

HIGHWAY DESIGN MANUAL

Chapter 5 - Basic Design

Revision 50

August 23, 2006

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BASIC DESIGN**

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5.1 INTRODUCTION

The Department is committed to developing projects which improve the movement of people and goods, while recognizing community needs and values. Projects should be safe, serviceable, constructible, economical to build and maintain, and in harmony with the community and its environmental, scenic, cultural, and natural resources. Successful designs result from a careful balance of safety, mobility, and capacity needs with social, economic, and environmental needs.

This chapter provides guidance regarding the basic elements of highway design to designers and other project developers. The information presented is not all-inclusive, but must be used in conjunction with information found in other chapters and documents adopted by the Department to achieve the most appropriate design meeting the goals and objectives of the project.

5.1.1 Project Development & Public Involvement

There are various phases of development through which a project design must evolve. These phases are described in the *Project Development Manual*. Projects should be progressed through these phases with the aid and advice of project stakeholders, which include the Regional Functional Units, the Main Office, the public, and appropriate advisory and regulatory agencies. Early, effective, and continuous stakeholder involvement fosters meaningful participation and sense of ownership in the project development process. The open exchange of information and concerns between the Department and stakeholders benefits projects by identifying key issues early in the process, developing consensus for project solutions, and building trust among stakeholders.

5.1.2 Nonconforming Features

During the project development process, design element trade-offs are routinely considered. Quantitative measures are to be used, whenever feasible, to compare and evaluate the effects of trade-offs. When the Department evaluates such trade-offs in the course of considering transportation needs and community needs, public safety (whether driving, riding, walking, or bicycling) remains the foremost issue to consider.

Variances from standard values established for the critical design elements listed in Chapter 2 of this manual require a justification and approval as described in that chapter. In addition to the critical design elements, there are other design elements with established values or parameters that must be considered when scoping and designing a project. These other elements are important because they can have a considerable effect on the cost, scope, schedule, and quality of a project. Any decisions to vary from recommended values or accepted practices for these elements need to be explained and documented as nonconforming features in the scoping and design approval documents and, when identified after design approval, in the project files. The more significant the deviation or the more important an element is to quality design, the more detailed the explanation will be. For example, an explanation similar in detail

to the requirements for nonstandard features is appropriate if the Department proposes to build an acceleration lane to 75% of the values in AASHTO's *A Policy on Geometric Design of Highways and Streets*, 2004, or not attain the compound curve ratio. However, not achieving the minimum length of a superelevation runoff by a few meters would only warrant a brief explanation in the report.

The following is a listing of some of the other elements which are described in detail in this and other chapters. It is being provided to give a representative sample of items to be considered when scoping and designing a project. It is not in priority order or intended to be all-inclusive.

- Level of service (This is a critical design element on interstate projects only)
- Clear zone
- Intersection radii (including accommodation of identified oversized vehicles)
- Intersection and decision sight distance
- Superelevation runoff/runout length
- Minimum length of vertical curves
- Lane drops
- Broken back curves
- Compound curves
- Auxiliary lane lengths
- Adequate provisions for pedestrians and bicyclists (See Chapter 18 of this manual)
- Transit and high-occupancy vehicle facilities and accommodations
- Design storm for drainage facilities (see Chapter 8)
- Curbing
- Guide rail
- Permanent and temporary soil erosion and sediment control

5.2 SPEED STUDIES, HIGHWAY CAPACITY, AND LEVEL OF SERVICE

Traffic data and a capacity analysis are used to develop the geometric design, evaluate alternatives, design traffic signals, etc. The data collection and analysis depends on the project type, highway functional class, and the presence of cross roads or major driveways. Refer to Section 5.2.3 of this chapter for guidance on using older data and capacity analysis.

5.2.1 Traffic Data

5.2.1.1 Data Acquisition Methods

For most projects, the Pedestrian Generator Checklist, as described in Chapter 18, is used to determine the need for pedestrian facilities to accommodate existing, latent, seasonal and projected future pedestrian traffic. However, pedestrian traffic data acquisition may be necessary to determine the appropriate treatments and design of pedestrian facilities in areas of high pedestrian volumes and/or special use areas, e.g., central business and walking districts, colleges, amusement parks, etc.

Pedestrian data acquisition can be accomplished through pedestrian counts, pedestrian questionnaires, and pedestrian origin and destination studies. For information on pedestrian data acquisition, refer to the following:

- *Sketch-Plan Method for Estimating Pedestrian Traffic for Central Business Districts and Suburban Growth Corridors*: www.enhancements.org/trb/1578-06.pdf
- *Guidebook on Methods to Estimate Non-Motorized Travel, Volumes 1 & 2*:
www.fhwa.dot.gov/tfhrc/safety/pubs/vol1/title.htm
www.fhwa.dot.gov/tfhrc/safety/pubs/vol2/title.htm

For methods of gathering motorized traffic counts, refer to the Regional Planning Group, the *Traffic Engineering Handbook*, and EI 01-001 Traffic Monitoring Standards. Where actual ground counts are not readily available, secondary traffic data (i.e., data that was not obtained specifically for the project) may be used for:

- Projects on routes with little delay (LOS B or better). The level of service (LOS) should be observed during peak periods, which may include:
 - The weekday AM and PM peaks.
 - Saturday noon-hour peaks near shopping areas or malls.
 - Friday and Sunday nights on summer recreation routes.
 - Saturday and Sunday AM and PM peaks near ski areas.
 - Immediately before and after regular sporting events, concerts, or other special events.
- Maintenance-type projects (e.g., pavement preventive maintenance and bridge preventive maintenance projects).
- Construction lane closures or detours.

Secondary traffic data includes the annual average daily traffic (AADT) data from the *Highway Sufficiency Ratings* and the annual *Traffic Volume Report*. Additional sources may be available from the Highway Data Services Bureau and the Regional Planning Group. *The Highway Capacity Manual*, Regional data, or Exhibit 5-1 (below), and the *Traffic Engineering Handbook*, can be used to obtain the design hourly volume (DHV), directional design hourly volume (DDHV), and any other required traffic data.

Exhibit 5-1 Design Hourly Volume as a Function of AADT

DHV as a Percentage of AADT	Primary Function of Route
38%	Highly Recreational Route
24%	Partially Recreational Route
19%	Secondary Rural Route
15%	Main Rural Route
12%	Suburban Route
8%	Urban Through Route

Data based on the *Traffic Engineering Handbook*, Institute of Traffic Engineers (ITE), 1992, p. 50, Figure 2-16.

5.2.1.2 Traffic Projections

The projected traffic volumes are to be determined using the traffic data required by Section 5.2.1.3, growth rates, and the traffic volumes from planned development and reasonably anticipated/foreseeable projects. Refer to the *Project Development Manual* (PDM) Appendix 5 for the design year. Contact the Regional Planning Group, MPO, and municipal planners for growth rates and the traffic volumes from planned development and reasonably anticipated/foreseeable projects.

To project latent and future pedestrian traffic volumes, refer to the following documents:

- Sketch-Plan Method for Estimating Pedestrian Traffic for Central Business Districts and Suburban Growth Corridors: www.enhancements.org/trb/1578-06.pdf
- Guidebook on Methods to Estimate Non-Motorized Travel, Volumes 1 & 2: www.fhwa.dot.gov/tfhrc/safety/pubs/vol1/title.htm
www.fhwa.dot.gov/tfhrc/safety/pubs/vol2/title.htm

5.2.1.3 Data Requirements

The following subsections present the traffic data that will generally be required to perform a capacity analysis. The Transportation Research Board's *Highway Capacity Manual* (HCM) or software program should be referenced to determine the specific traffic data and physical data required.

A. All Feasible Build and No-Build Alternatives

Determine the existing and design year (as appropriate):

- Percentage of trucks, buses, and RVs.
- Highway AADT.
- Highway DHV (two-way).
- Highway Directional Design Hourly Volume (DDHV) (one-way).
- Highway two-way (design hour) percent trucks.
- Ramp/turning roadway DHV.
- Peak-hour factor.
- Free-flow speed on highway and ramps.
- Weaving volumes.
- Ramp volumes and adjacent ramp volumes.
- Parking and bus stops per hour.
- Average travel speeds.
- Bicycle DHV (order of magnitude to determine appropriate facility).
- Pedestrian DHV (for existing or proposed sidewalks, signalized intersections, and transit-related pedestrian facilities).

B. Additional Requirements for Alternatives With Potential for Capacity or Level-of-Service Improvements

For 3R alternatives on interstates or other freeways, and reconstruction, new construction, bridge replacement, and major bridge rehabilitation alternatives, determine the following existing and design-year parameters:

- Peak-hour turning movement volumes for intersections with identified accident or operational problems.
- Peak-hour turning movement volumes for all major intersections with crossroads or commercial driveways.

Note: A major intersection for traffic count purposes is a signalized intersection, an intersection approaching any of the warrants for signalization in accordance with the *Official Compilation of Codes, Rules and Regulations of the State of New York Title 17 Transportation (B) Chapter V (a.k.a. New York State Manual of Uniform Traffic Control Devices (NYS MUTCD))*, or an intersection approaching the warrants for a turn lane as contained in Chapter 9 of AASHTO's *A Policy on Geometric Design of Highways and Streets*, 2004.

Traffic flow diagrams should be developed for commuter travel periods (e.g., A.M. or P.M. peak hours). The diagrams should show:

- For each link, the current AADT, DHV, DDHV, and design-hour percent trucks.
- For all major intersections with crossroads or commercial driveways, the current design-hour turning movement volumes, design-hour percent trucks, and AADTs on all approaches for intersections.

Some highways have a noon peak period that should be shown and considered in the project's geometric and traffic signal design. Also, there may be a need to give traffic volumes for other peak periods for commercial generators or special events (e.g., Saturday peak shopping hours, concert performances, fairs).

The traffic flow diagram shown in the HCM's Input Worksheet for signalized intersections shall be used as the standard format for presenting traffic turning volumes.

The correlation between volumes and level-of-service is not direct. Level-of-service computations based on volume may not accurately represent the traffic conditions on congested highway segments when vehicles are moving very slowly. The volume at LOS F can be the same as the volume for a higher level of service due to slow speeds and low throughput. Therefore, travel speeds are essential for assessing whether the traffic volumes reflect a forced-flow condition or a free-flow condition in potentially congested areas.

Where the existing mainline level of service is D or worse (refer to Section 5.2.2), the average travel speeds, averaged over the hour measured, should be determined for the peak hours of the day. The average speeds over a segment of highway may be determined using the test vehicle, license plate, or photography methods, as described in the *Traffic Engineering Handbook*. Peak-period traffic volumes and average travel speeds can be fed into the Congestion Needs Assessment Model used by Regional Planning to assess vehicle hours of delay (VHD).

C. Proposed Signal Installations

The ETC+5 peak-hour turning movement volumes should be determined for proposed signal installations that will meet the signalization warrants in the design year, but do not meet the warrants for the ETC+0 year. The analysis of the ETC+5 traffic data can be used to determine if a signal should be installed as part of the project or in a future signal requirements contract. Regardless, the highway geometry (e.g., pavement width) should be designed to accommodate the proposed signal.

5.2.2 Level of Service and Capacity Analysis

5.2.2.1 Level of Service (LOS)

Level of service is a qualitative measure describing operational conditions within a traffic stream, based on service measures such as speed and travel time, freedom to maneuver, traffic interruptions, comfort, and convenience. Levels of service are given letter designations, from A to F, with LOS A representing the best operating condition and LOS F the worst. Level of service is specifically described for various types of highways or portions of highways in the *Highway Capacity Manual*.

LOS C or better is desirable and LOS D is the minimum for the design year of a noninterstate project. Level of service criteria for interstate highways are given in Chapter 2 of this manual. Some projects, especially in urban areas, may provide levels of service below those shown in Chapter 2, or required above, due to social, economic, and environmental and/or policy/intergovernmental decisions made during project scoping and design. On interstate projects, such decisions for lesser levels of service are to be made as nonstandard features in accordance with Chapter 2, Section 2.8 of this manual. For noninterstate projects, lower levels of service are to be treated as nonconforming features and explained as appropriate.

5.2.2.2 Capacity Analysis Requirements

Capacity analysis is a set of procedures used for estimating the traffic-carrying ability of facilities over a range of defined operational conditions. It provides tools to assess facilities and to plan and design improved facilities. Capacity analysis is performed using existing and projected (design year) design-hour traffic volumes. The existing and design-year levels of service of the following elements are to be determined for each alternative, including the no-build alternative.

- Highway.
- All approaches of intersections and driveways/entrances with one-way volumes of 100 vehicles per hour (vph) or more.
- Ramps.
- Weaving sections.
- Merges and diverges.
- Service roads and frontage roads.

For projects with an objective to reduce congestion, estimates of the existing and design-year vehicle hours of delay should be determined for the build and no-build alternatives. The results of the analysis should be included in the project's design approval document for evaluation of the various project alternatives.

5.2.2.3 Capacity Analysis Methodology

Capacity analyses are to be consistent with the most recent version of the HCM. General announcements of the availability of HCM revisions will be made via Engineering Bulletins.

Department **policy** requires the designer to use capacity analysis software consistent with the HCM. For economic, efficiency, and quality assurance purposes, the Design Quality Assurance Bureau preapproves a limited number of software programs for general use. The approved software programs and contact persons are announced on the Department's Internet site. Before running the software, designers should apply the latest patches or updates linked on the Department's Internet site to help ensure the software produces reasonably accurate results.

Judgement must be used whenever a new software release becomes available or when revisions to the HCM are made, as to whether previously completed analyses should be reevaluated. While many factors may enter into this decision, the overriding consideration is whether it is likely that a new analysis will significantly change the design, investment, and/or environmental decisions. The final determination on whether to redo an analysis rests with the Regional Design Engineer.

Refer to Section 5.9.2 for guidance regarding intersection capacity and level-of-service analysis. Additionally, refer to the roundabout pages on the Department's Internet and IntraDOT sites for guidance and requirements on roundabout capacity and level-of-service analysis.

5.2.2.4 Exceptions to the Required Capacity Analysis Methodology

Proposals to use an analysis procedure other than the HCM or the Department-approved capacity software must be submitted to the Main Office for approval. Proposals for projects in preliminary planning, up through the project scoping stage, should be submitted to the Office of Corridor Management in the Planning and Strategy Group. Proposals for projects in either the preliminary design or detailed design stage should be submitted to the Design Quality Assurance Bureau.

There are cases when capacity and level of service are inadequate measures to document the traffic performance of an existing or proposed facility. These cases often involve complex geometric and/or signal control situations (e.g., Intelligent Transportation System/Advanced Traffic Management System); roadways or ramps which are oversaturated; or where the proximity of controls (e.g., signalized intersections) cause spillback affecting nearby locations. In these cases, use of queue analysis and/or traffic simulation models to estimate other traffic performance measures should be considered in addition to capacity and level of service. Contact the Design Quality Assurance Section or the Office of Corridor Management in the Planning and Strategy Group for guidance in these situations.

5.2.3 Updating Traffic Data and Capacity Analysis

Accurate design-year traffic data is needed to help evaluate the effectiveness of feasible alternatives and to produce the most cost-effective designs that achieve full expected service life. Desirably, current traffic data should be used. However, since regathering data and redoing analysis is costly and time consuming, it may be acceptable to use older data and analysis under certain conditions. Consider updating the capacity analysis, traffic diagrams, and design year- traffic forecast (prior to distribution of the draft Design Approval Document, Design Approval, and PS&E) if any of the following factors have the potential to impact the proposed design:

- The estimated project completion date is postponed by more than 4 years (e.g., the ETC+20 design year is changed from 2025 to 2030).
- New development has or is expected to occur.
- Travel patterns have or are expected to change.
- Project limits have been expanded or modified.

Traffic data, forecasts, and analyses, whether current or not, should be reviewed with the Regional Transportation Systems Operations Engineer. If updated information is being considered, consult with the Regional Planning & Program Manager and the Regional Transportation Systems Operations Engineer on the need for, and how to do, an update of the design-year traffic volumes, traffic diagrams, and capacity analysis.

If the older data will be used, consider spot checking current traffic patterns to determine if the older data projected to the current year is representative of current conditions. Average hourly speed data can be checked using the floating car method. Critical turning movements should be recounted, as necessary, to ensure adequate storage length, number of turn lanes, etc., is provided.

The rationale for the retention and use of older data needs to be documented in the Design Approval Document or, if design approval has already been obtained, in the permanent project files.

5.2.4 Speed Studies

Speed studies provide an essential measure for evaluating highway geometry. The speed study results also serve as the basis for selecting a design speed within the acceptable range for the highway's functional class (refer to Section 2.7 of this manual). The Regional Transportation Systems Operations Group should be consulted on how to conduct these studies in order to obtain statistically reliable results.

As an exception to a formal speed study, the Regional Transportation Systems Operations Engineer can select an off-peak 85th percentile speed equal to or above the regulatory speed based on their expertise and experience.

Note: The regulatory speed alone may not be a reasonable indicator of the off-peak 85th percentile speed. Numerous studies (including FHWA's "Effects of Raising and Lower Speed Limits on Selected Roadway Sections," 1997) have shown that speed limits have only a very minor effect on operating speeds and cannot reliably be used to predict the operating speed.

5.2.4.1 Speed Terminology

A. 85th Percentile Speed (a.k.a. Operating Speed)

The operating speed is a single speed that reflects the majority of motorists. Rather than use an average speed, which may only accommodate half the highway motorists, the Department and most transportation agencies use the internationally accepted off-peak 85th percentile speed to represent the operating speed. The 85th percentile speed is the operating speed that only 15% of the motorists exceed during off-peak hours.

B. Recommended Speed

The recommended speed is the maximum speed, under optimal conditions, considered appropriate for a particular location (ref. 17 NYCRR Chapter 5 (a.k.a. NYS MUTCD) Section 230.1). The recommended speed should consider the alignment and sight distance. Other physical conditions, such as narrow lanes, roadside development, steep grades, etc., may also be considered.

The recommended speed based on the vertical sight distance should be determined from Appendix B of this chapter. The recommended speed based on the horizontal sight distance should be based on Section 5.8.2.4. The recommended speed based on the superelevation and radius should be determined by (in order of preference):

- Calculating the speed from the geometry and equation from Section 5.7.3 of this chapter.
- Using a ball bank indicator reading of 10° for horizontal alignment.
- Using Figure 231-1 of the NYS MUTCD for horizontal alignment when the radius and superelevation are known.

Note: Each method will result in slightly different results.

C. Advisory Speed

The advisory speed is defined in Section 230.1 of the NYS MUTCD as the recommended speed rounded to the nearest 5 mph.

D. Regulatory or Legal Speed Limit

The Regulatory or Legal Speed Limit is the maximum speed along a highway segment allowed by local or state regulations. It may also be referred to as the posted speed when regulatory signs are posted. When regulatory signs are not posted, the speed limit is the statutory speed.

E. Statutory Speed Limit

The statutory speed limit is 55 mph as established by the NYS Vehicle and Traffic Law.

5.2.4.2 Speed Study Methods

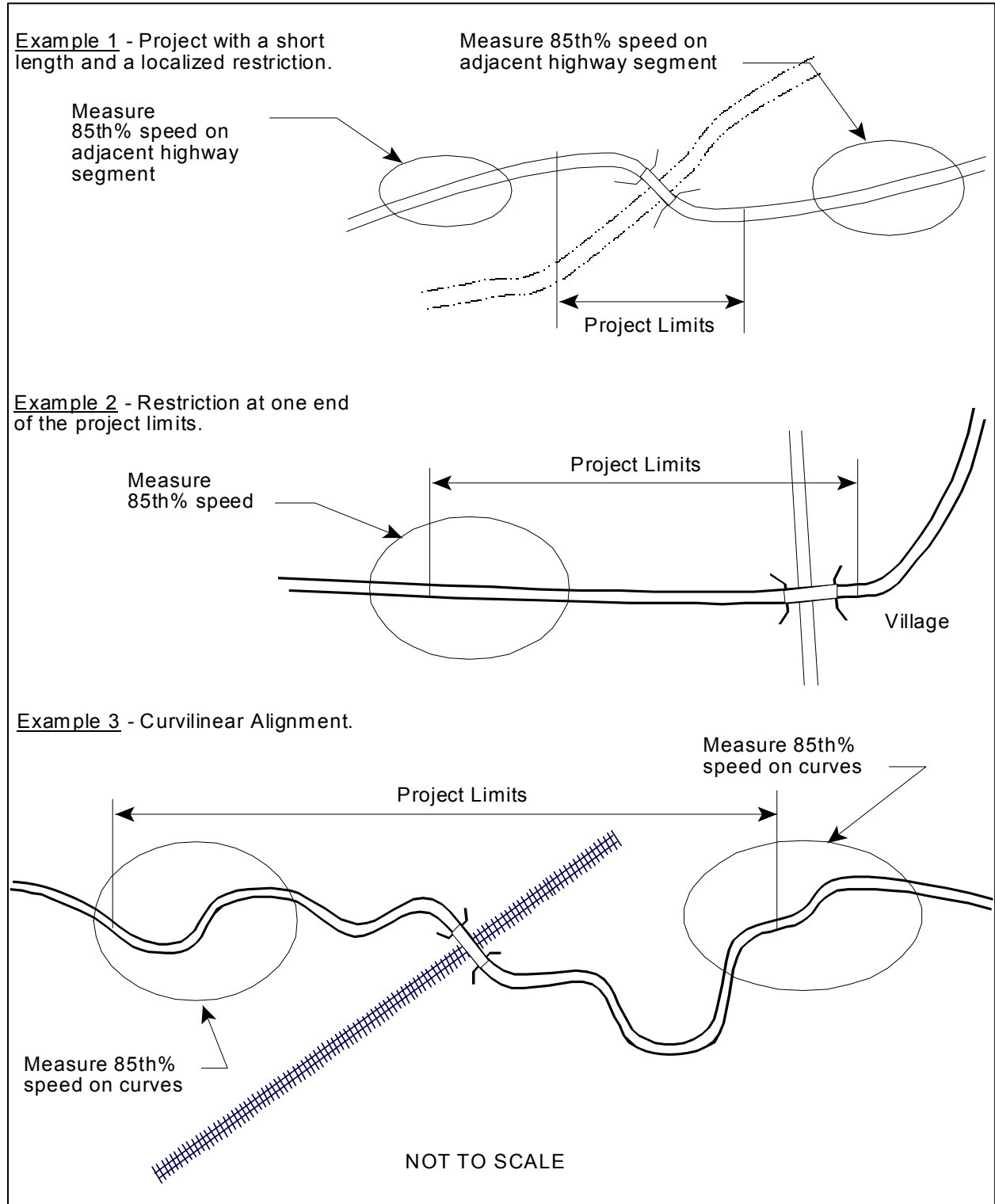
The existing operating speed can be determined or estimated during the off-peak hours by using (in order of preference):

1. Speed measuring devices.
2. A radar spot speed study of at least 30 vehicles (preferably 50 vehicles) that can be performed during off-peak periods. This is generally only practical for highways with 250 vpd or greater.
3. The data used to set a speed limit at the project site, if such data is still representative of current and anticipated operating conditions.
4. Test cars or following-car techniques during off-peak periods.
5. The state-wide operating speed study for a similar facility. This information is available from the Highway Data Services Bureau in the Office Technical Services.

5.2.4.3 Speed-Study Location

Select a speed-study location where motorists are not affected by localized nonstandard features or traffic control devices (e.g., stop signs, narrow bridges, sharp curves). The study may need to analyze both directions to ensure that it measures the highest speeds. Refer to Exhibit 5-2 for examples of how to locate the speed study.

Exhibit 5-2 Speed Study Locations



5.3 ACCIDENT ANALYSIS

Identifying the cause(s) of accidents usually will provide an insight into what corrective measures can be taken to minimize future accidents. New York State currently suffers over 1300 fatal accidents and 189,000 injury accidents per year on its highways. Approximately 40 percent of the fatal accidents and 30 percent of the injury accidents occur on the State Highway System. The estimated average cost of a fatal accident in New York State is \$3,220,000 and the cost of an injury accident is \$62,400. Therefore, in addition to normal duty and obligations, there are significant economic benefits to society in minimizing the frequency and severity of accidents.

The purpose of an accident analysis is to identify safety problems by studying and quantifying accidents within and immediately adjacent to the project limits, and identifying abnormal patterns and clusters. The analysis should then isolate and identify the causes of accident patterns and clusters, and suggest appropriate countermeasures. The Regional Transportation Systems Operations Group can either perform or assist in the conduct and interpretation of the analysis. Refer to Section 5.3.6 of this section for guidance on using older data and analysis.

5.3.1 Applicability

An accident analysis shall be performed on every highway and bridge project that offers an opportunity to address accident causes or severity. Exceptions include:

- 2R and minor bridge rehabilitations that may use the safety screening discussed in Section 5.3.5 of this chapter to determine if a full accident analysis is needed.
- Pavement preventive and corrective maintenance projects, which are subject to a road safety audit under the Department's SAFETAP program.
- Bridge preventive maintenance projects, such as Element-Specific Cyclical Bridge Work.

5.3.2 Timing

An accident analysis can aid in the development and evaluation of project alternatives, and in determining the need for safety improvements. Therefore, accidents must be analyzed early in project scoping and documented in the Project Scoping Report and in the Design Approval Document (DAD).

5.3.3 Responsibility

Project developers, in conjunction with the Regional Transportation Systems Operations Group, are responsible for retrieving and analyzing accident data in accordance with this procedure and for incorporating appropriate accident countermeasures (safety improvements) into each capital project. To achieve the Department's goal of continually improving highway safety for the public, effective accident countermeasures must be designed into its projects to the maximum extent possible.

5.3.4 Accident Analysis Procedures

The following are the specific steps to be followed in the Accident Analysis Procedure during the development of a capital project:

1. The study area shall extend 0.5 km beyond the project limits. Identify the study area by reference marker (for State highways) or link/node (for local roads). Also identify the area by physical boundaries (cross streets, intersecting roads, jurisdictional boundaries, etc.), if they exist.
2. Identify the time period of the analysis; the most recent 3 years available are normally used. On a low-volume highway, the number of accidents may be low, with a high accident rate due to low traffic volume and a short study segment. In this case, it may be necessary to examine the accident history over more than 3 years (5 years suggested) to have enough data to analyze adequately. Similarly, for a highway with a very large number of accidents, 2 years may be statistically adequate.
3. Collect all accident data and records for the analysis (including pedestrian and bicycle accidents) as follows:
 - Obtain computerized accident data for the study area from the Department's Safety Information Management System (SIMS). Most situations will be covered by the State Accident Surveillance System (SASS) for State highways and by the Centralized Local Accident Surveillance System (CLASS) for local roads/streets; both SASS and CLASS are now contained in the enhanced SIMS.
 - Check the Priority Investigation Location (PIL) list, the Safety Deficient Location (SDL) list, the Priority Investigation Intersection (PII) list, and the Specialty PIL lists, and determine if any location within the study area has been on these lists. Generally, the 3 most recent lists for each of these should be consulted. These lists are available in SIMS. They contain locations that exceed thresholds established by the Department and have statistically significantly higher accident rates (accident-prone sites) than expected for highway segments with similar characteristics.

- Retrieve police and motorist accident reports (MV-104A and MV-104) as needed for the study area. These "hardcopy" accident reports are available from the Office of Safety and Security Services. Order the necessary accident case documents either by requesting them electronically through SIMS.
 - A site inspection should be made to observe items that would indicate past accidents (such as damaged guide rail, skid marks, etc.) and the potential of the study area for future accidents (such as school zones, playgrounds, parks, etc.). Also, since some accidents often go unreported or are generally underreported, discussions with local residents, police, and elected officials may help identify an unreported/underreported safety problem or better quantify a marginal one.
4. Identify, discuss, and consider including (if not already implemented) the recommendations made in any prior Highway Safety Investigation (HSI) studies performed within the last 5 years involving the study area. These HSI studies can be obtained from the Regional Transportation Systems Operations Group.
 5. Calculate the severity distribution of the accidents and determine if it is normal or abnormal. The methodology for this determination can be found in the TE-164 (Safety Benefits Evaluation Form) Instructions. See page A-32 of Highway Safety Improvement Program: Procedures and Techniques. An electronic version of the TE-164 methodology is also available from the Transportation Systems Operations Bureau.
 6. First, calculate the accident rate(s) in accidents per million vehicle miles (MVM) for the entire study area, using all accidents (nonintersection and intersection accidents). Next, calculate the accident rate(s) for linear segments within the study area that have different highway characteristics, development density/land use (AADT; number of lanes; divided or undivided; functional class; rural or urban; controlled access or uncontrolled access) using all accidents. Then, calculate the accident rate(s) for individual intersections (in accidents per million entering vehicles (MEV)) within the study area, using only intersection accidents.

$$\text{Segment Accident Rate (acc/MVM)} = \frac{1,000,000 \times \text{No. of accidents per year}}{365 \times \text{AADT} \times 0.621 \times \text{Segment length (in kilometers)}}$$

$$\text{Intersection Accident Rate (acc/MEV)} = \frac{1,000,000 \times \text{No. of accidents per year}}{365 \times (\frac{1}{2} \text{ the sum of AADTs on all approaches})}$$

Note: Since accidents are coded to reference markers placed approximately every 0.16 km, the segment length used in the above formula must also be in 0.16 km increments corresponding to the reference markers used for the accident rate.

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7. Compare the calculated accident rate(s) to the statewide average accident rate(s) for similar facilities. The current statewide average accident rates are listed in the "Annual Update of Average (Mean) Accident Rates and Accident Costs/Severity Distribution" produced by the Office of Safety and Security Services. These rates can be found in the Department's Safety Information Management System (SIMS) and on the Department's Internet site. If the project limits include highway segments having different characteristics (urban/rural functional class, divided/undivided, number of lanes, controlled/uncontrolled access), accident rates should be computed for each segment/intersection and compared to the appropriate statewide rate. The amount an accident rate varies from the statewide average for similar facilities can help identify and quantify an accident problem on the overall highway segment under study.
8. Organize, summarize, and analyze all the collected accident data. This involves assembling an Accident History (use form TE-213 or equivalent), constructing a Collision Diagram (use Form TE-56 or equivalent) and completing an Accident Summary Sheet (Figure 23 in Highway Safety Improvement Program: Procedures and Techniques). Consult with the Regional Transportation System Operations Group to assist with determining accident patterns and causes. The Regional Safety Evaluation Engineer in each Region is familiar with these techniques and is experienced in their application.

The accident analysis should identify specific locations with clusters of accidents. An accident cluster is defined as an abnormal occurrence of similar accident types occurring at approximately the same location or involving the same geometric features. The severity of the accidents should also be considered.

A history of accidents is an indication that further analysis is required to determine the cause(s) of the accident(s) and to identify what actions, if any, could be taken to mitigate the accidents. There are 6 general elements that may contribute to or cause an accident. These are:

- Condition or actions of the driver. Was the driver alert, asleep, or under the influence of drugs or alcohol? Was poor judgement exercised (e.g., extreme speed)?
- Condition of the vehicle. Did the brakes fail? Were the tires worn?
- Environmental conditions. Inclement weather, fog, or slippery pavement.
- Condition of the engineering features of the highway or bridge. These include the alignment, width, superelevation, pavement condition, guide rail, clear zone, etc.
- External causes such as deer and other motorists.
- Missing or improper signing, delineation, or other traffic control devices not in accordance with the *NYS MUTCD*.

When analyzing the accident data, do not put too much weight on certain contributing circumstances which have tended to become "catch-alls". The fact that all the accidents are listed as due to "driver error", "speed too fast", or "following too close" is not a reason to conclude that highway geometrics were not involved and that no further consideration is required. Also, as part of the accident analysis, it is important to take the accident summaries, reports, and collision diagrams into the field to examine them at the actual field locations. This will help determine both the factors contributing to the accidents and possible mitigation measures.

9. Using the data and analysis results obtained from the above, identify, evaluate, and select appropriate accident countermeasures (solutions to accident problems) to incorporate into the project (including adjustments to the project limits if necessary). For accident countermeasure ideas, refer to:
 - Table 1 in Appendix D of Highway Safety Improvement Program: Procedures and Techniques. Although this table is extremely useful, it is not all-inclusive and should be used as a guide rather than a standard.
 - The Department's Internet site for a list of "Accident Reduction Factors" for various improvements.
 - Tables 7-13 and 7-14 in the 1999 *Traffic Engineering Handbook*.
 - The Regional Safety Evaluation Engineer in the Regional Transportation System Operations Group for assistance.

Where capital construction is proposed as the safety improvement, a safety benefit-cost ratio should be calculated. The methodology for determining safety benefits is contained in the TE-164 Safety Benefits Evaluation Form Instructions and Annual Update. Use the TE-204 Project Benefit and Cost Summary Form to complete the safety benefit-cost calculation.

5.3.5 Safety Screening

2R and Minor Bridge Rehabilitation projects may undergo a safety screening to determine if a full accident analysis is needed. The steps for the screening are:

1. Follow the full accident analysis procedure steps 1-7 with the exception that police and motorist accident reports are not needed. (These steps can be quickly accomplished using readily available products from the Department's Safety Information Management System (SIMS) and the computerized TE-164 methodology.)

2. If the accident history review indicates the following, a full accident analysis is not needed.
 - The overall three-year accident rate is less than the average rate for a comparable type of facility, as shown in SIMS.
 - The occurrence of Fatal, Injury, and combined Fatal+Injury accidents is not above average.
 - Locations listed on the regular Priority Investigation Location (PIL) list within the project limits are addressed. A PIL is considered addressed if it has been investigated in the last five years and the recommendations implemented or are incorporated into the proposed project.
 - Locations listed on the Fixed Object & Run-Off Road PIL list within the project limits are addressed.
 - Locations listed on the Wet-Road PIL list within the project limits are addressed.

Note: Segments that do not meet all of the above shall undergo an accident analysis using the methodology in Section 5.3.4 of this chapter.

5.3.6 Reviewing, Using, and Updating Older Data and Analysis

The original accident analysis should be reviewed during the project development process. In most cases, the review needs only to be done shortly before project design approval. In rare cases, it should also occur in the final design stage:

Prior to project design approval, the original accident analysis should be compared with the latest available computerized accident data included in the Department's SIMS to determine if there has been a major change in accident patterns or clusters at the project site. The accident analysis should be updated if a new accident pattern or cluster has appeared, and cost-effective mitigation measures should be recommended, as appropriate.

The recommendations resulting from the accident analysis should be reevaluated if substantial changes have occurred at the project site that may affect accidents. These changes may include, among others, different traffic patterns or substantial volume changes, increased intensity or change in type of development (commercial, industrial, residential, etc.), new/different traffic control devices (signals, signs, markings, etc.), roadway feature changes, etc.

Any revisions to the recommendations or proposed mitigation measures should be documented in the Design Approval Document.

If 3 or more years elapse between design approval and PS&E, the accident data should be reviewed prior to PS&E submittal and the analysis and recommendations revised, as described above. This review can be done in conjunction with the Regional Transportation Systems Operations Group. The designer should inform the Regional Design Engineer if there are any recommendations for changes affecting the project or any proposed modifications to the project.

5.4 TERRAIN DATA REQUIREMENTS

5.4.1 Terrain Data Deliverables

Terrain data deliverables for Capital Projects consist of base mapping, digital terrain models (DTMs), hydraulic cross sections, and orthoimagery. When a project requires base mapping it should also require a DTM. Following is a brief discussion of each.

- Base Mapping - Base mapping is a 3D graphic representation in MicroStation DGN format of the terrain features. Base mapping used for design development and right of way is generally provided to plot at 1:250 scale.
- Digital Terrain Model (DTM) - A digital terrain model is a triangulated 3D surface in InRoads DTM format, which is used to automate some of the engineering calculations and presentations of project designs. The digital terrain model is the source for the development of project alignments, typical sections, cross sections, quantities, and layout of design elements.
- Hydraulic Cross Sections - Hydraulic cross sections are cross sections taken upstream and downstream of a bridge. These sections are perpendicular to the stream/river and the associated flood plain. Hydraulic cross sections consist of line strings of 3D points (in MicroStation DGN format) taken perpendicular to the direction of the channel flow. For bridges (e.g., new and/or replacement bridges) over waterways, hydraulic cross sections require a 3D surface (in InRoads DTM format) of the bottom of the waterway within 100 m upstream and downstream of the proposed bridge fascia locations. For cross sections required for hydraulic purposes, refer to Appendix 3B of the *Bridge Manual* for DTM requirements, and refer to the Survey Standards & Procedures Manual for field procedures.
- Orthoimages - Orthoimages are scanned aerial photographs which have been corrected for distortion effects of camera orientation angle and terrain relief to achieve a uniform scale. These raster images are mosaicked to form a single image that extends beyond a project's mapping. These orthoimages form an image backdrop referenced to the mapping which can be valuable for displays at public hearings, and used directly for scaled measurements.

5.4.2 Process for Requesting Terrain Data

While the terrain data requests will typically originate from design, the data should also serve the requirements of construction when project logistics and resources allow, thus eliminating the need for additional terrain data collection during the construction stage. The project designer and Regional Land Surveyor should determine the terrain data requirements for the project.

Once the terrain data requirements have been decided, the terrain data may be obtained by various methods (e.g., any combination of in-house photogrammetry, in-house field survey, and use of consultants.). For Department designed projects, terrain data should be acquired through in-house photogrammetry and/or field survey as applicable. When in-house resources are not available, terrain data should be acquired using field survey and/or photogrammetric consultants. For consultant designed projects, terrain data collection may be included as part of the consultant design agreement, performed by Department personnel, or both. The Regional Land Surveyor is generally responsible for obtaining the field survey data through in-house or consultant forces and for coordinating the photogrammetric data deliverables. If photogrammetric mapping is required, a "Request for Photogrammetric Services" shall be submitted to the Regional Land Surveyor, who coordinates regional requests. If survey mapping is required, the request should also be submitted to the Regional Land Surveyor.

5.4.3 Method of Terrain Data Collection

Terrain data should be collected by either photogrammetry, field survey, or a combination of both. Refer to Sections 5.4.3.1 and 5.4.3.2 for guidance regarding these methods of terrain data collection. Refer to Section 5.4.3.3 for a discussion of the positional tolerances that can be obtained using the various methods. Refer to Section 5.4.4 for the terrain data needs by project type.

5.4.3.1 Field Survey

Field survey deliverables consist of base mapping, DTMs, and hydraulic cross sections. Field survey products are compiled according to the *Land Surveying Standards & Procedures Manual* and the *CADD Standards and Procedure Manual*. Field survey data should be obtained using data collection methods that are compatible with the Department's standard CADD software packages (e.g., MicroStation and InRoads).

Field survey work is required on most projects as either the initial mapping of the project or to provide supplemental field survey information. Field survey may specifically be requested to compile roadway pavement elevations, or to locate property lines, right of way (ROW), utility facilities, sign data, and underwater areas, which are unavailable through aerial photography.

For hydraulic cross sections, field survey, or a combination of field survey and photogrammetry can be used. Only field survey can obtain underwater data or data in areas of dense foliage. Refer to the *Land Surveying Standards & Procedure Manual* for information regarding field survey data requirements for waterways.

5.4.3.2 Photogrammetry

Photogrammetric deliverables consist of base mapping, DTMs, partial hydraulic cross sections, and orthoimages. Detailed information on photogrammetry products and how to request them is available in the *Catalog of Photogrammetric Services*. All mapping and DTMs are compiled following the *CADD Standards and Procedure Manual* and the *Specifications for Photogrammetric Stereocompilation*. For orthoimagery, photogrammetry must be requested for the mapping, DTM, and the generation of the orthoimage. Hydraulic cross sections can be partially produced by photogrammetry, but under water sections or areas in dense foliage require field survey.

Photogrammetry is more cost-effective than field survey for initial mapping of medium to large projects. However, there are cases where field survey or a combination of field survey and photogrammetry are needed:

- If a project has urban streets, dense foliage, or design features that require a higher accuracy, field survey should be the preferred alternative for these areas.
- On projects where obstructed aerial views occur, the designer should determine if the photogrammetric data needs to be supplemented with field survey elevations.
- Consultation with the Regional Land Surveyor should include consideration of the resource cost to provide all mapped deliverables over the life of the project development.

When a combination of field survey and photogrammetry are used, the photogrammetric mapping and DTMs are merged with the field survey mapping and DTMs to create a single deliverable. All users of the project data should be aware of the differences in the positional tolerances of these two data types as shown in Exhibit 5-3. The designer should request enough field survey to assure that the survey data extends beyond any critical design area. Refer to the *Land Surveying Standards & Procedures Manual* for information regarding field survey data requirements for bridge replacements. When field survey data will be collected in addition to the photogrammetric data, the field survey data should be collected first to help facilitate the development of the DTM.

5.4.3.3 Terrain Data Accuracies

The accuracy of the DTM surface is contingent on the terrain data accuracy. The DTM surface portrays the existing ground surface and is constructed from lines and points that form a triangulated network that defines the features and terrain character. The ground surface between the measured points is interpolated. The overall accuracy and quality of the DTM surface is based on the density of points, the selected location of the points, and the accuracy of the points. With the exception of points, the accuracies listed in Exhibit 5-3 are for the DTM surface. They refer to the DTM surface accuracy that can be expected using survey and photogrammetry. The table lists the accuracies based on a new standard which requires that 95% of the points will meet the indicated accuracies.

Exhibit 5-3 Terrain Data Accuracies ^{1,2}

Feature	Obtained by Survey		Obtained by Photogrammetry	
	Horizontal (mm)	Vertical (mm)	Horizontal (mm)	Vertical (mm)
Points (Door Sills, corner of frames & grates)	25	50	75	100
Structures (Buildings, Walls, Bridges, Culverts)	75	50	75 <small>See Note 3</small>	100 <small>See Note 3</small>
Hard Paved Surfaces (Driveways, Roadways, Sidewalks)	75 (curbed) 150 (uncurbed)	50	75	100
Underground Features (Drainage Lines, Utilities Mains)	100	100	N/A	N/A
Graded Areas (Lawns, Gravel Drives)	200	200	200	200
Sparsely Vegetated Natural Areas (Open Fields)	400	400	400	400

Notes:

1. The accuracy of terrain data is the difference between a location on the DTM surface and the actual location of that point.
2. The accuracies listed in the above table are based on the two standard deviation level which means that 95% of the tested points will be within the listed accuracy. In the past a one standard deviation level of reporting was used which meant that 68% of the tested points were within the listed accuracy.
3. The tops of vertical surfaces (faces of curbs and walls) are offset to avoid data conflicts. Photogrammetry uses the roof overhang to portray buildings rather than the building walls.

5.4.4 Terrain Data Needs by Project Type

The following factors should be considered when determining the type of terrain data necessary for a project:

- Size and scope (or type) of the project.
- Level of accuracy needed for terrain data to design and eventually construct the project. Some types of projects require more vertical accuracy in areas where existing and proposed pavement alignments are to be tied together in the field. 2R or 3R Projects need more vertical accuracy along the entire length of roadways where the proposed alignment is to match into existing conditions. These more accurate pavement DTMs should be completed by field survey.
- Time required to move from data collection to the start of design.
- Estimated data collection resources required.

Exhibit 5-4 indicates the project work type, recommended terrain data deliverable, suggested levels of accuracy, and typical mapping width that is generally required based on project type. As indicated in Exhibit 5-4, some projects may require more than one type of terrain data deliverable. Refer to sections 5.4.4.1 and 5.4.4.2 for additional guidance regarding terrain data by project type.

5.4.4.1 Project Type

In addition to the guidance provided in Exhibit 5-4, consideration should be given to the following:

- 2R/3R Projects require higher accuracy terrain data along the roadway to provide sufficient information to make informed decisions on which types of surface treatments are utilized on a project. Decisions on how to improve an existing pavement cross slope to ensure it conforms to standards should be based on having accurate terrain data. An engineer's ability, to accurately estimate the work and material quantities required to provide a finished road surface which meets standards, is affected by the accuracy of the terrain data.
- Higher accuracy terrain data is necessary for urban streets out to faces of buildings (including wide sidewalks, porch steps and building sills) to ensure proper drainage and access to the roadway.
- Major bridge rehabilitations, such as superstructure replacements, require accurate terrain data for the location of the substructure and approach roadways. DTMs for bridge projects (e.g., bridge replacements, bridge widenings) require accurate tie-downs to existing profiles at the approaches, especially where no other work is anticipated for the project.

- Projects to construct a highway on new alignment, add through-travel lanes, or significantly alter the horizontal or vertical alignment, require Type I Noise Studies (per Chapter 3 of the *Environmental Procedures Manual (EPM)*). These studies generally require base mapping and DTMs extending 150 m from the centerline of the outside travel lanes (i.e., a 300 m plus mapping width). There may be some Type I projects where the 150 m could be reduced (e.g., where a noise barrier analysis will not be possible, lack of access control). Designers should contact their Regional Environmental Coordinator to determine if a noise study is required and any special terrain data requirements.
- Most pavement preventive and/or corrective maintenance type projects (e.g., 1R, microsurfacing, chip seal, and quick-set slurry) do not require a terrain data deliverable. However, limited data, such as pavement elevations where superelevation adjustments are anticipated, may be needed for a 1R project.
- Other Projects and Miscellaneous/Special Projects may require project-wide terrain data. For example, drainage reconstruction or construction of a recharge basin require project-wide base mapping, and other projects may require very limited data. If only limited terrain data is needed, then it should be collected using field survey.

5.4.4.2 Width of Mapping Limits

Following are some additional considerations regarding mapping width:

- Mapping widths should be kept as narrow as possible but should include sidewalks, roadside ditches and backslopes, embankments (critical to the support of the roadway), drainage structures, roadway guide rail, signs, driveway entrances, bridge structures, and all objects within the potential clear zone. In urban or suburban areas, the minimum mapping width on 2R/3R projects will generally go out to the front faces of buildings, while on Reconstruction (& Bridge Replacements) or New Construction Projects the mapping width generally will run along the rear of buildings.
- Mapping widths should include at a minimum, all area within existing highway boundary so the terrain data will be sufficient for ROW mapping purposes.
- The mapping width limit can vary within a project to cover intersecting roads, ramps, and drainage features.

5.4.5 Field Editing of Terrain Data

Field edits should consider locating, identifying, measuring or labeling the following features:

- Utility pole numbers, valves or manholes, types of overhead or underground lines, and utility owners.
- Building structure addresses, owner/business names, and structure type.
- Storm or sanitary sewer inverts, pipe sizes and directions of flow, and material types.
- Pavement or building structure materials.
- Plant species, size and or condition.
- Sign wording, type and size.
- Open drainage flow patterns and/or stream flow directions.
- Cross culverts sizes, types and inverts.
- Guide rail, headwalls and other highway appendage types and/or materials.
- Traffic signal controller boxes, pull boxes and signal head locations.

Mapping and DTMs from field survey generally include feature annotation from the original survey.

Photogrammetric Mapping or DTM products generally require field editing to add or clarify feature information. The field editing is generally completed after the project mapping or DTM has been completed by Photogrammetry, and before design work begins. Most field editing can be completed by either the designer, or by a survey field crew, but some more precise field locations of edited information will necessitate field crew measurement with survey instruments. During a field edit, the mapping or DTM surface should be compared with actual field terrain to ensure that it portrays what is currently present on the project.

Exhibit 5-4 Terrain Data Requirements by Project Type

Project Work Type (Per PDM Appendix 5)	Terrain Data Deliverables ¹	Typical Mapping Width ⁴
Safety Related Work	Base Mapping & DTM (may be required)	Determine on a project by project basis
Pavement Preventive and Corrective Maintenance (e.g., 1R Projects)	No Base Mapping ² or DTM	NA
Resurfacing, Restoration & Rehabilitation (2R/3R)	Base Mapping ⁵ & DTM	Map to front of buildings or to limit of expected work.
Reconstruction & New Construction	Base Mapping ⁵ & DTM	Map to rear of buildings or to limit of expected work.
Minor Intersection Reconstruction	No Base Mapping ² or DTM	NA
Major Intersection Reconstruction	Base Mapping ⁵ & DTM	Map to front of buildings or to limit of expected work.
Preventive & Corrective Bridge Maintenance	No Base Mapping ² or DTM	NA
Minor Bridge Rehabilitation	No Base Mapping ² or DTM	NA
Major Bridge Rehabilitation	Base Mapping ⁵ , DTM & HCS ³	Map to front of buildings or to limit of expected work.
New & Replacement Bridges	Base Mapping ⁵ , DTM & HCS ³	Map to rear of buildings or to limit of expected work.
Other Projects and Miscellaneous/ Special Projects	Determine on a project by project basis	Determine on a project by project basis

Notes:

1. The base mapping and DTMs meet the requirements of the *CADD Standards and Procedure Manual*.
2. Instead of new base mapping consider the use of record plans or new imagery supplemented by field survey checks.
3. Hydraulic Cross Sections (HCS) may be required. The need for HCS should be discussed with the Structures Design and Construction Group.
4. Projects that require Type I noise analysis generally require base mapping and DTMs extending 150 m from the outside travel lanes.
5. Orthoimagery may be useful for information within and beyond the base mapping extent and for presentations at public meetings.

5.5 RIGHT OF WAY (ROW)

The designer is responsible for determining the right of way needs necessary for the construction and maintenance of a proposed project. An assessment of right of way needs should be made during the project scoping stage. Specific right of way needs are determined after the various design alternatives have been identified and evaluated. Each alternative's potential impact upon the residents, environment, neighborhood, businesses, land use, and users should be examined and evaluated. The designer should coordinate with all involved program area groups to gain a varied perspective on the impacts of all alternatives. This should be done as early as possible and programmed into the project schedule.

5.5.1 Abstract Request Maps

Once properties which are affected by the various alternatives being considered are identified, the designer should submit the proposed right of way limits to the Right of Way Mapping Group (i.e., consultant or Regional). These proposed right of way limits will be outlined on base mapping, as described in Chapter 3 of the *Right of Way Mapping Procedure Manual*, to create an Abstract Request Map (ARM). The Right of Way Mapping Group sends the ARM to Regional Real Estate for forwarding to the Department of Law (DOL).

An ARM is prepared to obtain the necessary title data for the properties that may be acquired by the project. It provides the DOL with a means of identifying the properties for which title data is required. Supplemental ARMs should be submitted whenever changes in a project's work limits occur which will affect which properties are being acquired. DOL requires title data before they can provide title certification of most right of way acquisitions. Title certification is required by Real Estate (i.e., Regional and Main Office) before compensation offers can be extended to land owners.

The size of the ARM will vary depending upon whether it includes just the preferred alternative, or all of the feasible alternatives. The decision on how many alternatives to include should be based upon the size of the project, the amount of time needed to research the title data, the cost to the Department for requesting additional title searches, and the complexity of the title data along the project's corridor. The designer should consult with the Regional Real Estate Group and review the project schedule to determine when this information needs to be available. ARMs should generally be submitted to the Real Estate Division a minimum of 12 to 24 months prior to the PS&E for the project, depending upon the amount and complexity of the title data requested.

A "Table of Temporary Reference Numbers" (TRNs) is generated as part of the ARM. This table lists all proposed acquisitions from properties that could be affected by the project. (Refer to Chapter 3 of the *Right of Way Mapping Procedure Manual* for more information on TRNs). This table will be updated and further expanded during later stages of the project to tabulate the anticipated right of way acquisitions.

5.5.2 Design Approval Document (DAD) and Preliminary Plans

The designer should provide information about the magnitude, types, and overall cost of preliminary right of way for each of the feasible alternatives in the Design Approval Document (DAD), for both federally and state-funded projects. This information is provided to the public and other evaluators of the project to assist them in determining the magnitude of the right of way acquisitions and the proposed limit to which the acquisitions extend into private and public properties for each feasible alternative.

All feasible alternatives which involve right of way acquisitions should be shown on the preliminary plans in the appendix of the DAD. These preliminary plans should include, along with existing and proposed highway alignments, the schematic delineation of the approximate limits of existing and proposed right of way (see Section 9.2 of Appendix B of the Design Procedure Manual).

Note: Right of Way Plans, for use in a separate right of way approval process, are not required as part of the documentation of right of way required for a project. The contract plans will provide the Department's documentation of what right of way was determined to be necessary to be acquired for a project.

In addition, the DAD should also include (in the appendix) for each feasible alternative, a "Table of Anticipated ROW Acquisitions" which lists all property owners from whom right of way is anticipated to be acquired (Ref. *Project Development Manual Chapter 4*). A tabulated list is not required for a project which does not have ROW acquisitions.

The "Table of Anticipated ROW Acquisitions" should include the following information for each property from which a ROW Acquisition will be appropriated:

- Land owner's name
- Type of acquisition
- Estimated ROW area to be acquired

This summary of ROW information will be utilized by private land owners, municipalities, and FHWA (if federally funded) to evaluate the magnitude and limit of the ROW acquisitions as part of the project review process. This information will also be used by the Regional Real Estate Group (upon receipt of the final Design Approval Document) to obtain Acquisition Phase Authorization.

5.5.3 Right of Way Determination

The design should include proposed ROW lines on the working plans which encompass the areas required to access, construct, and maintain the proposed facility. The designer shall allow room beyond the construction limits (toe or top of slope) for construction equipment and for future maintenance operations, such as mowing or cleaning ditchlines. The type of acquisitions should be determined by the use for which the land is taken, the party for whom the access will be provided, and whether the need for the land will continue after the construction contract is completed. If no work extends beyond the existing highway boundary, there is no need to acquire additional ROW. General guidance for width of right of way to be acquired beyond the construction limit includes:

- A distance of approximately 3 m - 4 m is desirable when it can be obtained with little extra cost or impact to the adjacent property, such as in rural areas with no nearby dwellings.
- A minimum of 0.5 m - 1.5 m should be used where right of way costs are more expensive or impacts are more significant, such as on front lawns of houses or in commercial areas with limited building setbacks.
- A minimum of 0.3 m should be considered in urban settings where buildings are set close to the roadway, or outside of sidewalks which are separated or detached from the highways by a wide utility strip or grass area.

In addition to cost, consideration should be given to visual aesthetics, maintenance activities, roadside safety (i.e., clear zones and clear areas), regional guidance such as "Guidelines for the Adirondack Park", future development (e.g., zoning setbacks), accommodation of utilities, drainage design, soil erosion and sediment control during construction, and disruption to adjacent property owners, when determining taking lines. Discussion with all involved functional units, municipalities, utility companies, and regulatory agencies should occur early in the design process to ensure all impacts are fully evaluated.

The reestablishment of driveways, private sidewalks, and other approaches to private lands should be accomplished by use of releases. This work shall only include what is necessary to reconnect a privately owned approach to the adjoining highway. This work should not include any construction activities that are critical to the successful completion of the project. Therefore, work done within a release should not include grading for roadway support, installation of highway drainage (as opposed to those driveway culverts which do not form a part of the highway drainage system), municipal utility lines or structures, or construction of public sidewalks. Refer to Section 5.5.6.6 for additional guidance regarding reestablishment of approaches to private lands.

Taking lines should generally avoid frequent angle points. When angle points in the taking lines are necessary, they should generally be kept a reasonable distance (3 m minimum) from property lines which are transverse to the roadway, to avoid being mistaken for property line corners between adjacent owners.

Refer to Section 5.5.6 for additional guidance regarding types of right of way and access.

5.5.4 Taking Line Review Meeting

Once the preferred alternative is chosen for a project and the initial right of way taking lines are detailed, the designer is to schedule a meeting (commonly referred to as a "Taking Line Review") to discuss the limits and types of the proposed right of way acquisitions, any concerns, the project schedule, and make final determinations regarding the size and type of acquisition(s) to be mapped. On large projects, it may be advisable to break the project into segments and schedule separate meetings to discuss each segment. The taking line review meeting is to include the project designers, consultant manager (for consultant-designed projects), and Regional representatives from:

- Real Estate
- Survey
- Landscape Architecture
- Environmental Services
- Right of Way Mapping

Representatives from Regional Construction, Maintenance, Transportation System Operations, and Program & Project Management are to be invited to attend the meeting. If taking line changes become necessary after the meeting, the group should be reconvened to discuss the changes.

For a taking line review meeting, the designer should portray the following information on project base mapping so that it is easily understood by the attendees. Colored lines or colored shading may be used to improve clarity.

- Baselines and center lines.
- Proposed construction work limits such as toes and tops of slopes or safety-related clear areas.
- Anticipated construction operations and stages, traffic control plans, erosion and sediment control plans.
- Proposed structures such as bridges with wingwalls, buildings, sidewalks, retaining walls, and sign and lighting structures.
- Existing private underground services such as utility lines, wells, septic systems, and storage tanks (especially when the site is known as a former gasoline station location).
- Approximate boundary of contaminated soils, if known.
- Existing and proposed access control delineated and labeled.
- Existing and proposed aboveground and underground private and municipal utilities (e.g., fire hydrants, underground utility lines & structures, utility poles, signal poles, pull boxes).
- Proposed drainage facilities, including piping, underground structures, headwalls, open ditchlines with the direction of flow indicated, and stormwater management facilities.
- Existing highway boundary lines and proposed right of way acquisitions.
- Types of acquisitions indicated and labeled with the purpose of each easement.
- The limit of work on all side roads and driveways.

- Any building acquisitions and all structure encroachments into the ROW.
- The separate identification of all properties from which ROW is being acquired but were not identified, or were identified but are no longer needed on the Abstract Request Map.

In addition to the project mapping, the designer is to provide cross sections with the proposed construction work limits and right of way limits shown for reference during the Taking Line Review.

5.5.5 Design Phases V-VI, Final Design Stage

The contract plans will document what right of way acquisitions were determined to be necessary to construct and maintain the project with the ROW acquisition maps serving as documentation of the actual right of way acquisition. Thus, the contract plans should include an accurate representation of all the right of way acquisition maps which demonstrate the properties which are to be appropriated for that project. To provide this documentation, the contract plans should include a graphical presentation of all acquisitions on the general plans. Separate "Acquisition Plans" should be prepared for projects in which the general plans would otherwise be too congested to clearly portray both the construction improvements and the right of way acquisitions on the same plan sheets. In addition to the general plans or acquisition plans, a "Table of Right of Way Acquisitions" shall be prepared. This table is expanded from the Design Approval Document "Table of Anticipated Right of Way Acquisitions." To keep this information current and inclusive of all changes that occur during design refinement, frequent communication between the designer and ROW Mapping Group is necessary, so that all changes can be reflected on both the contract plans and the ROW Acquisition Maps. The designer should also contact other groups when changes affect their interests.

Design changes in areas of land acquisitions need to be communicated to the Regional Real Estate Group during final design, so they are aware of potential impacts to adjacent landowners. Regional Real Estate meets with each of the affected landowners along a project to describe the type and size of the acquisition that the State is appropriating from their property. These discussions include how the project will affect the topography, structures, and landscaping of a property. Therefore, Regional Real Estate needs to be kept abreast of construction impacts and any changes to those impacts on adjacent land parcels and receive periodic updates of general highway plans, profiles, and cross sections.

Design changes in areas of land acquisitions that impact environmental issues (e.g., historic, parkland, wetland) need to be communicated to the Regional Landscape and Environmental Section during final design, so that they are aware of any changes to permits or mitigation needs.

The "Table of Right of Way Acquisitions" shall include:

- Reputed owner's name.
- Map and parcel numbers.
- Types of acquisitions. PEs and TEs shall include the purpose of the easement.
- ROW area to be acquired.
- State highway number (on projects which include more than one state highway).

A copy of this table should be forwarded from Design to Regional Real Estate at least two weeks prior to PS&E, for Real Estate's use as a checklist to determine if all acquisitions have been processed, and for obtaining ROW Certification. This list in the plans will provide a tabulation of all ROW acquisitions for use by the Contractor and EIC, as well as for historic reference of what ROW was acquired for that specific project.

5.5.6 Types of Right of Way and Access

Right of way is usually acquired by appropriation. Appropriation is the acquisition of property by the government through the right of eminent domain. **The amount of right of way acquired shall be limited to only what is necessary to access, construct, or maintain a highway and its designed features and appurtenances.**

The different types of right of way acquisitions and access are described in Sections 5.5.6.1 through 5.5.6.9.

5.5.6.1 Fee with full access - Fee (W/A)

A. Definition

Acquiring absolute right, title, or estate to a parcel of land for use by the state for purposes related to highways or other transportation related facilities.

B. Types of Use

Fee with full access is used for the construction or maintenance of roadway pavements, structures, appurtenances, and their supporting foundations. Fee acquisitions should be appropriated to include all permanent structures which are part of the highway infrastructure, but are not within the existing highway right of way. These should include wingwalls, headwalls, guide rail, sign structures, signal equipment, public sidewalks, drainage structures, and retaining walls used to support the highway. In addition, fee acquisitions should be appropriated to include all highway elements which are necessary to support or protect the integrity of the highway (e.g., roadside ditches or side slope protection installations) or to mitigate environmental impacts associated with the proposed project (e.g., the acquisition of land for wetland creation).

In certain situations such as in highly developed commercial areas, a fee acquisition may reduce a commercial property to below a standard size lot required by local zoning or reduce a building setback below the minimum requirement. These two situations could cause undue hardship on the owner should they end up with a substandard lot. The implications of a fee acquisition in these cases far outweighs the cost of the land, therefore, a Permanent Easement acquisition may be more appropriate.

Acquisition of ROW should be avoided around areas which include private wells and septic systems, underground tanks, private drainage systems which collect, transport, or discharge storm water from a private property, and retaining walls which support private property embankments. Appropriation of these facilities will implicate the state for their maintenance responsibility or liability in the future.

5.5.6.2 Fee without access - Fee (W/OA)

A. Definition

Same definition as Fee W/A, except that the remainder parcel of the abutting owner is denied direct access across the fee parcel to the public highway. Fees W/OA that are purchased to limit access are usually acquired at a minimum width of approximately 0.5 m, but can include the entire acquired parcel.

B. Types of Use

Fee without access is used to control (deny) access onto "limited access" types of highways such as interstates or parkways, or to control access in highly congested or accident prone portion of highways. Fees W/OA may also include all of the types of use listed under Fee W/A.

5.5.6.3 Permanent Easement (PE)

A. Definition

Permanent easement is the acquisition of certain rights and interest to use or control a property for a designated purpose. In most cases, the property owner retains the use of the property for other functions which do not interfere with the purpose of the easement.

B. Types of Use

Permanent easements provide for the limited use of private property which is necessary for highway purposes. The PE Map must describe the specific right that is being acquired and for what purpose. Examples of this use are:

- Drainage - To control the direction and maintain the flow of storm water. This may include minor underground drainage lines which collect storm water from low areas adjacent to the highway, or discharge storm water to naturally occurring watercourses which lie adjacent and downstream of the highway. (See also, discussion of rights of entry in Section 5.5.6.8.)
- Sight Distance - To allow for clearing and maintaining of a critical sight distance area.
- Slopes - To maintain the stability of a side slope along a highway which does not support a critical highway element, (e.g., large back slope out from a ditchline).
- Viewsheds - To allow for the conservation and development of roadside view sheds and natural features.
- Maintenance Operations - To allow maintenance crews access to highway structures or other appurtenances for the intent of maintaining their integrity or purpose.
- Bank Stabilization - Banks of streams or rivers which are susceptible to erosion near a highway may require stabilization efforts to be maintained.
- Commercial Access Control - Along highways, where commercial access control is desired, a PE can be acquired for highway purposes to allow for construction of roadside traffic control elements (PEs can be used in these instances, as a last resort, where minimum commercial lot sizes, setbacks, or green spaces would be reduced and property value would be significantly compromised by a fee taking).
- Clear zones and clear areas - To create and maintain clear zones and clear areas.
- Railroad properties - For construction of any permanent highway bridge structures across an operating railroad property, in most situations a PE is acquired from the applicable owner. In some situations, specific railroad companies have not agreed to PEs, but have provided permits to allow for the construction work and future maintenance.
- Contaminated soil - To acquire the rights of access and/or use a piece of real estate without owning the underlying fee and contamination liability. Refer to Section 5.5.6.9 A for additional guidance.
- Snow fence - to allow for the construction and maintenance of permanent snow fence installations.

5.5.6.4 Temporary Easement (TE)

A. Definition

Temporary easements acquire the use or control of a piece of property for specific use(s) during a construction project, for a set or limited duration of time (usually the length of the construction contract). The owner is compensated for their inconvenience, loss of value, or loss of access on the TE.

B. Types of Use

Temporary easements should be used for work which is essential to the proper, timely, and safe completion of the project, but not for work which restores private access to a highway. Examples of temporary access are:

- For construction and removal of a temporary detour or onsite diversion, including bridges.
- For construction and removal of temporary pedestrian bridges or walkways.
- To demolish or raze a structure on a property where the state has taken title to the structure, but does not own the underlying property.
- To slightly modify the land features or grade characteristics of an adjacent property that improves the safe use or integrity of the highway while not affecting the existing land use.
- To allow access for specialty construction equipment such as pile drivers or cranes.
- For stream realignment including the excavation or clearing of a new streambed or backfilling and seeding a former streambed both of which reside on the same owner's property.
- For use by the contractor for the temporary storage of equipment or materials used on the construction project (if deemed beneficial to the Department), or for temporary access by the contractor across private property.
- To install and maintain temporary soil erosion control measures.

5.5.6.5 Temporary Occupancy (TO)

A. Definition

A temporary occupancy maps a specific area of private property, which under Section 404 of the Eminent Domain Procedure Law and Section 30 Subdivision 17 of the Highway Law allows the state or its designees (contractors) to enter upon for project-related business. A TO allows for compensation to the landowner up to \$2500 for loss of use or damage to their property during construction activities. However, since the land is not appropriated, some situations have arisen during which construction work has been delayed by the landowner, or the assessed damages have exceeded the \$2500 limit. In some cases, the TOs have been reprocessed as TEs; duplicating much of the effort.

B. Types of Use

Temporary occupancies are discouraged and shall only be processed with the concurrence of the Regional Real Estate Group. TOs are only to be used in isolated situations where there is a definite advantage to the state, and then, only used on areas which are noncritical to the completion of the project.

5.5.6.6 Reestablishment of Approaches to Private Lands

Section 54a of the Highway Law, Reestablishment of Approaches to Private Lands, allows the Department to reestablish existing entrances, approaches, or driveways to meet the new highway grade. Entrances, approaches, and driveways have been interpreted to include driveway, curbs, sidewalks, stairs, etc. Before the contractor is allowed to make any adjustments outside the State's ROW, a release from the property owner must be obtained as discussed in Section 107-14 of the *Contract Administration Manual, MURK Part 1A*. The release provided in Section 107-14 should be used. A release is a nonbinding agreement (without compensation) between a landowner and the state to allow for the reconnection of a private or commercial access to a highway. No TE or TO maps are used for this purpose, and no compensation is paid to the land owner since the reconnection is for their benefit. No project-related work should be included under this release that, if the owner were to deny access, would prohibit the contractor from completing an essential element of a project.

Refer to Appendix A of this chapter for the Driveway Design Policy.

5.5.6.7 Planting Trees and Shrubs Along State Highways

Section 19 of the Highway Law, Planting Trees and Shrubs Along State Highways, allows the Department to plant trees and shrubs on private property with the consent of the property owner. If plantings on private property are to be specified, form HC91, illustrated in Section 107-14 of the *Contract Administration Manual, MURK Part 1A* must be used to obtain the property owner's permission before the work can begin.

5.5.6.8 Rights of Entry

The rights of entry discussed in Sections 5.5.6.8 A and B should be used with caution. If exercised inappropriately or without proper cause, it could lead to claims filed by the adjacent land owners. These rights do provide for access in situations where the integrity of the roadway is threatened or the safety to the public users of the highway could be in jeopardy. For any work in a stream or creek which is performed outside the existing highway boundary and alters the channel location, flow characteristics or the underlying land use, should be accomplished within ROW acquired by appropriation. This appropriation should compensate the adjoining land owner for any change in the riparian rights they had prior to this work.

A. Section 45 of the NYS Highway Law

This section states that DOT employees or contractors working for the state can enter upon lands adjacent to a state highway or which contain a stream or creek to:

- Open, maintain, or construct an existing ditch or drain for the free passage of water for drainage of such highway.
- Construct, reconstruct, or maintain drainage channels in order to keep the waters of such streams or creeks within their proper channel and prevent their encroachment upon state highways or bridges.
- Remove or change position of a fence or other obstruction, which in DOT's judgement, prevents the free flow of water under or through a state bridge or culvert.
- Remove private fences or obstructions which cause snow to drift in and upon a state highway, or to construct or remove temporary snow fences which prevent the drifting of snow in or upon a state highway.
- Inspect, remove, or prune trees which in DOT's judgement, constitute a danger to the users of the adjacent highway.

BASIC DESIGN**B. Section 404 of the Eminent Domain Procedure Law (EDPL) and Section 30, Subdivision 17 of the Highway Law**

These sections of the law allow for DOT employees or contractors working for the state to enter upon private land, prior to acquiring any real property, to engage in work connected with a proposed public project. This right of entry shall be for the purpose of making surveys, test pits and borings, or other investigations needed for the project. The state's representatives shall be responsible to notify the private land owners, by mail, prior to entry upon the land. The state shall also be liable to the landowner for any damages caused by or as a result of entry.

5.5.6.9 Special Considerations**A. Contaminated Soil**

Acquisitions along properties which have in the past or still do contain commercially sold or used hazardous materials (including petroleum based) should be investigated for possible contamination of the soil on the site. Procedures described in Chapter 5 (Hazardous Waste and Contaminated Materials) of the *Environmental Procedures Manual* should be followed and investigations coordinated with the Regional Environmental Contact. When acquisitions are deemed necessary on properties which have been determined as contaminated, care should be used in determining the limits and types of acquisitions due to possible legal implications. Therefore, the following guidance is provided to assist in these determinations:

- Outer limits of the soil contamination in areas of possible ROW acquisitions should be determined as closely as present technology allows.
- Existing sources of the contamination should be investigated and appropriate action taken to prevent further contamination. If any possible sources of contamination are located within a proposed acquisition, (such as underground petroleum storage tanks or piping system which leaks), it shall either be avoided, or removed and appropriately disposed of. This removal shall be performed under the use of a Temporary Easement.
- Acquisitions of hazardous waste contaminated soils which are absolutely necessary, (other than petroleum based contamination) shall be acquired as Permanent Easements. This action avoids acquiring the underlying fee title and the possible contamination liability. Final determinations of these type of acquisitions should be coordinated with the Department's Office of Legal Affairs.

- Acquisitions of petroleum-based contaminated soils, (which do not include any remaining sources of the contamination) are regulated by different federal and state statutes than other hazardous wastes, and thereby have different liabilities associated with them. Thus, fee acquisition of petroleum contaminated soils may be permitted, if the Department does not acquire any part of the system from which the release is believed to have occurred. If uncertain of the potential implications of a specific acquisition, seek legal counsel from the Department's Office of Legal Affairs.

B. Utility Easements

Utilities acquire easements from private land owners for the purpose of locating their facilities across private property. These easements are generally affected when a proposed project requires acquisition of some or all of the land rights of the same property that the easement is located upon. The two ways the Utility easement may be affected are as follows:

- An acquisition in which the Utility is required to relocate their facility - In this case, all project-related relocations of utility facilities located on private property will be reimbursed from construction funds pursuant to Section 10 (24-b) of the Highway Law, and Chapter 13 of this manual. By reimbursement for this relocation, all existing Utility easements located within proposed acquisitions shall be assumed to be compensated for and extinguished.
- An acquisition in which the Utility is not required to relocate their facility - In this case, the Utility retains their easement rights that they held prior to the proposed acquisition. The proposed acquisition is thus made "subject to" the rights previously held by that Utility.

5.5.7 Encroachments

Encroachments exist on many highway rights of way. Generally, the owners should be requested by Regional Transportation Maintenance to remove these encroachments. However, an encroachment may be allowed to remain if it can be shown that the structure in no way impairs or interferes with the free and safe flow of traffic on the highway. Encroachments are allowed to occur when a "Use and Occupancy Permit" has been granted, however, FHWA must also approve an encroachment that remains on a project requiring FHWA's design approval. The designer, in consultation with the other program area groups, may recommend to the Regional Director that the encroachment remain. If approval is granted, the Real Estate Group is responsible for managing the encroachment.

5.5.8 Excess Right of Way

Excess right of way is defined as existing transportation property beyond that which is sufficient to ensure safe, efficient operation of the highway as it exists and as it will exist in the foreseeable future. Changes in the highway alignment often result in an excess of right of way, or an existing excess is noticed in the design process. Excess right of way is established on a project specific basis. When determining excess right of way, the designer must consider the following:

- Probability of the need for future improvement (check the present volume/capacity ratio, level of service, accident rate, etc.).
- Horizontal sight distance.
- Adequate clear zone widths.
- Surface and subsurface drainage.
- Snow storage.
- Pedestrian facilities.
- Bicycle facilities.
- Bus turnouts.
- Traffic control devices.
- Utilities.
- Access control.
- Effects on property owners.
- Wetland mitigation.
- Preservation of views and aesthetics.

The Real Estate Group has responsibility for the disposal of excess right of way. See M.A.P. 7.8-5-1 Disposal of Surplus Real Estate and A02-5-29 Excess Property Identification for details of the procedure.

5.5.9 ROW Markers

Right of Way (ROW) Markers along a highway delineate the right of way:

- To assist adjacent land owners in the identification of the limits of the highway boundary adjacent to their property.
- To assist maintenance crews in determining the limits of the highway which they are maintaining.
- To monument the limits of the right of way, which provides secondary control for future reestablishment of the highway boundary.

5.5.9.1 Where and When to use ROW Markers

ROW Markers are intended to delineate the boundary between the highway and private property, and mark any changes in the direction of that boundary line. All new right of way limits should be monumented as part of their associated construction projects. ROW Markers should be installed at all angle points along the proposed or new right of way boundary.

ROW Markers are not intended to monument the property lines between private properties. Therefore, no markers should be placed at property lines, except in unavoidable situations where an acquisition has to end at a property line. Recommendations on where and when to place ROW Markers should be reviewed by the Regional Land Surveyor.

5.5.9.2 Which ROW Markers to Use

The Department uses concrete and steel pin and cap ROW markers. Refer to the Department's 625 series standard sheets for the ROW marker details. The following factors need to be considered when choosing between the various types of ROW markers. Proposed ROW Marker locations and types should be reviewed by the Regional Land Surveyor.

