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SECTION 1 - STREET DESIGN CRITERIA

1.1.0 GENERAL

This Section provides guidelines for the assignment of street classifications and their respective design criteria.

1.2.0 CLASSIFICATIONS AND FUNCTIONAL CHARACTERISTICS

1.2.1 General Street Classifications

Street classifications are used to categorize streets according to their functions. There are three (3) major street classifications for urban roadways: local streets, collector streets and arterial streets. In addition, functions and design standards for highways and alleys are also included in this document.

1.2.2 Functional Characteristics

The following reflect general functional characteristics for each street classification. In addition, Figure 1-1, in Section 1.7.0 of this Transportation Criteria Manual (Manual) illustrates the access versus mobility characteristic as it pertains to each street classification.

A. **Alley.** An alley is a passageway designed primarily to provide access to or from the rear or side of property otherwise abutting on a public street.

B. **Local Street.** The primary function of a local street is to serve abutting land use and traffic within a neighborhood or limited residential district. A local street is not generally continuous through several districts.

C. **Collector Street.** The primary function of a collector street is to intercept traffic from intersecting local streets and expedite the movement of this traffic in the most direct route to an arterial street or other collector street.

D. **Arterial Street.** Arterial streets are designed to carry high volumes of through traffic. Access is usually limited to intersections and major driveways. Arterial streets serve as a link between major activity centers within the urban area.

E. **Freeway.** Freeways are divided arterial highways designed with full control of access and grade separations at all intersections. Freeways provide movement of high volumes of traffic at relatively high speeds. This system carries most of the trips entering and leaving the urban area, as well as most of the through movements by-passing the central city.

F. **Parkway.** A parkway is a freeway which does not have continuous frontage roads. Parkways have a greenspace buffer between the roadway and adjacent development and preserves and enhances the natural landscape as much as possible.

The functional classification for each street shall be identified upon the time of the submittal of preliminary plans.

1.3.0 GEOMETRIC DESIGN CRITERIA

1.3.1 General Design Criteria

A. Grades. The following design criteria are based on material from the Institute of Transportation Engineers Report, Guidelines for Urban Major Street Design, 1983, Sections 6.1, 6.3 and 6.4.

Grades have an economic effect on vehicle operating costs and time losses and they also affect highway capacity and safety.

The grade line is a series of straight lines connected by parabolic vertical curves to which the straight lines are tangent. Under all conditions this line should be smooth flowing. Short, choppy grades are unsightly and disrupt operating conditions.

1. Maximum Grades.

   Maximum grades are determined primarily by the operation characteristics of vehicles on grades. Driving practices with respect to grades vary greatly, but nearly all passenger cars can readily negotiate upgrades as steep as seven (7) to eight (8) percent. Passenger vehicle speeds decrease progressively with steeper grades.

   The effect of grades on bus or truck speeds is most pronounced. On upgrades, the maximum speed a bus or truck can maintain is dependent on the grade length and steepness, and on the ratio of the gross vehicle weight to engine horsepower. This will not only affect speed, but may also be a pronounced effect on the capacity of the street where there are appreciable bus and/or truck volumes. Table 1-7 indicates maximum permissible grades. However, such grades should be used infrequently.

   The maximum gradient range for roadways carrying bus traffic is six (6) to eight (8) percent. (Urban Public Transportation: Systems and Technology, Vukan R. Vuchic. Englewood Cliffs, NJ: Prentice-Hall, 1981). To adequately exploit the travel time and speed advantage of an exclusive bus lane, the maximum recommended grade for a high-occupancy vehicle (HOV) lane or busway is four (4) percent (Institute of Transportation Engineers, Transportation and Traffic Engineering Handbook, 2nd ed. Englewood Cliffs, NJ: Prentice-Hall, 1982).

2. Minimum Grades.

   Minimum grades are governed by drainage conditions. With curbed pavements, longitudinal grades should be provided to facilitate surface drainage. A minimum grade of 0.4 percent is used.

3. General Controls for Vertical Alignment.

   The following are general design controls which should be addressed in determining vertical alignments:

   a. The grade line should be smooth flowing.

   b. The "roller coaster" type profile should be avoided.

   c. Undulating grade lines should be appraised for their effect upon traffic operations.

   d. A broken-back grade line (successive vertical curves in the same direction) generally should be avoided.

   e. It is desirable to reduce the grade through intersections on roadways with moderate to steep grades.

   f. A sag vertical or flat grade is desirable in advance of such features as channelizations and ramp takeoffs in order to provide good visibility.

   g. Steep downgrades should be avoided, whenever practicable, at the approach to traffic signals and stop signs.

4. Vertical Curves.

   Vertical curves should be simple in application and should result in a design that is safe, comfortable in operation, pleasing in appearance and adequate for drainage.

   For simplicity, the parabolic curve with an equivalent axis center on the vertical point of intersection is recommended in roadway profile design (see Figure 1-2 in Section 1.7.0 of this Manual).

   Figures 1-3 and 1-4 in Section 1.7.0 of this Manual indicate the length of vertical curve in relation to algebraic difference in grades necessary to maintain safety and comfort for crest vertical curves and sag vertical curves.

   Maximum grade breaks of 0.8 percent or less may be used without a vertical curve.

   Note that sight distance required from intersecting streets or driveways along vertical curves is not addressed in Figures 1-2, 1-3 and 1-4 in Section 1.7.0 of this Manual. An intersecting street or driveway may not be appropriate along a vertical curve when required sight distance from side street or driveway is not attainable. If it is essential that a side street or driveway intersect the main street along a vertical curve, then it may be necessary to reduce the vertical curve so that necessary sight distance is available. Horizontal and vertical alignments should not be designed independently. They complement each other and poorly designed combinations can spoil the good points and aggravate the deficiencies of each. Horizontal alignment and profile are among the more important design elements of a roadway.

Comfort control criteria as defined in the American Association of State Highway and Transportation Officials (AASHTO) for sag vertical curves is generally discouraged. This criterion, however, may be used when the subdivision is provided with adequate fixed-source lighting (street lights). The City Engineer and the Director of the Department of Transportation Services shall be consulted in regard to procedural and funding requirements pertaining to fixed-source lighting.

B. Minimum Horizontal Radii.

The following design criteria is based on material from the AASHTO Manual, A Policy on Geometric Design of Highways and Streets, 2001, Chapters 3, 4, 5, and 6.

The minimum radius of a roadway is directly related to a roadway's design speed, superelevation and side friction factor.

The 2001 AASHTO Manual, Exhibit 3-29, "Maximum Safe and Comfortable Speed for Horizontal Curves on Low-speed Urban Streets," was utilized in establishing the following radii:

For a superelevation (e) = -0.02, typical for normal crown

A design speed of:

20 mph relates to a minimum allowable radius of 100 feet.
25 mph relates to a minimum allowable radius of 180 feet.
30 mph relates to a minimum allowable radius of 300 feet.
35 mph relates to a minimum allowable radius of 470 feet.
40 mph relates to a minimum allowable radius of 725 feet.

From the 2001 AASHTO Manual, Exhibit 3-39, "Side Friction Factors for Rural Highways and High-speed Urban Streets,"

A design speed of:

45 mph relates to a side friction factor (f) of 0.145
50 mph relates to a side friction factor (f) of 0.140

The minimum safe radius (R) is calculated from the formula

$R = V^2 / [15(e+f)]$ (eq. 1-1)

For design speed (V) = 45 mph,

$R = (45^2) / [15(-0.02+0.145)] = 1{,}080$, say 1,000 feet

For design speed (V) = 50 mph,

$R = (50^2) / [15(-0.02+0.140)] = 1{,}389$, say 1,400 feet

The above values for the minimum horizontal radii are reflective of the standards set forth in this Manual.

Superelevation rate, "e" may be varied thereby resulting in different values for "R" (minimum centerline radius). Changes in the above values for "e", however, should lend consideration to intersecting cross street designs. Tangent lengths between curves may also need to be extended to provide for proper superelevation runoff.

C. Intersection Design.

The following design criteria were adapted from the latest edition of the Institute of Transportation Engineers reports, Recommended Guidelines for Subdivision Streets, Section 2.05 and Guidelines for Major Street Design, Section 9.5. This section lends guidance for proper intersection design regarding proper roadway alignments in the intersection area.

1. Vertical Alignment within Intersection Area.

Intersection areas should be designed with a flat grade. In the more difficult terrains, this becomes economically impractical.

The design speed for the major street at any intersection shall be maintained through the intersection approaches. The minor street may be designed with a change in grade based on reduced design speeds between the maximum grade in the approach and the cross-slope of the intersected street not to exceed eight (8) percent for local streets and six (6) percent for collector streets. The change in grade shall be accomplished by means of a vertical curve of length equal to the minimum length for that approach for that intersection type as indicated in Table 1-7.

2. Horizontal Alignment within Intersection Area.

The horizontal approach to an intersection should be tangent for a length of fifty (50) to one hundred (100) feet (see Table 1-7). Note that these tangent lengths are minimum. Longer tangents are highly desirable. The tangent distance is measured from the curb line of one (1) street to the first point of curvature on the intersecting street. In this regard, radii greater or equal to one thousand (1000) feet may be considered tangent.

Where driveways are not limited to right in and right out movements, requirements for local streets (as indicated in Table 1-7) should apply. It is desirable for all intersections to meet at approximately a ninety (90) degree angle. However, necessary sight distance for streets intersecting from the outside of a curve is generally attainable. Skewed intersections should be avoided and in no case should the angle be less than eighty (80) degrees or greater than one hundred (100) degrees. Studies have shown that skewed intersections have generally higher accident rates than those intersecting at ninety (90) degrees. Desirable alignments will also provide for increased visibility of traffic control devices such as stop signs or yield signs and will also provide increased visibility of cross traffic.

3. Minimum Curb Radius.

   As curb radius is increased, paving costs and intersection area required for a pedestrian to traverse are increased and higher turning speeds are encouraged. Substandard radii result in unnecessary lane encroachment and increased traffic conflict and accident potential. Reasonable design values of fifteen (15) feet are recommended for intersection radii of two (2) local streets, based on curb clearance of three (3) feet and without lane encroachment for a typical width street, using the AASHTO design passenger vehicle. This design will also accommodate garbage trucks and moving vans with wide swings. An increased radius of twenty (20) feet for the local-collector or collector-collector intersection is predicated upon a desire to slightly improve the maneuverability of a vehicle in entering or leaving the collector. A collector intersection with an arterial street should have a twenty-five (25) foot radius. An arterial-arterial intersection should have a thirty (30) foot radius.

4. Minimum Centerline Offset of Adjacent Intersection.

   Several studies of intersection design types have shown T-type intersections to be far safer than cross-type. Extensive use of T intersections in residential subdivisions is strongly recommended. One disadvantage, however, is "corner cutting" when inadequate offset exists between adjacent intersections. To reduce this hazardous practice, offsets of at least one hundred and fifty (150) feet between center lines are required. In the case of two (2) collector-street intersections, this offset shall not be less than three hundred (300) feet in order to allow for left-turn storage between intersections.

   Offset intersections have disadvantages when one (1) or both such streets is a collector intersecting an arterial street, if volumes will be such to warrant traffic signals. Operations at such locations are more complicated than those for normal cross-type intersections. Therefore, other design solutions should be sought if signalization might otherwise be required. When offset intersections are used at an arterial street, they should be located to avoid conflicting left turns (this is especially important where two (2) way, left-turn lanes are to be provided or where left-turn slots are used in a fairly narrow median). Such left-turn conflicts exist when an intersection offsets to the right rather than to the left.

   The distance between intersection offsets is measured from the center line intersection of one (1) intersecting roadway and the centerline intersection of the next intersecting roadway, measured along the centerline of the intersected roadway. Multileg intersections [over four (4)] are undesirable from the control and safety standpoint.

5. Drainage Structures.

The location of drainage structures, inlets, catch basins, etc., should be consistent with the intended use of the roadway and in accordance with the City's Design and Construction Standards (DACS) - Drainage Criteria Manual.

Inlets or catch basins should not be located within the corner curb return or within ten (10) feet from the point of curvature of the curb return. Clearance is needed to allow space for street lights, street name signs, utility poles, pedestrians, sidewalk ramps, etc.

At intersections which have valley drainage, the crowns of the intersecting streets will culminate in a distance of forty (40) feet from the intersecting curb lines unless otherwise noted on the construction plans. Inlets on intersecting streets shall not be constructed within fifty (50) feet of the valley drainage.

Valley gutters should not be designed across streets with collector or higher classification.

6. Sight Distance.

Intersections should be planned and located to provide as much sight distance as possible. A basic requirement for all controlled intersections is that drivers must be able to see the control device well in advance of performing the required action. Stopping sight distance on all approaches is needed as a minimum. Obstruction-free sight triangles are desirable, in both the horizontal and vertical planes as related to assumed driver eye height and position.

The Stopping Sight Distance (SSD) in feet is determined from the formula:

$$SSD = 1.47\,PV + \frac{V^2}{30\,(f \pm g)} \qquad \text{(eq. 1-2)}$$

Where V = Design speed in miles per hour

P = Perception-reaction time in seconds (2.5 seconds)

f = Coefficient of friction for wet pavement (.30 to .40)

g = Percent of grade divided by 100 (+ for upgrade; - for downgrade)

Entering Intersection Sight Distance (ISD) at intersections controlled by "stop" signs may be measured as shown in Figure 1-

5, in Section 1.7.0 of this Manual. The resultant sight triangle should be free of sight obstructions such as parked vehicles, buildings, walls, hedges, bushes, low growing trees or guardrail (if located on a crest where the rail forms a sight restriction), above an assumed driver eye height line of sight to target.

This height is three and one-half (3.5) feet for passenger cars and six (6) feet for SU and WB-50 design vehicles, related to an approaching vehicle (target) four and one-fourth (4.25) feet high. The sight line is based on the time required for the stopped vehicle to clear the intersection versus the distance a vehicle will travel along the major street. See Table 1-1 for minimum sight distance.

7. Median Design at Intersections.

   End treatment of medians at intersections should be designed to accommodate the design vehicle turning at a reasonable rate of speed. Semicircular radii may be used on the noses of medians up to six (6) feet wide. Bullet-nosed medians should be used for medians of greater width. A minimum fifty (50) foot control radius or a seventy-five (75) foot control radius is required as stated in Table 1-2. Figure 1-6 and Figure 1-7, in Section 1.7.0 of this Manual, illustrate examples of providing adequate curves at the medians.

TABLE 1-1
MINIMUM SIGHT DISTANCE*
Design Speed for Major Roadway (mph)

		30	**35**	**40**	**45**	**50**	**55**
CASE I	Cond. A	200	250	325	400	475	550
	Cond. B**	350	410	470	530	590	650
	Cond. C**	400	460	520	580	640	700
CASE II	Cond. A	400	470	540	610	680	750
	Cond. B**	475	550	625	700	775	850
	Cond. C**	510	590	670	750	830	900
CASE III	Cond. A	400	500	650	800	1000	1200
	Cond. B**	475	550	650	800	1000	1200
	Cond. C**	510	590	670	800	1000	1200

Where,
CASE I is the Absolute minimum from driveways (other than industrial driveways).
CASE II is the Absolute minimum from all streets and industrial driveways.
CASE III is the Desirable minimum from all driveways and all streets.

Condition A - Entering onto or crossing a 2 or 3 lane street.**
Condition B - Entering onto or crossing a 4 or 5 lane street.***
Condition C - Entering onto or crossing a street with more than 5 lanes.***

* This Table is for flat grades only. The AASHTO *Policy on Geometric Design of Highways and Streets, 2001 Edition*, should be referenced in obtaining minimum sight distances whenever grades are not flat.

** For each Case Type, minimum sight distances to the left need not exceed distances identified for Condition A.

*** If median shadowing is > 20', then the intersection can be considered as 2 separate intersections, utilizing Condition A.

Source: City of Round Rock, Department of Transportation Services

Table 1-2 REQUIRED CONTROL RADII		
Street Classification	Intersecting Street	Control Radius
Arterial	Arterial	75'
Arterial	Major Collector (Divided)	75'
Arterial	Major Collector (Undivided)	50'
Arterial	Local Collector	50'
Arterial	Local Steet	*
Major Collector (Divided)	Major Collector (Divided)	50'
Major Collector (Divided)	Major Collector (Undivided)	50'
Major Collector (Divided or Undivided)	Local Collector	50'
Major Collector (Divided or Undivided)	Local Street	50'
Local Collector	Local Collector	50'
Local Collector	Local Street	50'
Local Street	Local Street	35'
* Local streets should not be designed to intersect with arterial streets. In the event of such an occurrence, see Department of Transportation Services.		

D. Tapers.

The following design criteria was adapted from the Institute of Transportation Engineers report, Guidelines for Urban Major Street Design, 1983, Sections 4.1 through 4.8 and from the latest edition of the Uniform Design Standards Manual of the Metropolitan Transit Authority of Harris County.

1. Terminology.

In order to discuss the various elements of turn-lane channelization, a standard terminology must be established. Figure 1-8 in Section 1.7.0 of this Manual illustrates the concepts.

a. APPROACH TAPER is that portion of the roadway geometry from the point where all approaching traffic must shift laterally, to the beginning point of the bay taper.

b. BAY TAPER is from the edge of the adjacent through traffic lane to the beginning of the full width of the turn storage lane.

c. STORAGE LENGTH is the distance from the end of the bay taper to the intersection nose or stop line.

d. INTERSECTION NOSE is the radius or distance from the end of the storage bay to the near edge of the cross-route exit lane for the left-turning vehicle. For left-turn bays the cross-route exit reference is normally the centerline of an unchannelized two (2) way street or the far edge of the median in a channelized street.

e. DEPARTURE TAPER of a left-turn bay is from the point where through traffic beyond the intersection begins a lateral shift to the left to the point where the through lane is adjacent and parallel to the centerline.

2. Approach Tapers.

In general, a taper that causes all vehicles to transition laterally should be moderately long. However, lengths are constrained in urban areas. The taper length is a direct product of slope angle, which is most related to expected operating speeds.

In a study by the Department of Public Works, County of Sacramento, California, three (3) equations were tested to establish taper lengths.

$$L = W * S \quad \text{(eq. 1-3)}$$
$$L = (W * S * S) / 60 \quad \text{(eq. 1-4)}$$

Where:

L = Length in feet
S = Design Speed - Speed in miles per hour
W = Lateral offset in feet from centerline (double yellow)

This study included recording the speed of vehicles at the beginning and end of the approach taper and noting where the driver stays between the lane lines. Based on the results:

Equation 1-4 is recommended for posted speeds of forty (40) mph or less. Equation 1-3 is recommended for posted speeds of forty-five (45) mph or greater.

See Figures 1-8 and 1-9 approach tapers in Section 1.7.0 of this Manual.

3. Bay Tapers.

There is a great disparity throughout the United States in the design of bay tapers. The transition lengths and the corresponding curve radii vary widely because of the different philosophies regarding the type of entry a turning vehicle should make. Some feel that the transition should be smooth and gradual. Thus, in these areas, large radii and long transition lengths are used. This type of design also is favored because of the ease of street cleaning operations.

Opponents of this philosophy point out that unobservant drivers will tend to drift into the turn lane and may cause unnecessary conflicts with other vehicles as they try to get back to the through lane. It is their contention that to avoid this possible conflict, turn lanes should stand out and that short transition lengths and small radii should be used. The use of shorter bay tapers also increases the potential storage length for closely spaced intersections or major driveways.

