

Road Safety Audit

Lummi Nation Reservation





Road Safety Audit

Lummi Nation Reservation

Prepared By

Patrick Andridge, E.I.T.

Opus International Consultants Inc. Detroit Office Suite 210, 27333 Meadowbrook Road, Novi, MI 48377 USA

Reviewed By

ANDREW

POPESSIONAL

Andrew Ceifetz, P.E., CAPM Jesse Arsenault, P.Eng Ed Koltonowski Brad Lincoln, P.E.

10

Telephone: Facsimile:

+1 248 539 2222 +1 248 349 6862

Date: Reference: Status:

August 2017 H-U0630.00 Final



© Opus International Consultants Inc. 2017

ENGINE

Executive Summary

A Road Safety Audit (RSA) is a formal safety performance examination of an existing or future road or intersection by an independent, multi-disciplinary team. The Lummi Nation retained Opus International Consultants Inc. and Gibson Traffic Consultants, Inc. **to lead an audit of the Tribe's road** network. Several routes and intersections were identified in the Request for Proposal but the scope was expanded to include all significant routes within the Reservation.

A typical road safety audit includes eight steps from the identification of an audit location and the identification of an audit team to the development of a report detailing potential recommendations to address identified safety concerns. This final report is delivered to the project owner (the Lummi Nation) who then have the opportunity to act on, or respond to, recommendations.

Field reviews were conducted by the audit team from June 5th through June 8th, including day, night, and raining weather conditions. A significant portion of the field review included the collection of geolocated video recording along the network under both day and night time conditions. Over the four-day field review, the audit team also facilitated a kick-off meeting with the Tribe and other transportation related stakeholders as well as a preliminary findings presentation to provide the project owner (the Lummi Nation) with initial thoughts based on early observations.

Based on these activities, several positive safety practices were identified as well as a number of safety concerns. Primarily, the positive aspects noted during the field review included sidewalk and trail development, several modern roundabout installations, the placement of several speed feedback signs, and existing plans to address some of the more significant concerns within the Reservation. Safety concerns noted within the Reservation were primarily focused around narrow travel lanes and narrow or non-existent shoulders, intersection concerns at Haxton Way and Slater Rd, clear zone / sight distance issues along curves and at intersections, and curve warning signs and associated delineation. The following table provides a high-level summary with additional details provided in Section 5 of the report.

Recommendations designed to address each of the identified concerns have been presented in the following report. These include proven collision modification factors (where available), brief descriptions of each treatment, and an approximate cost range associated with each.

A Highway Safety Manual (HSM) analysis was conducted to provide the Tribe with a data driven estimate of current safety performance along the road network within the Reservation. This analysis **indicated that the Tribe's road network is, broadly speaking, operating as expected regarding** safety performance. Based on the HSM analysis, it was expected that the Reservation would experience approximately 47 crashes each year, however, only 39 crashes were reported each year during the study period (2012 – 2016). This simply means that for the condition / configuration of the network, there are no areas experiencing an inordinate amount of collisions; it does not mean that there are not areas where improvements can be made to improve safety and operations within the Reservation.

The following table provides a high-level summary of each safety concern as well as the measurable recommendations identified through this study. These and additional treatment recommendations are discussed in the body of the report.

	Concern	Risk Rating	Treatment	Cost Estimate (\$thousands)	Extent	Lifetime Crash Reduction	BCR
1	Kwina, Marine, and Lummi Shore Intersections	F	Convert to Roundabout Flashing Beacons LED Stop Signs Restripe Primary Route	\$1,250 \$3.6 \$4.5 \$3.5	1 Location 4 Intersections 4 Intersections 1/4 Mile Curve	11.55 0.7 2.5 0.33	0.4 8.8 25.0 2.7
2	Pedestrian / Bike Facilities	E / F	Pave Gravel Shoulders Widen Existing Paved Shoulders	\$1,700 \$50	~24 Miles of 6' ~1.4 Miles of 1-2'	12.8 1.3	0.3 1.2
3	Turning Movements at Haxton Way & Slater Rd	D / E	Convert to Roundabout Dilemma Zone Detection Monitoring Speed Feedback Sign Protected Left Turn Movement Advanced Warning Signs	\$1,000 \$60 \$10 \$10 \$2	1 Intersection 1 Approach 1 Installation In Installation 4 Approaches	22.8 2.2 0.98 3.3 1.96	1.0 1.7 4.4 9.5 44.1
4	Narrow Lanes / No Shoulders	D/E	Widen Narrow Pavement Pave Gravel Shoulders	\$50 \$1,700	~1.4 Miles of 1-2' ~24.5 Miles of 6'	2.2 2.7	2.0 0.1
5	Unmarked Curves	D/E	Boom Mower Attachment Install Chevrons and Curve Warning Signs Raised Pavement Markers Flatten Side Slope Bemove or Belocate Fixed Objects	\$40 \$9.6 \$140 \$15 - \$100 \$5 - \$30	1 Boom Mower 24 Signs 4 miles Varies Varies	8.3 14.56 4.2 9.4 16.8	9.3 68.2 1.4 28.2 - 4.2 151 2 - 25 2
6	Clear Vision at Intersections	D	Remove or Relocate Fixed Objects Flashing Beacons LED Stop Signs	\$5 - \$30 \$9 \$7	Varies 8 Intersections 8 Intersections	3 1.3 0.39	27.0 – 4.5 6.5 1.6
7	Speeding	D	Speed Feedback Sign	\$20	2 Installations	1.68	3.8
8	Skewed Intersection & Hidden Stop Signs	D	"Stop Ahead" Pavement Markings	\$2	5 Approaches	2.45	55.1
9	Safe Waiting Areas at Bus Stops	D	N/A				
10	Downhill Stretch of WB Lummi View Dr	D	Icy Curve Warning Sign High Friction Pavement Surface Treatment	\$15 \$20	1 Installation 2 Installations	3.8 3.57	11.4 8.0
11	Lack of Intersection Warning	C/D	Advanced Street Name Signs Intersection Lighting Transverse Rumble Strips	\$9.6 \$60 \$30	6 Intersections 6 Intersections 6 Intersections	0.35 1.5 1.4	1.6 0.7 2.1
12	Jersey Barrier Installation	C/D	N/A				
13	Guardrail Condition & Placement	с	Install New Guardrail	\$1,000	5 Miles	18.8	0.5
14	Target Arrow Placement	B / C	N/A				
15	Roundabout Splitter Islands	В	N/A				

Contents

1	Introduction11.1Background2
2	Road Safety Audit32.1Road Safety Audit Team
3	Site Characteristics63.1Study Location3.2Road User Characteristics93.3Collision Analysis11
4	Existing Safety Measures
5	Safety Concerns and Suggestions235.1 Existing Concerns and Suggestions255.2 Other Recommendations96
6	Highway Safety Manual Analysis976.1 Existing Performance.986.2 Benefit Cost Ratios.100
7	Summary 104
Арре	A-1 Additional Field Observation Photos A-1 Historic Traffic Volumes A-11 HSM Detailed Results A-15

Figures

Figure 1 - RSA Eight-Step Process	1
Figure 2 - Original RSA Routes	2
Figure 3 - Video Logged Routes (Daytime – Above, Nighttime – Below)	7
Figure 4 - Site Photographs	8
Figure 5 - Road User Photographs	10
Figure 6 – Collision Diagram (All Collisions of All Severities, 2012 – 2016)	11
Figure 7 - Collision Severity Distribution	13
Figure 8 - Collision Type Distribution	13
Figure 9 - Temporal Collision Trends	14
Figure 10 - Environmental & Geometric Collision Trends	16
Figure 11 - Wet, Icy, & Snowy Road Condition Collision Heatmap (All Severities)	17
Figure 12 - Dark, Unlit Collision Heatmap (All Severities)	19
Figure 13 - Westbound Approach turning Northbound	. 26
Figure 14 - Westbound Approach turning Southbound	. 26
Figure 15 - Northbound Approach continuing Northbound	. 26
Figure 16 - Collision Diagram	27
Figure 17 - Local LED Stop Sign Example - Northbound Northwest Dr & Slater Rd	. 29
Figure 18 - Example of Chicken Tracks / Guidance Pavement Markings	. 30
Figure 19 - Mock Guidance Sign – Westbound Approach	31
Figure 20 - Vulnerable Road Üsers	. 33
Figure 21 - Pedestrian and Bicyclist Involved Collisions (2012-2016)	. 34
Figure 22 - Bike Lane Pavement Marking - Bellingham, WA	. 36
Figure 23 - Haxton Way & Slater Rd Approaches (Westbound - Left, Eastbound - Right, Northbound	d -
Bottom)	. 38
Figure 24 - Haxton Way & Slater Rd Collision Diagram	. 39
Figure 25 - Northbound Haxton Way Right Turn Lane	41
Figure 26 -Potential Sign Configuration (R3-7 Right with W16-8P Plaque)	. 44
Figure 27 - Potential Right Turn Lane Revisions (Existing – Left, Proposed – Right)	. 45
Figure 28 - Example Lane Widths (Mackenzie Rd, Top, and Chief Martin Rd, Bottom)	. 48
Figure 29 - Run off Road Collisions & Potential Paved Shoulder Locations	. 50
Figure 30 - Unmarked Curve Examples	. 52
Figure 31 - Curved Road Segment Collisions	. 53
Figure 32 - Typical Curve Warning Signs (Source: FHWA MUTCD)	. 54
Figure 33 - Lummi View Dr Signed Curve	55
Figure 34 - Raised Pavement Reflectors (Source: FHWA)	. 56
Figure 35 - Utility Pole Mounted Delineator (Source: AASHTO)	. 56
Figure 36 - Example Boom Mower Attachment	57
Figure 37 - Cagey Rd & Chief Martin Rd – Left, Haxton Way & Cagey Rd Intersection Sight Distance	959
Figure 38 - Design Stopping Sigh Distance (WSDOT Design Manual)	. 60
Figure 39 - Northbound approach to Haxton Way & Lummi Shore Dr	. 62
Figure 40 - Pedestrian Impact Curve (Top) and Vehicle Severity Curves (Bottom)	. 64
Figure 41 - Average Observed Speed Above Posted Speed Limit	. 66

Figure 42 - Significantly Skewed Intersections (Haxton Way & Red River Rds - Top Left, Ha	xton Way
& Lummi Shore Dr - Top Right, Smokehouse Rd & Lummi Shore Rd - Bottom)	70
Figure 43 - Red River Rd Skew Alternative (Not Drawn to Scale)	72
Figure 44 - Comparison of Bus Stop Facilities	74
Figure 45 - Lummi Shore Rd	76
Figure 46 - Northbound Approach to S & N Red River Rds	79
Figure 47 - Unpinned vs Pinned Jersey Barrier along Lummi Shore Rd	83
Figure 48 - Guardrail Installations	85
Figure 49 - Reconstructed Culverts	
Figure 50 - Run off Road Collision Locations (Intersection Related Not Included)	
Figure 51 - Target Arrow Approach at N Red River Rd & Lake Terrell Rd	
Figure 52 - Reservation Roundabout	93
Figure 53 - "Keep Right" at Roundabout (Source: City of Sacramento)	
Figure 54 - Painted Splitter Island	95
-	

Tables

Table 1 - Collision Frequency	5
Table 2 - Collision Severity	5
Table 3 - Collision Risk Assessment	5
Table 4 - HSM Analysis	32
Table 5 - Observed Collision Analysis	32
Table 6 - HSM Analysis	
Table 7 - HSM Analysis	47
Table 8 - Observed Collision Analysis	47
Table 9 - HSM Analysis	51
Table 10 - HSM Analysis	58
Table 11 - Observed Collision Analysis	58
Table 12 - Observed Collision Analysis	
Table 13 - Traffic Calming Examples	67
Table 14 - HSM Analysis	69
Table 15 - HSM Analysis	73
Table 17 - HSM Analysis	
Table 17 - HSM Analysis	
Table 18 - Observed Collision Analysis	82
Table 19 - Observed Collision Analysis	

1 Introduction

The Lummi Nation retained Opus International Consultants Inc. (Opus) and Gibson Traffic Consultants Inc. to lead an Operational Road Safety Audit (RSA) on the road network within the Reservation boundaries, with an emphasis on the Whatcom County-maintained roads. The objective of this study was to conduct a formal safety performance examination of the study area with an independent, multidisciplinary team. RSA's are a proactive approach to addressing safety of all road users and involve identifying both safety issues and developing mitigation measures.

The RSA followed the eight-step process which is detailed in Figure 1 below.



Figure 1 - RSA Eight-Step Process

The objectives of the RSA are to:

- review road safety within the study area;
- identify physical and operational issues that may affect road safety; and
- develop and evaluate potential countermeasures to reduce the frequency and severity of collisions.

The following sections will detail the RSA process, the methodology for this analysis, and data obtained throughout the study. The report will also present all significant findings and safety issues as well as provide recommended mitigation strategies.

1.1 Background

The Lummi Nation Reservation is located in the northwestern area of the State of Washington, to the west of the City of Bellingham. The terrain is gently rolling in and around the Reservation with land uses consisting of single family residential, commercial, and industrial establishments as well as several institutional centers. The major routes within the reservation include both major and minor collectors with the remaining roads consisting of local and private routes.¹ The initial request for proposal (RFP) issues by the Tribe included specific locations for consideration. Figure 2 provides the boundaries of the reservation and the routes identified by the RFP for review during the RSA.



Figure 2 - Original RSA Routes

The highlighted routes represent the more heavily trafficked **roads within the Reservation. The Tribe's** main administrative, health, education, and community service centers are located along these routes **as well as the Tribe's tr**ansit bus routes and the Ferry terminal on the southwest end of the peninsula. **Additionally, the Tribe's casino is located in the northern end of the Reservation in the southeast** quadrant of Slater Rd and Haxton Way.

¹<u>http://www.wsdot.wa.gov/data/tools/geoportal/</u>

2 Road Safety Audit

An RSA is a formal safety performance examination of an existing or future road or intersection by an independent audit team. **RSA's help** to promote road safety by identifying safety issues during the planning, design, and implementation stages, promoting awareness of safe design practices, integrating multimodal safety concerns, and considering human factors.

2.1 Road Safety Audit Team

Location:	Lummi Nation Reservation	
	Whatcom County, Washington	
Audit Team Members:	Andrew Ceifetz, P.E., CAPM Jesse Arsenault, P.Eng Patrick Andridge, EIT Edward Koltonowski, President Brad Lincoln, P.E.	Opus Opus Opus Gibson Gibson
Project Owner:	Lummi Nation	
Review Date:	June 4 – 8 th , 2017	
Audit Stage:	Operational	
Start-up Meeting:	June 5 th , 2017	
Preliminary Findings Meeting:	June 8 th , 2017	
Attended By:	Lummi Nation Planning Lummi Nation Public Works Lummi Nation Law Enforcement Whatcom County Whatcom County Sherriff Whatcom County Fire District 8 Gibson Traffic Consultants Inc. Opus International Consultants In	С.

The RSA team members conducted this audit to the best of their professional abilities within the onsite time available and by referring to provided information. While every attempt has been made to identify significant safety issues, the project owner is reminded that responsibility for the design, construction, and performance of the roadways remains with the agency with jurisdictional authority.

2.2 Road Safety Audit Materials

The RSA was based on the following data and analysis:

Site Review: Site visits were conducted from June 4th to the 8th during both day and nighttime periods to review the Reservation transportation network, adjacent land uses, and to observe traffic operations and conflicts.

Traffic Counts: Historic and recently collected traffic counts were collected and provided by Gibson Traffic Consultants. A summary of the traffic counts collected for the RSA is provided in the Appendix

Review of Collision Data and Analysis of Collision Trends: Collision data was provided by the Washington State Department of Transportation (WSDOT) for more than six (6) years, from January 2011 to April 2017. This was trimmed to January 2012 through the end of December 2016.

Identification of Mitigation Measures: On the basis of the above tasks, road safety issues and potential collision causes were identified. Mitigation measures were identified to address the safety issues and possible collision causes, along with the collision reductions that are anticipated to result from their implementation.

