

Collapse of the Interstate 5 Skagit River Bridge
Following a Strike by an Oversize Combination Vehicle
Mount Vernon, Washington
May 23, 2013



Accident Report

NTSB/HAR-14/01
PB2014-106399



**National
Transportation
Safety Board**

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Highway Accident Report

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Safety Board**

490 L'Enfant Plaza, S.W.
Washington, D.C. 20594

National Transportation Safety Board. 2014. *Collapse of the Interstate 5 Skagit River Bridge, Following a Strike by an Oversize Combination Vehicle, Mount Vernon, Washington, May 23, 2013.* Highway Accident Report NTSB/HAR-14/01. Washington, DC.

Abstract: On Thursday, May 23, 2013, about 7:05 p.m. Pacific daylight time, a 2010 Kenworth truck-tractor in combination with a 1997 Aspen flatbed semitrailer hauling an oversize load was traveling south on Interstate 5 (I-5) near Mount Vernon, Washington. The oversize combination vehicle had a permit for the route of travel and was being led by a pilot/escort vehicle, a 1997 Dodge Ram pickup truck. As the oversize combination vehicle traveled across the I-5 bridge above the Skagit River, its oversize load struck the bridge, damaging the structure. As a result of contact damage to the bridge's truss structure, span 8 of the 12-span bridge collapsed into the Skagit River. Two passenger vehicles, a southbound 2010 Dodge Ram pickup truck towing a Jayco travel-trailer and a northbound 2013 Subaru XV Crosstrek, fell into the river. Eight vehicle occupants were involved in the collapse; three received minor injuries and five were uninjured.

Safety issues identified during the investigation included the following: permitting and route surveying for oversize loads; pilot/escort vehicle operations, guidelines, and driver training; commercial driver operations for transporting oversize loads; state practices for high load bridge strikes; and requirements for low-clearance signage.

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Acronyms and Abbreviations

AAMVA	American Association of Motor Vehicle Administrators
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
CAMI	Civil Aerospace Medical Institute
CDBRR	Critical Damage Bridge Repair Report
CDL	commercial driver's license
CFR	<i>Code of Federal Regulations</i>
CVSA	Commercial Vehicle Safety Alliance
ECM	electronic control module
EMS	emergency medical services
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FMCSRs	<i>Federal Motor Carrier Safety Regulations</i>
GETS	Government Emergency Telecommunications Service
GPS	global positioning system
I-5	Interstate 5
LIDAR	light detection and ranging
LRFD	Load and Resistance Factor Design
MUTCD	<i>Manual on Uniform Traffic Control Devices for Streets and Highways</i>
NPCSI	National Pilot Car Safety Institute
NTSB	National Transportation Safety Board
P/E	pilot/escort
P/EVO	pilot/escort vehicle operator
PFD	personal flotation device
psi	pounds per square inch
RCW	<i>Revised Code of Washington</i>
SC&RA	Specialized Carriers & Rigging Association
WAC	<i>Washington Administrative Code</i>
WASHTO	Western Association of State Highway and Transportation Officials
WSDOT	Washington State Department of Transportation

Executive Summary

Investigation Synopsis

On Thursday, May 23, 2013, about 7:05 p.m. Pacific daylight time, a 2010 Kenworth truck-tractor in combination with a 1997 Aspen flatbed semitrailer hauling an oversized load (referred to here as “the oversized combination vehicle”) was traveling south on Interstate 5 (I-5) near Mount Vernon, Washington. The oversized combination vehicle had a permit for the route of travel and was being led by a pilot/escort vehicle, a 1997 Dodge Ram pickup truck. As the oversized combination vehicle traveled across the I-5 bridge above the Skagit River, the oversized load struck the bridge, damaging its structure. The oversized combination vehicle continued to travel across the bridge and came to a stop on I-5 south of the bridge.

As a result of contact damage to the bridge’s truss structure, span 8 of the 12-span bridge collapsed into the Skagit River. Two passenger vehicles, a southbound 2010 Dodge Ram pickup truck towing a Jayco travel-trailer and a northbound 2013 Subaru XV Crosstrek, fell into the river. Two other vehicles were damaged during the event: a 2000 Kenworth truck-tractor in combination with a 1996 refrigerated semitrailer in the southbound passing lane made contact with the oversized combination vehicle, and a southbound 1995 BMW 525i received undercarriage damage. Eight vehicle occupants were involved in the bridge span collapse; three received minor injuries and five were uninjured.

Probable Cause

The National Transportation Safety Board determines that the probable cause of the Interstate 5 Skagit River Bridge span collapse was a strike to the bridge structure by an oversized combination vehicle that failed to travel in a lane with adequate overhead clearance due to deficiencies in the interdependent system of safeguards for oversized load movements. These deficiencies included (1) insufficient route planning by Mullen Trucking LP and the oversized combination vehicle driver; (2) failure of the certified pilot/escort vehicle driver to perform required duties and to communicate potential hazards, due in part to distraction caused by cell phone use; and (3) inadequate evaluation of oversized load permit requests and no provision of low-clearance warning signs in advance of the bridge by the Washington State Department of Transportation.

Safety Issues

The crash investigation focused on the following safety issues:

- **Permitting and route surveying for oversized loads.** Before an oversized vehicle may travel on public roadways, its operator must obtain permits from the local jurisdictions responsible for the route of travel. The operator must provide the jurisdiction granting permit approval with information about the dimensions of the oversized vehicle, which the jurisdiction should compare to the proposed route to determine if the oversized vehicle can transit safely through and under roadway

structures, such as bridges. This safety issue concerns the shared responsibilities among those involved in the permitting process.

- **Pilot/escort vehicle operations, guidelines, and driver training.** When an oversize vehicle travels through a route that has structures with limited clearance, such as bridges and tunnels, the permitting authority often requires a pilot/escort vehicle to lead (and sometimes trail) the permitted load. The driver of the pilot/escort vehicle uses a vehicle-installed height pole to test the clearance of any structure that the oversize load will pass through and warns the driver of the oversize vehicle if there may be a clearance problem. In this case, the pilot/escort vehicle driver failed to accurately assess the bridge's minimum vertical clearance and allowed the oversize combination vehicle to travel in the right lane of the bridge without notifying the oversize vehicle driver of the low clearance in that lane.
- **Commercial driver operations for transporting oversize loads.** Currently, any driver with a commercial driver's license may transport a permitted oversize load. The performance of the driver of the oversize combination vehicle demonstrated that drivers conducting oversize load operations need special knowledge to plan safe routes, coordinate effectively with pilot/escort vehicles, and control and position oversize loads.
- **State practices for high load bridge strikes.** When oversize loads travel the highways, they sometimes strike parts of bridges and other structures that cross over the roadway, as occurred in this case. The state highway office responsible for infrastructure repairs should inform the office responsible for commercial vehicle services and permitting of oversize loads of any at-risk structures so it can implement reasonable countermeasures to protect such structures. This investigation indicated that Washington State had no formal mechanism for identifying procedural and operational factors that result in high load bridge strikes, and it had not instituted countermeasures aimed at reducing the number of high load bridge strikes.
- **Requirements for low-clearance signage.** The Skagit River Bridge was not posted with low-clearance signage. Had there been such signage, it is possible that the drivers involved in this bridge strike would have taken greater precautions when approaching the bridge and might have realized that the oversize combination vehicle should not attempt transit via the right lane.

Recommendations

As a result of this investigation, the National Transportation Safety Board makes recommendations to the Federal Highway Administration; the 50 states, the District of Columbia, and the Commonwealth of Puerto Rico; the Washington State Department of Transportation; the American Association of State Highway and Transportation Officials; the American Association of Motor Vehicle Administrators; the Commercial Vehicle Safety Alliance; the Specialized Carriers & Rigging Association; and Nokia HERE, Google Inc., and Rand McNally.

1. Crash and Investigation

1.1 The Crash

1.1.1 Narrative

On Tuesday, May 21, 2013, a commercial driver employed by Mullen Trucking LP drove his truck-tractor to the company terminal in Aldersyde, Alberta, Canada. After picking up an unloaded semitrailer from the terminal, he drove from Aldersyde to the Thunder and Lightning Welding Ltd. manufacturing terminal in Nisku, Alberta, to pick up his load. The assembled vehicle was a 2010 Kenworth truck-tractor in combination with a 1997 Aspen flatbed semitrailer hauling an oversize load (referred to in this report as “the oversize combination vehicle.”) The load was one section of a multipart steel casing shed.¹ The load was the first of four such loads going to Vancouver, Washington, where they would be loaded onto a ship for transport to Alaska. (Figure 1 below shows the oversize combination vehicle with the casing shed section loaded on it.)



Figure 1. The oversize combination vehicle with the casing shed section loaded on it.

On Wednesday, May 22, 2013, the driver secured, weighed, and measured the oversize load. He also worked with his employer to obtain the necessary transport permits.

Before leaving Nisku, the driver used a commercially made height pole and tape measure to determine the dimensions of the vehicle and load. The height pole was constructed of two

¹ This section was a rectangular box structure with the left and right (longitudinal) sides open; when joined with other sections, they would constitute a complete modular shed for use in oil field work.

hollow plastic pipes that, when joined, telescoped to a height of 15 feet. The pole was graduated in 1/4-inch increments. The driver hooked this pole to the top of the load and let it hang down straight. Because the load height exceeded 15 feet, he then used a steel tape measure (with somewhat worn numbers) to determine the distance from the bottom of the pole to the ground. He determined the load height to be 15 feet 9 inches, the width to be 11 feet 6 inches, and the length of the semitrailer to be 70 feet 11 inches. (Postcrash, NTSB investigators measured the overall height as 15 feet 11 inches.) The full length of the tractor, semitrailer, and load was 93 feet 7 inches. (See figure 2.) The oversize load weighed 44,000 pounds; the total weight of the truck-tractor, the semitrailer, and the load was 88,700 pounds.

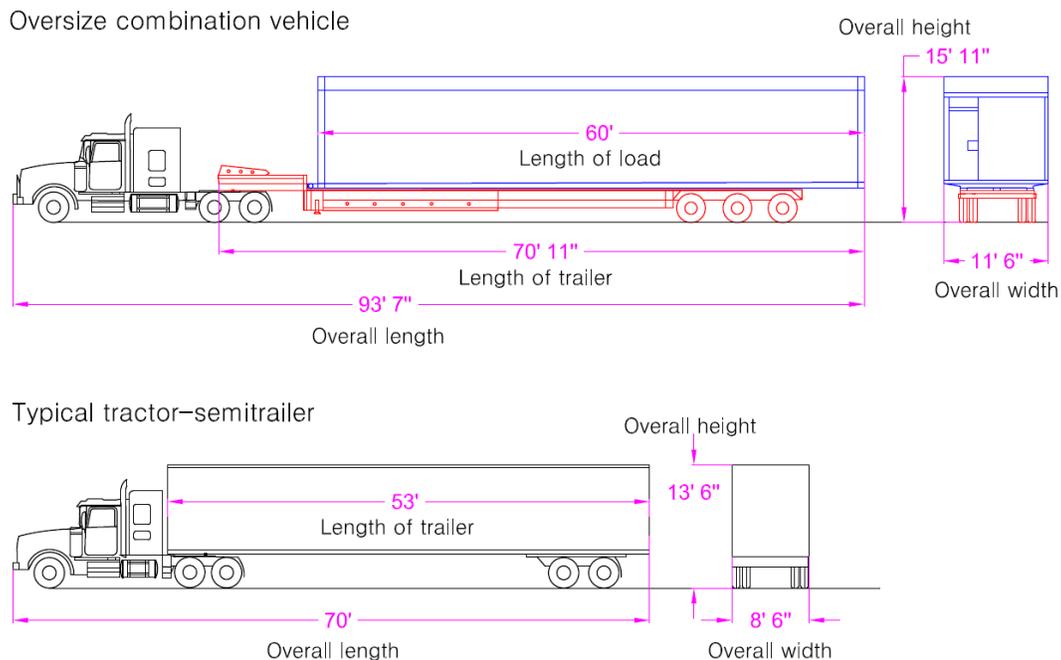


Figure 2. Size of the oversize combination vehicle, compared to a typical tractor-semitrailer.

Due to the length, width, and height of the oversize combination vehicle, the carrier, Mullen Trucking, was required to obtain various oversize vehicle permits to enable the vehicle to travel along the route the company intended it to take. The driver transmitted the oversize dimensions to the company's permit coordinator for submission to the Canadian provinces of Alberta and British Columbia, as well as to the state of Washington, to obtain oversize vehicle permits. When the jurisdictions approved the permits, the carrier faxed them to the driver that same day.

The driver departed the Nisku terminal at 5:00 p.m.² on May 22 with his oversize combination vehicle and the necessary permits, traveling west through the Canadian provinces of Alberta and British Columbia. Because the height and width of the oversize combination vehicle exceeded legal limits in the jurisdictions to be traversed, pilot/escort vehicles were also required to accompany it along portions of the route, as follows:

² The driver's logbook recorded his activities in central daylight time. The NTSB has adjusted these times to reflect Pacific daylight time. Unless otherwise noted, all times in this report are provided in Pacific daylight time.

- No pilot/escort vehicle was required in Alberta;
- One trailing pilot/escort vehicle was required in British Columbia;
- Two pilot/escort vehicles (a leading vehicle with a height pole and a trailing vehicle) were required on the two-lane roadway between the US port of entry at Sumas, Washington, and the junction with Interstate 5 (I-5); and
- One leading pilot/escort vehicle with a height pole was required to travel the route in Washington State along I-5.

En route, the driver stopped in Valemount, British Columbia, and logged sleeper berth time from midnight until 9:00 a.m. the following morning. On May 23, the driver started driving about 9:15 a.m. On behalf of Mullen Trucking, the driver of the oversize combination vehicle had contracted with G&T Crawlers to obtain a pilot/escort vehicle driver. The driver and his load cleared the US port of entry at Sumas, Washington, about 6:30 p.m. on May 23. At the port of entry, the oversize combination vehicle was required to pass through a US Customs x-ray machine to examine it for contraband. The driver noted that the vehicle barely “squeezed through” the 16-foot vertical clearance of the x-ray machine. While at the port of entry, the driver met the leading pilot/escort vehicle driver from G&T Crawlers, and they agreed to communicate via the citizen’s band radios in their respective vehicles as they traveled the route.

The leading pilot/escort vehicle driver checked the Washington State special transportation permit and saw that the total height listed for the load was 15 feet 9 inches. She set her height pole at 16 feet 2 inches (5 inches above the height of the load as recorded on the permit), in accordance with the guidance provided by the Washington State pilot car training/certification program. This pilot/escort vehicle driver led the oversize combination vehicle from the port of entry to I-5 with the assistance of a trailing pilot/escort vehicle. At the junction with I-5, the trailing pilot/escort vehicle was no longer required, and it returned to the port of entry. The leading pilot/escort vehicle remained in front of the oversize combination vehicle south on I-5 to the Skagit River Bridge. (See figure 3 for a map showing the location of the bridge span collapse and figures 4 and 5 for views of the bridge. [Note: More detailed diagrams of the bridge structure appear later in this report.])

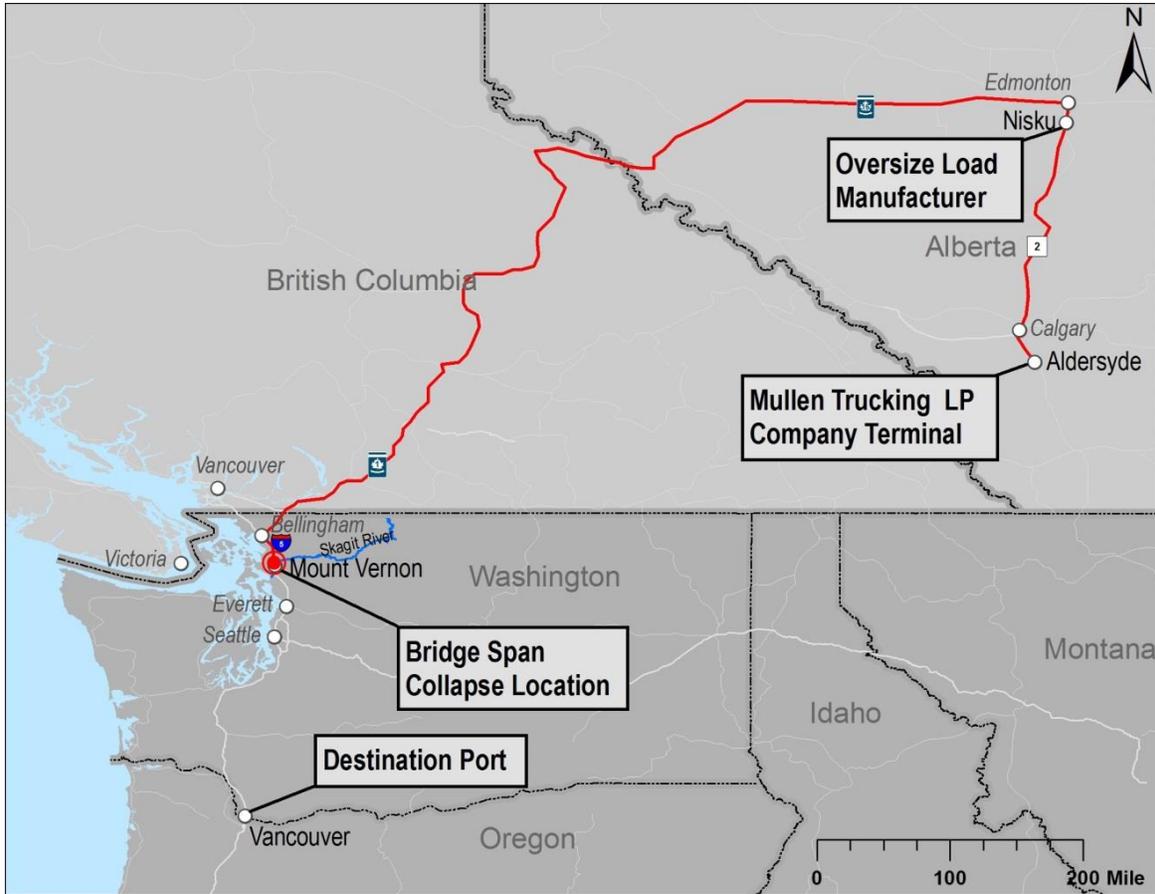


Figure 3. Map showing the location of the Skagit River Bridge span collapse. (The route of the oversized combination vehicle appears in red.)



Figure 4. Aerial view, looking west, at the Skagit River (through-truss) Bridge before the span collapse. The span that collapsed is labeled, and the large red arrow shows the southbound direction of travel of the oversized combination vehicle. (Image captured by Google Earth.)



Figure 5. Looking northward at the Skagit River Bridge on May 24, 2013. The through-truss structure is the portion above the roadway.

The pilot/escort vehicle and the oversize combination vehicle traveled south on I-5 and approached the bridge over the Skagit River with both vehicles in the right lane. The oversize combination vehicle was traveling about 60 mph and following the pilot/escort vehicle at a distance of about 400 feet.³ The pilot/escort vehicle driver told National Transportation Safety Board (NTSB) investigators that the height pole on her vehicle did not strike the bridge as she crossed it. She also told investigators that she was not sure, but she believed she was traveling in the center of the right lane as she crossed the bridge. An officer's note on the Washington State Patrol on-scene statement taken from the pilot/escort vehicle driver stated that the driver was "trying to hug the fog line."⁴ As the oversize combination vehicle, also traveling in the right lane, approached the through-truss bridge,⁵ a 2000 Kenworth truck-tractor in combination with a 1996 refrigerated semitrailer began passing it in the left lane.⁶ The driver of the oversize combination vehicle told investigators that he felt "squeezed" by this passing vehicle, so he moved his vehicle to the right.

As the oversize load entered the through-truss structure, its upper right corner collided with the north portal and multiple sway braces on the far right side of the truss structure on both spans 8 and 7. The impacts caused sufficient damage to load-bearing members of the bridge's structure to initiate buckling in the upper chord of the west truss, which resulted in the

³ The speed of 60 mph and the distance between the vehicles were determined based on an analysis of surveillance video of the bridge span collapse. (See video discussion in section 1.1.2.)

⁴ The fog line is the right edge lane marker.

⁵ A through-truss bridge has truss members above and below the bridge deck, and the roadway passes through the superstructure at the bridge deck level.

⁶ The report will refer to this vehicle as the "2000 Kenworth truck."

subsequent collapse of the northernmost through-truss bridge span.⁷ As a result of the bridge impact and the collapsing bridge deck, the oversized combination vehicle tipped to the left and the upper left leading edge of its casing shed load struck the upper right side of the refrigerated semitrailer of the 2000 Kenworth truck. Four vehicles (the pilot/escort vehicle, the oversized combination vehicle, the 2000 Kenworth truck, and a 1995 BMW 525i behind the 2000 Kenworth truck in the left lane) successfully cleared the collapsing bridge span. The pilot/escort vehicle, the oversized combination vehicle, and the BMW stopped on the shoulder south of the bridge.⁸ Despite the damage his vehicle sustained, the driver of the 2000 Kenworth truck said he was unaware of making contact with the oversized combination vehicle and did not stop at the scene. He and his vehicle were located later.⁹

Two other passenger vehicles, a southbound 2010 Dodge Ram pickup truck towing a Jayco travel-trailer and a northbound 2013 Subaru XV Crosstrek, fell with the collapsing bridge span into the Skagit River. A driver and a passenger occupied the Dodge pickup, and a driver occupied the Subaru. First responders rescued these three people from their vehicles and transported them to local hospitals for treatment of minor injuries. Their vehicles were later retrieved from the river when the collapsed span was recovered. (See figure 6 below.)



Figure 6. Bridge span 8 in the Skagit River.

⁷ The collapsed section, span 8, was 160 feet long. Bridge geometry is described in section 1.6 of this report.

⁸ The driver of the BMW only realized after leaving the scene that his car had incurred undercarriage damage.

⁹ Investigators were only able to locate this driver several weeks after the crash by using the video records of the I-5 truck scales and by tracking license registration information.

1.1.2 Video Recording Information

Postcrash, investigators collected several video recordings of the oversize combination vehicle transporting the oversize load along its route and as the vehicle traversed the Skagit River Bridge at the time of the span collapse. The NTSB Recorders and Materials Laboratories analyzed the videos.

Two of the recordings came from building-mounted security cameras. One of these surveillance videos was from a car dealership located to the north and west of the Skagit River Bridge, at a distance of less than 1 mile. The third video was from a dashboard camera in a Washington State Patrol car that was traveling northbound on I-5. That patrol car video showed a view of the pilot/escort vehicle and the oversize combination vehicle traveling in the southbound lanes about 2.5 miles north of the Skagit River Bridge.

The surveillance video from the car dealership showed the progress of both the oversize combination vehicle and the 2000 Kenworth truck over the Skagit River Bridge. It showed the 2000 Kenworth truck in the left lane in the process of overtaking the oversize combination vehicle in the right lane as they approached the bridge. It showed the structure of the bridge deflecting as the oversize load passed. The video ended before the semitrailer carrying the oversize load had cleared the collapsing span.¹⁰

1.2 Survival Factors

This section discusses the vehicle occupant injuries, the rescue operations, and the emergency preparedness and communications of first responders.

1.2.1 Occupant Injury

Eight occupants in six vehicles were involved in this event. In addition to the six vehicle drivers, the 2010 Dodge Ram and the 1995 BMW each contained one passenger. No fatalities or serious injuries resulted from this event; three people suffered minor injuries, and five were not injured.

Table 1 summarizes the occupant injury information for each of the vehicles.

¹⁰ The collapse severed the fiber optic cable network and negatively affected the power grid, which resulted in a disruption of the video.