- Safety - Consider whether pedestrians, bicyclists, land owners, or vehicular traffic could be exposed to a hazard by placing a high or low concrete marker adjacent to, or within a sidewalk, public path, lawn area, or driveway.
- Aesthetics - Consideration should be given to the visual impact of ROW markers on a project area. For example, the placement of a line of high concrete markers (fence post look) may be visually intrusive to the project area. In situations where markers will be visually evident and could potentially create a less than desirable effect on the area's aesthetics, use of low or steel pin markers should be considered. Any use of concrete markers on or adjacent to historically significant or contributing properties, should be coordinated with the regional contact for historic and cultural resources.
- Land Use - Consider the present or anticipated land use for the adjacent properties. It is not desirable to install concrete markers in existing or proposed parking lots, driveways or sidewalks, maintained lawn areas, or on parklands. In contrast, it is advisable to consider the use of either high or low concrete markers near cultivated fields (since they need to be seen to be avoided), and use high concrete markers in unimproved areas which are heavily underbrushed, swampy, or include standing water, to simplify their rediscovery in the future. Low concrete or steel pin markers are appropriate along interstates which also have fencing to delineate the right of way limits. Low concrete or steel pin markers should be used on or near commercial properties, depending on proximity to walks or driveways, and the resulting landscaped appearance after installation.

- Ground Conditions - Consider the types of ground materials or the underground utilities where markers are to be set. Rock outcroppings may necessitate the use of steel pin markers (by drilling and grouting), and high water table or unstable soils may warrant concrete markers to ensure their stability. While underground utilities warrant care on the contractor's part during installation, the designer may need to include a special note to establish the depth that a marker is to be set over utilities or pipes.

5.6 ECONOMIC ANALYSIS

The objective of economic analysis is to help select the most efficient transportation project or plan that minimizes the use of valuable resources (money, land, time, materials, manpower, etc.). A variety of methods exist for selecting the most cost-beneficial projects or for selecting a superior alternative from among a group of proposals. The following are brief descriptions of four common methods used by the Department, with simple examples of each. Exhibit 5-5 offers a reference to determine which method is usually used for various project types, and the functional unit generally responsible for the analysis.

Exhibit 5-5 Economic Analysis Problem Types, Analysis Methods, Guidance in Force, and Contact for More Information

Analysis Type	Method	Guidance	Contact
Bridge Rehabilitation vs. Replacement	Life Cycle Cost	Bridge Manual Section 19	Structures Division
Bridge Abandonment vs. Preservation Decisions	User Benefits Agency costs	Economic Analysis Worksheet for Bridges	Mobility Management Bureau
Pavement Rehabilitation Alternatives	Life Cycle Cost	Comprehensive Pavement Manual Chapter 3	Materials Bureau
Accident Reduction Treatments	User Benefits Agency Costs	Highway Safety Improvement Program Procedures and Techniques Manual	Traffic Engineering and Highway Safety Division
Mobility Betterment	Incremental B/C Ratios	Highway User Cost Accounting Package	Mobility Management Bureau
Social, Economic & Environmental Impacts	B/C Ratios	Environmental Procedures Manual	Environmental Analysis Bureau

Methods

1. Present Worth Method - When two or more alternatives are capable of performing the same functions, the superior alternative will have the largest present worth when determining the present worth of benefits, and the smallest present worth when determining the present worth of costs. All alternatives must have the same lives and be mutually exclusive. The present worth for a single future benefit is calculated from the equation:

$$P_s = F(1 + i)^{-n}$$

The present worth for uniform annual benefits is calculated from the equation:

$$P_u = A \frac{(1 + i)^n - 1}{i(1 + i)^n}$$

Where: P = Present Worth
 F = Future Benefit
 A = Benefits per period (usually annual)
 i = Interest rate per period (usually annual)
 n = Number of compounding periods

The present worth of the net benefit of each alternative should be calculated by subtracting present alternative costs from present worth benefits.

Example: Given two projects, A and B, $i = 5\%$. A costs \$10,000 today and has a single future benefit of \$11,500 two years in the future. B costs \$8,000 today and has benefits of \$4,500 in each of the next two years.

$$\text{Present worth of the net benefit (Alt. A)} = -\$10,000 + \$11,500 (1 + .05)^{-2} = \$431$$

$$\text{Present worth of the net benefit (Alt. B)} = -\$8,000 + \$4,500 \times \frac{(1 + .05)^2 - 1}{0.05 (1 + .05)^2} = \$367$$

Alternative A is superior, since the present worth of the net benefit for Alt. A is higher than the present worth of the net benefits of Alt. B.

2. Equivalent Uniform Annual Cost (EUAC) (also called Annual Return Method and Capital Recovery Method). The EUAC method assumes that each alternative will be replaced by an identical twin at the end of its useful life. The alternatives must be mutually exclusive and infinitely renewed up to the duration of the longest-lived alternative. The annual cost is given by the equation:

$$A = P \frac{i(1 + i)^n}{(1 + i)^n - 1}$$

Where: A = Annual Cost
 P = Present Cost
 i = Annual interest rate
 n = Number of years

Example: Given two highway improvement projects and the following information, determine which is superior over a 30-year period at an annual rate of 4%.

	<u>A</u>	<u>B</u>
Type	<u>Rehabilitation</u>	<u>Pavement Resurfacing</u>
Life	30 years	10 years
Cost	\$1,800,000	\$450,000
Maintenance	\$5,000/year	\$20,000/year

$$EUAC(A) = \$1,800,000 \times \frac{0.04(1+0.04)^{30}}{(1+0.04)^{30} - 1} + \$5000 = \$109,040$$

$$EUAC(B) = \$450,000 \times \frac{0.04(1+0.04)^{10}}{(1+0.04)^{10} - 1} + \$20,000 = \$75,485$$

Alternative B is superior, since its annual cost of operation is the lowest. It is assumed that three pavement resurfacing projects each with a life span of 10 years and cost of \$450,000 will be built to span the 30-year period.

3. Capitalized Cost Method - There are times when a series of equivalent uniform annual costs (EUAC) will start at some future date and must be combined with lump sum payments in other years. This is accomplished by converting the EUAC to a capitalization amount in the year the annual payments start. The capitalization amount is the amount of money that when invested today at the effective interest rate would give an annual return equal to the annual payments. It can be determined by the following equation:

$$CA = \frac{EUAC}{i}$$

Where: CA = Capitalization amount in year annual payments start
 EUAC = Equivalent Uniform Annual Cost
 i = Effective interest rate

The Capitalization amount in some future year can be converted to a Present Cost in a similar manner as the present worth is calculated above.

Example: A decision must be made whether to spend \$500,000 on a bridge rehabilitation project now or to do nothing and replace the bridge in the future at a cost of \$1M. Without the rehabilitation, the bridge would last ten years before replacement. The rehabilitation would add 15 years to the life of the bridge and, thus, the bridge would require replacement in 25 years. The effective interest rate is 4 percent and a new bridge life is 50 years. For perpetual bridge replacement:

$$EUAC = \$1,000,000 \times \frac{0.04(1+0.04)^{50}}{(1+0.04)^{50} - 1} = \$46,500$$

$$CA = \frac{\$46,500}{0.04} = \$1,164,000$$

Bridge Rehabilitation

1.	Present Cost of Rehabilitation	\$500,000
2.	Present Cost of Capitalization Amount occurring in 25 years: $P = \$1,164,000 (1+.04)^{-25}$	<u>\$437,000</u>
3.	Total Present Cost of this Alternative	\$937,000

Delay Rehab and Replace in Ten Years

	Present Cost of Capitalization Amount in 10 years $P = \$1,164,000 (1+.04)^{-10}$	\$786,000
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The analysis shows that delaying the rehabilitation and replacing the bridge in ten years will have the lowest life-cycle cost.

4. Benefit-Cost Ratio Method - To determine the B/C Ratio, the present worth of all benefits is divided by the total present worth of all costs. The project is usually considered acceptable if the B/C Ratio exceeds 1.

When the Benefit/Cost Ratio is used, disbursements by the initiators, or sponsors, are costs. Disbursements by the users of the project are known as disbenefits. It is often difficult to determine whether a cash flow is a cost or a disbenefit. The numerical result can be considerably different, since if it is disbenefit, it is subtracted from the numerator, and if it is a cost, it is added to the denominator.

Example: Given a public works project with:

Estimated benefits	=	\$ 1,600,000
Present costs	=	\$ 650,000
Additional cash flow item(s)	=	\$ 200,000

$$\text{Assume additional item(s) is a cost: } B/C = \frac{\$ 1,600,000}{\$650,000 + \$200,000} = 1.88$$

$$\text{Assume additional item(s) is a disbenefit: } B/C = \frac{\$1,600,000 - \$200,000}{\$ 650,000} = 2.15$$

For this reason, the B/C method should not be used to rank competing alternatives unless an incremental analysis is used. The optimum alternative may not necessarily be the one with the greater B/C. In order to do an incremental analysis, first determine that the B/C is greater than one for each alternative. Then, for each possible pair of alternatives, calculate the ratio:

$$\frac{B_2 - B_1}{C_2 - C_1}$$

If the ratio exceeds 1, alternative 2 is superior to alternative 1. Otherwise, alternative 1 is superior.

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Example: Given two highway improvements with the following information:

<u>Condition</u>	Annual Road <u>User Costs</u>	Annual Highway <u>Costs</u>	
Existing Roads	\$ 5,730	\$ 46	
Plan 1	4,760	234	
Plan 2	4,697	264	
	Annual Incremental	Annual Incremental	
<u>Comparison</u>	<u>Benefits</u>	<u>Costs</u>	<u>B/C</u>
Plan 1 vs. Existing	\$ 970	\$ 188	5.2
Plan 2 vs. Existing	1,033	218	4.7
Plan 2 vs. Plan 1	63	30	2.1

Both Plans are superior to the existing situation. However, when compared to each other, Plan 2 is superior to Plan 1.

5.7 DESIGN ELEMENTS

5.7.1 Design Vehicle

The Design Vehicle is the largest vehicle that frequently uses a facility. Projects with several types of facilities may have different design vehicles for each part. The physical and operating characteristics of the design vehicle are controlling parameters in highway design. Designs should accommodate the size and maneuverability of the design vehicle to allow it to operate without encroachment into adjacent travel or parking lanes. Such designs help reduce collisions and operational delays from lane encroachments.

5.7.1.1 Minimum Design Vehicle for Various Routes

The geometric characteristics of the various design vehicles are found in Chapter II of AASHTO's, *A Policy on Geometric Design of Highways and Streets*, 2004. Below are the minimum required design vehicles for various highway categories:

- For interstate highways, Designated Qualifying and Access Highways on the Designated Truck Access Highway Network, and their interchanges, the minimum design vehicle is the WB-20.
- For parkways, the design vehicle is the largest vehicle that will be regularly used on the highway, typically either an SU vehicle representing a maintenance vehicle or large school bus (S-BUS-12). (Note that Parkways are highways where commercial traffic is prohibited.)
- For most other noninterstate highways, the minimum design vehicle is the single unit truck (SU), which will also accommodate a large school bus (S-BUS-12). Some projects may require the larger city transit bus (CITY-BUS), articulated bus (A-BUS), WB-15, WB-19, WB-20, or larger design vehicle.

5.7.1.2 Encroachments

Vehicle encroachments occur when any portion of a vehicle extends beyond the vehicle's lane. With the exception of some low speed local streets and roads, designs that cause frequent encroachments are undesirable as they may increase the likelihood of delays and collisions. However, designs that eliminate encroachments may also reduce safety since large turning radii allow faster turning speeds and wide turning paths create longer walking distances for pedestrians and may increase confusion for motorists confronted with large paved areas. In order to provide a balanced design, encroachments are generally acceptable for:

- Shoulders at intersections (Refer to Chapter 3, Section 3.2.5.2 for a discussion of additional shoulder pavement thickness at intersections).
- Intersections along low-speed urban streets.

- Intersections along low-volume rural roads.
- Single left turns that require two receiving travel lanes.
- Double left and right turns that cannot accommodate side by side operation of the design vehicles. (Designs should accommodate a passenger car along side the design vehicle.)

5.7.1.3 Oversized Vehicles

The selected design vehicle is often not the largest vehicle that may use the facility. Oversized vehicles require additional paved areas that are often not practical to construct due to the infrequency of these vehicles. We recognize that these oversized vehicles will occasionally be present and may encroach into other lanes and/or traverse shoulders and curbs. Designers should check proposed designs using the largest oversized vehicle anticipated to use the facility. This helps determine what changes would be needed to accommodate the oversized vehicle and helps decision makers determine whether or not such changes are practical.

Designers should contact their Regional Transportation Systems Operations Group to help determine an appropriate oversized vehicle. For many areas, the oversized vehicle is a modular home unit on a WB 20 trailer. The dimensions of the trailer load may be assumed to be a maximum of 4.9 m high including the trailer, 4.9 m wide, and 17 m to 24.5 m long. The wheel path for this vehicle can be easily checked using a WB 20 design vehicle. The vehicle overhangs should be checked to evaluate the location of trees, signals, poles, signs, shrubs, street appurtenances, etc.

When oversized vehicles encroach beyond the traveled way, the designer may need to consider:

- Traversable curb.
- Full depth shoulders.
- Wide shoulders.
- Stabilized areas behind curbing.
- Relocation of signals, poles, signs, trees, shrubs, street appurtenances, etc.
- Removable signs and street appurtenances.

As an alternative to a site specific evaluation of oversized vehicles, the Region may coordinate with the Office of Safety and Security Services to develop alternative routing that bypasses a particular site.

5.7.2 Sight Distance

Sight distance is the length of road ahead visible to the driver. This distance should be long enough for the driver to see a situation and successfully react to it. There are a number of different types of sight distances important in highway design. Refer to Section 5.9.5.1 of this chapter for a discussion of intersection sight distance.

5.7.2.1 Stopping Sight Distance

Stopping sight distance is the distance necessary for a vehicle traveling at or near the design speed to stop before reaching a stationary object in its path. There are three types of stopping sight distance. These are: stopping sight distance for a crest vertical curve, stopping sight distance for a sag vertical curve (also called "headlight sight distance") and stopping sight distance for horizontal curves. Each of these types is equally important and only when all three conditions have been satisfied, can stopping sight distance requirements be considered satisfied. Stopping sight distance is one of the critical design elements and is discussed in Chapter 2 and the "Standards for Non-Freeway Resurfacing, Restoration and Rehabilitation (3R) Projects". The NYSDOT "Vertical Highway Alignment Sight Distance Charts" in Appendix B of this chapter provide values for stopping sight distance and length of vertical curve for various algebraic differences in grade.

5.7.2.2 Passing Sight Distance

Passing sight distance is only a concern on two-lane, two-way roadways. On these highways, provision for passing is an important factor in maintaining the capacity of the highway. For a vehicle to pass a slower vehicle it has overtaken, it must occupy the lane regularly used by opposing traffic. To do so, the driver must be able to see far enough ahead to determine that the road is clear of opposing traffic and there is sufficient distance to complete the passing maneuver. Values for passing sight distance are found in Chapter 3 of AASHTO's *A Policy on Geometric Design of Highways and Streets*, 2004. The NYSDOT "Vertical Highway Alignment Sight Distance Charts" in Appendix B of this chapter presents values for passing sight distance as a function of length of crest vertical curve and algebraic difference in grade.

5.7.2.3 Decision Sight Distance

Decision sight distance is the distance required for a driver to recognize a complex situation and safely react to it. Values for decision sight distance are substantially longer than for stopping sight distance. The increased sight distance is beneficial whenever the motorist encounters a condition which may increase the likelihood for error in information reception, decision-making, or control actions. The increased distance provides a greater margin for safety and is desirable where these kinds of errors are more likely, such as at interchanges and intersections, approaches to lane drops, and other locations where competing sources of information greatly complicate the tasks of driving. Further discussion and values for decision sight distance are found in Chapter 3 of AASHTO's *A Policy on Geometric Design of Highways and Streets*, 2004.

5.7.2.4 Horizontal Sight Distance

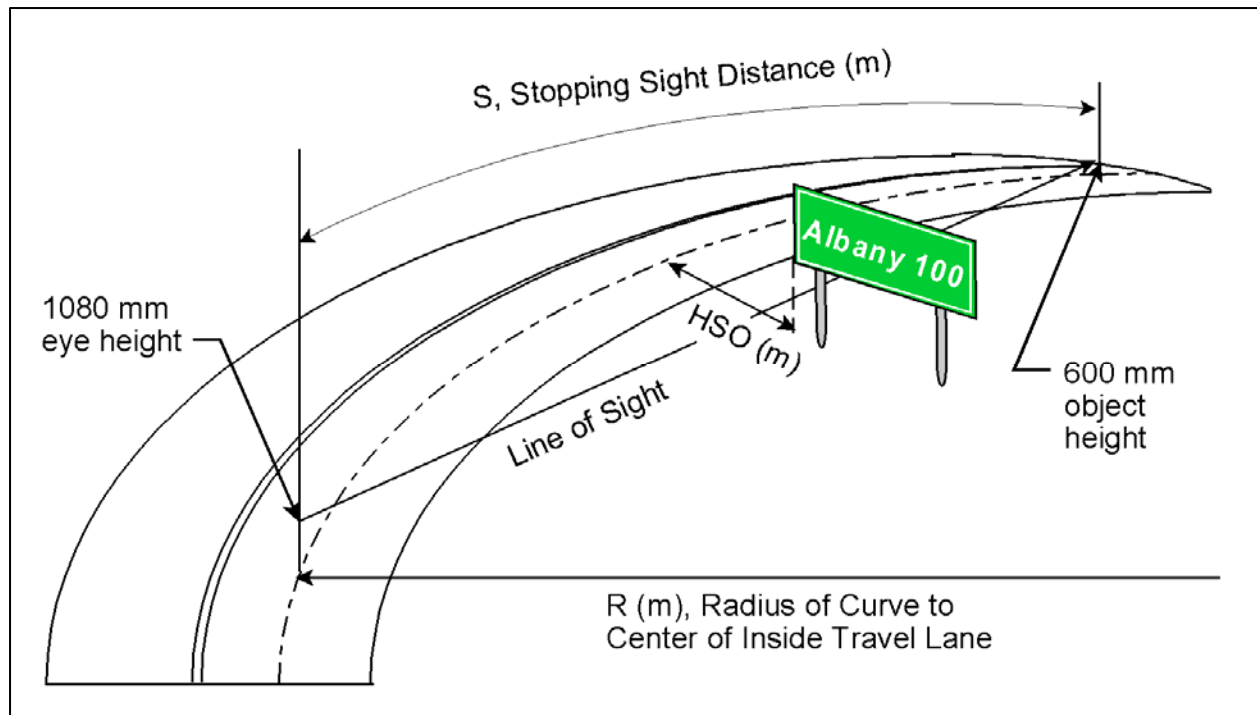
Concrete barriers and other similar items have grown in popularity in recent years. The effect of these barriers must be considered along with other visual obstructions when determining sight distance. A concrete barrier placed on the inside of a horizontal curve will restrict the sight distance around that curve. This is a common problem on curvilinear urban freeways with concrete median barrier. Refer to Chapter 10, Section 10.2.2.5 of this manual for median barrier options.

The following equation, a graphical method using CADD, or field measurements should be used to ensure sufficient stopping sight distance is provided along horizontal curves with obstructions, such as signs, concrete barrier, retaining walls, bridge abutments, etc., (see Exhibit 5-6). The equation is valid for curves with radii to the center of the inside lane that is equal or greater than the stopping sight distance. The eye height is 1080 mm and the object height is 600 mm.

$$HSO = R (1 - \cos (28.65 S/R))$$

- Where: HSO = Horizontal Sightline Offset (m)
 R = Curve Radius to Center of Inside Travel Lane (m)
 S = Stopping Sight Distance (m) Measured Along the Travel Lane.

Exhibit 5-6 Horizontal Sight Distance



5.7.3 Horizontal Curves

The horizontal alignment of a highway consists of a number of straight (tangent) sections connected by horizontal curves. These curves are sections of a circle or spiral. Curves should be designed to minimize vehicles skidding off the traveled way (excessive vehicle yaw) or overturning (excessive vehicle roll). Refer to Chapter 2 of this manual for curve radii, design speeds, and superelevation rates for various facilities.

5.7.3.1 Horizontal Curve Design to Minimize Vehicle Skidding Crashes

The point at which a vehicle begins to skid is based on a complex interaction of many variables, including:

- Traveled way superelevation, radius, grade, and coefficient of friction adjusted for weather, wear, and surface roughness.
- Vehicle mass, center of gravity, suspension, number of tires, velocity, antilock braking system, stability control system, steering angle, and acceleration/deceleration (i.e., accelerating or braking).
- Tire size, compound, tread design, wear, temperature, inflation, and contact patch.
- Motorist.

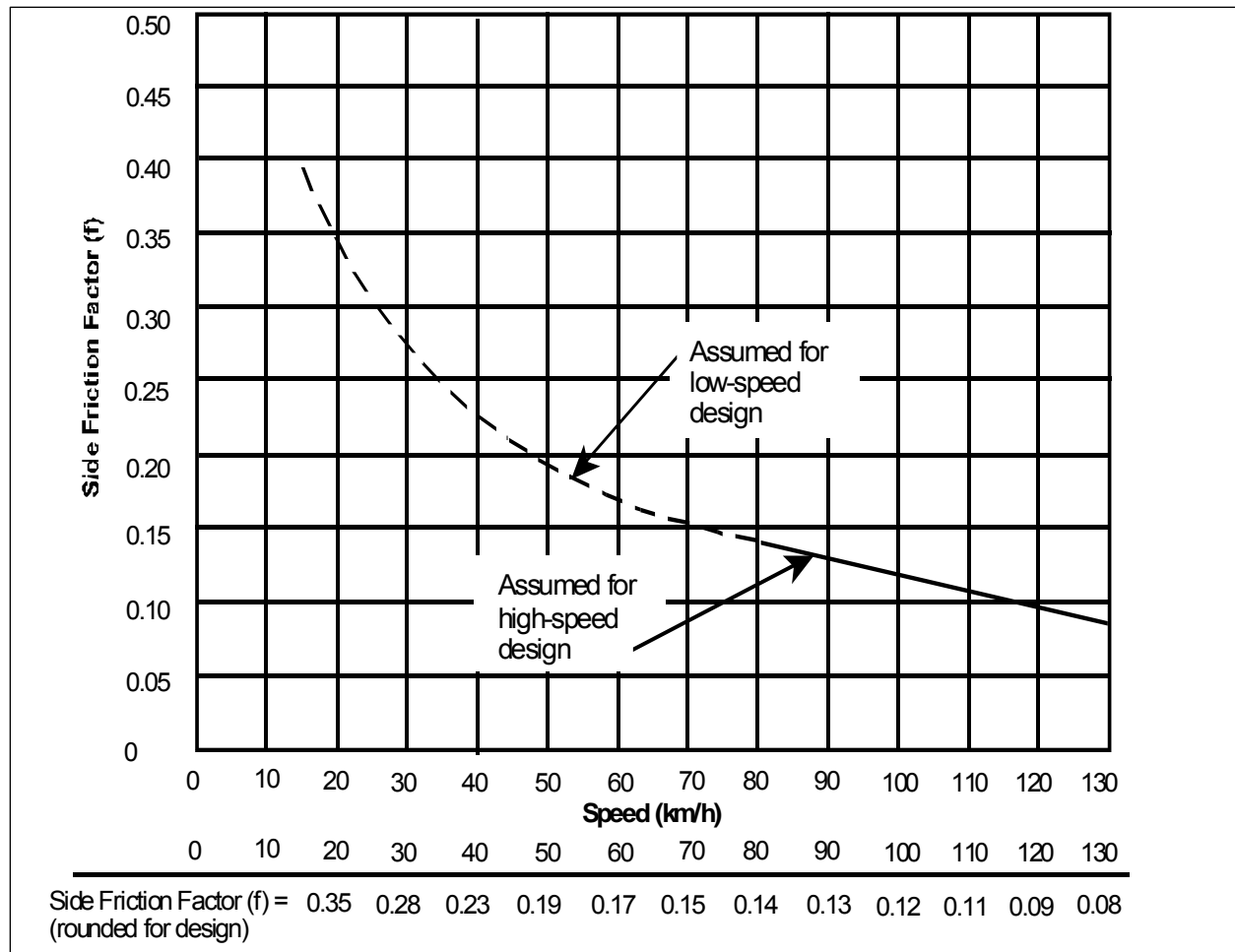
The following basic horizontal curve equation accounts for most of these variables (Ref. Equation 3-10 from AASHTO's *A Policy on Geometric Design of Highways and Streets*, 2004).

$$R = \frac{V^2}{127(0.01e + f)}$$

The basic horizontal curve equation can be used to calculate:

- Radius, speed, or superelevation for all low-speed urban streets.
- The minimum radius for the selected design speed and maximum superelevation rate for rural highways and high-speed urban streets. Do **NOT** use the basic horizontal curve equation to determine the superelevation for intermediate curves (i.e., having radii greater than the minimum) on turning roadways, rural highways, and high-speed urban streets. Refer to Chapter 2 of this manual for the applicable superelevation table for these facilities.
- The recommended speed based on the radius and superelevation rate for all curves, as discussed in Section 5.2.4.1 B of this chapter. The recommended speed is shown in Exhibits 5-8 and 5-9.

Exhibit 5-7 Side Friction Factor



Where:

- R = Radius (m). The horizontal curve radius to help prevent a vehicle from sliding out of its travel lane is based on a combination of the vehicle speed, side friction factor, and superelevation. Measured to the centerline for highways and the inside edge of the travel lane for turning roadways.
- V = Speed (km/h). The approach design speed is used to determine the curve design speed.
- f = Side Friction Factor from Exhibit 5-7. The side friction factor is the ratio of the lateral forces to the normal forces acting on a vehicle traveling around a curve. The friction factor is used to account for the complex interaction of the vehicle (mass, center of gravity, suspension, number of tires, and velocity) and the traveled way (coefficient of friction adjusted for weather, wear, and surface roughness). Exhibit 5-7 shows the side friction factor for speeds of 15 km/h through 130 km/h and was used to create Exhibits 3-12 of AASHTO's *A Policy on Geometric Design of Highways and Streets*, 2004.

e = Superelevation in percent. The superelevation is the banking of the traveled way cross slope to counter the centrifugal forces of a vehicle traveling around a curve. The basic horizontal curve equation minimizes the use of superelevation, which minimizes the margin of safety since the cornering vehicle must use large amounts of side friction to avoid sliding off the curve. Refer to the superelevation distribution method 2 discussion in Chapter 3 of AASHTO's *A Policy on Geometric Design of Highways and Streets*, 2004.

Note: The superelevation for intermediate curves on rural highways and high-speed urban streets is based on superelevation distribution method 5, as discussion in Chapter 3 of AASHTO's *A Policy on Geometric Design of Highways and Streets*, 2004. Superelevation distribution method 5 uses a number of complex equations to place added superelevation on intermediate curves. As the radius decreases, the added superelevation allows the side friction demand to increase gradually, which increases the margin of safety over superelevation distribution method 2. AASHTO's intent is to provide additional superelevation on curves with large radii to avoid violating driver expectancy. Motorists negotiating large radius curves are more likely to overdrive the curve and less likely to anticipate large cornering forces. The additional superelevation also allows the remaining available side friction to be used for changing roadway conditions, evasive maneuvers, braking, accelerating, etc.

The minimum radii and maximum percent of superelevation are found in Chapter 2 of this manual for new construction, reconstruction, and bridge projects with over 400 ADT. For 1R projects and 2R/3R projects, refer to Chapter 7 of this manual for allowable values. For bridge projects with 400 ADT or less, refer to Chapter 4 of this manual. The maximum and minimum values should not be confused with desirable values. In new construction or reconstruction of high speed facilities, the largest radius possible is usually the most desirable solution.

When evaluating nonstandard horizontal curves, note that the side friction factor can be reduced by longitudinal forces from braking, accelerating, and the increased tractive forces needed to maintain speed on steep inclines. Where these actions are likely additional superelevation and other measures should be considered.

Exhibit 5-8 Recommended Speed on Horizontal Curves to Avoid Skidding (Low Speed)

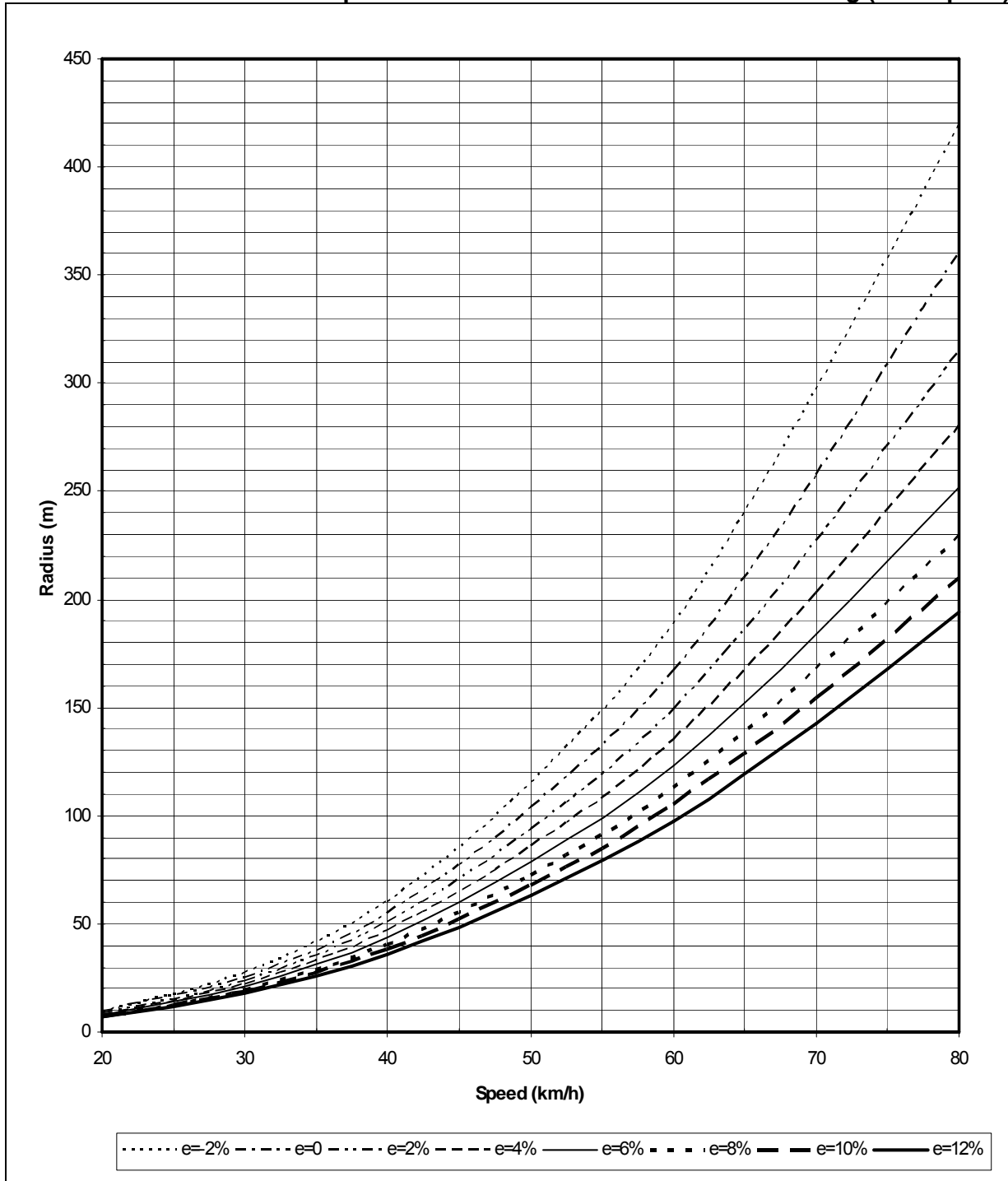
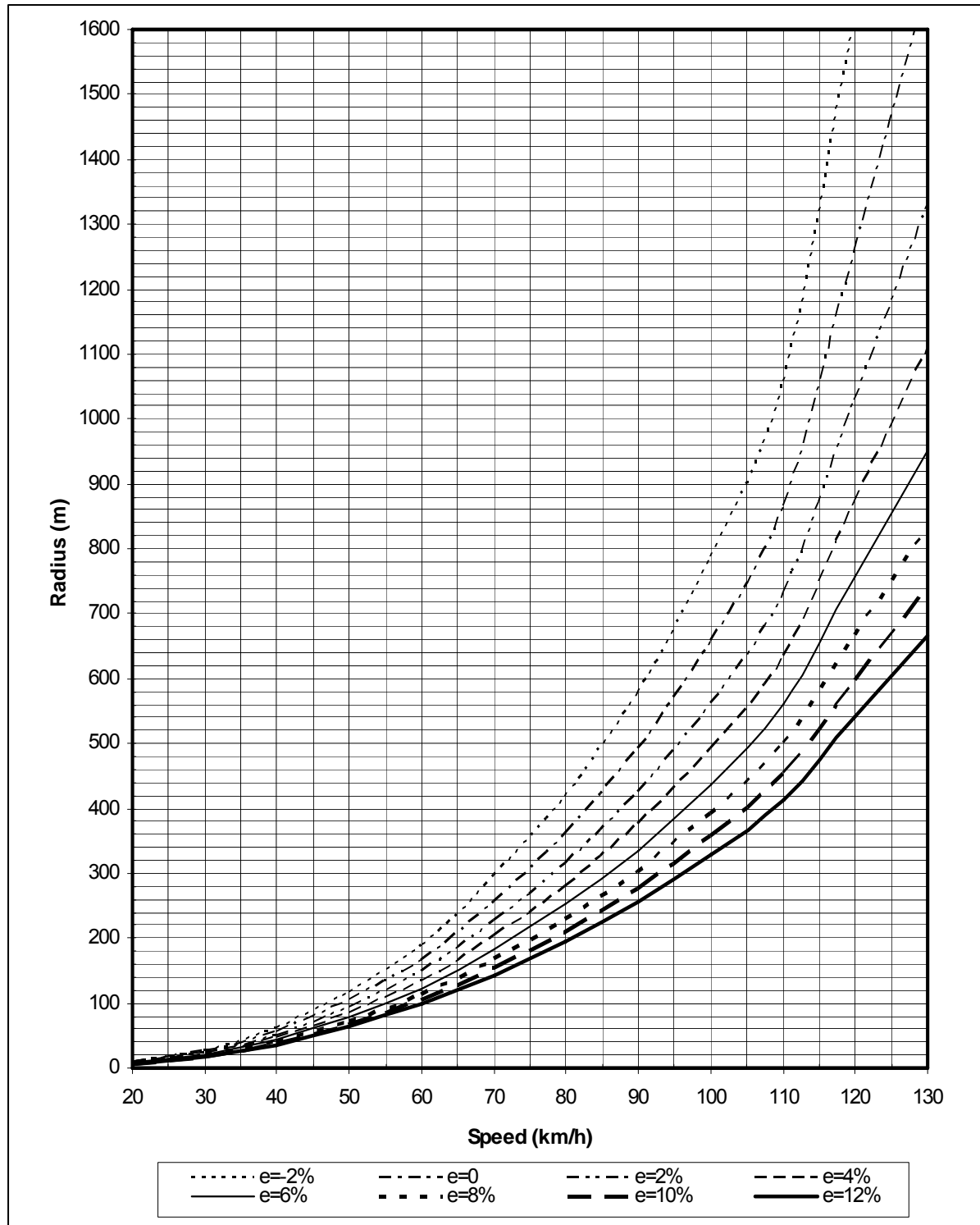


Exhibit 5-9 Recommended Speed on Horizontal Curves to Avoid Skidding



5.7.3.2 Horizontal Curve Design to Avoid Vehicle Rollover Crashes

The typical passenger car will skid long before it rolls over on the pavement, particularly in wet weather. Trucks, vans, and sport utility vehicles have much higher centers of gravity and may rollover before skidding, particularly in dry weather and at lower speeds. Vehicle rollover is generally not a limiting factor that influences horizontal curves meeting current standards. Vehicle rollover should be considered for nonstandard curves, particularly when they are likely to violate driver expectancy (such as a nonconforming compound curve), which is discussed in Section 5.8.3 of this chapter.

The point at which a vehicle begins to rollover is based on a complex interaction of many variables, including those listed in Section 5.7.3.1 of this chapter. Based on *The Effectiveness of Truck Rollover Warning Systems*, August, 2000, the horizontal curve equation to determine the point of impending rollover is:

$$R = \frac{V^2}{127 (0.01e + a/g)}$$

Where:

- R = Radius (m). The horizontal curve radius to help prevent a vehicle from rolling over is based on a combination of the vehicle speed, superelevation, and the maximum allowable lateral acceleration for given vehicle. For multilane facilities, the radius is measured to the inside edge of the inner most travel lane. For two lane facilities, the radius can be measured to the centerline or inside edge of the inner most travel lane.
- V = Speed (km/h). The approach design speed is used to determine the curve design speed.
- e = Superelevation or banking of the traveled way cross slope.
- a = The maximum allowable lateral acceleration for given vehicle, determined from:

$a = \frac{(RT - SM)g}{1.15}$	<p>Where:</p> <ul style="list-style-type: none"> RT = Rollover Threshold based on vehicle characteristics (g). SM = Safety Margin (usually 0.1g). g = Acceleration due to gravity (9.81 m/s²). a = Maximum allowable lateral acceleration for given vehicle (m/s²).
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Exhibits 5-10 and 5-11 present the horizontal curve rollover speeds for large trucks with weights of 36 to 45 metric tons. The approximate Rollover Threshold (RT) for some selected vehicles are:

<u>Vehicle</u>	<u>Rollover Threshold</u>
Passenger cars	1.0g to 1.4g
SUV, vans, light trucks	0.8g to 1.2g
Large trucks with weights of 36 to 45 metric tons	0.36g
High center-of-gravity tankers	0.22g

Note: Based on *Rollover of Heavy Commercial Vehicles*, University of Michigan Transportation Research Review, October - December, 2000, significant changes in lateral acceleration (from a nonconforming compound curve or nonstandard curve radius) can induce significant dynamic effects for unrestrained loads (e.g., a partially full liquid tanker). Rapid steering input induces a change in the lateral acceleration that may cause the load to displace further than it would for a more-gentle curve. This overdampening or overshooting of the load causes a dynamic effect that can reduce the rollover thresholds to as low as 0.22g for vehicles with rectangular-shaped tanks or cargo areas. The horizontal curve rollover speeds for these vehicles without any adjustments or margin of safety is nearly equivalent to the speeds shown in Exhibits 5-10 and 5-11 for the 36 to 45 metric ton truck.

Solutions to an existing truck rollover problem may include:

- Provide additional signing with flashing lights.
- Install a truck rollover warning system (flashing lights are activated by truck approach speeds).
- Increase the superelevation up to a maximum of 8.0%.
- Increase the lane width. A wider lane width allows maneuvering area for large vehicles to steer to the outside of the curve for a brief moment to induce a righting force and to reduce speed.
- Reconstruct the horizontal alignment to current standards.

Exhibit 5-10 Recommended Speed on Horizontal Curves to Avoid Truck Rollovers (Low Speed)

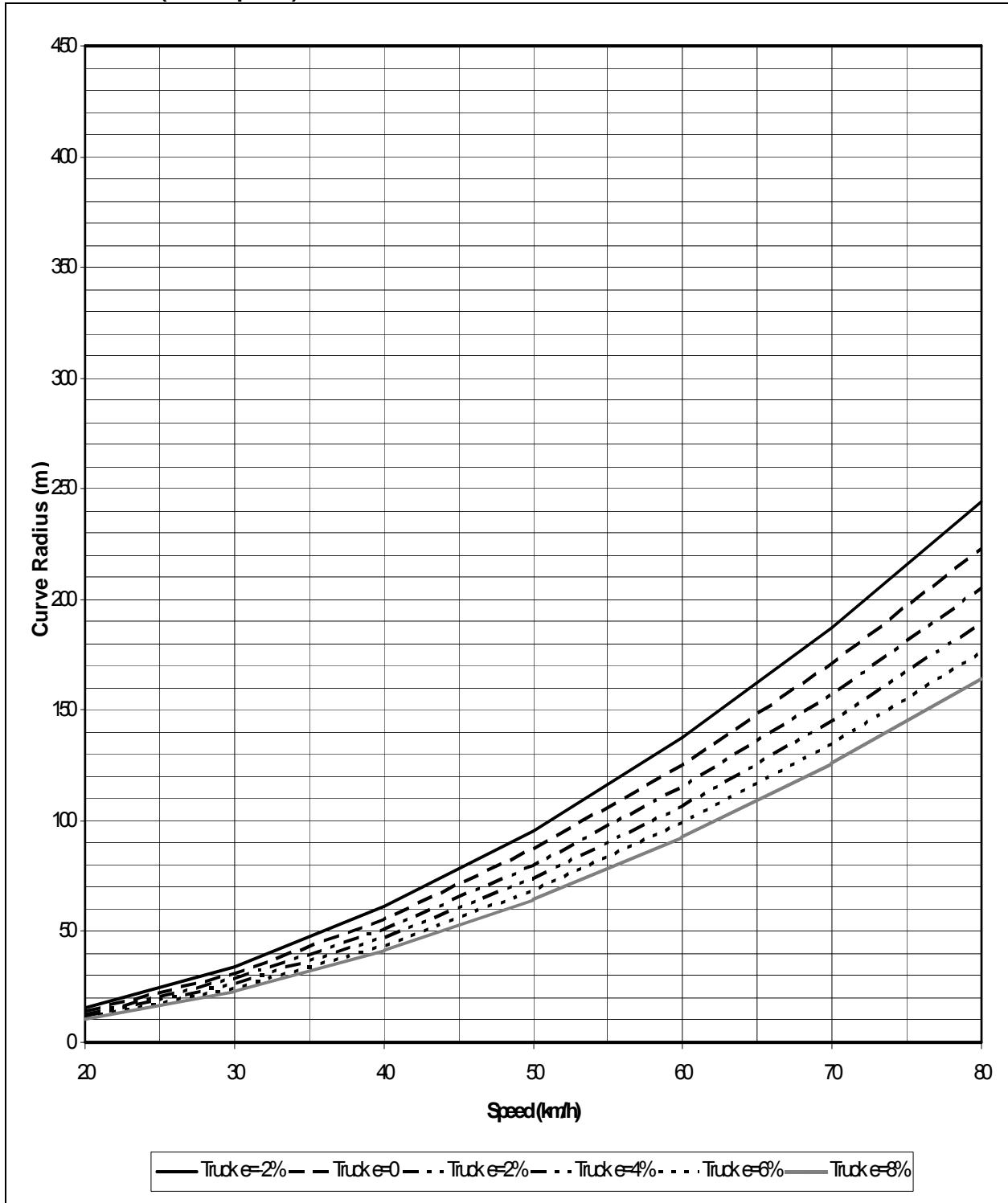
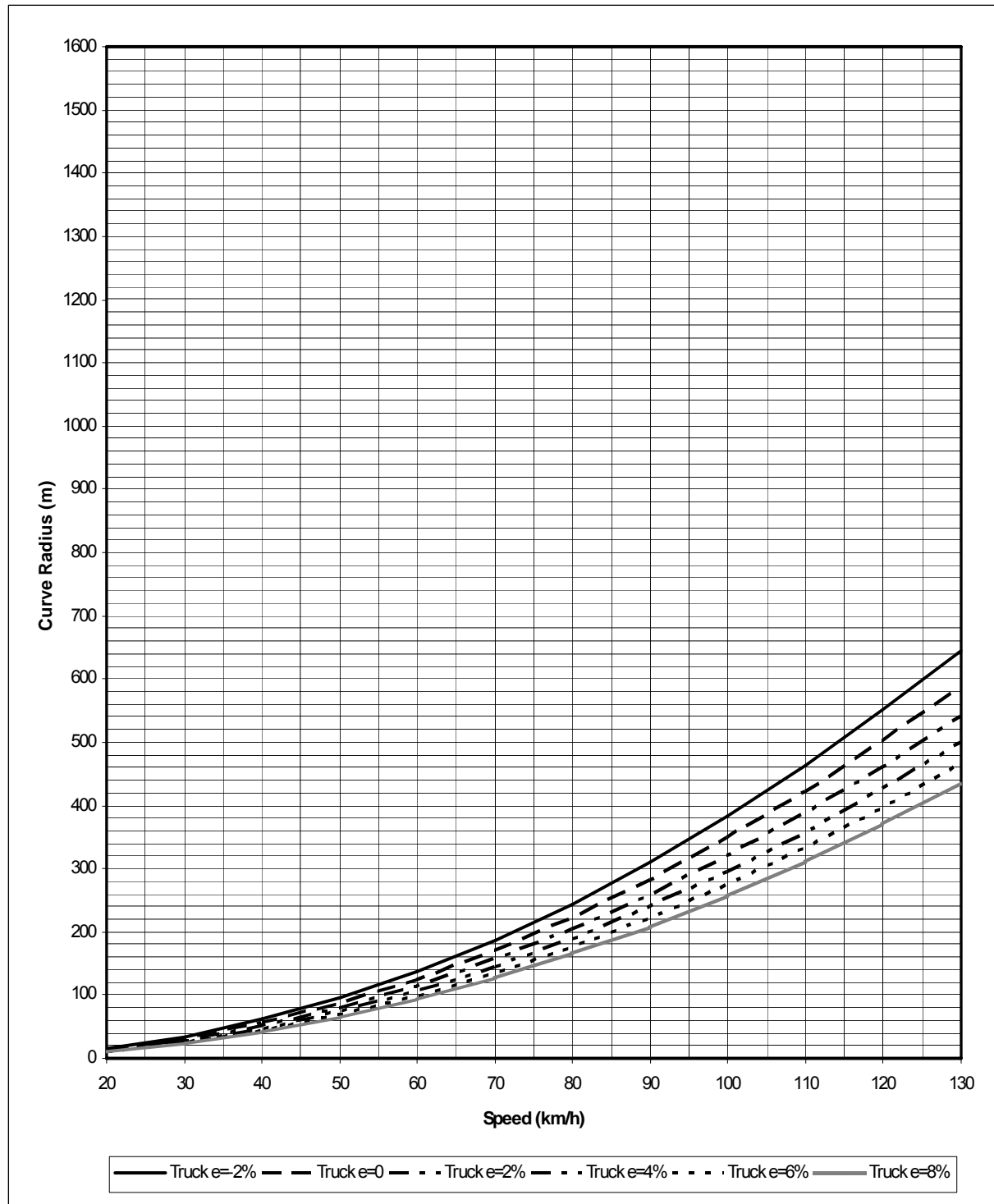


Exhibit 5-11 Recommended Speed on Horizontal Curves to Avoid Truck Rollovers



5.7.3.3 Superelevation Transitions

The purpose of transitions at the ends of horizontal curves is to change the cross slope from normal crown to full superelevation and back. The length of these transitions should be chosen to provide a smooth-riding and pleasant-appearing transition. Superelevation transitions can be achieved over a tangent-spiral or tangent-circular curve combination. In both cases, the length of the transition is found in Exhibit 5-15 in this section. Exhibits 5-13 and 5-14 indicate the methods of attaining superelevation.

Refer to Chapter 3, Section 3.2.5.1 of this manual for the shoulder cross slope along superelevated sections.

A. Runoff

In a transition, the runoff is the distance used to change the section from the point where adverse crown is removed (the high side is level) to the point where full superelevation is achieved. The runoff (L_r) is determined from the lane width (w) in meters, number of lanes (n_l), percent superelevation (e_d), an adjustment factor for the number of lanes to be rotated (b_w), and the maximum relative gradient (Δ) from Exhibit 5-12, in percent.

Superelevation Runoff Equation:
$$L_r = \frac{w e_d (n_l b_w)}{\Delta}$$

Exhibit 5-12 Maximum Relative Gradient

Design Speed (km/h)	Maximum Relative Gradient (%)
20	0.80
30	0.75
40	0.70
50	0.65
60	0.60
70	0.55
80	0.50
90	0.47
100	0.44
110	0.41
120	0.38
130	0.35

Exhibit 5-13 Method of Attaining Superelevation

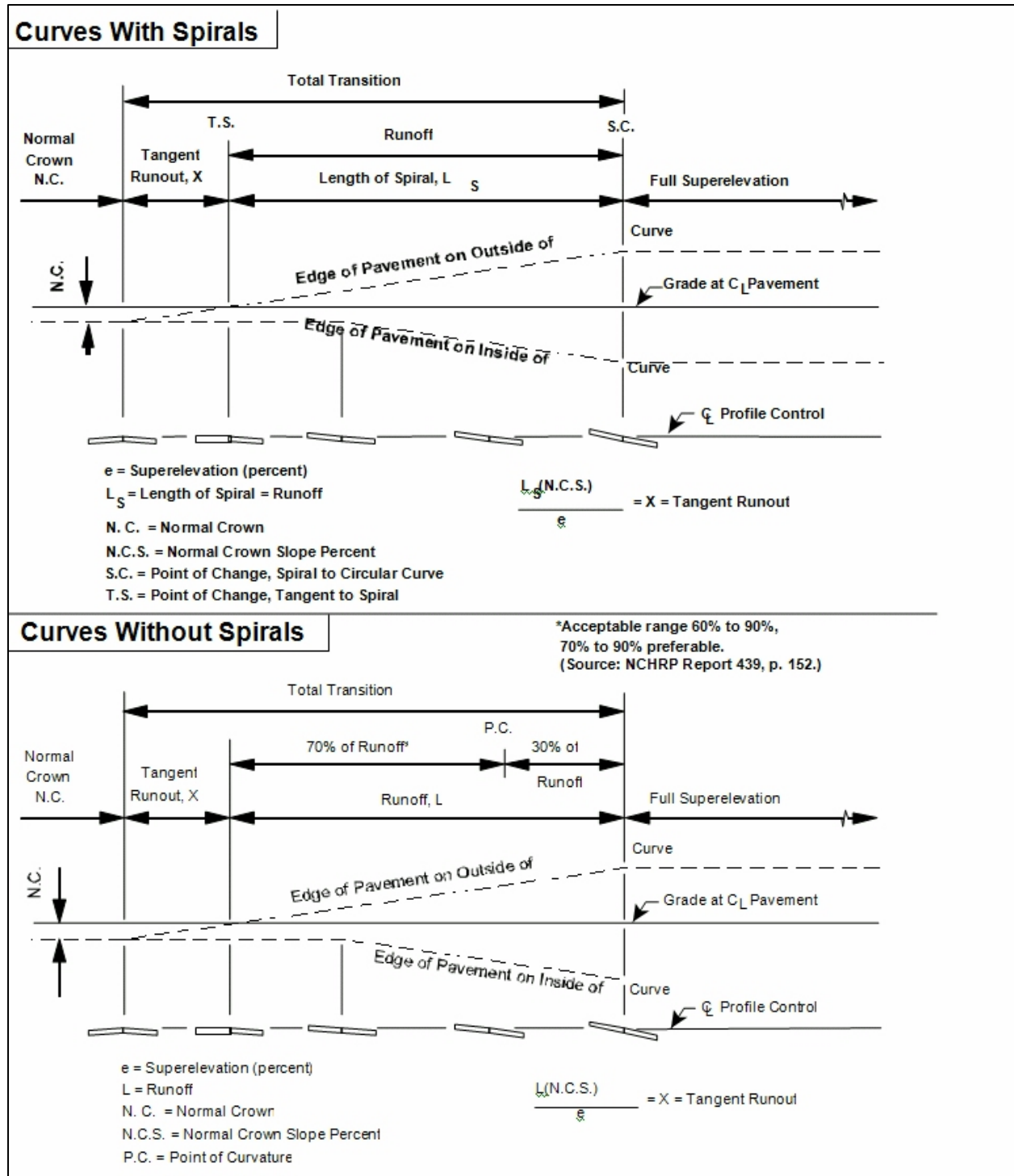
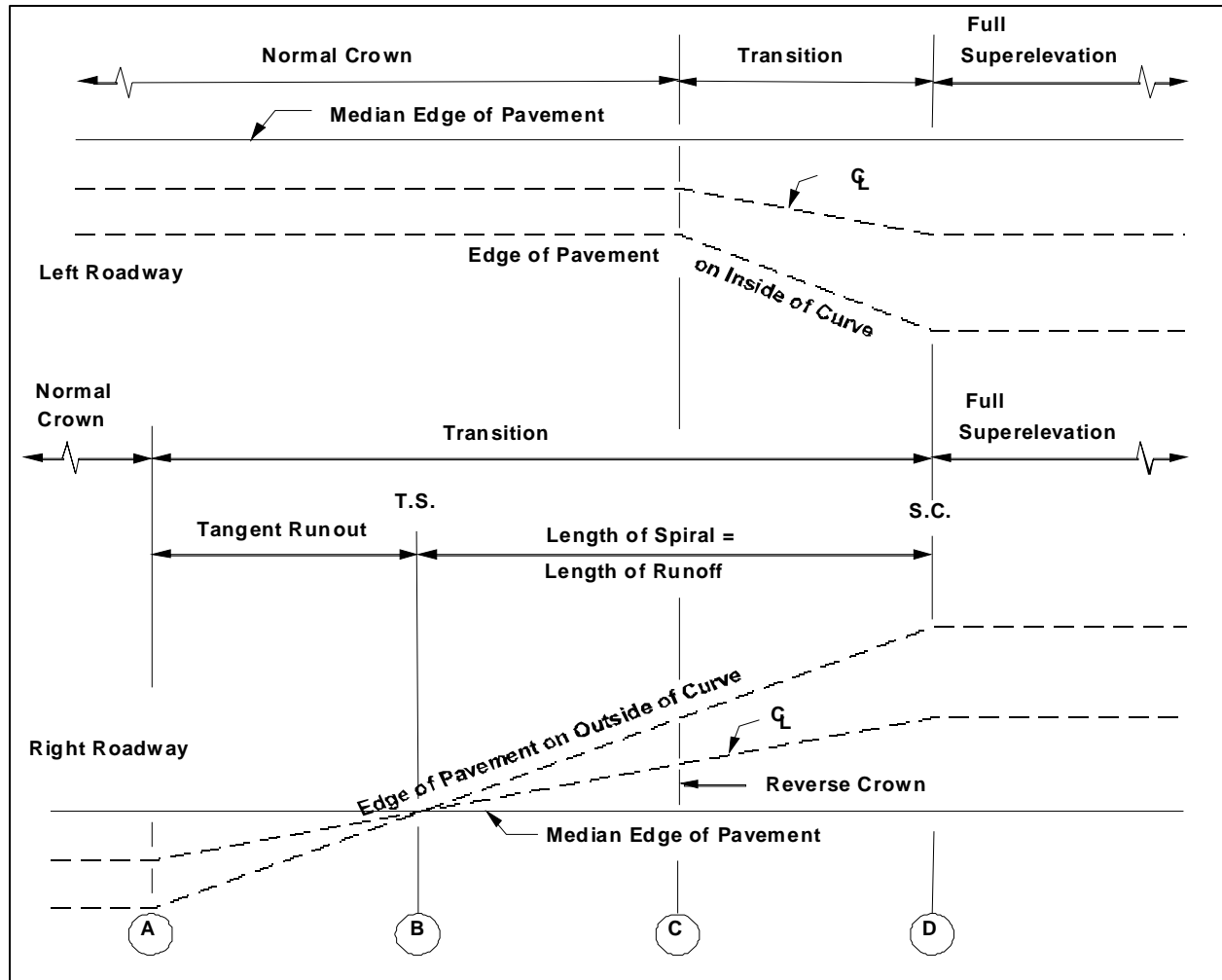
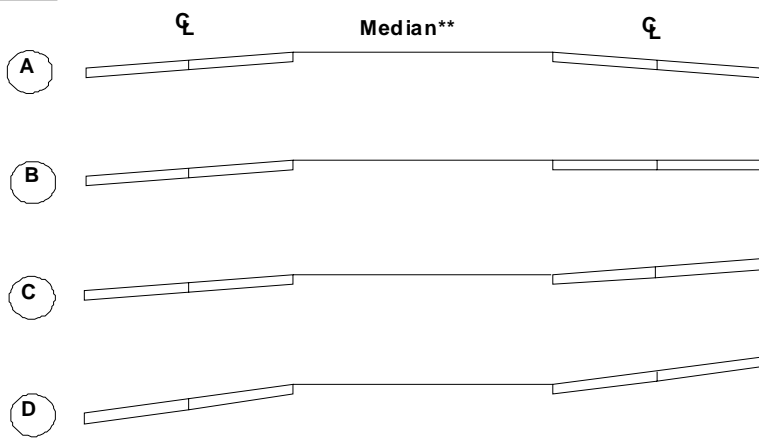


Exhibit 5-14 Method of Attaining Superelevation – Four Lane Divided Highway*



Sections for Curve to Left*



*Figure depicts curve to left with pavement rotating about median edges of traveled way. Curve to right will be similar but opposite hand.
 **Shoulders not Shown

The length of runoff for 1 lane rotated and 2 lanes rotated should be determined from the superelevation runoff equation or by Exhibit 5-15, which assumes a 3.6 m wide lane. For other situations, the runoff equals the length of 1 lane rotated multiplied by the factor ($n_1 b_w$) provided below:

<u>Number of Lanes Rotated</u>	<u>Length to Increase Relative to 1 Lane Rotated ($n_1 b_w$)</u>
1	1
1.5	1.25
2	1.5
2.5	1.75
3	2
3.5	2.25

A spiral is a curve of constantly changing radius. The radius at each end matches the alignment into which it is going. A spiral curve provides a smooth, natural path for a vehicle entering or leaving the circular curve. The spiral curve is used to achieve only the runoff portion of the banking transition. The runout portion is placed on the tangent.

As a general rule, spirals are to be used for new or reconstructed curves. Introducing spiral transitions in curves that do not have them will shift the center line of the circular curve toward the center of the curve radius.

B. Runout

Runout is the change from a normal crown section to a section with no adverse cross slope (i.e., $e = 0$ on the high side of the traveled way). To effect a smooth edge of pavement profile, the rate of removal should equal the relative gradient used for the superelevation runoff. For sections with -2% cross slope, the runout length can be determined using the 2.0% superelevation row in Exhibit 5-15, adjusted as needed for the number of lanes rotated. For 1.5% or other cross slopes, the runout length should be determined using the runoff equation provided in Section 5.7.3.3 A using a percent superelevation (e_d) equal to the cross slope.

To avoid ponding storm water on the traveled way, a minimum grade of 0.5% should be maintained where the transition has travel lanes superelevated less than the normal cross slope.

Exhibit 5-15 Superelevation Runoff L_r (m) for Horizontal Curves

e (%)	$V_d = 20$ km/h		$V_d = 30$ km/h		$V_d = 40$ km/h		$V_d = 50$ km/h		$V_d = 60$ km/h		$V_d = 70$ km/h		$V_d = 80$ km/h		$V_d = 90$ km/h		$V_d = 100$ km/h		$V_d = 110$ km/h		$V_d = 120$ km/h		$V_d = 130$ km/h			
	Number of Lanes Rotated. Note that 1 lane rotated is typical for a 2 lane highway, 2 lanes rotated is typical for a 4 lane highway, etc. (See Exhibit 3-30).																									
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
1.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
2.0	9	14	10	15	11	17	12	18	13	20	14	22	15	23	16	25	18	26	19	28	21	31	23	34	25	37
2.2	10	15	11	17	12	18	13	20	14	22	15	23	16	25	18	26	19	28	21	31	23	34	25	37	28	40
2.4	11	16	12	19	13	20	14	22	16	24	17	26	18	28	20	29	21	32	23	34	25	37	28	40	31	44
2.6	12	18	13	21	14	22	16	23	17	26	19	28	20	30	21	32	23	34	25	37	28	40	31	44	35	49
2.8	13	19	14	22	15	23	17	25	18	27	20	30	21	32	23	34	25	37	28	40	31	44	35	49	40	55
3.0	14	20	14	22	15	23	17	25	18	27	20	29	22	32	23	34	25	37	28	40	31	44	35	49	41	57
3.2	14	22	15	23	16	25	18	27	19	29	21	31	23	35	26	39	28	42	30	45	32	48	35	52	43	61
3.4	15	23	16	24	17	26	19	28	20	31	22	33	24	37	28	42	30	45	32	48	35	52	43	61	45	65
3.6	16	24	17	26	19	28	20	32	22	32	24	35	26	39	28	44	32	47	34	51	37	56	45	65	48	70
3.8	17	26	18	27	20	29	21	32	23	34	25	37	27	41	29	44	31	47	33	50	36	54	39	59	50	75
4.0	18	27	19	29	21	31	22	33	24	36	26	39	29	43	31	46	33	49	35	53	38	57	41	62	53	80
4.2	19	28	20	30	22	32	23	35	25	38	27	41	30	45	32	48	34	52	37	55	40	60	43	65	56	85
4.4	20	30	21	32	23	34	24	37	26	40	29	43	32	48	34	51	36	54	39	58	42	63	45	68	59	90
4.6	21	31	22	33	24	35	25	38	28	41	30	45	33	50	35	53	38	56	40	61	44	65	47	71	62	95
4.8	22	32	23	35	25	37	27	40	29	43	31	47	35	52	37	55	39	59	42	63	45	68	49	74	65	100
5.0	23	34	24	36	26	39	28	42	30	45	33	49	36	54	38	57	41	61	44	66	47	71	51	77	70	105
5.2	23	35	25	37	27	40	29	43	31	47	34	51	37	56	40	60	43	64	46	68	49	74	53	80	72	110
5.4	24	36	26	39	28	42	30	45	32	49	35	53	39	58	41	62	44	66	47	71	51	77	56	83	75	115
5.6	25	38	27	40	29	43	31	47	34	50	37	55	40	60	43	64	46	69	49	74	53	80	58	86	78	120
5.8	26	39	28	42	30	45	32	48	35	52	38	57	42	63	44	67	47	71	51	76	55	82	60	89	80	125
6.0	27	41	29	43	31	46	33	50	36	54	39	59	43	65	46	69	49	74	53	79	57	85	62	93	82	130
6.2	28	42	30	45	32	48	34	52	37	56	41	61	45	67	47	71	51	76	54	82	59	88	64	96	84	135
6.4	29	43	31	46	33	49	35	53	38	58	42	63	46	69	49	74	52	79	56	84	61	91	66	99	86	140
6.6	30	45	32	48	34	51	37	55	40	59	43	65	48	71	51	76	54	81	58	87	63	94	68	102	88	145
6.8	31	46	33	49	35	52	38	56	41	61	45	67	49	73	52	78	56	83	60	90	64	97	70	105	90	150
7.0	31	47	34	50	36	54	39	58	42	63	46	69	50	76	54	80	57	86	61	92	66	99	72	108	92	155
7.2	32	49	35	52	37	56	40	60	43	65	47	71	52	78	55	83	59	88	63	95	68	102	74	111	94	160
7.4	33	50	36	53	38	57	41	61	44	67	48	73	53	80	57	85	61	91	65	97	70	105	76	114	96	165
7.6	34	51	36	55	39	59	42	63	46	68	50	75	55	82	58	87	62	93	67	100	72	108	78	117	98	170
7.8	35	53	37	56	40	60	43	65	47	70	51	77	56	84	60	90	64	96	68	103	74	111	80	120	100	175
8.0	36	54	38	58	41	62	44	66	48	72	52	79	58	86	61	92	65	98	70	105	76	114	82	123	102	180
8.2	37	55	39	59	42	63	45	68	49	74	54	81	59	89	63	94	67	101	72	108	78	117	84	127	104	185
8.4	38	57	40	60	43	65	47	70	50	76	55	82	60	91	64	97	69	103	74	111	80	119	86	130	106	190
8.6	39	58	41	62	44	66	48	71	52	77	56	84	62	93	66	99	70	106	76	113	81	122	88	133	108	195
8.8	40	59	42	63	45	68	49	73	53	79	58	86	63	95	67	101	72	108	77	116	83	125	91	136	110	200
9.0	40	61	43	65	46	69	50	75	54	81	59	88	65	97	69	103	74	110	79	119	85	128	93	139	112	205
9.2	41	62	44	66	47	71	51	76	55	83	60	90	66	99	70	106	75	113	81	121	87	131	95	142	114	210
9.4	42	63	45	68	48	73	52	78	56	85	62	92	68	102	72	108	77	115	83	124	89	134	97	145	116	215
9.6	43	65	46	69	49	74	53	80	58	86	63	94	69	104	74	110	79	118	84	126	91	136	99	148	118	220
9.8	44	66	47	71	50	76	54	81	59	88	64	96	71	106	75	113	80	120	86	129	93	139	101	151	120	225
10.0	45	68	48	72	51	77	55	83	60	90	65	98	72	108	77	115	82	123	88	132	95	142	103	154	122	230

5.7.3.4 Widening Along Horizontal Curves

Travel lane widening along horizontal curves compensates for vehicle off-tracking, steering difficulty, and lane infringement. The need for travel lane widening is common along relatively sharp horizontal alignments. This need is exacerbated by narrow lane widths, narrow shoulder widths, or the lack of spiral transitions. It applies to both one-way and two-way facilities. It does not apply to turning roadways at intersections or interchanges, which are to be designed using Table 2-9 in Chapter 2 of this manual.

A. Benefits of Widening Along Sharp Horizontal Curves

Table 7 in FHWA's *Safety Effectiveness of Highway Design Features, Volume II: Alignment*, November, 1992, shows that the accident rate can be reduced by 5% to 21% by widening the traveled way along horizontal curves. Widening or providing paved shoulders along a horizontal curve can also result in substantial accident reductions.

B. Design of Widening Along Sharp Horizontal Curves

Refer to Exhibit 3-51 in AASHTO's *A Policy on Geometric Design of Highways and Streets*, 2004, for the recommended pavement widening along horizontal curves. The values are based on three traffic conditions and should be modified by Exhibit 3-52 when other traffic conditions will be present. Although paved shoulders provide some compensation when travel lanes are not widened along sharp horizontal curves, the highway should be designed so that vehicles only use the shoulder in emergency situations. When the right of way is severely constrained and paved shoulders are provided, a portion of the paved shoulder width may be subtracted from the above values since drivers can use part of the paved shoulder to increase the offset between passing vehicles. However, if there is frequent truck traffic (>10%), bicycle traffic, or a history of side-swipe, run-off-the-road, head-on, fixed-object, or rollover accidents, the full pavement widening values should be used.

When widening the traveled way, the additional paved width should be added equally to both sides of the curve along spiraled curves, as shown in Exhibit 5-16, and to the inside edge of the curve for curves without spiral transitions, as shown in Exhibit 5-17. The pavement structure of the traveled way widening should be designed to meet the rigors of the additional vehicular traffic. Since the traveled way widening is often directly over the shoulder, the existing shoulder may require removal and replacement with the appropriate course(s) where the shoulder is severely deteriorated, unpaved, or inadequate to handle the projected traffic.

As shown in Exhibits 5-16 and 5-17, the centerline markings should be placed along the centerline of the final, surfaced roadway. The edge striping should be located so that the normal shoulder width, from the tangent or unwidened curved sections, are maintained along the curve to permit use of the shoulder by bicyclists, pedestrians, and stopped vehicles.

Exhibit 5-16 Cross Section View of Travel Lane Widening Along Spiral Curves

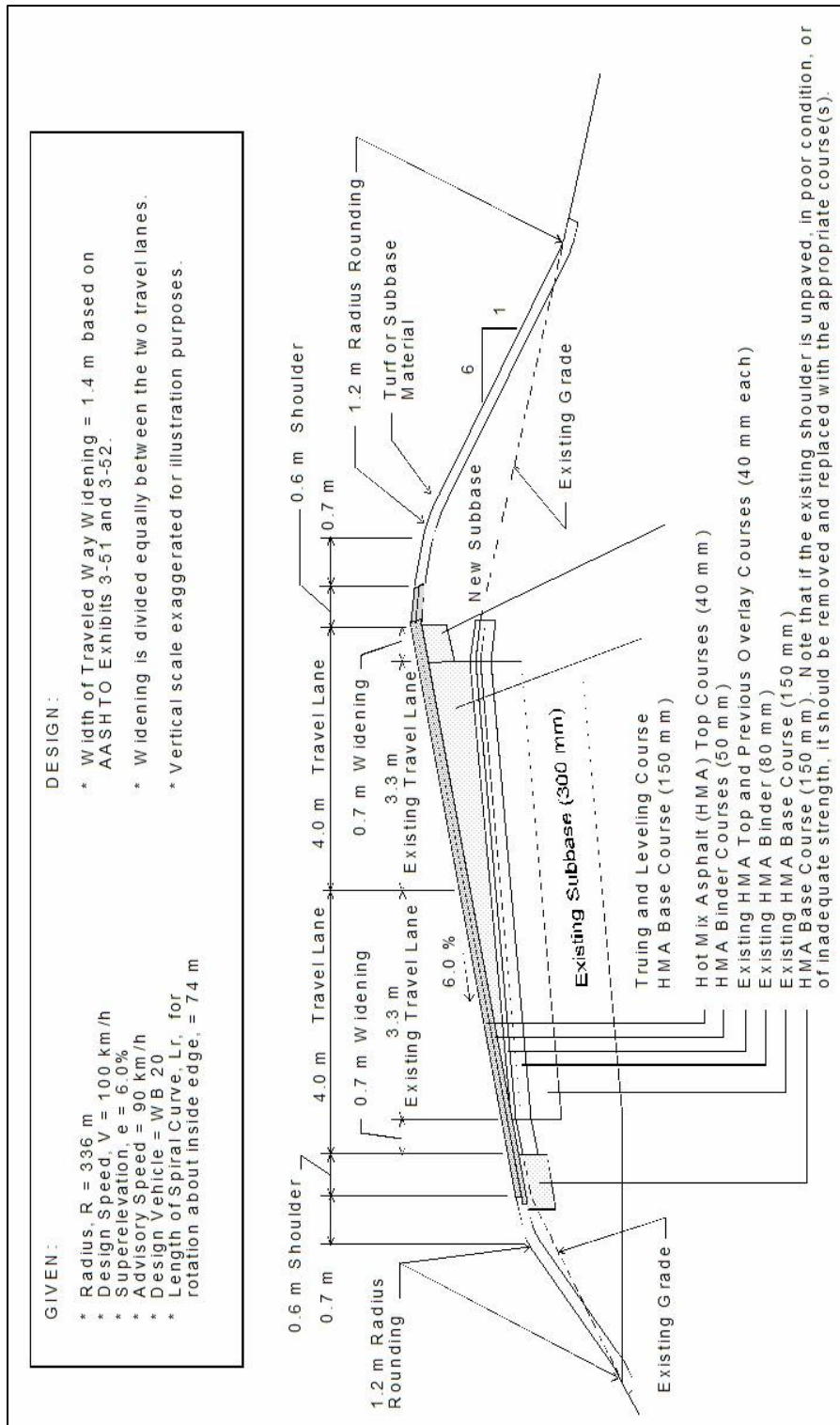
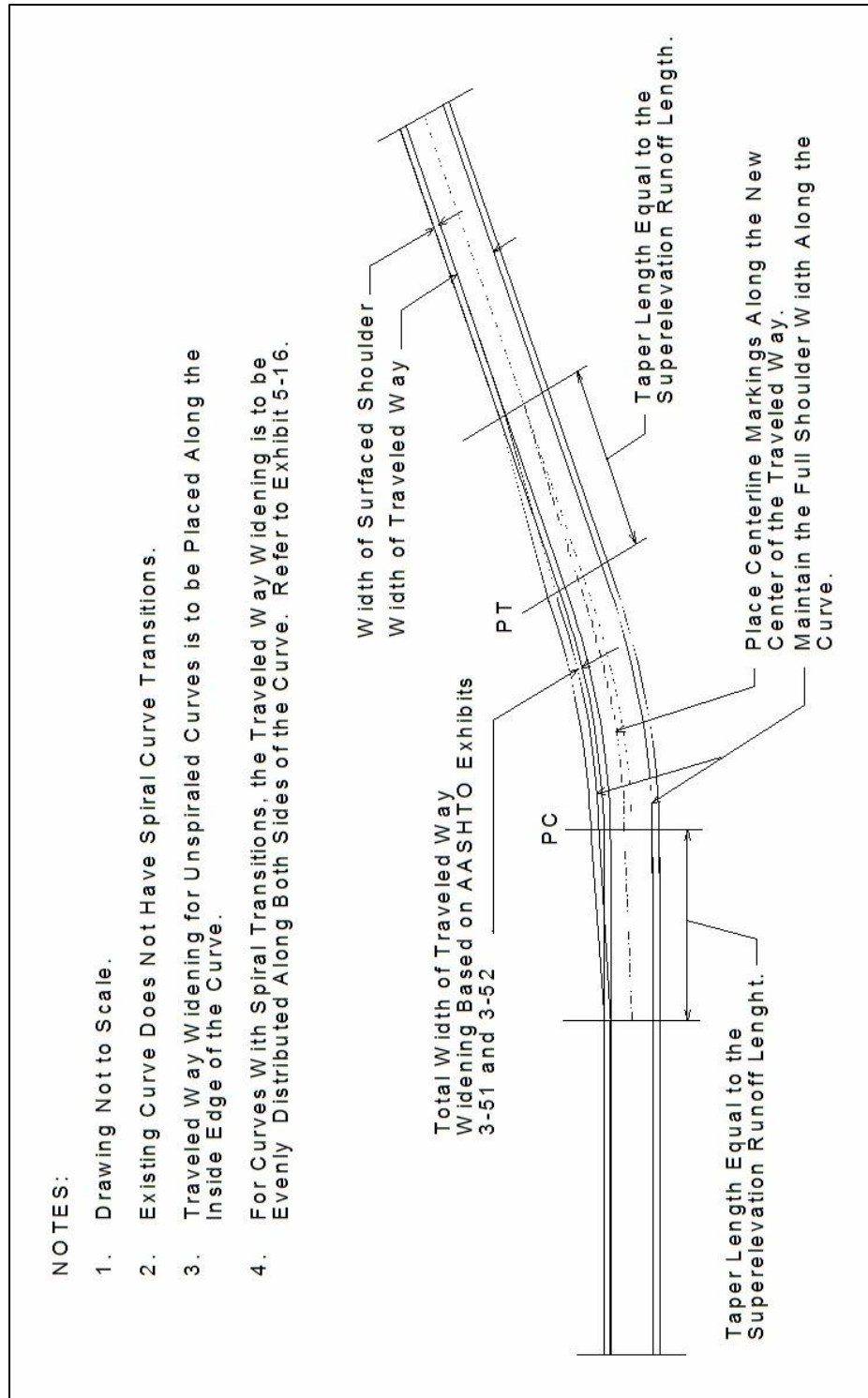


Exhibit 5-17 Plan View of Travel Lane Widening Along Curves Without Spiral Transitions



5.7.3.5 Combinations of Curves

Avoid combinations of circular curves occurring together, whenever possible. There are a number of special types of these combinations.