Project Documents Available for the RSA:

- Traffic Counts within the Reservation
- Collision Data provided by WSDOT
- Tribal Safety Plan
- Tribal Transportation Plan
- Previous Lummi Reservation RSA Material
- Kwina Corridor Plan
- Kwina Triangle Analysis
- Lummi Tribal Transit Schedule and Locations

All documents were provided to Opus prior to or during the RSA.

2.3 Road Safety Audit Process

A road safety audit framework was applied in both the analysis and presentation of findings. The expected frequency and severity of collisions caused by each safety issue have been identified and rated according to categories shown in Table 2. These two risk elements were then combined to obtain a risk assessment on the basis of the matrix shown in Table 3. Consequently, each safety issue is assessed on the basis of a ranking between F (highest risk and highest priority) and A (lowest risk and lowest priority). For each safety issue identified, possible mitigation measures have been suggested.

Estim	deney	
Exposure	Probability	Frequency Rating
Medium \rightarrow High	High	Frequent
Low \rightarrow High	Medium \rightarrow High	Occasional
Low → Medium	Low	Rare

Table 1 - Collision Frequency

Table 2 - Collision Severity

Typical Collisions Expected (per audit item)	Expected Collision Severity	Severity Rating
Collisions involving high speeds or heavy vehicles, pedestrians, or bicycles	Probable fatality or incapacitating injury	High
Collisions involving medium to high speed; head-on, crossing, or off-road collisions	Moderate to severe injury	Moderate
Collisions involving medium to low speeds; left-turn and right-turn collisions	Minor to moderate injury	Low
Collisions involving low to medium speeds; rear-end or sideswipe collisions	Property damage only	Negligible

Table 3 - Collision Risk Assessment

Frequency Rating	Severity Rating				
inequency nating	Negligible	Low	Moderate	High	
Frequent	С	D	E	F	
Occasional	В	С	D	E	
Rare	Α	В	С	D	
Collision Risk Rankings -	nkings - A: Lowest priority		F: Highest prior	ty	

3 Site Characteristics

3.1 Study Location

The road network throughout the Lummi Nation Reservation services local Tribal Members as well as visitors to the Casino and ferry dock to Lummi Island. Additionally, Slater Rd, which generally forms the northern boundary of the reservation also services the Philips 66 refinery and consequently a significant number of heavy commercial vehicles. The peninsula where the reservation is situated is wooded and hilly in nature with most residences and other activity occurring near the shoreline. The exception to this is the central area along Kwina Rd and Haxton Way which provides access to the **Tribe's various services, including the Tribal Administration offices and the Casino.**

In addition to the routes specifically requested in the original RFP, several outlying concerns were raised during the kick-off meeting held on June 5th. These additional routes and locations were observed during the field reviews conducted over the course of the following week with the vast majority recorded via video log. Figure 3 provides a compiled list of routes covered during this process.



Figure 3 - Video Logged Routes (Daytime – Above, Nighttime – Below)

A number of general observations were made over the course of the field review. These are summarized below with some illustrative site photographs provided in Figure 4 - Site Photographs

. Additional photos are provided in the appendix.

General Observations:

- Generally narrow lanes and narrow or non-existent shoulders along most routes
- Significant number of pedestrians and bicyclists throughout reservation
- Fresh pavement markings throughout reservation
- Excellent sign condition throughout reservation
- Lighting is present at various locations throughout the reservation



Southbound Haxton Way



Eastbound S Red River Rd



Eastbound S Red River Rd at Haxton Way



Southbound Haxton Way at Smokehouse Rd

Figure 4 - Site Photographs

3.2 Road User Characteristics

A variety of travel modes were observed, listed below and shown in Figure 5:

Passenger cars utilize the network and land uses summarized in Section 3.1. A significant number of year-round and seasonal residences are located within the Reservation.

Additionally, passenger cars may access Lummi Island via the Ferry Dock located near the southwestern tip of the peninsula.

Commercial Vehicles were occasionally observed traversing the reservation. Current construction along Slater Rd significantly reduced the number of commercial vehicles observed during field observations. However, it was noted during the kick-off meeting that there are normally more commercial vehicles along Slater Rd.

Buses, including school buses, regularly utilize stops along the study corridor.

Non-motorized users including pedestrians and bicyclists were observed during field observations.

Others such as motorcycles are also known to utilize the surrounding network.



Figure 5 - Road User Photographs

3.3 Collision Analysis

Collision data was obtained from the Washington State Department of Transportation for over six (6) years, from January 2011 to April 2017. From this data set, collisions from January 2012 through December 2016 was used for analysis to help ensure that all post-collision updates to the dataset have been completed. A total of 214 collisions were reported within the study area during the five-year period. A diagram of these collisions is shown in Figure 6. It must be noted that of the 214 total collisions, 209 were plottable while all of the fatal and series injury collisions were plottable. It should also be noted that due in part to the map scale, collisions may be overlapping with the most severe collision types shown in any location along the road network.



Figure 6 – Collision Diagram (All Collisions of All Severities, 2012 – 2016)

Collision data for January through April of 2017 was not included in the yearly analyses, as it has not been certified as complete. It should be noted that one fatality was reported in April, 2017.

Below are graphical representations of the data analyzed from the 214 collisions shown on the collision plot for the Reservation as a whole. As summarized in Figure 7, approximately 47 percent of the reported collisions resulted in at least one injury or fatality. This is compared to only 32 percent of all collisions in the State of Washington in 2014 (most recent annual collision statistics summary available).² Collision type distribution is summarized in Figure 8 with the most prevalent collision type being run off road collisions, representing almost half (47 percent) of the collisions. The second and third most prevalent collision types were rear-end and angle/left turn head on collisions.

The following collision trends are highlighted:

- The intersections of Haxton Way & Slater Rd, Kwina & Marine Dr & Lummi Shore Dr (colloquially known as the Kwina Triangle), and Slater Rd & Ferndale experience the greatest number of intersection related collisions in the reservation.
 - Within the last year, changes have been made to the intersection of Slater Rd & Ferndale Rd which appear to be (based on local opinion) addressing the historic collision patterns at this location.
- A significant portion of the reported collisions in the reservation involved run off road collisions.
- Recent installations of sidewalks and separated paths appear to be having a positive impact in mitigating pedestrian and bicyclist collisions.
- Almost one quarter of collisions occurred under wet road conditions.
- Almost thirty percent of the collisions reported on the reservation occurred under dark lighting conditions with no street lights.

² <u>http://www.wsdot.wa.gov/mapsdata/crash/pdf/2014_Annual_Collision_Summary.pdf</u>

CollisionSeverity



Figure 7 - Collision Severity Distribution







3.3.1 Temporal Collision Trends

Figure 9 - Temporal Collision Trends

As illustrated in the temporal trend summary in Figure 9, collisions on the reservation have experienced a somewhat increasing trend in recent years, although the yearly count has fallen slightly from its recent peak in 2014. When looking at the distribution of collisions by month of year, there does not appear to be a significant peak during any particular season when considering all collisions. There is a slight peak in fatal and serious injury collisions during the late fall and early winter months, but given the lower number of fatal and serious injury collisions it is difficult to draw a statistically significant conclusion.

When considering the distribution of collisions by day of week, all collisions and fatal and serious injury tend to perform similarly with Friday and Saturday accounting for the weekly peak days. Breaking things down to the hourly level, there appears to be a peak during the afternoon hours for all crashes with a broader afternoon peak identified for fatal and serious injury collisions. It should be

noted that a number of fatal and serious injury collisions occurred during the later evening (7 – 9PM) despite traffic volumes typically being lower during these periods. This suggests a common contributing factor(s) for late evening crashes. For example, approximately 46% of the 24 fatal or serious injury collisions which occurred from 7 to 9PM were under dark, unlit conditions while 21% were impaired.



3.3.2 Environmental Collision Trends

Figure 10 - Environmental & Geometric Collision Trends

When looking at collisions by environmental and geometric characteristics some trends rise to the surface, as summarized in Figure 10. First, approximately one-third of all collisions reported within the reservation were within or related to an intersection with a significant portion of the remaining collisions consisting of run off road events. Additionally, over thirty percent of the fatal and serious injury collisions reported within the reservation occurred on wet road surfaces. Most of these collisions appear to be located around the higher crash intersections, including Slater Rd and Haxton Way Slater Rd and Elder Rd. Figure 11 provides a heatmap showing icy, snowy, and wet road crashes of all severities.



Figure 11 - Wet, Icy, & Snowy Road Condition Collision Heatmap (All Severities)

Just under thirty percent of all collisions occurred under dark conditions with no street lights present. That proportion increases to over forty percent of all fatal and serious injury collisions with over half of all fatal and serious injury collisions taking place at night. Figure 12 provides a heatmap identifying the location of collisions which occurred under dark conditions with no lighting present. Additionally, the vast majority of all collisions, as well as fatal and serious injury collisions, took place on straight, level road segments within the reservation.



Figure 12 - Dark, Unlit Collision Heatmap (All Severities)

4 Existing Safety Measures

Existing safety measures have been identified in the table below. The Tribe and County are encouraged to continue implementing such safety measures to improve overall safety along roads and intersections in the City.



Existing Safety Measure

Sidewalk & Side path Installation

Several sidewalks and side paths have been constructed in recent years throughout the reservation, including those along Kwina Rd, the northern portions of Haxton Way, and new construction for facilities along Lummi View Dr and Lummi Shore Rd. This helps to remove pedestrians from vulnerable positions within or along the roadside. Additional lengths of sidewalk were observed under construction during the field review with additional segments planned for the future.

Photo

Roundabouts

Several intersections within the reservation (Haxton Way at Kwina Rd and Haxton Way at Smokehouse Rd) have have been converted to roundabouts in recent years. Roundabouts help to reduce the severity of collisions occurring at an intersection and can have a calming effect on traffic in terms of vehicle speeds.

elp to reduce the sions occurring at an d can have a calming in terms of vehicle

Lighting in Residential Areas

Several residential areas throughout the reservation have lighting along the roadway. This provides illumination for pedestrians and other vulnerable road users and help highlight the roadway for motorists.



21

Existing Safety Measure

Speed Feedback Signs

Speed feedback signs were observed in operation at several locations around the reservation. These installations alert drivers to speeding behavior and can have a calming effect on traffic speeds. Additionally, it was noted that some signs have data collection capabilities which could be useful in future traffic studies.



5 Safety Concerns and Suggestions

The following sections detail the findings made during the RSA, including safety concerns and suggestions. Safety concerns have been identified based on existing conditions along with suggestions to address each concern. The safety concerns, risk ratings, and suggestions are summarized below with additional detail provided in the following sections.

#	Safety Concern	Risk Rating	Suggestion
1	Kwina, Marine, and Lummi Shore Intersections (aka Kwina Triangle)	F	 Programmed Improvements (roundabout) Improve Stop Sign Visibility Restripe primary routes, add chicken tracks/guidance markings Install route guidance signs
2	Pedestrian / Bike Facilities	E/F	 Widen shoulder where sidewalk is not feasible
3	Turning Movements at Haxton Way & Slater Rd	D / E	 Roundabout Protected Westbound left turn movement Dilemma zone monitoring Speed feedback sign for eastbound approaching traffic Right-in / Right-out Only Driveway Revise northbound right turn pavement markings
4	Narrow Lanes / No Shoulders	D / E	 Review network for opportunities to widen lanes and / or shoulders
5	Unmarked Curves	D / E	SigningDelineatorsIncrease clearzone on the inside of curves
6	Clear Vision at Intersections	D	 Increase clear zones to improve sight distance Review crosswalk, stop bar, and stop/yield sign placement
7	Speeding	D	 Install additional speed feedback signs at candidate locations Consider traffic calming measures in residential areas
8	Skewed Intersection & Hidden Stop Signs	D	 Realign heavily skewed intersections Systemic Stop Bar Installation Program

#	Safety Concern	Risk Rating	Suggestion
9	Safe Waiting areas at Bus Stops	D	 Install concrete pad at bus stop locations Considering lighting installations at bus stop locations
10	Downhill Stretch of WB Lummi View Dr	D	 Consider installation of icy road feedback systems Review potential changes to winter maintenance activities & thresholds Consider high-friction surfacing
11	Lack of Intersection Warning	C / D	 Install advanced intersection warning signs Consider additional lighting installations Consider installation of transverse rumble strips
12	Jersey Barrier Installation	C/D	Re-pin jersey barrier
13	Guardrail Condition & Placement	С	 Review need for guardrail Update guardrail installations and terminals to current standards
14	Target Arrow Placement	в/С	 Reposition existing target arrows Install target arrows where missing
15	Roundabout Splitter Islands	В	Install "Keep Right" SignsPaint island curbs

5.1 Existing Concerns and Suggestions

The following sections provide details regarding the observed safety concerns as listed at the beginning of this section. Following the discussion of each safety concern, a series of potential treatment recommendations follow, including a brief description of the treatment, any collision modification factors (CMF) / collision reduction factors (CRF) where available, an approximate cost range (\$, \$\$, \$\$\$, \$\$\$, \$\$\$, and estimated benefit cost ratios for the locations addressed. For a more detailed summary, see the combined table located in Section 6.2. The information here is intended to provide approximations of potential expected collision reductions. In depth analyses and planning activities should be completed before any project to confirm or revise any information as necessary.

Safety Concern #1: Kwina, Marine, & Lummi Shore Intersections

Kwina Rd, Marine Dr, Lummi Shore Dr, and Lummi Shore Rd form a triangular series of intersections in a relatively small area. To further complicate things, there is a significant grade differential in the area and mature tree growth in the center of the triangle, further restricting sight distance. During field observations, other drivers regularly hesitated on several approaches, not always sure which vehicle was to be given the right of way. This was observed despite the stop signs which provide this guidance. Additionally, the significant skew associated with the northern, southern, and eastern intersections may make it more difficult for approaching drivers to look for oncoming or cross traffic. Figure 13, Figure 14, and Figure 15 provide the view of this location from several approaches and angles.



Figure 13 - Westbound Approach turning Northbound



Figure 14 - Westbound Approach turning Southbound



Figure 15 - Northbound Approach continuing Northbound

Given relatively high speeds (posted 35mph limit with observed speeds around 45mph along Marine Dr) the grade differential, curves, and other intersecting roadways, this location experienced ten collisions from 2011 through 2016. Figure 16 illustrates the number, type, and severity of the reported collisions. As shown in the figure, run off road collisions are the most frequent followed by left turn head on collisions. Several resulted in injuries with the majority occurring under dry road conditions.





E> Ty	xpected Collision /pes:	Angle, Left Turn Head On, Run off Road, Rear End
E>	pected Frequency:	Frequent
E>	pected Severity:	High
Ri	sk Rating:	F

Suggestions

Programmed Improvements

Given the history of collisions at this location as well as the potential for serious collisions in the future, the Tribe has already taken steps to address the complex nature of the group of intersection. While these plans are in the early stages, they are expected to move forward with a final plan within the next two years. Options discussed include the construction of a roundabout, a more traditional intersection, or the closure of one of the legs to reduce the level of complexity. Initial feedback suggests a more traditional intersection or a roundabout are the likely candidates. These should address the concerns and issues raised at this location as they would require regrading and a realignment of the approaches.

Treatment	Collision Modification / Reduction Factor	Approx. Cost Range
Reconstruct Intersection Cluster as Single Intersection	Unavailable	\$\$\$+
Convert Cluster to Roundabout ³	<i>0.56 Modification / 44% Reduction in</i> All Serious and Minor Injury Collisions	\$\$\$+

Improve Stop Sign Visibility

In the near term, changes to stop sign placement, type, and number could improve visibility increasing the likelihood that drivers will be aware of the upcoming intersection. This could include the installation of secondary stop signs on all stop controlled approaches at this location. This has already been completed on the southbound Lummi Shore Dr/Rd approach. Consideration could also be given to the installation of LED stop signs which have a series of LED lights designed to flash, making the sign more conspicuous for approaching drivers. Figure 17 shows an example of an LED stop sign located nearby.

³ <u>http://www.cmfclearinghouse.org/detail.cfm?facid=215</u> (No current collision modification factors apply directly to the unique scenario presented by this location. The referenced CMF provides a reference point for consideration.)



