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E 200 DESIGN CONTROLS AND CRITERIA

In making a study for a new highway or the improvement of traffic conditions in existing streets, traffic data must be made available and included in the design considerations. Pertinent traffic data for this purpose are available from either the Department of Traffic of the City of Los Angeles or the Division of Highways of the State of California. These data will indicate the level of service which the improvement is expected to provide, and such provisions as geometric features: width, alignment, grades, etc.

E 210 TRAFFIC DATA

Generally, the street designer requires traffic data which should include present volumes for the days of the year and times of the day. Also, there should be traffic trends stated from which an estimate may be made of future volumes. These data help the designer plan the type of highway.

The distribution of vehicles by types and by weights determines the traffic load, which is expressed as the traffic index (T.I.). This determines the required structural section, lane widths, turning radii, etc., for the highway. The flow pattern and diagrams aid in determining the geometrics of intersections, median strips, channelization, access control, traffic controls, etc. The analysis of accident data and volume is used in establishing economic justifications for budgeting purposes and priority of project construction for the correction of hazardous traffic conditions. These calculations are generally done by the Coordinating Division of the Bureau of Engineering.

E 211 VOLUME

The specific types of traffic volume counts that are generally used by the street designer are as follows.

E 211.1 Annual (Total): Continuous traffic counts (or periodic adjusted counts) are taken of the total volume within a street without regard to direction of flow for a period of one year. This annual count in terms of vehicles per year is used in preparing traffic flow maps, determining future trends, and computing accident rates (per million miles).

E 211.2 Average Daily Traffic: Average Daily Traffic (ADT) in vehicles per day represents the total traffic for the year (Subsection E 211.1) divided by 365 days, or the average volume per day. This count is used in the developing of the arterial street system, the programming of capital improvements, and the design of the structural elements. Its direct use in the geometric design of highways is not appropriate because it does not indicate the significant variation in the traffic occurring during the various months of the year, days of the week, and hours of the day.

Since traffic volumes may either greatly exceed or fall far below the ADT for a considerable number of years or days of the year, the capacity of a highway designed solely on the basis of the ADT count would be incapable of handling efficiently the greater volumes for those periods of very high volumes.

E 211.3 Hourly Traffic: The traffic pattern for most City streets shows considerable variation in traffic volume during different hours of the day (such as rush hour) and even a greater volume variation throughout the year. The most satisfactory measurement of these fluctuations in traffic volume for design purposes is a time period of one hour. However, the design should not be predicated on the maximum peak hour of the year because the traffic would rarely reach sufficient volume to make full use of the resulting facility. Yet, using the average hourly traffic as the design volume (which would be determined by averaging the maximum volume during peak hours with the minimum, say, after midnight) would produce a design totally inadequate to handle peak loads.

Various studies have been made to determine the range of the peak hourly volumes and the relationship of these peak hours to the ADT in terms of number of vehicles and percentages. For purposes of this Part of the Manual, all of the factors considered leading to the following conclusion need not be included in this manual. For a more comprehensive treatment, reference is made to
various previously mentioned sources shown in Section E 020(F).

The conclusion reached by most authorities is that the 30th highest hourly volume for the year is the optimum choice from the standpoint of both economy and vehicular accommodation. This means that the peak hourly volume of traffic can be accommodated at all times except when it exceeds the 30th highest hourly volume. The design hourly volume (DHV) should be the 30 HV of the future year chosen for design. Where streets have a high seasonal traffic fluctuation or where the traffic flow is radically different, the use of the 10th, 20th, 50th, or some other value may be more accurate.

The ratio of the DHV to the ADT (future) is normally 10 to 12 percent for major streets and 12 to 14 percent for freeways. The maximum hourly volume in urban areas averages 1.2 to 1.4 times the 30th highest hourly volume.

DHV (in vehicles per hour) finds its greatest application in:

1. Determining the length and magnitude of peak periods.
2. Evaluating capacity deficiencies.
3. Establishing traffic controls, since volume is one of the warrants for the:
   a. Installation of signs, signals, and markings.
   b. Designation of through streets, one-way streets, unbalanced flow, and traffic routing.
   c. Prohibition of parking, stopping, and turning.
4. Geometric design or redesign of streets and intersections.

**E 211.4 Directional Movements**: The foregoing discussion relating to the ratio of the ADT to the 30th DH takes into account only the total traffic movement in both directions. On all multilane facilities, however, consideration of the directional traffic loads may be of greater importance.

For example, a tabulation of traffic by direction of movement shows that in downtown areas during peak hours, an average of 55 percent of the traffic was moving in the heavier direction, in intermediate areas 61.6 percent, and in outlying areas 65.6 percent.

As an illustration of the effect of the above, a four-lane highway in a rural area has a lane capacity of 1500 vehicles per hour and a nominal total capacity of 6000 vehicles per hour. During the rush hour the directional traffic (using the above value of 65.6 percent) will total 4500+ vehicles per hour. The highway capacity is therefore inadequate for carrying the peak load.

For this reason, in contemplating the design of a highway and in determining its capacity, the DHV for one direction should be computed by multiplying the total two-way ADT by the percentage that the 30 HV is of the two-way ADT and by the percentage of traffic in the predominant direction during the design hour. Thus, if the two-way design hourly volume is 15 percent of the two-way ADT and the directional distribution is 60-40 percent, the one-way DHV is 0.15 x 0.60 x ADT, or 9 percent of the two-way ADT.

**E 211.5 Composition of Traffic**: Vehicles of different sizes and weights have different operating characteristics which must be considered in determining highway capacity. The larger the proportion of trucks in a traffic stream, the greater

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### EFFECT OF COMMERCIAL VEHICLES ON PRACTICAL CAPACITIES OF MULTILANE FACILITIES

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<td>10</td>
<td>91</td>
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Figure E 211.5
the effective traffic load, and the more highway capacity is needed. For example, Figure E 211.5 shows that with a percentage of 20 percent of trucks in a traffic stream, the capacity of the highway is only 63 percent of that highway carrying only passenger vehicles. Although this chart indicates only the effect of truck traffic and terrain on capacity, there are numerous other factors that will further reduce capacity, such as bus stops, slower turning movements at intersections, etc. These last-mentioned factors are discussed under Section E 550, Intersections at Grade.

Truck traffic is expressed as the percentage of total traffic during the design-hour, total two-way traffic in the case of a 2-lane highway, and total traffic in the predominant direction of travel in the case of multilane highways.

Since peak truck traffic does not usually coincide with peak passenger flow, observations must be made of truck traffic percentage which is considered representative of the 30th highest or design hour.

E 211.6 Projection of Traffic: New highways or improvement of existing highways should be based not on current traffic volume alone, but on the future traffic expected to use the facility. Estimating of future traffic for a particular facility is generally based on a 20-year period. There is little justification for going beyond this point because of probable changes in the general regional economy, population trends, and land development abutting and in the vicinity of the highway.

Traffic can be estimated with reasonable accuracy where there are sufficient current and past traffic data available and where contemplated or likely development within the near future, that is apt to affect traffic flow, is known. Components used to determine future traffic are as follows:

   a. Existing traffic.
   b. Attracted (or diverted) traffic.

2. Traffic Increase.
   a. Normal traffic growth.
   b. Generated traffic.
   c. Development traffic.

Expanding current traffic volumes to future volumes is done on the basis of daily volumes. Design volumes, which are usually hourly volumes, are obtained by applying appropriate factors, as will be shown in the succeeding discussion.

