Appendix C: Dr. Ray's evaluation of the 2008 update

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Ms. Paula Hammond
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Chief John R. Batiste
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RE: **Review of WSDOT's Cable Median Barrier Policy**

Dear Secretary Hammond and Chief Batiste:

In 2007 I participated in the preparation of Secretary MacDonald's and Chief Batiste's report to Governor Gregoire (i.e., the 2007 Governor's Report) regarding the effectiveness of cable median barrier and WSDOT's policy on the use of cable median barriers.[1] In June 2008 I was contacted by WSDOT personnel and asked if I would review the updated cable median barrier policy that resulted from Secretary MacDonald's and Chief Batiste's report as well as assess the performance of cable median barrier in light of the addition of the 2007 crash data. I am pleased to present this letter report containing my review of WSDOT's cable median barrier policy.

SCOPE OF WORK

I was specifically asked to address the following issues in my report:

1. With the addition of calendar year 2007 crash data, and additional installations included in the analysis, how is cable median barrier performing?
2. Evaluate progress made by WSDOT toward implementing recommendations presented in the 2007 report.
3. Evaluate WSDOT's use of the performance screening criteria outlined in the 2007 report.
4. Provide constructive input on the course of action WSDOT is pursuing.

The following letter report is my review of the updated WSDOT cable median barrier policy and the four points above will be addressed in the following sections.

[1] Douglas B. MacDonald and John R. Batiste, "Cable Median Barrier Reassessment and Recommendations," Washington State Department of Transportation, Olympia, Washington, 29 June 2007.

ISSUE 1: UPDATE OF CABLE MEDIAN BARRIER PERFORMANCE

The 2007 Governor's Report included a review of crash data of all the cable median barrier sites in the state of Washington using the 1993 through 2006 crash data. Since that report was written, an additional year of crash data has become available and 43 additional miles of cable median barrier were added to the Washington State highway system bringing the total amount of cable median barrier installed up to about 177 miles. In addition, 440 additional median and cross-median crashes occurred in 2007 which were added to the crash data. WSDOT personnel added the additional data to the prior study and updated the crash rates allowing a more up-to-date review of the performance.

WSDOT provided me with the cable median barrier crash data files for 1993 through 2007. The data includes data on the number of crashes both before and after the installation of cable median barriers as well as other important information like the length of each installation and the traffic volume by year. WSDOT began using cable median barriers in 1995 and in the intervening 13 years 177 miles have been installed. Between 1993 and 2007, 2547 median and median cross-over crashes have been documented on police crash reports in the State of Washington. Crash reports are generally generated by the police agency investigating a crash except when less than $700 in property damage is involved. Since higher severity crashes involve either injuries or extensive property damage, it is safe to assume that nearly all serious crashes are documented in a police crash report.

Lower severity crashes are very often unreported especially if the damage to the vehicle is so minor that the vehicle can be driven from the scene. For this reason, all statistics based on police crash reports tend to over state the severity of roadside barrier crashes. This is particularly true for cable barriers since they are generally quite forgiving and many times result in drive-away collisions. A review of WSDOT's maintenance and repair records showed that in 2007 there were 482 repairs of cable median barriers, including about 295 records that were matched to a police crash report. In 2007, 370 cable median barrier crashes were documented in police crash reports so the likely total number of cable median barrier crashes was probably over 480, a little over 75 percent of which were reported to the police. It appears that about 25 percent of all cable median barrier crashes in Washington State are so minor that they are not even reported to the police. This is consistent with other studies of cable guardrails in Iowa and North Carolina documented in NCHRP Report 490.[2] [3]Of course, some very minor collisions would not even require repair. In reviewing the cable median barrier crash statistics, therefore, it should be noted that one quarter of the crashes are so minor that the crash is never reported to the police.

The WSDOT crash data classifies a "cross-median crash" as any collision even when the vehicle travels across the median and enters the opposing lanes of traffic whether another vehicle was struck or not. A median related crash, on the other hand, is any crash where the vehicle enters the median regardless of whether the cable median barrier was struck. In evaluating cable median barriers two issues must be examined: (1) how effective are cable median barriers at reducing median cross-over crashes and (2) how effective are cable median barriers at minimizing injuries. These two questions can be answered by looking at the crash rates for median cross-over crashes and all median related crashes, respectively.

While it is interesting to look at the number of cross-median crashes and the severity of those crashes, looking at the number of crashes can be misleading. With the addition of the 43 miles of cable median barrier in 2007, the installation of cable median barrier in the

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[2] M. H. Ray, J. A. Weir, J. A. Hopp, In-Service Performance of Traffic Barriers, National Cooperative Highway Research Program Report No. 490, ISBN 0-309-08762-7, National Academy of Sciences, Washington, D.C., 2003.

[3] M. H. Ray and J. A. Weir, "Unreported Collisions with Post-and-Beam Guardrails in Connecticut, Iowa and North Carolina," Transportation Research Record No. 1743, Transportation Research Board, Washington, D.C., 2001.

State of Washington is nearly complete. Another seven miles of cable median barrier are currently under contract and another 27 miles are programmed for installation by the end of 2011 so by the end of 2011 there will probably be 211 miles of cable median barrier installed. There will, doubtless, be small projects that add or remove small sections of cable median barrier for a variety of reasons (e.g., lane widening) but essentially the installed inventory of cable median barrier on the access controlled highway system will be constant after 2011. Traffic volume, however, will continue to grow so it is likely that there will be a small increase in the number of serious or fatal crashes each year even if the state-wide cross-median crash rate remains constant. Crash rates provide a more balanced view of the performance of any roadside hardware since the affects of the amount of installed inventory and traffic growth are eliminated allowing for a direct comparison of risk to the travelling public.