Figure 17 - Local LED Stop Sign Example - Northbound Northwest Dr & Slater Rd

Treatment	Collision Modification / Reduction Factor	Approx. Cost Range
Double Mounted Stop Signs	Unavailable	\$
Retroreflective Sign Post Strips	Unavailable	\$
Flashing Beacons ⁴	<i>0.84 Modification / 16% Reduction in Angle Collisions of All Severities</i>	\$\$
LED Stop Signs ⁵	0.59 Modification / 41.1% Reduction in Angle Collisions of All Severities	\$\$

Restripe Primary Route, Add Chicken Tracks / Guidance Markings

While a long-term countermeasure is already programmed, there are several short-term, low-cost suggestions which might help to improve operations at this location in the meantime. One recommendation is the restriping of the center and edge lines along the main route (Marine Dr to Lummi Shore Rd) to help reduce confusion. Alternatively, the installation of chicken tracks / guidance markings could provide additional guidance for drivers navigating through the intersections. Figure 18 provides an example of these treatments.

⁴ <u>http://www.cmfclearinghouse.org/detail.cfm?facid=450</u>

⁵ <u>http://www.cmfclearinghouse.org/detail.cfm?facid=4074</u>


Figure 18 - Example of Chicken Tracks / Guidance Pavement Markings

Treatment	Collision Modification / Reduction Factor	Approx. Cost Range
Restripe Primary Route Pavement Markings ⁶	0.81 Modification / 19% Reduction in Run off Road Serious and Minor Injury Collisions	\$
Chicken Tracks / Guidance Markings	Unavailable	\$

⁶ <u>http://www.cmfclearinghouse.org/detail.cfm?facid=91</u>

Install Route Guidance Signs

An additional short-term, low-cost recommendation is the installation of guidance signs on approaches to the area. These would provide drivers with information regarding the correct direction of travel through the series of intersections, potentially reducing confusion and hesitation. Figure 19 provides a typical guidance sign as well as an example of what such a sign might look like on one of the approaches.



Figure 19 - Mock Guidance Sign – Westbound Approach

Treatment	Collision Modification / Reduction Factor	Approx. Cost Range
Route Guidance Signs	Unavailable	\$

Collision Reduction Analysis

Highway Safety Manual Analysis

Based on the existing geometry, traffic volumes, and the results of the HSM analysis, this cluster of intersections is expected to experience approximately three collisions annually. Based on the historic reported collisions at this location, the intersection has only experienced an annual average of 1.2 collisions per year, meaning this location is currently performing better than would be expected. This may reflect the local knowledge of the drivers, who understand the complexity of the intersection and adjust their driving behavior accordingly. It remains a significant priority for collisions and the potential for severe collisions, however, and Table 4 summarizes the estimated impacts of the recommendations listed previously. It must be noted that those recommendations lacking collision modification factors (CMF) or those which do not apply to all collision types of all severities cannot be tested in the analysis and have been omitted.

Table 4 - HSM Analysis

Condition	Observed Average Collision Frequency (collisions / year)	Expected Annual Collision Frequency (collisions / year)	Estimated Reduction in Expected Collisions (collisions / year)	High Level Cost Estimate	Estimated Benefit Cost Ratio
Existing	1.2	2.95	N / A	N/A	N/A
Convert to Roundabout	N / A	2.18	0.77	\$1M	1

Observed Crash Analysis

Table 5 provides estimated collision reductions for this location based on historic collision data. This is due to the more specific nature of the CMFs available for these treatments.

10010 0 00001 1	od oomoron nangon	0			
Condition	Observed Average Collision Frequency (collisions / year)	Applicable Collision Frequency (collisions / year)	Estimated Reduction in Collisions (collisions / year)	High Level Cost Estimate	Estimated Benefit Cost Ratio
Existing	1.2	N / A	N / A	N / A	N / A
Flashing Beacon	N / A	0.6	0.1	\$3,600	8.75
LED Stop Signs	N / A	0.6	0.25	\$4,500	25.0
Restripe Primary Route	N / A	0.6	0.11	\$3,500	2.7

Table 5 - Observed Collision Analysis

Safety Concern #2: Pedestrian / Bike Facilities

Significant levels of pedestrian and bicycle activity were observed throughout the Reservation. While there are some areas with robust non-motorized facilities to service these road users, even with the construction of additional facilities underway there is still a significant portion of the Reservation where none are available. Unfortunately, these areas lacking facilities tend to also lack shoulders, have poor clear zones, and have roads with narrow lane widths. This raises the potential for serious or fatal interactions between motor vehicles and non-motorized road users. Thanks, in part, to the existing and ongoing work to improve the availability of non-motorized facilities in the Reservation there have been only four pedestrian or bicyclist involved collisions within the last five years. However, the potential remains for a serious collision to occur. While pedestrian and bicyclist involved collisions are typically relatively rare, when they do occur, there is a significant chance that they would result in a serious injury or fatality. Figure 20 shows several instances of pedestrians and bicyclists on the Reservation in areas without adequate non-motorized facilities. It should be noted that, as previously mentioned, the Tribe has already taken significant steps to provide excellent facilities in areas around the Reservation.





Figure 20 - Vulnerable Road Users

Figure 21 provides the location and severity of all reported pedestrian and bicyclist involved collisions during the study period.



Figure 21 - Pedestrian and Bicyclist Involved Collisions (2012-2016)

Expected Collision Types:	Pedestrian Involved, Bicyclist Involved
Expected Frequency:	Occasional / Frequent
Expected Severity:	High
Risk Rating:	E/F

Suggestions

Continue Sidewalk / Multi-Use Trail Development

As mentioned previously, the Tribe already has a series of well-developed non-motorized facilities throughout the Reservation. It is recommended that a review of candidate locations continue and be developed as funding becomes available. This will help to build out the non-motorized network over time, improving pedestrian and bicyclist safety. A pedestrian/bicycle needs study (including specific ped/bike counts, surveys of potential users, etc.) may help identify the locations most desirous of enhancements. Observations made during the Road Safety Audit included Lummi Shore Rd and Smokehouse Road, though other locations are likely candidates.

This process could also include the development of sidewalk and trail maps made available online and as hardcopies at various locations throughout the Reservation. This would help to encourage non-motorized traffic in areas where facility improvements have been implemented and may serve to entice additional visitors to those areas.

Treatment	Collision Modification / Reduction Factor	Approx. Cost Range
Continued Sidewalk / Multi-Use Trail Development	Unavailable	\$\$
Development & Distribution of Trail Maps & Information	Unavailable	\$

Widen shoulder where sidewalk is not feasible

In those areas where construction of a sidewalk or other multi-use trail is not feasible, consideration should be given to the development and / or widening of paved shoulders along the roadside. While a physically separated sidewalk is generally the preferred approach, various real-world constraints may not allow for this. In such cases, a wider paved shoulder would provide pedestrians and bicyclist some additional space to move them out of the travel lanes.

The shoulders serve the additional function of providing some recovery area for any errant motorists.

Treatment	Collision Modification / Reduction Factor	Approx. Cost Range
Pave Gravel Shoulder (Convert No Shoulder to 5+ ft Paved) ⁷	0.58 Modification / 42% Reduction in All Collisions of All Severities	\$\$
Widen Paved Shoulder (3 to 6ft) ⁸	0.82 Modification / 18% Reduction in All Collisions of All Severities	\$\$

Mark Existing Bike Lanes

Some bike lanes were observed in the Reservation; examples include Kwina Rd and Lummi View Dr near the Ferry Terminal. Bike lane pavement markings could be added as it is only assumed that the paved area between the edgline and sidewalk is dedicated to bicycles. These would help alert drivers to the potential for bicycle traffic in the roadway and reinforce the correct area of the road being made available to bicyclists. Figure 22 shows an example of this type pavement marking taken in Bellingham, WA.



Figure 22 - Bike Lane Pavement Marking - Bellingham, WA

⁷ <u>http://www.cmfclearinghouse.org/detail.cfm?facid=5409</u>

⁸ <u>http://www.cmfclearinghouse.org/detail.cfm?facid=5281</u>

Treatment	Collision Modification / Reduction Factor	Approx. Cost Range
Install Bike Lanes ⁹	0.94 Modification / 5.6% Reduction in All Collisions of All Severities in Urban Areas	\$

Collision Reduction Analysis

Highway Safety Manual Analysis

Based on existing geometry, traffic volumes, and the results of the HSM analysis, segment portions of the Reservation network are expected to experience approximately 29 collisions per year. Based on the historic reported collisions at this location, the intersection has only experienced an annual average of 25 collisions per year, meaning this location is currently performing slightly better than would be expected. It remains a priority for collisions and the potential for severe collisions, however, and Table 6 summarizes the estimated impacts of the recommendations listed previously. It must be noted that those recommendations lacking collision modification factors (CMF) or those which do not apply to all collision types of all severities cannot be tested in the analysis and have been omitted.

Condition	Observed Average Collision Frequency (collisions / year)	Expected Annual Collision Frequency (collisions / year)	Estimated Reduction in Expected Collisions (collisions / year)	High Level Cost Estimate	Estimated Benefit Cost Ratio
Existing	24.6	29.14	N / A	N/A	N/A
Pave Gravel Shoulders ¹⁰	N / A	27.86	1.28	\$1.7M	0.34
Widen Existing Paved Shoulders	N / A	29.01	0.13	\$50,000	1.19

Table 6 - HSM Analysis

⁹ <u>http://www.cmfclearinghouse.org/detail.cfm?facid=4656</u>

¹⁰ This includes roads where shoulder paving would be feasible based on existing geometry. It does not take right-of-way / easement availability into account. Effectively, it includes all roads in the HSM analysis except those roads in heavily populated residential areas or where sidewalk facilities, shoulders, or other physical constrictions exist along the roadside.

Safety Concern #3: Turning Movements at Haxton Way & Slater Rd

The intersection of Haxton Way and Slater Rd serves a significant amount of traffic as it is one of the **main entry points to the Reservation. The Tribe's Casino and Gas Station / Mini Mart are located in** the southeast quadrant of the intersection and both intersecting roads serves as primary routes. This location experienced seventeen intersection related collisions from 2011 through 2016, one of which was a fatality, with two additional collisions resulting in severe injuries. The intersection is a standard four-way, signalized intersection with no significant skew. The traffic signals are mounted in a box span configuration on mast arms which help to ensure they are centered over the correct lane and **placed more directly in the driver's line of site.** Figure 23 **provides the driver's perspective of several** approaches to the intersection.





Figure 23 - Haxton Way & Slater Rd Approaches (Westbound - Left, Eastbound - Right, Northbound - Bottom)

The collision diagram for this location is provided in Figure 24, and shows the lane use for each approach. As shown in the diagram, the majority of collisions at this location consist of left-turn headon collisions along Slater Rd. Operations were reviewed at the intersection but no significant issues were observed with the traffic signal timing which would suggest any contributing factors related to the collision pattern.



Figure 24 - Haxton Way & Slater Rd Collision Diagram

Additional concerns were raised regarding the placement and pavement marking layout for the northbound right turn lane. This portion of the facility services the casino, the gas station, and finally the intersection itself. The current pavement marking layout technically restrict those points where drivers are permitted to enter the turn lane. It was noted that there is confusion among drivers regarding when to turn into the lane depending on which turn they ultimately intended to take. This has resulted in several near misses and was raised as a concern during the kick-off and subsequent meetings. Figure 25 provides a view of this approach.



Figure 25 - Northbound Haxton Way Right Turn Lane

Expected Collision Types:	Left Turn Head On, Angle, Rear End, Sideswipe-Same
Expected Frequency:	Occasional / Frequent
Expected Severity:	Medium
Risk Rating:	D/E

Suggestions

Roundabout

_

Given the significant portion of angle and left turn head on collisions at this location, there may be cause to convert the signalized intersection to a roundabout. This would virtually eliminate the potential for these types of collisions and help regulate speeds in the area. Typically, roundabouts experience an increase in the number of property damage only crashes along with a significant reduction in fatal and injury crashes.

Treatment	Collision Modification / Reduction Factor	Approx. Cost Range
Convert Signalized Intersection to	0.52 Modification / 48% Reduction in	\$\$\$+
	All Collisions of All Severities	

¹¹ <u>http://www.cmfclearinghouse.org/detail.cfm?facid=225</u>

Protected Westbound Left Turn Movement

Given the significant portion of westbound left turn head on collisions at the intersection, there may be cause to implement a protected westbound-to-southbound left-turn movement. This would provide drivers making the left turn from Slater Rd onto southbound Haxton Way a dedicated period of time to complete the maneuver while no conflicting traffic is present. This should reduce the potential for left-turn head-on collisions at the intersection, which represent both the greatest number of historic collisions here as well as the most severe.

To mitigate any negative impacts this might have on the level of service of the intersection, a right turn only signal could be added to the northbound Haxton Way approach to allow right turn movements while the protected westbound left turn phase is in effect.

Treatment	Collision Modification / Reduction Factor	Approx. Cost Range
Protected Left Turn Movement ¹²	0.78 Modification / 22% Reduction in All Serious and Minor Injury Collisions	\$\$

Dilemma zone monitoring

Dilemma zone monitoring utilizes Intelligent Transportation Systems (ITS) technology to monitor the presence, speed, and position of approaching vehicles to the intersection. If a vehicle is approaching **the intersection and is expected to reach it within the "dilemma zone" (period of time** during the yellow light where a driver may not have enough time to come to a complete stop) the system can safely adjust the signal timing accordingly. There are different approaches to exactly how this is accomplished, but has been shown to help reduce collisions at intersections. This would be expected to help reduce the potential for left turn head on collisions at the intersection.

Treatment	Collision Modification / Reduction Factor	Approx. Cost Range
Dilemma Zone Detection / Monitoring ¹³	0.92 Modification / 8.2% Reduction in All Collisions of All Severities	\$\$

Speed Feedback Sign for Eastbound Approaching Traffic

The Tribe and County have made extensive use of speed feedback signs and trailers throughout the Reservation. Discussion suggests these have had a positive effect on driver behavior. Consideration should be given to the installation of one such sign along the eastbound Slater Rd approach to the intersection. This would alert drivers of the presence of an upcoming intersection and help remind

¹² <u>http://www.cmfclearinghouse.org/detail.cfm?facid=6399</u>

¹³ <u>http://www.cmfclearinghouse.org/detail.cfm?facid=4857</u>

them of the speed limit and their current travel speed. This may be helpful as the long, straight stretch of Slater Rd approaching the intersection is more conducive to speeding when coming out of the hillier areas to the west.

Treatment	Collision Modification / Reduction Factor	Approx. Cost Range
Speed Feedback Sign ¹⁴	0.95 Modification / 5% Reduction in All Collisions of All Severities	\$

Revise Northbound Right Turn Pavement Markings and Signs

The current right turn lane pavement markings may be causing some confusion for drivers heading northbound on Haxton Way. This is due, in part, to the right turn only pavement markings present along the full length of the turn lane, which may conflict with actual maneuvers when drivers enter the turn lane at the southern end but travel the full length and turn right at Slater Rd instead of one of the earlier driveways. Consideration should be given to restriping the pavement markings on this approach to further clarify admissible maneuvers. This could include revising the right turn pavement markings leading up to the driveways and the intersection with Slater Rd, as well as replacing the solid white pavement marking separating the earlier portions of the right turn lane with dashed markings. This would let drivers know to watch for lane changing maneuvers further along the right turn lane. Figure 27 shows the current lane and pavement marking configuration for the northbound approach along Haxton Way as well as potential changes.

Adding Lane Use signing (such as R3-8 series signs from the Manual on Uniform Traffic Control Devices) or the example shown in Figure 26 may also help better inform drivers.



Figure 26 - Potential Sign Configuration (R3-7 Right with W16-8P Plaque)

¹⁴ <u>http://www.cmfclearinghouse.org/detail.cfm?facid=6885</u>



45

H-U0630.00 | August 2017

Opus International Consultants Inc. Gibson Traffic Consultants, Inc.

Treatment	Collision Modification / Reduction Factor	Approx. Cost Range
Revise Right Turn Pavement Markings	Unavailable	\$

Right-in / Right-out Only Driveway

Conversion of the northernmost driveway to right-in / right-out only through the use of a traffic control order, signing, and / or an entry island would limit the number of potentially conflicting turning movements close to the intersection. A mountable curb has already been installed in the median in this area with the intent of discouraging left turn movements into and out of this driveway. Flexible posts could be added to the existing installation to further discourage these types of movements.

