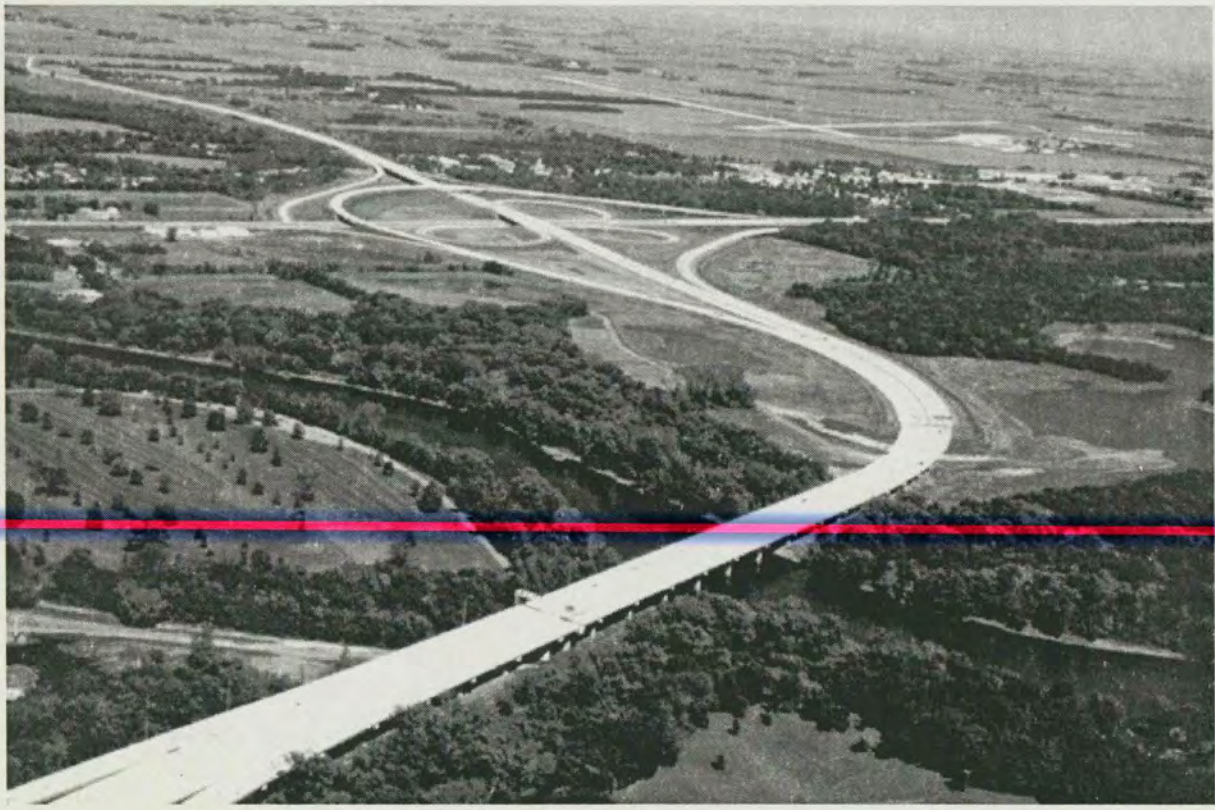
Design Manual
English

Iowa Department of Transportation

Iowa Department of Transportation
Highway Division



Design Manual—English

Prepared by the Methods Section
Office of Design

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General Information

Chapter 1

About This Manual

Originally Issued: 09-01-95

The *Design Manual* is published by the Methods Section in the Office of Design. This manual is in English units. The companion manual is in metric units.

Most sections of the *Design Manual* are intended to give guidance or information on how a certain aspect of design is normally handled. To a lesser extent, the manual is also used to document normal design policy.

The *Design Manual* is meant to be a resource, not a cookbook or something that restricts innovation. The judgment of the Design Projects Engineer in consultation with the Design Engineer may supersede the guidance given in this manual. However, if deviation is made from normal policy, a design exception shall be prepared clearly documenting the situation and reasons.

Effective Dates

There will be no specific effective date indicated for material published in this manual. Instead of this, the date the section was originally issued will be indicated (see above) and if the page is revised, it will be indicated at the bottom of the page (see below).

If a project is started after material is published in the *Design Manual*, it should follow the policies or guidelines in the manual. However, projects already under development when new material is published will have to be looked at on a case-by-case basis. If possible, the new guidance should be followed, but it will depend on how much of the design has already been completed and other considerations.

In some cases there will be a fixed date when a new design must be implemented (for example, there may be a specific deadline set by the FHWA for using improved safety appurtenances like guardrail terminals). The Methods Section will notify designers of any such deadlines but they will not be indicated in the *Design Manual*.

Densities for Use in Estimating Quantities

Originally Issued: 06-02-00

The following densities should be used for estimating quantities of Hot Mix Asphalt (HMA) material.

Table 1

HMA	145 pcf
Crushed HMA for use as Subbase	127 pcf
Base Course	145 pcf
Intermediate Course	145 pcf
Surface Course	145 pcf

The following densities should be used for estimating quantities of granular material.

Table 2

Granular Subbase	135 pcf
Granular Backfill	125 pcf
Granular Blanket	125 pcf
Granular Shoulders	140 pcf
Special Backfill (treatment)	140 pcf
Porous Backfill	120 pcf
Class "A" Crushed Stone	140 pcf
Class "D" Rip-Rap	110 pcf
Erosion Stone	120 pcf
Recycled Pavement	135 pcf
Macadam Stone	130 pcf
Crushed Concrete for use as Subbase	135 pcf
P.C.C. Pavement Broken for use as Class "E" Rip-Rap	120 pcf
Rolled Stone Base	140 pcf
Modified Subbase	140 pcf

Design Guides for New and Reconstructed Highways

Originally Issued: 12-31-97

The tables in this section contain recommended design values for various roadway features. These tables are only for new and reconstructed highways. Higher values to increase safety (for features like the clear zone, stopping sight distance, radius, etc.) should be used within reasonable economic limits.

These guides are not meant to be applied rigidly to every situation. There will be situations when special site conditions (such as environmental, aesthetic, or economic considerations) warrant deviation from the values in the tables. It is acceptable to deviate from these values with the approval of the Design Engineer. Design exceptions should be prepared when appropriate.

Freeways

Definition: Multi-lane divided highways with full access control—access allowed only at interchanges.

	Rural		Urban	
design speed (mph)	70		60	
expected regulatory speed (mph)	65		55	
level of service (capacity analysis)	B		C	
clear zone (ft)	(a)		(a)	
minimum radius (ft)	2050 (b)(c)		1340 (b)(c)	
horizontal curves—minimum length (ft)	1050 (b)(d)		900 (b)(d)	
vertical curves—minimum length (ft)	210 (b)		180 (b)	
crest vertical curves—desirable k	405 (b)		245 (b)	
sag vertical curves—minimum k	181 (b)		136 (b)	
stopping sight distance (ft)	730 (b)		570 (b)	
maximum gradient (%)	3 (e)		3 (e)	
normal median width (ft)	64 (f)		varies	
	outside lane	inside lane(s)	outside lane	inside lane(s)
lane pavement width (ft)	14 (g)	12	14 (g)	12
shoulder width (ft)	8 (h)	6 (i)	8 (h)	6 (i)
shoulder type	(j)		(j)	
curbs	NA		(k)	
foreslope	6:1 (l)		6:1 (l)	
normal outside ditch (depth × width) (ft)	5 × 10 (m)		5 × 10 (m)	
normal median ditch depth (ft)	4		4	
backslope	2.5:1		2.5:1	
bridge width—new (ft)	lane pavement widths + shoulder widths			
bridge width—existing (ft)	lane widths + 3 foot offset on each side (n)			
transverse slopes	(o)		(o)	
vertical clearance—over primary (ft)	16.5 (p)		16.5 (p)	
vertical clearance—over non-primary (ft)	14.5 (p)(q)		14.5 (p)(q)	
vertical clearance—over railroad (ft)	23.5 (r)		23.5 (r)	
vertical clearance—under any structure (ft)	16.5 (p)		16.5 (p)	

(a) Depends on design speed, traffic volume, cross section, and horizontal alignment. See Section 1C-2 of this Manual. Measured from edge-of-traveled way.
(b) Based on design speed. See Section 6D-1 of this Manual for more information regarding stopping sight distance and Section 6D-5 for more information regarding vertical curve design.
(c) Based on $e_{max} = 6\%$.
(d) Includes spiral length.
(e) 4 % is acceptable on non-interstate freeways.
(f) From edge-of-pavement to edge-of-pavement.
(g) Actual driving-lane width is 12 feet. Painted edge line is offset 12 feet from the inside edge of the lane. On PCC pavement, roughness pattern is used outside the painted edge line, regardless of shoulder type.
(h) Actual shoulder width is 10 feet due to 2 feet of lane pavement width outside the painted edge line.
(i) 10-foot shoulder width should be used when there are 3 or more through lanes in one direction.
(j) Paved for interstate. Granular for non-interstate. Consider paved for non-interstate if design year ADT > 10,000.
(k) Curbs are not desirable on high-speed facilities. If required, a sloped curb should be used on the outside edge of a full-width shoulder.
(l) Barn-roof cross section is acceptable at high-fill locations as illustrated on Typical 2112.
(m) May use 4 × 8, 3 × 5, or swale depending on right-of-way impacts.
(n) Design loading should be sufficient to accommodate legal loads. Bridge rail and approach guardrail should be upgraded, if necessary.
(o) 8:1 with drainage structures. 10:1 without drainage structures.
(p) Includes provision for 3" HMA overlay. Vertical clearance is maintained above all lanes and shoulders. See Section 1C-2 for vertical clear zone guidelines.
(q) The designer may provide additional vertical clearance when site conditions warrant.
(r) May vary. Need to verify each railroad's requirement.

Expressways

Definition: Multi-lane divided highways with at-grade intersections, often in combination with interchanges at high-volume intersections and primary routes.

	Rural		Urban	
design speed (mph)	70		60	
expected regulatory speed (mph)	65		55	
level of service (capacity analysis)	B		C	
clear zone (ft)	(a)		(a)	
minimum radius (ft)	2050 (b)(c)		1505 (b)(d)	
horizontal curves—minimum length (ft)	1050 (b)(e)		900 (b)(e)	
vertical curves—minimum length (ft)	210 (b)		180 (b)	
crest vertical curves—desirable k	405(b)		245 (b)	
sag vertical curves—minimum k	181 (b)		136 (b)	
stopping sight distance (ft)	730 (b)		570 (b)	
maximum gradient (%)	4		4	
normal median width (ft)	64 (f)		varies	
	outside lane	inside lane(s)	outside lane	inside lane(s)
lane pavement width (ft)	14 (g)	12	14 (g)	12
shoulder width (ft)	8 (h)	6 (i)	8 (h)	6 (i)
shoulder type	granular (j)		granular (j)	
turn-lane width (ft)	12		12	
auxiliary-lane width (ft)	12		12	
curbs	NA		(k)	
foreslope	6:1 (l)		6:1 (l)	
normal outside ditch (depth × width) (ft)	5 × 10 (m)		5 × 10 (m)	
normal median ditch depth (ft)	4		4	
backslope	2.5:1		2.5:1	
bridge width—new (ft)	lane pavement widths + shoulder widths			
bridge width—existing (ft)	lane widths + 3 foot offset on each side (n)			
transverse slopes	(o)		(o)	
vertical clearance—over primary (ft)	16.5 (p)		16.5 (p)	
vertical clearance—over non-primary (ft)	14.5 (p)(q)		14.5 (p)(q)	
vertical clearance—over railroad (ft)	23.5 (r)		23.5 (r)	
vertical clearance—under any structure (ft)	16.5 (p)		16.5 (p)	

(a) Depends on design speed, traffic volume, cross section, and horizontal alignment. See Section 1C-2 of this manual. Measured from edge-of-traveled way.
(b) Based on design speed. See Section 6D-1 of this Manual for more information regarding stopping sight distance and Section 6D-5 for more information regarding vertical curve design.
(c) Based on $e_{max} = 6\%$.
(d) Based on $e_{max} = 4\%$.
(e) Includes spiral length.
(f) From edge-of-pavement to edge-of-pavement.
(g) Actual driving-lane width is 12 feet. Painted edge line is offset 12 feet from the inside edge of the lane. On PCC pavement, roughness pattern is used outside the painted edge, regardless of shoulder type.
(h) Actual shoulder width is 10 feet due to extra 2 feet of lane pavement width outside the painted edge line.
(i) 10-foot shoulder width should be used when there are 3 or more through lanes in one direction.
(j) Consider paved shoulders if design year ADT > 10,000.
(k) Curbs are not desirable on high-speed facilities. If required, a sloped curb should be used on the outside edge of a full-width paved shoulder.
(l) Barn-roof cross section is acceptable at high-fill locations as illustrated on Typical 2112.
(m) May use 4 × 8, 3 × 5, or swale depending on right-of-way impacts.
(n) Design loading should be sufficient to accommodate legal loads. Bridge rail and approach guardrail should be upgraded, if necessary.
(o) 8:1 with drainage structures. 10:1 without drainage structures. 6:1 at sideroads.
(p) Includes provision for 3" HMA overlay. Vertical clearance is maintained above all lanes and shoulders. See Section 1C-2 for vertical clear zone guidelines.
(q) The designer may provide additional vertical clearance when site conditions warrant.
(r) May vary. Need to verify each railroad's requirement.

Super-Two Highways

Definition: Rural two-lane undivided highways with enhanced geometrics to improve operational and safety features. Intersections are at-grade.

design speed (mph)	70
expected regulatory speed (mph)	55
level of service (capacity analysis)	B
clear zone (ft)	(a)
minimim radius (ft)	2050 (b)(c)
horizontal curves minimum length (ft)	1050 (b)(d)
vertical curves minimum length (ft)	210 (b)
crest vertical curves desirable k	405 (b)
sag vertical curves minimum k	181 (b)
stopping sight distance (ft)	730 (b)
maximum gradient (%)	4 (e)
lane pavement width (ft)	14 (f)
shoulder width (ft)	8 (g)(h)

shoulder type	granular
turn-lane width (ft)	12 (h)(i)
auxiliary-lane width (ft)	12 (j)
foreslope	6:1 (k)
normal ditch (depth × width) (ft)	5 × 10 (l)
backslope	2.5:1
bridge width—new (ft)	lane pavement widths + shoulder widths (m)
bridge width—existing (ft)	lane widths + offset (n)
transverse slopes	(o)
vertical clearance—over primary (ft)	16.5 (p)
vertical clearance—over non-primary (ft)	14.5 (p) (q)
vertical clearance—over railroad (ft)	23.5 (r)
vertical clearance—under any structure (ft)	16.5 (p)

(a) Depends on design speed, traffic volume, cross section, and horizontal alignment. See Section 1C-2 of this manual. Measured from edge-of-traveled way.

(b) Based on design speed. See Section 6D-1 of this Manual for more information regarding stopping sight distance and Section 6D-5 for more information regarding vertical curve design.

(c) Based on $e_{max} = 6\%$.

(d) Includes spiral length.

(e) Maximum gradient up to 6% is allowed for areas with mountainous terrain (see definition in AASHTO's *A Policy on Geometric Design of Highways and Streets*).

(f) Actual driving-lane width is 12 feet. Painted edge line is offset 12 feet from centerline. On PCC pavement, roughness pattern is used outside the painted edge line.

(g) Actual shoulder width is 10 feet due to 2 feet of lane pavement width outside the painted edge line.

(h) Shoulder width adjacent to right-turn lanes is 6 feet.

(i) See Section 6A-1 for right and left-turn lane warrants.

(j) Includes passing lanes, climbing lanes, and speed-differential lanes.

(k) Barn-roof cross section is acceptable at high-fill locations as illustrated on Typical 2113.

(l) May use 4 × 8, 3 × 5, or swale depending on right-of-way impacts.

(m) When bridge length is greater than 800 feet, 8-foot shoulders are desirable for storage of vehicles in emergencies, but 6-foot shoulders are acceptable.

(n) Design loading should be sufficient to accommodate legal loads. Bridge rail and approach guardrail should be upgraded, if necessary.

Design Year ADT	Offset—each side (feet)
0–750	0
751–2000	1
2001–4000	2
> 4000	3

(o) 8:1 with drainage structures. 10:1 without drainage structures. 6:1 at sideroads.

(p) Includes provision for 3" HMA overlay. Vertical clearance is maintained above all lanes and shoulders. See Section 1C-2 for vertical clear zone guidelines.

(q) The designer may provide additional vertical clearance when site conditions warrant.

(r) May vary. Need to verify each railroad's requirement.

Rural Two-Lane Highways

Definition: Rural undivided highways with at-grade intersections.

design speed (mph)	60	
expected regulatory speed (mph)	55	
level of service (capacity analysis)	B	
clear zone (ft)	(a)	
minimum radius (ft)	1340 (b)(c)	
horizontal curves—minimum length (ft)	900 (b)(d)	
vertical curves—minimum length (ft)	180 (b)	
crest vertical curves—desirable k	245 (b)	
sag vertical curves—minimum k	136(b)	
stopping sight distance (ft)	570 (b)	
maximum gradient (%)	4 (e)	
	NHS	Non-NHS
lane pavement width (ft)	14 (f)	14 (f)
shoulder width (ft)	8 (g)(h)	8 (g)(h)(i)
shoulder type	granular	
turn-lane width (ft)	12 (h)(j)	
auxiliary-lane width (ft)	12	
foreslope	6:1 (k)	
normal ditch (depth × width) (ft)	5 × 10 (l)	
backslope	2.5:1	
bridge width—new (ft)	lane pavement widths + shoulder widths (m)	
bridge width—existing (ft)	lane widths + offset (n)	
transverse slopes	(o)	
vertical clearance—over primary (ft)	16.5 (p)	
vertical clearance—over non-primary (ft)	14.5 (p)(q)	
vertical clearance—over railroad (ft)	23.5 (r)	
vertical clearance—under any structure (ft)	16.5 (p)	

(a) Depends on design speed, traffic volume, cross section, and horizontal alignment. See Section 1C-2 of this manual. Measured from edge-of-traveled way.

(b) Based on design speed. See Section 6D-1 of this Manual for more information regarding stopping sight distance and Section 6D-5 for more information regarding vertical curve design.

(c) Based on $e_{max} = 6\%$.

(d) Includes spiral length.

(e) Maximum gradient up to 6% is allowed for areas with mountainous terrain (see definition in AASHTO's *A Policy on Geometric Design of Highways and Streets).*

(f) Actual driving-lane width is 12 feet. Painted edge line is offset 12 feet from centerline. On PCC pavement, roughness pattern is used outside the painted edge line.

(g) Actual shoulder width is 10 feet due to 2 feet of lane pavement width outside the painted edge line.

(h) Shoulder width adjacent to major right-turn lanes is 6 feet. Shoulder width adjacent to minor right-turn lanes is 4 feet.

(i) If design year ADT < 3000, shoulder width may be 8 feet. If design year ADT < 2000, shoulder width may be 6 feet.

(j) See Section 6A-1 for right and left-turn lane warrants.

(k) Barn-roof cross section is acceptable at high-fill locations as illustrated on Typical 2113.

(l) May use 4 × 8, 3 × 5, or swale depending on right-of-way impacts.

(m) When bridge length is over 1000 feet, 8-foot shoulders are desirable for storage of vehicles in emergencies, but 4-foot shoulders are acceptable.

(n) Design loading should be sufficient to accommodate legal loads. Bridge rail and approach guardrail should be upgraded, if necessary.

Design Year ADT	Offset—each side (feet)
0–750	0
751–2000	1
2001–4000	2
> 4000	3

(o) 8:1 with drainage structures. 10:1 without drainage structures. 6:1 at sideroads.

(p) Includes provision for 3" HMA overlay. Vertical clearance is maintained above all lanes and shoulders. See Section 1C-2 for vertical clear zone guidelines.

(q) The designer may provide additional vertical clearance when site conditions warrant.

(r) May vary. Need to verify each railroad's requirement.

Transitional Facilities

Definition: Roadways that transition between a high-speed rural driving environment and a reduced-speed urban environment.

design speed (mph)	55	50	45
expected regulatory speed (mph)	50	45	40
level of service (capacity analysis)	B	C	C
clear zone (ft)	(a)	(a)	(a)
minimum radius (ft)	1190 (b)(c)	930 (b)(c)	730 (b)(c)
vertical curves—minimum length (ft)	165 (b)	150 (b)	135 (b)
crest vertical curves—desirable k	185 (b)	140 (b)	100 (b)
sag vertical curves—minimum k	115 (b)	96 (b)	79 (b)
stopping sight distance (ft)	495 (b)	425 (b)	360 (b)
maximum gradient (%)	5	6	6
lane pavement width (ft)	same width as connecting rural facility		
shoulder width (ft)	same width as connecting rural facility (d)		
shoulder type	same as connecting rural facility (d)		
turn-lane width (ft)	12	12	12
auxiliary-lane width (ft)	12	12	12
curbs	(d)	(d)	(d)
foreslope	6:1 (e)	6:1 (e)	6:1 (e)
normal outside ditch (depth × width) (ft)	5 × 10 (f)	5 × 10 (f)	5 × 10 (f)
backslope	2.5:1	2.5:1	2.5:1
bridge width—new (ft)	lane pavement widths + shoulder widths (g)		
bridge width—existing (ft)	lane widths + offset (h)		
transverse slopes	(i)	(i)	(i)
vertical clearance—over primary (ft)	16.5 (j)	16.5 (j)	16.5 (j)
vertical clearance—over non-primary (ft)	14.5 (j)(k)	14.5 (j)(k)	14.5 (j)(k)
vertical clearance—over railroad (ft)	23.5 (l)	23.5 (l)	23.5 (l)
vertical clearance—under any structure (ft)	16.5 (j)	16.5 (j)	16.5 (j)

(a) Depends on design speed, traffic volume, cross section, and horizontal alignment. See Section 1C-2 of this manual. Measured from edge-of-traveled way.

(b) Based on design speed. See Section 6D-1 of this Manual for more information regarding stopping sight distance and Section 6D-5 for more information regarding vertical curve design.

(c) Based on e_{max} = 4%. Nonsuperelevated curves should be according to AASHTO's *A Policy on Geometric Design of Highways and Streets* Exhibit 3-26.

(d) If an urban cross section is used, a 3-foot offset to the bottom edge of a sloped curb is used. See Section 3C-2.

(e) Barn-roof cross section is acceptable at high-fill locations as illustrated on Typicals 2112 and 2113.

(f) May use 4 × 8, 3 × 5, or swale depending on right-of-way impacts.

(g) If an urban cross section is used, the bridge width should be the lane widths plus the width of the curb offsets. Present and future need for sidewalk(s) should be evaluated for each bridge. Bridge endposts should be shielded with guardrail or an impact attenuator.

(h) Design loading should be sufficient to accommodate legal loads. Bridge rail and approach guardrail should be upgraded, if necessary.

Design Year ADT	Offset—each side (feet)
0–750	0
751–2000	1
2001–4000	2
> 4000	3

(i) 8:1 with drainage structures. 10:1 without drainage structures. 6:1 at sideroads.

(j) Includes provision for 3" HMA overlay. Vertical clearance is maintained above all lanes and shoulders. See Section 1C-2 for vertical clear zone guidelines.

(k) The designer may provide additional vertical clearance when site conditions warrant.

(l) May vary. Need to verify each railroad's requirement.

Reduced-Speed Urban Facilities

Definition: Roadways with urban cross sections and reduced speeds. A roadway with an urban cross section controls surface drainage using curbs and an enclosed storm sewer system.

design speed (mph)	40	35	30
expected regulatory speed (mph)	35	30	25
level of service (capacity analysis)	C	C	C
clear zone (ft)	10 (a)	10 (a)	10 (a)
minimum radius (ft)	565 (b)(c)	420 (b)(c)	300 (b)(c)
vertical curves—minimum length (ft)	120 (b)	105 (b)	90 (b)
crest vertical curves—desirable k	70 (b)	50 (b)	30 (b)
sag vertical curves—minimum k	64 (b)	49 (b)	37 (b)
stopping sight distance (ft)	305 (b)	250 (b)	200 (b)
maximum gradient (%)	6	7	8
lane width (ft)	12 (d)	12 (d)	12 (d)
parking-lane width (ft)	10 (e)	10 (e)	10 (e)
turn-lane width (ft)	12 (f)	12 (f)	12 (f)
curbs	(g)	(g)	(g)
bridge width—new (ft)	lane widths + 3-foot offset on each side (h)		
bridge width—existing (ft)	lane widths + offset (i)		
vertical clearance—over primary (ft)	16.5 (j)	16.5 (j)	16.5 (j)
vertical clearance—over non-primary (ft)	14.5 (j)(k)	14.5 (j)(k)	14.5 (j)(k)
vertical clearance—over railroad (ft)	23.5 (l)	23.5 (l)	23.5 (l)
vertical clearance—under any structure (ft)	16.5 (j)	16.5 (j)	16.5 (j)

(a) Clear zone is measured from back-of-curb.
(b) Based on design speed. See Section 6D-1 of this Manual for more information regarding stopping sight distance and Section 6D-5 for more information regarding vertical curve design.
(c) Based on e_{max} = 4%. Nonsuperelevated curves should be according to AASHTO's *A Policy on Geometric Design of Highways and Streets* Exhibit 3-40.
(d) A 31-foot pavement section is used for two-lane facilities as shown on Standard Road Plan RH-45B. A 53-foot pavement section is used for four-lane facilities as shown on Standard Road Plan RH-47B. Narrower cross sections may be used with approval of the Design Engineer in areas with restricted right-of-way.
(e) Curb offset width may be included as part of the parking-lane width.
(f) For continuous two-way left-turn lanes, 14 feet should be used. Widths of 10 to 12 feet may be used with approval of the Design Engineer. See Section 6C-6 for more information regarding continuous two-way left-turn lanes.
(g) See Section 3C-2.
(h) Lane widths do not include curb and gutter. Present and future need for sidewalk(s) should be evaluated for each bridge.
(i) Lane widths do not include curb and gutter. Design loading should be sufficient to accommodate legal loads.

Design Year ADT	Offset—each side (feet)
0–750	0
751–2000	1
2001–4000	2
> 4000	3

(j) Includes provision for 3" HMA overlay. Vertical clearance is maintained above all lanes and shoulders. See Section 1C-2 for vertical clear zone guidelines.
(k) The designer may provide additional vertical clearance when site conditions warrant.
(l) May vary. Need to verify each railroad's requirement.

Ramps and Loops

Definition: Facilities that allow access at interchanges.

	one-lane ramps		two-lane ramps		loops	
design speed (mph)	60 (a)		60 (a)		30 (b)	
clear zone (ft)	(c)		(c)		(c)	
maximum superelevation (%)	6		6		6	
horizontal curves—minimum length (ft)	300 (d)		300 (d)		NA	
vertical curves—minimum length (ft)	180 (d)		180 (d)		30 (d)	
crest vertical curves—desirable k	245 (d)		245 (d)		30 (d)	
sag vertical curves—minimum k	136 (d)		136 (d)		37 (d)	
stopping sight distance (ft)	570 (d)		570 (d)		200 (d)	
maximum gradient (%)	5 (e)		5 (e)		5 (e)	
lane width (ft)	16 (f)		24 (g)		18 (h)	
	left (i)	right (i)	left (i)	right (i)	left (i)	right (i)
shoulder width (ft)	4	6	(j)	(j)	4	6
shoulder type	(k)		(k)		(k)	
foreslope	6:1 (l)		6:1 (l)		6:1 (l)	
normal ditch (depth × width) (ft)	5 × 10 (m)		5 × 10 (m)		5 × 10 (m)	
backslope	2.5:1		2.5:1		2.5:1	
bridge width—new (ft)	lane widths + full shoulder width					
bridge width—existing (ft)	lane widths + 3-foot offset on each side (n)					
vertical clearance—over primary (ft)	16.5 (o)		16.5 (o)		16.5 (o)	
vertical clearance—over non-primary (ft)	14.5 (o)(p)		14.5 (o)(p)		14.5 (o)(p)	
vertical clearance—over railroad (ft)	23.5 (q)		23.5 (q)		23.5 (q)	
vertical clearance—under any structure (ft)	16.5 (o)		16.5 (o)		16.5 (o)	

(a) Applicable to high speed merge/diverge areas and adjacent curves. Other curves along ramp should meet or exceed anticipated operating speed.
(b) 25 mph and 35 mph design speeds are acceptable under certain conditions.
(c) Depends on design speed, traffic volume, cross section, and horizontal alignment. See Section 1C-2 of this manual. Measured from edge-of-traveled way.
(d) Based on design speed. See Section 6D-1 of this Manual for more information regarding stopping sight distance and Section 6D-5 for more information regarding vertical curve design.
(e) May be increased to 6% if steeper gradient complements desired vehicle operations.
(f) If any portion of the ramp is designed with a radius between 150 and 249 feet, a lane width of 18 feet should be used for that portion.
(g) Both lanes. Avoid degrees of curvature less than 9°30′ to preclude lane-widening requirement.
(h) 18 feet if the radius of the major portion of the loop curvature (not the tapers) is 150–250 ft. Otherwise, 16 feet. Radii less than 150 feet are not recommended.
(i) When facing in the direction of travel.
(j) Depends on ramp type. See Section 6B-1.
(k) Shoulders for ramps shall be the same material as the mainline shoulders. Both shoulders of loops shall be paved.
(l) Barn-roof cross section is acceptable at high-fill locations as illustrated on Typical 2113.
(m) May use 4 × 8, 3 × 5, or swale depending on right-of-way impacts.
(n) Design loading should be sufficient to accommodate legal loads. Bridge rail and approach guardrail should be upgraded, if necessary.
(o) Includes provision for 3" HMA overlay. Vertical clearance is maintained above all lanes and shoulders. See Section 1C-2 for vertical clear zone guidelines.
(p) The designer may provide additional vertical clearance when site conditions warrant.
(q) May vary. Need to verify each railroad's requirement.

Clear Zones

Originally Issued: 07-12-96

This section provides guidelines for determining clear zones on primary highways. A highway's clear zone is the total roadside border area available for safe use by errant vehicles.[1] Within the clear zone, all slopes should be no steeper than 3:1 and free of objects that would interfere with a motorist's ability to regain control of an errant vehicle. The desired width of the clear zone depends on traffic volumes, speeds, and roadside geometry. The location from which the clear zone is measured ("edge of traveled way" or "back of curb") and the appropriate procedure for determining the clear zone depend on the type of highway.

Rural, Transitional and Other High-Speed Roadways

For freeways, expressways, super-two highways, rural two-lane highways, and transitional facilities, the designer should use Table 1 to determine the appropriate clear zone. Refer to page 4 for clear zone distances for temporary traffic control zones. The clear zone for high-speed roadways is measured from the edge of traveled way, exclusive of auxiliary lanes such as climbing lanes, turning lanes, or partially-paved shoulders.

Table 1 gives a range of allowable clear zone widths. The lower value in this range should be considered the minimum clear zone width, while the higher value should be considered the desirable width. In application, features that are made significantly more costly by a wider clear zone (for example, box culverts) should generally be designed to provide at least the minimum clear zone width. On the other hand, features whose costs are not affected in a major way by the clear zone width (i.e., new trees or utility poles) should be located outside the desirable clear zone, or even further from the roadway if the available right-of-way permits. Any evaluations of existing features should be based on the minimum clear zone width.

[1] *AASHTO Roadside Design Guide* (Washington D.C., 1996)xix.

Table 1: Clear zone distances (in feet from edge of traveled way).[2]

		fill slope (fs)			cut slope (cs)		
design speed (mph)	design ADT	fs ≥ 6:1	4:1 ≤ fs < 6:1	fs < 4:1	cs < 4:1	4:1 ≤ cs < 6:1	cs ≥ 6:1
speed < 40	ADT < 750	7–10	7–10	—**	7–10	7–10	7–10
	750 ≤ ADT < 1500	10–12	12–14	—**	10–12	10–12	10–12
	1500 ≤ ADT < 6000	12–14	14–16	—**	12–14	12–14	12–14
	ADT ≥ 6000	14–16	16–18	—**	14–16	14–16	14–16
40 ≤ speed < 50	ADT < 750	10–12	12–14	—**	8–10	8–10	10–12
	750 ≤ ADT < 1500	12–14	16–20	—**	10–12	12–14	14–16
	1500 ≤ ADT < 6000	16–18	20–26	—**	12–14	14–16	16–18
	ADT ≥ 6000	18–20	24–28	—**	14–16	18–20	20–22
50 ≤ speed < 60	ADT < 750	12–14	14–18	—**	8–10	10–12	10–12
	750 ≤ ADT < 1500	16–18	20–24	—**	10–12	14–16	16–18
	1500 ≤ ADT < 6000	20–22	24–30	—**	14–16	16–18	20–22
	ADT ≥ 6000	22–24	26–32*	—**	16–18	20–22	22–24
60 ≤ speed < 65	ADT < 750	16–18	20–24	—**	10–12	12–14	14–16
	750 ≤ ADT < 1500	20–24	26–32*	—**	12–14	16–18	20–22
	1500 ≤ ADT < 6000	26–30	32–40*	—**	14–18	18–22	24–26
	ADT ≥ 6000	30–32*	36–44*	—**	20–22	24–26	26–28
speed ≥ 65	ADT < 750	18–20	20–26	—**	10–12	14–16	14–16
	750 ≤ ADT < 1500	24–26	28–36*	—**	12–16	18–20	20–22
	1500 ≤ ADT < 6000	28–32*	34–42*	—**	16–20	22–24	26–28
	ADT ≥ 6000	30–34*	38–46*	—**	22–24	26–30	28–30

*Where a site specific investigation indicates a high probability of continuing accidents, or such occurrences are indicated by accident history, the designer may provide clear zone distances greater than 30 feet as indicated. Clear zones may be limited to 30 feet for practicality and to provide a consistent roadway template if previous experience with similar projects or designs indicates satisfactory performance.

**Since recovery is less likely on the unshielded, traversable 3:1 slopes, fixed objects should not be present in the vicinity of the toe of these slopes. Recovery of high-speed vehicles that encroach beyond the edge of the shoulder may be expected to occur beyond the toe of slope. Determination of the width of the recovery area at the toe of slope should take into consideration right-of-way availability, environmental concerns, economic factors, safety needs, and accident histories. Also, the distance between the edge of the travel lane and the beginning of the 3:1 slope should influence the recovery area provided at the toe of slope.

Adjustments for horizontal curves should be applied at selected locations. The clear zone should be considered for widening at curves, using Table 2, when an accident history suggests the need for additional clear zone width or when all of the following criteria are met:

- the radius of the curve is less than 2860 feet
- the curve occurs on a high-speed roadway (design speed of 55 mph or greater)
- the curve occurs on a normally tangent alignment (one where the curve is preceded by a tangent more than a mile in length)

Use the following equation to determine the clear zone distance when widening at horizontal curves:

$$CZ_c = (L_c)(K_{cz})$$

[2] *AASHTO Roadside Design Guide*, 3-4.

where:

CZ_c = clear zone on outside of curvature, in feet

L_c = clear zone distance, in feet (from Table 1)

K_{cz}= curve correction factor (from Table 2)

Table 2: Horizontal curve adjustments.

K_{cz} (curve correction factor)[3]

radius (ft.)	design speed (mph)						
	40	45	50	55	60	65	70
2860	1.08	1.10	1.12	1.15	1.19	1.22	1.27
2290	1.10	1.12	1.15	1.19	1.23	1.28	1.33
1910	1.11	1.15	1.18	1.23	1.28	1.33	1.40
1640	1.13	1.17	1.22	1.26	1.32	1.39	1.46
1430	1.15	1.19	1.25	1.30	1.37	1.44	
1270	1.17	1.22	1.28	1.34	1.41	1.49	
1150	1.19	1.24	1.31	1.37	1.46		
950	1.23	1.29	1.36	1.45	1.54		
820	1.26	1.34	1.42	1.52			
720	1.30	1.38	1.48				
640	1.34	1.43	1.53				
570	1.37	1.47					
380	1.54						

As Figure 1 shows, the clear zone should be adjusted only on the outside of the first curve following the tangent. If the alignment is generally curvilinear, no adjustment factor should be applied. Similarly, if the alignment is curvilinear preceding the curve in question, then no adjustment factor should be applied. Generally, the added clear zone width called for by the horizontal curve adjustment factor should be thought of as a desirable clear zone rather than a minimum. If the minimum width called for by Table 1 can be achieved, but the added width cannot be, a barrier would not normally be needed. The horizontal curve adjustment factor should be applied to projects where grading is a significant part of the project and available right-of-way allows for a wider clear zone.

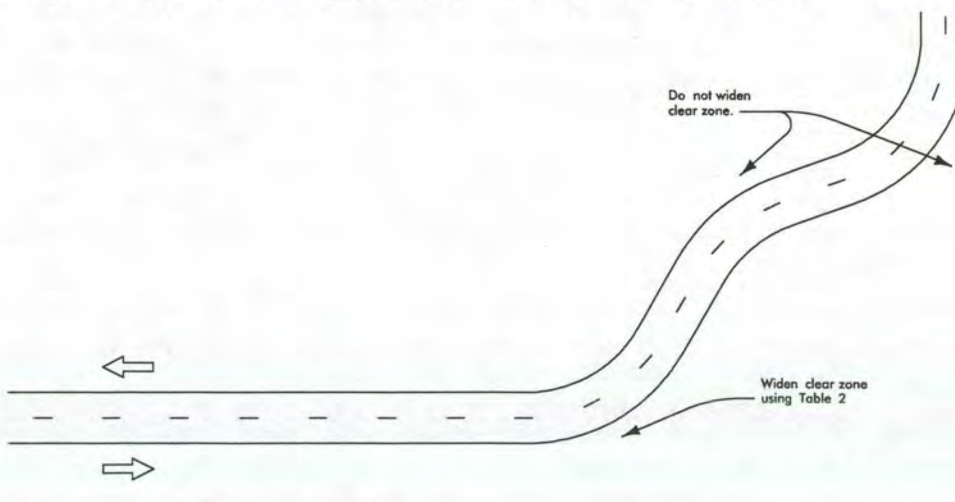


Figure 1: Clear zone adjustment at horizontal curves.

[3] *AASHTO Roadside Design Guide*, 3-5.

Reduced-Speed Urban Facilities

For reduced-speed urban roadways (those with urban cross sections and expected regulatory speeds of 35 mph or less) the clear zone should be 10 feet normal and 12 feet desirable, measured from the back of the curb. The Department normally purchases right-of-way 12 feet back of the curb in urban areas to provide for the desirable clear zone width. Where no reasonable alternative exists, aboveground utilities may be accommodated in the outermost 2-foot width of the right-of-way. On projects where safety is the principal goal, the clear zone may be designed to higher standards. Design exceptions may be justified on a case specific basis.

When the primary road extension has an expected regulatory speed limit of 25 mph or less, while the desirable clear zone remains the same, the minimum may be reduced to 6 feet measured from the back of curb.

If a turning lane, auxiliary lane, or paved shoulder results in a curb outside the normal roadway width, then a minimum 4-foot clear zone measured from the back of this curb should be provided.

If on-street parking is allowed on the primary highway, normal clear zone provisions cannot be met. A minimum operational clearance of 2 feet between the traffic and the parked vehicles needs to be provided within the roadway cross section. In this case, any objects, such as luminaire or sign supports, should be constructed no closer than 1.5 feet from the back of the curb.

Preferably, all objects should be placed outside of the minimum clear zone. If this placement is not practical, objects proven to be "breakaway", such as certain sign supports, may be constructed or allowed to remain in place within the clear zone. Objects broken away in a crash could possibly injure pedestrians; breakaway objects may not be recommended for locations between the curb and sidewalk if high volumes of pedestrian traffic are expected. In all cases, the near edge of any object should be no closer than 1.5 feet to the back of the curb to allow for a minimum operational clearance.

The above provisions apply only to urban primary highway extensions. When portions of side streets under the city's jurisdiction are reconstructed as part of a project on a primary highway, recommended practices in the Department's *Urban Design Aids* and *Alternate Urban Design Guide* should be followed. The Department retains the right to ensure that adequate sight distance is provided at any intersections or accesses.

Clear Zone Distances for Temporary Traffic Control Zones

Clear zones for temporary traffic control zones must be approached from a unique perspective. Unlike permanent situations where the life of a project is anywhere from 20 to 50 years, the life of a temporary traffic control zone is measured in weeks or months. If this relatively short life span is used to calculate a ratio of benefits versus cost, the analysis usually favors an unshielded option. Therefore, field performance is used to determine a reasonable clear zone distance.

An effort should be made to provide as much clear recovery area as possible without undo cost or interference. However, in situations where ideal clear zone distances are not possible or are impractical, the Department has adopted the following minimum requirements regarding clear zone determination in temporary traffic control zones:

- On two-lane rural roadways with alternating one-way traffic controlled by signals or flaggers, the minimum clear zone distance shall be the outside edge of the shoulder or 10 feet, whichever is less.
- On two-lane rural roadways where both lanes of traffic remain open, the clear zone shall be 10 feet.
- On non-interstate four-lane divided roadways the minimum clear zone shall be the greater of 10 feet or the outside edge of the shoulder.

- For interstate roadways the minimum clear zone distance shall be 15 feet or the outside edge of the shoulder, whichever is greater. For more information, see Section 9B-9.

Vertical Clear Zones

The horizontal clear zones described above should extend vertically a sufficient distance to effectively eliminate obstacles. Where feasible, the clear zone should extend vertically at least 14 feet 6 inches. If this is not possible, a benefit/cost analysis may be necessary to determine if shielding or other treatment is warranted.

Keep in mind the difference between vertical clearance and the vertical clear zone. The values for vertical clearance that are provided in Section 1C-1, should be maintained above all lanes and shoulders. The vertical clear zone referred to above should be maintained throughout the entire horizontal clear zone.

Applying Clear Zone Guidelines

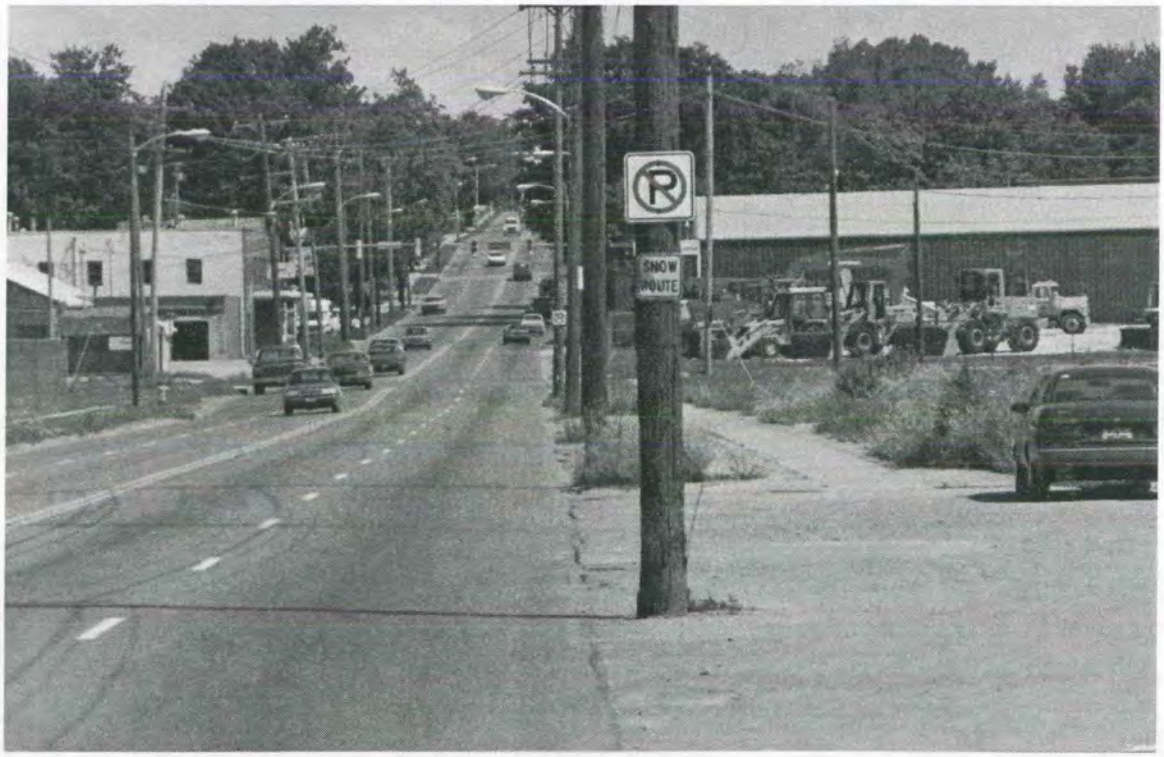
From a safety standpoint, it is always preferable to remove objects from the roadside. Where removing an object is not feasible, there are other options, listed below in order of preference:

- Relocate the object to a point where it is less likely to be hit.
- Reduce impact severity by using an appropriate breakaway device.
- Shield the object with a longitudinal traffic barrier and/or crash cushion if it cannot be eliminated, relocated, or redesigned.
- Delineate the object if the above alternatives are not appropriate.

Relocated objects should be placed outside the recommended clear zone, preferably near the right-of-way line. Each additional foot that an object is offset from the roadway provides an incremental safety benefit to drivers. However, the next foot out from a given offset provides less benefit than the previous one provided. If a significantly greater offset from the roadway can't be achieved, other options may be considered.

Some objects may be redesigned so that they will readily break away when struck by a vehicle. When other alternatives are not feasible, then the object may need to be shielded with a longitudinal barrier. Chapter 8 of this manual covers the design of these barriers.

The guidelines given above are intended to be applied with some limited flexibility. Examples of this flexibility can be found on urban roadways where buildings are close to the road. In cases where providing the minimum clear zone would require the purchase of a business or home, a design exception could be considered to avoid that purchase. Utility accommodations above ground may be precluded at these locations. Any exceptions to the provisions of this policy shall be approved by the Design Engineer.



Before

After

Utility poles and other obstacles were relocated outside the clear zone on this project in Des Moines, greatly improving safety and the appearance of the area.

Preliminary Survey Procedure

Originally Issued: 09-22-00

This section provides information relevant to preliminary survey requests and preliminary surveys, and how these tie into creating a Digital Terrain Model (DTM).

Survey Requests

Planning

A survey request layout should be provided to Preliminary Survey and Photogrammetry by November 1 of each calendar year. The Planning DTM mapping limits will be defined by an aerial photo with mapping boundaries penciled in or electronically drawn on the perimeters of the corridor as per the Project Management Team's needs. Planning DTM mapping limits are provided to the Photogrammetry Section in the "Order Aerial Photography" event. The photography used to generate the Planning DTM will be flown at a flight height of 3,000 feet or lower.

Design Section

A survey request should be provided to Preliminary Survey that defines the preferred alignment corridor. The field survey will be conducted in a narrowly defined corridor along the preferred construction alignment. For this event, the survey layout shall be an aerial photo with mapping boundaries penciled in or electronically drawn on the perimeters of the construction corridor. This layout shall be a product of the Project Management Team's preferred alignment decision. Photogrammetrically collected data and field collected data are combined to create a Design Level DTM.

Preliminary Survey

The current policy is to obtain preliminary surveys to 3rd order Class I accuracy for survey centerlines (including side roads) and 3rd order Class II accuracy for the remainder of the survey. Below is the procedure used to accomplish this accuracy and eliminate any duplication of work by the preliminary and cornerstone parties.

1. All preliminary engineering surveys shall be done in such a manner as to insure that the survey centerline is at least 3rd order Class I (1:10,000) accuracy.
2. Preliminary engineering survey parties shall check the accuracy of their surveys by tying to cornerstone surveys where available or by running a closed traverse.
3. If the error of closure on the traverse run to determine the accuracy of survey is not within the prescribed limits, it indicates that an error in field work has been made and the work should be checked and the error corrected.
4. On projects where the preliminary engineering survey was done and the District Land Surveyor finds the preliminary survey centerline is less than 3rd order Class I, the Supervisor of Surveys, Office of Road Design shall be notified and requested to make the appropriate adjustments to bring the survey within prescribed limits of accuracy.

5. The District Land Surveyor shall tie the land corners to the survey centerline or local project control other than outlined in 4 above.
6. All field notes obtained by the District Land Surveyor shall be kept in the district files.

Preliminary Survey Information

All requests for additional preliminary survey information beyond the normal data furnished by our ground surveys shall be submitted to the Survey Supervisor. The purpose of this coordination of survey is to provide the best utilization of our crews, determine need of additional survey for necessary and possible correction of data collected, and the proper utilization of RCE survey. Even in situations where the District agreed to provide additional survey data, this should be submitted through the Survey Supervisor.

Aerial photography is being obtained and updated for all primary highway improvement projects. This should provide an adequate corridor on each side of the proposed centerline. Preliminary survey crews will provide necessary ground control so that a DTM can be generated through stereo plotter operation. This procedure should effectively reduce the problem of disruption of survey scheduling caused by moving back survey crews to pick up additional preliminary survey information.

Final Design DTM

Upon completion of the Preliminary Survey, all field data collected at critical points and at critical lines will be merged into the original Planning DTM. Field generated point and line data will supercede photogrammetrically collected data. The Planning DTM supplemented with field data then becomes the Final Design DTM.

Interchange Review

Originally Issued: 12-20-99

On April 1, 1999, the Federal-Aid Oversight Agreement between the Iowa DOT and the FHWA took effect. This agreement established responsibilities for the design and construction of federal-aid transportation projects in accordance with ISTEA and TEA-21.

As part of the Federal-Aid Oversight Agreement, all interchange designs on the interstate system should be submitted to the FHWA. On the non-interstate system, only selected interchanges will be submitted to the FHWA.

All interchange designs should be submitted to the Methods Section for review, regardless of whether or not FHWA submittal is required.

Consultant designs should be routed through the Consultant Coordination Section.

Preliminary Review

The following information should be submitted to the Methods Section six weeks before the D2 event so the preliminary approval can be sent out 4 weeks prior to D2:

- Title sheet
- Typical paving cross sections for mainline, sideroad and ramps
- Mainline plan and profile sheets
- Sideroad plan and profile sheets
- Traffic projections (turning traffic volumes)
- Proposed interchange ramp configuration
- Proposed ramp profile grades
- Sideroad left-turn channelization and right-turn deceleration lanes required at ramp intersections

Final Review

The following information should be submitted to the Methods Section 4 weeks before the D5 event so the final approval can be sent out 2 weeks prior to D5:

- Final geometric plan of interchange showing ramp baseline geometry and curve data
- Final ramp plan and profile sheets
- Geometric and staking details of nonstandard ramp merge/diverge areas
- Mainline plan and profile sheets
- Sideroad plan and profile sheets
- Typical paving cross sections for mainline, sideroad, and ramps

- Traffic projections (turning traffic volumes)
- Ramp intersection geometric layout and details

For review purposes only (do not show on the final plan) show the turning path off-tracking on the ramp intersection geometric layout (see Figure 1). The following items should be labeled:

- Design vehicle for each turning movement
- Turning radius of outside tire path for each turning movement
- Lane width dimensions

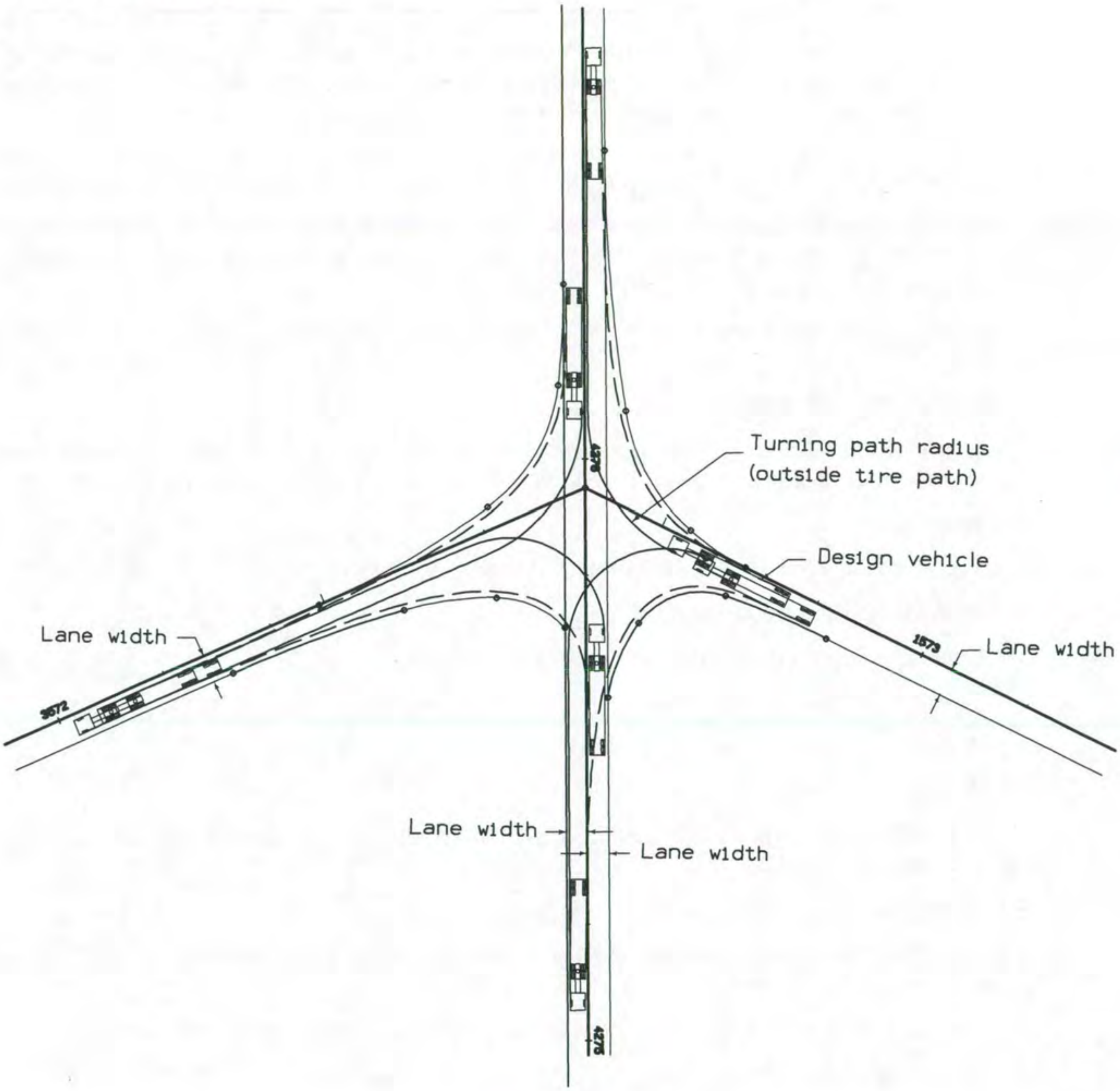


Figure 1

Access Review

Originally Issued: 09-01-95

Before beginning a project, the designer shall determine whether access rights and right-of-way are to be acquired. In order to make these determinations, the Project Concept Statement, the Minutes of the Project Review Meeting, and any other pertinent information must be reviewed. Using this information and the following guidelines, the designer can then determine whether to submit the project plans to the Access Policy Administrator (in the Office of Maintenance Services) and the Office of Right of Way.

When Access Rights Will Not Be Acquired

If access rights will not be acquired for the project, plans do not need to be submitted to the Access Policy Administrator, and a Final Access Review will not be issued. Submittal of plans to the Office of Right of Way will depend on whether right-of-way will be acquired for the project.

When Right-of-Way Will Be Acquired

If access rights will not be acquired, but additional right-of-way will be acquired, entrance locations shall normally be designed in compliance with Priority VI Rules and Regulations, as stated in Section 112.9 of the "Iowa Primary Road Access Management Policy" (hereafter referred to as the "Access Policy"). If the particular situation requires deviations from the Access Policy's Rules and Regulations, the following shall apply:

- No deviations are to be incorporated into the final design plan without the prior written approval of the Access Policy Administrator.
- Any problem that may occur with the design of an access due to the requirements of the policy shall be submitted to the Access Policy Administrator along with an explanation of the problem, the intended design to alleviate the problem, and a request for a waiver to the policy.
- The Access Policy Administrator will render a decision and advise in writing the Office of Design and the Office of Right of Way. This response will become a part of the correspondence file.

If right-of-way will be acquired, project plans shall also be submitted to the Office of Right of Way (the D-5 event). This submittal should include statements taken from the Project Concept Statement and copies of any other information pertaining to access. If the Project Concept Statement does not address access, the Access Policy Administrator should be contacted for guidance on how access will be handled on the project.

When Right-of-Way Will Not Be Acquired

If access rights will not be acquired and the project will be completed within the existing right-of-way, the Project Concept Statement will provide this information. The Project Concept Statement should also indicate that existing entrances will be allowed in the same locations as before the project. In such cases, designers should leave entrances in the same locations providing the entrance designs do not conflict with the Access Policy (for example, adequate sight distance must be maintained).

In most cases when neither access rights nor right-of-way will be acquired, project plans do not need to be submitted to either the Access Policy Administrator or the Office of Right of Way. An exception to this would be if an entrance design deviates from the Access Policy. In such cases, the Access Policy Administrator shall be contacted for approval, as described above.

When Access Rights Will Be Acquired

If access rights will be acquired as part of the project, the Minutes of the Project Review Meeting will provide this information. The minutes should also state the appropriate spacing requirements for accesses. In such cases, project plans complying with these spacing requirements shall be submitted to both the Access Policy Administrator and the Office of Right of Way. The procedure below shall be followed in completing these activities:

1. Prior to submitting plans to the Office of Right of Way (the D-5 event), the designer submits the following information to the Access Policy Administrator, along with a request for review and determination of final access locations:
    - One set of design plans showing property lines, names of property owners, drainage structures, design grades, profiles, typicals, side road connections, and when applicable, interchange layouts.
    - Copies of all correspondence relating to access, including the Project Concept Statement and the Minutes of the Project Review Meeting.
    - Recommended access locations based on those shown at the corridor hearing by the Planning and Programming Division.
    - Other pertinent information, such as previous correspondence with cities, counties, or property owners.
2. The final access locations and accessways determined by the Access Policy Administrator and the District Office Design Engineer are incorporated into the final design plan. The plan is then submitted to the Office of Right of Way.

Changes in the access locations must receive written approval of the Access Policy Administrator, who will be responsible for coordinating any changes with the District Office Design Engineer. If necessary because of property line stationing, the exact stationing may be altered slightly without written approval when

- The access location continues to serve the property(ies) for which it was intended, and
- Proper spacing requirements are met.

The Access Policy Administrator shall be advised in writing of any change in the stationing of an access location from that listed in the Final Access Review.

Field Examination Checklist (New and Reconstructed Highways)

Originally Issued: 12-20-99

Field Exam Requests

The Design Projects Engineer should submit a request to schedule a Design Field Exam (D2) to the Pre-Design/Field Exam Engineer (Field Exam Engineer) approximately 4 to 6 weeks prior to the desired field exam date. The following information should be included in the request:

- County name
- Project number
- Project identification number (PIN)
- Project location, as stated in the production schedule
- Anticipated date plans will be available for review. Five copies of the plans should be provided to the Field Exam Engineer for distribution at least 2 weeks before the scheduled field exam (1 – Field Exam Engineer, 1 – Federal Highway Administration, and 3 – District Office).
- Any special information about the project and/or attendees

The Field Exam Engineer will contact the appropriate District Office Development Engineer to schedule the field exam. If necessary, the Field Exam Engineer will make reservations for lodging. The District Office Development Engineer will contact any non-DOT personnel such as county engineers, city engineers, other affected state agencies, etc.

The Field Exam Engineer will then send out confirmation (via Lotus Notes) of the scheduled field exam. Distribution of this confirmation note should include the following personnel:

- District Office Development Engineer
- District Office Construction Engineer
- District Office Maintenance Engineer
- FHWA representative
- Design Engineer
- Assistant Design Engineers
- Pavement Design Engineer
- Soils Design Engineer
- Assistant Bridges and Structures Engineer
- Preliminary Bridge Engineer
- Methods (if there is interchange, geometric, or lighting issues)
- Right of Way Design representative

- FHWA
- Records Center
- Design Projects Engineer

The confirmation note should include the following information:

- County name
- Project number
- PIN
- Project location
- Date of field exam
- Meeting location and time
- Departure location and time for central office personnel

Plan Development Prior to Field Exam

Prior to the field exam, the Design Projects Engineer should review the plans for completeness. The field exam plans should contain, but not be limited to the following:

- Preliminary title sheet
- Project concept letter, if available
- Overall plan layout for large complicated projects
- Typical cross sections
- Plan and profile sheets
- Preliminary cross sections
- Side road plan and profile sheets
- Reference information and bench marks
- Bridge and/or culvert situation plan sheets
- On-site detour plan and profile
- Staging and traffic control sheets

Title Sheet

The following information should be included on the title sheet:

- County name
- Project number
- PIN
- County map showing project location
- Design data, project information, traffic, etc.
- Preliminary earthwork quantities (borrow required or waste generated)

Typical Cross Sections

At least half of Sheet B.01 should be left blank for taking notes.

The following information should be included:

- Typical cross section(s) for mainline grading and/or paving
- Typical cross section(s) for side roads (paved and/or granular)
- Typical cross section(s) for shoulders
- Typical cross section(s) for on-site detour paving and/or runarounds
- Any other applicable typical cross sections

Plan and Profile Sheets

The following information should be shown in the plan view:

- Plan view of design and related information
- Horizontal alignment
- Bridge and culvert information—drainage arrows; drainage area; existing culvert descriptions; proposed type, size, and location of new structures; carry drainage ahead or back.
- Intercept lines
- Access control and access locations
    1. Side road locations, including traffic data and reference to the appropriate side road plan and profile sheet
    2. Entrance locations
- On-site detours
- Turn lanes (The use of turning lane pavement markings will be determined by the District Engineer. See Section 7D-3)
- Any questions to be discussed during the field exam should be surrounded by a "cloud" to stand out on the plans.

The following items should be shown in the profile view:

- Profile with grades, lengths of vertical curves, K value, and design speed
- Existing ground line
- Existing roadway profile and/or railroad profile, if applicable. If the existing roadway is to be used as constructed (UAC) as part of a "new" four-lane roadway construction, then the K values and design speed of the existing vertical curves (especially crest vertical curves) should be reviewed and noted. Assume the posted speed limit will be raised to 65 mph (70 mph design speed). Specific locations with concerns, such as a side road or entrance located beyond a vertical curve not meeting the higher speed criteria, should be noted for review on the field exam.
- Entrance profiles with grades
- Ditch grades
- Ditch bar chart with descriptions

- Bench information for foreslopes and/or backslopes
- Cut and fill quantities with borrow or waste circled

Plan Review Prior to Field Exam

The Field Exam Engineer will review the plans to become familiar with the scope of the project and the proposed design. The following checklist is provided for this review:

- Are plans complete enough to conduct the field exam and are they legible?
- Check the typical section. Are L, R, and BW correct for the assumed pavement thickness?
- Review the disposition shown for all drainage areas, whether diversion of water appears possible, and if the outlets for drainage areas are being cut out.
- Is the proposed profile grade high enough for adequate snow storage or is it too high requiring too much borrow?
- Do taper lengths, spirals, vertical curves, etc. conform to current design standards?
- What are the right-of-way impacts? Are "line shifts" necessary to minimize excess right-of-way? Are right-of-way "need" lines shown on the plans?
- Is design year traffic for the mainline and side roads shown on the plans?
- Is/are detour route(s) required for construction? If so, have any recommendations been made by Design? Does the map on the title sheet cover the detour area?
- Review the proposals made for the disposition of waste.
- Review the proposals made for the disposition of removal items.
- Review whether the class of access control has been shown.

Checklist for the Field Examination

- ❑ Review the preliminary plans for any new items that should be included and/or any old items that should be removed since the preliminary data was obtained.
- ❑ Review the profile grades and horizontal alignment to determine if it fits the terrain. Also, do the proposed horizontal and vertical geometrics provide a good economical design to accomplish the intended need?
- ❑ Review drainage in regard to the following aspects:
- Does the proposed grade line provide adequate positive drainage?
- What relationship does drainage have with adjacent property?
- Are the proposed drainage structures satisfactory, is there a diversion of water, and what is the condition of the structures being extended?
- Do structures in drainage channels need provisions for the future lowering of the channel (this is of particular importance in regard to river bottoms and Northern Iowa flatland); attention should be given to established drainage ditches?
- Are ditches, as proposed, going to satisfactorily drain the road without excessive erosion problems or diversion of water?
- Are there areas which appear to need intercepting ditches or are there any proposed which appear to be unnecessary?

- Determine if any "letdown" structures are needed in backslopes or side ditches.
- Examine channel changes to determine if they are warranted.

- ❑ Review whether proposed drives and field entrances give satisfactory access and whether there is adequate sight distance on the side roads for entering the primary road. In addition, the team will determine whether there are any proposed drives or entrances which appear unneeded and unwarranted.
- ❑ Review whether the abutments of two span bridges over the mainline encroach on sight distance on horizontal curves.
- ❑ The indication of needed horizontal line shifts will be reviewed by the team and a determination made of the apparent effect of the proposed road on the adjacent right-of-way. Review damage to farmsteads; see if minimum ditches are possible. Can we provide mowable backslopes either in our design or in the ROW agreement?
- ❑ Do entrances provide access to every part of the property?
- ❑ Can entrances with steep grades be adjusted or moved in order to reduce the grade?
- ❑ The team will review soils from the following aspects:

- Determine if there are areas that appear unstable and need special attention for grade or alignment.
- Determine whether there is an estimate of "boulders" required for bid item. If so, this will normally be proposed by the Soils Engineer with District Office concurrence.
- Determine whether there appears to be changes needed in the "shrink factors." If so, this will normally be proposed by the Soils Engineer with District Office concurrence.

- ❑ The team will make proposals for borrow considering the following aspects:

- Are there any particularly desirable areas for borrow?
- Can excess right-of-way serve as borrow area?
- Can the selected borrow improve either snow, aesthetics, or wetland mitigation?
- If the borrow needs to be drained is there a suitable drainage channel? Who owns the drainage channel?
- Consider oversize ditches and widened backslopes for borrow.

- ❑ The following aspects of roadside development and erosion control should be considered by the team:

- Are there any areas requiring special erosion control work during grading?
- Are there areas which might be considered scenic or historic which can be preserved or enhanced?
- Can inlets of ditches be raised to help upstream erosion conditions?
- Are proposed ditches going to satisfactorily drain the road without erosion problems or diversion of water?
- Are there trees or similar environmentally sensitive areas which can be saved?
- Are there any areas that appear to be wetlands and could line shifts minimize impacts to these areas? If line shifts cannot minimize the impacts, what type of mitigation is needed? Are there impacts to any ponds or ponds that need to be drained?

- ❑ Review the traffic staging and whether some roads need to be kept open to maintain traffic or if runarounds or detours are required. If so, review the proposals as to how traffic will be handled and where they will be placed. The type of detour surfacing should be discussed, as well as any agreements needed with the county.
- ❑ Review if there are areas that may need to involve possible winter carry over of traffic control in the construction zone. Determine who will be responsible for maintaining the traffic control during this time period.
- ❑ Review the need for shielding obstacles, steep embankments, or other areas of concern. Review flattening foreslopes and extending culverts to eliminate the use of guardrail.
- ❑ Review the proposals for disposition of removal items such as pavement (will it be used as subbase?), bridges, culverts, guardrail, etc.
- ❑ Ascertain the stations of locating tile lines.
- ❑ Review the fencing requirements on fully controlled access roads with particular attention given to culvert areas and special ditch areas for livestock control.
- ❑ Review existing lighting at secondary and minor roads and determine who owns these and is responsible if they are disturbed. The location and construction of these should be noted.

Field Exam Plan Notes

- The Field Exam Engineer should list all people participating in a field examination and their identification on the title sheet of the plans.
- The Field Exam Engineer will have the responsibility of obtaining notes documenting all decisions made during the field examination.
- The Field Exam Engineer should check each sheet of the plans to make sure all questions are answered and that all proposals are accounted for, approved, changed, or further courses of action indicated. General notes affecting the whole project should be on the title sheet.

Post Field Exam

- The field exam plans will be reviewed with the Assistant Design Engineer, Design Projects Engineer, the designer, and the Field Exam Engineer following the field exam. After discussion of the plans, the Assistant Design Engineer initials and dates the field exam plan.
- A detailed post field exam letter will be written by the Field Exam Engineer covering all of the major areas of discussion, decisions made, and any requests for additional information, survey, or unanswered questions. All items of discussion and differing opinions must be resolved and documented in the letter.
- The field exam letter should be addressed to the District Office Design Engineer.
- Copies of the field exam letter should be sent to the following (use the applicable individual names in place of the position titles):

    Design Engineer
    Assistant Design Engineers
    Pavement Design Engineer
    Soils Design Engineer
    Methods Engineer (w/ attachment)
    Roadside Development
    Design Section Engineer (w/ attachment)
    Preliminary Bridge Engineer (w/ attachment)

Resident Construction Engineer (w/ attachment)
ROW Director
ROW - Utilities
Development Support - Railroad
Development Support – Value Engineering
Development Support - Agreements
FHWA Division Administrator (w/ attachment)
Project Planning Director (w/ attachment)
Project Planning – Hearings (w/ attachment)
Program Management Director
Engineering Division Director
Transportation Safety – Traffic Control (w/ attachment)
Maintenance – Entrances/Access Permits
Contracts – Production Schedule
Consultant (if applicable) (w/ attachment)

Field Examination Checklist (3R and 4R Projects)

Originally Issued: 09-22-00

Pre-Field Exam

- ❑ Approved concept statement and "plan package" prepared by the Field Exam Engineer is assigned by the Assistant Design Engineer to responsible section for development.
  - Concept plan package contains:
    - ❑ Project initiation letter from Assistant Design Engineer
    - ❑ Final concept statement and other pertinent correspondence
    - ❑ 11"x17" "as built" plans of roadway to be repaired
- ❑ Section Engineer assigns package to designer to prepare the field exam plan (this is usually the same person responsible for the project).
  - Preparation includes making a field exam title sheet, necessary typicals to meet concept criteria, copy of concept on 11"x17" paper, copy of Field Exam Checklist items (see below), copy of original plan furnished in plan package, 1 blank 11"x17" page for additional field exam notes.
  - All sheets are 11"x17" and field exam copies are made as necessary. Usually 4-11"x17" plans are given out to field exam personnel, and 2-8 ½"x14"plans for official field exam plan and backup.
  - Field Exam Checklist (to be provided by the District)
    - ❑ Patching quantities—full depth, partial depth, and surface
    - ❑ Locations and lengths (i.e. station to station) for leveling and strengthening
    - ❑ Areas of haul-outs
    - ❑ Survey for culvert extensions (for reinforced concrete box (RCB) extensions - 100 feet each side of the structure and 100 feet left and right of centerline at 25-foot intervals, provide a 20-scale drawing)
    - ❑ Survey for safety dikes (100 feet each side of proposed safety dike and up to 100 feet from centerline of roadway). For large ones only.
    - ❑ Survey and 20-scale of proposed right turn lanes (from centerline of side road back 400 feet and up to 75 feet from centerline of roadway, cross section every 50 feet)
    - ❑ Survey of horizontal curves (at least 3 locations within full super - edges and centerline)
    - ❑ Embankment and pipe quantities for flattening transverse slopes (National Highway System (NHS) routes ONLY); items to be tabulated by location.
    - ❑ Names and addresses of affected utility companies
    - ❑ Locations of entrances to be reshaped
    - ❑ Names of affected state events
    - ❑ Locations of mailboxes to be relocated to a minimum of 8 feet from the pavement edge
    - ❑ Survey trees within the roadside recovery area.
    - ❑ Number and location of EF joints

- ❑ Disposition of bridge handrail and guardrail, including posts
- ❑ Inventory of existing guardrail (use tables found in Quantities for Barrier Removal, located at S:\Users\Methods\Guardrail\BarrierQuantities.doc, and tables found in Variables Needed for Barrier Design, located at S:\Users\Design\Methods\Guardrail\BarrierVariables.doc)
- ❑ Locations (station to station) for longitudinal joint repair
- ❑ Locations and quantities of engineering fabric to be placed over random cracks
- ❑ Tabulation of adjustment of fixtures
- ❑ Clearing and grubbing quantities

- Other items to be discussed/reviewed with the District during the field exam and noted on the plans should include the following:

  - ❑ Contractor furnish borrow? **(Yes) / (No)**
  - ❑ Full depth patches to be Portland concrete cement (PCC)? **(Yes) / (No)**
  - ❑ Full depth PCC patches to be doweled? **(Yes) / (No)**
  - ❑ Soils to determine and provide tabulation of subdrains? **(Yes) / (No)**
  - ❑ Pollution Prevention Plan (PPP) required? **(Yes) / (No)**
  - ❑ Field Office? **(Yes) / (No)**
  - ❑ Construction Survey? **(Yes) / (No)**
  - ❑ Survey by Office of Design? **(Yes) / (No)**
  - ❑ Pavement markings for turn lanes as determined by the District? **(Yes) / (No)**

❑ After submitting field exam package to person for preparation, the Section Engineer will contact the District Engineer to set up a field exam date and time (usually 2 to 6 weeks after project is assigned).

- If concept statement is unclear about need for subdrains, contact Soils Engineer to verify if they will be needed. (Soils personnel do not usually attend the field exam.)
- If any culvert, RCB, and/or bridge work is noted in concept, advise Preliminary Bridge Engineer of impending field exam date and if anyone will attend. Whether representative attends or not, provide copy of proposed field exam plan to Preliminary Bridge Engineer no later than 1 week prior to trip.

❑ The Section Engineer will write a memo to the District Engineer confirming date, time, meeting location, when Central Office personnel will leave Ames, statement that no plans will be sent in advance, and statement about whether representative from the Office of Bridges and Structures should or does not need to attend. Distribution is as follows: Design Engineer, both Assistant Design Engineers, District Construction Engineer, District Maintenance Engineer, Field Exam Engineer (write on his/her copy asking if van is available), Assistant Bridges and Structures Engineer, Preliminary Bridge Engineer, Soils Engineer, FHWA representative (if necessary), Records Center, Project Scheduling Engineer.

- If the Field Exam Engineer is attending, he/she will be responsible for transportation. If the Field Exam Engineer is not attending, then the Section Engineer will be responsible for transportation.

Field Exam

❑ Local field exam personnel are to meet District personnel at agreed time and place.

❑ Begin Field Exam notes (usually with contrasting color or markings).

- Note taker is usually the Field Exam Engineer, senior design technician, Assistant Section Engineer, Section Engineer or other person from Design familiar with the procedure.

- Write the field exam date and attending personnel, including their position, on the title sheet.
- Prior to beginning the exam, the Design person in charge will recap concept of proposed project.
- Any items discussed on review are written on plans.
- After the field exam is over, Design person in charge will recap the day's exam and note any disagreements and change any errors noted on the review plans.
- The notes on the official 8 ½"x14" plan need to be legible and able to be understood by any future reviewers. Notes should be specific and self-explanatory.

Post Field Exam

- ☐ If necessary recopy field exam information on backup plan.
- ☐ Set up time with Assistant Design Engineer to review field exam plan.
- ☐ When reviewing plan with Assistant Design Engineer it is important to have all Design personnel in attendance.
- ☐ Section Engineer or Design representative in charge of the field exam is to draft a letter under the Section Engineer's name. Note that even if the Field Exam Engineer is present, he/she will not be writing the field exam letter.
    - The letter will be sent to the District Engineer along with 3 copies of the plans. The letter will indicate when information is needed from various sections and departments.
    - Distribution to:

      Design Engineer
      Assistant Design Engineer
      District Construction Engineer
      District Resident Construction Engineer w/ field exam plan
      Field Exam Engineer
      Assistant Bridge Engineer
      Preliminary Bridge Engineer w/ field exam plan
      Soils Engineer w/ field exam plan
      Records Center
      ROW Director
      ROW Design Supervisor

      And others as necessary:

      ROW Utilities Officer
      ROW Agreements officer
      Roadside Development
      Program Management
      Project Scheduling Engineer
      FHWA representative w/ field exam plan

Lighting Warrants Request

Originally Issued: 09-01-95

The review of lighting warrants and light pole relocations should be made early in a project's development so that lighting plans may be included as a part of the final plan. As soon as possible after the field exam, the design sections should provide the necessary information to the Office of Traffic and Safety so appropriate lighting needs can be determined.

Interchange Lighting

All new interchanges that are built, including those involving county roads, will normally include lighting as a part of the design plan. The following guidelines shall be followed in determining their lighting needs.

- Lighting design for new urban interchanges should be consistent with that of adjacent interchanges.
- Lighting design for rural diamonds will normally include lighting for only the ramp terminals with the sideroad. Depending on ramp volumes and ramp exit curvatures, lighting at ramp exit tapers may also be included.
- On new interchanges that include loops, lighting should be included for the loop exit tapers. An individual interchange designed with loops may also warrant additional lighting at the entrance ramp taper and around the inside of the loop.
- Lighting for new cloverleaf interchanges will normally include full lighting around the loops and lighting at the ramp exit and entrance tapers.

For existing unlit interchanges, PPM 630.03 (interchange and freeway lighting) will be used to determine when lighting should be installed. When an existing interchange is to be lit, the lighting design should be consistent with lighting for new interchanges.

Inform the Office of Traffic and Safety whenever existing lighting must be removed or relocated. They will furnish details of the necessary lighting modification for inclusion in the design plan.

Intersection Lighting

When designing a new intersection, or redesigning an old intersection, designers must decide whether to consider lighting as a part of the design plan. This decision is based on the types of roads that are intersecting and the intersection's location. The following guidelines apply.

Intersection of Two Primary Roads

When an intersection involves two primary roads, inform the Office of Traffic and Safety of the project. If the intersection is already lit, they will develop a new lighting layout to be included in the design plan. If an unlit primary-to-primary intersection is to be reconstructed, also supply Traffic and Safety with traffic turning volumes, so the intersection may be reviewed against the criteria of PPM 630.01 to determine if lighting is warranted.

If two primary roads intersect within the corporate limits of a city, the city is responsible for lighting, according to the administrative rules. Traffic and Safety will not normally review warrants for such intersections, nor will the department include lighting work for them in its plans.

Intersection of a Primary Road with a Local Road

If an intersection involves a county road and a primary road, the county is responsible for lighting, according to the administrative rules. Ordinarily, Traffic and Safety will not review warrants for such locations.

If the primary road intersects with a road within the corporate limits of a city, regardless of whether the intersecting road is a primary road, county road, or city street, the city is responsible for lighting. Again, the Office of Traffic and Safety will not routinely review lighting warrants for these intersections.

Projects That Affect Existing Lighting

Inform the Office of Traffic and Safety of any projects that will involve the removal or relocation of any existing lights. This includes the lighting of interchanges, primary-to-primary intersections, primary-to-secondary intersections, or city streets. Traffic and Safety will determine whose responsibility the lighting is and determine if the lighting will be replaced or relocated as part of the project. The following page provides a form that you may photocopy and use for sending this information to the Office of Traffic and Safety.

To: Office of Traffic and Safety Date ____________

From: ____________

Subject: INTERSECTION LIGHTING

County: ____________

Project PIN Number: ____________

Proposed Letting Date: ____________

Intersection of ____________ and ____________

Is the existing intersection lighted? yes / no

Is the existing intersection a "Y" that is being reconstructed into a "T" intersection? yes / no

Does either of the primary routes change direction at this intersection? yes / no

Will this intersection be channelized after reconstruction? yes / no

NOTE: Attached are the turning movements at this intersection.

Design Public Hearing Displays

Originally Issued: 12-31-97

A design public hearing display is a CADD-generated color drawing used to present design details for a proposed project. The display is presented on paper to the general public at informational meetings and public hearings. For presentations to the Commission or department staff, it may be projected electronically or presented on paper. The display contains only the information that is relevant for understanding the geographic layout of the project.

Preparation of design public hearing displays requires coordination between the Office of Right of Way and the Office of Design.

Office of Right of Way

As soon as the R1 event (Right of Way—Layout) is complete, the Office of Right of Way sends copies of the plans to the transportation centers so they can respond to the concerns of the public. Copies are also sent to the Office of Project Planning—the office responsible for scheduling the hearing. Right of Way shall inform the Office of Design when this occurs, so Design can access the current right-of-way information (see page 3 for more details). This ensures that Design and the transportation centers have consistent information.

The Office of Right of Way is also responsible for all right-of-way information on the public hearing display. Right of Way personnel will make filled shapes for permanent acquisitions and temporary easements and place parcel numbers and the names of property owners at an appropriate scale and orientation.

Office of Design

The Office of Design is responsible for the remainder of the display preparation. Design personnel will create filled shapes for pavement, paved medians, bridges, box culverts, and other design features.

As soon as the display is complete, Design personnel shall notify the Hearings Section of the Office of Project Planning and the Transportation Center Development Engineer so the display can be reviewed.

Items to be Included

The following table lists the features included on a public hearing display and the color used to represent each item (see also, the example legend on page 4).

Feature	Color
pavement	yellow
raised median	black
painted median	black diagonal pattern over yellow
granular surface	gray
sidewalk or bikeway	purple
bridges and box culverts	red
permanent right-of-way	blue
temporary easement	tan
property lines	red (dashed line)
north arrow and scale	black
predetermined access location	black (diamond shape)

Borrow areas should be outlined in black and labeled. The fill color of borrow areas will be either blue or tan, depending on whether the borrow area falls within permanent right-of-way or a temporary easement.

All other lines and all text are presented in black.

Text

The text on the display should also be limited to the information that is relevant for understanding the geographic layout of the project. The following text should be included:

- beginning and ending of project
- property owner names and parcel numbers
- text which labels geographic features (for example, "borrow", "pond", "house", etc.)
- roadway stationing
- entrances (both proposed and closed)
- township, range, and section

All other text (such as horizontal curve data, culvert data, bridge text, and utility text) should not be included.

Process

Because a public hearing display may be presented various times, it is important that the exact same display is presented each time—regardless of any changes made to the `k#.dgn` and `j#.row` files between presentations.

The following steps describe the general process that should be followed when creating a public hearing display. Following these steps will ensure that the same information is displayed at each presentation. Documentation for specific CADD procedures is available from the Office of Design's Automation Coordination Section (ODAC).

1. Create two blank files named `k#.pub` and `k#.lok`.
2. Reference all active design files (`k#.dgn`, `j#.row`, `k#.pho`, `k#.txt`, `k#.lok` and `j#.lok`) into `k#.pub`. The order these files are referenced is important so text and line work are not covered by filled shapes. See ODAC's documentation for more information on referencing these files.
3. Create the plot file(s). This will lock in the correct settings for plotting and allow the manipulation of active elements and reference files in the `k#.pub` file without affecting plotting. See ODAC's documentation for more information on creating plot files.
4. Create filled shapes and place the fence plotting outlines in `k#.pub`.
5. Copy the necessary elements (such as the north arrow, scales, etc.) into `k#.pub`. Scale and/or rotate them as necessary so they are oriented correctly to match the plotting outlines.
6. After Right of Way provides notification of the completed R1 event, replace the blank `k#.lok` file with a copy of `k#.dgn`. At this point, the permissions on `k#.lok` should be changed so that no changes can be made by anyone.
7. Detach `k#.dgn` and `j#.row` in `k#.pub` and the plot file(s). The files will now reflect the new `k#.lok` and `j#.lok` files, rather than the `k#.dgn` and `j#.row` files. From this point on, any changes made to the `k#.dgn` and `j#.row` files will not show up on the public hearing display.
8. Plot the public hearing display.

Examples

The following color examples illustrate (1) a legend, (2) an urban display, and (3) a rural display.

LEGEND

PROPOSED PAVEMENT

PROPOSED RAISED MEDIAN

PROPOSED PAINTED MEDIAN

PROPOSED GRANULAR SURFACE

PROPOSED SIDEWALK OR BIKEWAY

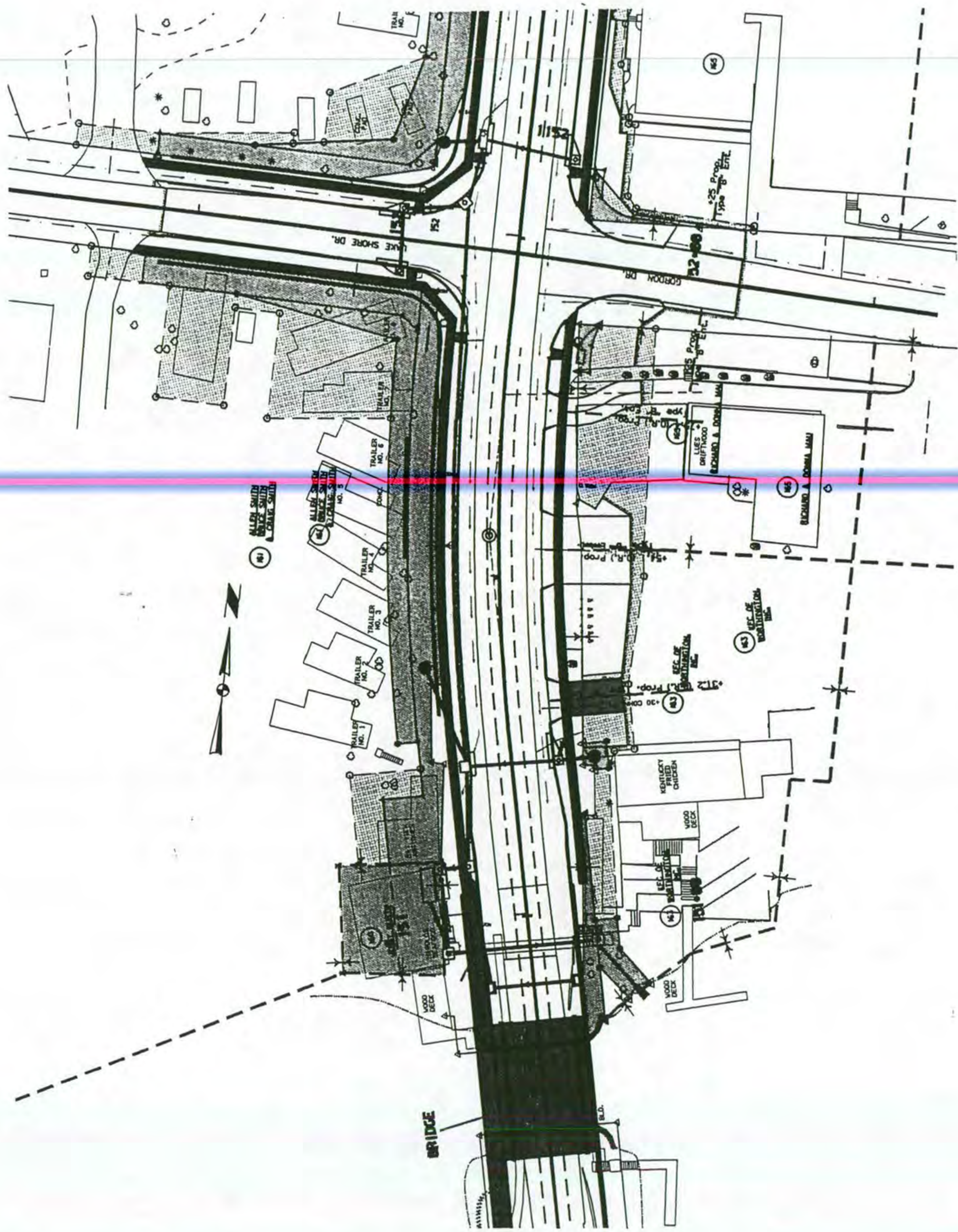
BRIDGES AND CULVERTS

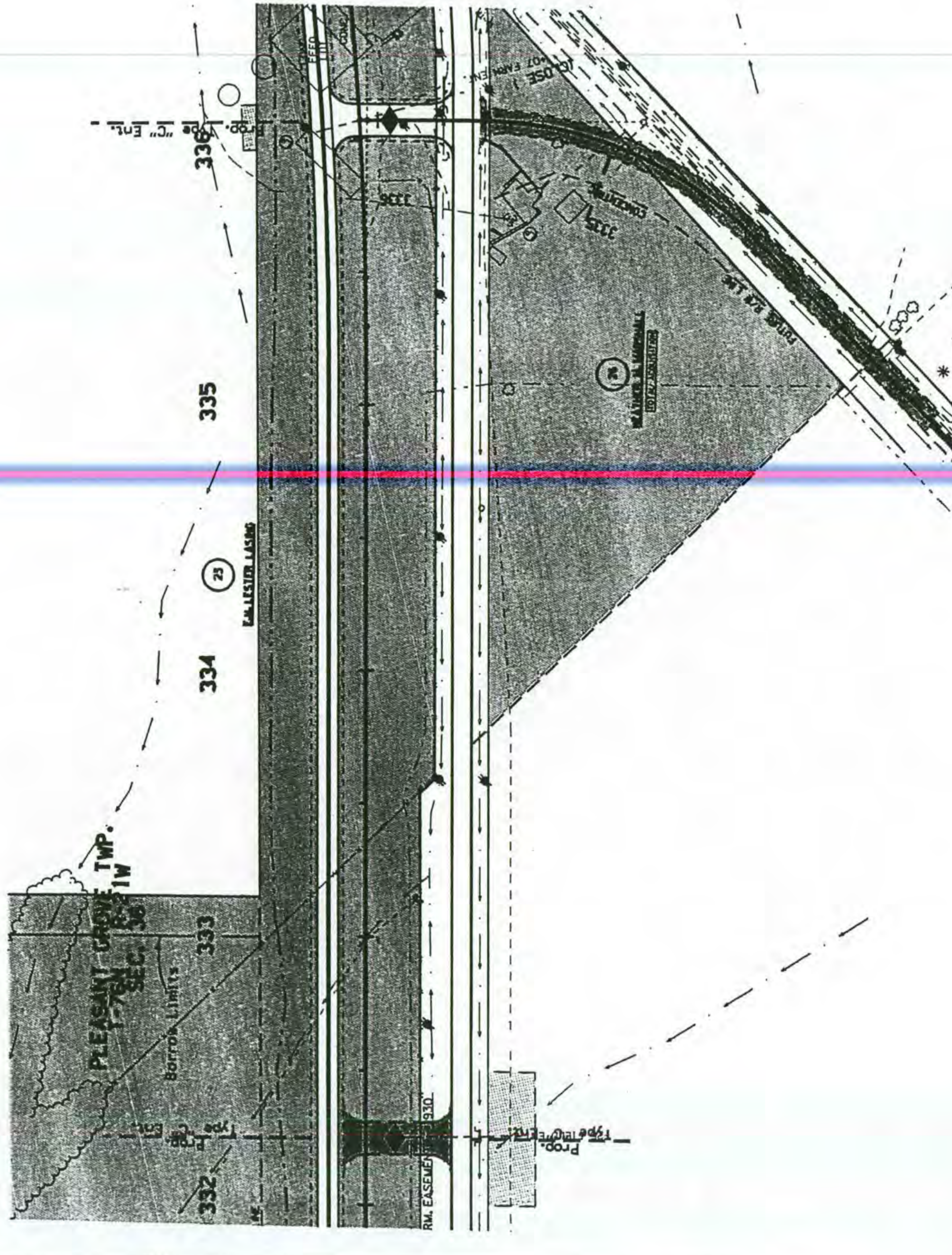
PROPOSED PERMANENT RIGHT OF WAY

PROPOSED TEMPORARY EASEMENT

PROPERTY LINES

ACCESS LOCATION


BRIDGE
TRAILER NO. 1
TRAILER NO. 2
TRAILER NO. 3
TRAILER NO. 4
TRAILER NO. 6
TRAILER NO. 7
ALLEN SMITH BRUCE SMITH & CRAIG SMITH
LAKE SHORE DR.
GORDON DR.
KENTUCKY FRIED CHICKEN
WOOD DECK
KFC OF WORTHINGTON, INC.
LUES DRIFTWOOD
RICHARD & DONNA MAU


PLEASANT GROVE TWP.
T-76N R-21W
SEC. 36
Borrow Limits
332
333
334
335
336
Prop. Type "C" Ent.
E.M. LESTER LASING
RM. EASEMENT 930
FUTURE R/W LINE

Certification of Plans

Originally Issued: 05-02-97

All official plans shall be certified in accordance with the requirements set forth by the Iowa Engineering and Land Surveying Examining Board. The official plan is the final plan submitted to the Office of Contracts for letting.

A professional engineer or other licensed professional must certify every sheet in a plan. This is done by indicating on the signature block which sheet numbers are covered by the licensee's seal.

Primary Signature Block

The primary signature block is placed on the title sheet and should contain:

- the seal of the engineer who is in overall charge of the project's design. This engineer will normally be the Design Projects Engineer or Assistant for projects designed by the Department and for projects designed by consultants, an engineer designated by the consulting firm as being in responsible charge of the design.
- the engineer's signature and the date, handwritten in ink that contrasts in color with the plan's print.
- the engineer's name, printed or typed.
- the engineer's license renewal date.
- the sheet numbers that are covered by the engineer's seal.

I hereby certify that this plan was prepared by me or under my direct personal supervision and that I am a duly licensed Professional Engineer under the laws of the State of Iowa.

Signature ______ Date

Printed or Typed Name

My license renewal date is December 31, ______

Pages or sheets covered by this seal: A.01, B.01, C.01, X.01-X.05

Figure 1: The primary signature block is placed on the title sheet. Sheet numbers listed are those covered by the engineer's seal.

Other Signature Blocks

Parts of the plan that are designed under the direction of other licensed professionals should have separate signature blocks that relate to their part of the project (see Figure 2). These signature blocks should be placed on the first plan sheet that is covered by their seal.

Each signature block should list the sheet numbers that are covered by the licensed professional's seal. Plan information prepared under the direction of separate licensees should not be placed on the same sheet. In other words, two licensed professionals should not be responsible for the same plan sheet.

A separate signature block should not be used on sheet C.01, even if the quantity estimates were checked primarily by another licensed engineer. The Roadway Design block is used for sheets related to road design that are included in other types of projects (such as bridge projects).

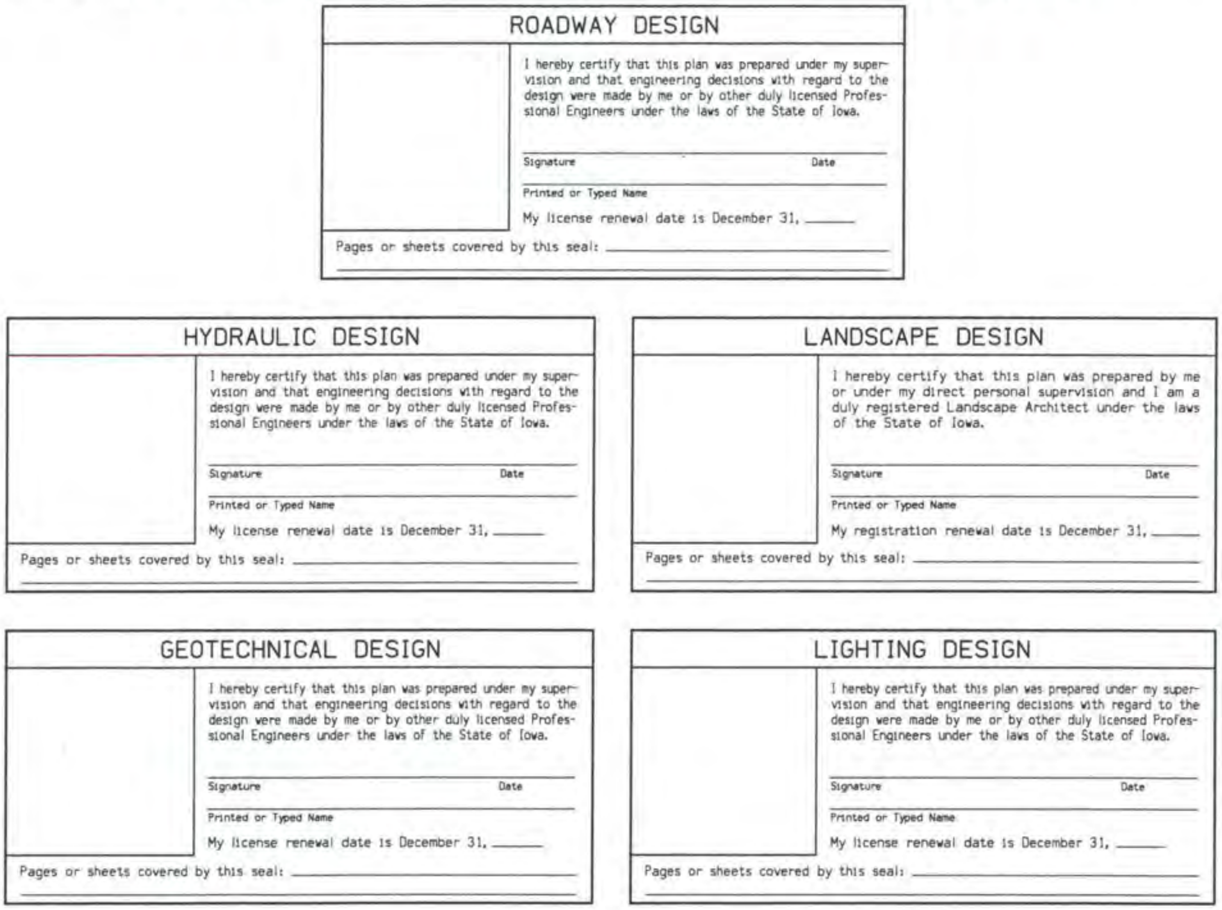


Figure 2: Separate signature blocks are used for parts of the plan designed under the direction of other licensed professionals.

Index of Seals

If parts of the plan are being certified by other licensed professionals, the title sheet should also contain an index of seals. This is a tabulation that identifies the sheet number where any other signature blocks are located, as well as the licensee's name and area of design (see Figure 3).

INDEX OF SEALS		
SHEET NO.	NAME	TYPE
A.01	Kent D. Nicholson	Primary Signature Block
A.03		See Revision Sheet
P.01	Jay L. Chiglo	Lighting Design
Q.01	Robert L. Stanley	Geotechnical Design
V.01	William D. Tucker	Structural Design

Figure 3: The index of seals is included on the title sheet if there are other signature blocks in the plan. If there are revisions, the revision sheet number(s) should be handwritten onto the index.

Plan Revisions

The A-series plan sheets following the title sheet, the legend sheet, and map sheets (if needed) should be reserved for revision sheets (see Section 1E-2).

If sheets are being revised or new sheets added, the appropriate signature block should be placed on the revision sheet and signed by the licensed professional in charge of the revised or added sheets. Signature blocks for revisions should be filled out in the same manner as the other blocks, with the revised sheet numbers listed that are covered by the seal.

If there is more than one plan revision, a different revision sheet should be used each time.

The sheet number of the revision sheet(s) should also be handwritten onto the index of seals on the original title sheet (see Figure 3).

Plan Sheets Prepared for the Office of Bridges and Structures

If plan sheets are being prepared for inclusion in a bridge project, a Design Sheet block (see Figure 4) should be placed on each sheet. The signature block of the licensed professional responsible for these sheets should be placed on the first design sheet.

The Office of Bridges and Structures will place the design sheets in an appropriate location within their plan and fill out the overall sheet numbers.

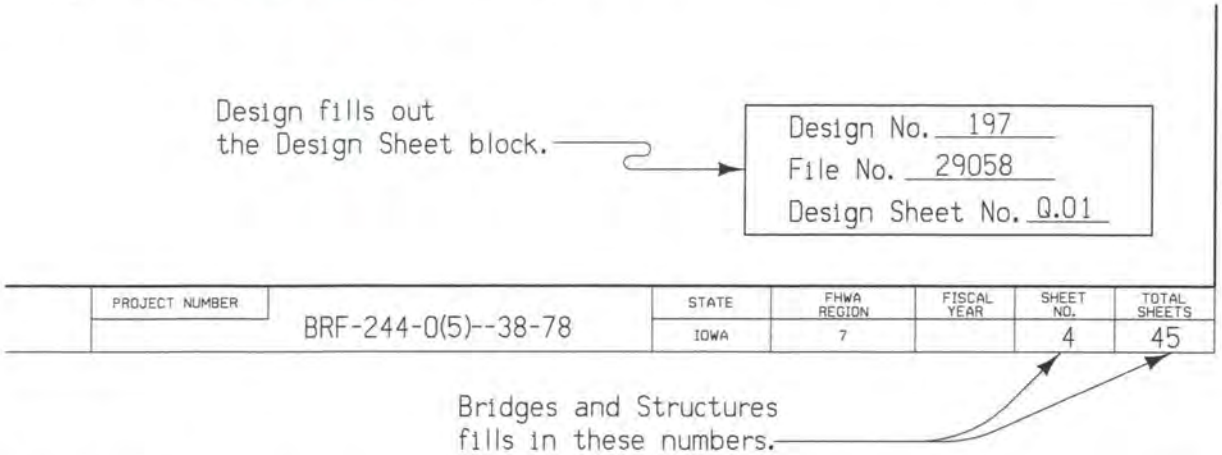


Figure 4: The Design Sheet block should be placed on all sheets prepared for inclusion in a bridge project.

Plan Organization

Originally Issued: 02-26-99

Plan sheets should be numbered as follows:

page number	description
A.01	title sheet
A.02, A3, …	location map sheets (if needed)
A.0* (*whatever number follows the previous A sheets)	legend sheet
A.0* , … (*whatever number follows the previous A sheets)	revision sheets (if needed)
B.01, B.02, …	typical cross sections
C.01, C.02, …	estimate of quantities and general information
D.01, D.02, …	plan and profile sheets—mainline
E.01, E.02, …	plan and profile sheets—side road and channel change
F.01, F.02, …	plan and profile sheets—detour
G.01, G.02, …	reference ties and bench marks
H.01, H.02, …	right-of-way sheets (urban)
J.01, J.02, …	staging and traffic control sheets
K.01, K.02, …	interchange geometric staking, jointing and edge profiles
L.01, L.02, …	intersection geometric staking, jointing and edge profiles
M.01, M.02, …	storm sewer sheets
N.01, N.02, …	traffic signal sheets
P.01, P.02, …	lighting layout sheets
Q.01, Q.02, …	soils sheets
R.01, R.02, …	borrow sheets and schematic hauling diagram
S.01, S.02, …	soils stabilities sheets
T.01, T.02, …	tabulation of earthwork quantities
U.01, U.02, …	500 series, modified standards and special details
V.01, V.02, …	bridge and culvert situation plans
W.01, W.02, …	cross sections—mainline
X.01, X.02, …	cross sections—side roads and channel change
Y.01, Y.02, …	cross sections—ramps and loops
Z.01, Z.02, …	cross sections—borrows

Plan Revisions

Originally Issued: 12-20-99

The following procedure should be used when making revisions to final project plans:

- A memo should be sent from the Section Engineer to the District Engineer stating a revision is planned. This memo should provide a short description of the proposed plan revision. See page 3 of this section for a sample memo. A template for this memo can be found in s:\Users\Design\Methods\Templates\Memo.dot.
- A revision sheet should be included at the end of the A sheets (see Section 1E-2). The revision sheet should include a listing and description of any revised or added sheets, as well as a signature block of the licensed professional in charge of the revised or added sheets (see Section 1E-1).
- Keep in mind that when the revisions are certified the same plan sheet should never be certified by different licensed professionals.
- A cover memo should be attached to the front of the plans listing the sheets that have been revised. See page 4 for of this section for a sample cover memo. A template for this cover memo can be found in s:\Users\Design\Methods\Templates\CoverMemo.dot.
- Do not replace the original title sheet. Information may be handwritten onto the revision block and the index of seals (see Section 1E-1) on the title sheet, but the rest of the title sheet should not be changed. Even though sheets are being added to the plan, it is not necessary to change the index of sheets or the total number of sheets that are listed on the original title sheet.
- Sheets that are added to a plan should be inserted in the appropriate location and numbered as usual except with a lower-case alpha character extension. For example, if two sheets are being inserted between J.01 and J.02, they should be numbered J.01a and J.01b. If the new sheet is being added at the end of the series, it may be numbered as usual, without the alpha character extension.

Federal-Aid Projects Requiring Oversite

For federal-aid projects that require oversite from the FHWA (see the April 1999 Oversite Agreement or contact the Methods Section in the Office of Design), follow these additional steps:

- Have the cover letter requesting approval from FHWA typed and signed by the Design Engineer. See page 5 for a sample cover letter requesting FHWA approval. A template for this cover letter can be found in s:\Users\Design\Methods\Templates\FHWALetter.dot.
- Mail one set of half-size plans with the cover letter requesting approval to FHWA. In case of urgency, verbal approval may be received prior to written approval.

When FHWA approval is received (when necessary), provide Printing with one set of revised plans and a copy of the cover memo for each person or office to which it should be mailed. Indicate in parentheses on the cover memo the number and size of plans that each person or office should receive. Printing will make copies of the plans and send them out with the cover memo attached.

Individuals or offices that normally receive the cover memo and plans include:

- District Office (5 sets, half size)
- Resident Construction Engineer (5—2 full size, 3 half size)
- Central Construction (1, half size)
- Assistant Design Engineer (1, half size)
- Design Projects Engineer (1, half size)
- FHWA (1, half size) (for federal-aid projects requiring oversite)
- Records Center (cover letter only)
- Others as needed (such as Office of Materials, cities, counties, consultants)

A sample memo, sample cover memo, and sample FHWA letter can be found on the following pages.

Sample Memo to District Engineer

IOWA DEPARTMENT OF TRANSPORTATION

TO OFFICE: District X

DATE: September 8, 2000

ATTENTION: District Engineer

REF: County Name
Project Number
PIN:

FROM: Section Engineer

OFFICE: Design

SUBJECT: Plan Revision

This memo is to inform you of an upcoming plan revision for this project. The revision will involve …

The project letting was on February 11, 2000.

XXX:mk

cc: Mitch Dillavou—Design Engineer
Dan Ohman—Assistant Design Engineer
Norm McDonald—Office of Bridges and Structures
John Adam—Office of Materials
John Smythe—Office of Construction
Assistant District Engineer
Resident Construction Engineer
Bobby Blackmon—FHWA
Consultant (when applicable)
Original—Central Files

Sample Cover Memo

DATE: September 8, 2000

TO: District Engineer

COUNTY:

FROM: Office of Design

PROJECT:

LETTING DATE: April 25, 2000

WORK TYPE:

The following sheets have been revised or added for this project: A.04, B.02, C.01, C.02, C.09.

See sheet A.04 for a description and signature blocks for the revisions.

cc: Mitch Dillavou—Design Engineer (1)
Dan Ohman—Asst. Design Engineer (1)
John Smythe—Office of Construction (1)
John Adam—Office of Materials (1)
District Engineer (5)
Assistant District Engineer (1)
Resident Construction Engineer (5) (2 full size)
Section Engineer (1)
Bobby Blackmon—FHWA (1)
Consultant (1) (when applicable)
Original—Central Files

Sample Letter to FHWA

IOWA DEPARTMENT OF TRANSPORTATION

TO OFFICE: Federal Highway Administration

DATE: September 8, 2000

ATTENTION: Bobby Blackmon

REF: County Name
Project Number
PIN:

FROM: Mitch Dillavou

OFFICE: Design

SUBJECT: Plan Revision

This project involves PCC pavement widening on Interstate 80 over the Iowa River.

The project letting was on February 11, 2000.

This revision involves adjusting the vertical profile, pipe grades, project length, traffic control, and staging.

We request Federal Highway Administration approval and participation for this revision.

MJD:mk

Attach.

cc: D. E. Ohman
E. J. Ranney
J. M. Smythe
District Engineer
Assistant District Engineer
Consultant (when applicable)

Road Design Details

Design Manual
Chapter 1
General Information

Originally Issued: 09-22-00

This section contains information related to modifications and revisions of road design details. Road design details are developed to aid the designer in the development of detailed design plans. The Road Design Details Manual contains current approved road design details. This information may also be accessed through DesignNet or via the World Wide Web on the Design Department's home page.

There are four types of road design details: design and tabulation forms, standard notations, design detail sheets, and typicals.

Design and Tabulation Forms

These are numbered between 100 and 199. Many of these forms are used for listing and tabulating quantities of materials required for a project. Others are tables used for listing design or quantity information relevant to a project such as circular curve data or tabulation of utilities. These forms are usually placed on the "C" sheets of a plan. The exception is 107-20, Tabulation of Template Quantities and Adjustments, which is placed in the "T" sheets. Figure 1 demonstrates sample design and tabulation forms.

CIRCULAR CURVE AND SUPERELEVATION DATA									101-10B 09-27-94
NO.	Δ	R	T	L	E	e	L	m	x

sample design form

TABULATION OF EXISTING PAVEMENT									102-5 02-23-93
			COARSE AGGREGATE						
			TYPE						
NO.	LOCATION	EXISTING PAVEMENT Type	GRAVEL	CRUSHED STONE	SOURCE	DURA-BILITY CLASS	PAVEMENT THICKNESS Inches	REINFORCE-MENT Type	TYPICAL DETAIL

sample tabulation form

Figure 1: Sample design and tabulation forms.

Standard Notations

These are numbered between 200 and 299. They provide information pertaining to the construction of the project itself and are placed on the "C" sheets of a plan. Figure 2 shows a sample standard notation.

```
10-27-98                                                        213-4
The contractor shall apply necessary moisture to the construction
area and haul roads to prevent the spread of dust.  Refer to Article
1107.07 of the current Standard Specifications for additional details.
```

Figure 2: Sample standard notation.

Design Detail Sheets

These are numbered between 500 and 599. Design detail sheets provide construction details for a specific design situation. Detail sheets are similar to standard road plans, but feature design situations that are less frequently encountered and are more specialized. They are usually placed on the "U" sheets of a plan. Figure 3 demonstrates a design detail sheet.

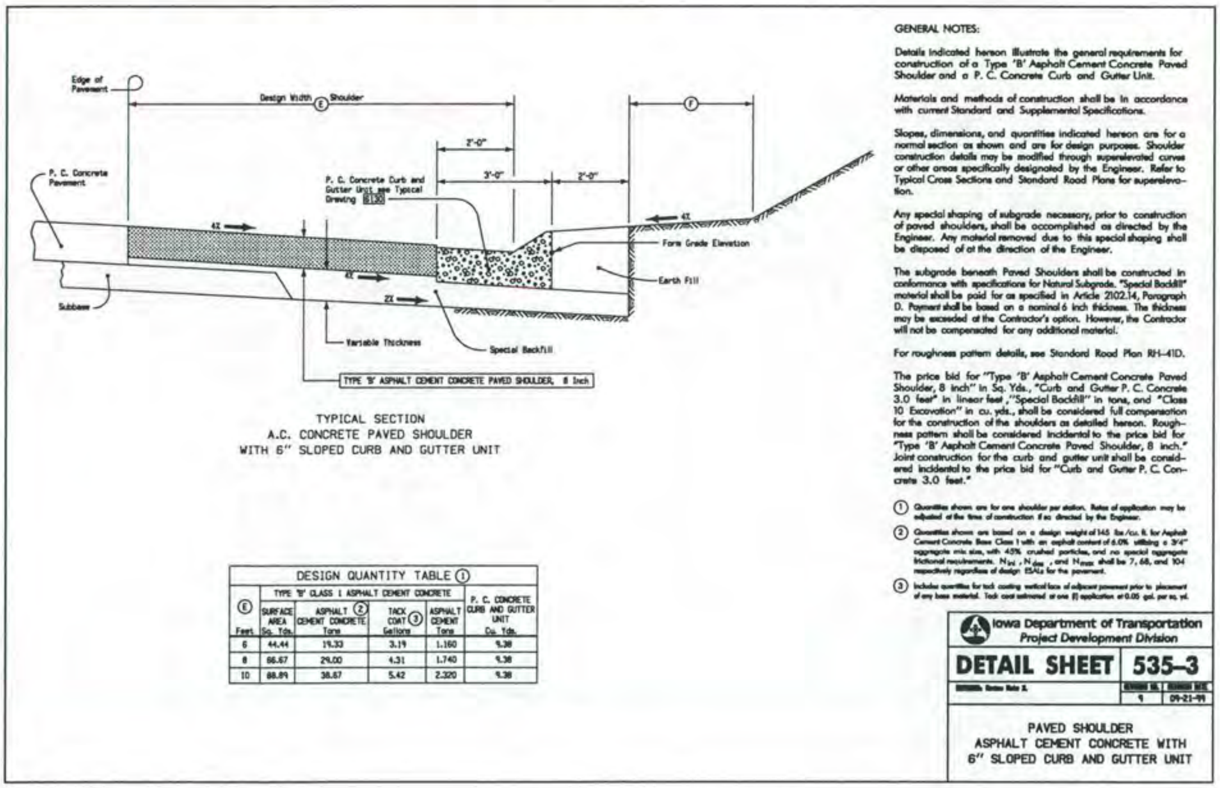


Figure 3: Sample detail sheet.

Typicals

These are numbered between 1000 and 9999. Typicals are similar to design detail sheets, but are more focused on a particular design feature. They are placed on the "B" sheets of a plan. Figure 4 shows a sample road design detail typical.

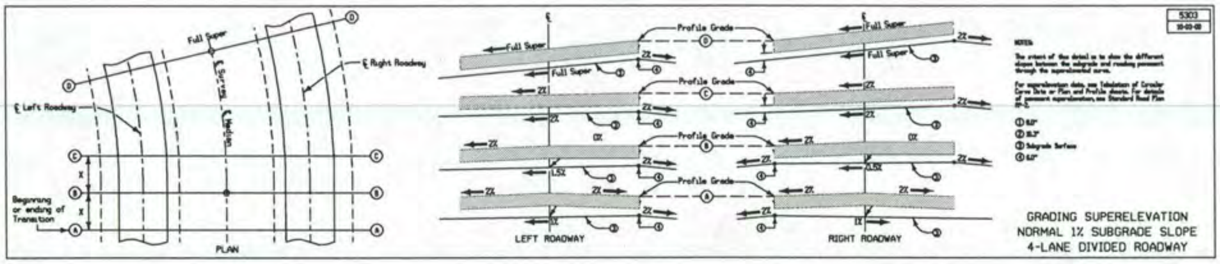


Figure 4: Sample road design detail typical.

Modifications of Road Design Details

Occasionally it is necessary to modify a road design detail. The process is slightly different for each type.

Design and Tabulation Forms

When a design or tabulation form is modified, the date shall be removed and replaced with the word MODIFIED. The box should then appear similar to Figure 5.

108-8A
MODIFIED

Figure 5: The box in upper right hand corner of modified design or tabulation form should appear similar to above.

Standard Notations

When a standard notation is modified, the number in upper left of the notation and the date in the upper right shall be removed. The note should be renamed allowing reference to the note in the plans.

Design Details

When a design detail is modified, everything in the title block (lower right hand corner of the sheet) is removed except for a description of the detail. The borders should also be removed. The box should then appear similar to Figure 6.

MODIFIED DETAIL SHEET 535-3
PAVED SHOULDER
ASPHALT CEMENT CONCRETE WITH
6" SLOPED CURB AND GUTTER UNIT

Figure 6: Box in lower right hand corner of modified design detail should appear similar to above.

Typicals

When a typical is modified, the date shall be removed and replaced with the word MODIFIED. The box should then appear similar to Figure 7.

Figure 7: Box in upper right hand corner of modified typical should appear similar to above.

Road Design Detail Revisions

Occasionally it is necessary to revise road design details to incorporate changes in technology, procedures, or specifications. **The changes will be made only by the Methods Section.**

Standard Road Plans

Originally Issued: 06-02-00

This section contains information related to modifications and revisions of standard road plans. Standard road plans are developed to show standardized design features, construction methods, and approved materials. The Standard Road Plans Manual contains all current FHWA approved standard road plans. This information may also be accessed through DesignNet or via the World Wide Web on the Design Department's home page.

Title Block

The title block is to be located in the lower right hand corner of the standard road plan. Within the title block is the latest revision date and number, and a brief statement describing the latest revision. Figure 1 shows a typical standard road plan title block and Figure 2 shows a typical standard road plan.

Figure 1: Standard road plan title block.

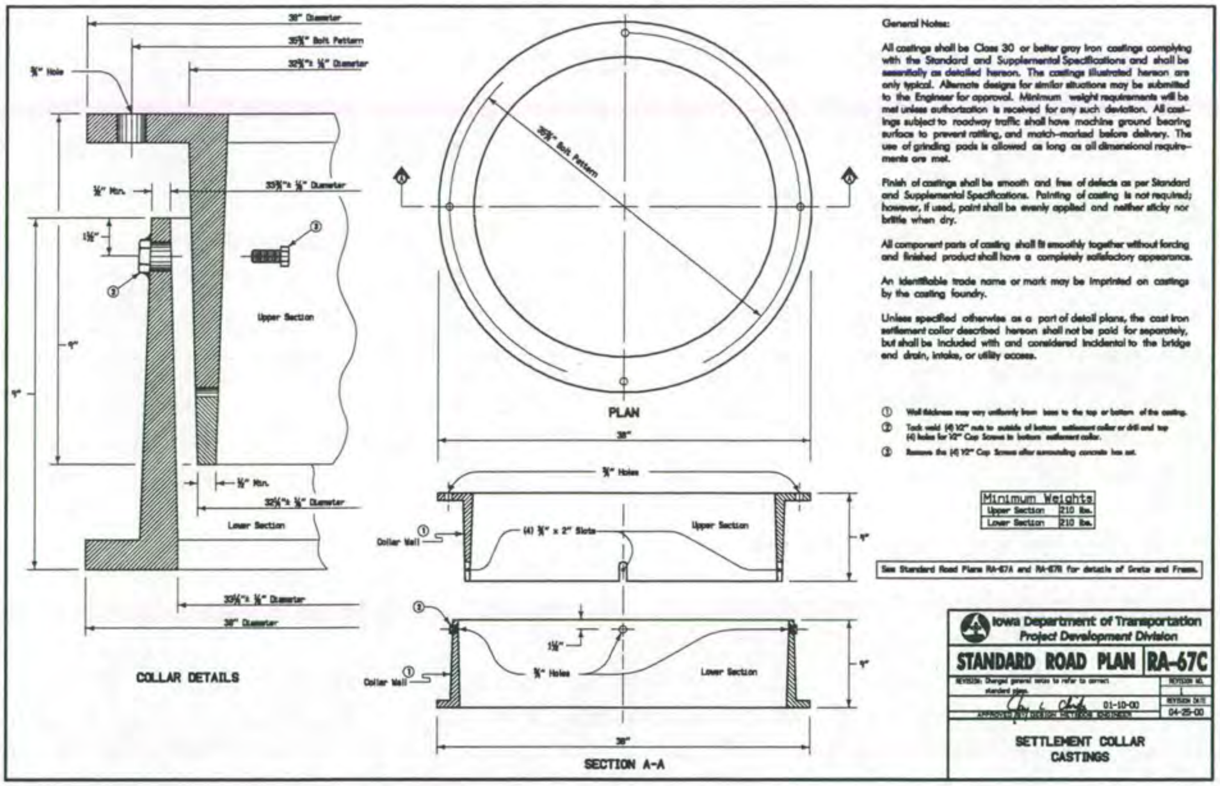


Figure 2: Sample standard road plan.

Modifications of Standard Road Plans

Occasionally it is necessary to modify a standard road plan to fit a specific design situation. Once a standard has been altered, the standard title block in the lower right hand corner will be removed and replaced with descriptive text, see Figure 3.

MODIFIED RE-67C

SETTLEMENT COLLAR
CASTINGS

Figure 3: Modified standard road plan text to replace title block.

A modified standard road plan appears in Figure 4.

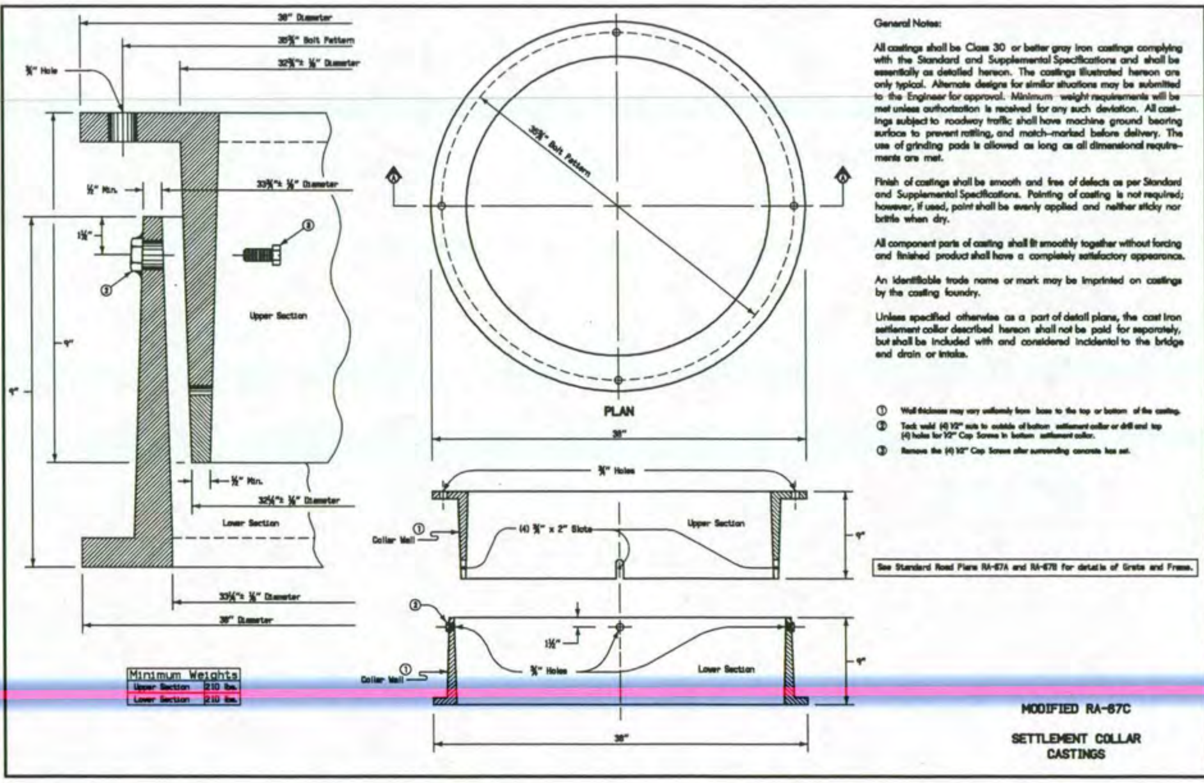


Figure 4: Sample modified standard road plan.

Modified standard road plans are added as part of the project plans and are included in the Index of Sheets. They are also to be listed in the certification block that is signed by the Design Engineer in charge of the plans.

Standard Road Plan Revisions

Occasionally it is necessary to revise the standard road plans to incorporate changes in technology, procedures, or specifications. **These changes will be made only by the Methods Section.**

Plan Submittals for County Review

Originally Issued: 04-20-01

All primary road projects that require the modification of county roads are subject to review by and recommendations of the County Engineer. After the field exam of the project, a copy of the field exam plans should be provided to the District Engineer for review by the County Engineer. All submittals for County review will be through the District Engineer. Recommended changes affecting county roads, as well as any agreements between the County and DOT, should be handled by the District Engineer.

At such time as project plans are completed to the ROW submittal stage, another set of plans for the project will be provided to the DOT District Engineer. The plans will serve as final design, confirming our action on previous recommendations made by the County.

Title Sheet

Originally Issued: 09-22-00

This section contains information regarding title sheets. Section 1E-2 lists the various plan sheets associated with a project. This section goes into further detail concerning title sheets.

The Title Sheet should contain the following Design and Tabulation forms: Mileage Summary (Tab 105-1), Index of Sheets (Tab 105-3), Standard Road Plans (Tab 105-4), and Design Data (Tab 101-4, 101-5, 101-6, or 101-7 depending on the type of highway). The Title Sheet should also include Type of Work, Project Location, Project Number, Project Identification Number (PIN), R.O.W. Project Number, County, Design Team, Revision Block, Primary Signature Block, Index of Seals, total number of pages or sheets, Letting Date, References to Specifications and Value Engineering remarks. These items will vary depending on the type of project. If there is room on the Title Sheet itself, a Project Location Map and Scale should also be provided; otherwise, they may be placed on the next sheet. Figure 10 at the end of this section demonstrates a Title Sheet.

Mileage Summary (Tab 105-1)

The mileage summary provides a table in linear feet and miles of the lengths of project divisions (when applicable), equation corrections, bridges, and large box culverts. The mileage summary will remain basically the same for a grading, paving, and resurfacing project.

Divisions shall terminate where a change in funding occurs across (i.e. perpendicular to) the centerline or when a project identification is changed, for example county lines or city corporate lines. A county or corporate line that borders a roadway (see Figure 4) is not considered a termination point for a division. All project lengths should be given in feet with an accuracy of one hundredth of a foot. The total and net length of each division shall also be given in to the nearest one thousandths of a mile.

Equation corrections should be determined and added or subtracted to obtain the proper project length of the project. Two types of equations may be encountered in a mileage summary: minor equations of less than 100 feet, or major equations of 100 feet and over. Figure 1 illustrates the two methods of correcting the mileage summary with a minor and major correction—Division 1 demonstrates a minor equation and Division 2 demonstrates a major equation.

Bridges

Bridge lengths (either out to out distance or paving notch) should be accounted for in the mileage summary by including, omitting, or deducting their respective lengths. Bridge lengths should be included in the roadway length only when resurfacing of the bridge floor is part of the work being done on the project. Bridge lengths should be omitted in projects where no work is being done on the bridge.

On projects where a bridge is being built or improved, the length should be deducted from the roadway project length. A total bridge length should be shown for the division and/or project and should be included in the total project length.

Culverts

Box culverts which have a span of more than 20 feet measured along centerline between inner faces of outside walls, and including inner walls of any multiple structure (see Figure 2) are treated in the same manner as a bridge.

MILEAGE SUMMARY — 105-1 — 09-27-94

DIV.	LOCATION	LIN. FT.	MILES
1	Rural:		
	Sta. 10+00.00 to Sta. 25+32.26	1532.26	
	Equation: Sta. 18+75.00 (Back) =		
	Sta. 18+94.50 (Ahead)		
	(Shortens Line)	19.50	
	Deduct Bridge at Sta. 21+32.00	125.00	
	Total Length of Roadway in Division 1	1387.76	0.263
	Total Length of Bridge in Division 1	125.00	0.024
	Total Length of Division 1	1512.76	0.287
2	Urban:		
	Sta. 25+32.26 to Sta. 35+32.26	1000.00	
	Equation: Sta. 35+32.26 (Back) =		
	Sta. 36+50.00 (Ahead)		
	Sta. 36+50.00 to Sta. 62+50.00	2600.00	
	Omit Bridge at Sta. 53+20.00	498.00	
	Total Net Length of Division 2	3102.00	0.587
	Total Net Length of Roadway in Project	4489.76	0.850
	Total Net Length of Bridge in Project	125.00	0.024
	Total Net Length of Project	4614.76	0.874

Figure 1: Sample Mileage Summary with equations.

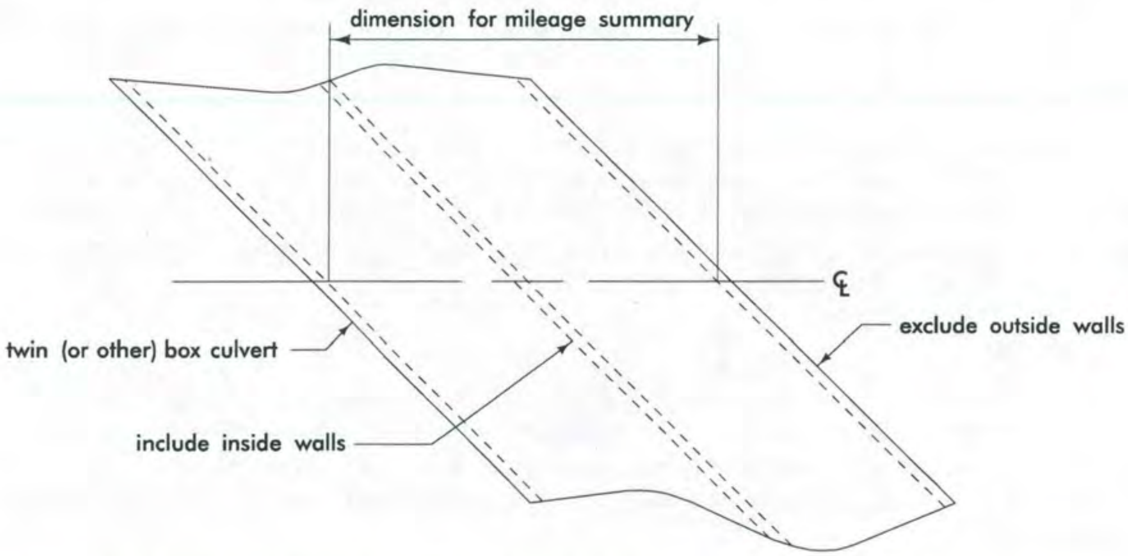


Figure 2: Box culvert dimension for Mileage Summary.

Projects with no Mileage Summary

Some projects, for example resurfacing a small intersection, will not have a mileage summary. If a project does not have a mileage summary, then a notation (see Figure 3) will be used in place of Design Typical 105-1. Projects with no mileage summary will be located on the location map by a small circle and a PROJECT LOCATION label.

NO MILEAGE SUMMARY

Figure 3: Notation for projects with no mileage summary.

Mile Post

The Iowa Pavement Management System uses the milepost system for project location, data collection, and analysis. In order to insure the integrity of the project history files, it has been determined that the Office of Design will locate all design projects by milepost limits which have a structural impact on the roadway, for example overlays, widening units, subdrain installation, inlays, reconstruction, etc.

Obtain route milepost number for one or more key locations within project limits and determine appropriate mileposting of beginning and ending points of project. Show these milepost numbers as part of the project location map on the title sheet. Care must be given to ensure correct mileposting where dual numbered routes exist or where route relocations require equations in mileposting. Figure 4 provides an example.

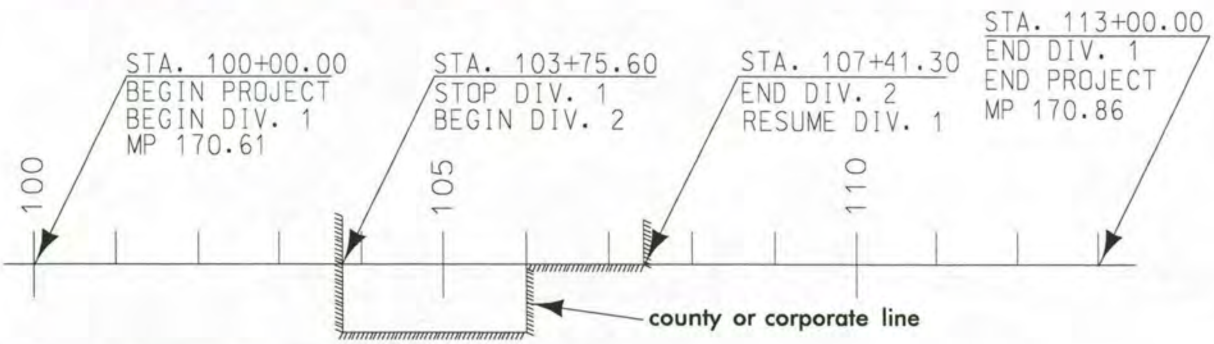


Figure 4: Mileposting example.

Index of Sheets (Tab 105-3)

The Index of Sheets provides a listing of all of the pages or sheets included in a project. Section 1E-2 of this Manual explains the numbering system to be used.

Standard Road Plans (Tab 105-4)

This provides a table of Standard Road Plans which apply to the project. The dates used in this table are the revision dates provided on the Standard Road Plans used. If room doesn't exist on the title sheet, this tab may be placed in the "C"sheets. A note similar to Figure 5 should appear on the title page.

Refer to Sheet C.03 for
Standard Road Plans

Figure 5: Standard Road Plans location box.

Design Data (Tab 101-4, 101-5, 101-6, or 101-7)

The Design Data consists of major controls or services for which a highway is designed. Design Details 101-4, 101-5, 101-6,or 101-7 should be used to show the data depending on the location (Rural or Urban) and the type (Primary or Interstate) of highway being constructed.

Other Information

As mentioned, the following information should also be included.

Type of Work

This provides the statement of the work to be performed, for example HMA RESURFACING WITH MILLING, or PCC PAVEMENT - NEW. This statement is tied to the work type code. Refer to a table of work type codes for proper code descriptions. Contact the Office of Contracts for work types not listed in the table of work type codes.

Project Location

This provides a brief statement of the project location, for example ON IA. 18 FROM NORA SPRINGS TO EAST OF RUDD 0.89 MILES.

Project Location Map and Scale

The Title Sheet should also provide a map of the project location along with a scale. A small Iowa state map with the county or counties involved marked, see Figure 6, should be a part of the project location map.

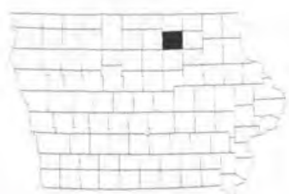


Figure 6: Sample state map to be used as part of the project location map.

If the project is such that a large map is required, or if the tab sheets fill a large enough area that placing a map on the Title Sheet isn't possible, the map and scale may instead be placed on the next sheet. If the map and scale are placed on the next sheet, a note should be placed on the Title Sheet referring to the project location map, see Figure 7.

```
For Project Location Map
Refer to Sheet No. A.02
```

Figure 7: Project map location box.

Project Number and Project Identification Numbers (PINs)

The Office of Contracts provides these numbers. The Project Number should be listed in the upper left, upper right and lower right of the Title Sheet. The segment and section PINs should be listed in the upper right of the Title Sheet.

R.O.W. Project Number

The Office of Right of Way provides this number. It should be located in the upper right of the Title Sheet.

County

The county in which the project takes place should be listed in the center and at the bottom of the Title Sheet. If the project is located in more than one county, the county in which the project begins should be listed first.

Design Team

The project engineer and other individuals or consultants involved with the design of the project should be listed at the bottom of the Title Page.

Revision Block

A Revision Block should be included. Revisions included in this box are generally those made during the construction of the project and are included in the "As-Built" plans.

Primary Signature Block

The Primary Signature Block should include the name and seal of the engineer who is overall in charge of the project's design. See Section 1E-1 of this Manual for more information regarding signature blocks.

Index of Seals

Since project plans often will require several engineers' signatures, an index of seals should be provided that will list the names of those engineers, the types of signature blocks, and the pages on which their signature blocks appear. A space should be left after the name of the engineer who is in overall charge of the project's design to provide for revisions. See Section 1E-1 of this Manual for more information regarding signature blocks.

Total

This should appear in the upper right hand corner of the Title Sheet and provide a count of the total number of pages or sheets in the project plan.

Letting Date

A box for the letting date should be provided in the upper left hand corner of the Title Sheet. The Office of Contracts will insert the letting date.

References to Specifications

A box shall be provided stating which specifications apply to the construction work on a project. This box should be similar to Figure 8.

> The Iowa Department of Transportation Standard Specifications for Highway and Bridge Construction, series of 1997, plus current Supplemental Specifications and Special Provisions shall apply to construction work on this project.

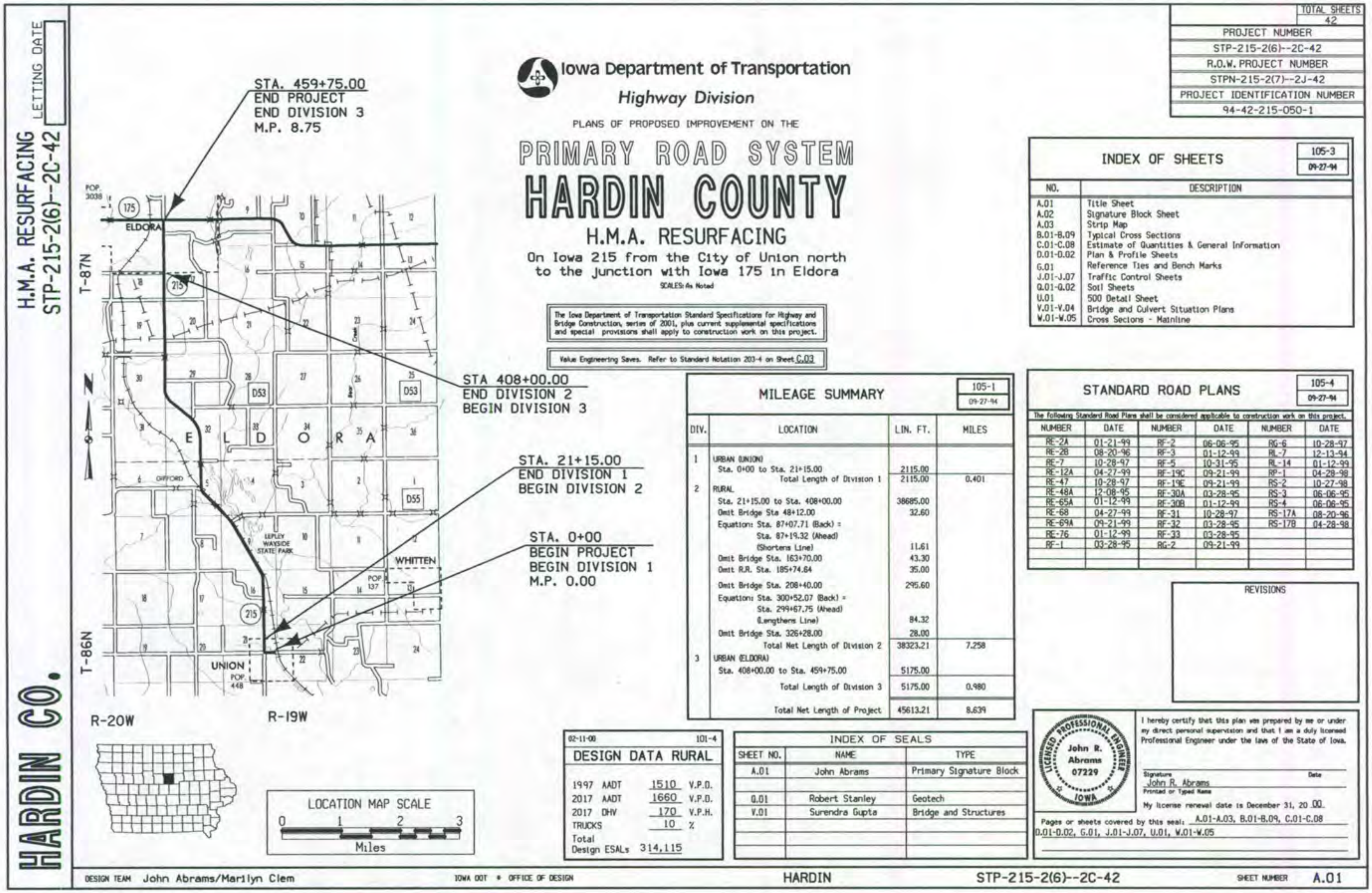
Figure 8: Sample reference to specifications box.

Value Engineering Remarks

A box should be provided referring to the Value Engineering Standard Notation (203-4), similar to Figure 9. This box will state the page or sheet on which the standard notation appears.

> Value Engineering Saves. Refer to Standard Notation 203-4 on Sheet C.02

Figure 9: Sample value engineering box.



LETTING DATE

H.M.A. RESURFACING
STP-215-2(6)--2C-42

HARDIN CO.

Iowa Department of Transportation
Highway Division

PLANS OF PROPOSED IMPROVEMENT ON THE

PRIMARY ROAD SYSTEM

HARDIN COUNTY

H.M.A. RESURFACING

On Iowa 215 from the City of Union north to the junction with Iowa 175 in Eldora

SCALES: As Noted

The Iowa Department of Transportation Standard Specifications for Highway and Bridge Construction, series of 2001, plus current supplemental specifications and special provisions shall apply to construction work on this project.

Value Engineering Saves. Refer to Standard Notation 203-4 on Sheet C.03

TOTAL SHEETS
42
PROJECT NUMBER
STP-215-2(6)--2C-42
R.O.W. PROJECT NUMBER
STPN-215-2(7)--2J-42
PROJECT IDENTIFICATION NUMBER
94-42-215-050-1

INDEX OF SHEETS (105-3, 09-27-94)

NO.	DESCRIPTION
A.01	Title Sheet
A.02	Signature Block Sheet
A.03	Strip Map
B.01-B.09	Typical Cross Sections
C.01-C.08	Estimate of Quantities & General Information
D.01-D.02	Plan & Profile Sheets
G.01	Reference Ties and Bench Marks
J.01-J.07	Traffic Control Sheets
Q.01-Q.02	Soil Sheets
U.01	500 Detail Sheet
V.01-V.04	Bridge and Culvert Situation Plans
W.01-W.05	Cross Secions - Mainline

MILEAGE SUMMARY (105-1, 09-27-94)

DIV.	LOCATION	LIN. FT.	MILES
1	URBAN (UNION)		
	Sta. 0+00 to Sta. 21+15.00	2115.00	
	Total Length of Division 1	2115.00	0.401
2	RURAL		
	Sta. 21+15.00 to Sta. 408+00.00	38685.00	
	Omit Bridge Sta 48+12.00	32.60	
	Equation: Sta. 87+07.71 (Back) = Sta. 87+19.32 (Ahead) (Shortens Line)	11.61	
	Omit Bridge Sta. 163+70.00	43.30	
	Omit R.R. Sta. 185+74.64	35.00	
	Omit Bridge Sta. 208+40.00	295.60	
	Equation: Sta. 300+52.07 (Back) = Sta. 299+67.75 (Ahead) (Lengthens Line)	84.32	
	Omit Bridge Sta. 326+28.00	28.00	
	Total Net Length of Division 2	38323.21	7.258
3	URBAN (ELDORA)		
	Sta. 408+00.00 to Sta. 459+75.00	5175.00	
	Total Length of Division 3	5175.00	0.980
	Total Net Length of Project	45613.21	8.639

STANDARD ROAD PLANS (105-4, 09-27-94)

The following Standard Road Plans shall be considered applicable to construction work on this project.

