Caterpillar Inc.
PO Box 1875
Peoria, Illinois 61656-1875

Contract Deliverable to the Center for Disease Control and Prevention

Contract 200-2002-00563

"Construction Vehicle and Equipment Blind Area Diagrams"

Caterpillar Inc.

Contract Modification - Final Report

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Table of Contents

Introduction

The National Institute for Occupational Safety and Health (NIOSH) has identified a risk for highway and street construction workers to injury from movement of construction vehicles and equipment within the work zones as well as from passing motor vehicle traffic. Collision occurrences have been attributed in part to limited visibility around the equipment. In analyzing data collected on fatalities and serious nonfatal injuries occurring from 1992-1998, NIOSH researchers found that traffic control devices and jobsite management techniques alone will not completely eliminate the risk to workers. Collision occurrences have been attributed in part to limited visibility around the equipment. Therefore, new technology is needed to help detect the presence of people in the direct path of construction equipment and warn the operator of an impending collision.

To better direct the development of the new technology, it is important to understand where current visibility limitations are around typical construction equipment. With this information, researchers can better perform worker exposure assessments across the different types and makes of construction equipment. Worker exposure data can then be used to help select the appropriate technologies such as radar systems, radio signal detection systems etc. that can help minimize the risk to workers.

The Center for Disease Control and Prevention awarded Caterpillar Inc. a contract to "obtain diagrams of the blind areas around 24 different vehicles or machines that are used in the construction industry" (Contract Award 200-2002-00563). A contract modification was awarded to extend the data to fourteen more machines. This document is the final report for the modified contract and includes descriptions, pictures, and blind area diagrams for the vehicles and machines tested. Physical measurements were made for 10 of the machines and computer simulation was used for 4. The test procedures used are included as an appendix.

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Blind Area Diagram for Construction Vehicle – Ground Plane

Dozer

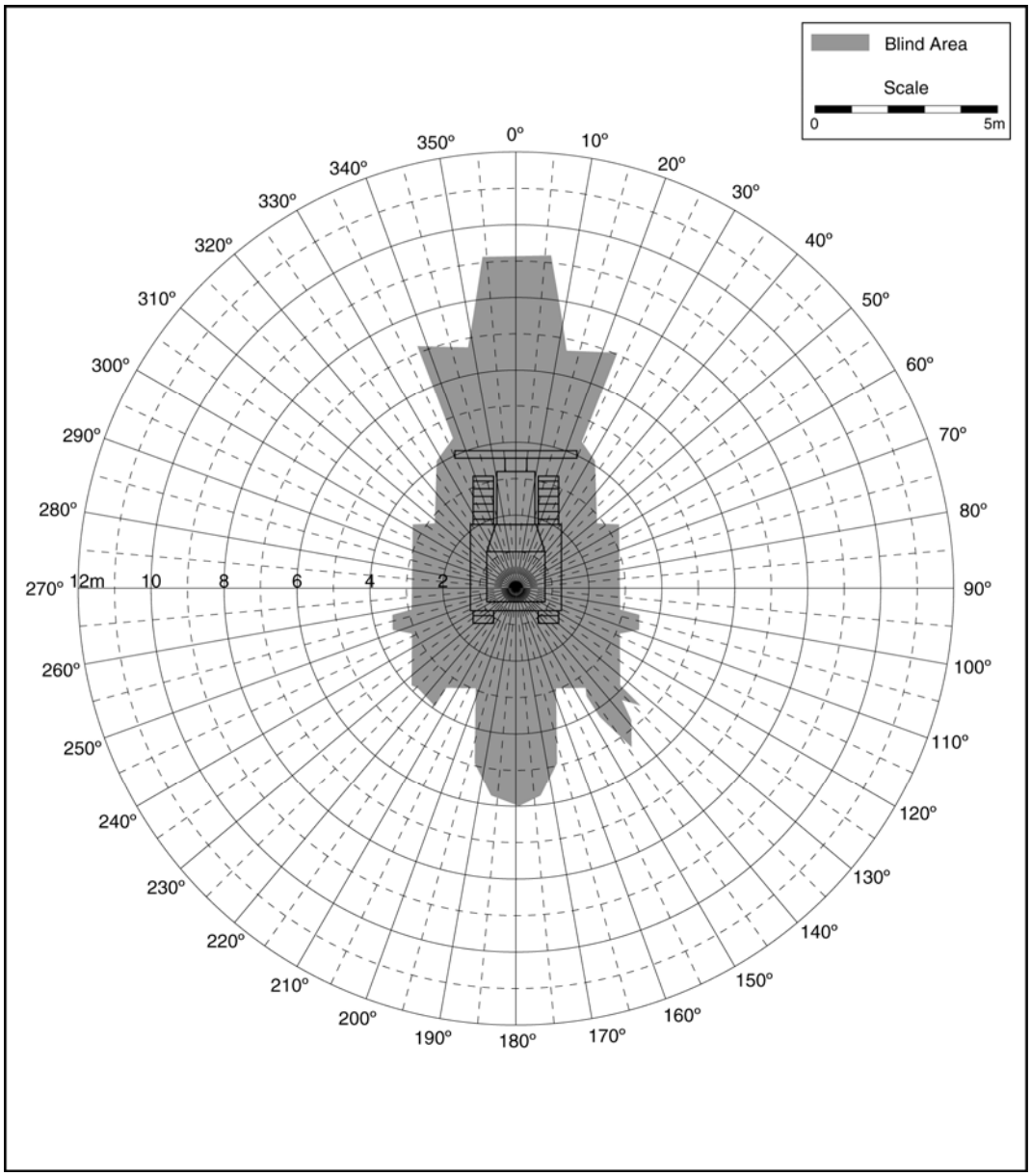
John Deere 700H

Caterpillar Inc.
PO Box 1875
Peoria, Illinois 61656-1875

Contract # 200-2002-00563

Blind Area Diagram for Construction Machine – Ground Plane

Dozer (Manufacturer and Model)	John Deere 700H
GVW	25,800 lb
Serial #	T0700HX906617
Machine Dimensions	10’ wide (blade) 14’ 11” long
Operator Enclosure	Closed ROPS
Attachments	10’ wide, 3’11” high Power Angle & Tilt Blade
Other Information	None
Measurement Technique	Physical



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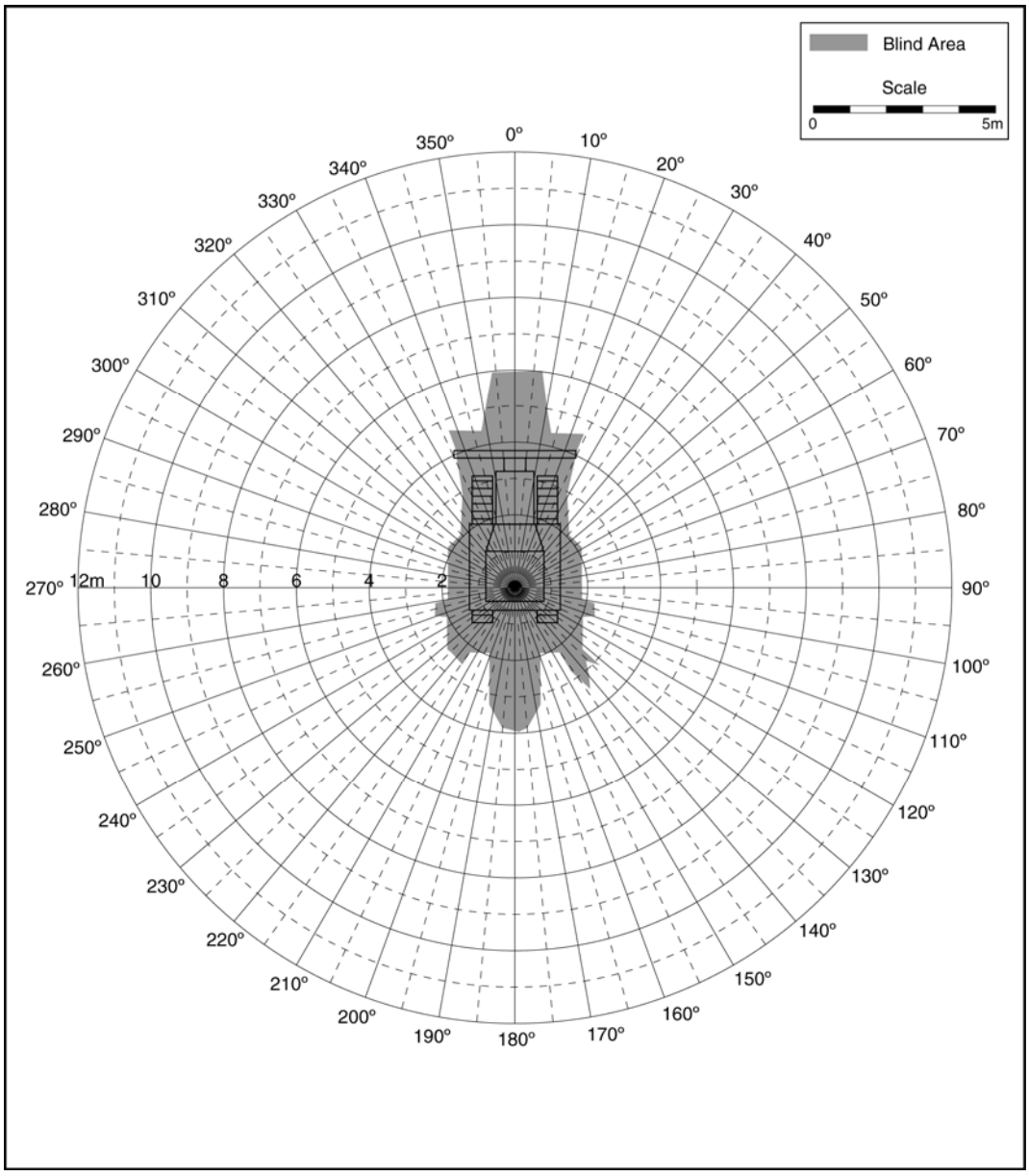
Blind Area Diagram for Construction Machine –900 mm Plane

Dozer (Manufacturer and Model)	John Deere 700H
GVW	25,800 lb
Serial #	T0700HX906617
Machine Dimensions	10’ wide (blade) 14’ 11” long
Operator Enclosure	Closed ROPS
Attachments	10’ wide, 3’11” high Power Angle & Tilt Blade
Other Information	None
Measurement Technique	Physical



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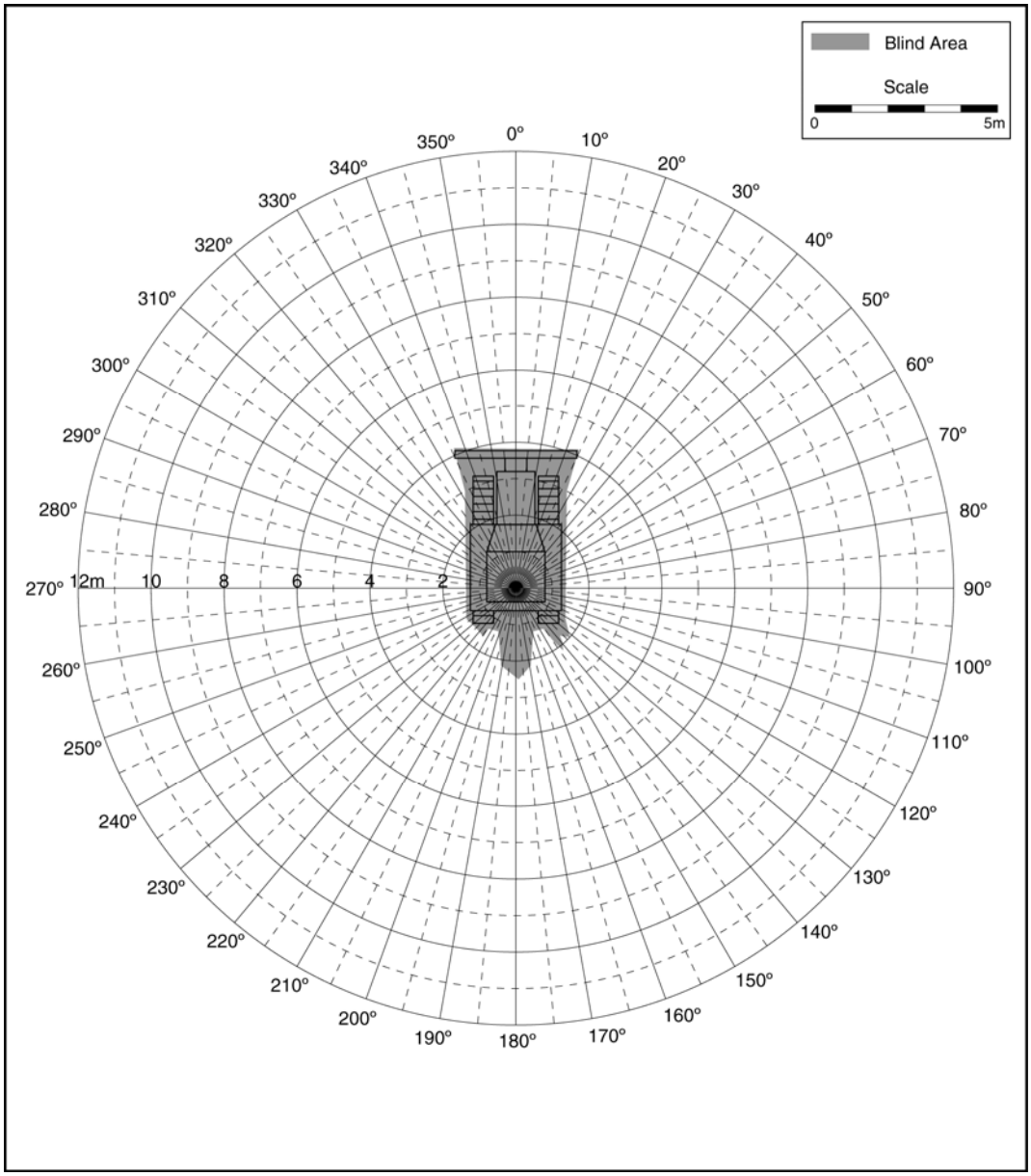
Blind Area Diagram for Construction Machine – 1500 mm Plane

Dozer (Manufacturer and Model)	John Deere 700H
GVW	25,800 lb
Serial #	T0700HX906617
Machine Dimensions	10’ wide (blade) 14’ 11” long
Operator Enclosure	Closed ROPS
Attachments	10’ wide, 3’11” high Power Angle & Tilt Blade
Other Information	None
Measurement Technique	Physical



Loader

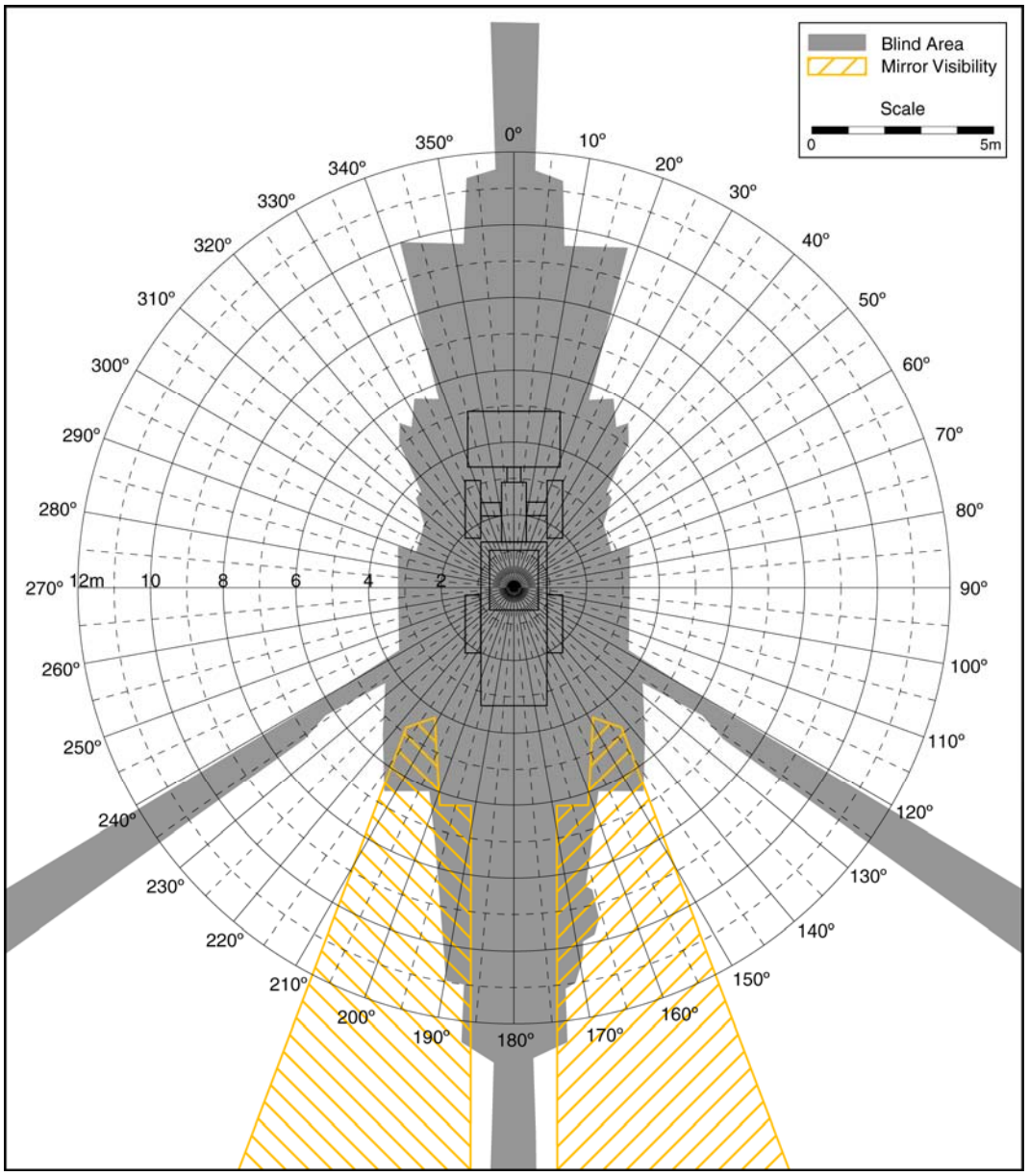
Volvo L110E
Caterpillar 924Gz

Caterpillar Inc.
PO Box 1875
Peoria, Illinois 61656-1875

Contract # 200-2002-00563

Blind Area Diagram for Construction Vehicle – Ground Plane

Loader (Manufacturer and Model)	Volvo L110E
GVW	40,000 lbs
Serial #	L110EV60054
Machine Dimensions	9’ 5” wide (bucket) 26’ 3” long
Operator Enclosure	Closed ROPS
Attachments	None
Other Information	None
Measurement Technique	Physical



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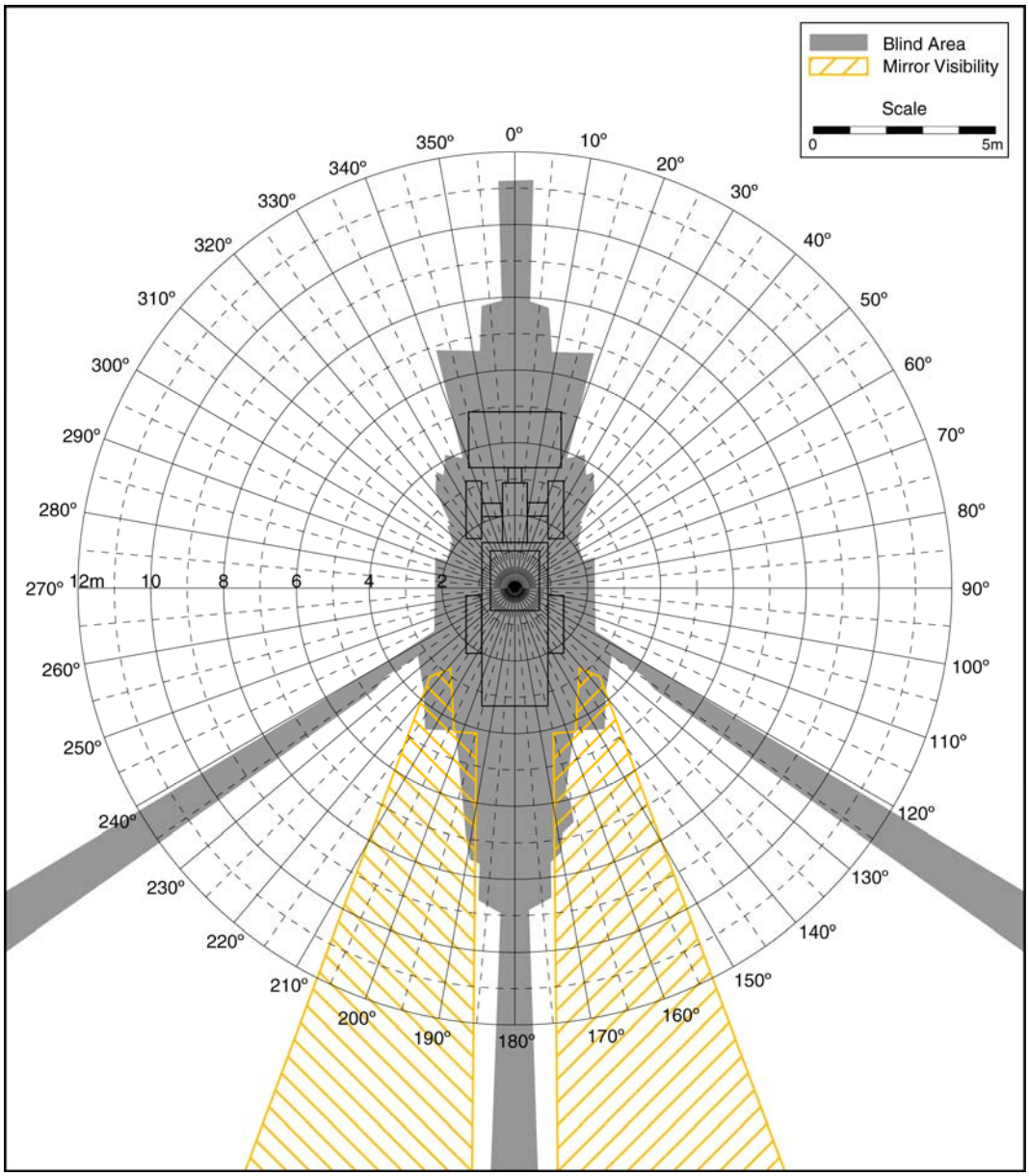
Contract # 200-2002-00563

Blind Area Diagram for Construction Vehicle – 900 mm Plane

Loader (Manufacturer and Model)	Volvo L110E
GVW	40,000 lbs
Serial #	L110EV60054
Machine Dimensions	9’ 5” wide (bucket) 26’ 3” long
Operator Enclosure	Closed ROPS
Attachments	None
Other Information	None
Measurement Technique	Physical