Treatment	Collision Modification / Reduction Factor	Approx. Cost Range
Left Turn Restrictions at Driveway	Unavailable	\$

Install Driveway Guidance Signs

In addition to restriping the right turn lane pavement markings, or as a standalone treatment, consideration should be given to installing driveway / right turn guidance signs along the right turn lane. These would consist of guidance signs to provide drivers with information regarding which driveway to use depending on the facility they intend to access. These would be relatively low cost and may help to reduce driver confusion.

Treatment	Collision Modification / Reduction Factor	Approx. Cost Range
Advanced Warning Signs ¹⁵	0.65 Modification / 35% Reduction ¹⁶ in	\$
5 5	Angle Collisions of All Severities	

¹⁵ <u>http://www.cmfclearinghouse.org/detail.cfm?facid=1684</u>

¹⁶ This CMF has been rated at two stars which represents a lower rating regarding study methodology.

Collision Reduction Analysis

Highway Safety Manual Analysis

Based on the existing geometry, traffic volumes, and the results of the HSM analysis, the intersection of Slater Rd and Haxton Way is expected to experience approximately 3.93 collisions annually. Based on the historic reported collisions at this location, the intersection has only experienced an annual average of 3.4 collisions per year, meaning this location is currently performing better than would be expected. Table 7 summarizes the estimated impacts of the recommendations listed previously. It must be noted that those recommendations lacking collision modification factors (CMF) or those which do not apply to all collision types of all severities cannot be tested in the analysis and have been omitted.

1 abic 7 - 1 15101 Analysis					
Condition	Observed Average Collision Frequency (collisions / year)	Expected Annual Collision Frequency (collisions / year)	Estimated Reduction in Expected Collisions (collisions / year)	High Level Cost Estimate	Estimated Benefit Cost Ratio
Existing	3.4	3.93	N / A	N / A	N / A
Convert to Roundabout	N / A	2.41	1.52	\$1.25M	0.82
Dilemma Zone Detection Monitoring	N / A	3.71	0.22	\$60,000	1.65
Speed Feedback Sign	N / A	3.79	0.14	\$10,000	4.41

Table 7 - HSM Analysis

Observed Crash Analysis

Table 8 provide estimated collision reductions for this location based on historic collision data. This is due to the more specific nature of the CMFs available for these treatments.

	i Comsion Anarys	13			
Condition	Observed Average Collision Frequency (collisions / year)	Applicable Collision Frequency (collisions / year)	Estimated Reduction in Collisions (collisions / year)	High Level Cost Estimate	Estimated Benefit Cost Ratio
Existing	3.4	N / A	N / A	N / A	N / A
Protected Left Turn Movement	N / A	1	0.22	\$10,000	9.46
Advanced Warning Signs	N / A	0.8	0.28	\$2,000	44.09

Table 8 - Observed Collision Analysis

Safety Concern #4: Narrow Lanes / No Shoulders

Most of the roadways throughout the Reservation were noted as having relatively narrow lane widths and / or no or limited shoulder area. These issues increase the potential for sideswipe-opposite direction collisions as well as run off road collisions. These issues may be compounded along hilly or curve segments of roadway where the driver is taxed more significantly in the guidance and navigation tasks associated with driving. Figure 28 provides some example locations where narrow lanes and / or shoulders were observed, along with any measured lane widths.



Figure 28 - Example Lane Widths (Mackenzie Rd, Top, and Chief Martin Rd, Bottom)

Expected Collision Types:	Sideswipe-Opposite, Run off Road, Head On
Expected Frequency:	Frequent
Expected Severity:	Low / Medium
Risk Rating:	D / E

Suggestions

Review Network for Opportunities to Widen Lanes and / or Shoulders

A review of the road network should be conducted to identify potential locations for lane and / or shoulder widening activities in the future. This would be impacted or guided by several consideration and restraints, including:

- Historic run off road collision locations
- Availability of existing right of way
- Feasibility of obtaining easements where right of way does not currently exist
- Presence of physical or environmental obstructions (existing buildings / structures, wetlands / protected areas, etc.)

Areas where these align (i.e. high collision location where right of way is available or easements are feasible that are not obstructed by structures or sensitive environmental areas) may be good candidate locations of the widening of travel lanes or the addition of paved shoulders. These have been shown to help reduce the potential for sideswipe-opposite, head on, and run off road collisions. Figure 29 provides the location and severity of typical run off road collisions (fixed object, overturn, etc.) which were reported on the Reservation during the study period. Roadways with narrow or no shoulder have been highlighted in the figure where existing geometric restrictions do not already preclude the addition of paved shoulders, providing locations for potential improvements.



Figure 29 - Run off Road Collisions & Potential Paved Shoulder Locations

Treatment	Collision Modification / Reduction Factor	Approx. Cost Range
Widen Narrow Pavement ¹⁷	0.69 Modification / 31.5% Reduction in All Collisions of All Severities	\$\$\$
Pave Gravel Shoulder (Convert No Shoulder to 5+ ft. Paved) ¹⁸	0.58 Modification / 42% Reduction in All Collisions of All Severities	\$\$

Collision Reduction Analysis

Highway Safety Manual Analysis

Based on the existing geometry, traffic volumes, and the results of the HSM analysis, the segments highlighted in Figure 29 are expected to collectively experience approximately 2.42 collisions annually. Based on the historic reported collisions at this location, the intersection has only experienced an annual average of 2.2 collisions per year, meaning this location is currently performing better than would be expected. Table 9 summarizes the estimated impacts of the recommendations listed previously. It must be noted that those recommendations lacking collision modification factors (CMF) or those which do not apply to all collision types of all severities cannot be tested in the analysis and have been omitted.

Table 9 - HSI	VEALIALYSIS				
Condition	Observed Average Collision Frequency (collisions / year)	Expected Annual Collision Frequency (collisions / year)	Estimated Reduction in Expected Collisions (collisions / year)	High Level Cost Estimate	Estimated Benefit Cost Ratio
Existing	2.2	2.42	N / A	N / A	N / A
Widen Narrow Pavement	N / A	2.2	0.22	\$50,000	2.01
Pave Gravel Shoulder	N / A	2.15	0.27	\$1.7M	0.07

Table 9 - HSM Analysis

¹⁷ <u>http://www.cmfclearinghouse.org/detail.cfm?facid=6862</u>

¹⁸ <u>http://www.cmfclearinghouse.org/detail.cfm?facid=5409</u>

Safety Concern #5: Unmarked Curves

Given the hilly and sometimes winding nature of portions of the road network, several curves were identified within the Reservation. Many of the curves observed during the field review did not have advanced curve warning signs or chevrons and other delineation through the curve itself. These locations may have an increased risk for run off the road collisions, sideswipe-opposite, or head on collisions. This may be especially true during the summer months with increased numbers of tourists and visitors who may not be as familiar with the local area. Figure 30 provides examples of unmarked curves identified within the Reservation.



Lead into Curve



S Red River Rd Blind Curve Figure 30 - Unmarked Curve Examples

Figure 31 provides the location and severity of all collisions reported as occurring on curved segments of roadway during the five-year study period. It should be noted that the collisions occurring at Kwina Rd and Haxton Way would be considered collisions occurring at a roundabout.



Figure 31 - Curved Road Segment Collisions

As shown in the preceding figure, the curves at the Kwina triangle, along N and S Red River Rd, along Lummi Shore Rd between Cagey Rd and Scott Rd, and at the western end of Slater Rd as it turns into Beach Way are locations lacking curve warning signage with a reported crash history. These locations serve as example, but a systemic treatment approach could be used to apply the following recommendations based on the geometric characteristics of locations across the Reservation as funding is made available.

Expected Collision Types:	Sideswipe-opposite, Run off Road, Head On
Expected Frequency:	Occasional / Frequent
Expected Severity:	Medium
Risk Rating:	D/E

Suggestions

Signing

Several warning signs exist which are designed to warn drivers of upcoming changes in roadway geometry. These include curve warning signs and advisory speed warning signs in advance of curves. The type of sign typically depends on several factors, some of which include the approach speed limit and the severity of the curve itself. Figure 32 provides a series of example curve warning and advisory signs.



Figure 32 - Typical Curve Warning Signs (Source: FHWA MUTCD)

Additional chevron signs and target arrow signs could be installed along the curve itself to help highlight the roadway geometry. These could be supplemented with retroreflective strips along the sign posts, LED lights, or other beacons depending on the severity of the curve. Figure 33 provides an example of some existing curve treatments **along Lummi's roads**.





Figure 33 - Lummi View Dr Signed Curve

Treatment	Collision Modification / Reduction Factor	Approx. Cost Range
Install Chevrons and Curve Warning Signs ¹⁹	0.69 Modification / 30.6% Reduction in All Collisions of All Severities	\$ - \$\$

¹⁹ <u>http://www.cmfclearinghouse.org/detail.cfm?facid=1909</u>

Delineators

Supplemental curve treatments include the installation of roadside delineators. These could take the form of in pavement retroreflective markers, post mounted markers, markers installed on utility poles. These reflective markers help to highlight the curvature of the road and guide the driver through the turn. Figure 34 and Figure 35 provide some example treatment installations.



Figure 34 - Raised Pavement Reflectors (Source: FHWA)



Figure 35 - Utility Pole Mounted Delineator (Source: AASHTO)

A good candidate location for this is along Lummi Shore Rd from Lummi View Dr up to Haxton Way and along both N and S Red River Rds. These routes are generally darker at night, curvy, and have a crash history along their lengths.

Treatment	Collision Modification / Reduction Factor	Approx. Cost Range
Raised Pavement Markers ²⁰	0.87 Modification / 13% Reduction in All Collisions of All Severities	\$

²⁰ <u>http://www.cmfclearinghouse.org/detail.cfm?facid=5498</u>

Increase Clear Zone on the Inside of Curves

Where feasible, consideration should be given to clearing the inside of sharper curves, in some cases further in than the minimum required. This would help to improve sight distance through the inside of the curve, increasing the distance drivers have to view oncoming traffic. This can be accomplished with existing equipment at minimal cost. While there is already some level of clearing and vegetation management underway, additional clearing could be performed up to the utility poles or other obstructions. This could be particularly beneficial along N and S Red River Rds as well as portions of Lummi Shore Rd from Cagey Rd to Marine Dr.

This could be accomplished, in part, through the use of an extendable arm mower allowing maintenance staff to reach farther into the clear zone from the stable roadway. Figure 36 provides an example of one such tool. Various configurations of equipment (including standalone or hydraulic attachments for existing equipment) exist, but local dealers should be investigated for compatibility wi**th Lummi's existing equipment**.



Figure 36 - Example Boom Mower Attachment

Treatment	Collision Modification / Reduction Factor	Approx. Cost Range
Increase Clear Zone Distance	Unavailable	\$ - \$\$
Flatten Side Slope (1V:3H to 1V:4H) ²¹	0.82 Modification / 18% Reduction in Run off Road Collisions of All Severities	\$\$
Remove or Relocate Fixed Objects Out of the Clear Zone ²²	0.62 Modification / 38% Reduction in All Collisions of All Severities	\$ - \$\$

²¹ <u>http://www.cmfclearinghouse.org/detail.cfm?facid=28</u>

²² <u>http://www.cmfclearinghouse.org/detail.cfm?facid=1024</u>

Collision Reduction Analysis

Highway Safety Manual Analysis

Based on the existing geometry, traffic volumes, and the results of the HSM analysis, the segments of N Red River Rd, S Red River Rd, and Lummi Shore Rd were expected to experience approximately 7.88 collisions annually. Based on the historic reported collisions at this location, the intersection has only experienced an annual average of 7.8 collisions per year, meaning this location is currently performing roughly as expected. It remains a priority with the potential for severe collisions, however, and Table 10 summarizes the estimated impacts of the recommendations listed previously. It must be noted that those recommendations lacking collision modification factors (CMF) or those which do not apply to all collision types of all severities cannot be tested in the analysis and have been omitted.

Table TO - I ISIVI Analysis					
Condition	Observed Average Collision Frequency (collisions / year)	Expected Annual Collision Frequency (collisions / year)	Estimated Reduction in Expected Collisions (collisions / year)	High Level Cost Estimate	Estimated Benefit Cost Ratio
Existing	7.80	7.88	N / A	N / A	N / A
Improve Clearzone Distance	N / A	7.05	0.83	\$40,000	9.3
Raised Pavement Markers	N / A	7.04	0.84	\$138,000	1.37
Install Chevrons and Curve Warning Signs	N / A	5.80	2.08	\$9,600	68.23

Table 10 HSM Analysis

Observed Crash Analysis

Table 11 provide estimated collision reductions for this location based on historic collision data. This is due to the more specific nature of the CMFs available for these treatments.

Table 11 - Observed Collision Analysis

Condition	Observed Average Collision Frequency (collisions / year)	Applicable Collision Frequency (collisions / year)	Estimated Reduction in Collisions (collisions / year)	High Level Cost Estimate	Estimated Benefit Cost Ratio
Existing	7.80	N/A	N / A	N/A	N / A
Flatten Side Slopes (1V:3H to 1V:4H)	N / A	2.6	0.47	\$15,000 - \$100,000	28.19 – 4.23
Remove or Relocate Fixed Object	N / A	2.2	0.84	\$5,000 - \$30,000	151.16 – 25.19

Safety Concern #6: Clear Vision at Intersections

Concerns around sight distance at intersections within the Reservation were raised in the RFP and during the kick-off meeting. Visibility was considered during the field review, and several intersections were identified where limited sight distance may be a concern. The restricted visibility at these locations requires drivers to pull forward more often in order to look for any cross traffic, exposing them to potential collisions. These incidents have the potential to result in more severe injuries as collisions of this nature tend to result in angle or left turn head on collisions. Figure 37 provides an example of an intersection identified as having limit sight distance.



Figure 37 - Cagey Rd & Chief Martin Rd – Left, Haxton Way & Cagey Rd Intersection Sight Distance

Expected Collision Types:	Angle, Left Turn Head On
Expected Frequency:	Occasional / Frequent
Expected Severity:	Low / High
Risk Rating:	D

Suggestions

Increase Clear Zones to Improve Sight Distance

Similar to the increased clearing of zones along the inside of sharp curves, some locations may benefit from increased clear zone maintenance at intersections. This reduces obstructions and provides the driver with additional visibility when approaching an intersection and scanning for oncoming or cross traffic. Per the Washington State DOT Design Manual:

The setback distance for the sight triangle is 18 feet from the edge of traveled way. This is for a vehicle stopped 10 feet from the edge of traveled way. The driver is almost always 8 feet or less from the front of the vehicle; therefore, 8 feet are added to the setback. When the stop bar is placed more than 10 feet from the edge of traveled way, providing the sight triangle to a point 8 feet back of the stop bar is desirable.

Chapter 1310.05 Intersection Sight Distance²³

Additionally, Figure 38 provides the design stopping sight distance from the WSDOT Deign Manual. The exhibit provides the required stopping sight distance in feet for several design speeds.

