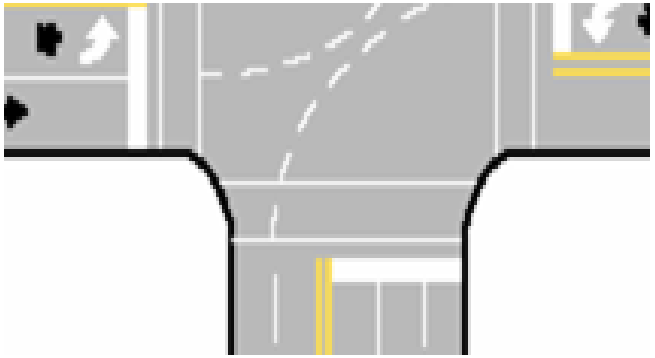
Intersection Design

Intersections

- More **complicated** area for drivers
- Main function is to provide for **change of direction**
- Source of congestion in urban areas
- Concern for safety (fender benders in urban, fatals in rural)



Types of Intersections

- **Grade separated** with ramps (freeway interchange)
- Grade separated without ramps (over or underpass with **no access**)
- ***At-grade***
  - Conventional
  - Roundabouts
  - New concepts (e.g., "continuous flow")

Design Objectives

- "To reduce the severity of potential conflicts between motor vehicles, pedestrians, and facilities while facilitating the convenience, ease, and comfort of people traversing the intersection." AASHTO
- Provide ease/control of access consistent with the function of intersecting roadways

Operational Requirements

- Provide adequate **sight distance** – for approach and departure maneuvers
- Minimize turning and through **conflicts**
- Provide **natural paths** for permitted movements
- Avoid geometry (**sharp curves/steep grades**) that complicates the driving task and adversely impacts acceleration or deceleration

Intersection Sight Distance – ISD

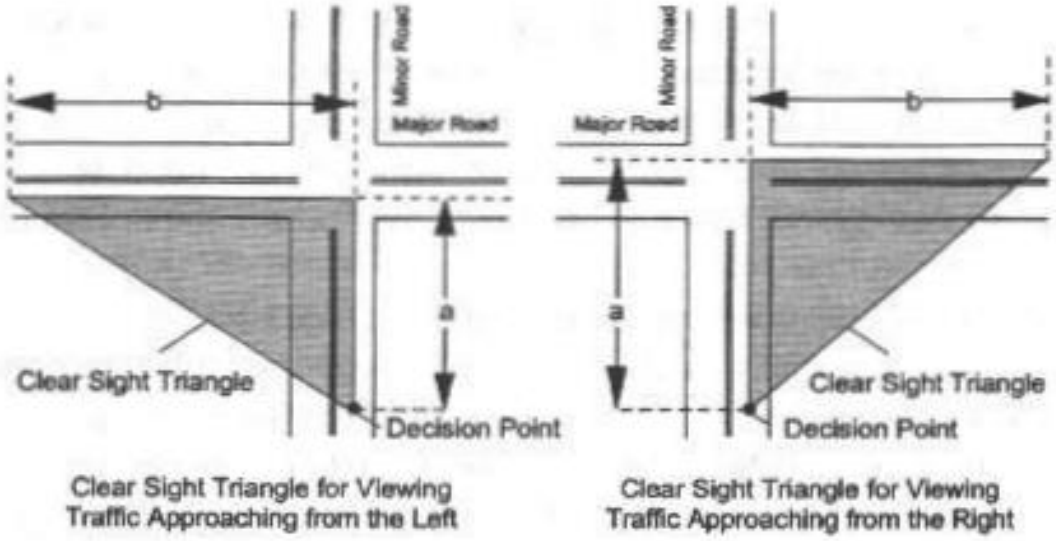
- Allow drivers to have an **unobstructed view** of intersection
- Definition: Required ISD is the **length** of cross road that must be visible such that the driver of a turning/crossing vehicle can **decide** to and **complete** the maneuver without conflict with vehicles approaching the intersection on the cross road.

Adequate ISD

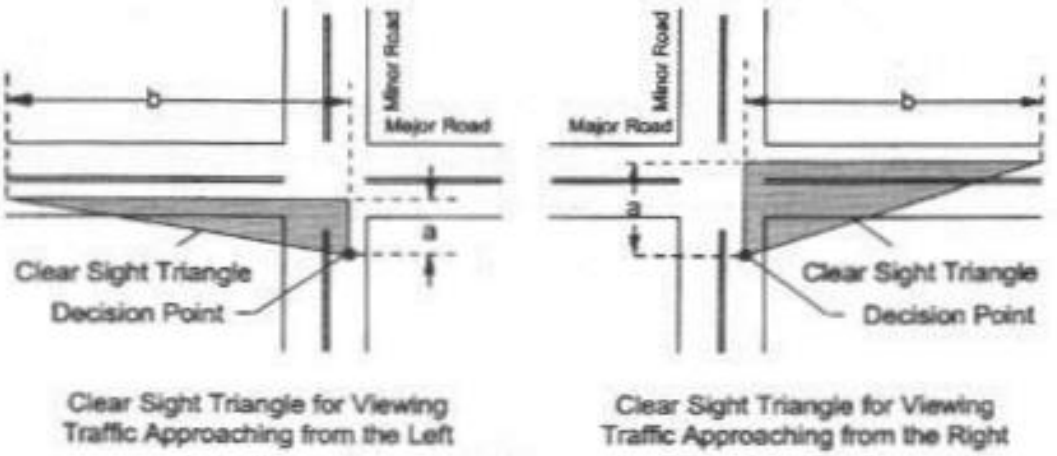
- **Sight Triangle** – area free of obstructions necessary to complete maneuver and avoid collision – **needed for approach and departure** (from stop sign for example)
- Allows driver to anticipate and avoid collisions
- Allows drivers of stopped vehicles enough view of the intersection to decide when to enter

Sight Triangle

- Area free of obstructions necessary to complete maneuver and avoid collision – **needed for approach and departure** (from stop sign for example)
- Consider horizontal as well as vertical, object below driver eye height may not be an obstruction
- AASHTO assumes 3.5' above roadway



A -- Approach Sight Triangles



B -- Departure Sight Triangles

Exhibit 9-50. Intersection Sight Triangles


Hidden Vehicle

ISD Cases

- **No control**: vehicles adjust speed
- **Stop control**: where traffic on minor roadway must stop prior to entering major roadway
- **Yield control**: vehicles on minor roadway must yield to major roadway traffic
- **Signal control**: where vehicles on all approaches are required to stop by either a stop sign or traffic signal
- ***All way stop***
- Stopped major roadway **left-turn** vehicles – must **yield** to oncoming traffic

Case A– No Control

- Minimum sight triangle sides = distance traveled in **3 seconds** (design or actual?) = 2 seconds for P/R and 1 second to actuate brake/accel.
- **Assumes vehicles slow ~ 50% of midblock running speed** (rural???)

