ROAD SAFETY AUDIT

Cornelius Pass Road
Multnomah County, Oregon
July 1-3, 2008

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Executive Summary

A road safety audit is a formal safety performance examination of an existing or future road or intersection by an independent and multidisciplinary audit team. Road safety audits help improve road safety by identifying safety issues, promoting awareness of safe design, operational, and maintenance practices, supporting consideration of multimodal approaches to safety, and including human factors more directly in safety needs assessment and solution development.

Multnomah County asked the Oregon Division of the Federal Highway Administration to coordinate a road safety audit of Cornelius Pass Road to evaluate the effectiveness of the road safety audit concept and to assess safety issues along Cornelius Pass Road and develop safety suggestions for consideration by the County.

Cornelius Pass Road is located in the northwest part of the Portland, Oregon metropolitan area and connects two major regional arterial highways, US 26 and Highway 30, providing the most direct connection between the communities of Scappoose and St. Helens with major employment centers in Washington County. While the roadway spans two jurisdictions, Washington County and Multnomah County, this audit only covered the portion of the roadway within Multnomah County.

Crash summaries were obtained from the Oregon Department of Transportation and detailed crash reports (for crashes to which law enforcement responded) were studied to better understand crash types, likely causes, and potential crash remediation actions.

The road safety audit team conducted a site visit in July of 2008. This review was designed to identify current and future safety concerns based on the audit team's multidisciplinary knowledge, assessment of crash summary data, discussions with County staff, and physical review of the roadway.

The team identified several broad safety issues and offered suggestions for treatments, these were designed to cover the full array of actions, including design, operations, maintenance, planning, and even policy actions. Due to the constrained nature of the roadway the team focused suggestions on low cost actions that could be taken to deliver improved safety performance in the near term. The team also established a prioritization based on the expected frequency and severity of crashes. The intent is to establish a priority based on the likelihood of an event occurring and the severity of the outcome should that event occur. Overall the audit recommendations should provide as wide an array of information as possible to allow the County to develop a range of prioritization and implementation strategies.

The safety issues and suggestions, in rough priority order, are shown in tabular form (risks are ranked from A, lowest risk level, to F, highest risk level):

Safety Issue		Risk Ranking	Suggestions
1	Hazards are present in the clear zone	E	▪ Install additional roadside barriers ▪ Install additional end treatments ▪ Relocate or delineate utility poles ▪ Delineate rock walls ▪ Reduce pavement drop-offs ▪ Improve roadway delineation ▪ Update roadside protection policy
2	Potential for unanticipated change in centerline pavement markings	D	▪ Remove existing skip lines ▪ Consider durable no-passing marking ▪ Re-mark short section near County line as no-passing zone
3	Guardrails and barriers do not provide consistent shielding along corridor	D	▪ Increase guardrail delineation ▪ Upgrade end treatments ▪ Re-set critical sections of guardrail ▪ Conduct guardrail needs analysis
4	Vehicles crossing over centerline	D	▪ Install profiled centerline ▪ Consider select curve widening
5	Sign size and conspicuity may not be sufficient to meet driver needs	C	▪ Consider larger and brighter signs ▪ Upgrade street name signs and install advance intersection signs ▪ Install house numbers ▪ Install interim milepost markers ▪ Update sign placement policy ▪ Assess sign needs
6	Curve signing not consistent throughout corridor	C	▪ Ensure consistency of chevron signs ▪ Update sign policy ▪ Verify advisory curve speed posting
7	Signs and delineators were obscured by dirt and grime	C	▪ Increase frequency of cleaning ▪ Update cleaning policy
8	Intersection sight lines are restricted at several locations	C	▪ Measure intersection sight distance ▪ Take physical actions to improve sight distance
9	Visibility is limited for vehicles turning at Sheltered Nook Road	C	▪ Consider vehicle activated advance sign to warn of stopped vehicles ▪ Install stop bar at Sheltered Nook
10	Traffic volumes and composition indicate roadway operates beyond its functional capacity	Not applicable	▪ Conduct a study on road function including hazardous material routing
11	Right turn lane from eastbound Highway 30 may encourage	C	▪ Install right turn edgeline ▪ Address right-turn edge drop-off ▪ Develop right-turn lane design to

Safety Issue		Risk Ranking	Suggestions
	excessive speeds		control speeds ▪ Include right turn overlap in signal re-design
12	Posted speed limit may exceed operating speed	Not applicable	▪ Consider speed zone review
13	Curve sightlines are limited	B	▪ Increase mowing and brushing
14	Topography limits communication coverage	Not applicable	▪ Improve radio communications for maintenance and emergency services
15	Unfamiliar drivers may be unaware of constrained nature of corridor	Not applicable	▪ Consider designation as safety corridor ▪ Develop corridor safety policy
16	Constrained roadway geometry makes winter driving potentially hazardous	A	▪ Consider activated driver warning signs ▪ Consider weather monitoring system
17	T-intersections are potentially confusing for drivers	A	▪ Install dual arrow sign at stem of T intersection
18	Driver's may be confused by perception of roadway alignments at Skyline Road	A	▪ Install additional landscaping ▪ Consider altering sign angles ▪ Install delineators

This road safety audit has identified a range of safety issues on Cornelius Pass Road, prioritized those issues, and developed safety suggestions. Multnomah County is invited to consider the issues and suggestions, and, to complete the audit process, should prepare a short written response to each of the issues and options identified in this report

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1.0 Introduction

A road safety audit is an independent assessment of a roadway's safety performance, examined both in terms of its current condition and expected future safety performance. An interdisciplinary team was assembled to evaluate Cornelius Pass Road from the point it crossed the Multnomah County Line to its terminus at Highway 30 (figure 1 shows a map of the area). The road safety audit was requested by the County as a means of assessing the benefits of road safety audits. In Oregon efforts are on-going to provide road safety audits to State, county, and local agencies. The Federal Highway Administration has sponsored a number of road safety audits around the nation to demonstrate the benefits of a proactive approach to highway safety, including the identification of problems and the development of mitigations. This review was supported by FHWA as part of this national effort.

1.1 Background

Cornelius Pass Road is located in the northwest part of the Portland, Oregon metropolitan area. It provides a connection between two major regional arterial highways, US 26 and Highway 30 and provides the most direct connection between the communities of Scappoose and St. Helens with major employment centers in Washington County. The road is classified as a rural arterial.[1] The roadway also spans two jurisdictions, Washington County and Multnomah County. While this audit is focused on the section of the roadway in Multnomah County, the demarcation between the jurisdictions is simply an administrative one.

In order to properly understand the road in its functional context, particularly as it transitions from US 26[2], a broader review of the road in its regional context is required.

At its southern terminus at an interchange with Highway 26, the roadway commences as a five lane urban arterial (center turn lane with two through lanes in each direction); the road then traverses through more suburban terrain and land development patterns characterized by businesses plaza developments and adjacent apartment complexes. At the Union Road intersection the roadway transitions to a two lane roadway and remains two lanes until its terminus with Highway 30.

[1] For further information on the concept of functional classification consult http://www.fhwa.dot.gov/planning/fctoc.htm

[2] In contrast the transition at the US 30 end is more pronounced as the roadway physically ends at the T-intersection with Highway 30.

The initial rural section consists of a two lane highway on gently ascending and flowing alignment and the road scene provides open vistas of the surrounding farmland. There is a T-intersection on the left and then the roadway ascends the rise, and intersects Germantown Road at a skew angle[3]. Past Germantown Road the road continues down a slight downgrade and then climbs back up the hillside. The open farmland gives way to more lightly forested land as the road continues upgrade past the T-intersection with Kaiser Road and through the intersection with Skyline Drive (with Skyline stop controlled).

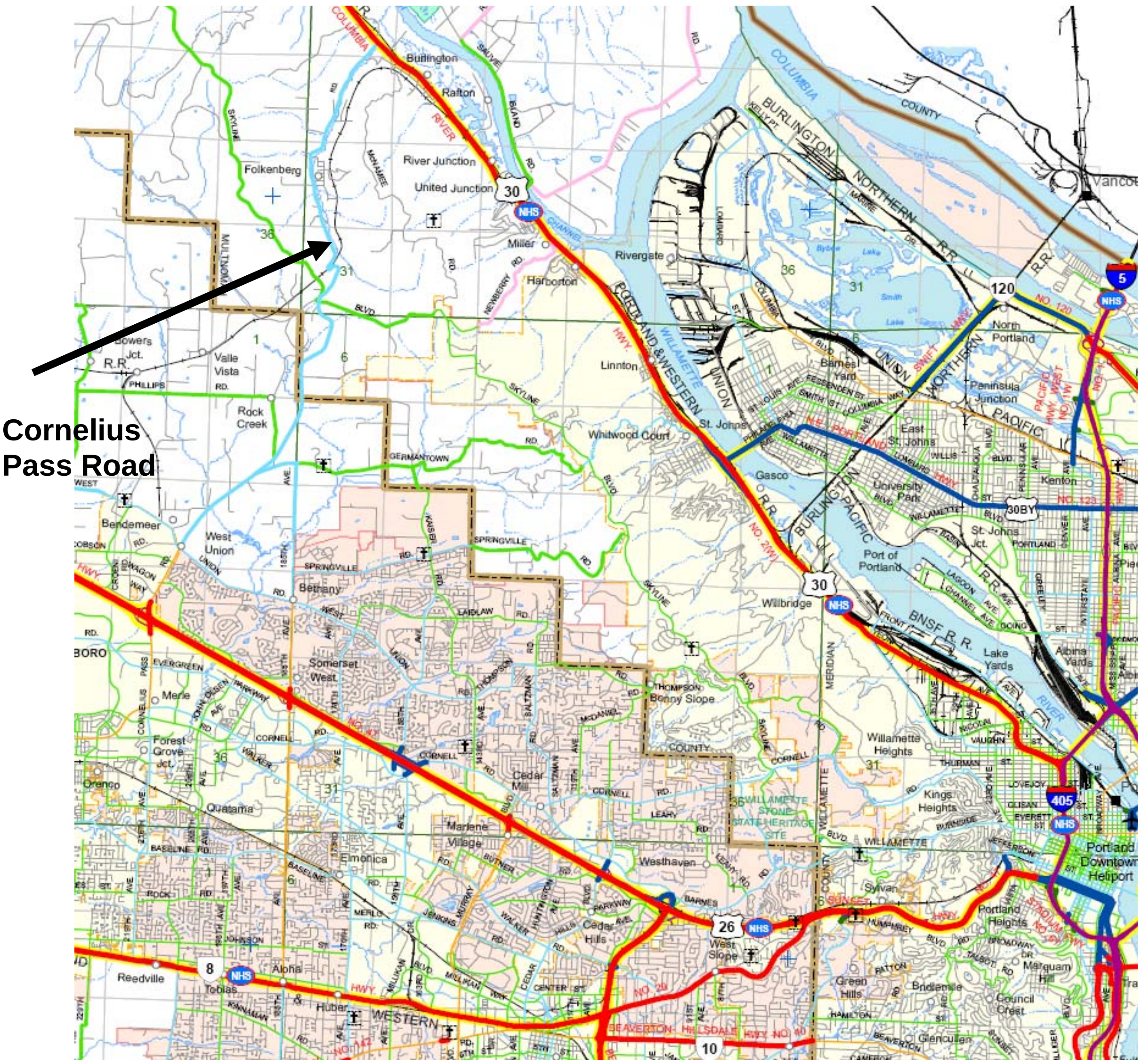

Figure 1: Regional context for Cornelius Pass Road (Source: Oregon Department of Transportation)

[3] Germantown Road is stop controlled with a flashing red beacon for the side road and yellow beacons for the mainline approaches.