Design Speed (mph)	Design Stopping Sight Distance (ft)	Kc	Ks	VCL _m (ft)
25	155	12	2 <u>6</u>	75
30	200	19	3 <u>7</u>	90
35	250	29	49	105
40	305	44	6 <u>4</u>	120
45	360	61	7 <u>9</u>	135
50	425	84	96	150
55	495	114	115	165
60	570	151	136	180
65	645	193	157	195
70	730	247	18 <u>1</u>	210
75	820	312	206	225
80	910	384	231	240

Figure 38 - Design Stopping Sigh Distance (WSDOT Design Manual)

²³ <u>http://www.wsdot.wa.gov/publications/manuals/fulltext/M22-01/1310.pdf</u>

Treatment	Collision Modification / Reduction Factor	Approx. Cost Range
Increase Clear Zone Distance	Unavailable	\$ - \$\$
Remove or Relocate Fixed Objects Out of the Clear Zone ²⁴	0.62 Modification / 38% Reduction in All Collisions of All Severities	\$ - \$\$

Review Crosswalk, Stop Bar, and Stop / Yield Sign Placement

The layout of signs and pavement markings should be reviewed at intersections with known sight distance issues. Relatively minor changes in pavement marking and sign placement may help to position drivers more safely when approaching the intersection and looking for conflicting traffic flows. This is especially true for the intersection of Haxton Way and Lummi Shore Dr. Northbound traffic on Haxton Way turning right onto Lummi Shore are unable to see the stop sign until the last second. Other candidate locations include the intersections comprising the Kwina Triangle, Slater Rd and Ferndale Rd, and the intersections of North and South Red River Rd with Haxton Way. These locations all have restricted sight distance. Additional measures could include the installation of secondary stop signs, increasing the conspicuity of the intersection. Figure 39 **illustrates this concern from the driver's perspective.**

⁶¹

²⁴ <u>http://www.cmfclearinghouse.org/detail.cfm?facid=1024</u>



Figure 39 - Northbound approach to Haxton Way & Lummi Shore Dr

Treatment	Collision Modification / Reduction Factor	Approx. Cost Range
Double Mounted Stop Signs	Unavailable	\$
Retroreflective Sign Post Strips	Unavailable	\$
Flashing Beacons ²⁵	0.84 Modification / 16% Reduction in Angle Collisions of All Severities	\$\$
LED Stop Signs ²⁶	0.59 Modification / 41.1% Reduction in Angle Collisions of All Severities	\$\$

Collision Reduction Analysis

Highway Safety Manual Analysis

Based on the existing geometry, traffic volumes, and the results of the HSM analysis, the intersections of Haxton Way and Lummi Shore Dr, Haxton Way and both N and S Red River Rds, Slater Rd and Ferndale Rd, and the Kwina Triangle were expected to experience approximately 6.62 collisions annually. Based on the historic reported collisions at this location, the intersection has only experienced an annual average of 3.6 collisions per year, meaning these locations are collectively performing better than expected. It remains a priority with the potential for severe collisions, however, and Table 12 summarizes the estimated impacts of the recommendations listed previously, based on historic reported collisions.

Table 12 - Observed Collision Analysis

Condition	Observed Average Collision Frequency (collisions / year)	Applicable Collision Frequency (collisions / year)	Estimated Reduction in Collisions (collisions / year)	High Level Cost Estimate	Estimated Benefit Cost Ratio
Existing	7.80	N / A	N / A	N / A	N / A
Remove or Relocate Fixed Object	N / A	0.4	0.15	\$5,000 - \$30,000	27.0 - 4.5
Flashing Beacons	N / A	0.8	0.13	\$9,000	6.5
LED Stop Signs	N / A	0.8	0.33	\$7,000	1.6

²⁵ <u>http://www.cmfclearinghouse.org/detail.cfm?facid=450</u>

²⁶ <u>http://www.cmfclearinghouse.org/detail.cfm?facid=4074</u>

Safety Concern #7: Speeding

Speeding drivers were raised as a general concern during the kick-off meeting. These concerns included drivers along stretches of roads with existing higher speeds limits as well as along residential streets. When traveling at high speeds, especially in congested areas or those with the potential for pedestrian and bicycle traffic, drivers have less time to react to changing road conditions. Higher speeds have also been associated with increases in collision severity. Figure 40 shows the general trend between increased travel speeds and collision severity.



Figure 40 - Pedestrian Impact Curve (Top) and Vehicle Severity Curves (Bottom) (Source: Dept. for Transport - London²⁷)

²⁷ https://nacto.org/docs/usdg/relationship_between_speed_risk_fatal_injury_pedestrians_and_car_occupants_richards.pdf

E× Ty	pected Collision	All
Ex	pected Frequency:	Frequent
Ex	pected Severity:	Low
Ri	sk Rating:	D

Figure 41 shows areas of the Reservation where speeding is occurring on a regular basis. This map is not exhausted, as it depends on locations where recent speed studies have been completed, as noted in the accompanying legend. Those locations where the average observed speed is significantly higher than the posted speed limit may benefit from the following recommendations.


Figure 41 - Average Observed Speed Above Posted Speed Limit (Segments with speed feedback sign noted, not exact locations)

Install Additional Speed Feedback Signs

The Tribe and County have already installed and operate several speed feedback signs throughout the Reservation and have noted some positive impacts on driver behavior. A review of any reported near misses and the locations of speeding citations should be reviewed. This may assist the Tribe and the County in identifying potential additional locations for the deployment of speed feedback signs and / or trailers. These signs remind the driver of the legal speed limit, alert them to their actual travel speed, and may also be used to collect additional traffic volume information which may be used to help guide future planning and safety studies. Potential candidate locations include Slater Rd and the segment of Lummi View Dr between both ends of MacKenzie Rd.

Treatment	Collision Modification / Reduction Factor	Approx. Cost Range
Speed Feedback Sign ²⁸	0.95 Modification / 5% Reduction in All Collisions of All Severities	\$

Consider Traffic Calming Measures in Residential Areas

A number of traffic calming measures exist which may help reduce the number and speed of vehicles traveling through residential areas. Different treatments are designed to address different issues, and should be reviewed to identify local needs and potential candidate locations. Table 13 provides a high-level summary of some typical traffic calming measures and the aspects of driver behavior they are intended to address. It should be noted that the following is not an exhaustive list and is only intended to provide a series of example measures.

Table 13 - Traffic Calming Examples



²⁸ <u>http://www.cmfclearinghouse.org/detail.cfm?facid=6885</u>



Optical Speed Bars

68

Collision Reduction Analysis

Highway Safety Manual Analysis

Based on the existing geometry, traffic volumes, and the results of the HSM analysis, the segments of Slater Rd and Lummi View Dr between both ends of MacKenzie Dr were expected to collectively experience approximately 7.04 collisions annually. Based on the historic reported collisions at these locations, the segments experienced an annual average of 8.2 collisions per year, meaning these locations are currently performing worse than expected. This is especially true for Slater Rd. Table 14 summarizes the estimated impacts of the recommendations listed previously. It must be noted that those recommendations lacking collision modification factors (CMF) or those which do not apply to all collision types of all severities cannot be tested in the analysis and have been omitted.

Table 14 - HSM Analysis					
Condition	Observed Average Collision Frequency (collisions / year)	Expected Annual Collision Frequency (collisions / year)	Estimated Reduction in Expected Collisions (collisions / year)	High Level Cost Estimate	Estimated Benefit Cost Ratio
Existing	8.2	7.04	N/A	N/A	N/A
Speed Feedback Signs	N / A	6.8	0.24	\$20,000	3.78

Safety Concern #8: Skewed Intersection & Hidden Stop Signs

Several intersections within the Reservation have significant skews. This restricts sight distance and makes it more difficult for physically impaired drivers to turn to look for traffic. Heavily skewed intersections also slow turning speeds and may force larger vehicles to turn into oncoming traffic lanes to complete the maneuver. The intersections of Haxton Way with both S and N Red River Rd as well as Haxton Way and Lummi Shore Dr were identified as intersections with significant skew angles. Other locations with significant skews or restricted sight distance exist at Slater Rd & S Red River Rd, **Smokehouse Rd & Lummi Shore, and locations around the "Kwina Triangle".** Figure 42 provides a series of images showing the driver's perspective at these locations.



Figure 42 - Significantly Skewed Intersections (Haxton Way & Red River Rds - Top Left, Haxton Way & Lummi Shore Dr - Top Right, Smokehouse Rd & Lummi Shore Rd - Bottom)

Expected Collision Types:	Angle, Left Turn Head On, Rear End
Expected Frequency:	Occasional
Expected Severity:	Medium
Risk Rating:	D

Realign Heavily Skewed Intersections

While other steps may be taken to help improve safety at these locations (i.e. increasing clear zone and repositioning pavement markings and sign placement, as discussed previously) the long-term solution is a realignment of these intersections to reduce the severity of the skew angle. Figure 43 provides an example layout for such a reconstruction at the Red River intersections with Haxton Way.

Treatment	Collision Modification / Reduction Factor	Approx. Cost Range
Reduce Skew Angle ²⁹	Modification and Reduction Factors are based on a formula	\$\$\$

²⁹ <u>http://www.cmfclearinghouse.org/detail.cfm?facid=5188</u>



Figure 43 - Red River Rd Skew Alternative (Not Drawn to Scale)

Implement Systemic Stop Bar Installation Program

During field observations, it was noted that a significant portion of stop controlled roadways do not currently have painted stop bars. A systemic installation program is recommended to install stop bars at locations currently lacking them. This would provide drivers with an additional indicator that an intersection is ahead, as well as encouragement to stop at an appropriate location.

Treatment	Collision Modification / Reduction Factor	Approx. Cost Range
Install Stop Bar	Unavailable	\$
"Stop Ahead" Pavement Markings	0.69 Modification / 31% Reduction in All Collisions of All Severities	\$

Collision Reduction Analysis

Highway Safety Manual Analysis

Based on the existing geometry, traffic volumes, and the results of the HSM analysis, the intersections of Haxton Way & N and S Red River Rds, and Lummi Shore Rd & Smokehouse Rd were expected to collectively experience approximately 1.85 collisions annually. Based on the historic reported collisions at this location, the intersections have only experienced an annual average of 0.4 collisions per year, meaning these locations are currently performing better than expected. Table 15 summarizes the estimated impacts of the recommendations listed previously. It must be noted that those recommendations lacking collision modification factors (CMF) or those which do not apply to all collision types of all severities cannot be tested in the analysis and have been omitted.

Condition	Observed Average Collision Frequency (collisions / year)	Expected Annual Collision Frequency (collisions / year)	Estimated Reduction in Expected Collisions (collisions / year)	High Level Cost Estimate	Estimated Benefit Cost Ratio
Existing	0.4	1.85	N / A	N/A	N/A
"Stop Ahead" Pavement Markings	N / A	1.36	0.49	\$2,000	55.1

Table 15 - HSM Analysis

Safety Concern #9: Safe Waiting Areas at Bus Stops

The Tribe provides a regular transit service throughout the Reservation with designated bus stops along the route. While some of these stops have, or are programmed to receive, sheltered waiting areas, a significant number are currently marked by a single bus stop sign driven into the grassy clear zone. Based on discussions with local community leaders and members, this sometimes results in pedestrians waiting on the edge line of the road. In some cases, it was noted that groups of school children waiting for the bus spill onto the roadway. This is particularly hazardous at locations where there is not sufficient overhead lighting. Figure 44 provides examples of bus stops observed during the field review.



Figure 44 - Comparison of Bus Stop Facilities

Expected Collision Types:	Pedestrian
Expected Frequency:	Rare
Expected Severity:	High
Risk Rating:	D

Install Paved Pad at Bus Stop Locations

A review of bus stop use should be conducted to ascertain the level of use at each location. This would help to identify stops which may no longer be necessary, as well as highlighting those locations experiencing higher than average use. If any of these locations do not already have a shelter, or are not already programmed for some level of improvement, consideration should be given to building them out further. This could range from the installation of a paved pad to a full stop with seating and shelter. These would provide transit users with a safer area to wait for the bus and helps make them more conspicuous as they wait for the next bus.

Treatment	Collision Modification / Reduction Factor	Approx. Cost Range
Install Paved Pad	Unavailable	\$

Consider Lighting Installations at Bus Stop Locations

A significant number of bus stop locations are not situated near existing overhead lighting. This is particularly problematic during the winter months when transit riders may be waiting at the stop during the early morning or late evening hours. Hazards are compounded when there is no dedicated waiting area and pedestrians may cluster along or within the travel lanes of the roadway. Opportunities should be identified to provide lighting at high priority locations where some is not already provided. This would illuminate the pedestrians along the roadway, alerting drivers more easily to their presence.

Treatment	Collision Modification / Reduction Factor	Approx. Cost Range
Roadside Lighting ³⁰	0.58 Modification / 42% Reduction in Nighttime & Vehicle / Pedestrian Serious and Minor Injury Collisions	\$\$

Collision Reduction Analysis

Given the difficulty in reporting and identifying pedestrian involved crashes, it is difficult to identify areas for improvement based on the current collision history. In effect, there is no strong pattern to guide the selection of treatment locations. However, per the 2015 National Safety Council collision cost estimates, one fatality is associated with a \$1.5M loss. If even one fatality is prevented by treatments in this category it would have a significantly positive benefit-cost ratio.

³⁰ <u>http://www.cmfclearinghouse.org/detail.cfm?facid=436</u>

Safety Concern #10: Downhill Stretch of North/Westbound Lummi View Dr

The North/Westbound portion of Lummi View Dr from Cagey Rd to Lummi View Dr, and southern portion of Lummi Shore Rd on the southern side of the peninsula was identified as an area of concern during discussions. This is due in part to the curve of the road, the downhill slope, and the potential for foggy conditions turning into icing on the roadway. These conditions combine to increase the risk associated with lane departure and run off road collisions. There is a combination of guardrail and concrete barrier installed along the southern edge of the road / peninsula to help prevent vehicles from completely leaving the roadway, but these also serve as fixed object hazards in their own right. Figure 45 provides the driver's perspective of this portion of roadway.





Figure 45 - Lummi Shore Rd

Expected Collision Types:	Run off Road / Fixed Object, Sideswipe-Opposite
Expected Frequency:	Occasional
Expected Severity:	Moderate
Risk Rating:	D

Consider Installation of Icy Road Feedback Systems

ITS packages exist which detect when conditions are conducive to develop icy road cover. These could be implemented along this stretch of roadway to alert drivers when there is potential for black ice or other slick conditions. This would help drivers adjust their behavior accordingly, i.e. lowering speeds, taking turns less sharply, etc. and range from relatively low cost sign installations to more expensive / conspicuous detection and alert systems.

Treatment	Collision Modification / Reduction Factor	Approx. Cost Range
Icy Pavement Warning Signs	Unavailable	\$
Icy Curve Warning System ³¹	0.82 Modification / 18% Reduction in All Collisions of All Severities	\$\$

Review Potential Changes to Winter Maintenance Activities & Thresholds

Considering reviewing existing winter maintenance activities to identify changes which may help reduce or prevent icing along the roadway. This could include consideration of alternative deicing materials, preemptive maintenance, or more frequent plowing or application of grit materials. Any changes would require cooperation between the agencies as well as a thorough review of material and operational availability of resources.

Treatment	Collision Modification / Reduction Factor	Approx. Cost Range
Revise Winter Maintenance Strategies	Unavailable	\$ - \$\$

Consider High-Friction Surfacing

Consideration should be given to the potential for a high-friction surface treatment at spot locations along the roadway. While this countermeasure is relatively more expensive, it can be very effective what applied at precise locations and may reduce friction loss on the roadway under some icy conditions. This could even be limited to the downhill lane along Lummi View Dr to reduce the treatment area.

Treatment	Collision Modification / Reduction Factor	Approx. Cost Range
High Friction Pavement Surface Treatment ³²	0.76 Modification / 24% Reduction in All Collisions of All Severities	\$\$

³¹ <u>http://www.cmfclearinghouse.org/detail.cfm?facid=4114</u>

³² <u>http://www.cmfclearinghouse.org/detail.cfm?facid=7900</u>

Collision Reduction Analysis

Highway Safety Manual Analysis

Based on the existing geometry, traffic volumes, and the results of the HSM analysis, the segment of Lummi Shore Rd from Cagey Rd to Lummi View Dr was expected to collectively experience approximately 2.39 collisions annually. Based on the historic reported collisions at this location, the intersections have only experienced an annual average of 2.4 collisions per year, meaning these segment is currently performing as expected. Table 17 summarizes the estimated impacts of the recommendations listed previously. It must be noted that those recommendations lacking collision modification factors (CMF) or those which do not apply to all collision types of all severities cannot be tested in the analysis and have been omitted.

lable 16 - HSM Analysis					
Condition	Observed Average Collision Frequency (collisions / year)	Expected Annual Collision Frequency (collisions / year)	Estimated Reduction in Expected Collisions (collisions / year)	High Level Cost Estimate	Estimated Benefit Cost Ratio
Existing	2.4	2.39	N / A	N / A	N / A
Icy Curve Warning System	N / A	2.01	0.38	\$15,000	11.4
High Friction Pavement Surface Treatment	N / A	1.88	0.51	\$20,000	8.0

Safety Concern #11: Lack of Intersection Warning

on Haxton Way

As noted during the field reviews, there are a significant portion of intersections within the Reservation that lack advanced intersection warning signs. This results in uncertainty around the upcoming location of an intersection, particularly for visitors or tourists unfamiliar with the area, as well as drivers not realizing a stop controlled intersection is ahead. Figure 46 **provides the driver's** perspective along Haxton Way approaching N & S Red River Rd. As shown in the figure, only N Red River Rd has intersections guidance signs, despite S Red River Rd coming between N Red River Rd and the guidance sign shown here.