Table 1. Occupant injury summary*

	Uninjured	Minor	Serious	Fatal
2010 Kenworth Oversize Combination Vehicle Driver	1	0	0	0
1997 Dodge Ram (Pilot/Escort) Driver	1	0	0	0
2000 Kenworth Truck Driver	1	0	0	0
2010 Dodge Ram/Trailer Driver	0	1	0	0
2010 Dodge Ram/Trailer Passenger	0	1	0	0
2013 Subaru XV Crosstrek Driver	0	1	0	0
1995 BMW 525i Driver	1	0	0	0
1995 BMW 525i Passenger	1	0	0	0
TOTAL	5	3	0	0
*The injury levels were evaluated according to 49 <i>Code of Federal Regulations</i> 830.2, which defines fatal injury as “any injury which results in death within 30 days of the accident” and serious injury as “any injury which: (1) requires hospitalization for more than 48 hours, commencing within 7 days from the date the injury was received; (2) results in a fracture of any bone (except simple fractures of fingers, toes, or nose); (3) causes severe hemorrhages, nerve, or tendon damage; (4) involves any internal organ; or (5) involves second- or third-degree burns, or any burn affecting more than 5 percent of the body surface.”				

The driver of the southbound 2010 Dodge Ram pickup truck pulling a travel-trailer was a 48-year-old male. His passenger was a 56-year-old female. Both were transported to Skagit Valley Hospital, treated, and released. The female returned to the hospital later that night for additional checking. The hospital admitted her at 1:37 a.m. on May 24, held her for observation, and discharged her at 3:49 p.m. the same day. Medical records indicated she suffered head, back, and hip pain, and gastrointestinal bleeding.

The driver of the northbound Subaru XV Crosstrek was a 20-year-old male. He was taken to United General Hospital in Sedro Woolley, Washington, and was treated and released. He suffered head and chest contusions and neck pain.

1.2.2 Emergency Response

At 7:05:27 p.m., the Skagit County Emergency Communications Center began to receive 911 calls. According to the incident log, people were reported to be in the river. Response units were dispatched within 1 minute, and the Washington State Department of Transportation (WSDOT) was advised. The first unit reported on scene about 7:08 p.m. The US Coast Guard was en route by 7:17 p.m.; a helicopter from the Whidbey Island Naval Air Station was dispatched by 7:32 p.m.; and a Skagit County Sheriff’s Office rescue boat was on scene by 7:38 p.m. The battalion chief from the Mount Vernon Fire Department was the incident commander. The Skagit County Sheriff’s Office coordinated the rescue of the victims, assisted by the Mount Vernon and Burlington Police and Fire Departments.¹¹

¹¹ The Skagit County Sheriff’s Office requested additional rescue services from the Snohomish Tribal Police Department, the US Coast Guard, the Washington State Fish and Wildlife Department, the Naval Air Station at Whidbey Island, and George Larson Water Rescue.

Responders removed the driver of the Subaru XV Crosstrek from the collapsed span in the river at 7:43 p.m. That driver was sitting on the roof of his vehicle when the rescue boat approached, and responders gave him a personal flotation device (PFD) tethered to a rope. He was able to stand on a section of bridge deck and access the boat. When first responders reached the 2010 Dodge Ram, its driver was standing on the running board on the driver side of the vehicle, and the passenger was sitting inside the pickup truck with water up to her knees. Rescuers gave them PFDs and roped them to first responders because the water current was a concern. The passenger was loaded onto a backboard and placed in a rescue boat with the driver; they were taken to the south shore of the river. The injured were en route to hospitals by 8:56 p.m. The Central Valley Ambulance Authority provided emergency medical services (EMS). At 11:00 p.m., the Washington State Patrol transported the driver of the oversized combination vehicle to a hospital to provide a blood specimen for toxicological testing. At the request of the NTSB, the specimen was split, and half was provided to the Civil Aerospace Medical Institute (CAMI) for alcohol and drug testing.

A Skagit County Radio Communications Plan was in place for the fire and EMS radio systems. The *Skagit 911 Standard Operating Guidelines* document additional fire and EMS procedures and all radio procedures used by law enforcement. Response organizations reviewed the radio and telephone communications that occurred on the day of the bridge span collapse. The collapse severed the fiber optic cable network for some landline service. During the emergency, the high volume of telephone traffic related to the bridge span collapse saturated the telephone system. Following standard procedures, another telephone service compensated for this failure by rerouting calls using its undamaged fiber optic network. High call volume immediately after the collapse also overloaded cell phone service and resulted in temporary rejection of some attempted calls. Saturation of the telephone system did not affect primary communications between first responders because they used radio communications.

Skagit 911 reported problems with placing calls using the Government Emergency Telecommunications Service (GETS), and no GETS calls were successfully connected.¹² A GETS training program was in place, but training sessions were not conducted on a regular basis, training records were incomplete, and software deficiencies were found in a backup telephone system. In the months following the bridge span collapse, Skagit 911 completed a comprehensive software upgrade that restored full functionality to the phone systems during high call volumes and implemented training in GETS emergency communications.

1.3 Vehicles

Six vehicles were involved in the bridge span collapse. This section focuses on the oversized combination vehicle and summarizes the damage to the other vehicles.

¹² GETS is a system managed by the US Department of Homeland Security Office of Emergency Communications. The system was established to support authorized national security and emergency preparedness users to facilitate a call when the landline network is congested and the probability of making a normal call is reduced. GETS users receive an access card (GETS card), which has both a universal GETS access number and a personal identification number.

1.3.1 Damage

Oversize combination vehicle. The 2010 Kenworth truck-tractor showed no signs of damage. The oversize load—the casing shed section—sustained deformation damage to its upper right front corner. Scratches and dents were present along the entire length of the right top edge of the load. Scratches were also found on the upper left front side of the casing shed. The overall frame of the load was distorted rearward, most noticeably at its top right corner, where slight buckling had occurred. The entire load had shifted to the left on the semitrailer. (Figures 7 and 8 show the damage to the upper right front corner of the load. Note: Figure 7 is a facing view of the vehicle, so the right corner of the load is on the left in the photo. The same is true for the photo in figure 8.)



Figure 7. The oversize load, with the area of damage circled.

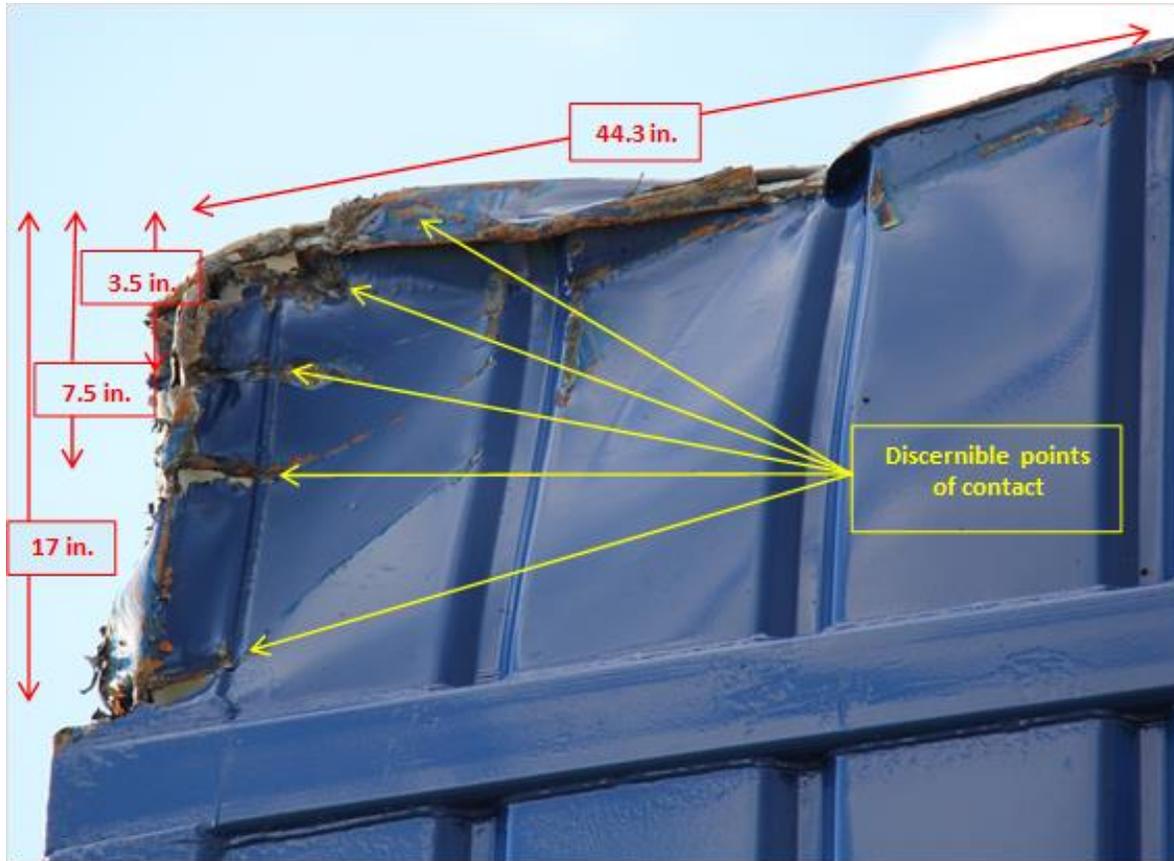


Figure 8. The upper right corner of the oversize load, with damage dimensions.

The 44,000-pound shed section had been secured to the semitrailer by four 1/2-inch steel chains with ratcheting load binders and two 4-inch-wide synthetic cargo straps. The chains secured each corner of the shed section to the semitrailer. The webbed cargo straps laterally traversed the load at the front and the rear (the rear strap was positioned about 7 feet forward of the back wall of the casing shed section). The chain at the load's lower right front corner and the portion of the cargo strap that crossed the lower forward part of the load were both broken. Chain links and sections of the cargo straps were found on the bridge deck south of the collapsed section. Minor leftward shifting of the semitrailer's frame rails relative to its suspension had also occurred. The tops of the wheel wells on all three semitrailer axles showed tire marks where the load fully depressed the suspension, most noticeably on the left side.

1997 Dodge Ram pickup truck—pilot/escort vehicle for the oversize load. The pilot/escort vehicle was in front of the oversize combination vehicle and clear of the falling bridge structure during the collapse. It was not damaged.

2000 Kenworth truck. The 2000 Kenworth truck-tractor with a 1996 Utility refrigerated semitrailer was in the left lane passing the oversize combination vehicle at the time of the bridge strike. This vehicle left the scene of the bridge span collapse but was later identified from video evidence. When investigators located the 2000 Kenworth truck, they found evidence of contact with the oversize vehicle's casing shed section on the upper right side of the refrigerated

semitrailer. (See figure 9.) Although his vehicle was on the bridge as it was collapsing and was struck by the oversized load, the driver of the 2000 Kenworth truck told investigators he had not realized that he had been involved in the event and had continued driving.



Figure 9. Blue transfer paint from the oversized load found postcrash on the upper right side of the refrigerated semitrailer of the 2000 Kenworth truck.

1995 BMW 525i. The 1995 BMW 525i had been behind the 2000 Kenworth truck in the left southbound lane; its driver saw the oversized combination vehicle strike the bridge. After seeing the strike, the BMW driver slowed down but then realized the bridge span was collapsing and sped up to clear it. The BMW occupants said they felt a bump but were not sure whether it was caused by disruption of the road surface due to the collapse or by contact with debris in the roadway. The BMW drove clear of the bridge and stopped. The occupants of the BMW did not realize until they were leaving the scene that their vehicle had received undercarriage damage.

2010 Dodge Ram pickup truck and 2009 Jayco travel-trailer. The 2010 Dodge Ram pickup hauling the 2009 Jayco travel-trailer was traveling behind the oversized combination vehicle in the right southbound lane. This pickup and trailer entered the collapsing portion of the bridge and were later found in the river among the bridge debris.

Postcrash, NTSB investigators examined the vehicle recovered from the river at an impound lot. The front bumper was deformed, particularly to the left of its center. It exhibited scrape and paint marks. The roof was deformed downward in the center and had scrape and paint marks. The airbags had not deployed. The travel-trailer was crushed.

2013 Subaru XV Crosstrek. The Subaru XV Crosstrek sport utility vehicle that had been traveling on the northbound portion of the bridge fell into the river as the span collapsed. The Crosstrek was damaged primarily at its front and its right rear corner. The front was crumpled, and the front bumper was displaced. Scrape and paint marks were found in the damaged region at the front of the vehicle. The upper portion of the right rear corner of the vehicle had extensive scrape marks, and the metal there was torn and showed paint transfers. The driver's front and both left and right side curtain airbags had deployed.

1.3.2 Postcrash Inspection of the Oversize Combination Vehicle

Mechanical inspection. NTSB investigators examined the mechanical systems of the 2010 Kenworth truck-tractor and the 1997 Aspen flatbed semitrailer. The engine and electrical systems were intact and functional. The air system for the brakes and the suspension for both the truck and the semitrailer were intact and functional. None of the brakes were out of adjustment, and no brake pad or brake drum cracks or defects were observed. The tires on all six axles of the combination unit remained inflated. The outside sidewalls of the outside tires on both sides of axle 4 had minor cuts. Tire contact marks were observed inside the tops of the wheel wells on axles 4, 5, and 6 (the semitrailer axles); darker and more obvious marks were on the left, compared to the right, side of the semitrailer. The tires were inflated near to recommended pressures, with the exception of the right outside tire on axle 5; it was at 74 pounds per square inch (psi), about 26 percent below the recommended pressure.¹³

Low air pressure warning tests were conducted. The low air warning lights in the cab came on at 60 psi. However, the tractor protection valve, designed to keep at least 20 psi of air supplied to the tractor for a controlled stop in the event of a sudden loss of air, allowed air to continue to escape below 20 psi, and the air supply to the tractor dropped to 0 psi. Per 49 *Code of Federal Regulations* (CFR) 393.43(b), failure of a tractor protection valve to close before the pressure drops below 20 psi is a violation of the *Federal Motor Carrier Safety Regulations* (FMCSRs), and this would have placed the vehicle out of service, according to the Commercial Vehicle Safety Alliance (CVSA) out-of-service criteria.

The truck-tractor was equipped with an electronically controlled Caterpillar C15 Acert engine. The electronic control module (ECM) had the capability to record "critical events," which include vehicle speed, engine rpm, brake circuit status, throttle percentage, and other associated data, in the event of a sudden deceleration or hard braking. The Washington State Patrol downloaded the ECM the day after the bridge span collapse. The ECM stored no critical events, and no diagnostic codes were active at the time of the download.

¹³ The Commercial Vehicle Safety Alliance out-of-service criteria do not consider a tire to be out of service until it is 50 percent less than the maximum inflation pressure listed on the sidewall, in this case, 120 psi. The right outside tire on axle 5 would not have been considered out of service.

Size and weight. The 2010 Kenworth truck-tractor was pulling a 3-axle Aspen flatbed semitrailer, configured to its full expandable length. The overall length of the oversize combination vehicle was 93 feet 7 inches; the width was 11 feet 6 inches.¹⁴ The postcrash height measurements, taken with the vehicle on a level surface, at the four corners of the oversize load (which presented the highest portion of the oversize combination vehicle) using a height stick and metal tape measure, appear in table 2. (Because these measurements were taken after the event, with the load damaged and distorted, they may not reflect exact precrash conditions.)

Table 2. Postcrash height measurements of the oversize combination vehicle.

	Left*	Right
Front	15' 10 ⁷ / ₈ "	15' 11 ¹ / ₁₆ "
Rear	15' 6 ¹³ / ₁₆ "	15' 5 ⁵ / ₈ "
*Left is the driver side.		

The maximum permissible gross vehicle weight in Washington State is 105,500 pounds; however, the weight limit can be affected by vehicle design characteristics such as tire size and load rating, axle weight rating, and axle spacing. The permissible weight limit for the oversize combination vehicle was 95,680 pounds.¹⁵ The oversize combination vehicle weighed about 88,700 pounds and did not require a permit based on its weight.

Rearward field of view. The truck was equipped with both driver and passenger side sets of rearview mirrors, all but one of which were centered about 20 inches outboard of the truck cab. The driver (left) side mirror set included four mirrors: a rectangular 7- by 16-inch flat mirror, a 6-inch circular convex mirror mounted above the flat mirror, an 8-inch circular convex mirror mounted below the flat mirror, and a 6-inch circular convex mirror mounted on an extendable arm farther outboard of the other mirrors. (The mirror on the extended arm was centered about 30 inches outboard of the truck cab). The passenger (right) side mirror set included three mirrors: a rectangular 7- by 16-inch flat mirror, a 5- by 6-inch rectangular convex mirror mounted above the flat mirror, and an 8-inch circular convex mirror mounted below the flat mirror.

Investigators used 3D scans of the accident truck-tractor when it was coupled to a very similar casing shed and semitrailer to analyze the mirrors on the vehicle. The left and right side flat (plane) mirrors located inboard of the casing shed each had a substantial blind spot in the driver's rearward field of view.¹⁶ This rearward blind spot, with a span of more than 23 feet at a distance of 200 feet behind the vehicle, would have made lane changes hazardous without a trailing pilot/escort vehicle. (See figure 10.)

¹⁴ Based on the specifications of the manufacturer of the casing shed section, the dimensions of the oversize load were 60 feet long, 11 feet 6 inches wide, and 12 feet 3 inches high. The load weighed 44,000 pounds.

¹⁵ This limit was derived by adding 18,180 pounds for the steer axle (rated at 600 psi of tire width), 34,000 pounds for the tandem axle on the tractor, and 43,500 pounds for the 3-axle set on the semitrailer.

¹⁶ The blind spots on the right and left extended laterally outward at angles of about 3° and 2°, respectively. Extension of the obstructed sight line revealed that for a 12-foot-wide lane, the adjacent right and left lanes could be completely obscured at distances of about 248 feet and 260 feet, respectively.

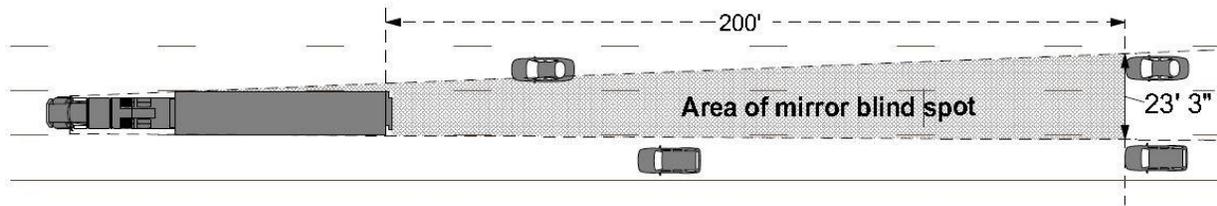


Figure 10. Diagram showing the blind spot in the rearward field of view through the flat mirrors on the crash tractor.

As noted above, in addition to the flat mirrors, the driver side of the tractor was equipped with a smaller, round, convex mirror mounted outboard of the flat mirror that extended to within a few inches of the edge of the casing shed. This mirror covered essentially all of the blind area to the left side of the vehicle, but the reflected image would appear distorted, because the curvature of the mirror produced an image that appeared smaller and farther away.

1.3.3 Postcrash Inspection of the Pilot/Escort Vehicle

The pilot/escort vehicle was undamaged, and no mechanical inspection was conducted. The pilot/escort vehicle was equipped with a roof-mounted light bar, an oversize load banner, and a single height pole.

The company that provided this pilot/escort vehicle, G&T Crawlers, used a height pole that consisted of a telescoping painter's pole made of yellow plastic with a 39-inch-long black vehicle radio antenna attached to its top. Atop the antenna was a 1 1/2-inch-diameter rubber ball secured to the antenna with red tape. The plastic portion of the height pole was marked with 1/8-inch gradations. The plastic portion telescoped to 18 feet. The pole was mounted on the front bumper of the pilot/escort vehicle in a metal tube support located 9 inches inboard from the right edge of the bumper. Because the metal tube slanted slightly to the left, toward the centerline of the vehicle, the height pole also leaned to the left. The top section of the height pole (radio antenna) was more flexible than the plastic portion, and the weight of the rubber ball atop the antenna caused the antenna to lean still farther leftward toward the centerline of the vehicle. With the vehicle on a level surface, NTSB investigators measured the horizontal distance from the metal tube to the vertical distance of the leaning antenna and determined that the ball was 16 inches to the left of the metal tube. Because of the slant, the height pole's contact point (top of the ball) was 25 inches inboard of the right side edge of the pilot/escort vehicle's front bumper.

The pilot/escort vehicle driver said she set the vertical distance from the top of the pole (the ball) to the roadway surface at 16 feet 2 inches when she met the permitted vehicle at the Canadian–US border.¹⁷ She set the pole at this height because she reviewed the permit and saw that the load height was listed as 15 feet 9 inches, and the Washington State training guidelines for pilot/escort vehicle drivers recommend that the pole height be at least 3–6 inches above the height of the load as recorded on the permit.

¹⁷ While on the scene at the south side of the bridge, the Washington State Patrol measured the height from the ground to the top of the height pole on the pilot/escort vehicle at 16 feet.

Figure 11 is a photo of the pilot/escort vehicle with the height pole in place; figure 12 shows a diagram of the pilot/escort vehicle viewed from the front and provides the dimensions of the vehicle and height pole as documented by NTSB investigators.



Figure 11. Pilot/escort vehicle, showing the placement of the height pole on the front bumper.

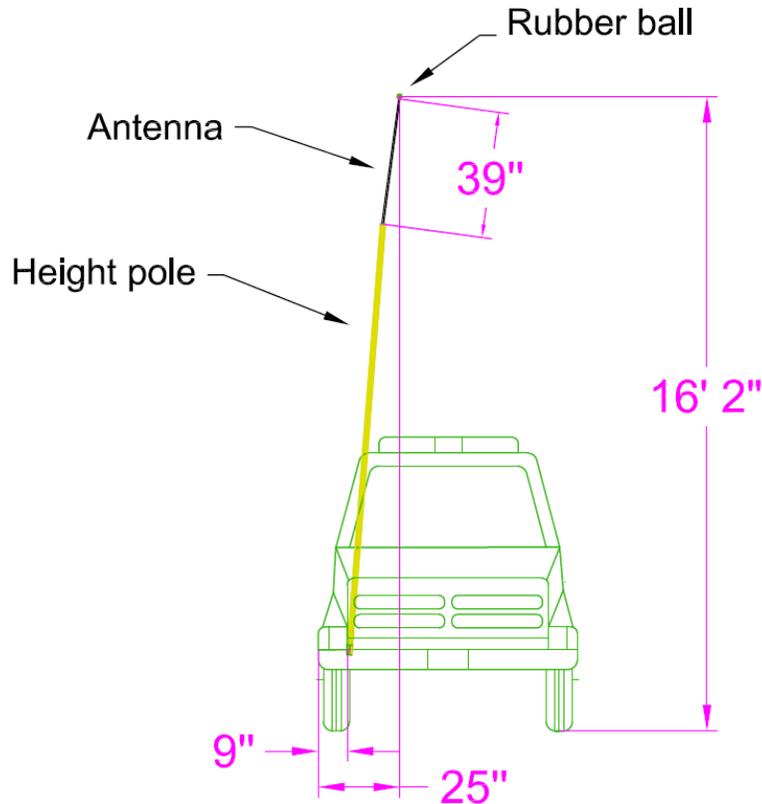


Figure 12. Diagram of the pilot/escort vehicle, viewed from the front. (The measurement of 16 feet 2 inches is the vertical distance from the roadway surface to the top of the height pole [the rubber ball].)

1.4 Drivers

This section presents the licensing, fitness, toxicology, driving history, and hours-of-service status of the driver of the oversize combination vehicle. It also provides relevant information about the pilot/escort vehicle driver, including cell phone use, as well as a summary of witness interviews.

1.4.1 Oversize Combination Vehicle Driver

The 41-year-old male driver was 6 feet 2 inches tall and weighed 212 pounds. He had held a class 1 commercial driver's license (CDL) for 22 years; the province of Alberta had issued his current license.¹⁸ His most recent medical examination had been on February 7, 2013, and its authority was to expire in February 2015. In that examination, the driver's primary care physician provided the following assessment for the driver: "healthy, no concerns." The driver's

¹⁸ The Federal Highway Administration has determined that CDLs issued by Canadian jurisdictions under the *Canadian National Safety Code* meet the commercial driver testing and licensing standards in 49 CFR Part 383.

hearing and vision were good, and he did not wear glasses or contact lenses. A review of the driver's prescription medications revealed none that would have impaired his cognitive performance. The results of the alcohol and drug tests conducted on the driver's blood specimen taken on the night of the bridge span collapse were negative (including the results of the tests conducted by CAMI).