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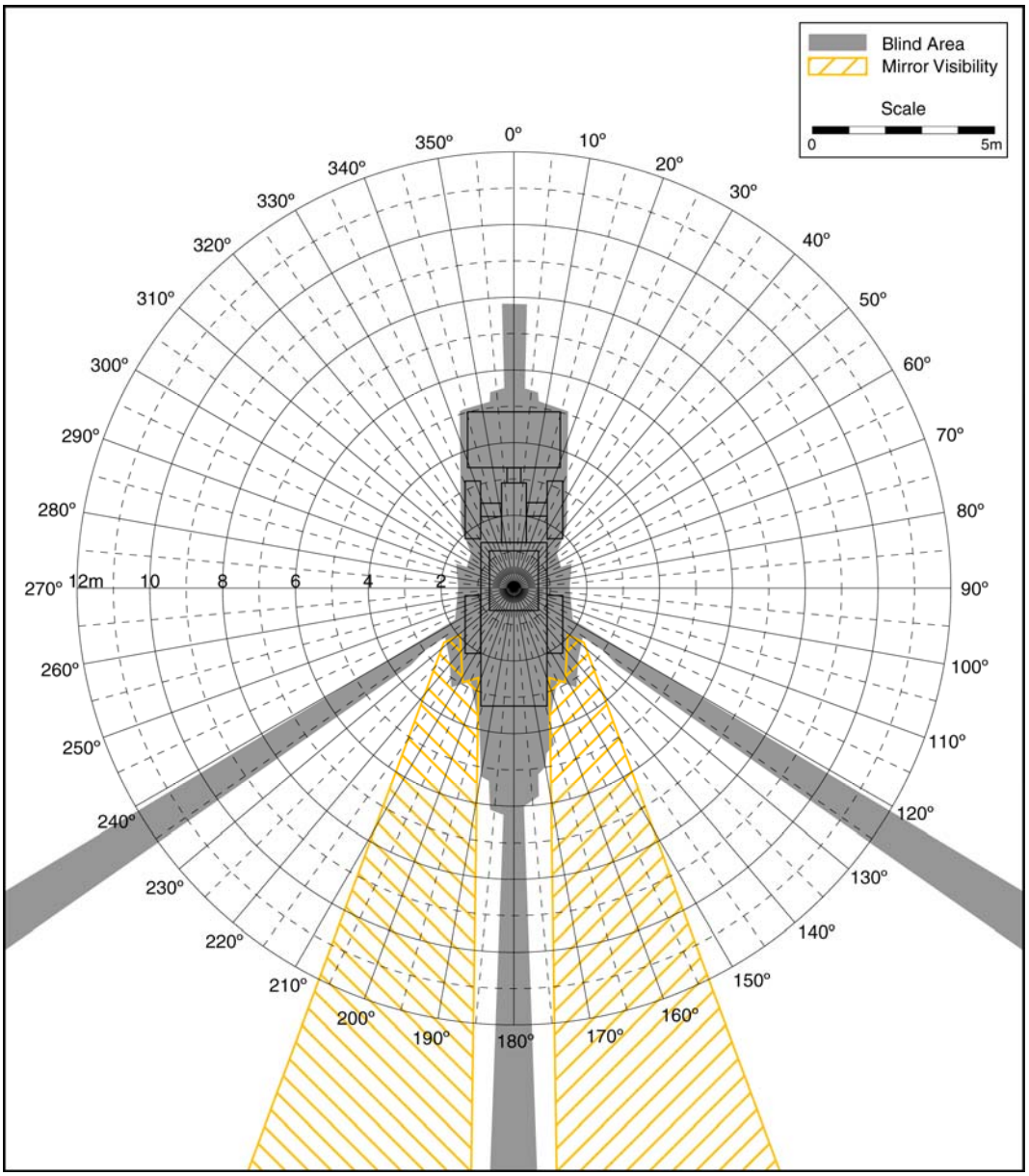
Blind Area Diagram for Construction Vehicle – 1500 mm Plane

Loader (Manufacturer and Model)	Volvo L110E
GVW	40,000 lbs
Serial #	L110EV60054
Machine Dimensions	9’ 5” wide (bucket) 26’ 3” long
Operator Enclosure	Closed ROPS
Attachments	None
Other Information	None
Measurement Technique	Physical



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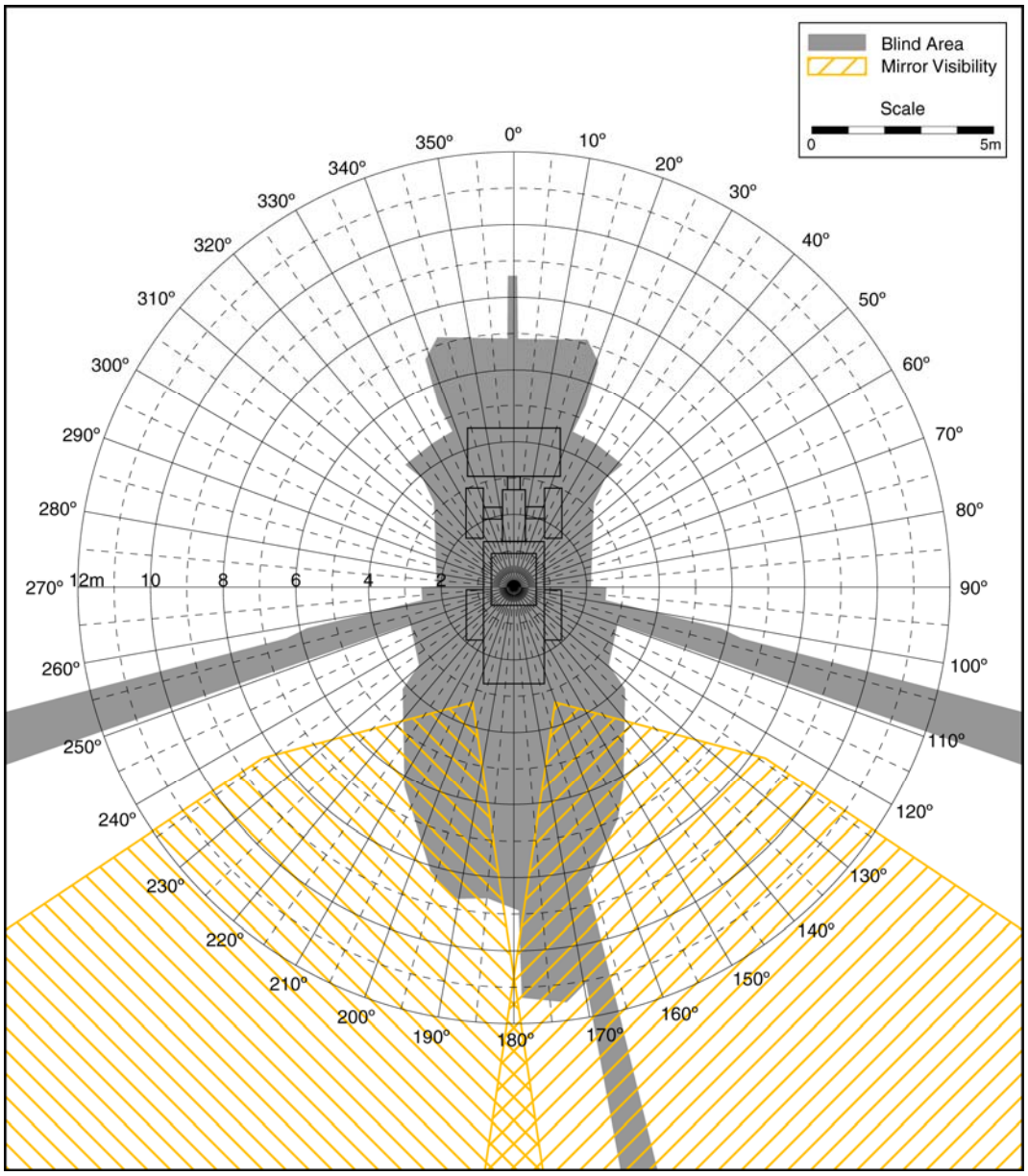
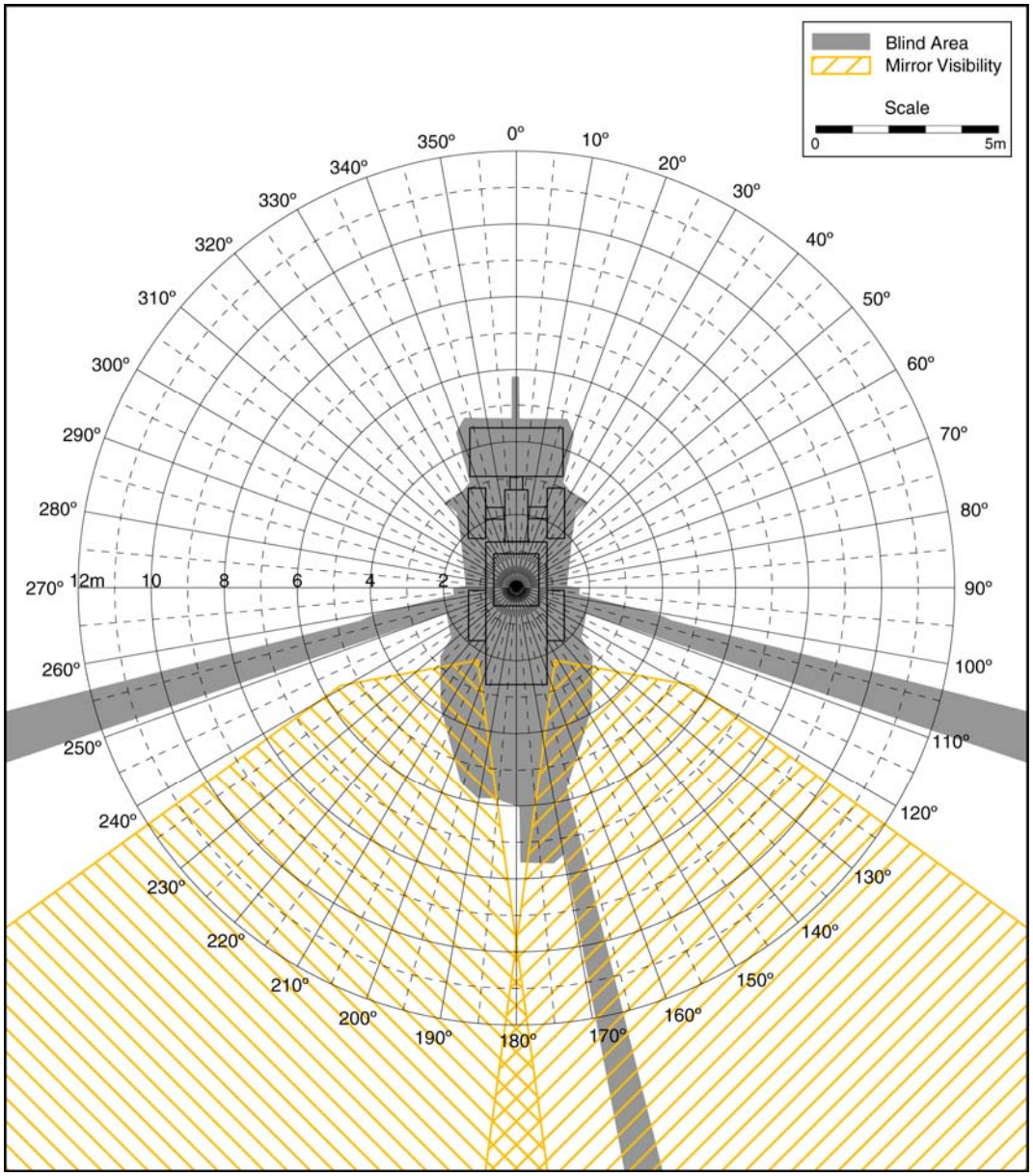
Blind Area Diagram for Construction Vehicle – Ground Plane

Loader (Manufacturer and Model)	Caterpillar 924Gz
GVW	22,500 lb
Serial #	6YW00704
Machine Dimensions	7’ 7” wide (bucket) 22’ 11” long
Operator Enclosure	Closed ROPS
Attachments	None
Other Information	None
Measurement Technique	Physical



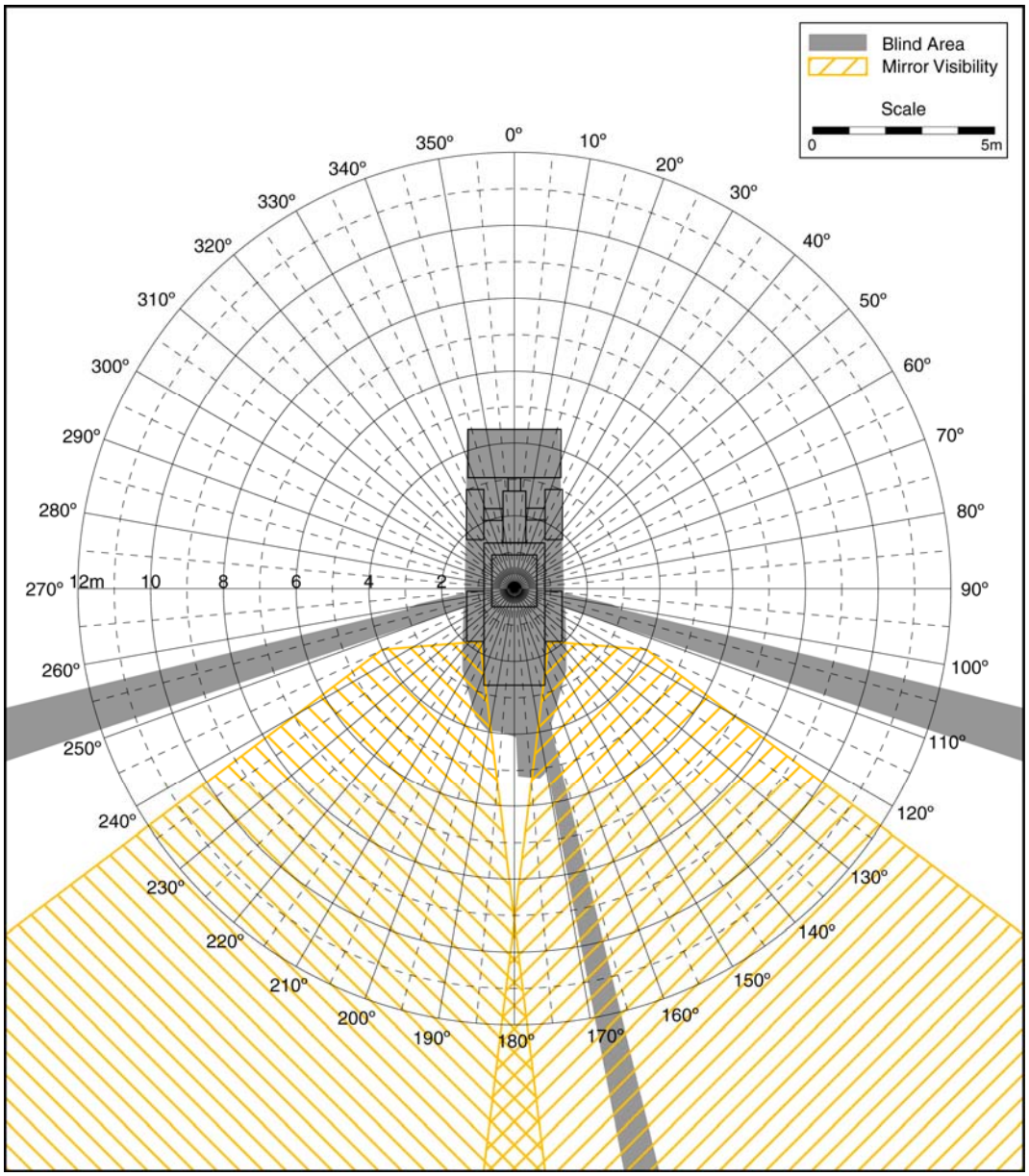
Blind Area Diagram for Construction Vehicle – 900 mm Plane

Loader (Manufacturer and Model)	Caterpillar 924Gz
GVW	22,500 lb
Serial #	6YW00704
Machine Dimensions	7’ 7” wide (bucket) 22’ 11” long
Operator Enclosure	Closed ROPS
Attachments	None
Other Information	None
Measurement Technique	Physical



Blind Area Diagram for Construction Vehicle – 1500 mm Plane

Loader (Manufacturer and Model)	Caterpillar 924Gz
GVW	22,500 lb
Serial #	6YW00704
Machine Dimensions	7’ 7” wide (bucket) 22’ 11” long
Operator Enclosure	Closed ROPS
Attachments	None
Other Information	None
Measurement Technique	Physical

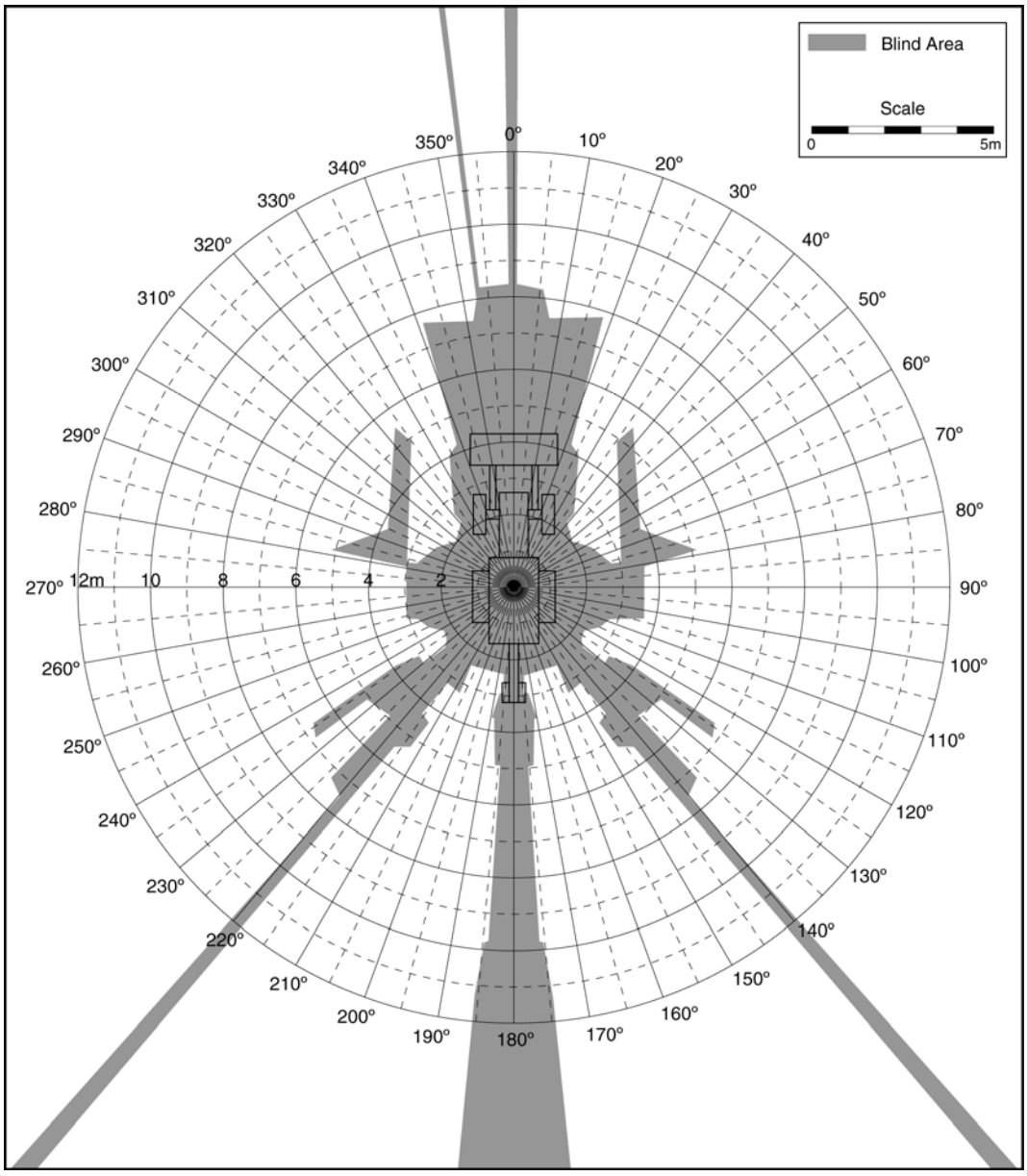


Backhoe Loader

John Deere 310 SG
Caterpillar 426C

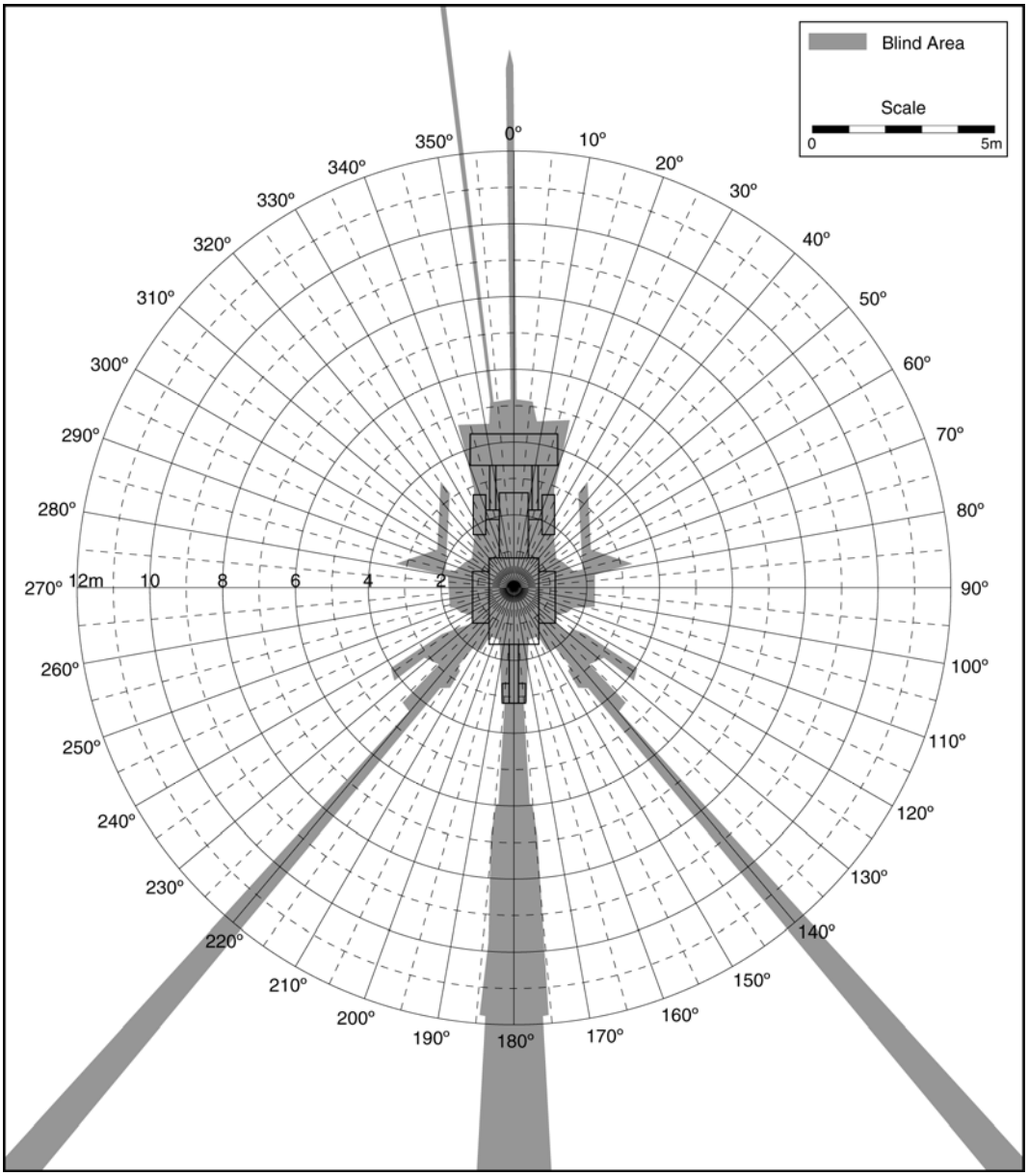
Blind Area Diagram for Construction Vehicle – Ground Plane

