Executive summary and summary of recommendations

Introduction

This report contains a detailed review of the fatal collision on I-5 in Marysville on Feb. 13, 2007, statewide cable median barrier performance and other cross-median collisions on I-5 in Marysville.

The review of the Feb. 13 collision brings together analysis by nationally recognized independent experts, the Washington State Patrol Major Accident Investigation Team and testing data from Washington State Department of Transportation's Materials Laboratory. This research determined the likely reasons the SUV in the Feb. 13 collision traveled over one run of cable median barrier and through a second run of cable median barrier.

The report also discusses WSDOT's cable median barrier program as one of the opportunities to reduce the toll of collisions involving vehicles crossing the median into on-coming traffic.

Important recommendations are made in the report, including:

- Continue the use of cable median barrier as a general practice on suitable highways with medians of appropriate width.
- Pursue research and development needs that were brought to light during the review of the Feb. 13 collision.
- Install concrete barrier on I-5 in Marysville, the most noteworthy recommendation to the many citizens who have expressed their concern about the freeway in Marysville.

The recommendation for a concrete barrier on I-5 near Marysville

The recommendation that will have the greatest immediate interest comes from independent expert Malcolm Ray, P.E., Ph.D, and can be found in Chapter 1. After reviewing data and the crash scene and developing his conclusions with both WSDOT and WSP, Ray believes that I-5 in the Marysville area exhibits several characteristics not thoroughly understood by safety specialists, that suggest an unusually high risk of median crossovers, especially in the southbound direction.

Accordingly, this 10-mile section of I-5 should be equipped with a concrete barrier to supplement cable barrier to provide the highest possible level of protection against southbound drivers crossing the median and entering northbound lanes. This recommendation is preliminarily estimated to be $27 million. This is a high cost in relation to available funds and highway safety project needs elsewhere in the state. This recommendation is made in the context of complicating considerations, chiefly that any type of barrier in the median must be evaluated both for the benefit it affords by protecting against crossing into opposing traffic, but also for the risk it presents to errant drivers and others when a vehicle enters the median and strikes a barrier, especially a hard barrier. Severe damage and injury may result, not only to occupants of the vehicle driven off the road, but also to others exposed to danger if the vehicle is redirected into traffic. In short, no barrier system provides one hundred percent protection against crossovers, and all barrier systems present tradeoffs between their particular benefits and risks.

The toll of median and cross-median fatal and disabling collisions has dropped sharply in locations where cable median barrier was installed.

Apart from the 10-mile stretch of I-5 in Marysville, not a single crossover fatality has been recorded on Washington's freeways in locations where cable median barrier has been installed.

The configuration recommended in this report will lower the risk that southbound vehicles will cross into the northbound lanes, as has happened on 19 occasions in the last nine years in the Marysville area. But it will create a new risk to northbound drivers who may hit the concrete barrier or may be hit by a northbound vehicle that ricochets off of the concrete barrier. There is no escape from this benefit-risk trade-off.

Apart from special circumstances in Marysville, cable median barrier has performed excellently and saved many lives on state highways in Washington

The report reveals in detail the positive side of cable median barrier use and how significantly crossover collisions contribute to serious injury collisions for motorists. It makes the case for a strong program, as Washington and an increasing number of other states have pursued, for installing median crossover protection. Neither cable median barrier nor any other system offers a guarantee that it will prevent all crossover collisions. Specific systems have widely varying costs and are best suited to specific situations. Subsidiary information about cable median barrier performance was brought to light while preparing this report and led to recommendations by Ray, WSP and WSDOT.

Cable median barriers have an important role to play in solving the crossover problem, however, cable median barrier systems require a median width of 24-feet or wider and are not suitable for a narrow median, where concrete barrier or other rigid barriers must be used instead. Indeed, strategies that can be selected, depending on the setting, range from centerline rumble strips and simple flexible breakaway markers to guardrail, concrete barrier, cable barrier and even a median so wide that momentum likely won't carry a vehicle into opposing traffic.

Washington state freeways include approximately 180 center line miles of divided highway that are potential candidates for cable median barrier. By the end of 2006, 135 miles of cable median barrier have been installed and all 185 miles are scheduled to be completed by 2008.

This program has produced dramatic and demonstrable safety results. Apart from the 10-mile stretch of I-5 in Marysville, not a single crossover fatality has been recorded on Washington's freeways in locations where cable median barrier has been installed.