McClanahan first reported median cross-over crash rates in the State of Washington in 2004 as shown in Table 1.[4] At the time these first rates were calculated, only 24 miles of low-tension cable median barrier had been installed so the rate was based on a relatively small installed inventory. The 2007 Governor's Report up-dated the rates based on an installed inventory of 134 miles and the most recent data was based on an installed inventory of 177 miles as shown in Table 1.[5] The crash rates for before and after cable median barrier installation are very similar in each of these reports. The small differences simply reflect the small random variations that occur from year to year and from site to site. As shown in the 2007 Governor's Report, the total "after" cable median barrier crash rate varied from site to site with the lowest rates being zero on many of the highway segments and the highest being 0.841 on I-5 in Marysville. The differences in the statewide average rates are consistent with what would be expected variation from year to year.

Table 1. Before and After Cable Median Barrier Median Cross-Over Crash Rates in the State of Washington, 1993-2007.

	Date Range	Median Cross-Over Crash Rate (crashes / 100 MVMT)	
		All Severities	Serious Injury and Fatal
After the installation of Cable Median Barriers			
McClanahan paper	1993-2002	0.510	0.040
2007 Governor's Report	1993-2006	0.607	0.118
2008 WSDOT Review	1993-2007	0.584	0.143
Before the installation of Cable Median Barriers			
McClanahan paper	1993-2002	2.120	0.500
2007 Governor's Report	1993-2006	2.009	0.464
2008 WSDOT Review	1993-2007	1.855	0.471

§ All segments included including Marysville and those with short periods of "after" data.

In the 2007 Governor's Report the three sections with the highest fatal and serious injury cross median crash rates were I-90 in Moses Lake (1.216), I-5 in Marysville (0.200) and I-5 in Vancouver (0.117). In fact, these were the only highway sections with non-zero

[4] McClanahan, Doug, Albin, Richard B., and Milton, John C., "Washington State Cable Median Barrier In-Service Study," presented at the 83rd Annual Meeting of the National Transportation Research Board, Washington, DC, 2004.

[5] Douglas B. MacDonald and John R. Batiste, "Cable Median Barrier Reassessment and Recommendations," Washington State Department of Transportation, Olympia, Washington, 29 June 2007.

serious and fatal median cross-over crash rates after cable barrier had been installed. The 1993-2007 data indicate that the highest three rates today are I-90 in Moses Lake (0.712), I-5 in Marysville (0.242) and I-5 in Lewis County (0.196). I-5 in Marysville appears on both lists which confirm that this site has recurring cross median collisions and needs additional attention. Moses Lake also appears on both lists but the rate in the 1993-2007 data are much less than the rate measured just one year before (i.e., 0.712 versus 1.216). The rate for the Moses Lake section in the 2007 Governor's Report resulted from a single serious injury crash that happened not long after the barrier was installed in 2005. Moses Lake has now dropped its rate by almost half since nothing further has occurred at the site although additional vehicle mileage has continued to accrue. The change in rates at Moses Lake illustrates that highway sections that have only recently had cable barriers installed or are relatively short can experience large changes in rates. Before an accurate rate can be calculate, a certain amount of vehicle miles travelled must accumulate at the site to make the rate comparable to other state-wide rates. The Moses Lake section is probably not a site with a long term experience of cross median collisions. The rate should continue to drop in the coming years. The third highway segments in the two lists are different indicating typical random variations in the rates. With the 2007 Governor's Report had three sites with non-zero serious and fatal cable median barrier cross-over rates, the 1993-2007 data shows seven sites with non-zero rates. This is an indication that as more data are collected more sites will experience the occasional crash and the rates will begin to balance out.

Most importantly, however, is the fact that the rates calculated in 2007 are very similar to those calculated this year with the addition of the 2007 data. Cable median barriers in Washington are continuing to provide good cross-over protection as demonstrated by the very low cross-median crash rates.

The other aspect of cable median barrier performance can be measured by examining the median related crashes. In 1993 through 2007 there were 1158 median related crashes in Washington State. Of these 1158 cable median barrier crashes, 57 penetrated the cable median barrier and entered the opposing lanes of traffic resulting in a failure rate of 4.9 percent (i.e., 57 of 1158 crashes crossed over the median). Of the 1158 cases, an additional 71 (6.1 percent) penetrated the cable median barrier but were contained within the median (i.e., the vehicle penetrate the barrier but did not enter the opposing lanes of travel). The percentage of cable penetrations (i.e., the percent crossing the median into the opposing lanes plus those penetrating the barrier but not entering the opposing lanes) is, therefore, about 11 percent. Stated another way, 89 percent of the cable median barrier collisions are contained by the cable median barrier. This agrees with other studies of cable median barrier where the containment percentage is generally around 90 percent.

While an 11 percent penetration rate might seem large, it is actually not much different than other types of median barriers. For example, in WSDOT's analysis of concrete median barriers summarized for the 2007 Governor's Report, the penetration percentage for concrete barriers was found to be seven percent. Even though concrete barriers are large, heavy and rigid, they still allow seven percent of striking vehicles to go over or through the barrier. In light of the increased flexibility of the cable median barrier and its lower occupant severity, an 11 percent penetration rate is reasonable.

In Washington State's 13 years of using cable median barriers 27 serious injury or fatal crashes have occurred representing 2.3 percent of all cable median barrier crashes as shown in Table 2. Ten of the 1030 (i.e., 1.0 percent) cable median barrier crashes where the vehicle was restrained or redirected resulted in serious or fatal injuries. When the vehicle is contained by the barrier, the serious and fatal injury percentage was 1.0 percent whereas when the vehicle penetrated the barrier, the serious and fatal injury percentage was 13.3 percent. When the vehicle was able to enter the opposing lanes and completely cross the median, the percentage of serious and fatal injuries increases dramatically to 24.6 percent.

Table 2 shows the increased risk associated with penetrating the barrier. Clearly the cross-median crashes are far more severe than the crashes where the cable median barrier contains the vehicle.

Table 2. Serious and Fatal Injury Risk in Cable Median Barrier Collisions by the Result of the Collision in the State of Washington, 1993-2007.