The design of bay tapers in the City should conform to standards indicated in <u>Figure 1-10</u>, in Section 1.7.0 of this Manual.

4. Departure Tapers for Left-Turn Bays.

There are two (2) different designs for developing the departure taper. The variation relates to the point of the start of the taper in a channelization that provides a full shadowed lane. The first variation starts the taper at the point of full median width, while the other begins the taper at the end of the storage lane, as shown in <u>Figure 1-9</u>, in Section 1.7.0 of this Manual. Beginning at the end of the storage lane and ending at the beginning of the approach taper provides a flatter angle which is easier for a vehicle to negotiate. It requires less widening and/or parking restrictions and is recommended as the desirable design guide.

5. Acceleration/Deceleration Lanes.

Acceleration lanes are seldom used along urban major streets. However, when they are used, the transition taper design may be the same as for an approach taper. Many agencies utilize the rule of thumb that allows one (1) foot of lateral displacement per mph of the roadway into which the vehicle is emerging ($L = W * S$). Thus, a twelve (12) foot (W) acceleration lane merging with a street having a speed of thirty (30) mph (S) would produce a three hundred and sixty (360) foot taper. A deceleration lane is actually a right-turn lane (or left if on a one (1) way roadway) and therefore should be designed in accordance with bay-taper principles.

6. Through-lane Tapers.

When all traffic must transition to the left or right, the design represents an approach-taper condition. For an added through lane approaching an intersection, the transition into the lane may be made by either an approach or a bay-taper design. However, the termination of the added lane beyond the intersection (a lane drop) should be handled by the approach-taper type of design.

7. Tapers on Horizontal Curves.

For a left-turn bay, the taper may be longer if the horizontal curve direction is to the driver's left. Conversely, the tapers may be shorter if the curve is to the driver's right. Figure 1-11, in Section 1.7.0 of this Manual, illustrates the reason for this, based upon the deflection angle required from a tangent line to the curve.

Adjustment of "standard" local design criteria is most appropriate for turn-lane tapers located on curves of 500 foot radius or less. The adjustment can be determined graphically.

E. Median and Median Breaks.

The following design criteria was adapted from the Institute of Transportation Engineers report, Guidelines for Urban Major Street Design, 1983, Sections 7.1 through 7.4. and Section 12.5.

1. Function.

A median is that portion of a divided highway separating the traveled way for traffic in opposite directions. Medians or two (2) Way Left Turn Lanes (2-WLTL) should be considered for all major urban streets of four (4) or more lanes.

Medians can provide major benefits to traffic operations on the route. Curbed medians can provide space for traffic control devices, for storage of left-turn and/or U-turn traffic. Flush medians can also provide a recovery area for out-of-control vehicles and an emergency stopping place for disabled vehicles. Some median designs can reduce headlight glare and serve as a refuge area for pedestrians and bicyclists. Where sufficient width is provided, medians may allow for future expansion of the through roadway. Good median design can smooth traffic flow and reduce conflicts.

Other functional and urban design values may be enhanced by medians. Wider medians can provide a location for drainage systems, lighting, utilities and other roadway facilities. A well-designed median can lend an orderly and attractive character both to the neighborhood and to the street that it serves.

An eight (8) to twenty (20) foot curbed median often represents a good trade-off of operational advantages and disadvantages, if used for major streets on new alignment or through undeveloped areas and where access limitations are practical (reverse lot frontage subdivisions or combined access for direct connection tracts). With crossover access spacing of six hundred (600) to one thousand (1,000) feet, including left-turn bays, a balance can be struck between efficient service to through traffic and secondary service to abutting development.

Wider roadways requiring three (3) lanes in each direction, resulting in seven (7) lanes if used-with the 2-WLTL concept, can produce severe problems for pedestrian crossings. The unprotected width to be traversed can be unsafe at local or mid-block locations and can restrict traffic signal efficiency. Where such large numbers of lanes are needed, curbed medians may be warranted.

2. Types.

   Medians may be depressed, raised or flush with respect to their adjacent traveled way. Depressed medians may be edged with raised curbs or they may slope from the edge of the roadway directly. Often sections wider than sixteen (16) feet are depressed to collect drainage. Side slopes of 10:1 (6:1 minimum) are preferred to allow for vehicle recovery. Flush medians are typically narrow and paved. They do not prevent access to adjacent property and serve the purpose of separating opposing flows at less cost. Raised medians may be preferred for access control and landscaping purposes where drainage is not a problem. Raised medians also provide a positive visual barrier which prevents erratic cross-traffic movements.

3. Median Width.

   The width of a median is its most important geometric design consideration. Table 1-3 indicates widths necessary to accomplish certain functions, based on the passenger vehicle for primary design of crossing protection and U-turns.

4. Median Break Spacing.

   The fewer driveways on a major, urban street, the more effectively it will serve its primary function. Spacing should be maintained between driveways and intersections appropriate to the character of the driveway and roadway.

   Driveway spacing should allow reasonable deceleration of vehicles approaching on the street and acceleration by vehicles entering the street. Median breaks for driveways should not be contemplated unless sufficient length is available to accommodate deceleration tapers and storage lengths. Table 1-4 reflects median and median break criteria. This criterion is based on the National Cooperative Highway Research Program (NCHRP) Report No. 93.

Full-function median openings (see Figures 1-12 through 1-20 in Section 1.7.0 of this Manual) on major arterials should be allowed only where the minimum spacing for signalized intersections are practicable. At intermediate locations along major arterials, limited-function openings may be provided at the spacing listed in Table 1-4.

High volume driveways on major arterials should only be located opposite streets or other driveways when the minimum spacing requirements for signalized locations are met. Otherwise, T-intersection configurations should be designed. When driveways are located opposite street intersections the two (2) should have compatible design elements.

On streets other than major arterials, full-function median openings are acceptable at the spacing listed in Table 1-4. On both major and minor arterials, access to public streets will have priority over access to private property.

TABLE 1-3

RECOMMENDED MEDIAN WIDTHS

(LOG TO LOG)

Function	Desirable Width
Separation of Opposing Traffic	6' *
Pedestrian Refuge & Space for Traffic Control	20'
Left Turn, Speed Change and Storage	20'
Crossing / Entering Vehicle Protection	20'
* Cannot accommodate left turn lanes.	
Source: Based on the latest edition of the ITE Guidelines for Urban Major Street.	

F. Turn Lanes and Channelization.

The following design criteria was adapted from the ITE Report, Guidelines for Urban Major Street Design, 1983, Sections 9.3 and 9.4. and from the AASHTO manual, A Policy on Geometric Design of Highways and Streets, 1984 and from Research Report 258-1, Project 3-18-80-258, Center for Transportation Research, Bureau of Engineering Research, The University of Texas at Austin, January, 1984.

1. Turn Lanes.

   The primary purpose of left-turn lanes at intersections is to provide storage space. A secondary purpose of turn lanes is to provide a location for deceleration removed from the through traffic lanes, thereby maintaining the capacity of the through roadway. Studies have demonstrated that accident experience is significantly reduced when left-turn lanes are provided at intersections of two (2) major streets, i.e., collectors and arterials.

TABLE 1-4

MEDIAN OPENING CRITERIA

Design Speed (mph)	Minimum Spacing* Distance "C" (Figure 1-18)	Minimum Spacing Distance "B" + "C" (Figure 1-18)
	100' Minimum Storage Requirement **	150' Minimum Storage Requirement ***
30	350'	500'
35	425'	575'
40	500'	650'
45	600'	750'
50	750'	900'

* Plus storage lengths based on peak hour volumes (See Table 1-5)
** Minimum storage when turning into a local street
*** Minimum storage when turning into a collector street or arterial

Source: NCHRP Report No. 93, 1970

   At a minimum, storage lengths should be one hundred and fifty (150) feet when turning into a collector or an arterial and one hundred (100) feet when turning into a local street. At any unsignalized intersections, the storage length, exclusive of taper may be based on the number of turning vehicles likely to arrive in an average two (2) minute period within the peak hour with each vehicle accounting for approximately twenty (20) feet of storage.

At signalized intersections, the storage length depends on the signal cycle length, the signal phasing arrangement and the rate of arrivals and departures of left-turning vehicles (see Table 1-5).

TABLE 1-5

STORAGE LENGTH OF LEFT TURN BAY (FOR ARTERIAL)**

Lmax(av)	City of Round Rock Standard	City of Round Rock Dual Left Standard
0	0	-
6	150	-
8	200	-
10	250	-
12	300	200
14	340	200
16	370	200
17	400	300
18	425	300
20	450	300
21	475	300
22	500	300
23	525	300
24	550	300
25	575	350

Storage lengths exceeding four hundred (400) feet should be discouraged. All proposals for turn bays exceeding four hundred (400) feet will require the approval of the Director of the Department of Transportation Services.

** Similar applications could be used for other street classifications.

Lmax (av) = 5.5 (Lavg$^{0.58}$) (based on average condition)

Source: Based on Research Report 258-1, University of Texas Center for Transportation Research, 1984

Dual left-turn and right-turn lanes are successful where traffic volumes exceed the capacity of a single lane and the cross-street is of sufficient width to receive two (2) vehicles turning abreast. For dual right-turn lanes and dual left-turn lanes from one (1) way streets, the inside lane must be a mandatory turn.

2. Channelization.

a. Channelization of intersections is the separation or regulation of conflicting traffic movement into definite paths of travel by the use of pavement markings, raised islands or other suitable means to facilitate the safe and orderly movements of both vehicles and pedestrians. The main objectives of intersection channelization are to assure orderly traffic movement, increase capacity, improve safety and provide maximum convenience. To carry out these objectives, channelization is employed for one (1) or more of the following purposes:

   i. Separation of conflicts.
   ii. Control of angle of conflict.
   iii. Reduction of excessive pavement areas.
   iv. Regulation of traffic and indication of proper use of the intersection.
   v. Arrangements to favor predominant turning movements.
   vi. Protection of pedestrians.
   vii. Protection and storage of turning and crossing vehicles.
   viii. Location of traffic control devices.
   ix. Prohibition of specific movements.

   Small, isolated channelization islands should be avoided. Islands should be readily visible and designs with numerous small islands should be discarded in favor of those with a few large ones. Long narrow islands may be undesirable adjacent to turn lanes. Islands with at least one hundred (100) square feet are desirable but, under very restricted conditions, seventy-five (75) square feet may be used. Islands used for pedestrian refuge desirably should be six (6) feet wide, with a minimum of four (4) feet. If wheelchair access is to be considered, the minimum width of a curb ramp shall be thirty-six (36) inches, exclusive of flared sides.

b. The following principles should be considered and addressed in meeting conditions at particular intersections. However, if they are disregarded, the objectives of channelization will not be achieved and the resulting design may be hazardous and inefficient.

   i. Reduce the area of conflict; large paved intersectional areas invite hazardous vehicle and pedestrian movements.
   ii. When traffic streams cross without merging and weaving, make the crossing at or near right angles. If traffic signal control is planned, the crossing angle may be less than right angle with suitable signal design and visual clues.
   iii. Merge traffic streams at small angles.
   iv. The speed of a traffic stream entering an intersection may

be controlled by funneling.

v. Provide refuge (shadowing) for turning and crossing vehicles where possible and necessary with channelization.

vi. Use channelization to separate conflict points within an intersection.

vii. Block prohibited turns with well-delineated channelization.

viii. Channelization may provide locations for the installation of essential traffic control devices to enhance their visibility.

G. Environmental Considerations.

Application of the street design criteria contained in this Manual to new subdivisions and site developments must take into consideration all applicable environmental standards, including restrictions on cut and fill and development setbacks from waterways and critical environmental features. Requirements of the street design criteria shall not be considered as sole justification for any references. It is advisable to delineate all required setbacks and other applicable environmental protection measures prior to designing streets.

Minor deviations from the street design criteria may be applied for, on a case-by-case basis, in order to protect specific environmental features on severely constrained tracts provided that proposed deviations meet minimum safety standards and are approved by the City Engineer and the Director of the Department of Transportation Services.

1.3.2 Classification Design Criteria

A. The following includes specific design criteria for each street classification noted in Section 1.2.2 of this Manual as required to attain adequate levels of service and safety. Table 1-7 summarizes the general design criteria for each of the street classification noted in Section 1.2.2. of this Manual.

1. Above-minimum design values should be used whenever feasible, to assure maximum safety and operational characteristics of a transportation system. Minimum values should be recognized and used when constraints encountered are present in such quantities to justify use of minimum values.

2. Traffic volumes indicated in this Manual reflect typical ranges pertaining to the street classification. These ranges <u>are not</u> intended to be used as a sole basis for determining the street classifications. Rather, streets should be classified in regard to their functional characteristics.

3. Various roadway cross-sections may be used to meet specific needs or goals; cross sections shall <u>not</u> be the sole basis for determining

street classifications.

4. Minimum centerline radii shown in the tables are based on a normal crown section.

5. Design speed is an important function of roadway design. The proper design speed selection is influenced by the character of terrain, the density and type of adjacent land use, the classification and function of the roadway, the traffic volumes expected to use the roadway and by economic and environmental considerations. For example, the design of a roadway in level terrain is often based on a higher design speed than one in mountainous terrain; for one in a rural area, a higher design speed than one in an urban area; and for a high-volume highway, a higher design speed than one carrying low traffic volumes. It is important to recognize and treat individual roadways based on their specific characteristics. The design speed should be determined based on the design engineer's judgments on what design criteria are the most feasible for that particular roadway within the ranges provided in this Manual.

   It is desirable to have a uniform design speed throughout the length of the roadway. Changes in terrain and other physical controls may dictate a change in design speed on certain sections. If so, the introduction of a lower design speed should not be abrupt but should be affected over sufficient distance to permit drivers to change speed gradually before reaching the section of roadway with the lower design speed.

B. **Local Streets.**

Local streets are intended primarily to serve traffic within a neighborhood or within a limited district. Local streets are not continuous through several districts. Average Daily Traffic (ADT) is generally less than two thousand (2000) vehicle trips daily.

1. Local Street - Residential

   In a residential neighborhood, a local street typically serves Single Family-Large Lot (SF-1), Single-Family Standard Lot (SF-2), Two Family (TF), Townhouse (TH) or Multifamily (MF) zoned dwelling units in number. Local streets should be designed to minimize through traffic movement; on-street parking is usually permitted.

2. Local Street – Non-Residential

   Non-residential local streets serve low density areas. As with regular local streets, they are not intended to carry through traffic movement.

3. Local Street - Rural.

   Rural local streets serve low density areas. They should only be designed to connect two (2) local streets or a residential collector with a local street and are not intended to carry through traffic.

C. **Collector Street.**

These streets collect traffic from other streets, serving as the most direct route to an arterial or other collector street. The two (2) types of collector streets are local (with or without on-street parking) and major. ADT is generally between two thousand (2000) and six thousand (6000) vehicle trips daily.

1. Collector, Local.

   A residential collector street generally serves to collect traffic from local streets within a residential district and is not intended to continue through several districts. Residential collector streets provide access to abutting property with SF-1 and SF-2 zoning, MF zoning and OF zoning and generally provide on-street parking. Such streets typically exist within a subdivision adjacent to single family and to multifamily developments.

2. Collector, Major.

   This type of a collector street serves as principal access to commercial developments. Large vehicles such as delivery trucks can be expected to utilize this type of collector. Driveways should be limited and designed to accommodate higher traffic volumes. On-street parking is generally not permitted. Multifamily developments may front on these collectors provided adequate off-street parking is available.

NOTE: See Section 7 of this Manual for additional information pertaining to bicycle design criteria. The street cross-sections noted in this Section may need to be increased to account for bicycle routes.

D. **Arterial Street.**

1. General.

   Arterial streets represent the primary network of streets for the through movement of traffic in an urbanized area. Arterial streets generally move high volumes of traffic (ADT greater than 6000 vehicles) for great distances and at relatively high speeds. The City of Round Rock Transportation Master Plan, as amended, identifies the streets that compose the arterial street network. Access to abutting property should therefore be limited or restricted, with on-street parking generally prohibited. Single-family residential development should not normally front on arterial streets. In most instances, the minimum travel lane should be twelve (12) feet as a large variety of vehicles can be expected to utilize the system. Arterials are typically spaced every one (1) to two (2) miles within the network system.

NOTE:

- See Section 7 of this Manual for additional information pertaining to bicycle design criteria. The street cross-sections noted in this Section may need to be increased.
- As a means of assuring proper placement of utilities, the City may require easement dedications from the applicant.
- The Director of Transportation Services should be consulted for design criteria and applicability of one way arterials.

E. **Cul-de-sac.**

Cul-de-sac streets are open at one (1) end, the closed end constructed so as to facilitate traffic circulation in the reverse direction. Single outlet streets serve a network of streets with one (1) point of access. The maximum length shall be seven hundred and fifty (750) feet, measured from the centerline of the nearest intersecting street to the center point of the cul-de-sac. Lengths exceeding seven hundred and fifty (750) feet, however, will require a recommendation from the City's Fire Department and approval by the Planning and Zoning Commission.

Local streets may terminate in a cul-de-sac (see Figure 1-21 in Section 1.7.0 of this Manual). Collectors and arterial streets shall not terminate in a cul-de-sac.

The use of islands with cul-de-sac bubbles is not recommended (see Figure 1-22 in Section 1.7.0 of this Manual). When islands are proposed, a maintenance agreement must be established between the applicant and the City.

1. Cul-de-sac, Local.

   Local cul-de-sacs are intended to serve residential dwelling units. Throat width and curb basis shall meet the same design criteria as required for a general local street (see Figure 1-23 in Section 1.7.0 of this Manual).

2. Cul-de-sac, Commercial.

   Cul-de-sacs serving primarily commercial use shall have a throat designed to commercial collector criteria. Islands should be discouraged and are not permitted without the approval of the Director of Transportation Services (see Figure 1-24, in Section 1.7.0 of this Manual).

3. Cul-de-sac, Industrial.

   The vehicles serviced by this type of cul-de-sac are often large, therefore, islands will not be permitted without the approval of the Director of Transportation Services. The throat shall be designed to industrial collector standards (see Figure 1-25, in Section 1.7.0 of this Manual).

Dead-end streets that are stubbed out for future extension to the adjacent property must terminate in an open-ended cul-de-sac (as illustrated in Figure 1-25A, in Section 1.7.0 of this Manual), unless the dead-end street is less than one hundred and fifty (150) feet long, in which case the cul-de-sac bubble may be omitted. If the stubbed-out street is not extended when the adjacent property is developed, a bubble is required on the adjacent property, or access to the dead-end street from the adjacent property must be prohibited.

F. Single Outlet Streets.

Traffic issues pertaining to single outlet streets are partially mitigated by: (1) providing mid-block turnarounds (or cross-streets/loop streets), (2) increased pavement widths and (3) utilization of divided roadways, as noted in Table 1-6.

The criteria pertaining to single outlet streets are applicable to new developments whether the single outlet is temporary or permanent. When future extensions to the street system are anticipated, which will provide additional outlets, a temporary restriction may be placed on the amount of development allowed, until an additional outlet becomes available (see Figure 1-28 in Section 1.7.0 of this Manual).

TABLE 1-6
SINGLE OUTLET STREETS*

ADT	Street Width (LOG - LOG)
Less than 300	27’
300 - 1000	37’
1000 - 2500	37’
2500 - 4000	2 @ 24’ w/20’ min. median width
Greater than 4000	2 @ 24’ w/20’ min. median width
* If the distance exceeds 750', the single outlet street must be designed with 2 @ 24’ w/16' minimum median width.	
Source: City of Round Rock, Department of Transportation Services	

G. Alley.

An alley is a passageway designed primarily to provide access to property. The existing/planned street network in the immediate vicinity should impact the decision for planning one (1) or two (2) way alleys. Typically, a one (1) way alley should not be encouraged unless the alley is short. Parking in alleys should be restricted.

