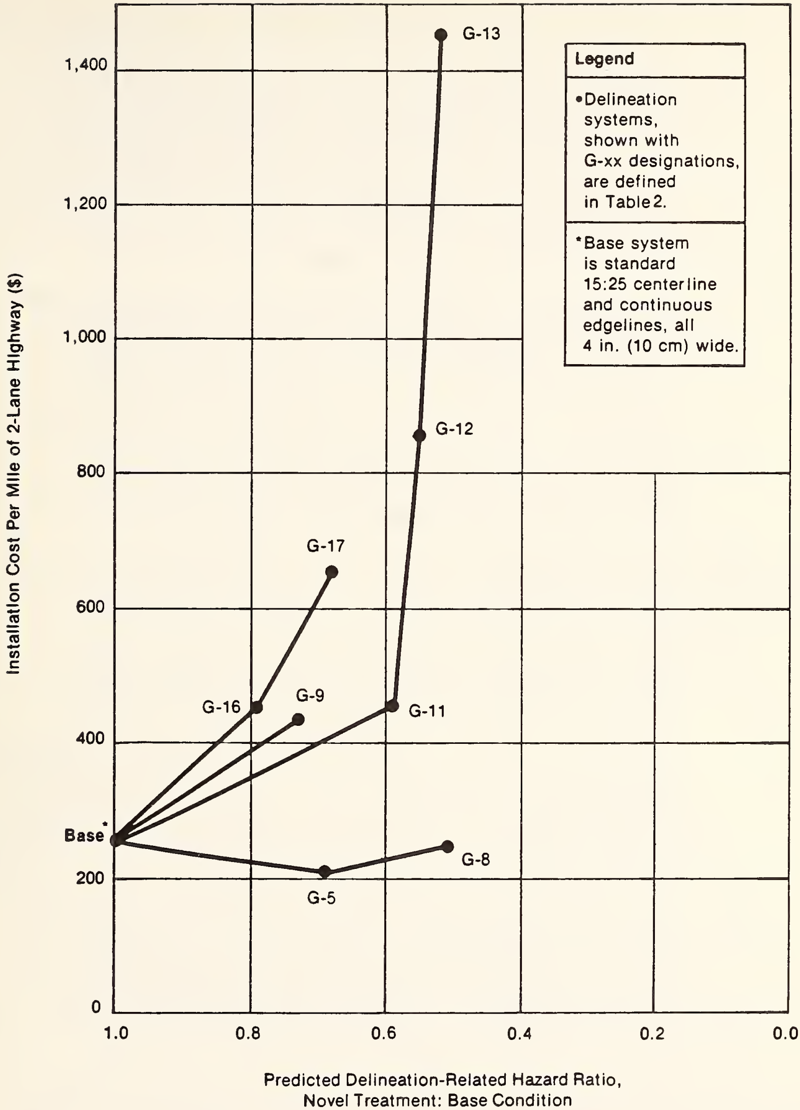


Figure 1. Initial cost vs. predicted effectiveness.

(5) Where especially severe visibility conditions occur due to frequent fog or blowing sand, consideration should be given to a continuous RPM supplement—at the spacing pattern recommended above—on highways with the proposed general standard 10:30 centerline. Although the one test of System G-10 yielded unsatisfactory results, the two "bracketing" systems—G-9 and G-11—showed dry-night hazard reductions of 27-41 percent. The wet-day and wet-night evaluations of System G-11 showed that significant benefits can be derived from the supplemental treatment under adverse operating conditions. Similar advantages should be expected for System G-10.

(6) Where additional reflective devices are considered desirable and the 80-foot (24.4-m) RPM centerline supplement cannot be applied because of snow-plowing problems, continuous post-mounted delineators should be installed at intervals of 400-528 feet (122-161 m) on tangents. On curves, the present MUTCD spacing recommendations should probably be retained. The delineator posts should be installed on both sides of the road, but drivers in a given direction need to see reflective elements only on the near side. Refer to Figure 1 for an indication of initial cost versus predicted safety effectiveness for System G-16.

<u>Systems for Further Research</u> — Due to field study limitations within the project, several promising delineation systems yielded inconclusive results. The following additional research should be considered:

(1) The use of a single solid centerline on two-lane passing-restricted highways should be investigated more comprehensively. Additional traffic performance field studies are warranted, especially on narrower pavements (e.g., 18-20 feet or 5.5-6.1 m). A thorough review should also be made of the potental passing hazard associated with driver misunderstanding of the single stripe. On very narrow, low-volume roads, consideration should be given to evaluating the selective use of a single solid centerline just in the vicinity of curves and other hazards.

(2) The installation of post-mounted delineators over long sections of two-lane highway should be evaluated on narrower, more winding alignments. Tradeoffs should be studied between delineator spacing and the selective use of edgelines. Unlike previous studies, however, the longitudinal change in lateral placement variance should be defined as a key performance measure.

<u>Systems Not Warranting Further Research</u> — Several delineation systems appear to fall outside desirable bounds of cost or effectiveness. These

systems, and the reasons for suggesting a cessation of further research, are as follows:

(1) Systems G—4 and G—6, without edgelines, performed very well in one case and very poorly in the other. Sufficient national experience has accumulated to warrant the use of edgelines, at least narrow ones, on all pavement widths of 20 feet (6.1 m) or greater.

(2) System G—11, while it performed very satisfactorily, would become obsolete under the proposal for a maximum 10-foot (3-m) stripe in the broken centerline pattern.

(3) Systems G—12 and G—13, which include RPM supplements on both sides of the lane, did not appear to yield a safety gain justifying the very large installation expense. Figure 1 clearly shows the rapidly diminishing returns on the initial investment.

(4) The extremely expensive systems involving an RPM-only centerline did not yield sufficient safety benefits to justify their general application on two-lane rural highways. Systems G—14 and G—18, which had reflective markers only on the centerline, did not seem to change accident potential in a statistically significant sense. System G—15, by far the most elaborate and costly system considered, did show a substantial 68 percent reduction in predicted hazard. But since the initial cost is about 900 percent greater than the base condition paint-only system, it is doubtful that even with the extended life of the RPM's, a sufficiently attractive benefit/cost estimate could be derived to overcome the tremendous threshold costs.

Practices for Isolated Horizontal Curves

The curve-specific delineation systems studied included centerline raised pavement marker supplements and post-mounted delineators, used separately and in combination. Based on the traffic performance measures obtained at two study sites, the following recommendations are offered for the treatment of high-hazard horizontal curves:

(1) Where their use is feasible, retroreflective pavement markers (RPM's) are preferred over post-mounted delineators (PMD's). Unlike PMD's, RPM's serve well as both "far" and "near" delineation. In their former role, pavement markers present a more accurate perspective of the driving surface; in their latter role, they have a significant effect on mean lateral placement that delineators generally do not.

(2) To benefit drivers on the outside of the curve without adversely affecting the lateral placement of vehicles moving in the opposite direction, one-way RPM's should be installed on the centerline. These markers—containing amber reflective elements and installed at 40-foot (12.2-m) intervals—should face traffic moving to the left on the curve. Although not specifically evaluated, behavioral findings to date suggest that drivers on the inside of the curve would be best served by one-way crystal RPM's placed on the near side between the edgeline and edge of pavement. The resulting two-line system of one-way markers should substantially reduce the probability of potentially hazardous centerline and shoulder encroachments.

(3) When RPM's cannot be used because of economic or maintenance problems, consideration should be given to the installation of post delineators on the outside of the curve. Although not likely to be as beneficial as RPM supplements, PMD's apparently do provide some degree of near as well as far delineation (e.g., off-center driving was not reduced but placement variance was).

(4) In order to provide the approaching driver with unambiguous guidance as to the proper path of travel, it is highly desirable to use two colors of retroreflector on the delineator posts. Drivers moving on the outside curve should see crystal reflectors on their near-right, and drivers moving on the inside curve should see amber reflectors on their far-left. Otherwise, the current MUTCD standards for mounting height and offset from the shoulder appear satisfactory.

CHAPTER II

RESEARCH OBJECTIVES AND APPROACH

This research project was initiated in 1975 to develop surrogate measures of rural traffic safety which would allow the timely evaluation of more economically and environmentally sound delineation policies for two-lane highways. As mentioned in the Executive Summary, the project had the following four objectives:

- To establish relationships between traffic performance and accident probability on two-lane rural highways.
- To develop an experimental design for field testing the effectiveness of conventional and novel delineation treatments.
- To evaluate the effect of selected delineation treatments on traffic performance and associated accident probability.
- To make recommendations for the design and use of delineation treatments.

For administrative convenience, the research contract was divided into two phases. Phase I addressed the first two objectives and Phase II addressed the latter two objectives.

Before proceeding to a detailed, chapter-by-chapter discussion of the study techniques and findings, an overview of the experimental approach is in order. Chapter II provides this overview in the form of a work flow diagram (Figure 2) and a brief text summarizing important procedural aspects of the seven major research tasks.

PHASE I RESEARCH APPROACH

As suggested above, the prime objective of Phase I was to evaluate short-term observations of traffic performance as predictors of long-range accident potential on two-lane rural highways, assuming that both standards of service are sensitive to type of delineation. Given that successful predictors could be identified for use in a field evaluation methodology, a parallel Phase I objective was to assign research priorities to a series of specific delineation treatments to be tested in Phase II.

Task I-1: Traffic Performance Field Studies

Essential ingredients to any attempt at modeling traffic system behavior are adequate and accurate data bases from which to formulate dependent and independent variables. In the present study, in which accident potential was correlated to a rather limited number of variables describing vehicular operation and the driving environment, it was also

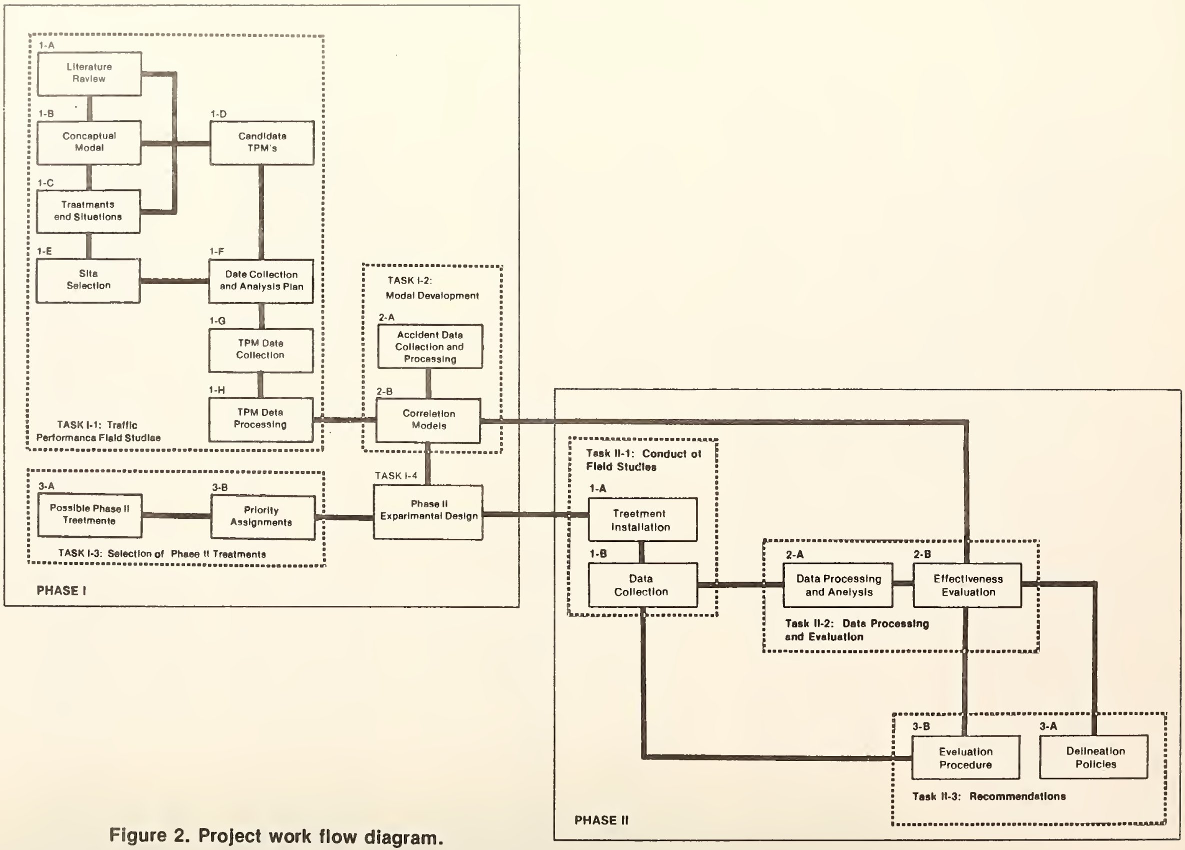


Figure 2. Project work flow diagram.

important that the data bases be sufficiently comprehensive. Unusual care was required to control those extraneous environmental factors which could not be easily quantified.

The development of the Phase I experimental design and independent variable data base was the major thrust of Task I-1. These development activities can be described as belonging to one of three informal stages of work: conceptual planning, preparation for field studies, and data collection and processing.

The first stage, conceptual planning, consisted of Subtasks A through D (see Figure 2). These subtasks were conducted simultaneously and were very much interactive. The literature review provided guidance as to those traffic performance measures (TPM's) most likely to be indicative of erratic or unsafe driving behavior. This review assisted in the development of a conceptual accident-probability model and candidate TPM's (independent variables), but it was in turn influenced and directed in part by the specific roadway situations and delineation treatments selected for study. One of the criteria for selection of the situations and treatments was the need to collect field data containing adequate variability: only if the situations and types of field measures were fully compatible could a robust data set be developed to enhance the statistics of the subsequent modeling effort.

The second stage of activity in Task I-1 involved site selection and the drafting of a data collection and analysis plan. This plan presented the experimental design for Phase I, procedures and forms for data collection, and a tentative description of the types of data processing and analytic modeling to be performed. Basically, it combined findings from Subtasks B, C, and D, and to a limited extent, E. Only a preliminary set of candidate sites had been identified by the time the plan had to be submitted for approval and the data collection begun. Later difficulties in site selection, in fact, required some revision to the description matrices used to categorize the field study sites.

The third and final stage of Task I-1 work was the collection and processing of traffic performance data at 32 field study sites in six eastern states. All sites were on two-lane rural highways in the low to moderate volume range, generally having a tangent, winding, or isolated-curve type of alignment. At each site, minimum samples of 100 free-flowing observations were obtained with tapeswitches during both daylight and darkness in dry weather. These large amounts of field data were then processed by a series of computer routines to make the prescribed candidate independent variables ready for modeling in Task I-2. Also near the end of Task I-1, the derived TPM statistics were studied for significant differences and trends relative to site characteristics short of the actual accident histories.

<u>Task I-2: Model Development</u>

This task called for the development of the dependent variable data base (Subtask A) and its use in the statistical modeling effort

(Subtask B). The assembling and processing of the accident data proved to be more cumbersome than anticipated. Although more of the complications and nuances of the required procedures are discussed in Chapter VI, some basic background information is in order at this point.

As partially noted in the Acknowledgements for this report, the team of Science Applications, Inc. (SAI) and Alan M. Voorhees & Associates, Inc. (AMV) obtained accident data for several hundred miles of two-lane rural highway for a related (but separate) delineation research study. This data base was in fact an aggregation of numerous, relatively short sections of highway meeting certain geometric, delineation, and traffic volume specifications. In the tangent and winding categories of alignment, the minimum study section length was three miles (4.8 km), and for the isolated horizontal curve, about 0.5 mile (0.8 km). These were judged to be the shortest sections of highway over which a unique, meaningful accident history might have developed over a recent period of two to six years.

In the Field Evaluation Study, 25-50 specific study sections were to be selected, each containing a suitable location for monitoring traffic performance measures. The one very large assumption, of course, was that most of the overall study section's relevant physical characteristics could be represented in the few hundred feet of monitored highway. To the extent that extraneous geometric, roadside, and other environmental effects occurred in the mileage used for a site's accident data base, the weaker would be the simplified correlation between accident potential and TPM's under each of the operating conditions to be modeled.

The following steps were taken to minimize the distortions resulting from the homogeneity assumption:

- TPM's were observed as vehicles traversed stations representing each basic type of horizontal alignment prevailing in a study section (see Chapter IV).

- Cross-sectional dimensions remained constant throughout each study section.

- An effort was made to select highway sections having delineation neither badly worn nor newly installed, and of constant quality over each section.

- Accidents which could in no reasonable way be related to the presence or lack of continuous delineation were removed from consideration, and the remaining dry-weather accidents were stratified into day versus night occurrences to reflect the subsets of TPM data.

- The overall environmental "noise factor" was acknowledged by stressing that only relative accident potential was to be predicted, not a rigorously accurate absolute value for any unique site to which the models might be applied.

Task I-3: Selection of Phase II Treatments

To control those potential environmental effects on traffic performance not directly represented in an accident-probability model, it is best to obtain input data for the model at a relatively small number of study sites having generalizable physical features. At each such site, several configurations or levels of delineation can be evaluated in a logical sequence of augmentation. To determine the most appropriate delineation treatments to be considered in making up the Phase II staged experimentation, Task I-3 took a two-part approach.

First, a broad list of conventional and novel treatments was compiled from a review of existing literature and contacts with selected researchers and State Traffic Engineers. The one formal guideline for this subtask was that the treatments had to, as a minimum, encompass the general categories of pavement markings, raised pavement markers, and post-mounted delineators. Conventional treatments were said to be those specifically sanctioned in some way by the Manual on Uniform Traffic Control Devices, whereas novel treatments could consist of variations in pattern, color, or means of application.(1)* In order to keep the list of candidate treatments from becoming unnecessarily cumbersome, the desired goal of achieving greater cost effectiveness was mentioned to the surveyed parties, and a few suggestions considered truly exotic were not passed on to the priority assignment procedure followed in the next subtask.

The second part of the Task I-3 approach was to take the list of 38 candidate treatments and ask the project staff to systematically assign research priorities with a weighted-rank evaluation technique. Seven specific evaluation questions were asked within the broad criteria of "Possible Effects on Traffic System," "Ease and Scope of Implementation," and "Relative Costs of Treatment." Responding to each multiple-choice question resulted in the assignment of penalty points and, after reviewing the total points assigned each treatment in the matrix, research priority rankings between 1 and 38 were generated. The aggregation of rankings from seven staff members was then compared to the results of earlier field surveys, and composite indices of perceived research need were developed to assist in the formulation of Phase II experimental delineation systems. Fourteen unique systems were ultimately chosen for evaluation on the basis of the research priority rankings.

Task I-4: Phase II Experimental Design

The official Scope of Work required only that this task describe a general experimental design for testing and evaluating the accident

*Number denotes source as it appears in the List of References, pp. 328-329.

reduction potential of delineation treatments. However, it appeared appropriate to also specify how this general approach might be used to evaluate highly ranked treatments identified in Task I-3. This latter need was fulfilled by structuring a series of three- or four-level tests at each of nine sites which would take advantage of logical delineation augmentations. This list of desired evaluations remained tentative, though, until the study sites and the arrangements for treatment implementation were confirmed early in the Phase II schedule. The final experimental design is presented in Chapter VIII.

As for the general evaluation procedure outlined for use in Phase II, it consisted basically of a data collection portion and an analysis portion. The former was developed by applying Phase I field experience to refine the plan issued for that data collection activity. The analysis portion summarized the prospective methods for evaluating traffic performance data to detect trends of practical significance.

The last section of Chapter VIII highlights some additional data collection and analysis guidelines written for Phase II. The general evaluation procedure actually developed in Task I-4 is not presented verbatim in this final report, since it was susceptible to further change as a result of Phase II experience with its application. Rather, a number of the procedure's elements have been refined and/or expanded, and it has been written in manual format for inclusion as Appendix I.

PHASE II RESEARCH APPROACH

In Phase II, additional field data were to be obtained for the dual purpose of validating the Phase I accident-probability models and subsequently evaluating the safety effectiveness of several conventional and novel delineation systems.

Task II-1: Conduct of Field Studies

This first task within Phase II, while conceptually planned earlier, required intensive short-range logistical planning. Figure 2 shows the task to consist of a "treatment installation" subtask and a "data collection" subtask. However, the first of these subtasks involved a wide-ranging site search as well as both the initial and ongoing coordination of treatment installation.

Two tangent-type study sites were selected on the Maine Facility, where both treatment implementation and data collection were to be provided by government personnel. Other states were considered for possible Phase II participation on the basis of their highway agency's previously expressed willingness to assist in site selection and the eventual installation of experimental treatments.

For logistical convenience, contacts with prospective states also tended to favor those in geographic proximity to the project office (Washington, D.C. area) and/or the home of the data collection subcontractor

(State College, Pennsylvania). Recognizing the need at most Phase II sites to sequentially augment an initial, rather minimal, experimental delineation system, the site search focused on those highways due to receive pavement overlays in the summer or early fall of 1976. A total of nine highway sections were eventually chosen in Virginia, Maryland, Pennsylvania, and Maine. These sections (or study sites) are described in Chapter IX and Appendix E.

The confirmation of these study sites was very much dependent upon prospects for the timely installation of the special paint striping and markers required. This latter work was to be performed by regular state maintenance crews in response to case-by-case requests by the research team. Opportunities for its performance were limited by other delineation needs within each state as well as the uncertain schedule of the paving contractor, the availability of raised pavement markers and suitable weather for their successful installation, and the progress of the data collection effort. The efficient routing of the Penn State data collection team, in the context of all of these other dynamic events and the need for a minimal driver acclimation time, posed a significant scheduling challenge. This challenge was also aggravated near the end by the rather sudden onset of unusually severe winter weather.

Over an actual working period of about eight months, traffic was monitored for 32 combinations of site and treatment. In each case, 100-150 vehicles were observed on dry pavement under both day and night visibility conditions, and for most of the raised-pavement-marker and post-mounted-delineator treatments at the Maine Facility sites, wet-weather data were also obtained. Two relative durations of driver acclimation were examined at the Maine Facility and for certain treatments at two isolated horizontal curves located elsewhere.

Task II-2: Data Processing and Evaluation

Traffic performance data were processed as they became available using the computer software developed in Phase I of the project. Additionally, a new post-processor program was written to summarize the more important measures and test for statistically significant differences betweeen various treatments and operating conditions.

Prior to applying any of the products of the Phase I accident-probability modeling to statistically different performance measures, however, a limited "model validation" effort was conducted. This effort required the collection and analysis of both accident data and traffic performance data associated with the conventional "base condition" delineation system historically present. The "validation" activity provided reasonably satisfactory results for a two-variable accident-probability model. While still open to further testing, the model and the accompanying insights on performance measure interpretation were considered sufficiently reliable to utilize in evaluating the balance of the Phase II field data and deriving policy recommendations therefrom.

Task II-3: Recommendations

The two subtasks required under this task were similar only in the sense that both drew recommendations from the techniques and findings developed throughout the two-year research study. One subtask involved suggested delineation deployment policies for the roadway situations evaluated in Phase II, while the other synthesized and refined procedural elements of both phases to propose a generalized delineation evaluation methodology.

A total of 21 unique delineation systems were evaluated with regard to their relative effects on nighttime variances of lateral placement and speed, predicted dry-night driving hazard, and initial installation cost. Eighteen of the systems apply to long sections of tangent or winding alignment, denoted as the "general roadway situation"; the other three systems are applicable only at isolated horizontal curves. Delineation systems for the general roadway situation were categorized as being appropriate for "immediate implementation," worthy of "further research," or "not warranting further research."

The policy recommendations encompass rural pavement markings (reduced stripe-to-gap centerline and narrower edgelines), raised pavement markers (as a supplement to striping), and post-mounted delineators (longer spacing on tangents and selective use on curves). The specific types or brands of delineation material or device did not bear heavily on the deployment policies considered. At the levels of sensitivity and precision inherent in the evaluation technique, only basic delineation concepts are truly relevant. The primary distinctions relate to the presence or absence of a delineation treatment; the increasingly subtle the differences in configuration, dimension, or design detail, the less one should expect to observe meaningful differences in traffic performance.

CHAPTER III

CONCEPTUAL PLANNING

The prime objective of Phase I was to evaluate short-term observations of traffic performance as predictors of long-range accident potential, assuming that both standards of service are sensitive to type of delineation. The specific operational situations and performance measures selected for detailed study were to be determined early in the research program. This chapter discusses the Task I—1 conceptual planning that established the fundamental scenarios and evaluative tools for Phase I and, by precedent, Phase II as well.

DELINEATION SITUATIONS AND TREATMENTS

Guidelines

Comparatively few, rather broad constraints were placed upon the conceptual planning, as follows:

- As a minimum, the roadway situations and delineation treatments selected for field study were supposed to include the basic treatment/situation combinations for which accident data were collected by an SAI/AMV team under Contract DOT-FH-11-8587 ("Cost-Effectiveness and Safety of Alternative Roadway Delineation Treatments").

- The selected treatment/situation combinations had to be reliably represented by 25-50 study sites chosen from among the several hundred identified and categorized according to SAI's experimental design.

- In the Phase I Data Collection and Analysis Plan which required FHWA approval, site selection matrices were to be presented describing targeted ranges for key geometric, traffic, and delineation variables; also, consideration had to be given to appropriate stratifications of time, weather, visibility, and surface conditions.

The basic delineation situations incorporated in the SAI experimental design in effect at the time of AMV's conceptual planning were distinguished by the type of horizontal alignment. The three types were defined as follows:

- Tangent — A predominately straight roadway with horizontal curves of 3 degrees or less.

- Winding — A predominately curved roadway with degrees of curvature greater than 3 degrees and tangents of less than 1,500 feet (457 metres) between curves.

- Isolated Horizontal Curve — On an overall alignment tending to be more tangent than winding, a curve greater than 3 degrees which is desirably isolated from other significant curves by 1/2 mile (4/5 kilometre) or more.

Other site variables included number of lanes (two or four undivided lanes), roadway width (traveled lanes only), average daily traffic volume, shoulder width, and delineation system (presence or absence of centerline, edgelines, post delineators, etc.). For the horizontal curve only, the additional variable of degree of curvature was applied.

The SAI site classification matrices typically displayed these variables in nested pairs; that is, only two ranges of each variable were defined, and these ranges were usually open-ended. For example, a two-lane site might have a traveled way either less than 20 feet (6.1 metres) wide or ≥ 20 feet.

Procedures

Due to the largely unknown sensitivities and possibly subtle interactions between certain geometric elements of a roadway and the tracking of vehicles over that roadway, somewhat finer-grained site classification appeared desirable in this study. However, if too many cells were defined for the site classification matrices, sample size restrictions would mean that fewer situation-specific matrices could be considered. In the end, less comprehensive delineation policy recommendations could be made.

A number of possible experimental designs were drafted to explore compromises between level of cell specificity, the range of policy-sensitive situations of interest, and sampling intensity (i.e., number of sites per cell). Tentative stratifications were drawn in some cases by examining the distribution of characteristics for the 100-odd SAI sites which had been theretofore identified. Lastly, the three site selection matrices proposed in the Data Collection and Analysis Plan had to eventually be modified slightly to better fit the availability of acceptable field study sites.

Results

Figures 3, 4, and 5 show the ranges of site characteristics utilized for Phase I data collection and model development. The cells are identified by the sequential numbers in the lower right-hand corners. Although an early objective was to "fill" each matrix in a balanced manner such that each row contained "X" sites and each column contained "Y" sites (at a sampling intensity of one site per cell), certain cells simply could not be filled without inordinately long search efforts. The dotted cells are those where unusually rare combinations of characteristics had apparently been defined.

Delineation System	Roadway Feature							
	Roadway Width (ft.)	16 - 18	19 - 21				22 - 24	
	Volume (1975 ADT)	500 - 2,000	500 - 2,000		2,000 - 5,000		500 - 2,000	2,000 - 5,000
	Shoulder Width (ft.)	≥ 4	< 4	≥ 4	4	≥ 4	< 4	≥ 4
Painted Centerline Only		1	2	3	4	5	6	7
Painted Centerline and Edgelines		8	9	10	11	12	13	14

Notes:
- Predominately "pure" tangent, with no curves greater than 3 degrees.
- Desirably 10 miles long, minimum 3 miles.
- 1 foot = 0.30 metre and 1 mile = 1.61 kilometres.
- Dotted cells indicate desired site types which could not be found.

Figure 3. Two-lane tangent situation site selection matrix.

Delineation System	Roadway Feature					
	Roadway Width (ft.)	16 - 18	19 - 21			
	Volume (1975 ADT)	500 - 2,000	500 - 2,000		2,000 - 5,000	
	Shoulder Width (ft.)	< 4	< 4	≥ 4	< 4	≥ 4
Painted Centerline Only		1	2	3	4	5
Painted Centerline and Edgelines		6	7	8	9	10

Notes :

- Predominately "curved," with degrees of curvature greater than 3 degrees and tangents of less than 1,500 feet (457 metres) between curves; also, two consecutive, reversed curves of 5 degrees or more, neither leading into study section, and separated by no more than 500 feet (152 metres) of tangent.
- Desirably 10 miles long, minimum 3 miles.
- 1 foot = 0.30 metre and 1 mile = 1.61 kilometres.

Figure 4. Two-lane winding situation site selection matrix.

Delineation System	Roadway Feature						
	Degree of Curvature	3 - 6			> 6		
	Roadway Width (ft.)	16 - 18	19 - 21	22 - 24	16 - 18	19 - 21	
	Volume (1975 ADT)	500 - 2,000	2,000 - 5,000	2,000 - 5,000	500 - 2,000	500 - 2,000	2,000 - 5,000
	Shoulder Width (ft.)	< 4	≥ 4	≥ 4	< 4	≥ 4	≥ 4
Painted Centerline Only		1	2		3		4
Painted Centerline and Edgelines		5		6	7	8	
Painted Centerline and Edgelines Plus Post-Mounted Delineators			9	10		11	12

Notes:
- Reasonably isolated from other curves, desirably by 1/2 mile (4/5 kilometre) or more.
- 1 foot = 0.30 metre.
- Dotted cells indicate desired site types which could not be found.
- No sites were sought for cross-hatched cells.

Figure 5. Two-lane isolated horizontal curve site selection matrix.

The rarity of certain site types was anticipated, but there were good reasons not to design the classification matrices simply on the basis of the most commonly found characteristics. First, a fair range of site types was needed in order to develop an adequately robust set of TPM data for modeling. Second, accident potential is often higher for non-standard facilities than for those on which drivers are more accustomed to driving. In sum, the data base for an accident-probability model requires variation in both accident-rate variables and TPM variables (hopefully correlated variability).

LITERATURE SEARCH

Guidelines

Given the delineation situations to be modeled, appropriate traffic performance measures had to be developed. All TPM's adopted had to have either a previously demonstrated relationship to safety, or an intuitively appealing potential for a meaningful relationship. While vehicular speed and lateral placement were expected to be among the primary raw measures, the proper formulation of these and other possibilities warranted a systematic investigation. The first step in this investigation was a review of published literature for known TPM/accident relationships.

Procedures

The search for pertinent literature was conducted primarily at the library of the Institute of Transportation Studies (formerly the Institute of Transportation and Traffic Engineering) at the University of California at Berkeley. However, use was also made of the HRIS/TRIS information retrieval system and the library facilities of the University of Michigan Highway Safety Research Institute in Ann Arbor. The highlights of the literature review are summarized below.

Results

A comprehensive and partially annotated bibliography prepared in 1974 by Haney and Weber identified relationships between speed limits, speed distributions, and motor vehicle accidents.(2) The bibliography lists approximately 700 articles and papers published between 1920 and 1974. A frequent conclusion of these publications was that lower speed limits would result in corresponding reduction in the mean speed of traffic, the dispersion of speeds about their mean, the number of vehicles traveling at high speeds, and the frequency of serious and fatal accidents. Haney and Weber concluded that "existing data do not contain sufficient detail concerning the pre-accident situation to clearly define the causes of accidents or to suggest countermeasures that might prevent them."

In 1957, Thomas conducted a study of pavement edgelines on 24-foot (7.3-metre) surfaces in Louisiana.(3) While he did not specifically consider relationships between accidents and TPM's, he did investigate each of these parameters separately. His general conclusions were that edgelines do not appreciably affect either TPM's or accidents. However, a definite relationship was found to exist between speed and placement, with faster vehicles traveling closer to the centerline than slower vehicles.

Tarragin and Rudy in 1960 evaluated the effectiveness of highway illumination and delineation with respect to improving traffic operations.(4) Nine different conditions of illumination and delineation were studied, but no apparent relationship was found to exist between speeds, lateral placements, and accident rates.

Powers and Michael followed this study in 1961 with a project considering the effects on speed and accidents of improved delineation at three rural sites.(5) The locations included a narrow bridge, a hazardous intersection, and a seemingly adequate intersection. Although the findings were statistically inconclusive, it appeared that the new delineation treatments resulted in a small increase in speeds and a small reduction in accidents.

In 1963, the Arizona Highway Department published a research report discussing the costs and effects of post delineators versus edgelines.(6) The study concluded that these treatments had no significant effects on either lateral placement or accident experience. It was observed, however, that night speeds increased when roadway delineation was installed and that edgelines resulted in higher night speeds than did post delineators.

The relationship between speed and accidents was addressed by Goen in 1965.(7) This study utilized data gathered in previous studies as well as data compiled by the National Safety Council. Goen concluded that both accident rates and fatality rates are related to speed. Furthermore, he defined this relationship to be an exponential one, with accident and fatality rates increasing exponentially with increases in speed. He proposed specific relationships and on the basis of these relationships performed a benefit/cost analysis for various degrees of speed reduction.

A 1966 report by Roth and DeRose discussed the first results of a ramp color delineation study.(8) This project evaluated the number of erratic driving maneuvers before and after the installation of color-coded delineation treatments. Results of the study indicated that traffic was channeled into appropriate lanes further in advance of the exit ramp when color-coded treatments were in place. Also, there was a 30-32 percent reduction in erratic driving maneuvers.

A second report discussing further results of the color-coding study was published by Roth in 1970.(9) In addition to driver interviews, this research also considered accident records one year before to one year after installation of the color-coded delineation treatments.

Erratic driving maneuvers were again significantly reduced, and although accidents could not be directly related to the color codes, the increase in accidents in the non-color-coded direction was three times greater than in the color-coded direction.

In 1967, Robert Owens prepared a paper which discusses the effects of rumble strips at rural stop locations.(10) Although relationships between TPM's and accidents were not specifically addressed, it was concluded that rumble strips in advance of a stop sign are effective in reducing average approach speed and the frequency of accidents.

The Research Triangle Institute in 1969 published a report discussing the relationship between speed and accidents.(11) As in earlier studies, the results of the Institute's project suggested a U-shaped relationship between involvement rate and deviation of speed from the mean. A more theoretical approach to this same problem was outlined in a paper by Jan Gustavsson in 1971.(12) The author developed a mathematical model in his attempt to relate certain traffic characteristics (e.g., speed, vehicle-miles-traveled, number of overtakings, and number of meetings) to the frequency of various accident types. Again, the results of this model tended to agree with speed/accident relationships observed in previous research.

In 1972, Kemper, et al., reviewed the extent of overtaking and passing accidents on rural two-lane highways.(13) It was found that over 40 percent of all accidents involved either an overtaking or a passing maneuver. Potential savings in accident costs for various remedial actions were discussed.

That same year, Taylor, McGee, et al., finished NCHRP Report 130.(14) In addition to providing a comprehensive state-of-the-art review and various delineation policy evaluation tools and recommendations, several TPM-oriented experiments were reported in the appendices. The one most relevant to this literature review is Appendix Q by Pagano. His study utilized multiple linear regression in an attempt to relate accident rates to speed and lateral placement on two-lane horizontal curves. A model was developed which suggested that lateral placement variance and deceleration into the curve were most strongly related to accidents. Regression results involving speed distribution statistics at first glance appeared to cast doubt on the overall findings. That is, no significant correlation was found between accident rate and speed variance, and a negative correlation was found with mean speed. Although not suggested by Pagano, these results might well have been due to hidden factors such as the mixture of site types. Significantly lower mean speeds in the data base may indicate sites having poor overall design features. Such features could degrade safety to a greater extent than lower operating speeds could possibly compensate for.

CONCEPTUAL MODEL

Guidelines

As exemplified by the NCHRP study results cited above, some rather complicated interactions take place between highway geometrics, delineation treatments, environmental conditions, traffic performance measures, and accident potential. Given certain extreme or erratic values of TPM's, various geometric and surface conditions in turn influence the probability of an accident occurring. For instance, horizontal alignment, lane width, and delineation may relate directly to the number of excursions from the proper lane, but the expected accident rate would also be affected by the lateral distance available for recovery—described in large part by the width of the shoulder or the opposing lane.

In order to separate the confounding effects of geometrics, delineation, and traffic volume from the primary relationship sought between accident experience and TPM's, it became evident that a stepwise analytic approach would be appropriate. Early steps would seek to explain as much of the variation in accident rates as possible using intuitively appealing TPM variables, and later steps would relate a portion of the remaining variation to supplementary independent variables describing cell locations in the site selection matrices. The balance of this chapter discusses the conceptual model for this analytic approach and the development of candidate TPM variables.

Nature of Model

Stepwise multiple linear regression was selected as being the most suitable analytical technique. Anticipating a rather limited sample size, it was felt that the final regression equation should contain no more than three to five independent variables. Hopefully, a majority of the acceptable terms would be traffic performance measures, either basic tracking and flow statistics or such statistics normalized by geometric elements with which they might interact to define hazard.

The candidate independent variables other than TPM's were as follows:

- Degree of curvature or central angle for isolated horizontal curves.
- Width of traveled way (i.e., that surface bounded either by the edges of the high-type pavement or by edgelines if they exist).
- Shoulder width (i.e., distance from edge of traveled way to upper breakpoint of side slope, assuming adequate maintenance of asphalt, gravel, or grass surface).
- Average daily traffic volume at the time of TPM data collection.

- Type of delineation present during the data collection effort, including:
  - Centerline only
  - Centerline and edgelines
  - Centerline, edgelines, and post delineators

Obviously, type of delineation differs from the other candidate independent variables in that it cannot assume a continuous range of values, but rather only the three identified above. In order to mathematically include such a discrete variable in the regression analysis, it was therefore necessary to make use of "dummy variables," each of which assume an arbitrarily defined on/off status depending upon the type of delineation at a given site. The three possible Phase I delineation systems were uniquely defined by setting the values of two dummy variables, X_1 and X_2, according to the following table:

Delineation System	X_1	X_2
Centerline Only	1	1
Centerline and Edgelines	1	0
Centerline, Edgelines, and Post Delineators	0	0

In order to select for the ultimate regression a few of the more explanatory variables from both the TPM and physical-attribute categories, preliminary analyses were to treat the categories separately. This approach would not only suggest which variables should be "forced into" the ultimate regression, but it would also provide additional evidence of the complementary predictive roles played by the two types of independent variable.

CANDIDATE TRAFFIC PERFORMANCE MEASURES

Guidelines

In the context of this study, a traffic performance measure was defined as any measurable parameter that describes the flow of traffic at a point or over a section of two-lane highway. Under this definition, the following parameters could be included as TPM's:

- Speed
- Lateral Placement
- Headway
- Brake Applications
- Erratic Maneuvers

For each of these TPM's, various statistics can be used to quantify the parameter. For example, speed can be expressed in terms of an average or mean, variance, skewness, profile, or percentile, etc. The statistic used for evaluation purposes depends upon the objective of the study or the treatment being evaluated. Given the aim of the planned regression modeling, it was desirable to compute several intuitively appealing statistics for each possibly relevant TPM, so that the quality of the prediction (i.e., correlation) might be maximized.

Procedures

In this project, it was proposed to develop models relating accidents to TPM's for three broad geometric situations—tangent sections, winding sections, and isolated horizontal curves. Critical to the model development was the collection of data for those traffic performance measures most likely to be related to accidents and at the most appropriate locations along the test section. To supplement engineering judgment, a selection methodology employing the Information-Decision-Action (IDA) sequence file and an Accident-Prior-Movement (APM) analysis seemed appropriate. Both the IDA and APM analytical techniques were presented in NCHRP Report 130 as part of a methodology for selecting and evaluating delineation treatments.(14)

In NCHRP 130, an IDA task analysis procedure was utilized to translate driver performance requirements to information (delineation and signing) requirements. Simply stated, an IDA analysis defines, for a specific geometric situation, the desired driver action, determines the decision necessary to effect these actions, and then specifies the information needed by the driver to make the required decision. The most useful elements of the IDA analysis for its application to this study were the actions required by the driver in order to properly negotiate a particular situation. These actions could be translated into traffic performance measures. Further discussion of the IDA task analysis can be found in Appendix B of NCHRP Report 130. Included in that appendix is a table (B—3) listing several IDA sequence files developed for 13 classical highway situations.

Another approach to identifying the appropriate TPM's for a given situation was to define the possible accident types which can occur and determine possible vehicle movements that could have preceded each type of accident. Traffic performance measures could then be chosen to describe or quantify those prior movements. In NCHRP 130, "Problem Analysis Guideline Forms" were developed for several highway situations (see Appendix R). These forms list in matrix format possible accident types and prior movements, as well as information requirements.

TPM's for Tangent Situation

Identification by IDA Sequence File — A tangent section can be categorized as a steady-state situation. This means that a driver's task requirements are limited to maintaining continuous adjustive control, both lateral and longitudinal. Except for transitional situations that arise such as at intersections or during passing maneuvers, an IDA model for the rural tangent section is characterized by a lack of change. Shown in Table 3 are the actions required by the driver and the corresponding TPM parameters.

Table 3. Identification of TPM's for tangent section, from IDA model.

Location	Driver Action	Possible Traffic Performance Measures
Continuous along section	1. Maintain lane position	1. Lateral placement a. Spot-location b. Continuous- or multiple-location 2. Centerline encroachment 3. Shoulder encroachment
	2. Maintain speed	4. Speed a. Spot b. Continuous 5. Acceleration/deceleration
	3. Maintain headway	6. Headway

The table indicates that there are only three control actions required of the driver along a tangent. He should maintain his speed (ideally at the speed limit or at a reasonable speed dependent upon the geometrics), maintain a position in his lane, and keep a reasonable distance (headway) from the vehicle in front of him. The TPM's listed in the third column are those which can numerically describe those driver actions. These measures correlate well with those identified in the literature search.

Identification by Prior Movement Analysis — As shown in Figure 6, there are four different accident types likely to occur on a two-lane tangent section without any intersections or other situations which would require a change in the driving task. These include the head-on and sideswipe for opposite-direction vehicles, and the rear-end and run-off-road types for same-direction vehicles. Displayed across the top of the figure are possible prior movements leading to such accidents. Those prior movements that are appropriate to a particular accident type are indicated by a "bullet" (●). Note that the associated TPM's are identical to those identified through the IDA analysis approach.

Accident Type \ Prior Movement		High Speed	Rapid Deceleration	Short Headway	Shoulder Encroachment	Centerline Encroachment
Opposite Direction	1. Head-On					●
	2. Side-Swipe					●
Same Direction	3. Rear-End	●	●	●		
	4. Run-Off-Road	●			●	

Traffic Performance Measures	High Speed	Rapid Deceleration	Short Headway	Shoulder Encroachment	Centerline Encroachment
1. Speed	●				
2. Speed Profile		●			
3. Headway			●		
4. Lateral Placement				●	●
5. Shoulder Encroachment				●	
6. Centerline Encroachment					●

Figure 6. Accident type/prior movement/TPM relationships for two-lane tangent situation.

TPM's for Winding Sections and Isolated Horizontal Curves

Identification by IDA Sequence File — The driving task for these situations is much more demanding than for the tangent situation. Adjustments to the steady-state control behavior associated with the tangent are required in order to safely negotiate the curvature. Guidance for these adjustments must be provided at certain key locations to inform the driver of the necessary actions.

For two-lane curved alignments, the IDA approach also identified speed and lateral placement as the primary indicators of driving behavior. However, four specific locations were suggested for measurement points: (1) advance of curve, (2) point of curvature, (3) curve midpoint, and (4) point of tangency. Since the driving task usually results in adjustments to both speed and lateral placement through a curved section, the relative extent to which these TPM's change between consecutive measurement points should reflect the degree of driving difficulty and therefore hazard.

Identification by Prior Movement Analysis — The probability of leaving the intended lane on a cruved alignment, a prelude to most rural crashes, should be reflected statistically in certain speed and lateral placement measures. Also, rapid deceleration within a lane might indicate erratic behavior which could lead to an accident. With an emphasis on speed variations and the frequency of centerline and shoulder encroachments, the APM analysis suggested the same basic TPM's and measurement points as did the IDA approach.

Headway, brake applications, and erratic maneuvers were considered to be of secondary importance and no specific plan for collecting these data directly was devised. Under the low to moderate traffic volumes established in the experimental design matrices, headways are likely to be so large as to render this a rather insensitive predictor of accident potential; in any case, volume level would serve as an indirect measure of headway. Brake applications and erratic maneuvers not reflected in the speed and lateral placement statistics would be too difficult to monitor in the types of roadway situations to be studied.

CHAPTER IV

PREPARATION FOR PHASE I FIELD STUDIES

Having identified the basic study site characteristics and the raw traffic performance data to be collected, the actual locations and procedures for conducting the Phase I field studies had to be selected and prepared. This chapter presents the detailed site selection criteria and procedures, the macro and micro configurations of measurement apparatus, and the sampling requirements.

SELECTION OF STUDY SITES

Guidelines

The Field Evaluation Study, for logistical reasons, was constrained to select sites from among a few states located in the eastern half of the country. Since sites were supposed to be chosen from among those identified for the SAI project, this meant that candidate states included Connecticut, Ohio, Maryland, Virginia, Georgia, and Louisiana. It would have been highly desirable to await the availability of physical data on all sites in these states before selecting the most promising locations at which to field check sites for this study. However, the schedule interface between research projects would not allow this, and the review of potential sites had to be performed on a state-by-state as-available basis.

In addition to meeting—and desirably falling near the center of—the allowable cell ranges described in Figures 3, 4, and 5, field study sites were to satisfy the very restrictive criteria listed in Table 4. Since criteria 3 through 6 taken together define an extremely high-quality driving environment, the research team was prepared to accept minor deviations in order to complete site selection within the alloted time.

Procedures

The pace of site selection was determined largely by the arrival of the necessary descriptive data from the SAI research group. As the full set of data became available for a given eastern state, AMV would go through the following "filtering" steps in the office:

- Sites whose documented physical characteristics appeared to fit the AMV experimental design matrices would be so-classified. Others would be filed for possible use should the matrices be redrawn at a later date.

- Accident histories at the candidate sites underwent a cursory review. If no accidents were reported between 1969

Table 4. Phase I site selection criteria.

No.	Criterion	Specifications
1	Alignment of Monitored Subsection Representative of Overall Highway Section	Each several-mile-long SAI "site" must contain one or more subsections having appropriate horizontal alignment and acceptably small gradients; briefly, the objective features are as follows: • Tangent — There should be a pure tangent section of at least 0.68 mile (1.10 km) in length, ending in horizontal curves no sharper than 3 degrees. • Winding — An "S" curve is required, consisting of two consecutive, reversed curves separated by a tangent no longer than 500 feet (152 m). The curves should be roughly equivalent and at least 5 degrees or sharper in order to establish a clear distinction with respect to the tangent situation. • Curve — The horizontal curve should be isolated from other curves by 0.3 - 0.5 mile (0.5 -0.8 km) and should be on a highway tending more toward the tangent definition than the winding definition.
2	Inconspicuous Parking	Accessible, safe, and reasonably inconspicuous equipment-van parking places must be available near the geometrically appropriate subsections identified according to Criterion 1. For the isolated curve situation, there should be a parking place on each side of the highway. All setups are limited by a maximum lead-in cable length of 1,000 feet (305 m).
3	Minimal Roadside Distractions	There should be no potentially significant roadside features which might affect vehicle tracking or accident occurrence adjacent to the subsection where TPM's are to be determined. Examples include severe slopes and/or guardrail close to the road; driveways providing visual contrast with the highway pavement and/or disruptive traffic turning movements; and excessive visual noise such as conspicuous fence and pole lines, reflective signs, stationary light sources, and multiple mailboxes.
4	Good Pavement	The pavement surface must be reasonably crack-free and sound to allow attachment of sensitive electrical tapeswitches.
5	Minimal Shoulder Contrast	Shoulders affording significant visual contrast with the main pavement should be avoided at all sites if possible, but they definitely cannot be accepted at sites without edgelines.
6	Average Delineation Maintenance	The delineation should be neither badly worn or newly installed.

and 1974, a site would be rejected due to uncertainty over whether the accident experience was truly nil or simply not properly recorded and filed.

The last step in selecting a field study site was to inspect in person each candidate site identified in the office. This field inspection included the following items of work:

- Checking roadway geometrics and delineation for consistency over the route and for compatibility with the intended cell of the site matrix. (The ADT estimate previously available was not checked in the field due to the excessive delays it would have imposed upon the engineer(s) on the inspection team.)

- Locating geometrically appropriate subsections at which to observe traffic performance (see Table 4).

- Finding adequate equipment-van parking places and seeking permission to park from the involved property owners.

- Evaluating and photographing the driving environment with regard to the other criteria listed in Table 4. This photo documentation utilized drive-through Super 8-mm film as well as 35-mm color slides.

- Locations where traffic sensors were to be installed and the van parked were noted with small paint marks at the pavement edge, as well on a field sketch.

- Approval for roadway instrumentation was sought from appropriate state highway authorities.

Results

Upon completion of the companion project's initial site searches in the six eastern states, a total of 151 study sections had been identified. However, review of all of these for purposes of the Field Evaluation Study netted only 19 of the 32 required. Fifty of the 151 candidates were set aside because they failed to fall within the AMV study design. The primary reasons for rejecting sites at this level were that several had no delineation at all and/or had very low ADT volumes. Highway sections carrying fewer than 500 vehicles per day would have required inordinately long periods of time for collection of adequate TPM samples.

The second level of evaluation, comprised of a brief review of the accident histories at candidate sites, resulted in the rejection of five additional sites having no reported accidents over a recent six-year period. This minor rejection still allowed an accident data base with more than adequate variation for regression-modeling purposes.

The last level of site evaluation—field checking—resulted in the selection of 19 sites and the rejection of 35 sites. (Eight sites had to be field checked to confirm their classification as duplicate sites and 34 redundant sites were not field checked because satisfactory study sites falling within the same cell descriptions had been previously selected.) In addition to rejecting sites because of their failure to satisfy the selection criteria listed in Table 4, a few were found to have current characteristics different than those documented for SAI's historical accident analyses. It was vital, of course, that site characteristics be essentially constant (except for minor growth in traffic volumes) over the time periods used to compile both the accident and TPM data bases for modeling purposes.

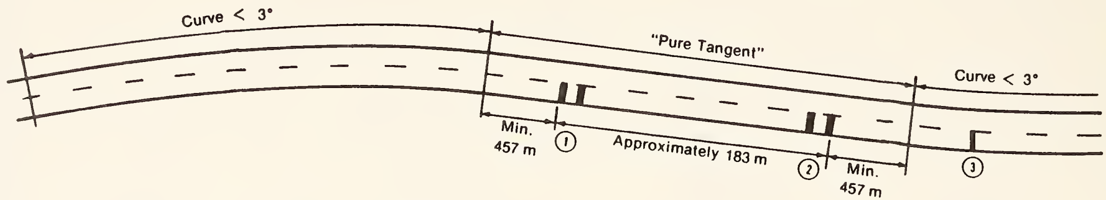
Having obtained only 19 of the required 32 study sites by the anticipated means, a special effort had to be made by the SAI and AMV team to locate the balance of the requirement. The states of Maryland and Virginia were initially chosen for renewed searching due to their moderate winter weather and nearness to AMV-Penn State offices. When these two states failed to yield the total remaining need, the study team turned to Pennsylvania and completed the effort. In summary, the 32 sites described in Appendix A were geographically distributed as follows:

Table 5. Geographic distribution of Phase I study sites.

State	Number of Sites			
	Tangent	Winding	Curve	Total
Connecticut	2	2	1	5
Pennsylvania	0	1	1	2
Maryland	2	2	6	10
Virginia	5	4	1	10
Georgia	0	0	1	1
Louisiana	3	1	0	4
All	12	10	10	32

CONFIGURATIONS OF MEASUREMENT APPARATUS

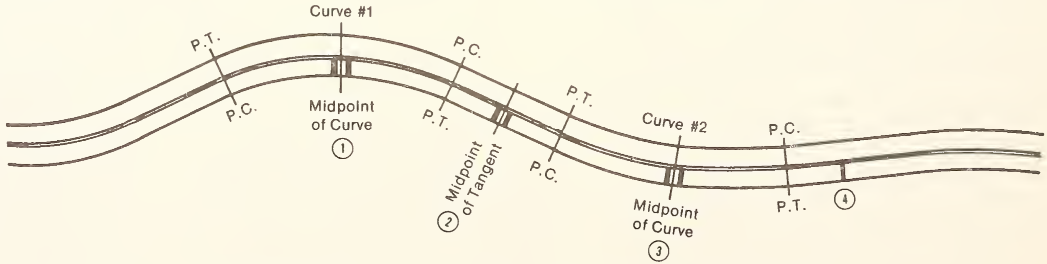
As discussed above and illustrated in Figures 7, 8, and 9, each study section had to contain a particular type of subsection (i.e., test site) a few hundred feet long over which traffic performance was to be monitored. The layout and specific features of the monitoring equipment are described in the following few paragraphs.



Station	Location	Measurement
(1) & (2)	Points on tangent section no closer than 457 m (1,500 ft.) from nearest curve	Speed Lateral Placement*
(3)	Any point beyond Station (2)	Volume

*Includes centerline and shoulder encroachments.

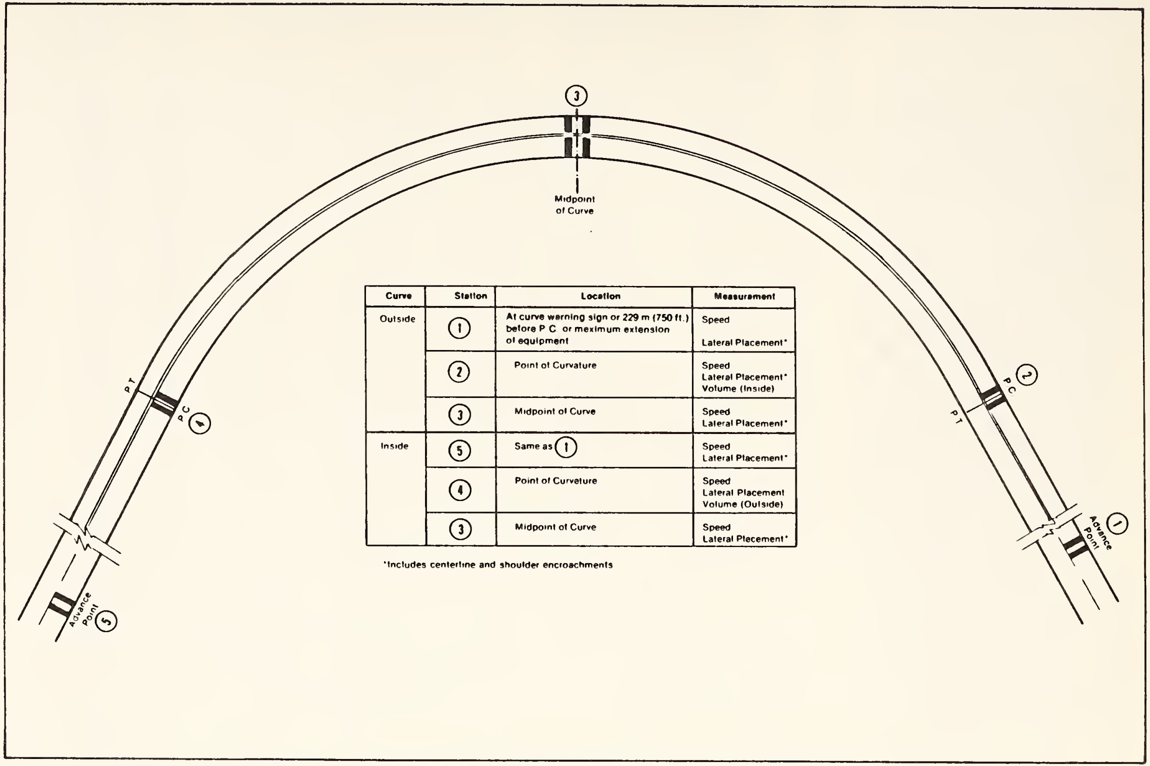
Figure 7. Configuration of measurement apparatus for tangent situation.



Station	Location	Measurement
1	Midpoint Curve #1	Speed Lateral Placement*
2	Midpoint of Tangent	Speed Lateral Placement*
3	Midpoint Curve #2	Speed Lateral Placement*
4	Any point beyond Station 3	Volume

*Includes centerline and shoulder encroachments.

Figure 8. Configuration of measurement apparatus for winding situation.



Curve	Station	Location	Measurement
Outside	(1)	At curve warning sign or 229 m (750 ft.) before P C or maximum extension of equipment	Speed Lateral Placement*
	(2)	Point of Curvature	Speed Lateral Placement* Volume (Inside)
	(3)	Midpoint of Curve	Speed Lateral Placement*
Inside	(5)	Same as (1)	Speed Lateral Placement*
	(4)	Point of Curvature	Speed Lateral Placement Volume (Outside)
	(3)	Midpoint of Curve	Speed Lateral Placement*

*Includes centerline and shoulder encroachments

Figure 9. Configuration of measurement apparatus for horizontal curve.

Macro-Level Configuration

The system used to measure vehicle performance at critical points in a test site's alignment utilized pairs of resistance-based electrical tapeswitches, shown in the preceding series of figures as small solid-black bars. The critical points chosen for establishing these traps were suggested by the Accident-Prior-Movement Analysis discussed in Chapter III. Due to equipment limitations, however, it was decided to forego monitoring the point of tangency at winding and isolated curve sites. For the tangent situation, two traps were installed about 600 feet (183 metres) apart in order to determine the extent of TPM variation due to uncontrolled aspects of the driving environment (i.e., those aspects not quantifiable for the modeling or otherwise held constant between sites).

If there was a choice as to where the equipment van might be parked in a concealed manner, that location requiring the lead-in cables to cross the minimum number of driveways was chosen. While cables as long as 1,000 feet (305 metres) could be stretched to connect the tapeswitches to the monitoring console in the van, attempts were made to minimize their exposure to environmental disturbances.

Micro-Level Configuration

The traffic sensor system consisted of tapeswitches applied with two-sided adhesive tape and covered by dull gray duct tape; lead-in cables and adapters; and a Vehicle Placement and Event Monitor (VPEM). The VPEM contained D'Arsonval meters for lateral placement measurement and digital clocks (precise to 0.01 second) to collect data for speed calculations. A pneumatic tube counter was also installed well downstream of the monitoring area in order to obtain an hourly volume profile.

As a vehicle crossed successive tapeswitches, the 50-mark lateral placement meters and digital clocks would "freeze" at the measured values until manually reset. This prevented confusion of readings when vehicle platooning occurred, and it allowed the accurate recording of values before subsequent free-flowing vehicles arrived.

Reading of the lateral placement meters was generally to the nearest half or whole mark, or to within 1 or 2 percent of the calibrated length of tapeswitch. Possible additional measurement errors consisted of 0.2 percent within the VPEM itself (determined under laboratory conditions) and 1 - 2 percent related to the tapeswitch calibration process. In total, the error in the determination of true lateral placement for an individual activation was expected to be 2 - 4 percent of the calibrated switch length, or 3 - 6 inches (7.6 - 15.2 cm). Since there was no reason to suspect a significant systematic bias in this error, the individual deviations from actuality were of little consequence when averaged over a large sample.

The error of the speed "measurement" was a function of the clock's resolution (± 0.01 second), the trap length, the amount of error in the physical layout of the trap, and the magnitude of the vehicle's speed itself. For example, Table 6 gives expected errors for various combinations of the these factors. Note that the error of ± 0.3 foot (9.1 cm) indicated in the "worst-case" section is larger than would normally be expected, as the traps were measured with a cloth tape to the nearest 0.1 foot (3.0 cm). In general, for a trap length of 22 ± 0.2 feet (6.71 ± 0.06 m) and a speed of 50 mph (80.5 km/h), the speed estimate would be ± 2 mph (3.2 km/h) of the true value. This result is comparable to the accuracy expected from a radar speedmeter.

SAMPLING REQUIREMENTS

Guidelines

The choice of the sample size to be used in the conduct of the data collection effort was one of the more important decisions to be made in the planning phase of the project. It would have been inappropriate to arbitrarily select the sample size and then assume that the estimates thereby obtained are sufficiently accurate to yield valid conclusions. Instead, it was essential that a statistical analysis be conducted to determine the required sample size. The purpose of this section is to present the results of such an analysis.

The exact sample size required in any statistical analysis is dependent upon the size of the interval and the level of confidence which is desired. Consider, for example, the problem of estimating the true population mean from a sample. For any given level of confidence, it is necessary to increase the sample size in order to decrease the size of the interval within which the true population mean can be expected to occur. The size of the sample is also dependent upon the particular parameter being estimated. At a given level of confidence, a smaller sample is required to estimate the population mean than is required to estimate the population variance. Since several different parameters based on means and variances were considered in this study, it was necessary to conduct sample size analyses for both statistics.

Procedure and Results for Estimate of Mean

Assuming a normally distributed sample of either speed or lateral placement observations, the following equation was used for determining the required sample size:

Table 6. Expected errors for speeds computed from tapeswitch traps.

Ideal Values			Worst-Case Combinations of Possible Values			
Speed (mph)	Trap (ft)	Clock (sec)	Trap (ft)	Clock (sec)	Error (mph)	Error (percent)
30	22	0.50	21.7 22.3	0.51 0.49	-1.00 +1.02	-3.3 +3.4
40	22	0.375	21.7 22.3	0.385 0.365	-1.58 +1.65	-4.0 +4.1
50	22	0.30	21.7 22.3	0.31 0.29	-2.28 +2.42	-4.6 +4.8
50	44	0.60	43.7 44.3	0.61 0.59	-1.17 +1.18	-2.3 +2.4
60	22	0.25	21.7 22.3	0.26 0.24	-3.11 +3.34	-5.2 +5.6
60	44	0.50	43.7 44.3	0.51 0.49	-1.59 +1.63	-2.6 +2.7

Note: 1 mph = 1.61 km/h
1 foot = 0.305 metre

$$n = \left\{ \frac{Z_\alpha \sigma}{d} \right\}^2$$

where:

n	=	required sample size,
d	=	$(\bar{Y} - \mu)$,
$\bar{Y}$	=	estimated population mean,
μ	=	true population mean,
σ^2	=	true population variance, and
Z_α	=	defined such that the integral of the standard normal density from Z_α to ∞ equals α.

Table 7 identifies the sample size required for various values of "d" and "σ^2." In all cases, a 95 percent confidence level was assumed. Past research has indicated that a sample variance of 50-100 mph^2 (129 - 259 km^2/h^2) is typical in speed studies, whereas a variance of 144 in^2 (929 cm^2) is common in lateral placement studies. As mentioned in the preceding section, a confidence interval of $\pm$ 2 mph (3.2 km/h) for estimating mean speed was sufficient because a radar speedmeter can yield no better an estimate; hence, a sample size of 100 appeared adequate and was accepted as the minimum. For 100 observations, the typical confidence interval for lateral placement estimation is about $\pm$ 2.5 inches (6.4 cm), an acceptable value slightly less than the measurement error of the tapeswitch system itself (discussed earlier).

Table 7. Sample size requirements for estimation of the mean.

TPM	Confidence Interval	Population Variance (σ^2)	Required Sample Size (n)	Confidence Level (percent)
Speed (mph)	$\pm$ 1	49	190	95
		100	390	95
	$\pm$ 2	49	50	95
		100	100	95
Lateral Placement (inches)	$\pm$ 6	144	15	95
	$\pm$ 3	144	65	95
	$\pm$ 2	144	140	95

Note: 1 mph = 1.61 km/h
1 inch = 2.54 cm

Procedure and Results for Estimate of Variance

The sample size required to estimate population variance was determined by expressing the confidence interval as follows:

$$\frac{fs^2}{X^2_{\alpha_1}} \leq \sigma^2 \leq \frac{fs^2}{X^2_{\alpha_2}}$$

where:

f = degrees of freedom (i.e., sample size minus 1),

s^2 = sample variance,

σ^2 = population variance, and

$X^2_{\alpha_{1,2}}$ = value of the Chi-Square distribution with f degrees of freedom which is exceeded with the probability $\alpha_{1,2}$ (e.g., for a 95 percent confidence level $\alpha_1 = 0.025$ and $\alpha_2 = 0.975$).

Using this expression, it was possible to construct Table 8. As can be seen, a larger sample size is required in order to obtain the same degree of accuracy found above in the estimation of the mean. The results of this analysis indicated that in order to maintain an error of no more than ± 10 percent in the estimate of standard deviation for lateral placement observations, a sample of 150 observations would be desirable. A sample of 100 was considered the practical minimum and yields a confidence interval of ± 14 percent at the 95 percent significance level.

Table 8. Sample size requirements for estimation of lateral placement variance.

Sample Size	Level of Confidence	Predicted Error of the Estimate (percent)	Predicted Error of Estimated Standard Deviation (percent)
250	95	± 20	± 10
	90	± 17	± 8
150	95	± 24	± 11
	90	± 20	± 9
100	95	± 29	± 14
	90	± 24	± 11
80	95	± 33	± 15
	90	± 27	± 13
50	95	± 43	± 19
	90	± 35	± 16

CHAPTER V

COLLECTION, PROCESSING, AND ANALYSIS OF TPM DATA

The full background of the Phase I field studies has now been described. This chapter elaborates on the actual data collection experiences, describes briefly the editing and computer processing of traffic performance data, and presents a series of statistical comparisons of the means and variances of the observed speed and lateral placement distributions.

DATA COLLECTION EXPERIENCES

Guidelines

The two primary temporal variations in the driving environment—weather and ambient light condition—required an early determination of those combinations feasible for study within the time constraints of the project. The usefulness of delineation is most critical under adverse weather conditions, particularly at night. However, the infrequent and unpredictable nature of rainfall precluded the possibility of collecting sufficient wet-weather TPM data for modeling.

The other important stratification, day versus night, could be more easily accommodated. Since typically only 20 percent of the average daily traffic volume occurs in darkness, there would be little difficulty in obtaining daytime as well as the essential nighttime TPM data. The data collection crew was expected to work from fairly early in the morning until about 11 p.m., when long headways would make a continuation of the effort impractical.

Typical Data Collection Day

The amount of time required to obtain the 200 or more observations at a site (100 under each light condition) depended upon several factors, the most important being ADT volume. Other factors included time of arrival at the site, type of site, the amount of switch position layout by the advance inspection party, time of sunset, and the extent of equipment reliability. The "typical" days portrayed in Tables 9 and 10 are therefore not really typical, but rather are hypothesized schedules realistic only under a set of "standard conditions" and low to moderate traffic volumes.

Rates of Data Collection

Figure 10 is a plot of the total number of hours of data collection required to complete a site versus the site ADT. As can be seen, the relationship is exponential. The reason for the envelope instead of a single curve is twofold. First, the time requirements appear to have been operator-dependent; that is, each operator appears to have had

Table 9. Typical first day at study site.

Time Period	Activity
3:00 - 6:00 p.m.	Deployed Equipment • Identified site, truck position, tapeswitch locations • Made final measurements for speed traps • Installed tapeswitches; measured as-installed positions; set calibration marks • Reeled-out cable and connected to switches • Set up traffic counter
6:00-7:00 p.m.	Calibrated Tapeswitches
7:00-7:30 p.m.	Waited for Darkness
7:30-11:00 p.m.±	Collected Night Data • Continued data collection until sufficient sample was obtained or volume was too low to justify continuation • Number of "dry nights" spent at any one site depended primarily on the ADT and month of year (i.e., time of sunset relative to peak hour) • In order to maintain a high capture rate, Operator No. 1 read the observations from the VPEM and reset for the next observation while Operator No. 2 recorded the information

Table 10. Typical second day at study site.

Time Period	Activity
8:00 a.m.- 12:00 p.m.±	Collected Daytime Data • Continued data collection until desired sample was obtained • Volumes were higher than at night, so daytime requirements did not control the number of days at a given site • Data collection task assignments same as for night
12:00-7:30 p.m.	What was done during this period was dependent upon the amount of data collected on the previous night • If night sample was complete, data collection equipment was picked up and moved to next site; if time permitted, it was set up for night data collection at that site • If night sample was not complete, this period was used to perform repair and maintenance operations on the equipment
7:30-11:00 p.m.±	Completed Night Data Collection • Again, this depended upon the site ADT and the actual time of sunset

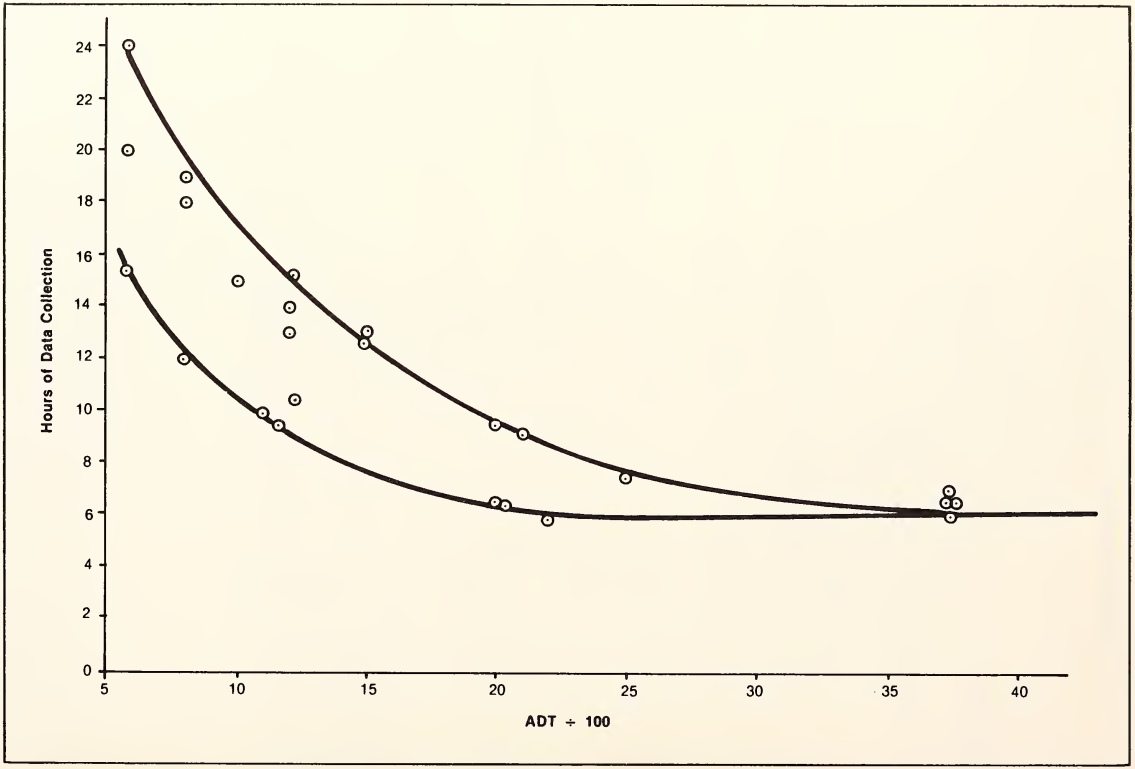


Figure 10. Total data collection time required versus ADT volume.

a different "capture rate." This is probably due to the use of various recording and reset techniques during data collection.

Second, the curves are also dependent upon the time at which night data collection could begin. This is shown more dramatically in Figure 11. Curves No. 1 and 2 represent the amount of time required to collect 100 night observations when data collection was begun during the first half of the peak period. Curve No. 1 represents a 5:00 p.m. start and Curve No. 2 represents a 5:30 p.m. start. Each successive curve (3—5) represents a start time which is one-half hour later than the previous curve. Finally, the dashed curve represents the estimated number of hours based on an 8:30 p.m. starting time. This curve was estimated on the basis of data collection experience after 8:30 p.m. at Phase I sites.

Wet-Weather Data

According to field trip reports and data collection records, rain occurred at 10 of the 32 sites during some portion of the data collection period. Again, according to the records, rain data were taken at five of these sites—CT 19, CT 30, VA 24, VA 43, and MD 60. However, most of the sample sizes were well below the minimum 100 required for meaningful analyses. The reasons for the small sample sizes were as follows:

- In several instances, particularly in the early stages of Phase I, these rain periods were used to repair and maintain the data collection equipment.
- As the intensity of the data collection effort increased, and the data collection crews worked long hours to collect dry data, the rain periods were needed for rest.
- Several of the rain periods were too short to accomplish the collection of a significant number of observations.
- In general, rain caused delays in the installation of the tapeswitches at new set-ups rather than in collecting data after the switches were in place. Hence, considerable delay might be encountered before dry data collection could start, but wet weather data could not be gathered as the equipment was not operational.

PROCESSING OF RAW TPM DATA

Transmittal and Keypunching

Upon completion of data collection at a site or group of sites, Pennsylvania Transportation Institute (PTI) provided AMV tabulated TPM data with supplementary field diagrams and notes. This information was conveyed on the forms shown in Appendix B. (Not shown is the simple

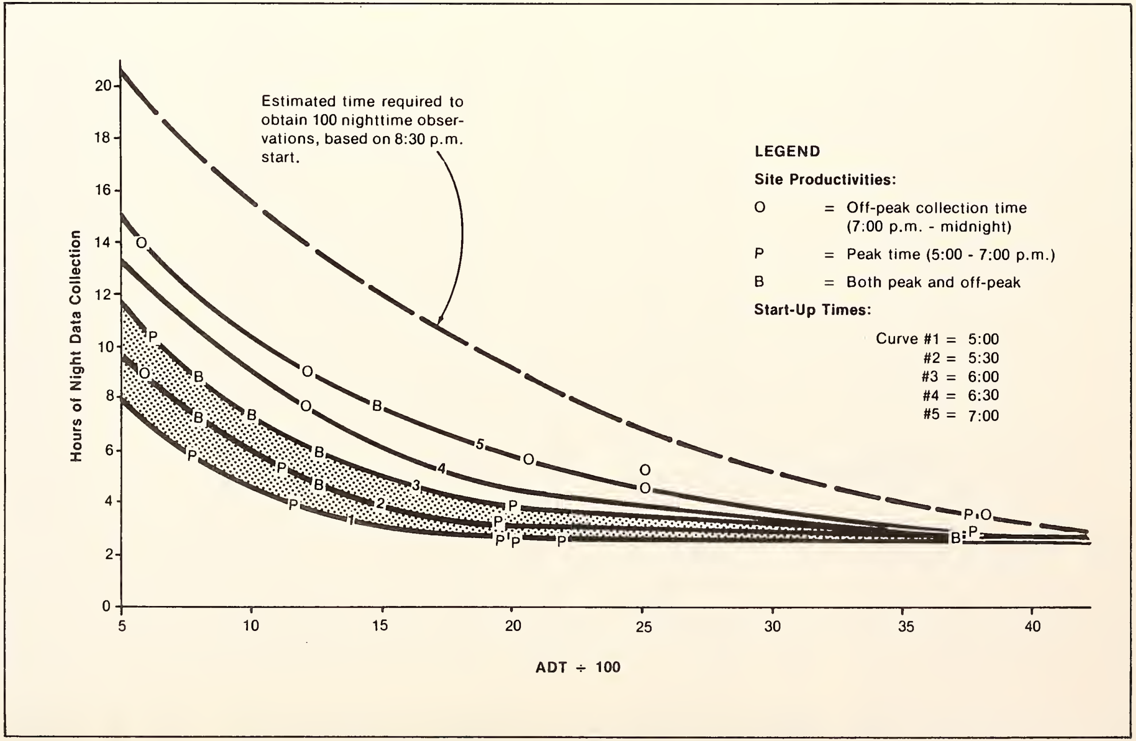


Figure 11. Hours required to obtain nighttime sample, by ADT volume and data collection start-up time.

schematic for tangent sites.) The comments section on Table 52 (Appendix B) generally was used to note those observations which were recorded with an opposing vehicle in the vicinity. This situation was assinged a special identifier which was keypunched, along with all of the other alphanumeric data, directly from the field forms.