	Total Crashes	Serious and Fatal Crashes	
	No.	No.	Row Percent
Restrained	885	8	0.9
Redirected	145	2	1.4
Contained in median	71	3	4.2
Crossed the median	57	14	24.6
Total	1158	27	2.3

According to the 1993-2007 crash data summarized in Table 3, the statewide average total median related crash rate before cables median barriers were installed was 7.641 crashes/100 MVMT. The total median related crash rate nearly doubled to 14.662 median related crashes/100 MVMT after the introduction of cable since formerly unobstructed medians now contained cable median barriers which could be struck. While the rate of total median related crashes almost doubled, the serious injury and fatal median related crash rate was more than cut in half from 0.845 serious injury and fatal median related crashes /100 MVMT before the installation of cable median barriers to only 0.338 serious injury and fatal median related crashes /100 MVMT after cable median barriers were installed. This represents a reduction in the median related serious and fatal injury crash rate of 60 percent, an impressive achievement in providing safer highways which has saved lives and reduced the severity of injuries in median related crashes.

Table 3. Before and After Cable Median Barrier Median Related Crash Rates in the State of Washington, 1993-2007.

	Date Range	Median Cross-Over Crash Rate (crashes / 100 MVMT)	
		All Severities	Serious and Fatal
Before cable median barriers	1993-2002	7.641	0.845
After cable median barriers	1993-2006	14.662	0.338
Reduction (%)	1993-2007	-91.9	60.0

§ All segments included including Marysville and those with short periods of "after" data.

Beginning in about 2004, WSDOT began to install high tension cable median barrier rather than the generic low-tension cable median barrier it had been using since the mid-1990's. The first proprietary high-tension cable median barrier was developed by BRIFEN in the United Kingdom. The BRIFEN system was tested according to NCHRP Report 350 guidelines at the Motor Industry Research Association (MIRA) in the UK in May of 1999. The FHWA accepted the BRIFEN system for general use on the National Highway System (NHS) in April 2001.[6] Several other manufacturers began to develop high-tension cable median barriers. Trinity Highway Safety Products obtained FHWA approval for what would

[6] Fredrick G. Wright, Jr., FHWA acceptance letter B-82, Federal Highway Administration, Washington, D.C., 10 April 2001.

become known as the CASS cable median barrier in May of 2003.[7] WSDOT began installing the high-tension CASS system in the 2004 construction season because it was easier to maintain and cost competitive with the low-tension cable median barrier. Today, about 75 percent of the cable median barrier installed in Washington State is high-tension cable median barrier.

The 1993-2007 crash data was used to compare the performance of the high-tension to the low-tension cable median barrier and the results are summarized in Tables 4 and 5. As shown in Table 5, the high-tension cable median barrier installations appear to result in fewer median cross-overs (i.e., 3.3 versus 5.8 percent) and result in more redirections (i.e., 21.9 versus 7.2). Table 4 shows the severity of each of these outcomes. For both types of median barriers, crossing the median is by far the most hazardous result of a crash with more than 20 percent of the cases resulting in a serious or fatal injury. The lowest severity result is to be contained within the median where the percentages of serious and fatal injuries are 1.25 percent for low-tension and 1.1 percent for high-tension cable median barrier. These data would seem to suggest that the high-tension cable median barrier is more effective at reducing the number of median cross-over crashes and has a slightly lower proportion of serious and fatal injury crashes.

Unfortunately, for purposes of comparing barrier effectiveness in Washington, it is difficult to isolate changes in barrier type from changes in placement. At about the same time WSDOT was changing from the low to the high tension cable median barrier systems, it also changed its barrier placement standards in response to a failed crash test at the Federal Outdoor Impact Laboratory. This test indicated that cable median barriers should not be installed on the backslope of a 6:1 depressed median. In response to the test result, WSDOT issued design guidance in 2004 that instructed project designers not to install cable median barrier in the area between one and six feet of the center line of the ditch. Following a change in federal guidance, WSDOT altered their installation guidance again in 2006, such that cable median barrier would not be placed in an area one foot to eight feet from the center line of the ditch in a depressed median. Since WSDOT changed the barrier and the placement guidelines at the same time, it is difficult to determine if the improved performance indicated for the high-tension cable median barrier in Tables 4 and 5 is due to better performance of the barrier itself, better placement guidelines, or both.

Table 4. Comparison of the Crash Severity of High and Low Tension Cable Median Barriers the State of Washington, 1993-2007.

Median Barrier Type	Crash Type	Total Crashes	Serious and Fatal Crashes	
		No.	No.	Row Percent
Low Tension	Contained in median	642	8	1.25
	Redirected	53	1	1.9
	Crossed median	43	11	25.6
High Tension	Contained in median	314	3	1.0
	Redirected	92	1	1.1
	Crossed median	14	3	21.4

[7] Michael S. Griffin, FHWA acceptance letter B-119, Federal Highway Administration, Washington, D.C., 13 May 2003.

Table 5. Comparison of the Crash Result for High and Low Tension Cable Median Barriers the State of Washington, 1993-2007.

Median Barrier Type	Crash Type	Total Crashes	
		No.	Percent
Low Tension	Contained in the median	642	87.0
	Redirected	53	7.2
	Crossed median	43	5.8
	Total	738	100.0
High Tension	Contained in median	314	74.8
	Redirected	92	21.9
	Crossed median	14	3.3
	Total	420	100.0

Because it is not possible to separate out all the factors in the analysis it is not possible to state whether the low or high tension barrier is the better system. In fact, the low-tension cable median barrier results actually represent WSDOT policy during the first half of the cable median barrier program (i.e., 1994 through 2004) whereas the high-tension cable median barrier results represent the results of WSDOT's policy during the second half of the program (i.e., 2004 through the present). What Tables 4 and 5 do suggest is that as WSDOT's cable median barrier policy has evolved, it has evolved in such a way that the barriers are being used more effectively as lessons are learned through field observation and research. The results in Tables 4 and 5 indicate that the current policy is an improvement over the older policy.