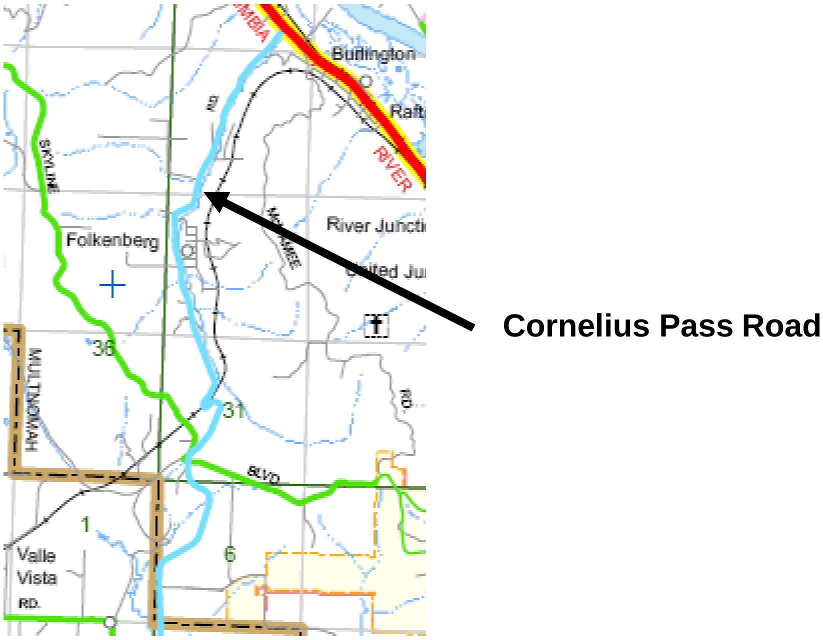

Figure 2: Cornelius Pass Road section from Multnomah County line to Highway 30 (Source: Oregon Department of Transportation)

A turn bay is provided on the mainline at Skyline Drive for left turns in both directions. Past Skyline Drive the character of the adjacent land and road itself changes. The adjacent area is heavily wooded on both sides of the roadway and the terrain is much steeper..While the road continues as a two lane rural road, the steeper topography results in the road assuming a more curvilinear alignment. The road continues its descent and then traverses through a tight S-curve.[4] A few houses are located off the roadway in the lower sections of the road with the road continuing on a downgrade until its intersection with Highway 30. The initial downgrade section has a number of curves marked with advisory speed plaques. The road continues past a T-intersection with Sheltered Nook Road (stop on minor approach) where the road is nearly on a flat alignment. The road then continues on a gentle descent with the horizontal curves generally become more gradual (greater radii) towards the terminus at Highway 30 where the road ends at a signalized intersection.

1.2 Context

This road safety audit is a review of an existing roadway. Multnomah County asked the Oregon Division of the Federal Highway Administration to conduct a road safety audit review to independently assess the safety performance of the roadway and to suggest potential safety improvements to the roadway. While the Oregon Department of Transportation (ODOT) has proposed a project for alignment improvements to the intersection of Highway 30 and Cornelius Pass Road (additional turn lanes and improvement to the signal control and layout) per the County there are no plans for any

[4] The alignment of the more northerly curve has a tighter (shorter) radius then the southern curve.

improvements to Multnomah County's portion of the road in the next 20 years of either a short term or long term nature aside from ordinary maintenance and operations. While the road safety audit is an independent assessment of the safety of the roadway, understanding the context in which investments are made is important to ascertain what types of solutions are likely to be implemented. Given the fiscal restrictions discussed above, this review focused on suggesting lower cost improvements. While the focus was on low cost safety investments, a number of issues dealt with road management and, or a broader note, a few underlying issues involved development of network and policy solutions on a regional scale to address current traffic composition and likely future trends in traffic growth and composition.

1.3 Road Safety Audits

A road safety audit is a formal safety performance evaluation of an existing or future road or intersection by an independent audit team. Road safety audits promote road safety by identifying existing safety concerns and potential future concerns and are applicable at any project stage. These audits also serve to promote the application of safe design, construction and maintenance practices, promote awareness of human factors principles into roadway design and management, and increase implementation of safety analysis tools and safety techniques. Figure 4 shows the steps in a typical road safety audit and distinguishes the actions of the audit team from those of the project owner. This review followed these steps, with this report serving as the formal report of the team's findings.

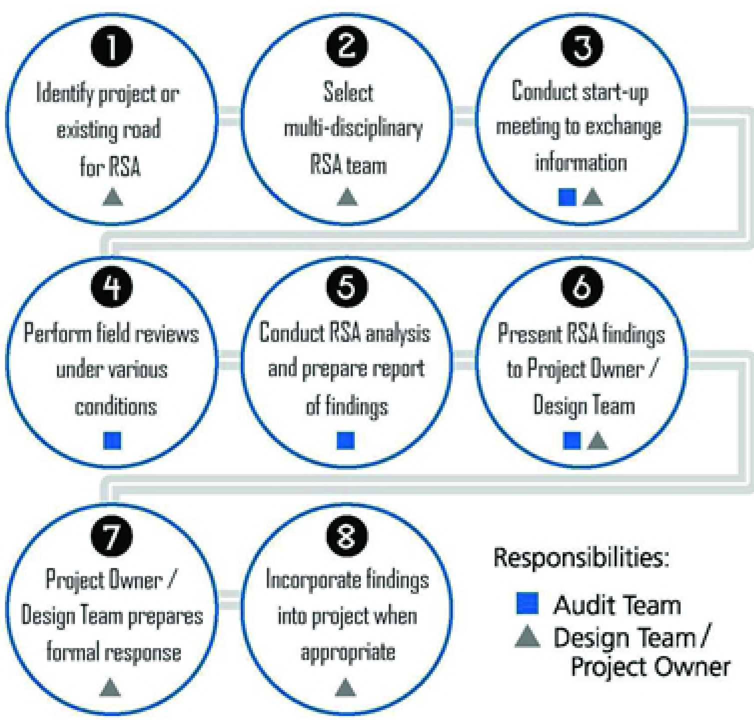

Figure 4: The road safety audit process

The audit team has conducted this audit to the best of its professional abilities within the time available and making use of the material made available. Because this was an in-service audit (an audit of an existing road) and there were no existing plans of the facility, specifics on roadway geometry were not available (with the exception of the planned improvements at the intersection with Highway 30). Responsibility for the design, construction, and performance of the roadway remains with the County.

1.4 Audit Team and Process

The audit team and the project material on which the audit was based are described in Appendix A. Site visits were conducted in July of 2008 to understand the existing conditions and surroundings as well as to identify safety concerns. The independent road safety audit team visited the corridor on July 1st and 2nd, 2008, observing the existing conditions and vehicle operations on Cornelius Pass Road. Site reviews were conducted at various times throughout the day; while the early morning peak traffic was not observed, the team did observe traffic and vehicle operations during the afternoon peak and at other points throughout the morning and afternoon. The audit team drove the roadway in a passenger van and two members rode as passengers in the County's dump truck to observe issues associated with truck operations. Audit team members also walked select portions of the corridor to observe vehicle operations, study objects outside the traveled way and to, in general, increase familiarity with the physical conditions in the corridor. Finally, a nighttime review was made of the roadway. After the field visit, a closeout meeting was held with the County to present preliminary findings from the road safety audit. Notes from the site visits are contained in Appendix B.

A road safety audit often includes a categorization of issues to establish a prioritization based on the expected frequency and severity of crashes. The intent is to establish a means to prioritize identified issues and thus assist in developing solutions. Thus each safety issue is assessed on a qualitative level between F (highest risk and highest priority) and A (lowest risk and lowest priority)..Overlaid on this matrix are cost ranking and action efficiency assessments; these are designed to identify the efficiency of suggestions and prioritize actions, highlighting those that can be addressed at low cost or by using in-house staff. The interplay of these elements serves to assist an agency to develop an array of strategies for future improvements. Providing a wide array of information possible allows the County to develop a range of prioritization and implementation strategies.

It bears reiterating that the primary function of the road safety is the identification of and assessment of safety issues and the subsequent review and formal response to those issues by the owning and operating agency.

Table 1: Frequency Rating

Exposure	Probability	Expected Crash Frequency	Frequency Rating
High	High	5 or more crashes per year	**Frequent**
Medium	High		
High	Medium	1 to 5 crashes per year	**Occasional**
Medium	Medium		
Low	High		
High	Low	Less than 1 crash per year, but more than 1 crash every 6 years	**Infrequent**
Low	Medium		
Medium	Low	Less than 1 crash every 6 years	**Rare**
Low	Low		

Table 2: Severity rating

Typical Crash Type Expected	Expected Crash Severity	Severity Ranking
Crashes involving high speeds, heavy vehicles, pedestrians, or bicycles	High	**Extreme**
Crashes involving medium to high speed ; head-on, crossing, or run-off-the-road crashes	High - Moderate	**High**
Crashes involving medium to low speeds, left-turn and right-turn crashes	Moderate	**Moderate**
Crashes involving low to medium speeds; rear-end or sideswipe crashes	Low	**Low**

Table 3: Crash Risk Assessment

Severity / Frequency	Low	Moderate	High	Extreme
Frequent	C	D	E	F
Occasional	B	C	D	E
Infrequent	A	B	C	D
Rare	A	A	B	C

A: Lowest risk level
B: Low risk level
C: Moderately low risk level
D: Moderately high risk level
E: High risk level
F: Highest risk level

Cost Ranking
Low – repair or replacement with in-stock items (e.g. brushing, sign replacement)
Moderate – minor new construction (e.g. new guardrail end terminals)
High – moderate to high new construction (e.g., long new guardrail run)

Action Efficiency
High – actions could be performed by County maintenance forces during periodic activities
Moderate – actions that could be performed by in-house staffs but might involve rental of specialized equipment or use of special crews
Low – actions that would involve hiring a third party

1.5 Crash History

Crash summaries for the audit segment were provided by both ODOT and the County. The County provided police crash reports from 2003 to 2007, inclusive. As these reports included only those crashes for which law enforcement had responded and due to the desire to provide a complete assessment of all crashes[5] on the roadway, additional crash data was requested from the Oregon Department of Transportation. That information covered the period from 1993 to 2007.[6] The table and charts show key data based on reportable crashes for the 1993 to 2007 period.

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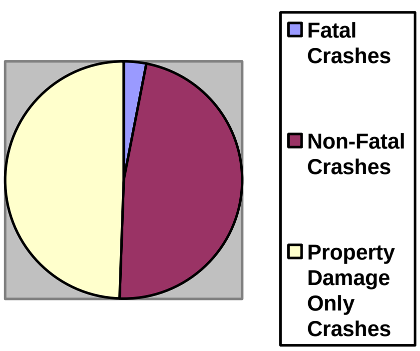
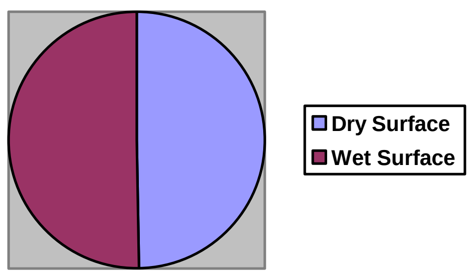
[5] See http://www.oregon.gov/ODOT/TD/TDATA/car/CAR_Main.shtml for the criteria for legally reportable crashes, which has changed over time.

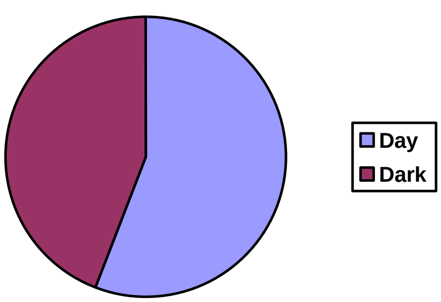
[6] Due to changes in the vehicle fleet, vehicle type, volumes and roadway, crash analyses are typically performed using 3 to 5 years of data. While vehicle fleets and volumes have certainly changed on this route, there have been only selected roadway improvements such that the roadway geometry has remained consistent over many years thus a longer crash history was considered useful for illustrative purposes.