A. Compound Curves

A compound curve is two or more curves of different radii but curving in the same direction and connected together. When this cannot be avoided, the ratio between the successive curve radii should be a maximum of 1:1.5 for mainline and 1:2 for ramps. Larger radius curves followed by lesser radius curves are of special concern because of inconsistencies with driver expectation.

B. Broken-Back Curve

A broken-back curve is two curves, turning in the same direction, with a short tangent between them. On new construction or reconstruction, a minimum tangent of 450 m should be provided between curves turning in the same direction.

C. Reverse Curves

A reverse curve is two curves, turning in opposite directions, and connected together. A tangent section between reverse curves that is of sufficient length to provide for full runoff and runout for both curves is desirable. If sufficient distance (i.e., more than 100 m) is not available to permit the tangent runout lengths to return to a normal crown section, a large area can be at the same plane with the edges of pavement and centerline at the same elevation. This condition results in poor transverse drainage. To prevent drainage problems, the superelevation runoff lengths should be increased until they abut, thus providing one instantaneous level section. The pavement is continuously rotated from full superelevation in one direction to full superelevation in the other. If the minimum superelevation runoff lengths cannot be obtained for each curve, realignment should be considered.

5.7.4 Vertical Alignment

5.7.4.1 Grades

Grades affect the operating characteristics of vehicles. Braking distances increase on downgrades and decrease on uphill grades. It is difficult for heavy vehicles to maintain their speed on steep- uphill grades. Consideration should be given to adjusting the required stopping sight distance to account for the effects of grade. Chapter 3 of AASHTO's *A Policy on Geometric Design of Highways and Streets*, 2004, contains a detailed discussion of the effects of grade.

The maximum allowable grade on a roadway is generally determined by its functional classification, the design speed, and the terrain. See Chapter 2 of this manual for the appropriate values and a discussion of terrain and design speed.

The minimum grade will generally be controlled by the design of the drainage system. In cut sections, it is desirable to have a minimum grade of 0.5% to avoid constructing special ditches. While flatter grades may be acceptable in some situations, curbed roadways and superelevation transition sections with less than 1% of cross slope should have a minimum grade of 0.5%. In fill sections, a level profile may provide adequate drainage.

When evaluating the vertical alignment, the placement of a sag vertical curve on a structure should be avoided whenever possible due to fabrication problems as well as drainage problems on curbed structures.

5.7.4.2 Vertical Curves

Vertical curves provide for a gradual change in grade between the approach tangents. Vertical curves should be designed to provide sufficient sight distance, comfortable operation, efficient drainage, and a pleasant appearance. Long vertical curves generally have a more pleasing appearance than short vertical curves. When faced with a choice, designers should use shorter sag vertical curves in favor of providing longer crest vertical curves.

A. Crest Vertical Curves

The provision of adequate sight distance for the design speed is the primary factor in the safe operation of crest vertical curves. The minimum stopping sight distance should be provided in all cases. Wherever economically and physically feasible, additional sight distance should be provided. AASHTO recommends providing the desirable stopping sight distance in these instances.

For appearance and comfort, even small changes in grade generally warrant a vertical curve. For appearance, AASHTO recommends a minimum length of 0.6 times the design speed. (For example, a 100 km/h speed would result in a minimum length of 60 m.)

The minimum length of crest vertical curves should be the greater of:

1. Six-tenths of the design speed.
2. The length needed to provide the minimum stopping sight distance.

B. Sag Vertical Curves

Four criteria are used to establish the minimum length of sag vertical curves. They are sight distance, riding comfort, drainage and appearance.

Sight Distance

When a vehicle traverses a sag vertical curve at night, only a portion of the roadway is lighted by the vehicle's headlights. The lighted distance is considered the headlight sight distance. The minimum headlight sight distance required in a sag vertical curve is equal to the stopping sight distance for the design speed.

Riding Comfort

Riding comfort is the effect of the change in vertical direction. The effects of riding comfort are greater on sag vertical curves than on crest vertical curves. The gravitational and centrifugal forces are combining rather than opposing. There is a detailed discussion of riding comfort in Chapter 3 of AASHTO's *A Policy on Geometric Design of Highways and Streets*, 2004.

Drainage

In sag vertical curves, the surface drainage of curbed pavements requires special attention. Flat gradients may result in ponding. The design of the drainage system may control the minimum vertical curve length on curbed roadways. Generally, providing a minimum grade of 0.30% within 15 m of the level point ensures adequate roadway surface drainage. Refer to Chapter 8, Section 8.7.4.4 of this manual.

Appearance

The need for a minimum length of vertical curve may be based on appearance. For this purpose, AASHTO recommends a minimum length of 0.6 times the design speed.

The minimum length of sag vertical curves should be the greater of:

1. The length needed to provide the headlight sight distance.
2. The length needed to provide adequate riding comfort.
3. The length needed to provide adequate drainage.
4. Six-tenths of the design speed.

C. Intersections on Vertical Curves

Vertical and horizontal sight distances are crucial elements in the design of intersections. At all design speeds, the sight distance needed to perform entering and crossing maneuvers is considerably longer than the minimum stopping sight distance. For further discussion, see Section 5.9 "Intersections at Grade."

5.7.5 Climbing Lanes

A climbing lane is an additional lane provided to permit the passing of slow-moving traffic in the uphill direction. Its purpose is to improve the operational and safety characteristics of the roadway. It is desirable to provide a climbing lane when the grade, traffic volume, and the heavy vehicle volume combine to significantly degrade traffic operations. Heavy vehicles are those with a mass to power ratio of 120 kg/kW or greater.

On two-way, two lane roadways, meeting the following three conditions would justify a climbing lane. However, other conditions may arise on low-volume highways where sufficient passing opportunities are not available where it might be advantageous to provide a climbing lane even though the following warrants are not met.

1. An upgrade traffic flow rate in excess of 200 vph.
2. An upgrade truck flow rate in excess of 20 vph.
3. One of the following conditions exists:
 - a. A 15 km/h or greater speed reduction is expected for a typical heavy truck based on Exhibit 3-59 of AASHTO's *A Policy on Geometric Design of Highways and Streets*, 2004.
 - b. The level of service on the grade is E or F.
 - c. A reduction of two or more levels of service between the approach and the grade.

On multilane highways and freeways, a climbing lane is justified when both of the following conditions are met:

1. A 15 km/h or greater speed reduction is expected for a typical heavy truck based on Exhibit 3-59 of AASHTO's *A Policy on Geometric Design of Highways and Streets*, 2004.
2. Either of the following conditions is met:
 - a. There is a drop of more than one level of service between the desired design level of service and the level of service on the grade.
 - b. The level of service on the grade is E or F.

The point of need for the climbing lane is the spot where the truck operating speed is reduced 15 km/h. The climbing lane should be developed through an abrupt 45 m taper starting 75 m before the point of need.

Ideally, the climbing lane should be extended beyond the crest to a point where the truck operating speed is within 15 km/h of the highway operating speed. Due to the poor acceleration characteristics of heavy trucks, it may be impractical to obtain the desired length. In these cases, the climbing lane should be extended as far as practical. For the minimum passing sight distance and appropriate taper lengths, refer to Tables 262-1 and 262-2 of the NYS MUTCD.

5.7.6 Emergency Escape Ramps

Long, descending grades distinctly increase the potential for heavy vehicles to experience loss of braking ability. For grades where this is an identified problem, a properly designed emergency escape ramp at an appropriate location can safely slow and stop out-of-control vehicles away from the main traffic stream. Sandpiles, arrester beds, dragnets, and ascending-grade gravity ramps, alone or in combination may be used.

See Chapter 3 of AASHTO's *A Policy on Geometric Design of Highways and Streets*, 2004, and Chapter 10 of this manual for a general discussion of emergency escape ramps. See Chapters 10 and 16 of this manual and Chapter 8 of AASHTO's *Roadside Design Guide* for specific information on arresting devices and attenuation systems.

5.7.7 Travel Lanes and Shoulders

Refer to Chapter 2 of this manual for the minimum and desirable travel lane and shoulder widths. Refer to Chapter 3 of this manual and the Comprehensive Pavement Design Manual for information on pavement sections.

5.7.8 Lane Drops

Lane drops are used whenever it becomes necessary to reduce the number of through lanes. Proper lane balance should be maintained to reduce bottlenecks and reoccurring congestion. A capacity analysis should be performed to evaluate the consequences of any lane reduction.

On freeways, the lane reduction should be effected between interchanges or at a two-lane exit ramp. To allow for adequate signing, the lane reduction should be located at least 600 m to 900 m from the previous interchange and beyond any acceleration lane. The reduction should not be made so far downstream that motorists become accustomed to the number of lanes and are surprised by the lane reduction. Visibility of the lane reduction is an important consideration. Desirable locations are on tangents, on approaches to crest vertical curves, and on the uphill side of sag vertical curves. Lane drops on moderate to sharp horizontal curves should be avoided.

AASHTO suggests that the lane reduction be on the right side of the roadway. Speeds are generally lower in the right-hand lane and the merging maneuver is more common than a merge from the left. Following exit ramps, there is usually less traffic in the right-hand lane.

The lane drop shall be tapered. The minimum taper length should be in accordance with the merge taper lengths in Table 262-2 of the NYS MUTCD.

A three- or four-lane highway transitioning to a two-lane, two-way roadway produces another lane drop situation. The lane shift can be centered or placed on either side. The appropriate signing and pavement markings for these situations are shown in the NYS MUTCD.

5.7.9 Medians

Medians are desirable for streets with four or more traffic lanes. The primary functions of medians are to provide the following:

- Storage space for left-turning vehicles
- Separation of opposing traffic streams
- Access control to/from minor access drives and intersection
- Traffic Calming

For additional information on medians, refer to Chapter 3, Section 3.2.8 of this manual. Chapter 2, Section 2.7 includes minimum widths for Interstates, other freeways and multilane, rural, divided arterials. Refer to Section 5.9.8.2 C for information on Two-Way Left-Turn Lanes.

5.7.10 Median - Emergency Crossovers

Median crossovers are needed to facilitate maintenance and emergency operations on controlled-access facilities. Maintenance crossovers may be required at one or both ends of an interchange. Crossovers may be provided on rural freeways when the interchange spacing exceeds 8 km. Generally emergency crossovers are placed every 5 km to 6.5 km between interchanges. The placement of the crossovers should be coordinated with the Regional Highway Maintenance Engineer. The appropriate police and emergency services should be contacted for their input.

Maintenance and emergency crossovers should not be located within 450 m of the end of a ramp. Crossovers should be situated at locations where decision sight distance is available. If possible, they should not be located on curves requiring superelevation.

To minimize the effect on an out-of-control vehicle, crossovers should be constructed with seeded side slopes of 1:10 or flatter. A rounding with a 15 m radius should be provided at the crossover's toe of slope and at the intersection of the mainline fill and the crossover fill. If drainage is carried through the median in a pipe with a diameter greater than 300 mm at a location accessible to an errant vehicle, a slanted grate should be used over the beveled end of the pipe. The 15 m rounding and the slanted grate may be eliminated when guide railing on the mainline adequately shields the motorist from the hazard.

The minimum recommended crossover width is 7.5 m. On narrow medians, a greater width of pavement may be necessary to safely accommodate turning vehicles. Crossovers should not be used in restricted-width medians. The median must be wide enough to store a typical maintenance vehicle. The surface and shoulders should be designed to support the appropriate maintenance equipment.

A parallel-type deceleration lane should be provided. See Chapter 10 of AASHTO's *A Policy on Geometric Design of Highways and Streets*, 2004. Its length should be determined from this AASHTO policy. It should be designed to accommodate the appropriate maintenance vehicle and surfaced with the same type of material and have the same cross slope as the mainline shoulder. A design speed of 100 km/h should be used and a 1.2 m shoulder provided. The design speed may be decreased on low-speed facilities. An acceleration lane is normally not provided. However, in special circumstances, an acceleration lane may need to be evaluated, depending on traffic volume, speed, accident history, etc.

When the crossover is constructed in an area with a median barrier, the median barrier should be designed to limit the hazard. Opposing end sections should be shielded from oncoming traffic. It may be necessary to design the barrier to guide vehicles away from the median opening or to use impact attenuators. See Chapter 10, Section 10.2.5 of this manual for suggested flare rates.

5.7.11 Roadway Clear Zone

A clear unobstructed roadside is highly desirable. The term "clear zone" is used to designate the width that the Department has committed to maintain as an unobstructed, traversable area provided beyond the edge of the traveled way for the recovery of errant vehicles.

The desirable width of the clear zone is influenced by the traffic volumes, speed, horizontal curvature, and embankment slopes. Although AASHTO has established desirable design values for clear zone widths, actual values may vary for different projects or project segments. Project-specific values, determined by sound engineering judgment during design, shall be documented in the Design Approval Document.

Most Department projects require the establishment of design clear zone widths. See Chapter 10 of this manual for specific requirements and guidance.

5.7.12 Vertical and Horizontal Clearances

Vertical and horizontal clearances are important elements in the design of a highway. Clearances to be considered are:

- Vertical over and horizontal along a roadway.
- Vertical over and horizontal beside a railroad.
- Vertical over and horizontal beside a waterway.
- Vertical and horizontal between a roadway and an airway.

5.7.12.1 Roadway

The policy for vertical clearance over a roadway is stated in Section 2 of the Department's Bridge Manual. Vertical clearance is a critical design element and is discussed in Chapter 2 of this manual. Vertical clearance is the minimum vertical clear distance to an obstruction over any part of a highway's pavement or shoulders.

Horizontal clearance is one of 17 critical design elements and is discussed in Chapter 2 of this manual. The clear zone(s) for a project are determined from guidance in documents such as Chapter 10 of this manual and AASHTO's *Roadside Design Guide*.

5.7.12.2 Railroad Clearances

The minimum vertical clearance over the operating mainline tracks of a railroad is generally 6.71 m. Other clearances may be justified on some occasions. See Chapter 23 of this manual and Section 2 of the Department's Bridge Manual. The Structures Division will provide guidance, with the cooperation of the Rail Design Support Section of the Design Services Bureau.

5.7.12.3 Waterway Clearances

The Department's policy on the minimum vertical clearance over streams and navigable waterways is contained in Chapter IV C and D of the Department's Bridge Manual. The Structures Division will provide guidance on specific projects.

The United States Coast Guard shall be contacted to determine the required horizontal clearance along navigable waterways.

5.7.12.4 Airway Clearances

Whenever a project is proposed within 3.2 km of an airport or heliport, the vertical and horizontal clearance between the highway and the airway must be considered. The guidelines for these clearances are contained in Part 75 (Approval of Privately Owned Airports) of Title 17 of the *Official Compilation of Codes, Rules and Regulations of the State of New York*. The Aviation Division in the Main Office and the Regional Aviation Liaison will provide assistance. The Aviation Division in the Main Office must be notified of any possible conflicts.

The administrator of the airport or heliport should be contacted to determine the facility's long range plans. Any planned changes in the operation of the facility should be considered in the development of the plan and profile of the highway.

5.7.13 Passive Snow Control

Passive snow control involves the mitigation of blowing and drifting snow conditions on roadways through the installation of engineered snow fence, planting of shelterbelts, or by design of an aerodynamic roadway cross section. Use of passive snow control techniques will improve roadway safety by reducing whiteouts and drifting. Removal of snow by mechanical means is approximately 100 times more expensive than trapping snow by passive control. Passive snow control measures should be considered where implementation is feasible and cost-effective.

More detailed information on the design and installation of passive snow control measures can be found in references 7 and 19 in Section 5.10 of this chapter.

5.7.13.1 Snow Fences

Snow fences may be permanent or temporary. Permanent fences erected on private property will require the acquisition of a permanent easement. Temporary fences may be erected on private property under Article 3, Section 45 of the Highway Law. Some important factors for designing snow fences are:

- The most important factor in designing a snow fence is capacity. Fences should be of adequate height to store the average annual amount of snow that will be transported (blown) through the problem area.
- To maximize effectiveness, fences should be at least 2.4 m in height, but may be as short as 2 m in areas of limited snow transport or restricted right of way.
- Fences should be located at least 35 times their effective height (total height minus ambient snow depth) from the road shoulder.
- A single row of tall fences is preferable to multiple rows of shorter fences.
- Fences should be perpendicular to prevailing wind directions but departures up to 25° are acceptable. They should be placed parallel to the roadway whenever possible.
- A gap equal to 10% of the total fence height should be left under the fence to reduce snow deposition near the fence. Deposition at the fence reduces the fence's efficiency.

5.7.13.2 Shelterbelts

Also referred to as "living snow fences," shelterbelts are multiple rows of trees, preservation of agricultural crops, or shrubs planted to provide protection from wind-driven snow. There are many advantages to shelterbelts as compared to snow fences, including roadside beautification, wildlife benefits, little or no maintenance after establishment, and long service life. The Regional Landscape Architect and Maintenance Environmental Coordinator should be consulted whenever shelterbelts are considered.

Some design tips for planting shelterbelts are:

- Trees should be placed no closer than 3 times their mature height from the edge of shoulder.
- Generally, trees should be coniferous. Shrubs may be effective in areas of limited blowing and drifting snow.
- Two or more staggered rows should be planted to provide full coverage and to prevent gaps caused by plant loss or damage.
- Trees should be spaced so that crown closure will be achieved within ten years.
- Shrubs may be used where cost or space limitations do not allow for the planting of trees.
- An effective shelterbelt can be achieved by requesting farmers to leave six to eight rows of corn stalks standing through the winter. The minimum setback from the road shoulder should be 35 times the effective stalk height (height minus ambient snow depth).

5.7.13.3 Drift-Free Roads

Providing an aerodynamic roadway cross section will allow the roadway to be swept clear by the wind. It should be recognized that this is generally not a good solution where whiteouts are a problem. However, there may be some instances where the existing cross section may be contributing to the visibility problem and roadway redesign will be a viable alternative to mitigate the problem.

In some areas it may be possible to reduce drifting by altering the cross section to provide for additional snow storage upwind from the road. Minor grading on private property may be accomplished with a property release from the owner.

The following guidelines, implemented individually or in combination, as appropriate, will improve drift-prone areas:

- Backslopes and foreslopes should be flattened to a 1:6 slope or flatter.
- Ditches should be widened as much as possible.
- The profile of the road should be raised to 0.6 m above the ambient snow cover.
- Provide a ditch that is adequate for storing the snow plowed off the road.
- Widen cuts to allow for increased snow storage.
- Eliminate the need for guide rail.
- If existing W-beam guide rail appears to be contributing to a drifting problem, consideration should be given to replacing the W-beam with cable or box beam guide rail.

5.7.14 Parking

5.7.14.1 On-Street Parking

On-street parking spaces in village and urban settings complete for usable streetscaping and pedestrian space. Early contact with local officials and business owners is important to identify acceptable locations for parking spaces.

On-street parking adds an element of traffic calming whereby drivers are inclined to lower their speeds when confronted with slow-moving drivers looking for a parking space, or drivers of parked vehicles opening their doors. However, care must be taken in introducing any new on-street parking. Since high-speed traffic is not compatible with slow-moving vehicles and limited sight distances, on-street parking is not to be added to facilities with design speeds of 80 km/h or more. When adding on-street parking to low-speed facilities, the designer should consider:

- The impact on the highway's safety and capacity.
- Snow removal.
- Midblock crossings and curb bulb-outs to help motorists anticipate and see pedestrians among the parked vehicles.
- Parked vehicles can block emergency vehicles, such as fire trucks, from direct access to buildings.

To provide for adequate sight distance, vehicle turning paths, and emergency vehicles, parking is to be restricted near an intersection, fire house, commercial driveway, railroad crossing, fire hydrant, safety zone, pedestrian crosswalk, etc. As an exception, parking may be permissible opposite a minor T-intersections along a low speed highway. Refer to §1202 of the NYS Vehicle & Traffic Law for additional guidance (Note that §1621 of the NYS Vehicle & Traffic Law allows the Department to establish other distances).

A. Parallel Parking

On local roads and streets, collector roads and streets, and arterials, parallel parking is a design consideration due to land-use patterns and a lack of off-street parking facilities. Chapter 2 of this manual presents minimum parking lane widths for functional classifications of highways. Parking stalls should 6.6 m to 7.8 m long. Parking lanes normally are not carried across bridges unless the bridge is less than 15 m in length, in which case it may be considered.

B. Diagonal (Angled) Parking

Front-in diagonal parking is to be avoided due to restricted driver visibility while backing out of the parking space into traffic. Where this type of parking exists, it should generally be eliminated by providing parallel parking or back-in diagonal parking in low-speed areas, and off-street facilities in high-speed areas.

Back-in diagonal parking allows motorists to back into parking stalls, similar to backing into parallel spaces, while retaining the greater parking density of diagonal spaces. Backing into the space is no more disruptive to traffic than parallel parking. Compared to front-in diagonal parking, back-in diagonal parking places the motorist in a much better position to view motor vehicle and bicycle traffic when pulling out of the parking stall. It also makes it safer to load groceries and other items into the rear of the vehicle. Back-in diagonal parking has been successful in Canada, Washington State, and other areas.

In instances where other parking measures are not feasible and no related accident experience exists, front-in diagonal parking may be retained on local streets and collectors where design speeds are 60 km/h or less and traffic volumes are low.

Diagonal parking stalls should be 2.5 m to 2.7 m wide and 5.2 m to 5.5 m long. Although wheel stops are desirable to prevent parked vehicles from encroaching into the sidewalk area, they should not be installed since they will interfere with snow removal operations. A snow storage area may be used to prevent parked vehicles from encroaching into the sidewalk area.

C. On Street Parking Requirements for Persons with Disabilities

Parking requirements for persons with disabilities requires special consideration, and includes some requirements that are mandatory. This section and Standard Sheet M608-4R1 contain information on requirements for accessible parking for persons with disabilities in accordance with the "Americans with Disabilities Act Accessibility Guidelines for Buildings and Facilities" (ADAAG), the Vehicle and Traffic Law, and the State Building Code.

While there are no specific standards specifically related to accessible on-street parking, there is an ADA "program access" requirement to provide accessible on-street parking when other on-street parking is provided. In general, accessible on-street parking should be located near facilities such as post offices, drug stores, medical facilities, Social Security offices, neighborhood markets, convenience stores, etc. Passenger loading zones are places specifically designated for dropping off or picking up passengers and can be ideal locations for accessible on-street parking. Passenger loading zones are commonly found at park and ride lots, schools, rest areas, and other similar locations.

Where on-street accessible parking spaces are provided:

- The cross slope should not exceed 2.0%.
- Back-in diagonal spaces are preferred as they allow an area, outside the travel lane, for exiting and entering the vehicle (Refer to Section 5.7.14.1 B of this chapter).
- A curb ramp should be provided. Accessible parking spaces that are located adjacent to intersections may provide an opportunity to use the sidewalk curb ramps at the intersections as the routes to and from the parking spaces.
- An additional 1.5 m should be added to the stall length where a parallel type stall is used to allow for a wheel chair to access the sidewalk curb ramp.
- Where possible, drainage inlets should not be placed within the accessible parking stall.
- Street appurtenances and utility poles should be relocated, as needed, to allow a vehicle's door to be fully opened.

The Regional Landscape Architect can provide additional advice regarding the location and design of accessible on-street parking spaces.

5.7.14.2 Off-Street Parking

When on-street parking spaces are eliminated to improve traffic operation and safety, replacement off-street parking should be considered in accordance with Section 10-40 of the Highway Law. The off-street lots should be located as close as possible to the eliminated on-street spaces to provide adequate access to properties formerly served by the on-street spaces. The number of off-street spaces provided should approximate the numbers of eliminated on-street spaces unless a parking utilization study indicates otherwise.

A. Off-Street Parking for Persons Who Are Not Disabled

- Stall widths of 2.9 m or 3.0 m should be provided for lots with short-duration, high-turnover parking and for lots serving customers with packages.
- Stall widths of 2.6 m or 2.7 m should be used for lots with longer duration, low-turnover parking.

B. Off-Street Accessible Parking

All off-street accessible parking spaces must also comply with the provisions of Section 1101.1(d)(4) of the NYS Uniform Fire Protection and Building Code as required by the NYS Vehicle and Traffic Law. Additionally, off-street accessible parking spaces must conform to the requirements of ADAAG, especially Section 4.1.2(5), which requires:

- When passenger vehicle parking is provided as part of a Department project, the number of accessible parking spaces must be consistent with ADAAG requirements. Access aisles must be at least 2.44 m wide.
- All parking spaces that have 2.44 m wide, or wider, access aisles should be designated as "van accessible" with a supplemental sign mounted below the required "reserved parking" sign.
- The minimum vertical clearance in parking lots and on the entry level of parking garages that exceed 90 m² in area must be 2.9 m. The vertical clearance in parking lots and garages that have areas of 90 m² or less and on all levels other than the entry level of garages exceeding 90 m² in area shall be 2.5 m.

The Regional Landscape Architect and Regional Transportation Systems Operations Engineer should be contacted for further information on design of off-street parking lots including stall depths, aisle widths, and other layout dimensions and features such as provisions for persons with disabilities, landscaping, and lighting (see Chapter 12 of this manual).

5.7.15 Access Control

Access control is the regulation of public access to and from properties and roads abutting highway facilities to preserve safety and capacity. These regulations are categorized as full control of access, partial control of access, and driveway or intersection approach regulations.

Full control of access gives preference to through traffic by providing access connections only with selected public roads utilizing interchanges. Criteria for interstate highways and other freeways are presented in Chapter 2 of this manual. Interchange access control principles are presented in Chapter 6 of this manual.

Partial control of access gives preference to through traffic to a degree that, in addition to access connections with selected public roads utilizing interchanges, there may be some at-grade intersections and/or driveway connections.

Driveway and intersection approach regulations allow access to and from all abutting properties and streets in a controlled manner.

Access control should be included in the design of all highways, especially where the likelihood of commercial development exists. The extent of control should be coordinated with the local land-use plan to ensure that the desired degree of control can be maintained through local zoning ordinances. Access management will enhance highway safety and minimize vehicle delays.

Refer to Exhibit 5-18 for a key to highway access issues.

Exhibit 5-18 Highway Access Issues

Access Issues	Department Requirements, Guidance, and Procedures	Law, Regulations, and Policy
General Access Management	<ul style="list-style-type: none"> • Best Practices on Arterial Management, 1997. • HDM § 3.2.8 - Medians. 	AASHTO's <i>A Policy on Geometric Design of Highways and Streets</i> , adopted as standards by FHWA for the NHS.
ROW Acquisition and Management	<ul style="list-style-type: none"> • HDM Ch 5, § 5.5.6 - Types of ROW and Access. • Real Estate Manual/Directives - Nonmotor vehicle access (e.g., locked gate access to billboards) and relinquishment of ROW. • Highway Work Permit Process¹. 	<ul style="list-style-type: none"> • 23 CFR 620B "Relinquishment of Highway Facilities" • 23 CFR 713C "Disposal of Rights-of-Way."
Accommodation of Utilities	<ul style="list-style-type: none"> • HDM Ch 13 - Utilities. • Highway Work Permit Process¹. 	<ul style="list-style-type: none"> • 17 NYCRR Part 131 "Accommodation of Utilities within State Highway Right-of-Way." • AASHTO's Utility Guide(s). • 23 CFR 645 B - Accommodation of Utilities. • Accommodation Plan for Longitudinal Use of Freeway Right of Way by Utilities, 1995. • Requirements for the Design and Construction of Underground Utility Installations Within the State Highway Right of Way. • Section 52 of the NYS Highway Law "Permits for work within State highway right of way."
Access Control Limits	<ul style="list-style-type: none"> • HDM Ch 2, § 2.6.15 - Access Control. • HDM Ch 2, § 2.7 - Standards. • HDM Ch 5, § 5.7.10 - Access Control. • HDM Ch 6, § 6.04.09 - Control of Access [Limits]. • HDM Ch 3, § 3.2.9 C - Access Control. • Highway Work Permit Process¹. 	<ul style="list-style-type: none"> • AASHTO's <i>A Policy on Design Standards - Interstate System</i>. • AASHTO's <i>A Policy on Geometric Design of Highways and Streets</i>, adopted as standards by FHWA for the Interstate and NHS, respectively.
Driveways	<ul style="list-style-type: none"> • HDM Ch 5, § 5.7.11 - Driveways. • HDM Ch 5, Appendix A, NYSDOT's "Policy and Standards for Design of Entrances to State Highways" (a.k.a. Driveway Design Policy). • Highway Work Permit Process¹. 	<ul style="list-style-type: none"> • Section 52 of the NYS Highway Law "Permits for work within State highway right of way." • 17 NYCRR Part 125 "Entrances to State Highways."
Freeway Breaks in Access	<ul style="list-style-type: none"> • PDM Appendix 8 - Freeway Access Modification Procedures. • Highway Work Permit Process¹. 	FHWA 2/11/98 Federal Register Notice "Interstate System Access Modification Policy, Application and Implementation."

Note:

1. The Highway Work Permit Process is for work not progressed by Department projects or maintenance forces.

5.7.16 Driveways

Where driveways are allowed for access to and from the highway, they are to be designed in conformance with the latest edition of the Department's "Policy and Standards for Design of Entrances to State Highways" included as Appendix A of this chapter. When curb is used for driveway control, it shall be consistent with the guidance and requirements of Chapters 3 and 10 of this manual.

To obtain adequate geometrics for driveway entrances, it may be necessary to extend the limit of work beyond the existing highway boundary. Section 5.5.6.6 discusses releases for "Reestablishment of Approaches to Private Lands" to be used for this work.

5.7.17 Frontage Roads - Service Roads

Frontage roads are partially or uncontrolled access highways parallel to controlled access highways. Frontage roads:

- Provide access to the adjoining property and local traffic circulation.
- Segregate lower speed local traffic from higher speed through traffic.
- Help preserve the safety and capacity of the controlled access highway by reducing or eliminating access points to the through highway.

The design criteria of the frontage road should be based upon its functional classification. See Chapter 2, Section 2.7.5.6 of this manual. Frontage roads are generally local roads or streets. In most cases they should be turned over to the local unit of government for maintenance.

For further discussion of frontage roads, see Chapter 4 of AASHTO's *A Policy on Geometric Design of Highways and Streets*, 2004.

5.7.18 High-Occupancy Vehicle (HOV) Lanes

HOV lanes are travel lanes along freeways and other multilane highways which are designated solely for use by carpools, vanpools, buses, and other vehicles carrying a specified minimum number of people. When operated at a suitable level of service, an HOV lane is more efficient than a conventional-use lane because more people are moved per hour. An HOV lane can be constructed with the capability of being reversed to serve the peak hour direction. HOV lane(s) may provide an alternative solution to existing or projected congestion problems when environmental, fiscal, or policy decisions preclude construction of additional or adequate numbers of conventional lanes.

Drivers may be encouraged to use HOV lanes through incentives such as reduced, reliable travel times compared to adjacent conventional use lanes, special access ramps, reduced tolls, special toll booths, and preferred and/or cheaper parking at the job site. More detailed information including design guidelines for HOV facilities can be found in Chapter 24 of this manual.

5.7.19 Transit

5.7.19.1 Bus Stops

Bus stops are generally located where there is concentrated commercial, residential, office, or industrial development or at intersections of arterial or major collector streets. Bus stops can be provided at the far side or the near side of an intersection or at midblock. Whenever possible, bus stops should be located at the far side of intersections to facilitate bus and traffic operations. The transit operator should be consulted for all bus stop placements. Pedestrian design treatments such as placing bus stops at signalized intersections, and providing adequate sight distance for pedestrians should be considered when pedestrians will be required to cross the road.

The curb adjacent to the bus stop should be painted and signs posted to clearly identify the area as no parking or stopping except for buses. Pedestrian facilities should be provided (e.g., sidewalks and wheelchair access ramps). A marked pedestrian crosswalk should be considered if one is not in the immediate vicinity and there are pedestrian generators (e.g., school, commercial areas, residential areas, a sidewalk, a park) on the other side of the street. See Chapter 18 for a discussion of marked crosswalks.

Ideally, bus passenger shelters should be provided at every bus stop. Transit providers should be consulted on shelter design. Design standards must comply with the requirements of the *Americans with Disabilities Act Accessibility Guidelines for Buildings and Facilities* (See Chapter 18 for further information). Chapter 24, Section 24.3.5 in this manual provides additional information on bus stops.

5.7.19.2 Bus Turnouts

A bus turnout is a bus stop (see Section 5.7.19.1) located in a recessed area adjacent to lanes of moving traffic. A turnout should be considered whenever potential for auto/bus conflicts warrants separation of transit and general-purpose vehicles, but especially where a bus stopping in a travel lane may be unsafe or impede traffic flow.

Turnouts must be designed to safely accommodate bus ingress and egress movements and passenger loading and unloading activity. Conflicts with driveways should be avoided for the length of the turnout. The transit operator should be contacted to ensure the turnout will be used by the bus drivers. See Section 5.9.9 of this chapter, Chapter 24, Section 24.3.6 of this manual, and Chapter 4 of AASHTO's *A Policy on Geometric Design of Highway and Streets*, 2004.

5.7.19.3 Bus Turnarounds

Bus turnarounds are facilities that expedite a bus's return to the service route. Turnarounds can be used at the termini of routes to turn transit vehicles or they can be incorporated into a land-use development design.

Turnarounds should be designed to allow a bus to turn in a counter-clockwise direction to improve the driver's visual capabilities. The design should allow adequate space for a bus to pass a standing vehicle. A jug-handle bus turnaround design may be used at midblock bus terminal locations. "Cul de sac" and loop designs are acceptable for developments that do not have internal roadway networks to return a bus efficiently to the arterial roadway. They should be used only at the end of a bus route. The transit operator should be consulted for all turnaround placements and designs. Chapter 24, Section 24.3.7 in this manual provides additional information on bus turnarounds.

5.7.20 Pedestrians

The needs of pedestrians, especially disabled pedestrians, are an important part of the roadway environment in rural as well as in urban areas. The needs of the pedestrian are important considerations during scoping and design. Chapter 18 of this manual provides specific design details and standards for pedestrian accommodation. Coordinate with the Bicycle/Pedestrian Coordinator when assessing the need for pedestrian facilities and the Regional Landscape Architect for assistance designing appropriate facilities.

5.7.21 Bicyclists

The accommodation of bicyclists is important as more and more cyclists are utilizing the transportation system recreationally, for commuting, and the delivery of goods and services. The benefits derived in relieving congestion, reducing air pollution, lowering energy costs, promoting healthy lifestyles, and contributing to quality communities should not be underestimated. Project developers should coordinate with the Regional Pedestrian/Bicycle Coordinator in assessing the need for bicycle facilities and the Regional Landscape Architect for assistance designing appropriate facilities.

A discussion on necessary provisions for bicyclists and specific design standards is included in Chapter 17 of this manual.

5.8 DESIGN CONSIDERATIONS

5.8.1 Driver Expectancy

Drivers expect and anticipate certain geometric and operational characteristics along a roadway. Roadway features that violate driver expectancy have a direct influence on safety. Drivers, particularly those unfamiliar with or inattentive to their surroundings, can be lulled into complacency and may react inappropriately when confronted with unexpected changes. To reduce potential collisions, designer's should maintain consistency throughout a highway segment and gradually transition from one segment to another. Gradual transitions notify and prepare the driver for upcoming changes. When gradual transitions are not practical, warning signs, lighting, flashing warning lights, and additional sight distance should be considered.

Some typical features to avoid are:

- Sharp horizontal curves (i.e., those curves requiring a design speed drop of 15 km/h or more following long tangents).
- Upgrading alignment without corresponding cross section improvements. (This can cause an erroneous and possibly a false illusion of improved safety, which may encourage operating speeds that are excessive for the pavement width and clear zone.)
- Compound curves - See Section 5.7.3.3A.
- Broken back curves - See Section 5.7.3.3B.

5.8.2 Geometric Considerations

5.8.2.1 Combination of Horizontal and Vertical Alignment

Horizontal and vertical alignments should not be designed independently. They complement each other and their interrelationship can have a significant effect on the operational and safety characteristics of a section of roadway. Proper combinations of horizontal alignment and profile should be determined by engineering study and consideration of the nine (9) general controls listed on pages 281 and 282 of AASHTO's, *A Policy on Geometric Design of Highways and Streets*, 2004.

5.8.2.2 Right of Way Impacts

The effects of land acquisition must be considered in every stage of a project's development. Although it is of primary importance to meet appropriate standards for the selected highway, designers must not be so concerned with traffic data and standards that they neglect entirely the value of local culture and the natural beauty of the land traversed. Much controversy can be avoided by knowing what features are considered important by the people who live in the

project area and by designing to minimize a project's impact on those features without compromising safety.

Some principles to keep in mind when designing projects are:

- In rural areas, shallow fill sections generally require less right of way than cut sections because they reduce the amount of roadside ditching. (Shallow fill sections are also less susceptible to blowing and drifting snow problems than cut sections.)
- Although right of way impacts cannot always be avoided, many times they can be reduced through creative design efforts, particularly in sensitive areas. The use of centerline shifts, special ditches, lawn pipes, tip-up shoulders, field inlets, and gabions are just a few of the techniques which could be considered when investigating alternative designs.
- The cost of right of way is an important factor to consider when investigating project alternates. Right of way cost should be balanced against construction and future maintenance costs.

5.8.2.3 Balancing Cuts and Fills

When developing a roadway profile, it is generally cost-effective to provide a balance between cut and fill sections. However, the need to minimize impacts to adjacent properties often overrides the benefit of a highway with balanced cuts and fills.

5.8.3 Joint Use of the Highway Corridor

The joint use of transportation corridors is a legitimate and necessary utilization of right of way. The accommodation of pedestrians, bicyclists, and utilities, along with transit, commercial, and private motor vehicles, provides a more comprehensive transportation system resulting in significant cost, mobility, and environmental benefits. The designer must recognize the positive implications of this sharing of the transportation corridor and consider not only the safe, efficient movement of vehicles, but also, the movement of people, the distribution of goods, and the provision of essential services.

5.8.4 Social, Economic, and Environmental Considerations

Throughout the project development process, consideration must be given to mitigation for areas impacted by Department projects. Mitigation is defined by the Council on Environmental Quality as avoiding, minimizing, rectifying, reducing/eliminating, and compensating for impacts. Detailed information is provided in the NYSDOT *Project Development Manual* and *Environmental Procedures Manual*.

5.8.5 Utilities

Utility facilities occupy State highway right of way either by law or by permission of the Department. Utility occupation is subordinate and subject to the use of the right of way by the Department for highway or other purposes authorized by law. It is in the public interest for utilities to be accommodated within the highway right of way.

Utilities must be considered when scoping and designing a project. Early coordination between the Department and utilities is vital to a successful design. With early and reliable utility as-built information, many costly relocations can often be reduced or eliminated through minor design changes. While it may be necessary for designers to make adjustments for utility accommodations, acceptable safety standards must always be maintained.

Some types of utility relocations are eligible for reimbursement by the Department, but the Department does not subsidize utility accommodations. For additional information refer to Part 131 (Accommodation of Utilities Within State Highway Right-of-Way) of Title 17 of the "Official Compilation of Codes, Rules, and Regulations of the State of New York" and Chapters 10 and 13 of this Manual.

5.8.6 Increasing Capacity Without Adding Lanes

As congestion increases and there is less opportunity to provide additional lanes, there are a number of options that can and should be considered when designing a project to relieve congestion. The following subsections briefly describe some of the measures that may be used. Mobility measures are described in more detail in Chapter 24 of this manual. The design effort for these measures should be coordinated with the Regional Planning and Program Manager and the Regional Transportation Systems Operations Group.

5.8.6.1 Intelligent Transportation Systems (ITS)

Applying the technologies of advanced communications, information processing, sensing systems, and computer control systems to control vehicles operating on the highway and transportation network is known as ITS. Employing ITS strategies can improve the operation of the existing transportation system by redirecting traffic to avoid congestion, providing assistance to drivers and other travelers on planning and following optimal routes, increasing the reliability of and access to information on public transportation routes and schedules, and refocusing safety efforts on accident avoidance rather than just minimizing the consequences of accidents. It will include such strategies as rapid response to road accidents to restore traffic flow, changeable message signs to inform drivers of current road conditions, better information on ridesharing opportunities, control of traffic movement, route guidance systems, and electronic toll collection, to name a few.

5.8.6.2 Ramp Metering

Ramp meters are considered to be a very cost-effective technique for improving traffic flow on freeways, protecting mainline capacities and improving overall operational efficiencies during peak flow periods. A ramp meter is a modified traffic signal which is located on a ramp and which operates at a controlled rate to regulate the flow of traffic from the ramp to the freeway. The rate at which vehicles are released into the freeway lane is based on the freeway traffic volume. When congestion on the freeway is heavy, the release rate is less frequent. During off-peak periods, the signal may revert to pretimed intervals or may be taken out of service until the next period of congestion. Further information can be found in Chapter 24, Section 24.5.1 of this manual.

5.8.6.3 Reversible-Flow Traffic Lanes

When the peak travel demand on a multiple lane facility is significantly greater in one direction than in the other and that demand is reversed between the morning and evening periods, reversible-flow operation may be justified. It can be applied to mixed-use traffic on undivided or divided urban arterials and to express buses or other HOVs on arterials or freeways. Reversible-flow lanes are usually located in the center or median lane(s). During off-peak periods the operation on arterials can revert back to the normal traffic pattern. It is generally desirable to separate reversible-flow traffic lanes from the mixed-use traffic by physical barriers. In addition, the lanes to be reversed and the direction of traffic flow can be designated by specific traffic signals suspended over each lane and by permanent signs advising motorists of changes in traffic regulations and the hours they are in effect. Further information on reversible-flow lanes may be found in Chapter 24, Section 24.2.4 of this manual.

5.8.6.4 Shoulders as Travel Lanes on Freeways

On a freeway that requires increased capacity due to congestion, converting the existing shoulder to a travel lane may be the most expedient and economical method of adding capacity when compared to the alternative of purchasing additional right of way and adding a new lane. It may be done, for example, when queues develop at freeway-to-freeway interchanges, or when congestion occurs at bottlenecks or merge points, or when peak periods exceed 3 hours in duration. Care should be taken to ensure that the resultant loss of the shoulder(s) does not produce more congestion-related problems and accidents than it eliminates. Driving on the shoulders of state-controlled access highways is prohibited and must be authorized by the Department. Further discussion of the use of freeway shoulders as peak-hour travel lanes is found in Chapter 24, Section 24.5.4 of this manual.

5.8.6.5 Priority Treatment for HOVs on Arterials

Providing priority treatments for buses at traffic signals on arterial streets has the potential for reducing delays, in effect, increasing capacity. For example, turn restrictions are often used to increase capacity where limited space prevents the addition of a lane or lanes. The turn restrictions may disrupt bus routes and schedules by forcing them to travel greater distances. By exempting buses from the turning restrictions, distances and travel time can be reduced, reducing delays to the greater number of bus passengers. Passive systems for granting priority to HOVs involve signal timing adjustments to favor the direction of flow with the greater number of HOVs, or providing special HOV phases on facilities with reserved lanes or streets. Active systems include special equipment for buses which allow preemption of normal traffic signal cycles. Further information on priority treatment systems can be found in Chapter 24, Section 24.5.8 of this manual.

5.8.6.6 Upgrading the Signal System from Pretimed to Actuated Control

Actuated signal systems adjust the signal timing based on vehicle detection systems. Vehicle detection systems are described in Chapter 11, Section 11.3.2 of this manual.

5.8.6.7 Coordinated Signal System

Coordinated signal systems are two or more synchronized signals that allow vehicles to travel through each signal without stopping. Coordinated signal systems are described in Chapter 11, Section 11.3.3.5F of this manual.

5.8.6.8 Elimination of On-Street Parking

Elimination of on street parking can reduce the delay caused by traffic slowing while vehicles enter and exit the parking lane. The parking lane can help provide space for turn lanes and/or a median to prevent mid-block left turns. Refer to Section 5.7.14.2 for a discussion of off-street parking areas.

5.8.6.9 Eliminating Mid-Block Left Turns

The installation of raised medians can improve capacity and safety on uncontrolled access facilities by eliminating mid-block left turn maneuvers. Roundabouts, U-turns, jug handles, or indirect lefts can help provide access for those who would otherwise make a left turn. Refer to Section 5.9.1 for a discussion of these intersection configurations.

5.8.6.10 Converting a 2 or 4 Lane Section with Shoulders to a 3 or 5 Lane Section

Where ROW is severely constrained, a two-way left-turn lane (TWLTL) may provide more overall benefit to safety and capacity than wide shoulders depending on the travel speeds, traffic volume, turning volumes, frequency of commercial driveways, and accident history. Refer to Section 5.9.8.2 C for a discussion of TWLTL.

5.8.7 Traffic Calming

Traffic calming recognizes the significance of sharing the transportation corridor by employing techniques to reduce vehicle speeds and decrease car dominance, generally in residential neighborhood areas and central business districts. The purpose of traffic calming is to control vehicle traffic to provide an area compatible with other street activities and land usage. Examples of traffic calming measures include slow points, street closures, and narrow and short streets. Further information on traffic calming can be found in Chapter 25 of this manual.

5.8.8 Aesthetics

The visual quality of travel corridors should be considered along with the safe, efficient movement of people and goods. The lands adjacent to highways are the most visible to the traveling public, often defining the image and character of the locale and region.

The creation or preservation of an attractive landscape can contribute to safety, environmental, and economic benefits. The careful blending of the highway with the natural and cultural landscape, the careful grading of cut and fill slopes, and the selective preservation of vegetation, supplemented with new plantings where appropriate, help to:

- Define the highway for the motorist.
- Reduce the potential for erosion.
- Reduce the need for precautionary signing and guide rail.
- Reduce construction costs.
- Integrate the project into the surrounding area.

To minimize the visual impact from adjacent sensitive viewing locations, particularly along high-volume roadways, the feasibility of screening the highway should be investigated during design. Project developers should coordinate with the Regional Landscape Architect in assessing the project needs and in designing appropriate measures.

5.9 INTERSECTIONS AT GRADE

Highway crossings may be grade separated or at-grade (signalized and unsignalized). Grade-separated crossings do not provide access between the crossing highways unless an interchange is constructed. Interchanges consist of special purpose roadways (ramps) which provide either partial or complete access between the highways. The decision whether to provide an at-grade or a grade-separated highway crossing is a trade-off between providing optimal service to through traffic on one or both highways and providing access to surrounding land uses and should be based on the highway functional classification and operational and safety considerations. The type of crossing selected should meet capacity, safety, and mobility needs and be consistent with Regional land use plans. Chapter 10 of AASHTO's *A Policy on Geometric Design of Highways and Streets*, 2004, provides guidance on the selection of a type of crossing.

Intersections influence and, in some cases, are a prime determinant of operating conditions on each intersecting highway and consequently merit special consideration in design. In urban or suburban areas, accidents and capacity constraints are often concentrated at intersections.

Intersections should provide access between highway approaches at a level of service consistent with driver expectations for the highway, incorporate cost effective mitigation of accident patterns on existing facilities and address safety issues on new facilities.

Design of intersections should be consistent with the design considerations and recommendations contained in Chapter 18 of this manual and Chapter 9 of AASHTO's *A Policy on Geometric Design of Highways and Streets*, 2004.

5.9.1 Types of Intersections

The basic at grade intersection types are the circular, angular, and nontraditional intersections. Circular intersections include the traffic circle, rotary, and roundabout. Angular intersections include three-leg, such as T- or Y- intersections, four-leg, and the multileg. Nontraditional intersections include the Super-Street Median Crossover and Continuous Flow Intersection. Operational considerations for selecting an intersection layout include design-hour volumes and predominant movements, types and mix of vehicles, pedestrians, bicyclists, approach speeds, number of approaches, and safety needs. Local conditions and right of way costs often influence the intersection that is feasible and the associated design elements. The alignment and grade of intersecting highways combined with accident patterns may require channelizing the intersection regardless of the traffic volumes (Refer to Section 5.9.4 of this Chapter).

General objectives for intersection design are:

- To provide adequate sight distances.
- To minimize points of conflict.
- To simplify conflict areas.
- To limit conflict frequency.
- To minimize severity of conflicts.
- To minimize delay.
- To provide acceptable capacity for the design year.

Roundabouts are frequently able to address the above objectives better than other intersection types in both urban and rural environments and on high- and low-speed highways. Thus, when a project includes reconstructing or constructing new intersections, a roundabout alternative is to be analyzed to determine if it is a feasible solution based on site constraints, including ROW, environmental factors, and other design constraints. Exceptions to this requirement are where the intersection:

- Has no current or anticipated safety, capacity, or other operational problems.
- Is within a well working coordinated signal system in a low-speed (<80 km/h) urban environment with acceptable accident histories.
- Is where signals will be installed solely for emergency vehicle preemption.
- Has steep terrain that makes providing an area, graded at 5% or less for the circulating roadways, infeasible.
- Has been deemed unsuitable for a roundabout by the Roundabout Design Unit.

When the analysis shows that a roundabout is a feasible alternative, it should be considered the Department's preferred alternative due to the proven substantial safety benefits and other operational benefits.

Note: A feasible alternative is a reasonable solution that meets the objectives in a cost-effective and environmentally sound manner. The preferred alternative is the feasible alternative that the Department is leaning toward recommending for design approval. The preferred alternative can change if a new feasible alternative is identified and as the feasible alternatives are evaluated during preliminary design.

5.9.1.1 Circular Intersections

Traffic circles and rotaries, popular during the first half of the 20th century, typically have serious operational and safety problems, which include the tendency to lock-up at higher volumes. These intersection types are not to be constructed and should be evaluated for reconstruction when included in a multicourse resurfacing (i.e., 2R/3R project) or reconstruction project.

Roundabouts offer unique solutions to traffic operations and safety problems at intersections. Generally, for the same traffic volume, delays are less at roundabouts as compared to other controlled intersections (typical delay reductions are 30-70%). Roundabouts will accommodate large volumes of left turn movements with less delay than signalized intersections. If left turns are minimal, or most of the traffic is making similar moves (i.e., there is a significantly dominant direction of traffic), then a conventional controlled intersection may offer less vehicular delay. With regard to safety, roundabouts reduce vehicle speeds and result in significantly fewer accidents. A study by the Insurance Institute for Highway Safety found that construction of roundabouts resulted in a 39% overall reduction in accidents; a 76% reduction in injury accidents and an 89% reduction in fatal or incapacitating accidents. No other intersection type has been found to provide that magnitude of safety improvement. See Exhibit 5-19 for examples of a one-lane roundabout, a two-lane roundabout, and a roundabout corridor.

Designers should refer to the roundabout pages on the Department's Internet and IntraDOT sites for the latest requirements, guidance, and public involvement materials for roundabouts. Additionally, designers should contact their Regional expert or the Roundabout Unit in the Design Services Bureau for guidance and assistance throughout the development of the roundabout design.

The initial layout, preliminary plans, and advance detail plans for the roundabout should be reviewed by designers with considerable roundabout design experience. For multi-lane roundabouts, roundabouts with more than 4 legs, and roundabouts with unusual geometry, the Roundabout Unit should be included in the review by e-mailing the ProjectWise location to roundabouts@dot.state.ny.us.

5.9.1.2 Angular Intersections

A. 3 Legged (T Intersections)

T-intersections are one of the most commonly used intersection types. Refer to sections 5.9.2 through 5.9.8 of this chapter for guidance and requirements applicable to these intersections.

B. Closely Spaced T Intersections

Closely spaced opposing T intersections are offset ("dog leg") intersections, where either the main street or side street approach legs are not aligned with each other. Offset intersections can result in operational problems, depending on the offset distance, traffic control, and the amount of traffic going from one offset leg to the other. Consult with the Regional Transportation Systems Operations Engineer to determine the appropriateness of aligning offset intersection legs.

At offset intersections and divided highway crossings, where the distance between the nearest edges of the two intersecting roadways is 9.14 m or more, two separate intersections exist and must be independently controlled with appropriate intersection control. The Vehicle and Traffic Law definition of roadway is "That portion of a highway improved, designed, marked, or ordinarily used for vehicular travel, exclusive of the shoulder or slope." See Exhibit 5-20.

Note: Title I, Article 1, Section 120(b) of the NYS Vehicle and Traffic Law states when two roadways intersect a highway 30 ft or more apart, each crossing shall be regarded as a separate intersection. Use 9.14 m in place of 30 ft.

Offset intersection approaches or roadways within 9.14 m of each other may be considered one intersection for the purpose of traffic control. Consult with the Regional Transportation Systems Operations Engineer to determine appropriate traffic control at offset intersections. Coordination of geometric design and traffic control is especially critical at these intersections.

C. 3 Legged (Y-Intersections)

Y-intersections experience widespread operational and safety problems and should be avoided. If an accident problem is identified, existing Y-intersections should be realigned to T-intersections, replaced by a roundabout, or their retention discussed in the Design Approval Document. The rationale for retention should be based on the lack of a related accident pattern, excessive grade, or unreasonable reconstruction costs and/or impacts. When the angle is 60° or more from a right angle, additional signing may be needed to clearly mark the through route, particularly for 3-legged intersections.

Chapter 9 of AASHTO's *A Policy on Geometric Design of Highways and Streets*, 2004, and NCHRP 279 *Intersection Channelization Design Guide* provide more detailed information on Y type intersections.

D. Four-Leg

Four-leg intersections are one of the most common intersection types. There are numerous variations involving channelization, traffic control, skew, and number of through and turning lanes. Refer to sections 5.9.2 through 5.9.8 of this chapter for guidance and requirements applicable to these intersections.

E. Multileg

Multileg intersections are those with 5 or more intersection legs and should be avoided whenever practical. Refer to sections 5.9.2 through 5.9.8 of this chapter for guidance and requirements applicable to these intersections.

5.9.1.3 Nontraditional Intersections

Nontraditional intersections require special consideration and treatment, they should be developed in consultation with the Regional Transportation Systems Operations Engineer. Additional information, including the layout, applicability, design features, safety performance, and operational performance of the following intersections discussed below are covered in FHWA's *Signalized Intersections: Informational Guide*.

A. Jughandle (Indirect Left Turns)

Where operational or safety concerns preclude left turns from the median lane, indirect left turns or jughandles can, if adequate advance signing is provided, provide safe and efficient left-turn access by diverting left turns to separate turning roadways which cross the mainline or intersect the cross street at a different location. See Exhibit 5-21.

B. Quadrant Roadway Intersection

A quadrant roadway intersection includes an extra roadway between two legs of the intersection. The roadway is bidirectional, forces left turning traffic to travel a greater distance, and creates two T intersections that can operate with a three phased signal. The design removes all left turns from the major intersection, which can be signalized with a 2 phase signal, greatly increasing the green time for the through movements. A key element of this design is to locate the quadrant roadway a sufficient distance back from the major intersection to eliminate the potential of queue spillback.

C. Others

Several other nontraditional intersection types have been developed. They include:

- Median U-Turn Crossover
- Continuous Flow Intersection
- Super-Street Median Crossover

Exhibit 5-19 Roundabout Intersections

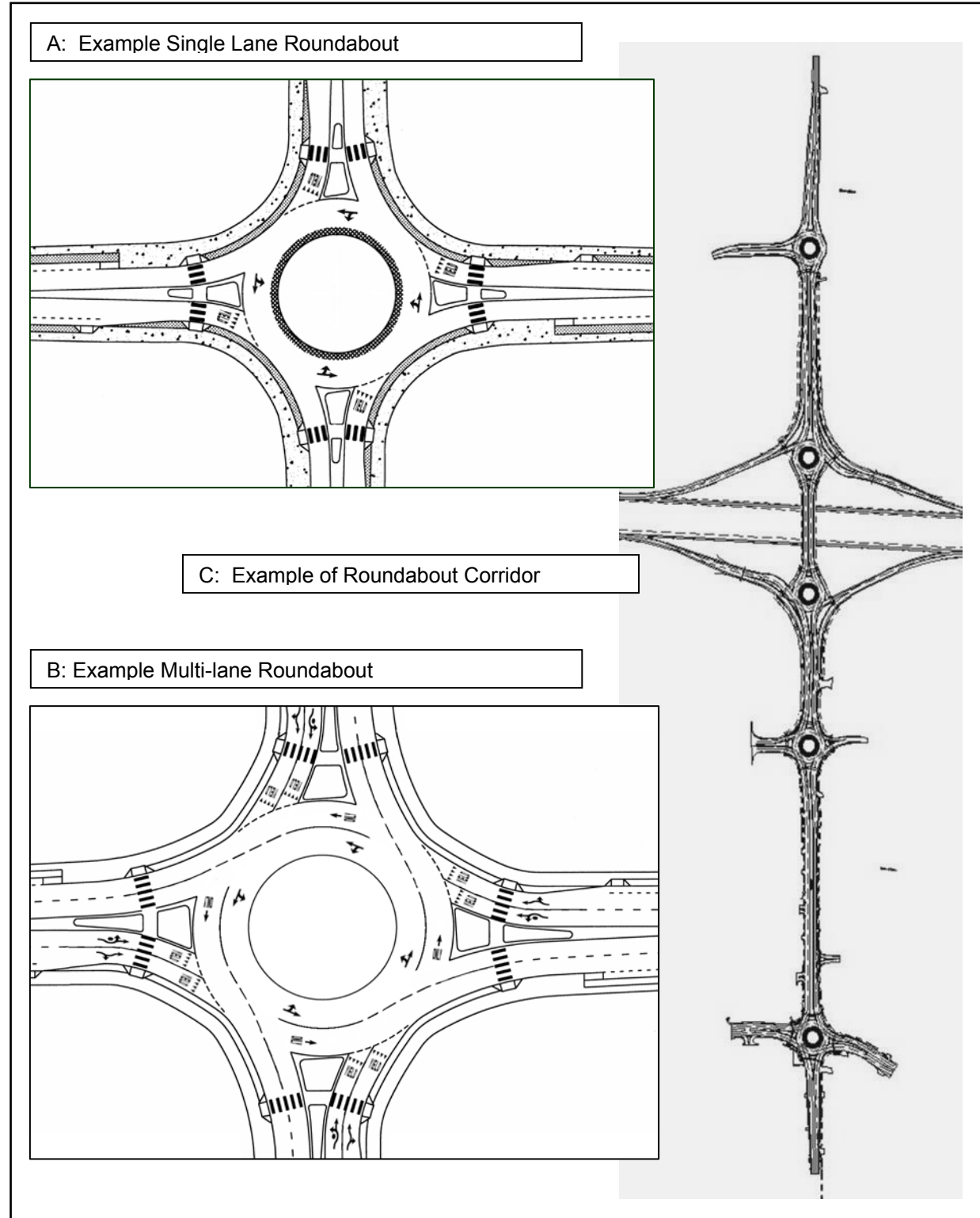


Exhibit 5-20 Divided Highway Crossings and Offset Intersections

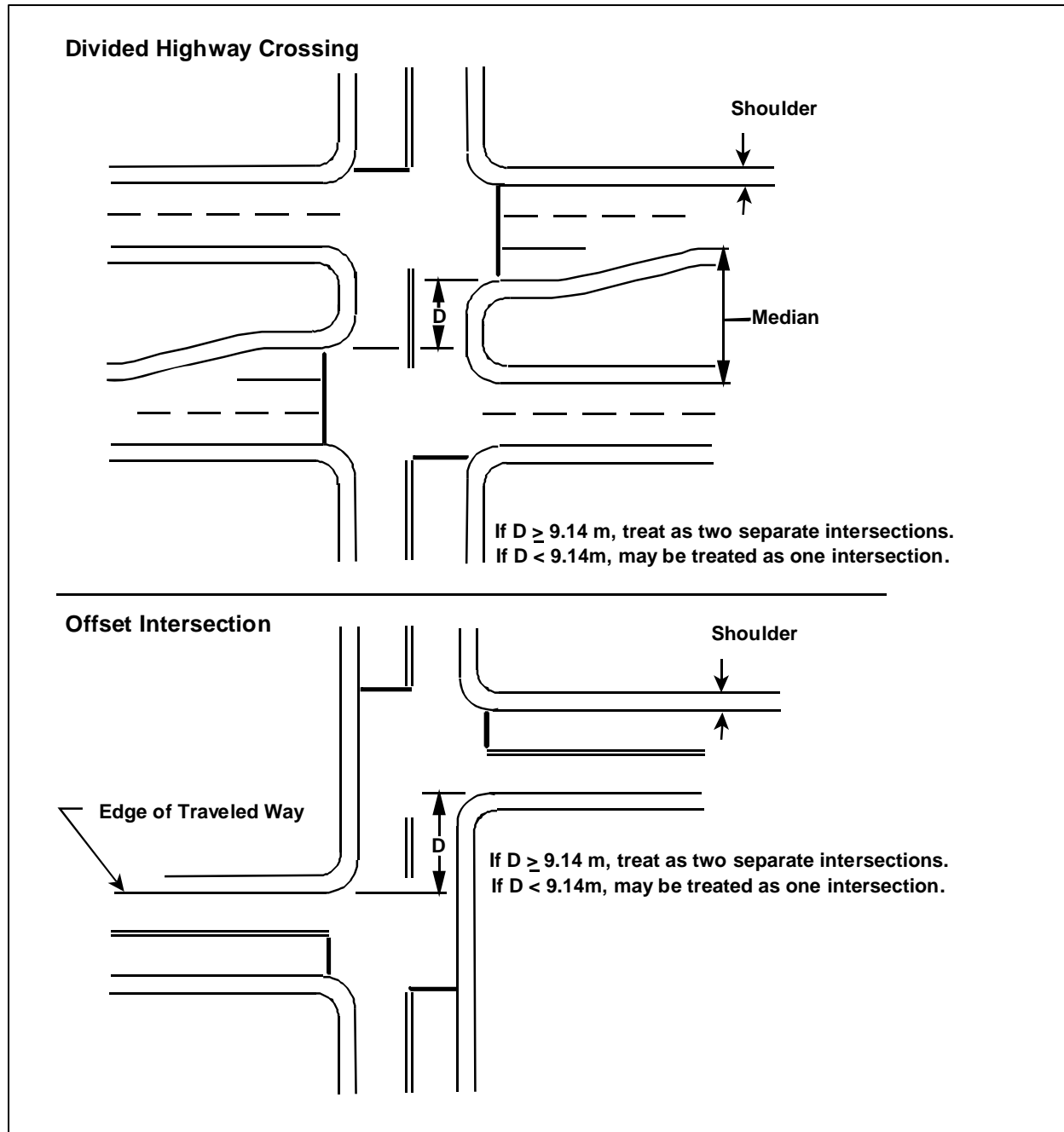
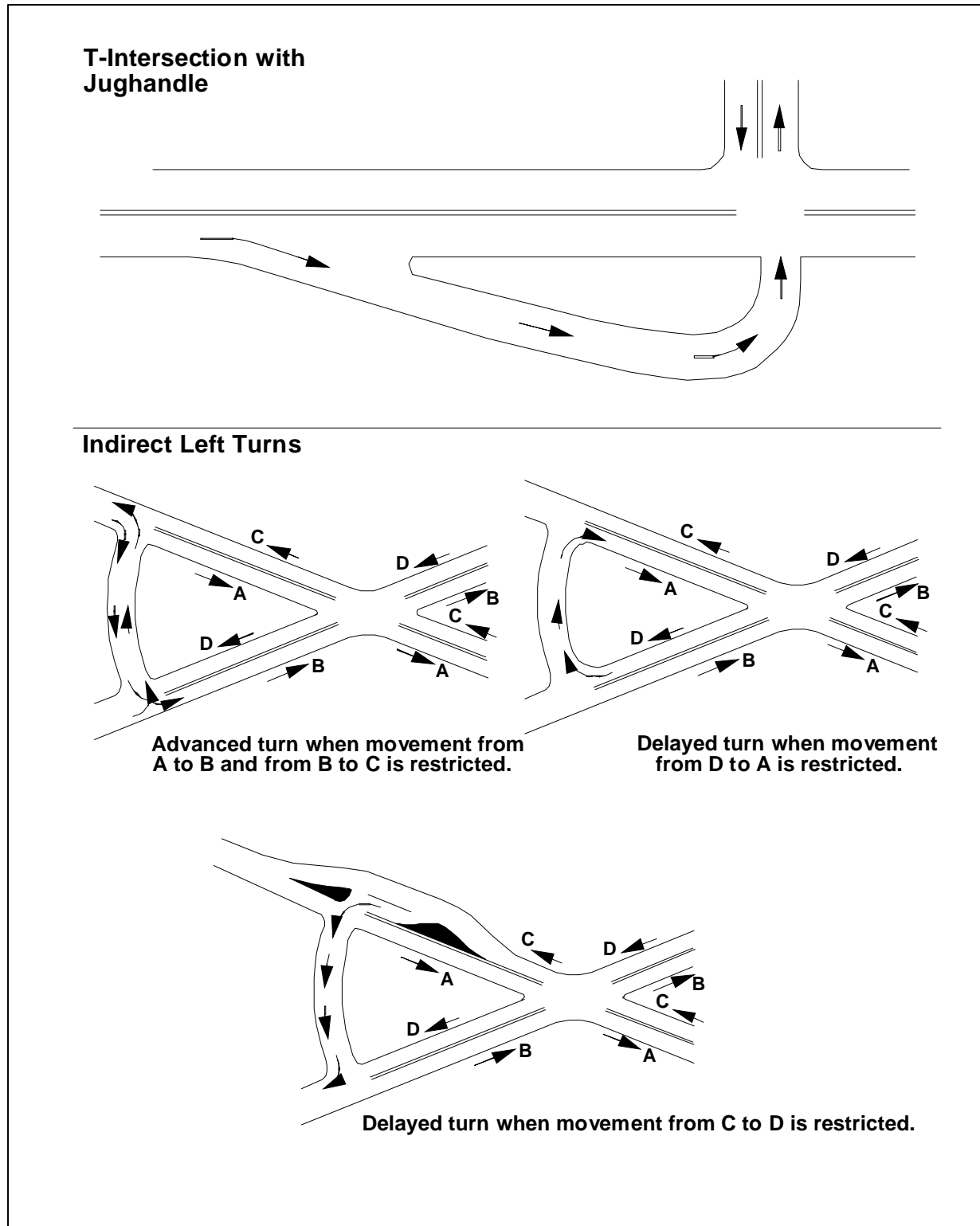


Exhibit 5-21 Jug Handles and Indirect Left Turns



5.9.2 Intersection Capacity and Level-of-Service Analysis

5.9.2.1 Motorized Traffic

The *Highway Capacity Manual* (HCM) quantifies the quality of traffic flow in terms of levels of service (LOS). As indicated in Section 5.2, there are six levels of service with LOS A representing very low levels of delays and F representing high levels of delays associated with congestion. Level of service should be a consideration for every project except preventive maintenance projects. The intersection design elements and traffic control techniques selected should meet the level of service objective.

Levels of service and capacity for signalized intersections are calculated for each lane group (a lane group may be one or more movements), each intersection approach, and the intersection as a whole. The intersection level of service is merely a weighted average of the individual approaches and may not be considered a valid measure of the quality or acceptability of an intersection design since it can conceal poor operating conditions on individual approaches. It is a common error to consider an average intersection LOS C as acceptable while one or more lane groups are at LOS F. Correct intersection design practice strives to provide design-year LOS D or better on each lane group in urban areas and LOS C in rural areas.

In some cases, it may be necessary to accept LOS E or F on individual lane groups due to unreasonable costs or impacts associated with improving the level of service. In such cases, acceptance of LOS E or F should be agreed to in the scoping/design process and explained in the Design Approval Document. Note that seconds of delay should be used in design approval documents as it may be easier for the public and decision makers to understand.

Level of service for signalized and unsignalized intersections is based on control delay, as shown in Exhibit 5-22. Control delay is defined as the average vehicle delay in seconds caused by the traffic control device compared to the uncontrolled condition. This includes the delay due to deceleration from the free-flow speed to the back of queue (if any), queue move-up (as needed), stopping/yielding, and accelerating to the free-flow speed.

Exhibit 5-22 Control Delay and Level of Service (LOS)

LOS	Unsignalized Control Delay (s)	Signalized Control Delay (s)
A	≤ 10	≤ 10
B	> 10 - 15	> 10 - 20
C	> 15 - 25	> 20 - 35
D	> 25 - 35	> 35 - 55
E	> 35 - 50	> 55 - 80
F	> 50	> 80

(Ref. pages 16-2 and 17-2 of the *Highway Capacity Manual*, 2000.)

Levels of service at unsignalized intersections are only calculated for minor movements since the through movement on the major street is not affected by intersection traffic control. The level of service for signalized intersections and unsignalized intersections can be compared. When a traffic signal is installed, the introduction of delay to the main street usually increases overall intersection delay.

Refer to Section 5.2.2.3 of this chapter for a discussion of the traffic analysis software to be used for signalized, roundabout, and other unsignalized intersection capacity analysis. Refer to the roundabout pages on the Department's Internet and IntraDOT sites for requirements and guidance when performing roundabout capacity analysis. Refer to the procedures in the HCM for requirements and guidance when performing capacity analysis for other types of intersections (i.e., the HCM procedure is not to be used for roundabouts). Capacity analysis must be reviewed by someone with expertise in capacity analysis and signal operations to ensure proper modeling of the intersection configuration and the signal operation.

Intersection turning counts for AM, PM, and other peak periods, peak-hour factors (PHF), and the percentage of heavy vehicles are foremost among the data required for the capacity analysis. The PHF, as defined in the HCM, is critical to the analysis, and site-specific data, rather than default values, should be used. Data on the number of pedestrians, location and frequency of bus stops and parking are required for signalized intersection analysis. Section 5.2 of this chapter elaborates on required traffic volume data.

Refer to Chapter 11 of this manual for the detailed design of traffic control devices (i.e., signs, signals, pavement markings, etc.).

5.9.2.2 Pedestrian Level of Service

For high density main streets and central business/walking districts with very high peak pedestrian traffic volumes, it may be necessary to determine sidewalk, crosswalk, and transit-related stairwell, ramp, and corridor pedestrian LOS. One example of the quantitative guidelines available to determine pedestrian LOS is shown below in Exhibit 5-23:

Exhibit 5-23 Level of Service Criteria for Pedestrians at Signalized Intersections

LOS	Pedestrian Delay (s/p)	Likelihood of Noncompliance
A	<10	Low
B	>10-20	
C	>20-30	Medium
D	>30-40	
E	>40-60	High
F	>60	Very High

(Ref: Exhibit 18-9 on page 18-8 of the *Highway Capacity Manual*, 2000.)

This exhibit provides LOS criteria for pedestrians at signalized intersections, based on pedestrian delay. When pedestrians (p) experience more than 30 seconds (s) of delay, they become impatient, and may take greater risks and cross at inappropriate times. This exhibit includes a guide for the likelihood of pedestrian noncompliance (i.e., disregard for signal indications). The values reflect low to moderate conflicting vehicle volumes. At intersections with high conflicting vehicle volumes, pedestrians have little choice but to wait for the walk signal, and observed noncompliance is less (refer to the *Highway Capacity Manual* for more guidance).

5.9.2.3 Balancing Level of Service

Where it is not feasible to simultaneously improve LOS for all traffic modes through design and operational modifications, tradeoffs are necessary. The *Highway Capacity Manual* should be referenced to establish an optimum LOS for each mode that appropriately balances the competing needs of motorists and pedestrians.

5.9.3 Intersection Geometrics

When establishing the intersection geometry, designers should recognize the following driver expectations so as to make the navigation and decision making process simpler for the driver:

- The number of through-lanes approaching and leaving an intersection will be the same
- The most important route will be the most direct.
- Left turns from an arterial street will be made from the left-hand-lane, while right turns are made from the right lane and
- What appears to be a through-lane will not be dropped at an exclusive turning lane.

The following discussion applies to traditional intersection designs. Refer to Chapter 18 for bicycle and pedestrian considerations and refer to the roundabout pages on the Department's Internet and IntraDOT sites for requirements and guidance on roundabouts.

5.9.3.1 Intersection Approaches

Avoid using short radius curves or unnatural travel paths near the intersection (i.e., a hooked intersection), only for the sake of reducing intersection skew. Turning vehicles often follow smoother, more natural travel paths rather than conforming to abrupt alignment changes. Abrupt approach alignment can lead to encroachments into opposing lanes, unwanted detector actuation, prematurely worn pavement markings, accidents, and poor visibility. If poor approach visibility cannot be avoided, provide SIGNAL AHEAD (W2-17) or STOP AHEAD (W2-15) signs on the appropriate approach(es).

The intersection approach curves, where traffic is not always required to stop, must be consistent with the design speed established for each approaching roadway in accordance with the requirements of Chapter 2 of this manual.

Certain intersection types with sharp radius curves or stop conditions require motorists to reduce their speed below the anticipated operating speed. Strict application of the design speed (measured along the open highway) for the intersection approaches may not be needed or appropriate. Therefore, intersection approach curves may be designed with a design speed of 20 km/h below the design speed of the approach highway where all of the following are met:

- The design speed of the approach highway was established in accordance with Section 5.2.4 of this manual.
- The curve will be within 300 m of an intersection.
- The curve is on a leg of a roundabout or the minor leg of a T intersection (that is stop controlled or yield/signal controlled with an acute angle of 60 degrees or more).
- The intersection does not violate driver expectancy and adequate sight distance and/or advance warning devices will be used.
- The curvature will not obscure the back of queue during the design hour (i.e., the horizontal sight distance and stopping sight distance are adequate).

Note: Studies have shown that limiting the change in the design speed to 20 km/h can reduce the crash rate. Additionally, a study specific to roundabouts showed that successive reverse curves prior to a roundabout can also reduce crash rates.

Speed reductions of more than 20 km/h along the approach to an intersection require a nonstandard feature justification since a vehicle's ability to decelerate is diminished when negotiating sharp radius curves. Two and four way stop controlled intersections may use a reduced speed only if justified as a nonstandard feature since these intersection types often lend themselves to future signalization and much higher operating speeds.

5.9.3.2 Highway Alignment Through an Intersection

Abrupt alignment changes within the intersection can lead to encroachments into opposing lanes, unwanted detector actuation, prematurely worn pavement markings, accidents, and poor visibility. The vertical alignment should not place low points within the intersection.

Horizontal alignment shifts are permitted, but not desirable, for traffic entering the intersection from an approach with design speeds of 60 km/h or less. When approach traffic may enter the intersection at speeds over 60 km/h, a smooth alignment using tangents or horizontal curves, based on the design speed of the approach, is needed. This accommodates off-peak periods when traffic may move through signalized intersections at the approach design speed.

5.9.3.3 Intersection Angle

A right-angle intersection provides the shortest crossing distance and minimizes the duration of exposure to conflicting vehicles. A right-angle intersection also provides the optimal sight line for drivers to judge the relative position and speed of other vehicles (including bicycles) in or approaching the intersection and to view pedestrians approaching or in the crosswalks. However, intersection angles skewed no more than 30° from a right angle typically do not significantly increase crossing distances or decrease visibility and can be a safe, adequate design.