A review of the driver's logbook and receipts, as well as the times and locations recorded by the vehicle's global positioning system (GPS), indicated no violations of either Canadian or US hours-of-service rules. Telephone records show that 3 minutes before the crash, the driver placed a call on his cell phone; the call lasted 29 seconds. The driver was not on a cell phone call or using the citizen's band radio at the time of the bridge strike.

The driver had worked for Mullen Trucking for about 8 years. He typically worked 20 days a month, and the majority of his transported loads were specialized oversize and/or overweight loads. He stated that, since coming to work for Mullen Trucking, he had moved several loads similar to the one that struck the I-5 bridge.

When asked about his commercial driver training, the driver stated he had attended a school offered through the Teamsters Union. The school provided 1 1/2 weeks of classroom training and a week of behind-the-wheel training with an instructor before the trainee took the CDL test. The driver passed the test the first time he took it. When asked about annual or recurrent training, the driver said that every 2 years he takes refresher training developed by Smith System Driver Improvement, provided through Mullen Trucking; the last time he did so was about 2 years before the bridge span collapse.¹⁹ His CDL history with Alberta authorities showed no past violations or crashes.

When asked about his experience with the route, the driver stated he had taken oversize loads across the Skagit River Bridge four or five times since joining Mullen Trucking. He said he had taken a load northbound over the bridge earlier in May 2013 and had taken a load southbound over the bridge 2 years prior to the bridge span collapse.²⁰

1.4.2 Pilot/Escort Vehicle Driver

The pilot/escort vehicle driver was a 55-year-old female who, when interviewed, described her health as "good." She told NTSB investigators she did not have any medical conditions or allergies and was experiencing no health issues on the day of the event. She gave her height as 5 feet 4 inches and her weight as 180 pounds. She reported no problems with her vision and did not wear glasses or contact lenses. When interviewed, she stated that she does not regularly take any prescription medications, over-the-counter medications, or vitamins. The pilot/escort vehicle driver told investigators she consumes less than one alcoholic drink a week

¹⁹ For more information on this training, see [Smith System Training Solutions](#), accessed July 15, 2014.

²⁰ The NTSB obtained Mullen Trucking's permits for its vehicles traveling over the Skagit River Bridge for the 6 months prior to the bridge span collapse (December 3, 2012, through May 15, 2013); the carrier operated 53 trips transporting oversize loads. Heights of loads ranged from 13 feet 6 inches to 16 feet 4 inches, and widths varied from 9 feet 0 inches to 15 feet 0 inches. All these vehicles and loads cleared the bridge structure; however, the NTSB does not know the lane(s) used during the bridge transits.

and did not consume any alcohol in the 3 days prior to the bridge span collapse. She was not required to complete postcrash toxicological testing, and no testing was done.

She told NTSB investigators she was using her cell phone with a hands-free headset at the time of the bridge crossing.²¹ She said she was engaged in a conversation with her business partner (husband) about the next day's routing of the oversize load she was escorting. She was upset and concerned about a particular route segment that would involve movement of the load under a pedestrian bridge. Cell phone records indicate she was on the phone for 4–5 minutes before beginning to cross the bridge. These records also show that during the 30 minutes preceding the bridge strike, the pilot/escort driver was engaged in five cell phone calls that accounted for about half of the driving time.

The pilot/escort vehicle driver held a basic driver's license issued by Washington State with no endorsements or restrictions; it was issued in August 2011 and would expire in May 2014. Her Washington State driving history showed one speeding violation in October 2010. She held a Washington State pilot/escort vehicle certificate/card, which was issued in January 2012. It was valid for 3 years and would expire in January 2015. She told investigators she had worked as a pilot/escort vehicle driver since 1982 and had received training through "Evergreen."²² She stated she completes the training program every 3 years and had taken it most recently in January 2012.

1.4.3 Witnesses

Driver of the 2000 Kenworth truck. Investigators located and interviewed the driver of the southbound 2000 Kenworth commercial truck that passed the oversize combination vehicle in the course of the collapse event sequence.²³ The driver of the 2000 Kenworth truck stated he had been hauling a load of bottled water from Hope, Alberta, to the Tacoma, Washington, area. The driver said he had crossed into the United States at the Sumas border crossing and made his way to I-5. As he went through the Bow Hill scale (located about 6.75 miles north of the bridge), he saw the oversize combination vehicle that later struck the bridge. He said he noticed the oversize load because it was "empty inside" and memorable. After leaving the scale, the driver of the 2000 Kenworth proceeded southbound across the Skagit River Bridge. He said his vehicle was in the southbound left lane, and the pilot/escort vehicle and the oversize combination vehicle were both in the southbound right lane. He recalled hearing a noise as he passed the oversize combination vehicle, but he said he thought his load was "jumping" on the semitrailer. He stated that he passed the pilot/escort vehicle in the middle of the bridge.

²¹ When interviewed by NTSB investigators, the driver admitted to having been on her phone as she approached and crossed the bridge; however, she initially told an on-scene Washington State Patrol officer that she had not been on her phone.

²² The Evergreen Safety Council is a private, nonprofit, nongovernmental association that states that its mission is "to prevent accidental deaths and injuries by being a resource for safety training, consulting, and information for businesses and citizens of Washington State and the Greater Northwest." For additional information, see the [Evergreen website](#), accessed July 15, 2014.

²³ Investigators compiled a list of commercial vehicles known to have been in the immediate area from weigh station data for vehicles headed southbound through the Bow Hill scale. The characteristics of the vehicles were identified on video of the bridge span collapse; investigators used the scale's traffic records to obtain contact information. They also viewed surveillance camera footage from nearby businesses and a dash-mounted camera in a Washington State Patrol car to document commercial vehicles traveling near the oversize combination vehicle.

Driver of a noncommercial vehicle that passed the oversize combination vehicle. Investigators located and interviewed the driver of a 2001 Ford Ranger that had been traveling southbound on I-5 at the time of the collapse event. That driver held a CDL and worked as a part-time truck driver. He stated he had hauled wide loads.

This driver told investigators he was traveling in the passing lane. He had overtaken the oversize combination vehicle and was still in the passing lane but had not overtaken the pilot/escort vehicle as they crossed the bridge. He estimated the distance between the pilot/escort vehicle and the oversize combination vehicle at 300–450 feet. The witness stated he was looking at the pilot/escort vehicle and saw its height pole strike four or five bridge elements. The Ford Ranger driver also said he looked in his mirror and saw the oversize load strike the bridge and tip to the left. He said he thought the truck and load were going to roll over. As the oversize combination vehicle continued across the bridge, it came back down on its tires. When asked, he could not recall the position of the pilot/escort vehicle in its lane, and he did not recall seeing a commercial vehicle similar to the 2000 Kenworth truck next to the oversize combination vehicle.

Passenger of the BMW 525i. Immediately after clearing the bridge, the BMW 525i pulled over to the side of the road, as did the pilot/escort vehicle and the oversize combination vehicle. In an interview following the crash, the BMW 525i passenger told the Washington State Police that the pilot/escort driver got out of her vehicle and seemed very upset. She reported that the pilot/escort driver said, “It’s my fault... I should have had him move over to the middle of the road.”

1.5 Motor Carrier Operations

This section discusses Mullen Trucking LP, its oversight by both Canadian and Federal Motor Carrier Safety Administration (FMCSA) regulators, and the operational aspects of moving oversize loads. It also addresses the permitting process and the certification and training of pilot/escort drivers in Washington and other states.

1.5.1 Mullen Trucking LP

Company. The motor carrier transporting the oversize load was Mullen Trucking LP, located in Aldersyde, Alberta, Canada, about 35 miles south of Calgary. The company operates under the authority of both the Province of Alberta and the FMCSA.²⁴ The carrier began operations in 1949 as a for-hire trucking company operating solely in Canada. Over the years, the company has expanded its operations; today, a number of associated companies operate under the umbrella of the Mullen Group. Mullen Trucking has about 125 drivers, consisting of 95 annual lease drivers and 30 full-time employee drivers. It operates 127 truck-tractors and 390 semitrailers. Most of the carrier’s business is transporting “heavy haul” oversize loads.

Drivers. Mullen Trucking has a structured process for hiring drivers that includes a 5-day orientation/training course and requires applicants to pass a written test with a score of 80 percent or better. Once hired, drivers move through a series of four progressively less

²⁴ The company’s US Department of Transportation number is 158799, and its motor carrier number is 14495.

restrictive driver classifications based on experience, safe driving record, and evaluation by company management, until the carrier allows them to drive all loads and cargo types. The carrier requires the owner-operator drivers under annual lease arrangements to follow the same rules as its employee drivers. Mullen Trucking pays drivers using a percentage formula for each load they haul. According to the carrier, it experiences a driver turnover rate of about 8 percent per year.

Vehicle maintenance. Mullen Trucking has a preventative maintenance program for company and leased vehicles, and it schedules routine maintenance every 25,000 miles. All vehicles are subject to a CVSA level I examination every time they return from a trip; Mullen Trucking mechanics inspect each vehicle before dispatching it from the terminal yard.²⁵ The NTSB obtained the inspection records for the truck-tractor of the oversize combination vehicle and found it had received the required annual inspection each year since 2009. The carrier employs eight full-time qualified truck and semitrailer mechanics who conduct all the maintenance on its vehicles, except for tire maintenance. The carrier contracts with an outside vendor for tire maintenance and replacement.

1.5.2 Motor Carrier Oversight

Canadian carrier oversight. Mullen Trucking was the subject of an Alberta, Canada, audit on March 26, 2013, and received a “Satisfactory” rating. The audit included an inspection of the records of 20 drivers and 19 vehicles to assess the carrier’s compliance with requirements for drivers and vehicles. Alberta inspectors found minor violations by Mullen Trucking in each category; however, the point count and percentages calculated did not warrant a rating of less than “Satisfactory.”

US carrier oversight. Mullen Trucking had US operating authority, and the Office of Motor Carrier Safety conducted a compliance review of the carrier on March 20, 1989, which resulted in a “Satisfactory” rating.²⁶ From 2006 through 2010, the FMCSA rated Mullen Trucking as an “H” carrier, which meant it rated the carrier’s performance as better than 75 percent of all other carriers in the SAFESTAT system.²⁷ As of June 1, 2013, Mullen Trucking had no Safety Management System alerts.

The FMCSA conducted a postcrash compliance review of Mullen Trucking on May 30, 2013. It found violations concerning compliance with 49 CFR Part 382 (drug and alcohol program), Part 391 (driver files), Part 395 (hours of service), and Part 396 (vehicle maintenance). The FMCSA’s final rating for the 2013 compliance review was “Satisfactory.”

As of June 1, 2013, FMCSA Safety and Fitness Electronic Records data indicated that the carrier had been the subject of 271 roadside inspections in the 24 months prior to May 23, 2013. These inspections resulted in a 14.7 percent out-of-service rate for the “Vehicle” factor, which compares to a national average of 20.7 percent; a 0 percent out-of-service rate for the “Driver”

²⁵ There are seven levels of CVSA roadside inspections. A level I inspection is the most comprehensive; it examines the driver, the driver’s paperwork, and the vehicle (including under-vehicle examination).

²⁶ The Office of Motor Carrier Safety was reorganized and became the FMCSA in 2000.

²⁷ Prior to December 2010, the FMCSA used the SAFESTAT system to rank carrier safety performance.

factor, which compares to a national average of 5.5 percent; and a 1.0 percent out-of-service rate for the “Hazardous Materials” factor, which compares to a national average of 4.5 percent. The data also indicated that the carrier had three crashes (of sufficient seriousness to warrant vehicle tow-away) in the 24 months prior to May 23, 2013.

1.5.3 Oversize Load Operations

The government agency having jurisdiction over the roadway grants specialized permits for transport of loads on its highways and roadways in cases in which (1) the load or (2) the vehicle and load exceed state size and/or weight limitations. States and provinces are the entities primarily responsible for setting size and weight limits, and standards vary from state to state and province to province. Federal size and weight standards exist for vehicles using the US Interstate Highway System; however, there are no federal regulations relating to permitting.

For the oversize combination vehicle, Mullen Trucking had to obtain multiple permits to enable it to travel along the intended route. In Washington State, permits are required for vehicles exceeding 14 feet in height and 8 feet 6 inches in width, as well as for trailers exceeding 53 feet in length (WSDOT 2012). Permits are also required for rear overhangs (the distance from the center of the rear axle to the rearmost point on the trailer or load) exceeding 15 feet. The permit the oversize combination vehicle was operating under at the time of the bridge strike listed a vehicle height of 15 feet 9 inches, a vehicle width of 11 feet 6 inches, a semitrailer length of 70 feet 4 inches, and a rear overhang of 6 feet 4 inches. The vehicle did not require a permit based on its weight. A Washington State website provides information on roadway/vehicle size restrictions (WSDOT 2014).

1.5.4 Permit Application and Issuance Process

Mullen Trucking had established practices for transporting oversize and overweight loads through various jurisdictions. The carrier had a permit coordinator on staff to perform the permitting tasks. This permit coordinator received information from the driver of the oversize combination vehicle concerning the shipment’s width, length, height, and weight, as well as a description of it. The coordinator used the load’s origin, destination, and route of travel to identify the states/provinces through which it would be traveling.²⁸

Once it had determined the necessary information about the load, route, and jurisdictional permit requirements, Mullen Trucking began the permit request process. The state of Washington automatically issued the permit that Mullen Trucking requested; that is, WSDOT received the permit request via Web input, and it issued the permit based on information submitted via the website. No WSDOT personnel reviewed the request. The WSDOT permit contained the following information concerning the I-5 route:

²⁸ Each US state and each Canadian province has a website concerning the routing of oversize vehicles and loads. The NTSB also considered cities and counties with permit requirements as jurisdictions with regard to permitting. A number of sources provide routing and other permit information. For example, the Western Association of State Highway and Transportation Officials (WASHTO) publishes the *Guide for Uniform Laws and Regulations Governing Truck Size and Weight*. Washington State is a member of WASHTO.

“ROUTE DOES NOT GUARANTEE HEIGHT CLEARANCES **”**

<i>Route Nbr</i>	<i>MP From</i>	<i>MP to</i>	<i>Restriction Comment</i>
5	254.82	182.63	<i>Route OK - WSDOT Does Not Guarantee Height Clearances</i>

"The Department does not guarantee height clearances; therefore, on any route where the height is in question, a front escort vehicle equipped with a height pole should be used."

The Mullen Trucking permit coordinator transmitted copies of the WSDOT permit to the driver and arranged the necessary pilot/escort drivers.²⁹ Because the escort company originally contacted by Mullen Trucking could not accept the job, the driver of the oversize combination vehicle called G&T Crawlers to take the escort assignment for the I-5 route segment.

1.5.5 Pilot/Escort Vehicle Operations

Pilot/escort vehicle operator. G&T Crawlers provided one of several pilot/escort vehicles for transport of the oversize load. G&T Crawlers operated out of a residence in Olympia, Washington; the driver was, with her husband, an owner of the company. She was not required to have, and did not possess, a CDL.

Pilot/escort vehicle regulations and guidelines. Regulations issued by WSDOT on pilot/escort vehicle and operator requirements appear in the *Washington Administrative Code* (WAC) at WAC 468-38-100. The code addresses the responsibilities of pilot/escort vehicles assigned to front and rear oversize load movements, including equipment requirements.

The WAC requires that an operator of a pilot/escort vehicle be certified with the state as having received department-approved base level training. Additionally, a pilot/escort vehicle operator with a Washington State driver's license must have a valid pilot/escort vehicle certificate/card issued by the state, which must be on the operator's person while performing pilot/escort duties. Operators with a driver's license from a jurisdiction other than Washington State may acquire a state pilot/escort vehicle certificate/card subject to periodic review of the issuing jurisdiction's certification program. Washington State pilot/escort vehicle certificates/cards must be renewed every 3 years.

With respect to pretrip procedures for pilot/escort vehicle drivers, the WAC lists a number of requirements, including the following:

- a) The pilot/escort vehicle driver must discuss with the operator of the extra-legal vehicle the aspects of the move,^[30] including, but not limited to, the vehicle configuration, the route, and the responsibilities that will be assigned or shared.

²⁹ In this case, the Mullen Trucking coordinator faxed copies of the permits to the driver on location at the manufacturer's terminal where he picked up the oversize load.

³⁰ The WAC refers to oversize loads as "extra-legal" movements.

- b) Prerun the route, if necessary, to verify acceptable clearances.
- c) Review the special permit conditions with the operator of the extra-legal vehicle.
- d) Determine proper position of required pilot/escort vehicles and set procedures to be used among the operators.
- e) Check the two-way communication system to ensure clear communications and predetermine the channel to be used.

The WAC also details the responsibilities of the pilot/escort vehicle driver when assigned to be in front of the oversize load movement. Specifically, the WAC states that the driver shall do the following:

- a) Notify the operator of the extra-legal vehicle, and the operator(s) of any trailing pilot/escort vehicle(s), about any condition that could affect either the safe movement of the extra-legal vehicle or the safety of the traveling public, in sufficient time for the operator of the extra-legal vehicle to take corrective action. Conditions requiring communication include, but are not limited to, road surface hazards; overhead clearances; obstructions; traffic congestion; pedestrians; etc.
- b) In accordance with training, be far enough in front of the extra-legal vehicle to signal to oncoming traffic to stop in a safe and timely manner before entering a narrow structure or otherwise restricted highway where an extra-legal vehicle has entered and must clear before oncoming traffic can enter.
- c) In accordance with training, do not be any farther ahead of the extra-legal vehicle than is reasonably prudent considering the speed of the extra-legal vehicle, other traffic, and highway conditions. Do not exceed one-half mile distance between pilot/escort vehicle and extra-legal vehicle in order to maintain radio communication, except when necessary to travel a long narrow section of highway.

The WAC specifically states that a pilot/escort vehicle may not contain passengers, human or animal, except for a certified individual in training status or a necessary flag person. WAC 468-38-100 does not include any prohibitions against nonemergency use of portable electronic devices while driving.

The Evergreen Safety Council provides Washington pilot car certification training. Guidance documents include the *Pilot/Escort Vehicle Operator Handbook* (Evergreen Safety Council 2012) and the *Pilot Car Escort Best Practices Guidelines* (SC&RA, FHWA, and CVSA 2004). The Specialized Carriers & Rigging Association (SC&RA) drafted the best practices guidelines with funds provided by a grant from the Federal Highway Administration (FHWA) Office of Freight Management and Operations and in cooperation with the CVSA.

The *Pilot/Escort Vehicle Operator Handbook* recommends that pilot/escort vehicle operators measure bridge lanes from their midpoints when using height poles. It further recommends that the height pole be strong enough not to break if it hits an overpass or bridge

structure, be constructed so that one section will slide into another to allow for adjustment and storage, and have a mount capable of absorbing stress from constant wind load and possible overhead impacts but of sufficient rigidity to prevent changes in pole elevation or attitude. It also states that, although height poles are commercially available, it is cost-effective for operators to construct their own height poles and mount them to their vehicles. The handbook recommends that the height pole be mounted on the left side of the front of the vehicle to provide the operator visual alignment with overhead obstructions (Evergreen Safety Council 2012, 4–28).

According to the National Pilot Car Safety Institute (NPCSI), state laws generally follow the guidance in the *Pilot/Escort Vehicle Operator Handbook*, requiring “a height-measuring pole made of a non-conductive, non-destructive, flexible or frangible material” when escorting a load exceeding a certain height (Evergreen Safety Council 2012). The NPCSI website provides an equipment link to a retail service, where height poles and accessories are available for purchase.

The *Pilot/Escort Vehicle Operator Handbook* (Evergreen Safety Council 2012, 2-6 and 2-7) states the following:

It is recommended that the lead P/EVO manage the spacing between the permitted vehicle and the P/E vehicle based on the ‘one plus one section rule;’ allowing one second of lead-space for every 10 feet of the permitted vehicle’s length, with an added one second when exceeding 40 miles per hour. In some states, such as Washington, the lead pilot vehicle shall not lead the permitted load by more than ½ mile.^[31]

As a matter of company policy concerning lead distances for pilot/escort vehicles, the *Mullen Trucking LP Driver & Owner Operator Reference* states, “A pilot vehicle should travel between 300 to 1000 meters (1000 feet to 3280 feet) ahead of an over-dimensional vehicle.”

1.6 Highway

This section provides a physical description of the highway and the bridge, as well as the state and federal policies relevant to bridge strikes by high loads.

1.6.1 Highway Description

I-5 is the westernmost interstate route in the United States, running north-south from Canada—through the states of Washington, Oregon, and California—to Mexico. Approximately 50 miles south of the US/Canadian border and 60 miles north of Seattle, Washington, I-5 crosses over the Skagit River at Mount Vernon, Washington.³²

Travel lane geometry. The Skagit River Bridge was built in 1955, and it originally accommodated one lane of traffic in each direction. Travel lanes were centered under the highest vertical clearance of the overhead sway braces, and wide shoulders extended to the edges of the bridge under the lower portion of the sway braces. A center lane divider separated the

³¹ In the quoted material, “P/EVO” stands for pilot/escort vehicle operator and “P/E” stands for pilot/escort.

³² The river crossing location is milepost 228.25.

northbound and southbound travel lanes. In 1956, I-5 north and south of the bridge was widened to four lanes, providing two lanes in each direction (including on the bridge).

The I-5 travel lanes north and south of the Skagit River Bridge were 12 feet wide, in accordance with American Association of State Highway and Transportation Officials (AASHTO) policy (AASHTO 2011, 4-7, 4-8, and 8-2). The paved shoulders adjacent to the travel lanes north of the bridge were 8 feet wide; south of the bridge, the paved shoulders were 10 feet wide. Both the yellow center lane markings and the white edge lane markings were retro-reflective pavement lines.³³

As the roadway traversed the Skagit River Bridge structure, the travel lanes narrowed from 12 feet to 11 feet 4 inches.³⁴ Adjacent to the right lanes were 26-inch-wide paved right shoulders, extending from the edge lane markings to the barriers on the outsides of the bridge deck.³⁵ Adjacent to the left travel lanes were 30-inch-wide median shoulders. There were 32-inch-tall concrete traffic barriers at the outside edges of the bridge deck and in the center median. (See figure 13.)

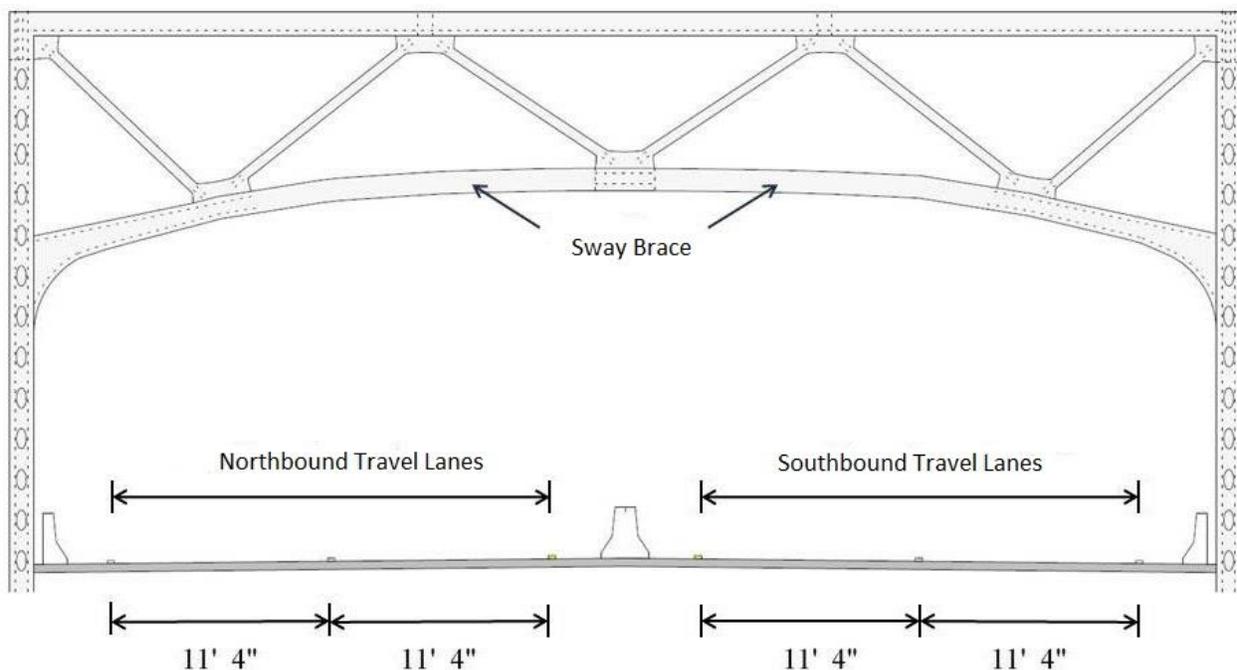


Figure 13. Cross section diagram of the Skagit River Bridge, showing the elliptical shape of the sway braces of the through-truss structure.