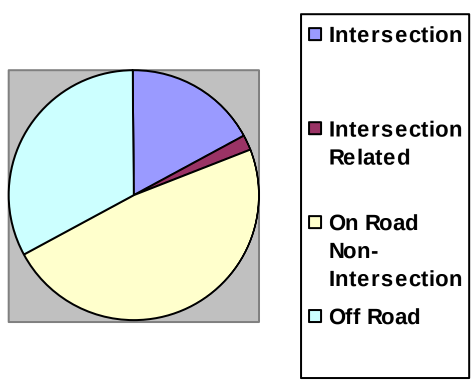
Table 4: Crash Summary

Year	Fatal crashes	Injury crashes	Property Damage Only Crashes	Total Crashes	People Killed	People Injured
2007	1	6	16	23	1	8
2006	0	7	8	15	0	12
2005	0	11	5	16	0	19
2004	0	5	4	9	0	8
2003	1	6	6	13	2	8
2002	0	9	8	17	0	9
2001	0	5	12	17	0	8
2000	1	9	11	21	1	13
1999	0	8	9	17	0	22
1998	1	6	2	9	1	14
1997	0	6	6	12	0	14
1996	1	5	6	12	1	8
1995	2	10	5	17	2	18
1994	0	4	7	11	0	8
1993	0	7	4	11	0	12

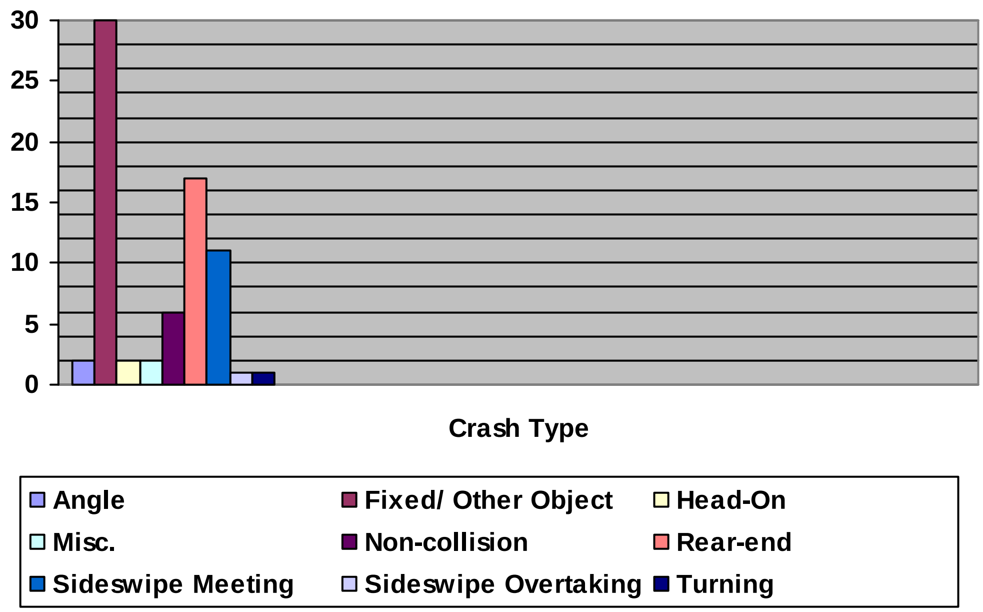




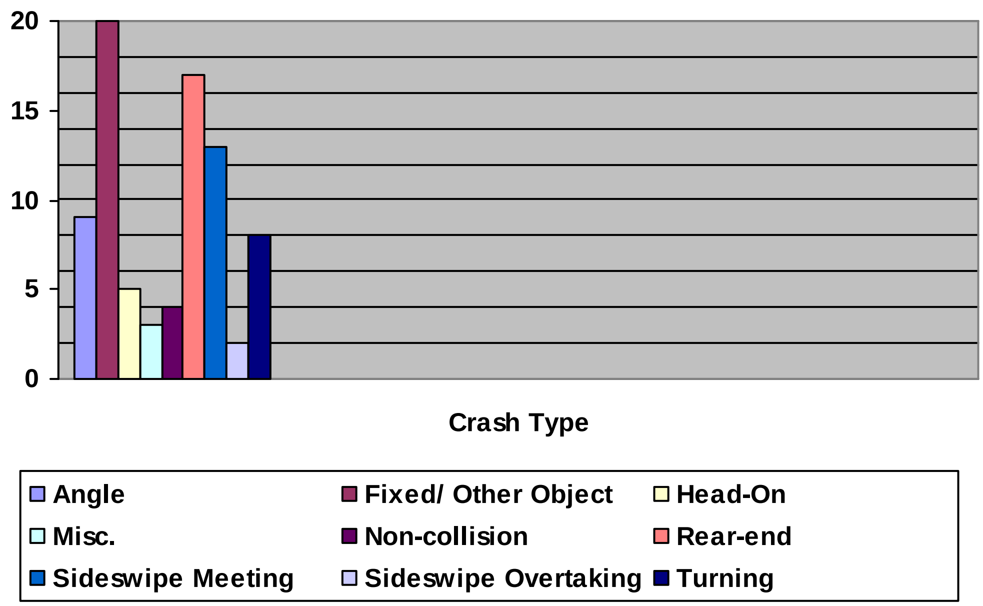




Non-Fatal crashes (1998 - 2007)



Property Damage Only Crashes (1998 - 2007)



Perhaps not surprisingly the data reveals that there is a near-even split between crashes occurring under dry pavement conditions and under wet pavement conditions, perhaps reflecting the consequences of a constrained roadway section. This may also be reflected in the near even split for crashes by day and by night, even though day conditions and volumes would appear to indicate a predominance of day crashes. The bar chart also shows the predominance of fixed object crashes in the corridor. An analysis of property damage only crashes also conforms the predominance of fixed object crashes but also indicates that rear-end crashes are important. The crash data emphasizes the finding of the road safety audit review that fixed object crashes represent a major safety concern on Cornelius Pass Road

In addition to this summary, law enforcement crash reports (all crashes to which the Multnomah County Sheriffs Office responded) from 2003 to 2007 (inclusive) were reviewed. While the crash database summary from ODOT provides a global picture of all crashes, the road safety audit team decided, based on early discussions with the County, that a more complete analysis would be desirable. As there had been a number of high profile crashes on this route over the past several years, because this was an in-service audit, and since the County wanted to ensure there was a link between field assessments and actual crashes, the atypical step was taken of reviewing all crashes to which law enforcement responded. This was a rich data source as it contained the actual crash reports, including narrative descriptions, eyewitness accounts and subsequent analyses. Not unexpectedly, these crashes aligned with concerns cited in the road safety audit field reviews, as there were a number of fixed object collisions with trees, overturns on steep embankments, curve loss-of-control crashes, and crossover crashes. More surprising, given the high number of fixed objects off the traveled way, was the limited incidence of serious injuries or fatalities. While the incidence of serious and fatal crashes was low, and determining causality and possible remediation is complex, the Road Safety Audit Team did not want to ignore this important data and consequently made educated assessments based on the crash data, narratives, and knowledge gained from field inspection in the prioritization and development of solutions.

AUDIT FINDINGS

2.1 Positive Initial Steps Taken

The audit team noted that prior to the conduct of the audit the County had taken a number of steps to improve safety along the roadway and these deserve to be acknowledged. First, the County staff initiated and continually supported the road safety audit process. The County expressed a clear interest in having an audit conducted on this roadway, which, notably, was the first such audit conducted in this county or for any other county roadway in the State. Moreover, the County continually supported the efforts of the audit team by generously providing crash data, history of the roadway, future proposals for the roadway, logistical support for the roadway audit team, use of maintenance facilities on Skyline Road for the road safety audit team to meet and stage work, and hosted a one day training session for county and ODOT staff prior to the actual road safety audit. Further, the County graciously provided staff and equipment for making road measurement and closing the roadway to allow superelevation measurements to be taken on the S-curves during the team's review and later for a series of superelevation checks and curve radii calculations during the end of July.

The County has also initiated a number of steps to improve safety on the route. Cornelius Pass Road had a number of passing zones throughout the route prior to the summer of 2008. County maintenance staff have marked the entire section[7] of Cornelius Pass Road under County jurisdiction as a no-passing zone through the use of paint striping and by so doing created new pavement markings throughout the roadway. Additionally, new reflective pavement markings had been placed to increase the conspicuity of the centerline marking at night.

The roadway is comprised of a series of horizontal curves providing a flowing alignment. Chevron signs have been installed for several of the sharper curves. About 10 years ago the County had realigned the roadway in the vicinity of the S-curves just north of the descent after Skyline Road. The tight radii curves at this location are clear breaks with the remainder of the alignment but the sharp curves at this location are made quite conspicuous for the approaching drivers through the use not only of chevron signs but concrete shoulder barrier placed through the curves, delineators placed on the concrete barrier, and overhead lighting in the S-curves.

In addition to the lighting for the S-curves roadway lighting was present at other key locations in the corridor, and based on the team's assessment of night-time driving conditions, the lighting provided adequate guidance at critical points on the roadway.

The road safety audit team established a field location at the County's maintenance office on Skyline Drive, which is approximately 1/2 mile from Cornelius Pass Road, providing ready access to the roadway. The proximity of the County maintenance facility

[7] After several drive-through runs of the roadway were conducted it was determined there was a short section, approximately 200 feet, at the beginning of the county jurisdiction that was not marked (revised marking) to a no-passing zone; one of the recommendations of this review, included later, was to re-mark this short section as a no-passing zone.

and the proactive position established for winter maintenance would appear to make a difference as relatively few crashed occur during inclement winter weather conditions. Cornelius Pass Road received top priority for winter road maintenance on the County's system. The County noted that during winter weather or potential winter conditions (snow and ice forming on the roadway), the maintenance facility is staffed 24 hours a day and periodic trips are made on the roadway to monitor, first-hand the road conditions.

The high level of winter maintenance is echoed in the annual maintenance initiative on the road – one weekend each year the entire roadway is closed to perform maintenance, including brush and vegetation clearing, pavement maintenance, sign cleaning and repair, and other similar maintenance work. The volumes on the facility and the narrow cross section and absence of shoulder make partial direction closures and repair under active traffic using alternate one-way operations infeasible.

2.2 In-Service Analysis

The road safety audit team provided an in-service assessment of the roadway. As this was an in-service audit with a lack of as built plans and no conceptual or preliminary plans for improvements (with the exception of the Highway 30 intersection) and as detailed crash reports were not available at the time of the audit, the effort focused nearly exclusively on an assessment of the road's likely safety performance (this focus is typical for in-place road safety audits). The findings were grouped by issue type, and, in line with earlier discussions, the findings were prioritized by both degree of concern (a dual function of the likely severity of a potential crash and the likelihood of a crash) and recommendations were prioritized based on relative cost to implement and ease of implementation. This allows users of this road safety audit review to structure and analyze different management and investment strategies.

2.3 Safety Issue 1: Hazards in the Clear Zone

There are numerous features within the clear zone that constitute roadside hazards on Cornelius Pass Road. These features include the cut and fill slopes along the roadway, man-made objects (telephone poles, stone walls, mailboxes), and natural objects (trees, bushes, stumps). This categorization is used to help define an approach to prioritize the hazards and develop proposals for solutions.

The natural terrain transitions from rolling to steeply forested north of Skyline Road. With the roadway having been benched into the hillsides to accommodate a narrow roadway prism in most cases, there are often steep drop-offs present. The narrow to non-existent shoulders make the unshielded side slopes a greater hazard than would typically be present for a standard roadway section. Unprotected non-recoverable side slopes (3:1 to 4:1) and critical (steeper than 3:1) are present along Cornelius Pass Road, particularly in the area north of Skyline Road. Several of the reported crashes are single vehicle run off the road crashes indicating that vehicles leaving the travel lanes may fail to regain control before colliding with a fixed object or travelling down a slope.

The lower section of Cornelius Pass Road in the SB direction had two rock walls close to the roadway. The aged concrete and moss covering made the wall difficult to see in the daylight hours due to shadows from trees and very difficult to see at night as the wall did not markedly stand out from the dark background.

There were numerous utility poles along the corridor. Several of the poles were close to the roadway; moreover, several of these were not delineated or were located near the outside of curves where they might be struck by errant vehicles. Of note, several crash reports noted collisions with utility poles although it was difficult to determine which pole had been struck. Perhaps even more surprising was that in none of those crashes did serious injuries apparently result.

As noted, the narrow traveled way and lack of continuous shoulders and, where present, only narrow shoulders, points to the need for improved efforts to keep vehicles on the roadway. As may be expected, the narrow travel way, curvilinear alignment, and speeds increase the likelihood of vehicles occasionally straying across the paved edge of the roadway. The likely incursions of a vehicle's tires onto the gravel shoulder could result in, and was noted to result in, a drop-off condition at several locations. An errant driver losing control of a vehicle due to a tire straying of the edge of the paved roadway may attempt to wrest control back, with the tire scrubbing the edge of the paved roadway prism; the driver may become frustrated by efforts to redirect the vehicle and may overcorrect by pulling hard on the steering wheel. This can cause the vehicle to lurch to the right or to cross over the centerline and collide with an opposing direction vehicle or continue and run off the roadway on the opposite side.

The review also noted other fixed objects adjacent to the roadway, beyond the already mentioned telephone poles and drop-offs, which are also remarkable due to the limited number of incidences, and in this case, the limited efforts necessary for their removal. For example, on the outside of one curve, just beyond the useable shoulder, lay a tree stump. While a single point hazard, its existence is less remarkable for its representation of the range of fixed objects than by the ease with which this one hazard could be removed. There were also numerous small trees and brush which could grow into larger and potentially more difficult-to-remove hazards (such objects can also reduce sight distance although that is dealt with in a separate issue section of the report).

