29.28 ARTERIAL AND MAJOR COLLECTOR GEOMETRIC DESIGN, INCLUDING ROUNDABOUTS

29.28.010 Geometric Standards

Geometric standards have been developed to provide adequate safety for the traveling public. This chapter sets the minimum standards for geometric design of streets classified as major collector and above, as shown on the Street Plan Functional Classification Map, Figure 3 in the Grand Junction Circulation Plan. These streets are intended for higher traffic volumes and throughput than the local streets and minor collector streets discussed in Chapter 29.20. They function in transition from direct land use access to movement of traffic.

Roundabouts provide safety improvements, less delay than other forms of control, community enhancement and increased traffic circulation at some intersections. Roundabouts can efficiently handle many intersections with decreased delay and greater efficiency than traffic signals. This section defines the roundabout and provides a link to general design criteria.

29.28.020 Arterial and Collector Streets

(a) Arterial Streets

Principal arterials shall be designed to provide a high degree of mobility and serve longer trips, implying a higher operating speed and level of service. These streets are designated on the Street Plan Functional Classification Map in the Grand Junction Circulation Plan. Minor arterial streets interconnect with and augment the Principal arterial system. These streets accommodate trips of shorter lengths and may also serve more access functions than principal arterial streets.

(b) Collector Streets

Collector streets provide both land access and movement within residential, commercial and industrial areas. Operating speeds are lower than arterial streets.

(c) Pedestrians and Bicyclists

Pedestrians and bicyclists are users of the street system and street design needs to include consideration for them. The adopted Pedestrian & Bicycle Plan shows existing and future pedestrian and bicycle facilities.

29.28.030 Right of Way, Street Lane Widths, and Street Lengths

The required right-of-way width for a street is indicated in the Street Sections located in the Appendix. Additional widths may be required for needed through and turn lanes, and where it is necessary to accommodate slopes and drainage structures.

29.28.040 Alignments - Horizontal Alignment

Streets shall extend to the boundary lines of the land to be subdivided. Proposed streets with widths different from existing streets to which they are being connected must be transitioned using pavement transition taper standards.

All designs shall be based on the Horizontal Curve Design Criteria.

Horizontal Curve Design Criteria

Design Criteria	Major Street[1]		
	Low Speed Collector	Collector/ Arterial	Arterial
Min. Design Speed (mph)	30	35	40
Min. Center Line Radius[2] (ft)	335	510	SEE[4]
Min. Horizontal Sight Distance (ft)	200	250	325
Min. Reverse Curve Tangent (ft)	0	200	200
Min. Approach Tangent at Intersections[3]	100	200	300

1 These criteria are to be used without super-elevation.

2 Radii shown are based on the street having a crown section with a pavement cross-slope of 2% on each side of the crown. For minimum radii required for other cross-slopes or where super-elevation is provided and approved, see Table 3-13 in "A Policy on Geometric Design of Highways and Streets," AASHTO, 2018 Edition or most current edition.

3 Where a curved road approaches an intersection, these tangent sections must be provided on the approach to the intersection to provide for adequate sight distance for traffic control devices at the intersection.

4 The maximum super-elevation rate allowed is e=6%. Where super-elevation is used, runoff lengths shall conform to Table 3-9 in "A Policy on Geometric Design of Highways and Streets," AASHTO, 2018 Edition or most current edition.

29.28.050 Alignment - Vertical Alignment - Grades

Grades, curve length and vertical sight distance shall be designed to ensure proper drainage, sight distance and safety for vehicles and pedestrians. Grades of streets shall not be less than 0.5%. The grade of a street may be reduced only when matching existing streets or property. Maximum street grades shall be 8%. For algebraic differences of 0.5% or less, grade breaks shall be required for adequate drainage.

Design Controls for Vertical Curves

Design Speed MPH	Stopping Sight Distance (feet)	Crest "K" Values	Sag "K" Values
20	115	7	17
25	155	12	26
30	200	19	37
35	250	29	49
40	305	44	64
45	360	61	79
50	425	84	96
55	495	114	115
60	570	151	136

From Table 5-3, AASHTO A Policy on Geometric Design of Highways and Streets, 2018
1 All minimum stopping sight distances for vertical curves with crests must be shown on the construction plans. Sight distances are based on design speeds.