Case A– No Control

- **Prefer** appropriate SSD on both approaches (minimum really)
- Provided on **lightly traveled** roadways
- Provide **control if sight triangle not available**
- Assumes vehicle on the left yields to vehicle on the right if they arrive at same time

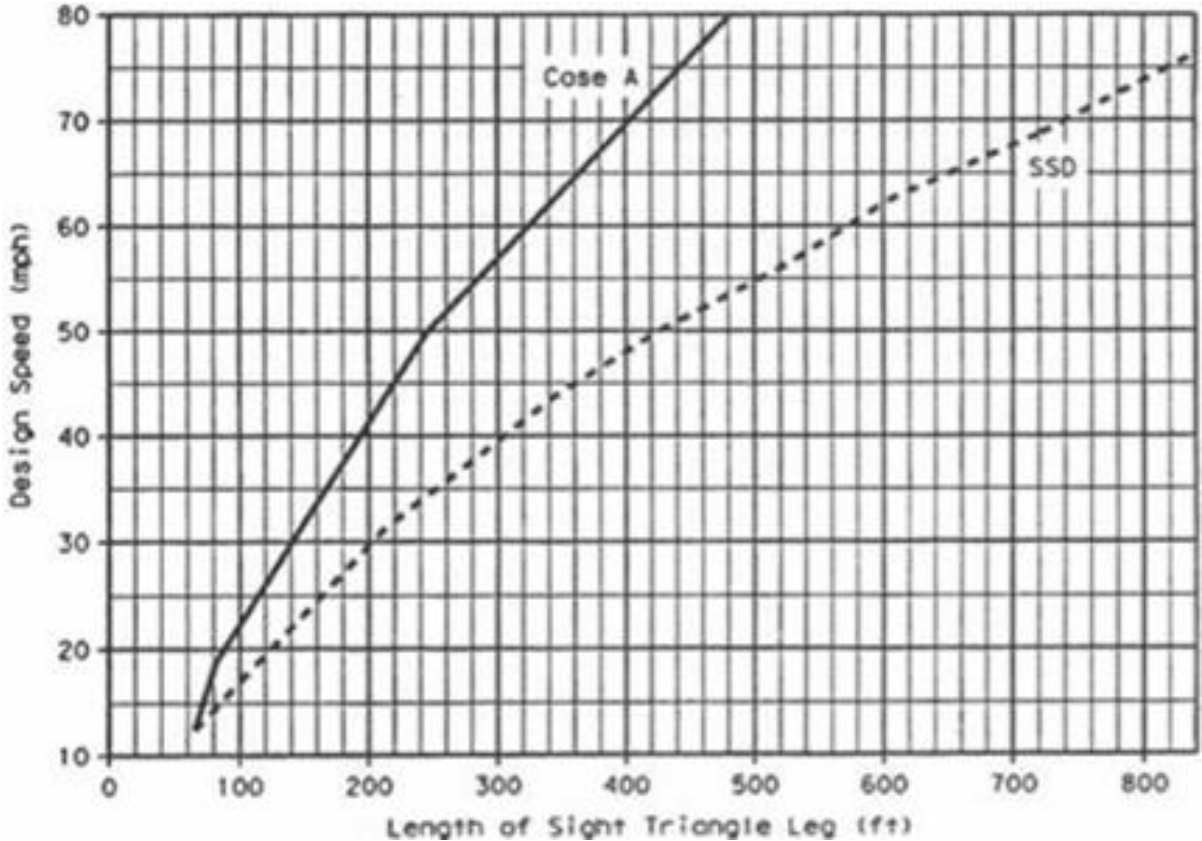
Metric		US Customary	
Design speed (km/h)	Length of leg (m)	Design speed (mph)	Length of leg (ft)
20	20	15	70
30	25	20	90
40	35	25	115
50	45	30	140
60	55	35	165
70	65	40	195
80	75	45	220
90	90	50	245
100	105	55	285
110	120	60	325
120	135	65	365
130	150	70	405
		75	445
		80	485

Note: For approach grades greater than 3%, multiply the sight distance values in this exhibit by the appropriate adjustment factor from Exhibit 9-53.

Can use table or graph

Modify for grade

US Customary														
Approach grade (%)	Design speed (mph)													
	15	20	25	30	35	40	45	50	55	60	65	70	75	80
−6	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.2	1.2	1.2	1.2	1.2	1.2	1.2
−5	1.0	1.0	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.2	1.2	1.2	1.2
−4	1.0	1.0	1.0	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
−3 to +3	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
+4	1.0	1.0	1.0	1.0	1.0	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
+5	1.0	1.0	1.0	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
+6	1.0	1.0	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9

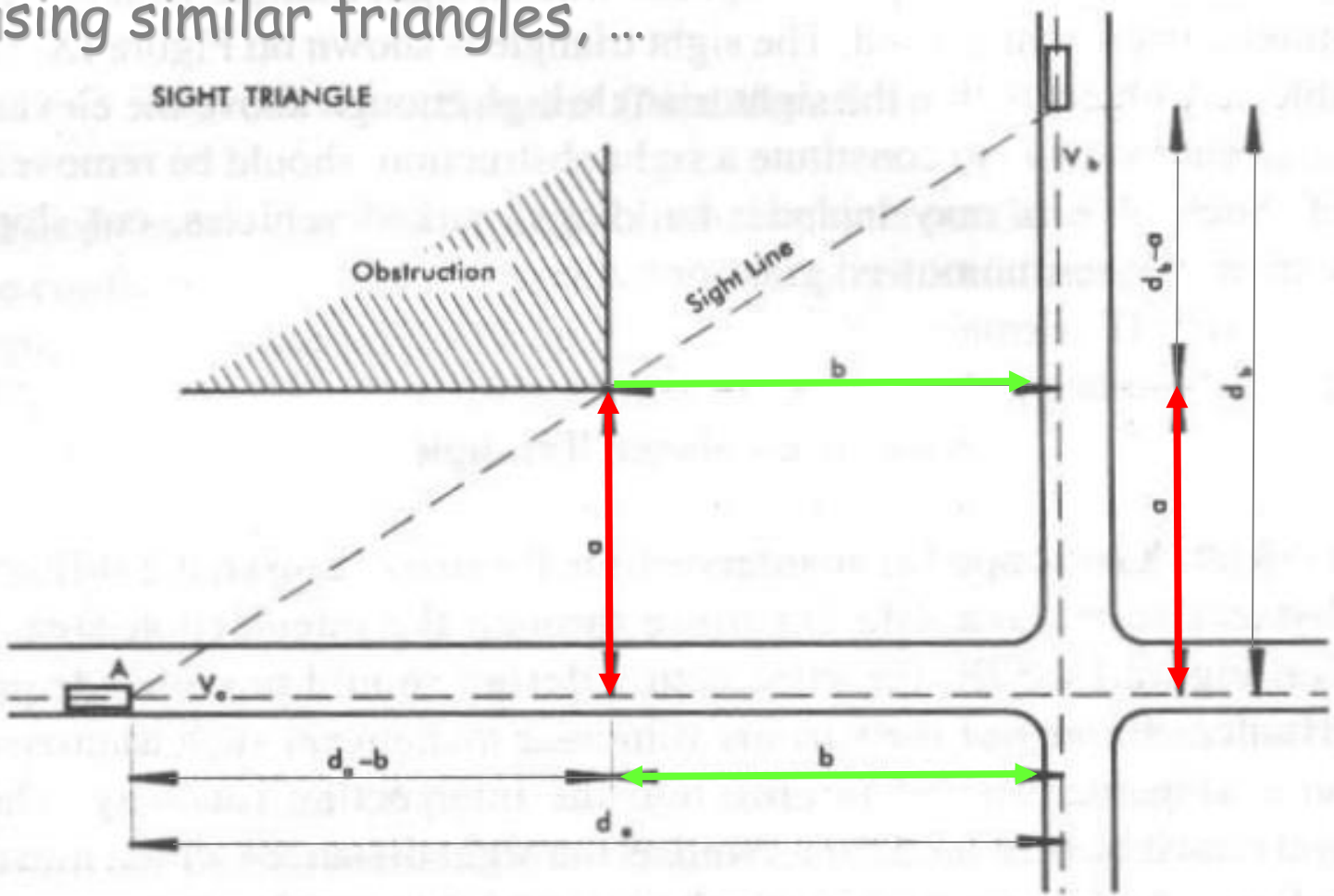


Minimum Distances for Sight Triangle: No Control	
Speed (mph)	Distance (ft)
10	45
15	70
20	90
25	110
30	130
35	155
40	180
50	220
60	260
70	310