1. Alley, One (1) Way.

   Where applicable, the direction of travel on a one (1) way alley should be consistent with the surrounding street network (see Figure 1-26, in Section 1.7.0 of this Manual).

2. Alley, Two (2) Way.

   In an effort to reduce the potential for motorist confusion, the combining of two (2) and one (1) way alleys in the same subdivision should be avoided (see Figure 1-27, in Section 1.7.0 of this Manual).

Table 1-7
Geometric Design Criteria Summary Table

Functional Classification	TCM Figure	ROW Width (Feet)	Paving Width LOG-LOG (Feet)	Median Width LOG-LOG (Feet)	Curb Basis (Feet)	Design Speed (mph)	Typical Length of Street (Feet)	Typical Spacing of Cross Street (Feet)	Minimum Centerline Radius (Feet)	Side-walk Width (Feet)
Local										
Local, Residential	1-29	50	27	-	9.5	25, 30	<1500	300	180,300	4
Local, Non-Residential	1-30	65	37	-	12	25, 30	<1500	300	180,300	4
Local, Rural	1-31	90	27	-	27.5	25, 30	<1500	300	180,300	4
Collectors										
Local (No Parking)	1-32	65	27	-	17	30, 35	<1 mi	300	300,470	4
Local (w/Parking)	1-33	65	37	-	12	35	1-2 mi	500	470	4
Major (4-Lane)	1-34	80	48	-	14	35	<2 mi	500	470	4
Major (5-Lane)	1-35	90	60	-	13	35	<2 mi	500	470	4
Major (4-Lane Divided)	1-36	100	2@24	20	14	var	> 1mi	1000	var	5
Arterials										
MAD 4	1-37	100	2@24	20	14	45	>1 mi	1000	1000	5
MAD 6	1-38	124	2@36	20	14	45	>1 mi	1000	1000	5
MAD 8	1-39	150	2@48	20	17	50	>2 mi	1300	1400	5

Table 1-7 (Cont'd)
Geometric Design Criteria Summary Table

Functional Classification	Min. Tangent Length sep. curves	Max. Sust'nd Grade (%)	Max. Grade <500' (%)	Minimum Horizontal Tangent Length Approaching			Min. Spacing between Median Opening	Minimum Landing w/ Grade <2% Approaching		
				Loc	Col	Art		Loc	Col	Art
Local										
Local, Residential	50	9	9	50	50	50	-	50	50	50
Local, Non-Residential	50	9	9	50	50	50	-	50	50	50
Local, Rural	50	9	9	50	50	50	-			
Collectors										
Local (No Parking)	100	7	7	50	50	50	-	80	80	100
Local (w/Parking)	100	7	7	50	50	50	-	80	80	125
Major (4-Lane)	100	7	7	50	75	75	-	80	80	125
Major (5-Lane)	100	7	7	50	75	75	-	80	80	125
Major (4-Lane Divided)	100	7	7	50	75	75	Var	80	100	125
Arterials										
MAD 4	150	6	6	-	75	75	450 Minimum 750 Desirable	-	125	125
MAD 6	200	6	6	-	75	75	450 Minimum 750 Desirable	-	125	125
MAD 6	200	6	6	-	75	100	450-750	-	125	125

1.4.0 RESERVED FOR FUTURE EXPANSION

1.5.0 RESERVED FOR FUTURE EXPANSION

1.6.0 HIGHWAYS

A. All highway designs should conform with the latest edition of the State Department of Highways and Public Transportation (SDHPT) Highway Design Division Operations and Procedures Manual and must be approved by the SDHPT District Engineer.

B. The latest edition of the Highway Design Division Operations and Procedures Manual should be consulted for complete design details.

1.7.0 FIGURES

Figure 1-1 Relationship of Street Classification with Access and Mobility

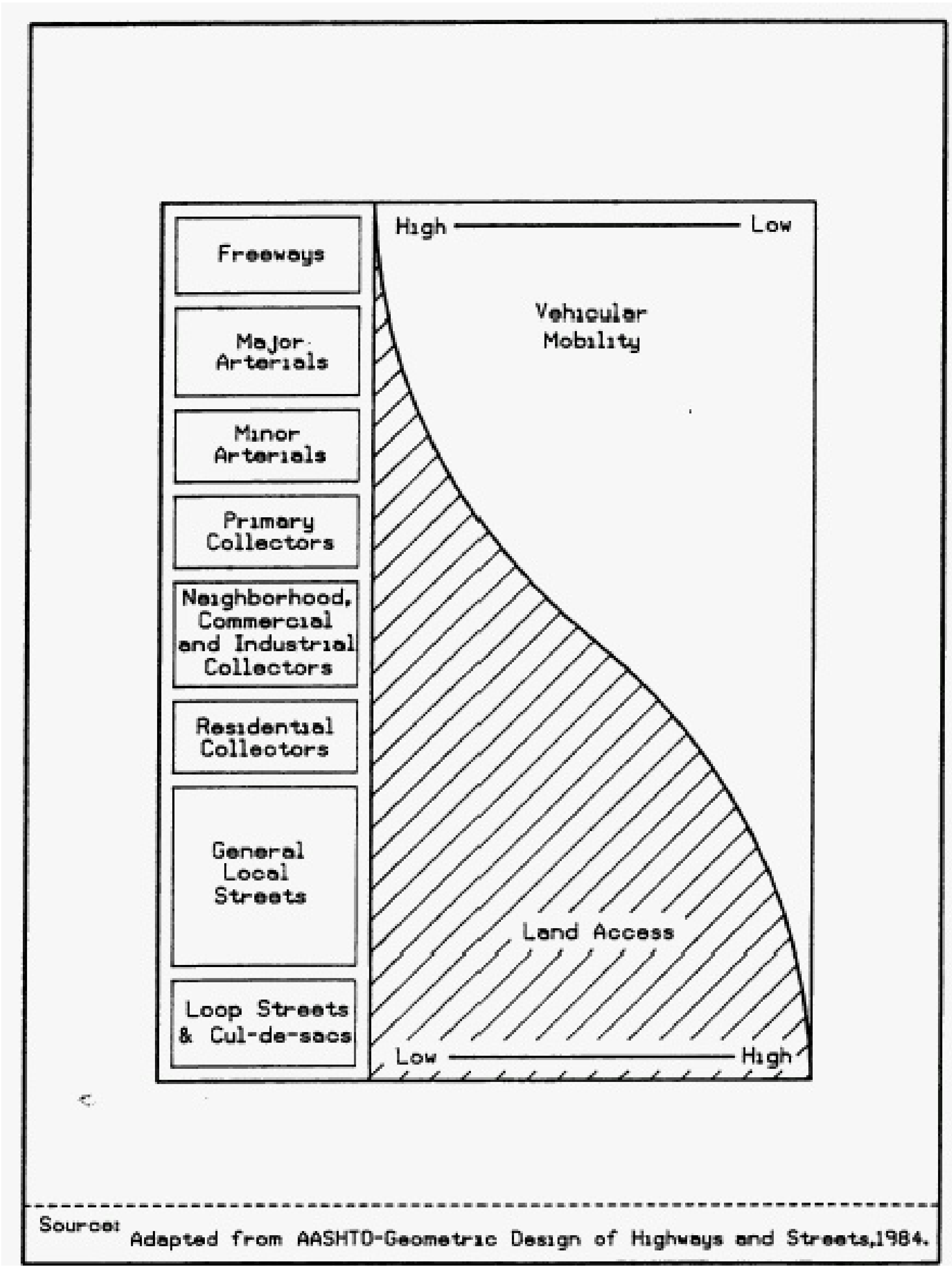


Figure 1-2 Types of Vertical Curves

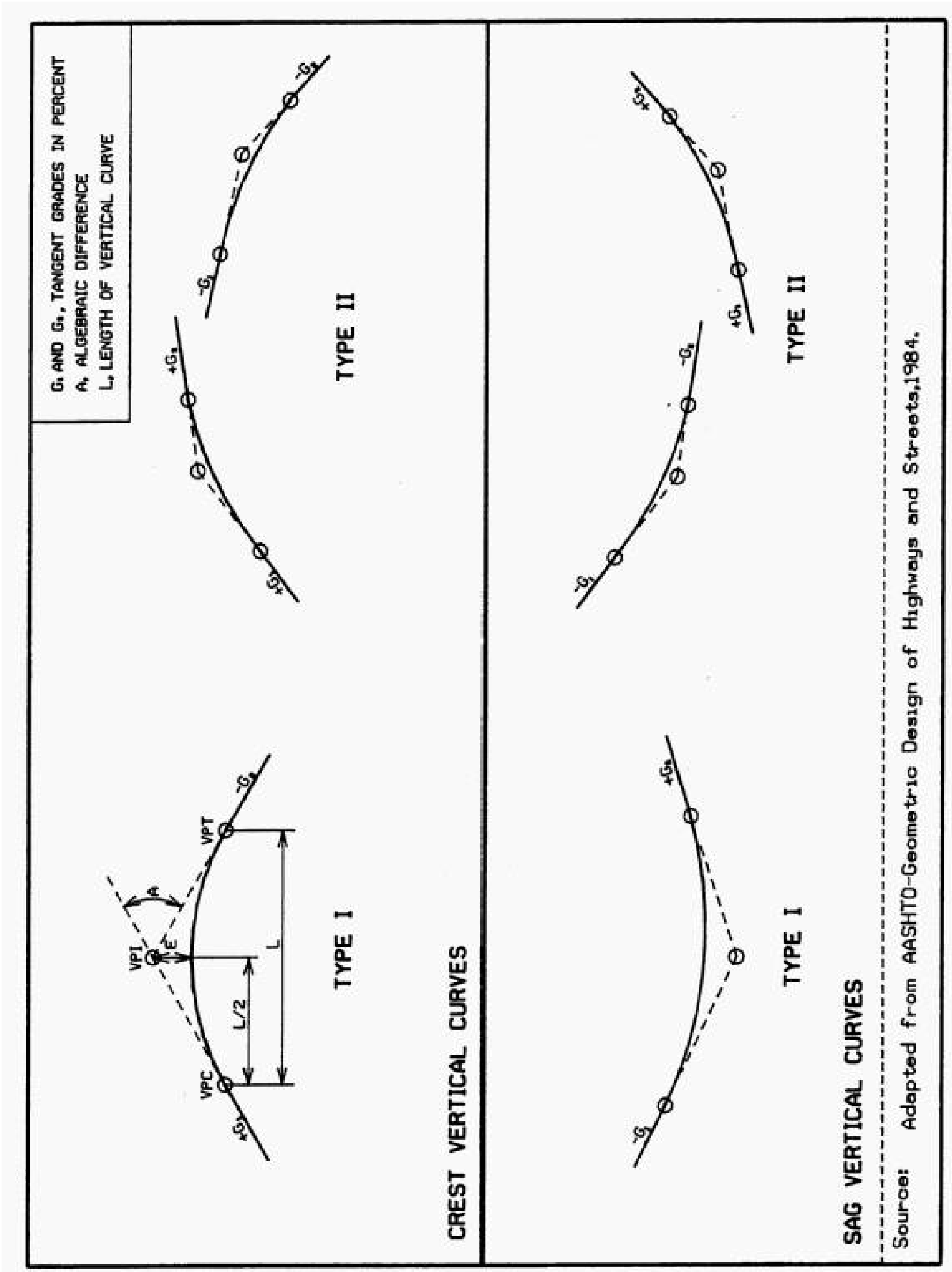


Figure 1-3 Design Controls for Crest Vertical Curves

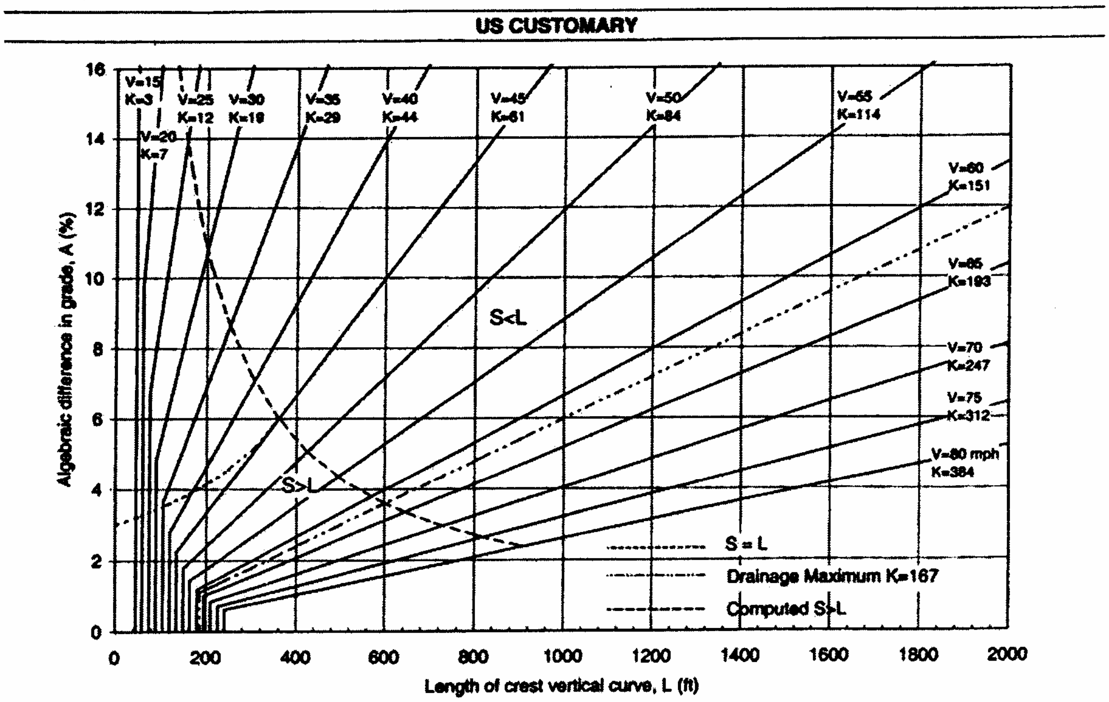


Figure 1-4 Design Controls for Sag Vertical Curves

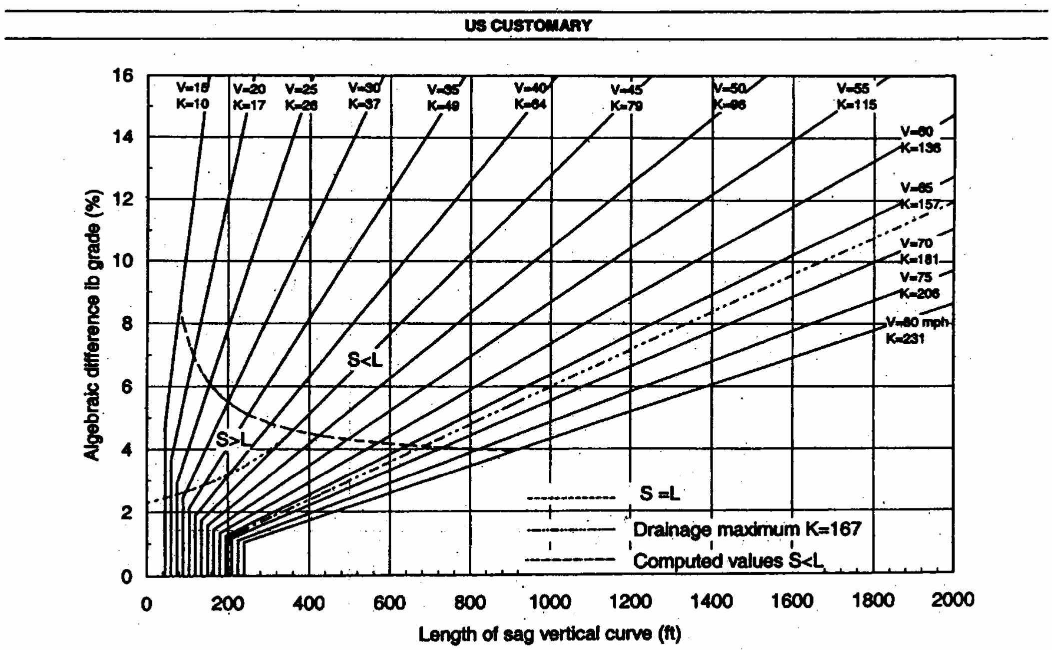
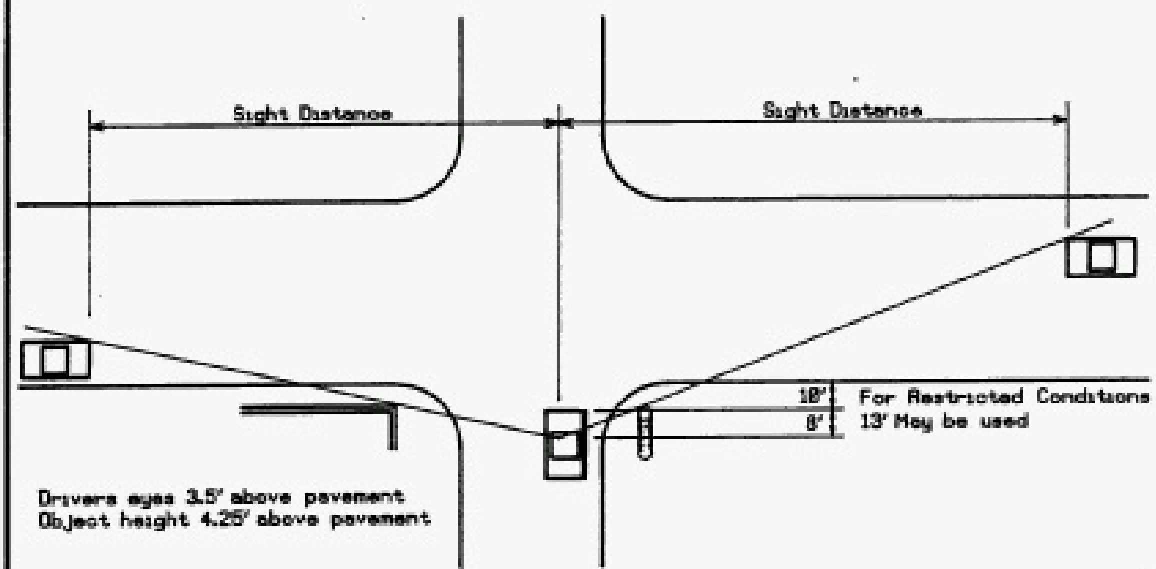
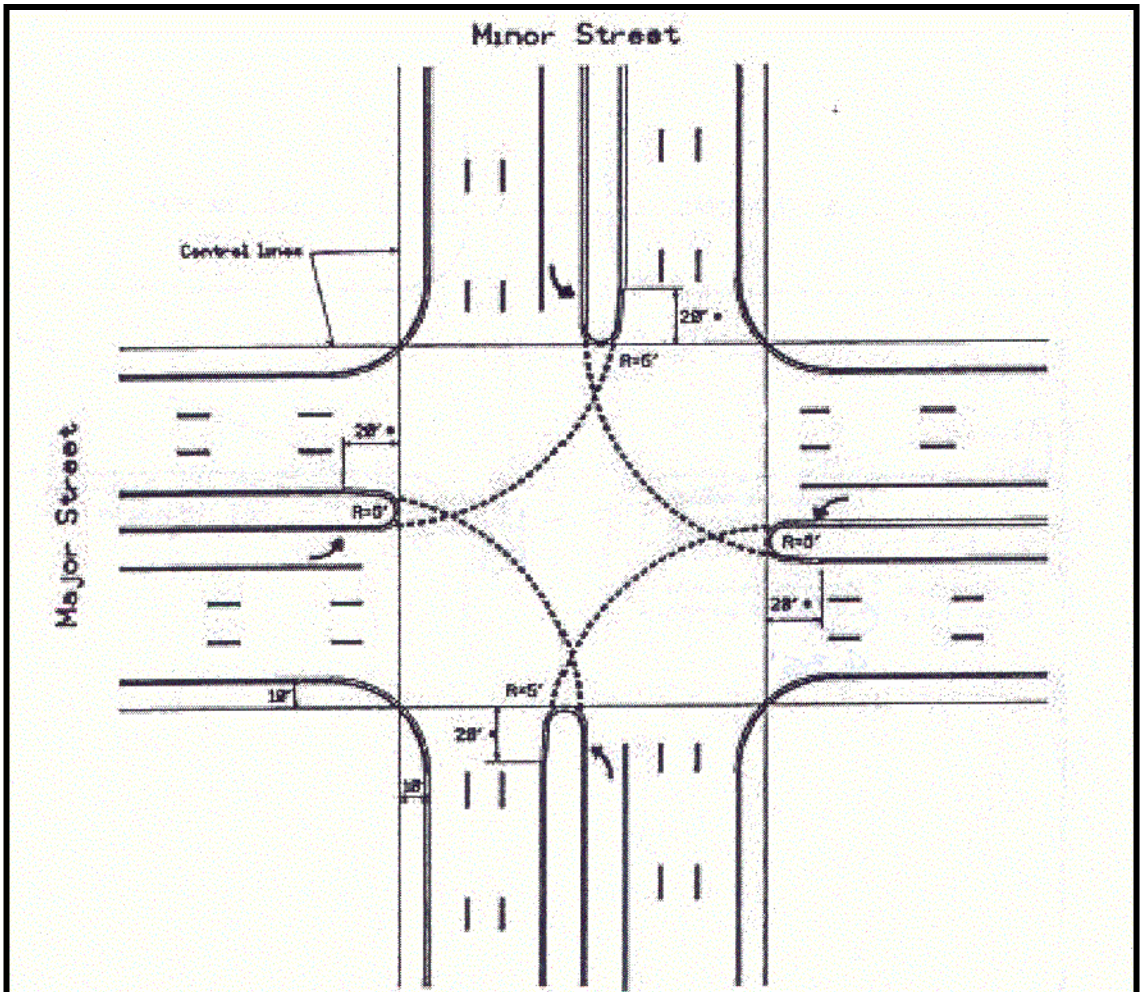