Motorcycle collisions with roadside safety hardware have become an emerging area of concern in recent years as more motorcycles populate the roadways. No roadside hardware systems in the U.S. are designed specifically to accommodate motorcycles so while cable median barrier are probably more hazardous to motorcyclists than automobile operators, the same can be said of every other type of guardrail and median barrier. In 2005, 224 motorcyclists across the U.S. were fatally injured in a collision with a guardrail. In fact more motorcyclists were killed in guardrail collision that operators of passenger cars according to the 2005 FARS data.[8] Gabler found that while 55 percent of registered vehicles are passenger cars and only three percent are motorcycles, motorcyclists accounted for 42 percent of the people fatally injured in guardrail collisions compared to 32 percent who were passenger car occupants.[6] While these statistics indicate that motorcycle safety with respect to roadside barriers needs to be addressed, there is no evidence that cable median barriers are more or less hazardous to motorcyclist than other types of post-and-beam barriers like the very common strong-post w-beam guardrail.

WSDOT is also investigating the use of cable median barriers on narrow medians. Several transportation agencies both in the US and abroad have used cable median barriers in very narrow medians to provide cross-over protection in areas where there is a history of cross-over crashes. Cable

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[8] H. C. Gabler, "The Risk of Fatality in Motorcycle
http://www.irfnews.org/files/pdfs/Clay-Gabler.pdf

median barriers have been used in Sweden on so-called 2+1 cross-sections like the highway shown in Figure 1 (i.e., a three lane cross section where the middle lane alternates between directions of travel. For example, in one section there might be two lanes going north and one going south separated by a cable median barrier and then at another location the arrangement switches with two lanes going south and one north).[9] In this cross-sectional arrangement there is no room for lateral clearance between the back of the cable and opposing traffic but the barrier does inhibit the vehicle from encroaching as far as it would without positive barrier protection. A study of this arrangement indicated that fatal crashes on 2+1 highway segments were reduced by 90 percent over a no-barrier solution.[10] [11]This cross-section arrangement has been used to the satisfaction of the Swedish transportation agencies for nearly 20 years. In July of 2007, Oregon DOT installed two miles of cable median barrier in a four-lane cross-section with an eight-foot paved median on SR 26 in Cherryville, a cross-section very similar to the Swedish 2+1 cross section.[12] The cable median barrier was installed to try to find a solution to a head-on crash experience in this particular section of roadway. Cable median barrier may provide a way for WSDOT to treat some narrow median sites with a high crash experience following the example of the Oregon DOT.

ISSUE 2: REVIEW OF POLICY IMPLEMENTATON

In my 2007 report I made one recommendation for median protection on I-5 in Marysville, four recommendations for changes to cable median barrier policy and three recommendations for further research on the use of cable median barriers. This section will summarize WSDOT's progress in implementing these recommendations during the past year. My original recommendations are repeated in an italicized font and my review of WSDOT's implement following in a normal type face.

Marysville Design Recommendation

I recommend that WSDOT install a concrete median barrier approximately 10 to 12-feet from the inside edge of the northbound traveled lanes. The concrete barrier should nearly eliminate cross-median crashes. Placing it closer to the northbound lanes will help minimize the number of serious median related crashes since most of the serious median events seem to be associated with southbound traffic. Southbound vehicles that enter the median will have more room to stop or recover but the concrete median barrier will be a last wall of protection for northbound vehicle occupants. The concrete barrier should be placed such that sufficient room is available for an emergency lane since police, fire, rescue and maintenance personnel will still need access to the far left shoulder of the highway and not providing an adequate shoulder will place these personnel in danger. WSDOT may also want to consider leaving the high-tension cable median barrier in place on the southbound side. This would provide some of the benefits of a more flexible and forgiving barrier system (i.e., the cable median barrier) while preventing cross-median crashes with the more rigid system (i.e., the concrete median barrier).

In December of 2007 the Governor's 2008 Supplemental Budget included $27 million to install concrete median barriers along 10 miles of I-5 in Marysville. After

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[9] See http://en.wikipedia.org/wiki/2%2B1_road

[10] T. Berg, A Carlsson and M. Larsson, "Swedish Vision Zero Experience," International Journal of Crashworthiness, Woodhead Publishing, Vol. 8, No. 2, January 2003.

[11] Magnus Larsson, Nimmi Candappa and Bruce Corben, "Flexible Barrier Systems Along High-Speed Roads: A Lifesaving Opportunity," Monash University for VicRoads, December 2003

[12] Marcus Hathcock, "Do we need more cable barriers? Deadly crash in corridor makes some wonder whether safety project should be expanded," The Sandy Post, Feb 17, 2008, http://www.portlandtribune.com/news/story.php?story_id=120330837925830200 .

examining several options, WSDOT engineers decided to remove the low tension cable median barrier on the northbound side of I-5 and place a concrete median barrier 10 feet from the edge of the travel lane. The high-tension cable median barrier on the southbound side of I-5 will remain in place to add a further level of protection. The project is scheduled to go out for bids in the spring of 2009 with construction to begin in the 2009 summer construction season. WSDOT has adopted my recommendation and is proceeding promptly with implementing the concrete barrier solution for Marysville.

Policy Recommendation No. 1
I recommend that WSDOT continue its use of cable median barrier. The cable median barrier program has been very effective statewide in reducing the number and severity of median cross-over crashes and has doubtless saved many lives.

My first general policy recommendation was that the cable median barrier is performing well in most areas of Washington State and its use provides a considerable benefit to the travelling public. While it is important to monitor cable median barrier performance to identify poorly performing segments as early as possible, the cable median barrier is effective and contributes to the overall safety of motorists in Washington State. In 2007 WSDOT installed another 43 miles of cable median barrier and 3.5 miles are under contract for construction in the near future. WSDOT has adopted my recommendation that the cable median barrier continue to be used in Washington State.