From Garber and Hoel

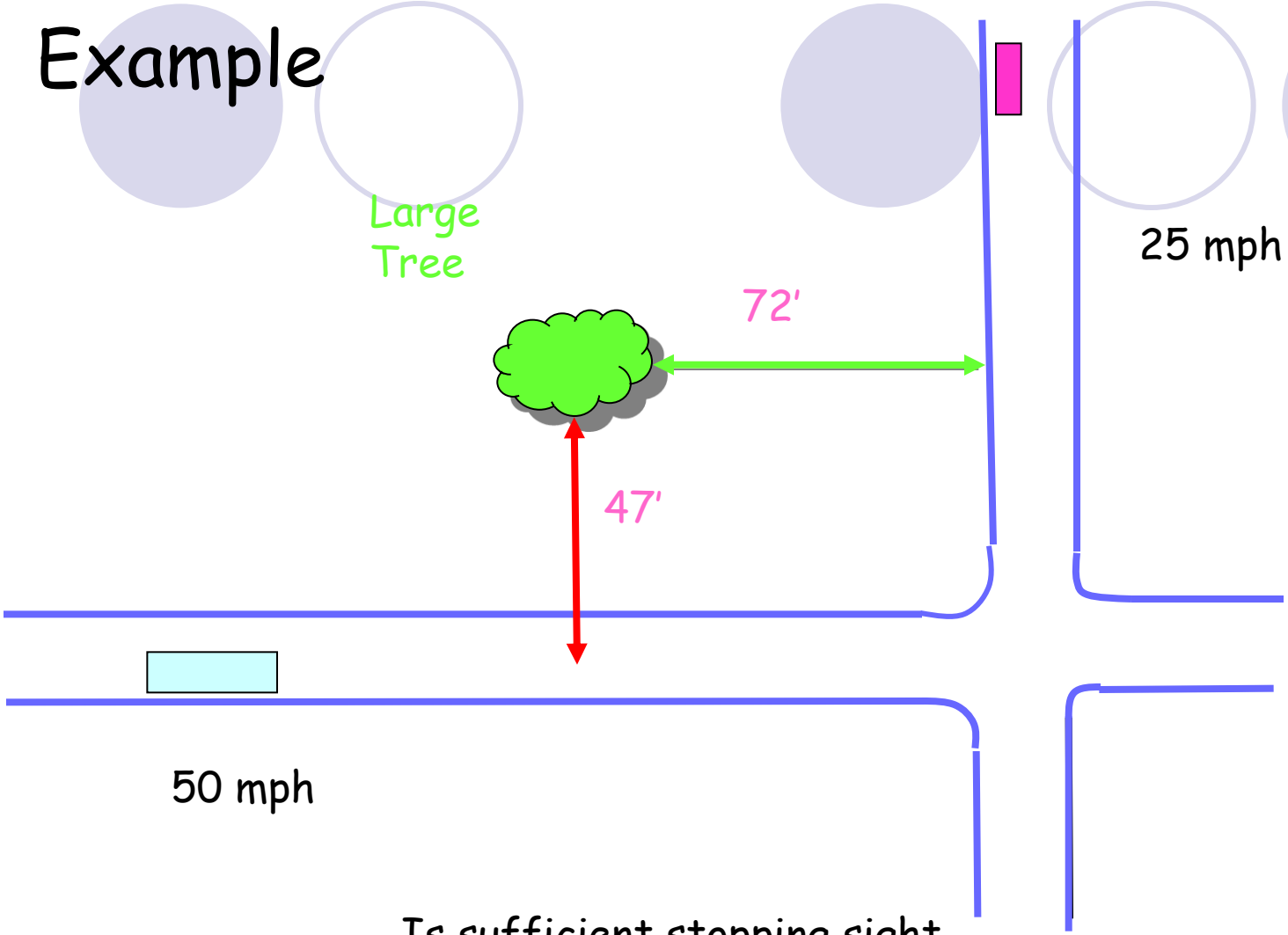
A little lower than Green Book Values

using similar triangles, …



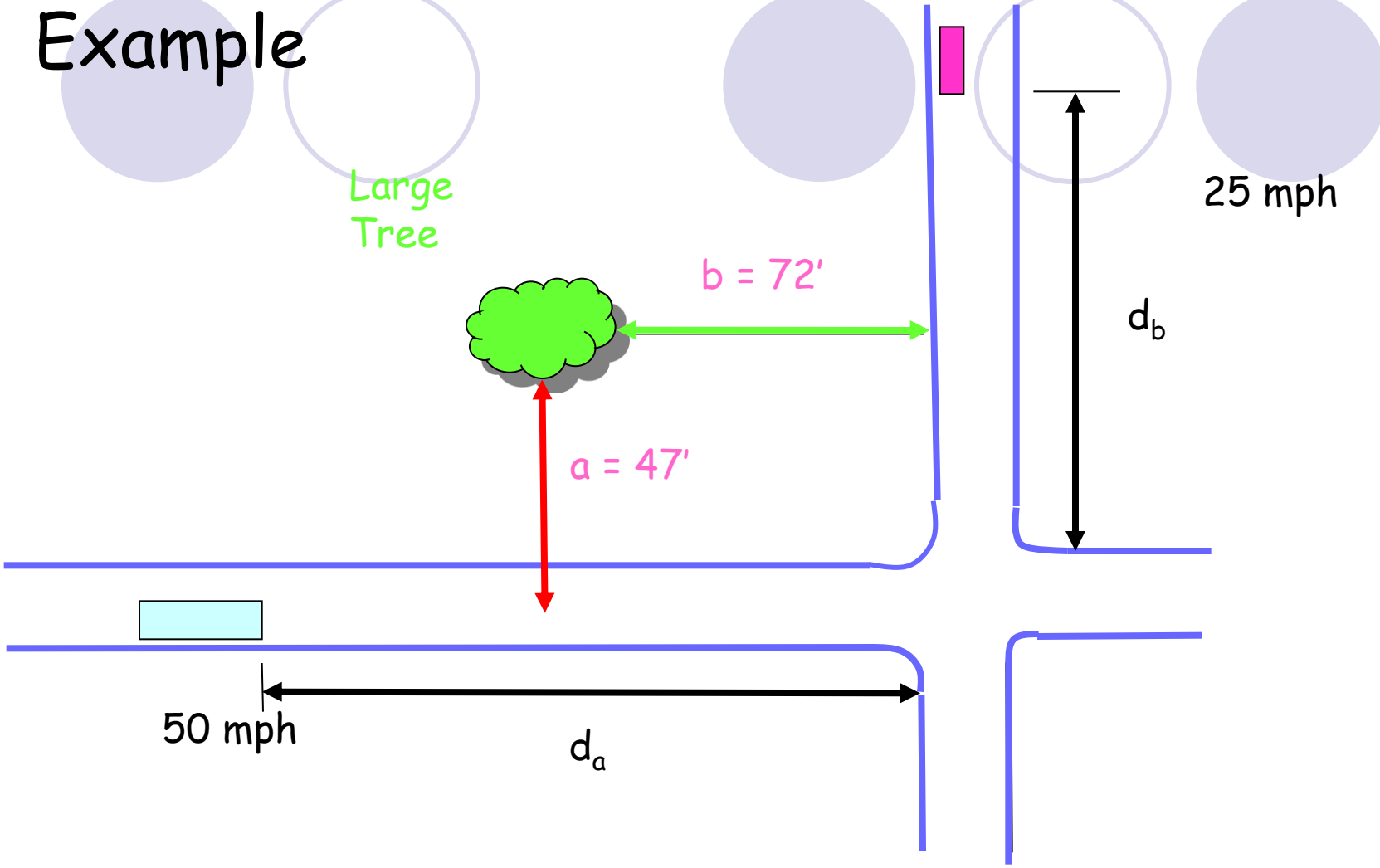
can set critical speed to available stopping distance, $d_b = a \times \frac{d_a}{d_a - b}$

Example



Is sufficient stopping sight distance provided?