Editing

Initially, field data received from PTI were input directly to a computerized data processing program. This program computed all derived TPM's (discussed in Chapter VII) as well as the basic statistics of the speed and lateral placement distributions. However, early reviews of the computer output clearly indicated the need for some type of editing for reasonableness. Specifically, it was obvious that a number of erroneous readings had been recorded, and that these false readings were affecting the overall statistics and TPM's being generated for possible use in the modeling effort.

After the raw data had been initially processed by the program, the same data was input again with an optional edit feature in effect. This feature searched for lateral placement observations which for a given vehicle passage differed by two feet (0.61 m) or more between the two tapeswitches in a trap. A differential this large was considered to define a highly improbable angle of departure from the traveled lane. Due to a wave phenomenon associated with tapeswitch activations, a false value would almost always be closer to the centerline than a true value which might not have registered. Hence, if the program detected a large lateral placement differential between consecutive tapeswitches, it discarded the larger of the two values. If both lateral placement readings from a trap were kept, they were averaged to produce a single value for the station.

Upon manually reviewing the second print-out for a given data set, there still seemed to be questionable values in some cases. Without biasing the results, it appeared possible and desirable to conduct a carefully objective human search for additional perturbations. In the event that a datum in the output list was of suspicious origin, horizontal and vertical comparisons were made to identify any patterns in the numbers which may be present. Also, any special notes which the data collection team made were checked to determine if they might explain a dubious value. When an explanation was obtained, the wayward value was manually eliminated from the data base. Since the several thousand observations were all reviewed by the same person, consistent criteria were applied throughout the editing procedure.

Derivation of Basic Statistics

After all editing was completed, the revised data base was again processed by the computer program, with the key distribution statistics listed as shown in Table 11. These statistics were also automatically

Table 11. Sample output from field data processing program.

STATISTICAL SUMMARY OF OBSERVED TRAFFIC PERFORMANCE MEASURES
ME 2 (TANGENT) UNDER DRY NIGHTTIME CONDITIONS
CELL 22

LATERAL PLACEMENT MEASURES

TRAP NUMBER (PROCEEDING IN D.O.T.):	1	2
NUMBER OF OBSERVATIONS:	150.	150.
MEAN PLACEMENT (FROM EDGE OF TRAVELED LANE):	3.5	3.5
RT. TIRE PLACEMENT OF 15TH-PERCENTILE VEHICLE:	2.2	1.9
LT. TIRE PLACEMENT OF 85TH-PERCENTILE VEHICLE:	10.2	10.3
VARIANCE (FT.**2):	1.4	1.8
STANDARD DEVIATION (FT.):	1.2	1.3
COEFFICIENT OF SKEWNESS:	0.34	-0.01
KURTOSIS:	2.75	2.73
NUMBER OF COMPUTED CENTERLINE ENCROACHMENTS:	6.	3.
NUMBER OF COMPUTED SHOULDER ENCROACHMENTS:	0.	0.

SPEED MEASURES

TRAP NUMBER (PROCEEDING IN D.O.T.):	1	2
NUMBER OF OBSERVATIONS:	150.	150.
MEAN SPEED (MPH):	50.4	50.0
SPEED OF 15TH-PERCENTILE VEHICLE:	41.0	41.0
SPEED OF 85TH-PERCENTILE VEHICLE:	57.0	57.0
VARIANCE (MPH**2):	62.0	62.6
STANDARD DEVIATION (MPH):	7.9	7.9
COEFFICIENT OF SKEWNESS:	-0.47	-0.04
KURTOSIS:	3.47	3.90

punched onto cards for later input into the regression process as candidate independent variables.

ANALYSIS AND FINDINGS

Guidelines

The results of the regression analyses of accident rates versus traffic performance measures will be discussed in Chapter VII. At this point, however, it is worthwhile to present the findings related to the raw speed and lateral placement data alone, with an emphasis on how the means and variances differed across various locations and conditions. These measures were analyzed to determine how they varied (1) between data collection stations, (2) by day versus night, and (3) by delineation treatment. In comparing mean values, both the t-test and the non-parametric sign test were used to derive statistical inferences. In comparing variances, the F-test was employed. In all cases, the 95 percent probability level was used for statistical significance.

Vehicle Speed

Tangent Situation — Table 53 in Appendix C summarizes the vehicle speed data, both means and variances, for the tangent situation. Since the 12 sites did not have the same speed limit, comparison of mean speeds between sites is not appropriate.

The first comparison made was to determine if speed means or speed variances differed between traps. One would expect that these values would not differ significantly along the tangent situation, which is normally free from geometric constraints that would influence the driving pattern. In comparing the mean speeds between station 1 (upstream) and station 2 (downstream), it was found that there were, in all cases for both day and night, statistically equal means. The largest difference in speeds was 1.7 mph (2.7 km/h), which is a statistically insignificant difference. Neither station tended to show a higher mean speed. In addition, speed variances were equal for all but one station comparison. This finding further supports the original hypothesis that driving behavior, as measured by TPM's, is fairly consistent (or more appropriately, without significant noise) on a tangent type of highway.

The next question addressed was whether speeds varied between day and night conditions. Using a non-parametric sign test, it was found that the night speeds were generally higher than the day speeds; however, none of the differences were statistically significant based on a t-test. A factor which may have caused generally higher speeds at night was a smaller percentage of trucks during this period as compared to the daytime. When the variances were compared, only five of 24 comparisons showed a lack of equality, and again there was no trend for either trap having the larger variance.

A third comparison was made to determine if either speed statistics differed between the two delineation treatments of centerline and centerline with edgeline. However, since the speed limits were sometimes not equal between vertically opposed cells in Figure 3, any differences found cannot be attributed solely to the possible effects of delineation.

Winding Situation — Table 54 in Appendix C lists the mean speeds and speed variances at the three observation stations for each of the winding sites. For this geometric situation, one would expect larger differences in speeds (both means and variances) between consecutive stations because of the change in alignment. It was found, however, that there were no statistically significant differences in mean speeds between stations 1 and 2 or 2 and 3, under both day and night conditions. Furthermore, there was no consistent trend as to how the speeds changed between consecutive stations. While there were no statistical differences found between the means, the average difference in means for the winding situation, 1.2 mph (1.9 km/h), was higher than the corresponding value for the tangent sites, which was 0.5 mph (0.8 km/h).

Similar results were also found when the variances were compared between stations. Of the 40 possible comparisons, only four showed statistically different speed variances.

In the comparison of day to night mean speeds, a non-parametric sign test revealed that 67 percent of the night speeds were higher, but none of the day/night differences were statistically significant. As in the case of the tangent sites, there was a smaller percentage of trucks during the nighttime, which could have accounted for some higher mean speeds during that period. Speed variances were found to be statistically equal for nearly all day/night comparisons.

For the same reason stated previously in the discussion of tangent sites, it was difficult to factor out the effect of delineation treatment on the mean or variance of speed. The speed limits ranged from 30-55 mph (48-89 km/h) and were unequal between otherwise similar experimental cells.

Horizontal Curve Situation — Tables 55 and 56 in Appendix C list the mean speed and speed variances, respectively, for the horizontal curve sites. Since data were collected for both directions of travel, the values for the inside and outside curves are shown in seperate sections. The expected speed profile for the curve situation was that there would be a slight decrease in speed between the advance point (about 500 feet or 152 m before the curve) and the point of curvature, and a more significant decrease between the latter position and the midpoint of the curve. These speed changes, especially between the last two stations, should be higher than for the winding section because the driver is changing his speed from a relatively free-flow condition to a more restrictive condition somewhat unexpectedly. In a winding situation, drivers establish a safe speed that they can negotiate through a series of curves.

The statistical comparison of mean speeds between consecutive stations revealed the following:

- For nearly every site there was a reduction in speed from the advance point to the point of curvature and then again to the curve midpoint. The reduction in speed appeared to be related to degree of curvature.

- 20 percent of the station differences for both day/night and inside/outside were statistically significant.

- Based on speeds at the midpoints of the curves, vehicles on the outside traveled at the same speed as vehicles on the inside of the curves.

In comparing the variances, it was found that similar to mean speeds, variances generally decreased from the advance point to the curve midpoint. Nearly 20 percent of the station comparisons had statistical differences, with a majority of these occurring between the first two stations.

The day/night comparisons of mean speeds revealed that in 72 percent of the cases, day speed was higher than night speed. Since these differences were not statistically significant, however, the analysis was inconclusive. When speed variances were compared statistically, unequal variances were found for 25 percent of the comparisons, but there was no consistent trend for either day or night having the higher value.

Similar to the tangent and winding sites, the horizontal curve sites had different speed limits. Since this was reflected in their mean speeds, a comparison of the means or variances between the three delineation treatment levels would be inconclusive.

Lateral Placement

Tangent Situation — Table 57 in Appendix C lists the mean and variance values of lateral placement for both data collection stations and for day and nighttime periods. Mean lateral placement was measured, in all cases, from the right edge of the traveled lane to the right front tire of passing vehicles. As with speed measurements, comparisons were made between consecutive stations, between day and nighttime conditions, and between delineation treatments.

In statistically comparing the lateral placement between stations, it was found that 40 percent of the means were statistically different. For unknown reasons, 16 of the 24 comparisons showed a higher value for the first station (i.e., vehicles were closer to the centerline). The average of all mean placements at the upstream station during the day was 2.6 feet (0.79 m) while at the downstream station it was 2.5 feet (0.76 m); however, the difference is not statistically significant.

When lateral placement variances were statistically compared, the result was that 14 of 24 comparisons showed statistically different variances. There was no trend for either station having the larger variance.

Lateral placement at night was found to be closer to the centerline than during the daytime, for nearly all comparisons. The average difference was 0.4 foot (12 cm), which is statistically significant. When day/night variances were compared, 50 percent were found statistically different; however, there was no apparent trend for either day or night being higher.

Mean lateral placement values were also compared between treatments to determine if edgelines had any effect on vehicle positioning within lane. Of the four equal cell comparisons that could be made, three showed that lateral placement was closer to the edge of the traveled lane when the edgeline was present. Due to the small number of comparisons, this finding is not conclusive. When variances were compared across treatments, no differences could be detected.

Winding Situation — Table 58 in Appendix C lists the mean and variance lateral placement statistics for the ten winding sites. For every site, the statistics for the inside curve precede those for the outside curve, despite the actual order in which the curves were encountered by the monitored vehicles (see Table 49 in Appendix A). Since the two monitored curves were on an alignment of almost continuous curvature, this appeared to be a reasonable transposition.

With the travel path from an inside curve to an outside curve, one would expect that the lateral placement profile would be increasingly further away from the edgeline. On inside curves, motorists tend to "hug" the right edge, while on outside curves they tend to move toward the centerline.

Figure 12 shows that the expected profile did in fact appear. In comparing the mean placement values between traps, there were only two cases where both day and night values were not significantly different. Changes in vehicle placement through a reverse curve were both significant in degree and consistent in profile. Also, when the placement variances were compared, 65 percent of the station comparisons had statistically significant differences.

A review of mean lateral placement values for day versus night showed that at night, motorists move closer to the centerline, as was found for the tangent situation. This phenomenon is vividly illustrated in Figure 12. When the lateral placement variances were compared, 53 percent were significantly different, with a general trend towards higher variance at night.

Any effect of delineation treatment (centerline only versus centerline and edgeline) on mean lateral placement could not be determined from the data. However, when the variances were compared, there was a trend,

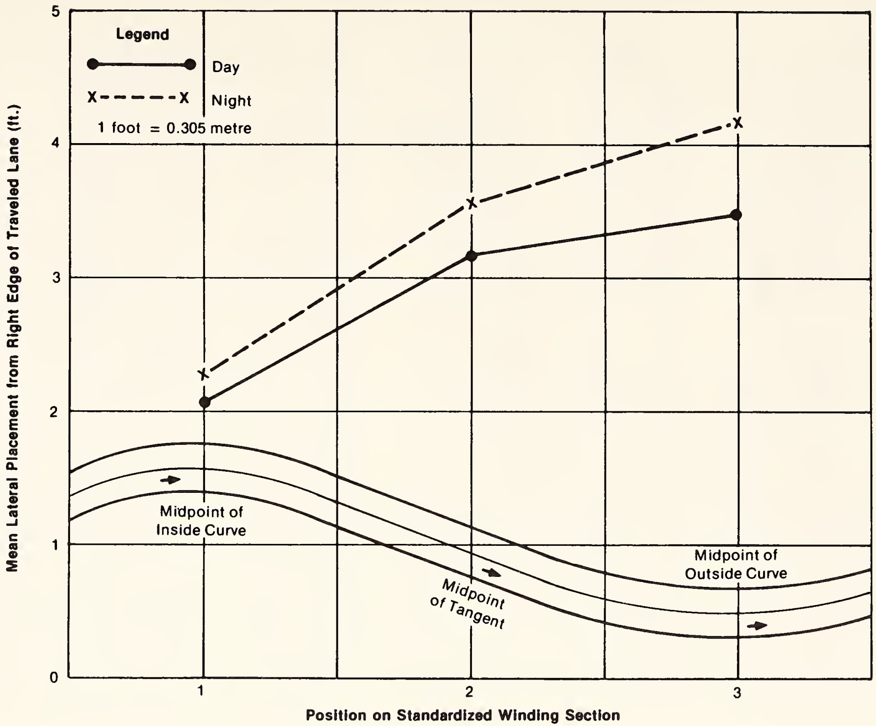


Figure 12. Lateral placement profile for winding sites.

although not statistically conclusive, for higher variance at sites without edgelines.

Horizontal Curve Situation — Table 59 in Appendix C lists the mean lateral placement for day and night and for inside and outside curve measurements. Table 60 lists the respective variances.

Similar to the winding situation, it was predicted that the mean and variance of lateral placement would change as drivers moved from the tangent into the curve. For the inside curve, motorists would tend to "cut the corner"; therefore, lateral placement should move closer to the edge from the beginning of the curve to the midpoint. For the outside curve, the reverse would be true.

Figure 13 presents lateral placement profile for all sites combined and both directions of travel. While some specific sites had slight variations, the lateral placement profiles for the aggregation of sites changed as expected. Between the advance point and point of curvature, there was little or no change, but between the point of curvature and the curve midpoint, lateral placement changed significantly.

Between-station comparisons of mean lateral placement showed that for 70 percent of the comparisons, the means were statistically different. Vehicle placement changes as high as 3.2 feet (0.98 m) were observed. In comparing lateral placement variance between stations, it was found that 74 percent (59 out of 80 possible) of the station comparisons had unequal variances; however, there was no trend as to which station had the higher values.

When lateral placement means during the day were compared to equivalent night values, it was again found that motorists move closer to the centerline at night. This placement change is illustrated in Figure 13. Unequal day/night variances were found in 40 percent of the station comparisons, but there was no trend evident as to which period of the day was higher.

For the ten horizontal curve sites, there were three delineation treatments—centerline only; centerline and edgeline; and centerline, edgeline, and post delineators. Due to the differences in site characteristics between treatment types and the few sites for which data were available, it was impossible to statistically determine the effects of delineation treatments. Any differences found would likely be attributed to chance or more significantly, other geometric factors.

Summary of Basic TPM Findings

The analysis of TPM data in this section was limited to the mean and variance statistics of speed and lateral placement. Some of the TPM's derived from these basic parameters are discussed in Chapter VII in the context of the regression modeling.

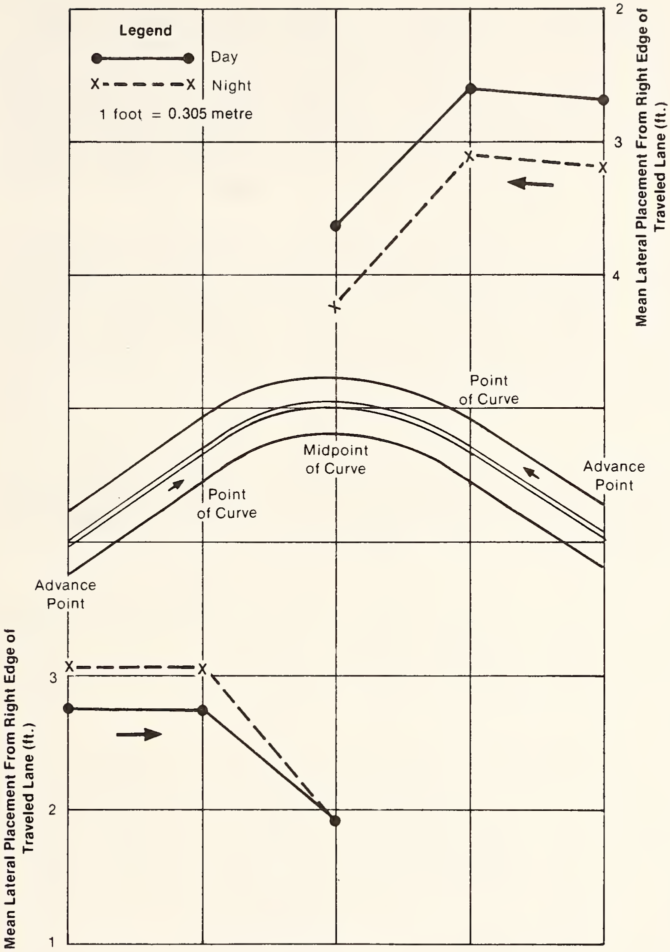


Figure 13. Lateral placement profile for horizontal curves.

Tables 12A and 12B summarize the results of the speed and lateral placement analyses, respectively. As shown in Table 12A, means and variances of speed tended to be insensitive TPM's, especially for the tangent and winding situations. Statistically significant differences were difficult to detect for most comparisons. This analysis did not provide any evidence that mean speeds or speed variances can be modified by delineation treatment. Therefore, it appears doubtful that these particular statistics would be suitable for evaluating the effectiveness of experimental delineation treatments. Previous research, such as that reported in 1972 by Taylor, McGee, et al., has generally come to the same conclusion.(14)

As shown in Table 12B, there was much more variation found in lateral placement statistics for all three situations. Although motorists tend to maintain a reasonably uniform speed over most sections of level highway, the same tendency does not hold for lateral placement. The amount of change in the mean and variance of lateral placement appears to be most strongly influenced by geometrics, and probably to some extent, by delineation. Although the relationship of variation in these placement measures to unsafe operation is not demonstrated until the latter part of Chapter VII, such a relationship does appear intuitive at this point.

It is evident from these results that lateral placement statistics vary more than speed statistics and would therefore be more sensitive to delineation treatments. This observation was also made in NCHRP Report No. 130, based on several similar studies.(14)

Table 12A. Were there statistically significant differences between speed TPM's?

Situation	Between Traps		Day vs. Night		Between Treatments	
	Means	Variances	Means	Variances	Means	Variances
Tangent	No	No	Not statistically conclusive, but night speeds are typically higher	No	Not conclusive	Not conclusive
Winding	No	No	Not statistically conclusive, but 2/3 of night speeds are higher	No	Not conclusive	Not conclusive
Horizontal Curve	20% are statistically different; reduction in speed from advance point to curve mid-point	Not statistically conclusive, but variance general-ly decreases	Not statistically conclusive, but approx. 3/4 of night speeds are lower	No	Not conclusive	Not conclusive

Table 12B. Were there statistically significant differences between lateral placement TPM's?

Situation	Between Traps		Day vs. Night		Between Treatments	
	Means	Variances	Means	Variances	Means	Variances
Tangent	40% of trap compari-sons have different means; no trend	58% of trap com-parisons have un-equal variances; no trend	Yes, night place-ment closer to centerline	50% of comparisons have unequal vari-ances; no trend	Not conclusive but trend is closer to edge with edgeline	No
Winding	Yes, all but 2 com-parisons	65% of trap com-parisons have un-equal variances	Yes, night place-ment closer to centerline	53% of comparisons have unequal vari-ances	Not conclusive	Not conclusive but sites with-out edgeline have higher variance
Horizontal Curve	Yes, 70% of trap comparisons have dif-ferent means	Yes, 74% of trap comparisons have unequal vari-ances; no trend	Yes, night place-ment closer to centerline	40% of comparisons have unequal vari-ances	Not conclusive	Not conclusive

CHAPTER VI

PHASE I ACCIDENT ANALYSIS

Chapter VI discusses the creation and analysis of the dependent-variable data base used in the accident-probability modeling. Emphasis is placed on the accident classification technique designed to enhance the correlation effort, and on trends in key accident statistics across various situation types and operating conditions. This intra-data-base analysis is analogous to that presented in the preceding chapter for the TPM data (i.e., the independent variables). Only after some degree of familiarity could be obtained with both the dependent and independent variable data could the modeling of their interrelationship be capably and confidently undertaken.

ACCIDENT CLASSIFICATION AND PROCESSING

Pertinent Accident Measures

Accident experience can be expressed in different ways and can include all or portions of the total accidents occurring over a section of roadway. The question that arose early in the analysis was: Which of the many accident statistics should be used in the model development?

There are three commonly accepted ways to express accident statistics for a given location and over a given time period, as follows:

- Accident Frequency — actual number of occurrences which may be stratified into various classifications
- Accident Rate — number of occurrences divided by the traffic volume to account for the level of exposure; usually expressed as accidents per million vehicle-miles or per million vehicles
- Accident Severity — typically an index which takes into account the severity of the accidents (i.e., fatality, injury, or property-damage-only); can be expressed in terms of frequency or exposure rate

For this study, accident rate was chosen as the most logical measure to use as the dependent variable because the sites had different lengths and traffic volumes. However, accident frequency and severity rate were also developed for each of the sites and compared.

Since the objective of the modeling was to relate accident histories to the traffic performance measures collected at the sites, it was hypothesized that certain subsets of the accident data would be more highly correlated than the entire set of accidents. For example, one could assume that TPM's during nighttime conditions would be more closely related to night accidents alone than to all accidents. Therefore, the accidents were grouped into several subsets as follows:

- Total Accidents — all accidents except those occurring during snowy or icy pavement conditions or during fog conditions. Snow- and ice-related accidents were deleted to eliminate the unfavorable bias for northern states as opposed to southern states. Also, when any of these three conditions occur, traffic performance measures are likely to be quite different than those observed during field data collection.

- Delineation-Related — a portion of the total accidents which were identified as being possibly related to the presence or absence of delineation. An accident with any one or more of the characteristics given in Table 13 was classified as not related to delineation.

Table 13.
Criteria for identifying non-delineation-related accidents.

1.	Collision Type			
	A. Train			
	B. Animal			
	C. Fixed object within travel lanes			
2.	Maneuver			
	A. U-turn		D. Parking	
	B. Starting		E. Backing	
	C. Improper turning			
3.	Traffic Control			
	A. Police officer			
	B. Railroad crossing			
4.	Major Factor			
	A. Driver-related			
		• Improper turn		
		• Backing onto roadway		
		• Stopped on roadway		
		• Avoid animal or object		
	B. Vehicle-related			
		• Defective equipment		
		• Struck by object		
	C. Roadway-related			
		• Road defect		
5.	Vehicle Type			
	A. Farm truck			
	B. Emergency vehicle			

- Non-Intersection-Related — a portion of the total accidents which did not occur in or near any intersection within the study section.

- Light Condition — total accidents grouped into daytime and nighttime periods to correspond with the TPM's observed within day versus night hours.

- Pavement Condition — total accidents grouped into wet and dry pavement conditions.

With these groupings of accidents, it was possible to develop several accident rates for possible input to the modeling. These rates are best described by the matrix presented as Figure 14.

Figure 14. Accident rates of interest.

	Pavement / Light	Non-Intersection		Non-Intersection and Intersection	
		Dry	Wet and Dry	Dry	Wet and Dry
Total Accidents	Day				
	Night				
	Day and Night				
Delineation-Related Only	Day				
	Night				
	Day and Night				

Data Collection and Processing

The accident data were received directly from Science Applications, Inc. who had responsibility for collecting this information from the various states. In most cases, the data consisted of listings of individual accident characteristics coded onto keypunch forms. The study years ranged from as early as 1969 (if available) to as recent as December 1975. Only accident data for the years (or quarters thereof) corresponding to the periods when the present delineation treatments were in place were utilized. The study period for a given site always consisted of a multiple of 12 continuous months, in order to avoid introducing possible seasonal biases.

For a tangent or winding section, all accidents occurring over the entire section length (usually 3-5 miles or 4.8-8.1 km) were provided.

For an isolated horizontal curve, accidents were of interest if they occurred within a subjectively established zone of influence extending 750 feet (229 m) beyond the points of curvature. From the accident listings provided by SAI, the accidents were sorted into the following classifications:

- Accident Severity
  - Fatal
  - Injury
  - PDO
- Time of Day
  - Night (strictly hours of total darkness)
  - Day (all other periods)
- Surface Condition
  - Dry
  - Wet
  - Snow or ice
- Weather Condition
  - Fog
  - Rain
  - Clear
- Location
  - Intersection
  - Non-intersection
- Delineation-Related
  - Delineation-related
  - Non-delineation-related

With the accidents sorted as noted above, it was then possible to calculate the appropriate accident and severity rates. For the tangent and winding sections, the accident rates were expressed in units of accidents per million-vehicle-miles-traveled and calculated using the following equation:

$$\text{Accident Rate} = \frac{(10^6)\ (N)}{(L)\left(\sum_i ADT_i\right)(P_f)(L_f)}$$

where:

N	=	number of accidents occurring during a given time period and under a specifically defined set of roadway surface and lighting conditions,
L	=	section length in miles (1 mile = 1.61 km),
ADT_j	=	average daily traffic during time period j, either a year or a portion thereof,
P_f	=	a factor to account for the average percent of the time period during which the weather conditions present at the time of accidents (N) can be expected, and
L_f	=	a factor to account for the average percent of the ADT occurring under the ambient light conditions present at the time of accidents (N).

Since the isolated curve was being considered as a point location, the section length (L) was omitted from the above equation leaving the accident rate expressed in accidents per million vehicles. By introducing the two factors P_f and L_f, actual accident rates could be estimated for dry/wet pavement conditions and for night/day light conditions based on the volumes that occurred during those conditions. When the two rates for one or the other types of condition were combined, the resulting factor would be unity.

Accident severity rate statistics were also calculated using the equation noted above. In this case, only fatality and injury accidents were accumulated as (N).

To obtain an overall accident or severity rate for the entire study period at a particular site, the periodic rates computed with the equation above were averaged. All sorting and rate calculations were done by computer to insure accuracy. Table 14 is an example computer printout showing the accidents by year and by category in Part A, appropriate accident and severity rates in Part B, and accidents by type of maneuver in Part C.

ACCIDENT ANALYSIS AND FINDINGS

This section describes the general characteristics of the accident data base. Summary presentations are keyed to the following two sets of accident data:

- Total accidents — for general background information
- Delineation-related accidents occurring on dry pavement outside the influence of intersections — because these conditions are also descriptive of the TPM data collection.

Table 14. Sample of accident analysis program output.

ACCIDENT SUMMAPY FORM

SITE NUMBER: PA 879	SITUATION: WINDING
DATA PERIOD: 1/69 TO 1/76	SECTION LENGTH: 3.79 MILES
NUMBER OF INTERSECTIONS: 5	DRY DAYS PER YEAR: 222
DAYTIME VOLUME: 75% ADT	RAIN DAYS PER YEAR: 131

PART A. ACCIDENT STRATIFICATION BY YEAR

CATEGORY	1969	1970	1971	1972	1973	1974	1975
AVERAGE DAILY TRAFFIC VOLUME:	5450	5450	4403	4757	4672	4899	5046
TOTAL NUMBER OF ACCIDENTS:	21	0	14	14	18	16	28
FATALITY ACCIDENTS:	0	0	1	0	0	0	1
INJURY ACCIDENTS:	6	0	8	3	4	5	7
PDO ACCIDENTS:	15	0	5	11	14	11	20
NON-INTERSECTION:	19	0	12	13	16	13	25
INTERSECTION:	2	0	2	1	2	3	3
DRY:	10	0	7	9	11	6	15
WET:	8	0	4	0	5	7	8
SNOW OR ICE:	3	0	2	5	1	2	5
FOG:	0	0	1	0	1	1	0
DAY:	9	0	11	8	9	11	18
NIGHT:	12	0	3	6	9	5	10
DELINEATION RELATED:	18	0	13	12	10	11	22
NON-DELINEATION RELATED:	3	0	1	2	8	5	6

Table 14. Sample of accident analysis program output. (continued)

ACCIDENT SUMMARY FORM

SITE NUMBER: PA 879	SITUATION: WINDING
DATA PERIOD: 1/69 TO 1/76	SECTION LENGTH: 3.79 MILES
NUMBER OF INTERSECTIONS:5	DRY DAYS PER YEAR: 222
DAYTIME VOLUME: 75% ADT	RAIN DAYS PER YEAR: 131

PART B. AVERAGE ACCIDENT RATE AND SEVERITY RATE

	NON-INTERSECTION		NON-INTERSECTION AND INTERSECTION	
	DRY	DRY AND WET	DRY	DRY AND WET
ACCIDENT RATE				
ALL DAY:	1.63	1.52	1.79	1.81
ALL NIGHT:	3.69	3.32	4.02	3.72
ALL DAY AND NIGHT:	2.14	1.97	2.35	2.28
DEL-RELATED DAY:	1.20	1.19	1.31	1.33
DEL-RELATED NIGHT:	3.05	2.81	3.05	2.90
DEL-RELATED DAY/NIGHT:	1.66	1.59	1.74	1.72
SEVERITY RATE				
ALL DAY:	0.60	0.55	0.60	0.62
ALL NIGHT:	0.84	0.83	0.84	0.83
ALL DAY AND NIGHT:	0.66	0.62	0.66	0.67
DEL-RELATED DAY:	0.50	0.48	0.50	0.48
DEL-RELATED NIGHT:	0.67	0.72	0.67	0.72
DEL-RELATED DAY/NIGHT:	0.54	0.54	0.54	0.54

AVERAGE ANNUAL NUMBER OF ACCIDENTS PER MILE: 3.96

AVERAGE ANNUAL NUMBER OF NON-INTERSECTION ACCIDENTS PER MILE: 3.43

NOTE: ACCIDENT RATES ARE EXPRESSED IN TERMS OF ACCIDENTS PER MILLION VEHICLE MILES

Table 14. Sample of accident analysis program output. (continued)

ACCIDENT SUMMARY FORM

SITE NUMBER: PA 879	SITUATION: WINDING
DATA PERIOD: 1/69 TO 1/76	SECTION LENGTH: 3.79 MILES
NUMBER OF INTERSECTIONS: 5	DRY DAYS PER YEAR: 222
DAYTIME VOLUME: 75% ADT	RAIN DAYS PER YEAR: 131

PART C. ACCIDENT STRATIFICATION BY TYPE

ACCIDENT TYPE	ALL REPORTED ACCIDENTS	TOTAL ACCIDENTS[1]	DEL-RELATED, NON-INTERSECTION, DRY PAVEMENT ACCIDENTS	
			DAY	NIGHT
SINGLE VEHICLE				
RUN-OFF-ROAD:	59	43	13	13
FIXED-OBJECT:	5	5	0	0
OTHER:	1	1	0	0
MULTIPLE VEHICLE				
HEAD-ON:	2	2	0	1
SIDE-SWIPE: (SAME DIRECTION)	5	5	1	3
SIDE-SWIPE: (OPPOSITE DIRECTION)	11	10	3	2
REAR-END:	13	11	3	0
ANGLE:	15	13	2	0
OTHER:	0	0	0	0

[1] Excludes snow, ice, and fog-related accidents.

Included in Appendix D are selected accident statistics for each of the study sites.

Accident Experience by Situation Type

Table 15 shows the size and basic stratifications of the Phase I accident data base.

Table 15. Number of accidents by situation type.

Situation	Number of Sites	Accidents				
		All Reported	Total[1]	Delineation-Related, Non-Intersection, Dry-Pavement		
				Day	Night	Total
Tangent	12	490	449	105	90	195
Winding	10	410	360	92	83	175
Horizontal Curve	20	78	71	16	19	35
Total	42	978	880	213	192	405

[1]Excludes snow, ice, and fog-related accidents.

It should be noted that TPM data were collected at only ten of the isolated horizontal curve sites; however, there were so few accidents at these ten sites over the study years that it was necessary to augment the data base for modeling purposes. This was done by selecting ten additional SAI sites which had similar geometric, delineation, and traffic volume characteristics.

Table 16 shows the ranges and mean values for accident rates by situation type. The rates for the tangent and winding sites are expressed in terms of accidents per million vehicle-miles, while the rates for the isolated curves are expressed as accidents per million vehicles.

As might be expected, the accident rates for the winding sites were, on the average, higher than for the tangent sites. This was true for both the total accident base and the delineation-related/non-intersection/dry-pavement subset. Also, as suggested by Table 15 as well, the latter subset of accidents had significantly lower rates for all three situations.

Table 16. Distribution of accident rates by situation.

Accident Set	Statistic	Accident Rates		
		Tangent (acc/MVM)[1]	Winding (acc/MVM)[1]	Isolated Curve (acc/MV)[2]
Total Accidents	Range	0.42-6.93	0.82-5.75	0.0-2.44
	Mean	1.88	2.61	0.77
Delineation-Related, Non-Intersection, Dry-Pavement Accidents	Range	0.42-2.31	0.47-4.40	0.0-2.44
	Mean	1.16	1.99	0.64

[1] Accidents per million vehicle-miles (1 mile = 1.61 km)

[2] Accidents per million vehicles

Even when the original ten horizontal curve sites were augmented by ten additional sites, the number of accidents and the corresponding rates were low, ranging from 0.0 to 2.44 accidents per million vehicles. The overall average was 0.77 ACC/MV for total accidents and 0.64 ACC/MV for the selected subset. As will be noted later, the paucity of accident data for the curve situation made it difficult to develop a strong correlation with TPM's, especially for night accidents.

Accident Severity

Table 17 lists the percent distribution of accidents by severity, for the three situations and for both total accidents and the selected subset. Two to three percent of the accidents resulted in death and 34-57 percent resulted in injury. The distribution of accidents by severity was quite similar across the situation types, although the isolated curve sites had the highest combined percentage of fatalities and injuries.

Accident Types

Table 18 lists the percent distribution of accidents by type for both data sets. The "run-off-road" accident was clearly the most prevalent type, regardless of geometric situation. In addition, it is interesting to note that this type occurred more frequently at the winding and isolated horizontal curve sites than at the tangent sites. One would certainly expect a greater propensity for running off the road in situations where there is a change in alignment. This type of accident comprised an even greater percentage when only delineation-related, non-intersection, dry-pavement accidents were considered.

Day Versus Night Accidents

Table 19 shows the percent distribution of accidents, for both data sets, occurring during day and nighttime conditions. Summing accidents across all situations, it was found that 45 percent of the total accidents and 48 percent of the delineation-related, non-intersection, dry-pavement accidents took place at night. Typically, only 20 percent of the 24-hour volume moves during hours of darkness, suggesting significantly higher nighttime accident rates. This was the result at nearly all sites, as shown in Appendix D, and it serves to emphasize the importance of providing more effective nighttime delineation.

Delineation-Related Accidents

As noted earlier in this chapter, a group of accidents was identified as being "possibly" related to delineation or the lack thereof. It was hypothesized that this group of accidents could be reduced through improved delineation techniques. For each of the three geometric situations, the percent of total accidents classified as delineation-related was as follows:

Table 17. Percent distribution of accident severity by situation.

Accident Set	Severity Type	Percent Distribution		
		Tangent	Winding	Horizontal Curve
Total Accidents	Fatal	2	2	3
	Injury	34	38	42
	Property-damage-only	64	60	55
		100	100	100
Delineation-Related, Non-Intersection, Dry-Pavement Accidents	Fatal	2	3	3
	Injury	43	42	57
	Property-damage-only	55	55	40
		100	100	100

Table 18. Percent distribution of accident types by situation.

Accident Set		Accident Type	Percent Distribution		
			Tangent	Winding	Horizontal Curve
Total Accidents	Single Vehicle	Run-off-road	36	64	52
		Fixed object	16	7	13
		Other	1	1	1
			53	72	66
	Multiple Vehicle	Head-on	3	2	4
		Side-swipe, same direction	9	5	4
		Side-swipe, opposite direction	5	8	8
		Rear-end	11	4	9
		Angle	17	6	5
		Other	2	3	4
			47	28	34
Delineation-Related, Non-Intersection, Dry-Pavement Accidents	Single Vehicle	Run-off-road	48	68	71
		Fixed object	3	5	6
		Other	2	1	0
			53	74	77
	Multiple Vehicle	Head-on	3	2	0
		Side-swipe, same direction	12	4	8
		Side-swipe, opposite direction	8	12	6
		Rear-end	12	2	0
		Angle	8	2	3
		Other	4	4	6
			47	26	23

Table 19. Percent distribution of accidents by light condition and situation type.

Accident Set	Light Condition	Percent Distribution		
		Tangent	Winding	Horizontal Curve
Total Accidents	Day	55	56	47
	Night	45	44	53
Delineation-Related, Non-Intersection, Dry-Pavement Accidents	Day	52	53	49
	Night	48	47	51

- Tangent — 68 percent
- Winding — 80 percent
- Curve — 74 percent
- Combined — 74 percent

CHAPTER VII
ACCIDENT-PROBABILITY MODELING

The general hypothesis to be studied was that each of several traffic performance measures and geometric variables could be used to independently predict a portion of the accident potential. The traffic performance measures would indicate the manner in which drivers traverse a given section of roadway, and the geometric variables would in effect define the available factor of safety inherent in the roadway design. Extreme values of traffic performance measures in combination with a limited factor of safety would be expected to result in an above-average accident rate.

MODELING METHODOLOGY

Specific topics covered in this section include the driving situations modeled, the candidate independent variables, the general approach to model specificity, and the use of a correlation matrix and stepwise multiple linear regression program.

Situations Modeled

After preliminary analyses of the TPM data and trial iterations of the regression modeling methodology, it was decided to combine for modeling purposes the data sets for the tangent and winding situations. The rationale, briefly summarized, was as follows:

- The amount of change in certain key TPM's between two observation stations at a given site should reflect overall driving difficulty and hazard.

- Increasing the sample size (i.e., number of sites per model), from 12 for the tangent and 10 for the winding section to 22 for the combined situation, should increase significantly the confidence in the predicted driving hazard.

For the winding sites within the new general situation, two pairings of observation stations or traps were considered. One utilized measurements from the intervening tangent and the midpoint of the outside curve, and the other utilized measurements from the tangent and the midpoint of the inside curve. This second pairing was expected to demonstrate TPM variations more indicative of accident hazard, since drivers tend to "hug" the edge of the pavement on inside curves where potential shoulder encroachments can have serious, but often unforeseen, consequences.

To conform with the two-trap scenario discussed above, TPM data from only two of the three isolated horizontal curve stations (for each direction of travel) were input to the modeling of this separate situation type. (This situation had to be considered separately because of the difference in the accident exposure measures.) Here, the advance point trap and the midpoint-of-curve trap were used because the maximum variation in TPM's generally occurred between these two stations. TPM's for each direction of travel (inside curve and outside curve) were entered as separate terms in the regression. As with the combined tangent/winding situation, day operation was treated separately from night operation.

Candidate Independent Variables

A large number of possible independent variables was easily calculated with the computer program mentioned in Chapter V. In addition to the basic speed and lateral placement distribution statistics shown in Table 11, there were several other intuitively appealing candidate terms. Many of these terms, examples of which are listed in Table 20, normalize an absolute speed or placement measure against some geometric element with which it might interact to more accurately predict hazard potential. In each case, the term was constructed such that the intuitive relationship to accident rate would require a positive coefficient in the regression equation.

The intuitive reasonableness criterion for independent variable selection should be stressed. Hopes for achieving a higher mathematical correlation do not justify the consideration of overly abstract terms not easily rationalized in a single sentence. (Superficial algebraic complexity, such as the expression in Table 20 for deceleration, should not be confused with conceptual complexity.)

Although earlier analyses suggested that speed means and variances would likely be weak variables for modeling, another speed statistic was considered a better candidate. This TPM, called the skewness index, differs from zero in relation to the degree of non-normality in the speed distribution. Greater positive skew would indicate that a higher percentage of the sample is above a given mean and perhaps operating in a hazardous range. Taylor's 1965 research study also found evidence to this effect, concluding that the accident rate is significantly higher at locations where the speed distribution is non-normal.(15) He also reported that the best parameter for determining non-normality is the skewness of the distribution.

General Approach to Model Specificity

The daytime and nighttime TPM data sets could each be regressed against several of the accident rates shown in Figure 14 (Chapter VI). Different dependent variables could be considered in two overall sequences, as follows:

- From most general toward most specific.
- From most specific toward most general.

Table 20. Selected examples of derived TPM's.

Term	Verbal Description
$\frac{\overline{LP}_e}{LW}$; $LW - \overline{LP}_e$	For a given placement relative to edge of road, increasing lane widths would allow greater clearance with opposing traffic.
$\frac{\overline{LP}_e}{SW}$	On the other hand, for a given placement sufficiently close to the edge of the road, increasing shoulder widths would enhance the probability of recovering from an encroachment.
$\frac{\lvert \overline{LP}_e - \overline{LP}_c \rvert}{LW}$	When the distance from the outside edge of the traveled lane to the right tire equals the distance from the left side of vehicle body to the centerline, there is maximum clearance with hazards on both sides.
$\frac{NCE + NSE}{VPH}$	The sum of measured centerline and shoulder encroachments, normalized by exposure, should be very directly related to accident potential.
$P_{ce} + P_{se}$	Assuming a normal distribution of LP_e and LP_c and knowing the means and standard deviations, it is possible to compute encroachment probabilities.
$K - LP_{e.15}$; $K - LP_{c.15}$	The placement at which only 15 percent of the drivers operate to the right of ($LP_{e.15}$) or to the left of ($LP_{c.15}$), when subtracted from a constant K, should reflect degree of hazard.
$\frac{LP_s{}^2}{LW}$	Increasing lateral placement variance, normalized against lane width, might indicate a potential for erratic behavior of an unsafe nature.
$\frac{\lvert LP_i - LP_{i+1} \rvert}{(LW) \text{ or } (D_{i \rightarrow i+1})}$	Increasing placement differentials between locations (i) and (i+1) may suggest an increasing probability of leaving the proper lane.

Table 20. Selected examples of derived TPM's. (continued)

Term	Verbal Description
$\frac{\left\lvert LP_{s_i}^2 - LP_{s_{i+1}}^2 \right\rvert}{LW}$	More "noisy" tracking behavior, indicated by lateral placement variance changes along the pathway, may relate to accident potential.
S_s^2	The larger the variance of the speed distribution, the greater the number of encounters between vehicles moving at significantly different speeds.
$S_{pct} > S.L.$	As the percent of drivers exceeding the speed limit increases, the overall accident potential should increase.
SI	As the Skewness Index of the speed distribution becomes increasingly positive, a higher percent of the sample is operating above the mean speed, perhaps in a hazardous range.
$\left\lvert \frac{(S_i - S_{i+1})(S_i + S_{i+1})}{2 D_{i \rightarrow i+1}} \right\rvert$	Overall acceleration or deceleration between locations (i) and (i+1), if sufficiently great, may contribute to loss of control or rear-end collisions.

"Most general" would include total accidents anywhere along the highway section, under both conditions of light and pavement. "Most specific" would include only those accidents occurring under conditions present when and where TPM data were collected (i.e., delineation-related accidents in nighttime or daytime, or dry pavement, and outside the influence of intersections).

Starting with the most specific model seemed to be the most reasonable and efficient approach. The chances of developing an acceptable correlation between accident experience and TPM's should be greatest when both dependent and independent variables reflect essentially the same operating conditions. However, care would have to be exercised to avoid using "noisy" accident rates which might result if the accident data were over-stratified. If after affirming that this latter possibility appeared remote, a satisfactory model could not be obtained at even the most detailed, intuitive level, the continuation of the modeling process would be pointless. If on the other hand a rather specific model were in fact developed, the generalizing process would be continued only to that level where an unacceptable loss of predictive power resulted, and all alternatives would not have to be tested.

Use of Correlation Matrix and Stepwise Regression

Input to the modeling process included the dependent variables in the sequence suggested in the preceding section, all basic and derived traffic performance measures, and the key physical variables discussed in the "Conceptual Model" section of Chapter III. Utilizing the BMDP package of statistical programs, a correlation matrix was generated for all of these inputs.(16)

Review of the correlation matrix resulted in the elimination of a number of independent variables. There were essentially two reasons for eliminating a variable from further consideration at this stage, including:

- It was observed to be uncorrelated with any of the dependent variables, or

- Its arithmetic relationship to the dependent variables was not an intuitively appealing one (i.e., sign of coefficient was negative rather than positive as expected).

All of the 50-60 variables remaining after analysis of the correlation matrix were considered available for use in the modeling effort. However, to maintain a fair and clearly visible level of competition among the diverse candidate terms, no more than 5-6 independent variables were input to any single regression. As a set, any variables thus input were required to meet the following constraints:

- There must be some intuitive appeal for utilizing this particular set of variables to explain accident histories.

- There must be a low degree of correlation among the candidate TPM's (a necessary but not sufficient condition for guaranteeing the independence of these variables).

The first constraint was used primarily to ensure that various categories of TPM were appropriately represented in each set of candidate variables. For instance, lateral placement—previously shown to be a sensitive TPM—should be well-represented by at least one "mean" term and one "variance" term, whereas possible speed measures could be de-emphasized. The second constraint was compatible with the lack of cross-product terms in the regression and the need to maximize the explanatory power of each independent variable.

The formulation of candidate variables and variable sets was an ongoing process throughout the regression analyses. As knowledge was gained with respect to the mathematical performance of certain key variables and variable types, new sets could be formed and previously conceived sets dissolved. Following all of the guidelines and constraints stated earlier, a few entirely new TPM expressions were incorporated into some of the sets.

Regression analyses utilized a stepwise multiple linear regression program known as BMDP2R.(16) Output from the program included the coefficients computed for each variable entered into the equation as well as a statistical analysis of the regression results (i.e., standard error and significance of the coefficients, standard error and significance of the regression, percent of the total variation explained, and identification of the residuals from each observation of the dependent variable).

In conclusion, it should be emphasized once again that the intent of the modeling effort was never to "fit a curve," but rather to construct an intuitively appealing model which could effectively predict differences in accident histories based upon easily obtained TPM data.

MODELING RESULTS

This section presents the "family" of models developed in the last four steps of the final regression run, reviews the residuals for a two-variable and a five-variable model, and discusses briefly the performance of selected independent variables.

A Family of Accident-Probability Models

In a recent Transportation Research Board paper reporting modeling results from Phase I of the project, the only accident-probability model discussed was the one defined after five independent variables had "entered" in the stepwise regression process.(17) This model is shown again at the bottom of Table 21. Given the sample-size constraints on the number of variables which could be allowed on the right-hand side of the equation (five), this model provided a surprisingly good (and inherently the best) "fit" of the Phase I data. However, pending the

Table 21.
Four accident-probability models developed in Phase I stepwise regression.

Number of Independent Variables	Standard Error of Estimate	R^2	Model and (Standard Errors of Regression Coefficients)
2	1.61	0.66	$AR^1 = -0.22 + \underset{(0.27)}{1.15}\,CI + \underset{(6.4)}{25.3}\,DPV$
3	1.49	0.72	$AR^1 = -1.10 + \underset{(0.25)}{1.08}\,CI + \underset{(6.0)}{27.2}\,DPV + \underset{(1.02)}{2.00}\,SI$
4	1.41	0.77	$AR^1 = 7.66 + \underset{(0.24)}{1.10}\,CI + \underset{(5.8)}{29.2}\,DPV + \underset{(1.02)}{2.61}\,SI - \underset{(0.263)}{0.462}\,RW$
5	1.33	0.80	$AR^1 = 8.07 + \underset{(0.234)}{0.982}\,CI + \underset{(5.5)}{28.5}\,DPV + \underset{(1.04)}{3.26}\,SI - \underset{(0.248)}{0.435}\,RW - \underset{(0.141)}{0.246}\,SW$

[1]Number of nighttime, delineation-related, non-intersection, dry-pavement accidents per million vehicle-miles (1 mile = 1.61 kilometre).

Notes:
- Independent variables defined elsewhere.
- 21 data points used in regression (12 tangent and 9 winding sections).

outcome of later validation attempts, it would be wiser to present for consideration (but not application) all four of the multi-variate equations developed in the same overall regression run. The balance of Table 21 provides this previously missing reportage. The dependent and independent variables in the equations were defined as follows:

- AR — Number of nighttime, delineation-related, non-intersection accidents per million vehicle-miles (dry pavement condition only)
- CI — Centrality index
- DPV — Difference in lateral placement variance
- SI — Skewness index
- RW — Roadway width measured between outside edges of the two traveled lanes (ft)
- SW — Shoulder width (ft)

The centrality index is expressed as:

$$CI = \frac{\left| \overline{LP}_e - \overline{LP}_c \right|}{0.1\ LW}$$

where:

$\overline{LP}_e$ = mean lateral placement of the right vehicle tire with respect to the right edge of the traveled way (ft),

$\overline{LP}_c$ = mean lateral placement of the left side of the vehicle with respect to the centerline of the roadway (ft), and

LW = width of traveled lane (ft).

As the value of the centrality index approaches zero, lateral clearance on each side of the vehicle is maximized. For the winding roadway situation, the centrality index was computed for the midpoint of the inside curve. The upstream trap was used for tangent sites.

The difference in lateral placement variance is expressed as:

$$DPV = \frac{\left| LP_{s_1^2} - LP_{s_2^2} \right|}{LW}$$

where:

$LP_{s_i^2}$ = variance of lateral placement with respect to the right edge of the traveled way, measured at Station i.

In the case of tangent roadways, the variances at the two established traps were subtracted and then divided by the average lane width. For winding section "S" curves, the difference was computed between the inside curve and the midpoint of the intervening tangent (or point of reverse curvature).

The skewness index, SI, is the absolute value of the coefficient of skewness for the speed distribution. As this statistic becomes increasingly positive, a higher percentage of the traffic stream is traveling at a rate far above or far below the mean speed. For the winding roadway situation, the skewness index was computed for the midpoint of the inside curve. The upstream trap was used for tangent sites.

Quality of Fit

In addition to noting the standard regression statistics shown in Table 21, two other model evaluation techniques appeared appropriate. One was simply to plot predicted versus actual accident rate and visually inspect the resulting scatter diagram. The other technique was to tabulate each residual (actual minus predicted rate) and look for biases or trends in the overall tabulation. It also seemed logical to pursue the two technques only for the "fattest" and "thinnest" members of the "family" (i.e., the five-variable and the two-variable models).

Figures 15 and 16 show the predicted versus actual accident rates for the two models to be reviewed in further detail. Simple linear regression was used to draw a best-fit line through the plotted points on each figure. This line, described by the y-hat equation, represents the multi-variate model in two dimensions. The y=x equation illustrates a perfect fit or ideal model. The extent to which the actual model fits the data points is reflected in both the slope and the R^2 value of the y-hat equation (both values would ideally be equal to 1).

Table 22 lists the residuals from the Phase I regression analysis. Also tabulated are the alignment type, state, average historical ADT, and number of accidents associated with each site or regression "case." Simple correlations between model residual and the latter two site descriptions were sought, but neither were significant. Most enlightening, however, was the relationship of residual to state supplying the accident data. Table 23 shows much better predictions for the Maryland, Georgia, and Louisiana sites than for the Virginia, Pennsylvania, or Connecticut sites. Such biases were long suspected due to the diversity of accident reporting and filing systems.

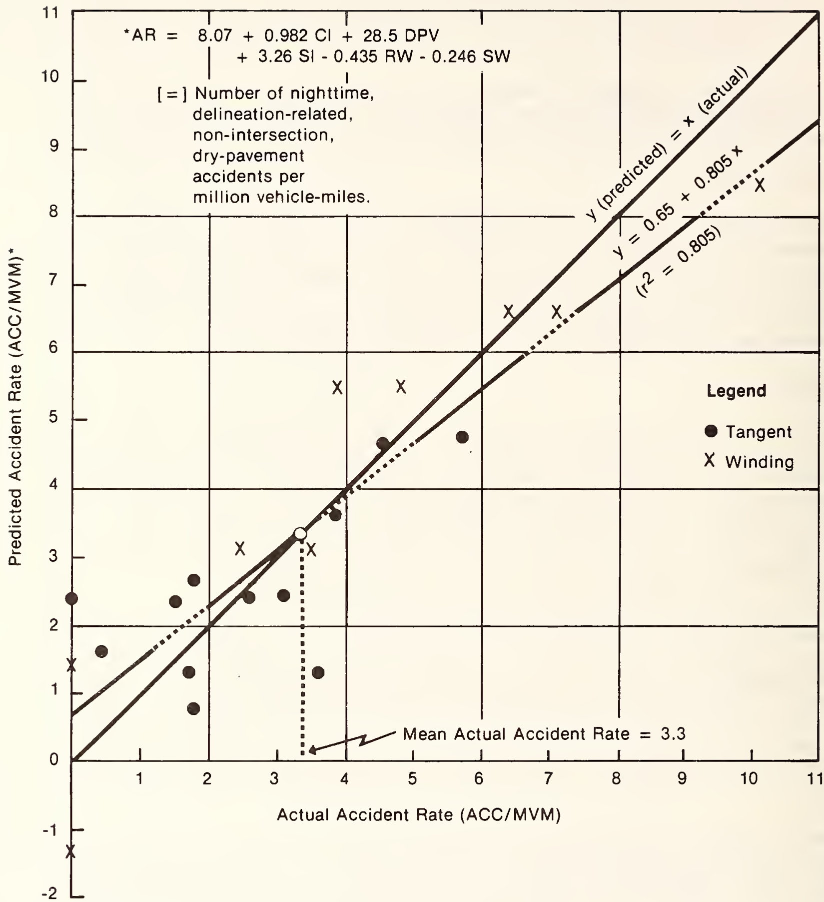


Figure 15. Fit of five-variable accident-probability model to Phase I data points.

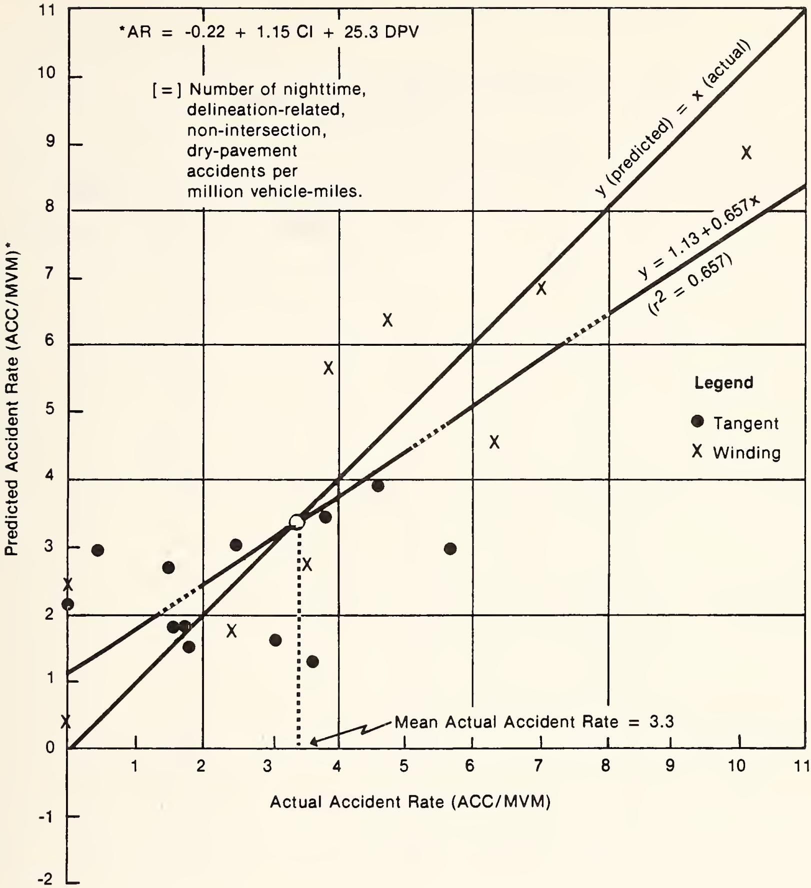


Figure 16. Fit of two-variable accident-probability model to 21 Phase I data points.

Table 22. Residuals for 21 Phase I cases.

Alignment Type	Case Number	State	Average ADT	Number of Modeled Accidents[1]	Residual ACC/MVM[2] (Actual—Predicted)	
					Five-Variable Model	Two-Variable Model
Tangent	1	VA	1,235	5	+0.56	+1.48
	2	LA	1,270	3	+0.05	-0.43
	3	LA	1,025	15	-0.05	+0.61
	4	VA	4,025	28	+0.92	+2.76
	5	LA	3,700	15	-0.87	-0.02
	6	MD	725	2	+0.23	+0.34
	7	VA	1,600	2	-0.87	-1.19
	8	VA	1,560	10	+0.34	-0.10
	9	MD	3,350	1	+1.02	+0.21
	10	VA	3,925	2	-1.17	-2.53
	11	CT	1,375	0	-2.35	-2.18
	12	CT	3,100	7	+2.27	+2.27
Winding	13	CT	650	4	+0.41	+0.68
	14	VA	825	0	-1.38	-2.43
	15	LA	575	0	+1.43	-0.41
	16	PA	3,760	12	-0.18	+1.82
	17	VA	3,300	31	-0.72	-1.59
	18	GA	700	3	-0.65	+0.71
	19	MD	1,400	10	+0.38	+0.14
	20	VA	900	5	-1.46	-1.75
	21	MD	4,250	41	+1.74	+1.41

[1] Nighttime, delineation-related, non-intersection, dry-pavement accidents.

[2] ACC/MVM = Accidents per million vehicle-miles (1 mi. = 1.61 km).

Table 23. Phase I residuals by state.

State	Residual ACC/MVM (Actual—Predicted)[1]			
	Five-Variable Model		Two-Variable Model	
	By Case	Average of |Residual|	By Case	Average of |Residual|
Maryland	+0.23 +1.02 +0.38 +1.74	0.84	+0.34 +0.21 +0.14 +1.41	0.52
Georgia	-0.65	0.65	+0.71	0.71
Louisiana	+0.05 -0.05 -0.87 +1.43	0.60	-0.43 +0.61 -0.02 -0.41	0.37
Virginia	+0.56 +0.92 -0.87 +0.34 -1.17 -1.38 -0.72 -1.46	0.93	+1.48 +2.76 -1.19 -0.10 -2.53 -2.43 -1.59 -1.75	1.73
Pennsylvania	-0.18	0.18	+1.82	1.82
Connecticut	-2.35 +2.27 +0.41	1.68	-2.18 +2.27 +0.68	1.71

[1] Nighttime, delineation-related, non-intersection, dry-pavement accidents per million vehicle-miles (1 mi. = 1.61 km).

Performance of Selected Independent Variables

Figures 17, 18, and 19 show the two-variable accident/TPM relationships for each of the independent TPM variables selected in the overall regression analysis. Considering the nature of multiple linear regression and the values of R^2 obtained for the models, one would not expect too striking a trend in any of these two-variable plots. Figure 18 is especially interesting in this regard, however. The reasonably good band of points passing through the origin is disturbed by only four wayward points out of the total sample of 21.

The order in which the three TPM's entered the regression suggests the following:

- Centrality index, describing deviation from an "ideal" central path within the lane, is the strongest predictor of accident potential.
- The extent to which the variance of lateral placement varies along a highway is also a strong surrogate measure.
- The skewness index for the speed distribution appears to qualify as an acceptable indicator of hazardous operation.

Other TPM variables shown on Table 20 did not fare as well. The regression yielding the models shown in Table 21 was also offered as independent variables the following terms describing actual or potential excursions from the proper lane:

- Total observed encroachment rate — (NCE + NSE)/VPH
- Total of encroachment probabilities assuming normal distribution of lateral placement — $(P_{ce} + P_{se})$
- A constant less the lateral placement to the left of which 15 percent of the drivers operate — $(K - LP_{c.15})$
- A constant less the lateral placement to the right of which 15 percent of the drivers operate — $(K - LP_{e.15})$

While none of these variables was strong enough to enter the regression, their intuitive appeal suggests that they might still be studied as independent measures of effectiveness.

As for the physical-attribute variables, the regression showed that while roadway width and shoulder width were significant indicators of hazard, traffic volume and the dummy variables for basic delineation system did not contribute significantly. This is not to say that these latter variables did not indirectly influence accident potential, but rather that a good portion of their effects had already been accounted

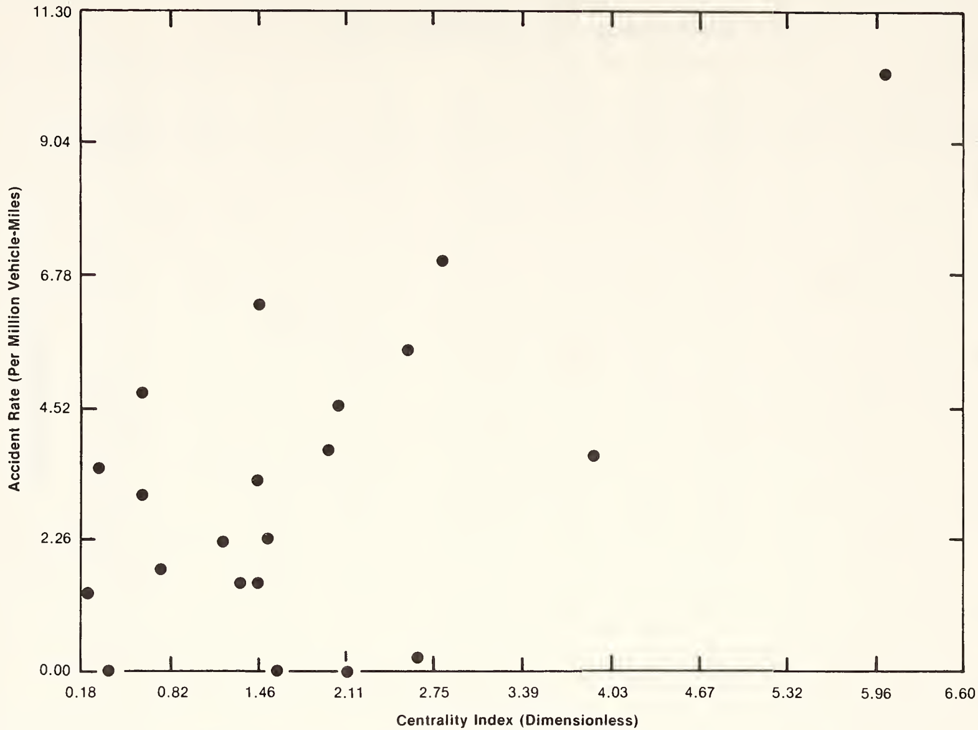


Figure 17. Tangent/winding accident rate versus lateral placement centrality index.

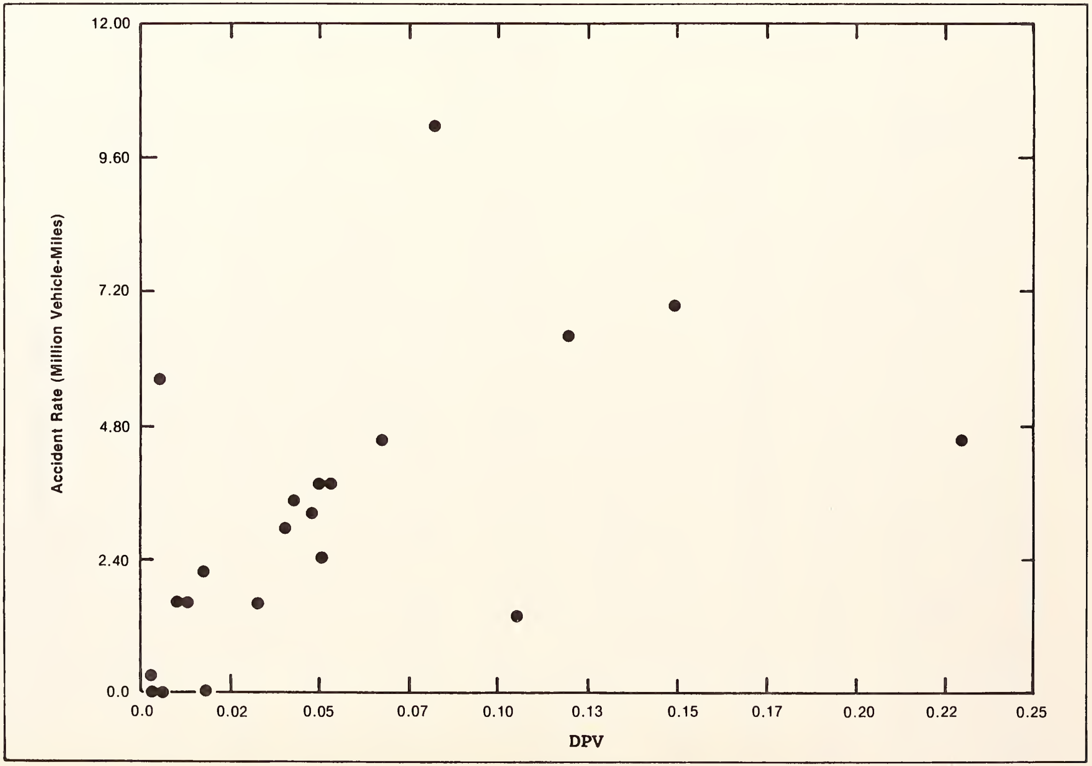


Figure 18. Tangent/winding accident rate versus differential in lateral placement variances.

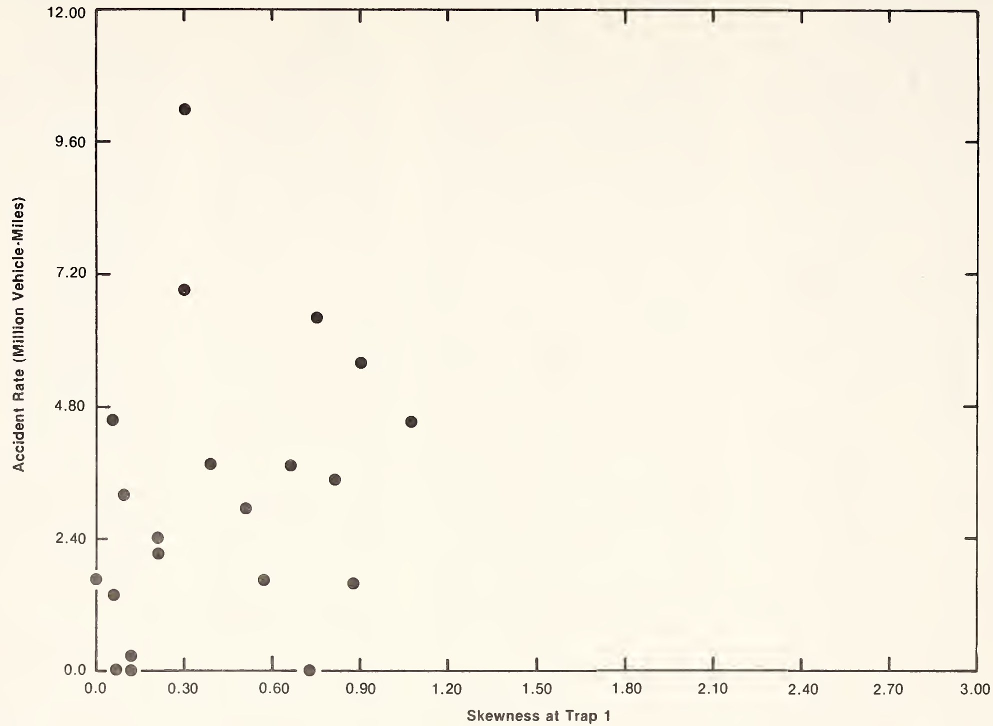


Figure 19. Tangent/winding accident rate versus speed skew.

for. Specifically, for the range of ADT involved, accident experience normalized by volume should substantially diminish the importance of ADT as an independent variable. Also, the role of delineation ideally should have already been reflected through the observed traffic performance measures.

Conclusions

The regression models developed for tangent and winding roadway situations, while seemingly quite good, must be qualified in several ways. Their application by other researchers should be considered only after noting these qualifications and studying the evaluation results reported in Chapter X.

First, the nature of the dependent variable must be reiterated. The equations compute a value representing a rather limited portion of all accidents taking place on two-lane rural highways. Table 15 suggests that delineation-related, non-intersection accidents occurring on dry pavements constitute only about 40 percent of all reported accidents. Furthermore, the models deal only with nighttime accidents, which are but half of the subset just defined. It should also be recalled that "delineation-related" refers to all those accidents not clearly associated with the non-delineation related factors listed in Table 13. In short, none of the models should be considered a "black box" capable of accurately predicting the overall accident rate for any particular section of rural highway. Rather, the more relevant value of the models is that they add credibility to the traffic performance measures previously studied solely on the basis of intuition and judgment.

Secondly, it must be emphasized that the mathematical modeling efforts were based on data collected at a limited number of field sites. While the Phase I data base was considered sufficient for the regression analyses performed, no means were readily available for statistically validating the significant variables and their relationship to accident potential. The need for a limited evaluation with applicable Phase II field data was clearly indicated, and final judgment as to the utility of each of the models as a delineation evaluation tool was reserved for discussion in Chapter X.

Thirdly, the evaluation and potential application of the models should be restricted to the types of locations and operating conditions represented in the Phase I data base. Specifically, the data base included only two-lane rural highway sites having a pavement width of 16—24 feet or 4.9—7.3 m (most were 20—22 feet or 6.1—6.7 m), an ADT of 500—5,000 vehicles per day, and some form of centerline delineation. The further a candidate study site deviates from the more prevalent Phase I lane widths and shoulder widths, the more likely that the four- and five-variable models will yield irrational results (e.g., a negative accident rate.) In light of the relatively small improvements in the quality of model fit contributed by the terms RW and SW (see Table 21), it may be desirable to lessen the importance of the geometric constraints somewhat by utilizing the two- or three-variable model.

Lastly, a statistically significant accident-probability model was not developed for isolated horizontal curves, daylight operation, nor adverse weather conditions. However, it would appear reasonable to assume that the same types of traffic performance measures could be considered as before-and-after effectiveness indicators under other geometrically similar test conditions. Those experimental delineation treatments resulting in statistically significant and intuitively beneficial changes in these indicators could be judged more conducive to traffic safety than the base treatments to which they are compared.

CHAPTER VIII

PHASE II EXPERIMENTAL DESIGN

Tasks I—3 and I—4 of the research project, begun about midway into the Phase I work schedule, assumed the successful development of sensitive delineation evaluation tools for use in the second phase of study. As discussed in Chapter II, these tasks required the identification of preferred experimental treatments, a ranking of their perceived research priority, and the refinement of a generalized evaluation methodology. The current chapter describes in detail the field and staff surveys used to meet the first two requirements (constituting Task I—3 work), and it outlines the plans and techniques for the field testing of the experimental treatments (developed in Task I—4).

GENERATION AND RANKING OF CANDIDATE TREATMENTS

Guidelines

The first part of the effort involved the development of a broad list of delineation treatments for possible evaluation within the scope of Phase II and perhaps subsequent research activities. In addition to applying the staff's combined knowledge of the state-of-the-art of delineation, the following sources were utilized to generate candidate treatments:

- Existing delineation literature, including the state-of-the-art update prepared for Contract DOT-FH-11-8587.(18)
- FHWA personnel and researchers of on-going delineation-related contracts.
- Contacts with selected State Traffic Engineers.

The delineation treatments were to encompass, as a minimum, the general categories of pavement markings, raised pavement markers, and post-mounted delineators. Treatments were also to be categorized as either "conventional" (i.e., sanctioned in some way by the Manual on Uniform Traffic Control Devices)(1) or "novel" (i.e., reasonable variations in pattern, width, color, etc.).

The specific stress on novel treatments stems from heightened interests of late in achieving greater cost- as well as safety-effectiveness in the area of traffic operations and control. Novel applications of traditional materials, such as a painted centerline with reduced stripe-to-gap ratio, have a potential for saving a substantial number of dollars on a state or national scale. In order to produce research results with significant and immediate impact upon delineation policies, it was mandated that the selected experimental treatments be judged to offer:

- Likely improvements in traffic performance and safety at approximately the same costs as current techniques, or

- Current levels of traffic performance and safety at reduced costs.

The second part of the selection of experimental treatments—the assignment of research priorities to the candidates—was based on judgments by several members of the research staff, as described later in this section.

<u>The Listing and Preliminary Evaluation of Candidate Treatments</u>

A review of appropriate literature and the informal questioning of project participants led to the development of an initial list of 20 delineation treatments. These treatments are shown in Table 24 within the framework of a field survey form. This survey was distributed to the following states and FHWA officials:

- State Traffic Engineers of Arizona, California, Georgia, Idaho, Louisiana, Maryland, Michigan, Pennsylvania, and Virginia. These nine states were selected because of the quality of cooperation provided earlier to the site selection effort for Contract DOT-FH-11-8587 ("Cost-Effectiveness and Safety of Alternative Roadway Delineation Treatments").

- The nine FHWA Regional Traffic Operations Engineers.

- Nine selected individuals of the Federal Highway Administration's Offices of Research, Development, and Traffic Operations.

A review of the number of respondents by treatment will show that only one state and one regional engineer failed to reply. The scoring system utilized penalty points, and the average for each treatment/respondent combination is shown in the right-most column. Average scores of 3.00 or greater should be considered indifferent to negative.

In addition to these 27 "structured" surveys, a general letter of inquiry was sent to nine selected independent researchers. These individuals, and frequently their colleagues and fellow committee members as well, had noted experience in researching improved means of driver guidance. In contrast to the state and FHWA engineers, however, only two of the nine persons responded in a positive manner with a list of suggested treatments.

All of the "additional ideas for evaluation" provided by the respondents were scrutinized for reasonableness within the guidelines presented earlier. A new list of 38 candidate treatments, with the field suggestions added to the original set of 20 treatments, was then compiled for evaluation by project staff members. Presented in the first column

Table 24. Ranked preferences for Phase II experimentation.
Number of responses by category.