³³ Retro-reflectivity is the property of a surface that allows a large portion of the light coming from a point source to be returned directly back to a point near its origin.

³⁴ Lane width is measured from the centerline of pavement markings; the travel lane pavement markings are approximately 4 inches wide from edge to edge. The travel lane width between the lane markings is approximately 11 feet.

³⁵ Shoulder width is measured from the centerline of the edge pavement marking to the edge of the concrete traffic barrier.

Speed, traffic, and signage. The posted speed limit for I-5 in the vicinity of the bridge is 60 mph.³⁶ An 85th percentile speed study, conducted on June 12, 2007, indicated that 85 percent of the traffic was traveling at or below an average speed of 68 mph.

In 2012, the average daily traffic count on I-5 in the vicinity of the Skagit River Bridge for traffic in both directions was 67,378 vehicles per day. The daily traffic for the years 2005 to 2012 varied little from an average of 66,983, with about 1,000 more vehicles traveling northbound than southbound daily. The traffic mix for 2012 along I-5 in the vicinity of the Skagit River Bridge was 88.7 percent passenger vehicles, 5.3 percent single-unit trucks and buses, and 6.0 percent truck-tractor combination units.³⁷ With the exception of a pedestrian who died in a crash on a southbound off-ramp in 2012, no fatal collisions occurred within a 5-mile distance of the Skagit River Bridge between 2007 and 2012. Police reported 10 traffic crashes on the bridge for 2012; all were collisions of passenger cars or pickup trucks, and 3 involved injuries.

Existing signage on I-5. There were 18 signs in the mile of I-5 southbound immediately preceding the Skagit River Bridge. All but one (a Merge sign on the left) were posted to the right of the travel lanes. Of the 18 signs, 5 provided route direction information, 4 were traffic control signs, 2 informed drivers of reduced lateral clearance, and 7 provided traveler information (such as Gas, Food, Lodging and Adopt-a-Highway signs). No signs were posted to the right or left of the travel lanes on the bridge (228 feet of bridge deck leading to the through-truss overhead structure), and no signs were posted on the bridge's overhead structure. The northbound mile of I-5 approaching the bridge contained 13 signs; 5 were route signs (including 2 overhead exit signs), 3 were traffic control signs, and 5 provided traveler information. No signs were posted in either direction indicating the bridge's vertical clearance.

1.6.2 Bridge Description

When describing specific sections of the bridge structure in this report, the following terminology is used. "Nodes" are the connection points between truss members. "Truss nodes" are broken into the upper chords and lower chords. They consist of the ends of associated members with gusset plates on either side. The nodes are numbered independently for each span from the south to the north, starting at node 0 and continuing to node 6. They are further identified as to whether they are associated with the east or west truss (E or W) and whether they are from the upper or lower chords of the truss (U or L). For example, the third node from the south end in the upper chord of the west truss would be identified as node U3W. Individual truss members are identified based on the nodes that the components connect. For instance, a diagonal member connecting nodes U3W and L2W would be identified as L2W-U3W.

³⁶ The posted speed limit was reduced from 70 mph to 60 mph in January 2007 for the segment of I-5 near the Skagit River. The state reduced the speed limit in response to the urban expansion in Skagit County along this stretch of I-5.

³⁷ Semitrailer combination units accounted for 5.4 percent of the traffic mix, including 0.6 percent double-trailer and triple-trailer combination units.

The Skagit River Bridge³⁸ consisted of 12 spans with a total length of 1,111 feet 9 inches.³⁹ The four center spans (spans 5, 6, 7, and 8) crossing the Skagit River were independent through-truss spans.⁴⁰ Each truss span was 160 feet long and made of riveted steel sections. (Refer to figure 13 to see the overhead bridge truss structure.)

The east and west trusses were connected by riveted plate floor beams at the lower chords (below the roadway) and by sway braces at and below the upper chords (above the roadway). The sway braces were themselves truss structures made up of riveted structural shapes. The lower chords of the sway braces were elliptically curved to form archways across the traffic lanes. The load on the oversize combination vehicle struck the north portal, all of the sway braces in span 8, and five of the sway braces in span 7.⁴¹

Figure 14 below illustrates the structure of the Skagit River Bridge. (The northernmost truss span, span 8, is the one that collapsed into the river.) Figure 15 shows the nodes on the truss structure (view is of the east truss).

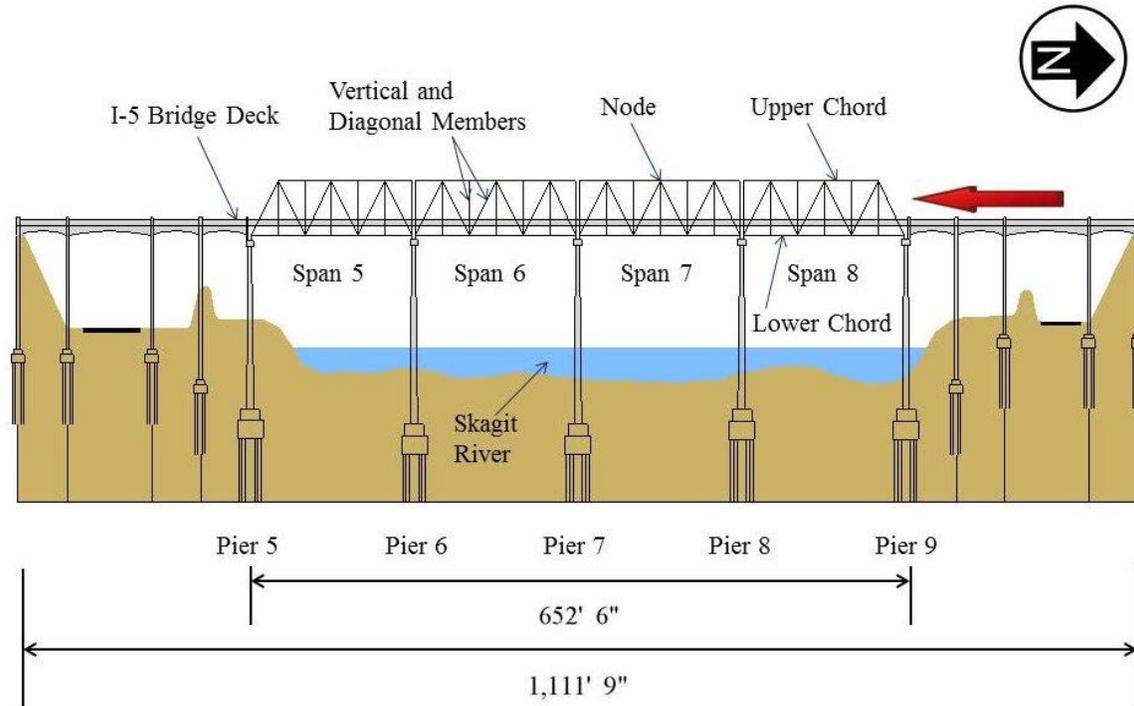


Figure 14. Components and layout of the Skagit River Bridge. (The red arrow shows the southbound direction of travel of the oversize combination vehicle.)

³⁸ The National Bridge Inventory identifies this bridge as #4794A.

³⁹ Construction documents numbered the spans 1–12 beginning with the southernmost span. Each span was supported by a bridge pier at each end; the 13 piers were also numbered from south to north.

⁴⁰ The total length of the four through-truss spans was 652 feet 6 inches.

⁴¹ On a through-truss bridge, the portal is the entrance to the structure that is composed of the frame members primarily needed to transfer the loads from the top lateral system to the substructure. They are typically inclined frames constructed of members having increased capacity to transfer the higher loads.

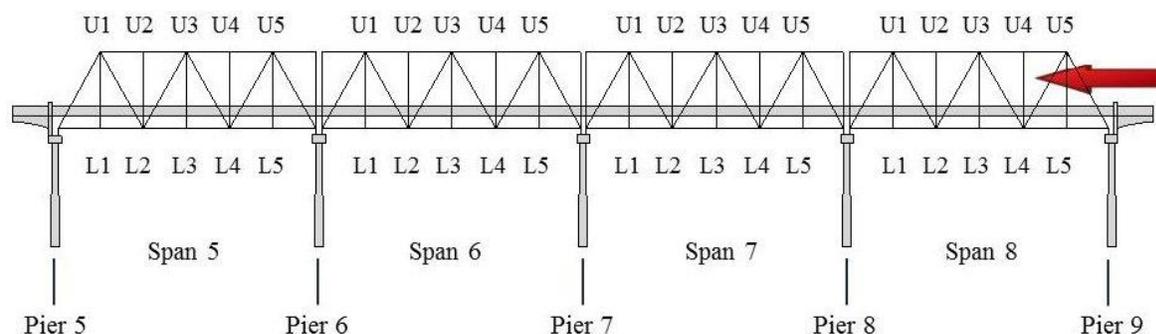


Figure 15. Bridge truss diagram showing the locations of nodes. (The red arrow shows the southbound direction of travel of the oversized combination vehicle.)

The *AASHTO Load and Resistance Factor Design (LRFD) Bridge Design Specifications* classify the Skagit River Bridge as a fracture-critical⁴² bridge (AASHTO 2012). As part of this classification, the bridge is by definition a non-load-path-redundant structure.⁴³

The FHWA has classified the Skagit River Bridge as “functionally obsolete” since 1983. The FHWA classified the bridge as obsolete due to its narrow shoulders, low vertical clearances, and narrow lanes that did not meet current minimum design standards.⁴⁴

Washington State has 7,840 bridges; the United States has 607,380 bridges. Approximately 22 percent of all the bridges in the state are rated as functionally obsolete, which compares to a 14 percent national average.

Washington State has 104 through-truss bridges on the Interstate, US Highway, and State Highway Systems; the number of through-truss bridges in the state increases to 158 if local bridges are included. The United States has 9,632 through-truss bridges. Approximately 48 percent of the through-truss bridges in Washington State are classified as functionally obsolete, which compares to a 21 percent national average.

⁴² AASHTO LRFD specification 2012 defines fracture-critical as “a component in tension whose failure is expected to result in the collapse of the bridge or the inability of the bridge to perform its function.”

⁴³ For a redundant structure, there must be at least one alternate load path with sufficient strength and stability to maintain serviceability following failure of one main supporting member. The current *AASHTO LRFD Bridge Design Specifications* recommend that multiple-load-path and continuous structure designs be used unless there are compelling reasons not to do so.

⁴⁴ According to the FHWA, a functionally obsolete bridge is not inherently unsafe. Functionally obsolete bridges include those that have inadequate vehicular capacity or substandard geometric features, such as narrow lanes, narrow shoulders, poor approach alignment, or inadequate vertical or horizontal underclearance.

1.6.3 Highway Vertical Clearances

Vertical clearance data. After the collapse, NTSB investigators measured the vertical distance from the bridge deck to the bottom of each of the sway braces on the remaining three spans of the Skagit River Bridge. Table 3 summarizes the 280 survey measurements of vertical height clearance taken of the bridge in the southbound direction of travel.

Table 3. Vertical height clearances on spans 5–7 on the Skagit River Bridge in the southbound direction.

Location of Measurement	Average Height Above Road Surface	Minimum	Maximum
Outside barrier, lower face at road surface (road edge)	14' 10½"	14' 9"	15' ½"
Fog (edge) line—solid white line	15' 9"	15' 8"	15' 11"
Midpoint of outside (right) lane	17' 0"	16' 11½"	17' 1"
Lane dividing line—broken white line	17' 9"	17' 8"	17' 10"
Midpoint of outside (left) lane	18' 0"	17' 11"	18' 1"
Edgeline, outside—solid yellow line	18' ½"	17' 11½"	18' 1"
Inside barrier, lower face at road surface (road edge)	18' ½"	17' 11"	18' 1½"
NOTE: Measurements were taken in feet and tenths of feet—a decimal foot format—and the reconstruction report table in the investigative docket contains those measures. For this report's discussion, those measures have been converted to feet/inch format.			

Washington State bridge strike records. The WSDOT routine bridge inspection report dated August 25, 2012, for the Skagit River Bridge stated that the following sways and portals had high load strikes:⁴⁵

- Span 5 U1 portal has a small dent.
- Span 6 U2 sway is bent 1-inch deflection over 12-inch distance.
- Span 6 U5 sway is bent 1-inch deflection over 8-inch distance.
- Span 7 U4 sway is bent 2 ½-inch deflection over 10-inch distance.
- Span 7 U5 sway is bent ½-inch deflection over 4-inch distance.
- Span 8 U0 sway is bent 1-inch deflection over 15-inch distance.

⁴⁵ High load strikes are indicated by damage to overhead structures resulting from loads that did not clear the vertical distance above the roadway.

- Span 8 U3 sway has two small nicks.
- Span 8 U5 portal is bent ½-inch deflection over 4-inch distance in two places.

Each of the six routine bridge inspection reports prepared by WSDOT for the Skagit River Bridge dating back to September 14, 2003, shows high load strikes on the sways and portals. Three of four interim bridge inspection reports also show high load strikes. In all, nine of ten bridge inspection reports for this structure over a 10-year period show high load bridge strikes.

A different type of report (the WSDOT bridge damage inspection report), dated November 29, 2012, documented a high load strike starting with span 5 in the northbound direction that resulted in structural damage and a priority 1 repair.^{46,47}

NTSB investigators also looked at strikes on other bridges in Washington State. Table 4 provides an inventory of 15 high load strikes on through-truss bridges in the state from January 2008 through May 2013. The inventory is divided into three categories: (1) high load strikes resulting in significant structural damage and a Critical Damage Bridge Repair Report (CDBRR) being sent to the FHWA;⁴⁸ (2) high load strikes resulting in structural damage that necessitated a site visit by the WSDOT Bridge Preservation Office (significance of structural damage varied and generally required priority 1 repair); and (3) high load strikes reported by others (generally by region maintenance) that resulted in minor damage.

⁴⁶ This report stated, “Span 5 U1 portal had a 16-inch section bent out of plane 3-inches with a 3-inch tear in the steel; Span 5 U2 sway brace had a 14-inch section pushed up 1.5 inches; and Span 5 U3 sway brace was gouged.”

⁴⁷ A priority 1 repair is made in response to a deficiency in a primary bridge element that could cause a major impact to the bridge, such as load restrictions. This type of deficiency may lead to more extensive and costly structural repairs if not completed as soon as possible. Priority 1 is the highest priority assigned to a routine type of repair which, if left uncompleted, could become an urgent or emergency repair by the next inspection.

⁴⁸ In Washington State, a CDBRR must be completed when a bridge inspection identifies a significant structural problem requiring an emergency load restriction, a lane closure, or a bridge closure, or when a bridge has failed.

Table 4. High load strikes on through-truss bridges in Washington State from January 2008 through May 2013.

Route	Structure ID#	Bridge Name	Date ^a	Report Note
High load strikes^b resulting in significant structural damage and CDBRR being sent to the FHWA (1)				
I-5	4794A	Skagit River	5/24/2013	Collapse of span 8 in Skagit River
High load strikes resulting in structural damage that necessitated a site visit by the WSDOT Bridge Preservation Office (significance of structural damage varied but generally required priority 1 repair) (12)				
US-97	6539A	Biggs Rapids–Sam Hill Br	1/28/2008	Damage inspection
SH-4	4999A	Elochoman River	6/26/2008	High load damage inspection
US-12	2311A	Wishkah River	5/7/2009	High load truss strike
SH-25	2658A	Spokane River	5/10/2010	South portal and first interior sway strike
SH-155	JJ	Columbia River Grand Coulee	11/17/2010	High load impact to south portal and first three sway braces
SH-207	2657A	Wenatchee River	4/6/2011	None
US-101	3765B	Humtulpis River	5/18/2011	Damage to north portal
SH-4	4999A	Elochoman River	7/8/2011	High load damage inspection
US-101	1084A	Hoquiam River–Simpson	8/11/2011	Bridge strike by logging truck
US-101	1084A	Hoquiam River–Simpson	11/9/2011	High load strike on south portal
US-101	1084A	Hoquiam River–Simpson	8/17/2012	High load strike to north approach truss
I-5	4794A	Skagit River	11/29/2012	High load strike damage to south portal and the following two sway braces
High load strikes reported by others (generally by region maintenance) that resulted in minor damage; no WSDOT Bridge Preservation Office inspection performed in response to damage (2)				
SH-410	3523A	White River	8/25/2009	Damage photos filed
US-101	1084A	Hoquiam River–Simpson	9/9/2011	No inspection by Bridge Preservation Office
^a Inspection date.				
^b For the purposes of this table, a strike is indicated by a report of damage.				

1.6.4 Washington State Statutes and Regulations

WSDOT vehicle height laws. The *Revised Code of Washington* (RCW) contains the state's permit laws. RCW 46.44.020 states that it is unlawful for any vehicle with or without load to exceed a height of 14 feet above the level surface on which the vehicle stands.

WSDOT overheight regulations. The WAC contains the regulations of Washington State executive branch agencies by authority of the statutes. WAC 468-38-070(1)(b) addresses overheight vehicle permitting, stating that any moves involving height, especially permitted moves exceeding 14 feet, are governed by the ability to clear overhead obstructions, such as bridges, underpasses, wires, overhead signs, and other objects.

WSDOT bridge list website. The WSDOT bridge list website is available to the public so that commercial operators, commercial vehicle drivers, pilot/escort drivers, and public service personnel can check the vertical clearances along a designated route. The website provides the following information:

Forward —

The Bridge List is usable as a guide for clearances, but because of physical changes to highways and other possible inconsistencies due to new construction, overlays, etc., it cannot be guaranteed. As is stated on all permits, the operator ‘shall be responsible and liable for all accidents, damage or injury...and...shall hold blameless...the Washington State Department of Transportation and members thereof...’ The operator is also ‘responsible to clear overhead obstructions.’ WAC 468-38-070 states, ‘It is the responsibility of the permit applicant to check, or prerun, the proposed route and provide for safe maneuvers around the obstruction or detours as necessary.’

Instructions for Use —

It is emphasized here that the Bridge List is only a guide, and WSDOT assumes no responsibility for its completeness or accuracy, or for any damage or injury resulting from its use or misuse.

Consulting this Bridge List does NOT relieve the operator of responsibility to establish a usable route.

To use the clearance list efficiently:

- B. Check the ‘MIN’ column relative to the route and direction of the intended trip.
 - 1. If the height of the load is less than the ‘MIN’ for a bridge, the load should clear in all lanes.
 - 2. If the load’s height is greater than the ‘MIN’ for any bridge:
 - a. If the height of the load is less than the ‘MAX’ column, the load should clear the bridge, but the operator must determine the proper lane to travel.
 - b. If the height of the load is greater than the ‘MAX’ column, the load will not clear, and an alternate route should be determined.

The WSDOT bridge list website provided the information in figure 16 concerning the Skagit River Bridge.⁴⁹ The permitted height of the oversize combination vehicle, 15 feet 9 inches, was greater than the bridge’s southbound MIN clearance of 14 feet 5 inches, and less than its southbound MAX clearance of 17 feet 3 inches (as characterized in instruction B.2.a above).

⁴⁹ See [WSDOT bridge list](#), page 100, accessed July 15, 2014. Note that the WSDOT instructions for the use of this list state that the clearances listed are usable vertical clearances approximately 3 inches less than the actual measurement, based on the best available information, but they are not guaranteed for complete accuracy, due to continuing construction activities.

Mile Post	Bridge Number	Crossing Name	Location	Structure Identification Number	Rdwy Width <= 20'	Vertical Clearances				Bridge Length	Span Type
						NB or EB		SB or WB			
						Max	Min	Max	Min		
221.08	534/1	SR 534 UC	3.4 N SNOHOMISH CO	0008650B		1604	1602	1602	1601	240	PCG
221.08		JCT SR 534									
221.50	5/703C	BENT CULVERT	3.8 N SNOHOMISH CO	0008650C						21	SCulv
223.60	5/703.5C	DRAINAGE CULVERT	2.6 N JCT SR 534	0009392B						75	SCulv
223.95	5/704	I-5 UNDER MT VERNON RD S	2.9 N JCT SR 534	0009392A		1711	1703	1711	1709	230	PCB
225.12	5/706	I-5 UNDER ANDERSON RD	4.0 N JCT SR 534	0009563A		1700	1607	1703	1611	208	PCG
225.64	5/707	I-5 UNDER BLACKBURN ST	4.7 N JCT SR 534	0004535A		1809	1501	1606	1506	194	CTB
226.39	5/708	I-5 OVER SR 536/KINCAID ST	5.3 N JCT SR 534	0004563A						146	CTB
226.40		JCT SR 536	5.3 N JCT SR 534								
226.72	5/709	I-5 UNDER 2ND ST	0.3 N JCT SR 536	0016793A		1805	1805	1805	1805	650	PTCBox
226.99	5/710	GN RY OC	0.6 N JCT SR 536	0004768A						467	CBox PCG
227.73	5/711	SR 536 OC	1.3 N JCT SR 536	0004795A						124	CTB
227.75		JCT SR 538	1.3 N JCT SR 536								
228.25	5/712	SKAGIT R	0.7 N JCT SR 538	0004794A		1703	1403	1703	1405	1112	STrus CTB
228.86	5/712.5	I-5 UNDER GEORGE HOPPER RD	1.1 N JCT SR 538	0009547A		1605	1605	1604	1604	209	PCB
229.33	5/713E	GAGES SLOUGH	1.7 N JCT SR 538	0004795B						104	CS
229.33	5/713W	GAGES SLOUGH	1.7 N JCT SR 538	0004795C						104	CS
230.14	5/714	SR 20 & BN RY OC	2.4 N JCT SR 538	0004833A						244	CTB PCG

Figure 16. WSDOT bridge list information for I-5 bridges; Skagit River Bridge information is highlighted. (Source: WSDOT) (Note that the bridge list table expresses the vertical clearance data in four-digit numbers that represent feet and inches. For example, the number “1405” in the table represents a vertical clearance of 14 feet 5 inches.)

1.6.5 Guidance on Low-Clearance Signage

Manual on Uniform Traffic Control Devices for Streets and Highways (MUTCD). The current (2009) MUTCD recommends that low-clearance signage be used to warn road users of structures with vertical clearances less than 12 inches above the statutory maximum vehicle height (FHWA 2009, Section 2C.27). The language concerning low-clearance signage requirements that appears in the 2009 MUTCD has not changed since the 1961 edition and has appeared in the MUTCD editions published in 1971, 1978, 1988, 2000, and 2003. Figure 17, below, shows images of low-clearance signs taken from figure 2C-5 of the current MUTCD.