Example



$$d_b = a \times \frac{d_a}{d_a - b}$$

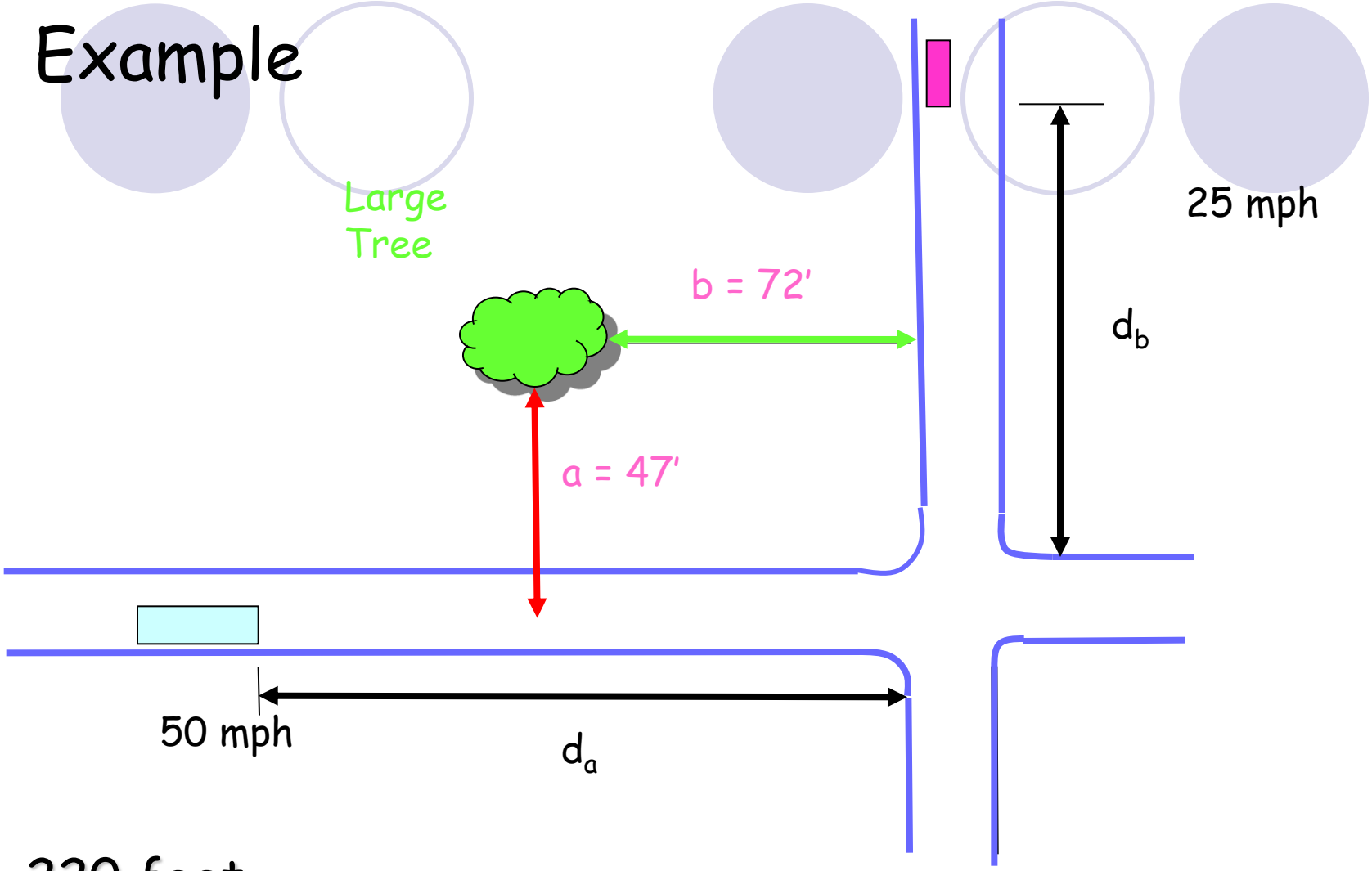
Minimum Distances for Sight Triangle: No Control

Speed (mph)	Distance (ft)
10	45
15	70
20	90
25	110
30	130
35	155
40	180
50	220
60	260
70	310

From Garber and Hoel

d_a = 220 feet

Example



d_a = 220 feet

$d_b = \frac{47' (220')}{220' - 72'} = 69.9'$

$$d_b = a \times \frac{d_a}{d_a - b}$$

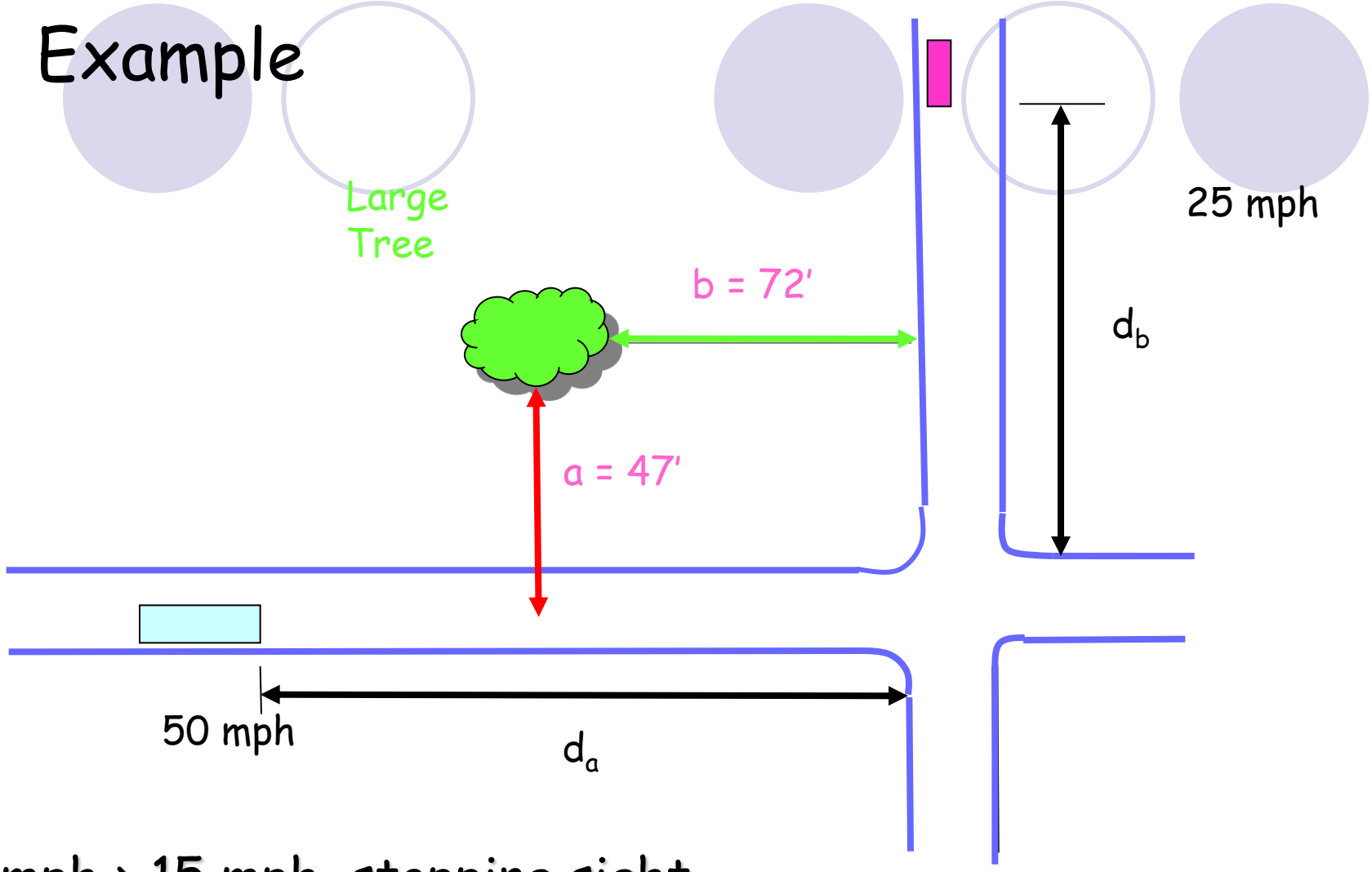
Minimum Distances for Sight Triangle: No Control

Speed (mph)	Distance (ft)
10	45
15	70
20	90
25	110
30	130
35	155
40	180
50	220
60	260
70	310

From Garber and Hoel

d_b = 69.9 feet corresponds to 15 mph

Example



25 mph > 15 mph, stopping sight distance is not sufficient for 25 mph

Case B – Stop Control

Three Sub Cases – Maneuvers

- **Turn left** on to major roadway (clear traffic left, enter traffic right)
- **Turn right** on to major roadway (enter traffic from left)
- **Crossing** (clear traffic left/right)

Case B – Stop Control

- Need ISD for departure and completion even if vehicle comes into view at point of departure = 1.47 $V_{major} * t_g$ where gap time, t_g=**7.5-11.5s**;
- add more time for grade or multilane;
- decrease by 1s. for right turns

Design vehicle	Time gap (s) at design speed of major road (t_g)
Passenger car	7.5
Single-unit truck	9.5
Combination truck	11.5

Note: Time gaps are for a stopped vehicle to turn right or left onto a two-lane highway with no median and grades 3 percent or less. The table values require adjustment as follows:

For multilane highways:

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, from the left, in excess of one, to be crossed by the turning vehicle.