29.28.060 Clearance of Structures

A minimum of 17.5 feet shall be provided for all overhead sign structures. The clearance shall be measured from the crown of the street to the lowest portion of the structure. A minimum vertical clearance of 16.5 feet for all other structures shall be provided on all arterial streets and designated truck routes. A minimum clearance of 14.5 feet may be allowed on collector streets per CDOT 2018 Roadway Design Guide.

29.28.070 Stopping Sight Distance

Stopping sight distance is defined as the length of roadway ahead visible to the driver. The minimum stopping sight distance available on a roadway must be sufficiently long to enable a vehicle traveling at or near the roadway design speed to stop before reaching a stationary object in its path or react to a traffic control device such as a stop sign.

The appropriate stopping sight distance shall be provided. The distances shown assume vehicles traveling on wet pavement on flat grades. Factors that take in to account the effect of grade on stopping sight distance shall be used in determining appropriate stopping sight distance where the grades are 3% or higher.

Minimum Stopping Sight Distance

Design Speed (MPH)	Stopping Sight Distance (Ft.)
20	115
25	155
30	200
35	250
40	305
45	360
50	425
55	495
60	570

Based on Table 5-3, AASHTO A Policy on Geometric Design of Streets and Highways, 2018

Effect of Grade on Stopping Sight Distance

Design Speed (MPH)	Downgrades			Upgrades		
	3%	6%	9%	3%	6%	9%
20	116	120	126	109	107	104
25	158	165	173	147	143	140
30	205	215	227	200	184	179
35	257	271	287	237	229	222
40	315	333	354	289	278	269
45	378	400	427	344	331	320
50	446	474	507	405	388	375
55	520	553	593	469	450	433
60	598	638	686	538	515	495

From Exhibit 3-2, AASHTO A Policy on Geometric Design for Highways and Streets, 2018

29.28.080 Cross Section

(a) Cross Slopes

The typical cross slope is 2% crown to provide for adequate drainage to the pavement edge. The maximum cross slope on the tangent sections shall not exceed 4%. The minimum cross slope shall be 1%.

(b) Super-elevation

Super-elevation shall be designed in accordance with the Horizontal Curve Design Criteria.

(c) Clear Zones

All roadways shall meet clear zone requirements as set forth in the current edition of the AASHTO Roadside Design Guide. Where under-improved streets are constructed (for example, a half-street construction), the minimum shoulder width shall be provided.

(d) Roadside Barrier and Bridge Rails

Roadside barriers shall be required in accordance with warrants, design criteria and standards for roadside barriers and bridge rails as defined in the current edition of the AASHTO Roadside Design Guide.

29.28.090 Tapers and Transitions- Road Width Transition Tapers

When constructing a roadway that will connect with an existing roadway of a different width, a transition taper is required. These ratios are not to be used in the design of exclusive turn lanes**.**

Minimum Road Width Transition Tapers

Design Speed (MPH)	Transition Run/Offset (Ft/Ft)
30 or less	15 / 1
35	20 / 1
40	25 / 1
45	45 / 1
50	50 / 1
55	55 / 1
60	60 / 1

Table based on Section 3B-8, MUTCD.

29.28.100 Bicycle Treatments

Bicycle facilities are required as shown on the Pedestrian and Bicycle Plan and the street sections included in the Appendix. Provisions for bicycle facilities and crossings shall be in accordance with the AASHTO Guide for Development of Bicycle Facilities. Refer to Chapter 28.48 for design guidance on bicycle facility types, and minimum adherence standards. Refer to the Pedestrian and Bicycle Plan for additional guidance on designing bikeway facilities and bikeway crossings.

29.28.110 Intersections

Generally, there are two types of intersections: unsignalized and signalized. Each of these may have several different configurations and levels of traffic control. A roundabout is a form of an unsignalized intersection and is specifically discussed in Section 29.28.220. All intersections shall conform to the guidelines set forth in AASHTO and the MUTCD. For streets with bicycle facilities, refer to Chapter 29.48 for additional guidance on bicycle intersection treatments as well as the street sections located within the Appendix.