Driver encounters S Red River Rd Intersection before Signed Intersection

Advanced Intersection Sign for N Red River Rd heading Northbound



N Red River Rd Located after the Bridge

Figure 46 - Northbound Approach to S & N Red River Rds

Expected Collision Types:	Angle, Head on Left Turn, Rear End
Expected Frequency:	Occasional / Frequent
Expected Severity:	Low
Risk Rating:	C / D

Install Advanced Intersection Warning Signs

Advanced intersection warning could include intersection guidance signage as well as warning signs for upcoming stop signs, traffic signals, or hidden intersection. Installation of appropriate signs in advance of intersection help to alert the driver of the potential for cross traffic as well as the need to stop under certain conditions. These signs would assist with driver guidance as well as improving traffic safety.

Treatment	Collision Modification / Reduction Factor	Approx. Cost Range
Advanced Street Name Signs ³³	0.984 Modification / 1.6% Reduction in All Collisions of All Severities	\$

Consider Additional Lighting Installations

A number of intersections within the Reservation currently lack lighting. Some examples include the residential streets that intersect Lummi Shore Dr. This may hinder drivers in their search for a specific intersection or make the potential for cross traffic less evident. The installation of lighting at these locations would help to illuminate the intersection, making navigation easier for drivers, as well as helping to illuminate any pedestrians or other road users in the area.

Treatment	Collision Modification / Reduction Factor	Approx. Cost Range
Provide Intersection Lighting ³⁴	0.62 Modification / 38% Reduction in Nighttime Serious and Minor Injury Collisions	\$

³³ http://www.cmfclearinghouse.org/detail.cfm?facid=2449

³⁴ <u>http://www.cmfclearinghouse.org/detail.cfm?facid=433</u>

Consider Installation of Transverse Rumble Strips

The installation of transverse rumble strips should be considered at stop controlled locations throughout the Reservation. These strips provide drivers with an audible and tactile feedback, alerting them of the presence of a stop ahead and may prove beneficial. Some constraints exist around sound levels when installed near residential areas.

Treatment	Collision Modification / Reduction Factor	Approx. Cost Range
Install Transverse Rumble Strips on Stop Controlled Approaches ³⁵	0.745 Modification / 25.5% Reduction in Fatal and Serious Injury Collisions of All Types	\$\$

Collision Reduction Analysis

Highway Safety Manual Analysis

Based on the existing geometry, traffic volumes, and the results of the HSM analysis, the intersections of Haxton Way & S Red River Rd, the Kwina Triangle, and Haxton Way & MacKenzie Rd were expected to collectively experience approximately 4.56 collisions annually. Based on the historic reported collisions at this location, the intersection has only experienced an annual average of 2.0 collisions per year, meaning this location is currently performing better than expected. It remains a priority with the potential for severe collisions, however, and Table 17 summarizes the estimated impacts of the recommendations listed previously. It must be noted that those recommendations lacking collision modification factors (CMF) or those which do not apply to all collision types of all severities cannot be tested in the analysis and have been omitted.

Table I / - HSIVI Analysis					
Condition	Observed Average Collision Frequency (collisions / year)	Expected Annual Collision Frequency (collisions / year)	Estimated Reduction in Expected Collisions (collisions / year)	High Level Cost Estimate	Estimated Benefit Cost Ratio
Existing	2.0	4.56	N / A	N / A	N / A
Advanced Street Name Signs	N / A	4.51	0.05	\$9,600	1.64

³⁵ http://www.cmfclearinghouse.org/detail.cfm?facid=2705

Observed Crash Analysis

Table 18 provide estimated collision reductions for this location based on historic collision data. This is due to the more specific nature of the CMFs available for these treatments.

Table 18 - Observe	ed Collision Analy	ysis			
Condition	Observed Average Collision Frequency (collisions / year)	Applicable Collision Frequency (collisions / year)	Estimated Reduction in Collisions (collisions / year)	High Level Cost Estimate	Estimated Benefit Cost Ratio
Existing	2.0	N / A	N / A	N / A	N / A
Provide Intersection Lighting	N / A	0.4	0.15	\$60,000	0.72
Install Transverse Rumble Strips	N / A	0.836	0.20	\$30,000	2.1

 $^{^{\}rm 36}$ All stop controlled intersection fatal and serious injury collisions in the Reservation

Safety Concern #12: Jersey Barrier Installation

Jersey barrier installations have been positioned along portions of Lummi Shore Rd along the eastern side of the peninsula. These are intended to prevent drivers from leaving the roadway and falling over the beachside cliffs. It was noted during the field review that these barriers have not been pinned together, as is typical for such an installation, or pinned to the ground. This leaves open the potential that a vehicle striking the barrier may move single pieces, increasing the risk that the barrier will not **serve it's intended purpose.** Figure 47 provides an example of the observations made during the field review.



Figure 47 - Unpinned vs Pinned Jersey Barrier along Lummi Shore Rd

Expected Collision Types:	Fixed Object
Expected Frequency:	Rare
Expected Severity:	Medium / High
Risk Rating:	C / D

Re-pin jersey barrier

These barrier installations should be repined, at the very least, to each other. Ideally, they should be reconnected to each other and pinned to the ground. This would improve their ability to keep vehicles on the paved roadway without shifting and creating additional hazards.

Treatment	Collision Modification / Reduction Factor	Approx. Cost Range
Re-pin Jersey Barrier	Unavailable	\$

Safety Concern #13: Guardrail Condition & Placement

Several runs of guardrail have been installed at locations throughout the Reservation. The majority of these are located intermittently along the outer edge of the peninsula providing protection from the beach side cliffs along Lummi Shore Rd. Other installations have been installed in an attempt to guard utilities and other infrastructure located relatively closely to the roadway. These installations do not appear to have sufficient run-out length or appropriate end terminals. This increases the potential for fixed object impacts behind the guardrail or the guardrail ends themselves. Figure 48 provides an example of some of the guardrail installations identified around the Reservation.





Figure 48 - Guardrail Installations

Additionally, some locations were identified that may benefit from guardrail installations. The primary locations include the recently reconstructed culvert sections located along Haxton Way and Lummi Shore Dr. Initial site reviews suggest these locations may meet the minimum clear zone requirements but still represent a potential hazard if a vehicle was to leave the roadway and follow the slope into the creek. Figure 49 highlights these locations.



Figure 49 - Reconstructed Culverts

Expected Collision Types:	Fixed Object
Expected Frequency:	Rare
Expected Severity:	Medium
Risk Rating:	С

Installations of guardrail require their own warrant process. As such it would be inappropriate to specific locations for installation based on this high-level review. Locations experiencing run off road collisions may be candidate areas for review. Figure 50 provides the location and severity of run off road collisions within the Reservation during the study period. These collisions will be used in the crash reduction analysis for illustrative purposes only as a number of them will likely not warrant guardrail installation.



Figure 50 - Run off Road Collision Locations (Intersection Related Not Included)

Review need for guardrail

Sections of roadway prone to run off road collisions, or those areas with significant objects or other hazards near the roadway should be cataloged and reviewed for potential guardrail installations. Hazards in these areas should be reviewed to determine if other mitigating measures could be employed (removing, relocating, etc.). If other measures are unfeasible, consideration should be given to the installation of appropriately designed runs of guardrail to protect vehicles from the hazard.

Treatment	Collision Modification / Reduction Factor	Approx. Cost Range
Install New Guardrail ³⁷	0.53 Modification / 47% Reduction in Serious and Minor Injury Run off Road Collisions	\$\$

Update guardrail installations and terminals to current standards

Locations with existing guardrail installations should be reviewed to assess need, condition, and conformance with current standards. Locations where the need is still present but do not meet current conditions and standards requirements should be prioritized and programmed for replacement. This would help to ensure that, moving forward, critical sections of guardrail are replaced and updated as funding becomes available.

Treatment	Collision Modification / Reduction Factor	Approx. Cost Range
Upgrade Existing Guardrail Installations	Unavailable	\$\$

Collision Reduction Analysis

Observed Crash Analysis

Based on the historic reported collisions in the Reservation, there was an annual average of 16.4 run off road collisions per year. It remains a priority with the potential for severe collisions and Table 19 summarizes the estimated impacts of the recommendations listed previously.

³⁷ <u>http://www.cmfclearinghouse.org/detail.cfm?facid=38</u>

Table 19 - Observed Collision Analysis

Condition	Observed Average Collision Frequency (collisions / year)	Applicable Collision Frequency (collisions / year)	Estimated Reduction in Collisions (collisions / year)	High Level Cost Estimate	Estimated Benefit Cost Ratio
Existing	16.4	N/A	N / A	N / A	N/A
Install New Guardrail	N / A	4.0	1.88	\$1M	0.5

Safety Concern #14: Target Arrow Placement

Target arrows are typically installed opposite three legged intersections or along curves. These warning signs are intended to alert the driver of changes in roadway geometry. It was noted during field observations that several locations may benefit from the installation of target arrows or the repositioning of existing arrows. For example, the curve from westbound N Red River Rd to northbound Lake Terrell Rd already has a target arrow installed. However, this arrow is not visible when approaching the sharp turn from the east, limiting any potential benefits. Figure 51 provides a series of images illustrating this issue.



Figure 51 - Target Arrow Approach at N Red River Rd & Lake Terrell Rd

Other locations, such as the residential streets which intersect with Lummi Shore Rd may benefit from the installation of target arrows. These would further delineate the roadway and reduce the potential for barrier strikes in these locations.

Expected Collision Types:	Fixed Object
Expected Frequency:	Rare
Expected Severity:	Low / Medium
Risk Rating:	B / C

Reposition Target Arrows

Existing target arrow placement should be reviewed for visibility from all approaches. Where feasible, trimming of vegetation and maintenance may be sufficient to improve sign visibility. When this is not possible, consideration should be given to repositioning the target arrows so they are visible from a greater distance for oncoming drivers.

Treatment	Collision Modification / Reduction Factor	Approx. Cost Range
Reposition Target Arrows	Unavailable	\$
Clear Obstructing Vegetation	Unavailable	\$

Install Target Arrows Where Missing

Consideration should be given to installing target areas at those locations currently lacking them. This will help to reduce the potential for run off the road collisions at these locations by better alerting the driver to changes in roadway geometry.

Treatment	Collision Modification / Reduction Factor	Approx. Cost Range
Install Target Arrows	Unavailable	\$

Safety Concern #15: Roundabout Splitter Islands

Several roundabouts have been installed at locations throughout the Reservation. While they appear to be working well in regards to traffic operations and associated safety benefits, it was noted that they do not currently have regulatory or warning signs posted in the splitter islands on the approaches. These signs help to guide the driver around the roundabout in the correct direction as well as alerting the driver of the presence of a median. Figure 52 provide a comparison between the existing roundabout splitter islands on the Reservation and those more typical installations.



Figure 52 - Reservation Roundabout

Expected Collision Types:	Fixed Object
Expected Frequency:	Rare
Expected Severity:	Low
Risk Rating:	В

Install "Keep Right" Signs

"Keep Right" regulatory signs should be install on the roundabout splitter islands. These signs would help guide any motorist unfamiliar with the area or with roundabouts in general regarding the correct direction of flow through the intersection. Figure 53 provides an example of such an installation.



Figure 53 - "Keep Right" at Roundabout (Source: City of Sacramento)

Treatment	Collision Modification / Reduction Factor	Approx. Cost Range
Install "Keep Right" Signs	Unavailable	\$

Paint island curbs

Consideration should be given to painting the island curbs yellow or with a retroreflective paint. This would help to illuminate their presence for oncoming vehicles under dark conditions, reducing the potential for curb strikes. Figure 54 provides an example of such an installation.



Figure 54 - Painted Splitter Island

Treatment	Collision Modification / Reduction Factor	Approx. Cost Range
Paint Curb Islands	Unavailable	\$

5.2 Other Recommendations

Coordination on Tsunami Warning & Evacuation Plans

Given the Reservations location along the shoreline, tsunami drills and preparedness are an important part of life in the Pacific Northwest. Tsunami evacuation route signs are posted along designated routes throughout the Reservation to help guide motorists to safer areas. It is recommended that the Tribe consider increased coordination with the County, Law Enforcement, and Emergency Services to develop evacuation plans. These could include designated responsibilities regarding road closures and temporary conversion to one-way routes to facilitate evacuation, determining which agencies are responsible for which roadways or areas, and developing a command structure for use during large scale emergencies or natural disasters.

Ferry Dock Queueing Alternatives

Concerns were raised regarding motor vehicle queueing at the Ferry Dock during the weekends of the peak summer months. Vehicles queue along Haxton Way while waiting to board the ferry to cross to Lummi Island. There are existing pavement markings designating portions of the roadway for ferry queueing but there are concerns that the queue may have a negative impact on operations under worst case scenarios. Some alternative recommendations include the creation of a shuttle service based in different areas of the Reservation. Examples could include a designated parking area at the casino or at the high school where ferry-goers could park and take a shuttle down to the Ferry Dock. This would help to reduce the queue at the dock itself and potentially provide the Tribe with additional revenue depending on the specifics of the shuttle service.

An additional option discussed would be to hold platoons of ferry bound vehicles at the Casino or high school parking lots and release them when the ferry arrives. This would provide storage for vehicles off the roadway but would potentially result in large platoons of vehicles all heading to the same location at the same time. This may cause operational issues or the potential for speeding behavior as drivers head to the ferry dock.

Traffic Management Plan for the Lummi Stommish Water Festival

The Tribe holds an annual event open to the general public. Traffic peaks during this event, requiring assistance from law enforcement to help manage traffic patterns. Development of traffic management plan for this event could be used to identity issues with practices and lay out a plan with traffic patterns, areas of responsibility, and procedures to help law enforcement manage the influx of vehicular and pedestrian traffic.

6 Highway Safety Manual Analysis

The Highway Safety Manual (HSM) introduces a science-based technical approach to incorporating safety into traditional roadway planning and safety analyses. The first edition of the HSM (2010) provides the best factual information and tools in a useful form to facilitate roadway planning, design, operations, and maintenance decisions based on precise consideration of their safety consequences. The primary focus of the HSM is the introduction and development of analytical tools for predicting the impact of transportation project and program decisions on road safety.

Collision Modification Factors (CMF) were applied as necessary for the base conditions (i.e. converting stop controlled intersections to roundabouts, etc.). The following section provides a high-level summary of the results with additional details provided in the appendix.

It should be noted that several intersections have been altered in recent years, limiting the applicability of this analysis at those specific locations as it utilizes collision data from the period before, during, and after the change occurred. Most notably, this includes changes at the intersection of Slater Rd and Ferndale Rd, Haxton Way and Kwina Rd, and Haxton Way and Smokehouse Rd.