Policy Recommendation No. 2
When cable median barriers must be placed near the breakpoint between a nominal 10:1 and nominal 6:1 slope in the median, the following options should be considered:

a. *For single-runs of 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 in front of (i.e., between the breakpoint and the traveled lane) the slope breakpoint. Any crash tested cable median barrier can be used in this situation (i.e., low-tension or high-tension). This arrangement will allow 12 feet of dynamic deflection distance for back-side hits, provide an adequate emergency lane, minimize the chance of bumper height problems associated with SUV's and pickup trucks traversing slopes prior to contacting the barrier and provide some recovery space for vehicles leaving the near lanes of travel.*
b. *For double-runs of cable median barrier, if there is at least 11 feet from edge of the nearest traveled lane to the slope breakpoint, the cable median barrier should be placed at least one foot in front of the slope breakpoint. Any crash tested cable median barrier can be used in this situation (i.e., low-tension or high-tension). This arrangement will provide an adequate emergency lane, minimize the chance of bumper height problems associated with SUV's and pickup trucks traversing slopes prior to contacting the barrier and provide some recovery room for vehicles leaving the near lanes of travel. 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 in front of the slope breakpoint, a cable median barrier with a wider window of protection should be used to minimize the chance of newer SUV and pickup trucks from over-riding the barrier. Other types of cable median barriers that can be used behind the slope break point are:*
    i. *Any test level four cable median barrier or*

ii. 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.

While I do not believe that test level four barriers are appropriate for general highway conditions, the higher rail height of typical test level four barriers should provide additional protection for SUV's in the interim period between the new full-scale crash testing guidelines being adopted and the development of new test level three hardware. I also encourage WSDOT to perform full-scale crash testing of cable median barriers on typical median cross-sections to develop barrier options with established performance on typical median cross-sections.

Implementation of this recommendation is still in progress. There are several development efforts aimed at developing four-cable median barriers for use on 4:1 slopes and test level four barrier may also help address this need. If these new barriers are successfully tested on 4:1 slopes the placement on the slope should be less critical. WSDOT is in the process of revising its cable median barrier policy as reflected in Chapter 700 (Traffic Barriers) of the WSDOT Design Manual. The revision is expected to (1) removed the low tension cable median barrier as an option for new installations, (2) add the slope placement details described in parts a and b of my recommendations and (3) recommend the use of test level four cable median barriers or four cable median barriers. The revisions to the Design Manual should address this recommendation.

Policy Recommendation No. 3

WSDOT should develop a field inspection procedure to ensure that all wedge-and-socket connections are sound and the wedges are firmly seated into the sockets. All such connections on the low-tension cable median barriers should be field checked in a reasonable period of time to ensure that the cable forces are correctly transmitted to the foundation.

While WSDOT shifted exclusively to the use of high-tension cable median barrier around 2004, there are still about 44 miles of low-tension barrier in the inventory. WSDOT has sponsored an on-going project with Texas Transportation Institute (TTI) to develop a retrofit design for the low-tension cable median barrier that would eliminate the socket and wedge connection. TTI crash-tested an alternate connection on July 11, 2008, and is analyzing the data from that test. This research is scheduled to be complete sometime this year.

The WSDOT Materials Division developed an inspection procedure which was distributed to the maintenance personnel in March of 2007. WSDOT maintenance personnel inspected all the socket-and-wedge connections in low tension barriers during March of 2007 and its maintenance crews continue to inspect the connection after any collisions with the low-tension cable median barrier. The inspection procedure involved re-tensioning and re-seating every socket-and-wedge connection on low tension cable barrier installations to make sure that the connections were property installed. WSDOT has adopted my recommendation and quickly performed the field inspections to ensure the socket-and-wedge connection in the low-tension cable median barrier were properly seated.

Policy Recommendation No. 4

WSDOT should develop install recommendations based on a periodic review of crash history for installing both cable median barrier and concrete median barrier. Currently, installation recommendations are based primarily on the median characteristics such as median width and traffic volume. Engineering judgment and installation recommendations based on highway geometry should be the first criteria in deciding on locations for median *barrier but crash history should also play a role for locations like Marysville where the site geometry are simply not accurate predictors of the magnitude of the cross-median problem.*

WSDOT's use of the screening process that I recommended in the 2007 Governor's Report is discussed in detail in the next section (i.e., Issue 3).

Research Recommendation No. 1

Placement in the median – Research on the proper placement of cable median barriers is desperately needed. The only guidance in this area is either outdated or never completed. Recently 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 NCHRP project is programmed for this year that will look at the issue of guardrail and median barrier placement on slopes. NCHRP 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 so it should be possible for WSDOT personnel to encourage the project team to include the issues of cable median barrier placement in the project scope. NCHRP 22-17, "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 has recently been expanded.

There has been a great deal of activity nationally aimed at improving and better understanding the use of cable median barriers. NCHRP Project 22-21, "Median Cross-Section Design for Rural Divided Highways," was awarded to the Midwest Roadside Safety Facility of the University of Nebraska in January of 2006. This project was a follow-on project to NCHRP Project 17-14, "Improved Guidelines for Median Safety." Unfortunately, the data collection needed for Project 17-14 proved to be very expensive, and the data limitations hampered the strength of the recommendations. NCHRP Project 22-21 seeks to develop similar recommendations by focusing on the design of a few typical median cross-sections. NCHRP Project 22-22, "Placement of Traffic Barriers on Roadside and Median Slopes," is pending and should begin shortly. NCHRP Project 22-25, "Development of Guidance for the Selection, Use, and Maintenance of Cable Barrier Systems", which includes a WSDOT engineer on the project panel, was awarded to the National Crash Analysis Center of George Washington University in April 2008. All of these projects are addressing important aspects of median design and the placement of cable median barriers within the median. National highway research agencies like the NCHRP are presently engaged in nearly $2.5 million in research aimed directly at understanding and improving median safety and effectively using cable median barriers. WSDOT has implemented my recommendation and is both participating in and observing research efforts on cable median barrier taking place nationally.