E 211.61 Current Traffic, Existing and Attracted: Current traffic is the volume of traffic that would use a new or improved facility if it were open to traffic. In the improvement of an existing facility, the current traffic is made up of the existing traffic using the highway (prior to improvement) plus the existing traffic attracted to it from other facilities upon completion. In the case of a new highway, the current traffic is made up entirely of attracted traffic.

Depending on the type and location of the highway, current traffic may be established from:

1. Traffic counts on existing facilities that are apt to influence the flow of traffic on the improvement (the traffic counts are the existing ADT on the highway plus the ADT attracted to it from other facilities).

2. Roadside interview origin-and-destination studies.

3. Comprehensive (home interview) origin-and-destination studies in suburban or urban areas.

4. A combination of these counts or studies.

E 211.62 Traffic Increase: After the current traffic volume on an improvement is established, it is then necessary to determine the probable traffic in some future year selected for design. The current traffic, which represents only the existing trips that would be made over the improvement when opened to traffic, will be increased by normal growth, generated traffic, and development traffic.

E 211.621 Normal Traffic Growth: Normal traffic growth is the increase in traffic volume due to general increase in number and usage of motor vehicles.

By the exercise of good judgment and in consideration of the increase in population and in motor vehicle registration and travel, a curve of the past trend of motor vehicle increase per year can be projected. This projection will show the estimate and trend for future vehicle increase and use at the region, state, or locality in which a particular highway is situated.
As an example, assume that from the values picked off the projection, the current year shows an increase of 7.5 percent and 11.2 percent for the future 20 years hence. The current ADT volume is 6000 vehicles. The future volume 20 years hence, including normal traffic growth, can be determined by the following calculation:

$$\frac{11.2\%-7.5\%}{7.5\%} = 49\%$$

and 6000 vehicles $\times$ 1.49\% = 8940 vehicles (20 years hence). Values for generated and development traffic must be determined separately and added to this value.

**E 211.622 Generated Traffic:** Generated traffic consists of motor vehicle trips (other than by public transit) that would not have been made if the new facility had not been provided. Generated traffic is made up of three categories:

1. New trips not previously made by any mode of travel.
2. Trips that previously were made by public transit.
3. Trips that previously were made to a different destination, but for which the change is attributable to the attractiveness of the improved highway and not to change in land use.

Regardless of the reason for generated traffic, the net result is traffic increase on a given improvement. Most of this traffic develops within the first year or two after a new facility is opened.

In areas where data are not available, generated traffic will have to be based almost entirely on judgment, with experience in other localities serving as a guide. Logical estimates may include generated traffic as being generally 5 and 25 percent of the current traffic.

**E 211.623 Development Traffic:** Traffic due to improvements on adjacent land over and above the development which would have taken place had not the new or improved highway been constructed is called “development traffic.” This component of future traffic, unlike that of generated traffic, continues to develop for many years after a new facility is constructed. Increased traffic due to normal development of adjacent land is included in normal growth, but experience with many improved highways indicates that adjacent land is developed more rapidly than land elsewhere. The additional traffic resulting therefrom should be accounted for in estimating future traffic volume.

For example, it is more likely that vacant land will be built upon than that additional improvements will be made on land already occupied with buildings. Land near railroads and watercourses is likely to encourage industrial development, and high ground is likely to be improved with homes. Past trends and the opinions of local businessmen are valuable guides in predicting future development.

In general, however, the method of obtaining development traffic appears crude and the volumes obtained are only approximate, but in many cases the volume from this cause is appreciable. The omission of this item in estimating future traffic may explain why the volumes for a number of prominent improvements in the past proved to be underestimated.

**E 211.624 Traffic Projection Factor:** The ratio of future traffic to current traffic is called the “traffic projection factor.” The traffic increases that this factor reflects combine those due to normal traffic growth, generated traffic, and development traffic, previously discussed. The future year (for design) should be specified with every traffic projection factor. The traffic projection factor is then obtained by adding the percentages of increase for each item of traffic growth in relation to current traffic, dividing the sum by 100, and adding 1 to the result.

For example, the current traffic count (present-year) on an existing street in which further improvement is contemplated has an ADT of 24,000 vehicles. The design year is 20 years hence. Based on the previous discussion, the estimated normal traffic growth 20 years hence is 68% of the present-year traffic. Generated traffic is assumed to be 18% of the current traffic. Development traffic is estimated to be 8200 trips per day on this street section 20 years hence, or an increase of 8200/24,000 = 34% of the current volume. Thus, the total traffic increase is $68 + 18 + 34 = 120$ percent. The traffic projection factor 20 years hence is 2.20, and future ADT = 24,000 $\times$ 2.20 = 52,800 vehicles.
E 211.625 Design Traffic Data: The design hour volume represents the "load" which the highway must accommodate and determines, to a large degree, the type of facility, pavement widths, and other geometric features. The usual procedure employed in arriving at the DHV where the essential design traffic data are available may be demonstrated as follows: It was found in the example given in Subsection E 211.624 that an ADT of 52,800 vehicles will use the improvement in the design year 20 years hence. Local studies indicate that the DHV is 13% of ADT, or $K = 13\%$, the two-way directional flow ($D$) = 61%, and the truck traffic ($T$) is equal to 7% of the one-way DHV. Using these data, the DHV 20 years hence = 52,800 $\times 0.13 \times 0.61 = 4200$ vehicles in one direction of travel, of which 7% are trucks, or approximately 3900 passenger cars and 300 trucks.
E 220 DESIGN VEHICLE PHYSICAL CHARACTERISTICS AND MINIMUM CLEARANCES

The State of California establishes the required clearances between motor vehicles and highway structures and other highway appurtenances as well as some of the physical characteristics of the motor vehicles permitted to use state highways. The Public Utilities Commission sets the clearances required between railroad facilities and motor vehicle structures. The discussion that follows is a summary of the regulations as extracted from AASHO’s *A Policy on Geometric Design of Rural Highways*, the State’s Planning and Design Manuals, the Motor Vehicle Code, and the Public Utility Commission Pamphlet. See Section E 020 F (1a), (5a), (5b), (5c), and (10).

For all projects financed by the State or jointly financed by the City and the State, the City must follow the State’s standards. All other projects done solely under the City’s jurisdiction and financing should follow the State’s standards but may use the City’s standards for clearances. See Subsection E 222.11.

These clearances, the regulations governing the physical characteristics of vehicles, and the relative percentage of the various sized vehicles using the highways must be considered in the design of vehicle storage capacity, structures, pavements (types and thickness), and other highway design elements and facilities.

Relative to the above factors to be used in designing the various highway elements, the determination of the types and/or maximum size motor vehicles permitted to use a particular street is generally based on the street classification and local ordinances. Unless specifically posted or where ordinances prohibit their use, major and secondary highways should be designed to carry the maximum legal size motor vehicles. See Section E 221. Residentially-zoned streets and cul-de-sacs are normally designed to be used only by single unit trucks and busses and by passenger vehicles.

E 221 DESIGN VEHICLE PHYSICAL CHARACTERISTICS

For geometric and structural highway design purposes, the design vehicle characteristics considered are size, weight, power (acceleration) and deceleration (stopping distance). See Figure E 221.

E 221.1 Size: The size determines the radius of curves, lane widths, parking or storage dimensions for turning movements, and horizontal and vertical clearances.

E 221.11 Length: The length of vehicle directly affects the minimum turning radius and the parking or storage dimensions. Its length of wheelbase and overhang indirectly affects the vertical clearance between the pavement and the vehicle; e.g., in steep driveways. It indirectly affects the lane widths to the extent that additional lane widths may be necessary in order to accommodate the turning of the longest vehicles. The maximum length vehicle permitted in California is a semi-trailer with a maximum length of 40 feet together with a truck combination, making a total length of 65 feet.