6.1 Existing Performance

		-		Empirica	Bayes Analysis (Site	-Specific)		
		Predicted av	erage crash frequency ashes/year)	1			Observed Crashes (crashes/year)	
	Npredicted (TOTAL)	Npredicted (FI)	Npredicted (PDO)	Npredicted (ped)	N _{predicted} (bike)	Nobserved (TOTAL)	Nobserved (segment)	Nobserved (intersection)
Rural 2-Lane	73.898	26.291	47.607	+	-	39	27	13
Rural Multilane	-	-		-	-	-	-	-
Urban/ Suburban	-	-	8	÷	+	¥	14	
Total	73.898	26.291	47.607	-	-	39	27	13

				Ex.	pected Crashes crashes/year)	-		
	Nexpected (TOTAL)	Nexpected (FI)	Nexpected (PDO)	Nexpected (vehicle)	N _{expected} (ped)	N _{expected} (bike)	N _{expected} (segment)	N _{expected} (intersection)
Rural 2-Lane	47.4	16.9	30.6	47.4	-	-	29.1	18.3
Rural Multilane	1	-		-	÷	+	-	-
Urban/ Suburban	-		-	-	÷	-	-	-
Total	47.4	16.9	30.6	47.4	e e e e e e e e e e e e e e e e e e e	-	29.1	18.3

Rank		Highest Expected Avera	ige Crashes		Excess
1.	(INT) Slater Rd @ Haxton Way	Lummi Nation	Control = 4SG	Major AADT: 8,000 / Minor AADT: 5,482	3.93
2.	(SEG) Haxton Way, Kwina Rd to Boynton Rd	Lummi Nation	Length = 1.86 mi	AADT: 5,187	2.67
3.	(SEG) Slater Rd, S Red River Rd to Haxton Way	Lummi Nation	Length = 0.71 mi	AADT: 10,621	2.12
4.	(INT) Slater Rd @ Ferndale Rd	Lummi Nation	Control = 4ST	Major AADT: 10,621 / Minor AADT: 1,000	1.70
5.	(SEG) Lummi Shore Rd, Lummi View Dr to Smokehouse Rd	Lummi Nation	Length = 2.36 mi	AADT: 1,500	1.57
6.	(SEG) Lummi Shore Rd, Scott Rd to Kwina Rd	Lummi Nation	Length = 0.76 mi	AADT: 2,916	1.48
7.	(SEG) Haxton Way, Lummi Shore Dr to Kwina Rd	Lummi Nation	Length = 0.87 mi	AADT: 4,000	1.47
8.	(INT) Haxton Way @ Kwina Rd	Lummi Nation	Control = 4SG	Major AADT: 5,187 / Minor AADT: 3,893	1.43
9.	(INT) Slater Rd @ Lake Terrell Rd	Lummi Nation	Control = 4ST	Major AADT: 2,177 / Minor AADT: 1,397	1.38
10.	(INT) Marine Dr @ Lummi Shore Rd	Lummi Nation	Control = 3ST	Major AADT: 3,906 / Minor AADT: 2,916	1.35

Rank	and the second	Highest Excess Expecte	ed Crashes		Excess
1.	(SEG) Slater Rd, Elder Rd to Lake Terrell Rd	Lummi Nation	Length = 1 mi	AADT: 2,177	1.51
2.	(SEG) S Red River Rd, Haxton Way to Slater Dr	Lummi Nation	Length = 1.2 mi	AADT: 225	0.48
3.	(SEG) Slater Rd, Haxton Way to Elder Rd	Lummi Nation	Length = 1.5 mi	AADT: 2,177	0.44
4.	(INT) Cagey Rd @ Chief Martin Rd	Lummi Nation	Control = 3ST	Major AADT: 330 / Minor AADT: 252	0.31
5.	(INT) Slater Rd @ Ferndale Rd	Lummi Nation	Control = 4ST	Major AADT: 10,621 / Minor AADT: 1,000	0.30
6.	(SEG) S Red River Rd, Hillaire Rd to Haxton Way	Lummi Nation	Length = 1.1 mi	AADT: 225	0.28
7.	(SEG) N Red River Rd, Hillaire Rd to Haxton Way	Lummi Nation	Length = 1.12 mi	AADT: 247	0.26
8.	(SEG) MacKenzie Rd, Lummi View Dr to Lummi View Dr	Lummi Nation	Length = 0.65 mi	AADT: 150	0.22
9.	(SEG) N Red River Rd, Curve to Hillaire Rd	Lummi Nation	Length = 1.6 mi	AADT: 600	0.19
10.	(SEG) Slater Rd, Lake Terrell Rd to Curve	Lummi Nation	Length = 1.01 mi	AADT: 2,177	0.19

Rank	Highest Predicted Total Crashes				
1.	(INT) Slater Rd @ Haxton Way	Lummi Nation	Control = 4SG	Major AADT: 8,000 / Minor AADT: 5,482	4.17
2.	(SEG) Sucia Dr, Cleo Rose Ln to End	Lummi Nation	Length = 1.42 mi	AADT: 1,591	3.18
3.	(SEG) Haxton Way, Kwina Rd to Boynton Rd	Lummi Nation	Length = 1.86 mi	AADT: 5,187	3.09
4.	(INT) Marine Dr @ Lummi Shore Rd	Lummi Nation	Control = 3ST	Major AADT: 3,906 / Minor AADT: 2,916	2.28
5.	(INT) Marine Dr @ Lummi Shore Dr	Lummi Nation	Control = 3ST	Major AADT: 3,906 / Minor AADT: 2,916	2.14
6.	(SEG) Slater Rd, S Red River Rd to Haxton Way	Lummi Nation	Length = 0.71 mi	AADT: 10,621	2.07
7.	(SEG) Haxton Way, Lummi Shore Dr to Kwina Rd	Lummi Nation	Length = 0.87 mi	AADT: 4,000	1.69
8.	(SEG) Lummi Shore Rd, Scott Rd to Kwina Rd	Lummi Nation	Length = 0.76 mi	AADT: 2,916	1.62
9.	(INT) Kwina Rd @ Lummi Shore Dr	Lummi Nation	Control = 3ST	Major AADT: 3,893 / Minor AADT: 2,916	1.61
10.	(SEG) Lummi Shore Rd, Lummi View Dr to Smokehouse Rd	Lummi Nation	Length = 2.36 mi	AADT: 1,500	1.60

Rank	Highest Predicted Fatal & Injury Crashes					
1.	(INT) Slater Rd @ Haxton Way	Lummi Nation	Control = 4SG	Major AADT: 8,000 / Minor AADT: 5,482	1.42	
2.	(SEG) Sucia Dr, Cleo Rose Ln to End	Lummi Nation	Length = 1.42 mi	AADT: 1,591	1.02	
3.	(SEG) Haxton Way, Kwina Rd to Boynton Rd	Lummi Nation	Length = 1.86 mi	AADT: 5,187	0.99	
4.	(INT) Marine Dr @ Lummi Shore Rd	Lummi Nation	Control = 3ST	Major AADT: 3,906 / Minor AADT: 2,916	0.94	
5.	(INT) Marine Dr @ Lummi Shore Dr	Lummi Nation	Control = 3ST	Major AADT: 3,906 / Minor AADT: 2,916	0.89	
6.	(INT) Slater Rd @ Lake Terrell Rd	Lummi Nation	Control = 4ST	Major AADT: 2,177 / Minor AADT: 1,397	0.69	
7.	(INT) Slater Rd @ Ferndale Rd	Lummi Nation	Control = 4ST	Major AADT: 10,621 / Minor AADT: 1,000	0.69	
8.	(INT) Kwina Rd @ Lummi Shore Dr	Lummi Nation	Control = 3ST	Major AADT: 3,893 / Minor AADT: 2,916	0.67	
9.	(SEG) Slater Rd, S Red River Rd to Haxton Way	Lummi Nation	Length = 0.71 mi	AADT: 10,621	0.67	
10.	(INT) Haxton Way @ Lummi Shore Rd	Lummi Nation	Control = 3ST	Major AADT: 5,184 / Minor AADT: 1,039	0.64	

6.2 Benefit Cost Ratios

Based on the Highway Safety Manual Analysis, Crash Modification Factors, and estimated costs derived in part from the Washington State Department of Transportation's Bid Item Unit Price Tabulation Standard Items Report, several benefit cost ratios were developed. These ratio estimates were only feasible for those treatments with defined collision modification factors. The remaining treatments are still expected to result in collision reductions.

This process involved the estimation of the annual reduction in collisions associated with each treatment, as well as an estimated construction cost. The costs associated with fatal and injury crashes as well as injury crashes was derived from the WSDOT 2015 crash statistics³⁸ and the most recently available **National Safety Council's 2015 estimated costs for uni**ntentional injuries³⁹. Weighted average collisions costs were developed and applied to treatments as appropriate. The following table provides a summary of the treatments where benefit cost ratios could be developed.

It must be reiterated that these are high-level planning style cost and benefit estimates and do not take design level considerations into account.

³⁸ <u>http://www.wsdot.wa.gov/mapsdata/crash/pdf/2015</u> Annual Collision Summary.pdf

³⁹ <u>http://www.nsc.org/NSCDocuments_Corporate/estimating-costs.pdf</u>

THIS PAGE INTENTIONALLY LEFT BLANK
	Concern	Treatment	Treatment Cost Estimate	Extent	Expected Life	Annual Crash Reduction	Crash Reduction over life of Treatment	Weighted Crash Cost	Туре	Benefit	BCR
		Convert to Roundabout	\$1,250,000	1 Location	15	0.77	11.55	\$50,000	F&I	\$519,600	0.4
4	Kwina, Marine, and Lummi	Flashing Beacons	\$3,600	4 Intersections	7	0.1	0.7	\$50,000	F&I	\$31,500	8.8
1	Shore Intersections	LED Stop Signs	\$4,500	4 Intersections	10	0.25	2.5	\$50,000	F&I	\$112,500	25.0
		Restripe Primary Route	\$3,500	Quarter Mile Curve	3	0.11	0.33	\$30,000	I.	\$9,500	2.7
h	Dedectrion / Dike Escilition	Pave Gravel Shoulders	\$1,700,000	~24 Miles of 6' shoulder on both sides	10	1.28	12.8	\$50,000	F&I	\$575,800	0.3
2	Pedestrian / Bike Facilities	Widen Existing Paved Shoulders	\$50,000	~1.4 Miles of 1-2' shoulder extensions	10	0.13	1.3	\$50,000	F&I	\$58,500	1.2
		Convert to Roundabout	\$1,000,000	1 Intersection	15	1.52	22.8	\$50,000	F&I	\$1,025,700	1.0
		Dilemma Zone Detection Monitoring	\$60,000	Detection on 1 approach	10	0.22	2.2	\$50,000	F&I	\$99,000	1.7
3	Turning Movements at	Speed Feedback Sign	\$10,000	1 Installation	7	0.14	0.98	\$50,000	F&I	\$44,100	4.4
	Haxton way & Slater Ru	Protected Left Turn Movement	\$10,000	In Installation	15	0.22	3.3	\$30,000	I	\$94,600	9.5
		Advanced Warning Signs	\$2,000	4 Approach installations	7	0.28	1.96	\$50,000	F&I	\$88,200	44.1
	Narrow Lanes / No	Widen Narrow Pavement	\$50,000	~1.4 Miles of 1-2' shoulder extensions	10	0.22	2.2	\$50,000	F&I	\$99,000	2.0
4	Shoulders	Pave Gravel Shoulders	\$1,700,000	~24.5 Miles of 6' shoulder on both sides	10	0.27	2.7	\$50,000	F&I	\$121,500	0.1
		Improve Clear Zone (Boom Mower Attachment)	\$40,000	1 Boom Mower Attachment	10	0.83	8.3	\$50,000	F&I	\$373,400	9.3
		Install Chevrons and Curve Warning Signs	\$9,600	24 Sign Installations	7	2.08	14.56	\$50,000	F&I	\$655,000	68.2
		Raised Pavement Markers	\$140,000	4 miles	5	0.84	4.2	\$50,000	F&I	\$189,000	1.4
5	Unmarked Curves	Flatten Side Slope (Low)	\$15,000	Varies	20	0.47	9.4	\$50,000	F&I	\$422,900	28.2
		Flatten Side Slope (High)	\$100,000	Varies	20	0.47	9.4	\$50,000	F&I	\$422,900	4.2
		Remove or Relocate Fixed Objects (Low)	\$5,000	Varies	20	0.84	16.8	\$50,000	F&I	\$755,800	151.2
		Remove or Relocate Fixed Objects (High)	\$30,000	Varies	20	0.84	16.8	\$50,000	F&I	\$755,800	25.2
		Remove or Relocate Fixed Objects (Low)	\$5,000	Varies	20	0.15	3	\$50,000	F&I	\$135,000	27.0
C		Remove or Relocate Fixed Objects (High)	\$30,000	Varies	20	0.15	3	\$50,000	F&I	\$135,000	4.5
6	Clear vision at intersections	Flashing Beacons	\$9,000	8 Intersections	10	0.13	1.3	\$50,000	F&I	\$58,500	6.5
		LED Stop Signs	\$7,000	8 Intersections	3	0.13	0.39	\$30,000	I.	\$11,200	1.6
7	Speeding	Speed Feedback Sign	\$20,000	2 Installations	7	0.24	1.68	\$50,000	F&I	\$75,600	3.8
8	Skewed Intersection & Hidden Stop Signs	"Stop Ahead" Pavement Markings	\$2.000	5 Approach installations	5	0.49	2.45	\$50,000	F&I	\$110,200	55.1
9	Safe Waiting areas at Bus	N/A									
	Downhill Stretch of WB	Icy Curve Warning Sign	\$15.000	1 Installation	10	0.38	3.8	\$50,000	F&I	\$171,000	11.4
10	Lummi View Dr	High Friction Pavement Surface Treatment	\$20.000	2 Installations	7	0.51	3.57	\$50,000	F&I	\$160,600	8.0
		Advanced Street Name Signs	\$9.600	6 Intersections	7	0.05	0.35	\$50,000	F&I	\$15,700	1.6
11	Lack of Intersection Warning	Intersection Lighting	\$60,000	6 Intersections	10	0.15	1.5	\$30,000	I	\$43,000	0.7
	J. J	Transverse Rumble Strips	\$30.000	6 Intersections	7	0.2	1.4	\$50,000	F&I	\$63,000	2.1
12	Jersey Barrier Installation	N/A	,,								
12	Guardrail Condition &				10	1 00	10 0	\$20,000	,	\$528 700	0 5
13	Placement	Install New Guardrail	\$1,000,000	5 Miles	10	1.00	10.0	Ş50,000	1	ş556,700	0.5
14	Target Arrow Placement	N/A									
15	Roundabout Splitter Islands	N/A									

102

7 Summary

The Opus / Gibson road safety audit team reviewed the Lummi Nation road network over a four-day period. During this time, several meetings were held with the Tribe and other transportation related stakeholders to develop a heuristic understanding of the road network and safety performance. From these field reviews and discussions, a number of positive activities and practices were noted. These included:

- Good Pavement Marking Visibility
- Good Sign Visibility
- Sidewalk & Side Path Installations
- Roundabouts
- Lighting in Residential Areas
- Speed Feedback Signs

In addition to existing benefits, several ongoing projects were noted, including the installation of additional sidewalks, bus stop shelters, and plans in progress to address concerns at Kwina Rd & Marine Dr. These practices indicate a proactive approach to road safety within the Tribe and Reservation.

A detailed Highway Safety Manual (HSM) analysis was conducted on the major routes identified within the Reservation. This included both segments and intersections, and was supported through geolocated recordings of routes around the Reservation. Based on existing conditions, the analysis suggests that the Reservation road network is operating as expected, with some exceptions. Despite this, there are several potential areas for improvement which may help to further improve the safety performance of the network.

As part of the audit, a number of safety concerns were also noted, with a series of potential recommendations provided in the body of the report. The following table provides a high-level summary of the measurable recommendations.