NUMBER	DATE	NUMBER	DATE	NUMBER	DATE
RE-2A	01-21-99	RF-2	06-06-95	RG-6	10-28-97
RE-2B	08-20-96	RF-3	01-12-99	RL-7	12-13-94
RE-7	10-28-97	RF-5	10-31-95	RL-14	01-12-99
RE-12A	04-27-99	RF-19C	09-21-99	RP-1	04-28-98
RE-47	10-28-97	RF-19E	09-21-99	RS-2	10-27-98
RE-48A	12-08-95	RF-30A	03-28-95	RS-3	06-06-95
RE-65A	01-12-99	RF-30B	01-12-99	RS-4	06-06-95
RE-68	04-27-99	RF-31	10-28-97	RS-17A	08-20-96
RE-69A	09-21-99	RF-32	03-28-95	RS-17B	04-28-98
RE-76	01-12-99	RF-33	03-28-95		
RF-1	03-28-95	RG-2	09-21-99		

REVISIONS

02-11-00 101-4

DESIGN DATA RURAL

1997 AADT	1510	V.P.D.
2017 AADT	1660	V.P.D.
2017 DHV	170	V.P.H.
TRUCKS	10	%
Total Design ESALs	314,115	

INDEX OF SEALS

SHEET NO.	NAME	TYPE
A.01	John Abrams	Primary Signature Block
Q.01	Robert Stanley	Geotech
V.01	Surendra Gupta	Bridge and Structures

LICENSED PROFESSIONAL ENGINEER
John R. Abrams
07229
IOWA

I hereby certify that this plan was prepared by me or under my direct personal supervision and that I am a duly licensed Professional Engineer under the laws of the State of Iowa.

Signature Date

John R. Abrams
Printed or Typed Name

My license renewal date is December 31, 20 00.

Pages or sheets covered by this seal: A.01-A.03, B.01-B.09, C.01-C.08 D.01-D.02, G.01, J.01-J.07, U.01, W.01-W.05

DESIGN TEAM John Abrams/Marilyn Clem | IOWA DOT • OFFICE OF DESIGN | HARDIN | STP-215-2(6)--2C-42 | SHEET NUMBER A.01

Figure 10: Sample Title Page.

Location Map Sheets

Originally Issued: 04-20-01

Occasionally, it is not possible to place a map of a project location on the Title Sheet. A large amount of information in the tabulations may make it difficult to fit a legible map on the Title Sheet. Or perhaps a project covers a long stretch of road, making it difficult to produce a legible map in the space provided on the Title Sheet.

When it is not possible to place a map on the Title Sheet, the map may be placed on a separate page called a Location Map Sheet. Typically, this sheet is placed immediately after the Title Sheet and before the Legend Sheet. Sections 1F-1 and 1F-3 provide more information on Title Sheets and Legend Sheets. Figure 1 illustrates an example of a Location Map Sheet that was created because a large amount of information in the tabulation sheets made it impossible to place a legible map on the Title Sheet. Figure 2 demonstrates an example of a Location Map Sheet created because the project covered a long stretch of road, thus making it impossible to place a legible map on the Title Sheet. In this case, several match lines were required. The designer should place match lines where appropriate.

It is possible for a Location Map Sheet to consist of more than one sheet. An example is a project located such that a rural map and one or more city maps are required. Figure 3 demonstrates an example of such a case where several division breaks occurred at several corporate limits. In this case, the rural map was placed on the Title Sheet and the city maps were placed on Location Map Sheets. Figure 3 shows one of the city maps created.

Location Strip Maps are used occasionally on certain types of projects, for example interstate inlays, resurfacing, or patching. This type of sheet is to be placed immediately after the Title Sheet or Location Map Sheet and before the Legend Sheet. Figure 4 illustrates an example of a Location Strip Map Sheet.

At the least, a Location Map Sheet will include: beginning and ending stations and mileposts for the project, station equations, division breaks, a Location Map Scale, a small Iowa state map with the county or counties involved marked, a north arrow, and range and township numbers. Other information, such as that seen in Figure 1 regarding the wetland mitigation site, may also be included.

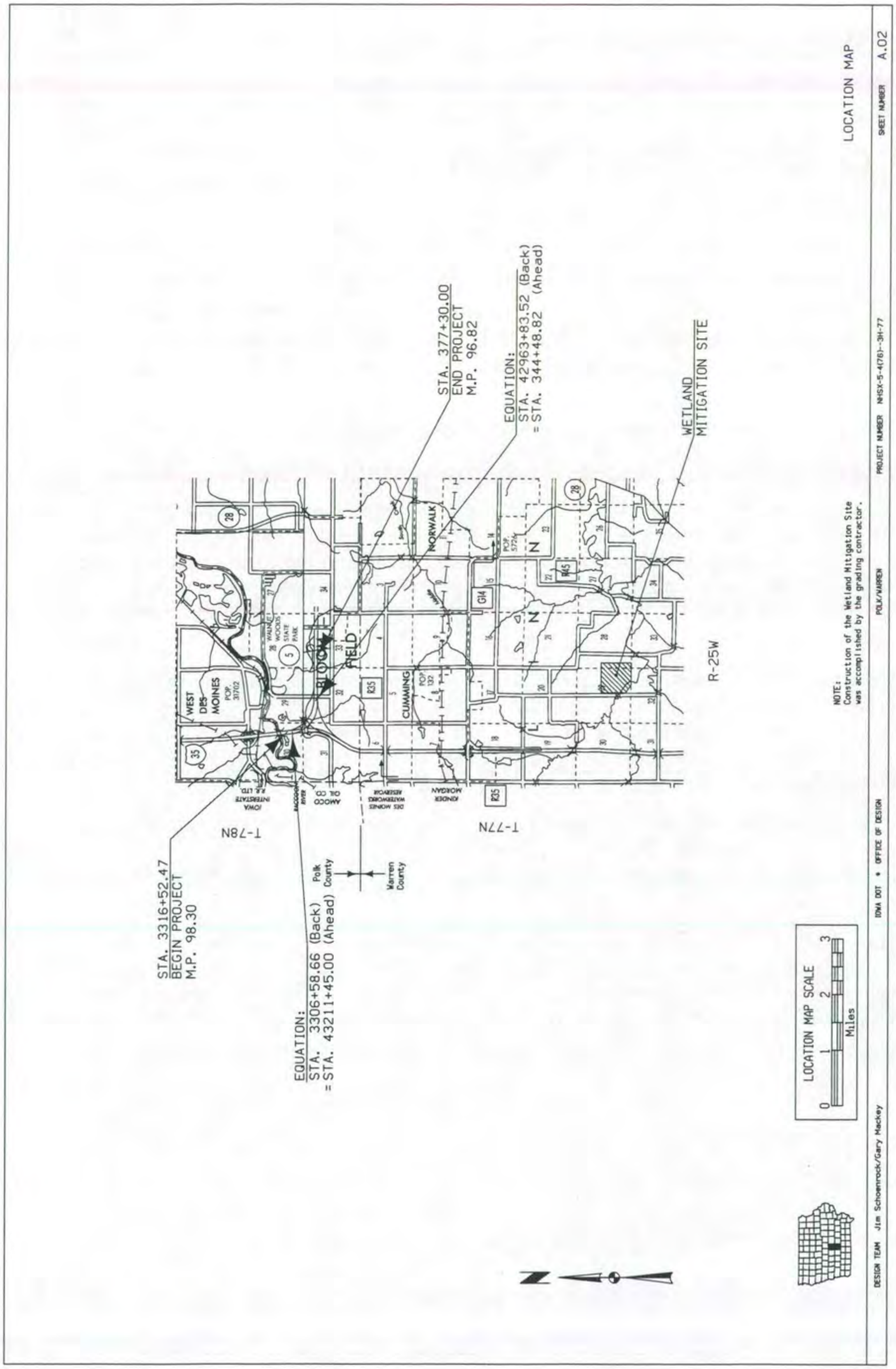


Figure 1: Sample Location Map Sheet.

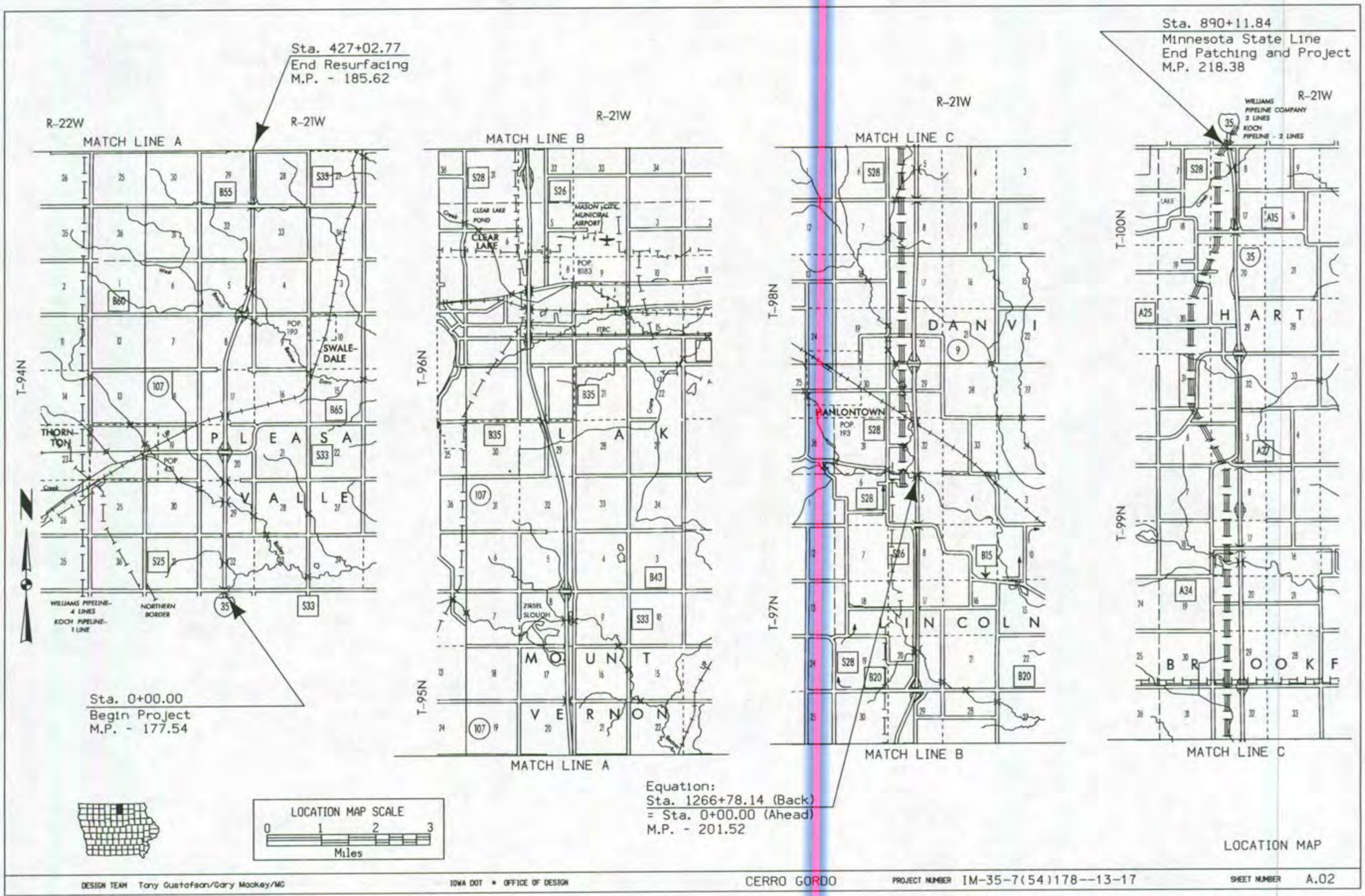


Figure 2: Sample Location Map Sheet.

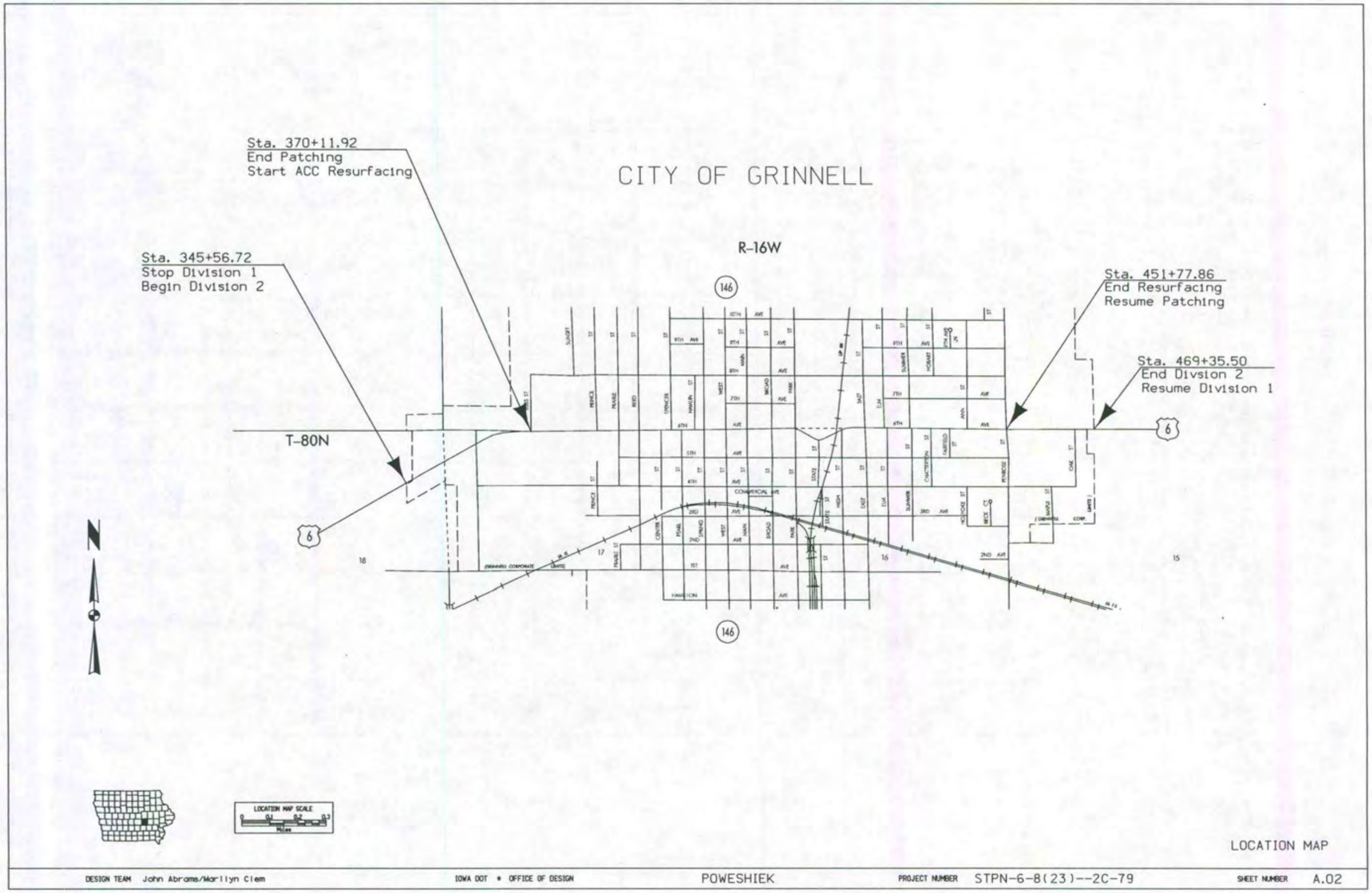


Figure 3: Sample Location Map Sheet.

Figure 4: Sample Location Strip Map Sheet.

Legend and Symbol Information Sheet

Originally Issued: 04-20-01

This section contains information regarding the Legend and Symbol Information Sheet. As the name implies, the Legend and Symbol Information Sheet provides a listing of symbols and legends used on the plan sheets. Typically, the Legend and Symbol Information Sheet will be prepared by the Photogrammetry Section.

The symbols and legends used on plan sheets can be broken down into five main groups: Standard Symbols, Utility Legend, Right of Way Legend, Unique Symbols for this Project, and Conventional Signs. Figure 1 illustrates a sample Legend and Symbol Information Sheet.

Standard Symbols

This is a standard list that is the same for all projects. Not all symbols listed in the Standard Symbols, however, are used on each project.

Utility Legend

This is a list of symbols associated with utilities unique to a particular project. The symbols in this list are derived from the Standard Symbols list, but provide further information regarding ownership.

Right of Way Legend

This is a standard list of symbols associated with right of way. Symbols in this list include existing and proposed right of way and easements, borrows, excesses, property lines, and access control.

Unique Symbols for This Project

This is a list of symbols unique to a particular project. This list differs from the Utility Legend in that these symbols are not derived from the Standard Symbols list. If there are no unique symbols for a project, this box does not appear.

Conventional Signs

This is a standard list of symbols for survey lines, section corners, proposed profile grades, railroads, existing and proposed field tiles and culverts, and streams.

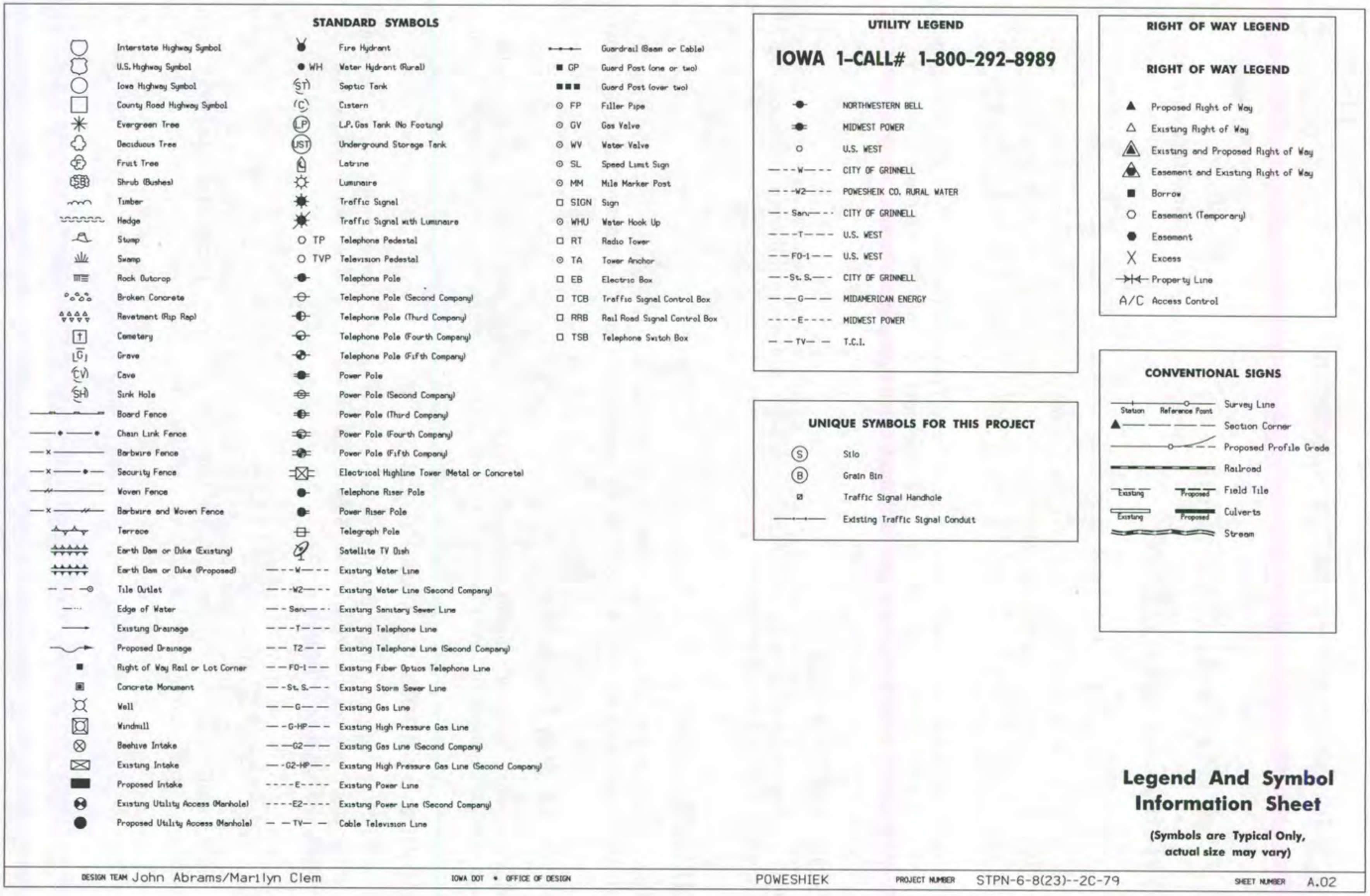


Figure 1: Sample Legend and Symbol Information Sheet.

Plan Revision Sheets

Originally Issued: 04-20-01

This section contains information regarding the Plan Revision Sheet. Plans occasionally require a few revisions after field crews have had a chance to review them. Tabulation 111-23 is used to keep track of these revisions. This tabulation is to include all changes and corrections to the original plans. A short description of each change and a reason for the change should be included. In addition, the revision date should be shown on the sheets that have been revised.

Tabulation 111-23 is placed in the "A" sheets on a sheet called the Plan Revision Sheet. This sheet is placed after the Legend Sheet and will typically be the last of the "A" sheets. Figure 1 illustrates a Plan Revision Sheet. When the Plan Revision Sheet requires an engineer's signature, the signature block should be placed as shown in Figure 2.

Section 1E-3 of this Manual provides more information regarding the procedures used to make revisions to final project plans.

LISTING OF PROJECT REVISIONS

111-23
09-27-94

DATE	SHEET NO.	DESCRIPTION OF REVISIONS
8/07/98	A.01	Total sheets increased from 67 to 86. Index of Sheets (Tabulation 105-3): Added sheets A.02 and V.05-V.22.
	A.03	Added sheet to plans.
	B.05	Typical BR-1. Added note 1 to typical.
	C.01	Estimated Project Quantities (Tabulation 100-1B): Added Bid Item 2401--206000 "Removals, as per plan" with 1.00 unit of Lump Sum. Added Bid Item 2402--120000 "Excavation, Class 20" with 20.20 Cubic Meters. Added Bid Item 2403--100010 "Structural Concrete (Bridge)" with 11.60 Cubic Meters. Added Bid Item 2404--100200 "Reinforcing Steel, Epoxy Coated" with 916 Kilograms. Estimated Reference Information (Tabulation 100-4A): Note for Bid Item 2214--101200 "Pavement Scarification" changed sheet number from U.12 to U.11. Note for Bid Item 2303--120214 "ACC Base Type B" changed sheet number from U.12 to U.11. Note for Bid Item 2303--161976 "ACC Surface Course, Type A" changed sheet number from U.12 to U.11.
	C.02	Estimated Reference Information (Tabulation 100-4A): Added note for Bid Item 2401--206000 "Removals, as per plan" Added note for Bid Item 2402--120000 "Excavation, Class 20" Added note for Bid Item 2403--100010 "Structural Concrete (Bridge)" Added note for Bid Item 2404--100200 "Reinforcing Steel, Epoxy Coated"
	V.05-V.22	Added sheets to plan.
		Reason: Addition to plans of details to repair abutment backwalls at bridge Sta. 232+14.834 and Sta. 278+25.100.
11/14/98	A.01	Revised Standard Road Plans Tabulation Added standards RA-61, RA-66A.
	A.03	Listing of Project Revisions: Added revision items.
	C.01	Estimated Project Quantities (Tabulation 100-1B): Added Bid Item 2503--400610 "RA-61 Intake" Added Bid Item 2503--140600 "Concrete 1000 Storm Sewer Pipe 600 mm Dia." Estimated Reference Information (Tabulation 100-4A): Added note for bid items 2503--400610 "RA-61 Intake" and 2503--140600 "Concrete 600 mm Storm sewer Pipe".

LISTING OF PROJECT REVISIONS

111-23
09-27-94

DATE	SHEET NO.	DESCRIPTION OF REVISIONS
	C.04	Added Tabulations 104-5A, 104-5B to sheet.
	W.10-W.14	Corrected the ditching and recalculated template quantities.
		Reason: Addition to plans of intake and storm sewer to correct a drainage problem.

LISTING OF PROJECT REVISIONS

111-23
09-27-94

DATE	SHEET NO.	DESCRIPTION OF REVISIONS

DESIGN TEAM Tony Gustafson/Gary Mackey — IOWA DOT • OFFICE OF DESIGN — BUTLER/BREMER COUNTY — PROJECT NUMBER STPN-3-5(52)--2J-12 — SHEET NUMBER A.03

Figure 1: Sample Plan Revision Sheet.

LISTING OF PROJECT REVISIONS

111-23
09-27-94

DATE	SHEET NO.	DESCRIPTION OF REVISIONS
05-19-00	A.01	Added revision date to revision box and sheet number A.04 to Index of Seals tabulation on the Title Sheet.
	A.04	Added to plan summary of revisions, signature block for revisions.
	C.09	Revised Tabulation 104-5C for subdrain line number 6. Changed beginning station of line from 13102+60 to 13103+20. Changed porous backfill quantity from 2566 Mg to 1604 Mg.
	Q.35	Revised the trench drain lengths located beneath the ramp bridge approach.
	Q.36	Added sheet to plans to detail the installation of the rammed aggregate piers located beneath the ramp bridge abutment.
		Reason: Rammed aggregate piers were added to speed consolidation (fill-induced settlement), thus minimizing the necessary delay between embankment completion and bridge abutment construction.

GEOTECHNICAL DESIGN

LICENSED PROFESSIONAL ENGINEER
Robert L. Stanley
08468
IOWA

I hereby certify that this plan was prepared by me or under my direct personal supervision and that I am a duly licensed Professional Engineer under the laws of the State of Iowa.

Signature ______ Date ______

Robert L. Stanley
Printed or Typed Name

My license renewal date is December 31, 20 00

Pages or sheets covered by this seal: A.04, Q.36

DESIGN TEAM Tony Gustafson/Gary Mackey/MG | IOWA DOT • OFFICE OF DESIGN | POLK COUNTY | PROJECT NUMBER NHSX-5-5(71)--3H-77 | SHEET NUMBER A.04

Figure 2: Sample Plan Revision Sheet with signature block.

Alignments

Horizontal Curve Design

Originally Issued: 09-22-00

Circular curves are used to join intersecting straight lines (or tangents). This section provides information relevant to simple circular curves. A simple circular curve is a constant radius arc used to join two tangents. Figure 1 shows the components of a simple circular curve.

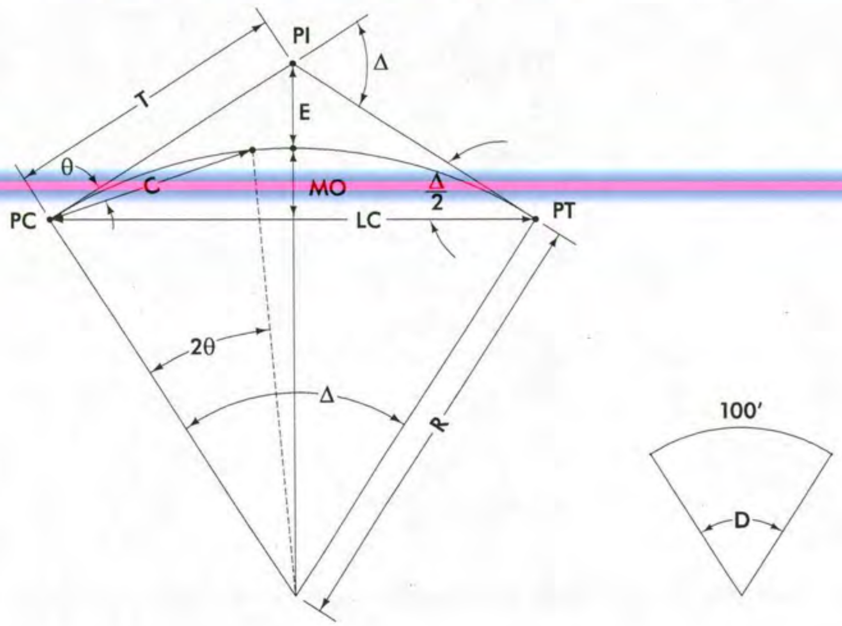


Figure 1: Components of a simple circular curve

Definitions

PI = Point of Intersection of back tangent and forward tangent.

PC = Point of Curvature – point of change from back tangent to circular curve.

PT = Point of Tangency – point of change from circular curve to forward tangent.

LC = Total chord length, or long chord, from PC to PT in feet for the circular curve.

D = Degree of curvature. The central angle which subtends a 100 foot arc, see Figure 1. The degree of curvature is determined by the appropriate design speed.

Δ = Total intersection (or delta) angle between back and forward tangents.

T = Tangent distance in feet. The distance between the PC and PI or the PI and PT.

L = Total length in feet of the circular curve from PC to PT measured along its arc.

E = External distance (radial distance) in feet from PI to the mid-point of the circular curve.

R = Radius of the circular curve measured in feet. The radius is determined by the appropriate design speed: Sections 1C-1, 2A-2, and 2A-3 of this Manual provide further information, or refer to AASHTO's *A Policy on Geometric Design of Highways and Streets*, 2001.

θ = Deflection angle from a tangent to a point on the circular curve.

Δ/2 = Deflection angle for full circular curve measured from tangent at PC or PT.

C = Chord length in feet, where a chord is defined as a straight line connecting any two points on a curve.

S = Arc length in feet along a curve.

MO = Middle ordinate. Length of the ordinate from the middle of the curve to the LC.

Formulas

$$D = \frac{18000}{\pi} \Big/ R$$ (D in decimal degrees)

$$\Delta = D \times \left(\frac{L}{100}\right)$$ (Δ & D in decimal degrees)

$$T = R \times \left(\tan\frac{\Delta}{2}\right)$$ (Δ in decimal degrees)

$$E = T \times \left(\tan\frac{\Delta}{4}\right)$$ (Δ in decimal degrees)

$$\Delta = \frac{180}{\pi} \times \frac{L}{R}$$ (Δ in decimal degrees)

$$LC = 2 \times R \times \left(\sin\frac{\Delta}{2}\right)$$ (Δ in decimal degrees)

$$MO = R \times \left(1 - \cos\frac{\Delta}{2}\right)$$ (Δ in decimal degrees)

$$C = 2 \times R \times \left(\sin\frac{\theta}{2}\right)$$ (θ in decimal degrees)

$$S = \frac{200}{D} \arcsin\frac{C}{2R}$$ (D in decimal degrees)

Superelevation

Sections 2A-2 and 2A-3 of this Manual provide more information regarding superelevation.

Plan Curve Data

The following Plan Curve Data should be provided on the plan sheets for each horizontal curve: Δ, D, T, L, E, R. For superelevated curves the rate of superelevation (e) and runout length (x) should also be shown. The length of transition (m) should be included if a spiral is not used.

Iowa Department of Transportation
Office of Design

2A-2
English

Superelevation

Design Manual
Chapter 2
Alignments

Originally Issued: 01-04-02

Superelevation is the banking of the roadway along a horizontal curve so that motorists can safely and comfortably maneuver the curve at reasonable speeds.

Information in this section does not apply to reduced-speed urban facilities (roadways with urban cross sections and expected regulatory speeds of 35 mph or less). For information about superelevation on reduced-speed urban facilities or any other special cases not covered in this section, refer to chapter three of AASHTO's *A Policy on Geometric Design of Highways and Streets* (the "Greenbook") or contact the Methods Section (Geometric Design) for assistance.

Superelevation Rate (e)

The superelevation rate is the cross slope of the pavement at full superelevation. In Iowa, the maximum rate of superelevation is limited to 8% on existing roadways due to the risk of slipping sideways in winter conditions. New and reconstructed rural facilities are limited to 6% so that the special high-side shoulder treatment illustrated on Typical 2014 is not necessary. New and reconstructed urban facilities are limited to 4% because of the possibility of a large number of drives and entrances adjoining the curve as well as the possibility of having to stop on the curve at signalized and other intersections. The Department's current policy on maximum superelevation rates is summarized in the following table.

Table 1: Maximum superelevation rates.

	Rural Facilities	Urban Facilities
New or Reconstruction	6%	4%
3R/4R	8%*	6%

*3R/4R projects on facilities originally designed with 6% max will also be limited to 6%.

Axis of Rotation

The axis of rotation is the point on the cross section about which the roadway is rotated to attain the desired superelevation. For standard situations the axis of rotation is shown on the appropriate Standard Road Plan (RP series). For cases not covered by the Standards, the axis of rotation should be clearly shown on a detail sheet.

Undivided highways should be superelevated with the axis of rotation at the roadway's centerline (see Figure 1).

Figure 1: The axis of rotation for undivided highways.

Multi-lane highways with depressed medians should be superelevated with the axis of rotation at the median edges of the traveled way (see Figure 2). With this method, the cross section of the median remains relatively uniform. This method is also used for two-lane roadways that will ultimately become one direction of a divided highway.

For two-lane roadways that will ultimately become one direction of a divided highway with depressed medians, the axis of rotation should be at the future median edge of the traveled way.

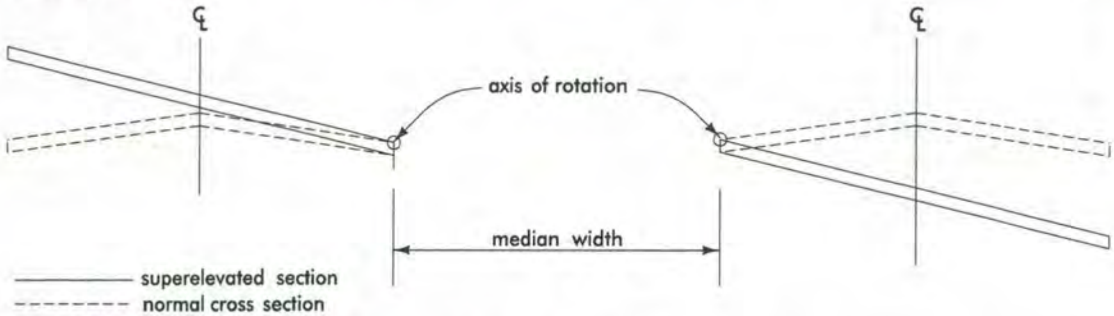


Figure 2: The axis of rotation for multi-lane highways with depressed medians.

Although the Greenbook suggests moving the axis of rotation back to the roadway centerlines for wider medians, the Department's policy is to keep the axis of rotation at the median edge of the traveled way, regardless of median width. This method may require more earthwork, but it is preferred for reasons of constructability, simplicity of design, and the appearance of a uniform median cross section. Facilities that have wide medians with independent profile grades and/or construction centerlines may be treated as two-lane (undivided) highways, if the resulting median cross section is acceptable.

Highways with painted medians are rotated about the centerline (see Section 3E-1 for definitions of the various medians). Highways with closed medians (concrete barrier rail) or raised medians (with curbs) are special cases. Contact the Methods Section (Geometric Design) for assistance with determining the axis of rotation.

The normal axis of rotation for ramps should be at the baseline, which is usually located at the edge of the slab (see Figure 3).

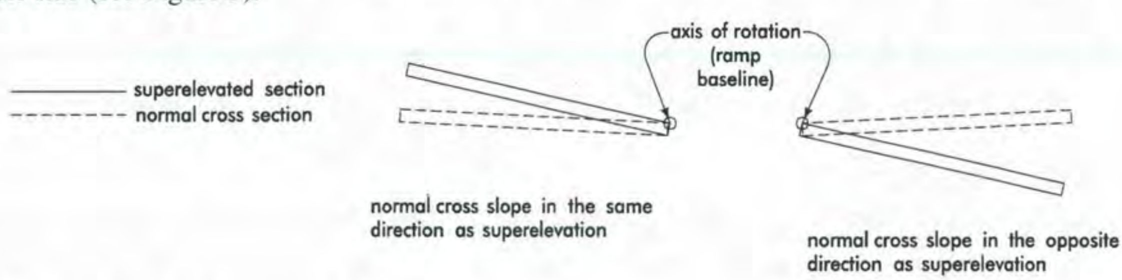


Figure 3: The axis of rotation for ramps.

Superelevation Transition

The roadway cross section at a superelevated curve transitions between normal crown and full superelevation at each end of the curve. Four locations define where and how the transition occurs (see Figure 4). First, the cross section is at "normal crown" and transitions to the second point, "adverse crown removed"—the point at which the high side of the curve is a level plane. From this point, the cross section transitions to the third point, "crown removed"—where the entire roadway is on one plane at the normal cross slope. From this point, the cross section transitions to the fourth point, full superelevation.

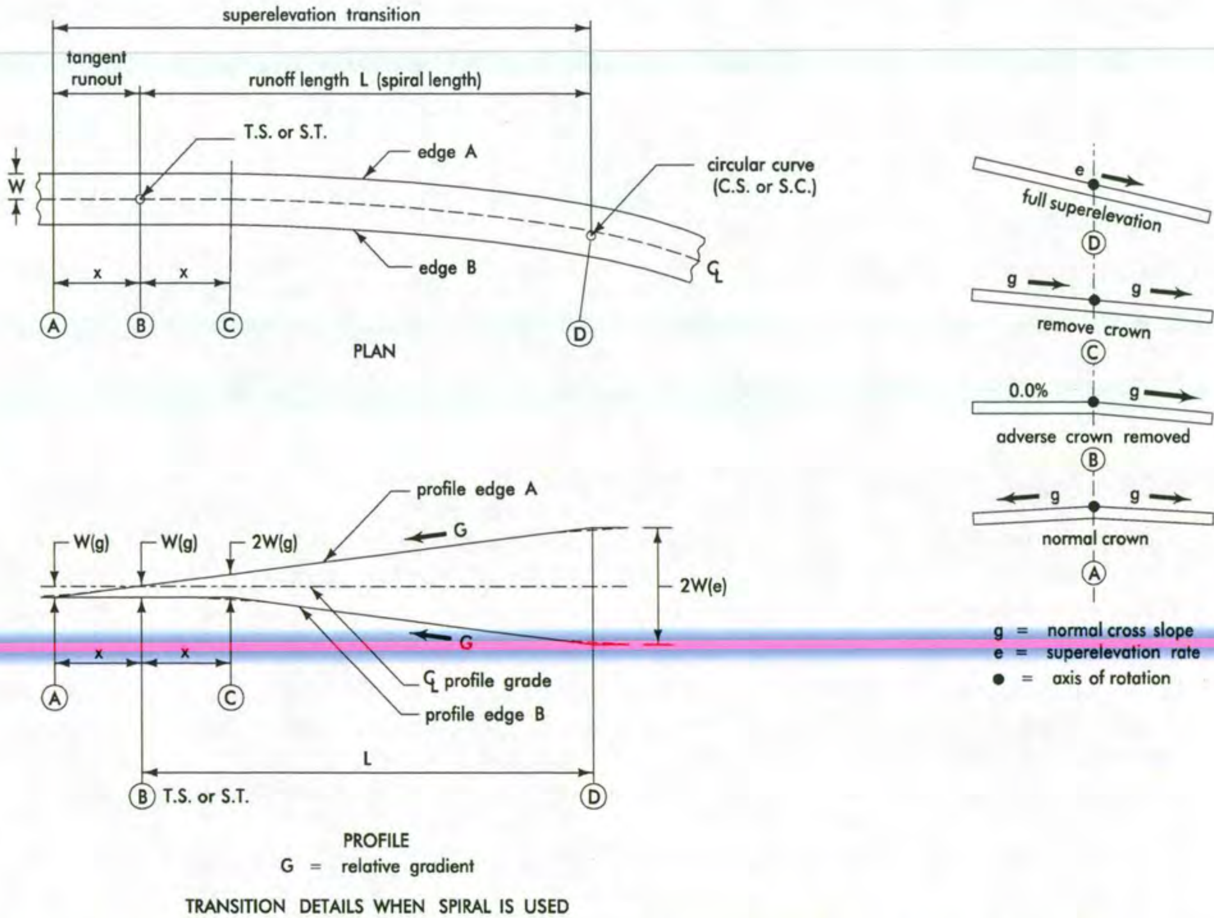


Figure 4: The superelevation transition when a spiral is used (two-lane undivided highway).

Transition Definitions

The following definitions are applicable for transitional components at both ends of circular curves. Always start on the tangent and work toward the curve.

For roadways with normal cross sections on two planes (mainline roadways), the tangent runout (x) is defined as the distance required to transition the outside lane of the roadway from the normal cross slope rate to a zero (flat) cross slope (i.e., normal crown to adverse crown removed), or vice-versa. The runoff length (L) is defined as the distance required to transition the outside lane of the roadway from a zero (flat) cross slope (i.e., adverse crown removed) to full superelevation, or vice-versa.

For roadways with normal cross sections on one plane (ramp-type roadways), the definitions for x and L are the same but their application is somewhat theoretical. See Standard Road Plan RP-3 for details.

The variable m equals 30% of the runoff length (L). It locates the portion of the transition area located in the circular curve for non-spiraled curves. See the RP-series Standard Road Plans.

Design

When designing superelevation transitions, the following variables must be determined:

- e: full superelevation (%)
- L: runoff length (ft)
- x: tangent runout (ft)
- m: for transitions without spiral curves (ft)

For four-lane divided, two-lane undivided, and ramp-type roadways with normal 2 percent cross slopes, the tables in Section 2A-3 may be used to determine e, L, and x. For curves with radii not shown in the table or roadways with cross slopes other than 2 percent, the values must be calculated manually.

Calculating Manually

The full superelevation (e) can be calculated using the equations provided in the 2001 edition of the Greenbook. The Methods Section (Geometric Design) also has a calculator program available which can be used to calculate e.

The runoff length (L) must be long enough so that the transition from adverse crown removed to full superelevation is relatively gradual—for reasons of general appearance and driving comfort. Runoff length is calculated using the relative gradient (G), formerly called the edge slope ratio. Relative gradient is defined as the difference in longitudinal profile between the edge of traveled way and the axis of rotation. To determine the runoff length (L), use the following equation:

$$L = \left[\frac{12e}{G}\right]\alpha$$

where:

e = full superelevation (%)

G = relative gradient (%)

α = adjustment factor (dimensionless)

When calculating L_1, simply use the G value from Table 2. Values for G not given in Table 2 may be interpolated directly.

Table 2: Relative Gradient (G).

Design Speed (mph)	Maximum Relative Gradient (and Equivalent Maximum Relative Slopes) for Profiles Between the Edge of Two-Lane Traveled Way and the Centerline (%)	
	Maximum Relative Gradient (G)	Equivalent Maximum Relative Slope
15	0.78	1:128
20	0.74	1:135
25	0.70	1:143
30	0.66	1:152
35	0.62	1:161
40	0.58	1:172
45	0.54	1:185
50	0.50	1:200
55	0.47	1:213
60	0.45	1:222
65	0.43	1:233
70	0.40	1:250
75	0.38	1:263
80	0.35	1:286

The adjustment factor (α) is used to adjust for different roadway widths. It can be calculated by the following equation:

$$\alpha = 1 + 0.0417\,(w - 12)$$

where:

w = the distance from the axis of rotation to the outside edge of traveled way (ft).

When determining w, remember that the edge of traveled way is not always the edge of the lane pavement. For example, for a two-lane undivided highway with 14-foot lane pavement widths, the edge of traveled way is at the location of the painted edge line (12 feet offset from centerline). Therefore, a w value of 12 should be used in superelevation transition calculations. Also, if w is less than 12, use $\alpha = 1$ (w = 12).

Table 3: Adjustment factor (α) for common roadway widths.

Roadway Type	α
two-lane undivided highway (w = 12 ft)	1
four-lane divided highway (w = 24 ft)	1.5
standard ramp (w = 16 ft)	1.167
standard loop (w = 18 ft)	1.250

To determine the runout length (x), use the following equation:

$$x = \frac{L(g)}{e}$$

where:

g = the normal cross slope (ft/ft)

L = runoff length (ft)

e = full superelevation (%)

To determine m (for transitions without spiral curves), use the following equation:

$$m = 0.3(L)$$

Spiral Curves

Spiral curves shall be used when e is greater than or equal to 3.0%.

Pavement Width

The Designer should check pavement width when using short radii to ensure that the pavement is wide enough to handle offtracking.

Design Value Reporting

Values for e, L, x, and m (if applicable) may be specified on Tabulation 101-10B.

Standard Road Plans

The appropriate Standard Road Plan(s) from the RP series should be included in the plans.

Superelevation Tables

Originally Issued: 01-04-02

Tables 1 through 6 contain values for e, L, and x for some common roadway widths at different maximum superelevation rates. L and x for a given design speed should not be less than the minimums indicated on the tables. The values given in the tables are based on a normal cross slope of 2 percent. Values of L and x are rounded up to the next foot.

Values of e for radii not given in Tables 1 through 12 should not be interpolated due to the nonlinear relationship of e with design speed and curve radii. See page 4 of Section 2A-2 for information on calculating e for intermediate radii.

! Tables 1 through 6 are used only for the indicated radii and only for roadways with normal cross slopes (2%). See page 4 of Section 2A-2 for instructions on how to calculate the variables manually for other radii or cross slopes.

Table values may be used for roadways with other values of w as long as the normal cross slope is 2%. Simply multiply the values for L and x obtained from Tables 4, 5, or 6 by the appropriate adjustment factor (•). See page 5 of Section 2A-2 for information on determining α.

Table 1: Two-Lane Undivided Highways (w = 12 feet), e_{max} = 4%, normal cross slope (2%)

Table 2: Four-Lane Divided Highways (w = 24 feet), e_{max} = 4%, normal cross slope (2%)

Table 3: Ramps (w = 16 feet) and Loops, e_{max} = 4%, normal cross slope (2%)

Table 4: Two-Lane Undivided Highways (w = 12 feet), e_{max} = 6%, normal cross slope (2%)

Table 5: Four-Lane Divided Highways (w = 24 feet), e_{max} = 6%, normal cross slope (2%)

Table 6: Ramps (w = 16 feet) and Loops, e_{max} = 6%, normal cross slope (2%)

Table 1: Two-Lane Undivided Highways (w = 12 feet), e_{max} = 4%, normal cross slope (2%)

radius (ft.)	design speed (mph)																													
	15			20			25			30			35			40			45			50			55			60		
	e	L	x	e	L	x	e	L	x	e	L	x	e	L	x	e	L	x	e	L	x	e	L	x	e	L	x	e	L	x
23000	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0
20000	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0
17000	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0
14000	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0
12000	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0
10000	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	RC	53	53
8000	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	RC	51	51	RC	53	53
6000	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	RC	48	48	RC	51	51	2.3	60	53
5000	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	RC	44	44	RC	48	48	2.3	58	51	2.5	67	53
4000	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	RC	41	41	2.0	45	44	2.3	55	48	2.6	66	51	2.8	75	53
3500	NC	0	0	NC	0	0	NC	0	0	NC	0	0	RC	39	39	RC	41	41	2.2	49	44	2.5	59	48	2.7	70	51	3.0	81	53
3000	NC	0	0	NC	0	0	NC	0	0	NC	0	0	RC	39	39	2.1	44	41	2.4	54	44	2.7	64	48	2.9	75	51	3.3	87	53
2500	NC	0	0	NC	0	0	NC	0	0	RC	36	36	2.0	39	39	2.4	49	41	2.6	58	44	2.9	69	48	3.2	82	51	3.5	94	53
2000	NC	0	0	NC	0	0	RC	34	34	RC	36	36	2.3	45	39	2.6	54	41	2.9	64	44	3.2	77	48	3.5	90	51	3.8	102	53
1800	NC	0	0	NC	0	0	RC	34	34	2.1	38	36	2.4	47	39	2.7	56	41	3.0	67	44	3.3	80	48	3.7	94	51	3.9	104	53
1600	NC	0	0	NC	0	0	RC	34	34	2.2	41	36	2.6	49	39	2.9	59	41	3.2	71	44	3.5	84	48	3.8	97	51	4.0	106	53
1505	NC	0	0	NC	0	0	RC	34	34	2.3	42	36	2.6	51	39	2.9	61	41	3.3	73	44	3.6	86	48	3.9	99	51	4.0	107	53
1400	NC	0	0	RC	32	32	2.0	34	34	2.4	43	36	2.7	52	39	3.0	63	41	3.4	75	44	3.7	88	48	3.9	100	51			
1200	NC	0	0	RC	32	32	2.2	38	34	2.5	46	36	2.9	56	39	3.2	67	41	3.6	79	44	3.9	92	48	4.0	102	51			
1190	NC	0	0	RC	32	32	2.2	38	34	2.5	46	36	2.9	56	39	3.2	67	41	3.6	80	44	3.9	93	48	4.0	102	51			
1000	NC	0	0	RC	32	32	2.4	41	34	2.7	50	36	3.1	60	39	3.5	72	41	3.8	84	44	4.0	96	48						
930	NC	0	0	2.0	33	32	2.5	42	34	2.8	51	36	3.2	62	39	3.6	74	41	3.9	86	44	4.0	96	48						
900	NC	0	0	2.1	34	32	2.5	43	34	2.8	52	36	3.2	63	39	3.6	75	41	3.9	87	44									
800	RC	31	31	2.2	36	32	2.6	44	34	3.0	54	36	3.4	66	39	3.8	78	41	4.0	88	44									
730	RC	31	31	2.3	37	32	2.7	46	34	3.1	56	36	3.5	68	39	3.9	80	41	4.0	89	44									
700	RC	31	31	2.3	38	32	2.7	47	34	3.2	57	36	3.6	69	39	3.9	81	41												
600	RC	31	31	2.5	40	32	2.9	50	34	3.4	61	36	3.8	73	39	4.0	83	41												
565	RC	31	31	2.5	41	32	3.0	51	34	3.4	62	36	3.8	74	39	4.0	83	41												
500	2.1	32	31	2.6	43	32	3.1	53	34	3.6	65	36	3.9	76	39															
450	2.2	34	31	2.7	44	32	3.2	55	34	3.7	67	36	4.0	77	39															
420	2.3	35	31	2.8	45	32	3.3	57	34	3.8	69	36	4.0	77	39															
400	2.3	36	31	2.8	46	32	3.4	58	34	3.8	70	36																		
350	2.4	37	31	3.0	49	32	3.6	61	34	3.9	72	36																		
300	2.6	39	31	3.2	52	32	3.7	64	34	4.0	73	36																		
250	2.7	42	31	3.4	55	32	3.9	67	34																					
205	2.9	45	31	3.6	59	32	4.0	69	34																					
200	3.0	46	31	3.7	60	32																								
150	3.3	51	31	3.9	64	32																								
125	3.5	54	31	4.0	65	32																								
100	3.8	58	31																											
75	4.0	61	31																											
70	4.0	62	31																											
	R_{min} = 70			R_{min} = 125			R_{min} = 205			R_{min} = 300			R_{min} = 420			R_{min} = 565			R_{min} = 730			R_{min} = 930			R_{min} = 1190			R_{min} = 1505		

NC = Normal Crown

RC = Remove Crown

spiral curvature not required above heavy line

Table 2: Four-Lane Undivided Highways (w = 24 feet), e_{max} = 4%, normal cross slope (2%)

radius (ft.)	design speed (mph)																													
	15			20			25			30			35			40			45			50			55			60		
	e	L	x	e	L	x	e	L	x	e	L	x	e	L	x	e	L	x	e	L	x	e	L	x	e	L	x	e	L	x
23000	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0
20000	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0
17000	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0
14000	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0
12000	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0
10000	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	RC	80	80
8000	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	RC	77	77	RC	80	80
6000	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	RC	72	72	RC	77	77	2.3	90	80
5000	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	RC	67	67	RC	72	72	2.3	86	77	2.5	101	80
4000	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	RC	62	62	2.0	67	67	2.3	83	72	2.6	98	77	2.8	113	80
3500	NC	0	0	NC	0	0	NC	0	0	NC	0	0	RC	58	58	RC	62	62	2.2	73	67	2.5	89	72	2.7	105	77	3.0	121	80
3000	NC	0	0	NC	0	0	NC	0	0	NC	0	0	RC	58	58	2.1	66	62	2.4	80	67	2.7	96	72	2.9	113	77	3.3	130	80
2500	NC	0	0	NC	0	0	NC	0	0	RC	55	55	2.0	59	58	2.4	73	62	2.6	87	67	2.9	104	72	3.2	123	77	3.5	141	80
2000	NC	0	0	NC	0	0	RC	51	51	RC	55	55	2.3	67	58	2.6	81	62	2.9	96	67	3.2	115	72	3.5	135	77	3.8	153	80
1800	NC	0	0	NC	0	0	RC	51	51	2.1	57	55	2.4	71	58	2.7	84	62	3.0	101	67	3.3	120	72	3.7	140	77	3.9	157	80
1600	NC	0	0	NC	0	0	RC	51	51	2.2	61	55	2.6	74	58	2.9	89	62	3.2	106	67	3.5	126	72	3.8	146	77	4.0	160	80
1505	NC	0	0	NC	0	0	RC	51	51	2.3	63	55	2.6	76	58	2.9	91	62	3.3	109	67	3.6	129	72	3.9	148	77	4.0	160	80
1400	NC	0	0	RC	49	49	2.0	51	51	2.4	65	55	2.7	78	58	3.0	94	62	3.4	112	67	3.7	132	72	3.9	151	77			
1200	NC	0	0	RC	49	49	2.2	56	51	2.5	69	55	2.9	84	58	3.2	100	62	3.6	119	67	3.9	139	72	4.0	153	77			
1190	NC	0	0	RC	49	49	2.2	57	51	2.5	69	55	2.9	84	58	3.2	101	62	3.6	120	67	3.9	139	72	4.0	153	77			
1000	NC	0	0	RC	49	49	2.4	61	51	2.7	74	55	3.1	90	58	3.5	108	62	3.8	127	67	4.0	143	72						
930	NC	0	0	2.0	50	49	2.5	63	51	2.8	77	55	3.2	93	58	3.6	111	62	3.9	129	67	4.0	144	72						
900	NC	0	0	2.1	50	49	2.5	64	51	2.8	78	55	3.2	94	58	3.6	112	62	3.9	130	67									
800	RC	46	46	2.2	54	49	2.6	67	51	3.0	81	55	3.4	99	58	3.8	117	62	4.0	133	67									
730	RC	46	46	2.3	56	49	2.7	69	51	3.1	85	55	3.5	102	58	3.9	120	62	4.0	133	67									
700	RC	46	46	2.3	57	49	2.7	70	51	3.2	86	55	3.6	104	58	3.9	121	62												
600	RC	46	46	2.5	60	49	2.9	74	51	3.4	91	55	3.8	109	58	4.0	124	62												
565	RC	46	46	2.5	61	49	3.0	76	51	3.4	94	55	3.8	111	58	4.0	124	62												
500	2.1	48	46	2.6	64	49	3.1	80	51	3.6	98	55	3.9	114	58															
450	2.2	51	46	2.7	66	49	3.2	83	51	3.7	101	55	4.0	116	58															
420	2.3	52	46	2.8	68	49	3.3	85	51	3.8	103	55	4.0	116	58															
400	2.3	54	46	2.8	69	49	3.4	87	51	3.8	105	55																		
350	2.4	56	46	3.0	73	49	3.6	91	51	3.9	108	55																		
300	2.6	59	46	3.2	77	49	3.7	96	51	4.0	109	55																		
250	2.7	63	46	3.4	83	49	3.9	101	51																					
205	2.9	68	46	3.6	89	49	4.0	103	51																					
200	3.0	68	46	3.7	89	49																								
150	3.3	76	46	3.9	96	49																								
125	3.5	81	46	4.0	97	49																								
100	3.8	87	46																											
75	4.0	92	46																											
70	4.0	92	46																											
	R_{min} = 70			R_{min} = 125			R_{min} = 205			R_{min} = 300			R_{min} = 420			R_{min} = 565			R_{min} = 730			R_{min} = 930			R_{min} = 1190			R_{min} = 1505		

NC = Normal Crown

RC = Remove Crown

spiral curvature not required above heavy line

Table 3: Ramps (w = 16 feet), e_{max} = 4%, normal cross slope (2%)

radius (ft.)	design speed (mph) 15			20			25			30			35			40			45			50			55			60		
	e	L	x	e	L	x	e	L	x	e	L	x	e	L	x	e	L	x	e	L	x	e	L	x	e	L	x	e	L	x
23000	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0
20000	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0
17000	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0
14000	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0
12000	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0
10000	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	RC	62	62
8000	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	RC	60	60	RC	62	62
6000	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	RC	56	56	RC	60	60	2.3	70	62
5000	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	RC	52	52	RC	56	56	2.3	67	60	2.5	78	62
4000	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	RC	48	48	2.0	52	52	2.3	64	56	2.6	76	60	2.8	88	62
3500	NC	0	0	NC	0	0	NC	0	0	NC	0	0	RC	45	45	RC	48	48	2.2	57	52	2.5	69	56	2.7	81	60	3.0	94	62
3000	NC	0	0	NC	0	0	NC	0	0	NC	0	0	RC	45	45	2.1	51	48	2.4	62	52	2.7	74	56	2.9	88	60	3.3	101	62
2500	NC	0	0	NC	0	0	NC	0	0	RC	42	42	2.0	46	45	2.4	57	48	2.6	68	52	2.9	81	56	3.2	95	60	3.5	110	62
2000	NC	0	0	NC	0	0	RC	40	40	RC	42	42	2.3	52	45	2.6	63	48	2.9	75	52	3.2	89	56	3.5	105	60	3.8	119	62
1800	NC	0	0	NC	0	0	RC	40	40	2.1	44	42	2.4	55	45	2.7	66	48	3.0	78	52	3.3	94	56	3.7	109	60	3.9	122	62
1600	NC	0	0	NC	0	0	RC	40	40	2.2	48	42	2.6	58	45	2.9	69	48	3.2	83	52	3.5	98	56	3.8	113	60	4.0	124	62
1505	NC	0	0	NC	0	0	RC	40	40	2.3	49	42	2.6	59	45	2.9	71	48	3.3	85	52	3.6	100	56	3.9	115	60	4.0	124	62
1400	NC	0	0	RC	38	38	2.0	40	40	2.4	51	42	2.7	61	45	3.0	73	48	3.4	87	52	3.7	103	56	3.9	117	60	R_{min} = 1505		
1200	NC	0	0	RC	38	38	2.2	44	40	2.5	54	42	2.9	65	45	3.2	78	48	3.6	93	52	3.9	108	56	4.0	119	60			
1190	NC	0	0	RC	38	38	2.2	44	40	2.5	54	42	2.9	65	45	3.2	78	48	3.6	93	52	3.9	108	56	4.0	119	60			
1000	NC	0	0	RC	38	38	2.4	48	40	2.7	58	42	3.1	70	45	3.5	84	48	3.8	99	52	4.0	112	56	R_{min} = 1190					
930	NC	0	0	2.0	39	38	2.5	49	40	2.8	60	42	3.2	72	45	3.6	86	48	3.9	100	52	4.0	112	56						
900	NC	0	0	2.1	39	38	2.5	50	40	2.8	60	42	3.2	73	45	3.6	87	48	3.9	101	52	R_{min} = 930								
800	RC	36	36	2.2	42	38	2.6	52	40	3.0	63	42	3.4	77	45	3.8	91	48	4.0	103	52									
730	RC	36	36	2.3	44	38	2.7	54	40	3.1	66	42	3.5	79	45	3.9	93	48	4.0	104	52									
700	RC	36	36	2.3	44	38	2.7	54	40	3.2	67	42	3.6	81	45	3.9	94	48	R_{min} = 730											
600	RC	36	36	2.5	47	38	2.9	58	40	3.4	71	42	3.8	85	45	4.0	96	48												
565	RC	36	36	2.5	48	38	3.0	59	40	3.4	73	42	3.8	86	45	4.0	97	48												
500	2.1	37	36	2.6	50	38	3.1	62	40	3.6	76	42	3.9	89	45	R_{min} = 565														
450	2.2	40	36	2.7	52	38	3.2	65	40	3.7	79	42	4.0	90	45															
420	2.3	41	36	2.8	53	38	3.3	67	40	3.8	80	42	4.0	90	45															
400	2.3	42	36	2.8	54	38	3.4	68	40	3.8	81	42	R_{min} = 420																	
350	2.4	44	36	3.0	57	38	3.6	71	40	3.9	84	42																		
300	2.6	46	36	3.2	60	38	3.7	75	40	4.0	85	42																		
250	2.7	49	36	3.4	64	38	3.9	78	40	R_{min} = 300																				
205*	2.9	53	36	3.6	69	38	4.0	80	40																					
200*	3.0	53	36	3.7	69	38	R_{min} = 205																							
150*	3.3	59	36	3.9	75	38																								
125*	3.5	63	36	4.0	76	38																								
100*	3.8	68	36	R_{min} = 125																										
75*	4.0	72	36																											
70*	4.0	72	36																											
	R_{min} = 70																													

NC = Normal Crown

RC = Remove Crown

***Note: Pavement width of 16' will not accommodate offtracking if radius is less than 250'.**

Loop Superelevation Transition					
design speed	radius	width	e	L	x
mph	ft.	ft.	%	ft	ft.
25	150	18	4.0	86	43
30	250	18	4.0	91	46
35	350	16	4.0	90	45

Note: Loops are designed using turning roadway criteria.

Table 4: Two-Lane Undivided Highways (w = 12 feet), e_{max} = 6%, normal cross slope (2%)

Design speed (mph): 25–50

radius (ft)	25			30			35			40			45			50		
	e	L	x	e	L	x	e	L	x	e	L	x	e	L	x	e	L	x
23000	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0
20000	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0
17000	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0
14000	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0
12000	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0
10000	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0
8000	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0
6000	NC	0	0	NC	0	0	NC	0	0	NC	0	0	RC	45	45	RC	48	48
5000	NC	0	0	NC	0	0	NC	0	0	RC	41	41	RC	45	45	2.2	54	48
4000	NC	0	0	NC	0	0	RC	39	39	RC	41	41	2.3	51	45	2.7	65	48
3500	NC	0	0	NC	0	0	RC	39	39	2.1	44	41	2.6	57	45	3.0	72	48
3060	NC	0	0	RC	36	36	RC	39	39	2.4	50	41	2.8	64	45	3.3	79	48
3000	NC	0	0	RC	36	36	RC	39	39	2.4	50	41	2.9	65	45	3.4	81	48
2510	NC	0	0	RC	36	36	2.3	45	39	2.8	58	41	3.3	74	45	3.8	91	48
2500	NC	0	0	RC	36	36	2.3	45	39	2.8	58	41	3.3	74	45	3.8	91	48
2050	RC	34	34	2.2	40	36	2.7	53	39	3.3	67	41	3.8	85	45	4.3	103	48
2000	RC	34	34	2.2	40	36	2.8	54	39	3.3	69	41	3.8	86	45	4.3	104	48
1800	RC	34	34	2.4	44	36	3.0	58	39	3.6	74	41	4.1	92	45	4.6	110	48
1660	RC	34	34	2.6	47	36	3.2	61	39	3.7	77	41	4.3	96	45	4.8	115	48
1600	2.1	35	34	2.7	48	36	3.3	63	39	3.8	79	41	4.4	98	45	4.9	117	48
1400	2.3	39	34	2.9	53	36	3.6	69	39	4.1	85	41	4.7	105	45	5.2	125	48
1340	2.4	41	34	3.0	55	36	3.7	71	39	4.2	87	41	4.8	107	45	5.3	127	48
1200	2.6	44	34	3.3	59	36	3.9	75	39	4.5	92	41	5.0	113	45	5.5	133	48
1065	2.8	49	34	3.5	64	36	4.1	80	39	4.7	98	41	5.3	119	45	5.8	138	48
1000	3.0	51	34	3.7	67	36	4.3	83	39	4.9	101	41	5.4	122	45	5.9	141	48
900	3.2	55	34	3.9	70	36	4.5	87	39	5.1	106	41	5.7	127	45	6.0	143	48
835	3.3	57	34	4.0	73	36	4.7	90	39	5.3	109	41	5.8	130	45	6.0	144	48
800	3.4	59	34	4.1	75	36	4.8	92	39	5.4	111	41	5.9	131	45			
700	3.7	63	34	4.4	80	36	5.1	98	39	5.7	117	41	6.0	134	45			
660	3.8	65	34	4.5	82	36	5.2	100	39	5.8	119	41	6.0	135	45			
600	4.0	68	34	4.7	85	36	5.4	104	39	5.9	122	41						
510	4.3	74	34	5.1	92	36	5.7	110	39	6.0	124	41						
500	4.3	74	34	5.1	93	36	5.7	111	39									
450	4.5	78	34	5.3	97	36	5.9	114	39									
400	4.8	82	34	5.6	101	36	6.0	116	39									
380	4.9	84	34	5.7	103	36	6.0	116	39									
350	5.1	87	34	5.8	105	36												
300	5.4	92	34	6.0	108	36												
275	5.5	95	34	6.0	109	36												
250	5.7	98	34															
200	6.0	102	34															
185	6.0	103	34															

25 mph: R_{min} = 185; 30 mph: R_{min} = 275; 35 mph: R_{min} = 380; 40 mph: R_{min} = 510; 45 mph: R_{min} = 660; 50 mph: R_{min} = 835

Design speed (mph): 55–80

radius (ft)	55			60			65			70			75			80		
	e	L	x	e	L	x	e	L	x	e	L	x	e	L	x	e	L	x
23000	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0
20000	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0
17000	NC	0	0	NC	0	0	NC	0	0	NC	0	0	NC	0	0	RC	69	69
14000	NC	0	0	NC	0	0	NC	0	0	RC	60	60	RC	63	63	RC	69	69
12000	NC	0	0	NC	0	0	RC	56	56	RC	60	60	RC	63	63	2.1	74	69
10000	NC	0	0	RC	53	53	RC	56	56	2.1	62	60	2.3	72	63	2.5	87	69
8000	RC	51	51	2.0	54	53	2.3	63	56	2.5	75	60	2.8	88	63	3.1	107	69
6000	2.2	57	51	2.6	69	53	2.9	81	56	3.2	96	60	3.6	113	63	4.0	137	69
5000	2.6	67	51	3.0	80	53	3.3	94	56	3.7	112	60	4.2	132	63	4.6	160	69
4000	3.1	80	51	3.6	95	53	4.0	111	56	4.4	133	60	4.9	157	63	5.5	189	69
3500	3.4	88	51	3.9	105	53	4.4	122	56	4.9	146	60	5.4	171	63	5.8	202	69
3060	3.8	97	51	4.3	114	53	4.8	133	56	5.3	158	60	5.7	182	63	6.0	207	69
3000	3.8	98	51	4.3	116	53	4.8	135	56	5.3	160	60	5.8	184	63			
2510	4.3	110	51	4.8	128	53	5.3	149	56	5.8	173	60	6.0	190	63			
2500	4.3	110	51	4.8	129	53	5.3	149	56	5.8	173	60						
2050	4.8	123	51	5.3	142	53	5.8	162	56	6.0	180	60						
2000	4.9	124	51	5.4	144	53	5.8	163	56									
1800	5.1	131	51	5.6	150	53	6.0	167	56									
1660	5.3	136	51	5.8	154	53	6.0	168	56									
1600	5.4	138	51	5.9	156	53												
1400	5.7	146	51	6.0	160	53												
1340	5.8	148	51	6.0	160	53												
1200	5.9	151	51															
1065	6.0	153	51															

55 mph: R_{min} = 1065; 60 mph: R_{min} = 1340; 65 mph: R_{min} = 1660; 70 mph: R_{min} = 2050; 75 mph: R_{min} = 2510; 80 mph: R_{min} = 3060

NC = Normal Crown

RC = Remove Crown

spiral curvature not required above heavy line

Table 5: Four-Lane Undivided Highways (w = 24 feet), $e_{max} = 6\%$, normal cross slope (2%)

design speed (mph)

radius (ft)	25			30			35			40		
	e	L	x	e	L	x	e	L	x	e	L	x
23000	NC	0	0	NC	0	0	NC	0	0	NC	0	0
20000	NC	0	0	NC	0	0	NC	0	0	NC	0	0
17000	NC	0	0	NC	0	0	NC	0	0	NC	0	0
14000	NC	0	0	NC	0	0	NC	0	0	NC	0	0
12000	NC	0	0	NC	0	0	NC	0	0	NC	0	0
10000	NC	0	0	NC	0	0	NC	0	0	NC	0	0
8000	NC	0	0	NC	0	0	NC	0	0	NC	0	0
6000	NC	0	0	NC	0	0	NC	0	0	NC	0	0
5000	NC	0	0	NC	0	0	NC	0	0	RC	62	62
4000	NC	0	0	NC	0	0	RC	58	58	RC	62	62
3500	NC	0	0	NC	0	0	RC	58	58	2.1	66	62
3060	NC	0	0	RC	55	55	RC	58	58	2.4	74	62
3000	NC	0	0	RC	55	55	RC	58	58	2.4	75	62
2510	NC	0	0	RC	55	55	2.3	67	58	2.8	87	62
2500	NC	0	0	RC	55	55	2.3	67	58	2.8	87	62
2050	RC	51	51	2.2	59	55	2.7	79	58	3.3	101	62
2000	RC	51	51	2.2	61	55	2.8	80	58	3.3	103	62
1800	RC	51	51	2.4	66	55	3.0	87	58	3.6	110	62
1660	RC	51	51	2.6	70	55	3.2	92	58	3.7	116	62
1600	2.1	53	51	2.7	72	55	3.3	95	58	3.8	119	62
1400	2.3	59	51	2.9	80	55	3.6	103	58	4.1	128	62
1340	2.4	61	51	3.0	83	55	3.7	106	58	4.2	131	62
1200	2.6	67	51	3.3	89	55	3.9	113	58	4.5	138	62
1065	2.8	73	51	3.5	96	55	4.1	120	58	4.7	147	62
1000	3.0	76	51	3.7	100	55	4.3	124	58	4.9	151	62
900	3.2	82	51	3.9	106	55	4.5	131	58	5.1	159	62
835	3.3	86	51	4.0	110	55	4.7	135	58	5.3	164	62
800	3.4	88	51	4.1	112	55	4.8	138	58	5.4	167	62
700	3.7	95	51	4.4	119	55	5.1	147	58	5.7	175	62
660	3.8	98	51	4.5	123	55	5.2	151	58	5.8	179	62
600	4.0	102	51	4.7	128	55	5.4	157	58	5.9	183	62
510	4.3	110	51	5.1	138	55	5.7	166	58	6.0	186	62
500	4.3	111	51	5.1	139	55	5.7	167	58	$R_{min} = 510$		
450	4.5	117	51	5.3	145	55	5.9	171	58			
400	4.8	123	51	5.6	152	55	6.0	174	58			
380	4.9	126	51	5.7	154	55	6.0	174	58			
350	5.1	130	51	5.8	158	55	$R_{min} = 380$					
300	5.4	138	51	6.0	163	55						
275	5.5	143	51	6.0	164	55						
250	5.7	147	51	$R_{min} = 275$								
200	6.0	154	51									
185	6.0	154	51									
	$R_{min} = 185$											

radius (ft)	45			50			55			60		
	e	L	x	e	L	x	e	L	x	e	L	x
23000	NC	0	0	NC	0	0	NC	0	0	NC	0	0
20000	NC	0	0	NC	0	0	NC	0	0	NC	0	0
17000	NC	0	0	NC	0	0	NC	0	0	NC	0	0
14000	NC	0	0	NC	0	0	NC	0	0	NC	0	0
12000	NC	0	0	NC	0	0	NC	0	0	NC	0	0
10000	NC	0	0	NC	0	0	NC	0	0	RC	80	80
8000	NC	0	0	NC	0	0	RC	77	77	2.0	81	80
6000	RC	67	67	RC	72	72	2.2	86	77	2.6	103	80
5000	RC	67	67	2.2	81	72	2.6	100	77	3.0	120	80
4000	2.3	77	67	2.7	97	72	3.1	120	77	3.6	143	80
3500	2.6	86	67	3.0	108	72	3.4	132	77	3.9	157	80
3060	2.8	96	67	3.3	119	72	3.8	145	77	4.3	171	80
3000	2.9	97	67	3.4	121	72	3.8	147	77	4.3	173	80
2510	3.3	111	67	3.8	137	72	4.3	164	77	4.8	193	80
2500	3.3	111	67	3.8	137	72	4.3	165	77	4.8	193	80
2050	3.8	127	67	4.3	154	72	4.8	184	77	5.3	214	80
2000	3.8	129	67	4.3	156	72	4.9	187	77	5.4	216	80
1800	4.1	137	67	4.6	165	72	5.1	197	77	5.6	225	80
1660	4.3	144	67	4.8	172	72	5.3	204	77	5.8	232	80
1600	4.4	146	67	4.9	176	72	5.4	208	77	5.9	234	80
1400	4.7	157	67	5.2	187	72	5.7	218	77	6.0	240	80
1340	4.8	160	67	5.3	191	72	5.8	221	77	6.0	240	80
1200	5.0	169	67	5.5	200	72	5.9	227	77	$R_{min} = 1340$		
1065	5.3	179	67	5.8	208	72	6.0	230	77			
1000	5.4	183	67	5.9	211	72	$R_{min} = 1065$					
900	5.7	190	67	6.0	215	72						
835	5.8	195	67	6.0	216	72						
800	5.9	197	67	$R_{min} = 835$								
700	6.0	201	67									
660	6.0	202	67									
600	$R_{min} = 660$											

radius (ft)	65			70			75			80		
	e	L	x	e	L	x	e	L	x	e	L	x
23000	NC	0	0	NC	0	0	NC	0	0	NC	0	0
20000	NC	0	0	NC	0	0	NC	0	0	NC	0	0
17000	NC	0	0	NC	0	0	NC	0	0	RC	103	103
14000	NC	0	0	RC	90	90	RC	95	95	RC	103	103
12000	RC	84	84	RC	90	90	RC	95	95	2.1	110	103
10000	RC	84	84	2.1	92	90	2.3	108	95	2.5	131	103
8000	2.3	95	84	2.5	113	90	2.8	133	95	3.1	160	103
6000	2.9	121	84	3.2	144	90	3.6	170	95	4.0	206	103
5000	3.3	140	84	3.7	168	90	4.2	198	95	4.6	240	103
4000	4.0	166	84	4.4	199	90	4.9	235	95	5.5	284	103
3500	4.4	183	84	4.9	218	90	5.4	256	95	5.8	302	103
3060	4.8	200	84	5.3	237	90	5.7	274	95	6.0	310	103
3000	4.8	202	84	5.3	240	90	5.8	276	95	$R_{min} = 3060$		
2510	5.3	223	84	5.8	260	90	6.0	286	95			
2500	5.3	224	84	5.8	260	90	$R_{min} = 2510$					
2050	5.8	243	84	6.0	270	90						
2000	5.8	244	84	$R_{min} = 2050$								
1800	6.0	250	84									
1660	6.0	252	84									
1600	$R_{min} = 1660$											

NC = Normal Crown

RC = Remove Crown

spiral curvature not required above heavy line

Table 6: Ramps (w = 16 feet), e_{max} = 6%, normal cross slope (2%)

radius (ft)	design speed (mph) 25			30			35			40		
	e	L	x	e	L	x	e	L	x	e	L	x
23000	NC	0	0	NC	0	0	NC	0	0	NC	0	0
20000	NC	0	0	NC	0	0	NC	0	0	NC	0	0
17000	NC	0	0	NC	0	0	NC	0	0	NC	0	0
14000	NC	0	0	NC	0	0	NC	0	0	NC	0	0
12000	NC	0	0	NC	0	0	NC	0	0	NC	0	0
10000	NC	0	0	NC	0	0	NC	0	0	NC	0	0
8000	NC	0	0	NC	0	0	NC	0	0	NC	0	0
6000	NC	0	0	NC	0	0	NC	0	0	NC	0	0
5000	NC	0	0	NC	0	0	NC	0	0	RC	48	48
4000	NC	0	0	NC	0	0	RC	45	45	RC	48	48
3500	NC	0	0	NC	0	0	RC	45	45	2.1	52	48
3060	NC	0	0	RC	42	42	RC	45	45	2.4	58	48
3000	NC	0	0	RC	42	42	RC	45	45	2.4	59	48
2510	NC	0	0	RC	42	42	2.3	52	45	2.8	68	48
2500	NC	0	0	RC	42	42	2.3	52	45	2.8	68	48
2050	RC	40	40	2.2	46	42	2.7	61	45	3.3	79	48
2000	RC	40	40	2.2	47	42	2.8	62	45	3.3	80	48
1800	RC	40	40	2.4	51	42	3.0	68	45	3.6	86	48
1660	RC	40	40	2.6	55	42	3.2	72	45	3.7	90	48
1600	2.1	41	40	2.7	56	42	3.3	74	45	3.8	92	48
1400	2.3	46	40	2.9	62	42	3.6	80	45	4.1	99	48
1340	2.4	48	40	3.0	64	42	3.7	83	45	4.2	102	48
1200	2.6	52	40	3.3	69	42	3.9	88	45	4.5	108	48
1065	2.8	57	40	3.5	75	42	4.1	93	45	4.7	114	48
1000	3.0	59	40	3.7	78	42	4.3	96	45	4.9	118	48
900	3.2	64	40	3.9	82	42	4.5	102	45	5.1	124	48
835	3.3	67	40	4.0	85	42	4.7	105	45	5.3	128	48
800	3.4	69	40	4.1	87	42	4.8	107	45	5.4	130	48
700	3.7	74	40	4.4	93	42	5.1	114	45	5.7	136	48
660	3.8	76	40	4.5	95	42	5.2	117	45	5.8	139	48
600	4.0	80	40	4.7	100	42	5.4	122	45	5.9	142	48
510	4.3	86	40	5.1	107	42	5.7	129	45	6.0	145	48
500	4.3	87	40	5.1	108	42	5.7	130	45	R_{min} = 510		
450	4.5	91	40	5.3	113	42	5.9	133	45			
400	4.8	96	40	5.6	118	42	6.0	135	45			
380	4.9	98	40	5.7	120	42	6.0	136	45			
350	5.1	101	40	5.8	123	42	R_{min} = 380					
300	5.4	108	40	6.0	127	42						
275	5.5	111	40	6.0	127	42						
250	5.7	114	40	R_{min} = 275								
200*	6.0	120	40									
185*	6.0	120	40									
	R_{min} = 185											

radius (ft)	design speed (mph) 45			50			55			60		
	e	L	x	e	L	x	e	L	x	e	L	x
23000	NC	0	0	NC	0	0	NC	0	0	NC	0	0
20000	NC	0	0	NC	0	0	NC	0	0	NC	0	0
17000	NC	0	0	NC	0	0	NC	0	0	NC	0	0
14000	NC	0	0	NC	0	0	NC	0	0	NC	0	0
12000	NC	0	0	NC	0	0	NC	0	0	NC	0	0
10000	NC	0	0	NC	0	0	NC	0	0	RC	62	62
8000	NC	0	0	NC	0	0	RC	60	60	2.0	63	62
6000	RC	52	52	RC	56	56	2.2	67	60	2.6	80	62
5000	RC	52	52	2.2	63	56	2.6	78	60	3.0	93	62
4000	2.3	60	52	2.7	75	56	3.1	93	60	3.6	111	62
3500	2.6	67	52	3.0	84	56	3.4	103	60	3.9	122	62
3060	2.8	75	52	3.3	93	56	3.8	113	60	4.3	133	62
3000	2.9	76	52	3.4	94	56	3.8	114	60	4.3	135	62
2510	3.3	86	52	3.8	106	56	4.3	128	60	4.8	150	62
2500	3.3	87	52	3.8	106	56	4.3	128	60	4.8	150	62
2050	3.8	99	52	4.3	120	56	4.8	143	60	5.3	166	62
2000	3.8	101	52	4.3	121	56	4.9	145	60	5.4	168	62
1800	4.1	107	52	4.6	128	56	5.1	153	60	5.6	175	62
1660	4.3	112	52	4.8	134	56	5.3	159	60	5.8	180	62
1600	4.4	114	52	4.9	137	56	5.4	161	60	5.9	182	62
1400	4.7	122	52	5.2	146	56	5.7	170	60	6.0	186	62
1340	4.8	125	52	5.3	148	56	5.8	172	60	6.0	187	62
1200	5.0	132	52	5.5	155	56	5.9	177	60	R_{min} = 1340		
1065	5.3	139	52	5.8	162	56	6.0	179	60			
1000	5.4	143	52	5.9	164	56	R_{min} = 1065					
900	5.7	148	52	6.0	167	56						
835	5.8	151	52	6.0	168	56						
800	5.9	153	52	R_{min} = 835								
700	6.0	157	52									
660	6.0	157	52									
600	R_{min} = 660											

radius (ft)	design speed (mph) 65			70			75			80		
	e	L	x	e	L	x	e	L	x	e	L	x
23000	NC	0	0	NC	0	0	NC	0	0	NC	0	0
20000	NC	0	0	NC	0	0	NC	0	0	NC	0	0
17000	NC	0	0	NC	0	0	NC	0	0	RC	80	80
14000	NC	0	0	RC	70	70	RC	74	74	RC	80	80
12000	RC	65	65	RC	70	70	RC	74	74	2.1	86	80
10000	RC	65	65	2.1	72	70	2.3	84	74	2.5	102	80
8000	2.3	74	65	2.5	88	70	2.8	103	74	3.1	124	80
6000	2.9	94	65	3.2	112	70	3.6	132	74	4.0	160	80
5000	3.3	109	65	3.7	130	70	4.2	154	74	4.6	187	80
4000	4.0	130	65	4.4	155	70	4.9	183	74	5.5	221	80
3500	4.4	142	65	4.9	170	70	5.4	199	74	5.8	235	80
3060	4.8	155	65	5.3	184	70	5.7	213	74	6.0	241	80
3000	4.8	157	65	5.3	186	70	5.8	214	74	R_{min} = 3060		
2510	5.3	174	65	5.8	202	70	6.0	222	74			
2500	5.3	174	65	5.8	202	70	R_{min} = 2510					
2050	5.8	189	65	6.0	210	70						
2000	5.8	190	65	R_{min} = 2050								
1800	6.0	195	65									
1660	6.0	196	65									
1600	R_{min} = 1660											

NC = Normal Crown

RC = Remove Crown

***Note: Pavement width of 16' will not accommodate offtracking if radius is less than 250'.**

Loop Superelevation Transition					
design speed	radius	width	e	L	x
mph	ft.	ft.	%	ft.	ft.
25	150	18	6.0	129	43
30	250	18	6.0	136	45
35	350	16	6.0	136	45

Note: Loops are designed using turning roadway criteria.

Compound Horizontal Curve Design

Originally Issued: 01-04-02

Simple horizontal curves, such as those discussed in Section 2A-1, are preferred for their ease of computation and staking. However, situations often arise when a compound horizontal curve better suits a given design situation. Ramps and loops are two examples. Turning movements for many design vehicles are also best represented by compound horizontal curves.

Essentially, a compound curve consists of two curves that are joined at a point of tangency and are located on the same side of a common tangent. Though their radii are in the same direction, they are of different values.

The most commonly used compound horizontal curve designs are two-centered and three-centered. Figure 1 illustrates a two- and a three-centered compound curve. It is possible for a curve to have four or more centers; however, these are complicated to compute and stake. Three curves should be considered a practical limit for compound curves.

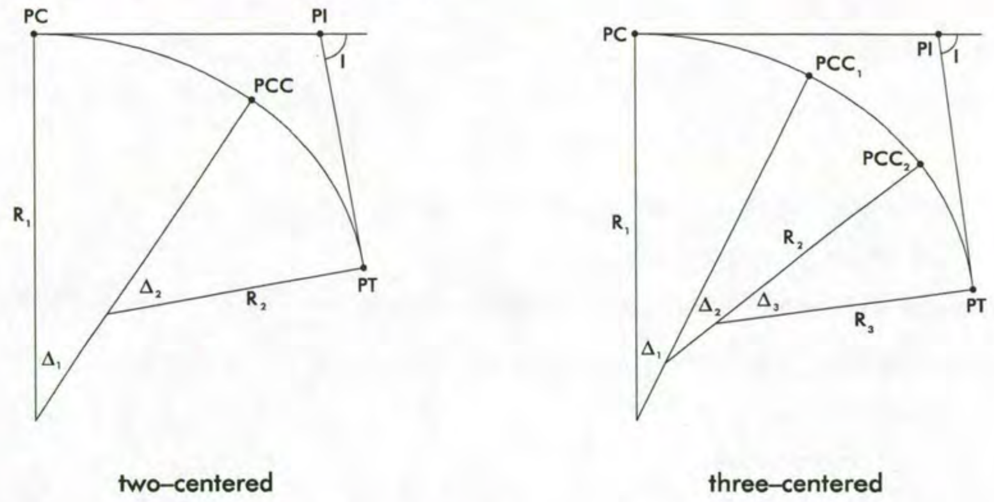


Figure 1: Two- and three-centered compound curves.

Definitions

PI = Point of Intersection of back tangent and forward tangent.

PC = Point of Curvature—point of change from back tangent to circular curve.

PT = Point of Tangency—point of change from circular curve to forward tangent.

PCC = Point of Compound Curvature.

T_L = Long Tangent of the compound curve.

T_S = Short Tangent of the compound curve.

I = Total intersection angle of the compound curve.

X = Distance from PC to PT in the direction of the backward tangent.

Y = Perpendicular distance from the backward tangent to the PT.

Formulas

Relationships between intersection angles and radii can be found using information in Section 2A-1 of this Manual.

Two-centered Compound Curves

Figure 2 provides a more detailed illustration of a two-centered curve.

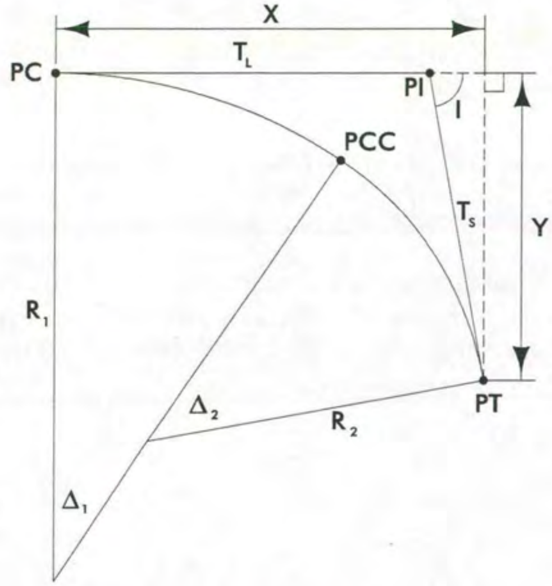


Figure 2: Components of a two-centered compound curve.

The following formulas correspond to Figure 2.

Δ_1 = Intersection angle of the flatter curve (decimal degrees).

Δ_2 = Intersection angle of the sharper curve (decimal degrees).

R_1 = Radius of the flatter curve.

R_2 = Radius of the sharper curve.

$$I = \Delta_1 + \Delta_2$$

$$X = R_2 \times \sin I + (R_1 - R_2) \times \sin \Delta_1$$

$$Y = R_1 - R_2 \times \cos I - (R_1 - R_2) \times \cos \Delta_1$$

$$T_L = \frac{R_2 - R_1 \times \cos I + (R_1 - R_2) \times \cos \Delta_2}{\sin I}$$

$$T_S = \frac{R_1 - R_2 \times \cos I - (R_1 - R_2) \times \cos \Delta_1}{\sin I}$$

$$\sin \Delta_1 = \frac{T_L + T_S \times \cos I - R_2 \times \sin I}{R_1 - R_2}$$

$$\sin \Delta_2 = \frac{R_1 \times \sin I - T_L \times \cos I - T_S}{R_1 - R_2}$$

Three-centered Compound Curves

Figure 3 provides a more detailed illustration of a three-centered curve.

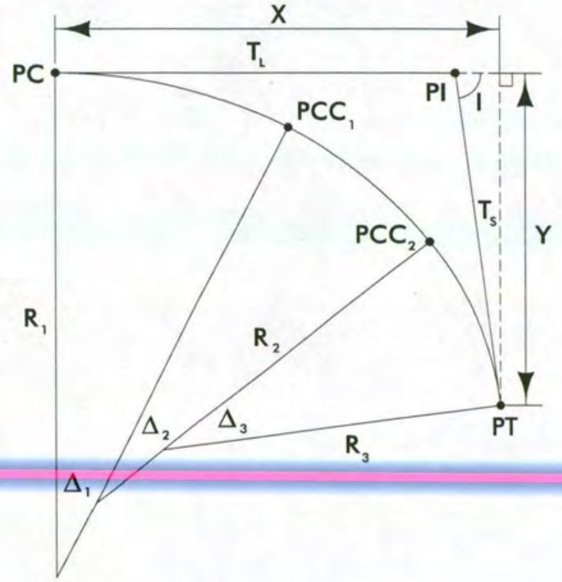


Figure 3: Components of a three-centered compound curve.

The following formulas correspond to Figure 3.

Δ_1 = Intersection angle of the flattest curve (decimal degrees).

Δ_2 = Intersection angle of the middle curve (decimal degrees).

Δ_3 = Intersection angle of the sharpest curve (decimal degrees).

R_1 = Radius of the flattest curve.

R_2 = Radius of the middle curve.

R_3 = Radius of the sharpest curve.

$I = \Delta_1 + \Delta_2 + \Delta_3$

$$X = (R_1 - R_2) \times \sin \Delta_1 + (R_2 - R_3) \times \sin(\Delta_1 + \Delta_2) + R_3 \sin I$$

$$Y = R_1 - R_3 \times \cos I - (R_1 - R_2) \times \cos \Delta_1 - (R_2 - R_3) \times \cos(\Delta_1 + \Delta_2)$$

$$T_L = \frac{R_3 - R_1 \times \cos I + (R_1 - R_2) \times \cos(\Delta_2 + \Delta_3) + (R_2 - R_3) \times \cos \Delta_3}{\sin I}$$

$$T_S = \frac{R_1 - R_3 \times \cos I - (R_1 - R_2) \times \cos \Delta_1 - (R_2 - R_3) \times \cos(\Delta_1 + \Delta_2)}{\sin I}$$

Superelevation

Sections 2A-2 and 2A-3 of this Manual provide more information regarding superelevation.

Plan Curve Data

Each curve of a compound curve should be treated independently as a horizontal curve and the following Plan Curve Data should be provided on the plan sheet for each curve: Δ, D, T, L, E, and R. For superelevated curves the rate of superelevation (e) and runout length (x) should also be shown. The length of transition (m) should be included if a spiral is not used. At intersections, e, x, and m are not required for returns.

Vertical Curve Design

Originally Issued: 09-22-00

This section provides information relevant to vertical curves. Vertical curves are used to smooth changes in vertical direction. They fall into one of two categories: crest or sag and can be symmetrical or unsymmetrical. A crest occurs when the arc of the curve is below the VPI. A sag occurs when the arc is above the VPI. Figures 1 and 2 illustrate the components of a vertical curve.

Symmetrical

Typically, vertical curves are symmetrical. This means the tangent length from VPC to VPI equals the tangent length from VPI to VPT. It is not necessary for the VPC and the VPT to be at the same elevation to have a symmetrical vertical curve.

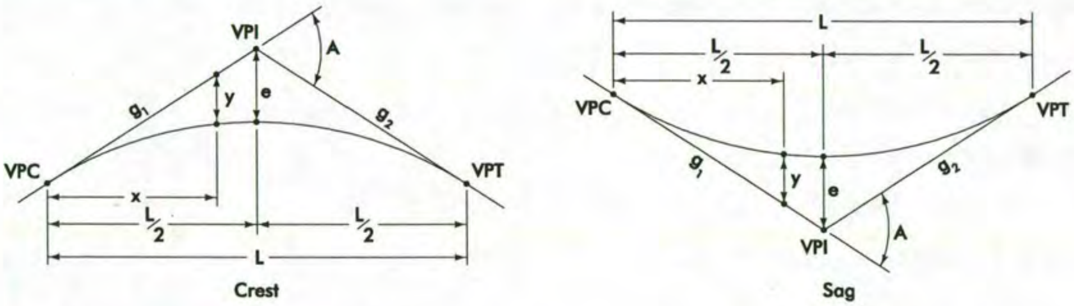


Figure 1: Symmetrical vertical curves.

Unsymmetrical Vertical Curves

There are certain situations when an unsymmetrical vertical curve will better satisfy constraints. An unsymmetrical curve is a curve in which the tangent length from VPC to VPI does not equal the tangent length from VPI to VPT. As already mentioned, symmetrical vertical curves are more common than unsymmetrical vertical curves, but since the designer is likely to encounter both, equations for both are provided.

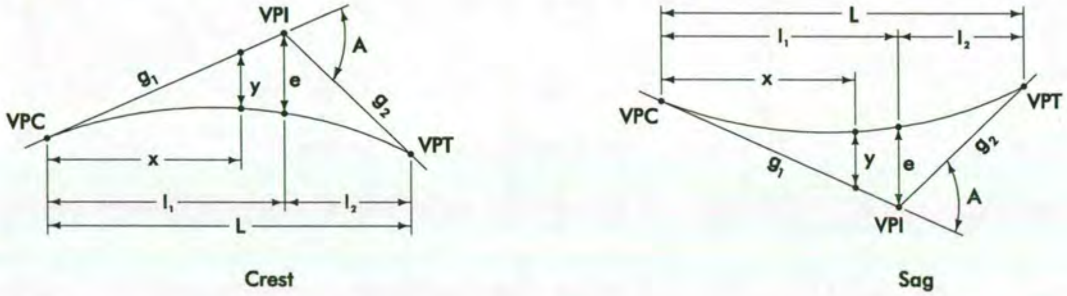


Figure 2: Unsymmetrical vertical curves.

Definitions

Note: g_1 and g_2 are gradients, or tangent grades, of a slope given in percent. These gradients are determined by dividing the difference in elevation of two points by the horizontal distance between them and then multiplying by 100. The definitions below apply to crest and sag vertical curves.

A = Algebraic difference in gradients, $g_2 - g_1$.

L = Total length of vertical curve.

K = Rate of vertical curvature.

l_1 = Length of curve 1 (unsymmetrical vertical curve only).

l_2 = Length of curve 2 (unsymmetrical vertical curve only).

VPC = The Vertical Point of Curvature.

VPT = The Vertical Point of Tangency.

VPI = The Vertical Point of Intersection.

x = Horizontal distance to any point on the curve from the VPC.

x_t = Turning point, which is the minimum or maximum point of the curve.

e = Middle ordinate, which is the vertical distance from the VPI to the arc.

y = Vertical distance at any point on the curve to the tangent grade.

r = Rate of change of grade.

E_{VPC} = Elevation of VPC.

E_{VPT} = Elevation of VPT.

E_x = Elevation of a point on the curve at a distance x from the VPC.

E_t = Elevation of the turning point.

Formulas

Symmetrical Vertical Curves

$A = g_2 - g_1$	g_1 and g_2 are in percent
$K = \frac{L}{A}$	L is given in feet and g_1 and g_2 are in percent
$r = \frac{A}{100L}$	L is given in feet and g_1 and g_2 are in percent
$e = \frac{AL}{800}$	L is given in feet
$y = \frac{4ex^2}{L^2} = \frac{1}{2}rx^2 = \frac{Ax^2}{200L}$	measured from the tangent that passes through VPC and VPI: L and x are given in feet
$E_x = E_{VPC} + g_1x + \frac{1}{2}rx^2$	L and x are given in feet: convert g_1 to a decimal
$x_t = -\frac{g_1}{r}$	x_t is in feet: convert g_1 to a decimal
$E_t = E_{VPC} - \frac{g_1^2}{2r}$	convert g_1 to a decimal

Unsymmetrical Curves

$A = g_2 - g_1$	g_2 and g_1 are in percent
$K = \dfrac{L}{A}$	L is in feet and g_1 and g_2 are in percent
$r = \dfrac{A}{100L}$	L is in feet and g_1 and g_2 are in percent
$r_1 = \dfrac{A}{100L} * \dfrac{l_2}{l_1}$	r_1 is the rate of change of grade for the tangent through VPC and VPI: L, l_1, and l_2 are in feet
$r_2 = \dfrac{A}{100L} * \dfrac{l_1}{l_2}$	r_2 is the rate of change of grade for the tangent through VPI and VPT: L, l_1, and l_2 are in feet
$e = \dfrac{Al_1l_2}{200L} = \dfrac{1}{2}r_1l_1^2 = \dfrac{1}{2}r_2l_2^2$	L, l_1, and l_2 are in feet
$E_{x1} = E_{VPC} + g_1x + \dfrac{1}{2}r_1x^2$	gives the elevation on the left branch of an unsymmetrical curve, x is given in feet: g_1 is converted to a decimal
$E_{x2} = E_{VPT} - g_2x + \dfrac{1}{2}r_2x^2$	gives the elevation on the right branch of an unsymmetrical curve, x is given in feet: g_2 is converted to a decimal
$x_{t1} = -\dfrac{g_1}{r_1}$	if turning point occurs in left branch, where x_{t1} is given in feet: convert g_1 to a decimal
$x_{t2} = -\dfrac{g_2}{r_2}$	if turning point occurs in right branch, where x_{t1} is given in feet: convert g_2 to a decimal
$E_{t1} = E_{VPC} - \dfrac{g_1^2}{2r_1}$	if turning point occurs in left branch: convert g_1 to a decimal
$E_{t2} = E_{VPT} - \dfrac{g_2^2}{2r_2}$	if turning point occurs in right branch: convert g_2 to decimal

Design Considerations

Several items must be considered in the process of designing a vertical curve. Of particular importance are:

- Stopping sight distance for crests and headlight sight distance for sags
- Rate of change of grade
- Drainage
- Appearance

Section 6D-5 of this Manual provides additional guidance on the design of vertical curves. AASHTO's *A Policy on Geometric Design of Highways and Streets* provides a comprehensive guide, including a number of useful tables and graphs, to the design of vertical curves. The designer should consult these resources.

Plan Curve Data

The following Plan Curve Data should be provided on the plan sheets for each vertical curve: K, elevation and station of PI, and length of curve.

Spiral Curve Design

Originally Issued: 09-22-00

Spiral curves are generally used to provide a gradual change in curvature from a straight section of road to a curved section. Figure 1 shows the placement of spiral curves in relation to circular curves. Figure 2 shows the components of a spiral curve. Spiral curves are necessary on high-speed roads from the standpoint of comfortable operation and gradually bringing about the full superelevation of the curves[1]. A spiral should be utilized with a circular curve with a superelevation of 3% or greater.

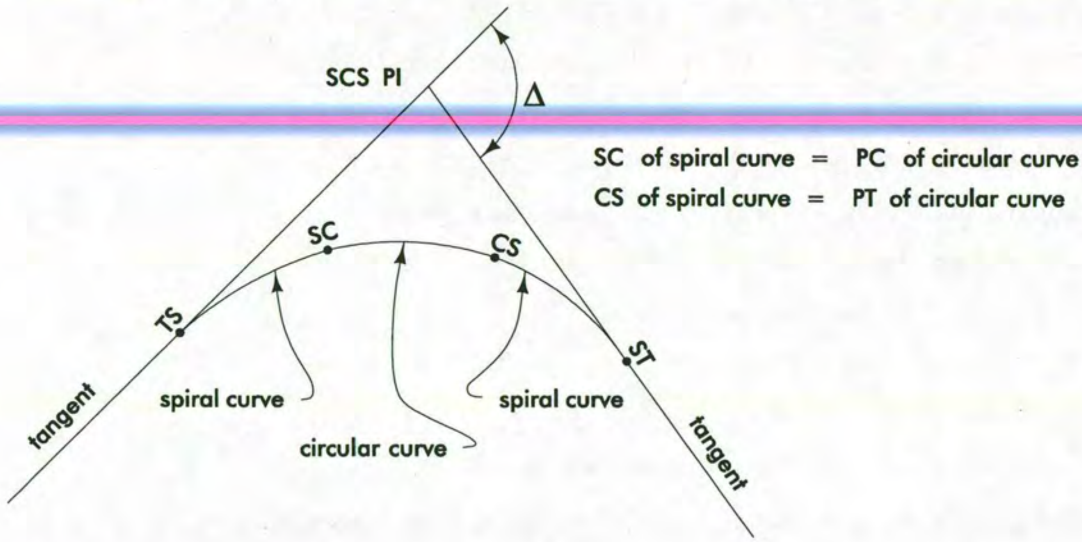


Figure 1: Placement of spiral curve.

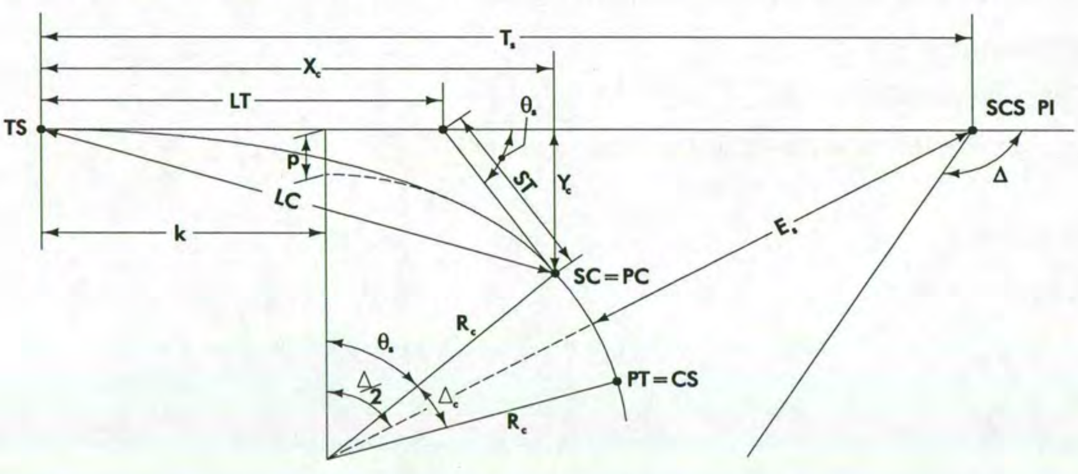


Figure 2: Components of a spiral curve (based on Hickerson, p. 175).

[1] Hickerson, T.F., *Route Location and Design*. 2nd ed. (New York: McGraw-Hill, Inc., 1964), 168.

Definitions

SCS PI = Point of intersection of main tangents.

TS = Point of change from tangent to spiral curve.

SC = Point of change from spiral curve to circular curve.

CS = Point of change from circular curve to spiral curve.

ST = Point of change from spiral curve to tangent.

LC = Long chord.

LT = Long tangent.

ST = Short tangent.

PC = Point of curvature for the adjoining circular curve.

PT = Point of tangency for the adjoining circular curve.

T_s = Tangent distance from TS to SCS PI or ST to SCS PI.

E_s = External distance from the SCS PI to the center of the circular curve.

R_c = Radius of the adjoining circular curve.

D_c = Degree of curve of the adjoining circular curve, based on a 100 foot arc.

D = Degree of curve of the spiral at any point, based on a 100 foot arc.

l = Spiral arc from the TS to any point on the spiral ($l = l_s$ at the SC).

l_s = Total length of spiral curve from TS to SC.

L = Length of the adjoining circular curve.

θ_s = Central (or spiral) angle of arc l_s.

Δ = Total central angle of the circular curve from TS to ST.

Δ_c = Central angle of circular curve of length L extending from SC to CS.

p = Offset from the initial tangent.

k = Abscissa of the distance between the shifted PC and TS.

Y_c = Tangent offset at the SC.

X_c = Tangent distance at the SC.

x and y = coordinates of any point on the spiral from the TS.

Formulas

$$D_c = \frac{18000}{\pi} \Big/ R_c$$ R_c given in feet, D_c in decimal degrees

$$D_c = 200 * \frac{\theta_s}{l_s}$$ θ_s and D_c in decimal degrees, l_s in feet

$$l_s = 200 * \frac{\theta_s}{D_c}$$ θ_s and D_c in decimal degrees, l_s in feet

$\theta_s = \frac{l_s * D_c}{200}$ — θ_s and D_c in decimal degrees, l_s in feet

$\Delta = \frac{180 * L}{\pi * R_c}$ — L and R_c in feet

$\theta_s = \frac{l_s}{2 * R_c}$ — θ_s in radians, l_s and R_c in feet

θ_s (decimal degrees) = $\frac{180}{\pi} * \theta_s$ (radians)

$X_c = \left(\frac{l_s}{100}\right) * \left(100 - 0.00304628\theta_s^{\ 2}\right)$ — θ_s in decimal degrees, l_s in feet

$Y_c = \left(\frac{l_s}{100}\right) * \left(0.58178\theta_s - 0.0000126598\theta_s^{\ 3}\right)$ — θ_s in decimal degrees, l_s in feet

$p = Y_c - R_c * (1.0 - \cos\theta_s)$ — Y_c, R_c and p in feet and θ_s in decimal degrees

$A = \frac{100 * D_c}{l_s}$ — A and l_s in feet, D_c in decimal degrees

$k = \frac{1}{2} l_s - 0.000127 A^2 * \left(\frac{l_s}{100}\right)^5$ — A and l_s in feet

$T_s = (R_c + p) * \tan\frac{\Delta}{2} + k$ — T_s, R_c, p, and k in feet, Δ in decimal degrees

$E_s = (R_c + p) * \text{exsec}\frac{\Delta}{2} + p$ — Es, R_c, p, and k in feet, Δ in decimal degrees, and exsecα is defined as $(\tan\alpha)(\tan\frac{1}{2}\alpha)$

$LT = X_c - (Y_c * \cot\theta_s)$ — LT, X_c, and Y_c in feet, θ_s in decimal degrees

$ST = \frac{Y_c}{\sin\theta_s}$ — ST and Y_c in feet, θ_s in decimal degrees

$LC = l_s - 0.00034 A^2 * \left(\frac{l_s}{100}\right)^5$ — LC, A and l_s in feet

$\Delta_c = \Delta - 2 * \theta_s$ — Δ_c, Δ, and θ_s measured in decimal degrees

Plan Curve Data

The following Plan Curve Data shall be provided on the plan sheets for each spiral curve: Δ, D_c, E_s, T_s, l_s, θ_s, p, k, X_c, Y_c, LT, ST, LC, and SCS PI stationing.

Reverse Curve Design

Originally Issued: 09-22-00

This section provides information pertaining to the design of reverse curves. Reverse curves are commonly used to redirect through lanes at channelized intersections and high-speed median crossovers. They are also utilized in interchange ramps and to realign crossroads at skewed intersections.

A reverse curve is two circular curves with opposite deflection angles. The curves may have equal or unequal radii and/or deflection angles. The curves may be continuous or separated by a short tangent section, see Figure 1. The tangent length is normally determined by superelevation transition requirements. Each of the curves in a reverse curve is treated in a similar manner as a horizontal curve (see Section 2A-1).

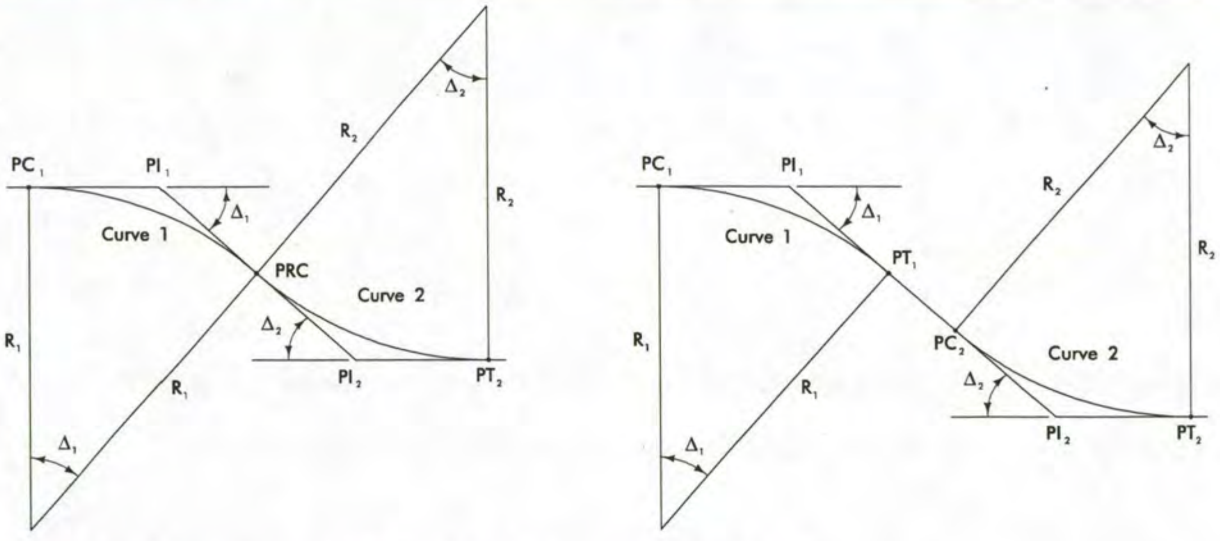


Figure 1: Reverse curves without and with a tangent section between.

Lane Redirection

Channelized Intersections

At channelized intersections with redirected through lanes, a PRC (Point of Reverse Curve) is preferred because superelevation is undesirable. In most cases, the radii R_1 and R_2, and deflection angles Δ_1 and Δ_2 will be the same, as will the deflection angles. The designer may take advantage of this symmetry to reduce calculations. Minimum radii are selected based upon maintenance of normal crown cross slopes at design speed.

Median Crossovers

Reverse curves in median crossovers are separated by a short tangent section from PT_1 to PC_2 (see Figure 1) that allows the superelevation to transition from the slope of Curve 1 to the slope of

Curve 2. Determining the length of this tangent is the first step in designing the reverse curve. The minimum length of this tangent will be equal to the superelevation tangent runout length (x) of Curve 1 plus the superelevation tangent runout length (x) of Curve 2. Sections 2A-2 and 2A-3 of this Manual provide more information concerning superelevation and Section 3E-3 provides more information regarding median crossovers. The designer is encouraged to consult the Methods Section in the Office of Design for further assistance with median crossover design.

Interchange Ramps

Reverse curves are used on interchange ramps when necessary. Tangent sections between the curves are required to accommodate the high-speed superelevation transitions. The minimum tangent length between the curves is equal to the sum of 70% of the tangent runoff length (L) for each curve. More specific criteria for reverse curve interchange ramps will be detailed in a section to be issued in the future.

Realignment of Crossroads

Reverse curves may also be used when realigning crossroads to reduce skew. Refer to Section 6A-8 of this Manual for more details concerning intersection alignment.

Example: Lane Redirection at an Intersection

Given a design speed of 50 mph and a lane width of 12', we wish to design a reverse curve to redirect a through lane to accommodate a 16' median for a left turn lane, as seen in Figure 2. Assume a normal crown (NC) section.

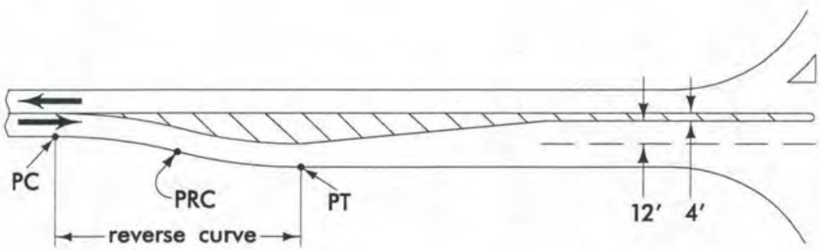


Figure 2: Reverse curve used to redirect a through lane at an intersection.

1. Simplify calculations by setting R_1 and R_2 in Figure 1 equal to each other. Parallel offsets result in Δ_1 and Δ_2 being equal to each other. This produces the situation illustrated in Figure 3.

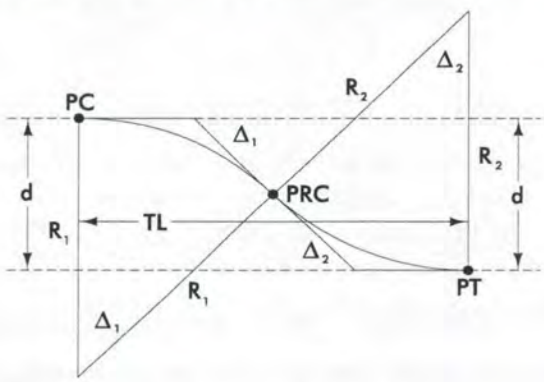


Figure 3: Reverse curve for lane redirection in example problem.

2. Using Table 1 in Section 2A-3 with a normal crown (NC), R = 8000 feet.
3. Since the median is 16', d in Figure 3 is 16'. With trigonometry it can be shown that

   $\cos\Delta = \dfrac{2R - d}{2R}$ from which Δ = 2.562559° (2°33′45.21″).

4. Using the formulas in Section 2A-1 with R and Δ as knowns, the remaining circular components may be calculated:

   $$T = R \times \left(\tan\frac{\Delta}{2}\right) = 178.93'$$

   $$L = \frac{\Delta \times \pi \times R}{180} = 357.80'$$

   $$E = T \times \left(\tan\frac{\Delta}{4}\right) = 2.00'.$$

   This information will be identical for both curves in the reverse curve.

5. The total length (TL) for the reverse curve can be calculated with the following formula:

   $$TL = \sqrt{(R_1 + R_2)^2 - (R_1 + R_2 - d)^2} = 715.36'$$

Cross Sections

Curbs

Originally Issued: 09-01-95

This section provides guidelines for the design of curbs on primary highways. For definitions of the various highway types referred to in this section, see Section 1C-1.

General Curb Design Information

The Department recognizes three curb designs:

- 6-inch standard curbs
- 4-inch sloped curbs
- 6-inch sloped curbs

Details of these curb designs can be found in the Road Design Details manual.

The use of other curb designs is discouraged, but may be necessary where site conditions dictate. For projects at spot locations, it is acceptable to use a curb design that perpetuates the design that is predominant in the adjacent roadway sections.

A regulatory speed greater than 35 mph is considered "high-speed" when designing curbs. If possible, curbs should not be used in high-speed locations.

Guardrail and Curbs

It is not desirable to use guardrail alongside curbs. Every effort should be made to remove fixed objects or relocate them outside the clear zone, instead of using guardrail. If there is no other alternative to using guardrail, it may be used alongside a 4-inch sloped curb, normally with the installation line at the face of the curb. If 6-inch curbs are being used throughout the rest of the project, the curb should be transitioned to a 4-inch sloped curb throughout the guardrail installation.

Reduced-Speed Urban Facilities

On reduced-speed urban roadways (regulatory speeds of 35 mph or less), a 6-inch standard curb is normally used for controlling surface drainage and access. Normally, the 31-foot back-to-back design is used for two-lane facilities and the 53-foot back-to-back design is used for four-lane facilities. Both of these designs provide at least a 2-foot offset to the face of the curb. In some situations, it is necessary to use a 49-foot back-to-back design for a four-lane facility (this design provides no curb offset but is still acceptable in special situations, such as when there is limited right-of-way).

For reduced-speed urban roadways with a raised median, the normal offset to the face of the median curb is 2 feet.

Curbs for stop sign islands should match the design of the curb used on the mainline.

Transitional Facilities

Transitional facilities are highways approaching or within urban areas that normally have regulatory speeds between 40 and 50 mph.

Curbs are not desirable on transitional facilities since the regulatory speeds are greater than 35 mph. However, when determining whether or not curbs should be used on transitional roadways you should also consider the best way to handle drainage, the need for access control, the degree of property development, and the presence of pedestrian traffic.

If curbs are being used on transitional roadways, the following guidelines apply:

- If the regulatory speed is 40, 45, or 50 mph, a 6-inch sloped curb should be used. The normal offset to the bottom edge of the sloped curb is 3 feet. This offset should apply to both the median and outside curbs.
- Curbs for stop sign islands should match the design of the curb used on the mainline.

Freeways, Expressways, Super-Two Highways, and Rural Two-Lane Highways

Freeways, expressways, super-two highways, and rural two-lane highways have regulatory speeds of 55 mph or greater and because of these high speeds, curbs are not desirable. On existing facilities, curbs should normally be eliminated where it is practical to do so. However, in some instances curbs may be necessary because of drainage or right-of-way considerations (in particular for urban freeways). In these cases, the following guidelines apply:

- The Design Engineer should approve the use of any curbs on these high-speed facilities.
- A 4-inch sloped curb may be used on the outside edge of a full-width paved shoulder. The shoulder should be paved for the segment where the curb is used. Where surface drainage requirements are unusually high, a 6-inch sloped curb may be used instead.
- Painted medians are normally used to channelize intersections. If the intersection requires a raised median to control drainage, the designer may use a 4-inch sloped curb. In some cases, 6-inch sloped curbs may also be appropriate. In any case, the curb on the median side requires a 6-foot offset measured from the edge of the traveled way to the bottom edge of the sloped curb.

Stop sign islands should be designed using 4-inch sloped curbs. The designer should offset the island from the edge of traveled way of the mainline by 2 feet beyond the normal shoulder width. For traffic on the stop approach, the island should be offset by 2 feet from the edge of traveled way. In both cases, this offset is measured to the bottom edge of the sloped curb.

Shoulders at Superelevated Curves

Originally Issued: 05-02-97

This section describes the appropriate shoulder cross sections to use through superelevated curves.

The shoulder treatment shall extend from the location where the superelevation transition begins before the P.C., throughout the curve, until normal crown is achieved beyond the P.T. In other words, the treatment should begin and end at point A, as illustrated on the RP series of Standard Road Plans.

Curves on the Mainline

Superelevation up to 7%

Typical 2019 (granular shoulders) and Typical 2012 (paved shoulders) illustrate cross sections for curves with superelevation up to 7%.

As noted on these typicals, the low-side shoulder shall slope in the same direction as the superelevation at a rate of 4% as long as the superelevation is less than 4%. If the superelevation is between 4 and 7%, the low-side shoulder shall have the same slope as the mainline pavement.

The high-side shoulder shall slope in the opposite direction of the superelevation at a rate of 4%, as long as the grade break between the two slopes is less than 8%. If this is not the case, then the slope of the high-side shoulder is flattened until the grade break is 8%. For example, if the mainline pavement is superelevated at 5%, the high-side shoulder would need to slope away at 3%.

Superelevation greater than 7%

If the superelevation is greater than 7%, the low-side shoulder is treated the same as described above. High-side shoulders, however, are treated differently. Typical 2016 illustrates this treatment for paved shoulders and Typical 2014 covers granular shoulders.

On paved shoulders, the entire high-side shoulder is paved and sloped at 1% in the same direction as the superelevation.

As shown on Typical 2014, granular shoulders are handled differently. Part of the shoulder is paved and sloped the same as the mainline pavement. The rest of the shoulder remains granular and slopes away at 1%. The granular part of the shoulder is sloped away so that no granular material erodes onto the traveled way. This creates, however, a grade break between the mainline pavement and the shoulder that is greater than 8%. This is acceptable because the partially paved area moves the breakpoint farther away from the normal driving surface. The wider paved area also gives vehicles some extra room to maneuver the steeply superelevated curve. The thickness of this partially paved shoulder shall be the same as the thickness of the mainline pavement.

Ramps

One-lane Ramps

If the superelevation on a one-lane ramp is less than 7%, the shoulder treatment is the same as described above (Typicals 2019 and 2012). However, if the superelevation is greater than 7%, then the entire high-side shoulder is paved as shown on Typical 2016. Note that this is applicable for both paved and granular shoulders. Typical 2014 does not apply to granular shoulders on one-lane ramps. Low-side shoulders are treated the same as described above (Typicals 2019 and 2012).

Two-lane Ramps

As discussed in Section 6B-1, two-lane ramps may have the narrow shoulders that are typically used with ramps. In a few cases, however, they may have shoulders the same width as the main line.

If a two-lane ramp has narrow shoulders, shoulder treatment on superelevated curves is treated the same as one-lane ramps.

If a two-lane ramp has wide shoulders that match the mainline, shoulder treatment on superelevated curves is treated the same as curves on the mainline.

Loops

High side and low side shoulders of loops shall be paved regardless of superelevation or shoulder width.

Subgrade Slopes

Originally Issued: 05-02-97

As illustrated on Typicals 2113 and 5103, subgrade cross sections consist of a 1% slope to one side and a 2% slope to the other side. The breakpoint between these two slopes is located at either the left or the right edge of pavement. Edge subdrains are installed on the "downhill" side of the 1% slope. The reason behind this asymmetrical cross section is so that adequate drainage can be achieved with subdrains on only one side of the roadway. This is more economical than if subdrains are required on both sides. There may be certain areas, however, where the breakpoint needs to transition from one side of the centerline to the other.

Two-lane Highways

On two-lane highways, the breakpoint may go on either the left or right side of the centerline. However, once a side has been chosen, it becomes the default and the breakpoint remains on that side except at superelevated curves and in certain cut areas.

Superelevation

In some cases when the roadway crown transitions to a superelevated curve, the breakpoint may need to transition to the other side of the centerline as shown in Figure 1. Typicals 2114A and 2114B illustrate the transitions required. As the cross section returns to normal crown, the breakpoint is transitioned back to the default side.

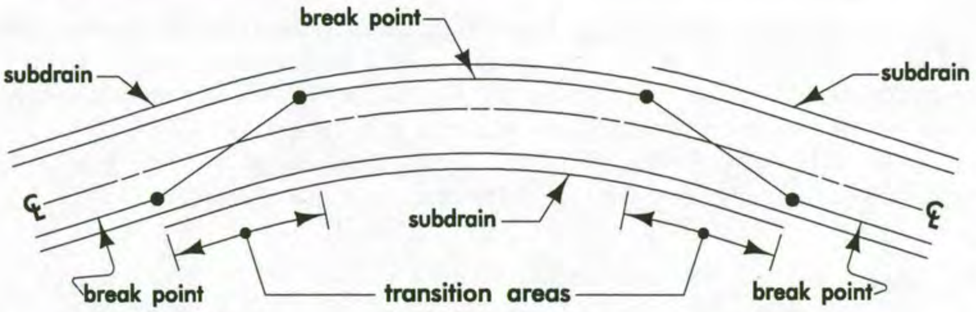


Figure 1: Transition of the breakpoint to the other side of the centerline. Subdrains are installed on both sides of the highway in the transition area.

Cut Areas

In rare cases, the breakpoint may have to be transitioned as the roadway approaches a cut area. In a cut area where the overall cross section slopes predominantly in one direction and the ditch on the uphill side is shallow (less than 4 feet deep as measured from the edge of pavement), the 1% slope should be in the opposite direction of the original grade (see Figure 2). The reason for this is so that groundwater can be intercepted and discharged by the subdrain.

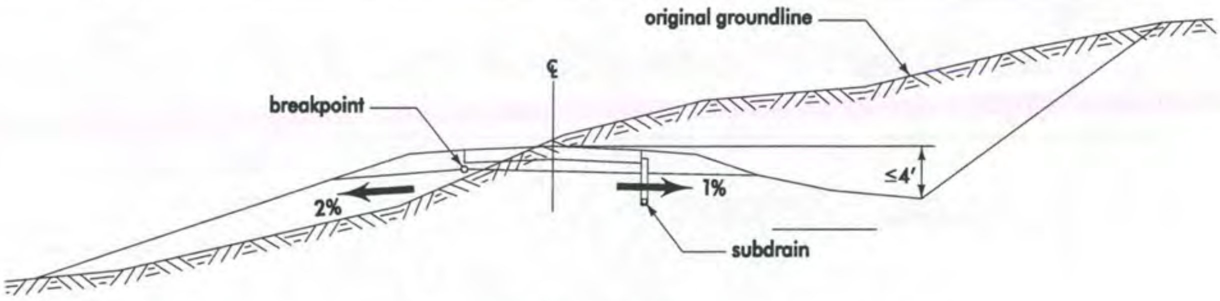


Figure 2: Through cut areas with shallow ditches, the 1% slope should be in the opposite direction of the original grade.

In cases where the breakpoint has been transitioned to the other side in a cut area, it should be transitioned back to the default side once beyond the cut area. Transition of the breakpoint should take place over a distance of 50 feet and subdrains should be placed on both sides of the roadway in transition areas (see Figure 3).

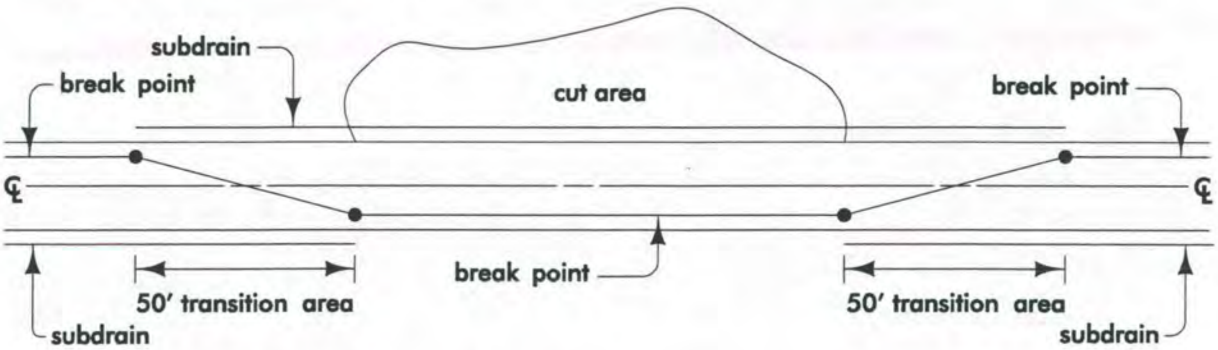


Figure 3: Transition of the breakpoint at a cut area.

Four-lane Divided Highways

On four-lane divided highways, the 1% slope should be away from the median on both sides of the highway. The one exception is at superelevated curves, where the subgrade slope is in the same direction as the superelevation. This means one side of the facility will have the subdrains on the median side of the pavement. As the cross section returns to normal crown beyond the curve, the breakpoint is transitioned back so that the 1% slope is again away from the median on both sides. Typical 5303 illustrates subgrade cross sections within a superelevated curve.

Tabulation

Typical 2113 is used to tabulate subgrade dimensions for a two-lane highway. Typical 5103 is used to tabulate subgrade dimensions for a four-lane divided highway. The subgrade cross sections should be tabulated at the beginning and ending of the project and at the beginning and ending of each transition area. The variables X and Y are functions of the subbase thickness and the pavement thickness. Remember to include Typical 2114A or 2114B or Typical 5303 if there are superelevated curves.

Grading on Multi-Year Projects

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As shown on typicals 2113 and 5103, the final subgrade cross sections consist of a 1% slope to one side and a 2% slope to the other side (see Figure 1). See Section 3D-1 for more information on this cross section and why it is used. For projects that are graded and paved in separate years, water may not drain off the 1% graded surface prior to paving. Water infiltration then creates a wet subgrade. Prior to paving in the following year, the soil in these areas has to be reworked to dry it out and then recompacted. In some cases, the soil has to be replaced and then recompacted.

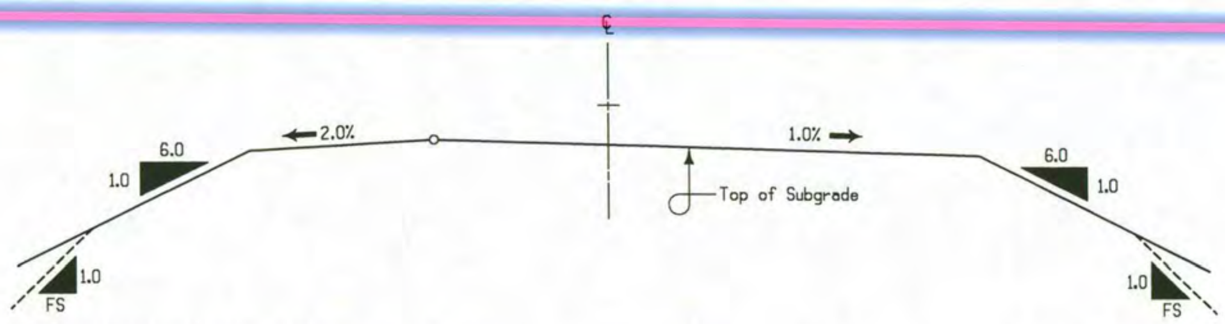

Figure 1: Final subgrade cross section.

In order to prevent this problem, the subgrade cross sections in the first year are graded to a temporary 2% slope in both directions (see Figure 2). Typical 2115 should be included in the plans for two-lane grading projects. Typical 5104 should be included in the plans for four-lane divided grading projects. Standard Note 214-1 should also be included in the grading plans.

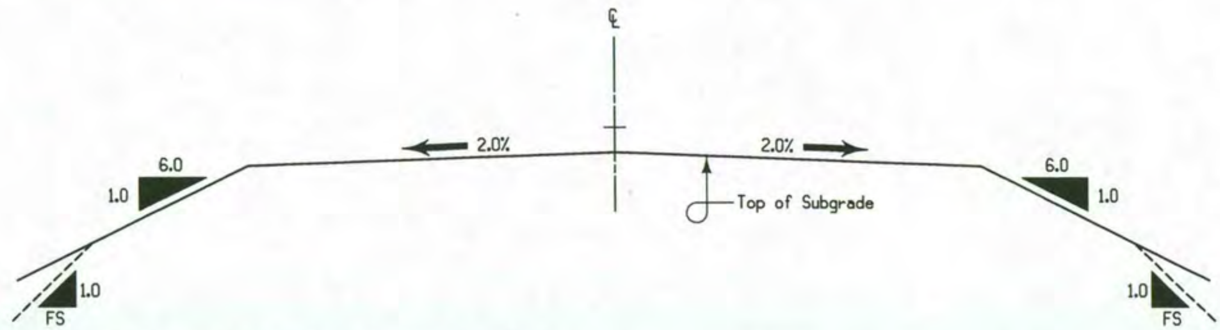

Figure 2: Temporary subgrade cross section.

Prior to paving in the following year, the subgrade is trimmed to the final 1%–2% cross section (see Figure 3). The trimmed material is used as earth shoulder fill and should be included in excavation required for "Earth Shoulder Construction." The designer should add a note in the "Estimate Reference Information" that indicates the volume for "Earth Shoulder Construction" that is available from this trimmed material.

Typical 2214 should be included in the paving plans for two-lane projects. Typical 3221 should be included in the paving plans for four-lane divided projects.

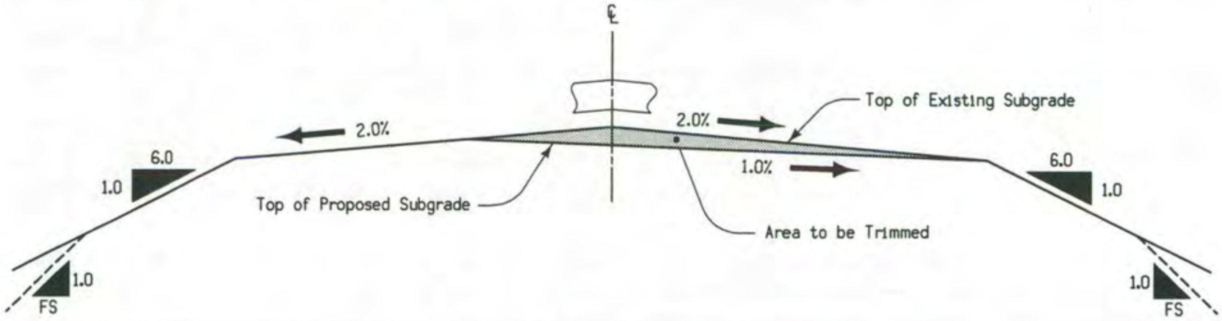

Figure 3: Temporary subgrade is trimmed before paving

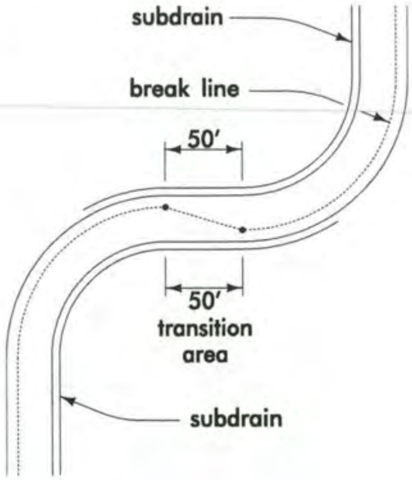

Figure 3: The breakpoint should transition from one side to the other over a distance of 50 feet. Subdrains are installed on both sides of the highway in this transition area.

Tabulation

Typical 2113 is used to tabulate subgrade dimensions for a two-lane highway. Typical 5103 is used to tabulate subgrade dimensions for a four-lane divided highway. The subgrade cross sections should be tabulated at the beginning and ending of the project and at the beginning and ending of each transition area. The variables X and Y are functions of the subbase thickness and the pavement thickness. Consult the Soils Section and Pavement Design to determine the appropriate values for X and Y. Remember to include Typical 2114 or Typical 5303 if there are superelevated curves.

Medians

Originally Issued: 12-20-99

Medians are a physical separation of opposing traffic lanes. They benefit the vehicle operator by providing freedom from interference of opposing traffic, reducing headlight glare, and providing protection for left-turning vehicles. They may also provide a refuge for pedestrians.

Determining Median Warrants and Type

The use of medians and the median type to be used depends on:

- The type of highway being planned
- Traffic volumes
- The development of property adjacent to the highway
- Speeds
- The type of access control
- Available right-of-way

Types of Medians

There are four basic types of medians recommended for use by the Iowa DOT. These are depressed, raised, painted, and closed. Table 1 provides guidance for determining an appropriate median type.

Table 1: Suggested medians for roadway types.

Roadway Classification	Expected Regulatory Speed (mph)	Median Type	
		Rural	Urban
Freeway	65–Rural, 55–Urban	Depressed Closed	Depressed Closed
Expressway	65–Rural, 55–Urban	Depressed Closed	Depressed Closed
Super-Two Highway	55	Painted*	---
Rural Two-Lane Highway	55	Painted*	---
Transitional Facilities	40 to 50	Depressed Raised Painted	
Reduced Speed Urban Facilities	25 to 35	---	Raised Painted

* For channelizing

Depressed Medians

Depressed medians are used with divided highways which have a common ditch (see Figure 1). The normal median width, measured from the inside edges-of-traveled way, is 64 feet. Where median widths exceed 100 feet, a median may be used or consideration may be given to designing the facility as separate two-lane roadways.

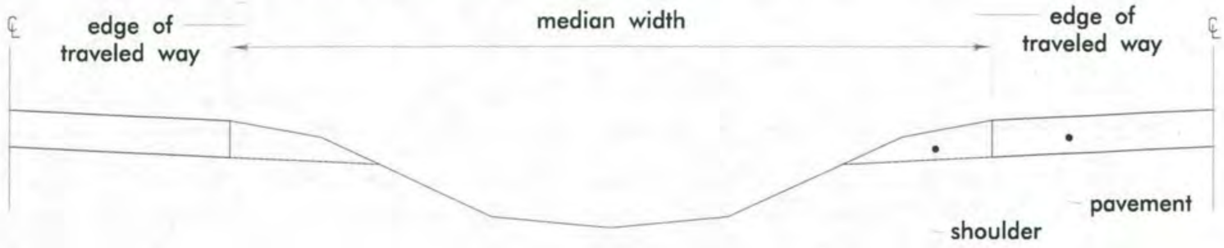

Figure 1: Depressed median.

Raised Medians

Raised medians are illustrated in Figure 2. This type of median is used typically in urban or transitional areas where curbs are used on the outside of the pavement. The median width for a raised median, as defined by distance from back-of-curb to back-of-curb, should be a minimum of 3 feet. Section 3C-2 provides information on where curbs are warranted, the type of curb to use, and curb offset distances from the edge of traveled way.

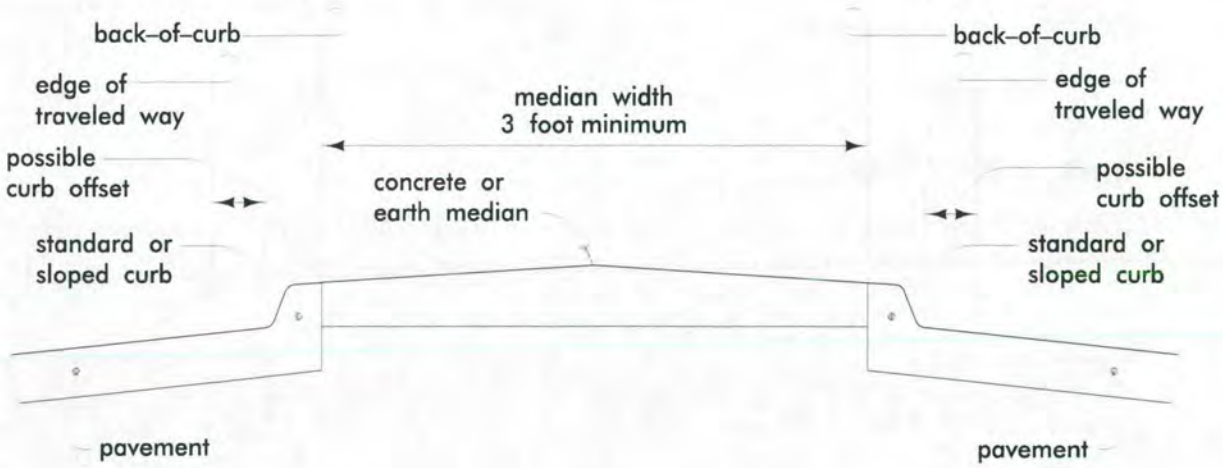

Figure 2: Raised median.

Painted Medians

Painted medians are illustrated in Figure 3. Painted medians are yellow paint-striped and thus provide no physical barrier other than distance between opposing traffic lanes. Their efficiency relies solely on a driver's ability to readily perceive the painted indication. Painted medians are preferred over raised medians on transitional and high-speed facilities (expected regulatory speeds greater than 35 mph). The minimum width of the painted median adjacent to the turning lane should be 4 feet. For access control measurements, the beginning or end of a painted median is the point where 2 feet separate the opposing traffic lanes.

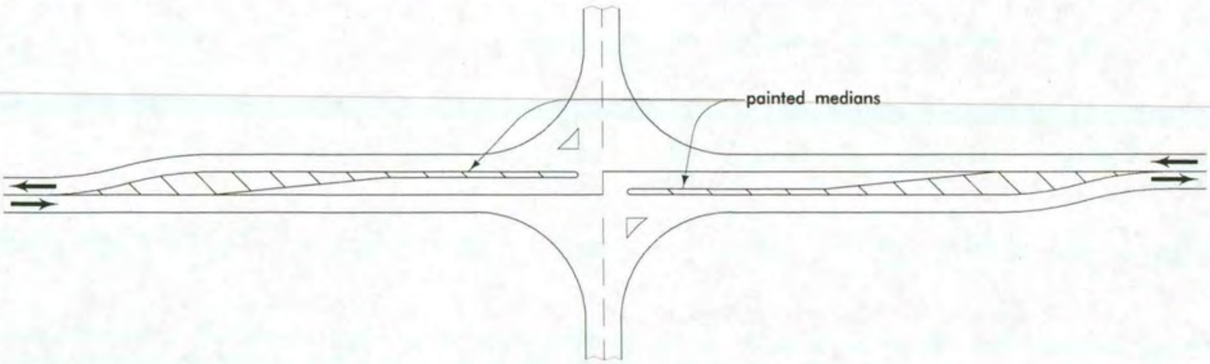

Figure 3: Painted median.

Closed Medians

Closed medians are illustrated in Figure 4. Closed medians are normally used on freeways or expressways in locations with very high traffic volumes or where the amount of separation between opposing directions of travel is minimal or being reduced (such as when inside lanes are being added in the existing median).

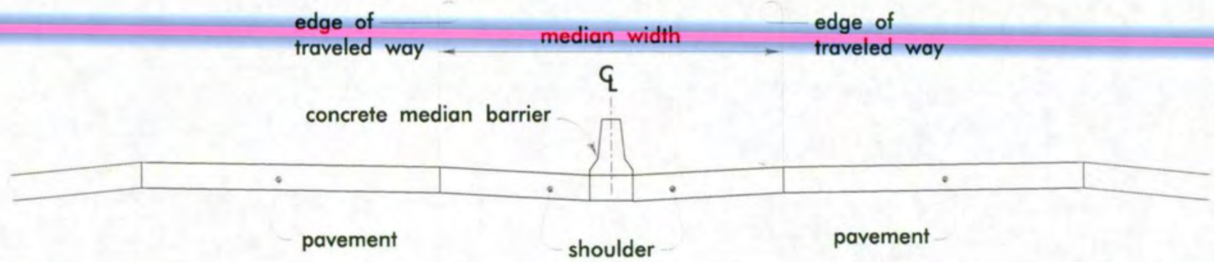

Figure 4: Closed median.