E 221.12 Width: The width of the vehicle directly affects the lane width and parking dimensions and indirectly affects the radius of curvature. Also, to maintain at least the same horizontal clearance, wider vehicles require wider lanes which in turn require wider structures and/or rights of way. The maximum width of vehicle is 8 feet.

E 221.13 Height: The height of the vehicle directly affects the vertical clearance between vehicles and structures, the sight distance, and the driveway clearance. The maximum height of vehicle permitted in the State of California is 13.5 feet.

Vehicles are designed so that no portion of the undercarriage is lower than the lowest portion of the rim of the wheel. The tire size determines the lowest point of the rim. Passenger cars usually have a minimum clearance of at least 6 inches, although it may be less when the car is fully loaded.

The level of the average driver’s eyes above the pavement surface for passenger vehicles is 3.75 feet.

E 221.2 Weight: The weight determines the design of the structural pavement cross-section and the appurtenant highway structures. State regulations permit a maximum wheel load of 9500 pounds on any one wheel supporting one end of an axle and a maximum load of 18,000 pounds per axle.
E 221.3 Acceleration and Power: The vehicle's ability to accelerate is basically dependent on the power. The acceleration and power enable the vehicle to maintain speed on uphill grades, make it necessary to provide uphill as well as level passing lanes, and are major factors in determining the maximum allowable grades.

Modern cars have the ability to accelerate at a greater rate than as indicated on Figure E 221.3, below. This maximum acceleration is usually used for ascending steep grades or for overtaking other vehicles. But for normal acceleration, the curves on the figure show, for example, that a vehicle whose initial speed is 30 mph will require 400 feet to attain a speed of 40 mph.

In terms of maximum rates of acceleration, passenger cars vary from 4 to 6 mph/sec. and trucks from 1.5 to 2 mph/sec.
**E 221.4 Deceleration:** The rate of deceleration determines the safe stopping distance and safe sight distance. Trucks generally require longer distances to come to a stop under emergency conditions than passenger cars. Based on the U.S. Bureau of Public Roads tests conducted in 1955 on various types of vehicles, the distances required for brake system application and braking are as shown in Figure E 211.4A, on preceding page. See Subsection E 041.6 (3b1).

From the figure below, it can be seen that all vehicles traveling at an initial speed of 20 mph and decelerating to a stop will require a distance ranging from 23 feet for a passenger car to 67 feet for a truck-tractor and will lie in the 85 percentile group. Those vehicles falling outside of this group require either more or less distance due to more extreme conditions of the braking systems, reaction times, and other miscellaneous causes. Figure E 221.4B, below, indicates the distance traveled by a passenger vehicle while decelerating. For example, a vehicle decelerating at a *comfortable rate* would travel about 125± feet from 50 mph to 40 mph, and at a *leisurely rate* about 230± feet from 50 mph to 40 mph.

**DISTANCE TRAVELED WHILE BRAKING**

![Diagram of distance traveled while braking](image)

**E 221.5 Minimum Turning Radii:** Based on the discussion previously presented, the designer determines the largest size vehicle expected to use a particular street. This vehicle should then be able to negotiate a turn without striking or mounting the curbs or encroaching on the lane lines that delineate the median opening or channelized intersections.

The simplest method of determining the minimum turning radii to be used on these streets is the use of the turning vehicle templates. A pair of clear plastic templates is included in the pocket of the cover of this manual. These templates, which are drawn to a scale of 1' = 20' and 1' = 40', outline the minimum turning radius path required for the largest legal-sized tractor-trailer truck combination.

The template is placed on the drawing to see if any part of the wheel path or overhang path encroaches on the proposed curb or paint lane lines that demarcate the median opening or traffic islands. The adjustment of the location of the channelized openings and required lane widths can then be readily effected by this method.

**E 222 CLEARANCES**

Clearance is that distance by which a vehicle clears an object (such as other cars, hillsides, structures, walls, abutments, curbs or pavements, etc.) or the clear space between them.

On projects involving structures and requiring structural design, the Bridge and Structural Design Division of the Bureau of Engineering concerns itself with the use of the State's standards on clearances. The street designer is usually concerned only when realignment, widening, resurfacing, and/or grade changes are contemplated under or over existing structures.

Other areas in which the street designer is concerned are determination of clearances for sight distance, steep driveways, and turning radii in channelization or intersection projects. See Subsection E 221.5.

Some of the methods used for checking clearances are included in this manual, such as design charts, tables, and formulas. Where they do not apply, it usually is necessary to resort to field measurements or to scaling of dimensions on plans, or the use of templates.

Two plastic vehicular templates are available in the pocket cover of this manual. These templates are used for determining the vertical clearance.
between the undercarriage of the vehicle and the critical pavement sections on steep streets and driveways. One template represents the composite shortest passenger vehicle; the other represents the composite longest passenger vehicle.

Both templates should be used in checking vertical clearances. For additional instructions on their use, see Subsection E 635.4, Design Check of Vehicular Vertical Clearance. For psychological as well as visual reasons, greater horizontal clearances are required between the vehicle and the obstruction on:

1. The vehicle’s right side than on the left side.
2. Underpasses than on overpasses.
3. Short-length than on long-length structures.

In addition, because of higher allowable speeds and larger volumes of truck traffic, greater horizontal clearances are required on major highways than on local streets.

**E 222.1 State of California Standards:** The following is taken from the State’s Planning Manual, Part 7 — Design, Structure Clearances (7-309). See Section E 020F(5b). Only the numbers referring to paragraphs in the State’s Manual have been changed to correspond to this Part of the Manual.

**E 222.11 Through Roadbeds:** These clearances are for through highways other than interchanges, grade separations, and miscellaneous structures.

**E 222.111 Structure Clearances — State:** The clearances given below constitute minimum standards.

1. Horizontal Clearances: In determining the horizontal clearance to bridge piers, abutments, sign structures, and light standards, measurements should be from the edge of the traveled way unless otherwise stated. Additional horizontal clearance should be provided where necessary to meet sight distance requirements.
   a. Two-lane State Highways: 10 feet on each side.
   b. Through Roadbed on Divided Highways and Freeway to Freeway Connections: The clearance to the left of traffic should be 6 feet on 4-lane and 6-lane designs and 9 feet on separated roadways and on facilities with more than 6 lanes. On the right side, the clearance should be 11 feet.
   c. Single-lane Ramps: The clearances should be 4½ feet to the left and 9 feet to the right of traffic. If curbs are to be used, the clearance on the left is measured from the curb line; if there are no curbs, it is measured from the edge of the traveled way. On the right it is measured from the edge of the traveled way regardless of curbs.
   d. Two-lane Ramps, Speed-change Lanes, and Collector Roads: The clearances should be 4½ feet to the left and 9 feet to the right of traffic when there is a full shoulder.
   e. Other Roads and Frontage Roads: On all other roads, including frontage roads, the clearances to the face of bridge piers, abutments, retaining walls, and other obstructions should be as follows:
      1. Two-way traffic: 6 feet on each side.
      2. One-way traffic: 4½ feet on the left and 6 feet on the right in the direction of traffic.

Where provision is to be made for sidewalks, the pier, abutment, or wall should be placed at the edge of the sidewalk nearest the property line.

f. Clearances to Retaining Walls: The clearance to the left of traffic should equal the shoulder width. On the right side, it should be 11 feet for the through roadbed and 8 feet for speed-change lanes, ramps, and collector roads. In the case of extensive walls, 10 feet may be used on the right with special approval.