Figure 1-5 Desirable Sight Triangle



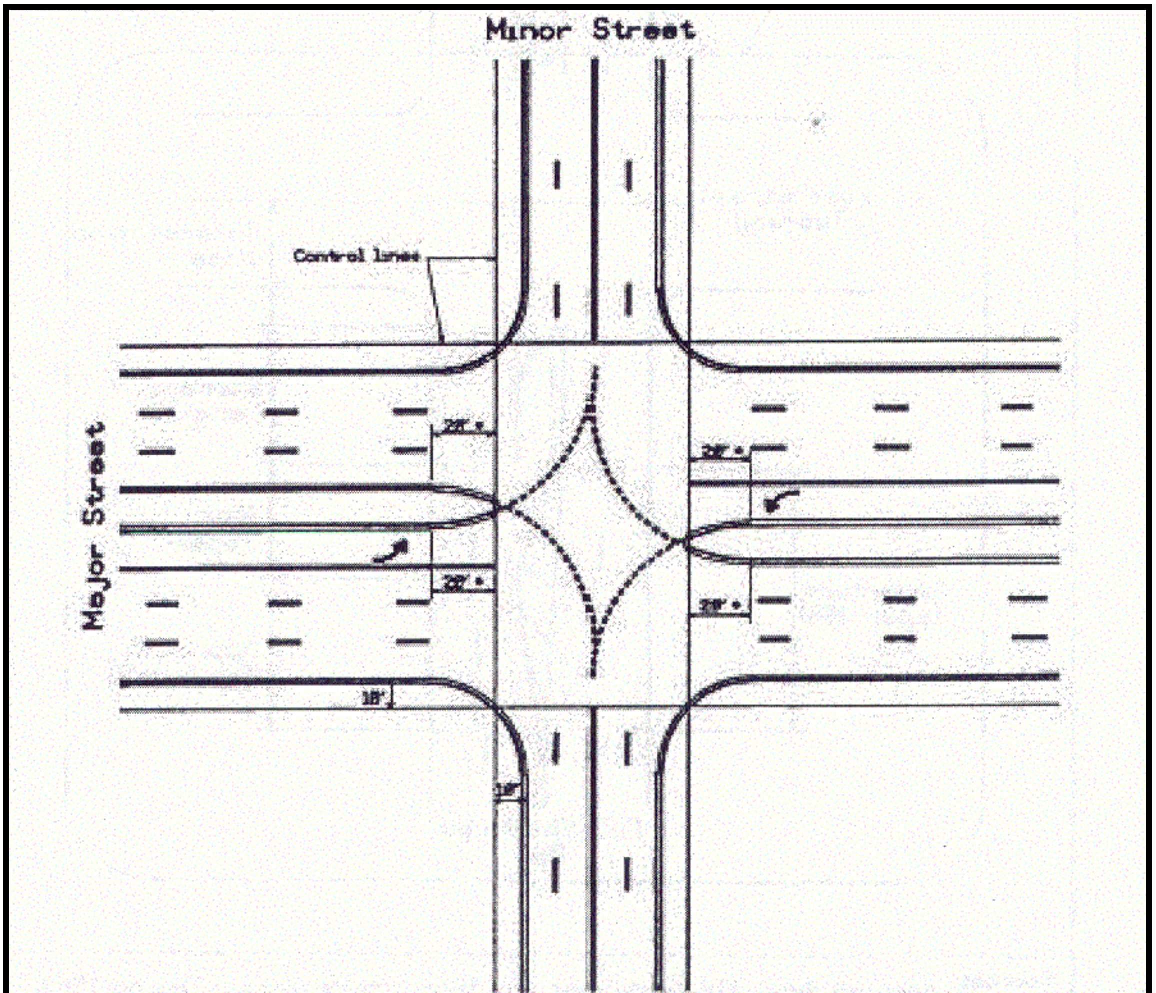
Source: Adapted from ITE, Guidelines for Urban Major Street Design, 1983.

Figure 1-6 Intersection Nose Treatment, Six Lane Divided Roadways



* Distance may vary on skewed intersections, provided that the 75' control radius is achieved.

Figure 1-7 Intersection Nose Treatment, Six Lane Divided and Neighborhood Collector



* Distance may vary on skewed intersections, provided that the 50
control radius is achieved.

Figure 1-8 Design Elements of Left Turn Bay Channelization

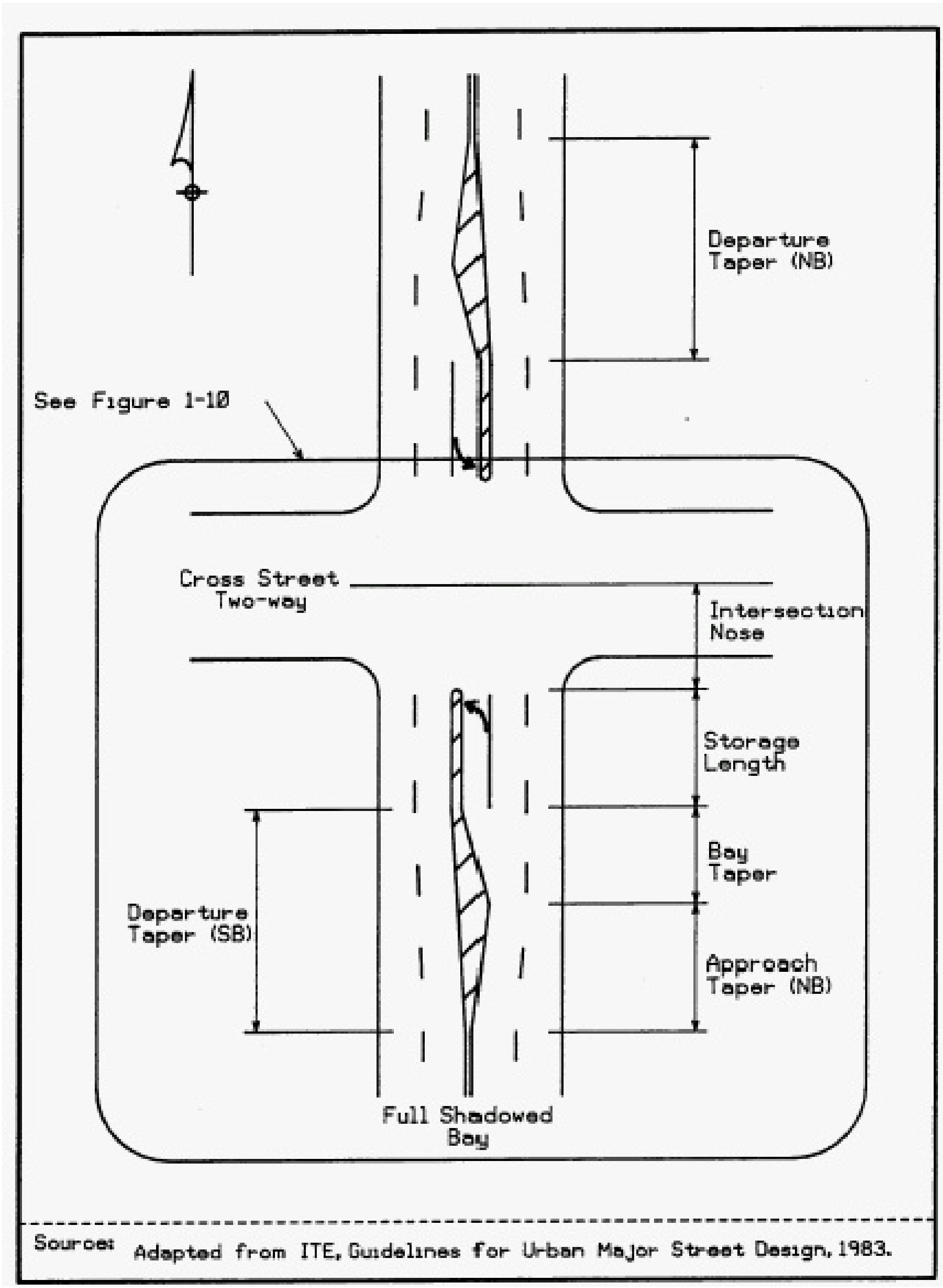


Figure 1-9 Left Turn Channelization

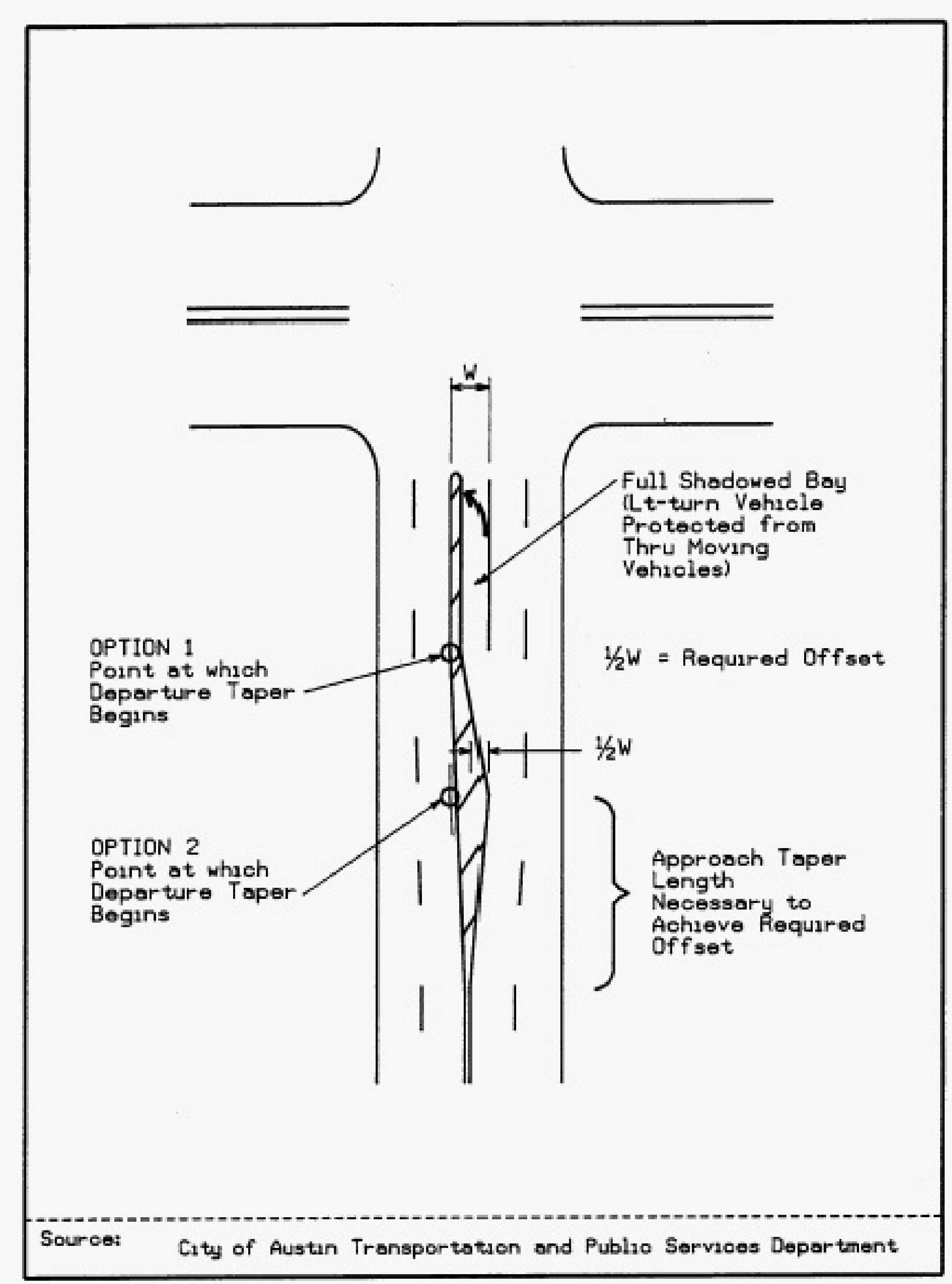
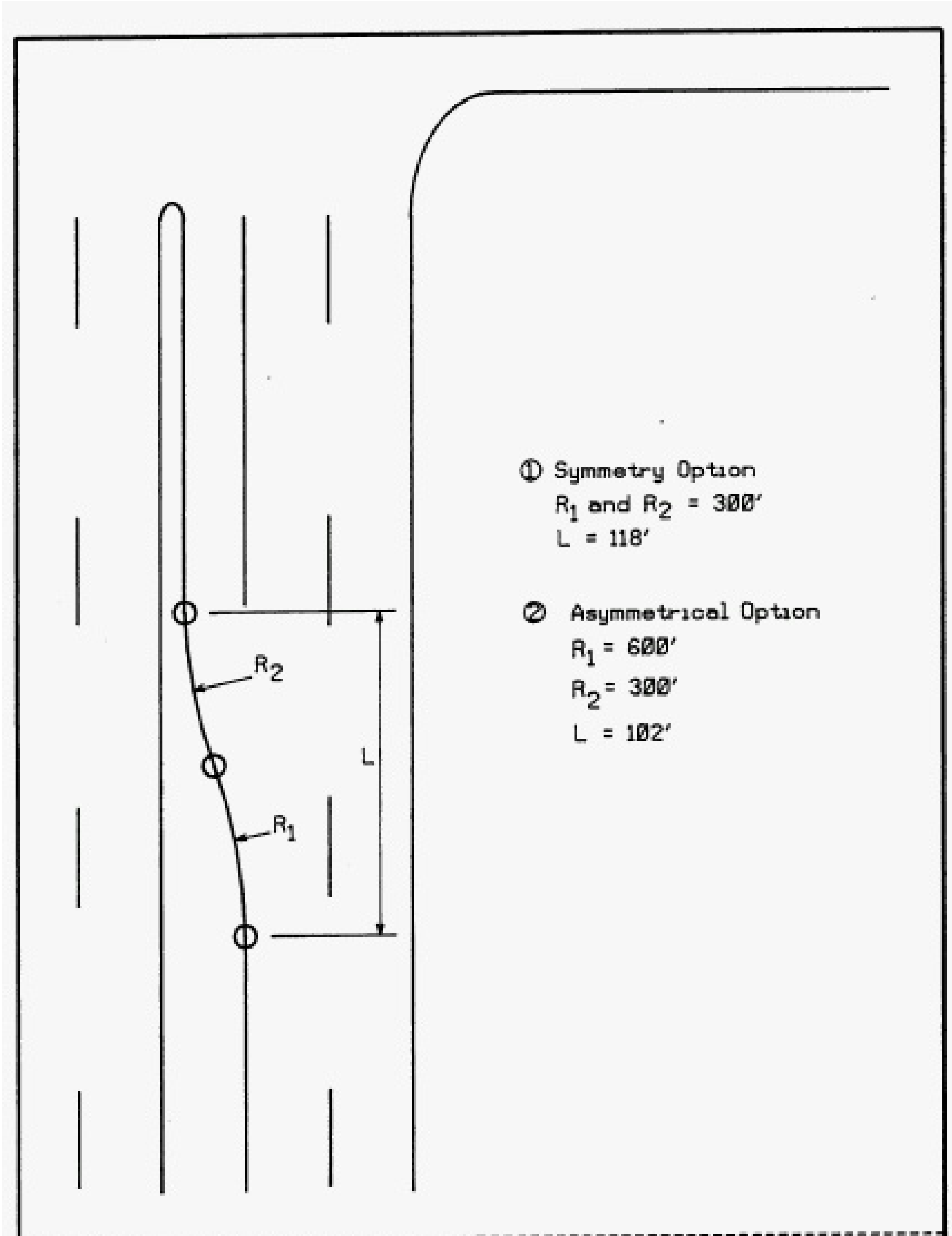
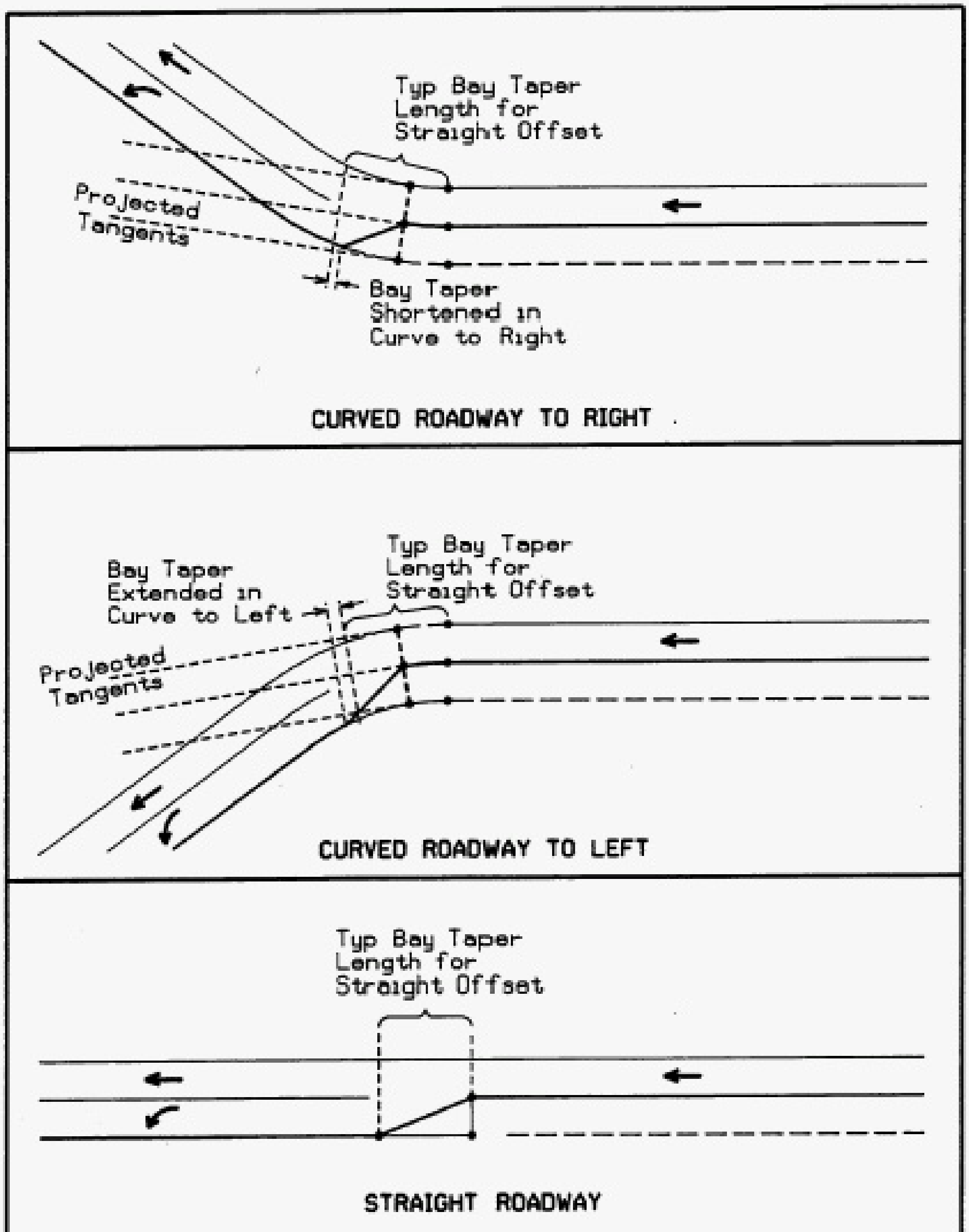