Median Crossings

Originally Issued: 01-04-02

This section discusses the design considerations involved with median crossings. There are 3 types of median crossings: median openings, median turnarounds, and median crossovers. This section will discuss median openings and median turnarounds in more detail, whereas median crossovers are discussed in more detail in Section 3E-3 of this Manual.

Median Openings

Divided highways with at-grade intersections require median openings at various locations, such as public-road connections and points of private access. The design of the opening should be based on traffic volumes and types of turning vehicles. Refer to Section 112.9(4) of the *Iowa Primary Road Access Management Policy* for minimum design criteria for Type "B" and "C" entrances. Type "A" entrances are generally designed on a case-by-case basis. See also sections 3K-2 and 3K-3 of this Manual for more information regarding entrances. The access management policy also provides information helpful for determining spacing between median openings.

According to the *Iowa Primary Road Access Management Policy*, the width of a median opening should be at least 40 feet. Median openings may be paved or non-paved. It is desirable to limit the gradient on median crossovers to the range of 3-5%. The shape of median ends at the opening may be circular or bullet-nose. The shape normally depends on the effective median width at the end of the opening. See AASHTO's *A Policy on Geometric Design of Highways and Streets* (2001) for details on the design and use of median ends. Very wide medians (in excess of 64 feet) for which semicircular or bullet-nose end treatments are inappropriate may not be subject to the 40 foot minimum width requirement. Contact the Methods Section for the appropriate design width.

Section 3E-1 of this Manual provides an explanation of the four different types of medians. Only raised and depressed medians apply to this section.

Raised Medians

All median openings within raised medians should be paved. The need for left-turn storage lanes should be determined on each project or location based upon median width, type of side road or access, and turning traffic volumes. See AASHTO's *A Policy on Geometric Design of Highways and Streets* (2001).

Depressed Medians

Public-Road Connections

Median openings within depressed medians at public-road connections should be paved and include left-turn lanes, regardless of the side road's surface type, see Figure 1. Refer to Section 6C-5 of this Manual for more information on warrants and design of left-turn lanes. Public-road connections are generally defined as side roads owned and maintained by a public entity. They include state routes, county roads, city streets, frontage roads, and all park and institutional roads. Where adjoining public roads have been designated but not developed, the median opening should be constructed but not paved and should include grading for left turn lanes.

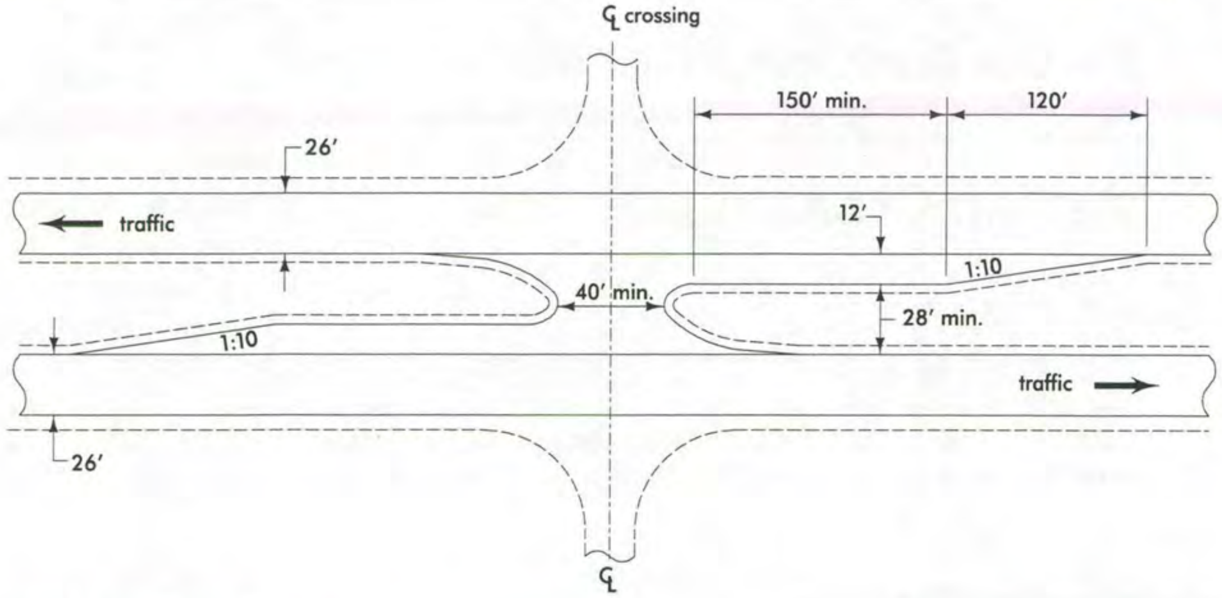

Figure 1: Paved surfaced depressed median opening.

Points of Private Access

Median openings within depressed medians at points of private access, for example Type "B" and "C" entrances, should normally be surfaced with granular material, see Figure 2. However, if the turning traffic volume using the opening at a private access is greater than 50 vpd, then paving the opening should be considered.

Openings at points of private access should normally be designed without left-turn storage lanes and in no case should an unpaved opening be designed with a left-turn storage lane.

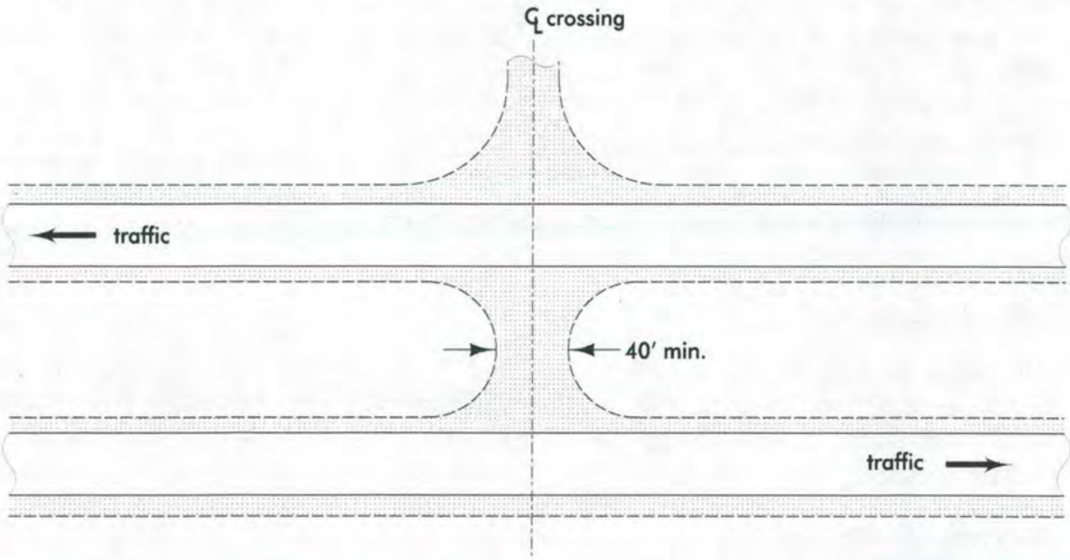

Figure 2: Granular surfaced depressed median opening.

Median Turnarounds

Median turnarounds, see Figure 3, are provided at selected locations on divided highways for crossing by authorized vehicles only. Unlike median openings, median turnarounds are not located at at-grade intersections. Two general categories of vehicles use median turnarounds: governmental services vehicles (maintenance, traffic services, and emergency) and law enforcement vehicles. Median turnarounds should be designed with these vehicles in mind. Other design considerations include:

- Locate in areas where adequate stopping and departure sight distance exists. It is best to use conservative values for stopping sight distance.
- Choose a turnaround width and radii that are adequate for all authorized user vehicles. Ideally, the median width at the selected location will allow the design vehicle to complete a U-turn maneuver without backing up.
- Use a granular surface.
- Design the turnaround to minimize its visibility to the general traveling public. Low vegetation will help to minimize the visibility of the turnaround.
- In no case should curbs or pavement markings be used in a depressed median turnaround.
- If 10:1 side slopes do not already exist at the turnaround site, grade the site to achieve 10:1 side slopes. If a culvert is required under the turnaround, grade to an 8:1 side slope.

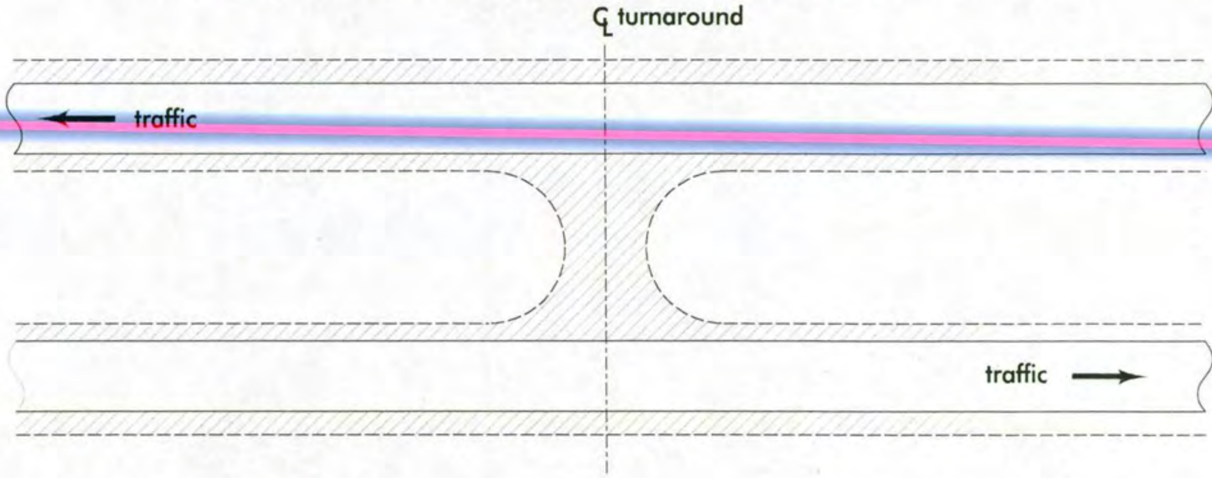

Figure 3: Median turnaround.

Interstates and freeways will be designed with median turnarounds only where specifically requested and authorized by the District Engineer.

Median Crossovers

Originally Issued: 01-04-02

This section discusses the design considerations involved with median crossovers. Median crossovers are used on divided four-lane highways during construction staging. Unlike other types of median crossings they are designed for high-speed operation. Two types of median crossovers exist: temporary (Figure 1) and permanent (Figure 2). Temporary median crossovers are used to divert traffic around work areas, whereas permanent median crossovers are used to divert traffic in areas where two lane highways are being converted to four lane divided highways. The 531 Road Design Details provide construction details for temporary and permanent median crossovers with standard median widths.

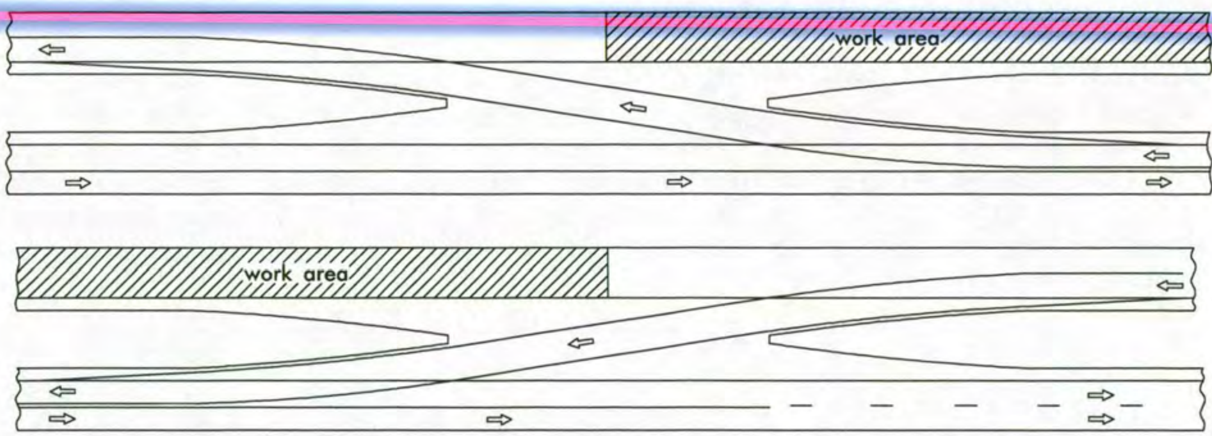

Figure 1: Temporary median crossovers.

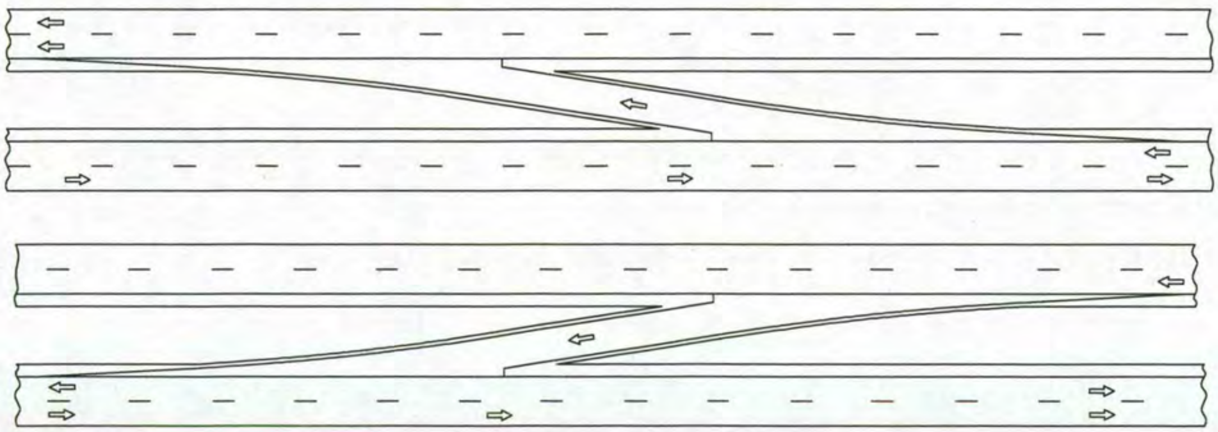

Figure 2: Permanent median crossovers.

Design Considerations

Several considerations are involved with the design of a median crossover:

- The design speed for median crossovers should be the posted speed prior to the construction area, with the minimum design speed being 10 mph below the posted unless unusual site conditions require that a lower speed be used.
- Median crossovers should be located to provide the maximum advance warning to the driver based on the vertical and horizontal alignment at the site. The driver should be able to see the entire crossover area well in advance of the median crossover.
- Advance signing and proper pavement markings are also necessities for the safe operation of a median crossover. Standard Road Plans RS-50(A), RS-50(B), RS-66(1), RS-66(2), RS-67A, RS-67B, RS-68A, and RS-68B provide traffic control and pavement marking details for median crossovers.
- No access points should occur in a crossover area.
- Road Design Detail 500-18 applies to permanent crossovers. Road Design Detail 500-19 may be used with temporary crossovers. In certain situations, a cross roadway culvert may be used in place of Road Design Detail 500-19.

Example

A single lane median crossover is required to redirect traffic around a work area. The road is a 65 mph four lane divided highway with a 50-foot median. The width of a crossover (W) should equal the approach lane width plus 2 feet on each side, see Figure 3. For a single lane crossover, the width should be W = 12' + 2' + 2' = 16'. To simplify construction, the radii for the crossover and all offsets and drops are measured to the edge of the 16-foot lane. The 12-foot lane lines are for pavement markings only.

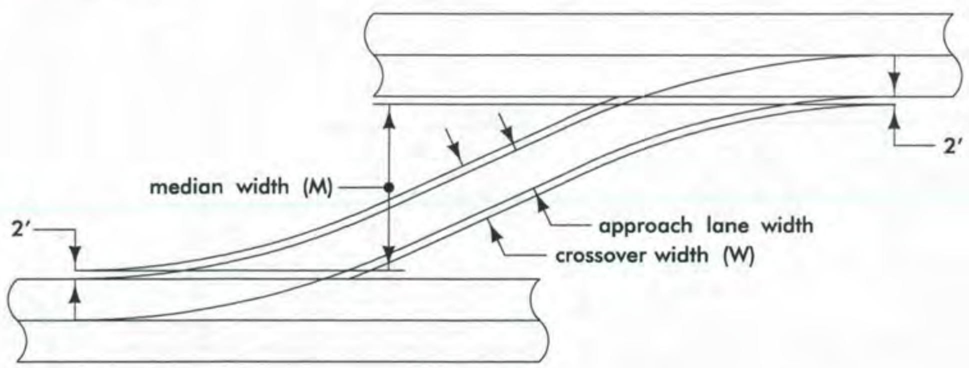

Figure 3: Establishing crossover pavement width.

Figure 4 on the next page shows how to set up the geometric calculations to determine the length "bd" and the curve data for curves R_1 and R_2 when the median is on tangent alignment and is uniform in width throughout the length of the median crossover.

1. For median crossovers, the radius is set at 3500 feet.
2. Curves R_1 and R_2 are normally the same to permit use of the crossover in either direction of travel.
3. A transition length, L, is provided between the reverse curves to permit change in cross slope. The length L is twice the "x" value found in the superelevation tables in Section 2A-3 of this Manual. This length will accommodate reversal of the 2% normal crown slope at the selected

design speed, which will be 65mph (the posted speed before the construction area). For a single lane crossover, x = 56 feet (from Table 4 in Section 2A-3), thus L = 2 x 56' = 112 feet.

4. The median width for calculation purposes is 46 feet (50'-2'-2' = 46') because the 3500-foot radius curves are located at the edge of the 16-foot lane, which ties into a 2-foot parallel offset from the inside edge of slab, see Figure 2.
5. The length "bd" is determined by solving the two right triangles "abc" and "abd" in Figure 3.
   a) triangle "abc" is solved by setting side "ac" equal to R_1+R_2+W = 3500' +3500' + 16' = 7016 feet. Side "bc" = L = 112 feet and ∠ acb = 90°.
   b) the hypotenuse "ab" is used to solve triangle "abd".
   c) Triangle "abd" is solved by setting side "ad" equal to R_1+R_2-M = 3500' + 3500 – 46' = 6954'.
6. The Δ for curves R_1 and R_2 = ∠dab - ∠cab.
7. If R_1 = R_2, all curve data will be the same for both curves. If R_1 and R_2 are not equal, the curve data must be calculated for each curve using the common delta and the individual radius.

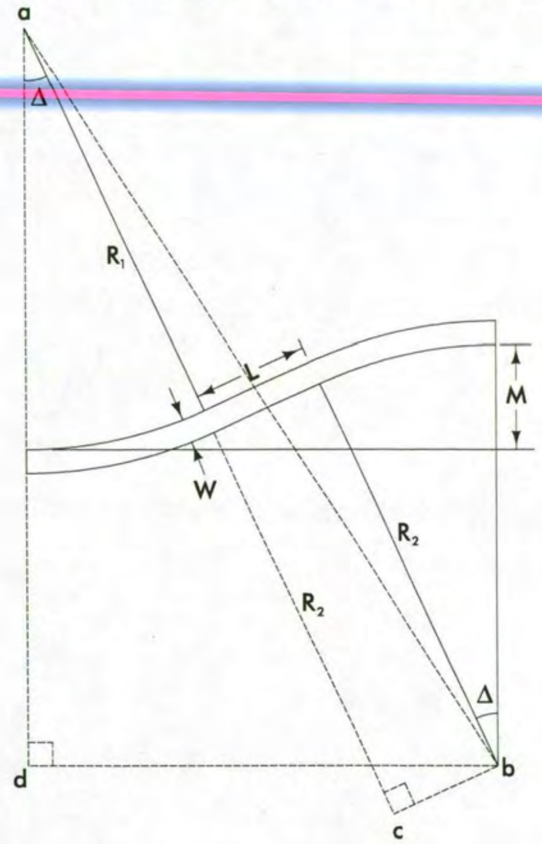

Figure 4: Median crossover geometry.

Berms and Benches

Originally Issued: 09-22-00

This section provides information regarding berms and benches. Berms and benches are used for stability, special drainage, erosion control, and fencing. Utilization and placement of benches and berms should be reviewed with the Soils and Roadside Development Sections in the Office of Design.

Backslopes

Backslope Benches

Figure 1 shows Design Detail 4104, Typical Cross Section Earth Excavation Bench Backslope, which provides design criteria for backslope benches in areas of deep cuts. Included in Figure 1 are plan and elevation views useful with Design Detail 4104. This type of bench is normally used in cut sections over 25 feet deep measured from the ditch bottom to the top of the cut; however, the location of the bench may not necessarily occur at the 25 foot level, depending upon soil conditions. The design, location, and possible additional need for backslope benches need to be coordinated with the Soils Section.

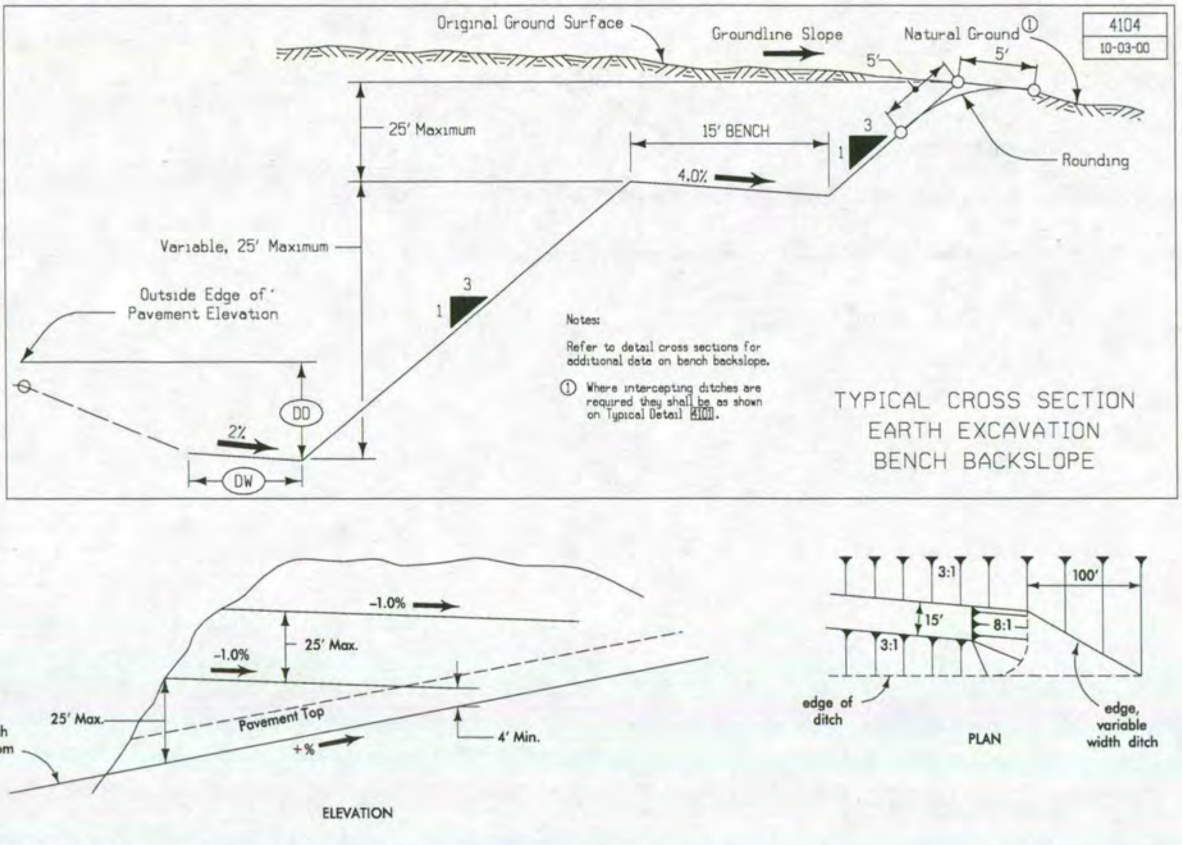

Figure 1: Design Typical 4104 with plan and elevation views.

Bench Cuts in Rock

Situations occasionally arise that require placing cut areas through rock. Design Details 4110, Typical Cross Section Excavation in Rock, and 4111, Excavation in Rock Using Pre-Splitting Method, provide design criteria for bench cuts in cases where solid rock is encountered. Design Detail 4107, Typical Cross Section Stepped Backslope, provides criteria for cases where shale is encountered. Application, usage, design, location, and possible additional need for backslope benches in rock cut areas need to be coordinated with the Soils Section.

Foreslopes

Berms

Occasionally berms are necessary to stabilize foreslopes. Figures 2 and 3 provide design criteria for two types of foreslope berms: general and stability. Design Typical 4106, Special Berms for Ponding Areas, provides design criteria for a ponding berm.

Bench Cuts

Bench cuts may also be necessary to stabilize "sliver fill" foreslopes. Figure 4 provides design criteria for designing bench cuts beyond the standard "steps" required by Section 2107.03 of the Standard Specifications. The need for, design of, and location of these benches are determined by the Soils Section.

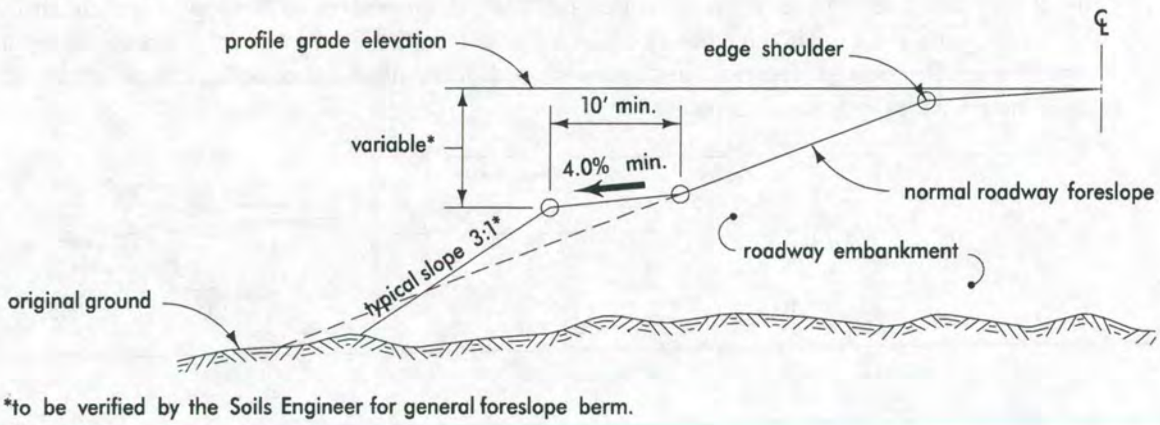

Figure 2: General foreslope berm.

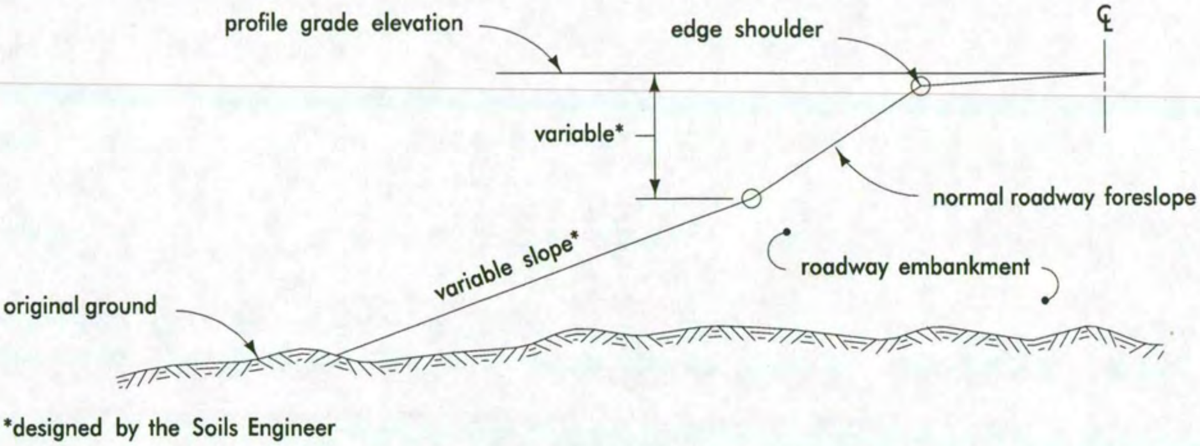

Figure 3: Stability foreslope berm.

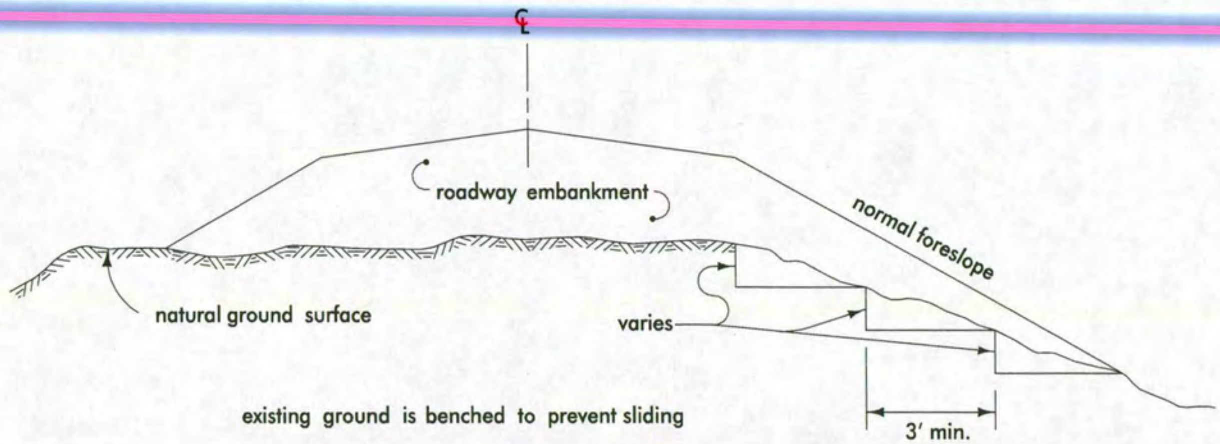

Figure 4: Bench cuts used to stabilize foreslope.

Design of Urban Entrances

Originally Issued: 09-22-00

The design of urban entrances is important in maintaining traffic flow and avoiding a reduction in level of service. Entrances located in an urban area are to be located and designed to minimize the interference of driveway usage with through traffic while providing optimum conditions for the driveway user.

This section provides guidelines for the design of urban entrances and serves as a supplement to the *Iowa Primary Road Access Management Policy*, Iowa Administrative Code 761—Chapter 112(306A), which describes access control on primary roads. The designer is urged to consult this resource. All urban plans with paved entrances should be reviewed by the Office of Traffic and Safety. Section 1D-8 of this Manual provides the access review submittal procedure. Any exceptions to the access policy should be noted in the letter.

Factors in Urban Entrance Design

A number of factors should be considered for each entrance design including: available right-of-way, locations of adjacent entrances, mainline operating speed, anticipated traffic volumes of mainline and entrance, distance from intersections, drainage conditions, and other criteria considered pertinent by the designer. Special consideration should be given to the land use of the property to be served by an entrance, particularly in cases of commercial entrances. In the design and location of an entrance every effort should be made to perpetuate internal circulation patterns and avoid reduction of commercial value of the property being served.

Entrances to be constructed should conform to the Iowa Primary Road Access Management Policy and to Standard Road Plan RB-3.

Entrance Types

There are three types of entrances, based on function.

Type A

These entrances generally provide access to shopping centers or major employment centers. These entrances are designed like city streets with large returns, turning lanes, traffic signals if needed, turning templates, and design vehicles. Geometric, staking, and jointing layouts may be required. These entrances are designed on a case-by-case basis

Type B

These entrances are considered commercial entrances and often serve gas stations, cafes, and other small commercial activities. These entrances are typically 24 to 45 feet wide depending on volume, mainline design speed, design vehicle, and circulation. Standard Road Plan RB-3 Case 1 paved entrances will generally be used on all Type "B" entrances.

Type C

Residential entrances are the typical Type "C" entrances. These entrances are typically 15 to 35 feet wide depending on mainline design speed and design vehicle. RB-3 Case 2 paved entrances will generally be used if there is a sidewalk present or if the sidewalk is to be replaced.

Design Considerations

Figure 1 shows a cross-section of a typical entrance.

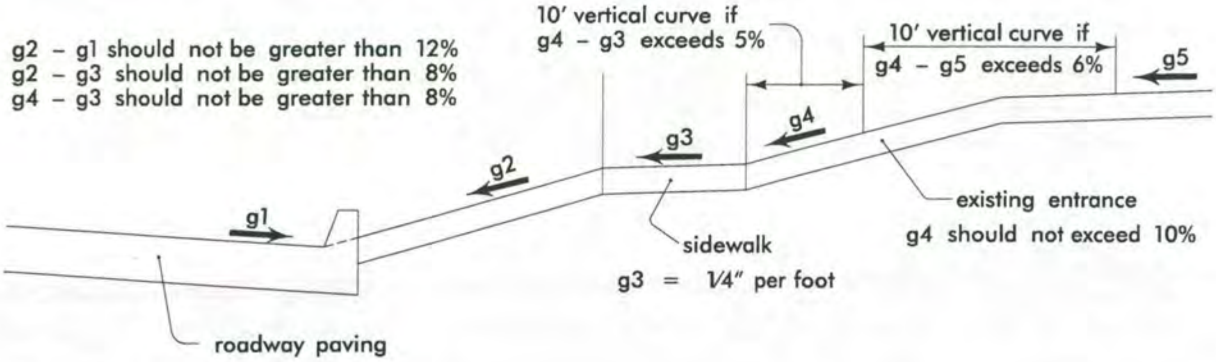

Figure 1: Cross section of entrance.

The entrance profile (g2) should slope upward (positive grade) from the gutter line to the curb side of the sidewalk (if present) with a maximum algebraic difference of 15% between the cross slope of the traveled way (g1) and the positive slope of the driveway (g2). Vertical curves should be used if g4-g3 exceeds 5% or if g4-g5 exceeds 5%. The designer should check the entrance profile with a template similar to Figure 2 to ensure ample vertical clearance between the driveway surface and the underside of the design vehicle in the maximum range. The designer should also consider any special vehicles that may use the entrance, such as limousines or campers, to ensure ample vertical clearances exist for these vehicles.

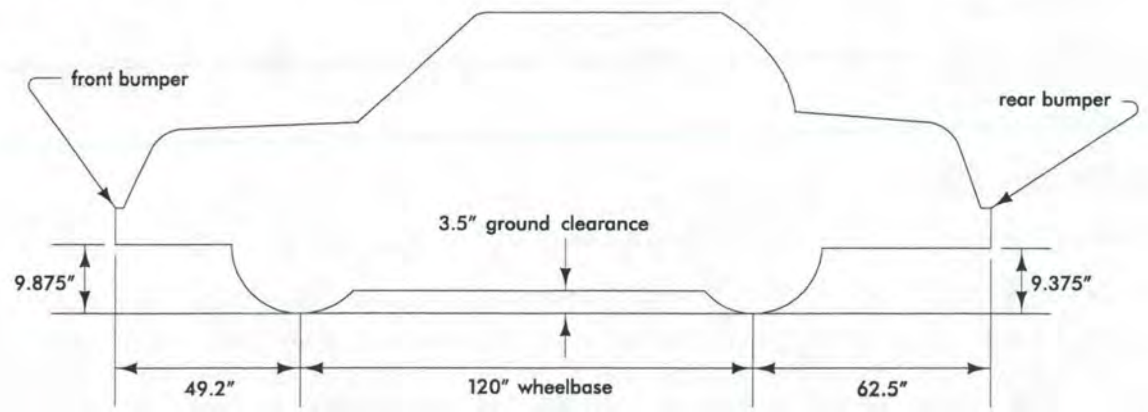

Figure 2: Design vehicle.

All entrances in urban settings should be paved to prevent aggregate from washing onto the pavement, curb, and gutters. Normal practice is to pave with 6 inches of Portland Cement Concrete pavement. If the existing drive is not paved, pave the first 10 feet from the back of curb or to the edge of the existing sidewalk. Type "A" entrances may require thicker pavements based on traffic and design vehicle.

All entrances should be constructed so as not to impair drainage within the highway right-of-way nor alter the stability of the highway subgrade and at the same time not impair or materially alter drainage of the adjacent areas. All culverts, catch basins, drainage channels, and other drainage structures required under driveways as the result of property being developed should be installed in accordance with current standards and specifications.

Standard Road Plan RB-3 covers construction details for most urban type entrances. Case 1 is used on most Type "B" entrances and on some Type "C" entrances in high-speed areas. Case 2 is used on most Type "C" entrances and on Type "B" entrances where space is limited along the curb. Case 3 is used with alleys, drives where the existing drive is too narrow, and in areas where there are no sidewalks. It is also important that a 2% cross slope be maintained on sidewalks to fulfill ADA requirements.

Entrance Widths

Table 1 below provides minimum and maximum values to be considered for entrance width "W" and radii "R".

Table 1: Minimum and Maximum Values for "W" and "R".

Type	"W" (ft.) (d)				"R" (ft.)	
	Single Entrance		Joint Entrance			
	Min.	Max.	Min.	Max.	Min.	Max.
Type A	(a)	(a)	(a)	(a)	(a)	(a)
Type B	24	45	24	45	5 (b)	15
Type C	15	30	20	35	5 (b) (c)	10 (c)

(a) Designed on a case by case basis. It may have up to five 12-foot lanes with a median of approved design.
(b) Radius should equal distance between back of curb to street side of sidewalk, but not to exceed maximum radius.
(c) Flares may be used instead of return radii. The flare shall be constructed at a 2:1 ratio; the 2 is measured parallel to the entrance centerline and the 1 is measured perpendicular to the entrance centerline.
(d) The width of the entrance is measured at the street side of the sidewalk. If a sidewalk is not present, the width is to be measured 10 ft. back of the curb.

Special Considerations

On some urban extensions, it may not be possible to provide a traffic lane adjacent to the curb greater than 12 feet in width. In these cases, if there is substantial traffic in the outer traffic lane, consideration should be given to using RB-3 Case 1 entrances for all Type "C" entrances.

If the width of any existing entrance is less than the minimum for that type of entrance, consideration should be given to removing and replacing the existing entrance behind the sidewalk as shown for Case 3 in Standard Road Plan RB-3.

Standard Road Plan RB-3 has been developed to cover construction details for most urban type entrances. Special entrance details other than those shown on RB-3 should be included in the plans.

Drainage

Chapter 4

Introduction to Urban Drainage

Originally Issued: 12-15-96

This part of Chapter 4 (Sections 4A-1 to 4A-9) provides guidelines for designing urban drainage systems (storm sewers). These guidelines are primarily for use with the interstate and primary road systems in Iowa's urban areas. Note that these guidelines are not necessarily policies: the designer should use sound engineering judgment, including technical and economic analysis, in applying the guidelines to any given situation. The Design Engineer and the Bridges and Structures Engineer will provide guidance for special and unique designs and will clarify any requirements which seem unclear, contradictory, or unnecessary.

Many other sections in this manual explain a situation or procedure that can be understood without knowing what is in the preceding sections (each section stands alone). However, the sections in this chapter fit together to describe major steps in the design of a storm sewer (they do not stand alone). Thus, the designer will not, for example, be able to understand how to choose and locate intakes (Sections 4A-5 and 4A-6) without first understanding the Rational Method (Section 4A-4). Experienced designers may be able to skip sections when they already know how to do something, but those unfamiliar with urban drainage design should read the sections in the order in which they appear.

The remainder of this section (4A-1) describes sources of information needed during the design process and provides a series of design standards. Much of this information can also be found at appropriate locations throughout the chapter.

Drainage Information Sources

Drainage information can come from many different state, federal, and local offices. A number of different jurisdictions may be involved with the design of a single drainage system, depending on the size and location of the project. The more information that is available to the designer, the better the final design will be. However, a lack of information may result in an unsatisfactory drainage system design.

In the Office of Design, the Preliminary Survey Section and Photogrammetry are the two primary sources of information. Preliminary Survey provides the basic survey information for the project including

- plan and profile sheets,
- 10 scales,
- 20 scales,
- cross sections,
- locations and elevations of existing storm sewer,
- locations of existing utilities.

Preliminary Survey can also provide drainage plats and utility plats for the project. Photogrammetry can provide topography maps, quad maps, and aerial photos of the project.

The city where the project is built may provide

- zoning plans,
- planning maps,
- future street and storm sewer plans,
- drainage studies,
- plans for existing systems.

The city may also have plans for future construction or replacement of sanitary sewer and other utilities.

The United States Army Corps of Engineers may provide

- flood studies,
- levee construction plans,
- flood control plans,
- other information about flood plains and flood control areas.

Finally, the designer should conduct a field review of the project to become familiar with the area and any special drainage problems that may exist. The survey drainage plats will show drainage areas for the existing system. Refer to these drainage areas when deciding on the locations and sizes of intakes in the proposed drainage system. However, be aware that the drainage areas will change to accommodate the new intake locations.

Storm Sewer Design Standards

Table 1: General

minimum pipe size	15 in*
minimum velocity of flow	3 ft/s
maximum velocity of flow	15 ft/s

*The FHWA requires a minimum 24-inch pipe under all pavement on the National Highway System (NHS).

Table 2: Manning "n" (Manning's Equation)

concrete pipe	0.013
vitrified clay	0.013
corrugated metal	0.024
paved invert	0.021
fully lined	0.013
ductile iron	0.013
cast iron	0.013

Effects of Roadway Geometrics on Urban Pavement Drainage

Originally Issued: 09-01-95

Geometric features of roadway design greatly influence the ability of highway pavement surfaces to drain. Geometric features for pavements with urban cross sections include curbs, gutter configurations, lateral pavement slopes, longitudinal pavement grades, shoulders, and parking lanes. The effects of these geometric features on pavement drainage are discussed in this section.

Cross Slopes

A pavement's cross slope is often a compromise between the need for a relatively steep cross slope for drainage and a relatively flat cross slope for driver comfort. Two-lane highways in Iowa normally use a 2.0% cross slope. When additional lanes are added, the outside lanes normally use a 3.0% cross slope, as shown on Typicals 3205 and 3206. Right turn lanes and auxiliary lanes may be sloped between 3.0% and 4.0%.

On multi-lane facilities, increasing cross slope on each successive lane is an effective measure for reducing water depth on the pavement. Where practical, the designer can slope inside lanes toward the median. This will keep median water from running across several lanes of pavement. If a curb and gutter section is added outside the pavement lane(s), the curb and gutter section may use a depressed or steeper cross slope, as shown on Typicals 2209 and 2210.

Parabolic crowns have been used in the past to increase gutter capacity on relatively flat longitudinal grades. However, they will no longer be used except in special situations because they are more difficult to construct.

If a grade is less than 0.4%, one of the rolling-profile designs discussed below should be considered.

Longitudinal Grades

It is important that minimum longitudinal grades be maintained on curbed pavement to avoid ponding and the accumulation of debris. The designer can maintain minimum grades in very flat terrain by using a rolling centerline profile. The minimum centerline grade when designing new pavements in Iowa is normally 0.4% for curbed sections. Flatter grades must be approved by the Design Engineer.

Rolling Gutter Profile

When existing pavement is being widened, the centerline grade is already fixed. However if the existing grade is less than the minimum design grade of 0.4%, the designer still needs to find a way to meet drainage needs. The design normally used for such situations is the rolling gutter profile. To achieve a rolling gutter profile, the designer varies the cross slopes of sections of pavement. An example of this is illustrated in Figure 1. The cross slopes can be varied from a minimum of 2.0% to a maximum of 5.0% to achieve the required gutter grade. Generally for curbed pavement, gutter grades should not be less than 0.3% without the approval of the Design Engineer.

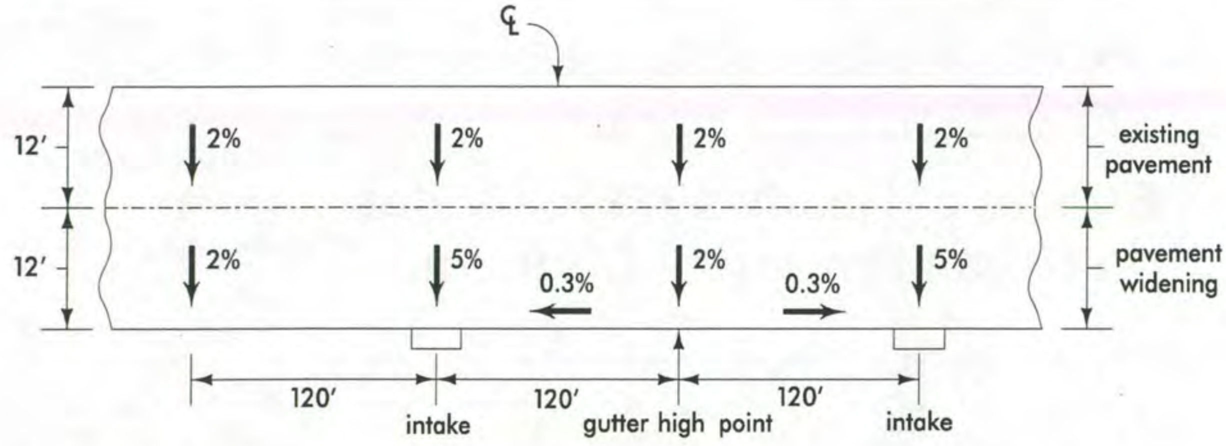

Figure 1: Rolling gutter profile for pavement widening project when centerline profile is flat.

Gutters on Vertical Curves

A long vertical curve or a vertical curve on a flat grade will create a flat area at the curve's crest or sag. If the flat area is large enough, water may pond or leave debris in the gutter. To check for this problem, the designer should use the following formula.[1]

$$\frac{L}{A} > 167$$

where: L is the length of the vertical curve in feet, and

A is the algebraic difference of the centerline grades in percent ($g_2 - g_1$).

If L/A is greater than 167, the designer should use special shaping to maintain a constant gutter grade of 0.3% within 50 feet of the curve's low point, as shown in Figure 2. To maintain a constant gutter grade while the centerline grade approaches zero, the pavement's cross slope is varied in a fashion similar to the procedure for the rolling gutter profile shown in Figure 1. This special shaping should also be used when flanking intakes are present (see section 4A-3).

If L/A is less than 167, it is not necessary to provide the special shaping shown in Figure 2 because the grade of the gutter is steep enough to carry the water to the intake at the low point. Note that minimum gutter grades should be checked on crest vertical curves as well.

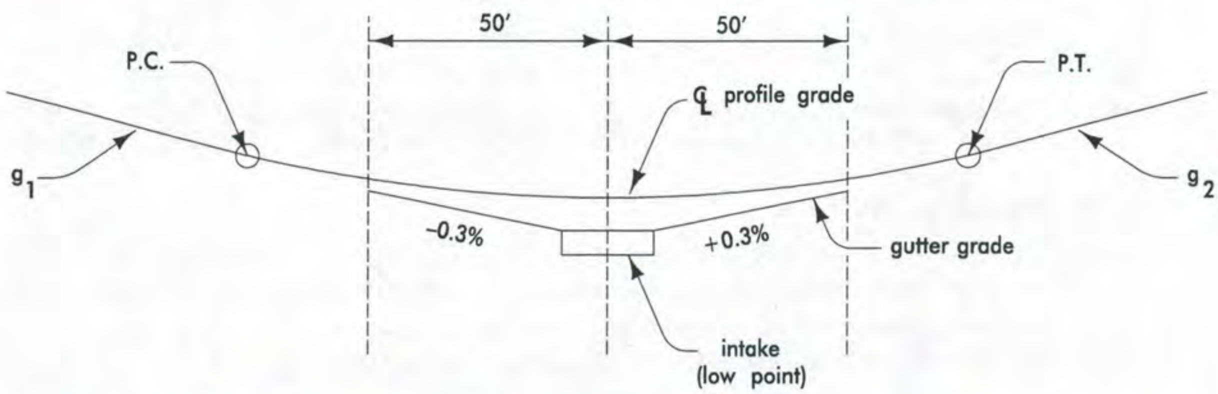

Figure 2: Sag vertical curve requiring minimum gutter grade.

[1] AASHTO *A Policy on Geometric Design of Highways and Streets* (Washington, D.C., 2001) 275.

Table 3: Recurrence Intervals

section of storm sewer/situation	recurrence interval (design frequency)
intakes and spread on primary highways and city streets	2 year storm
intakes and spread on freeways and interstate highways	10 year storm
small storm sewer (lateral and branch lines)	10 year storm
large storm sewer (48 inches or larger)	25 year storm
subways, sag vertical curves, and high liability areas	50 year storm
depressed freeway sections	50 year storm
major storm checks	100 year storm

Table 4: Maximum Spacing of Intakes and Utility Accesses

pipe diameter	maximum spacing
15 in	400 ft
18–30 in	500 ft
36–42 in	700 ft
≥ 48 in	1200 ft

Time of Concentration (T_c)

At least 5 minutes should be used for the time of concentration.

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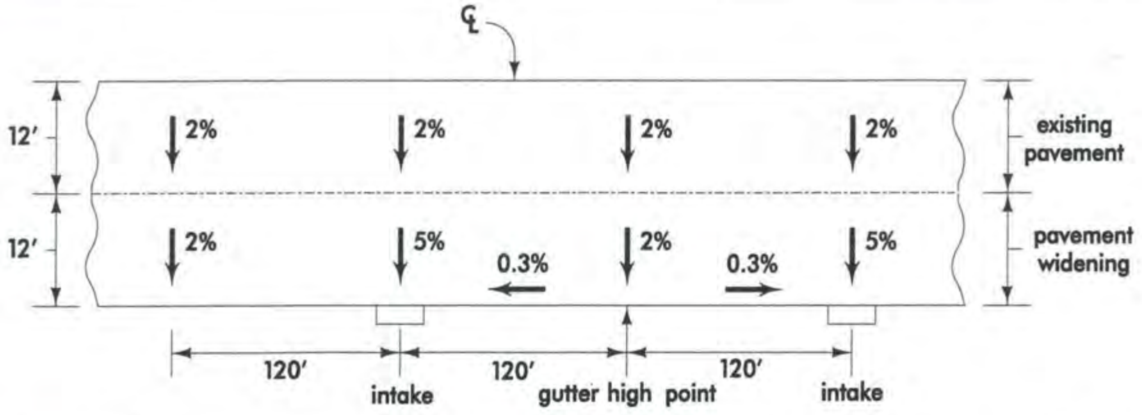

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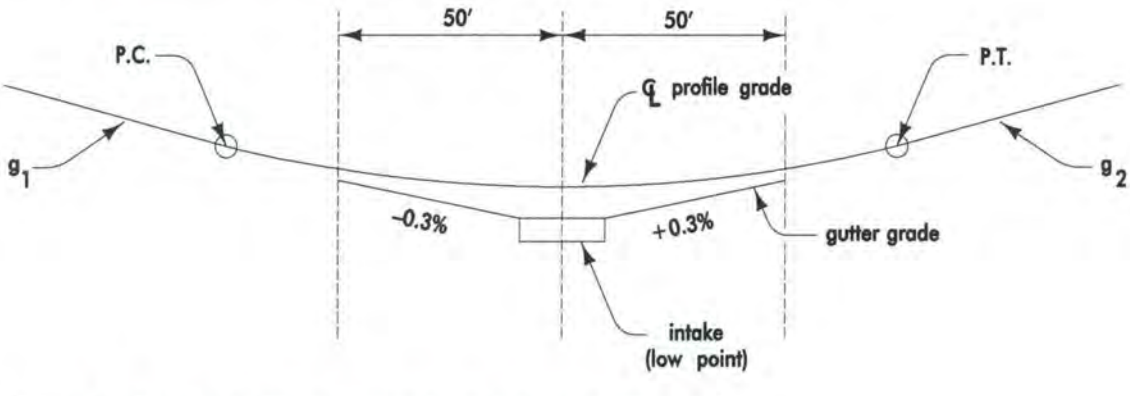

Figure 2: Sag vertical curve requiring minimum gutter grade.

[1] AASHTO *A Policy on Geometric Design of Highways and Streets* (Washington, D.C., 1990) 286.

Location of Vertical Curves

The locations of vertical curves can be critical to pavement drainage. For instance, a sag located in the middle of a block may result in extra intakes and storm sewer unless the low spot is the natural outlet for drainage. On the other hand, a sag located in the middle of an intersection may cause ponding problems and create a need for grate intakes and special shaping. Therefore, when laying grades, the designer should make drainage requirements a priority. The best locations for the low points of sag vertical curves are at the ends of street returns and at other locations where intakes are already needed.

Staking Intersections

When staking intersections, the designer should avoid the ponding or trapping of water. The following guidelines should be observed as well:

- stake returns so that water will flow toward intakes or away from the intersection
- avoid placing intakes at or near pedestrian curb ramps
- maintain at least 0.3% grades whenever possible
- maintain positive drainage laterally and longitudinally

Preliminary Locations of Intakes and Utility Accesses

Originally Issued: 09-01-95

During the preliminary design of a roadway drainage system, the designer will (1) estimate the locations of intakes and utility accesses, (2) choose the appropriate accesses to be used, and (3) number all intakes and accesses to facilitate design and construction. This section provides guidelines for all of these procedures.

Drainage Maps

The first step in designing a roadway drainage system is to prepare a drainage map that shows the entire area to be drained by the proposed improvements. Contour maps serve as excellent drainage maps when supplemented by field reconnaissance. These maps can be furnished by the preliminary survey crew.

Intake Locations

Determining the sizes and locations of intakes is often a trial and error procedure. However, if the designer places intakes in all of the common locations on a project, the locations of additional intakes can be determined by the spread of water on the pavement and the capacities of the intakes.

Common Locations

The primary goal in using intakes is to prevent traffic, both vehicular and pedestrian, from being forced to travel through spreads and flows of water. With this in mind, the following are common locations for intakes:

- At the bottoms (low points) of all sag vertical curves.
- On all upstream approaches to intersections. The objective is to pick up the water before it can enter an intersection. The best locations are at the ends of street returns. If pedestrian ramps are present at the intersection, the intake should pick up the water before it gets to any ramps.
- Upstream from pedestrian ramps when they are located away from intersections (i.e., at mid-block).
- Upstream from "Type A" entrances if a review determines that an intake is needed.
- On the uphill sides of bridges. The designer should avoid allowing water to run onto a bridge. It may also be necessary to place intakes on the downhill side if no drains are provided on the bridge. See other sections of this manual for information about bridge end drains.
- Where a change in superelevation causes water to cross the highway pavement. Place the intake so that it will pick up water in the gutter before the water can cross the pavement.
- Where a change to a flatter grade creates the potential for debris to deposit.

Additional Locations

After placing intakes at common locations, the designer should determine additional locations where intakes are needed. The following guidelines will assist in this process.

- Avoid locating intakes in the middles of intersections. Grate intakes are not allowed in the driving lanes or returns of primary highways. However, grate intakes may be used on the outside edges of curbed shoulders and on side streets.
- Avoid locating intakes in street returns. Water will tend to bypass such intakes and pond or swirl in the intersection. Do not locate intakes in crosswalks or in other locations where pedestrians are likely to cross.
- A good location for an intake is above an existing storm sewer, assuming the spacing is right and the existing storm sewer pipe can be used. This is a good way to avoid additional intakes, storm sewer pipes, and utility accesses.
- Avoid placing intakes and utility accesses on top of existing utilities. Also, avoid relocating those utilities, if possible. Placing storm sewer above other utilities can cause costly maintenance problems. However, utility relocation can also be costly. One possible solution might be to locate longitudinal storm sewer pipe on the opposite side of the roadway, away from the other utilities.

Unusual Situations

Often, unusual situations warrant additional intakes or other drainage devices. Such situations include when unusually large amounts of water must be dealt with or when heavily traveled roadways are being designed. The following guidelines indicate how the designer should handle such situations.

- Major water flows should be intercepted before they reach the pavement. Ditches, intakes, and culverts are some of the methods used to intercept the water.
- Springs, subdrains, and tile lines should be intercepted. Both ditches and intakes may be used.
- When spread of water on the pavement exceeds the allowable lane encroachment, the designer should add an additional intake. We will calculate the amount of allowable lane encroachment in Section 4A-5.
- On major highways (interstates, freeways, and other National Highway System roadways), the designer should place flanking intakes surrounding all low points (see Figure 1). These flanking intakes pick up silt before the velocity in the gutter becomes too slow, and they reduce ponding at the low point if volumes of water are high or if the intake at the low point becomes plugged. As Figure 1 indicates, the centers of the flanking intakes should be placed 0.3 feet above the low point of the gutter.

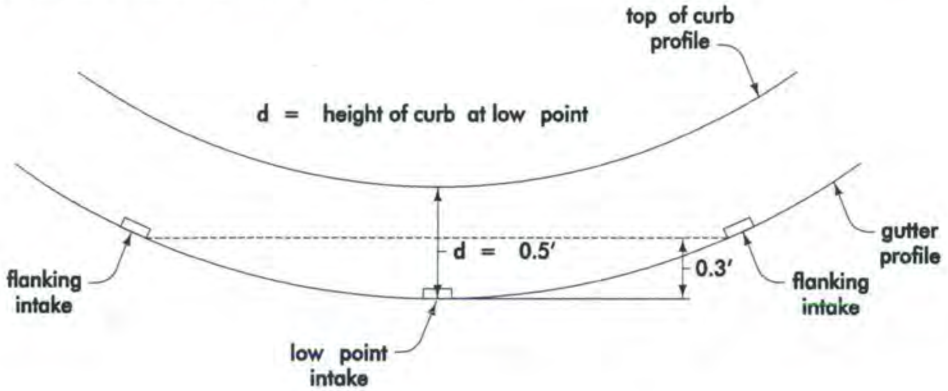

Figure 1: Location of flanking intakes.

Utility Access Locations

After the intakes have been located, it is necessary to locate utility accesses (manholes) for the most economic and efficient design of the storm sewer system. The designer should place utility accesses at all of the following locations:

- where two or more pipes join together
- where pipes change shape or size
- where pipe needs to change direction
- where there is a change in grade (i.e., from 1% to 5%)
- where there is a change in elevation (i.e., when the flow line drops a foot)

On long tangents where none of the above conditions exist, the designer should locate utility accesses at intermediate points. The maximum spacing allowed between accesses is shown below.

Table 1: Maximum spacing between utility accesses.

pipe diameter (in)	maximum spacing (ft)
15	400
18–30	500
36–42	700
≥ 48	1200

Every effort should be made to place utility accesses at the locations listed above. However, designers should also try to avoid locating accesses in the following locations:

- over existing utilities
- in intersections or thru lanes

When a utility access is needed within a roadway, the designer should attempt to place it on a shoulder or median.

Standard Utility Accesses

Standard utility accesses are shown on Standard Road Plans RA-49, and RA-50. The RA-49 access is rectangular shaped and is usually formed and cast in place. On the other hand, the RA-50 access consists of precast units of circular concrete pipe. Each unit of the pipe is normally four feet in height, and units are stacked on top of each other to reach the needed depth. Each type of access has restrictions on where and with what sizes of sewer pipe it should be used. The following paragraphs describe those restrictions and provide other guidelines for the design of utility accesses.

Pipe Size Restrictions

The inside dimensions of both the RA-49 access is 4 feet by 4 feet. This means that normally the maximum size of storm sewer pipe that can be used with these accesses is 36 inches (inside diameter). Larger sized sewer pipes will require a modified RA-49 or a special design.

The size of storm sewer pipe also restricts the use of the RA-50 utility access. The sections of concrete pipe used to construct the RA-50 cannot maintain structural integrity if a hole (or notch) larger than one-half the diameter or height of a section is cut in the side (see Figure 2). The outside diameters of any sewer pipes entering the RA-50 must be small enough to fit in such a hole. However, sections of the large-diameter concrete pipe are seldom any longer than four feet. Because of this limit, the maximum size sewer pipe that can be used with the RA-50 utility access is normally 18 inches (inside diameter).

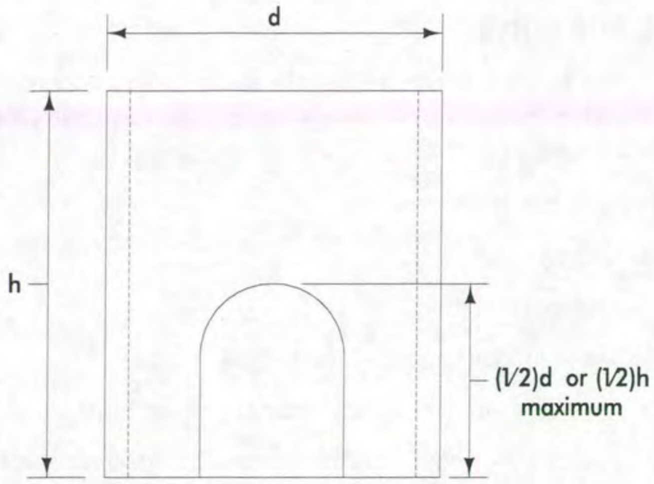

Figure 2: Maximum allowable hole or notch in RA-50 utility access.

Skews and Multiple Storm Sewers

When two or more storm sewer pipes meet at a utility access or when a storm sewer pipe is skewed, the designer should draw the utility access to scale to determine dimensions, both vertical and horizontal. This will ensure that it's possible to accommodate all pipe connections, rather than allowing field construction to discover a problem, resulting in delays, work orders, etc.

Numbering For Storm Sewer Systems

After all the intakes and utility accesses have been tentatively located, they must be numbered to facilitate the processes of design and construction. Normal procedure is to begin at the upstream end of the drainage system and proceed down stream. Figure 3 shows a possible system of numbering for a typical drainage system.

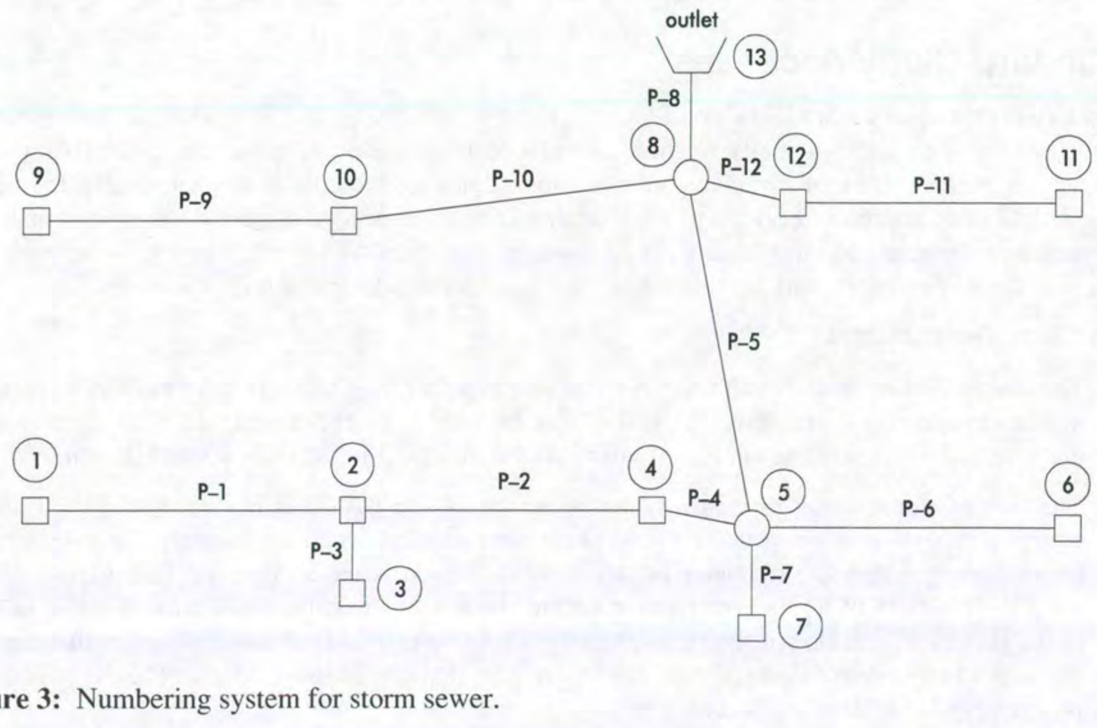

Figure 3: Numbering system for storm sewer.

To avoid confusion during the design process, it is critical that a drainage area have the same number as the inlet or intake within it. Once a number is assigned to a drainage area or intake, the designer should not change it in future revisions of the design plan. If intakes are added or moved, additional numbers must be assigned. Thus, in areas where the number of intakes is tentative, the designer should leave a few extra numbers available so that any additional intakes do not need to be numbered out of order.

Normally, the numbering of storm sewer pipe is based on the intake or utility access it drains. For example, the pipe coming out of intake number 9 would be called P9. However, sometimes a pipe coming into an intake or utility access also needs a number, so the numbering of more than one pipe is based on a single intake. In such cases, letters are used to supplement the numbering system. For example, intake number 9 would have pipes numbered P9A, P9B, P9C, etc. Pipes will be located on the design plan by the location description of the intake or utility access they are attached to.

The Rational Method

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Before calculating the sizes of intakes and pipes or determining their final locations, the designer must estimate how much water is discharged into each intake or culvert inlet. The calculation used for this is referred to as "The Rational Method," and it depends primarily on the following formula:

$$Q = CIA$$

where:

Q = an estimate of the peak rate of runoff, measured in cubic feet per second

C = the fraction of rainfall that appears as surface runoff from the drainage area (the ratio of surface runoff to rainfall)

I = the average rainfall intensity, measured in inches per hour

A = the drainage area, measured in acres (the area of land that drains into a given intake or culvert inlet)

The average rainfall intensity (I) is the most unwieldy factor in the calculation. "I" is based on values of T_c and T, where:

T_c = the rainfall intensity averaging time (measured in minutes), usually referred to as the "time of concentration." T_c is the time required for water to flow from the hydraulically most distant point in the watershed (drainage area) to the intake or culvert inlet.

T = the recurrence interval (or design frequency). T represents the severity of the storm (i.e., once every 2 years, 10 years, etc.) for which a given drainage area is designed.

The Rational Method generally assumes a worst case scenario for a given recurrence interval. That is, the storm sewer is designed for conditions created by the worst storm expected during the recurrence interval. The Rational Method depends on a number of other assumptions as well. Factors that affect the results obtained by The Rational Method are discussed at the end of this section.

Drainage Area (A)

The area (A) is the drainage area, measured in acres. The drainage area is defined as the combined area of all surfaces that drain into a given intake or culvert inlet. The following are some points the designer should consider when determining a drainage area:

- How are individual lots graded? Rear to front, half to rear?
- Will the existing contour lines remain the same, or will the area be regraded?
- Which way will water run down the gutters of the streets?
- At intersections, will the water turn the corner or flow across the intersection?
- Will water run the same direction for all rainfall intensities?

Using a plan sheet or drainage map, draw the drainage area for each intake. Any of the following may be useful in determining the correct area:

- USGS topographic maps
- Aerial photos
- Contour maps
- Drainage maps
- Cross sections
- Field reviews

The designer should be certain to measure the drainage area *in acres* using planimeters or scales.

Runoff Coefficient (C)

The runoff coefficient (C), also called the "coefficient of imperviousness," is a unitless value representing the ratio of runoff to rainfall. Factors that contribute to C are related to the condition of the land, what is on the land, and the character of the rainfall. The following factors have been identified by various experts. In some cases, they overlap.

- Character of the soil
- Shape of the drainage area
- Previous moisture conditions
- Slope of the watershed
- Amount and type of surface storage
- Percentage of impervious surface
- Land use
- Interception by vegetation or animal life
- Amount of roof drainage
- Duration of rainfall
- Intensity of rainfall
- Recurrence interval (design frequency)

The actual ratio of runoff to rainfall is probably impossible to determine. However, several authors have published tables of C values based on the type of area in question. We reproduce these as Tables 1, 2, and 3. Normally, the designer should decide the appropriate value of C for each drainage area using these tables. However in some cases, special concern for high intensity rainfall (i.e., a 100-year recurrence interval) may warrant the use of Figure 1, which suggests C values based on not only the imperviousness of the land, but also on the intensity of rainfall expected.

Table 1: Runoff coefficients.[1]

description of area	runoff coefficients
Business:	
downtown areas	0.70–0.95
neighborhood areas	0.50–0.70
Residential:	
single-family areas	0.30–0.50
multi-units, detached	0.40–0.60
multi-units, attached	0.60–0.70
residential (suburban)	0.25–0.40
apartment dwelling areas	0.50–0.70
Industrial:	
light areas	0.50–0.80
heavy areas	0.60–0.90
parks, cemeteries	0.10–0.25
playgrounds	0.20–0.35
railroad yard areas	0.20–0.40
unimproved areas	0.10–0.30

Table 2: Runoff coefficients.[2]

type of drainage area	runoff coefficients
concrete and bituminous pavements	0.70–0.95
gravel and macadam surfaces	0.40–0.70
impervious soil	0.40–0.65
impervious soils with turf*	0.30–0.55
slightly pervious soils*	0.15–0.40
pervious soils*	0.05–0.10
wooded areas (depending on slope and cover)	0.05–0.20

* For slopes from 1 to 2 percent

[1] American Concrete Pipe Association, *Concrete Pipe Design Manual* (Arlington, Virginia, 1970).

[2] Ritter and Paquette, *Highway Engineering* (New York, The Ronald Press Co., 1951).

Table 3: Runoff coefficients.[3]

character of surface	runoff coefficients
Streets:	
asphaltic	0.70–0.95
concrete	0.80–0.95
brick	0.70–0.85
drives and walks	0.75–0.85
roofs	0.75–0.95
Lawns (sandy soil):	
flat, 2%	0.05–0.10
average, 2% - 7%	0.10–0.15
steep, 7%	0.15–0.20
Lawns (heavy soil)	
flat, 2%	0.13–0.17
average, 2% - 7%	0.18–0.22
steep, 7%	0.25–0.35

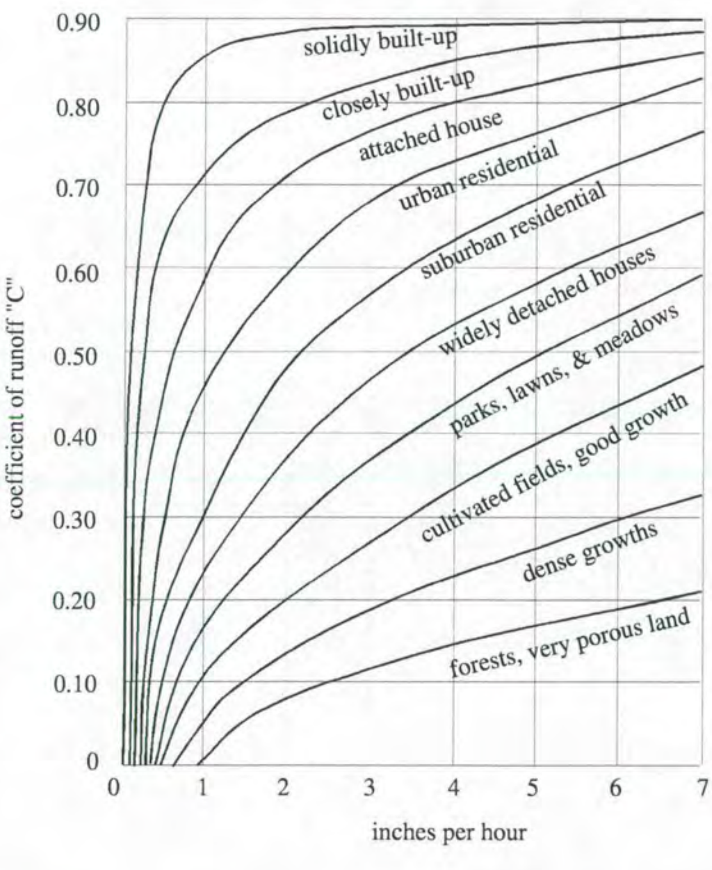

Figure 1: Runoff coefficient vs. intensity for varying imperviousness.[4]

[3] ASCE-WPCF, "Design and Construction of Sanitary and Storm Sewers," *ASCE Manuals and Reports on Engineering Practice No. 37* (New York, 1969).

[4] Ordon, C.J., "A Modified Rational Formula for Storm Sewer Runoff," *Water and Sewage Works* (June 1954) vol. 101, 275-277.

For urban design, the designer should try to select one value of C that best describes a given drainage area. In fact, it may be that one C value adequately describes an entire project. However, when a single drainage area is composed of distinct parts with different runoff coefficients, the designer may use a weighted average to find a composite C. The equation used for this average is:

$$C = \frac{(C_1A_1 + C_2A_2 + C_3A_3 ... + ... C_nA_n)}{\text{total area}}$$

where A_1, A_2, A_3, and A_n are the areas of the distinct parts and C_1 is the C value for A_1, C_2 is the C value for A_2, and so on. If there is a large deviation in values of C for a given drainage area or if there are separate drainage areas with different outlet storm sewers, separate C values for each area may be used.

Rainfall Intensity, I

The rainfall intensity (I), measured in inches per hour, is the average rainfall intensity that is expected to fall on a drainage area over the duration of a storm. The designer determines "I" from:

- the recurrence interval (T), measured in years, and
- the storm duration, measured in minutes.

The Rational Method uses the time of concentration (T_c), discussed below, as the storm duration.

Recurrence Interval, T

The recurrence interval (T) varies for each element of a storm sewer system, depending on how vital it is to avoid flooding in the area being drained. The recurrence interval is therefore selected using the following guidelines.

- 2-year interval: Used for the design of intakes and the spread of water on the pavement for primary highways and city streets.
- 10-year interval: Used for the design of intakes and the spread of water on the pavement for freeways and interstate highways. Also used for the design of smaller storm sewer pipe on most lateral, branch, and longitudinal lines.
- 25-year interval: Used for the design of major storm sewer lines (48-inch diameter and above).
- 50-year interval: Used for the design of subways (underpasses) and sag vertical curves where storm sewer pipe is the only outlet. Also used for depressed freeway sections and for high liability areas.
- 100-year interval: Used for the major storm check on all projects.

Time of Concentration, T_c

The time of concentration (T_c) is defined as the time it takes for runoff to travel from the hydraulically most distant point in a drainage area to a point of reference downstream (the intake or culvert). The Rational Method assumes that the peak runoff rate occurs when the rainfall intensity (I) lasts as long or longer than T_c. T_c is therefore used as the storm duration and must be estimated for each drainage area as a part of selecting the appropriate value of "I."

T_c for intakes normally consists of at least two components:

T_c (overland flow)
T_c (gutter flow)

The designer should add a third component if overland flow is channelized (i.e., streams, ditches, paved ditch liners, etc.) upstream from the location where the flow enters the highway gutter. However, T_c (overland flow) is usually the only significant component, and in most cases the other two components can be ignored. The following procedures describe how to determine T_c(overland flow). If T_c (gutter flow) is significant, it is calculated separately and added to T_c (overland flow) to get the total. Procedures for calculating T_c (gutter flow) are given later in this section.

T_c (Overland Flow)

The most accurate description of T_c (overland flow) (hereafter referred to as T_c) is generally considered to be the kinematic wave equation. The overland flow component of the kinematic wave equation is shown below.

$$T_c = \frac{(K)(L)^{0.6}(n)^{0.6}}{(I)^{0.4}(S)^{0.3}}$$

where:

T_c = time of concentration (overland flow), measured in minutes

L = overland flow length, measured in feet

n = Manning roughness coefficient (see Figure 3)

I = rainfall intensity rate, measured in inches per hour

S = the average slope of the overland area

K = 56/60 = 0.933

The kinematic wave theory is consistent with the latest concepts of fluid mechanics, and it considers all those parameters found important in overland flow when the flow is turbulent (and where the product of the rainfall intensity and length of the slope is in excess of 500).

Determining T_c and "I" (preferred method)

The preferred method for determining T_c (and hence "I") uses a nomograph (shown in Figure 2) for the solution to the kinematic wave equation. The method involves a trial and error procedure, wherein the designer first guesses a value of "I" and uses it in Figure 2 to determine a value of T_c. The values of "I" and T_c are then checked against the appropriate value found in Table 5 (pages 14 through 17), using the recurrence interval (T) chosen for the particular problem. The designer should repeat the procedure until the "I" that is used produces close agreement in the values of T_c found in Table 5. This procedure is illustrated in the following example.

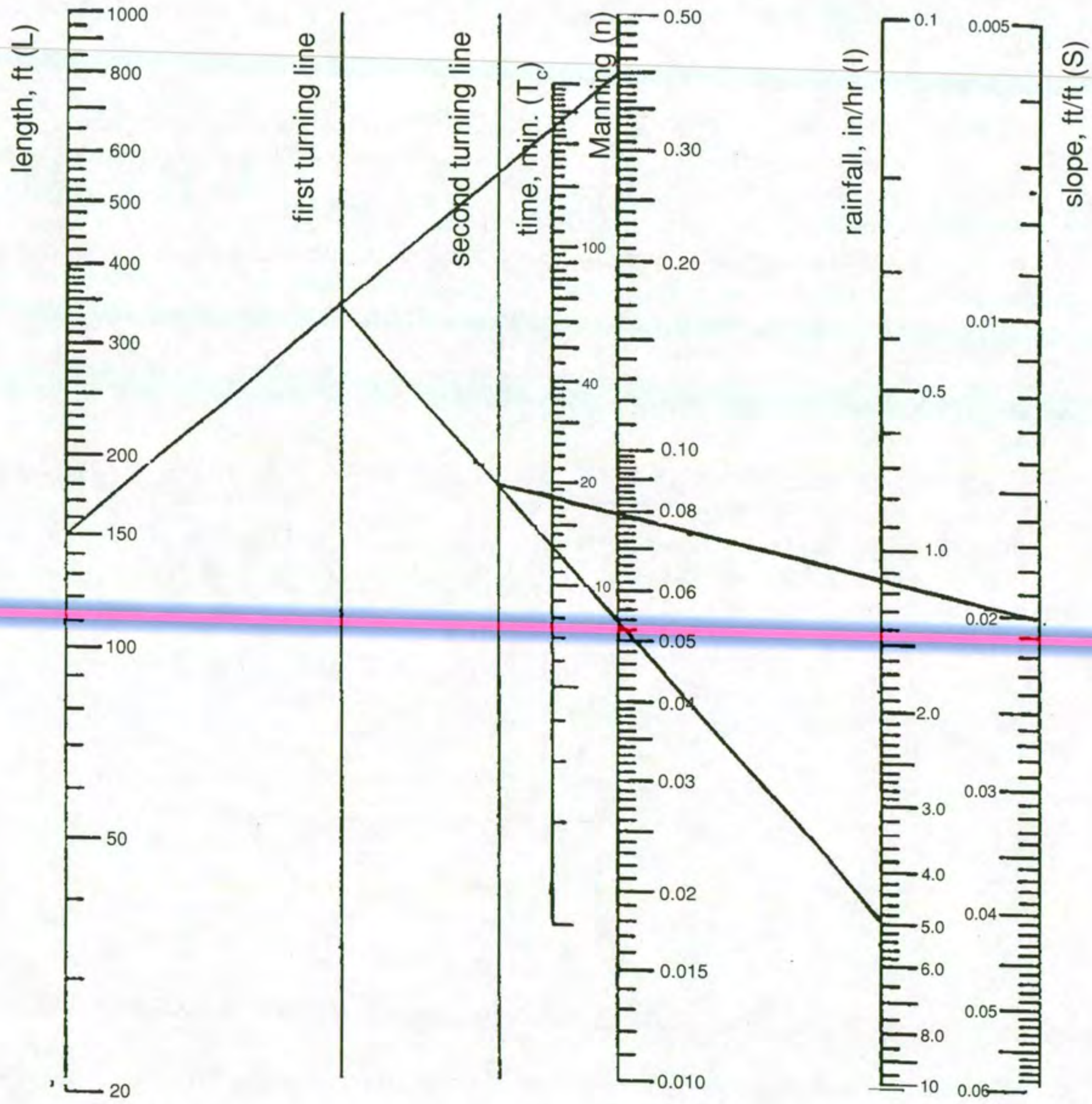

Figure 2: Nomograph for determining time of concentration for overland flow, Kinematic Wave Formulation.[5]

Example 1

Given:

Overland flow length: L = 150 ft

Average slope: S = 0.02

Manning coefficient: n = 0.4 (grass, see Figure 3)

Recurrence interval: T = 10 years

Location: Keokuk, Iowa

[5] FHWA, *Design of Urban Highway Drainage* (1979).

Find: "I"

Solution:

1. Use the nomograph in Figure 2, as follows:
   a. Draw a line from "L = 150" on the length scale to "n = 0.4" on the Manning scale.
   b. Find the point where this line crosses the first turning line. This is the first turning point.
   c. Guess a value of "I" (5 inches/hour).
   d. Draw a line from the first turning point to "I = 5" on the rainfall scale.
   e. Find the point where this line crosses the second turning line. This is the second turning point.
   f. Draw a line between the second turning point and "S = 0.02" on the slope line.
   g. Read the value of T_c (18 minutes) where the last line you drew crosses the time line.
2. Determine the appropriate climatic Sectional Code the geographical area (page 17 for Keokuk) and use it as follows:
   a. Keokuk is located in Southeast Iowa; the Sectional Code is 09. Choose the current interval column T for the problem (T = 10 years).
   b. Convert the rainfall in inches to intensity in inches per hour by dividing the rainfall in inches by the duration in hours. This produces the table below for Sectional Code 09.

section	Duration (min.)	10-year (I= inches)	Intensity (in/hr)
09	5	0.56	6.7
09	10	0.98	5.9
09	15	1.26	5.0
09	30	1.73	3.5
09	60	2.19	2.19
...	...	...	...

   c. Find the appropriate rainfall intensity (I = 5 in/hr) and select the according time of concentration (T_c = 15min).
3. Compare T_c from the nomograph (18 minutes) and T_c from the table (15 minutes). Since they do not match, try the procedure again for a different value of "I."
   a. Try I = 4.25 in/hr
   b. This produces values of:
      T_c = 22 from the nomograph (Figure 2)
      T_c = 22 from the table above (using interpolation)
   c. I = 4.25 in/hr produces close agreement between the nomograph and the interpolated value from the table. Assume "I" is 4.25 in/hr and T_c is 22 minutes.

When using the nomograph, the designer should use Manning roughness coefficients of n = 0.013 for concrete and n = 0.40 for grass. These values closely agree with normal flow data. Manning coefficients for other surfaces may be obtained from flow experiments. See Figure 3 for other values of the coefficient.

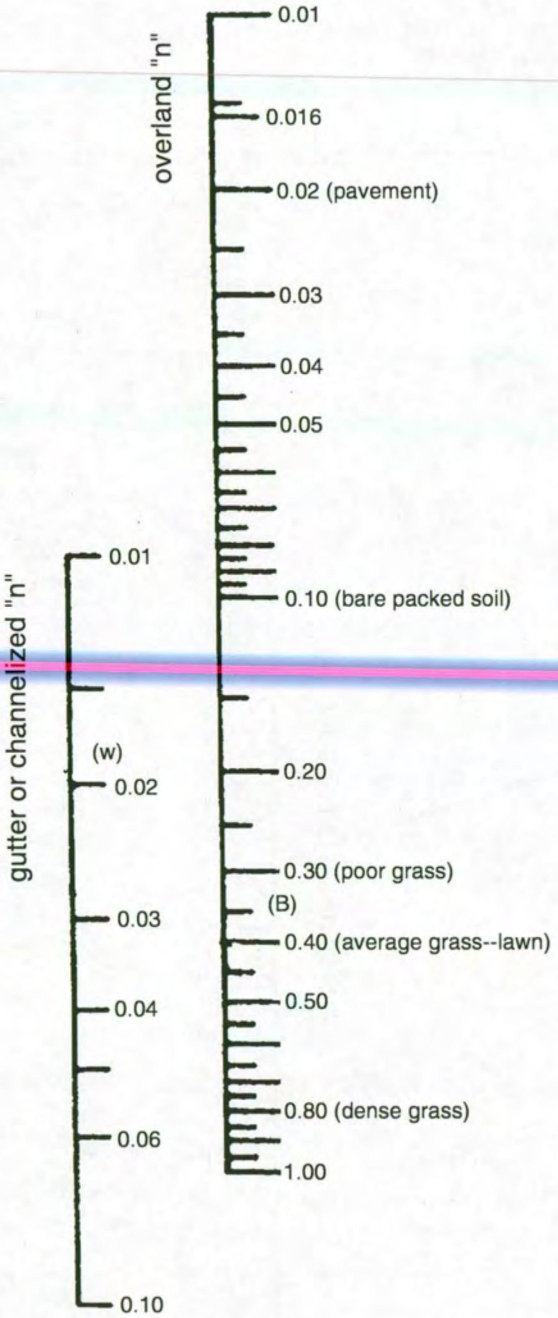

Figure 3: Manning roughness coefficient (n).

Determining T_c and "I" (other methods)

Two other methods are commonly used to find the time of concentration (T_c) in urban areas: the Kirpich formula and the Kerby formula. After using either formula to calculate T_c, the designer should then use Table 5 to determine "I."

The Kirpich formula is the most commonly used formula for estimating T_c in both urban and rural areas. According to Kirpich,

$$T_c = 0.0078\left(\frac{L}{S^{0.5}}\right)^{0.77}$$

where:

T_c = time of concentration (overland flow), measured in minutes

L = length of travel, measured in feet

S = slope—the difference in elevation between the intake and the most remote point divided by the length (L)

This produces the nomograph shown in Figure 4.

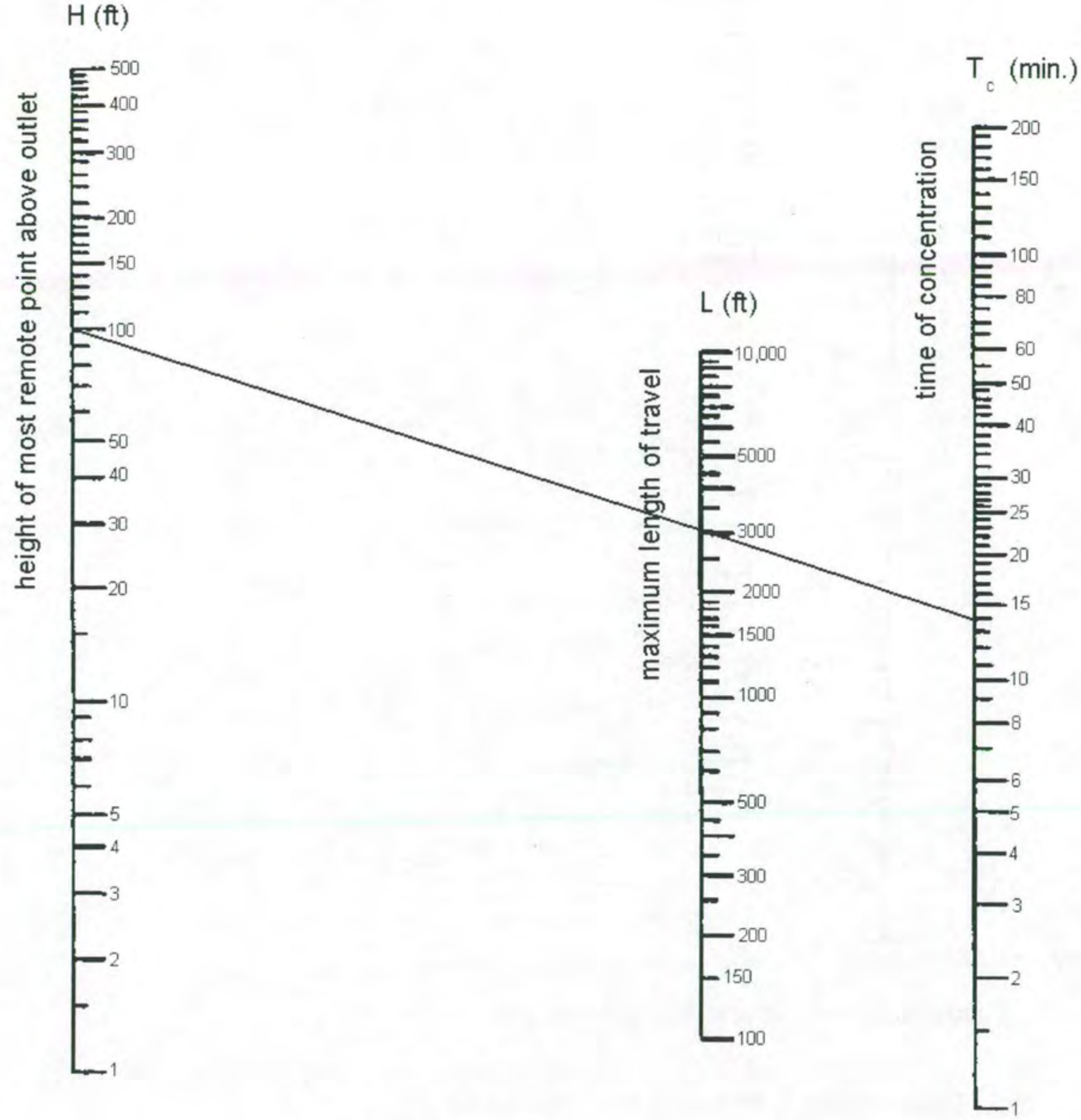

Figure 4: Nomograph for T_c using the Kirpich formula.[6]

[6] Kirpich, P.Z., *Civil Engineering*, Vol.10, No. 6, (June 1940) 362.

Example 2

H = 100'

L = 3000'

Using the given information, $S = \dfrac{100 - 0}{3000} = 0.0333$

Then $T_c = 0.0078\left(\dfrac{3000}{.0333^{0.5}}\right)^{0.77}$ = 13.75 min. (use 14 min.).

Using the nomograph, draw a straight line from H = 100 on the height scale to L = 3000 on the length scale. Extend this line to the time of concentration scale (see Figure 4) and determine where it crosses (about 14 min.). This is the time of concentration, T_c.

Because of the database that was used, some authors suggest that the following modifications be made to the value of T_c estimated by the Kirpich formula.

- Use T_c from the equation for natural basins with well-defined channels, for overland flow on bare earth, and for mowed-grass roadside ditches.
- Multiply T_c by 2 for overland flow, grassed channels.
- Multiply T_c by 0.4 for overland flow, concrete or asphalt surfaces.
- Multiply T_c by 0.2 for concrete channels.

Another formula that is used is Kerby (1959). Kerby's formula is based on the drainage of military airfields. T_c (Kerby) is for overland flow only. If channelized flow occurs in a drainage area, the time of concentration will be the time of the overland flow plus the time in the channel.

According to Kerby,

$$T_c = 0.83\left(\frac{N \times L}{S^{0.5}}\right)^{0.467}$$

where:

T_c = time of concentration (overland flow), measured in minutes

L = length from the extremity of the drainage area (in a direction parallel to the slope) to the location of a defined channel, measured in feet

S = slope—the difference in elevation between the extreme edge of the drainage area and the point in question divided by the horizontal distance between the two points

N = 0.02 for smooth impervious surfaces
0.10 for smooth bare packed soil, free of stones
0.20 for poor grass, cultivated row crops, or moderately rough bare surfaces
0.40 for pasture or average grass cover
0.60 for deciduous timberland
0.80 for conifer timberland with deep forest litter or dense grass cover

T_c (Gutter Sections)

Solving for the T_c component in gutter sections is also a trial and error procedure. The designer should use Manning's Equation or the nomograph in Figure 2 of Section 4A-5 to calculate Q for the gutter section. Q is then divided by the cross-sectional area to calculate velocity and determine the approximate time in the gutter. Unless the water is carried in the gutter for a long distance, the T_c in the gutter will be a very small part of the total T_c for the drainage area.

Normally, the largest part of the distance to the intake is overland, with little time spent in the gutter. The time of flow in the gutter is insignificant unless it is a minute or more, and can normally be ignored.

The Basis for Calculating "I"

Rainfall intensities are shown in Table 5, Sectional Mean Frequency Distribution for Storm Periods of 5 Minutes to 10 days and Recurrence Interval of 2 Months to 1000 Years in Iowa. The Climatic Sectional Codes for Iowa are shown in Figure 5. Rainfall intensities for any duration and recurrence interval at any location in Iowa can also be determined from the following equation:

$$I = \frac{a\,T^m}{(T_c + b)^n}$$

where:

I = rainfall intensity, measured in inches per hour

T = recurrence interval, measured in years

T_c = storm duration, measured in minutes

a, b, m, and n = coefficients shown in Table 4

Table 4: Coefficients for rainfall intensity equation.

location	a	b	m	n
Charles City	33	10	0.180	0.775
Davenport	47	15	0.184	0.824
Des Moines	57	18	0.179	0.852
Dubuque	43	12	0.204	0.817
Keokuk	48	14	0.192	0.828
Omaha	42	13	0.221	0.821
Sioux City	50	14	0.208	0.849

The HYDRAIN computer system may also be used to determine "I." When using the HYDRO program on the HYDRAIN system, IDF curves may be developed for different design storms (recurrence intervals). These curves should be saved for use during storm sewer design and analysis. See the HYDRAIN user manual for more information.

Some Things to Consider When Using the Rational Method

The Rational Method is based on a large number of assumptions. Thus, when evaluating results, the designer or engineer should consider how exceptions or other unusual circumstances might affect those results. The following are some factors that might not normally be considered, yet could prove important.

1. A storm sewer will be in place for 50 years, more or less, and will be subjected to whatever storms come along. The total system needs to be designed for all these storms at the least total cost.
2. The storm duration gives the length of time over which an average rainfall intensity (I) persists. Neither the storm duration nor "I" say anything about how the intensity varies during the storm, nor do they consider how much rain fell before the period in question.

3. A 20% variation in the value of C, up or down, has the same effect as changing a 5-year recurrence interval to a 15-year or a 2-year interval respectively.

4. The chance of all design assumptions being satisfied simultaneously is less than the chance that the rainfall rate used in the design will actually occur. This, in effect, creates a built-in factor of safety.

5. Another built-in factor of safety is the usual design practice of having the hydraulic grade line near the top of the pipe (or box). Since the top of the storm sewer pipe is always a few feet lower than the street elevation, a rainfall intensity greater than the intensity for which the sewer is designed does not automatically mean that flooding will occur.

6. A decided difference can exist between intense point rainfall (rainfall over a small area) and mean catchment area rainfall (average rainfall). This is particularly true for thunderstorms and for drainage areas greater than about 300 acres. For that reason the rational method should be applied to drainage areas less than 200 acres.

7. In an irregularly shaped drainage area, a part of the area that has a short time of concentration (T_c) may cause a greater runoff rate (Q) at the intake (or other design point) than the runoff rate calculated for the entire area. This is because parts of the area with long concentration times are far less susceptible to high-intensity rainfall. Thus, they skew the calculation.

8. A portion of a drainage area which has a value of C much higher than the rest of the area may produce a greater amount of runoff at a design point than that calculated for the entire area. This effect is similar to that described in item 7 above.

Figure 5 : Climatic Sectional Code for Iowa.

Table 5: Sectional Mean Frequency Distribution for Storm Periods of 5 Minutes to 10 Days and Recurrent Intervals of 2 Months to 100 Year in Iowa.[7]

Rainfall (inches) for given recurrence interval T, return period in years.

*Sectional code (see Figure 5 Iowa map)

01-Northwest	04-West Central	07-Southwest
02-North Central	05-Central	08-South Central
03-Northeast	06-East Central	09-Southeast

*section	duration	2-year	5-year	10-year	25-year	50- year	100-year
01	10-day	4.81	5.84	6.70	8.02	9.11	10.31
01	5-day	3.77	4.68	5.43	6.61	7.60	8.75
01	72-hr	3.33	4.21	4.99	6.07	7.12	8.23
01	48-hr	3.01	3.81	4.52	5.60	6.53	7.52
01	24-hr	2.75	3.50	4.14	5.11	5.97	6.92
01	18-hr	2.59	3.29	3.89	4.80	5.61	6.50
01	12-hr	2.39	3.05	3.60	4.45	5.19	6.02
01	6-hr	2.06	2.62	3.11	3.83	4.48	5.19
01	3-hr	1.76	2.24	2.65	3.27	3.82	4.43
01	2-hr	1.59	2.03	2.40	2.96	3.46	4.01
01	1-hr	1.29	1.64	1.95	2.40	2.81	3.25
01	30-min	1.02	1.30	1.53	1.89	2.21	2.56
01	15-min	0.74	0.95	1.12	1.38	1.61	1.87
01	10-min	0.58	0.73	0.87	1.07	1.25	1.45
01	5-min	0.33	0.42	0.50	0.61	0.72	0.83
02	10-day	5.04	6.26	7.32	8.93	10.37	11.40
02	5-day	4.13	5.05	5.80	7.00	8.03	9.28
02	72-hr	3.53	4.45	5.15	6.33	7.30	8.30
02	48-hr	3.30	4.11	4.78	5.80	6.67	7.67
02	24-hr	2.98	3.72	4.38	5.33	6.14	7.07
02	18-hr	2.80	3.50	4.12	5.01	5.77	6.65
02	12-hr	2.59	3.24	3.80	4.64	5.34	6.15
02	6-hr	2.24	2.79	3.29	4.00	4.61	5.30
02	3-hr	1.91	2.38	2.80	3.41	3.93	4.52
02	2-hr	1.73	2.16	2.54	3.09	3.56	4.10
02	1-hr	1.40	1.75	2.06	2.51	2.89	3.32
02	30-min	1.10	1.38	1.62	1.97	2.27	2.62
02	15-min	0.80	1.00	1.18	1.44	1.66	1.91
02	10-min	0.63	0.78	0.92	1.12	1.29	1.48
02	5-min	0.36	0.45	0.53	0.64	0.74	0.85
03	10-day	5.04	6.17	7.07	8.29	9.20	10.19
03	5-day	3.94	4.86	5.64	6.84	7.75	8.77
03	72-hr	3.44	4.33	5.14	6.19	7.00	7.84

[7] Huff, Floyd A. & Angel, James R. *Rainfall Frequency Atlas of the Midwest.* Bulletin 71, 1992.

*section	duration	2-year	5-year	10-year	25-year	50- year	100-year
03	48-hr	3.20	4.02	4.69	5.62	6.34	7.09
03	24-hr	2.91	3.67	4.31	5.11	5.73	6.36
03	18-hr	2.74	3.45	4.05	4.80	5.39	5.98
03	12-hr	2.53	3.19	3.75	4.45	4.99	5.53
03	6-hr	2.18	2.75	3.23	3.83	4.30	4.77
03	3-hr	1.86	2.35	2.76	3.27	3.67	4.07
03	2-hr	1.69	2.13	2.50	2.96	3.32	3.69
03	1-hr	1.37	1.72	2.03	2.40	2.69	2.99
03	30-min	1.08	1.36	1.59	1.89	2.12	2.35
03	15-min	0.79	0.99	1.16	1.38	1.55	1.72
03	10-min	0.61	0.77	0.91	1.07	1.20	1.34
03	5-min	0.35	0.44	0.52	0.67	0.69	0.76
04	10-day	5.22	6.31	7.16	8.24	9.21	10.27
04	5-day	4.06	4.94	5.74	7.04	8.13	9.27
04	72-hr	3.51	4.37	5.13	6.28	7.26	8.46
04	48-hr	3.16	3.97	4.71	5.86	6.81	7.82
04	24-hr	2.94	3.64	4.30	5.27	6.08	7.00
04	18-hr	2.76	3.42	4.04	4.95	5.72	6.58
04	12-hr	2.56	3.17	3.74	4.58	5.29	6.09
04	6-hr	2.20	2.73	3.23	3.95	4.56	5.25
04	3-hr	1.88	2.33	2.75	3.37	3.89	4.48
04	2-hr	1.71	2.11	2.49	3.06	3.53	4.06
04	1-hr	1.38	1.71	2.02	2.48	2.86	3.29
04	30-min	1.09	1.35	1.59	1.95	2.25	2.59
04	15-min	0.79	0.98	1.16	1.42	1.64	1.89
04	10-min	0.62	0.76	0.90	1.11	1.28	1.47
04	5-min	0.35	0.44	0.52	0.63	0.73	0.84
05	10-day	5.20	6.22	7.22	8.61	9.66	10.88
05	5-day	4.05	4.94	5.72	6.92	7.98	9.18
05	72-hr	3.47	4.41	5.16	6.22	7.06	8.12
05	48-hr	3.13	3.93	4.67	5.75	6.52	7.33
05	24-hr	2.91	3.64	4.27	5.15	5.87	6.61
05	18-hr	2.74	3.42	4.01	4.84	5.52	6.21
05	12-hr	2.53	3.17	3.71	4.48	5.11	5.75
05	6-hr	2.18	2.73	3.20	3.86	4.40	4.96
05	3-hr	1.86	2.33	2.73	3.30	3.76	4.23
05	2-hr	1.69	2.11	2.48	2.99	3.40	3.83
05	1-hr	1.37	1.71	2.01	2.42	2.76	3.11
05	30-min	1.08	1.35	1.58	1.91	2.17	2.45
05	15-min	0.79	0.98	1.15	1.39	1.58	1.78
05	10-min	0.61	0.76	0.90	1.08	1.23	1.39
05	5-min	0.35	0.44	0.51	0.62	0.70	0.79
06	10-day	5.21	6.27	7.12	8.25	9.27	10.35
06	5-day	4.12	4.89	5.61	6.70	7.75	9.00

*section	duration	2-year	5-year	10-year	25-year	50- year	100-year
06	72-hr	3.59	4.53	5.31	6.42	7.35	8.42
06	48-hr	3.21	4.15	5.05	6.02	6.87	7.83
06	24-hr	3.06	3.84	4.44	5.42	6.25	7.13
06	18-hr	2.88	3.61	4.17	5.09	5.88	6.70
06	12-hr	2.66	3.34	3.86	4.72	5.44	6.20
06	6-hr	2.30	2.88	3.33	4.07	4.69	5.35
06	3-hr	1.96	2.46	2.84	3.47	4.00	4.56
06	2-hr	1.77	2.23	2.58	3.14	3.62	4.14
06	1-hr	1.44	1.80	2.09	2.55	2.94	3.35
06	30-min	1.13	1.42	1.64	2.01	2.31	2.64
06	15-min	0.83	1.04	1.20	1.46	1.69	1.93
06	10-min	0.64	0.81	0.93	1.14	1.31	1.50
06	5-min	0.37	0.46	0.53	0.65	0.75	0.86
07	10-day	5.47	6.54	7.53	9.00	10.25	11.66
07	5-day	4.26	5.30	6.20	7.59	8.71	9.86
07	72-hr	3.85	4.79	5.56	6.78	7.80	8.99
07	48-hr	3.53	4.38	5.11	6.19	7.09	8.04
07	24-hr	3.22	3.93	4.57	5.56	6.45	7.28
07	18-hr	3.03	3.69	4.30	5.23	6.06	6.84
07	12-hr	2.80	3.42	3.98	4.48	5.61	6.33
07	6-hr	2.41	2.95	3.43	4.17	4.84	5.46
07	3-hr	2.06	2.52	2.92	3.56	4.13	4.66
07	2-hr	1.87	2.28	2.65	3.22	3.74	4.22
07	1-hr	1.51	1.85	2.15	2.61	3.03	3.42
07	30-min	1.19	1.45	1.69	2.06	2.39	2.69
07	15-min	0.87	1.06	1.23	1.50	1.74	1.97
07	10-min	0.68	0.83	0.96	1.17	1.35	1.53
07	5-min	0.39	0.47	0.55	0.67	0.77	0.87
08	10-day	5.45	6.61	7.57	8.99	10.09	11.04
08	5-day	4.32	5.37	6.26	7.64	8.78	9.99
08	72-hr	3.67	4.68	5.64	6.90	7.96	9.24
08	48-hr	3.39	4.30	5.06	6.28	7.35	8.60
08	24-hr	3.11	3.87	4.65	5.78	6.73	7.74
08	18-hr	2.92	3.64	4.37	5.43	6.33	7.28
08	12-hr	2.71	3.37	4.05	5.03	5.86	6.73
08	6-hr	2.33	2.90	3.49	4.34	5.05	5.80
08	3-hr	1.99	2.48	2.98	3.70	4.31	4.95
08	2-hr	1.80	2.24	2.70	3.35	3.90	4.49
08	1-hr	1.46	1.82	2.19	2.72	3.16	3.64
08	30-min	1.15	1.43	1.72	2.14	2.49	2.86
08	15-min	0.84	1.04	1.26	1.56	1.82	2.09
08	10-min	0.65	0.81	0.98	1.21	1.41	1.63
08	5-min	0.37	0.46	0.56	0.69	0.81	0.93
09	10-day	5.44	6.50	7.35	8.45	9.33	10.42

*section	duration	2-year	5-year	10-year	25-year	50- year	100-year
09	5-day	4.31	5.45	6.32	7.60	8.69	9.95
09	72-hr	3.79	4.87	5.74	6.95	7.88	8.98
09	48-hr	3.50	4.46	5.20	6.35	7.32	8.40
09	24-hr	3.14	4.03	4.67	5.67	6.58	7.59
09	18-hr	2.95	3.79	4.39	5.33	6.19	7.13
09	12-hr	2.73	3.51	4.06	4.93	5.72	6.60
09	6-hr	2.36	3.02	3.50	4.25	4.93	5.69
09	3-hr	2.01	2.58	2.99	3.63	4.21	4.86
09	2-hr	1.82	2.34	2.71	3.29	3.82	4.40
09	1-hr	1.48	1.89	2.19	2.66	3.09	3.57
09	30-min	1.16	1.49	1.73	2.10	2.43	2.81
09	15-min	0.85	1.09	1.26	1.53	1.78	2.05
09	10-min	0.66	0.85	0.98	1.19	1.38	1.59
09	5-min	0.38	0.48	0.56	0.68	0.79	0.91

Example 3

Determine the rainfall intensity I (in/hr) in Des Moines, Iowa with a recurrence interval T = 25 years and storm duration of $T_c = 30$ minutes.

From Figure 5, Des Moines is in Sectional Code 05-Central

From Table 5: I = 1.91 inches per 30 minutes

I = 1.91 in/30 min x 60 min/hr = 3.8 in/hr

Calculating Spread and Checking Intake Location

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After using The Rational Method (Section 4A-4) to find the rate of water runoff (Q) from each drainage area, the designer then calculates how much that runoff encroaches on the roadway while flowing in the gutter. The quantity of interest in this calculation is the spread. Spread is the distance from the curb to the outermost edge of the flow of water (the width, w). In this section, procedures for calculating spread on roadways with various geometric features are described, and then the spread is used to determine whether the intake locations chosen in the preliminary design phase are appropriate.

The procedures described in this section are only for calculating the spread of water running in the gutter. Water that ponds in a gutter's low point due to an intake's limited capacity is discussed in Section 4A-6.

Encroachment Limits

In this manual, "spread" refers to the distance from the curb to the outermost edge of the water, while "encroachment" refers only to how far the water *encroaches* on the driving lanes of the roadway. The two quantities may differ if the roadway has a gutter section or if a shoulder is between the curb and the driving lanes.

After using the procedures in this section to calculate the spread caused by each drainage area's runoff, the designer compares the encroachment onto the driving lanes with the limits for the particular roadway, shown in Table 1 below. When encroachment exceeds the allowable limits, intakes normally must be added or relocated. Another trial calculation is then done to check for encroachment. This trial and error procedure is repeated until the design is within allowable limits.

Table 1: Encroachment limits.

type of road	recurrence interval	allowable lane encroachment
street	2-year storm	100% encroachment no curb overtopping
primary highway	2-year storm	1/2 lane
freeway	10-year storm	no encroachment
interstate	10-year storm	no encroachment

The value for maximum spread was originally chosen so 9 feet of the driving lane could be maintained on primary highways. For example on a four-lane road (49 feet B-B) encroaching 1/2 the outside lane (6 feet) would leave 18 feet for driving or two 9-foot driving lanes. The spread may vary from 6 to 7 feet depending on the outside lane width.

Types of Gutter Sections

The amount of water a gutter can carry, and thus the amount of spread for a given value of Q, depends on the type of gutter section being used. The two gutter sections normally encountered in design (the triangle and the multi-triangle) are shown below in Figure 1. The following paragraphs describe how to determine spread for each type of gutter.

Figure 1: Types of gutter sections.

Triangular Sections and Manning's Equation

The spread (or width, w) of water on a roadway with a triangular gutter section depends on the following equation:

$$w = \frac{d}{S_X} = Z \times d$$

where:

- d = the depth of the water in the gutter, measured in feet
- S_x = the cross slope of the gutter section
- Z = $1/S_x$

To calculate the depth of water (d), the designer must use either Manning's equation or the nomograph in Figure 2. Manning's equation is given as:

$$d = \left[\frac{nQ}{(K)(Z)(S_L)^{0.5}} \right]^{0.375}$$

where:

- n = the Manning coefficient
- Q = the rate of flow in the gutter in cfs (CIA, see Section 4A-4)
- K = 0.56
- Z = $w/d = 1/S_x$ (S_x = cross slope of gutter section)
- S_L = the longitudinal grade of the gutter line

Type of Gutter or Pavement	Manning's n*
Concrete Gutter, troweled finish	0.012
Asphalt Pavement:	
Smooth texture	0.013
Rough texture	0.016
Concrete gutter-asphalt pavement:	
Smooth	0.013
Rough	0.015
Concrete pavement:	
Float finish	0.014
Broom finish	0.016
*For gutters with small slope, where sediment may accumulate, increase above values of "n" by 0.02	

Reference: USDOT FHWA HDS-3

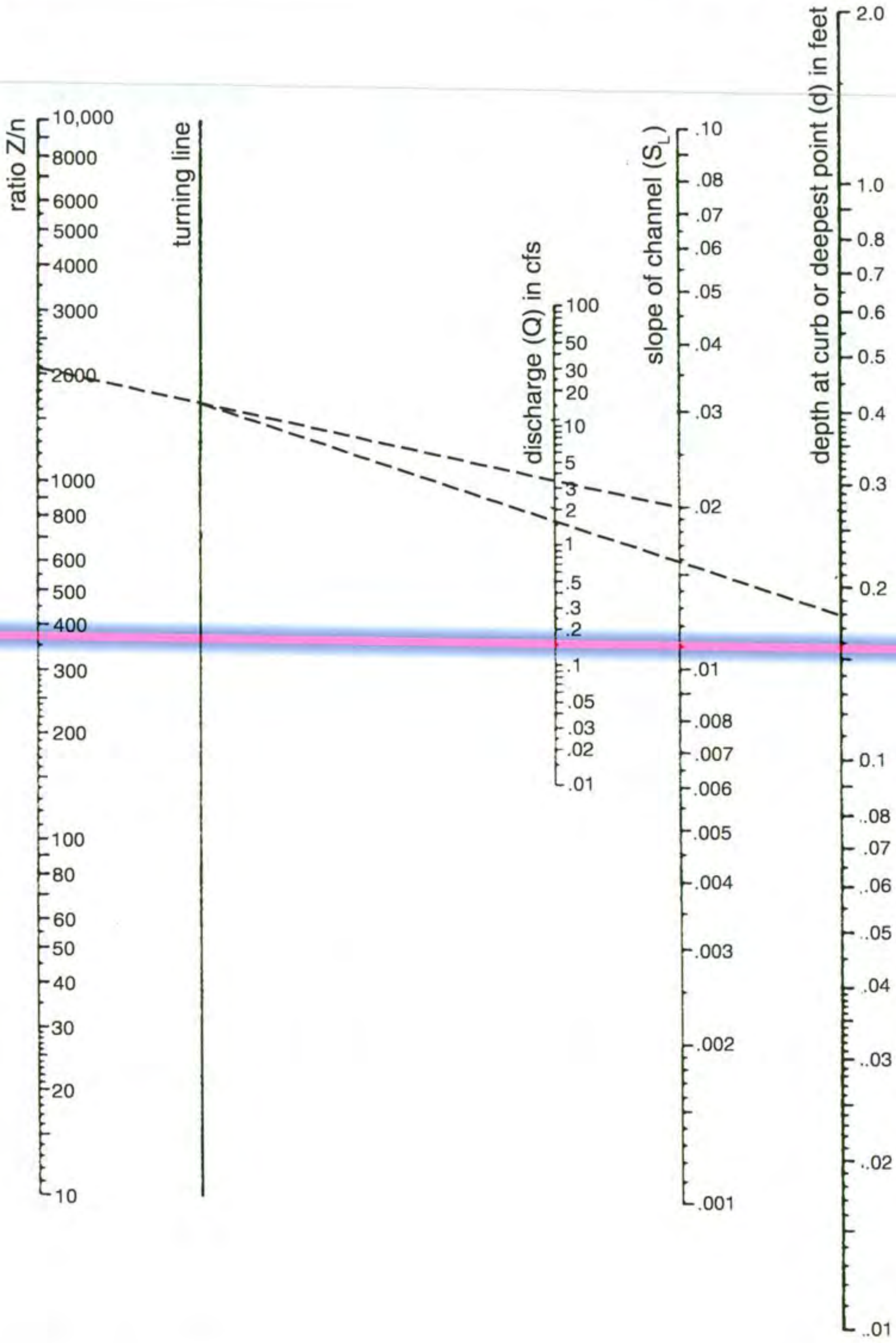

Figure 2: Nomograph for flow in triangular channels.[1]

Manning's equation assumes that the cross slope of the gutter section is constant. Of course, this is true only for simple-triangle gutter sections. Multi-triangle sections require the designer to apply the equation (or more often the nomograph) to several different triangles to create a composite that accurately represents the shape of the gutter section. This procedure is described on page 5.

[1] FHWA, *Design of Urban Highway Drainage* (1979).

Simple-Triangle Gutter Sections

As mentioned previously, the designer may calculate spread using the nomograph in Figure 2, rather than using Manning's formula directly. From the nomograph, the designer determines the water depth (d) in the gutter, then calculates the spread (w) from the formula given on page 2. An example of a typical calculation of spread for a simple-triangle gutter section is given below.

Example 1

Given:

S_x = 0.03 (the cross slope of the gutter section)

n = 0.016 (Manning's coefficient for PC pavement)

Q = 1.6 cfs (calculated using Q = CIA from Section 4A-4)

S_L = 0.02 (the longitudinal grade of the gutter line)

Find "w"

Solution:

1. Calculate Z:

$$Z = \frac{1}{S_x} = \frac{1}{0.03} = 33.33$$

2. Calculate Z/n:

$$\frac{Z}{n} = \frac{33.33}{0.016} = 2083$$

3. Use the nomograph in Figure 2 as follows:
   a. Draw a line from Z/n = 2083 on the "ratio Z/n" line to S_L = 0.02 on the "slope of channel" line.
   b. Find the point where the line drawn in step "a" crosses the "turning line." This is the turning point.
   c. Draw a line between the turning point and Q = 1.6 cfs on the "discharge" line.
   d. Extend the line drawn in step "c" to the "depth at curb or deepest point" line. Read d = 0.18 feet.
4. Calculate the spread (w) of water on the pavement:

$$\begin{aligned} w &= d \times Z \\ &= 0.18 \times 33.33 \\ &= 6.0 \text{ feet} \end{aligned}$$

If the encroachment limits allow a spread of six feet or more, no additional intakes will be required.

Multi-Triangle Gutter Sections

Calculating spread for multi-triangle gutter sections is often a trial and error procedure, in which the gutter section is broken up into three simple triangles, as shown in Figure 3. Values of Q are then estimated for each section and compared to the total Q calculated from The Rational Method (Section 4A-4). Finally, when correct values of Q have been found for each section, the spread is calculated from the water depths that the values of Q give.

The first step in determining spread for the multi-triangle section is to assume the section is the simple-triangle section "1" shown in Figure 3. The designer then solves for d_1 using the nomograph in Figure 2. Using this solution, $w_1 = d_1 \times Z$ is calculated. If w_1 is less than the three feet of gutter in Figure 3, spread does not encroach onto the second triangle and the correct value of spread (w) has been found. However, if w_1 is greater than three feet, spread must be calculated for the entire multi-triangle section.

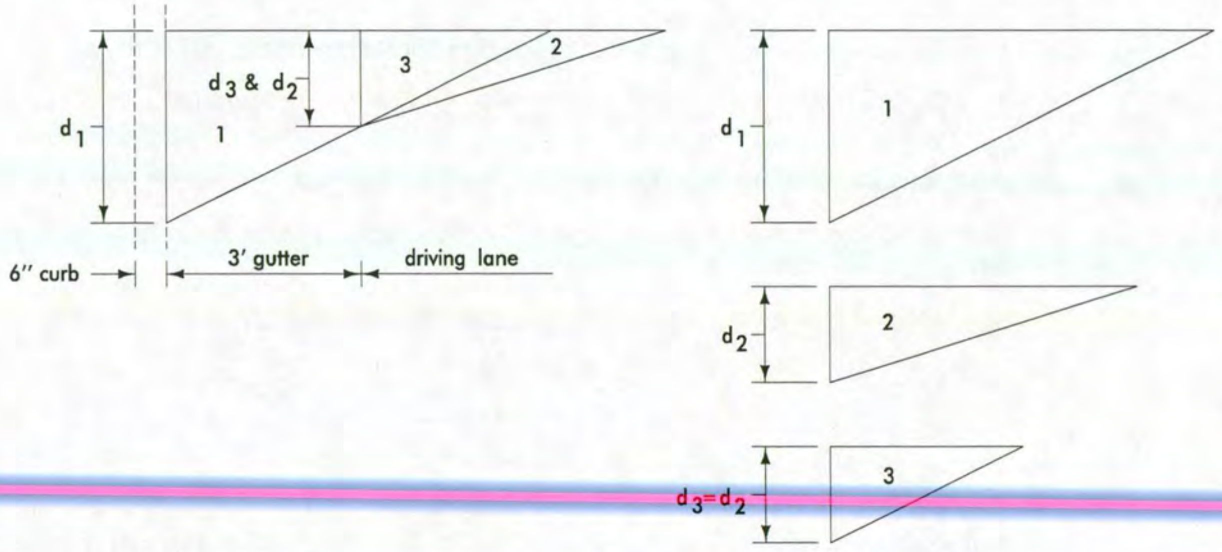

Figure 3: Multi-triangle gutter section.

When spread must be calculated for the entire multi-triangle gutter section, the designer must use a trial and error procedure in which estimates of d_1 and d_2 (= d_3) from Figure 3 are used to estimate values of Q_1, Q_2, and Q_3. The procedure is repeated until $Q_1 + Q_2 - Q_3 = Q$, where Q is the value determined from Q = CIA. The following example illustrates the procedure.

Example 2

Given:

31-foot B-B Pavement

S_1 = 0.045 (the gutter cross slope of Triangle 1)

S_2 = 0.020 (the gutter cross slope of Triangle 2)

S_3 = 0.045 (the gutter cross slope of Triangle 3)

n = 0.016 (Manning's coefficient for PC pavement)

Q = 2.4 cfs (calculated from Q = CIA)

S_L = 0.005 (the longitudinal grade of the gutter)

Find: w = the width of water at the intake (spread)

Solution:

1. Calculate Z_1:

$$Z = \frac{1}{S_1} = \frac{1}{0.045} = 22.22$$

2. Calculate Z_1/n:

$$\frac{Z_1}{n} = \frac{22.22}{0.016} = 1389$$

3. Use the nomograph in Figure 2 to solve for d_1, the depth for a single triangle with a 0.045 cross slope, S_1.

   a. Draw line from 1389 on the Z/n line to 0.005 on the "slope of channel" line, S_L.

   b. Find the point where the line drawn in step "a" crosses the "turning line." This is the turning point.

   c. Draw a line between the turning point and Q = 2.4 cfs on the "discharge" line.

   d. Extend the line drawn in step "c" to the "depth at curb" line to get a value of d_1 = 0.31 feet.

4. Calculate the width of water on the pavement (spread):

$$\begin{aligned} w_1 &= d_1 \times Z_1 \\ &= 0.31 \times 22.22 \\ &= 6.89 \text{ feet} \end{aligned}$$

Since w_1 = 6.89 feet is wider than the 3-foot gutter section used for the 31-foot B-B roadway, the multi-triangle section is involved and the trial and error procedure must be used (d_1 will be less than 0.31 feet because the gutter volume will be greater than was initially assumed).

5. For the first trial, estimate a value of d less than 0.31 feet. Try d = 0.25 feet:

$$d_1 = 0.25 \text{ feet}$$

$$d_2 = d_1 - (w \times S_1)$$

$$= 0.25 - (3 \times 0.045) = 0.115 \text{ feet}$$

6. Calculate Z_2:

$$Z_2 = \frac{1}{S_2} = \frac{1}{0.020} = 50.00$$

Calculate Z_3:

$$Z_3 = \frac{1}{S_3} = \frac{1}{0.045} = 22.22$$

7. Calculate Z_2/n:

$$\frac{Z_2}{n} = \frac{50}{0.016} = 3125$$

Calculate Z_3/n:

$$\frac{Z_3}{n} = \frac{22.22}{0.016} = 1389$$

8. Use the nomograph in Figure 2 and the assumed values of d_1, d_2, and d_3 to find values of Q_1, Q_2, and Q_3:

   a. Find the turning point for Triangles 1 and 3 using Z_1/n = 1389 and S_L= 0.005.

   b. Draw a line from the turning point to d_1 = 0.25 feet.

   c. Where the line in step "b" crosses the "Q" line, read 1.3 cfs for the value of Q_1.

e. Where the line in step "d" crosses the "Q" line, read 0.16 cfs for the value of Q_3.

f. Find the turning point for Triangle 2 using $Z_2/n = 3125$ and $S_L = 0.005$.

g. Draw a line from the turning point to $d_2 = 0.115$ feet.

h. Where the line in step "g" crosses the "Q" line, read $Q_2 = 0.34$ cfs.

9. Calculate: $Q_{total} = Q_1 + Q_2 - Q_3 = 1.3 \text{ cfs} + 0.34 \text{ cfs} - 0.16 \text{ cfs} = 1.48 \text{ cfs}$.

   $Q_{total} = 1.48$ cfs does not equal the Q = 2.4 cfs calculated from the Rational Method. Thus, a second trial is necessary.

10. In the second trial, try:

$$d = d_1 = 0.29 \text{ feet}$$
$$d_2 = d_3 = 0.29 - (3.0 \times 0.045) = 0.155 \text{ feet}$$

11. As in the first trial, use the nomograph and the values of d_1, d_2, and d_3 to come up with:

$$Q_1 = 2.00 \text{ cfs}$$
$$Q_2 = 0.86 \text{ cfs}$$
$$Q_3 = 0.36 \text{ cfs}$$

12. Calculate: $Q_{total} = Q_1 + Q_2 - Q_3 = 2.0 + 0.86 - 0.36 = 2.5$ cfs.

13. Since 2.5 cfs is very close to 2.4 cfs, use d = 0.29 feet.

14. The spread on the pavement is then:

$$\begin{aligned} w &= 3.0 \text{ (for gutter section)} + (d_2 \times Z_2) \\ &= 3.0 + (0.155 \times 50) = 3.0 + 7.75 \\ &= 10.75 \text{ feet} \end{aligned}$$

If encroachment limits allow only 6 feet of spread, additional intakes will be required.

Checking Intake Locations

After calculating spread, the designer compares the encroachment of water onto the pavement's driving lanes to the encroachment limits in Table 1. If the encroachment limits have been exceeded, the intake must be relocated or else an additional intake must be added. In either case, the designer will need to calculate Q for the new drainage area(s), then calculate new values of spread to decide whether the encroachment is now acceptable. These procedures must be repeated until the encroachment is within acceptable limits.

Sizing Intakes

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At this stage in the design process, the designer has normally determined an intake's location with a fairly high degree of certainty. What remains is to decide how large the intake should be. This decision is based on how much water must be dealt with (the rate of flow, Q) and, in some cases, how much encroachment of water onto the driving lanes can be tolerated (based on Table 1 in Section 4A-5). This section of the manual describes the standard intakes used by the Iowa DOT and how to adjust for non-standard intakes. It also provides rules for deciding which intakes to use (based on their capacities).

General Rules for Sizing and Locating Intakes

The designer normally chooses the size of an intake with the goal of intercepting 85% to 90% of the water flowing past the intake's location. Intercepting 100% of the water is not economical at most locations because it takes 33% of the curb opening to intercept the last 15% of the water (shown in Figure 1). Nonetheless, the designer should observe the following minimums when choosing an intake:

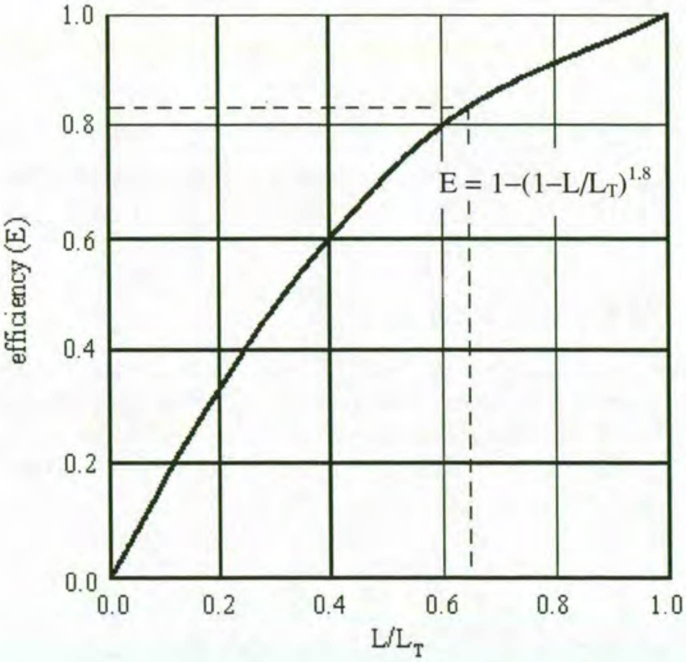

Figure 1: Inlet interception efficiency for curb-opening and slotted-drain intakes,[1] where L is the curb opening length and L_T is the curb opening length required to intercept 100% of the gutter flow.

[1] FHWA, "Drainage of Highway Pavements," *Hydraulic Engineering Circular No. 12* (March 1984).

- Curb opening type intakes should intercept a minimum of 85% of the water
- Grate type intakes should intercept a minimum of 78% of the water

If an intake intercepts less than the minimum, a longer opening or additional intakes should be used. Additionally, intakes at the low points of sag vertical curves and at the ends of curb and gutter sections should always intercept 100% of the water.

Capacities for Standard Intakes

Standard Iowa DOT intakes are shown in Standard Road Plans RA-40 toRA-48 and RA-60 to RA-70. Table 1 indicates the size or "length of opening" for each. To determine what percentage of a flow an intake will capture, the designer uses Figure 2, 3, or 4. The following indicate which figure to use with each standard intake:

- Figure 2: RA-40 and RA-41 intakes
- Figure 3: RA-43 intake and RA-41 intake with RA-42 extension
- Figure 4: RA-70 intake and RA-41 with two RA-42 extensions

To use the figures, find the spread, w, (calculated in Section 4A-5) on the bottom left of the figure and draw a vertical line to intersect the longitudinal grade of the gutter, S_L. Then draw a horizontal line across the chart to the gutter cross slope, S_x. At this intersection point, draw a vertical line to the top of the figure and read the inlet interception rate (Q/Q_0). This quantity is the ratio of water intercepted by the intake divided by the total flow of water.

Table 1: Standard intakes.

type	length of opening (L)
RA-40	4′
RA-41	4’
RA-41 with RA-42 extension	9’ 2’’
RA-41 with two RA-42 extensions	14’ 4’’
RA-43	8′
RA-70	12′–18′

Capacities for Other Intakes

If the RA-41 with or without extensions, the RA-70 intake (where L is variable) or a nonstandard intake is used, the designer will normally need to make adjustments to Figure 2, 3, or 4 because the dimensions will often be different than those shown at the bottom of the figure. These dimensions are illustrated in Figure 5. They are the length of the intake's opening (L), the width of special shaping around the intake (W), and the depth of the intake depression (a).

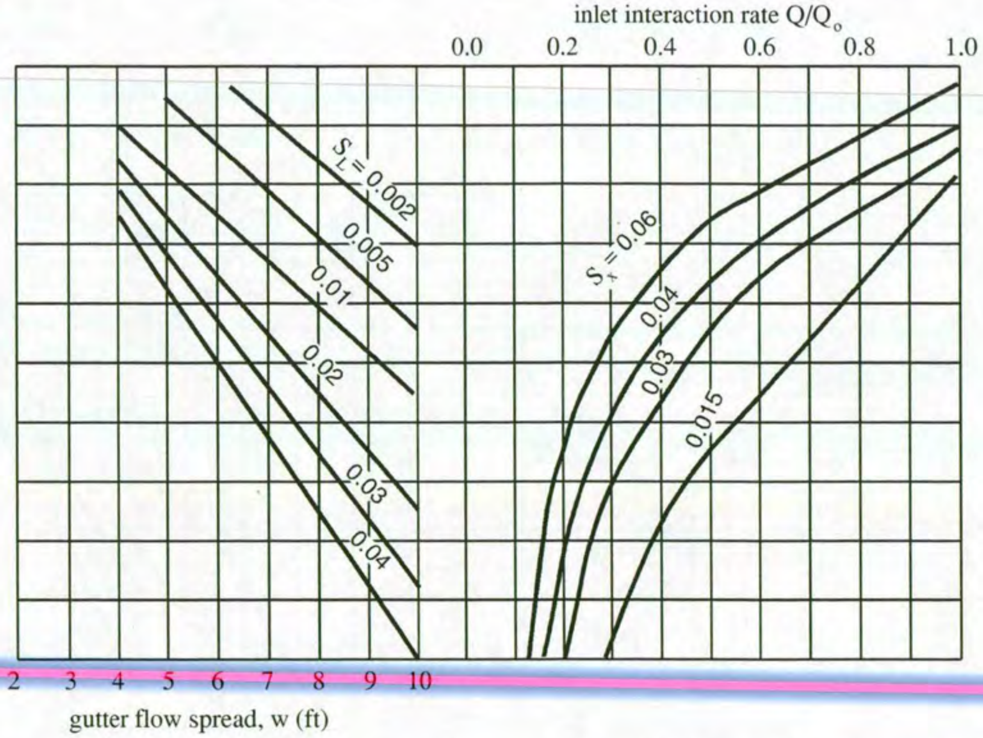

Figure 2: Capacity of curb-opening inlet on constant grade. W = 2 ft., a ≥ 3 in., L = 4 ft., h ≥ y_o (for use with the RA-40 and RA-41 intakes)[2]

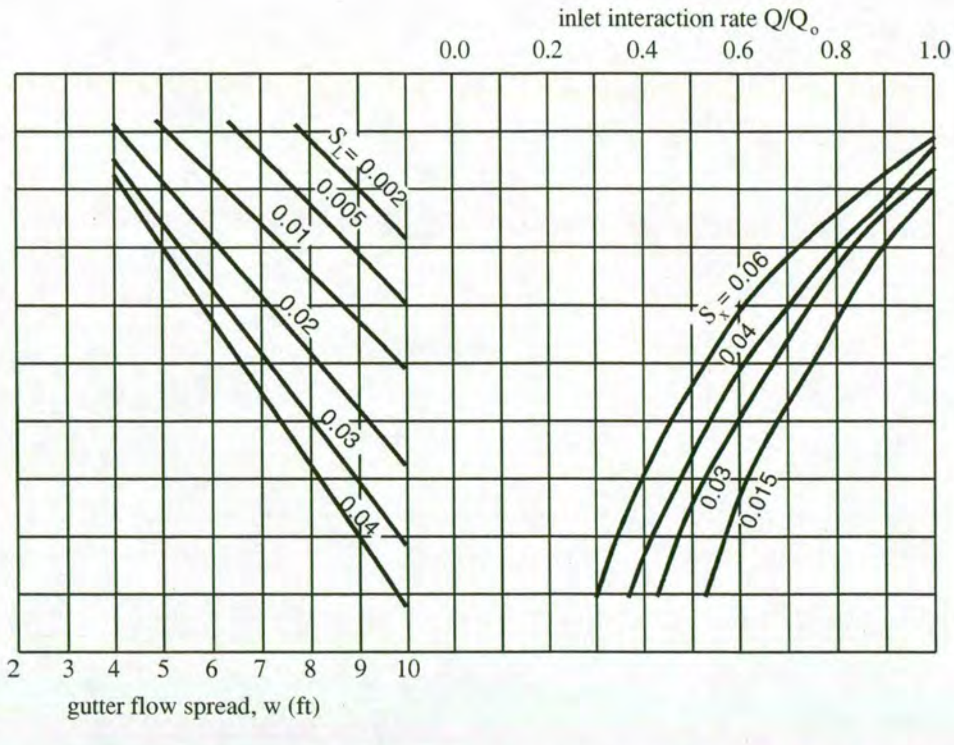

Figure 3: Capacity of curb-opening inlet on constant grade. W = 2 ft., a ≥ 3 in., L = 8 ft., h ≥ y_o (for use with the RA-43 intake and the RA-41 intake with an RA-42 extension)[2]

[2] Iowa State University, Engineering Extension (Civil Engineering), *Urban Drainage Short Course for Iowa Department of Transportation Highway Division* (November 1979).

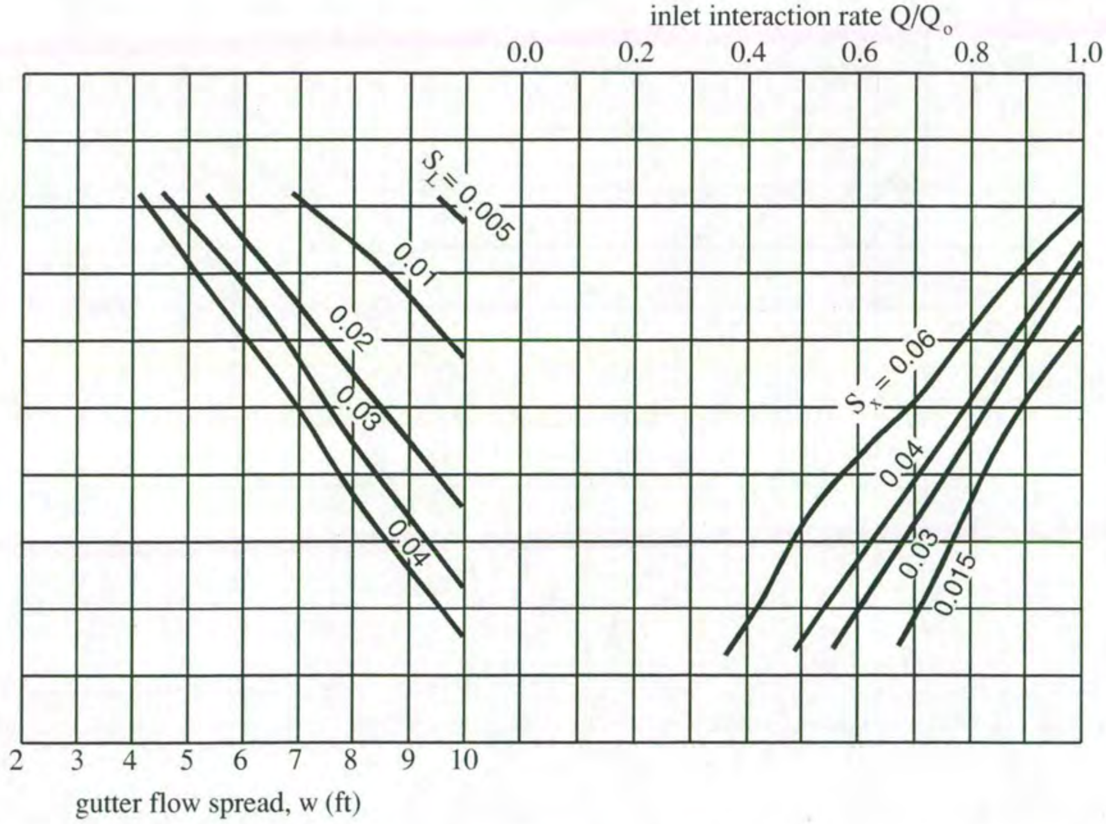

Figure 4: Capacity of curb-opening inlet on constant grade. W = 2 ft., a ≥ 3 in., L = 12 ft., h ≥ y_o (for use with the RA-70 intake and the RA-41 intake with two RA-42 extensions)[2]

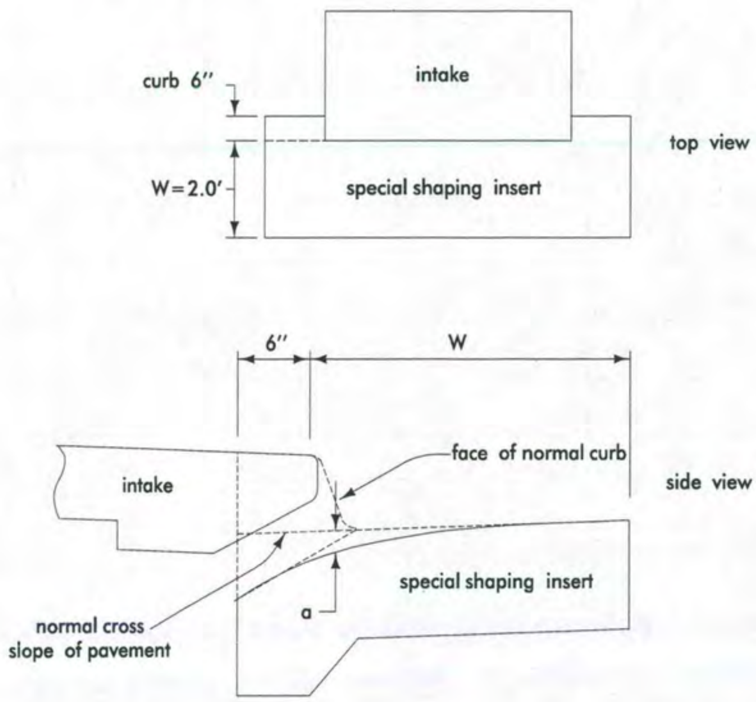

Figure 5: Standard intake and special shaping insert (illustrating "a" and "W").

If the length of the curb opening (L) is different than the L's used in Figures 2, 3, and 4, the designer may calculate Q/Q_0 using the following formula:

$$\frac{Q}{Q_0} = \frac{L_{actual}}{L_{from\ figure}}$$

The width of special shaping (W) is the width of the intake insert minus the width of the curb (both measured in feet). For example, the standard insert for an RA-43 intake is 2.5 feet wide, so W = 2.5 feet - 0.5 feet (for curb) = 2.0 feet.

If calculating the capacity (Q/Q_0) of a non-standard intake and the value of W is different from the value used in the figure (Figure 2, 3, or 4), assume that a 1 foot change in W from the W shown in the figure will result in a 25% change in Q/Q_0 from the Q/Q_0 shown in the figure. So if W is increased by 1 foot, the intake's Q/Q_0 will increase by 1/4. Similarly, if W is decreased by 1 foot, Q/Q_0 will decrease by 1/4. This relationship can be inferred from Table 2.

The intake depression (a) is the vertical distance (measured in inches) that the intake is depressed below the gutter grade at the face of curb. If the value of "a" is different for an intake than the value shown in the figure (Figure 2, 3, or 4), the effect on Q/Q_0 is similar to the effect for a difference in W. If the value of "a" is increased by 1 inch, Q/Q_0 increases by 1/4, and if "a" is decreased by 1 inch, Q/Q_0 decreases by 1/4. This relationship can also be inferred from Table 2.

Table 2: Adjustments for variations in depression dimensions (to be used with Figures 2,3, and 4, and with Figures 7, 8, and 9)

value in figure	actual values for proposed intake	effect on Q/Q_0
W = 2′, a = 2″	W = 2′, a = 1″	reduce 1/4
W = 1′, a = 1″	W = 1′, a = 2″	increase 1/4
W = 2′, a = 2″	W = 1′, a = 2″	reduce 1/4
W = 1′, a = 1″	W = 2′, a = 1″	increase 1/4
W = 2′, a = 2″	W = 2′, a = 3″	increase 1/4

Intakes Located in Sags

When an intake is located at the low point, or sag, of a vertical curve, the designer must follow special procedures to select the appropriate intake. In such a situation, the gutter grade on both sides of the low point rapidly approaches zero. Thus the procedure given in Section 4A-5 for calculating spread cannot be used because it assumes a constant gutter grade. Additionally, the intake must be designed to pick up 100% of the water flow from both sides of the intake. The designer should therefore follow the three steps given below to decide which intake is appropriate.

Step 1 is to decide whether the intake operates as an orifice (intake submerged) or a weir (intake not submerged) for the design storm (assuming the intake is a curb opening type). Figure 6 is used to make this decision. On the left side of Figure 6, find the total gutter flow at the intake (total Q from both directions). From Q, go horizontally to intercept the length of the intake opening (L_i). Then go down to read the height of the water, h_m, at the bottom of the chart. If the water is over 0.5 feet deep, the intake opening is submerged and the intake is operating as an orifice.