2. Vertical Clearances:
   a. Major Structures: The standard clearance should be 15 feet over the traveled way and 14 feet above the shoulders. The 14-foot clearance may be reduced over the top of curb or sidewalk area if the traveled way clearance requirements are also satisfied. A clearance of 16½ feet is required on certain routes.
   b. Minor Structures: The vertical clearance for pedestrian overcrossings and other structures of a similar nature should be 17 feet over the traveled way and 16 feet above the shoulders. If a pedestrian structure is protected by a major structure, a clearance greater than that of the major structure need not be provided. The clearance for overhead sign structures should be 18 feet. These clearances should be measured in the same manner.
as for major structures. When a vertical clearance of 16½ feet is provided over major structures, the requirements of Subsection E 222.112 (2) should apply.

E 222.112 Structure Clearances — Interstate:
Except for the vertical clearances established below, the policy on structure clearances set forth under Subsection E 222.111 should apply to highways which are part of the National System of Interstate and Defense Highways.

1. Major Structures: The vertical clearance should be 16½ feet over the entire width of traveled way and shoulders of the through facility, speed-change lanes, ramps, and collector roads on all parts of the Interstate System classified as rural and on selected portions classified as urban.

2. Minor Structures: The vertical clearance for pedestrian overcrossings should be 18½ feet on portions of the highway system where the major structure clearance is 16½ feet. If such an overcrossing is protected by a major structure, a clearance greater than that of the major structure need not be provided.

The foregoing clearances should be measured in the same manner as for major structures. Where the 16½-foot clearance is not provided for major structures, the clearances should conform to Subsection E 222.111 (2b). Sign structures should have a clearance of 18 feet.


E 222.113 Tunnel Clearances: In one-way highway tunnels, the minimum side clearance from the edge of the traveled way should be 4½ feet on the left and 6 feet on the right. For two-way tunnels, this clearance shall be 6 feet on each side.

The minimum vertical clearance should be 15 feet measured at any point over the traveled way and 14 feet above the gutter at the curb line.

E 222.114 Lateral Clearances for Elevated Structures: The minimum horizontal clearance between elevated highway structures, such as freeway viaducts and ramps, and adjoining buildings or other structures should be 15 feet for single-deck structures and 20 feet for double-deck structures. Spot encroachments on this clearance are permissible only with the advance approval of the State Division of Highways.

E 222.115 Structures Across or Adjacent to Railroads: Regulations governing clearances on railroads and street railroads with reference to side and overhead structures, parallel tracks, crossings of public roads, highways, and streets are established by the State Public Utilities Commission.

1. Normal Horizontal and Vertical Clearances: Although General Order No. 26-D specifies a minimum vertical clearance of 22½ feet above tracks on which freight cars not exceeding a height of 15½ feet are transported, a minimum of 23 feet is to be used in design to allow for reballoasting and normal maintenance of track. See Subsection E 041.6 (10).

At underpasses, General Order No. 26-D establishes a minimum vertical clearance of 14 feet above any public road, highway, or street. However, the clearances specified under Subsection E 222.111 (2) should be used.

All curbs, including median curbs, should be designed with 10 feet of clearance from the track centerline measured normal thereto.

The principal clearances which affect the design of highway structures and curbs are summarized in Figures E 222.115A and B, below. It should be noted that collision walls may be required for the clearances given in Columns (3) and (4) of Figure E 222.115B, below. Usually, no collision walls are required if the clearance is 10 feet or more on tangent track and 11 feet or more on curved track.

2. Off-Track Maintenance Clearance: The 18-foot horizontal clearance is intended for sections of railroad where the railroad company is using or definitely plans to use off-track maintenance equipment. This clearance is provided on one side of the railroad right of way.

On federal-aid projects, where site conditions are such that off-track maintenance clearance at an overpass is obtained at additional cost, federal-aid funds may be used for the costs of such overhead designs that provide up to 18 feet horizontal clearance on one side of the track. In such cases, the railroad is required to present a statement that off-track maintenance equipment is being used, or is definitely planned to be used along that section of the railroad right of way crossed by the overhead structure.
3. Overheight Freight Car Clearance: On certain railroad lines described below, the Public Utilities Commission requires increased vertical clearance to allow for the operation of overheight freight cars (more than 15½ feet high). The minimum clearance prescribed for these lines is shown in Figure E 222.115A, below. It should be noted that these certain railroad lines are subject to additions or deletions by the Public Utilities Commission from time to time.

4. Approval: All plans involving clearance from a railroad track should be submitted to the railroad for approval as to railroad interests. Such clearances are also subject to approval by the Public Utilities Commission.

To avoid delays, early consideration must be given to railroad problems when design is started on a project.

### MINIMUM VERTICAL CLEARANCES ABOVE HIGHEST RAIL

<table>
<thead>
<tr>
<th>Type of Structure</th>
<th>Normal Freight</th>
<th>Overheight Freight</th>
<th>No Freight Cars Operated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Highway overhead and other structures including through railroad bridges</td>
<td>23'-0&quot;</td>
<td>24'-2&quot;</td>
<td>19'-0&quot;</td>
</tr>
</tbody>
</table>

Figure E 222.115A

### MINIMUM HORIZONTAL CLEARANCES TO CENTERLINE OF NEAREST TRACK

<table>
<thead>
<tr>
<th>(1) Type of Structure</th>
<th>(2) Off-Track Maintenance Clearance</th>
<th>(3) Tangent-Track Clearances</th>
<th>(4) *Normal Curved-Track Clearances</th>
<th>Curved Track Clearances when Space is Limited</th>
<th>(5) Curves from 0 Degrees to 12 Degrees</th>
<th>(6) Curves of 12 Degrees or more</th>
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</thead>
<tbody>
<tr>
<td>Through Railroad Bridge</td>
<td>None</td>
<td><strong>8'-0&quot;</strong></td>
<td><strong>9'-0&quot;</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Highway Overhead and Other Structures</td>
<td>18'-0&quot; Clear to Face of Pier or Abutment on Side Required by RR for Equipment Road</td>
<td>8'-6&quot;</td>
<td>9'-6&quot;</td>
<td><strong>8'-6&quot; Minimum</strong></td>
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<td></td>
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<tr>
<td>Curbs</td>
<td></td>
<td>10'-0&quot;</td>
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<td></td>
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</tbody>
</table>

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*The minimum, in general, is one foot greater than for tangent track.

**Greater clearance is necessary if walkway is required.

***With approval of Public Utilities Commission.

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E 222.12 Miscellaneous Roadbeds: These clearances are for roadbeds that are a part of other than through structures, such as interchanges, grade separations, etc.
E 230 SPEED

The speed adopted by a driver depends on the physical characteristics of the highway and its roadsides; the weather; the presence of other vehicles; the speed limitations, either legal or control devices; and the attitude and judgment of the driver in evaluating these conditions. While any one of these may govern, often these conditions are combined.

The large majority of drivers (about 85%) do not constantly adjust their speed to the highway, but rather choose some approximate uniform speed that seems to be safe for a given set of existing conditions. The other 15% will drive at either a higher or lower rate than the prevailing rate adopted by this majority.

It is impractical to design the highway to accommodate this 15%, since it is economically unfeasible to design to the higher standards required for a faster driver. On the other hand, designing for the slower driver may be more economical with respect to construction, but would probably result in higher vehicular operating costs, dissatisfaction to the majority of drivers, and danger to the faster drivers when adverse traffic conditions prevail.

On rural highways, the physical characteristics of the highway largely govern the speed of the driver when traffic and weather are favorable. State maximum speed laws and economic considerations, such as providing limited access highways, grade separations, etc., limit the designer in determining some of the physical characteristics of the highway. Therefore, under ideal conditions, most rural highways are designed for a maximum speed of 65 miles per hour.