The following list provides some preliminary ideas generated by the project staff Please assign a ranking to each (by checking the appropriate column), indicating how important you consider the further field evaluation of the treatment You are strongly encouraged to list additional delineation treatments you feel should be studied

Delineation Treatment	Respondent	Need for Further Field Testing: 1 Very Important	2 Relatively Important	3 No Opinion	4 Relatively Unimportant	5 Unimportant	Average Rank
I. CONVENTIONAL							
A PAVEMENT MARKINGS							
1 Continuous edgelines on narrow roads (i e . less than 22 feet)	*State Traffic Engineers*	1	6	0	1	0	2 12
	FHWA Regional	5	1	0	1	1	2 00
	FHWA Headquarters	4	4	0	1	0	1 78
2 Partially beaded paint striping	*State Traffic Engineers*	0	1	5	0	2	3 38
	FHWA Regional	1	2	2	1	2	3 12
	FHWA Headquarters	1	1	2	3	2	3 44
B RAISED PAVEMENT MARKERS (RPM s)							
1 RPM's as replacement for painted centerline or lane lines	*State Traffic Engineers*	4	2	1	1	0	1 88
	FHWA Regional	0	5	0	3	0	2 75
	FHWA Headquarters	1	4	1	1	1	2 62
2 RPM's as supplement to painted centerline or lane lines	*State Traffic Engineers*	5	2	1	0	0	1 50
	FHWA Regional	3	4	0	1	0	1 88
	FHWA Headquarters	5	2	1	0	1	1 89
C POST-MOUNTED DELINEATORS (PMD's)							
1 Continuous PMD's in place of edgelines	*State Traffic Engineers*	0	4	1	2	1	3 00
	FHWA Regional	1	1	1	5	0	3 25
	FHWA Headquarters	0	3	0	5	1	3 44
2 Continuous PMD's as a supplement to edgelines	*State Traffic Engineers*	0	5	0	3	0	2 75
	FHWA Regional	2	1	0	4	1	3 12
	FHWA Headquarters	0	4	1	3	1	3 11
3 PMD's just on curved sections of roadway	*State Traffic Engineers*	1	6	1	0	0	2 00
	FHWA Regional	1	6	0	1	0	2 12
	FHWA Headquarters	4	3	0	1	1	2 11
4 Substantially variant spacing of PMD's (e g . 200 feet versus 528 feet)	*State Traffic Engineers*	2	4	0	2	0	2 25
	FHWA Regional	2	4	2	0	0	2 00
	FHWA Headquarters	2	1	3	2	0	2 62

Table 24. Ranked preferences for Phase II experimentation. (continued)

Delineation Treatment	Respondents		Need for Further Field Testing: 1 Very Important	2 Relatively Important	3 No Opinion	4 Relatively Unimportant	5 Unimportant	Average Rank
II. NOVEL								
A PAVEMENT MARKINGS								
1 Reduced stripe-to-gap ratio for centerlines and lane lines (e g . to 1 7. with a 5-foot stripe and a 35-foot gap)	*State Traffic Engineers*		3	2	2	1	0	2.12
	FHWA	*Regional*	3	3	1	1	0	2.00
		Headquarters	5	2	0	2	0	1.89
2 Single stripe for the continuous centerline	*State Traffic Engineers*		1	2	2	2	1	3.00
	FHWA	*Regional*	0	6	1	1	0	2.38
		Headquarters	2	2	1	0	4	3.22
3 Narrower striping for some centerlines lane lines. and edgelines	*State Traffic Engineers*		0	3	1	2	2	3.38
	FHWA	*Regional*	1	4	1	1	1	2.62
		Headquarters	2	3	1	1	2	2.78
4 Edgelines just on curved sections of roadway	*State Traffic Engineers*		0	4	2	0	2	3.00
	FHWA	*Regional*	2	3	1	1	1	2.50
		Headquarters	5	1	1	1	1	2.11
5 Centerline (probably a single stripe). just on curved sections of very narrow roads (e g . 18 feet or less)	*State Traffic Engineers*		2	4	1	1	0	2.12
	FHWA	*Regional*	1	4	1	1	1	2.62
		Headquarters	1	4	2	2	0	2.56
6 Pyramidal paint stripes as centerlines or lane lines on one-way highways	*State Traffic Engineers*		0	0	4	2	2	3.75
	FHWA	*Regional*	0	1	6	1	0	3.00
		Headquarters	2	1	3	0	3	3.11
7 Transverse stripes with decreasing separation. to induce speed reductions	*State Traffic Engineers*		0	5	1	1	1	2.75
	FHWA	*Regional*	0	3	0	5	0	3.25
		Headquarters	1	2	1	2	3	3.44

Table 24. Ranked preferences for Phase II experimentation. (continued)

Delineation Treatment	Respondent	Need for Further Field Testing 1 Very Important	2 Relatively Important	3 No Opinion	4 Relatively Unimportant	5 Unimportant	Average Rank
B RAISED PAVEMENT MARKERS (RPM's)							
1 RPM's in place of paint to form "edge-line"	State Traffic Engineers	1	3	1	3	0	2.75
	FHWA Regional	2	1	2	2	1	2.88
	FHWA Headquarters	1	2	0	6	0	3 22
2. RPM's on paved shoulder to supplement painted edgelines	State Traffic Engineers	1	4	0	3	0	2 62
	FHWA Regional	1	5	1	0	1	2 00
	FHWA Headquarters	1	4	0	3	1	2.89
3 RPM's just on curved sections of roadway	State Traffic Engineers	1	4	1	1	1	2 62
	FHWA Regional	3	3	1	1	0	2 00
	FHWA Headquarters	2	5	0	1	1	2.33
4 RPM's to provide advance warning of intersections	State Traffic Engineers	0	5	1	1	1	2.75
	FHWA Regional	2	2	2	2	0	2.50
	FHWA Headquarters	0	4	1	3	1	3 11
C. POST-MOUNTED DELINEATORS (PMD's)							
1 PMD's using special shapes to convey more meaning per device	State Traffic Engineers	0	1	2	2	3	3 88
	FHWA Regional	0	1	2	2	3	3.88
	FHWA Headquarters	1	4	1	3	0	2 67
III. ADDITIONAL IDEAS FOR EVALUATION							
(feel free to continue on other sheets of paper)	State Traffic Engineers	3	1	0	0	0	---
	FHWA Regional	1	2	0	0	0	---
	FHWA Headquarters	3	1	0	0	0	---

of Table 25, each of the candidate experimental treatments was to be evaluated against a "base" delineation treatment or system. As a result, careful examination of the list will show that while there are, in fact, 38 experimental treatments, only 36 are unique. This resulted from the apparent need to evaluate curve-related applications of both post-mounted delineators (PMD's) and edgelines against two different base delineation systems (treatment numbers 11—12 and 20—21).

Staff Assessments of Research Potential

Table 25 illustrates the evaluation matrix used for project staff assessments of research potential. The seven staff members, ranging from engineer-level to senior vice president, were asked to approach the evaluation task as follows:

- Scan the three broad evaluation criteria, the seven "sub-criteria" to which penalty points are to be assigned, and the list of candidate treatments.

- Assign penalty points to each treatment/sub-criterion combination by placing an "X" in the selected column. (The number of responses by cell is shown as an italic digit in Table 25.)

- From a table describing relative criterion importance (as expressed numerically in the first column of Table 26), select one relationship (indirectly a set of three weighting factors) to be applied to all treatments in the evaluation matrix.

Neither Table 25 nor Table 26 show the actual weighting factors which were selected indirectly by judging relative criterion importance. Briefly, these were determined separately for each respondent by assuming that the "importance" equation he chose should reflect the relative sizes of the three treatment-specific products of theoretical average penalty-point score times weighting factor. Theoretical average point score would in every case be 1.5 for the first three sub-criteria and 2 for all subsequent sub-criteria (see spread of possible point assignments near top of Table 25). Hence, for respondents A and D who felt that both "costs" and "effects" are 50 percent more important in determining research potential than "ease and scope of implementation," the computation of overall treatment score reads as follows:

Overall Score =

$$\left(\sum_{\text{Pts.}} \text{Driver Acceptance, Sensitivity of TPM's, \& Overall Safety}\right) \times$$

$$(\text{Weighting Factor for Effects}) +$$

$$\left(\sum_{\text{Pts.}} \text{Installation Difficulty, Frequency of Situation}\right) \times$$

Table 25. Research potential of selected delineation treatments, as assessed by project staff.

	EXPERIMENTAL DELINEATION TREATMENT	BASE DELINEATION TREATMENT	POSSIBLE EFFECTS ON TRAFFIC SYSTEM						EASE AND SCOPE OF IMPLEMENTATION						RELATIVE COSTS OF EXPERIMENTAL TREATMENT						STAFF ASSESSMENTS OF RELATIVE RESEARCH POTENTIAL [Ranking Between 1 and 38]							
			Driver Acceptance		Sensitivity of TPM's to Treatment Change		Overall Safety		Difficulty of Installation			Frequency of Delineation Situation[1]			Installation			Maintenance			Project Staff Member							
			1	2	1	2	1	2	1	2	3	1	2	3	1	2	3	1	2	3								
			Probably Favorable	Ambivalent	Effects Likely	Effects Uncertain	Probably Enhanced	Effects Uncertain	< Base Treatment	≈ Base Treatment	> Base Treatment	Continuous	Only on Curves	Spot Locations	< Base Treatment	≈ Base Treatment	> Base Treatment	< Base Treatment	≈ Base Treatment	> Base Treatment	A	B	C	D	E	F	G	Avg.[2]
1	Continuous edgelines on *narrow* roads (<22 ft.)	Centerline only	7		7		6	1		2	5	■					7			7	22	9½	2	11½	7	8½	8	6½
2	Edgelines at alternative offsets from centerline on extra-wide two-lane pavement	Edgeline 12-13 ft. from centerline, to delineate standard lane width		7	3	4		7		6	1	■				6	1		6	1	34	18	13	11½	12	11½	14	17½
3	Partially or intermittently beaded paint striping	Fully or continually beaded paint striping		7		7		7		6	1	■			7			4	1	2	11½	9½	10½	4½	4	23	8	6½
4	Lighter shade of yellow for paint striping	Standard Highway Yellow		7		7		7		7		■			1	6		1	6		11½	18	23	11½	12	27½	8	14½
5	RPM's as *replacement* for painted centerline or lanelines	Paint stripes only	5	2	7		5	2			7	■					7	3	2	2	11½	1½	2	27½	6	13½	2½	5
6	RPM's as *supplement* to painted centerline or lanelines	Paint stripes only	6	1	5	2	5	2			7	■					7		1	6	11½	9½	6½	11½	23½	8½	29	9
7	Exit gore delineation with reflectorized RPM's *replacing* paint	Painted gore	6	1	6	1	5	2		2	5			■			7	3	2	2	27	9½	16	35½	10	8½	5	14½
8	Exit gore delineation with reflectorized RPM's *supplementing* paint	Painted gore	6	1	6	1	6	1			7			■			7		1	6	27	26	20½	24	16	23	35½	26
9	Continuous post-mounted delineators (PMD's) *in lieu* of edgelines	Standard continuous edgelines	1	6	4	3	1	6		2	5	■			1	1	5	3	3	1	1	32½	25½	27½	23½	19½	8	19
10	Continuous PMD's as *supplement* to edgelines	Standard continuous edgelines	7		5	2	5	2			7	■					7			7	11½	9½	30	11½	20	8½	15	10½
11	*PMD's just on curved sections* of roadway	Centerline only	7		6	1	7				7		■				7		2	5	18½	18	18½	18½	8½	16½	13	14½
12	*PMD's just on curved sections* of roadway	Centerline with continuous edgelines	6	1	4	3	6	1			7		■				7		2	5	18½	18	18½	18½	37	16½	19	21½
13	Substantially variant spacing of PMD's (i.e., greater than 500 ft.)	Traditional close spacing of about 200 ft.		7		7		7	6	1		■			7			6	1		3	1½	10½	2	1½	2	12	2

Table 25. Research potential of selected delineation treatments, as assessed by project staff. (continued)

	EXPERIMENTAL DELINEATION TREATMENT	BASE DELINEATION TREATMENT	POSSIBLE EFFECTS ON TRAFFIC SYSTEM						EASE AND SCOPE OF IMPLEMENTATION						RELATIVE COSTS OF EXPERIMENTAL TREATMENT						STAFF ASSESSMENTS OF RELATIVE RESEARCH POTENTIAL (Ranking Between 1 and 38)							
			Driver Acceptance		Sensitivity of TPM's to Treatment Change		Overall Safety		Difficulty of Installation			Frequency of Delineation Situation[1]			Installation			Maintenance			Project Staff Member							
			1	2	1	2	1	2	1	2	3	1	2	3	1	2	3	1	2	3								
			Probably Favorable	Ambivalent	Effects Likely	Effects Uncertain	Probably Enhanced	Effects Uncertain	< Base Treatment	≈ Base Treatment	> Base Treatment	Continuous	Only on Curves	Spot Locations	< Base Treatment	≈ Base Treatment	> Base Treatment	< Base Treatment	≈ Base Treatment	> Base Treatment	A	B	C	D	E	F	G	Avg.[2]
14	PMD with back plate	PMD without back plate		7		7		7	1	6		■				1	6		4	3	11½	26	28½	29½	28½	38	28	29½
15	*Reduced stripe-to-gap ratio* for centerlines and lanelines	Standard ratio of 3:5		7	1	6		7		7		■			7			7			4½	4	10½	4½	4	5½	1	3
16	*Single* solid stripe as centerline where passing is prohibited	Double striping		7	1	6		7	5	2		■			7			7			2	4	4	4½	1½	2	4	1
17	*Narrower striping* for some centerlines, lanelines, and edgelines	Standard 4- to 6-inch wide striping		7		7		7		7		■			6	1		6	1		11½	4	10½	4½	4	5½	8	4
18	*Wider striping* of centerline and lanelines through critical areas	Standard 4- to 6-inch wide striping	2	5	3	4	1	6		6	1			■		1	6		1	6	27	30	32½	35½	37	33½	33½	37
19	Edgelines just in advance of intersections, narrow bridges, tunnels, etc.	Centerline only	4	3	5	2	7			1	6			■			7			7	27	26	27	31	32	23	30	32½
20	*Edgelines just on curved sections* of roadway	Centerline only	7		7		7			1	6		■				7			7	18½	18	6½	18½	8½	16½	17½	10½
21	*Edgelines just on curved sections* of roadway	Centerline and continuous PMD's	5	2	3	4	3	4		1	6		■				7			7	36	34	6½	18½	37	30	27	29½
22	Single-stripe centerline, just on curved sections of very narrow roads	No formal delineation	4	3	7		5	2			7		■				7			7	32	18	16	18½	18	36½	17½	23
23	Variations in shape, spacing, and color of paint stripes delineating freeway deceleration lanes	Standard white lanelines used along approximately half the length of the full-width deceleration lane	3	4	2	5	1	6		2	5			■		4	3		4	3	27	37½	35½	29½	32	2	22	28
24	Pyramidal or triangular-shaped paint stripes as lane lines on one-way roadways	Standard rectangular paint stripes	2	5	1	6	1	6		1	6	■				2	5		1	6	34	22	34	33	28½	19½	24	32½
25	Transverse stripes with decreasing separation to induce speed reduction	No transverse stripes other than stoplines and crosswalks	3	4	6	1	6	1			7			■			7			7	27	26	31	24	21	33½	38	34
26	Beaded centerline frequently supplemented with RPM's (no edgelines)	Beaded centerline and edgelines (no RPM's)	1	6	4	3		7	1	2	4	■			1	2	4	3	3	1	6	35½	14	1	14½	11½	26	12
27	Centerline stripes of sand-filled paint (no glass beads), with reflectorized RPM's	Standard glass-beaded centerline only	3	4	4	3	2	5			7	■				1	6		3	4	34	9½	25½	11½	23½	13½	31	21½

Table 25. Research potential of selected delineation treatments, as assessed by project staff. (continued)

No.	EXPERIMENTAL DELINEATION TREATMENT	BASE DELINEATION TREATMENT	POSSIBLE EFFECTS ON TRAFFIC SYSTEM: Driver Acceptance 1 Probably Favorable	Driver Acceptance 2 Ambivalent	Sensitivity of TPM's to Treatment Change 1 Effects Likely	Sensitivity of TPM's to Treatment Change 2 Effects Uncertain	Overall Safety 1 Probably Enhanced	Overall Safety 2 Effects Uncertain	EASE AND SCOPE OF IMPLEMENTATION: Difficulty of Installation 1 < Base Treatment	Difficulty of Installation 2 ≈ Base Treatment	Difficulty of Installation 3 > Base Treatment	Frequency of Delineation Situation[1] 1 Continuous	Frequency of Delineation Situation[1] 2 Only on Curves	Frequency of Delineation Situation[1] 3 Spot Locations	RELATIVE COSTS OF EXPERIMENTAL TREATMENT: Installation 1 < Base Treatment	Installation 2 ≈ Base Treatment	Installation 3 > Base Treatment	Maintenance 1 < Base Treatment	Maintenance 2 ≈ Base Treatment	Maintenance 3 > Base Treatment	STAFF ASSESSMENTS OF RELATIVE RESEARCH POTENTIAL (Ranking Between 1 and 38), Project Staff Member: A	B	C	D	E	F	G	Avg[2]
28	RPM's *in lieu* of paint to form "edgeline"	Standard painted edgeline	5	2	4	3	4	3			7	■					7	3	1	3	4½	31	6½	11½	17	29	11	14½
29	RPM's as *supplement* to painted edgeline	Standard painted edgeline	5	2	5	2	4	3			7	■					7		3	4	11½	35½	2	11½	14½	26	16	17½
30	*RPM's just* on *curved sections* of roadway	Standard paint striping only	7		5	2	5	2			7		■				7		1	6	18½	18	16	18½	19	16½	33½	20
31	RPM's to denote special lanes (e.g., auxiliary lanes, turn pockets, etc.)	Paint striping only	6	1	5	2	5	2			7			■			7		1	6	27	26	35½	24	34½	23	23	31
32	RPM's to provide advance warning of intersections (e.g., by "boxing" the conflict area)	Painted stopbars only	4	3	6	1	3	4			7			■			7		1	6	37½	26	20½	24	26½	33½	35½	35
33	RPM clusters just at the start and end of no-passing zones	Standard barrier stripe supplemented by regulatory and warning signs		7	1	6		7		1	6			■		1	6		2	5	37½	37½	37½	37½	34½	31	37	38
34	RPM's on paved shoulder to warn of road narrowing	Centerline with converging edgelines (no PMD's)	6	1	6	1	4	3			7			■			7	1	3	3	27	9½	32½	24	26½	23	25	25
35	Retro-reflectors recessed in pavement to supplement centerlines and lane lines	Paint stripes supplemented by RPM's		7		7		7		3	4	■				3	4	1	5	1	18½	32½	23	33	23½	27½	20½	27
36	PMD mounting higher and further from roadway edge	Standard lateral offset of 2-6 ft. from outer edge of shoulder and mounting height of 4 ft above near roadway edge		7	1	6		7		7		■				7		4	3		7	9½	23	7	12	4	20½	8
37	Shape- and/or color-coded PMD's	Standard button-type, amber or crystal reflector	3	4	1	6	1	6		6	1		■			4	3		4	3	18½	14	28½	33	30	36½	2½	24
38	"Lines-in-the-sky" (i.e., overhead cables with little pennants, applied near adverse vertical curvature where ground-mounted delineation may be less effective)	Conventional paint striping and post-mounted delineators	3	4	3	4	1	6		1	6			■		1	6		2	5	27	26	37½	37½	32	33½	32	36

[1] Completed in advance of survey by Principal Investigator.

[2] Rankings in preceding seven columns were averaged to form single new distribution of 38 numbers. In order to remove coincidental ties resulting from averaging process, values in new distribution were then re-ranked and listed under "Avg."

Table 26. Relative importance of evaluation criteria, for purposes of determining matrix weighting factors.

Relative Criterion Importance		Increasing emphasis on effectiveness →	Staff Members Choosing this Description
Numerical Description	Verbal Description		
1.5 x 1 = 1.5 x 2 = 3 1.5 x 1 = 2.0 x 2 = 3 2.0 x 1 = 2.0 x 2 = 3	Combinations assigning more importance to costs than to implementation or effects		None
1 = 2 = 3	All criteria of equal importance		None
1 = 1.5 x 2 = 3	Criteria 1 and 3 are 50 percent more important than 2		A, D
1 = 1.5 x 2 = 1.5 x 3	Criterion 1 is 50 percent more important than 2 and 3		B
1 = 2.0 x 2 = 1.5 x 3	Criterion 1 is twice as important as 2 and 50 percent more important than 3		E, G
1 = 2.0 x 2 = 2.0 x 3	Criterion 1 is twice as important as 2 and 3		C
1 = 3.0 x 2 = 2.0 x 3	Criterion 1 is three times as important as 2 and twice as important as 3		F

Legend: Criteria defined as follows—
1 = Possible Effects on Traffic System
2 = Ease and Scope of Implementation
3 = Relative Costs of Experimental Treatment

$$\left(\text{Weighting Factor for Ease \& Scope}\right) +$$

$$\left(\sum_{\text{Pts.}} \text{Installation Costs, Maintenance Costs}\right) \times$$

$$\left(\text{Weighting Factor for Relative Costs}\right)$$

$$= (1.5 + 1.5 + 1.5)(4) + (2 + 2)(3) + (2 + 2)(3)$$

$$= 18 + 12 + 12$$

$$= 42$$

Note that the set of weighting factors is (4, 3, 3) and that the products (18, 12, 12) are in the specified arithmetic relationship.

Each rater's 38 overall treatment scores were listed in ascending sequential order and assigned ranks between 1 and 38. When two or more treatments shared the same score, each was given the average of the ranks which would have been assigned had these positions in the sequence been infinitesimally different from one another. The rankings for each of the seven staff members, A through G, are shown on the right side of Table 25. The individual rankings were also combined to yield an average staff assessment of each treatment's relative research need.

Selection of "Top 10" Experimental Treatments

Given the amount of survey information developed to this point, a variety of interpretations was possible. The types of separate and combined (or consensus) rankings chosen for consideration were for the following groupings of respondent:

- State Traffic Engineers Only — From Table 24, average decimal ranks for the states were extracted and compiled in an ascending sequential order. Prior to assigning sequence numbers, however, 18 "neutral" values of 3.00 were inserted to bring the sample size to a par with the set of 38 staff rankings. This new distribution notionally represented state "failures to suggest" as well as direct evaluative responses. Rankings of 1 through 38 were then assigned, with ties handled as they were for staff assessments (described earlier).

- Aggregate of State Traffic Engineers, FHWA Personnel, and Independent Researchers — First, researcher suggestions which resembled any of the official 38 candidate treatments were assigned point scores (1.00 or 2.00) based on their positions on the prioritized lists submitted. Second, all "failures to suggest" by both FHWA groups and the independent researchers were assigned neutral scores to normalize the set of responses to 38. Third, scores for all four groups were combined, giving each state response twice the weight of a response from the other surveyed groups. Lastly, rankings between 1 and 38 were assigned as done previously for the separate sets of staff and state scores.

- Aggregation of Staff Members — The combined rankings in the last column of Table 25 were considered by themselves and in relation to the rankings described immediately above for the aggregation of field responses.

- All Field and Staff Participants — A set of overall "consensus" rankings was developed by computing simple arithmetic averages of the respective rankings described in the two preceding paragraphs, and then re-ranking the computed values in order to remove coincidental ties.

The overall consensus rankings were used to select the "top 10" experimental treatments in terms of the perceived need for their additional field testing. Table 27 lists these "top 10" treatments and shows for comparative purposes the other three types of ranking. Note that for each of these latter groups, one or more of its individual "top 10" does not appear among the consensus "top 10." To give secondary research priority to such treatments, Table 28 was created. It lists eight additional candidate treatments, each of which ranked among a group's "top 10" but not among the consensus "top 10."

DEVELOPMENT OF MULTI-LEVEL EXPERIMENTS

Implications of Past Research

Although considered in the formulation of the original 20 candidate experimental treatments, the results of previous research were reviewed again prior to proceeding with the design of Phase II field tests. By basic type of delineation, the following three paragraphs provide a brief overview of some of the pertinent qualitative findings:

- Pavement Markings — Several studies of edgelines have been performed, but there has been rather limited research on alternative centerline configurations. Except perhaps for certain interrelated findings documented in NCHRP Report 130,(14) most research on the traffic operations effects of pavement markings has not been adequately interpreted in a safety sense. The NCHRP results did provide encouragement to conduct additional, comprehensive research on the types of markings listed in Tables 27 and 28. For instance, one finding of the project was that the installation of edgelines decreases lateral placement variance throughout a roadway section, and another finding was that fluctuations of this TPM appear inversely related to safety.

- Raised Pavement Markers — There has been relatively little research on RPM's employed as a system of continuous delineation. The NCHRP project cited above did evaluate RPM treatments similar to those proposed in the current study.

Table 27. "Top 10" research priority rankings and selected experimental applications.

Experimental Delineation Treatment [1]	Base Delineation Treatment [1]	Research Priority Ranking				Number of Sites [2]		
		State T.E.'s	All Field	Staff	Consensus	Tangent	Winding	Curve
Reduced stripe-to-gap ratio for centerlines and lanelines *	Standard Stripe-to-gap ratio of 3:5	5	1	3	1½	3	0	0
Single solid stripe as centerline where passing is prohibited *	Double striping	24/38 15/20	3	1	1½	0	1	0
RPM's as *replacement* for painted centerline or lanelines	Paint stripes only	2	2	5	3½	0	1	0
Substantially variant spacing of PMD's (e.g., 200 Feet versus 528 feet)	Traditional close spacing of about 200 ft.	7	5	2	3½	1	0	0
Narrower striping for some centerlines, lanelines, and edgelines *	Standard 4- to 6-inch wide striping	35½/38 17½/20	8	4	5	2	0	0
Continuous edgelines on *narrow* roads (< 22 ft.)	Centerline only	5	7	6½	6	2	1	0
RPM's as *supplement* to painted centerline or lanelines	Paint stripes only	1	6	9	7	2	0	1
RPM's *in lieu* of paint to form "edgeline" *	Standard painted edgeline	11½	4	14½	8	0	0	0
PMD's just on curved sections of roadway	Centerline only	3	9½	14½	9½	0	0	1
Edgelines just on curved sections of roadway *	Centerline only	24/38 15/20	13½	10½	9½	0	0	0

[1] 1Ft. = 0.305m and 1in. = 2.54cm; *novel treatment.

[2] Two or more treatments evaluated sequentially at any one of nine actual sites.

Table 28. Rankings and selected experimental applications of 8 treatments favored by particular group(s).

Experimental Delineation Treatment [1]	Base Delineation Treatment [1]	Research Priority Ranking				Number of Sites [2]		
		State T.E.'s	All Field	Staff	Consensus	Tangent	Winding	Curve
PMD mounting higher and further from roadway edge *	Standard lateral offset of 2-6 ft. from outer edge of shoulder and mounting height of 4 ft. above near roadway edge	24/38 15/20	20	8	11	0	0	0
PMD's just on curved sections of roadway	Centerline with continuous edgelines	3	9½	21½	12	0	0	1
RPM's just on curved sections of roadway *	Standard paint striping only	8½	12	20	13	0	0	1
RPM's as *supplement* to painted edgeline *	Standard painted edgeline	8½	15	17½	14	2	1	0
Single-stripe centerline, just on curved sections of very narrow roads *	No formal delineation	5	16	23	17	0	0	0
Edgelines just on curved sections of roadway *	Centerline and continuous PMD's	24	13½	29½	19	0	0	0
Partially or intermittently beaded paint striping *	Fully or continually beaded paint striping	35½	37	6½	20½	0	0	0
Continuous PMD's as *supplement* to edgelines	Standard continuous edgelines	11½	33	10½	20½	1	0	0

[1] 1Ft. = 0.305m and 1 in. = 2.54cm; * = novel treatment.

[2] Two or more treatments evaluated sequentially at any one of nine actual sites.

Results were favorable, especially in terms of reductions in lateral placement variance. However, additional field evaluation was suggested to validate the tentative findings.

- Post-Mounted Delineators — There has been no known published research on the relative effects of post-mounted delineators at a wide spacing, such as 528 feet (161 m), as opposed to the traditional close spacing of 200 feet (61 m). Likewise, no one has objectively evaluated delineators placed at greater lateral offset and height, a practice which might have significant impact upon maintenance requirements.

Experimental Situations

As discussed extensively in earlier chapters, this research project has dealt with sections of two-lane rural highways distinguished by type of horizontal alignment. The three types of alignment, which in effect constitute three basic delineation situations for continuing study, were defined as follows:

- Tangent — A predominately straight roadway with horizontal curves of 3 degrees or less.

- Winding — A predominately curved roadway with degrees of curvature greater than 3 degrees and tangents of less than 1,500 feet (457 metres) between curves.

- Isolated Horizontal Curve — On an overall alignment tending to be more tangent than winding, a curve greater than 3 degrees which is desirably isolated from other significant curves by 1/2 mile (4/5 kilometre) or more.

The last three columns of Table 27 indicate, by number of sites utilized, those treatment/situation combinations considered most appropriate for high-priority experimentation. Selections were based on the following factors:

- Some treatments are inherently suited only to tangent or only to curved roadways (e.g., passing generally allowed or prohibited, given that test sites do not have significant grades).

- Driving behavior was hypothesized to be more sensitive to some delineation treatments in one situation than another.

- Those experimental treatments within the "top 10" according to the State Traffic Engineers should receive more extensive field evaluation, if not in terms of applicable situations, at least in terms of the number of test sites selected per situation type.

To account for this last factor and also to take advantage of natural sequences of delineation augmentation, some of the treatment/situation combinations in Table 28 were also selected for study.

Treatment Configurations

Figures 20 through 23 illustrate schematically the Phase II delineation systems by study site. Additional descriptive details can be found in Chapter XI and Appendix E, and a few of the treatments are also shown in Chapter IX photographs.

Sites 1 and 2 (Figure 20) were located on the DOT's instrumented Maine Facility. For most of the experiments, however, it was necessary to find sites within the geometric constraints that had a very faded centerline and edgeline, or no delineation at all. This condition was required so that novel treatments such as narrow-width lines, short mark-to-gap lines, or raised pavement markers could be tested without the influence of the standard marking. Since moderate traffic volumes were desired to expedite data collection, the preferred sites were those where resurfacing had just been performed, rather than at previously unmarked low-volume locations.

For the tangent and winding test sections, it was decided that an experimental treatment should be applied for at least one mile and preferably three miles or more. This is necessary to ensure that drivers become properly acclimated to the treatment prior to arriving at the location where TPM's are to be measured. Also, final data collection should probably not occur until one or two weeks have passed since treatment installation.

OTHER EXPERIMENTAL GUIDELINES FOR PHASE II

This section highlights some of the more important procedural aspects of the Phase II experimental design. The details of the recommended field evaluation methodology based on project experiences are presented in Appendix I.

Site Selection

Cross-Sectional Features of Overall Highway — Roadway width and shoulder width are the only physical attributes of the driving environment which can be directly input to any of the Phase I accident-probability models. If consideration is to be given to model application, the ranges of these and all other environmental variables present (explicitly or implicitly) in the Phase I data base should not be significantly violated in selecting study sites. This prescribes roadways at least 16 feet (4.9 m) wide, and opposing lanes delineated by some sort of centerline. Lane and shoulder widths should not significantly exceed 12 and 8 feet (3.7 and 2.4 m), respectively.

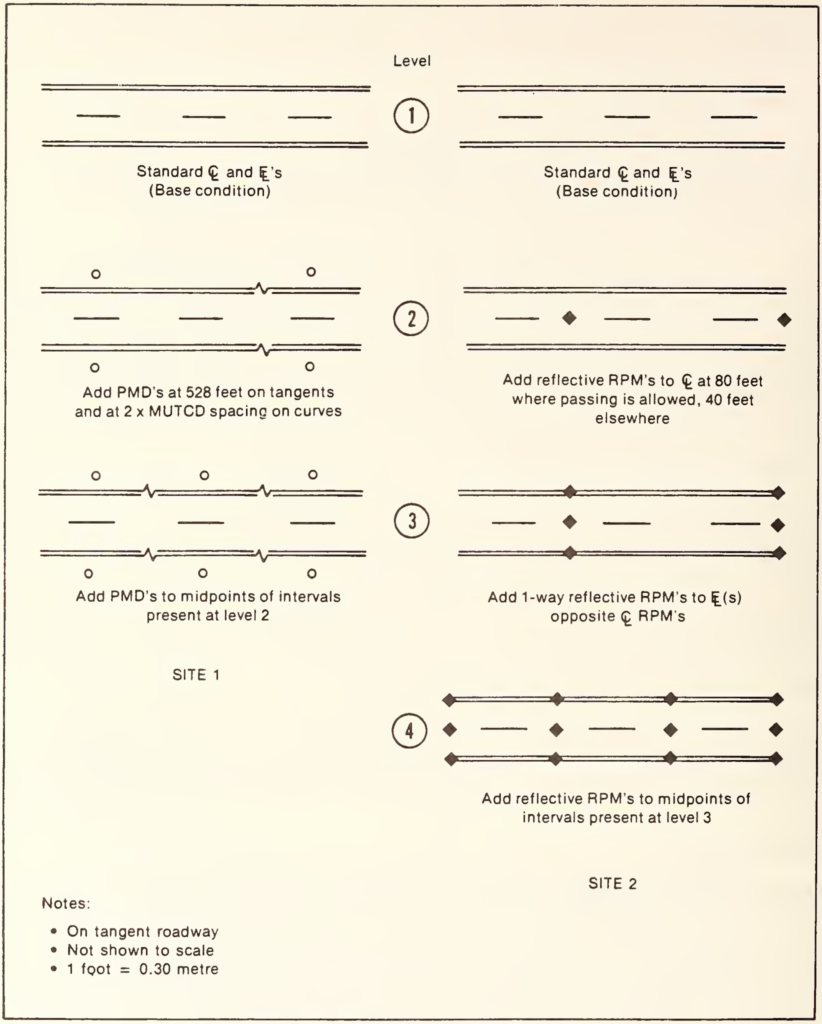


Figure 20. Maine Facility experiments.

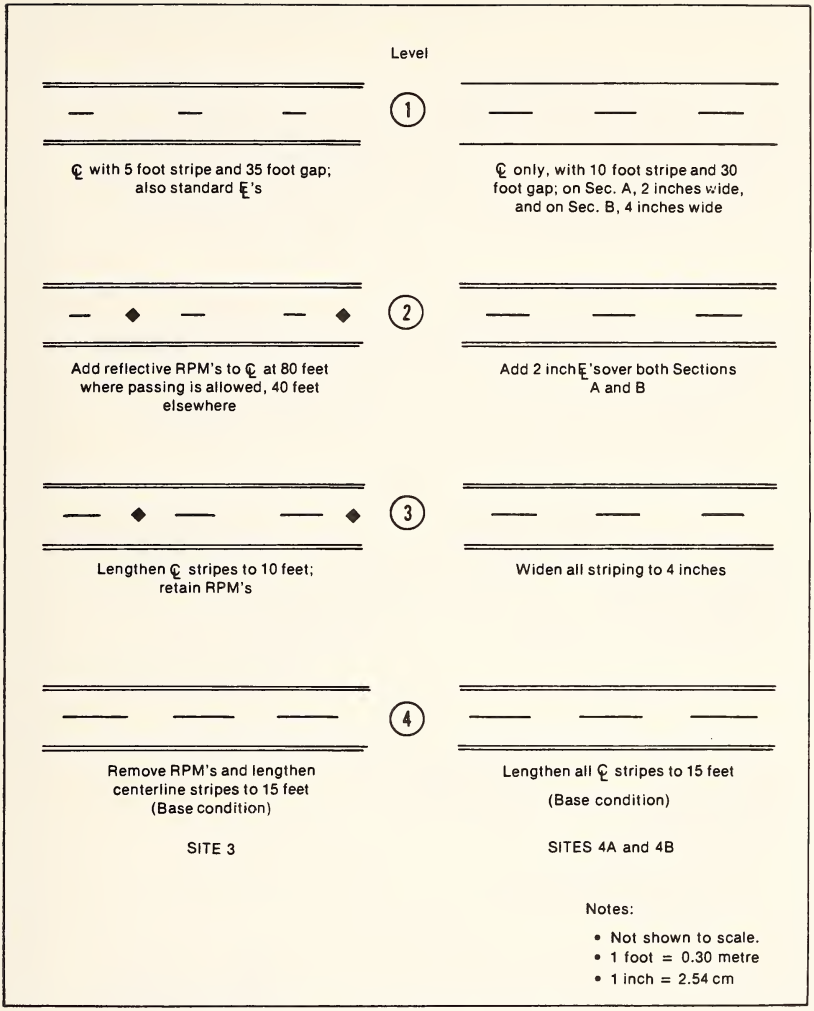


Figure 21. Additional tangent experiments.

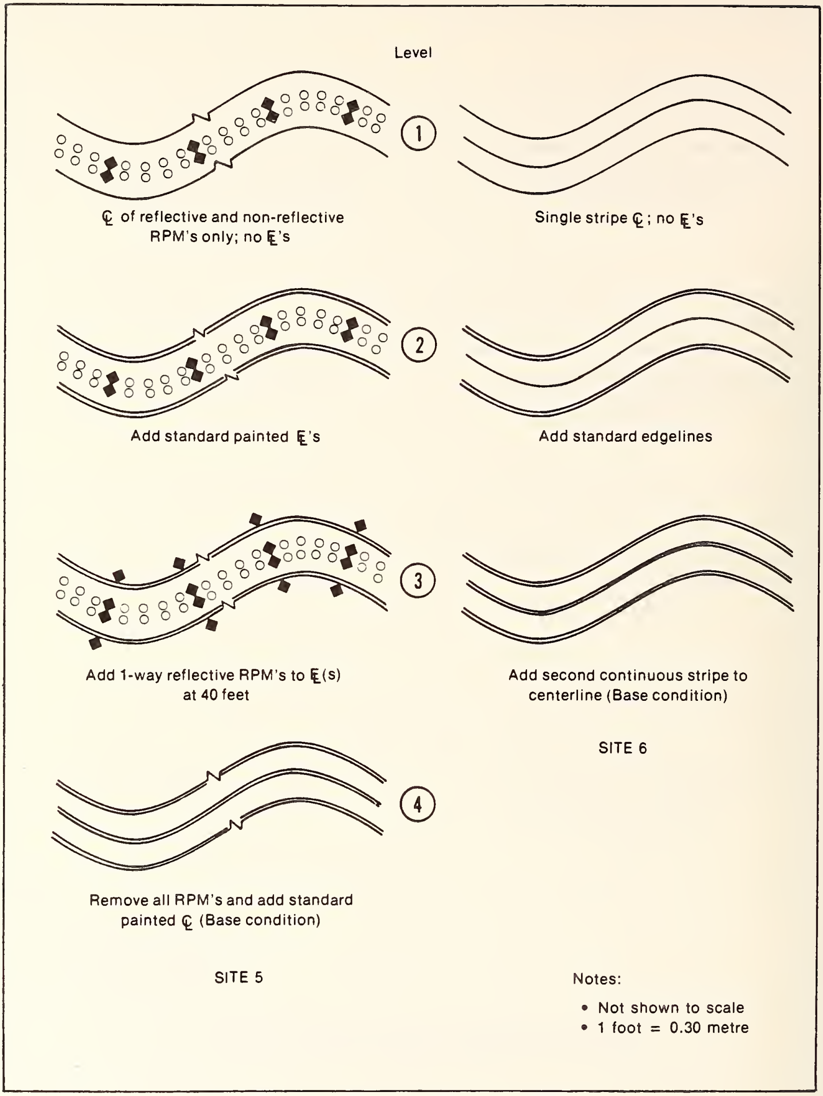
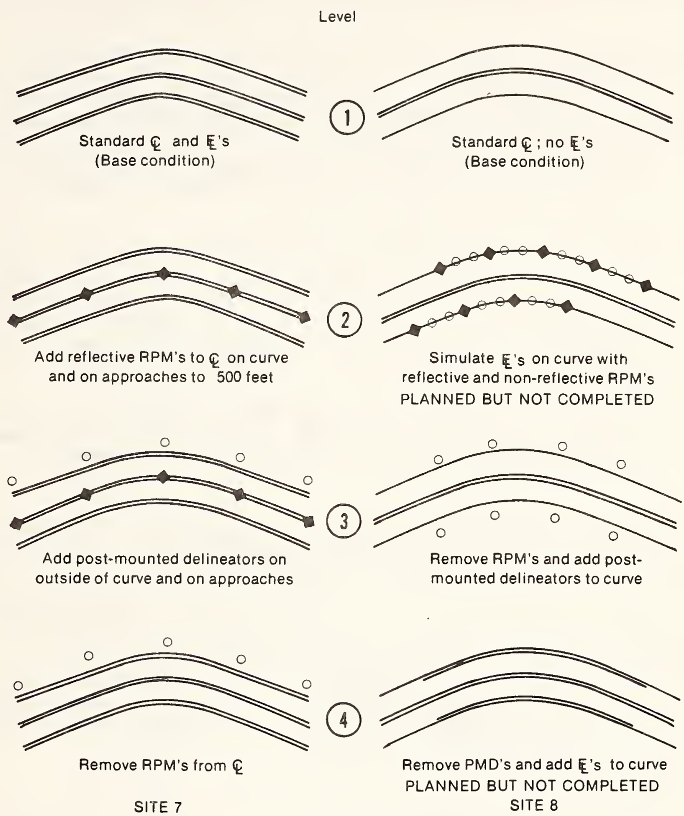


Figure 22. Winding situation experiments.



Notes:

- Not shown to scale.
- 1 foot = 0.30 metre.

Figure 23. Isolated horizontal curve experiments.

A site should not be configured so as to require the placement of measurement traps in the vicinity of extraneous spot-location delineation, driveways, or other roadside features which may influence driver behavior.

Subsection Geometrics — Within the alignment categories of tangent, winding, and isolated horizontal curve, each site should contain at least one subsection having the geometrics specified for Phase I data collection. To recapitulate, these subsection criteria were as follows:

- Tangent — There should be a pure tangent section of at least 0.68 mile (1.10 km) in length, ending in horizontal curves no sharper than 3 degrees.
- Winding — An "S" curve is required, consisting of two consecutive, reversed curves separated by a tangent no longer than 500 feet (152 m). The curves should be roughly equivalent and at least 5 degrees or sharper in order to establish a clear distinction with respect to the tangent situation.
- Curve — The horizontal curve should be isolated from other curves by 0.3-0.5 mile (0.5-0.8 km) and should be on a highway tending more toward the tangent definition than the winding definition.

Despite the general nature of the combined tangent/winding accident-probability models, desired analyses of the TPM data base require the same geometric distinctions made in the Phase I research.

Traffic Volume — In general, it is desirable to select test sites with an ADT approximating 3,500—the midpoint of the higher ADT class in the Phase I site selection matrices. This is a good volume level at which to collect data: measuring equipment installation is relatively easy as traffic interference is not too high, yet there is enough traffic to obtain the desired sample sizes within a reasonable time (usually one day and one night will be sufficient).

Data Collection

Ambient Visibility and Pavement Condition — Full samples of traffic performance data should, of course, be obtained under nighttime, fog-free dry-pavement conditions. Since it will not require additional calendar days of field work, data can also be collected for the corresponding daytime period. Unfortunately, the vagarious nature of rainfall and fog at most locations is such that the evaluation of delineation treatments under inclement operating conditions is generally infeasible. Especially difficult would be the collection of statistically adequate samples under uniformly wet or foggy conditions to reliably detect before-to-after TPM changes that are meaningful.

Data Collection Technique — An improved type of measurement trap was adopted as a result of Phase I data collection experiences. A detailed description of the new system and its placement are described in Chapter IX and Appendix I of this report.

Data Analysis

The first step in the analysis of the field data should be to evaluate the basic speed and lateral placement statistics, looking for statistically significant changes. Secondly, the results of this evaluation can be interpreted in one of the following ways:

- Where no significant changes occurred, the lower cost treatment would be preferred on the basis of observed traffic performance.

- Where significant changes do occur on a tangent or winding site under nighttime, dry-pavement conditions, the regression model yielding the best "validation" results might be applied to estimate relative changes in the expected level of delineation-related accidents. A number of derived traffic performance measures can be examined in a before-and-after sense, but the emphasis should be on those measures whose relationship to accident potential has previously been demonstrated.

The third and subsequent analysis steps are more difficult. Conclusions about the effectiveness of the alternative delineation treatments might be drawn or extended to the following cases:

- Isolated Horizontal Curves — An accident-probability model for curves was not developed in the present research study, but the main reason appeared to be the sparseness of the accident experience at these locations. Intuitively, the same independent variables would apply; they can certainly be evaluated short of the actual arithmetic manipulations of the model. Also, based on findings reported in NCHRP Report 130, deceleration into the curve should be emphasized as a measure of effectiveness.(14)

- Daytime Traffic Operations — The unsuccessful regression analyses performed in search of a daytime accident-probability model did not necessarily refute the intuitive reasonableness of the candidate independent variables. Realizing that their significance as indicators of hazards is less due to the greater environmental "noise" during the day as opposed to night, these variables can still be considered as legitimate measures of effectiveness.

- Wet and Foggy Driving Conditions — The relative effectiveness of alternative delineation treatments can vary sharply by weather condition. For instance, painted pavement markings become almost invisible during a nighttime rain, but retroreflective raised pavement markers become strikingly visible under these same conditions.

This project will have quantitively estimated the safety performance of the experimental treatments on a dry, clear night. Based on visibility effects either known or currently under research elsewhere, it should be possible to predict at least qualitatively the relative safety performance in a more adverse driving environment. (Limited wet-weather field data were, in fact, obtained in Phase II at the Maine Facility sites.)

CHAPTER IX

PLANNING AND CONDUCT OF PHASE II FIELD STUDIES

This chapter describes the development of the traffic performance data base for further evaluating the Phase I models and for comparing the effectiveness of Phase II alternative delineation treatments. Main sections of the chapter include: site selection and treatment installation; measurement apparatus and sampling requirements; and collection and processing of raw data. All important aspects of these topics are at least summarized herein. In a few cases, however, references are made to more detailed background material located in earlier chapters.

SITE SELECTION AND TREATMENT INSTALLATION

Guidelines

Chapter VIII presented both the geometric criteria for site selection and the delineation treatments to be evaluated. Other experimental objectives guiding the site search were the following:

- The instrumented Maine Facility, with several miles satisfying the project's definition of a tangent delineation situation, would be used for at least the two evaluation series illustrated in Figure 20 (see Chapter VIII).

- Five of the remaining seven study sites should be located on highways where pavement overlay projects are scheduled for the late summer or early fall of 1976 (i.e., during initial weeks of Phase II data collection).

- The search for the non-Maine sites should concentrate on Mid-Atlantic states whose highway officials had earlier expressed an interest (or at least a willingness) to install a variety of novel delineation treatments.

This last guideline—geographic proximity to the research team's facilities—would improve the timely coordination of treatment installation, allow for reasonably convenient inspection tours by the researchers and/or the FHWA, and decrease travel time consumed by the data collection crew. An offsetting disadvantage would be that several of the Mid-Atlantic states, as opposed to states further south, might experience autumm snowfalls which would severely retard data collection efforts.

Weather was also an important factor to consider in locating sites for which some rather unique delineation materials had already been selected. Of greatest concern were the raised pavement markers (RPM's) intended for installation at four sites (not counting the Maine Facility). Because of the temporary nature of their presence in each site's prescribed experimental series of treatments, the RPM's would have to be applied with butyl asphalt adhesive pads. However, the successful application of these pads requires a minimum ambient temperature of about 45-50^{o}F (7-10^{o}C). Maryland, the one Mid-Atlantic state voicing interest in RPM evaluation, was known to experience such a temperature range during much of those limited months available for the Phase II field studies. To the extent that the locations of scheduled pavement overlay projects would allow, sites in coastal or southern counties were clearly preferred.

Procedures and Results

The research team had gained substantial relevant experience in the Phase I site search and selection process. Senior members of the team again conducted the process, and again applied the detailed, rather comprehensive criteria and considerations discussed in earlier chapters of this final report. Special care was exerted to avoid selecting TPM monitoring locations where drivers might be influenced by extraneous, often subtle roadside features.

The general characteristics of the nine field study sites are discussed below by each of the four involved states. For a full listing of the alignments and conceptual treatments, refer again to Figures 20 through 23 in the preceding chapter. Additional details on the specific geometrics, traffic characteristics, and delineation at the sites can be found in Chapter XI and Appendix E.

Maine — Through correspondence and two personal inspection trips, arrangements were completed in the fall of 1976 for the Maine Facility experiments illustrated in Figure 20 (presented earlier). Site 1, for the evaluation of post-mounted delineation at alternative spacings, consisted of about 2-1/2 miles (4 km) of essentially straight highway beginning at the Facility's western end and proceeding east. Site 2, for the evaluation of retroreflective raised pavement markers as a supplment to conventional center- and edgelines, covered a similar distance at the eastern end of the Facility. Figure 24 shows the Site 2, Level 4 delineation system as it appeared on a dry night. (Traffic was not monitored in the vicinity of the white guardposts, however.)

Pennsylvania — In Centre and Clearfield Counties of central Pennsylvania, two study sites convenient to Penn State University were chosen. Site 6, a heavily traveled section of winding highway in Clearfield County, was used to examine the characteristics of traffic flow under one- and two-line delineation systems (see Chapter VIII, Figure 22). In contrast, the study site selected in Centre County was a horizontal curve isolated by more than a mile (1.6 km) from the nearest adjacent curves.

While the Site 8 schematics in Figure 23 show that several types of spot-location delineation treatments were to be evaluated at this isolated horizontal curve, an unexpected shoulder improvement project was launched by State maintenance officials shortly after studies at the

Figure 24. Reflective RPM supplement to conventional center- and edgelines.

Figure 25. Centerline of 5-foot (1.52-m) stripes and a reflective RPM in alternate 35- foot (10.67-m) gaps.

site had begun. The only evaluation made, therefore, was a with-and-without test of color-coded post-mounted delineators placed on each side of the roadway in the vicinity of the curve.

Maryland — Sites 3, 5, and 7 were located in three different counties of Maryland. Site 3, a newly resurfaced tangent highway in west-central Washington County, provided an excellent test location for potentially more cost-effective centerline treatments. (The level 2 configuration at this site is pictured in Figure 25.) Site 5 was a rather narrow, moderately traveled section of winding highway located in north-central Carroll County. The high potential for shoulder and centerline encroachments on such a roadway was considered in designing the novel centerline application of RPM's shown in Figure 26. Lastly, another isolated horizontal curve was selected for study in Charles County a few miles south of the Washington, D.C. metropolitan area. Identified as Site 7, this curve was between 7 and 8 degrees in severity, was located on a narrow roadway, and appeared to suffer from rather restricted sight distance. Figures 23 and 27 illustrate the treatments evaluated at this study site.

Virginia — The last two sites, 4A and 4B, were both located on the same tangent-type highway just a few miles east of Culpeper, Virginia. The first two treatment levels at these sites consisted of a centerline with 30-foot (9.14-m) gaps and 10-foot (3.05 m) stripes in both 2- and 4-inch (5- and 10-cm) widths, with and without narrow edgelines. (See Figure 21.) The third and fourth treatment levels were identical at the two sites and included strictly 4-inch (10 cm)-wide striping on both sides of each traveled lane. The opportunity to replicate traffic performance measurements for the 10:30 and 15:25 stripe-to-gap ratios seemed especially appropriate in view of the current trend among the states toward the lower ratio.

The confirmation of the Phase II study sites was very much dependent upon prospects for the timely installation of the special paint striping and markers required. This latter work was to be performed by regular State maintenance crews in response to case-by-case requests by the research team. Opportunities for its performance were limited by other delineation needs within each state as well as the uncertain schedule of the paving contractor, the availability of raised pavement markers and suitable weather for their successful installation, the need for a minimal driver acclimation time, and the progress of the data collection effort.

MEASUREMENT APPARATUS AND SAMPLING REQUIREMENTS

This section describes the major equipment components, layout, and utilization requirements associated with the Maine Facility and Penn State University data collection systems.

Figure 26. Winding highway delineated with all-RPM centerline and contrasting shoulders.

Figure 27. PMD's and centerline RPM's on isolated horizontal curve.

Traffic Measurement Stations

For measuring vehicular speed and lateral placement at critical points in a test section's horizontal alignment, detection traps were located in the same manner specified for the Phase I field studies. Refer to Figures 7, 8, and 9 (Chapter IV) to review the particular trap locations for the tangent, winding, and isolated horizontal curve alignment types, respectively. It should be recalled that these locations and the measurements sought were selected primarily on the basis of the accident/prior-movement analysis discussed in Chapter III.

Maine Facility Equipment

Field data at Sites 1 and 2 were collected for the project by government personnel operating the Maine Facility. The data collection system utilized did not involve the Facility's permanent instrumentation, but rather, consisted of traps and recording devices placed in an ad hoc fashion at points requested by the principal investigator during a personal inspection trip.

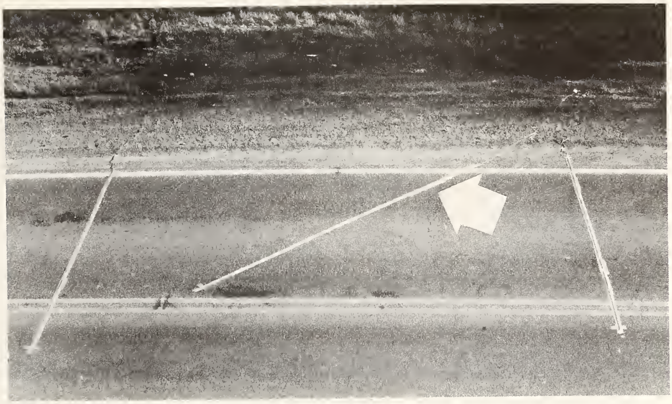
Each measurement station included three separate pressure-sensitive coaxial cables inlaid in soft asphaltic strips placed on top of the existing asphalt concrete pavement. Two contiguous traps were formed by the cables: the upstream and intermediate cables, six feet (183 cm) apart and perpendicular to the edgeline, were used to determine speed; the downstream cable, slanted at 45 degrees, was used in conjunction with the intermediate cable to estimate the lateral placement of a vehicle's front right tire with respect to the edgeline. This latter estimate was derived from the known trap geometry and a ratio of the speeds from the two contiguous traps.

A TDC automatic traffic data recorder was used for the on-site speed computations and storage of data on tape cassettes. Individual speeds were recorded to the nearest whole mile per hour, and the average unbiased error for lateral placement estimation was about 3-1/2 inches (9 cm).

Penn State University Equipment

As a result of its Phase I data collection experiences, PSU converted to a Z-shaped detection trap having operating principles similar to the Maine Facility scheme. The "Z" is formed by three separate tapeswitches as opposed to the previous arrangement of two parallel tapeswitches only. Both speed and lateral placement can now be derived from simple digital clock readings and accurate physical measurements of the tapeswitch layout. This obviates the earlier need for the time-consuming tapeswitch calibration process.

Figure 28 is a photograph of a typical PSU measurement trap. While the tapeswitches were covered with a dull gray duct tape, there was initially some concern that driver behavior may be affected by the visual



Front right tire activates diagonal tapeswitch.

Figure 28. Z-shaped measurement trap consisting of 3 tapeswitches.

Trap in nearside lane.

Figure 29. Oblique view of typical trap installation.

or auditory impact of the tapeswitches. However, when viewed at a typical oblique angle (Figure 29), the trap is not nearly as conspicuous as Figure 28 suggests. Since the thickness of the installed tapeswitches is only about half that of a pneumatic road tube, the tactile or auditory impact is also relatively insignificant.

In addition to the tapeswitches, the data collection system includes lead-in cables and adapters; a six-channel timing console; a 1,000-watt portable generator; and a pneumatic-tube traffic counter. Figure 30 shows the spooling arrangement for the cables and also the electrical generator used to sustain the system. The traffic counter was installed well downstream of the traps to obtain an hourly volume profile.

The timing unit, shown in Figure 31, was designed and built for the project by the University's Department of Electrical Engineering. Its portable metal cabinet houses six digital clocks for displaying time intervals to the nearest millisecond, twelve start/stop rotary switches, and nine tapeswitch amplifiers. Each pair of clocks is assigned to a specific Z-trap: one clock measures travel time between the upstream perpendicular tapeswitch and the diagonal tapeswitch, and the companion clock measures overall travel time between parallel tapeswitches (see Figure 28). The digital clocks "freeze" at the measured values until manually reset. This prevents confusion of readings when vehicle platooning occurs, and it allows the accurate manual recording of values before subsequent free-flowing vehicles arrive. The translation of the two time intervals to speed and lateral placement is explained in Appendix I. Average expected measurement errors have been estimated to be only ± 0.4 mph (0.6 km/h) for speed and ± 2 inches (5 cm) for placement.

Required Sample Size

The last major section of Chapter IV discussed in some detail the sample size requirements for estimating the mean and variance of typical speed and lateral placement distributions. Throughout that discussion and the brief one which follows, sample size, of course, refers to the number of observations to be obtained under a given operating condition. Both Phase I and Phase II were mandated to examine a minimum of two conditions, dry daytime and dry nighttime.

To reiterate the earlier sample size presentation, it was concluded that while 100 observations were sufficient for predicting the mean of either TPM distribution, 150 observations were desirable for estimating the variance of lateral placement. The analyses leading to this 100—150 sample size requirement were based on the following assumptions:

- Both basic TPM distributions are normally distributed.
- A confidence interval of ± 10 percent should be used.
- There should be at least a 95 percent probability of the sample statistic falling within this confidence interval.

Figure 30. Lead-in cables and electrical generator.

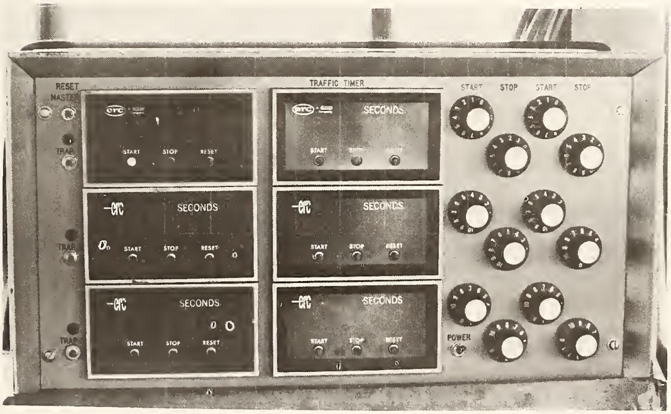


Figure 31. PSU traffic timing console.

Phase II sites, as a set, did not require the wide range of average daily traffic (ADT) volumes present in Phase I. Hence, the more recently studied sites generally were selected so that their ADT's were in the higher allowable range (i.e., 2,000—5,000 vehicles per day) in order to expedite TPM data collection. It was expected to be relatively easy to collect at least 125 observations within a reasonable time period, with 150 still being the desired goal. At the 95 percent significance level, a sample size of 125 yields a confidence interval of about ±12 percent for the standard deviation of lateral placement.

COLLECTION AND PROCESSING OF RAW DATA

Improvements in Efficiency of Data Collection

The average time spent to collect traffic performance data for a given experimental cell was noticeably less in Phase II than it was in Phase I. This was due in part to the higher traffic volumes mentioned above, but certain other efficiencies were also realized with each Phase II data collection system.

Maine Facility — In terms of average time saved per test condition, the primary feature of this system was that the sensors were left on the pavement over the life of the sequential evaluations. However, this benefit probably would have been largely offset by increased hardware costs if more than the two Maine Facility sites had been simultaneously instrumented.

PSU Technique — As shown in Table 9 (Chapter V), as many as three to four hours were required in Phase I to deploy and make operational all of the data collection equipment. A significant portion of this time, about an hour, was devoted to tapeswitch calibration. Set-up operations in Phase II were more typically conducted in about two hours because of the following factors:

- The new Z-trap technique did not require tapeswitch calibration to obtain lateral placement information.
- After the first data collection visit to a site, the crew was familiar with appropriate locations for the traps, lead-in cables, and monitoring van. (Phase I sites were visited only once by the crew.)
- Greater stability in the staffing of the crew provided the two individuals with valuable experience, leading to a more efficient division of responsibilities.

Format of Field Data

TPM data were mailed to AMV in two different formats, each somewhat different than that used for Phase I data collection and processing.

Maine Facility data sets (Sites 1 and 2) consisted of computer tabulations of actual speed and placement values for each free-flowing vehicle traversing each of the two measurement stations. (A free-flowing vehicle was defined as one having a headway with the preceding vehicle of at least six seconds.) The following additional data fields were provided for each vehicle record:

- Number of axles, for estimating vehicle type and tread width.
- A code indicating whether an opposing vehicle was in the vicinity (i.e., if one of the trap cables extended into the other lane received an actuation within 4 seconds ($\pm$) of a full trap actuation in the primary direction).
- Real time of the observation.

Penn State data (for the other seven sites) included field tabulations of the four or six clock readings for each vehicle (two or three traps depending upon site type), plus a diagram showing trap layout measurements. Vehicle type was noted as either "automobile" (four tires) or "truck" (six or more tires). Also, a notation was made if there was opposing traffic at the time the clocks registered the time intervals recorded.

In all cases, lateral placement measurements were referenced to the outside edge of the traveled lane, defined as the physical edge of the pavement for roadways without edgelines, and the midpoint of the edgeline for roadways with edgelines. In the latter case, any pavement or stabilized material outside the edgeline was considered to be part of the shoulder width. Other data recorded for each site included the average daily traffic volume, width of traveled way, speed limit, length and degree of curve (if any), and type of delineation.

Computation of Basic Distributional Statistics

The field data processing program developed in Phase I was modified to accept either of the two new input formats as well as the original input format. A few minor enhancements to the output or report formats were also made. Table 11 (Chapter V) illustrates the most comprehensive of the program's reports.

The editing feature previously used to cull out perturbations in the data base was not exercised in Phase II. This was possible because the newer data, no longer partially composed of lateral placement readings taken from D'Arsonval meters, appeared to contain fewer unusual and seemingly erroneous values. The only editing performed was to set aside computed lateral placement values which were negative to the point of implying tire placement to the right of any paved shoulder instrumentation. Such an error was attributed to the misreading of a clock.

In addition to the basic speed and lateral placement statistics shown in Table 11, a number of other potential effectiveness measures was also computed by the program and punched onto cards. These measures were generally arithmetic combinations of one or two distributional statistics and a traffic volume or geometric variable with which it (they) might interact to reflect degree of hazard. As discussed in Chapter XI, the punched cards were subsequently input to a post-processing program to prepare TPM summary tables and between-condition test statistics.

CHAPTER X

EVALUATION OF ACCIDENT-PROBABILITY MODELS

Prior to interpreting the results of the Phase II traffic performance field studies, a review was conducted of the actual and predicted accident rates associated with the base condition delineation systems. Selected accident statistics were first compared to the Phase I data base to verify that the Phase II sites did not demonstrate any striking historical peculiarities. This being the case, a variety of additional analyses were possible. One was a small before-and-after edgeline tabulation for the Maine Facility. A far more important analysis, however, was a check on the predictive power the previously documented accident probability models.

PHASE II ACCIDENT DATA

This section reviews the procedures used to obtain and manipulate the Phase II accident data. Several brief analyses of selected accident data characteristics are also presented.

Data Collection and Processing

With the exception of the two Maine Facility sites, where 1975 edgeline installation confined the study period to just one year (1976), a recent two- to six-year interval could be readily identified for each site during which the so-called "base condition" delineation system was present. This system was a centerline only for Site 8 and a centerline with edgelines at all other sites. These lines were always a nominal 4 inches (10 cm) wide and were configured in the standard MUTCD pattern (i.e., 15:25 centerline module and continuous edgelines).(1) Relevant physical characteristics of the sites, including the distance used for the aggregation of accident data, are presented in Appendix E.

The cooperating states of Maine, Pennsylvania, Maryland, and Virginia were requested to provide summary tabulations of the identified accident records. For the tangent and winding site types, all accidents occurring over the several-mile section length were desired. For each of the two isolated horizontal curves, accidents occurring within a subjectively established zone of influence extending 750 feet (229 m) beyond the points of curvature were of interest. In addition to these accident data, average daily traffic volume estimates for the identified sites and years were also sought and provided.

To ensure comparability to Phase I statistics, the Phase II accident data were processed in an identical fashion. Discussed in detail in the first eight pages of Chapter VI, the sorting and computational procecures had the following basic features:

- The setting aside of snow-, ice-, and fog-related accidents.
- The identification of those accidents clearly not related to the presence or absence of continuous delineation.
- The stratification of accidents on the basis of intersection involvement, ambient light, and pavement surface condition.
- The use of one-million-vehicle-miles for tangent and winding sections—and one-million-vehicles for isolated curves—as the units of accident exposure.
- The partition of total accident exposure to match each of the four possible combinations of surface and light condition (i.e., dry-night, dry-day, wet-night, and wet-day).
- The resulting estimation of true accident rate under a given environmental condition.

Accident Experience by Site

Table 29 shows the number of accidents in several selected categories for each of nine field study sites. Site numbers 1-8 correspond to the previously used numbering sequence for Phase II sites. In addition to these eight FHWA sites, however, a ninth site in Illinois (numbered 10 for extra distinction) was also selected to augment the model evaluation effort.

Site 10 was studied in exactly the same manner as the Phase II FHWA sites, but under the auspices of another AMV research contract. The TPM data and the accident data necessary for a model check were made available courtesy of the Illinois Department of Transportation. As a result, a total of seven tangent and winding roadway sections (Sites 1-6 and 10) could be considered in conjunction with the Phase I accident-probability models.

Table 29 indicates that delineation-related, non-intersection, dry-pavement accidents represented an average of 41.5 percent of the "total" category. This is remarkably close agreement with the figure of 41.4 percent obtained in Phase I (see Table 15, Chapter VI). The agreement is especially interesting in view of the fact that many Phase I sites lacked edgelines, while all but one of the Phase II sites had edgelines as a base condition treatment. A later summary of accident rates also raises this point of curiosity.

Also worthy of note in Table 29 are the relatively small numbers of delineation-related, non-intersection, dry-pavement, nighttime accidents. This is the accident type utilized in the accident-probability modeling. With the exception of Site 6, however, no more than five such accidents were reported for any one site over the periods studied.

Table 29. Number of Phase II accidents by study site.

Site Number	Site Type [1]	Number of Years of Data	Accidents During Base Condition Study Period				
			All Reported	Total [2]	Delineation-Related, Non-intersection, Dry-Pavement		
					Day	Night	Total
1	T	1	15	10	3	2	5
2	T	1	9	7	4	0	4
3	T	2	7	7	1	2	3
4	T	6	43	42	15	3	18
5	W	2	42	36	9	5	14
6	W	6	111	90	22	19	41
7	HC	3	3	3	0	2	2
8	HC	6	5	4	0	1	1
10 [3]	T	5	49	47	11	3	14

[1] T = tangent, W = winding, HC = isolated horizontal curve.
[2] Excludes snow, ice, and fog-related accidents.
[3] Five-mile section of Illinois Route 185 (courtesy of IDOT).

Phase II versus Phase I Accident Rates

Table 30 compares accident rate ranges and means between site types and project phases. Being quite sensitive to the number of sites considered, the ranges do not agree very closely between phases. Strikingly similar, however, are the mean rates.

Tables 29 and 30, taken together, do not show significant disparities between the general nature of accident occurrence at Phase II as opposed to Phase I sites. Hence, no obstacle to model validation would appear to exist due to extreme outliers in the set of dependent variables.

Accident History of Maine Facility

Table 31 presents selected results from the 1973-1976 accident data base established for the Maine Facility. (Appendix G contains more detailed rate information for three of these years.) The two innermost columns listing numbers of accidents correspond to the "all reported" and "total" categories defined earlier. The column headed "Delin.-Related Rate" refers to all delineation-related accidents, undistinguished with regard to ambient light, wet versus dry pavement, or proximity to an intersection. It should be noted, however, that in defining the site mileage for the accumulation of accident data, a long bridge, a small town, and a few curves of greater than 3 degrees were deducted from the Facility's total length. This was done in order to avoid low-speed and curve-related accidents not in general conformance with the project's definition of a rural tangent delineation situation.

Unfortunately, due to the very infrequent nature of the most narrow accident category shown on Table 31, the rates and rate differences in the two rightmost columns are not statistically conclusive as to edgeline effectiveness. However, a comparison of the "Delin.-Related Rates" appears to suggest a moderate to slight improvement between 1973 (without edgelines but also with a higher speed limit) and 1976 (with edgelines and a 55 mph (88 km/h) speed limit). Twelve- or 18-month comparisons involving 1974 data yield more mixed results. The extent to which changes in typical operating speeds have clouded the analysis is problematical and can only be addressed by reviewing trends for similar highways within the state of Maine.

MODEL EVALUATION

In this section, the predictive power of five accident-probability models (or equations) is checked by inputting available TPM data and comparing predicted accident rate to actual accident rate. The models evaluated include the four developed in this project (presented in Chapter VII), plus the Penn State model for high-accident curves (mentioned in Appendix Q of NCHRP Report 130(14)). Emphasis is placed on the two-variable and five-variable AMV models, whose development residuals were discussed in the earlier chapter.

Table 30. Distributions of Phase I and Phase II accident rates.

Accident Set	Phase of Project	Statistic	Accident Rates		
			Tangent (acc/MVM)[1]	Winding (acc/MVM)[1]	Isolated Curve (acc/MV)[2]
Total Accidents	I	Range	0.42—6.93	0.82—5.75	0.0—2.44
		Mean	1.88	2.61	0.77
	II	Range	1.28—2.43	2.28—3.16	0.63—1.14
		Mean	1.75	2.72	0.88
Delineation-Related, Non-Intersection, Dry-Pavement Accidents	I	Range	0.42—2.31	0.47—4.40	0.0—2.44
		Mean	1.16	1.99	0.64
	II	Range	0.55—1.41	1.66—1.75	0.30—1.09
		Mean	0.98	1.70	0.70

[1]Accidents per million vehicle-miles (1mile = 1.61 Kilometres).

[2]Accidents per million vehicles

[3]Excludes snow, ice, and fog-related accidents.

Table 31. Maine Facility accident experience before and after edgelines.

Site Number	Time Period	Status of Edgelining	Average ADT[1]	Number of Reported Accidents	Number Less Snow, Ice, & Fog Acc.	Delineation-Related Rate (ACC/MVM)	Delineation-Related, Non-Intersection, Dry-Night (Number & Rate)[2]	Before-After (ACC/MVM)
1	Jan—Dec 74	Before	2,100	12	9	1.55	(0) 0.0	-2.68
7.89 mi.	Jan—Dec 76	After	2,100	15	10	1.57	(2) 2.68	
(12.7 km)	Jan—Dec 73	Before	2,100	13	12	2.38	(3) 4.21	+1.53
	Jul 75—Dec 76	After	2,100	20	12	1.19	(2) 1.79	+1.02
	Jul 73—Dec 74	Before	2,100	19	14	1.63	(3) 2.81	
2	Jan—Dec 74	Before	2,355	8	5	0.67	(2) 3.80	+3.80
5.30 mi.	Jan—Dec 76	After	2,620	9	7	1.20	(0) 0.0	
(8.5 km)	Jan—Dec 73	Before	2,230	6	5	1.31	(0) 0.0	0.0
	Jul 75—Dec 76	After	2,575	15	11	1.24	(0) 0.0	+2.53
	Jul 73—Dec 74	Before	2,315	12	7	0.63	(2) 2.53	

1 To account for rather significant seasonal fluctuations in traffic volume, quarterly ADT estimates were used to compute accident rates.

2 (X)Y = X accidents, Y rate (in accidents per million vehicle-miles; 1 mi. = 1.61 km).

Phase I Models versus Phase II Data

Table 32 presents the independent TPM variables, the actual accident rates, and the predicted accident rates for six tangent and two winding study sites. Sites 1–6 are Phase II FHWA sites, and the site identified as No. 10 is a supplemental Illinois site (as previously noted). Sites 4A and 4B represent the same dependent variable tested against two separate sets of independent variables; hence, subsequent analyses of Site 4 prediction residuals use averages of the results shown on this table.

It is apparent that the predictive power of the four accident-probability models, as judged in the context of the limited Phase II data, decreases as the equations grow from two to five variables. The two-variable model yields the closest fit in four of the seven cases and gives only one prediction more than one standard error removed from the actual accident rate. At the other end of the range, the five-variable model provides only one "good" prediction, and this is in a case where no accidents of the relevant type were even reported.

Figure 32 illustrates even more clearly the sharply differing degrees to which the two-variable and five-variable models are able to predict the actual accident rates developed for the seven Phase II sites. It is obvious that the five-variable model severely underestimates the actual accident rates; on the other hand, the two-variable model produces a comparable number of predictions above and below the line representing the ideal model.

Still another evaluation technique is to compute the residual for each prediction by subtracting predicted accident rate from actual accident rate and expressing the result with the proper algebraic sign. This was done in developing Table 33. Note that the two-variable model yielded an algebraic average residual for all seven study sites of only -0.01 ACC/MVM. Setting aside Sites 1 and 2 (the Maine Facility), this average is still only +0.73 ACC/MVM, well within the standard error of the regression of 1.61. If all residuals are first converted to their absolute values (as done in Table 23, Chapter VII), the seven-site average is 1.11, and the five-site average is 0.81. These values are also well within the standard error and are quite comparable to the better values of this statistic shown earlier in Table 23.

Penn State Curve Accident Model

Another accident-probability model worthy of a validation check is equation (Q–8) in NCHRP Report 130.(14) This model, developed by Pagano at The Pennsylvania State University, provided much of the impetus to the current research project.

An attempt was made in Phase I to fit the PSU model to the data for AMV's 20 isolated horizontal curves, but with a very poor outcome. Although not vigorously pursued, the lack of fit was attributed to

Table 32. Comparison of predicted to actual accident rates at Phase II sites.

Site Number	Site Type[1]	Roadway Width (ft.)	Shoulder Width (ft.)	Traffic Performance Measures[2]			Actual Accidents[3]			Predicted Accident Rates[4]			
				CI	DPVx10	SI	Number of Years	Number of Accidents	Rate	Two-Variable Model	Three-Variable Model	Four-Variable Model	Five-Variable Model
1	T	22.0	8	2.256	0.481	0.110	1	2	2.68	3.59	2.86	1.67	0.48*
2	T	23.0	10	2.292	0.156	0.519	1	0	0.0	2.81*	2.84*	1.37	-0.01
3	T	23.2	10	0.625	0.280	0.299	3	2	1.89	1.21	0.93	-0.77*	-2.10*
4A	T	21.0	10	1.787	0.114	1.141	6	3	0.87	2.12	3.42*	3.23*	2.27*
4B	T	21.4	8	0.156	0.020	0.670	6	3	0.87	0.01	0.46	-0.25	-0.81*
5	W	18.8	11	1.662	0.032	0.132	2	5	3.10	1.77	1.05*	1.24*	-0.66*
6	W	23.2	10	0.138	0.616	0.554	6	19	3.05	1.50	1.83	0.34*	-0.78*
10[5]	T	21.0	3	0.587	0.085	0.096	5	3	0.97	0.67	-0.04	-0.90*	-0.67*

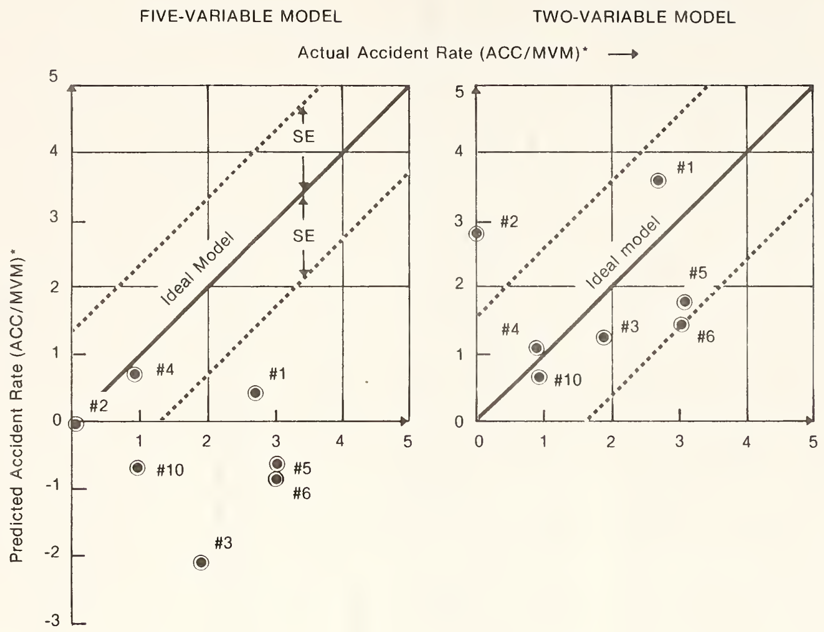
[1]T = tangent and W = winding.

[2]TPM's defined in Chapter VII.

[3]Nighttime, delineation-related, non-intersection, dry-pavement accidents; rate expressed as accidents per million vehicle-miles (1 mi. = 1.61 km).

[4]Same accident definition as footnote 3; four models are presented in Table 21 (Chapter VII); best prediction underlined and those outside "actual" $\pm$ one standard error are starred (*).

[5]Five-mile section of Illinois Route 185 (courtesy of IDOT).



Notes:

*No. of nighttime, delineation-related, non-intersection, dry-pavement accidents per million vehicle-miles.

•Models defined in Chapter VII.

•SE = Standard error of the estimate (1.61 for two-variable model and 1.33 for five-variable model).

•#X identifies Site No. X.

Figure 32. Fit of AMV models to 7 Phase II data points.

Table 33. Phase II residuals for five-variable and two-variable models.

Site Number	Accident Rate Residual = Actual Rate — Predicted Rate[1]			
	Five-Variable Model		Two-Variable Model	
	+	—	+	—
1	2.20			0.91
2	0.01			2.81
3	3.99		0.68	
4	0.14			0.20
5	3.76		1.33	
6	3.83		1.55	
10	1.64		0.30	
Averages	2.22		0.96	1.31
	+2.22		− 0.01	

[1] Rates and models are defined in Table 21 (Chapter VII).

the generally high accident frequency at the PSU curves, and to problems with accident classification and scaling of the dependent variable (i.e., in terms of accidents per million vehicle-miles instead of accidents per million vehicles).