Expected Crash Types: Off road and fixed object crashes

Expected Frequency: Frequent

Expected Severity: High

Risk Ranking: E (high risk level)

Suggestions:
Install additional roadside barriers
The American Association of State Highway and Transportation Officials' (AASHTO) Roadside Design Guide (2002 edition) advises a roadway should have clear zone of at least 50 feet for a design speed of 60 mph and a design average daily traffic of over 6000 vehicles where a non-recoverable or critical slope is present. Along Cornelius Pass Road there are topographical constraints that do not permit ready widening of the roadway prism or provision of standard or even reduced width shoulders (4 to 6 feet). Given these constraints a roadside barrier may initially appear warranted for embankments having a 3:1 slope (or steeper) and a height of 17 feet or greater. These guardrail criteria would evidently include much of the roadway. Given the high costs this length of guardrail would entail, a process of further prioritization is in order. The physical limitations imposed by the topography (creating a constrained width) means that guardrail may be difficult to place in some locations as the guardrail posts would not have sufficient soil embedment and resistance to opposing overturning moments if a vehicle were to strike the guardrail. Slope stabilization through soil nailing or construction of retaining walls might thus be necessary to provide sufficient soil resistance for the guardrail posts. Identification of further hazard ranking would allow

prioritization of installation to those sections where the likelihood for run-off-the road crashes was highest, such as the outside of sharp curves, or the first curve after a long tangent section.

Roadside barriers (guardrails) should be considered to reduce the risk associated with steep cut banks and steep fill slopes, particularly as the risk of run-of-the-road crashes is increased by the winter road conditions, the volume of traffic, speeds, the narrow cross section, limited shoulder, frequent horizontal curves, and limited clear zone. First priority should be given to sharp curves in the section especially when preceded by conditions likely to cause high deceleration rates and potentially excessive speeds through the curves.[8] While the slopes on either side of the roadway are steep and embankments high, a full treatment of all sections with roadside barrier would likely be expensive. Recognizing cost issues, this audit recommends that priority be given to the more critical sections, those fronting horizontal curves and having steep side slopes. This would serve to address the high collision severity associated with run-off-the-road crashes and reduce the need for end treatments, which, themselves, can be problematic.

A review of guardrail installation warrants should be made to ensure that the treatments on this roadway are consistent in terms of application and risk to the driver. While a road safety audit commonly addresses overall needs and identifies specific concerns to serve as examples, it does not nor is it intended to replace a detailed engineering study of a roadway and complete identification of specific deficiencies. Nonetheless, recognizing the physical constraints along the corridor, the fiscal constraints on large-scale investments voiced by the County, and the concern identified by the County that more detail was desired on the approach to hazard identification and prioritization, particularly in the area of fixed objects, this road safety audit attempts such a prioritization. This prioritization is based on a hierarchal identification of potential hazards according to the process outlined below:

1) Is the object of hazard within the clear zone?[9]
2) How far from the edge of the traveled way is the object or hazard? This serves to define the potential of reaching the hazard (low, medium, or high).
3) Are there specific features associated with the road alignment that would increase the likelihood of a vehicle leaving the traveled way? This serves to

[8] In cases with long downgrades which precede curves, with limited sight distance before a curve, and with curves where limited sight distance does not allow seeing through the entire curve, drivers may make poor speed entry decisions and enter at an excessive speed requiring braking in the curve and/or loss of control. Further, the high number and close spacing of horizontal curves supports viewing curves in sequence as well. Thus the presence of “out of sequence” curves where a curve’s radius may be sufficiently different from the preceding curve in a set of curves may also cause a driver to fail to appropriately slow, even though the individual curve may not be overly sharp.

[9] The clear zone is an unobstructed and relatively flat area beyond the edge of the traveled way that allows a driver to stop safely or regain control of a vehicle that leaves the traveled way. The AASHTO Roadside Design Guide establishes widths based on speed, volumes, and road geometry.

identify if there is a greater propensity for leaving the roadway (e.g., on the outside of sharp curves, on a curve following a sustained downgrade).

4) How severe is the hazard?
5) Are there crashes associated with the object or hazard? In particular, are severe crashes associated with impacts with or into the hazard or object?

This hierarchical process serves as a means for prioritizing based on potential outcome. Recognizing that cost effectiveness of treatments is also important; the final assessment includes determining a relative cost associated with protecting or removing the hazard. The team did not intend to conduct a full needs analysis; rather, key sites were chosen to illuminate the process. The following section includes an example showing how this methodology is applied.

The steep embankment northbound just prior to the S-curves is unshielded and has only a minimal shoulder past the striped edge line. Large trees are present about 10 feet off the edge of the traveled way and a steep (1:1 or steeper) drop-off (in excess of 100 feet) exists. While these conditions lead to a high ranking based on severity of outcome, the roadway is on tangent alignment at this point and there is no record of adverse crash history. Additionally, the length of the hazard, the constrained roadway prism, and the likely need to perform slope stabilization would result in a relatively costly remediation (placement of guardrail). Thus, guardrail is not considered cost-effective in this location.

Proceeding southbound from Highway 30, the driver is presented with a series of rock walls on the right. The rock walls are linear hazards but the ends are considered point hazards. The potential for an errant vehicle to strike the walls is considered high as approaching vehicles come off Highway 30 with its considerably more open road context leading to higher expected speeds, while horizontal curves become introduced in this section. The consequence of a crash is also considered severe as errant vehicles would abruptly stop upon collision with attendant high deceleration forces. The cost of treatment of these point hazards, however, would be relatively low. Given the high severity and moderate to high expected likelihood of errant vehicles in spite of no adverse crash history, installing appropriate end treatments, such as tapered end cut into the back slope, is considered a high priority. Removal or relocation of the rock walls is not feasible as they provide slope stability in the presence of steep cut slopes. The walls are masonry rock walls with the rocks forming a rough curvilinear surface paralleling the roadway. While the rough surface may be a concern for vehicle snagging, a fronting guardrail would reduce the shoulder width and a cast-in-place safety shape rock wall would be expensive; the road safety audit team concludes that while this should be examined an appropriate end treatment remains the far higher priority. Currently the ends are unprotected. Casting a concrete safety shape end section which could then be itself terminated by standard practice of burying into the back slope of the cut would provided a safe transition. Similarly an alternative design could be employed to use a guardrail end section buried into the back slope or terminal section. Given the presence of the cut section and, limited space to generate acceptable end section performance, a buried into the back slope treatment is recommended.

In the opposing direction a slight curve to the right is followed by a curve to the left. Both curves are unsigned and follow a section of the roadway where, based on observation and roadway character (the descending grade and the transition out of the section with a high density of horizontal curves), vehicle speeds are likely to increase. Additionally, there was a recent fatal crash at this location where a vehicle went off the roadway embankment. While the crash report does not enable firm conclusions to be made on the cause, the severity may be addressed by guardrail installation. Moreover, the physical conditions here would appear to allow installation with sufficient offset from the traveled way and allow installation of a crash worthy end terminal without requiring extensive additional grading or fill material.

Delineate rock walls

While the recommend treatment for the rock walls is to install a crash-worthy end treatment, the leading edge of these walls should be delineated as the walls are close to the roadway, on horizontal curves, and difficult to see due to the forest canopy and dark color of the walls.

Relocate or delineate the utility poles in the corridor

The unprotected utility poles could be relocated further away from the roadside, but should be consistently and better delineated to warn drivers about their presence. While undergrounding is an option, the sparse residential density and terrain makes that a costly option with limited opportunities for reasonable cost recovery through user charges. Due to the greater likelihood for vehicles to lose control while negotiating horizontal curves, especially those that are sharper then the operating speed on the roadway, select relocation of poles close to the roadway and within sharp horizontal curves should be considered although no outstanding examples were present; if relocation is not practical shielding with guardrail should be considered, although this introduces the need to address end treatments. Indeed, in one location past Sheltered Nook it appeared a guardrail run had been installed to shield a pole although the roadway curvature at this point did not seem any more severe than other curves in that section nor was the side slope excessively steep.

Introduce an asphalt wedge during repaving or under maintenance operations to limit pavement drop-offs

While acknowledging that pavement resurfacing is both a relatively costly and future year action (the condition of the pavement during the review did not indicate a need for resurfacing), future planned resurfacing should strongly consider incorporating an asphalt wedge to minimize sharp drop-offs. The bevelled edge reduces the sharpness of the pavement edge drop-off and the associated loss of driver control allowing an errant driver to regain control.[10] Shoulder rock could also be pulled up adjacent to the traveled way. While valuable in the short run, the traffic volume and limited paved width support consideration of a more permanent asphalt wedge.

Improve roadway delineation

The number and variety of potentially hazardous objects close to the traveled way serve to further emphasize the importance of ensuring vehicles stay on the paved road surface. Given the topographical constraints and the cost of improvements for the roadway prism, improved roadway delineation on Cornelius Pass Road should be a high priority. An all -weather presence for both edgelines and centerlines, with the additional consideration of a profiled line to provide audible warning to errant vehicles that they were leaving the traveled surface, would be of great benefit. While these represent point hazards, additional delineation of fixed objects should be considered. The road safety audit team recognizes that while delineators are not expensive, the number of fixed objects in the corridor is sizeable and full delineation might be both high cost and difficult to manage for long-term maintenance; thus a prioritization of sites is recommended.

[10] Further information on the "safety edge" is available at the FWHA website at http://safety.fhwa.dot.gov/roadway_dept/docs/sa07023/ Picture source also FHWA

Additional information on pavement edge drop-offs can be found at http://www.aaafoundation.org/pdf/PEDO_report.pdf

Roadside protection policy and process

Due to the number and variety of potentially hazardous objects close to the traveled

way, additional treatment approaches should be considered. Due to low cost, object hazard markers should be considered more widely; however, due to the large number of objects this could result in a high number of delineators. Long term maintenance, relatively high initial cost, and consistency among routes in the County needs to be considered; thus, the sites should be considered strategically. Removal, or relocation of, or making point fixed objects breakaway (where possible) also needs to be considered programmatically. This audit has attempted to address a few locations but should not take the place of a thorough hazard assessment process. The County should thus develop a policy to determine where guardrail is warranted along Cornelius Pass Road. Finally, the County should develop a policy for the control of devices on or adjacent to roadside safety features; although specific instances were noted with mailboxes located within the end terminal of a guardrail, the policy should be broad enough to extend to all devices that might be installed to prevent interference with sight lines, or the proper visibility of signs.[11]

Cost Ranking: Low cost (for select site treatments e.g. sharper horizontal curves); moderate cost for more widespread treatment

Action Efficiency: High – these actions could be performed by County maintenance forces during annual road closure

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2.4 Safety Issue 2: Thermoplastic skip lines mixed with painted double no-pass lines.

As noted previously, several months ago the County took a proactive position and striped the entire corridor as a no-passing zone (the corridor had previously had sections where passing was allowed). While the audit team concluded that this was a positive safety step and should be retained, the marking patterns and material created concerns in the near future. The existing passing stripe was not obliterated in advance of the placement of the solid yellow lines, thus leaving a non-standard and potentially confusing marking to the driver. Of more concern is that the outer no-pass solid line has

[11] To assure consistency in application across the county roadway system, the policy actions, though herein focusing just on Cornelius Pass Road should be consistent in approach across the system for similar roadways.

been marked with paint while the existing passing line, marked in thermoplastic, has been retained.

This creates a potential safety problem as the two materials wear at different rates: the paint will wear much faster than the thermoplastic such that after traffic, rain, and beginning of winter the marking will appear to allow passing. While these "revealed passing zones" will be in the same location as the original passing zones, this will negate the safety benefits of a no-passing zone; further, immediate correction will be highly unlikely and undesirable in winter conditions due to cold temperatures, wet pavement conditions, and potential snow and ice conditions as winter intrudes.

Expected Crash Types: Sideswipe and head-on crashes

Expected Frequency: Occasional

Expected Severity: High

Risk Ranking: D (moderately high risk level)

Suggestions

A two-stage approach is suggested. The existing skip lines should be permanently removed by grinding and shot-blasting. This would leave a consistent no-pass marking. The second stage would involve analyzing the cost effectiveness of placing a durable no-passing line in place of the painted lines. The analysis should also consider the use of a profiled line to provide an audible warning to drivers who cross the centerline. Use of a durable marking product would provide a greater presence throughout the year and should yield improved retroreflectivity especially in inclement weather conditions and would remove the need for yearly re-tracing. The ice and snow conditions and the attendant plowing, however, would necessitate that the line be recessed to prevent destruction by the plow blades. Since the elevation (and attendant linear roadway distance) affected by snow and ice is not known and the elevation gain is fairly rapid, a continual durable line should be considered for the entire corridor that is under County jurisdiction.