On city streets, speeds are governed by the presence of other vehicles en masse, rather than by the physical characteristics of the street. Added factors are the control of speeds by legal authority and other retarding forces such as pedestrians, side friction from constant vehicular ingress and egress, turning movements, closely-spaced intersections, and other physical and psychological conditions peculiar to urban environs.

In view of these factors, the City has adopted for City streets the tabulated form shown in Figure E 230, below.

<table>
<thead>
<tr>
<th>Class of Highway</th>
<th>Design Speed</th>
<th>Roadway Width</th>
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</thead>
<tbody>
<tr>
<td>Major</td>
<td>50 mph</td>
<td>80 feet</td>
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<tr>
<td>Secondary</td>
<td>50 &quot;</td>
<td>64 &quot;</td>
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<td>Collector</td>
<td>40 &quot;</td>
<td>40 &quot;</td>
</tr>
<tr>
<td>Local—Flat</td>
<td>30 &quot;</td>
<td>36 &quot;</td>
</tr>
<tr>
<td>Local—Hillside</td>
<td>25 &quot;</td>
<td>28 &quot;</td>
</tr>
</tbody>
</table>

Figure E 230

Based on the above design speed for a given highway classification, other design criteria and limitations, such as maximum superelevation, minimum sight distances, horizontal curvature, etc., are also discussed in this Part of the Manual.
E 240 HIGHWAY CAPACITY

Highway capacity pertains to the ability of a roadway to accommodate traffic movements. Like speed, it is affected by various factors, such as traffic conditions, geometric features, and highway type. See Section E 650, Intersections at Grade. An analysis of highway capacity must be made by the designer because of the effect of these factors on design. The design elements used are based on the capacity figures for the future demand and the design capacity values.

Highway capacity is generally classified into two categories — capacity with uninterrupted flow where continuous traffic movements can be maintained for a substantial distance, and capacity with interrupted flow, a characteristic of City streets with at-grade intersections. Although the City is primarily concerned with interrupted flow, these two types of flow will be discussed here in broad general terms. Interrupted flow, the influence of the intersection, and the specific determination of intersection flow are presented in greater detail in Section E 650, Intersections at Grade.

E 241 UNINTERRUPTED FLOW

A free-flowing freeway or certain multilane arterial highways have the highest capacity, and this capacity can be more readily and precisely determined than that of most other local or city streets. The Highway Capacity Manual, Table No. 5, Section E 020F(3b), lists the basic capacity for multiline highways at 2000 passenger cars per lane per hour; the practical capacity for urban conditions (35-40 mph) is 1500 passenger cars per lane per hour and for rural conditions (45-50 mph) is 1000 passenger cars per lane per hour. If the highway standards are below normal, the design deficiencies which tend to reduce capacity are:

1. Lane widths less than 11 feet.
2. Inadequate or marginal lateral clearances to vertical obstructions, such as retaining walls, poles, parked cars, etc.
3. Absence or inadequacy of shoulders.
4. Use by commercial vehicles.
5. Location and design of interchange facilities, such as poorly designed or inadequate acceleration or deceleration lanes.
6. The profile and alignment, where substandard design is used for providing sight distance and grades.
7. Driveway access frequency.
8. Signal spacing and timing.

E 242 INTERRUPTED FLOW

In urban areas, interrupted flow will occur due to many factors, including the following:

1. Number and geometrics of intersections.
2. Volume of cross-traffic.
3. Lane and street widths.
4. Parking conditions.
5. Percent of truck traffic.
6. Percent of turning vehicles.
8. Pedestrian movements.

Generally, uninterrupted flow capacities are used as a basis of capacity and then modified when interrupted flow conditions prevail.

E 243 EQUATING VARIOUS HIGHWAY CAPACITY TERMINOLOGY

The terms used for the different degrees of highway capacity are indicated in Section E 030, Definitions. The “Highway Capacity Manual” relates the ability of a highway to carry traffic to two levels: practical capacity and possible capacity. See Section E 020F(3a). AASHO accepted this terminology and introduced an additional term, design capacity. See Section E 020F(1b). The “Highway Capacity Manual” has since eliminated the terms practical capacity and design capacity and substituted the single word capacity for what had been referred to as possible capacity. The “Highway Capacity Manual” also introduced the level of service concept. See Section E 020F(4a). The six levels of service which are shown in Section E 654, Signalized Intersection Capacity, are a qualitative measure of operating conditions from excellent to intolerable, including capacity. AASHO’s “A Policy on Geometric Design of Rural Highways,” 1965 Edition, refers to the “Highway
Capacity Manual,” 1965 Edition, for basic values but continues the use of the terms design capacity and possible capacity. See Sections E 020F(1b) and (4a) respectively.

Although the terminology is different, the overall concepts in each publication are compatible. For example, the AASHO design capacity, Section E 020F(1b), is the same in essence as the “Highway Capacity Manual,” Section E 020F(4a), maximum service volume for a selected level of service. Also, numerically, the AASHO term possible capacity is identical to the “Highway Capacity Manual” term capacity. Therefore, the relations presented on the figures in Section E 650, Intersections at Grade, are equally applicable to the “Highway Capacity Manual,” Section E 020F(3a), the “Highway Capacity Manual,” Section E 020F(4a), and the AASHO procedure, Section E 020F(1b).
E 250 DRAINAGE CONTROLS AND CRITERIA

One of the factors that may exert a controlling influence on the street design is drainage and its disposal. Although this phase is normally handled by the Storm Drain Design Division or the Storm Drain Sections of the Districts, it is essential for the street designer to have some basic knowledge of the problems, responsibilities, liabilities, etc., of the City, the property owner, and the storm drain designer.

One of the controlling factors of immediate concern to the street designer is the City's policy of not permitting a street or alley to be improved or partially improved without providing a means for adequate drainage.

For example, it is not permitted to design a street improvement so that the water from the abutting property and the proposed improvement drains onto an unimproved street, or a partially improved street without drainage control, or other private property.

However, if it can be established that the amount of water involved is negligible and will not damage, erode, or otherwise worsen the existing drainage conditions of the existing street section or of private property, construction may be permitted. If a considerable amount of water is involved which drains onto private property, and a drainage easement or a waiver is obtained from the property owners, the proposed street improvement may be permitted.

Other controlling factors as dictated by drainage are based on studies that have to be made by the storm drain designer, such as a joint analysis of rainfall frequency and duration, the longitudinal street grade, pavement cross-slopes, curb and inlet types, and spacing of inlets or discharge points. This information is needed to determine whether or not the width of water on the pavement during selected storm frequencies is great enough to unduly interfere with traffic flow.

Since the controls and criteria involved for the above studies require extensive treatment, reference is made in this regard to Part G of the Manual, Storm Drain Design. In addition, other aspects of drainage control and criteria as related to street design are covered in various sections of this Part of the Manual, such as Chapters E 400, Cross-Section Elements, and E 500, Grade Determination, etc., and under subsections such as Gutters, Curbs, Cross-Sections, etc.
E 260 OTHER ELEMENTS AFFECTING GEOMETRIC DESIGN

There are many other factors affecting or controlling the geometric design in addition to the basic elements previously covered. Generally in rural areas, the topography controls, and in City streets, meeting existing conditions is a more important consideration. Other items that generally affect City street design are:

1. Economic and Social Conditions: Available finances; new developments; redevelopment of blighted areas; safety, comfort, and convenience; greater accessibility; etc.