In spite of the Phase I results, another check was made of the PSU model using Phase II data for Sites 7 and 8. Table 34 shows an equally poor outcome, however. A portion of the large discrepancies may be due to the fact that the curves in the PSU data base were all more severe than the two Phase II FHWA curves. Specifically, the radii of the PSU curves ranged 143-763 feet (44-233 m), while the radii of the FHWA curves ranged 819-1,146 feet (250-350 m).

Conclusions

Although the limited number of Phase II sites available for model evaluation prevented a full-scale validation effort, the analysis presented in this chapter for seven tangent/winding data points proved to be very informative. For a rather minimal sacrifice in Phase I data fit, a two-variable model was shown to produce much better agreement with the independent Phase II data then did a previously published five-variable model. The smaller model is both easier to apply and less likely to yield irrational or wayward estimates of accident potential. Mindful of the several qualifications discussed at the conclusion of Chaper VII, then, the two-variable model was selected as one of several tools for evaluating the balance of the Phase II field data.

The modeling exercise showed just two lateral placement parameters to be fairly effective indicators of delineation-related driving hazard; hence, under operating conditions or at site types for which the model is inapplicable, it seems reasonable to simplify the analysis of safety effectiveness by focusing on these same two parameters as direct evaluative measures. This focus is especially appropriate for the Phase II horizontal curves, since the Penn State accident-probability model should not be directly applied.

Table 34. Check of Penn. State curve accident model. (14)

Quantity	Station on Outside Curve	Site Number 7	Site Number 8
Nighttime Lateral Placement Variance (ft^2)	Point of Curve	0.978	0.835
	Midpoint	0.988	1.555
Nighttime Average Speed (mph)	Point of Curve	42.3	53.0
	Midpoint	40.6	52.3
Distance L (mi.)	P.C.→Midpoint	.0473	.0379
Rate for "All Accidents," ACC/MVM[1]	Predicted	42.68	47.88
	Actual	3.18	1.59
Rate for "Curve-Related Accidents," ACC/MVM[2]	Predicted	42.08	44.69
	Actual	3.18	1.27

Note: 1 ft. = 0.30 m and 1 mi. = 1.61 km.

[1] All reported accidents for both directions of travel; total of day and night occurrences. Predicted from: A = -21.87 + 23.26 PVR + 0.027 D where:

$$PVR = LP_s2_{Midpt} / LP_s2_{pc} \text{ and } D = \frac{(\bar{S}_{pc} - \bar{S}_{Midpt})(\bar{S}_{pc})}{L}.$$

[2] All reported accidents less ice, snow, animal, etc. occurrences. Predicted from: A = -17.24 + 19.59 PVR + 0.026 D.

CHAPTER XI
EXPERIMENTAL CHANGES IN BASIC SPEED AND LATERAL PLACEMENT MEASURES

Chapters VIII, IX, and X have described the selection of delineation treatments for Phase II evaluation, the collection and initial processing of the associated traffic performance data, and the accident-probability models which might be used to interpret the practical significance of the data. The findings of the field studies are presented and discussed in the balance of the report. Chapter XI provides a brief overview of the statistical testing methodology, plus a detailed site-by-site analysis of the experimental treatments and their effects on basic TPM distributional parameters. The main text concludes with Chapter XII's estimation of delineation-related accident potential, synthesis of findings by delineation system, and recommended revisions to practice.

STATISTICAL TESTING METHODOLOGY

Scope of Phase II Data Base

Traffic performance measures were obtained for a large number of experimental combinations of delineation treatment, environmental condition, and driver acclimation time. Table 35 shows the scope of this data base.

The treatments are more fully described in subsequent sections of this chapter; the categories covered have been repeated here to allow selective reading of the site-by-site analyses which follow. The "levels" of delineation were illustrated schematically in Figures 20 through 23. "Cell" number, wherever found in data tables or text, consists of two digits: the first digit is the site number and the second is the level number. (An exception is Site 4A, which has a "90" series of cell numbers to distinguish it from the "40" series used for Site 4B.)

As shown in Table 35, TPM data were collected for two different durations of driver acclimation time for seven experimental delineation systems. The actual days of acclimation allowed for all data sets are shown in Appendix F by cell and environmental condition. The criterion for qualitatively distinguishing "short" (S) from "longer" (L) acclimation times was generally one week.

Summary and Analysis Program

The size and complexity of the data base warranted a computerized approach to summarizing and statistically testing the many performance measures. Utilizing output cards punched by the field data reduction program, a post-processor routine was written for these purposes. Table 36 is an example report produced by this post-processor routine. The table includes four primary data columns, each column containing

Table 35. Scope of Phase II TPM data base.

Site Number[1]	Treatments Evaluated			Delineation "Levels"		Environmental Condition			
						Day		Night	
	Paint	Raised Pavement Markers	Post-Mounted Delineators	Number	Number with Two Acclimation Times[2]	Dry	Wet	Dry	Wet
1			X	3	2	X	X	X	X
2		X		4	3	X	X	X	X
3	X	X		4	0	X		X	
4 A	X			4	0	X		X	
4 B	X			4	0	X		X	
5	X	X		4	0	X		X	
6	X			3	0	X		X	
7_I		X	X	4	1	X		X	
7_O		X	X	4	1	X		X	
8_I			X	2	1	X		X	
8_O			X	2	1	X	X	X	

[1] I = Inside Curve and O = Outside Curve.

[2] Actual Days of Acclimation Listed in Appendix F.

Table 36. Sample output from TPM statistical post-processor program.

ITEM	CELL 21	T(DF) / F	CELL 22	T(DF) / F	CELL 23	T(DF) / F	CELL 24
DELINEATION TREATMENT:	CENTERLINE EDGELINES		CTR & EDGELINES CTR RPM'S 80FT.		CTR & EDGELINES C&E RPM'S 80FT.		CTR & EDGELINES C&E RPM'S 40FT.
INSTALL. DATE & DOE:	**/**/**, ***		10/ 1/76, 1		10/12/76, 12		10/27/76, 27
DATA COLLECTION PERIOD:	DAY - NIGHT		DAY - NIGHT		DAY - NIGHT		DAY - NIGHT
DATE(S) & D.O.W.(S): DAY(S) OF EXPERIMENT: DAYS OF ACCLIMATION: ADT & PERCENT TRKS:	9/30-31, THU-FRI 0 - 1 *** -*** 3130 2.8		10/ 7- 8, THU-FRI 7 - 8 6 - 7 3650 2.0		10/21-22, THU-FRI 21 - 22 9 - 10 2070 2.1		11/ 5- 6, FRI-SAT 36 - 37 9 - 10 2340 1.6
SPEED -- MEAN, (NUMBER OF OBSER.), VARIANCE							
TRAP UPSTREAM:	51.7 (145) 50.4	1.46(292) 1.23	50.4 (150) 62.0	0.90(289) 1.06	51.2 (142) 65.4	0.80(254) 1.23	50.4 (126) 80.7
T-VAL(DF), F-VAL:	0.40(286), 1.19		0.38(298), 1.01		0.98(280), 1.21		0.20(250), 1.02
TRAP DOWNSTREAM:	51.3 (145) 42.5	1.55(286) 1.47	50.0 (150) 62.6	2.20(282) 1.27	52.2 (142) 79.4	1.48(263) 1.01	50.6 (126) 78.9
MORE INTERCELL STAT:			0.49(279), 1.30	1.29(237) 1.60	0.01(251), 1.30		
LATERAL PLACEMENT -- MEAN, (NUMBER OF OBSER.), VARIANCE				(Average LW = 11.5' for all cells.)			
TRAP UPSTREAM:	4.3 (145) 1.9	5.44(284) 1.34	3.5 (150) 1.4	0.55(290) 1.05	3.4 (142) 1.3	1.71(232) 1.73	3.1 (126) 2.3
T-VAL(DF), F-VAL:	2.27(288), 1.10		0.05(294), 1.29		1.90(273), 1.45		1.92(244), 1.38
TRAP DOWNSTREAM:	3.9 (145) 1.7	3.00(293) 1.06	3.5 (150) 1.8	1.27(271) 1.96	3.7 (142) 0.9	1.30(229) 1.83	3.5 (126) 1.7
MORE INTERCELL STAT:			5.93(279), 1.41	6.63(254) 1.23	2.17(234), 1.65		

trap-specific distributional parameters for a particular combination of cell, environmental condition, and driver acclimation time.

Report Format — Column heading information describes the following miscellaneous quantities:

- Delineation system
- Treatment installation date and the corresponding day of overall experimentation at the site (DOE)
- Pavement and ambient light condition prevailing at the time of data collection
- Data collection date(s) and day(s) of week (D.O.W.(s))
- Data collection day(s) of experiment and the resulting days of driver acclimation
- ADT and percent trucks measured at the time of TPM data collection

Basic speed and placement statistics are tabulated below each of these headings. For each identified trap and data collection period, a series of three numbers are shown in the format XX.X (YYY) ZZ.Z. XX.X is the sample mean, YYY the number of observations, and ZZ.Z the sample variance.

Between-trap and between-condition differences in mean speed or mean placement were assessed statistically with a t-test based upon unequal and unknown population variances. The computed t-value ("T-VAL") and degrees of freedom ("DF") for each test are shown in Table 36 in the appropriate location either vertically between "trap upstream" and "trap downstream" or horizontally between each of the four major "cell" columns of the table. T-values representing statistically different means are underscored with either one or two lines, corresponding to significance at the 95 or 99 percent confidence level, respectively.

Between-trap and between-condition differences in the variance of speed or placement were assessed with an F-test. "F" is the ratio of the variances being compared and is always expressed as a number greater than 1. Associated with a particular F-value are two values for degrees of freedom; these values are the sizes of the two samples for which the two variances were computed. F-values ("F-VAL") are presented in Table 36 in the same respective positions described above for the t-values. Significance is also indicated in the same manner.

Each of the two lines on Table 36 entitled "More Intercell Statistics" contain test statistics for three trap-specific comparisons not shown directly between primary data columns. The trap chosen for these "leap-frog" comparisons was the upstream trap for a tangent site, the midpoint of the inside curve for a winding section, and the midpoint of the curve (by direction) for an isolated horizontal curve. Groups of these special test statistics are oriented on the table in an intuitive fashion; for instance, under the "Cell 22" column are the t-value, t-test degrees of freedom, and the F-value for comparing cell 21 to cell 23 at the upstream trap. The next two groups of numbers in the line apply to the cell 21:cell 24 and cell 22:cell 24 comparisons, respectively.

Program Application — As stated at the outset, the post-processor routine served two purposes. One was to present in a single machine-written table the key nighttime or daytime statistics for a typical four-level series of delineation evaluations. At a site where field studies were conducted for two durations of acclimation and/or wet as well as dry conditions, several such tables are required to present all of the data at least once. In these cases, data for the "base condition" treatment are usually repeated on two or more tables. As compactly as possible, Appendix F tabulates all of the detailed speed and lateral placement data collected in Phase II of the project.

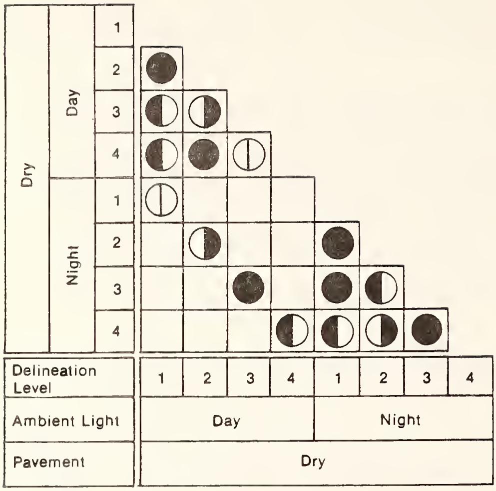
The other purpose of the post-processor was to provide an efficient means for making all reasonable between-trap and between-condition statistical tests. Using a systematic checklist technique, these many tests were accomplished by successively rearranging the input data and iterating the program's execution.

In order to condense the results of the numerous executions into a somewhat more digestible format, ragged matrices of the type illustrated in Figure 33 were manually prepared. These figures should be largely self-explanatory, with the exception that they do not indicate which value in a particular comparison is larger or smaller. Other than for the selected performance data discussed later in this chapter, the tables in Appendix F would have to be consulted to determine the actual values compared in these figures. The main objectives of the graphical summaries are to show overall TPM sensitivity (or insensitivity), inter-trap consistency, and general trends such as might be detected for day versus night operation.

FIELD STUDY FINDINGS

Site 1 Test Results

Treatments Evaluated — At this tangent site on the western end of the Maine Facility, two alternative spacings of post-mounted delineators (PMD's) were compared to the base condition of standard centerline and edgelines only. The base condition at the site was denoted as "level 1." Level 2 consisted of PMD's spaced at 528 feet (161 m) on pure tangent sections and at twice the recommended MUTCD intervals on the few relatively slight curves within the 2-1/2 miles (4 km) treated.(1) The monitored eastbound drivers always saw crystal delineators on their right, and on curves, they also saw amber delineators on their left. Level 3 simply involved the placement of an additional delineator at the midpoint of each gap present at level 2.



Mean Lateral Placement

LEGEND

Delineation System

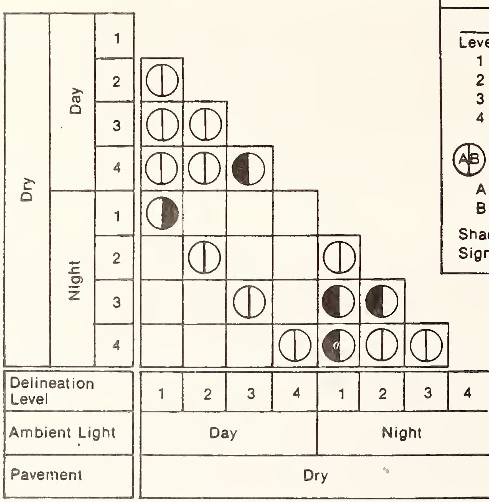
Level	Description
1	5:35 Centerline, STD.Edgelines
2	5:35 CTR w/RPM's,STD. Edgelines
3	10:30 CTR w/RPM's, STD. Edgelines
4	15:25 Centerline, STD. Edgelines

Statistical Indications

(A|B) TPM's at Two Traps Compared

A = Trap Upstream
B = Trap Downstream

Shaded Sections Indicate
Significance at 95% Level



Lateral Placement Variance

Figure 33. Sample compilation of statistically significant TPM differences.

Speed and lateral placement distributional statistics for the base condition upstream trap are shown in the top two lines of Table 37. Subsequent lines contain the experimental changes from the base-condition or "baseline" values, with changes significant at a 95 percent or greater confidence level indicated by an asterisk (*). Findings based on Table 37's selected statistics are interpreted in the next few paragraphs.

Speed Findings — Somewhat surprisingly, mean speeds for the base condition did not differ significantly between day and night or between dry and wet pavement. The average across the four environmental conditions was about 54 mph (86 km/h). Speed variance was significantly lower during the day than at night (as expected), but pavement condition was not an influence. Average daytime variance was approximately 36 mph^2 (94 km^2/h^2) and average nighttime variance was nearly 50 percent higher at 51 mph^2 (132 km^2/h^2).

Table 37 shows that while nighttime mean speed initially increased 2.4 mph (3.9 km/h) under the closer PMD spacing, none of the other three nighttime tests resulted in a statistically significant change from the base condition. This one significant speed increase is quite intuitive, but its true relationship to the presence of the PMD's is in doubt because of the four unexpected daytime speed increases. These latter increases, all statistically significant, averaged 1.5 mph (2.4 km/h) for the long delineator spacing and 2.3 mph (3.7 km/h) for the closer delineator spacing.

With the small increases in daytime mean speed came increases in speed variance, those for level 2 dry pavement averaging a significant 16 mph^2 (42 km^2/h^2) higher. More important to the overall experimentation at this site, however, are the consistent decreases in nighttime speed variance. For the longer available acclimation times, the 528-foot (161-m) PMD spacing resulted in a variance reduction of about 20 percent (10 mph^2 or 26 km^2/h^2), and the 264-foot (81-m) spacing resulted in a reduction of about 28 percent (14 mph^2 or 36 km^2/h^2). If the daytime increases are attributed to seasonal changes in the types of drivers sampled, then the observed nighttime decreases are, in fact, understated. Regardless, level 3's 100 percent augmentation of PMD's over level 2 can be seen to yield only a 40 percent further reduction in speed variance (i.e., 8/20).

Lateral Placement Findings — Table 37 indicates that mean lateral placement relative to the right edge of the traveled lane increased for the base condition as visibility conditions worsened. During the daytime, average placements on dry and wet pavements were statistically the same at about 3.3 feet (1.01 m). At night, however, mean placement on a dry pavement was 4.0 feet (1.22 m) and on a wet pavement, it was 4.3 feet (1.31 m). Both nighttime values indicate a statistically significant shift to the left, and they appear to reflect the driver's desire to physically move his eyes closer to the centerline under adverse visibility conditions.

Table 37. Baseline TPM statistics and experimental changes thereto.

Site Number	Level Number	Pavement	Daytime				Nighttime			
			ΔSpeed		ΔPlacement		ΔSpeed		ΔPlacement	
			Mean	Variance	Mean	Variance	Mean	Variance	Mean	Variance
1 Tangent	1	D	53.8	36.9	3.3	1.6	53.2	50.0	4.0	1.6
		W	54.4	35.4	3.2	1.3	53.3	51.8	4.3	1.2
	2S	D	+1.5*	+18.8*	0.0	-0.1	-0.4	-20.3*	-0.2	-0.1
	2L	D	+1.6*	+13.4*	+0.1	-0.1	+1.3	-10.2	+0.1	-0.5*
		W	+0.7	+1.1	+0.6*	+0.2	-2.0*	-3.1	+0.1	0.0
	3S	D	+2.7*	+1.9	+0.2	-0.2	+2.4*	-3.0	+0.4*	-0.3
	3L	D	+1.9*	+5.8	+0.3*	-0.3	+0.7	-13.8*	0.0	-0.4*
		W	-1.7*	+8.4	+0.8*	-0.3				
2 Tangent	1	D	51.3	45.9	3.8	1.6	51.7	50.4	4.3	1.9
	2S	D	-0.8	+10.5*	-0.2*	-0.3*	+0.7	-6.6	-1.1*	-0.7*
	2L	D	+0.1	+6.3	-0.5*	-0.3	-1.3	+11.6	-0.8*	-0.5*
		W	51.9	65.1	3.8	1.7	49.7	52.0	3.4	1.7
	3S	D	+1.0	-3.7	-0.7*	-0.3*	-1.0	+8.0	-0.9*	-0.7*
	3L	D	+0.4	+10.8*	-0.6*	-0.3*	-0.5	+15.0	-0.9*	-0.6*
		W	-1.3	-4.5	-0.7*	-0.2	-0.1	-1.0	+0.4*	-0.2
	4S	D	+1.1	+10.1*	-0.7*	-0.1	+0.3	-1.7	-0.9*	-0.5*
	4L	D	+1.0	+6.1	-0.6*	+0.7*	-1.3	+30.3*	-1.2*	+0.4
		W	-3.5*	-8.8	-1.6*	-0.3	+0.3	+0.1	0.0	+1.0*

Table 37. Baseline TPM statistics and experimental changes thereto. (Continued)

Site Number	Level Number	Pavement	Daytime				Nighttime			
			ΔSpeed		ΔPlacement		ΔSpeed		ΔPlacement	
			Mean	Variance	Mean	Variance	Mean	Variance	Mean	Variance
3 Tangent	1	D	+1.3	+0.2	+0.8*	−0.1	+2.2*	−16.1*	+0.4*	+0.3*
	2	D	+1.5	−14.4*	+0.3*	−0.2	+2.3*	−20.8*	0.0	+0.1
	3	D	+1.0	−3.3	+0.2	−0.3*	+1.6	−21.8*	−0.5*	−0.2
	4	D	53.0	59.0	2.2	1.1	51.2	61.8	2.6	0.9
4 A Tangent	1	D	+2.3*	−11.8	+1.6*	0.0	+1.5	+4.4	+1.5*	0.0
	2	D	+4.0*	−17.4*	+0.8*	−0.1	+1.8*	−16.1*	+0.4*	0.0
	3	D	+3.7*	−8.4	+0.4*	−0.2*	+1.1	−4.4	+0.5*	+0.2
	4	D	53.1	50.6	1.1	0.8	53.9	39.4	1.4	0.5
4B Tangent	1	D	+5.4*	−14.6*	+0.8*	−0.8*	+1.2	−2.9	+0.9*	+0.1
	2	D	+4.5*	+8.3	−0.7*	−0.8*	+1.9*	−1.0	+0.1	+0.2
	3	D	+3.7*	−14.6*	−0.2	−0.7*	+1.7*	+3.3	−0.2	+0.2
	4	D	51.5	49.0	2.4	1.5	55.6	38.5	2.6	0.7
5 Winding	1	D	−2.1*	+6.9*	+0.4*	−0.1	−3.5*	+11.6*	+0.5*	0.0
	2	D	−0.6	+1.6	+0.2*	0.0	−2.6*	−1.5	+0.2*	−0.1
	3	D	−1.1	+11.6*	+0.5*	+0.1	−2.4*	−3.0	+0.7*	−0.1
	4	D	46.8	19.2	1.1	0.5	47.3	22.4	1.0	0.5
6 Winding	1	D	−3.5*	+6.5	−0.2	−0.2	−4.7*	−22.0*	−0.6*	−0.4*
	2	D	−3.6*	+0.7	−0.6*	−0.2	−1.8*	−5.1	−1.4*	−0.4*
	3	D	46.1	26.3	2.3	1.0	44.8	35.7	3.0	1.3

Table 37. Baseline TPM statistics and experimental changes thereto. (continued)

Site Number	Level	Pavement	Daytime				Nighttime			
			ΔSpeed		ΔPlacement		ΔSpeed		ΔPlacement	
			Mean	Variance	Mean	Variance	Mean	Variance	Mean	Vairance
7 Inside Curve	1	D	40.7	25.2	1.2	0.3	41.5	24.8	1.3	0.5
	2	D	−0.2	−4.9	−0.2*	+0.1	−1.9*	+2.1	−0.3*	−0.1
	3	D	+0.2	−0.5	0.0	+0.1*	−2.5*	+2.3	−0.4*	−0.1
	4S	D	−0.2	+2.4	+0.4*	+0.2*	−1.8*	−2.8	+0.2	0.0
	4L		+0.2	−2.3	+0.1	+0.2*	−1.4*	+9.7*	−0.1	−0.1
7 Outside Curve	1	D	40.7	26.5	3.5	1.1	40.6	29.5	3.7	1.0
	2	D	+1.6*	−5.1	−0.5*	−0.5*	−0.9	−2.3	−1.1*	−0.4*
	3	D	+0.9	+7.4	−0.4*	−0.4*	−1.1	−10.4*	−1.0*	−0.5*
	4S	D	+0.2	−5.7	−0.3*	−0.3*	−0.2	−1.9	−0.1	−0.1
	4L		+0.9	−3.8	−0.1	−0.3*	−1.4*	−6.8	−0.2	−0.3*
8 Inside	1	D	52.8	29.2	1.3	0.6	52.9	28.3	1.9	1.1
	3S	D	+0.6	+6.9	+0.1	0.0	−0.4	+12.1*	−0.1	−0.2
	3L		+0.7	+10.5	−0.3*	−0.1	−0.2	+17.0*	−0.2	+0.1
8 Outside	1	D	51.3	28.0	2.0	1.4	52.3	31.1	3.0	1.6
		W	48.9	38.0	2.1	1.0				
	3S	D	+1.5*	+11.8*	−0.1	−0.5*	−1.6*	+11.3*	−0.8*	−0.4
	3L		+0.7	+17.4*	−0.2	−0.4*	−0.1	+13.9*	−1.2*	−0.5*

Notes: ☐ Dotted cells contain baseline TPM values for given combination of treatment level and pavement condition. Other cells show changes in each baseline value for same pavement condition, with statistically significant changes starred (*).

Speed in mph (1 mph = 1.61 km/h) and placement in feet (1 ft. = 0.305.) at upstream trap for tangent sites (1-4B), midpoint of inside curve for winding sites (5-6), and midpoint of curve, by direction, for curve sites (7-8).

As anticipated, the post delineators had negligible effect on baseline mean placement during both daytime and nighttime operating conditions. The variance of lateral placement was also essentially the same across all daytime tests, but decreased quite significantly at night with the PMD's in place. This latter reduction for the longer acclimation times was about 30 percent or 0.5 ft^2 (465 cm^2) for both delineator spacings.

In summary, the installation of post delineators at a 528-foot (161-m) spacing had the seemingly beneficial effects of reducing speed variance by 20 percent and placement variance by 30 percent. Changing to a 264-foot (81-m) spacing improved the speed variance reduction by an additional 8 percent, but it did not further improve the reduction in placement variance.

Site 2 Test Results

Treatments Evaluated — At this tangent site on the eastern end of the Maine Facility, high-intensity retroreflective raised pavement markers (RPM's) were evaluated as supplements to standard center and edge striping. Being tested first, the base condition striping was again denoted as "level 1." Level 2 consisted of amber RPM's placed in every second centerline gap at a nominal 80-foot (24.4-m) spacing. Level 3 supplemented the edgeline with a one-way crystal RPM opposite each centerline RPM. Lastly, level 4 involved the addition of appropriate amber and crystal markers so as to have a 40-foot (12.2-m) spacing on both sides of the monitored lane.

In the discussion to follow, reference is again made to Table 37. Selected TPM statistics for Site 2 are on the lower half of the table's first page.

Speed Findings — For the base-condition treatment, dry-pavement mean speeds were again essentially equal between daylight and darkness. Each value fell in the "range" of 51-52 mph (82-84 km/h). While a slightly lower speed variance was measured during the daytime as opposed to the nighttime, the difference is not statistically significant.

In 12 day and night dry-pavement comparisons, the RPM treatments were never found to change mean speed by a statistically significant amount. Comparing level 3 and level 4 wet-pavement mean speeds to those observed at level 2, only one out of four tests proved significant.

Table 37 shows that dry-pavement speed variance increased over the baseline condition in 75 percent of the tests made at each of the with-RPM treatment levels, but most of the increases are not statistically significant. A trend does seem to exist, however, for increasing variance with increasing intensity of marker application. For the longer available acclimation time, level 2 showed no significant changes, level 3 an inexplicably significant daytime increase of 24 percent or about 11 mph^2 (28 km^2/h^2), and level 4 an alarmingly large nighttime increase of 60 percent or about 30 mph^2 (79 km^2/h^2).

Lateral Placement Findings — The mean lateral placement under daytime, dry-pavement conditions was 3.8 feet (1.16 m). Interestingly, this value is greater than the respective Site 1 value by exactly the 0.5-foot (15-cm) difference in lane widths. This means that the average automobile driver operated the same distance from the centerline at both locations (about 2.2 feet or 67 cm). As expected, the day mean placement was smaller than the night mean placement. The 0.5-foot (15-cm) day/night difference is statistically significant and comparable to the 0.7-foot (21-cm) difference observed at Site 1.

The effects of the RPM supplement on both the mean and variance of lateral placement were in most cases quite dramatic. Table 37 shows that treatment levels 2S through 4S reduced dry-pavement mean placement by an average of 0.6 foot (18 cm) in the daytime and 1.0 foot (30 cm) at night. The size and consistency of these effects are quite remarkable for three reasons:

- Daytime placement was significantly influenced by a device commonly thought to serve only at night.
- The magnitude of the shift appears to be essentially independent of marker pattern.
- The resulting mean placements of about 3.2 feet (98 cm) in the daytime and 3.3 feet (1.01 m) at night indicate that the average automobile was driven significantly closer to the idealized central lane position.

For level 2 and level 3 RPM treatments, dry-pavement placement variance was reduced by about 20 percent or 0.3 ft^2 (279 cm^2) during daylight hours and 30 percent or 0.6 ft^2 (557 cm^2) during hours of darkness. Apparently, the visual field became "oversaturated" by the level 4 treatment, however, since the variance trend reversed and showed slight to moderate increases over the baseline day/night values. The data-collection-period to data-collection-period change in both the means and variances of lateral placement are illustrated in Figures 34 and 35.

During daylight hours, the wet-pavement lateral placement distribution under level 2 was statistically the same as the dry-pavement distribution under level 1 (see Table 37). The daytime mean placement at these first two levels decreased substantially (20-40 percent) under later treatment levels, though, and improved the centrality of the average vehicle within the delineated lane. Placement variance for the wet-daytime condition fell by small, statistically insignificant amounts in moving from level 2 to level 4.

Lastly, traffic performance was also evaluated at this site on a wet pavement during hours of darkness. This is certainly a critical delineation situation, and one where the visibility of common paint striping is substantially degraded and the visibility of RPM's substantially

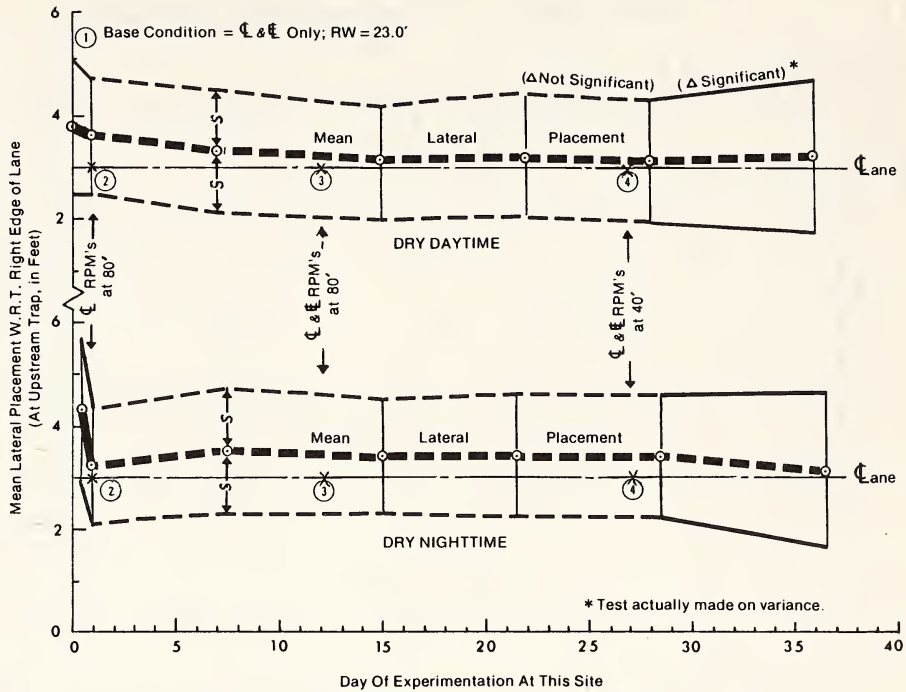


Figure 34. Site 2 lateral placement under dry pavement conditions (upstream trap).

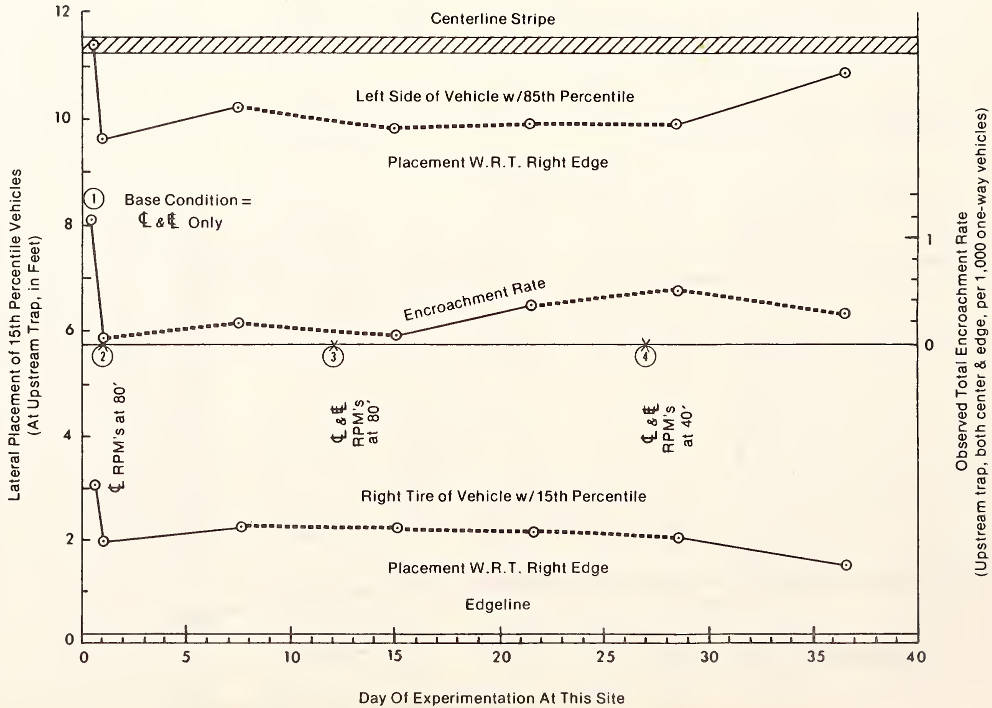


Figure 35. Site 2 encroachment potential under dry nighttime conditions (upstream trap).

enhanced. Table 37 shows that for all three marker treatments, wet-night mean placement fell in the range of 3.4-3.8 feet (1.04-1.16 m). While not quite as good as the dry-nighttime performance of RPM's, this range is significantly more centralized than that prevailing on a dry night for the paint striping alone. At levels 2 and 3, the values for lateral placement variance were statistically no different between wet-night and wet-day conditions, and quite closely resembled the 1.6 ft^2 (0.15 m^2) observed under the dry daytime base condition. The very heavy application of RPM's at level 4 was found to significantly increase placement variance, however, even in this very adverse operating environment. Recall that a similar trend reversal occurred for the level 4 treatment under dry pavement conditions.

In summary, the use of RPM's as a supplement to paint striping was found to have either insignificant or beneficial effects on speed and placement in most cases evaluated. Mean speed was not influenced, and for treatment levels 2 and 3, the effects on speed variance were minimal. Mean placements changed significantly from the baseline values for all of the marker patterns, resulting in more centralized lane placement for the average vehicle. For levels 2 and 3, the RPM supplements also appeared to typically decrease placement variance by 20-30 percent. Level 4, with RPM's at 40-foot (12.2-m) intervals on both sides of the lane, showed evidence of being an "over-delineated" case. Significant increases in both speed and lateral placement variances were observed at this level.

Site 3 Test Results

Treatments Evaluated — The experiments at this site also involved RPM supplements to the centerline, but unlike Site 2, the centerline striping patterns supplemented were also novel. Because of this latter fact, the sequence of treatments had to begin with a bare pavement and move toward a base-condition striping-only system as treatment level 4. All levels had standard 4-inch (10-cm) painted edgelines. The level 1 centerline module was a 5-foot (1.5-m) stripe followed by a 35-foot (10.7-m) gap. Level 2 included a medium-intensity retroreflective RPM at the midpoint of every other gap, for a nominal marker spacing of 80 feet (24.4 m). For level 3, the RPM's were left in place and the centerline stripes were lengthened to 10 feet (3.05 m). Finally, for the level 4 base condition, the markers were removed and the centerline strips extended to provide the standard 15:25 stripe-to-gap ratio.

In the discussion below, reference is made to Table 37. Selected TPM statistics for Site 3 are shown in the top four lines of the table's second page.

Speed Findings — The sample mean speed for the baseline night condition was slightly lower than for the day condition, but the difference is not statistically significant. The average of the two means is about 52 mph (84 km/h). Baseline speed variances were also equivalent, averaging slightly over 60 mph^2 (155 km^2/h^2).

The level 1-3 novel treatments caused small increases in mean speed. The increases in the daytime, ranging from 1.0 to 1.5 mph (1.6 to 2.4 km/h), are not statistically significant; however, the 5:35 centerline treatments at levels 1 and 2 caused a significant nighttime speed increase of about 2.2 mph (3.5 km/h). In light of the Site 2 finding that RPM supplements do not affect mean speed, this change would have to be attributed to the reduced stripe-to-gap ratio. As such, it compares well to the 2.5 mph (4.0 km/h) increase in the "unlimited sight distance," with-edgeline test documented in Appendix O of NCHRP Report 130. (14)

Table 37 shows that wherever an experimental change in speed variance was statistically significant, it was a reduction over the baseline case. Treatment levels 2 and 3, with the centerline RPM supplement, resulted in variance reductions of about 21 mph^2 (54 km^2/h^2). Expressed as a percentage, this 35 percent reduction is similar to the 30 percent change reported for the same RPM spacing at Site 2. Since a sizeable decrease in speed variance was also observed at level 1, however, at least a portion of the overall reduction would appear to be related to the reduced stripe-to-gap ratio.

Lateral Placement Findings — For the base condition, daytime mean placement was 2.2 feet (67 cm) and the nighttime mean placement was significantly greater at 2.6 feet (79 cm). The variances were statistically no different between day and night, averaging 1.0 ft^2 (929 cm^2).

Comparing level 3 mean placements to those at level 4 for the standard paint striping, the daytime difference is insignificant and the nighttime difference shows a significant 0.5-foot (15-cm) reduction with the novel centerline system. The reduction results in a mean placement comparable to that observed in the daytime. At treatment levels 1 and 2, however, the lateral placement means increased significantly over the baseline values in three of the four comparisons. The 0.3-0.8 foot (9-24 cm) increases indicate that the average automobile under the novel treatments was better centered within the 11.6-foot (3.54-m) delineated lane.

The variance of lateral placement was slightly lower at level 3 than it was at level 4, but only the 25 percent daytime reduction of 0.3 ft^2 (279 cm^2) was statistically significant. The only other experimental change of significance was the nighttime increase of 0.3 ft^2 (279 cm^2) observed for level 1 (i.e., with a reduced stripe-to-gap ratio but no RPM supplement).

In summary, it was found that the novel centerlines, characterized by reduced stripe-to-gap ratios and RPM supplements, resulted in small increases in mean speed but substantial reductions in speed variance. At night, average speeds rose about 2 mph (3 km/h) and the variance of speed fell by as much as 35 percent or 21 mph^2 (54 km^2/h^2).

All experimental treatments had either insignificant or beneficial effects on mean placement. Lateral placement variance followed a similar trend for levels 2 and 3 with RPM's in place, but it increased by one-third for the level 1 (without-RPM) nighttime condition.

Site 4A Test Results

Treatments Evaluated — All treatments evaluated at this tangent site consisted of paint striping only. Within this category, though, both reduced stripe-to-gap centerline and narrow-width striping were tested. The level 1 delineation system was nothing more than a 2-inch (5-cm) wide, 10-foot (3-m) long centerline stripe placed at the normal 40-foot (12-m) cycle. There were no edgelines and the dark grass-and-gravel shoulder provided little contrast with the asphaltic pavement. For the second treatment level, 2-inch (5-cm) edgelines were added with no evidence of the waviness often attributed to substandard stripe widths. Level 3 simply involved widening the edgelines and the 10:30 centerline to 4 inches (10 cm). Again, the paint application was so carefully controlled that the wider stripes completely overlaid the narrower stripes and the centerline pattern held within 0.1-0.2 foot (3-6 cm) of the earlier dimensions. Lastly, the centerline stripes were lengthened by 5 feet (1.5 m) to bring the level 4 treatment up to the standard 15:25 base condition.

In the discussion to follow, reference is again made to Table 37. Selected TPM statistics for Site 4A can be found near the middle of the table's second page.

Speed Findings — As with all previously discussed study sites, day and night mean speeds were statistically equivalent. Both values fell in the "range" of 53-54 mph (85-87 km/h). While the daytime speed variance was 28 percent higher than the nighttime speed variance, the difference is not statistically significant.

Mean speeds increased somewhat with reduced quantities of paint on the pavement, a finding in agreement with the results at Site 3. The daytime increases were significant at all treatment levels and averaged 3.3 mph (5.3 km/h). Nighttime increases were only about half the respective daytime values, and only the level 2 change was significant.

The variance of speed decreased somewhat in five of the six day/night comparisons to the baseline condition. Level 3's reductions were not statistically significant, but those at level 2 were. This 2-inch (3-cm), 2-line delineation system was accompanied by an average day/night reduction in speed variance of about 17 mph^2 (44 km^2/h^2). As percentages, this amount was a 35 percent improvement during daylight hours and a 40 percent improvement in hours of darkness. The variance changes for level 1 were of mixed sign and statistically insignificant.

Lateral Placement Findings — Unusually small baseline mean placements were measured at this site: 1.1 foot (34 cm) by day and 1.4 foot (43 cm) at night. Also unexpected was the fact that the 0.8 ft^2 (743 cm^2) variance associated with the smaller mean placement was significantly larger than the 0.5 ft^2 (465 cm^2) variance associated with the larger mean placement. The most probable explanation of these phenomena is that the percentages of trucks sampled at the level 4 base condition were very high (38 percent by day and 23 percent by night).

Unlike level 4, truck percentages at levels 1-3 ranged from 4-13 percent during the day to 3-7 percent during the nighttime.

In computing centrality within the lane, it is assumed that the relevant vehicle width is from the right front tire to the left side of the body (i.e., the average of the track and body widths). It is further assumed that this width is 5.5 feet (1.68 m) for the typical automobile and 6.75 feet (2.06 m) for the typical large truck. Based on these assumptions, the difference in average vehicle width between samples with about 30 percent trucks (such as at level 1) and samples with about 8 percent trucks (such as at levels 2-4) would be about 0.3 foot (9 cm). Hence, mean placement increases shown in Table 37 with respect to the edgeline overstate the change in placement with respect to the centerline by this same 0.3 foot (9 cm). At night for levels 2 and 3, for instance, the tabulated 0.4-0.5 foot (12-15 cm) increase from baseline placement, when reduced by the change in average vehicle width, would show that the driver's offset from the centerline is statistically unchanged. Because of such complexities, it is best to compute the previously defined "centrality index" for each vehicle and then analyze the overall average index. Analysis in the next chapter is based on such an approach.

The placement differences shown in Table 37 for treatment level 1 should also be interpreted in recognition of the fact that the reference point changed between levels 1 and 4 with the addition of the edgeline. (Recall that lateral placement was measured with respect to the center of the edgeline if one exists, or from the pavement edge otherwise). Hence, after subtracting the 0.8 foot (24 cm) that the edgeline was placed from the pavement edge at the upstream trap, the actual leftward shift of the average right tire becomes 0.7-0.8 foot (21-24 cm). This shift, part of which was undoubtedly due to a narrower average vehicle width, represents only a 0.3-foot (9-cm) change from level 2 during hours of darkness. In the daytime, no change in actual placement can be attributed to the addition of the narrow edgelines.

Placement variance was not significantly different among most of the conditions evaluated at this site. The only statistically significant change was a 25 percent or 0.2 ft^2 (186 cm^2) reduction for the level 3 daytime condition.

In summary, small increases in mean speed and decreases in speed variance were observed for the novel paint treatments. However, portions of these changes were probably due to lower truck percentages in comparison to the base condition. The substantial change in the composition of the traffic also complicated the analysis of lateral placement trends. Mean placement tended to shift leftward with the lesser paint applications, especially where there were no edgelines. Most of the apparent shift can be attributed to seasonal changes in average vehicle width, though, and a full analysis requires the carefully derived centrality index discussed in Chapter XII. Somewhat surprisingly, the variance of lateral placement was unaffected by the novel paint treatments, even the very minimal system without edgelines.

Site 4B Test Results

Treatments Evaluated — At this last tangent study site, the characteristics of both the roadway and the experimental treatments were quite similar to those already described for Site 4A. Level 1 also lacked edgelines and had a 10:30 centerline pattern; the only difference with the previous site was that here the striping was a standard 4 inches (10 cm) wide. For level 2, however, the same 2-inch (5-cm) edgelines were added at both sites. Levels 3 and 4 were identical and provided a replication of the important with-edgeline test of the 10:30 versus 15:25 centerline configuration.

Speed Findings — This was the only tangent roadway to show a statistically significant difference in baseline mean speeds between day and night operating conditions. Daytime speeds averaged 51.5 mph (82.9 km/h) and many nighttime speeds exceeded the speed limit by averaging 55.6 mph (89.5 km/h). Speed variance under the two conditions were virtually the same as at Site 4A. The daytime variance of 49 mph^2 (127 km^2/h^2) was 27 percent larger than the nighttime variance, but the difference is statistically insignificant.

Higher mean speeds were once again observed at the less paint-intensive novel treatment levels. The level 2 and level 3 increases over baseline speeds were also very similar to those measured at Site 4A, averaging about 4 mph (6 km/h) in the daytime and 2 mph (3 km/h) at night. While level 1 resulted in a significant daytime speed increase as well (over 5 mph or 8 km/h), the small nighttime increase is not statistically significant.

Only two out of the six comparisons of speed variance show a significant change from the base condition. The two changes, occurring during daylight hours for treatment levels 1 and 3, were equal at nearly 15 mph^2 (39 km^2/h^2) and represent a 30 percent reduction.

Lateral Placement Findings — Base-condition mean lateral placement, 2.4 feet (73 cm) by day and 2.6 feet (79 cm) at night, was about twice as large as measured at Site 4A. This was the case despite the similar high percentage of trucks monitored. The doubling of the daytime mean placement between sites was accompanied by a doubling of the placement variance; however, nighttime variance at Site 4B was only 40 percent higher than at Site 4A.

Mean lateral placement with respect to the edgeline did not change significantly between level 3 (the 10:30 centerline) and level 4 (the 15:25 centerline). Treatment level 2, with both reduced stripe-to-gap ratio and narrower striping, showed a difference only in the daytime (an inexplicable 0.7-foot or 21-cm decrease). In reviewing the level 1 placement change shown in Table 37, it should be noted that the edgeline at this site was applied about 0.4 foot (12 cm) from the pavement edge. Hence, after subtracting the amount the reference point moved between levels 1 and 4, it can be seen that the right tire of the average level 1 vehicle was about 0.5 foot (15 cm) to the left of where it was with the standard two-line system in place. This leftward movement is similar to the 0.7-foot (21-cm) shift noted for the 2-inch (5-cm), 10:30 centerline at Site 4A's level 1.

At this site's upstream trap, the nighttime variance of lateral placement was statistically constant across all novel paint treatments. Substantial 50 percent reductions in placement variance, on the order of 0.7-0.8 ft^2 (650-743 cm^2) occurred during the daytime at each level between 1 and 3.

In summary, it was found that mean speeds increased slightly with the less paint-intensive treatments, and speed variance either was unaffected or favorably reduced. Mean lateral placement was also rather insensitive across the three edgelined cases; in the absence of the edgeline, however, the average vehicle shifted leftward on the pavement about 0.5 foot (15 cm). Lastly, placement variances were unchanged across all nighttime conditions and substantially reduced across all daytime conditions.

Site 5 Test Results

Treatments Evaluated — The project's most novel treatments were evaluated on this 20-foot (6.1-m) winding roadway. Although not originally intended as a "treatment" to be evaluated, a strong contrast between the new asphalt overlay and the white stone shoulders was present throughout the experiments and cannot be ignored in the analysis. The level 1 delineation system included this shoulder contrast plus a centerline composed entirely of raised pavement markers. Solid centerline stripes were simulated with non-reflective yellow buttons placed at a nominal 5-foot (1.5-m) spacing. Medium-intensity retroreflective RPM's were installed in lieu of certain of the buttons to provide better nighttime centerline visibility. Specifically, one- and two-way reflective markers were placed so that where a viewing driver was prohibited from passing (as he was throughout the monitored S-curve), he would see a double line of reflectors at 40-foot (12-m) intervals; at all other locations for the given direction of travel, he would see only a single reflector at 80-foot (24-m) intervals.

For the level 2 system, the RPM centerline was retained and standard 4-inch (10-cm) white edgelines were added. Level 3 brought supplemental RPM's to these edgelines; the markers were medium-intensity, one-way devices to serve only the nearside traffic. (Between the contrasting shoulder, the new glass-beaded edgeline, and the supplemental RPM's on the right side—and the heavy application of RPM's only 9.4 feet (2.9 m) to the left—the driver was quite literally between the "rock and the hard place.") Lastly, all raised pavement markers were removed and a standard painted centerline was applied to bring level 4 to the base condition.

As noted at the end of Table 37, the winding-section analysis at this stage is limited to the trap at the midpoint of the inside curve. For the specific S-curve monitored at Site 5, the inside curve was 8 degrees in severity and 860 feet (262 m) long. Speed and lateral placement statistics for the trap on this curve are shown near the bottom of Table 37's second page.

Speed Findings — As with four of the five previously discussed study sites, there is no statistical significance to the difference between day and night baseline mean speeds. Their average at this location was 47 mph (76 km/h). The respective speed variances were both statistically no different and unusually low, falling between 19 and 22 mph^2 (49 and 57 km^2/h^2).

For the level 2 and level 3 treatments, daytime mean speeds were statistically unchanged from the base condition; at level 1, however, there was about a 2-mph (3-km/h) reduction in daytime speed. During hours of darkness, mean speeds fell approximately 2-1/2 mph (4 km/h) for the two edgelined cases and 3-1/2 mph (5-1/2 km/h) for the center-RPM's-only case.

Speed variance changed significantly from the day/night baseline values in three of six comparisons. All three changes were increases and ranged from 7-12 mph^2 (18-31 km^2/h^2), representing adverse changes of 35-50 percent for level 1 and an unexplicably large 60 percent for level 3 in the daytime.

Lateral Placement Findings — Baseline mean lateral placement at the midpoint of the inside curve was 1.1 foot (34 cm) by day and 1.0 foot (30 cm) at night. Since the percentages of trucks sampled were 8 percent and 22 percent, respectively, the unusual occurrence of a smaller nighttime placement may be due primarily to the fact that the average nighttime vehicle was 0.2 foot (6 cm) wider than the average daytime vehicle. The day and night variances of lateral placement were both equal to 0.5 ft^2 (465 cm^2).

The level 3 RPM edgeline supplement appeared to cause rather large leftward increases in baseline mean lateral placement (i.e., 0.7 foot or 21 cm at night and 0.5 foot or 15 cm during the day). However, level 2 day and night increases of 0.2 foot (6 cm) suggest that about a third of the leftward shift was due to the novel RPM centerline and about two-thirds were due to the supplemental markers on the edgeline. Since the nighttime truck percentage fell significantly between the base condition and the other treatment levels, the noted shifts slightly overstate the amounts that the driver actually relocated his vehicle. Final judgment should await the presentation of centrality indices in the next chapter.

The apparent 0.4-0.5 foot (13-15 cm) increases in mean placement shown in Table 37 for level 1 are entirely due to the leftward movement in the reference point between levels 1 and 4 (e.g., from the pavement edge to the new edgeline). In fact, if the 0.6-foot (18-cm) edgeline offset is subtracted from the apparent day/night increases and the results are then compared to the with-edgeline increases noted for level 2, it can be seen that the average driver is 0.3 ft (9 cm) closer to the centerline with the edgeline in place. As with Sites 4A and 4B, however, it is not strictly the average vehicle's placement on the pavement that should be assessed for safety implications. Rather, the more comprehensive and indicative measure is the one defining the vehicle's centrality within the delineated lane perceived by the driver. Certainly this type of measure better reflects motorist responsiveness to the total delineation system.

Somewhat surprisingly, the variance of lateral placement at the midpoint of the inside curve was statistically unchanged across all of these very novel and very strong experimental treatments. The degree to which the variance changes along the roadway section, previously shown related to accident potential, remains to be evaluated, however.

In summary, nighttime mean speeds were found to be reduced by 2-1/2 - 3-1/2 mph (4 - 5-1/2 km/h) as a result of the novel RPM applications. In the absence of edgelines, speed variance was 35-50 percent higher, and the average driver operated 0.3 foot (9 cm) further from the centerline. After accounting for interlevel differences in average vehicle width, it appears that in the presence of the edgelines, the type of centerline had no meaningful effect on lateral placement. When the nearside edgeline was supplemented with reflective RPM's at 40-foot (12-m) intervals, vehicles moved an average of 0.4 foot (12 cm) closer to the edgeline. Lastly, lateral placement variance at the single trap was not significantly affected by any of the novel treatments.

Site 6 Test Results

Treatments Evaluated — Several one- and two-line striping systems were evaluated on this 24-foot (7.3-m) winding roadway. Level 1 of the three-level experimentation involved a simple single-stripe centerline without edgelines. Wherever passing was prohibited in either or both directions, a 4-inch (10-cm) solid yellow stripe was applied; at those infrequent locations in the overall study mileage where passing was allowed in both directions, a broken line was naturally used. There was rather minimal color contrast between the new asphalt overlay on the travel lanes and the dark gravel shoulders. Level 2 included the same centerline with standard white edgelines offset an average of 0.9 foot (27 cm) from the pavement edge. Finally, for the level 3 base condition, the centerline was restored to a standard two-line combination (e.g., a double solid yellow unit throughout the S-curve monitored).

This last paint application came after the level 2 system had been largely eradicated by several months of wear in a particularly severe Pennsylvania winter. As a consequence, the entire delineation system had to be repainted in the process of converting to level 3. In so doing, the new traveled lane width became 11.6 feet (3.54 m), which was 0.4 foot (12 cm) wider than the level 2 lane but still 0.5 foot (15 cm) narrower than the level 1 lane.

As noted at the end of Table 37, the winding-section analysis at this stage is limited to the trap at the midpoint of the inside curve. For the specific S-curve monitored at Site 6, the inside curve was 13 degrees in severity and 810 feet (247 m) long. Speed and lateral placement statistics for the trap on this curve are shown at the bottom of Table 37's second page.

Speed Findings — Base condition mean speed was about 46 mph (74 km/h) during daylight hours and 45 mph (72 km/h) at night. The respective baseline speed variances were approximately 26 mph^2 (68 km^2/h^2) and 36 mph^2 (93 km^2/h^2), indicating a significant 35 percent nighttime increase.

Contrary to the findings at the previously discussed tangent sites, the less paint-intensive treatments evaluated at this location resulted in decreases rather than increases in mean speed. The reductions, ranging 2-5 mph (3-8 km/h), occurred under all four experimental conditions.

Only one comparison of speed variances showed a statistically significant change, but the change was very large. At night for the level 1 centerline-only case, the variance of the sampled speed distribution dropped by 22 mph^2 (57 km^2/h^2), an amazing 62 percent.

Lateral Placement Findings — Baseline mean lateral placement was 2.3 feet (70 cm) in the daytime and a typical 0.7 foot (21 cm) larger at night. The two variances were 1.0 ft^2 (929 cm^2) and 1.3 ft^2 (1,208 cm^2), respectively.

Table 37 shows fairly large experimental reductions in mean placement in three of four comparisons. Especially interesting are the large changes due solely to the doubling of the centerline. At level 2 where the white edgeline appeared "stronger" than the single yellow center stripe, the average driver operated 0.6-1.4 feet (18-43 cm) closer to the edgeline than he did at level 3. If one accounts for the 0.4-foot (12-cm) decrease in lane width cited above, the rightward movement away from the centerline was a very substantial 1.0-1.8 feet (30-55 cm).

The secondary comparison of mean lateral placements should be between levels 1 and 2: the single-stripe centerline with and without edgelines.

Taking the differences between the appropriate pairs of means in Table 37, there seems to have been an increase in placement at level 1 of 0.4 foot (12 cm) by day and 0.8 foot (24 cm) at night. However, if the 0.9-foot (27-cm) difference in lane widths is considered, it appears that the daytime driver did, in fact, operate 0.5 foot (15 cm) further right on the pavement to maintain about the same degree of centrality within the wider traveled lane. At night, the lack of an edgeline caused the driver to operate 0.4 foot (12 cm) closer to the centerline than he did during the daytime.

Both novel treatment levels were accompanied by the same day/night reductions in lateral placement variance. The daytime changes were statistically insignificant, but at night, relatively large reductions of 30 percent from the baseline values were measured. These changes, especially for the case without edgelines, were very much unexpected and should be regarded with caution.

In summary, the novel treatments appeared to cause 2-5 mph (3-8 km/h) reductions in mean speeds. The variance of speed was not affected during the day, but it showed a sharp decline at night for the no-edgeline system. Results for mean placement revealed that the average driver, by moving rightward in the lane, was more dependent on the edgeline for guidance when the centerline consisted of one instead of the usual two stripes. Lastly, significant nighttime reductions of 30 percent in placement variance were observed for both novel treatments, but the reason is unclear.

Site 7 Test Results

Treatments Evaluated — The delineation systems tested at this isolated horizontal curve involved post-mounted delineators and RPM centerline supplements, used separately and in combination. Level 1, the base condition, consisted of standard centerline and edgelines only. Two-way, medium-intensity retroreflective RPM's were added to the centerline for level 2. The markers were installed at a 40-foot (12.2-m) spacing throughout the 7-degree, 500-foot (152-m) curve and out to about 400 feet (122 m) on both approaches.

At level 3, post-mounted delineators (PMD's) were added to the outside of the curve at the recommended MUTCD spacing over the same distance covered by the RPM's.(1) Specifically, this entailed delineators at 80-foot (24.4-m) intervals on the curve itself, plus two additional installations before the point of curvature and beyond the point of tangency. The delineator posts were offset from the narrow shoulder the specified minimum distance, placing them 5-6 feet (1.5-1.8 m) from the pavement edge. On each post, a single 3-inch (7.6-cm) diameter corner-cube retroreflector was mounted for each direction of travel. Drivers on the outside of the curve viewed crystal reflectors on their near-right, and drivers on the inside of the curve saw amber reflectors on their far-left. Finally, for level 4, the RPM's were removed from the centerline and the post delineators were retained.

Selected speed and lateral placement statistics are presented on the third page of Table 37 by side of curve traveled (i.e., inside versus outside). Since essentially the same delineation system is being evaluated at each level, however, the discussion to follow intermingles the results for the two directions of travel.

Speed Findings — Baseline mean speeds at the midpoint of curve were statistically equivalent across all four combinations of ambient light and travel direction. The grand mean speed was 40.9 mph (65.8 km/h). The four baseline values for speed variance were also nearly the same and averaged 26 mph^2 (67 km^2/h^2).

As anticipated, daytime mean speeds were generally not affected by the addition of either type of reflective device. The one exception was a very small, but statistically significant, increase of 1.6 mph (2.6 km/h) for the outside curve at level 2 (i.e., centerline RPM supplement only). At night, mean speeds on the outside curve showed slight but statistically insignificant reductions from the baseline value; however, traffic moving on the curve to the right slowed down significantly for all experimental treatments. The speed reductions caused by the RPM and PMD treatments individually were very similar and averaged 1.7 mph (2.7 km/h). When the treatments were combined at level 3, the speed on the inside curve was reduced 2.5 mph (4.0 km/h).

The variance of speed during the daytime was statistically unchanged across all experimental conditions. At night, only two of the eight comparisons to baseline variance were significant. For the longer available acclimation time with post delineators only, speed variance at the midpoint of the inside curve rose by nearly 40 percent to 34.5 mph^2 (89.4 km^2/h^2). (This came after a small initial reduction in variance.) The other statistically significant change occurred for the combined level 3 system on the inside curve. Here, the change was a favorable 35 percent reduction in speed variance to only 19.1 mph^2 (49.5 km^2/h^2).

Lateral Placement Findings — At the midpoint of the 7-degree inside curve, the baseline mean placements of 1.2-1.3 feet (37-40 cm) were very similar to those measured on the 8-degree inside curve at Site 5. Drivers also tended to "straighten the roadway" by operating off-center in the lane on the outside curve. Daytime mean placement of 3.5 feet (1.07 m) and nighttime mean placement of 3.7 feet (1.13 m) suggest that a fair number of drivers actually encroached on the centerline. A more detailed analysis of the lateral placement distribution showed that 15 percent of the motorists allowed the left side of their vehicle to encroach on the opposing lane by more than 1 foot (30 cm). The degree to which the experimental reflective devices decreased this hazardous base condition should be a sensitive measure of their relative effectiveness.

Table 37 shows that treatment levels 2 and 3 reduced outside-curve mean placement by about 0.5 foot (15 cm) during the day and 1.0 foot (30 cm) at night, whereas the level 4 treatment had no statistically significant effects. This indicates that the centerline RPM supplement had a clearly beneficial influence and the PMD's did not. The RPM's also reduced the 85th percentile lateral placement by an average of 0.7 foot (21 cm) during the day and by a substantial 1.6 foot (49 cm) at night.

On the inside curve for the longer available acclimation time, the level 4 PMD's were again found to have no effect on mean placement. The RPM systems caused a slight decrease in daytime placement and a 0.3 - 0.4 foot (9 - 12 cm) reduction in nighttime placement. This latter change is adverse in view of the baseline value of only 1.3 feet (40 cm). By moving away from the centerline RPM's, however, the 15th percentile driver only reduced his day/night placement by 0.2 foot (6 cm), i.e., from 0.6 foot (18 cm) to 0.4 foot (12 cm).

The variance of lateral placement on the outside curve was significantly reduced, as might be expected, by all experimental treatments. Level 2 and level 3 treatments containing RPM's were slightly more effective, reducing placement variance over 40 percent during both daylight and darkness. The level 4 PMD's reduced baseline variance by about 30 percent under the two light conditions. During the daytime, placement variances on the inside curve appeared to increase slightly; at night there were no significant changes.

In summary, neither the mean nor the variance of speed were significantly affected by the reflective devices during the daytime. The only consistent nighttime effects were small reductions in mean speed; these reductions ranged 1.7-2.5 mph (2.7-4.0 km/h) on the inside curve but were statistically insignificant on the outside curve. The RPM centerline supplement substantially reduced centerline encroachments on the outside of the curve; however, they also caused drivers on the inside curve to move even closer to the edgeline. Lastly, the RPM systems reduced nighttime lateral placement variance over 40 percent, and the PMD's alone caused a reduction of slightly less than 30 percent.

Site 8 Test Results

Treatments Evaluated — Because of State maintenance activities at this isolated horizontal curve, the planned experiments had to be terminated prematurely. The only treatment compared to the base condition of centerline-only was a two-sided installation of post-mounted delineators. To be consistent with the sequence numbers presented in the Phase II experimental design, the base condition was denoted level 1 and the centerline/PMD system was denoted as level 3.

Level 3 included PMD's placed at 100-foot (30.5-m) intervals throughout the 5-degree, 400-foot (122-m) curve and out to 200 feet (61 m) on both approaches. Posts were offset from the pavement edge about the same 5-6 feet (1.5-1.8 m) used at Site 7. The corner-cube retroreflectors were also color-coded as before; that is, regardless of direction, drivers always saw crystal on their right and amber on their left.

This coding was felt to provide the approaching driver a more accurate perspective of the curve's alignment.

Selected speed and lateral placement statistics are presented at the very end of Table 37. While the statistics are listed by side of curve traveled, the discussion to follow intermingles the results for the inside curve and the outside curve.

<u>Speed Findings</u> — Baseline mean speeds did not differ significantly between day and night. The average for the midpoint of the inside curve was 52.9 mph (85.2 km/h) and the average for the midpoint of the outside curve was 51.8 mph (83.4 km/h). The slightness of the curve is further illustrated by the fact that the advance-point mean speeds never exceeded the midpoint-of-curve speeds by more than 2 mph (3.2 km/h); at the more severe Site 7 curve, the differential was 3-5 mph (4.8-8.1 km/h).

The baseline variances of speed were statistically equivalent across all four combinations of travel direction and ambient light. Their overall average was a rather low 29 mph^2 (75 km^2/h^2).

For the longer available acclimation time at this site, mean speeds were statistically unaffected by the presence of the delineators. The effects on the variance of speed, however, appear to have been both significant and adverse. Variance was observed to increase by 10-17 mph^2 (26-44 km^2/h^2), representing changes as large as 60 percent. Most peculiar is the fact that the largest increase was recorded for the outside curve during the daytime.

A review of the complete data set in Appendix F shows that daytime speed variance was much larger for level 3 even at the advance-point trap, 300 feet (91 m) before the first PMD. It would seem, therefore, that other factors may have caused most or all of the noted increase. All observations were made at midweek while the nearby university was in session, so weekend versus weekday variations in driving population were not a factor. A more suspect change, however, was the general appearance of the driving environment between the mid-September baseline data collection and the mid-October level 3 data collection. Because of the nearness of trees and cultivated fields to the traveling surface, this site more than any other was susceptible to variations in such subtle but potentially influential environmental variables.

<u>Lateral Placement Findings</u> — As indicated on Table 37, there were sizable differences between day and night baseline placement means. During the day, lateral placement on the inside curve averaged 1.3 feet (40 cm), and on the outside curve it averaged 2.0 feet (61 cm). These values increased at night to 1.9 feet (58 cm) and 3.0 feet (91 cm), respectively. The placement on the outside curve is again a matter of some concern, since the lane is only 8.9 feet (2.71 m) wide. Adding to the mean placement a typical automobile width, it appears that the average vehicle was very close to a centerline encroachment. Clearly,

then, a substantial fraction of the passing vehicles operated well into the opposing lane.

The day/night ranges in baseline lateral placement variance were 0.6-1.1 ft^2 (557-1,022 cm^2) on the inside of the curve and 1.4-1.6 ft^2 (0.13-0.15 m^2) on the outside of the curve. These latter values—together with the large placement means already noted—suggest that at least under adverse visibility conditions, a significant potential exists for sideswipe and head-on collisions. The site is isolated by more than a mile of tangent on both approaches, and the resulting driver tendency to "straighten out" this one unexpected and unwanted curve is quite apparent.

Mean placement on the inside of the curve was not significantly affected at night despite the presence of nearside delineators fairly close to the road. During the day at the longer available acclimation time, however, the average motorist drove a significant 0.3 foot (9 cm) closer to the pavement edge than he did without the lightweight steel posts in place.

Quite different results were obtained for vehicles traveling the outside of the curve. While the daytime placement effects of the PMD's were insignificant, those at night were both substantial and beneficial. Table 37 shows that the average driver operated more than a foot (30 cm) further to the right, at a nearly ideal central lane placement.

The variance of lateral placement was experimentally unchanged on the inside curve, but substantially reduced on the outside curve. Reductions during both day and night visibility conditions were about 30 percent of the baseline values; for instance, the initially very large nighttime variance of 1.6 ft^2 (0.15 m^2) was reduced by the PMD's to a more moderate value of 1.1 ft^2 (0.10 m^2).

In summary, the post delineators at this test location had no statistically significant effects on mean speed at the midpoint of the curve. The large increases in speed variance, especially during the daytime, are not intuitive and may reflect unknown variables at work. Post-mounted delineation did not generally influence either the mean or the variance of lateral placement on the inside of the curve; on the outside of the curve, however, very substantial and very beneficial reductions of about 30 percent were noted for both placement statistics.

CHAPTER XII
SAFETY EFFECTIVENESS OF EVALUATED DELINEATION SYSTEMS

This last chapter further assesses the safety implications of the Phase II field data, and on the basis of four unweighted evaluation parameters, recommends the deployment or further investigation of 21 unique delineation systems. Each system's experimental performance is compared to that of a conventional centerline and edgeline system. The evaluation parameters compared include initial installation cost, nighttime speed variance, nighttime lateral placement variance, and predicted delineation-related accident potential (computed with the previously discussed two-variable regression model).

EVALUATION OF ACCIDENT POTENTIAL AND OTHER DERIVED PERFORMANCE MEASURES

While the basic distributional means and variances discussed in Chapter XI provide a certain amount of worthwhile information, a statistically reliable estimation of safety effectiveness requires measures more descriptive of the overall vehicle trajectory. Just two such measures are now considered adequate for the assessment of delineation effectiveness. One describes the degree to which the average driver operates off-center in the delineated lane; this centrality index, or "CI," takes into account lane width and vehicle types sampled as well as mean lateral placement. The other measure shown indicative of delineation-related driving hazard is the term called "DPV." DPV is the difference between the lateral placement variances sampled independently at two critical points on a roadway's horizontal alignment, normalized (or divided) by lane width.

Site-Specific Tables of Derived Safety Effectiveness

The following tables and brief paragraphs present the computed values for the CI and DPV safety indicators. For each of the two isolated horizontal curves (Sites 7 and 8), average deceleration entering the curve is also shown.

On the far right of the tables for the tangent and winding sections (Sites 1-6), predicted delineation-related hazard is displayed for the dry nighttime condition. Each rate was derived using the two-variable accident-probability model developed in Chapter VII and evaluated in Chapter X. Wherever either or both of the TPM variables are significantly different in a comparison of experimental treatment to base treatment, a ratio of the respective hazard rates was also computed. Significance in the comparison of derived variables was determined as follows:

- For CI, mean lateral placement with respect to the right edge of the traveled lane had to show a statistically significant difference between conditions (using a t test).

- For DPV, the intertrap difference in placement variances had to be statistically significant (using an F test) for one and only one of the two compared conditions.

Effectiveness of Post Delineators at Site 1

Centrality Index — As discussed earlier, PMD's along a basically tangent highway have negligible effect on mean lateral placement. Table 38 shows that the dry-nighttime centrality index at the upstream trap changed significantly from the baseline value for only one experimental condition. The change was an adverse one, but it occurred only initially for the closer delineator spacing and diminished after an additional week of driver acclimation.

The daytime centrality indices were in most cases substantially lower, and hence better, than the respective nighttime values. However, somewhat larger than expected indices developed for the dry-day condition under close PMD spacing and the wet-day condition under both PMD spacings.

Difference in Placement Variances — Because of the apparent insensitivity of lateral placement to post delineation, most past studies have been based primarily on speed effects. To eliminate this over-reliance on environmentally sensitive speed statistics, the present study also utilized the new DPV measure. Table 38 shows significant reductions in DPV for all nighttime conditions. These reductions—when input to the accident-probability model—result in 9-32 percent decreases in predicted delineation-related driving hazard.

Effectiveness of RPM Supplements at Site 2

Table 39 reveals substantial decreases in CI for all dry-night tests of the RPM supplements. After the longer available acclimation times, DPV was also favorably reduced for the two-line RPM systems (i.e., levels 3L and 4L).

The estimated delineation-related accident rates for all three RPM supplemental treatments show a sharp decline from the base-condition rate. Most interesting, however, are the very minor improvements gained by augmenting the initial level 2 centerline supplement.

Effectiveness of Novel Centerlines at Site 3

Table 40 shows rather mixed results for this study site. With a fairly large reduction in DPV and only a small increase in CI, the 5:35 centerline supplemented by reflective RPM's compares very well with the standard 15:25 centerline. It is quite inexplicable, though, why level 3 performed so poorly and level 1 so well.

Table 38. Safety effectiveness of post delineators at Site 1.

Level	Delineation System	Pavement	Daytime TPM's[1] CI	Daytime TPM's[1] DPV X 10	Nighttime TPM's[1] CI	Nighttime TPM's[1] DPV X 10	Nighttime Predicted Hazard[2] Rate / Ratio[3]
1	Standard Centerline and Edgelines	Dry	1.014	0.485	2.256	0.481	3.59 / 1.00
		Wet	0.895	0.398	2.745	0.190	
2S	Standard Centerline and Edgelines, Post Delineators @ 528 ft. (161 m) on Tangents	Dry	1.004	0.562	1.783	0.229	2.41 / 0.67
2L		Dry	1.106	0.527	2.438	0.275	3.28 / 0.91
		Wet	1.862	0.585	2.948	0.152	
3S	Standard Centerline and Edgelines, Post Delineators @ 264 ft. (80 m) on Tangents	Dry	1.398	0.434	2.900	0.105	3.38 / 0.94
3L		Dry	1.556	0.462	2.290	0.013	2.45 / 0.68
		Wet	2.243	0.035			

[1] Defined in Chapter VII; CI = centrality index and DPV = difference in placement variances divided by lane width; days of acclimation for "S" and "L" data sets indicated in Appendix F.

[2] From two-variable model of nighttime, delineation-related, non-intersection, dry-pavement accidents per million vehicle-miles (1 mi. = 1.61 km).

[3] $Rate_i/Rate_1$; computed only if one or both TPM's changed significantly (significantly different TPM's are underlined).

Table 39. Safety effectiveness of RPM treatments at Site 2.

Level	Delineation System	Pavement	Daytime		Nighttime		
			TPM's[1]		TPM's[1]		Predicted Hazard[1]
			CI	DPV X 10	CI	DPV X 10	Rate / Ratio[2]
1	Standard Centerline and Edgelines	Dry	1.416	0.416	2.292	0.156	2.81 / 1.00
2S	Standard Centerline and Edgelines, Reflective RPM's Added to Centerline @ 80 ft. (24.4m).	Dry	0.963	0.132	0.288	0.214	0.65 / 0.23
2L		Dry	0.539	0.017	0.865	0.352	1.67 / 0.59
		Wet	1.375	0.094	0.643	0.150	
3S	Standard Centerline and Edgelines, Reflective RPM's on Both Center- and Edgelines @ 80 ft. (24.4m).	Dry	0.165	0.170	0.647	0.070	0.70 / 0.25
3L		Dry	0.403	0.117	0.736	0.365	1.55 / 0.55
		Wet	0.242	0.173	1.460	0.571	
4S	Standard Centerline and Edgelines, Reflective RPM's on Both Center- and Edgelines @ 40 ft. (12.2m).	Dry	0.241	0.338	0.761	0.163	1.07 / 0.38
4L		Dry	0.358	0.830	0.231	0.555	1.45 / 0.52
		Wet	1.460	0.010	0.611	1.192	

1 Defined in Chapter VII; CI = centrality index and DPV = difference in placement variances divided by lane width; days of acclimation for "S" and "L" data sets indicated in Appendix F.

2 From two-variable model of nighttime, delineation-related, non-intersection, dry-pavement accidents per million vehicle-miles (1 mi. = 1.61 km).

3 $Rate_i/Rate_1$; computed only if one or both TPM's changed significantly (significantly different TPM's are underlined).

Table 40. Safety effectiveness of novel centerlines at Site 3.

Level	Delineation System	Dry Daytime		Dry Nighttime		
		TPM's[1]		TPM's[1]		Predicted Hazard[2]
		CI	DPV X 10	CI	DPV X 10	Rate / Ratio[3]
1	5:35 Centerline, Std. Edgelines	0.083	0.014	0.119	0.121	0.22 / 0.18
2	5:35 Ctr. W/RPM's, Std. Edgelines	0.881	0.103	0.813	0.065	0.88 / 0.73
3	10:30 Ctr. W/RPM's Std. Edgelines	1.040	0.108	1.647	0.277	2.37 / 1.96
4	15:25 Centerline, Std. Edgelines	1.259	0.095	0.625	0.280	1.21 / 1.00

1 Defined in Chapter VII; CI = centrality index and DPV = difference in placement variances.

2 From two-variable model of nighttime, delineation-related, non-intersection, dry-pavement accidents per million vehicle-miles (1mi. = 1.61 km).

3 $Rate_i/Rate_4$; computed only if one or both TPM's changed significantly (significantly different TPM's are underlined).

Effectiveness of Novel Striping at Site 4A

As indicated in Table 41, the centrality index was significantly lower for all three novel treatment levels. In contrast, DPV was statistically unchanged. The predicted delineation-related accident rates for levels 2-4 suggest that safety is not adversely affected by the use of substandard line widths or a reduced stripe-to-gap ratio.

Effectiveness of Novel Striping at Site 4B

The results summarized in Table 41 corroborate Site 4A's conclusion regarding less paint-intensive delineation systems. Additionally, but unlike the unintuitive earlier finding, the Site 4B values for CI and DPV at level 1 demonstrate a substantial safety benefit due to edgelines.

Effectiveness of RPM Treatments at Site 5

Despite the very heavy and very expensive application of raised pavement markers at this site, vehicular tracking performance (shown in Table 42) was materially improved only by the most elaborate, level 3 installation. A very sizable 68 percent hazard reduction was computed, but it required RPM's on both sides of the lane in addition to standard painted edgelines.

Effectiveness of One- and Two-Line Systems at Site 6

Table 42 shows large but decidedly mixed effects due to the two novel striping systems. The average driver was much less centrally positioned within the traveled lane in the absence of either the edgeline or one of the two solid yellow centerline stripes. Considering the relative nighttime visibility of white versus yellow paint, it would seem that the off-center driving could have been due in part to a visual imbalance in the "strength" of the center as opposed to the edge delineation. The lower values for DPV may reflect greater driver concentration on following the less conspicuous delineation through the winding section S-curve.