Figure 1-10   Turn Bay Taper Design



Source: City of Austin Transportation and Public Services Department

Figure 1-11 Effects of Curves on Turn Bay Taper Design



Source: Adapted from ITE, Guidelines for Urban Major Street Design, 1983.

Figure 1-12 Typical Median Application for Providing Left Turn Deceleration and Storage into Driveways or Cross Streets

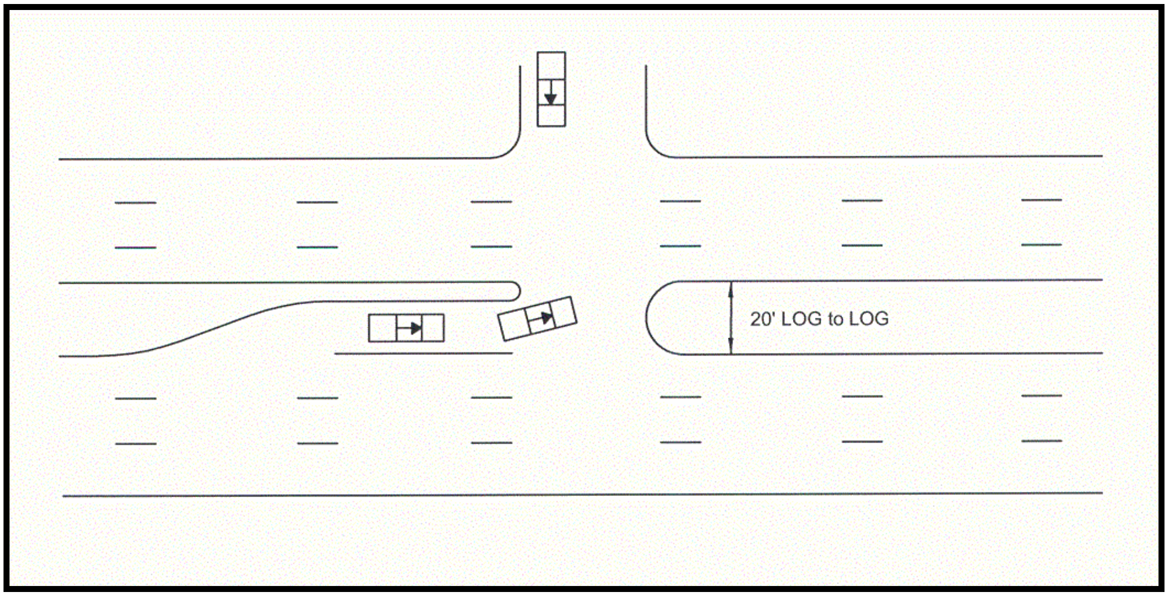


Figure 1-13 Typical Median Application for Providing Crossing Vehicle Protection from a Driveway or Cross Street

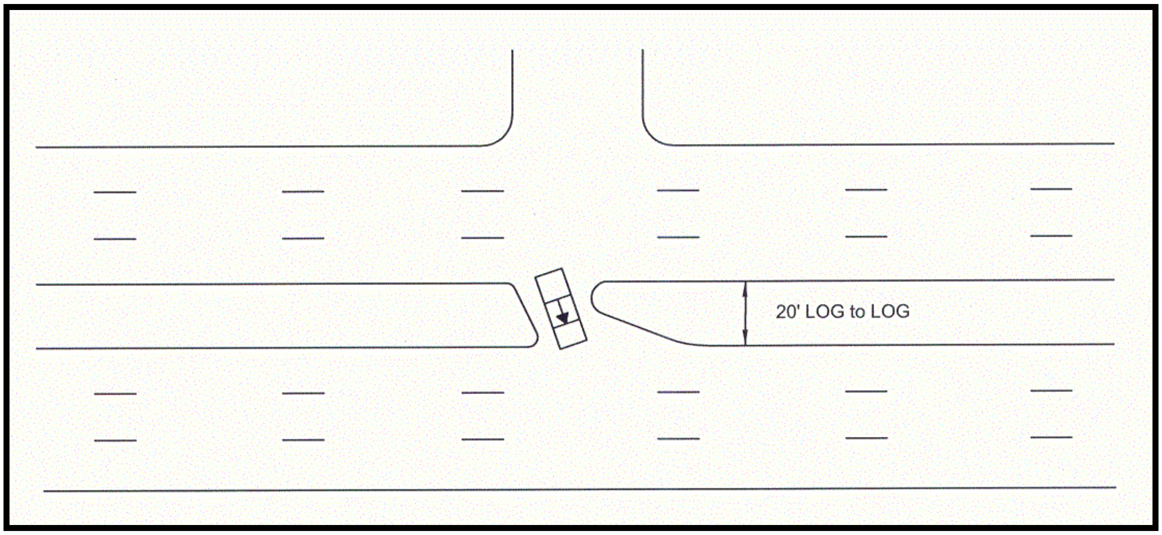


Figure 1-14 Typical Median Application Limiting Movement to Entering Left Turn - One Direction

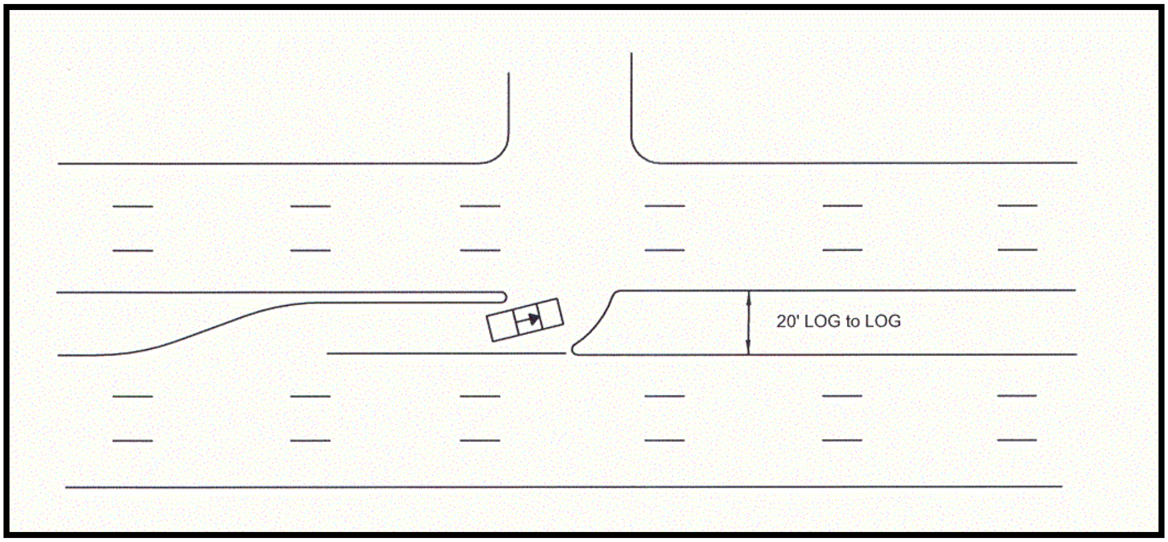


Figure 1-15 Typical Median Application Limiting Movement to Entering Left Turn - Two Directions

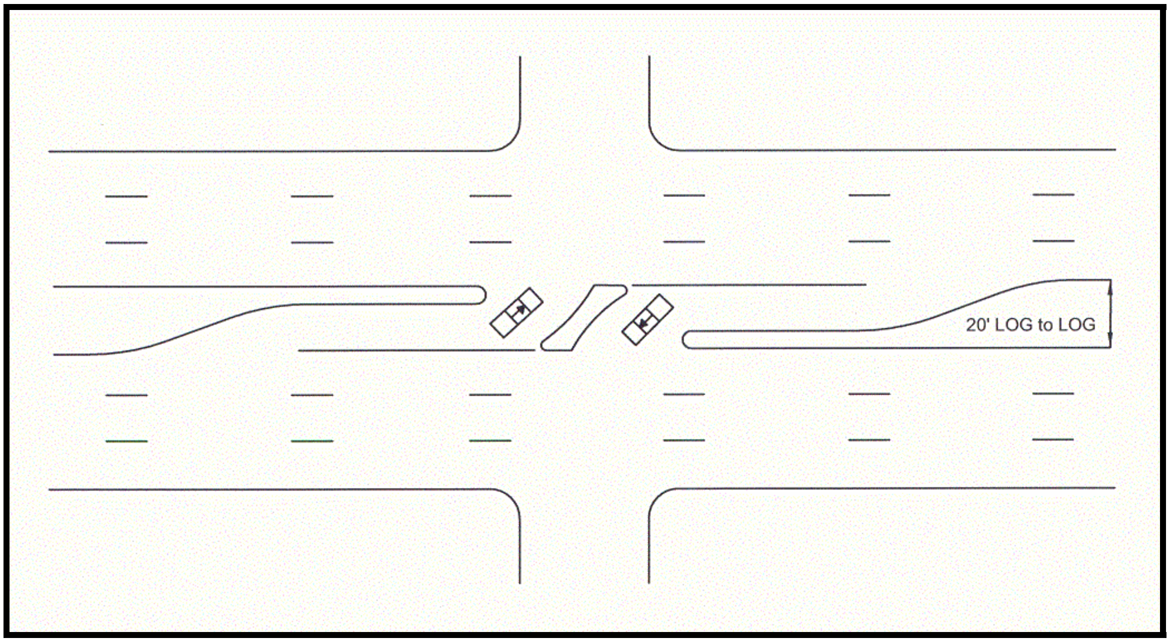


Figure 1-16 Typical Median Application Providing "U" Turn Movements

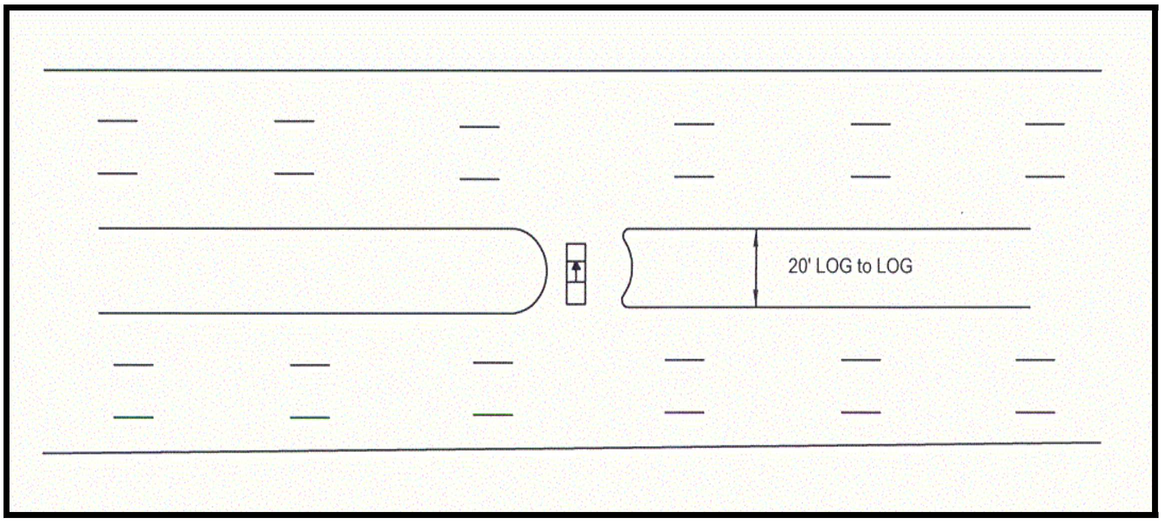


Figure 1-17   Typical Median Application, Channelized "T"

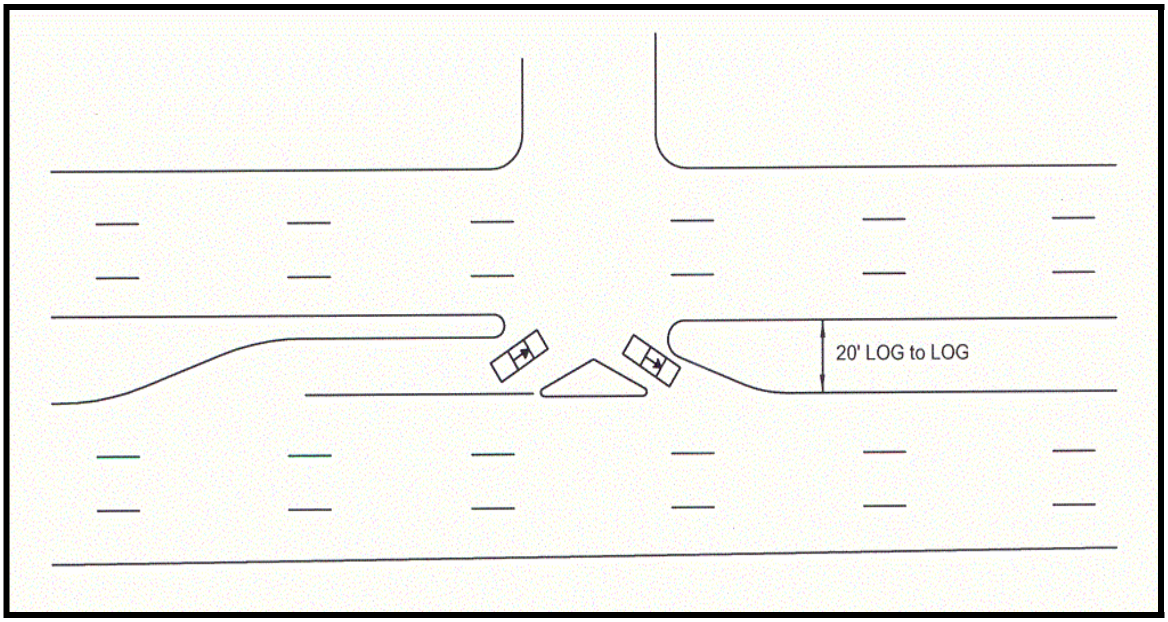
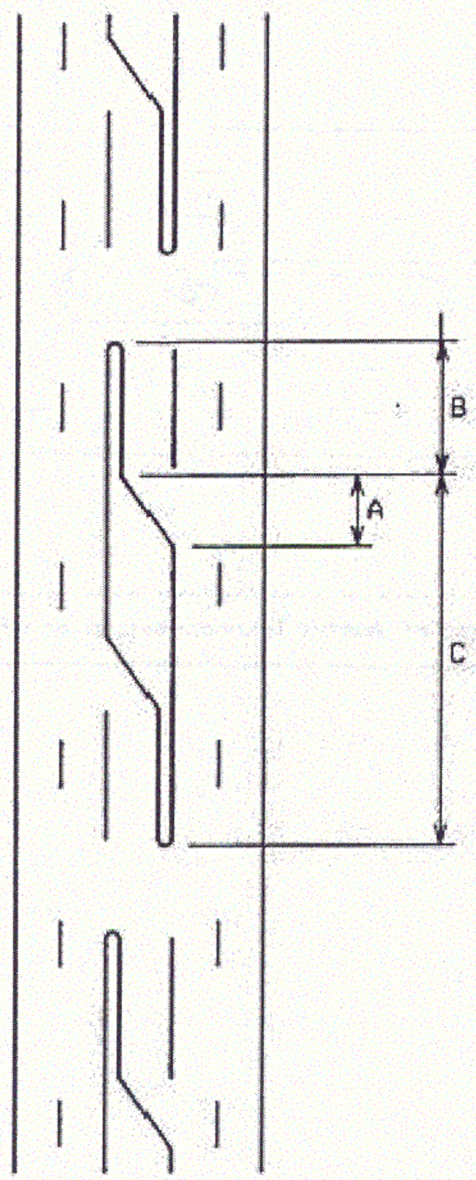


Figure 1-18   Median Breaks



Distance A = Bay Taper from Figure 1-9
Distance B = Storage Length from Table 1-5
Distance C = Required Spacing from Table 1-4