For minor road approach grades:

If the approach grade is an upgrade that exceeds 3 percent; add 0.2 seconds for each percent grade for left turns

Exhibit 9-54. Time Gap for Case B1—Left Turn from Stop

Metric				US Customary			
		Intersection sight distance for passenger cars				Intersection sight distance for passenger cars	
Design speed (km/h)	Stopping sight distance (m)	Calculated (m)	Design (m)	Design speed (mph)	Stopping sight distance (ft)	Calculated (ft)	Design (ft)
20	20	41.7	45	15	80	165.4	170
30	35	62.6	65	20	115	220.5	225
40	50	83.4	85	25	155	275.6	280
50	65	104.3	105	30	200	330.8	335
60	85	125.1	130	35	250	385.9	390
70	105	146.0	150	40	305	441.0	445
80	130	166.8	170	45	360	496.1	500
90	160	187.7	190	50	425	551.3	555
100	185	208.5	210	55	495	606.4	610
110	220	229.4	230	60	570	661.5	665
120	250	250.2	255	65	645	716.6	720
130	285	271.1	275	70	730	771.8	775
				75	820	826.9	830
				80	910	882.0	885

Note: Intersection sight distance shown is for a stopped passenger car to turn left onto a two-lane highway with no median and grades 3 percent or less. For other conditions, the time gap must be adjusted and required sight distance recalculated.

Exhibit 9-55. Design Intersection Sight Distance—Case B1—Left Turn From Stop

Left turn

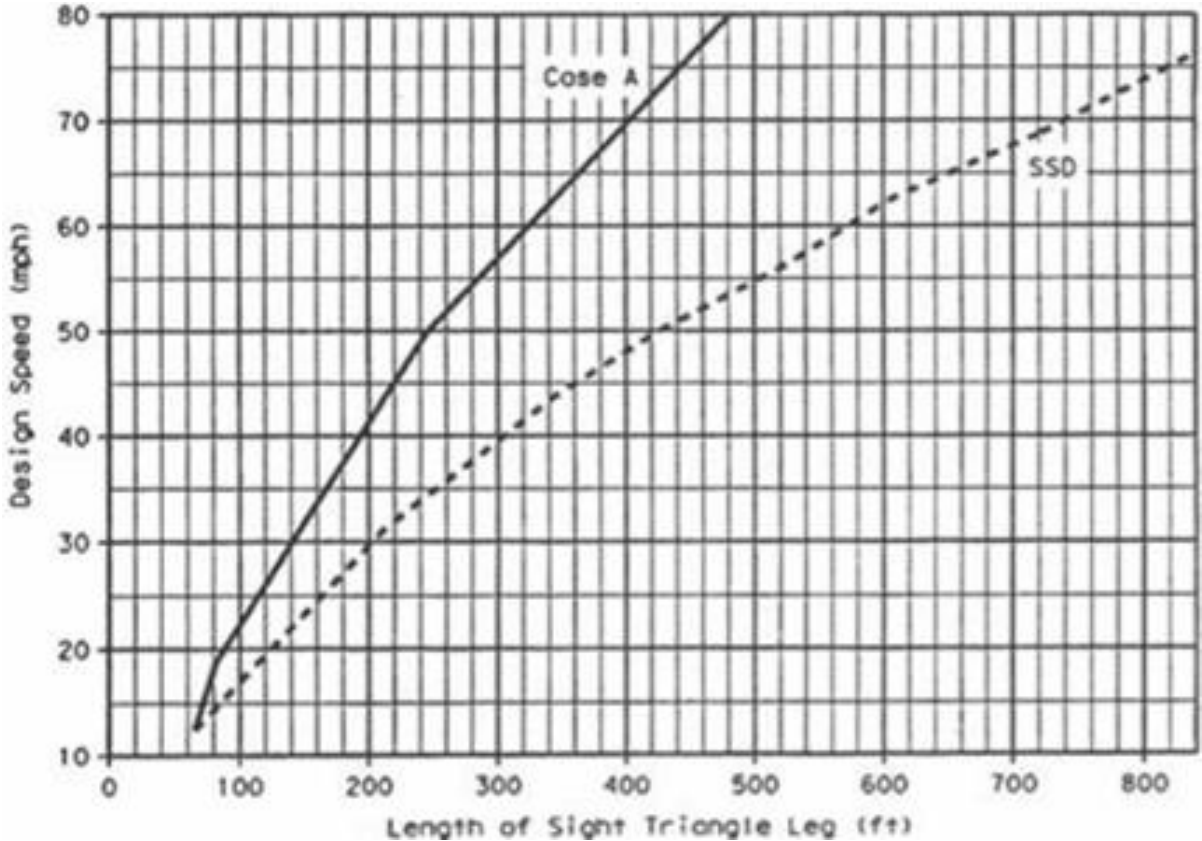
Metric		US Customary	
Design speed (km/h)	Length of leg (m)	Design speed (mph)	Length of leg (ft)
20	20	15	70
30	25	20	90
40	35	25	115
50	45	30	140
60	55	35	165
70	65	40	195
80	75	45	220
90	90	50	245
100	105	55	285
110	120	60	325
120	135	65	365
130	150	70	405
		75	445
		80	485

Note: For approach grades greater than 3%, multiply the sight distance values in this exhibit by the appropriate adjustment factor from Exhibit 9-53.

Can use table or graph

Modify for grade

US Customary														
Approach grade (%)	Design speed (mph)													
	15	20	25	30	35	40	45	50	55	60	65	70	75	80
−6	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.2	1.2	1.2	1.2	1.2	1.2	1.2
−5	1.0	1.0	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.2	1.2	1.2	1.2
−4	1.0	1.0	1.0	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
−3 to +3	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
+4	1.0	1.0	1.0	1.0	1.0	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
+5	1.0	1.0	1.0	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
+6	1.0	1.0	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9



right turn and crossing

Design vehicle	Time gap (s) at design speed of major road (t_g)
Passenger car	6.5
Single-unit truck	8.5
Combination truck	10.5

Note: Time gaps are for a stopped vehicle to turn right onto or cross a two-lane highway with no median and grades 3 percent or less. The table values require adjustment as follows:

For multilane highways:
For crossing a major road with more than two lanes, add 0.5 seconds for passenger cars and 0.7 seconds for trucks for each additional lane to be crossed and for narrow medians that cannot store the design vehicle.

For minor road approach grades:
If the approach grade is an upgrade that exceeds 3 percent, add 0.1 seconds for each percent grade.