Selected Traffic Performance Measures at Site 7

Although not statistically validated for isolated horizontal curves, the measures CI and DPV in this operating situation also have a strong intuitive relationship to accident potential. Table 43, therefore, shows the centrality index computed at the midpoint of the curve and the difference in placement variances taken between the advance-point trap and the midpoint-of-curve trap (i.e., over that distance likely to show the largest, most sensitive value).

As suggested in the earlier discussion of mean lateral placement trends at this site, a large benefit in lane centrality is achieved with the centerline RPM supplement. However, a moderate disbenefit develops

Table 41. Safety effectiveness of novel striping at Sites 4A and 4B.

Site No.	Level	Delineation System[1]	Dry Daytime TPM's[2] CI	Dry Daytime TPM's[2] DPV X 10	Dry Nighttime TPM's[2] CI	Dry Nighttime TPM's[2] DPV X 10	Dry Nighttime Predicted Hazard[3] Rate	Dry Nighttime Predicted Hazard[3] Ratio[4]
4A	1	2-in., 10:30 Centerline, No Edgelines	0.315	0.002	0.053	0.020	-0.11	-
	2	2-in., 10:30 Centerline, 2-in. Edgelines	1.076	0.103	1.359	0.049	1.47	0.69
	3	4-in., 10:30 Centerline, 4-in. Edgelines	1.817	0.102	1.012	0.053	1.08	0.51
	4	4-in., 15:25 Centerline, 4-in. Edgelines	2.272	0.057	1.787	0.114	2.12	1.00
4B	1	4-in., 10:30 Centerline, No Edgelines	0.642	0.090	1.239	0.159	1.61	161.
	2	4-in., 10:30 Centerline, 2-in. Edgelines	1.498	0.011	0.210	0.102	0.28	-
	3	4-in., 10:30 Centerline, 4-in. Edgelines	0.353	0.128	0.354	0.004	0.20	-
	4	4-in., 15:25 Centerline, 4-in. Edgelines	0.145	0.193	0.156	0.020	0.01	1.00

[1] 1 inch = 2.54cm.

[2] Defined in Chapter VII; CI = centrality index and DPV = difference in placement variances.

[3] From two-variable model of nighttime, delineation-related, non-intersection, dry-pavement accidents per million vehicle-miles (1 mi. = 1.61 km).

[4] $Rate_i/Rate_4$; computed only if one or both TPM's changed significantly (significantly different TPM's are underlined).

Table 42. Safety effectiveness of winding section treatments.

Site No.	Level	Delineation System	Dry Daytime		Dry Nighttime			
			TPM's[1]		TPM's[1]		Predicted Hazard[2]	
			CI	DPV X 10	CI	DPV X 10	Rate	Ratio[3]
5	1	"Centerline" of RPM's Only, No Edgelines	1.317	0.187	1.496	0.192	1.99	1.12
	2	"Centerline" of RPM's Only, Std. Edgelines	1.301	0.084	1.565	0.097	1.83	1.03
	3	"Centerline" of RPM's Edgelines w/RPM's	0.628	0.101	0.614	0.029	0.56	0.32
	4	Painted Centerline, Std. Edgelines	1.748	0.520	1.662	0.032	1.77	1.00
6	1	Single-Stripe Centerline, No Edgelines	1.818	0.011	1.380	0.053	1.50	1.00
	2	Single-Stripe Centerline, Std. Edgelines	1.846	0.399	2.144	0.123	2.56	1.71
	3	Std. 2-Stripe Centerline, Std. Edgelines	1.031	0.238	0.138	0.616	1.50	1.00

1 Defined in Chapter VII; CI = centrality index and DPV = difference in placement variances.

2 From two-variable model of nighttime, delineation-related, non-intersection, dry-pavement accidents per million vehicle-miles (1 km = 1.61 km).

3 $Rate_i/Rate_b$, where b = 4 for Site 5 and b = 3 for Site 6; computed only if one or both TPM's changed significantly.

(Significantly different TPM's are underlined).

Table 43. Selected traffic performance measures at Site 7.

Side of Curve	Level	Delineation System	Derived Traffic Performance Measures[1]					
			Dry Daytime			Dry Nighttime		
			CI	DPV X 10	DECEL	CI	DPV X 10	DECEL
IN	1	Standard Centerline and Edgelines Only	1.387	0.609	0.288	1.011	0.791	0.403
	2	Ctr. RPM's @ 40 ft., Curve + 400ft. (Adv. Pt. @ PC + 500 ft.)	1.695	0.731	0.304	1.819	0.347	0.418
	3	Ctr. RPM's + Amber PMD's on Left @ 80 ft., Curve + 400 ft.	1.295	0.504	0.327	1.875	0.460	0.490
	4S	Std. Center and Edge-lines, Plus Amber PMD's on Left @ 80 ft., Curve + 400 ft.	0.402	0.202	0.334	0.697	0.207	0.246
	4L		1.235	0.429	0.292	1.286	0.632	0.411
OUT	1	Standard Centerline and Edgelines Only	3.748	0.398	0.296	4.189	0.240	0.386
	2	Ctr. RPM's @ 40 ft., Curve + 400ft. (Adv. Pt. @ PC + 500 ft.)	2.708	0.282	0.252	1.722	0.092	0.296
	3	Ctr. RPM's + Crystal PMD's on Right @ 80 ft., Curve + 400 ft.	2.955	0.021	0.233	1.979	0.105	0.436
	4S	Std. Center and Edge-Lines, Plus Crystal PMD's on Right @ 80 ft., Curve + 400 ft.	3.265	0.293	0.276	3.977	0.354	0.355
	4L		3.621	0.232	0.377	3.795	0.200	0.298

[1] CI (centrality index) computed at midpoint of curve; DECEL (deceleration in mph/sec) and DPV (difference in placement variances divided by lane width) computed between advance-point trap and midpoint-of-curve trap.

Note: 1ft. = 0.30m and 1mph = 1.61km/h.

for traffic on the inside curve. These findings suggest that it may be advisable to use one-way reflective markers to serve only traffic moving around the curve to the left.

The other two performance measures listed in Table 43 describe vehicle trajectory between a point about 500 feet (152 m) in advance of the curve and the midpoint of the curve, or over a total distance of 750 feet (229 m). The DPV measure changed significantly only for the initial driver reaction to the post delineator installation at level 4. In this case, the term was favorably reduced for both directions of travel. The speed differential used to compute the deceleration measure "DECEL" was in every case a statistically significant 3-5 mph (4.8-8.0 km/h), and the listed decelerations do not really show one treatment better than another.

<u>Selected Traffic Performance Measures at Site 8</u>

On this more gentle curve experimentally treated with post delineators, different performance measures were impacted by direction of travel. Similar to the result at Site 7, the initial impact on traffic moving to the right was to increase the value of DPV (see Table 44). Fortunately, the effect became insignificant after a longer period of driver acclimation. Vehicles on the inside curve also showed some shifting away from the original central lane position, but the nighttime changes are not statistically significant.

Unlike the Site 7 results, the PMD's here had a large beneficial effect on the average vehicle's lane centrality on the outside curve. This could have been due to the somewhat more isolated nature of the curve (hence a more novel installation) and/or the greater freedom of choice granted the driver by the more gentle curvature (i.e., less of a comfort need to "straighten the curve").

On the inside curve, the long-term effect of the PMD's on deceleration into the curve was not meaningful. Small but statistically significant increases in DECEL were observed for the outside curve, however. Since the approach speeds were essentially equivalent between the with- and without-PMD cases, the significant decelerations mainly reflect small decreases in midpoint-of-curve speeds. To the extent that these slightly larger decelerations were associated with the driver's improved tracking performance, the changes are not adverse.

RECOMMENDED DELINEATION DEPLOYMENT PRACTICES

The objectivity and comprehensiveness of the delineation evalautions performed in this research project allow recommended revisions to practice to be stated with a fair degree of confidence. This last section reviews current estimates of relative installation costs; reveals which delineation systems provided a better overall performance than existing standard systems; and lastly, recommends the immediate implementation, further research, or cessation of research of the treatments evaluated herein.

Table 44. Selected traffic performance measures at Site 8.

Side of Curve	Level	Delineation System	Derived Traffic Performance Measures[1]					
			Dry Daytime			Dry Nighttime		
			CI	DPV X 10	DECEL	CI	DPV X 10	DECEL
IN	1	Standard Centerline Only	1.490	0.084	0.169	0.163	0.005	0.114
	3S	PMD's @ 100 ft. (Amber Left, Crystal Right), Curve + 200 ft. (Adv. Pt. @ PC + 500 ft.)	1.107	0.266	0.103	0.381	0.567	0.227
	3L		2.056	0.109	0.192	0.649	0.275	0.129
OUT	1	Standard Centerline Only	0.822	0.004	0.158	2.838	0.113	0.160
	3S	PMD's @ 100 ft. (Amber Left, Crystal Right), Curve + 200 ft. (Adv. Pt. @ PC + 500 ft.)	0.609	0.262	0.222	1.134	0.158	0.279
	3L		0.369	0.031	0.318	0.344	0.053	0.332

[1] CI (centrality index) computed at midpoint of curve; DECEL (deceleration in mph/sec) and DPV (difference in placement variances divided by lane width) computed between advance-point trap and midpoint-of-curve trap.

Note: 1ft. = 0.30m and 1mph = 1.61 Km/h.

Relative Installation Costs of Experimental Systems

Each of the delineation systems described in earlier sections was broken into its several component treatments, and estimates were made of the 1976 initial installation costs. Most (but not all) unit cost data were extracted from an implementation study performed for the FHWA by the California Department of Transportation.(19) The following assumptions were made by AMV as to individual treatment costs for a two-lane rural highway:

- A standard broken yellow centerline (with a stripe-to-gap ratio of 15:25) costs $75/mile ($47/km), 45 percent of which is attributable to the paint itself.
- A single solid yellow stripe, 4 inches (10 cm) wide, costs $100/mile ($62/km) to install.
- A pair of standard 4-inch (10-cm)-wide white edgelines costs $180/mile ($112/km); the paint itself costs $55 or 30 percent of the total.
- The installation cost (materials plus labor) for non-snowplowable RPM's averages $3.00 for each reflective marker and $1.50 for each non-reflective marker.
- Post-mounted delineators cost $10 each to install.

Applying these unit costs to the delineation specifications described in detail in Chapter XI, Table 45 was developed. Another underlying assumption was that passing is allowed in both directions on tangent sections and prohibited in both directions on curvilinear sections. The base treatment costs are shown in the dotted cells of the table.

Practices for the General Roadway Situation

Table 46 summarizes the most pertinent study findings as to the costs and effects of continuous tangent/winding delineation systems. The 18 systems evaluated are listed by general category of the component treatments, i.e., striping only, striping plus raised pavement markers, striping plus post-mounted delineators, and raised pavement markers only. The systems, numbered G—1 through G—18, are compared in every case to a base condition of standard MUTCD centerline with edgelines. Statistically insignificant changes are indicated with a dash (—).

Systems for Immediate Implementation — Several less paint-intensive delineation systems performed as well or better than the more expensive base condition. With emphasis on Systems G—3 through G—8 in Table 46, the following recommendations are made:

Table 45. Assumed delineation system installation costs.

Site Number	Cost by Treatment Level ($/Mile)[1]			
	1	2	3	4
1	$255	$455	$655	N/A
2	$255	$455	$855	$1,455
3	$235	$435	$445	$255
4A	$55	$205	$245	$255
4B	$65	$215	$245	$255
5	$3,175	$3,355	$3,755	$380
6	$100	$280	$380	N/A
7	$380	$580	$1,240	$1,040
8	$200	N/A	$1,255	N/A

[1] 1 mile = 1.61 km; dotted cell is base condition; passing allowed in both directions on tangent sites & prohibited in both directions on curvilinear sites.

Table 46. Evaluation of costs and effects of continuous delineation systems.

Delineation Category	Experimental Delineation System: Description[1]	Experimental Delineation System: No.	Study Site No.	% Changes to Base Characteristics[2]: Initial Cost to Install[3]	Night Variances[4]: Speed	Night Variances[4]: Placement	Predicted Dry-Night Hazard[5]
Striping Only	Single solid centerline						
	• w/o edgelines	G-1	6	↓74	↓60	↓30	-
	• w/4-in. edgelines	G-2	6	↓26	-	↓30	↑71
	4-in., 5:35 centerline						
	• w/4-in. edgelines	G-3	3	↓ 8	↓25	↑30	↓82
	2-in., 10:30 centerline						
	• w/o edgelines	G-4	4A	↓78	-	-	-
	• w/2-in. edgelines	G-5	4A	↓20	↓40	-	↓31
	4-in., 10:30 centerline						
	• w/o edgelines	G-6	4B	↓75	-	-	↑+ +
	• w/2-in. edgelines	G-7	4B	↓16	-	-	-
	• w/4-in. edgelines	G-8	4B	↓ 4	-	-	-
			4A	↓ 4	-	-	↓49
Striping and RPM's	4-in., 5:35 centerline						
	• Ctr. RPM's @ 80 ft. (w/4-in. edgelines)	G-9	3	↑71	↓35	-	↓27
	4-in., 10:30 centerline						
	• Ctr. RPM's @ 80 ft. (w/4-in. edgelines)	G-10	3	↑75	↓35	-	↑96
	4-in., 15:25 centerline						
	• Ctr. RPM's @ 80 ft. (w/4-in. edgelines)	G-11	2	↑78	-	↓25	↓41

Table 46. Evaluation of costs and effects of continuous delineation systems. (continued)

Delineation Category	Experimental Delineation System		Study Site No.	% Changes to Base Characteristics[2]			
	Description[1]	No.		Initial Cost to Install[3]	Night Variances[4] Speed	Night Variances[4] Placement	Predicted Dry-Night Hazard[5]
Striping and RPM's (cont'd)	4-in., 15:25 centerline • RPM's on both sides of lane @ 80 ft. (w/4-in. edgelines)	G-12	2	235 ↑	-	30 ↓	45 ↓
	4-in., 15:25 centerline • RPM's on both sides of lane @ 40 ft. (w/4-in. edgelines)	G-13	2	471 ↑	60 ↑	-	48 ↓
	Centerline of reflective & non-reflective RPM's • w/4-in. edgelines	G-14	5	783 ↑	-	-	3 ↑
	• w/4-in. edgelines supplemented by RPM's @ 40 ft.	G-15	5	888 ↑	-	-	68 ↓
Striping and PMD's	4-in., 15:25 centerline • w/PMD's @ 528 ft. (w/4-in. edgelines)	G-16	1	78 ↑	-	30 ↓	21 ↓
	4-in., 15:25 centerline • w/PMD's @ 264ft. (w/4-in. edgelines)	G-17	1	157 ↑	30 ↓	25 ↓	32 ↓
RPM's Only	Centerline of reflective & non-reflective RPM's • w/o edgelines	G-18	5	736 ↑	50 ↑	-	12 ↑

1 1 in. = 2.54 cm and 1 ft. = 0.305m.; RPM = raised pavement marker and PMD = post-mounted delineator.

2 Base-condition delineation system consisted of edgelines with double solid centerline at sites 5 and 6 and 15:25 centerline at other sites; all striping 4 inches (10 cm) wide.
(↑ means a statistically significant increase of percentage shown),
(↓ means a statistically significant decrease of percentage shown),
(– means any change was statistically insignificant).

3 See Table 45 and accompanying text.

4 Dry-night values for upstream trap at tangent sites (Nos. 1, 2, 3, 4A, and 4B) and midpoint-of-inside-curve trap at winding sites (Nos. 5 and 6).

5 Using Chapter VII's two-variable accident-probability model based on centrality within the lane and longitudinal change in placement variance. See Tables 38-42.

(1) Beginning with the next repainting cycle, System G-8 (with no-passing barrier striping as appropriate) should be applied to all rural two-lane highways. At two sites where this system was studied, the predicted delineation-related hazard on a dry night was found to be either unchanged or substantially reduced. An immediate cost savings of about 4 percent should also result.

(2) Where the quality control associated with the painting equipment will allow, the 10:30 centerline on new or newly resurfaced highways should be accompanied by edgelines 2-3 inches (5-8 cm) wide (System G-7). No adverse safety effects were predicted at the two locations where narrower edgelines were tested in combination with a reduced centerline stripe-to-gap ratio. In comparing System G-7 to System G-8, an additional 12 percent in striping costs would be saved.

(3) Systems G-3 and G-5 could be applied in a controlled fashion over long sections of tangent-type highway. In the vicinity of no-passing zones, however, it would be advisable to revert to System G-7 or G-8.

(4) To overcome possible target-value problems for System G-3 under adverse visibility conditions (e.g., fog and nighttime rain), serious consideration should be given where practical to the supplemental centerline use of reflective raised pavement markers (RPM's). A combination of one- and two-way amber markers is suggested: wherever passing is allowed for a given direction of travel, the driver would see reflective elements at 80-foot (24.4-m) intervals, and where passing is prohibited for the same direction, he would see the reflectors at 40-foot (12.2-m) intervals. As shown on Table 46, delineation-related driving hazard on a dry night alone might be reduced by 30-80 percent. See Figure 36 for an indication of initial cost versus predicted safety effectiveness for System G-9.

(5) Where especially severe visibility conditions occur due to frequent fog or blowing sand, consideration should be given to a continuous RPM supplement—at the spacing pattern recommended above—on highways with the proposed general standard 10:30 centerline. Although the one test of System G-10 yielded unsatisfactory results, the two "bracketing" systems—G-9 and G-11—showed dry-night hazard reductions of 27-41 percent. The wet-day and wet-night evaluations of System G-11 showed that significant benefits can be derived from the supplemental treatment under adverse operating conditions. Similar advantages should be expected for System G-10.

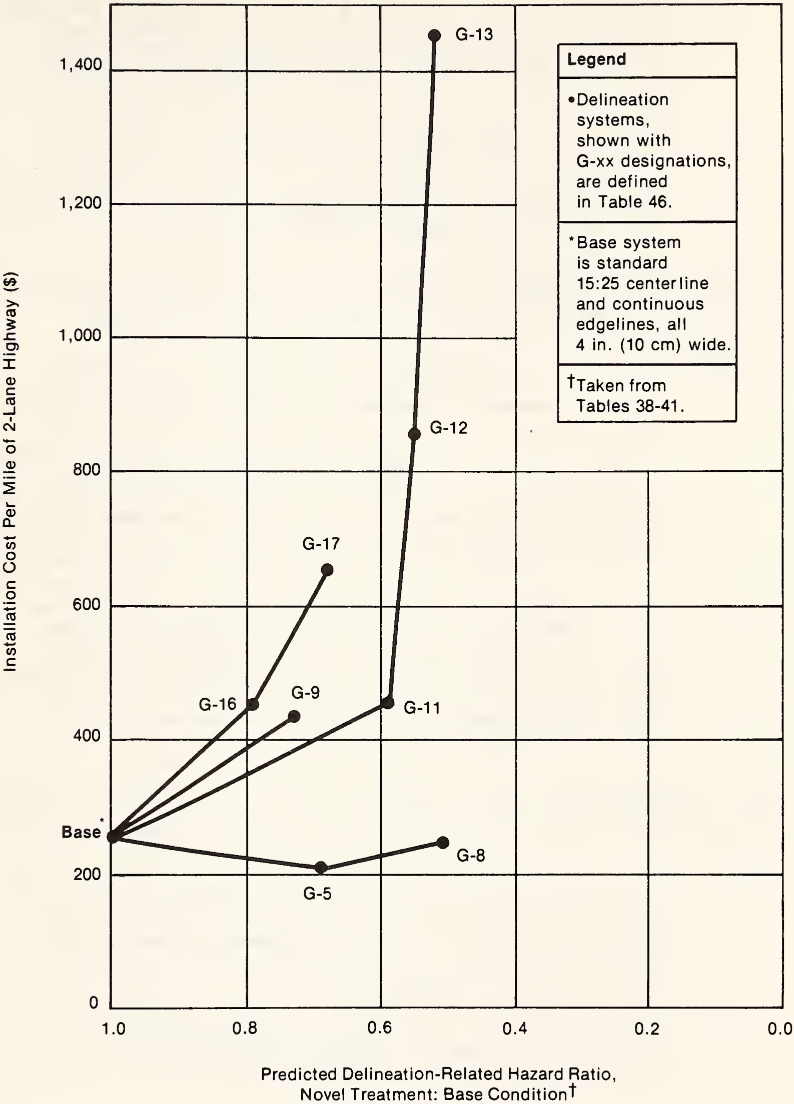


Figure 36. Initial cost vs. predicted effectiveness

(6) Where additional reflective devices are considered desirable and the 80-foot (24.4-m) RPM centerline supplement cannot be applied because of snow-plowing problems, continuous post-mounted delineators should be installed at intervals of 400-528 feet (122-161 m) on tangents. On curves, the present MUTCD spacing recommendations should probably be retained.(1) The delineator posts should be installed on both sides of the road, but drivers in a given direction need to see reflective elements only on the near side. Refer to Figure 36 for an indication of initial cost versus predicted safety effectiveness for System G-16.

Systems for Further Research — Due to field study limitations within the project, several promising delineation systems yielded inconclusive results. The following additional research should be considered:

(1) The use of a single solid centerline on two-lane passing-restricted highways should be investigated more comprehensively. Additional traffic performance field studies are warranted, especially on narrower pavements (e.g., 18-20 feet or 5.5-6.1 m). A thorough review should also be made of the potental passing hazard associated with driver misunderstanding of the single stripe. On very narrow, low-volume roads, consideration should be given to evaluating the selective use of a single solid centerline just in the vicinity of curves and other hazards.

(2) The installation of post-mounted delineators over long sections of two-lane highway should be evaluated on narrower, more winding alignments. Tradeoffs should be studied between delineator spacing and the selective use of edgelines. Unlike previous studies, however, the longitudinal change in lateral placement variance should be defined as a key performance measure.

Systems Not Warranting Further Research — Several delineation systems appear to fall outside desirable bounds of cost or effectiveness. These systems, and the reasons for suggesting a cessation of further research, are as follows:

(1) Systems G-4 and G-6, without edgelines, performed very well in one case and very poorly in the other. Sufficient national experience has accumulated to warrant the use of edgelines, at least narrow ones, on all pavement widths of 20 feet (6.1 m) or greater.

(2) System G-11, while it performed very satisfactorily, would become obsolete under the proposal for a maximum 10-foot (3-m) stripe in the broken centerline pattern.

(3) Systems G-12 and G-13, which include RPM supplements on both sides of the lane, did not appear to yield a safety gain justifying the very large installation expense. Figure 36 clearly shows the rapidly diminishing returns on the initial investment.

(4) The extremely expensive systems involving an RPM-only centerline did not yield sufficient safety benefits to justify their general application on two-lane rural highways. Systems G-14 and G-18, which had reflective markers only on the centerline, did not seem to change accident potential in a statistically significant sense. System G-15, by far the most elaborate and costly system considered, did show a substantial 68 percent reduction in predicted hazard. But since the initial cost is about 900 percent greater than the base condition paint-only system, it is doubtful that even with the extended life of the RPM's, a sufficiently attractive benefit/cost estimate could be derived to overcome the tremendous threshold costs.

Practices for Isolated Horizontal Curves

The curve-specific delineation systems studied included centerline raised pavement marker supplements and post-mounted delineators, used separately and in combination. Based on the traffic performance measures obtained at two study sites, the following recommendations are offered for the treatment of high-hazard horizontal curves:

(1) Where their use is feasible, retroreflective pavement markers (RPM's) are preferred over post-mounted delineators (PMD's). Unlike PMD's, RPM's serve well as both "far" and "near" delineation. In their former role, pavement markers present a more accurate perspective of the driving surface; in their latter role, they have a significant effect on mean lateral placement that delineators generally do not.

(2) To benefit drivers on the outside of the curve without adversely affecting the lateral placement of vehicles moving in the opposite direction, one-way RPM's should be installed on the centerline. These markers—containing amber reflective elements and installed at 40-foot (12.2-m) intervals—should face traffic moving to the left on the curve. Although not specifically evaluated, behavioral findings to date suggest that drivers on the inside of the curve would be best served by one-way crystal RPM's placed on the near side between the edgeline and edge of pavement. The resulting two-line system of one-way markers should substantially reduce the probability of potentially hazardous centerline and shoulder encroachments.

(3) When RPM's cannot be used because of economic or maintenance problems, consideration should be given to the installation of post delineators on the outside of the curve. Although not likely to be as beneficial as RPM supplements, PMD's apparently do provide some degree of near as well as far delineation (e.g., off-center driving was not reduced but placement variance was).

(4) In order to provide the approaching driver with unambiguous guidance as to the proper path of travel, it is highly desirable to use two colors of retroreflector on the delineator posts. Drivers moving on the outside curve should see crystal reflectors on their near-right, and drivers moving on the inside curve should see amber reflectors on their far-left. Otherwise, the current MUTCD standards for mounting height and offset from the shoulder appear satisfactory.(1)

APPENDIX A

PHASE I STUDY SITE PHYSICAL CHARACTERISTICS

Features described herein include the location, traffic composition, lane width, shoulder width, and speed limit of each of the 42 study sites used in the Phase I accident-probability modeling. Additional length and degree-of-curvature information is provided for the subset of 30 curvilinear sites.

Table 47. Summary of tangent site characteristics.

Delineation System	Cell No.	Site Number	Location		Overall Section Length (mi.)	1975 Traffic			Roadway Width (ft.)	Shoulder Width (ft.)	Speed Limit (mph)
			Route[1] Number	Description of Endpoints		ADT	Percent Trucks Day	Percent Trucks Night			
Centerline Only	1	VA 56	56	Rt. 29 - Rt. 151	4.83	1,180	14.3	1.8	18.2	5	55
	2	LA 32	67	North from Clinton	3.65	1,340	11.9	5.5	20.0	3	55
	3	LA 7	343	U.S. 90 - Rt. 14	13.00	1,500	18.0	3.0	21.0	8	55
	4	VA 50	738	Rt. 193 - Rt. 684	3.82	4,900	4.4	0.8	20.2	1	40
	5	LA 29	13	U.S. 90 - Rt. 1115	7.50	4,015	7.8	6.8	20.0	6	55
Centerline & Edgelines	8	MD 60	336	East from Rt. 335	3.54	900	12.7	2.8	18.8	5	50
	9	VA 13	40	Rt. 735 - Rt. 35	6.53	1,500	28.2	23.5	20.0	2	55
	10	VA 16	10	Rt. 40 - Rt. 31	9.50	1,550	20.3	12.4	20.0	7	55
	11	MD 106	108	Laytonsville - Etchison	2.60	3,450	2.2	5.1	20.0	2	50
	12	VA 25	US 15	Rt. 22 - I-64	6.42	1,700	12.1	0.9	19.4	5	55
	13	CT 19	169	Hillandale Rd. - Rt. 101	3.20	1,500	9.1	5.2	22.0	3	55
	14	CT 30	44	Rt. 21 - R.I. Line	3.35	2,100	8.5	9.8	22.0	6	55

Notes:

1 foot = 0.30 metre and 1 mile = 1.61 km

[1] State route unless otherwise indicated

Table 48. Summary of winding site characteristics.

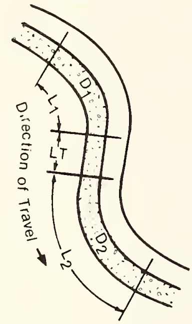
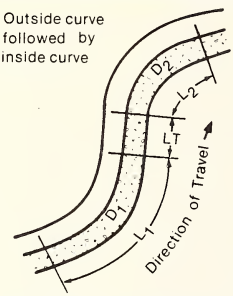
Delineation System	Cell No.	Site Number	Location		Overall Section Length (mi.)	1975 Traffic			Roadway Width (ft.)	Shoulder Width (ft.)	Speed Limit (mph)
			Route[1] Number	Description of Endpoints		ADT	Percent Trucks Day	Percent Trucks Night			
Centerline Only	1	CT 6	148	Rt. 79 - Rt. 81	6.31	670	7.0	0.0	18.6	1	25
	2	VA 5	US 522	South from Cuckoo	3.90	850	12.2	3.2	20.6	2	45
	3	LA 13	77	I-10 - Rt. 386	3.40	590	7.2	0.0	19.4	8	35
	4	PA 2	US 522	North from Shirleysburg	3.41	1,850	4.1	6.0	18.8	3	40
	5	VA 51	215	Rt. 28 - Fauquier County Line	5.69	3,410	7.8	0.9	20.4	5	40
Centerline & Edgelines	6	VA 43	271	East from Rock-ville	3.58	2,460	17.3	3.4	16.2	2	45
	7	MD 4	137	East from Rt. 25	5.75	1,550	1.7	0.0	21.0	2	45
	8	VA 27	6	Rt. 755 - Nelson County Line	3.03	1,025	7.6	4.6	19.8	7	40
	9	MD 3	130	East from US 140	3.82	4,720	3.1	0.9	20.0	1	25
	10	CT 32	58	Rt. 15 - Rt. 136	3.27	3,725	4.2	2.2	24.4	4	35

Notes:

1 foot = 0.30 metre and 1 mile = 1.61 km

[1]State route unless otherwise indicated

Table 49. Geometric details of winding site "S Curves."

Definition of Geometric Elements	Site Number	Curve #1 D_1 (°)	Curve #1 L_1 (ft.)	Curve #1 Central ∡ (°)	Tangent LT (ft.)	Curve #2 D_2 (°)	Curve #2 L_2 (ft.)	Curve #2 Central ∡ (°)	L_1 + LT + L_2 (ft.)
Inside curve followed by outside curve 	CT 6	9	280	25	105	9	410	37	795
	VA 5	14½	502	73	510	10	588	59	1,600
	LA 13	9	240	21½	68	9	570	51½	878
	PA 2	9½	306	29	370	7	322	22½	998
	VA 51	5	449	22½	350	5	443	22	1,242
	VA 43	15½	230	35½	60	8	303	24	593
Outside curve followed by inside curve 	MD 4	5	382	19	162	5	493	24½	1,037
	VA 27	8	487	39	93	8	1,225	98	1,805
	MD 3	9	225	20½	0	18	400	72	625
	CT 32	5½	385	21	150	7½	400	30	935

Note: 1 foot = 0.30 metre

Table 50. Summary of isolated horizontal curve site characteristics.

Delineation System	Cell No.	Site[1] Number	Route[2] Number	Position on Route	1975 Traffic ADT	Percent Trucks (2-way avg.) Day	Percent Trucks (2-way avg.) Night	Degree of Curve (deg.)	Length of Curve (ft.)	Central Angle (deg.)	Roadway Width (ft.)	Shoulder Width (ft.)	Speed Limit (mph)
Centerline Only	1	MD 94	667	1.4 mi. south of Rt. 413	580	5.4	0.4	5	325	16	16.6	3	35
	2	PA 1	26	Between Spring Mills & Millheim	2,830	4.6	1.6	4	580	23	18.3	5	55
		CT 10	9A	M.P. 9.1	4,300	--	--	3	260	8	20.0	4	55
		MD 36	261	M.P. 4.3	5,825	--	--	4	475	19	20.0	5	50
	3	CT 20	316	0.9 mi. north of Rt. 66	1,380	8.5	0.0	20	475	95	20.4	1	35
		CT 2	622	M.P. 3.5	650	--	--	24	210	50	18.0	3	35
Centerline & Edgelines	5	MD 50	425	1.3 mi. south of Rt. 484	1,330	14.5	6.2	3½	820	28½	16.8	3	50
	6	GA 25	US 129	M.P. 3.4 (just north of S2156)	2,830	4.8	5.4	4	915	36½	22.6	5	55
		LA 31	13	M.P. 16.2 (near Rt. 370)	4,000	--	--	5	1,400	70	24.0	12	55
		MD 31	26	M.P. 3.3	5,050	--	--	3	790	23½	24.0	6	50
	8	MD 57	335	M.P. 7.0 (near Rt. 336)	1,240	9.3	1.2	8	460	37	21.0	5	50
		MD 56	313	M.P. 4.5	550	--	--	6	370	22	20.0	4	50
		MD 71	US 50	M.P. 1.3	1,400	--	--	7½	475	35½	20.0	5	50
Centerline, Edgelines, & Post-Mounted Delineators	9	MD 100	12	Near US 13 Bypass	3,720	9.6	2.2	4	450	18	20.3	4	50
	10	VA 24	US 15	0.4 mi. north of Rivanna River	2,000	17.4	11.0	4	700	28	20.8	8	55
		CT 31	44	1.6 mi. east of Rt. 21	3,000	--	--	5	635	32	22.0	4	55
		WA 36	101	M.P. 15.6	3,200	--	--	4	845	34	24.0	7	55
	11	MD 97	667	1.9 mi. west of US 13	1,200	15.2	1.4	6½	850	55	21.0	5	50
	12	MD 87	213	M.P. 11.2 (0.4 mi. south of Brick Schoolhouse Rd.)	2,540	11.7	2.0	8½	450	38	20.7	8	50
		WA 48	510	M.P. 11.5	3,000	--	-	10	420	42	20.0	4	35

Notes:

1 foot = 0.30 metre and 1 mile = 1.61 km

[1] TPM data were collected only at first site in each cell

[2] State route unless otherwise indicated

APPENDIX B

DATA COLLECTION FORMS USED IN PHASE I

This appendix contains the tabular and schematic forms used by The Pennsylvania State University during Phase I field data collection.

Table 51. Equipment calibration form.

SITE #________

Trap Lengths No. 1______No. 2______No. 3______

Trap Width No. 1______No. 2______No. 3______

Channels

Clock Channels

No. 1 Start____ Stop____ No. 2 Start____ Stop____ No. 3 Start____ Stop____

Calibration Date______

Time______

Channel

Distance from Edge of Pavement						
0						
1/4						
1/2						
3/4						
4/4						

Calibration Date______

Time______

Channel

0						
1/4						
1/2						
3/4						
4/4						

Comments

Calibration Date______

Time______

Channel

Distance from Edge of Pavement						
0						
1/4						
1/2						
3/4						
4/4						

Calibration Date______

Time______

Channel

0						
1/4						
1/2						
3/4						
4/4						

Table 52. TPM data form.

STATE________ DATE________ TIME BEGIN____:____ AM PM SITUATION TYPE:________

SITE #________ WEATHER________ TIME END____:____ AM PM ________

Vehicle Type	Comments	Lateral Placement Readings						Digital Clock Readings			Radar Speeds		
		Ch	Ch	Ch	Ch	Ch	Ch	1	2	3	1	2	3

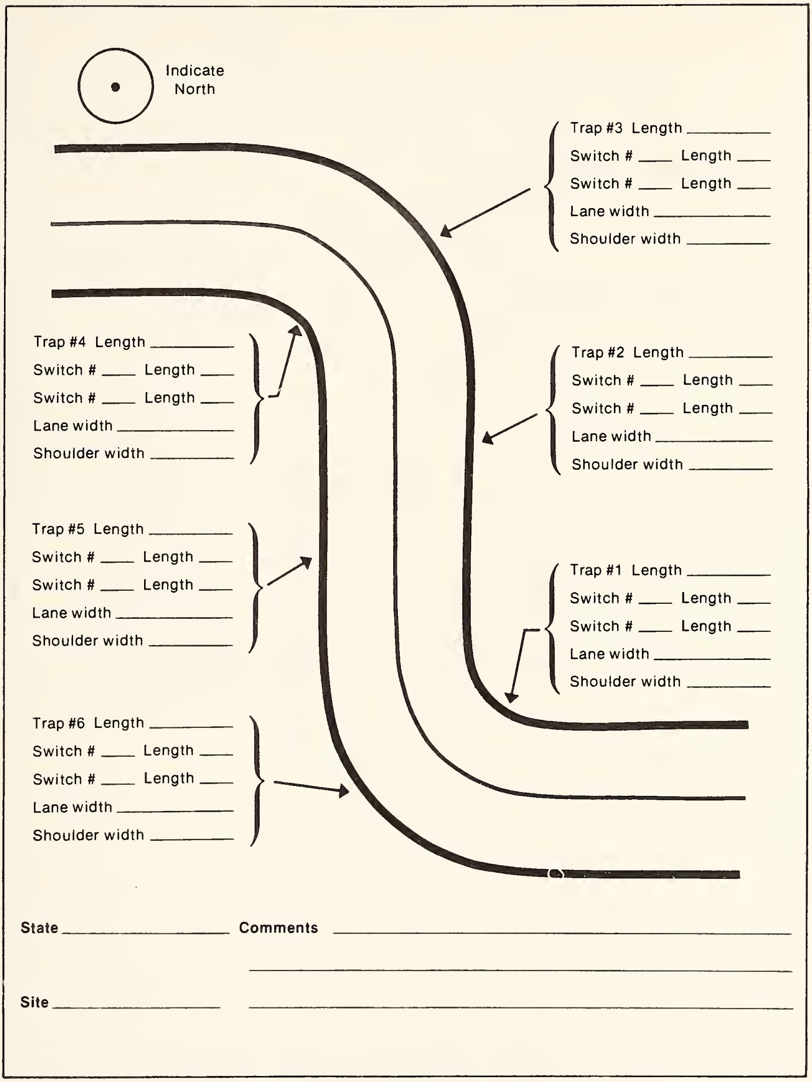


Figure 37. Set-up schematic for winding site.

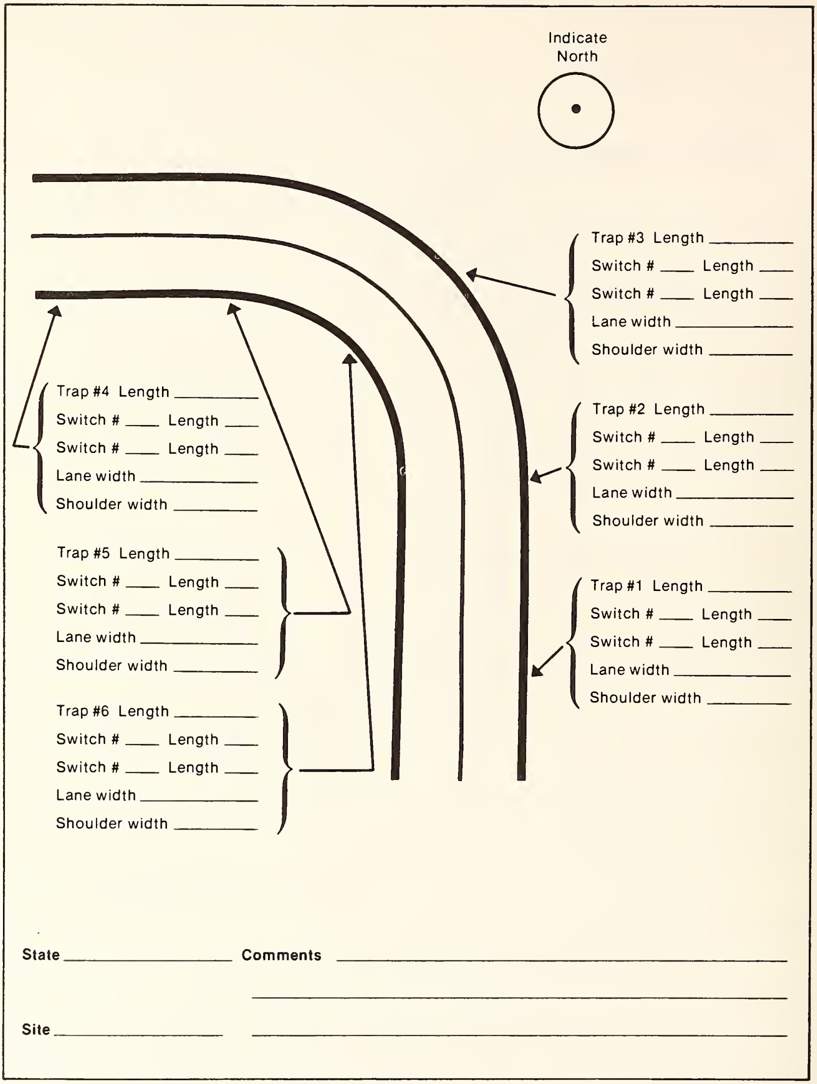


Figure 38. Set-up schematic for isolated curve.

APPENDIX C

SUPPORTING TPM STATISTICS FOR PHASE I

Presented herein is a series of eight tables containing the means and variances of the Phase I speed and lateral placement data sets.

Table 53. Speed data for tangent sites.

Site Number	Speed Limit (mph)	Mean Speed (mph)			
		Day		Night	
		Upstream Station 1	Downstream Station 2	Upstream Station 1	Downstream Station 2
VA 56	55	49.2	49.8	50.6	51.2
LA 32	55	55.5	55.2	56.3	56.6
LA 7	55	57.5	57.4	56.9	56.9
VA 50	40	47.6	46.3	51.6	51.1
LA 29	55	54.9	54.4	56.7	55.5
MD 60	50	51.3	51.0	52.4	51.6
VA 13	55	56.7	56.8	57.2	57.8
VA 16	55	56.9	56.6	57.3	57.1
MD 106	50	47.8	48.2	48.3	46.6
VA 25	55	55.9	55.0	56.1	55.1
CT 19	55	49.6	49.0	49.8	49.7
CT 30	55	52.4	52.6	53.5	53.5
		Speed Variance $(mph)^2$			
VA 56	55	72.0	72.3	72.5	68.1
LA 32	55	68.7	81.0	100.8	92.5
LA 7	55	77.8	81.1	93.5	103.7
VA 50	40	61.5	69.6	57.0	56.3
LA 29	55	60.7	55.3	68.1	77.5
MD 60	50	98.9	90.0	112.2	96.4
VA 13	55	59.5	62.0	52.7	51.5
VA 16	55	47.6	47.1	65.4	65.6
MD 106	50	77.5	74.8	55.8	39.7
VA 25	55	41.5	51.3	45.0	59.5
CT 19	55	59.6	57.4	53.2	57.8
CT 30	55	57.0	59.2	63.6	64.7

Note:

1 mph = 1.61 km/h

Table 54. Speed data for winding sites.

Site Number	Speed Limit (mph)	Mean Speed (mph)					
		Day			Night		
		Midpoint Inside Curve 1	Midpoint Tangent 2	Midpoint Outside Curve 3	Midpoint Inside Curve 1	Midpoint Tangent 2	Midpoint Outside Curve 3
CT 6	30	37.3	38.1	40.0	39.6	40.7	41.9
VA 5	40	46.0	48.1	47.2	47.2	49.9	48.5
LA 13	35	41.4	40.2	38.8	43.0	41.6	39.7
PA 2	40	48.0	50.2	50.7	45.2	46.8	47.6
VA 51	55	49.9	49.7	49.4	49.0	48.8	48.0
VA 43	55	37.7	39.1	38.4	41.6	41.4	42.0
MD 4	45	40.8	42.9	41.0	43.7	46.3	44.5
VA 27	40	43.0	44.1	44.0	43.4	44.8	46.1
MD 3	30	33.8	33.3	30.6	37.3	31.5	29.2
CT 32	35	40.4	39.6	40.4	39.7	42.2	42.4
		Speed Variance $(mph)^2$					
CT 6	30	43.6	34.2	31.1	43.0	46.3	31.0
VA 5	40	53.6	48.1	42.1	45.7	46.2	40.0
LA 13	35	51.4	42.4	55.7	62.3	56.6	41.7
PA 2	40	31.4	35.0	41.7	38.4	43.1	42.5
VA 51	55	60.2	66.5	59.5	36.0	43.2	56.0
VA 43	55	48.5	34.4	39.5	27.3	26.1	28.7
MD 4	45	33.6	39.2	46.0	32.4	34.2	32.6
VA 27	40	34.0	36.2	38.1	36.6	35.9	45.2
MD 3	30	12.1	14.3	22.2	17.2	20.3	14.5
CT 32	35	33.6	31.4	28.2	24.3	23.2	20.4

Note: 1 mph = 1.61 km/h

Table 55. Mean speed data for horizontal curves.

Site Number	Speed Limit (mph)	Mean Speed — Inside Curve (mph)					
		Day			Night		
		Advance Point	Point of Curve	Curve Midpoint	Advance Point	Point of Curve	Curve Midpoint
		1	2	3	1	2	3
MD 94	35	43.2	43.0	42.2	43.0	41.7	40.9
PA 1	55	54.6	53.5	52.6	53.8	52.2	50.8
CT 20	35	42.8	34.3	31.0	42.3	33.9	30.3
MD 50	50	50.3	48.1	46.8	49.9	47.8	46.7
GA 25	55	60.2	59.3	56.9	56.9	56.0	54.6
MD 57	50	50.7	47.6	45.0	50.4	46.3	44.0
MD 100	50	51.0	48.2	46.5	49.3	45.6	43.8
VA 24	50	55.0	54.3	53.5	55.8	54.5	53.9
MD 97	50	50.3	47.0	44.9	51.5	46.6	45.6
MD 87	50	54.5	50.4	46.1	53.6	49.2	45.0
		Mean Speed — Outside Curve (mph)					
MD 94	35	40.1	39.8	39.3	39.6	38.9	38.4
PA 1	55	52.5	51.9	52.6	53.0	51.9	51.6
CT 20	35	38.8	35.7	31.9	37.4	34.3	30.7
MD 50	50	49.6	47.6	47.4	50.4	48.2	47.5
GA 25	55	58.9	57.9	56.0	58.0	57.3	55.9
MD 57	50	49.3	46.5	44.2	49.8	46.5	44.1
MD 100	50	45.7	45.3	45.2	45.9	45.3	44.3
VA 24	50	50.3	49.6	50.2	51.4	51.4	51.5
MD 97	50	50.6	48.5	46.7	50.9	48.3	45.9
MD 87	50	53.9	50.7	48.5	50.9	46.7	45.3

Note: 1 mph = 1.61 km/h

Table 56. Speed variance data for horizontal curves.

Site Number	Speed Variance — Inside Curve $(mph)^2$					
	Day			Night		
	Advance Point 1	Point of Curve 2	Curve Midpoint 3	Advance Point 1	Point of Curve 2	Curve Midpoint 3
MD 94	86.2	66.3	61.5	88.7	72.3	65.0
PA 1	54.6	53.5	52.6	53.8	52.2	50.8
CT 20	48.9	24.0	19.7	53.7	25.1	23.2
MD 50	72.4	58.3	57.3	51.1	43.1	39.2
GA 25	60.2	59.3	56.9	56.9	56.0	54.6
MD 57	74.5	51.2	35.9	88.7	55.0	52.3
MD 100	50.4	34.2	30.4	49.7	33.0	30.4
VA 24	49.1	38.5	41.5	34.9	32.5	30.3
MD 97	76.9	38.5	39.7	58.1	35.3	33.3
MD 87	35.5	26.8	25.7	33.5	28.4	29.6
	Speed Variance — Outside Curve $(mph)^2$					
MD 94	64.2	58.7	57.5	70.5	64.8	60.6
PA 1	52.5	51.9	52.6	59.5	57.0	52.5
CT 20	54.2	53.2	47.5	61.7	26.0	20.1
MD 50	79.1	88.1	68.1	76.4	73.8	62.4
GA 25	54.3	43.3	40.8	43.4	42.0	38.4
MD 57	62.4	50.4	44.2	84.8	59.0	58.8
MD 100	51.3	49.7	56.1	33.0	29.3	29.5
VA 24	47.2	45.1	48.7	39.8	31.0	36.4
MD 97	44.9	36.0	32.4	53.6	48.8	50.1
MD 87	42.3	27.3	24.9	49.7	37.0	35.0

Note:

$1\ (mph)^2 = 2.59\ (km/h)^2$

Table 57. Lateral placement data for tangent sites.

Site Number	Lane Width (ft.)	Mean Lateral Placement from Right Edge of Traveled Lane (ft.)			
		Day		Night	
		Upstream Station	Downstream Station	Upstream Station	Downstream Station
		1	2	1	2
VA 56	9.1	2.5	1.9	2.8	2.1
LA 32	10.0	2.6	2.8	3.3	3.0
LA 7	10.5	2.8	3.1	3.6	3.3
VA 50	10.1	3.2	3.0	3.6	3.1
LA 29	10.0	2.5	2.0	2.9	2.4
MD 60	9.4	2.4	1.8	2.9	2.3
VA 13	10.0	1.7	2.6	2.2	3.3
VA 16	10.0	2.8	2.6	2.9	2.8
MD 106	10.0	2.1	1.9	1.8	1.9
VA 25	9.7	3.2	2.7	3.4	3.4
CT 19	11.0	3.3	3.1	3.6	3.1
CT 30	11.0	2.5	2.8	2.9	3.1
		Lateral Placement Variance ($ft.^2$)			
VA 56	9.1	1.0	0.7	1.0	0.6
LA 32	10.0	1.3	1.7	1.9	1.4
LA 7	10.5	1.6	3.3	1.6	2.3
VA 50	10.1	0.8	2.6	1.2	1.3
LA 29	10.0	0.6	0.8	0.6	0.7
MD 60	9.4	1.1	1.0	1.7	1.2
VA 13	10.0	1.3	1.1	2.7	1.7
VA 16	10.0	2.7	3.0	0.8	0.9
MD 106	10.0	0.5	0.9	0.7	1.0
VA 25	9.7	1.6	1.2	1.1	1.1
CT 19	11.0	1.1	1.2	0.9	1.1
CT 30	11.0	1.2	1.2	1.2	1.7

Note:

1 ft. = 0.30 metre and 1 $ft.^2$ = 0.093 m^2

Table 58. Lateral placement data for winding sites.

Site Number	Lane Width (ft.)	Mean Lateral Placement from Right Edge of Traveled Lane (ft.)					
		Day			Night		
		Midpoint Inside Curve	Midpoint Tangent	Midpoint Outside Curve	Midpoint Inside Curve	Midpoint Tangent	Midpoint Outside Curve
		1	2	3	1	2	3
CT 6	9.3	2.0	2.5	3.0	2.6	3.2	3.6
VA 5	10.3	1.5	2.6	3.6	1.3	2.5	5.1
LA 13	9.7	1.3	2.7	3.3	2.3	3.3	4.6
PA 2	9.4	1.1	1.9	2.9	1.2	2.4	3.3
VA 51	10.2	2.0	2.6	3.8	2.7	3.3	4.1
VA 43	8.1	1.1	1.8	1.6	0.8	2.1	2.9
MD 4	10.5	2.1	4.3	3.6	1.1	4.1	4.0
VA 27	9.9	2.2	2.6	3.4	2.3	3.3	4.1
MD 3	10.0	2.8	3.5	4.7	2.9	4.3	5.2
CT 32	12.2	4.8	7.0	5.2	5.5	7.8	5.4
		Lateral Placement Variance (ft.^{2})					
CT 6	9.3	1.1	1.0	1.0	0.7	1.1	1.3
VA 5	10.3	0.9	1.4	2.2	2.1	2.2	3.9
LA 13	9.7	1.6	2.8	3.0	2.8	2.8	4.1
PA 2	9.4	0.5	1.9	1.3	0.8	1.9	2.3
VA 51	10.2	0.9	1.9	1.4	0.9	3.2	2.0
VA 13	8.1	1.1	2.0	0.7	0.7	0.8	1.4
MD 4	10.5	2.2	1.3	2.0	0.7	2.3	2.3
VA 27	9.9	1.1	1.4	1.4	1.2	1.7	1.4
MD 3	10.0	1.5	2.4	2.4	1.8	2.7	2.0
CT 32	12.2	5.9	8.1	3.1	6.2	5.8	4.0

Note:

1 ft. = 0.30 metre and 1 ft.^{2} = 0.093 m^2

Table 59. Mean lateral placement data for horizontal curves.

Site Number	Lane Width (ft.)	Mean Lateral Placement from Right Edge of Traveled Lane — Inside Curve (ft.)					
		Day			Night		
		Advance Point	Point of Curve	Curve Midpoint	Advance Point	Point of Curve	Curve Midpoint
		1	2	3	1	2	3
MD 94	8.3	2.4	1.8	1.4	2.7	2.3	1.6
PA 1	9.0	2.6	1.2	1.9	2.8	1.4	2.1
CT 20	10.2	4.9	7.1	5.6	4.9	7.6	5.0
MD 50	8.4	1.7	1.9	1.5	2.1	2.0	1.4
GA 25	11.3	3.3	2.6	2.7	3.1	2.6	2.3
MD 57	10.5	2.6	3.6	1.7	3.1	3.9	1.3
MD 100	10.0	2.5	1.6	1.5	2.6	2.1	1.4
VA 24	10.4	1.8	1.6	2.4	2.3	2.4	2.3
MD 97	10.5	3.6	3.4	2.0	3.7	3.5	2.3
MD 87	10.7	2.7	3.0	-0.2	2.9	3.4	0.4
		Mean Lateral Placement from Right Edge of Traveled Lane — Outside Curve (ft.)					
MD 94	8.5	2.5	3.2	3.5	3.0	3.5	4.5
PA 1	9.3	1.7	2.3	2.1	2.3	2.8	3.0
CT 20	10.8	4.7	3.7	6.5	5.4	3.7	6.9
MD 50	8.7	2.0	1.5	2.1	2.0	2.6	2.6
GA 25	11.7	3.0	2.7	4.1	3.9	3.0	4.7
MD 57	10.9	3.9	3.1	3.9	5.5	3.8	5.7
MD 100	10.3	1.9	2.0	2.8	2.3	2.4	4.1
VA 24	11.0	2.2	2.3	3.8	2.5	2.3	4.2
MD 97	10.5	3.0	2.5	4.0	2.8	2.8	4.6
MD 87	10.0	1.8	2.7	3.6	2.7	3.6	4.3

Note:

1 ft. = 0.30 metre

Table 60. Lateral placement variance data for horizontal curves.

Site Number	Lateral Placement Variance — Inside Curve (ft.^{2})					
	Day			Night		
	Advance Point 1	Point of Curve 2	Curve Midpoint 3	Advance Point 1	Point of Curve 2	Curve Midpoint 3
MD 94	1.2	1.1	1.7	1.2	0.9	1.2
PA 1	1.1	0.7	1.2	1.1	0.8	1.4
CT 20	2.8	1.8	4.0	3.1	1.9	3.7
MD 50	0.8	0.9	0.7	3.4	0.9	1.6
GA 25	1.3	0.7	1.5	1.9	0.6	0.9
MD 57	1.3	1.7	1.2	2.1	3.2	0.7
MD 100	1.2	0.9	0.7	1.4	0.9	0.7
VA 24	1.2	0.8	1.5	1.3	1.0	1.4
MD 97	1.5	1.0	3.3	1.1	1.1	1.7
MD 87	2.9	0.7	9.7	1.5	1.9	4.1
	Lateral Placement Variance — Outside Curve (ft.^{2})					
MD 94	1.5	2.3	2.0	1.5	2.2	2.9
PA 1	1.3	0.8	1.0	1.7	1.3	2.4
CT 20	3.7	2.1	4.5	3.2	1.3	3.8
MD 50	4.2	4.9	1.5	1.4	7.9	1.4
GA 25	1.4	2.0	1.5	1.6	2.9	1.6
MD 57	1.4	1.8	5.6	1.9	2.7	6.4
MD 100	0.9	0.7	1.7	1.0	0.7	1.5
VA 24	1.0	1.8	1.6	0.8	1.0	1.4
MD 97	1.3	0.9	3.8	1.7	1.0	4.4
MD 87	1.2	5.3	1.7	5.8	6.6	4.7

Note:

1 ft. = 0.30 metre and 1 ft.^{2} = 0.093 m^2

APPENDIX D

PHASE I ACCIDENT RATES TABULATED BY SITUATION

This appendix contains selected accident statistics for the Phase I study sites. Special attention should be paid to the nonintersection, delineationrelated drynight rates listed in the fifth column from the right in the tables.

Table 61. Accident rates for tangent sites.

Delineation Treatment	Cell No.	Site Number	Average ADT Volume	Avg. No. of Accidents Per Mile Per Year	Avg. No. of Non-Intersection Accidents Per Mile Per Year	Non-Intersection Average Accident Rates[1]											
						Total Accidents						Delineation-Related					
						Dry			Dry & Wet			Dry			Dry & Wet		
						Day	Night	D&N	Day	Night	D&N	Day	Night	D&N	Day	Night	D&N
Centerline Only	1	VA 56	1,235	0.55	0.55	0.97	4.35	1.58	0.67	3.84	1.24	0.55	3.06	1.01	0.38	2.62	0.77
	2	LA 32	1,270	0.49	0.49	0.46	4.23	1.21	0.64	3.00	1.12	0.46	2.54	0.87	0.64	1.80	0.87
	3	LA 7	1,025	1.09	0.88	1.40	9.75	3.00	1.19	7.80	2.45	0.98	4.58	1.66	0.87	3.77	1.42
	4	VA 50	4,025	4.54	3.10	1.59	6.23	2.61	1.44	4.55	2.11	1.37	5.71	2.31	1.25	4.03	1.86
	5	LA 29	3,700	2.08	1.68	0.95	2.70	1.34	0.80	2.46	1.18	0.76	1.78	0.97	0.66	1.79	0.91
Centerline & Edgelines	8	MD 60	725	1.85	1.85	2.11	21.48	7.34	1.46	21.65	6.93	0.70	3.84	1.55	0.49	9.44	2.90
	9	VA 13	1,600	0.77	0.56	0.86	2.22	1.10	0.70	2.06	0.94	0.28	1.50	0.49	0.30	1.59	0.52
	10	VA 16	1,560	1.08	0.95	1.21	4.20	1.82	1.09	3.48	1.61	0.79	1.72	0.98	0.72	1.63	0.91
	11	MD 106	3,350	3.46	2.69	1.77	3.73	2.24	1.64	3.92	2.18	1.77	1.80	1.79	1.63	2.62	1.87
	12	VA 25	3,925	1.14	0.88	0.90	3.52	1.50	0.77	2.92	1.26	0.41	0.44	0.42	0.37	0.43	0.36
	13	CT 19	1,375	0.21	0.21	0.76	0.00	0.64	0.50	0.00	0.42	0.76	0.00	0.64	0.50	0.00	0.42
	14	CT 30	3,100	1.19	0.94	0.72	3.60	1.34	0.55	3.00	1.07	0.56	3.60	1.22	0.44	2.69	0.92

Note:

[1]Accidents per million vehicle miles; 1 mi. = 1.61 km

Table 62. Accident rates for winding sites.

Delineation Treatment	Cell No.	Site Number	Average ADT Volume	Avg. No. of Accidents Per Mile Per Year	Avg. No. of Non-Intersection Accidents Per Mile Per Year	Non-Intersection Average Accident Rates[1]											
						Total Accidents						Delineation-Related					
						Dry			Dry & Wet			Dry			Dry & Wet		
						Day	Night	D&N	Day	Night	D&N	Day	Night	D&N	Day	Night	D&N
Centerline Only	1	CT 6	650	0.48	0.37	1.62	3.44	1.99	1.06	3.36	1.51	1.22	3.47	1.66	0.80	2.85	1.21
	2	VA 5	825	0.62	0.55	1.26	0.94	1.18	1.35	3.64	1.79	0.59	0.00	0.47	0.72	0.00	0.57
	3	LA 13	575	0.18	0.18	0.90	2.20	1.18	0.64	1.56	0.82	0.90	0.00	0.71	0.69	0.00	0.50
	4	PA 2	3,760	3.96	3.59	4.58	10.11	5.70	4.43	10.90	5.75	3.97	6.38	4.40	4.03	7.80	4.78
	5	VA 51	3,300	2.75	2.61	1.49	5.71	2.42	1.43	4.68	2.10	0.96	4.78	1.80	0.96	3.81	1.60
Centerline & Edgelines	6	GA 15	700	0.38	0.29	1.23	2.44	1.48	0.86	2.20	1.13	1.23	2.44	1.48	0.86	2.20	1.13
	7	MD 4	1,400	1.97	1.76	1.00	8.54	2.89	1.02	10.76	3.48	0.77	7.04	2.33	0.68	9.72	2.90
	8	VA 27	900	1.24	1.06	2.65	6.80	3.78	1.84	6.68	3.15	1.86	3.89	2.39	1.29	4.19	2.05
	9	MD 3	4,250	8.38	7.88	2.15	11.33	3.98	2.76	14.25	5.07	2.04	10.24	3.69	2.60	12.30	4.56
	10	CT 32	4,100	2.55	1.83	0.68	2.35	1.01	1.06	2.45	1.34	0.68	2.06	0.96	1.04	2.30	1.30

Note:

[1]Accidents per million vehicle mile; 1 mi. = 1.61 km

Table 63. Accident rates for horizontal curve sites.

Delineation Treatment	Cell No.	Site Number	Average ADT Volume	Avg. No. of Non-Intersection Accidents Per Mile Per Year	Non-Intersection Average Accident Rates[1]											
					Total Accidents						Delineation-Related					
					Dry			Dry & Wet			Dry			Dry & Wet		
					Day	Night	D&N	Day	Night	D&N	Day	Night	D&N	Day	Night	D&N
Centerline Only	1	MD 94	612	4.00	1.58	0.00	1.26	1.10	0.00	0.88	1.58	0.00	1.26	1.10	0.00	0.88
	2	PA 1	2,600	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		CT 10	4,050	6.67	0.20	0.00	0.16	0.29	0.00	0.23	0.20	0.00	0.16	0.29	0.00	0.23
		MD 36	5,600	14.07	0.17	3.73	0.89	0.12	2.59	0.61	0.17	3.05	0.75	0.12	2.11	0.52
	3	CT 20	825	1.67	0.79	0.00	0.63	0.52	0.00	0.42	0.79	0.00	0.63	0.52	0.00	0.42
		CT 2	600	8.33	1.46	6.37	2.44	0.95	4.15	1.59	1.46	6.37	2.44	0.95	4.15	1.59
Centerline & Edgelines	5	MD 50	1,638	10.77	1.76	5.19	2.45	1.66	5.36	2.40	0.56	2.55	0.96	0.39	3.54	1.02
	6	GA 25	2,300	7.14	0.35	6.16	1.51	0.24	4.29	1.05	0.35	6.16	1.51	0.24	4.29	1.05
		LA 31	3,435	3.70	0.42	1.01	0.54	0.49	1.60	0.71	0.42	1.01	0.54	0.49	1.60	0.71
		MD 31	4,900	4.44	0.66	0.00	0.53	0.46	0.00	0.37	0.66	0.00	0.53	0.46	0.00	0.37
	8	MD 57	1,125	7.50	0.92	3.68	1.47	1.27	2.55	1.53	0.92	0.00	0.74	1.27	0.00	1.02
		MD 56	538	6.35	0.00	16.73	3.35	0.00	11.60	2.32	0.00	0.00	0.00	0.00	0.00	0.00
		MD 71	1,475	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Centerline, Edgelines, & Post-Mounted Delineators	9	MD 100	2,200	2.22	0.00	1.76	0.35	0.00	1.22	0.24	0.00	1.76	0.35	0.00	1.22	0.24
	10	VA 24	2,152	4.40	0.68	2.86	1.11	0.47	1.97	0.77	0.29	1.53	0.54	0.20	1.05	0.37
		CT 31	2,750	9.72	0.96	3.18	1.41	0.63	2.73	1.05	0.64	2.12	0.93	0.42	2.04	0.74
		WA 36	3,150	1.25	0.00	2.17	0.43	0.00	0.86	0.17	0.00	2.17	0.43	0.00	0.86	0.17
	11	MD 97	1,012	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	12	MD 87	3,312	17.14	0.88	3.75	1.46	0.61	2.60	1.01	0.60	2.47	0.98	0.42	1.71	0.68
		WA 48	2,675	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Note:

[1] Accidents per million vehicles

APPENDIX E

CHARACTERISTICS OF PHASE II STUDY SITES

Similar to Appendix A, this appendix describes the location, traffic composition, lane width, shoulder width, and speed limit of each Phase II study site. Additionally, information is provided on the alignment characteristics of curvilinear sites and the treatment acclimation distances for all sites.

Table 64. Phase II study site characteristics.

Site No.	Location		Overall Section Type and Length[1] (mi.)	Average 1976–1977 Traffic[2]			Roadway Width[3] (ft.)	Shoulder Width[3] (ft.)	Speed Limit (mph)
	Route No.	Description of Endpoint(s)		ADT	Percent Trucks				
					Day	Night			
1	U.S. 2	ME 23N - ME 152	7.9 - T	2,225	1.9	1.0	22.0	8	55
2	U.S. 2	ME 152 - ME 7N	5.3 - T	2,835	1.9	1.4	23.0	10	55
3	MD 67	South from US 40A	2.8 - T	3,090	14.8	7.3	23.2	10	55
4	VA 3	West from VA 663	3.6 - T	3,435	18.5	8.4	21.5	9	55
5	MD 482	East from MD 27	4.6 - W	4,225	8.7	9.1	19.1	11	50
6	PA 879	West of Curwensville	3.8 - W	5,525	22.3	11.1	23.3	10	45
7	MD 227	1.6 mi. W. of US 301	0.4 - HC	2,575	5.5	1.2	18.2	3	40
8	PA 45	1.6 mi. E. of PA 144	0.4 - HC	4,715	11.4	3.1	18.5	3	55
10	IL 185	M.P. 3.81 - M.P. 8.59	4.8 - T	2,450	3.2	1.2	21.0	3	55

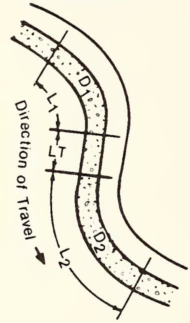
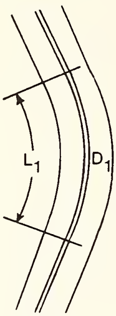
Note: 1 foot = 0.30 metre and 1 mile = 1.61 km.

[1]T = tangent, W = winding, HC = isolated horizontal curve; "length" is that distance used for defining "base condition" accident rates and may not be continuous mileage (i.e., a few curves were deleted to satisfy tangent definition).

[2]Average of field counts from several data collection periods.

[3]Average for all levels of delineaton system evaluated. (See widths by level in Appendix F.)

Table 65. Geometric details of curvilinear study sites.

Definition of Geometric Elements	Site Number	Curve #1 D_1 (°)	Curve #1 L_1 (ft.)	Curve #1 Central ∡ (°)	Tangent LT (ft.)	Curve #2 D_2 (°)	Curve #2 L_2 (ft.)	Curve #2 Central ∡ (°)	L_1 + LT + L_2 (ft.)
Inside curve followed by outside curve 	5	8	860	69	120	7	620	43½	1,600
	6	13	810	105	400	17	900	153	2,110
	7	7	500	35					
	8	5	400	20					

Note: 1 foot = 0.30 metre

Table 66. Treatment acclimation distances.

Site No.	Direction of Travel	Range of Treatment Application	Location of Traps[1]	Acclimation Distance (mi.)
1	EB	VDS 399 → VDS 336	VDS 341	2.2
2	WB	VDS 004 → VDS 072	VDS 067	2.4
3	NB	M.P. 9.3 → M.P. 11.8	M.P. 11.0	1.7
4A	EB	M.P. 9.4 → M.P. 8.1	M.P. 8.7	0.7
4B	EB	M.P. 12.6 → M.P. 9.4	M.P. 10.8	1.8
5	WB	M.P. 3.0 → M.P. 1.6	M.P. 2.0	1.0
6	EB	Sta. 474 → Sta. 369	Sta. 405	1.3
7	Both	Curve ± 400 ft.	PC + 500 ft.	N/A
8	Both	Curve ± 200 ft.	PC + 500 ft.	N/A
10	WB	Not applicable	650E @ 1800N	N/A

Note: 1 mi. = 1.61 km. and 1 ft. = 0.30 m.

[1]Midpoint of monitored subsection for tangent and winding sites; "advance point" stations for isolated horizontal curves.

APPENDIX F

TPM SUMMARY TABLES SHOWING SELECTED TEST STATISTICS

Presented herein is a series of computer-written tables whose primary purpose is to list the means and variances of the Phase II traffic performance data. Secondary purposes are to show selected between-treatment and between-condition values of t, F, and df (used in testing for statistically significant TPM differences), and to describe the miscellaneous temporal characteristics of the data collection periods.

To access specific subsets of data, reference should be made to the index tables which introduce the detailed data for a given study site; these index tables are listed, of course, in the Table of Contents. Refer to the first section of Chapter XI for a discussion of table format and interpretation.

Table 67. Index for Table 68.

SITE NO. 1 — ME 2W

Sheet	Column[1]	Cell	Environmental Code[2]	Days of Acclimation Time
A	1	11	DNT	N/A
	2	12	DNT	8-9
	3	13	DNT	1-2
	4	13	DNT	8-9
B	1*	11	DNT	N/A
	2	12	DNT	11-12
	3	13	DNT	8-9
	4	13	DDY	9
C	1	11	DDY	N/A
	2	12	DDY	8
	3	13	DDY	1-2
	4*	13	DDY	9
D	1*	11	DDY	N/A
	2	12	DDY	11
	3	13	DDY	9
	4*	13	DNT	8-9
E	1*	11	DNT	N/A
	2	11	WNT	N/A
	3	11	WDY	N/A
	4*	11	DDY	N/A
F	1*	12	DNT	11-12
	2	12	WNT	13-14
	3	12	WDY	13-14
	4*	12	DDY	11

[1] * = These data were already presented in an earlier column.

[2] DNT = Dry-Night, DDY = Dry-Day, WNT = Wet-Night, WDY = Wet-Day.