When intersection angles are skewed more than 30° from a right angle, consideration should be given to realigning one or more approaches especially if operational or safety problems can be attributed to the skew. Methods for realigning the approaches are detailed in Chapter 9 of AASHTO's *A Policy on Geometric Design of Highways and Streets*, 2004. Also see Section 5.9.3.1.

5.9.3.4 Pavement Width

Table 2-7 in Chapter 2 of this manual and Chapter 3 of AASHTO's *A Policy on Geometric Design of Highways and Streets*, 2004, guide the selection of pavement widths for turning roadways at channelized intersections. The pavement width is dependent upon the size of the design vehicle, the curvature of the roadway, and the number of lanes. At unchannelized intersections where there is minimal space available, the turning path of the design vehicle governs.

5.9.3.5 Superelevation of At-Grade Intersection Turning Roadways

Sharp curvature and short lengths of intersection turning roadways often preclude the development of full superelevation at a desirable rate. The use of compound curves and/or spirals with gradually changing curvature can assist in developing a desirable superelevation rate. Chapter 2 of this manual lists superelevation rates for intersection curves in relation to design speeds. Superelevation runoff and rollover should also conform to Section 5.7.3 of this chapter.

5.9.3.6 Intersection Cross Slopes

The cross slope at intersecting roadways affects drainage flow patterns, adjacent sidewalks, travel speeds, and safety. Cross sections and contour plans are often needed, especially at major intersections, to ensure a smooth transition to and from the intersection pavement and to ensure they are constructed to drain properly.

A. Traveled-Way Cross Slopes at Intersections

When both facilities are at normal cross slopes, the approach traveled-way cross slope should be treated as follows (Refer to Exhibit 5-24). Note, the cross slope should be designed for design year conditions. For example, the cross slopes of existing stop controlled intersections that will likely become signalized before the design year should be designed as signalized intersections.

- If the off-peak 85th percentile vehicle from the minor approach(es) will stop or travel less than 70 km/h through the intersection, normal cross slope should generally be retained on the major highway. The edge of traveled way along the minor approach(es) should be adjusted, using the maximum relative gradient from Section 5.7.3.3 of this chapter, to achieve a cross section that matches the edge of traveled way along the major highway. Vertical curves are to be used to adjust the vertical alignment.
- If the off-peak 85th percentile vehicle from the minor approach(es) will travel 70 km/h or more through the intersection, the intersection is to be flattened. A minimum grade of 0.5% should be used to prevent storm water from ponding within the intersection. The edge of traveled way along each approach should be adjusted using the maximum relative gradient from Section 5.8.3.1 of this chapter to achieve an approach cross section that matches the edge of traveled way along the intersecting highway. Vertical curves are to be used to adjust the vertical alignment.

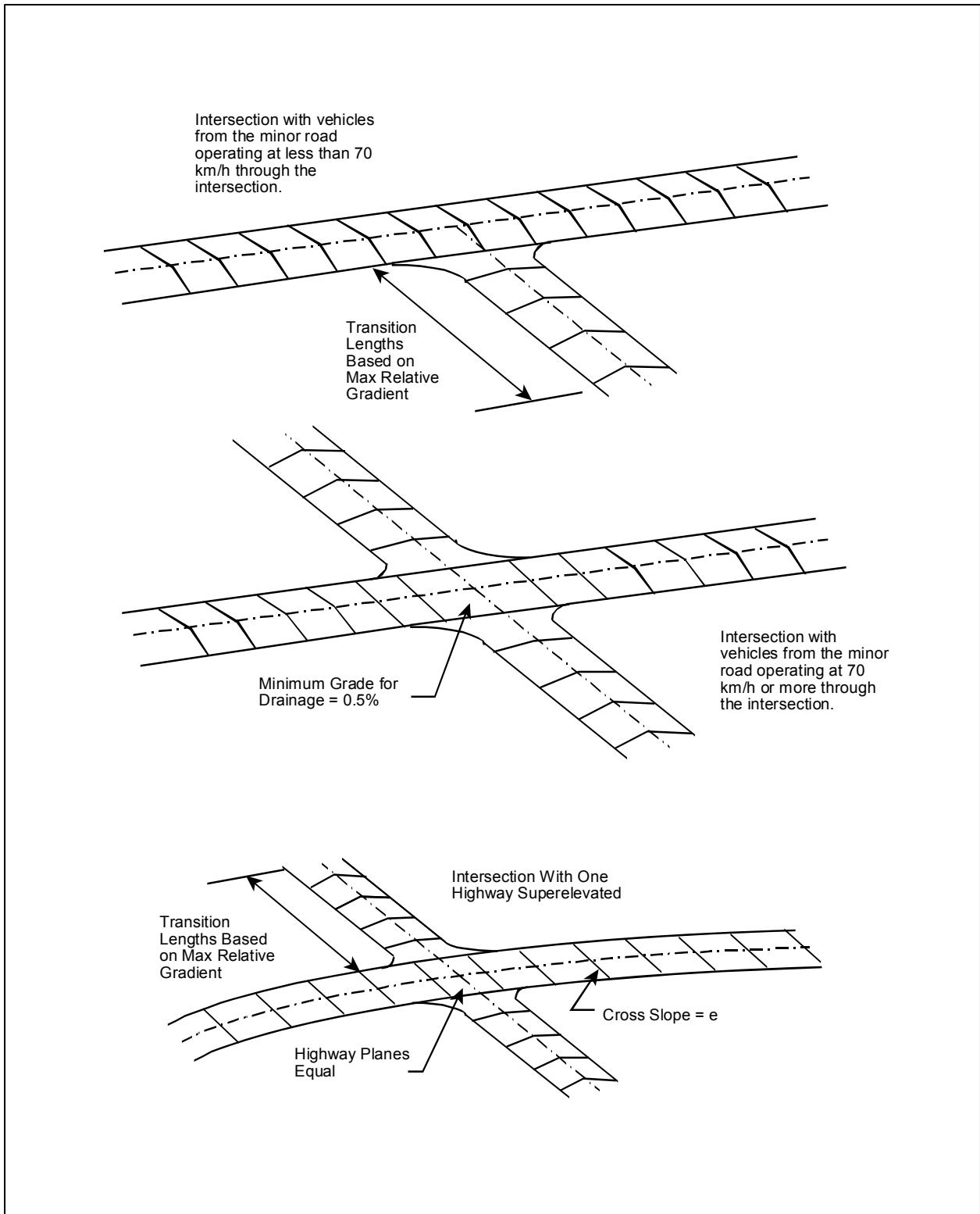
When superelevation is needed through the intersection, an additional 2.0% of superelevation, up to a maximum of 8.0%, may be used to achieve a compatible intersection design. The approach cross slopes for the traveled way should be treated as follows (Refer to Exhibit 5-24):

- If a highway requires superelevation through the intersection, it is to be provided by adjusting vertical alignments and the cross section of the intersecting highway. The edge of traveled way should be adjusted using the maximum relative gradient from Section 5.7.3.3 of this chapter to match the edge of traveled way along the superelevated highway. Vertical curves are to be used to adjust the vertical alignment.
- If two intersecting roadways require superelevation, one of the curves should be relocated. In extreme cases, a broken back curve may be needed.

B. Shoulder Cross Slopes at Intersections

Shoulder cross slope rates may be increased or flattened to minimize impacts to adjacent sidewalk and drainage facilities. The maximum rollover rate between the traveled way and shoulder is 8.0%. Desirably, the edge of the shoulder should be adjusted using the maximum relative gradient from Section 5.7.3.3 of this chapter. However, more rapid rates of change may be used to meet site specific constraints.

Exhibit 5-24 Cross Slopes for Intersecting Highways



5.9.3.7 Intersection Turning Radii

Intersection radii should accommodate the design vehicle turning path. Refer to Section 5.7.1 for a discussion of the appropriate design vehicle. The minimum designs for the inner edge of pavement for turning paths should conform to Chapter 9 of AASHTO's *A Policy on Geometric Design of Highways and Streets*, 2004. Any combination of radii, offsets, and tapers which will approximate the results of the AASHTO designs may be used. The design should consider both the need to keep the intersection area to a minimum and the types of vehicles turning.

If curbs are used, flatter curves provide more room to maneuver. Depending on the intersection angle and design vehicle, asymmetric three centered compound curves will generally reduce the area of the intersection over simple curves with or without tapers. Refer to Chapter 9 of AASHTO's *A Policy on Geometric Design of Highways and Streets*, 2004, for layouts of three-centered compound curves.

The effect of curb radii on design vehicle turning paths and crosswalk length is shown in Chapter 9 of AASHTO's *A Policy on Geometric Design of Highways and Streets*, 2004. For larger vehicles turning through more than 90°, three-centered curves or offset-simple curves with tapers or spirals are the preferred design since they fit vehicle paths better and require less pavement area than simple curves do.

Radii design on urban and suburban streets must consider the needs of all users including pedestrians, buses, and trucks. An increase in curb radii may result in an increase in the space needed to accommodate pedestrian facilities for persons with disabilities, an increase in crosswalk distances, and an increase in required right of way or corner setbacks. It may be necessary to provide an island for refuge or offset the crosswalk to reduce crossing distance.

5.9.4 Principles of Channelization

Intersections which are skewed and have enlarged corner radii tend to have enlarged paved areas which can result in uncontrolled movements, long pedestrian crossings and unused pavement. Channelization in the form of properly placed flush or raised islands can control traffic movements by reducing the pavement area available. Examples of channelized skew intersections are shown in Chapter 9 of AASHTO's *A Policy on Geometric Design of Highways and Streets*, 2004 and NCHRP 279 *Intersection Channelization Design Guide*.

Properly designed channelization increases operational efficiency and safety by separating or eliminating conflict points and delineating travel paths for turning movements. People-moving capacity can be enhanced by channelizing exclusive paths for high occupancy vehicles and transit. The following principles should be applied to intersection channelization:

- Areas of Conflict - Points of conflict should be separated whenever possible and desirable vehicle paths should be clearly defined.
- Refuge Islands - Provide safe refuge for pedestrians and other nonmotor vehicle users.

- Prohibited Movements - Undesirable or wrong way movements should be physically discouraged or prohibited.
- Preference to Major Movements or Designated Vehicles - High priority traffic movements should be facilitated.
- Effective Traffic Control - Desired traffic control schemes should be facilitated and desirable or safe vehicle speeds should be encouraged.
- Turning Roadway Alignment and Terminals - Traffic streams should cross at right angles and merge at flat angles and decelerating, stopped or slow vehicles should be removed from the through traffic stream.
- Size of Islands.
- Curbing of Islands.
- Island Offsets.
- Surface Treatment for Raised Islands.

5.9.4.1 Areas of Conflict

Wide paved intersection areas are generally undesirable. The problems inherent in conflicting movements become magnified due to insufficient guidance and the inability of drivers to anticipate movements of other vehicles within these areas. Desirable vehicle paths should be clearly defined. Channelization reduces areas of conflict by using pavement markings or islands to separate and/or regulate traffic movements into defined travel paths.

Large intersection conflict areas are typical of skewed intersection approach legs. Channelization can reduce conflict area by reducing the angle at which specific flows intersect. Indirect left-turn roadways and jughandles (see Exhibit 5-21) can enhance safety and capacity by separating left-turn conflicts from the rest of the intersection. Refer to Chapter 9 of AASHTO's *A Policy on Geometric Design of Highways and Streets*, 2004, for more guidance and example configurations.

Where large design vehicles must be accommodated by a wide pavement area, it is common practice to stripe the pavement area for the turning path of a car and allow the larger vehicle to drive over the striping. This practice helps discourage erratic maneuvers by cars or any tendency for cars to form more than one travel lane.

5.9.4.2 Prohibited Movements

Specific movements which are, depending on traffic volume, speed, and other conditions, undesirable from a safety or operational perspective should be prevented or discouraged by channelization. Examples of such movements may include, but are not limited to, left turns out of driveways or side streets, and wrong-way turns. Raised islands or judicious design of curb radii are particularly effective in discouraging prohibited movements.

5.9.4.3 Preference to Major Movements or Designated Vehicles

Directing free flowing alignment to favor major movements should be considered. Major right-turn movements are often given such priority by channelizing them away from the intersection proper and providing separate traffic control as shown in Exhibit 5-25 and discussed in Section 5.9.4.6.

The channelized path should conform to natural paths of the movement, should be introduced gradually to eliminate any surprise or abrupt movements, and should provide adequate turning width and radii for the design vehicle. Exclusive through lanes, turning lanes, and turning roadways (i.e., by-passes) can be channelized, as a component of a comprehensive plan, to give priority to designated vehicles such as buses, high-occupancy vehicles, taxis, carpool vehicles, and bicycles.

Turning roadway elements (e.g., width, radii, and superelevation) are to be designed in accordance with Chapter 2, Section 2.7.5 of this manual and Section 5.9.4.6 of this chapter.

5.9.4.4 Refuge Islands

Traffic islands can enhance pedestrian safety by providing a refuge area. Refuge areas can permit two-stage crossings which can improve traffic signal efficiency by allowing the time allocated for pedestrian movements to be reduced. All islands in pedestrian paths, whether curbed or uncurbed, must be accessible to persons with disabilities in accordance with the requirements of the *Americans with Disabilities Act Accessibility Guidelines* (refer to Chapter 18 of this manual). Curbed islands should be delineated to enhance nighttime visibility. Approach end treatment (e.g. offset, flare, height transition, ramping) should conform to Chapter 9 of AASHTO's *A Policy on Geometric Design of Highways and Streets*, 2004.

Where design speeds are 60 km/h or less, vertical-faced curbs may be used for islands designed for pedestrian refuge.

Where design speeds are above 60 km/h, but less than 80 km/h, low-deflection barrier systems, either with or without curbing, should be considered for protecting pedestrian refuge islands. Any such barrier should be placed as close as practical to the face of any type of curb, and in no case farther than 0.3 m behind it. The decision to use a curbed island should consider the potential hazard that curbing may pose to errant vehicles. The designer should weigh the anticipated number and frequency of pedestrian use of the island against the vehicular volume. If pedestrian use of the island is anticipated to be infrequent, consideration of the motorist safety would favor not using barriers. If no barrier is to be used, the preferred curbing alternatives would be 150 mm mountable at the low end and middle of this speed range and 100 mm mountable curb for speeds approaching 80 km/h.

When design speeds are 80 km/h or greater (high-speed traffic), the designer must again weigh the frequency of need for pedestrian use against the number of motorists and the degree of potential hazard that a barrier system would present to them. If pedestrian concerns govern, a low-deflection barrier system, preferably with impact attenuating end treatments (see Chapter 10 of this manual), should be used. If it is judged that motorist concerns govern, preference should be given to either using a flush-delineated or raised or depressed island, without a curb or barrier. If, after consideration of all factors, it is determined that a curbed island without barriers is needed, 100 mm 1:3 traversable curbs are to be used. As in all cases above, shoulders or curb offsets from the traveled way should be provided to satisfy the requirements given in Chapter 2 of this manual and Section 5.9.4.8 of this chapter.

Refer to Chapter 3, Section 3.2.9 of this manual for a discussion of various curb types and their uses. When barriers and curbing will be used, refer to Chapter 10, Section 10.2.2.4 of this manual for special considerations and requirements.

5.9.4.5 Effective Traffic Control

Proper channelization enhances the effectiveness of actuated traffic signal control at intersections with complex or high volume turning movements by isolating traffic flows which move through the intersection during separate signal phases. Exclusive turning lanes permit efficient use of protected signal phasing.

Exclusive right-turning roadways can, under certain traffic conditions, expedite a heavy right-turn movement by forming a separate yield-controlled intersection with the cross street 9.14 m or more downstream (measured along the travel way edge of the cross street) of the near edge of the intersection of the through lanes. See Exhibit 5-24. The 9.14 m (or greater) separation is measured between the edges of the adjacent roadways as defined by one of the following.

- Pavement marking defining the edges of the travel lanes.
- In lieu of markings, whatever serves as the edges of the travel lanes. The measurement is not dependent upon the type of material existing within the channelizing island area. The island could be flush or raised, paved or unpaved, traversable or nontraversable.

If the separation between the adjacent roadways is less than 9.14 m, the intersection approach and right-turning roadway must be controlled as one intersection, which may negate the benefits of the turning roadway. Consult with the Regional Transportation Systems Operations Engineer to determine the appropriate traffic control.

The Regional Transportation Systems Operations Engineer should also determine if the cross street through movement is light enough to provide sufficient gaps for right-turning traffic during the cross street through movement phase. A heavy, conflicting cross street through movement (volume-to-capacity ratio in excess of 0.85) is not likely to provide additional gaps for right turns other than those provided by the signal. The limited availability of gaps may also result in an unacceptable number of rear end accidents on the turning roadway. Right-turn efficiency and safety can be improved by adding either a through lane or an acceleration lane on the receiving roadway to eliminate the merge or increase the efficiency of merging traffic. To avoid degrading traffic operations and safety, the acceleration lane should be built to standard length per Chapter 10 of AASHTO's *A Policy on Geometric Design of Highways and Streets*, 2004.

Channelization may require the installation of additional traffic control devices such as yield signs and turn or directional assemblies. At more complex locations, wrong-way signing may be needed but should not be substituted for a design that discourages or prevents wrong-way movements. Provide adequate advance signing for indirect left turns and jug handles. Advance signing is especially important if the indirect left turn is to be executed from the right lane.

Proper channelization can encourage desirable or safe vehicle speeds. Large turning radii and speed change lanes can help reduce the speed differential between turning and through traffic. Small turning radii, stop signs, and oblique entrance angles can reduce vehicle speeds in areas with high pedestrian volumes.

5.9.4.6 Turning Roadway Alignment and Terminals

Channelized right-turning roadways are sometimes called right-turn slip lanes or right-turn bypass lanes. There are two types of channelized right-turning roadways for at-grade intersections: right-turning roadways with corner islands and free-flowing right-turning roadways.

A Right-Turning Roadways with Corner Islands

Right-turning roadways with corner islands are either yield, stop, or signal controlled at the entrance to the intersecting roadway. They do not include acceleration lanes, as shown in the upper left corner of Exhibit 5-25.

The alignment of the edge of traveled way where the turning roadway either diverges from or merges with the through highway should be designed with spirals and/or compound curves. The spirals or compound curves should be long enough to avoid sudden deceleration by drivers while still on the through highway, to provide a natural turning path and to develop superelevation in advance of the maximum curvature. Desirable types of alignments and maximum lengths of spiral for intersection curves and circular arcs for compound intersection curves are shown in Chapter 9 of AASHTO's *A Policy on Geometric Design of Highways and Streets*, 2004. When turning from a high-speed highway, a deceleration lane is desirable. Deceleration lanes should be designed in accordance with Chapter 10 of AASHTO's *A Policy on Geometric Design of Highways and Streets*, 2004.

A 90° to 60° angle between the turning roadway and intersecting roadway provides the optimal sight line for drivers entering the highway from the turning roadway to judge the relative position and speed of approaching vehicles. Turning roadways that enter the highway at angles of less than 60° without an acceleration lane require the entering motorist to look over their shoulder to view approaching vehicles and are undesirable.

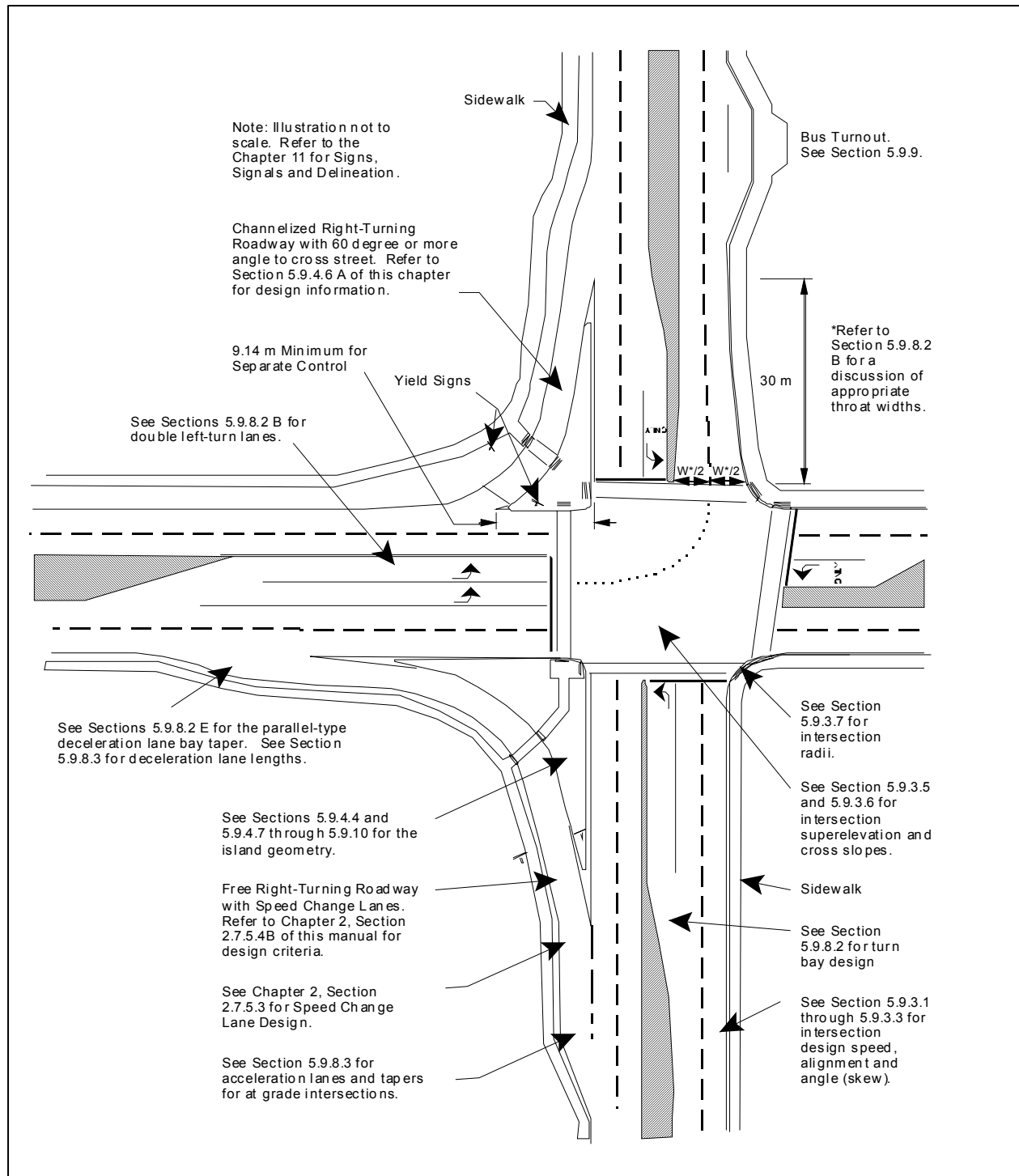
B Free-Flow, Right-Turning Roadways

Right-turning roadways with acceleration lanes are called free-flow, right-turning roadways. They function as ramps for an at-grade intersection.

The alignment of the edge of traveled way where the free-flow, right-turning roadway diverges from the through highway should be designed with spirals and/or compound curves. The spirals or compound curves should be long enough to avoid sudden deceleration by drivers while still on the through highway, to provide a natural turning path and to develop superelevation in advance of the maximum curvature. For high-speed highways, deceleration lanes are desirable.

Free-flow, right-turning roadways should be designed with a near-tangent approach to the highway to encourage use of the acceleration lane, as shown in the lower left corner of Exhibit 5-25. Taper- or parallel-type acceleration lanes are required to allow motorists to use their mirrors to merge into traffic. Acceleration and deceleration lanes should be designed in accordance with Section 5.9.8.3 of this chapter.

Exhibit 5-25 High-Capacity Signalized Intersection With Double Left-Turn Lanes and Right-Turning Roadways



5.9.4.7 Size of Islands

Islands should be large enough to effectively channelize traffic flows in advance of the intersection. Small raised islands can lead to maintenance problems and may be difficult for motorists to see and react to. Chapter 9 of AASHTO's *A Policy on Geometric Design of Highways and Streets*, 2004, specifies the smallest size curbed islands which normally should be considered. Smaller islands should be flush and color contrasted with the remainder of the pavement. Contrasting surface texture may also be appropriate. The painted area of a wide turning roadway (as described in Section 5.9.4.1) can be included in the legally required minimum 9.14 m separation mentioned in Section 5.9.4.6 and the minimum island area. Islands need to be large enough to accommodate all of the following as appropriate: signs, delineators, pedestrian storage, barriers, landscaping, etc.

Both Chapter 9 of AASHTO's *A Policy on Geometric Design of Highways and Streets*, 2004, and NCHRP Report 279 *Intersection Channelization Design Guide* recommend specific dimensions for islands as a function of their use.

5.9.4.8 Curbing of Islands

Refer to Section 5.9.4.4 for a discussion of curbing issues related to refuge islands and islands in general. When it is decided to curb raised islands that are not intended as pedestrian refuges, mountable curbing should be used to allow errant drivers to maintain control of their vehicle. The decision to use a curbed island should consider the potential hazard that curbing may pose to medium (between 60 km/h and 80 km/h) and high-speed traffic (80 km/h or greater). Raised islands bordering high-speed through lanes should be located outside the shoulder area and should use only the 100 mm mountable or the traversable curbs. Refer to Chapters 3 and 10 of this manual.

5.9.4.9 Island Offsets

Curbed islands should be offset from the travel lane in accordance with Chapter 9 of AASHTO's *A Policy on Geometric Design of Highways and Streets*, 2004. Offsets are also recommended for uncurbed islands, but they are not essential. Islands with mountable curbing should be offset from through travel lanes but do not need to be offset from turning roadways unless there is a need to minimize exposure to traffic.

When approach shoulders are used, the shoulders should be continued past the island and the offset between the island and the travel lane should be the shoulder itself except where a deceleration or turning lane is provided. No additional offset from the shoulder edge is necessary, but some may be advantageous at higher operating speeds.

5.9.4.10 Surface Treatment for Raised Islands

Small islands ($<18 \text{ m}^2$) at intersections should be paved. Easily maintained paving material that cannot be scattered by traffic should be used.

Large islands ($\geq 18 \text{ m}^2$) may be paved or turfed. Large islands in residential areas may be landscaped provided that the plantings do not interfere with sight distance or grow larger than 100 mm in trunk diameter. Islands should not be landscaped without the concurrence of the Regional Transportation Maintenance Group or other maintenance entity if the island is to be maintained by others. Although usually not needed for small islands, large islands should have inlets in the center or along the curbed edges to prevent drainage from adversely impacting adjacent roadways.

5.9.5 Intersection Sight Distance

Each intersection has the potential for several different types of vehicular conflict. Providing sight distance at intersections allows drivers to perceive potentially conflicting vehicles. Intersection sight distance should allow drivers sufficient time to stop or adjust their speed, as needed, to avoid a collision in the intersection. The driver of a vehicle approaching an intersection should have an unobstructed view of the entire intersection, including traffic control devices, and sufficient lengths along the intersecting highway to permit the driver to anticipate and avoid potential collisions. Sight distance also allows the drivers of stopped vehicles a sufficient view of the intersecting highway to decide when to enter the intersecting highway or cross it. Sufficient sight distance for motor vehicles also provides sight distances for bicyclists and pedestrians.

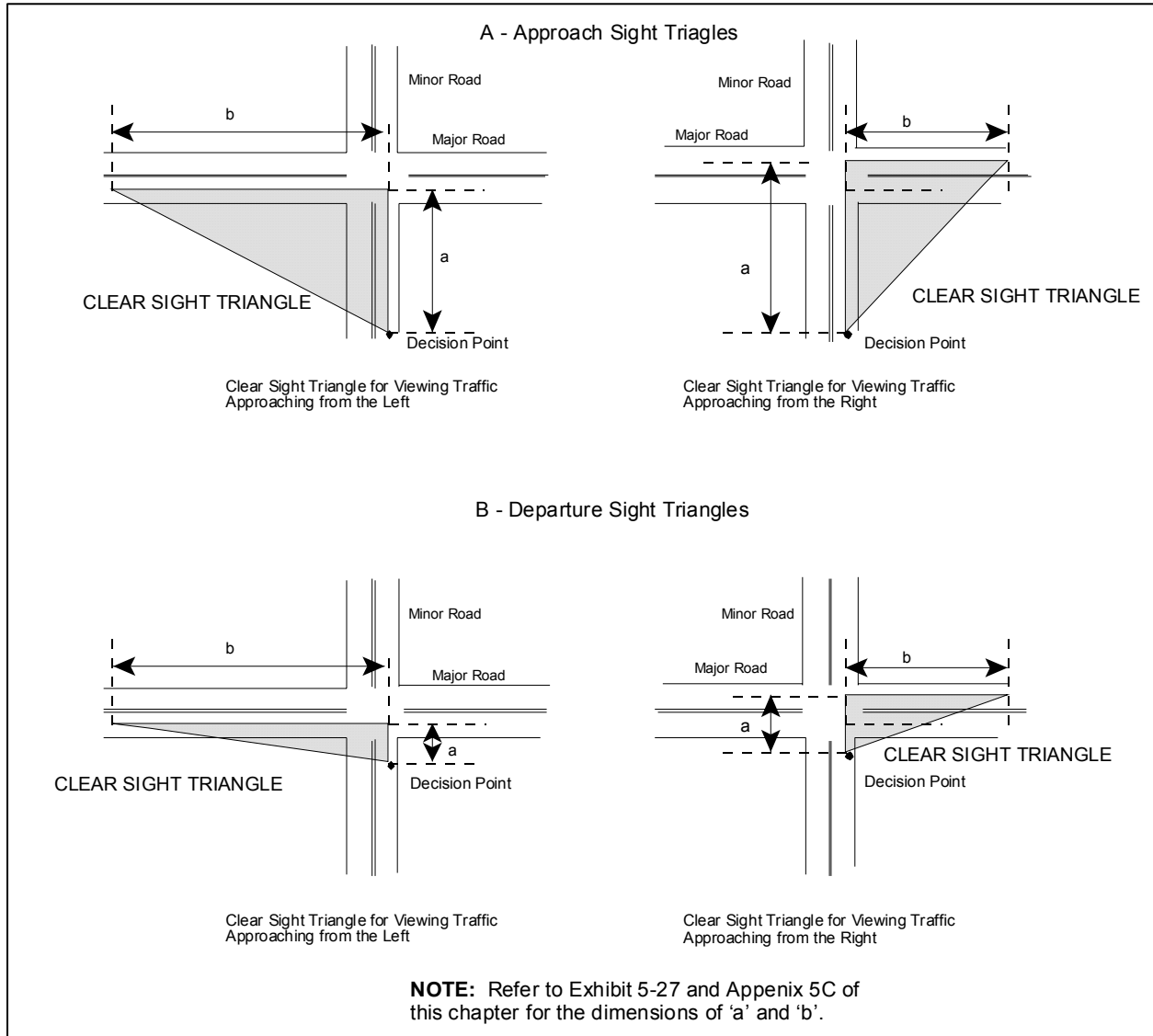
Note: If the Intersection Sight Distance cannot be met, consideration should be given to adding warning signs or signaling.

5.9.5.1 Sight Triangles

Each quadrant of an intersection should contain a triangular area free of obstructions that might block an approaching driver's view of potentially conflicting vehicles and the presence of pedestrians. These areas are known as clear sight triangles. The intersection sight distance is measured along the "a" and "b" legs of the sight triangle, not the hypotenuse.

The dimensions of the legs of the sight triangles depend on the design speeds of the intersecting roadways and the type of traffic control used at the intersection. Two types of clear sight triangles are considered in intersection design, approach sight triangles and departure sight triangles. The length of the legs of this triangular area, along both intersecting roadways, should be such that the drivers can see any potentially conflicting vehicles in sufficient time to slow or stop before colliding within the intersection. Exhibit 5-26 depicts typical approach and departure sight triangles.

Exhibit 5-26 Approach and Departure Sight Triangles



Approach Sight Triangle - The vertex of the sight triangle on a minor-road approach (or an uncontrolled approach) represents the decision point for a minor-road driver. The decision point is the location at which the minor-road driver should begin to brake and stop if another vehicle is present on an intersecting approach. Although desirable at high-volume intersections, approach sight triangles like those shown in Exhibit 5-26-A are not needed for intersection approaches controlled by stop signs or traffic signals.

Departure Sight Triangle - A second type of clear sight triangle provides sight distance sufficient for a stopped driver on a minor-road approach to depart from the intersection and enter or cross the major road. Departure sight triangles shown in Exhibit 5-26-B should be provided for stop-controlled and some signalized intersection approaches as discussed in Case D - Intersections with Traffic Signal Control.

The profiles of the intersecting roadways should be designed to provide recommended sight distances for drivers on the intersection approaches. Within a sight triangle, any object that would obstruct the driver's view should be removed or lowered, if practical. Particular attention should be given to the evaluation of clear sight triangles at interchange ramps/crossroad intersections where features such as bridge railings, piers, and abutments are potential sight obstructions. The determination of whether an object constitutes a sight obstruction should consider both the horizontal and vertical alignment of both intersecting roadways, the motorist eye height, and the object height, as shown below:

<u>Vehicle Type</u>	<u>Eye Height</u>	<u>Object Height</u>
Passenger Car	1080 mm	1080 mm
Single Unit or Combination Truck	2330 mm	1080 mm

5.9.5.2 Intersection Movements

The recommended dimensions of the sight triangles vary with the type of traffic control used at an intersection. Exhibit 5-27 provides a quick reference to the procedures for intersection sight distance. Detailed procedures for determining intersection sight distance follow.

5.9.5.3 Intersection Sight Distance Design Guidance

Intersection skew is more of a concern at unsignalized intersections than signalized ones. A traffic signal should not, however, be installed to compensate for intersection skew unless the Regional Transportation Systems Operations Engineer determines that it is warranted (see Section 5.9.7). Sight lines between the intersecting highways, even at signalized intersections, are a concern because of right-turn-on-red, flashing signal operation, and power failure.

The intersection sight distance values may be adjusted for intersections skewed at an angle of less than 60° degrees. This adjustment can be made by assuming a greater number of lanes being crossed.

The sight distance of intersections adjacent to bridges can be obstructed or severely limited by bridge railing or approach guide railing. In such cases, sight distance may be improved by relocating the intersection, offsetting the railing by providing a wider shoulder on the bridge and approach or, if practicable, changing to an alternative railing design which optimizes sight distance. Ramp terminal intersections should be designed in the same manner as any other at-grade intersection with the corresponding traffic control.

Exhibit 5-27 Intersection Sight Distance Quick Reference

Traffic Control & Maneuver		Traffic Control & Maneuver	Appendix 5C Tables	How to Use Tables in Appendix 5C of this Chapter
Class A - Intersection with no control		approach	A & G	Use table distances for "a" dimension on minor approach legs and "b" dimension on major approaches. Adjust for grade on all approaches using Table G. There are no correction factors for vehicle type.
Class B - Intersection with stop control on the minor road	Case B1 - Left turn from the minor road	departure*	B1	Use table to determine "b" dimension along major road. The "a" dimension is half the receiving travel lane width, plus any median, plus the lane widths being crossed, plus a minimum of 4.4 m (4.5 m to 5.4 m desirable) for the distance between the driver's eye and edge of traveled way. No adjustment for grade.
	Case B2 - Right turn from the minor road	departure	B23	Use table to determine "b" dimension along major road. The "a" dimension is half the receiving travel lane width plus a minimum of 4.4 m (4.5 m to 5.4 m desirable) for the distance between the driver's eye and edge of traveled way. No adjustment for grade.
	Case B3 - Crossing maneuver from the minor road	departure*	B23	Use table to determine "b" dimension along major road. The "a" dimension is the distance from the middle of the furthest lane crossed to the outside edge of the traveled way nearest the stopped vehicle plus a minimum of 4.4 m (4.5 m to 5.4 m desirable) for the distance between the driver's eye and edge of traveled way. No adjustment for grade.
Case C - Intersections with yield control on the minor road	Case C1 - Crossing maneuver from the minor road	approach*	C1 & G	Use table to determine the "a" dimension along the minor road and the "b" dimension along undivided major roads. Use Table G to adjust for grade. For divided roadways, the "b" dimension is based on case B3 for wide medians and B1 for narrow medians.
	Case C2 - Left or right turn from the minor road	approach*	C2	Use table to determine "b" dimension along major road. Use 25 m for the "a" dimension on the minor road assuming the vehicle enters the intersection at a turning speed of 16 km/h and for left turns, the major road is only 2 lanes wide. (Note that if a stop is occurs, the distance "b" based on cases B1, B2, or B3 result in lower values and, therefore, do not need to be checked.) No adjustment for grade.
Case D - Intersections with traffic signal control		2.4 m from the stop bar on all approaches	Normally none	First vehicle stopped on one approach should be viewable by first vehicle stopped on all others. Permissive left turners should have sufficient sight distance to select gaps. For flashing yellow, use cases B1 and B2 for the minor road approaches. For approaches with right-turn-on-red, use case B2.
Case E - Intersections with all-way stop control		2.4 m from the stop bar on all approaches	Normally none	First vehicle stopped on one approach should be viewable by first vehicle stopped on all others.
Case F - Left turns from the major road		departure	F	Applies to intersections and left turns into driveways. Check at three-legged intersections and driveways on horizontal curves or crest vertical curves. The "b" dimension is along the major roadway travel lanes being crossed. The "a" dimension is from the eye of the turning motorist to the middle of the furthest travel lane being crossed. Use case B3 when the median width can store the design vehicle length plus 2 m.

5.9.6 Access Control on Uncontrolled Access Facilities

When projected volumes approach capacity (v/c of 0.90 or greater), intersection radii including exclusive turn lanes and jug handles should, if practicable, be protected by acquiring right of way without access. Greater length of access control should be considered if the cost would not increase appreciably.

5.9.7 Signalization

The decision to install or modify a traffic signal rests with the Regional Transportation Systems Operations Engineer. Both the Federal MUTCD and NYS MUTCD contain warrants for installing traffic signals at previously unsignalized or new intersections. Traffic signals should normally only be installed if one or more of the warrants in Part 271 of the NYS MUTCD are met and a traffic engineering study indicates that a signal may be justified. A traffic signal is not justified merely because one or more of the warrants are met. The NYS MUTCD warrants are based on vehicular and pedestrian volumes, accidents, progressive signal system needs, school crossings, the need for an interruption of continuous traffic on the major road, peak-hour volume, peak-hour delay, four-hour volumes, and systems (to establish traffic flow networks).

Before deciding to build a new signalized intersection or make major improvements to an existing signalized intersection (e.g., reconfigure the intersection, major widening on more than one approach), the alternative of using a roundabout is to be analyzed per Section 5.9.1 of this chapter.

Refer to Chapter 11, Section 11.3 of this manual for requirements and guidance on traffic signals.

5.9.8 Intersection Widening

Intersection widening increases intersection capacity and enhances safety by adding auxiliary lanes to serve heavier traffic maneuvers through the intersection. There may, however, be substantial impact to pedestrian traffic as a result of longer pedestrian crossing distances and more complex traffic signal phasing, especially where pedestrian volumes are high. The most common types of intersection widening include addition of exclusive left-turn lanes, exclusive right-turn lanes, and right-turn acceleration lanes. Capacity of the through movement can be increased by adding through lanes upstream of and through the intersection with a downstream taper back to the normal roadway width. Right-turn lanes and acceleration lanes pose special difficulties for bicyclists by requiring them to weave across or merge with higher-speed traffic. Chapter 18 of this manual illustrates a design treatment for right-turn lanes.

5.9.8.1 Additional Through Lanes

Capacity analysis may indicate the need for additional through lanes on the approach to a signalized intersection. The additional through lane(s) must then be carried through the intersection and downstream for sufficient distance to provide a safe merge back into the continuous through lanes as shown in Exhibit 5-28. Since added lanes are generally utilized less than the continuous through lanes, a lane utilization factor should be used. The merge taper should conform to merge taper requirements in Table 262-2 of the NYS MUTCD. The approach and departure taper should desirably conform to merge taper requirements in Table 262-2. As a minimum, they should be one half the length "L" determined from Table 262-2. A capacity analysis (e.g., using Synchro and Sim Traffic) should be used to determine the storage length for through and turning vehicles. Both the additional through lane and any exclusive left- or right-turn lane on that approach should be long enough to prevent queues in the through lane from blocking the turn lane entrance and vice versa.

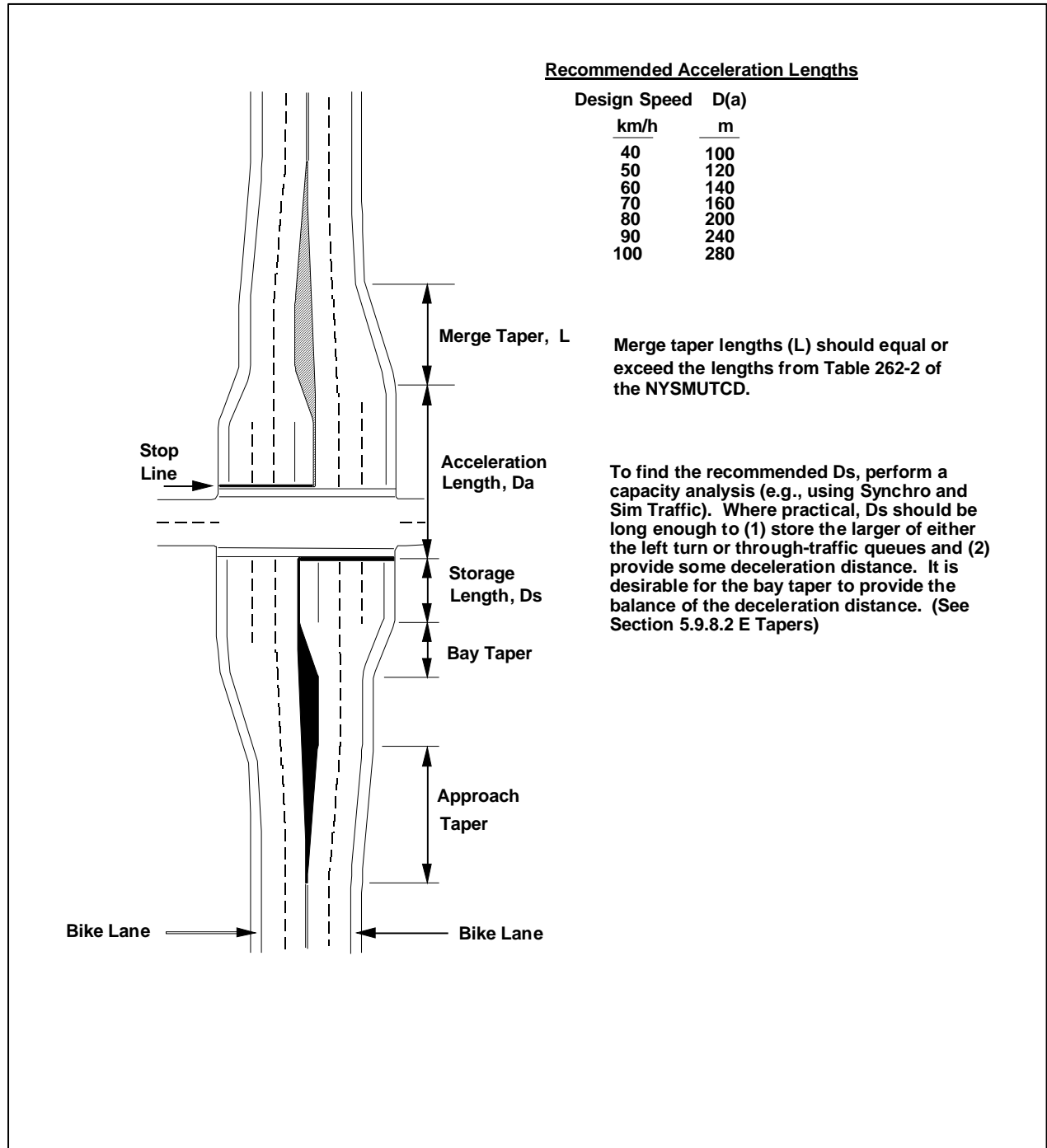
5.9.8.2 Turning Lanes

Exclusive left and right turning lanes increase capacity and enhance safety by removing turning vehicles from the through lanes. This reduces the interference to through traffic associated with vehicles decelerating and queuing in preparation for their turning movement. Exclusive left-turn lanes on multilane highways should always be considered since their absence requires left-turning vehicles to decelerate and/or stop in the high-speed lane. Exclusive left-turn lanes on two-lane highways allow the left-turning vehicle to decelerate and stop without obstructing through traffic.

Turning lane width should be in accordance with Chapter 2 of this manual. Alignment and sight distance criteria should not be compromised for the channelized movement.

A very important aspect of left-turn lane design is its placement relative to opposing through traffic. Left-turn lanes "offset" from through-traffic and the opposing left-turn lane provide a greater view of oncoming traffic, improving driver acceptance of gaps (see Exhibit 5-32). Research has indicated that older drivers in particular need this offset design. **This design feature is particularly critical at intersections where left turns are allowed to operate as "permitted" movements conflicting with opposing through-traffic.**

Exhibit 5-28 Intersection Widening for Heavy Through Traffic



A. Left-Turn Lanes

The decision to construct left-turn lanes should consider:

- The volume of left-turning traffic and the volume of opposing traffic. In some cases, capacity analysis may clearly indicate a need for left-turn lanes. Exhibit 9-75 in Chapter 9 of AASHTO's *A Policy on Geometric Design of Highways and Streets*, 2004, includes traffic volume criteria to be considered in determining the need for left turn lanes along two-lane highways.
- The accident history. An accident pattern of rear-end accidents involving queued left turners or vehicles turning left in front of opposing traffic is often mitigated by exclusive left-turn lanes. NYSDOT accident reduction factors show an average reduction of around 30% when a left-turn lane is installed and is an appropriate alternative to mitigate a left-turn accident problem.
- The accident potential and the anticipated operating speeds (i.e., the possible severity of an accident).
- Sight distance on the mainline affecting the ability to see a vehicle waiting to turn.
- The construction costs.
- The right of way impacts.

B. Double Left-Turn Lanes

Double left-turn lanes should be considered at signalized intersections with high left-turn demands or where a reduction in green time allocated to that left-turn movement can significantly benefit the intersection operation. While capacity analysis identifies the need for and impact of double left-turn lanes, left-turn demands over 300 vph and/or storage needs should trigger consideration of them. Fully protected signal phasing shall be provided for double left turns.

Provide adequate throat width on the approach receiving the double left turns to compensate for offtracking characteristics of turning vehicles and the relative difficulty of side-by-side left turns. Exhibit 5-25 shows a method of expanding the throat width to facilitate the double left turns. A car and the design vehicle should be able to comfortably turn side-by-side. An 11 m wide throat is desirable for double left turns with turning angles greater than 90°. Narrower throats can be provided for more favorable turning angles. A 9 m throat width may be adequate for 90° turns. In constrained situations with favorable turning angles less than 90°, 8 m throat widths may be acceptable. However, throat widths less than 9 m should normally be avoided since they can restrict turning traffic flow and reduce the operational benefit of double left-turn lanes. On the other hand, excessive pavement width, which can mislead drivers, should also be avoided.

If practicable, the intersection should be designed to allow the double left turn to be executed concurrently with the opposing left turn. This allows the flexibility in the signal phasing to serve the double left-turn movement concurrently with either the opposing left turns or the adjacent through movement. If the turning paths of the double left and the opposing left-turn overlap, the left turns cannot be served concurrently.

Dotted lines, in accordance with the NYS MUTCD, are the appropriate pavement markings used to separate the two-abreast turning lanes and especially opposing turning lanes. The dotted lines should reflect turning paths and have a gap of between 1.2 m and 2.0 m.

The design should prevent through traffic from accidentally entering and becoming trapped in the double left-turn lanes. The turning lanes should be fully shadowed wherever possible.

C. Two-Way Left-Turn Lanes (TWLTL)

Two-way left-turn lanes (TWLTL) are flush medians that may be used for left turns by traffic from either direction on the street. The TWLTL is appropriate where there is a high demand for mid-block left turns, such as areas with (or expected to experience) moderate or intense strip development. Used appropriately, the TWLTL design has improved the safety and operational characteristics of streets as demonstrated through reduced travel times and accident rates. The TWLTL design also offers added flexibility since, during spot maintenance activities, a travel lane may be barricaded with through traffic temporarily using the median lane.

TWLTL can reduce delays to through traffic, reduce rear-end accidents, and provide separation between opposing lanes of traffic. However, they do not provide a safe refuge for pedestrians, can create problems with closely spaced access points, and can encourage strip development with closely spaced access points. Consider other alternatives, before using TWLTL, such as prohibiting midblock left-turns and providing for U-turns.

TWLTLs should generally be limited to streets with no more than two through lanes in each direction. Seven-lane cross sections will likely cause pedestrian crossings to become too long and left turns very difficult in heavy traffic since oncoming vehicles may limit visibility and left turn opportunities. For six lane sections, a raised median design should be considered.

Consider installation of TWLTLs where:

- An accident study indicates that a TWLTL will reduce accidents.
- There are unacceptable through traffic delays or capacity reductions because of left turning vehicles.
- There are closely spaced access points or minor street intersections. A general rule is side road plus driveway density of 12 or more entrances per kilometer.

When one of the above conditions are met, the site may be considered suitable for the use of a TWLTL. Design guidance and requirements include:

- The desirable length of a TWLTL is at least 80 m.
- Consider street lighting in accordance with Chapter 12 of this manual.
- Pavement markings, signs, and other traffic control devices must be in accordance with the NYS MUTCD and NYS Standard Sheet 685-2.
- Provide clear channelization when changing from TWLTL to one-way left-turn lanes at intersections.
- Desirable and minimum widths for the TWLTL design are provided in Chapter 2 of this manual.

D. Right-Turn Lanes

The decision to install exclusive right-turn lanes should be based on a comparison, using capacity analysis, of intersection operations with and without the turn lanes. At signalized intersections, exclusive right-turn lanes optimize benefits of right-turns-on-red and protected right-turn movements served concurrently (overlapped) with a crossroad protected left-turn phase. Exclusive right-turn lanes may also be used on high-speed roadways to provide deceleration for right-turning vehicles clear of the through lanes. Right turn lanes may be effective at reducing:

- Rear-end collisions.
- Side swipe and head on collisions with opposing vehicles caused by motorists passing the turning vehicle.

Refer to Section 5.9.4.6 for guidance on channelized right-turning roadways.

E. Tapers for Turn Lanes

The length of the widened pavement should provide for turning-lane length and bay taper plus, in the case of left-turn lanes, the approach and departure tapers.

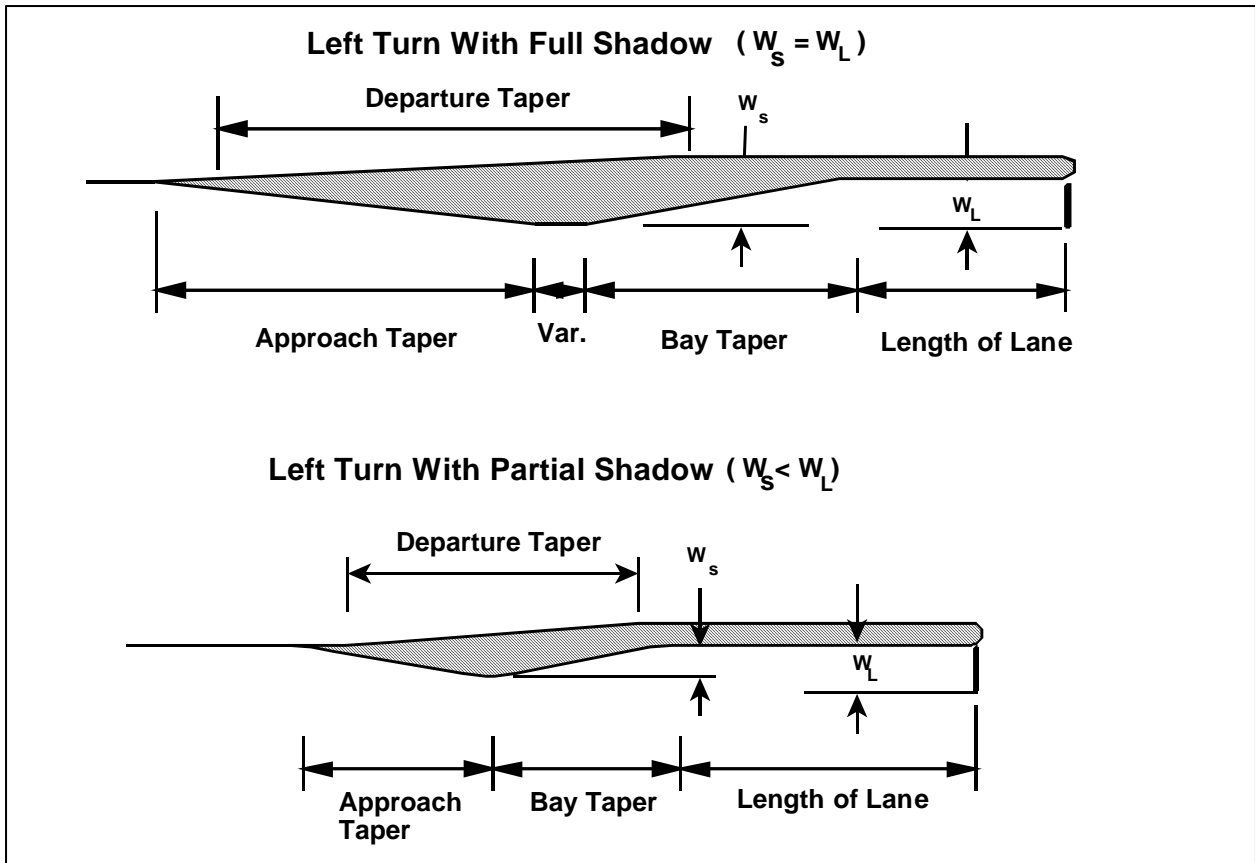
Approach tapers gradually divert through traffic to the right around the left-turn lane. Departure tapers guide through traffic, downstream of the intersection, to the left, back to the normal alignment where the through lane is adjacent to and parallel to the center line. Approach and departure tapers may be straight-line tapers, may include curves on both ends, or may include a reverse curve. The approach and departure taper should desirably conform to merge taper requirements in Table 262-2 of the NYS MUTCD. As a minimum, they should be one half the length "L" determined from Table 262-2.

Bay tapers guide turning traffic from through lanes into the turn lane. Bay tapers should be long enough to promote a smooth entry to the turn lane but short enough to enable motorists to identify the widening as a turn lane rather than another through lane. Bay tapers can be straight line tapers, with or without short curves at either end, or they can include a reverse curve as shown in Chapter 9 of AASHTO's *A Policy on Geometric Design of Highways and Streets*, 2004. A straight-line bay taper length equal to the product of the design speed (S) in km/h and the lateral shift (W) in meters divided by 4 (i.e., $SW/4$) is desirable. Minimum lengths for straight-line bay tapers in urban areas are based on taper rates ranging from 8 longitudinally to 1 transversely (8:1) for peak hour travel speeds up to 50 km/h through 15:1 at 80 km/h. Bay taper lengths should not exceed one-half the taper requirements in Table 262-2 of the NYS MUTCD. Bay tapers can be designed to fit specific needs within the above guidelines (e.g., to distinguish the auxiliary lane from the through lane).

Figure 5-20 shows how the approach taper and the bay taper can be designed to "shadow" or protect the left-turn lane from encroachments by through traffic. In rural and open urban areas, a fully shadowed turn lane permits the complete lateral shift of through traffic upstream of the bay taper. In constrained urban areas, the approach taper and the bay taper can be combined to partially shadow the turn lane by positioning through traffic to continue and complete its shift to the right while the left-turn lane is developing.

While the total turn lane and bay taper length desirably consists of the sum of the required lengths for storage and deceleration, constraints may necessitate assuming some deceleration within the through lanes prior to entering the taper. Deceleration lane length and tapers should conform to Chapter 9 of AASHTO's *A Policy on Geometric Design of Highways and Streets*, 2004. Exhibit 5-29 shows a typical left-turn lane.

Exhibit 5-29 Shadowing Left-Turn Lanes



F. Queue Storage

To function as designed, exclusive turning lanes must be long enough to prevent queued through traffic from blocking the entrance to the turn lane as well as queued turning traffic from blocking the through lane.

The needs of the individual components of the turn-lane length and their relationship to the total length can vary by time of day. Storage lengths, particularly for left turns, are considerably more complex and depend on the rate of arrivals, rate of departures, and in the case of signalized intersections, cycle length, phasing, and system progression, if any. The desirable design storage length at signalized intersections is twice the length required for the average signal cycle. A minimum of one and one-half the length required by the average cycle should be provided to accommodate surges in traffic which could otherwise cause operational problems which affect subsequent signal cycles.

Double left-turn lanes should be considered for left turn volumes over 300 vph. The storage length for double left turn lanes may be reduced to approximately one half of that needed for a single lane operation unless downstream conditions encourage unbalanced use.

A capacity analysis (e.g., using Vissim or Synchro and Sim Traffic) should be used to determine both left- and right-turn storage requirements. Since storage requirements are dependent on the traffic signal operation, the Regional Transportation Systems Operations Group should be involved in the design or, as a minimum, the review of the storage lengths. A high percentage of trucks warrants additional storage length.

At unsignalized intersections, desirable storage length should be adequate to store the number of turning vehicles expected to arrive in an average 2 minute period within the peak hour. All turning lanes should be able to store at least two passenger cars or a car and one truck, representing the design vehicle, if there are over 10% trucks in the stream. Assume a spacing of 2 m between queued vehicles.

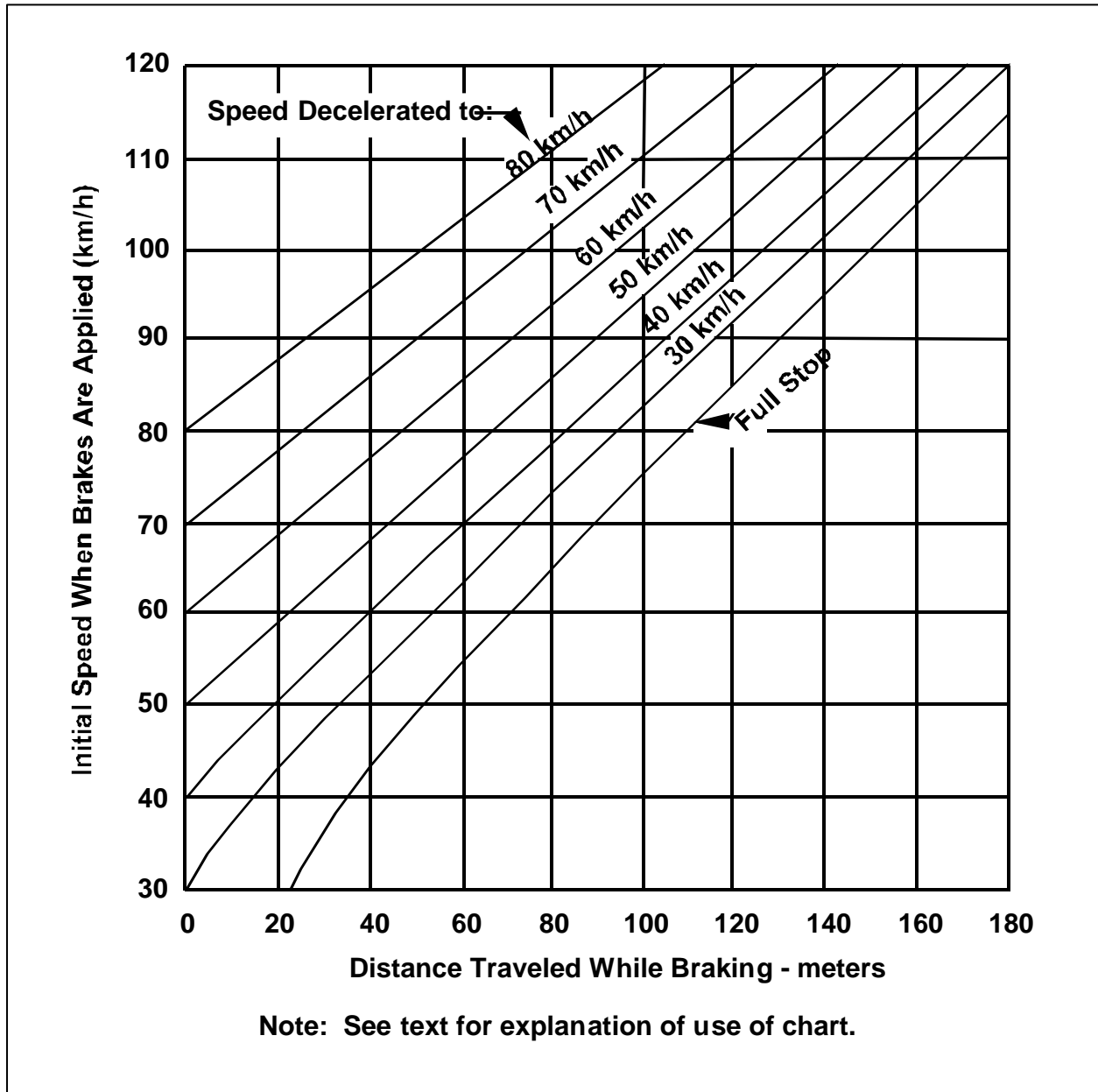
G. Turn Lane Lengths Based on Deceleration Distance

In constrained locations where desirable left-turn lane lengths may result in unacceptable costs or impacts, an alternative design method for constrained locations uses Exhibit 5-30 to determine the deceleration distance for braking at a comfortable rate. To use Exhibit 5-30 enter the chart from the left with the expected operating speed and follow the horizontal line until it intersects the line representing the appropriate speed (usually zero) decelerated to.

Then follow a vertical line down to the bottom of the chart and read or interpolate the deceleration distance along the horizontal axis. The deceleration distance is then added to a storage length equal to 1.0 m for every 3 vehicles per hour (vph) turning left. For an intersection approach having a design-hour, left-turn volume of 120 vph and an 85th

percentile approach speed of 80 km/h, the storage distance would be 40 m and the deceleration distance from Exhibit 5-30 would be 105 m. The total left-turn lane length (exclusive of tapers) would be 145 m. If constraints preclude the above method, contact the Design Quality Assurance Bureau Highway Design Manual Section for guidance.

Exhibit 5-30 Deceleration Distances for Passenger Cars Approaching Intersections (Braking at a Comfortable Rate)



5.9.8.3 Speed Change Lanes for At Grade Intersections

Speed change lanes minimize the disruption to through traffic from turning vehicles.

A. Suitability

The decision whether or not to provide acceleration lanes should be based on the volume of both through and entering traffic, the intersection geometry, and the 85th percentile speed of through traffic. Generally, right-turn acceleration lanes are not necessary when right-turning volumes are low and the traffic flow being entered has an 85th percentile speed equal to or less than 60 km/h. Acceleration lanes should be provided when both through and entering traffic volumes are high and the 85th percentile speed of through traffic is over 80 km/h. An acceleration lane may be necessary when right-turn volumes are high regardless of speeds on the intersected highway or the turning roadway intersects the highway at less than 60° as shown in Exhibit 5-25. Acceleration lanes are not usually needed at signalized intersections unless the turning movement is not controlled by the signal.

B. Speed Change Lane Geometry

Merging and diverging is most efficient when the angle is small (10° - 15°) and speed differentials are at a minimum. Acceleration or merging lanes should be long enough for merging traffic to attain the average speed of through traffic. Short or nonexistent merging distance can increase the potential for rear-end and other merging accidents. Substandard acceleration lane lengths may be worse than no acceleration lane due to the possibility of violating driver expectancies. Exhibits 10-70 and 10-71 from AASHTO's *A Policy on Geometric Design of Highways and Streets*, 2004, should be used to determine the speed change lane lengths. The turning roadway speed should be used to determine the initial speed and the off-peak 85th percentile speed of the highway that the traffic is entering should be used to determine desirable lane lengths. In urban areas or low speed rural areas, the minimum speed change lane lengths should be based on a speed on 20 km/h below the highway design speed.

C. Tapers for Speed Change Lanes

For speed change lanes, the deceleration taper should conform the bay taper as described in Section 5.9.8.2 E. Where high speeds are anticipated, the taper should conform to Chapter 10 of AASHTO's *A Policy on Geometric Design of Highways and Streets*, 2004.

5.9.8.4 Safety Widening At Rural Intersections

The potential for rear-end accidents at intersections on high-speed (80 km/h and up), two-lane rural roads can be reduced by providing a left-turn slot to separate slowing or stopped turning traffic from high-speed through traffic. Safety widening should be considered where:

- The available stopping sight distance is less than the decision sight distance specified in Chapter 3 of AASHTO's *A Policy on Geometric Design of Highways and Streets*, 2004, for a stop on a rural road (avoidance maneuver A).
- There is an accident pattern correctable by separating left-turning traffic from through traffic
- Higher traffic volumes increase the time a left-turning vehicle must sit in the travel lane waiting for gaps in traffic; increasing the potential for rear-end collisions.

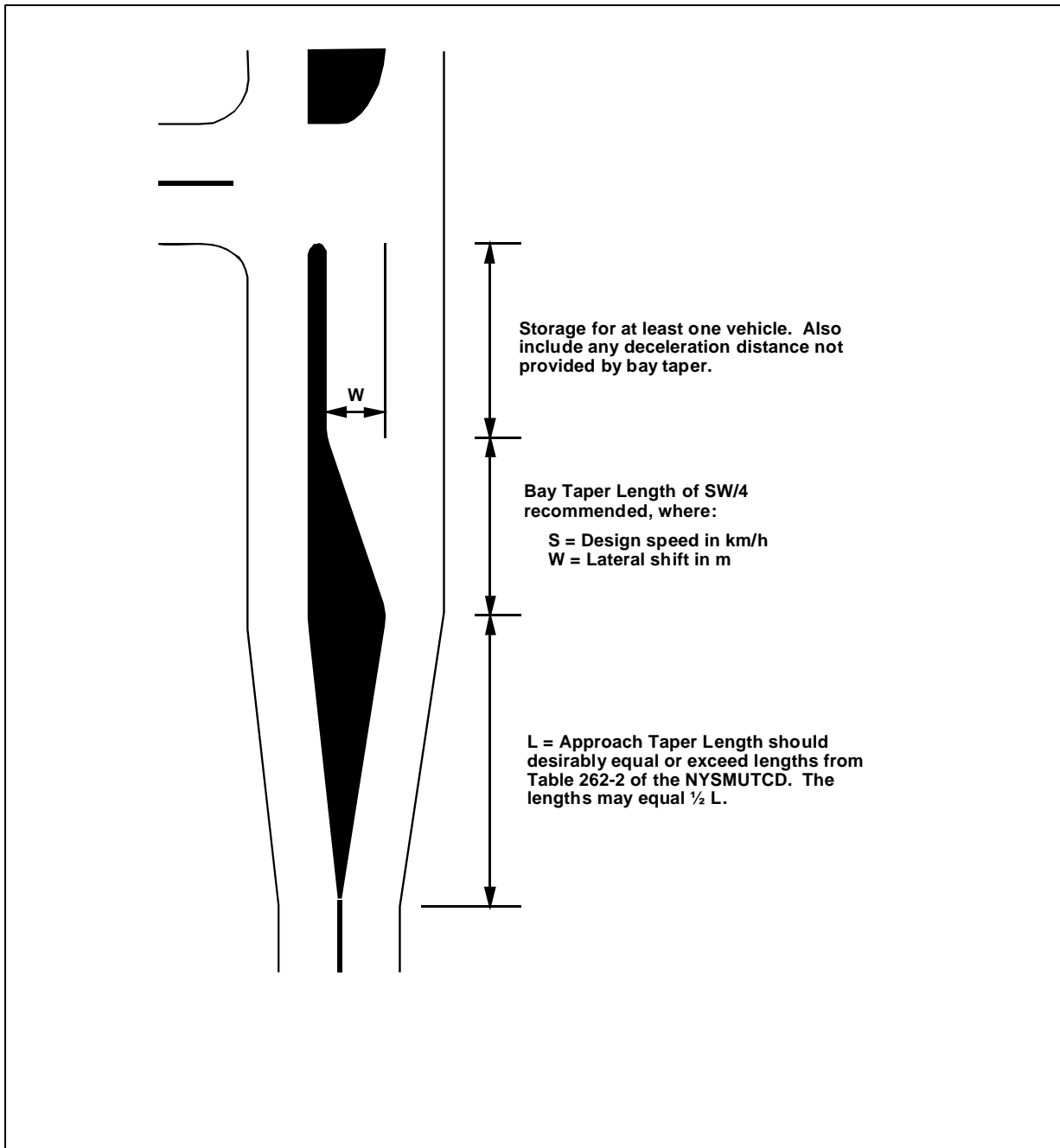
Since safety widening addresses a speed differential rather than a capacity need, it should, if practicable, provide full deceleration distance from the 85th percentile speed in the total length of the bay taper plus the full-width turn lane. Chapter 10 of AASHTO's *A Policy on Geometric Design of Highways and Streets*, 2004, or in more constrained conditions, Exhibit 5-30 can be used to determine the deceleration distance required. In addition to the deceleration distance, provide storage for at least one design vehicle. The widening should conform to Exhibit 5-31. If constraints preclude standard taper and deceleration lengths, provide the optimal practical design and document the nonconforming left-turn lane in the Design Approval Document.

The use of a shoulder by-pass lane (i.e., a widened and/or "beefed-up" shoulder that is striped for use by through traffic to go around left turning vehicles) is currently not an acceptable practice and should not be used in lieu of safety widening. This should not be confused with the practice of beefing-up shoulders that remain striped as shoulders (see Chapter 3, Section 3.2.5.2).

5.9.9 Bus Stops/Turnouts

Bus stops and turnouts should, if practicable, be located at the far side of intersections to facilitate bus and traffic operations. Bus turnouts at intersections with a free right turn should be located 15 m downstream of the end of the right-turn acceleration lane merge taper. Bus turnouts should be provided if the bus stop is on the receiving side of a double left- or right-turn movement and there are only two lanes serving traffic departing the intersection. See Exhibit 5-25 and Section 5.7.18.

Exhibit 5-31 Safety Widening at T-Intersection on Rural Two-Lane Road



5.9.10 Divided Highway Median Openings in Urban Areas

Refer to Chapter 3, Section 3.2.8.2 for guidance on choosing between raised or flush medians. The median at an intersection leg should be the same type as on the highway approach. If left-turn volumes require substantial storage for queued left-turning vehicles on an intersection approach which has a continuous two-way, left-turn lane, consider striping the median as a one-direction, left-turn lane far enough upstream of the intersection to provide the storage length required for the left-turning volume.

Raised median openings with left-turn lanes should be provided only at major cross streets and to serve large traffic generators or emergency vehicles. Pedestrian and bicycle travel patterns are to be considered. The designer should, if practicable, avoid opening the median for low-volume (one-way, design-hour volume of 100 vph or less) intersecting streets and left-turn movements from the arterial. U-turn movements should be accommodated at major intersections. The availability of alternate travel paths (e.g., frontage roads) should be considered and may permit elimination of median openings for cross streets with one-way, design-hour volumes over 100 vph. Consider providing roundabouts or indirect, left-turning roadways or jughandles for left turn access if ROW costs and impacts are not excessive. See Exhibit 5-21.

If the median is not wide enough to provide refuge for side-street vehicles crossing one direction of mainline traffic at a time, consider leaving the median unopened if signal warrants are not met. Mainline speeds, traffic volumes, and sight distance are among the factors to be considered in this determination.

Design of median openings should consider the need for traffic to access properties on the other side of the raised median between median openings. Chapter 9 of AASHTO's *A Policy on Geometric Design of Highways and Streets*, 2004, describes design considerations and alternatives for "direct" (from the median left-turn lane at the intersection) and "indirect" U-turns (other than from the median left-turn lane at the intersection). If direct U-turns are to be encouraged, the left-turn lane should be long enough to store both left turn and U-turn traffic. Refer to Chapter 3 of this manual and Chapters 4 and 9 of AASHTO's *A Policy on Geometric Design of Highways and Streets*", 2004, for further design guidance including length of median opening, turning path radii, and median end shape.

A simple median opening of minimum design which accommodates the design vehicle may be sufficient at minor intersections on a low-speed divided highway with low to moderate traffic volumes. Higher speeds, mainline through volumes, turning demand, and cross street flow require median design adequate to accommodate turning movements with little or no interference between traffic movements.

To improve operations and sight distance at intersections where the median width is 5 m to 8 m, provide a flush divider to the right of the left-turn lane to direct the left-turning vehicle as far to the left as possible thereby reducing the potential for opposing left-turning vehicles to obstruct each other's view of opposing through traffic. See Exhibit 5-32.

Special attention must be given to all aspects of traffic operations and safety in all medians over 8 m wide. See Exhibit 5-32. Signalized divided intersections where opposing left-turn lanes or the left edges of traveled way are separated by more than 9.14 m should be treated as two intersections with separate traffic signals and/or stop or yield signs. If the median is not wide enough to allow storage of arriving vehicles between the two signals, special signal phasing (double clearances) must be provided to clear turning and cross-street traffic from the median area between the two signals. The design shown in Exhibit 5-33 eliminates the need for two separate signals by locating the opposing left-turn lanes within 9.14 m of each other. This design also provides the flexibility to provide signal phasing which serves both left turns concurrently.

The design of unsignalized divided highway crossings should consider the possibility of eventual signalization or other improvements to the crossing. Safety concerns can result in signalization or reconstruction of high-speed, divided highway crossings long before traffic volumes do.