Figure 1-19 Typical Median Opening Layout

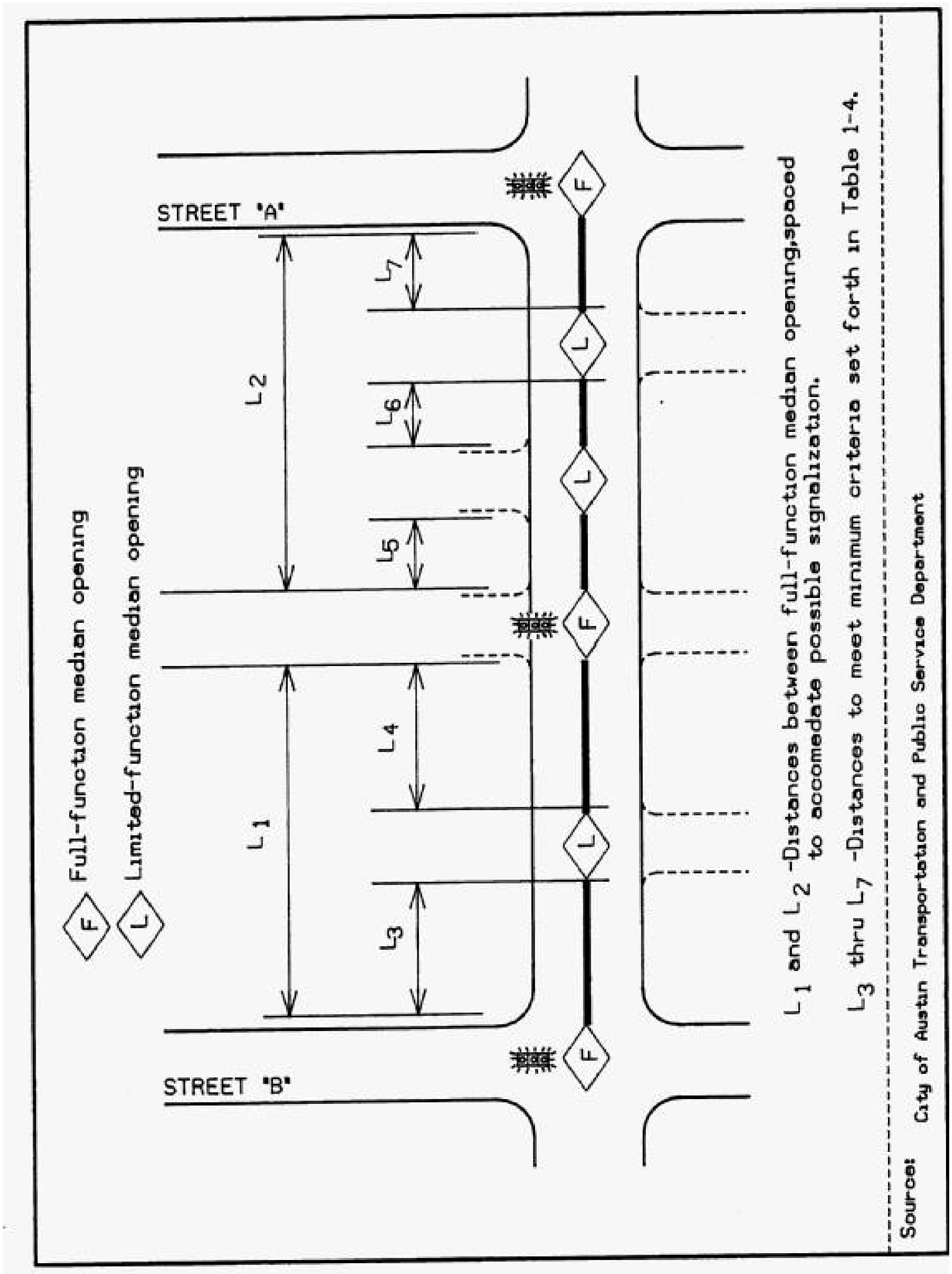
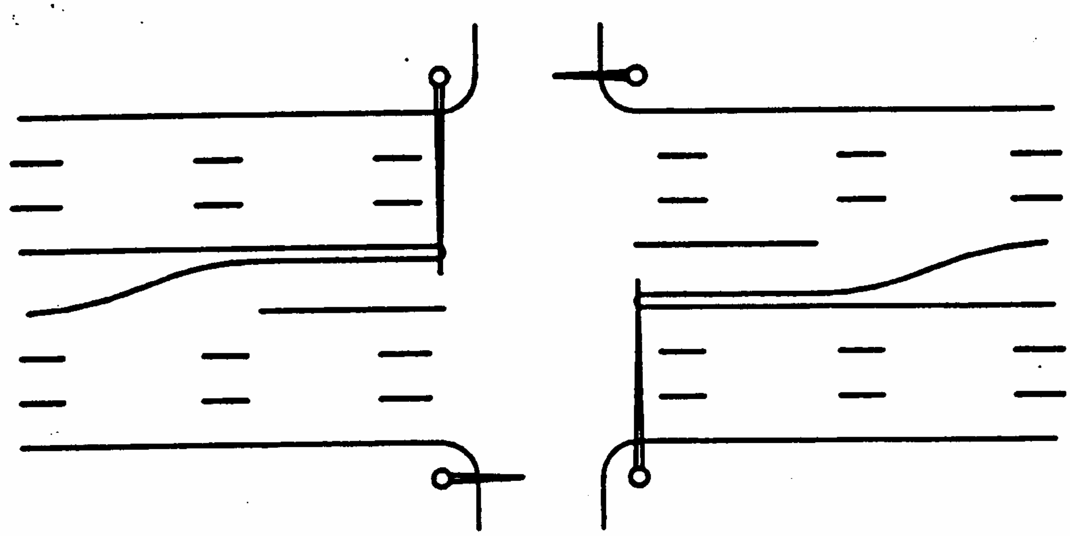