TABLE 68A. DETAILED SPEED AND LATERAL PLACEMENT REPORT FOR ROUTE ME 2W (TANGENT)

ITEM	CELL 11	T(DF) / F	CELL 12	T(DF) / F	CELL 13	T(DF) / F	CELL 13
DELINEATION TREATMENT:	CENTERLINE EDGELINES		CTR & EDGELINES PMD'S AT 528FT.		CTR & EDGELINES PMD'S AT 264FT.		CTR & EDGELINES PMD'S AT 264FT.
INSTALL. DATE & DOE:	**/**/**, ***		10/ 7/76, 2		10/21/76, 16		10/21/76, 16
DATA COLLECTION PERIOD:	DRY - NIGHT		DRY - NIGHT		DRY - NIGHT		DRY - NIGHT
DATE(S) & D.O.W.(S): DAY(S) OF EXPERIMENT: DAYS OF ACCLIMATION: ADT & PERCENT TRKS:	10/ 5- 6, TUE-WED 0 - 1 *** -*** 2580 0.0		10/15-16, FRI-SAT 10 - 11 8 - 9 2240 0.0		10/22-23, FRI-SAT 17 - 18 1 - 2 2100 0.0		10/29-30, FRI-SAT 24 - 25 8 - 9 1960 0.7
SPEED -- MEAN, (NUMBER OF OBSER.), VARIANCE							
TRAP UPSTREAM:	53.2 (125) 50.0	0.51(232) 1.69	52.8 (145) 29.7	3.71(244) 1.59	55.6 (129) 47.0	2.16(257) 1.30	53.9 (150) 36.2
T-VAL(DF), F-VAL:	0.70(247), 1.16		0.39(287), 1.16		1.23(256), 1.03		2.23(298), 1.07
TRAP DOWNSTREAM:	52.6 (125) 43.2	0.07(251) 1.26	52.5 (145) 34.3	2.63(255) 1.33	54.5 (129) 45.7	2.84(263) 1.19	52.3 (150) 38.5
MORE INTERCELL STAT:			2.74(252), 1.06	0.89(245) 1.38	1.67(292), 1.22		
LATERAL PLACEMENT -- MEAN, (NUMBER OF OBSER.), VARIANCE				(Average LW = 11.0' for all cells.)			
TRAP UPSTREAM:	4.0 (125) 1.6	1.72(259) 1.09	3.8 (145) 1.5	4.35(272) 1.16	4.4 (129) 1.3	2.56(268) 1.07	4.0 (150) 1.2
T-VAL(DF), F-VAL:	2.75(239), 1.49		1.35(286), 1.21		4.41(256), 1.09		3.53(298), 1.01
TRAP DOWNSTREAM:	3.6 (125) 1.1	0.31(266) 1.13	3.6 (145) 1.2	1.20(264) 1.13	3.7 (129) 1.4	1.10(263) 1.18	3.6 (150) 1.2
MORE INTERCELL STAT:			2.35(247), 1.27	0.10(246) 1.36	2.05(288), 1.25		

TABLE 68B. DETAILED SPEED AND LATERAL PLACEMENT REPORT FOR ROUTE ME 2W (TANGENT)

ITEM	CELL 11	T(DF) / F	CELL 12	T(DF) / F	CELL 13	T(DF) / F	CELL 13
DELINEATION TREATMENT:	CENTERLINE EDGELINES		CTR & EDGELINES PMD'S AT 528FT.		CTR & EDGELINES PMD'S AT 264FT.		CTR & EDGELINES PMD'S AT 264FT.
INSTALL. DATE & DOE:	**/**/**, ***		10/ 7/76, 2		10/21/76, 16		10/21/76, 16
DATA COLLECTION PERIOD:	DRY - NIGHT		DRY - NIGHT		DRY - NIGHT		DRY - DAY
DATE(S) & D.O.W.(S):	10/ 5- 6, TUE-WED		10/18-19, MON-TUE		10/29-30, FRI-SAT		10/30-30, SAT-SAT
DAY(S) OF EXPERIMENT:	0 - 1		13 - 14		24 - 25		25 - 25
DAYS OF ACCLIMATION:	*** -***		11 - 12		8 - 9		9 - 9
ADT & PERCENT TRKS:	2580 0.0		2240 2.9		1960 0.7		1960 0.7
SPEED -- MEAN, (NUMBER OF OBSER.), VARIANCE							
TRAP UPSTREAM:	53.2 (125) 50.0	1.53(224) 1.25	54.5 (102) 39.8	0.81(210) 1.10	53.9 (150) 36.2	2.52(294) 1.18	55.7 (148) 42.7
T-VAL(DF), F-VAL:	0.70(247), 1.16		0.66(202), 1.02		2.23(298), 1.07		2.52(294), 1.06
TRAP DOWNSTREAM:	52.6 (125) 43.2	1.60(219) 1.07	54.0 (102) 40.5	2.01(214) 1.05	52.3 (150) 38.5	2.08(296) 1.05	53.9 (148) 40.5
MORE INTERCELL STAT:			0.89(245), 1.38	3.07(256) 1.17	1.45(223), 1.07		
LATERAL PLACEMENT -- MEAN, (NUMBER OF OBSER.), VARIANCE			(Average LW = 11.0' for all cells.)				
TRAP UPSTREAM:	4.0 (125) 1.6	0.53(225) 1.47	4.1 (102) 1.1	0.50(223) 1.08	4.0 (150) 1.2	3.11(295) 1.13	3.6 (148) 1.3
T-VAL(DF), F-VAL:	2.75(239), 1.49		2.52(198), 1.38		3.53(298), 1.01		2.77(279), 1.61
TRAP DOWNSTREAM:	3.6 (125) 1.1	1.11(225) 1.36	3.8 (102) 0.8	1.33(241) 1.46	3.6 (150) 1.2	2.58(290) 1.40	3.3 (148) 0.8
MORE INTERCELL STAT:			0.10(246), 1.36	2.64(254) 1.20	3.36(231), 1.22		

TABLE 68C. DETAILED SPEED AND LATERAL PLACEMENT REPORT FOR ROUTE ME 2W (TANGENT)

ITEM	CELL 11	T(DF) / F	CELL 12	T(DF) / F	CELL 13	T(DF) / F	CELL 13
DELINEATION TREATMENT:	CENTERLINE EDGELINES		CTR & EDGELINES PMD'S AT 528FT.		CTR & EDGELINES PMD'S AT 264FT.		CTR & EDGELINES PMD'S AT 264FT.
INSTALL. DATE & DOE:	**/**/**, ***		10/ 7/76. 2		10/21/76. 16		10/21/76. 16
DATA COLLECTION PERIOD:	DRY - DAY		DRY - DAY		DRY - DAY		DRY - DAY
DATE(S) & D.O.W.(S):	10/ 5- 5. TUE-TUE		10/15-15. FRI-FRI		10/22-23. FRI-SAT		10/30-30. SAT-SAT
DAY(S) OF EXPERIMENT:	0 - 0		10 - 10		17 - 18		25 - 25
DAYS OF ACCLIMATION:	*** -***		8 - 8		1 - 2		9 - 9
ADT & PERCENT TRKS:	2580 1.2		2240 1.3		2100 0.0		1960 0.7
SPEED -- MEAN, (NUMBER OF OBSER.), VARIANCE							
TRAP UPSTREAM:	53.8 (421) 36.9	2.28(224) 1.51	55.3 (150) 55.7	1.50(289) 1.43	56.5 (150) 38.8	1.00(295) 1.10	55.7 (148) 42.7
T-VAL(DF), F-VAL:	1.03(840), 1.04		0.46(298), 1.09		1.33(298), 1.00		2.52(294), 1.06
TRAP DOWNSTREAM:	53.3 (421) 38.3	3.60(234) 1.34	55.7 (150) 51.2	0.21(293) 1.32	55.5 (150) 38.7	2.29(296) 1.05	53.9 (148) 40.5
MORE INTERCELL STAT:			4.64(257), 1.05	3.25(242) 1.16	0.55(292), 1.30		
LATERAL PLACEMENT -- MEAN, (NUMBER OF OBSER.), VARIANCE			(Average LW = 11.0' for all cells.)				
TRAP UPSTREAM:	3.3 (421) 1.6	0.06(270) 1.06	3.3 (150) 1.5	1.65(298) 1.09	3.5 (150) 1.4	0.62(296) 1.01	3.6 (148) 1.3
T-VAL(DF), F-VAL:	1.56(806), 1.52		0.13(279), 1.73		2.94(285), 1.54		2.77(279), 1.61
TRAP DOWNSTREAM:	3.2 (421) 1.0	1.45(286) 1.70	3.3 (150) 0.9	1.39(298) 1.03	3.2 (150) 0.9	0.98(296) 1.05	3.3 (148) 0.8
MORE INTERCELL STAT:			1.94(280), 1.15	2.67(275) 1.16	2.25(296), 1.09		

TABLE 68D. DETAILED SPEED AND LATERAL PLACEMENT REPORT FOR ROUTE ME 2W (TANGENT)

ITEM	CELL 11	T(DF) / F	CELL 12	T(DF) / F	CELL 13	T(DF) / F	CELL 13
DELINEATION TREATMENT:	CENTERLINE EDGELINES		CTR & EDGELINES PMD'S AT 528FT.		CTR & EDGELINES PMD'S AT 264FT.		CTR & EDGELINES PMD'S AT 264FT.
INSTALL. DATE & DOE:	**/**/**, ***		10/ 7/76, 2		10/21/76, 16		10/21/76, 16
DATA COLLECTION PERIOD:	DRY - DAY		DRY - DAY		DRY - DAY		DRY - NIGHT
DATE(S) & D.O.W.(S):	10/ 5- 5, TUE-TUE		10/18-18, MON-MON		10/30-30, SAT-SAT		10/29-30, FRI-SAT
DAY(S) OF EXPERIMENT:	0 - 0		13 - 13		25 - 25		24 - 25
DAYS OF ACCLIMATION:	*** -***		11 - 11		9 - 9		8 - 9
ADT & PERCENT TRKS:	2580 1.2		2240 2.5		1960 0.7		1960 0.7
SPEED -- MEAN, (NUMBER OF OBSER.), VARIANCE							
TRAP UPSTREAM:	53.8 (421) 36.9	3.30(640) 1.36	55.4 (326) 50.3	0.55(307) 1.18	55.7 (148) 42.7	2.52(294) 1.18	53.9 (150) 36.2
T-VAL(DF), F-VAL:	1.03(840), 1.04		0.12(650), 1.06		2.52(294), 1.06		2.23(298), 1.07
TRAP DOWNSTREAM:	53.3 (421) 38.3	4.10(660) 1.24	55.3 (326) 47.4	2.25(306) 1.17	53.9 (148) 40.5	2.08(296) 1.05	52.3 (150) 38.5
MORE INTERCELL STAT:			3.25(242), 1.16	0.27(265) 1.02	2.33(338), 1.39		
LATERAL PLACEMENT -- MEAN, (NUMBER OF OBSER.), VARIANCE				(Average LW = 11.0' for all cells.)			
TRAP UPSTREAM:	3.3 (421) 1.6	0.46(709) 1.06	3.4 (326) 1.5	2.23(296) 1.09	3.6 (148) 1.3	3.11(295) 1.13	4.0 (150) 1.2
T-VAL(DF), F-VAL:	1.56(806), 1.52		4.09(613), 1.65		2.77(279), 1.61		3.53(298), 1.01
TRAP DOWNSTREAM:	3.2 (421) 1.0	2.56(720) 1.15	3.0 (326) 0.9	2.96(293) 1.06	3.3 (148) 0.8	2.58(290) 1.40	3.6 (150) 1.2
MORE INTERCELL STAT:			2.67(275), 1.16	6.57(298) 1.31	5.98(320), 1.24		

TABLE 68E. DETAILED SPEED AND LATERAL PLACEMENT REPORT FOR ROUTE ME 2W (TANGENT)

ITEM	CELL 11	T(DF) / F	CELL 11	T(DF) / F	CELL 11	T(DF) / F	CELL 11
DELINEATION TREATMENT:	CENTERLINE EDGELINES		CENTERLINE EDGELINES		CENTERLINE EDGELINES		CENTERLINE EDGELINES
INSTALL. DATE & DOE:	**/**/**, ***		**/**/**, ***		**/**/**, ***		**/**/**, ***
DATA COLLECTION PERIOD:	DRY - NIGHT		WET - NIGHT		WET - DAY		DRY - DAY
DATE(S) & D.O.W.(S):	10/ 5- 6. TUE-WED		10/ 6- 7. WED-THU		10/ 6- 6. WED-WED		10/ 5- 5. TUE-TUE
DAY(S) OF EXPERIMENT:	0 - 1		1 - 2		1 - 1		0 - 0
DAYS OF ACCLIMATION:	*** -***		*** -***		*** -***		*** -***
ADT & PERCENT TRKS:	2580 0.0		2510 3.3		2510 3.3		2580 1.2
SPEED -- MEAN, (NUMBER OF OBSER.), VARIANCE							
TRAP UPSTREAM:	53.2 (125) 50.0	0.08(245) 1.04	53.3 (122) 51.8	1.34(234) 1.46	54.4 (151) 35.4	1.06(270) 1.04	53.8 (421) 36.9
T-VAL(DF), F-VAL:	0.70(247), 1.16		0.02(242), 1.01		0.91(299), 1.16		1.03(840), 1.04
TRAP DOWNSTREAM:	52.6 (125) 43.2	0.75(242) 1.21	53.2 (122) 52.3	0.54(245) 1.27	53.7 (151) 41.2	0.64(257) 1.07	53.3 (421) 38.3
MORE INTERCELL STAT:			1.46(243), 1.41	0.80(182) 1.35	0.68(175), 1.40		
LATERAL PLACEMENT -- MEAN, (NUMBER OF OBSER.), VARIANCE			(Average LW = 11.0' for all cells.)				
TRAP UPSTREAM:	4.0 (125) 1.6	1.64(243) 1.30	4.3 (122) 1.2	7.39(263) 1.08	3.2 (151) 1.3	0.70(283) 1.15	3.3 (421) 1.6
T-VAL(DF), F-VAL:	2.75(239), 1.49		4.39(240), 1.20		1.56(290), 1.48		1.56(806), 1.52
TRAP DOWNSTREAM:	3.6 (125) 1.1	0.41(245) 1.05	3.7 (122) 1.0	5.08(252) 1.14	3.1 (151) 0.9	1.61(280) 1.12	3.2 (421) 1.0
MORE INTERCELL STAT:			5.23(255), 1.20	5.38(201) 1.04	8.00(217), 1.25		

TABLE 68F. DETAILED SPEED AND LATERAL PLACEMENT REPORT FOR ROUTE ME 2W (TANGENT)

ITEM	CELL 12	T(DF) / F	CELL 12	T(DF) / F	CELL 12	T(DF) / F	CELL 12
DELINEATION TREATMENT:	CTR & EDGELINES PMD'S AT 528FT.		CTR & EDGELINES PMD'S AT 528FT.		CTR & EDGELINES PMD'S AT 528FT.		CTR & EDGELINES PMD'S AT 528FT.
INSTALL. DATE & DDF:	10/ 7/76. 2		10/ 7/76. 2		10/ 7/76. 2		10/ 7/76. 2
DATA COLLECTION PERIOD:	DRY - NIGHT		WET - NIGHT		WET - DAY		DRY - DAY
DATE(S) & D.O.W.(S):	10/18-19. MON-TUE		10/20-21. WED-THU		10/20-21. WED-THU		10/18-18. MON-MON
DAY(S) OF EXPERIMENT:	13 - 14		15 - 16		15 - 16		13 - 13
DAYS OF ACCLIMATION:	11 - 12		13 - 14		13 - 14		11 - 11
ADT & PERCENT TRKS:	2240 2.9		2100 0.0		2100 2.0		2240 2.5
SPEED -- MEAN. (NUMBER OF OBSER.). VARIANCE							
TRAP UPSTREAM:	54.5 (102) 39.8	3.31(170) 1.22	51.3 (84) 48.7	4.23(153) 1.34	55.1 (150) 36.5	0.40(337) 1.38	55.4 (326) 50.3
T-VAL(DF). F-VAL:	0.66(202). 1.02		1.19(166). 1.01		2.14(298). 1.03		0.12(650). 1.06
TRAP DOWNSTREAM:	54.0 (102) 40.5	3.99(170) 1.22	50.0 (84) 49.3	3.95(154) 1.31	53.6 (150) 37.6	2.69(323) 1.26	55.3 (326) 47.4
MORE INTERCELL STAT:			0.72(211). 1.09	1.12(188) 1.26	4.77(131). 1.03		
LATERAL PLACEMENT -- MEAN. (NUMBER OF OBSER.). VARIANCE			(Average LW = 11.0' for all cells.)				
TRAP UPSTREAM:	4.1 (102) 1.1	1.91(176) 1.04	4.4 (84) 1.2	3.97(193) 1.32	3.8 (150) 1.5	3.48(285) 1.04	3.4 (326) 1.5
T-VAL(DF). F-VAL:	2.52(198). 1.38		5.34(165). 1.17		4.96(279). 1.73		4.09(613). 1.65
TRAP DOWNSTREAM:	3.8 (102) 0.8	1.49(170) 1.23	3.6 (84) 1.0	2.93(164) 1.12	3.2 (150) 0.9	1.52(291) 1.01	3.0 (326) 0.9
MORE INTERCELL STAT:			2.16(238). 1.38	5.93(193) 1.33	7.66(143). 1.27		

Table 69. Index for Table 70.

SITE NO. 2 — ME 2E

Sheet	Column[1]	Cell	Environmental Code[2]	Days of Acclimation Time
A	1	21	DNT	N/A
	2	22	DNT	0
	3	23	DNT	3
	4	24	DNT	1-2
B	1*	21	DNT	N/A
	2	22	DNT	6-7
	3	23	DNT	9-10
	4	24	DNT	9-10
C	1	22	WNT	7-8
	2	23	WNT	8-9
	3	24	WNT	7-8
	4	22	WNT	7-8
D	1	21	DDY	N/A
	2	22	DDY	0
	3	23	DDY	3
	4	24	DDY	1
E	1	21	DDY	N/A
	2	22	DDY	6
	3	23	DDY	10
	4	24	DDY	9
F	1	22	WDY	7
	2	23	WDY	9
	3	24	WDY	8
	4	22	WDY	7

[1] * = These data were already presented in an earlier column.

[2] DNT = Dry-Night, DDY = Dry-Day, WNT = Wet-Night, WDY = Wet-Day.

TABLE 70A. DETAILED SPEED AND LATERAL PLACEMENT REPORT FOR ROUTE ME 2E (TANGENT)

ITEM	CELL 21	T(DF) / F	CELL 22	T(DF) / F	CELL 23	T(DF) / F	CELL 24
DELINEATION TREATMENT:	CENTERLINE EDGELINES		CTR & EDGELINES CTR RPM'S 80FT.		CTR & EDGELINES C&E RPM'S 80FT.		CTR & EDGELINES C&E RPM'S 40FT.
INSTALL. DATE & DOE:	**/**/**, ***		10/ 1/76, 1		10/12/76, 12		10/27/76, 27
DATA COLLECTION PERIOD:	DRY - NIGHT		DRY - NIGHT		DRY - NIGHT		DRY - NIGHT
DATE(S) & D.O.W.(S):	9/30-31, THU-FRI		10/ 1- 1, FRI-FRI		10/15-15, FRI-FRI		10/28-29, THU-FRI
DAY(S) OF EXPERIMENT:	0 - 1		1 - 1		15 - 15		28 - 29
DAYS OF ACCLIMATION:	*** -***		0 - 0		3 - 3		1 - 2
ADT & PERCENT TRKS:	3130 2.8		3660 1.3		3180 0.7		2240 1.7
SPEED -- MEAN, (NUMBER OF OBSER.), VARIANCE							
TRAP UPSTREAM:	51.7 (145) 50.4	0.92(290) 1.15	52.4 (150) 43.8	2.04(293) 1.33	50.7 (150) 53.4	1.56(305) 1.20	52.0 (175) 48.7
T-VAL(DF), F-VAL:	0.40(286), 1.19		1.37(298), 1.04		0.12(298), 1.08		0.46(348), 1.09
TRAP DOWNSTREAM:	51.3 (145) 42.5	0.02(293) 1.01	51.4 (150) 42.0	0.67(294) 1.29	50.8 (150) 54.3	1.00(315) 1.02	51.6 (175) 53.2
MORE INTERCELL STAT:			1.10(293), 1.16	0.42(305) 1.04	0.54(320), 1.11		
LATERAL PLACEMENT -- MEAN, (NUMBER OF OBSER.), VARIANCE				(Average LW = 11.5' for all cells.)			
TRAP UPSTREAM:	4.3 (145) 1.9	7.84(277) 1.54	3.2 (150) 1.2	1.66(298) 1.03	3.4 (150) 1.2	0.47(322) 1.19	3.4 (175) 1.4
T-VAL(DF), F-VAL:	2.27(288), 1.10		0.01(296), 1.20		0.14(298), 1.07		1.16(347), 1.15
TRAP DOWNSTREAM:	3.9 (145) 1.7	5.34(290) 1.16	3.2 (150) 1.5	1.75(293) 1.33	3.4 (150) 1.1	1.53(320) 1.11	3.6 (175) 1.2
MORE INTERCELL STAT:			6.44(275), 1.59	6.01(287) 1.34	2.12(321), 1.15		

TABLE 70B. DETAILED SPEED AND LATERAL PLACEMENT REPORT FOR ROUTE ME 2E (TANGENT)

ITEM	CELL 21	T(DF) / F	CELL 22	T(DF) / F	CELL 23	T(DF) / F	CELL 24
DELINEATION TREATMENT:	CENTERLINE EDGELINES		CTR & EDGELINES CTR RPM'S 80FT.		CTR & EDGELINES C&E RPM'S 80FT.		CTR & EDGELINES C&E RPM'S 40FT.
INSTALL. DATE & DOE:	**/**/**, ***		10/ 1/76, 1		10/12/76, 12		10/27/76, 27
DATA COLLECTION PERIOD:	DRY - NIGHT		DRY - NIGHT		DRY - NIGHT		DRY - NIGHT
DATE(S) & D.O.W.(S):	9/30-31, THU-FRI		10/ 7- 8, THU-FRI		10/21-22, THU-FRI		11/ 5- 6, FRI-SAT
DAY(S) OF EXPERIMENT:	0 - 1		7 - 8		21 - 22		36 - 37
DAYS OF ACCLIMATION:	*** -***		6 - 7		9 - 10		9 - 10
ADT & PERCENT TRKS:	3130 2.8		3650 2.0		2070 2.1		2340 1.6
SPEED -- MEAN, (NUMBER OF OBSER.), VARIANCE							
TRAP UPSTREAM:	51.7 (145) 50.4	1.46(292) 1.23	50.4 (150) 62.0	0.90(289) 1.06	51.2 (142) 65.4	0.80(254) 1.23	50.4 (126) 80.7
T-VAL(DF), F-VAL:	0.40(286), 1.19		0.38(298), 1.01		0.98(280), 1.21		0.20(250), 1.02
TRAP DOWNSTREAM:	51.3 (145) 42.5	1.55(286) 1.47	50.0 (150) 62.6	2.20(282) 1.27	52.2 (142) 79.4	1.48(263) 1.01	50.6 (126) 78.9
MORE INTERCELL STAT:			0.49(279), 1.30	1.29(237) 1.60	0.01(251), 1.30		
LATERAL PLACEMENT -- MEAN, (NUMBER OF OBSER.), VARIANCE			(Average LW = 11.5' for all cells.)				
TRAP UPSTREAM:	4.3 (145) 1.9	5.44(284) 1.34	3.5 (150) 1.4	0.55(290) 1.05	3.4 (142) 1.3	1.71(232) 1.73	3.1 (126) 2.3
T-VAL(DF), F-VAL:	2.27(288), 1.10		0.05(294), 1.29		1.90(273), 1.45		1.92(244), 1.38
TRAP DOWNSTREAM:	3.9 (145) 1.7	3.00(293) 1.06	3.5 (150) 1.8	1.27(271) 1.96	3.7 (142) 0.9	1.30(229) 1.83	3.5 (126) 1.7
MORE INTERCELL STAT:			5.93(279), 1.41	6.63(254) 1.23	2.17(234), 1.65		

TABLE 70C. DETAILED SPEED AND LATERAL PLACEMENT REPORT FOR ROUTE ME 2E (TANGENT)

ITEM	CELL 22	T(DF) / F	CELL 23	T(DF) / F	CELL 24	T(DF) / F	CELL 22
DELINEATION TREATMENT:	CTR & EDGELINES CTR RPM'S 80FT.		CTR & EDGELINES C&E RPM'S 80FT.		CTR & EDGELINES C&E RPM'S 40FT.		CTR & EDGELINES CTR RPM'S 80FT.
INSTALL. DATE & DOE:	10/ 1/76. 1		10/12/76. 12		10/27/76. 27		10/ 1/76. 1
DATA COLLECTION PERIOD:	WET - NIGHT		WET - NIGHT		WET - NIGHT		WET - NIGHT
DATE(S) & D.O.W.(S): DAY(S) OF EXPERIMENT: DAYS OF ACCLIMATION: ADT & PERCENT TRKS:	10/ 8- 9. FRI-SAT 8 - 9 7 - 8 3650 0.0		10/20-21. WED-THU 20 - 21 8 - 9 2070 1.5		11/ 3- 4. WED-THU 34 - 35 7 - 8 2340 0.0		10/ 8- 9. FRI-SAT 8 - 9 7 - 8 3650 0.0
SPEED -- MEAN. (NUMBER OF OBSER.). VARIANCE							
TRAP UPSTREAM:	49.7 (123) 52.0	0.16(250) 1.02	49.6 (130) 51.0	0.50(218) 1.02	50.0 (103) 52.1	0.34(218) 1.00	49.7 (123) 52.0
T-VAL(DF). F-VAL:	0.39(243). 1.16		0.28(258). 1.02		0.69(204). 1.12		0.39(243). 1.16
TRAP DOWNSTREAM:	50.0 (123) 44.7	0.84(251) 1.17	49.3 (130) 52.1	1.47(214) 1.12	50.7 (103) 58.3	0.73(205) 1.30	50.0 (123) 44.7
MORE INTERCELL STAT:			0.34(218). 1.00	0.0 (245) 1.00	0.16(250). 1.02		
LATERAL PLACEMENT -- MEAN. (NUMBER OF OBSER.). VARIANCE			(Average LW = 11.5' for all cells.)				
TRAP UPSTREAM:	3.4 (123) 1.7	2.89(247) 1.16	3.8 (130) 1.5	2.47(183) 1.83	3.4 (103) 2.7	0.09(194) 1.58	3.4 (123) 1.7
T-VAL(DF). F-VAL:	5.21(244). 1.11		0.99(239). 1.80		2.31(184). 2.02		5.21(244). 1.11
TRAP DOWNSTREAM:	2.5 (123) 1.5	8.56(223) 1.87	3.7 (130) 0.8	0.80(190) 1.63	3.8 (103) 1.3	8.05(222) 1.15	2.5 (123) 1.5
MORE INTERCELL STAT:			0.09(194). 1.58	0.0 (244) 1.00	2.89(247). 1.16		

TABLE **70D.** DETAILED SPEED AND LATERAL PLACEMENT REPORT FOR ROUTE ME 2E (TANGENT)

ITEM	CELL 21	T(DF) / F	CELL 22	T(DF) / F	CELL 23	T(DF) / F	CELL 24
DELINEATION TREATMENT:	CENTERLINE EDGELINES		CTR & EDGELINES CTR RPM'S 80FT.		CTR & EDGELINES C&E RPM'S 80FT.		CTR & EDGELINES C&E RPM'S 40FT.
INSTALL. DATE & DOE:	**/**/**, ***		10/ 1/76, 1		10/12/76, 12		10/27/76, 27
DATA COLLECTION PERIOD:	DRY - DAY		DRY - DAY		DRY - DAY		DRY - DAY
DATE(S) & D.O.W.(S): DAY(S) OF EXPERIMENT: DAYS OF ACCLIMATION: ADT & PERCENT TRKS:	9/30-30, THU-THU 0 - 0 *** -*** 3130 2.0		10/ 1- 1, FRI-FRI 1 - 1 0 - 0 3660 0.0		10/15-15, FRI-FRI 15 - 15 3 - 3 3180 0.7		10/28-28, THU-THU 28 - 28 1 - 1 2240 4.0
SPEED -- MEAN, (NUMBER OF OBSER.), VARIANCE							
TRAP UPSTREAM:	51.3 (644) 45.9	1.12(210) 1.23	50.5 (150) 56.4	2.19(292) 1.34	52.3 (150) 42.2	0.19(323) 1.33	52.4 (175) 56.0
T-VAL(DF), F-VAL:	1.47(***), 1.12		0.29(298), 1.02		0.02(296), 1.22		0.73(348), 1.02
TRAP DOWNSTREAM:	50.7 (644) 40.9	0.69(202) 1.41	50.3 (150) 57.5	2.60(281) 1.67	52.3 (150) 34.5	0.61(322) 1.60	51.8 (175) 55.0
MORE INTERCELL STAT:			1.72(231), 1.09	1.87(257) 1.22	2.30(316), 1.01		
LATERAL PLACEMENT -- MEAN, (NUMBER OF OBSER.), VARIANCE			(Average LW = 11.5' for all cells.)				
TRAP UPSTREAM:	3.8 (644) 1.6	2.35(246) 1.27	3.6 (150) 1.3	3.53(298) 1.02	3.1 (150) 1.3	0.17(321) 1.16	3.1 (175) 1.5
T-VAL(DF), F-VAL:	7.16(***), 1.42		2.12(297), 1.13		0.31(297), 1.18		2.30(341), 1.34
TRAP DOWNSTREAM:	3.3 (644) 1.1	0.48(226) 1.02	3.3 (150) 1.1	1.91(298) 1.01	3.1 (150) 1.1	1.88(317) 1.02	2.8 (175) 1.1
MORE INTERCELL STAT:			6.69(244), 1.24	6.48(284) 1.07	3.35(322), 1.19		

TABLE 70E. DETAILED SPEED AND LATERAL PLACEMENT REPORT FOR ROUTE ME 2E (TANGENT)

ITEM	CELL 21	T(DF) / F	CELL 22	T(DF) / F	CELL 23	T(DF) / F	CELL 24
DELINEATION TREATMENT:	CENTERLINE EDGELINES		CTR & EDGELINES CTR RPM'S 80FT.		CTR & EDGELINES C&E RPM'S 80FT.		CTR & EDGELINES C&E RPM'S 40FT.
INSTALL. DATE & DOE:	**/**/**. ***		10/ 1/76. 1		10/12/76. 12		10/27/76. 27
DATA COLLECTION PERIOD:	DRY - DAY		DRY - DAY		DRY - DAY		DRY - DAY
DATE(S) & D.O.W.(S):	9/30-30. THU-THU		10/ 7- 7. THU-THU		10/22-22. FRI-FRI		11/ 5- 5. FRI-FRI
DAY(S) OF EXPERIMENT:	0 - 0		7 - 7		22 - 22		36 - 36
DAYS OF ACCLIMATION:	*** -***		6 - 6		10 - 10		9 - 9
ADT & PERCENT TRKS:	3130 2.0		3650 1.4		2070 4.1		2340 2.2
SPEED -- MEAN. (NUMBER OF OBSER.). VARIANCE							
TRAP UPSTREAM:	51.3 (644) 45.9	0.21(86) 1.14	51.4 (72) 52.2	0.31(107) 1.09	51.7 (341) 56.7	0.88(390) 1.09	52.3 (184) 52.0
T-VAL(DF). F-VAL:	1.47(***). 1.12		0.0 (142). 1.16		1.70(680). 1.07		1.44(366). 1.04
TRAP DOWNSTREAM:	50.7 (644) 40.9	0.88(87) 1.10	51.4 (72) 45.0	1.42(110) 1.18	52.7 (341) 53.0	2.22(385) 1.06	51.3 (184) 50.1
MORE INTERCELL STAT:			0.99(633). 1.24	1.80(282) 1.13	0.88(130). 1.00		
LATERAL PLACEMENT -- MEAN. (NUMBER OF OBSER.). VARIANCE			(Average LW = 11.5' for all cells.)				
TRAP UPSTREAM:	3.8 (644) 1.6	3.45(92) 1.23	3.3 (72) 1.3	0.64(104) 1.00	3.2 (341) 1.3	0.11(303) 1.69	3.2 (184) 2.3
T-VAL(DF). F-VAL:	7.16(***). 1.42		1.37(142). 1.02		0.63(679). 1.11		0.89(342). 1.74
TRAP DOWNSTREAM:	3.3 (644) 1.1	2.07(86) 1.14	3.0 (72) 1.3	1.50(101) 1.09	3.3 (341) 1.2	1.87(363) 1.08	3.1 (184) 1.3
MORE INTERCELL STAT:			7.42(756). 1.22	5.01(264) 1.38	0.62(168). 1.70		

TABLE 70F. DETAILED SPEED AND LATERAL PLACEMENT REPORT FOR ROUTE ME 2E (TANGENT)

ITEM	CELL 22	T(DF) / F	CELL 23	T(DF) / F	CELL 24	T(DF) / F	CELL 22
DELINEATION TREATMENT:	CTR & EDGELINES CTR RPM'S 80FT.		CTR & EDGELINES C&E RPM'S 80FT.		CTR & EDGELINES C&E RPM'S 40FT.		CTR & EDGELINES CTR RPM'S 80FT.
INSTALL. DATE & DOE:	10/ 1/76, 1		10/12/76, 12		10/27/76, 27		10/ 1/76, 1
DATA COLLECTION PERIOD:	WET - DAY		WET - DAY		WET - DAY		WET - DAY
DATE(S) & D.O.W.(S):	10/ 8- 8, FRI-FRI		10/21-21, THU-THU		11/ 4- 4, THU-THU		10/ 8- 8, FRI-FRI
DAY(S) OF EXPERIMENT:	8 - 8		21 - 21		35 - 35		8 - 8
DAYS OF ACCLIMATION:	7 - 7		9 - 9		8 - 8		7 - 7
ADT & PERCENT TRKS:	3650 2.0		2070 2.6		2340 0.0		3650 2.0
SPEED — MEAN, (NUMBER OF OBSER.), VARIANCE							
TRAP UPSTREAM:	51.9 (151) 65.1	1.47(300) 1.07	50.6 (151) 60.6	1.97(134) 1.08	48.4 (68) 56.3	3.14(139) 1.16	51.9 (151) 65.1
T-VAL(DF), F-VAL:	0.67(297), 1.23		2.24(296), 1.27		0.68(134), 1.09		0.67(297), 1.23
TRAP DOWNSTREAM:	51.3 (151) 52.9	1.41(300) 1.11	52.5 (151) 47.6	3.11(125) 1.09	49.2 (68) 51.6	1.96(131) 1.03	51.3 (151) 52.9
MORE INTERCELL STAT:			3.14(139), 1.16	0.0 (301) 1.00	1.47(300), 1.07		
LATERAL PLACEMENT -- MEAN, (NUMBER OF OBSER.), VARIANCE				(Average LW = 11.5' for all cells.)			
TRAP UPSTREAM:	3.8 (151) 1.7	4.55(300) 1.11	3.1 (151) 1.5	5.53(134) 1.07	2.2 (68) 1.4	9.14(141) 1.19	3.8 (151) 1.7
T-VAL(DF), F-VAL:	1.75(300), 1.07		0.89(299), 1.15		3.69(134), 1.01		1.75(300), 1.07
TRAP DOWNSTREAM:	3.5 (151) 1.5	2.05(298) 1.20	3.2 (151) 1.3	1.96(125) 1.09	2.9 (68) 1.4	3.51(136) 1.11	3.5 (151) 1.5
MORE INTERCELL STAT:			9.14(141), 1.19	0.0 (300) 1.00	4.55(300), 1.11		

Table 71. Index for Table 72.

SITE NO. 3 — MD 67

Sheet	Column	Cell	Environmental Code[1]
A	1	34	DNT
	2	33	DNT
	3	32	DNT
	4	31	DNT
B	1	34	DDY
	2	33	DDY
	3	32	DDY
	4	31	DDY

[1]DNT = Dry-Night and DDY = Dry-Day.

TABLE 72A. DETAILED SPEED AND LATERAL PLACEMENT REPORT FOR ROUTE MO 67 (TANGENT)

ITEM	CELL 34	T(DF) / F	CELL 33	T(DF) / F	CELL 32	T(DF) / F	CELL 31
DELINEATION TREATMENT:	15:25 CENTERLINE STD. EDGELINES		10:30CTR W/RPM'S STD. EDGELINES		5:35 CTR W/RPM'S STD. EDGELINES		5:35 CENTERLINE STD. EDGELINES
INSTALL. DATE & DOE:	2/23/77, 120		12/ 2/76, 37		11/15/76, 20		10/26/76, 0
DATA COLLECTION PERIOD:	DRY - NIGHT		DRY - NIGHT		DRY - NIGHT		DRY - NIGHT
DATE(S) & D.O.W.(S):	4/12-12, TUE-TUE		12/ 8- 8, WED-WED		11/19-19, FRI-FRI		11/ 4- 4, THU-THU
DAY(S) OF EXPERIMENT:	168 -168		43 - 43		24 - 24		9 - 9
DAYS OF ACCLIMATION:	48 - 48		6 - 6		4 - 4		9 - 9
ADT & PERCENT TRKS:	3090 25.5		3090 2.3		3090 1.3		3090 0.0
SPEED -- MEAN, (NUMBER OF OBSER.), VARIANCE							
TRAP UPSTREAM:	51.2 (136) 61.8	1.83(257) <u>1.54</u>	52.8 (130) 40.0	0.90(276) 1.02	53.5 (156) 41.0	0.16(310) 1.11	53.4 (156) 45.7
T-VAL(DF), F-VAL:	1.10(262), <u>1.43</u>		0.59(257), 1.07		0.43(310), 1.08		0.75(310), 1.03
TRAP DOWNSTREAM:	52.2 (136) 43.3	0.20(263) 1.01	52.4 (129) 42.8	1.07(275) 1.03	53.2 (156) 44.2	0.50(310) 1.07	52.8 (156) 47.1
MORE INTERCELL STAT:			<u>2.69</u>(261), <u>1.51</u>	<u>2.50</u>(269) <u>1.35</u>	0.73(281), 1.14		
LATERAL PLACEMENT -- MEAN, (NUMBER OF OBSER.), VARIANCE			(Average LW = 11.6' for all cells.)				
TRAP UPSTREAM:	2.6 (136) 0.9	<u>4.82</u>(264) 1.19	2.1 (130) 0.7	<u>4.49</u>(284) <u>1.35</u>	2.6 (156) 1.0	<u>3.50</u>(308) 1.19	3.0 (156) 1.2
T-VAL(DF), F-VAL:	<u>6.07</u>(264), <u>1.38</u>		<u>7.30</u>(249), <u>1.44</u>		<u>4.07</u>(310), 1.08		<u>2.73</u>(310), 1.12
TRAP DOWNSTREAM:	3.4 (136) 1.2	<u>3.22</u>(263) 1.14	2.9 (129) 1.1	0.82(274) 1.01	3.0 (156) 1.1	<u>2.36</u>(307) 1.24	3.3 (156) 1.3
MORE INTERCELL STAT:			0.33(289), 1.13	<u>3.18</u>(290) <u>1.35</u>	<u>7.88</u>(284), <u>1.60</u>		

TABLE 72B. DETAILED SPEED AND LATERAL PLACEMENT REPORT FOR ROUTE MD 67 (TANGENT)

ITEM	CELL 34	T(DF) / F	CELL 33	T(DF) / F	CELL 32	T(DF) / F	CELL 31
DELINEATION TREATMENT:	15:25 CENTERLINE STD. EDGELINES		10:30CTR W/RPM'S STD. EDGELINES		5:35 CTR W/RPM'S STD. EDGELINES		5:35 CENTERLINE STD. EDGELINES
INSTALL. DATE & DOE:	2/23/77, 120		12/ 2/76, 37		11/15/76, 20		10/26/76, 0
DATA COLLECTION PERIOD:	DRY - DAY		DRY - DAY		DRY - DAY		DRY - DAY
DATE(S) & D.O.W.(S): DAY(S) OF EXPERIMENT: DAYS OF ACCLIMATION: ADT & PERCENT TRKS:	4/12-12, TUE-TUE 168 -168 48 - 48 3090 29.5		12/ 8- 8, WED-WED 43 - 43 6 - 6 3090 12.3		11/19-19, FRI-FRI 24 - 24 4 - 4 3090 9.6		11/ 4- 4, THU-THU 9 - 9 9 - 9 3090 7.7
SPEED — MEAN, (NUMBER OF OBSER.), VARIANCE							
TRAP UPSTREAM:	53.0 (147) 59.0	1.07(273) 1.06	54.0 (130) 55.7	0.52(262) 1.25	54.5 (156) 44.6	0.23(301) 1.33	54.3 (154) 59.2
T-VAL(DF), F-VAL:	0.12(288), 1.05		0.59(258), 1.07		1.24(310), 1.01		0.39(307), 1.01
TRAP DOWNSTREAM:	52.9 (143) 62.1	0.56(270) 1.04	53.5 (130) 59.6	0.08(256) 1.35	53.5 (156) 44.0	0.51(303) 1.33	53.9 (155) 58.4
MORE INTERCELL STAT:			1.71(290), 1.32	1.39(299) 1.00	0.29(277), 1.06		
LATERAL PLACEMENT -- MEAN, (NUMBER OF OBSER.), VARIANCE				(Average LW = 11.6' for all cells.)			
TRAP UPSTREAM:	2.2 (147) 1.1	1.35(275) 1.38	2.4 (130) 0.8	0.98(280) 1.12	2.5 (156) 0.9	4.29(308) 1.06	3.0 (154) 1.0
T-VAL(DF), F-VAL:	7.72(287), 1.10		7.04(257), 1.15		2.32(309), 1.13		2.27(307), 1.02
TRAP DOWNSTREAM:	3.2 (143) 1.3	0.08(271) 1.32	3.2 (130) 1.0	3.83(279) 1.10	2.8 (156) 1.0	4.13(309) 1.08	3.2 (155) 1.0
MORE INTERCELL STAT:			2.30(294), 1.24	6.26(295) 1.16	5.18(281), 1.19		

Table 73. Index for Table 74.

SITE NO. 4A — VA 3E

Sheet	Column	Cell	Environmental Code[1]
A	1	94	DNT
	2	93	DNT
	3	92	DNT
	4	91	DNT
B	1	94	DDY
	2	93	DDY
	3	92	DDY
	4	91	DDY

[1]DNT = Dry-Night and DDY = Dry-Day.

TABLE 74A. DETAILED SPEED AND LATERAL PLACEMENT REPORT FOR ROUTE VA 3E (TANGENT)

ITEM	CELL 94	T(DF) / F	CELL 93	T(DF) / F	CELL 92	T(DF) / F	CELL 91
DELINEATION TREATMENT:	4IN., 15:25 CTR 4IN. EDGELINES		4IN., 10:30 CTR 4IN. EDGELINES		2IN., 10:30 CTR 2IN. EDGELINES		2IN., 10:30 CTR NO EDGELINES
INSTALL. DATE & DOE:	3/24/77, 170		11/18/76, 44		11/ 8/76, 34		10/ 5/76, 0
DATA COLLECTION PERIOD:	DRY - NIGHT		DRY - NIGHT		DRY - NIGHT		DRY - NIGHT
DATE(S) & D.O.W.(S): DAY(S) OF EXPERIMENT: DAYS OF ACCLIMATION: ADT & PERCENT TRKS:	4/18-18, MON-MON 195 -195 25 - 25 3400 23.3		12/ 3- 3, FRI-FRI 59 - 59 15 - 15 3400 3.4		11/12-12, FRI-FRI 38 - 38 4 - 4 3120 5.2		10/26-26, TUE-TUE 21 - 21 21 - 21 3820 7.0
SPEED — MEAN, (NUMBER OF OBSER.), VARIANCE							
TRAP UPSTREAM:	53.9 (128) 39.4	1.46(264) 1.13	55.0 (149) 35.0	1.15(285) 1.50	55.7 (150) 23.3	0.40(199) 1.88	55.4 (114) 43.8
T-VAL(DF), F-VAL:	1.34(254), 1.14		0.92(296), 1.11		0.21(300), 1.05		0.40(226), 1.04
TRAP DOWNSTREAM:	52.9 (129) 34.7	1.99(274) 1.12	54.3 (149) 39.0	1.92(282) 1.60	55.6 (152) 24.4	0.71(204) 1.72	55.0 (114) 42.0
MORE INTERCELL STAT:			2.63(237), 1.69	1.80(234) 1.11	0.54(229), 1.25		
LATERAL PLACEMENT -- MEAN, (NUMBER OF OBSER.), VARIANCE	LW = 10.4'		LW = 10.4'		LW = 10.5'		LW = 11.4'
TRAP UPSTREAM:	1.4 (128) 0.5	5.78(275) 1.27	1.9 (149) 0.7	2.24(289) 1.41	1.8 (150) 0.5	13.34(236) 1.12	2.9 (114) 0.5
T-VAL(DF), F-VAL:	2.84(253), 1.23		3.55(296), 1.09		2.18(300), 1.11		1.31(226), 1.05
TRAP DOWNSTREAM:	1.1 (129) 0.6	5.01(268) 1.06	1.6 (149) 0.6	0.51(297) 1.16	1.6 (152) 0.5	13.85(246) 1.03	2.8 (114) 0.5
MORE INTERCELL STAT:			3.99(265), 1.11	16.23(237) 1.01	10.30(255), 1.25		

TABLE 74B. DETAILED SPEED AND LATERAL PLACEMENT REPORT FOR ROUTE VA 3E (TANGENT)

ITEM	CELL 94	T(DF) / F	CELL 93	T(DF) / F	CELL 92	T(DF) / F	CELL 91
DELINEATION TREATMENT:	4IN., 15:25 CTR 4IN. EDGELINES		4IN., 10:30 CTR 4IN. EDGELINES		2IN., 10:30 CTR 2IN. EDGELINES		2IN., 10:30 CTR NO EDGELINES
INSTALL. DATE & DOE:	3/24/77, 170		11/18/76, 44		11/ 8/76, 34		10/ 5/76, 0
DATA COLLECTION PERIOD:	DRY - DAY		DRY - DAY		DRY - DAY		DRY - DAY
DATE(S) & D.O.W.(S):	4/18-18, MON-MON		12/ 2- 3, THU-FRI		11/13-13, SAT-SAT		10/25-25, MON-MON
DAY(S) OF EXPERIMENT:	195 -195		58 - 59		39 - 39		20 - 20
DAYS OF ACCLIMATION:	25 - 25		14 - 15		5 - 5		20 - 20
ADT & PERCENT TRKS:	3400 37.7		3400 12.8		3120 3.8		3820 9.3
SPEED -- MEAN, (NUMBER OF OBSER.), VARIANCE							
TRAP UPSTREAM:	53.1 (120) 50.6	4.54(244) 1.20	56.8 (156) 42.2	0.43(306) 1.27	57.1 (155) 33.2	2.48(298) 1.17	55.4 (149) 38.8
T-VAL(DF), F-VAL:	1.27(236), 1.25		1.49(310), 1.07		0.71(307), 1.21		1.49(295), 1.21
TRAP DOWNSTREAM:	51.8 (120) 63.3	4.45(222) 1.60	55.8 (156) 39.5	1.25(310) 1.01	56.6 (156) 40.1	3.12(300) 1.17	54.3 (150) 46.7
MORE INTERCELL STAT:			5.11(226), 1.52	2.86(239) 1.30	1.93(303), 1.09		
LATERAL PLACEMENT -- MEAN, (NUMBER OF OBSER.), VARIANCE	LW = 10.4'		LW = 10.4'		LW = 10.5'		LW = 11.4'
TRAP UPSTREAM:	1.1 (120) 0.8	3.81(228) 1.49	1.5 (156) 0.6	4.94(306) 1.22	1.9 (155) 0.7	7.86(297) 1.20	2.7 (149) 0.8
T-VAL(DF), F-VAL:	2.58(238), 1.07		0.21(307), 1.23		0.94(307), 1.18		1.88(297), 1.00
TRAP DOWNSTREAM:	1.4 (120) 0.9	0.97(207) 1.96	1.5 (156) 0.5	4.18(306) 1.27	1.8 (156) 0.6	11.10(291) 1.43	2.9 (150) 0.8
MORE INTERCELL STAT:			7.82(243), 1.22	14.48(255) 1.01	12.83(288), 1.47		

Table 75. Index for Table 76.

SITE NO. 4B — VA 3W

Sheet	Column	Cell	Environmental Code[1]
A	1	44	DNT
	2	43	DNT
	3	42	DNT
	4	41	DNT
B	1	44	DDY
	2	43	DDY
	3	42	DDY
	4	41	DDY

[1] DNT = Dry-Night and DDY = Dry-Day.

TABLE 76A. DETAILED SPEED AND LATERAL PLACEMENT REPORT FOR ROUTE VA 3W (TANGENT)

ITEM	CELL 44	T(DF) / F	CELL 43	T(DF) / F	CELL 42	T(DF) / F	CELL 41
DELINEATION TREATMENT:	4IN., 15:25 CTR 4IN. EDGELINES		4IN., 10:30 CTR 4IN. EDGELINES		4IN., 10:30 CTR 2IN. EDGELINES		4IN., 10:30 CTR NO EDGELINES
INSTALL. DATE & DOE:	3/24/77, 170		11/18/76, 44		11/ 8/76, 34		10/ 5/76, 0
DATA COLLECTION PERIOD:	DRY - NIGHT		DRY - NIGHT		DRY - NIGHT		DRY - NIGHT
DATE(S) & D.O.W.(S): DAY(S) OF EXPERIMENT: DAYS OF ACCLIMATION: ADT & PERCENT TRKS:	4/19-19, TUE-TUE 196 -196 26 - 26 3400 18.9		12/ 2- 2, THU-THU 58 - 58 14 - 14 3400 2.0		11/12-12, FRI-FRI 38 - 38 4 - 4 3120 1.9		10/23-23, SAT-SAT 18 - 18 18 - 18 3820 5.1
SPEED -- MEAN, (NUMBER OF OBSER.), VARIANCE							
TRAP UPSTREAM:	55.6 (125) 38.5	2.22(268) 1.09	57.3 (150) 41.8	0.23(302) 1.12	57.5 (156) 37.5	0.92(309) 1.05	56.8 (155) 35.6
T-VAL(DF), F-VAL:	0.62(249), 1.19		2.10(295), 1.23		0.36(303), 1.27		0.50(302), 1.34
TRAP DOWNSTREAM:	56.1 (127) 46.0	0.56(272) 1.12	55.6 (150) 51.6	2.59(301) 1.08	57.7 (154) 47.7	1.61(307) 1.00	56.5 (155) 47.6
MORE INTERCELL STAT:			2.52(265), 1.03	1.68(261) 1.08	0.65(300), 1.17		
LATERAL PLACEMENT -- MEAN, (NUMBER OF OBSER.), VARIANCE	LW = 10.6'		LW = 10.6'		LW = 10.7'		LW = 11.1'
TRAP UPSTREAM:	2.6 (125) 0.7	1.52(273) 1.30	2.4 (150) 0.9	2.75(303) 1.06	2.7 (156) 0.9	7.34(308) 1.14	3.5 (155) 0.8
T-VAL(DF), F-VAL:	1.67(250), 1.03		3.99(298), 1.00		6.61(308), 1.14		3.07(305), 1.22
TRAP DOWNSTREAM:	2.8 (127) 0.8	0.91(275) 1.27	2.9 (150) 1.0	5.05(298) 1.21	3.4 (154) 0.8	3.77(305) 1.22	3.8 (155) 1.0
MORE INTERCELL STAT:			1.24(276), 1.23	8.60(270) 1.08	9.98(299), 1.20		

TABLE 76B. DETAILED SPEED AND LATERAL PLACEMENT REPORT FOR ROUTE VA 3W (TANGENT)

ITEM	CELL 44	T(DF) / F	CELL 43	T(DF) / F	CELL 42	T(DF) / F	CELL 41
DELINEATION TREATMENT:	4IN., 15:25 CTR 4IN. EDGELINES		4IN., 10:30 CTR 4IN. EDGELINES		4IN., 10:30 CTR 2IN. EDGELINES		4IN., 10:30 CTR NO EDGELINES
INSTALL. DATE & DOE:	3/24/77, 170		11/18/76, 44		11/ 8/76, 34		10/ 5/76, D
DATA COLLECTION PERIOD:	DRY - DAY		DRY - DAY		DRY - DAY		DRY - DAY
DATE(S) & D.O.W.(S): DAY(S) OF EXPERIMENT: DAYS OF ACCLIMATION: ADT & PERCENT TRKS:	4/19-19, TUE-TUE 196 -196 26 - 26 3400 39.1		12/ 2- 2, THU-THU 58 - 58 14 - 14 3400 30.8		11/13-13, SAT-SAT 39 - 39 5 - 5 3120 12.2		10/23-23, SAT-SAT 18 - 18 18 - 18 3820 2.6
SPEED -- MEAN, (NUMBER OF OBSER.), VARIANCE							
TRAP UPSTREAM:	51.5 (127) 49.0	4.77(246) 1.42	55.2 (156) 34.4	1.13(292) 1.66	56.0 (156) 57.3	1.14(292) 1.66	56.9 (156) 34.4
T-VAL(DF), F-VAL:	2.54(252), 1.06		0.54(305), 1.33		0.53(310), 1.00		0.29(310), 1.08
TRAP DOWNSTREAM:	53.7 (127) 52.1	1.26(262) 1.14	54.8 (156) 45.7	1.00(307) 1.25	55.6 (156) 57.1	1.50(287) 1.80	56.7 (156) 31.8
MORE INTERCELL STAT:			5.28(277), 1.17	7.00(246) 1.42	2.62(311), 1.00		
LATERAL PLACEMENT -- MEAN, (NUMBER OF OBSER.), VARIANCE	LW = 10.6'		LW = 10.6'		LW = 10.7'		LW = 11.1'
TRAP UPSTREAM:	2.4 (127) 1.5	1.66(225) 1.87	2.2 (156) 0.8	5.09(310) 1.12	1.7 (156) 0.7	14.91(310) 1.03	3.2 (156) 0.7
T-VAL(DF), F-VAL:	0.15(251), 1.16		4.64(309), 1.17		2.53(310), 1.02		3.61(309), 1.16
TRAP DOWNSTREAM:	2.5 (127) 1.3	1.98(249) 1.37	2.7 (156) 0.9	7.31(304) 1.33	2.0 (156) 0.7	16.59(310) 1.10	3.5 (156) 0.6
MORE INTERCELL STAT:			5.61(217), 2.09	5.62(219) 2.02	9.45(310), 1.08		

Table 77. Index for Table 78.

SITE NO. 5 — MD 482

Sheet	Column	Cell	Environmental Code[1]
A	1	54	DNT
	2	53	DNT
	3	52	DNT
	4	51	DNT
B	1	54	DDY
	2	53	DDY
	3	52	DDY
	4	51	DDY

[1] DNT = Dry-Night and DDY = Dry-Day.

TABLE 78A. DETAILED SPEED AND LATERAL PLACEMENT REPORT FOR ROUTE MD 482 (WINDING)

ITEM	CELL 54	T(DF) / F	CELL 53	T(DF) / F	CELL 52	T(DF) / F	CELL 51
DELINEATION TREATMENT:	STD. CENTERLINE STD. EDGELINES		CTR, RPM'S ONLY EDGELINES W/RPMS		CTR, RPM'S ONLY STD. EDGELINES		CTR, RPM'S ONLY NO EDGELINES
INSTALL. DATE & DOE:	12/29/76, 58		12/10/76, 39		11/30/76, 29		11/ 1/76, 0
DATA COLLECTION PERIOD:	DRY - NIGHT		DRY - NIGHT		DRY - NIGHT		DRY - NIGHT
DATE(S) & D.O.W.(S):	4/26-26, THU-THU		12/15-15, WED-WED		12/ 6- 6, MON-MON		11/11-11, THU-THU
DAY(S) OF EXPERIMENT:	176 -176		44 - 44		35 - 35		10 - 10
DAYS OF ACCLIMATION:	118 -118		5 - 5		6 - 6		10 - 10
ADT & PERCENT TRKS:	4210 22.3		4230 2.3		4230 0.7		4230 0.6
SPEED -- MEAN, (NUMBER OF OBSER.), VARIANCE							
TRAP INSIDE CURVE:	47.3 (119) 22.4	4.10(240) 1.15	44.9 (127) 19.4	0.42(256) 1.08	44.7 (131) 20.9	1.44(282) 1.63	43.8 (154) 34.0
T-VAL(DF), F-VAL:	2.02(239), 1.21		5.50(249), 1.20		5.52(265), 1.05		4.55(306), 1.00
TRAP P.R.C./TANGENT:	48.5 (127) 18.6	0.64(248) 1.26	48.1 (126) 23.4	0.51(258) 1.06	47.8 (136) 22.1	1.62(286) 1.54	46.8 (154) 34.1
T-VAL(DF), F-VAL:	0.47(252), 1.17		1.50(249), 1.16		1.91(262), 1.33		2.02(304), 1.09
TRAP OUTSIDE CURVE:	48.2 (128) 21.8	1.35(252) 1.09	49.0 (126) 20.1	0.00(254) 1.46	49.0 (134) 29.4	1.18(284) 1.26	48.2 (152) 37.1
T-VAL(DF), F-VAL:	1.51(244), 1.03		7.30(251), 1.03		7.01(258), 1.40		6.45(304), 1.09
MORE INTERCELL STAT:			4.46(244), 1.07	5.51(271) 1.52	1.84(277), 1.75		
LATERAL PLACEMENT -- MEAN, (NUMBER OF OBSER.), VARIANCE	LW = 9.4'		LW = 9.4'		LW = 9.4'		LW = 10.0'
TRAP INSIDE CURVE:	1.0 (119) 0.5	7.00(237) 1.25	1.7 (127) 0.4	5.31(256) 1.06	1.2 (131) 0.4	3.67(277) 1.01	1.5 (154) 0.5
T-VAL(DF), F-VAL:	3.40(244), 1.06		3.81(251), 1.06		6.38(260), 1.25		6.72(297), 1.42
TRAP P.R.C./TANGENT:	1.4 (127) 0.6	6.88(249) 1.24	2.0 (126) 0.5	3.26(251) 1.26	1.7 (136) 0.4	4.40(281) 1.80	2.1 (154) 0.6
T-VAL(DF), F-VAL:	6.21(239), 1.70		5.38(246), 1.31		2.18(264), 1.25		6.82(304), 1.06
TRAP OUTSIDE CURVE:	2.0 (128) 0.9	3.63(209) 2.76	2.4 (126) 0.3	6.63(257) 1.30	1.9 (134) 0.4	9.48(284) 1.37	2.7 (152) 0.6
T-VAL(DF), F-VAL:	9.14(235), 1.79		9.55(249), 1.23		8.09(263), 1.01		14.21(297), 1.35
MORE INTERCELL STAT:			2.04(241), 1.18	5.51(244) 1.17	1.82(272), 1.07		

TABLE 78B. DETAILED SPEED AND LATERAL PLACEMENT REPORT FOR ROUTE MD 482 (WINDING)

ITEM	CELL 54	T(DF) / F	CELL 53	T(DF) / F	CELL 52	T(DF) / F	CELL 51
DELINEATION TREATMENT:	STD. CENTERLINE STD. EDGELINES		CTR, RPM'S ONLY EDGELINES W/RPMS		CTR, RPM'S ONLY STD. EDGELINES		CTR, RPM'S ONLY NO EDGELINES
INSTALL. DATE & DOE:	12/29/76, 58		12/10/76, 39		11/30/76, 29		11/ 1/76, 0
DATA COLLECTION PERIOD:	DRY - DAY		DRY - DAY		DRY - DAY		DRY - DAY
DATE(S) & D.O.W.(S):	4/26-26, THU-THU		12/15-15, WED-WED		12/ 6- 6, MON-MON		11/11-11, THU-THU
DAY(S) OF EXPERIMENT:	176 -176		44 - 44		35 - 35		10 - 10
DAYS OF ACCLIMATION:	118 -118		5 - 5		6 - 6		10 - 10
ADT & PERCENT TRKS:	4210 8.3		4230 12.8		4230 2.1		4230 11.5
SPEED -- MEAN, (NUMBER OF OBSER.), VARIANCE							
TRAP INSIDE CURVE:	46.8 (118) 19.2	1.79(255) 1.61	45.7 (140) 30.8	0.81(265) 1.48	46.2 (131) 20.8	2.61(280) 1.26	44.7 (151) 26.1
T-VAL(DF), F-VAL:	2.70(252), 1.43		3.44(289), 1.05		3.96(269), 1.00		3.62(303), 1.05
TRAP P.R.C./TANGENT:	48.4 (136) 27.4	0.85(287) 1.07	47.9 (155) 29.3	0.84(293) 1.41	48.4 (141) 20.7	2.87(293) 1.20	46.8 (154) 25.0
T-VAL(DF), F-VAL:	1.87(252), 1.28		1.50(272), 1.21		0.45(273), 1.12		0.36(307), 1.08
TRAP OUTSIDE CURVE:	49.7 (127) 35.0	1.11(259) 1.01	48.9 (134) 35.3	0.41(256) 1.52	48.6 (136) 23.3	2.79(289) 1.16	47.0 (155) 27.0
T-VAL(DF), F-VAL:	4.41(232), 1.82		4.62(269), 1.15		4.26(265), 1.12		3.92(304), 1.03
MORE INTERCELL STAT:			1.08(246), 1.08	3.65(265) 1.36	1.60(282), 1.18		
LATERAL PLACEMENT -- MEAN, (NUMBER OF OBSER.), VARIANCE	LW = 9.4'		LW = 9.4'		LW = 9.4'		LW = 10.0'
TRAP INSIDE CURVE:	1.1 (118) 0.5	5.58(254) 1.17	1.6 (140) 0.6	2.85(269) 1.14	1.3 (131) 0.5	2.48(269) 1.15	1.5 (151) 0.4
T-VAL(OF), F-VAL:	4.52(242), 2.03		3.54(283), 1.21		5.93(264), 1.19		5.64(296), 1.44
TRAP P.R.C./TANGENT:	1.6 (136) 1.0	3.16(236) 2.09	1.9 (155) 0.5	0.82(294) 1.13	1.8 (141) 0.4	2.20(290) 1.50	2.0 (154) 0.6
T-VAL(DF), F-VAL:	5.26(253), 1.25		1.75(276), 1.13		3.38(219), 2.81		0.88(304), 1.24
TRAP OUTSIDE CURVE:	2.2 (127) 1.2	4.37(217) 2.31	1.7 (134) 0.5	3.98(238) 2.20	2.2 (136) 1.1	0.82(261) 1.51	2.1 (155) 0.8
T-VAL(OF), F-VAL:	9.94(215), 2.53		1.69(272), 1.07		7.64(234), 2.35		6.24(286), 1.79
MORE INTERCELL STAT:			2.83(245), 1.02	5.43(245) 1.12	0.61(277), 1.31		

Table 79. Index for Table 80.

SITE NO. 6 — PA 879

Sheet	Column[1]	Cell	Environmental Code[2]
A	1	63	DNT
	2	62	DNT
	3	61	DNT
	4*	63	DNT
B	1	63	DDY
	2	62	DDY
	3	61	DDY
	4*	63	DDY

[1]* = These data were already presented in an earlier column.

[2]DNT = Dry-Night and DDY = Dry-Day.

TABLE 80A. DETAILED SPEED AND LATERAL PLACEMENT REPORT FOR ROUTE PA 879 (WINDING)

ITEM	CELL 63	T(DF) / F	CELL 62	T(DF) / F	CELL 61	T(DF) / F	CELL 63
DELINEATION TREATMENT:	DOUBLE CTRLINE STD. EDGELINES		SINGLE CTRLINE STD. EDGELINES		SINGLE CTRLINE NO EDGELINES		DOUBLE CTRLINE STD. EDGELINES
INSTALL. DATE & DDE:	4/ 1/77, 157		11/24/76, 29		10/26/76, 0		4/ 1/77, 157
DATA COLLECTION PERIOD:	DRY - NIGHT		DRY - NIGHT		DRY - NIGHT		DRY - NIGHT
DATE(S) & D.O.W.(S):	5/ 3- 3, TUE-TUE		12/16-16, THU-THU		11/ 5- 5, FRI-FRI		5/ 3- 3, TUE-TUE
DAY(S) OF EXPERIMENT:	189 -189		51 - 51		10 - 10		189 -189
DAYS OF ACCLIMATION:	32 - 32		22 - 22		10 - 10		32 - 32
ADT & PERCENT TRKS:	5290 18.5		5080 9.6		6200 5.1		5290 18.5
SPEED -- MEAN, (NUMBER OF OBSER.), VARIANCE							
TRAP INSIDE CURVE:	44.8 (105) 35.7	2.37(215) 1.17	43.0 (130) 30.6	5.12(219) 2.24	40.1 (153) 13.7	7.19(159) 2.62	44.8 (105) 35.7
T-VAL(DF), F-VAL:	1.05(211), 1.18		1.89(266), 1.14		5.69(298), 1.40		1.05(211), 1.18
TRAP P.R.C./TANGENT:	45.7 (108) 42.1	1.95(199) 1.57	44.3 (147) 26.8	2.73(286) 1.40	42.7 (154) 19.1	4.16(174) 2.20	45.7 (108) 42.1
T-VAL(DF), F-VAL:	6.08(196), 1.89				9.95(287), 1.64		6.08(196), 1.89
TRAP OUTSIDE CURVE:	41.0 (106) 22.3				38.2 (141) 11.7	5.16(183) 1.91	41.0 (106) 22.3
T-VAL(DF), F-VAL:	5.14(198), 1.60				4.57(292), 1.17		5.14(198), 1.60
MORE INTERCELL STAT:			7.19(159), 2.62	0.0 (209) 1.00	2.37(215), 1.17		
LATERAL PLACEMENT -- MEAN, (NUMBER OF OBSER.), VARIANCE	LW = 11.6'		LW = 11.2'		LW = 12.1'		LW = 11.6'
TRAP INSIDE CURVE:	3.0 (105) 1.3	10.34(197) 1.56	1.6 (130) 0.9	7.49(276) 1.05	2.4 (153) 0.9	4.39(195) 1.48	3.0 (105) 1.3
T-VAL(DF), F-VAL:	1.21(205), 1.53		2.60(264), 1.19		1.54(305), 1.07		1.21(205), 1.53
TRAP P.R.C./TANGENT:	2.8 (108) 2.1	6.11(162) 2.85	1.9 (147) 0.7	3.69(297) 1.34	2.3 (154) 1.0	3.49(176) 2.12	2.8 (108) 2.1
T-VAL(DF), F-VAL:	6.91(206), 1.49				10.36(285), 1.17		6.91(206), 1.49
TRAP OUTSIDE CURVE:	4.1 (106) 1.4				3.5 (141) 1.1	3.79(215) 1.21	4.1 (106) 1.4
T-VAL(DF), F-VAL:	6.36(209), 1.03				9.07(282), 1.26		6.36(209), 1.03
MORE INTERCELL STAT:			4.39(195), 1.48	0.0 (209) 1.00	10.34(197), 1.56		

TABLE 80B. DETAILED SPEED AND LATERAL PLACEMENT REPORT FOR ROUTE PA 879 (WINDING)

ITEM	CELL 63	T(DF) / F	CELL 62	T(DF) / F	CELL 61	T(DF) / F	CELL 63
DELINEATION TREATMENT:	DOUBLE CTRLINE STD. EDGELINES		SINGLE CTRLINE STD. EDGELINES		SINGLE CTRLINE NO EDGELINES		DOUBLE CTRLINE STD. EDGELINES
INSTALL. DATE & DOE:	4/ 1/77, 157		11/24/76, 29		10/26/76, 0		4/ 1/77, 157
DATA COLLECTION PERIOD:	DRY - DAY		DRY - DAY		DRY - DAY		DRY - DAY
DATE(S) & D.O.W.(S):	5/ 3- 3, TUE-TUE		12/ 9- 9, THU-THU		11/ 5- 5, FRI-FRI		5/ 3- 3, TUE-TUE
DAY(S) OF EXPERIMENT:	189 -189		44 - 44		10 - 10		189 -189
DAYS OF ACCLIMATION:	32 - 32		15 - 15		10 - 10		32 - 32
ADT & PERCENT TRKS:	5290 31.5		5080 14.6		6200 20.8		5290 31.5
SPEED -- MEAN, (NUMBER OF OBSER.), VARIANCE							
TRAP INSIDE CURVE:	46.1 (122) 26.3	5.51(241) 1.03	42.5 (121) 27.0	0.19(245) 1.21	42.6 (126) 32.8	5.10(245) 1.25	46.1 (122) 26.3
T-VAL(DF), F-VAL:	2.37(248), 1.01		2.27(239), 1.19		2.74(248), 1.09		2.37(248), 1.01
TRAP P.R.C./TANGENT:	47.6 (128) 26.0	5.24(241) 1.24	44.1 (121) 32.2	0.68(243) 1.07	44.5 (124) 30.2	4.64(248) 1.16	47.6 (128) 26.0
T-VAL(DF), F-VAL:	7.94(243), 1.56		7.51(220), 1.10		5.63(224), 1.92		7.94(243), 1.56
TRAP OUTSIDE CURVE:	43.0 (126) 16.7	7.06(187) 1.76	38.5 (103) 29.4	4.13(183) 1.87	41.1 (126) 15.7	3.78(250) 1.06	43.0 (126) 16.7
T-VAL(DF), F-VAL:	5.21(232), 1.57		5.59(214), 1.09		2.37(223), 2.09		5.21(232), 1.57
MORE INTERCELL STAT:			5.10(245), 1.25	0.0 (242) 1.00	5.51(241), 1.03		
LATERAL PLACEMENT -- MEAN, (NUMBER OF OBSER.), VARIANCE	LW = 11.6'		LW = 11.2'		LW = 12.1'		LW = 11.6'
TRAP INSIDE CURVE:	2.3 (122) 1.0	4.40(240) 1.21	1.7 (121) 0.8	2.93(245) 1.00	2.1 (126) 0.8	1.65(242) 1.22	2.3 (122) 1.0
T-VAL(DF), F-VAL:	2.28(247), 1.27		0.63(230), 1.53		2.96(248), 1.02		2.28(247), 1.27
TRAP P.R.C./TANGENT:	2.0 (128) 1.3	1.05(247) 1.01	1.8 (121) 1.3	0.62(230) 1.56	1.7 (124) 0.8	1.80(242) 1.57	2.0 (128) 1.3
T-VAL(DF), F-VAL:	10.81(243), 1.45		10.79(217), 1.01		13.17(233), 1.74		10.81(243), 1.45
TRAP OUTSIDE CURVE:	3.7 (126) 1.9	1.31(227) 1.45	3.5 (103) 1.3	0.26(222) 1.11	3.5 (126) 1.4	1.09(246) 1.31	3.7 (126) 1.9
T-VAL(DF), F-VAL:	9.18(230), 1.84		12.36(196), 1.54		10.63(234), 1.71		9.18(230), 1.84
MORE INTERCELL STAT:			1.65(242), 1.22	0.0 (242) 1.00	4.40(240), 1.21		

Table 81. Index for Table 82.

SITE NO. 7 — MD 227

Sheet	Column[1]	Cell	Environmental Code[2]	Days of Acclimation Time
Right (Inside) Curve:				
A	1	71	DNT	N/A
	2	72	DNT	7
	3	73	DNT	6
	4	74	DNT	5
B	1*	71	DNT	N/A
	2	74	DNT	21
	3	74	DDY	21-22
	4	71	DDY	N/A
C	1*	71	DDY	N/A
	2	72	DDY	7
	3	73	DDY	6-7
	4	74	DDY	6
Left (Outside) Curve:				
D	1	71	DNT	N/A
	2	72	DNT	8
	3	73	DNT	7
	4	74	DNT	6
E	1*	71	DNT	N/A
	2	74	DNT	22-23
	3	74	DDY	22
	4	71	DDY	N/A
F	1*	71	DDY	N/A
	2	72	DDY	8
	3	73	DDY	7
	4	74	DDY	6

[1]* = These data were already presented in an earlier column.

[2]DNT = Dry-Night and DDY = Dry-Day.