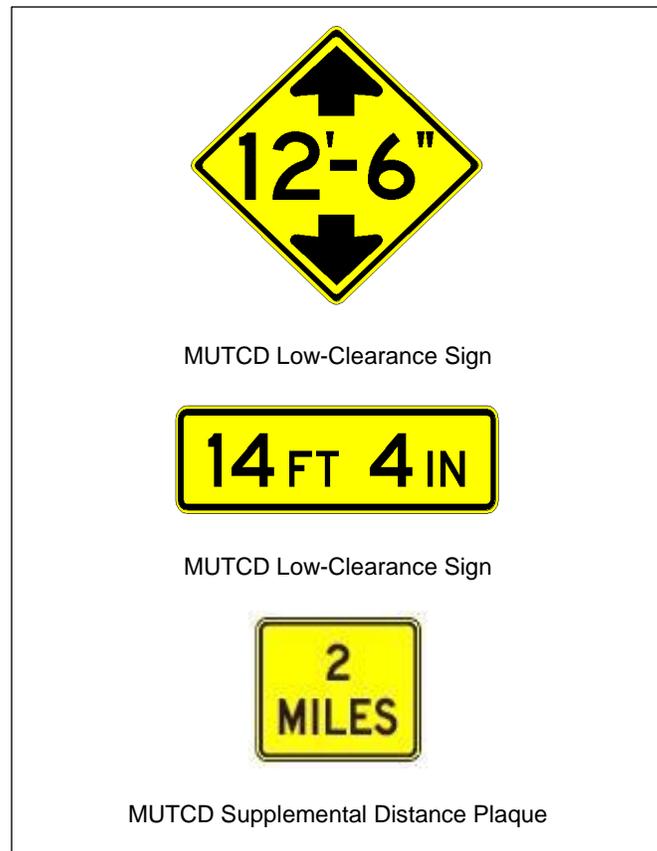


Figure 17. Low-clearance signs from figure 2C-5 of the current MUTCD. (Source: MUTCD)

Twenty-six states, the District of Columbia, and the Commonwealth of Puerto Rico comply with the MUTCD, requiring, at a minimum, the posting of low-clearance signs on structures with vertical clearances less than 12 inches above their statutory maximum vehicle heights. Twenty-two states go further and require the posting of low-clearance signs on structures with clearances greater than the 12-inch MUTCD minimum. Two states (New York and Connecticut) have low-clearance signage requirements that do not comply with the requirements of the MUTCD.

WSDOT low-clearance signage policy. The statutory maximum vehicle height in Washington State is 14 feet. If Washington State adhered to the minimum requirements in the 2009 MUTCD, its low-clearance policy would be to install signage to warn road users of structures with vertical clearances less than 15 feet. Washington State provides an additional 3-inch buffer, requiring low-clearance signage on structures with vertical clearances less than 15 feet 3 inches over the travel lanes. In accordance with this policy, WSDOT did not post low-clearance signs on the Skagit River Bridge.

Over the years, AASHTO and its predecessor organization, the American Association of State Highway Officials (AASHO), have provided information concerning the maximum permissible heights of vehicles. In 1954, AAHSO noted the majority of states had an upper limit of 12 feet 6 inches for vehicle height. Today, 19 states and Puerto Rico allow vehicle heights of

14 feet or greater. AASHTO recommends, via its publication *A Policy on Geometric Design of Highways and Streets*, commonly known as the “Green Book” (AASHTO 2011, 8–4), the following concerning vertical clearance:

8.2.9 Vertical Clearance

The vertical clearance to structures passing over freeways should be at least 4.9 m [16 ft] over the entire roadway width, including auxiliary lanes and the usable width of shoulders with consideration for future resurfacing. In highly developed urban areas, where attaining a 4.9 m [16 ft] clearance would be unreasonably costly, a minimum clearance of 4.3 m [14 ft] may be used if there is an alternative freeway facility with a minimum 4.9 m [16 ft] clearance.

NTSB investigators conducted a survey of the states to determine their statutory maximum vehicle height and low-clearance signage requirements.⁵⁰ They found that statutory maximum vehicle heights vary from a low of 13 feet 6 inches to a high of 15 feet. Thirty-one states and the District of Columbia set the maximum vehicle height at 13 feet 6 inches; sixteen states and Puerto Rico set it at 14 feet; two states set it at 14 feet 6 inches; and one state (Alaska) sets it at 15 feet. Figure 18 shows the statutory maximum vehicle height in each state.

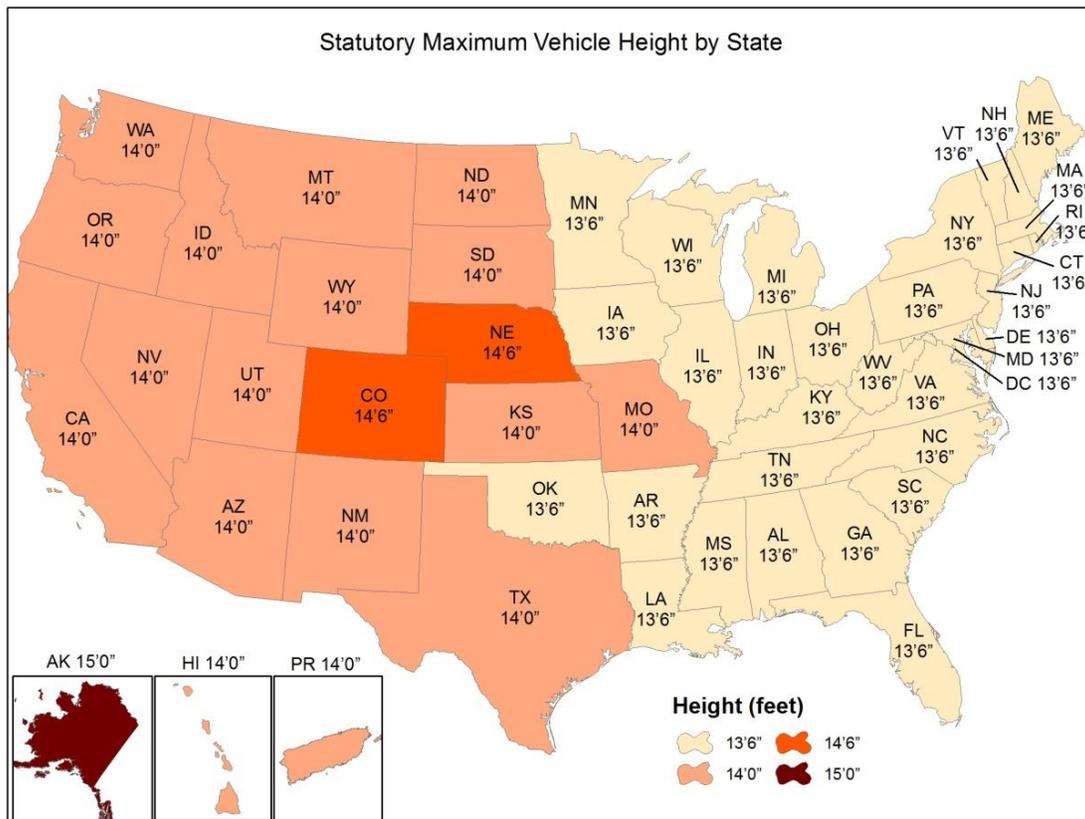


Figure 18. Statutory maximum vehicle heights in the United States.

⁵⁰ The District of Columbia and the Commonwealth of Puerto Rico were included in this survey.

Low-clearance signage requirements also vary from state to state. Appendix B provides the low-clearance signage requirements of each state. Appendix C contains the history of AASHO and AASHTO guidance on vertical clearance of highway structures.

1.6.6 Postcrash Actions by WSDOT

Following the May 2013 bridge span collapse, WSDOT constructed a temporary replacement for span 8 and reopened the Skagit River Bridge to I-5 traffic on June 19, 2013. In August 2013, WSDOT awarded a contract to upgrade the vertical clearance of the Skagit River Bridge to 18 feet across all lanes in the three remaining through-truss spans (spans 5, 6, and 7). The upgrade replaced the elliptically curved lower truss members on the sway braces with straight members to create a uniform vertical clearance across the bridge. The contract also included a proposal to retrofit several bridge supports with reinforced steel components to add strength to the bridge. While that work was underway, crews also performed maintenance activities, including replacing rivets below the deck and painting. WSDOT completed the installation of a permanent replacement for span 8 on September 15, 2013.⁵¹

WSDOT told the NTSB it is transforming its bridge clearance data into geospatial format and developing interactive maps for data users. WSDOT is also supplementing the online information available about the permitting process and expanding its guidance in this subject area. WSDOT also stated that it has undertaken efforts to provide bridge clearance information in its online process for self-issuance of oversize load permits and to provide truck drivers with supplemental information about safe load routing.⁵²

⁵¹ The WSDOT project cost \$8.5 million and was funded through federal emergency relief funds administered by the FHWA. See [Skagit River Bridge Replacement](#), accessed July 15, 2014.

⁵² This information is based on an e-mail communication from the WSDOT deputy northwest region administrator, dated January 7, 2014.

2. Safety Issue Analysis

This analysis first addresses the collision sequence of the oversize combination vehicle's striking the bridge and the resulting collapse of a span of the Skagit River Bridge. Then, it considers the following questions: how was this oversize combination vehicle permitted to be on the bridge; why did the use of a pilot/escort vehicle fail to prevent the bridge strike; could commercial drivers be better trained to provide safe transportation of oversize loads; and what actions could the state of Washington have taken with respect to this roadway that might have prevented the bridge strike? These questions highlight the interrelated processes that must be coordinated to conduct the special highway operation of moving oversize loads safely.

The analysis covers the following main safety issues:

- Permitting and route surveying for oversize loads;
- Pilot/escort vehicle operations, guidelines, and driver training;
- Commercial driver operations for transporting oversize loads;
- State practices for high load bridge strikes; and
- Requirements for low-clearance signage.

Some factors the NTSB investigated were found to be unrelated to the bridge collapse. The NTSB examined the work history, sleep history, and medical records of the oversize combination vehicle driver and interviewed him about his quality of sleep; the NTSB found no indication that he was fatigued or experiencing health problems. There was no evidence of driver impairment from drugs or alcohol. Among similar carriers, Mullen Trucking's safety record was above average, and both US and Canadian federal authorities had exercised their oversight responsibilities with respect to ensuring Mullen Trucking's safety status. The bridge strike occurred approximately 2 hours before sunset on a clear May afternoon, and weather was not a factor. When NTSB investigators examined the 2010 Kenworth truck combination unit that had been transporting the oversize load, they found that its mechanical systems were not a factor in the bridge strike. Therefore, the NTSB concludes that none of the following were factors in the crash: (1) driver fatigue, (2) driver health, (3) driver impairment, (4) federal commercial vehicle oversight by the United States or Canada, (5) weather conditions, or (6) mechanical condition of the oversize combination vehicle.

2.1 Collision Sequence and Subsequent Bridge Span Collapse

The NTSB reconstructed the elements of the bridge span collapse by considering the physical configuration of the through-truss bridge structure, the evidence of the collision sequence, and the vehicle dynamics involved in this collision.

The surveillance video evidence available from businesses near the bridge showed that the oversize combination vehicle was traveling in the right lane and the 2000 Kenworth truck was in the left lane when it began its passing maneuver before reaching the bridge. Based on the video evidence, the oversize combination vehicle was calculated to be traveling about 60 mph, and the 2000 Kenworth truck's speed was calculated to be about 64 mph.⁵³

Damage patterns and paint transfers clearly showed that the load on the oversize combination vehicle struck the north portal and all the sway braces over the southbound lane in span 8, as well as five of the sway braces in span 7. Further, the shapes and positions of the impact damage to the oversize combination vehicle's load were consistent with the shapes of the damage to the bridge structure. Video evidence clearly showed the sequence of the collapse.

Based on the geometry of the oversize combination vehicle, its assumed position on the semitrailer (centered), and the damage to the north portal, the right edge of the oversize combination vehicle's load was 2 inches over the right edge lane marker (the fog line) as the vehicle entered the through-truss portion of the bridge. Because of the load's successive impacts with the north portal and the sway braces of span 8, as well as the bridge deck's movement, the oversize combination vehicle's movement became erratic. Its movements are indicated both by the damage patterns and by the paint transfer to the passing 2000 Kenworth truck. From the video evidence and damage patterns on the bridge structure, the NTSB concludes that the bridge span collapse sequence began when the oversize load struck sway brace 4 in span 8 on the west truss, causing deformation of the adjacent vertical member (L4-U4), which pulled the attached upper chord member (U3-U5) downward, causing a buckling failure in that upper chord member at node U4. The NTSB further concludes that, because the Skagit River Bridge was a non-load-path-redundant structure, buckling of the upper chord on the west truss resulted in the failure of the east truss and the collapse of span 8.

2.1.1 Clearance of the Oversize Load

The north portal and the sway braces that laterally traversed the highway defined the vertical clearance between the highway and the bridge structure. The average vertical clearances for the sway braces above the southbound roadway appear in table 3 (in section 1.6.3). Because vertical clearance measurements between similar locations on the sway braces for spans 5 through 7 were generally consistent, it is reasonable to assume that the collapsed span 8 had similar clearances.⁵⁴ The lowest vertical clearance across the southbound travel lanes was at the

⁵³ These speed calculations are ± 3 mph.

⁵⁴ Investigators took 280 measurements of the vertical heights of the sway braces. The difference between the minimum and maximum measured distance above similar locations along the bridge (edge barriers, lane markings, and lane midpoints) was no greater than 2.75 (2 3/4) inches with a standard deviation of less than 0.75 (3/4) inch from the average.

right edgeline and ranged from 15 feet 8 inches to 15 feet 11 inches (see table 3). The static height of the oversize combination vehicle, as measured by its driver, was 15 feet 9 inches.⁵⁵ Therefore, the NTSB concludes that the height of the casing shed load on the oversize combination vehicle was greater than the vertical clearance at the right edgeline of the southbound travel lanes on the Skagit River Bridge.

2.1.2 Lane Position of the Oversize Combination Vehicle

The travel lanes of I-5 narrowed from 12 feet to 11 feet 4 inches on the Skagit River Bridge.⁵⁶ Considering that the lane lines were approximately 4 inches wide, a vehicle could have an overall width of 11 feet 8 inches before physically intruding into the adjacent lane or shoulder. At a width of 11 feet 6 inches, the oversize load had only a 2-inch margin of error before extending over the shoulder or into the adjacent lane.⁵⁷ The driver of the oversize combination vehicle was concerned about the presence of the 2000 Kenworth truck that was passing his vehicle, which caused him to move to the right. As the lane narrowed on the bridge, his vehicle position was 2 inches onto the right shoulder, where the vertical clearance was lower than over the travel lanes.

To clear the vertical bridge structure, the 11-foot-6-inch-wide oversize load would have needed to intrude into the left travel lane a minimum of 21 inches.⁵⁸ Had Mullen Trucking taken into account the width and height of the load with respect to the restricted vertical clearance and the reduced lane width on the bridge, it would have realized that to ensure safe passage over the Skagit River Bridge, the oversize combination vehicle would need to travel near the middle of the roadway or in the left lane. To be assured of having such a transit position, control of traffic for both southbound through lanes would have been required. At a minimum, such an operation would have required notifying the driver of the oversize combination vehicle of this need before he reached the bridge and providing a trailing pilot/escort vehicle to control passing traffic. Although the state permit did not require a trailing pilot/escort vehicle for this portion of the route, the motor carrier could have chosen to provide one. Mullen Trucking made no provision for a second pilot/escort vehicle to accompany this oversize load. Therefore, the NTSB concludes that Mullen Trucking did not adequately consider the vertical clearance or the reduced width of the travel lanes on the Skagit River Bridge when planning the route of the oversize combination vehicle.

2.1.3 Lane Position of the Pilot/Escort Vehicle

A pilot/escort vehicle driver operating in Washington State has numerous responsibilities, which are outlined at WAC 468-38-100. With respect to checking the vertical clearance and lane width along the intended route of an oversize load, the WAC states that the pilot/escort vehicle

⁵⁵ Postcrash measurement determined that the height of the load was 15 feet 11 inches. However, measurements can be affected by the shifting of the load on the trailer, the positioning of the load on a flat surface, and the angle of measurement. Such considerations could also explain discrepancies between pre- and post-event measurements of the pilot/escort vehicle and its height pole.

⁵⁶ The highway lane width is measured between the centers of the pavement lines.

⁵⁷ Per RCW 46.44.010, the width limit on Washington State roads was 8 feet 6 inches; the oversize load was 3 feet wider than the vehicle width limit.

⁵⁸ To achieve 6 inches of overhead clearance, the intrusion would increase to about 45½ inches.

driver must discuss all aspects of the move with the oversize load driver. This responsibility includes conducting a prerun of the route, if necessary, to verify acceptable clearances. Additionally, while in transit, the pilot/escort vehicle driver must notify the operator of the oversize load vehicle of any condition that could affect the safe movement of the load or the safety of the motoring public, including obstructions, overhead clearances, and narrow lane widths/structures.

The pilot/escort vehicle driver did not provide any advance notice about the reduced overhead clearance or the narrow lane widths on the Skagit River Bridge to the driver of the oversize combination vehicle. Therefore, the NTSB concludes that by not communicating any information about the narrow lane widths on the bridge or the reduced overhead clearance in the right lane of travel to the oversize combination vehicle driver before they reached the Skagit River Bridge, the pilot/escort vehicle driver failed to fulfill the duties of a pilot/escort driver.

NTSB investigators examined the height pole connected to the front bumper of the pilot/escort vehicle. The pole was positioned at an inboard angle of about 5° and was set so that its highest point was 16 feet 2 inches above the road surface. Because of this orientation and mounting location, the top of the height pole was about 25 inches inboard of the right side of the pilot/escort vehicle.

Based on the measured geometries of the bridge and the height pole, the right tire of the pilot/escort vehicle would have to have traveled atop the right lane edgeline for the pole to have made contact with the sway brace. (See figure 19.)

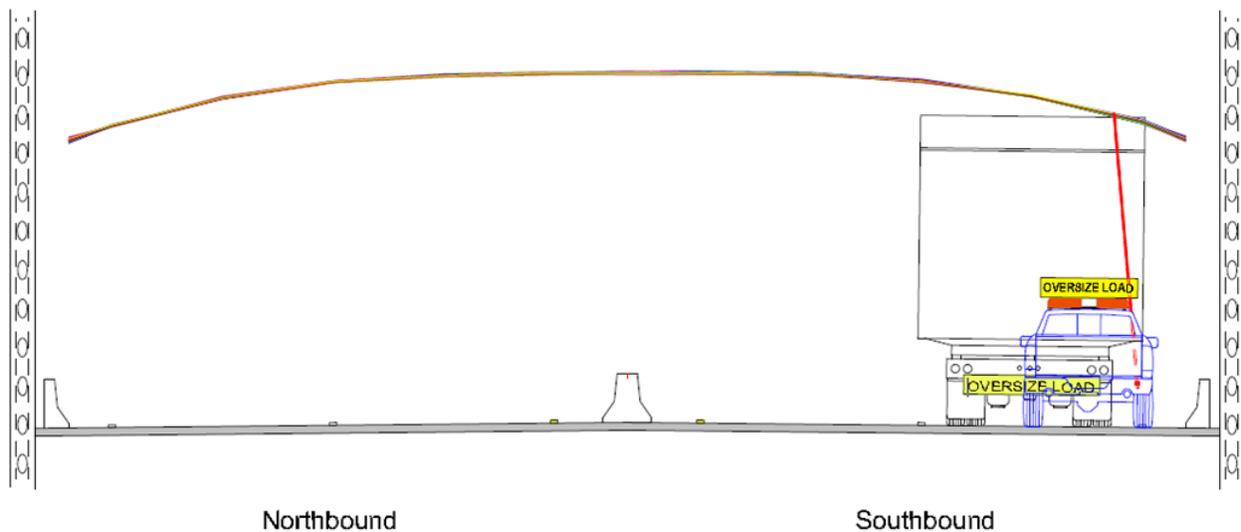


Figure 19. Image of the approximate position of the pilot/escort vehicle in the roadway necessary to ensure contact with the low-clearance sway braces.

When interviewed by NTSB investigators, the pilot/escort vehicle driver stated she was not sure where within the right lane she was traveling, but she believed she was in the center of the lane as she crossed the bridge. However, a Washington State Patrol on-scene statement form

for this crash included an officer's note that the pilot/escort vehicle driver indicated she was "trying to hug the fog line."

In a written statement, the pilot/escort vehicle driver said her vehicle's height pole did not strike the bridge. Investigators located and interviewed the driver of a 2001 Ford Ranger who had been traveling southbound on I-5 at the time of the collapse event. That driver held a CDL and worked as a part-time truck driver. That witness told investigators he was in the passing lane and had passed the oversize combination vehicle but had not overtaken the pilot/escort vehicle as they crossed the bridge. The witness stated he was looking at the pilot/escort vehicle and saw its height pole strike four or five bridge elements.

Cell phone records indicate that the pilot/escort vehicle driver was engaged in a cell phone conversation (using a hands-free headset) while her vehicle was approaching and crossing the Skagit River Bridge. She initially told an on-scene Washington State Patrol officer that she had not been on her phone. However, when interviewed by NTSB investigators, the pilot/escort vehicle driver admitted to having been on the phone. She told NTSB investigators she was conversing with her business partner (her husband) about the next day's routing of the oversize load; she was disturbed about a portion of that route that would involve escorting the load under a pedestrian bridge.

While it is not possible to determine with absolute certainty whether the height pole on the pilot/escort vehicle struck the bridge structure, the driver's cell phone conversation would have distracted her attention from her escort duties and diminished her ability to recognize whether the height pole struck the bridge. The NTSB concludes that the pilot/escort vehicle driver was distracted by her hands-free cell phone conversation, which reduced her attention to her escort duties.

2.1.4 Separation Distance and Ability to Stop or Change Lanes

A vehicle-mounted camera system in a Washington State Patrol car captured images of the pilot/escort vehicle and the oversize combination vehicle about 2.5 miles north of the Skagit River Bridge. The patrol car was traveling northbound, and the video captured clear images of the two vehicles traveling southbound in the right lane. Analysis of the imagery estimated the speed of the oversize combination vehicle as 53 mph (± 2 mph) and the following distance behind the pilot/escort vehicle as 395 feet (± 10 feet). Based on these estimates, the following time behind the pilot/escort vehicle was 5.09 seconds (± 0.32 sec). In addition to the video evidence, the pilot/escort vehicle operator stated she was trying to stay 4 to 5 seconds ahead of the oversize combination vehicle, a distance of about 325 to 425 feet, depending on speed.

To determine an appropriate separation distance, NTSB investigators reviewed the guidance provided by Washington State and by Mullen Trucking. Regulations for pilot/escort vehicles operating in the state, as reflected in WAC 468-38-100, require the pilot/escort vehicle driver to notify the oversize combination vehicle driver about any condition that could affect the safe movement of the load in sufficient time for the oversize load driver to take corrective action. The *Mullen Trucking LP Driver & Owner Operator Reference* states, "A pilot vehicle should travel between 300 to 1000 meters (1000 feet to 3280 feet) ahead of an over-dimensional vehicle."

Various factors, including vehicle weight and environmental conditions, affect a vehicle's braking distance, and braking distance is an important factor in determining the appropriate following distance between a vehicle transporting an oversize load and a pilot/escort vehicle. According to guidance provided in the student handbook for pilot/escort vehicle operators,⁵⁹ the calculations of the separation time and distance between the pilot/escort vehicle and the oversize combination vehicle, based on their speeds as they crossed the bridge, should have been about 10 seconds and 865 feet, respectively (Evergreen Safety Council 2012).⁶⁰ The NTSB concludes that even if the pilot/escort vehicle driver had communicated the reduced overhead clearance in the right lane to the oversize combination vehicle driver while she was on the bridge, she was not maintaining an adequate lead distance, and the oversize combination vehicle was following too closely, to provide sufficient time for the oversize combination vehicle to stop before reaching the low-clearance hazard.

2.1.5 Rear Visibility from the Oversize Combination Vehicle

The NTSB could not find any indications that the driver of the oversize combination vehicle intended to change lanes; moreover, he could not have done so safely while being passed by the 2000 Kenworth commercial truck. To complete a lane change safely, the driver of the oversize combination vehicle would have needed a clear view of potential conflicting traffic beside and immediately behind him. Regulatory requirements for rearview mirrors on large trucks are fairly basic, but Washington State law (RCW 46.37.400[1]) requires mirrors on the left (driver) and right (passenger) sides of the vehicle to provide the driver a rearward "view of the highway for a distance of at least 200 feet to the rear of ... vehicle."