After several drive-through runs of the roadway were conducted, it was determined there was a short section, approximately 200 feet, at the beginning of the County jurisdiction that was not marked (revised marking) to a no-passing zone; this short section should be re-marked as a no-passing zone.

Cost Ranking: Low cost for stripe grinding; moderate initial cost for use of durable striping product (e.g. thermoplastic). If the durable striping product also incorporates a profiled pattern this would increase the cost somewhat but would also address the later recommendation to minimize centerline crossings. Given the traffic volumes and potential risks associated with vehicles crossing the centerline, and the longer cycles between pavement marking re-laying, the life cycle costs for this durable marking are considered highly cost effective.

Action Efficiency: High for stripe grinding as this work could be performed by County staff (assuming the County has this equipment). Moderate efficiency could be achieved for the inclusion of durable marking as this specialized work may entail a contractor; however, the scope of work is straightforward.

2.5 Issue 3: Existing Guardrails and Barriers

Issue 1 dealt with hazards in the clear zone; this issue deals with the adequacy of existing barriers in the corridor. At several locations guardrail was observed with outdated end treatments. This is a safety concern as in the event of a crash an inadequately functioning end terminal may cause severe injury. The issue with end treatments extends not just to the type of end treatment but also the associated issue of grading around the end of the terminal. Assuring a relatively flat runout area for errant vehicles colliding with a barrier assures that vehicles do not otherwise overturn even if the end terminal performs satisfactorily

As was the case for other features along the roadway, guardrail conspicuity was often minimal. While guardrails are themselves a hazard, although generally less so than the hazard they are shielding, efforts need to be directed to keeping vehicles on the roadway and allowing recovery prior to colliding with an object that is unrecoverable (e.g., side slope, tree, ditch, or guardrail).

The road safety audit also noted several deficiencies with existing guardrail runs. Some sections were too far back from the roadway such that shoulder and roadside discontinuities may result in the rail being hit at an undesirable height.[12] On some guardrail runs, the supporting posts were leaning, which resulted in a lower height of the rail and may indicate that there would be insufficient resistance in the case of a crash. Further compounding this latter concern was the apparent minimal support for some guardrail posts. Providing adequate support behind posts helps ensure the rail functions as intended. Several existing barriers appeared to be too short to adequately shield the hazardous object they were installed to shield. Finally, there were, as previously mentioned, several sections of the roadway where additional guardrail runs appeared warranted but had not been installed.

Expected Crash Types: Run-off-road crashes and rear end crashes

Expected Frequency: Occasional

Expected Severity: High

Risk Ranking: D (moderately high risk level)

Suggestions:
Guardrail delineation
A number of suggestions for general delineation improvement have already been made and include increased road edgeline delineation, the use of roadway delineators, and increased use of curve warning signs with greater retroreflectivity through brighter sheeting and greater size of sign blanks. A new suggestion is offered hereto increase the conspicuousness of the barrier itself, by including delineators inlaid within the rail itself or including roadside delineator posts mounted on or just behind the guardrail posts. The intent is to markedly increase the delineation of the roadway and of objects just outside the traveled way.

[12] Guardrail is designed to allow vehicles to collide at some variation in height and still be effective. However, if the fronting slope of the guardrail is not relatively flat, vehicles leaving the roadway may hit the guardrail at a too high or too low height to allow proper rail contact with the vehicle, thus increased occupant injury.

End treatments
Guardrail end treatments should be upgraded to meet current standards. Prior to upgrading end treatments an overall assessment of guardrail needs should be conducted to see what opportunities exist to eliminate the need for certain guardrail terminals ends. Given the topography and narrow shoulders, providing a smoothly graded terminal runout area is difficult, thus emphasis should be given to proper terminal selection to minimize the need for large runout areas or tying guardrail sections into longer runs to avoid both the runout area and to reduce the number of terminal ends, which are in themselves a hazard.

Re-setting existing guardrails
Certain existing guardrail should be reset and guardrail shoulders re-graded to provide a smooth, continuous guardrail approach to ensure the rail functions as intended.

Guardrail needs analysis
A guardrail needs analysis should be done comprehensively in league with a hazard assessment for the entire roadside.[13] This review should include the need for barriers, a prioritization to identify the most needed areas, and an assessment of length of need for the attendant guardrail runs.

Cost Ranking: Low cost for cleaning or installing delineators on the guardrails ; moderate costs for installing proper end treatments; high costs for resetting guardrail and re-grading approaches; and high cost for new guardrail installations or reconstruction of existing runs (should lower cost repositioning and grading prove to be insufficient).

Action Efficiency: Moderate to high for guardrail end treatments and high for delineation. While cost for new runs may be large, the degree of hazard in some locations should result in cost-effective determination given the potential severity of prevented crashes.

2.6 Issue 4: Vehicles Crossing over Centerline

The report has already well identified and discussed concerns given the overall curvilinear alignment of the roadway and the narrow traveled way. While noting that the County has recently re-striped the roadway to eliminate passing zones, there are still concerns over vehicles straying over the centerline. With the volumes and limited sight distances available to see around curves, these crossings raise the possibility of potential head-on crashes. The team noted that trucks, due to their greater width relative to passenger cars, tended to off-track and would sweep wheels over the edgeline or over the centerline. Team members also noted vehicles had a tendency to "flatten" the curves and thus stray over the centerline. These issues were more

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[13] An example of a system wide analysis process can be found at http://www.sys.virginia.edu/techreps/2004/sie-040002.pdf

apparent north of Sheltered Nook Road coming into the long straightway and through the curves in this section; the team presumed that drivers were more likely to increase speeds given the less curvilinear nature of this section, northbound drivers may also feel less constrained and increase speeds after having exited the more constrained section. Further, as drivers can see across curves, they may be more inclined to “cut” the horizontal curves.

The audit team noted that the northern (second) S-curve location, the sharpness of the curve lead to a high incidence of observed cases where truck tires strayed onto the right gravel shoulder. Vehicles appeared to be traversing this curve as a compound curve with radius decreasing into the curve (SB). While the curve is well signed, vehicle speeds as observed were slow, and the strong upgrade also reduces speeds naturally, trucks were still observed having difficulty in negotiating this curve while staying within the lane.

Expected Crash Types: Run-off-road crashes and opposing direction (head on crashes)

Expected Frequency: Occasional

Expected Severity: Moderate to High; low for the S-curve due to much lower speeds

Risk Ranking: D (A for the S-curve)

Suggestions:
A centerline rumble strip or profiled marking should be considered to provide an audible warning to drivers that they are crossing the centerline.Though more expensive, and as there are limited opportunities, select widening on curves could be examined. This widening would have the added benefit of addressing the off-tracking of vehicles (primarily assumed to be trucks) to the outside of curves which are expected to contribute to the formation of edge drop-offs.

For the S-curve, the team suggests that the pavement be extended to accommodate truck off-tracking. Improved drainage should be considered to intercept the runoff from the cut rock slope and prevent ice formation in the winter; the water and ice may serve as visual or physical deterrents to needed off-tracking and result in crowding to the opposite direction of travel.

Cost Ranking: Low to moderate for centerline rumble strips or profiled marking. Given the winter weather conditions encountered, the markings would likely need to be recessed below the pavement surface to prevent their unintended removal during snow plowing. Given the previous recommendation to remark the roadway with a more durable pavement marking product, however, the incremental additional costs for providing profiled durable markings may be manageable. In contrast, curve widening would be moderate to high cost depending on the widening provided. For the S-curve work the rank is considered moderate as pavement work would involve minor widening; drainage work would be marginally more expensive.

Action Efficiency: High for profiled markings as this could be done by County forces, or by a contractor, or by State striping crews with the County reimbursing ODOT for the cost; even if the work were contracted, the work should be relatively straightforward. Curve widening would likely be of moderate efficiency given that work could be accomplished by County crews although the limited number of such opportunities might result in a relatively high cost per application. For the S-curve work the efficiency is moderate as work could be done in-house but may involve drainage analysis.

2.7 Safety Issue 5: Signing throughout Corridor

The road safety audit and this discussion have emphasized the key importance of the adequacy of delineation along this corridor due to the narrow roadway prism, minimal shoulders, winter weather conditions, and curvilinear alignment. While delineation is of prime importance, the visibility and conspicuity of traffic signs also needs to be given priority. The road safety audit and discussions with County staff found that most signs are made with engineering grade sign sheeting.[14] While this sheeting type is acceptable; it limits the conspicuousness of the signs (especially at night or when the signs are dirty). Further, most signs are the standard size signs; larger sign sizes would increase the forward visibility distance for drivers for such key feature as curve warning signs and intersection street name signs.

The rural character of the adjacent land uses and topography leads to limited roadside development. While there are limited houses and driveways on the corridor, house addresses range from non-existent (or un-locatable) to hard-to-see lettering, to address markers that are not located consistently with respect to the driveway. Most of the address signs could not be seen at night as they were not retroreflective. The house number signing is of concern as visitors and emergency personnel may not be able to locate the properties or those searching for addresses may make undesirable actions on the mainline (e.g., abrupt stops, making a sharp turn without signalling) as part of the search process.

Expected Crash Types: Run-off-road crashes and rear end crashes

Expected Frequency: Occasional

Expected Severity: Moderate (moderate-high in curves)

[14] New federal regulations have been published on minimum traffic sign retroreflectivity levels and are available at http://safety.fhwa.dot.gov/roadway_dept/retro/sign/sign_newreq
Agencies have until January 2012 to establish and implement a method to maintain minimum levels of retroreflectivity.

Risk Ranking: C (moderately low risk level)

Suggestions:

Use of larger and brighter signs

Larger signs (36 in. by 36 in.) in place of the current 24 in. by 24 in. signs should be considered. The current size is considered adequate for warning and STOP signs, but could be increased for critical signs to improve visibility and conspicuity. Brighter sign sheeting should be considered throughout the road. The currently used Engineering grade sheeting should be replaced with high intensity sheeting or other more highly retroreflective sheeting type.

Larger font for street name signs and use of Intersection Ahead signs

The speeds in the corridor, high volume of traffic and lack of lighting at the intersections support increased lettering size for street name signs. "Intersection Ahead" warning signs (especially plaques for street name and distance to intersection) are also encouraged. Providing advance indication allows drivers to slow in advance of the turn rather than abruptly stopping and allows following drivers time to made speed adjustments. Given the lack of left turn lanes (except at Skyline) the advance intersection warning signs would be particularly valuable in this corridor.

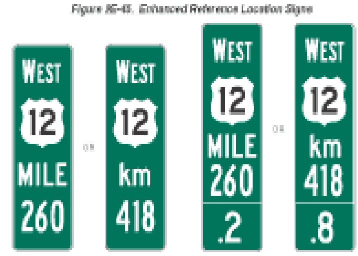
House numbers

Retroreflective house numbers would be beneficial throughout the corridor to aid visitors, delivery firms, and emergency responders. If used, they should assure uniformity (e.g., follow ODOT standard for letter/number height) understanding that standardization may necessitate a policy for County manufacture and installation.

Interim milepost markers

Improving location accuracy and awareness would be aided by the installation of interim mile point reference markers (right). These would help drivers to locate intersecting streets and houses and would also be helpful in assuring location accuracy for any incident.

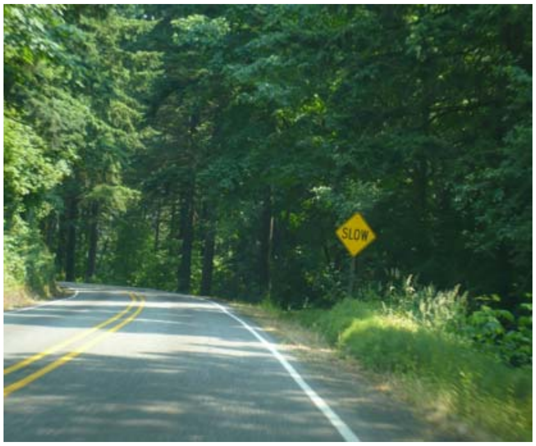
Figure 2E-48. Enhanced Reference Location Signs



Sign placement policy

A corridor-level policy would be beneficial to assure consistent sign placement, especially for curve warning signs. The audit team recognizes that the policy needs to allow engineering judgment as there were several observed cases where the close physical spacing of the curves made it difficult to adhere to set distances.