TABLE 82A. DETAILED SPEED AND LATERAL PLACEMENT REPORT FOR ROUTE MO 227 (RTCURVE)

ITEM	CELL 71	T(DF) / F	CELL 72	T(DF) / F	CELL 73	T(DF) / F	CELL 74
DELINEATION TREATMENT:	CTR & EDGELINES RTCURVE		CTR & EDGELINES CTR RPM'S 40FT.		CTR & EDGELINES PMDS & CTR RPMS		CTR & EDGELINES PMD'S AT 80 FT.
INSTALL. DATE & DOE:	**/**/**, ***		11/10/76, 48		11/ 3/76, 41		10/ 8/76, 15
DATA COLLECTION PERIOD:	DRY - NIGHT		DRY - NIGHT		DRY - NIGHT		DRY - NIGHT
DATE(S) & D.O.W.(S):	9/24-24, FRI-FRI		11/17-17, WED-WED		11/ 9- 9, TUE-TUE		10/13-13, WED-WED
DAY(S) OF EXPERIMENT:	1 - 1		55 - 55		47 - 47		20 - 20
DAYS OF ACCLIMATION:	*** -***		7 - 7		6 - 6		5 - 5
ADT & PERCENT TRKS:	2410 3.1		3080 0.6		2960 1.9		2150 2.6
SPEED -- MEAN, (NUMBER OF OBSER.), VARIANCE							
TRAP ADVANCE POINT:	45.4 (128) 36.2	1.33(272) 1.06	44.4 (150) 38.3	0.36(295) 1.01	44.7 (147) 38.0	3.14(216) 1.04	42.2 (100) 36.3
T-VAL(DF), F-VAL:	2.01(248), 1.37		4.24(289), 1.45		5.06(281), 1.53		1.14(198), 1.33
TRAP POINT OF CURVE:	44.0 (127) 26.3	3.79(269) 1.00	41.6 (152) 26.4	0.45(299) 1.06	41.4 (149) 24.9	0.10(238) 1.10	41.3 (114) 27.4
T-VAL(DF), F-VAL:	3.88(249), 1.06		3.42(299), 1.02		4.03(292), 1.09		2.39(213), 1.24
TRAP INSIDE CURVE:	41.5 (124) 24.8	3.07(266) 1.08	39.6 (149) 26.9	1.02(293) 1.01	39.0 (146) 27.1	1.11(229) 1.23	39.7 (101) 22.0
T-VAL(DF), F-VAL:	5.60(245), 1.45		7.29(289), 1.43		8.54(284), 1.40		3.28(187), 1.65
MORE INTERCELL STAT:			4.05(265), 1.09	2.80(219) 1.13	0.14(229), 1.22		
LATERAL PLACEMENT -- MEAN, (NUMBER OF OBSER.), VARIANCE				(Average LW = 9.1' for all cells.)			
TRAP ADVANCE POINT:	2.8 (128) 1.2	0.97(237) 1.69	2.7 (150) 0.7	6.53(292) 1.18	2.0 (147) 0.9	5.32(228) 1.26	2.6 (100) 0.7
T-VAL(DF), F-VAL:	6.34(241), 1.63		12.76(297), 1.23		4.27(282), 1.48		7.01(207), 1.05
TRAP POINT OF CURVE:	2.0 (127) 0.8	5.23(255) 1.28	1.5 (152) 0.6	1.11(299) 1.02	1.6 (149) 0.6	2.49(237) 1.12	1.9 (114) 0.7
T-VAL(DF), F-VAL:	7.15(243), 1.46		6.61(292), 1.43		8.07(290), 1.31		3.63(213), 1.31
TRAP INSIDE CURVE:	1.3 (124) 0.5	4.08(250) 1.24	1.0 (149) 0.4	0.43(293) 1.06	0.9 (146) 0.4	5.96(207) 1.12	1.5 (101) 0.5
T-VAL(DF), F-VAL:	12.87(219), 2.38		19.84(278), 1.75		11.60(266), 1.94		10.69(194), 1.38
MORE INTERCELL STAT:			4.40(254), 1.17	1.66(216) 1.04	5.68(202), 1.20		

TABLE 82B. DETAILED SPEED AND LATERAL PLACEMENT REPORT FOR ROUTE MD 227 (RTCURVE)

ITEM	CELL 71	T(DF) / F	CELL 74	T(DF) / F	CELL 74	T(DF) / F	CELL 71
DELINEATION TREATMENT:	CTR & EDGELINES RTCURVE		CTR & EDGELINES PMD'S AT 80 FT.		CTR & EDGELINES PMD'S AT 80 FT.		CTR & EDGELINES RTCURVE
INSTALL. DATE & DOE:	**/**/**, ***		10/ 8/76, 15		10/ 8/76, 15		**/**/**, ***
DATA COLLECTION PERIOD:	DRY - NIGHT		DRY - NIGHT		DRY - DAY		DRY - DAY
DATE(S) & D.O.W.(S):	9/24-24, FRI-FRI		10/29-29, FRI-FRI		10/29-30, FRI-SAT		9/25-25, SAT-SAT
DAY(S) OF EXPERIMENT:	1 - 1		36 - 36		36 - 37		2 - 2
DAYS OF ACCLIMATION:	*** -***		21 - 21		21 - 22		*** -***
ADT & PERCENT TRKS:	2410 3.1		2280 0.0		2280 0.6		2410 0.0
SPEED -- MEAN, (NUMBER OF OBSER.), VARIANCE							
TRAP ADVANCE POINT:	45.4 (128) 36.2	1.39(279) 1.53	44.3 (153) 55.2	0.59(297) 1.27	43.8 (148) 43.3	0.23(266) 1.04	43.6 (125) 41.5
T-VAL(DF), F-VAL:	2.01(248), 1.37		2.07(297), 1.37		1.63(263), 2.04		1.54(241), 1.46
TRAP POINT OF CURVE:	44.0 (127) 26.3	1.96(278) 1.53	42.6 (153) 40.3	0.14(278) 1.90	42.7 (152) 21.2	0.43(255) 1.34	42.4 (129) 28.4
T-VAL(DF), F-VAL:	3.88(249), 1.06		3.58(298), 1.17		3.35(296), 1.08		2.73(254), 1.13
TRAP INSIDE CURVE:	41.5 (124) 24.8	2.10(269) 1.39	40.1 (147) 34.5	1.27(281) 1.50	40.9 (147) 22.9	0.34(263) 1.10	40.7 (127) 25.2
T-VAL(DF), F-VAL:	5.60(245), 1.45		5.39(288), 1.60		4.32(269), 1.89		4.00(235), 1.65
MORE INTERCELL STAT:			1.00(258), 1.08	1.26(249) 1.01	0.90(272), 1.37		
LATERAL PLACEMENT -- MEAN, (NUMBER OF OBSER.), VARIANCE			(Average LW = 9.1' for all cells.)				
TRAP ADVANCE POINT:	2.8 (128) 1.2	1.12(260) 1.21	3.0 (153) 1.0	3.85(299) 1.10	2.5 (148) 0.9	0.12(267) 1.10	2.5 (125) 0.8
T-VAL(DF), F-VAL:	6.34(241), 1.63		10.74(290), 1.59		8.93(283), 1.53		4.26(233), 1.70
TRAP POINT OF CURVE:	2.0 (127) 0.8	1.81(260) 1.18	1.9 (153) 0.6	2.46(303) 1.06	1.6 (152) 0.6	5.10(278) 1.22	2.1 (129) 0.5
T-VAL(DF), F-VAL:	7.15(243), 1.46		7.43(293), 1.43		4.47(297), 1.12		11.71(240), 1.69
TRAP INSIDE CURVE:	1.3 (124) 0.5	1.10(254) 1.16	1.2 (147) 0.4	0.23(290) 1.20	1.3 (147) 0.5	1.00(266) 1.84	1.2 (127) 0.3
T-VAL(DF), F-VAL:	12.87(219), 2.38		17.77(265), 2.28		12.99(275), 1.72		14.25(201), 2.88
MORE INTERCELL STAT:			0.85(263), 1.04	1.88(229) 1.77	0.79(271), 1.53		

TABLE 82C. DETAILED SPEED AND LATERAL PLACEMENT REPORT FOR ROUTE MO 227 (RTCURVE)

ITEM	CELL 71	T(DF) / F	CELL 72	T(DF) / F	CELL 73	T(DF) / F	CELL 74
DELINEATION TREATMENT:	CTR & EDGELINES RTCURVE		CTR & EDGELINES CTR RPM'S 40FT.		CTR & EDGELINES PMDS & CTR RPMS		CTR & EDGELINES PMD'S AT 80 FT.
INSTALL. DATE & DDE:	**/**/**, ***		11/10/76, 48		11/ 3/76, 41		10/ 8/76, 15
DATA COLLECTION PERIOD:	DRY - DAY		DRY - DAY		DRY - DAY		DRY - DAY
DATE(S) & D.O.W.(S):	9/25-25, SAT-SAT		11/17-17, WED-WED		11/ 9-10, TUE-WED		10/14-14, THU-THU
DAY(S) OF EXPERIMENT:	2 - 2		55 - 55		47 - 48		21 - 21
DAYS OF ACCLIMATION:	*** -***		7 - 7		6 - 7		6 - 6
ADT & PERCENT TRKS:	2410 0.0		3080 7.7		2960 9.0		2150 3.8
SPEED -- MEAN, (NUMBER OF OBSER.(, VARIANCE							
TRAP ADVANCE POINT:	43.6 (125(41.5	0.24(257(1.16	43.8 (154(35.9	1.16(295(1.23	44.6 (148(44.1	0.74(286) 1.11	44.0 (142) 48.8
T-VAL(DF), F-VAL:	1.54(241(, 1.46		2.50(290), 1.61		3.17(274), 1.76		2.14(271), 1.56
TRAP POINT OF CURVE:	42.4 (129(28.4	0.35(259(1.28	42.2 (153) 22.3	0.42(305(1.13	42.5 (154) 25.1	0.03(301(1.25	42.4 (153) 31.4
T-VAL(DF(, F-VAL:	2.73(254(, 1.13		3.22(304(, 1.10		2.70(300(, 1.02		3.08(301(, 1.13
TRAP INSIDE CURVE:	40.7 (127(25.2	0.25(257) 1.24	40.5 (153) 20.3	0.69(294) 1.22	40.9 (148(24.7	0.66(296) 1.12	40.5 (150(27.6
T-VAL(DF), F-VAL:	4.00(235(, 1.65		5.35(285(, 1.77		5.43(273), 1.78		4.82(262), 1.77
MORE INTERCELL STAT:			0.39(266(, 1.02	0.25(272(1.10	0.02(293), 1.36		
LATERAL PLACEMENT -- MEAN, (NUMBER OF OBSER.(, VARIANCE			(Average LW = 9.1' for all cells.)				
TRAP ADVANCE POINT:	2.5 (125) 0.8	1.07(274(1.21	2.7 (154) 1.0	2.56(300) 1.19	2.4 (148) 0.9	0.97(287(1.23	2.5 (142) 0.7
T-VAL(DF(, F-VAL:	4.26(233(, 1.70		8.12(282), 1.82		6.18(285(, 1.48		4.92(277), 1.42
TRAP POINT OF CURVE:	2.1 (129(0.5	3.01(277) 1.12	1.8 (153(0.6	0.79(305) 1.04	1.8 (154) 0.6	3.14(304) 1.18	2.0 (153) 0.5
T-VAL(DF), F-VAL:	11.71(240), 1.69		10.80(290(, 1.57		7.36(294(, 1.45		5.11(301), 1.05
TRAP INSIDE CURVE:	1.2 (127(0.3	2.60(276(1.21	1.0 (153) 0.4	2.45(297(1.13	1.2 (148) 0.4	5.60(293) 1.28	1.6 (150) 0.5
T-VAL(DF), F-VAL:	14.25(201(, 2.88		17.53(249), 2.86		12.98(260), 2.14		9.40(279), 1.36
MORE INTERCELL STAT:			0.04(273(, 1.37	5.76(272(1.76	8.08(290), 1.45		

TABLE 82D. DETAILED SPEED AND LATERAL PLACEMENT REPORT FOR ROUTE MD 227 (LTCURVE)

ITEM	CELL 71	T(OF) / F	CELL 72	T(OF) / F	CELL 73	T(OF) / F	CELL 74
DELINEATION TREATMENT:	CTR & EDGELINES LTCURVE		CTR & EDGELINES CTR RPM'S 40FT.		CTR & EDGELINES PMOS & CTR RPMS		CTR & EDGELINES PMO'S AT 80 FT.
INSTALL. DATE & ODE:	**/**/**, ***		11/10/76, 48		11/ 3/76, 41		10/ 8/76, 15
DATA COLLECTION PERIOD:	DRY - NIGHT		DRY - NIGHT		DRY - NIGHT		DRY - NIGHT
DATE(S) & D.O.W.(S):	9/23-23, THU-THU		11/18-18, THU-THU		11/10-10, WED-WED		10/14-14, THU-THU
DAY(S) OF EXPERIMENT:	0 - 0		56 - 56		48 - 48		21 - 21
DAYS OF ACCLIMATION:	*** -***		8 - 8		7 - 7		6 - 6
ADT & PERCENT TRKS:	2410 0.0		3080 0.0		2960 3.2		2150 0.0
SPEED -- MEAN, (NUMBER OF OBSER.), VARIANCE							
TRAP ADVANCE POINT:	45.1 (120) 50.3	2.52(224) 1.57	43.1 (155) 32.1	1.95(301) 1.04	44.3 (149) 33.3	0.45(293) 1.29	44.7 (150) 43.2
T-VAL(DF), F-VAL:	3.21(236), 1.27		2.87(302), 1.27		3.57(300), 1.24		3.92(292), 1.33
TRAP POINT OF CURVE:	42.3 (122) 39.8	1.39(229) 1.57	41.3 (152) 25.3	0.80(289) 1.63	41.8 (154) 41.3	0.05(299) 1.27	41.9 (149) 32.5
T-VAL(DF), F-VAL:	2.24(234), 1.35		2.68(300), 1.08		3.70(271), 2.16		2.33(295), 1.18
TRAP OUTSIDE CURVE:	40.6 (115) 29.5	1.27(241) 1.08	39.7 (150) 27.2	0.39(290) 1.42	39.5 (152) 19.1	1.57(288) 1.44	40.4 (149) 27.6
T-VAL(DF), F-VAL:	5.45(223), 1.71		5.34(303), 1.18		8.16(276), 1.74		6.21(285), 1.57
MORE INTERCELL STAT:			1.71(215), 1.54	0.27(242) 1.07	1.09(297), 1.01		
LATERAL PLACEMENT -- MEAN, (NUMBER OF OBSER.), VARIANCE			(Average LW = 9.1' for all cells.)				
TRAP ADVANCE POINT:	2.2 (120) 0.8	8.23(223) 1.59	1.4 (155) 0.5	1.09(295) 1.28	1.3 (149) 0.6	7.26(297) 1.06	2.0 (150) 0.6
T-VAL(DF), F-VAL:	2.21(238), 1.27		0.34(298), 1.32		2.64(286), 1.72		5.27(281), 1.67
TRAP POINT OF CURVE:	1.9 (122) 1.0	4.61(231) 1.54	1.4 (152) 0.6	1.48(288) 1.68	1.6 (154) 1.1	0.45(246) 3.05	1.5 (149) 0.3
T-VAL(DF), F-VAL:	13.83(235), 1.01		12.89(300), 1.12		10.70(275), 2.03		22.47(248), 2.59
TRAP OUTSIDE CURVE:	3.7 (115) 1.0	10.26(206) 1.74	2.6 (150) 0.6	1.13(300) 1.08	2.7 (152) 0.5	9.51(277) 1.73	3.6 (149) 0.9
T-VAL(DF), F-VAL:	12.37(227), 1.28		14.20(300), 1.17		15.68(296), 1.18		16.48(283), 1.59
MORE INTERCELL STAT:			9.52(200), 1.89	0.97(240) 1.09	10.32(282), 1.60		

TABLE 82E. DETAILED SPEED AND LATERAL PLACEMENT REPORT FOR ROUTE NO 227 (LTCURVE)

ITEM	CELL 71	T(OF) / F	CELL 74	T(OF) / F	CELL 74	T(OF) / F	CELL 71
DELINEATION TREATMENT:	CTR & EDGELINES LTCURVE		CTR & EDGELINES PMD'S AT 80 FT.		CTR & EDGELINES PMD'S AT 80 FT.		CTR & EDGELINES LTCURVE
INSTALL. DATE & DOE:	**/**/**, ***		10/ 8/76, 15		10/ 8/76, 15		**/**/**, ***
DATA COLLECTION PERIOD:	DRY - NIGHT		DRY - NIGHT		DRY - DAY		DRY - DAY
DATE(S) & D.O.W.(S): DAY(S) OF EXPERIMENT: DAYS OF ACCLIMATION: ADT & PERCENT TRKS:	9/23-23, THU-THU 0 - 0 *** -*** 2410 0.0		10/30-31, SAT- 37 - 38 22 - 23 2280 0.6		10/30-30, SAT-SAT 37 - 37 22 - 22 2280 1.9		9/24-24, FRI-FRI 1 - 1 *** -*** 2410 9.2
SPEED -- MEAN, (NUMBER OF OBSER.), VARIANCE							
TRAP ADVANCE POINT:	45.1 (120) 50.3	2.53(228) 1.50	43.0 (151) 33.6	4.53(301) 1.03	46.0 (152) 32.8	2.69(273) 1.26	44.1 (136) 41.2
T-VAL(OF), F-VAL:	3.21(236), 1.27		4.27(298), 1.21		4.81(297), 1.35		2.74(256), 1.28
TRAP POINT OF CURVE:	42.3 (122) 39.8	2.77(236) 1.43	40.3 (151) 27.8	4.78(302) 1.15	43.1 (155) 24.3	1.64(241) 1.33	42.0 (122) 32.1
T-VAL(OF), F-VAL:	2.24(234), 1.35		1.93(292), 1.22		2.69(305), 1.07		2.03(247), 1.21
TRAP OUTSIDE CURVE:	40.6 (115) 29.5	2.16(229) 1.30	39.2 (143) 22.7	4.38(292) 1.00	41.6 (152) 22.7	1.62(282) 1.17	40.7 (139) 26.5
T-VAL(OF), F-VAL:	5.45(223), 1.71		6.24(287), 1.48		7.32(293), 1.44		4.88(259), 1.56
MORE INTERCELL STAT:			1.62(228), 1.30	0.13(238) 1.11	2.51(277), 1.17		
LATERAL PLACEMENT -- MEAN, (NUMBER OF OBSER.), VARIANCE				(Average LW = 9.1' for all cells.)			
TRAP ADVANCE POINT:	2.2 (120) 0.8	3.83(263) 1.17	1.8 (151) 0.9	1.16(287) 1.55	1.7 (152) 0.6	6.98(274) 1.24	2.3 (136) 0.7
T-VAL(OF), F-VAL:	2.21(238), 1.27		1.16(290), 1.47		3.49(303), 1.13		8.21(253), 1.03
TRAP POINT OF CURVE:	1.9 (122) 1.0	0.40(228) 1.60	1.9 (151) 0.6	0.75(301) 1.19	2.0 (155) 0.5	5.21(234) 1.45	1.4 (122) 0.7
T-VAL(OF), F-VAL:	13.83(235), 1.01		17.00(287), 1.18		15.94(290), 1.54		17.06(259), 1.46
TRAP OUTSIDE CURVE:	3.7 (115) 1.0	1.75(225) 1.37	3.5 (143) 0.7	0.86(293) 1.10	3.4 (152) 0.8	0.29(273) 1.37	3.5 (139) 1.1
T-VAL(OF), F-VAL:	12.37(227), 1.28		16.55(292), 1.25		18.58(296), 1.36		9.91(265), 1.50
MORE INTERCELL STAT:			2.48(231), 1.25	2.02(247) 1.10	0.48(267), 1.50		

TABLE **82F.** DETAILED SPEED AND LATERAL PLACEMENT REPORT FOR ROUTE NO 227 (LTCURVE)

ITEM	CELL 71	T(DF) / F	CELL 72	T(DF) / F	CELL 73	T(DF) / F	CELL 74
DELINEATION TREATMENT:	CTR & EDGELINES LTCURVE		CTR & EDGELINES CTR RPM'S 40FT.		CTR & EDGELINES PMDS & CTR RPMS		CTR & EDGELINES PMD'S AT 80 FT.
INSTALL. DATE & DOE:	**/**/**, ***		11/10/76, 48		11/ 3/76, 41		10/ 8/76, 15
DATA COLLECTION PERIOD:	DRY - DAY		DRY - DAY		DRY - DAY		DRY - DAY
DATE(S) & D.O.W.(S): DAY(S) OF EXPERIMENT: DAYS OF ACCLIMATION: ADT & PERCENT TRKS:	9/24-24, FRI-FRI 1 - 1 *** -*** 2410 9.2		11/18-18, THU-THU 56 - 56 8 - 8 3080 10.3		11/10-10, WED-WED 48 - 48 7 - 7 2960 5.8		10/14-14, THU-THU 21 - 21 6 - 6 2150 6.4
SPEED -- MEAN, (NUMBER OF OBSER.), VARIANCE							
TRAP ADVANCE POINT:	44.1 (136) 41.2	1.09(285) 1.12	44.9 (151) 46.2	0.45(299) <u>1.35</u>	44.6 (154) 62.3	0.41(278) <u>1.94</u>	44.2 (151) 32.2
T-VAL(DF), F-VAL:	<u>2.74</u>(256), 1.28		1.99(288), <u>1.53</u>		<u>2.62</u>(293), <u>1.52</u>		<u>3.46</u>(292), 1.14
TRAP POINT OF CURVE:	42.0 (122) 32.1	<u>2.22</u>(256) 1.06	43.5 (153) 30.2	1.64(295) <u>1.36</u>	42.4 (151) 41.0	0.57(288) <u>1.45</u>	42.0 (143) 28.3
T-VAL(DF), F-VAL:	<u>2.03</u>(247), 1.21		<u>2.18</u>(294), <u>1.41</u>		1.12(299), 1.21		1.94(281), <u>1.36</u>
TRAP OUTSIDE CURVE:	40.7 (139) 26.5	<u>2.77</u>(278) 1.24	42.3 (149) 21.4	1.05(289) <u>1.58</u>	41.6 (153) 33.9	1.21(288) <u>1.63</u>	40.9 (153) 20.8
T-VAL(DF), F-VAL:	<u>4.88</u>(259), <u>1.56</u>		<u>4.00</u>(265), <u>2.16</u>		<u>3.71</u>(282), <u>1.84</u>		<u>5.65</u>(288), <u>1.55</u>
MORE INTERCELL STAT:			1.50(290), 1.28	0.42(278) 1.27	<u>2.57</u>(300), 1.03		
LATERAL PLACEMENT -- MEAN, (NUMBER OF OBSER.), VARIANCE				(Average LW = 9.1' for all cells.)			
TRAP ADVANCE POINT:	2.3 (136) 0.7	<u>3.78</u>(285) 1.15	1.9 (151) 0.8	0.42(302) 1.13	1.9 (154) 0.7	0.57(296) <u>1.43</u>	1.9 (151) 0.5
T-VAL(DF), F-VAL:	<u>8.21</u>(253), 1.03		<u>3.46</u>(302), 1.11		<u>2.25</u>(303), 1.09		<u>7.57</u>(288), <u>1.44</u>
TRAP POINT OF CURVE:	1.4 (122) 0.7	1.03(269) 1.23	1.6 (153) 0.9	1.11(297) <u>1.36</u>	1.7 (151) 0.7	<u>3.76</u>(275) <u>1.89</u>	1.4 (143) 0.4
T-VAL(DF), F-VAL:	<u>17.06</u>(259), <u>1.46</u>		<u>14.10</u>(288), <u>1.61</u>		<u>14.92</u>(302), 1.06		<u>21.52</u>(269), <u>2.19</u>
TRAP OUTSIDE CURVE:	3.5 (139) 1.1	<u>4.63</u>(251) <u>1.90</u>	3.0 (149) 0.6	1.52(298) 1.25	3.1 (153) 0.7	1.38(304) 1.09	3.2 (153) 0.8
T-VAL(DF), F-VAL:	<u>9.91</u>(265), <u>1.50</u>		<u>10.64</u>(290), <u>1.45</u>		<u>12.45</u>(305), 1.03		<u>14.05</u>(292), <u>1.52</u>
MORE INTERCELL STAT:			<u>3.22</u>(267), <u>1.52</u>	<u>1.97</u>(272) <u>1.39</u>	<u>2.92</u>(296), <u>1.36</u>		

Table 83. Index for Table 84.

SITE NO. 8 — PA 45

Sheet	Column[1]	Cell	Environmental Code[2]	Days of Acclimation Time
Right (Inside) Curve:				
A	1	81	DNT	N/A
	2	83	DNT	1
	3	83	DNT	16
	4*	81	DNT	N/A
B	1	81	DDY	N/A
	2	83	DDY	1
	3	83	DDY	16
	4*	81	DDY	N/A
Left (Outside) Curve:				
C	1	81	DNT	N/A
	2	83	DNT	0
	3	83	DNT	17
	4*	81	DNT	N/A
D	1	81	DDY	N/A
	2	83	DDY	0
	3	83	DDY	17
	4*	81	DDY	N/A

[1]* = These data were already presented in an earlier column.

[2]DNT = Dry-Night and DDY = Dry-Day.

TABLE **84A.** DETAILED SPEED AND LATERAL PLACEMENT REPORT FOR ROUTE PA 45 (RTCURVE)

ITEM	CELL 81	T(DF) / F	CELL 83	T(DF) / F	CELL 83	T(DF) / F	CELL 8(
DELINEATION TREATMENT:	CENTERLINE ONLY RTCURVE		CENTERLINE PMD'S AT (00FT.		CENTERLINE PMD'S AT 100FT.		CENTERLINE ONLY RTCURVE
INSTALL. DATE & DOE:	**/**/**, ***		10/11/76, 2(		(0/(1/76, 2(		**/**/**, ***
DATA COLLECTION PERIOD:	DRY - NIGHT		DRY - NIGHT		DRY - NIGHT		DRY - NIGHT
DATE(S) & D.O.W.(S):	9/21-2(, TUE-TUE		10/12-12, TUE-TUE		10/27-27, WED-WED		9/2(-2(, TUE-TUE
DAY(S) OF EXPERIMENT:	1 - 1		22 - 22		37 - 37		1 - 1
DAYS OF ACCLIMATION:	*** -***		1 - 1		(6 - 16		*** -***
ADT & PERCENT TRKS:	4480 3.6		4830 4.5		4830 3.2		4480 3.6
SPEED -- MEAN, (NUMBER OF OBSER.), VARIANCE							
TRAP ADVANCE POINT:	54.2 (102) 25.7	0.46(248) 1.85	54.5 (149) 47.6	1.35(287) 1.49	53.5 (156) 31.9	0.93(232) (.24	54.2 ((02) 25.7
T-VAL(DF), F-VAL:	1.70(207), 1.04		2.99(292), (.(7		0.52(302), 1.12		1.70(207), (.04
TRAP POINT OF CURVE:	53.0 (108) 24.8	1.10(251) 1.64	52.2 (145) 40.7	1.37(291) (.14	53.2 ((50) 35.8	0.30(251) 1.44	53.0 (108) 24.8
T-VAL(DF), F-VAL:	0.16(205), 1.14		0.32(291), 1.01		0.71(294), 1.27		0.16(205), 1.14
TRAP INSIDE CURVE:	52.9 ((02) 28.3	0.58(239) 1.43	52.5 (148) 40.4	0.29(296) 1.12	52.7 (150) 45.3	0.27(245) 1.60	52.9 (102) 28.3
T-VAL(DF), F-VAL:	1.78(202), 1.10		2.69(294), 1.(8		1.23(29(), 1.42		1.78(202), (.10
MORE INTERCELL STAT:			0.27(245), 1.60	0.0 (203) 1.00	0.58(239), 1.43		
LATERAL PLACEMENT -- MEAN, (NUMBER OF OBSER.), VARIANCE			(Average LW = 9.6' for all cells.)				
TRAP ADVANCE POINT:	1.9 (102) 1.1	2.20(236) 1.34	2.2 ((49) 1.5	0.84(284) 1.56	2.1 (156) 0.9	1.62(205) (.(7	1.9 ((02) 1.1
T-VAL(DF), F-VAL:	3.01(207), 1.32		4.14(282), 1.55		4.47(297), 1.28		3.01(207), 1.32
TRAP POINT OF CURVE:	2.3 (108) 1.4	2.68(202) 1.53	2.7 ((45) 0.9	0.88(291) 1.27	2.6 (150) 1.2	1.86(218) 1.20	2.3 (108) (.4
T-VAL(DF), F-VAL:	2.71(207), 1.33		7.92(291), 1.03		6.96(298), 1.00		2.71(207), (.33
TRAP INSIDE CURVE:	(.9 (102) 1.1	0.73(206) (.(8	(.8 (148) 0.9	0.78(292) 1.31	(.7 (150) 1.2	1.38(225) (.11	(.9 ((02) 1.1
T-VAL(DF), F-VAL:	0.32(202), 1.00		2.87(282), 1.60		2.97(297), 1.28		0.32(202), 1.00
MORE INTERCELL STAT:			1.38(225), 1.((	0.0 (203) 1.00	0.73(206), (.(8		

TABLE **84B.** DETAILED SPEED AND LATERAL PLACEMENT REPORT FOR ROUTE PA 45 (RTCURVE)

ITEM	CELL 81	T(DF) / F	CELL 83	T(DF) / F	CELL 83	T(DF) / F	CELL 81
DELINEATION TREATMENT:	CENTERLINE ONLY RTCURVE		CENTERLINE PMD'S AT 100FT.		CENTERLINE PMD'S AT 100FT.		CENTERLINE ONLY RTCURVE
INSTALL. DATE & DOE:	**/**/**, ***		10/11/76, 21		10/11/76, 21		**/**/**, ***
DATA COLLECTION PERIOD:	DRY - DAY		DRY - DAY		DRY - DAY		DRY - DAY
DATE(S) & D.O.W.(S): DAY(S) OF EXPERIMENT: DAYS OF ACCLIMATION: ADT & PERCENT TRKS:	9/21-21, TUE-TUE 1 - 1 *** -*** 4480 6.1		10/12-12, TUE-TUE 22 - 22 1 - 1 4830 15.8		10/27-27, WED-WED 37 - 37 16 - 16 4830 5.1		9/21-21, TUE-TUE 1 - 1 *** -*** 4480 6.1
SPEED -- MEAN, (NUMBER OF OBSER.), VARIANCE							
TRAP ADVANCE POINT:	54.6 (111) 31.4	0.01(259) 1.36	54.6 (165) 42.6	0.16(315) 1.15	54.5 (152) 37.2	0.14(248) 1.18	54.6 (111) 31.4
T-VAL(DF), F-VAL:	2.08(222), 1.11		1.73(326), 1.19		0.11(305), 1.11		2.08(222), 1.11
TRAP POINT OF CURVE:	53.0 (113) 34.7	0.56(244) 1.03	53.4 (165) 35.9	1.45(313) 1.14	54.4 (155) 41.1	1.87(253) 1.18	53.0 (113) 34.7
T-VAL(DF), F-VAL:	0.29(215), 1.19		0.06(309), 1.00		1.28(299), 1.04		0.29(215), 1.19
TRAP INSIDE CURVE:	52.8 (104) 29.2	0.82(236) 1.23	53.4 (149) 36.1	0.15(292) 1.10	53.5 (146) 39.7	0.94(240) 1.36	52.8 (104) 29.2
T-VAL(DF), F-VAL:	2.42(213), 1.07		1.74(312), 1.18		1.42(295), 1.07		2.42(213), 1.07
MORE INTERCELL STAT:			0.94(240), 1.36	0.0 (207) 1.00	0.82(236), 1.23		
LATERAL PLACEMENT -- MEAN, (NUMBER OF OBSER.), VARIANCE			(Average LW = 9.6' for all cells.)				
TRAP ADVANCE POINT:	1.2 (111) 0.6	5.58(265) 1.52	1.8 (165) 0.8	1.22(313) 1.41	1.7 (152) 0.6	4.71(242) 1.07	1.2 (111) 0.6
T-VAL(DF), F-VAL:	3.90(219), 1.36		2.83(328), 1.04		1.49(298), 1.45		3.90(219), 1.36
TRAP POINT OF CURVE:	1.7 (113) 0.8	3.91(252) 1.16	2.1 (165) 0.9	2.48(318) 1.01	1.8 (155) 0.9	1.53(251) 1.14	1.7 (113) 0.8
T-VAL(DF), F-VAL:	3.45(215), 1.19		7.10(310), 1.48		8.32(286), 1.75		3.45(215), 1.19
TRAP INSIDE CURVE:	1.3 (104) 0.6	1.35(217) 1.08	1.4 (149) 0.6	4.24(292) 1.20	1.0 (146) 0.5	2.33(204) 1.29	1.3 (104) 0.6
T-VAL(DF), F-VAL:	0.29(210), 1.14		4.14(311), 1.43		7.51(296), 1.21		0.29(210), 1.14
MORE INTERCELL STAT:			2.33(204), 1.29	0.0 (207) 1.00	1.35(217), 1.08		

TABLE 84C. DETAILED SPEED AND LATERAL PLACEMENT REPORT FOR ROUTE PA 45 (LTCURVE(

ITEM	CELL 81(	T(DF) / F	CELL 83	T)DF) / F	CELL 83	T(DF) / F	CELL 81(
DELINEATION TREATMENT:	CENTERLINE ONLY LTCURVE		CENTERLINE PMD'S AT 100FT.		CENTERLINE PMD'S AT 100FT.		CENTERLINE ONLY LTCURVE
INSTALL. DATE & DOE:	**/**/**, ***		10/11/76, 21		10/11/76, 21		**/**/**, ***
DATA COLLECTION PERIOD:	DRY - NIGHT		DRY - NIGHT		DRY - NIGHT		DRY - NIGHT
DATE(S(& D.O.W.(S(:	9/22-22, WED-WED		10/11-11, MON-MON		10/28-28, THU-THU		9/22-22, WED-WED
DAY)S) OF EXPERIMENT:	2 - 2		21 - 21		38 - 38		2 - 2
DAYS OF ACCLIMATION:	*** -***		0 - 0		17 - 17		*** -***
ADT & PERCENT TRKS:	4480 3.1		4830 1.3		4830 3.1		4480 3.(
SPEED -- MEAN, (NUMBER OF OBSER.), VARIANCE							
TRAP ADVANCE POINT:	53.3 (104(26.8	1.10(247) 1.50	52.5 (153(40.2	2.05(267(1.03	54.1 (125) 38.9	1.01(227) 1.45	53.3 (104) 26.8
T-VAL(DF(, F-VAL:	0.35(200(, 1.15		0.65(307(, 1.07		0.33)247), 1.19		0.35) 200), 1.15
TRAP POINT OF CURVE:	53.0 (100(30.9	1.31(236) 1.39	52.0 (156(43.1	2.18(262) 1.07	53.8 (125) 46.2	0.91)223) 1.50	53.0)100(30.9
T-VAL(DF(, F-VAL:	0.94(207(, 1.01		1.71(299(, 1.02		1.86(245), 1.03		0.94) 207(, 1.01
TRAP OUTSIDE CURVE:	52.3 (111) 31.1	2.08(252(1.36	50.7 (146(42.4	1.78)255) 1.06	52.2)122) 45.0	0.16)230) 1.45	52.3)111) 31.1
T-VAL(DF(, F-VAL:	1.34(213(, 1.16		2.37(296(, 1.05		2.27)243(, 1.16		1.34) 213(, 1.(6
MORE INTERCELL STAT:			0.16)230(, 1.45	0.0 (221) 1.00	2.08(252(, 1.36		
LATERAL PLACEMENT -- MEAN, (NUMBER OF OBSER.), VARIANCE				(Average LW = 8.9' for all cells.)			
TRAP ADVANCE POINT:	3.0 (104(1.5	3.24(216(1.08	2.5 (153) 1.4	1.84)276(1.35	2.7 (125(1.0	1.69(201) 1.46	3.0)104(1.5
T-VAL(DF(, F-VAL:	4.57(192), 1.74		1.43(302(, 1.26		5.11(247(, 1.(5		4.57) 192), 1.74
TRAP POINT OF CURVE:	2.3 (100(0.8	0.11)230(1.28	2.3 (156(1.1	1.98)262(1.07	2.0 (125(1.1	1.79)223) (.37	2.3)100) 0.8
T-VAL(DF(, F-VAL:	4.58(201), 1.86		0.89)296), 1.13		1.76(245), 1.08		4.58(20(), (.86
TRAP OUTSIDE CURVE:	3.0 (111(1.6	5.22(221) 1.29	2.2 (146(1.2	2.90)263(1.(4	1.8)122(1.1	7.68(215) (.46	3.0 ((11) 1.6
T-VAL(DF(, F-VAL:	0.01)213(, 1.07		2.20(297(, 1.12		7.00)245), 1.06		0.01(213), (.07
MORE INTERCELL STAT:			7.68)215(, (.46	0.0 (22() 1.00	5.22(221(, 1.29		

TABLE 84D. DETAILED SPEED AND LATERAL PLACEMENT REPORT FOR ROUTE PA 45 (LTCURVE)

ITEM	CELL 81	T(DF) / F	CELL 83	T(DF) / F	CELL 83	T(DF) / F	CELL 81
DELINEATION TREATMENT:	CENTERLINE ONLY LTCURVE		CENTERLINE PMD'S AT 100FT.		CENTERLINE PMD'S AT 100FT.		CENTERLINE ONLY LTCURVE
INSTALL. DATE & DOE:	**/**/**, ***		10/11/76, 21		10/11/76, 21		**/**/**, ***
DATA COLLECTION PERIOD:	DRY - DAY		DRY - DAY		DRY - DAY		DRY - DAY
DATE(S) & D.O.W.(S):	9/21-21, TUE-TUE		10/11-11, MON-MON		10/28-28, THU-THU		9/21-21, TUE-TUE
DAY(S) OF EXPERIMENT:	1 - 1		21 - 21		38 - 38		1 - 1
DAYS OF ACCLIMATION:	*** -***		0 - 0		17 - 17		*** -***
ADT & PERCENT TRKS:	4480 17.6		4830 14.7		4830 12.2		4480 17.6
SPEED -- MEAN, (NUMBER OF OBSER.), VARIANCE							
TRAP ADVANCE POINT:	51.5 (102) 42.0	2.40(215) 1.02	53.5 (156) 41.3	0.64(303) 1.19	54.0 (152) 49.1	2.87(228) 1.17	51.5 (102) 42.0
T-VAL(DF), F-VAL:	0.52(201), 1.28		0.47(310), 1.06		0.67(306), 1.03		0.52(201), 1.28
TRAP POINT OF CURVE:	52.0 (105) 32.8	2.49(236) 1.18	53.8 (156) 38.8	0.51(307) 1.23	53.4 (156) 47.6	1.90(248) 1.45	52.0 (105) 32.8
T-VAL(DF), F-VAL:	0.86(204), 1.17		1.38(302), 1.03		1.82(298), 1.05		0.86(204), 1.17
TRAP OUTSIDE CURVE:	51.3 (101) 28.0	2.08(237) 1.42	52.8 (149) 39.8	1.07(289) 1.14	52.0 (144) 45.4	0.93(240) 1.62	51.3 (101) 28.0
T-VAL(DF), F-VAL:	0.26(194), 1.50		0.90(303), 1.04		2.45(294), 1.08		0.26(194), 1.50
MORE INTERCELL STAT:			0.93(240), 1.62	0.0 (201) 1.00	2.08(237), 1.42		
LATERAL PLACEMENT -- MEAN, (NUMBER OF OBSER.), VARIANCE			(Average LW = 8.9' for all cells.)				
TRAP ADVANCE POINT:	2.6 (102) 1.4	1.72(200) 1.24	2.3 (156) 1.2	0.41(304) 1.29	2.3 (152) 0.9	2.12(183) 1.59	2.6 (102) 1.4
T-VAL(DF), F-VAL:	4.39(198), 1.41		3.25(309), 1.13		2.69(306), 1.14		4.39(198), 1.41
TRAP POINT OF CURVE:	1.9 (105) 1.0	0.31(225) 1.01	1.9 (156) 1.0	0.31(311) 1.00	2.0 (156) 1.0	0.59(225) 1.01	1.9 (105) 1.0
T-VAL(DF), F-VAL:	0.47(196), 1.41		0.64(303), 1.11		1.86(298), 1.09		0.47(196), 1.41
TRAP OUTSIDE CURVE:	2.0 (101) 1.4	0.74(184) 1.54	1.9 (149) 0.9	0.92(291) 1.02	1.8 (144) 1.0	1.46(187) 1.52	2.0 (101) 1.4
T-VAL(DF), F-VAL:	3.59(201), 1.00		3.91(302), 1.25		4.60(293), 1.05		3.59(201), 1.00
MORE INTERCELL STAT:			1.46(187), 1.52	0.0 (201) 1.00	0.74(184), 1.54		

APPENDIX G

SITE-SPECIFIC ACCIDENT RATES FOR BASE CONDITION DELINEATION

This appendix presents statistics on historical accident experience at nine Phase II study sites. Both accident rates and severity rates are listed for various combinations of ambient light and pavement condition. The format of the tables is discussed in Chapter VI.

Table 85. 1976 accident and severity rates for Site 1.

ACCIDENT SUMMARY FORM

SITE NUMBER: MAINE 1	SITUATION: TANGENT
DATA PERIOD: 1/76 TO 1/77	SECTION LENGTH: 7.89 MILES
NUMBER OF INTERSECTIONS: 12	DRY DAYS PER YEAR: 238
DAYTIME VOLUME: 80% ADT	RAIN DAYS PER YEAR: 109

PART B. AVERAGE ACCIDENT RATE AND SEVERITY RATE

	NON-INTERSECTION		NON-INTERSECTION AND INTERSECTION	
	DRY	DRY AND WET	DRY	DRY AND WET
ACCIDENT RATE				
ALL DAY:	1.10	0.89	1.72	1.64
ALL NIGHT:	4.40	3.02	4.40	3.02
ALL DAY AND NIGHT:	1.76	1.31	2.26	1.92
DEL-RELATED DAY:	1.10	0.75	1.72	1.51
DEL-RELATED NIGHT:	2.68	1.84	2.68	1.84
DEL-RELATED DAY/NIGHT:	1.41	0.97	1.91	1.57
SEVERITY RATE				
ALL DAY:	0.62	0.43	0.82	0.56
ALL NIGHT:	0.78	0.53	0.78	0.53
ALL DAY AND NIGHT:	0.65	0.45	0.81	0.56
DEL-RELATED DAY:	0.62	0.43	0.82	0.56
DEL-RELATED NIGHT:	0.78	0.53	0.78	0.53
DEL-RELATED DAY/NIGHT:	0.65	0.45	0.81	0.56

AVERAGE ANNUAL NUMBER OF ACCIDENTS PER MILE: 1.27
AVERAGE ANNUAL NUMBER OF NON-INTERSECTION ACCIDENTS PER MILE: 0.89

NOTE: ACCIDENT RATES ARE EXPRESSED IN TERMS OF ACCIDENTS PER MILLION VEHICLE MILES
ACCIDENT RATES WERE COMPUTED BY FACTORING THE ADT ON A QUARTERLY BASIS

Table 86. 1974 Accident and severity rates for Site 1.

ACCIDENT SUMMARY FORM

SITE NUMBER: MAINE 1	SITUATION: TANGENT
DATA PERIOD: 1/74 TO 1/75	SECTION LENGTH: 7.89 MILES
NUMBER OF INTERSECTIONS: 12	DRY DAYS PER YEAR: 238
DAYTIME VOLUME: 80% ADT	RAIN DAYS PER YEAR: 109

PART B. AVERAGE ACCIDENT RATE AND SEVERITY RATE

	NON-INTERSECTION		NON-INTERSECTION AND INTERSECTION	
	DRY	DRY AND WET	DRY	DRY AND WET
ACCIDENT RATE				
ALL DAY:	1.43	1.41	2.06	1.84
ALL NIGHT:	0.0	0.91	0.0	0.91
ALL DAY AND NIGHT:	1.15	1.31	1.64	1.65
DEL-RELATED DAY:	1.43	1.41	1.86	1.70
DEL-RELATED NIGHT:	0.0	0.91	0.0	0.91
DEL-RELATED DAY/NIGHT:	1.15	1.31	1.49	1.55
SEVERITY RATE				
ALL DAY:	0.19	0.13	0.39	0.27
ALL NIGHT:	0.0	0.0	0.0	0.0
ALL DAY AND NIGHT:	0.16	0.11	0.31	0.21
DEL-RELATED DAY:	0.19	0.13	0.19	0.13
DEL-RELATED NIGHT:	0.0	0.0	0.0	0.0
DEL-RELATED DAY/NIGHT:	0.16	0.11	0.16	0.11

AVERAGE ANNUAL NUMBER OF ACCIDENTS PER MILE: 1.14
AVERAGE ANNUAL NUMBER OF NON-INTERSECTION ACCIDENTS PER MILE: 0.89

NOTE: ACCIDENT RATES ARE EXPRESSED IN TERMS OF ACCIDENTS PER MILLION VEHICLE MILES
ACCIDENT RATES WERE COMPUTED BY FACTORING THE ADT ON A QUARTERLY BASIS

Table 87. 1973 Accident and severity rates for Site 1.

ACCIDENT SUMMARY FORM

SITE NUMBER: MAINE 1	SITUATION: TANGENT
DATA PERIOD: 1/73 TO 1/74	SECTION LENGTH: 7.89 MILES
NUMBER OF INTERSECTIONS: 12	DRY DAYS PER YEAR: 238
DAYTIME VOLUME: 80% ADT	RAIN DAYS PER YEAR: 109

PART B. AVERAGE ACCIDENT RATE AND SEVERITY RATE

	NON-INTERSECTION		NON-INTERSECTION AND INTERSECTION	
	DRY	DRY AND WET	DRY	DRY AND WET
ACCIDENT RATE				
ALL DAY:	1.10	1.70	1.10	2.16
ALL NIGHT:	4.21	4.19	4.21	4.19
ALL DAY AND NIGHT:	1.72	2.20	1.72	2.56
DEL-RELATED DAY:	0.76	1.47	0.76	1.93
DEL-RELATED NIGHT:	4.21	4.19	4.21	4.19
DEL-RELATED DAY/NIGHT:	1.45	2.01	1.45	2.38
SEVERITY RATE				
ALL DAY:	0.0	0.29	0.0	0.43
ALL NIGHT:	0.78	0.53	0.78	0.53
ALL DAY AND NIGHT:	0.16	0.34	0.16	0.45
DEL-RELATED DAY:	0.0	0.29	0.0	0.43
DEL-RELATED NIGHT:	0.78	0.53	0.78	0.53
DEL-RELATED DAY/NIGHT:	0.16	0.34	0.16	0.45

AVERAGE ANNUAL NUMBER OF ACCIDENTS PER MILE: 1.52
AVERAGE ANNUAL NUMBER OF NON-INTERSECTION ACCIDENTS PER MILE: 1.27

NOTE: ACCIDENT RATES ARE EXPRESSED IN TERMS OF ACCIDENTS PER MILLION VEHICLE MILES
ACCIDENT RATES WERE COMPUTED BY FACTORING THE ADT ON A QUARTERLY BASIS

Table 88. 1976 Accident and severity rates for Site 2.

ACCIDENT SUMMARY FORM

SITE NUMBER: MAINE 2	SITUATION: TANGENT
DATA PERIOD: 1/76 TO 1/77	SECTION LENGTH: 5.30 MILES
NUMBER OF INTERSECTIONS: 6	DRY DAYS PER YEAR: 238
DAYTIME VOLUME: 80% ADT	RAIN DAYS PER YEAR: 109

PART B. AVERAGE ACCIDENT RATE AND SEVERITY RATE

	NON-INTERSECTION		NON-INTERSECTION AND INTERSECTION	
	DRY	DRY AND WET	DRY	DRY AND WET
ACCIDENT RATE				
ALL DAY:	1.16	0.79	1.75	1.20
ALL NIGHT:	1.66	2.31	1.66	2.31
ALL DAY AND NIGHT:	1.26	1.10	1.73	1.42
DEL-RELATED DAY:	1.16	0.79	1.75	1.20
DEL-RELATED NIGHT:	0.0	1.17	0.0	1.17
DEL-RELATED DAY/NIGHT:	0.93	0.87	1.40	1.20
SEVERITY RATE				
ALL DAY:	0.0	0.0	0.0	0.0
ALL NIGHT:	0.0	1.17	0.0	1.17
ALL DAY AND NIGHT:	0.0	0.23	0.0	0.23
DEL-RELATED DAY:	0.0	0.0	0.0	0.0
DEL-RELATED NIGHT:	0.0	1.17	0.0	1.17
DEL-RELATED DAY/NIGHT:	0.0	0.23	0.0	0.23

AVERAGE ANNUAL NUMBER OF ACCIDENTS PER MILE: 1.32
AVERAGE ANNUAL NUMBER OF NON-INTERSECTION ACCIDENTS PER MILE: 1.13

NOTE: ACCIDENT RATES ARE EXPRESSED IN TERMS OF ACCIDENTS PER MILLION VEHICLE MILES
ACCIDENT RATES WERE COMPUTED BY FACTORING THE ADT ON A QUARTERLY BASIS

Table 89. 1974 Accident and severity rates for Site 2.

ACCIDENT SUMMARY FORM

SITE NUMBER: MAINE 2
DATA PERIOD: 1/74 TO 1/75
NUMBER OF INTERSECTIONS: 6
DAYTIME VOLUME: 80% ADT

SITUATION: TANGENT
SECTION LENGTH: 5.30 MILES
DRY DAYS PER YEAR: 238
RAIN DAYS PER YEAR: 109

PART B. AVERAGE ACCIDENT RATE AND SEVERITY RATE

	NON-INTERSECTION		NON-INTERSECTION AND INTERSECTION	
	DRY	DRY AND WET	DRY	DRY AND WET
ACCIDENT RATE				
ALL DAY:	0.27	0.19	0.54	0.37
ALL NIGHT:	5.64	3.87	5.64	3.87
ALL DAY AND NIGHT:	1.34	0.92	1.56	1.07
DEL-RELATED DAY:	0.27	0.19	0.27	0.19
DEL-RELATED NIGHT:	3.80	2.60	3.80	2.60
DEL-RELATED DAY/NIGHT:	0.98	0.67	0.98	0.67
SEVERITY RATE				
ALL DAY:	0.0	0.0	0.27	0.19
ALL NIGHT:	0.0	0.0	0.0	0.0
ALL DAY AND NIGHT:	0.0	0.0	0.22	0.15
DEL-RELATED DAY:	0.0	0.0	0.0	0.0
DEL-RELATED NIGHT:	0.0	0.0	0.0	0.0
DEL-RELATED DAY/NIGHT:	0.0	0.0	0.0	0.0

AVERAGE ANNUAL NUMBER OF ACCIDENTS PER MILE: 0.94
AVERAGE ANNUAL NUMBER OF NON-INTERSECTION ACCIDENTS PER MILE: 0.75

NOTE: ACCIDENT RATES ARE EXPRESSED IN TERMS OF ACCIDENTS PER MILLION VEHICLE MILES
ACCIDENT RATES WERE COMPUTED BY FACTORING THE ADT ON A QUARTERLY BASIS

Table 90. 1973 Accident and severity rates for Site 2.

ACCIDENT SUMMARY FORM

SITE NUMBER: MAINE 2
DATA PERIOD: 1/73 TO 1/74
NUMBER OF INTERSECTIONS: 6
DAYTIME VOLUME: 80% ADT

SITUATION: TANGENT
SECTION LENGTH: 5.30 MILES
DRY DAYS PER YEAR: 238
RAIN DAYS PER YEAR: 109

PART B. AVERAGE ACCIDENT RATE AND SEVERITY RATE

	NON-INTERSECTION		NON-INTERSECTION AND INTERSECTION	
	DRY	DRY AND WET	DRY	DRY AND WET
ACCIDENT RATE				
ALL DAY:	0.98	0.67	0.98	0.67
ALL NIGHT:	0.0	3.29	0.0	4.66
ALL DAY AND NIGHT:	0.79	1.20	0.79	1.47
DEL-RELATED DAY:	0.70	0.48	0.70	0.48
DEL-RELATED NIGHT:	0.0	3.29	0.0	4.66
DEL-RELATED DAY/NIGHT:	0.56	1.04	0.56	1.31
SEVERITY RATE				
ALL DAY:	0.29	0.20	0.29	0.20
ALL NIGHT:	0.0	0.0	0.0	1.38
ALL DAY AND NIGHT:	0.23	0.16	0.23	0.43
DEL-RELATED DAY:	0.0	0.0	0.0	0.0
DEL-RELATED NIGHT:	0.0	0.0	0.0	1.38
DEL-RELATED DAY/NIGHT:	0.0	0.0	0.0	0.28

AVERAGE ANNUAL NUMBER OF ACCIDENTS PER MILE: 0.94
AVERAGE ANNUAL NUMBER OF NON-INTERSECTION ACCIDENTS PER MILE: 0.75

NOTE: ACCIDENT RATES ARE EXPRESSED IN TERMS OF ACCIDENTS PER MILLION VEHICLE MILES
ACCIDENT RATES WERE COMPUTED BY FACTORING THE ADT ON A QUARTERLY BASIS

Table 91. Two-year average accident and severity rates at Site 3.

ACCIDENT SUMMARY FORM

SITE NUMBER: MD 67
DATA PERIOD: 10/73 TO 10/75
NUMBER OF INTERSECTIONS: 7
DAYTIME VOLUME: 80% ADT

SITUATION: TANGENT
SECTION LENGTH: 2.75 MILES
DRY DAYS PER YEAR: 253
RAIN DAYS PER YEAR: 104

PART B. AVERAGE ACCIDENT RATE AND SEVERITY RATE

	NON-INTERSECTION		NON-INTERSECTION AND INTERSECTION	
	DRY	DRY AND WET	DRY	DRY AND WET
ACCIDENT RATE				
ALL DAY:	D.21	0.15	0.47	0.33
ALL NIGHT:	1.89	1.34	7.13	5.06
ALL DAY AND NIGHT:	D.55	0.39	1.80	1.28
DEL-RELATED DAY:	0.21	0.15	D.47	0.33
DEL-RELATED NIGHT:	1.89	1.34	5.25	3.72
DEL-RELATED DAY/NIGHT:	D.55	0.39	1.43	1.01
SEVERITY RATE				
ALL DAY:	D.0	0.0	0.0	0.0
ALL NIGHT:	1.89	1.34	5.25	3.72
ALL DAY AND NIGHT:	D.38	0.27	1.05	0.74
DEL-RELATED DAY:	0.D	0.0	0.D	0.0
DEL-RELATED NIGHT:	1.89	1.34	5.25	3.72
DEL-RELATED DAY/NIGHT:	D.38	0.27	1.05	D.74

AVERAGE ANNUAL NUMBER OF ACCIDENTS PER MILE: 0.85
AVERAGE ANNUAL NUMBER OF NON-INTERSECTION ACCIDENTS PER MILE: D.36

NOTE: ACCIDENT RATES ARE EXPRESSED IN TERMS OF ACCIDENTS PER MILLION VEHICLE MILES

Table 92. Six-year average accident and severity rates at Site 4.

ACCIDENT SUMMARY FORM

SITE NUMBER: VA 3	SITUATION: TANGENT
DATA PERIOD: 1/70 TO 1/76	SECTION LENGTH: 3.60 MILES
NUMBER OF INTERSECTIONS: 2	DRY DAYS PER YEAR: 252
DAYTIME VOLUME: 80% ADT	RAIN DAYS PER YEAR: 109

PART B. AVERAGE ACCIDENT RATE AND SEVERITY RATE

	NON-INTERSECTION		NON-INTERSECTION AND INTERSECTION	
	DRY	DRY AND WET	DRY	DRY AND WET
ACCIDENT RATE				
ALL DAY:	1.23	1.13	1.90	1.59
ALL NIGHT:	2.31	1.79	2.86	2.17
ALL DAY AND NIGHT:	1.45	1.26	2.09	1.71
DEL-RELATED DAY:	1.09	1.03	1.69	1.44
DEL-RELATED NIGHT:	0.87	0.78	1.14	0.97
DEL-RELATED DAY/NIGHT:	1.05	0.98	1.58	1.35
SEVERITY RATE				
ALL DAY:	0.29	0.36	0.51	0.52
ALL NIGHT:	0.92	0.82	0.92	0.82
ALL DAY AND NIGHT:	0.41	0.45	0.59	0.58
DEL-RELATED DAY:	0.22	0.31	0.44	0.47
DEL-RELATED NIGHT:	0.30	0.39	0.30	0.39
DEL-RELATED DAY/NIGHT:	0.23	0.33	0.42	0.45

AVERAGE ANNUAL NUMBER OF ACCIDENTS PER MILE: 1.94
AVERAGE ANNUAL NUMBER OF NON-INTERSECTION ACCIDENTS PER MILE: 1.44

NOTE: ACCIDENT RATES ARE EXPRESSED IN TERMS OF ACCIDENTS PER MILLION VEHICLE MILES

Table 93. Two-year average accident and severity rates at Site 5.

ACCIDENT SUMMARY FORM

SITE NUMBER: MD 482	SITUATION: WINDING
DATA PERIOD: 1/74 TO 1/76	SECTION LENGTH: 4.60 MILES
NUMBER OF INTERSECTIONS: 16	DRY DAYS PER YEAR: 253
DAYTIME VOLUME: 80% ADT	RAIN DAYS PER YEAR: 106

PART B. AVERAGE ACCIDENT RATE AND SEVERITY RATE

	NON-INTERSECTION		NON-INTERSECTION AND INTERSECTION	
	DRY	DRY AND WET	DRY	DRY AND WET
ACCIDENT RATE				
ALL DAY:	1.41	1.54	2.49	2.53
ALL NIGHT:	4.98	3.94	6.21	5.69
ALL DAY AND NIGHT:	2.12	2.02	3.23	3.16
DEL-RELATED DAY:	1.41	1.54	2.34	2.31
DEL-RELATED NIGHT:	3.10	2.62	4.33	3.93
DEL-RELATED DAY/NIGHT:	1.75	1.76	2.74	2.63
SEVERITY RATE				
ALL DAY:	0.63	0.66	1.09	0.99
ALL NIGHT:	3.10	2.19	3.72	2.62
ALL DAY AND NIGHT:	1.12	0.97	1.62	1.32
DEL-RELATED DAY:	0.63	0.66	1.09	0.99
DEL-RELATED NIGHT:	1.86	1.31	2.47	1.74
DEL-RELATED DAY/NIGHT:	0.87	0.79	1.37	1.14

AVERAGE ANNUAL NUMBER OF ACCIDENTS PER MILE: 3.91
AVERAGE ANNUAL NUMBER OF NON-INTERSECTION ACCIDENTS PER MILE: 2.50

NOTE: ACCIDENT RATES ARE EXPRESSED IN TERMS OF ACCIDENTS PER MILLION VEHICLE MILES

Table 94. Six-year average accident and severity rates for Site 6.

ACCIDENT SUMMARY FORM

SITE NUMBER: PA 879
DATA PERIOD: 1/69 TO 1/76[1]
NUMBER OF INTERSECTIONS:5
DAYTIME VOLUME: 75% ADT

SITUATION: WINDING
SECTION LENGTH: 3.79 MILES
DRY DAYS PER YEAR: 222
RAIN DAYS PER YEAR: 131

PART B. AVERAGE ACCIDENT RATE AND SEVERITY RATE

	NON-INTERSECTION		NON-INTERSECTION AND INTERSECTION	
	DRY	DRY AND WET	DRY	DRY AND WET
ACCIDENT RATE				
ALL DAY:	1.63	1.52	1.79	1.81
ALL NIGHT:	3.69	3.32	4.02	3.72
ALL DAY AND NIGHT:	2.14	1.97	2.35	2.28
DEL-RELATED DAY:	1.20	1.19	1.31	1.33
DEL-RELATED NIGHT:	3.05	2.81	3.05	2.90
DEL-RELATED DAY/NIGHT:	1.66	1.59	1.74	1.72
SEVERITY RATE				
ALL DAY:	0.60	0.55	0.60	0.62
ALL NIGHT:	0.84	0.83	0.84	0.83
ALL DAY AND NIGHT:	0.66	0.62	0.66	0.67
DEL-RELATED DAY:	0.50	0.48	0.50	0.48
DEL-RELATED NIGHT:	0.67	0.72	0.67	0.72
DEL-RELATED DAY/NIGHT:	0.54	0.54	0.54	0.54

AVERAGE ANNUAL NUMBER OF ACCIDENTS PER MILE: 3.96
AVERAGE ANNUAL NUMBER OF NON-INTERSECTION ACCIDENTS PER MILE: 3.43

NOTE: ACCIDENT RATES ARE EXPRESSED IN TERMS OF ACCIDENTS PER MILLION VEHICLE MILES

[1]Year 1970 excluded.

Table 95. Three-year average accident and severity rates at Site 7.

ACCIDENT SUMMARY FORM

SITE NUMBER: MD 227	SITUATION: ISOLATED HORIZONTAL CURVE
DATA PERIOD: 1/73 TO 1/76	SECTION LENGTH: 0.36 MILES
NUMBER OF INTERSECTIONS: 1	DRY DAYS PER YEAR: 253
DAYTIME VOLUME: 80% ADT	RAIN DAYS PER YEAR: 106

PART B. AVERAGE ACCIDENT RATE AND SEVERITY RATE

	NON-INTERSECTION		NON-INTERSECTION AND INTERSECTION	
	DRY	DRY AND WET	DRY	DRY AND WET
ACCIDENT RATE				
ALL DAY:	0.0	0.47	0.0	0.47
ALL NIGHT:	5.43	3.83	5.43	3.83
ALL DAY AND NIGHT:	1.09	1.14	1.09	1.14
DEL-RELATED DAY:	0.0	0.47	0.0	0.47
DEL-RELATED NIGHT:	5.43	3.83	5.43	3.83
DEL-RELATED DAY/NIGHT:	1.09	1.14	1.09	1.14
SEVERITY RATE				
ALL DAY:	0.0	0.0	0.0	0.0
ALL NIGHT:	5.43	3.83	5.43	3.83
ALL DAY AND NIGHT:	1.09	0.77	1.09	0.77
DEL-RELATED DAY:	0.0	0.0	0.0	0.0
DEL-RELATED NIGHT:	5.43	3.83	5.43	3.83
DEL-RELATED DAY/NIGHT:	1.09	0.77	1.09	0.77

AVERAGE ANNUAL NUMBER OF ACCIDENTS PER MILE: 2.78
AVERAGE ANNUAL NUMBER OF NON-INTERSECTION ACCIDENTS PER MILE: 2.78

NOTE: ACCIDENT RATES ARE EXPRESSED IN TERMS OF ACCIDENTS PER MILLION VEHICLES

Table 96. Six-year average accident and severity rates at Site 8.

ACCIDENT SUMMARY FORM

SITE NUMBER: PA 45	SITUATION: ISOLATED HORIZONTAL CURVE
DATA PERIOD: 1/69 TO 1/76[1]	SECTION LENGTH: 0.38 MILES
NUMBER OF INTERSECTIONS:	DRY DAYS PER YEAR: 222
DAYTIME VOLUME: 80% ADT	RAIN DAYS PER YEAR: 131

PART B. AVERAGE ACCIDENT RATE AND SEVERITY RATE

	NON-INTERSECTION		NON-INTERSECTION AND INTERSECTION	
	DRY	DRY AND WET	DRY	DRY AND WET
ACCIDENT RATE				
ALL DAY:	0.30	0.55	0.30	0.55
ALL NIGHT:	1.50	0.94	1.50	0.94
ALL DAY AND NIGHT:	0.54	0.63	0.54	0.63
DEL-RELATED DAY:	0.0	0.37	0.0	0.37
DEL-RELATED NIGHT:	1.50	0.94	1.50	0.94
DEL-RELATED DAY/NIGHT:	0.30	0.48	0.30	0.48
SEVERITY RATE				
ALL DAY:	0.30	0.37	0.30	0.37
ALL NIGHT:	0.0	0.0	0.0	0.0
ALL DAY AND NIGHT:	0.24	0.29	0.24	0.29
DEL-RELATED DAY:	0.0	0.18	0.0	0.18
DEL-RELATED NIGHT:	0.0	0.0	0.0	0.0
DEL-RELATED DAY/NIGHT:	0.0	0.14	0.0	0.14

AVERAGE ANNUAL NUMBER OF ACCIDENTS PER MILE: 1.75
AVERAGE ANNUAL NUMBER OF NON-INTERSECTION ACCIDENTS PER MILE: 1.75

NOTE: ACCIDENT RATES ARE EXPRESSED IN TERMS OF ACCIDENTS PER MILLION VEHICLES

[1]Year 1970 excluded.

Table 97. Five year average accident and severity rates for supplemental Illinois site.

ACCIDENT SUMMARY FORM

SITE NUMBER: FA 01	SITUATION: TANGENT
DATA PERIOD: 1/72 TO 1/77	SECTION LENGTH: 4.78 MILES
NUMBER OF INTERSECTIONS:	DRY DAYS PER YEAR: 278
DAYTIME VOLUME: 79% ADT	RAIN DAYS PER YEAR: 80

PART B. AVERAGE ACCIDENT RATE AND SEVERITY RATE

	NON-INTERSECTION		NON-INTERSECTION AND INTERSECTION	
	DRY	DRY AND WET	DRY	DRY AND WET
ACCIDENT RATE				
ALL DAY:	1.13	1.01	2.13	2.30
ALL NIGHT:	1.29	1.00	3.42	2.92
ALL DAY AND NIGHT:	1.16	1.01	2.40	2.43
DEL-RELATED DAY:	0.96	0.88	1.79	1.97
DEL-RELATED NIGHT:	0.97	0.75	3.10	2.67
DEL-RELATED DAY/NIGHT:	0.96	0.85	2.07	2.12
SEVERITY RATE				
ALL DAY:	0.61	0.54	1.04	1.20
ALL NIGHT:	0.33	0.25	1.22	0.95
ALL DAY AND NIGHT:	0.55	0.48	1.08	1.15
DEL-RELATED DAY:	0.61	0.54	0.96	1.14
DEL-RELATED NIGHT:	0.33	0.25	1.22	0.95
DEL-RELATED DAY/NIGHT:	0.55	0.48	1.01	1.10

AVERAGE ANNUAL NUMBER OF ACCIDENTS PER MILE: 1.97
AVERAGE ANNUAL NUMBER OF NON-INTERSECTION ACCIDENTS PER MILE: 0.79

NOTE: ACCIDENT RATES ARE EXPRESSED IN TERMS OF ACCIDENTS PER MILLION VEHICLE MILES

APPENDIX H

TPM COMPARISONS BETWEEN VARIOUS COMBINATIONS OF TREATMENT, ENVIRONMENTAL CONDITION, AND ACCLIMATION TIME

Included herein is a series of "ragged matrices" indicating graphically the extent to which the distributions of speed and lateral placement were found to vary significantly between alternative operating conditions. Refer to Appendix F to obtain the actual TPM values compared.

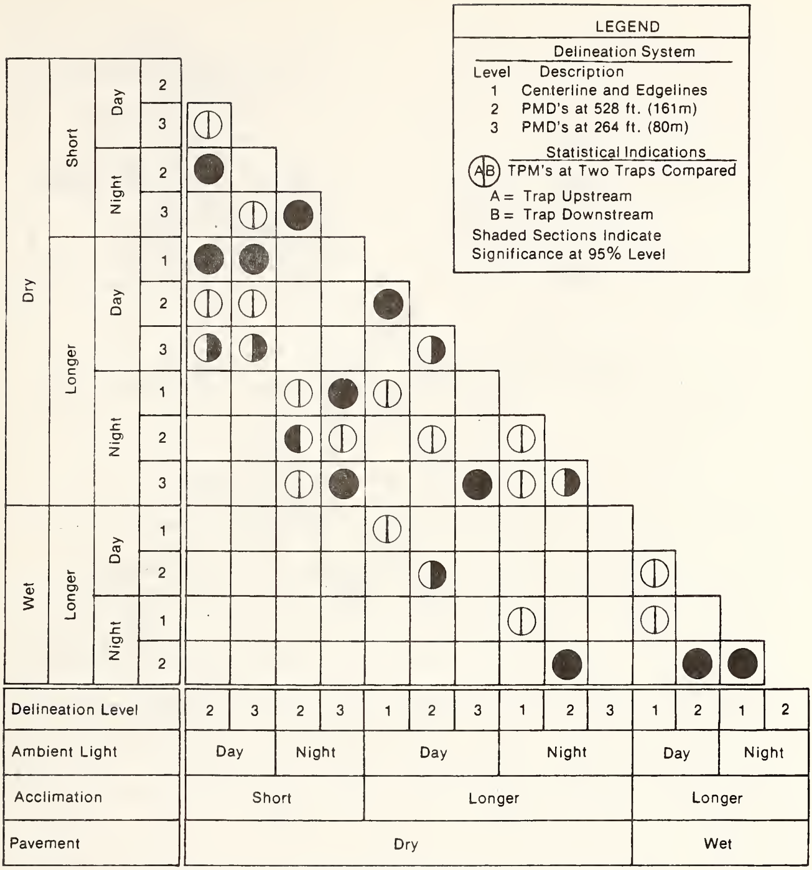


Figure 39. Site 1 statistical comparisons of mean speed.

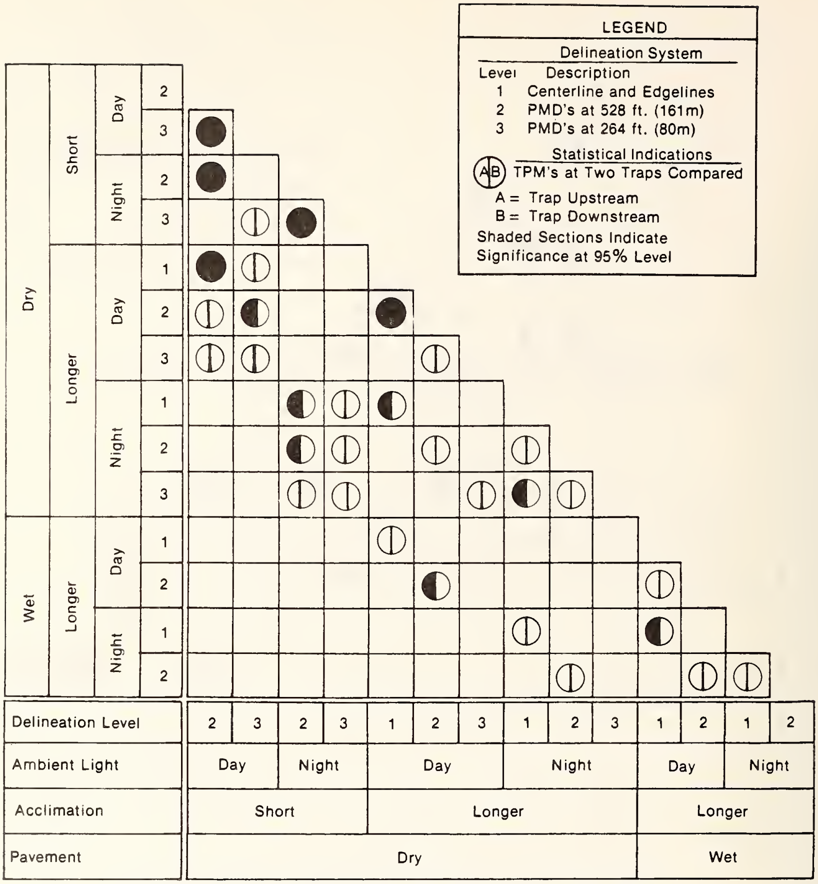


Figure 40. Site 1 statistical comparisons of speed variance.

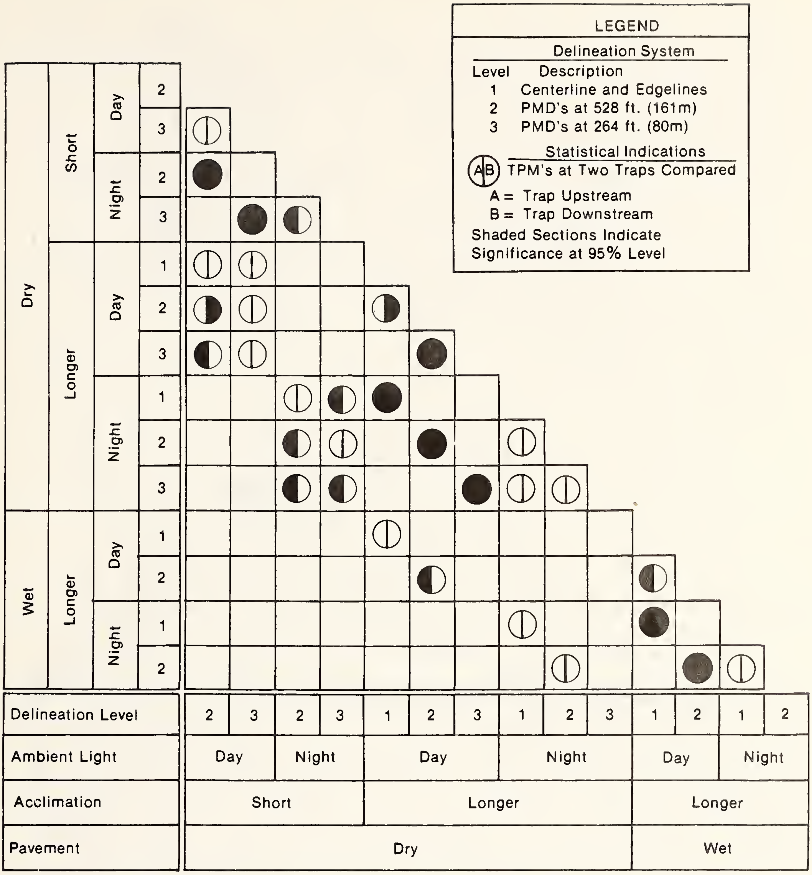


Figure 41. Site 1 statistical comparisons of mean placement.

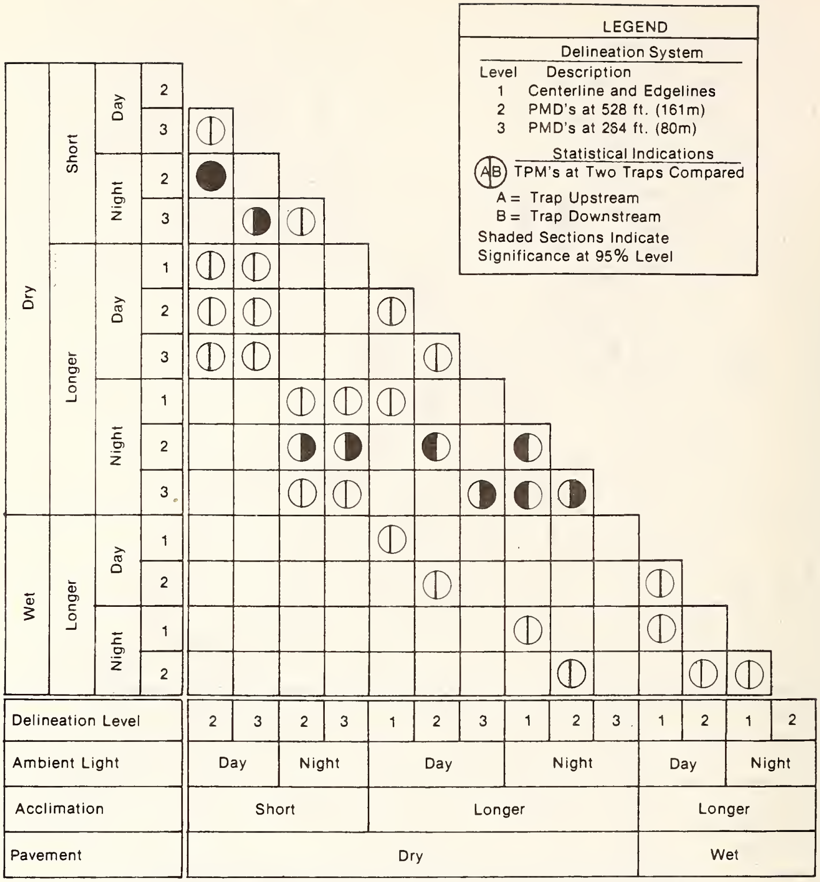


Figure 42. Site 1 statistical comparisons of placement variance.

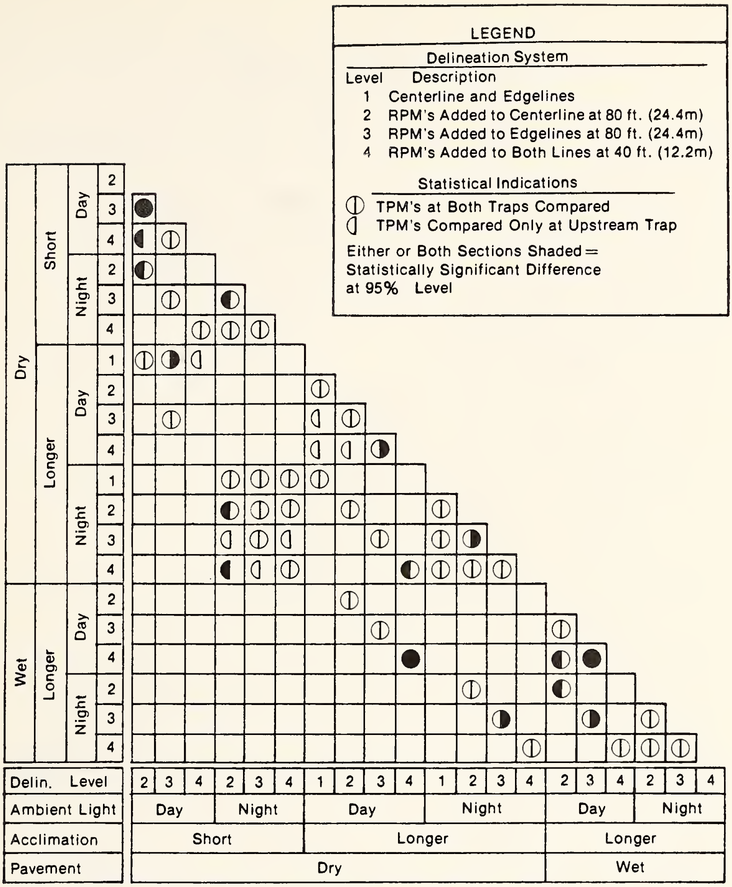


Figure 43. Site 2 statistical comparisons of mean speed.

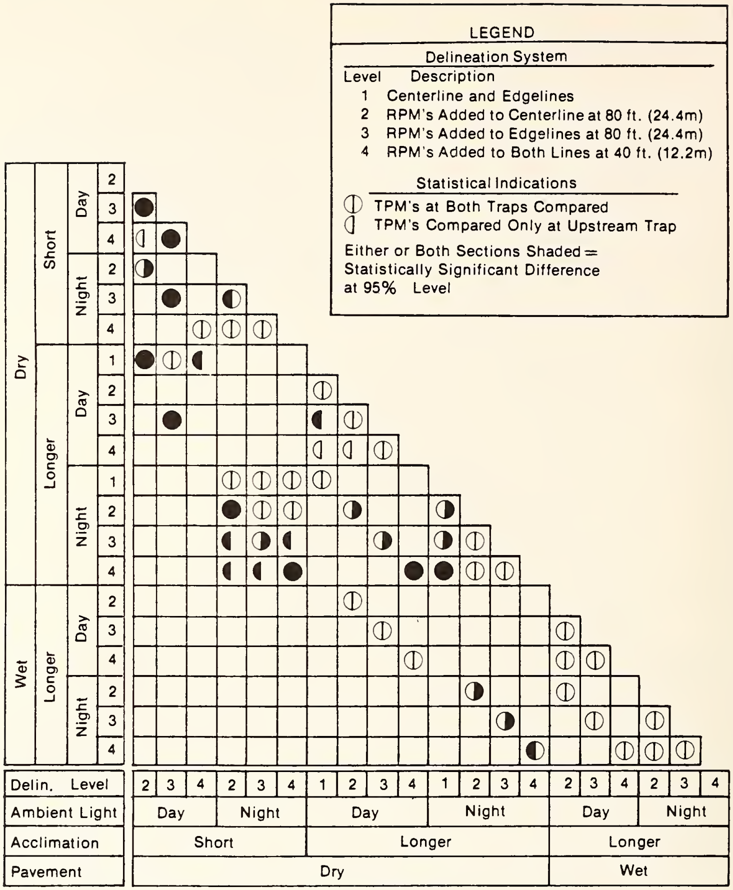


Figure 44. Site 2 statistical comparisons of speed variance.

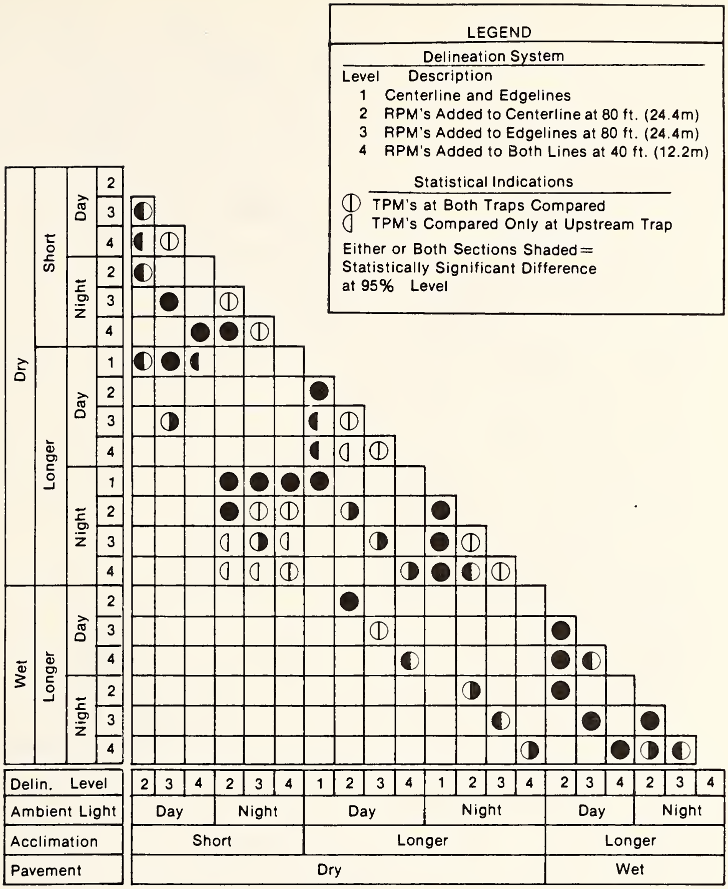


Figure 45. Site 2 statistical comparisons of mean placement.

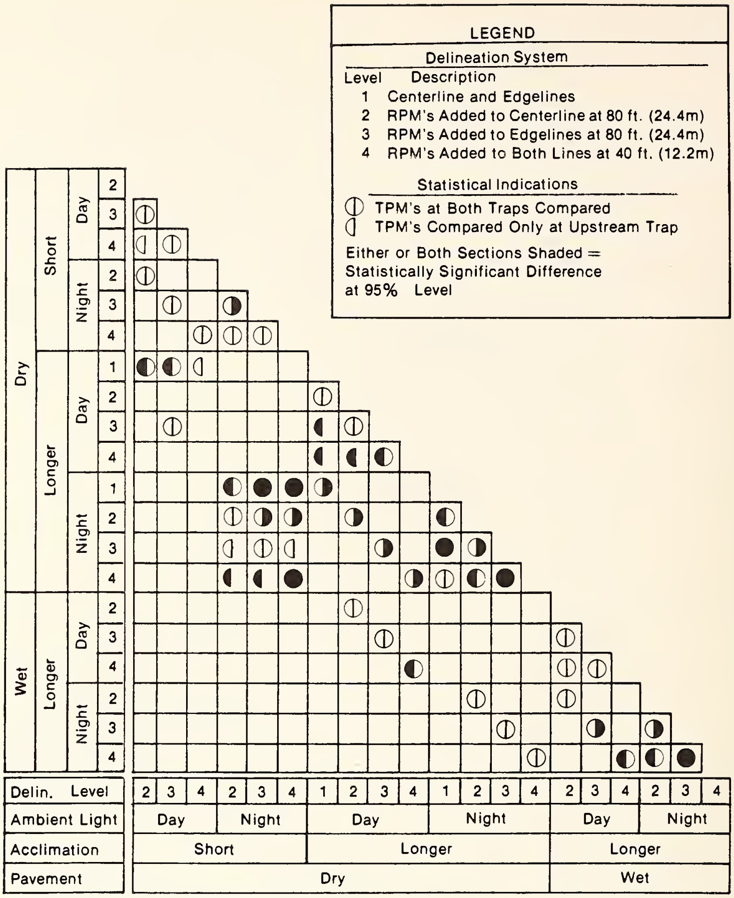
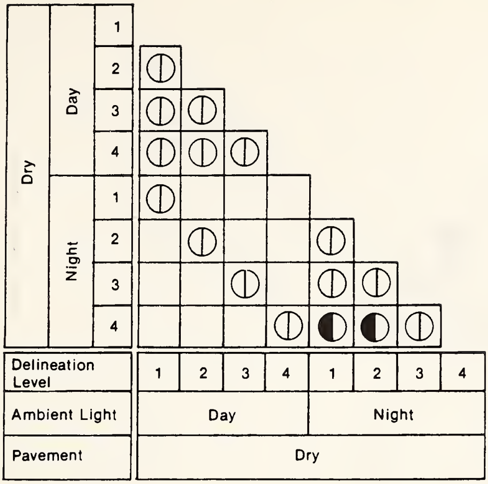
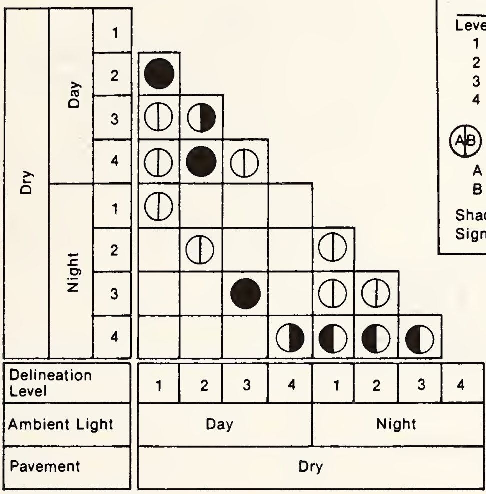


Figure 46. Site 2 statistical comparisons of placement variance.



Mean Speed



Speed Variance

LEGEND

Delineation System

Level	Description
1	5:35 Centerline, STD.Edgelines
2	5:35 CTR w/RPM's,STD. Edgelines
3	10:30 CTR w/RPM's, STD. Edgelines
4	15:25 Centerline, STD. Edgelines

Statistical Indications

(A|B) TPM's at Two Traps Compared

A = Trap Upstream
B = Trap Downstream

Shaded Sections Indicate
Significance at 95% Level

Figure 47. Site 3 statistical speed comparisons.