BHLoader (Manufacturer and Model)	John Deere 310SG
GVW	13,500 lb
Serial #	T0310SG919009
Machine Dimensions	7’ 2” wide (bucket) 23’ 6” long
Operator Enclosure	Closed ROPS
Attachments	None
Other Information	None
Measurement Technique	Physical



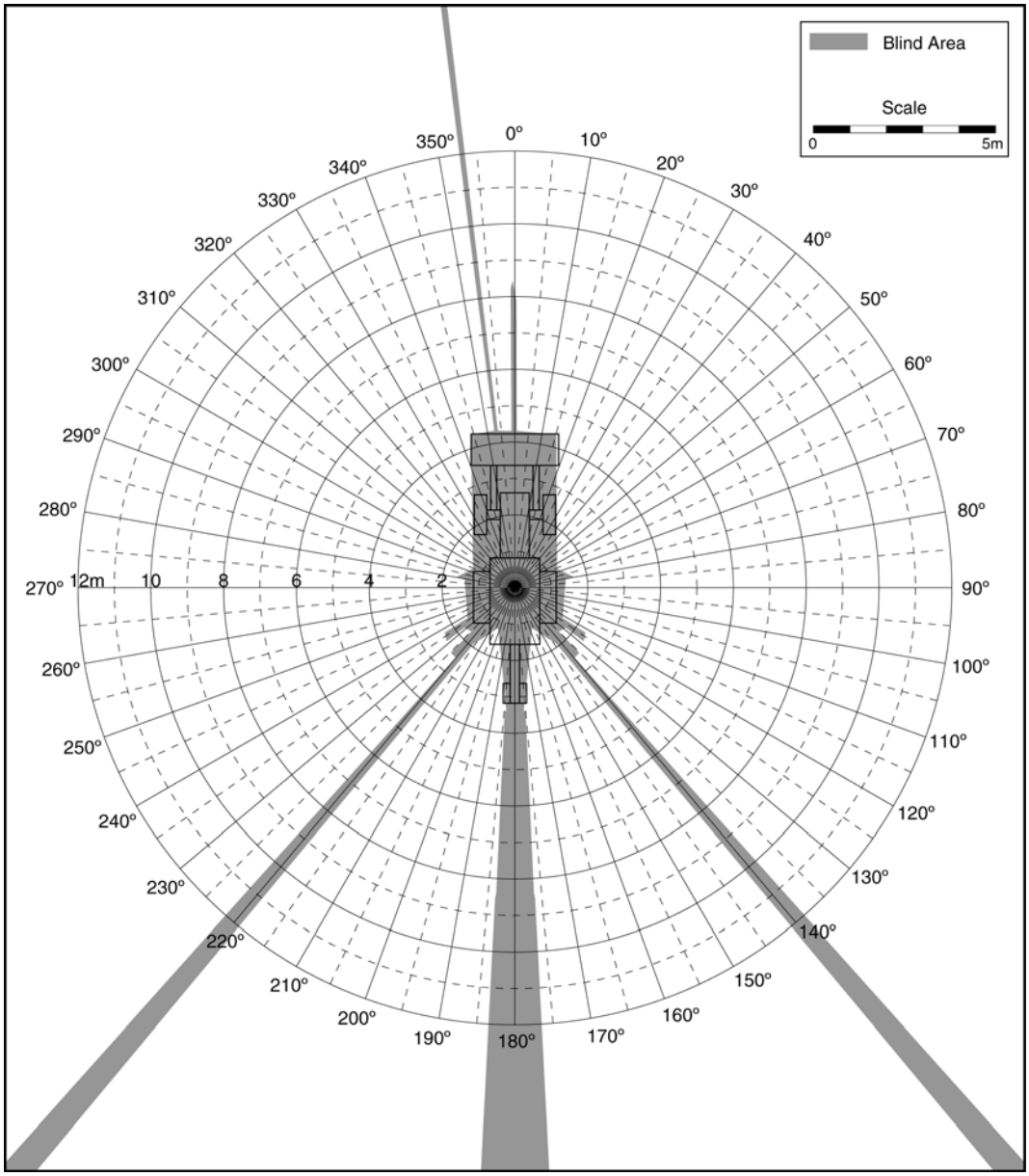
Blind Area Diagram for Construction Vehicle – 900 mm Plane

BHLoader (Manufacturer and Model)	John Deere 310SG
GVW	13,500 lb
Serial #	T0310SG919009
Machine Dimensions	7’ 2” wide (bucket) 23’ 6” long
Operator Enclosure	Closed ROPS
Attachments	None
Other Information	None
Measurement Technique	Physical



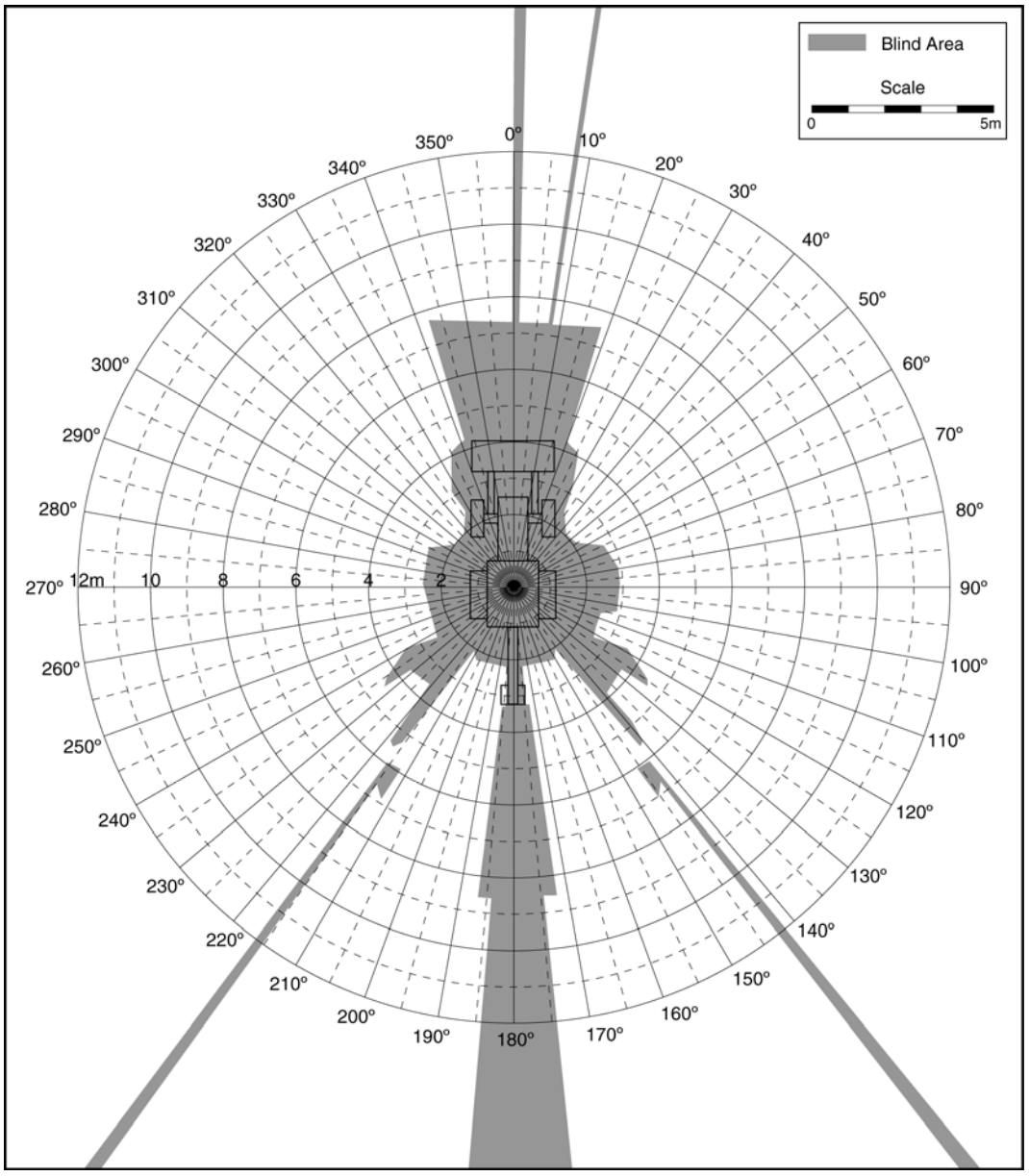
Blind Area Diagram for Construction Vehicle – 1500 mm Plane

BHLoader (Manufacturer and Model)	John Deere 310SG
GVW	13,500 lb
Serial #	T0310SG919009
Machine Dimensions	7’ 2” wide (bucket) 23’ 6” long
Operator Enclosure	Closed ROPS
Attachments	None
Other Information	None
Measurement Technique	Physical



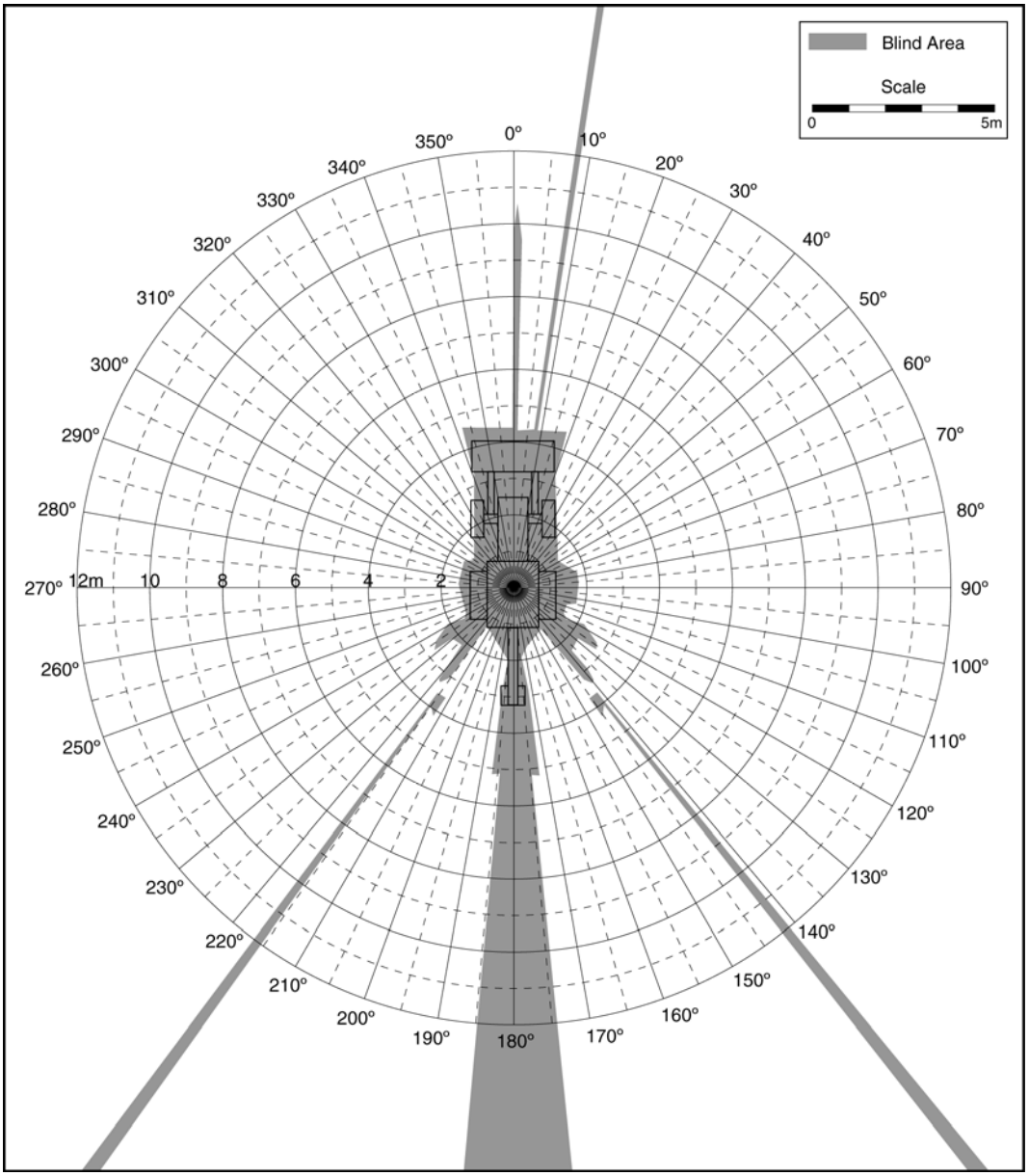
Blind Area Diagram for Construction Vehicle – Ground Plane

BHLoader (Manufacturer and Model)	Caterpillar 426C
GVW	15,500 lb
Serial #	6XN04144
Machine Dimensions	7’5” wide (bucket) 23’ 10” long
Operator Enclosure	Closed ROPS
Attachments	None
Other Information	None
Measurement Technique	Physical



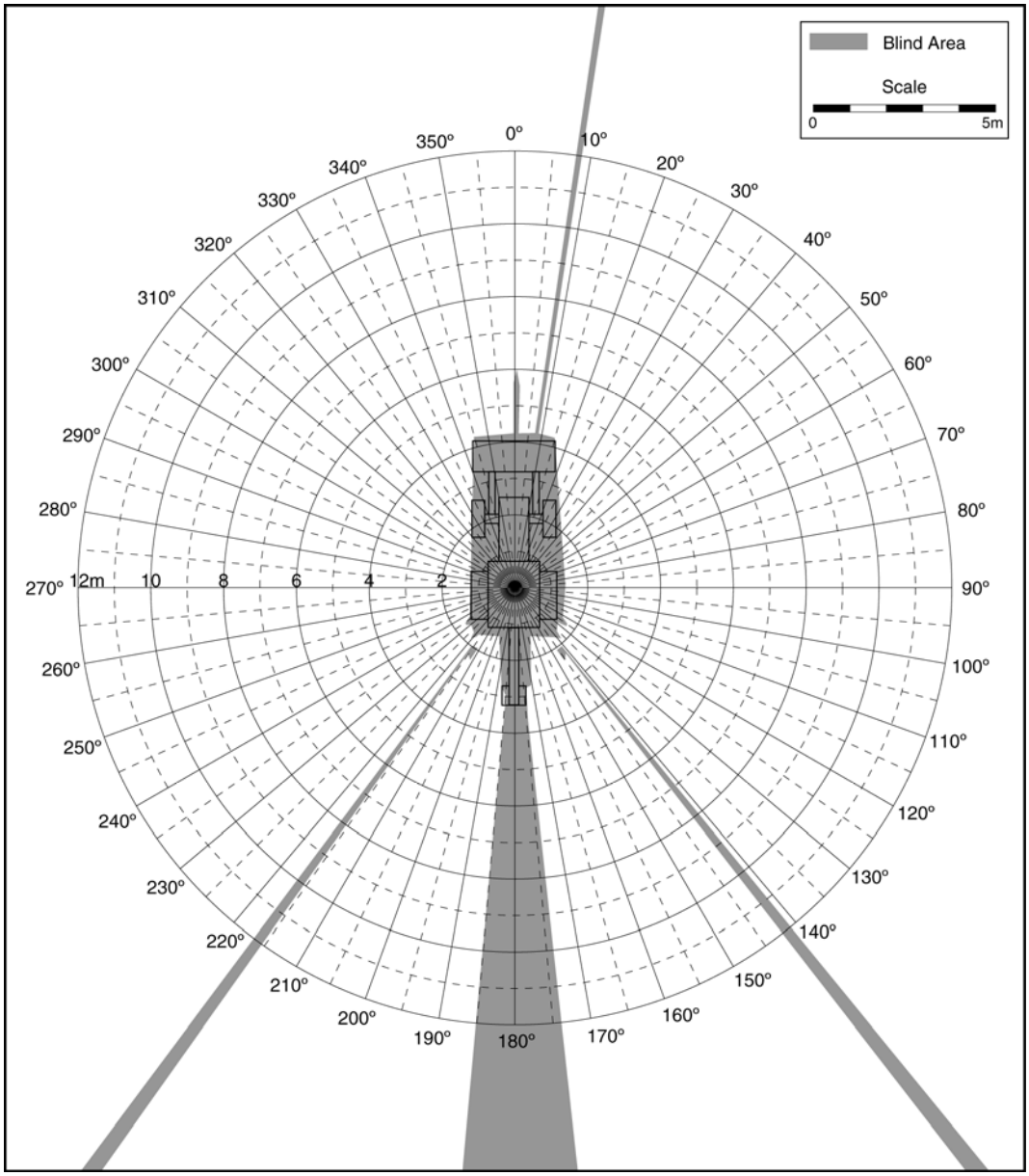
Blind Area Diagram for Construction Vehicle – 900 mm Plane

BHLoader (Manufacturer and Model)	Caterpillar 426C
GVW	15,500 lb
Serial #	6XN04144
Machine Dimensions	7’5” wide (bucket) 23’ 10” long
Operator Enclosure	Closed ROPS
Attachments	None
Other Information	None
Measurement Technique	Physical



Blind Area Diagram for Construction Vehicle – 1500 mm Plane

BHLoader (Manufacturer and Model)	Caterpillar 426C
GVW	15,500 lb
Serial #	6XN04144
Machine Dimensions	7’5” wide (bucket) 23’ 10” long
Operator Enclosure	Closed ROPS
Attachments	None
Other Information	None
Measurement Technique	Physical

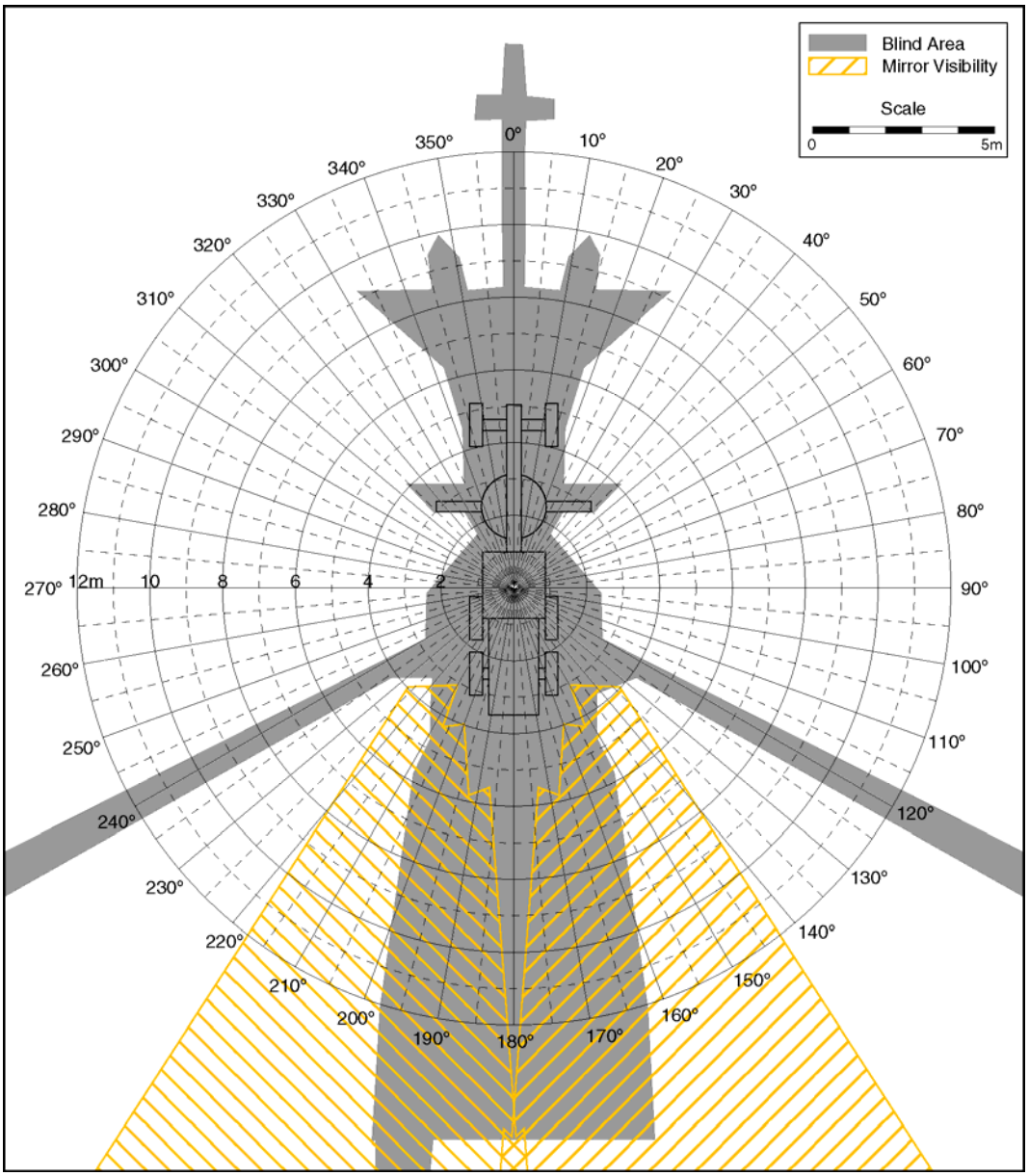


Grader

John Deere 772CHII

Blind Area Diagram for Construction Vehicle – Ground Plane

Grader (Manufacturer and Model)	John Deere 772 CH
GVW	31,750 lb
Serial #	DW772CH582732
Machine Dimensions	14’ wide (blade) 28’ 3” long
Operator Enclosure	Closed ROPS
Attachments	5 tooth ripper
Other Information	None
Measurement Technique	Physical