2. Terminal Facilities: Off-street parking, bus and railway terminals, freight terminals, airports, etc.

3. Public Transit Facilities: The design and arrangement of transit and pedestrian facilities, accommodation of the type of transit vehicle and spacing of stops, etc.

4. Traffic Operations During Construction: Temporary connections or detours are sometimes necessary during construction to maintain uninterrupted traffic flow; some locations may dictate the particular design of a temporary bypass as well as the main project.

5. Access Control — the use of cul-de-sacs: Frontage roads, alleys, etc., can affect the design as well as the street pattern.

6. Drainage: The location of sumps and drainage facilities can modify or alter street design.

The designer has little or no control over some of these factors and more control over others. Therefore, only some of these factors, where the exercise of some degree of control is possible at the design level, will be discussed.

E 261 SAFETY FEATURES AND ACCIDENT RECORDS

Many comprehensive studies have been made of highway accidents, their causes, and the safety measures to be taken for their prevention. Some of these safety measures are under the control of the highway designer and should be considered when designing a proposed highway or correcting an existing street. Therefore, the results of one of these studies that was made and tabulated by AASHO are shown on Figure E 261. The figure shows that there is a definite correlation between the lowering of design standards and the increase in the accident rate. There is also an indication that as the volume increases to an ADT of 9000 vehicles, the accident rate decreases sharply. This reduction is attributed to the heavy congestion, which causes a severe reduction of speed, prevents passing maneuvers, and results in an unsatisfactory type of operation.

Although it may be concluded from the figure that producing heavy congestion is a method of reducing accidents, a more desirable, more efficient, and safer method is meeting the geometric design standards as covered in this Part of the Manual. In this regard, some of the factors that should be considered in highway design are submitted for the designer's consideration:

1. Volume: Provide adequate facilities in order to increase the vehicular capacity and reduce the vehicular density.

2. Pavement and Lane Widths: Provide lane widths of at least 10 feet and pavement widths of at least 20 feet.

3. Lateral Clearances: Provide adequate lateral clearances to structures and other roadside features.


5. Alignment: Provide a good alignment by not incorporating constrictions, jogs, and excessive curvature in the design of proposed streets, and by eliminating them in existing streets.

6. Type of Highway: The type of highway is sometimes classified by the number of lanes or the degree of access control. Three-lane highways appear to have the highest accident rate. The rate may be reduced by adding another lane or increasing the degree of access control.

7. Access Control: (See Section E 262.) Statistics accumulated by AASHO indicate that an excellent degree of safety is obtained with controlled access design. This is where all types of hazardous highway access, such as cross traffic, traffic along the roadsides from parking, parking lots, driveways, etc., and pedestrian traffic are materially reduced.
or eliminated. Where feasible, some of the following methods should be used:

a. Cross Traffic: Efforts should be made to either:

1. Completely eliminate cross traffic by dead-ending intersecting streets or providing a grade separation

OR

2. Minimize conflict areas by means of channelization and right angle crossings.

b. Roadside Interference: This type of interference may be reduced or eliminated by providing frontage or service roads or access to off-street parking by means of alleys or side streets.

c. Pedestrian Traffic: Providing an overhead or underpass structure is one solution. Curb islands or safety zones reduce the area and time of pedestrian exposure to vehicular traffic on wide streets.

There are other means of introducing safety factors in a highway, such as prohibiting parking; providing signalization and traffic signs; etc. These efforts, coordinated with the above-mentioned design features, should result in safer, more efficient, and more satisfactory highway operations.

E 262 ACCESS CONTROL

AASHO defines control of access as “a condition where the right of owners or occupants of abutting land, or other persons, to access in connection with a highway is fully or partially controlled by public authority.” See Section E 020F. Full control of access gives preference to through traffic by providing access connections with selected public roads only, and by prohibiting crossings at grade or direct private driveway connections. Partial control of access gives preference to through traffic to a degree that, in addition to access connections with selected public roads, there may be some crossings at grade and some private driveway connections.

E 262.1 Types of Access Control Devices: Freeways are examples of fully controlled access highways. By the very nature of city streets, provisions must be made for access to abutting property. This means that the City’s main concern is with partial or limited access control of streets.

E 262.11 Frontage Roads: When a fully controlled freeway or partially controlled highway is developed through a City, some existing intersecting streets must be cut off in order to prevent promiscuous access to these main arteries. It is uneconomical to provide grade-separated crossings or to leave a large number of dead-end streets. One method is to provide a new street or make use of an existing street that parallels the freeway or highway to connect all or some of the cut-off streets. New subdivisions abutting main highways are also required to provide a frontage road as a means of access control.

In addition to access control, a frontage road provides circulatory movements for local or subdivision traffic. It provides continued access to the abutting residential, industrial, or commercial properties remaining. It provides, for short distances, an alternate route parallel to the main highway or freeway. Its chief function, however, is to keep local traffic isolated from the main highway except at predesignated access points.

The alignment and grade determination of the frontage roads are treated in the same manner as those of most other city streets. Design problems encountered will be covered elsewhere in this Part of the Manual.

E 262.12 Cul-de-Sacs and Dead-End Streets: Cul-de-sacs and dead-end streets are local streets terminated or closed at one end. Turnaround provisions are included at the ends of cul-de-sacs, but not in dead-end streets. Cul-de-sacs are used frequently in new subdivisions, or they may result from the development of freeways or partially controlled highways at points where access is controlled without frontage roads. Where a minor street is cut off so that it neither crosses the arterial route nor enters it, a cul-de-sac or a dead-end results. Dead-ends are used where existing improvements do not permit turnaround provisions from an economical or a design standpoint.

There are several advantages in cutting off access to a street. Normally a street, no matter how unimportant, is used by some traffic not destined for or originating in that particular block. Such traffic is eliminated entirely on a dead-end street, increasing the street value for residential purposes because of decreased noise and odor and increased safety.
Where an existing street is commercial in character, there are objections to dead-ending in that the commercial establishments are not readily accessible. This can have a depressing effect on some businesses (as in the case of gas stations). Rarely are commercial streets dead-ended.

Damage sometimes results from terminating streets, and an element of extra cost may be involved. Consideration should be given to possibilities for connecting two or more adjacent streets as an alternative to dead-ending them, to avoid possible damages and improve local circulation.

Other uses of cul-de-sacs, design of alignments, grades, and other related matters will be discussed in Section E 620 of this manual.

E 262.13 Alleys. Areas zoned for industry, commerce, and multiple residences are usually subject to heavy vehicular use. Where this type of property abuts a major or a secondary highway, the heavy flow of traffic generated in this area can sometimes create a complex traffic problem. Not only is vehicular access to the property impeded, but through vehicle movement along the major and secondary highways is seriously restricted.

A solution, or at least a partial solution, sometimes lies in providing some means of access control. In this regard, in addition to its other uses, an alley, where properly located, may serve as a means of access control. The access control is generally accomplished by denying ingress to and egress from the major or secondary highway to the abutting property. The alley is located at the rear of the property and provides vehicular access to the intersecting local streets. Off-street parking, residential driveways, delivery service, and garbage trucks are handled in this manner. This type of access control eliminates points of conflict where vehicles enter into a heavily congested street other than at an intersection. It also leaves lanes that would otherwise be used for parking, loading, etc., open for through traffic.

Alley design is dealt with in Section E 610 of this manual.
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This chapter covers the application of design criteria to the determination of grade. The term “grade” as used here will apply both to the vertical relationship between the road surface and the terrain and to the longitudinal rate of grade.