29.28.120 Unsignalized Intersections

There are three acceptable levels of traffic control at unsignalized intersections: yield controlled, two-way stop controlled and all-way stop controlled. The appropriate use of each of these is discussed in the following sections.

(a) Yield Controlled Intersections

Yield controlled intersections will not generally be allowed, except at roundabouts.

(b) Two-way Stop Controlled Intersections

Stop signs shall be used in accordance with the MUTCD.

(c) All-way Stop Controlled Intersections

An all-way or "multi-way" stop installation shall be used only where the criteria of the MUTCD are met.

29.28.130 Signalized Intersections

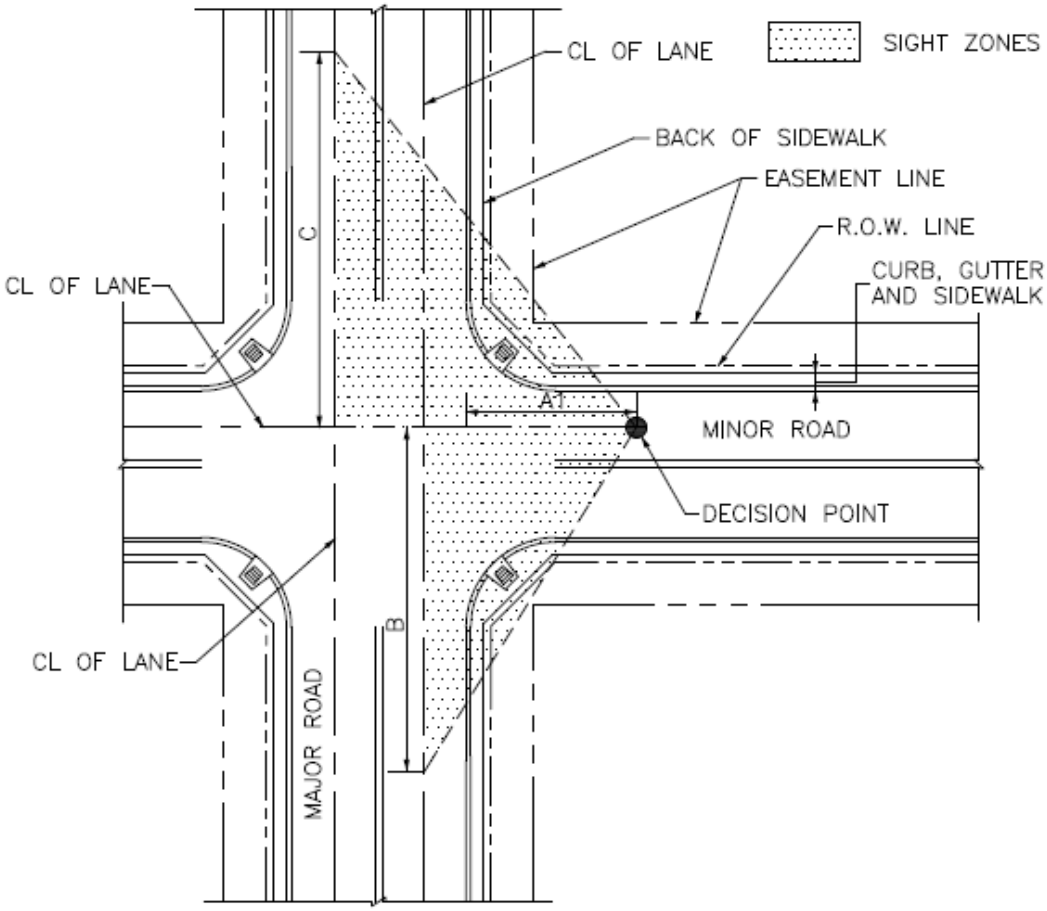
A signalized intersection shall only be installed after a careful analysis and engineering study of the roadway and traffic conditions at the intersection and on the corridor. When a signal is proposed on a corridor where signals are coordinated, the TIS (see Chapter 29.08) shall analyze the impacts to the progression of traffic on the corridor and on surrounding land uses. This analysis shall include the progression bandwidth, efficiency and level of service determinations, signal timing and phasing including pedestrian movements, and an analysis of the storage queue lengths for exclusive turn lanes. Signal installations shall meet the spacing criteria in Section 29.28.200. Traffic signal warrants and design criteria are thoroughly discussed in the MUTCD, Part IV.