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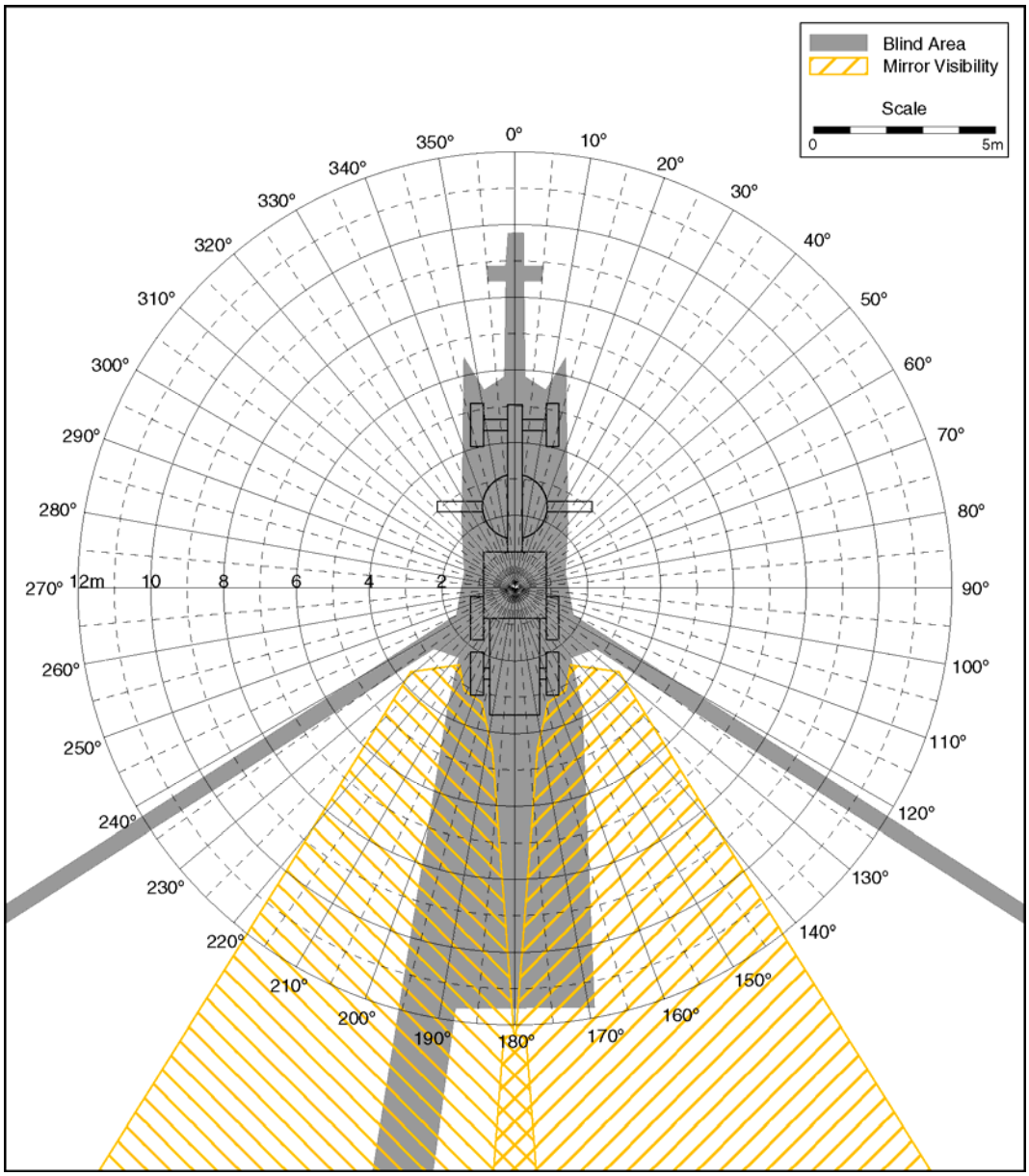
GVW	31,750 lb
Serial #	DW772CH582732
Machine Dimensions	14’ wide (blade) 28’ 3” long
Operator Enclosure	Closed ROPS
Attachments	5 tooth ripper
Other Information	None
Measurement Technique	Physical



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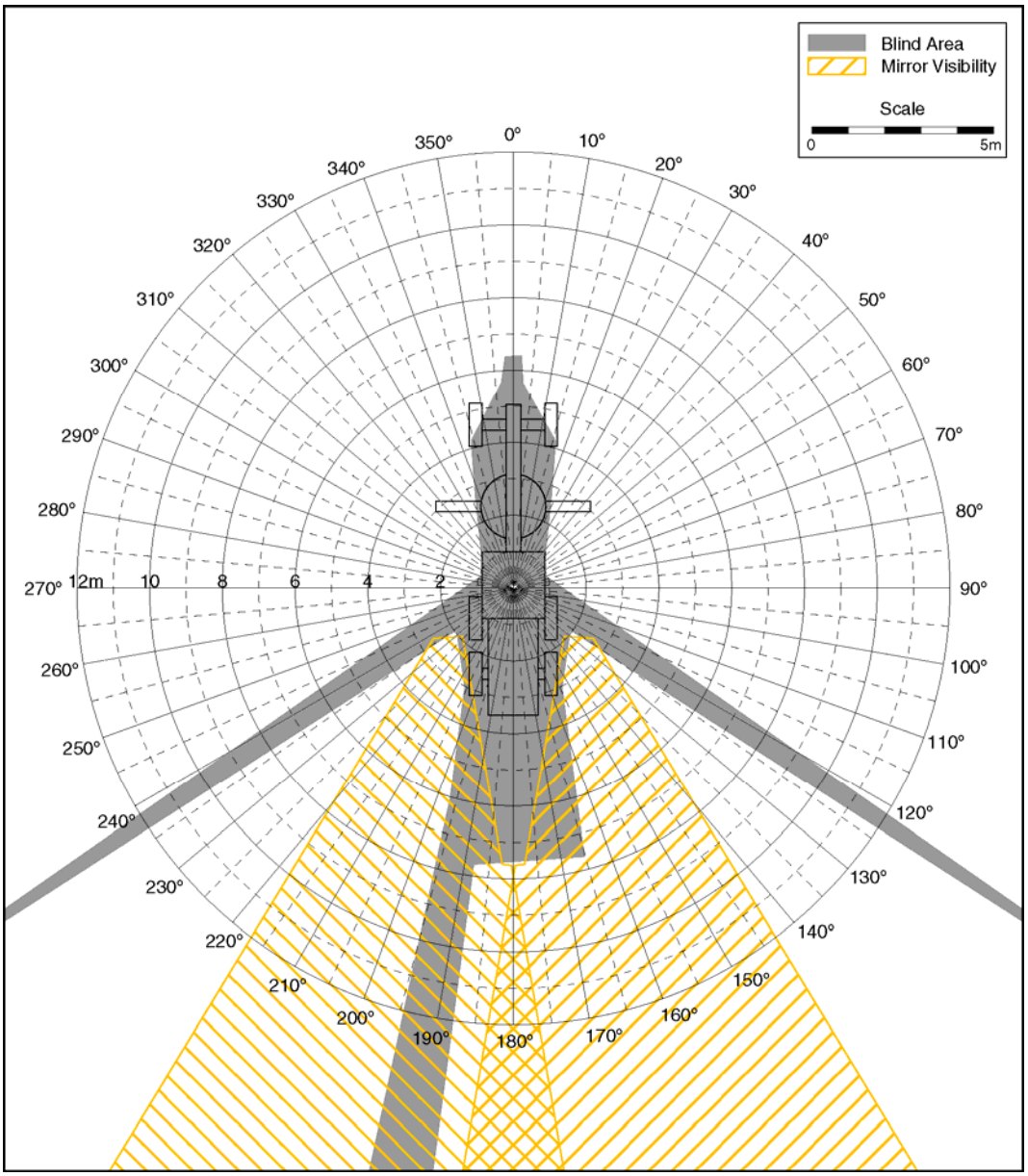
Attachments	5 tooth ripper
Other Information	None
Measurement Technique	Physical

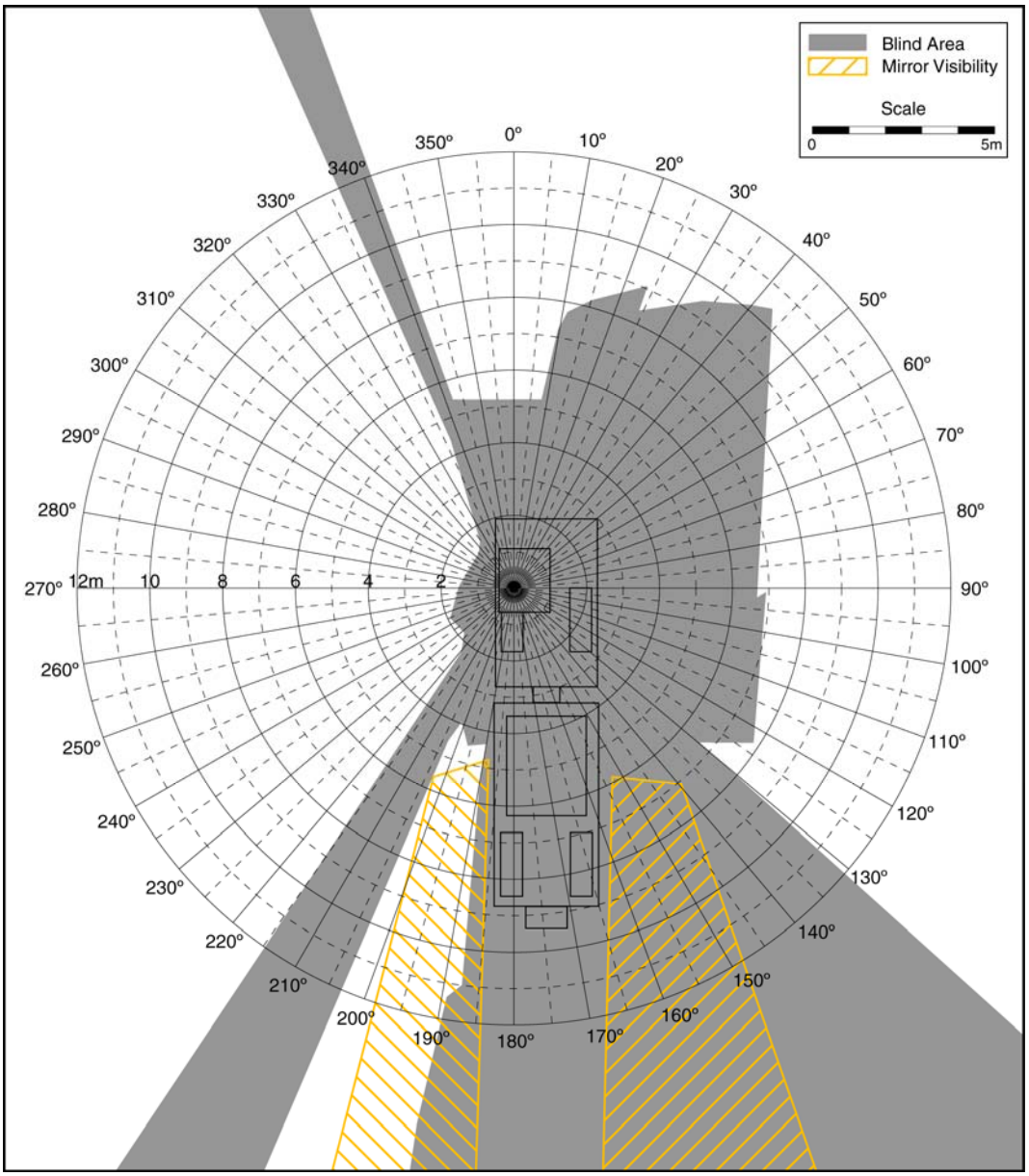


Scraper

John Deere 862B

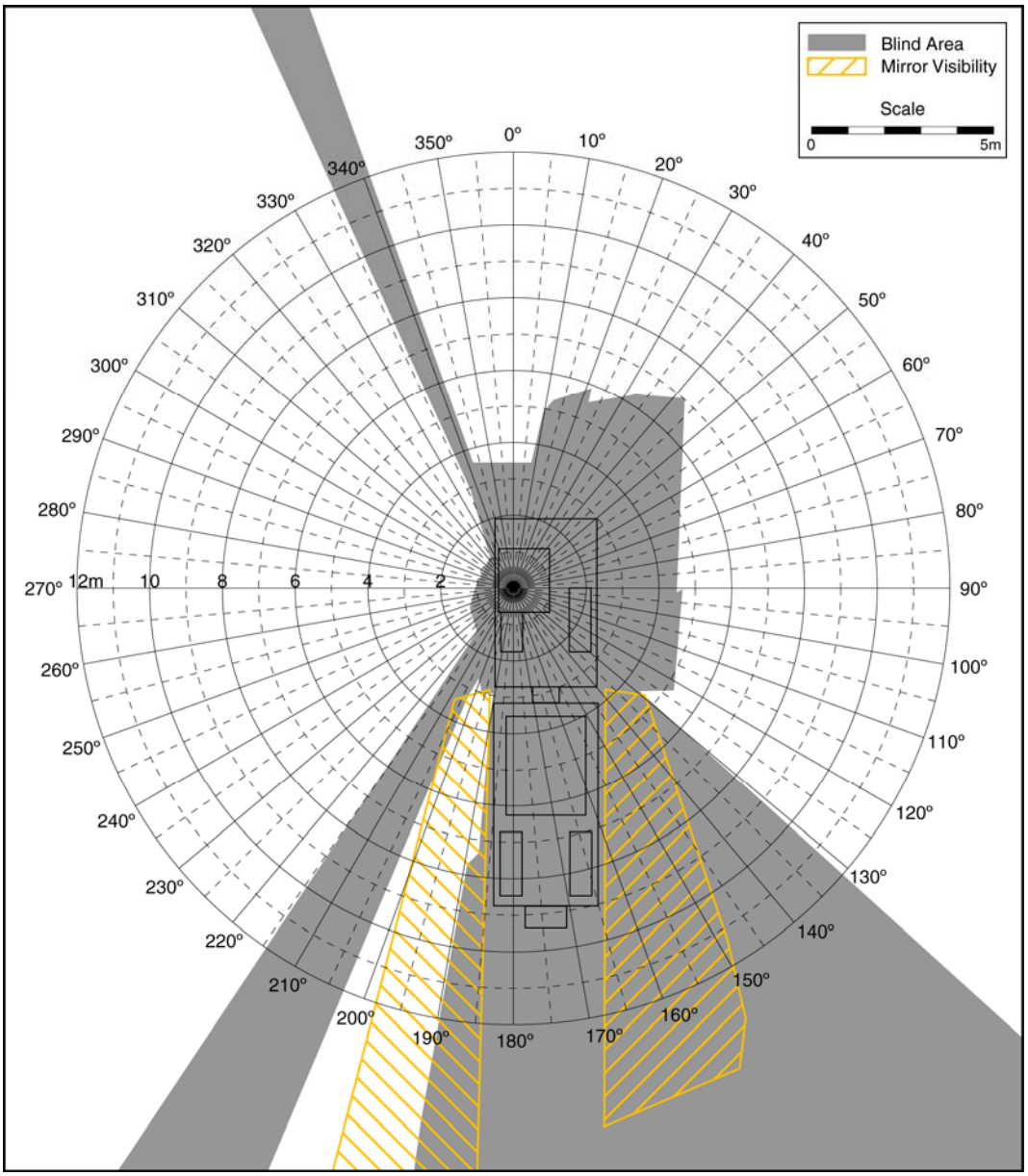
Blind Area Diagram for Construction Vehicle – Ground Plane

Scraper (Manufacturer and Model)	John Deere 862B
GVW	49,100 lb
Serial #	T0862BX744910
Machine Dimensions	9’ 5” wide(cutting edge) 36’ 8” long
Operator Enclosure	Closed ROPS
Attachments	None
Other Information	None
Measurement Technique	Physical



Blind Area Diagram for Construction Vehicle – 900 mm Plane

Scraper (Manufacturer and Model)	John Deere 862B
GVW	49,100 lb
Serial #	T0862BX744910
Machine Dimensions	9’ 5” wide(cutting edge) 36’ 8” long
Operator Enclosure	Closed ROPS
Attachments	None
Other Information	None
Measurement Technique	Physical



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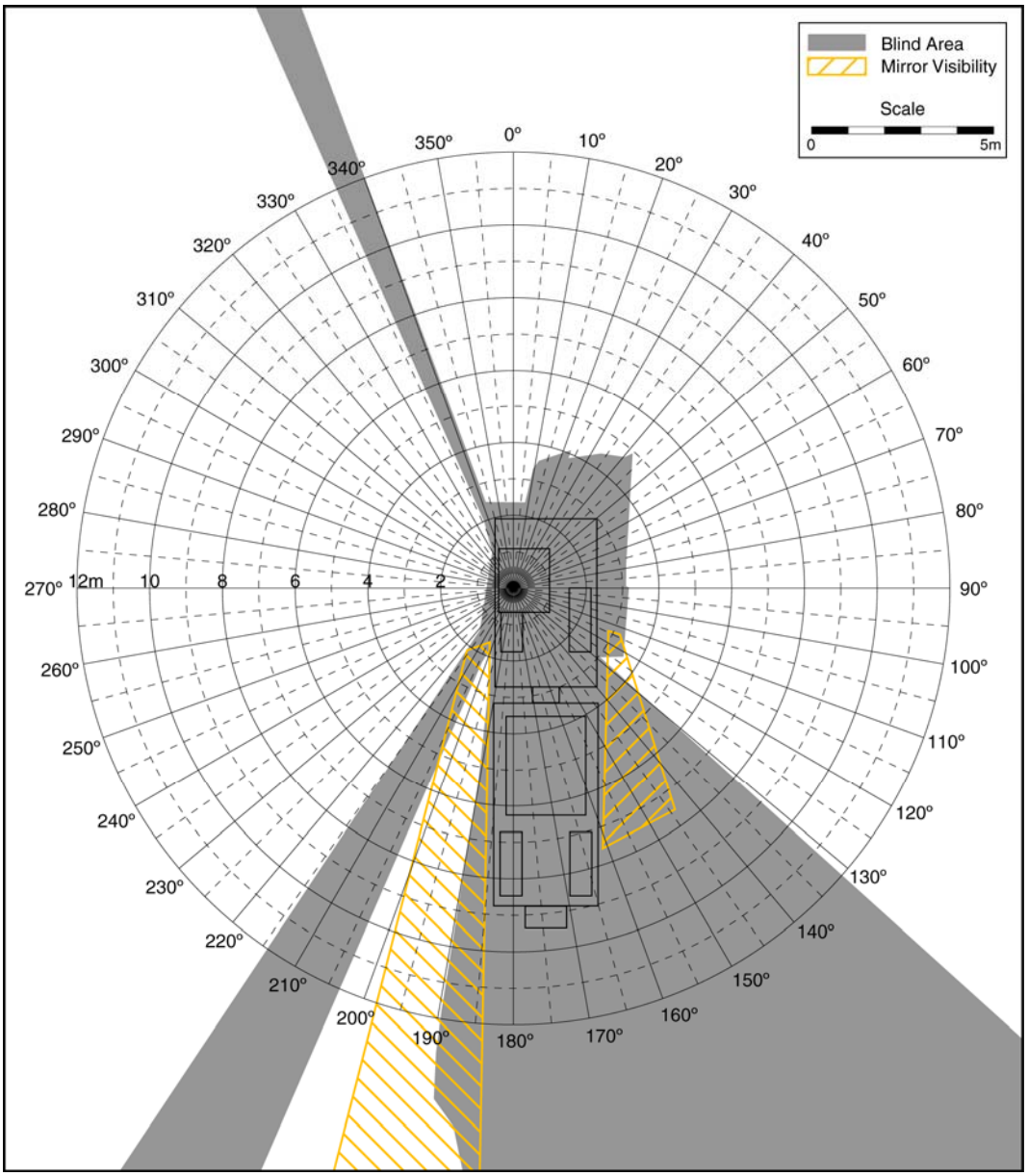
Scraper (Manufacturer and Model)	John Deere 862B
GVW	49,100 lb
Serial #	T0862BX744910
Machine Dimensions	9’ 5” wide(cutting edge) 36’ 8” long
Operator Enclosure	Closed ROPS
Attachments	None
Other Information	None
Measurement Technique	Physical



Cold Planer

Caterpillar PM565

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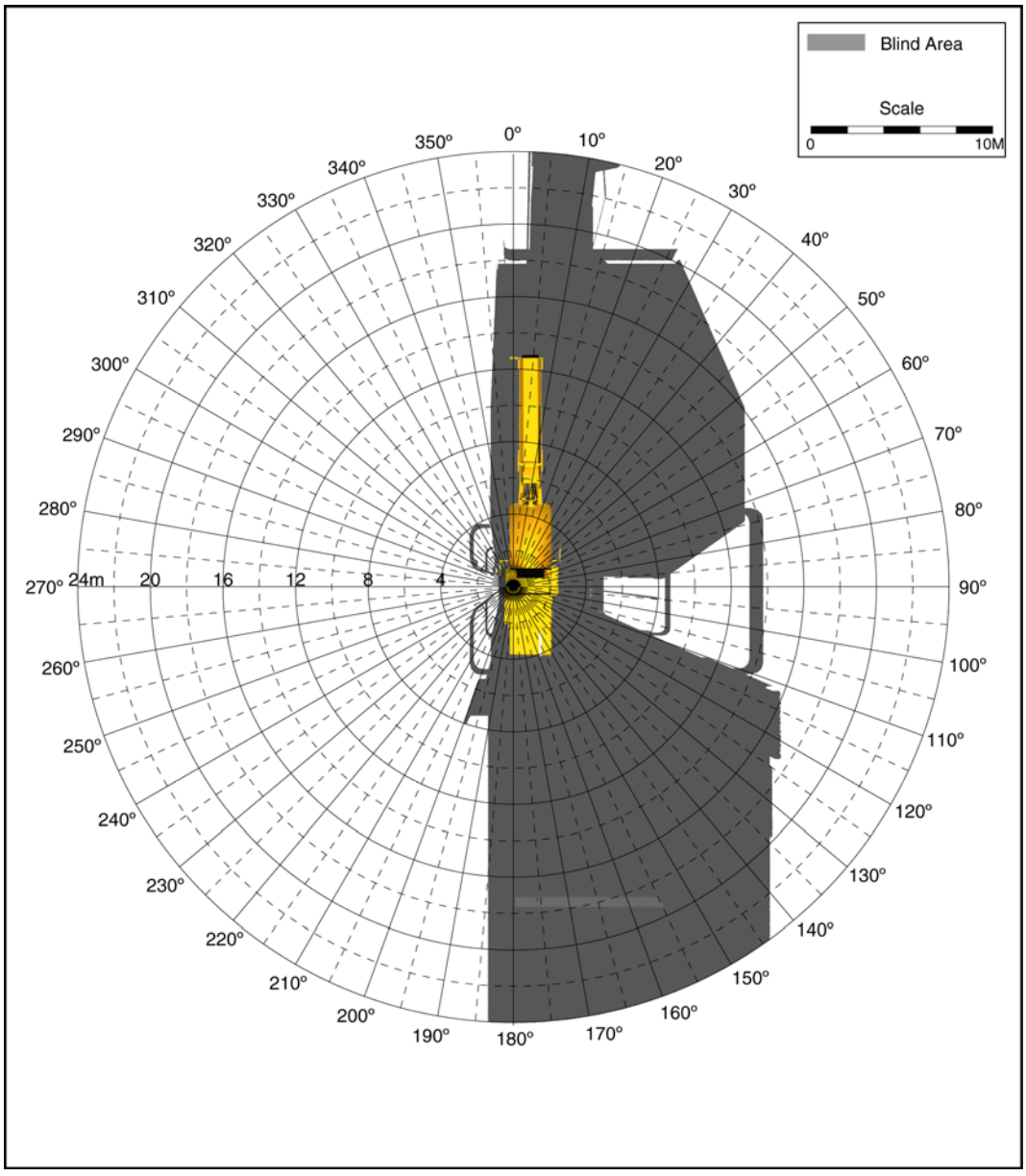
Blind Area Diagram for Construction Vehicle – Ground Plane

Cold Planer (Manufacturer and Model)	Caterpillar PM565C
GVW	83,500 lb
Serial #	
Machine Dimensions	10’ 7” wide 47’ 6” long
Operator Enclosure	Open
Attachments	None
Other Information	Standing operator
Measurement Technique	Simulation