The vertical alignment or grade line of a street in general is a series of straight lines and curves. The length of these lines is measured on the horizontal plane. For flat streets, using these horizontal lengths results in no practical errors. In steep grades, corrections may be necessary for calculations that require true lengths. For example, the true curb length on a 15 percent grade for a horizontal distance of 100 feet is 101.119 feet. For general criteria, vertical curve computations, and sight distances see Section E 320, Vertical Alignment, and Section E 340, Sight Distance.

The final location of the grade is affected by such factors as the street classification, terrain, topography, right of way, drainage, economics, available financing, etc. These factors are all interrelated and almost all apply in every design. Most of these factors have been discussed elsewhere in this Part of the Manual. Another controlling factor in grade location is the City’s specific policies in the application of the design criteria.

The following discussion will cover terrain and land development and their effect on the order of importance of the different design factors and the final grade determination. The type of terrain or intensity of land development may vary within a given project. It may become necessary to re-rank the order of importance of the design factors and, in so doing, change the grade either locally or throughout the entire project.

Terrain in which the average grade is 5 percent or less is considered flat.

Undeveloped Land: Land in its original condition, with no grading or man-made structures, is considered undeveloped.

1. Drainage:
   a. In nonlevel land, drainage may not be an important factor and the importance of the design controls is usually determined by other factors.
   b. In extremely flat areas the most important design consideration is drainage.

2. Where drainage is not critical, it is necessary to meet the highway design standards, as per street and highway classifications, for maximum design speed.

3. It is necessary to join the unimproved property at a grade favorable to future development.

Developed Land: Land on which grading has been done for the purpose of constructing streets and structures is considered developed.

1. As above, in nonlevel land, the drainage situation may not be a factor. However, in extremely flat areas, drainage consideration is even more important, due to the likely possibility of flood damage to improved property.

2. Highway Design Standards:
   a. In residential or suburban areas, meeting the highway design standards is most important except where drainage is critical.
   b. In the downtown central core or other highly developed districts, meeting the highway design standards and moving traffic are most important except where drainage is critical and right of way costs are prohibitive.

3. Existing Improvements:
   a. In residential or suburban areas, meeting the existing improvements is important but less critical and costly than drainage or meeting the highway design standards.
   b. In highly developed areas, meeting the existing improvements is generally more critical than in suburban areas.

Terrain in which the average grade is more than 5 percent is considered hillside or mountainous.
E 512.1 Undeveloped Land: The definition of undeveloped land given in Subsection E 511.1 applies here as well.

1. Terrain:
   a. In extremely steep or rugged terrain, the volume of earthwork as well as the maximum and minimum grade percentages are the limiting factors.
   b. In rolling terrain, the maximum and minimum percentages of grade will usually determine the grade and alignment, with lesser consideration given to earthwork.

2. Highway Design Standards:
   a. In steep terrain, for a given street or highway and design speed designation the highway design standards should be met. Usually in this type of terrain the design speed should be lowered in order to meet these standards.
   b. In rolling terrain, the normal design speed and the highway design standards control.

3. Existing Improvements:
   a. In steep terrain, meeting the property is relatively unimportant.
   b. In rolling terrain, future development of the abutting property should be considered.

4. Drainage may be an important consideration if extensive sump areas or watercourses are encountered.

E 512.2 Developed Land: The definition of developed land given in Subsection E 511.2 applies here as well.

1. Terrain:
   a. In mountainous areas, property development is much less intensified than in other types of terrain. In general, except for an occasional driveway to be met, the design controls are similar in mountainous areas for developed as well as undeveloped land.
   b. In rolling terrain, depending on the degree of development, a certain amount of earthwork has been or will be done in the development process. Therefore, in general, earthwork is not necessarily a critical factor. The ruling design factor in grade location will then be the maximum and minimum grades.

2. The street and highway design and maximum speed standards should be met.

3. The existing improvements should be joined.

4. Drainage is generally a problem only in regard to directing surface flow and in encountering an occasional sump condition or watercourse.
E 520 INTERSECTION GRADES CONTROLLED BY STREET CLASSIFICATION

Wherever possible, grades will be laid straight across intersecting streets without the use of benches. Where, due to steep grades, the use of a bench is unavoidable, the street of major importance will preferably be laid straight and the intersecting street benched. In the case of a T intersection, the through street will be on a straight grade and the grade of the side street may be flattened as necessary to meet the plane of the through street.

E 521 MAJOR HIGHWAY INTERSECTING MAJOR HIGHWAY

The grades of all legs of the intersection between two major highways should be set so that each will function as a through roadway. This requirement will usually make it necessary to construct drainage structures at these intersections to eliminate dips and cross-gutters.

E 522 MAJOR HIGHWAY INTERSECTING LOCAL STREET

The grades should favor the major highway, giving less consideration to the local street. Cross-gutters are permitted only across local streets.

E 523 LOCAL STREET INTERSECTING LOCAL STREET

More consideration should be given to grades for local collector than for noncollector streets. Cross-gutters are permitted across both local collector and noncollector streets.
E 530 DESIGN POLICY

At this point some of the specific design criteria used for the City's grade design policy are introduced. Further application of these design criteria is also presented for the specific types of projects listed in Chapter E 600, Design Criteria for Special Street Components and Projects. Other design details may be found under Section E 440, Concrete Gutters, E 660, Remodeling Improved Streets, and in other sections of this Part of the Manual.

E 531 DESIGN DETAILS

In order to present the specific design details for determining the grade for City streets, the street is divided into three separate areas: Between Intersections, Approaching Intersections, and Within Intersections.

E 531.1 Between Intersections: Because of all the complex factors involved, grades are usually developed on a trial and error basis. The curb grades should be established so as to direct drainage toward the street from the abutting property. The top of curb is then used as a reference in establishing the pavement grades. Wherever possible, the roadway should be designed with a level cross-section and a uniform crown. Normal crown should be maintained on all through streets. The curb grades should be laid in straight lines between intersections. Where straight grades are not practical, a reasonable balance should be maintained between meeting existing improvements, design standards, and construction costs.

The existing terrain or improvements may be such that the design of a street grade would entail the use of a grade less than the minimum permitted. To avoid using this flat grade, it may be desirable to create a sump. The grades approaching the sump would then be designed to exceed the minimum grade or at least equal it. A storm drain system must be available to use this method. An alternative method would be to create a high point at some strategic location and design the street grades setting the high point so that a grade results that equals or exceeds the minimum grade.

E 531.11 Rate of Grade (Longitudinal): In developing a longitudinal grade there is no particular desirable rate of grade that should be used. However, grades of 6 percent or less are preferable.

E 531.111 Maximum: The maximum desirable grade for major or secondary streets is 6 percent, with 7 percent being the absolute maximum. All other streets have a normal maximum limit of 15 percent. See Subsection E 321.1, Maximum Grades.

E 532.112 Minimum: The minimum desirable rate of grade is 0.400 percent. Where unavoidable, a rate of grade of 0.200 percent may be used. When using flat grades, concrete gutter should be used. See Subsection E 321.2, Minimum Grades.

E 531.12 Grade Breaks: The maximum grade break permitted between two adjoining chords varies with the location and circumstances.

E 531.121 Rate Differences: Connecting chords that have a grade difference of more than 1.25 percent on local streets and 0.50 percent on major and secondary highways should be replaced with vertical curves. Vertical curve calculations are shown in Section E 322, Vertical Curves.

E 531.122 Spacing: Grade breaks on vertical curves will normally be spaced at about 25-foot intervals on flat grades and about 10-foot intervals on steeper grades. The minimum spacing permitted is 5 feet. Use of the 5-foot minimum spacing may be unavoidable in some existing alleys. There is no maximum spacing. However, due to conditions that generally prevail in existing streets, the spacing between elevations will rarely exceed 100 feet.