29.28.140 Sight Distance

Street intersections and private access to public streets shall be planned and located to provide as much sight distance as possible. At a minimum, there must be sufficient sight distance for the driver on the minor street or driveway to cross or turn onto the intersecting street. Minimum sight distance values are provided for passenger cars turning left or right from a minor street. When grades are steeper than 3.0%, adjustment factors must be applied.

The operating speed on each approach is assumed to be, in order of desirability, a) the 85th percentile speed, b) the speed limit if based on an engineering study, or c) in the case of a new facility, 80 percent of the design speed.

Minimum Sight Distance for Left and Right Turns onto Major Street by Passenger Cars at Stop-Controlled Intersections



APPROACH SPEED	B	C
15 MPH	145 FT	170 FT
20 MPH	195 FT	225 FT
25 MPH	240 FT	280 FT
30 MPH	290 FT	335 FT
35 MPH	335 FT	390 FT
40 MPH	385 FT	445 FT
45 MPH	430 FT	500 FT
50 MPH	480 FT	555 FT

*BASED ON AASHTO FIGURE 9–15

NOTES:

SIGHT ZONE SHOULD BE EVALUATED FOR ALL APPROACHES.

A1 IS 18' MEASURED FROM THE MAJOR ROAD LIP OF GUTTER. IN CONSTRAINED SCENARIOS, A1 MAY BE REDUCED TO A MINIMUM OF 14.5' WITH CITY APPROVAL.

DISTANCE B MAY BE UTILIZED WITH CITY APPROVAL, WHEN THE INTERSECTION CONTROL ONLY ALLOWS RIGHT TURNS OUT FROM THE MINOR LEG.

Factors for the Effect of Grade on Sight Distance

Approach Grade (%)	Design Speed (MPH)									
	15	20	25	30	35	40	45	50	55	60
-6	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.2	1.2	1.2
-5	1.0	1.0	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
-4	1.0	1.0	1.0	1.1	1.1	1.1	1.1	1.1	1.1	1.1
-3 to +3	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
+4	1.0	1.0	1.0	1.0	1.0	0.9	0.9	0.9	0.9	0.9
+5	1.0	1.0	1.0	0.9	0.9	0.9	0.9	0.9	0.9	0.9
+6	1.0	1.0	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9

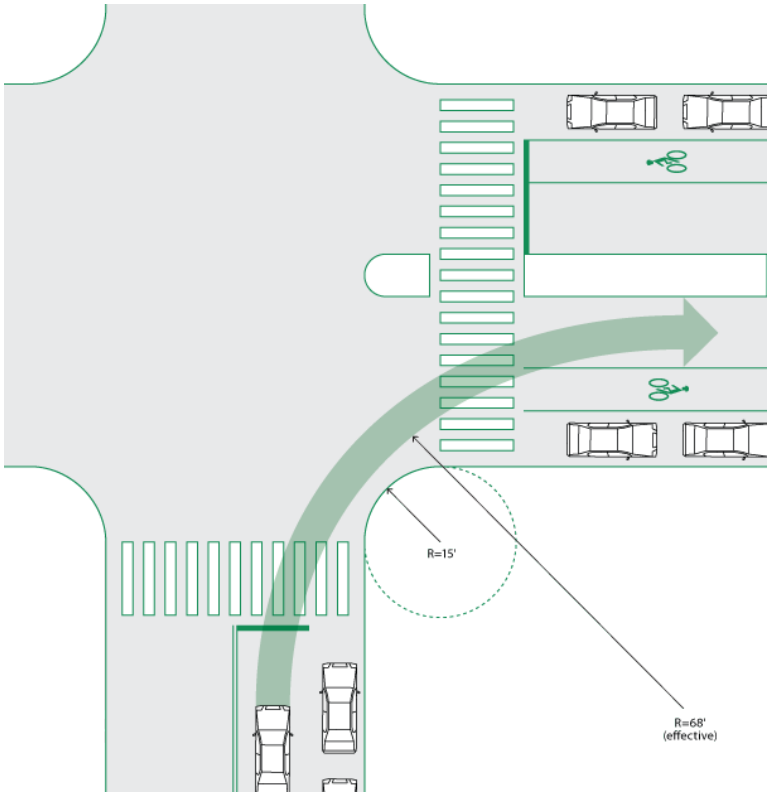
Based on Table 9-5, AASHTO A Policy on Geometric Design for Highways and Streets, 2018.