Assessment of sign needs



The audit noted the need to review some signs for appropriateness; certain curves appeared to be able to be safely navigated at the posted speed of the roadway, thus they do not need to be signed. The “oversigning” of a facility or network can lead to driver disregard of the signs, especially when the sign may be critical to safely negotiating a curve; in short, curve advisory signing should only be used if necessary per the Manual on Uniform Traffic Control Devices.

In other cases there seemed to be a number of unnecessary signs in the corridor (e.g. “Slow” sign). These signs may offer unspecific information to the driver, may distract from other more pertinent messages, or may obscure other signs. A comprehensive review of sign placement should suffice to address those few signs that are unneeded.

Cost Ranking: Low cost for sign placement, sheeting upgrades, and size. While the upgrade of sign sheeting and use of larger signs would entail additional costs, the long life span of signs means that the life cycle incremental costs are low.

Action Efficiency: High for all as this work could be performed by County staff.

2.8 Safety Issue 6: Signing for Curves

A wide variety of curve warning signs was present in the corridor. This variety is not uncommon and indeed is desirable to the extent that these different signs are designed to communicate different messages to the driver on how to properly drive the route and adjust speeds appropriately before entering the curve; however to assure consistent driver reactions:

- Advance warning signs should be consistent in the type of arrow and advisory speed plaque.
- In-curve delineation (delineators and/or chevrons) needs to be consistent within the curve (and among similar curves). For example, for some curves the chevrons were at an inconsistent height and inconsistent horizontal spacing making the path alignment through the curve difficult to discern. In some cases chevrons were present in one direction for a curve but were not present for the opposing direction.

- There needs to be consistency in the differential use of chevrons and arrow boards (i.e., W1-6, “One Direction Large Arrow sign”). Arrow boards should be restricted to those cases where the turn is very sharp.

While atypical for a road safety audit, a post-audit ball bank analysis[15] was made of curves in the corridor. Again, the intent was to conduct a final study but to establish whether a more comprehensive study of the corridor would be desirable. Due to the lack of shoulders ball bank reading were taken in full (for all curves studied) for each direction. In total 16 runs were conducted.[16]

ODOT’s process appears below.[17] While this analysis focuses on individual curves, considering driver actions over a set of curves is important, as discussed in footnote 8. The analysis indicated priority should be placed on (1) checking advisory speed posting for curve 5 given the difference between the ball bank reading and current advisory speed, (2) checking advisory speed posting for curve 6 as the low end of the reading supports a re-check, (3) verifying the posted speed for curve 8 is not “underposted”, and (4) checking the need for advisory speed posting for curve 13 since this was near the site of a fatal run-off-road crash and the near set of curves appears to allow generally higher uniform ball bank speeds.

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[15] For an example of the process see Florida Department of Transportation’s procedures at http://www.dot.state.fl.us/trafficoperations/Operations/Studies/MUTS/Chapter11.pdf. The analysis here used a Rieker RDS7-BB digital ball banking unit featuring an audible alert, see http://www.riekerinc.com/DigitalInclinometers.htm

[16] Subsequent analysis for curves 13 and 14 based on the chord offset method and field collection of banking provided rough confirmation though with lower speeds; see http://ceprofs.tamu.edu/mburris/Papers/TRR%201918%20-%20COMPARISON%20OF%20RADIUS%20ESTIMATING%20TECHNIQUES%20FOR%20HORIZONTAL%20CURVES.pdf.

[17] Oregon Department of Transportation’s policy is found at http://www.oregon.gov/ODOT/HWY/TRAFFIC-ROADWAY/docs/pdf/english_chapter_4.pdf

The comfortable safe curve speed to be placed on the curve sign rider is the speed that is 5-mph below the speed at which the ball-bank indicator reading exceeds the table value. If the ball-bank indicator reading has not exceeded the table value upon reaching 5-mph below the posted general speed, the curve sign and rider are not appropriate.

Values for Determining Comfortable Safe Speeds on Horizontal Curves
Using a Ball-bank Indicator

Curve Speed in Miles-per-Hour	Ball-Bank Reading Limiting Values in Degrees
15	13
20	13
25	13
30	13
35	10
40	10
45	10
50	10
55	10
60	7
65	7

Table 5: Ball Bank Curve Analysis

Curve Number	Curve Description (from Skyline to Highway 30)	Analysis (mph): speed exceeding value	Actual Posted Speed (mph)
1	S-curve	25	25
2	S-curve	15	15
3	Turn to left with chevrons and guardrail	30	30
4	Curve to right with chevrons	30-35	35
5	Curve to left with chevrons	35	None
6	Curve to right	Limited data 30-45	None
7	Right turn	25-30	25
8	Curve to left with chevrons (before Sheltered Nook)	30-35	25
9	Guardrail curve (past Sheltered Nook)	40	None
10	Curve after guardrail	45	None
11	Curve to left	Limited data 40	None
12	Curve to right	Limited data 40-45	None
13	Curve to left	40	None
14	Curve to right	45	None

Expected Crash Types: Run-off-road crashes and rear end crashes

Expected Frequency: Occasional

Expected Severity: Moderate

Risk Ranking: C (moderately low risk level)

Suggestions:

Chevron signs

Chevron signing should be reviewed to ensure compliance with MUTCD, especially with regard to orientation, spacing, height, and length of application. As a general note, the spacing should be consistent within each curve as much as practical, the horizontal alignment should be consistent within each curve, and the signing should continue for the full length of the curve.

Policy approach to signs

A corridor (and County-wide) policy should be developed regarding use of chevrons and arrow boards. Similar to the previously suggested policy for signs, this policy needs to assure that driver expectation is continually met through the information conveyed by curve warning signs.

Verification of advisory speed posting

Although advisory speeds generally appeared to be appropriate based on a drive-through, advisory speeds should be checked using a ball bank indicator. As noted, given the importance attached to this issue of curve warning signs, a full ball bank study of the corridor should be a high priority.

Cost Ranking: Low cost for sign placement and verification.

Action Efficiency: High for all as this work could be performed by County staff.

2.9 Issue 7: Maintenance of Signs and Delineators

Previous recommendations addressed upgrades to signing along Cornelius Pass Road. The audit also noted that many of the existing signs and delineators were obscured with a film of grime and algae on signs and delineators, reducing daytime and night-time visibility. While the number of delineators on the corridor is small and they are not placed uniformly through the corridor, immediate improvements could be made to increase their visibility. To ensure that there is an adequate level of sign visibility at day and night throughout the year the County should consider increasing the frequency of maintenance cycles.

Expected Crash Types: Run-off-road crashes and rear end crashes

Expected Frequency: Occasional

Expected Severity: Moderate

Risk Ranking: C (moderately low risk level)

Suggestions:
Cleaning
In the short-term the County should clean the signs and delineators in the corridor to assure their effective retroreflectivity.

Cleaning policy
The County should consider increasing the frequency of maintenance activities (decrease the maintenance cycle).

Cost Ranking: Very low cost for cleaning of signs and delineators

Action Efficiency: High for both suggestions as this work could be performed by County staff.

2.10 Safety Issue 8: Intersection Sight Lines (Highway 30, Kaiser Road, Skyline Road, Sheltered Nook Road, private driveways)

While intersection sight distance was not measured, visual checks were made to evaluate the adequacy of sight lines at intersections in the corridor. Given the terrain and rural character there were a not unexpected number of obstructions from natural objects such as trees, bushes, vegetation, and cut slopes. There were also reductions to the sight lines from man-made objects such as signs and poles.

The high truck traffic in the corridor and the expected higher-than-posted-speed operating speeds also deserves mention. While trucks typically take longer to stop than passenger vehicles at the same speeds, stopping distance for passenger vehicles is the standard used for highway design. The higher driver's eye distance for truck drivers increase the vertical sightlines and allow truck drivers to see further thus providing compensation for the reduced braking performance of trucks. In contrast, horizontal sight distanced is unaffected by the greater eye height of truck drivers.

Poles and signs may obscure the sight distance of an oncoming vehicle and require the driver to pull further forward or to stop beyond the stop bar. In some cases multiple man-made objects were aligned or the man-made objects had been placed to align with natural features. Limited sight distance reduces the driver's ability to see oncoming traffic or to judge acceptable gaps in traffic to enter or cross the roadway. Among natural features a range of constraints was present leading to a range of solutions and attendant costs. For example, there were sight distance restrictions caused by horizontal and vertical curves (Highway 30, Skyline Road (photo to left), Sheltered Nook, and several driveways) and there was a traffic signal obstruction for northbound drivers at Highway 30 (vertical curve combined with vegetation). These latter cases would necessitate more involved solutions than simple brushing or trimming (although that may reduce the severity of horizontal restrictions).

Expected Crash Types: Angle and rear-end crashes

Expected Frequency: Occasional

Expected Severity: Moderate

Risk Ranking: C (moderately low risk level)

Suggestions:

While improvements to the cross-sections on the mainline and side roads would increase sight distance a more focused approach would certainly be applicable here. The wide variety of objects creates a useful typology for solutions as well.

Measure intersection sight distance in the field to accurately determine shortcomings, identify blocking objects, and prioritize actions

As noted, the road safety audit team did not measure actual sight distances. To better ascertain the needs and to establish priorities, field measurements are needed to identify the specific blockage and the degree of obstruction.

Physical actions to improve sight distance
The following suggestions should be considered to improve intersection sight distance at the intersections. The recommendations below are general and are not specific to each intersection:

Short range and low cost actions:

- As many obstructions were related to long grass, increased mowing perhaps in combination with earlier mowing would reduce this obstruction. Grass obstructions are primarily in the right-of-way so removal may require coordination with adjacent landowners and implementation of a County-wide vision obstruction ordinance.
- Increase the frequency and intensity of brushing.
- The signal obstruction at Highway 30 should be resolved with the improvement project for the Highway 30 and Cornelius Pass Road intersection. In the interim a low cost solution would involve vegetation clearance to increase the ability for an approaching northbound driver to clearly discern the signal indication.
- Stop bars should be uniformly placed on all intersecting road approaches (most pointedly a stop bar should be placed at Sheltered Nook Road to establish a point for vehicles turning onto Cornelius Pass Road).

More moderate cost and longer term actions:

- Slope cutting should be considered to more permanently address the obstructions or at least reduce the frequency of brushing operations. This may be a cost issue should additional right-of-way need to be acquired and may further be a geotechnical issue should this result in steeper side slopes or the need to provide slope bracing.
- Seek agreements with adjacent landowners to mow (either by landowner or by County forces) sight obstructions on private property that interfere with sight lines.
- Consider movement of signs and utility poles. Signs are under the County's jurisdiction and thus involve only a single agency. Utility pole relocation may involve reimbursement to utility company for relocation of poles and cable reattachment. A coordinated analysis should determine which removals or relocations are most cost-effective.

Cost Ranking: Low cost (for select point treatments and less involved treatment of linear obstructions (e.g., sign relocation and increased mowing and brushing); moderate cost for more widespread treatments such as slope re-grading or layback

Action Efficiency: High – these actions could be performed by County maintenance forces during annual road closure or periodically throughout year without necessitating road closure (for those sites not adjacent to the road edge); moderate to low action efficiency is likely for slope laybacks which would likely entail geotechnical analysis and contractor efforts.

2.11 Issue 9: Sheltered Nook Road intersection

This review has identified the impacts the reduced cross-section, alignment, and roadside characteristics have on safety in the corridor. There are a few areas that merit further discussion. At Sheltered Nook Road the narrow cross section and adjacent topography does not permit the consideration of a cost-effective left turn lane. Further, the limited sight distance in both directions, northbound, due to the horizontal curve approaching the intersection and southbound due to the vertical crest curve and slight horizontal curve, means that left turning traffic has a difficult time discerning acceptable gaps. Approaching southbound traffic often cannot see left turn vehicles and northbound vehicles may not be able to see stopped vehicles in time to safely decelerate due to limited sight distance around the horizontal curve (this limited sight distance was apparently a factor in a serious multiple vehicle crash due to queued traffic waiting for a left turn vehicle). While there are only a few houses on Sheltered Nook Road, the road safety audit team did observe several vehicles wait to turn left onto the side road and out of Sheltered Nook; while the left turn exit is difficult; the limited sight distance to the left also means even the right turn is complicated as drivers must enter from a stopped position.