Exhibit 5-32 Left-Turn Slot With Divider on Right

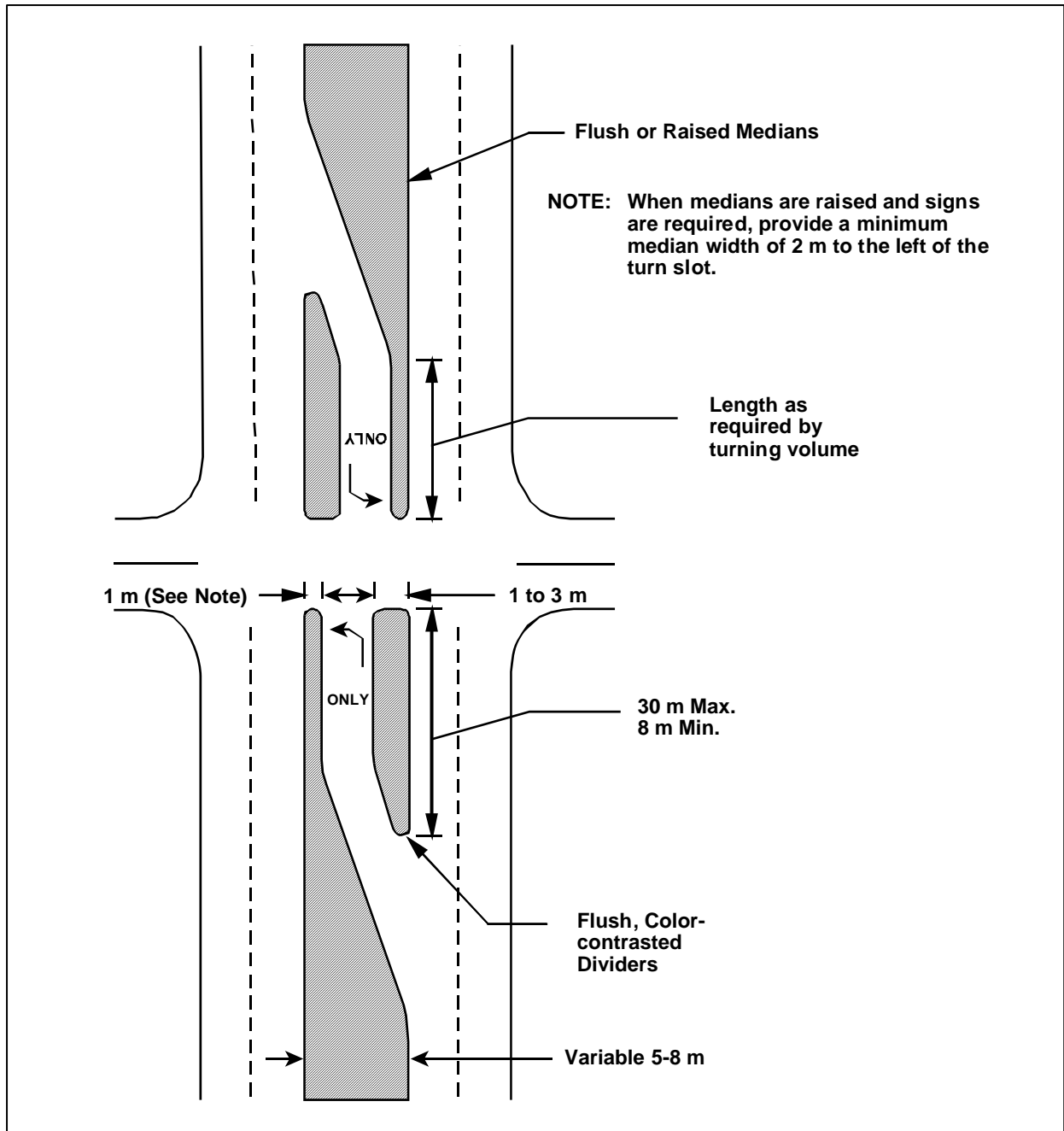
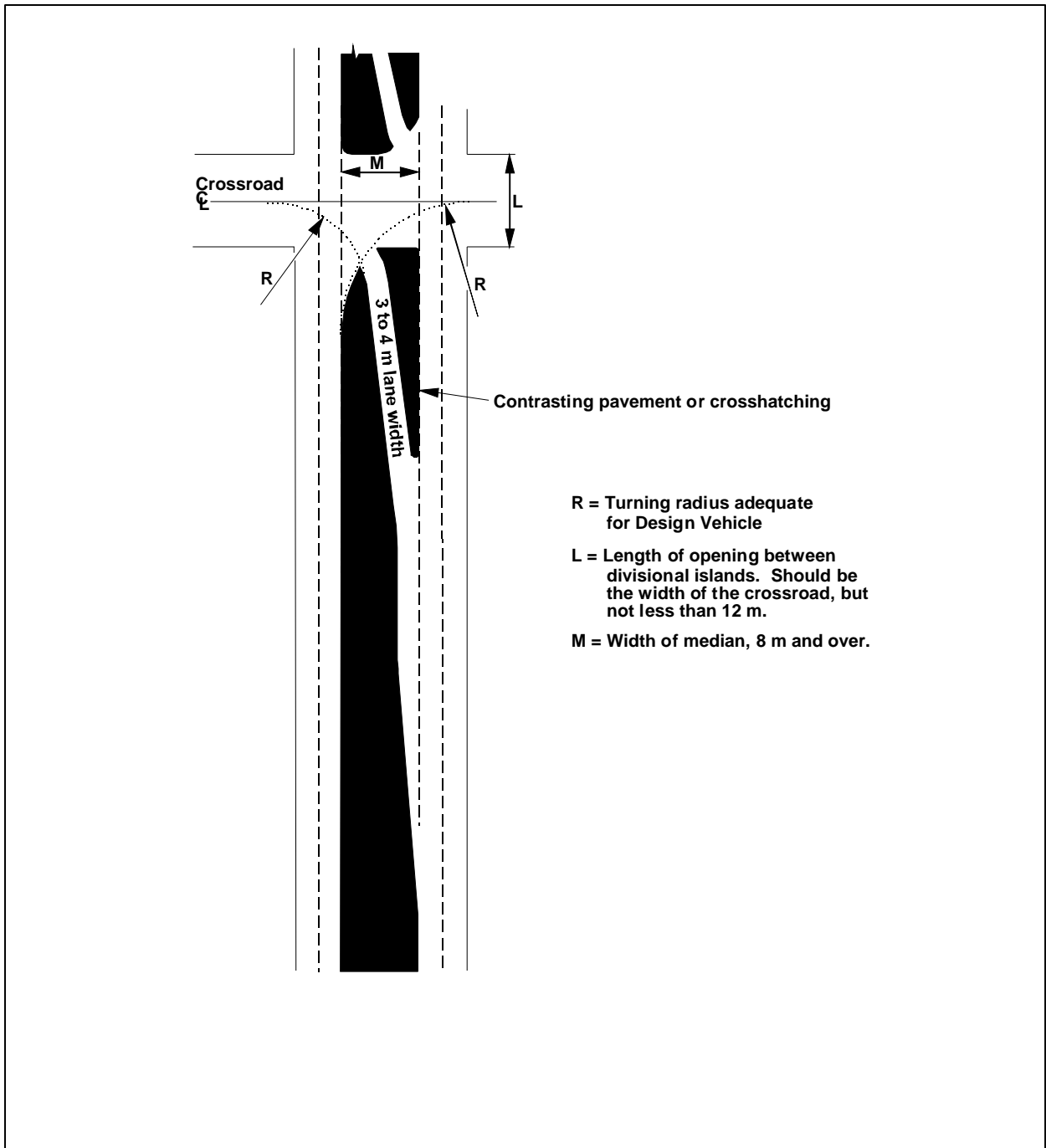


Exhibit 5-33 Design of Median Lanes for Medians Over 8 m Wide



5.10 REFERENCES

1. *A Policy on Geometric Design of Highways and Streets*, 2004, American Association of State Highway and Transportation Officials, Suite 225, 444 North Capitol Street, N.W., Washington, D.C. 20001.
2. *A Policy on Design Standards – Interstate System*, 2005, American Association of State Highway and Transportation Officials, Suite 225, 444 North Capitol Street, N.W., Washington, D.C. 20001.
3. *A Toolbox for Alleviating Traffic Congestion*, 1989, Institute of Transportation Engineers, 525 School St., S.W., Suite 410, Washington, D.C., 20024.
4. *Americans with Disabilities Act Accessibility Guidelines*, United States Access Board, 1331 F Street NW, Suite 1000, Washington DC 20004-1111.
5. Bridge Manual, 2006, Structures Design and Construction Division, New York State Department of Transportation, 50 Wolf Road, Albany, NY 12232.
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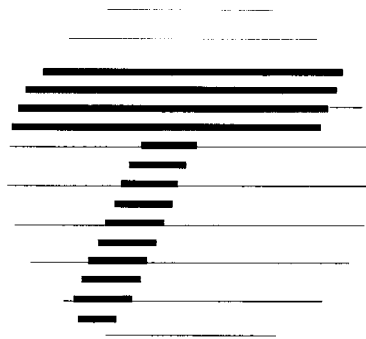
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APPENDICES

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**NEW YORK STATE
DEPARTMENT OF TRANSPORTATION**



**POLICY and STANDARDS
for the Design of Entrances to State
Highways**

November 24, 2003

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APPENDIX 5A DRIVEWAY DESIGN POLICY

POLICY AND STANDARDS FOR THE DESIGN OF ENTRANCES TO STATE HIGHWAYS

PREFACE

This policy (commonly referred to as the “Driveway Design Policy”) outlines the Department’s technical and procedural requirements involved in the planning, design, construction and maintenance of entrances to a State highway. While this policy is most commonly used for driveways, it applies to all entrances, including walkways, stairways, city and village streets, town and county highways, private access roads, subdivision roads (defined in Section 5A.10 of this policy), and roads owned by other State agencies and authorities.

Property owners seeking to build or improve an entrance to a State highway must, in addition to meeting applicable local requirements and the State Environmental Quality Review Act (SEQR), obtain and comply with all conditions of a New York State Department of Transportation Highway Work Permit. Issuance of the Highway Work Permit is contingent upon Department review and approval of the planning and design details of the entrance.

Property owners, developers, consultants, and local officials play important roles in the process and should be aware of specific portions of this policy.

- Sections 5A.2 and 5A.3 outline the responsibilities of the property owner. Since **residential driveways** have less impact on the highway system than commercial driveways and subdivisions, residential property owner responsibilities are generally limited to Sections 5A.2.1 and 5A.3.1 through 5A.3.6. Design requirements for residential driveways are detailed in Sections 5A.4, 5A.5, and 5A.9.
- Sections 5A.4, 5A.6, 5A.7, and 5A.9 contain **commercial driveway** design requirements, which may be useful to consultants hired by the property owner to plan and design the access to the highway.
- Section 5A.4, 5A.7, 5A.8, and 5A.9 contain **subdivision, municipal street and municipal highway** design requirements, which may be useful to developers and municipalities planning and designing access to a State highway.
- Sections 5A.2 and 5A.4 include procedural requirements and general design guidelines, respectively, which may interest **local government planning and review agencies or boards**.

This policy is in dual units. Metric units are shown with U.S. customary units in parentheses. Similarly, the metric NYSDOT Driveway Standard Sheet references (currently M608-6 through M608-9) are provided with references to Figures 5A-2 through 5A-5 (in U.S. customary units) in parentheses. The values are hard converted (not a precise conversion) to better represent the degree of accuracy needed.

**APPENDIX 5A
DRIVEWAY DESIGN POLICY**

COPIES

Electronic copies of this policy and the highway work permit forms are available on the Department's Internet home page under <http://www.dot.state.ny.us/traffic/tehsdmain.html>. For detailed information on the permitting process and its requirements, refer to the Department's Manual of Administrative Procedure 7.12-2 on Highway Work Permits.

CONTACT PERSON

Questions concerning this policy should be directed to the NYSDOT Highway Maintenance Resident Engineer. Names and phone numbers for the Resident Engineers are provided:

- On the Internet at <http://www.dot.state.ny.us/reg/regmenu.html>. Click on your location on the state map and then on the link for "organization, contacts & phone numbers."
- In the Government Listings (blue pages) of your local phone book. Look under State Offices, then Transportation Department of, and then Transportation Maintenance.
- By calling the Main Office Highway Work Permit Section at 1 (888) 783-1685.

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List of Current NYSDOT Driveway Standard Sheets

Standard Sheet M608-6	Driveway Design Guidelines
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Standard Sheet M608-8	Driveway Entrance Layout
Standard Sheet M608-9	Driveway Opening Limits

5A.1 INTRODUCTION

Section 52 of the New York State Highway Law and Section 1220-a of the New York State *Vehicle and Traffic Law* prohibit entrance on and work being performed on any State highway except pursuant to the authority of a permit and under rules and regulations prescribed by the Commissioner of Transportation.

In accordance with the exercise of these duties, the Department of Transportation has standards and procedures governing such work within the highway right of way including the construction of entrances to State highways so as to regulate traffic entering or leaving abutting properties. These policies, standards, and procedures protect the public through orderly control of traffic movements onto and from the highway, preserve the public's investment in highway capacity, and assure uniform design and construction of entrances and exits statewide.

A highway serves two major purposes as a part of a transportation facility. It must facilitate safe and efficient movement of people and goods and provide reasonably convenient access to the abutting property owner. Driveway regulation is intended to balance these two roles without allowing one to become a serious detriment to the other and is implemented by the Highway Work Permit review process described in this and other related publications. Available research links increased numbers and width of commercial access points and undesirable locations with increased accidents. Uncontrolled access can increase accidents, disrupt traffic flow, degrade air quality, reduce commercial viability of the corridor, result in early functional obsolescence of the facility, and require costly remedies. Good control of access can diminish these adverse impacts by minimizing points of conflict between through traffic and entering or exiting traffic and separating the highway from activities on abutting property.

The Highway Work Permitting process, which governs access from individual properties to State highways, begins when an application for a highway work permit is filed. To achieve a desired balance between the mobility and access functions of the State highway system, localities should join with the Department in looking beyond individual driveways and developments and apply a corridor or subarea perspective by coordinating access and land use control decisions.

The Department meets with local planning boards and other local officials and works pro-actively to increase public awareness about access control safety and mobility concerns. Through local officials, the Department encourages developers to apply for a highway work permit at a time early enough in the local process that both local land-use and access control concerns can be addressed in a coordinated fashion. The Department, local officials, and developers all benefit from this coordinated approach since it improves safety and mobility and reduces the potential for design changes.

DRIVEWAY DESIGN POLICY

A desired approach is for the local governments and Department to coordinate their respective decision-making processes when applicable and appropriate. One method of improving coordination is through the Department's Arterial/Access Management Initiative. The initiative is a collaboration between the Department and local governments which focuses on melding transportation and land-use management strategies to preserve and enhance mobility while promoting development along uncontrolled access facilities. A consistent recommended approach is to utilize the State Environmental Quality Review Act (SEQR) coordinated review process (See Section 5A.2.2.3 of this policy). Successful application of these efforts will allow for a more orderly and comprehensive consideration of transportation and access needs and may facilitate the accommodation of individual highway work permits.

The Department, through the Highway Work Permitting and SEQR processes, identifies impacts on State highways that would occur from proposed developments. As a condition of the Highway Work Permit, the Department requires developers to mitigate significant adverse traffic impacts on State highways caused by the permitted development. The Department recognizes the importance of development to local and regional economies and is committed to assisting developers and local governments coordinate the Highway Work Permitting process with the SEQR process.

The provisions, guidelines, standards, and procedures set forth in this publication are consistent with those for Department work and represent the official policy of the Department of Transportation governing driveway, walkway, and stairway entrances to State highways and shall become effective January 1, 2004, thereby superseding previous policy and standards adopted for these same purposes.

While this policy is intended to provide statewide uniformity, Department personnel responsible for access control will exercise judgement to provide the most effective and practical degree of access control. The Department of Transportation shall be the sole authoritative interpreter of the content and intent of this publication.

5A.2 GENERAL POLICY FOR THE DESIGN OF ENTRANCES TO STATE HIGHWAYS

5A.2.1 Non-Department Projects / Highway Work Permits

This section does not apply to Department projects. Highway work permits for entrances to State Highways are subject to the following conditions and limitations:

5A.2.1.1 Access to a State Highway

Any person, institution, or corporation desiring permanent, improved, or temporary access to, or performing work within a State highway right of way shall obtain a Highway Work Permit from the Department of Transportation and comply with all conditions of its issuance. Any approval by the Department is contingent upon the applicant signing the Highway Work Permit application, thereby promising to complete work required by the Department as specified in the permit.

Written application for such permit (see Form PERM 33, Highway Work Permit Application for Non-Utility Work, included in the back of this policy) shall be made to the Department of Transportation through the appropriate Resident Engineer, and shall be accompanied by plans, drawings, or a sketch indicating the work proposed, including the applicable design dimensions required. Applicants for permits to undertake residential driveway, walkway, or stairway approaches to or from a State highway shall use the enclosed Residential Driveway Form to supplement form PERM 33. Applications for work permits will be accepted only from property owners or their authorized agents who will be named as principal(s) on the performance bond (if required). Certification of legal ownership or owner's authorization may be required. On approval of the application by the Department, a permit will be issued stipulating conditions under which the installation is to be performed.

If a property owner, lessee, or agent fails to comply with the terms of a permit or to obtain a permit, the Department may halt the activity for which a permit is required until adequate corrections have been made. Costs incurred by the Department in correcting failures to comply with the terms and conditions of a permit, failures to obtain a permit, or defective workmanship or materials shall be borne by the permittee or person undertaking the activity. The provisions of this policy shall not apply to entrances already in existence on March 31, 2004 or permits submitted for approval by March 31, 2004. This policy shall apply to any **new driveways, walkways, or stairways** and **improvements** within the State right of way to existing driveway, sidewalk, walkway, or stairway submitted for approval **after** March 31, 2004. Improvement is defined as one or more of the following.

- Resurfacing (excludes driveway sealant).
- Rehabilitation and reconstruction.
- Replacement of existing drainage pipe.
- A change in width, grade, or location.
- A change in traffic control (excluding the installation of stop signs).

5A.2.1.2 Mitigation

A. New Driveways

Developers of commercial property and large subdivisions may, as a condition of the permit, be required to mitigate the impacts of their development to maintain the same level of service, safety, operation, and/or other measure of traffic conditions as the affected highway(s) would experience without the development. The impacts and required mitigation will be determined, subject to Department approval, by a Traffic Impact Study (TIS) conducted by the permittee based on full build-out of the development in the estimated year of completion. The TIS should be completed in accordance with Department requirements and is subject to approval by the Department under the Highway Work Permitting process and the SEQR lead agency as a component of the SEQR Environmental Review Process.

If traditional measures do not adequately quantify traffic impacts, the Department may select alternative measures including, but not limited to, increased travel time or delay, queue lengths, lengthened duration of congestion, and air quality. At locations where the highway is at or near capacity, traffic simulation programs defining queue length and speeds may be necessary to get an accurate understanding of the generated traffic's impact and the effectiveness of the mitigation.

Entrances to large traffic generators such as shopping centers, industrial plants, etc., may require improvements on or off the highway to accommodate the increased traffic flow caused by their presence. Such improvements may include, but are not limited to, acceleration, deceleration, through, or turning lanes, traffic signals on the State highway, extended throat lengths, provision of service or access roads, and appropriate internal circulation off the highway.

Improvements, as approved or directed by the Department, to the State highway to mitigate adverse traffic impacts from full build-out of the proposed action under SEQR are required under the work permit and are the responsibility of the permittee. Where the width of the highway right of way is insufficient to permit the construction of such improvements, the property owner may be required to provide to the Department additional right of way of sufficient width to construct such improvements or downsize the project such that the necessary mitigation can be accommodated within available right of way.

Mitigation of full build-out traffic impacts should be completed to the satisfaction of the Regional Traffic Engineer before opening of the development, unless phasing of work is allowed by the Department with adequate controls to assure the performance of future work.

Where strict application of this policy to new or improved driveways may create a severe economic hardship for the property owner, the Department may, at its discretion after an engineering review, grant exceptions to this policy where such exceptions are not likely to interfere with efficient and safe flow of traffic on the highway. In any event, the Department will be the sole authority for approving impact mitigation proposals.

B. Existing Driveways

Whenever a change or expansion of a business or other land use is expected to increase traffic flow on the State highway system through an existing driveway, it may be necessary for the owner to mitigate the impact of the increased traffic by improving the driveway and/or highway. Highway and driveway improvements may include, but are not limited to, driveway relocation or closure, signal installation or modification, and/or widening needed for the safe and efficient flow of traffic. The Regional Traffic Engineer may, in the interest of public safety, authorize restrictions on movements into and/or out of the driveway if the necessary improvements are not completed.

5A.2.1.3 SEQR Coordination

The Department will not issue a Highway Work Permit until all the SEQR requirements are met. The coordination of the two processes (Highway Work Permit and SEQR) is critical; however, the timing can lead to problems. The SEQR process is usually completed (sometimes months) before a permittee's application for a Highway Work Permit is submitted to the Department. If there has been no coordination between the local government and the Department during the SEQR process, delays can arise during the Highway Work Permitting process. To avoid unnecessary delays and problems, the following suggestions are offered.

- Local governments should notify the Department as early as possible when considering access to a State highway.
- SEQR lead agencies should invite and encourage early Department involvement to identify impacts. A coordinated review should be pursued. A coordinated review is defined by the SEQR Handbook as, "The process by which all involved agencies cooperate in one integrated environmental review."
- Lead agencies should consider the merits of the Scoping Phase of the SEQR process particularly when dealing with complex developments involving several agencies and impacts. It is during the scoping phase that involved agencies have an opportunity to express their data and information needs, concerns, and expectations. Scoping, if done correctly, can go a long way toward avoiding future confusion and unrealistic expectations.

Section 2.1 of the NYSDOT Environmental Procedures Manual discusses the Department's SEQR responsibilities. On projects requiring the issuance of a Highway Work Permit, the Department usually participates in the SEQR process as an involved agency and will:

- Issue a Record of Decision when the lead agency prepares an Environmental Impact Statement and issues a Record of Decision.
- Issue a SEQR determination when the Department is the lead agency.
- Coordinate with other involved agencies and issue a SEQR positive declaration if the lead agency has conducted an uncoordinated review processes and must prepare an Environmental Impact Statement.
- Not issue a SEQR determination on other projects.

5A.2.1.4 Arterial/Access Management Initiative

The Arterial/Access Management Initiative is a State and local collaborative process combining transportation planning and local land-use planning tools to protect the functional integrity of the highway network and provide safe and efficient access and mobility. The major elements of Arterial/Access Management include a combination of:

- Access management.
- Land use planning and controls.
- Corridor preservation.
- Transportation improvements.
- Finance techniques.

Access points are a major source of accidents and congestion on highways with abutting commercial strip development. In these areas, driveway spacing directly effects the highway's safety and functionality. Optimal driveway spacing cannot be precisely determined, but there is a consensus that driveway spacing on the order of 90 m to 150 m (300 ft to 500 ft), depending on the operating speed on the highway and the traffic generation of the development, is desirable to reduce accidents and maintain the flow of traffic. Achieving desirable spacing is particularly important on congested highways with existing or emerging commercial and retail development. It may be impractical to achieve desired spacing due to limited lot frontages, existing driveways and site constraints; nonetheless efforts should be made to improve driveway spacing even if the desired values cannot be attained.

Driveway spacing can sometimes be improved by consolidating the access to multiple sites. These and other access management techniques are typically implemented over time in cooperation with local government as a part of local access management plans and can also be included as elements of Department capital projects. To be effective, access management plans require a high level of coordination with local government, both in the development and implementation of the plans.

For additional information, refer to:

- TRB Circular 456 *Driveway and Intersection Spacing* for a discussion of spacing issues.
- *Best Practices in Arterial Management* NYSDOT Mobility Management Bureau, 1997, for a full discussion of access management techniques that can be used to achieve more functional driveway spacing and manage the effects of land development on arterials.
- NYSDOT's Internet web site at <http://www.dot.state.ny.us>.

5A.2.2 Department Projects**5A.2.2.1 Project Types**

On Department Reconstruction or Resurfacing, Restoration and Rehabilitation (2R/3R) contracts, the Department will alter, at its own expense, existing entrances to State highways to comply with the spirit and intent of the policy and standards herein.

On simple resurfacing projects (e.g., 1R) and other preventive and corrective maintenance projects, existing entrances are only altered if they contribute to safety or operational problems. If problems are identified, the driveway should be modified by the Department to comply with the spirit and intent of the policy and standards herein.

5A.2.2.2 Driveway Work Release

If the limit of work is extended beyond the existing highway right of way to obtain adequate driveway geometrics, the Department should attempt to obtain driveway work releases (see Form HC 199, Request for Reestablishment of Approaches to Private Lands, included in the back of this policy). If the property owner refuses to sign the driveway work release, he/she should be advised that the Department will proceed with the project without reestablishing the driveway. Any future work to reestablish the driveway will be the property owner's responsibility and will require a Highway Work Permit (see Form PERM 33, Highway Work Permit Application for Non-Utility Work, included in the back of this policy).

5A.2.2.3 Walkways and Stairways

If the limit of work is extended beyond the existing highway right-of-way to obtain walkway or stairway designs that meet the applicable requirements, the Department should attempt to obtain work releases (see Form HC 199, Request for Reestablishment of Approaches to Private Lands, included in the back of this policy). Any property owner who refuses to sign the work release should be advised that the Department will proceed with the project without reestablishing the walkway or stairway. Any future work to reestablish the walkway or stairway will be the property owner's responsibility and will require a Highway Work Permit (see Form PERM 33, Highway Work Permit Application for Non-Utility Work, included in the back of this policy).

5A.2.2.4 Exceptions

In cases where strict compliance with the provisions of this publication may cause severe hardship to the property owner, the Department may consider exceptions to permit existing driveway entrances to remain unaltered where this is not likely to interfere with efficient and safe flow of traffic on the highway. Driveway locations should not be altered in the field without consultation with the project designer.

5A.3 CONDITIONS AND LIMITATIONS OF HIGHWAY WORK PERMITS

This section does not apply to Department projects. Highway work permits for entrances to State Highways are subject to the following conditions and limitations.

5A.3.1 General Conditions

- Work should start within the time period specified in the permit. The permittee shall notify the Resident Engineer before work is started and when it is completed, on or before the estimated completion date. The Department may grant an extension of time if valid reasons exist for the delay.
- All work completed and materials used within the right of way shall meet the Department's current *Standard Specifications for Construction and Materials* and is subject to Department approval on a case-by-case basis.
- All work completed and materials used within the right of way shall meet the terms and stipulations of the permit. The Department will make every reasonable effort to include all required stipulations and conditions of work in the permit before the work begins. If additions or alterations to either the work or the conditions of the permit are required after work commences, written Department approval shall be secured before such additions or alterations are undertaken by the permittee.
- The entire cost of the work specified shall be borne by the permittee, his grantees, successors, and assignees.
- The permittee shall have a copy of the permit available at the site at all times during construction.
- Piped or channelized natural drainage shall not be permitted to flow onto a highway right of way unless special provisions are approved by the Department.
- The permittee shall remove all surplus materials to an area outside the right of way unless the permit provides for disposal at locations within the right of way. Excavated material from within the right of way shall be disposed of as directed by the Department.
- Mitigation work shall be completed to the Department's satisfaction before opening of any access to the State highway.

5A.3.2 Insurance

A permittee shall not hold the Department liable for any claim for damages arising from his/her negligence, or his/her contractor's negligence in operations covered by the permit. Protective liability insurance to cover the Department during the period of work within the right of way is mandatory and, with the exception of permits for major commercial driveways and subdivision streets, may be obtained from the Department at a nominal cost. Major commercial and subdivision permit applicants shall have their own protective liability insurance demonstrated by providing a Certificate of Insurance for Highway Work Permits.

5A.3.3 Inspection

The Department reserves the right of inspection by its authorized representatives of construction or reconstruction of any driveway, walkway or stairway within the highway right of way. As a condition of issuance of the highway work permit, the permittee shall reimburse the Department for the cost of on-the-job inspection in excess of one person-hour, sometimes required for major and minor commercial developments. For commercial driveways requiring more than 5 days of inspection time, the permittee may, as a condition of the permit, be required to hire a Consultant, subject to Department approval, to perform construction inspection and supervision services. These inspection agreements are detailed on the PERM 50 Form, Inspection and/or Supervision Payment Agreement for Highway Work Permits, available on the Department's Internet site at <http://www.dot.state.ny.us>.

5A.3.4 Performance Bonds and Deposits

A performance bond and/or a deposit (certified check) and/or a letter of credit naming the permittee as principal is required for a permit issued for various work stipulated in the permit in order to protect the Department against the cost of completing construction or correcting deficiencies. The deposit will be returned when the work is completed to the satisfaction of the Department and all conditions of the Highway Work Permit have been met. The performance guarantee and amount will be prescribed by the Department, consistent with the scope and magnitude of the work involved. A perpetual bond to assure proper maintenance of driveway elements and detention ponds essential to the proper functioning of the State highway may be required.

5A.3.5 Traffic Control and Work Site Safety

The permittee and/or contractor shall take all necessary precautions and employ appropriate methods to preserve traffic flow, prevent injury to persons, or damage to property from operations covered by the permit and shall use guide, warning and regulatory signs and safety devices in accordance with the *Title 17, Volume B of the NYCRR* (a.k.a. New York State Manual of Uniform Traffic Control Devices (NYS MUTCD)), the current NYSDOT *Standard Specifications for Construction and Materials* and other Department guidance. The Department may require the permittee to submit plans showing such precautions, methods, and traffic control devices. The Department may, as a condition of the work permit, impose work restrictions as necessary to minimize disruption to traffic flow during peak travel periods. In all cases, the Department will be the final authority in matters related to maintaining and protecting traffic. The Regional Traffic Engineering & Safety Group shall issue orders for all regulatory traffic control devices such as traffic signals, stop, yield, and one-way signs. The Department shall file such orders with the Secretary of State. Questions on interpretation of the NYS MUTCD should be referred to the Resident Engineer or Regional Traffic Engineer.

5A.3.6 Maintenance Responsibility

Property owners having access to a State highway shall be fully responsible for maintenance of their driveway and channelization including the portion from the highway right of way line to the outside edge of the highway shoulder or curb. This maintenance responsibility includes removal of snow and ice and keeping the portion within the highway right of way in a safe condition for the general public. Where the owner of a commercial property is required to construct acceleration, deceleration, or turning lanes on the State highway, the Department may, in the interest of public convenience, provide routine maintenance and remove snow and ice on the portions of these lanes constituting an integral part of the State highway. This in no way absolves the property owner of the overall maintenance responsibility for the reconstruction and major repair of these lanes, if necessary.

The property owner shall be responsible for the maintenance of ditches, pipes, catch basins, grates, detention ponds, and other drainage structures constructed in connection with providing access to his property, unless other legally binding arrangements, acceptable to the Department, are made. All traffic control devices, such as traffic signals, stop and yield signs, one-way or other regulatory signs, pavement markings, delineators, etc., installed by the property owner in the highway right of way with the permission of the Department, shall conform to the NYS MUTCD and, with the exception of traffic signals, be maintained, energized, and replaced by the property owner. Traffic signals installed by the permittee are maintained by the Department for an annual maintenance fee. The Department may, in the interest of public safety or convenience, maintain pavement marking installed by the permittee on the highway. The property owner shall also trim brush and maintain his/her property in such a manner as to maintain optimal sight distance. A maintenance agreement requiring the owner and his/her successors to maintain the above features specified should be filed with the deed in the County Clerk's office.

5A.3.7 Permit Traffic Signals

To provide safe and expedient movement of traffic to and from a commercial driveway, it may be necessary to install or modify a traffic signal on the State highway. If such traffic signal is at a private road or driveway, it shall be installed, and the energy costs to operate it shall be paid, by the property owner under the terms of a Permit to Install and Operate a Traffic Control Signal on State-Owned Property, issued by the Regional Traffic Engineer. The Department will operate and maintain the signal for an annual fee to be charged to the permittee as specified in the permit. Operation and maintenance of signals erected prior to April 1, 1986, may, at the Department's discretion, be done by the permittee under the terms of the existing maintenance agreement or by the Department for an annual fee. If a traffic signal is to be modified, it may be necessary to obtain a highway work permit as well as a permit for the signal modification.

5A.3.8 **Other Traffic Control Devices**

If deemed necessary by the Department, other traffic control devices such as flashing signals, regulatory and warning signs, delineators, pavement markings, etc., shall be installed by the permittee on commercial driveways in accordance with the NYS MUTCD. Questions on interpretation of the NYS MUTCD should be referred to the Resident Engineer or the Regional Traffic Engineer.

5A.4 GENERAL DESIGN REQUIREMENTS, AND GUIDELINES

The following general design requirements apply to all types of entrances. The design requirements set forth in this section are intended to maintain traffic service and safety on the roadway and convenience for the traveling public and the permittee and are based on the premise that the rights of highway users and abutting property owners can be mutually satisfied. The Department reserves the right to impose any additional requirements it deems necessary for public safety.

A driveway or a driveway system shall be so located as to provide:

- The most favorable vision (sight distance), and horizontal and vertical alignment conditions for users of the proposed driveway and the highway.
- No undue interference with nearby driveways, intersections, interchanges, and turning or acceleration and deceleration lanes.
- Maximum safety and convenience for vehicles, cyclists, pedestrians, and other users of highway right of way.
- Consistency with driveway spacing standards presented in this section.
- Consistency with any local adopted driveway spacing standards or arterial corridor management plan.

In the interest of public safety and traffic flow and convenience, the Department may restrict the placement of a driveway to a particular location along the owner's frontage, restrict the type of access, or require shifting of an existing driveway. When a property fronting on a State highway also fronts on and has access to any other public street, road, or highway that intersects the State highway, the Department may restrict access to the State highway if it determines that such access would be detrimental to the safety and/or operation of the State highway.

5A.4.1 Spacing

The following instructions are provided to help locate new or reconstructed driveways for a particular site. More detailed requirements and guidance are provided in Figure 5A-1 (in the back of this policy). The Department may modify this distance if an engineering determination indicates another dimension is more suitable for a particular site. The Department may restrict or prohibit specific movements if it determines that such movement(s) will interfere with safe and efficient traffic flow within or near an intersection.

Refer to Section 5A.2.1.4 of this policy for information on access management for land use planning and the development of multiple sites along a highway.

5A.4.1.1 Spacing from Ramps, Auxiliary Lanes, and Transitions

Permits will not be issued for entrances to State highways along acceleration or deceleration lanes, and lane tapers. The Department also prohibits construction of a driveway near expressway or other limited access highway ramps. To enforce this policy, the Department may purchase the owner's right of access to a public highway. Refer to NYSDOT *Highway Design Manual* Chapter 6 for specific access control limits at interchanges.

5A.4.1.2 Location Within Frontage

A driveway should be located entirely within the applicant's frontage, with spacing as per Figure 5A-1 to intersections and driveways serving adjacent properties. If the driveway extends onto adjoining property or is to be shared with other property owners, the permittee may be required to provide written agreement with the adjoining property owner(s).

5A.4.1.3 Number of Driveways

Normally only one driveway shall be permitted for each residential property, minor commercial, and subdivision. An additional driveway may be permitted by the Department if both sufficient frontage exists and extenuating circumstances justify a second driveway.

5A.4.2 Sight Distance

Inadequate sight distance or other safety or operational deficiencies may require that one-way or turn restrictions (e.g., no left turns) be imposed at the driveway.

5A.4.2.1 Intersection Sight Distance

Intersection sight distances should meet or exceed the values in Chapter 9 of AASHTO's latest *A Policy on Geometric Design of Highways and Streets*. Intersection sight distance at a driveway allows the drivers of approaching vehicles a sufficient view of the highway to decide when to enter the intersection to avoid collisions. Use of signals, turn restrictions, and/or acceleration lanes can mitigate nonconforming intersection sight distance. Lower sight distance values may be used if the Regional Traffic Engineer determines that they will not significantly degrade traffic safety and operations and there is no reasonable alternative.

5A.4.2.2 Stopping Sight Distance

Driveways should be located where the stopping sight distance meets or exceeds the values in AASHTO's latest *A Policy on Geometric Design of Highways and Streets*. Where the stopping sight distance is nonstandard, consider turn restrictions and/or speed change lanes (i.e., acceleration and deceleration lanes) as mitigation, and, if practical, locate the driveway for optimal sight distance.

5A.4.3 Median Openings on State Highways

Avoid median openings on divided highways for left turns to and from residential or commercial driveways. Existing median openings may be closed by the Department if it best serves the safety and operation of the State highway. The Department may, at its discretion, permit median openings to serve major commercial driveways if justified by a traffic engineering study. New median openings must be designed to mitigate operational and safety impacts. Refer to NYSDOT Highway Design Manual Sections 3.2.8.2, 3.2.8.3, and 5.10.6 for guidance on median treatments.

5A.4.4 Driveway Profile**5A.4.4.1 Profile Within Highway Edge of Pavement**

All driveways shall be constructed to slope away from the edge of the travel lane at the same slope as the highway shoulder which normally varies in slope from 2% to 6% (0.25 in/ft to 0.75 in/ft).

5A.4.4.2 Profile Beyond Highway Edge of Pavement

The profile beyond the highway edge of pavement is controlled by the:

- Drainage needs, discussed in Section 5A.4.5.
- Maximum grades provided on NYSDOT Driveway Standard Sheet M608-6 (Figure 5A-2). Where special circumstances require steeper driveway grades, contact the NYSDOT Traffic Engineer for assistance in establishing a safe profile design.
- Minimum vertical curve to accommodate the design vehicle. Whenever the driveway grade changes, the profile should be rounded by connecting the two different grades with a smooth vertical curve. Abrupt changes in driveway grade near the highway may cause operational and safety problems. Driveway profiles should prevent vehicle undercarriage damage and facilitate entering and exiting maneuvers. Refer to NYSDOT *Highway Design Manual* Chapter 3 for a graphical method of checking the driveway profile for compatibility with passenger vehicles.
- Sidewalk requirements, if applicable.

5A.4.5 Drainage

A driveway shall not adversely affect the highway drainage or drainage of adjacent properties. Drainage and the stability of the highway subgrade shall not be impaired by driveway construction or roadside development. The drainage design of a construction project shall not be compromised by field adjustments to compensate for altered driveway location. In no case shall the construction of a driveway cause water to flow across the highway pavement, pond on the shoulders, or pond in the ditch.

5A.4.5.1 Highway Drainage Ditches and Driveway Culverts

Where construction of a driveway necessitates crossing a highway ditch, a culvert pipe of adequate capacity shall be installed in the ditch. The low point of the driveway profile shall be at or close to the centerline of the pipe to direct runoff (flowing from the highway and adjacent property) into the ditch.

Driveway side slopes within the highway clear zone defined by the Department should be as flat as practical. Side slopes within the highway clear zone shall be:

- No steeper than 1 vertical on 6 horizontal for driveways on highways with operating speeds or design speeds of 80 km/h (50 mph) or greater.
- No steeper than 1 vertical on 3 horizontal for driveways on highways with operating speeds or design speeds of less than 80 km/h (50 mph).

Where there is a drainage ditch along the frontage, delineation (e.g., pavement markings, delineators, signs, curbing) should be provided to guide motorists to the driveway and away from the ditch.

Culvert pipe shall:

- Be adequate to carry the anticipated flow in the ditch per NYSDOT *Highway Design Manual* Chapter 8.
- Not be smaller than 375 mm (15 in) inside diameter, except in extreme conditions where the Department may approve a pipe with a 300 mm (12 in) inside diameter.
- Have structural material and gauge adequate to withstand the load from anticipated vehicular traffic across the driveway.
- Have tapered or flared pipe end sections, instead of head walls, within the highway clear zone defined by the Department. Pipe end sections shall meet current Department design policy in NYSDOT Engineering Instructions, Engineering Bulletins, and *Highway Design Manual* Chapter 10.
- Have a length determined as the sum of the width of the driveway and any driveway median measured along the ditch center line and the length needed to accommodate the side slope from the driveway surface to the top of the pipe.

5A.4.5.2 Curbing

Existing curbing may be saw cut to provide a driveway opening conforming to NYSDOT Driveway Standard Sheets M608-6 through M608-9 (Figures 5A-2 through 5A-5). Where drainage is carried along the curb, the driveway profile should be constructed with a short upgrade beyond the highway edge of pavement to prevent highway runoff from spilling onto private property. Where a short upgrade is not practical for residential and minor commercial driveways, a dropped curb, as shown on NYSDOT Driveway Standard Sheet M608-7 (Figure 5A-3), should be considered to divert a portion of the runoff being carried along the curb. Grate inlets and slotted inlets (pipe interceptor drains) to a stormwater system may also be considered.

Where an existing curb opening is no longer needed for access, new curbing, matching the adjacent curbing, should be installed.

5A.4.5.3 Drainage for Driveways With Nonconforming Profiles

Driveways with a continuous down grade from the highway may channel stormwater runoff from the highway onto private lands. Where profile adjustments are not practical, consideration should be given to providing gutter sections with grate inlets or slotted inlets (pipe interceptor drains) to a stormwater system.

Driveways with a continuous down grade to the highway may channel stormwater runoff from the private lands onto the highway. Where profile adjustments are not practical, consideration should be given to grate inlets or slotted inlets (pipe interceptor drains) to a stormwater system. A pipe with a top opening is impractical in dirt or gravel driveways or where debris may clog the opening or the pipe.

5A.4.5.4 Highway Work Permits

This section does not apply to Department projects. Highway work permits for entrances to State Highways are subject to the following conditions and limitations.

Ditches, gutters, and/or pipes on private property shall not drain into the highway drainage system unless expressly approved by the Department. Under no circumstances shall existing highway ditches or gutters be filled by the permittee without adequate provision for alternate drainage.

The Department may require the permittee to submit a drainage study, signed by a New York State Licensed Professional Engineer, justifying the drainage system proposed and pipe sizes used. A drainage study is normally required for commercial and subdivision driveways, especially for developments with large parking areas. Drainage studies requirements are discussed in NYSDOT's *Highway Design Manual* Chapter 8, Section 8.9.

5A.4.6 Sidewalks, Walkways and Stairways

All sidewalks, walkways, and stairways shall be constructed consistent with NYSDOT *Highway Design Manual* Chapter 18. Whenever a sidewalk or other pedestrian facility that intended to be used by the public is constructed, altered, added to, or restored, access for persons with disabilities shall be provided in accordance with the *Americans with Disabilities Act Accessibility Guidelines for Buildings and Facilities*.

Sidewalk Requirements:

- Sidewalk cross slope shall not exceed 2% (0.25 in/ft).
- Sidewalk grade shall not exceed the grade of the adjacent parallel highway.
- Ramped sidewalk sections across the driveway opening shall not be steeper than 8.3% (1 in/ft), unless it is technically infeasible due to terrain or other site constraints.
- Where sidewalks are provided to serve the public, curb ramps with detectable warnings shall be provided where pedestrian access routes cross curbs. Refer to the NYSDOT Standard Sheets for sidewalk curb ramp and detectable warning details.

Sidewalk Guidelines:

- Where a sidewalk is located close to the curbline and the driveway opening is a taper-type (see NYSDOT Driveway Standard Sheet M608-6 (Figure 5A-3)) or the curb drops at the sidewalk, the sidewalk should be warped to conform to the driveway profile provided the sidewalk will meet the above requirements. This may depress one or both edges of the sidewalk across the driveway.
- It may be necessary to discontinue the sidewalk across the driveway and construct a curb with curb ramps along each driveway edge or to provide convenient alternative access for persons with disabilities.
- In urban areas, it is aesthetically desirable for the sidewalk to have a profile that is as consistent as practicable.

DRIVEWAY DESIGN POLICY**5A.5 RESIDENTIAL DRIVEWAYS AND FIELD ENTRANCES**

Residential driveways and field entrances are defined in Section 5A.10 of this policy. They should be designed to permit access without unduly affecting traffic on the highway. Home business driveways and small subdivision driveways can, at the discretion of the Department and based on site specific conditions, be designed as either residential or minor commercial driveways, but should be wide enough to permit two-way traffic. Larger subdivision driveways may require a design typical of a major commercial driveway or an intersection.

For Department projects, refer to Section 5A.9 of this policy for instructions on the preparation of the Driveway Table and its use with NYSDOT Driveway Standard Sheets M608-6 through M608-9 (Figures 5A-2 through 5A-5).

For highway work permits, complete the PERM 33 and the Residential Driveway Form included at the end of this policy.

5A.6 MINOR COMMERCIAL DRIVEWAYS

Minor commercial driveways are defined in Section 5A.10 of this policy. They should be designed to permit access without unduly affecting traffic on the highway. Refer to Section 5A.9 of this policy for instructions on preparing the Driveway Table and its use with NYSDOT Driveway Standard Sheets M608-6 through M608-9 (Figures 5A-2 through 5A-5).

Minor commercial driveways that will routinely need to accommodate vehicles larger than AASHTO's Single Unit (SU) design vehicle are to be designed as major commercial driveways in accordance with Section 5A.7 of this policy. Examples include marinas, recreational areas, mobile home sales, modular home sales, and truck stops that do not meet the traffic volume of a major commercial driveway. In these cases, the Department may waive the Traffic Impact Study requirements in Section 5A.7.5. Where the oversized vehicle enters only occasionally, the driveway may be considered a minor commercial driveway provided the area that will need to accommodate the larger vehicle is either:

- Stabilized using gravel, stone, or other suitable material for uncurbed driveways or,
- A 100 mm (4 in) mountable or traversable curb is used and backed with asphalt concrete for curbed driveways.

5A.6.1 Access Control

Frontage of all commercial properties shall be controlled by positive means such as curbing or ditches which limits access to designated driveways. The purpose of the access control is to direct entering and exiting vehicles into a well-defined flow pattern and separate traffic movements on the private property from the highway traffic. This will provide maximum safety for motorists and minimize interference between traffic on the highway and on the property. Refer to Figure 5A-1 (at the back of this policy) for specific requirements and guidance.

5A.6.1.1 Driveway Configuration

The selected driveway configuration should minimize impact to the State highway. Intersection channelization islands may be used to separate entering from exiting traffic or to separate turning movements at driveway exits. Channelization islands are a portion of the intersection area (delineated using pavement markings, curbing, turf, or plantings) to physically delineate traffic movements. They shall be designed in accordance with NYSDOT *Highway Design Manual* Chapter 5, Section 5.9.4.

Minor commercial driveways may also use:

- Two-way drives.
- Two-way drives separated by an driveway island.
- One-way drives separated by an driveway island.
- One-way drives separated by a driveway median.

Driveway islands and medians are the areas between separated driveways to the same property.

- A driveway island is a raised area for separating multiple entrances or to place entering and exiting traffic at separate locations. Driveway islands also separate highway traffic from the activity on private property. Driveway islands have a minimum width (measured along the edge of highway) of 9 m (30 ft). They allow the separated entrances and/or exits to be treated as separate intersections with respect to traffic control.
- A driveway median is a narrow raised or physically separated area between the driveway entrance and exit to separate entering and exiting vehicles. Driveway medians are 1.2 m (4 ft) to 4.9 m (16 ft) wide. Driveway median widths between 4.9 m (16 ft) and 9 m (30 ft) should be avoided as they can confuse motorists when traffic control devices are used. The raised or physically separated areas normally extend the length of the driveway throat (defined below), minus any distance needed for the turning path of the design vehicle.

For one way roadways and highways with a raised or depressed median, mid-block driveways should be designed to accommodate rights in and rights out only. A raised channelization island or driveway median may be preferred in a two-way driveway opening to discourage wrong-way movements.

For highways without a raised median, a single two-way drive is preferred in most cases since one-way drives may be driven the wrong way and driveway medians may be hit by errant vehicles.

If two commercial driveways or driveway halves to the same property are constructed with less than 23 m (75 ft) between adjacent driveway openings, the entire shoulder area between the driveways shall be replaced with adequate traffic bearing material and, if operating speeds or the design speed on the highway is below 80 km/h (50 mph), the entire area between driveways shall be curbed (with drainage openings as necessary).

5A.6.1.2 Driveway Throat

The driveway throat is an access controlled portion of the driveway entrance that helps delineate the driveway and provides space to store entering and exiting vehicles. The access control between the parking areas and the edge of the driveway throat should be achieved using curbing, wide turfed areas, shrubs, median barrier, or other physical means (i.e., pavement markings and signs are not enough). The length selected for a particular driveway (measured along the driveway centerline) should be based on the operational, safety, and construction costs. The entrance should allow all entering traffic to pull off the highway before stopping. The exit throat length should prevent exiting vehicles from obstructing entering traffic, which could cause entering traffic to queue back onto the highway. The driveway throat should extend beyond the highway right of way line, if necessary.

5A.6.1.3 Clearances And Use of State Property

In rural and suburban areas, a minimum of 4.6 m (15 ft) should be provided between the right of way line and the near edge of a building, structure, or appurtenance serving vehicular traffic, exclusive of overhead appurtenances such as luminaires or canopies over gas pumps. This offset shall be sufficient to preclude the servicing and parking of vehicles on State property.

For sites where the property owner has been using State owned right of way for parking or other purposes, imposing standard driveway controls may create an economic hardship. In such cases, the property owner may be required to obtain a Permit for Use of State Owned Property from the Regional Real Estate Officer in accordance with the Department Manual of Administrative Procedure 7.12-2 and the Real Estate Division directives.

5A.6.2 Constrained Areas

The radii and taper-type minor commercial driveway designs in NYSDOT Driveway Standard Sheets M608-6 through M608-9 (Figures 5A-2 through 5A-5) were determined using AutoTurn software. The software modeled the sharpest possible turning path of a Single Unit Truck turning to and from the minor commercial driveway.

On Department projects when the driveway opening cannot be reasonably modified to meet the requirements in the NYSDOT Driveway Standard Sheets, the driveway shall be individually designed. The proposed design shall be checked using the turning path of the design vehicle. If the design vehicle cannot be accommodated without encroachment, the driveway should be documented as a nonconforming feature with an explanation in the project files.

In urban areas, a minimum offset of 1.2 m (4 ft) shall be provided from the shoulder or sidewalk to parking areas to prevent parked cars from overhanging into the shoulder or sidewalk. The Department may allow a single line of curb or barrier to be used only in constrained locations where a 1.2 m (4 ft) or more width cannot be installed and where it will not be a roadside hazard.

5A.6.3 Highway Work Permits

This section only applies to highway work permits. Refer to Form PERM 33 for the Highway Work Permit Application at the end of this policy. In addition, minor commercial driveway permit applications are to be accompanied by a completed Driveway Table and a plan as specified in Section 5A.6.3.1 of this policy. All plans or drawings submitted by the applicant shall be prepared, signed and/or stamped by a New York State licensed design professional (Engineer, Architect, Landscape Architect, or Land Surveyor).

5A.6.3.1 Plan Details

The plans shall include the following. (Plans for many minor commercial developments, as well as all major commercial developments require this information for the Department to render a proper review.)

- North directional arrow.
- Location and dimensions of existing highway pavement, curbs, guide rail, medians, sidewalk, stairways, bike paths, bike lanes, bus stops, utilities, traffic signs (include the sign text), signals, pavement markings, and right of way and property lines.
- Existing and proposed buildings and appurtenances.
- Design features to be incorporated in proposed construction or reconstruction:
 - ▶ Edge of driveway
 - ▶ Driveway grades or profile view of driveway.
 - ▶ Location of proposed median openings and guide rail.
 - ▶ Dimensions of roadside islands and driveway medians.
 - ▶ Dimensions and elevations of curbs and sidewalks relative to the pavement edge.
 - ▶ Location of authorized traffic signs, pavement markings, and proposed advertisement signs.
 - ▶ Locations of walkways and stairways.
- Existing and proposed drainage features and a report addressing their impacts:
 - ▶ Size, type, and grade of driveway culverts.
 - ▶ Highway drainage structures.
 - ▶ Direction of surface water flow on applicant's property.
- Distance from each existing and proposed driveway on the site to:
 - ▶ The nearest side road in each direction if within 300 m (1000 ft).
 - ▶ Nearest driveway on adjacent properties.
 - ▶ Streets, roads, or driveways opposite the site.
 - ▶ Adjacent property lines.
 - ▶ Beginning and ending reference markers.
- Provisions for maintaining safe traffic flow, pedestrian access and work site safety during construction and any work or work space restrictions required by the Department to minimize traffic impacts during peak traffic flow periods. The Department will recommend lane closing restrictions. Nighttime lane closures require our prior approval.
- Traffic signal plans must be shown on a separate sheet including pavement markings, turn lanes, driveways, sidewalks and pedestrian ramps, crosswalks, buildings, poles, power supply, pullboxes, conduit, controller, head layout including face numbering, detection, right-of-way lines and signing. All work must be referenced to the latest edition of the NYSDOT *Standard Specifications Construction and Materials*. The plans must show existing features, such as drainage and utilities, which may conflict with the proposed signal. Tables of Operations, Clearances, Switchpacks, Input Wiring and Loop Wiring must be included along with a Phasing Diagram and Estimate of Quantities.

The Department may require additional information (e.g., cross sections) as site-specific conditions warrant. An aerial photograph of the site is desirable.

The NYSDOT *Highway Design Manual* Chapter 21 and the NYSDOT *CADD Standards and Procedure Manual* may be used as a guide for the development of plan sheets. Upon completion, the Department will normally require as-built drawings for archival purposes.

5A.6.3.2 Plan Units

The Department uses the metric system of measurement. While the Department may, at its discretion, continue to accept U.S. Customary units, it may require metric design, especially where changes to the State highway necessitate revisions to the Department's record plans. Applicants should contact the Department early to determine the system of units to be issued.

AASHTO's latest *A Policy on Geometric Design of Highways and Streets* contains U.S. Customary and metric units. The NYSDOT *Highway Design Manual* is metric only with the exception of Chapter 4, which has both metric and U.S. Customary units. The NYSDOT Standard Sheets and the NYSDOT *Standard Specifications for Construction and Materials* are metric only. The *Americans with Disabilities Act Accessibility Guidelines for Buildings and Facilities* contains U.S. Customary and metric units.

5A.7 MAJOR COMMERCIAL DRIVEWAYS

Major commercial driveways are defined in Section 5A.10 of this policy. Major commercial driveways and highway improvements should be designed to accommodate expected directional traffic volumes and the type of vehicles expected to use them. The resulting design could range from one typical of a minor commercial driveway to one based on high-type intersection design principles.

The Department may allow major commercial driveways to use the radii Type 1 or Type 2 minor commercial driveway details shown in NYSDOT Driveway Standard Sheet M608-7 (Figure 5A-3). Taper-type driveways are not to be used. Entering speed, volume, pavement thickness, and design vehicle must be considered since the minor commercial driveway designs are intended for moderate volumes and AASHTO Single-Unit (SU) design vehicles. Major commercial drives that will use the Type 1 or Type 2 driveway details are to be tabulated in the Driveway Table in accordance with Section 5A.9 of this policy and may employ minor commercial driveway design details shown in NYSDOT Driveway Standard Sheets M608-6 through M608-9 (Figures 5A-2 through 5A-5).

Other major commercial drives are to be tabulated separately, and detailed individually in the plans similar to a highway intersection with a cross street. **The following sections are to be followed in addition to, or as an exception to, the requirements in Sections 5A.4 and 5A.6 of this policy and NYSDOT Driveway Standard Sheets M608-6 through M608-9 (Figures 5A-2 through 5A-5).**

5A.7.1 Traffic

The driveway and any other required highway improvements shall be designed in accordance with the intersection design guidance in NYSDOT *Highway Design Manual* Chapter 5 and AASHTO's latest *A Policy on Geometric Design of Highways and Streets*.

5A.7.1.1 Design Vehicle

The design vehicle shall be selected in accordance with NYSDOT *Highway Design Manual* Chapter 5 and AASHTO's *A Policy on Geometric Design of Highways and Streets*. The design vehicle should represent the largest type of vehicle expected to routinely use the driveway and is subject to Department approval. Industrial and commercial driveways used by large trucks should have adequate width, radii and pavement thickness to accommodate the appropriate design vehicle. The Department may require driveways on designated qualifying or access highways or within 1.6 km (1 mi) of a qualifying highway to be designed to accommodate the AASHTO WB-20 (WB-67 U.S. Customary) design vehicle, if such vehicles are expected to use the driveway.

The Department may require reconstruction of affected highways, interchanges and/or intersections, if the development will generate larger vehicles than the affected highway system is designed for.

5A.7.1.2 Level of Service

Major commercial driveway widths shall provide adequate capacity and design vehicle turning paths that do not interfere with other traffic movements. Multiple lane exits and entrances may be required to maintain the highway level of service. The level of service should be determined in accordance with NYSDOT *Highway Design Manual* Section 5.2.

5A.7.2 Layout

The driveway design should prevent the need for undue deceleration in a travel lane and preclude turning vehicle encroachment on adjacent highway and driveway travel lanes by the largest vehicle expected to routinely use the driveway. The minor commercial driveway layouts in NYSDOT Driveway Standard Sheets M608-6 through M608-9 (Figures 5A-2 through 5A-5) were developed to accommodate an AASHTO Single-Unit Truck and should not be used for larger design vehicles. Large vehicles and/or high speeds should not be accommodated by using driveway widths in excess of those permitted by Table 1 on NYSDOT Driveway Standard Sheet M608-6 (Figure 5A-2). The three-centered curves in AASHTO's latest *A Policy on Geometric Design of Highways and Streets* can accommodate large vehicle turning paths while minimizing driveway openings. An exception to the widths in Table 1 on NYSDOT Driveway Standard Sheet M608-6 (Figure 5A-2) may be granted by the Department for special cases (e.g., when a wider drive is required for a fire department entrance or for oversized vehicles).

5A.7.3 Corner Angle

The corner angle between the driveway centerline and the highway travel lane edge is determined by terrain, safety, and operational requirements. The corner angle shall be between 60° and 120°.

A corner angle of 90° should be used for two-way drives. Acute angle turns require significant reductions in travel speed and pose difficulties for trucks. Since flatter angles tend to encourage higher operating speeds, consider perpendicular driveways where pedestrian traffic is a concern.

A corner angle between 60° and 120° is permissible for one-way drives. Angled or one-way driveways may be considered where access is limited to right turns in and out. Consider angles flatter than 90° to facilitate the entrance of substantial truck traffic into through traffic on the highway.

5A.7.4 Material

All major commercial driveways shall have a paved surface extending from the edge of the travel lane to the highway right of way line or for 3 m (10 ft), whichever is greater.

The material and thickness of commercial driveways within the highway right of way shall be designed to provide adequate support for the volume and character of traffic using the driveway. The existing highway shoulder material shall be removed, if required by the Department, and the shoulder area paved with adequate driveway material, if determined necessary by the Department. In the nontraffic bearing areas of commercial entrances, use of loose stone such as pea gravel as a mulch or for decorative effect shall not be allowed without a suitable binder.

The material information shall be shown on the plans or drawing accompanying the permit application and shall be subject to review and approval by the Department. Under no circumstances may the material thickness be less than that provided for a similar minor commercial driveway using Table 3 on NYSDOT Driveway Standard Sheet M608-6 (Figure 5A-2).

5A.7.5 Highway Work Permits

This section only applies to highway work permits only. Refer to the attached PERM 33 for the Highway Work Permit Application at the end of this policy. In addition, major commercial driveway permit applications are to be accompanied by a 1:250 (1 in = 20 ft) or 1:500 (1 in = 40 ft) scale (as specified by the Department) plans or drawings indicating the items in Section 5A.6.2.1 of this policy and:

- The driveway width, pavement type, and thickness.
- Radii of driveway returns and other points of curvature.

The **Traffic Impact Study (TIS)** shall include details of internal vehicular, transit and pedestrian traffic circulation, parking, traffic control devices, actual and estimated traffic volumes, and any proposed additional pavement lanes or widening on the highway.

As a modification to the requirements in Section 5A.6.2, the plans and TIS shall be prepared by a **New York State Licensed Professional Engineer**. Additionally, the Department may require a ledger size paper plan labeled as a revised sheet to be included with the Department's record plans.

5A.8 STREETS AND HIGHWAYS OFF THE STATE HIGHWAY SYSTEM

Streets and highways off the State highway system include:

- City and village streets.
- Town and county highways.
- Private access roads.
- Subdivision roads (defined in Section 5A.10 of this policy).
- Roads owned by other State agencies and authorities.

Entrances to State highways classified by the Department as nonfreeways from streets and highways off the State highway system, shall:

- Be designed in accordance with the intersection design guidance in NYSDOT *Highway Design Manual* Chapter 5 and AASHTO's latest *A Policy on Geometric Design of Highways and Streets*.
- Otherwise be considered as major commercial driveways per this policy, unless otherwise directed by the Department.

All entrances to State highways classified by the Department as freeways shall:

- Be designed in accordance with the interchange design guidance in NYSDOT *Highway Design Manual* Chapter 6 and AASHTO's latest *A Policy on Geometric Design of Highways and Streets*.
- Follow the procedures and requirements in NYSDOT *Project Development Manual* Appendix 8, Freeway Access Modification Procedures.
- Otherwise be considered as major commercial driveways per this policy, unless otherwise directed by the Department.

5A.9 DRIVEWAY TABLE

Several variables for each drive must be defined in order for the contractor to construct driveways in accordance with the NYSDOT Driveway Standard Sheets M608-6 through M608-9 (Figures 5A-2 through 5A-5). These include:

1. Location — Mainline station of driveway centerline. For projects or permits without mainline stationing, include a reference (e.g., a number) to the driveway, which shall be located to the nearest 0.3 m (1 ft) on a separate plan sheet.
2. Side — “Left” or “Right” along the stationing. Use north, south, east or west as appropriate for nonstationed projects.
3. Existing Material (Asphalt Concrete, Portland Cement Concrete, Crushed Stone, Gravel, Dirt, or Grass) — The existing material is used by NYSDOT Driveway Standard Sheet M608-6 (Figure 5A-2), Table 3 Driveway Treatment: Materials & Thickness, to define the materials and thickness to be used within the pavement length (PL) and any transition length (TL), as required. Standard thicknesses are listed for both asphalt concrete and Portland cement concrete drives. If a commercial driveway requires a different thickness, the driveway should be designed as a Special Type SX as defined in item 9 of this section. The asphalt concrete layer composition is determined by the contractor in accordance with Table 608-1 of the NYSDOT Standard Specifications for Construction and Materials.

Note: The NYSDOT Driveway Standard Sheets assume the apron (area between the sidewalk and curb on Type 3 and 4 driveways) will be paved with the same material type as the driveway. In certain situations the designer may prefer to pave all aprons with the same material regardless of the driveway material. For example, a village or city may request all aprons be concrete for aesthetic purposes. In these situations an appropriate note should be added to the Driveway Table.

4. Class (Residential (R) or Minor Commercial (MC)) — Refer to definition in Section 5A.10 of this policy.
5. Width (W) — The width (W) is defined as the proposed driveway width beyond the taper or radius entrance. This will usually be the existing width or a revised width if the existing drive does not conform to the widths in NYSDOT Driveway Standard Sheet M608-6 (Figure 5A-2), Table 1 and an exception is appropriate (e.g., when a wider drive is required for a fire department entrance).

6. Corner Angle (θ_{IN}) — The corner angle is the angle between the roadway and driveway as if turning from the roadway onto the driveway.

Ninety degree entrances are desirable for two-way drives. Corner angles of 60° to 120° may be desirable for one-way commercial drives to reduce the driveway opening width. Refer to acceptable corner angle in NYSDOT Driveway Standard Sheet M608-7 (Figure 5A-3), Table 4.

Taper-type driveways should not be used for minor commercial driveways skewed more than 10° (θ_{IN} less than 80° or more than 100°) since the taper-type driveways require more pavement than radii type driveways and the additional pavement increases with the skew and width of the driveway opening.

The corner angle can be used to determine the “ Y_{IN} ” dimension and the “ Y_{OUT} ” dimension of the driveway to determine the overall curb opening limits using NYSDOT Driveway Standard Sheet M608-9 (Figure 5A-5).

7. Pavement Length (PL) — Refer to the definition on Standard Sheet M608-6 (Figure 5A-2). Any appropriate paving limit, meeting the minimum pavement length (MPL) requirements on NYSDOT Driveway Standard Sheet M608-6 (Figure 5A-2) can be specified in the driveway table. The material and thickness are defined in Table 3, Driveway Materials and Thickness on NYSDOT Driveway Standard Sheet M608-6 (Figure 5A-2).
8. Transition Length (TL) — Refer to the definition on NYSDOT Driveway Standard Sheet M608-6 (Figure 5A-2). The material and thickness are defined in Table 3, Driveway Materials and Thickness on NYSDOT Driveway Standard Sheet M608-6 (Figure 5A-2). If no transition is anticipated, the pavement length (PL) is assumed to be at a point where the existing driveway width and elevation can be matched and the TL in the driveway table should be left blank. If a transition length is anticipated, but exact limits cannot be determined in the design stage (i.e., limited survey data available), fill in the table with A.D.B.E (As Determined By Engineer). (Note: It is preferable to define the TL in the plans; use of A.D.B.E. should be avoided if possible).
9. Entrance Type — NYSDOT Driveway Standard Sheets M608-6 through M608-9 (Figures 5A-2 through 5A-5) provide details for four of the most common entrance types. If only a minor modification of the standard type is required, a note similar to one of the following should be provided on the Driveway Table.

"The drive at Sta. 3+231 Lt. shall be constructed in accordance with a Type 1 drive as shown in Figure 5A-3 of the NYSDOT "Policy and Standards for Design of Entrances to State Highways," except the driveway thickness shall be 200 mm of asphalt concrete."

"The drive at Sta. 3+231 Lt. shall be constructed in accordance with a Type 1 drive as shown on NYSDOT Driveway Standard Sheet M608-7, or latest revision, except the driveway thickness shall be 200 mm of asphalt concrete."

DRIVEWAY DESIGN POLICY

Minor modifications are changes that can be conveyed by notes but do not require a special detail in the plans.

Major commercial and other driveways for which the NYSDOT Driveway Standard Sheets will not be used shall be detailed in the plans and labeled as a special drive, Type SX, where X is the detail number (i.e., S1, S2, etc.). The special type driveway details should either be site-specific with all required dimensions, or use similar dimension labels as NYSDOT Driveway Standard Sheets M608-6 through M608-9 (Figures 5A-2 through 5A-5) and the Driveway Table.

10. Comments — Include additional design information, such as: curb reveal, one-way entrance, and multilane entrance.
11. Pay Items — The Driveway Table also includes a table indicating all separate pay items called out in the NYSDOT Driveway Standard Sheets M608-6 through M608-9 (Figures 5A-2 through 5A-5). The designer must fill in the project-specific Item numbers. Space has been left to add additional project specific driveway items as necessary.

5A.10 GLOSSARY OF TERMS

Refer to Figure 5A-2 for additional definitions.

AASHTO. The American Association of State Highway and Transportation Officials.

Capacity. The maximum hourly rate at which persons or vehicles can reasonably be expected to traverse a point or uniform section of a lane or roadway during a given time period under prevailing roadway, traffic, and control conditions. Refer to the most recent *Highway Capacity Manual* for more information.

Channelization. An at-grade separation or regulation of conflicting traffic movements into defined travel paths by pavement marking, raised islands, or other suitable means to facilitate the safe and orderly movement of vehicles and pedestrians.

Channelization Island. A portion of the intersection area (delineated using pavement markings, curbing, turf, or plantings) to physically delineate traffic movements.

Commercial Driveway. A driveway serving a commercial establishment, industry, governmental or educational institution, private utility, hospital, church, apartment building, or other comparable traffic generator. Types of commercial driveway designs include:

1. **Divided Commercial Driveway.** A driveway incorporating a raised median or other physical barrier to separate entering traffic from exiting traffic.
2. **Undivided Commercial Driveway.** A driveway with no physical barrier to separate entering traffic from exiting traffic.

Department. The New York State Department of Transportation.

Driveway. Every entrance or exit used by vehicular traffic to and from lands or buildings abutting a State highway.

Driveway Island. A raised area for separating multiple entrances or to place entering and exiting traffic at separate locations. Driveway islands also separate highway traffic from the activity on private property. Driveway islands have a minimum width (measured along the edge of highway) of 9 m (30 ft). They allow the separated entrances and/or exits to be treated as separate intersections with respect to traffic control.

Driveway Median. A narrow raised or physically separated area between the driveway entrance and exit to separate entering and exiting vehicles. Driveway medians are 1.2 m (4 ft) to 4.9 m (16 ft) wide. The raised or physically separated areas normally extend the length of the driveway throat (defined below), minus any distance needed for the turning path of the design vehicle. Refer to channelization islands for raised areas within the driveway intersection area to physically delineate traffic movements.

DRIVEWAY DESIGN POLICY

Driveway Throat. An access controlled portion of the driveway entrance that helps delineate the driveway and provides space to store entering and exiting vehicles.

Driveway Work Release. A document (attached form HC 199) signed by the owner permitting the State to enter and alter a driveway to accommodate changes of the highway alignment, grade, or cross-section in accordance with Section 54-A of the Highway Law.

Field Entrance. A driveway serving a farmyard, cultivated or uncultivated field, timberland, or undeveloped land not used for industrial, commercial, or residential purposes.

Frontage. The distance along the highway edge of pavement in front of the owner's property, measured between lines perpendicular to the centerline of the roadway from each property corner.

Highway Work Permit. A document specifying the authority and conditions under which an individual or organization may perform work within or adjacent to the State highway right of way.

Home Business Driveway. A driveway serving any business which is part of a private residence which produces actual or anticipated traffic volumes on a typical day of 20 or fewer vehicles during the hour of highest driveway activity.

Level of Service. A qualitative measure of operational characteristics within a traffic stream. Levels range from "A", representing the best operating conditions, to "F" representing traffic breakdown. Refer to the most recent *Highway Capacity Manual* for more information.

Major Commercial Driveway. Any commercial driveway where the actual or anticipated traffic volume on a typical day is either:

1. 100 or more one-way trips during the peak hour for either the adjacent roadway or the development.
- OR
2. 50 or more one-way trips during the 8th highest hour of annual driveway activity.

The traffic volumes may be determined by automatic recorders, the ITE Trip Generation Rates, or other method approved by the Regional Traffic Engineer.

May. A permissive condition. No requirement for design or application is intended.

Minor Commercial Driveway. Any commercial driveway where the actual or anticipated traffic volumes on a typical day are less than the values stipulated for a major commercial driveway.

NYS MUTCD. *Title 17, Volume B of the Official Compilation of Codes, Rules and Regulations of the State of New York* (NYCRR) and is commonly referred to as the New York State Manual of Uniform Traffic Control Devices (NYS MUTCD).

Municipal Streets and Highways. Streets and highways owned by a village, city, town, or county.

Permanent Easement. A permanent possession, by other than the landowner, of specified ownership rights to a parcel of land, usually to accommodate features that are supplementary to the highway such as drainage or slope grading. The State may acquire easements through the exercise of eminent domain.

Permittee. A municipality, public utility company, public benefit corporation (such as Water Authority), private corporation, partnership, association, or individual in whose name the permit has been issued.

Residential Driveway. A driveway serving four or fewer private homes or an apartment building for four or fewer family units.

Right of Way Line. The boundary between private property and State highway lands.

SEQR. The State Environmental Quality Review Act: Law and associated regulations governing environmental impact review of proposed actions as detailed in 6 NYCRR Part 617 of the New York Compilation of Codes, Rules and Regulations (NYCRR) and for Department actions, in 17 NYCRR Part 15.

Shall. A mandatory stipulation based on statutory or regulatory requirements.

Should. A recommended, but not mandatory condition.

Sidewalk, Walkway. An exterior pathway with a prepared surface intended for pedestrian use. Sidewalks generally parallel a roadway and are usually intended for public use. Other walkways described in this policy are general approaches to adjoining properties and may be intended for public or private use.

Stairway. One or more flights of steps, including landings, that form a portion of a pedestrian walkway approaching lands or buildings abutting a State highway.

Subdivision Road. A road, drive, or street laid out in a developed residential area by a contractor, builder, or company responsible for developing the area. This includes a new driveway serving more than four private homes or a multiple-unit dwelling containing more than four family units.

Temporary Driveway. A driveway which provides interim access to a property until either closed or reconstructed by authority of the Department as a condition of further development of either the property or the corridor.

Temporary Easement. A temporary possession, by other than the landowner, of specified ownership rights to a parcel of land, usually to accommodate the construction, but not maintenance or operation, of the facility.

Traffic Impact Study. A study of existing traffic conditions, anticipated traffic conditions with and without the development and the traffic impacts of the development. The study should include proposed mitigation of impacts and resulting traffic conditions.

5A.11 REFERENCES

1. *A Policy on Geometric Design of Highways and Streets*, 2001. American Association of State Highway and Transportation Officials (AASHTO), 444 North Capital Street, N.W., Suite 249, Washington, D.C. 20001.
2. *Americans with Disabilities Act Accessibility Guidelines for Buildings and Facilities*, December 1993. Landscape Architecture Bureau, Design Division, New York State Department of Transportation, 1220 Washington Ave., Albany, NY 12232.
3. *Best Practices in Arterial Management*, November, 1996. Mobility Management Bureau, New York State Department of Transportation, 1220 Washington Ave., Albany, NY 12232.
4. *CADD Standards and Procedure Manual*, Design Division, New York State Department of Transportation, 1220 Washington Ave., Albany, NY 12232.
5. *Guidelines for Driveway Location & Design*, 1987. Institute of Transportation Engineers (ITE), 525 School Street, S.W., Suite 410, Washington, DC 20024-2729.
6. *Highway Capacity Manual*, 2000. Transportation Research Board, National Research Council, 2101 Constitution Ave., N.W., Washington, DC 20418.
7. *Highway Design Manual*. Design Division, New York State Department of Transportation, 1220 Washington Ave., Albany, NY 12232.
8. *Manual of Administrative Procedures*. New York State Department of Transportation, 1220 Washington Ave., Albany, NY 12232.
9. *Title 17, Volume B of the Compilation of Codes, Rules and Regulations of the State of New York (NYCRR)*, a.k.a. New York State Manual of Uniform Traffic Control Devices, West Group, 620 Opperman Drive, PO Box 64833, St. Paul, MN 55164-9752.
10. *Public-Private Financing of Roadway Improvements Handbook*. Planning & Strategy Group, New York State Department of Transportation, 1220 Washington Ave., Albany, NY 12232.
11. *Standard Specifications for Construction and Materials*. Design Division, New York State Department of Transportation, 1220 Washington Ave., Albany, NY 12232.

DRIVEWAY DESIGN POLICY

5A-35

HC 199 (8/73) NEW YORK STATE DEPARTMENT OF TRANSPORTATION

REQUEST FOR REESTABLISHMENT OF APPROACHES TO PRIVATE LANDS
(Section 54-A Highway Law)

Region # _____ State Highway # _____ Contract # _____

Town _____ County _____

The undersigned owner of private lands located on the _____ side
of station _____ and the _____ side of station _____
and being further identified as _____

hereby requests that the Department of Transportation cause the reestablishment
of the entrance, approach or driveway on said lands to be adjusted to any new
highway grade made necessary by the construction or reconstruction of _____
_____ State Highway No. _____

in accordance with Section 54-A of the Highway Law of the State of New York,
which provides as follows:

" 54-A. Reestablishment of approaches to private lands

In the construction and reconstruction of any highway on the
state's system where a substantial change in the existing grade of
the highway is made, such change making necessary the reestablish-
ment of an existing entrance or approach to private lands, the
commissioner of transportation may, upon the request of the abutting
property owner affected, cause the reestablishment of the entrance,
approach or driveway to be adjusted to the new highway grade and
the cost thereof shall be a state charge payable from any money
available for the construction or reconstruction of state highways.
In such adjustment the details of the work shall be as determined
by the commissioner of transportation. The state shall not be
liable for the maintenance of such adjusted and reestablished
approaches or driveways beyond the outside edge of the road shoulder
nor shall it be liable for damages in connection therewith after the
completion of such adjustment work."