Figure 1-20 Typical Median Application, Full Function



Source: City of Austin Transportation and Public Services Department

Figure 1-21 Design Criteria for Elbow Streets

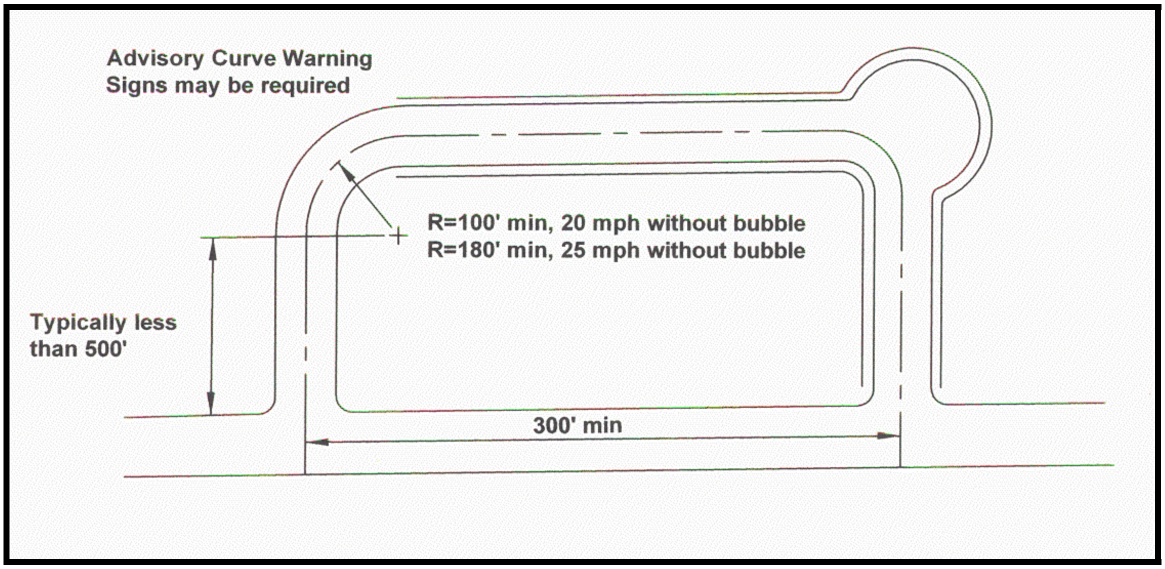


Figure 1-22   Design Criteria for Corner Bubble

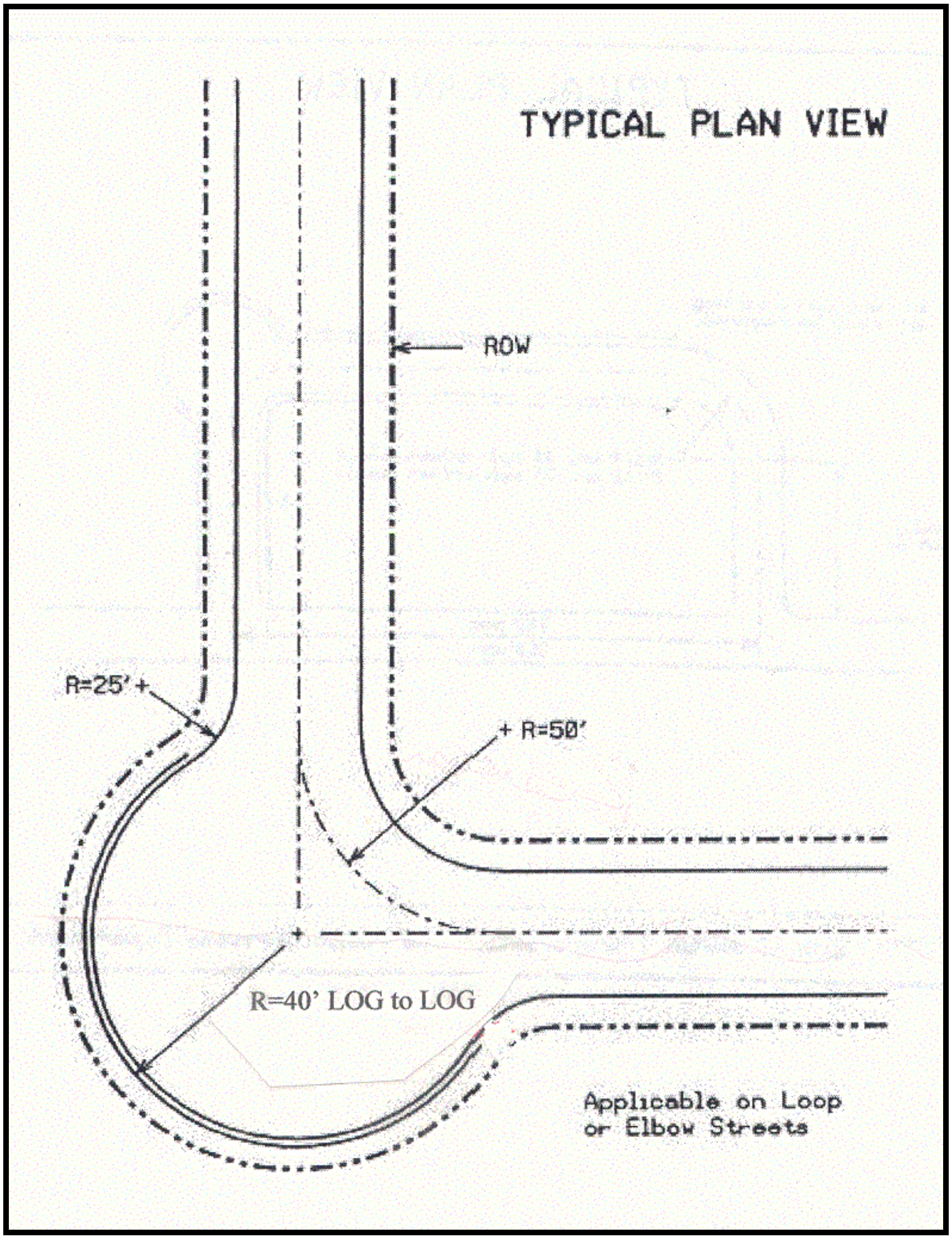


Figure 1-23   Design Criteria for Local Cul-de-Sac

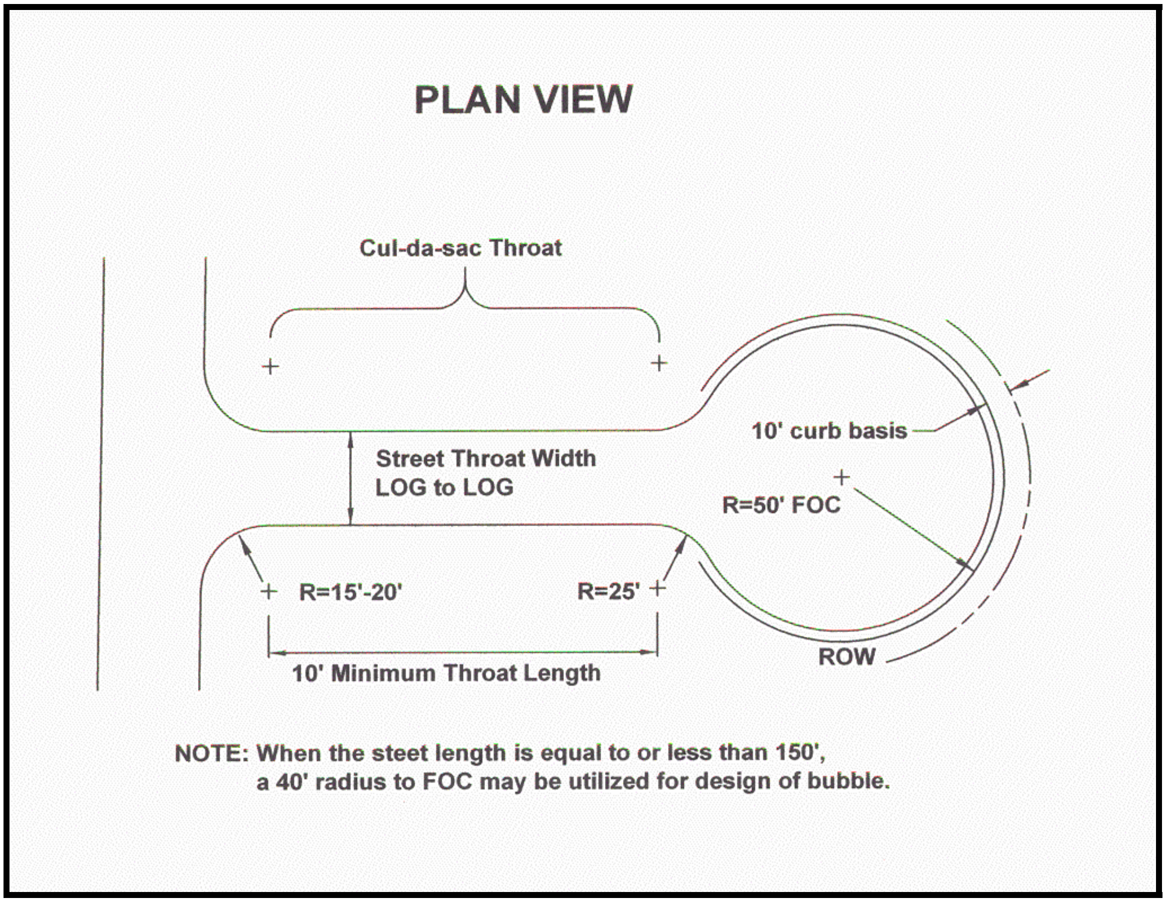


Figure 1-24 Design Criteria for Commercial Cul-de-Sac

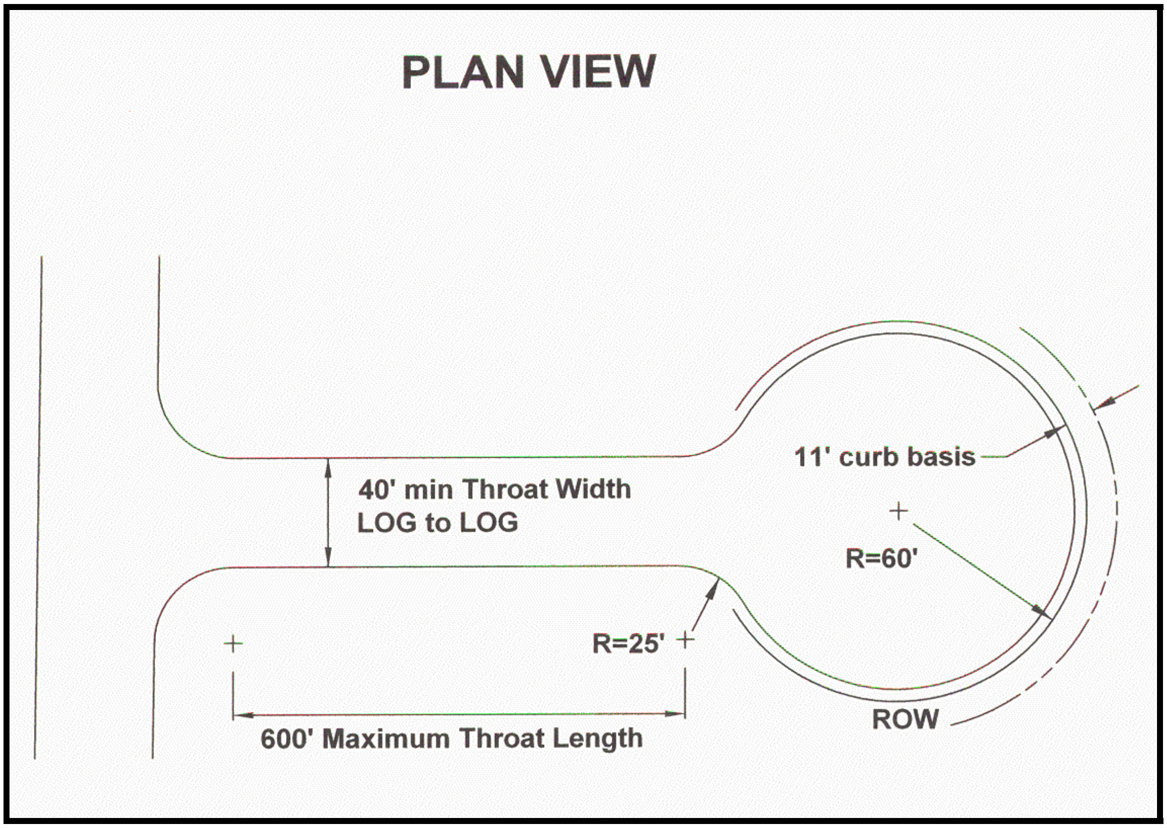


Figure 1-25 Design Criteria for Industrial Cul-de-Sac

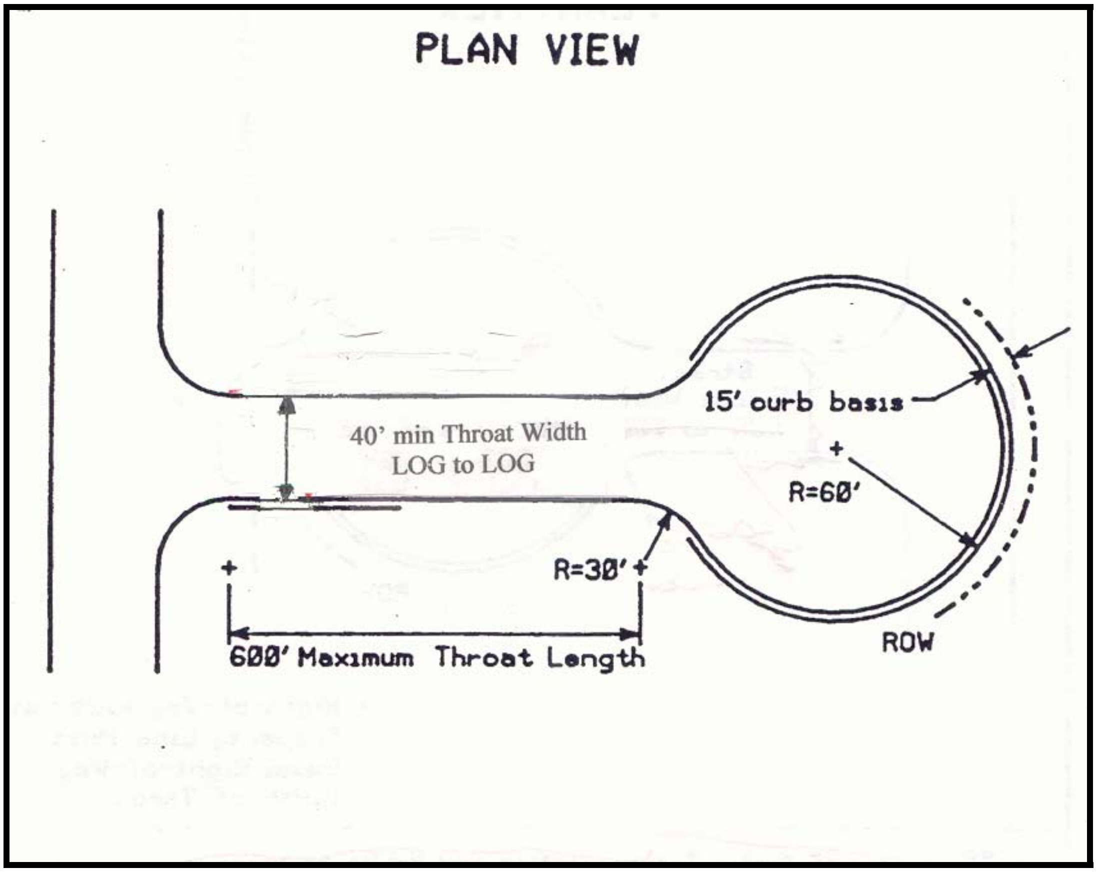


Figure 1-25A Design Criteria for Open-Ended Cul-de-Sac

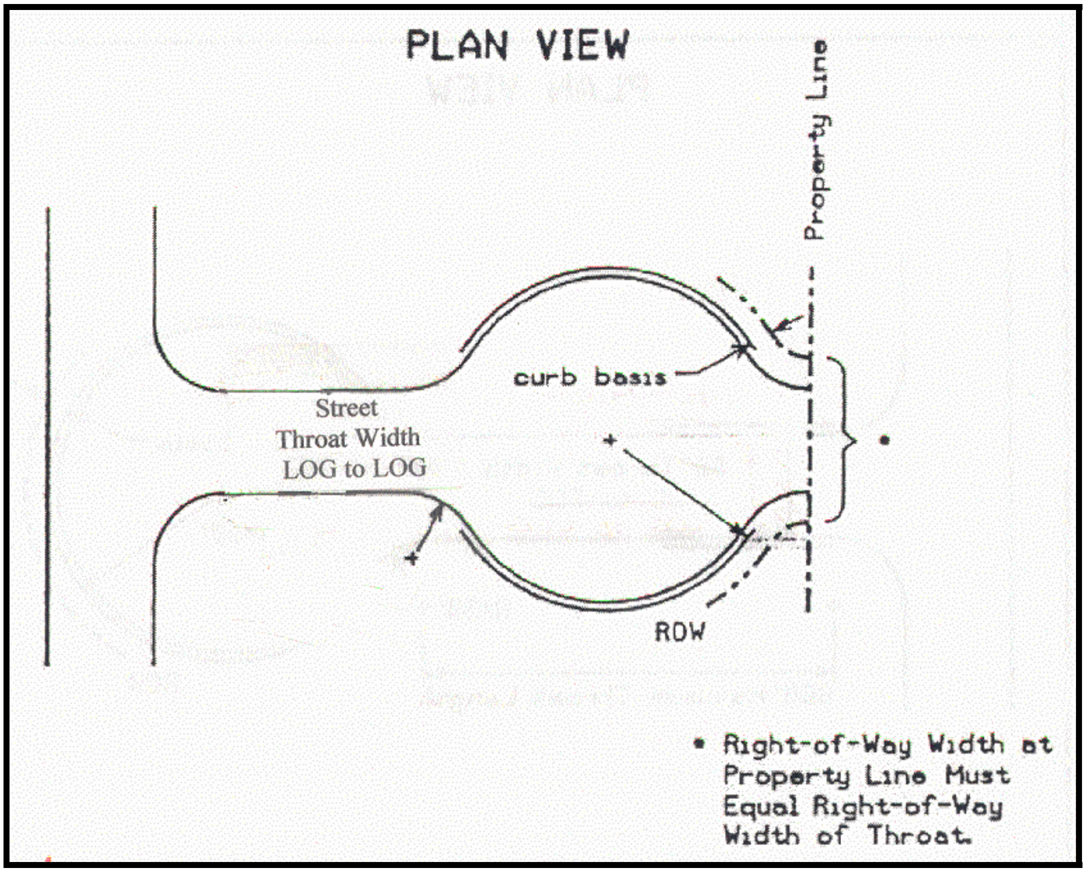


Figure 1-26 Design Criteria for One-Way Alleys

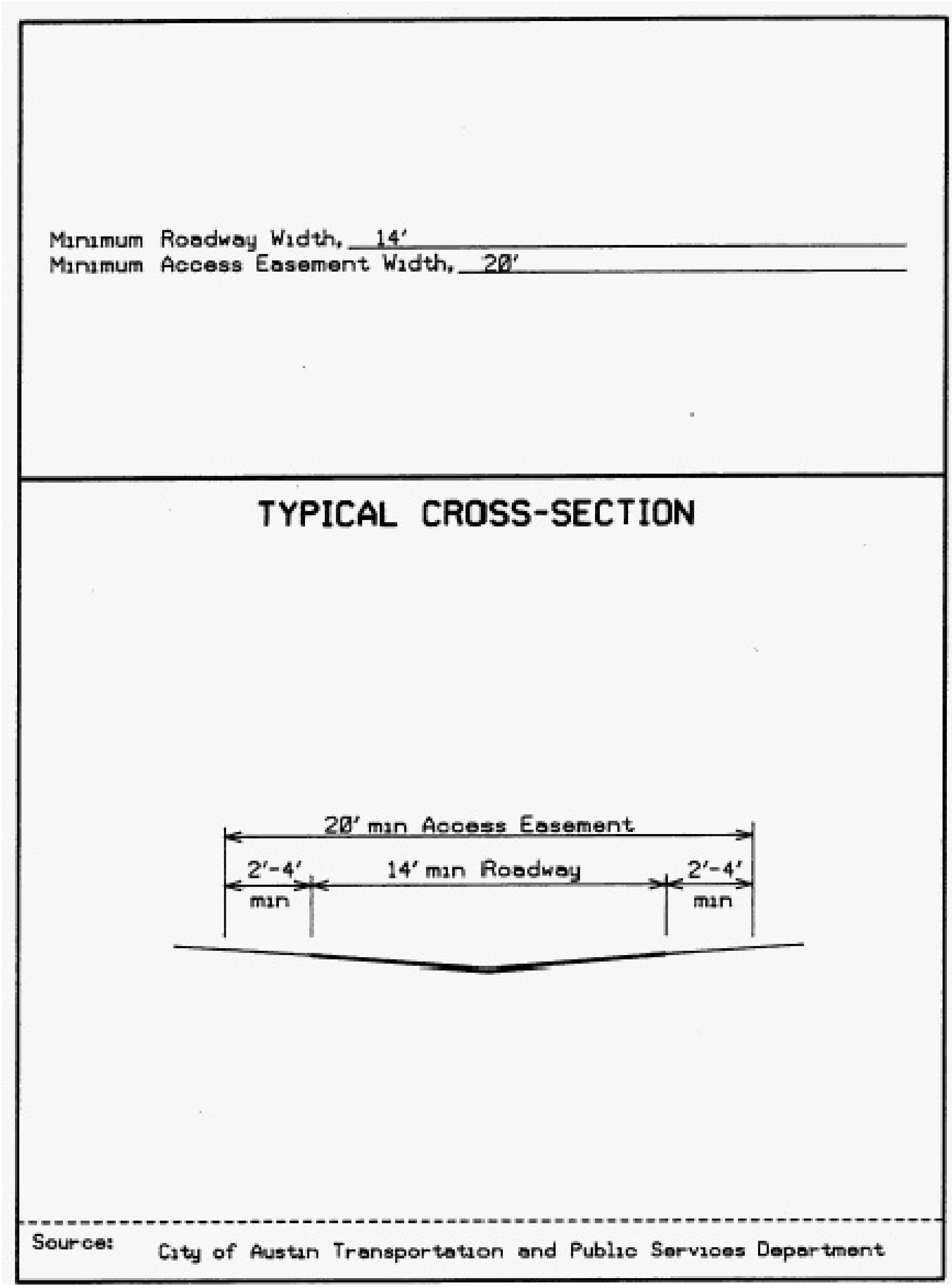


Figure 1-27   Design Criteria for Two-Way Alleys

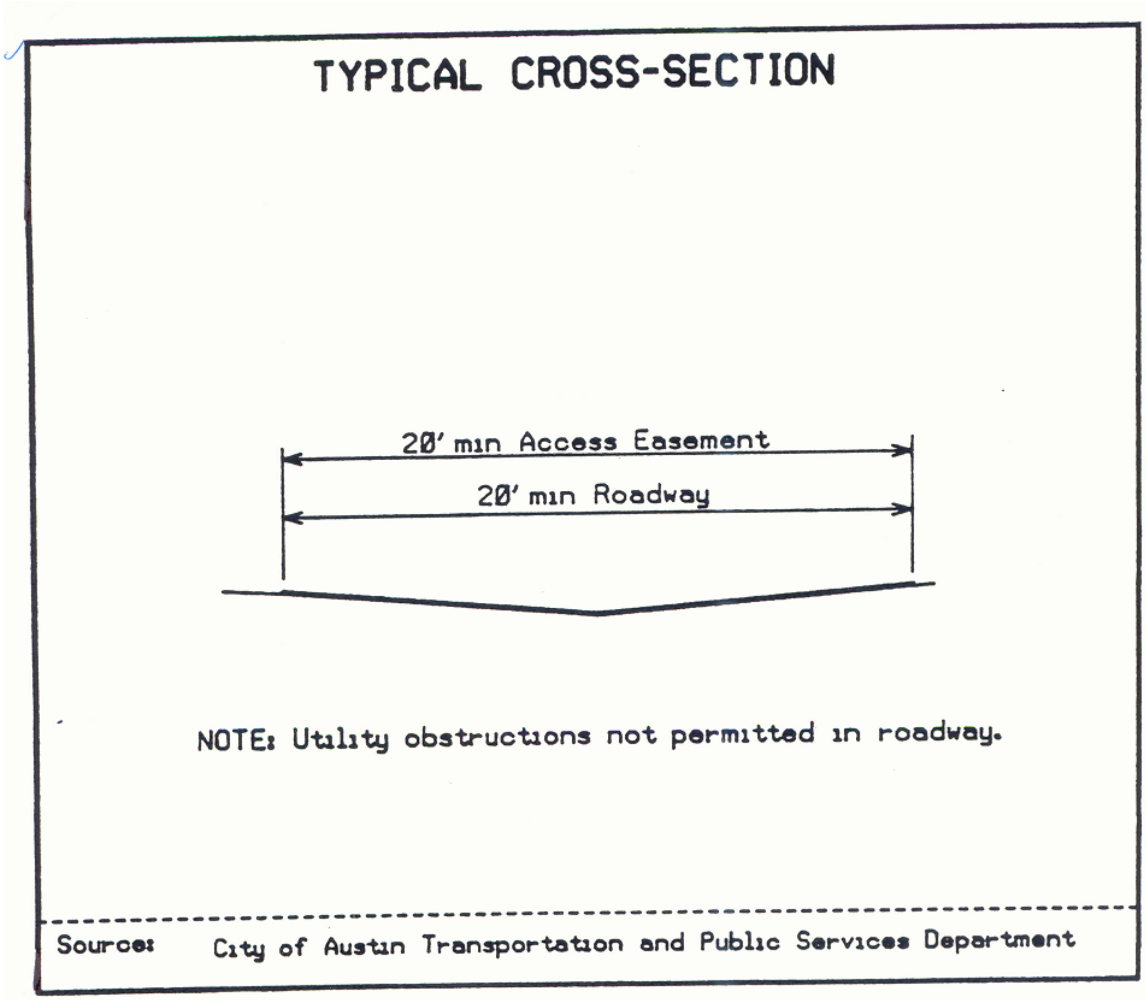


Figure 1-28   Cul-de-Sacs and Single Outlet Streets

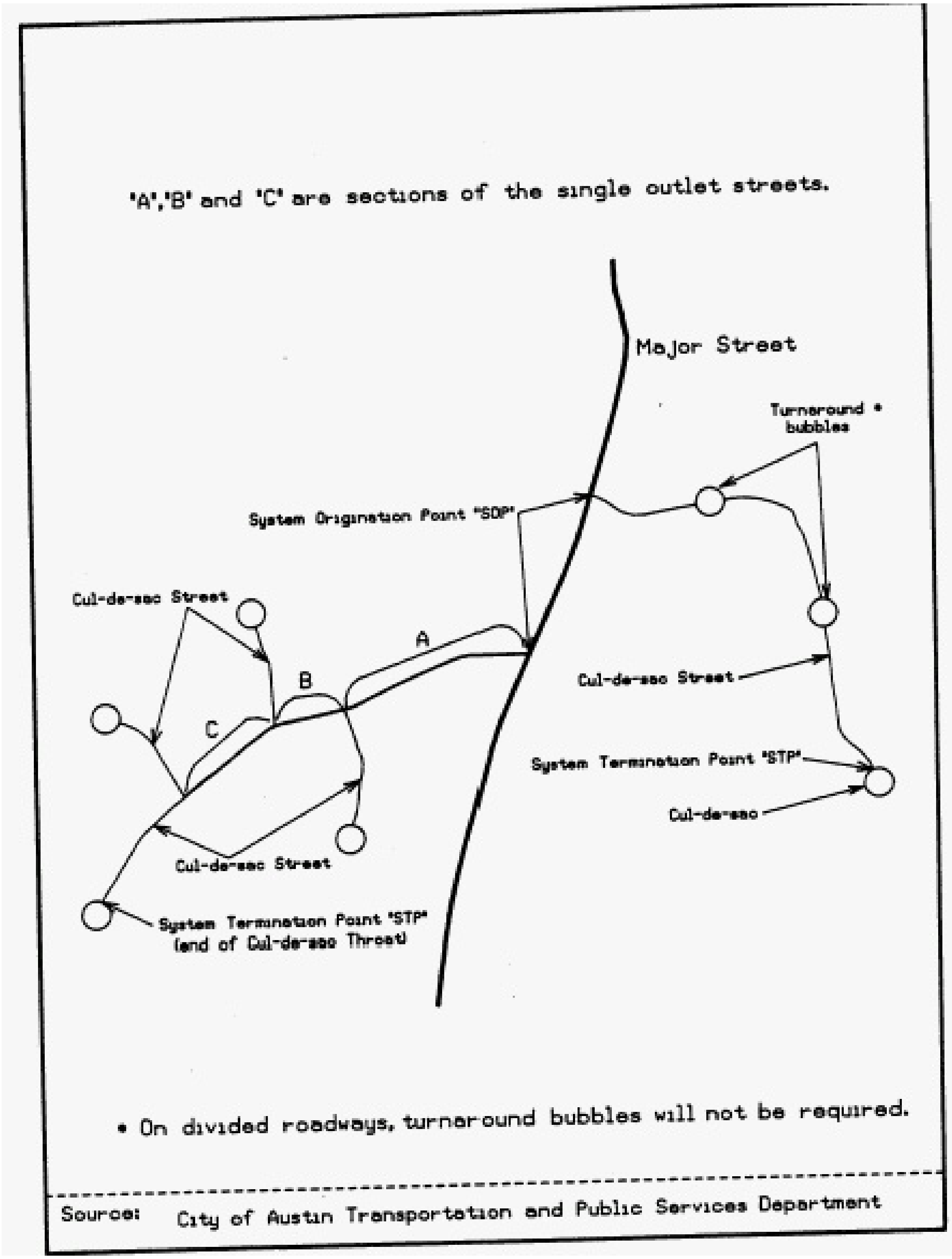


Figure 1-29 Design Criteria for Local Residential Streets

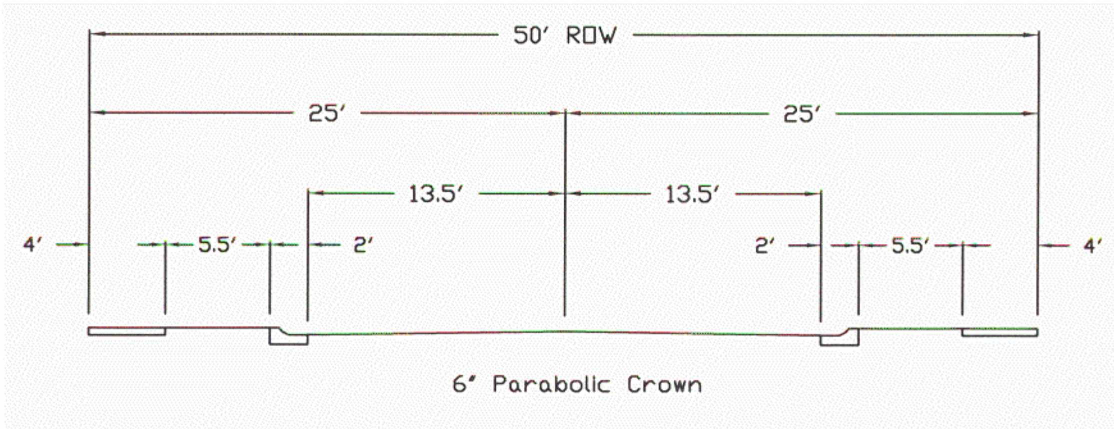


Figure 1-30 Design Criteria for Local, Non-Residential Streets

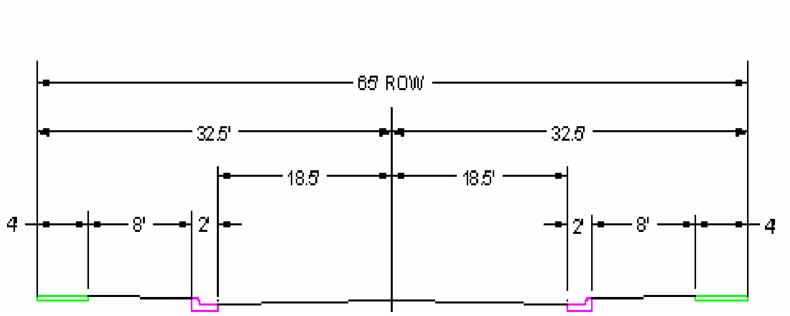


Figure 1-31 Design Criteria for Local Rural Street

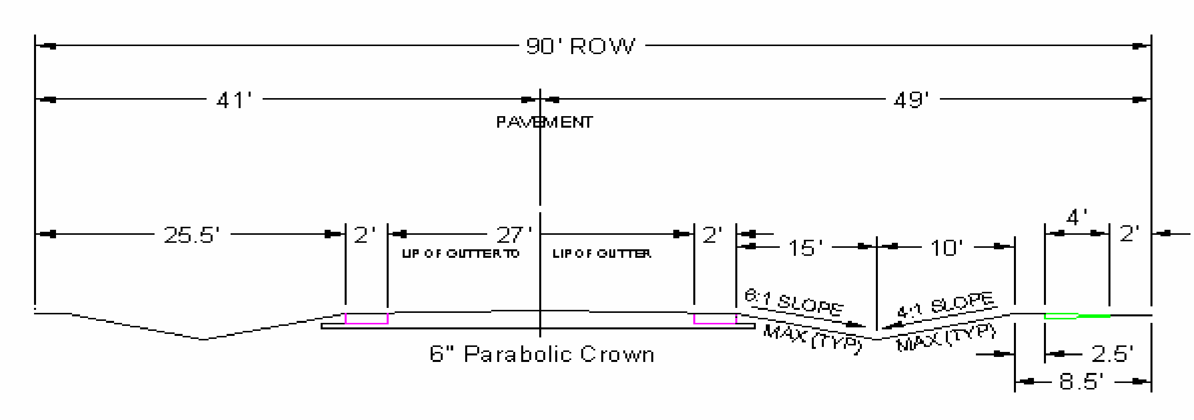


Figure 1-32 Design Criteria for Local Collector (without Parking)