No stop bar is provided on the Sheltered Nook Road approach to the intersection. While a stop sign provides the required regulatory control and warning to the driver, the Stop bars provide a clear indication to the approaching motorist of the need to stop and serve as a low-cost means to provide desired information redundancy. Further, the stop bar establishes positional control for the vehicle, so they are sufficiently far back to be out of the travel stream yet the left turners onto the mainline are positioned to have adequate views of the mainline traffic so as to properly select a gap.[18]

Expected Crash Types: Rear end and broadside crashes

Expected Frequency: Infrequent

Expected Severity: High (Low for stop bar)

Risk Ranking: C (moderately low risk level) ((A (lowest risk level) for stop bar))

Suggestions:
The existing cross section and topography to the east do not appear to allow adequate widening to construct a left turn bay, particularly considering the need for adequate tapering of the lane. Physical flattening of the vertical or horizontal curves would be very costly and are unlikely to be achieved in the near term. Given the physical and cost constraints an Intelligent Transportation System application to advise approaching

[18] Section 3B.16 of the 2003 Edition of the MUTCD states under the Standard section: “if used, stop lines shall consist of solid white lines extending across approach lanes to indicate the point at which the stop is intended or required to be made.” The MUTCD, however, does not provide guidance to determine when stop bars should be used.

drivers of the presence of stopped vehicles ahead is suggested. This could be accomplished by providing stopped vehicle detection via a pavement loop at the point where left turn vehicles stop. Upon a presence detection, signs some distance in either direction would warn of a vehicle stopped ahead to provide advance warning to drivers.

For the turn out of Sheltered Nook, the team suggests a stop bar at the intersection. While the use of stop bars typically is limited to higher volume roadways, even low volume roads should be and are marked with a stop bar at their intersection with a higher volume and higher speed roadway to clarify to the driver that a stop is required.

Cost Ranking: Low cost for vegetation removal or cutting; high cost for vertical curve or horizontal curve straightening; high cost for construction of left turn bay; moderate cost for construction of activated sign warning. For stop bar the ranking is considered low as a stop bar could be installed by County

Action Efficiency: High for vegetation removal; low for curve straightening and this would need to be performed by contract forces; while activated curve warning sign could be installed by contract the contract and associated work (saw cutting, foundation and sign installation) is relatively straightforward. For the stop bar installation the efficiency is considered high since markings could be installed by County crews.

2.12 Issue 10: Role of Cornelius Pass Road in Regional Road Network:

While the existing land use in the corridor is rural, discussions with County staff and the team's observations and knowledge of traffic patterns revealed that this route is used as a commuter route from Scappoose and St. Helens to access the employment centers in Washington County. The increase in residential development in Scappoose and St. Helens coupled with the development near Highway 26 has already resulted in increased traffic on the corridor. Finally the existing designation of this route as the hazardous material route (as hazardous materials are not permitted in the Sunset Tunnel on Highway 26) does not comport with a rural highway designation. The 1990 hazardous materials report is based on outdated information on volumes and possibly on relative crash frequencies on the candidate routes.

Expected Crash Types: All types of crashes previously identified would be expected to increase.

Expected Frequency: Varies

Expected Severity: Varies

Risk Ranking: Not applicable

Suggestions:
While the hazardous route study needs to be updated to reflect the increased volumes on this route, it is important that that analysis proceed in pace with and as part of a larger one of the function of the roadway in light of the future transportation and land use demands. A network review is needed to identify alternate routes for increasing commuter traffic, truck traffic, and hazardous materials traffic.[19]

A comprehensive assessment of the proposed function of this roadway in context of the regional road network and the comprehensive land use plans and regional transportation plan needs to occur.[20] As these are regional issues, Metro (the metropolitan planning organization for the Portland metro area) should be the agency to coordinate and conduct the study. The analysis should include hazardous materials network routing, truck routing in the region, and future commute patterns.

Cost Ranking: Moderate cost for study

Action Efficiency: Low; while the County would supply data and policy direction, the issues are regional in nature. Further, any solution will involve negotiations among at least the two counties (Multnomah and Washington) and the Oregon Department of Transportation for the hazardous material routing designation.

2.13 Issue 11: Geometry of Highway 30 Intersection

While acknowledging that the State has conceptual plans for the Highway 30 and Cornelius Pass Road intersection, there remain actions that can be taken in conjunction with or absent that project. The team noted that the sweeping eastbound right turn lane off Highway 30 resulted in high exiting speeds for Highway 30 traffic and created an undesirable speed "impression" for newly entering traffic.The lack of a deceleration/turning lane, edgeline delineation, and the presence of a large unpaved area adjacent to the turn raised concerns over the potential for drop-offs at high speeds. Further, the large unpaved area on the west side of the road is sometimes occupied by parked vehicles thus creating fixed object hazards.

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[19] As an example of how to apply guidelines for hazardous material routing see http://hazmat.fmcsa.dot.gov/nhmrr/PDFs/nrhmguide.pdf

[20] See the Metro Regional Transportation Plan update for 2035 at http://www.oregonmetro.gov/index.cfm/go/by.web/id=25038

The team also observed northbound queues extended along Cornelius Pass Road during peak travel hours; the limited visibility of the approaching signal was thus of concern.

Expected Crash Types: Run-off-road crashes (for right turn) and rear end crashes

Expected Frequency: Infrequent

Expected Severity: Moderate

Risk Ranking: D (moderately high risk level)

Suggestions:

Install edgelines and eliminate drop-off

Given the observed drop-offs and edge ravelling, the observed higher speeds traveled by vehicles making the right turn, and the absence of edge striping, edgelines should be considered on the right hand edge for the eastbound to southbound right turn. Additionally, the shoulder rock could be pulled back to eliminate the existing drop-off. These actions could proceed independently from the intersection improvement project.

Right turn lane design

ODOT has design plans for an eastbound right turn lane. This would be a benefit as it would provide a formal treatment for the deceleration lane from eastbound Highway 30. This eastbound to southbound right-turn-lane should be designed to prevent excessive speeds for drivers entering Cornelius Pass Road. This should be accomplished primarily by control of the radius. By ensuring the design speed on the turn is not at open road speed yet is sufficient to accommodate semi-trucks, users can be accommodated yet speeds controlled.

Signal design

The signal redesign proposed as part of the intersection work could include a right-turn overlap for northbound Cornelius Pass Road to turn right onto Highway 30.[21] This overlap would benefit Cornelius Pass Road as this should relieve the queue build-up which was observed during the field review.

[21] See the last page of the phasing chapter from the Connecticut Department of Transportation on overlap for more detail:
http://www.ct.gov/dot/lib/dot/Documents/dpublications/Phasing.pdf

Cost Ranking: Low for edgeline striping and adding shoulder rock. Even if the intersection improvement obliterates this work, the low initial cost, and the likelihood that any associated work at the intersection is a few years away means that this minor capital investment would likely be cost-effective. While a re-designed turning roadway would be expensive, as this is already included within the scope of the forthcoming ODOT project, any reduction in curve radius should be a cost savings.

Action Efficiency: High for edgeline marking and addition of shoulder rock as such work could be accomplished by the County. The re-alignment of the turning roadway would be more involved but the cost should be readily accommodated within the already scoped project for the intersection.

2.14 Issue 12: Evaluation of the Posted Speed Limit

The length of Cornelius Pass Road (within Multnomah County jurisdiction) has been posted at 45 mph. While no speed studies were conducted as part of this audit, the audit team, based on numerous travels along the length of the roadway, concluded that the posted speed may exceed the actual operating speeds. As previously noted in the Introduction to this report the roadway is rural in character; however, the topography changes just in advance of Skyline Road to substantially more forested, the alignment becomes more curvilinear, and the roadside contains long and steep side slopes.

Expected Crash Types: Run-off-road crashes

Expected Frequency: Not applicable

Expected Severity: Not applicable

Risk Ranking: Not applicable

Suggestions:

We suggest that a speed zone investigation be undertaken just south of the Skyline Road intersection to the terminus with US 30; this is made with some pause since speed management on this corridor is acknowledged to be problematic (limited shoulders means there are few opportunities to safely pull over drivers and there are limited locations for an officer to safely station adjacent to the roadway to monitor speeds; both these observations were conformed by Multnomah County sheriff's deputies). Further, it is well acknowledged that the raising and lowering of speed limits by itself has little effect on the 85th percentile speeds on a roadway.[22] Nonetheless,

[22] See http://www.fhwa.dot.gov/tfhrc/safety/pubs/speed/speed.htm

posted speeds provide important information to the driver about the corridor. Given the alignment, the team considers that a reduction in posted speeds may be desirable on this section because it may decrease the variation in speeds between vehicles. In accordance with standard practice[23] this would include the analysis of the 85th percentile speeds but would also include consideration of important geometric and safety concerns in the corridor (narrow traveled way, no to minimal shoulders, truck mix in traffic stream, etc).

Cost Ranking: Low cost for conducting study and similarly low cost for sign re-posting if a lowering of the posted speed is found reasonable

Action Efficiency: Moderate to high for two reasons: while the level of effort for the study is relatively minimal the larger issue rests with the enforcement follow-up effort that may be needed.

2.15 Issue 13: Sightlines around Curves

Issues 2 and 9 dealt with sight distance at intersections and centerline crossovers, respectively, with both issues dealing with sightlines. This section takes a corridor wide approach to the issue, examining opportunities to improve a driver's ability to see other vehicles. The constrained geometry does provide natural limitations to forward visibility around curves while the frequent nature of these curves highlights the importance of maximizing sight distance.

Expected Crash Types: Primarily rear-end crashes with some limited potential for head-on crashes

Expected Frequency: Infrequent

Expected Severity: Moderate

Risk Ranking: B (low risk level)

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[23] See http://www.oregon.gov/ODOT/HWY/TRAFFIC-ROADWAY/speed_zone_program.shtml for information on Oregon's speed zone program. While, as is the case nationally, Oregon's speed zone analysis relies heavily on the 85th percentile speed (the speed at or below which 85% of the vehicles are travelling) the Oregon speed zone analysis also takes into account accident history, roadside culture, traffic volumes, and roadway alignment, width and surface. The team's initial interpretation is that these factors support lowering the posted speed in this section of the roadway.

Suggestions:
Solutions to these issues are similar throughout the corridor and involve mowing and brushing and possible slope cutting. In some cases sight distance might be improved markedly (e.g., Skyline Drive) whereas the "hardscrabble" vegetation along most of the corridor limits major sight distance gains.

Cost Ranking: Low cost for mowing and brushing.

Action Efficiency: High as the County could do mowing and brushing operations; however, the benefits may be marginal due to the limited vegetation growing on the slopes provided sight distance limitations. The more often encountered rock slope sight distance blocks would be considerably more expensive to remove and would likely require contracts.

2.16 Issue 14: Emergency Communication Issues

Personal observation by team members, discussion with drivers, and discussion with County staff verified that cellular phone coverage was inconsistent in this portion of the roadway. The team observed drivers stopping in the market parking area just north of Skyline Drive and in the gravel area just south of the intersection with Highway 30 to use cell phones, presumably as these were relatively safe refuge areas and were near the edges of cell phone coverage before coverage was lost in the canyon. County staff also indicated that emergency services and County maintenance radio coverage was occasionally limited. Emergency calls from drivers may not be possible and not all emergency responders may be able to communicate with one another in the corridor. Obviously the range of emergency issue requiring cell phone or radio communication is vast and includes hazardous materials incidents, crashes, or mechanical breakdowns.

The road safety audit team makes a key distinction between types of coverage. Providing robust emergency services communications to responders and road maintenance staff has clear benefits in reducing response time and assuring timely delivery of needed services. Increasing personal cell phone coverage in the corridor, while offering improvements for timely notification of stranding or crashes, also carries large potential drawbacks due to the potential for increased distracted driving in a corridor demanding a high degree of driver attention.[24]

Expected Crash Types: None; applicable to post-crash notification or requests for assistance in case of vehicle breakdown

Expected Frequency: Not applicable

[24] See, for example, a case-crossover study from Australia on the relation between cell phone use and crashes http://www.bmj.com/cgi/rapidpdf/bmj.38537.397512.55v1

Expected Severity: Not applicable

Risk Ranking: Not applicable

Suggestions:
Improving radio communication for County maintenance personnel and for emergency services should be strongly encouraged to ensure adequate ability to communicate seamlessly among emergency providers and to assure timely maintenance actions. Improving the cell coverage is an action that cell phone carriers are likely to make based on return on investment; given the concerns from increased cell phone use resulting in increased driver distraction, we suggest the County take no proactive actions currently. To aid in post-incident response, as mentioned earlier, we suggest installation of interim mile markers to improve emergency response location and crash analysis. Providing interim mile markers would also help drivers identify their location for emergency services, where such cell phone coverage is available and make it easier for motorists to remember the location of an incident when they do get coverage.