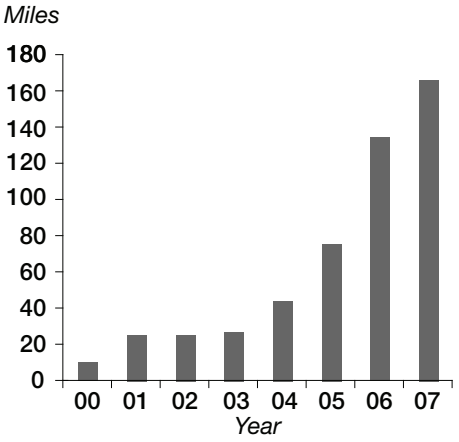
Washington state is a leader in highway traffic safety improvement. On the state highway system, from 1995 to 2006, the total number of crossover collisions resulting in disabling injuries or fatality decreased 38 percent. This was achieved while vehicle miles traveled increased 16 percent.

While median crossover collisions are still a big part of the highway safety problem, accounting for about 22 percent of the disabling injuries and fatalities on state highways, the trend is headed in the right direction. In 2006, 235 people suffered disabling injuries in crossover collisions, which was reduced by 39 percent from 1996. In 2006, 96 people died in crossover collisions, which was reduced by 31 percent from 1996.

There is a striking correlation between the improvement in the crossover injury and fatal collision statistics and the installation of cable median barrier. WSDOT has been at the forefront of a national trend to install cable median barrier, which now includes at least 24 other states. Ray's report on the experience with cable barrier in other states, which is included in Appendix B of this report, documents how other states are using cable barrier and how effectively the barrier has reduced cross-median collisions. Additional states likely will begin using cable barrier to reduce cross-median collisions. Additional information about WSDOT's cable median barrier policies and program is in Chapter 4.

Figure 0.1

From 2000, installation of cable median barrier on Washington state highways has grown more than 165 miles

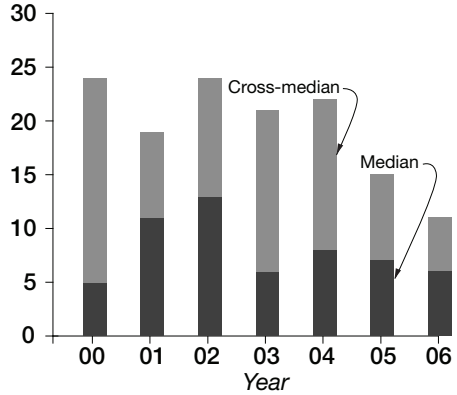


Source: WSDOT Headquarters Design Office

Figure 0.2

Median and cross-median fatal and disabling collisions

Fatal and disabling collisions

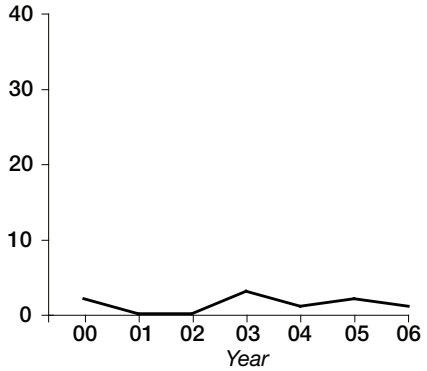


Source: WSDOT Transportation Data Office and Headquarters Design Office

Figure 0.3

Where cable median barrier has been installed, the number of fatal and disabling collisions after vehicle passed through cable median barrier has been very small.

Fatal and disabling collisions



Source: WSDOT Transportation Data Office and Headquarters Design Office

As the miles of divided highway protected by cable median barrier has increased safety performance relative to median crossovers on those same highways has dramatically improved.

Before and after data for the highway segments where cable median barrier was installed shows:

- Crossover median collisions decreased 74 percent after cable median barrier was installed, from about 42 per year to about 11 per year.
- Disabling and deadly median collisions dropped 71 percent, from about 18 per year to about 5 per year.
- There have been no fatal cross-median collisions since cable median barrier was installed, with the exception of I-5 in Marysville, where four fatal cross-median collisions have occurred.

Based on data WSDOT collected, during the next 10 years cable median barrier could prevent more than 64 fatal collisions and 69 disabling collisions in locations where WSDOT has installed cable median barrier. Additional statewide cable median barrier performance data can be found in Chapter 3, and results for individual freeway locations statewide can be found in Appendix A.

With these results in view, together with a sense of the largely favorable national experience with cable median barrier, Ray recommends that Washington state continue its program to install cable median barrier.