E 531.13 Crossfall (Transverse Slopes): The crossfall in a street is the difference in elevation between the two sides of the street. Street cross-sections should be held level on major or secondary highways and should not exceed 1.50 percent on other streets. Where it is necessary to meet existing improvements on existing streets in hillside areas, a maximum crossfall of 8 percent may be permitted.

The rate of crossfall is calculated by determining the difference in elevation at each end of a transverse section. The transverse section used should be normal to the curbs on tangent street sections or radial on curved street sections. To obtain the percentage of crossfall, this difference
in elevation (usually between the outer edges of gutter) is divided by the horizontal distance between elevations and the resulting quotient is then multiplied by 100.

**E 531.2 Approaching Intersections:** Where relatively level (transverse direction) streets in hillside areas intersect streets having a steep longitudinal grade, as the proposed level street approaches the intersection, crossfall must be developed to meet the grade of the intersecting street.

**E 531.21 Crossfall:** This may be effected by providing a smooth transition of gradually increasing crossfall starting at a distance of 75 feet from the BCR. See Figure E 531.3. Approximately two-thirds of the grade of the intersecting street is set at the BCR. The maximum crossfall at this point should not exceed 10 percent. The crossfall is then permitted to increase beyond the BCR until the intersection is reached, where the remaining one-third of the grade of the intersecting street is developed.

**E 531.3 Within Intersections:** After preliminary grades are set, the theoretical curb grades are extended on smooth lines across all intersecting streets. Crown sections are reduced at the approach to the intersection where transitions are required to meet the cross-gutters or depressed flow lines. The specific details are shown on Figure E 531.3.

**E 531.31 Grade Breaks:** On major and secondary highways, the desirable maximum grade break permitted within an intersection is the same as between intersections (0.50 percent). For local street intersections, T intersections, or local streets where permanent stop signs are installed, the desirable maximum is 3.50 percent, and the absolute maximum is 6 percent. See Figures E 531.3 and E 531.31A and B. However, use of the 5-foot minimum spacing may be unavoidable in some existing street intersections. See Figure E 531.3.

**E 531.311 Around Curb Returns:** A vertical curve should be used around a curb return where practical. The maximum grade change permitted per grade break is 3 percent.

**E 531.32 Rideovers:** In order to reduce the longitudinal grade break across intersections to provide a smoother riding line, rideovers are used. See various sections on Figures E 531.3; E 441.33A, Street Plan; and E 441.33B, Work Sheet Profile and Cross-Sections (Showing Nonintersecting Cross-Gutter). It is generally used where there is no surface drainage across the intersection. However, rideovers can also be used in connection with existing or proposed cross-gutters, provided there is adequate fall across an intersection. The rideover profile on the west side of "A" Street on Figure E 531.3 represents the flow line profile of the cross-gutter. This profile indicates that although a vertical curve (rideover) has been introduced into the cross-gutter flow line, drainage can take place across the intersection.

**E 531.33 Drainage:** Surface drainage is not normally permitted across intersections on major or secondary highways. Surface drainage across intersections of local streets, although not desirable, is permitted. However, cross-gutters must be provided, using the standards for construction indicated on Figures E 431.1, Types of Curbs and Gutter, and E 441.32, Low Flow Channels for Cross-Gutters. Since catch basins are not permitted within the curb return area, the policy is to design the gutter so that any sumps that will be created are located outside the curb return area. Due to the variation of grades approaching intersections, various drainage patterns are created, as indicated by the direction of the drainage arrows shown on Figure E 531.33.

**E 532 INTERSECTION DRAINAGE**

Referring to Figure E 532, different corners show the different drainage patterns involved and described in the discussions that follow.

**E 532.1 Corner A:** This shows the drainage approaching the curb return from both directions. The grades should be arranged for drainage to go completely around the return toward either the BCR or the ECR, whichever appears to give smoother grades. In either case, the low point is located outside the curb return area. This method requires only one catch basin for drainage. If there is not enough fall around the return, the flow line is elevated at some point within the return area (usually near the MCR), creating a flow line high point within the return area. In other words, the top of curb grade is established and the curb face is reduced by elevating the flow line. The absolute minimum curb face that should be produced in
this way is 4 inches at the high point of the flow line. See Subsection E 433.4, Curb Face Heights. The drainage is then directed away from this high point toward the two sumps that have been created. The two sumps are located outside the return area, one near the BCR and the other near the ECR. The water is then handled by a storm drain installation. If no storm drain system is available within a reasonable distance from the standpoint of economy, either a cross-gutter will have to be provided or the intersection and approaches may have to be remodeled as outlined in Section E 660, Remodeling of Improved Streets.

E 532.2 Corner B: This shows the drainage approaching the BCR and being directed around the return. If the grade around the return is too flat to meet the minimum standards as previously outlined, it may be necessary to follow a design pattern similar to that shown in corner A; that is, provide a high point in the flow line in the return area and direct the water toward a sump created at or near the BCR, or remodel the intersection or the intersection approach flow line grades as outlined in Section E 660, Remodeling Improved Streets.

E 532.3 Corner C: This shows another drainage pattern with a high point usually within the curb return area. If the existing grades from the curb return area are too flat, drainage can be facilitated by elevating the flow line at some point within the curb return area.

E 532.4 Corner D: This shows drainage toward the return area from the direction of the BCR and the ECR. A cross-gutter may be provided if a local street is involved and a storm drain system is not readily available at that corner. The water must be diverted from corner D to corner E and either picked up by some drainage structure or carried farther downstream to some other point of pickup. The flow line elevations of corner D are set so that the ECR, BCR, and MCR are higher than point V, the flow line PI. Normally, a straight grade is provided between the BCR flow line and point V. A straight grade is normally set between point V and point W, the flow line PI of corner E. The elevation at point X is normally set ¾-inch higher than point Y and ¾-inch above point Z, the elevation of point Y will be actually higher than that of point X. In order to provide more water-carrying capacity at point Y, the elevation of point Y should be lowered and/or the elevation of point X raised. This can be effected by designing a short, mild vertical curve or dip instead of the straight grade between the BCR of corner D and point V, the flow line PI and, if needed, raising the elevation of point X to a maximum of ¾-inch above point Z. Since normally a straight grade would be designed between points X and U raising the elevation of point X to ¾-inch (a nonstandard hike-up of the outer edge of cross-gutter above the cross-gutter flow line), the nonstandard hike-up would then transition to a normal hike-up at point U above point P. Since it is desirable to reach a normal hike-up as soon as possible, elevations providing normal hike-up should be designated at the centerline of the street between points S and T, or preferably at the quarterline between points Q and R.

E 532.5 Corner E: Based on the indicated drainage pattern, corner E should be designed so that the elevation at the BCR is higher than the flow line PI elevation W and the ECR flow line elevation. The MCR flow line elevation should be set at a lower elevation than the elevation at point W and higher than the ECR flow line, to aid in confining the water to a narrow stream and directing it toward the curbline.

E 532.6 Corners F and G: As previously discussed, storm drain considerations may modify the drainage pattern indicated on these corners. It may be decided that due to lack of water-carrying capacity of the street, the grades should be adjusted to carry a minimum of water by way of the cross-gutter, with most of the water being directed around the returns and down the intersecting street. On the other hand, the intersecting street may have a very small capacity, and little or no water may be permitted to drain around
the return. The water diversion is accomplished by adjusting the ECR and flow line PI elevations at corners F and G so that they are higher or lower than the BCR elevations. This adjustment controls the flow around the return and from the flow line PI's.