Exhibit 9-57. Time Gap for Case B2—Right Turn from Stop and Case B3—Crossing Maneuver

US Customary			
Design speed (mph)	Stopping sight distance (ft)	Intersection sight distance for passenger cars	
		Calculated (ft)	Design (ft)
15	80	143.3	145
20	115	191.1	195
25	155	238.9	240
30	200	286.7	290
35	250	334.4	335
40	305	382.2	385
45	360	430.0	430
50	425	477.8	480
55	495	525.5	530
60	570	573.3	575
65	645	621.1	625
70	730	668.9	670
75	820	716.6	720
80	910	764.4	765

Exhibit 9-58. Design Intersection Sight Distance—Case B2—Right Turn from Stop and Case B3—Crossing Maneuver

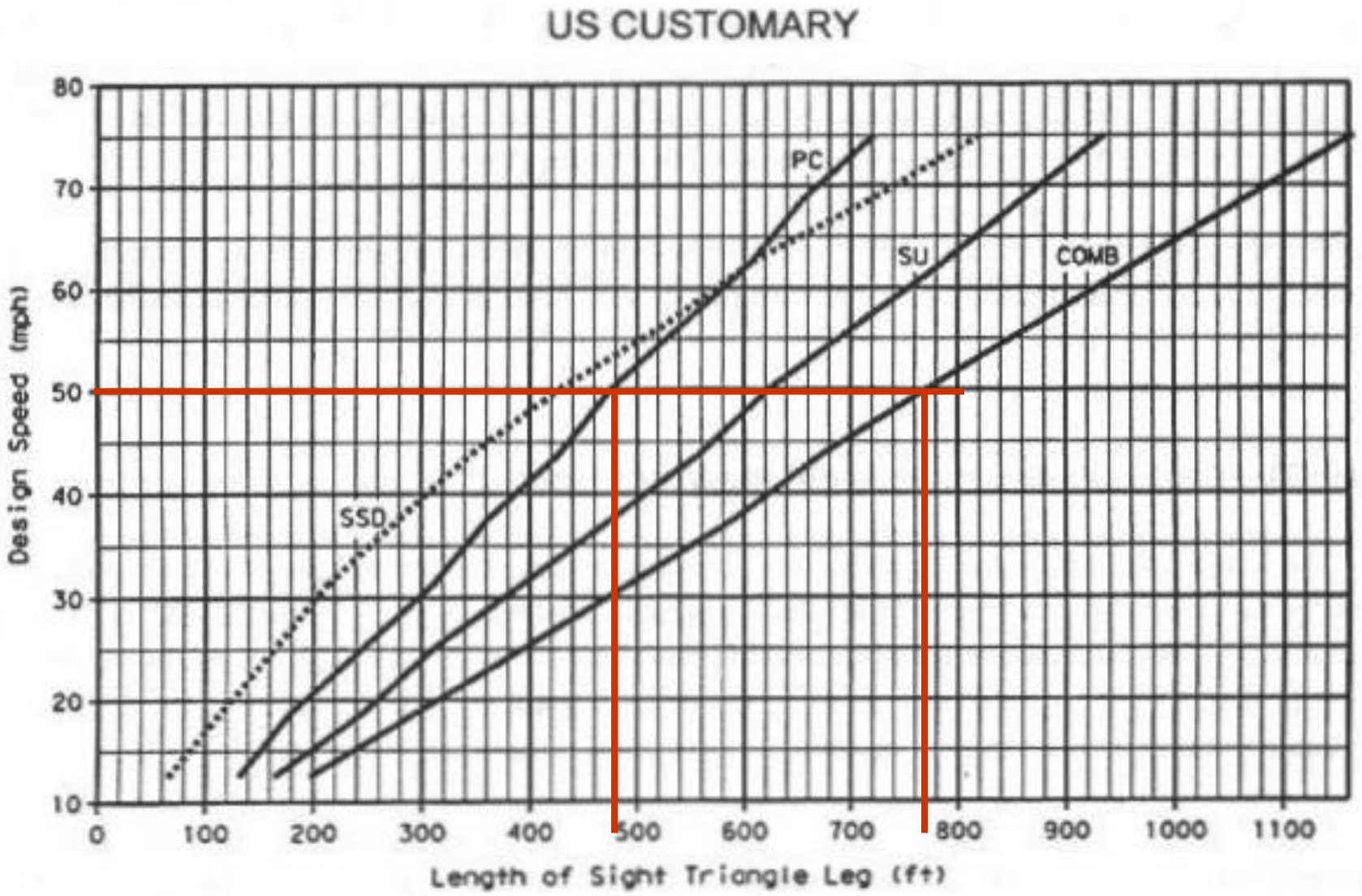


Exhibit 9-59. Intersection Sight Distance—Case B2—Right Turn from Stop and Case B3—Crossing Maneuver

Case C - Yield Control

- Minor Roadway Yields – must be able to see left/right – adjust speed – **possibly stop**
- **Sight distance exceeds that of stop control**
- Similar to no-control

Case C - Yield Control

- **Must** use minimum stopping sight distances for d_a and d_b
- SSD calculation should include effect of grade
- Required distance = **P/R + stopping distances**

Case C - Yield Control

- Typically Known – a, b
- Typically Assume V_a or V_b
- **Similar triangles** can be used to calculate safe approach speeds (given one approach speed) or allowable a and b.
- $d_a/d_b = (d_a - b)/a$
- $d_b = (d_a * a)/ (d_a - b)$

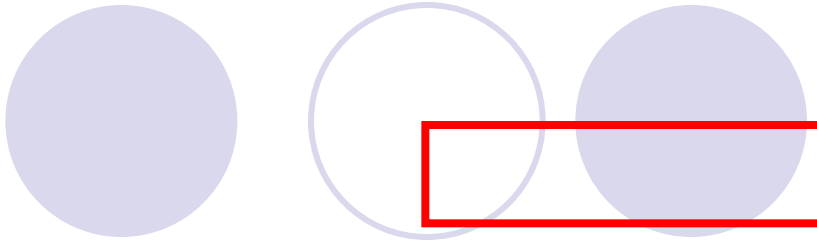
Yield Control

- Case C 1: Crossing maneuver from minor road
- Assumes minor road vehicles that do not stop decelerate to 60% of minor road speed
- Vehicle should be able to:
  - Travel from decision point to intersection decelerating to 60% of design speed
  - Cross and clear the intersection at the same (i.e., 60%) speed

Metric	US Customary
$t_g = t_a + \frac{w + L_a}{0.167 V_{minor}}$	$t_g = t_a + \frac{w + L_a}{0.88 V_{minor}}$ (9-2)
$b = 0.278 V_{major} t_g$	$b = 1.47 V_{major} t_g$
where:	where:
t_g = travel time to reach and clear the major road (s)	t_g = travel time to reach and clear the major road (s)
b = length of leg of sight triangle along the major road (m)	b = length of leg of sight triangle along the major road (ft)
t_a = travel time to reach the major road from the decision point for a vehicle that does not stop (s) (use appropriate value for the minor-road design speed from Exhibit 9-60 adjusted for approach grade, where appropriate)	t_a = travel time to reach the major road from the decision point for a vehicle that does not stop (s) (use appropriate value for the minor-road design speed from Exhibit 9-60 adjusted for approach grade, where appropriate)
w = width of intersection to be crossed (m)	w = width of intersection to be crossed (ft)
L_a = length of design vehicle (m)	L_a = length of design vehicle (ft)
V_{minor} = design speed of minor road (km/h)	V_{minor} = design speed of minor road (mph)
V_{major} = design speed of major road (km/h)	V_{major} = design speed of major road (mph)