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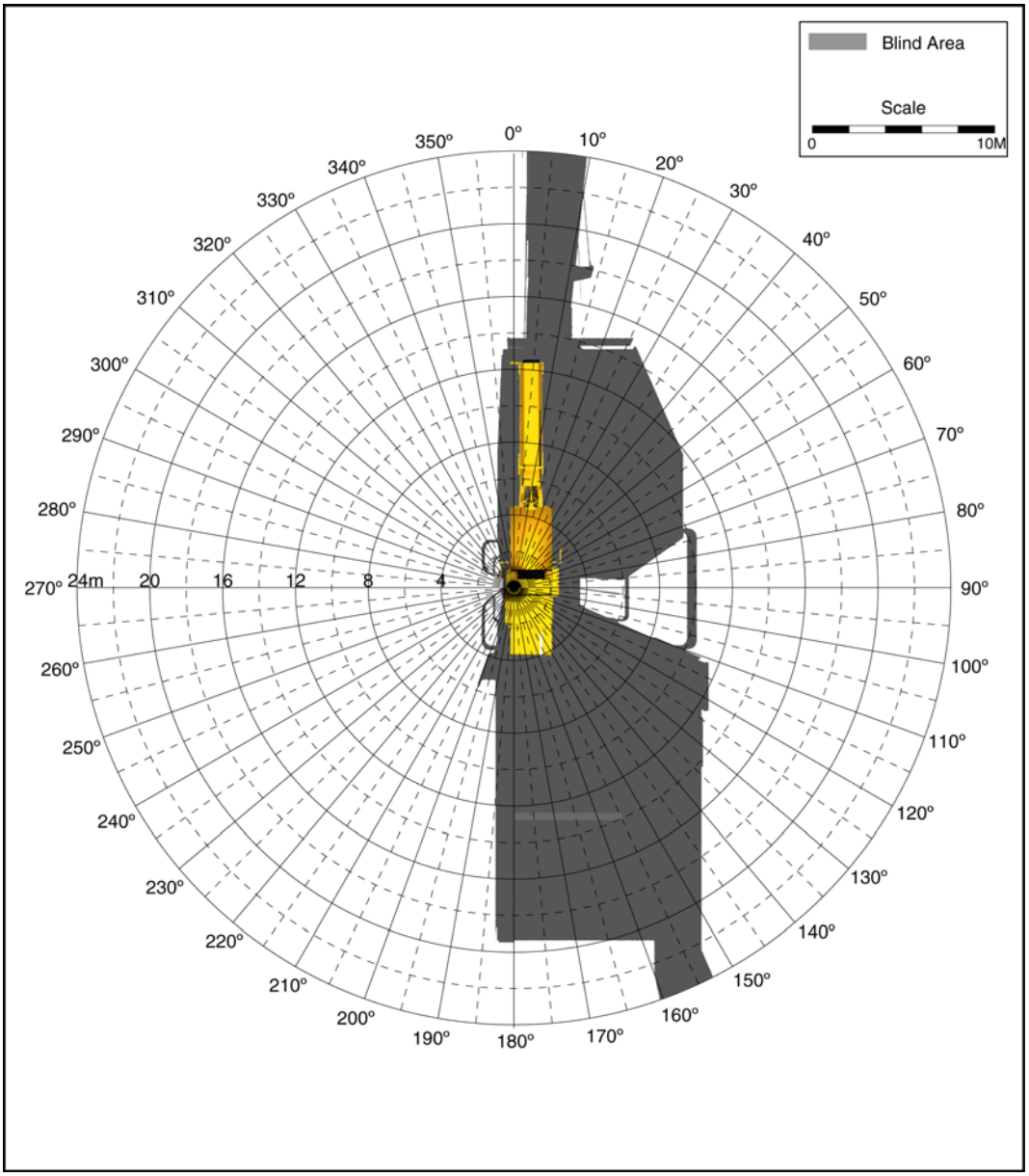
Blind Area Diagram for Construction Vehicle – 900 mm Plane

Cold Planer (Manufacturer and Model)	Caterpillar PM565C
GVW	83,500 lb
Serial #	
Machine Dimensions	10’ 7” wide 47’ 6” long
Operator Enclosure	Open
Attachments	None
Other Information	Standing operator
Measurement Technique	Simulation



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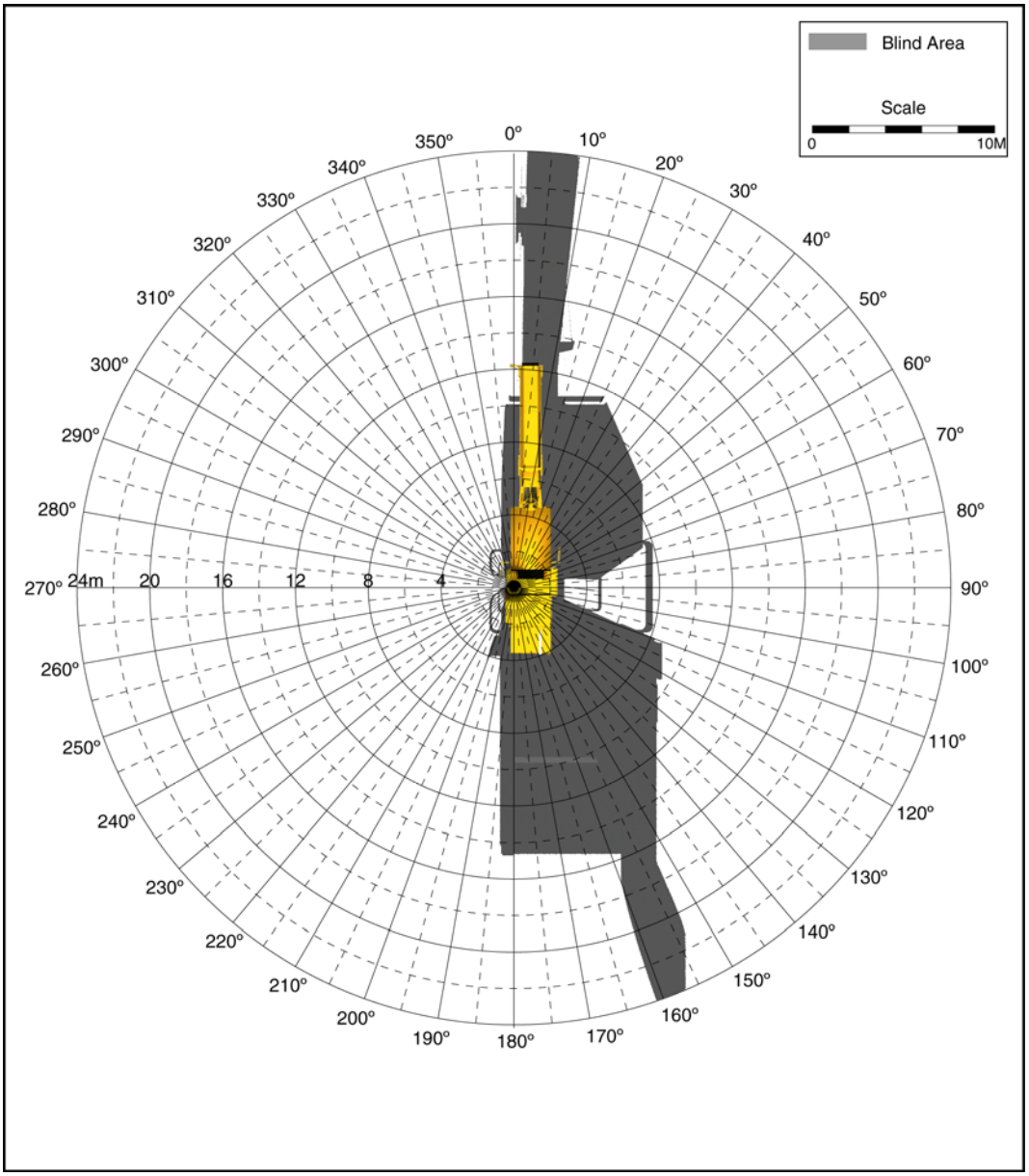
Blind Area Diagram for Construction Vehicle – 1500 mm Plane

Cold Planer (Manufacturer and Model)	Caterpillar PM565C
GVW	83,500 lb
Serial #	
Machine Dimensions	10’ 7” wide 47’ 6” long
Operator Enclosure	Open
Attachments	None
Other Information	Standing operator
Measurement Technique	Simulation

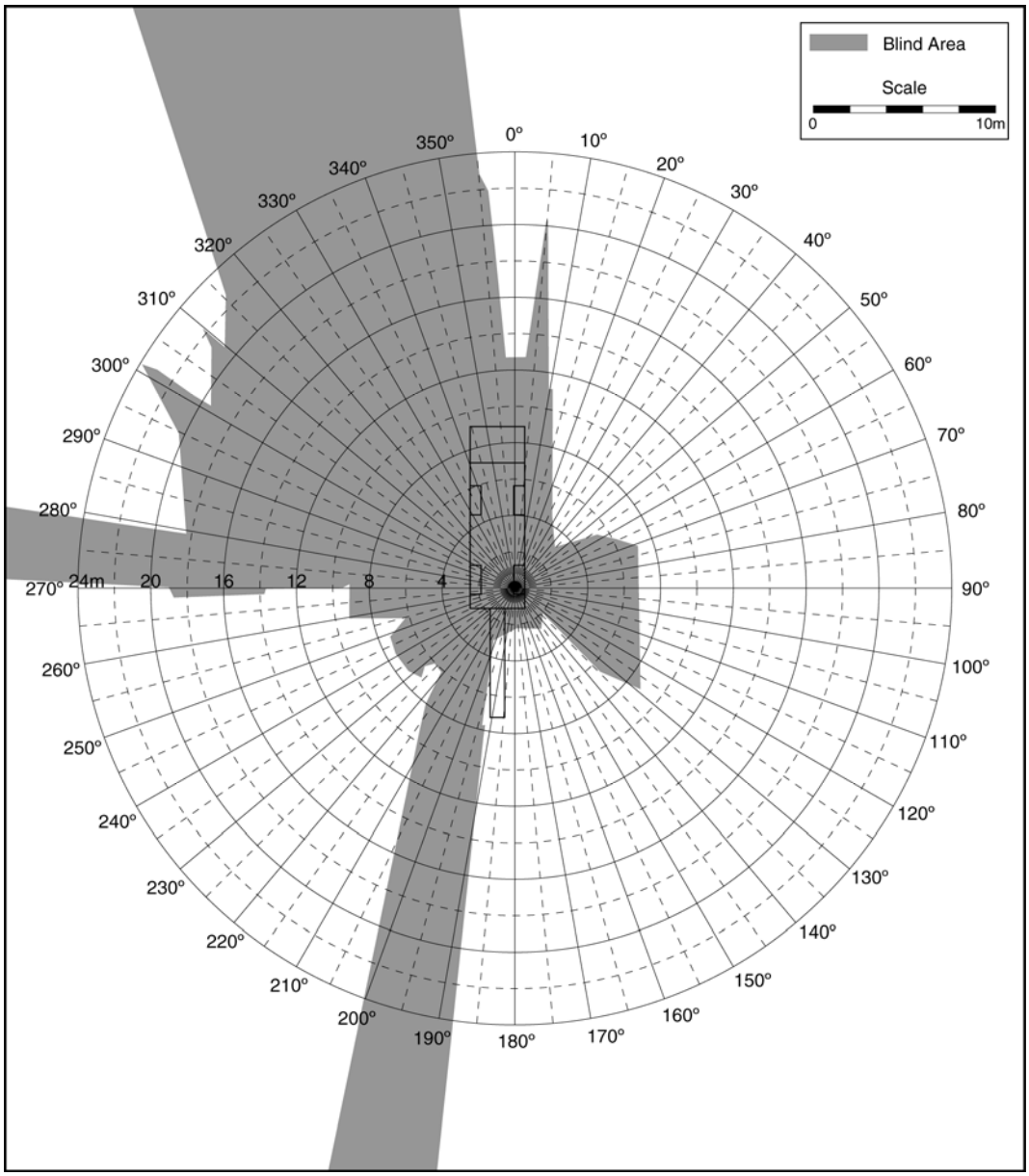


Transfer/shuttle buggy

Roadtec2500

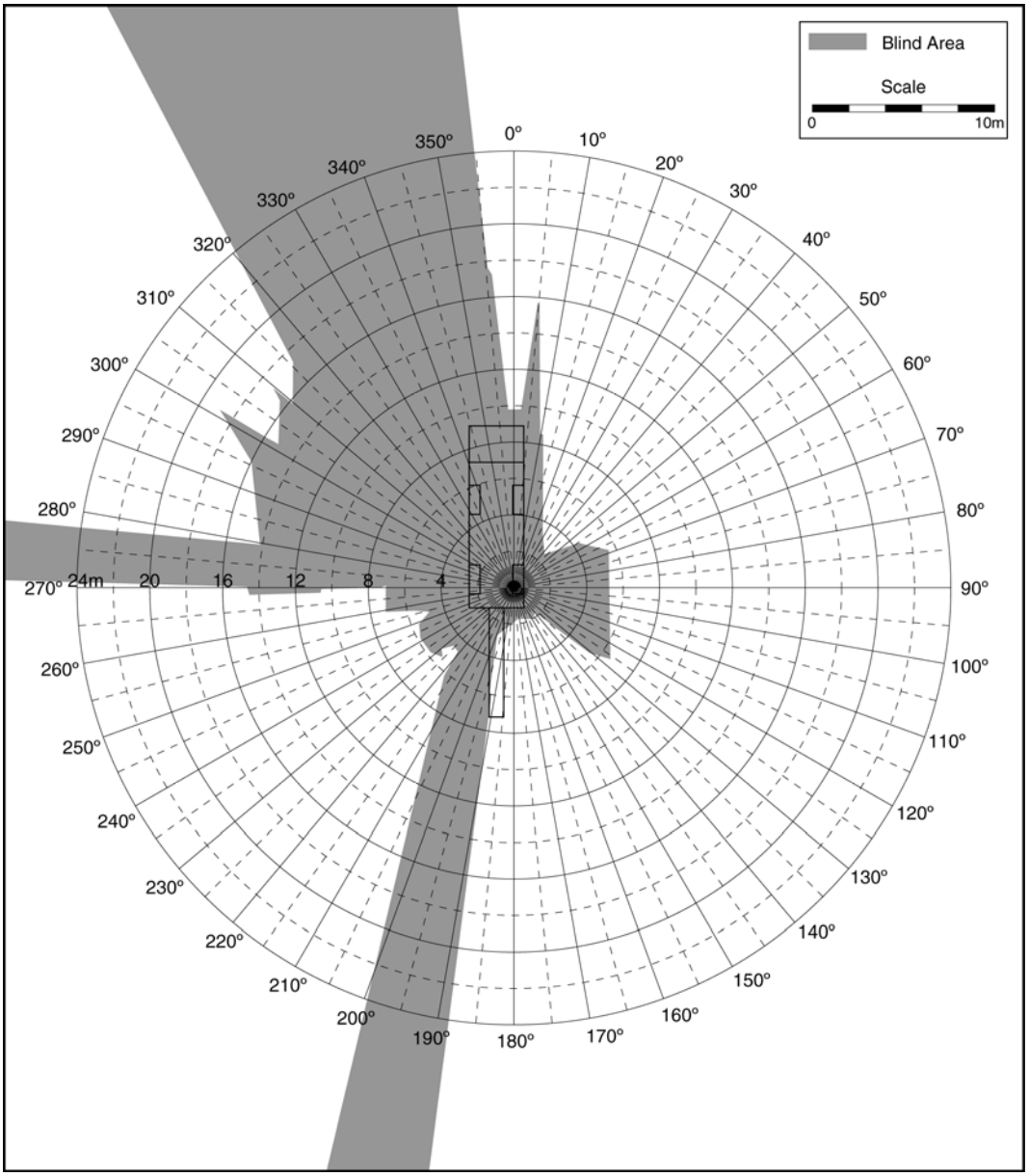
Blind Area Diagram for Construction Vehicle – Ground Plane

Transfer/shuttle buggy (Manufacturer and Model)	Roadtec 2500B
GVW	75,500 lb
Serial #	SB2500-B-531
Machine Dimensions	9’ 10” wide 52’ 9” long
Operator Enclosure	Open
Attachments	None
Other Information	None
Measurement Technique	Physical



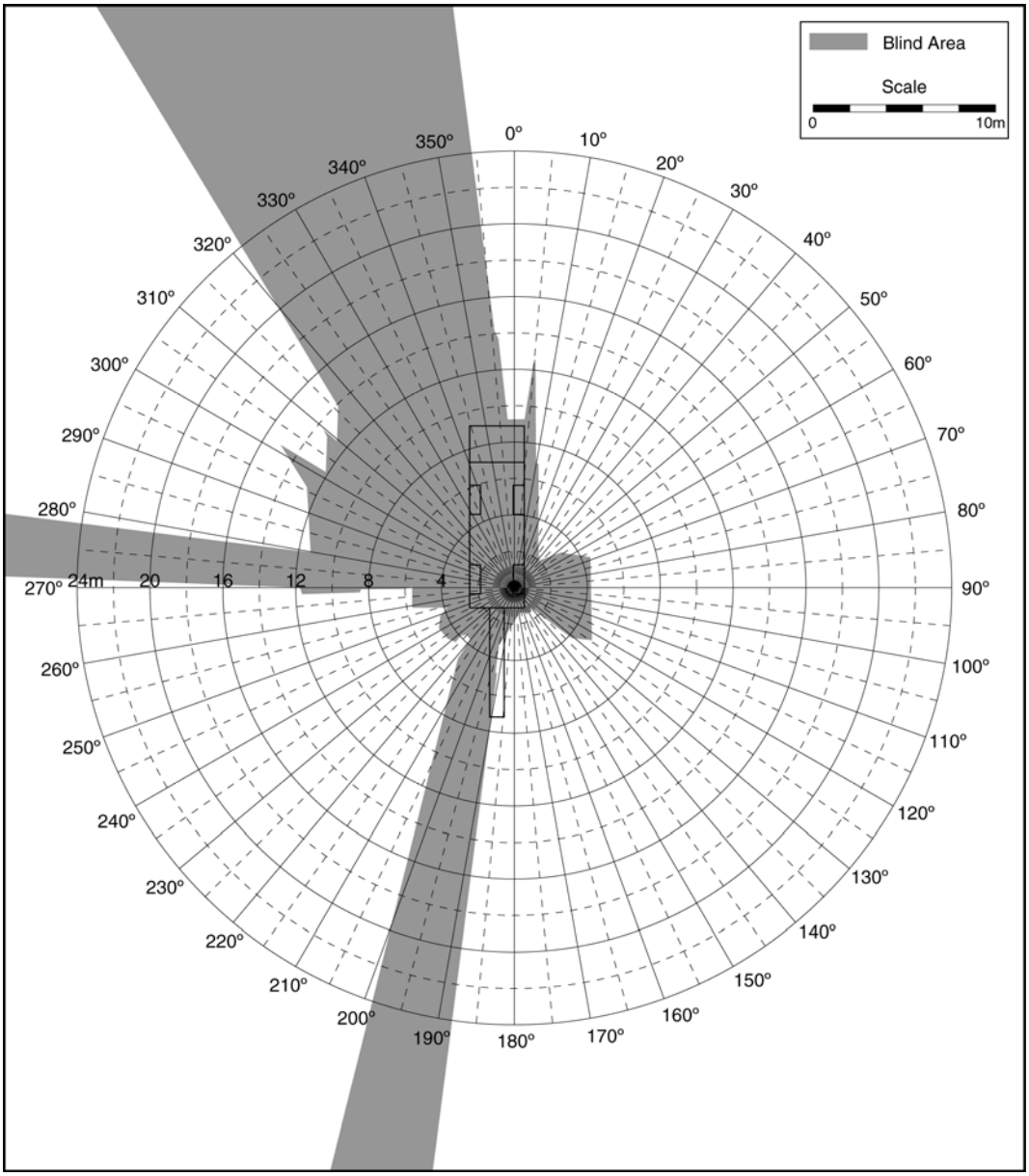
Blind Area Diagram for Construction Vehicle – 900 mm Plane

Transfer/shuttle buggy (Manufacturer and Model)	Roadtec 2500B
GVW	75,500 lb
Serial #	SB2500-B-531
Machine Dimensions	9’ 10” wide 52’ 9” long
Operator Enclosure	Open
Attachments	None
Other Information	None
Measurement Technique	Physical



Blind Area Diagram for Construction Vehicle – 1500 mm Plane

Transfer/shuttle buggy (Manufacturer and Model)	Roadtec 2500B
GVW	75,500 lb
Serial #	SB2500-B-531
Machine Dimensions	9’ 10” wide 52’ 9” long
Operator Enclosure	Open
Attachments	None
Other Information	None
Measurement Technique	Physical