Additional important topics presented

Cable median barrier is an evolving technology: The report calls attention to the fact that cable median barrier is, like many safety innovations, a technology still reaching its mature development. Several issues presented in this report underscore that case. More information can be found in Chapter 3.

Law enforcement is crucial, but isn't always a complete solution: The WSP Major Accident Investigation Team report, which is included in Appendix D, indicates that the driver of the Infinity SUV that drove into the median on Feb. 13, 2007, had just entered the highway from a ramp and was driving with a blood alcohol level of 0.07, just below 0.08, the legal limit to drive. Enforcement of speeding and distracted and impaired driving laws can help mitigate these risks, but it will not wholly solve problems of this kind, and it requires a heavy investment of limited law enforcement resources.

Driving behavior and roadway characteristics contributing to crossover collisions are not all understood and need more research: Ray has suggested that the exact kinds of problems that increase the frequency of run-off-the-road events is not as well understood as it should be. More research should be done on this question, using the Marysville stretch as a focus area for investigation.

A contributing factor to the Feb. 13 incident was a mechanical failure of the cable anchoring system, allowing the SUV to penetrate the second barrier: Investigators' analysis of the SUV's path into northbound traffic revealed the mechanical failure that allowed the SUV's force of impact to pull the cables from their anchors, leaving them slack on the ground. McKnight Laboratories, Inc., performed an extensive analysis of the cable anchoring systems and concluded that wedges had not been adequately and completely driven into the anchor housing assembly upon installation. This report is included in Appendix D.

WSDOT engaged a construction contractor to check all the installations in the Marysville area and correct any other improperly seated wedges. This work was completed in March 2007. WSDOT maintenance crews completed the same tasks on all similar cable median barrier installations across the state by March 2007.

Statewide data comparing cable median barrier and concrete barrier indicates that concrete barrier reduces the risk of cross-median collisions, but nearly doubles the overall risk of death or injury.

Recommendations arising from this aspect of the report, which are found in Chapter 5, include an improved installation specification and a regular anchor housing assembly inspection program.

The front bumper height on the Infinity SUV figured in two aspects of the investigation. More testing on the national level is called for: The override of the first cable median barrier, which is the newly-installed, proprietary high-tension system near the southbound shoulder, has raised questions about the performance of Federal Highway Administration-accepted barriers in relation to higher bumpers on many modern SUVs and pickup trucks. As was noted by Safety Quest, Inc., the cable median barrier was tested and installed in accordance with national guidelines and manufacturer specifications. However, the Safety Quest report, in Appendix D, noted that there is a need to consider the use of larger vehicles with higher bumpers and that the placement of barrier on slopes needs to be investigated further.

While crash testing barriers is a good tool to assess barrier performance, it is not practical to test every condition that may be encountered along the nation's highways. With the large number of different vehicles, speeds, angles of impact and roadside environments, it is necessary to test several conditions that represent the majority of conditions that may be encountered. Because of this, performance is often better assessed based on in-service evaluation. These studies can be a strain on resources. However, the findings may suggest the need for new research to further enhance barrier design and placement.

At times, automotive design changes have a significant affect on median barrier effectiveness. For example, taller vehicles will interact differently with barrier than those that are lower to the ground, heavier vehicles will interact differently than lighter ones, and more flexible vehicles will interact differently than more rigid ones. Adjusting median barriers to accommodate these trends takes creative engineering, time and money. The safety consequences of having a mix of very large and very small vehicles has been noted related to other crash types as well.

It is impractical – if not impossible – to change all existing barriers on highways statewide with every new piece of information or change in vehicle design. As WSDOT learns about the results of new research, it may revise designs or placement guidelines for new installations. The process of replacing older barriers can take years to fund and implement.

Excluding I-5 in Marysville, cable barrier has the lowest percentage of fatal and disabling collisions of all freeway median barrier types in Washington state.

The unavoidable problem of tradeoffs: WSDOT is careful about where median barriers are installed because drivers who run their cars off the highway may hit them. Concrete barriers and guardrails are relatively rigid. People in vehicles that hit these highway median barriers experience a significant force of impact, and deceleration is rapid. These forces often crush the vehicle, redirect it back into traffic and/or flip the vehicle. Well-designed median barriers minimize the force of impact on people in vehicles that hit the barrier, redirect the vehicle in a controlled manner and bring the vehicle to a controlled stop.