In Presence Of: _____ Dated: _____ L.S.

_____ L.S.
_____ L.S.

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State of New York
Department of Transportation

Form PERM 33 (8/01)

Highway Work Permit Application for Non-Utility Work

Instructions and Form

Submit three copies (photocopies acceptable)

INSTRUCTIONS FOR COMPLETING THE APPLICATION FOR HIGHWAY WORK PERMIT – NON-UTILITY

FRONT OF APPLICATION

An Applicant may not have all pertinent information at the time of completing the application form since certain information relative to fees, insurance and guarantee deposits may be contingent upon determinations to be made by the Department. In such cases, the information may be left blank and remittance withheld until the information is determined by the Department.

Please complete the following:

- Permittee's name and address. For more than one applicant, also fill in the joint applicant's name and address.
- Federal Identification Number of the company or individual Social Security Number.
- Applicant's telephone number. A telephone number where applicant can be contacted concerning the application. Please include area code.
- Project Identification No. and Highway Work Permit No. will be completed by the issuing office.
- Name of Contact person and their telephone number in case of emergency.
- If Highway Work Permit is to be returned to someone other than the applicant, complete this section.
- Estimate the cost of work being performed in the State highway right-of-way and place this figure on the blank line.
- Indicate anticipated duration of work to be performed with starting date and ending date on this line.
- You may provide your own insurance, purchase insurance through the Department, if available, or provide an Undertaking (for Utilities and Municipalities only). If you choose to provide your own insurance, a PERM 17 will be necessary. The PERM 17 may be obtained at the office you obtained this form from. It must be completed by your insurance company and accompany the permit application upon submission. The Policy number and expiration date of the PERM 17 should be shown on this line.
- Give a brief description of the proposed work that is to be done under this permit
- Plans and specifications should accompany this application for any work that involves construction within the State highway right-of-way. Place a check mark on the lines for plans and specifications if they are attached.
- Location of the project should be identified by: State Route; State Highway Number, if known; State Highway reference markers and Town and County in which work area is located.
- SEQR requirements: This may be required for larger projects – Contact the Regional Office of the Department of Transportation to determine if these requirements are necessary.
- Signature of applicant (permittee) and date.
- Signature of second applicant, if any, and date.

BACK OF APPLICATION

- Check type of work that will be performed.
- In the appropriate column indicate:
 - Manner in which insurance coverage is furnished the Department, i.e., PERM 17 (P17) or Under-Taking (UT) or Insurance Fee (IF), if available (N/A means the Department's insurance is not available).
- Indicate total amount of permit fee and insurance fee, if applicable.
- Indicate check number of Guarantee Deposit or Bond Number, if required. This will be determined by the Department upon submission of application.

Shaded areas will be completed by the Department of Transportation.

Remove the application form from the back of this packet and submit 3 copies to the Department for approval.

**RESPONSIBILITIES OF PERMITTEE
PURSUANT TO NON-UTILITY HIGHWAY WORK PERMITS**

FAILURE TO OBTAIN A PERMIT OR FAILURE TO COMPLY WITH THE TERMS OF A PERMIT MAY RESULT IN THE DEPARTMENT HALTING THE ACTIVITY FOR WHICH A PERMIT IS REQUIRED UNTIL ADEQUATE CORRECTIONS HAVE BEEN MADE.

PROTECTIVE LIABILITY INSURANCE COVERAGE

Permittee must have protective liability insurance coverage in accordance with Department requirements. See "Certificate of Insurance for Highway Permits" (Form PERM 17, NYSDOT).

Expiration of, or lack of, liability insurance automatically terminates the permit. Insurance coverage may be provided by furnishing the Department with one of the following:

1. A completed Certificate of Insurance for Highway Permits (Form PERM 17, NYSDOT).
2. Purchase the Department Blanket Policy for Highway Work Permits from the Department, if available. N/A shown on the Application in the insurance column means Department insurance coverage is not available for that type of project.
3. Provide an Undertaking. Undertakings are limited to Public Service Corporations and government units.

COMPENSATION INSURANCE AND DISABILITY COVERAGE

The permittee is required to have compensation insurance and disability coverage as noted in the provisions of the Worker's Compensation Law and Acts amendatory thereof for the entire period of the permit, or the permit is invalid.

NOTIFICATION

The following should be notified at the appropriate time as shown below:

1. Commissioner of Transportation, through Regional Office, one week prior to commencing work.
2. Area gas distributors 72 hours prior to any blasting.
3. Utility companies with facilities in work areas before starting work, in accordance with Industrial Code 53 (permission from utility company must be obtained before commencing work affecting utilities' facilities).
4. New York State Department of Transportation, Regional Signal Maintenance Shop, 3 days prior to starting work.
5. New York State Department of Transportation Regional Office at conclusion of work and return original copy of permit to Resident Engineer.

Permit Notification for Annual Permits: Notify by telephone, the Regional or Resident Engineer's Office in advance, when work is to be performed.

SITE CARE AND RESTORATION

An Undertaking, a bond or a certified check in an amount designated by the Department of Transportation may be required by the Regional Office, before a permit is issued, to guarantee restoration of the site to its original condition. If the Department is obliged to restore the site to its original condition, the costs to the Department will be deducted from the amount of the permittee's guarantee deposit at the conclusion of the work. Costs in excess of the Bond/guarantee deposit on file will be billed directly to the permittee.

The permittee is responsible for traffic protection and maintenance including adequate use of signs and barriers during work and evening hours. Anyone working within the State highway right-of-way will wear high visibility apparel (orange/yellow) and hard hat.

No unnecessary obstruction is to be left on the pavement or the State highway right-of-way or in such a position as to block warning signs during non-working hours.

No work shall be done to obstruct drainage or divert creeks, water courses or sluices onto the State highway right-of-way.

All false work must be removed and all excavations must be filled in and restored to the satisfaction of the Regional Maintenance Engineer.

Application is hereby made for a highway work permit:

For Joint application, name and address of Second Applicant below:

Name _____

Name _____

Address _____

Address _____

City _____ State _____ Zip _____

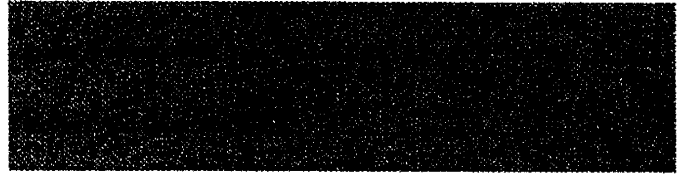
City _____ State _____ Zip _____

Federal I.D. No. or Social Security No. _____

Applicant Telephone No. _____

Contact person in case of emergency _____

Telephone No. of contact person _____



RETURN PERMIT TO (if different from above):

RETURN OF DEPOSIT/BOND TO (Complete only if different from permittee):

Name _____

Name _____

Address _____

Address _____

City _____ State _____ Zip _____

City _____ State _____ Zip _____

1. Estimated cost of work being performed in state highway right-of-way \$ _____

2. Anticipated duration of work: From _____ 20, _____ thru _____, 20 _____, to apply to the operation(s) checked on the reverse side.

3. Protective Liability Insurance covered by Policy No. _____ ; expires on _____ 20 _____

4. A \$20.00 fee will be charged for checks returned by the bank.

PROPOSED WORK (Brief description): _____

ATTACHED: Plans _____ Specifications _____ LOCATION: State Route _____ State Highway _____

between Reference Marker _____ and Reference Marker _____

Town of: _____ County of: _____

SEQR REQUIREMENTS (Check appropriate item):

____ Exempt ____ Ministerial ____ Type 11 ____ EIS or DEIS Lead Agency _____

If project is identified to be ministerial, exempt, or TYPE 11, no further action is required.

If project is determined to be other than ministerial, exempt, or TYPE 11, refer to M.A.P.7.12-2, Appendix A SEQR REQUIREMENTS FOR HIGHWAY WORK PERMITS.

Acceptance of the requested permit subjects the permittee to the restrictions, regulations and obligations stated on this application and on the permit.

Applicant Signature _____ Date _____ 20 _____

Second Applicant Signature _____ Date _____ 20 _____



PERMIT IS ISSUED CONTINGENT UPON LOCAL REQUIREMENTS BEING SATISFIED.

TEAR ON PERFORATION

CHECK TYPE OF OPERATION	Permit Fee	Insurance Fee	Perm 17 or Under Taking	Total Amount of Fee and/or Insurance
5. <input type="checkbox"/> Single job – Permit issued for each job				
a. <input type="checkbox"/> Driveway or roadway				
1. <input type="checkbox"/> Residential	\$ 15	\$ 25		
2. <input type="checkbox"/> Commercial – Minor	550	175		
a. <input type="checkbox"/> Home Business	100	75		
3. <input type="checkbox"/> Commercial – Major – (Less than 100,000 square feet Gross Building Area)	1400	N/A		
4. <input type="checkbox"/> Commercial – Major – (100,000 square feet Gross Building Area and Greater)	Actual cost with Minimum of \$2000 upon permit app.	N/A		
5. <input type="checkbox"/> Subdivision Street	900	N/A		
6. <input type="checkbox"/> Temporary access road or street	200	150		
b. <input type="checkbox"/> Improvement				
1. <input type="checkbox"/> Residential	15	25		
2. <input type="checkbox"/> Commercial				
Check additional description below:				
a. <input type="checkbox"/> Install sidewalk, curb paving, stabilized shoulder, drainage, etc.	200	150		
b. <input type="checkbox"/> Grade, seed, improve land contour, clear land of brush, etc.	100	75		
c. <input type="checkbox"/> Resurface existing roadway or driveway	50	50		
d. <input type="checkbox"/> Annual resurfacing of residential and commercial roadways or driveways.				
1. <input type="checkbox"/> Per County	150	N/A		
2. <input type="checkbox"/> Per Region	400	N/A		
c. <input type="checkbox"/> Tree Work				
1. <input type="checkbox"/> Residential	15	25		
2. <input type="checkbox"/> Commercial (not required for pruning if utility has annual maintenance permit)	25	50		
Check additional description below:				
a. <input type="checkbox"/> Removal or planting				
b. <input type="checkbox"/> Pruning, applying chemicals to stumps, etc.				
3. <input type="checkbox"/> Vegetation control for advertising signs	150/sign	75		
d. <input type="checkbox"/> Miscellaneous Construction				
1. <input type="checkbox"/> Beautifying ROW – (for Civic Groups only)	NC	25		
2. <input type="checkbox"/> Temporary signs, banners, holiday decorations				
a. <input type="checkbox"/> Not-for-profit organizations	NC	25		
b. <input type="checkbox"/> Organizations other than not-for-profit	25	25		
3. <input type="checkbox"/> Traffic control signals	500	175		
4. <input type="checkbox"/> Warning and entrance signs	25	50		
5. <input type="checkbox"/> Miscellaneous – Requiring substantial review	400	175		
6. <input type="checkbox"/> Miscellaneous	25	50		
6. <input type="checkbox"/> Encroachment caused by D.O.T. acquisition of property	25	50		
7. <input type="checkbox"/> Compulsory permit required for work performed at the request of D.O.T.				
a. <input type="checkbox"/> Building demolition or moving requested by D.O.T.	NC	25		
1. <input type="checkbox"/> Demolition 2. <input type="checkbox"/> Moving				
b. <input type="checkbox"/> Improvement to meet Department standards	NC	25		
8. <input type="checkbox"/> Miscellaneous	25	25		
9. <input type="checkbox"/> Adopt a Highway	NC	N/A		

TEAR ON PERFORATION

Guarantee Deposit Check Number or Bond Number _____

COSTS INCURRED BY ISSUANCE OF THIS PERMIT

All costs beyond the limits of the protective liability insurance, surety deposits, etc. are the responsibility of the permittee. The State shall be held free of any costs incurred by the issuance of this permit, direct or indirect.

SUBMITTING WORK PLANS

The applicant will submit work plans and/or a map as required by the Department. This shall include such details as measurements of driveways with relation to nearest property corner, positions of guys supporting poles and a schedule of the number of poles and feet of excavation necessary for completion of the work on the State right-of-way. A description of the proposed method of construction will be included.

Plan work with future adjustments in mind, as any relocation, replacement or removal of the installation authorized by this permit and made necessary by future highway maintenance, reconstruction or new construction, will be the responsibility of the permittee.

Driveway plans should be prepared in accordance with the POLICY AND STANDARDS FOR ENTRANCES TO STATE HIGHWAYS.

The permittee must coordinate the work with any state construction being conducted.

TRAFFIC MAINTENANCE

A plan detailing how the permittee intends to maintain and protect traffic shall be submitted with work plans. Traffic shall be maintained on the highway in a safe manner during working and non-working hours until construction is completed. The permittee is responsible for traffic protection and maintenance, including adequate use of signs, barriers, and flag persons during working and non-working hours until construction is completed.

All sketches will be stamped with "MAINTENANCE OF TRAFFIC SHALL BE IN CONFORMANCE WITH THE NEW YORK STATE MANUAL OF UNIFORM TRAFFIC CONTROL DEVICES."

COST OF INSPECTION AND SUPERVISION

Prior to issuance of the Highway Work Permit, the permittee may be required to sign an INSPECTION PAYMENT AGREEMENT FOR HIGHWAY WORK PERMITS (FORM PERM 50) agreeing to the payment of inspection charges and/or PAYMENT OF AGREEMENT FOR HIGHWAY WORK PERMITS DESIGN REVIEW (FORM PERM 51) for Department employees. Inspection charges will be based on number of work days. Design Review charges will be based on number of work hours.

SCOPE

Areas Covered: Permits issued are for highways, bridges and culverts over which the New York State Department of Transportation has jurisdiction. (Local governments issue permits for highways under their jurisdiction.)

Legal: The privilege granted by the permit does not authorize any infringement of federal, state or local laws or regulations, is limited to the extent of the authority of this Department in the promises and is transferable and assignable only with the written consent of the Commissioner of Transportation.

Commissioner's Reservation: The Commissioner of Transportation reserves the right to modify fees and to revoke or annul the permit at any time, at his discretion without a hearing or the necessity of showing cause.

Locations: Work locations must be approved by the Department.

Maintenance: Property owners having access to a state highway shall be fully responsible for the maintenance of their driveway in accordance with POLICY AND STANDARDS FOR ENTRANCES TO STATE HIGHWAYS.

Work Commencement: The Permittee shall have a copy of the permit available at the site during the construction period. Work should start within 30 days from validation date of permit or said permit may be revoked.

COMPLETION OF PROJECT

Upon completion of the work within the state highway right-of-way authorized by the work permit, the person and his or its successors in interest, shall be responsible for the maintenance and repair of such work or portion of such work as set forth within the Terms and Conditions of the Highway Work Permit.

State of New York
Department of Transportation

(Revised 11/03)

Residential Driveway Form

Instructions and Form

Submit with PERM 33

DRIVEWAY DESIGN POLICY

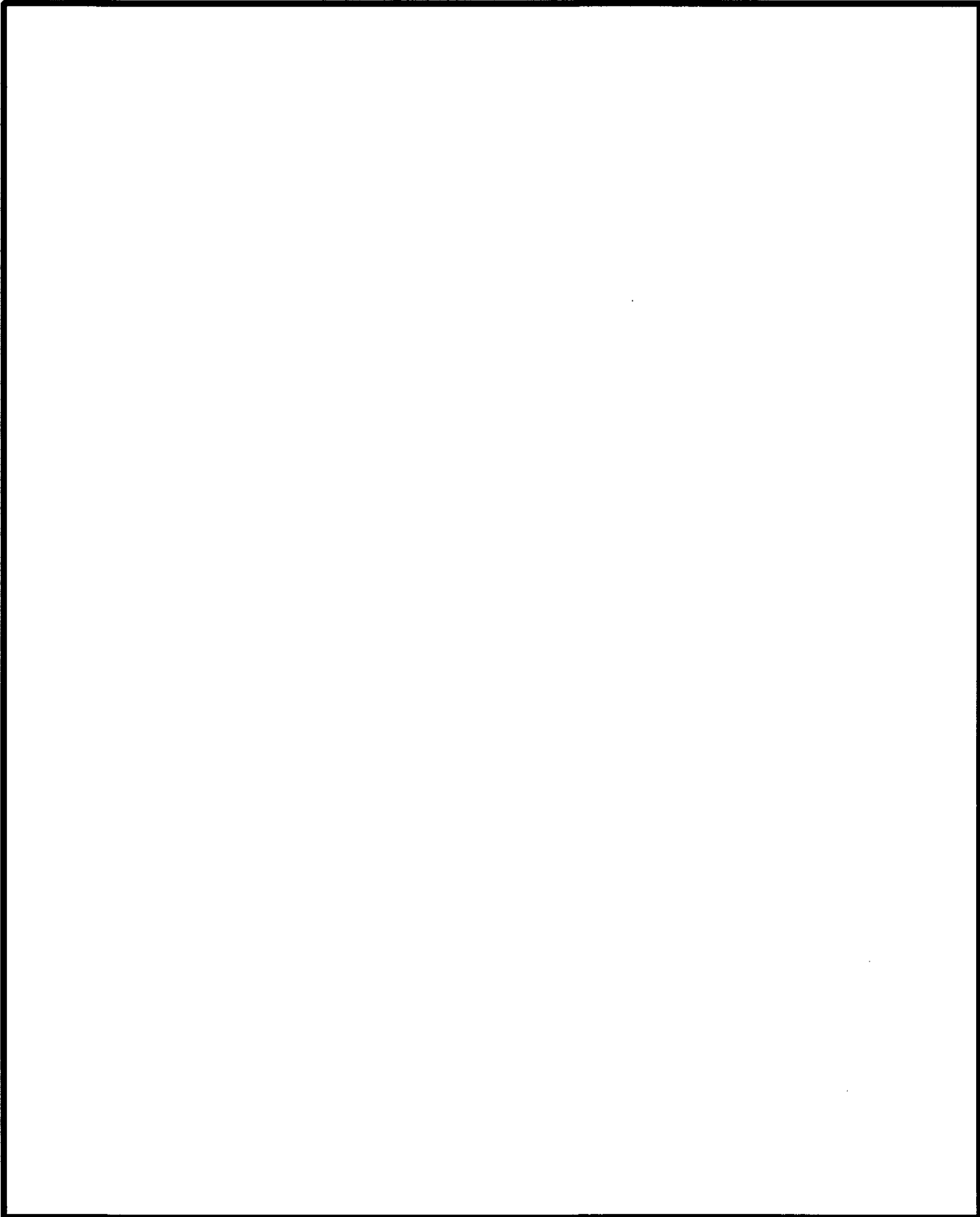
INSTRUCTIONS - This form is for residential driveway applicants only. This form is to be submitted with the PERM 33 *Highway Work Permit Application*. Refer to the New York State *Policy and Standards for the Design of Entrances to State Highways* (i.e., The Driveway Design Policy) for copies of the PERM 33 and for additional guidance and requirements. Complete the white sections of this form.

HELP - Contact the NYSDOT Resident Engineer listed on the Department's Internet home page <http://www.dot.state.ny.us/reg/regmenu.html>. The address and phone number are also listed in the Government Listings (blue pages) of your local phone book (typically under State Offices, Transportation Department of, Transportation Maintenance).

COPIES - The Driveway Design Policy is available from the New York State Department of Transportation online at <http://www.dot.state.ny.us/> or from the Plans Sales Office at (518) 457-2124.

#	Requirements and Questions	✓ or reply
1.	<p>Sketch of Driveway Site - A sketch with the following items should be completed on a copy of a tax map or site map and stapled to this form. If a tax map or site map is not available, place a sketch showing the items below on the following page. Please clearly label the items on the sketch and use a ruler or straight edge (The sketch must be clearly legible).</p> <ul style="list-style-type: none"> • North directional arrow. • Existing location and dimensions of the following items <u>along the frontage of the applicant's property</u>: <ul style="list-style-type: none"> ▸ Width of the outside highway travel lane. ▸ Width of the highway shoulder. ▸ If the applicant's property is a corner lot, include the distance from the edge of proposed driveway to the edge of pavement of the intersecting roadway. ▸ Curbs. ▸ Highway drainage (culverts, inlets, and ditches). ▸ Guide rail. ▸ Sidewalk. ▸ Utility poles and boxes. ▸ Traffic signs. ▸ Traffic signals. ▸ Property lines. • Existing and proposed buildings on the applicant's property. • Direction of surface water flow on applicant's property (i.e., direction that the rain water flows across the property). • Centerline of the proposed driveway(s). Refer to Figure 5A-1 of the Driveway Design Policy for restrictions on driveway locations. <p>The Department may require additional information as site-specific conditions warrant.</p> <p>The sketch need not be to scale if dimensions are provided. The dimensions should be as follows:</p> <ul style="list-style-type: none"> • Dimensions less than 30 m (100 ft) should be to the nearest 0.3 m (1 ft). • Dimensions of 30 m (100 ft) to 100 m (300 ft) should be to the nearest 3 m (10 ft). • Distances greater than 100 m (300 ft) need not be measured and can be noted as ">100 m (300 ft)" on the sketch. • U.S. customary (inches and feet) or metric units may be used. 	

Sketch of Driveway Site



DRIVEWAY DESIGN POLICY

#	Requirements and Questions	✓ or reply
2.	Location - Street address and the distance and direction from nearest cross street or State Highway Reference Marker (include number). Examples: 409 NY Route 7, Princetown, NY, 300 feet west of Kelly Station Road. 512 NY Route 20, Duanesburg, NY, 1000 feet east of Reference Marker 20 1619 1064.	
3.	Underground Utilities - Have the location flagged for underground utilities before construction. Up-State NY, call 1 (800) 962-7962. NYC and Long Island, call 1 (800) 272-4480. Date flagged (month/day/year) =	___/___/___
4.	Select Driveway Width - Select a preferred driveway width ranging from 9 ft to 24 ft for driveways 50 ft or less in length and 9 ft to 12 ft for driveways longer than 50 ft.	_____ ft.
5.	Maximum Grade - In urban areas, the maximum grade is 8% (1 inch per foot). In rural areas, the maximum grade is 12% (1.5 inches per foot). Maximum grade	_____
6.	Driveway Materials - • Existing driveway material = _____ • Proposed driveway material within 10 ft of traveled-way (Asphalt or Concrete) = _____	_____ _____
7.	Drainage - If the driveway will cross a ditch, a culvert with a tapered/flared end section is needed. (Culvert head walls may be permitted only if there is a run of existing guide rail along the highway that would prevent an errant vehicle from being abruptly stopped by the head wall.) • Inside diameter (15 in minimum) = _____ • Material = _____	_____ in _____
8.	Curb - Answer "No" if the highway is not curbed. Dropped curb is a 1 inch high curb running across the driveway opening. This helps keep storm water from flowing from the highway to a driveway with a downhill slope away from the highway. Will dropped curb be used? (Yes or No)	_____
9.	Corner Angle - Angle measured from the highway turning into the driveway. 90° is preferred. Angle must be between 60° and 120°.	_____ °
10.	Layout Method - Select the layout method using the table below. Attached are the layout instructions. Entrance Type (Radius or Taper) =	_____

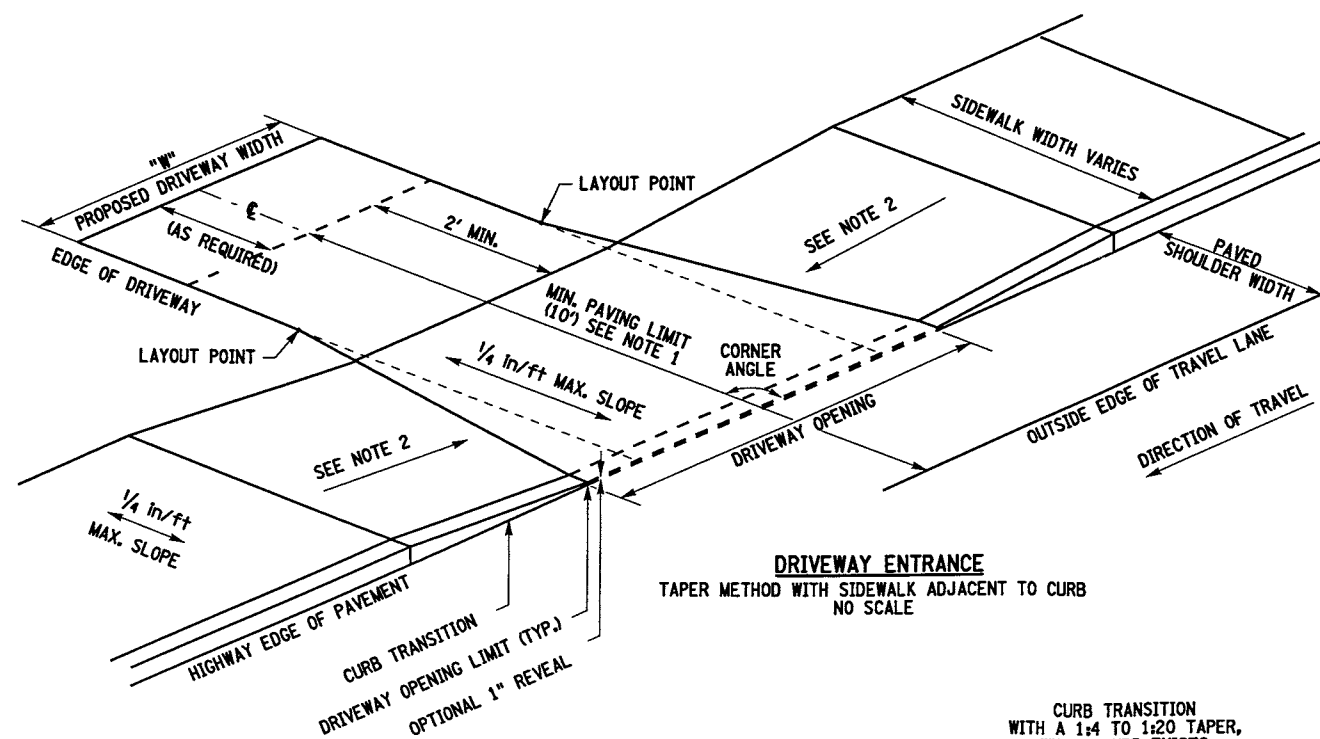
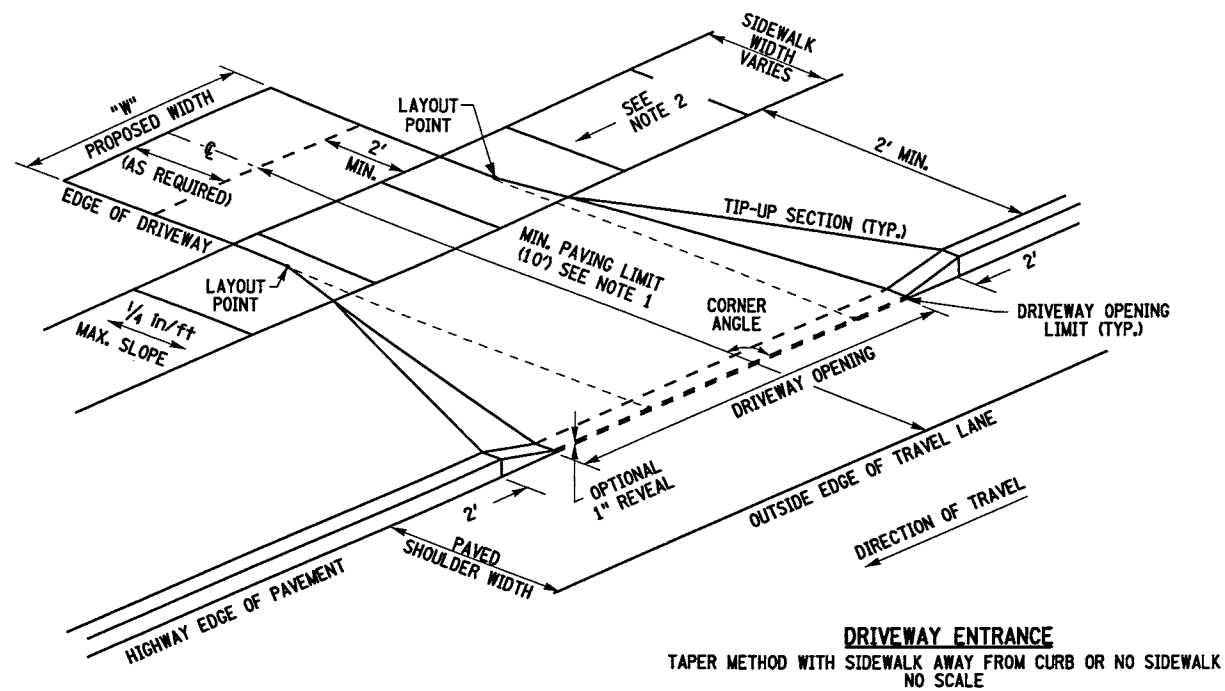
Driveway Entrance Type Selection

Entrance Type	Conditions for Use				
	Corner Angle*	Travel Lane and Paved Shoulder Width	Curb	Sidewalk	Highway Design Speed
Radius Type	60 - 120	Any	Use with or without curb	Use with or without sidewalk	Any
Taper Type	80 - 100	16 ft or greater	Use only with curb	Use with or without sidewalk	Only low speed (posted 40 mph or less)**

* The corner angle is the angle between the driveway centerline and the highway centerline.

** Unless otherwise directed by the Department.

CONSTRUCTION PLANS & PROFILES - The following pages are layout instructions for you or your driveway contractor.



CURB TRANSITION
WITH A 1:4 TO 1:20 TAPER,
WHERE CURB EXISTS
SEE NOTE 4

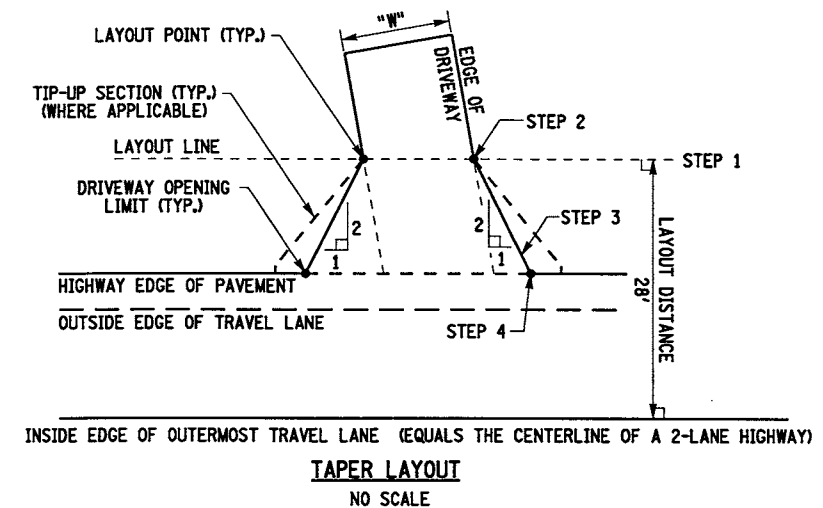
NOTES:

1. PAVE DRIVE A MINIMUM OF 2' BEYOND SIDEWALK. SIDEWALKS SHALL HAVE A 6" MINIMUM THICKNESS (IF PORTLAND CEMENT CONCRETE).
2. SIDEWALK RAMPS MUST HAVE A MAXIMUM SLOPE OF 1 in/ft EXCEPT WHERE THE HIGHWAY GRADE MAKES THIS IMPRACTICAL. IN SUCH CASES, USE A 15' RAMP LENGTH.
3. PLACE WIRE FABRIC REINFORCEMENT 3" BELOW THE TOP SURFACE OF PORTLAND CEMENT CONCRETE SIDEWALKS AND DRIVEWAYS.
4. NEW CURB SHALL NOT BE CONSTRUCTED. DETAIL SHOWS HOW TO CONSTRUCT A DRIVEWAY OPENING WHERE CURB IS PRESENT. IF CURB IS NOT PRESENT, OMIT THE TIP-UP SECTION AND CURB TRANSITION.
5. PAVED SHOULDER WIDTH MAY BE DESIGNATED AS A PARKING LANE, BIKE LANE, OR CURB OFFSET
6. ROUND SHARP CHANGES IN GRADE TO PREVENT VEHICLES FROM BOTTOMING OUT.

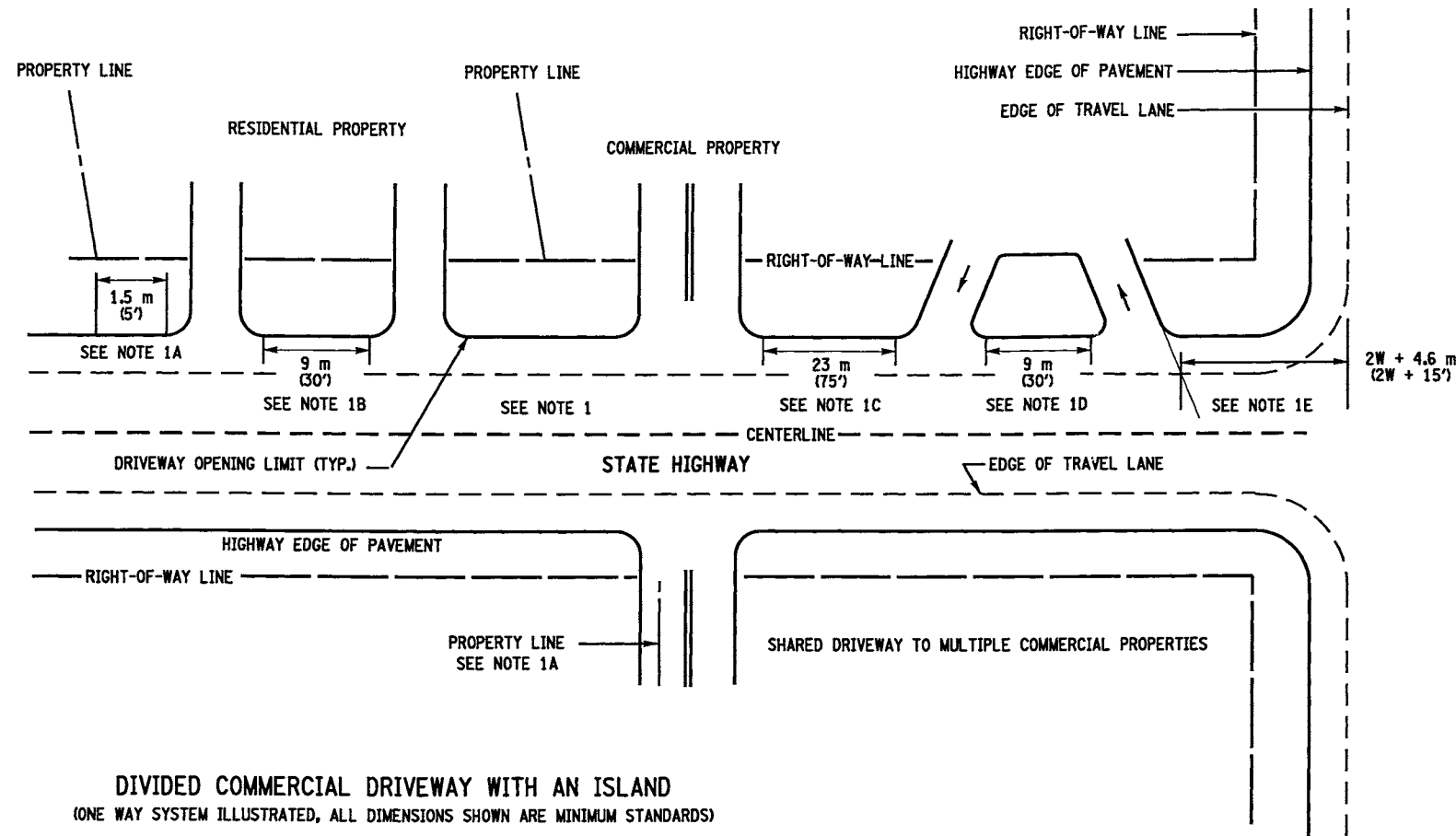
TAPER METHOD OF LAYOUT

TAPERS ARE NOT RECOMMENDED FOR DRIVEWAYS WITH CORNER ANGLES LESS THAN 80 DEGREES OR GREATER THAN 100 DEGREES. TAPERS ARE NOT RECOMMENDED FOR DRIVEWAYS WITH AN OUTER TRAVEL LANE + PAVED SHOULDER WIDTH OF LESS THAN 16'. REGARDLESS OF THE CORNER ANGLE OR COMBINED LANE AND PAVED SHOULDER WIDTH, TAPERS CAN BE USED IF THE DRIVEWAY ENTRANCE WIDTH WILL ACCOMMODATE THE TURNING MOVEMENTS OF A FULL-SIZED PICKUP TRUCK OR SUV WITHOUT ENCRANCHING INTO OTHER TRAVEL LANES OR TRAVELING OFF THE EDGE OF PAVEMENT.

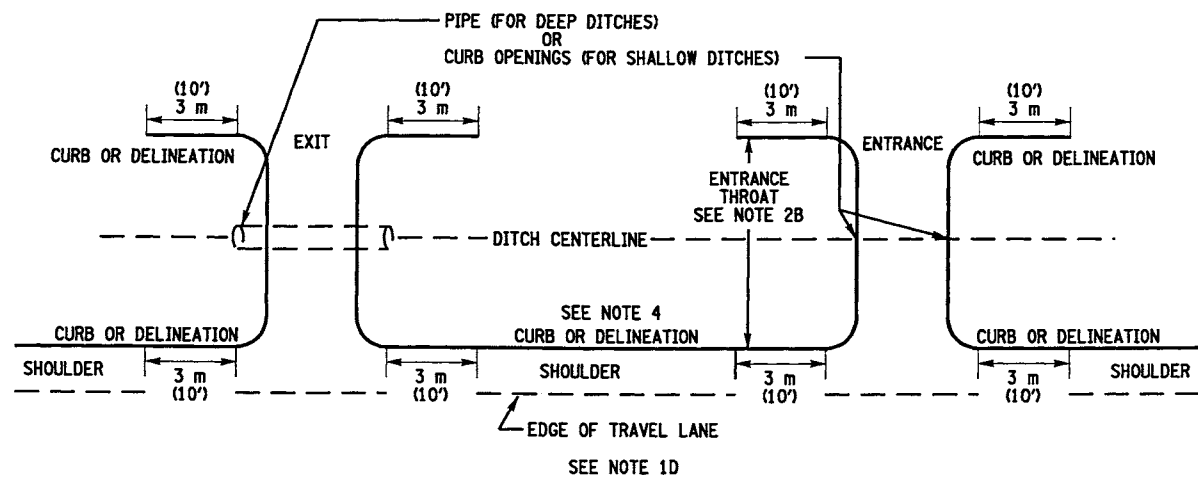
- STEP 1. SCRIBE A LINE (LAYOUT LINE) OFFSET THE 28' 'LAYOUT DISTANCE' FROM THE INSIDE EDGE OF THE OUTERMOST TRAVEL LANE.
- STEP 2. LOCATE THE TAPER LAYOUT POINT, WHICH IS AT THE INTERSECTION OF THE EDGE OF DRIVEWAY AND THE LAYOUT LINE.
- STEP 3. SCRIBE A 1:2 TAPER FROM THE LAYOUT POINT TO THE EDGE OF PAVEMENT.
- STEP 4. FIND THE DRIVEWAY OPENING LIMIT POINT WHICH IS WHERE THE TAPER INTERSECTS THE EDGE OF PAVEMENT.
- STEP 5. REPEAT STEPS 1 - 4 FOR THE OTHER SIDE OF THE DRIVEWAY OPENING.



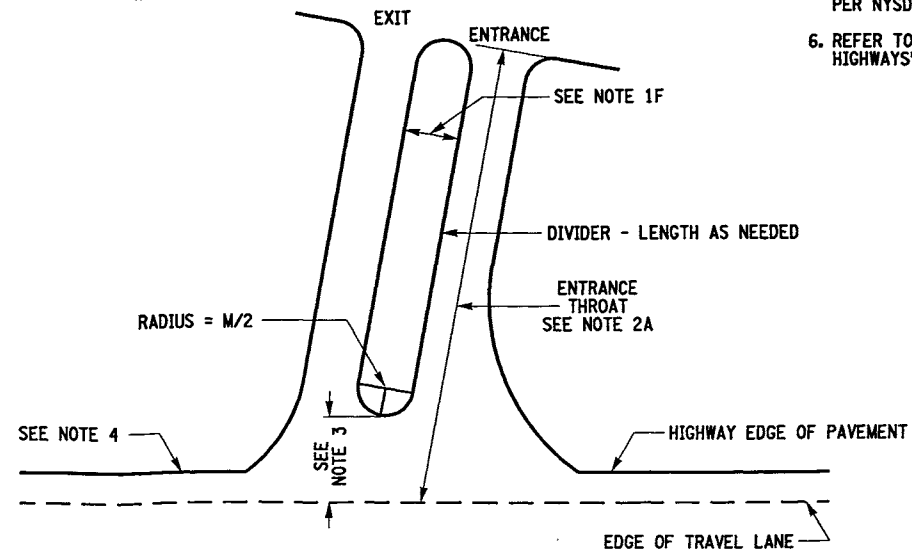
DRIVEWAY LOCATION STANDARDS
ALL DIMENSIONS SHOWN ARE MINIMUM STANDARDS



DIVIDED COMMERCIAL DRIVEWAY WITH AN ISLAND
(ONE WAY SYSTEM ILLUSTRATED, ALL DIMENSIONS SHOWN ARE MINIMUM STANDARDS)



DIVIDED COMMERCIAL DRIVEWAY WITH A MEDIAN



NOTES:

1. DRIVEWAY SPACING MEASURED ALONG THE HIGHWAY EDGE OF PAVEMENT:

- A. PROPERTY LINE: THE MINIMUM DISTANCE BETWEEN THE DRIVEWAY OPENING LIMIT AND THE POINT WHERE A PROJECTION (PERPENDICULAR TO THE CENTERLINE OF THE ROADWAY FROM THE NEAR PROPERTY CORNER) MEETS THE HIGHWAY EDGE OF PAVEMENT IS TO BE 1.5 m (5'). THIS RESTRICTION DOES NOT APPLY TO THE PROPERTY LINES BETWEEN OWNERS OF A SHARED DRIVEWAY.
- B. TWO DRIVES TO RESIDENTIAL PROPERTY (IF PERMITTED): THE MINIMUM DISTANCE BETWEEN THE DRIVEWAY OPENING LIMITS SHALL BE 9 m (30').
- C. ADJACENT DRIVEWAYS OR MULTIPLE DRIVEWAYS TO A COMMERCIAL PROPERTY: THE MINIMUM DISTANCE BETWEEN THE DRIVEWAY OPENING LIMITS SHALL BE 23 m (75'). IF THE DEPARTMENT ALLOWS AN EXISTING LESSER WIDTH TO BE RETAINED, THE ENTIRE SHOULDER AREA BETWEEN DRIVEWAYS SHALL BE REPLACED WITH ADEQUATE DRIVEWAY MATERIAL AND, IF SPEEDS ARE BELOW 80 km/h (50 mph), IT SHALL BE CURBED (WITH DRAINAGE OPENINGS AS NECESSARY).
- D. ONE-WAY COMMERCIAL DRIVES SEPARATED BY AN ISLAND: THE MINIMUM DISTANCE BETWEEN THE DRIVEWAY OPENING LIMITS SHALL BE 9 m (30').
- E. INTERSECTION: THE DISTANCE BETWEEN THE EDGE OF A DRIVEWAY (PROJECTED TO THE TRAVELED WAY) AND A SIDE ROAD TRAVEL LANE EDGE SHALL BE AT LEAST TWICE THE WIDTH OF THE DRIVEWAY PLUS 4.6 m (15'). IF PRACTICABLE, STRIVE FOR AT LEAST A 30 m (100') OFFSET TO A SIGNALIZED SIDE ROAD PAVEMENT EDGE.
- F. ONE-WAY COMMERCIAL DRIVES SEPARATED BY A MEDIAN: THE MEDIAN WIDTH (M) MAY BE 1.2 m TO 4.9 m (4' TO 16').
- G. REFER TO CHAPTER 6 OF THE NYS DOT HIGHWAY DESIGN MANUAL (NYS DOT HDM) FOR CONTROL OF ACCESS LIMITS FOR DIAMOND AND OTHER TYPES OF INTERCHANGES.

2. COMMERCIAL DRIVEWAY THROAT (MEASURED ALONG DRIVEWAY ENTRANCE):

- A. TWO-WAY DRIVES AND ONE-WAY DRIVES SEPARATED BY A MEDIAN: THE MINIMUM DEPTH OF ENTRANCE THROAT SHOULD BE 9 m (30') FOR MINOR COMMERCIAL DRIVES AND 15 m (50') FOR MAJOR COMMERCIAL DRIVES.
- B. ISLANDS: THE MINIMUM DEPTH OF THE ENTRANCE THROAT SHOULD BE AT LEAST ONE HALF THE WIDTH OF THE WIDEST DRIVEWAY.

3. COMMERCIAL DRIVEWAY MEDIANS SHOULD BE OFFSET TO AVOID TURNING PATH OF VEHICLE. AS A MINIMUM:

- A. ON CURBED HIGHWAYS, OFFSET THE END OF THE MEDIAN AT LEAST 1.2 m (4') BEHIND THE CURB LINE.
- B. ON HIGHWAYS WITH SHOULDERS, THE END OF THE MEDIAN SHALL NOT INFRINGE ON THE SHOULDER AND SHALL BE OFFSET AT LEAST 1.2 m (4') BEHIND THE OUTERMOST TRAVEL LANE, WHICHEVER IS GREATER.

4. CURBING:

- A. WHERE NO CURBING EXISTS, ANY PROPOSED NEW CURBING SHALL CONFORM TO CHAPTER 3, SECTION 3.2.9, OF THE NYS DOT HDM AND SHOULD BE OFFSET FROM THE TRAVEL LANE TO ALLOW THE INSTALLATION OF A STANDARD PAVED SHOULDER OR CURB OFFSET IN ACCORDANCE WITH NYS DOT HDM CHAPTER 2, SECTION 2.7.
- B. WHERE CURBING EXISTS AT THE EDGE OF HIGHWAY, CURBING SHALL MATCH THE ADJACENT CURB TYPE AND ALIGNMENT.

5. FIXED OBJECTS SHALL BE LOCATED OUTSIDE OF THE HIGHWAY'S CLEAR ZONE WIDTH PER NYS DOT HDM CHAPTER 10.

6. REFER TO THE "POLICY AND STANDARDS FOR THE DESIGN OF ENTRANCES TO STATE HIGHWAYS" SECTION 5A.4 FOR ADDITIONAL REQUIREMENTS AND THE NEED FOR PERMITS.

FIGURE 5A-1

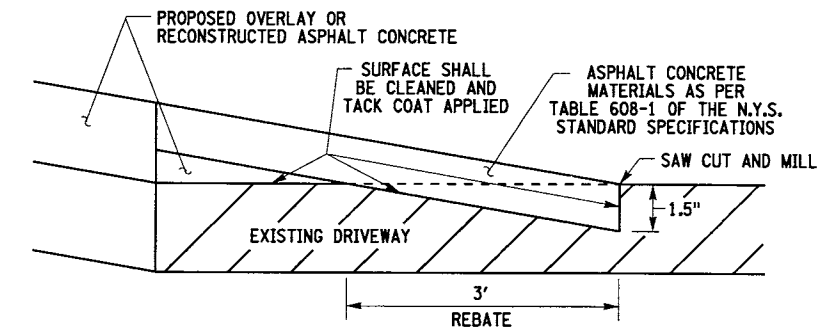
DEFINITION OF TERMS

- DRIVEWAY -**
EVERY ENTRANCE OR EXIT USED BY VEHICULAR TRAFFIC TO AND FROM LANDS OR BUILDINGS ABUTTING A STATE HIGHWAY.
- RESIDENTIAL DRIVEWAY -**
A DRIVEWAY SERVING FOUR OR FEWER PRIVATE HOMES OR AN APARTMENT BUILDING FOR FOUR OR FEWER FAMILY UNITS.
- COMMERCIAL DRIVEWAY -**
A DRIVEWAY SERVING A COMMERCIAL ESTABLISHMENT, INDUSTRY, GOVERNMENTAL OR EDUCATIONAL INSTITUTION, PRIVATE UTILITY, HOSPITAL, CHURCH, APARTMENT BUILDING, OR OTHER COMPARABLE TRAFFIC GENERATOR.
- MAJOR COMMERCIAL DRIVEWAY -**
ANY COMMERCIAL DRIVEWAY WHERE THE ACTUAL OR ANTICIPATED TRAFFIC VOLUME ON A TYPICAL DAY IS EITHER: (1) 100 OR MORE ONE-WAY TRIPS DURING THE PEAK HOUR FOR EITHER THE ADJACENT ROADWAY OR THE DEVELOPMENT, OR (2) 50 OR MORE ONE-WAY TRIPS DURING THE 8TH HIGHEST HOUR OF ANNUAL DRIVEWAY ACTIVITY.
- MINOR COMMERCIAL DRIVEWAY -**
ANY COMMERCIAL DRIVEWAY WHERE THE ACTUAL OR ANTICIPATED TRAFFIC VOLUMES ON A TYPICAL DAY ARE LESS THAN THE VALUES STIPULATED FOR A MAJOR COMMERCIAL DRIVEWAY.
- FIELD ENTRANCE -**
A DRIVEWAY SERVING A FARMYARD, CULTIVATED OR UNCULTIVATED FIELD, TIMBERLAND; OR UNDEVELOPED LAND NOT USED FOR INDUSTRIAL, COMMERCIAL, OR RESIDENTIAL PURPOSES.
- URBAN / RURAL -**
THE ENGINEER WILL DETERMINE THE AREA CHARACTER BASED ON NYS DOT HIGHWAY DESIGN MANUAL CHAPTER 2, SECTION 2.4.
- MINIMUM PAVING LIMIT ("MPL") -**
THE MINIMUM DISTANCE FROM THE OUTSIDE EDGE OF TRAVEL LANE THAT THE DRIVEWAY MUST BE PAVED AS MEASURED ALONG THE CENTERLINE OF THE DRIVEWAY (INCLUDES THE SHOULDER WIDTH).
- PAVEMENT LENGTH ("PL") -**
THE DISTANCE FROM THE HIGHWAY EDGE OF PAVEMENT TO THE END OF PROPOSED DRIVEWAY PAVEMENT AS MEASURED ALONG THE CENTERLINE OF THE DRIVEWAY (NOTE THAT "PL" IS MEASURED FROM DIFFERENT POINTS THAN "MPL")
- TRANSITION LENGTH ("TL") -**
THE DISTANCE ALONG THE CENTERLINE OF DRIVEWAY BEYOND THE DRIVEWAY PAVEMENT LENGTH ("PL") TO THE END OF PROPOSED DRIVEWAY WORK (USUALLY FOR GRADING, DRIVEWAY ENTRANCE LAYOUT, OR TRANSITION REASONS). THE TRANSITION LENGTH ONLY APPLIES TO NON-PAVEMENT DRIVEWAYS (EXAMPLE: DIRT, GRASS, GRAVEL, OR STONE DRIVEWAYS)
- DRIVEWAY OFFSET -**
THE DISTANCE FROM THE INSIDE EDGE OF THE OUTERMOST TRAVEL LANE (OR TURNING LANE) TO THE HIGHWAY EDGE OF PAVEMENT (EQUALS OUTERMOST TRAVEL LANE + PAVED SHOULDER OR CURB OFFSET).
- HIGHWAY EDGE OF PAVEMENT -**
THE OUTSIDE EDGE OF THE PAVED HIGHWAY SURFACE, INCLUDING ANY PAVED SHOULDER, BIKE LANE, PARKING LANE, OR CURB OFFSET.

GENERAL NOTES FOR DRIVEWAY STANDARD SHEETS

- GENERAL**
- A. THE DRIVEWAY STANDARD SHEETS APPLY TO FIELD ENTRANCES, RESIDENTIAL DRIVEWAYS AND MINOR COMMERCIAL DRIVEWAYS. FIELD ENTRANCES AND RESIDENTIAL DRIVEWAYS ACCOMMODATE AN AASHTO PASSENGER CAR DESIGN VEHICLE. MINOR COMMERCIAL DRIVEWAYS ACCOMMODATE AN AASHTO SINGLE UNIT TRUCK DESIGN VEHICLE.
- B. WORK PERFORMED OFF THE RIGHT-OF-WAY REQUIRES A DRIVEWAY RELEASE TO BE ACQUIRED BY THE ENGINEER.
- C. SEE THE DRIVEWAY TABLE IN THE CONTRACT PLANS FOR SPECIFIC DRIVEWAY LOCATIONS, WIDTHS ("W"), CORNER ANGLES, LENGTHS ("L"), MATERIAL, AND ENTRANCE TYPE.
- WIDTH/LENGTH**
- D. IF THERE ARE CONSTRAINTS THAT PREVENT THE CONSTRUCTION OF THE DRIVEWAY OPENING AS PER EITHER OF THE LAYOUT METHODS, THE ENGINEER MAY SPECIFY A SMALL CORNER CURB RADIUS OF 2' (OR "1/2 BULLNOSE" CURB ALONG LOW SPEED HIGHWAYS), PROVIDED THE DRIVEWAY OPENING MEETS THE WIDTH ON FIGURE 5A-5 "DRIVEWAY OPENING LIMITS."
- E. FOR RESIDENTIAL DRIVEWAYS, THE MINIMUM PAVING LIMIT SHALL BE 10' FROM THE OUTSIDE EDGE OF TRAVEL LANE OR 2' BEHIND ANY SIDEWALK, IF PRESENT, WHICHEVER IS GREATER. FOR MINOR COMMERCIAL DRIVEWAYS, THE MINIMUM PAVING LIMIT SHALL EXTEND TO THE RIGHT-OF-WAY LINE OR 2' BEHIND ANY SIDEWALK, IF PRESENT, OR 10' FROM THE OUTSIDE EDGE OF TRAVEL LANE, WHICHEVER IS GREATER. THE PAVING LIMIT MAY EXTEND BEYOND THE MINIMUM PAVING LIMIT FOR NEW DRIVEWAYS AND TO TRANSITION TO EXISTING PAVED DRIVEWAYS. THE PAVING LIMIT WILL BE NOTED IN THE DRIVEWAY TABLE OF THE CONTRACT PLANS.
- F. FOR GRADING AND CONSTRUCTION REQUIREMENTS OF TRANSITIONS FROM PLACED ASPHALT CONCRETE TO EXISTING ASPHALT CONCRETE DRIVEWAYS, REFER TO THE "TIE-IN TO EXISTING DRIVEWAYS" DETAIL AND TABLE 3 "DRIVEWAY MATERIALS AND THICKNESS".
- G. FOR PORTLAND CEMENT CONCRETE DRIVEWAYS, REFER TO THE 502 SERIES N.Y.S. STANDARD SHEETS FOR METAL REINFORCEMENT, JOINT TIES, SAWING AND SEALING, ETC.
- SITE CONDITIONS (SIDEWALK/CURB)**
- H. ANY SIDEWALK WHICH CROSSES A DRIVEWAY SHALL HAVE A MINIMUM THICKNESS OF 6" AND INCLUDE WIRE FABRIC REINFORCEMENT WITH 3" OF TOP COVER.
- I. TO PREVENT DRIVEWAY GRADES FROM EXCEEDING THE VALUES IN TABLE 2 - "MAXIMUM SLOPE", IT MAY BE NECESSARY TO DEPRESS THE SIDEWALK ACROSS THE DRIVEWAY. SIDEWALK RAMPS SHALL HAVE A MAXIMUM LONGITUDINAL SLOPE OF 1:12. WHERE THE HIGHWAY GRADE MAKES A 1:12 SLOPE IMPRACTICAL, THE RAMP LENGTH MAY BE RESTRICTED TO 15'.
- J. FOR TYPE 1 AND TYPE 2 DRIVEWAY ENTRANCES, IF THERE IS ABUTTING SIDEWALK AND THE OFFSET BETWEEN THE SIDEWALK AND THE BACK OF CURB IS LESS THAN 2', USE THE TYPE 4 SIDEWALK RAMP ON THE N.Y.S. "SIDEWALK CURB RAMP DETAILS" STANDARD SHEET.
- K. WHERE DRAINAGE IS CARRIED ALONG THE CURB, CONSTRUCT THE DRIVEWAY WITH A SHORT UPGRADE TO PREVENT RUNOFF FROM PONDING AT THE DRIVEWAY ENTRANCE (FLAT DRIVEWAY) OR RUNNING DOWN THE DRIVEWAY (DOWNHILL DRIVEWAY SLOPE). IF CONDITIONS MAKE THE ADDITION OF A SHORT UPGRADE IMPRACTICAL, CURB REVEAL ALONG THE DRIVEWAY OPENING MAY BE SPECIFIED BY THE ENGINEER. TYPICALLY, CURB REVEAL WILL NOT BE CONSTRUCTED IN RURAL AREAS. IF CURB REVEAL IS SPECIFIED FOR A SPECIFIC DRIVEWAY, IT WILL BE NOTED IN THE DRIVEWAY TABLE OF THE CONTRACT PLANS IN THE 'COMMENTS' COLUMN.

- ENTRANCE TYPE**
- L. THE ENGINEER MAY INTERCHANGE TYPE 1, TYPE 3 AND TYPE 4 RESIDENTIAL DRIVEWAYS TO BETTER MATCH THE EXISTING ENTRANCE TYPES ALONG THE HIGHWAY CORRIDOR WHILE CONSIDERING AVAILABLE SPACE, CONSTRUCTABILITY, SAFETY, AND FUNCTIONALITY. THE DRIVEWAY TYPE WILL COMPLY WITH TABLE 4 'DRIVEWAY ENTRANCE TYPE SELECTION' ON FIGURE 5A-3 'DRIVEWAY ENTRANCE DETAILS'.
- M. FOR DRIVEWAYS WITH VARYING WIDTHS AND/OR CURVED ALIGNMENTS, DETERMINE THE DRIVEWAY WIDTH AND CORNER ANGLE 16' FROM THE EDGE OF TRAVEL LANE.
- N. FOR A ONE-WAY DRIVEWAY ENTRANCE OR EXIT, THE DRIVEWAY ENTRANCE WIDENING IS ONLY NECESSARY ON ONE SIDE OF THE DRIVEWAY TO ACCOMMODATE THE ONE PARTICULAR TURNING MOVEMENT. ONE-WAY DRIVEWAYS WILL BE IDENTIFIED ON THE DRIVEWAY TABLE OF THE CONTRACT PLANS UNDER 'COMMENTS'. FOR CURBED HIGHWAYS, A SMALL CORNER CURB RADIUS OF 2' (OR '1/2 BULLNOSE' CURB ALONG LOW SPEED HIGHWAYS) SHALL BE CONSTRUCTED TO ELIMINATE A SHARP CORNER BEND IN THE CURBLINE (THIS IS SAFER FOR SNOWPLOW OPERATIONS).
- MATERIAL**
- O. FOR DRIVEWAY MATERIAL REQUIREMENTS, USE TABLE 3-'DRIVEWAY MATERIALS AND THICKNESS'.
- P. FOR FIELD ENTRANCES, THE MATERIAL WITHIN THE PAVEMENT LENGTH ("PL") CAN CONSIST OF GRAVEL OR STONE AND THEY MAY BE CONNECTED TO THE EDGE OF THE HIGHWAY SHOULDER WITHOUT REMOVING ANY OF THE EXISTING SHOULDER MATERIAL.



TIE-IN TO EXISTING DRIVEWAYS
FOR ASPHALT CONCRETE
NO SCALE

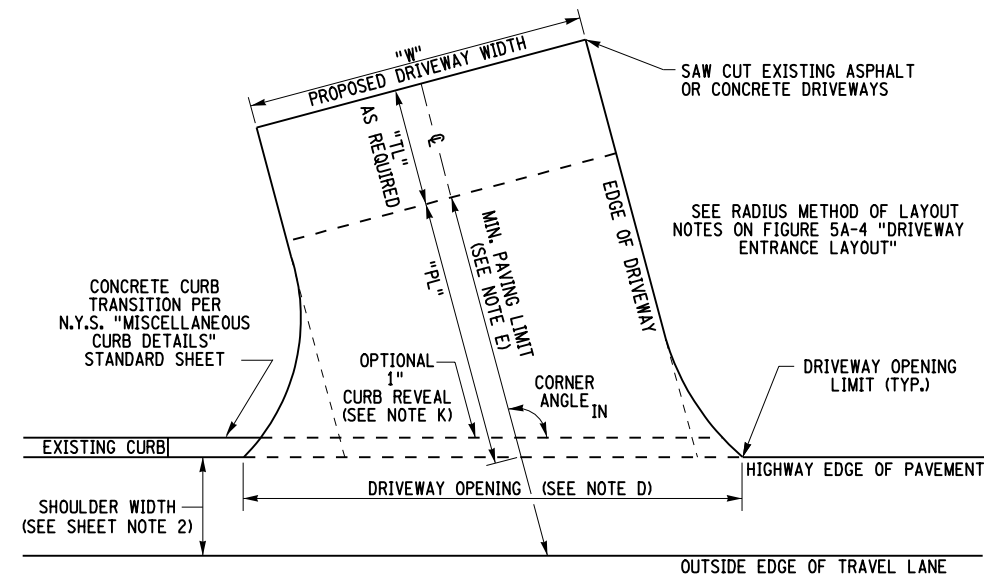
DRIVEWAY CLASSIFICATION	STANDARD WIDTH	PERMISSIBLE RANGE OF WIDTHS
RESIDENTIAL - - GREATER THAN 50' IN LENGTH - 50' OR LESS IN LENGTH	12'	9' TO 12'
MINOR COMMERCIAL - SHARED TWO-WAY DRIVEWAY - DIVIDED OR ONE-WAY DRIVEWAY - MULTI-LANE DRIVEWAY	24' 16' 12' LANES	22' TO 30' 12' TO 24' N/A

ROADWAY CLASSIFICATION	COMMERCIAL DRIVEWAY	RESIDENTIAL DRIVEWAY
RURAL	10%	12%
URBAN	6%	8%

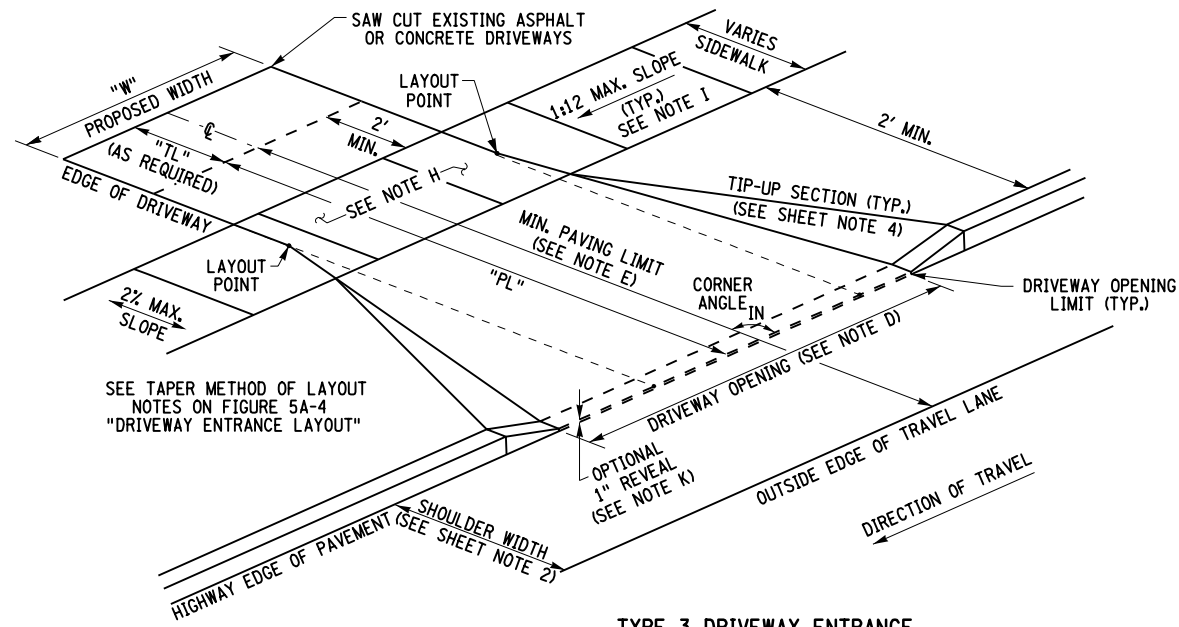
PROPOSED OR EXISTING DRIVE	WITHIN DRIVEWAY PAVEMENT LENGTH ("PL")			WITHIN TRANSITION LENGTH ("TL")		
	MATERIAL	THICKNESS FOR RESIDENTIAL (INCHES)	THICKNESS FOR MINOR COMMERCIAL (INCHES)	MATERIAL	THICKNESS FOR RESIDENTIAL (INCHES)	THICKNESS FOR MINOR COMMERCIAL (INCHES)
DIRT, GRASS, OR GRAVEL	(1) ASPHALT CONC. SW/D/BP (2) SUBBASE COURSE	3 6	4 8	(1) SUBBASE COURSE EXCAVATE AS NECESSARY	6	9
STONE	(1) ASPHALT CONC. SW/D/BP (2) SUBBASE COURSE	3 6	4 8	(1) STONE EXCAVATE AS NECESSARY	8	11
ASPHALT CONCRETE (RESURFACING)	(1) ASPHALT CONC. SW/D/BP (2) TRUING AND LEVELING COURSE	1.5 AS NECESSARY	1.5 AS NECESSARY	NOT APPLICABLE - ALL WORK ON AN EXISTING PAVED DRIVEWAY IS WITHIN THE DRIVEWAY PAVEMENT LENGTH		
ASPHALT CONCRETE (RECONSTRUCTION)	(1) ASPHALT CONC. SW/D/BP (2) SUBBASE COURSE	3 6	4 8	NOT APPLICABLE - ALL WORK ON AN EXISTING PAVED DRIVEWAY IS WITHIN THE DRIVEWAY PAVEMENT LENGTH		
PORTLAND CEMENT CONCRETE	(1) PORTLAND CEMENT CONC. SW/D (2) SUBBASE COURSE	6 6	6 8	NOT APPLICABLE - ALL WORK ON AN EXISTING PAVED DRIVEWAY IS WITHIN THE DRIVEWAY PAVEMENT LENGTH		

NOTE: ASPHALT CONC. SW/D/BP = ASPHALT CONCRETE SIDEWALKS, DRIVEWAYS, AND BICYCLE PATHS
PORTLAND CEMENT CONC. SW/D = PORTLAND CEMENT CONCRETE SIDEWALKS AND DRIVEWAYS

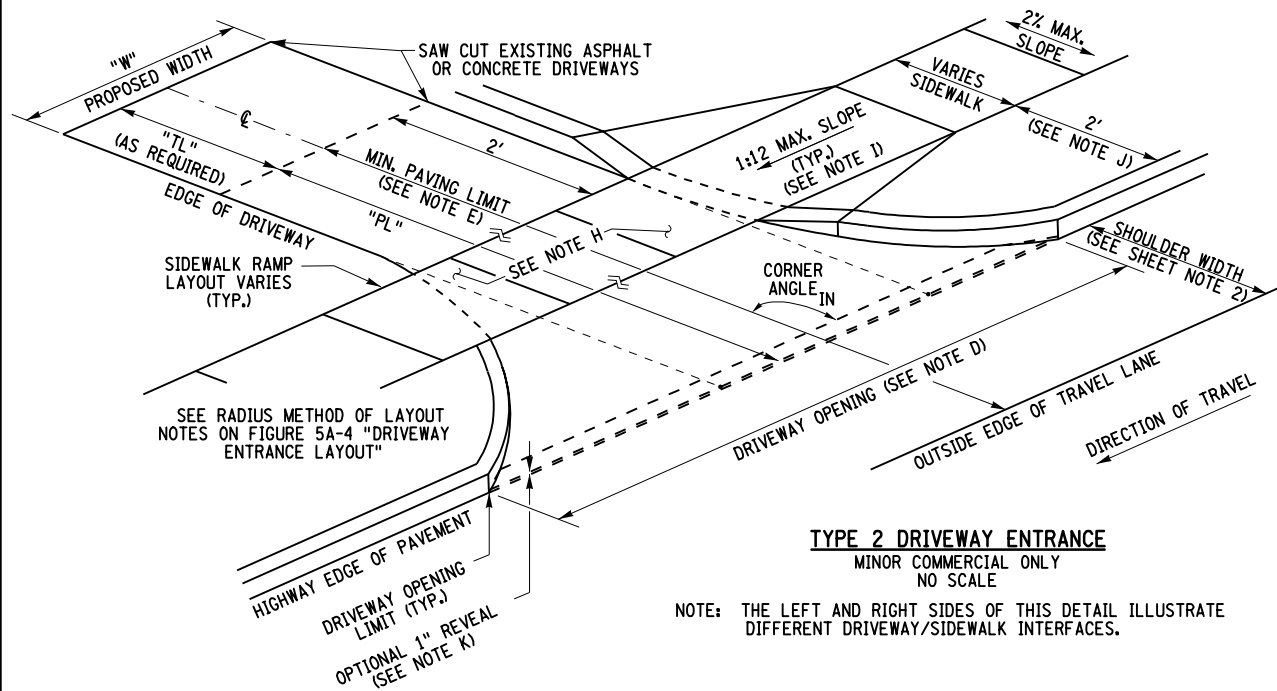
NOTE: ALL DIMENSIONS IN INCHES UNLESS OTHERWISE NOTED



TYPE 1 DRIVEWAY ENTRANCE
TYPICAL DRIVEWAY ENTRANCE TYPE
NO SCALE

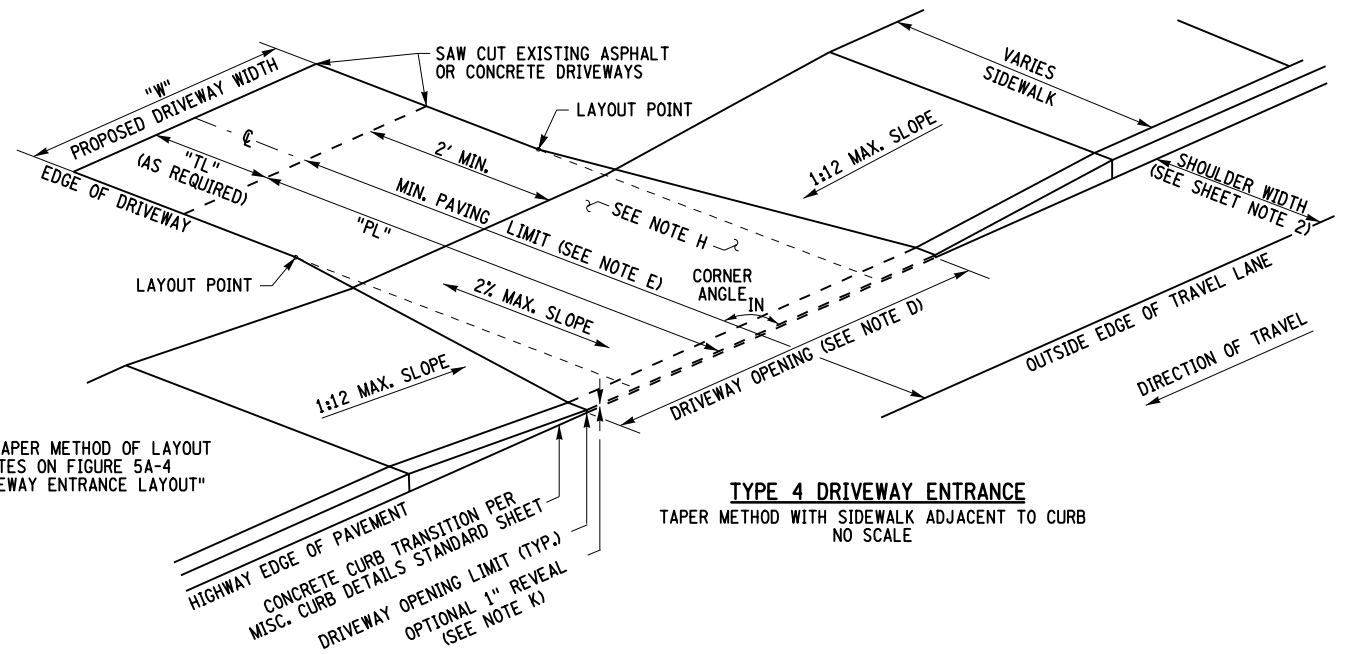


TYPE 3 DRIVEWAY ENTRANCE
TAPER METHOD WITH SIDEWALK AWAY FROM CURB OR NO SIDEWALK
NO SCALE



TYPE 2 DRIVEWAY ENTRANCE
MINOR COMMERCIAL ONLY
NO SCALE

NOTE: THE LEFT AND RIGHT SIDES OF THIS DETAIL ILLUSTRATE DIFFERENT DRIVEWAY/SIDEWALK INTERFACES.



TYPE 4 DRIVEWAY ENTRANCE
TAPER METHOD WITH SIDEWALK ADJACENT TO CURB
NO SCALE

- NOTES :
1. REFER TO FIGURE 5A-2 "DRIVEWAY DESIGN GUIDELINES" FOR GENERAL NOTES, NOTES REFERENCED BY A LETTER, AND DEFINITIONS OF TERMS.
 2. 'SHOULDER WIDTH' REFERS TO THE PAVED SHOULDER WIDTH. THE SHOULDER WIDTH MAY BE DESIGNATED AS A PARKING LANE, BIKE LANE, CURB OFFSET, OR OTHER PAVED AREA.
 3. THE DETAILS SHOW THE PAVEMENT LENGTH ("PL") EXTENDING TO THE MINIMUM PAVING LIMIT ("MPL"). HOWEVER, THE "PL" CAN EXTEND BEYOND THE "MPL" AS SPECIFIED ON THE DRIVEWAY TABLE IN THE CONTRACT DOCUMENTS
 4. A DRIVEWAY TIP-UP SECTION SHOULD EXTEND TO A LOGICAL TERMINI (EXAMPLE: SIDEWALK EDGE, WHERE THE DRIVEWAY GRADE MATCHES EXISTING GROUND, OR LAYOUT POINT). FOR REFERENCE, A REASONABLE LENGTH FOR TAPERING THE TIP-UP SECTION BACK TO THE EDGE OF DRIVEWAY IS 3 TO 4 TIMES THE LENGTH OF CURB DROP. THE TIP-UP SECTION IS NOT PART OF THE DRIVEWAY OPENING WIDTH. REFER TO THE N.Y.S. "MISCELLANEOUS CURB DETAILS" STANDARD SHEET FOR THE CURB TRANSITION.