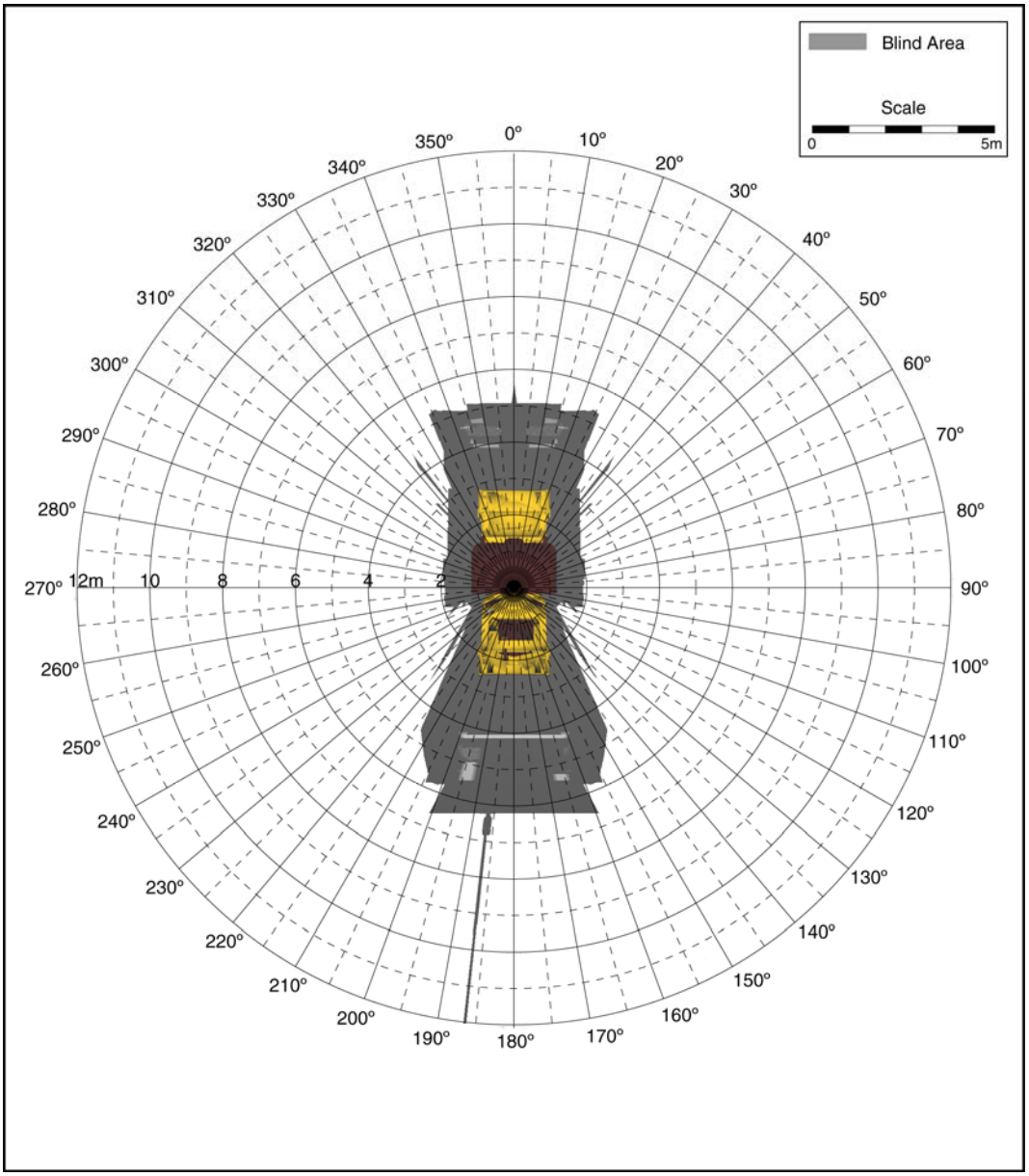


Large Roller

Caterpillar CB 534D

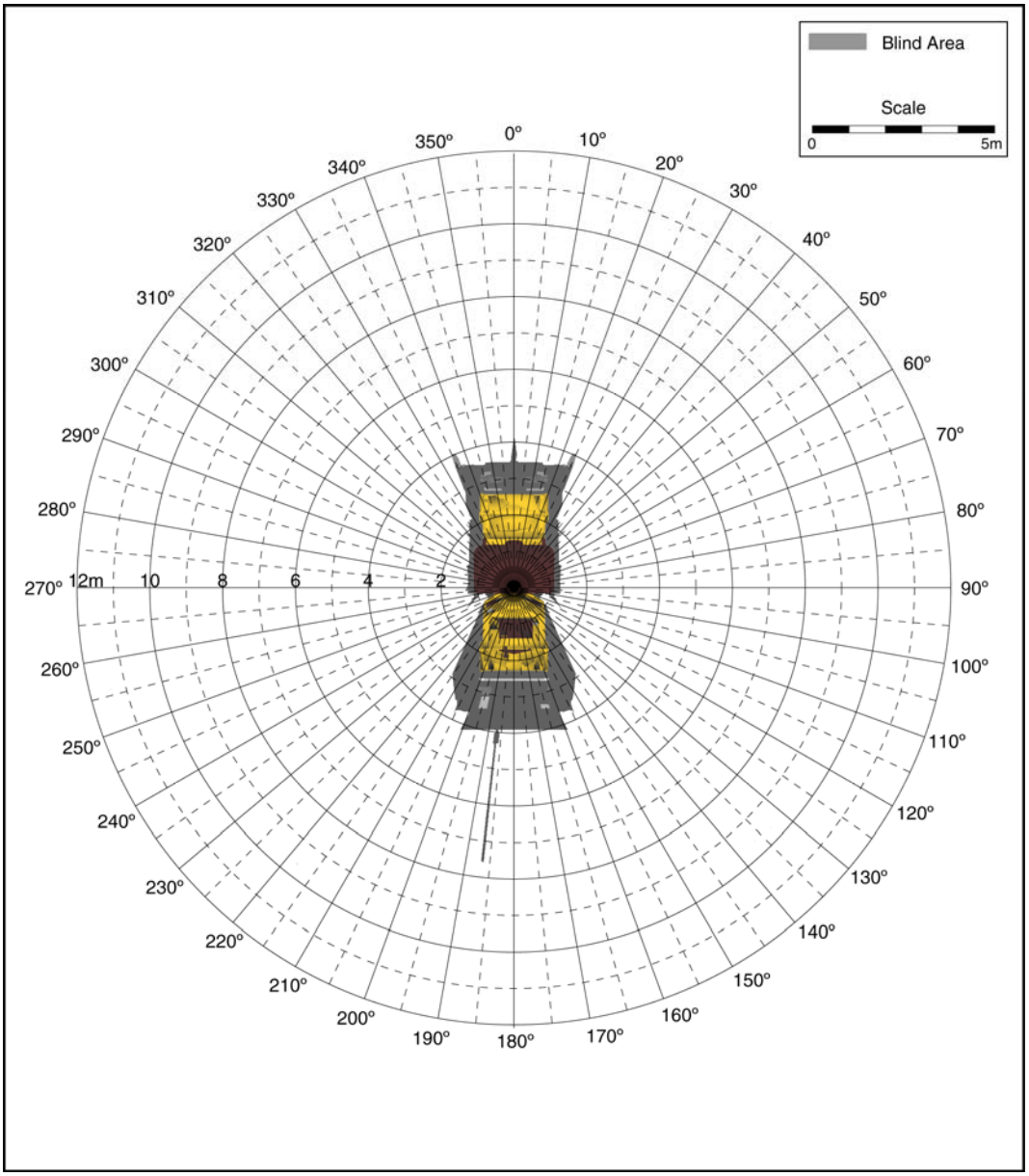
Blind Area Diagram for Construction Vehicle – Ground Plane

Large roller/ compactor (Manufacturer and Model)	Caterpillar CB 534D
GVW	22,000 lb
Serial #	
Machine Dimensions	6’ 1” wide 16’ 3” long
Operator Enclosure	Enclosed
Attachments	None
Other Information	None
Measurement Technique	Simulation



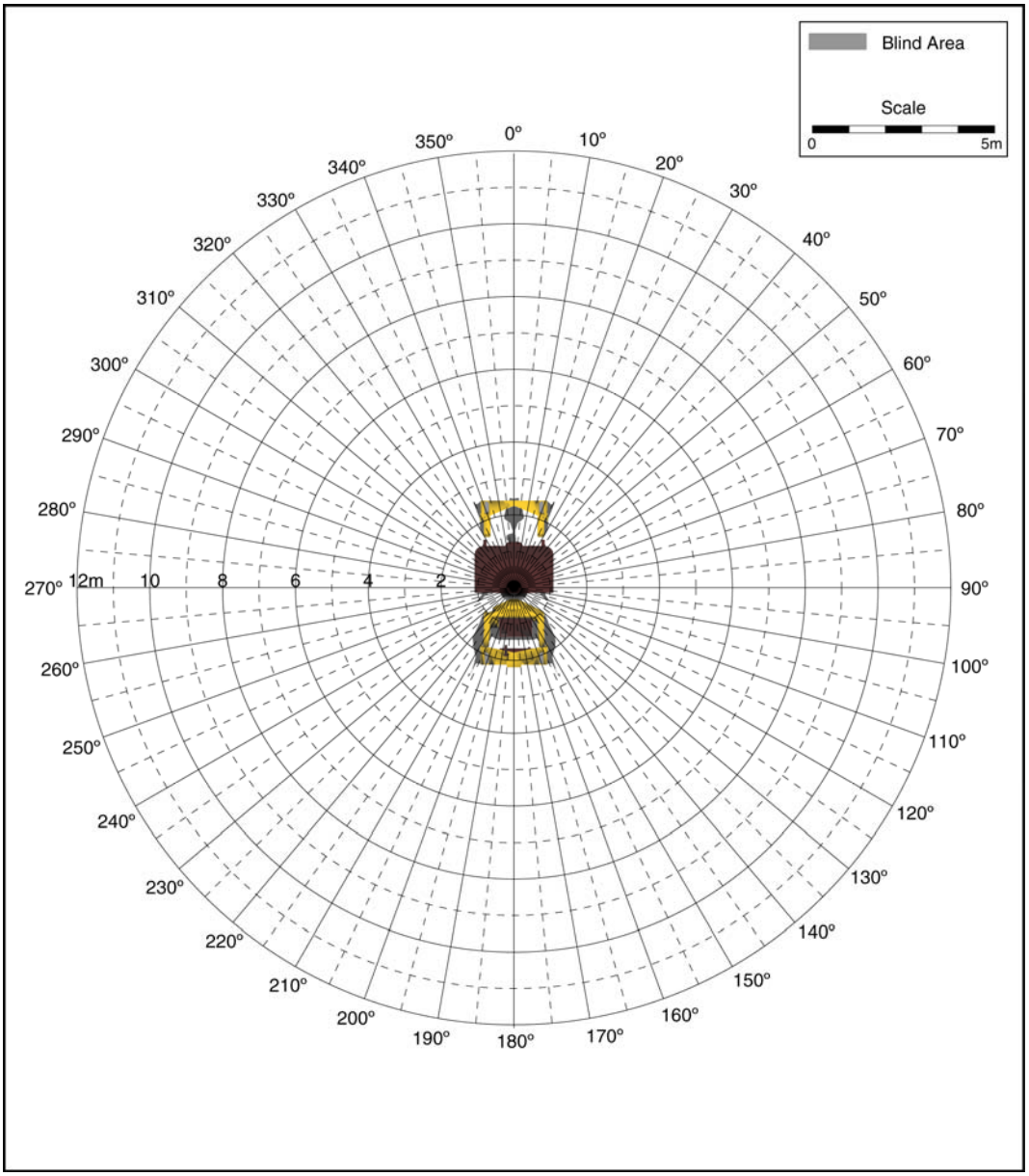
Blind Area Diagram for Construction Vehicle – 900 mm Plane

Large roller/ compactor (Manufacturer and Model)	Caterpillar CB 534D
GVW	22,000 lb
Serial #	
Machine Dimensions	6’ 1” wide 16’ 3” long
Operator Enclosure	Enclosed
Attachments	None
Other Information	None
Measurement Technique	Simulation



Blind Area Diagram for Construction Vehicle – 1500 mm Plane

Large roller/ compactor (Manufacturer and Model)	Caterpillar CB 534D
GVW	22,000 lb
Serial #	
Machine Dimensions	6’ 1” wide 16’ 3” long
Operator Enclosure	Enclosed
Attachments	None
Other Information	None
Measurement Technique	Simulation

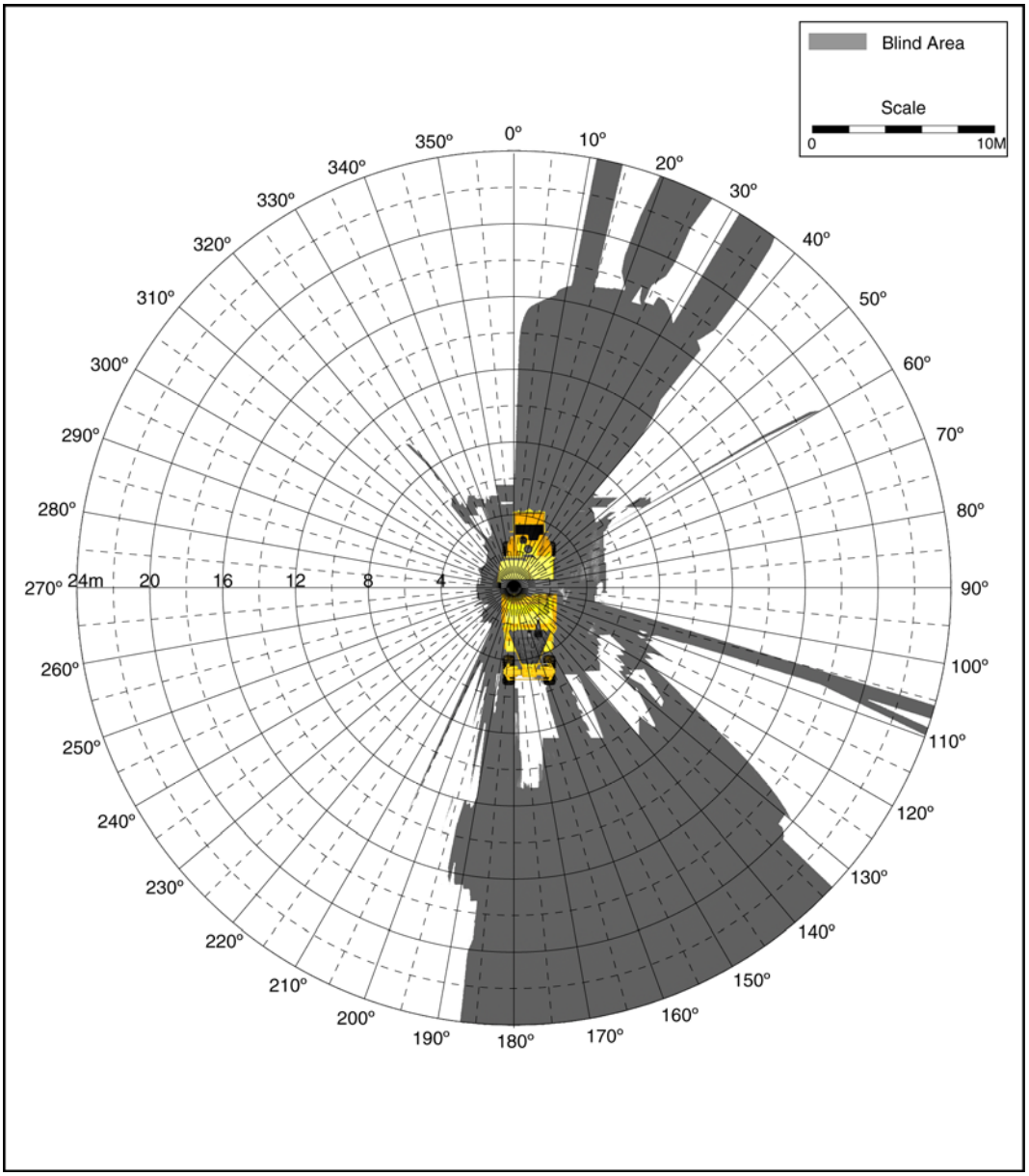


Road recycler/ reclaimer

Caterpillar RM 500

Blind Area Diagram for Construction Vehicle – Ground Plane

Road recycler/ reclaimer (Manufacturer and Model)	Caterpillar RM 500
GVW	53,000 lb
Serial #	
Machine Dimensions	9’ 10” wide 31’ 6” long
Operator Enclosure	Enclosed
Attachments	None
Other Information	None
Measurement Technique	Simulation



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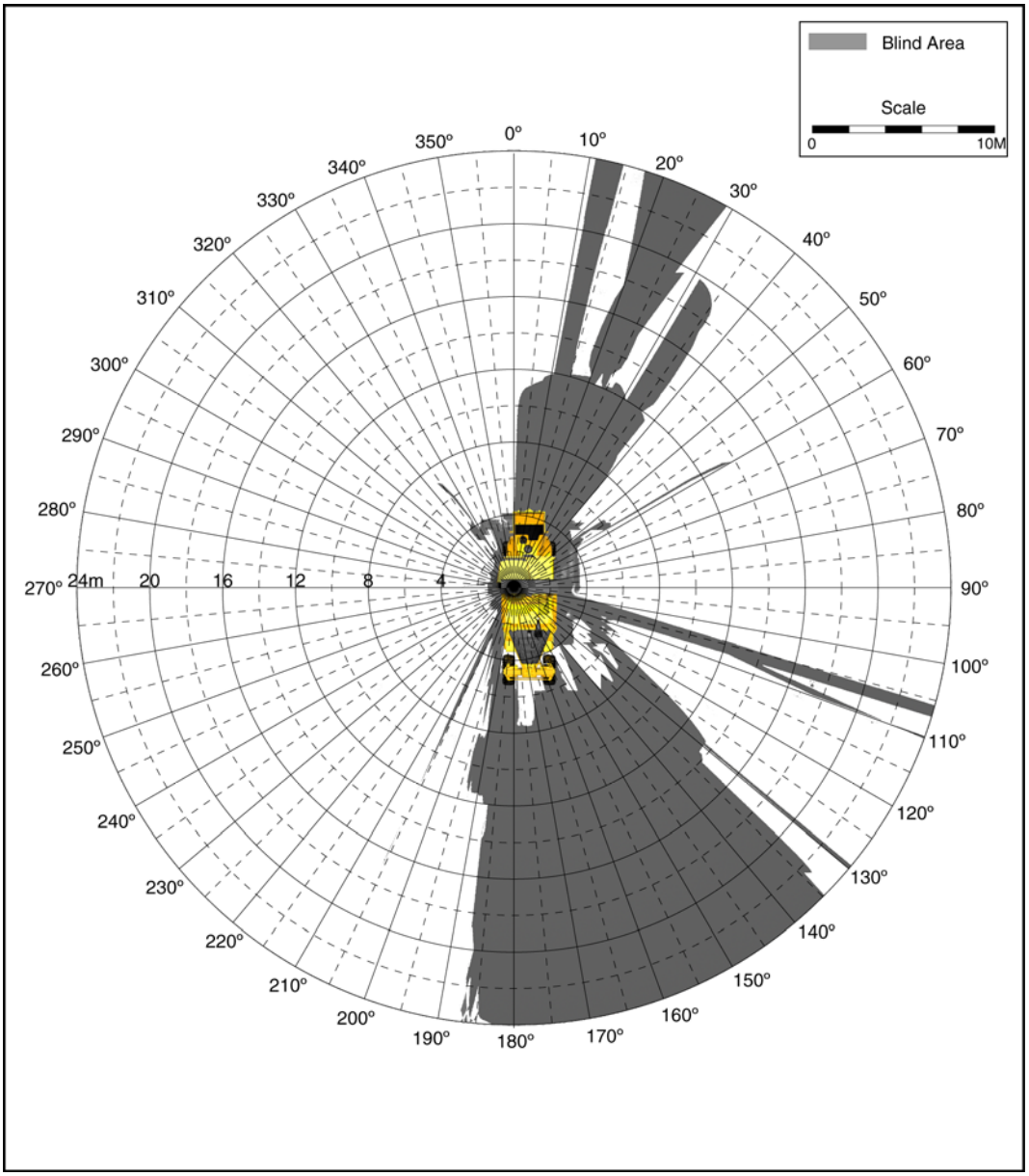
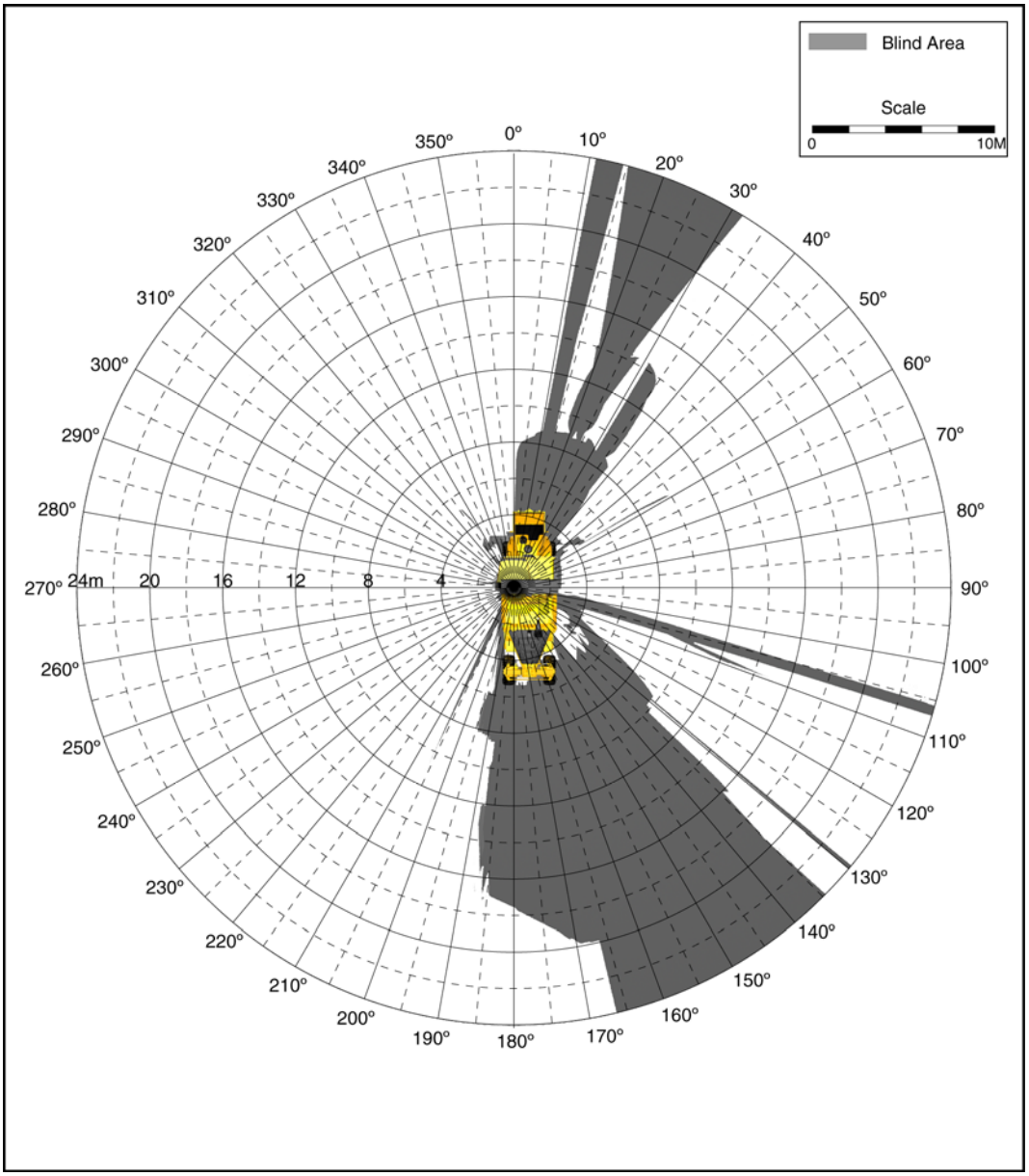
Blind Area Diagram for Construction Vehicle – 900 mm Plane

Road recycler/ reclaimer (Manufacturer and Model)	Caterpillar RM 500
GVW	53,000 lb
Serial #	
Machine Dimensions	9’ 10” wide 31’ 6” long
Operator Enclosure	Enclosed
Attachments	None
Other Information	None
Measurement Technique	Simulation



Blind Area Diagram for Construction Vehicle – 1500 mm Plane

Road recycler/ reclaimer (Manufacturer and Model)	Caterpillar RM 500
GVW	53,000 lb
Serial #	
Machine Dimensions	9’ 10” wide 31’ 6” long
Operator Enclosure	Enclosed
Attachments	None
Other Information	None
Measurement Technique	Simulation