This creates a dilemma for WSDOT engineers: How do they balance the need to prevent crossover collisions with the new risks that accompany median barriers? Statewide data comparing cable median barrier and concrete barrier indicates that concrete barrier reduces the risk of cross-median collisions, but nearly doubles the overall risk of death or injury. This is because vehicles that hit concrete barrier are more likely to rebound into another vehicle, which increases the number of people who could be killed or injured. If I-5 in Marysville is excluded, cable barrier has the lowest percentage of disabling and fatal collisions at 1.6 percent. This is lower than concrete barrier at 1.9 percent and guardrail at 2.5 percent. I-5 in Marysville appears to be a special case because it is the only location with cable barrier where fatalities have occurred.

Summary of recommendations

In Marysville

Replace the existing low-tension cable median barrier with concrete barrier along a 10-mile stretch of the shoulder of northbound I-5 in Marysville. The concrete barrier should nearly eliminate cross-median collisions. The recommendation has been made by Malcolm Ray, the independent expert, and endorsed by the WSP and WSDOT. The recommendation reflects that this section of southbound I-5 has a high number of cross-median crashes. This new barrier installation should be placed at least 10 feet away from northbound highway lanes to allow room for emergency vehicles and a refuge area for disabled vehicles. The estimated cost of this improvement is $27 million.

Keep the existing high-tension cable median barrier adjacent to the shoulder of southbound side of I-5 in Marysville. This was suggested by Ray for consideration by WSDOT in order to retain the advantage of a flexible barrier system given the apparent special exposures on this southbound section for errant vehicles entering the median. The cable barrier will absorb more of the force of impact, reduce the risk of rollovers, and reduce the risk of rebound collisions that involve other vehicles.

Locations other than Marysville I-5

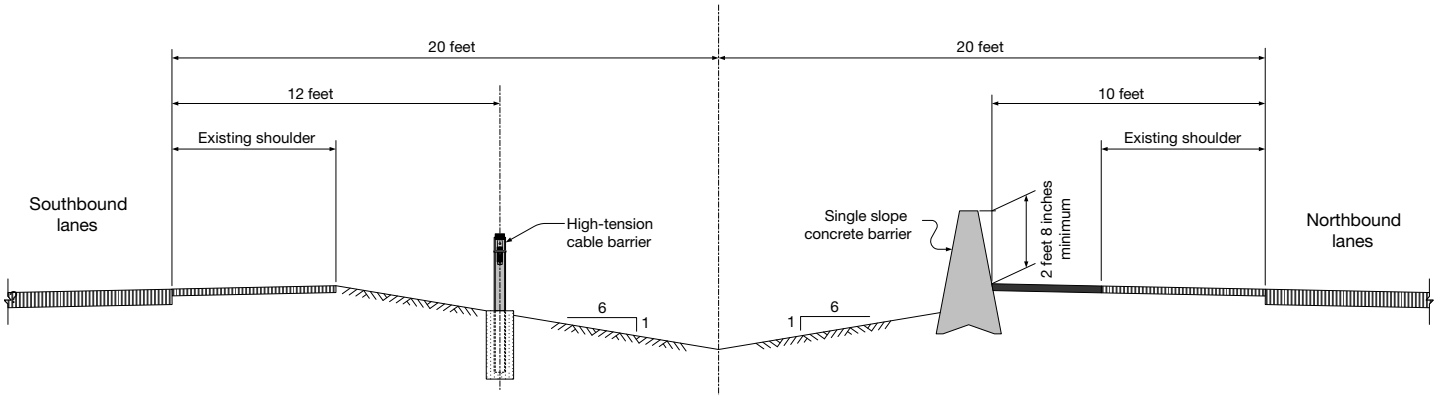
Continue installation of cable median barrier. The performance record of cable median barrier in locations across the state has been very favorable, and its cost-effectiveness in delivering improved protection against cross-median collisions has been so high that its use should be continued on state highways in accordance with WSDOT's policies. Independent expert Ray, echoes this recommendation in his report, as found in Chapter 1, page 29. Policy revisions and barrier retrofits may be developed as a result of new cable barrier technology and design, crash test results and evolving vehicle designs.

Recommendations on cable median installation and placement

Create procedures to install the cable-securing wedge in low-tension cable barrier systems. WSDOT and other state departments of transportation do not have a written procedure to install the cable-securing wedge inside the spring cable end assembly. WSDOT engineers will develop written instructions to help both construction and maintenance crews install the cable-securing wedge correctly.