29.28.150 Sight Zones

The location of sight zones at intersections are identified in GJMC 29.28.140 and sight zones along streets are identified in the Street Sections (see appendix). Design requirements within the sight zone for major collector and arterial streets are the same as for local and minor collector streets. Refer to GJMC 29.20.180.

29.28.160 Intersection Radii

Minimum intersection effective radii must be maintained at public street intersections and a 15 foot minimum flowline radius is required to allow for proper drainage in situations where flowline radii is less than the effective radii. The “effective” radius is different than the flowline radius in that effective radius accounts for on-street parking or bike lanes which can cause the effective radius for a turning vehicle to be much larger than the flowline radius. An effective turn radius that is too large can encourage drivers to maintain a high speed while turning, which can compromise the comfort and safety of pedestrians crossing in the crosswalk. The NACTO Urban Street Design Guide recommends design corner radii to limit turning speeds to 15 mph to support a comfortable pedestrian environment. Thus, when a bike lane or parking lane is present on one or both of the intersecting streets, either a bulb-out (see 29.28.165) should be provided to maintain the desired effective radii or the flowline radius should be designed to be less than the minimum intersection effective radius in order to encourage slower turning vehicle speeds.



Example of "Effective" Turn Radius (source: NACTO Urban Street Design Guide)

Minimum Intersection Effective Radii

Through Street[2]	Intersecting Street				
	Arterial	**Collector**	**Local Residential**	**Local Commercial**	**Local Industrial[1]**
Arterial	35'	30'	30'	30'	30'
Collector	30'	30'	25'	30'	30'

1 Radii at intersections with industrial streets shall be individually designed based on the turning requirements for the type of truck that will most commonly use the street.

2 At signalized intersections where right turn channelization islands are provided or high truck and bus volumes may use the access, a larger flowline radius may be required.

3 When bike lanes are present consider a reduced flowline radii to match the effective flowline of the intersection, with a minimum required flowline radius of 15 feet.

29.28.165 Bulb-Outs

If on-street parking is present, steps should be taken to prevent vehicles from parking too close to the intersection. Bulb-outs should be used to reduce the intersection width and prevent parking in the sight zone. This will result in shorter crossing distances for

pedestrians, increased sight distance, and increased visibility of pedestrians especially for turning vehicles, which will increase pedestrian safety and comfort at intersections.

29.28.170 Lane Requirements

Lane design through an intersection shall be consistent with the lane design of the streets forming the intersection.

(a) Lane Widths

Lane widths shall be consistent with the cross-sections as shown in the City Standard Street Details.

(b) Exclusive Turn Lanes.

(1) The purpose of an exclusive turn lane is to expedite the movement of through traffic, increase intersection capacity, permit the controlled movement of turning traffic, and promote the safety of all traffic. The provision of left-turn lanes is essential from both capacity and safety standpoints where left turns would otherwise share the use of a through lane. Right-turn lanes remove the speed differences in the main travel lanes, reducing the frequency and severity of rear-end collisions.

(2) Separate right turn lanes shall be required in accordance with the right turn warrant chart. Separate left turn lanes shall be required at all new signal locations and at unsignalized locations in accordance with the left turn warrant chart.

Warrants for Right Turn Lanes
Two Lane Roadways
Number of Peak Hour Turning Vehicles

DDHV[1] (vph)	≤ 35 MPH	40 MPH	45 MPH	50 MPH	55 MPH
200				73	35
300			120	41	24
400	200	200	50	30	19
500	150	125	35	25	16
600	75	50	25	20	14
800	50	30	15	15	11
1000	25	25	15	11	9
1200	20	20	15	9	8

1 DDHV – Directional Design Hourly Volume; volume of vehicles in the design hour using the through lane adjacent to which the right turn lane is to be constructed.