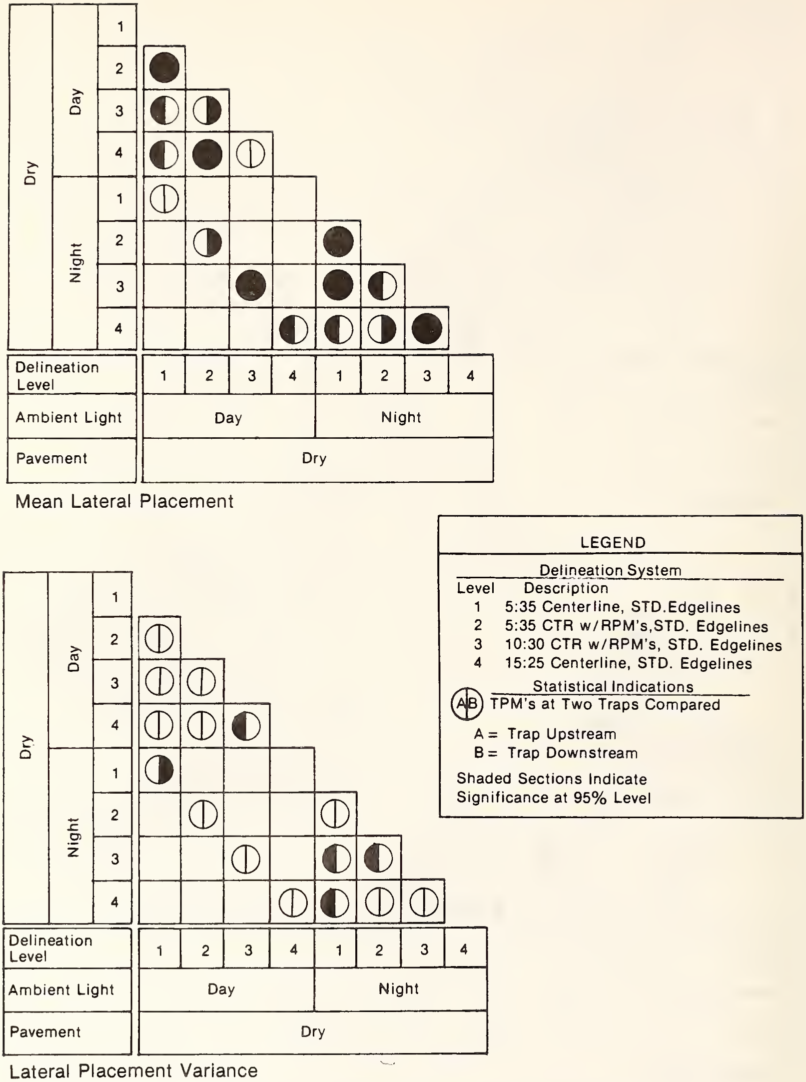


Figure 48. Site 3 statistical placement comparisons.

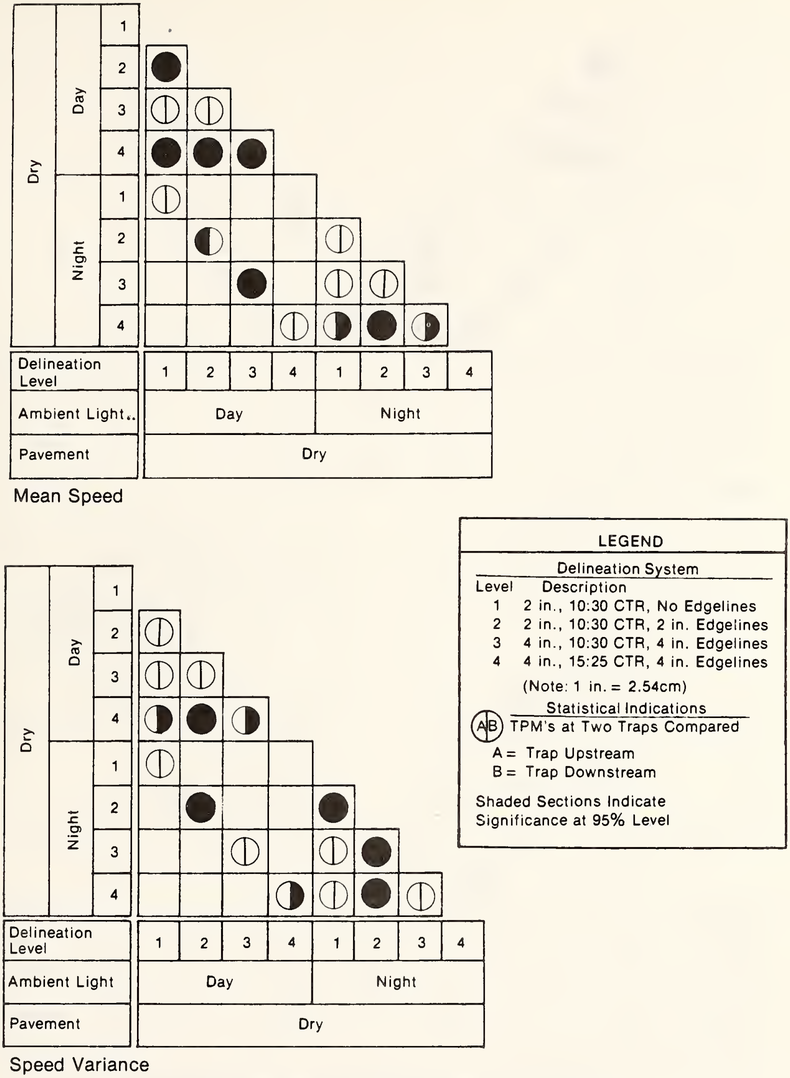
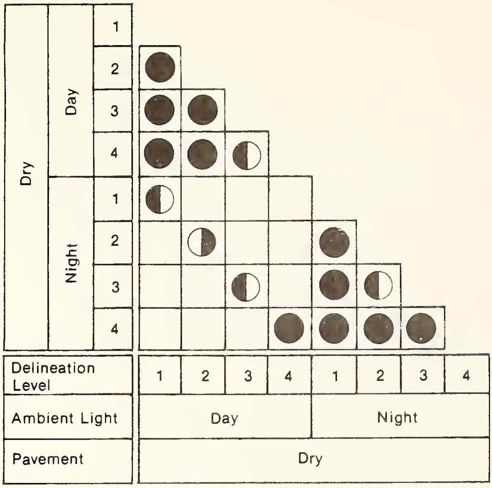
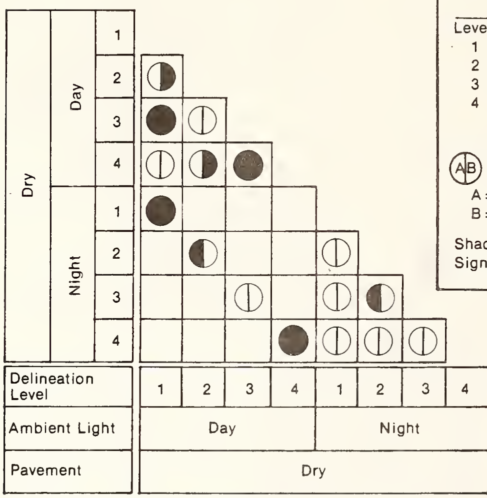


Figure 49. Site 4A statistical speed comparisons.



Mean Lateral Placement



Lateral Placement Variance

LEGEND

Delineation System

Level	Description
1	2 in., 10:30 CTR, No Edgelines
2	2 in., 10:30 CTR, 2 in. Edgelines
3	4 in., 10:30 CTR, 4 in. Edgelines
4	4 in., 15:25 CTR, 4 in. Edgelines

(Note: 1 in. = 2.54cm)

Statistical Indications

(A|B) TPM's at Two Traps Compared

A = Trap Upstream
B = Trap Downstream

Shaded Sections Indicate Significance at 95% Level

Figure 50. Site 4A statistical placement comparisons.

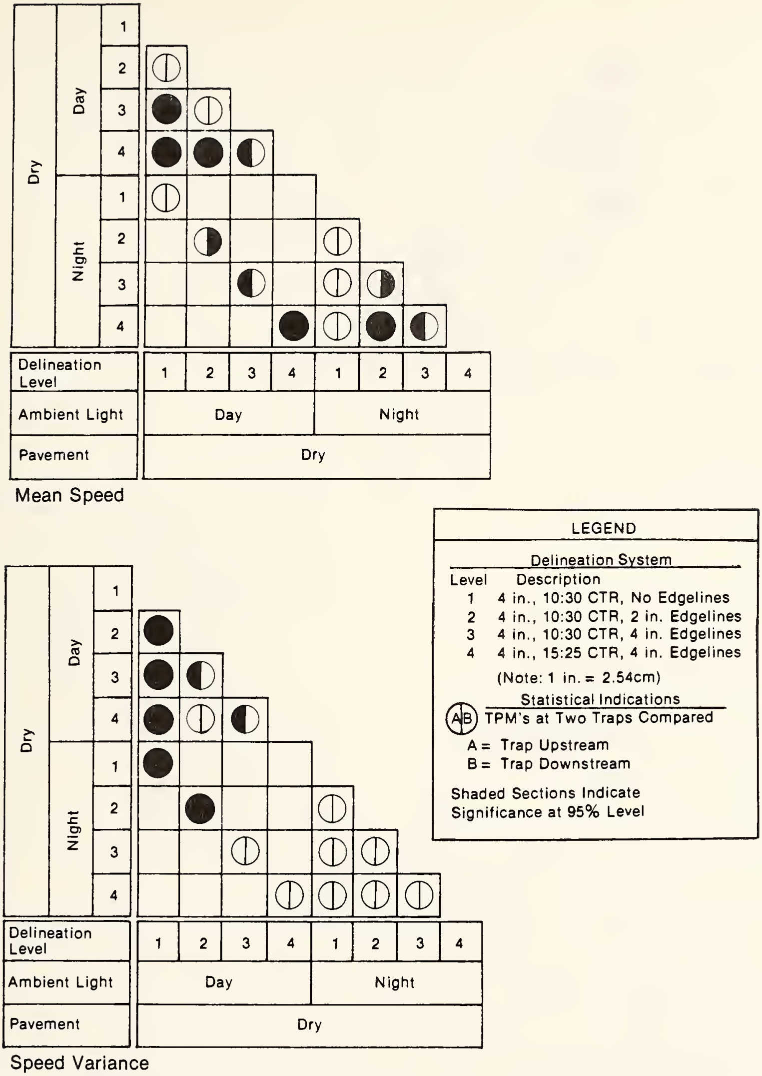
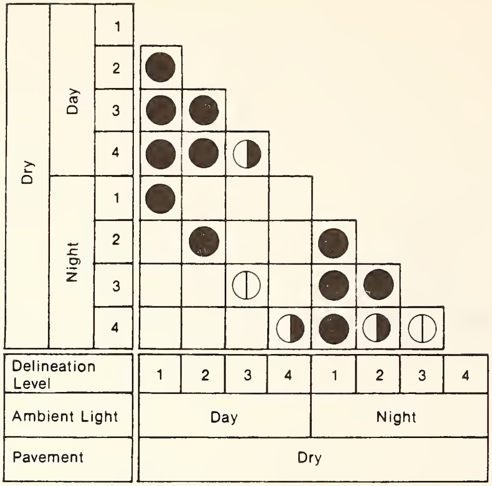


Figure 51. Site 4B statistical speed comparisons.



Mean Lateral Placement

LEGEND

Delineation System

Level	Description
1	4 in., 10:30 CTR, No Edgelines
2	4 in., 10:30 CTR, 2 in. Edgelines
3	4 in., 10:30 CTR, 4 in. Edgelines
4	4 in., 15:25 CTR, 4 in. Edgelines

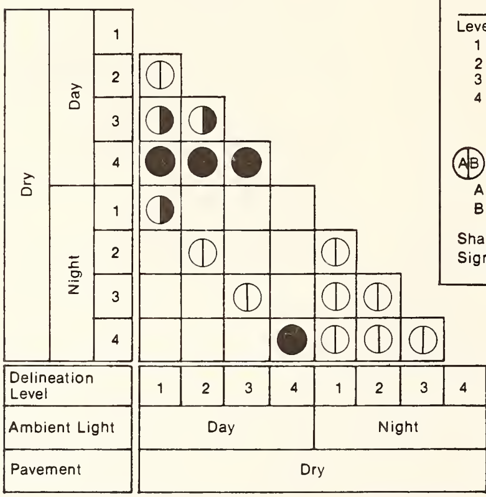
(Note: 1 in. = 2.54cm)

Statistical Indications

(A|B) TPM's at Two Traps Compared

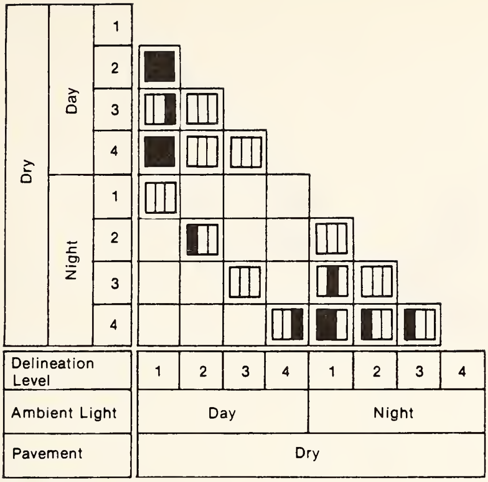
A = Trap Upstream
B = Trap Downstream

Shaded Sections Indicate Significance at 95% Level



Lateral Placement Variance

Figure 52. Site 4B statistical placement comparisons.



Mean Speed

LEGEND

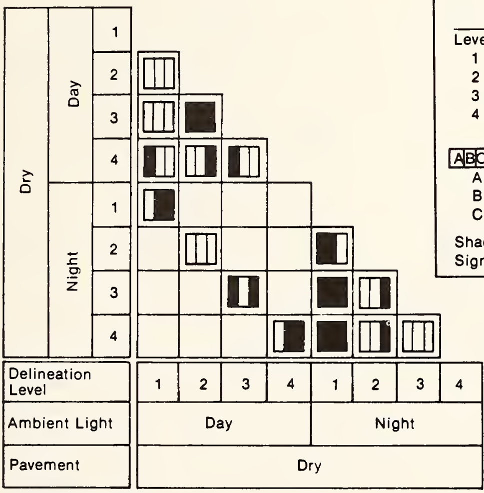
Delineation System

Level	Description
1	CTR, RPM's Only, No Edgelines
2	CTR, RPM's Only, STD. Edgelines
3	CTR, RPM's Only, Edgelines w/RPM's
4	STD. Centerline, STD. Edgelines

Statistical Indications

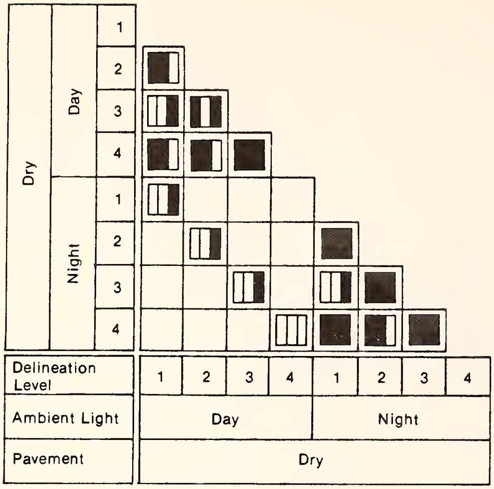
ABC TPM's at Three Traps Compared
A = Trap Inside Curve
B = Trap P.R.C./Tangent
C = Trap Outside Curve

Shaded Sections Indicate Significance at 95% Level



Speed Variance

Figure 53. Site 5 statistical speed comparisons.



Mean Lateral Placement

LEGEND

Delineation System

Level	Description
1	CTR, RPM's Only, No Edgelines
2	CTR, RPM's Only, STD. Edgelines
3	CTR, RPM's Only, Edgelines w/RPM's
4	STD. Centerline, STD. Edgelines

Statistical Indications

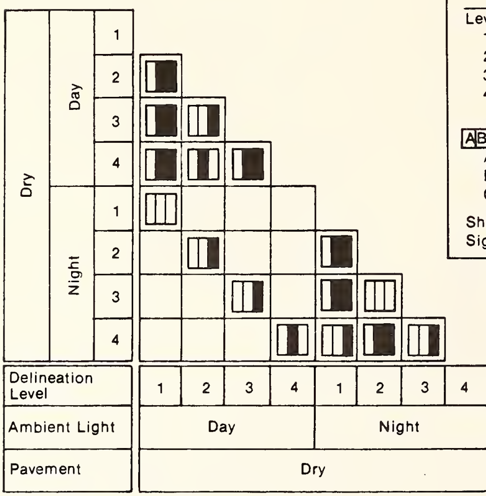
ABC TPM's at Three Traps Compared

A = Trap Inside Curve

B = Trap P.R.C./Tangent

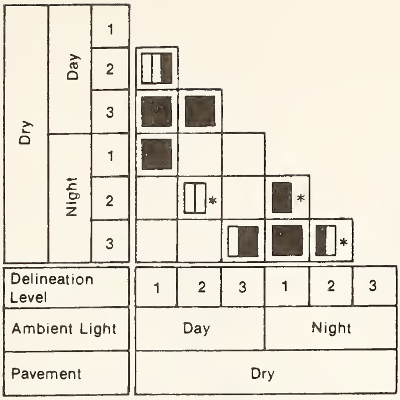
C = Trap Outside Curve

Shaded Sections Indicate
Significance at 95% Level

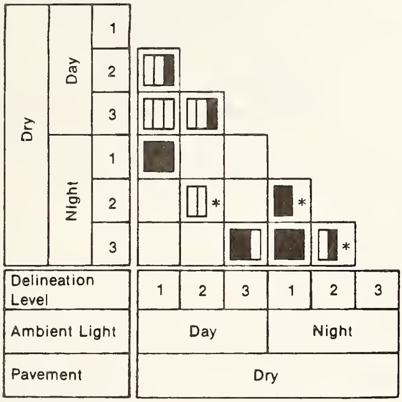


Lateral Placement Variance

Figure 54. Site 5 statistical placement comparisons.



Mean Speed



Speed Variance

LEGEND

Delineation System

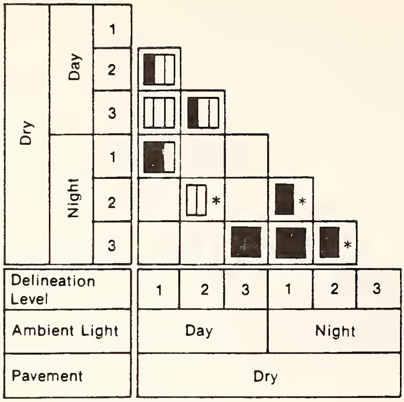
Level	Description
1	Single Centerline, No Edgelines
2	Single Centerline, STD. Edgelines
3	Double Centerline, STD. Edgelines

Statistical Indications

ABC TPM's at Three Traps Compared
A = Trap Inside Curve
B = Trap P.R.C./Tangent
C = Trap Outside Curve

Shaded Sections Indicate
Significance at 95% Level
(Trap C Data Not Obtained for * Conditions)

Figure 55. Site 6 statistical speed comparisons.



Mean Lateral Placement

LEGEND

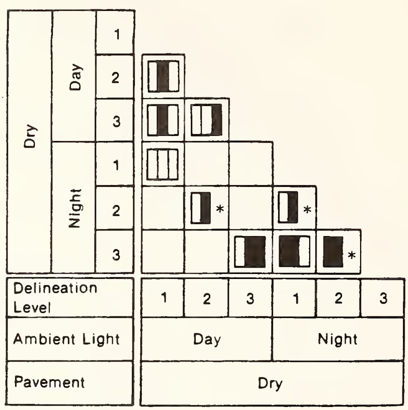
Delineation System

Level	Description
1	Single Centerline, No Edgelines
2	Single Centerline, STD. Edgelines
3	Double Centerline, STD. Edgelines

Statistical Indications

ABC TPM's at Three Traps Compared
A = Trap Inside Curve
B = Trap P.R.C./Tangent
C = Trap Outside Curve

Shaded Sections Indicate
Significance at 95% Level
(Trap C Data Not Obtained for * Conditions)



Lateral Placement Variance

Figure 56. Site 6 statistical placement comparisons.

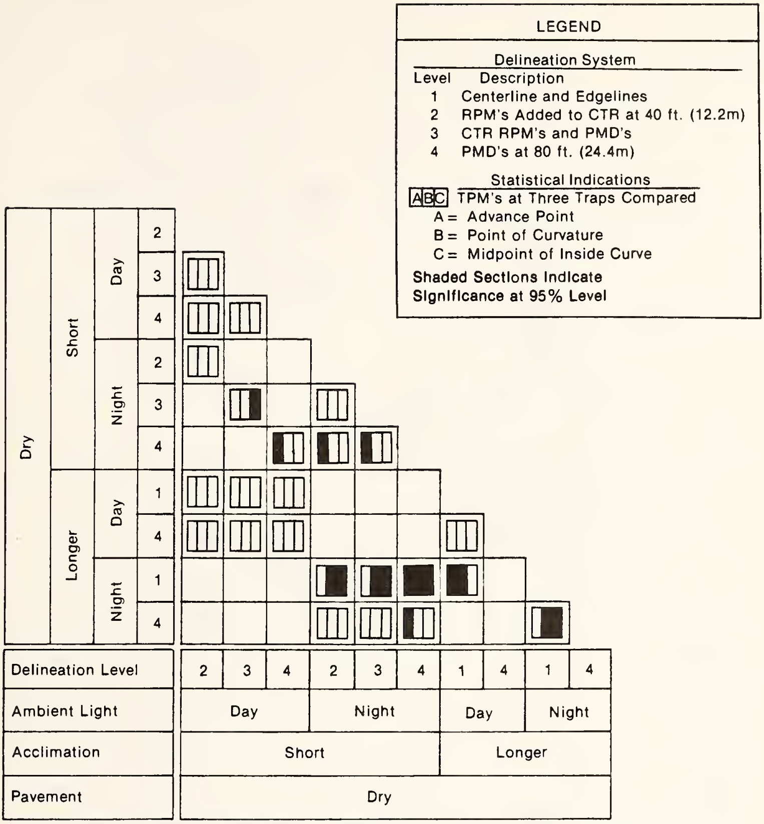


Figure 57. Site 7 statistical comparisons of mean speed on inside curve.

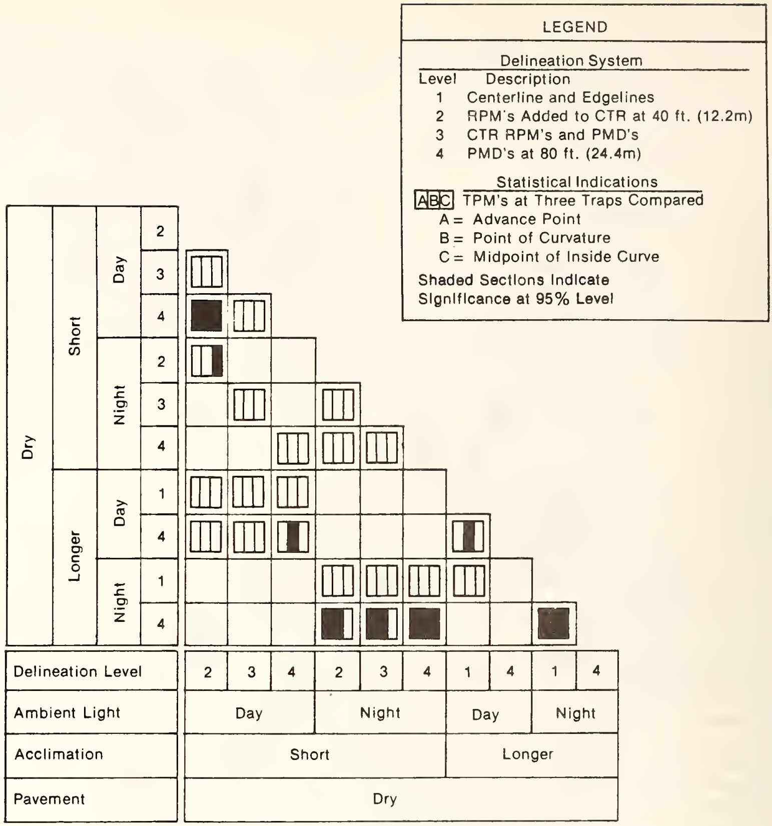


Figure 58. Site 7 statistical comparisons of speed variance on inside curve.

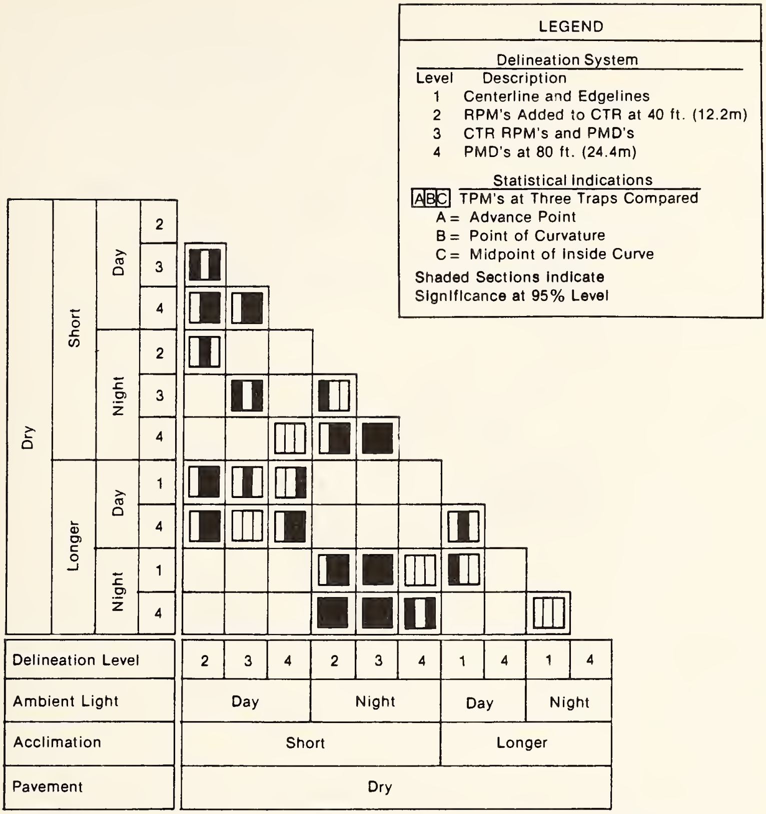


Figure 59. Site 7 statistical comparisons of mean placement on inside curve.

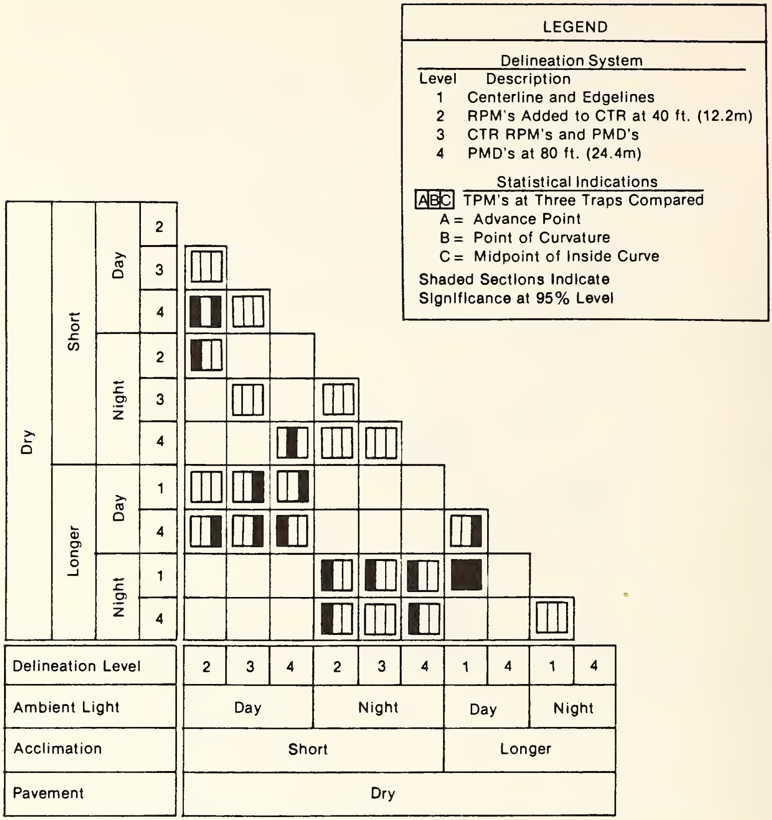


Figure 60. Site 7 statistical comparisons of placement variance on inside curve.

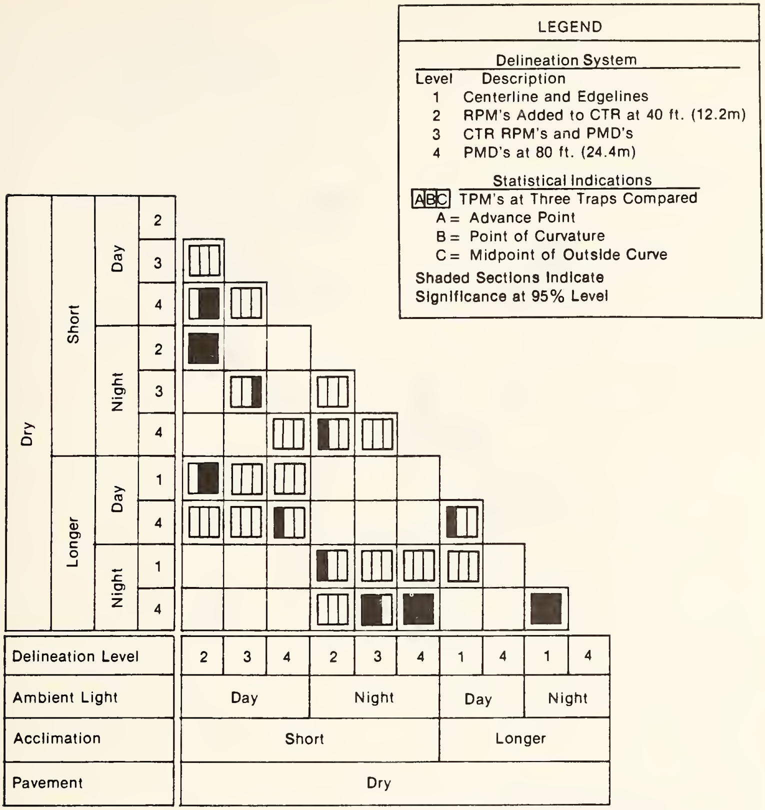


Figure 61. Site 7 statistical comparisons of mean speed on outside curve.

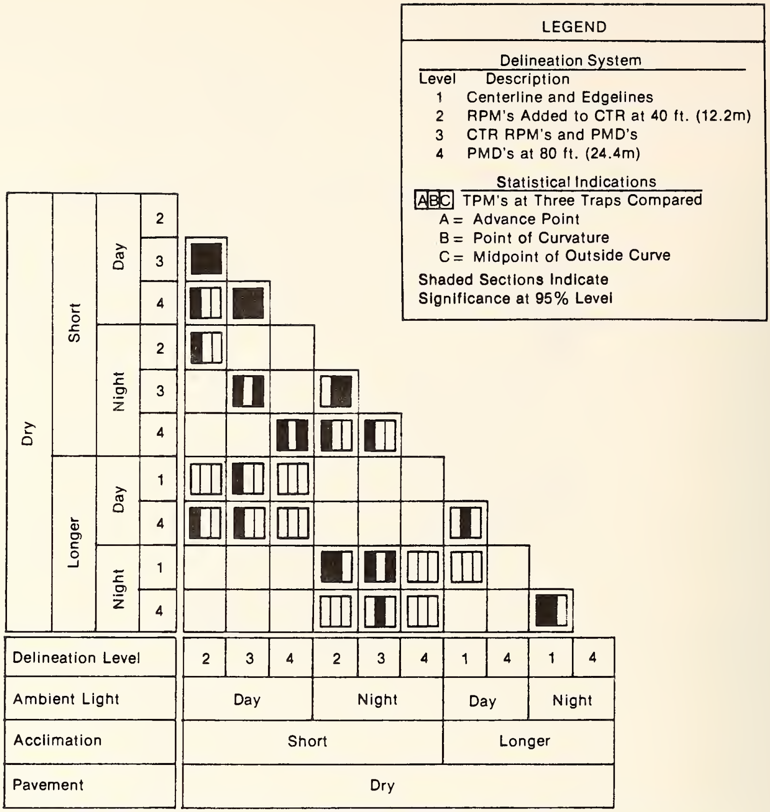


Figure 62. Site 7 statistical comparisons of speed variance on outside curve.

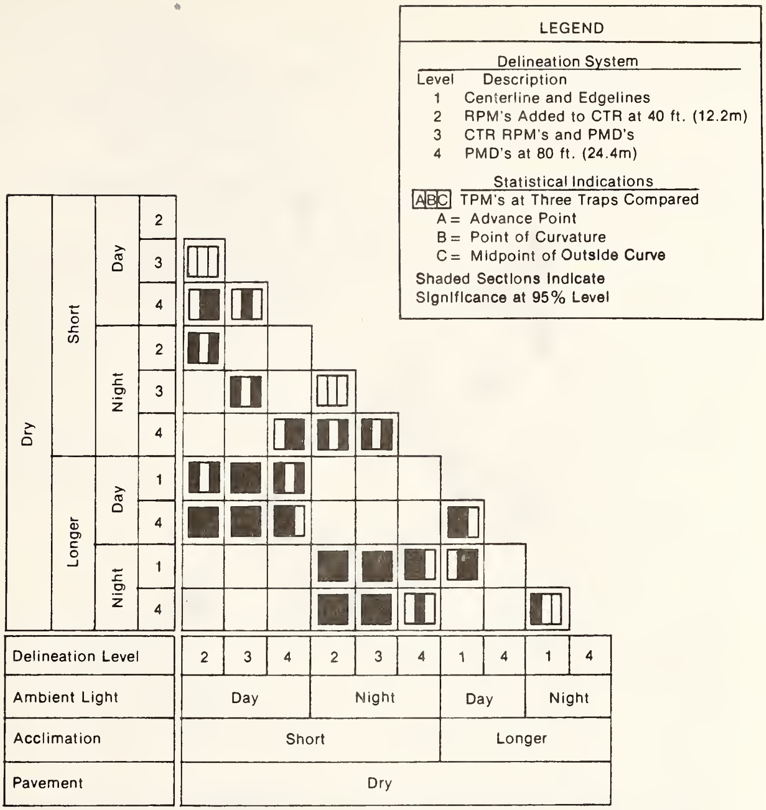


Figure 63. Site 7 statistical comparisons of mean placement on outside curve.

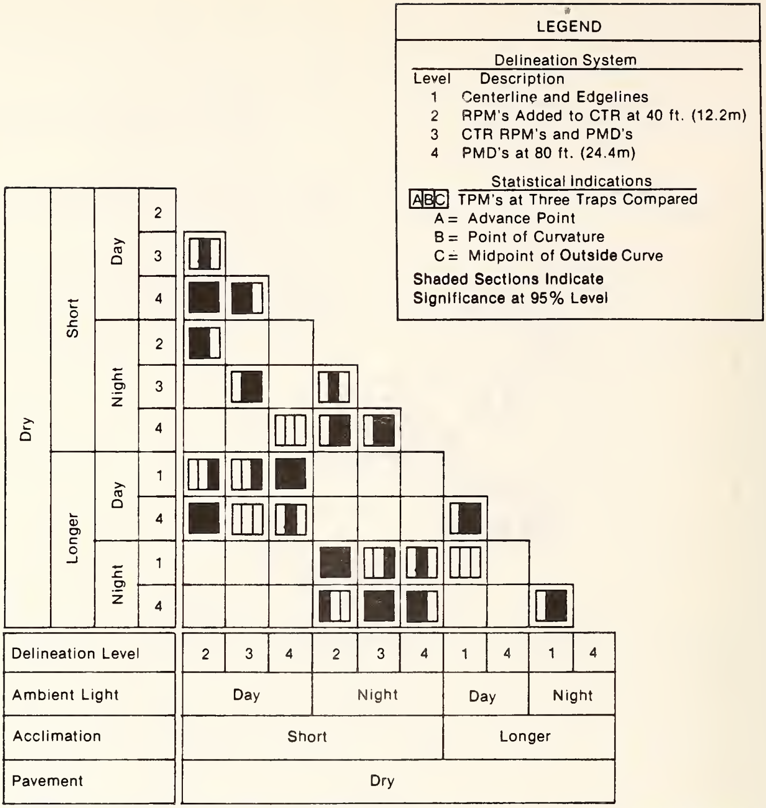
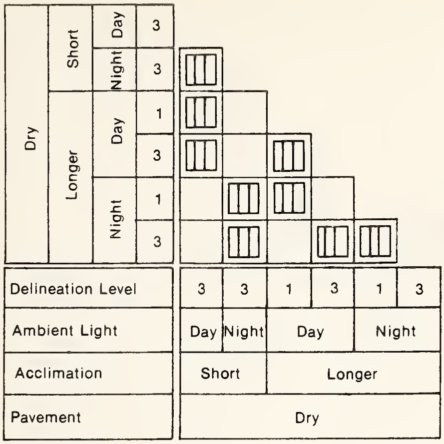


Figure 64. Site 7 statistical comparisons of placement variance on outside curve.



Mean Speed
(No Significant Differences)

LEGEND

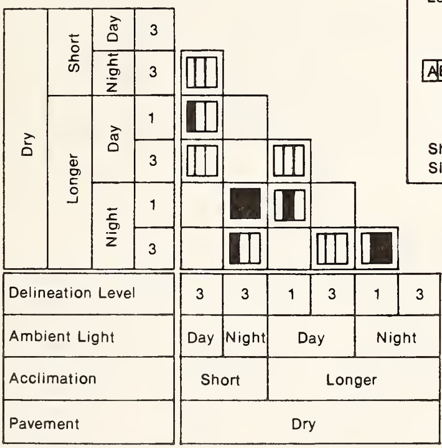
Delineation System

Level	Description
1	Centerline Only
3	PMD's, Both Sides at 100 ft. (30.5m)

Statistical Indications

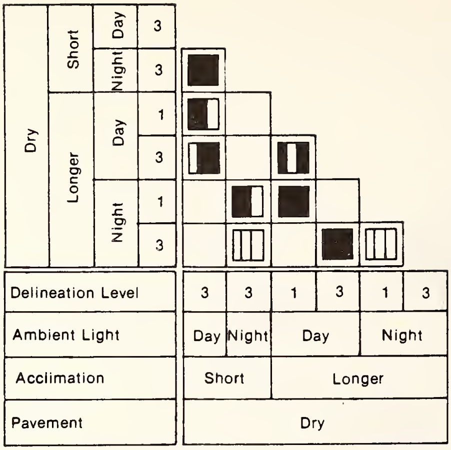
ABC TPM's at Three Traps Compared
A = Advance Point
B = Point of Curvature
C = Midpoint of Inside Curve

Shaded Sections Indicate Significance at 95% Level



Speed Variance

Figure 65. Site 8 statistical speed comparisons for inside curve.



Mean Lateral Placement

LEGEND

Delineation System

Level	Description
1	Centerline Only
3	PMD's, Both Sides at 100 ft. (30.5m)

Statistical Indications

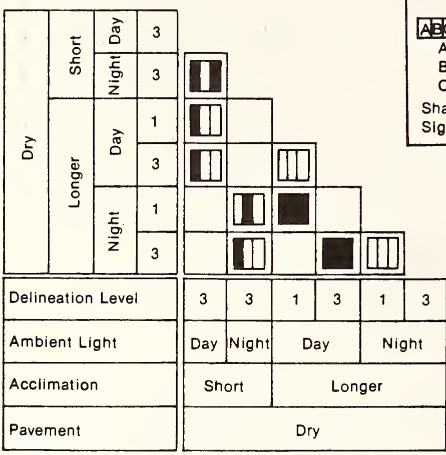
ABC TPM's at Three Traps Compared

A = Advance Point

B = Point of Curvature

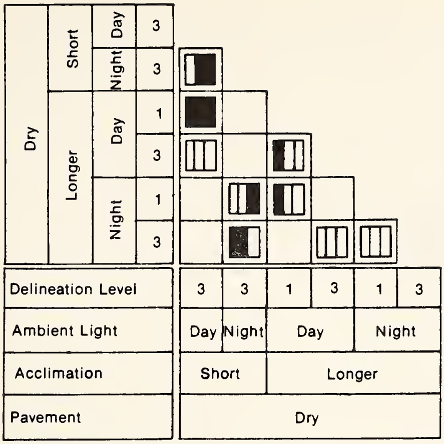
C = Midpoint of Inside Curve

Shaded Sections Indicate Significance at 95% Level



Lateral Placement Variance

Figure 66. Site 8 statistical placement comparisons for inside curve.



Mean Speed

LEGEND

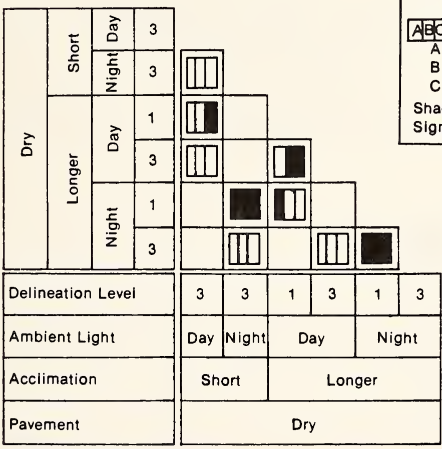
Delineation System

Level	Description
1	Centerline Only
3	PMD's, Both Sides at 100 ft. (30.5m)

Statistical Indications

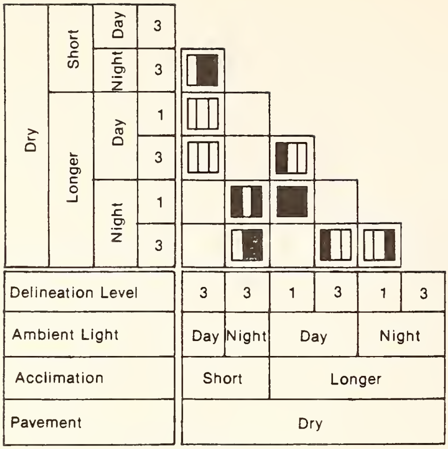
ABC TPM's at Three Traps Compared
A = Advance Point
B = Point of Curvature
C = Midpoint of Outside Curve

Shaded Sections Indicate
Significance at 95% Level



Speed Variance

Figure 67. Site 8 statistical speed comparisons for outside curve.



Mean Lateral Placement

LEGEND

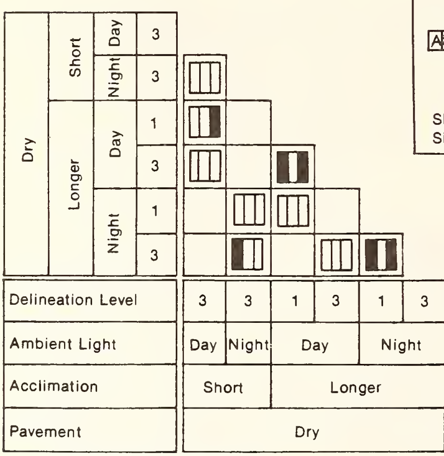
Delineation System

Level	Description
1	Centerline Only
3	PMD's, Both Sides at 100 ft. (30.5m)

Statistical Indications

ABC TPM's at Three Traps Compared
A = Advance Point
B = Point of Curvature
C = Midpoint of Outside Curve

Shaded Sections Indicate Significance at 95% Level



Lateral Placement Variance

Figure 68. Site 8 statistical placement comparisons for outside curve.

APPENDIX I

GENERAL METHODOLOGY FOR THE FIELD EVALUATION OF DELINEATION

INTRODUCTION

Contained herein is the recommended general evaluation methodology developed and refined during the course of an FCP research project entitled, "Field Evaluation of Selected Delineation Treatments" (DOT-FH-11-8834). This manual was written to stand by itself as an implementation document, but it would be highly desirable for the potential user to first review the final report for the referenced project (FHWA-RD-77-118).

TRAFFIC PERFORMANCE MEASURES AS INDICATORS OF ACCIDENT POTENTIAL

A number of previous field tests have shown that type of delineation can influence vehicular speed and lateral placement. However, these traffic performance measures in most cases have not been adequately interpreted in a full traffic operations and safety context. Unless a statistically significant change in speed or placement can be related in some fashion to accident potential, the change may not be of any practical significance.

A conceptual argument can be posed that certain accident types are due to one or more performance measures exceeding limits dictated by the highway design or adjacent traffic. The potential for this occurrence should be reflected in speed and lateral placement samples gathered for a large number of free-flowing vehicles. For instance, the further off-center the average driver operates in his lane, or the more that successive drivers deviate from the average position, the more likely that a sideswipe or run-off-road accident will occur. A serious problem has usually developed, however, in moving from this type of intuitive analysis to the point where intuition is confirmed through an actual mathematical correlation with accident history.

Two large national research projects in which this issue was addressed in some detail were the NCHRP study by Taylor, et al.,(14)* and the FHWA study by Stimpson, et al.(17) Each study met with some success in both intuitively and mathematically relating two-lane rural traffic accidents—or at least a relevant portion of such accidents—to carefully derived traffic parameters. The data collection and analysis procedures outlined below are fully compatible with those established in these two previous research activities.

SELECTION OF STUDY SITES

Experimental Situations

In order to develop generalizable estimates of the relative safety effectiveness of alternative delineation treatments applied to two-lane rural

*Number denotes source as it appears in list of references.

highways, prospective study sites should be distinguished by basic type of horizontal alignment. The following three types are recommended:

- Tangent — A predominately straight roadway with horizontal curves of 3 degrees or less.

- Winding — A predominately curved roadway with degrees of curvature greater than 3 degrees and tangents of less than 1,500 feet (457 metres) between curves.

- Isolated Horizontal Curve — On an overall alignment tending to be more tangent than winding, a curve greater than 3 degrees which is desirably isolated from other significant curves by 1/2 mile (4/5 kilometre) or more.

Cross-Sectional Features of Overall Highway

Certain constraints on site cross-sectional characteristics are necessary if the available accident-probability model is to be considered for the analysis of the field data collected.(17) The ranges of roadway width and shoulder width defined by the accident model's data base should not be significantly violated in selecting study sites. This prescribes roadways at least 16 feet (4.9 m) wide, with opposing lanes delineated by some sort of centerline. Lane and shoulder widths should not significantly exceed 12 and 8 feet (3.7 and 2.4 m), respectively.

Subsection Geometrics

Within the alignment categories of tangent, winding, and isolated horizontal curve, each site should contain at least one subsection having the geometrics specified below:

- Tangent — There should be a pure tangent section of at least 0.68 mile (1.10 km) in length, ending in horizontal curves no sharper than 3 degrees.

- Winding — An "S" curve is required, consisting of two consecutive, reversed curves separated by a tangent no longer than 500 feet (152 m). The curves should be roughly equivalent and at least 5 degrees or sharper in order to establish a clear distinction with respect to the tangent situation.

- Curve — The horizontal curve should be isolated from other curves by at least 0.3-0.5 mile (0.5-0.8 km) and should be on a highway tending more toward the tangent definition than the winding definition.

Traffic Volume

In general, it is desirable to select test sites with an ADT approximating 3,500. This is a good volume level at which to collect data:

measuring equipment installation is relatively easy as traffic interference is not too high, yet there is enough traffic to obtain the desired sample sizes within a reasonable time (usually one day and one night will be sufficient).

Additional Site Selection Criteria

Several miscellaneous considerations are important for the timely collection of reasonably unbiased traffic performance data. These additional criteria are as follows:

- Accessible, safe, and reasonably inconspicuous equipment-van parking places must be available near the geometrically appropriate subsections identified above. For the isolated curve situation, there should be a parking place on each side of the highway. All setups are limited by a maximum desirable lead-in cable length of 1,000 feet (305 m).

- There should be no potentially significant roadside features which might affect vehicle tracking adjacent to the subsection where the roadway is to be instrumented. Examples include severe slopes and/or guardrail close to the road; driveways providing visual contrast with the highway pavement and/or disruptive traffic turning movements; and excessive visual noise such as conspicuous fence and pole lines, reflective signs, stationary light sources, and multiple mailboxes.

- The pavement surface must be reasonably crack-free and sound to allow attachment of sensitive electrical tapeswitches or coaxial cables.

- Shoulders affording significant visual contrast with the main pavement should be avoided if possible.

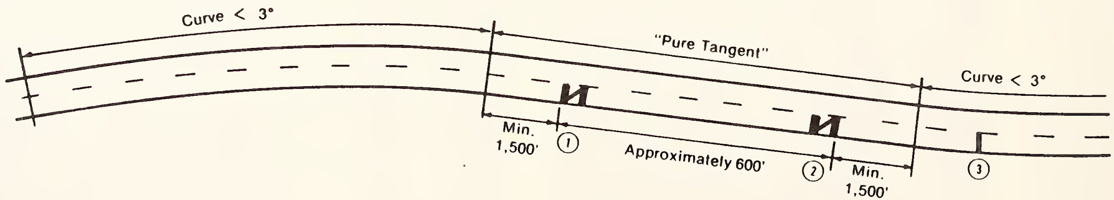
DATA COLLECTION

Traffic Measurement Stations

For measuring vehicular speed and lateral placement at critical points in a test section's horizontal alignment, detection traps should be located as shown in Figures 69-71 for the tangent, winding, and isolated horizontal curve alignment types, respectively. These trap locations are based on an analysis of accident/prior-movement relationships.

Recommended Instrumentation

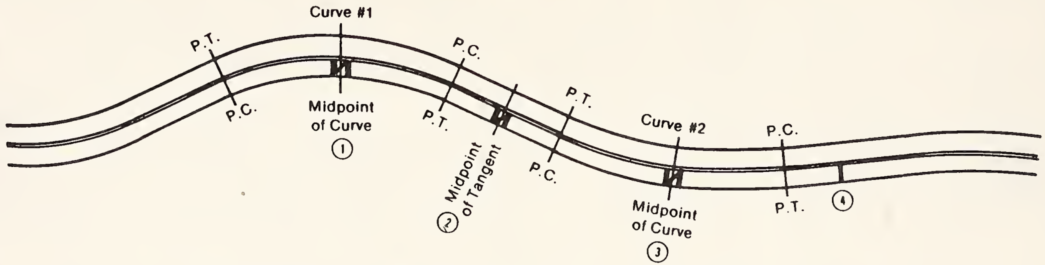
A Z-shaped configuration of three individual tapeswitches or sensor cables should be established at each traffic measurement station. Knowing certain measurements of the trap's geometry, both speed and lateral placement information can be derived from two high-precision digital clocks connected to appropriate pairs of sensors.



Station	Location	Measurement
(1) & (2)	Points on tangent section no closer than 1,500 feet from nearest curve	Speed Lateral Placement*
(3)	Any point beyond Station (2)	Volume

*Includes centerline and shoulder encroachments.

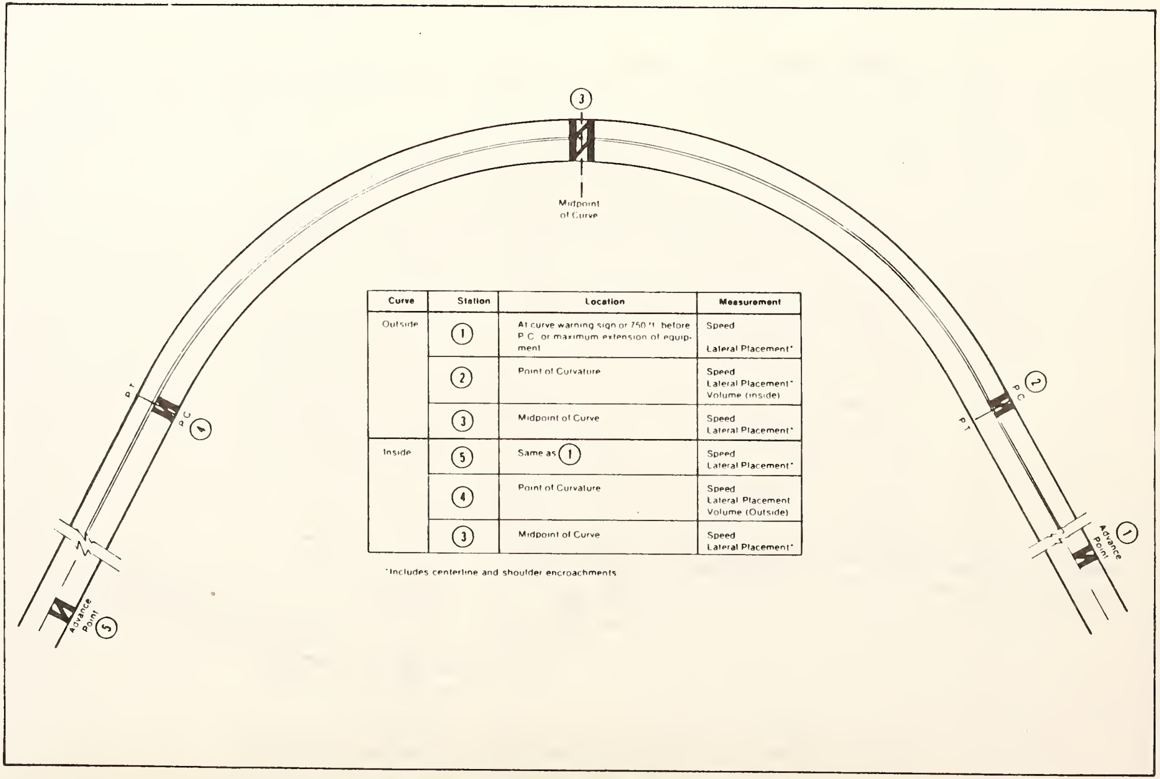
Figure 69. Configuration of measurement apparatus for tangent situation.



Station	Location	Measurement
①	Midpoint Curve #1	Speed Lateral Placement*
②	Midpoint of Tangent	Speed Lateral Placement*
③	Midpoint Curve #2	Speed Lateral Placement*
④	Any point beyond Station ③	Volume

*Includes centerline and shoulder encroachments.

Figure 70. Configuration of measurement apparatus for winding situation.



Curve	Station	Location	Measurement
Outside	1	At curve warning sign or 750 ft before P C or maximum extension of equipment	Speed Lateral Placement*
	2	Point of Curvature	Speed Lateral Placement* Volume (inside)
	3	Midpoint of Curve	Speed Lateral Placement*
Inside	5	Same as 1	Speed Lateral Placement*
	4	Point of Curvature	Speed Lateral Placement Volume (Outside)
	3	Midpoint of Curve	Speed Lateral Placement*

*Includes centerline and shoulder encroachments

Figure 71. Configuration of measurement apparatus for horizontal curve.

Figure 72 is a closeup photograph of a typical Z-trap composed of electrical tapeswitches. The tapeswitches are covered with dull gray duct tape for protecton and camouflage. As shown in Figure 73, this type of detection trap is reasonably inconspicuous when viewed from a typical flat angle. Since tapeswitches are only about half as thick as a pneumatic road tube, there is negligible tactile or auditory influence on the behavior of passing motorists.

In addition to the detection trap, the necessary data collection system includes lead-in cables and adapters; an electronic timing console having at least six channels; a portable electric generator; and a pneumatic-tube traffic counter. Figures 74 and 75 show some of the equipment utilized by The Pennsylvania State University for data collection within Contract DOT-FH-11-8834.

The timing console shown in Figure 75 was specially developed for the research project by the University's Department of Electrical Engineering. Its portable metal cabinet houses six digital clocks for displaying time intervals to the nearest millisecond, twelve start/stop rotary switches, and nine tapeswitch amplifiers. Each pair of clocks is assigned to a specific Z-trap: one clock measures travel time between the upstream perpendicular tapeswitch and the diagonal tapeswitch, and the companion clock measures overall travel time between parallel tapeswitches (see Figure 72). The digital clocks "freeze" at the measured values until manually reset. This prevents confusion of readings when vehicle platooning occurs, and it allows the accurate manual recording of values before subsequent free-flowing vehicles arrive. The translation of the two time intervals to speed and lateral placement is explained below. Average expected measurement errors have been estimated to be only $\pm$0.4 mph (0.6 km/h) for speed and $\pm$ 2 inches (5 cm) for placement.

Trap Measurements and Their Utilization

Figure 76 shows in schematic form the Z-trap layout. Sensors #1 and 3 must be parallel for the measurement of speed and are typically placed 22 feet (6.71 m) apart. Although their angle of preferred installation is somewhat exaggerated in the figure, they need not be exactly perpendicular to the centerline (as might be suggested by the designation "Z-trap.") However, since lateral placement (LP_e) is desired with respect to the right edge of the traveled lane, the two parallel sensors should be canted slightly in the direction shown in order to insure that the right rather than the left tire first touches all three sensors.

Sensor #2 should be placed at approximately a 45-degree angle from the direction of travel. The angle need be only approximate since R_1, R_S, LW, S, and L are all to be measured accurately. To avoid unwanted activations by vehicles moving in the opposite direction, the "live" portion of the sensors should stop about a foot (0.30 m) short of the centerline. Each transverse measurement is then made along the imaginary extension of the sensor to its intersection with the centerline.

Front right tire activates diagonal tapeswitch.

Figure 72. Z-shaped measurement trap consisting of 3 tapeswitches.

Trap in nearside lane.

Figure 73. Oblique view of typical trap installation.

Figure 74. Lead-in cables and electrical generator.

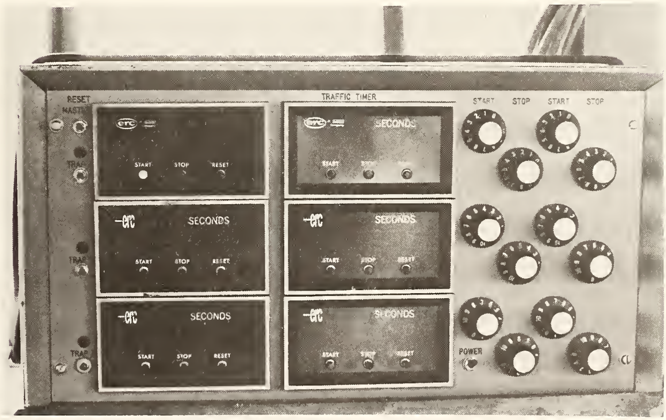


Figure 75. PSU traffic timing console.

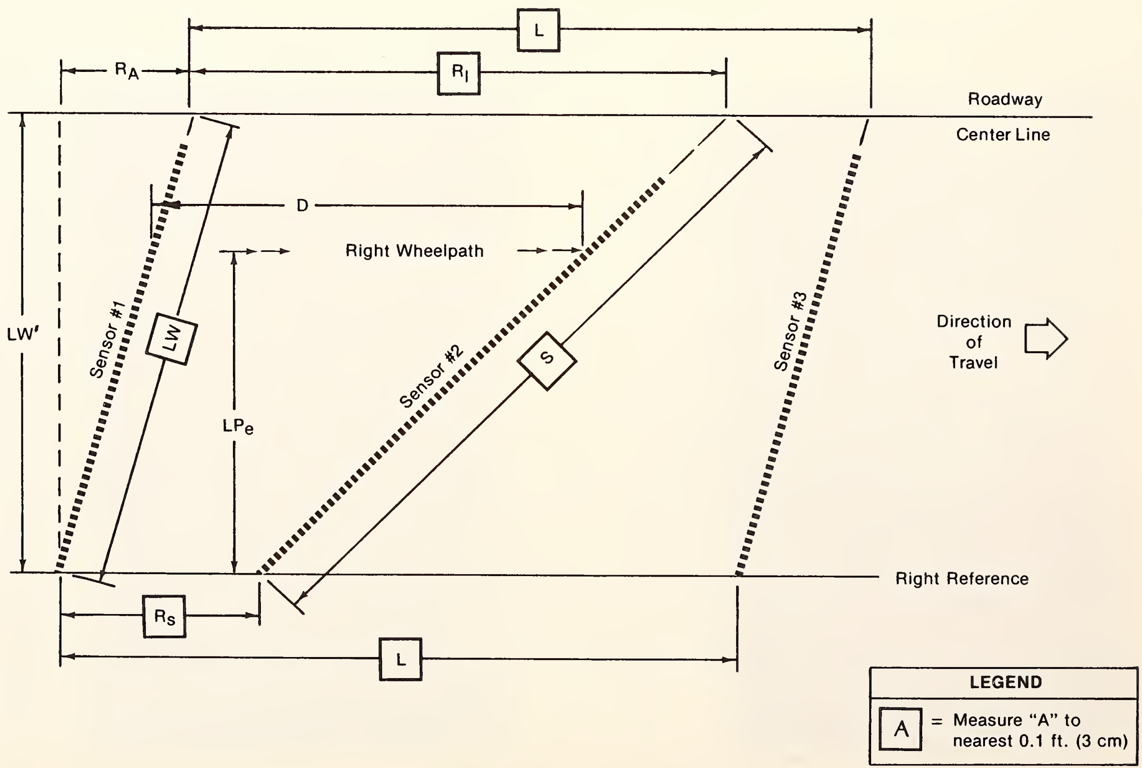


Figure 76. Z-trap geometry and required measurements.

The "right reference" line must be parallel to the centerline, but it need not be the true right edge of the traveled lane (i.e., the center of the edgeline if one is present, or the pavement edge otherwise). If a significant paved shoulder exists, for instance, it may be desirable to extend the instrumentation onto the shoulder in order to detect encroachments. In such a case, it is necessary to accurately measure the offset of the reference line from the defined right edge of traveled lane. This offset must later be subtracted from either the individual values of computed lateral placement or the sample mean placement.

The unboxed dimension variables shown in Figure 76 are used in intermediate calculations only and need not be measured in the field. Formulas presented below, however, assume that lateral placement LP_e and all boxed measurements are expressed in feet to an accuracy of ± 0.1 foot. Also, it has been assumed that derived speed, V, is to be expressed in miles per hour. If t_1 is defined to be the time (in seconds) required for a monitored vehicle to travel from sensor #1 to sensor #2, and t_2 is the time (in seconds) required for the same vehicle to travel from sensor #1 to sensor #3, then the following equations are defined:

- For speed in mph:

$$\boxed{V = 1.47\left(\frac{L}{t_2}\right)} \qquad (1)$$

- For lateral placement in feet:

$$R_A = \frac{S^2 - LW^2 - (R_1 - R_s)^2}{2(R_1 - R_s)} \qquad (2)$$

$$LW' = \sqrt{LW^2 - R_A^2} \qquad (3)$$

$$D = L\left(\frac{t_1}{t_2}\right) \qquad (4)$$

$$\boxed{LP_e = (D - R_s)\left(\frac{LW'}{R_1 - R_s}\right)} \qquad (5)$$

Figure 77 presents a suggested format for recording trap layout measurements on a winding section "S" curve. Only one direction of travel need be monitored, and it has been judged irrelevant whether drivers first pass through an inside curve (traps 1 and 4) or an outside curve (traps 3 and 6). The three data blocks filled in would obviously identify

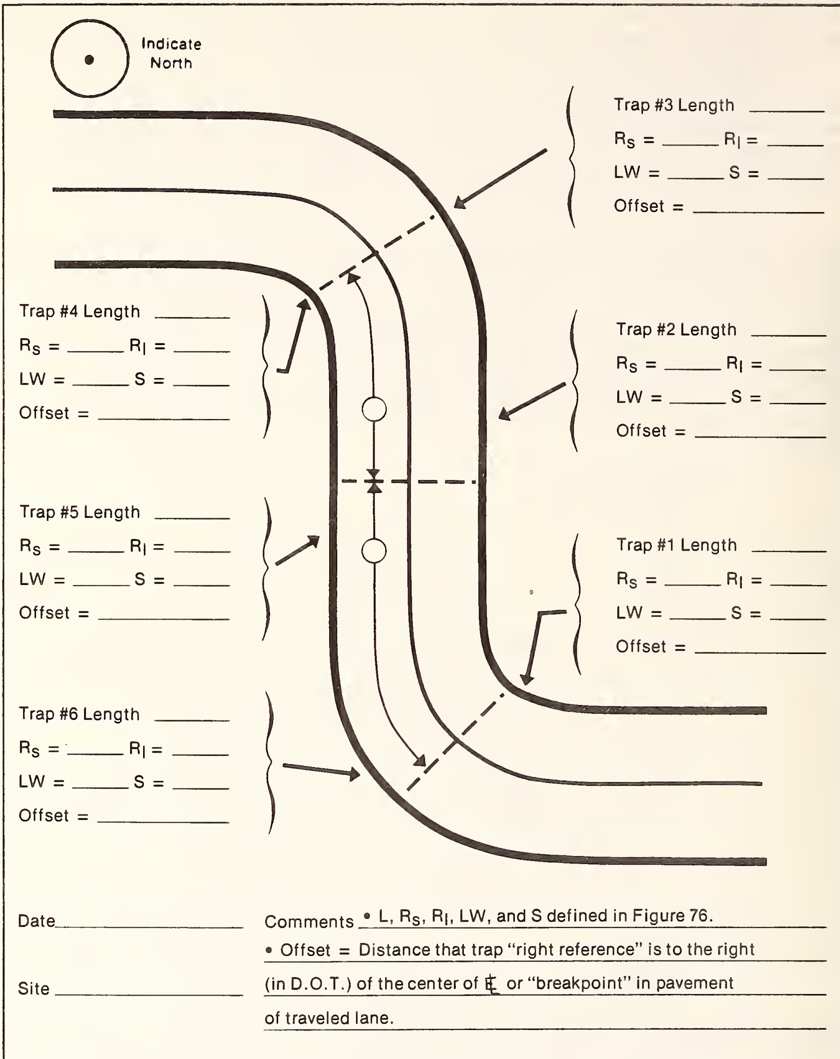


Figure 77. Set-up schematic for winding site.

the direction of travel being studied. Similar forms can be easily created for a tangent section and an isolated horizontal curve.

Sampling Requirements

The choice of sample size to be used in the collection of speed and lateral placement data is an important decision in planning a delineation evaluation study. It is inappropriate to arbitrarily select a convenient sample size and then assume that the statistical estimates thereby obtained are sufficiently accurate to yield valid conclusions.

An assumption of normally distributed speed and lateral placement observations, together with previous estimates of typical population variances, have been used in a standard statistical formula to determine the required sample size for estimating the true population mean. For a 95 percent significance level and a confidence interval of ±2 mph (±3.2 km/h) for estimating mean speed, a minimum sample size of 100 observations would be required. With this number of observations, the typical confidence interval for lateral placement estimation is about ±2.5 inches (±6.4 cm).

The sample size required in order to estimate true population variance has been determined by expressing the confidence interval in terms of sample variance, points in the Chi-Square distribution, and alternative values for degrees of freedom (i.e., sample size minus 1). A larger sample size is required in order to obtain the same degree of accuracy found above in the estimation of the mean. In order to maintain an error of no more than ±10 percent in the estimate of standard deviation for lateral placement observations, a sample of 150 observations would be desirable. A sample of 100 is considered the practical minimum and yields a confidence interval of ±14 percent at the 95 percent significance level.

On the basis of this sample size analysis and the relatively high manhour costs associated with sampling under low-volume conditions, it is recommended that the basic speed and lateral placement data be collected for a minimum of 100 vehicles during nighttime fog-free, dry-pavement conditions. Since it will not require additional calendar days of field work, data can also be collected for the corresponding daytime period. Unfortunately, the unpredictable nature of rainfall and fog at most locations is such that the evaluation of delineation treatments under inclement operating conditions is generally infeasible. Especially difficult would be the collection of statistically adequate samples under uniformly wet or foggy conditions to reliably detect meaningful before-to-after differences in the speed and lateral placement parameters.

Traffic performance data should be collected only for free-flowing vehicles, and if feasible, only when there is no opposing traffic in the vicinity. To be free-flowing, a vehicle should have a headway with the preceding vehicle of at least 5 seconds.

Since time values t_1 and t_2 are obtained for each of two or three detection traps, depending on site type, a total of four or six time intervals will be recorded for each monitored vehicle. For the estimation of vehicle centrality within the traveled lane, vehicle type should also be noted for each set of time readings. Suggested types include the "automobile" category (four tires) and the "truck" category (six or more tires). Other data recorded at the study site should include an hourly volume profile over a 24-hour period during which traffic performance data are collected; total pavement width; shoulder width; speed limit; length and degree of curve (if any); and type of delineation.

DATA ANALYSIS

Calculation of Means and Variances

Sample Mean — Where n is the number of speed or lateral placement observations and X_i is the ith observation in the sample, the sample mean is computed by:

$$\overline{X} = \frac{1}{n} \sum_{i=1}^{n} X_i \qquad (6)$$

Sample Variance — Variance is the standard deviation squared. The easiest-to-use computational formula for determining sample variance is as follows:

$$s_x^2 = \frac{1}{n-1} \left[\sum_{i=1}^{n} X_i^2 - \frac{1}{n} \left(\sum_{i=1}^{n} X_i \right)^2 \right] \qquad (7)$$

Estimation of Placement with Respect to Centerline — A key safety measure is centrality of vehicle placement within the delineated or traveled lane. Specifically, the distance between the right front tire and the right edge of the lane should be compared to the distance between the left side of the vehicle's body and the centerline. To estimate this latter distance, the following equations should be used:

- "Automobile" Class: $LP_c = LW' - LP_e - 5.50$ (8)
- "Truck" Class: $LP_c = LW' - LP_e - 6.75$ (9)

LP_e, as defined earlier, is the observed vehicle's lateral placement (expressed in feet) with respect to the right edge of the traveled lane. The values 5.50 and 6.75 represent judgments as to the average of the track and body widths (also in feet) for the respective vehicle classes. More refined values could perhaps be substituted. The individual values for LP_c should be accumulated and averaged using Equation (6).

Testing Parameter Changes for Statistical Significance

After the means and variances of speed and lateral placement have been calculated, the next step in the data analysis is to test the significance of between-treatment or between-condition differences in the four statistics.

Differences in Means — Experimental changes in a performance measure mean should be assessed with a t-test based upon unequal and unknown population variances. Known in statistics as the Fisher-Behren's Problem, the following hypotheses and equations are used in the analysis:

$$H_o : \mu_1 = \mu_2 \quad \text{and} \quad H_1 : \mu_1 \neq \mu_2 \tag{10}$$

$$t' = \frac{(\bar{X}_1 - \bar{X}_2)}{\sqrt{\dfrac{s_{x_1}^2}{n_1} + \dfrac{s_{x_2}^2}{n_2}}} \sim t(df) \tag{11}$$

$$df = \frac{\left(\dfrac{s_{x_1}^2}{n_1} + \dfrac{s_{x_2}^2}{n_2}\right)^2}{\dfrac{\left(\dfrac{s_{x_1}^2}{n_1}\right)^2}{n_1-1} + \dfrac{\left(\dfrac{s_{x_2}^2}{n_2}\right)^2}{n_2-1}} \tag{12}$$

To test the validity of the null hypothesis H_O (i.e., the true population means are equal), the respective values for the sample means ($\bar{X}_1$, $\bar{X}_2$), variances ($s_{x_1}^2$, $s_{x_2}^2$), and sample sizes (n_1, n_2) are input to Equations (11) and (12). For a chosen level of confidence, the computed value of the test statistic t' is then compared to the value of the t distribution for degrees of freedom df. A table for this distribution is found in every statistics textbook. If t' equals or exceeds the appropriate value of t, the difference in means is statistically significant.

Differences in Variances — Experimental changes in a performance measure variance should be assessed with an F-test. "F" is the ratio of the two variances being compared and is always expressed as a number greater than 1. Associated with a particular F value are two values for degrees of freedom; these values are the sizes of the two samples for which the two variances are computed. The three test statistics are, therefore, defined as follows:

$$F = \frac{s_{x_1}^2}{s_{x_2}^2}, \text{ where } s_{x_1}^2 > s_{x_2}^2 \qquad (13)$$

df_1 = degrees of freedom associated with greater mean square (i.e., larger variance $s_{x_1}^2$) (14)

df_2 = degrees of freedom associated with lesser mean square (i.e., smaller variance $s_{x_2}^2$) (15)

To test the statistical significance of a difference in variances at a chosen level of confidence, the value of the test statistic computed by Equation (13) is compared against a baseline value with degrees of freedom (df_1, df_2), found in a statistical table of the "points for the distribution of F." If the test statistic equals or exceeds the baseline value, the difference in variances is statistically significant.

Interpretation of Means and Variances

Speed Distribution — In many prior evaluations of roadway delineation, induced changes in mean speed have rarely exceeded 2-3 mph (3-5 km/h). Often this is the amount of increase for a less paint-intensive treatment. In a heavily delineated case, mean speed may decrease by a similar amount. These changes, while statistically significant, probably bear no practical significance. However, the determination of average speed is a byproduct easily obtained in the experimental procedures described to this point, and it should, therefore, be accomplished for completeness.

Speed variance, on the other hand, is a somewhat more sensitive performance measure. Reductions in both the variance and the skewness of the speed distribution are intuitively related to improvements in traffic safety. Limited findings in several past research studies have tended to support this relationship.

Lateral Placement Distribution — Mean lateral placement by itself is not a sufficiently comprehensive indicator of driver tracking performance at a given point on the roadway. Referenced to only one side of the lane, it describes the driver's proximity only to potential hazards on that side of the road. A better performance measure, called the centrality index (CI), is defined in the next section of the methodology. CI has the added advantage of accounting for possibly significant before-to-after changes in vehicle-type proportions sampled and the width of the traveled lane (e.g., the right-side reference point usually shifts from the pavement edge to the center of the edgeline when the latter is undergoing a before-and-after evaluation).

The variance of lateral placement has been statistically related to accident potential and should be emphasized as a measure of effectiveness. It tends to reflect the probability of excursions from the proper lane, especially when normalized or divided by the lane width.

Application of a Two-Variable Accident Probability Model

To further assess the quality of traffic performance on tangent and winding two-lane highways under an experimental delineation treatment, a two-variable accident-probability model can be applied. The model is limited in scope, as it yields an estimate of a very carefully defined type of driving hazard. The model or equation can only be used to compute the expected level of delineation-related, non-intersection accidents occurring during hours of darkness and on dry pavements. Thus, the equation developed should not be considered a "black box" which is able to accurately predict the overall accident rate for any particular section of rural highway.

The Model Defined — Equation (16) presents the model proposed for use. For a data base of 21 study sites, the equation was able to explain 66 percent of the sites' variation in the specialized accident type described above (i.e., $R^2 = 0.66$). The standard error of the estimate was 1.61 accidents per million vehicle-miles.

$$AR = -0.22 + 1.15\ CI + 25.3\ DPV \qquad (16)$$

where:

AR = Number of nighttime, delineation-related, non-intersection accidents per million vehicle-miles (dry pavement condition only)

CI = Centrality index

DPV = Difference in lateral placement variance

The centrality index is expressed as:

$$CI = \frac{\overline{LP}_e - \overline{LP}_c}{0.1\ LW} \qquad (17)$$

where:

$\overline{LP}_e$ = mean lateral placement of the right vehicle tire with respect to the right edge of the traveled way (ft),

$\overline{LP}_c$ = mean lateral placement of the left side of the vehicle with respect to the centerline of the roadway (ft), and

LW = width of traveled lane (ft).

As the value of the centrality index approaches zero, lateral clearance on each side of the vehicle is maximized. For the winding roadway situation, the centrality index is computed for the midpoint of the inside curve. The upstream trap is used for tangent sites.

The difference in lateral placement variance is expressed as:

$$DPV = \frac{LP_{s_1^2} - LP_{s_2^2}}{LW} \qquad (18)$$

where:

$LP_{s_i^2}$ = variance of lateral placement with respect to the right edge of the traveled way, measured at Station i.

In the case of tangent roadways, the variances at the two established traps are subtracted and then divided by the average lane width. For winding section "S" curves, the difference is computed between the inside curve and the midpoint of the intervening tangent (or point of reverse curvature).

The Model Applied — Equation (16) should be applied only to dry-nighttime traffic performance data collected on tangent or winding highway types in the manner described in earlier sections. To compare the predicted delineation-related hazard under two different treatments or between day and night, one or both of the terms on the right side of the equation should be statistically different between conditions. Significance is judged as follows:

- CI — The difference between the two means of lateral placement must be statistically significant (using a t test).

- DPV — The between-trap difference in the two variances of lateral placement must be statistically significant (using an F test) for one and only one of the experimental conditions.

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