Hydraulic Excavator

Caterpillar 325B
Caterpillar 320C

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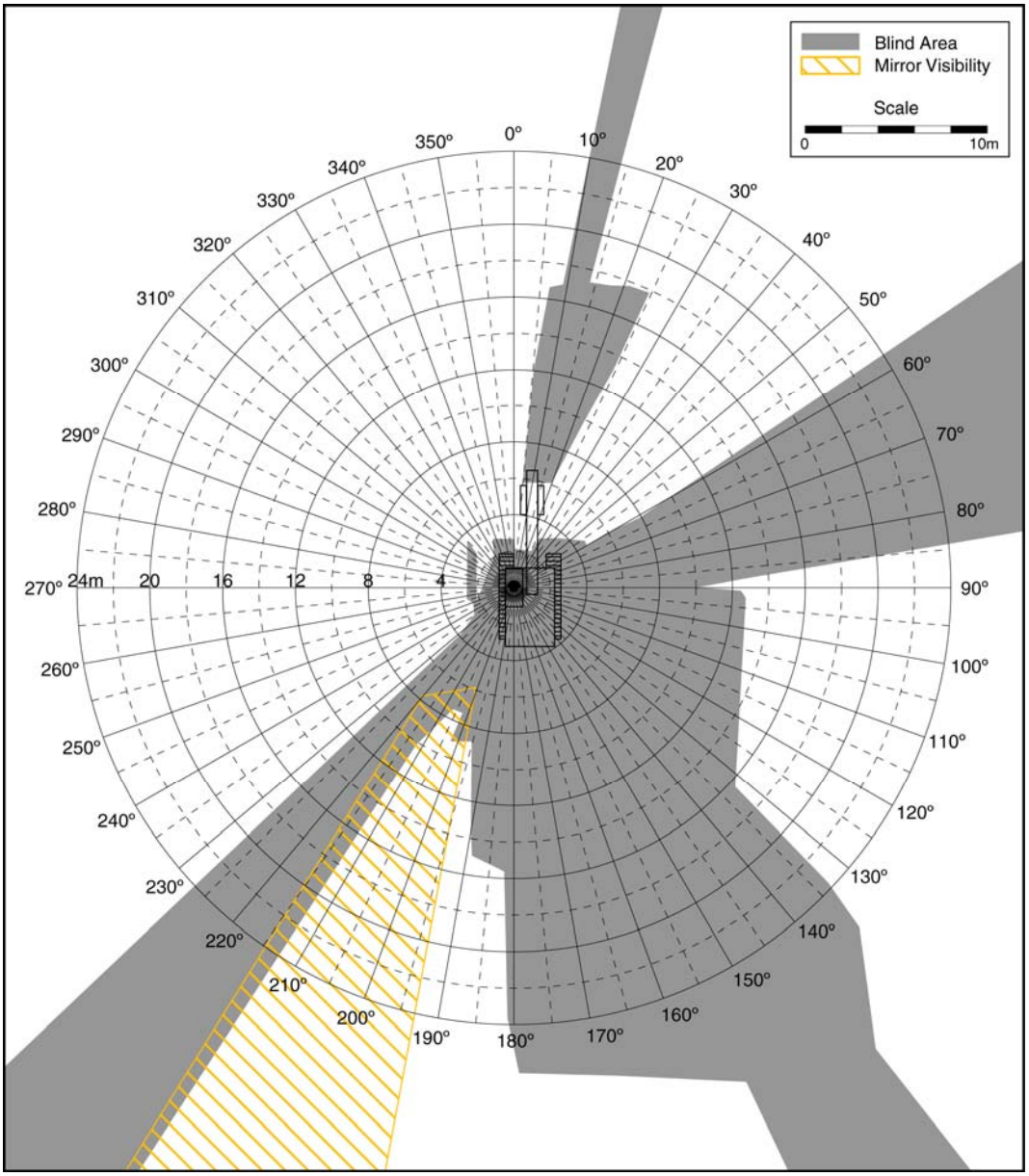
Blind Area Diagram for Construction Machine – Ground Plane

Hydraulic Excavator (Manufacturer and Model)	Caterpillar 325B
GVW	57,000 lb
Serial #	2JR02319
Machine Dimensions	9’ 10” wide 33’ 10” long
Operator Enclosure	Enclosed ROPS
Attachments	None
Other Information	None
Measurement Technique	Physical



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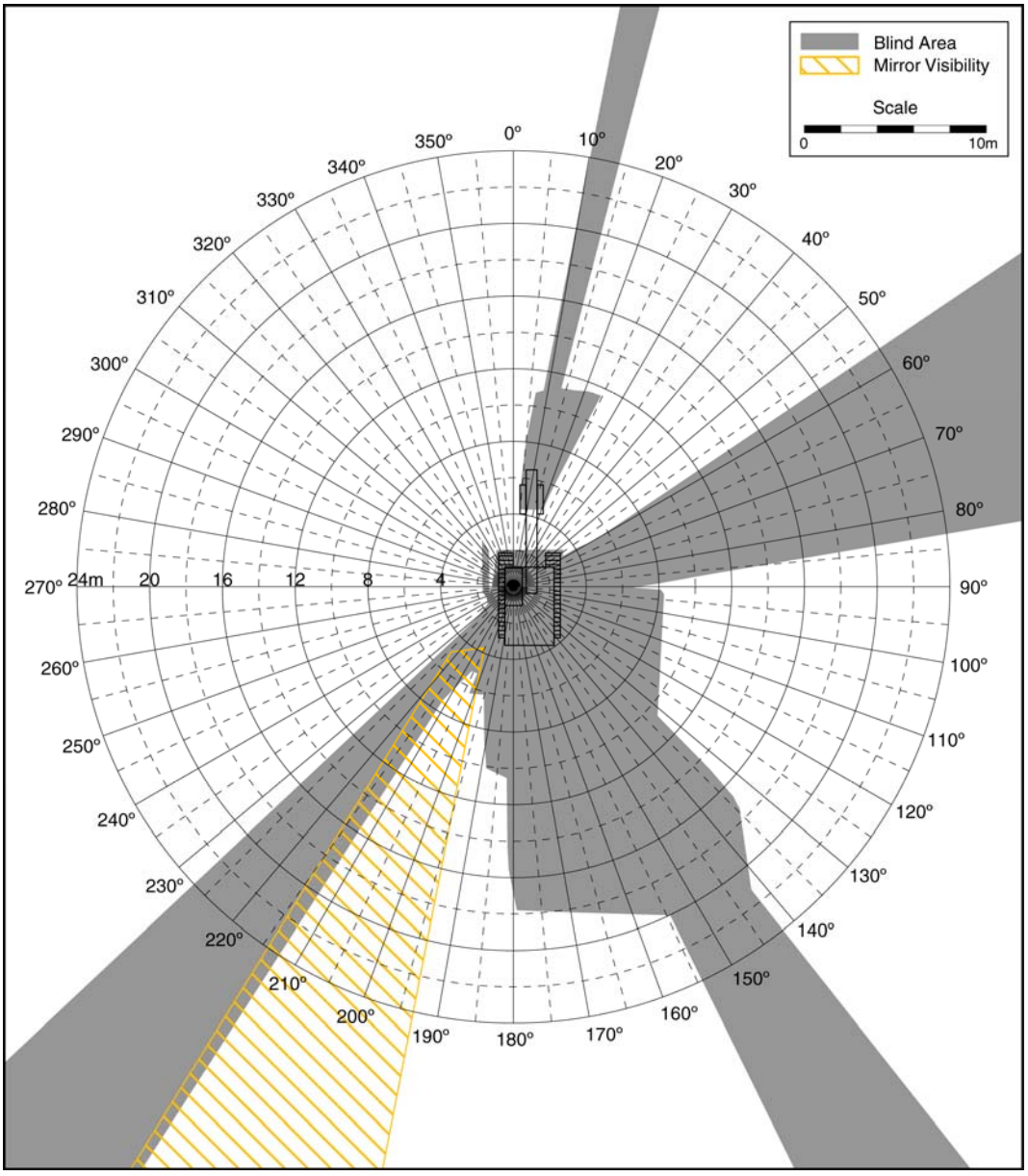
Blind Area Diagram for Construction Machine – 900 mm Plane

Hydraulic Excavator (Manufacturer and Model)	Caterpillar 325B
GVW	57,000 lb
Serial #	2JR02319
Machine Dimensions	9’ 10” wide 33’ 10” long
Operator Enclosure	Enclosed ROPS
Attachments	None
Other Information	None
Measurement Technique	Physical



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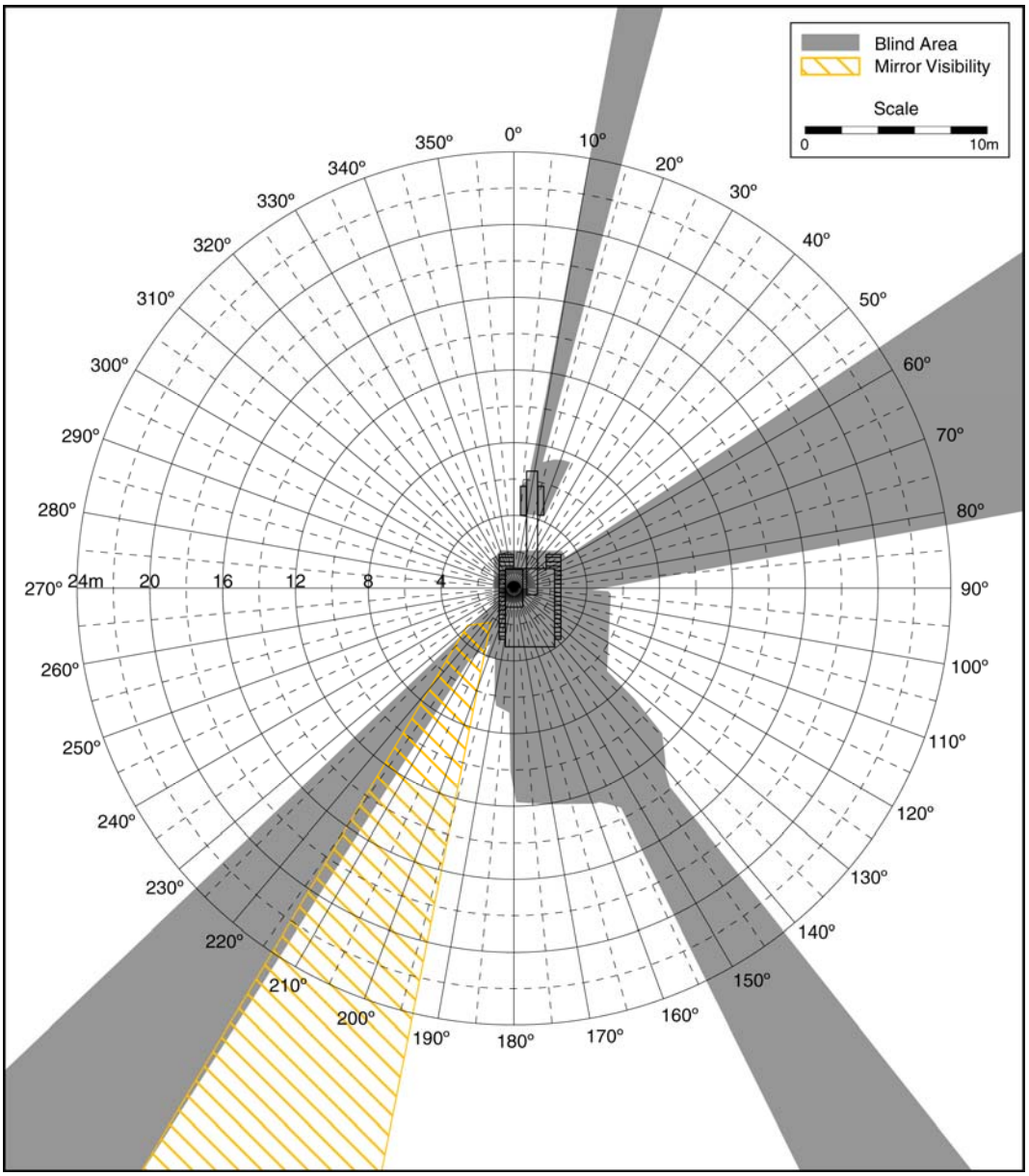
Blind Area Diagram for Construction Machine – 1500 mm Plane

Hydraulic Excavator (Manufacturer and Model)	Caterpillar 325B
GVW	57,000 lb
Serial #	2JR02319
Machine Dimensions	9’ 10” wide 33’ 10” long
Operator Enclosure	Enclosed ROPS
Attachments	None
Other Information	None
Measurement Technique	Physical



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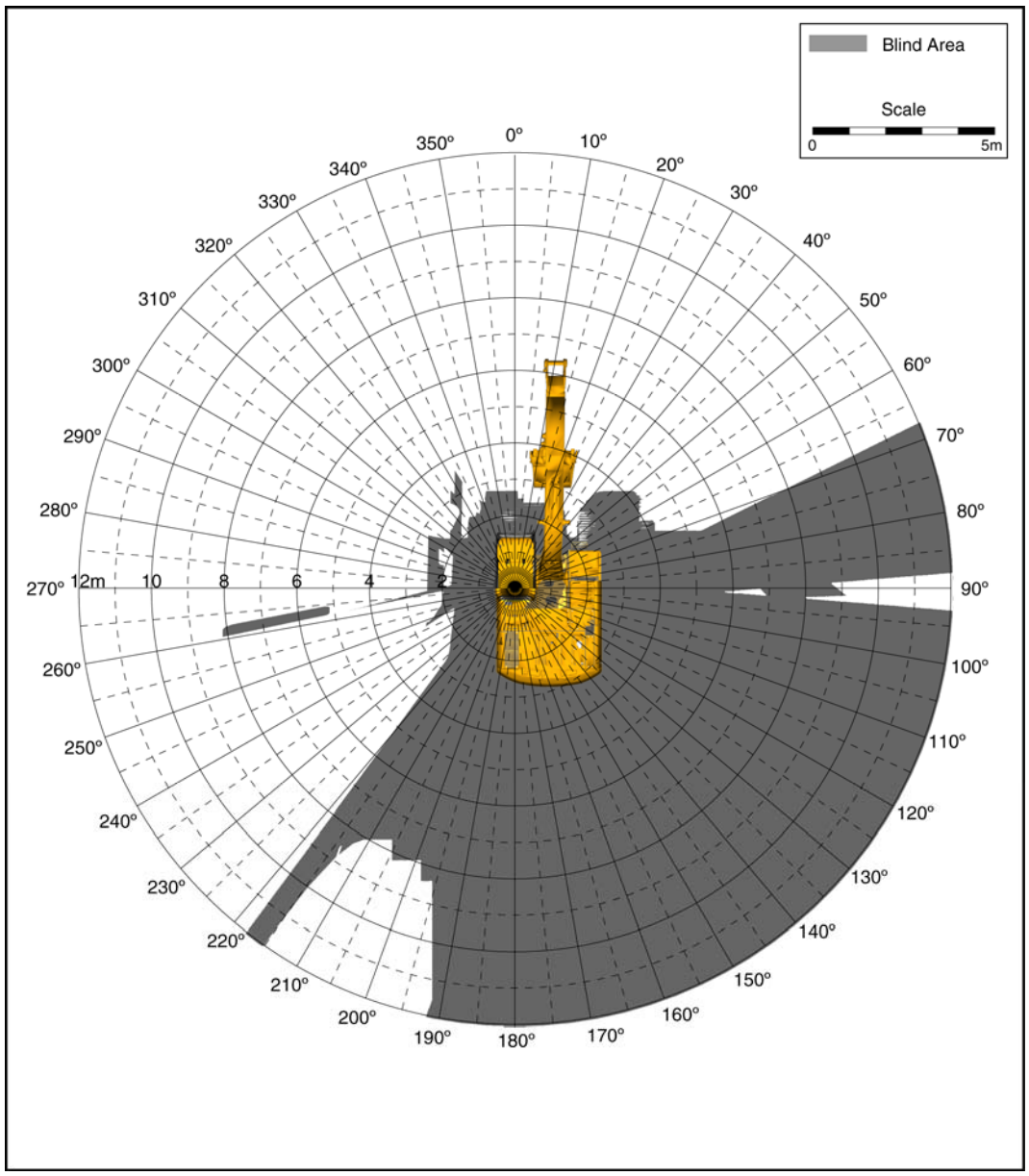
Blind Area Diagram for Construction Vehicle – Ground Plane

Hydraulic Excavator (Manufacturer and Model)	Caterpillar 320C
GVW	49,900 lb
Serial #	
Machine Dimensions	9’ 2” wide 31’ 0” long
Operator Enclosure	Enclosed ROPS
Attachments	None
Other Information	None
Measurement Technique	Simulation



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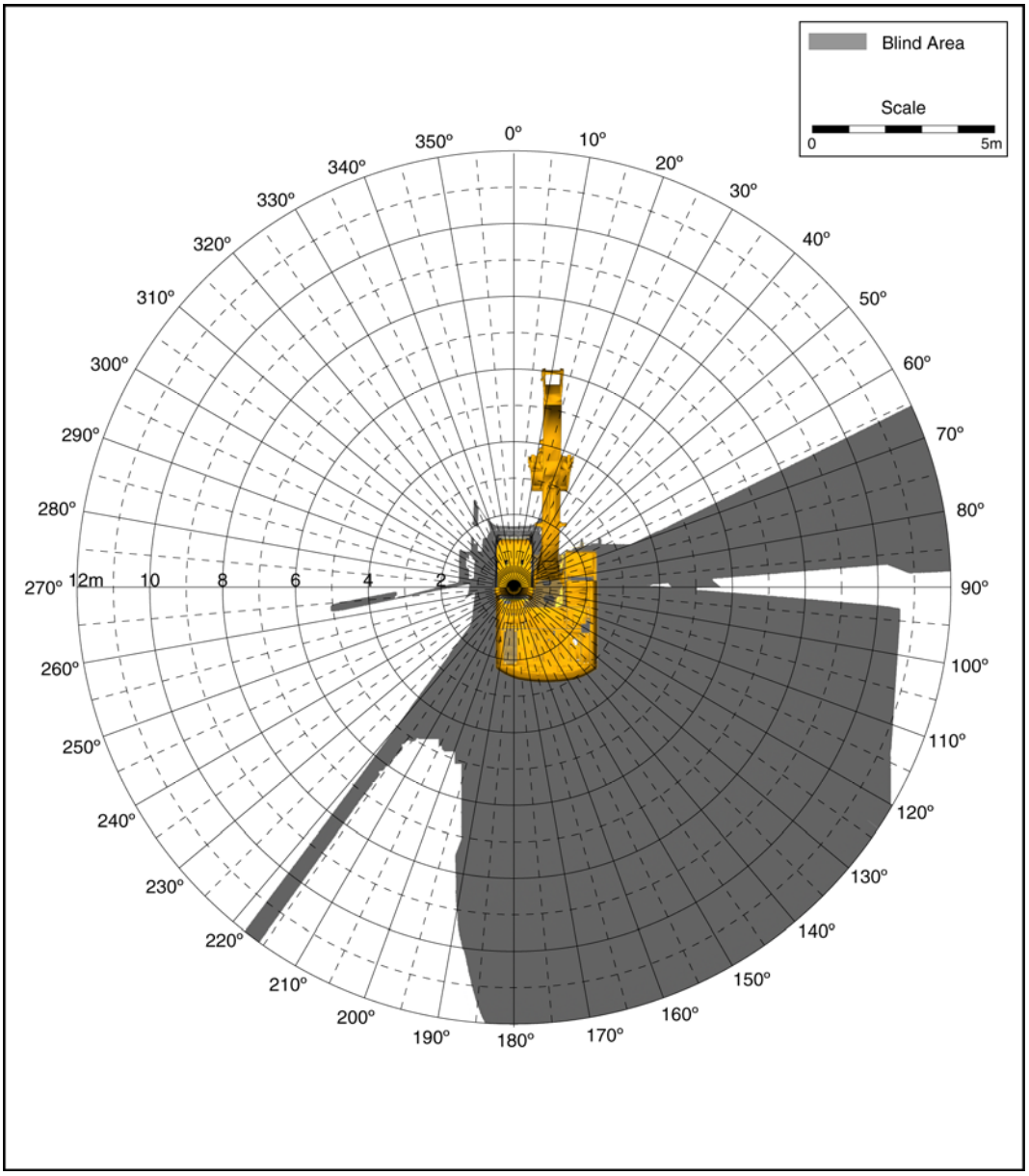
Contract # 200-2002-00563

Blind Area Diagram for Construction Vehicle – 900 mm Plane

Hydraulic Excavator (Manufacturer and Model)	Caterpillar 320C
GVW	49,900 lb
Serial #	
Machine Dimensions	9’ 2” wide 31’ 0” long
Operator Enclosure	Enclosed ROPS
Attachments	None
Other Information	None
Measurement Technique	Simulation



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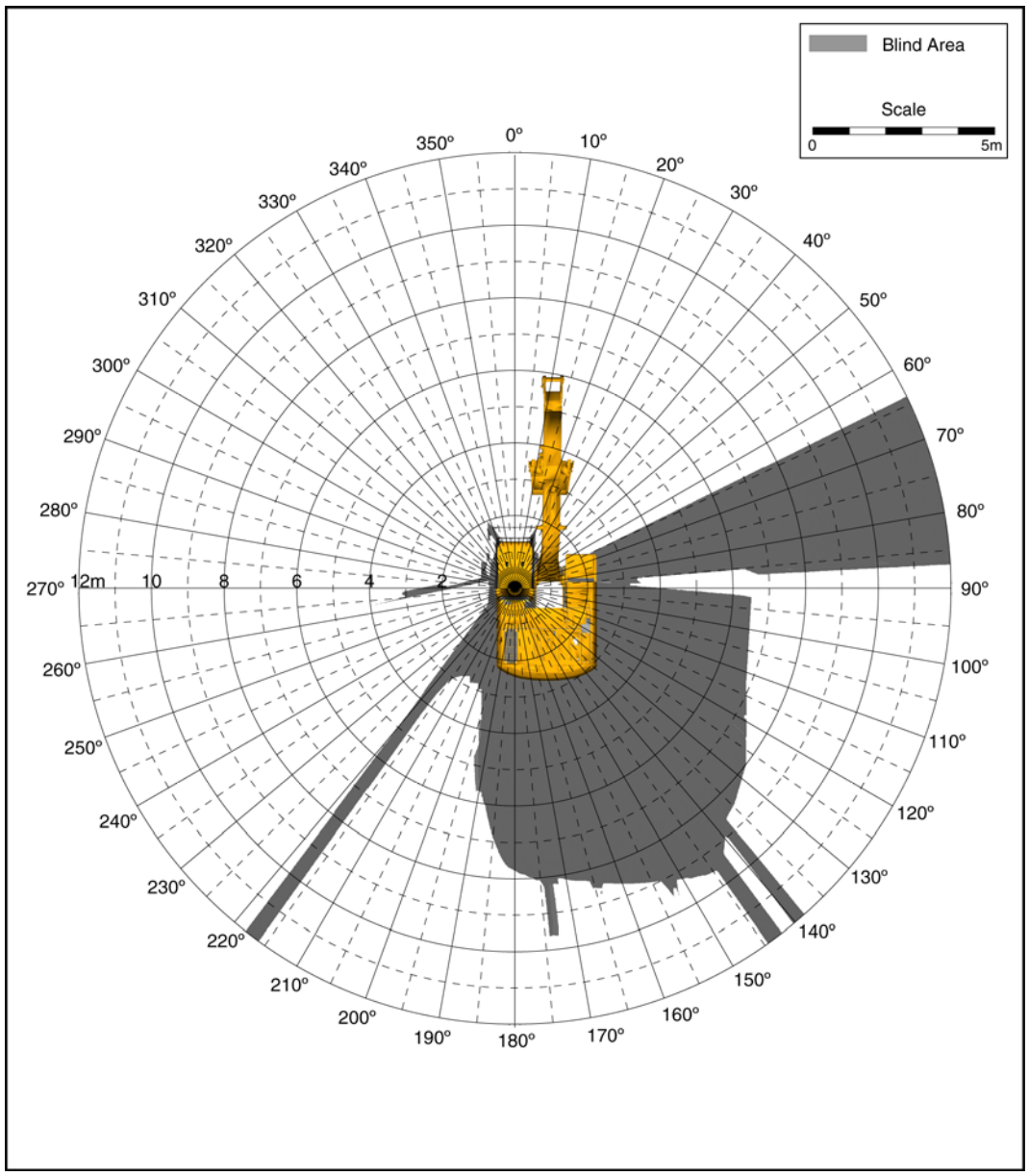
Blind Area Diagram for Construction Vehicle – 1500 mm