Warrants for Right Turn Lanes
Four Lane Roadways
Number of Peak Hour Turning Vehicles

DDHV[1] (vph)	≤ 35 MPH	40 MPH	45 MPH	50 MPH	55 MPH
300					75
400			145	75	40
500			95	57	32
600	170	160	65	42	26
800	80	70	37	28	19
1200	50	25	20	18	14
1600	20	15	14	13	10
2000	15	10	9	9	8

1 DDHV – Directional Design Hourly Volume; volume of vehicles in the design hour using the through lane adjacent to which the right turn lane is to be constructed.

Charts developed based on studies conducted by Kansas Department of Transportation and University of Nebraska

Warrants for Left Turn Lanes
Number of Peak Hour Turning Vehicles

DDHV	30-35 MPH	40 + MPH
100	30	14
200	15	12
300 +	12	12

DDHV – Directional Design Hourly Volume; volume of vehicles in the design hour using the through lane adjacent to which the right turn lane is to be constructed.

(3) Construction of turn lanes on state highways shall be determined in accordance with the State Highway Access Code.

(4) Dual left turn lanes at signalized intersections shall be considered when the peak hour left turn volume exceeds 300 vehicles/hour. An analysis of the signal timing is required to measure the effects of the protected movement on the rest of the intersection movements. Intersection geometry shall allow for the operation of dual lefts. Permissive dual left turns are prohibited.

(c) Left and Right Turn Lane Design

(1) The components of a left turn lane consist of a taper and the full width lane for storage as shown in the turn lane elements and design criteria. Right turn lanes shall be 11' in width (not including the gutter pan) and two-way left turn lanes shall be 12' in width.

Minimum Left-Turn Tapers for Redirecting Through Lanes

Design Speed (MPH)	Tapers
25	10:1
30	15:1
35	20:1
40	30:1
45	45:1
50	50:1
55	55:1
60	60:1

Based on Table 4-9 CDOT Access Code

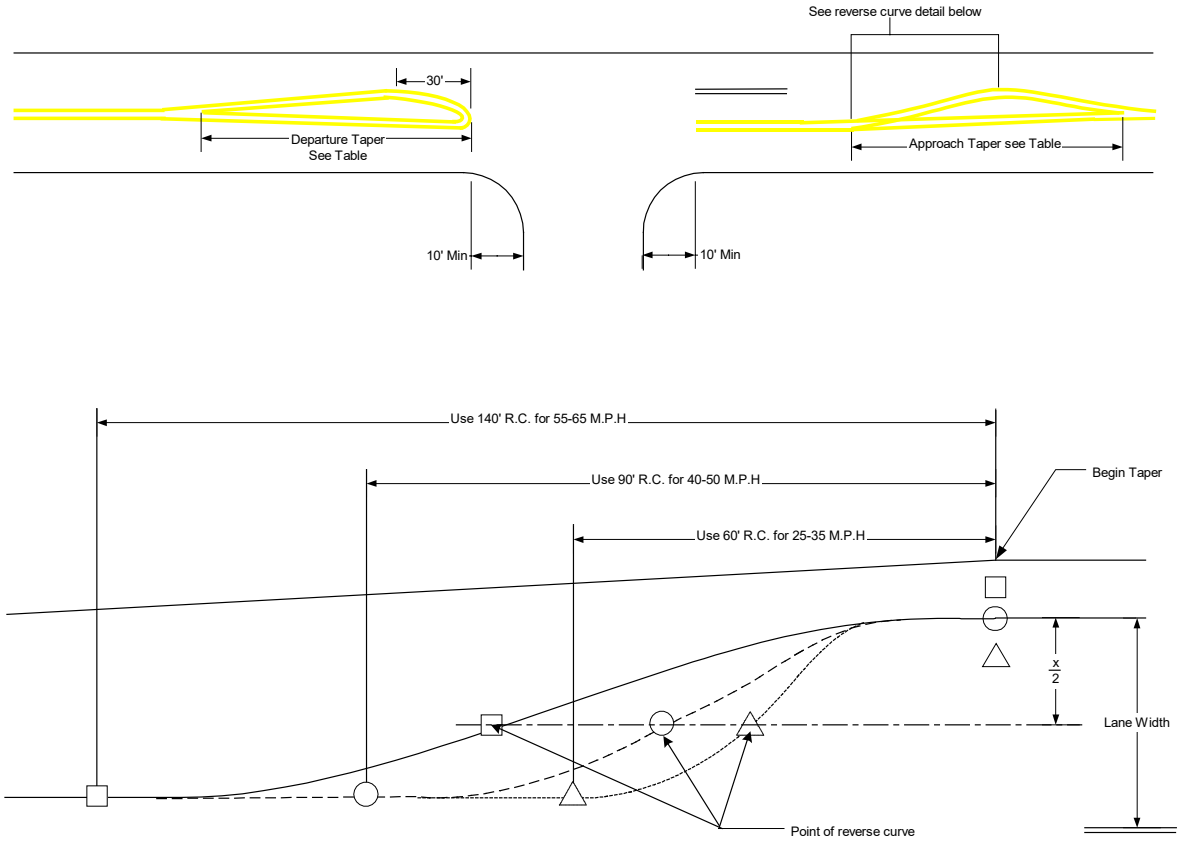
(2) Use the same ratio for both approach and departure tapers.