t_g

Figure on page 671, AASHTO "Green Book" 2001





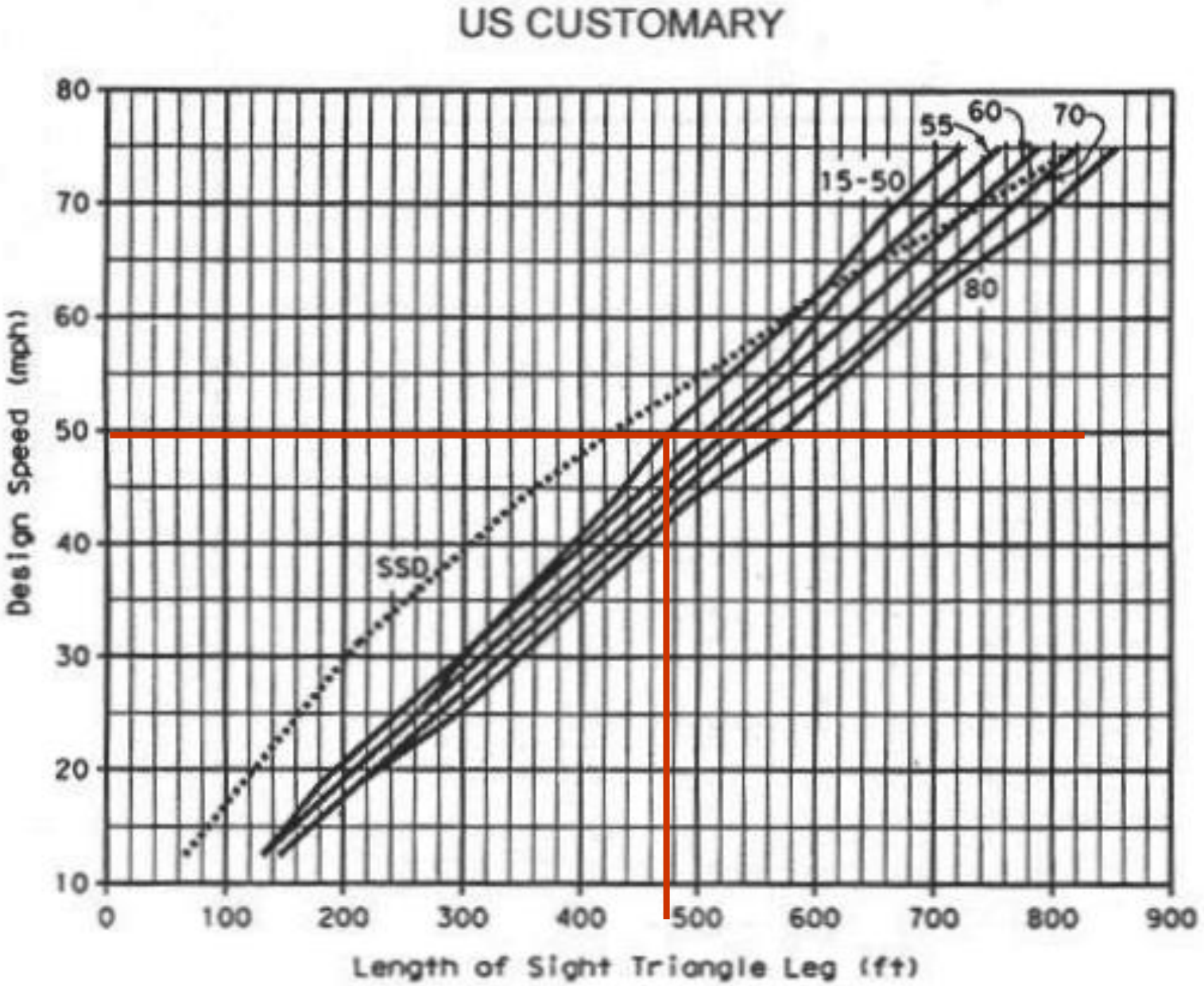


Exhibit 9-62. Length of Sight Triangle Leg Along Major Road for Passenger Cars—Case C1—Crossing Maneuver

Also …

- Case C2: Left and Right turns at **yield control**
- Case D: **Signal** control
- Case E: **All way stop**
- Case F: **Left turn from major**
- tg=5.5-7.5s + **multilane adjustment**
- **Effect of Skew**

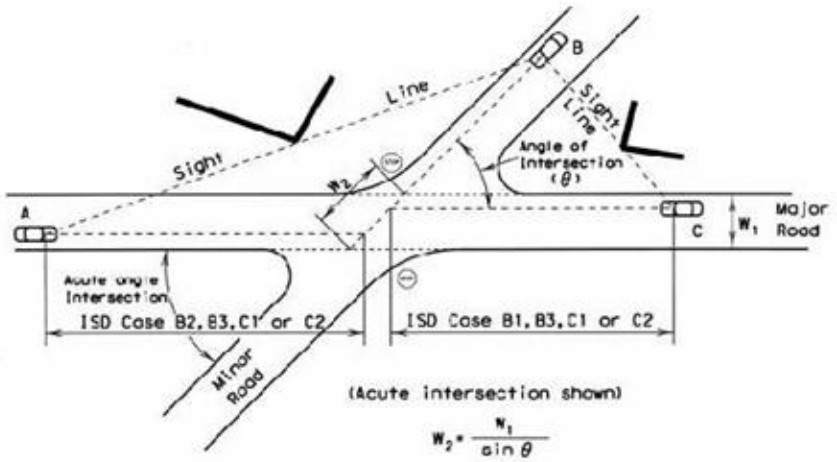
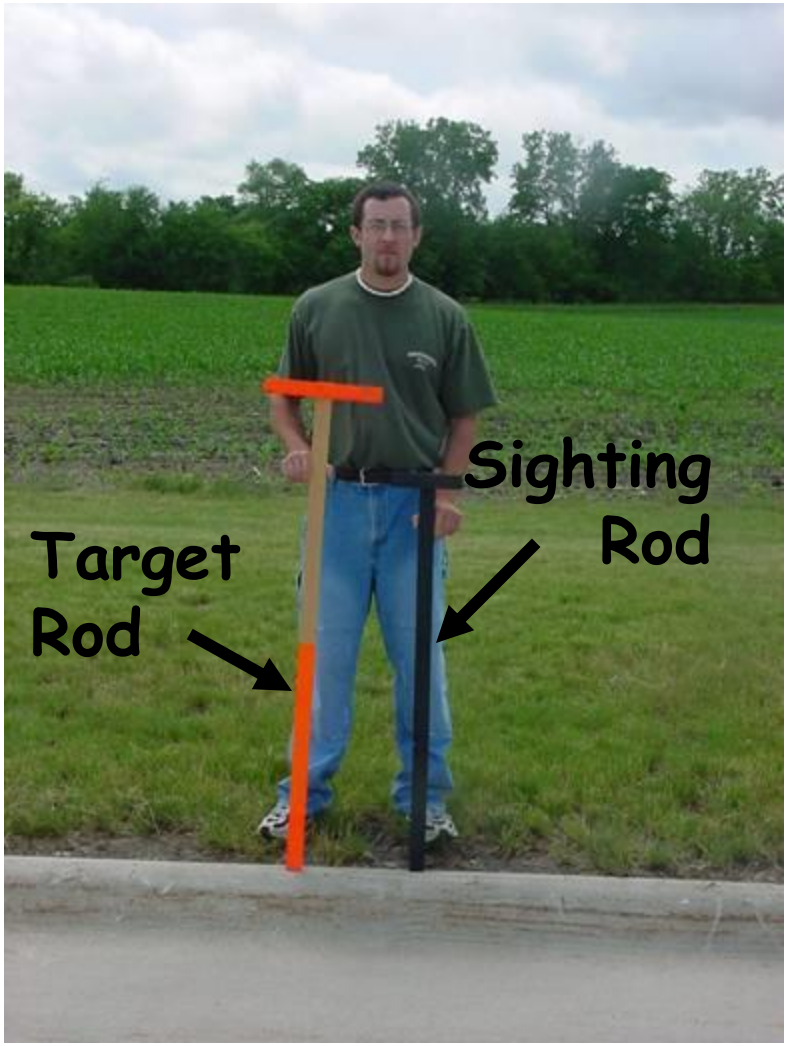