Hydraulic Excavator (Manufacturer and Model)	Caterpillar 320C
GVW	49,900 lb
Serial #	
Machine Dimensions	9’ 2” wide 31’ 0” long
Operator Enclosure	Enclosed ROPS
Attachments	None
Other Information	None
Measurement Technique	Simulation



Articulated 3-axle Dump Truck

Volvo A40D

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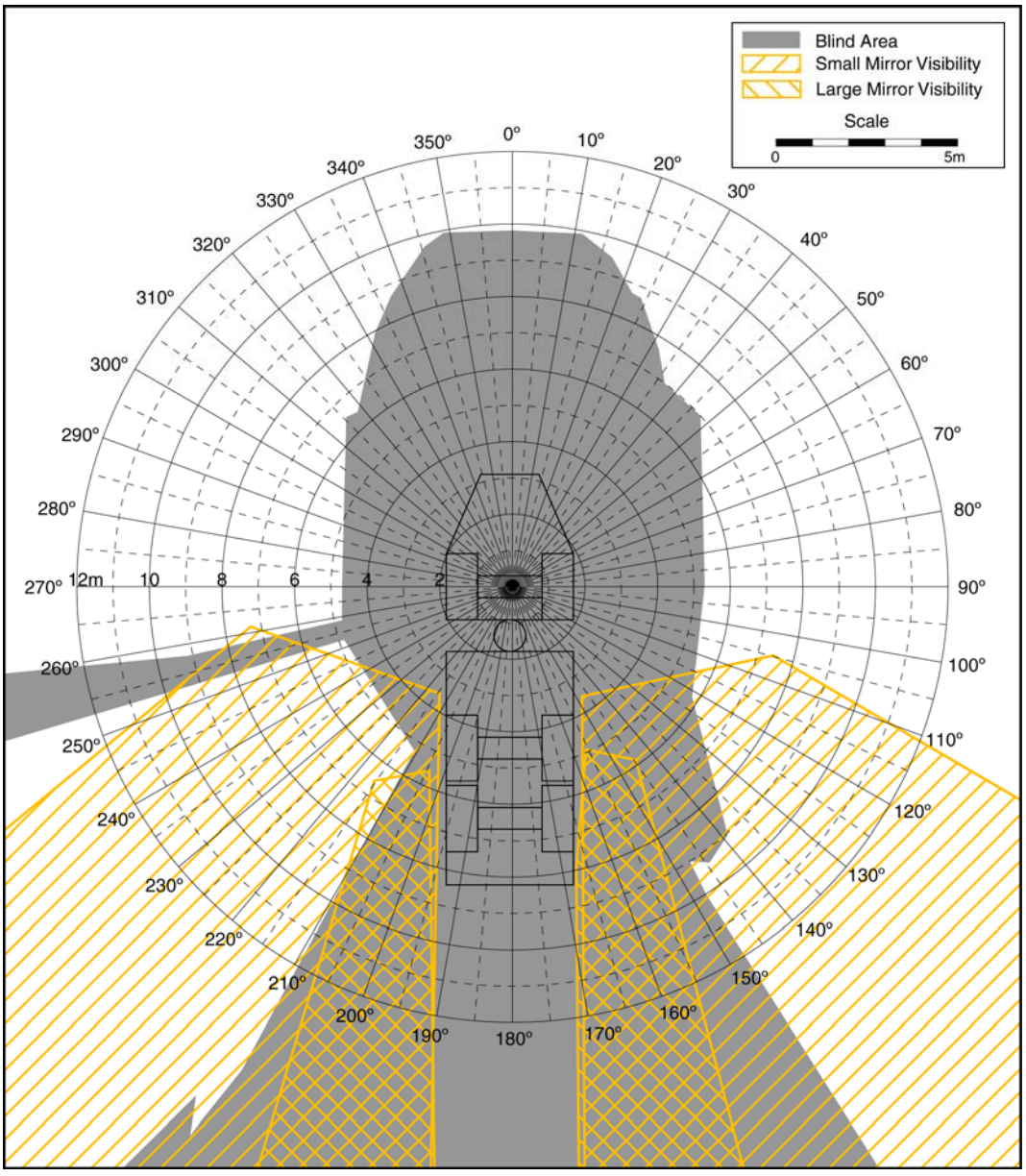
Blind Area Diagram for Construction Vehicle – Ground Plane

Articulated 3-axle Dump Truck (Manufacturer and Model)	Volvo A40D
GVW	150,000 lb. (loaded)
Serial #	V60202
Machine Dimensions	11’ 3” wide 37’ 0” long
Operator Enclosure	Closed ROPS
Attachments	None
Other Information	None
Measurement Technique	Physical



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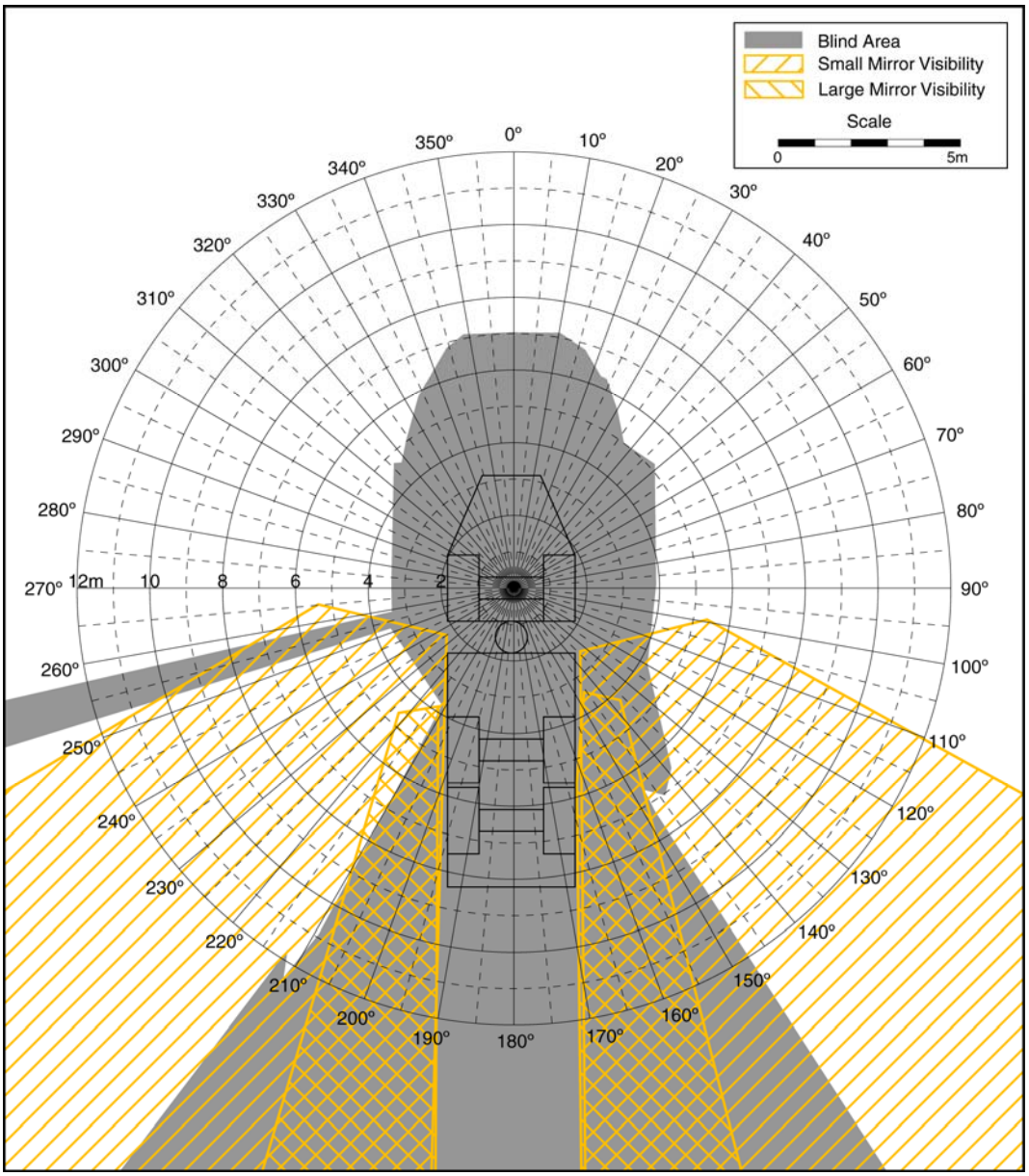
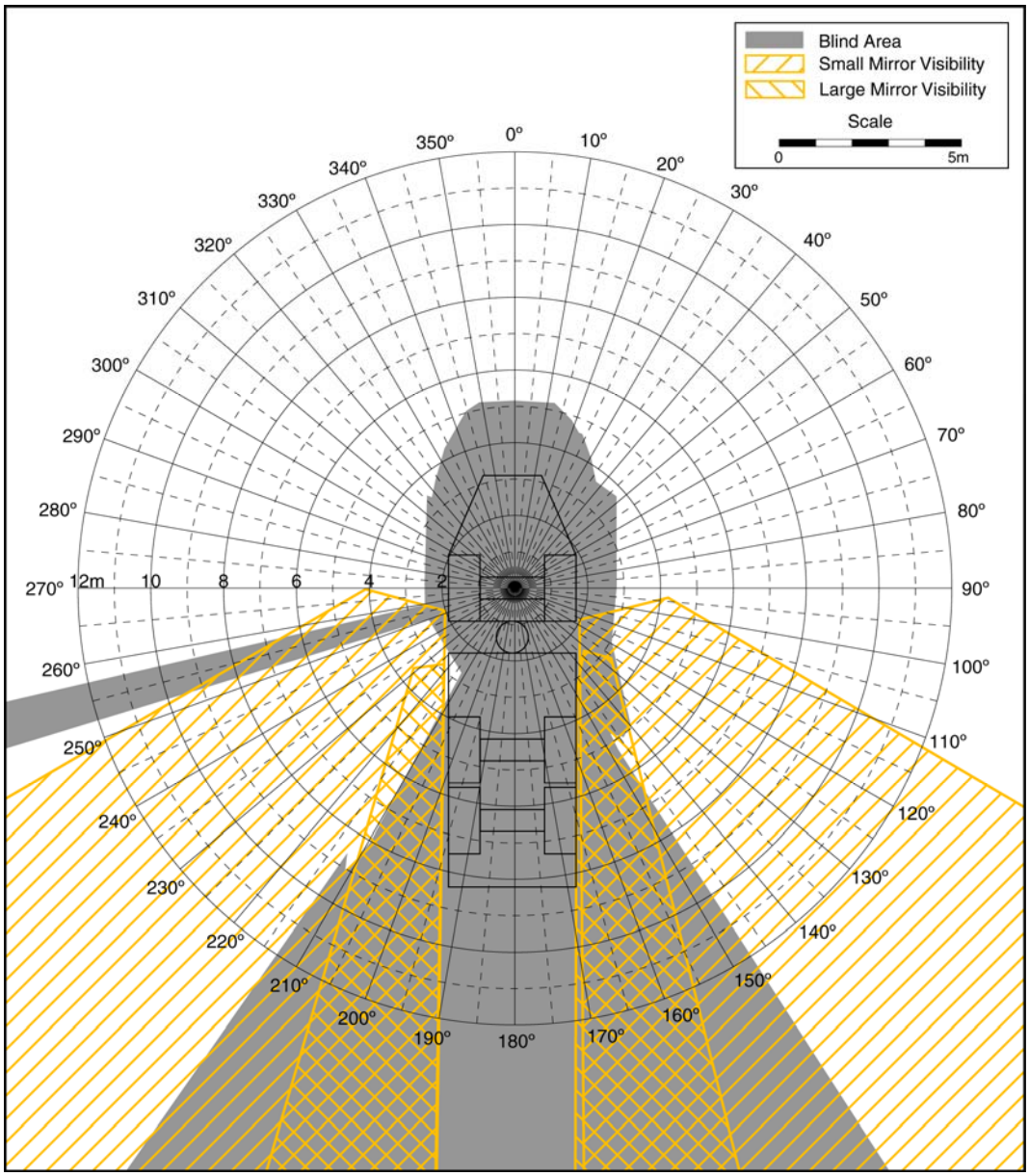
Blind Area Diagram for Construction Vehicle – 900 mm Plane

Articulated 3-axle Dump Truck (Manufacturer and Model)	Volvo A40D
GVW	150,000 lb. (loaded)
Serial #	V60202
Machine Dimensions	11’ 3” wide 37’ 0” long
Operator Enclosure	Closed ROPS
Attachments	None
Other Information	None
Measurement Technique	Physical



Blind Area Diagram for Construction Vehicle – 1500 mm Plane

Articulated 3-axle Dump Truck (Manufacturer and Model)	Volvo A40D
GVW	150,000 lb. (loaded)
Serial #	V60202
Machine Dimensions	11’ 3” wide 37’ 0” long
Operator Enclosure	Closed ROPS
Attachments	None
Other Information	None
Measurement Technique	Physical



Appendix

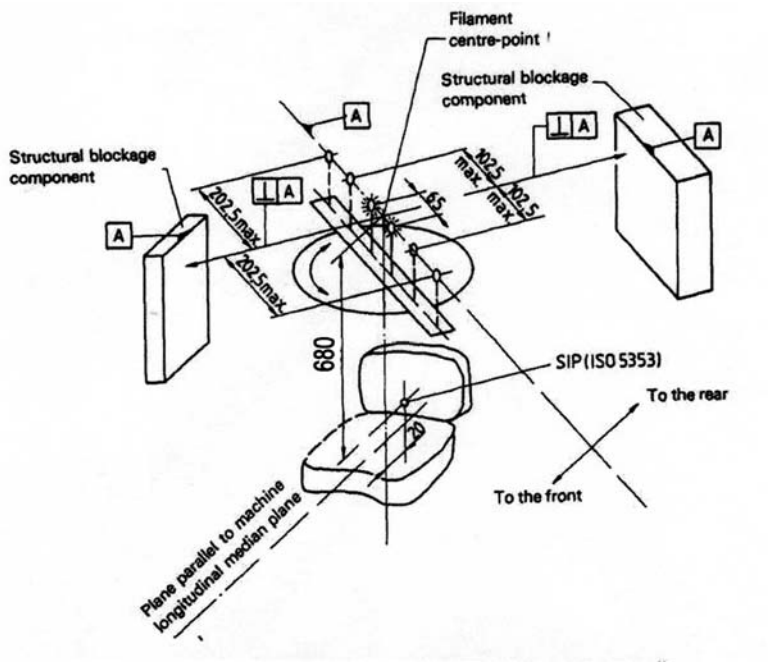
Test Procedure

Description of Test Measurement Method

A combination of physical measurements and computer simulation were used to generate the blind area diagrams. Both methods utilized the upcoming revision of the ISO 5006 "Earth-moving machinery - Operator's field of view Part 1: Test method" test procedure, which uses light sources to represent the operator's eyes. The eye point was representative of the 50th percentile worldwide operator as defined in ISO 3411 "Earth-moving machinery - Human physical dimensions of operators and minimum operator space envelope" and was 680mm above and 20mm in front of the Seat Index Point (SIP) as defined in ISO 5353 "Earth-moving machinery, and tractors and machinery for agriculture and forestry - Seat index point" (see Figure 1)**.** Light source horizontal spacings as defined in ISO 5006 for the various sectors of vision around the machine, shown in Figure 2, were used for mapping the shadows, which represent the visibility blind areas. These spacings represent the ability of an operator to move his head laterally to see around visibility blockages.

Blind areas were determined for three planes of elevation; the ground plane, a plane corresponding to the height of a 5th percentile female standing on the ground, and a plane corresponding to the height of channelizing devices which is 900 mm above the ground plane. For the second plane, 1500 mm above the ground plane was used. This is slightly less than the stature of the 5th percentile operator defined in ISO 3411 but represents the visibility of enough of the head that an operator can identify that there is a person in that area. Polar plots of the recorded data were generated with 5-degree increments and 1-meter intervals up to the 12 or 24-meter test circle perimeter, depending on machine size.

The indirect visibility, through the use of mirrors, was measured using a single light source in accordance with ISO/CD 14401-1 "Earth-Moving Machines - Surveillance and Rear-View Mirrors, Field of Vision - Part 1 - Test Method".



Dimensions in millimeters

Figure 1 - Arrangement of the test equipment.

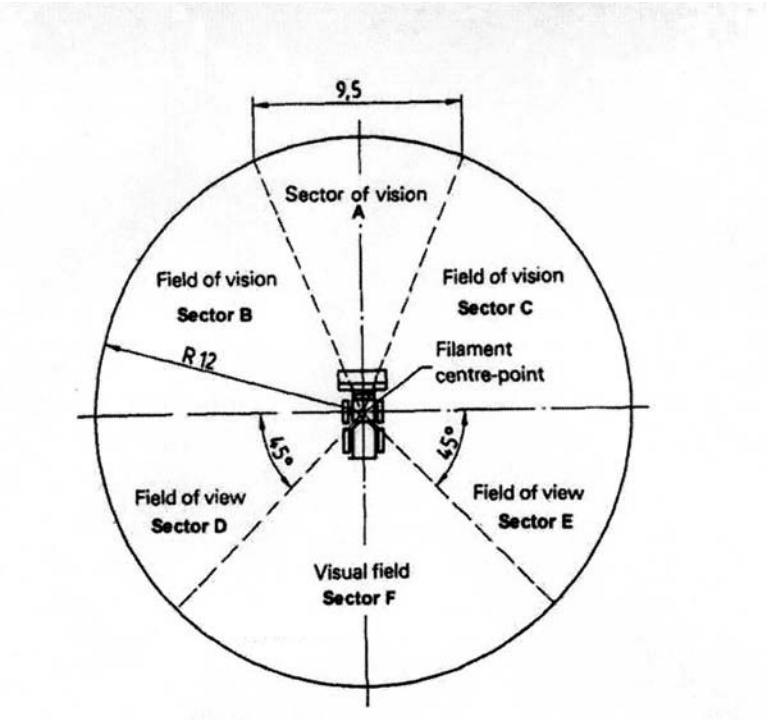


Figure 2 - Visibility test sectors

Physical Measurements

Physical measurements were made on 20 of the vehicles and machines. These tests were conducted in the semi-anechoic building used for sound testing at Caterpillar's Peoria Proving Ground. This facility provided the dark environment needed for the light/shadow technique to be used. The methodology used in the proposed revision of ISO 5006, ISO FDIS 5006, was used for these measurements. With this methodology, light bulbs, or more specifically filaments, are used to simulate the operator's eyes. The bulbs are mounted on a bar that allows each bulb to be moved horizontally, from a center position, up to 202.5 mm (405 mm total bulb spacing). The actual light support device used for the physical tests is shown in Figure 3. The filament spacing represents the range of eye movement that an operator will use to look around a blockage. Each filament casts a separate shadow due to a visibility blockage. If the two shadows overlap, a dark shadow is created, called a masking or blind area, where neither filament can "see". If the two shadows do not overlap, there is no blind area because at least one filament can "see" the area of interest.

A Pentax R115N Electronic Total Station surveying instrument was used to collect the data points that define the machine boundary and the blind areas. This instrument does not require a prism reflector for measurements and provides rectangular coordinates of the target. The target was mounted on an adjustable height stand for the planes 900 mm and 1500 mm above the ground plane. See Figure 4.

Figure 3. Light Support Device Test Setup.

Figure 4. Adjustable Target Stand.

Physical Measurements Test Procedure

1. Initial machine placement: The test engineer places the center of the SIP measuring device directly above the center of the visibility test circle. The best practice is to use a plumb bob to center the filament side-to-side with the front-to-back visually approximate.

2. Final machine placement: Once the side-to-side position is accurate, place the filament fixture in the cab at 680 mm above and 20 mm in front of the SIP. Use a plumb bob and straight edge to mark a reference point on the side of the machine. Hold the plumb bob at the reference point and move the machine forward or backward as necessary.

3. Position the implement attachments as described in ISO 5006. The position depends on the type and size of the machine being tested.

4. Adjust the bulb filament spacing for the sector of vision being recorded according to ISO 5006.

5. Position the support bar holding the light bulbs perpendicular to the visibility blockage being measured. A technique called "focusing" is used to ensure that the light bar is perpendicular to the vertical blockage. To "focus", the light bar is moved +/- 45 degrees from the approximate perpendicular position. The light bar is "focused" when the dark shadow, if there is one, is at its minimum width. If there is no dark shadow, the blockage does not create a blind area for the given filament spacing. Horizontal blockages are created by hoods, fenders, the bottom edges of windows, etc. and do not have a single point perpendicular to the blockage. In this case, the light bar is rotated to positions that will reasonably capture the blind area.

6. Measure and record the blind areas on the ground plane using the surveying instrument and target.

7. Repeat steps 3 - 6 until all blind areas in all of the sectors have been recorded.

8. Measure indirect visibility areas of mirrors.

9. Set surveying target height to 900 mm.

10. Repeat steps 3 - 8.

11. Set surveying target height to 1500 mm.

12. Repeat steps 3 - 8.

Computer Simulation

Caterpillar product designers use Pro-Engineer CAD software and, as a result, the operator visibility for many Cat machines can be simulated. The Caterpillar product groups provide the Pro-Engineer machine files for simulation, including implement attachments as agreed upon. The SIP coordinates are included in the Pro/E machine file for easy placement of the light test device. Maya software is used to generate the eye-point light sources, the shadows (visibility blockages), and the intersection of the shadows with the three horizontal planes requested. Mirrors are simulated in this software and are used to determine the indirect visibility areas.

Simulation Test Procedure

1. Initial machine placement: The test engineer places the center of the SIP measuring device directly above the center of the visibility test circle. To do this Caterpillar Inc. uses the coordinate offsets obtained from the ProE model and then locates the machine geometry in the Maya software. The 20mm forward offset of the filament center point in the location of the machine is maintained in the machine geometry ProE file.

2. The test engineer positions the implement attachments as described in ISO 5006. The position depends on the type and size of the machine being tested.

3. The test engineer positions two light sources at 680 mm above and 20 mm in front of the SIP. This point is used as the center point about which the light sources will pivot. Also, the test engineer adjusts the light source spacing for the sector of vision being recorded according to ISO 5006.

4. The test engineer positions the "support bar" between the light sources perpendicular to the visibility blockage being measured. A technique called "focusing" is used to ensure that the light bar is perpendicular to the vertical blockage. The light bar is "focused" when the dark shadow, if there is one, is at its minimum width. If there is no dark

shadow, the blockage does not create a masking for the given filament spacing. Horizontal blockages are created by hoods, fenders, the bottom edges of windows, etc. and do not have a single point perpendicular to the blockage. In this case, the light bar is rotated to positions that will reasonably capture the masking.

5. Once a blockage has been "focused" and a blind area exists, the test engineer saves the rendered file to disk with a descriptive name of the blockage. The rendered image will be a "pie slice" since the lights in the Maya setup file has been truncated to illuminate only the geometry that is being evaluated at the time.

6. The test engineer repeats steps 4 & 5 until all sectors and objects have been rendered.

7. Measure indirect visibility areas of mirrors.

8. The test engineer creates a new "ground plane" 900 mm above the true ground plane.

9. Repeat steps 4 -7.

10. The test engineer creates a new "ground plane" 1500 mm above the true ground plane.

11. Repeat steps 4 -7.

12. The test engineer uses PhotoShop to assemble the pie-shaped renderings into a composite image for each reference plane.