TABLE 4 - DRIVEWAY ENTRANCE TYPE SELECTION

DRIVEWAY ENTRANCE TYPE	ENTRANCE WIDENING METHOD	CONDITIONS FOR USE						RECOMMENDED USE
		DRIVEWAY CLASSIFICATION*	CORNER ANGLE	TRAVEL LANE AND SHOULDER WIDTH	CURB	SIDEWALK	HIGHWAY DESIGN SPEED	
TYPE 1	RADIUS	RESIDENTIAL OR MINOR COMMERCIAL	60° TO 120°	ANY	USE WITH OR WITHOUT CURB	USE WITH OR WITHOUT SIDEWALK	ANY SPEED	RECOMMENDED FOR ALL LOCATIONS (EXCEPT FOR MINOR COMMERCIAL WITH CURB)
TYPE 2	RADIUS	MINOR COMMERCIAL ONLY	60° TO 120°	ANY	USE ONLY WITH CURB	USE WITH OR WITHOUT SIDEWALK	ANY SPEED	RECOMMENDED ONLY FOR MINOR COMMERCIAL WITH CURB
TYPE 3	TAPER	RESIDENTIAL OR MINOR COMMERCIAL	80° TO 100°	16' ** OR GREATER	USE ONLY WITH CURB ***	USE ONLY WITH SIDEWALK OFFSET A MIN. OF 2' FROM THE EDGE OF PAVEMENT OR WITHOUT SIDEWALK	ONLY LOW SPEED (45 MPH OR LESS)	ALTERNATIVE ENTRANCE TYPE (TYPICALLY FOR URBAN AREA USE)
TYPE 4	TAPER	RESIDENTIAL OR MINOR COMMERCIAL	80° TO 100°	16' ** OR GREATER	USE ONLY WITH CURB ***	USE ONLY WITH SIDEWALK LESS THAN 2' FROM OR ADJACENT TO THE EDGE OF PAVEMENT	ONLY LOW SPEED (45 MPH OR LESS)	ALTERNATIVE ENTRANCE TYPE (TYPICALLY FOR URBAN AREA USE)

* THE TABLE ONLY APPLIES TO RESIDENTIAL AND MINOR COMMERCIAL DRIVEWAYS. FOR OTHER DRIVEWAY CLASSIFICATIONS (MAJOR COMMERCIAL, FIELD ENTRANCE, ETC.), REFER TO THE 'POLICY AND STANDARDS FOR THE DESIGN OF ENTRANCES TO STATE HIGHWAYS'.

** FOR DRIVEWAYS WITH A DRIVEWAY OFFSET LESS THAN 16', THE TAPER METHOD IS NOT GENERALLY RECOMMENDED, UNLESS IT CAN BE FIELD VERIFIED THAT THE DRIVEWAY ENTRANCE WIDTH WILL ACCOMMODATE THE VEHICLES THAT USE THE DRIVEWAY ON A REGULAR BASIS.

*** TYPE 3 AND 4 DRIVEWAY ENTRANCES CAN BE USED WITHOUT CURB IF A TAPER STYLE ENTRANCE BETTER MATCHES THE HIGHWAY CORRIDOR AESTHETICS OR SPECIFIC SITE CONDITIONS THAN A RADIUS STYLE ENTRANCE.

NOTE: ALL DIMENSIONS IN INCHES UNLESS OTHERWISE NOTED

DRIVEWAY ENTRANCE DETAILS
FIGURE 5A-3

DRIVEWAY OPENING LAYOUT

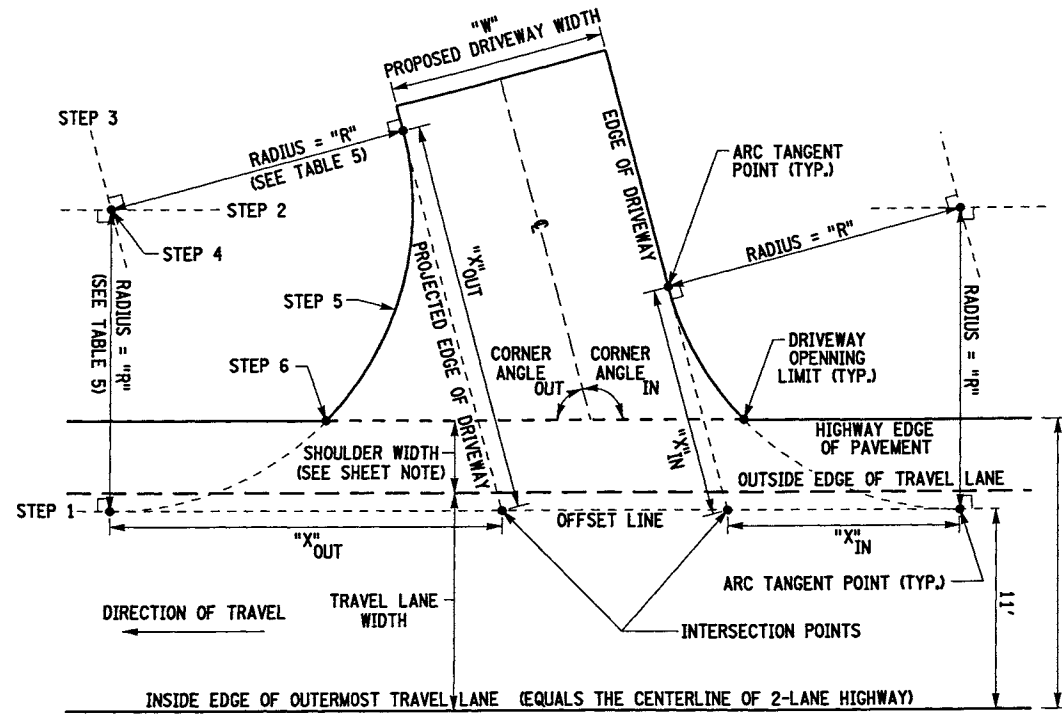
THERE ARE TWO RECOMMENDED DRIVEWAY OPENING WIDENING METHODS: (1.) THE RADIUS METHOD, WHICH UTILIZES A CIRCULAR ARC TO WIDEN THE DRIVEWAY, AND (2.) THE TAPER METHOD, WHICH UTILIZES A STRAIGHT TAPER WIDENING OUT AT AN ESTABLISHED FLARE RATE. THE RADIUS METHOD IS THE TYPICAL METHOD, ALTHOUGH THE TAPER METHOD IS A REASONABLE ALTERNATIVE FOR URBAN AREAS AND OTHER AREAS WHERE IT MIGHT BETTER MATCH THE HIGHWAY CORRIDOR AESTHETICS AND FUNCTIONALITY. SEE TABLE 4 - 'DRIVEWAY ENTRANCE TYPE SELECTION' ON FIGURE 5A-3 'DRIVEWAY ENTRANCE DETAILS' FOR ADDITIONAL VARIABLES CONCERNING THE SELECTION OF A DRIVEWAY OPENING WIDENING METHOD.

RADIUS METHOD OF LAYOUT

- STEP 1. LOCATE AN OFFSET LINE 11' PARALLEL FROM THE INSIDE EDGE OF THE OUTERMOST TRAVEL LANE.
- STEP 2. SCRIBE A LINE PARALLEL TO THE OFFSET LINE, OFFSET "R" METERS (SEE TABLE 5).
- STEP 3. SCRIBE A LINE PARALLEL TO THE EDGE OF DRIVEWAY (NEAR SIDE), OFFSET "R" METERS.
- STEP 4. FIND THE CENTER POINT OF THE CORNER RADIUS ARC, WHICH IS LOCATED AT THE INTERSECTION OF THE LINES FROM STEPS 2 AND 3.
- STEP 5. FROM THE CENTER POINT, SCRIBE AN ARC WITH RADIUS "R", WHICH IS TANGENT TO BOTH THE OFFSET LINE AND THE EDGE OF DRIVEWAY. THE ARC SHOULD INTERSECT THE LINES AT THE DISTANCES "X" LISTED IN TABLE 6. DISTANCES IN TABLE 6 ARE AS MEASURED FROM THE INTERSECTION POINT OF THE OFFSET LINE (NOT THE EDGE OF TRAVEL LANE) AND THE PROJECTED EDGE OF DRIVEWAY TO EITHER OF THE ARC TANGENT POINTS (SAME DISTANCE ALONG THE OFFSET LINE OR ALONG THE PROJECTED EDGE OF DRIVEWAY).
- STEP 6. FIND THE DRIVEWAY OPENING LIMIT POINT WHICH IS WHERE THE ARC INTERSECTS THE HIGHWAY EDGE OF PAVEMENT.
- STEP 7. REPEAT STEPS 1 - 6 FOR THE OTHER SIDE OF THE DRIVEWAY OPENING.

FIELD LAYOUT NOTES :

FOR THE RADIUS METHOD OF LAYOUT, IF OBSTRUCTIONS HINDER THE ABILITY TO SCRIBE THE CORNER ANGLE ARC FROM THE CENTER POINT, LOCATE POINTS ALONG THE ARC BY USING "X" VALUES FROM TABLES 8 THROUGH 10 ON FIGURE 5A-5 'DRIVEWAY OPENING LIMITS' AT VARIOUS DRIVEWAY OFFSETS ("Y" IS MEASURED FROM THE PROJECTED EDGE OF DRIVEWAY TO THE ARC).

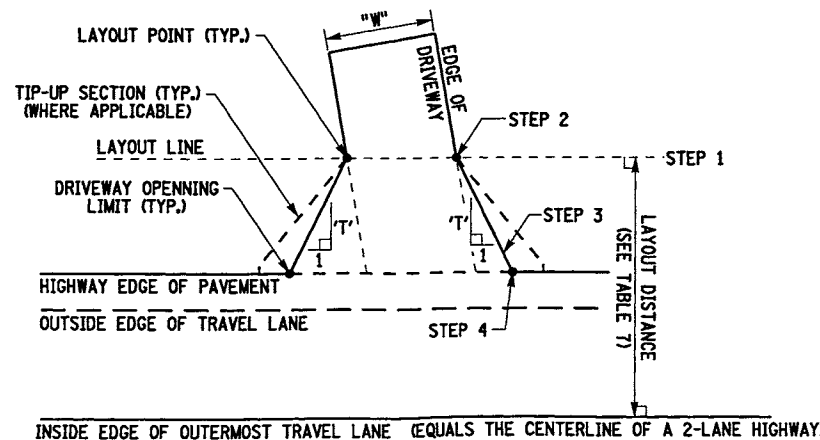


RADIUS LAYOUT
VALID FOR RESIDENTIAL OR MINOR COMMERCIAL DRIVEWAYS
(FOR THE VALUES OF "R" AND "X" SEE TABLES 5 AND 6, RESPECTIVELY)
NO SCALE

TAPER METHOD OF LAYOUT

TAPER METHOD OF LAYOUT IS NOT RECOMMENDED FOR DRIVEWAYS WITH CORNER ANGLES LESS THAN 80° OR GREATER THAN 100°, NOR IS IT RECOMMENDED FOR DRIVEWAYS WITH A DRIVEWAY OFFSET (OUTER TRAVEL LANE + PAVED SHOULDER) LESS THAN 16', UNLESS IT CAN BE FIELD VERIFIED THAT THE DRIVEWAY ENTRANCE WIDTH WILL ACCOMMODATE THE VEHICLES THAT USE THE DRIVEWAY ON A REGULAR BASIS.

- STEP 1. SCRIBE A LINE (LAYOUT LINE) OFFSET THE APPROPRIATE 'LAYOUT DISTANCE' (SEE TABLE 7) FROM THE INSIDE EDGE OF THE OUTERMOST TRAVEL LANE.
- STEP 2. LOCATE THE TAPER LAYOUT POINT, WHICH IS AT THE INTERSECTION OF THE EDGE OF DRIVEWAY AND THE LAYOUT LINE.
- STEP 3. SCRIBE A 1:T' (SEE TABLE 7) TAPER FROM THE LAYOUT POINT TO THE EDGE OF PAVEMENT (WITH 'T' BEING PERPENDICULAR TO THE EDGE OF TRAVEL LANE).
- STEP 4. FIND THE DRIVEWAY OPENING LIMIT POINT WHICH IS WHERE THE TAPER INTERSECTS THE EDGE OF PAVEMENT.
- STEP 5. REPEAT STEPS 1 - 4 FOR THE OTHER SIDE OF THE DRIVEWAY OPENING.



TAPER LAYOUT
VALID FOR RESIDENTIAL OR MINOR COMMERCIAL DRIVEWAYS
(FOR THE VALUE OF 'T' SEE TABLE 7)
NO SCALE

ALTERNATE TAPER METHOD OF LAYOUT

FOLLOW THE STEPS AS PER THE OTHER TAPER LAYOUT METHOD, EXCEPT FOR STEPS 3, AND 4. LOCATE THE DRIVEWAY OPENING LIMIT BY USING THE APPROPRIATE "Y" VALUE FROM EITHER TABLE 11 OR 12 ON FIGURE 5A-5 'DRIVEWAY OPENING LIMITS'. "Y" IS THE DISTANCE BETWEEN THE DRIVEWAY OPENING LIMIT AND THE INTERSECTION POINT OF THE PROJECTED EDGE OF DRIVEWAY AND THE EDGE OF PAVEMENT.

DRIVEWAY CLASSIFICATION	"R"
RESIDENTIAL "W" ≤ 13'	16'
RESIDENTIAL "W" > 13'	13'
MINOR COMMERCIAL (ALL WIDTHS)	33'

CORNER ANGLE	"X", FT		
	RESIDENTIAL DRIVEWAY ≤ 13' WIDE (R = 16')	RESIDENTIAL DRIVEWAY > 13' WIDE (R = 13')	MINOR COMMERCIAL DRIVEWAY (R = 33')
60°	28.5	23.0	56.8
65°	25.9	20.7	51.5
70°	23.6	18.7	46.9
75°	21.3	17.1	43.0
80°	19.7	15.7	39.4
85°	18.0	14.4	35.8
90°	16.4	13.1	32.8
95°	15.1	12.1	30.2
100°	13.8	11.2	27.6
105°	12.8	10.2	25.3
110°	11.5	9.2	23.0
115°	10.5	8.5	21.0
120°	9.5	7.5	19.0

TABLE 6 NOTES:
• DIMENSIONS AND ANGLES MAY BE INTERPOLATED FOR VALUES OTHER THAN THOSE SHOWN IN THE TABLE.
•• "X" REFERS TO EITHER "X"_{IN} OR "X"_{OUT}. THE CORNER ANGLE FOR X_{IN} + X_{OUT} MUST EQUAL 180°.

DRIVEWAY CLASSIFICATION	TAPER (1:T')	LAYOUT DISTANCE*
RESIDENTIAL	1:2	28'
MINOR COMMERCIAL	1:1.5	41'

* LAYOUT DISTANCE IS MEASURED FROM THE INSIDE EDGE OF OUTERMOST TRAVEL LANE. FOR A TYPICAL 12" WIDE TRAVEL LANE THIS IS EQUIVALENT TO AN OFFSET FROM THE OUTSIDE EDGE OF TRAVEL LANE OF 16' FOR RESIDENTIAL DRIVEWAYS OR 30' FOR MINOR COMMERCIAL DRIVEWAYS.

- NOTES :
1. REFER TO FIGURE 5A-2 "DRIVEWAY DESIGN GUIDELINES" FOR GENERAL NOTES.
 2. THE SHOULDER WIDTH REFERS TO THE PAVED SHOULDER WIDTH. THE SHOULDER WIDTH MAY BE DESIGNATED AS A PARKING LANE, BIKE LANE, CURB OFFSET, OR OTHER PAVED AREA.

NOTE: ALL DIMENSIONS IN INCHES UNLESS OTHERWISE NOTED

DRIVEWAY ENTRANCE LAYOUT
FIGURE 5A-4

TABLES 8 THROUGH 13 ARE FOR PRELIMINARY CURBLINE LAYOUT OF THE DRIVEWAY OPENING WIDTHS. USE THE LAYOUT METHODS DESCRIBED ON FIGURE 5A-4 "DRIVEWAY ENTRANCE LAYOUT" FOR FINAL DRIVEWAY LAYOUT (ALTHOUGH THE DRIVEWAY OPENING LIMITS SHOULD MATCH BETWEEN THE PRELIMINARY AND THE FINAL LAYOUT TECHNIQUES).

TABLE 8
DRIVEWAY OPENING "Y" (FT) VALUES FOR
RADIUS METHOD - RESIDENTIAL DRIVEWAYS ≤ 13' WIDE (R = 16')

CORNER ANGLE	DRIVEWAY OFFSET FROM INSIDE EDGE OF TRAVEL LANE (OR OFFSET FROM OUTSIDE EDGE OF A 12' TRAVEL LANE)										
	12' (0')	13' (1')	14' (2')	15' (3')	16' (4')	17' (5')	18' (6')	19' (7')	20' (8')	21' (9')	22' (10')
60°	22.3	19.7	17.4	15.7	14.1	12.5	11.2	9.8	8.9	7.9	6.9
65°	19.7	17.1	15.1	13.5	11.8	10.5	9.2	8.2	7.2	6.2	5.2
70°	17.7	15.1	13.1	11.5	10.2	8.9	7.9	6.6	5.9	4.9	4.3
75°	15.7	13.1	11.5	9.8	8.5	7.2	6.2	5.2	4.6	3.9	3.3
80°	14.1	11.5	9.8	8.5	7.2	5.9	5.2	4.3	3.6	3.0	2.3
85°	12.5	10.2	8.5	6.9	5.9	4.9	3.9	3.3	2.6	2.0	1.6
90°	10.8	8.9	7.2	5.9	4.9	3.9	3.3	2.6	2.0	1.6	1.0
95°	9.5	7.5	5.9	4.9	3.9	3.0	2.3	2.0	1.3	1.0	0.7
100°	8.5	6.6	4.9	3.9	3.0	2.3	1.6	1.3	1.0	0.7	0.3
105°	7.2	5.6	4.3	3.0	2.3	1.6	1.3	0.7	0.7	0.3	0.0
110°	6.6	4.6	3.3	2.3	1.6	1.0	0.7	0.3	0.3	0.0	0.0
115°	5.6	3.6	2.6	1.6	1.0	0.7	0.3	0.3	0.0	0.0	0.0
120°	4.6	3.0	2.0	1.3	0.7	0.3	0.0	0.0	0.0	0.0	0.0

TABLE 9
DRIVEWAY OPENING "Y" (FT) VALUES FOR
RADIUS METHOD - RESIDENTIAL DRIVEWAYS > 13' WIDE (R = 16')

CORNER ANGLE	DRIVEWAY OFFSET FROM INSIDE EDGE OF TRAVEL LANE (OR OFFSET FROM OUTSIDE EDGE OF A 12' TRAVEL LANE)										
	12' (0')	13' (1')	14' (2')	15' (3')	16' (4')	17' (5')	18' (6')	19' (7')	20' (8')	21' (9')	22' (10')
60°	17.4	14.8	12.8	11.2	9.8	8.5	7.2	6.2	5.2	4.6	3.6
65°	15.4	12.8	11.2	9.5	8.2	6.9	5.9	4.9	4.3	3.3	2.6
70°	13.5	11.2	9.5	8.2	6.9	5.9	4.9	3.9	3.3	2.6	2.0
75°	12.1	9.8	8.2	6.9	5.6	4.6	3.9	3.0	2.3	2.0	1.3
80°	10.8	8.5	6.9	5.9	4.6	3.6	3.0	2.3	2.0	1.3	1.0
85°	9.2	7.2	5.9	4.6	3.6	3.0	2.3	1.6	1.3	1.0	0.7
90°	8.2	6.2	4.9	3.9	3.0	2.3	1.6	1.3	1.0	0.7	0.3
95°	7.2	5.2	4.3	3.3	2.3	1.6	1.3	0.7	0.3	0.3	0.0
100°	6.2	4.6	3.3	2.3	1.6	1.3	0.7	0.3	0.3	0.0	0.0
105°	5.6	3.9	2.6	2.0	1.3	0.7	0.3	0.3	0.0	0.0	0.0
110°	4.6	3.3	2.0	1.3	1.0	0.3	0.3	0.0	0.0	0.0	0.0
115°	3.9	2.6	1.6	1.0	0.7	0.3	0.0	0.0	0.0	0.0	0.0
120°	3.3	2.0	1.0	0.7	0.3	0.0	0.0	0.0	0.0	0.0	0.0

TABLE 10
DRIVEWAY OPENING "Y" (FT) VALUES FOR
RADIUS METHOD - MINOR COMMERCIAL DRIVEWAYS (R = 33')

CORNER ANGLE	DRIVEWAY OFFSET FROM INSIDE EDGE OF TRAVEL LANE (OR OFFSET FROM OUTSIDE EDGE OF A 12' TRAVEL LANE)										
	12' (0')	13' (1')	14' (2')	15' (3')	16' (4')	17' (5')	18' (6')	19' (7')	20' (8')	21' (9')	22' (10')
60°	48.2	44.6	41.7	39.0	36.7	34.8	32.8	31.2	29.5	27.9	26.2
65°	43.3	39.4	36.7	34.1	32.2	30.2	28.2	26.6	24.9	23.6	22.3
70°	38.7	35.1	32.2	29.9	27.9	25.9	24.3	22.6	21.3	20.0	18.7
75°	34.8	31.2	28.5	26.2	24.3	22.6	21.0	19.4	18.0	16.7	15.7
80°	31.2	27.6	24.9	23.0	21.0	19.4	17.7	16.4	15.1	14.1	12.8
85°	27.9	24.6	22.0	20.0	18.0	16.7	15.1	13.8	12.8	11.5	10.5
90°	24.9	21.7	19.4	17.4	15.7	14.1	12.8	11.5	10.5	9.5	8.5
95°	22.3	19.0	16.7	14.8	13.5	11.8	10.5	9.5	8.5	7.5	6.9
100°	19.7	16.7	14.4	12.8	11.2	9.8	8.9	7.5	6.6	5.9	5.2
105°	17.7	14.8	12.5	10.8	9.2	8.2	6.9	5.9	5.2	4.6	3.9
110°	15.4	12.5	10.5	8.9	7.5	6.6	5.6	4.6	3.9	3.3	2.6
115°	13.5	10.8	8.9	7.2	5.9	4.9	4.3	3.3	2.6	2.3	1.6
120°	11.5	8.9	7.2	5.6	4.6	3.6	3.0	2.3	1.6	1.3	1.0

TABLE 11
DRIVEWAY OPENING "Y" (FT) VALUES FOR
TAPER METHOD - RESIDENTIAL DRIVEWAYS

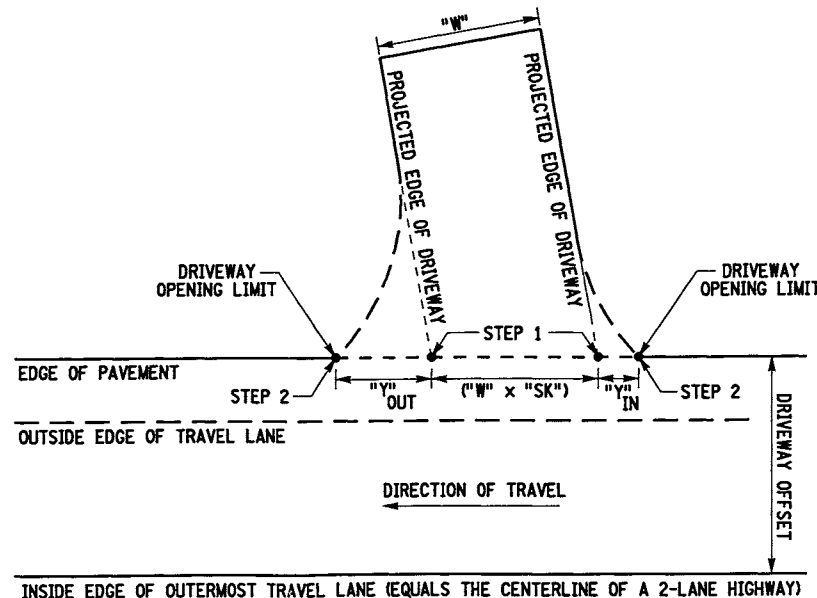
CORNER ANGLE	DRIVEWAY OFFSET FROM INSIDE EDGE OF TRAVEL LANE (OR OFFSET FROM OUTSIDE EDGE OF A 12' TRAVEL LANE)										
	12' (0')	13' (1')	14' (2')	15' (3')	16' (4')	17' (5')	18' (6')	19' (7')	20' (8')	21' (9')	22' (10')
80°	11.2	10.5	9.8	9.2	8.5	7.9	7.2	6.6	5.9	5.2	4.6
85°	9.8	9.2	8.5	7.9	7.5	6.9	6.2	5.6	5.2	4.6	3.9
90°	8.2	7.9	7.2	6.9	6.2	5.9	5.2	4.9	4.3	3.9	3.3
95°	6.9	6.6	6.2	5.6	5.2	4.9	4.3	3.9	3.6	3.3	3.0
100°	5.6	5.2	4.9	4.6	4.3	3.9	3.6	3.3	3.0	2.6	2.3

• SEE SHEET NOTE 3.

TABLE 12
DRIVEWAY OPENING "Y" (FT) VALUES FOR
TAPER METHOD - MINOR COMMERCIAL DRIVEWAYS

CORNER ANGLE	DRIVEWAY OFFSET FROM INSIDE EDGE OF TRAVEL LANE (OR OFFSET FROM OUTSIDE EDGE OF A 12' TRAVEL LANE)										
	12' (0')	13' (1')	14' (2')	15' (3')	16' (4')	17' (5')	18' (6')	19' (7')	20' (8')	21' (9')	22' (10')
80°	24.9	24.3	23.3	22.6	21.7	21.0	20.0	19.4	18.4	17.4	16.7
85°	22.3	21.7	21.0	20.0	19.4	18.7	18.0	17.1	16.4	15.7	15.1
90°	19.7	19.0	18.4	17.7	17.1	16.4	15.7	15.1	14.4	13.8	13.1
95°	17.4	16.7	16.1	15.4	15.1	14.4	13.8	13.1	12.8	12.1	11.5
100°	14.8	14.1	13.8	13.1	12.8	12.1	11.8	11.2	10.8	10.2	9.8

• SEE SHEET NOTE 3.



PRELIMINARY DRIVEWAY OPENING LAYOUT

ALTHOUGH THE DETAIL ONLY SHOWS A RADIUS ENTRANCE TYPE, THE DETAIL APPLIES TO BOTH RADIUS AND TAPER METHODS OF LAYOUT (FOR THE VALUES OF "Y" SEE TABLES 8 THROUGH 12) (FOR THE VALUE OF "SK" SEE TABLE 13)
NO SCALE

FIELD LAYOUT :

- STEP 1. LOCATE THE INTERSECTION POINTS OF THE PROJECTED EDGES OF DRIVEWAY AND THE EDGE OF PAVEMENT.
- STEP 2. ALONG THE EDGE OF PAVEMENT, MEASURE OUT FROM THE INTERSECTION POINTS AT DISTANCES "Y IN" AND "Y OUT" RESPECTIVELY TO LOCATE THE DRIVEWAY OPENING LIMITS. IN

TABLE 13 - DRIVEWAY OPENING WIDTH CALCULATION

CORNER ANGLE	DRIVEWAY OPENING WIDTH = "Y" _{IN} + ("W" x "SK") + "Y" _{OUT}						
	60°/120°	65°/115°	70°/110°	75°/105°	80°/100°	85°/95°	90°
SKEW FACTOR ("SK")	1.16	1.10	1.07	1.04	1.02	1.01	1.00

TABLE NOTE:

IF THE DRIVEWAY IS A ONE-WAY ENTRANCE OR EXIT, THEN "Y"(OUT) OR "Y"(IN), RESPECTIVELY, IS NOT INCLUDED IN THE EQUATION. ALTHOUGH FOR CURBED HIGHWAYS, ADDITIONAL DRIVEWAY OPENING WIDTH SHOULD BE ADDED TO ALLOW FOR A SMALL CORNER CURB RADIUS, TO ELIMINATE A SHARP CORNER BEND IN THE CURBLINE (THIS IS SAFER FOR SNOWPLOW OPERATIONS).

SAMPLE CALCULATION :

A 10' WIDE RESIDENTIAL DRIVEWAY CONNECTING WITH A CORNER ANGLE OF 70° (THEREFORE RADIUS METHOD REQUIRED) TO A HIGHWAY WITH A 12' WIDE TRAVEL LANE AND 4' PAVED SHOULDER (= 16' DRIVEWAY OFFSET), WOULD REQUIRE A DRIVEWAY OPENING WIDTH = "Y"_{70°} + ("W" x "SK") + "Y"_{110°} = 10.2 + (10 x 1.07) + 1.6 = 22.5'.

NOTES :

- REFER TO FIGURE 5A-2 "DRIVEWAY DESIGN GUIDELINES" FOR GENERAL NOTES, NOTES REFERENCED BY A LETTER, AND DEFINITION OF TERMS.
- THE DRIVEWAY OPENING WIDTH VARIES DEPENDING ON THE DRIVEWAY ENTRANCE WIDENING METHOD USED (RADIUS OR TAPER). THE TAPER METHOD GENERALLY WILL PROVIDE A MORE NARROW DRIVEWAY OPENING WIDTH.
- FOR DRIVEWAYS WITH A DRIVEWAY OFFSET LESS THAN 16', THE TAPER METHOD IS NOT GENERALLY RECOMMENDED, UNLESS IT CAN BE FIELD VERIFIED THAT THE DRIVEWAY ENTRANCE WIDTH WILL ACCOMMODATE THE VEHICLES THAT USE THE DRIVEWAY ON A REGULAR BASIS.
- DIMENSIONS AND ANGLES MAY BE INTERPOLATED FOR VALUES OTHER THAN THOSE SHOWN IN THE TABLES.
- "Y" REFERS TO EITHER "Y" IN OR "Y" OUT

NOTE: ALL DIMENSIONS IN INCHES UNLESS OTHERWISE NOTED

DRIVEWAY OPENING LIMITS
FIGURE 5A-5

VERTICAL HIGHWAY ALIGNMENT SIGHT DISTANCE CHARTS

APPENDIX 5B

November 24, 2003

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**APPENDIX 5B
VERTICAL HIGHWAY ALIGNMENT SIGHT DISTANCE CHARTS**

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APPENDIX 5B
VERTICAL HIGHWAY ALIGNMENT SIGHT DISTANCE CHARTS

5B-1

INTRODUCTION

The following charts should be used as a guide in the design of vertical highway alignments for new construction and reconstruction projects. Minimum values of curve lengths are calculated. Longer curves may be used where feasible and appropriate. The equations and tables are based on the AASHTO's "A Policy on Geometric Design of Highways and Streets," 2001.

SECTION I
LENGTH OF CREST VERTICAL CURVES
BASED ON MINIMUM STOPPING SIGHT DISTANCE

Computations are based on the following formulae:

$$S < L \quad L = AS^2 \div 658$$

$$S > L \quad L = 2S - (658 \div A)$$

Based on height of eye = 1080 mm and height of object = 600 mm

L = Length of Vertical Curve, m

S = Stopping Sight Distance, m

A = Algebraic Difference in Grade, %

Note: The minimum length of crest vertical curves should be the greater of:

1. Six-tenths of the design speed.
2. The length needed to provide minimum stopping sight distance using the above equations.

LENGTH OF CREST VERTICAL CURVES BASED ON MINIMUM STOPPING SIGHT DISTANCE

LENGTHS IN METERS

DIFF. IN PERCENT OF GRADE	DESIGN SPEED & MINIMUM STOPPING SIGHT DISTANCE														DIFF. IN PERCENT OF GRADE										
	30 km/h		40 km/h		50 km/h		60 km/h		70 km/h		80 km/h		90 km/h			100 km/h		110 km/h		120 km/h		130 km/h			
	35 m	50 m	50 m	65 m	65 m	85 m	85 m	105 m	105 m	130 m	130 m	160 m	160 m	185 m		185 m	220 m	220 m	250 m	250 m	285 m	285 m			
0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.7	
0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8
0.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.9
1.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.0
1.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.1
1.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22	22	1.2
1.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	64	64	64	1.3
1.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	31	101	101	101	1.4
1.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	62	132	132	132	1.5
1.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	89	159	159	159	1.6
1.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	113	183	183	183	1.7
1.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	135	205	205	205	1.8
1.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	154	224	224	224	1.9
2.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	171	241	241	241	2.0
2.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	187	257	257	257	2.1
2.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	201	271	271	271	2.2
2.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	214	284	284	284	2.3
2.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	226	297	297	297	2.4
2.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	237	309	309	309	2.5
2.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	247	321	321	321	2.6
2.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	257	334	334	334	2.7
2.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	266	346	346	346	2.8
2.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	276	358	358	358	2.9
3.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	285	371	371	371	3.0
3.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	295	383	383	383	3.1
3.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	304	396	396	396	3.2

LENGTH OF CREST VERTICAL CURVES BASED ON MINIMUM STOPPING SIGHT DISTANCE

LENGTHS IN METERS

DIFF. IN PERCENT OF GRADE	DESIGN SPEED & MINIMUM STOPPING SIGHT DISTANCE														DIFF. IN PERCENT OF GRADE
	30 km/h	40 km/h	50 km/h	60 km/h	70 km/h	80 km/h	90 km/h	100 km/h	110 km/h	120 km/h	130 km/h	130 km/h	285 m		
	35 m	50 m	65 m	85 m	105 m	130 m	160 m	185 m	220 m	250 m	285 m	285 m	285 m		
3.3	0	0	0	0	11	61	121	171	243	314	408	408	3.3		
3.4	0	0	0	0	17	67	127	177	251	323	420	420	3.4		
3.5	0	0	0	0	22	72	132	182	258	333	433	433	3.5		
3.6	0	0	0	0	28	78	138	188	265	342	445	445	3.6		
3.7	0	0	0	0	33	83	143	193	273	352	457	457	3.7		
3.8	0	0	0	0	37	87	147	198	280	361	470	470	3.8		
3.9	0	0	0	2	42	92	152	203	287	371	482	482	3.9		
4.0	0	0	0	6	46	96	156	209	295	380	494	494	4.0		
4.1	0	0	0	10	50	100	160	214	302	390	507	507	4.1		
4.2	0	0	0	14	54	104	164	219	309	399	519	519	4.2		
4.3	0	0	0	17	57	107	168	224	317	409	531	531	4.3		
4.4	0	0	0	21	61	111	172	229	324	418	544	544	4.4		
4.5	0	0	0	24	64	114	176	235	332	428	556	556	4.5		
4.6	0	0	0	27	67	117	179	240	339	437	568	568	4.6		
4.7	0	0	0	30	70	120	183	245	346	447	581	581	4.7		
4.8	0	0	0	33	73	123	187	250	354	456	593	593	4.8		
4.9	0	0	0	36	76	126	191	255	361	466	605	605	4.9		
5.0	0	0	0	39	79	129	195	261	368	475	618	618	5.0		
5.1	0	0	1	41	81	131	199	266	376	485	630	630	5.1		
5.2	0	0	4	44	84	134	203	271	383	494	642	642	5.2		
5.3	0	0	6	46	86	137	207	276	390	504	655	655	5.3		
5.4	0	0	9	49	89	139	211	281	398	513	667	667	5.4		
5.5	0	0	11	51	91	142	214	287	405	523	679	679	5.5		
5.6	0	0	13	53	93	144	218	292	412	532	692	692	5.6		
5.7	0	0	15	55	95	147	222	297	420	542	704	704	5.7		
5.8	0	0	17	57	97	149	226	302	427	551	716	716	5.8		

LENGTH OF CREST VERTICAL CURVES BASED ON MINIMUM STOPPING SIGHT DISTANCE

LENGTHS IN METERS

DIFF. IN PERCENT OF GRADE	DESIGN SPEED & MINIMUM STOPPING SIGHT DISTANCE														DIFF. IN PERCENT OF GRADE
	30 km/h	40 km/h	50 km/h	60 km/h	70 km/h	80 km/h	90 km/h	100 km/h	110 km/h	120 km/h	130 km/h	130 km/h			
	35 m	50 m	65 m	85 m	105 m	130 m	160 m	185 m	220 m	250 m	285 m	285 m	285 m		
5.9	0	0	19	59	99	152	230	307	434	561	729	729	729	5.9	
6.0	0	0	21	61	101	155	234	313	442	570	741	741	741	6.0	
6.1	0	0	23	63	103	157	238	318	449	580	753	753	753	6.1	
6.2	0	0	24	64	104	160	242	323	457	589	766	766	766	6.2	
6.3	0	0	26	66	106	162	246	328	464	599	778	778	778	6.3	
6.4	0	0	28	68	108	165	249	333	471	608	791	791	791	6.4	
6.5	0	0	29	69	109	167	253	339	479	618	803	803	803	6.5	
6.6	0	1	31	71	111	170	257	344	486	627	815	815	815	6.6	
6.7	0	2	32	72	113	173	261	349	493	637	828	828	828	6.7	
6.8	0	4	34	74	114	175	265	354	501	646	840	840	840	6.8	
6.9	0	5	35	75	116	178	269	359	508	656	852	852	852	6.9	
7.0	0	6	36	76	118	180	273	365	515	665	865	865	865	7.0	
7.1	0	8	38	78	119	183	277	370	523	675	877	877	877	7.1	
7.2	0	9	39	79	121	185	281	375	530	684	889	889	889	7.2	
7.3	0	10	40	80	123	188	285	380	537	694	902	902	902	7.3	
7.4	0	12	42	82	124	191	288	385	545	703	914	914	914	7.4	
7.5	0	13	43	83	126	193	292	391	552	713	926	926	926	7.5	
7.6	0	14	44	84	128	196	296	396	560	722	939	939	939	7.6	
7.7	0	15	45	85	130	198	300	401	567	732	951	951	951	7.7	
7.8	0	16	46	86	131	201	304	406	574	741	963	963	963	7.8	
7.9	0	17	47	87	133	203	308	411	582	751	976	976	976	7.9	
8.0	0	18	48	88	135	206	312	417	589	760	988	988	988	8.0	
8.1	0	19	49	89	136	209	316	422	596	770	1000	1000	1000	8.1	
8.2	0	20	50	91	138	211	320	427	604	779	1013	1013	1013	8.2	
8.3	0	21	51	92	140	214	323	432	611	789	1025	1025	1025	8.3	
8.4	0	22	52	93	141	216	327	437	618	798	1037	1037	1037	8.4	

LENGTH OF CREST VERTICAL CURVES BASED ON MINIMUM STOPPING SIGHT DISTANCE

LENGTHS IN METERS

DIFF. IN PERCENT OF GRADE	DESIGN SPEED & MINIMUM STOPPING SIGHT DISTANCE														DIFF. IN PERCENT OF GRADE
	30 km/h	40 km/h	50 km/h	60 km/h	70 km/h	80 km/h	90 km/h	100 km/h	110 km/h	120 km/h	130 km/h	130 km/h	285 m	285 m	
	35 m	50 m	65 m	85 m	105 m	130 m	160 m	185 m	220 m	250 m	285 m	285 m	285 m	285 m	
8.5	0	23	53	94	143	219	331	443	626	808	1050	1050	1050	1050	8.5
8.6	0	24	54	95	145	221	335	448	633	817	1062	1062	1062	1062	8.6
8.7	0	25	55	96	146	224	339	453	640	827	1074	1074	1074	1074	8.7
8.8	0	26	56	97	148	227	343	458	648	836	1087	1087	1087	1087	8.8
8.9	0	27	57	98	150	229	347	463	655	846	1099	1099	1099	1099	8.9
9.0	0	27	57	99	151	232	351	469	663	855	1111	1111	1111	1111	9.0
9.1	0	28	58	100	153	234	355	474	670	865	1124	1124	1124	1124	9.1
9.2	0	29	59	102	155	237	358	479	677	874	1136	1136	1136	1136	9.2
9.3	0	30	60	103	156	239	362	484	685	884	1149	1149	1149	1149	9.3
9.4	0	30	60	104	158	242	366	489	692	893	1161	1161	1161	1161	9.4
9.5	1	31	61	105	160	244	370	495	699	903	1173	1173	1173	1173	9.5
9.6	2	32	62	106	161	247	374	500	707	912	1186	1186	1186	1186	9.6
9.7	3	33	63	107	163	250	378	505	714	922	1198	1198	1198	1198	9.7
9.8	3	33	63	108	165	252	382	510	721	931	1210	1210	1210	1210	9.8
9.9	4	34	64	109	166	255	386	515	729	941	1223	1223	1223	1223	9.9
10.0	5	35	65	110	168	257	390	521	736	950	1235	1235	1235	1235	10.0
10.1	5	35	65	111	170	260	393	526	743	960	1247	1247	1247	1247	10.1
10.2	6	36	66	112	171	262	397	531	751	969	1260	1260	1260	1260	10.2
10.3	7	37	67	114	173	265	401	536	758	979	1272	1272	1272	1272	10.3
10.4	7	37	67	115	175	268	405	541	765	988	1284	1284	1284	1284	10.4
10.5	8	38	68	116	176	270	409	547	773	998	1297	1297	1297	1297	10.5
10.6	8	38	69	117	178	273	413	552	780	1007	1309	1309	1309	1309	10.6
10.7	9	39	69	118	180	275	417	557	788	1017	1321	1321	1321	1321	10.7
10.8	10	40	70	119	181	278	421	562	795	1026	1334	1334	1334	1334	10.8
10.9	10	40	70	120	183	280	425	567	802	1036	1346	1346	1346	1346	10.9
11.0	11	41	71	121	185	283	428	573	810	1045	1358	1358	1358	1358	11.0

LENGTH OF CREST VERTICAL CURVES BASED ON MINIMUM STOPPING SIGHT DISTANCE

LENGTHS IN METERS

DIFF. IN PERCENT OF GRADE	DESIGN SPEED & MINIMUM STOPPING SIGHT DISTANCE														DIFF. IN PERCENT OF GRADE								
	30 km/h		40 km/h		50 km/h		60 km/h		70 km/h		80 km/h		90 km/h			100 km/h		110 km/h		120 km/h		130 km/h	
	35 m	50 m	50 m	65 m	85 m	122	105 m	105 m	186	130 m	130 m	286	160 m	160 m		185 m	185 m	220 m	220 m	250 m	250 m	285 m	285 m
11.1	11	41	41	72	122	186	286	432	578	817	1055	1371	11.1										
11.2	12	42	42	72	123	188	288	436	583	824	1064	1383	11.2										
11.3	12	42	42	73	125	190	291	440	588	832	1074	1395	11.3										
11.4	13	43	43	74	126	192	293	444	593	839	1083	1408	11.4										
11.5	13	43	43	74	127	193	296	448	599	846	1093	1420	11.5										
11.6	14	44	44	75	128	195	298	452	604	854	1102	1432	11.6										
11.7	14	44	44	76	129	197	301	456	609	861	1112	1445	11.7										
11.8	15	45	45	76	130	198	304	460	614	868	1121	1457	11.8										
11.9	15	45	45	77	131	200	306	463	619	876	1131	1469	11.9										
12.0	16	46	46	78	132	202	309	467	625	883	1140	1482	12.0										
13.0	20	50	50	84	143	218	334	506	677	957	1235	1605	13.0										
14.0	23	54	54	90	154	235	360	545	729	1030	1330	1729	14.0										
15.0	27	57	57	97	165	252	386	584	781	1104	1425	1852	15.0										
16.0	29	61	61	103	176	269	411	623	833	1177	1520	1976	16.0										
17.0	32	65	65	110	187	285	437	662	885	1251	1615	2099	17.0										
18.0	34	69	69	116	198	302	463	701	937	1325	1710	2222	18.0										
19.0	36	73	73	122	209	319	488	740	989	1398	1805	2346	19.0										
20.0	38	76	76	129	220	336	514	779	1041	1472	1900	2469	20.0										

SECTION II
STOPPING SIGHT DISTANCE FOR
CREST VERTICAL CURVES

Computations are based on the following formulae:

$$S < L \quad S = \sqrt{658L \div A}$$

$$S > L \quad S = (329 \div A) + (L \div 2)$$

Based on height of eye = 1080 mm and height of object = 600 mm

L = Length of Vertical Curve, m

S = Stopping Sight Distance, m

A = Algebraic Difference in Grade, %

STOPPING SIGHT DISTANCE FOR CREST VERTICAL CURVES

LENGTHS IN METERS

DIFF. IN PERCENT OF GRADE	LENGTH OF CURVE														DIFF. IN PERCENT OF GRADE
	15 m	30 m	45 m	60 m	90 m	120 m	150 m	180 m	210 m	240 m	270 m	300 m	330 m		
0.1	3298	3305	3313	3320	3335	3350	3365	3380	3395	3410	3425	3440	3455	0.1	
0.2	1653	1660	1668	1675	1690	1705	1720	1735	1750	1765	1780	1795	1810	0.2	
0.3	1105	1112	1120	1127	1142	1157	1172	1187	1202	1217	1232	1247	1262	0.3	
0.4	830	838	845	853	868	883	898	913	928	943	958	973	988	0.4	
0.5	666	673	681	688	703	718	733	748	763	778	793	808	823	0.5	
0.6	556	564	571	579	594	609	624	639	654	669	684	699	714	0.6	
0.7	478	485	493	500	515	530	545	560	575	590	605	620	635	0.7	
0.8	419	427	434	442	457	472	487	502	517	532	547	562	577	0.8	
0.9	374	381	389	396	411	426	441	456	471	486	501	516	531	0.9	
1.0	337	344	352	359	374	389	404	419	434	449	464	479	494	1.0	
1.1	307	315	322	330	345	360	375	390	405	420	435	450	465	1.1	
1.2	282	290	297	305	320	335	350	365	380	395	410	425	440	1.2	
1.3	261	269	276	284	299	314	329	344	359	374	389	404	419	1.3	
1.4	243	250	258	265	280	295	310	325	340	355	370	385	400	1.4	
1.5	227	235	242	250	265	280	295	310	325	340	355	370	385	1.5	
1.6	214	221	229	236	251	266	281	296	311	326	341	356	371	1.6	
1.7	202	209	217	224	239	254	269	284	299	314	329	344	359	1.7	
1.8	191	198	206	213	228	243	258	273	288	303	318	333	348	1.8	
1.9	181	189	196	204	219	234	249	264	279	294	309	324	339	1.9	
2.0	172	180	187	195	210	225	240	255	270	285	300	315	330	2.0	
2.1	165	172	180	187	202	217	232	247	262	277	292	307	322	2.1	
2.2	158	165	173	180	195	210	225	240	255	270	285	300	315	2.2	
2.3	151	159	166	174	189	204	219	234	249	264	279	293	308	2.3	
2.4	145	153	160	168	183	198	213	228	243	258	273	287	301	2.4	
2.5	140	147	155	162	177	192	207	222	237	252	267	281	295	2.5	
2.6	135	142	150	157	172	187	202	217	232	247	262	276	289	2.6	

STOPPING SIGHT DISTANCE FOR CREST VERTICAL CURVES

LENGTHS IN METERS

DIFF. IN PERCENT OF GRADE	LENGTH OF CURVE													DIFF. IN PERCENT OF GRADE
	15 m	30 m	45 m	60 m	90 m	120 m	150 m	180 m	210 m	240 m	270 m	300 m	330 m	
2.7	130	137	145	152	167	182	197	212	227	242	257	271	284	2.7
2.8	125	133	140	148	163	178	193	208	223	238	252	266	279	2.8
2.9	121	129	136	144	159	174	189	204	219	234	248	261	274	2.9
3.0	118	125	133	140	155	170	185	200	215	230	244	257	270	3.0
3.1	114	122	129	137	152	167	182	197	212	226	240	253	265	3.1
3.2	111	118	126	133	148	163	178	193	208	223	236	249	261	3.2
3.3	108	115	123	130	145	160	175	190	205	219	233	245	257	3.3
3.4	105	112	120	127	142	157	172	187	202	216	229	241	253	3.4
3.5	102	109	117	124	139	154	169	184	199	213	226	238	250	3.5
3.6	99	107	114	122	137	152	167	182	196	210	223	235	246	3.6
3.7	97	104	112	119	134	149	164	179	194	207	220	231	243	3.7
3.8	95	102	110	117	132	147	162	177	191	204	217	228	240	3.8
3.9	92	100	107	115	130	145	160	175	189	202	214	225	236	3.9
4.0	90	98	105	113	128	143	158	173	186	199	211	223	233	4.0
4.1	88	96	103	111	126	141	156	170	184	197	209	220	231	4.1
4.2	86	94	101	109	124	139	154	168	182	194	206	217	228	4.2
4.3	85	92	100	107	122	137	152	166	180	192	204	215	225	4.3
4.4	83	90	98	105	120	135	150	165	178	190	201	212	223	4.4
4.5	81	89	96	104	119	134	149	163	176	188	199	210	220	4.5
4.6	80	87	95	102	117	132	147	161	174	186	197	208	218	4.6
4.7	78	85	93	100	115	130	145	159	172	184	195	205	215	4.7
4.8	77	84	92	99	114	129	144	158	170	182	193	203	213	4.8
4.9	75	83	90	98	113	128	142	156	168	180	191	201	211	4.9
5.0	74	81	89	96	111	126	141	154	167	178	189	199	209	5.0
5.1	73	80	88	95	110	125	140	153	165	176	187	197	207	5.1
5.2	71	79	86	94	109	124	138	151	164	175	185	195	205	5.2

STOPPING SIGHT DISTANCE FOR CREST VERTICAL CURVES

LENGTHS IN METERS

DIFF. IN PERCENT OF GRADE	LENGTH OF CURVE														DIFF. IN PERCENT OF GRADE
	15 m	30 m	45 m	60 m	90 m	120 m	150 m	180 m	210 m	240 m	270 m	300 m	330 m		
5.3	70	78	85	93	108	123	137	150	162	173	184	193	203	5.3	
5.4	69	76	84	91	106	121	136	149	160	172	182	192	201	5.4	
5.5	68	75	83	90	105	120	134	147	159	170	180	190	199	5.5	
5.6	67	74	82	89	104	119	133	146	158	168	179	188	197	5.6	
5.7	66	73	81	88	103	118	132	145	156	167	177	187	196	5.7	
5.8	65	72	80	87	102	117	131	143	155	166	176	185	194	5.8	
5.9	64	71	79	86	101	116	130	142	154	164	174	183	192	5.9	
6.0	63	70	78	85	100	115	129	141	152	163	173	182	191	6.0	
6.1	62	69	77	84	99	114	128	140	151	161	171	180	189	6.1	
6.2	61	69	76	84	99	113	127	139	150	160	170	179	188	6.2	
6.3	60	68	75	83	98	112	126	138	149	159	168	178	186	6.3	
6.4	59	67	74	82	97	112	125	137	147	158	167	176	185	6.4	
6.5	59	66	74	81	96	111	124	135	146	156	166	175	183	6.5	
6.6	58	65	73	80	95	110	123	134	145	155	165	173	182	6.6	
6.7	57	65	72	80	95	109	122	133	144	154	163	172	181	6.7	
6.8	56	64	71	79	94	108	121	132	143	153	162	171	179	6.8	
6.9	56	63	71	78	93	107	120	132	142	152	161	170	178	6.9	
7.0	55	62	70	77	92	107	119	131	141	151	160	168	177	7.0	
7.1	54	62	69	77	92	106	118	130	140	150	159	167	175	7.1	
7.2	54	61	69	76	91	105	118	129	139	149	158	166	174	7.2	
7.3	53	61	68	76	91	105	117	128	138	148	157	165	173	7.3	
7.4	52	60	67	75	90	104	116	127	137	147	155	164	172	7.4	
7.5	52	59	67	74	89	103	115	126	136	146	154	163	171	7.5	
7.6	51	59	66	74	89	102	114	125	135	145	153	162	170	7.6	
7.7	51	58	66	73	88	102	114	125	134	144	152	161	168	7.7	
7.8	50	58	65	73	88	101	113	124	134	143	151	160	167	7.8	

STOPPING SIGHT DISTANCE FOR CREST VERTICAL CURVES

LENGTHS IN METERS

DIFF. IN PERCENT OF GRADE	LENGTH OF CURVE														DIFF. IN PERCENT OF GRADE
	15 m	30 m	45 m	60 m	90 m	120 m	150 m	180 m	210 m	240 m	270 m	300 m	330 m		
7.9	50	57	65	72	87	100	112	123	133	142	150	159	166	7.9	
8.0	49	57	64	72	87	100	112	122	132	141	150	158	165	8.0	
8.1	49	56	64	71	86	99	111	121	131	140	149	157	164	8.1	
8.2	48	56	63	71	85	99	110	121	130	139	148	156	163	8.2	
8.3	48	55	63	70	85	98	110	120	130	138	147	155	162	8.3	
8.4	47	55	62	70	84	97	109	119	129	138	146	154	161	8.4	
8.5	47	54	62	69	84	97	108	119	128	137	145	153	160	8.5	
8.6	46	54	61	69	83	96	108	118	127	136	144	152	159	8.6	
8.7	46	53	61	68	83	96	107	117	127	135	143	151	158	8.7	
8.8	45	53	60	68	83	95	106	117	126	134	143	150	158	8.8	
8.9	45	52	60	67	82	95	106	116	125	134	142	149	157	8.9	
9.0	45	52	60	67	82	94	105	115	124	133	141	149	156	9.0	
9.1	44	52	59	67	81	94	105	115	124	132	140	148	155	9.1	
9.2	44	51	59	66	81	93	104	114	123	132	139	147	154	9.2	
9.3	43	51	58	66	80	93	104	113	122	131	139	146	153	9.3	
9.4	43	50	58	65	80	92	103	113	122	130	138	145	152	9.4	
9.5	43	50	58	65	79	92	102	112	121	129	137	145	152	9.5	
9.6	42	50	57	65	79	91	102	112	120	129	137	144	151	9.6	
9.7	42	49	57	64	79	91	101	111	120	128	136	143	150	9.7	
9.8	42	49	57	64	78	90	101	110	119	127	135	142	149	9.8	
9.9	41	49	56	64	78	90	100	110	119	127	134	142	149	9.9	
10.0	41	48	56	63	77	89	100	109	118	126	134	141	148	10.0	
10.1	41	48	56	63	77	89	99	109	117	126	133	140	147	10.1	
10.2	40	48	55	63	77	88	99	108	117	125	132	140	146	10.2	
10.3	40	47	55	62	76	88	98	108	116	124	132	139	146	10.3	
10.4	40	47	55	62	76	88	98	107	116	124	131	138	145	10.4	

STOPPING SIGHT DISTANCE FOR CREST VERTICAL CURVES

LENGTHS IN METERS

DIFF. IN PERCENT OF GRADE	LENGTH OF CURVE														DIFF. IN PERCENT OF GRADE
	15 m	30 m	45 m	60 m	90 m	120 m	150 m	180 m	210 m	240 m	270 m	300 m	330 m		
10.5	39	47	54	62	76	87	97	107	115	123	131	138	144	10.5	
10.6	39	47	54	62	75	87	97	106	115	123	130	137	144	10.6	
10.7	39	46	54	61	75	86	97	106	114	122	129	136	143	10.7	
10.8	38	46	53	61	75	86	96	105	114	121	129	136	142	10.8	
10.9	38	46	53	61	74	86	96	105	113	121	128	135	142	10.9	
11.0	38	45	53	60	74	85	95	104	113	120	128	134	141	11.0	
11.1	38	45	53	60	74	85	95	104	112	120	127	134	140	11.1	
11.2	37	45	52	60	73	84	94	103	112	119	126	133	140	11.2	
11.3	37	45	52	60	73	84	94	103	111	119	126	133	139	11.3	
11.4	37	44	52	59	73	84	94	102	111	118	125	132	139	11.4	
11.5	37	44	52	59	72	83	93	102	110	118	125	132	138	11.5	
11.6	36	44	51	59	72	83	93	102	110	117	124	131	137	11.6	
11.7	36	44	51	59	72	83	92	101	109	117	124	130	137	11.7	
11.8	36	43	51	58	71	82	92	101	109	116	123	130	136	11.8	
11.9	36	43	51	58	71	82	92	100	108	116	123	129	136	11.9	
12.0	35	43	50	58	71	82	91	100	108	115	122	129	135	12.0	
13.0	33	41	48	56	68	78	88	96	104	111	117	124	130	13.0	
14.0	31	39	46	54	66	76	84	92	100	107	113	119	125	14.0	
15.0	30	37	45	52	63	73	82	89	96	103	109	115	121	15.0	
16.0	29	36	44	50	61	71	79	87	93	100	106	112	117	16.0	
17.0	27	35	42	49	60	69	77	84	91	97	103	108	114	17.0	
18.0	26	34	41	47	58	67	75	82	88	94	100	105	110	18.0	
19.0	25	33	40	46	56	65	73	79	86	92	97	102	107	19.0	
20.0	24	32	39	45	55	63	71	77	84	89	95	100	105	20.0	

STOPPING SIGHT DISTANCE FOR CREST VERTICAL CURVES

LENGTHS IN METERS

DIFF. IN PERCENT OF GRADE	LENGTH OF CURVE														DIFF. IN PERCENT OF GRADE
	360 m	390 m	420 m	450 m	480 m	510 m	540 m	570 m	600 m	630 m	660 m	690 m	720 m		
0.1	3470	3485	3500	3515	3530	3545	3560	3575	3590	3605	3620	3635	3650	0.1	
0.2	1825	1840	1855	1870	1885	1900	1915	1930	1945	1960	1975	1990	2005	0.2	
0.3	1277	1292	1307	1322	1337	1352	1367	1382	1397	1412	1427	1442	1457	0.3	
0.4	1003	1018	1033	1048	1063	1078	1093	1108	1123	1138	1153	1168	1183	0.4	
0.5	838	853	868	883	898	913	928	943	958	973	988	1003	1018	0.5	
0.6	729	744	759	774	789	804	819	834	849	864	879	894	909	0.6	
0.7	650	665	680	695	710	725	740	755	770	785	800	815	830	0.7	
0.8	592	607	622	637	652	667	682	697	712	727	742	757	772	0.8	
0.9	546	561	576	591	606	621	636	651	666	681	696	711	726	0.9	
1.0	509	524	539	554	569	584	599	614	629	644	659	674	689	1.0	
1.1	480	495	510	525	540	555	570	585	600	614	629	643	657	1.1	
1.2	455	470	485	500	515	530	545	560	574	588	602	616	629	1.2	
1.3	434	449	464	479	494	509	523	538	552	565	578	591	604	1.3	
1.4	415	430	445	460	475	490	504	518	532	545	557	570	582	1.4	
1.5	400	415	430	445	459	473	487	501	514	526	539	551	562	1.5	
1.6	386	401	416	431	445	458	472	485	497	510	521	533	545	1.6	
1.7	374	389	404	418	432	445	458	470	482	494	506	517	528	1.7	
1.8	363	378	392	406	419	432	445	457	469	480	492	503	514	1.8	
1.9	354	368	382	395	408	421	433	445	456	468	479	489	500	1.9	
2.0	345	359	372	385	398	410	422	434	445	456	466	477	487	2.0	
2.1	336	350	363	376	388	400	412	423	434	445	455	465	475	2.1	
2.2	329	342	355	367	379	391	402	413	424	435	445	455	465	2.2	
2.3	321	335	347	359	371	382	394	404	415	425	435	445	454	2.3	
2.4	315	327	340	352	363	374	385	396	406	416	426	435	445	2.4	
2.5	308	321	333	345	356	367	377	388	398	408	417	427	436	2.5	
2.6	302	315	327	338	349	360	370	380	390	400	409	418	427	2.6	

STOPPING SIGHT DISTANCE FOR CREST VERTICAL CURVES

LENGTHS IN METERS

DIFF. IN PERCENT OF GRADE	LENGTH OF CURVE														DIFF. IN PERCENT OF GRADE
	360 m	390 m	420 m	450 m	480 m	510 m	540 m	570 m	600 m	630 m	660 m	690 m	720 m		
2.7	297	309	320	332	343	353	363	373	383	392	402	411	419	2.7	
2.8	291	303	315	326	336	347	357	366	376	385	394	403	412	2.8	
2.9	286	298	309	320	331	341	351	360	369	379	387	396	405	2.9	
3.0	281	293	304	315	325	335	345	354	363	372	381	390	398	3.0	
3.1	277	288	299	310	320	330	339	348	357	366	375	383	391	3.1	
3.2	273	284	294	305	315	324	334	343	352	360	369	377	385	3.2	
3.3	268	279	290	300	310	319	329	338	346	355	363	371	379	3.3	
3.4	264	275	286	296	305	315	324	333	341	350	358	366	374	3.4	
3.5	261	271	281	291	301	310	319	328	336	345	353	361	368	3.5	
3.6	257	267	278	287	297	306	315	323	332	340	348	356	363	3.6	
3.7	254	264	274	283	293	302	310	319	327	335	343	351	358	3.7	
3.8	250	260	270	280	289	298	306	315	323	331	339	346	354	3.8	
3.9	247	257	267	276	285	294	302	311	319	327	334	342	349	3.9	
4.0	244	254	263	273	281	290	299	307	315	322	330	337	345	4.0	
4.1	241	251	260	269	278	287	295	303	311	318	326	333	340	4.1	
4.2	238	248	257	266	275	283	291	299	307	315	322	329	336	4.2	
4.3	235	245	254	263	272	280	288	296	304	311	318	325	332	4.3	
4.4	233	242	251	260	268	277	285	292	300	307	315	322	329	4.4	
4.5	230	239	248	257	265	274	281	289	297	304	311	318	325	4.5	
4.6	227	237	246	254	263	271	278	286	293	301	308	315	321	4.6	
4.7	225	234	243	251	260	268	275	283	290	297	304	311	318	4.7	
4.8	223	232	240	249	257	265	273	280	287	294	301	308	315	4.8	
4.9	220	229	238	246	254	262	270	277	284	291	298	305	311	4.9	
5.0	218	227	236	244	252	260	267	274	281	288	295	302	308	5.0	
5.1	216	225	233	241	249	257	264	272	279	286	292	299	305	5.1	
5.2	214	223	231	239	247	255	262	269	276	283	289	296	302	5.2	

STOPPING SIGHT DISTANCE FOR CREST VERTICAL CURVES

LENGTHS IN METERS

DIFF. IN PERCENT OF GRADE	LENGTH OF CURVE														DIFF. IN PERCENT OF GRADE
	360 m	390 m	420 m	450 m	480 m	510 m	540 m	570 m	600 m	630 m	660 m	690 m	720 m		
5.3	212	221	229	237	245	252	259	267	273	280	287	293	299	5.3	
5.4	210	218	227	235	242	250	257	264	271	278	284	290	297	5.4	
5.5	208	217	225	233	240	248	255	262	268	275	281	288	294	5.5	
5.6	206	215	223	230	238	245	252	259	266	273	279	285	291	5.6	
5.7	204	213	221	228	236	243	250	257	264	270	277	283	289	5.7	
5.8	203	211	219	226	234	241	248	255	261	268	274	280	286	5.8	
5.9	201	209	217	225	232	239	246	253	259	266	272	278	284	5.9	
6.0	199	207	215	223	230	237	244	251	257	263	270	276	281	6.0	
6.1	198	206	213	221	228	235	242	248	255	261	267	273	279	6.1	
6.2	196	204	212	219	226	233	240	246	253	259	265	271	277	6.2	
6.3	194	202	210	217	224	231	238	244	251	257	263	269	275	6.3	
6.4	193	201	208	216	223	229	236	243	249	255	261	267	273	6.4	
6.5	191	199	207	214	221	228	234	241	247	253	259	265	270	6.5	
6.6	190	198	205	212	219	226	233	239	245	251	257	263	268	6.6	
6.7	189	196	204	211	218	224	231	237	243	249	255	261	266	6.7	
6.8	187	195	202	209	216	223	229	235	241	247	253	259	264	6.8	
6.9	186	193	201	208	214	221	227	234	240	246	251	257	263	6.9	
7.0	184	192	199	206	213	219	226	232	238	244	250	255	261	7.0	
7.1	183	191	198	205	211	218	224	230	236	242	248	253	259	7.1	
7.2	182	189	196	203	210	216	223	229	235	240	246	252	257	7.2	
7.3	181	188	195	202	209	215	221	227	233	239	244	250	255	7.3	
7.4	179	187	194	201	207	213	220	226	231	237	243	248	254	7.4	
7.5	178	185	192	199	206	212	218	224	230	236	241	247	252	7.5	
7.6	177	184	191	198	204	211	217	223	228	234	240	245	250	7.6	
7.7	176	183	190	197	203	209	215	221	227	233	238	243	249	7.7	
7.8	175	182	189	195	202	208	214	220	225	231	236	242	247	7.8	

STOPPING SIGHT DISTANCE FOR CREST VERTICAL CURVES

LENGTHS IN METERS

DIFF. IN PERCENT OF GRADE	LENGTH OF CURVE														DIFF. IN PERCENT OF GRADE
	360 m	390 m	420 m	450 m	480 m	510 m	540 m	570 m	600 m	630 m	660 m	690 m	720 m		
7.9	174	181	188	194	200	207	213	218	224	230	235	240	245	7.9	
8.0	173	180	186	193	199	205	211	217	223	228	233	239	244	8.0	
8.1	172	178	185	192	198	204	210	216	221	227	232	237	242	8.1	
8.2	170	177	184	191	197	203	209	214	220	225	231	236	241	8.2	
8.3	169	176	183	189	196	202	207	213	219	224	229	234	239	8.3	
8.4	168	175	182	188	194	200	206	212	217	223	228	233	238	8.4	
8.5	167	174	181	187	193	199	205	211	216	221	227	232	237	8.5	
8.6	166	173	180	186	192	198	204	209	215	220	225	230	235	8.6	
8.7	166	172	179	185	191	197	203	208	214	219	224	229	234	8.7	
8.8	165	171	178	184	190	196	201	207	212	218	223	228	233	8.8	
8.9	164	170	177	183	189	195	200	206	211	216	221	226	231	8.9	
9.0	163	169	176	182	188	194	199	205	210	215	220	225	230	9.0	
9.1	162	168	175	181	187	193	198	204	209	214	219	224	229	9.1	
9.2	161	168	174	180	186	191	197	202	208	213	218	223	227	9.2	
9.3	160	167	173	179	185	190	196	201	207	212	217	221	226	9.3	
9.4	159	166	172	178	184	189	195	200	205	210	215	220	225	9.4	
9.5	158	165	171	177	183	188	194	199	204	209	214	219	224	9.5	
9.6	158	164	170	176	182	187	193	198	203	208	213	218	223	9.6	
9.7	157	163	169	175	181	186	192	197	202	207	212	217	222	9.7	
9.8	156	162	168	174	180	186	191	196	201	206	211	216	220	9.8	
9.9	155	162	168	173	179	185	190	195	200	205	210	215	219	9.9	
10.0	154	161	167	173	178	184	189	194	199	204	209	214	218	10.0	
10.1	154	160	166	172	177	183	188	193	198	203	208	213	217	10.1	
10.2	153	159	165	171	176	182	187	192	197	202	207	211	216	10.2	
10.3	152	158	164	170	176	181	186	191	196	201	206	210	215	10.3	
10.4	151	158	164	169	175	180	185	190	195	200	205	209	214	10.4	

STOPPING SIGHT DISTANCE FOR CREST VERTICAL CURVES

LENGTHS IN METERS

DIFF. IN PERCENT OF GRADE	LENGTH OF CURVE														DIFF. IN PERCENT OF GRADE
	360 m	390 m	420 m	450 m	480 m	510 m	540 m	570 m	600 m	630 m	660 m	690 m	720 m		
10.5	151	157	163	168	174	179	184	189	194	199	204	208	213	10.5	
10.6	150	156	162	168	173	178	184	189	193	198	203	207	212	10.6	
10.7	149	155	161	167	172	178	183	188	193	197	202	206	211	10.7	
10.8	149	155	160	166	172	177	182	187	192	196	201	206	210	10.8	
10.9	148	154	160	165	171	176	181	186	191	196	200	205	209	10.9	
11.0	147	153	159	165	170	175	180	185	190	195	199	204	208	11.0	
11.1	147	153	158	164	169	174	179	184	189	194	198	203	207	11.1	
11.2	146	152	158	163	168	174	179	183	188	193	197	202	206	11.2	
11.3	145	151	157	162	168	173	178	183	187	192	197	201	205	11.3	
11.4	145	151	156	162	167	172	177	182	187	191	196	200	204	11.4	
11.5	144	150	156	161	166	171	176	181	186	190	195	199	203	11.5	
11.6	143	149	155	160	166	171	176	180	185	190	194	198	203	11.6	
11.7	143	149	154	160	165	170	175	180	184	189	193	197	202	11.7	
11.8	142	148	154	159	164	169	174	179	183	188	192	197	201	11.8	
11.9	142	147	153	158	163	168	173	178	183	187	192	196	200	11.9	
12.0	141	147	152	158	163	168	173	177	182	186	191	195	199	12.0	
13.0	135	141	146	151	156	161	166	170	175	179	183	187	191	13.0	
14.0	131	136	141	146	151	155	160	164	168	173	177	181	184	14.0	
15.0	126	131	136	141	146	150	154	159	163	167	171	174	178	15.0	
16.0	122	127	132	137	141	145	150	154	158	161	165	169	173	16.0	
17.0	119	123	128	132	137	141	145	149	153	157	160	164	167	17.0	
18.0	115	120	124	129	133	137	141	145	149	152	156	159	163	18.0	
19.0	112	117	121	125	129	133	137	141	145	148	152	155	158	19.0	
20.0	109	114	118	122	126	130	134	137	141	144	148	151	154	20.0	

SECTION III
LENGTH OF SAG VERTICAL CURVES
BASED ON MINIMUM HEADLIGHT SIGHT DISTANCE

Computations are based on the following formulae:

$$S < L \quad L = (AS^2) \div (120 + 3.5S)$$

$$S > L \quad L = 2S - [(120 + 3.5S) \div A]$$

Based on headlight height of 600 mm and a 1° upward divergence of the light beam from the longitudinal axis of the vehicle

L = Length of Vertical Curve, m

S = Headlight Sight Distance, m

A = Algebraic Difference in Grade, %

- Note: The minimum length of sag vertical curves should be the greater of:
1. The length needed to provide the headlight sight distance.
 2. The length needed to provide adequate riding comfort. (See section V)
 3. The length needed to provide adequate drainage.
 4. Six-tenths of the design speed.