Research Recommendation No. 2

Higher bumper heights of pickups and SUVs – As discussed earlier, pickup trucks and SUVs have continued to become larger resulting in increasing bumper heights. Newer pickup trucks and SUVs may not perform well in impacts with some types of roadside hardware due to the miss-match between the barrier heights and bumpers. NCHRP 22-14(3), Evaluation of Existing Roadside Safety Hardware Using Updated Criteria, is a new project that will perform crash tests of existing hardware like cable median barriers using the new proposed updated crash test procedures. Since the new crash test procedures recommend the use of newer pickup trucks with higher bumpers, some of the questions regarding bumper and barrier compatibility should be resolved. The Midwest Roadside Safety Facility at the University of Nebraska is also 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.*

NCHRP Project 22-14 is a series of three projects aimed at updating NCHRP Report 350, the document that specifies how roadside hardware crash tests are performed and evaluated. A draft of the update of Report 350 now referred to as the Manual for Analysis of Safety Hardware (MASH 2008), has been developed and is currently being balloted by AASHTO for adoption as an AASHTO standard. One of the factors indentified in the 2007 Governor's Report was the higher bumper height of more recent SUV's. This issue not only affects cable median barrier performance but the performance of many types of roadside hardware. The new MASH 2008 recommends using a new model SUV that is both heavier and has a higher bumper than the pickup truck test vehicle in Report 350. There are many activities going on nationally in this regard but some that particularly impact cable median barriers are Midwest Roadside Safety Facilities on-going efforts to design and crash test a four-cable median barrier, testing by several of the proprietary cable median barrier manufacturers to develop test level four cable median barriers and efforts to perform crash tests of several types of common roadside hardware with the new MASH 2008 pickup truck test vehicle. All these efforts are continuing and WSDOT personnel are monitoring these efforts.

Research Recommendation No. 3

Traffic conditions that promote median cross-overs – The conditions that promote cross-median crashes are not well understood. Traffic conflicts and impaired drivers seem to initiate most cross-median crashes but it has been difficult to predict which sites will respond well to treatment with cable median barriers and which should use concrete median barriers. Traffic conditions like 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. Such research would enable engineers to be pro-active and create designs that address a problem before fatal and disabling crashes occur.

As a result of my recommendation, WSDOT co-sponsored a research problem statement to NCHRP to study the issue of identifying highway and land-use characteristics that are associated with cross-median crashes.[13] The research problem statement was approved by AASHTO's Standing Committee on Research (SCOR) and assigned to the NCHRP as NCHRP Project 17-44, "Investigation of Contributing Factors Associated with Cross-Median Crashes and Identification of Appropriate Countermeasures." The first panel meeting is being held in July 2008 to develop a statement of work. The panel includes a WSDOT engineer. WSDOT acted on my recommendation and was able to get a new NCHRP project funded to investigate this issue.

ISSUE 3: REVIEW OF SCREENING CRITERIA

My fourth policy recommendation in the 2007 Governor's Report is repeated below in italic:

WSDOT should develop install recommendations based on a periodic review of crash history for installing both cable median barrier and concrete median barrier. Currently, installation recommendations are based primarily on the median characteristics such as median width and traffic volume. Engineering judgment and installation recommendations based on highway geometry should be the first criteria in deciding on locations for median barrier but crash history should also play a role for locations like Marysville where the site geometry are simply not accurate predictors of the magnitude of the cross-median problem.

[13] http://www.trb.org/NotesDocs/NCHRP_Announcement.pdf

I suggest the installation recommendations summarized in Table 6 based on the crash rate histories reported earlier in Table 1 (in the 2007 Governor's Report). I have based these recommendations on cross-median crashes of all severities because we should not wait until someone is killed in a crash to make a decision. Any median cross-over is a potential fatal crash and crash data can be collected more quickly based on crashes of all severities.

Table 6. Median barrier installation recommendations based on historical crash rates.

Crash Rate † *Cross-median crashes of all severities per 100 MVMT*	***Site Characteristics***	***Action***
Greater than 1.00	• *No median barrier,* • *30-ft or wider median and* • *6:1 or flatter slopes.*	*Evaluate cost benefit of using a cable median barrier.*
Greater than 2.00	• *No median barrier,* • *30 to 50 ft wide median,* • *6:1 or flatter slopes,* • *ADT > 75,000 vpd and* • *In rural/urban transition area.*‡	*Evaluate cost benefit of using a double-run of cable, w-beam, thrie-beam or concrete median barriers.*
Greater than 0.75	• *30 to 50 ft wide median,* • *Cable median barrier,* • *6:1 or flatter slopes,* • *ADT > 75,000 vpd 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 are Available, the section has experienced at least 100 MVMT. 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 ADT (e.g., 30 percent) in a relatively short distance or*
- *High ramp volumes in proportion to the mainline ADT.*

As part of this recommendation, I developed screening criteria for evaluating crash history as a factor in making decisions for barrier placement. This criteria was developed using an in-service evaluation approach and was presented to WSDOT in May/June 2007 The purpose of this screening criterion is to try to identify sites where cable median barrier is a good candidate for reducing cross-median crashes as well as identifying sites where cable median barrier does not seem to be performing well. The screening criteria summarized in Table 6 uses the total number of cross-median crashes in order to indentify candidate sites prior to a serious or fatal injury crash. As of the end of 2007 there were 35 highway segments where cable median barriers were installed. The cross-median crash rates in the before period are shown in Table 7 along with the screening recommendation that would have been used if this procedure had been in place when the decision to install a cable median barrier was made. For 12 of the segments, the segment was either too short or did not have adequate volume to calculate a reliable rate so it would not have been possible to make a recommendation based on crash history. The 12 segments where it was not possible to calculate an accurate rate plus the four segments that had rates below the median barrier threshold would still have been selected based on WSDOT policies for warranting median barriers. The fact that the rates either could not be calculated accurately or the rate was under the threshold simply means there was not adequate crash history to accurately assess these locations.