(3) Bay tapers shall be symmetrical reverse curves in accordance with the following:

i. Use 60’ Reverse Curve for 25-35 MPH

ii. Use 90’ Reverse Curve for 40-50 MPH

iii. Use 140’ Reverse Curve for 55-65 MPH



SYMMETRICAL REVERSE CURVES

(4) Storage lengths for turn lanes at signalized intersections shall be determined based on a signal timing analysis that predicts the 90% queue length required for the turn lane. At unsignalized intersections, the turn lane storage will be determined in accordance with the storage length table. Tapers for right turn lanes shall be designed in accordance with the right-turn lane taper table. Use of the reverse curve is encouraged as part of the taper length to allow vehicles to decelerate in the full lane width. If used, the difference in length between the required taper and the reverse curve shall be added to the required storage length of the turn lane.

Minimum Storage Lengths for Unsignalized Turn Lanes

Turning VPH	≤60	100	200	300
Required Storage Length	50	100	175	250

Based on Table 9-7 CDOT Design Guide

Minimum Right-Turn Tapers

Design Speed (MPH)	Tapers
25	7.5:1
30	8:1
35	10:1
40	12:1
45	13.5:1
50	15:1
55	18.5:1
60	25:1

Excerpted from Table 4-6, CDOT Access Code

(5) Standards for State Highway right turn and left turn speed change lanes are found in the State Highway Access Code.

29.28.180 Angles

Proposed public streets must intersect at 90° angles or as close to 90° as topography permits (no less than 80°). Intersections on sharp horizontal curves shall be prohibited based on sight distance and viewing angle for the driver.

29.28.190 Grades at Intersections

See GJMC 29.20.150 for design requirements for grades at intersections.

29.28.200 Spacing and Offsets of Intersections

(a) Principal Arterials

Signalized intersections shall be spaced at ½ mile intervals. Unsignalized intersections must be T-intersections spaced at least 600 feet apart, measured centerline to centerline. Unsignalized four legged intersections may be allowed on arterial streets provided that the design of the intersection precludes left turns onto and through movements across the arterial. If the overlap of left turn storage requirements for two T-intersections exceeds 600 feet, the minimum spacing must be increased to provide adequate left turn storage in both directions.

(b) Minor Arterials and Major Collectors

Signalized intersections shall be spaced no closer than 1/4 mile intervals. Unsignalized four-legged intersections must be spaced at least 300 feet apart. When T-intersections are used, the centerlines of streets not in alignment shall be offset a minimum of 150 feet and be 150 feet from the nearest four-legged intersection. If the left turn storage requirements for adjacent intersections overlap, the minimum spacing must be increased to provide adequate left turn storage in both directions. For spacing and offset requirements of driveways see GJMC 29.16.030.