If the curb is submerged, the maximum spread has been exceeded on primary highways, and it will be necessary to relocate the intake or add intakes to the system.

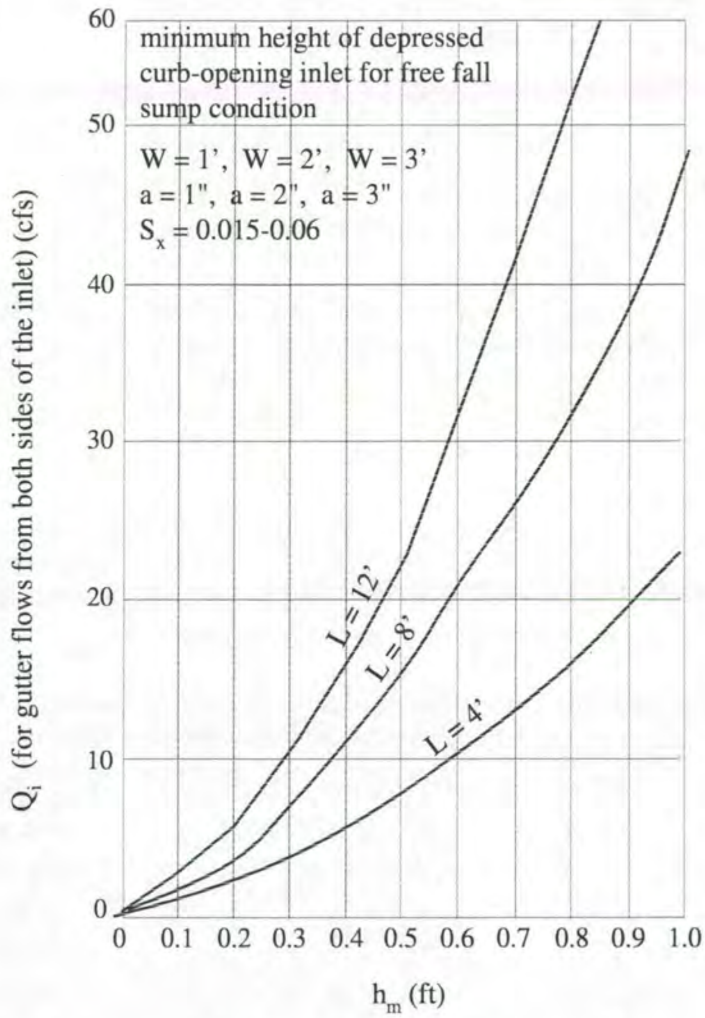

Figure 6: Height of curb opening needed for intake to operate as a weir.[3]

Step 2 is to check the ponding of water at the intake due to the limit on the intake's capacity. Figures 7, 8, and 9 are used for this purpose (note that these figures are designed only for when the intake operates as a weir). Normally Figure 7 will be used because it has W = 2 feet and a = 3 inches; Figures 8 and 9 are only for non-standard intakes. Using the figure appropriate to the intake, find the value of Q (total from both directions) on the left side of the figure. Go horizontally to the appropriate length of opening (L) and then down to read the water depth (d). The spread can then be calculated from w = (Z)(d), where $Z = 1/S_x$. Adjust for values of "a" and W not shown in the figures using Table 2, as with the adjustments for continuous grades. If the intake's opening is different than shown in the figures, interpolate between two curves in the appropriate figure. Note that Q's from both directions must be added together to get Q_i.

Step 3 is to check the spread caused by the longitudinal grade approaching zero near the intake. Use Figure 10 and the Q from each direction independently. The figure will show the spread at the curb (for each side of the intake) when the longitudinal slope is 0.002 (the minimum slope required to carry water in the gutter just before reaching the intake).

When allowable encroachment is exceeded (see Table 1, Section 4A-5), either by ponding or due to the leveling of the gutter grade, additional intakes must be added or existing intakes must be altered or relocated to reduce the Q approaching the intake. Often these are good locations for flanking intakes (see Section 4A-3).

[3] FHWA, *Design of Urban Highway Drainage, State of the Art* (August 1979).

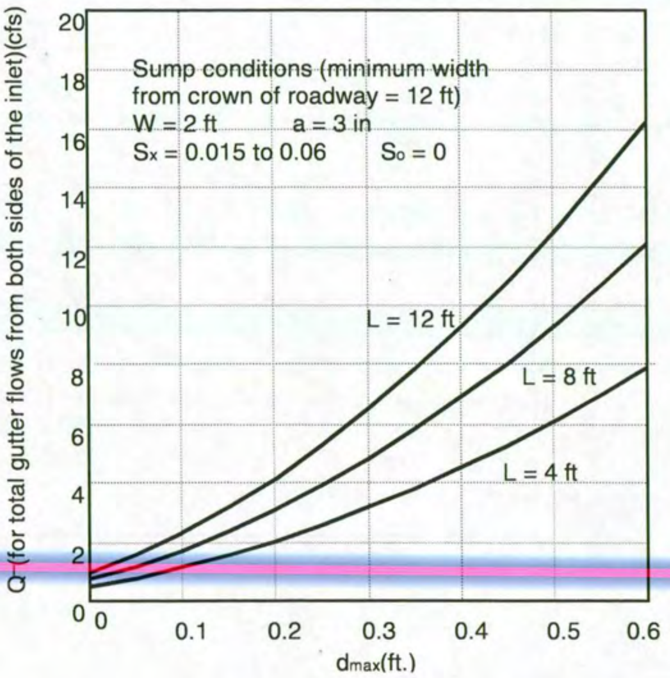

Figure 7: Depth of ponding when intake operates as a weir.[3]

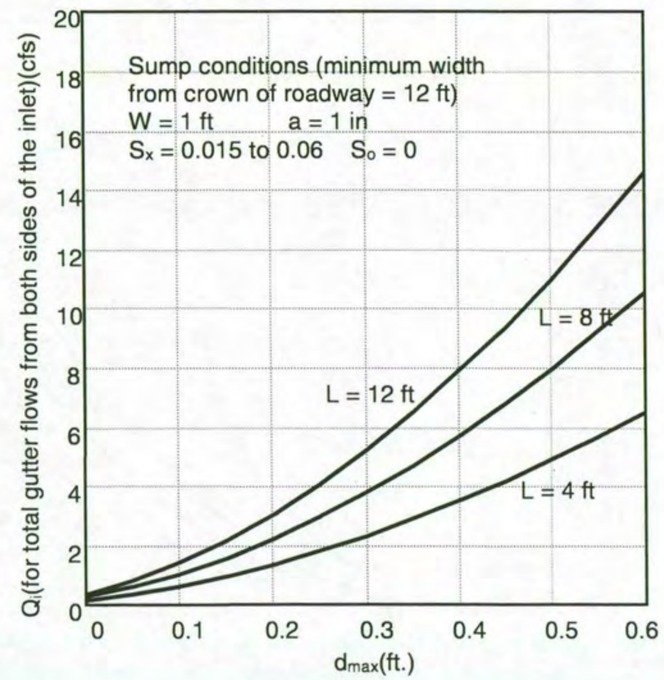

Figure 8: Depth of ponding when intake operates as a weir.[3]

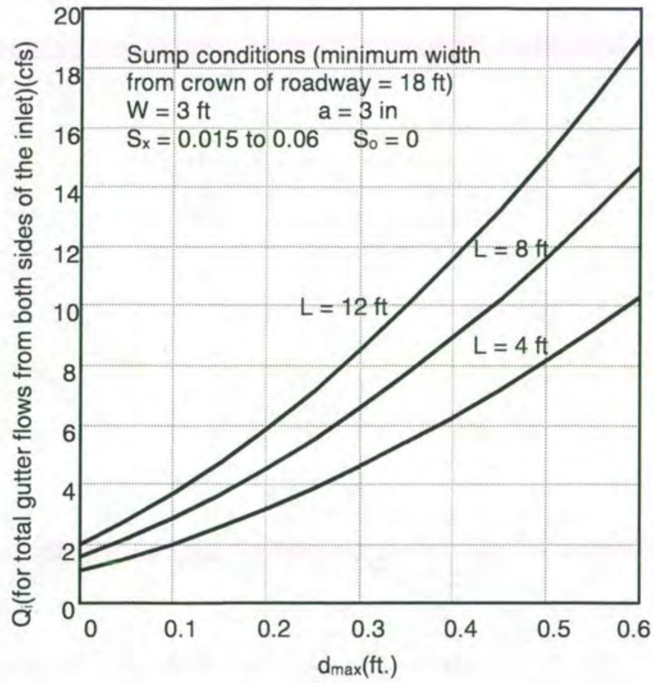

Figure 9: Depth of ponding when intake operates as a weir. [3]

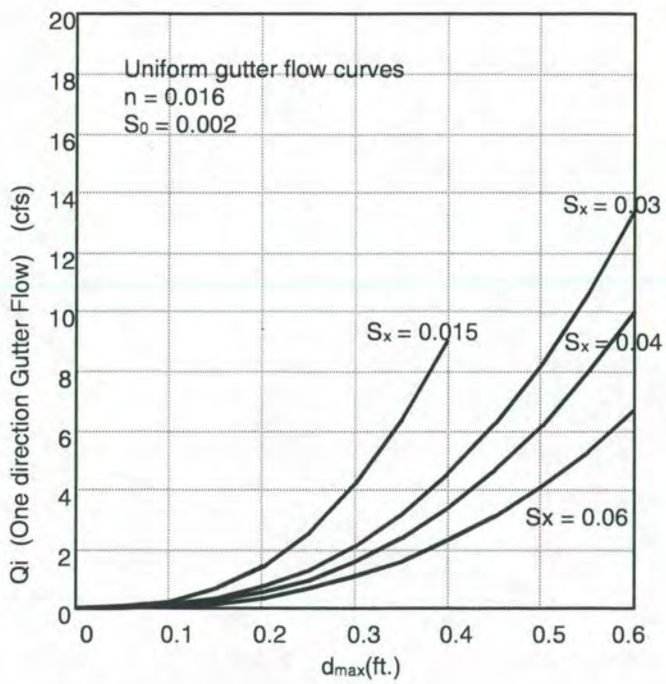

Figure 10: Depth of flow at intake where gutter grade is minimum. [3]

The Pavement Drainage Design Sheet

Originally Issued: 09-01-95

The Pavement Drainage Design Sheet shown in Figure 1 is used to record the results of the design process. The sheet allows the designer to more easily keep track of the results for a given intake and drainage area, and to see how the results for one drainage area affect the next in the series. If the preliminary design of a drainage area is unacceptable, the designer indicates this on the sheet and makes a second row for the revised drainage area. New rows are made on the sheet for each attempted design until an acceptable design is found. Thus the Pavement Drainage Design Sheet is a record of the process followed by the designer.

The following list describes the quantity placed in each column of the sheet, along with the section in this chapter that discusses the quantity. Following the list is a sample problem that illustrates the use of the Pavement Drainage Design Sheet. On page 6 is a blank Pavement Drainage Sheet for the designer to copy. Retain the original in the manual for future use.

Column 1: The intake number. This number is assigned to the drainage area and intake during the preliminary design process (Section 4A-3).

Column 2: The drainage area, A (measured in acres), for the intake (Section 4A-4).

Column 3: The runoff coefficient, C, that best describes the drainage area (Section 4A-4).

Column 4: The time of concentration, T_c (measured in minutes), for the drainage area. The minimum T_c is 5 minutes (Section 4A-4).

Column 5: The rainfall intensity, I (measured in inches/hour). "I" is found using T_c and the appropriate values in Table 5: 2 years for city streets and primary highways and 10 years for freeways and interstate highways (Section 4A-4).

Column 6: Discharge (Q_g) is the rate of flow of water in the gutter (measured in cubic feet per second). $Q_g = Q + Q_b$, where Q = CIA (Columns 2, 3, and 5) and where Q_b is the runoff not captured by the last intake upstream (Column 15). See Section 4A-4 for a discussion of Q = CIA.

Column 7: The longitudinal slope (S_L), or the grade, of the gutter at the intake (Section 4A-5).

Column 8: The cross slope (S_x) of the pavement at the intake (Section 4A-5).

Column 9: $Z/n = (1/S_x)/n$. Manning's coefficient (n) for PCC pavement is 0.016 (Section 4A-5).

Column 10: The depth of water at the curb, d (measured in feet). To determine d, use the equation or nomograph (Figure 2) in Section 4A-5 or see "Intakes Located in Sags" in Section 4A-6.

Column 11: The spread of water on the pavement, w (measured in feet). $w = d \times Z$. Check w against the allowable encroachment (Table 1, Section 4A-5). If w is very small (< 2.0 feet), the intake may not be necessary. If w exceeds the allowable encroachment, change to a different intake, relocate the intake, or add additional intakes (Section 4A-6). After making changes, repeat the calculations and check the encroachment again.

Column 12: The type (length) of intake chosen. See "Table 1: Standard intakes" in Section 4A-6 for making the initial choice.

Column 13: The percentage of the runoff intercepted by the intake (%Q). Use Figures 2, 3, and 4 in Section 4A-6.

Column 14: The runoff intercepted by the intake (Q_i). To find Q_i, multiply Q_g (Column 6) by %Q (Column 13).

Column 15: The runoff bypassing the intake (Q_b). To find Q_b, subtract Q_i (Column 14) from Q_g (Column 6). Add this amount to Q for the next intake downstream (See Column 6).

Column 16: Notes. This space can be used to describe the calculation results: for instance, whether the proposed intake is adequate.

The Pavement Drainage Design Sheet may be used for intakes in normal locations or for those located at the low points of sag vertical curves. For intakes located in sags, fill in most of the columns as with other intakes. The only differences are that the charts in Section 4A-6 must be used to find d (the depth of water) and w (the spread), and the drainage areas must be split to determine Q from both directions in the gutter at the intake. See "Intakes Located in Sags" in Section 4A-6.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Intake No.	Area acre	C	T_C min.	I_g in./hr.	Q_g cfs	S_L	S_X	Z/n	d ft.	w ft.	Intake Type	%Q	Q_i cfs	Q_b cfs	Notes
#1	0.50	0.3	8.2	4.1	0.62	0.01	0.03	2083	0.14	4.67	RA-40	94	0.58	0.04	OK
#2	0.90	0.4	10	4.0	0.04 1.44	0.006	0.03	2083	0.21	7.00	—	—	—	—	spread exceeds 6 ft.
#2	0.55	0.4	9	4.0	0.04 0.88	0.006	0.03	2083	0.18	6.00	RA-40	93	0.86	0.06	OK
#3	0.80	0.5	10	4.0	0.07 1.60	0.04	0.03	2083	0.15	5.00	RA-40 RA-43	56 89	 1.49	 0.18	too small use RA-43
#4	North 0.4	0.3	10	4.0	0.18 0.48	sag	0.03	—	0.18	6.00	RA-43	—	—	—	no more intakes required
	South 0.4	0.3	10	4.0	0.48	sag	0.03	—	—	—	—	—	—	—	

Figure 1: Sample of a completed drainage design worksheet (see Sample Problem).

Sample Problem for Pavement Drainage Design Sheet

The following example illustrates the use of a Pavement Drainage Design Sheet. The reader can follow this example in Figure 1.

The Pavement Drainage Design Sheet compiles results from procedures discussed throughout this chapter. Thus the example does not go through many of the calculations (i.e., Q = CIA, spread). For examples of these calculations, see the appropriate sections.

Given: The preliminary design of four intakes in series on a storm sewer line in Keokuk, Iowa.

Decide: Whether the preliminary intake locations are appropriate for the design storm (2-year).

Adjust: Intake locations or other design factors to correct the preliminary design.

Choose: The appropriate intake for each location.

Intake #1: $A = 0.50$ acres
$T_c = 8.2$ minutes
$C = 0.3$
$S_x = 0.03$
$S_L = 0.01$

Intake #2: $A = 0.90$ acres
$T_c = 10$ minutes
$C = 0.4$
$S_x = 0.03$
$S_L = 0.006$

Intake #3: $A = 0.45$ acres
$T_c = 10$ minutes
$C = 0.5$
$S_x = 0.03$
$S_L = 0.04$

Intake #4: $A = 0.40$ acres (water from south)
$T_c = 10$ minutes
$C = 0.3$
$S_x = 0.03$

$A = 0.40$ acres (water from north)
$T_c = 10$ minutes
$C = 0.3$
$S_x = 0.03$

1. Start with Intake #1 and fill in the blanks on the Pavement Drainage Design Sheet to decide whether the preliminary location is acceptable. Use procedures described in Sections 4A-4 and 4A-5 to calculate the needed quantities.

   a. Column 1: intake number = 1
   b. Column 2: drainage area (A) = 0.50 acres
   c. Column 3: C = 0.3
   d. Column 4: time of concentration (T_c) = 8.2 minutes
   e. Column 5: I (in inches per hour). Use Table 5, Section Code 09—Southeast (page 17 in Section 4A-4), with a recurrence interval (design frequency) of 2 years and a duration (T_c) of 8.2 minutes to get intensity (I) = 4.1 in./hr.
   f. Column 6: Q = CIA (in cubic feet per second, cfs). Multiply Column 2 by Column 3 by Column 5 to get Q = 0.62 cfs (runoff for a two-year storm).
   g. Column 7: longitudinal grade of the gutter (S_L) = 0.01
   h. Column 8: cross slope of the gutter (S_x) = 0.03
   i. Column 9: Z/n, where $Z = 1/S_x = 33.33$ and n (Manning's coefficient for pavement) = 0.016. Thus, Z/n = 2083. This quantity is used to find d in Column 10.
   j. Column 10: the depth of the water at the face of curb (d). Use Figure 2 in Section 4A-5 to get d = 0.14 feet.
   k. Column 11: the spread (w) = $Z \times d = 33.33 \times 0.14 = 4.67$ feet.

   Since the 4.67 feet of spread is less than the maximum allowable spread of 6.0 feet, the intake location is appropriate and no additional intakes are needed.

2. Since the location is correct, proceed to sizing the intake.

   a. Column 12: the intake type (based on length). Select the RA-40 intake as an initial choice.
   b. Column 13: the percentage of water intercepted by the intake (%Q). To find %Q, use the spread (w = 4.67 feet, Column 11), the longitudinal grade (S_L = 0.01, Column 7), and the pavement cross slope (S_x = 0.03, Column 8) in Figure 2 of Section 4A-6. Find Q/Q0 = 0.94. Thus, %Q = 94%.

   This percentage is greater than the 85% minimum required for a curb-opening type intake. The intake is therefore the correct one for the location.

3. Calculate how much water will be intercepted by this intake and how much will bypass it and be included in the calculations for the next intake.

   a. Column 14: the runoff intercepted by this intake (Q_i)

      $Q_i = Q_g$ (Column 6) x %Q (Column 13)

      = .58 cfs picked up by Intake #1

   b. Column 15: the runoff bypassing this intake (Q_b)

      $Q_b = Q_g$ (Column 6) – Q_i (Column14)

      = 0.04 cfs bypassing Intake #1 and added to Q_g (Cloumn 6 for Intake #2)

4. Follow the same procedure for Intake #2.

   a. Using the same procedure as in Step 1, find:
      d (Column 10) = 0.20 feet, and
      w (Column 11) = d × Z = 6.67 feet.

   w = spread = 6.67 feet. Assuming no gutter section, this exceeds the maximum lane encroachment of 6.00 feet. Consequently, the intake needs to be moved to reduce the drainage area.

   b. In trial #2, reduce the drainage area for Intake #2 by 0.35 acres and increase the drainage area for Intake #3 by 0.35 acres.
   c. Repeat the procedure for Intake #2 using A = 0.55 acres, to get:
      d = 0.18 feet
      w = 6.00 feet.

   Encroachment is now equal to the maximum allowable. Consequently, the intake location is now acceptable.

5. As in Step 2, size the intake.

   a. Select an RA-40 intake.
   b. Use Figure 2 in Section 4A-6 to get the percent of water picked up by the intake: %Q = 93%.

6. Follow the same procedure as in Step 3 to get:
   Q_i = 0.86 cfs
   Q_b = 0.07 cfs.

7. Repeat the procedures for Intake #3. Remember that 0.35 acres was added to drainage area #3 when drainage area #2 was adjusted. Therefore, use 0.80 acres for the adjusted drainage area in Column 2. Using the procedure in Step 1, we get:
   d = 0.15 feet
   w = 5.0 feet

8. Since the spread is less than 6 feet, select an intake.

   a. First try an RA-40 intake.
   b. Using Figure 2 in Section 4A-6, the percent of water picked up is 56%. This is less than the 85% minimum. We therefore try a larger intake.
   c. Try an RA-43 intake. Using Figure 3 in Section 4A-6, the percent of water picked up is 89%. Since 89% is greater than 85%, the RA-43 intake is the one to use.

9. Follow the same procedure as in Step 3 to get:
   Q_i = 1.49 cfs
   Q_b = 0.18 cfs

   Intake #4 is in a sag. We therefore follow the procedure in Section 4A-6 for "Intakes Located in Sags."

10. Fill in Columns 1 through 8 for each of the two drainage areas emptying into Intake #4. The procedure here is the same as with the other intakes except that there are two drainage areas and the gutter grade (Column 7) varies.

11. Check to see if the intake operates as an orifice or a weir, using Figure 6 in Section 4A-6.

    a. To begin, assume an RA-43 intake will be used. Since debris blocking the opening is an important concern at low points, RA-40 intakes are normally not used at such locations.
    b. Q is the total gutter flow from both sides of the intake. Therefore, add up the Q's from both directions:
       $Q = 0.48$ cfs + 0.48 cfs + 0.18 (Q_b from Intake #3) = 1.14 cfs
    c. Using Q in Figure 6, the minimum height of opening needed is 0.10 feet. The intake opening for an RA-43 is 0.5 feet. Thus, the intake operates as a weir and we can use Figure 7, 8, or 9 (Section 4A-6) to check the depth of the water at the intake.

12. Check the depth of water ponding at the intake.

    a. The RA-43 intake has w = 2 feet and a = 3 inches. Therefore, use Figure 7 (Section 4A-6) to check the depth (d_{max} in the figure).
    b. Using Q = 1.14 cfs (from Step 11b) and L = 8 feet (for RA-43 intake), the depth of water at the intake is less than 0.1 feet.

13. Check the depth of water flowing in the gutter as the water approaches the intake. In this step, we separately check the water from both directions. We also assume that the gutter flattens out to a 0.002 (0.2%) longitudinal grade as the water approaches the intake. Thus Figure 10 in Section 4A-6 is used to find d.

    a. Using Figure 10 for $Q_1 = 0.48$ cfs and $S_x = 0.03$, we get $d_1 = 0.16$ feet
    b. Using Figure 10 for $Q_2 = 0.66$ cfs and $S_x = 0.03$, we get $d_2 = 0.18$ feet

14. Calculate the spread of the water.

    a. Since d_2 (= 0.18 feet) is deeper than both d_1 (= 0.16 feet) and d (< 0.1 feet), the spread due to Q_2 is the only one we need to be concerned with.
    b. $d_2 = 0.18$ feet results in a spread of 6 feet for the pavement's 3% cross slope.

    No additional intakes will be needed at this location.

Often the designer can increase the capacity of an intake by depressing the intake and increasing the roadway's cross slope near the intake. Assuming an RA-43 intake (L = 8 feet) and a 3% cross slope are used, a total Q of 3 cfs would produce a depth (d) of 0.18 feet (using Figure 7 in Section 4A-6) and a spread (w) of 6 feet (using $w \times Sx = d$). However, if we increase the cross slope to 4%, a depth (d) of 0.24 feet and a flow (Q) of 4.5 cfs would be required to produce the 6-foot spread.

Similarly, increasing the cross slope would decrease the spread of water flowing in the gutter. Using a cross slope of 3% and assuming a maximum spread of 6 feet (d = 0.18 feet), Figure 10 in Section 4A-6 indicates that the maximum Q (in one direction) would be 0.6 feet. However, using a 4% cross slope, the maximum Q in one direction would be 1.0 cfs.

Since the Q flowing in the gutter is smaller than the Q for ponding at the intake (for either 3% or 4%), Q in the gutter is the controlling factor. Thus, by increasing the cross slope from 3% to 4%, we have nearly doubled the amount of water the intake can handle.

County ____________________

Project Number ____________________

Designer ____________________

Checked By ____________________

Date ____________________

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Intake No.	Area	C	T_c	I_g	Q_g	S_L	S_x	Z/n	d	w	Intake Type	%Q	Q_i	Q_b	Notes
	acre		min.	in./hr.	cfs				ft.	ft.			cfs	cfs	

Design of Storm Sewer Pipe

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This section discusses the last major step in designing a storm sewer system. In this step, the designer determines pipe length, pipe size, and the depths of intakes and utility accesses. These quantities can be determined only after deciding the intake and access locations, as described in the previous sections.

The design of each storm sewer system assumes one of the following types of hydraulic flow:

- Full pipes where the water is under pressure (pressure flow), or
- Partially full pipes where the water is not under pressure.

Most urban projects in Iowa are designed assuming the majority of the pipes will be partially full and only a few pipes will be near or at capacity. In designs with partially full pipes, the designer uses Design Worksheet 104-5 (sample shown in Figure 1). The process for completing the worksheet is discussed in this section. This section also discusses pressure flow situations, but only those situations where pressure flow occurs for one or just a few pipes. Finally, the section discusses checking a system for major (100-year) storms. Samples of typical design problems for each situation are provided at the end of the section.

Partially Full Pipes and Design Worksheet 104-5

Worksheet 104-5 is set up for the design of a storm sewer that flows partially full during the design storm (the design storm is that storm which is expected only once during the recurrence interval). The worksheet is used in a fashion similar to how the pavement drainage design worksheet (in Section 4A-7) was used. However, information in the first seventeen columns of Worksheet 104-5 can be transferred directly to the appropriate project tabulation.

Intakes and utility accesses are listed by number in Column 1 and information is given about the intake or access in subsequent columns (through Column 6). Columns 7 through 17 are used to describe the pipes that run between these intakes and accesses. Later columns of the worksheet are used to help calculate much of the information in Columns 1 through 17. The following descriptions of each column's contents will assist the designer in completing the worksheet:

Column 1: The number of the intake or utility access. This number should be the same as the number of the drainage area. If a utility access does not have a drainage area number, an unused number should be assigned.

Column 2: The location (station and distance left or right) of intakes and utility accesses. See *Standard Road Plans* for the location points on intakes and utility accesses. For example, the location of the RA-40 intake is the middle of the intake at the back of the curb.

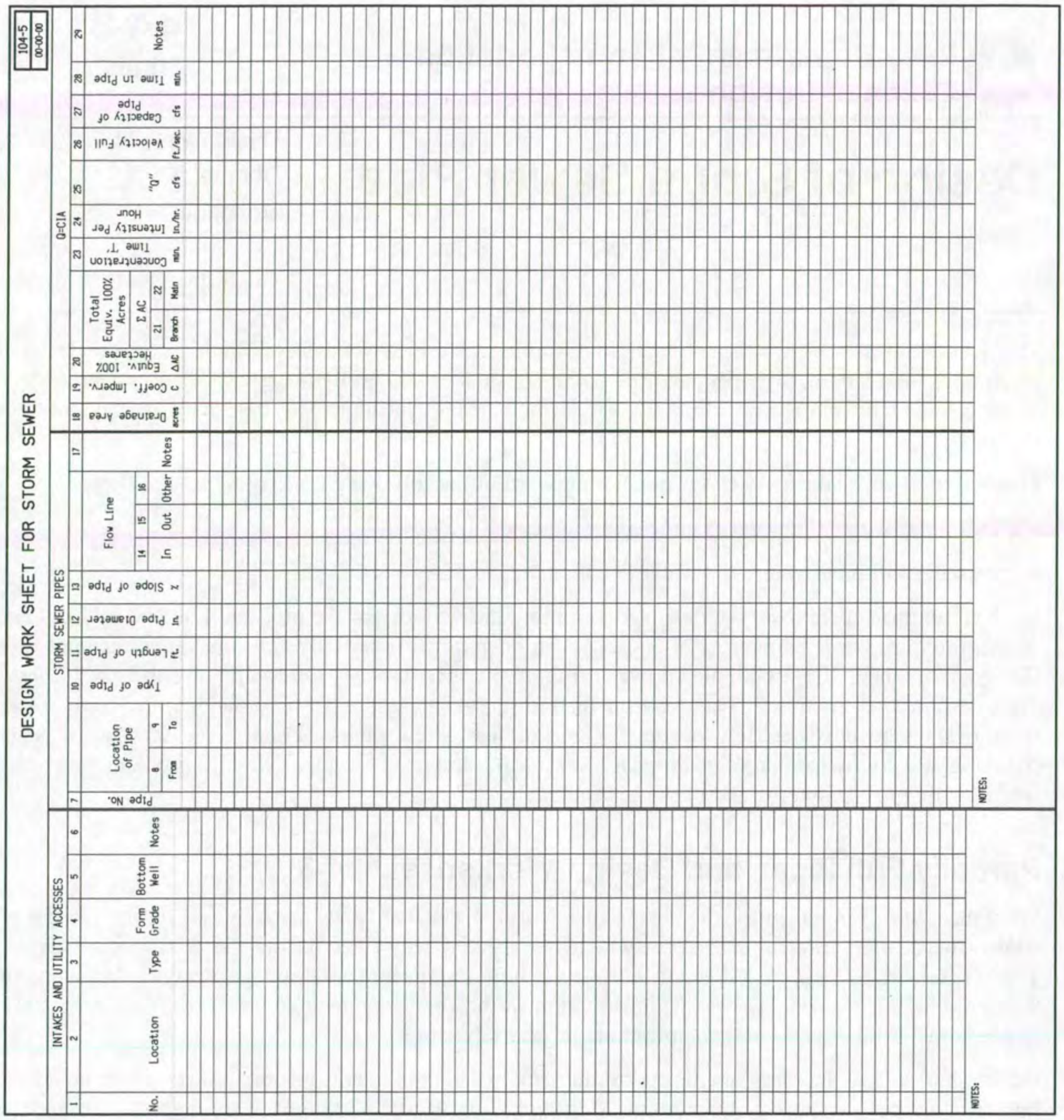


Figure 1: Sample of design worksheet 104-5 for storm sewer.

Column 3: The type of intake or utility access. See Section 4A-6 to determine the type (size) of the intake. Determine the type of utility access based on:

- Location (vehicular traffic or no vehicular traffic)
- Depth
- Size of intercepting storm sewer pipe

See Section 4A-3 for more information about choosing intake or utility accesses.

Column 4: The form (or gutter) grade. Determine from profile grades, staking sheets, or cross sections (see *Standard Road Plans).*

Column 5: The bottom of the well. This elevation is the top of the concrete slab base. Determine the bottom of the well by whichever of the following methods results in the lowest elevation:

- Determine the minimum acceptable depth of the intake or access by first checking in *Standard Road Plans* for that minimum depth (for the appropriate intake or access) and then subtracting the depth (approximately 4.0 feet) from the form grade (Column 4).
- Determine the intake or access depth needed for correct placement of the downstream pipe (the pipe containing water flowing out of the intake or access). To do this, first subtract the thickness of the downstream pipe from the flow line elevation at the pipe's inlet (see Figure 2). In most cases, the designer will need to wait until Column 14 on the worksheet ("flow line in") has been completed before completing this column. The thickness of the pipe is found on Standard Road Plan RF-1 (and in Table 1 of this section) using the pipe's type and diameter (Columns 10 and 12).

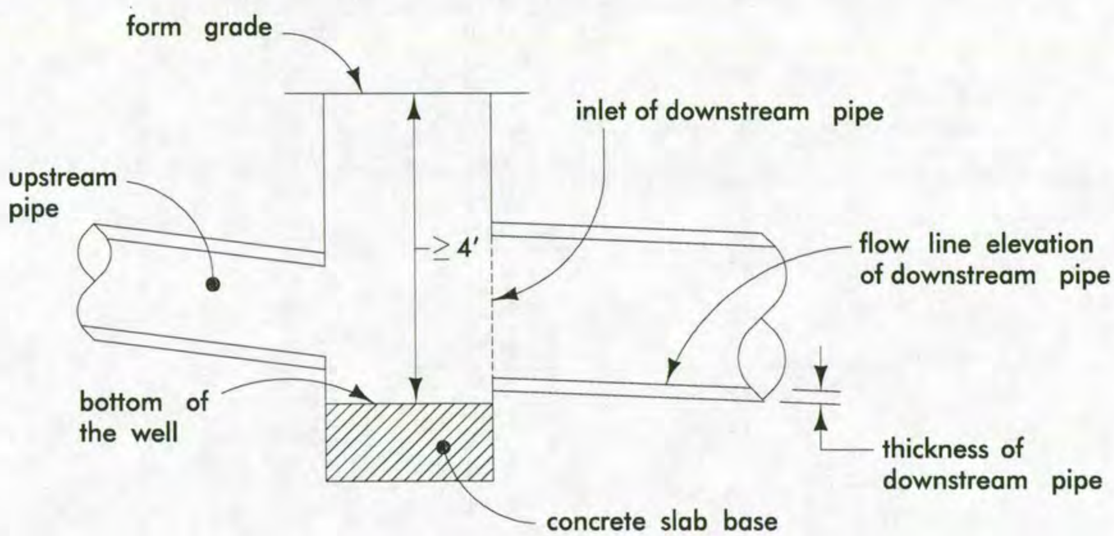


Figure 2: Depth of intake or utility access.

Generally, the bottom of the well will be below the elevation of the downstream pipe's flow line (at the inlet). This will create a sump, resulting in water ponding in the bottom of the well. Some cities will therefore require a fillet to be placed in the bottom of the well to eliminate ponding and to otherwise improve hydraulics. Other cities may want to retain the sump in the bottom of the well to trap silt. The designer should check with the city and add fillets when required. If a fillet is needed, then it needs to be indicated in the project tabulation (i.e., Tab 104-5A, notes column) or the contractor will probably request "extra" compensation.

Column 6: The number used to identify any special notes or instructions for the intake or utility access. Write the notes in the appropriate place below the tabulations.

Starting with Column 7, the worksheet is used to determine the pipes between the intakes and accesses listed in Columns 1 through 6.

Column 7: The pipe number (P-1, P-2, etc.). The pipe number should normally be the same as the intake or utility access it is draining. For example, the pipe that water flows into from Intake 2 would be called P-2. In some cases, more than one pipe must be associated with a single intake, and the numbering system must be supplemented with letters (P-2A, P-2B, etc.). See Section 4A-3 for more details.

Column 8: The location of the upstream end of the pipe. List the number of the intake or utility access upstream from the pipe ("from").

Column 9: The location of the downstream end of the pipe. List the number of the intake or utility access downstream from the pipe ("to"). If the pipe is identified by other than an intake or a utility access number, use a note in Column 17 to give a description and location (e.g., Outlet pipe into the side of RCB at Sta. 1+00, 20′ Rt).

Column 10: The strength (or class) of pipe used. Use 2000D pipe under roadways and 1500D pipe under shoulders. If the storm sewer is 9 feet or more under the pavement, see Standard Road Plans RF-32 and RF-33. A stronger pipe will be required under a railroad, especially if jacking the pipe is required. Check with the railroad to determine if they have special requirements. This contact may be made through the Office of Rail Transportation of the Iowa DOT. Table 1 shows the thickness of the pipe walls for each class at a variety of diameters.

Table 1: Thickness of pipe walls.

diameter of pipe (in)	2000D (ft)	1500D (ft)
15	0.19	0.17
18	0.21	0.19
21	0.23	0.21
24	0.25	0.22
27	0.27	0.23
30	0.29	0.25
33	0.31	0.27
36	0.33	0.28
42	0.38	0.31
48	0.42	0.35
54	0.46	0.39
60	0.50	0.42
66	0.54	0.46
72	0.58	0.50
84	0.67	0.58

Column 11: The length of the storm sewer pipe (measured in feet). The length of a storm sewer pipe is considered the horizontal distance from the inside of the upstream intake (or access) wall to the inside of the downstream intake (or access) wall (measured to the next whole foot). So if the distance is 17.4 feet, use 18 feet. When letdown structures (i.e., Typical 1401 or 1501) are used, calculate the exact distance, based on the slope of the pipe (Column 13). Round length to the nearest foot and adjust elbows and flow lines

accordingly. If concrete pipe and CMP (corrugated metal pipe) are used on the same run, tabulate them on separate lines on the tabulation form.

For Columns 12 and 13, make initial estimates of the pipe's diameter and slope as described below. However, the final decisions on these dimensions must wait until the discharge (Q) flowing through the pipe has been calculated in Column 25.

Column 12: The diameter of the storm sewer pipe (measured in inches). Try the smallest possible diameter as an initial estimate. The minimum diameter pipe used by the Iowa DOT is 15 inches. However, do not decrease the size of pipe as you move downstream. This would create a possible choke point where the pipe could get plugged.

On interstate and freeway projects, the FHWA requires a minimum of 24-inch diameter pipes.

Column 13: The slope of the storm sewer pipe. The slope should closely parallel the proposed contour of the ground. Especially on long runs, a grade that is too flat or too steep will either not have enough cover or will be too deep in the ground. Try the average slope of the ground as an initial estimate.

Column 14: The flow line (inside bottom of the pipe) at the upstream end of the pipe. This is the outlet elevation for the intake or access or, alternatively, the inlet elevation of the pipe. This elevation must be lower than the flow lines of any pipes entering the intake or access to avoid trapping water. To determine the flow line, check all flow lines and diameters for pipes entering the intake or access. The drop in elevation through the intake must be enough to maintain velocity and account for head losses. Ideally, the hydraulic grade line (top of the water when the pipe is partially full) should maintain a smooth slope and constant velocity throughout the storm sewer system. This will eliminate pressure flow, low velocities, water sitting in pipes, and silting.

If the outgoing pipe is the same diameter as the incoming pipes, drop the flow line at least 0.10 feet when passing through the intake or access. If the diameter of the outgoing pipe is larger than those of the incoming pipes, align the tops of the pipes, as shown in Figure 3. This will result in a small drop in the hydraulic gradient through the intake or access. On very flat grades, where aligning the tops of the pipes will make the slope of the downstream pipe too small to maintain the appropriate water velocity, try aligning lines that represent 80% of the pipes' diameters (0.8d). This is also shown in Figure 3. Keep in mind that these are the minimum elevation drops that can be used when elevation is a problem. On steeper grades, it may be necessary to make much larger drops in elevation through intakes or accesses to reduce the slopes of pipes and thereby keep the water's velocity under 15 ft./sec.

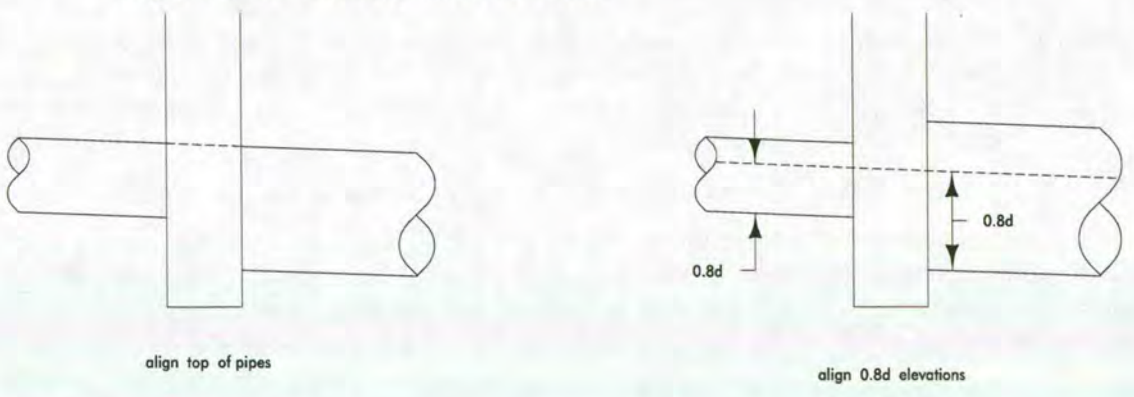


Figure 3: Pipe alignment.

Column 15: The flow line at the downstream end of the storm sewer pipe. This elevation is calculated by multiplying Column 11 (length) by Column 13 (slope) and subtracting the result from Column 14 (flow line in). Check the elevation of the next intake to make sure the pipe is not too shallow (at least 1 foot of cover is required).

Column 16: Other items in the system. Use this column when elbows or breaks in grade are used in storm sewer pipes. One example is a letdown structure. Explain the need for extra flow lines with a note in Column 17. Pipe profile sheets will also be helpful in showing such changes in elevation.

Column 17: The number used to identify any special notes or instructions for the storm sewer pipes. Write the notes in the appropriate place below the tabulations.

Beginning with Column 18, the rest of the chart is used to determine characteristics of the water flowing in the pipe. Many of these characteristics have already been determined using the Rational Method in Section 4A-4.

Column 18: The drainage area (measured in acres) which drains into the intake immediately upstream from the pipe (see Column 8, "From"). If a utility access that does not function as an intake is immediately upstream (no runoff is entering the storm sewer at this point), this column would be left blank (or 0.0 would be entered).

Column 19: The value of C (the runoff coefficient) assigned to the drainage area in Column 18. To simplify calculations, assign a C to the entire drainage area for the storm sewer system. See Section 4A-4 for more details.

Column 20: The equivalent acres (AC) for the drainage area in Column 18. Multiply Column 18 and Column 19.

Column 21: The equivalent acres from all branches that drain into the current pipe. Add all ACs from Column 20 that are upstream from this pipe.

Column 22: The total equivalent acres (AC), including AC from the current pipe.
Column 22 = Column 20 + Column 21.

Column 23: The time of concentration (T) for the pipe. This is the total time it takes for water to run from the most distant point in the pipe's drainage area (in terms of flow time) to the location of the pipe. This time includes T_c (overland flow), the time in gutters or drainage ditches, and the time in the pipes upstream from this pipe. At each intake and pipe junction, compare the time of concentration for the intake to the time of concentration for the upstream pipes at that point. Use whichever is the greatest. At the next intake or pipe junction downstream, add the time of water in this pipe and repeat the process. Repeat for each pipe in the system.

Column 24: The rainfall intensity, I. Using the time of concentration calculated in Column 23 as the duration and using the recurrence interval as the frequency, find the intensity (I) in Table 5 of Section 4A-4. See Section 4A-1 or Section 4A-4 for the appropriate recurrence interval for each situation.

Column 25: The rate of flow, Q, measured in cfs. Multiply Column 22 (AC) by Column 24 (I).

Now that we know the rate of flow in the pipe, we can use Figure 4 to check the initial estimates of pipe diameter and slope (Columns 12 and 13) to see if the pipe's capacity and the water's velocity are appropriate. Often this is a trial and error process, which is repeated until acceptable values of all quantities are found.

Column 26: The velocity of water in the pipe. Using Figure 4, find the water's velocity (diagonals from top left to bottom right) from the pipe's diameter (diagonals from bottom left to top right) and slope (horizontal lines). Adjust the diameter and slope until a velocity greater than 3 ft./sec. and less than 15 ft./sec is achieved.

Column 27: The capacity of the storm sewer pipe. Again using the pipe's diameter and slope in Figure 4, find the capacity (vertical lines). If the capacity is less than the rate of flow (Q) determined in Column 25, adjust the slope and pipe size until the capacity is greater than Q. Note that the adjustments must still leave the water's velocity within the parameters mentioned in Column 26.

Column 28: The amount of time the water is in the pipe (measured in minutes). Determine this time by dividing Column 11 (the length of the pipe) by Column 26 (the velocity) and then dividing the result by 60 to get the time in minutes.

After completing Column 28 for every pipe in the storm sewer system, Design Worksheet 104-5 should be finished. A sample problem illustrating this procedure is provided later in this section.

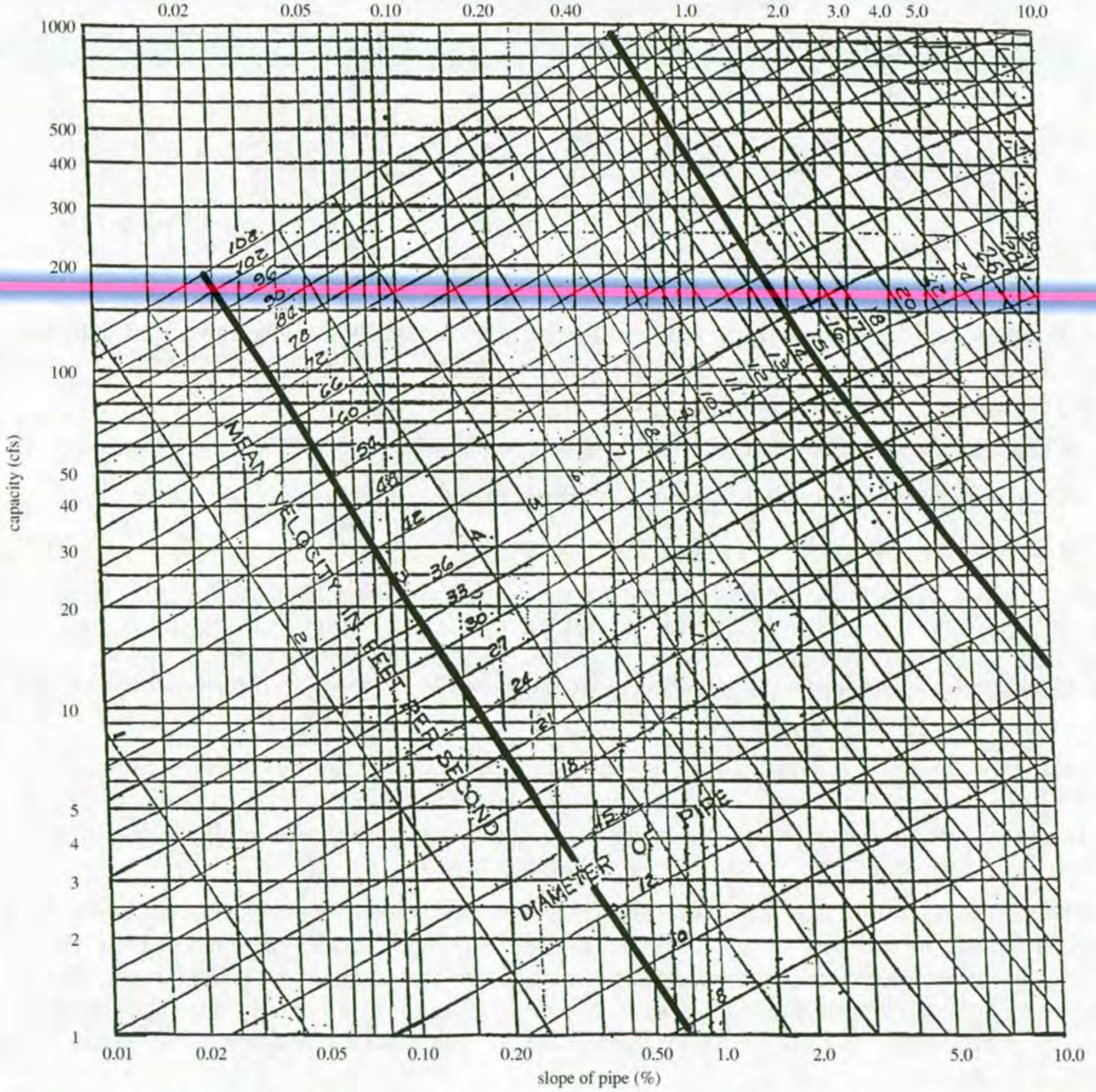


Figure 4: Capacity of circular storm sewers.

Generated using:

$$Q = VA$$
$$= \left(\frac{1.486}{n}\right)\left(R^{0.67}\right)\left(S^{0.5}\right)A$$

where:

Q = capacity (discharge if pipe is full)

V = velocity

A = cross sectional area of the pipe

R = hydraulic radius = $\frac{\text{cross sectional area of flow}}{\text{wetted perimeter}}$

S = slope of pipe

n = Manning's coefficient = 0.013

Pressure Flow Design

Pressure flow designs generally require many more calculations and allow much less room for error than non-pressure designs. Designers should therefore try to avoid pressure flows. Nonetheless, in the following situations, it may be necessary to consider pressure flow for parts of the storm sewer system:

- When the locations of other utilities restrict the size or location of a storm sewer pipe
- When pressure flow for a short distance is more economical than maintaining a partially full pipe
- When checking the system for major (100-year) storms

In any of these cases, it is important to understand the dynamics of pressure flow presented in this section. However, if water backs up for several pipes in a row during a design storm (causing the hydraulic grade line to be higher than the tops of the pipes), a pressure flow design will be necessary for the total system. If this is the case, see other design manuals for more information on the design of pressure flow storm sewer systems.

When a pressure flow situation arises, the two variables affected by the pressure are the water's velocity and the capacity of the pipe. These variables are affected because rather than using the slope of the actual pipe to determine them (in Figure 4), the designer instead uses the hydraulic gradient (the slope of the hydraulic grade line, shown in Figure 5 below).

The hydraulic grade line coincides with the water's surface in open channel flow and partially full pipes. However, in pressure flow, the hydraulic grade line represents the height to which water will rise in a piezometer at any point along a pipe. In storm sewer design, assume that intake wells act as piezometers (see Figure 5), showing pressure at the points in the storm sewer system where they are located. The pressure the intake wells measure is the pressure available to force the water through the storm sewer pipe.

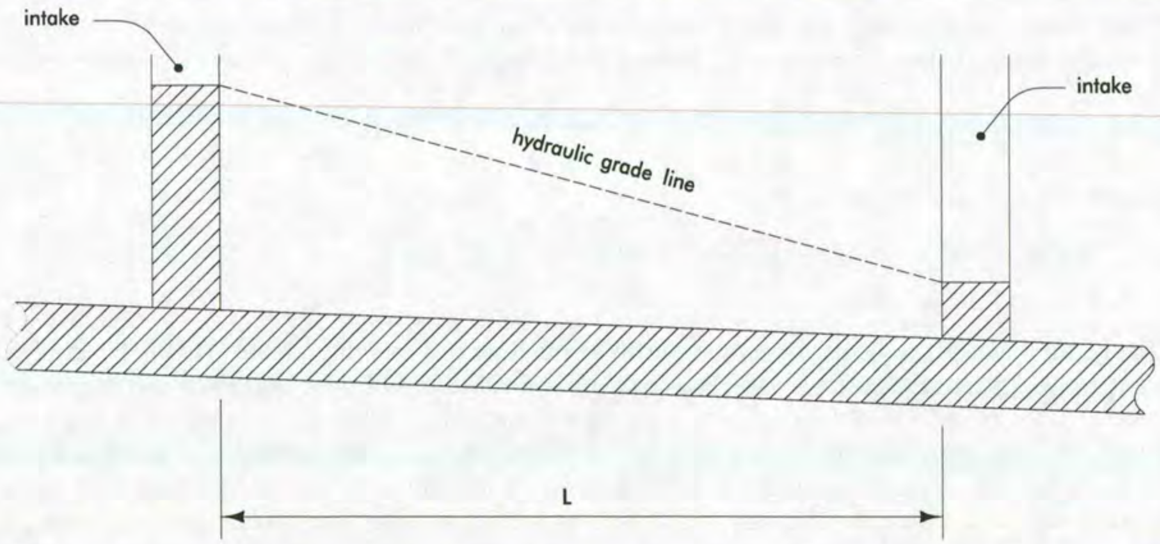


Figure 5: Intakes acting as piezometers.

To calculate the hydraulic gradient, subtract the water's elevation (measured from the baseline) in the downstream intake well from its elevation in the upstream intake well. Then divide by the length of the pipe:

$$\text{hydraulic gradient} = \frac{\text{elev}_{\text{upstream}} - \text{elev}_{\text{downstream}}}{\text{length}}$$

Using the hydraulic gradient in place of the pipe's slope, the designer can then determine the water's velocity and the pipe's capacity using Figure 4. The water's velocity for a design storm should be within the limits discussed earlier (3–15 ft./sec.). The pipe's capacity must be able to handle the design discharge (Q) without overflowing the intakes, and thus causing water to run out into the gutter.

Two sample problems illustrating these calculations for pressure flow situations are provided later in this section.

Check for Major Storms

One of the last procedures in designing a storm sewer system is the major storm check. Most structures in the system are designed for relatively minor storms with frequencies of ten years or less. However, the designer must also consider how the system will function when major storms occur (recurrence intervals of 50 or 100 years). While we don't expect the storm sewer to function normally during a major storm, it should function well enough to prevent serious property damage and dangerous situations for pedestrians and motorists.

The designer uses a 100-year recurrence interval to check for major storms. Three overriding concerns dominate the major storm check:

- Ponding on primary highways may not exceed 1 foot.
- Neither residential dwellings nor public, commercial, or industrial buildings may be inundated at the ground line, unless they are flood-proofed.
- Large flows of water may not be created in areas where such flows are particularly hazardous.

To avoid these situations, the designer may need to install drainage structures not called for by the system's normal recurrence interval.

When checking for major storms, the designer tries to decide how the excess water will be stored and how it will reach the storm sewer's outlet (river, lake, etc). Factors influencing these decisions include:

- Ponding at low points
- How much water bypasses intakes
- Capacity of the storm sewer (under pressure flow)
- Overland flow of water

One of the biggest problems for major storms is ponding in low-lying areas. This is because water that cannot get into the storm sewer tends to flow in roadways and over land into such areas. Often, the capacities of individual intakes or of the entire storm sewer system must therefore be increased in low-lying areas to accommodate major storms. When checking the capacities of these intakes and storm sewer, the designer assumes that the intake is 1 foot under water since 1 foot is the greatest depth permitted on primary highways. Figure 6 in Section 4A-6 is used to calculate the water depth since any intake would be operating as an orifice in this situation. The designer can also assume that most pipes in the storm sewer are under pressure flow. To determine the storm sewer pipe's capacity, calculate the hydraulic gradient from the intake that is 1 foot under water to the outlet (see Pressure Flow Sample Problem #2 later in this section).

Be certain to decide whether water will flow over land before it gets unacceptably deep. Check the capacity of the outlet storm sewer when the intake is under water to determine how much water will be carried by the storm sewer when the intake is submerged. When water flows over land, use open channel flow to determine the depth of water in drainage channels, ditches, or low areas.

The storm sewer's outlet pipe may also be under water during major storms. High-water elevations for rivers and creeks can be obtained from the Survey or Preliminary Bridge Sections to allow the capacity of the outlet to be calculated when it is submerged. If the outlet goes through a levee, then a flood gate or flap gate may be necessary. If the gate is closed, storage must be available to hold water until it can be pumped or until the gate can be opened.

Other methods of checking for major storms are available. Computer programs have been developed and are available for use. One such program is the HYDRAIN computer system. HYDRAIN is a good way to check for major storms because it will alert the designer when pressure flow occurs. It can also be used to design a system for pressure flow under normal design conditions. Use the HYDRA program in the HYDRAIN user manual.

A sample problem for a major storm check is provided later in this section. Forms for pressure flow design and examples of such designs can also be found in other design manuals. Form 104-5 in this manual was developed for partially full designs only. Do not use it for pressure flow, except over short distances or in the major storm check.

Sample Problem for Design Form 104-5

In this problem, complete Worksheet 104-5 in order to decide which pipes are appropriate for the intakes that were chosen in the sample problem of Section 4A-7. The results shown in Figure 6 are meant to accompany this sample problem, showing what we arrive at for each of the four intakes. The following information about the drainage area and pavement slopes for each intake was given for the earlier problem.

Intake #1: $A = 0.50$ acres
$T_c = 8.2$ minutes
$C = 0.3$
$S_x = 0.03$
$S_L = 0.01$

Intake #2: $A = 0.90$ acres
$T_c = 10$ minutes
$C = 0.4$
$S_x = 0.03$
$S_L = 0.006$

Intake #3: $A = 0.45$ acres
$T_c = 10$ minutes
$C = 0.5$
$S_x = 0.03$
$S_L = 0.04$

Intake #4: $A = 0.40$ acres (water from south)
$T_c = 10$ minutes
$C = 0.3$
$S_x = 0.03$

$A = 0.40$ acres (water from north)
$T_c = 10$ minutes
$C = 0.3$
$S_x = 0.03$

After solving the problem in Section 4A-7, we now also know the following information. The form (gutter) grade was determined from the profile grade, the staking sheets, and the cross sections for the project.

Intake Number	Intake Type	Intake Location	Form Grade
1	RA-40	Sta. 1+00, 15.5′ Lt	200.00
2	RA-40	Sta. 3+50, 15.5′ Lt	198.12
3	RA-43	Sta. 6+25, 15.5′ Lt	192.46
4	RA-43	Sta. 8+00, 15.5′ Lt	187.78

Additionally, an 8-inch diameter water main is located at Station 7+90. The top of the pipe has an elevation of 185.60.

Intake #1 and Pipe P-1

Begin the problem by filling out information we already know about the first intake and pipe.

Column 1: Intake # = 1

Column 2: Location = 1+00, 15.5′ Lt

Column 3: Type = RA-40

Column 4: Form Grade = 200.00

Column 5: For this intake, assume that the minimum intake depth is well below the flow line of the pipe. Thus:

$$\text{bottom of well} = \text{form grade} - 4.0 = 196.00$$

Column 6: There are no special notes for this intake.

Columns 7,8, & 9: We know from our preliminary design that pipe P-1 is between Intakes 1 and 2.

Column 10: For the purpose of this example, assume that this pipe is not under a roadway and that it is buried less than 9 feet underground. Thus, use a 1500D pipe.

Column 11: Calculate the length of pipe P-1 by subtracting the location of Intake 1 (Station 1+00) from the location of Intake 2 (Station 3+50). Then subtract the inside dimensions of the intakes (location point to inside dimension of wall).

$$[(3+50)-(1+00)]-(2\text{ ft}+2\text{ ft}) = 250\text{ ft} - 4\text{ ft} = 246\text{ ft}$$

Column 12: 15-inch storm sewer pipe is the minimum size allowable, so use 15 inches as a first estimate.

Column 13: Estimate a slope for the pipe by calculating the average ground slope between intakes. Subtract the form grades for the intakes (Column 4) and divide by the length of the pipe (Column 11) to get the average ground slope:

$$\frac{200.00-198.12}{246} = 0.76\%$$

Use a slope of 0.8% for pipe 1.

Column 14:

$$\begin{aligned}\text{Flow line in} &= \text{bottom of the well} + \text{pipe thickness}\\ &= 196.00\text{ (from Column 5)} + 0.17\text{ (from Table 1)}\\ &= 196.17\end{aligned}$$

Column 15:

$$\begin{aligned}\text{Flow line out} &= \text{flow line in} - (\text{length of pipe} \times \text{slope})\\ &= 196.17 - (246 \times 0.008)\\ &= 194.20\end{aligned}$$

Column 16 & 17: No special situations exist with this pipe which call for the use of these columns.

Column 18: Drainage area (A) = 0.5 acres

For Column 19, the designer may wish to use the runoff coefficient (C) calculated for the individual intake's drainage area. However, in this case, calculate an average value of C for all four intakes (using the method described in Section 4A-4). This method will result in the same overall value for Q, but it may throw off Q for the individual intakes.

Column 19:

$$\text{Ave. C Value} = \frac{(0.5x0.3)+(0.9x0.4)+(0.45x0.5)+(0.8x0.3)}{0.5+0.9+0.45+0.8}$$

$$= \frac{0.975}{2.65} = 0.367 \text{ (use 0.4)}$$

Column 20: $\Delta AC = 0.5 \times 0.4 = 0.20$

Column 21: Since this is the first intake in the system, the equivalent acres for previous intakes is zero.

Column 22: $\Sigma AC = \Delta AC = 0.20$

Column 23: $T = T_c = 8.2$ minutes (from Figure 1 Section 4A-7)

Column 24: Calculate intensity (I) as shown in Section 4A-4. From Table 5 of Section 4A-4 and using a recurrence interval of 10 years with a storm duration (T_c) of 8.2 minutes and interpolating, I = 0.83in/8.2min. x 60 min/h = 6.1 in./hr.

DESIGN WORK SHEET FOR STORM SEWER

104-5
00-00-00

INTAKES AND UTILITY ACCESSES

1 No.	2 Location	3 Type	4 Form Grade	5 Bottom Well	6 Notes
1	1+00, 15.5' Lt.	RA-40	200.00	196.00	
2	3+50, 15.5' Lt.	RA-40	198.12	193.91	
3	6+25, 15.5' Lt.	RA-43	192.46	188.18	
4	8+00, 15.5' Lt.	RA-43	187.78	182.63	

NOTES:

STORM SEWER PIPES / **Q=CIA**

7 Pipe No.	Location of Pipe 8 From	9 To	10 Type of Pipe	11 Length of Pipe (ft.)	12 Pipe Diameter (in.)	13 Slope of Pipe (%)	Flow Line 14 In	15 Out	16 Other	17 Notes	18 Drainage Area (acres)	19 Coeff. Imperv. (C)	20 Equiv. 100% Acres (ΔAC)	Total Equiv. 100% Acres Σ AC 21 Branch	22 Main	23 Concentration Time 'T' (min.)	24 Intensity (in./hr.)	25 "Q" (cfs)	26 Velocity Full (ft./sec.)	27 Capacity of Pipe (cfs)	28 Time in Pipe (min.)	29 Notes
P-1	1	2	1500D	246	15	0.80	196.17	194.20			0.50	0.4	0.20	-	0.20	8.2	6.1	1.22	4.8	6.0	0.9	
P-2	2	3	2000D	269	15	2.10	194.10	188.45			0.90	0.4	0.36	0.20	0.56	10.0	5.9	3.30	7.8	9.5	0.6	
P-3	3	4	1500D	167	15	3.17	188.35	183.05		1	0.45	0.4	0.18	0.56	0.74	10.6	5.7	4.29	9.8	11.5	0.3	
P-4	4	Outlet	1500D	100	15	0.55	182.95	182.40		2	0.80	0.4	0.32	0.74	1.06	10.9	5.7	6.04	4.5	5.5	0.4	Too Small
						0.40	182.80												4.2	7.5	0.4	OK

NOTES:

1. Existing 8" water main at Sta. 7+90, elevation of 185.60
2. Outlet at existing utility access, Sta. 8+25, 117' Lt., elevation of 182.40

Figure 6: Completed design worksheet for sample problem.

Column 25: $Q = CIA = 0.20 \times 6.1 = 1.22$ cfs

Now check the estimates of the pipe's diameter and slope by using Figure 4 to determine the water velocity and pipe capacity.

Column 26: Velocity = 4.8 ft./sec.

Column 27: Capacity = 6 cfs

Since the capacity is greater than Q and the velocity is between 3 and 15 ft./sec., the estimates of diameter and slope are acceptable. Consequently, the estimates for the pipe's slope and diameter (Columns 12 and 13) will be used.

Column 28: Calculate the time in the pipe (in minutes):

$$\text{Time (in min.)} = \frac{\text{Length}}{(60)(\text{velocity})}$$

$$\text{Time (in min.)} = \frac{246}{(60)(4.8)} = 0.9 \text{ minutes}$$

Intake #2 and Pipe P-2

Next, repeat the calculations for Intake and Pipe P-2. For the remaining intakes and pipes, describe only those entries where confusion might arise because the procedure is different than for #1.

Columns 1–4: See procedure for Intake #1.

Column 5: For this intake, assume that the downstream pipe's inlet is lower than four feet. Wait until the pipe's flow line is determined before trying to calculate Column 5.

Columns 6–9: See procedure for Intake/Pipe #1.

Column 10: Pipe #2 (P-2) runs under a street. Therefore use a 2000D pipe.

Column 11: See procedure for Pipe #1 (P-1).

Column 12: Estimate pipe's diameter at 15 inches since P-1 was 15 inches.

Column 13: See procedure for P-1.

Column 14: The flow line of P-1 at Intake 2 is 194.20 feet (Column 15 for P-1). Assuming a drop of 0.10 feet through Intake 2, the flow line in for P-2 will be 194.10 feet.

Columns 15–17: See procedure for P-1.

Now that the flow line has been calculated, return to Column 5 and determine the bottom of the well for Intake #2.

$$\begin{aligned}\text{bottom of well} &= \text{flow line in (P-1, Column 14)} - \text{thickness of pipe}\\ &= 194.10 - 0.19\\ &= 193.91 \text{ feet}\end{aligned}$$

$$\begin{aligned}\text{depth of intake} &= 198.12 \text{ (form grade)} - 193.91 \text{ (bottom of well)}\\ &= 4.21 \text{ feet}\end{aligned}$$

This is greater than the 4-foot minimum depth. 193.91 is therefore the correct value.

Column 18–20: See procedure for P-1. C (= 0.4) in Column 19 is the average for all four intakes.

Column 21: Equivalent acres = ΣAC (for P-1)

Column 22:

$$\begin{aligned}\Sigma AC &= \Sigma AC \text{ (for P-1)} + \Delta AC \text{ (for P-2)}\\ &= 0.20 + 0.36 = 0.56\end{aligned}$$

Column 23: T (P-2) = T_c(Intake #2) or T_c (Intake #1) + time in P-1, whichever is longer.

$$T_c \text{ (Intake \#2)} = 10 \text{ minutes}$$
$$T_c \text{ (Intake \#1)} = 8.2 \text{ minutes}$$
$$\text{Time in P-1 (Column 18)} = 0.9 \text{ minutes}$$
$$8.2 \text{ minutes} + 0.9 \text{ minutes} = 9.1 \text{ minutes}$$

Use the larger number, T (P-2) = 10 minutes.

Columns 24–28: See procedure for P-1.

Intake #3 and Pipe P-3

Repeat the calculations for Intake and Pipe 3.

Columns 1–9: See procedure for Intake/Pipe #2.

Column 10: P-3 is not under a roadway, and it is buried less than 9 feet underground. Thus, use a 1500D pipe.

Column 11: See procedure for P-2.

Column 12: Estimate pipe's diameter at 15 inches since P-2 was 15 inches.

Columns 13–14: The average slope of the ground = (192.46 - 187.78) / 167 = 2.8%. However, an 8-inch water main is located at Station 7+90, at an elevation of 185.60 (top of main). The presence of this main prevents the storm sewer pipe from having a 2.8% slope. Check to see whether the storm sewer should go over or under the water main:

1. Decide whether placing the storm sewer above the main will allow for the required 1 foot of cover. To do this, take the elevation of the top of the water main (185.60 ft.) and add the diameter of the storm sewer pipe (1.25 feet) and the thickness of the pipe's walls (2 × 0.17):

   Top of Storm Sewer = 185.60 + 1.25 + 2(0.17) = 187.19 feet

   Since the form grade at Station 8+00 is 187.78 due to the sag in the vertical curve, 1 foot of cover would not be maintained if the storm sewer were placed above the water main. The storm sewer must therefore be placed under the water main.

2. Since the storm sewer must go under the water main, determine the minimum elevation at which it can be placed. To do this, take the elevation of the 8-inch main's top (185.60 feet) and subtract 0.67 feet (the 8-inch diameter) and 0.10 feet (the thickness of the water main's walls). Then subtract 1.25 feet (the 15-inch diameter of the storm sewer) and 0.34 feet (the thickness of the pipe's walls):

$$\text{Storm sewer elevation} = 185.60 - (0.67 + 0.10 + 1.25 + 0.34)$$
$$= 183.24 \text{ feet}$$

   This is the highest elevation at which the storm sewer can be placed at Station 7+90.

3. Using this maximum elevation, determine the slope of the pipe. The slope is the difference in elevation between the "flow line in" (Column 14) and the maximum elevation under the water main. The "flow line in" is calculated by subtracting 0.10 from the "flow line out" of P-2:

Flow line in = 188.45 – 0.10 = 188.35

Using this elevation, the slope of the pipe between Intake #3 and the water main can be determined:

Pipe length = [(7+90)-(6+25)] – 4 (from Intake #3) = 161 feet

$$\text{Slope} = \frac{(188.35 - 183.24)}{161} = 3.17\%$$

Column 15:

Flow line out = Column 14 – (Column 11 x Column 13)

= 188.35 – (167 x 3.17%) = 183.05

Columns 16–17: See procedure for P-2. Add in note to describe water main location and elevation.

Columns 18–20: See procedure for P-2.

Column 21: Equivalent acres = ΣAC (for P-2) = 0.56

Column 22: Add Column 20 (= 0.18) to Column 21 (= 0.56) to get ΣAC = 0.74

Column 23: T (P-3) = Tc (Intake #3) *or* Tc (Intake #2) + time in P-2, whichever is longer.

$$T_c(\text{Intake \#3}) = 10 \text{ minutes}$$
$$T_c(\text{Intake \#2}) + \text{time in P-2} = 10 + 0.6 = 10.6 \text{ minutes}$$
$$T = \text{the longer time} = 10.6 \text{ minutes}$$

Columns 24–28: See procedure for P-2.

Intake #4 and Pipe P-4

Repeat the calculations for Intake and Pipe #4. P-4 is different from the other pipes because the downstream end of the pipe is the storm sewer's outlet. The outlet's elevation is set at 182.40 feet. Consequently, the pipe's slope is constrained by the outlet's elevation, the downstream flow line of P-3, and the slope of the ground above. Clearly, when using Figure 4 for this pipe, the designer has little room to manipulate the slope and must therefore rely primarily on changing pipe size.

Columns 1–10: See procedure for Intake/Pipe #3.

Column 11: The outlet is located 25 feet forward and 101.5 feet to the left of Intake #4. Taking into account the inside dimensions of the intake and the dimensions of the outlet, a 100-foot pipe will be needed.

Column 12: Try a 15-inch storm sewer pipe.

Column 13: Calculate slope using the outlet elevation (182.40 feet) and the flow line in (182.95 feet):

$$\frac{182.95 - 182.40}{100} = 0.55\%$$

Column 14: Subtract 0.10 from Column 15 for P-3:

183.05 – 0.10 = 182.95 feet

Column 15: Outlet elevation is 182.40 feet.

Column 16: Leave blank.

Column 17: Add note to describe outlet location and elevation.

Columns 18–25: See procedure for P-2.

Columns 26–27: Use Figure 4 to try to find a capacity for a 15-inch storm sewer pipe that will result in an acceptable velocity (3–15 ft./sec.).

The maximum capacity for a 15-inch pipe is 5.5 cfs. Since Q is 6.04 cfs (Column 25), the 15-inch pipe is too small. Therefore try an 18-inch pipe in Column 12 and recalculate the quantities affected by this change.

Column 14: Find the difference in the diameters of P-3 and P-4 and subtract this difference from the flow line out for P-3:

$$183.05 - (1.50 - 1.25) = 182.80$$

Column 13: Calculate the new slope:

$$\frac{182.80 - 182.40}{100} = 0.40\%$$

Column 27: Using Figure 4, find the capacity for an 18-inch pipe on 0.40% slope to be 7.5 cfs. Use the 18-inch diameter pipe.

This has been a simple storm sewer design. On most design problems, there are existing utilities, flat grades, clearance problems, shallow intakes, and other difficulties. Use sound engineering judgment in each of these cases to come up with a good design.

Pressure Flow Sample Problems

Sample Problem 1

Given: An existing storm sewer pipe (shown in Figure 7) is in good condition, and because of its location, could potentially be used in a new storm sewer. The relevant dimensions for the pipe are:

Length = 300 feet

Diameter = 24 inches

Slope = 1.0%

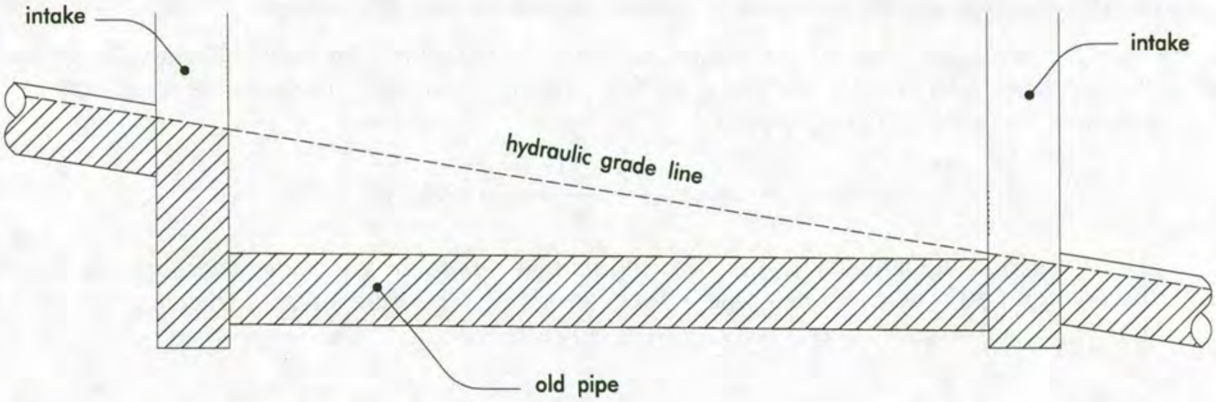


Figure 7: Old storm sewer pipe (Sample Problem 1).

Problem: Can the pipe actually be used in the new storm sewer, which has a design discharge of Q = 40 cfs at the upstream intake?

To decide whether the pipe can be used, first check its capacity and the velocity of the water when the pipe is less than full (no pressure).

1. Use the pipe's diameter and slope in Figure 4 to get a capacity of 24 cfs and a velocity of 7.3 ft./sec.

The water's velocity is acceptable, but the partially full capacity is below the design discharge for the new storm sewer. Rather than discarding the pipe, check to see if it can handle the discharge under pressure flow.

2. Returning to Figure 4, use the required capacity (Q = 40 cfs) to determine that the needed hydraulic gradient (rather than slope) for a 24-inch pipe is 3.0%. Be certain that the water's velocity remains between 3 and 15 ft./sec.
3. Calculate the elevation of water that will need to back up in the upstream intake to create the needed hydraulic gradient.
    a. As Figure 7 shows, the water's elevation in the downstream intake will be at or below the top of the pipe (assuming the next pipe does not have pressure flow). Thus, use the top of the pipe as the water elevation in the downstream intake.
    b. Multiply the length of the pipe (300 feet) and the hydraulic gradient (3.0%) to get 9.0 feet. Add the 9.0 feet to the top of the pipe at the outlet of the downstream intake. This is the elevation to which the water in the upstream intake will rise to carry the 40 cfs. If this elevation is above the intake form grade, the pipe will not have the capacity to carry 40 cfs and therefore will need to be replaced.

Sample Problem 2

Given: The outlet of a storm sewer goes under water when checking the system for a major storm (the high water elevation for the river, lake, etc. can be determined from survey information or preliminary bridge plans). The relevant factors already determined for the system are:

Q (discharge at upstream intake) = 50 cfs

Pipe length = 300 feet

Elevation of upstream pipe's outlet = 17 feet

High water elevation = 16 feet

Problem: What diameter will the pipe need to be to keep water from backing up into the previous pipe upstream?

As shown in Figure 8, the elevations of all parts of the pipe are below the high water elevation for the river. The designer can therefore assume pressure flow in all parts of the pipe.

1. Find the hydraulic gradient for the pipe by first subtracting the high water elevation for the river from the elevation of the water emerging from the upstream pipe. Then, divide the difference in elevation by the length of the pipe.

$$\text{hydraulic gradient} = \frac{17\,\text{ft} - 16\,\text{ft}}{300\,\text{ft}} = 0.0033 = 0.33\%$$

2. Using the hydraulic gradient as the slope in Figure 4, determine a pipe diameter that will be able to drain Q = 50 cfs. A 42-inch pipe will be needed. In choosing a pipe diameter, make certain that under pressure the water's velocity stays between 3 and 15 ft./sec. on the chart.

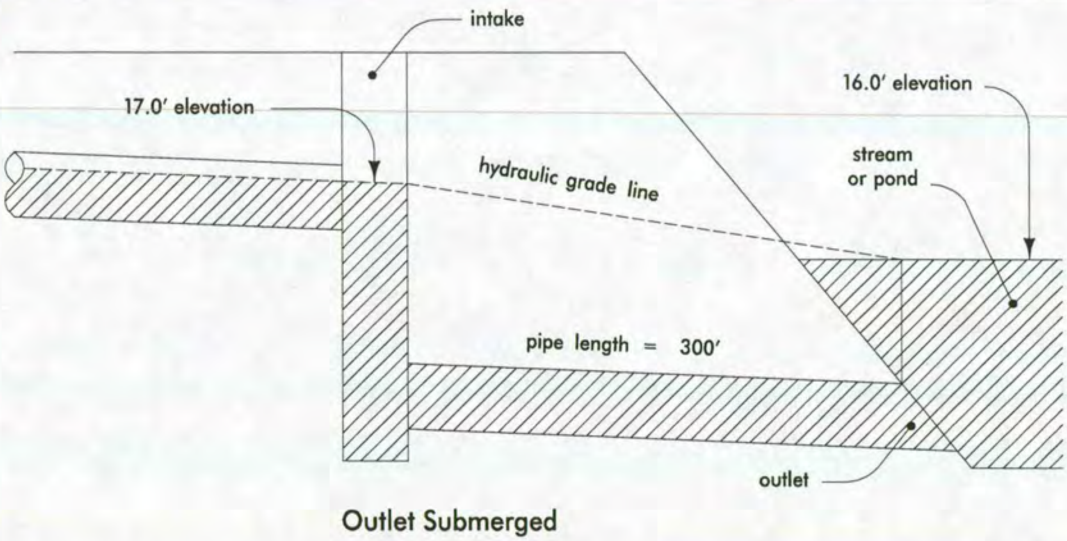


Figure 8: Storm sewer pipe with outlet submerged (Sample Problem 2).

Sample Problem for Major Storm Check

Try a 100-year storm check on the sample problem used earlier. In this example, all the water that bypasses Intakes 1, 2, and 3 will run downhill to the sag at Station 8+00 where Intake 4 is located. The critical point is therefore Station 8+00.

Step 1 in the check is to calculate Q for a 100-year storm at P-4 (Columns 18–25 on the design worksheet). Columns 18–23 are not changed by assuming this different design storm.

Column 24: Calculate intensity (I) as shown in Section 4A-4. Using a recurrence interval of 100 years and a storm duration (T_c) of 10.9 minutes, I = 9.2 in./hr.

Column 25: Q = CIA = 1.06 × 9.2 = 9.8 cfs.

Since 9.8 cfs is greater than the capacity (Column 27) of 7.5 cfs, we have pressure flow.

Figure 4 shows that it will take a 0.80% slope to carry 9.8 cfs. To calculate the height of water in Intake 4, take the flow line out (Column 15) and add the diameter of the pipe plus the length (Column 11) times the slope (0.80%):

$$182.40+1.50+(100x0.80) = 184.70$$

Since 184.70 is less than 187.78 (Column 4 - form grade of Intake 4), Intake 4 will not overflow. P-4 will handle the 100-year storm if the outlet is adequate.

Step 2 is to check the inlet capacity of Intake 4. Figure 9 in Section 4A-6 shows that water must be 0.44 feet deep to handle 9.8 cfs. Since the maximum allowable depth of water on the pavement is 1.0 foot, Intake 4 can handle all the water in the drainage area.

Step 3 is to check overland flow. Since water has not run over the top of the curb in this example (water depth = 0.4 feet), we do not need to check overland flow.

Cost Estimates and City Agreements

Originally Issued: 09-01-95

Prior to the letting of a project, the designer will need to prepare cost estimates and provide drainage information for the city agreement. This section provides details about what information is needed, when it is needed, and to whom the information must be provided.

Cost Estimates

When the public hearing on a project is held, the storm sewer design should be sufficiently complete to provide a cost estimate to the city. Especially on large projects, the city's cost will be quite high. The city will therefore need the estimated costs to secure the money for the project from the city budget.

Costs are divided into three categories: (1) 100 percent state costs, (2) 100 percent city costs, and (3) participating costs. These costs are allocated according to the following:

100 percent state costs:

- All transverse storm sewer under mainline pavement on primary highways
- All intakes on mainline pavement on primary highways
- All drainage structures which carry 100 percent state right-of-way water, including storm sewer pipe and intakes

100 percent city costs:

- All intakes that pick up 100 percent city water (areas outside state right-of-way)
- All storm sewers which carry 100 percent city water
- All additional work requested by the city on city storm sewer

Participating costs:

- Longitudinal storm sewer (except when water is 100% from state right-of-way)
- Utility accesses on longitudinal storm sewer (except when water is 100% from state right-of-way)
- Outfall storm sewer (sewer used to drain water from the project)
- Utility accesses on outfall storm sewer
- All intakes (except mainline pavement intakes) which pick up both city and state right-of-way water

Generally, participating costs are for appurtenances that carry water from both state right-of-way and city property. The requirements for assigning costs are found in rule 761-150.3(1)d of the Iowa Administrative Code (IAC). Refer to this rule if specific information is required.

City Agreements

When the final plans for letting are being completed, the city and the Department must prepare and sign a city agreement that details which of the storm sewer's costs will be paid by the city. For the preparation of this agreement, the designer must provide storm sewer tabulations and drainage maps to the Agreements Section (Office of Development Support). Along with the designer, the Agreements Section will determine the category for each intake, utility access, and storm sewer pipe, as well as the percentage of participation by the city and the state. Participating costs will generally be distributed according to the following formulas:

$$\text{State Participation} = \frac{\text{Iowa D.O.T. right-of-way area along the project}}{\text{Total area draining onto project limits}} \times 100\ \%$$

$$\text{City Participation} = 100\% - \text{State Participation}$$

The city agreement will contain a tabulation of all storm sewer to be paid for by the city. This includes 100 percent city costs and participating city costs. A cost estimate prepared by the Agreements Section may be included in the city agreement depending on estimated letting prices. The designer should check these tabulations to make sure they are correct when reviewing the city agreement before the final submittal to the city for approval.

Removing or Filling Existing Culverts

Originally Issued: 09-22-00

This section presents information related to the removal or filling of existing culverts. When an existing culvert no longer serves its purpose it may be removed from its location, or it may be left in place (abandoned) and filled with flowable mortar. Every job is different so each case needs to be reviewed individually to determine the best course of action.

Removing a Culvert

Usually existing culverts will be removed. If there is a conflict with the existing culvert being in the way of new construction, then the existing culvert must be removed. The most common example would be an old culvert that is to be replaced with a new one in the same location.

Pipe Culverts

Pipe culverts to be removed on grading projects shall be noted as such on the plan and profile sheet. Removal is incidental unless the existing pipe culvert has been encased in cast in place concrete (see Section 2102.13 of the Standard Specifications).

R.C.B. Culverts

All R.C.B. culverts not used for future drainage should be removed. R.C.B. culverts to be removed shall be included in the tabulation for the removal of structures and paid for by lump sum with size of existing R.C.B. noted. The option of filling the structure with flowable mortar in lieu of removing the structure shall be determined by consultation with the Soils Section and the Office of Bridges and Structures.

Stockpasses

Since stockpasses are installed at a property owner's request, unused stockpasses may not be removed unless permission is granted by the property owner. The exception is if a road is being converted to a four-lane roadway. In this case, if a stockpass has water flowing through it, a smaller pipe will be inserted into the stockpass to maintain the flow. Contact the Preliminary Bridge Section to determine the proper pipe size.

Filling and Abandoning a Culvert

Any culvert that is filled and abandoned must be shown and referenced on road plans to avoid future problems. Very long or tall culverts may require drilling holes in the pavement or shoulder to introduce flowable mortar. This will reduce the risk of voids in the middle of the structure.

When the culvert is to be filled and abandoned the headwalls of the culvert may need to be removed, depending on the situation. On a smaller construction job, such as resurfacing where there is no significant earthwork being done, the headwalls need to be removed because the remaining exposed section is a hazard. On major construction projects where the headwalls will be covered with fill during the grading process, the headwalls can remain in place because they will no longer be a hazard.

Documentation

Road Design Details 4315, Details of Culvert Abandonment with Flowable Mortar (for structures smaller than 4' X 6'), and 4316, Details of Culver Abandonment with Flowable Mortar (for structures 4' X 6' or larger), shall be used in the plans for filling and abandoning a culvert. Tabulation 110-9, Tabulation of Culvert Abandonment, shall be used for tabulating the quantities that are needed to fill and abandon a culvert.

R.C.B. culverts designated by the Preliminary Bridge Section, Soils Section, or others to be filled with flowable mortar shall be tabulated (Tabulation 110-9) and paid for as part of the flowable mortar bid item. Flowable mortar is considered incidental when the contractor elects to fill a R.C.B. rather than remove. Holes that are drilled for the placement of flowable mortar in long or tall culverts will be incidental to the flowable mortar bid item. The following notes should be included on the plans, depending on the amount of silt inside the culvert:

- "Silt inside the existing culverts need not be removed prior to placing flowable mortar."
- "Article 1109.03 shall not apply to this item." This note is to be used only when the amount of silt inside the culvert is not known.

If either the headwalls, or all or part of an existing culvert, are removed Tabulation 110-2, Removal of Existing Structures, needs to be included in the plans to denote this.

Subdrains

Originally Issued: 12-31-97

Without proper drainage a road can deteriorate prematurely. Excess water can cause pavement to heave during the wintertime when the water freezes. Excess water and heavy traffic may cause pavement to deteriorate due to a "pumping" motion that allows fine aggregates to be carried away from the roadway's base. For this reason, longitudinal subdrains are used to keep water from building up underneath the roadway. Subdrains are also installed in varying locations to drain water and serve stability or settlement-control purposes.

Subdrains

The design of longitudinal, backslope, and fill or foundation subdrains is done by the Soils Design Section. Soils Design provides subdrain locations, depth, size, outlet location and length plus the amount of porous backfill and crushed stone needed to install the drains.

The designer places this information in the appropriate Tabulation on an individual sheet in the plans and places the geotechnical signature block on the title sheet or the first sheet covered by that seal (see Section 1E-1 for more information on plan certification). Before turning the plan in for letting, Soils Design needs to review the information to verify that the subdrain information is correct and sign the geotechnical signature block.

Longitudinal and Backslope

Longitudinal subdrains are installed along the edge of the pavement to drain water from under the pavement. Backslope drains are placed in the backslope to drain water and assist in eliminating backslope slides. See Standard Road Plan RF-19C and RF-19E for designs of both types of drains and their outlets. The designer places this information on Tabulation 104-9. Section 3D-1 of this manual also contains important information pertaining to subdrain placement for changing subgrade slopes.

Fill or Foundation Drainage

On grading projects where there is fill and settlement or stability may be a problem due to soft soil or high water tables, subdrains and/or trench drains, frequently in conjunction with granular blankets, need to be installed to drain the water. These devices are installed underneath the roadway, typically at the base of the fill or in the natural ground. Examples of this procedure are located on Standard Road Plan RF-19A. Soils Design also frequently prepares additional drawings and other related material to show locations and additional information. Tabulation 104-5C is used to list the information given by Soils.

Tiles

Locating Tile Lines

If tile line locations are known, they should be shown on the plans. If the exact location of the tile lines cannot be precisely determined prior to construction, then the bid item Locating Tile Lines shall be included in the plans. During the field examination, the Resident Construction Engineer shall estimate the quantity (in stations) of tile lines that need to be located. This quantity shall be included in the plans on the "Estimated Project Quantities" Tabulation.

Placing Tile Lines

Tile lines that are intersected by roadway construction are modified or relocated as illustrated on Standard Road Plan RF-19B. Engineering judgement needs to be used to determine if the lines should be reconnected or if they should be emptied onto the right-of-way. Unlike longitudinal subdrains, the designer needs to estimate the quantities involved. These values shall be placed on Tabulation 104-5C.

Subdrains at Bridge Piers

On side piers, subdrains are used to carry water away from the ditch located beside the bridge pier. Subdrains at bridge piers are to be installed in accordance with Standard Road Plan RL-13. This quantity also needs to be estimated by the designer and placed on Tabulation 104-12.

Bridge End Drains

Originally Issued: 09-22-00

This section discusses the location and placement of bridge end drains. The current policy for installation of bridge end drains is as follows:

Location of End Drains

1. All new bridges should have an end drain installed at each corner located on the down hill end of the bridge to catch water running off the bridge and approaches.
2. All new bridges on superelevated curves should have an end drain installed on the low side downhill from the bridge.
3. On the uphill approach to new bridges when the grade is less than 1.6%, check the direction of the flow in the gutter. If the water flows away from the bridge, an end drain is required.
4. On urban sections with curb and gutter, end drains will not be required. Storm sewer intakes will be located as necessary to take care of drainage.
5. In areas where there is variable width or variable cross slope in the bridge approach section, check gutter elevations to determine direction of flow. If water flow away from the bridge, an end drain is needed.

Types of End Drains

End drains shall consist of two types: Standard Road Plans RF-38(1&2) and RF-39. The RF-38 end drain will be used when the roadway embankment is constructed of erosive soils (e.g. sand, loess) or the embankment exceeds 15 feet in height. The RF-39 end drain (sod flume) is to be used when the roadway embankment is constructed of non-erosive soils and does not exceed 15 feet in height.

A three step process is used to determine the location of the Bridge End Drains.

1. Determine inlet location.
2. Compute storm runoff in cfs for the design storm (refer to Sections 4A-1 and 4A-4 of this Manual)
3. Determine grate capacity.

Example 1

Shoulder widths are 6' and 10'

Skew angle is 30 degrees

Determine the inlet location

The inlet location is a function of various bridge characteristics, the bridge approach section and the placement of the guardrail. The best way to place the end drain is to draw the bridge situation plan, locate the joints in the approach section, and determine the position of guardrail and guardrail posts.

a) Standard Road Plan RF-38(1) shows the point from which DI1 and DI2 are measured. Standard Road Plan RE-65A shows the location station to be used for a guardrail installation at a bridge end.

b) Determine d_1 and d_2 for the bridge approach. Of the two, d_1 is always the shoulder width on the shorter side of the reinforced bridge approach section, and on the side of panels B and C.

c) Determine the skew angle case (see Section 7D-1 of this Manual).

d) Panel size is assumed to be 20 feet.

Note that the example gives a minimum requirement for intake location. Intakes can be moved a greater distance from the location station, if desired, but the designer should then verify that:

1. The intake is located approximately in the middle of two guardrail posts.
2. The intake is at a 5-foot minimum distance from the nearest joint and beyond the reinforced bridge approach section.

   If condition 1 or 2 is not met, the designer should extend the guardrail by 12.5 foot increments in the variable tangent section of the guardrail layout, then check the location of the intake at 6.25 foot increments until it meets the requirements.

From b, $d_1 = 6'$, $d_2 = 10'$

From c, case 2

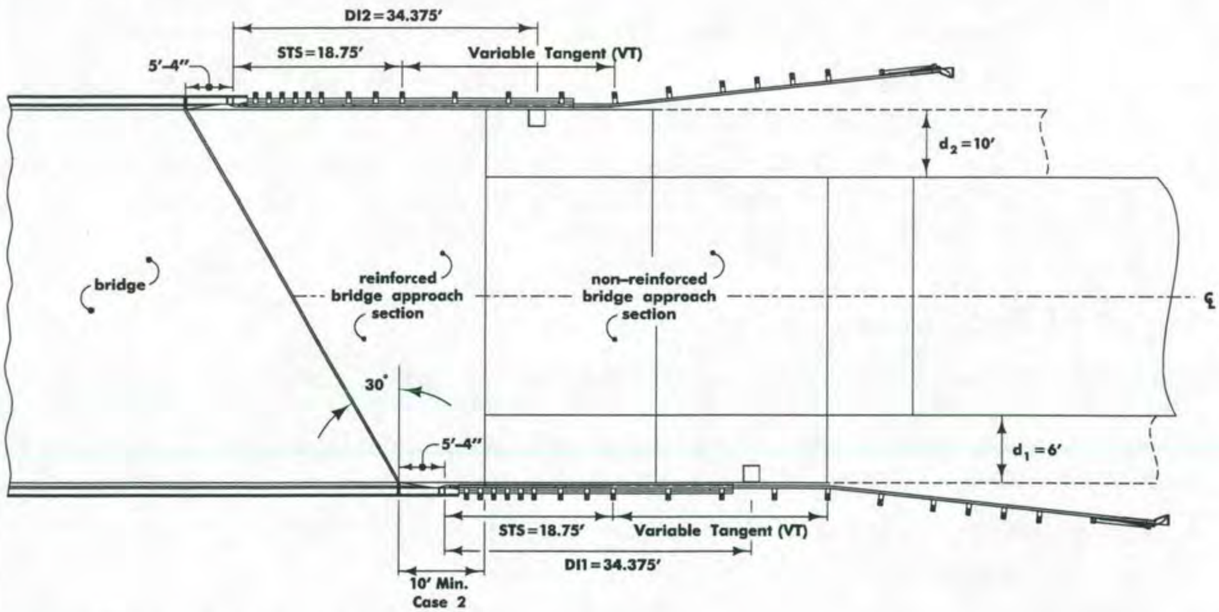


Figure 1: Location of the intakes.

Figure1 on the d1 side the joints are located at 5.33 ft., 25.33 ft., and 45.33 ft. from the location station.

DI1= 18.75 ft. + 6.25 ft. + 6.25/2 ft. = 28.125 ft., but the intake location is just 3 ft. from the nearest joint so it does not meet requirement #2. Therefore a variable tangent of 12.5 ft. should be added. Now the location of intake DI1 is 18.75 ft. +12.5 ft. + 6.25/2 ft. = 34.375 ft. from the location station which is more than 5 ft. from the nearest joint and between 2 guardrail posts, see Figure 1.

In Figure 1 on the d2 side, the joints are located at 28.33 ft., 48.33 ft., and 68.33 ft. from the location station.

DI2 = 18.75 ft. + 12.5 ft. + 6.25/2 ft. = 34.375 ft.

Example 2

Shoulder widths are 10' and 10'

Determine the inlet location

Skew angle is 10^{o}

D1 = 10'

D2 = 10'

Case1

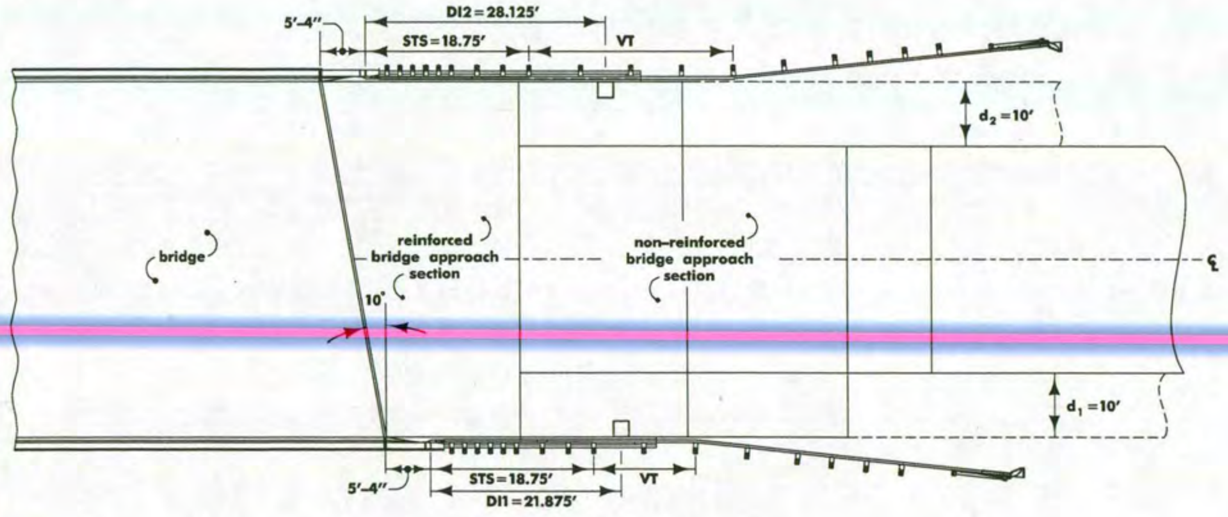


Figure 2: Location of the intakes.

DI1 = 18.75 ft. + 6.25/2 ft. = 21.875 ft.

DI2 = 18.75 ft. + 6.25 ft. + 6.25/2 ft. = 28.125 ft.

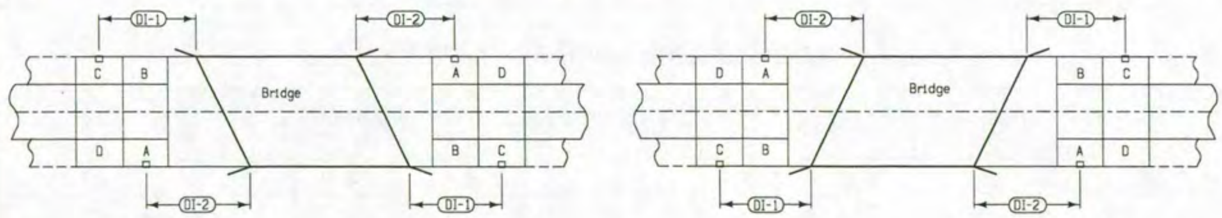


Figure 3: Panel locations.

Note: Figure 3 is taken from Standard Road Plan RF-38 (1) and shows the relative locations of panels A, B, C, and D with respect to the end of the continuously reinforced panel. When shoulders are not to be paved, shoulder panels are needed to accommodate intakes and meet the required 5-foot minimum distance from nearest joint.

Note: In the case of narrow bridge shoulders (2' or 4'), it may not be possible to locate an RF-38 end drain at the proposed location. Consider using a RF-39 end drain or drawing up the bridge/ guardrail situation to locate the RF-38 end drain further from the bridge. Additional panels may be necessary.

Determination of Grate Capacity

Grate capacity is determine using the equation:

$$Q_I = KD^{5/3}$$

To determine K, go to table.1 below. Using longitudinal grade S_L and cross slope S_T, select the K value from the table.

Table 1: K given S_T and S_L.

S_L \ S_T	0.00%	1.00%	2.00%	3.00%	4.00%	5.00%	6.00%
1.00%	29	23	19	17	15	14	13
2.00%	39	31	25	22	19	17	16
3.00%	43	34	28	25	22	20	18
4.00%	47	37	31	27	24	22	20
5.00%	54	40	33	28	25	23	22
6.00%	56	42	35	30	27	24	23

To determine D, take the storm runoff Q_R (see Section 4A-4) and use tables 2, 3, and 4 to interpolate for D. Tables 2, 3, and 4 below provide values for D for flows of 1, 2, and 3 cfs.

Table 2: Values of D for Q_R = 1 cfs.

S_L \ S_T	0.00%	1.00%	2.00%	3.00%	4.00%	5.00%	6.00%
1.00%	---	0.11	0.14	0.17	0.19	0.20	0.22
2.00%	---	---	0.13	0.15	0.16	0.18	0.19
3.00%	---	---	0.12	0.14	0.15	0.16	0.18
4.00%	---	---	0.11	0.13	0.14	0.16	0.17
5.00%	---	---	0.11	0.12	0.14	0.15	0.16
6.00%	---	---	0.10	0.12	0.13	0.14	0.16

Table 3: Values of D for Q_R= 2 cfs.

S_L \ S_T	0.00%	1.00%	2.00%	3.00%	4.00%	5.00%	6.00%
1.00%	---	0.14	0.19	0.22	0.24	0.26	0.28
2.00%	---	0.13	0.16	0.19	0.21	0.23	0.25
3.00%	---	0.12	0.15	0.18	0.20	0.21	0.23
4.00%	---	0.11	0.14	0.17	0.19	0.20	0.22
5.00%	---	0.11	0.14	0.16	0.18	0.19	0.21
6.00%	---	0.10	0.13	0.16	0.17	0.19	0.20

Multiply K by $D^{5/3}$ to determine intake capacity.

Bypass is calculated by subtracting grate capacity Q_I from storm runoff. If bypass is more than 10% of the storm runoff, a second intake may be needed.

Example 3

Suppose Q_R=1.5 cfs (storm runoff) and $S_T = 0.04$, $S_L = 0.05$.

First find K using or Table 1:

$K = 25$

Then find D using Tables 2, 3 and interpolating:

1 cfs	D=0.14	
1.5 cfs	D=0.16	(by interpolation)
2.0 cfs	D=0.18	

$Q_I = KD^{5/3}$ = interception by Grate

$D^{5/3} = 0.0472$

Q_I=25 (0.0472) = 1.18 cfs

Bypass = $Q_R - Q_I$

Bypass = 1.50-1.18=0.32 cfs

0.32 /1.50 =0.21 > 10 %

Therefore, a second intake is needed downstream of the first intake to reduce the amount of bypass. The second intake should also be space according to the rules defined on pages 1 and 2 of this chapter. The second intake may be joined to a common storm sewer outlet. The allowable bypass should not exceed 10 %.

Earth Work

Rock Excavation

Originally Issued: 06-02-00

This section discusses the procedure to be considered normal design practice for all projects involving the excavation of rock. Rock excavation is not done in shale, broken and weathered limestone, or similar rock. The Soils Design Section shall determine precisely where rock excavation is to occur.

1. Where the depth of rock excavation in any given area is 5 feet or less, design practice shall be to provide a normal ditch section. Refer to Design Detail 4101.
2. Where the depth of rock excavation is greater than 5 feet, the designer shall prepare the necessary typical sections to convey rock excavation requirements for the project. Design Details 4110 or 4111 shall be used as the basis for developing the necessary typical sections
3. The development of the required typical section shall be done jointly between the Design Section and the Soils Section to insure that the optimum section and requirements are specified for the project.
4. Where pre-splitting of the rock is required, it should be noted in the remarks column of Tab 107-25.

Borrow Design

Originally Issued: 09-22-00

This section provides information relevant to the acquisition and design of borrow areas. The following definitions apply:

- Mandatory Borrow Area. An area provided by the contracting authority from which the contractor shall obtain borrow material and operate in accordance with the plans and specifications. Mandatory borrow areas will be designated on the plans. Borrows designated as the source of "select" soil treatment, snow borrows and borrows to increase sight distance will normally be considered mandatory.
- Optional Borrow Area. An area provided by the contracting authority from which the contractor may obtain borrow material. If so obtained, the contractor is expected to operate in the area in accordance with the plans and specifications. Borrow areas are optional borrow areas unless specifically designated on the plans as mandatory borrow areas.
- Alternate Borrow Area. An area provided or to be provided by the contractor from which the contractor may obtain borrow material. Use shall be in accordance with the plans and specifications. The contractor is responsible for obtaining all rights and all permits, clearances, etc. associated with this area and for use of this material.
- Designated Borrow Area. A general term for borrow areas provided by the engineer, including mandatory and optional borrow areas.

The following procedure shall be incorporated as normal design practice for all road design projects which involve the acquisition of borrow areas:

1. It shall be the responsibility of the Soils Design Section in cooperation with the Office of Right of Way to locate and identify all specified borrow areas on the project plans. All potential borrow areas will be identified in the S1 submittal by the Soils Design Section. Locations of possible borrow areas will be reviewed for environmental, historical, or ecological significance. The S1 submittal should be completed before the first public hearing. Where it is possible, each borrow area shall be confined to one property only. Whenever possible the borrow area design should avoid gas lines, waterlines, wells, and wind breaks. Relocation should be avoided unless at the property owner's request. The addition of borrows during the negotiation phase should be avoided due to the problems this can create with acquisition. Each borrow area shall be identified by a letter designation (Borrow B, Borrow I, etc.). Borrow areas should be designed to provide 10 to 20% more than anticipated borrow needs.
2. The designer should coordinate with the Supervisor of Property Management in the Office of Right of Way and others on the possible use of excess right of way for borrow purposes. At such time as the plans are submitted to the Office of Right of Way for use in acquiring rights of way for the project, all proposed borrow locations shall be shown. It shall be the responsibility of the Section Engineer to notify the Supervisor of Right of Way Design of any changes that affect a proposed borrow area after R.O.W. submittal, such as a change in project concept which would eliminate the need for a borrow, etc.
3. Restoration of borrow areas shall normally be accomplished by one or more of the following procedures:

a. The borrow area shall have the surface topsoil removed to a specified depth, stockpiled, and respread uniformly over the area after the required borrow is removed. If the contractor's operation allows, topsoil may be respread directly without stockpiling.

b. The borrow area shall be restored by means of permanent seeding as part of current project or a separate Erosion Control Contract for the project.

c. As specified in R.O.W. agreement.

In addition, all borrow areas, stockpile areas, haul roads, and areas used for maneuvering equipment that are to be restored shall be tilled to an average depth of 16 to 20 inches prior to replacement of the topsoil or application of stabilizing crop or permanent seeding. The following general note shall be placed on the plans where borrow restoration is required.

> 06-22-84 213-3
>
> All borrow areas, stockpile areas, haul roads and areas used for equipment on this project will require subsoil tillage to an average depth of 16 inches to 20 inches prior to placement of topsoil and/or stabilizing crop seeding. Such tillage shall be accomplished on maximum of three foot centers and at right angles to the finished slope of the borrow.
>
> Equipment used to accomplish the tillage shall be equipped with an arrowhead-type shoe so as to provide lateral displacement and limit the movement of the subsoil to the surface. It shall be approved by the engineer for the use intended. This work will be considered incidental to other work on the project and no payment will be allowed.
>
> It is intended that following subsoil tillage, the area remains in a "loosened" condition. Additional compaction or the operation of heavy equipment, other than required for topsoil placement and shaping shall not be allowed on areas which have received subsoil tillage.

4. Iowa Code chapter 314.12 requires that all borrow areas shall be planned for restoration by means of removing and replacing the topsoil except in the following areas:

- Areas which obviously will not require topsoil replacement, for example lake or pond type borrows,
- Borrows in urban areas and sites having potential development,
- Borrows on which no topsoil exists in its original condition, for example sand, loess, or undrainable clays,
- Borrows where restoration by other means is specifically documented and agreed to by the property owner involved prior to plan completion.

Borrows which are incorporated into the project as an integral part of the roadway design by means of widening of ditches, flattening backslopes, or both, through areas of normal excavation shall be treated in the same manner as the remainder of the project.

5. It shall be the responsibility of the project engineer to review the layout and design of all proposed borrow areas with the Roadside Development Section prior to R.O.W. submittal. Particular attention shall be given to bottom shaping to ensure adequate and proper drainage. Generally, 2% slopes are required to ensure good drainage. Side slopes should be designed to ensure adequate control of erosion and to blend with the surrounding area. In addition, the Roadside Development Section shall provide a recommendation as to the type of restoration to be proposed for each borrow area. Where a borrow is to be restored by means other than replacing topsoil, specific recommendations as to type and amount of fertilizing and seeding required for each borrow area shall be made by the Roadside Development Section.

6. Normally, all borrow areas shall be included in the area planned for "Stabilizing Crop Seeding". Where permanent seeding is planned for borrow areas, it shall be so identified for accomplishment as part of the "Erosion Control Project" to be done at a later date.

7. The Office of Right of Way shall provide the Section Engineer copies of signed contracts or condemnations related to the disposition of any borrow area. If there are special considerations other than restoration of topsoil or reseeding, those issues will be addressed in the signed contract or condemnation. The various quantities required for borrow restoration shall then be appropriately corrected prior to turn-in for letting.

8. Normally the Office of Design's responsibility for identification of requirements for restoration of borrow areas will terminate when plans are submitted to the Office of Contracts. All Right of Way agreements which are finalized after that time and which require changes from the specified restoration methods shall be incorporated into the work by field forces.

9. All projects requiring borrows to be restored by means of topsoil replacement shall provide quantities for "Stripping, Salvaging, and Spreading Topsoil", on the specified borrow areas. The following general note shall be placed on the plans to describe the appropriate work to be done and shall apply to all borrow areas which are not otherwise restored.

```
01-09-90                                                      213-2
The contractor's attention is directed to the following consideration
in regard to removal and replacement of topsoil in borrow areas:
Quantities estimated for topsoil are calculated on the basis of
a uniform removal of topsoil to a depth of 12 inches.  The material
removed is to be spread uniformly to a minimum depth of 8 inches
over the borrow area upon completion of excavation work.
```

Although the Office of Design normally selects the borrow locations, the Office of Right of Way does have the option to review the proposed borrow location and recommend alternate sources based on land use and economic considerations.

Geometric Design

Chapter 6

Horizontal Intersection Design: Rural Two-Lane and Super-Two Highways

Originally Issued: 09-01-95

This section provides a procedure for designing intersections on rural two-lane and super-two highways.

The procedure should ***not*** be used for:

- intersections on four-lane highways.
- urban intersections.
- intersections on transitional highways (where speeds are slowing down as a rural roadway transitions into an urban or more-congested environment).
- signalized intersections. Signal warrants should be checked in the *Manual on Uniform Traffic Control Devices.* For signalized intersections, use *Highway Capacity Manual* procedures to determine lane configuration (some software packages incorporate procedures similar to the *Highway Capacity Manual.* These are also acceptable).

Before designing a rural intersection following these procedures, make sure there is adequate horizontal sight distance (see Section 6A-4). If sight distance requirements are not met, the profile grade may be changed or the intersection relocated.

Auxiliary Lane Warrants

The auxiliary lane warrants described in this section do ***not*** apply to:

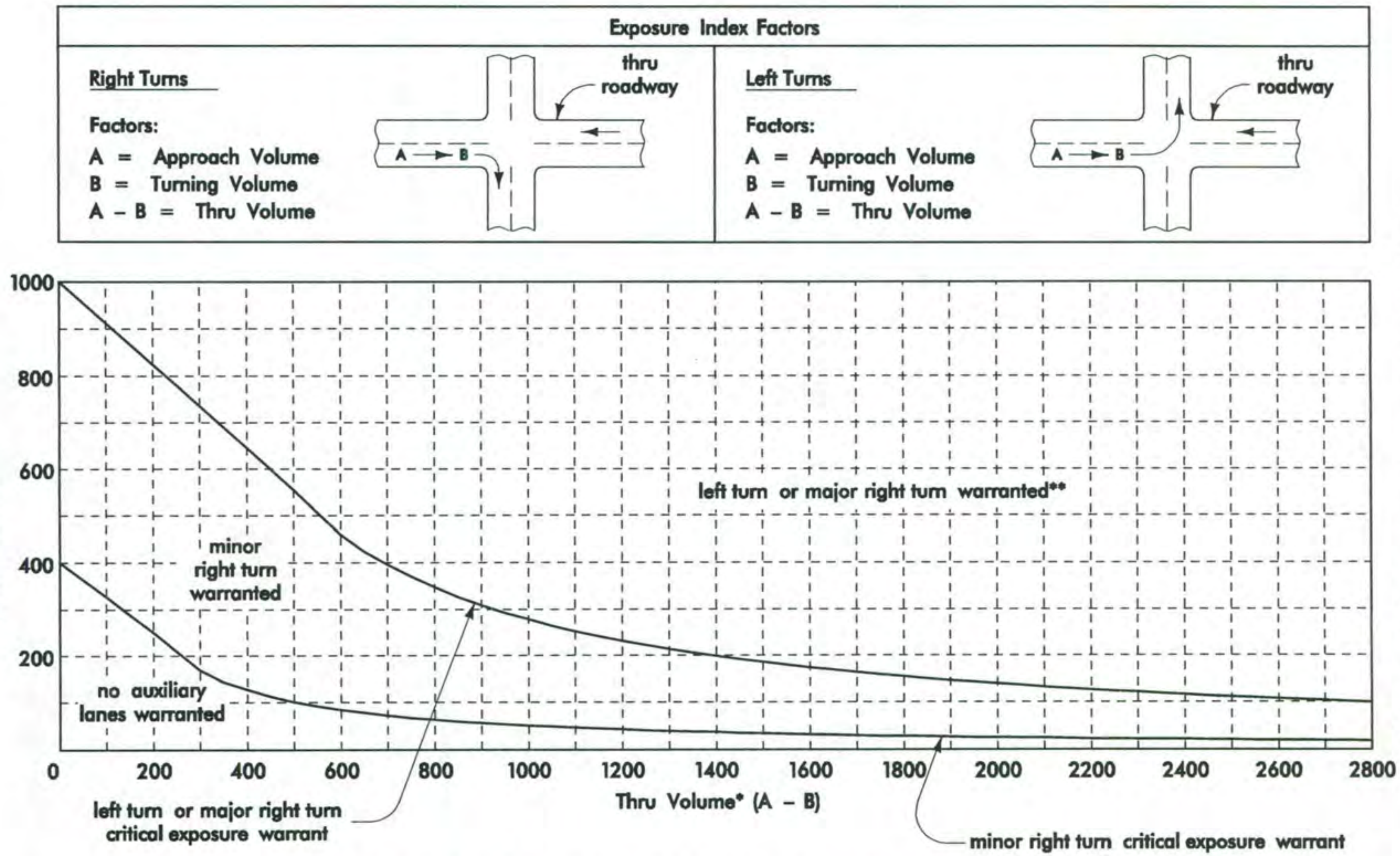
- intersections on four-lane highways.
- intersections where there is a stop condition on the mainline.
- 3R projects on non-NHS routes.

The need for auxiliary lanes is determined by plotting the thru traffic volume and the turning traffic volume on Figure 1 for rural two-lane highways or Figure 2 for super-two highways. Traffic volumes should be adjusted for the percentage of heavy vehicles. Divide each approach volume by the appropriate correction factor from Table 1 before plotting on Figure 1 or Figure 2.

Design year ADT is used to determine left-turn lane warrants. A left-turn lane provides a full-width lane for vehicle storage. If a left-turn lane is warranted on only one approach of the mainline at a four-way intersection, a left-turn lane should be provided on the opposite approach as well.

Warrants for right-turn lanes are based upon present ADT and are divided into two categories—major and minor. A major right-turn lane provides a full-width lane for deceleration from the design speed on the mainline. A minor right-turn lane assumes vehicles will decelerate to 30 mph on the mainline before entering the auxiliary lane.

On super-two highways, **all** warranted right-turn lanes should be designed according to the criteria given for major right-turn lanes.

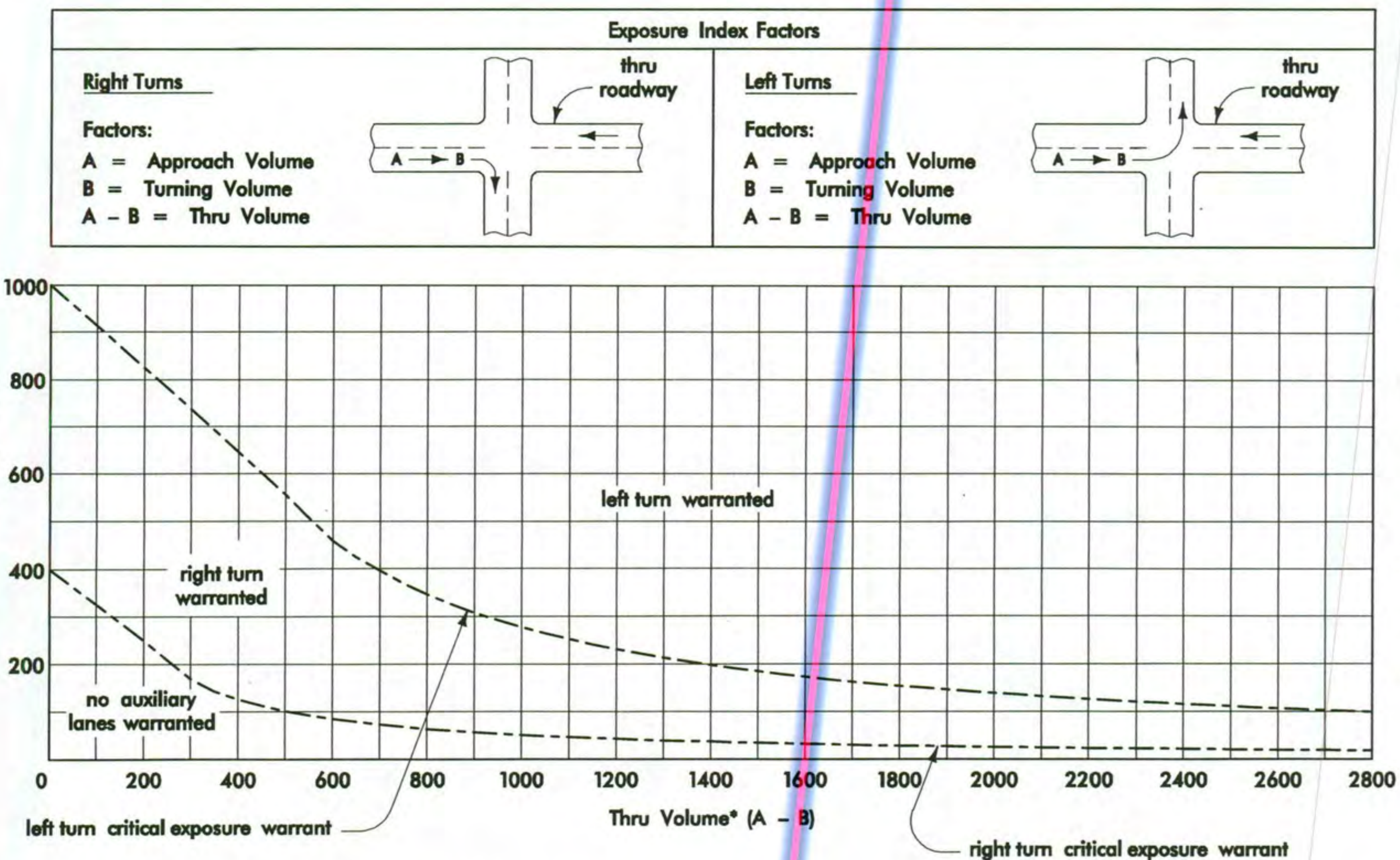


Traffic volume is based on current ADT for right turns, and design year ADT for left turns.

*Traffic volume must be adjusted for trucks based on Table 1.

**At gravel road intersections, use minor right turn.

Figure 1: Rural two-lane highway auxiliary lane warrants.



Traffic volume is based on current ADT for right turns, and design year ADT for left turns.

* Traffic volume must be adjusted for trucks based on Table 1.

Figure 2: Super-two highway auxiliary lane warrants.

Table 1: Truck adjustment factors. Divide each approach volume by the appropriate factor.

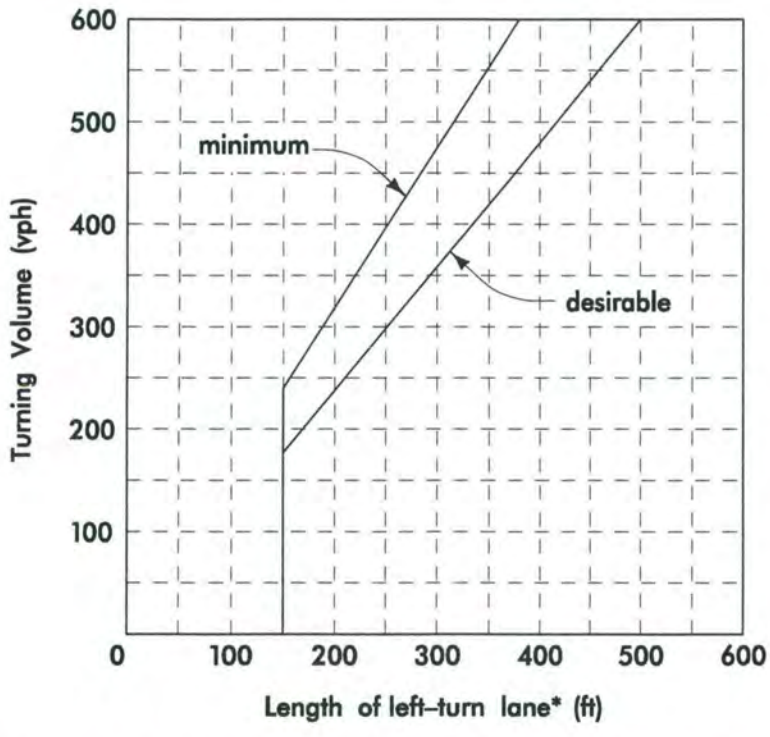
Truck %	Correction Factor	Truck %	Correction Factor	Truck %	Correction Factor	Truck %	Correction Factor
0	1.05	6	0.99	12	0.93	18	0.87
1	1.04	7	0.98	13	0.92	19	0.86
2	1.03	8	0.97	14	0.91	20	0.85
3	1.02	9	0.96	15	0.90	25	0.80
4	1.01	10	0.95	16	0.89	30	0.75
5	1.00	11	0.94	17	0.88	35	0.70

Auxiliary Lane Design

Left-Turn Lane Design

If a left-turn lane is warranted, begin by selecting the median width. Because curbs are not desirable on high-speed facilities, painted medians are normally used. For painted medians, the minimum median width is 16 feet. This accommodates a 12-foot turn lane and a 4-foot minimum width median between the left-turn lane and the opposing traffic lane.

The lane length and taper ratio are based upon storage requirements—the lane is not designed for deceleration. Develop the lane with a taper at a 10:1 ratio. Use Figure 3 to determine the length of the left-turn lane. The minimum length is 150 feet and the length should be increased in 25-foot increments (25 feet per vehicle is provided for storage).



*** Table value is rounded up to the nearest 25' increment for design. Minimum length is 150 feet.**

Figure 3: Left-turn lane storage length.

Full median width should be maintained throughout the storage lane length and the taper length. Reverse curves with 12,000-foot radii should be used to transition back to a two-lane roadway beyond the intersection (see Figure 4).

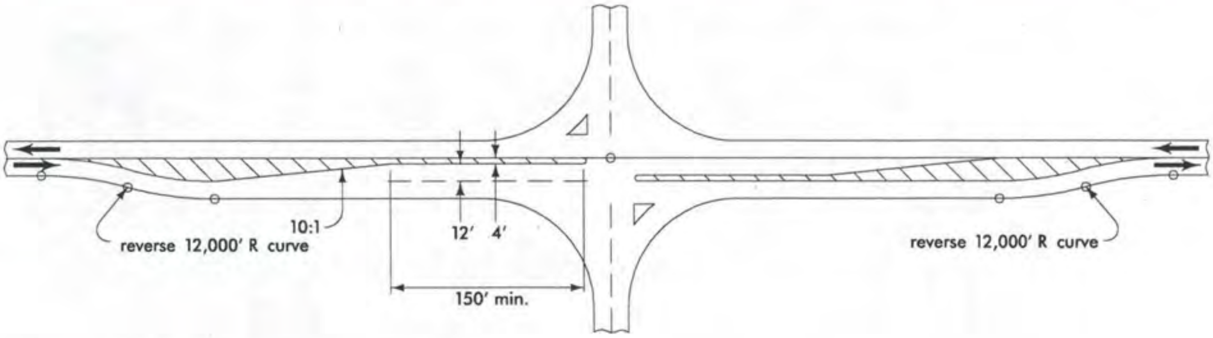


Figure 4: Rural channelized intersection.

To provide optimum operating characteristics for the approaching driver, the centerlines of the approaching legs can be offset by the median width (see Figure 5).

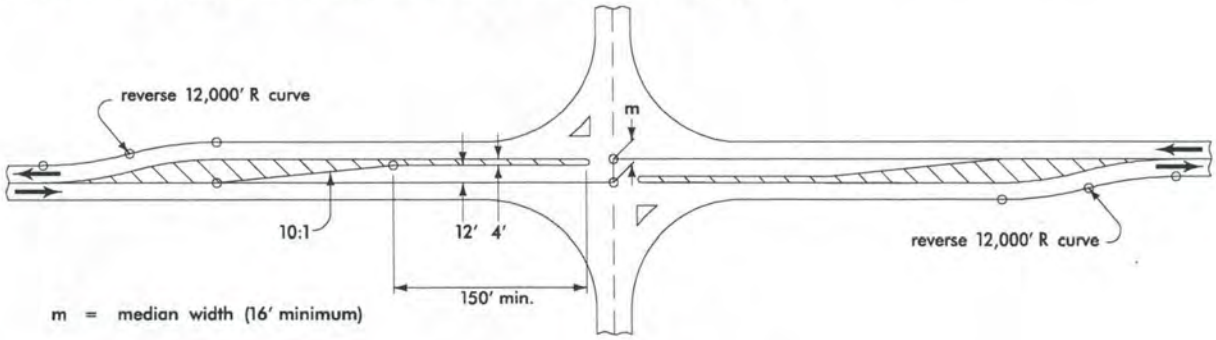


Figure 5: Rural channelized intersection with centerlines offset.

Major Right-Turn Lane Design

A major right-turn lane provides for full deceleration from the design speed on the mainline to the speed allowed by the control radius at the intersection. The control radius is the shortest radius of the intersection return. Use Table 2 to determine the length of the deceleration lane—the required length is a function of the design speed and the control radius. Correct for grades by multiplying the table value by the appropriate correction factor from Figure 6. The deceleration lane length does not include the taper or any portion of the intersection return.

On a super-two highway, all right-turn lanes should be designed as major right-turn lanes.

Table 2: Deceleration lane lengths for major right-turn lanes.

warrant	design speed (mph)	taper ratio	deceleration lane length (L)* (ft)				
major	40	15:1	295	280	265	235	185
	45		350	340	325	295	250
	50		405	395	385	355	315
	55		455	450	440	410	380
	60		500	490	480	460	430
	65		540	530	520	500	470
	70		590	580	570	550	520
control radius (ft)			50	70	90	150	230

*interpolate directly for intermediate control radii and design speeds

Use parallel type | Option—parallel or taper | Use taper type

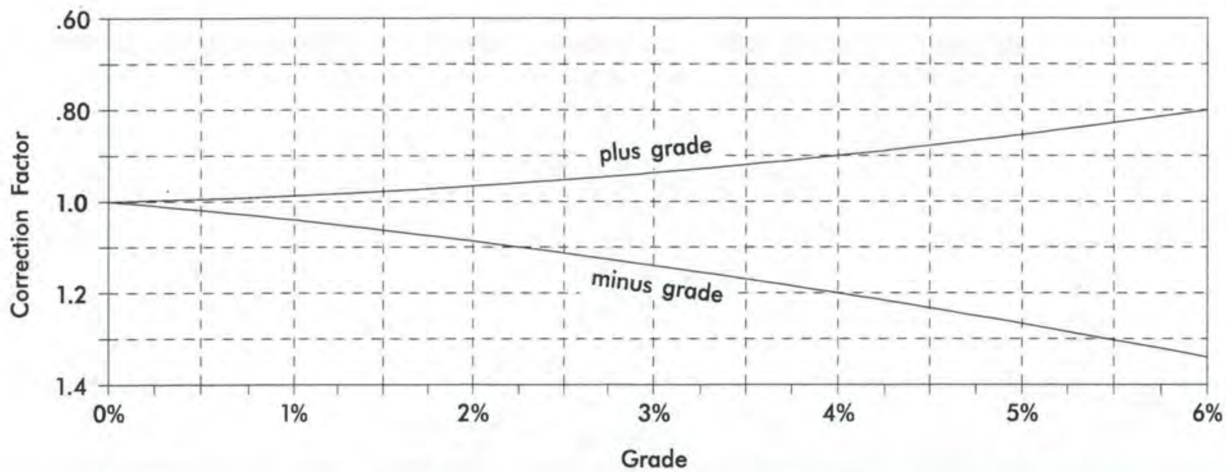


Figure 6: Gradient factor. Multiply the correction factor for grade by the deceleration lane length.

Deceleration lanes may be parallel (Figure 7) or taper type (Figure 8). Taper type lanes are only warranted with loop radii. Table 2 indicates which type to select. A 15:1 taper ratio is always used for a major warrant. A 6-foot shoulder should be constructed adjacent to the deceleration lane, using the same material as the mainline shoulder.

Special site conditions may require a design with lengths or tapers that differ from Table 2. In these cases, consult the Methods Section (Geometric Design) for assistance.

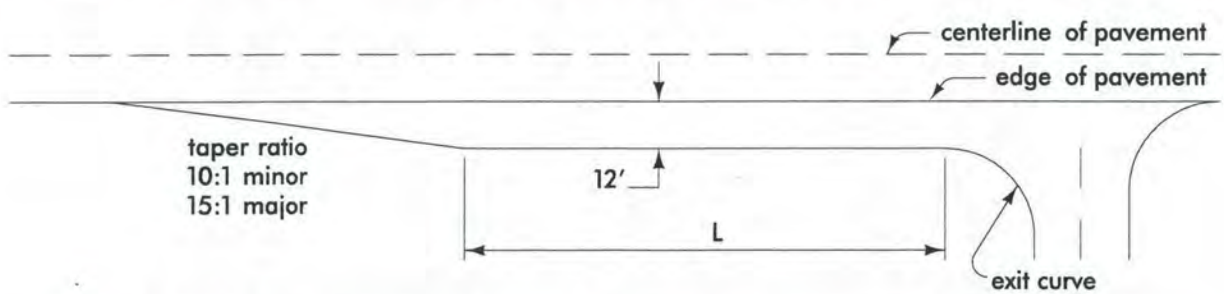


Figure 7: Parallel type right-turn deceleration lane (for major or minor right-turn lanes).

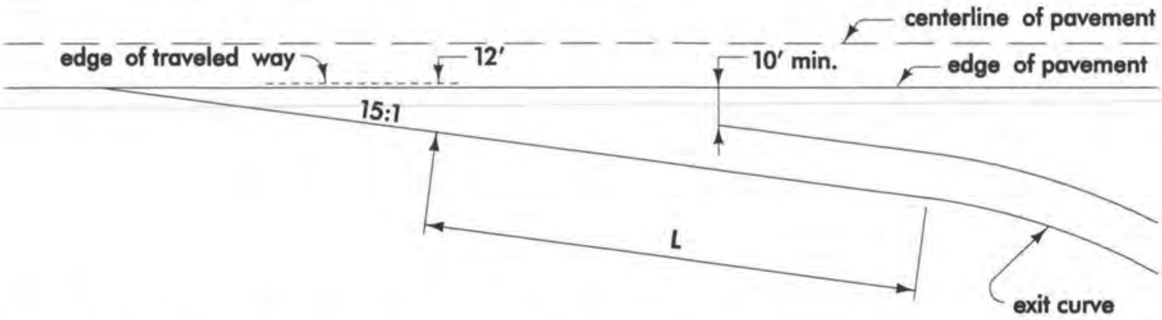


Figure 8: Taper type right-turn deceleration lane (for major right-turn lanes).

Minor Right-Turn Lane Design (rural two-lane highways only)

A minor right-turn lane provides for deceleration from 30 mph on the mainline to the speed allowed by the control radius at the intersection. When a minor right-turn lane is warranted use a design speed of 30 mph and a parallel-type layout with a 10:1 taper ratio (see Figure 7). The lane length can be determined from Table 3. Apply the appropriate correction factor for grade using Figure 6. As with major right-turn lanes, the lane length does not include the taper or any portion of the intersection return. A 4-foot shoulder should be constructed adjacent to the deceleration lane, using the same material as the mainline shoulder.

On a super-two highway, all right-turn lanes should be designed as major right-turn lanes.

Table 3: Deceleration lane lengths for minor right-turn lanes.

warrant	design speed (mph)	taper ratio	deceleration length (L)* (ft)			
minor	30	10:1	185	175	160	140
control radius (ft)			50	70	90	150

*interpolate directly for intermediate control radii

Intersections with Gravel Sideroads

Left-turn warrants and design for intersections with gravel sideroads are the same as with paved sideroads.

When the intersection of a rural two-lane highway with a gravel sideroad warrants a right-turn lane, only **minor** right-turn lane criteria should be used. When the intersection of a super-two highway with a gravel sideroad warrants a right-turn lane, only **major** right-turn lane criteria should be used.

Continue the deceleration lane pavement through the intersection to the point where the return radius meets the shoulder line of the deceleration lane (see Point X on Figure 9). At this point, begin the lane drop taper at a 10:1 (for rural two-lane) or 15:1 (for super-two) ratio.

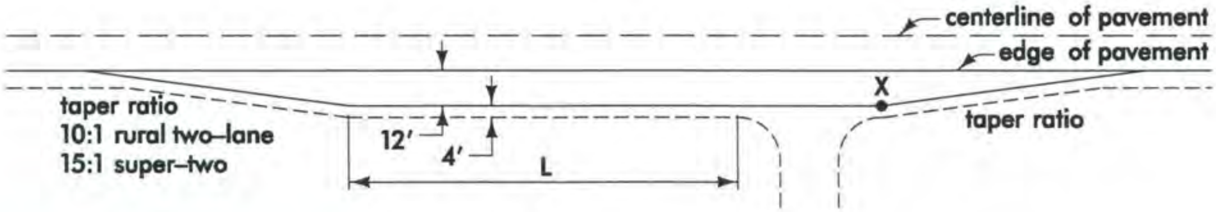


Figure 9: Right-turn deceleration lane for a gravel road intersection.

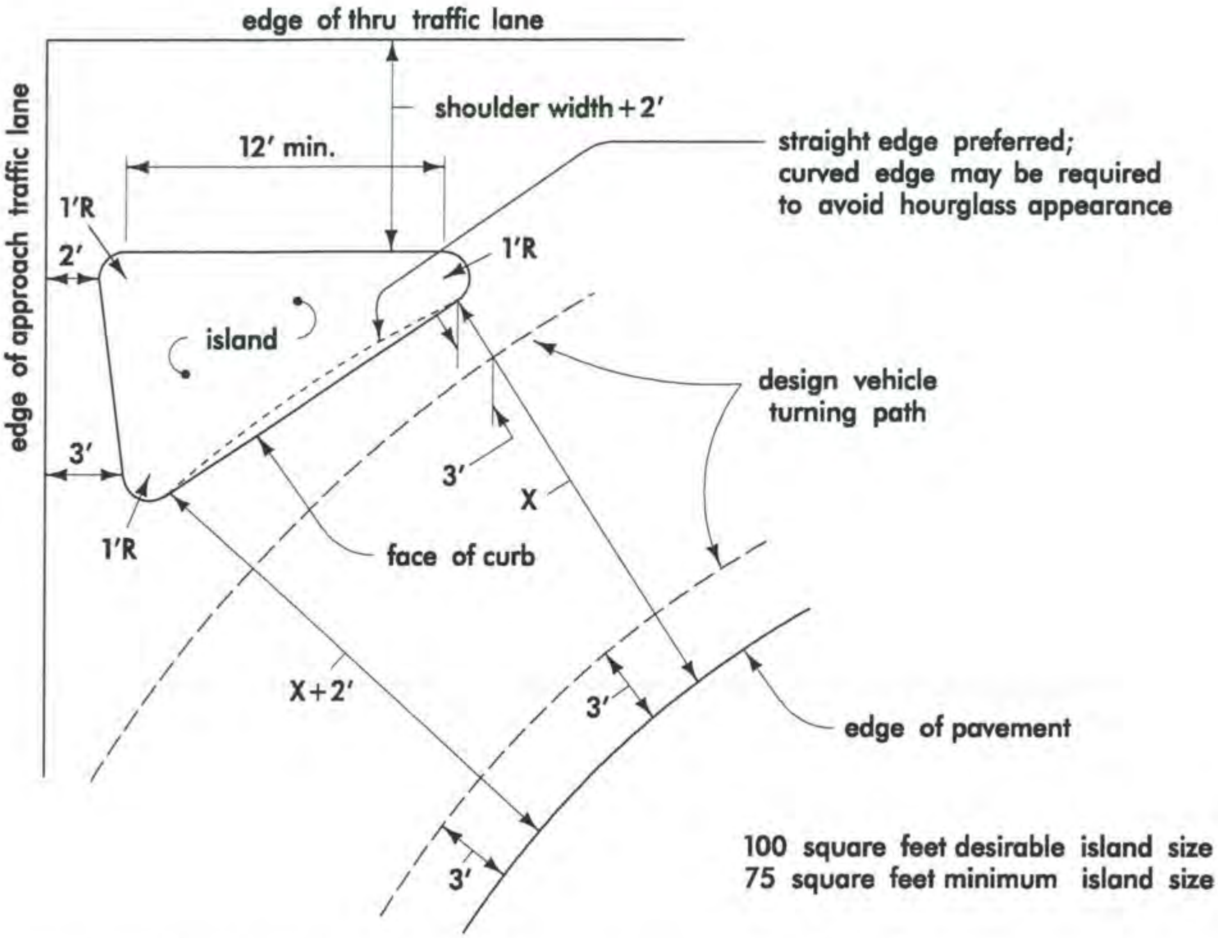
Stop-Sign Islands

Stop-sign islands are used to regulate traffic, aid the driver in negotiating the intersection, and protect and store crossing and turning vehicles.

Stop-sign islands are required on all paved sideroad approaches to the thru route. However, when the sideroad design year ADT is less than 100 vpd, the island is optional. Placement of the stop sign must meet MUTCD criteria. Therefore an island may be required even if the sideroad has less than 100 vpd in order to permit proper location of the stop sign.

Figure 10 illustrates requirements for the placement of islands. In order to command attention, the desired island size is 100 square feet. The minimum acceptable size for an island is 75 square feet.

Use 4-inch sloped curbs for stop-sign islands on rural roadways. See Section 3C-2 and Detail 6144 for more information about curbs on stop-sign islands.



Note: All island radii and offset dimensions are measured to face of curb.
"X" and "X+2" are measured radial to edge of pavement.
Refer to Detail 6144 for island design details.

Figure 10: Offset requirements for intersection stop-sign island.

Design Vehicle

The next step is to select an appropriate design vehicle. Based on a site evaluation, determine the largest vehicle that will frequently turn at the intersection (not just the occasional user). Consider:

- location of the intersection in relation to the surrounding land use (factories, parks, schools, etc.)
- the type of intersecting roadway (primary or secondary road, entrance, etc.)

Normally, the WB-50, the WB-62, or the WB-67 truck tractor-semitrailer combinations are appropriate at the intersection of two primary roadways. At other locations, such as non-primary, secondary, state park or institutional roads, the appropriate design vehicle may be a single-unit truck, bus or RV. Refer to Chapter 2 in AASHTO's *A Policy on Geometric Design of Highways and Streets* for more information about selecting a design vehicle.

Turning Path Placement

After determining the lane configuration and the design vehicle, select a turning-path radius and draw the turning path on a plan view of the intersection.

The selected design vehicle turning path should be centered within the traffic lane at the beginning and the end of the turn. Connect the entry and exit paths with a single turning radius, which cannot be shorter than AASHTO's minimum radius guidelines (see Table II-2 in *A Policy on Geometric Design of Highways and Streets*).

Left Turns

For most left turns, a 50-foot turning path radius is preferable. However, a longer radius may be used with very obtuse angles. Radius increments of 25 feet are preferred but 5-foot increments are acceptable.

In addition, the turning path for a left turn may swing wide to provide clearance for a vehicle waiting at the stop bar. Figure 11 illustrates a turning path for this situation.

Right Turns

At intersections with little or no skew, a 75-foot turning path radius for right turns is suitable. If the approach requires a stop-sign island, the turning radius may need to be increased to accommodate the island (see Figure 10).

Intersection skew may justify increasing or decreasing the turning path radius. Any alteration in radius should occur in preferred 25-foot increments or minimum 5-foot increments.

Approximately 3 feet of clearance should be maintained from median noses, islands, faces of curb, and pavement edges. Where encroachment or insufficient clearances exist for either left or right turns, the designer may select a different turning path radius or modify the geometrics of the intersection. This can be done by changing one or a combination of the following:

- the lane alignment (for example, by widening the median).
- the horizontal alignment of the mainline.
- the skew angle of the intersection. See Section 6A-8 for the Department's policy on the skew angle of intersections.

Carefully study the various options to determine the best solution for your situation.

The next step in the process is to graphically lay out the returns. When designing without the aid of CADD, draw the intersection at 20 scale. A drawing at this scale is necessary for accuracy.

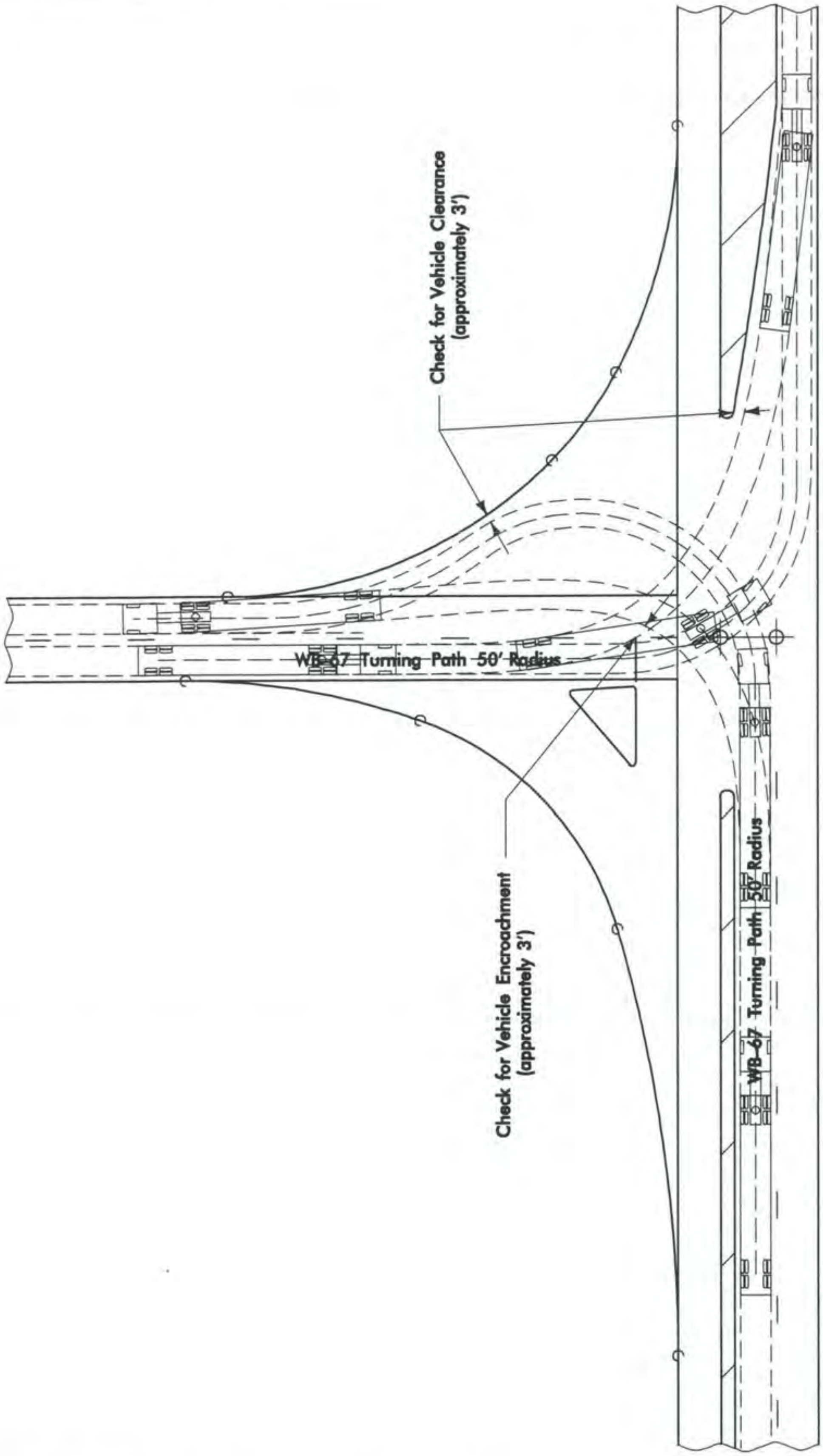


Figure 11: Left-turn movements for channelized intersection.