LENGTH OF SAG VERTICAL CURVES BASED ON MINIMUM HEADLIGHT SIGHT DISTANCE

LENGTHS IN METERS

DIFF. IN PERCENT OF GRADE	DESIGN SPEED & MINIMUM STOPPING SIGHT DISTANCE														DIFF. IN PERCENT OF GRADE								
	30 km/h		40 km/h		50 km/h		60 km/h		70 km/h		80 km/h		90 km/h			100 km/h		110 km/h		120 km/h		130 km/h	
	35 m	50 m	50 m	65 m	65 m	85 m	85 m	105 m	105 m	130 m	130 m	130 m	160 m	160 m		185 m	185 m	220 m	220 m	250 m	250 m	285 m	285 m
2.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	3	12	12	2.0
2.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	5	17	17	27	27	38	38	2.1
2.2	0	0	0	0	0	0	0	0	0	0	0	11	11	22	22	36	36	48	48	63	63	63	2.2
2.3	0	0	0	0	0	0	0	0	0	10	10	25	25	37	37	54	54	68	68	85	85	85	2.3
2.4	0	0	0	0	0	0	0	7	7	15	15	37	37	51	51	70	70	86	86	105	105	105	2.4
2.5	0	0	0	0	0	3	3	15	15	30	30	48	48	63	63	84	84	102	102	123	123	123	2.5
2.6	0	0	0	0	0	10	10	23	23	39	39	59	59	75	75	98	98	118	118	141	141	141	2.6
2.7	0	0	0	2	2	16	16	30	30	48	48	69	69	86	86	111	111	132	132	157	157	157	2.7
2.8	0	0	0	6	6	21	21	36	36	55	55	78	78	96	96	123	123	145	145	171	171	171	2.8
2.9	0	0	0	11	11	27	27	42	42	62	62	86	86	106	106	134	134	157	157	185	185	185	2.9
3.0	0	0	2	15	15	31	31	48	48	69	69	94	94	115	115	144	144	169	169	198	198	198	3.0
3.1	0	0	5	18	18	36	36	53	53	75	75	101	101	123	123	153	153	180	180	210	210	210	3.1
3.2	0	0	8	22	22	40	40	58	58	81	81	108	108	131	131	162	162	190	190	221	221	221	3.2
3.3	0	0	11	25	25	44	44	63	63	86	86	114	114	138	138	171	171	199	199	232	232	232	3.3
3.4	0	0	14	28	28	48	48	67	67	91	91	120	120	145	145	179	179	208	208	242	242	242	3.4
3.5	1	1	16	31	31	51	51	71	71	96	96	126	126	151	151	186	186	216	216	251	251	251	3.5
3.6	3	3	19	34	34	55	55	75	75	101	101	132	132	157	157	193	193	224	224	260	260	260	3.6
3.7	5	5	21	37	37	58	58	79	79	105	105	137	137	163	163	200	200	232	232	268	268	268	3.7
3.8	7	7	23	39	39	61	61	82	82	109	109	142	142	169	169	206	206	239	239	276	276	276	3.8
3.9	8	8	25	41	41	63	63	86	86	113	113	146	146	174	174	212	212	245	245	284	284	284	3.9
4.0	10	10	27	44	44	66	66	89	89	117	117	150	150	179	179	218	218	251	251	291	291	291	4.0
4.1	11	11	29	46	46	69	69	92	92	120	120	155	155	183	183	223	223	258	258	298	298	298	4.1
4.2	13	13	30	48	48	71	71	94	94	124	124	159	159	187	187	228	228	264	264	305	305	305	4.2
4.3	14	14	32	50	50	73	73	97	97	127	127	162	162	192	192	234	234	270	270	313	313	313	4.3
4.4	15	15	33	52	52	76	76	100	100	130	130	166	166	196	196	239	239	276	276	320	320	320	4.4
4.5	17	17	35	53	53	78	78	102	102	132	132	169	169	201	201	245	245	283	283	327	327	327	4.5
4.6	18	18	36	55	55	80	80	105	105	135	135	173	173	205	205	250	250	289	289	334	334	334	4.6
4.7	19	19	38	57	57	82	82	106	106	138	138	177	177	210	210	256	256	295	295	342	342	342	4.7

LENGTH OF SAG VERTICAL CURVES BASED ON MINIMUM HEADLIGHT SIGHT DISTANCE

LENGTHS IN METERS

DIFF. IN PERCENT OF GRADE	DESIGN SPEED & MINIMUM STOPPING SIGHT DISTANCE														DIFF. IN PERCENT OF GRADE								
	30 km/h		40 km/h		50 km/h		60 km/h		70 km/h		80 km/h		90 km/h			100 km/h		110 km/h		120 km/h		130 km/h	
	35 m	50 m	50 m	65 m	85 m	105 m	130 m	160 m	185 m	220 m	250 m	285 m	160 m	185 m		220 m	250 m	285 m	220 m	250 m	285 m	250 m	285 m
4.8	20	39	58	84	109	141	181	214	261	302	349	4.8											
4.9	21	40	60	85	111	144	184	219	266	308	356	4.9											
5.0	22	41	61	87	113	147	188	223	272	314	363	5.0											
5.1	23	43	62	88	115	150	192	227	277	320	371	5.1											
5.2	24	44	64	90	118	153	196	232	283	327	378	5.2											
5.3	25	45	65	92	120	156	200	236	288	333	385	5.3											
5.4	26	46	66	93	122	159	203	241	294	339	392	5.4											
5.5	26	47	67	95	124	162	207	245	299	345	400	5.5											
5.6	27	48	68	97	127	165	211	250	305	352	407	5.6											
5.7	28	49	69	99	129	168	215	254	310	358	414	5.7											
5.8	29	50	71	100	131	170	218	259	315	364	422	5.8											
5.9	29	50	72	102	133	173	222	263	321	371	429	5.9											
6.0	30	51	73	104	136	176	226	268	326	377	436	6.0											
6.1	31	52	74	106	138	179	230	272	332	383	443	6.1											
6.2	31	53	75	107	140	182	233	276	337	389	451	6.2											
6.3	32	53	77	109	142	185	237	281	343	396	458	6.3											
6.4	33	54	78	111	145	188	241	285	348	402	465	6.4											
6.5	33	55	79	112	147	191	245	290	353	408	472	6.5											
6.6	34	56	80	114	149	194	248	294	359	415	480	6.6											
6.7	34	57	81	116	152	197	252	299	364	421	487	6.7											
6.8	35	58	83	118	154	200	256	303	370	427	494	6.8											
6.9	35	58	84	119	156	203	260	308	375	433	502	6.9											
7.0	35	59	85	121	158	206	264	312	381	440	509	7.0											
7.1	36	60	86	123	161	209	267	317	386	446	516	7.1											
7.2	36	61	88	125	163	212	271	321	392	452	523	7.2											
7.3	37	62	89	126	165	215	275	326	397	459	531	7.3											
7.4	37	63	90	128	167	217	279	330	402	465	538	7.4											
7.5	38	64	91	130	170	220	282	334	408	471	545	7.5											

LENGTH OF SAG VERTICAL CURVES BASED ON MINIMUM HEADLIGHT SIGHT DISTANCE

LENGTHS IN METERS

DIFF. IN PERCENT OF GRADE	DESIGN SPEED & MINIMUM STOPPING SIGHT DISTANCE														DIFF. IN PERCENT OF GRADE								
	30 km/h		40 km/h		50 km/h		60 km/h		70 km/h		80 km/h		90 km/h			100 km/h		110 km/h		120 km/h		130 km/h	
	35 m	50 m	50 m	65 m	65 m	85 m	85 m	105 m	105 m	130 m	130 m	130 m	160 m	160 m		185 m	185 m	220 m	220 m	250 m	250 m	285 m	285 m
7.6	38	64	92	132	172	223	286	339	413	477	552	7.6											
7.7	39	65	94	133	174	226	290	343	419	484	560	7.7											
7.8	39	66	95	135	176	229	294	348	424	490	567	7.8											
7.9	40	67	96	137	179	232	297	352	430	496	574	7.9											
8.0	40	68	97	138	181	235	301	357	435	503	581	8.0											
8.1	41	69	98	140	183	238	305	361	440	509	589	8.1											
8.2	41	69	100	142	185	241	309	366	446	515	596	8.2											
8.3	42	70	101	144	188	244	312	370	451	521	603	8.3											
8.4	42	71	102	145	190	247	316	375	457	528	611	8.4											
8.5	43	72	103	147	192	250	320	379	462	534	618	8.5											
8.6	43	73	105	149	194	253	324	383	468	540	625	8.6											
8.7	44	74	106	151	197	256	328	388	473	546	632	8.7											
8.8	44	75	107	152	199	259	331	392	479	553	640	8.8											
8.9	45	75	108	154	201	262	335	397	484	559	647	8.9											
9.0	45	76	109	156	204	265	339	401	489	565	654	9.0											
9.1	46	77	111	157	206	267	343	406	495	572	661	9.1											
9.2	46	78	112	159	208	270	346	410	500	578	669	9.2											
9.3	47	79	113	161	210	273	350	415	506	584	676	9.3											
9.4	47	80	114	163	213	276	354	419	511	590	683	9.4											
9.5	48	81	116	164	215	279	358	424	517	597	691	9.5											
9.6	48	81	117	166	217	282	361	428	522	603	698	9.6											
9.7	49	82	118	168	219	285	365	433	528	609	705	9.7											
9.8	50	83	119	170	222	288	369	437	533	616	712	9.8											
9.9	50	84	120	171	224	291	373	441	538	622	720	9.9											
10.0	51	85	122	173	226	294	376	446	544	628	727	10.0											
10.1	51	86	123	175	228	297	380	450	549	634	734	10.1											
10.2	52	86	124	177	231	300	384	455	555	641	741	10.2											
10.3	52	87	125	178	233	303	388	459	560	647	749	10.3											

LENGTH OF SAG VERTICAL CURVES BASED ON MINIMUM HEADLIGHT SIGHT DISTANCE

LENGTHS IN METERS

DIFF. IN PERCENT OF GRADE	DESIGN SPEED & MINIMUM STOPPING SIGHT DISTANCE														DIFF. IN PERCENT OF GRADE
	30 km/h	40 km/h	50 km/h	60 km/h	70 km/h	80 km/h	90 km/h	100 km/h	110 km/h	120 km/h	130 km/h	130 km/h	285 m		
	35 m	50 m	65 m	85 m	105 m	130 m	160 m	185 m	220 m	250 m					
10.4	53	88	126	180	235	306	392	464	566	653	756			10.4	
10.5	53	89	128	182	237	309	395	468	571	660	763			10.5	
10.6	54	90	129	183	240	312	399	473	576	666	770			10.6	
10.7	54	91	130	185	242	314	403	477	582	672	778			10.7	
10.8	55	92	131	187	244	317	407	482	587	678	785			10.8	
10.9	55	92	133	189	247	320	410	486	593	685	792			10.9	
11.0	56	93	134	190	249	323	414	491	598	691	800			11.0	
11.1	56	94	135	192	251	326	418	495	604	697	807			11.1	
11.2	57	95	136	194	253	329	422	499	609	704	814			11.2	
11.3	57	96	137	196	256	332	425	504	615	710	821			11.3	
11.4	58	97	139	197	258	335	429	508	620	716	829			11.4	
11.5	58	97	140	199	260	338	433	513	625	722	836			11.5	
11.6	59	98	141	201	262	341	437	517	631	729	843			11.6	
11.7	59	99	142	202	265	344	440	522	636	735	850			11.7	
11.8	60	100	143	204	267	347	444	526	642	741	858			11.8	
11.9	60	101	145	206	269	350	448	531	647	747	865			11.9	
12.0	61	102	146	208	271	353	452	535	653	754	872			12.0	
13.0	66	110	158	225	294	382	489	580	707	817	945			13.0	
14.0	71	119	170	242	317	411	527	624	761	879	1018			14.0	
15.0	76	127	182	260	339	441	565	669	816	942	1090			15.0	
16.0	81	136	195	277	362	470	602	713	870	1005	1163			16.0	
17.0	86	144	207	294	384	500	640	758	924	1068	1236			17.0	
18.0	91	153	219	311	407	529	678	803	979	1131	1308			18.0	
19.0	96	161	231	329	430	558	715	847	1033	1193	1381			19.0	
20.0	101	169	243	346	452	588	753	892	1088	1256	1454			20.0	

SECTION IV
HEADLIGHT SIGHT DISTANCE FOR
SAG VERTICAL CURVES

Computations are based on the following formulae:

$$S < L \quad S = [3.5L + \sqrt{12.25L^2 + 480AL}] \div 2A$$

$$S > L \quad S = (AL + 120) \div (2A - 3.5)$$

Based on headlight height of 600 mm and a 1° upward divergence of the light beam from the longitudinal axis of the vehicle

L = Length of Vertical Curve, m

S = Stopping Sight Distance, m

A = Algebraic Difference in Grade, %

HEADLIGHT SIGHT DISTANCE FOR SAG VERTICAL CURVES

LENGTHS IN METERS

DIFF. IN PERCENT OF GRADE	LENGTH OF CURVE														DIFF. IN PERCENT OF GRADE
	15 m	30 m	45 m	60 m	90 m	120 m	150 m	180 m	210 m	240 m	270 m	300 m	330 m		
1.8	1470	1740	2010	2280	2820	3360	3900	4440	4980	5520	6060	6600	7140	1.8	
1.9	495	590	685	780	970	1160	1350	1540	1730	1920	2110	2300	2490	1.9	
2.0	300	360	420	480	600	720	840	960	1080	1200	1320	1440	1560	2.0	
2.1	216	261	306	351	441	531	621	711	801	891	981	1071	1161	2.1	
2.2	170	207	243	280	353	427	500	573	647	720	793	867	940	2.2	
2.3	140	172	203	235	297	360	423	485	548	611	674	736	799	2.3	
2.4	120	148	175	203	258	314	369	425	480	535	591	646	702	2.4	
2.5	105	130	155	180	230	280	330	380	430	480	530	580	630	2.5	
2.6	94	116	139	162	208	254	300	346	392	438	484	529	575	2.6	
2.7	84	106	127	148	191	234	276	319	362	404	447	489	532	2.7	
2.8	77	97	117	137	177	217	257	297	337	377	417	457	497	2.8	
2.9	71	90	109	128	166	203	241	279	317	355	393	430	468	2.9	
3.0	66	84	102	120	156	192	228	264	300	336	372	408	444	3.0	
3.1	62	79	96	113	148	182	217	251	286	320	354	389	423	3.1	
3.2	58	74	91	108	141	174	207	240	273	306	339	372	406	3.2	
3.3	55	71	87	103	135	166	198	230	262	294	326	358	390	3.3	
3.4	52	67	83	98	129	160	191	222	253	284	315	345	376	3.4	
3.5	49	64	79	94	124	154	184	214	244	274	304	334	364	3.5	
3.6	47	62	76	91	120	149	178	208	237	266	295	324	354	3.6	
3.7	45	59	73	88	116	145	173	202	230	258	287	315	344	3.7	
3.8	43	57	71	85	113	140	168	196	224	252	280	307	335	3.8	
3.9	42	55	69	82	110	137	164	191	218	246	273	300	327	3.9	
4.0	40	53	67	80	107	133	160	187	213	240	267	293	320	4.0	
4.1	39	52	65	78	104	130	156	183	209	235	261	287	313	4.1	
4.2	37	50	63	76	102	127	153	179	204	230	255	281	306	4.2	
4.3	36	49	61	74	99	125	150	175	200	225	250	275	299	4.3	

HEADLIGHT SIGHT DISTANCE FOR SAG VERTICAL CURVES

LENGTHS IN METERS

DIFF. IN PERCENT OF GRADE	LENGTH OF CURVE														DIFF. IN PERCENT OF GRADE
	15 m	30 m	45 m	60 m	90 m	120 m	150 m	180 m	210 m	240 m	270 m	300 m	330 m		
4.4	35	48	60	72	97	122	147	172	196	221	245	269	293	4.4	
4.5	34	46	59	71	95	120	144	168	192	216	240	264	287	4.5	
4.6	33	45	57	69	94	118	142	165	189	212	235	259	282	4.6	
4.7	32	44	56	68	92	116	139	162	185	208	231	254	276	4.7	
4.8	31	43	55	67	90	114	137	159	182	204	227	249	271	4.8	
4.9	31	42	54	66	89	112	134	157	179	201	223	244	266	4.9	
5.0	30	42	53	65	88	110	132	154	176	197	219	240	261	5.0	
5.1	29	41	52	64	86	108	130	151	173	194	215	236	257	5.1	
5.2	29	40	51	63	85	107	128	149	170	191	211	232	252	5.2	
5.3	28	39	50	62	84	105	126	147	167	187	208	228	248	5.3	
5.4	28	39	50	61	83	104	124	144	164	184	204	224	244	5.4	
5.5	27	38	49	60	81	102	122	142	162	182	201	221	240	5.5	
5.6	26	37	48	59	80	101	120	140	159	179	198	217	236	5.6	
5.7	26	37	48	58	79	99	119	138	157	176	195	214	233	5.7	
5.8	26	36	47	58	78	98	117	136	155	173	192	211	229	5.8	
5.9	25	36	46	57	77	96	115	134	153	171	189	207	226	5.9	
6.0	25	35	46	56	76	95	114	132	150	168	186	204	222	6.0	
6.1	24	35	45	56	75	94	112	130	148	166	184	201	219	6.1	
6.2	24	34	45	55	74	93	111	129	146	164	181	199	216	6.2	
6.3	24	34	44	54	73	92	109	127	144	162	179	196	213	6.3	
6.4	23	34	44	54	72	90	108	125	142	159	176	193	210	6.4	
6.5	23	33	43	53	72	89	107	124	141	157	174	191	207	6.5	
6.6	23	33	43	53	71	88	105	122	139	155	172	188	204	6.6	
6.7	22	32	42	52	70	87	104	121	137	153	170	186	202	6.7	
6.8	22	32	42	51	69	86	103	119	135	151	167	183	199	6.8	
6.9	22	32	42	51	69	85	102	118	134	150	165	181	197	6.9	

HEADLIGHT SIGHT DISTANCE FOR SAG VERTICAL CURVES

LENGTHS IN METERS

DIFF. IN PERCENT OF GRADE	LENGTH OF CURVE														DIFF. IN PERCENT OF GRADE
	15 m	30 m	45 m	60 m	90 m	120 m	150 m	180 m	210 m	240 m	270 m	300 m	330 m		
7.0	21	31	41	50	68	84	101	116	132	148	163	179	194	7.0	
7.1	21	31	41	50	67	83	99	115	131	146	161	177	192	7.1	
7.2	21	31	40	49	66	83	98	114	129	144	159	174	189	7.2	
7.3	21	31	40	49	66	82	97	113	128	143	158	172	187	7.3	
7.4	20	30	40	48	65	81	96	111	126	141	156	170	185	7.4	
7.5	20	30	39	48	64	80	95	110	125	140	154	168	183	7.5	
7.6	20	30	39	48	64	79	94	109	124	138	152	167	181	7.6	
7.7	20	29	39	47	63	78	93	108	122	136	151	165	179	7.7	
7.8	20	29	38	47	63	78	92	107	121	135	149	163	177	7.8	
7.9	19	29	38	46	62	77	91	106	120	134	147	161	175	7.9	
8.0	19	29	38	46	61	76	90	105	118	132	146	159	173	8.0	
8.1	19	29	37	45	61	75	90	104	117	131	144	158	171	8.1	
8.2	19	28	37	45	60	75	89	103	116	130	143	156	169	8.2	
8.3	19	28	37	45	60	74	88	102	115	128	141	155	168	8.3	
8.4	18	28	36	44	59	73	87	101	114	127	140	153	166	8.4	
8.5	18	28	36	44	59	73	86	100	113	126	139	151	164	8.5	
8.6	18	27	36	44	58	72	86	99	112	125	137	150	163	8.6	
8.7	18	27	36	43	58	71	85	98	111	123	136	149	161	8.7	
8.8	18	27	35	43	57	71	84	97	110	122	135	147	159	8.8	
8.9	18	27	35	43	57	70	83	96	109	121	133	146	158	8.9	
9.0	18	27	35	42	56	70	83	95	108	120	132	144	156	9.0	
9.1	17	26	35	42	56	69	82	94	107	119	131	143	155	9.1	
9.2	17	26	34	42	55	69	81	94	106	118	130	142	154	9.2	
9.3	17	26	34	41	55	68	80	93	105	117	129	140	152	9.3	
9.4	17	26	34	41	55	67	80	92	104	116	128	139	151	9.4	
9.5	17	26	34	41	54	67	79	91	103	115	126	138	149	9.5	

HEADLIGHT SIGHT DISTANCE FOR SAG VERTICAL CURVES

LENGTHS IN METERS

DIFF. IN PERCENT OF GRADE	LENGTH OF CURVE													DIFF. IN PERCENT OF GRADE
	15 m	30 m	45 m	60 m	90 m	120 m	150 m	180 m	210 m	240 m	270 m	300 m	330 m	
9.6	17	26	33	40	54	66	79	90	102	114	125	137	148	9.6
9.7	17	25	33	40	53	66	78	90	101	113	124	136	147	9.7
9.8	17	25	33	40	53	65	77	89	101	112	123	134	146	9.8
9.9	16	25	33	40	53	65	77	88	100	111	122	133	144	9.9
10.0	16	25	32	39	52	64	76	88	99	110	121	132	143	10.0
10.1	16	25	32	39	52	64	76	87	98	109	120	131	142	10.1
10.2	16	25	32	39	51	63	75	86	97	108	119	130	141	10.2
10.3	16	24	32	39	51	63	74	86	97	108	118	129	140	10.3
10.4	16	24	32	38	51	63	74	85	96	107	117	128	139	10.4
10.5	16	24	31	38	50	62	73	84	95	106	116	127	137	10.5
10.6	16	24	31	38	50	62	73	84	94	105	116	126	136	10.6
10.7	16	24	31	38	50	61	72	83	94	104	115	125	135	10.7
10.8	16	24	31	37	49	61	72	83	93	104	114	124	134	10.8
10.9	15	24	31	37	49	60	71	82	92	103	113	123	133	10.9
11.0	15	23	30	37	49	60	71	81	92	102	112	122	132	11.0
12.0	15	22	29	35	46	56	66	76	86	95	105	114	123	12.0
13.0	14	21	27	33	43	53	63	72	81	89	98	107	115	13.0
14.0	13	20	26	31	41	50	59	68	76	84	93	101	109	14.0
15.0	13	19	25	30	39	48	56	64	72	80	88	95	103	15.0
16.0	12	19	24	29	38	46	54	61	69	76	83	90	98	16.0
17.0	12	18	23	28	36	44	51	59	66	73	80	86	93	17.0
18.0	12	17	22	27	35	42	49	56	63	70	76	83	89	18.0
19.0	11	17	22	26	34	41	48	54	61	67	73	79	85	19.0
20.0	11	16	21	25	32	39	46	52	58	64	70	76	82	20.0

HEADLIGHT SIGHT DISTANCE FOR SAG VERTICAL CURVES

LENGTHS IN METERS

DIFF. IN PERCENT OF GRADE	LENGTH OF CURVE														DIFF. IN PERCENT OF GRADE
	360 m	390 m	420 m	450 m	480 m	510 m	540 m	570 m	600 m	630 m	660 m	690 m	720 m		
1.8	7680	8220	8760	9300	9840	10380	10920	11460	12000	12540	13080	13620	14160	1.8	
1.9	2680	2870	3060	3250	3440	3630	3820	4010	4200	4390	4580	4770	4960	1.9	
2.0	1680	1800	1920	2040	2160	2280	2400	2520	2640	2760	2880	3000	3120	2.0	
2.1	1251	1341	1431	1521	1611	1701	1791	1881	1971	2061	2151	2241	2331	2.1	
2.2	1013	1087	1160	1233	1307	1380	1453	1527	1600	1673	1747	1820	1893	2.2	
2.3	862	925	987	1050	1113	1175	1238	1301	1364	1426	1489	1552	1615	2.3	
2.4	757	812	868	923	978	1034	1089	1145	1200	1255	1311	1366	1422	2.4	
2.5	680	730	780	830	880	930	980	1030	1080	1130	1180	1230	1280	2.5	
2.6	621	667	713	759	805	851	896	942	988	1034	1080	1126	1172	2.6	
2.7	575	617	660	703	745	788	831	873	916	958	1001	1044	1086	2.7	
2.8	537	577	617	657	697	737	777	817	857	897	937	977	1017	2.8	
2.9	506	544	582	620	657	695	733	771	809	847	884	922	960	2.9	
3.0	480	516	552	588	624	660	696	732	768	804	840	876	912	3.0	
3.1	458	492	527	561	596	630	664	699	733	768	802	837	871	3.1	
3.2	439	472	505	538	571	604	637	670	703	737	770	803	836	3.2	
3.3	422	454	486	518	550	582	614	645	677	709	741	773	805	3.3	
3.4	407	438	469	500	531	562	593	624	655	685	716	747	778	3.4	
3.5	394	424	454	484	514	544	574	604	634	664	694	724	754	3.5	
3.6	383	412	441	470	499	529	558	587	616	645	675	704	733	3.6	
3.7	372	401	429	458	486	515	543	572	600	628	657	685	714	3.7	
3.8	363	391	419	446	474	502	530	557	585	613	640	668	696	3.8	
3.9	354	381	409	436	463	490	517	544	571	598	625	652	679	3.9	
4.0	346	373	399	425	452	478	505	531	557	584	610	636	663	4.0	
4.1	338	364	390	416	442	467	493	519	544	570	596	622	647	4.1	
4.2	331	356	381	407	432	457	482	507	532	557	582	607	633	4.2	
4.3	324	349	373	398	422	447	471	496	521	545	570	594	619	4.3	

HEADLIGHT SIGHT DISTANCE FOR SAG VERTICAL CURVES

LENGTHS IN METERS

DIFF. IN PERCENT OF GRADE	LENGTH OF CURVE														DIFF. IN PERCENT OF GRADE
	360 m	390 m	420 m	450 m	480 m	510 m	540 m	570 m	600 m	630 m	660 m	690 m	720 m		
4.4	317	341	365	389	413	437	461	485	509	533	557	581	605	4.4	
4.5	311	334	358	381	405	428	452	475	499	522	546	569	592	4.5	
4.6	305	328	351	374	397	420	443	466	489	511	534	557	580	4.6	
4.7	299	321	344	366	389	411	434	456	479	501	524	546	569	4.7	
4.8	293	315	337	359	381	403	425	447	469	491	513	535	557	4.8	
4.9	288	309	331	353	374	396	417	439	460	482	504	525	547	4.9	
5.0	283	304	325	346	367	389	410	431	452	473	494	515	536	5.0	
5.1	278	298	319	340	361	381	402	423	444	464	485	506	526	5.1	
5.2	273	293	314	334	354	375	395	415	436	456	476	496	517	5.2	
5.3	268	288	308	328	348	368	388	408	428	448	468	488	508	5.3	
5.4	264	283	303	323	342	362	381	401	421	440	460	479	499	5.4	
5.5	259	279	298	317	337	356	375	394	413	433	452	471	490	5.5	
5.6	255	274	293	312	331	350	369	388	407	425	444	463	482	5.6	
5.7	251	270	289	307	326	344	363	381	400	419	437	456	474	5.7	
5.8	247	266	284	302	321	339	357	375	394	412	430	448	466	5.8	
5.9	244	262	280	298	316	334	352	370	387	405	423	441	459	5.9	
6.0	240	258	275	293	311	329	346	364	381	399	417	434	452	6.0	
6.1	237	254	271	289	306	324	341	358	376	393	410	428	445	6.1	
6.2	233	250	267	285	302	319	336	353	370	387	404	421	438	6.2	
6.3	230	247	264	281	297	314	331	348	365	381	398	415	432	6.3	
6.4	227	243	260	277	293	310	326	343	359	376	392	409	425	6.4	
6.5	224	240	256	273	289	305	322	338	354	371	387	403	419	6.5	
6.6	221	237	253	269	285	301	317	333	349	365	381	397	413	6.6	
6.7	218	234	250	265	281	297	313	329	345	360	376	392	408	6.7	
6.8	215	231	246	262	278	293	309	324	340	356	371	387	402	6.8	
6.9	212	228	243	259	274	289	305	320	335	351	366	381	397	6.9	

HEADLIGHT SIGHT DISTANCE FOR SAG VERTICAL CURVES

LENGTHS IN METERS

DIFF. IN PERCENT OF GRADE	LENGTH OF CURVE														DIFF. IN PERCENT OF GRADE
	360 m	390 m	420 m	450 m	480 m	510 m	540 m	570 m	600 m	630 m	660 m	690 m	720 m		
7.0	209	225	240	255	270	286	301	316	331	346	361	376	392	7.0	
7.1	207	222	237	252	267	282	297	312	327	342	357	372	386	7.1	
7.2	204	219	234	249	264	278	293	308	323	337	352	367	381	7.2	
7.3	202	217	231	246	260	275	290	304	319	333	348	362	377	7.3	
7.4	200	214	228	243	257	272	286	300	315	329	343	358	372	7.4	
7.5	197	212	226	240	254	268	283	297	311	325	339	353	367	7.5	
7.6	195	209	223	237	251	265	279	293	307	321	335	349	363	7.6	
7.7	193	207	221	234	248	262	276	290	304	317	331	345	359	7.7	
7.8	191	204	218	232	245	259	273	286	300	314	327	341	354	7.8	
7.9	189	202	216	229	243	256	270	283	297	310	323	337	350	7.9	
8.0	186	200	213	227	240	253	267	280	293	306	320	333	346	8.0	
8.1	184	198	211	224	237	251	264	277	290	303	316	329	342	8.1	
8.2	183	196	209	222	235	248	261	274	287	300	313	326	338	8.2	
8.3	181	194	207	219	232	245	258	271	284	296	309	322	335	8.3	
8.4	179	192	204	217	230	243	255	268	281	293	306	318	331	8.4	
8.5	177	190	202	215	227	240	253	265	278	290	303	315	328	8.5	
8.6	175	188	200	213	225	238	250	262	275	287	299	312	324	8.6	
8.7	173	186	198	211	223	235	247	260	272	284	296	308	321	8.7	
8.8	172	184	196	208	221	233	245	257	269	281	293	305	317	8.8	
8.9	170	182	194	206	218	230	242	254	266	278	290	302	314	8.9	
9.0	168	180	192	204	216	228	240	252	264	275	287	299	311	9.0	
9.1	167	179	191	202	214	226	238	249	261	273	284	296	308	9.1	
9.2	165	177	189	200	212	224	235	247	259	270	282	293	305	9.2	
9.3	164	175	187	199	210	222	233	245	256	267	279	290	302	9.3	
9.4	162	174	185	197	208	220	231	242	254	265	276	288	299	9.4	
9.5	161	172	184	195	206	218	229	240	251	262	274	285	296	9.5	

HEADLIGHT SIGHT DISTANCE FOR SAG VERTICAL CURVES

LENGTHS IN METERS

DIFF. IN PERCENT OF GRADE	LENGTH OF CURVE														DIFF. IN PERCENT OF GRADE
	360 m	390 m	420 m	450 m	480 m	510 m	540 m	570 m	600 m	630 m	660 m	690 m	720 m		
9.6	159	171	182	193	204	216	227	238	249	260	271	282	293	9.6	
9.7	158	169	180	191	203	214	225	236	247	258	269	280	290	9.7	
9.8	157	168	179	190	201	212	223	233	244	255	266	277	288	9.8	
9.9	155	166	177	188	199	210	221	231	242	253	264	274	285	9.9	
10.0	154	165	176	186	197	208	219	229	240	251	261	272	283	10.0	
10.1	153	163	174	185	196	206	217	227	238	248	259	270	280	10.1	
10.2	151	162	173	183	194	204	215	225	236	246	257	267	278	10.2	
10.3	150	161	171	182	192	203	213	223	234	244	254	265	275	10.3	
10.4	149	159	170	180	191	201	211	222	232	242	252	263	273	10.4	
10.5	148	158	168	179	189	199	209	220	230	240	250	260	270	10.5	
10.6	147	157	167	177	187	198	208	218	228	238	248	258	268	10.6	
10.7	146	156	166	176	186	196	206	216	226	236	246	256	266	10.7	
10.8	144	154	164	174	184	194	204	214	224	234	244	254	264	10.8	
10.9	143	153	163	173	183	193	203	213	222	232	242	252	262	10.9	
11.0	142	152	162	172	182	191	201	211	221	230	240	250	259	11.0	
12.0	132	141	150	159	168	177	186	195	204	213	222	231	240	12.0	
13.0	124	132	141	149	157	166	174	182	191	199	207	215	224	13.0	
14.0	116	124	132	140	148	156	163	171	179	186	194	202	209	14.0	
15.0	110	118	125	132	140	147	154	161	168	176	183	190	197	15.0	
16.0	105	112	118	125	132	139	146	153	159	166	173	180	186	16.0	
17.0	100	106	113	119	126	132	139	145	151	158	164	171	177	17.0	
18.0	95	101	108	114	120	126	132	138	144	150	156	162	168	18.0	
19.0	91	97	103	109	115	121	126	132	138	144	149	155	161	19.0	
20.0	88	93	99	105	110	116	121	127	132	138	143	149	154	20.0	

SECTION V
MINIMUM LENGTH OF SAG VERTICAL CURVES
BASED ON RIDING COMFORT

Computations are based on the following formula:

$$L = (AV^2) \div 395$$

Based on centripetal acceleration not exceeding 0.3 m/s²

L = Length of Vertical Curve, m

V = Design Speed, Km/h

A = Algebraic Difference in Grade, %

MINIMUM LENGTH OF SAG VERTICAL CURVES BASED ON RIDING COMFORT

LENGTHS IN METERS

DIFF. IN PERCENT OF GRADE	DESIGN SPEED												DIFF. IN PERCENT OF GRADE
	30 km/h	40 km/h	50 km/h	60 km/h	70 km/h	80 km/h	90 km/h	100 km/h	110 km/h	120 km/h	130 km/h		
0.1	0	0	1	1	1	2	2	2	3	3	4	5	0.1
0.2	0	1	1	2	2	3	3	4	5	6	7	9	0.2
0.3	1	1	2	3	4	5	5	6	8	9	11	13	0.3
0.4	1	2	3	4	5	6	6	8	10	12	15	18	0.4
0.5	1	2	3	5	6	8	8	10	13	15	18	22	0.5
0.6	1	2	4	5	7	10	10	12	15	18	22	26	0.6
0.7	2	3	4	6	9	11	11	14	18	21	26	30	0.7
0.8	2	3	5	7	10	13	13	16	20	25	29	35	0.8
0.9	2	4	6	8	11	15	15	18	23	28	33	39	0.9
1.0	2	4	6	9	12	16	16	21	25	31	36	43	1.0
1.1	3	4	7	10	14	18	18	23	28	34	40	48	1.1
1.2	3	5	8	11	15	19	19	25	30	37	44	52	1.2
1.3	3	5	8	12	16	21	21	27	33	40	47	56	1.3
1.4	3	6	9	13	17	23	23	29	35	43	51	60	1.4
1.5	3	6	9	14	19	24	24	31	38	46	55	65	1.5
1.6	4	6	10	15	20	26	26	33	41	49	58	69	1.6
1.7	4	7	11	15	21	28	28	35	43	52	62	73	1.7
1.8	4	7	11	16	22	29	29	37	46	55	66	78	1.8
1.9	4	8	12	17	24	31	31	39	48	58	69	82	1.9
2.0	5	8	13	18	25	32	32	41	51	61	73	86	2.0
2.1	5	9	13	19	26	34	34	43	53	64	77	90	2.1
2.2	5	9	14	20	27	36	36	45	56	67	80	95	2.2
2.3	5	9	15	21	29	37	37	47	58	70	84	99	2.3
2.4	5	10	15	22	30	39	39	49	61	74	87	103	2.4
2.5	6	10	16	23	31	41	41	51	63	77	91	107	2.5
2.6	6	11	16	24	32	42	42	53	66	80	95	112	2.6

MINIMUM LENGTH OF SAG VERTICAL CURVES BASED ON RIDING COMFORT

LENGTHS IN METERS

DIFF. IN PERCENT OF GRADE	DESIGN SPEED											DIFF. IN PERCENT OF GRADE
	30 km/h	40 km/h	50 km/h	60 km/h	70 km/h	80 km/h	90 km/h	100 km/h	110 km/h	120 km/h	130 km/h	
2.7	6	11	17	25	33	44	55	68	83	98	116	2.7
2.8	6	11	18	26	35	45	57	71	86	102	120	2.8
2.9	7	12	18	26	36	47	59	73	89	106	125	2.9
3.0	7	12	19	27	37	49	62	76	92	109	129	3.0
3.1	7	13	20	28	38	50	64	78	95	113	133	3.1
3.2	7	13	20	29	40	52	66	81	98	117	137	3.2
3.3	8	13	21	30	41	53	68	84	101	120	142	3.3
3.4	8	14	22	31	42	55	70	86	104	124	146	3.4
3.5	8	14	22	32	43	57	72	89	107	128	150	3.5
3.6	8	15	23	33	45	58	74	91	110	131	155	3.6
3.7	8	15	23	34	46	60	76	94	113	135	159	3.7
3.8	9	15	24	35	47	62	78	96	116	139	163	3.8
3.9	9	16	25	36	48	63	80	99	119	142	167	3.9
4.0	9	16	25	36	50	65	82	101	123	146	172	4.0
4.1	9	17	26	37	51	66	84	104	126	149	176	4.1
4.2	10	17	27	38	52	68	86	106	129	153	180	4.2
4.3	10	17	27	39	53	70	88	109	132	157	184	4.3
4.4	10	18	28	40	55	71	90	111	135	160	189	4.4
4.5	10	18	28	41	56	73	92	114	138	164	193	4.5
4.6	10	19	29	42	57	75	94	116	141	168	197	4.6
4.7	11	19	30	43	58	76	96	119	144	171	202	4.7
4.8	11	19	30	44	60	78	98	122	147	175	206	4.8
4.9	11	20	31	45	61	79	100	124	150	179	210	4.9
5.0	11	20	32	46	62	81	103	127	153	182	214	5.0
5.1	12	21	32	46	63	83	105	129	156	186	219	5.1
5.2	12	21	33	47	65	84	107	132	159	190	223	5.2

MINIMUM LENGTH OF SAG VERTICAL CURVES BASED ON RIDING COMFORT

LENGTHS IN METERS

DIFF. IN PERCENT OF GRADE	DESIGN SPEED										DIFF. IN PERCENT OF GRADE	
	30 km/h	40 km/h	50 km/h	60 km/h	70 km/h	80 km/h	90 km/h	100 km/h	110 km/h	120 km/h		130 km/h
5.3	12	21	34	48	66	86	109	134	162	193	227	5.3
5.4	12	22	34	49	67	87	111	137	165	197	232	5.4
5.5	13	22	35	50	68	89	113	139	168	201	236	5.5
5.6	13	23	35	51	69	91	115	142	172	204	240	5.6
5.7	13	23	36	52	71	92	117	144	175	208	244	5.7
5.8	13	23	37	53	72	94	119	147	178	211	249	5.8
5.9	13	24	37	54	73	96	121	149	181	215	253	5.9
6.0	14	24	38	55	74	97	123	152	184	219	257	6.0
6.1	14	25	39	56	76	99	125	154	187	222	261	6.1
6.2	14	25	39	57	77	100	127	157	190	226	266	6.2
6.3	14	26	40	57	78	102	129	159	193	230	270	6.3
6.4	15	26	41	58	79	104	131	162	196	233	274	6.4
6.5	15	26	41	59	81	105	133	165	199	237	279	6.5
6.6	15	27	42	60	82	107	135	167	202	241	283	6.6
6.7	15	27	42	61	83	109	137	170	205	244	287	6.7
6.8	15	28	43	62	84	110	139	172	208	248	291	6.8
6.9	16	28	44	63	86	112	141	175	211	252	296	6.9
7.0	16	28	44	64	87	113	144	177	214	255	300	7.0
7.1	16	29	45	65	88	115	146	180	217	259	304	7.1
7.2	16	29	46	66	89	117	148	182	221	262	309	7.2
7.3	17	30	46	67	91	118	150	185	224	266	313	7.3
7.4	17	30	47	67	92	120	152	187	227	270	317	7.4
7.5	17	30	47	68	93	122	154	190	230	273	321	7.5
7.6	17	31	48	69	94	123	156	192	233	277	326	7.6
7.7	18	31	49	70	96	125	158	195	236	281	330	7.7
7.8	18	32	49	71	97	126	160	197	239	284	334	7.8

MINIMUM LENGTH OF SAG VERTICAL CURVES BASED ON RIDING COMFORT

LENGTHS IN METERS

DIFF. IN PERCENT OF GRADE	DESIGN SPEED											DIFF. IN PERCENT OF GRADE
	30 km/h	40 km/h	50 km/h	60 km/h	70 km/h	80 km/h	90 km/h	100 km/h	110 km/h	120 km/h	130 km/h	
7.9	18	32	50	72	98	128	162	200	242	288	338	7.9
8.0	18	32	51	73	99	130	164	203	245	292	343	8.0
8.1	18	33	51	74	100	131	166	205	248	295	347	8.1
8.2	19	33	52	75	102	133	168	208	251	299	351	8.2
8.3	19	34	53	76	103	134	170	210	254	303	356	8.3
8.4	19	34	53	77	104	136	172	213	257	306	360	8.4
8.5	19	34	54	77	105	138	174	215	260	310	364	8.5
8.6	20	35	54	78	107	139	176	218	263	314	368	8.6
8.7	20	35	55	79	108	141	178	220	267	317	373	8.7
8.8	20	36	56	80	109	143	180	223	270	321	377	8.8
8.9	20	36	56	81	110	144	183	225	273	324	381	8.9
9.0	21	36	57	82	112	146	185	228	276	328	386	9.0
9.1	21	37	58	83	113	147	187	230	279	332	390	9.1
9.2	21	37	58	84	114	149	189	233	282	335	394	9.2
9.3	21	38	59	85	115	151	191	235	285	339	398	9.3
9.4	21	38	59	86	117	152	193	238	288	343	403	9.4
9.5	22	38	60	87	118	154	195	241	291	346	407	9.5
9.6	22	39	61	87	119	156	197	243	294	350	411	9.6
9.7	22	39	61	88	120	157	199	246	297	354	416	9.7
9.8	22	40	62	89	122	159	201	248	300	357	420	9.8
9.9	23	40	63	90	123	160	203	251	303	361	424	9.9
10.0	23	41	63	91	124	162	205	253	306	365	428	10.0
10.1	23	41	64	92	125	164	207	256	309	368	433	10.1
10.2	23	41	65	93	127	165	209	258	312	372	437	10.2
10.3	23	42	65	94	128	167	211	261	316	375	441	10.3
10.4	24	42	66	95	129	169	213	263	319	379	445	10.4

MINIMUM LENGTH OF SAG VERTICAL CURVES BASED ON RIDING COMFORT

LENGTHS IN METERS

DIFF. IN PERCENT OF GRADE	DESIGN SPEED											DIFF. IN PERCENT OF GRADE
	30 km/h	40 km/h	50 km/h	60 km/h	70 km/h	80 km/h	90 km/h	100 km/h	110 km/h	120 km/h	130 km/h	
10.5	24	43	66	96	130	170	215	266	322	383	450	10.5
10.6	24	43	67	97	131	172	217	268	325	386	454	10.6
10.7	24	43	68	98	133	173	219	271	328	390	458	10.7
10.8	25	44	68	98	134	175	221	273	331	394	463	10.8
10.9	25	44	69	99	135	177	224	276	334	397	467	10.9
11.0	25	45	70	100	136	178	226	278	337	401	471	11.0
11.1	25	45	70	101	138	180	228	281	340	405	475	11.1
11.2	26	45	71	102	139	181	230	284	343	408	480	11.2
11.3	26	46	72	103	140	183	232	286	346	412	484	11.3
11.4	26	46	72	104	141	185	234	289	349	416	488	11.4
11.5	26	47	73	105	143	186	236	291	352	419	493	11.5
11.6	26	47	73	106	144	188	238	294	355	423	497	11.6
11.7	27	47	74	107	145	190	240	296	358	427	501	11.7
11.8	27	48	75	108	146	191	242	299	361	430	505	11.8
11.9	27	48	75	108	148	193	244	301	365	434	510	11.9
12.0	27	49	76	109	149	194	246	304	368	437	514	12.0
13.0	30	53	82	118	161	211	267	329	398	474	557	13.0
14.0	32	57	89	128	174	227	287	354	429	510	599	14.0
15.0	34	61	95	137	186	243	308	380	459	547	642	15.0
16.0	36	65	101	146	198	259	328	405	490	583	685	16.0
17.0	39	69	108	155	211	275	349	430	521	620	728	17.0
18.0	41	73	114	164	223	292	369	456	551	656	771	18.0
19.0	43	77	120	173	236	308	390	481	582	693	813	19.0
20.0	46	81	127	182	248	324	410	506	613	729	856	20.0

SECTION VI
PASSING SIGHT DISTANCE
FOR CREST VERTICAL CURVES

Computations are based on the following formulae:

$$S < L \quad S = \sqrt{864L \div A}$$

$$S > L \quad S = (L \div 2) + (432 \div A)$$

Based on height of eye = 1080 mm and height of object = 1080 mm

L = Length of Vertical Curve, m

S = Passing Sight Distance, m

A = Algebraic Difference in Grade, %

PASSING SIGHT DISTANCE FOR CREST VERTICAL CURVES

LENGTHS IN METERS

DIFF. IN PERCENT OF GRADE	LENGTH OF CURVE														DIFF. IN PERCENT OF GRADE
	15 m	30 m	45 m	60 m	90 m	120 m	150 m	180 m	210 m	240 m	270 m	300 m	330 m		
0.1	4328	4335	4343	4350	4365	4380	4395	4410	4425	4440	4455	4470	4485	0.1	
0.2	2168	2175	2183	2190	2205	2220	2235	2250	2265	2280	2295	2310	2325	0.2	
0.3	1448	1455	1463	1470	1485	1500	1515	1530	1545	1560	1575	1590	1605	0.3	
0.4	1088	1095	1103	1110	1125	1140	1155	1170	1185	1200	1215	1230	1245	0.4	
0.5	872	879	887	894	909	924	939	954	969	984	999	1014	1029	0.5	
0.6	728	735	743	750	765	780	795	810	825	840	855	870	885	0.6	
0.7	625	633	640	648	663	678	693	708	723	738	753	768	783	0.7	
0.8	548	555	563	570	585	600	615	630	645	660	675	690	705	0.8	
0.9	488	496	503	511	525	540	555	570	585	600	615	630	645	0.9	
1.0	440	447	455	462	477	492	507	522	537	552	567	582	597	1.0	
1.1	401	408	416	423	438	453	468	483	498	513	528	543	558	1.1	
1.2	368	375	383	390	405	420	435	450	465	480	495	510	525	1.2	
1.3	340	348	355	363	378	393	408	423	438	453	468	483	498	1.3	
1.4	317	324	332	339	354	369	384	399	414	429	444	459	474	1.4	
1.5	296	303	311	318	333	348	363	378	393	408	423	438	453	1.5	
1.6	278	285	293	300	315	330	345	360	375	390	405	420	435	1.6	
1.7	262	270	277	285	300	315	330	345	360	375	390	405	420	1.7	
1.8	248	255	263	270	285	300	315	330	345	360	375	390	405	1.8	
1.9	235	243	250	258	273	288	303	318	333	348	363	378	393	1.9	
2.0	224	231	239	246	261	276	291	306	321	336	351	366	381	2.0	
2.1	214	221	229	236	251	266	281	296	311	326	341	356	371	2.1	
2.2	204	212	219	227	242	257	272	287	302	317	332	347	362	2.2	
2.3	196	203	211	218	233	248	263	278	293	308	323	338	353	2.3	
2.4	188	195	203	210	225	240	255	270	285	300	315	330	345	2.4	
2.5	181	188	196	203	218	233	248	263	278	293	308	323	338	2.5	
2.6	174	182	189	197	212	227	242	257	272	287	302	317	332	2.6	

PASSING SIGHT DISTANCE FOR CREST VERTICAL CURVES

LENGTHS IN METERS

DIFF. IN PERCENT OF GRADE	LENGTH OF CURVE													DIFF. IN PERCENT OF GRADE
	15 m	30 m	45 m	60 m	90 m	120 m	150 m	180 m	210 m	240 m	270 m	300 m	330 m	
2.7	168	175	183	190	205	220	235	250	265	280	295	310	325	2.7
2.8	162	170	177	185	200	215	230	245	260	275	290	305	320	2.8
2.9	157	164	172	179	194	209	224	239	254	269	284	299	314	2.9
3.0	152	159	167	174	189	204	219	234	249	264	279	294	309	3.0
3.1	147	155	162	170	185	200	215	230	245	260	275	290	304	3.1
3.2	143	150	158	165	180	195	210	225	240	255	270	285	299	3.2
3.3	139	146	154	161	176	191	206	221	236	251	266	281	294	3.3
3.4	135	143	150	158	173	188	203	218	233	248	262	277	290	3.4
3.5	131	139	146	154	169	184	199	214	229	244	259	273	286	3.5
3.6	128	135	143	150	165	180	195	210	225	240	255	269	282	3.6
3.7	125	132	140	147	162	177	192	207	222	237	252	265	278	3.7
3.8	122	129	137	144	159	174	189	204	219	234	248	262	274	3.8
3.9	119	126	134	141	156	171	186	201	216	231	245	258	271	3.9
4.0	116	123	131	138	153	168	183	198	213	228	242	255	267	4.0
4.1	113	121	128	136	151	166	181	196	211	225	239	252	264	4.1
4.2	111	118	126	133	148	163	178	193	208	223	236	249	261	4.2
4.3	108	116	123	131	146	161	176	191	206	220	233	246	258	4.3
4.4	106	114	121	129	144	159	174	189	204	218	231	243	255	4.4
4.5	104	111	119	126	141	156	171	186	201	215	228	240	252	4.5
4.6	102	109	117	124	139	154	169	184	199	213	226	238	249	4.6
4.7	100	107	115	122	137	152	167	182	197	211	223	235	247	4.7
4.8	98	105	113	120	135	150	165	180	195	208	221	233	244	4.8
4.9	96	104	111	119	134	149	164	179	193	206	219	230	242	4.9
5.0	94	102	109	117	132	147	162	177	191	204	216	228	239	5.0
5.1	93	100	108	115	130	145	160	175	189	202	214	226	237	5.1
5.2	91	99	106	114	129	144	159	173	187	200	212	224	235	5.2

PASSING SIGHT DISTANCE FOR CREST VERTICAL CURVES

LENGTHS IN METERS

DIFF. IN PERCENT OF GRADE	LENGTH OF CURVE														DIFF. IN PERCENT OF GRADE
	15 m	30 m	45 m	60 m	90 m	120 m	150 m	180 m	210 m	240 m	270 m	300 m	330 m		
5.3	90	97	105	112	127	142	157	172	186	198	210	222	232	5.3	
5.4	88	95	103	110	125	140	155	170	184	196	208	220	230	5.4	
5.5	87	94	102	109	124	139	154	169	182	195	206	218	228	5.5	
5.6	85	93	100	108	123	138	153	167	180	193	205	216	226	5.6	
5.7	84	91	99	106	121	136	151	166	179	191	203	214	224	5.7	
5.8	82	90	97	105	120	135	150	164	177	190	201	212	222	5.8	
5.9	81	89	96	104	119	134	149	163	176	188	199	210	220	5.9	
6.0	80	87	95	102	117	132	147	161	174	186	198	208	218	6.0	
6.1	79	86	94	101	116	131	146	160	173	185	196	207	217	6.1	
6.2	78	85	93	100	115	130	145	159	172	183	194	205	215	6.2	
6.3	77	84	92	99	114	129	144	158	170	182	193	203	213	6.3	
6.4	75	83	90	98	113	128	143	156	169	180	191	202	212	6.4	
6.5	74	82	89	97	112	127	142	155	168	179	190	200	210	6.5	
6.6	73	81	88	96	111	126	141	154	166	178	189	199	208	6.6	
6.7	72	80	87	95	110	125	140	153	165	176	187	197	207	6.7	
6.8	72	79	87	94	109	124	139	152	164	175	186	196	205	6.8	
6.9	71	78	86	93	108	123	138	151	163	174	184	194	204	6.9	
7.0	70	77	85	92	107	122	137	150	161	173	183	193	202	7.0	
7.1	69	76	84	91	106	121	136	149	160	171	182	192	201	7.1	
7.2	68	75	83	90	105	120	135	147	159	170	180	190	199	7.2	
7.3	67	75	82	90	105	120	134	146	158	169	179	189	198	7.3	
7.4	66	74	81	89	104	119	133	145	157	168	178	188	197	7.4	
7.5	66	73	81	88	103	118	132	144	156	167	177	186	195	7.5	
7.6	65	72	80	87	102	117	131	144	155	166	176	185	194	7.6	
7.7	64	72	79	87	102	117	130	143	154	165	175	184	193	7.7	
7.8	63	71	78	86	101	116	129	142	153	164	173	183	192	7.8	

PASSING SIGHT DISTANCE FOR CREST VERTICAL CURVES

LENGTHS IN METERS

DIFF. IN PERCENT OF GRADE	LENGTH OF CURVE														DIFF. IN PERCENT OF GRADE
	15 m	30 m	45 m	60 m	90 m	120 m	150 m	180 m	210 m	240 m	270 m	300 m	330 m		
7.9	63	70	78	85	100	115	129	141	152	163	172	182	190	7.9	
8.0	62	69	77	84	99	114	128	140	151	161	171	180	189	8.0	
8.1	61	69	76	84	99	114	127	139	150	160	170	179	188	8.1	
8.2	61	68	76	83	98	113	126	138	149	160	169	178	187	8.2	
8.3	60	68	75	83	98	112	125	137	148	159	168	177	186	8.3	
8.4	59	67	74	82	97	112	125	137	147	158	167	176	185	8.4	
8.5	59	66	74	81	96	111	124	136	147	157	166	175	184	8.5	
8.6	58	66	73	81	96	110	123	135	146	156	165	174	183	8.6	
8.7	58	65	73	80	95	110	123	134	145	155	164	173	182	8.7	
8.8	57	65	72	80	95	109	122	133	144	154	163	172	180	8.8	
8.9	57	64	72	79	94	108	121	133	143	153	162	171	179	8.9	
9.0	56	63	71	78	93	108	120	132	142	152	161	170	178	9.0	
9.1	55	63	70	78	93	107	120	131	142	151	161	169	178	9.1	
9.2	55	62	70	77	92	107	119	131	141	151	160	168	177	9.2	
9.3	54	62	69	77	92	106	119	130	140	150	159	167	176	9.3	
9.4	54	61	69	76	91	106	118	129	139	149	158	167	175	9.4	
9.5	53	61	68	76	91	105	117	128	139	148	157	166	174	9.5	
9.6	53	60	68	75	90	104	117	128	138	147	156	165	173	9.6	
9.7	53	60	68	75	90	104	116	127	137	147	156	164	172	9.7	
9.8	52	60	67	75	90	103	115	126	137	146	155	163	171	9.8	
9.9	52	59	67	74	89	103	115	126	136	145	154	162	170	9.9	
10.0	51	59	66	74	89	102	114	125	135	144	153	161	169	10.0	
10.1	51	58	66	73	88	102	114	125	135	144	152	161	169	10.1	
10.2	50	58	65	73	88	101	113	124	134	143	152	160	168	10.2	
10.3	50	57	65	72	87	101	113	123	133	142	151	159	167	10.3	
10.4	50	57	65	72	87	100	112	123	133	142	150	158	166	10.4	

PASSING SIGHT DISTANCE FOR CREST VERTICAL CURVES

LENGTHS IN METERS

DIFF. IN PERCENT OF GRADE	LENGTH OF CURVE													DIFF. IN PERCENT OF GRADE
	15 m	30 m	45 m	60 m	90 m	120 m	150 m	180 m	210 m	240 m	270 m	300 m	330 m	
10.5	49	57	64	72	87	100	112	122	132	141	150	158	165	10.5
10.6	49	56	64	71	86	99	111	122	131	140	149	157	165	10.6
10.7	48	56	63	71	86	99	111	121	131	140	148	156	164	10.7
10.8	48	55	63	70	85	98	110	120	130	139	147	155	163	10.8
10.9	48	55	63	70	85	98	110	120	130	138	147	155	162	10.9
11.0	47	55	62	70	85	98	109	119	129	138	146	154	161	11.0
11.1	47	54	62	69	84	97	109	119	128	137	145	153	161	11.1
11.2	47	54	62	69	84	97	108	118	128	137	145	153	160	11.2
11.3	46	54	61	69	83	96	108	118	127	136	144	152	159	11.3
11.4	46	53	61	68	83	96	107	117	127	135	144	151	159	11.4
11.5	46	53	61	68	83	95	107	117	126	135	143	151	158	11.5
11.6	45	53	60	68	82	95	106	116	126	134	142	150	157	11.6
11.7	45	52	60	67	82	95	106	116	125	134	142	149	157	11.7
11.8	45	52	60	67	82	94	105	115	125	133	141	149	156	11.8
11.9	44	52	59	67	81	94	105	115	124	133	141	148	155	11.9
12.0	44	51	59	66	81	93	104	114	123	132	140	147	155	12.0
13.0	41	49	56	64	78	90	100	110	119	127	134	142	149	13.0
14.0	39	46	54	61	75	87	97	106	114	122	130	137	143	14.0
15.0	37	44	52	59	72	84	93	102	110	118	125	132	138	15.0
16.0	35	42	50	57	70	81	90	99	107	114	121	128	134	16.0
17.0	33	41	48	56	68	79	88	96	104	111	118	124	130	17.0
18.0	32	39	47	54	66	76	85	93	101	108	114	120	126	18.0
19.0	31	38	46	53	64	74	83	91	98	105	111	117	123	19.0
20.0	30	37	45	51	63	72	81	89	96	102	108	114	120	20.0

PASSING SIGHT DISTANCE FOR CREST VERTICAL CURVES

LENGTHS IN METERS

DIFF. IN PERCENT OF GRADE	LENGTH OF CURVE														DIFF. IN PERCENT OF GRADE
	360 m	390 m	420 m	450 m	480 m	510 m	540 m	570 m	600 m	630 m	660 m	690 m	720 m		
0.1	4500	4515	4530	4545	4560	4575	4590	4605	4620	4635	4650	4665	4680	0.1	
0.2	2340	2355	2370	2385	2400	2415	2430	2445	2460	2475	2490	2505	2520	0.2	
0.3	1620	1635	1650	1665	1680	1695	1710	1725	1740	1755	1770	1785	1800	0.3	
0.4	1260	1275	1290	1305	1320	1335	1350	1365	1380	1395	1410	1425	1440	0.4	
0.5	1044	1059	1074	1089	1104	1119	1134	1149	1164	1179	1194	1209	1224	0.5	
0.6	900	915	930	945	960	975	990	1005	1020	1035	1050	1065	1080	0.6	
0.7	798	813	828	843	858	873	888	903	918	933	948	963	978	0.7	
0.8	720	735	750	765	780	795	810	825	840	855	870	885	900	0.8	
0.9	660	675	690	705	720	735	750	765	780	795	810	825	840	0.9	
1.0	612	627	642	657	672	687	702	717	732	747	762	777	792	1.0	
1.1	573	588	603	618	633	648	663	678	693	708	723	738	753	1.1	
1.2	540	555	570	585	600	615	630	645	660	675	690	705	720	1.2	
1.3	513	528	543	558	573	588	603	618	633	648	663	678	692	1.3	
1.4	489	504	519	534	549	564	579	594	609	624	639	653	667	1.4	
1.5	468	483	498	513	528	543	558	573	588	603	617	631	644	1.5	
1.6	450	465	480	495	510	525	540	555	570	584	597	611	624	1.6	
1.7	435	450	465	480	495	510	524	539	553	566	580	593	605	1.7	
1.8	420	435	450	465	480	495	510	524	537	550	563	576	588	1.8	
1.9	408	423	438	453	468	482	496	510	523	536	548	561	573	1.9	
2.0	396	411	426	441	456	470	483	497	510	522	534	546	558	2.0	
2.1	386	401	416	431	445	459	472	485	497	510	522	533	545	2.1	
2.2	377	392	407	421	435	448	461	474	486	498	510	521	532	2.2	
2.3	368	383	398	412	425	438	451	463	475	487	498	510	521	2.3	
2.4	360	375	389	403	416	429	441	453	465	477	488	499	510	2.4	
2.5	353	368	381	395	408	420	432	444	456	467	478	489	499	2.5	
2.6	346	360	374	387	400	412	424	436	447	458	469	479	490	2.6	

PASSING SIGHT DISTANCE FOR CREST VERTICAL CURVES

LENGTHS IN METERS

DIFF. IN PERCENT OF GRADE	LENGTH OF CURVE														DIFF. IN PERCENT OF GRADE
	360 m	390 m	420 m	450 m	480 m	510 m	540 m	570 m	600 m	630 m	660 m	690 m	720 m		
2.7	340	354	367	380	392	404	416	428	439	449	460	470	480	2.7	
2.8	334	347	360	373	385	397	409	420	431	441	452	462	472	2.8	
2.9	328	341	354	367	379	390	402	413	423	434	444	454	464	2.9	
3.0	322	336	348	360	372	384	395	406	416	426	436	446	456	3.0	
3.1	317	330	343	355	366	378	388	399	409	420	429	439	448	3.1	
3.2	312	325	337	349	360	372	382	393	403	413	423	432	441	3.2	
3.3	308	320	332	344	355	366	377	387	397	407	416	426	435	3.3	
3.4	303	315	327	339	350	360	371	381	391	401	410	419	428	3.4	
3.5	299	311	322	334	345	355	366	376	385	395	404	413	422	3.5	
3.6	294	306	318	329	340	350	360	370	380	389	398	407	416	3.6	
3.7	290	302	314	325	335	346	356	365	375	384	393	402	411	3.7	
3.8	287	298	310	320	331	341	351	360	370	379	388	397	405	3.8	
3.9	283	294	306	316	327	337	346	356	365	374	383	391	400	3.9	
4.0	279	291	302	312	322	332	342	351	360	369	378	387	395	4.0	
4.1	276	287	298	308	319	328	338	347	356	365	373	382	390	4.1	
4.2	273	284	294	305	315	324	334	343	352	360	369	377	385	4.2	
4.3	269	280	291	301	311	321	330	339	348	356	365	373	381	4.3	
4.4	266	277	288	298	308	317	326	335	344	352	360	369	377	4.4	
4.5	263	274	284	294	304	313	322	331	340	348	356	364	372	4.5	
4.6	261	271	281	291	301	310	319	328	336	344	353	360	368	4.6	
4.7	258	268	278	288	298	307	316	324	333	341	349	357	364	4.7	
4.8	255	265	275	285	294	303	312	321	329	337	345	353	360	4.8	
4.9	252	263	273	282	291	300	309	318	326	334	342	349	357	4.9	
5.0	250	260	270	279	288	297	306	314	322	330	338	346	353	5.0	
5.1	247	258	267	277	286	294	303	311	319	327	335	342	350	5.1	
5.2	245	255	265	274	283	292	300	308	316	324	332	339	346	5.2	

PASSING SIGHT DISTANCE FOR CREST VERTICAL CURVES

LENGTHS IN METERS

DIFF. IN PERCENT OF GRADE	LENGTH OF CURVE														DIFF. IN PERCENT OF GRADE
	360 m	390 m	420 m	450 m	480 m	510 m	540 m	570 m	600 m	630 m	660 m	690 m	720 m		
5.3	243	253	262	271	280	289	297	305	313	321	329	336	343	5.3	
5.4	240	250	260	269	278	286	294	302	310	318	325	333	340	5.4	
5.5	238	248	257	266	275	284	292	300	308	315	322	330	337	5.5	
5.6	236	246	255	264	273	281	289	297	305	312	320	327	334	5.6	
5.7	234	244	253	262	270	279	287	294	302	310	317	324	331	5.7	
5.8	232	242	251	259	268	276	284	292	299	307	314	321	328	5.8	
5.9	230	239	249	257	266	274	282	289	297	304	311	318	325	5.9	
6.0	228	237	246	255	263	271	279	287	294	302	309	316	322	6.0	
6.1	226	236	244	253	261	269	277	285	292	299	306	313	320	6.1	
6.2	224	234	242	251	259	267	275	282	290	297	304	311	317	6.2	
6.3	223	232	240	249	257	265	273	280	287	294	301	308	315	6.3	
6.4	221	230	239	247	255	263	270	278	285	292	299	306	312	6.4	
6.5	219	228	237	245	253	261	268	276	283	290	297	303	310	6.5	
6.6	218	226	235	243	251	259	266	274	281	288	294	301	308	6.6	
6.7	216	225	233	241	249	257	264	272	279	286	292	299	305	6.7	
6.8	214	223	232	240	247	255	262	270	277	283	290	297	303	6.8	
6.9	213	221	230	238	246	253	261	268	275	281	288	294	301	6.9	
7.0	211	220	228	236	244	251	259	266	273	279	286	292	299	7.0	
7.1	210	218	227	235	242	250	257	264	271	277	284	290	297	7.1	
7.2	208	217	225	233	240	248	255	262	269	275	282	288	294	7.2	
7.3	207	215	223	231	239	246	253	260	267	274	280	286	292	7.3	
7.4	206	214	222	230	237	245	252	258	265	272	278	284	290	7.4	
7.5	204	212	220	228	236	243	250	257	263	270	276	282	288	7.5	
7.6	203	211	219	227	234	241	248	255	262	268	274	281	287	7.6	
7.7	201	210	218	225	233	240	247	253	260	266	273	279	285	7.7	
7.8	200	208	216	224	231	238	245	252	258	265	271	277	283	7.8	

PASSING SIGHT DISTANCE FOR CREST VERTICAL CURVES

LENGTHS IN METERS

DIFF. IN PERCENT OF GRADE	LENGTH OF CURVE														DIFF. IN PERCENT OF GRADE
	360 m	390 m	420 m	450 m	480 m	510 m	540 m	570 m	600 m	630 m	660 m	690 m	720 m		
7.9	199	207	215	222	230	237	244	250	257	263	269	275	281	7.9	
8.0	198	206	213	221	228	235	242	249	255	261	267	273	279	8.0	
8.1	196	204	212	220	227	234	240	247	253	260	266	272	278	8.1	
8.2	195	203	211	218	225	232	239	246	252	258	264	270	276	8.2	
8.3	194	202	210	217	224	231	238	244	250	257	263	269	274	8.3	
8.4	193	201	208	216	223	230	236	243	249	255	261	267	273	8.4	
8.5	192	200	207	214	221	228	235	241	247	254	260	265	271	8.5	
8.6	191	198	206	213	220	227	233	240	246	252	258	264	269	8.6	
8.7	190	197	205	212	219	226	232	238	245	251	257	262	268	8.7	
8.8	189	196	204	211	218	224	231	237	243	249	255	261	266	8.8	
8.9	187	195	202	210	216	223	229	236	242	248	254	259	265	8.9	
9.0	186	194	201	208	215	222	228	234	240	246	252	258	263	9.0	
9.1	185	193	200	207	214	221	227	233	239	245	251	256	262	9.1	
9.2	184	192	199	206	213	219	226	232	238	244	249	255	261	9.2	
9.3	183	191	198	205	212	218	224	231	237	242	248	254	259	9.3	
9.4	182	190	197	204	211	217	223	229	235	241	247	252	258	9.4	
9.5	181	189	196	203	209	216	222	228	234	240	246	251	256	9.5	
9.6	180	188	195	202	208	215	221	227	233	239	244	250	255	9.6	
9.7	180	187	194	201	207	214	220	226	232	237	243	248	254	9.7	
9.8	179	186	193	200	206	213	219	225	230	236	242	247	252	9.8	
9.9	178	185	192	199	205	211	218	224	229	235	240	246	251	9.9	
10.0	177	184	191	198	204	210	216	222	228	234	239	245	250	10.0	
10.1	176	183	190	197	203	209	215	221	227	233	238	243	249	10.1	
10.2	175	182	189	196	202	208	214	220	226	232	237	242	247	10.2	
10.3	174	181	188	195	201	207	213	219	225	230	236	241	246	10.3	
10.4	173	180	187	194	200	206	212	218	224	229	235	240	245	10.4	

PASSING SIGHT DISTANCE FOR CREST VERTICAL CURVES

LENGTHS IN METERS

DIFF. IN PERCENT OF GRADE	LENGTH OF CURVE															DIFF. IN PERCENT OF GRADE
	360 m	390 m	420 m	450 m	480 m	510 m	540 m	570 m	600 m	630 m	660 m	690 m	720 m			
10.5	173	180	186	193	199	205	211	217	223	228	234	239	244	10.5		
10.6	172	179	186	192	198	204	210	216	222	227	232	238	243	10.6		
10.7	171	178	185	191	197	203	209	215	221	226	231	237	242	10.7		
10.8	170	177	184	190	196	202	208	214	220	225	230	235	240	10.8		
10.9	169	176	183	189	196	202	207	213	219	224	229	234	239	10.9		
11.0	169	176	182	189	195	201	206	212	218	223	228	233	238	11.0		
11.1	168	175	181	188	194	200	206	211	217	222	227	232	237	11.1		
11.2	167	174	180	187	193	199	205	210	216	221	226	231	236	11.2		
11.3	166	173	180	186	192	198	204	209	215	220	225	230	235	11.3		
11.4	166	172	179	185	191	197	203	208	214	219	224	229	234	11.4		
11.5	165	172	178	184	190	196	202	207	213	218	223	228	233	11.5		
11.6	164	171	177	184	190	195	201	207	212	217	222	227	232	11.6		
11.7	164	170	177	183	189	195	200	206	211	216	221	226	231	11.7		
11.8	163	169	176	182	188	194	199	205	210	215	220	225	230	11.8		
11.9	162	169	175	181	187	193	199	204	209	214	219	224	229	11.9		
12.0	161	168	174	180	186	192	198	203	208	213	218	223	228	12.0		
13.0	155	161	168	173	179	185	190	195	200	205	210	215	219	13.0		
14.0	150	156	161	167	173	178	183	188	193	198	202	207	211	14.0		
15.0	144	150	156	161	167	172	177	182	186	191	195	200	204	15.0		
16.0	140	146	151	156	161	166	171	176	180	185	189	194	198	16.0		
17.0	136	141	147	152	157	161	166	171	175	179	184	188	192	17.0		
18.0	132	137	142	147	152	157	161	166	170	174	178	182	186	18.0		
19.0	128	134	139	144	148	153	157	161	166	170	174	178	181	19.0		
20.0	125	130	135	140	144	149	153	157	161	165	169	173	177	20.0		

SECTION VII
DESIGN VALUES FOR DECISION SIGHT DISTANCE

DECISION SIGHT DISTANCE						
LENGTHS IN METERS						
DESIGN SPEED (km/h)	AVOIDANCE MANEUVER					DESIGN SPEED (km/h)
	A	B	C	D	E	
50	70	155	145	170	195	50
60	95	195	170	205	235	60
70	115	235	200	235	275	70
80	140	280	230	270	315	80
90	170	325	270	315	360	90
100	200	370	315	355	400	100
110	235	420	330	380	430	110
120	265	470	360	415	470	120
130	305	525	390	450	510	130

* Avoidance Maneuvers:

- A = Stop on rural road.
- B = Stop on urban road.
- C = Speed/path/direction change on rural road.
- D = Speed/path/direction change on suburban road.
- E = Speed/path/direction change on urban road.

INTERSECTION SIGHT DISTANCE CHARTS



APPENDIX 5C

June 25, 2004

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**APPENDIX 5C
INTERSECTION SIGHT DISTANCE CHARTS**

5C-1

Table A Length of Sight Triangle Leg - Case A - No Traffic Control

Design speed (km/h)	Length of leg (m)
20	20
30	25
40	35
50	45
60	55
70	65
80	75
90	90
100	105
110	120
120	135
130	150

Note: For approach grades greater than 3%, multiply the sight distance values in this table by the appropriate adjustment factor in Table G.

Table G Adjustment Factors for Sight Distance Based on Approach Grade

Approach grade (%)	Design speed (km/h)											
	20	30	40	50	60	70	80	90	100	110	120	130
-6	1.1	1.1	1.1	1.1	1.1	1.1	1.2	1.2	1.2	1.2	1.2	1.2
-5	1.0	1.0	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.2	1.2	1.2
-4	1.0	1.0	1.0	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
-3 to +3	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
+4	1.0	1.0	1.0	1.0	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
+5	1.0	1.0	1.0	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
+6	1.0	1.0	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9

Note: Based on ratio of stopping sight distance on specified approach grade to stopping sight distance on level terrain.

APPENDIX 5C
INTERSECTION SIGHT DISTANCE CHARTS

Table B1 Design Intersection Sight Distance (in meters) - Case B1 - Left Turn From Stop

Design speed (km/h)	Passenger Car Lanes Crossed			Single-Unit Truck Lanes Crossed			Combination Truck Lanes Crossed		
	1	2	3	1	2	3	1	2	3
20	45	45	50	55	60	65	65	70	75
30	65	70	75	80	90	95	100	105	110
40	85	90	100	110	115	125	130	140	145
50	105	115	120	135	145	155	160	170	180
60	130	135	145	160	175	185	195	205	220
70	150	160	170	185	200	215	225	240	255
80	170	180	190	215	230	245	260	275	290
90	190	205	215	240	260	275	290	310	325
100	210	225	240	265	285	305	320	340	360
110	230	250	265	295	315	335	355	375	395
120	255	270	285	320	345	365	385	410	435
130	275	290	310	345	370	395	420	445	470

Table B23 Design Intersection Sight Distance (in meters) - Case B2 - Right Turn From Stop and -Case B3 - Crossing Maneuver

Design speed (km/h)	Passenger Car Lanes Crossed			Single-Unit Truck Lanes Crossed			Combination Truck Lanes Crossed		
	1	2	3	1	2	3	1	2	3
20	40	40	45	50	55	60	60	65	75
30	55	60	65	75	80	85	90	95	110
40	75	80	85	95	105	115	120	125	145
50	95	100	105	120	130	140	150	160	180
60	110	120	130	145	155	170	180	190	220
70	130	140	150	170	180	195	205	220	255
80	145	160	170	190	205	225	235	250	290
90	165	180	190	215	235	250	265	285	325
100	185	195	210	240	260	280	295	315	360
110	200	215	230	260	285	305	325	345	395
120	220	235	255	285	310	335	355	375	435
130	235	255	275	310	335	360	380	405	470

**APPENDIX 5C
INTERSECTION SIGHT DISTANCE CHARTS**

**Table C1 Length of Sight Triangle Leg Along Minor Road-Case C1-Crossing Maneuver at Yield
Controlled Intersections**

Major road design speed (km/h)	Passenger car Minor-road design speed (km/h)						
	20	30-80	90	100	110	120	130
	Design Values (m)						
20	40	40	40	40	45	45	45
30	60	55	60	60	65	65	70
40	80	75	80	80	85	90	90
50	100	95	95	100	105	110	115
60	120	110	115	120	125	130	135
70	140	130	135	140	145	150	160
80	160	145	155	160	165	175	180
90	180	165	175	180	190	195	205
100	200	185	190	200	210	215	225
110	220	200	210	220	230	240	245
120	240	220	230	240	250	260	270
130	260	235	250	260	270	280	290

Major road design speed (km/h)	Single unit truck Minor-road design speed (km/h)						
	20	30-80	90	100	110	120	130
	Design Values (m)						
20	50	40	40	45	45	45	50
30	70	55	60	65	65	70	70
40	95	75	80	85	85	90	95
50	115	95	100	105	110	110	115
60	140	110	120	125	130	135	140
70	160	130	140	145	150	155	160
80	185	150	160	165	170	175	185
90	205	165	175	185	190	200	205
100	230	185	195	205	215	220	230
110	250	205	215	225	235	240	250
120	275	220	235	245	255	265	275
130	295	240	255	265	275	285	295

Major road design speed (km/h)	Combination truck Minor-road design speed (km/h)						
	20	30-80	90	100	110	120	130
	Design Values (m)						
20	70	50	45	45	50	50	50
30	105	70	70	70	70	75	75
40	135	95	90	90	95	95	100
50	170	115	110	115	120	120	125
60	205	140	135	135	140	145	150
70	235	160	155	160	165	165	175
80	270	185	180	180	185	190	195
90	305	205	200	205	210	215	220
100	340	230	220	225	235	240	245
110	370	250	245	250	255	260	270
120	405	275	265	270	280	285	295
130	440	300	285	295	305	310	320

Note: For minor-road approach grades that exceed 3%, multiply the design value by the appropriate adjustment factor from Table

**APPENDIX 5C
INTERSECTION SIGHT DISTANCE CHARTS**

**Table C2 Design Intersection Sight Distance (in meters) - Case C2 - Left or Right Turn at Yield
Controlled Intersections**

Design speed (km/h)	Passenger Car Lanes Crossed			Single-Unit Truck Lanes Crossed			Combination Truck Lanes Crossed		
	1	2	3	1	2	3	1	2	3
20	45	50	55	60	60	65	70	75	75
30	70	75	80	85	90	100	105	110	115
40	90	95	105	115	120	130	135	145	150
50	115	120	130	140	150	160	170	180	190
60	135	145	155	170	180	195	205	215	225
70	160	170	180	195	210	225	235	250	265
80	180	190	205	225	240	255	265	285	300
90	205	215	230	255	270	290	305	320	340
100	225	240	255	280	300	320	335	355	375
110	245	260	280	310	330	350	370	390	410
120	270	285	305	335	360	385	405	425	450
130	290	310	330	365	390	420	435	460	485

**Table F Design Intersection Sight Distance (in meters) - Case F - Left Turns From the Major
Road**

Design speed (km/h)	Passenger Car Lanes Crossed			Single-Unit Truck Lanes Crossed			Combination Truck Lanes Crossed		
	1	2	3	1	2	3	1	2	3
20	35	35	40	40	45	45	45	50	50
30	50	55	55	55	65	70	65	70	75
40	65	70	75	75	85	90	85	95	100
50	80	85	95	95	105	110	105	115	125
60	95	105	110	110	125	135	130	140	150
70	110	120	130	130	145	155	150	160	175
80	125	135	145	145	165	180	170	185	200
90	140	155	165	165	185	200	190	210	225
100	155	170	185	185	205	220	210	230	250
110	170	185	200	200	225	245	230	255	275
120	185	205	220	220	245	265	255	275	300
130	200	220	235	235	265	290	275	300	325