Cost Ranking: Iinterim mile markers would be a low to moderate cost depending on the frequency of the markers. Increasing radio coverage may be expensive .

Action Efficiency: High for interim mile marker installation as this could be done by County staff but low for increasing radio coverage as this would require specialized equipment.

2.17 Issue 15: Safety Corridor:

A roadway safety audit is at its foundation a multidimensional examination of safety along a roadway. While this review has noted a number of safety issues the incompatibility between the roadway's physical alignment and width and its traffic demand cannot be addressed solely by engineering or enforcement actions. Increasing awareness of the limitations inherent in this roadway and encouraging cautious driving also needs to be pursued.

Expected Crash Types: All crashes

Expected Frequency: Varies

Expected Severity: Varies

Risk Ranking: Not applicable

Suggestions:
We recognize that funding for extensive upgrades may not be available, so an interim fix may be to identify the corridor as a safety corridor, especially for associated safety awareness actions such as encouraging headlight on during daylight hours and increased outreach among the media, law enforcement and the community. The safety corridor designation could also be coupled to an enhanced enforcement campaign, although the team is aware that the physical shoulder limitations make effective enforcement difficult and that enforcement campaigns would stretch already limited law enforcement staff.

Currently the County does not have a procedure for the designation of safety corridors. We suggest that the program used by ODOT be used as an example.[25]

Cost Ranking: Sign installation would be low cost; outreach activities would be low to moderate depending on the degree of outreach and methods employed.

Action Efficiency: High as all the suggested actions could be accomplished by County staff.

2.18 Issue 16: Ice and Snow Management

The report has previously noted the proactive actions of the County in establishing a 24 hour operations center at the maintenance yard on Skyline Drive, continually driving the road during inclement weather conditions to visually monitor for snow or ice formation, and responding to ice and snow on the corridor ice and snow which can cause driver loss of control. While these actions are laudable, snow or ice conditions can form rapidly, and the elevation and sheltered nature of the corridor mean that snow or ice can form and linger at certain spots earlier and remain longer than at less shaded spots. Thus, it is important to make drivers aware of snow and ice conditions in the corridor and to maintain an aggressive posture towards detection and response.[26]

Expected Crash Types: Primarily run-off-the-road crashes, rear-end crashes and some limited potential for head-on crashes

Expected Frequency: Infrequent

Expected Severity: Low

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[25] See http://www.oregon.gov/ODOT/TS/docs/Roadway/2006Safety_Corridor_Guidelines.pdf

[26] See the compilation of technologies for anti-icing and road weather information (based on a National Cooperative Highway Research Program report) at http://www.transportation.org/sites/sicop/docs/NCHRP20-7%28117%29.pdf

Risk Ranking: A (lowest risk level)

Suggestions:
Driver warning systems should be considered for installation in the corridor to advise drivers of icy road or weather conditions. An ice and snow detection system would be preferable to static signs, as the warning message would only be activated if there were a high probability of ice or snow formation based on pavement sensor data and corridor collected meteorological data (wind speed, dew point, relative humidity, etc.). A weather monitoring system would also serve to allow County staff a better opportunity to prepare for potential events and to respond to cases where snow or ice has formed rather than relying on a visual inspection by traversing the corridor. This also ensures drivers have proper information to make an informed decision in the corridor rather then relying entirely on innate driver knowledge based on general appreciation of ambient weather conditions and the attendant possibility of snow or ice formation.

ODOT is currently evaluating ice detection technology and motorist reaction to warnings on OR 140 between Klamath Falls and Medford. This pilot project, if successful, could be used as a basis for a system on Cornelius Pass Road.

Cost Ranking: Moderate for both the monitoring and response practice in place and for the driver warning system

Action Efficiency: High for County efforts on monitoring and response since this can be and has been accomplished with County staff and equipment. Installation of a snow and ice detection system would likely require a specialized contract to procure the proper monitoring equipment, activated sign, and for proper installation of sensors.

2.19 Issue 17: Driver guidance at T-intersections

Three of the four intersections on this portion of Cornelius Pass Road are T intersections. Unfamiliar drivers on Kaiser Road and Sheltered Nook Road approaching Cornelius Pass Road may require guidance concerning the absence of a through exit leg at the intersection (at the Highway 30 intersection the signal control and wider cross section of the intersecting road reduce possible driver confusion.

Expected Crash Types: Primarily rear-end crashes

Expected Frequency: Rare

Expected Severity: Low

Risk Ranking: A (lowest risk level)

Suggestions:
The review has previously called for the use of larger street name signs throughout the roadway to increase legibility distance and conspicuity. More directly, the audit suggests that the two-direction large arrow sign (MUTCD Sign W1-7) be considered at the opposing stem of the T to prevent any crossing-through movement (the location of the street sign at the opposing end of the stem could confuse drivers who think that the street continues on both sides of the mainline).

Cost Ranking: Low as signs would be inexpensive.

Action Efficiency: High since signs could be fabricated and installed by the County.

2.20 Issue 18: Driver Perception at Old Cornelius Pass Road/Skyline Road

The road safety audit team observed a potential for driver confusion at this intersection. Northbound drivers on Cornelius Pass Road could mistake the old roadway alignment as being part of the mainline. The new mainline has a horizontal curve whereas the old alignment creates a visual continuation of the mainline prior to Skyline Road. While the grass shoulder makes the separation of the roads apparent in the day, these visual cues are not present at night. Even a small potential straying could cause drivers to enter the opposing direction of traffic and with the horizontal curve to the right past Skyline, driver alignment correction is more difficult than on a tangent alignment.

Expected Crash Types: Primarily run-off-road crashes and head-on crashes

Expected Frequency: Rare

Expected Severity: Moderate

Risk Ranking: A (lowest risk level)

Suggestions:
Minor landscaping improvements could reduce this potential problem. Landscaping via bushes could obstruct a driver's view of Old Cornelius Pass Road**.** Changing the angle of the signs (only a minor adjustment would be needed) on Old Cornelius Pass Road would minimize potential confusion for drivers on Cornelius Pass Road. Finally, delineators on both sides of Cornelius Pass Road could improve guidance for drivers.

Cost Ranking: Low for landscape and sign adjustments; low also for delineator placement.

Action Efficiency: High for all markers as these could be installed by County forces.

3.0 Conclusions

The findings and suggestions are summarized in the table below:

Safety Issue		Risk Ranking	Suggestions
1	Hazards are present in the clear zone	E	▪ Install additional roadside barriers ▪ Install additional end treatments ▪ Relocate or delineate utility poles ▪ Delineate rock walls ▪ Reduce pavement drop-offs ▪ Improve roadway delineation ▪ Update roadside protection policy
2	Potential for unanticipated change in centerline pavement markings	D	▪ Remove existing skip lines ▪ Consider durable no-passing marking ▪ Re-mark short section near County line as no-passing zone
3	Guardrails and barriers do not provide consistent shielding along corridor	D	▪ Increase guardrail delineation ▪ Upgrade end treatments ▪ Re-set critical sections of guardrail ▪ Conduct guardrail needs analysis
4	Vehicles crossing over centerline	D	▪ Install profiled centreline ▪ Consider select curve widening
5	Sign size and conspicuity may not be sufficient to meet driver needs	C	▪ Consider larger and brighter signs ▪ Upgrade street name signs and install advance intersection signs ▪ Install house numbers ▪ Install interim milepost markers ▪ Update sign placement policy ▪ Assess sign needs
6	Curve signing not consistent throughout corridor	C	▪ Ensure consistency of chevron signs ▪ Update sign policy ▪ Verify advisory curve speed posting
7	Signs and delineators were obscured by dirt and grime	C	▪ Increase frequency of cleaning ▪ Update cleaning policy
8	Intersection sight lines are restricted at several locations	C	▪ Measure intersection sight distance ▪ Take physical actions to improve sight distance
9	Visibility is limited for vehicles turning at Sheltered Nook Road	C	▪ Consider vehicle activated advance sign to warn of stopped vehicles ▪ Install stop bar at Sheltered Nook
10	Traffic volumes and composition indicate roadway operates beyond its functional capacity	Not applicable	▪ Conduct a study on road function including hazardous material routing

Safety Issue		Risk Ranking	Suggestions
11	Right turn lane from eastbound Highway 30 may encourage excessive speeds	C	▪ Install right turn edgeline ▪ Address right-turn edge drop-off ▪ Develop right-turn lane design to control speeds ▪ Include right turn overlap in signal re-design
12	Posted speed limit may exceed operating speed	Not applicable	▪ Consider speed zone review
13	Curve sightlines are limited	B	▪ Increase mowing and brushing
14	Topography limits communication coverage	Not applicable	▪ Improve radio communications for maintenance and emergency services
15	Unfamiliar drivers may be unaware of constrained nature of corridor	Not applicable	▪ Consider designation as safety corridor ▪ Develop corridor safety policy
16	Constrained roadway geometry makes winter driving potentially hazardous	A	▪ Consider activated driver warning signs ▪ Consider weather monitoring system
17	T-intersections are potentially confusing for drivers	A	▪ Install dual arrow sign at stem of T intersection
18	Driver's may be confused by perception of roadway alignments at Skyline Road	A	▪ Install additional landscaping ▪ Consider altering sign angles ▪ Install delineators

Multnomah County is invited to consider the suggested changes. To complete the audit process, the owner is requested to prepare a short written response to each of the issues and options identified in this report.

Appendix A

Road Safety Audit Team and Materials

Location: Cornelius Pass Road between Multnomah County line and Oregon Highway 30

Audit Team:
Margaret Gibbs, P. Eng. P.T.O.E., Opus Hamilton Consultants Ltd.
Ty Reynolds, Associate Traffic Engineer, Clackamas County, Engineering Division
Joel McCarroll, P.E., Oregon Department of Transportation, Region 4
Craig Allred, Federal Highway Administration, Resource Center
Nick Fortey, P.E., Federal Highway Administration, Oregon Division

Project Owner: Multnomah County

Review Date: July 1 to 3, 2008

Audit Stage: In-service audit (audit of existing roadway)

Start up Meeting: July 1, 2008

Project Documents Available to Audit Team:

- Conceptual drawings for the intersection improvement at Highway 30 and Cornelius Pass Road prepared by the Oregon Department of Transportation
- Collision data summaries from 1993 to 2007 (inclusive) from the Oregon Department of Transportation
- Crash reports (law enforcement completed) from Multnomah County Sheriffs Office 2003 to 2007 (inclusive)
- Project fact sheet (June 2008)

Fact sheet provided prior to the start up meeting; crash reports, crash summaries, and the conceptual drawings were provided after the meeting.

Appendix B

Site Visit Summary

Project Name: Cornelius Pass Road
Site Visit Dates: July 1 to July 3 2008 (sunny and dry conditions)

Land use: The audit site is in a rural part of the Portland metropolitan area. The road has a number of driveways providing access to single family houses. There are four intersections along this section with public roads (a T-intersection with Kaiser Road, a four way intersection with Skyline Drive, a T-intersection with Sheltered Nook Road, and a T-intersection with Highway 30.

Road Users Characteristics: Traffic was moderate to heavy during periods observed. A high percentage of truck traffic was observed in this corridor although the proportional representation in mid to late afternoon decreased noticeably probably due to both a real reduction in truck traffic and the increase in commuter traffic for the peak afternoon commute period. No pedestrians were observed during the site visit. One cyclist was observed on Cornelius Pass Road although several cyclists were observed using Skyline Road and crossing over the Cornelius Pass intersection. A small percentage of motorcyclists was observed on the route.

Road and roadside physical characteristics:
Cornelius Pass Road is a two-lane rural road with a posted speed of 45 mph. The entire section within Multnomah County is striped as no-passing. Narrow gravel shoulder sections were present in a few areas as were guardrails.

The roadsides are characterized by steep cut and fill slopes over most of the road’s length. These slopes, along with the trees, vegetation, and rock walls, are roadside hazards.

Night-time conditions: Overhead lighting is present at the Skyline intersection and at the S-curve and at the intersection with Highway 30; otherwise there is no fixed lighting in the corridor.