In the case of the oversize combination vehicle, postcrash testing indicated that the left and right side flat (plane) mirrors on the tractor had significant blind spots in the driver's rearward field of view. A convex mirror on the left side of the tractor covered most of the blind spot to the left side of the vehicle, but this mirror's curvature made distance viewing challenging. Thus, the oversize combination vehicle driver's view of following traffic to the right of the oversize load was obstructed, and his view of following traffic to the left was distorted by the convex mirror; both of these factors could have negatively affected his ability to execute lane changes safely. In this case, a lane change would have significantly altered the situation. Had he moved his vehicle from the right lane to the left lane before transiting the bridge, his load would have had adequate vertical clearance and would not have struck the bridge. However, under the circumstances, his poor rearward visibility made such a lane change risky, without the assistance of a trailing pilot/escort vehicle that could have controlled following traffic before and during such a maneuver. Lacking both sufficient rear visibility and a trailing pilot/escort vehicle, the oversize combination vehicle could not have safely changed lanes. The NTSB concludes that had

⁵⁹ The *Pilot/Escort Vehicle Operator Handbook* provided by the Evergreen Safety Council states that the lead pilot/escort vehicle operator should not exceed a ½-mile lead (2,640 feet) of the permitted vehicle or be closer to it than a distance that could be covered in 4 seconds. It states that the separation distance should allow 1 second for every 10 feet of permitted vehicle length, plus an additional 1 second of distance for speeds of 40 mph and higher. It further states that a pilot/escort vehicle leading an overheight load must be far enough ahead to take critical measurements and communicate any problems to the oversize load driver while providing sufficient time for that driver to stop, change lanes, or maneuver through a hazard.

⁶⁰ The separation time is 9 seconds for the over 90-foot-long oversize vehicle plus 1 additional second for a travel speed above 40 mph, for a total of 10 seconds.

the driver of the oversize combination vehicle been able to move safely from the right to the left lane before reaching the bridge, it is likely that the vehicle would not have struck the bridge.

2.2 Permitting and Route Survey for Oversize Loads

2.2.1 Permitting Process

State and local jurisdictions establish the permit requirements for truck size, weight, designated routes, and conditions of travel. Both the standards and processes for issuing oversize/overweight permits vary by state. To receive federal funding, states may not unduly restrict freight travel, but federal regulations do not establish specific permit requirements.⁶¹ The WSDOT website for commercial vehicle services contains permit types and applications.⁶² It also has an online permitting system that allows authorized carriers to self-issue permits for oversize/overweight vehicles.

The permitting web page states that it is the carrier's responsibility to identify any hazards, such as low overhead clearance, along a proposed route of travel; and Washington, like many states, informs carriers that they should conduct route surveys before moving oversize loads to identify hazards but does not make it a requirement. Unless the state requires the carrier to submit a route survey as a condition of obtaining a permit, the carrier may choose whether to conduct a survey. In this instance, Mullen Trucking had a substantial history of moving oversize loads—on average twice a week—along the I-5 route. Conducting a route survey would have delayed transport, and the carrier decided that a survey was not needed based on its experience on that route. The NTSB concludes that a permitting process that enables a carrier to self-issue a permit via an online procedure, without engaging the state in any technical review of the requested permit, does not motivate carriers to conduct route surveys before transporting oversize loads.

Even had the carrier decided to conduct a route survey, it most likely would have done so using a pilot/escort vehicle equipped with a height pole to represent the oversize load. Regardless of how pilot/escort vehicle drivers place their height poles, a single point of measurement above the travel lane cannot capture the variable heights of arched structures or represent loads with varying height dimensions. The NTSB concludes that, given the inability of a height pole to represent a three-dimensional load across a lane of travel, conducting an effective route survey calls for using a mechanism that more accurately represents the dimensions of the intended load. Therefore, the NTSB recommends that AASHTO develop a method for replicating all the dimensions of an oversize load for use in pilot/escort vehicle operations. The NTSB further recommends that the American Association of Motor Vehicle Administrators (AAMVA) distribute to its members, and encourage the use of, the method developed by AASHTO in

⁶¹ Title 23 CFR Part 657 “Certification of Size and Weight Enforcement” and 23 CFR Part 658 “Truck Size, Weight and Route” contain regulations as they apply to the National Network of Highways, which includes the Interstate System plus other qualifying Federal-aid Primary System Highways. Title 23 CFR Part 658, appendix A, identifies the network by state; appendix C contains the size and weight provision by state.

⁶² See [WSDOT Commercial Vehicle Permits](#) and [WSDOT Online Permit Application Page](#), accessed July 15, 2014.

response to Safety Recommendation H-14-18 (above) for replicating all the dimensions of an oversize load for use in pilot/escort vehicle operations.

Mullen Trucking did not know the exact vehicle/load dimensions before the driver loaded the vehicle at the manufacturer's terminal. Once the vehicle was loaded and measured, the driver communicated the information to the company permit coordinator. Based on this information, the coordinator selected a route and submitted it via the online permitting process. Washington State issued the necessary permit through a Web transaction, and it cautioned that the state did not guarantee height clearances. The permit issued also stated "Route OK" for the I-5 segment.

The permit stated in three places that the state does not guarantee height clearances, and it required the use of one or two pilot/escort vehicles for some route segments. The permit contained no lane clearance information for any of the bridges on the route, and it included no restrictions as to which lanes the oversize vehicle must use. When issuing the permit, Washington State did not provide the carrier any critical assessment of the route based on the bridge clearance data it had compiled for the requested route of travel.

The instructions for the WSDOT bridge list advise users that drivers should check the "MIN" clearance column relative to the route and direction of the intended trip. They indicate that if the driver finds that the load's height is greater than the "MIN" clearance for any bridge but less than the "MAX" clearance, the load should be expected to clear the bridge, but the driver must determine the proper lane of travel. The bridge list data do not identify clearances by lane of travel and do not indicate that bridge list measurements include clearances over the shoulders.⁶³

Mullen Trucking had a full-time staff person responsible for obtaining and managing oversize load permits. That person either misinterpreted the clearance data for the Skagit River Bridge or failed to acquire and communicate needed clearance information to the driver of the oversize combination vehicle. The NTSB concludes that had Mullen Trucking studied and fully understood the clearance data on the bridge list, it might have identified the different vertical clearances for the lanes of travel on the Skagit River Bridge and defined a lane-specific route of travel for the oversize combination vehicle that would have enabled it to avoid striking the bridge. The bridge list data evidently were not sufficiently clear to Mullen Trucking to enable the carrier to determine the different clearances across travel lanes. The state is responsible for providing accurate and usable information about the vertical clearances of bridges and tunnels, which carriers rely on to judge the adequacy of their proposed routes. Therefore, the NTSB recommends that WSDOT revise its bridge list to provide lane-specific clearance data for all structures.

Because so many variations in routes and oversize loads are possible, Washington State takes the position that it is the carrier's responsibility to determine route clearance. However, the NTSB concludes that the protection of bridge infrastructure is too vital a state concern to leave the responsibility for assessing the risk associated with the transportation of oversize loads entirely with the motor carrier. Therefore, the NTSB recommends that WSDOT revise its permit

⁶³ As will be discussed in section 2.6, the height requirements that determine the necessity of posting low-clearance signs are measured over the travel lane.

process for commercial vehicle services to include a state evaluation of the route's overhead clearances and lane widths with respect to submitted load dimensions.

2.2.2 Oversize Load Procedures

Pilot/escort vehicle requirement. The Washington State permit for transporting the oversize load involved in this event required a lead pilot/escort vehicle but no trailing pilot/escort vehicle for the I-5 portion of the route. The state had posted no restrictions for the Skagit River Bridge (mile marker 228), despite the fact that lane width decreased 8 inches on the bridge, to 11 feet 4 inches, from the 12-foot-wide standard of the I-5 lanes north and south of the bridge.⁶⁴ Mullen Trucking chose not to employ a trailing pilot/escort vehicle, although this would have been a reasonable precaution, given the size of the load and the narrowed width of the travel lanes on the bridge. A trailing pilot/escort vehicle also would have made lane changes less difficult and less dangerous, given the limited rear visibility available to the oversize combination vehicle driver. Moreover, in 2007, Washington State had passed a Move Over Law, which was amended in 2010 to require drivers to yield the right-of-way by making a lane change when approaching emergency vehicles.⁶⁵ Had Mullen Trucking provided a trailing pilot/escort vehicle, the oversize combination vehicle would have been better prepared to make unexpected lane changes, in accordance with this law. The NTSB concludes that neither the state nor the motor carrier seemed aware of the necessity to take any precautions due to the lane width reduction on the Skagit River Bridge. Therefore, the NTSB recommends that WSDOT require both lead and trailing pilot/escort vehicles for any segment of a permitted route in which the permitted vehicle's dimensions are as wide as, or wider than, the travel lane.

Data changes underway. WSDOT has informed the NTSB that it is putting its bridge clearance data into a geospatial (rather than tabular) format and will be providing interactive maps, with the addition of application programming interfaces to facilitate use by third-party vendors. WSDOT also told the NTSB that it is working to include clearance information in its website process for the self-issuance of permits for oversize loads and to provide truck drivers with supplemental information about safe load routing. The NTSB commends WSDOT for beginning this important work and recommends that WSDOT provide a geospatial application for route-specific bridge clearance data as a component of the effort it has begun to improve the permit process for oversize loads.

2.3 Pilot/Escort Vehicle Operations, Guidelines, and Training

Like permit requirements for oversize vehicles, the requirements for pilot/escort vehicle operations vary by state, and many states require no specialized certification or training for this function. The primary purpose of the pilot/escort vehicle is to determine vertical clearance. In 2004, the SC&RA, in conjunction with several other transportation-related entities, including the FHWA and the CVSA, created the *Pilot Car Escort Best Practices Guidelines* to help standardize training and promote more uniform pilot/escort operations (SC&RA, FHWA, and

⁶⁴ This distance was 11 feet 4 inches measured to the centerline, compared to the 12-foot centerline distance approaching the bridge. Lane width between lines, from inside edgeline to inside edgeline, was 11 feet.

⁶⁵ RCW 46.61.212 defines the adjacent lanes of a roadway 200 feet before and after an emergency vehicle as an emergency zone.

CVSA 2004). These guidelines and the associated *Pilot Car Escort Training Manual* (FHWA, SC&RA, and CVSA 2004) were developed in response to the NTSB's 2001 report of an oversize load accident in Glendale, California (NTSB 2001). In this accident report, the NTSB issued safety recommendations to the FHWA and the FMCSA, in cooperation with a large group of industry associations, asking them to develop a model training program for pilot car drivers and model oversize/overweight vehicle movement guidelines.⁶⁶ The NTSB also asked the FHWA and AASHTO to encourage the states to adopt the model oversize/overweight vehicle movement guidelines.⁶⁷ The *Pilot Car Escort Best Practices Guidelines* have been widely distributed and are accepted as the industry standard for pilot/escort vehicle drivers.

2.3.1 State Certification and Training of Pilot/Escort Drivers

Pilot/escort vehicle operations are overseen at the state level. The Glendale report contained the following statements:

Pilot cars and escort vehicles help protect the traveling public, the infrastructure, and the oversized load itself. Pilot car drivers perform a safety-sensitive function and are an integral component of many oversize/overweight vehicle movements; consequently, it is important that they be trained and qualified.

One of the goals of the Glendale recommendations was to achieve uniformity of pilot/escort vehicle operations in terms of professional training and procedures among the states. When the NTSB completed the Glendale investigation in 2001, eight states had oversight procedures to ensure that pilot/escort vehicle drivers were trained and qualified. Today, the situation has improved, but only slightly; 12 states currently have certification requirements to train and qualify pilot/escort vehicle drivers.⁶⁸ The NTSB concludes that the lack of standardization of training for pilot/escort vehicle drivers among the states and the failure of the majority of states to require certification or training of such drivers leaves some pilot/escort vehicle drivers poorly prepared to carry out their duties. Pilot/escort vehicle drivers should be trained and qualified to operate in any state. Just as the drivers of vehicles transporting oversize loads need to work across state lines, so do the pilot/escort drivers who participate in oversize load transport teams. Carriers should not have to change escorts at state lines. Standardization of training for pilot/escort vehicle drivers would facilitate reciprocity among the states. Therefore, the NTSB recommends that AAMVA institute, with the assistance of AASHTO and the CVSA, a model training and certification process that includes reciprocity of certification in all 50 states, the District of Columbia, and the Commonwealth of Puerto Rico for drivers of pilot/escort vehicles, based on the *Pilot Car Escort Best Practices Guidelines*.

⁶⁶ Safety Recommendations H-01-31 and -33 were issued to the FHWA, the FMCSA, AASHTO, AAMVA, the California Professional Escort Car Association, the Texas Pilot Car Association, the United Safety Car Association, CVSA, and the SC&RA. The recommendation to AAMVA was classified "Closed—Acceptable Action;" for the remaining recipients, the recommendations were classified "Closed—Exceeds Recommended Action."

⁶⁷ Safety Recommendation H-01-34 was issued to the FHWA and AASHTO and was classified "Closed—Acceptable Action" for both recipients.

⁶⁸ Only the following states require some type of certification of pilot/escort vehicle drivers: Washington, Utah, Arizona, Colorado, Oklahoma, Georgia, Florida, Wisconsin, New York, North Carolina, Virginia, and Kansas. The other 38 states require no certification and collect no data concerning pilot/escort vehicle operations. For this reason, safety comparisons between those states with certification programs and those without such programs cannot be conducted.

2.3.2 Guidelines and Training Manual

During this investigation, investigators found that some parts of the *Pilot Car Escort Best Practices Guidelines* and the associated *Pilot Car Escort Training Manual* are in need of updating. Three areas surfaced for consideration: height pole placement in relation to load dimensions, low-clearance data on state bridge lists, and cell phone use.

Height pole placement. An illustration in the *Pilot Car Escort Best Practices Guidelines* shows the height pole on the left side of the pilot/escort vehicle, to the left of the driver's position (SC&RA, FHWA, and CVSA 2004, 11).⁶⁹ Yet in the associated training manual, the section concerning "Load Movement Preparation" states that "The preferred method of measuring overhead obstacles is at the lowest point of the travel lane." Neither the WAC, the *Pilot/Escort Vehicle Operator Handbook*, nor the *Pilot Car Escort Best Practices Guidelines* provide guidance for placing the height pole at the far edges of the load or for considering load-specific geometries that would require height poles to be more representative of the overall size of the load. Based on the conflicting and incomplete guidance found in these documents, the NTSB concludes that pilot/escort vehicle drivers would benefit from better and more consistent guidance about the setting and placement of height poles, with a focus on placement in relation to known obstacles. Specifically, pilot/escort vehicle drivers should be directed to consider all geometries of a given load, including its height and width. They should also be provided with examples of load shapes versus typical bridge or tunnel entries or other common hazards; given better guidance about how to measure bridge lanes over the width of a given load (not just at their midpoints); directed to base height pole placement on an evaluation of the overall size and shape of the load and possible hazards in the planned route; and provided specific guidance on the construction of height poles and mounts.

Bridge list clearance data. The discussion of vertical clearance in the *Pilot Car Escort Best Practices Guidelines* states the following (SC&RA, FHWA, and CVSA 2004, 15):

Some states, through their transportation departments, collect and make available roadway images and statistical data including vertical cross slope and horizontal geometry information that may be beneficial when preparing an over height route survey or escorting an over height load.

This advice is vague, and a pilot/escort vehicle driver could easily fail to notice it or even choose to ignore it. The NTSB concludes that pilot/escort vehicle drivers should be clearly directed to research the bridge clearance data for their route provided by state departments of transportation before undertaking any escort assignment.

Cell phone use by pilot/escort vehicle drivers. The pilot/escort vehicle driver was using her hands-free cell phone during her approach to and while crossing the Skagit River Bridge.⁷⁰ In the 30 minutes preceding the bridge strike, the pilot/escort driver was engaged in five cell phone

⁶⁹ Section 4.13.2 of the Washington State training manual for pilot/escort vehicle drivers, which uses the guidelines as the basis of its certification program, recommends that the height pole "be mounted on the left side of the escort vehicle to provide the operator visual alignment with the overhead obstruction." Section 4.13.3 states that the escort driver should measure (check the height of the obstruction) bridge lanes from their midpoints (that is, the midpoint of the roadway).

⁷⁰ RCW 46.61.667 prohibits the use of hand-held phones by drivers.

calls, which accounted for half of the driving time. The guidance in the *Pilot Car Escort Best Practices Guidelines* and associated documents was developed before concerns about driver distraction prompted the state of Washington to restrict drivers' use of hand-held portable electronic devices and before federal regulations were issued restricting commercial drivers' use of hand-held phones.⁷¹ The pilot/escort vehicle driver's use of a hands-free phone in this instance did not violate the regulations, but their enactment demonstrates the rising concern about the hazard posed by distracted driving. The NTSB maintains that the use of any portable electronic device while driving can be distracting. Moreover, the cognitive distraction experienced by the pilot/escort vehicle driver during her cell phone calls diminished her ability to identify hazards such as narrow lane widths, overhead clearances, and the sound or other perception of a height pole impact.⁷²

Pilot/escort vehicle drivers have more significant monitoring tasks than most other drivers do, given that they must operate their own vehicles while maintaining awareness of the height pole, the position and actions of the oversize vehicle they are escorting, and the risk posed to the oversize vehicle by obstructions along the route. Many states have enacted more stringent cell phone bans (for hand-held and hands-free operation) for novice drivers and passenger-carrying bus drivers, based on the recognition that such drivers face elevated safety risks. Pilot/escort drivers clearly also have elevated safety risks, as Washington State acknowledged by instituting the WAC prohibition against passengers and animals riding in pilot/escort vehicles during transport operations. The pilot/escort vehicle driver fulfills a safety-critical function that includes decision-making and communication tasks that require the driver's full attention. The NTSB concludes that, due to their special safety responsibilities, pilot/escort vehicle drivers should not engage in distracting activities and should be prohibited from using portable electronic devices (other than those designed to support the pilot/escort vehicle driving task) for nonemergency purposes, except to communicate safety-related information to the escorted vehicle. Therefore, the NTSB recommends that the 50 states, the District of Columbia, and the Commonwealth of Puerto Rico ban the nonemergency use by pilot/escort vehicle drivers of portable electronic devices (other than those designed to support the pilot/escort vehicle driving task), except to communicate safety-related information to the escorted vehicle.

The guidance documents for pilot/escort drivers may need improvement in additional areas beyond the three discussed above. The guidelines have not been updated for 10 years. The NTSB concludes that the *Pilot Car Escort Best Practices Guidelines* and related training materials would be improved by a thorough technical review to ensure that the information they contain reflects the most up-to-date recommended practices. Therefore, the NTSB recommends that the FHWA, the SC&RA, and the CVSA work together to revise the *Pilot Car Escort Best Practices Guidelines* and related training materials to ensure that they contain updated

⁷¹ See the [FMCSA Distracted Driving web page](#), accessed July 15, 2014. The federal final rule is at 76 *Federal Register* 75470.

⁷² The NTSB investigated a crash in 2004 with some similarity to this one with respect to cell phone distraction. In that crash, a driver with special responsibilities (a motorcoach driver) was distracted by use of a hands-free cell phone while transporting passengers on the George Washington Memorial Parkway in Alexandria, Virginia (NTSB 2006). In that crash, the driver was distracted by an agitated phone conversation with a relative concerning a work-related issue. The motorcoach driver was so distracted that he failed to move his vehicle from the right lane to the left lane, which resulted in the motorcoach's striking an arched bridge overpass.

recommended practices for pilot/escort vehicle operations, and disseminate the revised documents to groups that provide pilot/escort vehicle driver training.

2.4 Commercial Driver Operations for Transporting Oversize Loads

Currently, any driver with a CDL may transport a permitted oversize load. The circumstances of this crash illustrate both the complexity of oversize load operations and the coordination required between the oversize load driver and the pilot/escort vehicle driver. Pilot/escort driver training emphasizes that the pilot/escort driver should become part of a transport team working to move the oversize load safely; given that arrangement, the CDL driver has the role of team leader. However, CDL drivers are not required to have any specific training to transport oversize loads, either with respect to ensuring the safety of the load itself or to working effectively with the pilot/escort driver.

The investigation identified several shortcomings in the performance of the CDL driver. First, the driver did not know the clearances along his route. Although he may have been misled by the Mullen Trucking permit coordinator, who either did not adequately research the bridge list clearance information or did not communicate the vertical clearance restrictions by lane of travel, the driver of the oversize combination vehicle still had on-the-road responsibility for the load. A driver attempting to be both thorough and careful should have personally checked the route clearances.

Additionally, the driver was operating a vehicle that had a substantial limitation with respect to view of following traffic. As has already been noted, the driver should have had a rearward view of the highway for a distance of at least 200 feet. In this case, at that distance, the driver could not see two lane widths of following traffic. Although all oversize vehicles have some blind spots, a line-of-sight limitation of this magnitude called for a trailing pilot/escort vehicle to control passing traffic and to keep the CDL driver informed of traffic movements he could not see. Moreover, he did not make the best use of the leading pilot/escort vehicle available to him. The following distance the CDL driver maintained between his vehicle and the pilot/escort vehicle was inadequate to allow him to stop in time, should the leading pilot/escort vehicle report a clearance problem.

The investigation also indicated that the CDL driver did not fully understand one further aspect of the complicated operation of moving an oversize load. By shifting his vehicle to the right while being passed by the 2000 Kenworth truck, the driver of the oversize combination vehicle showed that he did not take sufficient account of the load's oversize width, especially given the bridge's narrowed lanes.⁷³

As indicated by the foregoing material, the bridge strike involved less than ideal performance on the part of the driver of the oversize combination vehicle in several areas specific to oversize load operations. The NTSB concludes that the circumstances of this bridge strike demonstrate that drivers conducting oversize load operations need special knowledge to plan safe routes, coordinate effectively with pilot/escort vehicles, and control and position oversize loads.

⁷³ Two signs preceding the bridge informed drivers of reduced lateral clearance on the bridge.

The FMCSRs at 49 CFR Part 383 set the requirements for CDLs. Specifically, 40 CFR 383.93, “Endorsements,” identifies special cases in which a CDL driver is required to take and pass specialized tests to obtain a license endorsement. Endorsements are required for CDL drivers to drive (1) double/triple trailers, (2) passenger vehicles, (3) tank vehicles, (4) vehicles carrying hazardous materials, and (5) school buses. Each endorsement has different testing requirements; some require only a knowledge test and some require both a knowledge and a skills test. In addition to its role in licensing, each state is responsible for establishing its own CDL endorsement requirements. CDL licensing requirements and endorsements differ by state, but most follow those outlined in the FMCSRs, as does Washington State. In addition to its CDL types based on the vehicle driven (A, B, and C), Washington State has five CDL endorsement categories (passenger, school bus, hazmat, double/triple trailers, and tank), as well as one that addresses a combination among those five (tank and hazmat). Washington State also has license restrictions (such as for airbrakes). But some states have adopted a larger set of CDL endorsements; for example, New York has 12 different endorsements, including those for driving tow trucks, transporting metal coils, and operating recreational vehicles with gross vehicle weight ratings of 26,000 pounds and higher.

A driver endorsement for special types of operations helps ensure that drivers are well prepared to carry out their duties safely. Requiring drivers of oversize loads to have an endorsement for such operations would better prepare them to perform challenging tasks safely. Therefore, the NTSB recommends that AAMVA develop, with assistance from the CVSA and the SC&RA, training and testing materials that address the challenges and unique operating characteristics of the transportation of oversize loads, and distribute the developed information to state licensing agencies to institute a CDL endorsement for oversize loads.

2.5 State Practices for High Load Bridge Strikes

2.5.1 High Load Bridge Strikes

WSDOT records for the Skagit River Bridge showed high load strikes on each of the routine bridge inspection reports dating back 10 years. The most recent routine inspection report prior to the collapse, dated August 25, 2012, documented eight high load strikes to the bridge. The WSDOT bridge damage inspection report dated November 29, 2012, documented a high load strike that resulted in structural damage and a priority 1 repair.