On 17 segments the crash history rate prior to installing a cable median barrier indicated a cable median barrier would be appropriate and, in fact, a cable median barrier was installed. One site, I-5 in Marysville, was identified for consideration of a double run of median barrier since the cross-over crash rate in the before period was over 2 cross-median crashes/100MVMT. As well documented in the 2007 Governor's Report, Marysville has been a site with recurring cross-median collisions and in the end, a double run of cable was tried at that location and now an unusual type of double run (i.e., cable on one side and concrete on the other) is being programmed for construction. Table 7 shows that had this type of screening procedure been available in the mid-1990's, Marysville would likely have been targeted for some other type of median barrier treatment.

Table 8 shows the screening criteria against the cross-median crash rates in the period after cable median barriers had been installed. The segment was too short or the volume was too small to calculate an accurate rate in 20 of the 35 highway segments so the decision to use cable median barrier would be based on policy warrants rather than crash history. The crash rates for 13 segments fell appropriately with the range suggested for cable median barrier but there were two segments where the rate exceeded 0.75 cross-median crashes/100 MVMT, the threshold for considering another median barrier alternative. One of the sites that the screening criterion recommends for another median barrier alternative is I-5 in Marysville. The Marysville segment was considered in the 2007 Governor's Report and as described earlier, a concrete median barrier has been planned for this site and construction should begin in 2009. I-5 in Fife also exceeded the threshold where another median barrier option should be considered. This segment was the scene of a fatal crash on July 22, 2007 but the segment had already been programmed for a concrete median barrier due to a highway widening project. Had the crash history screening criteria been available years earlier, these two locations would have been identified earlier and a benefit/cost analysis could have been performed to determine if there was a better median protection alternative available. Table 8 shows some other interesting features. I-90 at Moses Lake and I-90 in Spokane both show rates above 2.0 cross-median crashes/100MVMT but, in both cases, the traffic volume is less than 75,000 vehicles per day (vpd). The I-90 at Moses Lake segment has a relatively low traffic volume, far below the 75,000 vpd recommended in Table 6 and it is not in an urban/rural transition area so it is not selected by the screening procedure as an area the needs additional analysis. As discussed earlier, in all likelihood the high rate at this location is a statistical artifact of the one serious collision that occurred and the low volume in the segment and in a few years the rate should be at or below the state average. The I-90 segment in Spokane also exceeds the 0.75 cross-median crashes/100MVMT. Unlike Moses Lake, this section of highway appears to be in an urban/rural transition zone and the traffic volume has been steadily increasing in the past several years. Today, the traffic volume is about 70,000 vpd so it is likely that within the next few years the 75,000 vpd volume criterion will be met and this site might need to be considered for another type of median improvement.

The screening criterion I recommended in the 2007 Governor's Report identified two locations that exceeded the crash history rate for cable median barriers. Both had already been identified as sites with abnormally high cross-median collision rates and new median barriers are already planned at that location. The I-5 in Spokane example illustrates the value of using this type of screening criteria since it would allow an emerging location to be identified and corrected before it begins to exhibit high frequency cross median collisions like I-5 in Marysville.

Table 7. Total Crash Rates and Screening Recommendation for Median Barrier Alternatives in the State of Washington — Before Period, 1993-2007.

Segment Name	Total cross-median crash rate (crashes/100MVMT)	Recommendation
I-3 Silverdale	1.043	Consider Cable Median Barrier
I-5 Vancouver to Woodland	1.204	Consider Cable Median Barrier
I-5 Lewis Co. to Maytown	2.712	Consider Cable Median Barrier
I-5 Nisqually	1.139	Segment too Short for Determination
I-5 Puyallup River and Fife	0.901	Segment Below Cable Barrier Threshold
I-5 Marysville	2.282	Consider Double Run Median Barrier
I-5 Mt. Vernon	0.857	Segment Below Cable Barrier Threshold
I-5 Burlington	3.914	Consider Cable Median Barrier
I-5 Bellingham	2.387	Consider Cable Median Barrier
I-5 Ferndale	3.357	Consider Cable Median Barrier
I-5 Blaine	2.257	Segment Below Volume Threshold
SR12 Montesano	1.688	Consider Cable Median Barrier
SR13 Olympic Drive/Purdy	0.722	Segment Below Cable Barrier Threshold
SR18 Covington	2.728	Consider Cable Median Barrier
I-90 Issaquah	1.778	Segment too Short for Determination
I-90 George	3.593	Consider Cable Median Barrier
I-90 George/Moses Lake	4.585	Consider Cable Median Barrier
I-90 East Moses Lake	3.840	Consider Cable Median Barrier
I-90 Spokane	3.566	Consider Cable Median Barrier
SR99 Tukwila	1.295	Consider Cable Median Barrier
SR101 Olympia	1.399	Consider Cable Median Barrier
SR167 Sumner	0.319	Segment Below Cable Barrier Threshold
SR410 Sumner	1.611	Segment too Short for Determination
SR512 Puyallup	1.921	Consider Cable Median Barrier
SR522 Bothell	3.774	Segment too Short for Determination
SR12 Yakima 16th to 1st	0.000	Segment Below Volume Threshold
SR12 Yakima N 1st to Thorp	2.516	Consider Cable Median Barrier
SR182 from SR395 to SR12	3.411	Consider Cable Median Barrier
SR18 SE 312th Vicinity	0.000	Segment Below Volume Threshold
SR18 Casey Creek	0.000	Segment Below Volume Threshold
SR20 Fredonia	7.325	Segment Below Volume Threshold
SR82 Selah Creek	0.000	Segment Below Volume Threshold
I-90 Bellevue	0.000	Segment Below Volume Threshold
I-90 Vantage	0.000	Segment Below Volume Threshold
SR240 Richland	0.000	Segment Below Volume Threshold

Table 8. Total Crash Rates and Screening Recommendation for Median Barrier Alternatives in the State of Washington — After Period, 1993-2007.