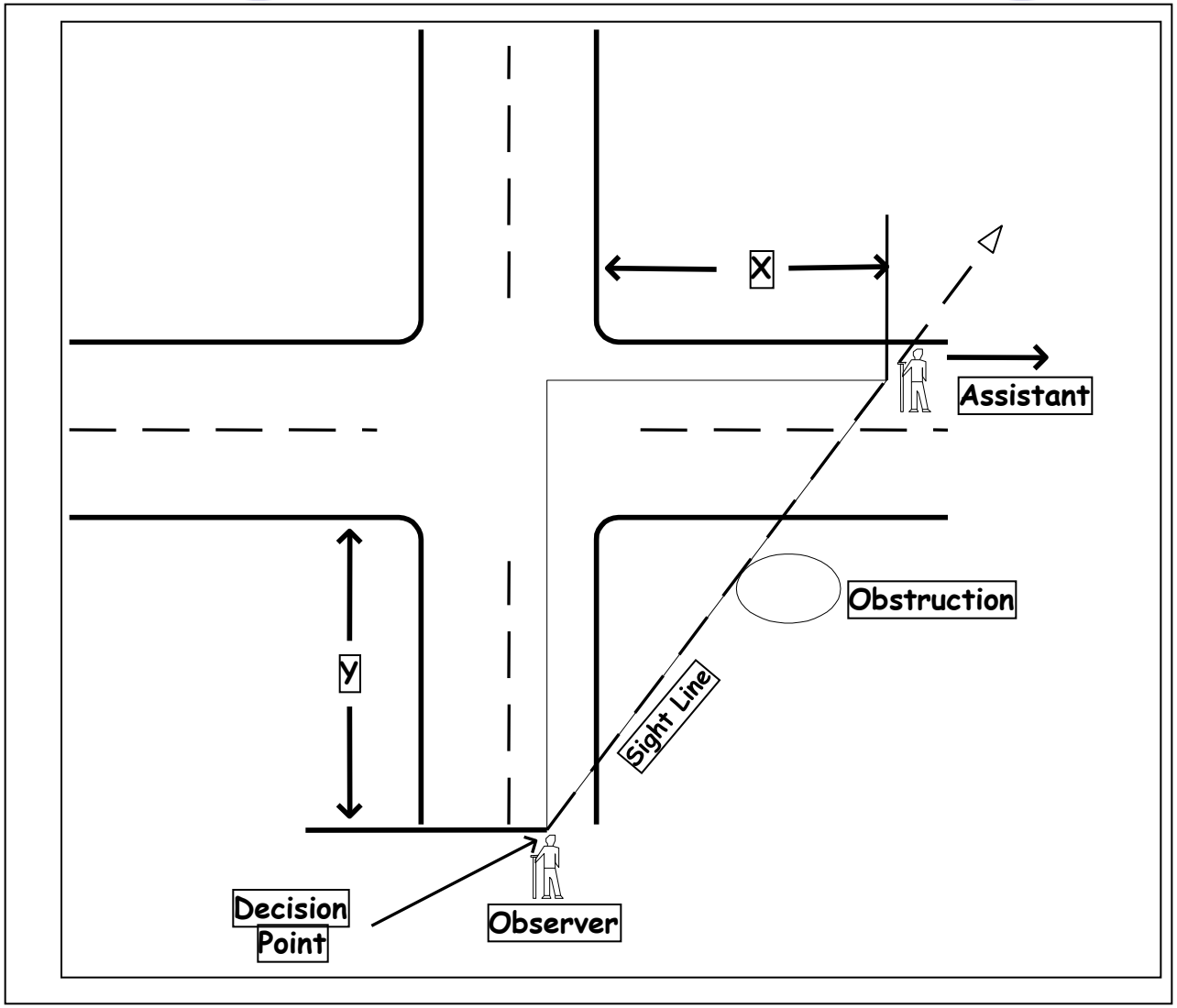
Exhibit 9-69. Sight Triangles at Skewed Intersections

Sighting Rod and Target Rod (AASHTO)

- For vertical sight distance with vertical curves
- Sighting rod- 3.5 feet tall
- Target rod- 4.25 feet tall (Top portion and bottom 2 feet are painted orange)

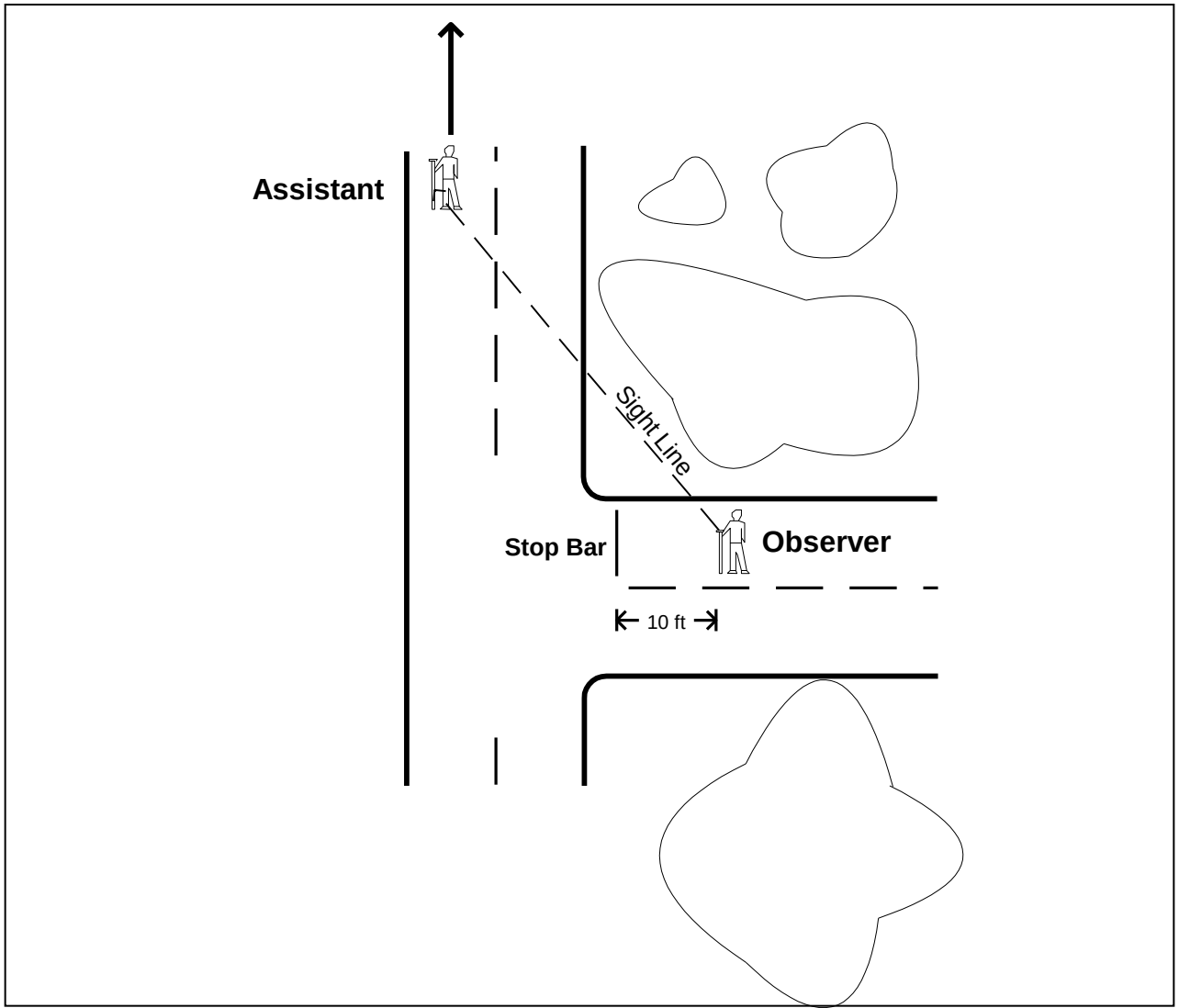


Measuring at an Uncontrolled Intersection




RESEARCH
PARK
Assistant
Movement of Assistant
Observer

Measuring at a Stop-controlled Intersection




STOP
4-WAY
Assistant with Target Rod (4.25 ft)
Observer with Sighting Rod (3.5 ft)