Figure 0.4

I-5 median cross section - Marysville recommendation



Provide additional dimensions of fabricated parts and materials specifications for low-tension cable barrier systems to design engineers. If WSDOT decides to install low-tension cable barrier systems in the future, engineers will modify standard plans and special provisions to add dimensions and materials specification for low-tension cable barrier components to ensure compatibility of components from multiple manufacturers. WSDOT currently is installing only high-tension cable median barrier systems.

Improve the design of the cable-securing wedge in low-tension cable barrier systems. If WSDOT decides to install low-tension cable barrier systems in the future, engineers will investigate designs to improve the cable-securing wedge.

Sponsor research to examine high-tension cable barrier performance on slopes and when struck by larger vehicles. WSDOT will request funding to sponsor research for new crash tests examining high-tension cable median barrier placement on slopes and its effectiveness with vehicles that have higher bumpers.

Until research examining high-tension cable barrier and slopes is complete, WSDOT will consider the following when placing cable median barrier near the breakpoint between a 10:1 and 6:1 slope in the median, as recommended by Ray: (a) For single run cable median barrier if there is at least 13 feet from edge of the nearest traveled lane to the slope breakpoint, the cable median barrier should be placed at least one foot before the slope breakpoint. This will allow the cable to deflect, or move laterally, up to 12 feet. This distance would also provide an emergency lane, and minimize the chance of bumper height problems associated with SUV's and pickup traversing slopes prior to striking the barrier.

(b) If installing a double run of cable median barrier, if there is at least 11 feet from the edge of the nearest traveled lane to the slope breakpoint, the cable median barrier should be placed at least one foot before the slope breakpoint. This arrangement will provide an adequate emergency lane, minimize the chance of bumper height problems associated with SUVs and pickup trucks traversing slopes prior to striking the barrier and provide some recovery room for vehicles leaving the near lanes. Deflection distance for back-side hits are not as much of a concern in this situation since the back of one barrier is shielded by the barrier on the other side of the median.

(c) When there is not sufficient space to position the barrier before the slope breakpoint, other types of cable median barriers should be used to minimize the chance of newer SUVs and pickup trucks from going over the barrier. Types of barrier that could be used behind the slope breakpoint could include:

- any National Cooperative Highway Research Program Test Report 350 Level 4 cable median barrier or
- a cable median barrier that is designed and crash tested such that its successful performance with newer SUVs and pickup trucks on terrains with typical slope breakpoints has been established.

In choosing installations for both cable median barrier and concrete median barrier, WSDOT should consider crash history as well as median characteristics and traffic volumes, as recommended by Ray. Engineering judgment and installation recommendations based on highway geometry should be the first criteria in deciding where to use median barrier. Crash history also should play a role for locations like Marysville, where the site geometry is simply not an accurate predictors of the magnitude of the cross-median problem. Ray makes the recommendation in Figure 0.5. Missouri uses a rate of 0.8

cross-median collisions per 100 million vehicle miles traveled as an installation recommendation, so practices in other states support the use of historical collision data in making barrier installation decisions.

Figure 0.5

Median barrier installation recommendations based on historical crash rates.

Crash rate † Cross-median crashes of per 100 million vehicle miles traveled	Site characteristics	Action
More than 1	No median barrier, median 30 feet or wider and 6:1 or flatter slopes.	Evaluate cost benefit of using a cable median barrier.
More than 2	No median barrier, 30- to 50-foot wide median, 6:1 or flatter slopes, average daily traffic more than 75,000 vehicles and in rural/urban transition area.‡	Evaluate cost benefit of using a double run of cable, w-beam guardrail, thrie-beam guardrail or concrete median barriers.
More than 0.75	30- to 50-foot wide median, cable median barrier, 6:1 or flatter slopes, average daily traffic more than 75,000 vehicles per day and in rural/urban transition area.‡	Evaluate cost benefit of replacing a cable median barrier with w-beam, thrie-beam or concrete median barriers.

† Crash rates should be calculated on sections that are at least two miles long, and where data is available, such that the section has experienced at least 100 million vehicle miles traveled. Crash rates calculated in shorter segments, or where there has not yet been sufficient traffic are liable to be inaccurate and overly sensitive to a few early crashes.