Graphic Layout of Return Radii

Draw the edge of pavement concentric to the turning path, at approximately 3 feet from the wheel path. Select return radii in 5-foot increments with up to three radii and/or tapers for one return (see Figures 12 and 13). Add the stop-sign island to the graphic layout (see Figure 10 for required offsets).

Geometric Plan

Using the graphic layout as a guide, set geometric controls and calculate the return geometry. An accurate geometric plot should be checked with the turning path template to assure that the actual geometrics closely approximate the graphic layout. If necessary, adjust the geometric controls and recalculate the geometry until a close approximation of the graphic layout is achieved.

Jointing

See Section 7A-3 for information on jointing rural intersections.

Design Review

If the design requires review by another office or agency, the following information is required:

- a 20 scale layout of the intersection. The selected design vehicle should be identified and the turning path shown on the layout, along with lane lines and proposed geometric data.
- design speed on the mainline and ADT traffic (including turning volumes).
- plan and profile sheets along the mainline and sideroad for distances sufficient to check sight distance at design speed.
- typical cross sections.

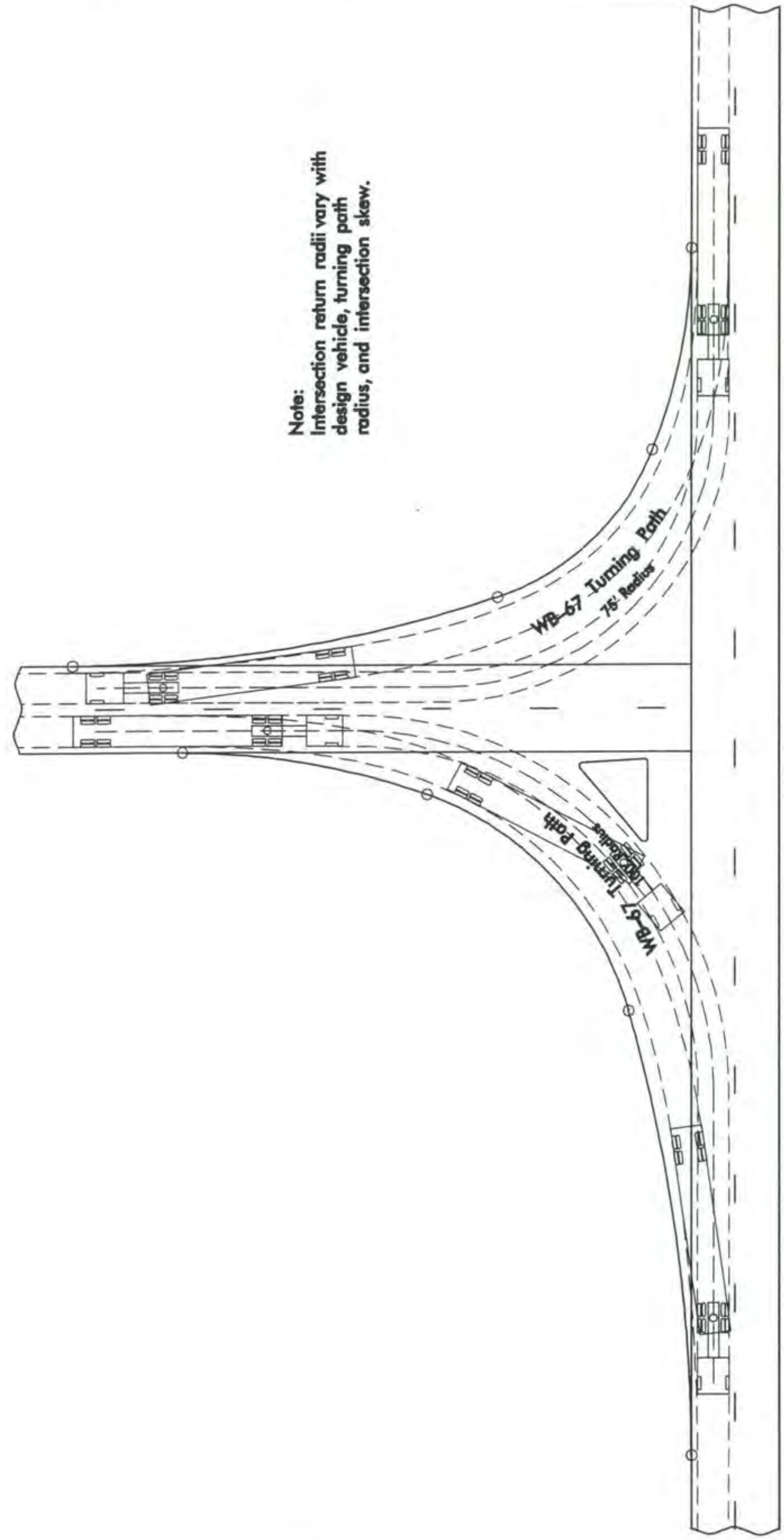


Figure 12: Intersection layout (little or no skew).

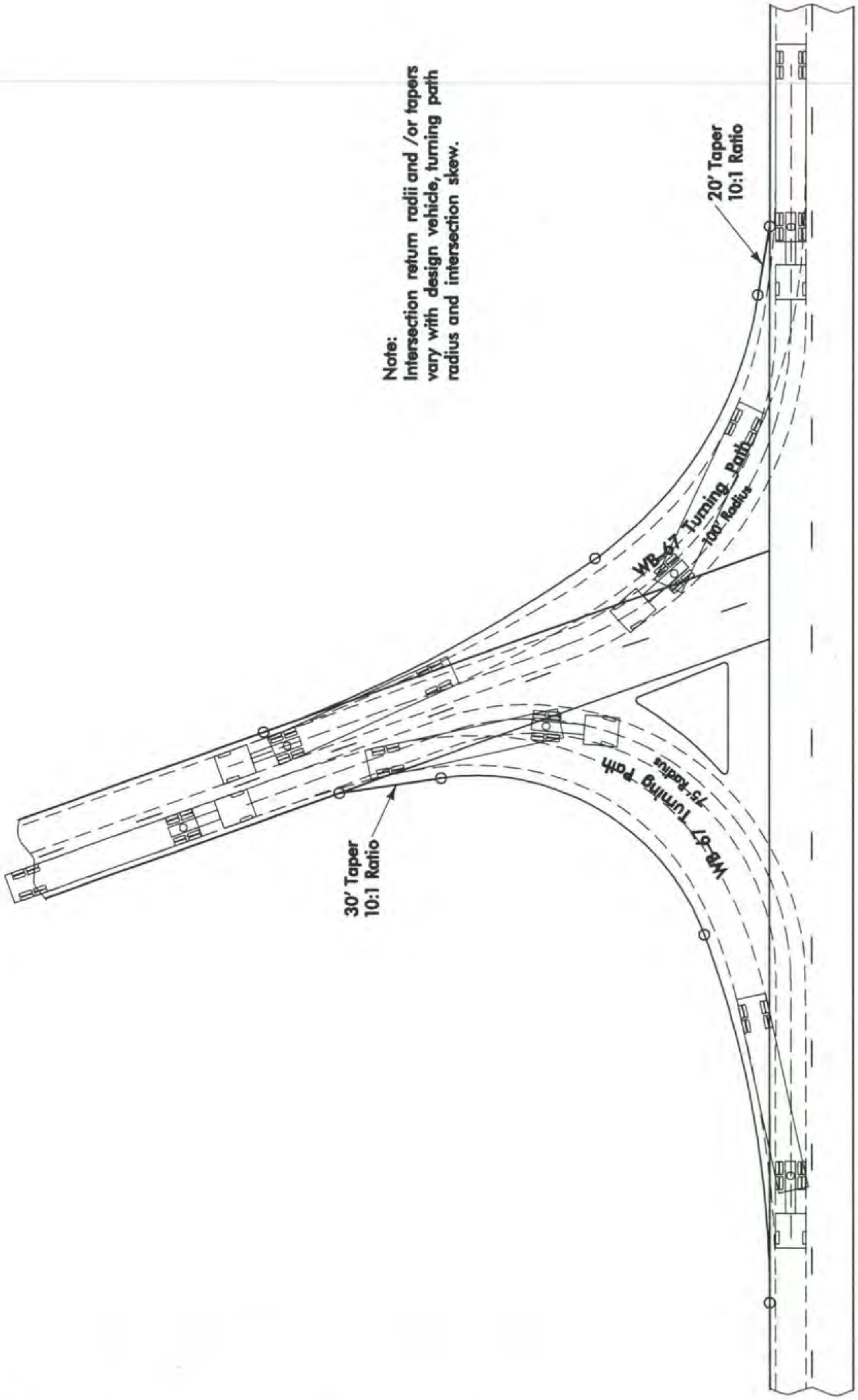


Figure 13: Intersection layout (skewed condition).

Horizontal Sight Distance at Intersections

Originally Issued: 09-01-95

When an intersection is designed (or redesigned) or when a request is made to add an entrance to the roadway near an existing intersection, it is always necessary to determine that adequate sight distances exist for drivers to negotiate the intersection. As shown in Figure 1, horizontal sight distance (d) is the leg of the sight triangle that is along the major roadway. The sight triangle is the right triangle designated by the stopped driver's eye, the middle of the intersection, and the approaching vehicle. An adequate sight distance is achieved when no part of the sight triangle is obstructed from the view of the stopped driver.

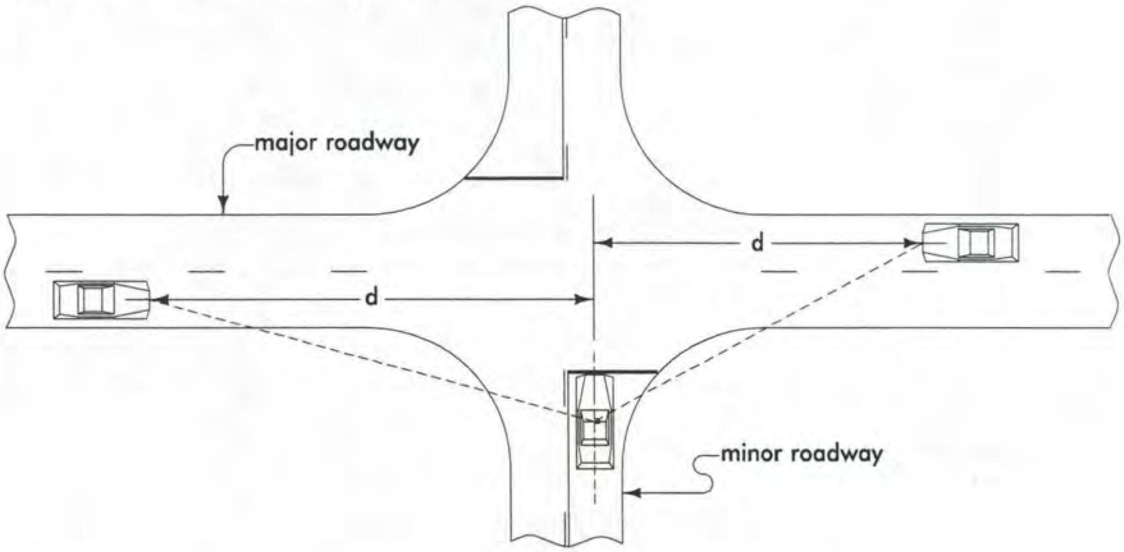


Figure 1: Horizontal sight distance.

It is desirable to have sight distances along the major road in excess of the minimum wherever feasible. Anything less than the minimum sight distance may restrict the safe operation of the intersection at the intended design speed. At intersections where conditions exist other than those presented herein, the designer should refer to AASHTO criteria to determine minimum horizontal sight distance requirements.

To ensure adequate horizontal sight distance at intersections and interchange ramp terminals, the following policy has been developed based on recommended AASHTO criteria:

- Sight distance for at grade intersections is based on a stop condition on the minor road.
- The sight triangle is based on the assumed location of the stopped driver's eye (14.5 feet behind the near edge of the traveled roadway), the time required for the stopped vehicle to enter the road (left turn movement) or to clear through traffic lanes (straight-across movement), and the speed of the approaching vehicle.

For design purposes, the passenger design vehicle (or P-vehicle) is used to determine the minimum sight distance. The straight-across movement is used to determine sight distance at four-way intersections, while the left turn movement is used at "T" or ramp intersections.

Calculating Horizontal Sight Distance

The equation below takes all of the above considerations into account to determine minimum sight distances for various roadways:

$$d = 1.47 \times V \times t_g$$

where:

d = Minimum sight distance along the major highway from the intersection, in feet:

V = Design speed on the major highway, in mph:

t_g = Time gap for vehicle to enter the highway (left-turn movement) or clear the through traffic lanes (straight-across movement).

Table 1 provides time gaps for left-turn and straight-across movements for various design vehicles. Time gaps are for a stopped vehicle at an intersection with a two-lane highway with no medians and grades of 3% or less. Adjustments for multi-lane highways are required as noted in the table.

Table 1: Time gaps for left-turn and straight-across movements

design vehicle	t_g left-turn movement(a) (seconds)	t_g straight-across movement(b) (seconds)
Passenger car	7.5	6.5
Single-unit truck	9.5	8.5
Combination truck	11.5	10.5

(a) For left-turns onto two-way highways with more than two lanes, add 0.5 seconds for passenger cars or 0.7 seconds for trucks for each additional lane to be crossed.

(b) For crossing a highway with more than two lanes, add 0.5 seconds for passenger cars or 0.7 seconds for trucks for each additional lane to be crossed and for narrow medians which cannot store the design vehicle.

Table 2 provides sight distance values for left-turn and straight-across movements for passenger cars. Time gaps are for a stopped vehicle at an intersection with a two-lane highway with no medians and grades of 3% or less. For other design situations the time gap should be adjusted as noted in Table 1 and sight distance recalculated.

Table 2: Intersection Sight Distance.

design speed (mph)	intersection sight distance left-turn movements (ft.)	intersection sight distance straight-across movements (ft.)
25	280	240
30	335	290
35	390	335
40	445	385
45	500	430
50	555	480
55	610	530
60	665	575
65	720	625
70	775	670
75	830	720
80	885	765

Adjustments for Superelevation and Skew

Normally, the grade across an intersection is so small that it need not be considered, but when there is superelevation at an intersection, the acceleration time of the crossing vehicle will be affected. An adjustment factor from Table 3 based on the superelevation of the thru roadway should be applied to the values in Table 2. On Ramp and T intersections, the grade of the thru roadway will also affect the acceleration time of the left turning vehicle. Thus, an adjustment factor from Table 3 based on the grade of the thru roadway should be applied in these cases as well.

Table 3: Adjustment factor for grade.

Grade*	-4% or greater	-2%	0%	+2%	+4%
Factor	0.7	0.9	1.0	1.1	1.3
Factors may be interpolated directly					

*Superelevation or Grade of Through Roadway

When two roads intersect at other than 90 degrees, an adjustment factor should be used for the skew angle, as shown below in Table 1.

Table 4: Adjustment factor for skew angle.

Angle	90	80	70	60	45
Factor	1.00	1.01	1.03	1.06	1.17
Factors may be interpolated directly					

On ramp and T-intersections, the skew angle has little effect on sight distance for left turn movements; therefore no adjustment is required.

Example

Determine the minimum sight distance for the four-way intersection of a two-lane undivided major highway with a minor road under stop control. The design speed of the major roadway is 55 mph with a cross slope of +3.5% and a skew angle of 75 degrees.

1. Since this is a four-way intersection, there will be left-turn and straight-across movements. Using Table 2 and a design speed of 55 mph the sight distance (d) is 610 feet.
2. Interpolate the adjustment factor from Table 1 for a 75 degree skew:

$$1.01 + 0.5 \times (1.03 - 1.01) = 1.02$$

3. Interpolate the correction factor from Table 2 for a +3.5% cross slope:

$$1.1 + 0.75 \times (1.3 - 1.1) = 1.25$$

4. Substitute into the following formula:

$$d_{corr} = (d) \times (\text{Skew Adjustment Factor}) \times (\text{Grade Adjustment Factor})$$

$$d_{corr} = (610') \times (1.02) \times (1.25) = 777.75'$$

5. Round d_{corr} to next higher 5′ increment:

$$d_{corr} = 780' \text{ minimum sight distance}$$

Procedures for Applying Horizontal Sight Distance

At the intersection of two roads or a road and a ramp, the minimum sight distance along the thru highway is taken from Table 2 or calculated using the formula from the same page, adjusted by the factors in Tables 3 and 4, and applied as shown in Figures 2 through 8 to determine the minimum sight triangle required for the intersection to function safely. Appropriate design modifications should be made, when required, to provide a sight triangle free of obstructions extending above the driver's line of sight. Assume the height of the driver's eye to be 3.50 feet and the top of an approaching vehicle to be 4.25 feet. Typical obstructions might be trees, buildings, guardrails, bridge rails or poor horizontal and vertical alignment.

Unique Situations

Figures 2 through 8 are designed to illustrate how sight distance is determined and used in unique situations that the designer might face. For example, Figure 2 considers the case where the major roadway is curved; thus the sight distance must be applied along a curved path.

Figure 3 indicates the use of sight distance in determining whether an access to either the major or minor road should be permitted. However even if the sight distance would permit it, no public or private access to the major roadway will be allowed within 300 feet of the intersection, measured along the centerline of the major roadway. Similarly, no portion of an access to the sideroad will be allowed within 100 feet of the near edge of the major roadway's thru traffic lane, measured along the centerline of the side road. These criteria are to be used only at intersections of a secondary road with a primary road. For other types of roadway intersections, refer to IAC 761-Chapter 112(306A) governing access.

Figure 4 illustrates a situation where the minor road intersects a four-lane roadway and the median is wide enough to accommodate a car. On such roadways (those with medians of 40 feet or wider), the sight distance can be treated as two stop conditions. The first is the normal stop, and the second is within the protection of the median.

Figures 5 and 6 illustrate typical sight distance requirements for ramp and T intersections, whereas Figure 7 indicates the requirements at diamond-type interchanges. At interchanges where loop or directional-type movements are provided, provision for unobstructed sight distance should be made in all quadrants providing these types of movements.

Railroad Crossings

Figure 8 represents the sight distance requirements for at-grade railroad crossings. An unobstructed line of sight should be provided within the sight triangle. The sight triangle should assume the height of the driver's eye to be 3.50 feet and the height of the approaching train to be 4.25 feet. We use 4.25 feet as a conservative number for the train height due to the lack of direction from AASHTO on this matter.

Sight distances of the order shown in Table 5 (on page 12) are desirable at any railroad-grade crossing not controlled by active warning devices. The attainment of those distances, however, is difficult and often impractical, except possibly in flat, open terrain.

In other than flat terrain, it may be necessary to rely on speed control signs and devices and to base sight distance on a reduced vehicle speed. Where sight obstructions are present, it may be necessary to install active traffic control devices that will bring all highway traffic to a stop before crossing the tracks and will automatically warn drivers in time to avoid an approaching train. Below are definitions of quantities used in Figure 8.

V_v = Velocity of the vehicle in mph (the design speed of the highway).

d_H = Sight distance leg along the highway (based on V_v only). This allows the driver of a vehicle proceeding at speed V_v to observe the tracks (with or without an active warning device) and to safely stop without encroaching into the crossing area.

V_T = velocity of the train in mph.

d_T = Sight distance leg along the railroad tracks (based on V_v and V_T). This and d_H are used to determine the minimum sight triangle that will permit the vehicle's driver to cross the tracks safely even though a train is observed at the distance d_T from the crossing.

Concluding Remarks

It is desirable to have sight distances along the major road in excess of the minimum wherever feasible. Thus, it should be stressed that this is a minimum sight distance, and anything less may restrict the safe operation of the intersection at the intended design speed. At intersections where conditions exist other than those presented herein, the designer should refer to AASHTO criteria and the information presented at the first part of this section in determining minimum sight distance requirements.

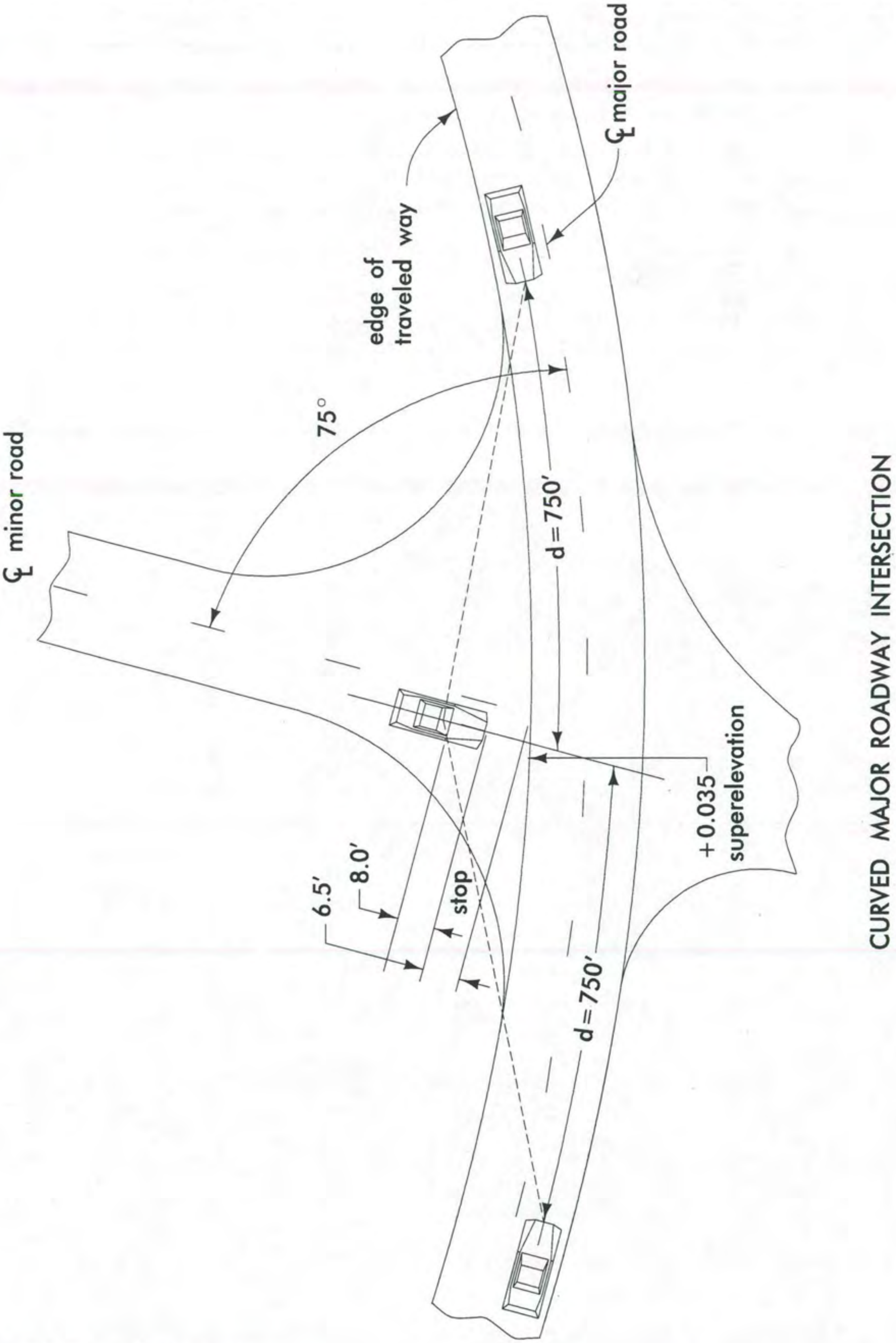


Figure 2: Curved major roadway

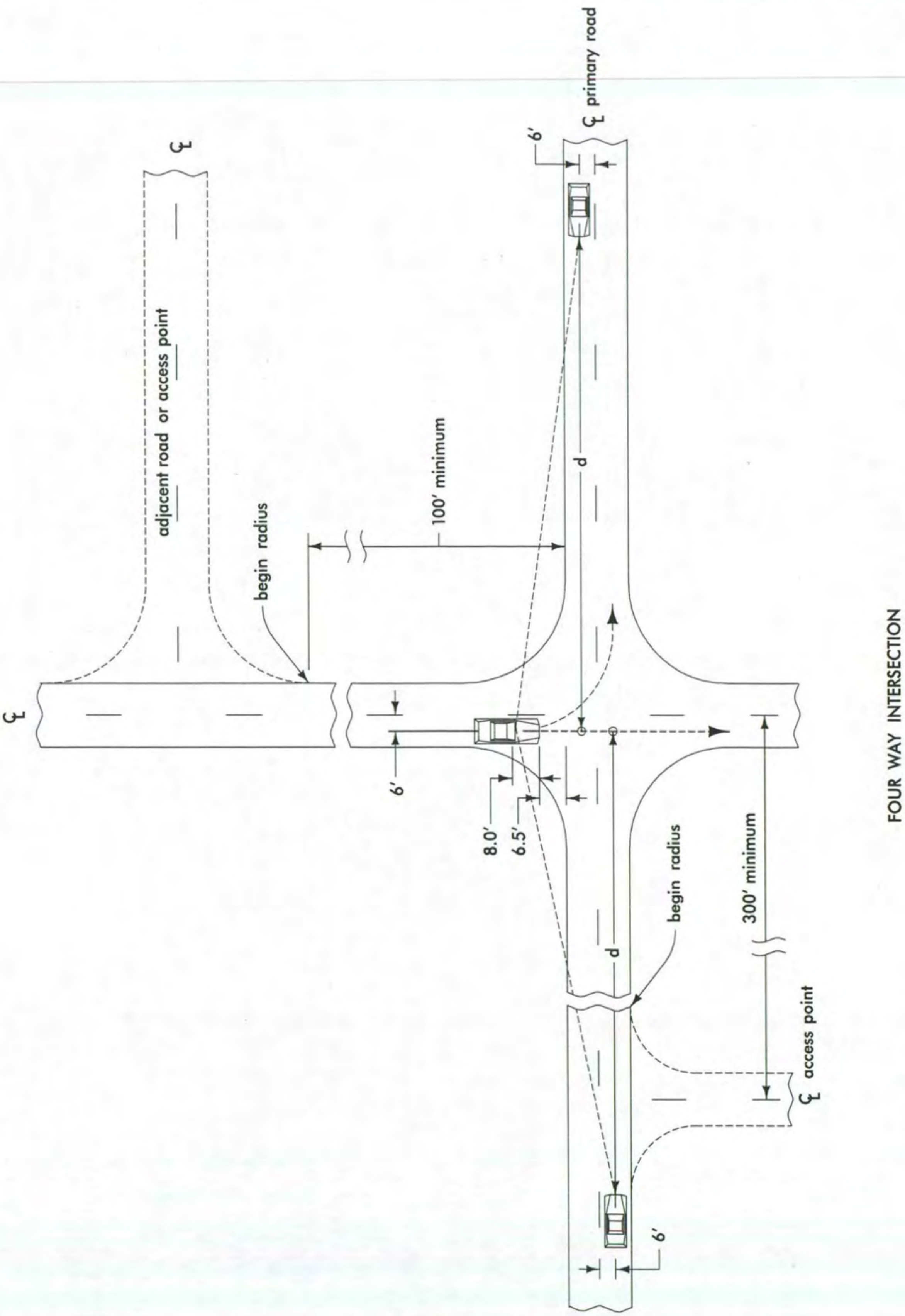


Figure 3: Four-way intersection (with secondary road).

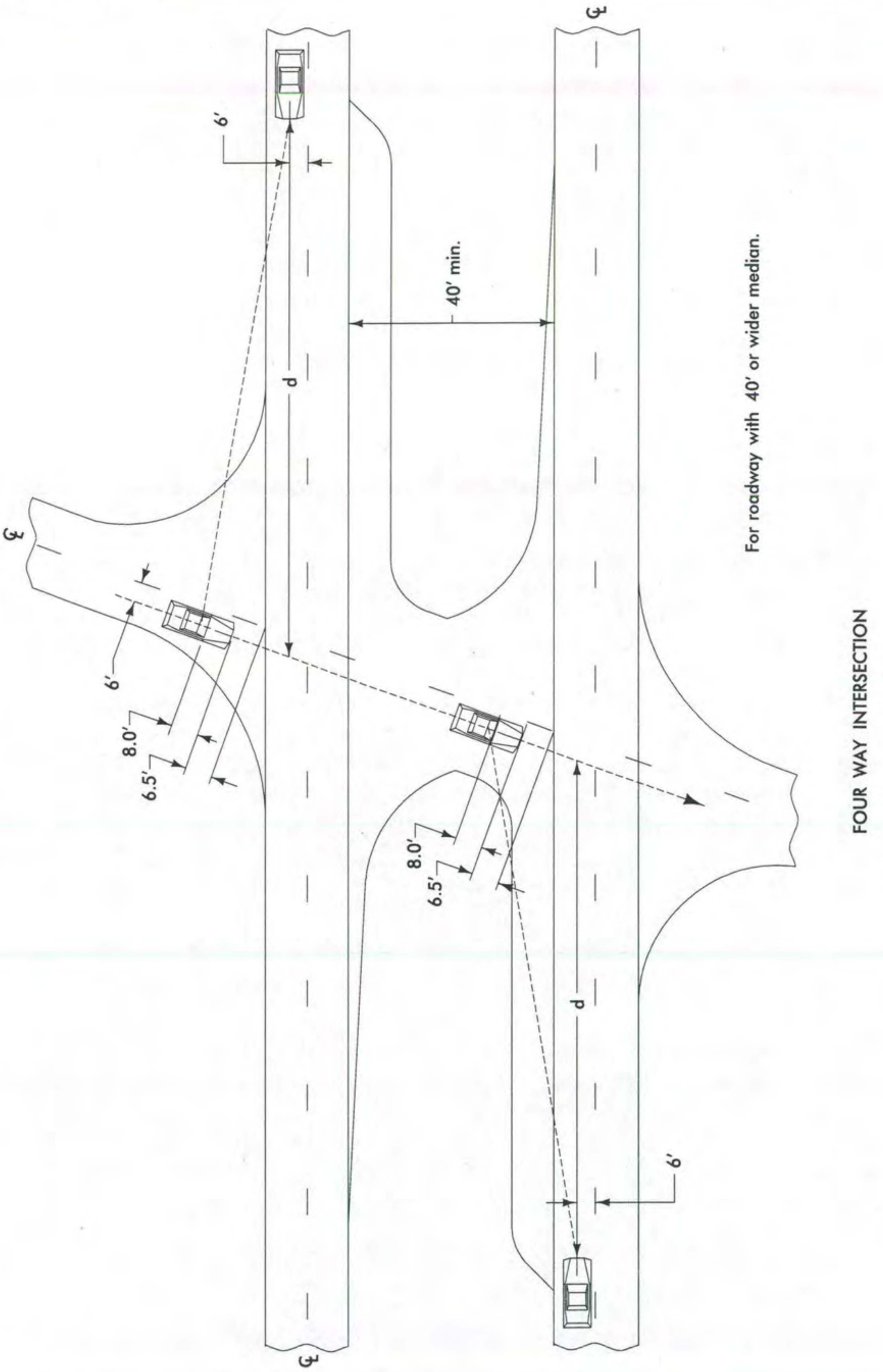


Figure 4: Four-way intersection (divided roadway).

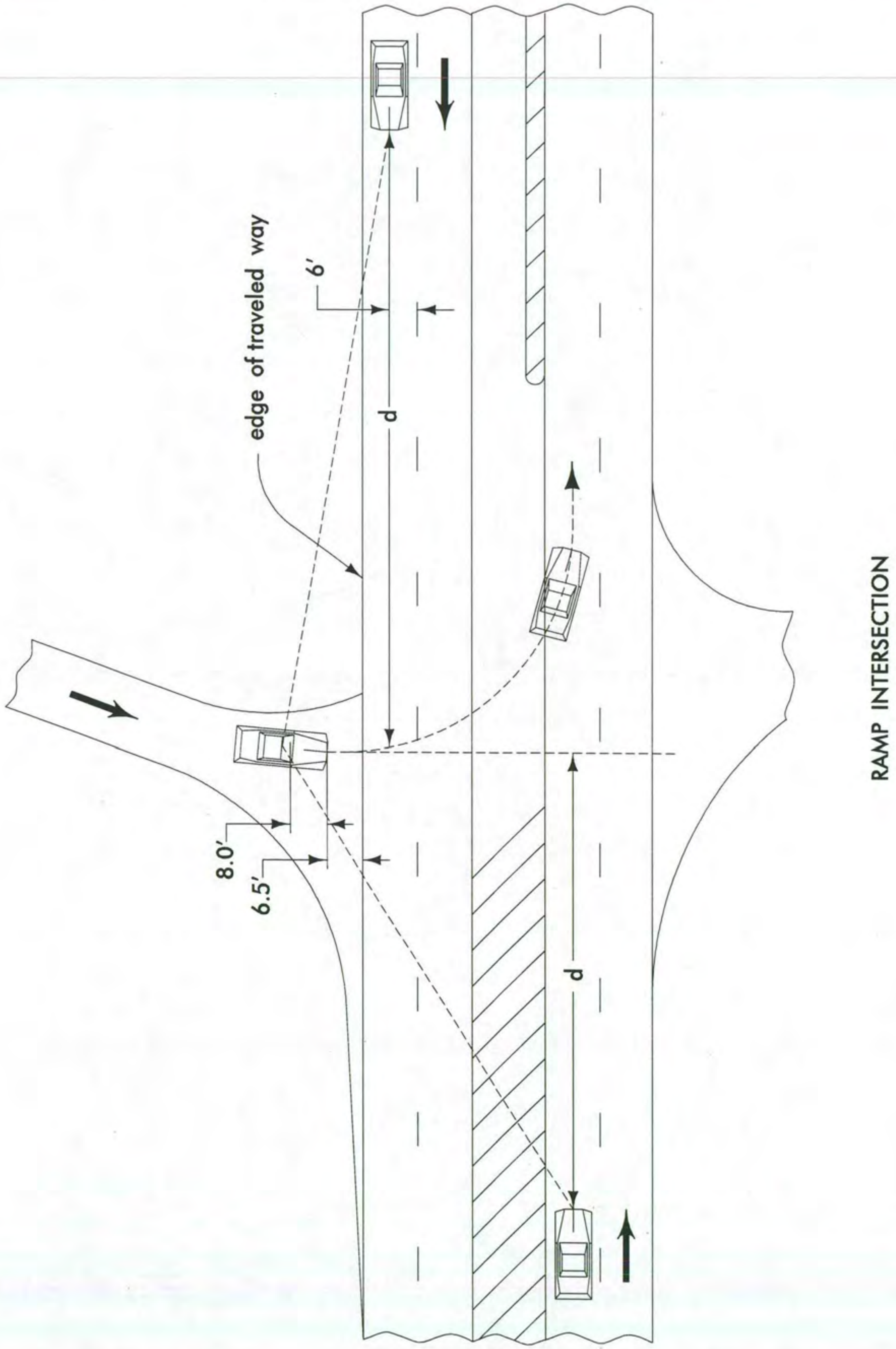


Figure 5: Ramp intersection.

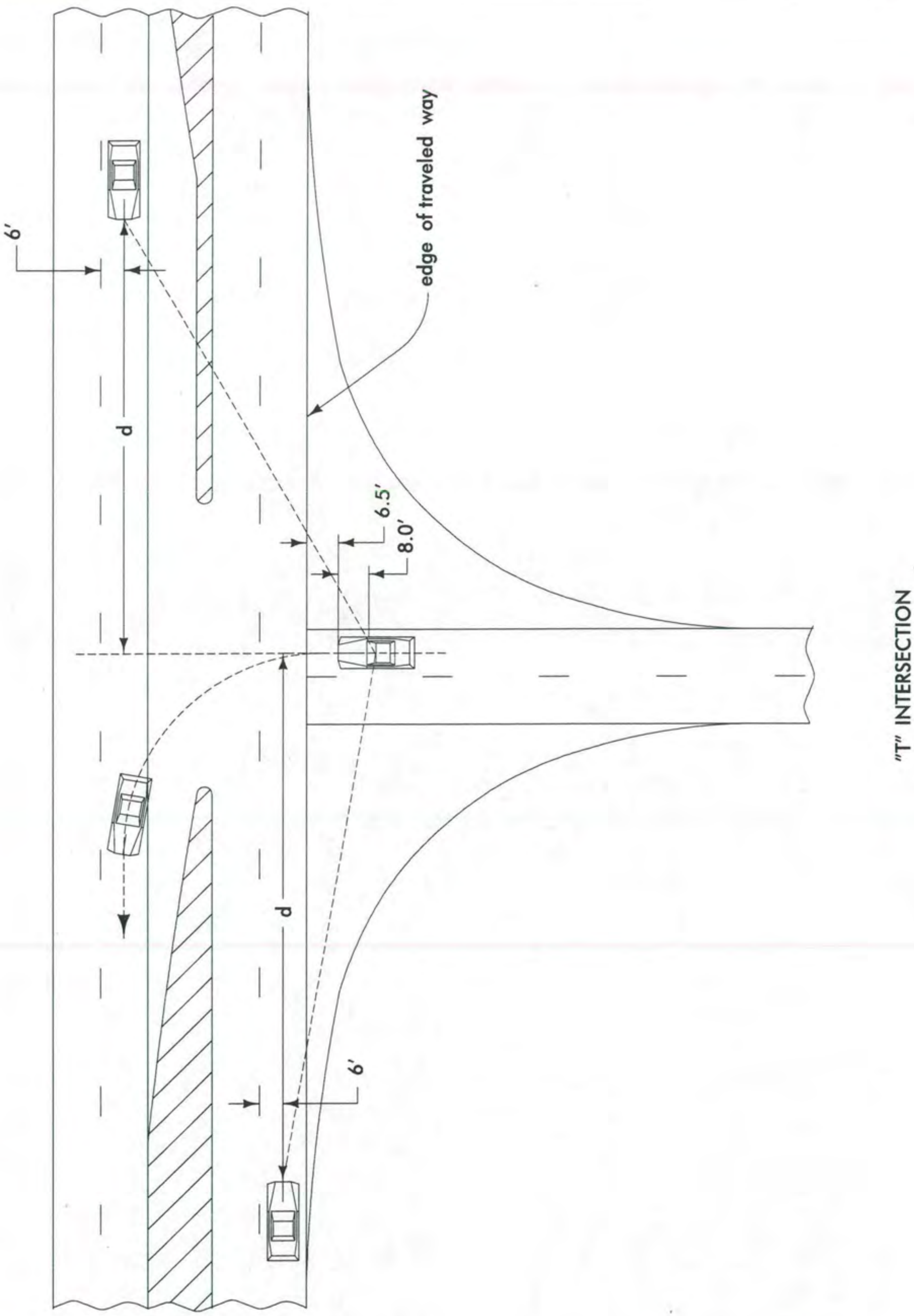


Figure 6: T intersection.

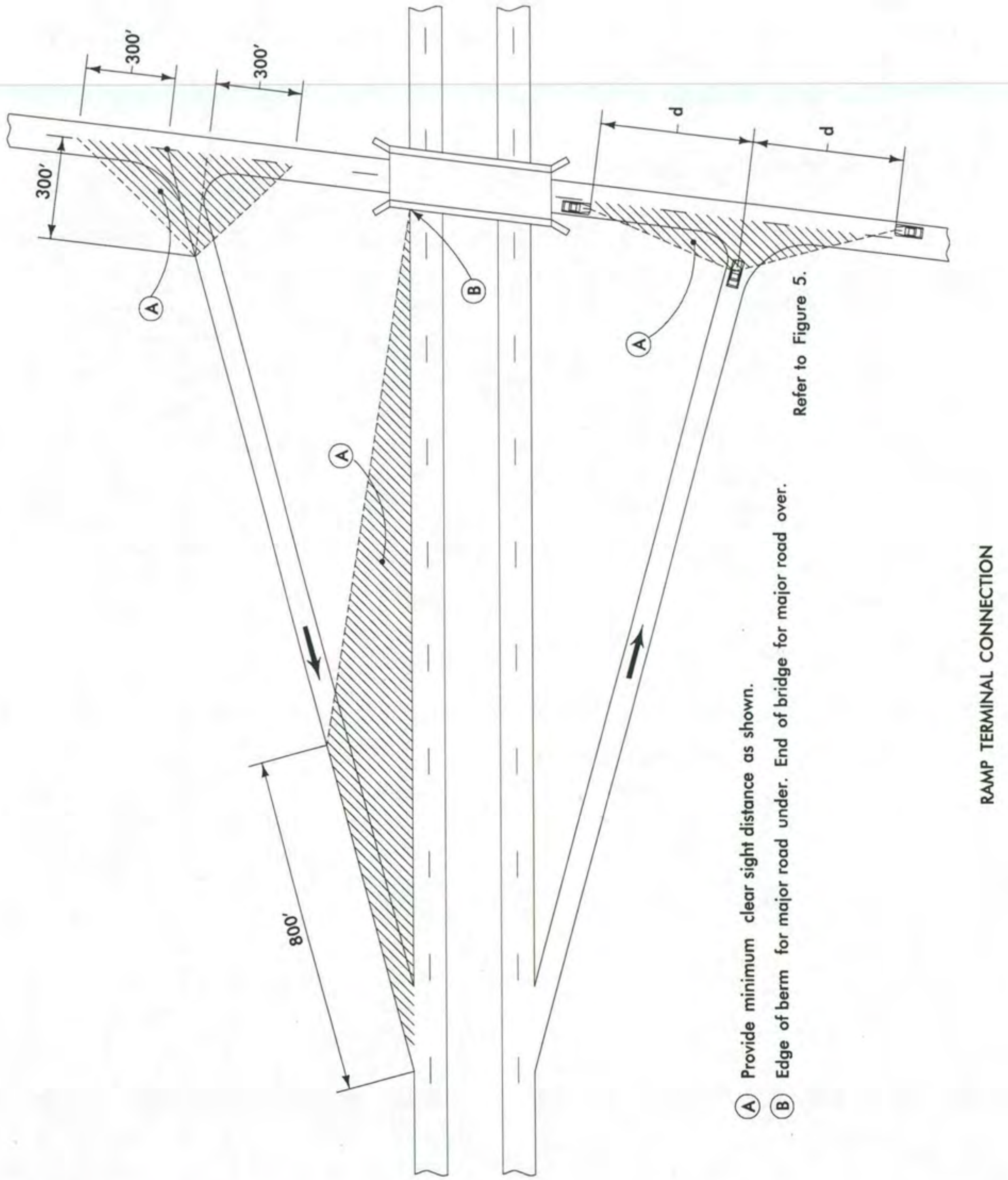


Figure 7: Ramp terminal connection.

Table 5: Required design sight distance for combination of highway and train vehicle speeds 65-foot truck crossing a single set of tracks at 90 degrees).

Train Speed (mph) V_T	Vehicle Speed (mph) V_v							
	10	20	30	40	50	60	70	80
	Distance along highway for crossing (ft) d_H							
	71	137	222	326	449	591	753	933
	Distance along railroad from crossing (ft) d_T							
10	146	106	99	100	105	111	118	126
20	293	212	198	200	209	222	236	252
30	439	318	297	300	314	333	355	378
40	585	424	396	401	419	444	473	504
50	732	530	494	501	524	555	591	630
60	878	636	593	601	628	666	709	756
70	1,024	742	692	701	733	777	828	882
80	1,171	848	791	801	838	888	946	1,008
90	1,317	954	890	901	943	999	1,064	1,134

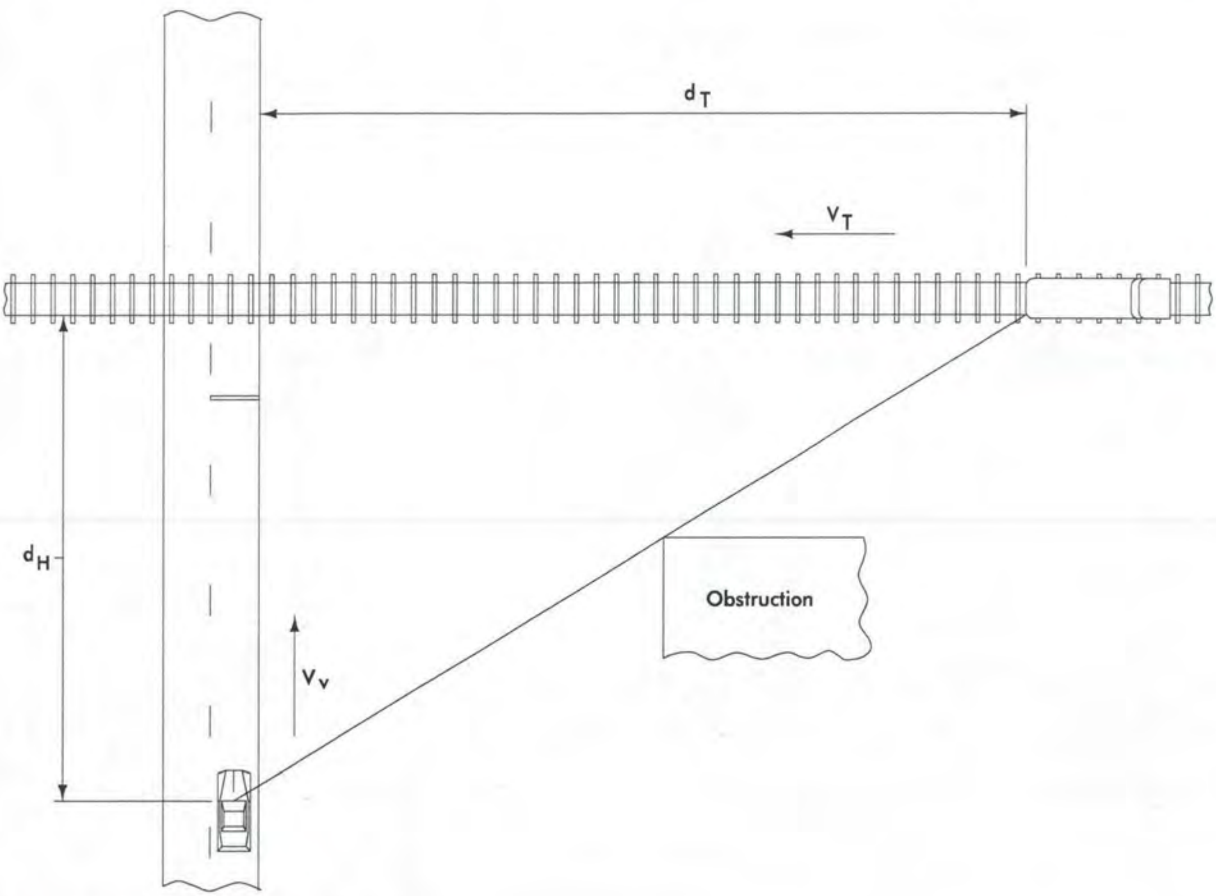


Figure 8: Railroad highway crossing.

Mainline Vertical Sight Distance at Intersections

Originally Issued: 09-01-95

Adequate vertical sight distance into intersections should always be considered as part of a project design. As shown in Figure 1, it is desirable to have a direct line of sight for 1,000 feet, measured from the center of the intersection (at the pavement's surface) to the driver's eye (assumed to be 3.5 feet in height). Greater sight distance should be obtained wherever possible.

In considering sight distance into an intersection, the designer should study the accident history, turning movements, right-of-way requirements, and overall effect that providing adequate sight distance will have on the project and intersection site. Generally, non-primary roads with traffic volumes below 750 vpd (present day) will not warrant extensive design modifications to achieve the desirable 1,000-foot sight distance. However, the best sight distance allowed by economics and conditions should be provided. Refer to Section 6A-4 to get minimum sight distance requirements for vehicles on the side road.

At intersections where channelization is used, 1,000 feet of sight distance to the median nose is considered a desirable minimum. Again, all factors influencing the intersection design should be considered when attempting to provide adequate sight distance to the median nose.

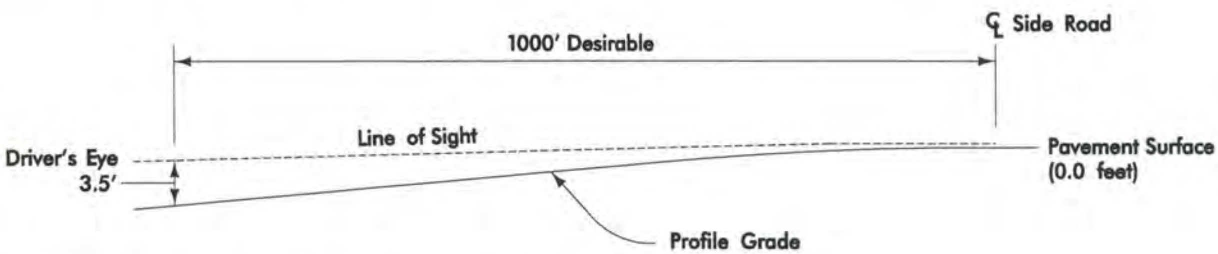


Figure 1: Desired vertical sight distance at intersections.

Rumble Strips at Intersections

Originally Issued: 09-01-95

On reconstruction or resurfacing projects that do not involve geometric changes or changes in stop conditions, the designer should not add rumble strips where they do not already exist unless the Office of Traffic and Safety requests them. If rumble strips do already exist, the designer shall place new rumble strips in the same locations as the original ones.

As shown in Figure 1, rumble strips will normally be located according to the following guidelines:

- First rumble strip located 200 feet in advance of the "STOP AHEAD" sign.
- Last rumble strip located 300 feet in advance of the stop bar.
- Intermediate rumble strip located at an equal distance between the first and last rumble strips.

If the existing rumble strips are at different locations or have different spacing than this, the Office of Traffic and Safety should be contacted.

If there is not a series of advance warnings and guide signs approaching a junction, the distance between the "STOP AHEAD" sign and the "STOP" sign is usually 750 feet. If there are one or more signs, the "STOP AHEAD" sign is moved away from the intersection so that it is still the first sign. This distance can be up to 1500 feet.

Whenever there is a change of alignment or stop conditions at an intersection, the Office of Traffic and Safety should be contacted to determine if rumble strips are to be placed.

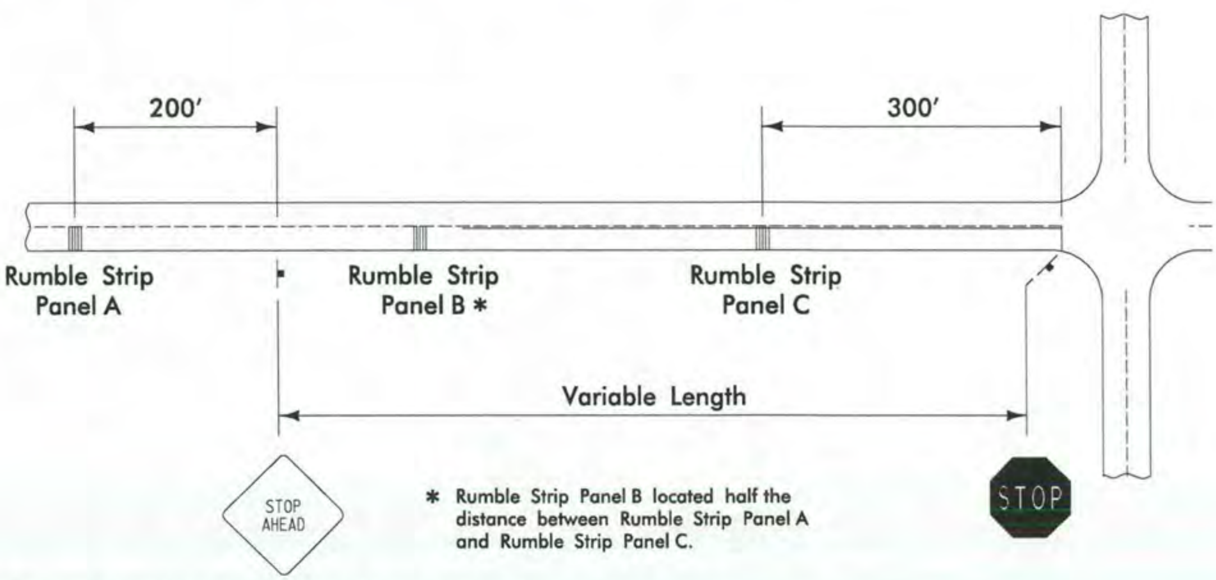


Figure 1: Typical rumble strip panel locations.

Intersection Alignment

Originally Issued: 07-12-96

This policy presents guidelines for the alignment of crossroads at intersections with new or reconstructed, rural, two-lane or multi-lane primary highways. It is not directly applicable to access locations allowed by the permitting process administered by the Maintenance Division. These guidelines apply to all two-way, stop-controlled intersections, regardless of whether the crossroad is under state or county jurisdiction. The policy provides guidelines for realigning intersections and the design criteria that is applicable.

Paved Crossroads

AASHTO recognizes intersection angles between 60º and 120º as acceptable.[1] NCHRP Report 279 recommends intersection angles of 75º to 90º be maintained wherever possible with angles as low as 60º considered acceptable.[2] Therefore, this policy establishes an angle of 90º between the primary route and the crossroad as ideal. Intersection angles between 90º and 75º are desirable. Angles between 75º and 60º are acceptable. Intersections with angles less than 60º will be realigned to provide a desirable intersection angle.

Traffic volume, accident history and design vehicle should be evaluated at intersections in the acceptable range to determine if realignment to the desirable range is warranted. Generally, if an intersection is realigned, the angle should be improved 15º or more to justify the additional cost.

Horizontal and vertical geometrics of the crossroad realignment should meet or exceed its functional classification design criteria. On an approach with reverse curves, the curve nearest the stop condition may use a minimum radius of 165 feet or one half the radius of the preceding curve, whichever is greater. A tangent alignment should be placed between the reverse curves to provide for superelevation transition. Approximately 100 feet of tangent alignment should be placed between the edge of traveled way on the primary route and the point of curvature (P.C.) or point of tangency (P.T.) of an approach curve.

Non-paved Crossroads

In general, non-paved crossroads should be realigned utilizing the same criteria as for paved crossroads. However, if a benefit-cost analysis reveals realignment would not be cost effective, intersection angles less than 60º are acceptable. When realignment is warranted, the geometric criteria will be determined as described for paved crossroads.

[1] AASHTO *A Policy on Geometric Design of Highways and Streets* (Washington D.C., 1994) 643-645.

[2] Transportation Research Board, National Cooperative Highway Research Program Report 279, *Intersection Channelization Design Guide* (Washington, D.C., 1985) 43.

General

Offset intersections are an acceptable design alternative if the crossroad through volume is very low and two intersections can resolve deficiencies associated with one intersection. Offset intersections must meet all design criteria individually. Offset intersections on two-lane routes are appropriate only when the offsets require through traffic on the crossroad to execute left-turns onto the primary route and right turns off the primary route. Offset intersection angles should fall within the desirable range.

Any modifications to a county road should be reviewed with the County Engineer including any primary road relocations that change the skew angle but otherwise make no changes to the county road.

Cross Sections of One-Way Ramps and Loops

Originally Issued: 09-01-95

This section provides design requirements for one-way ramps (also known as slip ramps or diagonal ramps) and loops (also known as loop ramps). Requirements are provided for both one-lane and two-lane facilities.

One-Lane Ramps and Loops

Because ramp and loop designs vary depending on whether they are part of the interstate or non-interstate system, ramp and loop design requirements are provided for both the interstate and non-interstate systems.

Interchanges on the Interstate System

Ramps are normally designed with a 16-foot pavement width. If any portion of the ramp is designed with a radius between 150 and 249 feet, a pavement width of 18 feet shall be used for that portion. An example would be where a free right-turn movement is designed at a ramp terminal. In this case, the transition in pavement width shall occur immediately prior to the ramp terminal. There is no reason to provide additional pavement width where it is not required by the roadway geometry.

Typical 7131 details the transition area and should be included in the plans if additional pavement width on a ramp is warranted.

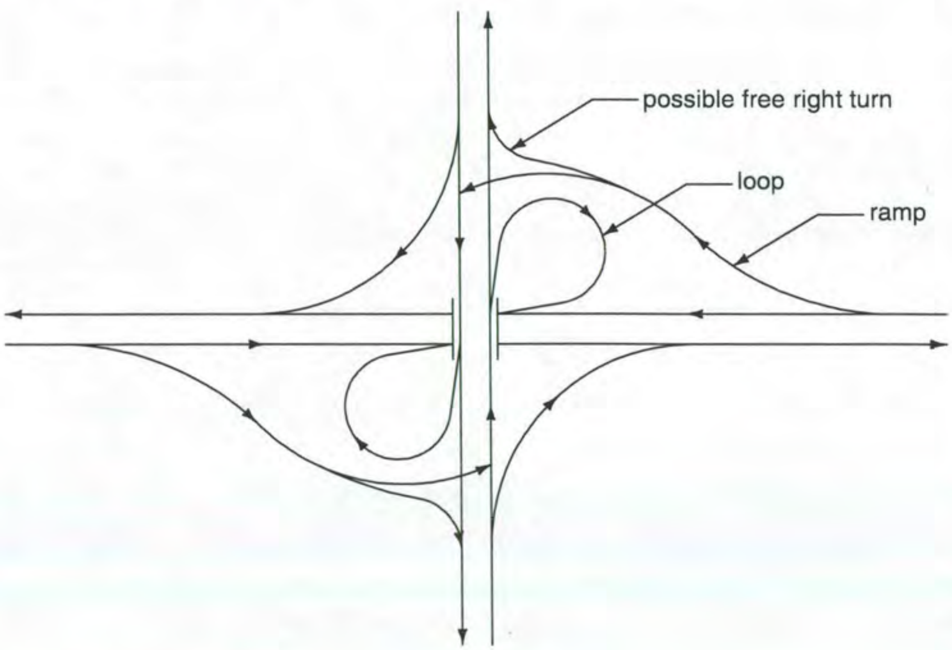


Figure 1: Illustration of ramps and loops.

Loops tend to be designed where right-of-way constraints prevent the development of ramps or where high traffic volumes create a need to eliminate at-grade—left-turn crossings. Alignments for loops usually involve compound horizontal curves, where the loop merges with the mainline.

A loop shall be designed for one constant cross section width. If the radius of the major portion of the loop curvature (not the tapers) is less than 250 feet, the pavement width shall be 18 feet for the entire loop. Otherwise, the pavement width for the entire loop shall be 16 feet.

Shoulders for ramps and loops on the interstate system are paved and shall be 4 feet wide on the left side and 6 feet wide on the right side when facing in the direction of travel. Refer to Section 3C-3 for information on shoulder treatment within the superelevated area of the ramp or loop.

Interchanges on the Non-Interstate System

For interchanges that are not part of the interstate system, pavement and shoulder widths shall be the same as indicated above for interstate ramps and loops. The shoulders shall be granular on both sides of a ramp and shall be paved on both sides of a loop.

The one exception to this occurs when the ramp is superelevated in excess of 7%, in which case the entire high-side shoulder is paved as shown on Typical 2016. Refer to Section 3C-3 for more information on shoulder treatment within the superelevated area of the ramp or loop.

Weigh Stations and Rest Areas

Ramps and loops at weigh stations on the interstate system have the same cross section requirements as interchange ramps and loops on the interstate system. Those on the non-interstate system have the same cross section requirements as interchange ramps and loops on the non-interstate system. The shoulder surface of a ramp shall match the adjacent mainline's shoulder surface, subject to the requirements associated with Typical 2016. Loop shoulders shall be paved.

Two-Lane Ramps

Two-lane ramps have the same design requirements as one-lane ramps except for the following:

- the pavement width for two-lane ramps is normally 24 ft.
- for ramps that allow high-speed merging, such as directional and semi-directional ramps, the shoulder widths shall be the same as the mainline shoulders (normally 6 and 10 feet). For ramps that require stopping or a large reduction in speed before merging, such as diamond-type ramps, the shoulder widths are the same as one-lane ramps (4 and 6 feet). These cases are illustrated in Figure 2. Refer to Section 3C-3 for information on shoulder treatment within the superelevated area of a two-lane ramp.

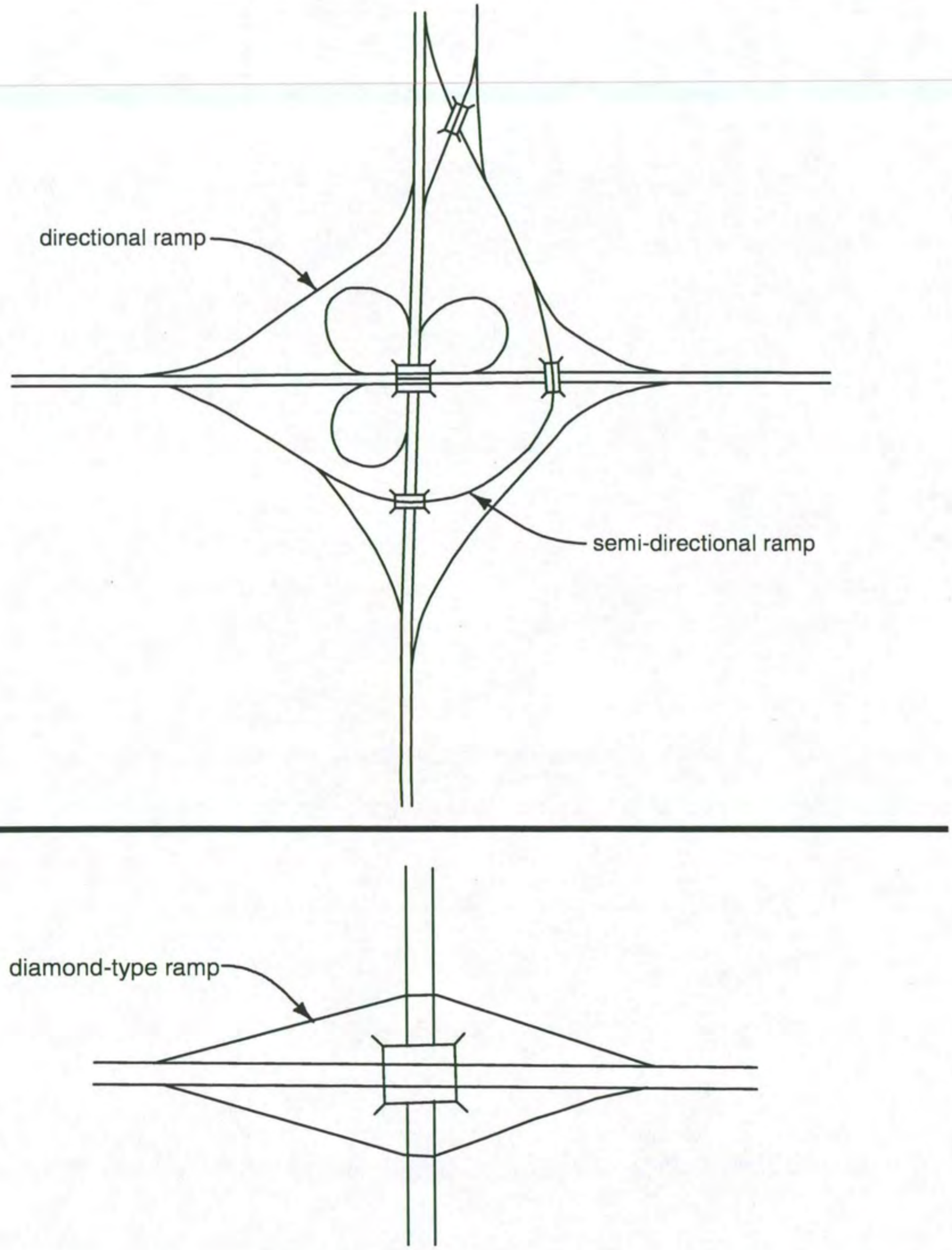


Figure 2: For directional and semi-directional two-lane ramps, the shoulder widths are as wide as the typical shoulders on the mainline. For diamond-type two-lane ramps, the shoulder widths are the same as one-lane ramps (4 and 6 feet).

County Roads through Interchanges

Originally Issued: 09-01-95

On projects where interchanges will be constructed at existing or proposed county roads, the same design criteria used for rural two-lane highways (non-NHS) should be used for the county road between the ramp terminals. Section 1C-1 summarizes this criteria.

Accesses and Safety Dikes at Ramp/Loop Terminals

Originally Issued: 04-20-01

This section discusses the proper procedure for locating accesses and safety dikes opposite to and near ramp/loop terminals. Proper location of accesses and safety dikes opposite of ramp/loop terminals is very important to the safety of drivers, especially in adverse driving conditions. Proper location of accesses near ramp/loop terminals is important to insure they do not conflict with the design of the terminal. The nearest access to a ramp/loop terminal is calculated from the ramp bifurcation; however, this should not be used as the location station for an entrance or dike opposite a ramp/loop terminal.

Location of an Access Opposite a Ramp/Loop Terminal

The centerline of an access should be centered on the center joint line 16 feet from the ramp baseline, see Figure 1. This will allow drivers to continue through the terminal without jogging to the right or left, as would happen if the access was centered along the ramp baseline.

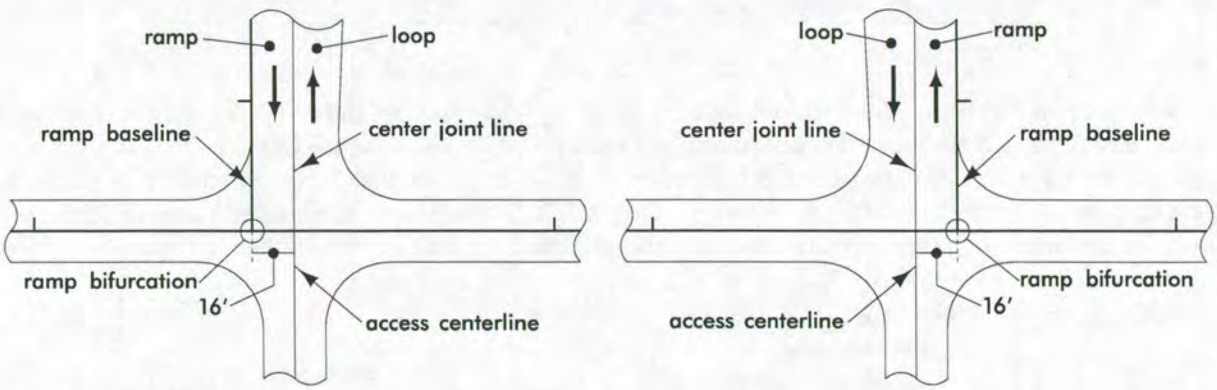


Figure 1: Location of an access at a ramp/loop terminal.

Location of a Safety Dike Opposite a Ramp/Loop Terminal

Safety dikes should be centered on the approach lane, see Figure 2. This will better allow drivers who accidentally continue through the terminal to use the dike as a recovery area, for there is less of a chance the driver would miss the dike than if the safety dike were centered across from the ramp baseline.

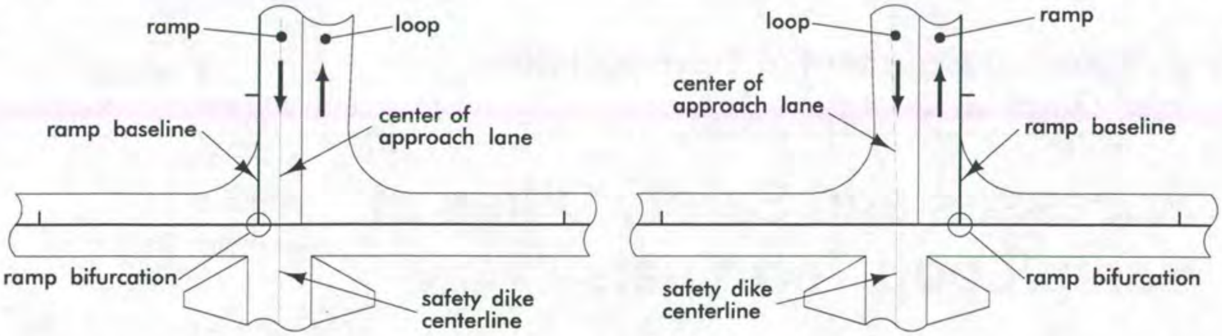


Figure 2: Location of a safety dike at a ramp/loop terminal.

Location of an Access Near a Ramp/Loop Terminal

According to the Iowa Access Management Policy, the location of an access along a side road at an interchange is measured from the point of ramp bifurcation. Roadway type classification determines the distances that should be used; these values are presented in Table 1 below.

Table 1: Minimum distances for access location near a ramp/loop terminal.

Roadway Type	Rural	Fringe	Built-up
Multi-lane Divided Highway	600'	600'	600'
Two-Lane Primary	600'	600'	300'
Secondary Road	600'	600'	600'
City Street	--	300'	300'

However, if a right-turn deceleration lane is required in advance of the ramp bifurcation point, the first access should be located a minimum of the appropriate distance in Table 1 from the point of ramp bifurcation or 150 feet from the beginning of the deceleration lane taper, whichever provides the greatest length from the ramp, see Figure 3. This will help to insure that relocated roads or driveways are not designed such that they are accessing the side road within the taper of the turn lane.

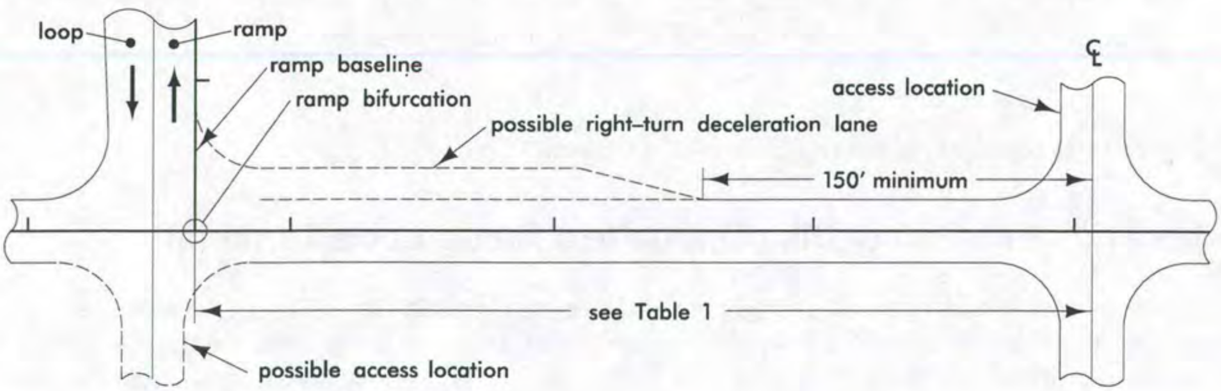


Figure 3: Location of an access near a ramp/loop terminal.

Adding, Dropping, or Redirecting through Lanes

Design Manual
Chapter 6
Geometric Design

Originally Issued: 06-02-00

Adding Lanes

When additional lanes are developed, such as for passing lanes, climbing lanes, additional lanes at intersections, or in other circumstances, they should be developed with a 15:1 taper ratio, as shown in Figure 1. This section discusses adding, dropping, and redirecting through lanes. Taper ratios for right- and left-turn lanes are discussed in Section 6A-1.

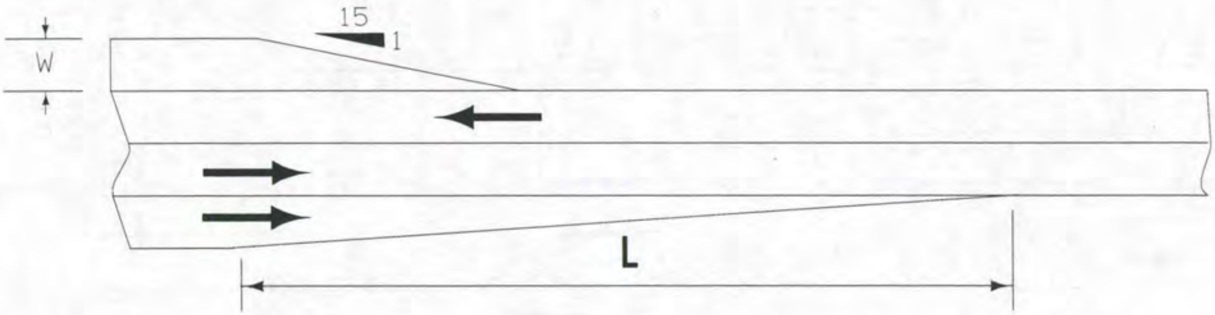


Figure 1: Adding or dropping through lanes.

Dropping Lanes

When dropping a through lane, the minimum length of taper can be determined by the following formulas:[1]

$$L = S^2 \frac{W}{60} \text{ for speeds of 40 mph or less}$$

$$L = SW \text{ for speeds of 45 mph or more}$$

where:

L = minimum length of taper

S = posted speed limit or 85th percentile speed

W = width of lane to be dropped or redirection offset

Preferably, taper ratios should be evenly divisible by 5 (15:1, 20:1, etc.) Calculations that result in odd ratios should be rounded up to the next increment of 5. Table 1 utilizes the formulas to determine

[1] FHWA, *Manual on Uniform Traffic Control Devices*, Washington, D.C., U.S. Government Printing Office, 1998.

the appropriate taper ratios for dropping a 12' wide lane. The ratio remains constant for a given design speed, while the length varies with the lane width.

Table 1: Length and Taper Ratio for Dropping 12' Lane

Design Speed (mph)	30	35	40	45	50	55	60	65	70
Taper Ratio	15:1	25:1	30:1	45:1	50:1	55:1	60:1	65:1	70:1
Length (L) in feet	180	300	360	540	600	660	720	780	840

Redirecting Lanes

The procedure for determining minimum taper ratios for redirecting through lanes is the same as shown in Table 1 for lane drops; however, for design speeds over 45 mph, the use of reverse curves rather than tapers is recommended. Figure 2 below illustrates a taper for redirecting through lanes and Figure 3 illustrates redirecting through lanes using reverse curves. Section 2D-1 of this Manual provides more information regarding reverse curves.

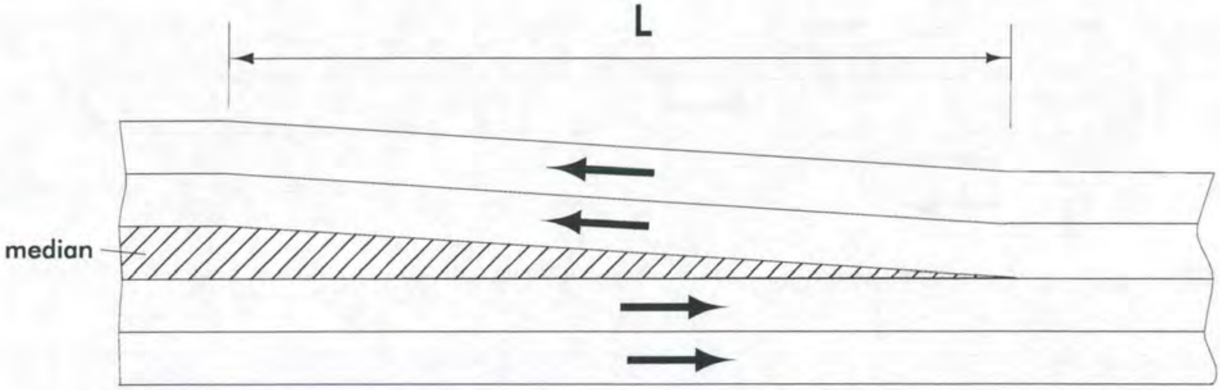


Figure 2: Redirecting through lanes using tapers.

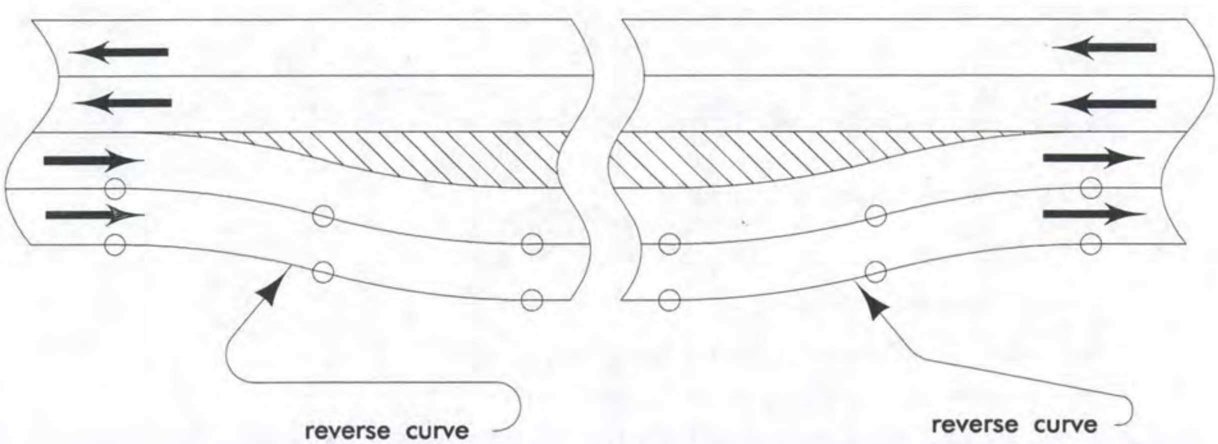


Figure 3: Redirecting through lanes using reverse curves.

Four-Lane Expressway Turn Lanes

Originally Issued: 01-04-02

This section discusses warrants and design for four-lane expressway turn lanes for both existing intersections and intersections that are in the design process. Turn lanes function to maintain smooth mainline traffic flow and facilitate turning movements. Thus both turning and mainline traffic are involved in the warranting process and should be considered in the design of turn lanes. Since each intersection is unique, the warrants and designs discussed in this section should be regarded as guidelines rather than rules. The designer will need to examine each intersection carefully to determine when turn lanes are warranted and, if so, the appropriate design.

Right Turn Lanes

When a right turn lane is warranted, it should be designed as a deceleration lane, see Figure 1, rather than a storage lane, and should normally be designed as a parallel lane.

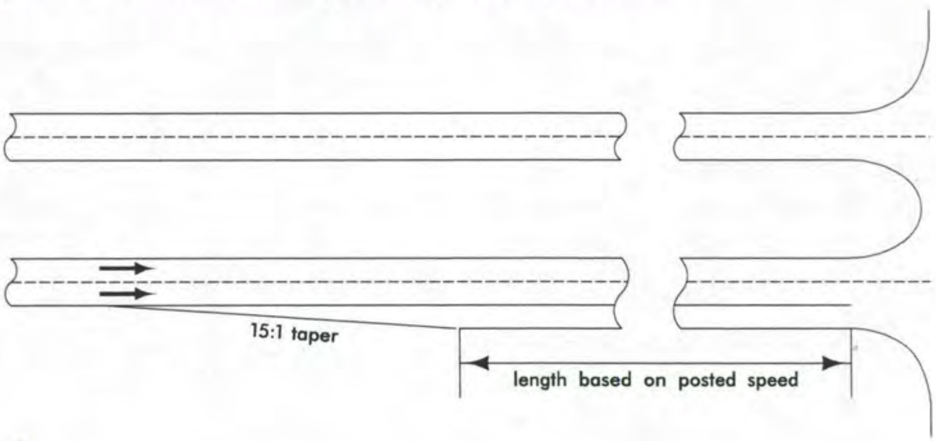


Figure 1: Deceleration right turn lane.

Right Turn Lane Warrants

The basic guidelines for when right turn lanes are warranted involve turning and approach (mainline) volume, and intersection location.

Turning and approach volumes

A right turn lane may be warranted if right turning traffic flow rate is greater than 30 vehicles per hour measured over a minimum of 15 minutes and either:

a. approach volume is greater than 400 vehicles per hour, or

b. approach truck traffic volume is greater than 20 vehicles per hour.

Intersection location

Intersection location may warrant a right turn lane even if turning and approach volumes don't. Local observations in the past have indicated that at some intersections on four-lane expressways within 5 miles of some urban areas with a population of 20,000 or greater, drivers have used the granular shoulders as right turn lanes. Therefore, areas similar to these should seriously be considered for right turn lanes even if volume warrants are not met.

Right turn lanes should be provided at all school locations regardless of turning and approach volumes. Other locations where right turn lanes may be judged to be warranted by the Project Management Team (PMT) include main entrances for towns, shopping areas, housing developments, attraction locations such as recreational areas, and locations that would have special users such as truck traffic or campers. Special attention should be given to intersections serving locations that attract elderly drivers such as drug stores, grocery stores, retirement developments, medical facilities, nursing homes, etc. Intersections with paved side roads should also be considered for right turn lanes.

Right Turn Lane Design

Right turn lanes should be designed as deceleration lanes with a 15:1 taper. The length of the parallel portion of the deceleration lane will normally depend on posted mainline speed and return radius. The posted mainline speed is used as the design speed for the parallel portion of the turn lane. Geometric design of an intersection determines the return radius. If a compound curve is used for the return radius, use the smallest of the radii for determining deceleration lane length. For example, given a mainline posted speed of 65 mph and a turning radius of 90 feet, the length of the parallel portion of the deceleration lane should be 520 feet. This was determined in the following manner. The posted mainline speed is 65 mph and this is used as the design speed for the parallel portion of the deceleration lane. Using Table 2 in Section 6A-1 of this Manual, a 90 foot radius with a 65 mph design speed corresponds to a 520 foot deceleration lane length. The length of the lane may need to be adjusted for grade, see Figure 6 in Section 6A-1 of this Manual.

To assist drivers on a sideroad determine the proper stopping point at an intersection, stop sign islands are placed at all paved sideroad approaches unless the sideroad ADT is less than 100 vpd, in which case an island is optional.

Offset Right Turn Lanes

When right turn lane warrants are met, offset (tapered) lanes, see Figure 2, may be considered in areas where sightline difficulties may occur, such as:

- at the base of a long or steep decline (grade = 5% or larger) or
- at the crest of a hill with a minimum K value.

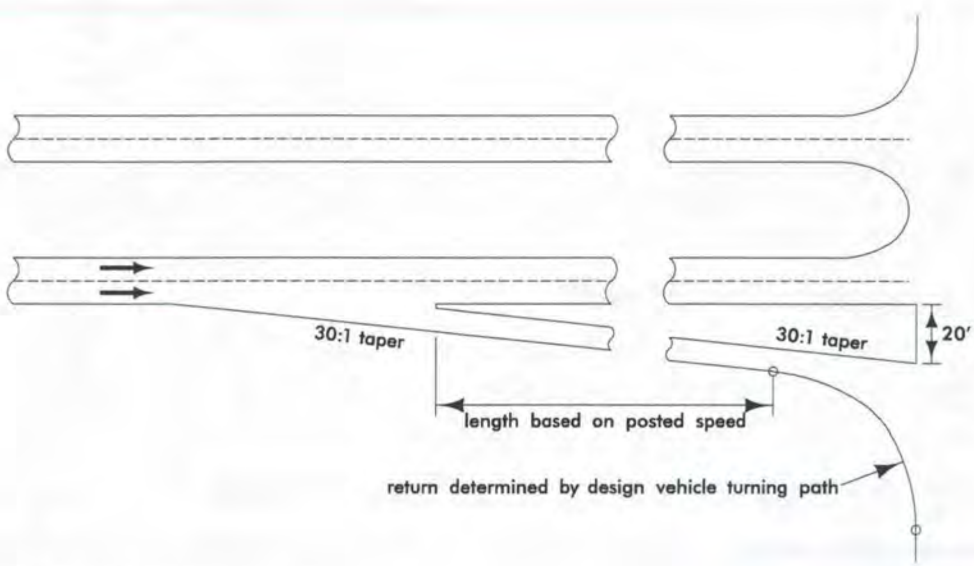


Figure 2: Offset right turn lane.

Left Turn Lanes

Left turn lanes provide storage in the median for left-turning vehicles, or when warranted, deceleration outside of the through traffic lanes for left-turning vehicles. All Type "A" and high volume Type "B" entrances should have left turn lanes provided, see Section 3E-2 of this Manual. If a left turn deceleration is not warranted, a left turn storage lane should be provided. Normally, left turn lanes are designed as parallel lanes.

Left Turn Deceleration Lane Warrants

The basic guidelines for when left turn deceleration lanes are warranted involve mainline turning and approach volume, and intersection location.

Turning and approach volume

A left turn deceleration lane may be warranted if left turning traffic flow rate is greater than 30 vehicles per hour measured over a minimum of 15 minutes and either:

a. approach volume is greater than 400 vehicles per hour, or

b. approach truck traffic volume is greater than 40 vehicles per hour.

Intersection location

Intersection location may warrant a left turn deceleration lane even if turning and approach volumes do not. To improve operational efficiency, left turn deceleration lanes should be considered for intersections located within approximately 5 miles of an urban area with a population of 20,000 or greater. Other locations where left turn deceleration lanes may be judged to be warranted by the PMT include schools, main entrances for towns, shopping areas, housing developments, attraction locations such as recreational areas, and locations that would have special users such as truck traffic or campers. Special attention should be given to intersections serving locations that attract elderly drivers such as drug stores, grocery stores, retirement developments, medical facilities, nursing homes, etc.

Left Turn Lane Design

Left turn storage lanes

Left turn storage lanes, see Figure 3, should be designed with a 10:1 taper. Turning volume determines left turn storage lane length (see Figure 3 in Section 6A-1 of this Manual), but a minimum length of 150 feet is required.

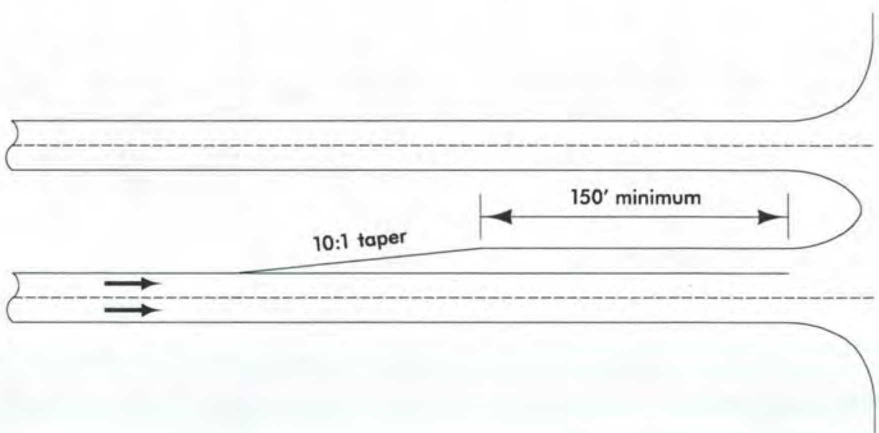


Figure 3: Left turn storage lane.

Left turn deceleration lanes

Left turn deceleration lanes, see Figure 4, should be designed with a 15:1 taper. The length of the parallel portion of a deceleration lane is determined using the posted mainline speed and a stop condition. Exhibit 10-73 in *A Policy on Geometric Design of Highways and Streets* (2001) provides deceleration lengths for various highway design speeds. For example, given a posted mainline speed of 65 mph (and using a stop condition) the parallel portion of a left turn deceleration lane should be 570 feet. This was determined by using the posted mainline speed of 65 mph as the highway design speed in Exhibit 10-73 and finding the deceleration length that corresponds with a stop condition. The length of the lane may need to be adjusted for grade, see Figure 6 in Section 6A-1 of this Manual.

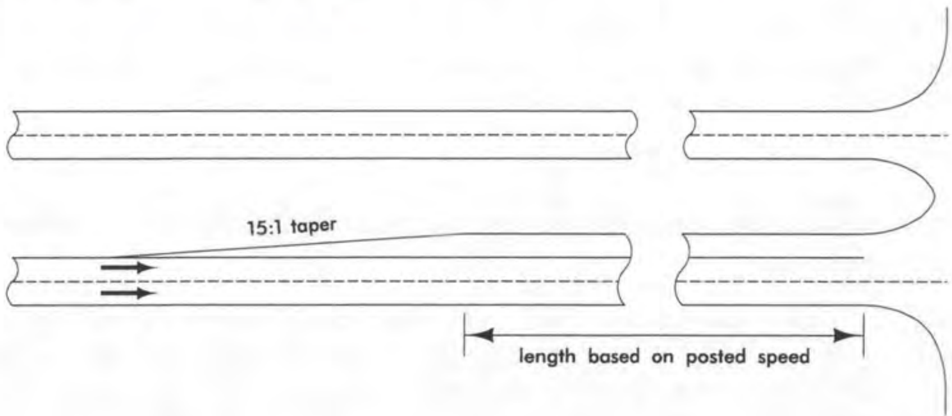


Figure 4: Left turn deceleration lane.

Offset Left Turn Lanes

The use of offset (tapered) left turn lanes should be limited on rural intersections. They should be considered only if:

- traffic signals will likely be installed or
- opposing left-turning vehicles create a significant sight distance problem.

If offset lanes are used, the median width should be reduced to 30 feet, as shown in Figure 5. Potential median drainage issues should be addressed before offset turn lanes are incorporated.

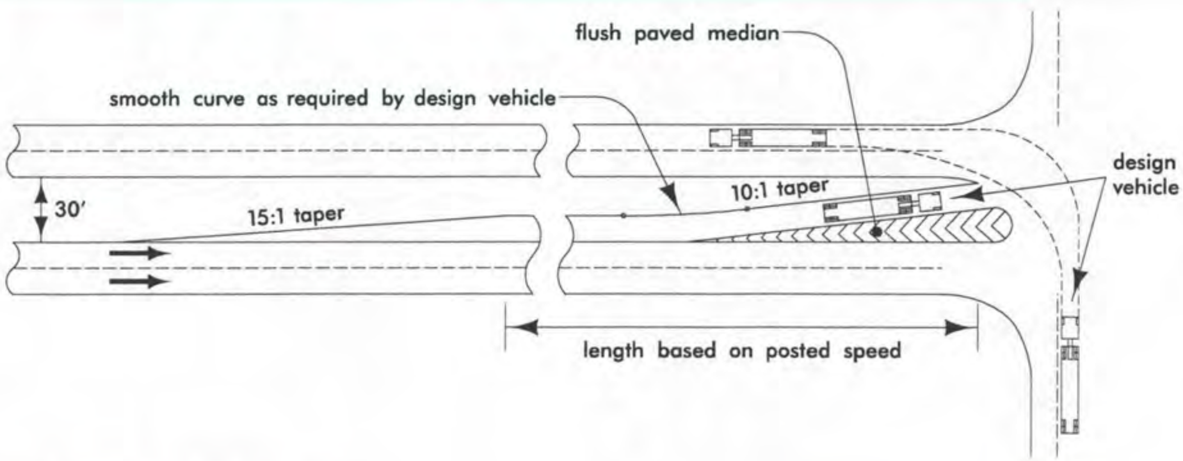


Figure 5: Offset left turn lane.

Continuous Two-Way Left-Turn Lanes (TWLTLs)

Originally Issued: 04-20-01

A problem that occasionally confronts designers in heavily trafficked urban and suburban areas is traffic turning left onto side streets or into entrances. Left turn lanes can alleviate this problem at side streets, but in some urban and suburban areas, mid-block entrances are too close to place turn lanes, or heavy volumes of left turning traffic cause backups along the main roadway. Cases such as these might be best handled with the use of continuous two-way left-turn lanes (TWLTLs).

A TWLTL is a lane placed between opposing lanes of traffic for the purpose of allowing traffic from either direction to make left turns off of a roadway. Figure 1 illustrates a TWLTL.

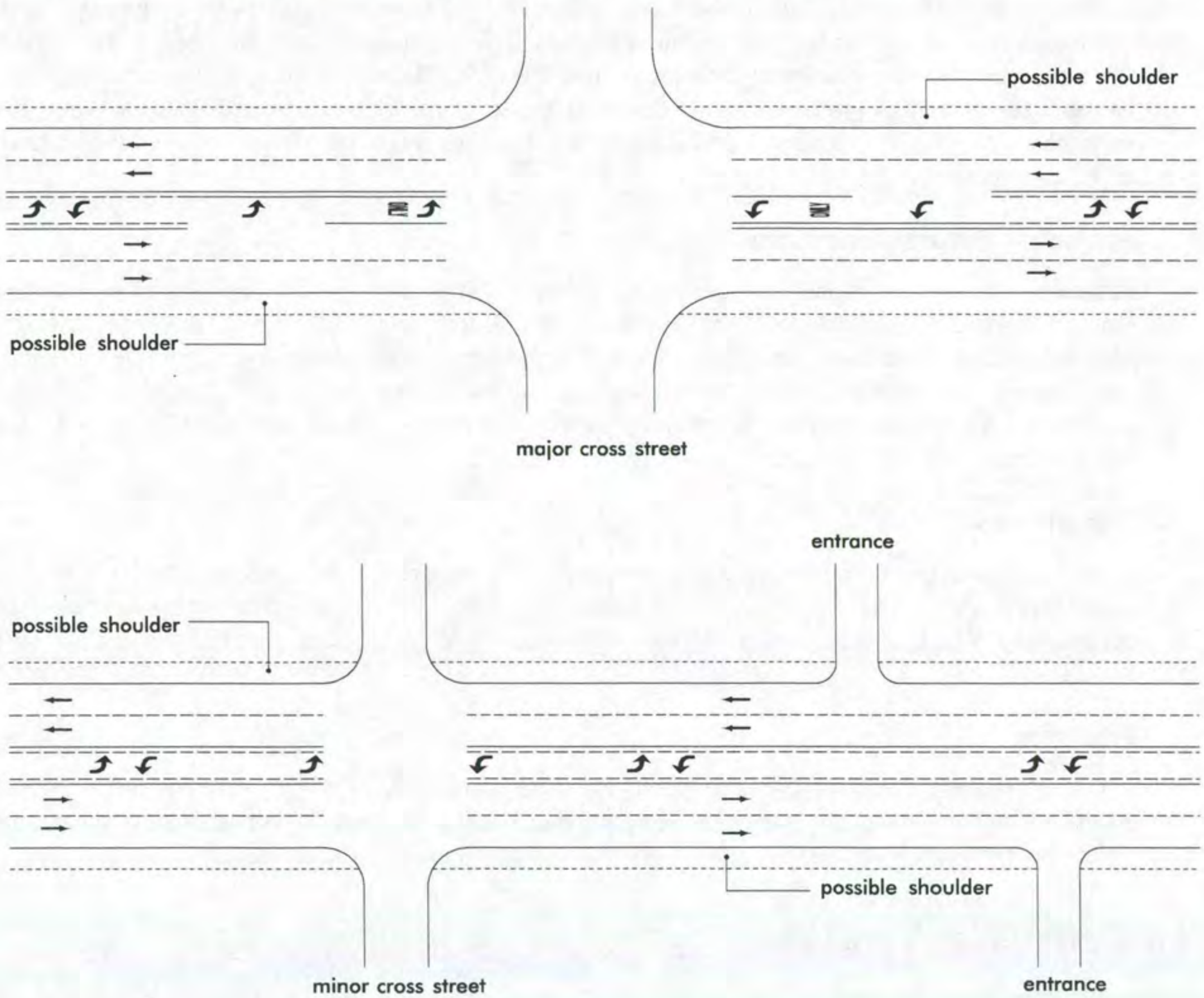


Figure 1: Continuous two-way left-turn lane (TWLTL).

Consideration of TWLTLs

Continuous two-way left-turn lanes offer several advantages. First, TWLTLs remove left turning vehicles from the through lanes, which can reduce delay to through vehicles and can lead to a reduction in rear-end and sideswipe collisions. Second, TWLTLs provide spatial separation between opposing lanes of traffic, which can lead to a reduction in head-on collisions. Finally, two-way left-turn lanes can also function as a lane for emergency vehicles.

Though TWLTLs offer several advantages, there are several considerations[1] involved with determining whether or not a TWLTL is an appropriate design. Existing and projected future conditions are two very important considerations, as are constraints and priorities.

Existing Conditions

Existing conditions include geometrics and traffic control, operational demands such as left turn volume, operational conditions such as capacity and level of service, safety conditions, and land use. Geometrics, for example sight distance requirements, may exclude the option of TWLTLs in some situations. Reduced level of service may indicate need for additional lanes. If the reduced level of service is a result of high left turn volume, TWLTLs may be a good alternative to adding lanes to both directions.

Safety issues such as the number of crashes, along with their severity, type and frequency should be considered. The need for a refuge area for pedestrians should also be factored in as the need for a refuge area may eliminate the option of a TWLTL. Land use should also be considered. Urban areas with high intersection and driveway densities may benefit from TWLTLs, whereas a suburban area with low driveway and intersection densities might be better served with turn lanes at the intersections.

Projected Future Conditions

Future projected conditions include traffic volumes (including trucks) and left turn volumes, along with type of land development and driveway and intersection densities. Projected volumes may indicate need for additional lanes: TWLTLs may serve as an alternative. Land development may require the addition of driveways and intersections, leading to an increase in left turn volumes. Two-way left-turn lanes may help to alleviate future problems with left turn movements.

Constraints

In addition to existing and future projected conditions, physical constraints such as right of way must be considered, along with economic limitations. Lack of sufficient funding may exclude the option of TWLTLs. Lack of available additional ROW may eliminate the possibility of a TWLTL.

Priorities

Priorities, namely cost, safety, and speed, must be identified. Though left turn lanes always benefit safety and flow, the priorities between cost, safety, and speed will ultimately determine the choice between no turn lanes at all, two-way left-turn lanes, or raised medians with turn bays.

Limitations for TWLTLs

There are some limitations to TWLTLs the designer must keep in mind. Extra street width may be required, resulting in an increased need for right of way. In addition, TWLTLs add another lane for

[1] Harwood, Douglas W. *Multilane Design Alternatives for Improving Suburban Highways*. National Cooperative Highway Research Program 282. Transportation Research Board, National Research Council, Washington, DC March 1986.

pedestrians and bicyclists to cross and do not provide a refuge area for them. Another limitation is that TWLTLs may not alleviate safety problems at closely spaced entrances and intersections, where queuing traffic can block left turning movements.

Placement of TWLTLs should be limited to suburban and urban areas only, as a TWLTL could be mistaken or misused as a passing lane in rural areas. The number of through lanes adjacent to the TWLTL should be limited to two in each direction. Normally, shoulders should not be sacrificed in order to place a TWLTL, as safety problems associated with removal of shoulders may outweigh advantages gained by the use of a TWLTL. However, if the engineer can document elimination of the shoulders will not create a safety problem, shoulders can be replaced with curb and gutter in order to accommodate the addition of a TWLTL. Traffic volumes in excess of 6,000 vpd would warrant consideration of a TWLTL on a two-lane facility, as 6,000 vpd is the volume at which additional lanes are considered for two-lane highways. Similarly, traffic volumes in excess of 10,000 to 12,000 vpd would warrant consideration of a TWLTL on a four-lane facility.

Design of TWLTLs

The normal width of a TWLTL is 14 feet, though 10 to 12 foot widths may be considered in areas with restricted right of way or pavement width. Pavement markings shall be in accordance with the MUTCD. The minimum length to be considered for a TWLTL should be ¼ mile, though shorter lengths may be considered if the engineer documents the need. Right turn lanes should also be considered at major intersections to further reduce delays to through traffic.

The design of transition areas that involve a lane drop is crucial. Transition areas should be located away from high volume driveways and signalized intersections.

Conversion from Four Lanes to Three Lanes

Many four lane undivided facilities may benefit from conversion to three lane facilities with TWLTLs. Several conversions have been completed in other states, as well as in Iowa. The results have been positive with reductions in accidents and increased popularity with the public. A portion of US 75 in Sioux Center, Iowa has been converted from a four-lane facility to three lanes with a TWLTL and the results have been very positive: a sharp decrease in accidents and excessive speeding, and support from both the public and businesses along the highway. Other four lane to three lane conversions in Iowa have demonstrated the ability to handle capacities as high as 16,000 ADT. The Office of Traffic and Safety should be consulted when considering converting from a four lane undivided facility to a three lane TWLTL facility.

Reasons to consider converting a four-lane facility to a three lane with a TWLTL include:

- high accident rates involving left turning movements, sideswipes, rear-ends, or crossing traffic
- the need for traffic calming
- pedestrian and bicyclist safety issues
- "defacto" left turn lanes: areas where a four-lane facility is operating like a three-lane facility, with the inside lanes operating as left turn lanes.

A number of factors[2] must be weighed into the decision to convert to a three lane with TWLTLs. Perhaps the most important is the function of the road. A road that serves primarily to move traffic through may not benefit from the conversion as much as a road that serves to access property. Areas that are prone to stop and go traffic such as school buses or delivery vehicles, or where slow moving

[2] Knapp, Keith, et. al. *Guidelines for the Conversion of Urban Four-Lane Undivided Roadways to Three-Lane Two-Way Left-Turn Lane Facilities.* Center for Transportation Research and Education, 2001

vehicles such as heavy trucks are common, may also fail to benefit from a conversion to three lanes. Conversion should be avoided in areas where there is on-street parking. Railroad crossings may also present a problem: the number of through lanes has been reduced which may result in longer queues—up to twice as long. An increase in delay for access from side streets may also result from a conversion to three lanes. Finally, an ADT of 15,000 to 17,500 should be considered as the maximum capacity a three lane with TWLTL facility can handle.

Typically, initial community reaction to the conversion will be negative since it seems logical to assume that eliminating a lane will reduce capacity and increase delays; however, though the number of through lanes has been reduced, capacity is generally not reduced and the resulting increase in delay is very minor since the delay caused by left turning traffic in through lanes has been eliminated. This slight increase in delay can act as a traffic calming device. The reduction in through lanes will also reduce lane changes and will benefit pedestrians and bicyclists since they are required to cross fewer lanes. Consideration should not be given to converting a four lane undivided roadway to a three lane roadway unless the community perceives the need to improve safety and/or to implement traffic calming.

Two-way left-turn lanes can be very effective in areas where the inside lane of a four lane facility is essentially acting as a turn lane, areas known as "defacto" left turn lanes. Left turning traffic is removed from the through lanes and the need for drivers trapped in the inside lane to switch lanes to pass a left turning vehicle is eliminated, thus further reducing the possibility of accidents. Though through traffic is reduced to one lane, delays increase only slightly since drivers are no longer trapped behind left turning vehicles.

Converting from a four-lane facility to a three-lane typically involves simply re-striping the roadway. When converting a four-lane facility to three lanes, it is important that the old paint markings be thoroughly removed and the TWLTL be marked according to the MUTCD. It is also important to examine turning movements at major intersections to determine if right turn lanes are needed. Before and after studies of the conversion should be completed and documented.

Parking on Urban Primary Highways

Originally Issued: 01-04-02

This section provides guidelines for parking lanes and parking restrictions on urban highways and side streets at intersections. The elimination of parking on primary highways is desirable. Parking along highways can: increase driver tension and accident rates; interfere with the driver's sight triangle; obstruct the driver's view of pedestrians, traffic signals, and traffic signs; increase congestion; and reduce capacity. However, due to economic considerations, physical limitations, and a lack of equivalent parking facilities, complete elimination of parking on primary highways is not possible.

Some of the guidelines in this section are based on Iowa Code; however, these guidelines are not necessarily design policy. Sound engineering judgment, including technical and economic analysis, should be used when applying these guidelines. In addition, the designer is encouraged to make use of turning templates or software to assist with the design of parking lanes near intersections.

Parking on Interstate Highways and Freeways

Parking on interstate highways and freeways is for emergencies only. Parking areas are provided at rest areas and scenic overlooks.

Parallel Parking Lanes on Primary Highways

Parallel parking may be allowed in areas where space is available and there is a lack of equivalent parking facilities. The city will be required to reimburse the Iowa DOT for the entire costs attributable to parking lane construction, including excavation, paving, sidewalk reconstruction, and additional right of way required. The following guidelines should be considered when designing parallel parking lanes:

- On Hot Mix Asphalt (HMA) resurfacing projects, the parking lanes may be resurfaced with the traffic lanes; however, the city will pay for the cost of resurfacing the parking lanes.
- Parking lanes, when provided, should be in block long segments or an equivalent length. Once introduced, parking should be continuous on one side and not shifted from one side of the street to the other.
- The desirable width of parallel parking lanes on new construction is 10 feet: 9 feet should be considered the minimum.
- When 10 or 11-foot traffic lanes are being resurfaced or re-striped as 12-foot lanes, existing adjacent parking lanes should maintain a minimum 8-foot width, with 10 feet being desirable.
- Parking lanes may be constructed sloping downward from the traffic lane between 2% and 6% or sloping upward between 1% and 6%, see Figure 1. A lip curb may be used to adjust the upward slope to the desired range, to prevent water from flowing along the construction joint or to delineate a parking lane from the driving lanes.

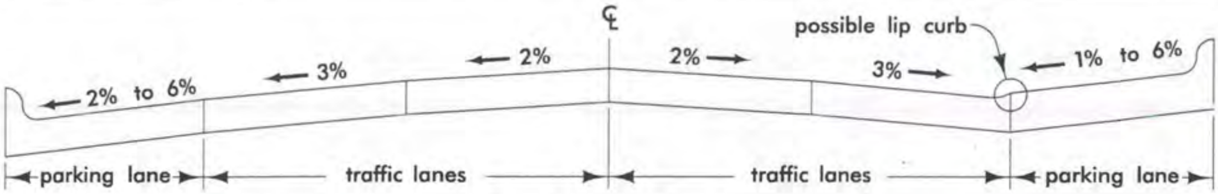


Figure 1: Parallel parking lane cross section.

- Continuity of traffic lanes should be maintained. The number of traffic lanes should not be reduced to add parking.
- The need for added traffic lanes or turning lanes may justify eliminating parking.
- At signalized intersections a capacity analysis is necessary to determine the need for extra lanes. It may be necessary to eliminate parking near intersections to add traffic lanes or turn lanes if right of way is not available.
- Protected parking, see Figure 2, should be used where possible. This will reduce pedestrian crossing distance.

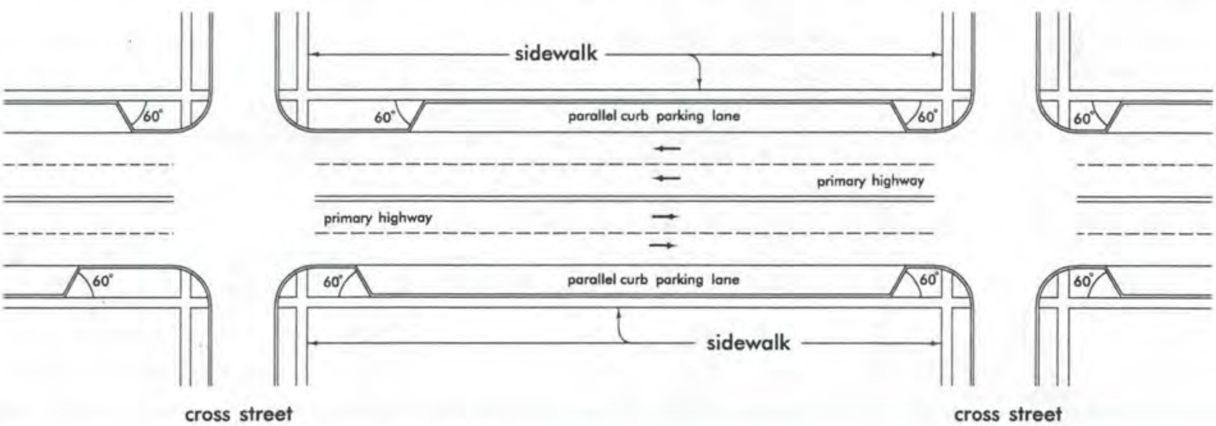


Figure 2: Protected parallel parking lane design.

Diagonal Parking Lanes on Primary Highways

Diagonal parking is to be eliminated on all Iowa DOT primary highway projects. This includes HMA resurfacing projects, reconstruction projects, and new construction. If a city objects to dropping diagonal parking, the following alternatives are available:

- In the case of "End of Route" primary extensions, the end segment in the business district containing the diagonal parking may on petition from local officials be considered for removal from the primary road system.
- Reconstructing the pavement to provide a barrier that will separate the diagonal parking area from the adjacent traffic lanes. This option will likely require wide right of way.
- Substituting parallel parking lanes.

Parking Restrictions on Primary Highways and Minor Streets

Iowa Code Section 321.358 lists a number of parking restrictions which apply to primary highways and minor streets, some of which are included here:

- No parking within 5 feet of a fire hydrant.
- No parking on a crosswalk
- No parking within 10 feet upon the approach to any flashing beacon, stop sign, or traffic-control signal located at the side of the roadway.
- No parking within 50 feet of a railroad crossing.
- No parking within 25 feet of the driveway entrance to any fire station on the near side of the street. In addition, there shall be no parking on the opposite side of the street within 75 feet of the driveway entrance to the fire station, see Figure 3.

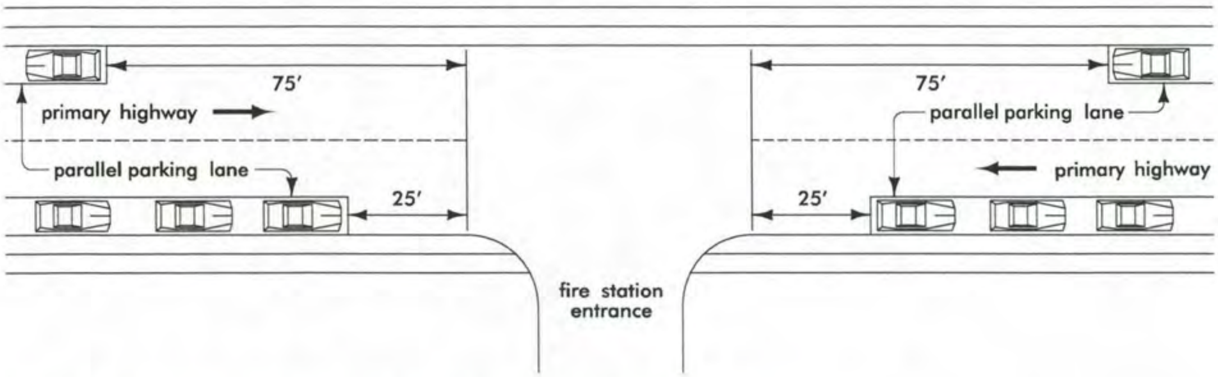


Figure 3: Parking along a street near a fire station driveway entrance.

- No parking in a manner which blocks access to a curb cut or ramp which is located on public or private property.

Additional Parking Restrictions on Primary Highways

Addition parking restrictions on primary highways include:

- At signalized intersections, parking will be prohibited on the primary highway a distance of 10 feet in advance of the near sidewalk or traffic-control signal and a distance of 5 feet beyond the far sidewalk, see Figure 4.

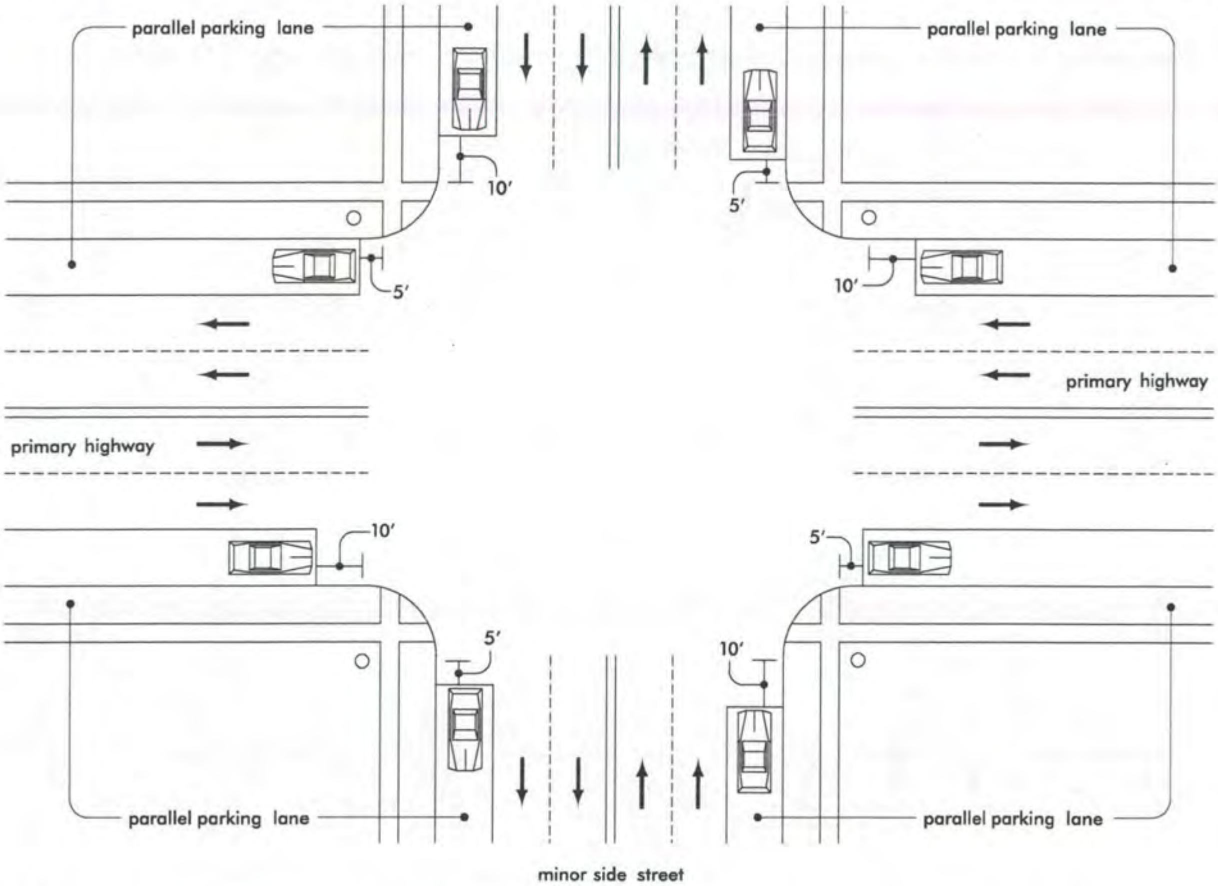


Figure 4: Parking restrictions at signalized intersections.

- At non-signalized intersections, parking will be prohibited on the primary highway a distance of 55 feet in advance of the near sidewalk and a distance of 22 feet beyond the far sidewalk, see Figure 5.

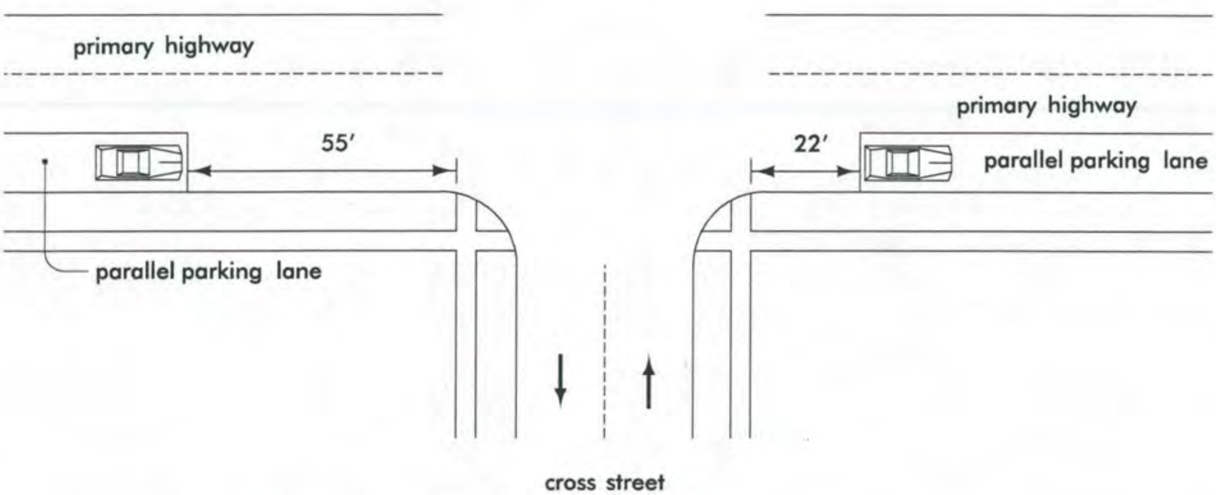


Figure 5: Parking restrictions at non-signalized intersections.

Additional Parking Restrictions on the Side Streets of Primary Highway Intersections

Additional restrictions apply to minor streets.

Minor Side Streets with Stop Signs

On minor side streets with two lanes and two parking lanes (whether parallel or angled), parking will be prohibited a distance of 35 feet in advance of the near sidewalk or stop sign and a distance of 35 feet beyond the far sidewalk, see Figure 6.

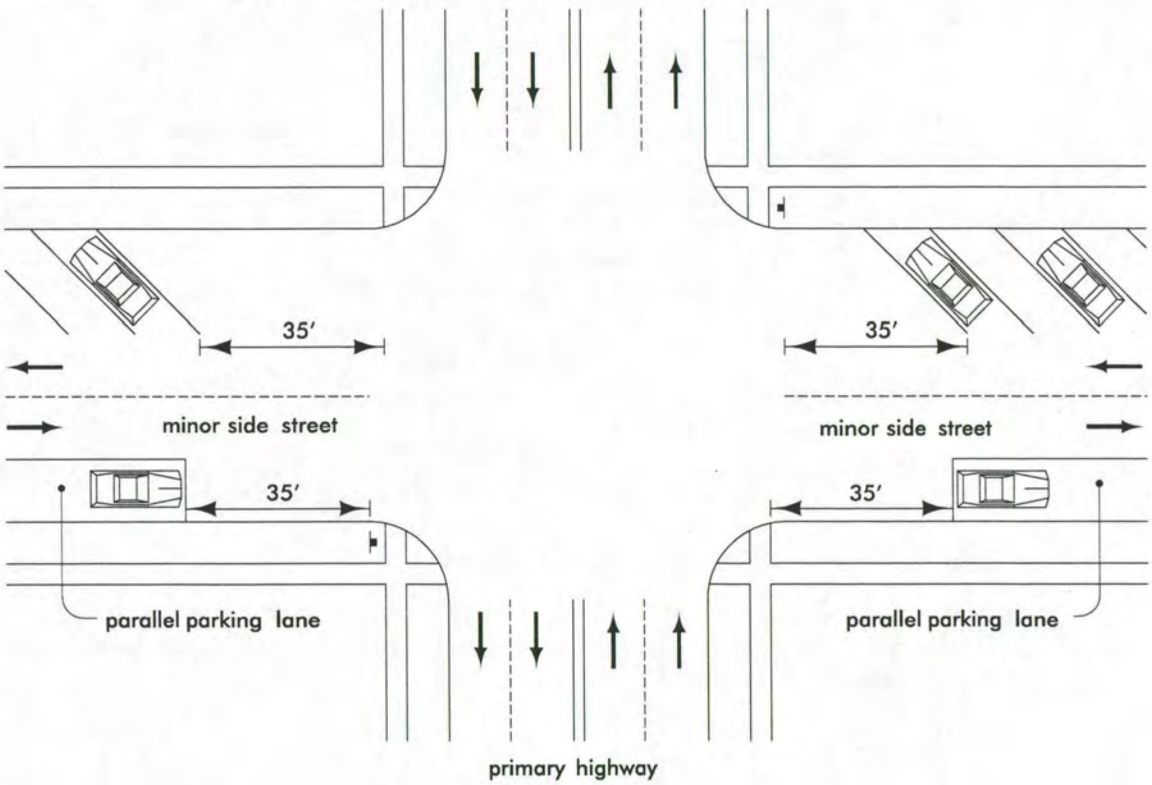


Figure 6: Parking restrictions on two-lane minor side street with stop signs.

On minor side streets with four traffic lanes and two parallel parking lanes, parking will be prohibited a distance of 35 feet in advance of the near sidewalk or stop sign and a distance of 5 feet beyond the far sidewalk, see Figure 7.

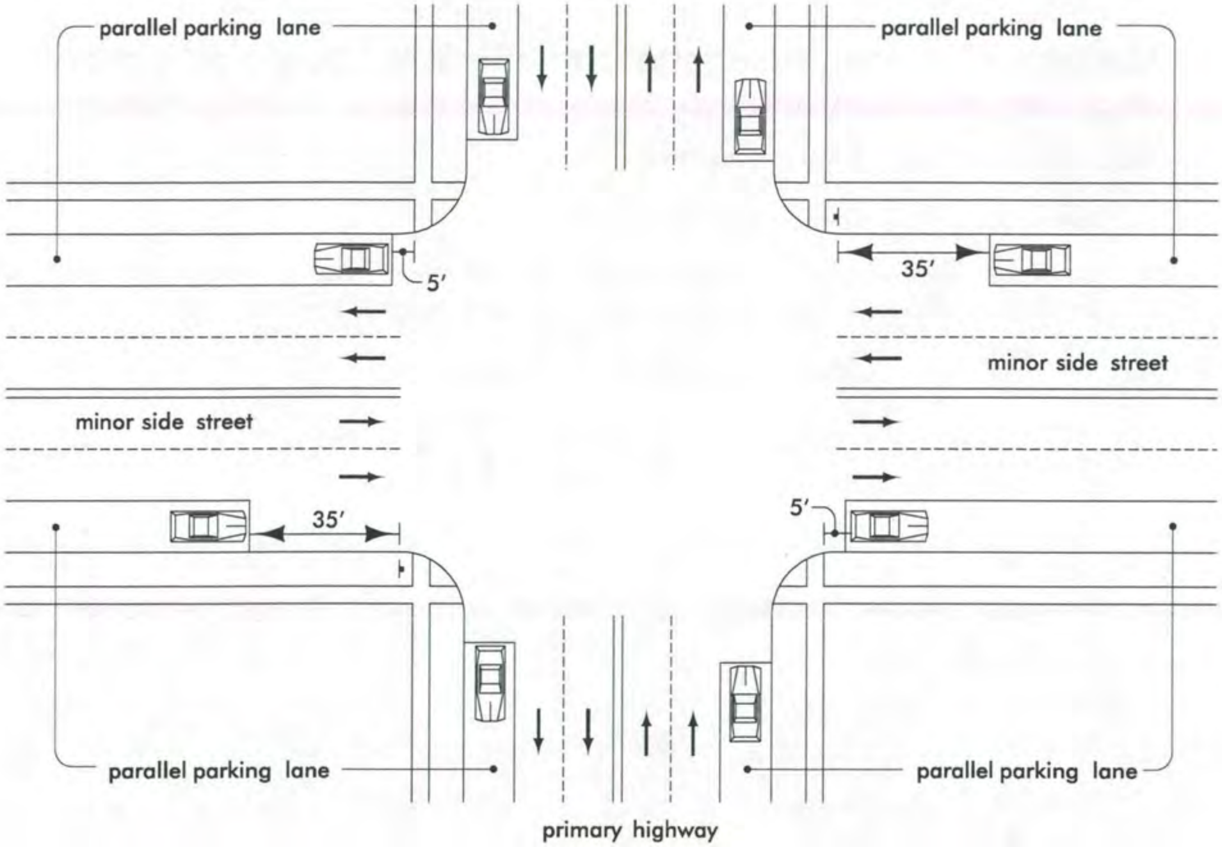


Figure 7: Parking restrictions on four-lane minor side street with stop signs.

Minor Side Streets with Traffic-Control Signals

On minor side streets with two traffic lanes and two parallel parking lanes, parking will be prohibited a distance of 10 feet in advance of the signal or near sidewalk and a distance of 35 feet beyond the far sidewalk, see Figure 8.

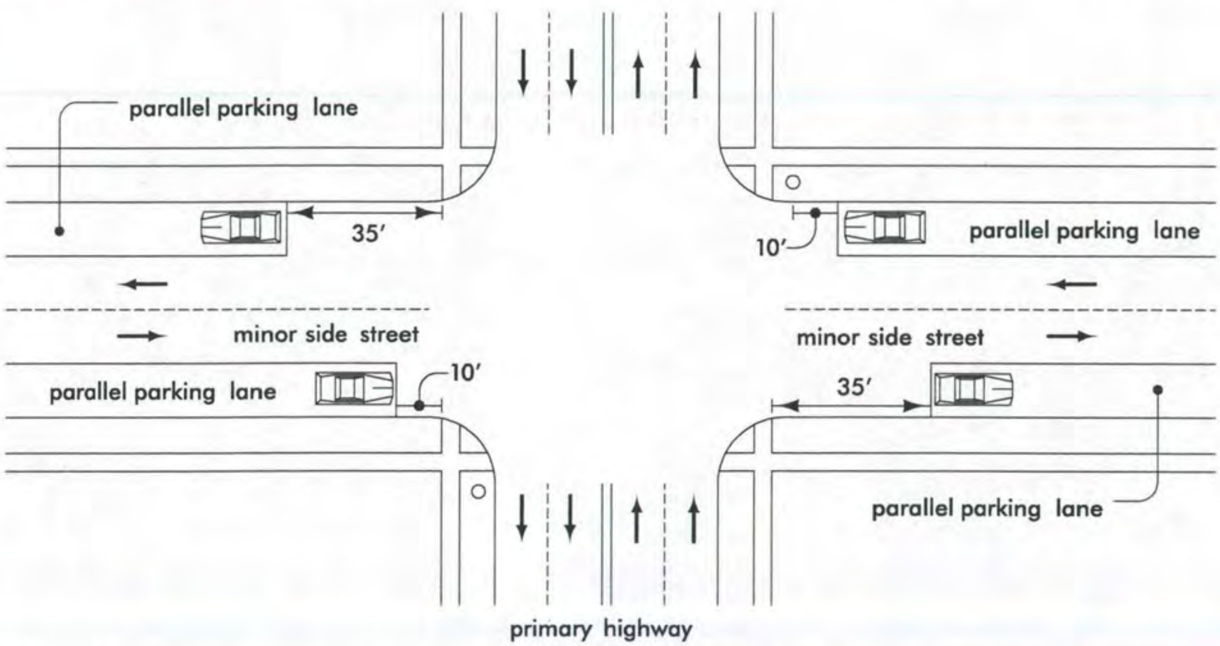


Figure 8: Parking restrictions on two-lane minor side street with traffic-control signals.

On minor side streets with four lanes and two parallel parking lanes, parking will be prohibited a distance of 10 feet in advance of the signal or near sidewalk and a distance of 5 feet beyond the far sidewalk, see Figure 4.

Diagonal Parking on Minor Side Streets with Traffic-Control Signals

For the case of an intersection with four traffic lanes, traffic control signals, and diagonal parking on the far side of the intersection, diagonal parking should be prohibited for 18 feet beyond the far side sidewalk to allow the parked car to back out without hitting a pedestrian in the far crosswalk, see Figure 9. Refer to Figure 9 for other parking restrictions.

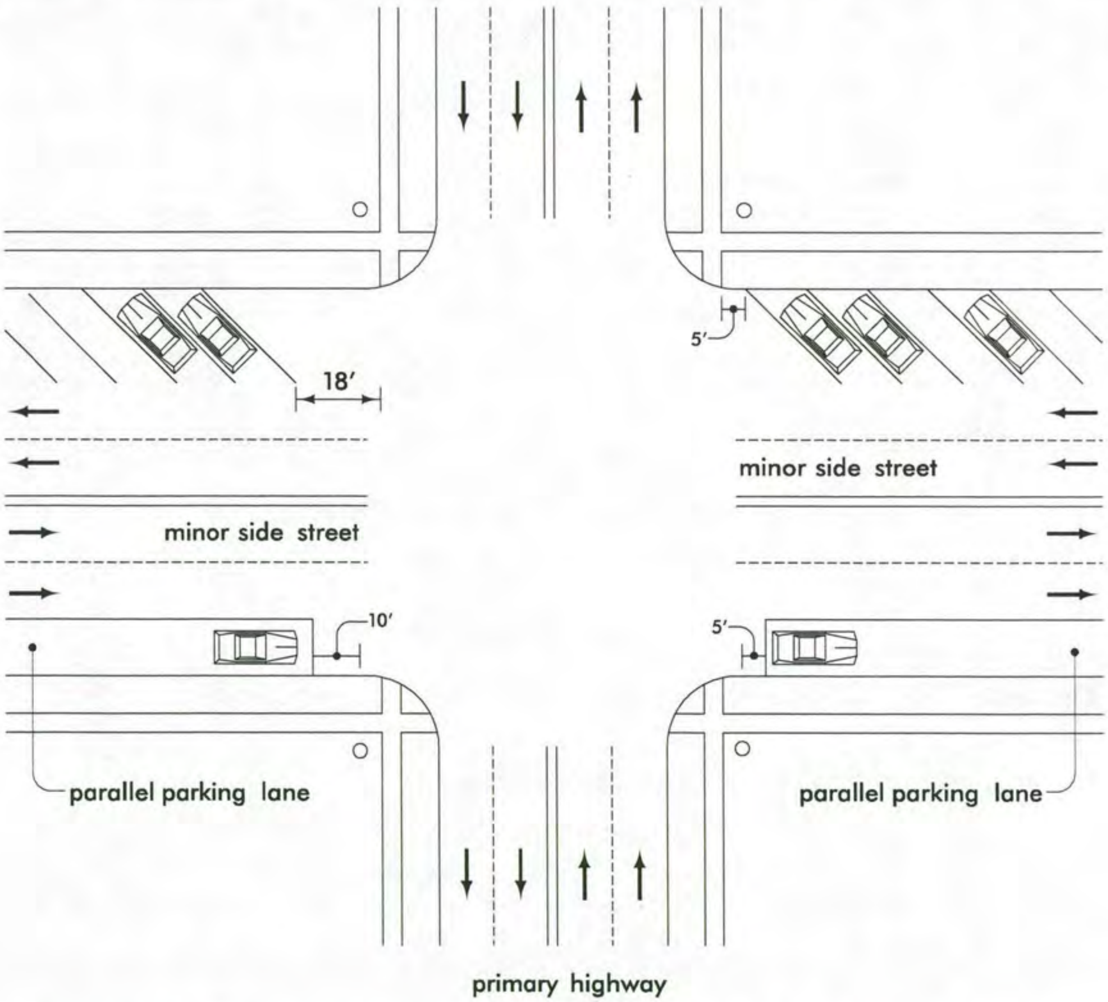


Figure 9: Diagonal parking restrictions on minor side streets with traffic-control signals.

Diagonal Parking on Minor Side Streets with Stop Signs

For the case of an intersection with four traffic lanes, stop signs, and diagonal parking on the far side of the intersection, diagonal parking should be prohibited for 18 feet beyond the far side sidewalk to allow the parked car to back out without hitting a pedestrian in the far crosswalk, and diagonal parking should be prohibited for 35 feet in advance of the near sidewalk or stop sign, see Figure 10. Refer to Figure 10 for other parking restrictions.

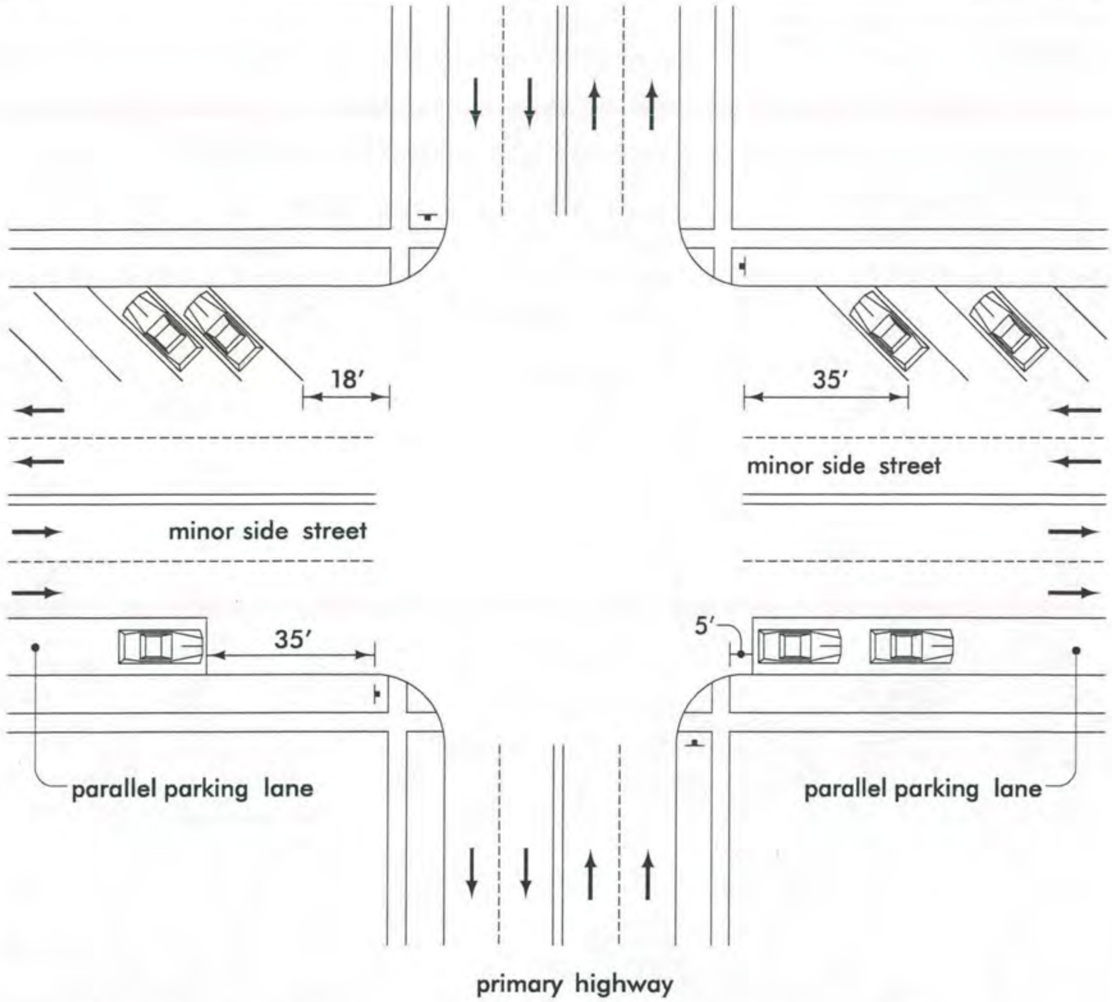


Figure 10: Diagonal parking restrictions on minor side streets with stop signs.

Major Intersections and Special Problems

Intersections involving capacity, special turning movements, and skewed angles will require specific engineering studies to determine parking restrictions. At signalized intersections, capacity analysis is necessary to determine the need for extra lanes. It may be necessary to add turn lanes and eliminate parking near the intersection.

Tandem Parking

One method to avoid long delays due to parallel parking maneuvers is to use a tandem parking system where two cars are parked together and a 16 foot gap is provided in front of and in back of the two cars, see Figure 10. When there is only one lane of traffic in each direction on the primary highway, tandem parking should be given strong consideration.

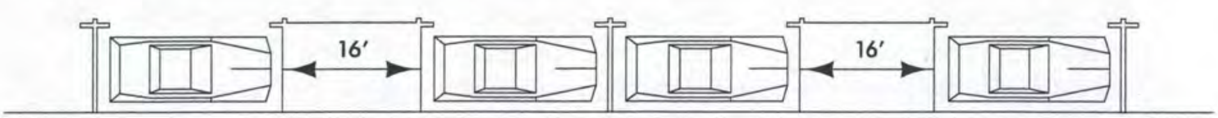


Figure 11: Tandem parking.

As demonstrated in Figures 11a and 11b, cars can pull into parking slots without stopping or backing in the traffic lane. In addition, the amount of time required to complete the maneuver is reduced compared to conventional parallel parking shown in Figure 11c.

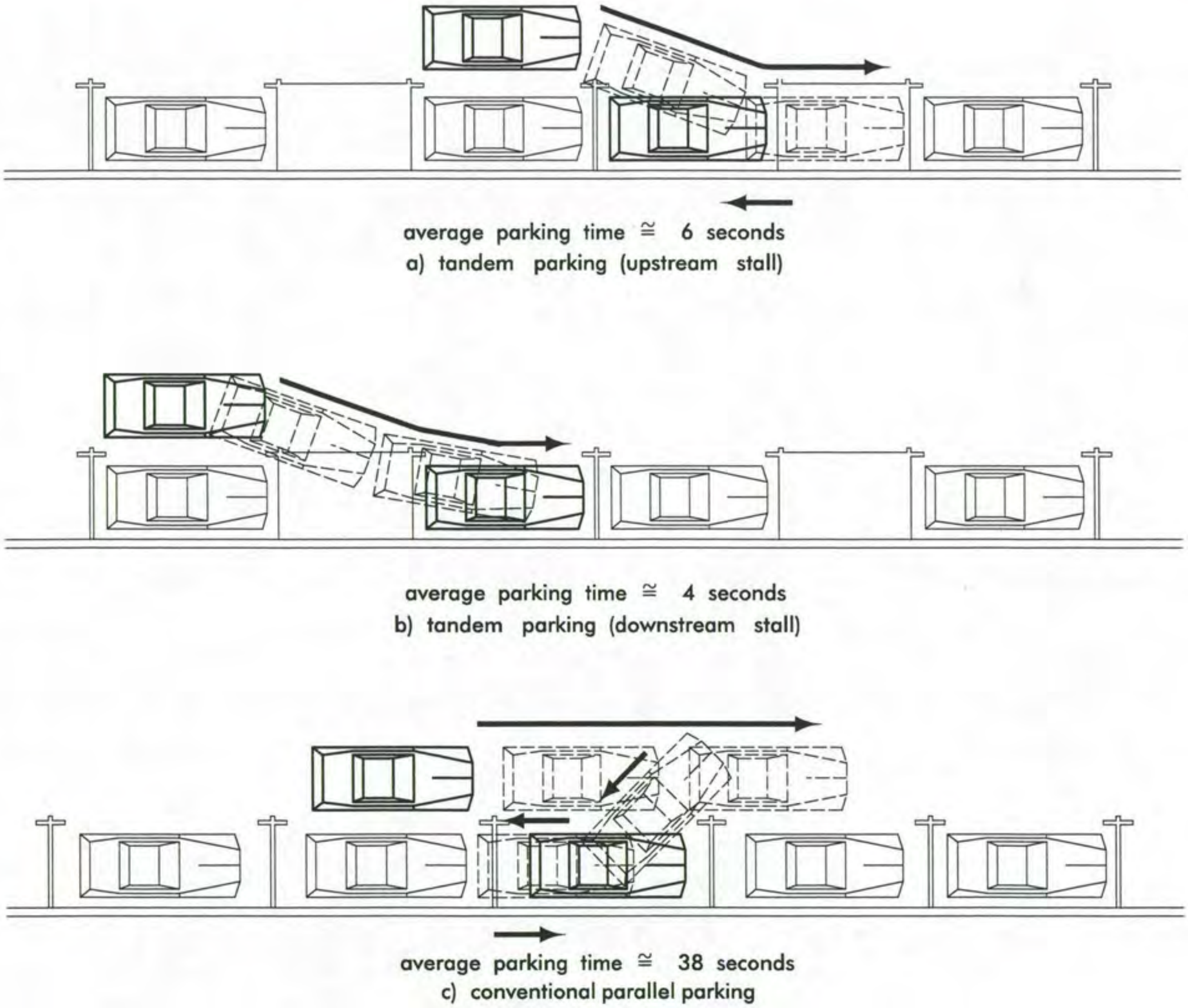


Figure 12: Maneuvers involved with parallel parking.

Other resources exist that discuss parking along urban highways, for example *Parking* by R. Weant and H. Levinson published by the Eno Foundation for Transportation, 1990 or AASHTO's *A Policy on Geometric Design of Highways and Streets*, 2001. The designer is urged to consult these resources. Calculations used for this section are available in "A Guide for Evaluating Parking on Primary Road Extensions," Iowa State Highway Commission, March 1967. If the designer has any questions regarding the values used in this section, he or she should consult this resource or contact the Methods Section in the Office of Design.