Segment Name	Total cross-median crash rate (crashes/100MVMT)	Recommendation
I-3 Silverdale	0.000	Consider Cable Median Barrier
I-5 Vancouver to Woodland	0.142	Consider Cable Median Barrier
I-5 Lewis Co. to Maytown	0.392	Consider Cable Median Barrier
I-5 Nisqually	1.012	Segment too Short for Determination
I-5 Puyallup River and Fife	0.886	Evaluate other median barrier option
I-5 Marysville	0.794	Evaluate other median barrier option
I-5 Mt. Vernon	0.287	Consider Cable Median Barrier
I-5 Burlington	0.000	Consider Cable Median Barrier
I-5 Bellingham	0.290	Consider Cable Median Barrier
I-5 Ferndale	0.000	Segment Below Volume Threshold
I-5 Blaine	0.000	Segment Below Volume Threshold
SR12 Montesano	0.000	Consider Cable Median Barrier
SR13 Olympic Drive/Purdy	0.000	Consider Cable Median Barrier
SR18 Covington	0.000	Segment Below Volume Threshold
I-90 Issaquah	0.000	Segment Below Volume Threshold
I-90 George	0.000	Consider Cable Median Barrier
I-90 George/Moses Lake	2.136	Consider Cable Median Barrier
I-90 East Moses Lake	1.009	Segment Below Volume Threshold
I-90 Spokane	1.479	Consider Cable Median Barrier
SR99 Tukwila	0.000	Segment Below Volume Threshold
SR101 Olympia	2.219	Segment Below Volume Threshold
SR167 Sumner	0.000	Consider Cable Median Barrier
SR410 Sumner	0.000	Segment Below Volume Threshold
SR512 Puyallup	0.490	Consider Cable Median Barrier
SR522 Bothell	1.929	Segment Below Volume Threshold
SR12 Yakima 16th to 1st	0.000	Segment Below Volume Threshold
SR12 Yakima N 1st to Thorp	0.000	Segment Below Volume Threshold
SR182 from SR395 to SR12	0.000	Segment Below Volume Threshold
SR18 SE 312th Vicinity	20.857	Segment Below Volume Threshold
SR18 Casey Creek	0.000	Segment Below Volume Threshold
SR20 Fredonia	0.000	Segment Below Volume Threshold
SR82 Selah Creek	0.000	Segment Below Volume Threshold
I-90 Bellevue	0.000	Segment Below Volume Threshold
I-90 Vantage	0.000	Segment Below Volume Threshold
SR240 Richland	0.000	Segment Below Volume Threshold

ISSUE 4: RECOMMENDATIONS

In reviewing the screening criteria I would like to make one small suggestion for a change. Currently, the note on Table 6 reads " crash rates should be calculated on sections that are at least two miles long and, where data are available, the section has experienced at least 100 MVMT." As illustrated by the example of I-90 Moses Lake, even 100 MVMT is probably too soon to calculate an accurate rate. Even one minor crash in the first 100MVMT would indicate another median barrier option should be used. In looking over the results of this first screening, I believe it would be more accurate and realistic to not calculate the rate until the vehicle miles travelled exceed 200 MVMT. I also believe the section length criterion can be dropped since a short section will simply take longer to meet the vehicle miles travelled criteria. I suggest that the note be changed to "crash rates should be calculated only on sections where the section has experienced at least 200 MVMT." I-5 in Nisqually, for example, has a relatively high rate of 1.012 cross-median crashes/100MVMT and at the end of 2007 had experienced 197.58 100MVMT. While the segment length is only 1.55 miles long, the segment has experience enough vehicle miles to calculate an accurate rate. The note in the 2007 version of Table 6 would forever exclude Nisqually from evaluation whereas my proposed change would likely include Nisqually in the screening process next year.

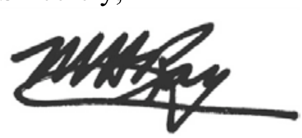
The quick comparison of the "old" WSDOT cable median barrier policy versus the "new" cable median barrier policy discussed earlier in this report raises very interesting questions about the evolution of median barrier policy. I recommend that WSDOT use the data assembled for this review and perform a more comprehensive review of the pre-2004 and post-2004 policies to see if it is possible to determine the effectiveness of low-tension versus high-tension cable median barrier and the effectiveness of the different versions of the placement policy. It may not be possible to separate these two effects but it should be possible to demonstrate that the post-2004 policy is an incremental improvement over the earlier policy.

CONCLUSIONS

In reviewing the last year of experience with cable median barrier in Washington State I find that in general the situation has remained the same. Sites with highest frequency cross-median collisions have been identified and programmed for improvements while the majority of installations appear to be performing well. WSDOT has made excellent progress on implementing all the recommendations I made in the 2007 Governor's Report. The screening process I suggested in 2007 looks like it will be useful in identifying locations where cross-median collisions is high or is increasing. I believe WSDOT has done an excellent job in collecting a diverse set of data for performing these analyses. WSDOT is one of the few States in the U.S. that can perform this type of screening analysis because unlike many States, it keeps better track of its installed inventory of cable median and can therefore merge the inventory data with traffic and crash data in order to perform benefit/cost evaluations of barrier alternatives.

I am hopeful that the foregoing analysis has helped to answer some of your questions about WSDOT's cable median barrier policy, its effectiveness and ways that it might be improved. If you should have any questions or comments, please contact me. I appreciate the opportunity to be of service to the WSDOT and the people of the State of Washington.

Sincerely,



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