‡ Rural/urban transition areas are areas that are characterized by several of the following characteristics:

- Interchanges spaced closer than two miles apart
- A change in speed limit
- A large change in average daily traffic (e.g., 30 percent) in a relatively short distance
- High ramp volumes in proportion to the mainline average daily traffic

Recommendations on cable median barrier maintenance and inspection

Make routine inspections of in-service cable median barrier systems. Field investigations should be made to determine that all wedge-and-socket connections in the low-tension cable median barrier system are sound. Inspections should be made whenever the barrier is hit and repaired, or periodically if the barrier is not hit. A representative sample of high-tension system installations also should be checked regularly. This recommendation was made by Ray and also by WSDOT.

Improve WSDOT's tracking procedures: Drivers who hit cable median barrier do not always report the collision to the WSP. As a result, collision data is incomplete and may, for example, omit incidents where drivers drive away uninjured from a cable median barrier hit. Also, it is important that collision records capture information engineers need to evaluate barrier systems and installations. WSDOT should continue to make use of cable median barrier repair records to gather information that may not be captured in collision records. WSDOT should continue to track barrier repairs and, if necessary, improve them to ensure that information is collected in ways that make it easier to track trends and issues.

Continue to monitor the performance of all cable median barrier. WSDOT will continue to monitor the performance of all cable median barrier on Washington state highways and will report on the barriers' performance annually for the next two years.

Recommendations for research and development of cable median barrier systems

Support and participate in research on the conditions that promote median crossovers, according to Ray. These conditions are not well understood. Traffic conflicts and impaired drivers seem to initiate most cross-median crashes, but it has been difficult to predict where cable median barriers will reduce cross-median crashes and where concrete median barriers should be used instead. Traffic conditions such as volume, mixing, interchange spacing, land use and speed limits appear to be related to the likelihood of cross-median crashes. Research should be performed to find good ways of predicting locations where cross-median crashes will be a problem. This will assist in assessing situations like Marysville, not only for appropriate engineering treatments but also for targeted enforcement activities and other strategies to combat driver and other factors to median crossovers.

Urge adoption of revised crash test criteria. Questions about whether the bumper height or the trajectory of the Infinity SUV in the Feb. 13 crash have drawn attention to the changing fleet mix in favor of larger and higher vehicles. The criteria currently used to evaluate the crashworthiness of a system are being rewritten, and proposed criteria include using a larger truck in crash tests. As systems are tested using larger vehicles, modifications to existing barrier systems may be identified that will improve their performance. Ideally, the new testing should be performed by a national testing program supported by cooperative research funds with participation from the Federal Highway Administration. If a national approach cannot be established, WSDOT should consider funding and administering its own tests to help better understand the problem. The Midwest Roadside Safety Facility at the University of Nebraska is developing a new four-cable median barrier system that may provide some insight into the interaction of newer pickups and SUVs and cable median barriers.

Urge additional testing of cable median barrier on slopes. The performance of the Infinity SUV in riding over the high-tension barrier also has raised questions about the adequacy of crashworthiness testing of cable median barriers installed on flat surfaces. Testing should be considered with the barrier placed on typical medians, many of which have slopes. This will help support decisions about which type and configuration of cable barrier and hardware to use, based on established performance when barriers are installed on the variety of cross sections encountered in real life. Ideally, the new testing should be performed by a national testing program supported by cooperative research funds with FHWA participation. If a national approach cannot be established, WSDOT should consider funding and administering its own tests to help better understand the problem.

According to Ray, research on the proper placement of cable median barriers in relation to median slopes is needed, and guidance in this area is either outdated or never was completed. Some crash tests of high-tension cable median barriers have been performed on 4:1 slopes, but a comprehensive study of vehicle behavior when traversing typical depressed medians is needed to determine exactly where barriers should and should not be located. A new National Cooperative Highway Research Program project is underway that will look at the issue of guardrail and median barrier placement on slopes. National Cooperative Highway Research Program 22-22, "Placement of Traffic Barriers on Roadside and Median Slopes," will examine a variety of types of guardrails and median barriers placed on slopes. WSDOT will encourage the project team to examine cable barrier placement. National Cooperative Highway Research Program 17-22, "Identification of Vehicular Impact Conditions Associated with Serious Ran-Off-Road Crashes," is examining real-world impact conditions to try and re-examine the most relevant crash test conditions. This project has been active since 2001 and recently has been expanded.

According to Ray, the research issues identified in this report are general in nature and affect every state that uses cable median barriers. Already-initiated or soon-to-be-initiated National Cooperative Highway Research Program research projects should provide valuable answers in five years or so. Ray recommends that WSDOT continue to actively monitor and participate in research to improve cable median barrier policy.