Stopping Sight Distance

Originally Issued: 01-04-02

Stopping sight distance consists of two components[1]: (1) brake reaction distance, which is the distance a vehicle travels from the moment a driver spots an object until the driver applies the brakes, and (2) braking distance, which is the distance the vehicle travels from the moment the brakes are applied until the vehicle comes to a stop.

Table 1 provides minimum stopping sight distances for various design speeds. Distances greater than those provided in Table 1 should be considered whenever site conditions allow.

Table 1: Minimum Stopping Sight Distance

design speed (mph)	minimum stopping sight distance (ft.)
30	200
35	250
40	305
45	360
50	425
55	495
60	570
65	645
70	730

Highway grade affects braking distance: uphill grades reduce it and downhill grades increase it. However, sight distance available for downhill grades is typically greater than it is for uphill grades, which in turn compensates for increased braking distance. Thus stopping sight distance is normally not adjusted for downhill grades. Since traffic usually traverses a grade in both directions, sight distance is not adjusted for uphill grades either. The exceptions are one-way roads or divided highways with independent profiles for the two roadways. In cases such as these, Table 2 on the next page may be used.

The values provided in Tables 1 and 2 are based on passenger car performance; however, these values also apply to trucks since truck drivers are typically seated higher thus increasing their sight distance. An exception is where horizontal sight distance is limited, for example along a horizontal curve in a cut section near the end of a long downhill grade. Here the backslope may interfere even with a truck driver's sight distance. In a situation such as this it is best to provide stopping sight distance in excess of that provided in Table 2 since truck speeds often match or exceed passenger car speeds.

[1] Fambro D.B., Fitzpatrick K., and Koppa, R.J., "Determination of Stopping Sight Distances," NCHRP Report 400, Transportation Research Board, Washington DC (1997).

Table 2: Stopping Sight Distance on Grades.

design speed (mph)	stopping sight distance downgrades (ft.)			stopping sight distance upgrades (ft.)		
	3%	6%	9%	3%	6%	9%
30	205	215	230	200	185	180
35	260	275	290	240	230	225
40	315	335	355	290	280	270
45	380	400	430	345	335	320
50	450	475	510	405	390	375
55	520	555	595	470	450	435
60	600	640	690	540	515	495
65	685	730	785	615	585	565
70	775	825	895	690	660	635

Passing Sight Distance

Originally Issued: 01-04-02

According to AASHTO's *A Policy on Geometric Design of Highways and Streets* (2001) passing sight distance can be broken into four components:

- The distance traveled by the passing vehicle during perception and reaction time and during the initial acceleration to the point of encroachment on the opposite lane.
- The distance the passing vehicle travels while in the opposite lane.
- The distance between the passing vehicle at the end of its maneuver and an opposing vehicle.
- The distance traveled by an opposing vehicle for 2/3 of the time the passing vehicle occupies the opposite lane.

The determination of passing sight distance is based on a single vehicle passing a single vehicle. Though it may be common for a vehicle to pass two or more vehicles, passing sight distance should be based on a single vehicle passing a single vehicle. Table 1 presents minimum passing sight distances. These values are based on the driver's eye height being 3.5 feet and the height of the object being 3.5 feet. The designer should make all efforts to exceed these values whenever possible. This is especially true for situations that involve uphill grades. Specific values aren't available for passing sight distances for uphill grades, but the designer should keep in mind that passing maneuvers on uphill grades will require distances greater than those presented in Table 1.

Table 1: Minimum Passing Sight Distance.

design speed (mph)	minimum passing sight distance (ft.)
30	1090
35	1280
40	1470
45	1625
50	1835
55	1985
60	2135
65	2285
70	2480

The minimum passing sight values presented in Table 1 should be used for design purposes only. These distances should not be used for placing no-passing zone pavement markings and signs—these values should be obtained from the MUTCD.

The designer should provide frequent passing opportunities for drivers. No table for a minimum number of passing opportunities per given distance for different design situations exists; however, providing frequent passing opportunities becomes increasingly more important as traffic volumes increase. If ample passing opportunities cannot be provided based on passing sight distance, the designer may want to consider alternative alignments or providing passing lanes.

Sight Distance on Vertical Curves

Originally Issued: 01-04-02

Stopping sight distance is an important factor in vertical curve design (Section 2B-1 of this Manual provides more information regarding vertical curves and Section 6D-1 of this Manual provides more information regarding stopping sight distance). The crest of a crest vertical obscures objects on the other side of the curve, as can be seen in Figure 1. Thus, crest curves must be designed to ensure the crest does not interfere with stopping sight distance.

Headlight sight distance is the controlling factor in sag vertical curves, though stopping sight distance is used in the actual design of a sag vertical curve. Related to sag curves is the issue of undercrossings. Structures placed over a roadway, especially a two-lane roadway, in an area of a sag curve can obscure objects on the other side of the curve. The vertical clearance of structures over a roadway in a sag curve must allow for adequate stopping sight distance.

Definition of "K"

Along equally spaced successive points of a vertical curve, the rate of change of grade is the same and is calculated as A/L, where A is the algebraic difference between grades and L is the length of the curve. The reciprocal, L/A, is the horizontal distance required to produce a one percent change in gradient. The quantity L/A, defined as K, is a measure of curvature. The value of K is helpful in determining minimum lengths of vertical curves for various design speeds. Once the algebraic difference between grades is known, the designer can use K values provided in this section or in Section 1C-1 to determine the required length for a vertical curve.

Crest Vertical Curves

Figure 1 illustrates the parameters used to determine the length of a vertical curve required to provide any specified value of sight distance required.

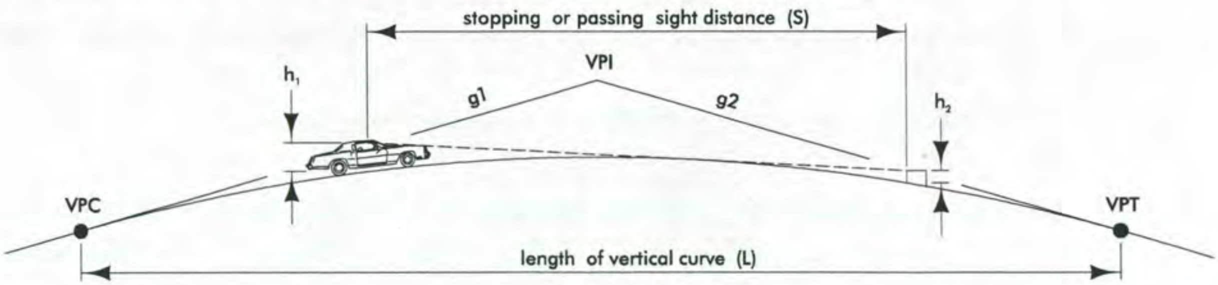


Figure 1: Parameters used to determine length of vertical curve.

where:

L = length of vertical curve in feet

S = stopping sight distance in feet

A = algebraic difference in grades in percent

h_1 = height of eye above roadway surface in feet

h_2 = height of object above roadway surface in feet

The general equations below provide the relationships between the parameters in Figure 1 for crest vertical curves.

$$L = \frac{AS^2}{200\left(\sqrt{h_1} + \sqrt{h_2}\right)^2} \qquad \text{if } S<L$$

$$L = 2S - \frac{200\left(\sqrt{h_1} + \sqrt{h_2}\right)^2}{A} \qquad \text{if } L<S$$

Stopping Sight Distance

With the height of the eye of the driver (h_1) set at 3.5 feet and the height of the object (h_2) set at 6 inches, the general equations simplify to:

$$L = \frac{AS^2}{1329} \qquad \text{if } S<L$$

$$L = 2S - \frac{1329}{A} \qquad \text{if } L<S$$

where L, S, and A are as described before.

Table 1 provides desirable K values for stopping sight distance on crest vertical curves for various design speeds. See Section 6D-1 of this Manual for more information regarding stopping sight distance. Desirable K values should be provided on all Iowa DOT projects. Minimum K values can be found in Exhibit 3-76 of the 2001 AASHTO Greenbook for situations when desirable K values are not possible. The designer should contact the Geometric Design squad in the Methods Section in the Office of Design when considering K values between desirable and minimum. The designer must document the need for using values less than desirable and must have the approval of the Section Engineer and/or Project Management Team (PMT) before proceeding with lesser K values. The Project Engineer is responsible for documenting PMT approval. The use of K values less than AASHTO minimums is not acceptable.

Table 1: Desirable K Values for Stopping Sight Distance.

design speed (mph)	stopping sight distance (ft.)	K_{des}
30	200	35
35	250	50
40	305	70
45	360	100
50	425	140
55	495	185
60	570	245
65	645	315
70	730	405

Drainage Considerations

When portions of a crest vertical curve on a curbed roadway have longitudinal grades of less than 0.3%, drainage may be a concern. If the length of this "flat" portion of the crest is less than 100 feet, drainage should not be a problem. K values of 167 or less will result in the "flat" portion of the crest being less than 100 feet. K values greater than 167 don't necessarily need to be avoided in such situations; rather, the designer must examine the drainage more carefully to ensure problems will not develop.

Passing Sight Distance

The same general equations given previously apply for passing sight distance. Section 6D-3 of this Manual provides more information regarding passing sight distance. The object height (h_2) is set at 3.5 feet to represent an approaching driver's eye level. The general equations simplify to:

$$L = \frac{AS^2}{2800} \qquad \text{if } S<L$$

$$L = 2S - \frac{2800}{A} \qquad \text{if } L<S$$

where L, S, and A are as described before.

Table 2 provides minimum K values for passing sight distance on crest vertical curves for various design speeds. The high minimum K values in Table 2 demonstrate how flat vertical curves need to be to provide passing sight distance. Typically, vertical curves are not designed for provide for passing sight distance because of the cut required to design the curve.

Table 2: Minimum K Values for Passing Sight Distance

design speed (mph)	passing sight distance (ft.)	K_{min}
30	1090	424
35	1280	585
40	1470	772
45	1625	943
50	1835	1203
55	1985	1407
60	2135	1628
65	2285	1865
70	2480	2197

Sag Vertical Curves

The four main controlling factors for determining sag vertical curve lengths are headlight sight distance, passenger comfort, drainage control, and appearance.

Headlight Sight Distance

A headlight height of two feet is assumed, as is a 1-degree upward angle of the headlight beam. With these assumptions the relationship between L, S, and A becomes:

$$L = \frac{AS^2}{400 + 3.5S} \qquad \text{if } S<L$$

$$L = 2S - \left(\frac{400 + 3.5S}{A}\right) \qquad \text{if } L<S$$

where L, S, and A are as described before.

Table 3 provides minimum K values based on stopping sight distances for various design speeds. Headlight and stopping sight distance are similar enough that K_{min} is based on stopping sight distance. Since the values presented in Table 3 are minimum values, the designer should consider using values greater than these whenever site conditions allow.

Table 3: Minimum K Values for Sag Vertical Curves.

design speed (mph)	stopping sight distance (ft.)	K_{min}
30	200	37
35	250	49
40	305	64
45	360	79
50	425	96
55	495	115
60	570	136
65	645	157
70	730	181

Passenger Comfort

Riding comfort on sag curves typically doesn't become a problem as long as centripetal acceleration does not exceed 1 ft./s^2. With this limit, the relationship between L and A becomes:

$$L = \frac{AV^2}{46.5}$$

where L and A are as described before and V is the design speed in mph. Lengths needed to provide ride comfort are typically about half that needed to meet headlight sight distance requirements, thus headlight, and subsequently stopping, sight distance control the length of a sag curve.

Drainage

The same drainage criterion used for crest vertical curves on curbed roadways applies to sag vertical curves: K = 167. As before, this should not be considered a maximum but rather an area where drainage should be examined more closely, when design speeds of 70 mph or more are used.

Appearance

The general controlling factor for appearance of a sag curve is K ≥ 100 for small to intermediate values of A, which corresponds to speeds of 50 mph and greater. Thus, for design speeds less than 50 mph the designer will want to strongly consider using K values greater than the minimum whenever site conditions allow. In general, the larger the K value, the better the appearance of a curve. The designer should always design a curve with the maximum K value site conditions will allow.

Undercrossings

Sight distance through undercrossings usually does not present a problem in the design of vertical curves. The vertical clearance of most overhead structures is such that stopping sight distance along the undercrossing roadway is easily met. The most common controlling factor is passing sight distance on a two-lane highway. Figure 2 shows the parameters involved with the sight distance at an undercrossing.

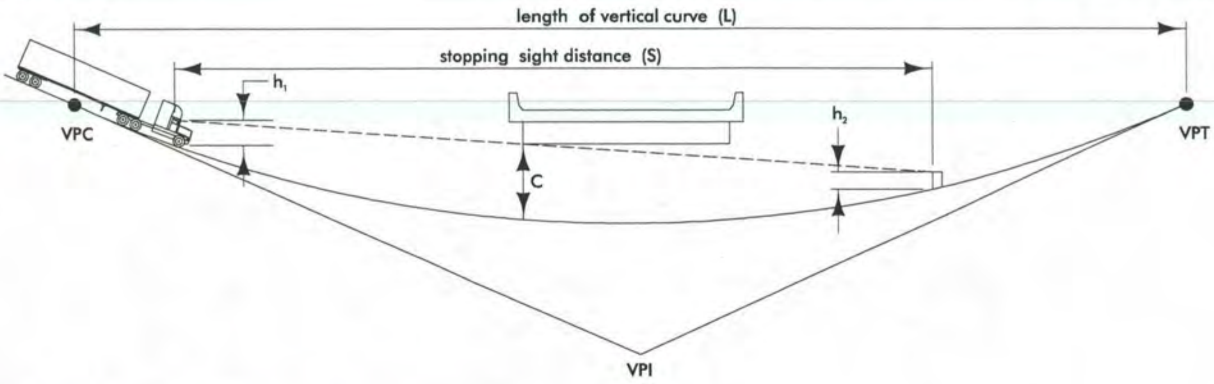


Figure 2: Sight distance at an undercrossing.

The equations for sag vertical curve length at an undercrossing are:

$$L = \frac{AS^2}{800\left(C - \frac{h_1 + h_2}{2}\right)} \qquad \text{if S<L}$$

$$L = 2S - \frac{800\left(C - \frac{h_1 + h_2}{2}\right)}{A} \qquad \text{if L<S}$$

where L, S, A, h_1, and h_2 are as described earlier in this section and C is the vertical clearance in feet.

With the height of the eye of the driver set at 8 feet for a truck driver and the height of the object set at 6 inches, these equations simplify to:

$$L = \frac{AS^2}{800(C - 4.25)} \qquad \text{if S<L}$$

$$L = 2S - \frac{800(C - 4.25)}{A} \qquad \text{if L<S}$$

Example

A bridge is being designed to pass over a rural two-lane highway with a design speed of 60 mph. The section of the two-lane highway where the bridge crosses over is a 1740 foot vertical sag curve with A = 3.15. The bridge clearance is 16.8 feet. Does adequate passing sight distance exist on the two-lane highway or does the bridge clearance need to be adjusted?

Start by assuming S<L and solve the appropriate equation for S

$$S = \sqrt{\frac{800L(C - 4.25)}{A}} = 2{,}355 \text{ feet}$$

S is actually greater than L so solve the appropriate equation for S

$$S = \frac{L}{2} + \frac{400(C - 4.25)}{A} = 2{,}464 \text{ feet}$$

Passing sight distance for a design speed of 60 mph is 2,135 feet, so adequate sight distance exists with a bridge clearance of 16.8 feet.

Pavement

Chapter 7

Jointing Guidelines

Originally Issued: 02-26-99

This section outlines some general guidelines to follow when jointing PCC Pavement. They are listed in order of importance. If you cannot meet all of the guidelines outlined below, you should meet those towards the top of the list first.

1. Joints should be at least 2 feet long. This is the minimum length needed to establish a joint.
2. Ninety degree angles are preferred between two joints and between a joint and the free edge of the pavement. Angles as small as 70 degrees may be used, but angles less than 70 degrees should not be used.
3. The number of joints intersecting at one point should not exceed four.
4. Longitudinal joints should be placed according to the Standard Road Plans. For mainline pavements, longitudinal joints are spaced at lane pavement width—12 or 14 feet. Consult the Pavement Design Section for any special cases.
5. The pavement width should be kept the same throughout a project, if possible, to simplify construction and jointing.
6. The C transverse joint is the primary transverse joint used when the pavement thickness is less than 8 inches. It normally has a maximum spacing of 15 feet. However, the spacing of C joints used in shoulders should match the spacing of the mainline joints, even if the mainline joint spacing is greater than 15 feet.
7. The CD transverse joint is the primary transverse joint used when the pavement thickness is 8 inches or greater. It has a maximum spacing of 20 feet. If the joint length is 2 feet, a C joint should be used instead of the CD.
8. On non-primary side roads and intersection returns connecting to the mainline, C joints may be used if the design year truck volumes are less than 200 vpd (regardless of the pavement thickness). Consult the Pavement Design Section for the appropriate transverse joint to use on primary routes with design year truck volumes less than 200 vpd.
9. A minimum spacing of 12 feet for transverse joints should be used.
10. Avoid unnecessary angles and bends in the length of a joint. This complicates the design and makes it difficult to construct.
11. If possible, maintain a joint as either working or non-working throughout its length.
12. Any section that may be manually paved (crossovers, intersection returns, etc.) should be able to be broken up so the entire area does not have to be paved all at one time. Use jointing that gives the contractor the option to pave the area in sections.
13. To help ease in the design of a jointing layout, transverse joints are not skewed at intersections.

14. The pavement engineer should be consulted to determine if a KT-3 or an L-3 longitudinal joint is needed if the pavement width is greater than "W" given a pavement thickness of "T".

T (in)	W (ft)
8	60
9	56
10	52
11	48
12	44
13	40

15. Joint dimensions are normally rounded to the nearest foot.
16. The DW joint is not shown on the jointing layout. Using the DW joint to aid in the placement of concrete is the contractor's option.
17. Carry out jointing details to the first skewed joint past the detailed area if there is room on the plans. This eliminates any confusion in the field about where the jointing detail ends and the skewed jointing begins.

Table 1 on the following page summarizes information on the various joints used by the Department, including the joint type, the method of load transfer, and whether the joint allows or prevents thermal movement. This table can be used to select an appropriate joint for various situations.

Table 1

Joint	Type			Method of Load Transfer					Thermal Movement				Comments
	Transverse	Longitudinal	Expansion	Aggregate Interlock	Key	Tie Bar	Dowel Bar	Skewed	Doweled to allow movement	Tied to prevent movement	Expansion joint allows movement	Lack of reinforcing allows movement	
B	X	X										X	Used between dissimilar materials or when other joints are not suitable.
C	X			X				X				X	Transverse joint used when T < 8". May also be used on non-primary routes if AADTT < 200 vpd.
CD	X			X			X	X	X				Transverse joint used when T ≥ 8". Use C joint when joint length is 2'.
CT	X			X		X				X			Tied contraction joint.
DW	X					X				X			Used by contractor as a stopping point.
HT	X					X				X			Used at the end of rigid pavement prior to placement of second slab.
RD	X						X		X				Joint between new and existing pavements, dowels are used.
RT	X					X				X			Joint between new and existing pavements, tie bars are used.
BT-1		X								X			Longitudinal joint used when T < 8", interchangeable with L-1 depending on paving sequence.
BT-2		X								X			Used when L-2 and the KT-2 are not possible, T ≥ 8".
BT-3		X								X			Joint used between new and existing pavements, tie bars are used.
BT-4		X								X			Joint used between new and existing pavements, tie bars are used.
K		X			X							X	T > 8", minimal usage.
KS		X			X					X			Used in reinforced pavements.
KT-2		X			X					X			Longitudinal joint used when T ≥ 8", interchangeable with L-2 depending on paving sequence.
KT-3		X			X					X			Longitudinal joint used with pavements of large width, interchangeable with L-3.
L-1		X		X						X			Longitudinal joint used when T < 8", interchangeable with BT-1.
L-2		X		X						X			Longitudinal joint used when T ≥ 8", interchangeable with KT-2 depending on paving sequence.
L-3		X		X						X			Longitudinal joint used with pavements of large width, interchangeable with KT-3 depending on paving sequence.
CF	X		X								X		4" expansion joint.
E	X	X	X								X		1" expansion joint.
ED	X		X				X		X		X		1" doweled expansion joint.
EE	X		X				X		X		X		2" doweled expansion joint.
EF	X		X				X		X		X		4" doweled expansion joint.
ES			X								X		Used in curb to match expansion joint in pavement.

Jointing Rural Intersections

Originally Issued: 02-26-99

This section describes how to joint rural intersections by following the guidelines outlined in Section 7A-2. The first example illustrates a step-by-step process for jointing a T-intersection. The second example discusses the jointing of an intersection at a divided highway.

Even though not all rural intersections will be exactly like the ones in these examples, the process described is applicable to other layouts.

Example 1—T-Intersection

The first example is a T-intersection of a rural two-lane highway and a paved sideroad. The intersection has returns on each side (see Figure 1) and the pavement thickness is 10 inches. The design year truck volume on the sideroad is 250 vpd.

Step 1: Place Joints with Predetermined Locations

Longitudinal Joints

Because the location of longitudinal joints for both the mainline and the sideroad are predetermined by the lane pavement width, these joints should be placed first. Within the intersection, the road that is paved first determines which joints are longitudinal and which are transverse. In this example, assume that the mainline is paved first. Since the mainline is a rural two-lane highway, the longitudinal joints are spaced at 14 feet—lane pavement width. The longitudinal joints running down the centerline and edges of the sideroad define the locations of the first transverse joints for the mainline (see Figure 1).

To determine an appropriate longitudinal joint to use, refer to Standard Road Plan RH-51 or Table 1 in Section 7A-2. Normally, the type of joint used depends on the pavement thickness. Since the pavement thickness is greater than 8 inches in this case, either a KT-2 or an L-2 joint is appropriate.

Joints at End-of-Taper

The only other joints with predetermined locations are the transverse joints that are placed where the end-of-taper sections terminate. End-of-taper sections are 2-foot wide sections placed at the ends of an intersection return (see Figure 1). They are used to prevent the return from narrowing to a point as it intersects with the pavement. Concrete less than 2 feet in width is weak and cracks readily.

As Figure 1 shows, normal practice is to place a transverse joint in the mainline or sideroad pavement where the end-of-taper section terminates. Standard Road Plan RH-50 and Table 1 in Section 7A-2 indicate that a CD joint should be used on the mainline since the pavement thickness is greater than 8 inches. On the sideroad, CD joints are also used since the design year truck volume is greater than 200 vpd (C joints could be used on the sideroad if the design year truck volume was less than 200 vpd).

Note that the transverse joints within the intersection are not skewed.

Step 2: Place Difficult Joints

Difficult locations to joint, such as intersection returns and traffic islands, are addressed next. After joints have been placed in these locations, the rest of the joints can be worked in around them.

Intersection Returns

The two intersection returns are shaded in Figure 1. To help vehicles negotiate the turn, a curved longitudinal joint (normally offset 12 feet from the free edge of the pavement) is placed in the intersection return to delineate the turning path. A second curved longitudinal joint (normally offset 24 feet from the free edge of the pavement) is placed if enough area is available.

Traffic Islands

Joint design at the traffic islands is not an exact process. It is done by trial-and-error until satisfactory results are achieved.

The first thought may be to place CD transverse joints at every radius point of the island (see Detail A, Figure 1). However, with this layout the 20-foot maximum and 12-foot minimum spacings for a CD joint are violated.

Detail B shows joints at the desired 20-foot interval. Although the spacing of this placement is correct, an awkward area of pavement is formed and a crack is likely to develop as shown in Detail B.

Detail C illustrates a combination of the methods used in the first two details. No rules of spacing are violated and no awkward areas of pavement exist.

The transverse joints attached to the island are extended across the sideroad and mainline pavements and across the intersection return adjacent to the island, as shown in Figure 1. The joints used in one area must also be acceptable for any other areas into which they are extended. If the extended joints do not satisfy spacing or other criteria in any adjacent areas, they must be redesigned in the original area.

Step 3: Place Remaining Joints

After the joints at difficult locations are placed, the remaining joints (generally transverse joints) are placed in appropriate locations. As noted in Step 1, the appropriate transverse joint for both the mainline and the sideroad is the CD joint. The maximum spacing for CD joints is 20 feet and the minimum spacing is 12 feet. Therefore, the remaining areas that need transverse joints should have CD joints spaced within this range.

Mainline and Sideroad

The placement of the remaining transverse joints on the mainline and sideroad is largely determined by the location of joints already placed in Steps 1 and 2 (see Figure 1). The remaining joints are spaced between 12 and 20 feet between these already-placed joints. However, you must also consider how these joints will be extended into the returns (described below).

Intersection Returns

After the transverse joints have been placed in the mainline and the sideroad, they are extended into the intersection returns to be used as transverse joints for those areas as well. As with other transverse joints, those in intersection returns must intersect with the free edge of the pavement. However, the acute angle between the joint and the pavement edge (and between the joint and other joints) must be greater than or equal to 70 degrees. Details A, B, C, and D in Figure 2 illustrate how to intersect joints with the free edge of the pavement (and with other joints) under various conditions.

- Detail A shows a transverse joint that intersects with the free edge of the pavement unaltered. This is acceptable because all angles between the transverse joint and the longitudinal joints and between the transverse joint and the free edge of the pavement are greater than 70 degrees.
- Detail B uses a dashed line to show the original position of a transverse joint whose angle with the free edge of the pavement is less than 70 degrees. This joint should be skewed to make it perpendicular to the free edge of the pavement, as shown by the solid line.
- Detail C illustrates a situation where skewing the joint to make it perpendicular to the free edge of the pavement causes the angle between the joint and the edge of the mainline to be less than 70 degrees. When this situation occurs, the joint is extended a minimum of 2 feet beyond the edge of the mainline or sideroad, and then it is skewed to make it perpendicular to the free edge of the pavement.
- Detail D shows the curved longitudinal joints that were placed in the intersection return in Step 2. Each of these joints terminates at an intersection with a transverse joint. The intersection of these joints is required to be at least 2 feet from the edge of the mainline or sideroad. This requirement determines the appropriate transverse joint at which the longitudinal joint terminates. The dashed line in the detail indicates the position of the longitudinal joint if it is extended too far. Because the intersection with the transverse joint is less than 2 feet from the pavement edge, the longitudinal joint is terminated at the previous transverse joint.

After all joints are placed, the layout should be checked to ensure that all joint spacings and angles are acceptable. If they are not, the spacing of the mainline or sideroad joints may need to be changed, one or more joints may be added, or joints within the returns may be modified.

Figure 2 shows all of the transverse joints appropriately placed.

Step 4: Label Joints

The completed jointing layout of the T-intersection is shown in Figure 3. As stated on Standard Road Plan RH-51, the L-2 and KT-2 joints may be used interchangeably, at the contractor's discretion, depending on the paving sequence. Therefore, the designer may identify the longitudinal joints as either L-2 or KT-2 on the jointing layout. The transverse joints in the end-of-taper sections are C joints because they are only 2 feet long—not long enough to use a doweled transverse joint like the CD. The joints on the right side of the traffic island are also C joints as specified on Detail Sheets 6143 and 6144.

It is not necessary to identify every joint on the jointing layout. A few key joints on the diagram should be identified and whenever a series of joints changes to a different type of joint, the joint at the location of the change should be identified. Also, any joint that may be a source of confusion should be identified.

Joint lengths are also shown on the jointing layout, normally rounded to the nearest foot. Similar to labeling joint types, not every length needs to be indicated. However, any length that cannot be inferred from the diagram should be labeled. For example, the distance the mainline or sideroad transverse joints extend into the intersection returns before being skewed perpendicular to the free edge of the pavement should be dimensioned (see Figure 3).

Example 2—Intersection at a Divided Highway

The jointing design process for a four-way intersection at a divided highway is basically the same as the T-intersection except that there is also a paved median opening to deal with.

As with the T-intersection, start out by placing the longitudinal joints that are predetermined by the lane pavement width. After doing this, place longitudinal joints through the opening (see Figure 4). The edges of the left-turn lanes define the location of two of these joints. The remaining longitudinal joints in the opening are spaced roughly a lane width apart—somewhere in the range of 10 to 16 feet is acceptable.

After this, the process is basically the same as the T-intersection:

- Place the transverse joints at the end-of-taper sections.
- Place the curved longitudinal joints in the return.
- Place the transverse joints around the islands. Figure 4 illustrates the design through this point.
- Place the remaining transverse joints and extend them into the returns and into the median opening. Refer back to the T-intersection example for details on how the joints should intersect with the free edge of the pavement and with other joints.
- Label the joints.

Figure 5 illustrates the final jointing layout.

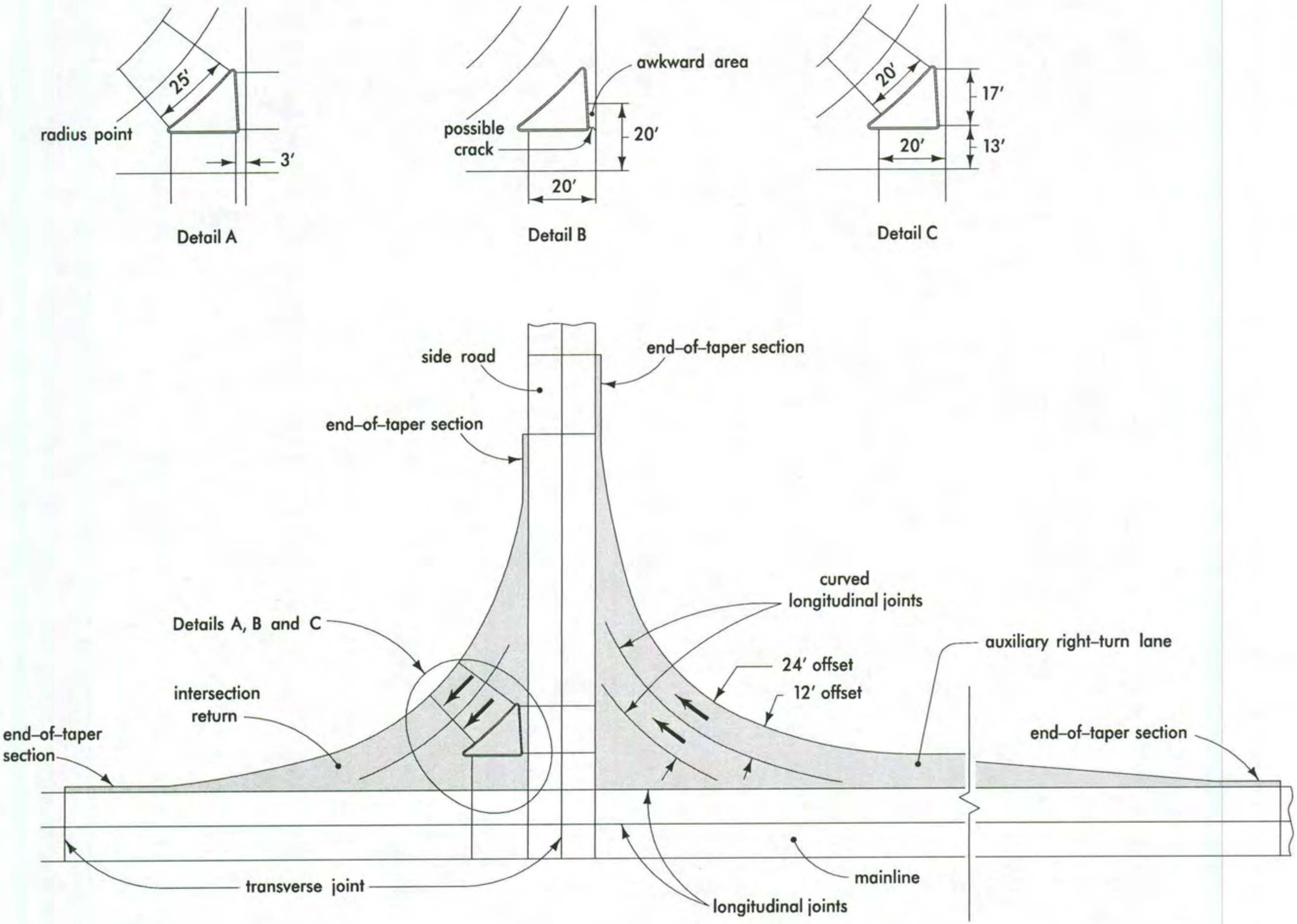


Figure 1: Placement of predetermined and difficult joints.

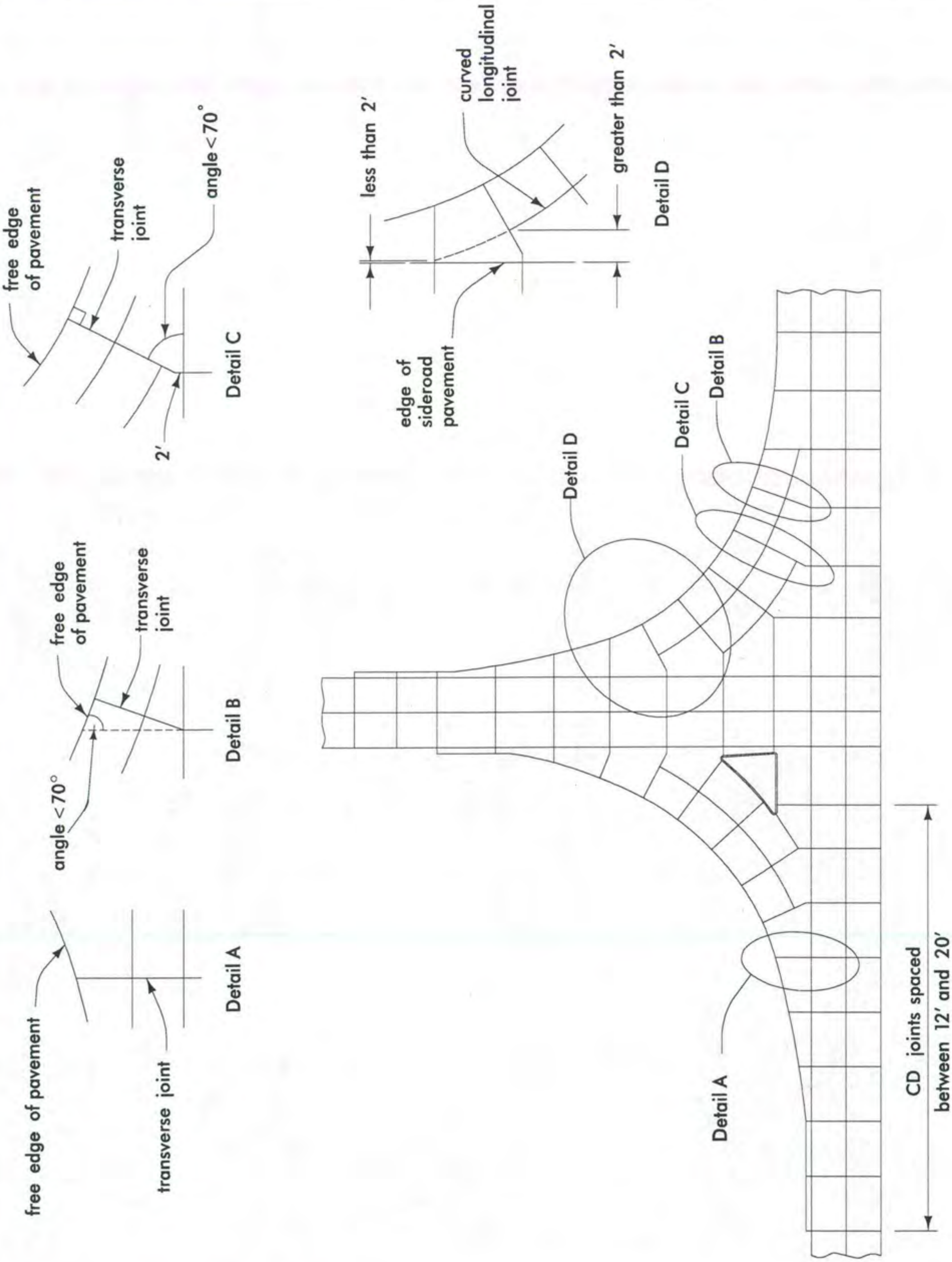


Figure 2: Placement of remaining joints.

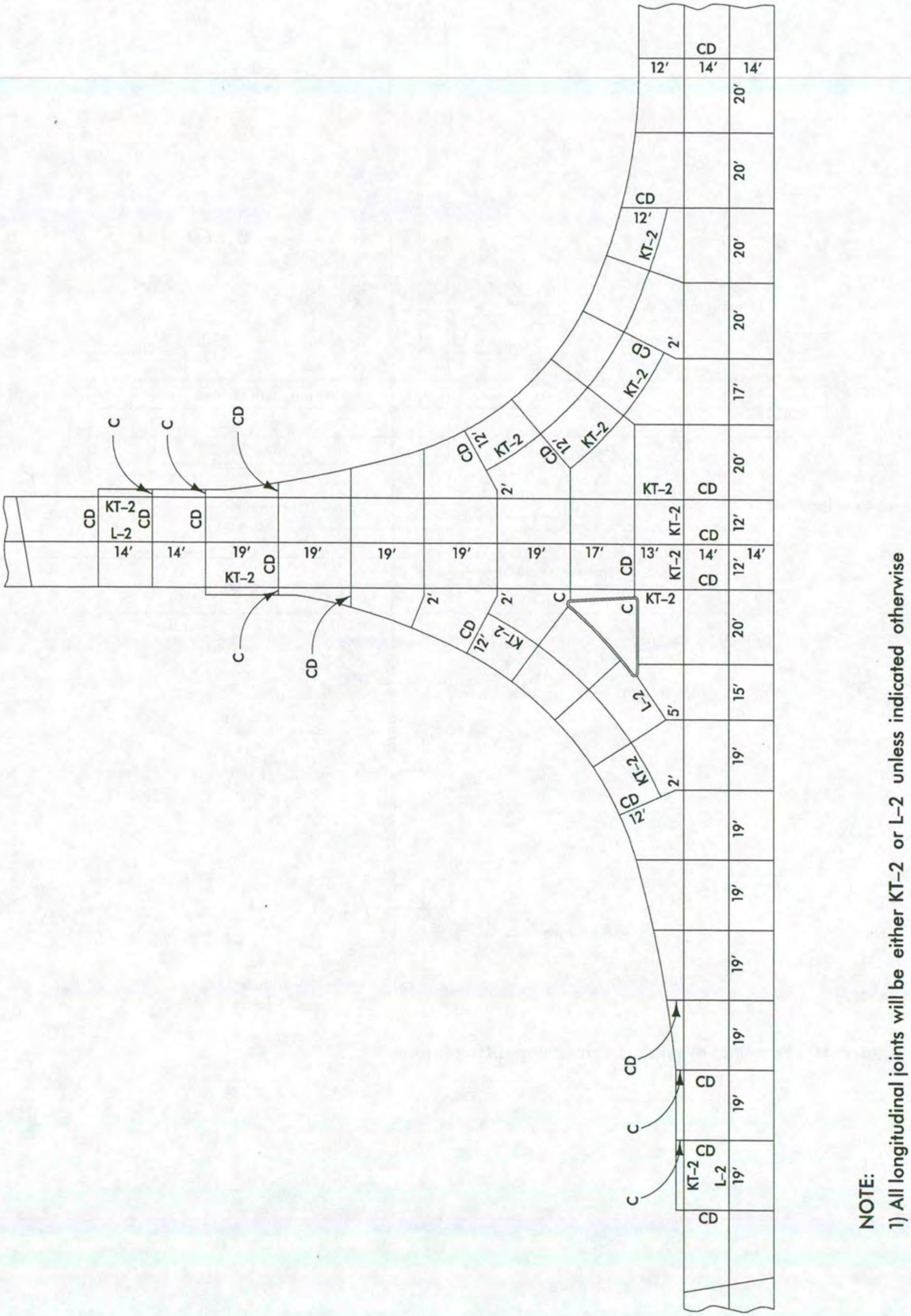


Figure 3: Final jointing layout.

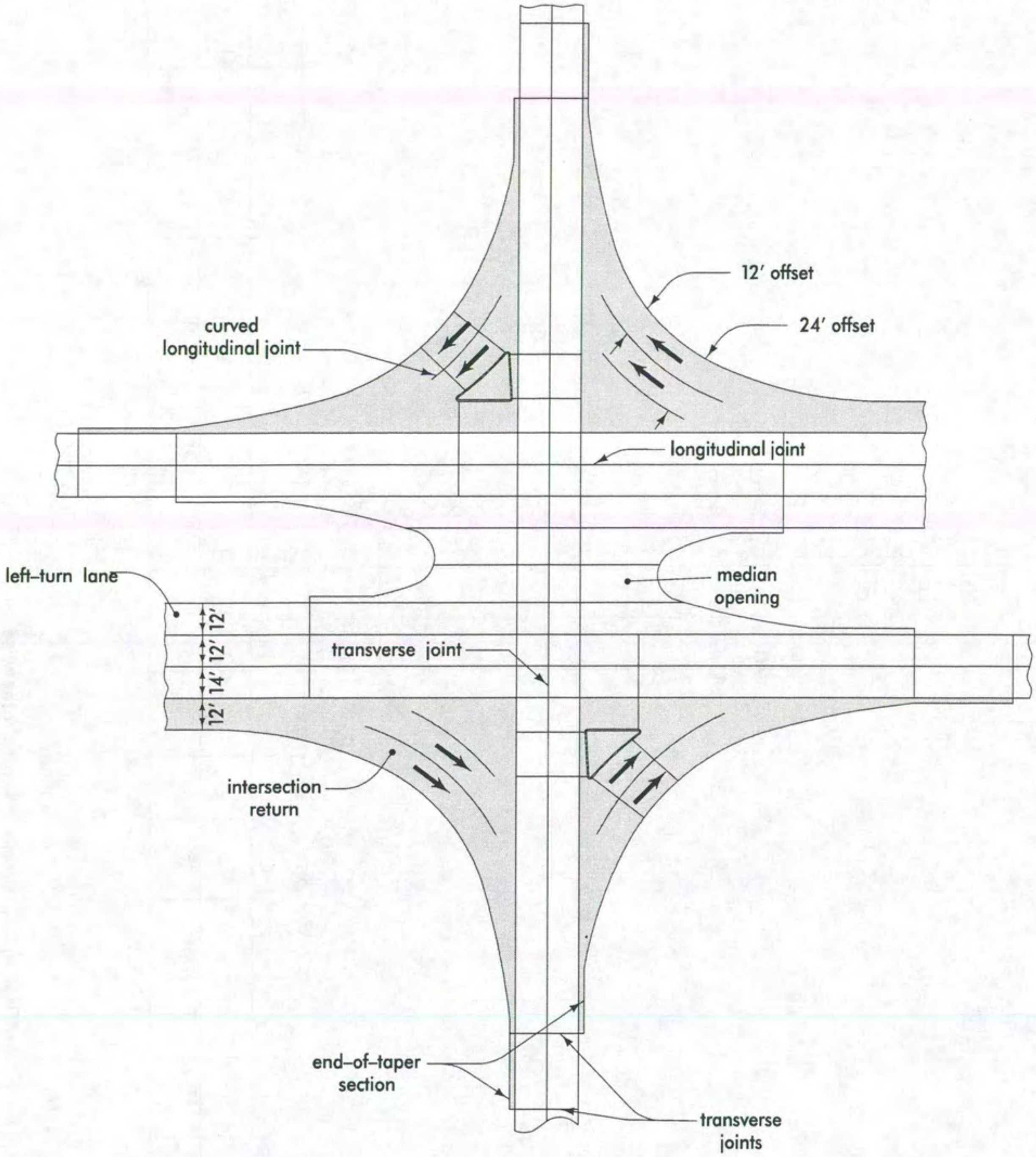
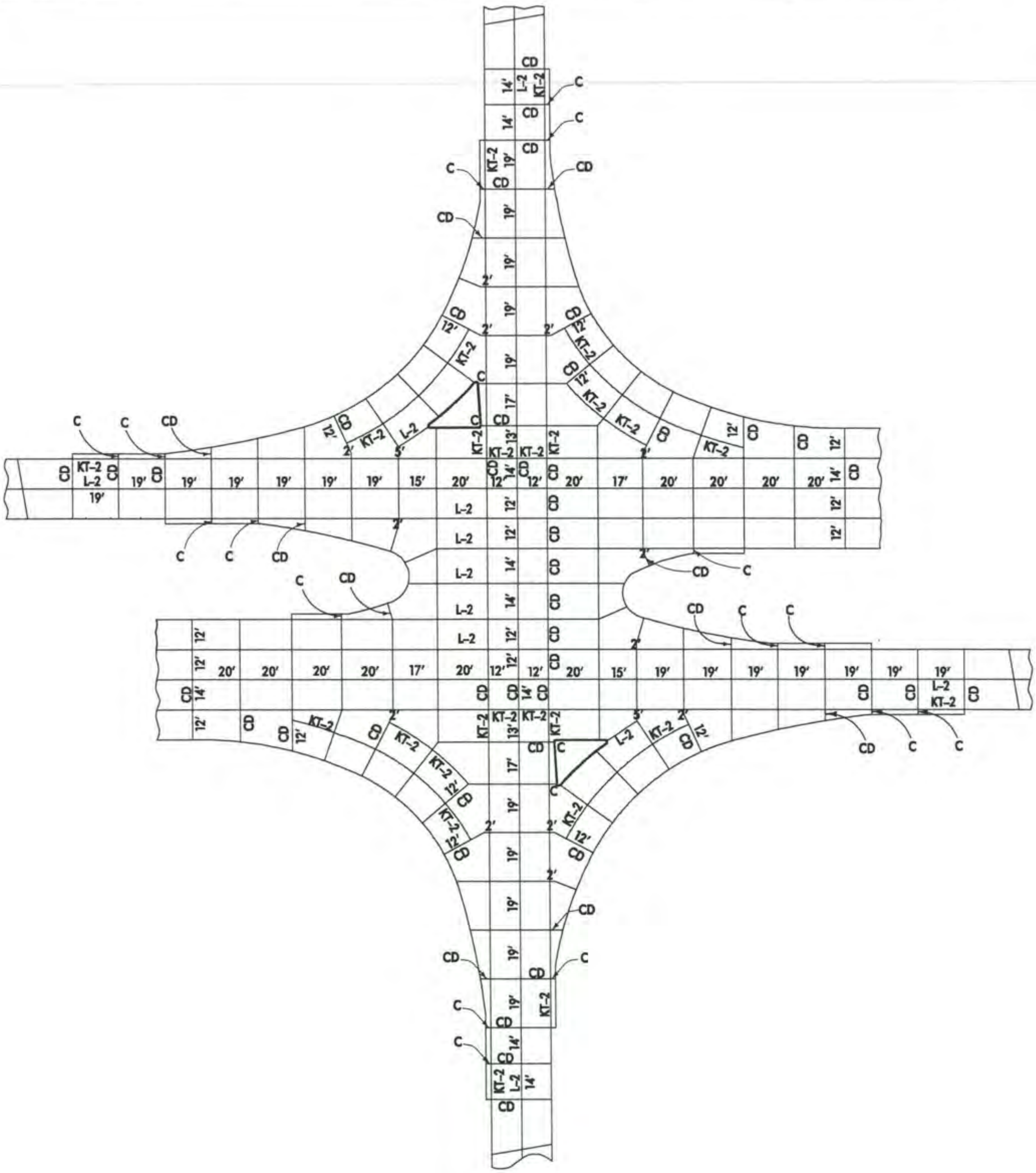


Figure 4: Placement of predetermined and difficult joints.



Note:
1) All longitudinal joints will be either KT–2 or L–2 unless indicated otherwise.

Figure 5: Final jointing layout.

Jointing Urban Intersections

Originally Issued: 02-26-99

This section describes how to joint urban intersections by following the guidelines outlined in Section 7A-2. The process will be illustrated through an example of the intersection of a reduced-speed urban highway and a city street. The intersection is curbed, includes several intakes, and the pavement thickness is 10 inches.

Even though not all urban intersections will be exactly like the one used in this example, the process described is applicable to other layouts.

Step 1: Place Joints with Predetermined Locations

Because the location of longitudinal joints for both the mainline and the city street is predetermined by the lane widths, these joints should be placed first. As illustrated on Standard Road Plan RH-47B, the 53-foot pavement section used for the mainline requires a longitudinal joint down centerline and one on each side of centerline, offset the 12-foot lane width. Standard Road Plan RH-45B illustrates a similar layout for the longitudinal joints of the city street with a 31-foot pavement section.

Within the intersection, the road that is paved first determines which joints are longitudinal and which are transverse. Generally, the mainline will be paved prior to the city street. Therefore, the longitudinal joints running down the city street define the locations of the first transverse joints for the mainline (see Figure 1).

To determine an appropriate longitudinal joint to use, refer to Standard Road Plan RH-51 or Table 1 in Section 7A-2. Normally, the type of joint used depends on the pavement thickness. Since the pavement thickness is greater than 8 inches in this case, either a KT-2 or an L-2 joint is appropriate.

Step 2: Place Difficult Joints

Intake locations and the boxouts at the corner radii of the intersection are addressed next. After joints have been placed at these locations, the rest of the joints can be worked in around them.

Joints at Intakes

The location of intakes is determined before the joints are laid out, so joints have to be worked in around them. To start out with, straddle the intake with two transverse joints spaced at 20 feet. These joints can be repositioned later if it helps with the placement of other joints. In the final layout, the intake does not have to be centered between the joints. As shown on Standard Road Plan RA-40, the joint may be as close as 2 feet from the intake on grade and as close as 4 feet at a low point.

Standard Road Plan RH-50 and Table 1 in Section 7A-2 indicate that a CD joint should be used on the mainline since the pavement thickness is greater than 8 inches. However, the CD joints straddling the intake do not extend all the way through the curb and gutter. The joints immediately surrounding the intake are specified on RA-40. EE expansion joints are placed to the left and right of the intake to prevent damage to the intake from the movement of the surrounding pavement. A B joint is placed in front of the intake (see Figure 2).

Joints at Boxouts

Before the mainline is paved, small areas near the corners are boxed-out. These boxed-out areas (shaded in Figure 1) are poured later, after the mainline has been paved. If the paver were to proceed straight through this area, instead of using boxouts, the returns of the city street would narrow to a point where they meet the mainline. Pavement less than 2 feet in width is weak and cracks readily. By using boxouts, this situation can be avoided without the expense of stopping the paver at the intersection.

The size and shape of boxouts varies depending on where they are used, but the width of boxouts is normally the same as the roadway's gutter width. When placing joints around the boxout remember to maintain intersecting angles greater than 70 degrees and joints at least 2 feet long. KT-2 or L-2 joints are used around the boxout. Figure 1 illustrates joints properly placed, both around the boxouts and extending outward from them.

Step 3: Place Remaining Joints

After the joints at intakes and boxouts are placed, the remaining joints (generally transverse joints) are placed in appropriate locations. As noted in Step 2, the appropriate transverse joint for the mainline is the CD joint. The maximum spacing for CD joints is 20 feet and the minimum spacing is 12 feet. Therefore, the remaining areas on the mainline that need transverse joints should have CD joints spaced within this range. Since the design year truck volume on the adjoining street is less than 200 vpd, C transverse joints are used there.

In Figure 2, notice how the C joints on the city street nearest the corners are skewed perpendicular to the free edge of the pavement (Section 7A-3 illustrates this technique in more detail). If this joint were carried straight through, instead of skewed, the acute angle between the joint and the free edge of the pavement would be less than 70 degrees, which is not acceptable.

After all joints are placed, the layout should be checked to ensure that all joint spacings and angles are acceptable. Figure 2 shows all of the transverse joints appropriately placed.

Step 4: Label Joints

The completed jointing layout of the intersection is shown in Figure 2. As stated on Standard Road Plan RH-51, the L-2 and KT-2 joints may be used interchangeably, at the contractor's discretion, depending on the paving sequence. Therefore, the designer may identify the longitudinal joints as either L-2 or KT-2 on the jointing layout.

It is not necessary to identify every joint on the jointing layout. A few key joints on the diagram should be identified and whenever a series of joints changes to a different type of joint, the joint at the location of the change should be identified. Also, any joint that may be a source of confusion should be identified.

Joint lengths are also shown on the jointing layout, normally rounded to the nearest foot. Similar to labeling joint types, not every length needs to be identified. However, any length that cannot be inferred from the diagram should be labeled.

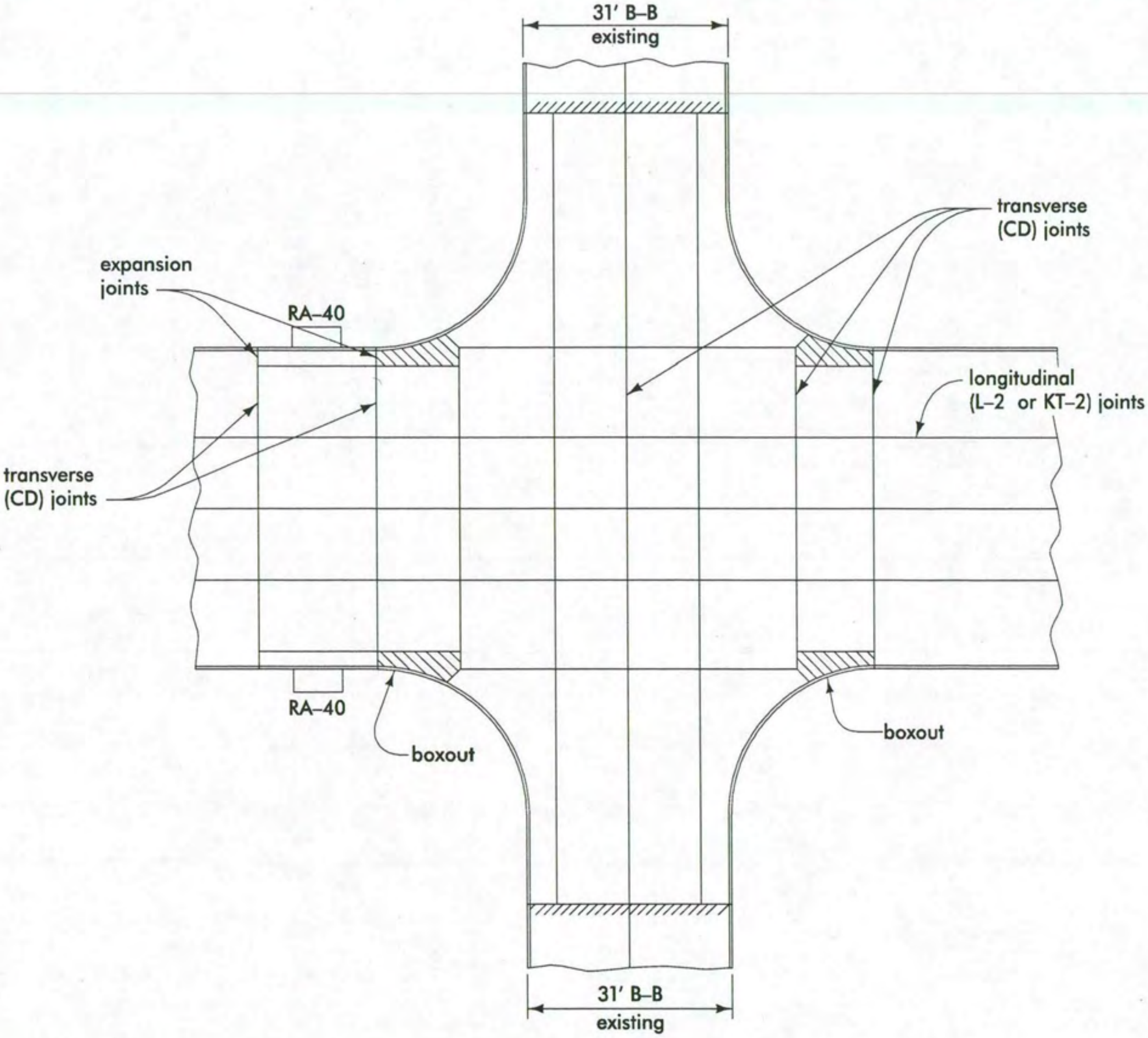


Figure 1: Placement of predetermined and difficult joints.

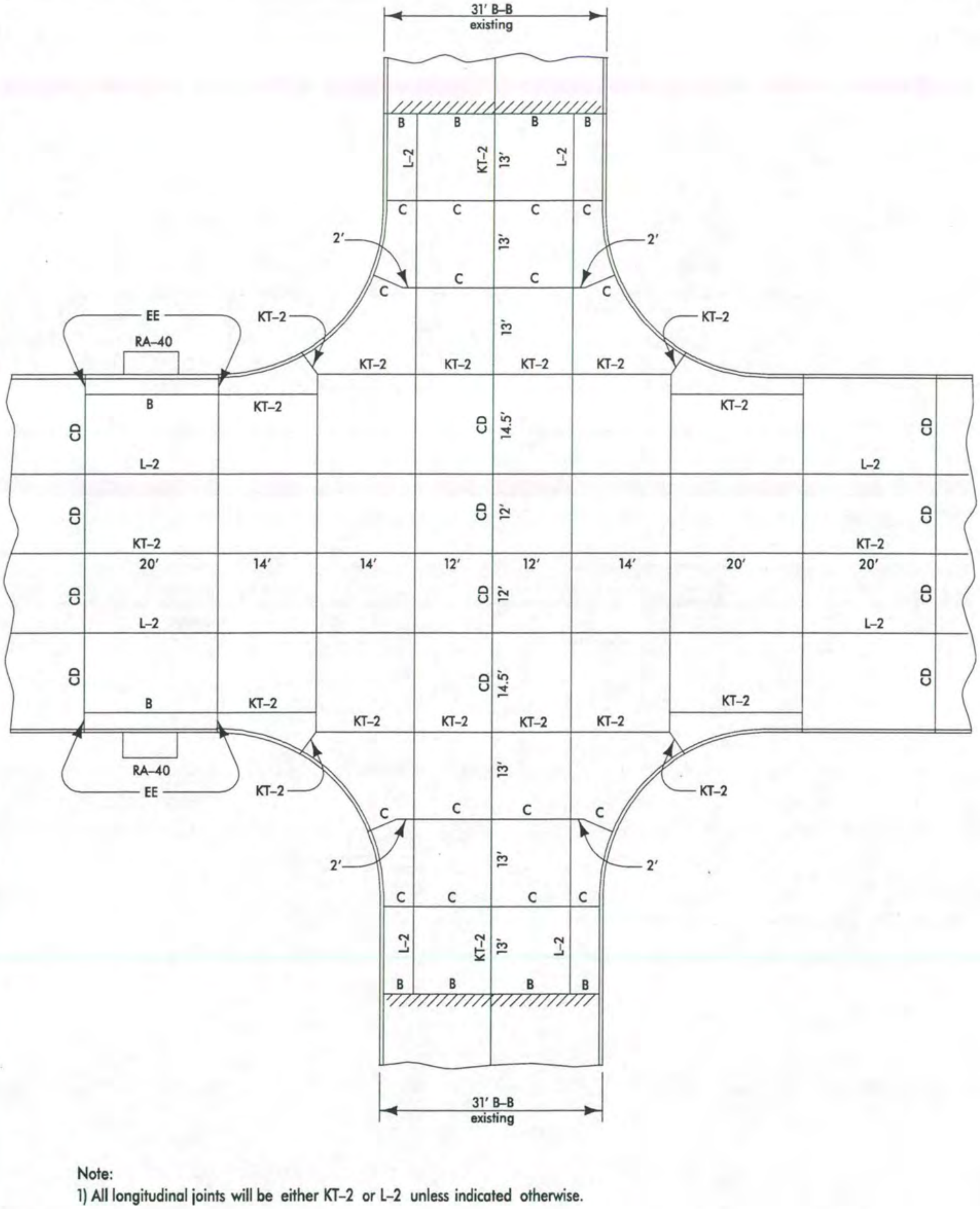


Figure 2: Final jointing layout.

Jointing Cul-de-Sacs

Originally Issued: 02-26-99

This section describes how to joint a cul-de-sac by following the guidelines outlined in Section 7A-2. The process is illustrated through an example of a city street that is terminated with a cul-de-sac. Assume the pavement thickness is 7 inches.

Step 1: Place Longitudinal Joints

The longitudinal joints running down the city street should be extended into the cul-de-sac. The remaining longitudinal joints in the cul-de-sac should be placed roughly a lane width apart—somewhere in the range of 10 to 16 feet is acceptable.

Standard Road Plan RH-51 or Table 1 in Section 7A-2 indicate that a BT-1 or L-1 are appropriate longitudinal joints, since the pavement thickness is less than 8 inches.

Step 2: Place Transverse Joints

The next step is to place the transverse joints. The maximum spacing for transverse joints is 20 feet and the minimum spacing is 12 feet. Therefore, the joints within the cul-de-sac should be spaced within this range (see Figure 1).

Standard Road Plan RH-50 or Table 1 in Section 7A-2 indicates that a C joint is the appropriate joint to use since the pavement thickness is less than 8 inches.

Step 3: Extend Joints through the Free Edge of the Pavement

When extending the previously placed joints through the free edge of the pavement, keep in mind that the acute angle between the joint and the pavement edge (and between the joint and other joints) must be greater than or equal to 70 degrees. Also, all joints should be at least 2 feet long. Details A, B, and C in Figure 2 illustrate how this can be accomplished.

- Detail A shows a transverse joint that is extended through the free edge of the pavement unaltered. This is acceptable because all angles between the transverse joint and the longitudinal joints and between the transverse joint and the free edge of the pavement are greater than 70 degrees.
- Detail B uses a dashed line to show the original position of a transverse joint whose angle with the free edge of the pavement is less than 70 degrees. This joint should be skewed to make it perpendicular to the free edge of the pavement, as shown by the solid line.
- Detail C illustrates a situation where skewing the joint to make it perpendicular to the free edge of the pavement would cause the angle between the joint and a longitudinal joint to be less than 70 degrees (shown by the dashed line). When this situation occurs, the joint is extended a minimum of 2 feet beyond the longitudinal joint, and then it is skewed to make it perpendicular to the free edge of the pavement. Both segments of the joint should be at least 2 feet long.

After all joints are placed, the layout should be checked to ensure that all joint spacings and angles are acceptable.

Step 4: Label Joints

The completed jointing layout for the cul-de-sac is shown in Figure 2. As stated on Standard Road Plan RH-51, the L-1 and BT-1 joints may be used interchangeably, at the contractor's discretion, depending on the paving sequence. Therefore, the designer may identify the longitudinal joints as either L-1 or BT-1 on the jointing layout.

Because the majority of the joints are either the C or the BT-1 or L-1, it is not necessary to identify every joint on the jointing layout. A note on the plan describing the transverse joints as C and longitudinal joints as L-1 or BT-1 except as noted otherwise is sufficient, provided that a few key joints on the diagram are identified. Whenever a series of joints changes to a different type of joint, the joint at the location of the change is identified. Any joint that may be a source of confusion should also be labeled.

Joint lengths are also shown on the jointing layout, normally rounded to the nearest foot. Similar to labeling joint types, not every length needs to be indicated. However, any length that cannot be inferred from the diagram should be labeled.

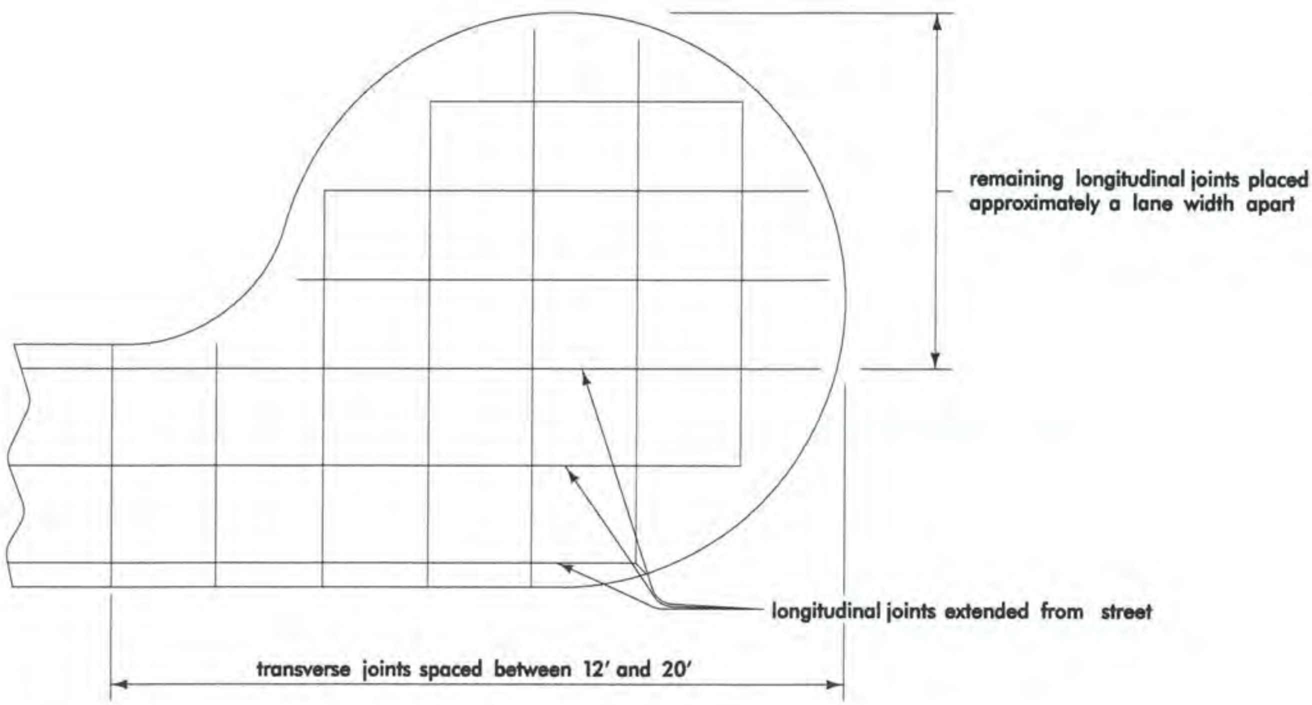
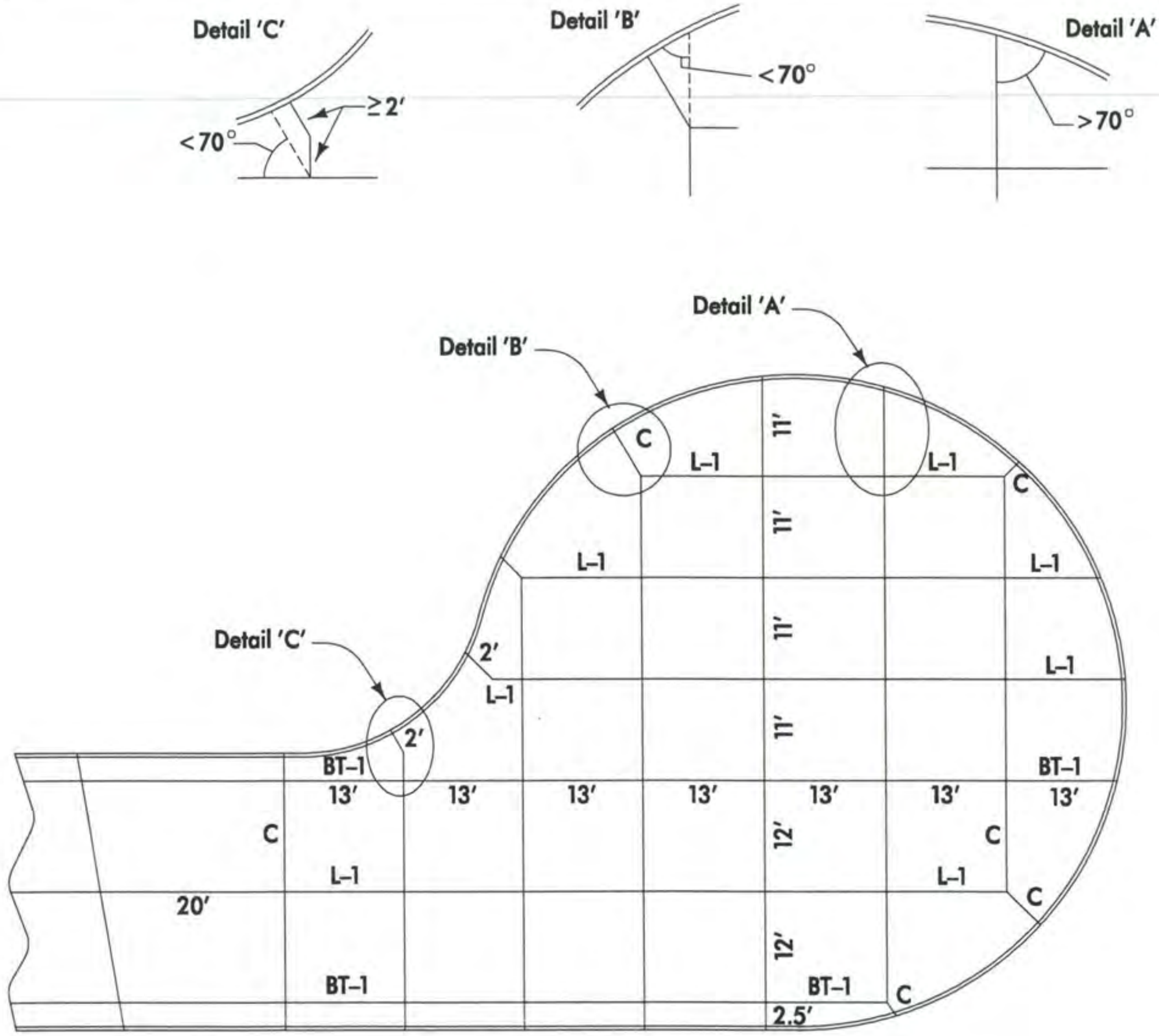


Figure 1: Placement of longitudinal and transverse joints.



NOTE:

1) All transverse joints will be 'C' unless indicated otherwise

2) All longitudinal joints will be either 'BT–1' or 'L–1' unless indicated otherwise

Figure 2: Final jointing layout.

Granular Surfacing

Originally Issued: 12-31-97

Projects that involve granular surfacing on county roads, median crossovers, and residential, farm and commercial entrances shall follow these guidelines:

- Granular surfacing shall be placed as stage construction.
- Stage 1 surfacing shall be done as part of the grading project. The normal design rate of application shall be 2220 tons per mile on county roads and 25 tons per station on entrances.
- Stage 2 surfacing will normally be done with the paving project. The normal design rate of application shall be 445 tons per mile on county roads and 10 tons per station on entrances.
- For grade-pave projects in which the surfacing cannot be placed in stages, the design rate of application will be 2330 tons per mile on county roads and 25 tons per station on entrances.

In all cases, the total rate of surfacing shall be shown on the project plans for both the grading project and the paving project.

Granular Surfacing

Originally Issued: 12-31-97

Projects that involve granular surfacing on county roads, median crossovers, and residential, farm and commercial entrances shall follow these guidelines:

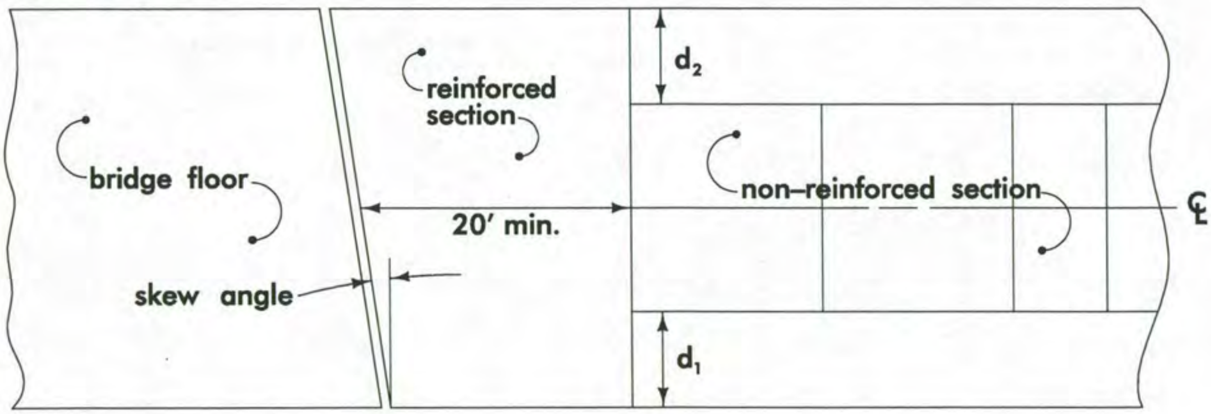
- Granular surfacing shall be placed as stage construction.
- Stage 1 surfacing shall be done as part of the grading project. The normal design rate of application shall be 2000 tons per mile on county roads and 25 tons per station on entrances.
- Stage 2 surfacing will normally be done with the paving project. The normal design rate of application shall be 400 tons per mile on county roads and 10 tons per station on entrances.
- For grade-pave projects in which the surfacing cannot be placed in stages, the design rate of application will be 2100 tons per mile on county roads and 25 tons per station on entrances.

In all cases, the total rate of surfacing shall be shown on the project plans for both the grading project and the paving project.

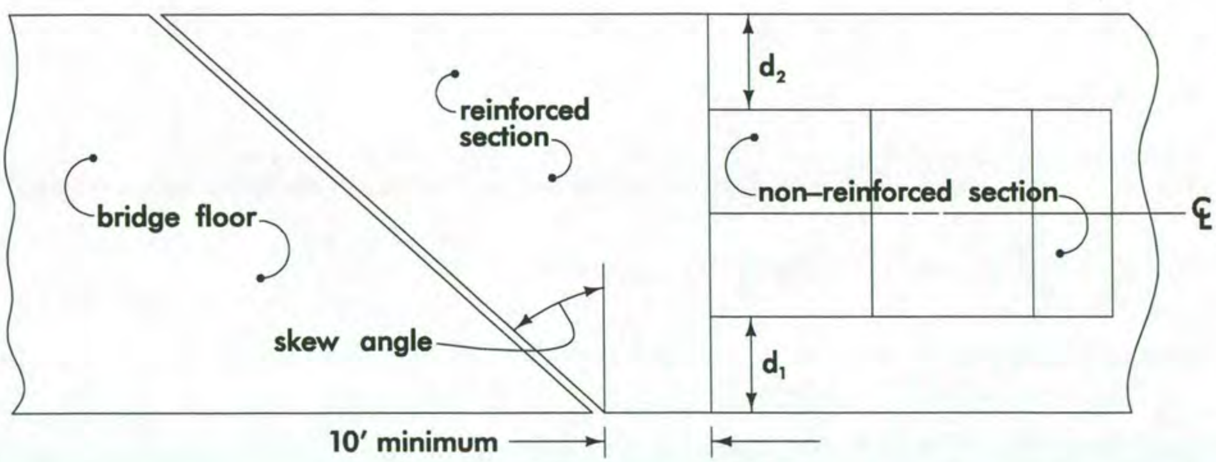
Determination of Reinforced Bridge Approach Section Dimension

Originally Issued: 06-02-00

This section provides information needed to determine proper reinforced bridge approach section dimensions. Two cases exist, as is seen in Figure 1 below. The two shoulder widths d_1 and d_2 are measured from the edge of the driving lane to the outside edge of the shoulder. Of the two shoulders d_1 and d_2, d_1 is always taken to be the shoulder located on the shorter side of the reinforced bridge approach section.



Case 1



Case 2

Figure 1: Case 1 and Case 2 bridge approach section layouts.

In Case 1 the reinforced bridge approach section dimensions are based on a 20' minimum distance, measured at the centerline of the road, from the paving notch to the end of the reinforced bridge approach section. Case 1 is common with small bridge skew angles. In Case 2 the reinforced bridge approach section dimensions are based on a minimum 10' distance from the paving notch to the end of the reinforced bridge approach section measured at the outside of the shoulder on the short side of the reinforced bridge approach section. Case 2 is common with large bridge skew angles. Examples are provided below to demonstrate how to determine which case is appropriate for determining reinforced bridge approach section dimensions.

Example 1

The skew angle for the bridge shown in Figure 2 is 10°. This bridge will be a two-lane bridge with 10' shoulders ($d_1 = d_2 = 10'$). Determine which case is appropriate to establish reinforced bridge approach dimensions.

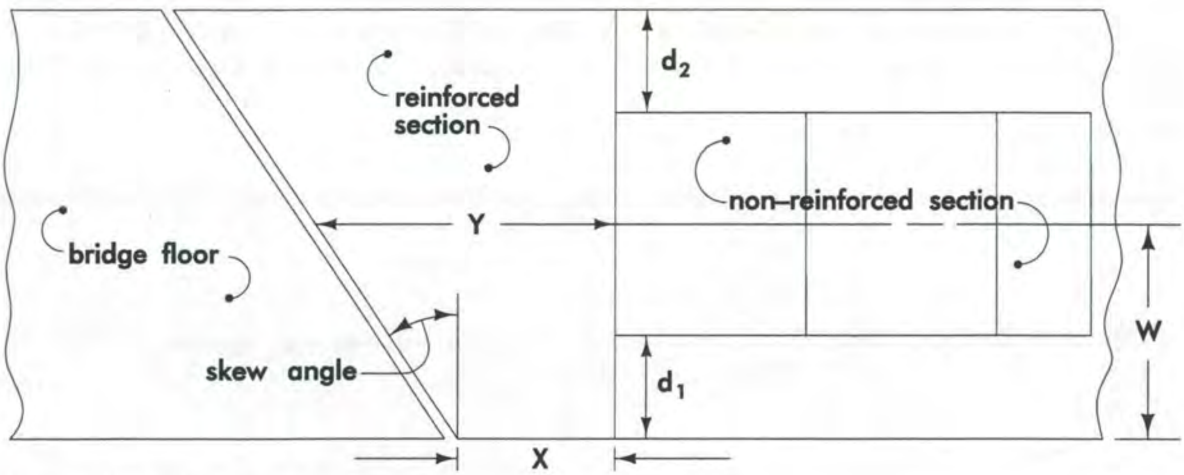


Figure 2: Bridge layout for examples.

First determine the width (W) to the centerline of the road:

12' + 10' = <u>22'</u>

Next, assume X = 10'.

Y = (22')(tan10°) + 10' = <u>13.87' < 20'</u>

However, Y must be at least 20' so use Case 1.

Example 2

The skew angle for the bridge shown in Figure 2 is 30°. This will be a two-lane bridge with $d_1 = 6'$ and $d_2 = 10'$. Determine which case is appropriate to establish reinforced bridge approach dimensions.

First determine the width (W) to the centerline of the road:

12' + 6' = <u>18'</u>

Next, assume X = 10'

Y = (18)(tan30°) + 10' = <u>20.39' > 20'</u>

Y is greater than 20', so use Case 2.

Once the designer has determined the proper case to use for the reinforced bridge approach dimensions, he or she should refer to Standard Road Plans RF-38 and RF-39 as well as RK-19B, C, F, G, H, and K for further information regarding reinforced bridge approach sections and approach pavement. The designer should also refer to Section 4C-2 of this manual regarding placement of bridge end drains.

Pavement Markings

Originally Issued: 12-20-99

Left and Right Turn Lane Pavement Markings

Pavement markings such as arrows and the word "Only" should not be used with left and right turn lanes unless specifically requested by the District Office. The District Office should request these pavement markings at the time of the field exam.

Treatment of Old Roadbeds

Originally Issued: 09-22-00

The treatment of old roadbeds depends on future use of the land. If the road has been abandoned and is to be converted to farmland, the roadbed must be obliterated. If the road follows the alignment of a proposed new highway, the roadbed is either rebuilt or obliterated depending on the position of the old roadbed relative to the proposed new roadbed. This section discusses each of these situations.

Conversion to Farmland

When an old roadbed is to be converted to farmland, it must be obliterated. Road Design Detail 4302, see Figure 1, provides information regarding obliteration of existing roadbeds. It is essential that the obliteration of the roadbed and conversion to farmland not disturb current drainage patterns. Refer to Section 10A-1 of this Manual for information regarding topsoiling.

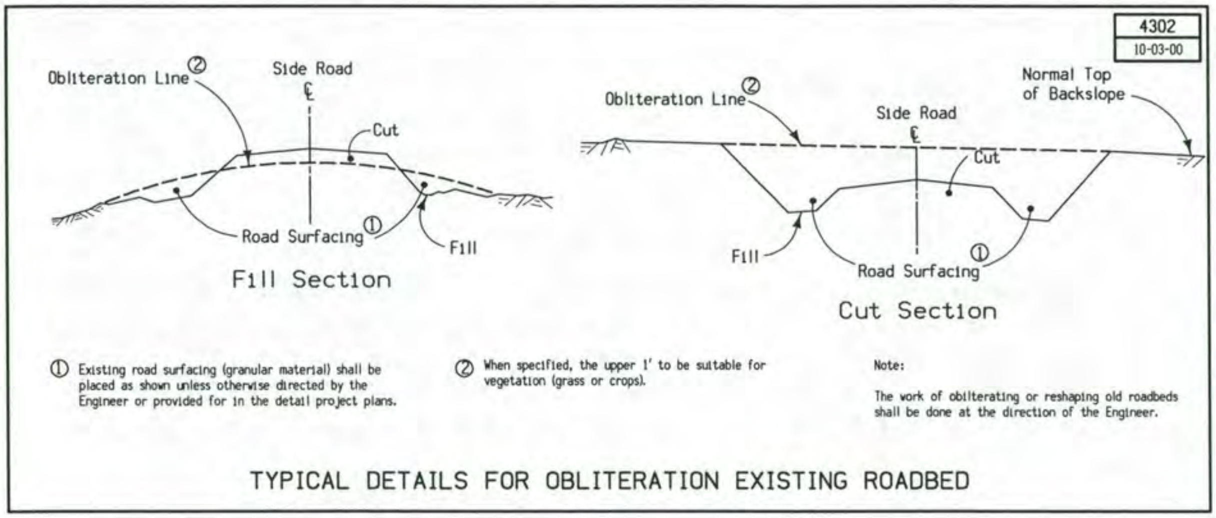


Figure 1: Road Design Detail Typical 4302.

New Highway Construction

Two cases are considered when proposed new highway construction generally follows the alignment of the original highway. In both cases, full depth ACC pavements are to be removed in their entirety and stockpiled for reprocessing back into the project or are to be disposed of by the contractor. Existing ACC resurfacing over PCC pavement is to be removed (typically by milling) and stockpiled for reprocessing back into the project or is to be disposed of by the contractor. This is necessary to comply with EPA requirements.

Composite ACC/PCC pavements (overlays) may be removed in one operation, crushed, and reprocessed back into the project as Special Backfill, shoulder material, or other approved uses. When the project concept includes pavement removal and reprocessing, one of the following provisions will be provided:

- Remove and stockpile.
- Remove, mill and/or crush, and use in project.
- Remove, mill and/or crush, and stockpile.

If crushing is specified, the gradation requirement and intended purpose (i.e., Special Backfill or Modified Subbase) shall be explicitly identified. Pavement removal and milling and/or crushing shall be included on one contract.

Case 1

Where existing pavement would be located within the proposed roadbed (see Figure 2), the old pavement shall be removed and should be reprocessed back into the project if economically feasible. Refer to current specifications for "Removal of Old Pavement," Article 2510 of the current Standard Specifications. The embankment shall be rebuilt according to Standard Road Plan RL-1A.

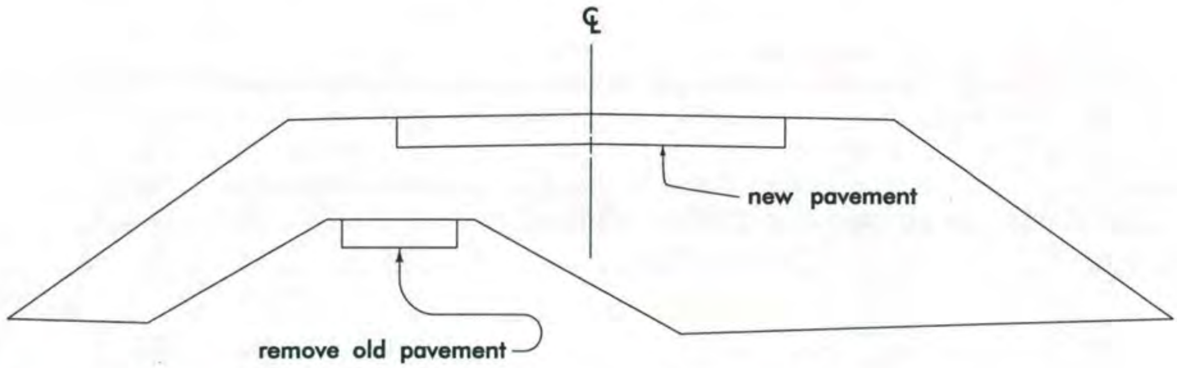


Figure 2: Existing pavement inside of proposed roadbed as outlined in Case 1.

Case 2

Where existing pavement would be partially or fully exposed, the old roadbed shall be obliterated and the old pavement shall be removed and should be reprocessed back into the project if economically feasible. Refer to current specifications for "Removal of Old Pavement," Article 2510 of the Current Standard Specifications. The roadbed shall be reshaped (see Figure 3) or covered over with a minimum of one foot of fill (see Figure 4), whichever method is appropriate to the conditions involved.

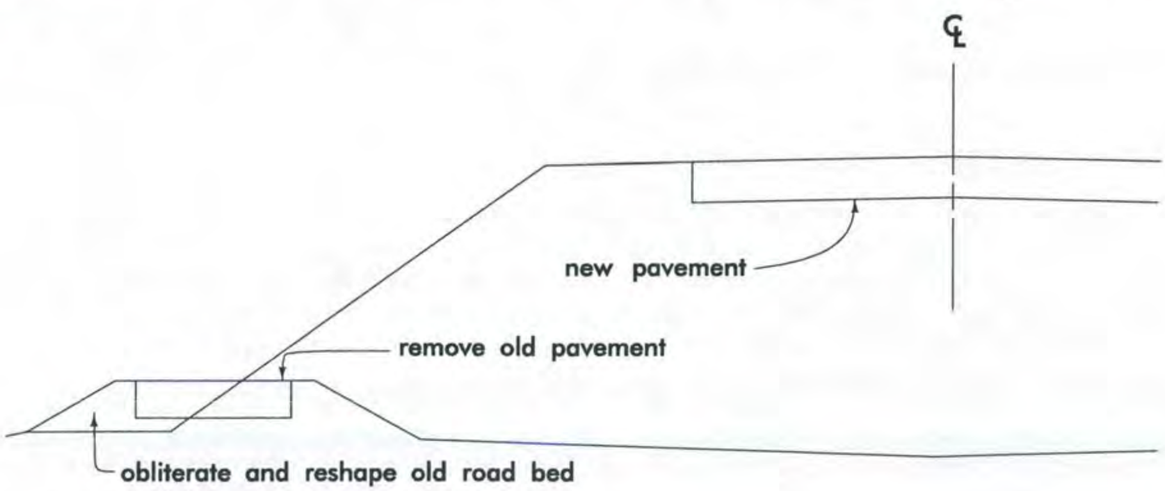


Figure 3: Reshaping roadbed as outlined in Case 2.

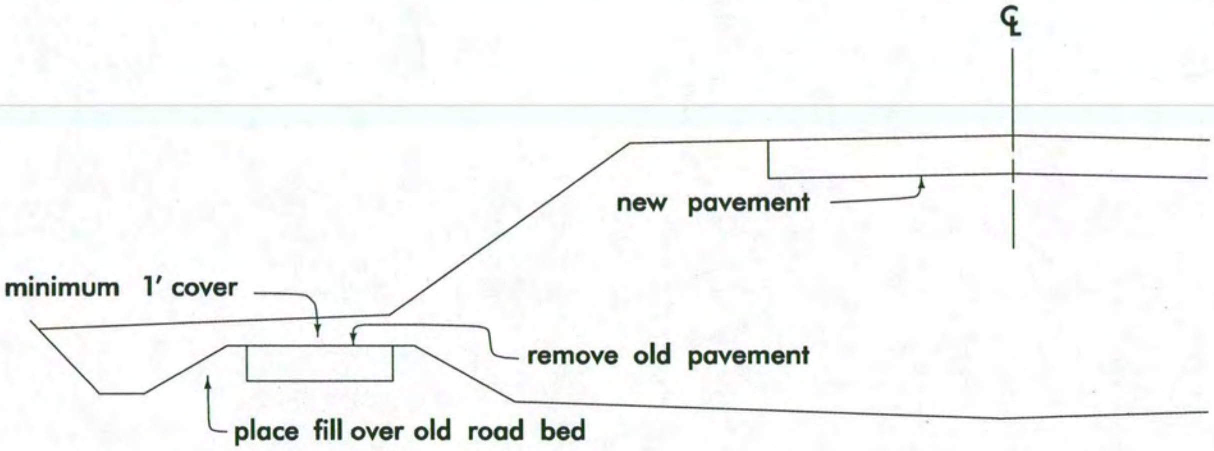


Figure 4: Covering old roadbed as outlined in Case 2.

Pavement Widening on Resurfacing Projects

Originally Issued: 04-20-01

Resurfacing projects on highways with lane pavement widths of 12 feet or less should be widened to 14 feet. This includes two-lane highways as well as the outside lane of expressways with granular shoulders (the inside pavement width of expressways should remain 12 feet).

Design Considerations

Areas where a widening unit has already been placed should be evaluated on a case-by-case basis to determine if an additional widening unit is appropriate. In most cases, the roadway will be widened.

Four lane highways should have an outside lane pavement width of 14 feet, but should have an inside lane pavement width of 12 feet. Two lane highways should have 14-foot pavement widths for both lanes. As Figure 1 shows, the white edge line should be painted 12 feet from the centerline, leaving a 2-foot section at the pavement edge which is considered part of the shoulder.

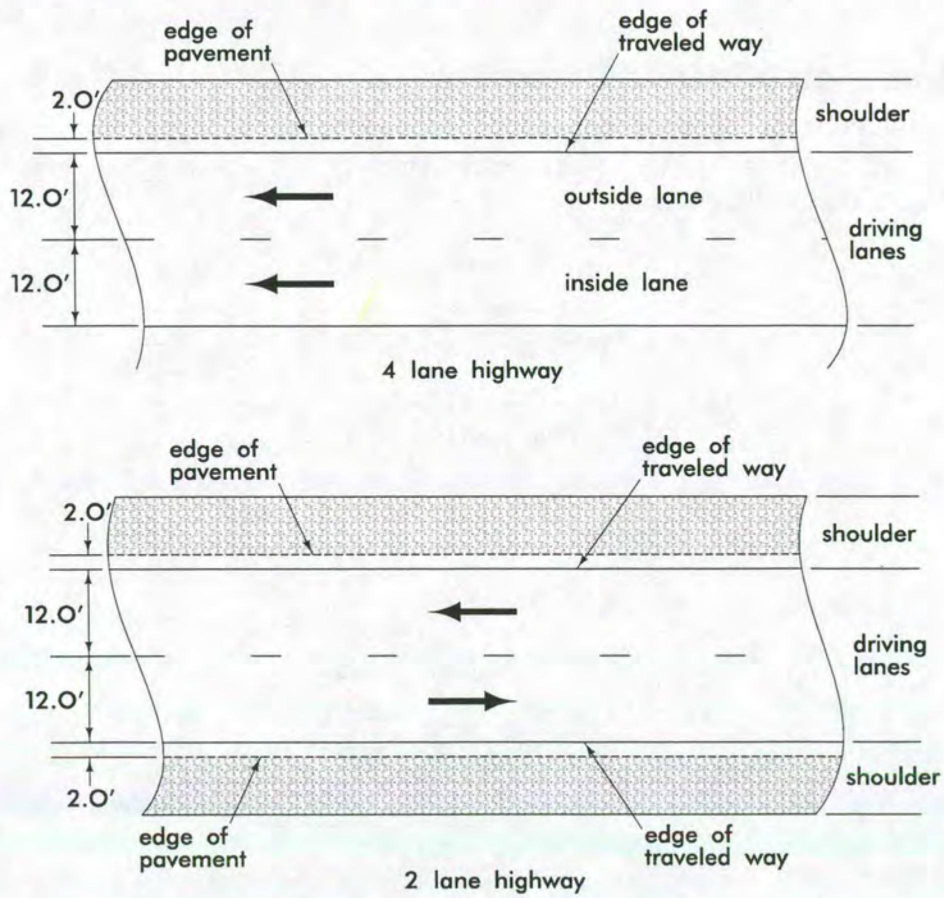


Figure 1: Lane markings for widened pavement.

A minimum 7 inch thick widening unit should be used (this does not include the overlying resurfacing thickness). For PCC pavement widening, use Standard Road Plan RG-1. For ACC pavement widening, use Standard Road Plan RG-8.

Fillets should still be used at paved and non-paved sideroads. At entrances, fillets should not be used where the pavement has been widened to 14 feet. However, if there are fillets at entrances already in place due to an earlier resurfacing project, they should be resurfaced.

Shoulder rumble strips on the outermost two feet of the pavement should not be used on resurfacing projects.

Highways That Should Not Be Widened

Highways with less than a 32-foot top (width of existing lanes and shoulders) should not be widened because a minimum two-foot shoulder is desirable outside of the pavement to stabilize the widening unit.

Where the lane pavement widths must remain at 12 feet or less, fillets should be used at non-paved side roads and entrances.

Shoulders

On a widened pavement, the designer should regard the 2-foot section of pavement outside the traffic lane as part of the normal shoulder, as Figure 1 shows. The normal shoulder will be composed of the 2-foot pavement width outside the traffic lane plus the additional width added to complete the shoulder.

Clear Zones on Widened Pavement

Figure 2 shows the clear zone to be used with a widened pavement. In all cases, the clear zone is measured from the edge of the traveled way, not from the edge of the widened part of the lane and not from the edge of the auxiliary lane.

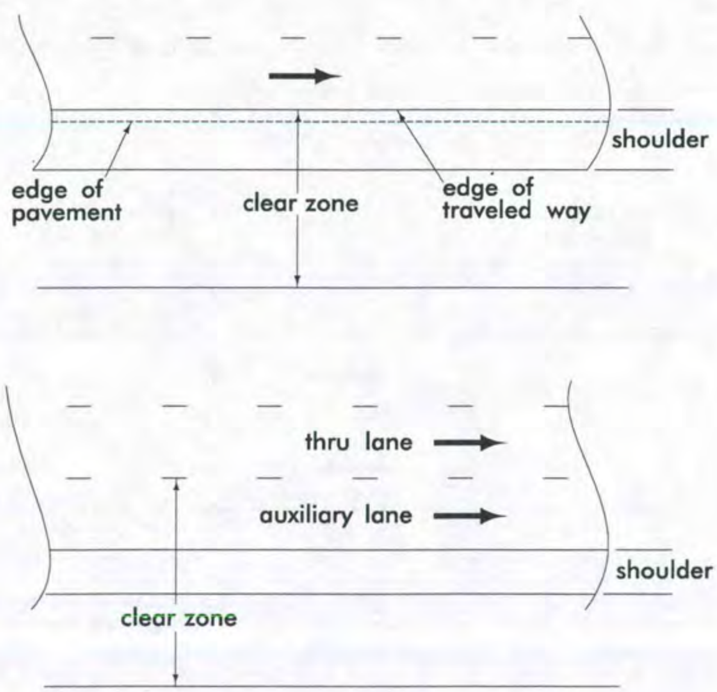


Figure 2: Clear zones on widened pavement.

Safety Design

Shielding Side Obstacles

Originally Issued: 09-23-97

Obstacles alongside the roadway, such as bridge piers and sign trusses, should be analyzed in order to determine the best way to protect motorists that have run off the road. Before shielding an obstacle with barrier, the designer should first determine if other treatment options are feasible. These options include removing the obstacle entirely, moving it outside the clear zone, making it breakaway (such as light poles), or making it traversable (such as small culvert openings).

This section provides information on determining (1) whether or not barrier is warranted, (2) what type of barrier system is most appropriate, (3) where to locate the installation, and (4) what length of barrier is needed to provide adequate protection. Information on shielding culverts, bridge endposts, median obstacles, embankments, standing water and other unique obstacles will be covered in other sections.

Warrants

Most rigid obstacles that cannot be removed from the clear zone and cannot be made breakaway or traversable should be shielded with barrier. For more information on applying the clear-zone concept, see Section 1C-2 of this manual and Chapter 3 of the AASHTO *Roadside Design Guide.* Consult the Methods Section if you believe an obstacle within the clear zone does not warrant barrier.

Choosing a Barrier System

The type of barrier system to use depends on the distance that the obstacle lies from the shoulder. The variable d is the distance from the edge of the design shoulder to the face of the obstacle (see Figure 1). Use the following table to determine an appropriate barrier system.

Table 1

d (ft)	barrier system
$d \geq 14$	cable guardrail (RE-29C)
$6.6 \leq d < 14$	w-beam guardrail with 6′–3″ post spacing (RE-54A and RE-55A)
$3.6 \leq d < 6.6$	w-beam guardrail with 3′–1½″ post spacing (RE-54B and RE-55B)
$1.6 \leq d < 3.6$	F-shape concrete barrier (RE-74A and RE-74B)
$d < 1.6$	concrete vertical wall (detail sheet available from the Methods Section)

Field Exam

Table 1 can also be used during the field exam to determine what type of barrier system is warranted. The form Variables Needed for Barrier Design, located at S:\Users\Design\Methods\Guardrail\BarrierVariables.doc, can be used to determine quantities for barrier installation. The form Quantities for Barrier Removal, located at S:\USERS\Design\Methods\Guardrail\BarrierQuantities.doc, can be used to tabulate quantities for barrier removal. If F-shape concrete barrier or concrete vertical wall is warranted, it will greatly increase the cost of an installation.

Locating the Installation Line

Normally, a barrier system should be placed 2 feet off the shoulder. An installation 2 feet off the shoulder is close enough to the roadway that earthwork required around the end terminal of the barrier will not be excessive. An installation closer to the roadway will also reduce the likelihood of an impact at a steep angle. At the same time, an installation 2 feet off the shoulder is far enough away from the roadway that there are not a large number of incidental hits.

Placing the barrier 2 feet off the shoulder is not always possible if the obstacle is close to the roadway. There must be enough space between the barrier and the obstacle to allow the barrier to deflect without coming into contact with the obstacle when it is impacted by a vehicle. There should also be enough space between the barrier and the obstacle to prevent high-profile vehicles that may lean over the barrier from snagging on the obstacle.

The various barrier systems have different space requirements to allow for barrier deflection and the tipping of high-profile vehicles:

- cable guardrail should have 12 feet between the installation and the face of the obstacle.
- w-beam guardrail with 6′–3″ post spacing should have 3 feet between the back of the posts and the face of the obstacle.
- w-beam guardrail with 3′–1½″ post spacing should have 2 feet between the back of the posts and the face of the obstacle.
- F-shape concrete barrier should have 5 inches between the back of the barrier and the face of the obstacle.
- concrete vertical wall should have 5 inches between the back of the barrier and the face of the obstacle.

Based on these requirements, the installation line can be located.

The installation line for cable guardrail should be placed 2 feet off the shoulder. If there is not adequate deflection space for cable guardrail, w-beam with normal (6′–3″) post spacing should be used with the installation line 2 feet off the shoulder. If there is not adequate deflection space for w-beam with normal post spacing, w-beam with narrow (3′–1½″) post spacing should be used with the installation line 2 feet off the shoulder. If the obstacle is too close to the roadway to allow the necessary space behind the guardrail with narrow post spacing, then the installation line may be moved closer to the shoulder. In this case, the installation line should be placed so that there is 2 feet between the back of the posts and the face of the obstacle.

If the obstacle is so close to the roadway that the guardrail would encroach on the shoulder, the F-shape concrete barrier should be used. The installation line should be placed so that there is 5 inches between the back of the concrete barrier and the face of the obstacle.

If the obstacle is so close to the roadway that the F-shape concrete barrier would encroach on the shoulder, concrete vertical wall should be used. The installation line for a barrier system with concrete vertical wall should be placed so that there is 5 inches between the back of the wall and the face of the obstacle.

The Shy-Line Offset

The shy-line offset is defined as the distance from the edge of the traveled way beyond which a roadside object will not be perceived as an obstacle and result in a motorist reducing speed or changing vehicle position on the roadway.[1] If possible, a barrier system should be installed beyond the shy-line offset.

Table 2: Shy-line Offset

design speed (mph)	shy-line offset Ls (ft)
80	12.0
70	10.0
60	8.0
50	6.5
40	5.0
30	3.5

After using the guidelines on page 2 for locating the installation line, you should determine whether or not the barrier is within the shy-line offset. If it is, the installation line should be moved farther away from the roadway if possible.

Length of Need

The total length of a guardrail installation is divided into three parts: the approach length (A), the trailing length (T), and the length adjacent to the obstacle (H) (see RE-54A).

To determine the length of need, the following variables must be determined:

- obstacle length, L_o (see Figure 1).
- lateral extent of the area of concern, L_A: the distance from the edge of traveled way to the far side of the obstacle or the distance from the edge of traveled way to the outside edge of the clear zone, whichever is smaller (see Figure 1).
- L_2: The *Roadside Design Guide* defines L_2 as the distance from the edge of traveled way to the installation line. When tabulating guardrail, however, this distance is given from the edge of pavement. This gives the contractor a more concrete point in the field from which to measure the installation line.
- design speed.
- traffic volume.

[1] *AASHTO Roadside Design Guide* (Washington, D.C., 1996) 5-18.

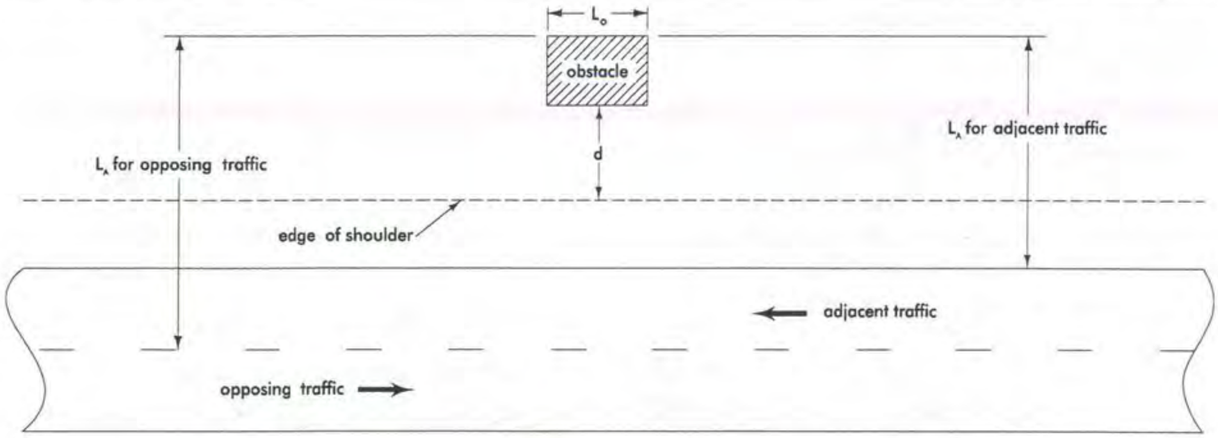


Figure 1: Before locating the installation line and determining the length of need, L_A, L_o, and d must be determined. Note that L_A is not always the distance to the back of the obstacle; it is this distance or the clear zone distance, whichever is smaller.

Based on the design speed and the traffic volume, the runout length (L_R) can be determined using Table 3. L_R is the theoretical distance needed for a vehicle that has left the roadway to come to a stop and it is used to determine the length of need.[2]

Table 3: Runout lengths.

Design Speed (mph)	Traffic Volume			
	ADT ≥ 10000	5000 ≤ ADT <10000	1000 ≤ ADT < 5000	ADT < 1000
	L_R (ft)	L_R (ft)	L_R (ft)	L_R (ft)
70	360	300	260	220
60	260	210	180	170
50	210	170	150	130
40	160	130	110	100
30	110	90	80	70

Determining the Length of Need Graphically

To determine the length of need graphically, see the procedures and examples in Chapter 5 of the *Roadside Design Guide*. See page 5 for more information on determining the appropriate combination of variable tangent (VT) and variable flare (VF).

The Trailing Length (T)

The trailing length (T) will not be required on one-way or divided highways.

On two-way, undivided highways you must determine if the obstacle is within the clear zone of the opposing traffic lane. Remember that for opposing traffic the clear zone is measured from the pavement centerline. If the obstacle is within the clear zone, the length of T is determined in the same manner as A.

Even if the obstacle is not within the clear zone for opposing traffic, the guardrail installation itself often is. Therefore it is still normally terminated with a breakaway end terminal (RE-76).

[2] Sicking, D.L. and Wolford, D.F., "Development of Guardrail Runout Length Calculation Procedures," NDOR Research Project Number SPR-PL-1(3) P479, University of Nebraska, Lincoln Nebraska, May 1996.

If the installation is well outside the clear zone for opposing traffic (such as on a four-lane undivided highway), a breakaway end terminal on the trailing side may not be needed. Contact the Methods Section if you are unsure.

Variable Tangent and Variable Flare

The Standard Road Plans indicate a variable tangent (VT) and a variable flare (VF). Different combinations of VT and VF may be used to meet the length of need. The best combination to use depends on the site characteristics.

In Figure 2, the installation on top minimizes the amount of guardrail needed by using VF. However, the amount of earthwork required increases because the installation terminates a greater distance into the ditch. The installation on the bottom minimizes the earthwork required by using no VF. This installation requires more guardrail but remains closer to the roadway. This design would be better in areas with steep foreslopes, where using no VF would minimize the amount of earthwork needed around the end terminal.

Tabulation

Tabulation 108-8B is used for systems with only w-beam guardrail. Tabulations 108-8A and 108-18B are used for systems with the F-shape concrete barrier along with 112-9 for the paved shoulder.

See Section 8B-10 for more information on tabulating guardrail.

Gaps between Barrier Installations

Gaps between barrier installations on the same side of the facility should not be less than 200 feet. If two obstacles are so close that this is not possible, then a continuous length of barrier should be run between them.

Obstacles on Horizontal Curves

If the obstacle is located on a horizontal curve, a special design may be required. Consult the Methods Section for assistance.

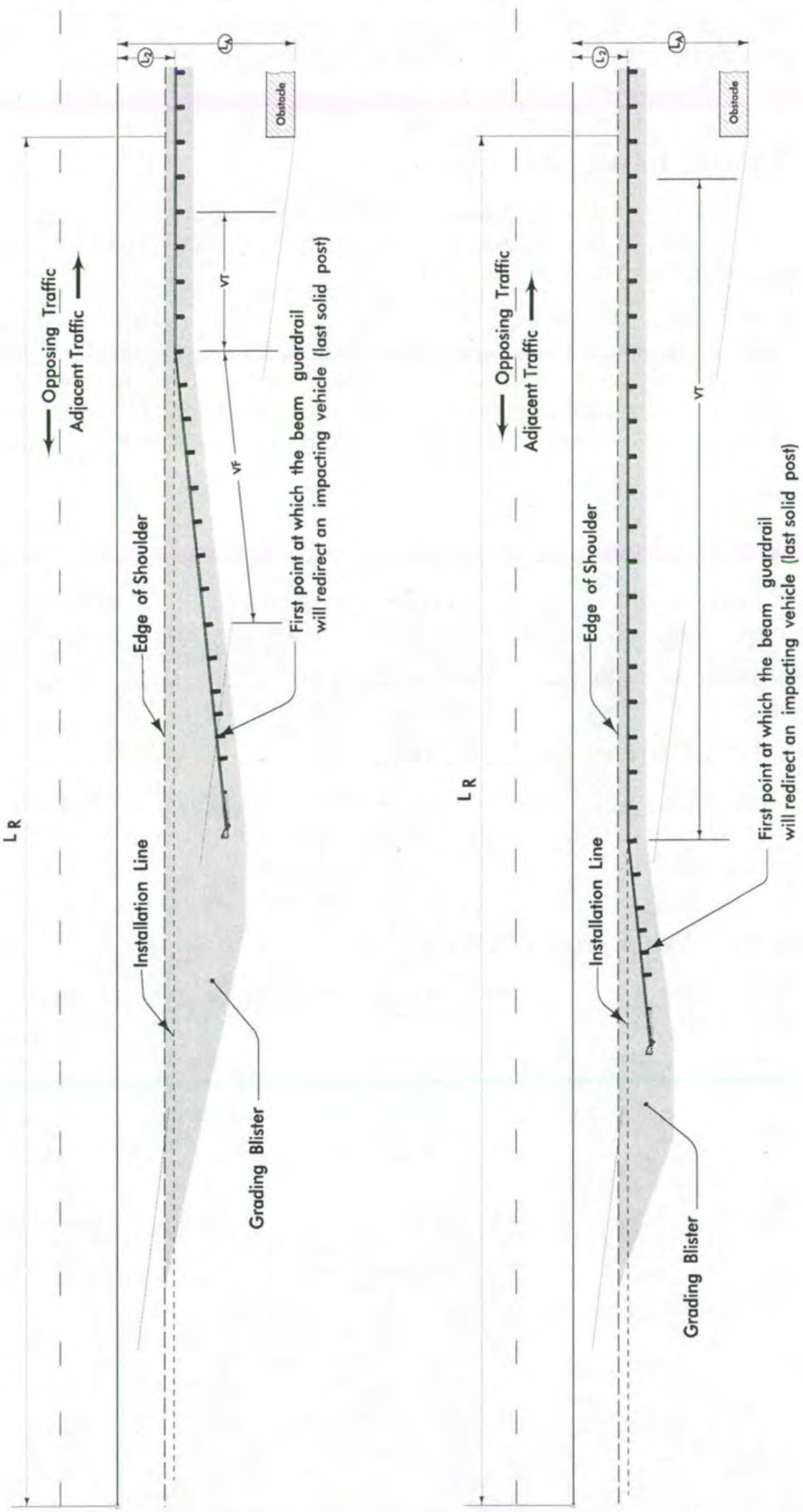


Figure 2: Determining the length of need graphically. The appropriate combination of VT and VF to use depends on site characteristics.

Shielding Median Obstacles

Originally Issued: 08-07-98

This section provides guidelines for shielding obstacles in the median, such as bridge piers and sign-truss footings.

Warrants

Most median obstacles should be shielded if located within the clear zone of either side of a divided highway (see Section 1C-2 for more information on clear zones). Normally, median obstacles are shielded with the w-beam encirclement design that has breakaway end anchorages on each end (see RE-56). In wide medians, the obstacle may be within the clear zone for one side of the facility but a significant distance outside the clear zone for the other side. In these cases, the obstacle may be shielded in one direction only (like side obstacles). For information about shielding side obstacles, see Section 8B-1.

On freeways with standard median widths (64 feet) all median obstacles should be shielded. On freeways and expressways with medians wider than standard width, median obstacles are not shielded if located outside of the clear zone for both directions. The maximum value listed in Table 1 of Section 1C-2 for the given design speed and ADT is to be used when determining the clear zone. Even if it is determined the obstacle is outside of the clear zone, grading should still be done as detailed on Standard Road Plan RL-12, in case the decision is made to install guardrail at a later time. Median obstacles adjacent to curves that follow a long tangent require special attention. The clear zone in these areas may need to be adjusted. See Section 1C-2 of this Manual.

Design

When using the RE-56 encirclement design, follow these guidelines:

- The distance between either end anchorage and the obstacle must be at least 50 feet. This minimum distance establishes the trailing lengths (T) at 50 feet and the approach lengths (A) at 62.5 feet. These lengths normally will not vary for the RE-56 design.
- The length adjacent to the obstacle (H) does vary but shall be greater than or equal to the actual length of the obstacle (two closely spaced obstacles, like bridge piers, are treated as one continuous obstacle). H must be measured in 12.5-foot increments to accommodate standard lengths of guardrail.
- The location station should be established at the trailing face of the obstacle on the side of the obstacle that has approach traffic traveling in the direction of increasing stationing (refer to RE-56). The location station is therefore always at the junction of H and T on the same side.
- If the obstacle is within a narrow median that does not accommodate this design, consult the Methods Section for assistance.

Grading

Standard Road Plan RL-12 illustrates the grading requirements for the encirclement design. For cases that involve differential grades, contact the Methods Section.

Tabulation

Tabulation 108-8C is used for tabulating the guardrail-related quantities. Tabulation 107-23 is used to tabulate grading-related quantities.

See Section 8B-10 for more information on tabulating guardrail.

Shielding Median Obstacles

Originally Issued: 08-07-98

This section provides guidelines for shielding obstacles in the median, such as bridge piers and sign-truss footings.

Warrants

Most median obstacles should be shielded if located within the clear zone of either side of a divided highway (see Section 1C-2 for more information on clear zones). Normally, median obstacles are shielded with the w-beam encirclement design that has breakaway end anchorages on each end (see RE-56). In wide medians, the obstacle may be within the clear zone for one side of the facility but a significant distance outside the clear zone for the other side. In these cases, the obstacle may be shielded in one direction only (like side obstacles). For information about shielding side obstacles, see Section 8B-1.

On freeways and expressways, median obstacles are not shielded if located outside of the clear zone for both directions. However, the grading should still be done as detailed on Standard Road Plan RL-12, in case it is decided to install guardrail at a later time. Median obstacles adjacent to curves that follow a long tangent require special attention. The clear zone in these areas may need to be adjusted. See Section 1C-2 of this Manual.

Design

When using the RE-56 encirclement design, follow these guidelines:

- The distance between either end anchorage and the obstacle must be at least 50 feet. This minimum distance establishes the trailing lengths (T) at 50 feet and the approach lengths (A) at 62.5 feet. These lengths normally will not vary for the RE-56 design.
- The length adjacent to the obstacle (H) does vary but shall be greater than or equal to the actual length of the obstacle (two closely spaced obstacles, like bridge piers, are treated as one continuous obstacle). H must be measured in 12.5-foot increments to accommodate standard lengths of guardrail.
- The location station should be established at the trailing face of the obstacle on the side of the obstacle that has approach traffic traveling in the direction of increasing stationing (refer to RE-56). The location station is therefore always at the junction of H and T on the same side.
- If the obstacle is within a narrow median that does not accommodate this design, consult the Methods Section for assistance.

Grading

Standard Road Plan RL-12 illustrates the grading requirements for the encirclement design. For cases that involve differential grades, contact the Methods Section.

Tabulation

Tabulation 108-8C is used for tabulating the guardrail-related quantities. Tabulation 107-23 is used to tabulate grading-related quantities.

See Section 8B-10 for more information on tabulating guardrail.

Barrier at Bridge Approaches

Originally Issued: 09-23-97

Barrier is used on bridge approaches to prevent vehicles from colliding with bridge endposts or with secondary obstacles under or near the bridge (such as steep embankments, sign-truss footings, rivers, railroads, and other roadways). All bridges on the primary road system shall be evaluated using criteria from this section to determine if barrier is warranted. Bridges on secondary roads must meet the same criteria if they are part of an interchange or an overhead separation. Other secondary road bridges that are involved in a project should have barrier installed that conforms with the current requirements of the Office of Local Systems.

Warrants

Tables 1 and 2 are used to determine whether or not the bridge endpost should be shielded and if so, what type of barrier system is most appropriate. Designers should also check for other roadside obstacles in the vicinity (secondary obstacles) that may warrant extending an approach barrier or adding a barrier not warranted by the bridge itself.

For two-way bridges, the clear zone needs to be determined. For more information on the clear-zone concept, see Section 1C-2 of this manual and Chapter 3 of the AASHTO *Roadside Design Guide*.

Trailing lengths of guardrail are not normally installed on the outside of dual bridges unless secondary obstacles warrant them.

Urban Bridges

For bridges on urban roadways, individual situations will influence barrier requirements. In general, however, the only bridges for which approach barrier is warranted are:

- Those which carry a sidewalk that is shielded by a concrete barrier. Refer to Standard Road Plan RE-46 for details of the barrier.
- Those with expected regulatory speeds greater than 35 mph.

Other barrier installations in urban areas should be justified on an individual basis.

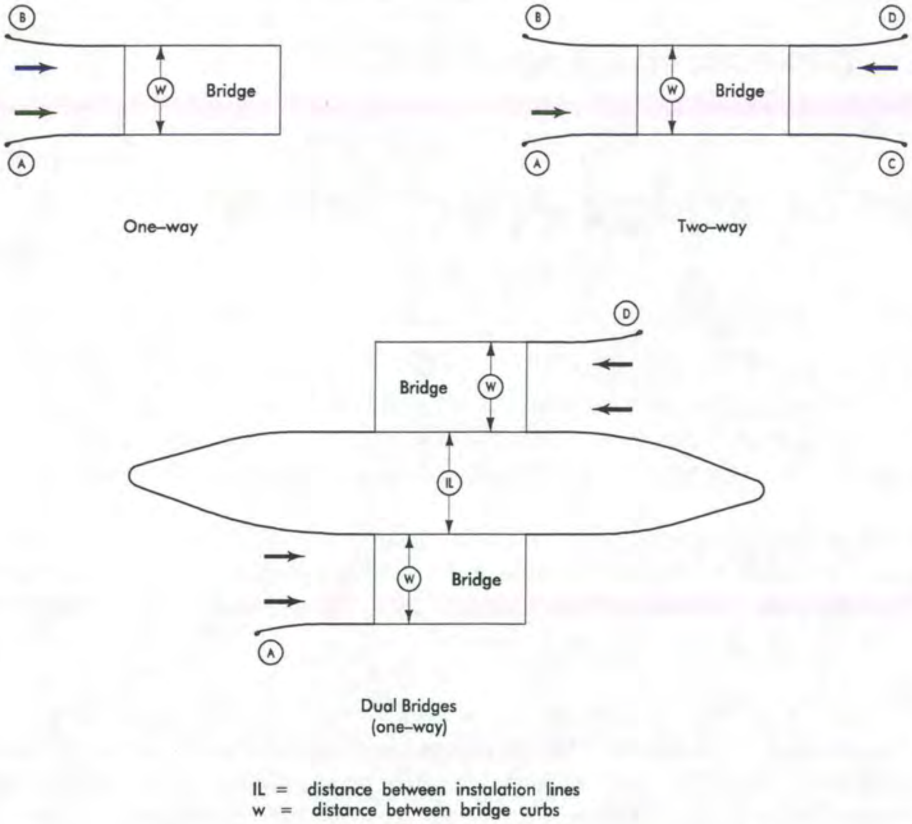


Figure 1: Barrier warrants at bridges. Use with Tables 1 and 2.

Table 1: Barrier warrants for bridge endposts.

Situation	W	Standard Road Plan	Tabulation	Barrier Required at Corners:
one-way	all widths	RE-65A	108-8A	A and B
two-way	> 2 × clear zone	RE-65A	108-8A	A and D
two-way	≤ 2 × clear zone	RE-65A	108-8A	A, B, C, and D
dual bridges (one-way)	all widths	outside: RE-65A median: see Table 2	outside: 108-8A median: see Table 2	A, D, and median

Table 2: Bridge endpost treatment on the median side.

IL (ft)	Barrier Type	Standard Road Plan or Detail Sheet	Tabulation
IL < 16.5	concrete barrier terminated with impact attenuator	special design RE-44A, RE-44C, Detail Sheet 540-19 (consult the Methods Section)	108-18A
16.5 ≤ IL < 22	steel-beam guardrail	special design (consult the Methods Section)	108-19
22 ≤ IL < 64	steel-beam guardrail	RE-67	108-19
64 ≤ IL < 80	steel-beam guardrail	special design (consult the Methods Section)	108-19
IL ≥ 80	steel-beam guardrail (approach side only)	RE-65A	108-8A

RE-65A Design

When shielding a bridge endpost with the RE-65A design, the designer must determine the length of guardrail needed, the number of posts, and the appropriate combination of variable tangent (VT) and variable flare (VF).

The length of guardrail needed to shield the endpost depends on the shoulder width of the bridge. At bridges with full-width shoulders and no secondary obstacles, only the minimum amount of rail (56.25 feet, no VT or VF) is required to shield the endpost. At bridges with less than full-width shoulders and no secondary obstacles, the guardrail should be extended until the end terminal is at least 1 foot off the shoulder. Use Table 3 to determine this length.

The distance 'X' used in Table 3 is the distance from the installation line to the outside edge of the design shoulder. The installation line is offset 4.5 inches from the bridge curb line (see Figure 2).

The length of thrie-beam given in Table 3 is the length that should be tabulated. As shown on Standard Road Plan RE-68, the standard transition section, which connects to the bridge, consists of two nested 12′–6″ sections of thrie beam and a 6′–3″ transition section ("nesting" is the practice of bolting two pieces of guardrail together to the same posts—one on top of the other). Table 3 also contains post quantities for various lengths of guardrail.

RE-65A illustrates a variable tangent (VT) and a variable flare (VF). Increasing the length of guardrail with VT or VF is for shielding secondary obstacles and also for extending the guardrail until the terminal is off the shoulder. When adding additional guardrail to shield secondary obstacles, the appropriate combination of VT and VF to use depends on site characteristics. Using more VF will shield the obstacle with less guardrail but will require more earthwork around the terminal. Using more VT will increase the amount of guardrail needed but since the installation remains closer to the roadway, less earthwork is required around the terminal. See Section 8B-1 for more information.

Table 3: Length of guardrail needed to position the terminal off the shoulder.

		X (ft)								
		X ≤ 1.3	1.3 < X ≤ 2.7	2.7 < X ≤ 4.0	4.0 < X ≤ 5.3	5.3 < X ≤ 6.7	6.7 < X ≤ 8.0	8.0 < X ≤ 9.3	9.3 < X ≤ 10.7	10.7< X ≤ 12.0
Layout Length	Case	S	F	F	F	F	F	F	F	F
	Standard Transition Section (ft)	18.75	18.75	18.75	18.75	18.75	18.75	18.75	18.75	18.75
	Variable Tangent (ft)	0	0	0	0	0	0	0	0	0
	Variable Flare (ft)	0	12.5	25.0	37.5	50.0	62.5	75.0	87.5	100.0
	Terminal (ft)	37.5	37.5	37.5	37.5	37.5	37.5	37.5	37.5	37.5
Material Required	Thrie-beam	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0
	Transition Section	6.25	6.25	6.25	6.25	6.25	6.25	6.25	6.25	6.25
	W-beam	37.5	50.0	62.5	75.0	87.5	100	112.5	125.0	137.5
	6″ x 8″ x 6′ CRT Posts	4	4	4	4	4	4	4	4	4
	6″ x 8″ x 7′ Posts (a)	7	7	7	7	7	7	7	7	7
	6″ x 8″ x 6′ Posts	2	4	6	8	10	12	14	16	18
Bid Items	Installation of Guardrail	56.25	68.75	81.25	93.75	106.25	118.75	131.25	143.75	156.25
	RE-69A, RE-69B, or RE-69C Terminal	1	1	1	1	1	1	1	1	1
	RE-76 Terminal	1	1	1	1	1	1	1	1	1
Grading dimensions	BY (ft)	8.0 – X	9.3 – X	10.7 – X	12.0 – X	13.3 – X	14.7 – X	16.0 – X	17.3 – X	18.7 – X
	Z (ft)	$Z = 20 + \frac{BY}{\tan 15}$								

(a) When an RE-69C is used, reduce the number of posts to 6.

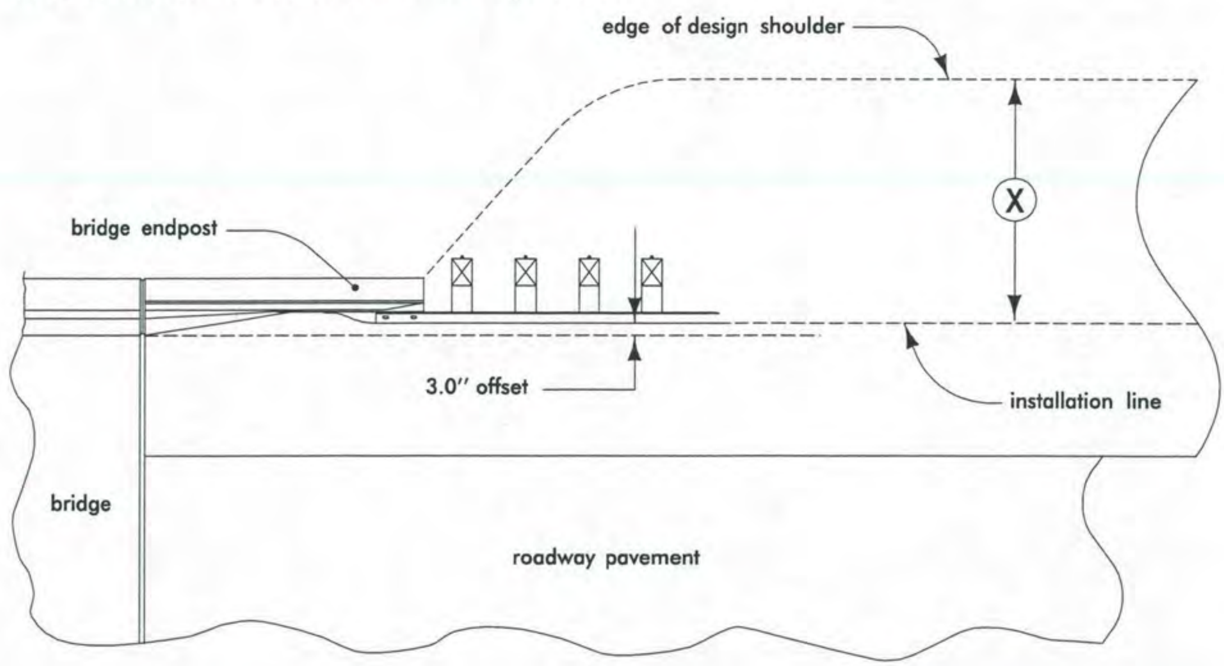


Figure 2

NOTE: The last two posts of the RE-76 Terminal section are included as part of that bid item.

RE-67 (Bullnose) Design

When shielding median endposts at dual bridges with the "bullnose" design, refer to Standard Road Plan RE-67. For cases involving differential grades, contact the Methods Section.

Table 4 gives the lengths of guardrail required for each section of a standard bullnose. The length given for the adjustment section is the amount of guardrail that should be tabulated, not the actual length of the section as constructed (the section's actual length will be determined during construction by lapping guardrail).

Table 5 provides the quantities of each post type to be tabulated for a bullnose. Situations where the distance between the two bridges is not covered by Tables 4 and 5 are considered special designs and should be referred to the Methods Section.

When using Tables 4 and 5, simply choose the IL value in the table that is closest to the measured IL.

Skewed Bridges

When using the RE-67 design with skewed bridges, there is a graphical method for determining the appropriate guardrail lengths and number of posts. Refer to Section 8B-3A or consult the Methods Section for assistance.

Non-Parallel Bridges

Non-parallel bridges require a special design. Consult the Methods Section for assistance.

Tabulation

For RE-65A installations, use Tabulation 108-8A. For RE-67 (bullnose) installations, use Tabulation 108-19.

See Section 8B-10 for more information on tabulating guardrail.

Connections to Bridge Endposts

Connections of guardrail systems to bridge endposts are the same for both the RE-65A and RE-67 barrier systems. However, the connections do vary depending on the type of bridge endpost. RE-69A is used for connections to current non-flared bridge endposts and RE-69B is used for connections to non-flared retrofit bridge endposts. RE-69C is used for connections to existing flared bridge endposts. RE-27B may be used in special situations when connecting to non-standard bridge endposts.

Note that the w-beam system uses a Standard Transition Section (Standard Road Plan RE-68) before attaching to the bridge endpost. On old bridges where the decision has been made to not retrofit the bridge rail, a special design will be required. Contact the Methods Section for assistance.

Table 4: Guardrail lengths for RE-67 (bullnose) at non-skewed, parallel bridges.

	A			T				Bid Item
IL (see Figure 1) (ft)	RE-68 Standard Transition Section (thrie-beam) (ft)	Curve #1 (ft)	RE-53 End Anchorage (ft)	Tangent Section (ft)	Curve #2 (ft)	Adjustment Section (ft)	RE-68 Standard Transition Section (thrie-beam) (ft)	Installation of Guardrail
22	18.75	50.0	12.5	—	43.75	6.25	18.75	150.0
24	18.75	50.0	12.5	6.25	43.75	12.5	18.75	162.5
26	18.75	62.5	12.5	—	43.75	18.75	18.75	175.0
28	18.75	62.5	12.5	6.25	43.75	12.5	18.75	175.0
30	18.75	62.5	12.5	12.5	43.75	6.25	18.75	175.0
32	18.75	75.0	12.5	6.25	43.75	25.0	18.75	200.0
34	18.75	75.0	12.5	12.5	43.75	18.75	18.75	200.0
36	18.75	75.0	12.5	18.75	43.75	12.5	18.75	200.0
38	18.75	75.0	12.5	25.0	43.75	6.25	18.75	200.0
40	18.75	87.5	12.5	18.75	43.75	25.0	18.75	225.0
42	18.75	87.5	12.5	25.0	43.75	18.75	18.75	225.0
44	18.75	87.5	12.5	31.25	43.75	12.5	18.75	225.0
46	18.75	87.5	12.5	37.5	43.75	6.25	18.75	225.0
48	18.75	100.0	12.5	31.25	43.75	25.0	18.75	250.0
50	18.75	100.0	12.5	43.75	43.75	18.75	18.75	256.25
52	18.75	100.0	12.5	43.75	43.75	12.5	18.75	250.0
54	18.75	100.0	12.5	50.0	43.75	6.25	18.75	250.0
56	18.75	112.5	12.5	43.75	43.75	25.0	18.75	275.0
58	18.75	112.5	12.5	50.0	43.75	18.75	18.75	275.0
60	18.75	112.5	12.5	56.25	43.75	12.5	18.75	275.0
62	1875	112.5	12.5	62.5	43.75	6.25	18.75	275.0
64	18.75	125.0	12.5	56.25	43.75	25.0	18.75	300.0

Table 5: Post quantities for RE-67 (bullnose) at non-skewed, parallel bridges.

IL (see Figure 1) (ft)	Single Spacer		No Spacer	
	6″ × 8″ × 6′	6″ × 8″ × 7′ (a)	6″ × 8″ × 6′	6″ × 6″ × 6′
22	18	14	2	1
24	20	14	2	1
26	22	14	2	1
28	22	14	2	1
30	22	14	2	1
32	26	14	2	1
34	26	14	2	1
36	26	14	2	1
38	26	14	2	1
40	30	14	2	1
42	30	14	2	1
44	30	14	2	1
46	30	14	2	1
48	34	14	2	1
50	35	14	2	1
52	34	14	2	1
54	34	14	2	1
56	38	14	2	1
58	38	14	2	1
60	38	14	2	1
62	38	14	2	1
64	42	14	2	1

(a) When an RE-69C is used, reduce the number of posts by 2.

NOTE: The last two posts of the RE-76 Terminal section are included as part of that bid item.

RE-67 (Bullnose) Installations at Skewed Bridges

Originally Issued: 09-22-00

The simplest way to design the bullnose system at skewed bridges is a graphical method using CADD. A MicroStation file called BullnoseEnglish located at S:\USERS\Design\Methods\dmanual\BullnoseEnglish is available from the Methods Section. This file contains a drawing of each non-skewed installation tabulated in Table 4 of Section 8B-3. Each element of the bullnose is indicated in a different color and labeled with a number.

- Standard Transition Section (STS): green (labeled 1 and 7)
- Curve #1: white (labeled 2)
- RE-53 End Anchorage: red (labeled 3)
- Curve #2: blue (labeled 5)
- Adjustment Section: yellow (labeled 6)

To determine the required length of guardrail and the number of posts, follow these steps:

1. Reference S:\USERS\Design\Methods\dmanual\BullnoseEnglish into a new CADD file with the graphic group lock on. Determined the IL distance for the bridge (see Figure 1) to the nearest foot and go to the saved view of the number. A drawing of a non-skewed installation for that IL should appear. Copy this drawing into the file and detach the reference file.

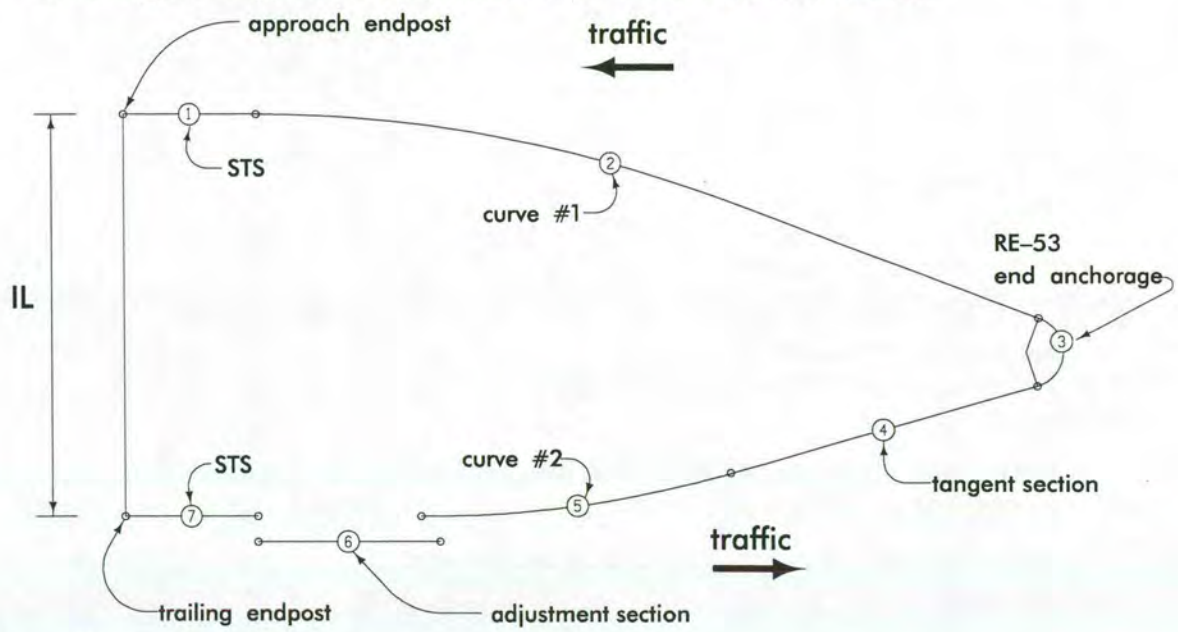


Figure 1: The basic drawing from the CADD file.

2. Draw a line starting from the approach endpost that is skewed ahead or back to the trailing endpost according to the given situation (see Figure 2).

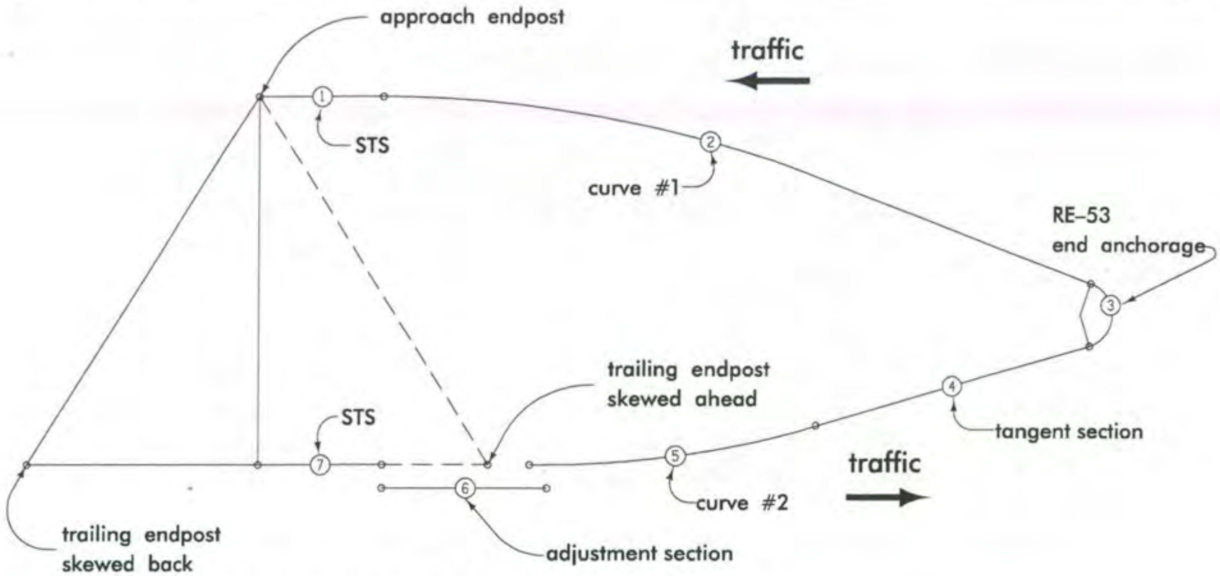


Figure 2: Draw the skew of the bridge.

3. Re-attach the trailing Standard Transition Section (element 7) to the trailing endpost.

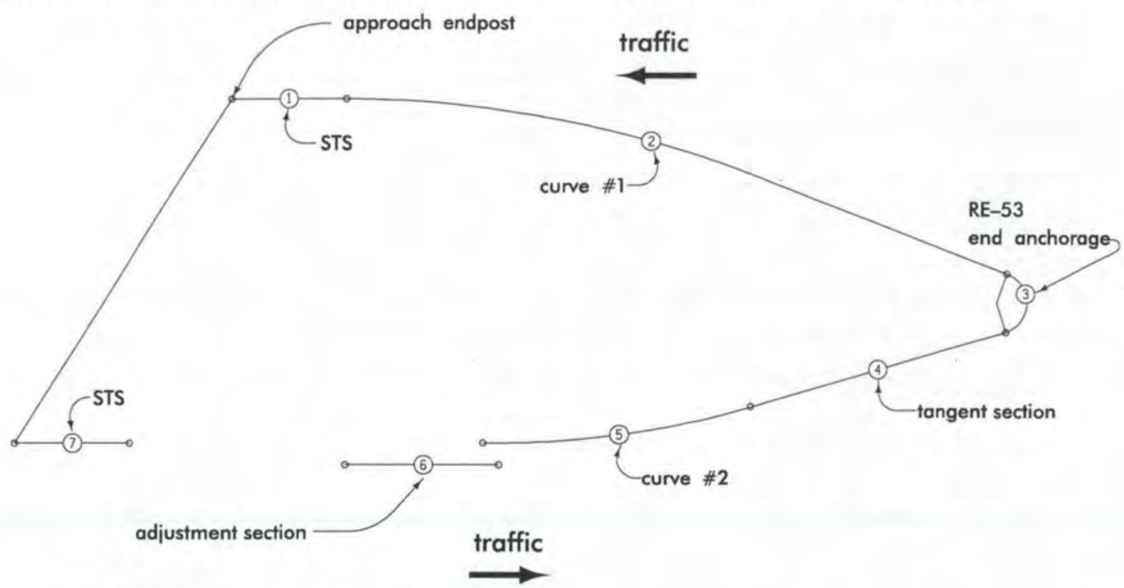


Figure 3: Move element 7 to the trailing endpost.

4. Adjust the Adjustment Section and, if necessary, the Section for Skewed Bridges (see Case 3) until an acceptable design is achieved, while at the same time minimizing the amount of guardrail used. The examples that follow illustrate how this is done for each of the five cases that may be encountered.

The total amount of w-beam guardrail tabulated should be an increment of 6.25 feet. This is the smallest manufactured length of w-beam guardrail.

5. The total number of posts can be calculated from the following:

- 6" x 8" x 7' posts with spacer = 14
- 6" x 8" posts with spacer = $\frac{\text{Section for Skewed Bridges + Curve \#1 + Tangent Section + Curve \#2 + Remaining Gap}}{6.25} + 2$

  (Round this number up. It includes the 6" x 8" posts in the STS sections.)
- 6" x 8" posts without spacer = 2
- 6" x 6" posts without spacer = 1

If the bridges are not parallel, a special design is required (see the Methods Section for assistance).

Case 1

The simplest case to handle is a bridge with no skew. For this situation, use Tables 4 and 5 in Section 8B-3.

Notice in Figure 4 how only a 22.4-foot gap needs to be filled by the Adjustment Section, but 25 feet is still tabulated because the total amount of guardrail tabulated needs to be an increment of 6.25 feet. The excess rail is overlapped or removed in the field.