Table 4 (in section 1.6.3) provides an inventory of 15 reported high load strikes on through-truss bridges in Washington State from January 2008 through May 2013. During this period, the Hoquiam River–Simpson Bridge on US 101 (#1084A) was struck four times; the Elochoman River Bridge on State Highway 4 (#4999A) and the Skagit River Bridge (#4794A) were each struck twice; and seven other through-truss bridges were struck once. All these bridges have evidence of repeated high load bridge strikes and, based on a comparison of bridge damage reports and routine inspection records, the number of high load strikes is underreported.

Because of their design, non-load-path-redundant through-truss bridges are of particular concern, but they are not the only structures experiencing high load strikes. An inventory of high load strikes on all bridges in Washington State from January 2008 through May 2013 revealed

10 high load strikes that resulted in critical damage, 62 that resulted in a priority 1 repair, and 20 that caused minor damage.

Federal and state highway maintenance systems focus on inspecting and repairing the infrastructure; they appear to have no formal mechanism for identifying procedural and operational factors that correlate to high load bridge strikes and could provide a better understanding of the problem. The lack of focus on prevention is demonstrated by the repeated high load strikes to bridges in Washington State that took place from January 2008 through May 2013.

The WSDOT Bridge and Structures Office does not report bridge strike data to the state's Office of Commercial Services, which is responsible for issuing permits for oversize loads. A process of formal communication between these offices could result in operational changes designed to reduce high load bridge strikes. Bridge strike data could also be used to target and assess the effectiveness of countermeasures associated with permitting, such as requiring special permits for oversize loads routed over bridges that experience high numbers of strikes. WSDOT is not unique among states with respect to lack of communication and coordination between the state offices for bridges/structures and those for oversize load permitting. In general, state departments of transportation do not use bridge strike data to identify countermeasures and evaluate their effectiveness. The NTSB concludes that states are missing opportunities to reduce bridge strikes by not having formal processes to communicate bridge strike data from the department of transportation offices responsible for bridges and structures to the department of transportation offices responsible for permitting operations, and by not using such data to track the effectiveness of bridge strike countermeasures.

2.5.2 Countermeasures for High Load Bridge Strikes

Many states have installed active sign technology to reduce the number of high load strikes to their bridges by placing high load warning systems in advance of the exit immediately preceding the low-clearance structure. These systems are designed to alert drivers of overheight vehicles in time to enable them to detour safely before reaching the structure. Laser sensors activate flashing beacons to alert drivers of vehicles with overheight loads that they will not clear the overhead structure.

Sensing technology and mobile LIDAR. Many state departments of transportation geospatially inventory their highway assets and track maintenance and repair activities using location data. Kentucky has demonstrated the effective use of mobile LIDAR technology to measure the vertical clearance along the Western Kentucky Parkway (Rister, McIntosh, and Whelan 2013).⁷⁴ When researchers compared system measurements taken from moving vehicles via LIDAR to on-location field measurements, they found that the results were within 1.2 inches.

At a September 2013 meeting of the Survey, Mapping, and Geosciences Subcommittee of the Civil GPS Service Interface Committee, which is a functioning committee of GPS.gov, a representative of the Tennessee Department of Transportation indicated in a presentation that the

⁷⁴ LIDAR, which stands for "light detection and ranging," is a remote sensing technology that measures distance by illuminating a target with a laser and analyzing the reflected light.

state had found that by using terrestrial LIDAR measurements rather than traditional survey methods, it could reduce its survey work time by 64 percent (Waters 2013). Such technologies offer accurate and practical methods for maintaining route clearance data.

Vehicle-to-infrastructure systems. In March 2013, the FHWA released a “Concept of Operations” report that reviewed five connected vehicle-to-infrastructure safety applications (Stephens and others 2013). Roadway safety for oversize loads was one of the applications. These systems can provide wireless in-vehicle alerts if low-clearance bridges are equipped to communicate with intelligent vehicles. Intelligent navigation systems could also synchronize with permitting systems for oversize loads to provide improved route guidance for drivers transporting oversize loads.

Commercial route navigation systems. Given the availability of good sources of data on bridge clearances and the types of navigation systems that are increasingly present in the cabs of commercial vehicles, commercial vehicle navigation systems could be used to provide drivers with clearance heights for a designated route. System providers, like Nokia HERE, Google Inc., and Rand McNally are already collecting their own real-world data for commercial vehicle operations.⁷⁵ Because these data are customized for commercial operations, such systems cost more than most navigation devices designed for personal use. Incentives could help to ensure that oversize load carriers adopt navigation systems with data customized for their operations. States could provide that incentive through the permitting process. The NTSB concludes that adding roadway clearance data to navigation systems on commercial motor vehicles would be a direct and efficient method of providing drivers with safe route information for oversize loads. Therefore, the NTSB recommends that Nokia HERE, Google Inc., and Rand McNally develop reliable clearance data for highway structures, and incorporate that data into commercial vehicle navigation systems to help improve the routing and permitting of oversize loads.

Examples of international countermeasures. A survey of the staff of the FHWA’s Office of Bridges and Structures conducted in February 2014 revealed no specific practices among the states for addressing bridge strikes. Bridge strikes are handled as they arise and on a case-by-case basis. Yet other countries have used countermeasures to prevent bridge strikes. In response to bridge strikes, the United Kingdom has installed black and yellow hazard markings to highlight the vulnerable part of the structure. To raise awareness of the risk and consequences of bridge strikes in the United Kingdom, organizations representing local authorities, bridge owners, and the private sector have produced “good practice” guides to help reduce high load bridge strikes. Alberta, Canada, has reduced its high load bridge strikes by developing a three-level system of safety measures. Australia has taken an innovative approach to reducing strikes at a tunnel in Sydney by developing a warning mechanism that projects the image of a stop sign onto a curtain of water when an overheight vehicle approaches the tunnel opening. The NTSB concludes that state and local jurisdictions and the commercial motor vehicle industry would benefit from additional and improved guidance about the risks of high load strikes and the countermeasures that could help prevent them.

⁷⁵ Nokia acquired the electronic mapping company NAVTEQ in 2007/2008, and the company was fully merged into Nokia in 2011 to form part of its HERE business unit.

Therefore, given the current lack of useful communication and coordination among the states concerning bridge strike data and the promising prospects for providing effective countermeasures to reduce bridge strikes, the NTSB recommends that the FHWA develop a best practices guide that the states can use to prevent bridge strikes by overheight vehicles. At a minimum, the guide should include (1) a framework for collecting bridge strike data and for ensuring communication of these data among the state agencies responsible for conducting bridge inspections and those responsible for issuing oversize load permits, to support the development of countermeasures; (2) practices for using the data to develop operational changes; (3) methods for evaluating bridge strike countermeasures; and (4) a review of countermeasures that have proven effective in reducing the number of bridge strikes by overheight vehicles in the states and in other countries.

2.6 Requirements for Low-Clearance Signage

2.6.1 Low-Clearance Signage Installation

Washington State has 22 through-truss bridges on its Interstate System; none are posted with low-clearance signs. Three of those bridges have about the same minimum vertical clearances over the travel lanes as the Skagit River Bridge.⁷⁶ Eight through-truss bridges on the interstates have minimum vertical clearances over the travel lanes of 15 feet 11 inches or less, meaning that the oversize load involved in the May 23, 2013, strike at the Skagit River Bridge might not have cleared those eight bridges if it had been traveling in their right lanes.⁷⁷

An NTSB survey (see appendix B) revealed that the policies in 18 states would have required the installation of low-clearance signs on the Skagit River Bridge. Low-clearance signs represent the state's last direct opportunity to warn the driver of a vehicle transporting an oversize load of an impending bridge strike, and studies have shown that the installation of clearance signage reduces the incidence of high load strikes. The NTSB concludes that low-clearance signs in advance of and on bridges and tunnels provide valuable warnings to drivers of vehicles carrying overheight loads to help them avoid striking overhead obstructions.

The statutory maximum vehicle heights for highway vehicles have increased over the years. In 1952, the majority of states limited vehicles to a maximum height of 12 feet 6 inches. Today, 19 states and Puerto Rico have a maximum height limit of 14 feet or greater. (Refer to figure 18 and appendix B for the current statutory maximum vehicle heights and low-clearance signage requirements among the states.) Bridges constructed prior to the 1960s were designed to a different standard than bridges today and are vulnerable to collision by overheight vehicles if they are not properly signed for low vertical clearance.

The requirement in the MUTCD concerning vertical clearance signage calls for the posting of low-clearance signage when the clearance is within 12 inches of the maximum vehicle height set by the state. The language for the low-clearance signage requirements in the current (2009) MUTCD has not changed since the 1961 edition.

⁷⁶ These three bridges have the following structure identification numbers: 11757A, 11757B, and 4856A.

⁷⁷ These eight bridges have the following structure identification numbers: 4367A, 4367B, 11757A, 11757B, 4856A, 6123B, 6123C, and PR.

The AASHTO policy for new bridge designs, as expressed in the Green Book from 1984 (first edition) through 2011, has been to adopt an absolute minimum vertical clearance of 16 feet for all overhead structures. Particular to through-truss structures for new bridge designs, the AASHTO policy states that vertical clearance should be a minimum of 17 feet. From the 1994 first edition through the 2012 sixth edition, the AASHTO *LRFD Bridge Design Specifications* have expressed the policy that the vertical clearance from the roadway to the overhead cross bracing of through-truss structures should not be less than 17.5 feet.⁷⁸ Given that the MUTCD does not reflect these changes in AASHTO policy concerning minimum vertical clearances, the NTSB concludes that the MUTCD has not been kept consistent with the revised AASHTO policy concerning bridge clearances. Therefore, the NTSB recommends that the FHWA and AASHTO work together to amend the MUTCD, in accordance with *A Policy on Geometric Design of Highways and Streets* and the *LRFD Bridge Design Specifications*, to include a requirement for low-clearance signage for highway structures that cross over a roadway. The requirement should provide a uniform minimum clearance height between the roadway and the bottom of the structure which, if not met, necessitates the installation of low-clearance signage. The NTSB also recommends that the FHWA notify the state departments of transportation of the circumstances of the collapse of the Skagit River Bridge span, and create a timetable for those states that need to change their low-clearance signage requirements to conform to the uniform minimum clearance requirement proposed in Safety Recommendation H-14-9 (above).

2.6.2 Signage for Arched Bridges

Following the NTSB investigation of a motorcoach bridge strike in Alexandria, Virginia (NTSB 2006), the National Park Service developed a low-clearance sign depicting a motorcoach bus in the right lane striking a stone arched bridge overpass, with a supplementary sign indicating that all buses should stay in the left lane while traveling under the arched bridge. Other countries have developed signs specific to arched overpasses. The United Kingdom developed a sign for the approach to an arched bridge that conveys that overheight vehicles should use the middle of the road while traveling underneath the bridge. The MUTCD does not contain a warning sign indicating the proper lane of travel for overheight vehicles traveling under an arched structure. For the same reasons that other countries and the National Park Service have developed signs specific to arched overpasses, the NTSB concludes that drivers of overheight vehicles would benefit from having a warning sign that indicates the proper lane of travel for their vehicles when traveling underneath an arched structure. Therefore, the NTSB recommends that the FHWA include in the MUTCD a requirement for signage indicating the proper lane of travel for overheight vehicles traveling under an arched structure.

⁷⁸ Appendix C provides a chronology of AASHO and AASHTO guidance on vertical clearance of highway structures.

3. Conclusions

3.1 Findings

1. None of the following were factors in the crash: (1) driver fatigue, (2) driver health, (3) driver impairment, (4) federal commercial vehicle oversight by the United States or Canada, (5) weather conditions, or (6) mechanical condition of the oversize combination vehicle.
2. The bridge span collapse sequence began when the oversize load struck sway brace 4 in span 8 on the west truss, causing deformation of the adjacent vertical member (L4–U4), which pulled the attached upper chord member (U3–U5) downward, causing a buckling failure in that upper chord member at node U4.
3. Because the Skagit River Bridge was a non-load-path-redundant structure, buckling of the upper chord on the west truss resulted in the failure of the east truss and the collapse of span 8.
4. The height of the casing shed load on the oversize combination vehicle was greater than the vertical clearance at the right edgeline of the southbound travel lanes on the Skagit River Bridge.
5. Mullen Trucking LP did not adequately consider the vertical clearance or the reduced width of the travel lanes on the Skagit River Bridge when planning the route of the oversize combination vehicle.
6. By not communicating any information about the narrow lane widths on the bridge or the reduced overhead clearance in the right lane of travel to the oversize combination vehicle driver before they reached the Skagit River Bridge, the pilot/escort vehicle driver failed to fulfill the duties of a pilot/escort driver.
7. The pilot/escort vehicle driver was distracted by her hands-free cell phone conversation, which reduced her attention to her escort duties.
8. Even if the pilot/escort vehicle driver had communicated the reduced overhead clearance in the right lane to the oversize combination vehicle driver while she was on the bridge, she was not maintaining an adequate lead distance, and the oversize combination vehicle was following too closely, to provide sufficient time for the oversize combination vehicle to stop before reaching the low-clearance hazard.
9. Had the driver of the oversize combination vehicle been able to move safely from the right to the left lane before reaching the bridge, it is likely that his vehicle would not have struck the bridge.

10. A permitting process that enables a carrier to self-issue a permit via an online procedure, without engaging the state in any technical review of the requested permit, does not motivate carriers to conduct route surveys before transporting oversized loads.
11. Given the inability of a height pole to represent a three-dimensional load across a lane of travel, conducting an effective route survey calls for using a mechanism that more accurately represents the dimensions of the intended load.
12. Had Mullen Trucking LP studied and fully understood the clearance data on the bridge list, it might have identified the different vertical clearances for the lanes of travel on the Skagit River Bridge and defined a lane-specific route of travel for the oversized combination vehicle that would have enabled it to avoid striking the bridge.
13. The protection of bridge infrastructure is too vital a state concern to leave the responsibility for assessing the risk associated with the transportation of oversized loads entirely with the motor carrier.
14. Neither the state nor the motor carrier seemed aware of the necessity to take any precautions due to the lane width reduction on the Skagit River Bridge.
15. The lack of standardization of training for pilot/escort vehicle drivers among the states and the failure of the majority of states to require certification or training of such drivers leaves some pilot/escort vehicle drivers poorly prepared to carry out their duties.
16. Pilot/escort vehicle drivers would benefit from better and more consistent guidance about the setting and placement of height poles, with a focus on placement in relation to known obstacles.
17. Pilot/escort vehicle drivers should be clearly directed to research the bridge clearance data for their route provided by state departments of transportation before undertaking any escort assignment.
18. Due to their special safety responsibilities, pilot/escort vehicle drivers should not engage in distracting activities and should be prohibited from using portable electronic devices (other than those designed to support the pilot/escort vehicle driving task) for nonemergency purposes, except to communicate safety-related information to the escorted vehicle.
19. The *Pilot Car Escort Best Practices Guidelines* and related training materials would be improved by a thorough technical review to ensure that the information they contain reflects the most up-to-date recommended practices.
20. The circumstances of this bridge strike demonstrate that drivers conducting oversized load operations need special knowledge to plan safe routes, coordinate effectively with pilot/escort vehicles, and control and position oversized loads.
21. States are missing opportunities to reduce bridge strikes by not having formal processes to communicate bridge strike data from the department of transportation offices

responsible for bridges and structures to the department of transportation offices responsible for permitting operations, and by not using such data to track the effectiveness of bridge strike countermeasures.

22. Adding roadway clearance data to navigation systems on commercial motor vehicles would be a direct and efficient method of providing drivers with safe route information for oversize loads.
23. State and local jurisdictions and the commercial motor vehicle industry would benefit from additional and improved guidance about the risks of high load strikes and the countermeasures that could help prevent them.
24. Low-clearance signs in advance of and on bridges and tunnels provide valuable warnings to drivers of vehicles carrying overheight loads to help them avoid striking overhead obstructions.
25. The *Manual on Uniform Traffic Control Devices for Streets and Highways* has not been kept consistent with the revised American Association of State Highway and Transportation Officials policy concerning bridge clearances.
26. Drivers of overheight vehicles would benefit from having a warning sign that indicates the proper lane of travel for their vehicles when traveling underneath an arched structure.

3.2 Probable Cause

The National Transportation Safety Board determines that the probable cause of the Interstate 5 Skagit River Bridge span collapse was a strike to the bridge structure by an oversize combination vehicle that failed to travel in a lane with adequate overhead clearance due to deficiencies in the interdependent system of safeguards for oversize load movements. These deficiencies included (1) insufficient route planning by Mullen Trucking LP and the oversize combination vehicle driver; (2) failure of the certified pilot/escort vehicle driver to perform required duties and to communicate potential hazards, due in part to distraction caused by cell phone use; and (3) inadequate evaluation of oversize load permit requests and no provision of low-clearance warning signs in advance of the bridge by the Washington State Department of Transportation.

4. Recommendations

Based on its investigation, the NTSB makes the following new safety recommendations.

To the Federal Highway Administration:

Develop a best practices guide that the states can use to prevent bridge strikes by overheight vehicles. At a minimum, the guide should include (1) a framework for collecting bridge strike data and for ensuring communication of these data among the state agencies responsible for conducting bridge inspections and those responsible for issuing oversize load permits, to support the development of countermeasures; (2) practices for using the data to develop operational changes; (3) methods for evaluating bridge strike countermeasures; and (4) a review of countermeasures that have proven effective in reducing the number of bridge strikes by overheight vehicles in the states and in other countries. (H-14-8)

Work with the American Association of State Highway and Transportation Officials to amend the *Manual on Uniform Traffic Control Devices for Streets and Highways*, in accordance with *A Policy on Geometric Design of Highways and Streets* and the *Load and Resistance Factor Design Bridge Design Specifications*, to include a requirement for low-clearance signage for highway structures that cross over a roadway. The requirement should provide a uniform minimum clearance height between the roadway and the bottom of the structure which, if not met, necessitates the installation of low-clearance signage. (H-14-9)

Notify the state departments of transportation of the circumstances of the collapse of the Skagit River Bridge span, and create a timetable for those states that need to change their low-clearance signage requirements to conform to the uniform minimum clearance requirement proposed in Safety Recommendation H-14-9. (H-14-10)

Include in the *Manual on Uniform Traffic Control Devices for Streets and Highways* a requirement for signage indicating the proper lane of travel for overheight vehicles traveling under an arched structure. (H-14-11)

To the Federal Highway Administration, the Specialized Carriers & Rigging Association, and the Commercial Vehicle Safety Alliance:

Work together to revise the *Pilot Car Escort Best Practices Guidelines* and related training materials to ensure that they contain updated recommended practices for pilot/escort vehicle operations, and disseminate the revised documents to groups that provide pilot/escort vehicle driver training. (H-14-12)

To the 50 states, the District of Columbia, and the Commonwealth of Puerto Rico:

Ban the nonemergency use by pilot/escort vehicle drivers of portable electronic devices (other than those designed to support the pilot/escort vehicle driving task), except to communicate hazard-related information to the escorted vehicle. (H-14-13)

To the Washington State Department of Transportation:

Revise your bridge list to provide lane-specific clearance data for all structures. (H-14-14)

Revise your permit process for commercial vehicle services to include a state evaluation of the route's overhead clearances and lane widths with respect to submitted load dimensions. (H-14-15)

Require both lead and trailing pilot/escort vehicles for any segment of a permitted route in which the permitted vehicle's dimensions are as wide as, or wider than, the travel lane. (H-14-16)

Provide a geospatial application for route-specific bridge clearance data as a component of the effort you have begun to improve the permit process for oversize loads. (H-14-17)

To the American Association of State Highway and Transportation Officials:

Develop a method for replicating all the dimensions of an oversize load for use in pilot/escort vehicle operations. (H-14-18)

Work with the Federal Highway Administration to amend the *Manual on Uniform Traffic Control Devices for Streets and Highways*, in accordance with *A Policy on Geometric Design of Highways and Streets* and the *Load and Resistance Factor Design Bridge Design Specifications*, to include a requirement for low-clearance signage for highway structures that cross over a roadway. The requirement should provide a uniform minimum clearance height between the roadway and the bottom of the structure which, if not met, necessitates the installation of low-clearance signage. (H-14-19)

To the American Association of Motor Vehicle Administrators:

Distribute to your members, and encourage the use of, the method developed by the American Association of State Highway and Transportation Officials in response to Safety Recommendation H-14-18 for replicating all the dimensions of an oversize load for use in pilot/escort vehicle operations. (H-14-20)

Institute, with the assistance of the American Association of State Highway and Transportation Officials and the Commercial Vehicle Safety Alliance, a model training and certification process that includes reciprocity of certification in all 50 states, the District of Columbia, and the Commonwealth of Puerto Rico for drivers of pilot/escort vehicles, based on the *Pilot Car Escort Best Practices Guidelines*. (H-14-21)

Develop, with assistance from the Commercial Vehicle Safety Alliance and the Specialized Carriers & Rigging Association, training and testing materials that address the challenges and unique operating characteristics of the transportation of oversize loads, and distribute the developed information to state licensing agencies to institute a commercial driver's license endorsement for oversize loads. (H-14-22)

To the American Association of State Highway and Transportation Officials and the Commercial Vehicle Safety Alliance:

Assist the American Association of Motor Vehicle Administrators in instituting a model training and certification process that includes reciprocity of certification in all 50 states, the District of Columbia, and the Commonwealth of Puerto Rico for drivers of pilot/escort vehicles, based on the *Pilot Car Escort Best Practices Guidelines*. (H-14-23)

To the Commercial Vehicle Safety Alliance and the Specialized Carriers & Rigging Association:

Assist the American Association of Motor Vehicle Administrators in developing training and testing materials that address the challenges and unique operating characteristics of the transportation of oversize loads, and distribute the developed information to state licensing agencies to institute a commercial driver's license endorsement for oversize loads. (H-14-24)

To Nokia HERE, Google Inc., and Rand McNally:

Develop reliable clearance data for highway structures, and incorporate that data into commercial vehicle navigation systems to help improve the routing and permitting of oversize loads. (H-14-25)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

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Adopted: July 15, 2014

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Appendix A. Investigation

The National Transportation Safety Board (NTSB) received notification of this collision on May 23, 2013, and launched investigators to address motor carrier, survival factors, human factors, vehicle, and highway issues.

The NTSB team included staff from the Office of Transportation Disaster Assistance and support staff from the Offices of Public Affairs, Government Affairs, and Research and Engineering. Then-Chairman Hersman was the spokesperson on scene.

The Washington State Department of Transportation, the Washington State Patrol, the Federal Highway Administration, the Federal Motor Carrier Safety Administration, and Mullen Trucking LP were parties to the investigation.

The NTSB held no public hearing in connection with this collision, and no depositions were taken.

Appendix B. Statutory Maximum Vehicle Height and Low-Clearance Signage Requirements by State

State	Statutory Maximum Vehicle Height	Low-Clearance Signage Requirements
Alabama	13' 6"	Less than 16' 0" – sign on structure.
Alaska	15' 0"	17' 0" or less – sign on structure. 16' 0" or less – sign on structure and advance warning sign at advance warning distance. 14' 6" or less – sign on structure and advance warning sign at advance warning distance and at 1 st upstream intersection.
Arizona	14' 0"	Less than 16' 0" and above 14' 6" – adjusted low-clearance sign on structure. 14' 6" or less – sign on structure and low-clearance sign installed on both sides of each approaching roadway in advance of the exit immediately preceding the structure (on freeways).
Arkansas	13' 6"	15' 0" or less.
California	14' 0"	15' 6" or less – sign on structure and two advance low-clearance signs shall be installed on the right side of the roadway. The first sign shall be placed in advance of the nearest intersecting street or highway or wide point in the road at which a motorist can detour or safely turn around. The second sign shall be placed in advance of the structure.
Colorado	14' 6"	15' 6" or less.
Connecticut	13' 6"	Whenever a restricted clearance of 14' 2" or less is identified, immediate action shall be taken to have signs installed warning motorists of the vertical clearance limitations. Low-clearance signs are typically installed in advance of the bridge and on the bridge fascia.
Delaware	13' 6"	Less than 14' 6".
Florida	13' 6"	14' 6" or less – low-clearance sign shall be placed in advance of every bridge or structure. 13' 6" or less – low-clearance sign or marking shall also be placed on the bridge beam or equivalent of every bridge or structure.
Georgia	13' 6"	Less than 14' 6".
Hawaii	14' 0"	Less than 17' 0" (on freeways).
Idaho	14' 0"	16' 0" or less – sign on structure and low-clearance sign should be used in advance of low bridges, underpasses, and other overhead structures where the sight distance to the overhead structure is restricted.
Illinois	13' 6"	Less than 14' 6" – sign on structure. Less than 14' 0" – sign on structure and low-clearance sign shall be erected in advance of the structure. Less than 13' 6" – sign on structure and advance sign consisting of a ___ miles ahead plate mounted beneath the low-clearance sign should be provided. This sign should be erected at a junction in advance of the structure that will permit a driver of a critical vehicle to choose an alternate route with a minimum of inconvenience.