29.28.210 Pedestrian Treatments

Accommodations for pedestrians must be designed into all intersections. Pedestrian accommodations include, but are not limited to sidewalks, crosswalks, pedestrian refuge islands, and accommodations for disabled pedestrians. Sidewalks are an integral part of urban streets and shall be included in the intersection design. Refer to the Bicycle and Pedestrian plan or city staff recommendations for detailed improvements at identified intersections. The Grand Junction Standard Contract Documents for Capital Improvements Construction shall be followed in designing and constructing pedestrian facilities. The intersection design shall conform to the standards set forth in the Americans with Disabilities Act. More information on the requirements can be found at http://www.access-board.gov/. Design of pedestrian facilities should also adhere to the latest guidance according to the U.S. Access Board's Public Right-of-Way Accessibility Guidelines (PROWAG). Where sidewalks are provided, accessible ramps must also be provided. Utility boxes, drainage inlets, signs, and other fixed objects shall not be located within the path defined by ramp. The ramp shall align with the sidewalk and must be located entirely within the marked crosswalk area.

(a) Crosswalks

Crosswalks shall be marked at signalized intersections and designed as part of the markings for the traffic signal. All crosswalk markings must conform to MUTCD standards. Crosswalks at un-signalized intersections or mid-block locations will only be considered when an engineering study is conducted in accordance with Institute of Traffic Engineers guidelines and indicates crosswalks would increase pedestrian safety. Refer to the current edition of the Grand Junction Pedestrian Crossing Treatment Installation Guidelines for guidance on applicability of pedestrian crossing treatments in different contexts, including at uncontrolled crossings. Refer to CDOT's Pedestrian Crossing Installation Guide for uncontrolled pedestrian crossings on state highways.

(b) Pedestrian Refuge Islands

Pedestrian refuge islands may be constructed where mid-block crosswalks are proposed. Islands should be at least 6' wide and 6' length in advance and departing of crosswalk. All Islands must conform to the minimum standards established in the MUTCD, and must meet the design criteria for curbing and medians.

29.28.220 Roundabouts

(a) Design Criteria

A roundabout brings together conflicting traffic streams, allows the streams to safely merge and traverse the roundabout, and exit in the desired directions. The geometric elements of the roundabout provide guidance to drivers approaching, entering, and traveling through a roundabout.

Good roundabout design places a high priority on speed reduction and speed consistency. Low vehicle speed provides safety benefits including reduced numbers and severity of crashes; more time for entering drivers to judge, adjust speed for and enter a gap in circulating traffic; and safer merging. Roundabout intersections typically operate with lower vehicle delays than other intersection control types.

A capacity analysis of any proposed roundabout shall be conducted in accordance with Highway Capacity methods. The analysis shall include consideration for the largest motorized vehicle likely to use the intersection.

Roundabouts shall be designed in conformance with the guidelines set forth in the NCHRP 1043 Guide for Roundabouts. All roundabout design is unique and the City will require review of the preliminary geometry prior to final design.

(b) Signing, Striping, and Pavement Markings

All signing, striping, and pavement markings shall follow the MUTCD standards.

(c) Lighting

Adequate lighting is essential for drivers to perceive the general layout and operation of the intersection in time to make the appropriate maneuvers. A lighting plan will be required as part of the construction drawings for roundabouts.

(d) Landscaping

Landscaping in the central island, the splitter islands and along the approaches is a benefit to both public safety and community enhancement. Landscaping shall follow these general principles:

(1) Make the central island more conspicuous;

(2) Improve the aesthetics of the area while complementing surrounding streetscaping as much as possible;

(3) Avoid obscuring the form of the roundabout or the signing to the driver;

(4) Maintain adequate sight distances;

(5) Clearly indicate to the driver that they cannot pass straight through the intersection;

(6) Discourage pedestrian movements through the center of the roundabout.

29.28.230 Landscaping – General Requirements

All new developments must provide landscaping that meets the requirements of the City's Zoning and Development Code. Any landscaping in the sight distance triangles at intersections shall meet the sight distance requirements in the Sight Distance detail.