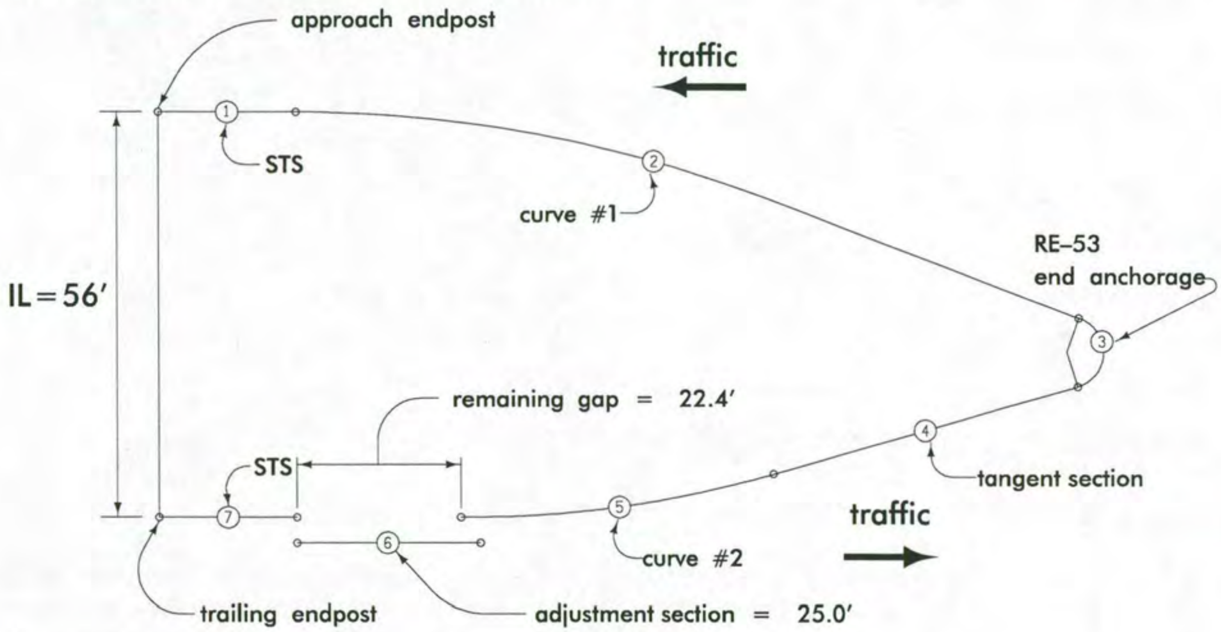


Figure 4: No skew.

Case 2

In Case 2, the trailing endpost is skewed ahead only a short distance. The skew can be taken care of by either reducing the amount of the Adjustment section or by leaving it the same as the non-skewed bridge.

In the example shown in Figure 2, the Adjustment Section can be reduced by 12.5 feet but this will not always be possible. This is where drawing the installation in CADD makes it easy to see what is required. Remember that the total amount of w-beam tabulated should be an increment of 6.25 feet.

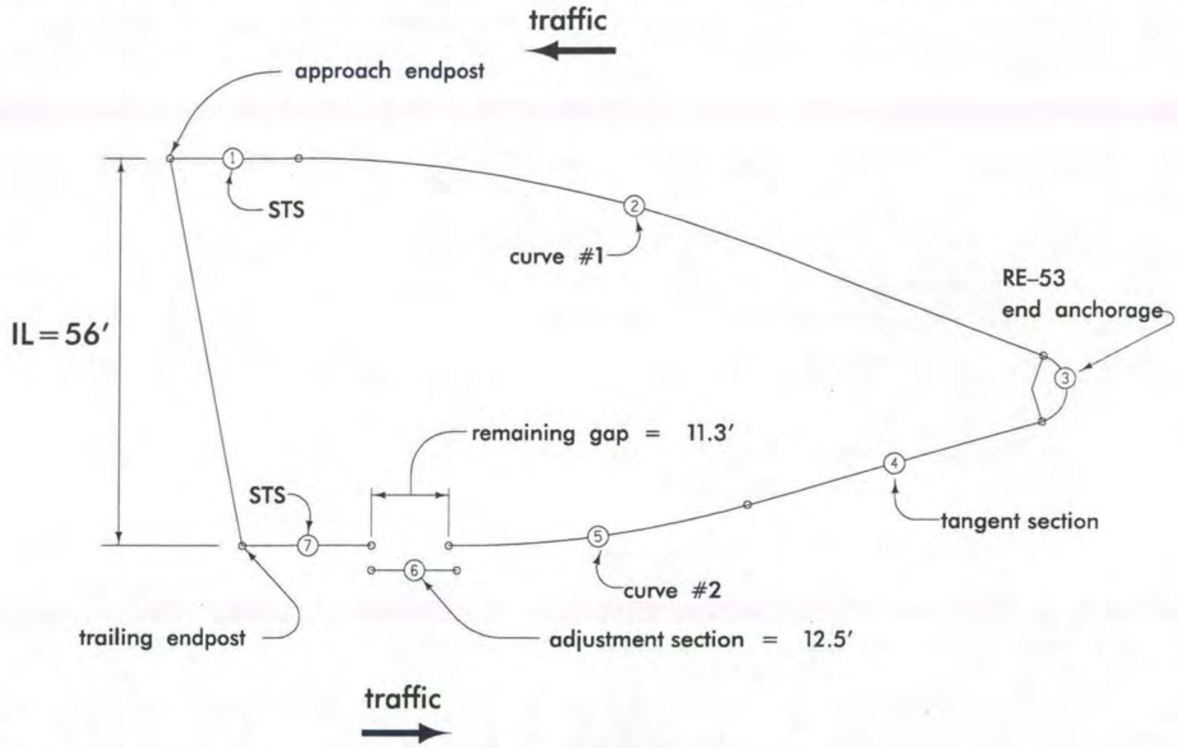


Figure 5: Trailing endpost skewed ahead a short distance.

Case 3

In Case 3, the trailing endpost is skewed ahead a large enough distance that guardrail is needed in the Section for Skewed Bridges. The Section for Skewed Bridges should always be an increment of 12.5 feet. Any excess rail should always occur at the Adjustment Section because this is usually where the bullnose is closed during construction.

In the example illustrated below, 50 feet of rail had to be added in the Section for Skewed Bridges. It was also possible to reduce the amount of Adjustment Section from 25 to 12.5 feet, to minimize the amount of guardrail needed.

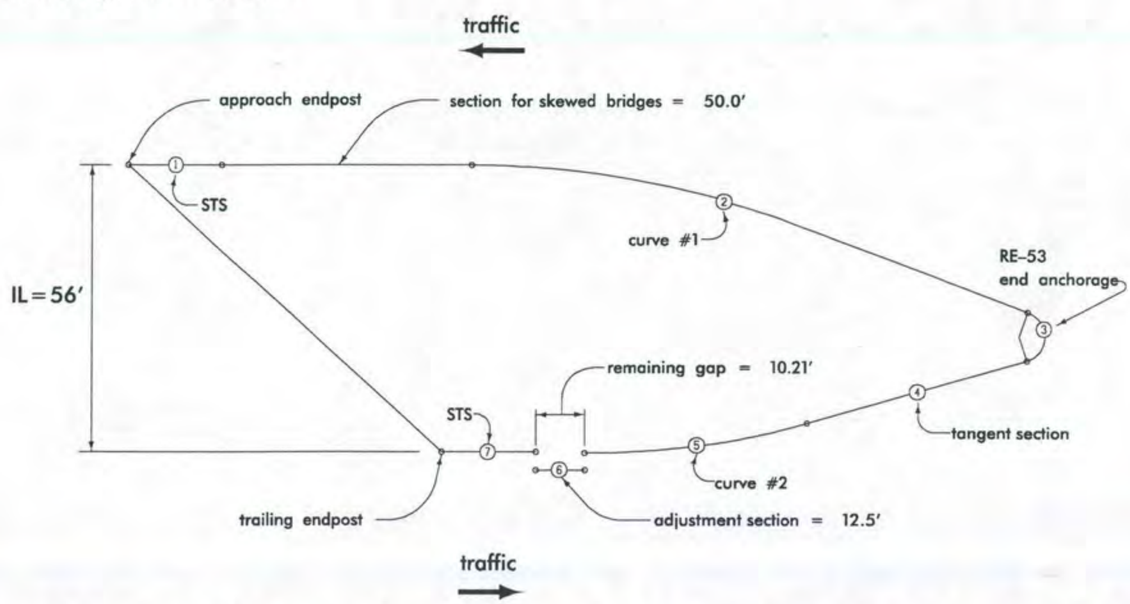


Figure 6: Trailing endpost skewed ahead a larger distance. The Section for Skewed Bridges and Adjustment Section should be minimized to save guardrail.

Case 4

In Case 4, the approach endpost is skewed ahead only a very short distance (usually only a few feet). The skew can be taken care of by the excess Adjustment Section that is available from rounding the total amount of w-beam guardrail up to an increment of 6.25 feet.

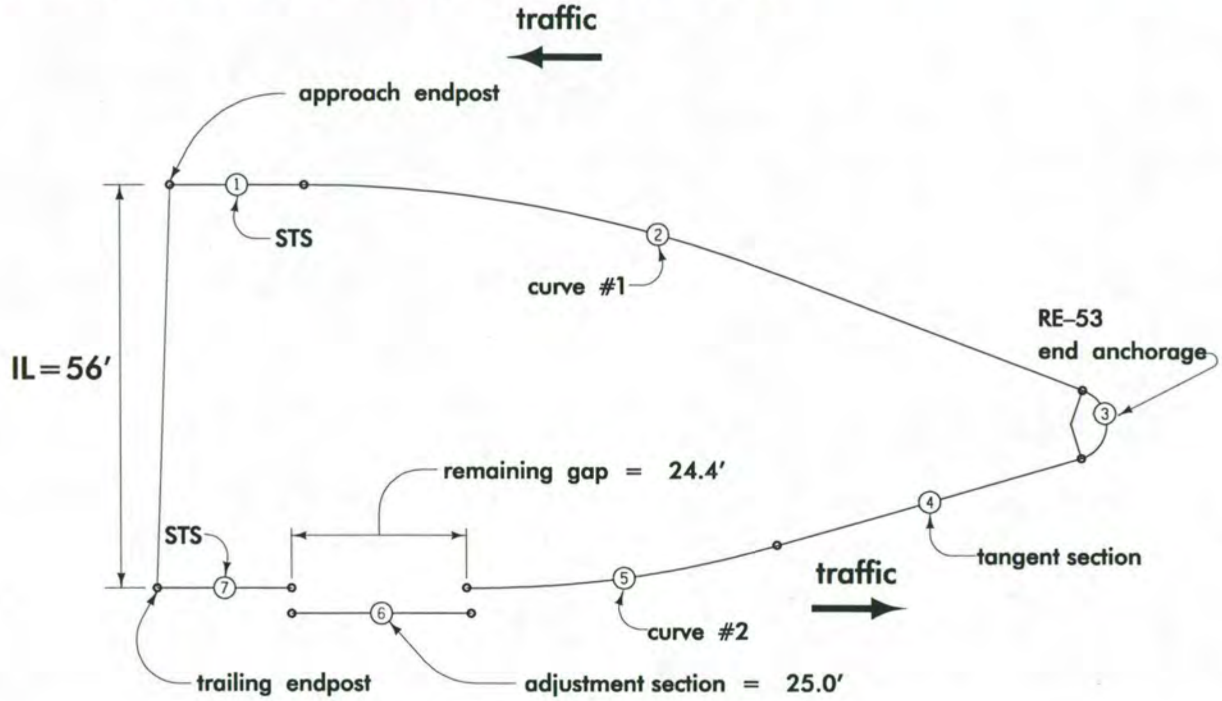


Figure 7: Approach endpost skewed ahead a very short distance.

Case 5

In Case 5, the approach endpost is skewed a large enough distance ahead that additional guardrail must be added in the Variable Tangent Section.

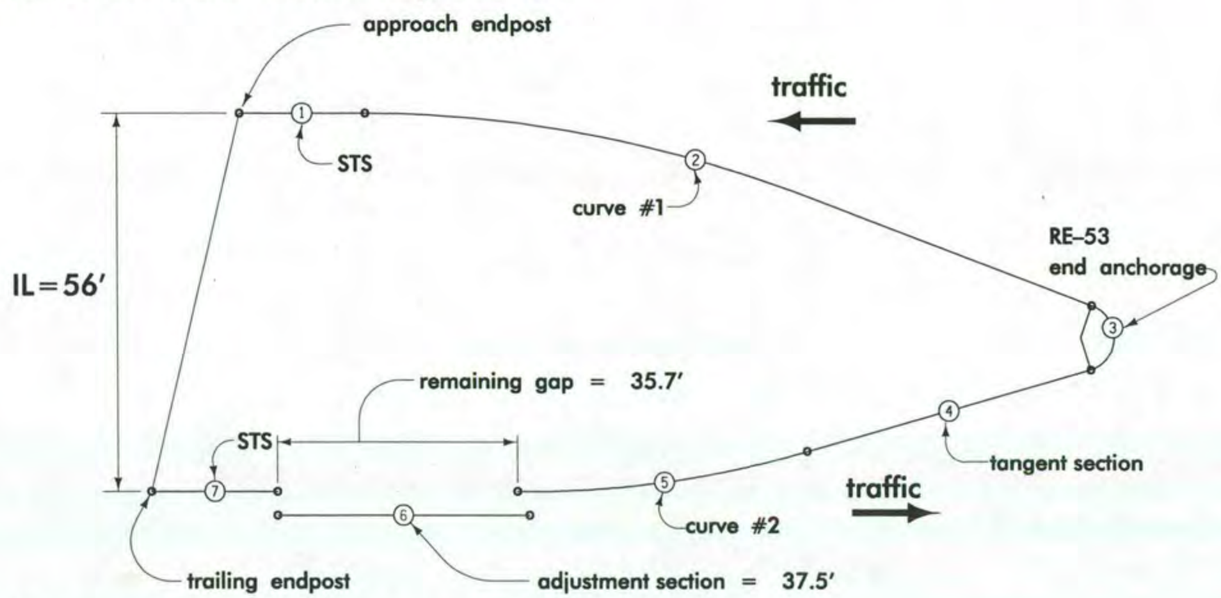


Figure 8: Approach endpost skewed ahead a larger distance.

Culvert Treatments

Originally Issued: 09-23-97

Culvert openings alongside the roadway should be analyzed to determine the best way to protect motorists that may run off the road. Smaller culvert openings can snag a wheel, causing a vehicle to lose control. Larger structures, such as box culverts, are a concern because of direct impacts, snagging, and drop-offs. It is therefore important to treat culverts in some manner to minimize risk for a motorist that has left the roadway. This section describes these treatments, including barrier design guidelines for when culverts need to be shielded. For more information on the treatment of culverts and other drainage structures, see Chapter 3 of the AASHTO *Roadside Design Guide*.

Culvert Guidelines

New and Reconstructed Highways

Except within medians, all pipe and box culverts, regardless of size, are extended to the clear zone. Even 18 and 24-inch diameter pipes are extended due to the enlarged opening created by the apron.

On divided highways, pipe culverts $\leq$ 36 inches in diameter are extended only to the normal foreslope on the median side. A pipe apron guard is installed on these pipes on the median side only.

Since culverts are extended to the clear zone or else made traversable with an apron guard, shielding with guardrail is normally not necessary on new and reconstructed highways.

3R Projects

Many culvert situations on 3R projects will have to be evaluated on a case-by-case basis. However, the following guidelines may be helpful to maintain a degree of consistency.

On freeways and expressways:

- box culverts and pipes > 36 inches in diameter are often extended to the clear zone or shielded.
- smaller pipe culverts are usually extended flush with the existing foreslope.

On other highways on the National Highway System (NHS):

- box culverts $\geq$ 6 feet across and pipes $\geq$ 6 feet in diameter are often extended to the clear zone or shielded. Minor right-of-way may be acquired if needed.
- smaller pipe and box culverts are usually extended flush with the existing foreslope, if they can be extended with pre-cast pipe sections. Some odd-shaped box culverts may not fit any pre-cast sizes or shapes and are therefore extended in-kind, usually to the clear zone.

For non-NHS highways:

- normally, box culverts $\geq$ 6 feet across and pipes $\geq$ 6 feet in diameter are used as constructed. Shielding or extending a large culvert is considered if accident history and/or a benefit/cost analysis indicate that treatment is warranted.
- smaller pipe and box culverts are usually extended flush with the existing foreslope, if they can be extended with pre-cast pipe sections.
- Right-of-way is normally not acquired for extending culverts on the non-NHS.

Grading and Culvert Extensions

Before shielding a culvert with barrier, other treatment options should be considered. These options include making the culvert traversable, extending the culvert beyond the clear zone, and eliminating the opening by connecting multiple culverts (sometimes feasible at interchanges or in the median).

Culvert openings should, in most cases, be made flush with the embankments from which they emerge. Protrusions of the culvert's headwall and the adjoining wingwalls should not be more than 4 inches above the terrain.

For larger culverts perpendicular to the roadway, it is preferable to extend them so their openings are outside the clear zone. For more information on applying the clear-zone concept, see Section 1C-2 of this manual and Chapter 3 of the AASHTO *Roadside Design Guide*. The designer should also flatten and extend the foreslope to cover the culvert, as shown on Typicals 4304 or 4311.

Extending the culvert reduces the chance that a driver will collide with the opening, and it normally does not interfere with the culvert's hydraulic function. However, in some cases, extending a culvert may not be practical due to economic considerations or right-of-way limitations. In such cases, other alternatives must be considered.

Guardrail

Before shielding a culvert with guardrail, first determine if extending the culvert outside the clear zone is feasible.

Barrier design for culverts is the same as side obstacles (see Section 8B-1), except for the following exceptions:

- Concrete barrier is not used to shield culverts. Use Table 1 to determine an appropriate type of barrier to use. The variable d is the distance from the edge of the design shoulder to the face of the obstacle.

Table 1

d (ft)	barrier system
$d \geq 14$	cable guardrail (RE-29C)
$d < 14$	w-beam guardrail with 6′–3″ post spacing (RE-54A or RE-55A)

- The task of locating the installation line for culverts is the same as for side obstacles until the installation line is at the edge of the shoulder and the headwall of the culvert is less than 3.6 feet from the installation line. If the culvert is in this region (very close to the shoulder), the installation line should be placed so that there is 6 inches between the back of the posts and the headwall.

Low Fill Situations

Posts are required to be embedded 3 feet into the ground. However, 3 feet of post embedment occasionally is not possible because of a low-fill situation over the culvert. Two different options exist for this condition:

- W-beam guardrail can be nested together and the posts over the culvert can be eliminated as shown on Standard Road Plan RE-66 ("nesting" is the practice of bolting two pieces of guardrail together to the same posts—one on top of the other). Spans of 12.5, 18.75, and 25 feet can be achieved with this method.[1,2]
- Standard Road Plan RE-37 can be used. Post embedment is not a factor with this method because steel posts are bolted directly to the top of the culvert.

The RE-66 is the preferred option, as long as the culvert is narrow enough to fit between the remaining posts (24′-4″)—taking into account the skew of the culvert. Use Table 2 to determine the appropriate RE-66. For culverts wider than 24'-4", the RE-37 method must be used.

Table 2

Culvert Width (Maximum)	Appropriate RE-66
11'-10"	RE-66A
18'-1"	RE-66B
24'-4"	RE-66C

Tabulation

Tabulation 108-8B is used when shielding culverts with guardrail.

See Section 8B-10 for more information on tabulating guardrail.

Safety Grates

From a safety standpoint, the use of safety grates to make a culvert traversable is a desirable alternative. However, because grated culverts are more easily plugged up with corn stalks and other debris, they are normally not used except in special situations.

Safety grates should never be installed on the outlet of a culvert unless the inlet has been similarly protected.

Detail Sheet 540-4A

Detail Sheet 540-4A is used with box culverts that are perpendicular to the roadway. When using this design, the following guidelines apply:

- Grate bar spacing will be a minimum of 24 inches and a maximum of 30 inches. The grate bars should be equally spaced along the cross bar.
- Guardrail or other treatment should be considered when the vertical drop (J) at the end of the sidewalls is greater than 2 feet. See "Details of Dimensions" on Detail Sheet 540-4A for the definition of "J."
- Grate bar and cross bar sizes depend upon the unsupported span of the member. Grate and cross bar size requirements are shown on Detail Sheet 540-4A. Do not exceed these span

[1] Mak, Bligh, Gripne, and McDevitt, "Long-Span Nested W-Beam Guardrails over Low-Fill Culverts," *Transportation Research Record No. 1367* (1992) 54-62.

[2] Rohde, Sicking, Beilenberg, Faller, Keller, and Polivka, "Development of a 7.62-m Long Span Guardrail System—Phase II," MwRSF Research Report No. TRP-03-88-99.

lengths. If longer bars are required, consult the Methods Section. Also, note that the crossbar diameter must be greater than or equal to the grate-bar diameter.

- Avoid midspan vertical supports if possible. If midspan supports are required, consult the Methods Section for assistance.
- "Details of Dimensions" on Detail Sheet 540-4A show the structure dimensions that need to be obtained from the original culvert plans.
- The culvert's skew angle is defined as shown on Detail Sheet 540-4A.
- Use Tabulation 108-24.

Pipe-Apron Guards

In addition to culverts in the median as discussed on page 1, pipe apron guards may be useful in other situations. Standard Road Plan RE-26 provides construction details for pipe apron guards.

In urban areas, a pipe-apron guard should normally be used on the inlets of all pipe culverts ≤ 36 inches in diameter. The pipe-apron guard keeps children from playing in a culvert and can prevent persons from being pulled into the culvert during flooding.

A pipe-apron guard also prevents debris from entering the culvert. Thus, it should also be considered for long crossroad culverts, particularly if they have bends.

Shielding Standing Water

Originally Issued: 09-23-97

If a body of water greater than 2 feet deep is within the clear zone it should be shielded with guardrail. This section provides information on determining (1) whether or not guardrail is warranted, (2) what type of guardrail is most appropriate, and (3) the length of guardrail needed to provide adequate protection.

Warrants

To determine whether or not guardrail is warranted, the designer should look at the normal pool elevation. If there is standing water greater than 2 feet deep within the clear zone, then guardrail is warranted. See Section 1C-2 and Chapter 3 of the AASHTO *Roadside Design Guide* for more information on applying the clear-zone concept.

Two-Way Undivided Highways

If the water is within the clear zone for the adjacent lane but outside the clear zone for the opposing lane, guardrail is needed for the adjacent lane only (T is not required as shown on RE-54). If T is not required and w-beam guardrail is being used, make sure that the RE-33A end terminal on the trailing side of the installation will also be outside the clear zone. If it is not then the installation should be terminated with an RE-76.

If the pond is within the clear zone for the opposing lane, both A and T are required (see RE-54).

Divided or One-Way Highways

If the water is within the clear zone on a divided or one-way highway, only A will be required (RE-55).

Type of Barrier

Cable guardrail may be used to shield standing water, as long as there is enough area behind the installation for the rail to deflect 12 feet. There should be no rigid obstacles, culvert openings, etc. within this 12-foot area. Cable guardrail should not be used if the slope behind the rail is steeper than 2:1.

If the deflection and slope criteria cannot be met, w-beam guardrail should be used.

Length of Need

To determine the length of need, follow these steps:

1. If the pond is within the clear zone for the adjacent lane, draw a line parallel to the roadway that is offset from the edge of traveled way the clear zone distance for the adjacent lane (line x in Figure 1).
2. Determine where this line intersects the normal pool elevation (points y in Figure 1). The distance between these two points is L_o (see Figure 1).
3. If the pond is within the clear zone for the opposing lane, draw a line parallel to the roadway that is offset from the edge of traveled way the clear zone distance for the opposing lane (line z in Figure 1).
4. Determine the location of the installation line L_2. The installation line is normally placed 2 feet off the shoulder.
5. The length of need beyond L_o is determined graphically using the *Roadside Design Guide's* methodology (see the procedures and examples in Chapter 5 of the *Roadside Design Guide).* The clear-zone distance should be used for L_A. See Section 8B-1 to determine L_R.
6. If w-beam guardrail is being used, you can add either variable tangent or variable flare (see RE-54) to achieve the appropriate length of need. Using variable flare will reduce the amount of guardrail needed but the installation will flare out a greater distance from the roadway. Using variable tangent will increase the amount of guardrail needed but will keep the installation closer to the roadway thereby reducing the amount of earthwork required (see RL-14). See Section 8B-1 for more information.

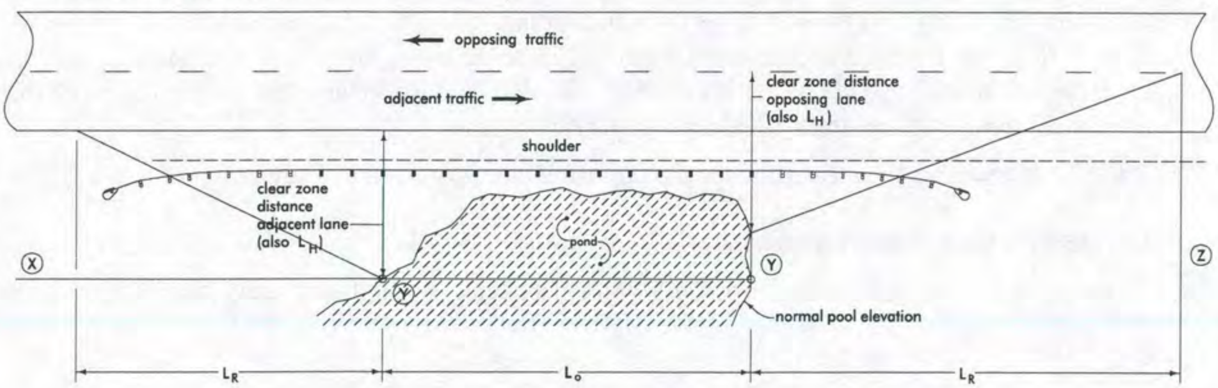


Figure 1: Determining the length of need for standing water.

Tabulation

Use Tabulation 108-8B with w-beam guardrail and Tabulation 108-9 with cable guardrail.

See Section 8B-10 for more information on tabulating guardrail.

Temporary Side Obstacle Treatment in Work Zones

Originally Issued: 01-20-97

Side obstacles on multi-lane divided highways are usually only shielded to protect one direction of traffic. At work zones, traffic may be routed to one side of the facility and run head-to-head, in which case vehicles traveling in the opposite direction may also need to be protected. This section provides information on temporarily shielding side obstacles in these situations with sand-filled plastic barrels.

Figure 1: Sand-filled barrels may be used to shield obstacles in work zones.

Sand-filled Barrels

There are various reasons why sand-filled barrels are appropriate for use in a work zone where traffic has been routed head-to-head:

- Sand-filled barrels are a non-redirective system. This means that an impacting vehicle will penetrate the system, instead of being redirected back onto the highway or shoulder. In the case of head-to-head traffic in work zones, this is more desirable than a redirective system that could potentially redirect the vehicle back onto the roadway.
- Sand-filled barrels are more economical than other alternatives. Their initial cost is low and they can be reused many times.
- If an installation is hit, protection can be quickly restored by replacing damaged barrels.
- Because the barrels are removed once traffic is returned to normal, there are no unnecessary barriers left on the roadside.

Warrants

When traffic is moved to one side of a divided highway, obstacle treatment should be considered for the new direction of traffic. Any obstacle that is unshielded and within the clear zone should be protected. See Section 1C-2 for more information on clear zones. In many cases, on a divided highway, this will include the trailing end of a guardrail installation.

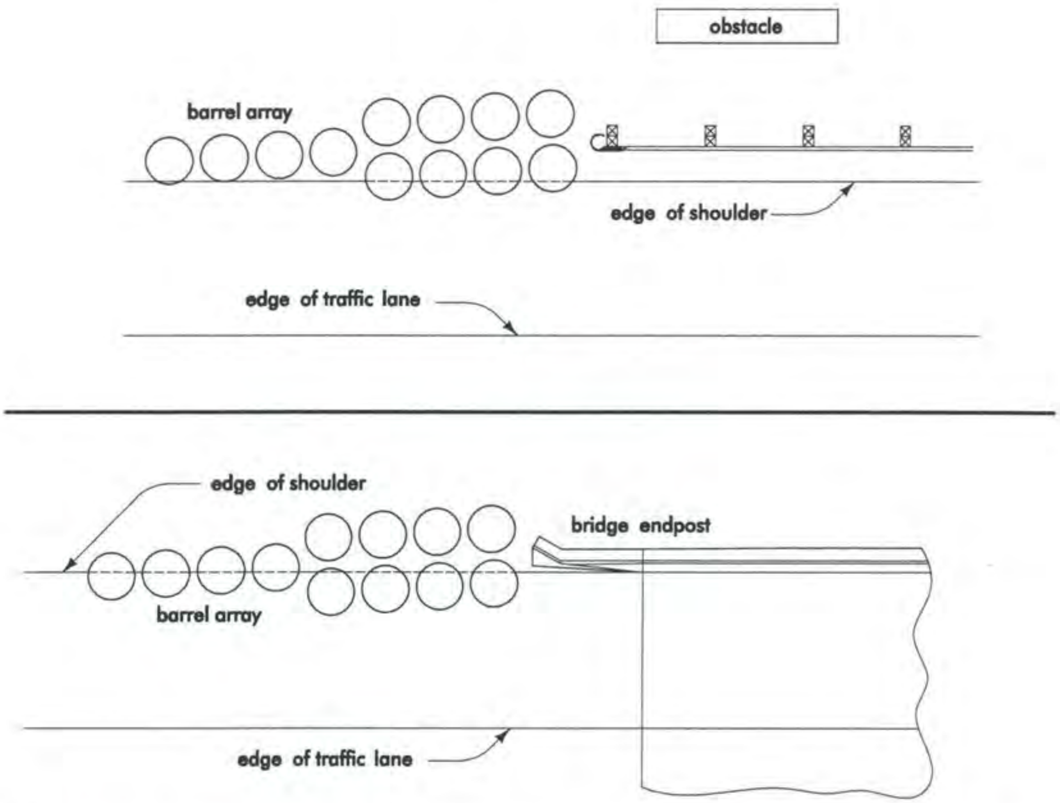


Figure 2: Plan view of two common side obstacles that may require temporary protection: the trailing end of a guardrail installation and an unshielded bridge endpost.

Design Information

When using sand-filled barrels for temporary side obstacle protection, include in the plans Standard Road Plan RE-73 and Tabulation 108-30. The designer should specify each location where temporary protection is required, as well as the layout dimensions, grading dimensions, and earthwork quantities. Use the equations in Table 1 to calculate the grading dimensions X, Y, and Z (see RE-73 for definitions of these variables).

Table 1

X	Y	Z
5.1 + L3 − SW	3.6 + L3 − SW	3.73 × Y
All units are in feet.		

The bid item to be used is *Temporary Attenuator, Sand-filled Plastic Barrel Arrays.*

The number of barrel sets that the contractor will have to obtain will often be less than the total number of locations tabulated because as work progresses, and depending on how traffic is staged, the same set of barrels may be moved to another location. It is up to the contractor to determine how many barrel sets are required. The designer need only specify the total number of locations.

Areas with Narrow Shoulders

As illustrated on Standard Road Plan RE-73, the barrel array is offset 2.5 feet from the face of the obstacle nearest the highway. This is to provide maximum safety for a vehicle impacting the system at an angle directly where the obstacle ends.

In some areas, the shoulder may not be wide enough to provide this 2.5-foot offset and also maintain a safe distance from the lane of traffic. The most common example of this is the older bridges on the interstate system that were constructed with only 3-foot shoulders. At these locations, a standard w-beam system should be installed instead of the sand-filled barrels.

Barrels should not be used at any location where the barrels would be within 3 feet of the traveled way. At these locations, a standard w-beam system should be installed.

Tabulating Guardrail

Originally Issued: 02-26-99

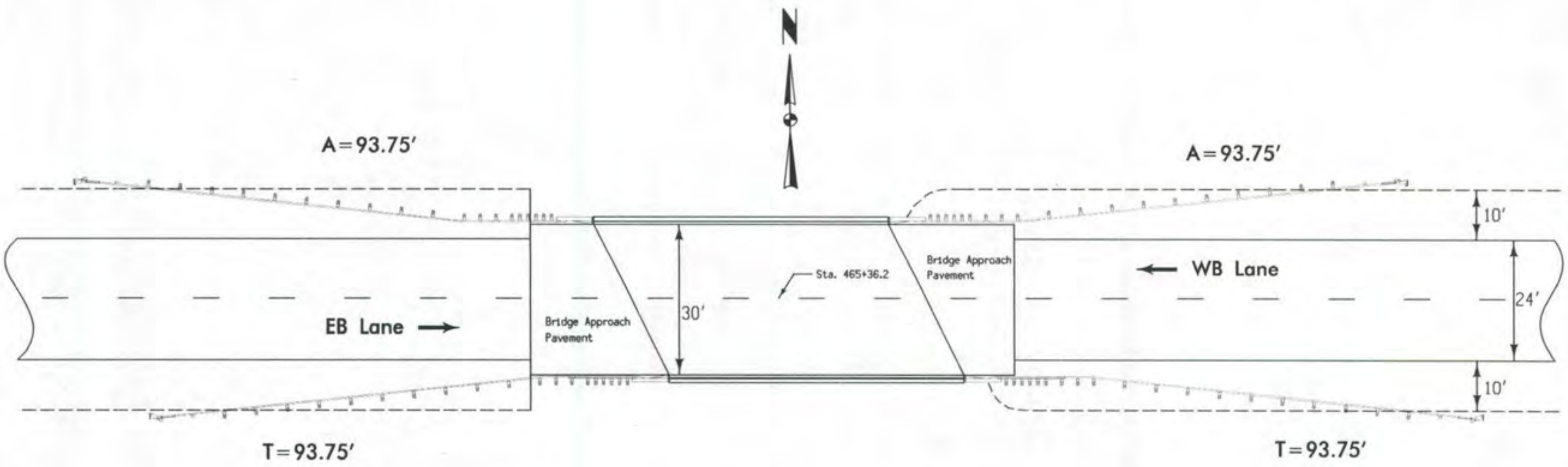
Tabulating guardrail can be confusing because the tabulations are set up to handle many different situations. Because of this, some columns are used for some situations but not used in other situations. Tabulating guardrail consistently makes it easier for contractors and inspectors to understand the designer's intent and helps ensure that the guardrail is installed correctly.

The examples on the following pages illustrate how to tabulate guardrail for some common situations.

- Example 1: single bridge with narrow shoulders (RE-65A).
- Example 2: dual bridges with bullnose installations (RE-67 and RE-65A).
- Example 3: side obstacle shielded with concrete barrier (RE-65B).
- Example 4: railroad signals (RE-63)
- Example 5: side obstacle shielded with w-beam guardrail (RE-54 or RE-55).
- Example 6: w-beam guardrail over a low-fill culvert (RE-66A, RE-66B, or RE-66C). This installation is a bit more complicated because posts are skipped and guardrail is nested above the culvert.
- Example 7: median obstacle shielded with the encirclement design (RE-56).

The column labeled *Direction of Traffic* in the tabulations simply indicates on which side of the highway the installation is located. The column labeled *Side* is used only with multi-lane divided highways to further clarify where the installation is located. Either "median" or "outside" is entered in this column.

Example 1—Single Bridge with Narrow Shoulders



TABULATION OF STEEL BEAM GUARDRAIL AT BRIDGE END POST, CONCRETE BARRIER AND RAILROAD SIGNALS

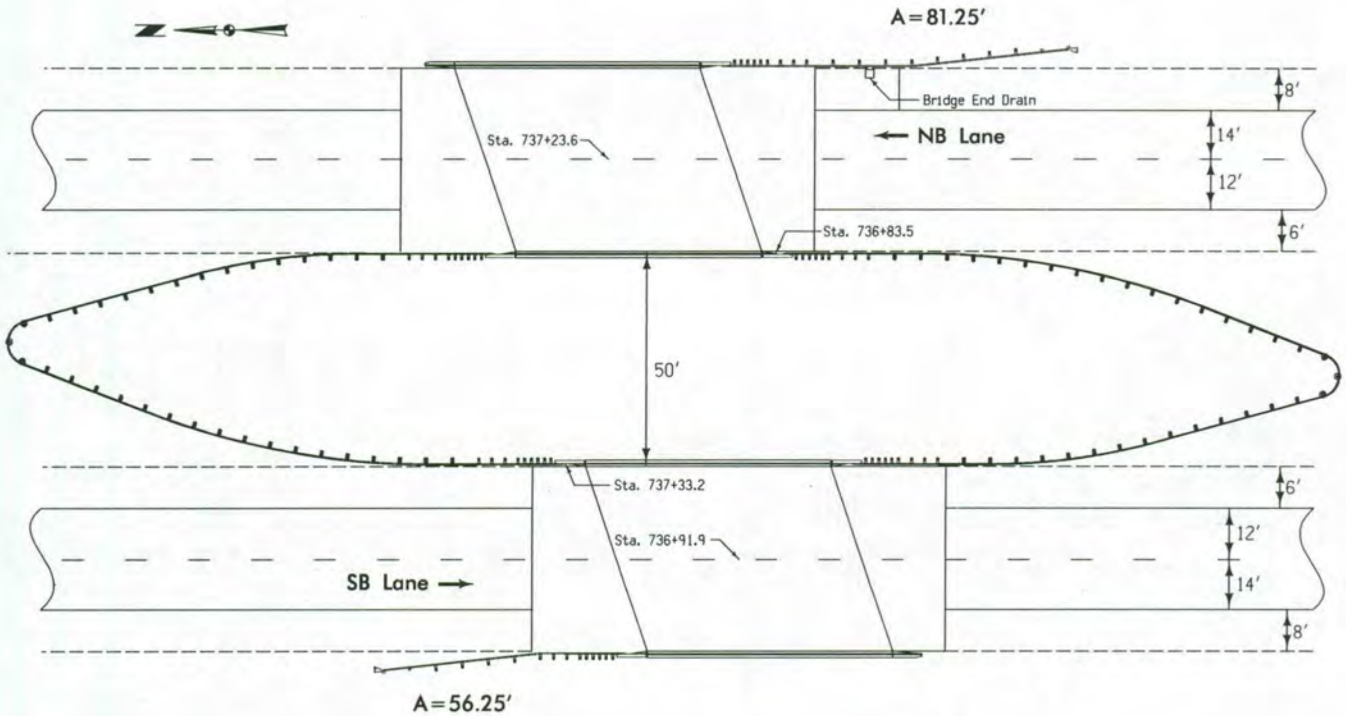
Refer to Standard Road Plans RE-48A-B, RE-63, RE-65A, and RE-65B

108-8A
04-30-02

No.	Location: ① Direction of Traffic	Location: End (A=Approach T=Trailing)	Location: Side (O = Outside M = Median)	Location: Station	Standard Road Plan	Case (F or S)	② L2 (Feet)	Layout Lengths: STS (18.75′) Lin. Ft.	Layout Lengths: VT Lin. Ft.	Layout Lengths: VF Lin. Ft.	Layout Lengths: ET Terminal (37.5′) Lin. Ft.	Materials Required: STS Thrie Beam (25.0′) Lin. Ft.	Materials Required: STS Transition Section (6.25′) Lin. Ft.	Materials Required: VT+VF+ET ③ 'W' Beam Lin. Ft.	Posts ④ 6″x 8″x 7′ with 6″x 8″ Spacer Blocks (6 or 7) No.	Posts ⑤ 6″x 8″x 6′ with 6″x 8″ Spacer Blocks No.	CRT Posts 6″x 8″x 6′ with 6″x 8″ Spacer Blocks (4) No.
1	WB	A	---	465+36.2	RE-65A	F	---	18.75	0	37.50	37.5	25.0	6.25	75.0	7	8	4
2	WB	T	---	465+36.2	RE-65A	F	---	18.75	0	37.50	37.5	25.0	6.25	75.0	7	8	4
3	EB	A	---	465+36.2	RE-65A	F	---	18.75	0	37.50	37.5	25.0	6.25	75.0	7	8	4
4	EB	T	---	465+36.2	RE-65A	F	---	18.75	0	37.50	37.5	25.0	6.25	75.0	7	8	4

No.	Delineators and Object Markers: Type	Delineator: Single White D-IW No.	Object Marker: Type 2 OM2-3YY No.	Object Marker: Type 3 OM-3L No.	Object Marker: Type 3 OM-3R No.	Bid Items: Installation of Guardrail STS·VT·VF·ET Lin. Ft.	Anchorage and Terminal Systems: RE-33B No.	RE-69A No.	RE-69B No.	RE-69C No.	RE-76 No.	Remarks
1	1	7	3	---	1	93.75	---	1	---	---	1	
2	1	---	3	1	---	93.75	---	1	---	---	1	
3	1	7	3	---	1	93.75	---	1	---	---	1	
4	1	---	3	1	---	93.75	---	1	---	---	1	

① Lane(s) to which the obstacle is adjacent.
② Applies to Standard Road Plan RE-63 only.
③ Includes (2) special 12.5′ sections of 'W' Beam, see RE-76.
④ (6) 6″x 8″x 7′ posts required when RE-63 or RE 69C is specified.
⑤ The last two posts of the RE-76 Terminal section are included as part of that bid item.



TABULATION OF STEEL BEAM GUARDRAIL AT BRIDGE END POST, CONCRETE BARRIER AND RAILROAD SIGNALS

108-8A
04-30-02

Refer to Standard Road Plans RE-48A-B, RE-63, RE-65A, and RE-65B

No.	LOCATION: Direction of Traffic ①	LOCATION: End (A=Approach T=Trailing)	LOCATION: Side (O = Outside M = Median)	LOCATION: Station	STANDARD ROAD PLAN	CASE (F or S)	② L2 (Feet)	LAYOUT LENGTHS: STS (18.75') Lin. Ft.	LAYOUT LENGTHS: VT Lin. Ft.	LAYOUT LENGTHS: VF Lin. Ft.	LAYOUT LENGTHS: ET Terminal (37.5') Lin. Ft.	MATERIALS REQUIRED: STS Thrie Beam (25.0') Lin. Ft.	MATERIALS REQUIRED: STS Transition Section (6.25') Lin. Ft.	MATERIALS REQUIRED: VT+VF+ET 'W' Beam ③ Lin. Ft.	MATERIALS REQUIRED: Posts ④ 6"x 8"x 7' with 6"x 8" Spacer Blocks (6 or 7) No.	MATERIALS REQUIRED: Posts ⑤ 6"x 8"x 6' with 6"x 8" Spacer Blocks No.	MATERIALS REQUIRED: CRT Posts 6"x 8"x 6' with 6"x 8" Spacer Blocks (4) No.	DELINEATORS AND OBJECT MARKERS: Type	Delineator Single White D-1W No.	Object Marker Type 2 OM2-3YV No.	Object Marker Type 3 OM-3L No.	Object Marker Type 3 OM-3R No.	BID ITEMS: Installation of Guardrail STS+VT+VF+ET Lin. Ft.	Anchorage and Terminal Systems RE-33B No.	RE-69A No.	RE-69B No.	RE-69C No.	RE-76 No.
3	SB	A	O	736+91.9	RE-65A	S	---	18.75	0	0	37.5	25.0	6.25	37.5	7	2	4	3	---	---	---	1	56.25	---	1	---	---	1
4	NB	A	O	737+23.6	RE-65A	S	---	18.75	25.0	0	37.5	25.0	6.25	62.5	7	6	4	3	---	---	---	1	81.25	---	1	---	---	1

① Lane(s) to which the obstacle is adjacent.
② Applies to Standard Road Plan RE-63 only.
③ Includes (2) special 12.5' sections of 'W' Beam, see RE-76.
④ (6) 6"x 8"x 7' posts required when RE-63 or RE 69C is specified.
⑤ The last two posts of the RE-76 Terminal section are included as part of that bid item.

REMARKS

TABULATION OF STEEL BEAM GUARDRAIL FOR STANDARD ROAD PLAN RE-67

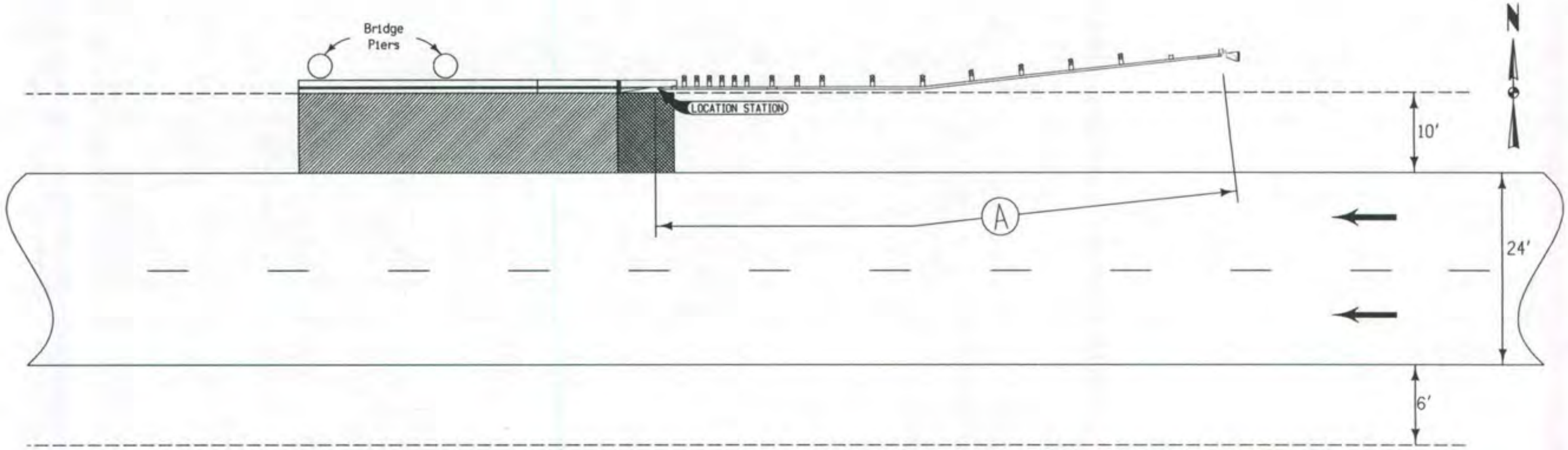
108-19
04-30-02

No.	LOCATION: Direction of Traffic ①	LOCATION: STATION	Ⓐ APPROACH SIDE LAYOUT LENGTHS: STS (18.75') Lin. Ft.	Ⓐ Section for Skewed Bridge Lin. Ft.	Ⓐ Curve # 1 Lin. Ft.	Ⓐ RE-53 Section (12.5') Lin. Ft.	Ⓣ TRAILING SIDE LAYOUT LENGTHS: Tangent Section Lin. Ft.	Ⓣ Curve # 2 Lin. Ft.	Ⓣ Section for Skewed Bridge Lin. Ft.	Ⓣ Adjustment Section ② Lin. Ft.	Ⓣ STS (18.75') Lin. Ft.	MATERIALS REQUIRED: STS Thrie Beam (50.0') Lin. Ft.	STS Transition Section (2) @ (6.25') Lin. Ft.	'W' Beam ③ Ⓐ+Ⓣ -37.5' Lin. Ft.	Posts 6"x 8"x 7' with 6"x 8" Spacer Blocks (12 or 14) ④ No.	Posts 6"x 8"x 6' with 6"x 8" Spacer Blocks No.	Posts 6"x 8"x 6' without Spacer Blocks (2) No.	Posts 6"x 6"x 6' without Spacer Blocks (1) No.	DELINEATORS AND OBJECT MARKERS: Type	Delineator Single White D-1W No.	Object Marker Type 2 OM2-3YV No.	Object Marker Type 3 OM-3L No.	Object Marker Type 3 OM-3R No.	BID ITEMS: Installation of Guardrail Ⓐ+Ⓣ Lin. Ft.	Anchorage and Terminal Systems RE-53 No.	RE-69A No.	RE-69B No.	RE-69C No.
5	SB	737+33.2	18.75	12.5	100.0	12.5	37.5	43.75	---	12.5	18.75	50.0	2 @ 6.25	218.75	14	35	2	1	4	---	---	1	---	256.25	1	2	---	---
5	NB	736+83.5	18.75	12.5	100.0	12.5	37.5	43.75	---	12.5	18.75	50.0	2 @ 6.25	218.75	14	35	2	1	4	---	---	1	---	256.25	1	2	---	---

① Lane(s) to which the obstacle is adjacent.
② Excess rail has been supplied for field adjustment at this point. This section will be divisible by 6.25'.
③ Includes (1) 12.5' long 5' radius section.
④ (12) 6"x 8"x 7' posts required when RE-69C is specified.

REMARKS

Example 3—Side Obstacle Shielded with Concrete Barrier



TABULATION OF STEEL BEAM GUARDRAIL AT BRIDGE END POST, CONCRETE BARRIER AND RAILROAD SIGNALS

108-8A
04-30-02

Refer to Standard Road Plans RE-48A-B, RE-63, RE-65A, and RE-65B

LOCATION					STANDARD ROAD PLAN	CASE	②	LAYOUT LENGTHS				MATERIALS REQUIRED						DELINEATORS AND OBJECT MARKERS					BID ITEMS						REMARKS
No.	① Direction of Traffic	End A=Approach T=Trailing	Side O = Outside M = Median	Station			(L2)	(STS) (18.75')	(VT)	(VF)	(ET) Terminal (37.5')	STS Thrie Beam (25.0')	STS Transition Section (6.25')	(VT)+(VF)+(ET) ③ 'W' Beam	Posts ④ 6"x 8"x 7' with 6"x 8" Spacer Blocks (6 or 7)	Posts ⑤ 6"x 8"x 6' with 6"x 8" Spacer Blocks	CRT Posts 6"x 8"x 6' with 6"x 8" Spacer Blocks (4)	Type	Delineator Single White D-1W	Object Marker Type 2 OM2-3YY	Object Marker Type 3 OM-3L	Object Marker Type 3 OM-3R	Installation of Guardrail (STS)+(VT)+(VF)+(ET)	Anchorage and Terminal Systems RE-33B	RE-69A	RE-69B	RE-69C	RE-76	
						F or S	Feet	Lin. Ft.	Lin. Ft.	Lin. Ft.	Lin. Ft.	Lin. Ft.	Lin. Ft.	Lin. Ft.	No.	No.	No.		No.	No.	No.	No.	Lin. Ft.	No.	No.	No.	No.	No.	
7	WB	A	O	879+56.4	RE-65B	---	---	18.75	12.5	0	37.5	25.0	6.25	50.0	7	4	4	3	---	---	---	1	68.75	---	1	---	---	---	

① Lane(s) to which the obstacle is adjacent.
② Applies to Standard Road Plan RE-63 only.
③ Includes (2) special 12.5' sections of 'W' Beam, see RE-76.
④ (6) 6"x 8"x 7' posts required when RE-63 or RE 69C is specified.
⑤ The last two posts of the RE-76 Terminal section are included as part of that bid item.

TABULATION OF CONCRETE BARRIER AT SIDE LOCATIONS

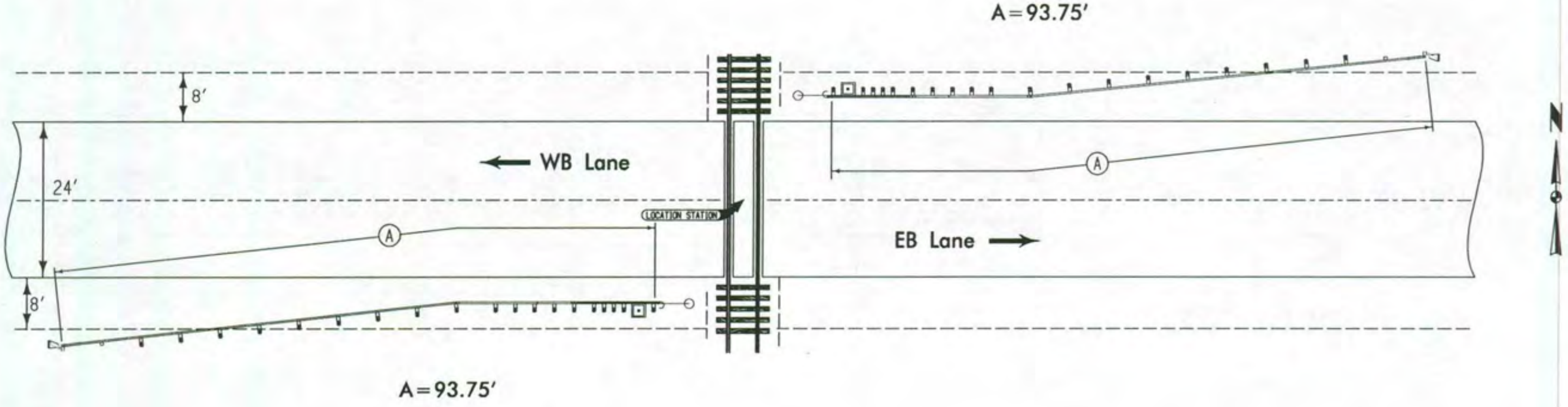
108-18B
04-25-00

Refer to Standard Road Plans RE-44C, RE-44E, RE-44F(1), RE-44F(2), RE-44G, RE-44H, RE-74A & RE-74B

① Lane(s) to which the installation is adjacent.

LOCATION				(L2C)	SIDE BARRIER				REMARKS
No.	① Direction of Traffic	Station to Station	Side	ft	Standard Road Plan	(L) Lin. Ft.	RE-44G Transition Section No.	RE-44H End Section No.	Concrete Barrier / Edge of Traveled Way / (L2C)
7	WB	879+56.4	--	10.0	RE-74A	30.0	1	1	

Example 4—Existing Railroad Signals



TABULATION OF STEEL BEAM GUARDRAIL AT BRIDGE END POST, CONCRETE BARRIER AND RAILROAD SIGNALS

Refer to Standard Road Plans RE-48A-B, RE-63, RE-65A, and RE-65B

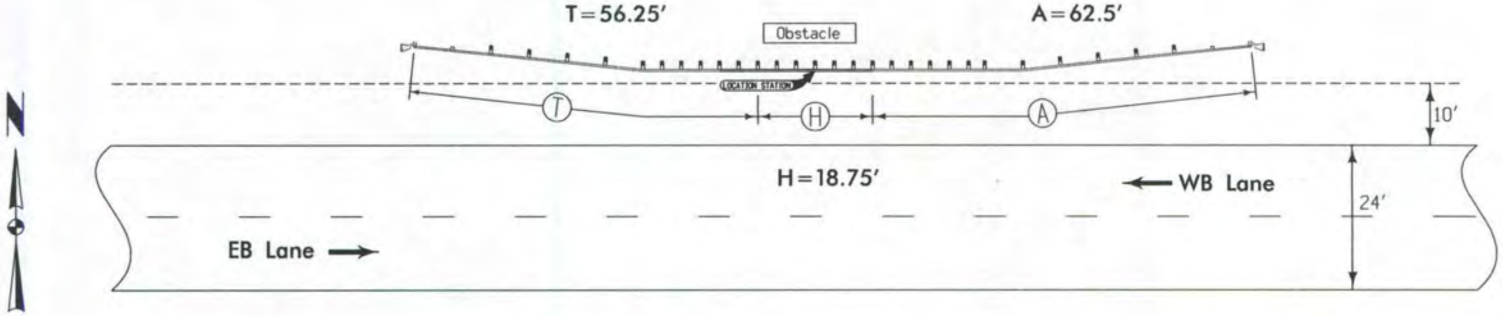
108-8A
04-30-02

LOCATION: No.	LOCATION: (1) Direction of Traffic	LOCATION: End (A=Approach, T=Trailing)	LOCATION: Side (O = Outside, M = Median)	LOCATION: Station	STANDARD ROAD PLAN	CASE (F or S)	(2) (L2) (Feet)	LAYOUT LENGTHS: (STS) (18.75′) (Lin. Ft.)	LAYOUT LENGTHS: (VT) (Lin. Ft.)	LAYOUT LENGTHS: (VF) (Lin. Ft.)	LAYOUT LENGTHS: (ET) Terminal (37.5′) (Lin. Ft.)	MATERIALS REQUIRED: STS Thrie Beam (25.0′) (Lin. Ft.)	MATERIALS REQUIRED: STS Transition Section (6.25′) (Lin. Ft.)	MATERIALS REQUIRED: (VT)+(VF)+(ET) (3) 'W' Beam (Lin. Ft.)	MATERIALS REQUIRED: Posts (4) 6″x 8″x 7′ with 6″x 8″ Spacer Blocks (6 or 7) (No.)	MATERIALS REQUIRED: Posts (5) 6″x 8″x 6′ with 6″x 8″ Spacer Blocks (No.)	MATERIALS REQUIRED: CRT Posts 6″x 8″x 6′ with 6″x 8″ Spacer Blocks (4) (No.)
8	WB	A	---	465+50.0	RE-63	S	4.0	18.75	12.5	25.0	37.5	25.0	6.25	75.0	6	9	4
9	EB	A	---	465+50.0	RE-63	S	4.0	18.75	12.5	25.0	37.5	25.0	6.25	75.0	6	9	4

No.	DELINEATORS AND OBJECT MARKERS: Type	Delineator: Single White 0-1W (No.)	Object Marker: Type 2 OM2-3YY (No.)	Object Marker: Type 3 OM-3L (No.)	Object Marker: Type 3 OM-3R (No.)	BID ITEMS: Installation of Guardrail (STS)+(VT)+(VF)+(ET) (Lin. Ft.)	Anchorage and Terminal Systems: RE-33B (No.)	RE-69A (No.)	RE-69B (No.)	RE-69C (No.)	RE-76 (No.)	REMARKS
8	9	3	3	1	1	93.75	RE-33B	---	---	---	1	
9	9	3	3	1	1	93.75	RE-33B	---	---	---	1	

(1) Lane(s) to which the obstacle is adjacent.
(2) Applies to Standard Road Plan RE-63 only.
(3) Includes (2) special 12.5′ sections of 'W' Beam, see RE-76.
(4) (6) 6″x 8″x 7′ posts required when RE-63 or RE 69C is specified.
(5) The last two posts of the RE-76 Terminal section are included as part of that bid item.

Example 5—Side Obstacle Shielded with W-Beam Guardrail



TABULATION OF STEEL BEAM GUARDRAIL FOR SIDE OBSTACLE

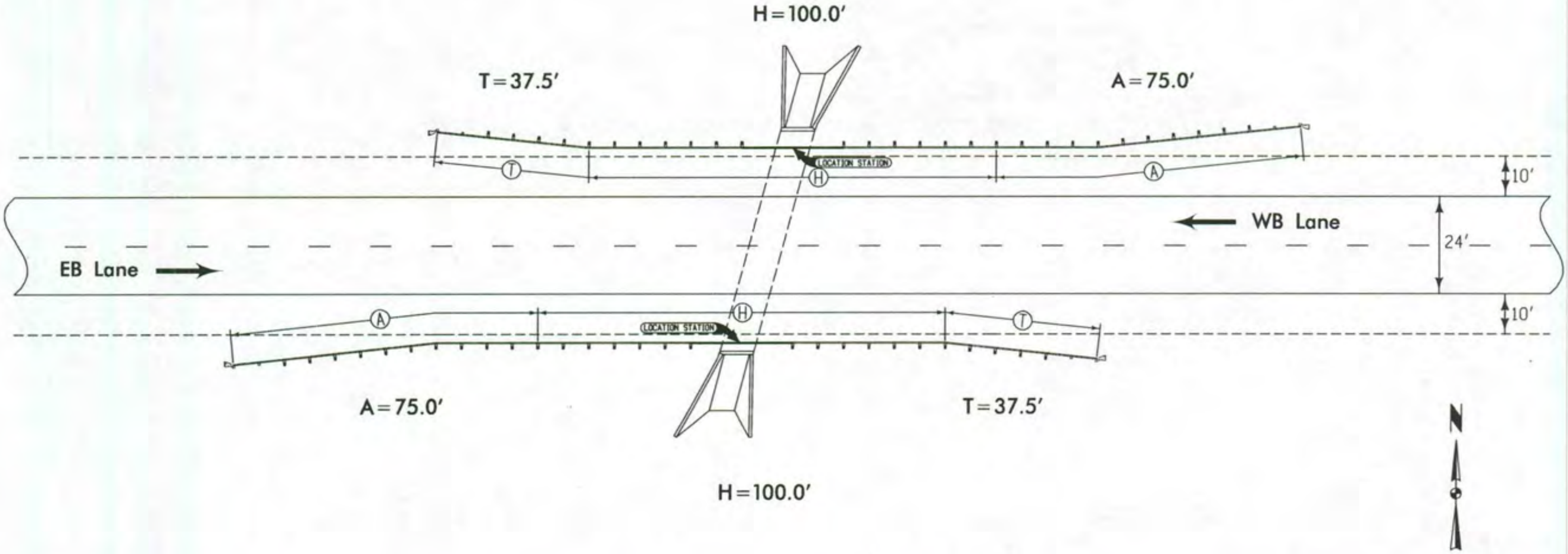
See Standard Road Plans RE-48A-B, RE-54A, RE-54B, RE-55A, RE-55B, RE-66A, RE-66B, or RE-66C

108-8B
04-30-02

LOCATION				STANDARD ROAD PLAN	(L2)	LAYOUT LENGTHS							CULVERT SPANNING	MATERIALS REQUIRED			DELINEATORS AND OBJECT MARKERS					BID ITEMS				REMARKS
No.	Direction of Traffic (1)	Side: O = Outside, M = Median	Station			Approach Side (A)			(H)	Trailing Side (T)			Standard Road Plan RE-66A, RE-66B or RE-66C	'W' Beam Guardrail (A)+(H)(2)+(T)(3)	CRT Posts 6"x 8"x 6' with 6"x 8" Spacer Blocks (4) each end	Posts (4) 6"x 8"x 6' with 6"x 8" Spacer Blocks	Type	Delineator: Single White D-1W	Object Marker: Type 2 OM2-3YV	Object Marker: Type 3 OM-3L	Object Marker: Type 3 OM-3R	Installation of Guardrail (A)+(H)+(T)	Anchorage and Terminal Systems RE-33A	Anchorage and Terminal Systems RE-76	Adaptor RE-37	
						(ET) Terminal (37.5')	(VF)	(VT)		(VT)	(VF)	(ET) Terminal (37.5')														
					Feet	Lin. Ft.	Lin. Ft.	Lin. Ft.	Lin. Ft.	Lin. Ft.	Lin. Ft.	Lin. Ft.		Lin. Ft.	No.	No.		No.	No.	No.	No.	Lin. Ft.	No.	No.	No.	
10	WB	---	812+23.7	RE-54B	12.0	37.5	0	25.0	18.75	18.75	0	37.5	---	137.5	8	20	6	---	---	1	1	137.5	---	2	---	

(1) Lane(s) to which the obstacle is adjacent.
(2) If Culvert Spanning is required use 2 H.
(3) Includes (2) special 12.5' sections of 'W' Beam, see RE-76.
(4) The last two posts of the RE-76 Terminal section are included as part of that bid item.

Example 6—W-Beam Guardrail over a Low-Fill Culvert



TABULATION OF STEEL BEAM GUARDRAIL FOR SIDE OBSTACLE

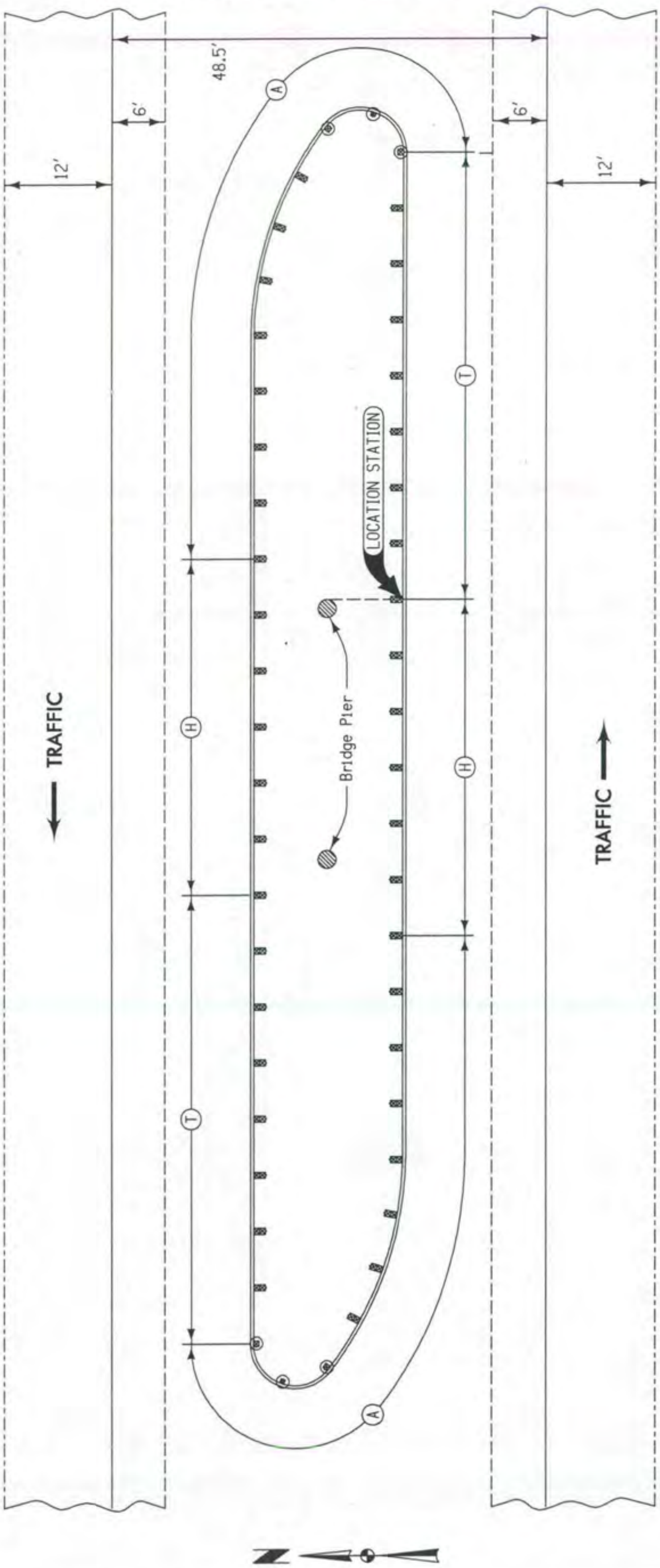
See Standard Road Plans RE-48A-B, RE-54A, RE-54B, RE-55A, RE-55B, RE-66A, RE-66B, or RE-66C

108-8B
04-30-02

LOCATION				STANDARD ROAD PLAN	(L2)	LAYOUT LENGTHS							CULVERT SPANNING	MATERIALS REQUIRED			DELINEATORS AND OBJECT MARKERS					BID ITEMS				REMARKS
No.	Direction of Traffic (1)	Side O = Outside M = Median	Station			Approach Side (A) (ET) Terminal (37.5′)	Approach Side (A) (VF)	Approach Side (A) (VT)	(H)	Trailing Side (T) (VT)	Trailing Side (T) (VF)	Trailing Side (T) (ET) Terminal (37.5′)	Standard Road Plan RE-66A, RE-66B or RE-66C	'W' Beam Guardrail (A)+(H)(2)+(T)(3)	CRT Posts 6″x 8″x 6′ with 6″x 8″ Spacer Blocks (4) each end	Posts (4) 6″x 8″x 6′ with 6″x 8″ Spacer Blocks	Type	Delineator Single White D-1W	Object Marker Type 2 OM2-3YY	Object Marker Type 3 OM-3L	Object Marker Type 3 OM-3R	Installation of Guardrail (A)+(H)+(T)	Anchorage and Terminal Systems RE-33A	Anchorage and Terminal Systems RE-76	Adaptor RE-37	
					Feet	Lin. Ft.	Lin. Ft.	Lin. Ft.	Lin. Ft.	Lin. Ft.	Lin. Ft.	Lin. Ft.		Lin. Ft.	No.	No.		No.	No.	No.	No.	Lin. Ft.	No.	No.	No.	
11	EB	---	1084+89.4	RE-54A	12.0	37.5	12.5	25.0	100.0	0	0	37.5	RE-66A	312.5	8	20	6	---	---	1	1	212.5	---	2	---	
12	WB	---	1085+02.3	RE-54A	12.0	37.5	12.5	25.0	100.0	0	0	37.5	RE-66A	312.5	8	20	6	---	---	1	1	212.5	---	2	---	

(1) Lane(s) to which the obstacle is adjacent.
(2) If Culvert Spanning is required use 2 H.
(3) Includes (2) special 12.5′ sections of 'W' Beam, see RE-76.
(4) The last two posts of the RE-76 Terminal section are included as part of that bid item.

Example 7—Median Obstacle Shielded with Encirclement Design



TABULATION OF STEEL BEAM GUARDRAIL FOR STANDARD ROAD PLAN RE-56 (108-8C, 10-02-01)

LOCATION		LAYOUT LENGTHS			MATERIALS REQUIRED				BID ITEMS		REMARKS
					'W' Beam Guardrail	BEAM GUARDRAIL POSTS					
NO.	STATION	(A) (62.5')	(H)	(T) (50.0')	2(A)+2(H)+2(T)	6″x 8″x 6′ without Spacer Blocks (4)	6″x 6″x 6′ without Spacer Blocks (2)	6″x 8″x 6′ with 6″x 8″ Spacer Blocks	Installation of Guardrail 2(A)+2(H)+2(T)	RE-53 ANCHOR SYSTEM (2)	
		Lin. Ft.	Lin. Ft.	Lin. Ft.	Lin. Ft.	No.	No.	No.	Lin. Ft.	No.	
13	943+60.9	62.5	37.5	50.0	300	4	2	42	300	2	

Cable Guardrail/W-Beam Guardrail Crossover

Originally Issued: 12-20-99

The cable guardrail/w-beam guardrail crossover is most often used at bridges near steep embankments. Thrie-beam and w-beam guardrail is used to shield the bridge endpost and then crossed over with cable guardrail, which is used to shield the steep embankment.

This crossover design was developed by the South Dakota DOT and has passed NCHRP Report 350 (test level 3) crash testing requirements.

The cable is run along the face of the w-beam guardrail and then terminated behind the thrie-beam standard transition section. Note that the w-beam terminal used with this design must be a buckling terminal not an energy-absorbing terminal like the FLEAT, which is normally used for terminating w-beam. Because of this, the w-beam should be terminated with a Modified Eccentric Loader Terminal (MELT). There is no longer a specific bid item for the MELT, so a 2599-series bid item should be used.

If the cable/w-beam crossover is used, Detail Sheets 540-20(1) through 540-20(6) should be included in the plans, as well as Tabulation 108-31.

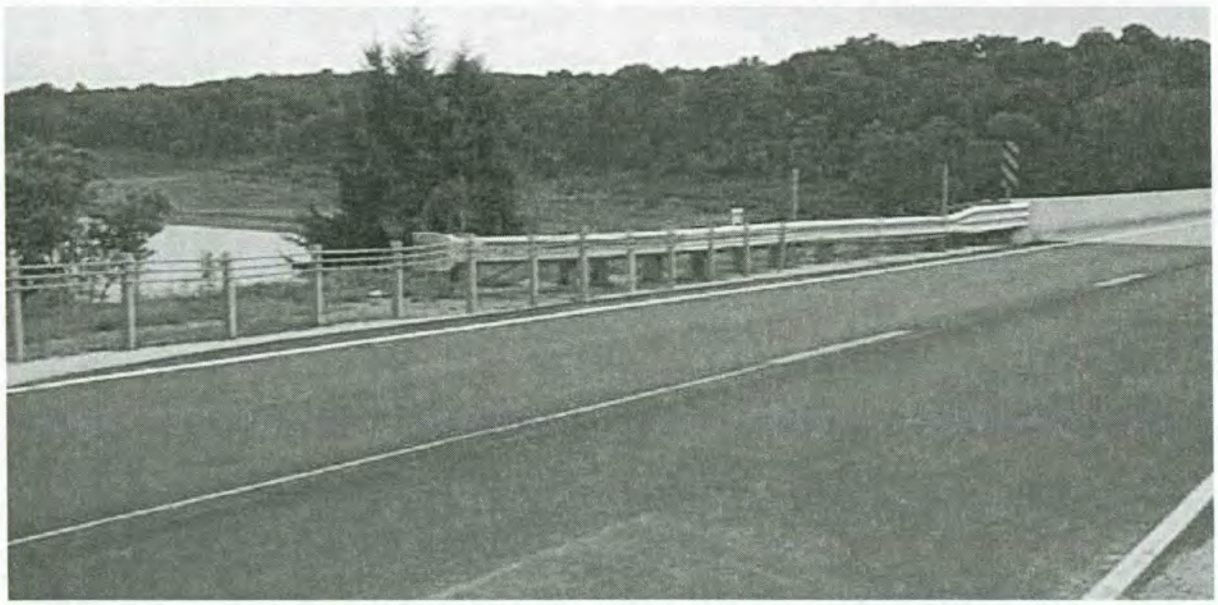


Figure 1: cable guardrail/w-beam guardrail crossover on US 17 south of Madrid.

Grading at Four-Span Bridges

Originally Issued: 09-23-97

Side piers at newly constructed four-span bridges are normally located about 30 feet from the edge of traveled way. At this distance, barrier is not warranted. However, special grading as illustrated on Standard Road Plan RL-13 is used to reduce the chance of an errant vehicle colliding with the piers. Use Table 1 to determine the approach and trailing lengths for this special grading. Bridge piers that are closer to the roadway will usually warrant barrier (see Section 8B-1).

Table 1: Approach and trailing lengths for Standard Road Plan RL-13.

Shoulder Width (ft)	≥ 6000 vpd		< 6000 vpd	
	AL (ft)	TL (ft)	AL (ft)	TL (ft)
4	380	270	350	250
6	350	250	320	230
8	320	230	295	210
10	295	210	270	190
12′ auxiliary lane	175	—	160	—

Figure 1: Side piers at newly-constructed four-span bridges require special grading, but no barrier.

Tabulation

Tabulation 104-12 should be used to specify AL and TL. In the column labeled *Direction of Traffic*, you specify which lane(s) the piers are adjacent to. For example, you would enter "WB" if the piers are adjacent to the westbound lanes, "SB" if the piers are adjacent to the southbound lanes, and so on.

Guardrail and Curbs

Originally Issued: 12-20-99

Guardrail is not desirable alongside curbs because of vaulting and other unpredictable effects caused by the curb. Every effort should be made to remove fixed objects or relocate them outside the clear zone instead of using guardrail. If there is no other alternative to using guardrail (as is often the case at bridges), it may be used alongside a 4-inch sloped curb, normally with the installation line at the face of the curb. If 6-inch curbs are being used throughout the rest of the project, the curb should be transitioned to a 4-inch sloped curb throughout the guardrail installation (see Figure 1). The 4-inch sloped curb should run from the end of the guardrail installation through the Z dimension, as shown on Standard Road Plan RL-14.

Typical 6151 may be used to indicate where the curb type changes.

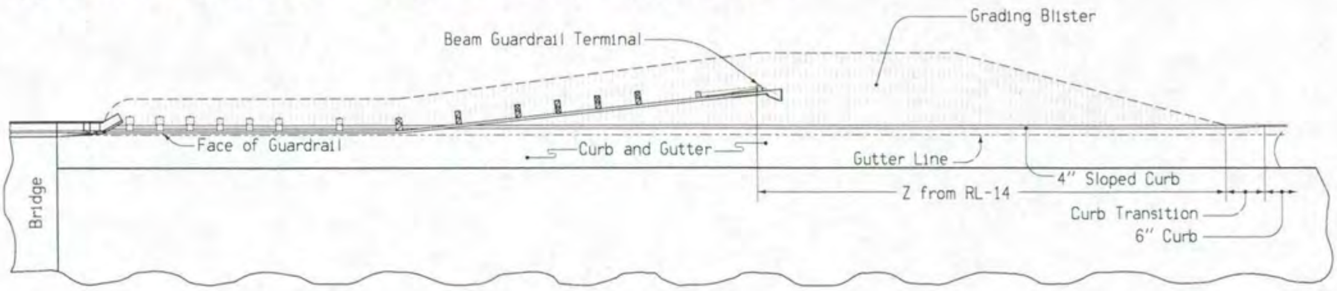


Figure 1: 4-inch sloped curb should be used throughout the guardrail installation.

Traffic Control

Fundamental Principles of Traffic Control

Originally Issued: 09-01-95

Problems of traffic control occur when traffic must be moved through or around road or street construction, maintenance operations, or utility work. No standard sequence of signs or other control devices can be set up as an inflexible arrangement for all situations due to the variety of conditions encountered. The guidelines in this chapter are directed to the safe and expeditious movement of traffic through zones of construction and maintenance and to the safety of the work force performing these operations. These guidelines are based on the following fundamental principles of traffic control.

A. Traffic safety in construction and maintenance zones should be an integral and high-priority element of every project from planning through design and construction.

- The basic principles used in the design of permanent roadways should also govern the design of traffic control in work zones.
- Appropriate traffic control, based on the complexity of the job, should be prepared by knowledgeable persons. Pertinent information should be gathered, analyzed, and used to prepare the traffic control plan.

B. Traffic movement should be inhibited as little as possible.

- Assume motorists will reduce their speed only if they perceive a need to do so. Therefore, reduced-speed zoning should be avoided as much as possible.
- Frequent and abrupt changes in geometrics (lane narrowing, dropped lanes, lane shifting) should be avoided. Proper distances between maneuvers must be maintained.
- Consideration should be given to the safe operation of work vehicles, especially on high-volume, high-speed roadways.
- Construction time should be minimized to reduce driver exposure to potential risks.

C. Motorists should be given clear and positive guidance when approaching and traversing construction areas.

- Proper warning, delineation, and channelization should be provided to assure positive guidance through the work area.
- Existing traffic controls (signs, pavement markings, etc.) that are inappropriate to or conflict with temporary traffic controls should be removed or covered so that motorists will not be misled.

D. The designer should make periodic reviews of actual traffic control installations. Special attention should be given to the effectiveness of the traffic control and any problems that have been encountered. This information will be useful for designing traffic control on future projects.

Traffic Control Zones

Originally Issued: 09-01-95

When traffic is affected by construction or maintenance activities, traffic control is needed to help guide and protect motorists, pedestrians, and workers in a traffic control zone. A traffic control zone is the segment of roadway between the first advance warning sign and the point beyond the work area where traffic is no longer affected. A traffic control zone can be divided into the following four parts, as shown in Figure 1.

- The Advance Warning Area
- The Transition Area
- The Activity Area
- The Termination Area

Advance Warning Area

An advance warning area is necessary in all traffic control zones because drivers need to know what to expect. Before reaching the work area, drivers should have enough time to alter their driving patterns. The advance warning area may vary from a series of signs starting a mile in advance of the work area to a single sign or flashing lights on a vehicle.

The advance warning area must be long enough to give motorists time to respond to changing conditions. Advance warning distances should be:

- 1/2 mile to 1 mile for freeways and expressways,
- 500 feet for most other roadways or open highways,
- at least one block for urban streets.

Transition Area

When work is performed within one or more traveled lanes, a lane closure is required. In such cases, a transition area becomes necessary. In the transition area, traffic is channelized from the normal highway lanes to the path required to drive around the work area. The transition area contains the tapers that are used to close lanes. Refer to Section 9A-3 for more information on tapers.

The transition area should be obvious to drivers. The correct path should be clearly identified by channelizing devices and pavement markings. On long-term projects, existing pavement markings should be removed when they conflict with the transition.

Activity Area

The activity area is that portion of the roadway where some closure is in effect and where the work activity is taking place. It can be divided into two spaces: the buffer space and the work space. Channelizing devices are to be placed adjacent to the traveled way to keep traffic out of these spaces.

Buffer Space

The buffer space is the open or unoccupied space between the transition area and the work space. The buffer space provides a margin of safety for both traffic and workers. If a driver does not see the advance warning or fails to negotiate the transition, the buffer space provides time for the driver to react before entering the work space. Lengths of buffer spaces range from 100 to 500 feet depending on the type of roadway. Refer to Standard Road Plans RS-3, RS-4, RS-63 and RS-64 for typical lengths of buffer spaces.

Work Space

The work space is that portion of the roadway which contains the work activity. The work space is closed to traffic and set aside for exclusive use by workers, equipment, and construction materials. The area is usually delineated by channelizing devices or shielded by barriers to exclude traffic and pedestrians.

Spacing of Channelizing Devices in Activity Areas

Devices placed adjacent to the traveled way to keep traffic out of the activity area should be spaced so that it is apparent a portion of the roadway is closed to traffic. The extent and type of activity, the speed limit of the roadway, and the vertical and horizontal alignment of the roadway all affect how the proper spacing is determined. The designer should avoid gaps in traffic control that may falsely indicate to drivers that they have passed the work area. If the work area includes intermittent activity throughout a 1-mile section, drivers should be reminded periodically that they are still in a work area. When the work zone exceeds 1/4 mile, additional type II barricades should be placed in the closed lane at 1000-foot intervals. Refer to pertinent Standard Road Plans for more information.

Termination Area

After motorists have passed the work area, they should have a positive indication that they may drive in the lane that has been closed. The termination area provides a short distance for traffic to clear the work space and return to the normal traffic lanes. It extends from the end of the activity area to the end of the downstream taper, or to the END ROAD WORK sign. When used, the downstream taper should be approximately 100 feet in length with a minimum of four channelizing devices.

For some work operations, such as spot-location maintenance repair, it may not be necessary to use a downstream taper since it will be obvious to drivers that they have passed the work area.

There are other occasions where the termination area could include a transition. For example, if a taper is used to shift traffic into opposing lanes past the activity area, then the termination area should include a taper to shift traffic back to its normal path.

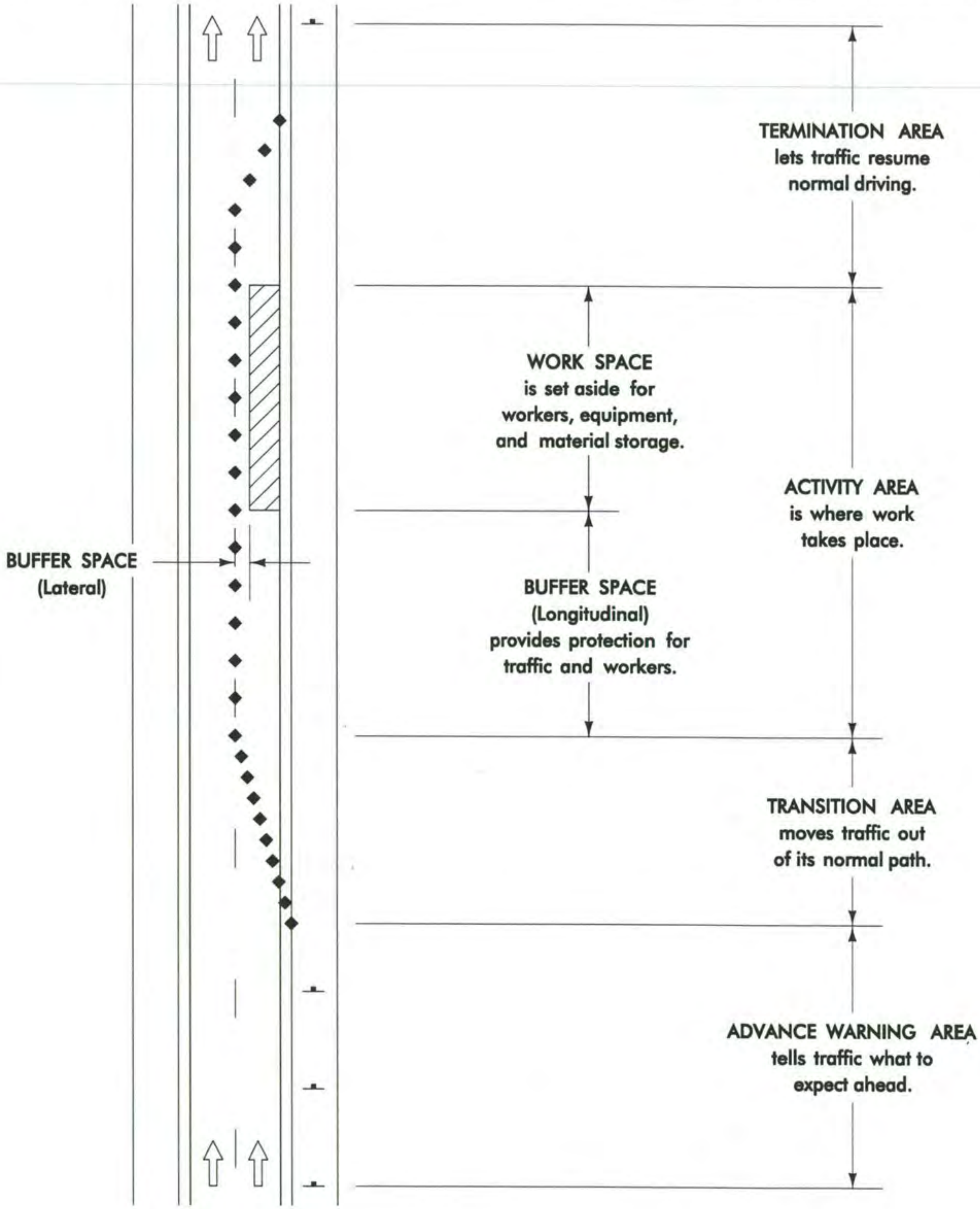


Figure 1: Work zone areas.

Tapers

Originally Issued: 09-01-95

The most important element in the transition area is the taper that provides channelization. An inadequate taper produces undesirable traffic operations, which could lead to accidents within the work area. This section describes the different types of tapers and their uses; each type is shown in Figure 1.

Merging Taper

A merging taper is used on multilane roadways when the number of traffic lanes is reduced. The length of the merging taper must be long enough for vehicles traveling side-by-side to adjust their speeds and merge into a single lane before the end of the transition. The minimum desirable length for a merging taper on all freeways, expressways, and other roadways having a posted speed of 45 mph or greater may be computed by the formula

$$L = W \times S$$

where L is the taper length in feet, W the width of the closed lane in feet, and S the posted speed in miles per hour. For merging tapers on urban, residential or other streets where the posted speeds are 40 mph or less, the length may be calculated by the formula

$$L = \frac{WS^2}{60}$$

where L, W, and S have the same values as above.

The taper length formulas above apply to ideal conditions (flat grades, straight alignment, etc.) and should be adjusted to provide adequate sight distances on approaches to channelization. Other field restrictions, such as proximity of ramps or crossroads to the work site, may warrant adjustment of the taper lengths. Better traffic operation will result when the taper lengths are increased rather than decreased below the minimum desirable lengths.

Shifting Taper

A shifting taper is used to direct traffic into a different travel path when a merge is not required. A minimum length of L/2 is adequate, where L is computed from the formulas for merging tapers. However, where space is available, the full values of L should be used to provide a high level of service on high-speed facilities. When using the formulas to calculate the length of a shifting taper, the value of W should be the lateral shift in feet, which may be more or less than a lane width.

An alternate method for shifting traffic when there is no merge is the use of horizontal curves designed for normal highway speeds. Horizontal curves allow the completion of lateral shifting maneuvers in less longitudinal distance than shifting tapers. Horizontal curves work best when the lateral distance is large, as in the case of high-speed median crossovers. However, care must be exercised so that differences in highway geometry do not present a safety problem.

Shoulder Taper

When a shoulder is closed on a high-speed facility, it should be treated as a closure of a portion of the roadway, and the work area on the shoulder should be preceded by a shoulder taper. Shoulder tapers should have a minimum length of L/3.

Two-Way Traffic Taper

Two-way traffic tapers are used in advance of a work area that occupies a portion of a two-way roadway in such a way that traffic from each direction must alternate through the work area. Traffic is controlled by a flagger or a temporary signal device. In this situation, a short taper having a maximum length of 100 feet should be used to direct traffic into the one-lane section. A longer taper encourages high-speed and early lane changes, possibly directing motorists into opposing traffic.

Distance Between Tapers

Sometimes several tapers must be used together in a series to provide adequate traffic control. When multiple tapers are used, sufficient distance must be maintained between them to give the motorist time to prepare for the next maneuver. Additional signing may be necessary and the motorist needs time to process the information. Examples of multiple taper use are shown in Figure 2. Tapers should be carefully located and spaced to accommodate traffic at ramps and intersections, particularly in urban areas.

Spacing of Channelizing Devices in Tapers

The spacing of channelizing devices in merging and shifting tapers should be a distance in feet which is approximately equal to the regulatory speed limit in mph. For example, if a taper is on a roadway with a speed limit of 55 mph, the devices should be spaced at 55 feet.

For two-way traffic tapers, a minimum of four channelizing devices should be spaced 25 to 30 feet apart, regardless of the speed limit.

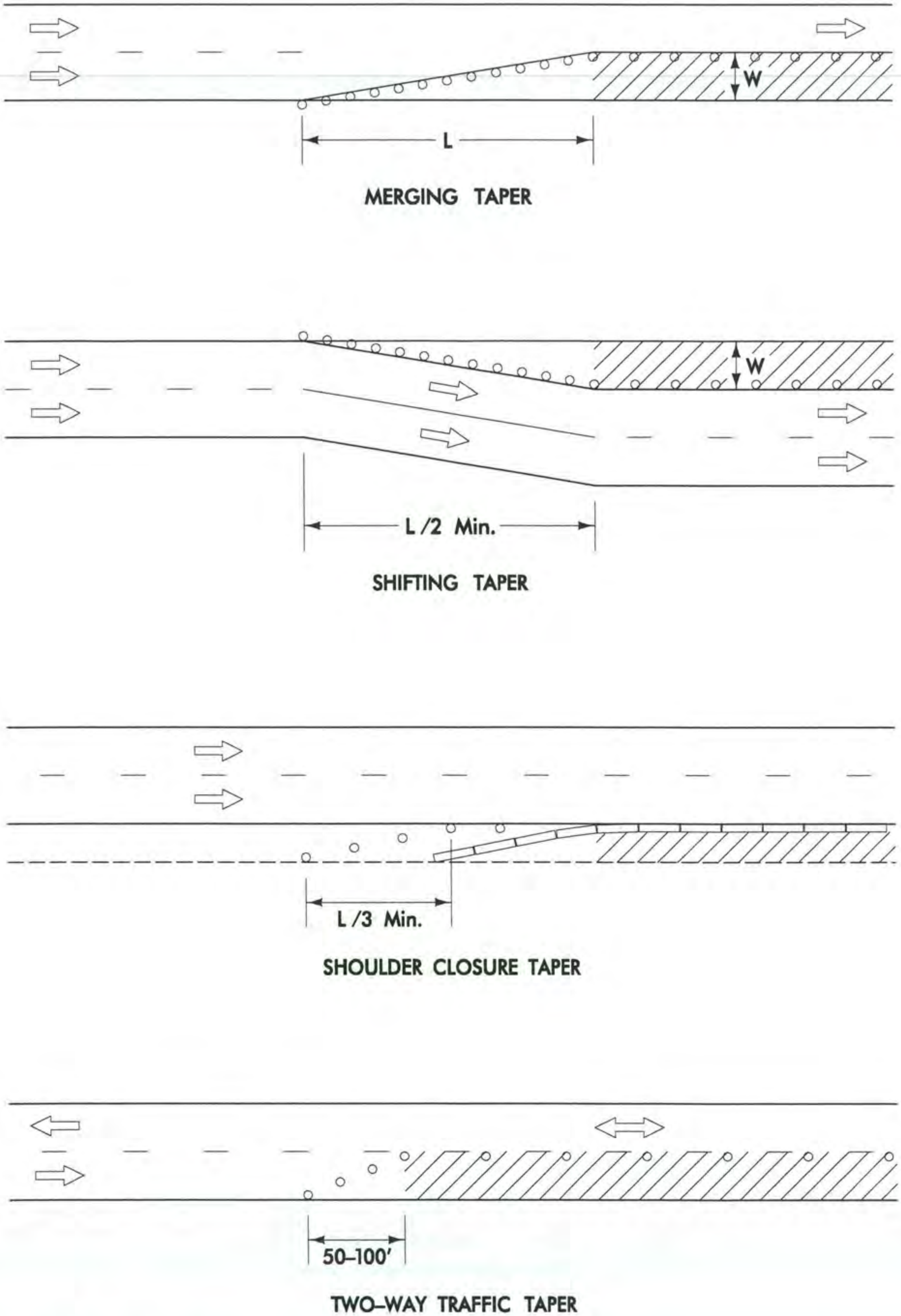


Figure 1: Taper details.

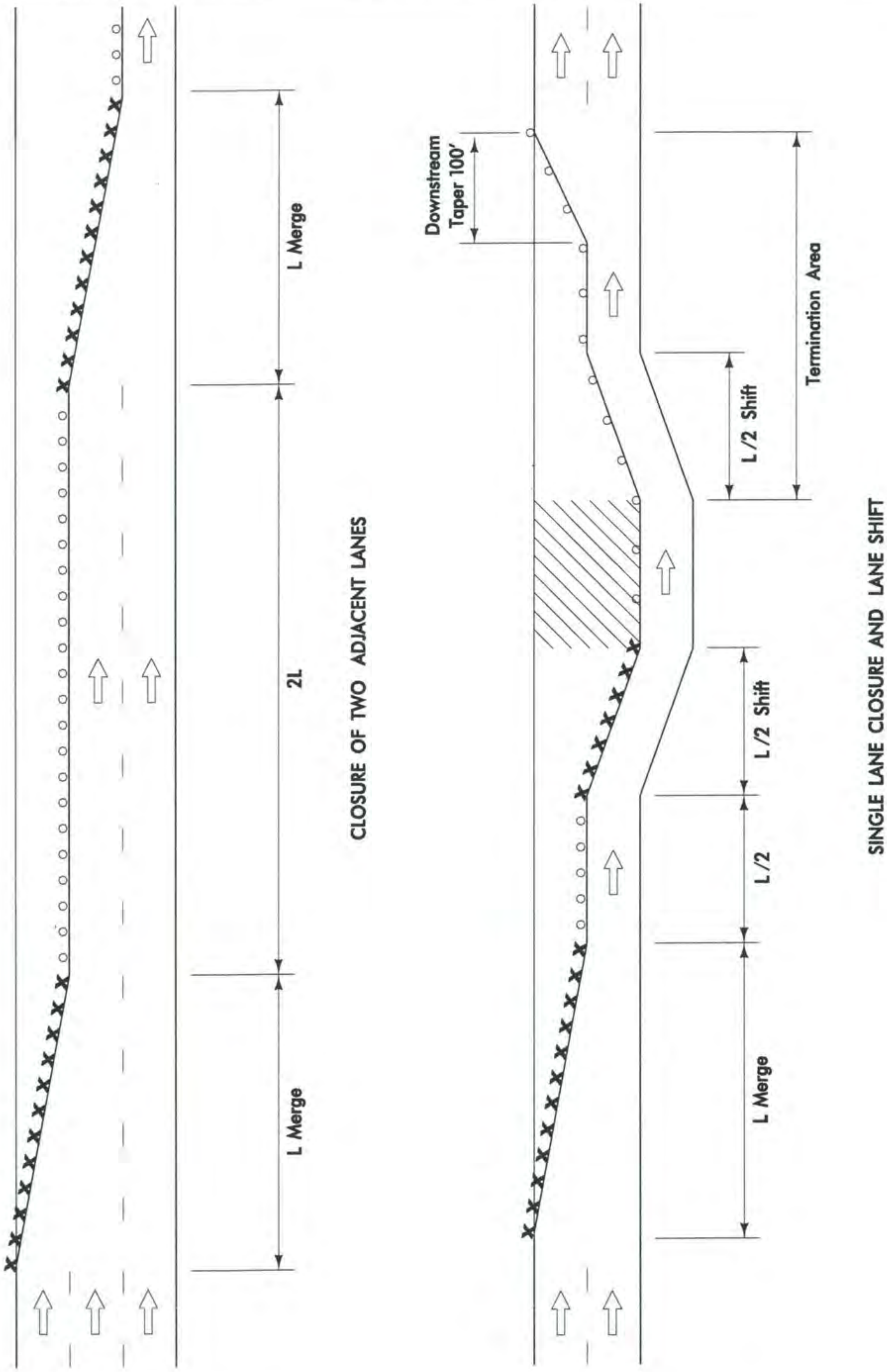


Figure 2: Use of multiple tapers.

Tapers

Originally Issued: 09-01-95

The most important element in the transition area is the taper that provides channelization. An inadequate taper produces undesirable traffic operations, which could lead to accidents within the work area. This section describes the different types of tapers and their uses; each type is shown in Figure 1.

Merging Taper

A merging taper is used on multilane roadways when the number of traffic lanes is reduced. The length of the merging taper must be long enough for vehicles traveling side-by-side to adjust their speeds and merge into a single lane before the end of the transition. The minimum desirable length for a merging taper on all freeways, expressways, and other roadways having a posted speed of 45 mph or greater may be computed by the formula

$$L = W \times S$$

where L is the taper length in feet, W the width of the closed lane in feet, and S the posted speed in miles per hour. For merging tapers on urban, residential or other streets where the posted speeds are 40 mph or less, the length may be calculated by the formula

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where L, W, and S have the same values as above.

The taper length formulas above apply to ideal conditions (flat grades, straight alignment, etc.) and should be adjusted to provide adequate sight distances on approaches to channelization. Other field restrictions, such as proximity of ramps or crossroads to the work site, may warrant adjustment of the taper lengths. Better traffic operation will result when the taper lengths are increased rather than decreased below the minimum desirable lengths.

Shifting Taper

A shifting taper is used to direct traffic into a different travel path when a merge is not required. A minimum length of L/2 is usually adequate, where L is computed from the formulas for merging tapers. When using the formulas to calculate the length of a shifting taper, the value of W should be the lateral shift in feet, which may be more or less than a lane width.

On high-speed facilities, the minimum length of shifting tapers should not be less than L/2 or 200 feet, whichever is greater. Shifting tapers shorter than 200 feet, regardless of the lateral shift, may lead to unsatisfactory operation. Where space is available, the full values of L should be used to provide a high level of service on high-speed facilities.

An alternate method for shifting traffic when there is no merge is the use of horizontal curves designed for normal highway speeds. Horizontal curves allow the completion of lateral shifting maneuvers in less longitudinal distance than shifting tapers. Horizontal curves work best when the lateral distance is large, as in the case of high-speed median crossovers. However, care must be exercised so that differences in highway geometry do not present a safety problem.

Shoulder Taper

When a shoulder is closed on a high-speed facility, it should be treated as a closure of a portion of the roadway, and the work area on the shoulder should be preceded by a shoulder taper. Shoulder tapers should have a minimum length of L/3.

Two-Way Traffic Taper

Two-way traffic tapers are used in advance of a work area that occupies a portion of a two-way roadway in such a way that traffic from each direction must alternate through the work area. Traffic is controlled by a flagger or a temporary signal device. In this situation, a short taper having a maximum length of 100 feet should be used to direct traffic into the one-lane section. A longer taper encourages high-speed and early lane changes, possibly directing motorists into opposing traffic.

Distance Between Tapers

Sometimes several tapers must be used together in a series to provide adequate traffic control. When multiple tapers are used, sufficient distance must be maintained between them to give the motorist time to prepare for the next maneuver. Additional signing may be necessary and the motorist needs time to process the information. Examples of multiple taper use are shown in Figure 2. Tapers should be carefully located and spaced to accommodate traffic at ramps and intersections, particularly in urban areas.

Spacing of Channelizing Devices in Tapers

The spacing of channelizing devices in merging and shifting tapers should be a distance in feet which is approximately equal to the regulatory speed limit in mph. For example, if a taper is on a roadway with a speed limit of 55 mph, the devices should be spaced at 55 feet.

For two-way traffic tapers, a minimum of four channelizing devices should be spaced 25 to 30 feet apart, regardless of the speed limit.

Speed Control

Originally Issued: 09-01-95

Studies have shown that reliance upon speed-zone signing alone is not an effective method of reducing travel speed in work zones. This should be recognized during the design of a project. Below are some guidelines for determining speed limits and advisory speeds through traffic control zones.

A. For roadways with a regulatory speed limit of 60 mph or greater:

- A regulatory 55 mph speed limit should be posted when traffic is placed in Two-Lane, Two-Way Operation (TLTWO, head-to-head);
- A 55 mph advisory speed should be posted for approaches to bridges where the work requires traffic to deviate onto the shoulder to cross the bridge.

B. On-site detours, shoulder runarounds, and temporary connections should have advisory speeds posted in accordance with the geometric design.

C. An advisory speed of 35 mph should be posted for one-lane bridges when traffic is controlled by temporary signals.

Traffic Control Plans

Originally Issued: 09-01-95

A formal traffic control plan (TCP) shall be included in the plans, specifications, and estimates (PS&E) for all projects. Such a plan may range in scope from a very detailed TCP designed solely for a specific project to a reference of standard plans. The degree of detail in the TCP will depend on the complexity of the project and on the interaction of traffic needs and construction activities. However, every TCP should include a set of traffic control notes, accompanied by a set of traffic control layouts when necessary.

Designers should make use of the videolog library and available aerial photos when preparing the traffic control plan so that unique characteristics within the traffic control zone may be identified.

The designer should also work with the respective District Office and the resident engineer so that potential problems may be identified and resolved during the design process. One should never assume that a problem will be resolved in the field during construction. If something is a problem during the design phase, then it will be a problem during construction.

General Information

The following items need to be considered when preparing the traffic control plan.

A. Type of work

B. Location

- any intersections within 1000 feet of the work area
- access to residences and businesses
- other projects in the vicinity
- sight distance

C. Traffic

- current traffic / peak hour volumes
- special events and recreational traffic
- pedestrians / bicyclists
- truck traffic
- existing speed limit
- roadway capacity

D. Existing Roadway

- number and type of traffic lanes (divided / undivided)
- shoulder widths

E. Staging

- location of work (on roadway, shoulder, sidewalk)
- number of lanes required for work activity
- hours during which lane closure is permitted
- length of work area
- time of exposure to risks
- proximity of traffic to unfinished work

Traffic Control Layouts

The *Manual on Uniform Traffic Control Devices for Streets and Highways* (MUTCD)[1] includes standard layouts for typical roadway work sites. However, numerous field situations occur where little or no guidance is offered by these layouts. Several important areas not covered are urban streets, moving operations, ramps, and intersections.

The department has developed additional typical layouts in an attempt to address the wide variety of work site conditions found in construction and maintenance work. It is useful to examine these layouts for information, as they represent input and discussion from a broad spectrum of knowledgeable persons in various areas of the department. The various traffic control layouts may be found in section RS of the *Standard Road Plans* and the 520 and 521 series of *Road Design Details.*

Layouts in the above referenced manuals are typical layouts. Special situations may exist for a given work site which require modification. Any changes must comply with principles set forth by the MUTCD and the department.

Traffic Control Notes

All traffic control plans must have a set of traffic control notes that describe the overall plan. Use Tabulation 108-23 for these notes.

In order to convey critical information more effectively, it is desirable to first list notes which contain specific project information, followed by notes of a more general nature. This helps to ensure that critical information is not overlooked by those responsible for executing the traffic control plan. The notes should be arranged in order of importance as follows.

1. Indicate whether thru traffic is to be maintained, or traffic is to be detoured off the project.
2. List Standard Road Plans, Detail Sheets and special layouts to be used.
3. Include notes that are unique to a specific project or type of work (e.g., special working hours, special barricade spacing, when to use special layouts).
4. Include standard traffic control notes.

[1] FHWA, *Manual on Uniform Traffic Control Devices*, Washington, D.C., U.S. Government Printing Office, 1988.

Items 1 through 3 will vary with each project. Item 4 will be similar on all projects. The following items indicate the wording you should use in writing the traffic control notes, filling in the appropriate information for each case.

Opening Traffic Control Notes (#1 & #2 above)

- Traffic will be maintained on [route number] at all times.

or:

[route number] will be closed to traffic.

- Traffic control on this project shall be in accordance with Standard Road Plans [plan number], and Detail Sheets [sheet number] contained in the plans. For additional complementary information, refer to Part VI of the *Manual on Uniform Traffic Control Devices* and to the current *Standard Specifications*.

Specific Project Notes (#3 on page 2)

For scarified areas on resurfacing projects:

- "ROUGH ROAD" signs shall be erected in advance of scarified areas in accordance with Article 2214.05 of the Standard Specifications.[2]

For resurfacing projects with at-grade intersections:

- Individual intersections that must be closed for the paving train (tack application through final rolling) to pass shall have a flagger stationed at each approach.

For patching projects on multilane highways:

- Where a patch extends into two traffic lanes, work shall be completed in the median lane first.

For coordination between several projects in the same area:

- The contractor shall coordinate traffic control with other projects in the area.

Standard Traffic Control Notes (#4 on page 2)

The following are general notes to be included in all projects. Sometimes, it will be obvious that slight modifications must be made to accurately describe the traffic control plan for a particular project. But, for the sake of uniformity, the notes should always appear in the same order.

- All traffic control devices shall be furnished, erected, maintained, and removed by the contractor.
- Where possible, all post-mounted signs shall be placed at least 2 feet beyond the curb or edge of shoulder.
- The location for storage of equipment by the contractor during nonworking hours shall be as approved by the engineer in charge of construction.
- (Add for Interstate work) Parking of private vehicles on Interstate right-of-way will not be allowed. Parking of unattended equipment within the median or storage of equipment within 50 feet of the edge of pavement will not be allowed.
- The engineer may require modifications to the pavement marking details shown. Conflicting permanent edge lines, centerlines, or lane lines shall be removed. As applicable, permanent

[2] Iowa Department of Transportation, *Standard Specifications for Highway and Bridge Construction*, Ames, IA.

edge lines, centerlines, and lane lines shall be placed before the roadway is returned to normal traffic. The current Standard Specifications and Supplemental Specifications shall apply.

- Proposed sign spacing may be modified as approved by the engineer to meet existing field conditions or to prevent obstruction of the motorist's view of permanent signing.
- Permanent signing that conveys a message contrary to the message of the temporary signing and not applicable to the working conditions shall be covered by the contractor when directed by the engineer.
- Proposed changes in the traffic control plan shall be reviewed with the Office of Construction before changes are made.

Review of Traffic Control Plans

Traffic control plans should be reviewed for completeness and accuracy. Selected projects will be reviewed by the Preliminary Traffic Control Committee. This committee represents various offices of the DOT, the FHWA, and the Iowa Highway Patrol. Its purpose is to provide guidance and make recommendations during the design phase on complex or unusual projects. The recommendations of the Preliminary Traffic Control Committee are subject to the approval of the Design Engineer.

Basic Requirements of Traffic Control Devices

Originally Issued: 09-01-95

A traffic control device is a sign, signal, marking, barricade, or other device placed on or adjacent to a street or highway to regulate, warn, or guide traffic. Traffic control devices assist motorists with guidance and navigation in order to traverse safely any road open to public traffic. The MUTCD[1] states:

"The purpose of traffic control devices and warrants for their use is to help insure highway safety by providing for the orderly and predictable movement of all traffic, motorized and non-motorized, throughout the national highway transportation system, and to provide such guidance and warnings as are needed to insure the safe and informed operation of individual elements of the traffic stream."

The MUTCD also sets forth basic principles that govern the design and use of traffic control devices. To be effective, a traffic control device should meet five basic requirements. It should:

- Fulfill a need,
- Command attention,
- Convey a clear, simple meaning,
- Command respect of the road user, and
- Give adequate time for proper response.

These principles will underlie the specifications in Sections 9B-2 through 9B-10, which describe the design and application of traffic control devices used in work zones.

[1] FHWA, *Manual on Uniform Traffic Control Devices*, Washington, D.C., U.S. Government Printing Office, 1988.

Signs

Originally Issued: 09-01-95

Street or highway construction and maintenance signs fall into the same three categories as do other traffic signs: namely, *Regulatory* signs, *Warning* signs, and *Guide* signs. This section describes the different types of signs, their proper use and their positioning.

Regulatory Signs

Regulatory signs impose legal obligations or restrictions on the motorist. Their use must be authorized by the officials having appropriate jurisdiction.

Regulatory signs are usually rectangular and carry a black legend and border on a white background. However, several regulatory signs are red and white and have differing shapes. These signs are the "STOP" sign, the "YIELD" sign, the "DO NOT ENTER" sign, and the "WRONG WAY" sign.

Some typical regulatory signs are shown in Part VI of the MUTCD[1].

Warning Signs

Warning signs for construction and maintenance projects are used to inform motorists of unusual conditions that may be expected when work is in progress.

Warning signs for work zones are 48" × 48", diamond shaped (square with one diagonal vertical) and have a black symbol or legend on an orange background. Some typical standard warning signs may be found in Part VI of the MUTCD.

In some instances, there may be no standard warning sign suitable for a given situation. Special signs may be designed with appropriate messages. However, in order to maintain uniformity, the use of non-standard signs should be held to a minimum and used only when approved by the State Traffic Engineer.

Advisory Speed Plates

Advisory speed plates are intended to be used in conjunction with warning signs to indicate a maximum recommended speed through the work area. A plate is to have a black legend on an orange background and must be mounted on the same assembly below the warning sign it supplements. It must not be used in conjunction with any sign other than a warning sign, nor can it be used alone.

Advisory speeds must be posted when the recommended maximum speed is at least 10 mph below the regulatory speed limit. The engineer in charge of construction may lower the advisory speed when deemed appropriate.

[1] FHWA, Manual on Uniform Traffic Control Devices, Washington, D.C., U.S. Government Printing Office, 1988.

Guide Signs

Guide signs show destinations, directions, distances, services, points of interest and other geographical or cultural information. They may be used if their placement does not distract from the more important regulatory and warning signs.

Part VI of the MUTCD states that the following informational signs are required at work zones:

- Standard route markings, to the extent that temporary route changes are necessary. This assembly shall include the black-on-orange detour marker (M4-8).
- Directional signs and street name signs. When used with detour routing, these signs may have a black legend on an orange background.
- Special information signs relating to the work being done. Examples are: "ROAD WORK NEXT 5 MILES," "END ROAD WORK," "DETOUR," and "PILOT CAR FOLLOW ME." These signs shall have a black message on an orange background.

Position of Signs

Signs are to be placed in a position where they will convey their messages most effectively. Sign location should be based on existing field conditions. As a general rule, signs should be placed on the right hand side of the roadway. A duplicate sign may be erected on the left hand side of the roadway when special emphasis is deemed necessary. Dual signs are required on divided highways.

According to Part VI of the MUTCD, in open areas warning signs should be placed approximately 1500 feet in advance of the condition to which they are calling attention. When a series of advance warning signs is used, the warning sign nearest the work site is to be placed approximately 500 feet from the point of restriction with additional signs at 500 to 1000 foot intervals. A *rule of thumb* for spacing between signs in a series is:

- 250 feet for urban, residential, or business districts, or for roads with speeds under 40 mph,
- 500 feet for urban arterials and rural roads, or for roads with speeds over 40 mph, and
- 1000 feet for expressways and freeways.

In addition, the advance warning distance on expressways and limited access facilities should be increased to one-half mile or more. Typical sequences and spacings of advance warning signs are shown in Part VI of the MUTCD.

Channelizing Devices

Originally Issued: 09-01-95

Channelizing devices are used to warn motorists of unusual conditions created by construction or maintenance activities in or near the traveled way, and to guide motorists safely past the work area. Channelizing devices include cones, vertical panels, drums, barricades, and barriers. Part VI of the MUTCD[1] describes in detail the different types of channelizing devices and their uses.

Spacing of Channelizing Devices

The spacing of channelizing devices through merging and shifting tapers should be a distance in feet which is approximately equal to the regulatory speed limit in miles per hour. For example, if a taper is on a roadway with a speed limit of 55 mph, the devices should be spaced 55 feet apart. For twoway traffic tapers, a minimum of four channelizing devices should be spaced 25 to 30 feet apart, regardless of the speed limit. See Section 9A-3 for more information on tapers.

Devices placed adjacent to the traveled way to keep traffic out of the activity area should be spaced so that it is apparent a portion of the roadway is closed to traffic. The extent and type of activity, the speed limit of the roadway, and the vertical and horizontal alignment of the roadway all affect how the proper spacing is determined. The designer should avoid gaps in traffic control which may falsely indicate to drivers that they have passed the work area. If the work area includes intermittent activity throughout a section of one mile or more, drivers should be reminded periodically that they are still in a work area. When the work zone exceeds 1/4 mile, additional Type II barricades should be placed in the closed lane at 1000-foot intervals. Refer to pertinentStandard Road Plans for more details about the spacing of channelizing devices.

Use of Channelizing Devices

When traffic control zones are to be in place during nighttime hours, drums must be used on all merging tapers, onsite detours, and high-speed crossovers. Refer to the RS series of the *Standard Road Plans* and the 520 and 521 series of the *Road Design Details* for more information.

Cones may be used during daylight hours only, but only as indicated in the appropriate Standard Road Plans and Road Design Details.

[1] FHWA, *Manual on Uniform Traffic Control Devices*, Washington, D.C., U.S. Government Printing Office, 1988.

Pavement Markings and Delineators

Originally Issued: 09-01-95

Pavement markings are very effective in guiding traffic through work zones. Pavement markings may be supplemented by raised pavement markers (RPMs) and delineators to outline the vehicular path and lead traffic around a work zone. This section describes the different types of pavement markings and delineators and presents guidelines for their use.

Pavement Markings

Drivers use pavement markings as a primary means of guidance. Pavement markings include lane lines, edge lines, centerlines, pavement arrows, and word messages. Whenever traffic is shifted from its normal path (lane closure, lane narrowing, lane shift), conflicting pavement markings should be removed. Exceptions to this may be made for short-term operations such as a work zone under flagger control and moving or mobile operations. Pavement markings are required on the following:

- Temporary "No Passing" zones,
- Lane closure tapers that precede temporary barrier rails,
- On-site detours (paved),
- Shoulder runarounds (paved),
- Two-lane, two-way operations (TLTWO),
- Lane width reductions,
- Lane shifts, and
- Edge line drop-offs.

Eight-inch wide edge lines and lane lines should be used to delineate crossovers and lane shifts on high-speed roadways (standard line width is 4 inches).

Whenever it is necessary to place a temporary pavement marking diagonally across a permanent lane surface, Section 2527 of the *Standard Specifications* requires removable tape to be used instead of regular traffic paint. The intent is to leave no diagonal scars across a permanent driving lane after the marking is removed because a motorist may interpret a scar as a pavement marking. Thus, the project plans should indicate which pavement markings are to be removable tape.

Raised Pavement Markers

Raised pavement markers are used to supplement standard pavement markings when a higher degree of nighttime visibility is warranted. Figure 1 shows a typical layout for raised pavement markers. Raised pavement markers are to be used with shifting tapers on high speed, multilane roadways.

Delineators

Delineators are post-mounted retroreflective units with minimum dimensions of approximately 3 inches. The reflector units can be seen up to 1,000 feet under normal conditions when reflecting the high beam of standard automobile headlights.

Delineators should not be used alone as channelizing devices in work zones but may be used to supplement the other channelizing devices in outlining the correct vehicle path. To be effective, several delineators need to be seen at the same time. The color of the delineator should be the same as the pavement marking that it supplements. Delineators are not to be used as warning devices.

Post-mounted delineators should be used with on-site detours and shoulder runarounds. They should be spaced no more than 50 feet apart.

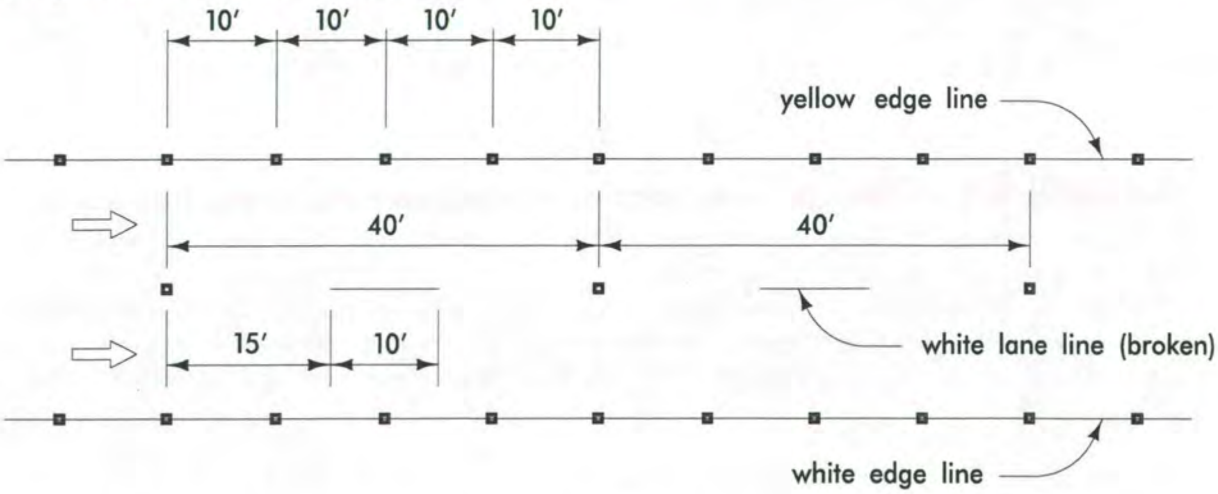

Figure 1: Raised pavement markings used to supplement pavement markings.

Warning Lights

Originally Issued: 09-01-95

Warning lights are used to indicate and delineate the safe path of travel. Flashing lights are to be mounted on barricades singly to indicate an obstacle on or adjacent to the roadway. Flashers are also effectively used to draw attention to warning signs in the traffic control zone. Steady-burn warning lights may be used at night on barricades or other channelizing devices to delineate the safe travel path.

Barricade lighting offers an extra measure of protection for nighttime traffic movements through a work area, especially in the following situations:

- Where reflectorized panels may be covered with dust or snow;
- In times of decreased visibility due to rain, snow, or fog;
- On barricades that are on curves, around corners, and in driveways;
- For alerting pedestrians and cyclists who travel without headlights;
- At dangerous locations and for channelization on high-speed highways.

Shown below are the principal types of warning lights and their uses.

- *Type A low-intensity flashing lights* are appropriate for use on a channelizing device to warn of an isolated obstacle at night or to call attention to warning signs at night.
- *Type B high-intensity flashing lights* are appropriate to use on advance warning signs day and night.
- *Type C steady-burn lights* are intended for use on a series of channelizing devices or on barriers to delineate the traveled way through and around obstructions in a temporary traffic control zone. However, since the department requires channelizing devices to be reflectorized with Type III or Type IV sheeting, Type 'C' steady-burning lights are not used in Iowa. For more information regarding reflective sheeting, refer to current Iowa DOT specifications for traffic control devices.

Floodlights

Originally Issued: 09-01-95

Construction activities often create conditions that pose more significant risk to drivers at night, when visibility is sharply reduced. Consequently, it becomes necessary to supplement traffic control devices with some sort of lighting during such periods.

When area lighting is not sufficient, floodlights are used to light work activities, flagger stations, and other areas that are restricted or pose potential risks to drivers. Floodlighting provides increased visibility so the driver may better understand the proper manner in which to pass through such areas.

Although floodlighting provides increased visibility, it may also enable the driver to see non-essential and distracting portions of the work area. In these situations, adequate delineation may be provided by channelizing devices or pavement markings, which will indicate a path without illuminating roadside distractions.

Generally, floodlighting should be used at the following locations:

- Median crossovers on unlit, high-speed facilities;
- On-site detours, shoulder detours, or areas where construction zone traffic is routed off the existing roadway;
- Temporary barrier rail that occupies a portion of a traffic lane;
- Unlit flagger stations during nighttime flagging operations.

Arrow Displays

Originally Issued: 09-01-95

Arrow displays are special lighting devices used to warn and guide traffic. They are generally trailer-mounted and operate on a self-contained power source. An arrow display is used for advance warning when a lane is closed. It tells motorists that they should merge into the adjacent lane, as indicated by the direction of the arrow.

Since arrow displays are highly visible up to a mile away, they are particularly effective under high-speed and high-density traffic conditions. At night, they are effective when other traffic control devices cannot provide adequate warning. During daylight hours, they provide advance warning of construction or maintenance activities that may be hidden from the motorist's view by high-volume traffic.

Arrow displays should be used for lane closures on multilane highways. When used for multiple lane closures, one arrow display may be used for each closed lane. The number of arrow displays must not exceed the number of lane closures. They should NOT be used under the following conditions:

- When the location of the work does not require any lanes to be closed,
- When all of the work is on or outside the shoulder and there is no interference which requires the adjacent traveled lane to be closed,
- On a normal two-lane, two-way roadway,
- When traffic is shifted out of its normal path and the number of traffic lanes remains the same.

Use of arrow displays under the above conditions will lead to the loss of credibility when they are used for lane closures.

Arrow displays should be located for optimum visibility. Care must be taken to avoid driver confusion in the vicinity of ramps, median crossovers, and sideroad intersections. In such cases, the arrow display should be placed on the shoulder near the beginning of the taper. Where the shoulders are too narrow or nonexistent, it should be placed in the closed lane behind the channelizing devices. Placement at the start of the taper is preferred to placement in the middle of the taper. Refer to Standard Road Plans RS-63 and RS-64 for the typical placement of arrow displays.

Arrow displays are capable of the following mode selections:

- Left or right flashing or sequential arrows,
- Left or right sequential chevrons,
- Double flashing arrows,
- Caution mode (4 or more lights arranged in a pattern which does not indicate direction).

In Iowa, left or right sequential chevrons are used for lane closures.

Changeable Message Sign

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A changeable message sign (CMS) is a traffic control device with the flexibility to display a variety of messages. Thus a CMS can be adapted to the needs of work zone traffic control as conditions change. The CMS should be used in conjunction with conventional signs, pavement markings, and lighting. CMS's have a wide variety of applications in work zones, some of which are:

- Speed control,
- Warning of road closures,
- Accident management,
- Notice of width restrictions,
- Advisories on construction scheduling,
- Advisories on traffic delays, and
- Warning of adverse conditions.

A CMS should be used only when a conventional post-mounted or skid-mounted sign would not be adequate. Frequent and prolonged use of a CMS will diminish its effectiveness.

The message panels on the CMS usually contain room for 3 lines of eight characters each. The message panel is visible from about one-half mile. Individual characters can be seen from 850 feet under normal conditions. Drivers need approximately one second per word to comprehend a message.

Temporary Barrier Rail

Originally Issued: 09-01-95

Temporary Barrier Rails (TBR) are concrete devices designed to prevent errant vehicles from penetrating into areas behind the barrier. The purpose is twofold: to protect vehicles and their occupants from the work area and to protect workers and equipment from vehicles leaving the traveled way. This section describes the various components of a TBR system and presents guidelines for its proper use.

Warrants for Use

The use of a TBR should be based on an engineering analysis that compares the relative severity of impacting the TBR versus that of hitting the unshielded object. Use may also be based on the probability of run-off-the-road accidents and economic factors. A TBR should be installed only if it reduces the severity of potential accidents. The frequency of accidents will not generally affect the severity. Refer to Standard Road Plan RE-71 for TBR dimensions. Listed below are situations where a TBR may be warranted.

- Bridge deck overlays
- Unprotected drop-offs on structures
- Drop-offs within 10 feet of the traveled way on the Interstate
- Bridge pier construction
- Excavations within the shoulder line
- Separation of two-way traffic in urban freeway work zones.

Placement of Temporary Barrier Rails

A TBR installation must be designed to provide adequate lane width for vehicles to traverse the work area, and at the same time provide sufficient space for construction activity. Many times, compromises must be made in order to achieve acceptable results.

It is desirable to maintain a minimum distance of 2.5 feet between the backside of the TBR and the work activity. A standard F-shape barrier is approximately 2 feet wide. Therefore, 4.5 feet should be allowed for the TBR installation. Occasionally, it is not possible to provide 2.5 feet behind the barrier, and modifications will be necessary (e.g., bridge approach work, stage construction of bridge replacements).

It is best to maintain a minimum width of 12 feet 5 inches between TBR and bridge rail or other barrier. This is sufficient clearance for legal-width loads to travel through the Traffic Control Zone. Whenever it is not possible to provide a 12 foot 5 inch clearance, contact the Office of Traffic and Safety so that advance signing can be posted in advance of the work area. If a TBR installation results in a lane width less than 10 feet 6 inches, contact the Design Traffic Control Engineer for a TBR design review.

If the distance between the backside of the barrier and a drop-off is less than 2 feet, the TBR should be tied down to prevent lateral displacement of the barrier. The approved tie down method is shown on Standard Road Plan RE-75

End Treatment

End treatment of the barrier is required if the approach end of the TBR terminates within the clear zone. Three methods of end treatment are available: approach flares, tapered end sections, and impact attenuators.

Approach Flares

The most common method of end treatment is an approach flare of 6:1 or flatter. For one lane traffic control with signals, the approach flare should terminate at the edge of the shoulder.

When the TBR does not encroach onto the traffic lanes, motorists are free to maintain speed through the work area. In this situation, the TBR should be offset 10 feet from the traveled way. For shoulder widths less than 10 feet, a blister should be built to attain a 10-foot offset. A shoulder taper (see Section 9A-3) of L/3 should precede the TBR to close the shoulder (see Figure 1).

Tapered End Sections

A special concrete-barrier-rail tapered end section is to be used on all TBR installations that terminate in the direction of oncoming traffic. Standard Road Plan RE-72 shows the only approved tapered end section. For roadways with posted speed limits of 35 mph or less, this end section is usually adequate end treatment.

Impact Attenuators

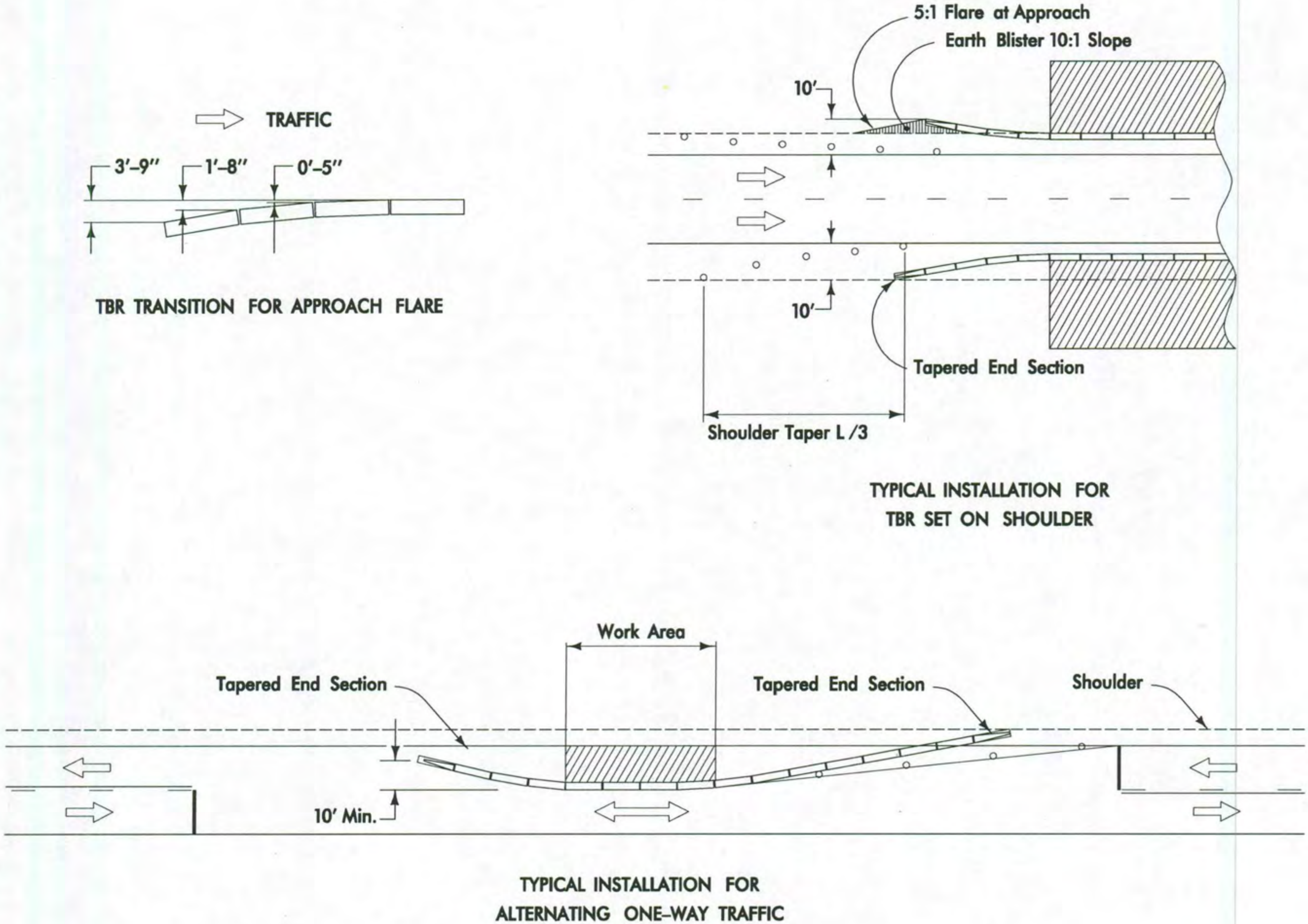
When a proper offset of the TBR end is not possible, an impact attenuator should be used. An impact attenuator safely decelerates or redirects an errant vehicle. Attenuators should be used to terminate TBR installations on the Interstate highway system if the barrier terminates within 30 feet of the edge of the traveled way.

Illumination and Reflection

Temporary barrier rail should have reflectors mounted on the traffic side at 10-foot intervals. The color of the reflectors (yellow or white) must be appropriate to the direction of traffic.

Temporary floodlighting should be used to light the approach end of the TBR. However, temporary floodlights may not be necessary on roadways with permanent lighting.

Figure 1: Typical TBR Installation



Road Closures

Originally Issued: 09-01-95

Often it becomes necessary to close a portion of a roadway to some or all traffic. There are several methods used to restrict roadway traffic. This section describes the different types of closures, their uses, and how they are paid for.

Road Closure Barricades

A road closure barricade is used to close a roadway to all traffic except contractors' equipment or officially authorized vehicles. The closure consists of a "ROAD CLOSED" sign mounted on a Type III Barricade. An orange plastic safety fence meeting Specification 4188.03 is placed completely across the roadway immediately behind the Type III Barricade. This type of closure is paid for as a Safety Closure according to Article 2518 of the *Standard Specifications*. Use Tabulation 108-13A. The contractor is paid for each road closure barricade installed. Appropriate advance warning signs such as "ROAD CLOSED AHEAD" should be erected as shown on Standard Road Plans RS-26A, RS-26B, and RS-27.

Road Closed to Thru Traffic

When the actual closure is some distance from the point where thru traffic must detour, local traffic may be allowed to use this section of roadway to access homes and businesses. A Type III Barricade containing a "ROAD CLOSED TO THRU TRAFFIC" sign and a Type A warning light should be placed at the last public road intersection prior to the closure. This type of closure is paid for as part of the lump sum Traffic Control bid item. Refer to Standard Road Plans RS-26A, RS-26B, and RS-27 for additional information.

Hazard Closures

A hazard closure consists of a Type III Barricade erected in the middle of the roadway with an orange plastic safety fence placed completely across the roadway immediately behind the barricade. Hazard closures are used primarily to warn contractor personnel or other authorized workers of dangerous conditions on the project. Hazard closures should be erected at locations where construction takes place near major threats to worker safety, such as streams, gullies, railroads, bridge approaches, and access locations.

Hazard closures should be tabulated on Tabulation 108-13A. The contractor will be paid for each hazard closure installed (use the Safety Closure bid item). Refer to Section 2518 of the *Standard Specifications* for additional information.

Introduction to Work Zone Activities

Originally Issued: 09-01-95

Each traffic control zone differs according to vehicle speed, traffic volumes, and the locations of work, pedestrians, and intersections. The goal of traffic control is safety, and the key factor in making the traffic control plan work is proper judgment. Sections 9C-1 through 9C-6 are designed to guide the designer in applying the basic principles discussed earlier in the chapter.

Section RS of the *Standard Road Plans* and sections 520 and 521 of *Road Design Details* show typical applications of various traffic control methods. Since there are endless combinations of geometry, location, and work, it is not possible to have a layout for every conceivable work zone situation. However, the layouts in these sections do provide a basis from which other layouts may be derived to fulfill the traffic control needs of a particular work zone situation.

The layouts contained in the *Standard Road Plans* and the *Road Design Details* represent minimum requirements for the situations depicted. Factors such as traffic volume, sight distance, and work area location may require modifications to these layouts. In any case, the guidelines contained in this manual and the MUTCD[1] must be satisfied.

[1] Federal Highway Administration, *Manual on Uniform Traffic Control Devices*, (Washington, D.C. 1988).

Work Located Off the Traveled Way

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Work located off the traveled way does not usually interfere with traffic directly. However, work activity within 15 feet of the traffic lanes may limit the area available for emergency use. Standard Road Plans RS-2 and RS-62 show traffic control methods for work adjacent to 2-lane and 4-lane roadways respectively.

Pavement Drop-Offs

When construction involves a pavement drop-off adjacent to the traveled way, motorists should be provided with proper warning. The following are guidelines for the treatment of pavement drop-offs and for warning motorists of their presence.

Two-Lane Roadways

The depth of a drop-off should be limited to a nominal 10 inches during non-working hours. The contractor should not be allowed to remove so much material that the drop-off cannot be reduced to 10 inches before work is suspended for the day. The edge of the drop-off should be delineated by a white edge line and channeling devices. Refer to Standard Road Plan RS-2.

Multilane Roadway

The traffic lane adjacent to the drop-off should remain closed to traffic. Refer to Standard Road Plans RS-63A, RS-63B, RS-64A, and RS-64B

Excavations

Excavations necessary to construct culvert extensions and bridge pier footings may warrant additional traffic control measures, especially when an excavation is within the shoulder line. Although these excavations are only 30 to 50 feet long, they are usually much deeper than a normal pavement drop-off. It would be impractical to fill them during non-working hours. Consequently, temporary concrete barriers may be warranted. Refer to Section 9B-9 for more information.

Work on Two-Lane Roadways

Originally Issued: 09-01-95

When work activity encroaches onto the traveled way of a two-lane roadway, special measures must be taken to accommodate traffic and separate it from the work zone. This section presents different methods used to control traffic on two-lane, two-way roadways during construction.

One-Lane Closed

When work is performed on one lane of a two-lane, two-way facility, the remaining lane must be used by traffic traveling in both directions. Alternating one-way traffic may be accomplished in several ways.

Single Flagger

For short work areas (100 feet or less) on low volume roads (2000 vpd or less), traffic can be maintained with one flagger. Refer to Standard Road Plan RS-20. The flagger must have an unobstructed view of approaching traffic for at least 1/4 mile and the work area may not be in an existing No Passing Zone. The flagger allows traffic in the open lane to flow freely and permits stopped traffic to proceed only when there are sufficient gaps in the opposing traffic flow. If excessive delays are encountered or sight distance is limited, a second flagger must be added.

Two Flaggers

The most common method for controlling one-way traffic during daylight hours is to use two flaggers, one at each end of the work area. Standard Road Plan RS-3 may be used for work areas up to 1/4 mile.

Two Flaggers with Pilot Car

Work activity such as resurfacing, patching, or milling requires lane closures in excess of 1/4 mile. Other work may involve particularly dangerous routes. In either case, the use of a pilot car is more effective than using flaggers alone. The pilot car guides a train of vehicles through the work area. Refer to Standard Road Plan RS-4.

Temporary Traffic Signals

When one-lane traffic is to be maintained during non-working hours, temporary traffic signals provide the necessary traffic control. Several layouts are available, including Standard Road Plans RS-5A, B, C, D, and E, RS-6, RS-10, RS-11, and RS-18. These layouts all have similar advance signing, which should also be used if special layouts are developed.

Controlling traffic with temporary signals depends upon the length of the one-lane section and the traffic volume. Each layout indicates the maximum traffic volumes that can be accommodated, based on the distance between signals. These layouts cover most conditions encountered in the field. For special cases, a modified signal-timing table can be calculated to accommodate longer stop-line-to-stop-line distances.

One-Lane Traffic Control with Stop Signs

Stop signs may be used to control traffic through short work areas on low volume roadways. The work area is limited to a length of 150 feet to ensure that motorists on opposite ends of the one lane section will have eye contact. For this reason, the alternating stop method may not be appropriate when the work area is within a No Passing Zone. Traffic volumes should not exceed 2000 vehicles per day in order to avoid possible traffic delays. Refer to Standard Road Plan RS-7 for more information.

Detours

Many times it is more economical to close the roadway and detour traffic. Detours fall into two categories: on-site and off-site.

On-Site Detour

On-site detours are short diversions (less than a mile) used to bypass a work area. They should be designed for speeds as near the posted speed limit as right-of-way restrictions will allow. On-site detours may be designed for two-way traffic or signalized one-way traffic. Standard Road Plans RS-8, 9, 10, and 11 give traffic control details for on-site detours.

Off-Site Detour

Off-site detours utilize existing roadways to divert thru traffic off the project route. Although the actual detour signing is handled by the Maintenance Division, the contractor must provide traffic control for local traffic that must use portions of the closed route within the Traffic Control Zone.

Standard Road Plans RS-26A and RS-26B show several different situations for a closed project route and the required traffic control. These layouts are intended primarily for work areas that extend beyond one or more intersections. Typical projects would include grading, paving, and shouldering.

When the actual work area is confined between intersections, use Standard Road Plan RS-27. Typical projects would include bridge or culvert work and spot locations where the activity area does not cross the intersection.

No Passing Zones

It is often necessary to place a temporary No Passing Zone through a traffic control area. The following guidelines are intended to aid in the proper use of No Passing Zones.

- An existing No Passing Zone should never be shortened for temporary traffic control.
- If an existing No Passing Zone is to be lengthened, an orange NO PASSING ZONE sign should be erected at the beginning of the No Passing Zone and the existing NO PASSING ZONE sign removed or covered.
- If the temporary No Passing Zone falls within an existing No Passing Zone, no additional signs should be added. The existing NO PASSING ZONE sign should remain in place.
- A No Passing Zone line that ends within 300 feet of the beginning of another such line should be connected to make one continuous zone. There should be only one NO PASSING ZONE sign at the beginning of the continuous No Passing Zone.

Centerline Drop-Offs

When work such as milling and resurfacing results in a centerline drop-off, special signing must be provided to alert drivers. Standard Road Plans RS-17A, B, and C show traffic control for various depths of drop-offs. The appropriate layout must be included in the project plans.

Work on Multi-Lane Roadways

Originally Issued: 09-01-95

When work activity encroaches onto the traveled way of a multi-lane facility, one or more traffic lanes need to be closed. This section presents various methods used to control traffic through work zones on multi-lane roadways.

Single Lane Closure

For single lane closures, Standard Road Plans RS-63A, RS-63B, RS-64A, and RS-64B provide the traffic control requirements.

Multiple Lane Closures

When two adjacent lanes are to be closed on a roadway with six lanes or more, special layouts should be developed. Since most 6-lane facilities are located in urban areas, the designer must be aware of all entrance and exit ramps within the traffic control zone so that taper lengths and sign spacing may be adjusted to accommodate existing field conditions.

If the highway is in a rural area, the traffic volumes will probably be such that peak-hour traffic can be carried in a single lane. In urbanized areas, peak-hour traffic volumes may be large enough to cause long delays and traffic queues if any lanes are closed. A brief capacity analysis should be done to determine when lanes may be closed. The traffic control plan should list the hours when work is permitted and when lanes may be closed.

Lane Closures Past Ramp Tapers

Standard Road Plans RS-65A and RS-65B give details for handling traffic in the vicinity of exit and entrance ramps.

Road Closures on Multi-Lane Roadways

Temporary road closures may be necessary when setting or removing beams on overhead bridges or when performing other overhead tasks. The closure is usually permitted to last no longer than 20 minutes and must be scheduled during very low traffic flows. Detail Sheets 521-15A and 521-15B illustrate traffic control for temporary road closures.

Two-Lane, Two-Way Operation (TLTWO)

Often the most efficient method of reconstructing a multi-lane divided highway is to close one roadway and to provide two-way operation on the other roadway. This is accomplished with high-speed crossovers at each end of the project. However, this situation violates what drivers normally expect and great care must be exercised in order for this scheme to operate safely.

Where TLTWO is used, the traffic control plan shall include provisions for the separation of opposing traffic except where:

- the TLTWO is located on an urban type street or arterial where operating speeds are low.
- drivers entering the TLTWO can see the transition back to one-way operation on each roadway.
- the FHWA has approved the nonuse of separation devices based on unusual circumstances.

Centerline striping, raised pavement markers, and complementary signing, alone or in combination, are not considered acceptable for positive separation purposes. In Iowa, the common method of positive separation is with tubular markers and CD channelizer/markers. Occasionally, temporary barrier rail (TBR) is used. Refer to 9B-9 for more information on the use of TBR.

The high-speed median crossovers used to switch traffic to the other roadway should be designed for the posted speed limit before construction. Detail Sheets 531-1C and 531-1D show crossover designs for various speeds and median widths. Standard Road Plan RS-66 shows the traffic control details for TLTWO and median crossovers.

Ramp crossovers are necessary if ramp traffic is to be maintained. Detail Sheet 531-2 shows the design of a typical ramp crossover. The length of the crossover as well as the location may have to be changed to accommodate existing ramp geometry. Standard Road Plans RS-26A, RS-26B, and RS-27 give details for traffic control at entrance and exit ramps within the TLTWO.

Control of Traffic Through Incident Areas

Originally Issued: 09-01-95

An incident is an emergency traffic occurrence, a disaster, or a special event. The intent of incident management for construction projects is to establish a plan which may be put into effect in a moment's notice so that traffic is kept moving past the incident area. This usually means signing alternate routes and obtaining approval from appropriate jurisdictions well in advance of construction start-up.