State	Statutory Maximum Vehicle Height	Low-Clearance Signage Requirements
Indiana	13' 6"	Less than 14' 6" – low-clearance warning sign should be provided for each structure.
Iowa	13' 6"	14' 9" or less – sign on structure. 13' 9" or less – sign on structure and low-clearance sign with a supplemental distance plaque shall also be placed at the nearest intersecting road at which a vehicle can detour or turn around.
Kansas	14' 0"	Any opening with the lowest vertical under clearance measuring less than 15' 9" – sign on structure as well as advance warning signs.
Kentucky	13' 6"	Less than 14' 6".
Louisiana	13' 6"	Less than 14' 6" – low-clearance sign shall be placed on the structure. If this sign cannot be placed on the structure then the low-clearance sign shall be placed on the ground in advance of the structure. Low-clearance sign with a distance ahead plaque shall be placed at the nearest intersecting road where a vehicle can detour or turn around.
Maine	13' 6"	Less than 14' 6".
Maryland	13' 6"	All overpasses less than 14' 6" in height above the roadway surface shall have a sign denoting the height above the roadway. Any structure that has a posted height limitation has a detour route sign in the field so that vehicles exceeding the limit can detour before being confronted with the height limitation.
Massachusetts	13' 6"	Less than 14' 6".
Michigan	13' 6"	Low-clearance signs are to be present for structures with under clearance of 16' 0" or less.
Minnesota	13' 6"	Less than 14' 6".
Mississippi	13' 6"	Less than 14' 6".
Missouri	14' 0"	15' 0" or less but more than 13' 6" – sign on structure and shoulder-mounted low-clearance sign shall be placed about 750 feet in advance of the structure. 13' 6" or less – sign on structure, shoulder-mounted low-clearance sign shall be placed about 750 feet in advance of the structure, and low-clearance sign shall be placed at the nearest intersecting road or wide point in the road at which a vehicle can detour or turn around.
Montana	14' 0"	Low-clearance signs should be installed along Interstate facilities in advance of and at any structure that has a vertical clearance of 16' 0" or less.
Nebraska	14' 6"	Low-clearance signs shall be installed on all structures on the state highway system with an overhead clearance of less than 15' 6".
Nevada	14' 0"	Greater than 15' 1" but less than 16' 0" – sign on structure if history of high load strikes. 14' 1" to 15' 0" – sign on structure. 14' 0" and under – sign on structure and advance low-clearance sign.

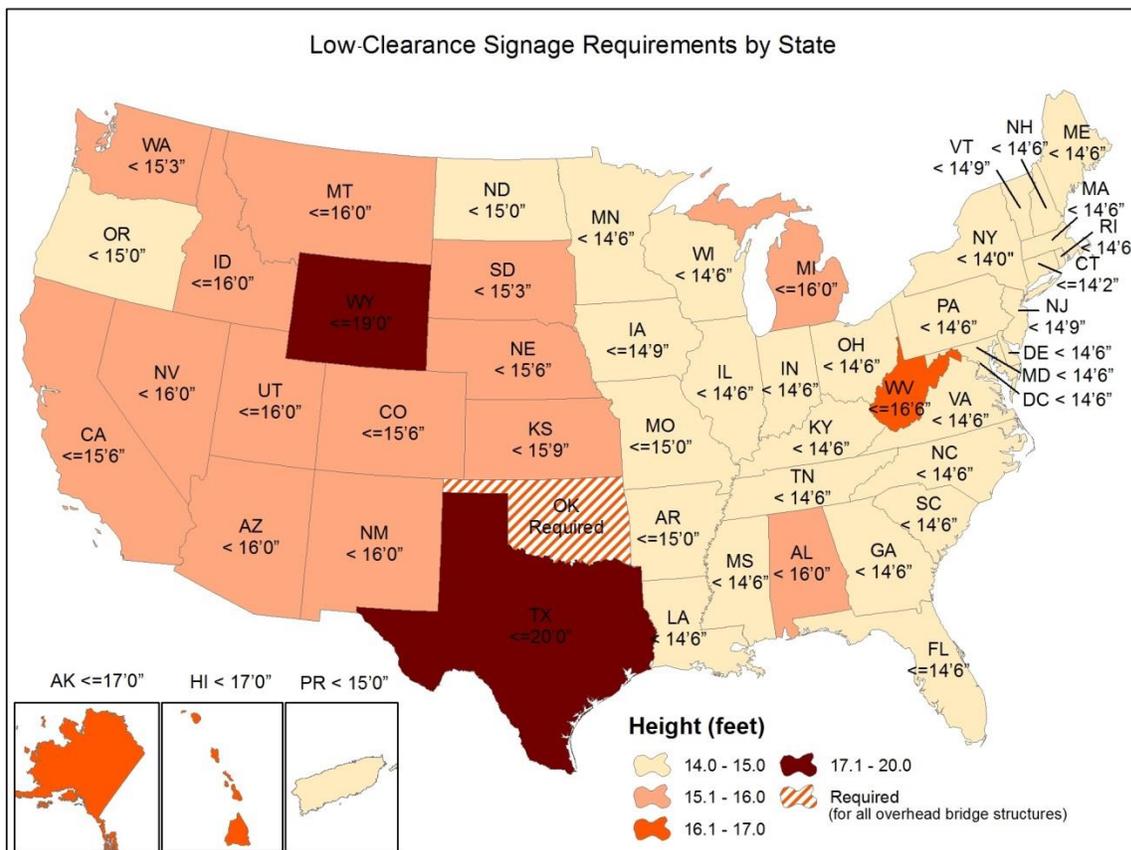
State	Statutory Maximum Vehicle Height	Low-Clearance Signage Requirements
New Hampshire	13' 6"	Less than 14' 6".
New Jersey	13' 6"	All owned bridges (which includes interstates) with a minimum vertical distance of less than 14' 9" are required to be posted for vertical clearance.
New Mexico	14' 0"	A vertical clearance sign denoting the minimum vertical clearance shall be posted for overhead structures with a minimum vertical clearance of less than 16' 0".
New York	13' 6"	Regulatory clearance signs shall be used to indicate legal overhead clearances at bridges and elevated structures when measured overhead clearance is less than 14' 0". Such legal overhead clearance shall be one foot less than the measured clearance (the vertical distance between the traveled portion of the roadway and the overhead structure).
North Carolina	13' 6"	Less than 14' 6". Where the clearance is less than the legal limit, a sign to that effect should be placed at the nearest intersecting road or wide point in the road at which a vehicle can detour or turn around. In the case of an arch or other structure under which the clearance varies greatly, two or more signs should be used as necessary on the structure itself, to give information as to the clearance over the entire roadway.
North Dakota	14' 0"	Less than 15' 0".
Ohio	13' 6"	The low-clearance sign shall be used to warn road users of clearances less than 14' 6".
Oklahoma	13' 6"	All overhead bridge structures on the State Highway system shall have minimum clearance posted on both sides of the structure. In addition, all minimum clearance shall be posted with an advance warning sign bearing the legend LOW-CLEARANCE __ FT. __ IN. when the clearance is less than 15' 0". Where the vertical clearance is 15' 0" or greater to the lowest point of the structure, advance warning signs need not be posted.
Oregon	14' 0"	The low-clearance sign is intended to warn motorists of clearances less than 15' 0" between the roadway or the shoulder and the structure. The sign shall be mounted on the structure and shall consist of the low-clearance dimension and an arrow directed at the low-clearance point. This sign shall always be used in conjunction with the "low-clearance" sign or the "low clearance on shoulder" x FT x IN sign.
Pennsylvania	13' 6"	The low-clearance sign may be used on bridges, underpasses, and other overhead structures where vertical clearance is less than 14' 6". When used, the low-clearance sign should be mounted overhead, generally directly above the roadway. In the case of an arch or other structure under which the clearance varies greatly, two or more signs should be used as necessary to give information as to the clearance over the entire roadway.
Rhode Island	13' 6"	Less than 14' 6".
South Carolina	13' 6"	The use of low-clearance signs should be in accordance with Section 2C.27 of the MUTCD.

State	Statutory Maximum Vehicle Height	Low-Clearance Signage Requirements
South Dakota	14' 0"	A low-clearance sign indicating low overhead clearance and showing the exact amount of clearance, less a 3" buffer, shall be used at low bridges, underpasses, tunnels, and other overhead structures where the measured clearance is less than 15' 3".
Tennessee	13' 6"	Less than 14' 6" across the width of the travel lanes.
Texas	14' 0"	The () FT () IN clearance sign should be used on or at every structure that spans a State-maintained roadway, except overhead sign structures, to show the vertical clearance up to 20' 0". Vertical clearances greater than 20' 0" are not required to be signed. On expressways and freeways, the low-clearance sign should be erected far enough in advance of an exit ramp in advance of the structure to enable a vehicle or load higher than the signed clearance to detour around the structure if it is less than 20' 0".
Utah	14' 0"	16' 0" or less.
Vermont	13' 6"	Less than 14' 9".
Virginia	13' 6"	14' 4" to 14' 5" – sign at structure shall be installed. 13' 6" to 14' 3" – sign at structure and sign at least 1500 feet in advance of structure shall be installed; and sign in advance of last alternate route and sign 150 feet past the last alternate route should be installed. Less than 13' 6" – sign at structure, sign at least 1500 feet in advance of structure, and sign in advance of last alternate route shall be installed; and sign 150 feet past the last alternate route may be installed.
Washington	14' 0"	14' 0" or greater but less than 15' 3" – install the low-clearance or the low-clearance with arrow at the low point on the structure and the advance low-clearance sign on the right shoulder. Less than 14' 0" – install the low-clearance or the low-clearance with arrow sign at the low point on the structure. Where the clearance varies, such as at arched structures or tunnels, additional signs may be used to provide effective clearance information. Install the low-clearance sign in advance of the closest intersecting road that provides a detour around the low-clearance obstruction. Supplement with an advisory distance plaque, showing the distance to the obstruction.
West Virginia	13' 6"	16' 6" or less.
Wisconsin	13' 6"	The low-clearance sign shall be used at all points where the clearance over any part of the usually traveled portion of the roadway is less than 14' 6". Where the clearance is less than 13' 6", an additional sign to that effect shall be placed at the nearest intersection on which a vehicle can detour onto. The appropriate XXX MILES AHEAD plaque shall be added to the advance sign. On all freeway/expressway interchanges, low-clearance signs shall be placed in advance of the exit overheight vehicles can use to avoid the low-clearance bridge, as well as at the bridge location itself where the bridge clearance is less than 14' 6".
Wyoming	14' 0"	Use bridge clearance signs for structures or overhead objects with 19' 0" of clearance or less over the roadway. On interstates, place a 48-inch bridge clearance height sign 250 feet past the exit gore. Use a median clearance sign when a bridge is 16' 0" or lower in height and place across from the advance exit speed sign.

State	Statutory Maximum Vehicle Height	Low-Clearance Signage Requirements
District of Columbia ^a	13' 6"	Less than 14' 6".
Puerto Rico ^b	14' 0"	Less than 15' 0".

^a The District of Columbia is a federal district and the capital of the United States.
^b Puerto Rico is a US territory.

See the map figure below for a graphic representation of each state's low-clearance signage requirement.



Appendix B Figure 1. Low-clearance signage requirements by state.

Appendix C. History of AASHO and AASHTO Guidance on Vertical Clearance of Highway Structures

AASHO and AASHTO Publications		
AASHO A Policy on Geometric Design of Rural Highways (Blue Book)		
<p>1954 Edition (pages 77 and 386) “Considerable variation exists among the States in regard to the maximum permissible heights of motor vehicles. Table II-6 shows that the majority of States limit vehicles to 12.5 foot height, the value recommended by the AASHO. Thirty-five States or 72 percent have upper limits of 12.5 feet for vehicle height, which dimension is considered to be the height of design semitrailer combinations.</p> <p style="text-align: center;">Table II-6 Legal Restrictions for Height and Width of Vehicles – 1952</p>		
Legal Maximum Permissible Dimension, Feet	Number of States	Percent of States at or below indicated value
HEIGHT		
12.5	35	72
13.0	2	76
13.5	8	92
14.0	2	96
No restriction	2	100
WIDTH		
8.0	47	96
8.5	2	100
Vertical Clearance		
<p>The clear height of all structures should be at least 14 feet over the entire width of traffic lanes, auxiliary lanes and clearances to curbs, including shoulders; see figure IX-5. The adequacy of 14 feet is verified by the State vehicle size restrictions as discussed under Height of Motor Vehicles in Chapter II. To insure continuing adequate vertical clearance of at least 14 feet an additional clearance, say 4 inches or more, should be provided initially to allow for one or two resurfacings.”</p>		

1965 Edition (pages 81, 86, and 521) “Considerable variation exists among the States in regard to maximum permissible heights of motor vehicles. Table II-4 shows that the majority of States limit vehicle height to 13.5 feet. Thirty-one States or 61 percent have an upper limit of 13.5 feet for vehicle height.

Table II-4
Legal Restrictions for Height and Width of Vehicles – December 1962

Legal Maximum Permissible Dimension, Feet	Number of States	Percent of States at or below indicated value
HEIGHT		
12.5	14	27.5
13.0	2	31.4
13.5	31	92.2
14.0	2	96.1
No restriction	2	100.0
WIDTH		
8.0	48	94.1
8.5	2	98.0
9.0	1	100.0

Vertical Clearance

The clear height of all structures should be at least 14 feet over the entire width of traffic lanes, auxiliary lanes, and lateral clearance areas to curbs, walls, or piers, including shoulders. See figure IX-5. The adequacy of 14 feet is verified by the State vehicle size restrictions as discussed under Height of Motor Vehicles in Chapter II. To insure continuing adequate vertical clearance of at least 14 feet an additional clearance, say 4 inches or more, should be provided initially to allow for resurfacing.”

AASHO A Policy on Arterial Highways in Urban Areas (Red Book)

1957 Edition (page 336) “The clear height of all structures above freeway pavements and shoulders should be at least 14 feet. Normally, an additional clearance of 4 inches or more should be provided initially to allow for future resurfacing. Vertical clearances of 15 feet or more have been suggested to accommodate an occasional high bodied vehicle. This may be justified in sparsely settled rural areas where alternate routes are not nearby, but in urban areas high vertical clearance is not necessary and may be undesirable where adjacent streets are available for the occasional high bodied vehicle.”

AASHO A Policy on Design of Urban Highways and Arterial Streets (Red Book)

1973 Edition (page 502) “The clear height of a freeway underpass is a matter of determination for the freeway route as a whole. This in turn may be governed by the standards on the freeway system. The clear height of all structures above freeway pavements and shoulders should be at least 14 feet or at least one foot greater than the legal height load. An additional clearance of 4 or more inches should be provided initially to allow for future resurfacing.

Some urban freeways are parts of systems or routes for which a minimum vertical clearance of 16 feet, plus an allowance for future resurfacing has been established. Interstate system standards call for such clearance for one route either passing through or around each urban area, but for other routes a lower vertical clearance is acceptable as a minimum. This dual standard is a practical recognition of the several governing features for an urban freeway. In the urban areas there are alternate parallel routes, not necessarily freeways, for use by the occasional high bodied vehicle.”

AASHTO A Policy on Geometric Design of Highways and Streets (Green Book)^a

1984 First Edition (page 634) “The vertical clearance to structures passing over freeways should be at least 16 ft over the entire roadway width, including auxiliary lanes and the usable width of shoulders. In highly developed urban areas, where attainment of the 16-ft clearance would be unreasonably costly, a minimum clearance of 14 ft may be used if there is a circumferential freeway facility with the minimum 16-ft clearance.

Because of their lesser resistance to impacts, the vertical clearance to sign trusses and pedestrian overpasses should be 17 ft. The vertical clearance from the deck to the cross bracing of through-truss structures should also be a minimum of 17 ft.

An allowance of 6 in. should be added to all vertical clearances to accommodate future resurfacing.”

(pages 921 and 922) “Although State laws vary somewhat, most States permit the vehicle height, including load, to be between 13.5 and 14.5 ft. The clear height of all structures above pavements and shoulders should be at least 1 ft greater than the legal height, and allowance should be made for future resurfacing.”

1990 Second Edition (pages 585 and 586) “The vertical clearance to structures passing over freeways should be at least 16 ft over the entire roadway width, including auxiliary lanes and the usable width of shoulders. In highly developed urban areas, where attainment of the 16-ft clearance would be unreasonably costly, a minimum clearance of 14 ft may be used if there is an alternate freeway facility with the minimum 16-ft clearance (with allowance for any future resurfacing).

Because of their lesser resistance to impacts, the vertical clearance to sign trusses and pedestrian overpasses should be 17 ft. The vertical clearance from the deck to the cross bracing of through-truss structures should also be a minimum of 17 ft.

An allowance of 6 in. should be added to all vertical clearances to accommodate future resurfacing.”

(page 876) “Although State laws vary somewhat, most States permit the vehicle height, including load, to be between 13.5 and 14.5 ft. The clear height of all structures above pavements and shoulders should be at least 1 ft greater than the legal height, and allowance should be made for future resurfacing.”

1994 Third Edition (page 559) “The vertical clearance to structures passing over freeways should be at least 4.9 m over the entire roadway width, including auxiliary lanes and the usable width of shoulders. In highly developed urban areas, where attainment of the 4.9 m clearance would be unreasonably costly, a minimum clearance of 4.3 m may be used if there is an alternate freeway facility with the minimum 4.9 m clearance (with allowance for any future resurfacing).

Because of their lesser resistance to impacts, the vertical clearance to sign trusses and pedestrian overpasses should be 5.1 m. The vertical clearance from the deck to the cross bracing of through-truss structures should also be a minimum of 5.1 m.

An allowance of 150 mm should be added to all vertical clearances to accommodate future resurfacing.”

(page 828) “Although State laws vary somewhat, most States permit the vehicle height, including load, to be between 4.1 m and 4.4 m. The clear height of all structures above traveled way and shoulders should be at least 0.3 m greater than the legal height, and allowance should be made for future resurfacing.”

2001 Fourth Edition (pages 510 and 511) “The vertical clearance to structures passing over freeways should be at least 4.9 m [16 ft] over the entire roadway width, including auxiliary lanes and the usable width of shoulders (with an allowance for future resurfacing). In highly developed urban areas, where attainment of the 4.9-m [16-ft] clearance would be unreasonably costly, a minimum clearance of 4.3 m [14 ft] may be used if there is an alternate freeway facility with the minimum 4.9-m [16-ft] clearance.

Because of their lesser resistance to impacts, the vertical clearance to sign trusses and pedestrian overpasses should be 5.1 m [17 ft]. Similarly, the vertical clearance from the deck to the cross bracing of through-truss structures should also be a minimum of 5.1 m [17 ft], with an allowance for future resurfacing.”

(page 767) “Although State laws vary somewhat, most States permit the vehicle height, including load, to be between 4.1 m [13.5 ft] and 4.4 m [14.5 ft]. The vertical clearance of all structures above the traveled way and shoulders should be at least 0.3 m [1 ft] greater than the legal vehicle height, and allowance should be made for future resurfacing.”

2004 Fifth Edition (pages 506 and 507) “The vertical clearance to structures passing over freeways should be at least 4.9 m [16 ft] over the entire roadway width, including auxiliary lanes and the usable width of shoulders (with an allowance for future resurfacing). In highly developed urban areas, where attainment of the 4.9-m [16-ft] clearance would be unreasonably costly, a minimum clearance of 4.3 m [14 ft] may be used if there is an alternate freeway facility with the minimum 4.9-m [16-ft] clearance.

Because of their lesser resistance to impacts, the vertical clearance to sign trusses and pedestrian overpasses should be 5.1 m [17 ft]. On urban routes with less than the 4.9-m [16-ft] clearance, the vertical clearance to sign trusses should be 0.3 m [1 ft] greater than the minimum clearance for other structures. Similarly, the vertical clearance from the deck to the cross bracing of through-truss structures should also be a minimum of 5.1 m [17 ft], with an allowance for future resurfacing.”

(page 763) “Although State laws vary somewhat, most States permit the vehicle height, including load, to be between 4.1 m [13.5 ft] and 4.4 m [14.5 ft]. The vertical clearance of all structures above the traveled way and shoulders should be at least 0.3 m [1 ft] greater than the legal vehicle height, and allowance should be made for future resurfacing.”

2011 Sixth Edition (page 8-4) “The vertical clearance to structures passing over freeways should be at least 4.9 m [16 ft] over the entire roadway width, including auxiliary lanes and the usable width of shoulders with consideration for future resurfacing. In highly developed urban areas, where attaining a 4.9-m [16-ft] clearance would be unreasonably costly, a minimum clearance of 4.3 m [14 ft] may be used if there is an alternate freeway facility with the minimum 4.9-m [16-ft] clearance.

Because sign trusses and pedestrian overpasses have lesser resistance to impacts, their vertical clearance should be 5.1 m [17 ft]. On urban routes with less than the 4.9-m [16-ft] clearance, the vertical clearance to sign trusses should be 0.3 m [1 ft] more than the minimum clearance for other structures. Similarly, the vertical clearance from the deck to the cross bracing of through-truss structures should also be a minimum of 5.1 m [17 ft].”

(page 10-21) “Although State laws vary somewhat, most States permit the vehicle height, including load, to be between 4.1 m [13.5 ft] and 4.4 m [14.5 ft]. The vertical clearance of all structures above the traveled way and shoulders should be at least 0.3 m [1 ft] greater than the legal vehicle height, and allowance should be made for future resurfacing.”

AASHO and AASHTO Standard Specifications for Highway Bridges^b

1969 10th Edition through 2002 17th Edition “Vertical clearance on state trunk highways and interstate systems in rural areas shall be at least 16 feet over the entire roadway width with an allowance for resurfacing. On state trunk highways and interstate routes through urban areas, a 16-foot clearance shall be provided except in highly developed areas. A 16-foot clearance should be provided in both rural and urban areas where such clearance is not unreasonably costly and where needed for defense requirements. Vertical clearance on all other highways shall be at least 14 feet over the entire roadway width with an allowance for resurfacing.”

AASHTO Load and Resistance Factor Design Bridge Design Specifications

1994 First Edition through 2013 Interim Revisions (Sixth Edition 2012) “The vertical clearance of highway structures shall be in conformance with the AASHTO publication *A Policy on Geometric Design of Highways and Streets for the Functional Classification of the Highway* or exceptions thereto shall be justified. Possible reduction of vertical clearance, due to settlement of an overpass structure, shall be investigated. If the expected settlement exceeds 1.0 in., it shall be added to the specified clearance.

The vertical clearance to sign supports and pedestrian overpasses should be 1.0 ft. greater than the highway structure clearance, and the vertical clearance from the roadway to the overhead cross bracing of through-truss structures should not be less than 17.5 ft.”

^a The 1965 AASHO *A Policy on Geometric Design of Rural Highways* (Blue Book) and the 1973 AASHO *A Policy on Design of Urban Highways and Arterial Streets* (Red Book) were combined into the first edition of AASHTO’s *A Policy on Geometric Design of Highways and Streets* (Green Book) published in 1984.

^b The last edition (17th edition) of the AASHTO *Standard Specifications for Highway Bridges* appeared in 2002. The Federal Highway Administration and the states established that the AASHTO *Load and Resistance Factor Design Bridge Design Specifications* be incorporated in all new bridge designs after 2007.