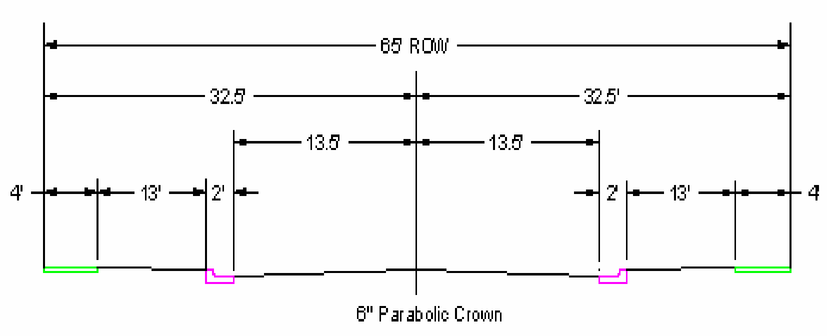

65' ROW
32.5'
32.5'
13.5'
13.5'
4'
13'
2'
2'
13'
4'
6" Parabolic Crown

Figure 1-33 Design Criteria for Local Collector (with Parking)

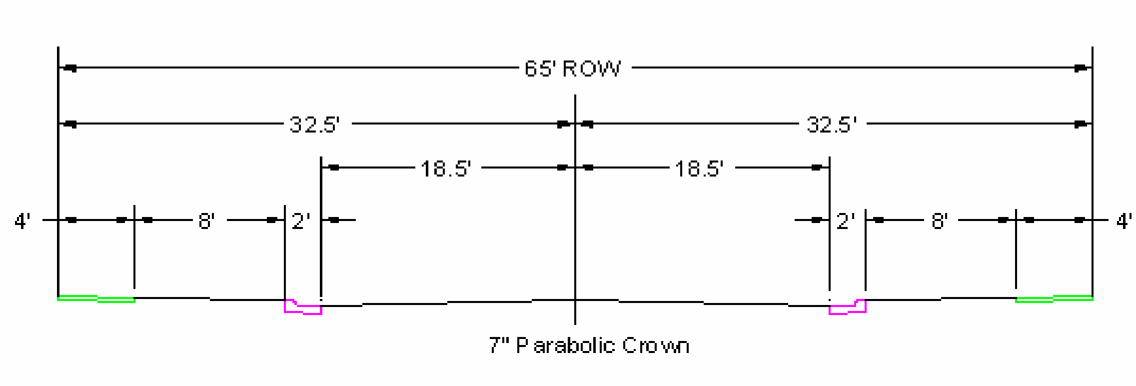


Figure 1-34 Design Criteria for Major Collector (4-lane)

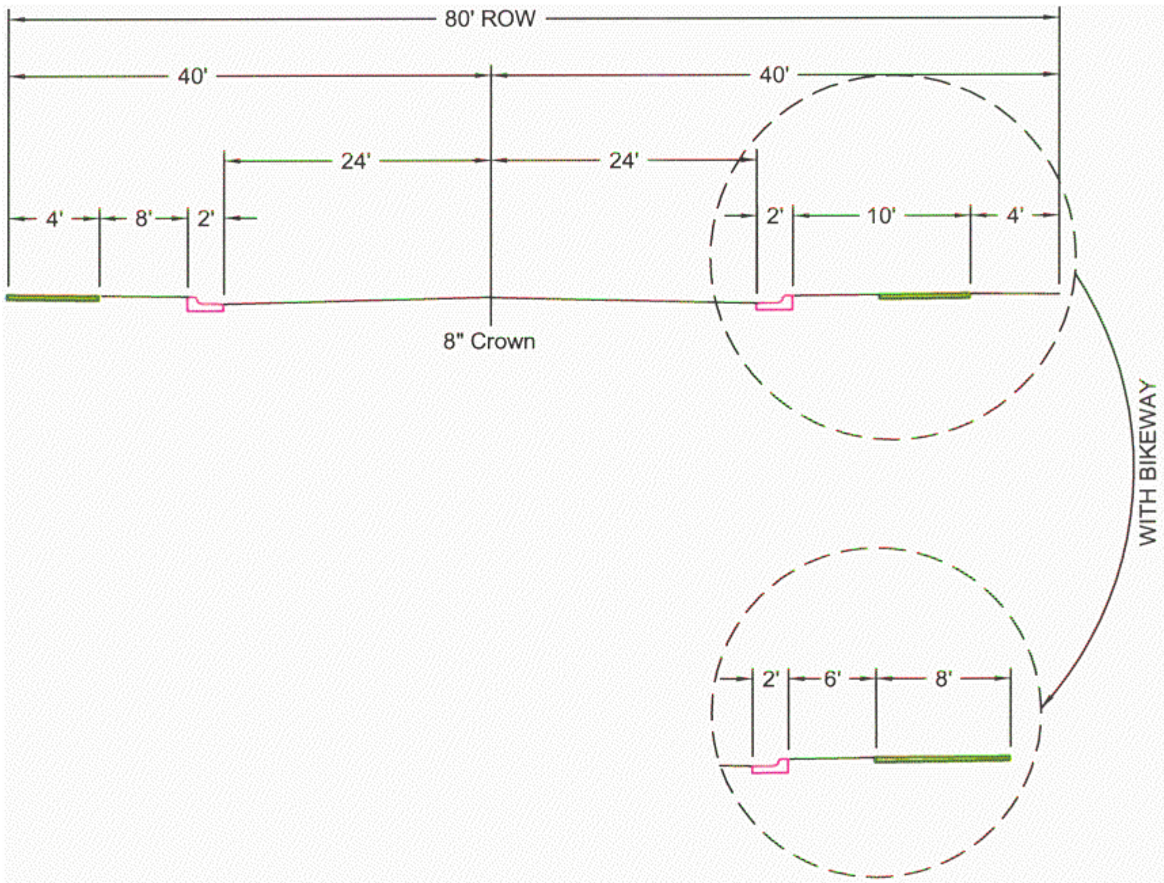


Figure 1-35 Design Criteria for Major Collector (5-lane)

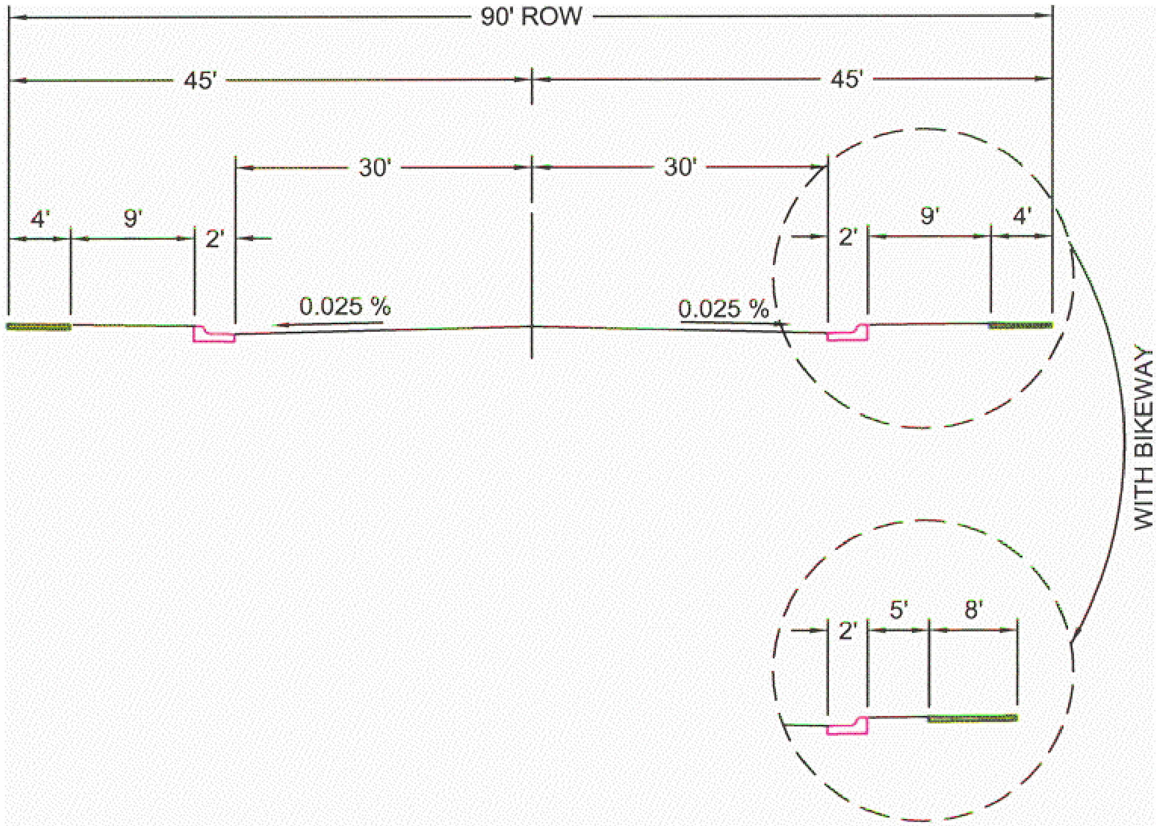


Figure 1-36 Design Criteria for Major Collector (4-lane Divided)

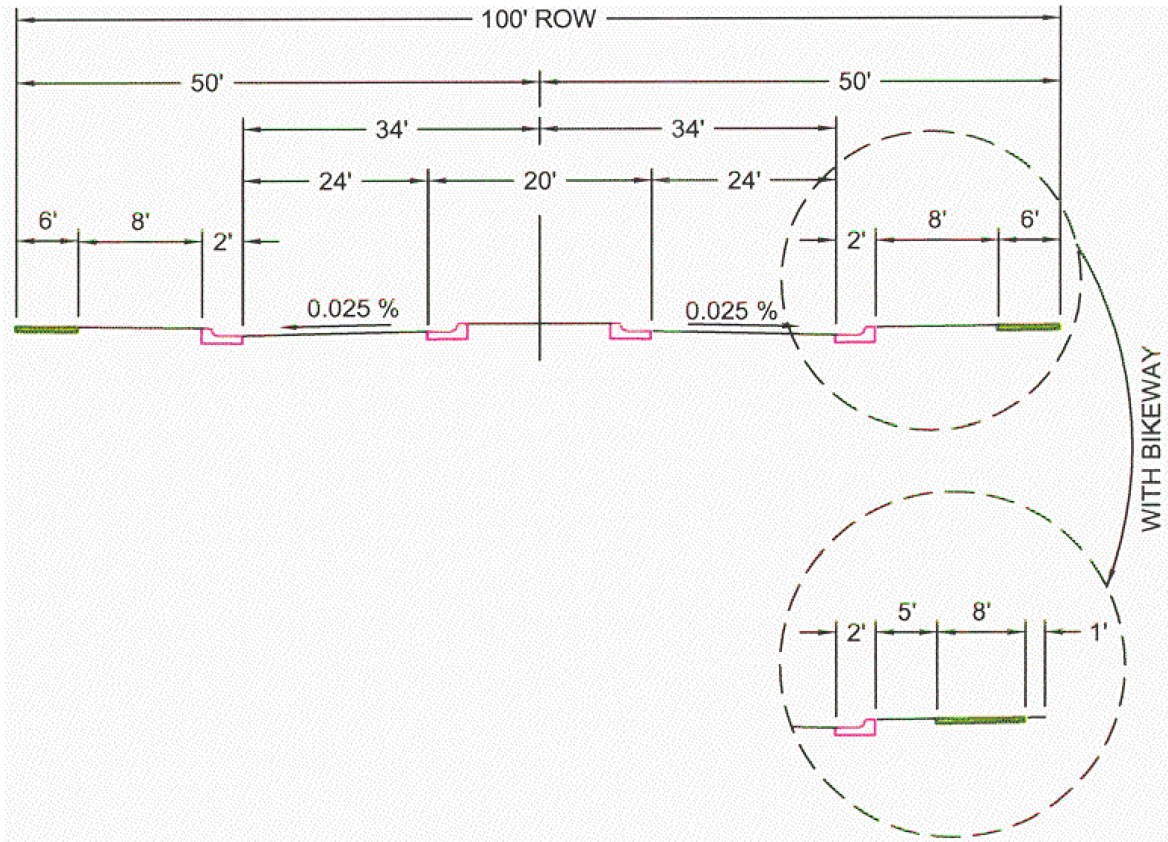


Figure 1-37   Design Criteria for MAD 4 Arterial

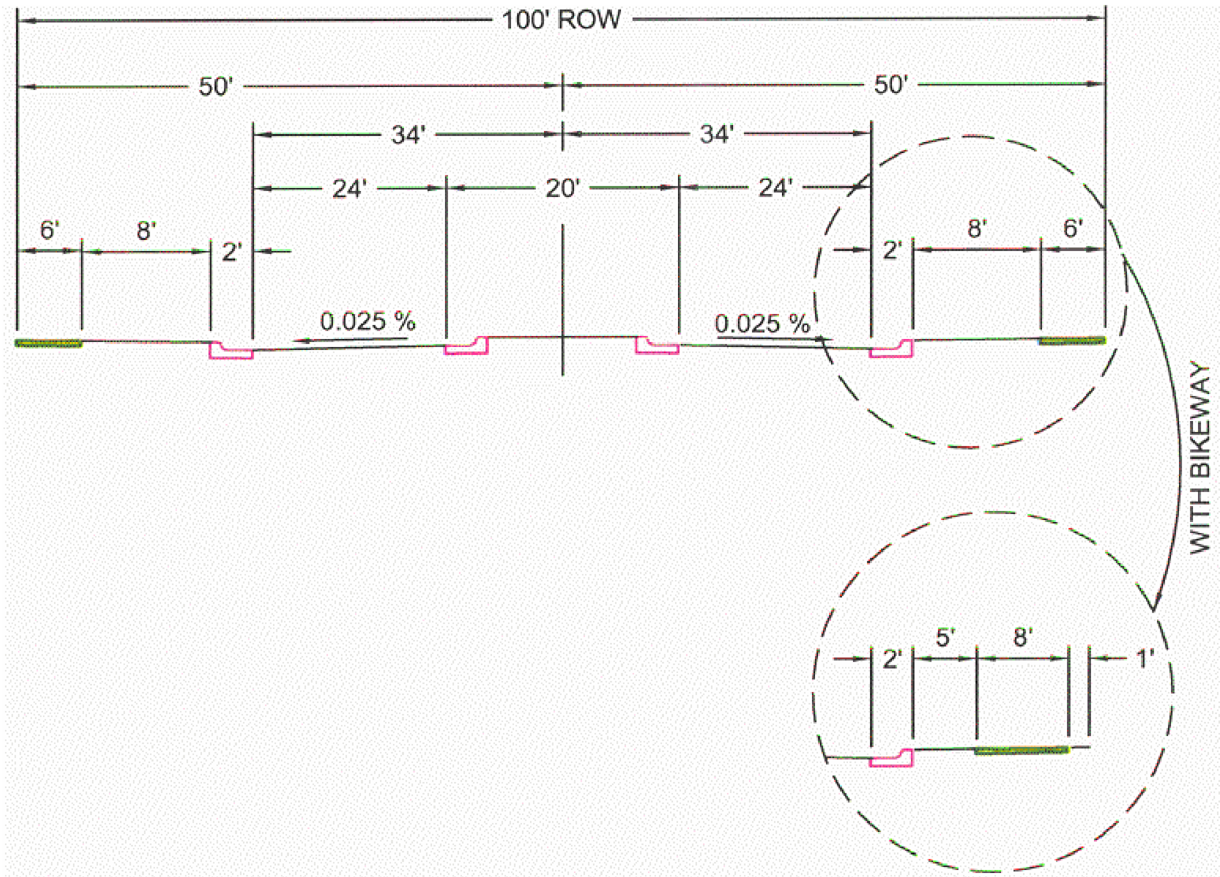


Figure 1-38   Design Criteria for MAD 6 Arterial

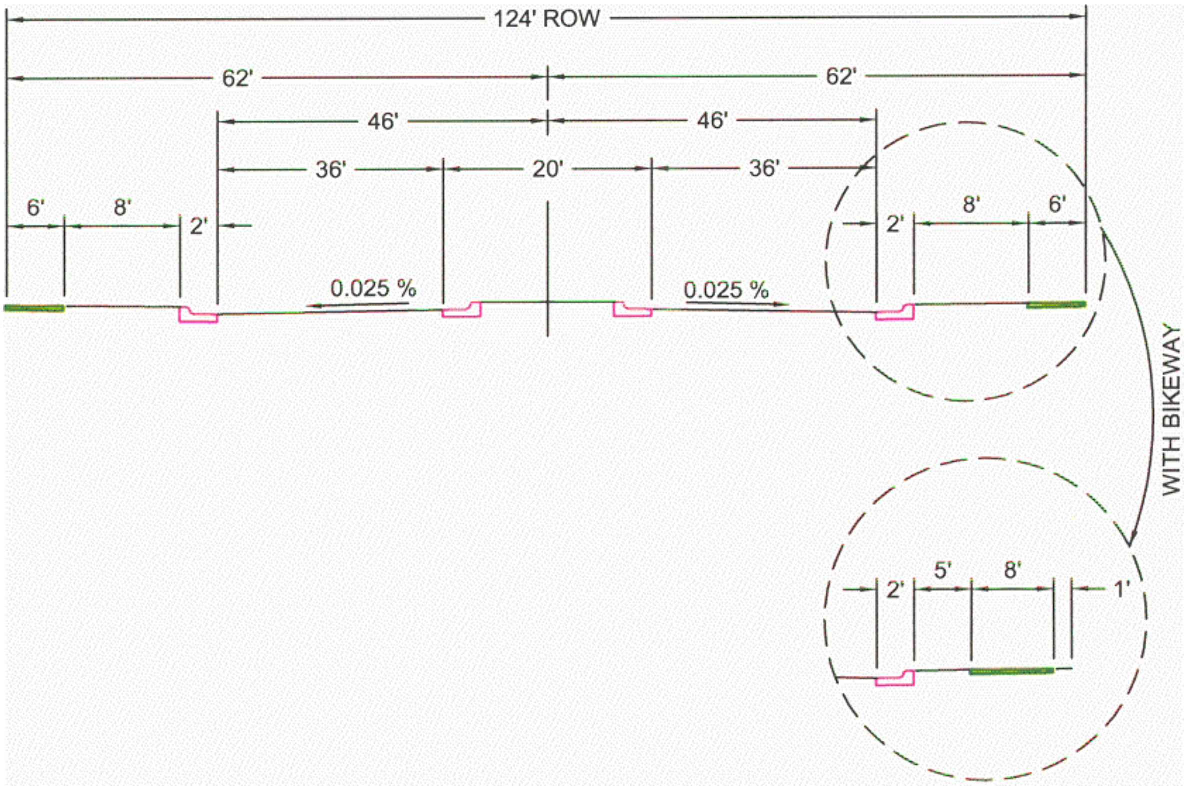


Figure 1-39 Design Criteria for MAD 8 Arterial