The responsibility for developing an incident management plan rests with the appropriate transportation center in accordance with Maintenance I.M. 1.255. Little information is necessary in the contract plans except for Standard Notation 254-1, which shall be included on all projects that use TLTWO traffic control and on other projects when directed by the Design Engineer.

On-Site Detours and Temporary Connections

Originally Issued: 09-01-95

On-Site Detours

On-site detours are short diversions (less than a mile) used to bypass a work area. By their very nature, on-site detours violate driver expectancy and must be properly designed for safe operation.

Normal practice is to use a minimum design speed of 35 mph for both horizontal and vertical alignment. On rural, high-speed roadways the design speed should be as near to the posted speed limit as right-of-way restrictions will allow.

Questions regarding detour surfacing or dust alleviation should be resolved during the field examination. The District will recommend the amount and type of roadway surfacing (if any) and the rate of application (if any) of dust alleviant. Generally, the dust alleviant will be a surface application of calcium chloride and water. The use of "Chemically Treated Surfacing" requiring plant-mixed materials is generally discouraged.

Temporary Connections

Temporary connections are used in staged construction to connect existing roadways to new or temporary roadways. As with onsite detours, temporary connections may violate driver expectancy. Therefore, they should be designed for operating speeds as close to the posted speed limit as possible within the existing right-of-way.

Detour Cross Sections

Typical cross sections for paved, two-lane detours will be 24-foot pavement, 3-foot shoulders, and 3:1 foreslopes. Refer to Road Design Detail 2612A and Table 1 on the next page for additional information.

Cross sections for paved, one-lane detours will be 14-foot pavement, 3-foot shoulders, and 3:1 foreslopes. Refer to Road Design Detail 2612B and Table 1 on the next page for additional information.

Detour Pavement

It will be the contractor's option to use P.C. Concrete or Hot Mix Asphalt. Refer to Road Design Details 2612A and 2612B for further information regarding pavement options. Pavement thickness determinations for either type of pavement should be obtained from the Pavement Engineer in the Office of Design. This work is bid as Detour Pavement, in square yards of paved surface area.

Drainage

Normal design practice is to provide corrugated metal pipe (without aprons) for temporary drainage culverts on detours. Concrete pipe may be provided only where extenuating circumstances indicate such use to be advantageous.

Removal of temporary culvert pipes will be considered incidental to the bid item for culvert pipe. The plans should specify that upon removal, these culvert pipes shall be the property of the contractor who will be responsible for proper disposal.

Traffic Control

Traffic control for onsite detours and temporary connections shall be in accordance with guidelines set forth in the *Standard Road Plans* (RS-8, 9, 10, 11) and the MUTCD. Refer to Section 9C-3 for additional information.

Table 1: Quantities for Paved Detour Construction

pavement thickness	subgrade width		special backfill (a)		granular shoulder (b)		earth shoulder fill + 60% shrinkage (b)	
	14' wide pavement	24' wide pavement	14' wide pavement	24' wide pavement	HMA	PCC	HMA	PCC
inches	feet	feet	tons	tons	tons	tons	yd^3	yd^3
7.0	23.3	33.3	56.0	91.0	12.58	13.49	0.76	1.02
8.0	23.9	33.9	56.0	91.0	12.58	13.49	2.80	3.37
8.5	24.1	34.1	56.0	91.0	12.58	13.49	3.86	4.61
9.0	24.4	34.4	56.0	91.0	12.58	13.49	4.95	5.88
9.5	24.7	34.7	56.0	91.0	12.58	13.49	6.07	7.18
10.0	24.9	34.9	56.0	91.0	12.58	13.49	7.18	8.51
10.5	25.2	35.2	56.0	91.0	12.58	13.49	8.34	9.88
11.0	25.5	35.5	56.0	91.0	12.58	13.49	9.51	11.28
11.5	25.7	35.7	56.0	91.0	12.58	13.49	10.71	12.71
12.0	26.0	36.0	56.0	91.0	12.58	13.49	11.92	14.17

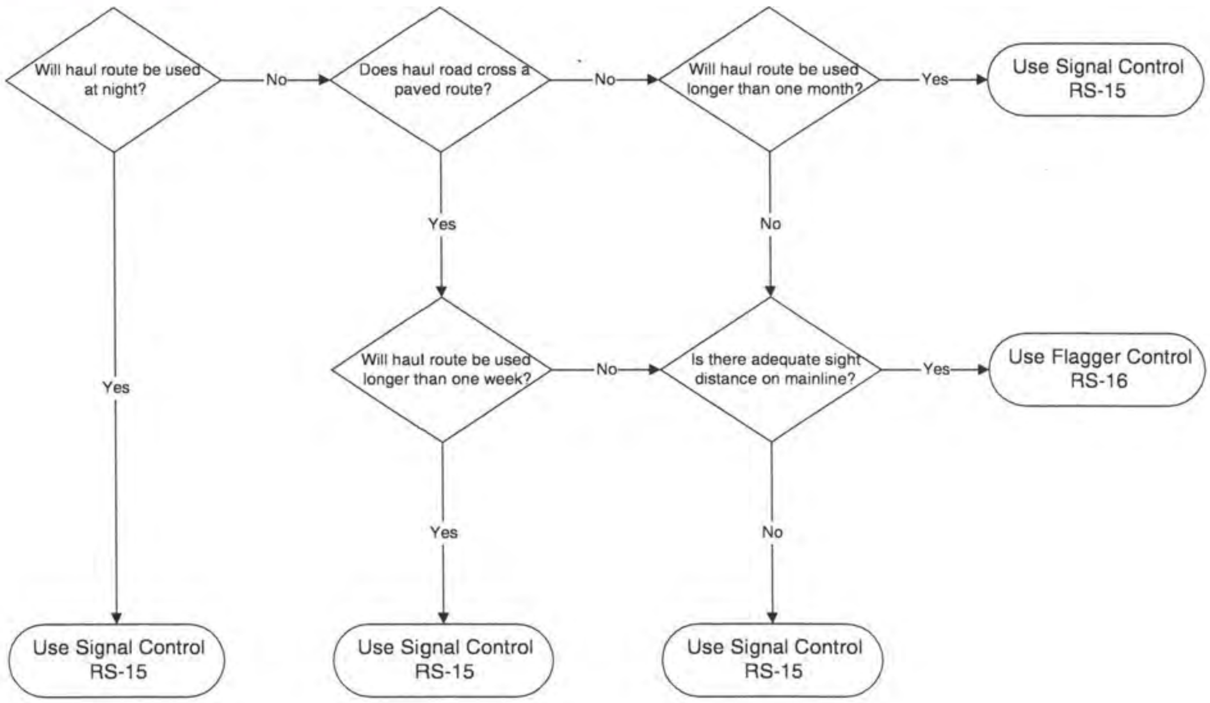
(a) per station

(b) per station per side

Haul Road Crossings

Originally Issued: 08-07-98

The following flow chart may be used to determine the most appropriate type of traffic control for haul road crossings.



Roadside Development and Erosion Control

Chapter 10

Topsoil Replacement

Originally Issued: 09-01-95

Topsoil Replacement Policy

Topsoil replacement is required on all external borrows and also on specified critical locations. Additionally, the intent is to make best use of all topsoil that will be excavated within template cut areas. If all topsoil obtained from template cut areas is not utilized in the specified critical locations, it is to be placed on foreslopes and other locations as discussed below. Unless needed to provide quantities for the specified critical locations, stripping of topsoil is not required from the template fill locations or the entire footprint of the construction area.

A. External Borrows

All external borrow areas that will subsequently be used for agriculture or other non-commercial uses should have topsoil replacement. The Office of Right of Way will determine, during appraisal, whether the borrow area has commercial or non-commercial potential, based on land-use and price. For topsoil replacement in external borrows, the top 12 inches of material at the borrow location (prior to construction) should be used to provide for a replacement depth of 8 inches. At pond borrows, topsoil should be replaced down to the design (stabilized) water level in the borrow.

B. Specified Critical Locations

Topsoil replacement is required at the following locations:

1. All sand/gravel cuts and fills, including foreslopes, backslopes, ditch bottoms, etc. (this will also address "slope dressing" concerns with sand.)
2. Exposed shale in backslopes and ditch bottoms.
3. Exposed rock of any kind (including shale) in medians and in foreslopes.
4. Backslopes, foreslopes, ditch bottoms, and internal borrows in very dense, hard clays or similar materials where establishment of vegetation is difficult. The Roadside Development Section may be consulted to assist in identifying these areas.
5. Construction through unique areas such as abandoned coal mines, acidic soil locations, etc.
6. Other specified critical locations identified by Soils Design and/or others.

The replacement thickness at these critical locations will typically be 8 inches in depth but variations may be considered depending on the amount of topsoil available. The topsoil should be placed within the final template as shown on the cross sections.

C. Additional Areas when Material is Available

If all topsoil available from template cut areas has not been utilized in specified critical locations as defined in Section B, the remaining topsoil should be placed to a depth of 8 inches within the final template as shown on the cross sections in the following locations:

1. Foreslopes, except possibly in areas of deep loess soil.
2. Other locations identified by Soils Design and/or others.

D. Exempt Areas

Topsoil should not be replaced at the following locations:

1. External borrows that will be used commercially.
2. Outside ditch bottoms in rock-cut areas (except shale).
3. Backslopes in rock-cut areas (except shale), whether the backslope cut is a steep "rock-type" backslope or a more gentle "soil-type" (i.e. 2.5:1) backslope.

Specific Responsibilities

Office of Right of Way

The Office of Right of Way is responsible for identifying commercial or non-commercial potential of external borrows during appraisal (see Section A above) and informing the Design Sections.

Soils Design Section

The Soils Design Section is responsible for:

1. Marking topsoil thicknesses on all cross sections.
2. Identifying the specified critical locations as listed in Section B.
3. Providing shrinkage estimates for topsoil.
4. Providing consultation on priorities for additional areas when material is present as discussed in Section C.
5. Providing consultation on disposal methods (i.e., Type B vs. Type C) for any topsoil materials that remain after all locations discussed in Sections B and C have been topsoiled.
6. Identifying the most optimum additional areas for obtaining topsoil if template cut locations do not provide enough material for all specified critical locations discussed in Section B.

Design Sections

The Design Sections are responsible for:

1. Computing quantities and completing Tabulation 103-4.
2. Specifically separating topsoil replacement quantities (bid items) from Class 10 or other quantities (bid items) to avoid "double payment."
3. Verifying that enough topsoil is generated in template cut areas to provide replacement in all areas listed in Section B.
4. Finalizing the listing of additional areas as discussed in Section C for material not used in Section B critical areas.
5. Identifying general areas available for stockpiling topsoil, when requested.
6. Reviewing right-of-way contracts to ensure that all agreements for topsoil have been addressed.

Stabilizing Crop Seeding, Fertilizing, and Mulching

Originally Issued: 09-01-95

For all projects requiring erosion control, the designer shall consult Roadside Development for assistance in determining rates and quantities for stabilizing crop seeding, fertilizing, and mulching. Roadside Development will provide you with a letter that lists the required bid items and the notes to be included in Tabulations 100-4, 100-4A, or 100-4B.

Erosion Control Devices

Originally Issued: 12-31-97

Erosion control devices should be considered on any project involving earthwork. Erosion control devices are used to control erosion on new projects until permanent seeding is in place. This section describes the different devices that are to be used.

For examples and specific information pertaining to these devices see Standard Road Plans RL-9 and RC-16A and RC-16B.

Silt Basin

A silt basin collects silt deposits from flowing water. Silt basins may be used in roadway ditches preceding drainage structure inlets, at ditch outlets that flow into standing water, and along ditch bottoms. Silt basins may be in ditch grades (1% to 2%) at approximately 200-foot spacing when the vertical height of the foreslope is equal to or less than 5 feet or 100-foot spacing when the height is greater than 5 feet.

The first location to place a basin is before an inlet. A natural silt basin may be constructed by elevating the inlet of a structure or by leaving the fill at the inlet 1 foot below the inlet flow line. This procedure creates a low area that disrupts and slows the water flow and allows the silt to settle out of the water.

Because the basins at inlets can only be used at one location, the silt basin shown on Standard Road Plan RL-9 is used most often. It is used to maintain the spacing along the ditch bottom and for a final device at the end of the ditch.

Silt Dike and Silt Ditch

Silt dikes and silt ditches trap silt in a depressed area to keep it from flowing onto private property. A silt dike and/or a silt ditch may be used when the natural ground slopes away from the foreslope and roadway ditch is not provided. A silt dike shall only be used when the vertical height of the foreslope is equal to or less than 5 feet.

A silt dike is constructed opposite the foreslope. A silt ditch is constructed by excavating the earth to a uniform depth below natural ground at the toe of the foreslope. Silt dikes and silt ditches may be used together or separately, depending on the situation. A silt dike may be constructed by taking the excavated material from a silt ditch and placing it to the side to form a silt dike.

Examples of a silt dike and silt ditch are shown on Standard Road Plan RL-9.

Silt Fence

Silt fence is constructed out of engineering fabric and is used to disrupt the flow of water. By doing this the soil and debris will settle out of the water and collect behind the silt fence. It should be placed anywhere from 10 feet away from the toe of the foreslope to the right-of-way line, running parallel to the foreslope. Silt fences should be used when the vertical height of the foreslope is greater than 5 feet. It should also be placed around intakes when they are constructed.

Silt fence may be placed up to a maximum length of 200 feet. For every segment of silt fence that is placed, a 20-foot segment shall be placed at the lower end skewed towards the foreslope to intercept runoff (see Figure 1). This amount should be placed in the tabulation and the bid items in addition to the original 200 feet.

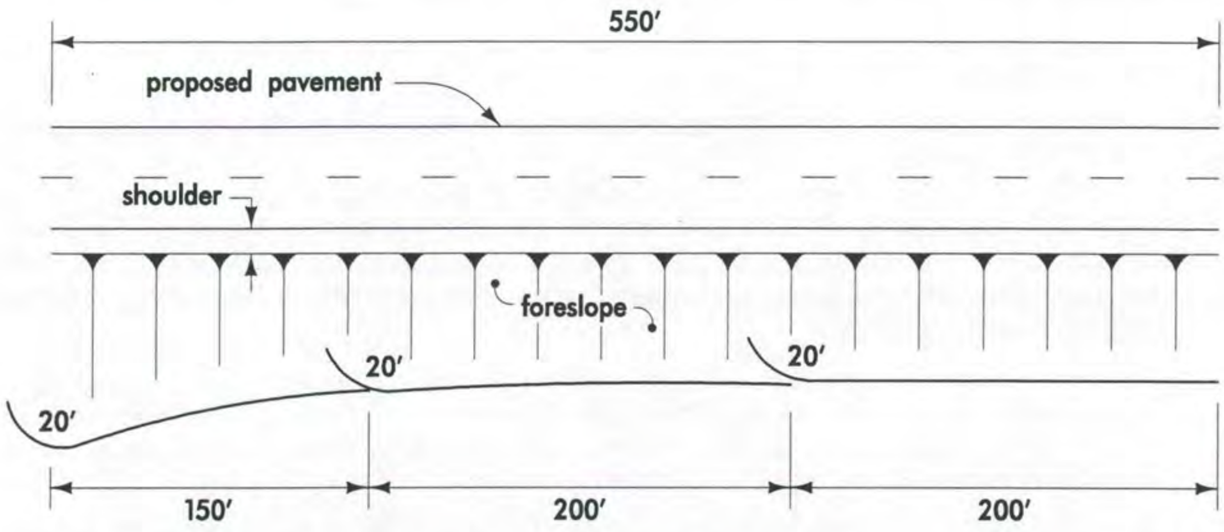


Figure 1: Silt fence placed at the toe of a foreslope.

Standard Road Plans RC-16A and RC-16B show erosion control details for silt fences.

Ditch Checks

Ditch checks are used to intercept soil and debris from water flowing through ditches. Ditch checks are installed at right angles to the flow of water. Like silt fences, ditch checks are constructed out of engineering fabric, and they may be used in roadway and silt ditches. Ditch checks are used when the vertical height of the foreslope is greater than 5 feet. The following spacing guidelines should be used when placing ditch checks:

Table 1: Guidelines for ditch checks spacing.

ditch grade	approximate spacing (ft)*
1–2%	400
2–4%	300
4–6%	200
≥ 6%	100

*For Loess and other highly erodible soils, these spacings should be decreased.

Standard Road Plans RC-16A and RC-16B show erosion control details for ditch checks.

Other Criteria

Soil conditions, such as erodibility, shall be considered when choosing an erosion control device. For example, sands and silts erode quickly, but clays are more stable. Highly erodible soils may require more devices with a closer spacing than more stable soils. Design decisions should be made on the field exam. For assistance in design or for more information, contact Roadside Development.

On paving projects where erosion control devices have already been installed on the grading project, it is the intent that these be maintained in functional condition during the paving contract. A certain percentage (determined by the designer) of the original quantity of erosion control devices from the grading project shall be included on the paving project to account for the reconstruction of the existing devices that are no longer functional. A note in the bid items shall distinguish this quantity. The paving project may also have locations of new devices exclusive to the paving project to be included in the bid items. Once again the quantities are dependent on the existing conditions of the project.

All projects involving earthwork over 5 acres shall also have a Pollution Prevention Plan (PPP). See Section 10D-1 for more information.

Storm Water Discharge Permits

Originally Issued: 09-23-97

In October 1990, the Environmental Protection Agency (EPA) approved the Final Storm Water Rule under the National Pollutant Discharge Elimination System (NPDES). Under this rule, qualified projects are required to have storm water discharge permits. The Iowa Department of Natural Resources (DNR) regulates these permits.

Templates for the various documents that need to be filled out for the permits can be accessed through the Office of Design shortcut; the templates are located in the Forms folder.

Qualified Projects

The DNR has defined a project as all the work done on a segment of roadway. This may include a number of contracts which are let separately, such as grading, paving, culverts and bridges, lighting, or erosion control. All of these separate contracts will be covered by the same permit.

The permits are required on any project that disturbs 5 or more acres of soil. To be on the safe side, the Department requires permits on any project with 4.5 or more acres disturbed.

The DNR defines disturbed soil as any soil that is exposed to erosive forces (wind or water). This definition includes projects like inlays and shoulder widening, as well as projects with a larger amount of earthwork and grading.

All projects that meet these criteria are required to have storm water discharge permits. In the Office of Design the permits are turned in along with plans to the Methods section, which then carries the permits to the Office of Construction.

Permits

Figure 1 shows the flowchart for the storm water discharge permitting process. Each storm water discharge permit application will have 3 parts:

- *Notice of Intent for Storm Water Discharges Associated with Industrial Activity for Construction Activities*
- *Public Notice of Storm Water Discharge (fill out the Public Notice Template)*
- Pollution Prevention Plan

Electronic versions of the *Notice of Intent* and *Public Notice Template* permit forms are then placed in the Docs folder within the Design folder in the project directory located on the W drive. In the Office of Design completed hardcopies of the *Notice of Intent* (with signature) and *Public Notice Template* permit forms are turned in with the project plans to the Methods Section. The Pollution Prevention Plan is included in the plans.

Designers can check the Office of Construction's database on the H drive to see what areas are already covered by a permit.

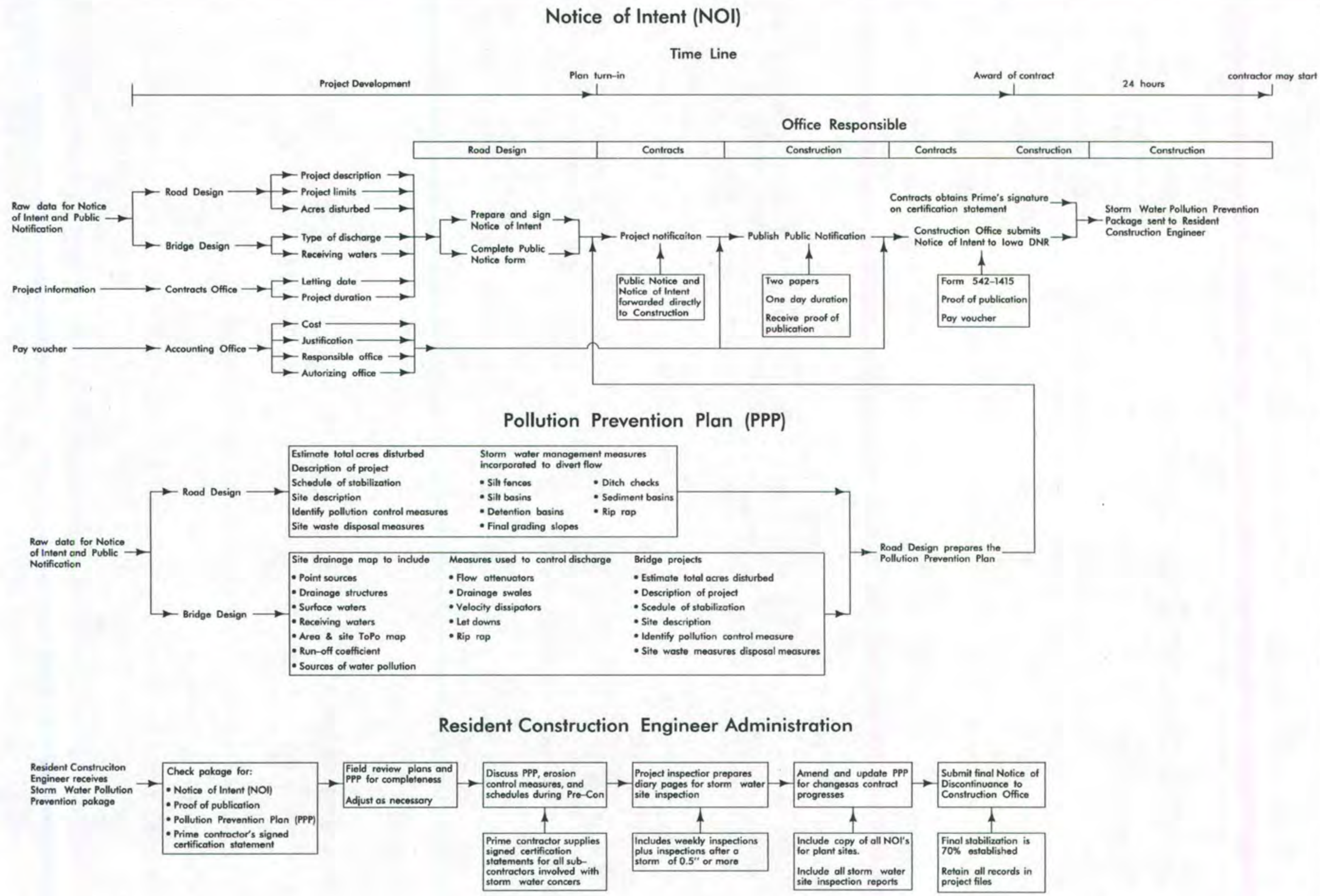


Figure 1: Storm water discharge permit flowchart.

Notice of Intent (NOI)

The *Notice of Intent for Storm Water Discharges Associated with Industrial Activity for Construction Activities* (General Permit No. 2) is the application to the DNR. It allows the DNR to monitor all the work being done in Iowa. Only one *Notice of Intent* form will be completed for each project even though there may be many contracts let within the project limits. The sample NOI at the end of this section demonstrates the information to be filled in by the Offices of Design and Construction.

Refer to the Pollution Prevention Plan for information on project description and receiving waters. The facility location should list the sections, townships, and ranges transected by the project, or for large projects the endpoints may be used. Include a verbal description from the production schedule or from the A.01 sheet of the plans. Use the letting date from the most current production schedule for the Timetable for Major Activities. Major activities would include grading, paving, final seeding, etc. This permit should be signed by the engineer who is in overall charge of the project's design. For in-house plans, the permit will be signed by the Design Projects Engineer. For projects designed by consultants, the permit will be signed by an engineer designated by the consulting firm as being in responsible charge of the design.

Public Notice of Storm Water Discharge

The *Public Notice of Storm Water Discharge* will be published in 2 newspapers for 1 day prior to starting work on the project. The publication of this public notice will be handled by the Office of Construction. Only one *Public Notice* form will be completed for each project even though there may be many contracts let within the project limits. An example of the Public Notice Template appears at the end of this section.

The number of discharge point sources shall be all points where a concentrated flow of water leaves the right-of-way within the project limits (such as rivers, streams, waterways, or sideroad ditches).

Pollution Prevention Plan (PPP)

Because the Pollution Prevention Plan must be on the project work site at all times, it will be in the project plans. The same Pollution Prevention Plan must appear in all plans that occur within a project's limits. Therefore, when a Pollution Prevention Plan is developed for a grading project, the same Pollution Prevention Plan must appear in all related plans for paving, culverts, bridges, lighting, erosion control, etc. The Pollution Prevention Plan for each contract within the project's limits will show the disturbed area for the entire project as well as for that individual contract. Any questions concerning Pollution Prevention Plans may be directed to the Office of Design's Roadside Development Section at (515) 239-1424. A sample PPP appears at the end of this section.

The Pollution Prevention Plan is located under Tabulation 110-12 or 110-12A in the quantity sheets (C sheets) in the project plans. Much of the information in the Pollution Prevention Plan is routine and is shown on the example Pollution Prevention Plan that has been included at the end of this section. The following information identifies the project specific information which the designer must determine.

Site Description

The site description should be very general to cover any extra work orders which may change the scope of work done.

Both the total acres and the disturbed acres need to be calculated. The total acres is calculated by multiplying the average right-of-way (ROW) width by the length of the project plus any extra acres for interchanges or borrows areas. For those contracts let separately, the designer must include the acres of the all the contracts in the project limits.

Disturbed acres include any soil that will be exposed to erosive forces. Inlay areas, re-graded shoulders, and borrows should also be counted as disturbed acres, not just the acres to be seeded.

For example, the total acres and disturbed acres on the Pella bypass project, which was located in northern Marion County near the Mahaska County line, were:

$$\begin{aligned}\text{total acres} &= (\text{average ROW width} \times \text{length of project}) + \text{interchange areas}\\ &= (350' \times 30{,}256') + (2000' \times 800')(2.5\text{ interchanges})\\ &= 337\text{ acres} \approx 350\text{ acres}\end{aligned}$$

$$\begin{aligned}\text{disturbed acres} &= \text{area of new pavement} + \text{area of new granular shoulders} + \text{area to be seeded}\\ &= 42\text{ acres} + 25\text{ acres} + 255\text{ acres}\\ &= 322\text{ acres} \approx 325\text{ acres}\end{aligned}$$

Soil Associations

The soil association for the project area must be determined. The Principle Soil Associations of Iowa map (see Figure 2 on page 6) gives the soil associations for Iowa. If the project is on the borderline between two soil associations, list both associations.

Once the soil associations are determined, use Table 1 on page 5 to determine the hydrologic soil groups. An average hydrologic group must be estimated.

For example, the Pella bypass is located in two soil associations on the Principle Soil Associations of Iowa map. The map and Table 1 give the following soil associations and hydrologic groups.

Soil Association	Hydrologic Group
Clinton-Keswick-Lindley	B-C-C
Otley-Mahaska-Taintor	B-B-C/D

Use estimated Hydrologic Group C.

Soil Conservation Service (SCS) Runoff Curve Number

The estimated average SCS runoff curve number for the entire project after completion is determined by using Table 2 on page 6 and the average hydrologic soil group to get a weighted average based on various surface covers (paved surfaces, granular surfaces, etc.).

For example, the Pella Bypass has 337 total acres: 42 acres of paving, 25 acres of granular surfaces and the rest in rural seeding. This gives the following percentages:

$$\text{paved surfaces} \rightarrow \frac{42\text{ acres}}{337\text{ acres}} = 12\,\%$$

$$\text{granular surfaces} \rightarrow \frac{25\text{ acres}}{337\text{ acres}} = 7\,\%$$

$$\text{rural seeding} \rightarrow 100\,\% - 12\,\% - 7\,\% = 81\,\%$$

To calculate the average SCS runoff curve number, multiply each percentage by the runoff number from Table 2 for hydrologic group C.

$$\text{paved surfaces} \rightarrow 0.12 \times 98 = 11.8$$
$$\text{granular surfaces} \rightarrow 0.07 \times 89 = 6.2$$
$$\underline{\text{rural seeding} \rightarrow 0.81 \times 71 = 57.5}$$

$$\text{average SCS runoff number} = 75.5 \approx 76$$

Location of Storm Water Discharge Controls

Part of the Pollution Prevention Plan is the reference or inclusion of plans which show locations of typical slopes, ditch grades, and major structural and non-structural controls. These items are usually found on the plan and profile sheets of the project.

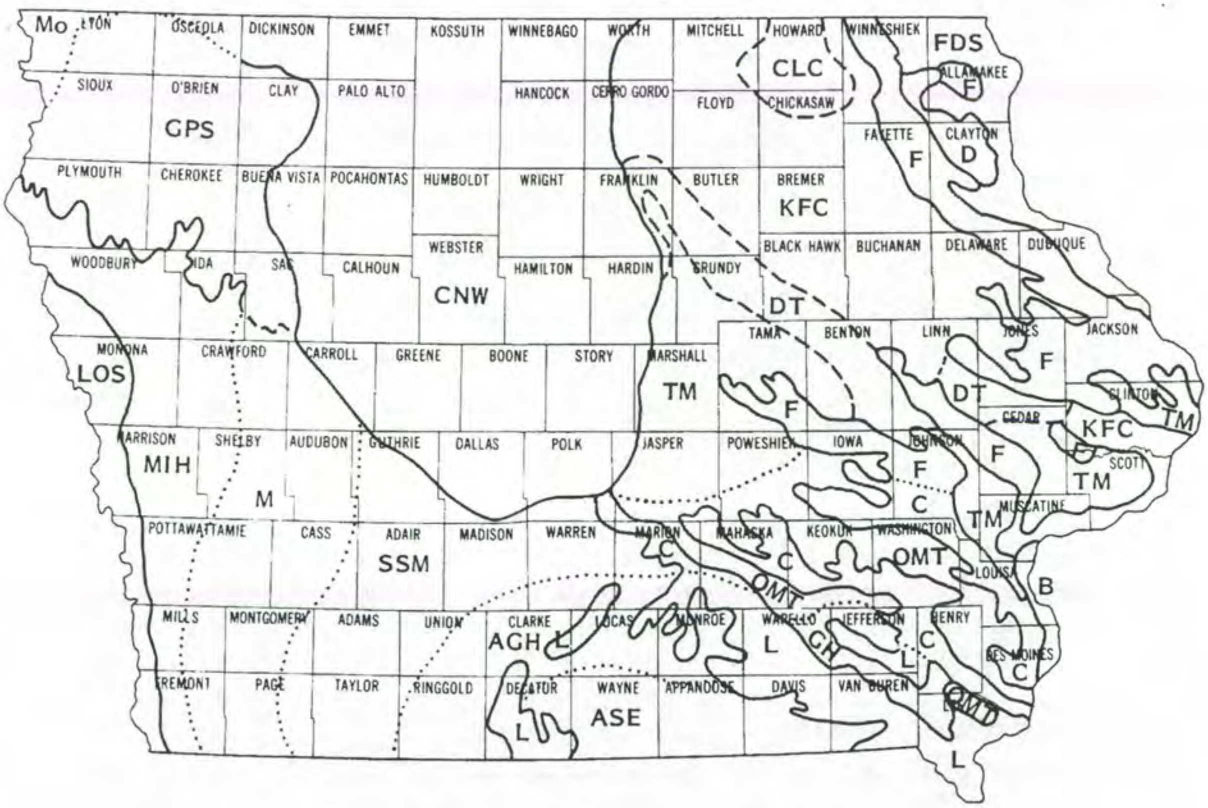
Some projects will not have plan and profile sheets, for example median foreslope flattening projects. In these cases, copies of old plan and profile sheets will be part of the Pollution Prevention Plan. Due to the number of these sheets, they will not be added to the project plans. Instead, they will be sent separately with the *Notice of Intent* and *Public Notice* permits to the Office of Contracts, which will forward them to the Resident Construction Engineer. These plan sheets should be clearly marked as a reference for the Pollution Prevention Plan.

Receiving Waterways

The first named waterway and the first named river which will be receiving runoff from the project need to be identified. These waterways may be found on large-size county maps or United States Geological Survey maps.

Controls

Site specific erosion-control practices and the contractor who is responsible must be listed in the Controls section of the Pollution Prevention Plan. For most projects, this can be easily done by making the appropriate corrections to the example Pollution Prevention Plan at the end of this section. All projects need to include the statement which says the project will be complete with the establishment of permanent perennial vegetation.



·········· Gradational Boundary – – – – – Tentative Boundary ——— Abrupt Boundary

Figure 2: Principle Soil Associations of Iowa (map reprinted from Special Report No. 42, I.S.U. Cooperative Extension Service, 1965).

Soil Association			
AGH	Adair-Grundy-Haig	GH	Grundy-Haig
ASE	Adair-Seymour-Edina	KFC	Kenyon-Floyd-Clyde
B	Mississippi River Bottom Soils	L	Lindley-Keswick-Weller
C	Clinton-Keswick-Lindley	LOS	Luton-Onawa-Salix
CLC	Cresco-Lourdes-Clyde	M	Marshall
CNW	Clarion-Nicollet-Webster	MIH	Monona-Ida-Hamburg
D	Downs	Mo	Moody
DT	Dinsdale-Tama	OMT	Otley-Mahaska-Taintor
F	Fayette	SSM	Shelby-Sharpsburg-Macksburg
FDS	Fayette-Dubuque-Stonyland	TM	Tama-Muscatine
GPS	Galva-Primghar-Sac		

The information on the following tables was extracted from Technical Release 55, Urban Hydrology for Small Watersheds, revised in 1986 by the U.S. Soil Conservation Service.

Table 2: Soil Association Hydrologic Groups

Soil Association		Hydrologic Soil Group(s)
B	Soils of Mississippi River Bottomland	B/D
AGH	Adair - Grundy - Haig	C - C - C/D
ASE	Adair - Seymour - Edina	C -D - D
C	Clinton - Keswick - Lindley	B - C - C
CLC	Cresco - Lourdes - Clyde	C - C - B/D
CNW	Clarion - Nicollete - Webster	B - B - B/D
D	Downs	B
DT	Dinsdale - Tama	B - B
F	Fayette	B
FDS	Fayette - Dubuque - Stonyland	B - B - B
GPS	Galva - Primghar - Sac	B - B - B
GH	Grundy - Haig	C - C/D
KFC	Kenyon - Floyd - Clyde	B - B - B/D
L	Lindley - Keswick - Weller	C - C - C
LOS	Luton - Onowa - Salix	D - D - B
M	Marshall	B
MIH	Monona - Ida - Hamburg	B - B - B
Mo	Moody	B
OMT	Otley - Mahaska - Taintor	B - B - C/D
SSM	Shelby - Sharpsburg - Macksburg	B - B - B
TM	Tama - Muscatine	B - B

Table 3: SCS Runoff Curve Numbers

Cover Description	Curve Numbers for Hydrologic Soil Group			
	A	B	C	D
Paved Surfaces	98	98	98	98
Granular Surfaces	76	85	89	91
Earth Shoulders	39	61	74	80
Urban Seeding	39	61	74	80
Rural Seeding	30	58	71	78

Sample Notice of Intent (NOI)

IOWA DEPARTMENT OF NATURAL RESOURCES
ENVIRONMENTAL PROTECTION DIVISION

Cashier's Use Only
17-1709 -

NOTICE OF INTENT FOR NPDES COVERAGE UNDER GENERAL PERMIT

No. 1 FOR "STORM WATER DISCHARGES ASSOCIATED WITH INDUSTRIAL ACTIVITY"

or

No. 2 FOR "STORM WATER DISCHARGES ASSOCIATED WITH INDUSTRIAL ACTIVITY FOR CONSTRUCTION ACTIVITIES"

or

No. 3 FOR "STORM WATER DISCHARGE ASSOCIATED WITH INDUSTRIAL ACTIVITY FROM ASPHALT PLANTS, CONCRETE BATCH PLANTS, ROCK CRUSHING PLANTS, AND CONSTRUCTION SAND AND GRAVEL FACILITIES."

PERMIT INFORMATION

Has this storm water discharge been previously permitted (Check One) ☐ Yes ☒ No.

If yes, please list permit number ____________

Under what General Permit are you applying for coverage?

General Permit No. 1 ☐ General Permit No. 2 ☒ General Permit No. 3 ☐

NPDES PERMIT FEE OPTIONS

For coverage under the NPDES General Permit the following fees apply:

☐ Annual Permit Fee $150 (per year)
or
☐ 4-year Permit Fee $450
☐ 3-year Permit Fee $300

Filled in by Office of Construction

Coverage by the 4-year and 3-year permit fees expires no later than the expiration date of the general permit (October 1, 2002). Maximum coverage is four years and three years, respectively.

FACILITY OR PROJECT INFORMATION

Enter the name and full address/location (not mailing address) of the facility or project for which permit coverage is requested.

NAME: **DOT project number(s)**		ADDRESS / LOCATION OF SITE: **Corridor or site description**	
CITY: **Nearest city**	COUNTY: **County**	STATE: **IA**	ZIP CODE: **Enter, or may leave blank**

CONTACT INFORMATION. Give name, mailing address and telephone number of a contact person (Attach additional information on separate pages as needed). This will be the address to which all correspondence will be sent and to which all questions regarding your application will be directed.

NAME:		ADDRESS:	
CITY:	STATE:	ZIP CODE:	TELEPHONE: ( )

Check the appropriate box to indicate the legal status of the operator of the facility.
☐ Federal ☒ State ☐ Public ☐ Private ☐ Other (specify) ________

Typically filled in by Office of Construction

SIC CODE* (General Permit No. 1 & 3 Applicants Only) ☐

* SIC code refers to Standard Industrial Classification code number used to classify establishments by type of economic activity.

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Page 1

FACILITY LOCATION OR LOCATION OF CONSTRUCTION SITE

Give the location by section/township/range or latitude/longitude (Attach additional information on separate pages as needed).

1/4 SECTION	SECTION	TOWNSHIP	RANGE	LATITUDE			LONGITUDE		
				DEGREES	MINUTES	SECONDS	DEGREES	MINUTES	SECONDS

See instructions under Notice of Intent

OWNER INFORMATION

Enter the name and full address of the owner of the facility.

NAME: **Iowa Department of Transportation Office of Construction**		ADDRESS: **800 Lincoln Way**	
CITY: **Ames**	STATE: **IA**	ZIP CODE: **50010**	TELEPHONE: **(515) 239-1280**

OUTFALL INFORMATION

Discharge Start Date **Typically, month of letting**

Is any storm water monitoring information available describing the concentration of pollutants in storm water discharges? ☐ Yes ☒ No.

NOTE: Do not attach any storm water pollutant information as part of this Notice of Intent.

Receiving Water(s):
Use same as listed in PPP and Public Notice

Compliance With The Following Conditions:	Yes	No
1. Will this Notice of Intent be included in the pollution prevention plan?	✓	
2. Has the pollution prevention plan been developed prior to the submittal of this Notice of Intent?	✓	
3. Will the Storm Water Pollution Prevention Plan comply with approved State (Section 467A.64, Code of Iowa) or local sediment and erosion plans?	✓	
4. Have two (2) public notices been published for at least one day in newspapers with the largest circulation in the area where the discharge is located (new applications only).		

Typical

Filled in by Office of Construction

GENERAL PERMIT NO. 2 AND GENERAL PERMIT NO. 3 APPLICANTS COMPLETE THIS SECTION.

Description of Project: **Corridor or site description plus additional information as desired**

For General Permit No. 3 - Is this facility to be moved this year? ☐ Yes ☐ No

Number of Acres of Disturbed Soil: **Fill this in** (Construction Activities Only)

Estimated Timetable For Activities / Projects:

From current production schedule: grading, paving, or permanent erosion control letting date

CERTIFICATION

I certify under penalty of law that this document was prepared under my direction or supervision in accordance with a system designed to assure that qualified people properly gathered and evaluated the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, this information is to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

NAME (please print) **Engineer who is in overall charge of the project**	TITLE: **Engineer's title**
SIGNATURE: **Handwritten signature (on permit to be turned in to Office of Construction)**	DATE: **Date of signature**

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Page 2

Public Notice Template

County: ____________________
DOT Project(s): ____________________
Letting: ____________________

Date Sent: **(Office of Construction will fill in.)**

Send To: Jaime Zweibohmer **e-mail:** jzweibohmer@cnaads.com
CNA (Customized Newspaper Advertising)
Phone: (800) 227-7636 Ext. 123 **Fax:** (515) 244-4855

For newspapers:

1. **(Office of Construction will fill in.)**
2. **(Office of Construction will fill in.)**

Please publish the following text as a legal notice in the next issue and run for one day only. (If the newspaper does not publish a legal section, please print as a public notice in the classified section.)

****

PUBLIC NOTICE OF STORM WATER DISCHARGE

The Iowa Department of Transportation plans to submit a Notice of Intent to the Iowa Department of Natural Resources to be covered under National Pollutant Discharge Elimination System (NPDES) General Permit No.2 "Storm Water Discharge Associated with Industrial Activity for Construction Activities."

The storm water discharge will be from highway construction activity located in ____________ County on _____ Highway _____. The project is ____.

(Choose One) The Public Lands Survey location is Township ___, Range ___, Section(s) __________. **(Or)** The Public Lands Survey location is from Township ___, Range ___, Section(s) _________ to Township ___, Range ___, Section(s) ________.

Storm water will be discharged from ____ point sources and will be discharged to the following streams: ____.

Comments may be submitted to the Storm Water Discharge Coordinator, IOWA DEPARTMENT OF NATURAL RESOURCES, Environmental Protection Division, 502 East 9th Street, Des Moines, IA 50319-0034. The public may review the Notice of Intent from 8:00 a.m. to 4:30 p.m. Monday through Friday at the above address after it has been received by the Department.

****

Example Pollution Prevention Plan

POLLUTION PREVENTION PLAN

110-12A
02-23-93

All contractors/subcontractors shall conduct their operations in a manner that minimizes erosion and prevents sediments from leaving the highway right-of-way. The prime contractor shall be responsible for compliance and implementation of the Pollution Prevention Plan (PPP) for their entire contract. This responsibility shall be further shared with subcontractors whose work is a source of potential pollution as defined in this PPP.

1. SITE DESCRIPTION

This Pollution Prevention Plan (PPP) is for the construction of a four-lane facility on Ia 163 in Marion County around the south side of Pella.

This PPP covers approximately 350 acres with an estimated 325 acres being disturbed. The portion of the PPP covered by this contract has 325 acres disturbed.

The PPP is located in an area of two soil associations (Clinton-Keswick-Lindley and Otley-Mahaska-Taintor). The estimated average SCS runoff curve number for this PPP sfter completion will be 76.

Refer to the grading plan (Marion County NHS-163-3(7)--19-63) for locations of typical slopes, ditchgrades, and major structural and non-structural controls. A copy of this plan will be on file at the project engineer's office. Runoff from this work will flow into various unnamed ditches and waterways which flow into Muchakinock Creek and the Des Moines River. Muchakinock Creek is a tributary of the Des Moines River.

POTENTIAL SOURCES OF POLLUTION:
Site sources of pollution generated as a result of this work relate to silts and sediment which may be transported as a result of a storm event. However, this PPP provides conveyance for other (non-project related) operations. These other operations have storm water runoff, the regulation of which is beyond the control of this PPP. Potentially this runoff can contain various pollutants related to site-specific land uses. Examples are:

Rural Agricultural Activities:
Runoff from agricultural land use can potentially contain chemicals including herbicides, pesticides, fungicides and fertilizers.

Commercial and Industrial Activities:
Runoff from commercial, industrial, and commerce land use may contain constituents associated with the specific operation. Such operations are subject to potential leaks and spills which could be commingled with run-off from the facility. Pollutants associated with commercial and industrial activities are not readily available since they are typically proprietary.

2. CONTROLS

At locations where runoff can move offsite, silt fence shall be placed along the perimeter of the areas to be disturbed prior to beginning grading, excavation or clearing and grubbing operations. Vegetation in areas not needed for construction shall be preserved. As areas reach their final grade, additional silt fences, silt basins, intercepting ditches, sod flumes, letdowns, bridge end drains, and earth dikes shall be installed as specified in the plans and/or as required by the project engineer. This will include using silt fence as ditch checks and to protect intakes. Temporary stabilizing seeding shall be completed as the disturbed areas are constructed. If construction activity is not planned to occur in a disturbed area for at least 21 days, the area shall be stabilized by temporary seeding or mulching within 14 days. No more than 750,000 square feet of exposed erodible area is allowed in any one grading spread without permission of the project engineer. Other stabilizing methods shall be used outside the seeding time period.

This work shall be done in accordance with Section 2602 of the Standard Specification. If the work involved is not applicable to any contract items, the work shall be paid for according to Article 1109.03 paragraph B.

As the work progresses, additional erosion control items may be required as determined by the engineer after field investigation. These may be items such as letdown structures, soil stabilization mats, and other appropriate measures to be installed by the paving or erosion control contractor as directed by the engineer. The erosion control contractor will complete the construction with the establishment of permanent perennial vegetation of all disturbed areas.

3. OTHER CONTROLS

Contractor disposal of unused construction materials and construction material wastes shall comply with applicable state and local waste disposal, sanitary sewer, or septic system regulations. In the event of a conflict with other governmental laws, rules and regulations, the more restrictive laws, rules or regulations shall apply.

APPROVED STATE OR LOCAL PLANS:
During the course of this construction, it is possible that situations will arise where unknown materials will be encountered. When such situations are encountered, they will be handled according to all federal, state, and local regulations in effect at the time.

4. MAINTENANCE

The contractor is required to maintain all temporary erosion control measures in proper working order, including cleaning, repairing, or replacing them throughout the contract period. Cleaning of silt control devices shall begin when the features have lost 50% of their capacity.

5. INSPECTIONS

Inspections shall be made jointly by the contractor and the contracting authority every seven calendar days and after each rain event that is ½" or greater. The contractor shall immediately begin corrective action on all deficiencies found. The findings of this inspection shall be recorded in the project diary. This PPP may be revised based on the findings of the inspection. The contractor shall implement all revisions. All corrective actions shall be completed within 3 calendar days of the inspection.

6. NON-STORM DISCHARGES

This includes subsurface drains (i.e. longitudinal and standard subdrains), slope drains and bridge end drains. The velocity of the discharge from these features may be controlled by the use of patio blocks, Class A stone or erosion stone.

Fencing

Originally Issued: 07-12-96

Fencing is intended to prevent unauthorized entry to and exit from a road system. Fencing shall be included as part of the design plan only on roadways with Priority 1 access control[1] (on interstate highways and other freeways only, not on expressways or lower level roadways).

Continuous fencing shall be provided on both sides of the freeway at least 1 foot inside the right-of-way limits and between the ends of dual bridges. Fences shall also be provided at culverts and livestock passes when needed to prevent livestock from entering the roadway. Typical fencing layouts can be found on Standard Road Plan RC-7.

New Construction

On new construction, fencing must be one of two types: field fence or chain link fence. Construction details for field fence are found on Standard Road Plans RC-8A, RC-8B(1), RC-8B(2) and RC-9. Two types of field fence, type 39 and type 47, are detailed on RC-8B(1). Type 47 field fence should be used on all DOT projects.

Details for chain link fence are found on Standard Road Plans RC-10 and RC-11. Chain link fence must be at least 6 feet high and is used only in areas where pedestrian traffic is anticipated. Normally, such areas include the following:

- Any area where three or more residences occur within 100 feet of the right-of-way or 20 or more residences occur within 500 feet of the right-of-way, along a 500-foot length of the highway. The 500-foot length is measured longitudinally along the highway centerline.
- Any area zoned residential (with platted lots and roadways) where construction of homes meeting the criteria above can be reasonably anticipated within the next 5 years.
- Any area that is zoned industrial and has industry present.
- Along the entire frontage of an official city, county, state, or federal park or preserve.
- Along the entire frontage of a baseball field, golf course, playground, etc., where pedestrian traffic is present or anticipated.
- Along the entire frontage of an abutting school property.
- Immediately adjacent to or abutting any walkway or bike path.

Chain link fence is normally installed outside the clear zone only. If circumstances require a chain link fence within the clear zone, a special design is required which replaces the top rail with a tension wire.

[1] Iowa Department of Transportation, *Iowa Primary Road Access Management Policy*, (Ames, IA, July 1995) 4.

Other than New Construction

Generally, fencing will be replaced in kind when repairs are made. However, field fence will be replaced with chain link fence when the conditions stated under "New Construction" *and* one of the following is met:

- Existing fence has deteriorated to a point where replacement is required.
- Replacing the fence is part of a planned reconstruction project.
- It is evident that existing fence is not controlling access as desired.

Transitions in Fencing Type

In many areas, the type of fencing needs to change because of either an existing or a planned change in land use. Designers should avoid frequently transitioning from one type of fence to another. However, when a change in fencing is warranted, it should be accomplished at a logical point, such as at an interchange, a bridge, or a large culvert (4 feet by 4 feet or larger). If no obvious transition point is apparent, the designer should seek a logical point within ¼ to ½ mile of the change in land use. Such decisions, as necessary, will be made jointly by the Design Engineer and the Transportation Center Development Engineer.

Miscellaneous

Bicycle Accommodation on Primary Highways

Originally Issued: 06-02-00

The Department's policy on bicycle accommodation is to provide safe, convenient and adequate bicycle facilities along the state highway system. The accommodation of bicyclists shall be considered as part of the development of all highway projects. This includes consideration of accommodation in addition to the normal roadway driving area.

The purpose of this section is to provide design guidelines for bicycle facilities when it has been determined that additional accommodation is appropriate. Three types of accommodation are addressed: bicycle lanes, paved shoulders, and separated paths. Refer to AASHTO's 1999 *Guide for the Development of Bicycle Facilities* for more information.

Bicycle Lanes

Bicycle lanes consist of extra pavement width built immediately adjacent to the driving lane. They are built on both sides of the roadway so that cyclists travel in one direction on each side—the same direction as the adjacent vehicular traffic. Pavement markings are used to clearly delineate the lanes as bicycle lanes.

Width

The minimum width for bicycle lanes should be 5 feet measured from the edge of traveled way to the gutterline.

Pavement Markings

A six-inch solid white line should be placed between the bicycle lane and the driving lane. This line should not cross pedestrian crosswalks or intersections. At signalized or stop-controlled intersections with right-turning vehicles, a six-inch wide dashed line should be used for a distance of 50–200 feet approaching the intersection. The dashed line should be used at other intersections with high volumes of right-turning traffic.

The painted bicycle symbol and directional arrow should be painted on the far side of each intersection and intermittently on long, uninterrupted sections of roadway.

Proper pavement markings and, in some cases, signing is especially important at intersections and at locations with exclusive right-turn lanes where vehicles need to cross over the bike lane to enter the right-turn lane. Refer to the AASHTO Guide and Part 9 of the MUTCD for diagrams and more information about how to handle these conflict points.

Consult the Office of Traffic and Safety for questions or guidance on unique situations regarding pavement markings.

Drainage Inlets

Curb-opening type drainage inlets (without metal grates on the pavement) are preferred in conjunction with bicycle lanes. The Department predominantly uses these types of inlets. If grated inlets are used, the Iowa Code mandates the use of inlet types that are safely traversable by bicycles.

Paved Shoulders

In rural areas, paved shoulders may be used to accommodate bicyclists. Both shoulders should be paved so cyclists can travel in the same direction as adjacent vehicular traffic.

If paved shoulders are used for bicycle accommodation, normally the entire shoulder is paved. This provides cyclists with some additional separation on high-speed roadways and eliminates the need for two maintenance operations on the shoulder. The minimum paved shoulder width should be 4 feet.

When rumble strips are used on the outermost 2 feet of a 14-foot lane pavement, the rumble strip pattern should be intermittent to allow cyclists to cross over when necessary. Refer to Standard Road Plan RH-41D for information on rumble strips.

Normally, paved shoulders will not be used on expressways or freeways to accommodate bicyclists because of the high speeds and traffic volumes associated with those facilities.

Separated Paths

In some cases, separated bicycle paths may be appropriate due to factors such as:

- the skill level/age of the expected cyclists.
- high traffic speeds (such as expressways with 65 mph posted speeds).
- high traffic/truck volumes.
- narrow roadways, shoulders, and bridges on existing roadways.

Width

The width of two-way separated paths should normally be 10 feet.

Horizontal Clearance

A minimum 2-foot horizontal clearance, 3 feet desirable, should be provided to obstructions. This area should also be graded to 6:1 or flatter on both sides of the path. Tunnels or undercrossings should be wide enough to accommodate emergency and maintenance vehicles if no other access is available within a reasonable distance. A typical ambulance width (including mirrors) is 11 feet.

Additional clearance may be needed on the inside of horizontal curves depending on the radius of the curve and the stopping sight distance. Refer to Table 4 on page 46 of the AASHTO Guide.

Vertical Clearance

The vertical clearance to obstructions should be a minimum of 8 feet. Enough vertical clearance should be provided to accommodate emergency and maintenance vehicles if no other access is available within a reasonable distance. A typical ambulance height is 8.5 feet.

Horizontal Alignment

If possible, horizontal curve radii should be at least 100 feet (this is based on a 20 mph design speed and a 15 degree lean angle). If this is not feasible because of site constraints, other options such as temporary widening, signing, and minor superelevation may be appropriate. See the AASHTO Guide for more information.

Grade

Grades should normally be limited to 5%. This may be exceeded for short distances (such as in areas with hilly terrain). Table 1 provides recommended grade restrictions. If these grades are not feasible, other mitigating features may be appropriate. See the AASHTO Guide for more information.

Table 1

Grade (%)	Distance (ft)
5–6	800
7	400
8	300
9	200
10	100
11+	50

Sight Distance

The AASHTO Guide provides a set of graphs and tables for determining stopping sight distance for bicycle paths. A 20 mph design speed should be used.

Drainage Structures

Normally, drainage structures underneath bicycle paths should be designed to the same design year storm as the roadway drainage structures. This is best accomplished by extending smaller structures through the path and moving the path in to cross larger structures, see Figure 1 on next the page.

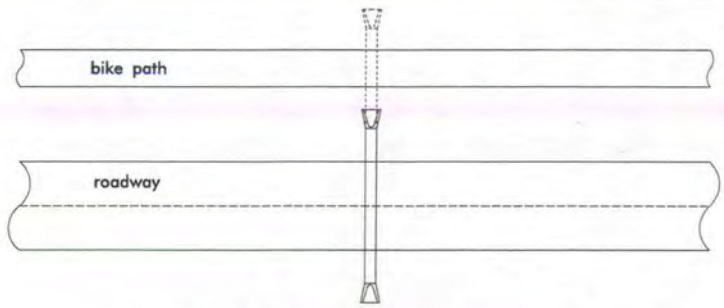
For bicycle paths placed on the backslope, smaller drainage structures should be extended through the path (normally, pipes less than 60 inches and box culverts less than 5 feet x 4 feet). For larger culverts, the path should be moved in to cross the structure and then moved back out to the backslope. If this is done, longitudinal drainage will have to be provided where the path crosses the ditch. Depending upon how close the path comes to culvert openings, safety railing may be needed on the culverts.

For bicycle paths on the foreslope, culverts should be extended as necessary.

Crossing at bridge locations presents special challenges. Most existing bridges will be too narrow to accommodate a full-width path (not to mention a barrier to separate bicycle traffic from vehicular traffic). In these situations, a separate structure or bridge widening should be considered. On lower-speed roadways, it may be possible to allow cyclists to cross the bridge on a narrowed path, separated with barrier.

Barriers

AASHTO stresses the importance of separation between two-way paths and the roadway to demonstrate that the path is an independent facility from the roadway. They recommend a barrier if a two-way path is within 5 feet of the roadway shoulder. Barrier or railing may also be warranted at culvert openings, steep embankments, dropoffs, or other areas of concern. If you are unsure of whether or not a barrier is warranted, consult the Methods Section for assistance.



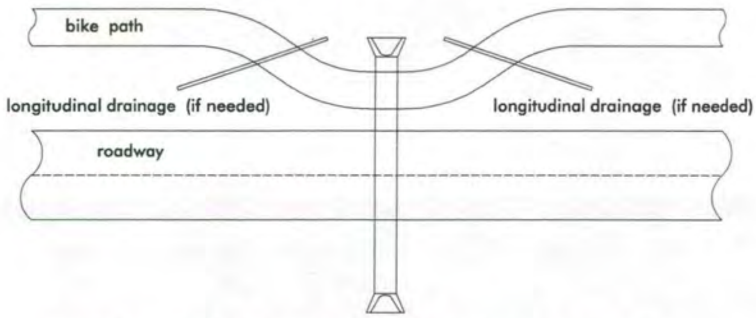


Figure 1: Accommodating drainage structures.

Pavement Thickness

Road Design Details 7402 and 7403 provide construction details for granular and paved surface bicycle paths. Type of maintenance vehicle will determine the need for and thickness of subbase material. Contact the Pavement Design section in the Office of Design.

Path-Roadway Intersections

Handling the intersection of the path with roadways is one of the most critical design issues when designing two-way separated paths. There is the potential for numerous conflicts with turning, through, and merging traffic. There are a variety of variables to consider including turning movements, right-of-way constraints, traffic signals, sight distance, refuge islands, and others.

The AASHTO Guide provides a good discussion of the issues that should be considered when intersecting roadways. Each intersection will need to be evaluated individually in detail to determine the safest way to move bicycle traffic through the intersection.

Pedestrian Sidewalk Design

Originally Issued: 07-12-96

Sidewalks are walkways that generally run parallel to vehicular roadways. Sidewalks are normally used only in urban areas, and they are usually designed for pedestrian use only (rather than for bicycles). Sidewalk construction and maintenance has traditionally remained the responsibility of cities, as established in 761-150.4(3) of the Iowa Administrative Code. However, the following guidelines describe situations that warrant sidewalk construction as part of a project's design plan.

Replacing Existing Sidewalk

The need to replace an existing sidewalk shall be determined during the field exam. A sidewalk shall be replaced at the Department's expense only when the sidewalk will be impacted by construction. Such circumstances include:

- When the sidewalk will be damaged by the operation of heavy equipment.
- When the sidewalk will be removed to lay underground pipe.
- When the sidewalk is within the grading or shaping limits.

A sidewalk may be replaced for other reasons as part of the Department's project, but replacement must be at the city's expense. An existing sidewalk should be replaced if it meets any of the following criteria:

- The sidewalk is in poor condition (cracks, faulting, etc.). Sidewalks in poor condition also may not meet the Americans with Disabilities Act (ADA) accessibility requirements.
- Other sidewalk in the area is being replaced and it would improve the appearance of the area to replace other portions of nearby sidewalk.
- The city has requested sidewalk improvements and is willing to assume the costs of construction and the purchase of any necessary right-of-way.

An existing sidewalk should also be replaced, repaired, or modified if it does not meet the accessibility requirements of the ADA. These requirements are summarized in the following section.

ADA Requirements

The Americans with Disabilities Act requirements for public sidewalks are set forth by the Architectural and Transportation Barriers Compliance Board and published in the *ADA Accessibility Guidelines* (ADAAG). The following is a summary of the Board's most recent guidelines for public sidewalks and section 14.2.1 of ADAAG can be referred to for more detailed explanation.

Width

ADAAG specifies that a sidewalk must have a minimum clear width of 36 inches. If a person in a wheelchair must turn around an obstruction in the sidewalk, the required widths may be greater than 36 inches. Refer to Figures 7(a) and (b) in ADAAG for requirements in this situation. The Department's normal practice is to construct sidewalks 48 inches wide.

Slope

The running slope of the sidewalk should be the minimum that is feasible, but does not have to be less than the slope of the adjacent roadway. The cross slope of the sidewalk shall not exceed 1:50 (2%).

Surfaces

ADAAG provides no specific measures for surface quality but states that, "surfaces shall be stable, firm, and slip-resistant and shall lie generally in a continuous plane with a minimum of surface warping."

Changes in Level

The allowable changes in level on a sidewalk are illustrated in the following figures. Any level changes more abrupt than this shall be ramped.

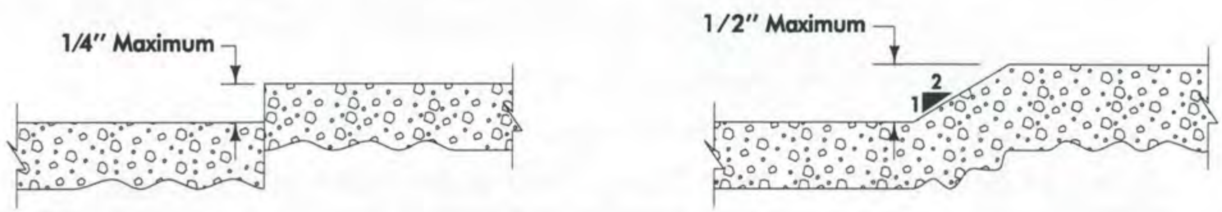


Figure 1: Allowable changes in level on a sidewalk.

Gratings

Gratings located on sidewalks shall not have spaces greater than 1/2 inches wide in the direction of pedestrian flow. It shall also not be located in the "continuous passage" which is defined by ADAAG as a continous, unobstructed path within the sidewalk.

Railroad Crossings

Where sidewalks cross railroads at grade, the sidewalk shall be level and flush with the top of the rail. The gap between the sidewalk and the rail shall not exceed 2.5 inches.

Separation

Unless the sidewalk is along an undeveloped frontage or rural road, the sidewalk shall be raised to curb height or separated from the roadway by curbs, planted parkways, or other barriers.

Curb Ramps

A curb ramp shall be constructed wherever a sidewalk crosses a curb or other change in level at each street crossing. For more information on curb ramp requirements, see sections 11A-3 and 11A-4.

Constructing New Sidewalk

The need to construct new sidewalk shall be determined during the field exam. Construction of a new sidewalk should be encouraged in any of the following situations, provided the city agrees to assume the costs of construction.

In Areas with Established Need or Usage

New sidewalk should be built in areas where need can be clearly established. Because pedestrian volumes are not easily quantified, purely practical considerations determine the need for sidewalks. For example, connector streets are more likely to have high pedestrian volumes than residential streets because pedestrians use them to access bus stops and commercial developments. Generally, the following two circumstances warrant a new sidewalk:

- A worn path exists, indicating substantial usage.
- The area is near a school, recreation area, or other development that is likely to generate large volumes of pedestrian traffic.

In Short Areas between Already Established Sections of Sidewalk

Sidewalk should also be built in areas where a sidewalk exists along most of a project's length, but is missing on a small number of lots (compared to the total). In such cases, the sidewalk should be made continuous through the area.

On Bridges

Sidewalks are important on bridges because without them pedestrians are forced to walk in the roadway. However, constructing sidewalks on bridges is very costly, and bridges without approach sidewalks are unlikely to have enough pedestrian traffic to warrant the expense. Consequently, sidewalks will be built on bridges at the Department's expense only if a recognizable system of sidewalks already exists approaching the bridge, or if the city agrees to build such a system concurrently with the highway project.

Cooperation with Cities

Generally, every effort should be made to cooperate with a city, provided the city commits to doing its share. The cooperation described above for a bridge walkway would be appropriate. Other possibilities might include providing extra grading for a sidewalk if the city agrees to construct the sidewalk, or constructing a sidewalk as part of the project if the city agrees to reimburse the Department. However, sidewalks that do not meet the guidelines set forth in this section should not be constructed at the Department's expense simply because a city wants them.

Sidewalks and Rural Cross Sections

Sidewalks generally should not be constructed in areas with rural cross sections, that is, cross sections without curbs. In rare instances when sidewalks are constructed in these areas, the sidewalk will be constructed at the top of the foreslope, as close to the right-of-way line as practical.

Terminating the Sidewalk

The point at which a reconstructed or new sidewalk terminates does not necessarily have to coincide exactly with the ending or beginning points of the project. The designer may choose to extend the sidewalk a short distance beyond the construction limits to a more logical or aesthetically pleasing stopping point.

ADA Curb Ramp Compliance (New Construction)

Originally Issued: 07-12-96

A public sidewalk curb ramp and level landing will be provided wherever a public sidewalk crosses a curb or other abrupt change in elevation. A perpendicular curb ramp will be constructed except in locations where there is insufficient right-of-way width, in which case it is permissible to construct a parallel or combined curb ramp. Illustrations and design guidelines are given on the following pages for these three types of curb ramps. Application of the guidelines does not require greater right-of-way width than that established by state or local practice.

The focus of this section is on curb ramp design requirements for new construction. Keep in mind that for new construction, diagonal and projected ramps are no longer permitted (see Section 11A-4 for illustrations of diagonal and projected ramps).

New construction, as related to curb ramps, is defined by the Department as any project where new curbs are being constructed. Refer to Section 11A-4 for information on curb ramp requirements for alterations, where the existing curb line is not being reconstructed.

The purpose of this section is to summarize the most recent design guidelines as set forth by the Architectural and Transportation Barriers Compliance Board. Included with each design criterion is a reference to the *ADA Accessibility Guidelines*, which can be referred to for more detailed explanation. The Department's standard curb ramp designs can be found on Standard Road Plan RB-6.

Perpendicular Curb Ramps

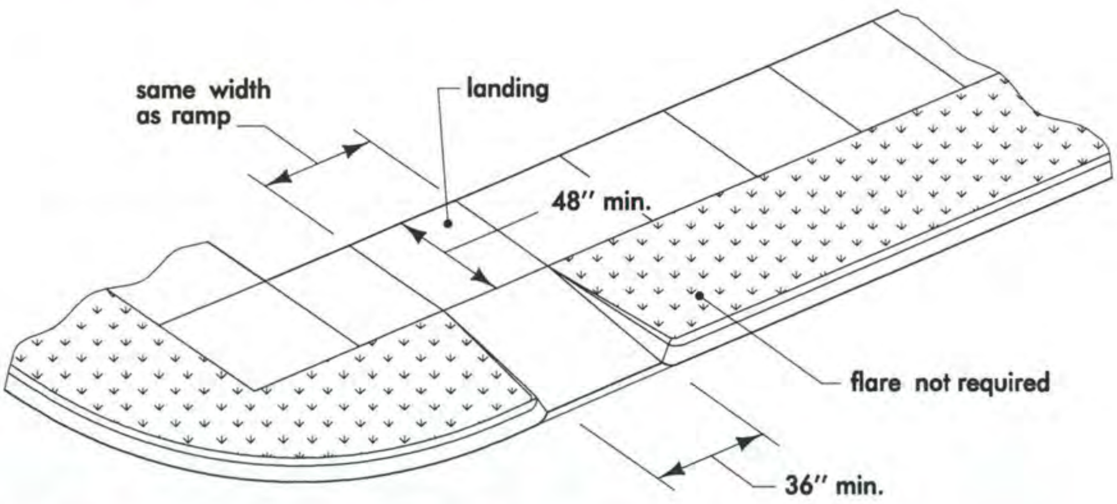


Figure 1: Perpendicular ramp with returned sides.

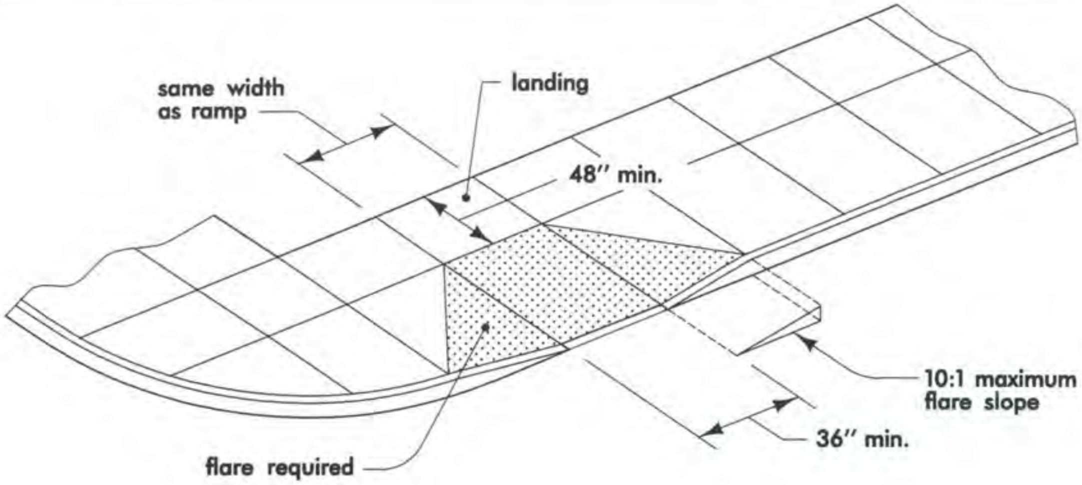


Figure 2: Perpendicular ramp with flared sides.

Width

The width of the ramp, not including flared sides, will be a minimum of 36 inches. {14.2.4(3)} The Department's normal design is a ramp that is as wide as the adjoining sidewalk.

Flared Sides

Where a side of a perpendicular ramp is contiguous with a public sidewalk, it will have flared sides with a maximum slope of 1:10 (10%). If the ramp is not contiguous with a sidewalk, or if it is protected by a railing or other barrier, the ramp may have returned sides or flared sides of any slope. {14.2.4(6)}

Marked Crossings

For areas with crosswalk markings, the bottom of the ramp run, exclusive of flared sides, will be wholly contained within the markings. {14.2.4(2)}

Ramp Slope

The maximum running slope of the ramp will be 1:12 (8.33%) and the maximum cross slope of the ramp will be 1:50 (2%). {14.2.4(5)}

Landings

A level landing will be provided at the top of the ramp run. The landing will be the same width as the ramp and will be a minimum of 48 inches long. The slope of the landing in any direction will not exceed 1:50 (2%). {14.2.4(4)(a)}

Transitions

The transition from the roadway to the ramp will be flush and free of abrupt changes. The slope of the roadway surface approaching a ramp will not exceed 1:20 (5%) for a distance of 24 inches out from the ramp. Gratings and similar appurtenances will not be located in this area. {14.2.4(8)}

Surfaces

The surface of the ramp will be stable, firm, and slip-resistant. Gratings and similar appurtenances on ramps or landings are not allowed. {14.2.4(7)(a)}

Parallel and Combination Curb Ramps

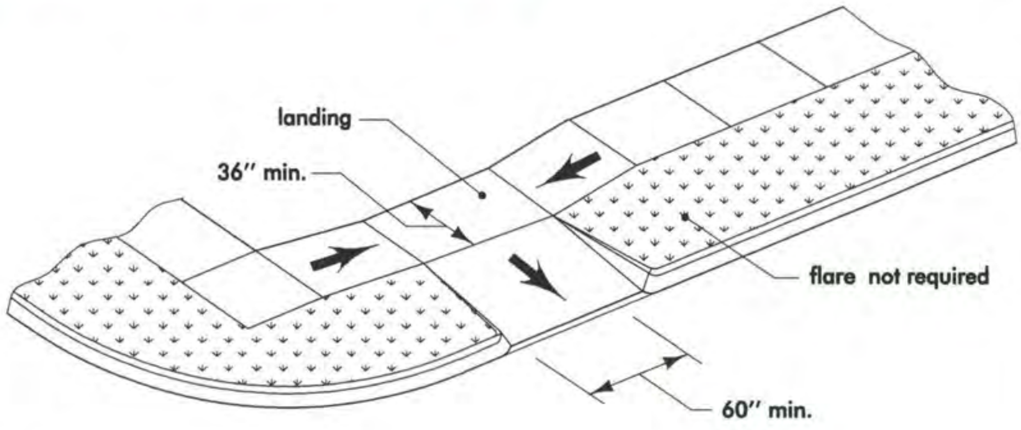


Figure 3: Combination ramp.

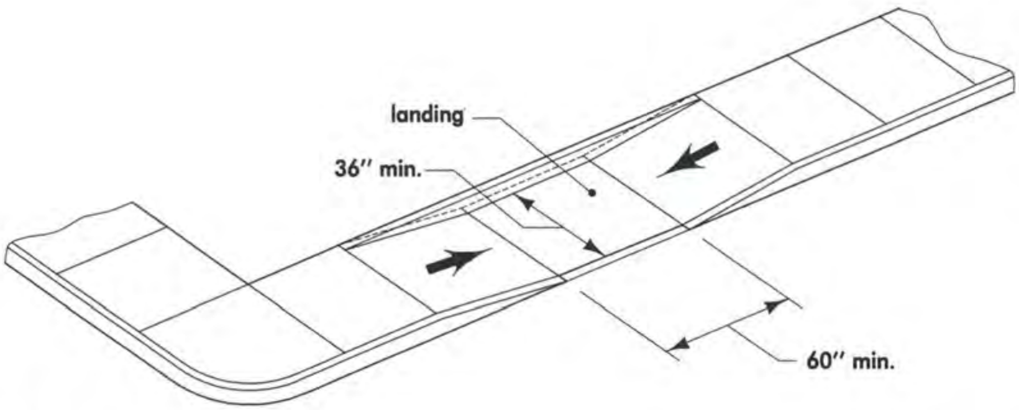


Figure 4: Parallel ramp.

If it is not possible to construct a perpendicular curb ramp because of right-of-way constraints, parallel or combination curb ramps may be used. {14.2.4(2)}

All of the applicable guidelines outlined for perpendicular ramps, also apply to parallel and combination ramps, except for the following differences:

Ramp Slope

Parallel ramps are not required to be any longer than 96 inches (measured from a level plane). If the ramp is built to at least 96 inches, the running slope of the ramp may exceed the recommended 1:12 slope. {14.2.4(5)}

Landings

The landing for parallel and combination type curb ramps will be the same width as the ramp and a minimum of 60 inches long. {14.2.4(4)(b)(c)}

ADA Curb Ramp Compliance (Alterations)

Originally Issued: 07-12-96

A public sidewalk curb ramp and level landing will be provided wherever a public sidewalk crosses a curb or other abrupt change in elevation. Design guidelines for the various types of curb ramps are given on the following pages. Application of the guidelines does not require greater right-of-way width than that established by state or local practice. The type of curb ramp used will be affected by site constraints, but when deciding what type of curb ramp to use, keep in mind the *ADA Accessibility Guideline's* specified order of preference:

1. perpendicular
2. parallel or combined
3. diagonal
4. projected

The focus of this section is on what is allowed when making alterations to existing sidewalk/roadway intersections, in contrast to new construction, where the guidelines are less flexible.

Alterations, as related to curb ramps, are defined by the Department as projects where the existing curb line is not being reconstructed. Refer to Section 11A-3 for information on curb ramp requirements for new construction, where new curbs are being constructed.

The purpose of this section is to summarize the most recent design guidelines as set forth by the Architectural and Transportation Barriers Compliance Board. Included with each design criterion is a reference to the *ADA Accessibility Guidelines*, which can be referred to for more detailed explanation. The Department's standard curb ramp designs can be found on Standard Road Plan RB-6.

Perpendicular Curb Ramps

See Section 11A-3 for illustrations of perpendicular curb ramps.

Width

The width of the ramp, not including flared sides, will be a minimum of 36 inches. {14.2.4(3)} The Department's normal design is a ramp that is as wide as the adjoining sidewalk.

Flared Sides

Where a side of a perpendicular ramp is contiguous with a public sidewalk, it will have flared sides with a maximum slope of 1:10 (10%). If the ramp is not contiguous with a sidewalk, or if it is protected by a railing or other barrier, the ramp may have a returned side or flare of any slope. {14.2.4(6)}

Marked Crossings

For areas with crosswalk markings, the bottom of the ramp run, exclusive of flared sides, will be wholly contained within the markings. {14.2.4(2)}

Ramp Slope

Optimal design: wherever it is feasible, the maximum running slope of the ramp will be 1:12 (8.33%) and the maximum cross slope of the ramp will be 1:50 (2%). {14.2.4(5)}

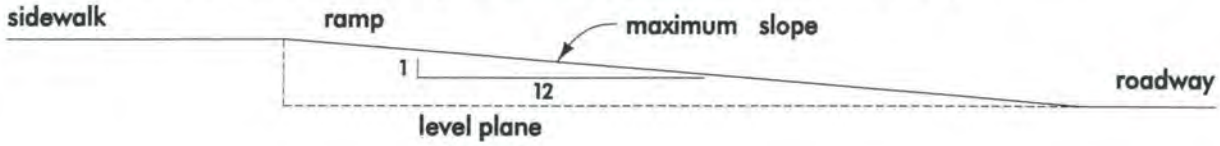


Figure 1

- Exception: where right-of-way or other site constraints make it infeasible to construct a 1:12 (8.33%) running slope, a maximum slope of 1:10 (10%) is permitted for a 6-inch maximum rise. {14.3.2(2)(d)(i)}

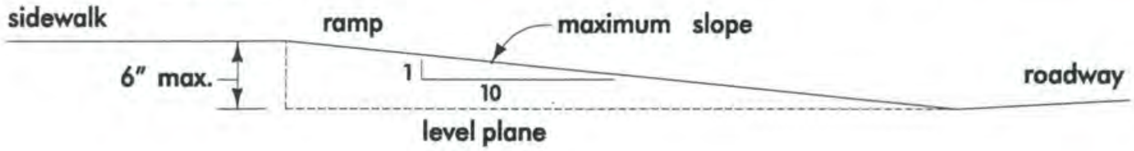


Figure 2

- Exception: where right-of-way or other site constraints make it infeasible to construct either of the preceding cases, a maximum slope of 1:8 (12.5%) is permitted for a 3-inch maximum rise. {14.3.2(2)(d)(ii)}

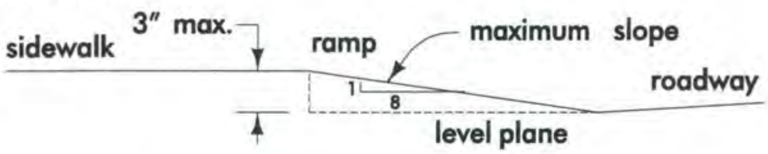


Figure 3

- Exception: perpendicular ramps are not required to be any longer than 72 inches (measured from a level plane). If the ramp is built to at least 72 inches, the slope of the ramp may exceed the recommended slopes outlined above. {14.3.2(2)(d)(iii)}
- Exception: at a site where it is infeasible to meet the 1:50 (2%) cross slope, the minimum feasible cross slope will be provided. {14.3.2(2)(d)(iv)}

Landings

A level landing will be provided at the top of the ramp run. {14.2.4(2)}

Optimal design: the landing will be the same width as the ramp and will be a minimum of 48 inches long. The slope of the landing in any direction will not exceed 1:50 (2%). {14.2.4(4)(a)}

- Exception: where right-of-way is insufficient to accommodate a landing 48 inches long, a landing of maximum feasible length will be constructed, but it must be at least 36 inches. Side flares on the ramp, in this case, will have a maximum slope of 1:12 (8.33%). {14.3.2(2)(c)(i)}

- Exception: where site conditions necessitate exceeding the 1:50 (2%) slope of the landing in any direction, the slope perpendicular to the curb face must not exceed 1:50 (2%). {14.3.2(2)(c)(iii)}
- Exception: where it is infeasible to provide a landing slope less than 1:50 (2%) perpendicular to the face of the curb, the minimum feasible slope in each direction will be provided. {14.3.2(2)(c)(iv)}

Transitions

Optimal design: the transition from the roadway to the ramp will be flush and free of abrupt changes. The slope of the roadway surface approaching a ramp will not exceed 1:20 (5%) for a distance of 24 inches out from the ramp. Gratings and similar appurtenances should not be located in this area. {14.2.4(8)}

- Exception: where the slope of the existing roadway approaching a ramp exceeds 1:20 (5%), the new ramp surface may be slightly crowned and projected beyond the curb face. The leading edge of the ramp at the roadway surface must be smoothly blended and the sides flared with no abrupt drop-offs. {14.3.2(2)(e)(ii)}

Surfaces

Optimal design: the surface of the ramp will be stable, firm, and slip-resistant. Gratings and similar appurtenances on ramps or landings are not allowed. {14.2.4(7)(a)}

- Exception: gratings and similar appurtenances are permitted at sites where an appurtenance already exists and it is infeasible to relocate it. {14.3.2(2)(e)(i)}

Parallel and Combination Curb Ramps

See Section 11A-3 for illustrations of parallel and combination curb ramps.

If it is not possible to construct a perpendicular curb ramp because of right-of-way or other constraints, parallel and combination curb ramps may be used. {14.2.4(2)}

All of the applicable guidelines outlined for perpendicular ramps, also apply to parallel and combination ramps, except for the following differences:

Ramp Slope

Exception: parallel ramps are not required to be any longer than 96 inches (measured from a level plane). If the ramp is built to at least 96 inches, the running slope of the ramp may exceed the recommended slopes. {14.2.4(5)}

Landings

Optimal design: the landing for parallel and combination type curb ramps will be the same width as the ramp and a minimum of 60 inches long. {14.2.4(4)(b)(c)}

- Exception: where it is not feasible to construct a parallel or combination ramp with a landing 60 inches long, a landing of maximum feasible length will be provided, but it must be at least 48 inches long. {14.3.2(c)(ii)}
- Exception: where the public pedestrian right-of-way width is less than 36 inches, a parallel ramp will be constructed, with a landing the width of the existing right-of-way. {14.3.2(2)(b)}

Diagonal and Projected Curb Ramps

Diagonal and projected (built-up) curb ramps are permitted in alterations only where other designs cannot be accommodated. {14.3.2(2)(a)}

The applicable guidelines outlined for the perpendicular curb ramps will apply for these alterations.

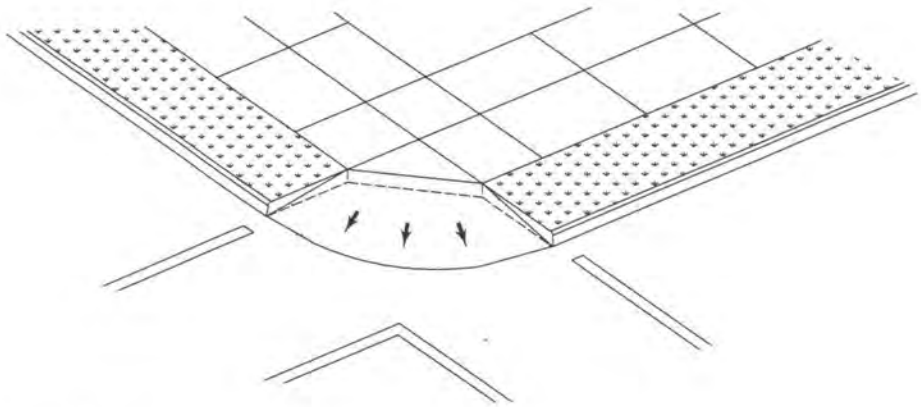


Figure 4: Diagonal ramp.

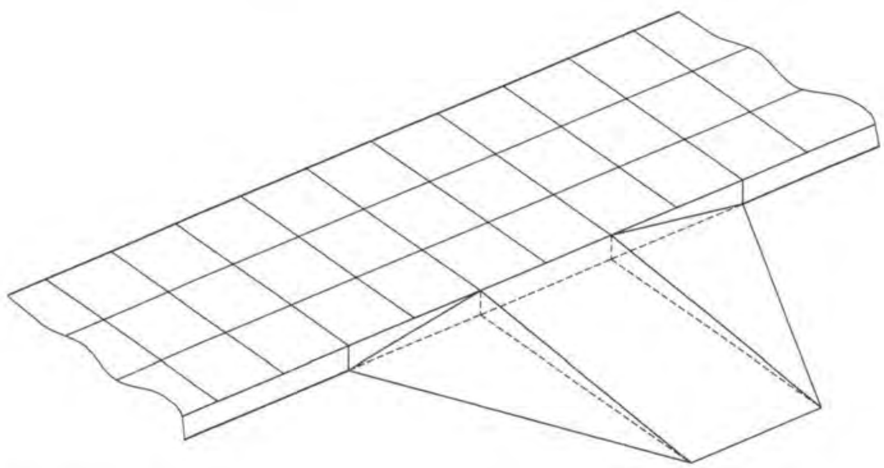


Figure 5: Projected ramp.

Lighting Information for Bridge Design

Originally Issued: 12-20-99

The Office of Bridges and Structures requires lighting hardware and wiring location information so new bridges can be designed to meet lighting needs of the area. After receiving the bridge situation plan, the site should be analyzed and components that are needed for lighting and other utilities are marked up on the plan. Refer to Bridge's Standard Sheet for Lighting Details (1030A) for details of these components. The following guidelines will help in determining what components are needed; however, each site should be examined individually. Some engineering judgment may need to be exercised to determine the best plan for the situation.

Conduit

Figure 1: Conduit is run through one or both bridge rails so utility cables may be run through the bridge.

The typical bridge rail conduit size is 2 inches in diameter. Conduit for the overhead and underdeck lighting is usually 1 inch in diameter. The Office of Bridges and Structures will specify a larger conduit size if they determine it is warranted.

Single Bridges

The following guidelines should be applied to determine if conduit is warranted through one or both bridge rails of a single bridge:

- If the bridge is part of an interchange, run conduit through both bridge rails. This will provide one conduit for interchange lighting and another conduit for other utilities.
- If the bridge is near an urban area, but not part of an interchange, run conduit through both bridge rails. One of the conduits may be used by a nearby city for street lighting, and the other conduit may be used for other utilities. A bridge with a pedestrian sidewalk would be included in this category.
- For all other bridges, run conduit through one bridge rail for other utilities. Check for existing utility lines on the plan sheet. If utility lines are present, run the conduit in the corresponding bridge rail. If no utility lines are apparent on the plan, the conduit may be placed in either bridge rail. Note the exception to this rule later in this section.

Dual Bridges

The following guidelines should be applied to determine if conduit is warranted through one or both bridge rails of a dual bridge:

- If the bridges are part of an interchange, run conduit through the outside bridge rails to accommodate lighting cables. If other utilities need to be run across the bridge, an additional conduit may be installed through the outside bridge rails. Since lighting and utilities are seldom located in the median, conduit will not likely be needed in the median side bridge rail.
- If the bridges are near an urban area, but not part of an interchange, run conduit through the outside bridge rail to accommodate lighting cables. If other utilities need to be run through the bridge, another conduit may be installed in the outside bridge rails. A bridge with a pedestrian sidewalk would be included in this category.
- For all other bridges, run conduit through one of the outside bridge rails to accommodate other utilities. Check the plan sheet for existing utility lines. Run conduit on the side of the bridge where utility lines are present. If no utility lines are apparent on the plan, the conduit may be placed in the outside bridge rail on either side.

Pole Bases

In some cases, the bridge will be part of a continuously-lit roadway, in which case one or more pole bases (blisters) may need to be constructed on the side of the bridge. Pole bases should be located on the bridge structure to provide sufficient lighting levels when lighting is constructed. At the same time, the pole bases should be located on the bridge in such a way as to minimize impact to the aesthetics of the bridge structure. Following the recommendation in the April 15, 1998, *Report of the Bridge Design Aesthetics Team*, this may best be accomplished by placing the pole base over the bridge piers as shown in Figure 2. If the length of the bridge permits lighting the structure sufficiently from the roadway, then light pole bases should not be used on the structure.

Pole bases are warranted near or in urban areas where continuous lighting is existing or planned, or a possibility within 20 to 40 years from the construction of the bridge. After 20 to 40 years, the bridge may likely undergo a rehabilitation that may be extensive enough to include retrofitting pole bases onto the structure. When such an extensive rehabilitation is planned, the need for lighting on the structure should be reconsidered and pole bases should be added as necessary.

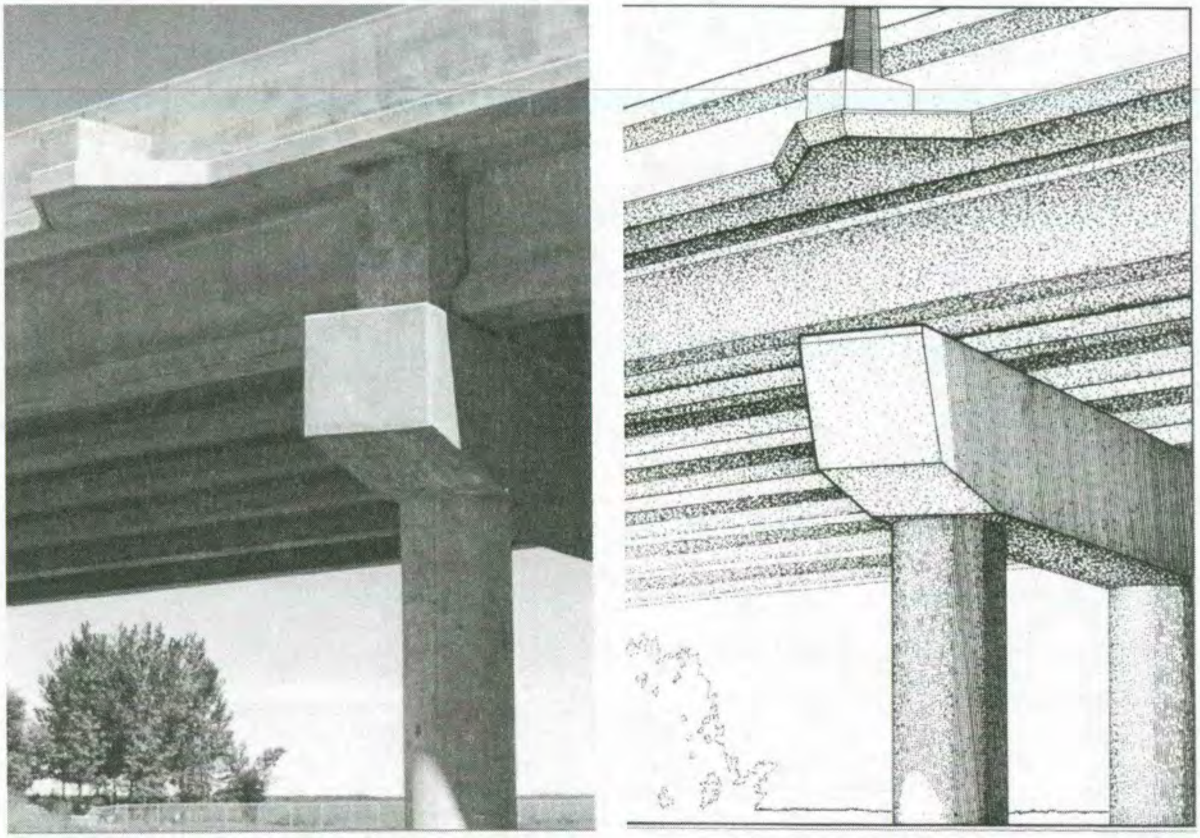


Figure 2: Pole base located off center of pier and over pier.

To determine how many pole bases are needed, the mounting height (MH) of the luminaire must be known. Normally, MH is assumed to be 40 to 50 feet for bridge-mounted lighting. For short bridges (length < 6 × MH), only one pole base is needed and it should be placed near the center of the bridge. For longer bridges (length > 6 × MH), several pole bases may be needed.

- if 6 × MH to < 12 × MH, then 2 bases are needed.
- if 12 × MH to < 18 × MH, then 3 bases are needed.
- if 18 × MH to < 24 × MH, then 4 bases are needed, and so on.

The following example illustrates how multiple poles should be spaced on a bridge that needs two pole bases:

$$\frac{S}{2}+\frac{S}{2}+S = 360\,\text{ft}$$
$$2S = 360\,\text{ft}$$
$$S = 180\,\text{ft}$$
$$\frac{S}{2} = 90\,\text{ft}$$

where :

S = distance between pole bases

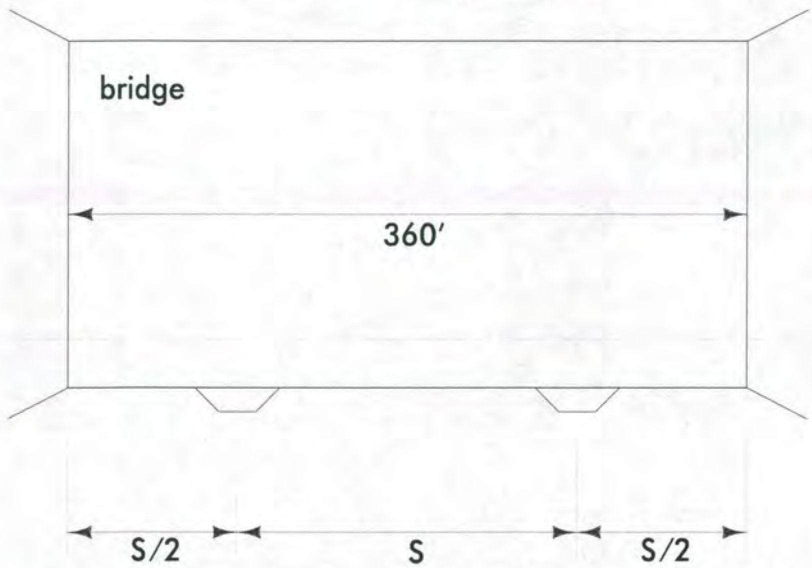


Figure 3: Generally, multiple pole bases should be spaced as shown in the example above.

If a bridge is being reconstructed in an area with existing lighting, the pole bases should be spaced in relation to the existing lighting with full consideration of the aesthetic design. As mentioned before, this may best be accomplished by placing the pole base over the bridge piers.

Single Bridges

If pole bases are warranted on a single bridge, their station location and side of the bridge should be specified on the bridge situation plan. If electrical lines are shown on the plan sheet on one side of the bridge, the pole bases should usually be placed on that side, otherwise either side of the bridge is acceptable.

Dual Bridges

For dual bridges, the same rules apply for determining how many pole bases are needed and how to space them. However, the pole bases should be provided on both bridges. Usually the pole bases are placed on the outside of the bridge and not on the median side.

Lighting Underneath Bridges

Conduits for underdeck lighting for single or dual bridges are warranted in the following cases:

- Sidewalks or other pedestrian facilities are being constructed under the bridge(s).
- A single bridge spans a roadway or interchange ramp where continuous lighting exists, is planned, or a possibility within 20 to 40 years from the construction of the bridge and the structure is greater than 60 feet wide. The same applies to a dual bridge with the width being the distance between the outside edges of both structures. After 20 to 40 years, the structure(s) may likely undergo a rehabilitation. When a rehabilitation is planned, the need for underdeck lighting on the structure should be reconsidered and the conduit and junction boxes should be added as necessary.

If underdeck lighting is warranted, the location station of the underdeck lighting outlet should be specified on the bridge situation plan.

Conduits and fixture boxes may be added externally to structure as needed; however, these may detract from the aesthetics of the bridge. The use of these should be discussed with the Office of Bridges and Structures for each situation.

Figure 4: Underdeck lighting using externally mounted conduits. Conduit and fixture boxes should be cast in concrete when possible to provide a more aesthetic appearance.

Junction Boxes

Junction boxes are used to connect electrical cable in conduits from outside of the bridge to conduit in the bridge. The following guidelines should be used in determining the location of junction boxes on a bridge:

- If a bridge rail contains a utility conduit, a junction box is needed at the both ends of the bridge rail.
- If pole bases are being constructed on a given side of the bridge, a junction box is needed on both ends of the associated bridge rail.

If underdeck lighting conduit is being constructed on a given side of the bridge, a junction box is needed on both ends of the associated bridge rail.

Project Automation

Iowa Department of Transportation
Office of Design

12A-1
English

Design Leveling Chart

Design Manual
Chapter 12
Project Automation

Originally Issued: 09-22-00

Plan		All centerlines	Edge of slab Edge of granular Back of Curb	Edge shoulder	General Text & Info. (including: leader lines, Ent.Text, Prop.Drainage Text, Scale Blk., etc.) M.L. 100 & 10 scales	Horiz. Curve Data, Horiz. Align.Annotation & leaderlines M.L. 100 & 10 scales	C.L. Tic Marks M.L. 100 & 10 scales	Clearing & Grubbing Shapes & info.	Proposed Drainage Structures, Pipes, Intakes, & Bridges	Ground line intercept line
Prof.		1	2	3	4	5	6	7	Proposed Drainage Structures, Pipes, Intakes, & Bridges 8	Profile grade line (prop.) 9
Plan			Face of Curb	"Pho" file Clip Lines (any sheet, any scale)	General Text & Info. (including: leader lines, Ent.Text, Prop.Drainage Text, Scale Blk., etc.) M.L. 50 scale	Horiz. Curve Data, Horiz. Align.Annotation & leaderlines M.L. 50 scale	C.L. Tic Marks M.L. 50 scale	Retaining Walls, Noise Barriers	Entrance Lines, Edge of Paved Ent., Entrance Pipes, Dikes	Sidewalk, Bike Path, Road Closure Barricade
Prof.	10	11	12	13	14	15	16	17	All remaining Existing data in the Profile area that doesn't go on level 19 (Ent. Profiles, etc.) 18	Existing C.L. Groundline 19
Plan	Intersection Layout Common Elements for Jointing, Staking, and Geometric layouts	Intersection Jointing Layout	Intersection Staking Layout	Intersection Geometric Layout	General Text & Info. (including: leader lines, Ent.Text, Prop.Drainage Text, Scale Blk., etc.) M.L. 20	Horiz. Curve Data, Horiz. Align.Annotation & leaderlines M.L. 20 scale	C.L. Tic Marks M.L. 20 scale		Slope lines & Slope terminators (non-borrow)	
Prof.	20	21	22	23	24	25	26	27	All remaining Prop. Data in the Profile area that doesn't go on levels 8, 9, and 29 (Ditch Grds., Bar Graphs, Balances, etc.) 28	Prop. "Profile" Grd. info. except Profile Grd. line 29
Plan	Geopak Points				General Text & Info. (including: leader lines, Ent.Text, Prop.Drainage Text, Scale Blk., etc.) S.R. - (rotated text) 100 & 10 scales	Horiz. Curve Data, Horiz. Align.Annotation & leaderlines S.R. (rotated text) 100 & 10 scales	C.L. Tic Marks S.R. 100 & 10 scales		Overlap Data (Even number M.L. "Plan" sheets)	Overlap Data (Odd number M.L. "Plan sheets)
Prof.	30	31	32	33	34	35	36	37	Overlap Data (Even number "Profile" sheet) 38	Overlap Data (Odd number "Profile" sheet) 39
Plan	Runaround & Detour (C.L. & Edge of Slab)	Storm Sewer Layout	Borrow work	Patterns	General Text & Info. (including: leader lines, Ent.Text, Prop.Drainage Text, Scale Blk., etc.) S.R. - (rotated text) 50 scale	Horiz. Curve Data, Horiz. Align.Annotation & leaderlines S.R. (rotated text) 500 scale	C.L. Tic Marks S.R. 50 scale	Geopak Visualization Points	Overlap Data (Even number S.R. "Plan sheets - Single Sheet or "Lt. End Dual" Sheet)	Overlap Data (Odd number S.R. "Plan sheets - Single Sheet or "Lt. end Dual" Sheet)
Prof.	40	Storm Sewer Layout 41	Borrow work 42	Patterns 43	44	45	46	47	48	49
Plan	Runaround & Detour (Text, details, & info.)	Sanitary Sewer Layout	M.L. - Working Info. & Field Exam Notes (NOT for final plan)	S.R. - Working Info. & Field Exam Notes (NOT for final plan)	General Text & Info. (including: leader lines, Ent.Text, Prop.Drainage Text, Scale Blk., etc.) S.R. - (rotated text) 20 scale	Horiz. Curve Data, Horiz. Align.Annotation & leaderlines S.R. (rotated text) 20 scale	C.L. Tic Marks S.R. 20 scale		Overlap Data (Even number S.R. "Plan" sheets - "Rt. End Dual" Sheet)	Overlap Data (Odd number S.R. "Plan" sheets - "Rt. End Dual" Sheet)
Prof.	50	Sanitary Sewer Layout 51	M.L. - Working Info. & Field Exam Notes (NOT for final plan) 52	S.R. - Working Info. & Field Exam Notes (NOT for final plan) 53	54	55	56	57	58	59
Plan	Sheet Shapes - M.L.	Sheet Shapes - S.R. (primary sideroad)	Sheet Shapes - S.R. (secondary sideroad, ramps, accessways, frontage roads, etc.)	Sheet Shapes - Other	**Office of Design Leveling Chart**					
Prof.	Sheet Shapes - ABC sheets or other "stand alone" types 60	Sheet Shapes - Profile 61	62	63	**New English - effective date 5-1-99**					6-7-99

Photogrammetry Leveling Chart

Originally Issued: 09-22-00

	C.L. Roadway 1	Curb EDGES –Dirt Road –Gran. Shld –Gravel Road –Gutter –Paved Road –Paved Shld 2	Entrance C.L. EDGES –Entrances –Parking –Sidewalk –Trails –Bank –Draw 3	Bridge Linework Culvert Linework 4	Airport Runway Concrete Slab Buildings Foundation 5	6	7	Guardrail ROW Rail Lot Corner Fences 100 or 10 8	Dike / Dam Retaining Wall Rock Outcropping Riprap, Sink Hole Terrace Tile Linework Tile Outlet 100 or 10 9
Drainage Arrows 100 or 10 10	Edge of Water Swamp 100 or 10 11	Utilities, Intakes Hydrants, Valves Luminaires, Manholes Sewer Lines, (See List) 100 or 10 12	Broken Concrete Cave, Cemetery Cistern, Tanks Signs, Wells, Windmills, Outhouse, (See List) 100 or 10 13	Section Corner Section Line 100 or 10 14	Trees, Hedge, Shrub, Bushes, Stump, (See List) 100 or 10 15	Railroad 100 or 10 16	Corporation Line 100 or 10 17	C.L. Tic Marks 100 or 10 18	Hortz. Align. Point (circle) 100 or 10 19
GPS Points 100 or 10 20	100 or 10 21	100 or 10 22	100 or 10 23	Survey Line 24	25	26	27	Guardrail ROW Rail Lot Corner Fences 50 28	Dike / Dam Retaining Wall Rock Outcropping Riprap, Sink Hole Terrace Tile Linework Tile Outlet 50 29
Drainage Arrows 50 30	Edge of Water Swamp 50 31	Utilities, Intakes Hydrants, Valves Luminaires, Manholes Sewer Lines, (See List) 50 32	Broken Concrete Cave, Cemetery Cistern, Tanks Signs, Wells, Windmills, Outhouse, (See List) 50 33	Section Corner Section Line 50 34	Trees, Hedge, Shrub, Bushes, Stump, (See List) 50 35	Railroad 50 36	Corporation Line 50 37	C.L. Tic Marks 50 38	Hortz. Align. Point (circle) 50 39
GPS Points 50 40	50 41	50 42	50 43	Survey Point Descriptions 44	Misc. Notes for File Information 45	46	47	Guardrail ROW Rail Lot Corner Fences 20 48	Dike / Dam Retaining Wall Rock Outcropping Riprap, Sink Hole Terrace Tile Linework Tile Outlet 20 49
Drainage Arrows 20 50	Edge of Water Swamp 20 51	Utilities, Intakes Hydrants, Valves Luminaires, Manholes Sewer Lines, (See List) 20 52	Broken Concrete Cave, Cemetery Cistern, Tanks Signs, Wells, Windmills, Outhouse, (See List) 20 53	Section Corner Section Line 20 54	Trees, Hedge, Shrub, Bushes, Stump, (See List) 20 55	Railroad 20 56	Corporation Line 20 57	C.L. Tic Marks 20 58	Hortz. Align. Point (circle) 20 59
GPS Points 20 60	20 61	20 62	20 63						

100 or 10 Scale (lv 8–23)
50 Scale (lv 28–43)
20 Scale (lv 48–63)

".pho" file Leveling Chart

For NEW English Projects only
Effective Date: May 1, 1999

6-7-99

Text File Leveling Chart

Design Manual
Chapter 12
Project Automation

Originally Issued: 09-22-00

	Entrance text Building text General text M.L. 1	Scale Blocks North Arrow M.L. 2	Intersection Angle Arc and text M.L. 3	Hwy. Sym. & text Sect. Line text Township Sec. Range M.L. 4	Bridge, Culvert, Tile text M.L. 5	Survey Line text, "plus & dist" to features M.L. 6	M.L. 7	8	M.L. or S.R. 9
Curve Data Alignment Text Leader Lines M.L. 100 or 10 Scale 10	Curve Data Alignment Text Leader Lines M.L. – 50 Scale 11	Curve Data Alignment Text Leader Lines M.L. – 20 Scale 12	Utilities text (size & notes) M.L. 13	Overlap Data (even # sheet) M.L. 14	Overlap Data (odd # sheet) M.L. 15	M.L. 16	M.L. 17	18	GPS point text M.L. or S.R. 19
20	Entrance text Building text General text S.R. 21	Scale Blocks Norht Arrow S.R. 22	Intersection Angle Arc and text S.R. 23	Hwy. Sym. & text North Arrows Sect. Line text Township Sec. Range S.R. 24	Bridge, Culvert, Tile text S.R. 25	Survey Line text, "plus & dist" to features S.R. 26	S.R. 27	28	M.L. or S.R. 29
Curve Data Alignment Text Leader Lines S.R. 100 or 10 Scale 30	Curve Data Alignment Text Leader Lines S.R. – 50 Scale 31	Curve Data Alignment Text Leader Lines S.R.– 20 Scale 32	Utilities text (size & notes) S.R. 33	Overlap Data (even # sheet) S.R. 34	Overlap Data (odd # sheet) S.R. 35	M.L. 36	M.L. 37	38	M.L. or S.R. 39
40	Entrance text Building text General text S.R. 2 41	Scale Blocks Norht Arrow S.R. 2 42	Intersection Angle Arc and text S.R. 2 43	Hwy. Sym. & text North Arrows Sect. Line text Township Sec. Range S.R. 2 44	Bridge, Culvert, Tile text S.R. 2 45	Survey Line text, "plus & dist" to features S.R. 2 46	S.R. 2 47	48	M.L. or S.R. 49
Curve Data Alignment Text Leader Lines S.R. 100 or 10 Scale 50	Curve Data Alignment Text Leader Lines S.R. 2 – 50 Scale 51	Curve Data Alignment Text Leader Lines S.R. 2 – 20 Scale 52	Utilities text (size & notes) S.R. 2 53	Overlap Data (even # sheet) S.R. 2 54	Overlap Data (odd # sheet) S.R. 2 55	M.L. 56	M.L. 57	58	Misc. Notes for File Information M.L. or S.R. 59
Centerline Stations M.L. & S.R. 100 or 10 Scale 60	Centerline Stations M.L. & S.R. 50 Scale 61	Centerline Stations M.L. & S.R. 20 Scale 62	63						

M.L. Data
S.R. Data
S.R. 2 Data
M.L. and /or S.R. Data

".txt" file Leveling Chart

For NEW English Projects only
Effective Date: May 1, 1999

6-7-99

GEOPAK® Element and File Naming Conventions

Originally Issued: 12-20-99

See Section 12A-10 for an example of how these conventions are used.

General

Operator Code

Section	Operator Code
Road 1, Road 2, Road 3, Road 4, Road 5	R1, R2, R3, R4, R5
Geometrics	GE
Soils	SO
Photogrammetry	PH
Section or Office	**Suggested Operator Code**
Roadside Development	RS
Right of Way	RW
Preliminary Bridge and Final Bridge	BR
Consultant	Use 2-letter abbreviation for company

Job Number

3-digit route number (i.e. US 520 would be 520, Interstate 35 would be 035)

Element Naming Conventions

Chains

The maximum chain name length for construction and survey chains is 6 characters, leaving 1 character for ramp notation.

Survey

mainline	SUR`jobnumber` (i.e. SUR520, SUR018, SUR006)
side road	SUR`sideRoadName`

Note: if survey and construction alignments are the same, use the construction naming convention.

Construction

mainline	ML`JobNumber` (i.e. ML520, ML018, ML006)
side road	`SideRoadName`
variable medians	`ConstructionChainName DirectionOfTravel` (i.e. if the direction of travel of the "bubble out" on US 520 is east, it would be ML520E1. If there are multiple bubbles, ML520E1, ML520E2, etc. This name can have up to 7 characters.
ramps and loops	`SideRoadName`A, `SideRoadName`B, `SideRoadName`C, `SideRoadName`D, etc. (i.e. at US 520 (mainline) and County Road D35 (sideroad): D35A, D35B, D35C, D35D.

Other Elements

	Left	Right	Both (Left and Right)	Median
Ditch Grades	DGL`beginning sta`	DGR`beginning sta`	DGB`beginning sta`	DGM`beginning sta`
Backslopes	BSL`beginning sta`	BSR`beginning sta`	BSB`beginning sta`	NA
Foreslopes	FSL`beginning sta`	FSR`beginning sta`	FSB`beginning sta`	NA
Barn Roof	BRL`beginning sta`	BRR`beginning sta`	BRB`beginning sta`	NA
Bench Grades	BGL`beginning sta`	BGR`beginning sta`	BGB`beginning sta`	NA
Note: `beginning sta` is only the numbers to the left of the "+" sign (i.e. 235 + 55.876 is 235)				

Points

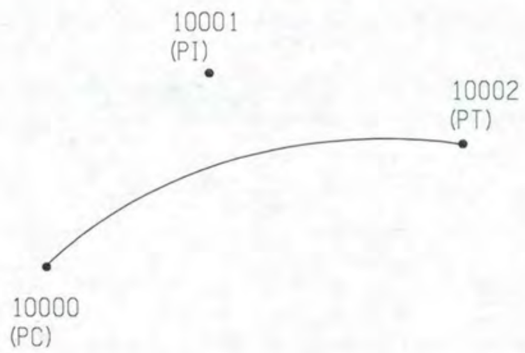
Only numeric point names should be used for critical alignment points. This is for the benefit of construction survey.

preliminary GPS and control points	1–999
Bridge	1000–1499
Transportation Center survey crews	1500–3499
Right-of-Way Design and Transportation Center Right-of-Way	
centerline points not numbered by Design	3500–3999
existing ROW points	4000–4999
new ROW points	5000–5999
temporary easement points	6000–6999
property points	7000–7999
section corners, lot corners, etc.	8000–8999
miscellaneous	9000–9999
Geometrics	
ramp, loop, etc. alignments	20,000–20,999
Road Design	
mainline alignment	21,000–21,999
side road alignments	22,000–22,999
detours, run arounds, returns, etc.	23,000–23,999
miscellaneous points	24,000–24,999

Curves and Spirals

Recommendation: name the curve according to the PI, PC, or PT point name used to store the curve.

Example: If point 10000 is used as one of the points to store the curve, the name of the curve would be 10000. There is no need to put a CUR in front of it—GEOPAK® will recognize that it's a curve.



Profiles

Existing Ground	Proposed	Edge of Slab (used for superelevation)
chain_E	chain_P	chain_S

File Naming Conventions

Design Files

main design file	kfilename.dgn
shape file (if multiple files are needed, *.shp1, *.shp2, etc.)	kfilename.shp
cross section design file	xs_chain.dgn
Project Manager PRJ file	kfilename.prj

Soil Files

main soils design file	kfilename.sol
cross section soils file	xs_chain.sol
project manager PRJ file	kfilename.prj

Input and .var Files

define.var	def_chain.var
user.var	user_chain.var
shape input file	shp_chain.inp
cross section input file	xs_chain.inp
cross section sheeting input file	xssht_chain.inp
preliminary earthwork input file—same filename for .txt and .log files	ewp_chain.inp
final earthwork input file—same filename for .txt and .log files	ewf_chain.inp
right-of-way input file	row_chain.inp

Cross Section Sheeting

Preliminary	
mainline	xs_chain.Wxx
sideroads	xs_chain.Xxx
ramps and loops	xs_chain.Yxx
borrows	xs_chain.Zxx
xx = 01, 02, 03, 04, etc.	
For all preliminary work, the sheet files will remain separated (i.e. individual SR sheet files, individual ramp sheet files, etc.)	
Final	
mainline	kfilename.Wxx
sideroads	kfilename.Xxx
ramps and loops	kfilename.Yxx
xx = 01, 02, 03, 04, etc.	
For final design, the cross section sheet files will be combined into one file. When these are created, delete all of the preliminary sheet files (xs_chain.Wxx, xs_chain.Xxx, xs_chain.Yxx, xs_chain.Zxx) and edit your cross section sheet input files to write to the final sheet files (kfilename.Wxx, kfilename.Xxx, kfilename.Yxx, kfilename.Zxx).	

In addition, the following lines in your sheet input file may have to be altered:

```
beginning x coord = 10020        /* 2000, 10020          1000, 10010 */
beginning y coord = 9948         /*2000, 9948            1000, 9974 */
```

Coordinate Geometry (COGO) Input

ChainJob#.iOperatorCode

The horizontal and vertical alignments should be in one input file. There should be a separate input file for the mainline and each side road. For interchanges, all ramps or loops should be combined into one input file.

For geometric submittal to the design squads, the format will be that all ramps and loops will be in one input file named:

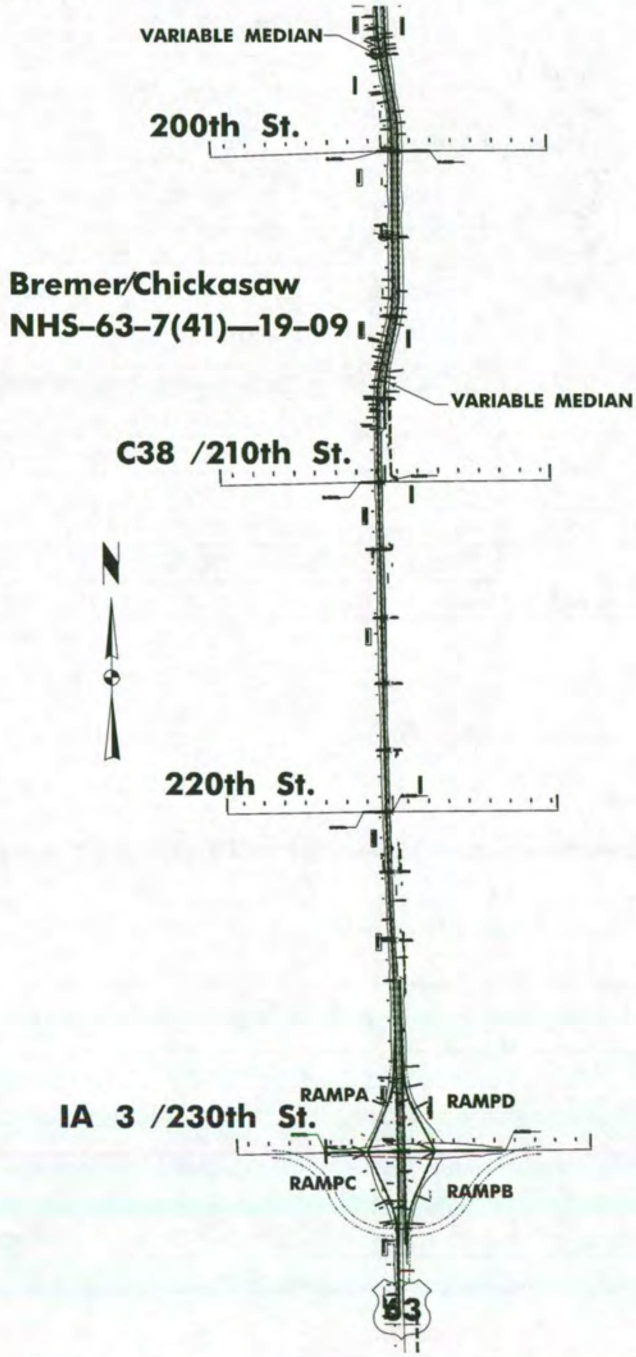
preliminary interchange design	sideroadchainprejob#.ige
final interchange design	sideroadchainfnljob#.ige

Suggestion: create a subdirectory within your project directory named "COGOInput" to store these input files and "COGOOutput" to store any output files. This will be a default in any new project directory setups.

Example: GEOPAK® Element and File Naming

Originally Issued: 12-20-99

The following example is for the Bremer/Chickasaw Highway 63 project (NHS-63-7(41)--19-09) designed by the Rural 3 Design Section.



General

Operator Code: R3

Job Number: 063

Element Naming Conventions

Chains

Survey

mainline	SUR063
side road	SURIA3, SUR220TH, SURC38, SUR200TH

Construction

mainline	ML063
side road	IA3, 220TH, C38, 200TH
variable medians	ML063N1, ML063S1
Ramp A	IA3A
Ramp B	IA3B
Ramp C	IA3C
Ramp D	IA3D

Other Elements

	Left	Right	Both (Left and Right)	Median
Ditch Grades	DGLbeginning sta	DGRbeginning sta	DGBbeginning sta	DGMbeginning sta
Backslopes	BSLbeginning sta	BSRbeginning sta	BSBbeginning sta	NA
Foreslopes	FSLbeginning sta	FSRbeginning sta	FSBbeginning sta	NA
Barn Roof	BRLbeginning sta	BRRbeginning sta	BRBbeginning sta	NA
Bench Grades	BGLbeginning sta	BGRbeginning sta	BGBbeginning sta	NA
Note: beginning sta is only the numbers to the left of the "+" sign (i.e. 235 + 55.876 is 235)				

Points

Points for setting the alignment centerlines should be numeric only.

Curves and Spirals

Recommendation: name the curve according to the PI, PC, or PT point name used to store the curve.

Profiles

Existing					
ML063_E	ML063S1_E	220TH_E	200TH_E	IA3B_E	IA3D_E
ML063N1_E	IA3_E	C38_E	IA3A_E	IA3C_E	
Proposed					
ML063_P	ML063S1_P	220TH_P	200TH_P	IA3B_P	IA3D_P
ML063N1_P	IA3_P	C38_P	IA3A_P	IA3C_P	
Edge of Slab (used for superelevation)					
ML063_S	ML063S1_S	220TH_S	200TH_S	IA3B_S	IA3D_S
ML063N1_S	IA3_S	C38_S	IA3A_S	IA3C_S	

File Naming Conventions

Design Files

Main Design File
k09063041.dgn
Shape File
k09063041.shp
Cross Section Files
xs_ML063.dgn
xs_C38.dgn
xs_IA3B.dgn
xs_IA3.dgn
xs_200TH.dgn
xs_IA3C.dgn
xs_220TH.dgn
xs_IA3A.dgn
xs_IA3D.dgn
Project Manager File
k09063041.prj

Input and .var Files

Define.var		
def_ML063.var	def_C38.var	def_IA3B.var
def_IA3.var	def_200TH.var	def_IA3C.var
def_220TH.var	def_IA3A.var	def_IA3D.var
User.var		
user_ML063.var	user_C38.var	user_IA3B.var
user_IA3.var	user_200TH.var	user_IA3C.var
user_220TH.var	user_IA3A.var	user_IA3D.var
Shape Input File		
shp_ML063.inp	shp_C38.inp	shp_IA3B.inp
shp_IA3.inp	shp_200TH.inp	shp_IA3C.inp
shp_220TH.inp	shp_IA3A.inp	shp_IA3D.inp
Cross Section Input File		
xs_ML063.inp	xs_C38.inp	xs_IA3B.inp
xs_IA3.inp	xs_200TH.inp	xs_IA3C.inp
xs_220TH.inp	xs_IA3A.inp	xs_IA3D.inp
Cross Section Sheeting Input File		
xssht_ML063.inp	xssht_C38.inp	xssht_IA3B.inp
xssht_IA3.inp	xssht_200TH.inp	xssht_IA3C.inp
xssht_220TH.inp	xssht_IA3A.inp	xssht_IA3D.inp
Preliminary Earthwork Input File		
ewp_ML063.inp	ewp_C38.inp	ewp_IA3B.inp
ewp_IA3.inp	ewp_200TH.inp	ewp_IA3C.inp
ewp_220TH.inp	ewp_IA3A.inp	ewp_IA3D.inp
Final Earthwork Input File		
ewf_ML063.inp	ewf_C38.inp	ewf_IA3B.inp
ewf_IA3.inp	ewf_200TH.inp	ewf_IA3C.inp
ewf_220TH.inp	ewf_IA3A.inp	ewf_IA3D.inp
Right-Of-Way Input File		
row_ML063.inp		

Cross Section Sheeting

Preliminary	
Mainline	xs_ML063.W01
	xs_ML063.W02
Side Roads	xs_IA3.X01
	xs_220TH.X01
	xs_C38.X01
	xs_200TH.X01
Ramps and Loops	xs_IA3A.Y01
	xs_IA3C.Y01
	xs_IA3B.Y01
	xs_IA3D.Y01
Borrows	xs_ML063.Z01
Final	
Mainline	k09063041.W01
	k09063041.W02
Side Roads	k09063041.X01
	k09063041.X02
Ramps and Loops	k09063041.Y01

Coordinate Geometry (COGO) Input

ML063063.iR3	IA3063.iR3	200TH063.iR3
ML063N1063.iR3	220TH063.iR3	IA3INT063.iR3
ML063S1063.iR3	C38063.iR3	

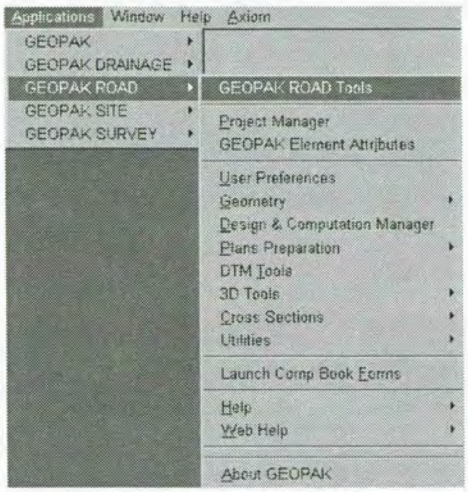
For Geometric submittal to the design squads:

preliminary interchange design	IA3pre063.ige
final interchange design	IA3fnl063.ige

GEOPAK® Road User Preferences (Using Project Manager)

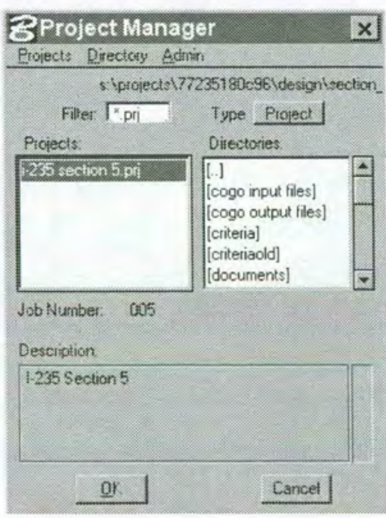
Originally Issued: 12-20-99

1. To bring up the **GEOPAK Road** toolbox select **Applications→GEOPAK Road→GEOPAK Road Tools.**



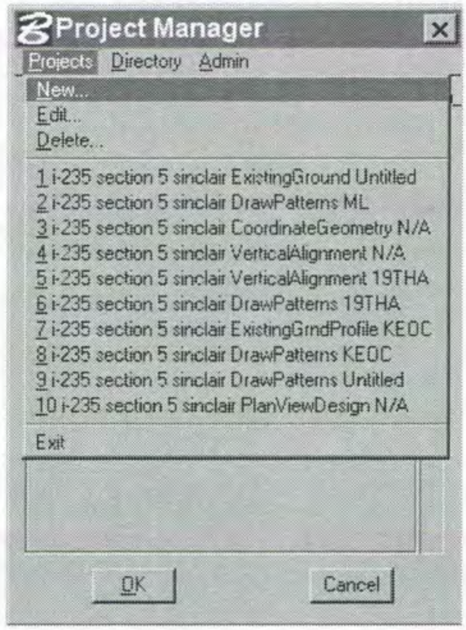
2. Select the upper left-hand button on the GEOPAK pallet. This is the **Project Manager** button. 

3. The **Project Manager** dialog box appears.

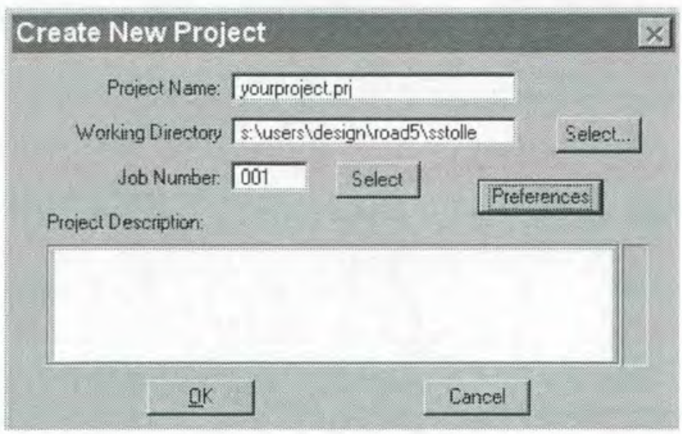


Change this to your current project directory by selecting the path here. This is where your Project Manager file will be located.

4. Select **Projects→New**.



5. This opens the **Create New Project** dialog box.



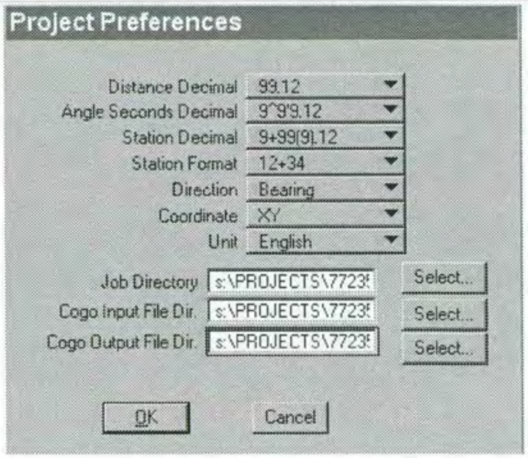
a. **Project Name**: type in a name descriptive of your project (such as the `kfilename`).

b. **Working Directory**: your project directory.

c. **Job Number**: the three-digit route number (034, 520, etc.). If a *.gpk* file has already been created, the **Select** button can be used to select the file. If this is a new project, just type in the route number.

d. **Project Description**: a short description of your project.

6. Now click on the **Preferences** button. This brings up the **Project Preferences** box.



a. Set the **Coordinate** to XY.

b. Set the **Unit** to Metric or English depending on your project.

c. Set the **Job Directory** to your project directory and the Input and Output directories to the appropriate directories.

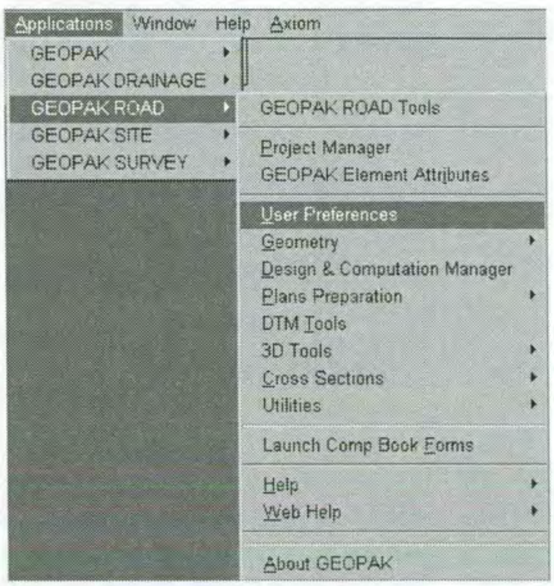
d. Click **OK**.

e. Click **OK** on the **Create New Project** box.

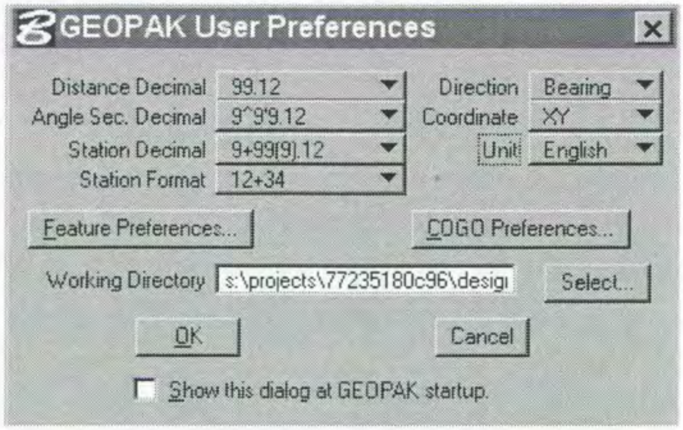
f. Click on **OK** in the next box to create your own *.gpk* file (this is *only* if you have created a new *.gpk* file). As a result, a file called `yourproject.prj` will be created in your selected directory.

g. Now highlight the project you just created and click **OK**.

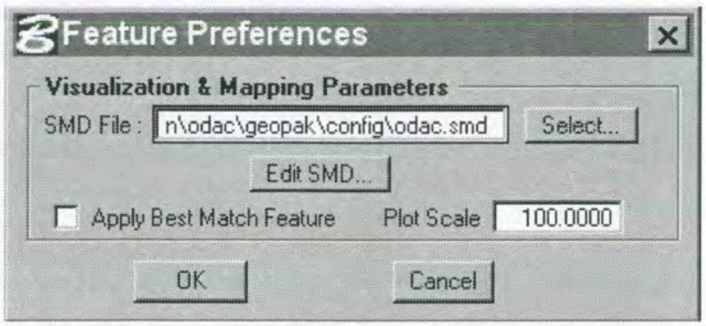
7. The **Feature Preferences** also need to be set. To do this, go to **GEOPAK User Preferences**.



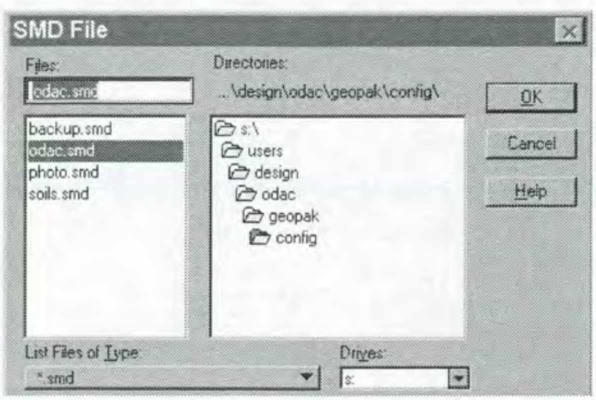
a. Click on **Feature Preferences**.



b. These preferences are for the Visualization Tool in COGO.



c. Select the specified path to the ODAC file.



8. Your Project Manager settings and user preferences for GEOPAK Road are now setup.

Sample Plan

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English

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Re-Issued: 01-04-02

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Revision Letters

Iowa Department of Transportation
Project Development Division

TO: Holders of Design Manual

FROM: Office of Design

SUBJECT: Revision to Manual (English)

REVISION DATE: 01-04-02

The enclosed pages are revisions and additions to the *Design Manual*. The table below provides instructions and a brief description of each revision.

This revision letter should be kept as a record of receipt of this revision. There is a tab at the end of the *Design Manual* titled "Revision Letters" where this letter and past letters should be placed.

Significant changes to the text in existing sections that are being revised have been highlighted with change bars (shown at left). The purpose of these is to make it easy to locate material that has changed.

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`http://www.dot.state.ia.us/design/desman.htm`

Questions concerning the distribution of revisions to the *Design Manual* should be directed to the Office of Finance, telephone (515) 239-1588. Questions or comments concerning information contained in the Design Manual should be directed to the Methods Section, Office of Design, telephone (515) 239-1851.

English Manual	
Table of Contents	Revised.
1B-4	"Densities for Use in Estimating Quantities." Revised. Change ACC to HMA.
1C-1	"Design Guides for New and Reconstructed Highways." Revised. Changes in K values and sight distances.
1C-2	"Clear Zones." Revised. Change degree of curvature to radius.
1D-8	"Access Review." Revised. Change "Transportation Center Development Engineer" to "District Office Design Engineer."
1D-14	"Lighting Warrants Request." Revised. Change "Office of Traffic Engineering and Safety" to "Office of Traffic and Safety."
1E-3	"Plan Revisions." Revised. Change "cover letter" to "cover memo."
1F-1	"Title Sheet." Revised. Corrections in Figures 1 and 10 and some minor wording changes.
1F-2	"Location Map Sheet." Revised. Correction on page 1.
2A-1	"Horizontal Curve Design." Revised. Change degree of curvature to radius and minor wording changes.
2A-2	"Superelevation." New.
2A-3	"Superelevation Tables." New.
2A-4	"Compound Horizontal Curve Design." New.
2B-1	"Vertical Curve Design." Revised. Add in reference to Section 6D-5.
2D-1	"Reverse Curve Design." Revised. Add in references to Sections 2A-2 and 2A-3 and minor changes in example problem.
3E-2	"Median Crossings." New.
3E-3	"Median Crossovers." New.
3K-2	"Design of Urban Entrances." Revised. Minor wording changes.

4A-2	"Effects of Roadway Geometrics on Urban Pavement Drainage." Revised. Change AASHTO reference on page 2.
4A-4	"The Rational Method." Revised. Minor corrections and wording changes.
4A-5	"Calculating Spread and Checking Intake Location." Revised. Add table on page 2 and add in equation for d_2 on page 6.
4A-6	"Sizing Intakes." Revised. Define L and LT for Figure 1 and change RA-68 to RA-70, other minor changes.
4C-1	"Subdrains." Revised. Correct reference on page 1.
4C-2	"Bridge End Drains." Revised. Minor changes to Figures 1, 2 & 3 and minor wording changes elsewhere.
6A-1	"Horizontal Intersection Design." Revised. Change degree of curvature to radius in Figures 4 & 5, changes in Table 2.
6A-4	"Horizontal Sight Distance at Intersections." Revised. Numerous changes related to changes in AASHTO Greenbook for 2001.
6A-7	"Rumble Strips at Intersections." Revised. Change "Office of Traffic Engineering" to "Office of Traffic and Safety."
6C-5	"Four-Lane Expressway Turn Lanes." New.
6C-6	"Continuous Two-Way Left-Turn Lanes (TWLTLs)." Revised. Change "Office of Traffic and Safety Engineering" to "Office of Traffic and Safety," add in additional material.
6C-8	"Parking on Urban Highways." New.
6D-1	"Stopping Sight Distance." New.
6D-3	"Passing Sight Distance." New.
6D-5	"Sight Distance on Vertical Curves." New.
7A-3	"Jointing Rural Intersections." Revised. Correct Figure 6, wording changes.
7A-4	"Jointing Urban Intersections." Revised. Change joints for side street to "C" joints.
7D-8	"Pavement Widening on Resurfacing Projects." Revised. Add in new Figure 2.
8B-1	"Shielding Side Obstacles." Revised. Revised runout lengths in Table 3.
8B-2	"Shielding Median Obstacles." Revised. Wording changes on page 1.
8B-3	"Barrier at Bridge Approaches." Revised. Change to 6"x8" wood posts, various other changes throughout the section.
8B-3A	"RE-67 (Bullnose) Installation at Skewed Bridges." Revised. Change to 6"x8" wood posts.
8B-10	"Tabulating Guardrail." Revised. Numerous changes in tab sheets.
9A-5	"Traffic Control Plans." Revised. Replace "transportation center" with "District Office" and complete last sentence on page 4.
9B-4	"Pavement Markings and Delineators." Revised. Minor change on page 1 and in Figure 1.
9B-9	"Temporary Barrier Rail." Revised. Change "Office of Traffic Engineering" to "Office of Traffic and Safety."
9C-6	"On-Site Detours and Temporary Connections." Revised. Add in Table 1 and minor wording changes.
10D-1	"Storm Water Discharge Permits." Revised. Add in several new figures and wording changes.
11A-1	"Bicycle Accommodation on Primary Highways." Revised. Minor wording changes.
Index	Revised.

Iowa Department of Transportation
Highway Division

TO: Holders of Design Manual

FROM: Office of Design

SUBJECT: Revision to Manual (English)

REVISION DATE: 04-20-01

The enclosed pages are revisions and additions to the *Design Manual*. The table below provides instructions and a brief description of each revision.

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English Manual	
Cover Page	Revised.
Table of Contents	Revised.
1C-1	"Design Guides for New and Reconstructed Highways." Revised. See change bars.
1C-2	"Clear Zones." Correct header on pages 3 & 5.
1D-9	"Field Examination Checklist." Revised. See change bars on pages 1 & 5.
1D-14	"Lighting Warrants Request." Revised. Lighting Transferred to Office of Traffic and Safety Engineering.
1E-2	"Plan Organization." Revised. Reorganize order of sheets.
1E-8	"Plan Submittals for County Review." New Section.
1F-1	"Title Sheet." Revised. Correction in Figure 1. Change Sta. 25+32.23 to Sta. 25+32.26.
1F-2	"Location Map Sheets." New Section
1F-3	"Legend and Symbol Information Sheet." New Section.
1F-4	"Plan Revision Sheets." New Section.
2C-1	"Spiral Curve Design." Revised. On page 3, change 0.058178 to 0.58178.
3J-1	"Berms and Benches." Revised. Modify Figure 1.
3K-2	"Design of Urban Entrances." Revised. Changed values in Table 1 and other minor changes, see change bars.
4A-3	"Preliminary Locations of Intakes and Utility Accesses." Revised. Change Standard Road Plan references and eliminate paragraph on location restrictions.
4A-7	"The Pavement Drainage Sheet." Revised. Change Standard Road Plan references, change reference to IDF charts to Table 5 and correct values in sample pavement drainage sheet.

4A-8	"Design of Storm Sewer Pipe." Revised. Change intake references, change references to IDF charts, other changes, see change bars.
6A-4	"Horizontal Sight Distance at Intersections." Revised. Change IAC Rule 820(06.C) to IAC 761-Chapter 112(306A)
6B-6	"Accesses and Safety Dikes at Ramp/Loop Terminals." New Section.
6C-1	"Adding, Dropping, or Redirecting Through Lanes." Revised. Added reference to Section 2D-1.
6C-6	"Continuous Two-Way Left-Turn Lanes (TWLTLs)." New Section.
7A-3	"Jointing Rural Intersections." Revised. Change "median crossing" to "median opening."
7A-4	"Jointing Urban Intersections." Revised. Change RA-3 to RA-40.
7D-8	"Pavement Widening on Resurfacing Projects." New Section.
8B-2	"Shielding Median Obstacles." Revised. See change bars.
8B-3	"Barrier at Bridge Approaches." Revised. See change bars.
8B-4	"Culvert Treatments." Revised. Change maximum span width to 24'-4" and other minor changes. See change bars.
8B-6	"Shielding Standing Water." Revised. Remove reference to Section 8B-5.
9C-4	"Work on Multilane Roadways." Revised. Change references to Standard Road Plans and Design Details, see change bars.
12A-9	"GEOPACK® Element and File Naming Conventions." Revised. See change bar on page 2.
Index	Revised.

Iowa Department of Transportation
Project Development Division

TO: Holders of Design Manual

FROM: Office of Design

SUBJECT: Revision to Manual (English)

REVISION DATE: 10-20-00

The enclosed pages are revisions and additions to the *Design Manual*. The table below provides instructions and a brief description of each revision.

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English Manual	
1C-1	"Design Guides for New and Reconstructed Highways." Revised. See change bars.
1C-2	"Clear Zones." Revised. See change bars.
1D-9	"Field Examination Checklist (New and Reconstructed Highways." Revised. See change bars.
3C-3	"Shoulders at Superelevated Curves." Revised. See change bars.
3D-1	"Subgrade Slopes." Revised. See change bars.
4A-4	"The Rational Method." Revised. See change bars.
6A-4	"Horizontal Sight Distance at Intersections." Revised. See change bars.
6B-1	"Cross Sections of One-Way Ramps and Loops." Revised. See change bars.
7D-3	"Pavement Markings." Revised. See change bars.
8B-1	"Shielding Side Obstacles." Revised. See change bars.
8B-3	"Barrier at Bridge Approaches." Revised. See change bars.
8B-10	"Tabulating Guardrail." Revised. See change bars.
9B-9	"Temporary Barrier Rail." Revised. See change bars.
10C-1	"Erosion Control Devices." Revised. See change bars.
10D-1	"Storm Water Discharge Permits." Revised. See change bars.
10E-1	"Fencing." Revised. See change bars.
11A-2	"Pedestrian Sidewalk Design." Revised. See change bars.

Iowa Department of Transportation
Project Development Division

TO: Holders of Design Manual

FROM: Office of Design

SUBJECT: Revision to Manual (English)

REVISION DATE: 09-22-00

The enclosed pages are revisions and additions to the *Design Manual*. The table below provides instructions and a brief description of each revision.

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English Manual	
Table of Contents	Revised.
1D-3	"Preliminary Survey Procedure." New section.
1D-10	"Field Examination Checklist (3R and 4R Projects)." New section.
1E-3	"Plan Revisions." Revised. See change bars.
1E-4	"Road Design Details." New section.
1F-1	"Title Sheet." New section.
2A-1	"Horizontal Curve Design." New section.
2B-1	"Vertical Curve Design." New section.
2C-1	"Spiral Curve Design." New section.
2D-1	"Reverse Curve Design." New section.
3J-1	"Berms and Benches." New section.
3K-2	"Design of Urban Entrances." New section.
4B-3	"Removing or Filling Existing Culverts." New section.
4C-2	"Bridge End Drains." New section.
5B-1	"Borrow Design." New section.
7D-4	"Treatment of Old Roadbeds." New section.
8B-3A	"RE-67 (Bullnose) Installations at Skewed Bridges." New section.
12A-1	"Design Leveling Chart." New section.
12A-2	"Photogrammetry Leveling Chart." New section.
12A-3	"Text File Leveling Chart." New section.
Index	Revised.