	Concern	Risk Rating	Treatment	Cost Estimate (\$thousands)	Extent	Lifetime Crash Reduction	BCR
1	Kwina, Marine, and Lummi Shore Intersections	F	Convert to Roundabout Flashing Beacons LED Stop Signs Restripe Primary Route	\$1,250 \$3.6 \$4.5 \$3.5	1 Location 4 Intersections 4 Intersections 1/4 Mile Curve	11.55 0.7 2.5 0.33	0.4 8.8 25.0 2.7
2	Pedestrian / Bike Facilities	E/F	Pave Gravel Shoulders Widen Existing Paved Shoulders	\$1,700 \$50	~24 Miles of 6' ~1.4 Miles of 1-2'	12.8 1.3	0.3 1.2
3	Turning Movements at Haxton Way & Slater Rd	D / E	Convert to Roundabout Dilemma Zone Detection Monitoring Speed Feedback Sign Protected Left Turn Movement Advanced Warning Signs	\$1,000 \$60 \$10 \$10 \$2	1 Intersection 1 Approach 1 Installation In Installation 4 Approaches	22.8 2.2 0.98 3.3 1.96	1.0 1.7 4.4 9.5 44.1
4	Narrow Lanes / No Shoulders	D / E	Widen Narrow Pavement Pave Gravel Shoulders	\$50 \$1,700	~1.4 Miles of 1-2' ~24.5 Miles of 6'	2.2 2.7	2.0 0.1
5	Unmarked Curves	D / E	Boom Mower Attachment Install Chevrons and Curve Warning Signs Raised Pavement Markers Flatten Side Slope Remove or Relocate Fixed Objects	\$40 \$9.6 \$140 \$15 - \$100 \$5 - \$30	1 Boom Mower 24 Signs 4 miles Varies Varies	8.3 14.56 4.2 9.4 16.8	9.3 68.2 1.4 28.2 - 4.2 151 2 - 25 2
6	Clear Vision at Intersections	D	Remove or Relocate Fixed Objects Flashing Beacons LED Stop Signs	\$5 - \$30 \$9 \$7	Varies 8 Intersections 8 Intersections	3 1.3 0.39	27.0 – 4.5 6.5 1.6
7	Speeding	D	Speed Feedback Sign	\$20	2 Installations	1.68	3.8
8	Skewed Intersection & Hidden Stop Signs	D	"Stop Ahead" Pavement Markings	\$2	5 Approaches	2.45	55.1
9	Bus Stops	D	N/A				
10	Downhill Stretch of WB Lummi View Dr	D	Icy Curve Warning Sign High Friction Pavement Surface Treatment	\$15 \$20	1 Installation 2 Installations	3.8 3.57	11.4 8.0
11	Lack of Intersection Warning	C/D	Advanced Street Name Signs Intersection Lighting Transverse Rumble Strips	\$9.6 \$60 \$30	6 Intersections 6 Intersections 6 Intersections	0.35 1.5 1.4	1.6 0.7 2.1
12	Jersey Barrier	C/D	N/A				
13	Guardrail Condition & Placement	с	Install New Guardrail	\$1,000	5 Miles	18.8	0.5
14	Target Arrow Placement	B / C	N/A				
15	Roundabout Splitter Islands	В	N/A				

Additional concerns and recommendations were identified within the report along with potential collision modification factors associated with potential treatments, when available. Consideration **should be given to each recommendation with appropriate responses drafted for the Tribe's records.** These recommendations may be used to help guide current and future safety and maintenance programs within the Lummi Nation.

Appendix

Additional Field Observation Photos

Car Passing Bicyclist on Westbound Marine Dr between Ferndale Rd and Nooksack River



Bicyclist on Westbound Marine Dr



Sign Does Not Depict Geometry of Roadway



Unprotected Box Culvert on Lummi Shore Dr



Pavement Surface Condition on Southbound Haxton Way (Chip Seal Flushing)



Unprotected Box Culvert on Haxton Way



Target Arrow in Wrong Location on Westbound Kwina Rd



Edge Loss / Vegetation on Northbound Hillaire Rd



Pavement Failure on Northbound Hillaire Rd





Target Arrow in Wrong Location on Westbound N Red River Rd at Lake Terrell Rd





Northbound Lake Terrell Rd Narrow Clear Zone

Target Arrow in Wrong Position





Edge Loss on Eastbound N Red River Rd West of Hillaire Rd

Defaced Signs on Robertson Rd, North of Cagey Rd



Pedestrians at Night on Lummi Shore Rd



Bicyclist at Night



Historic Traffic Volumes



#	Count Location	Count Type	Date of Count	Time of Count	ADT/TM	EB/NB	WB/SB
1	Slater Rd @ Haxton Way	TM	4/18/2017	4:00-6:00 PM	1,343		
		TM	10/29/2015	4:15-5:15 PM	1,201		
2	Haxton Way @ Kwina Rd	TM	4/18/2017	4:00-6:00 PM	665		
		TM	10/29/2015	4:00 - 5:00 PM	798		
3	Chief Martin Rd @ Kwina Rd	TM	4/18/2017	4:00 - 6:00 PM	410		
	-	TM	10/29/2015	4:00 - 5:00 PM	495		
4	Chief Martin Rd @ Business Dwy	TM	10/29/2015	4:00 - 5:00 PM	75		
5	Business Dwy (West) @ Kwina Rd	TM	4/18/2017	4:00 - 6:00 PM	412		
		TM	10/29/2015	3:45 - 4:45 PM	499		
6	Business Dwy (East) @ Kwina Rd	TM	10/29/2015	4:00 - 5:00 PM	517		
7	Dwy @ Kwina Rd	TM	10/29/2015	3:45 - 4:45 PM	491		
8	Dwy @ Kwina Rd	TM	10/29/2015	4:00 - 5:00 PM	524		
9	Dwy @ Kwina Rd	TM	10/29/2015	4:00 - 5:00 PM	444		
10	Dwy @ Kwina Rd	TM	10/29/2015	4:00 - 5:00 PM	475		
11	Lummi Shore Dr @ Kwina Rd	TM	4/18/2017	4:00 - 6:00 PM	413		
	_	TM	10/29/2015	4:00 - 5:00 PM	481		
		TM	10/15/2014	7:00 - 9:00 AM	307		
		TM	10/15/2015	4:00 - 6:00 PM	417		
12	Kwina Rd East of Haxton Way	Speed	10/29/2015	Weekday	3,893		
13	Chief Martin South of Dwy	Speed	10/29/2015	Weekday	252		
14	Kwina Rd West of Lummi Shore Dr	Speed	10/29/2015	Weekday	3,621		
15	Beach Way South of Slater Rd	Speed	9/5/14-9/12/14	7 day	2,080	32.1	31.6
		Speed	5/15/15-5/22/15	7 day	2,014	35.1	33.9
16	Haxton Way North of Balch Way	Speed	5/28/15-6/4/15	7 day	4,553	53.2	53.2
17	Haxton Way North of Lummi Shore Dr	Speed	5/28/15-6/4/15	7 day	5,184	39.6	42.3
18	Haxton Way North of Lummi View	Speed	5/28/15-6/4/15	7 day	3,967	38	42.3
19	Haxton Way South of Slater Rd	Speed	9/3/14-9/10/14	7 day	5,482	38	39.6
20	Lake Terrell Rd South of Slater Rd	Speed	9/3/14-9/10/14	7 day	1,244	42.3	40.5
		Speed	4/14/17-4/20/17	7 day	1,397	29.6	30.2
21	Lummi Shore Dr North of Marine Dr	Speed	6/20/15-6/29/15	7 day	1,039	33.9	33.9
22	Lummi View Dr North of Lummi Shore Rd	Speed	9/3/14-9/10/14	7 day	1,160	41.5	39.6
		Speed	5/29/15-6/5/15	7 day	788	39.6	40.5
23	Lummi View Dr North of Ruth Rd	Speed	5/29/15-6/5/15	7 day	2,294	37.3	37.3
24	Lummi View Rd South of Mackenzie Rd	Speed	9/3/14-9/10/14	7 day	1,124	30.5	32.1
25	Marine Dr West of Ferndale Rd	Speed	7/23/14-7/30/14	7 day	3,524	42.3	43.3
26	Slater Rd East of Ferndale Rd	Speed	7/17/14-7/21/14	5 day	10,621	54.8	54.8
27	Slater Rd West of Lake Terrell Rd	Speed	5/15/15-5/22/15	7 day	2,177	53.2	51.8
28	Marine Dr East of Lummi Shore Rd	Speed	10/16/14-10/22/14	7 day	3,906	44.3	43.6
29	Marine Dr @ Lummi Shore Dr (North)	TM	10/15/2014	7:00 - 9:00 AM	81		
		TM	10/15/2014	4:00 - 6:00 PM	160		
30	Marine Dr @ Lummi Shore Dr (South)	TM	4/18/2017	4:00 - 6:00 PM	506		
		TM	10/15/2014	7:00 - 9:00 AM	277		
		TM	10/15/2014	4:00 - 6:00 PM	430		
31	Marine Dr @ Lummi Shore Dr (East)	TM	4/18/2017	4:00 - 6:00 PM	437		
		TM	10/15/2014	7:00 - 9:00 AM	369		
		TM	10/15/2014	4:00 - 6:00 PM	497		
32	Haxton Way @ Cagey Rd	TM	4/18/2017	4:00 - 6:00 PM	463		
33	Haxton Way @ Lummi Shore Dr	TM	4/18/2017	4:00 - 6:00 PM	553		
34	Haxton Way @ Smokehouse Rd	TM	4/18/2017	4:00 - 6:00 PM	476		
35	N Red River Rd West of Haxton Way	Speed	4/14/17-4/20/17	/ day	247	35.8	35.2
36	Smokehouse Rd East of Haxton Way	Speed	4/14/17-4/20/17	7 day	937	38.4	39.2
37	Lummi Shore Rd North of Cagey Rd	Speed	4/14/1/-4/20/17	/ day	2,270	44.6	42.9
38	Scott Rd West of Lummi Shore Rd	Speed	4/14/17-4/20/17	7 day	303	37.8	35.2
39	Lummi Shore Rd South of Marine Dr	Speed	4/14/1/-4/20/17	/ day	2,916	38.6	36.8
40	Kwina Rd West of Haxton Way	Speed	4/14/1/-4/20/17	/ day	5/1	35.7	37.2
41	Haxton Way South of Kwina Rd	Speed	4/14/201/-4/20/17	/ day	5,187	46.2	43.3

HSM Detailed Results

Segments

1.00		Worksheet 1A – General Information and Input Data for Rural Two-Lane Two-Way Roadway Segments Right Shoulder Left Shoulder														E	mpirio	al Baye	s Analys	is	Wor	ksheet 1E	- Sur	nmary R	esults	for Rura	Two-L	ane Two	-Way R	oadway	Segmer	nts						
						1														-			-	-	Prope	rty Damag	e Only	(PDO)	F	atal and I	niury (F	n		Total	i.	-		
	1		1	1.1	-	Rig	ght Shoulder	Left	Shoulder		[-]	- 1	-	14	2	1	1			-														-	- 1			-
#	Roadway	Roadway Section	Jurisdiction	Length of segment, L (miles)	AADT (vehicles/day)	Lane width (feet) Width	Туре	Width	Type	Length of horizontal curve (miles)	Radius of curvature (feet) Spiral transition curve (presentinot present)	Superelevation variance (feet/foot)	Grade (%)	Driveway density (driveways/mile)	Persent (2 lane) / not present (1 lane) / present (2 lane) / not present)	Roadside hazard rating (1-7 scale)	Segment lighting (present/not present) Auto speed enforcement (present/not present	Additional CMF - 1	Additional CMF - 2	Additional CMF - 3	Additional CMF - Numeric	Observed Crashes N aserva (crashes/year)	Ovedispersion Parameter, k	Weighted Adjustment w (Equation A-5 from Part C Appendix)	Expected Average Crash Frequency, N espected (Equation A-4 from Part C Appendix)	Excess Expected Crashes Noterand - Nepecter	Crash Severity Distribution (proportion)	Predicted average crash frequency (crashes/year)	Roadway segment length (miles)	Crash rate (crashes/mile/year)	Crash Severity Distribution (proportion)	Predicted average crash frequency (crashes/year)	Roadway segment length (miles)	Crash rate (crashes/mile/year)	Crash Severity Distribution (proportion)	Previceo average crash requency (crashes/year)	Roadway segment length (miles)	Crash rate (crashes/mile/year)
1	Ferndale Rd	Slater Rd to Rayhorst Rd	Lummi Nation	0.4	1,000	10 0	Turf	0	Turf	N/A	N/A NP	0	1 2	.632 N	IP NP N	P 4	NP NP	N/A (1.000)	N/A (1.000)	N/A (1.000)	-	0.00	0.621	0.924	0.00	0.00	0.7	0.09	0.4	0.24	0.3	0.04	0.4	0.11	1.0	0.13	0.4	0.35
2	Marine Dr	Raynorts Rd to Marine Dr Ferndale Rd to Triangle	Lummi Nation	1.5	1,000	10 0	Turf	0	Turf	N/A N/A	N/A NP	0	2.6	0 N		P 4	NP NP	N/A (1.000)	N/A (1.000)	N/A (1.000)	-	0.40	0.156	0.924	0.52	-0.12	0.7	0.36	1.5	1.03	0.3	0.17	1.5	0.11	1.0	1.21	1.5	0.35
4	Marine Dr Southern Curve	Marine Dr to Lummi Shore Rd	Lummi Nation	0.1	3,906	11 0	Turf	o	Turf	0.09	267.29 NP	0	10	0 1	P NP N	P 4	NP NP	N/A (1.000)	N/A (1.000)	N/A (1.000)	-	0.40	2.360	0.440	0.46	-0.06	0.7	0.37	0.1	3.67	0.3	0.17	0.1	1.73	1.0	0.54	0.1	5.40
5	Marine Dr Northern Curve	Marine Dr to Lummi Shore Dr	Lummi Nation	0.1	1,200	10 0	Turf	0	Turf	0.05	194.57 NP	0	10	0 N		P 4	NP NP	N/A (1.000)	N/A (1.000)	N/A (1.000)	1	0.00	2.360	0.569	0.00	0.00	0.7	0.22	0.1	2.18	0.3	0.10	0.1	1.03	1.0	0.32	0.1	3.22
6	Kwina Rd	Lummi Shore Dr/Rd to Chief Martin Rd	Lummi Nation	0.7	3,621	12 5	Paved	5	Paved	N/A	N/A NP	0	2.9	20 N	IP NP N	IP 3	P NP	N/A (1.000)	N/A (1.000)	N/A (1.000)	-	0.20	0.352	0.769	0.70	-0,50	0.7	0.58	0.7	0.86	0.3	0.27	0.7	0.41	1.0	0.85	0.7	1.27
7	Kwina Rd	Chief Martin Rd to Haxton Way	Lummi Nation	0.3	3,893	12 5	Paved	5	Paved	N/A	N/A NP	0	3.4 6	.897 N	IP NP N	P 3	P NP	N/A (1.000)	N/A (1.000)	N/A (1.000)	2	0.00	0.814	0.787	0.00	0.00	0.7	0.23	0.3	0.78	0.3	0.11	0.3	0.37	1.0	0.33	0.3	1.15
8	Kwina Rd	Haxton Way to Dike Rd	Lummi Nation	0.2	571	12 5	Paved	5	Paved	N/A	N/A NP	0	0.4 1	1,76 N	IP NP N	P3	NP NP	N/A (1.000)	N/A (1.000)	N/A (1.000)	_	0.20	1.388	0.955	0.04	0.16	0.7	0.02	0.2	0.14	0.3	0.01	0.2	0.06	1.0	0.03	0.2	0.20
10	Hillaire Pd	Dike Rd to Hillaire Rd Kwina Dd to N Ded Diver Dd	Lummi Nation	1.0	5/1	9 0	Turf	0	Turf	N/A N/A	N/A NP	0	1.8	0 0		P 3	NP NP	N/A (1.000)	N/A (1.000)	N/A (1.000)	-	0.00	0.437	0.960	0.00	0.00	0.7	0.06	0.5	0.12	0.5	0.03	1.0	0.06	1.0	0.09	0.5	0.17
11	Slater Rd	Ferndale Rd to imhoff Rd	Lummi Nation	0.5	10 621	11 6	Paved	5	Paved	N/A	N/A NP	0	0.7	0 1		P 3	NP NP	N/A (1 000)	N/A (1.000)	N/A (1 000)	-	0.00	0.482	0.592	0.00	0.00	0.7	0.00	0.5	1.98	0.3	0.46	0.5	0.94	1.0	1.43	0.5	2.92
12	Slater Rd	imhoff Rd to 5 Red River Rd	Lummi Nation	0.3	10.621	11 6	Paved	6	Paved	N/A	N/A NP	0	1.7 1	1.11 N		P 3	NP NP	N/A (1.000)	N/A (1.000)	N/A (1.000)		0.40	0.874	0.577	0.65	-0.25	0.7	0.57	0.3	2.11	0.3	0.27	0.3	1.00	1.0	0.84	0.3	3.11
13	Slater Rd	S Red River Rd to Haxton Way	Lummi Nation	0.7	10,621	11 6	Paved	6	Paved	N/A	N/A NP	0	1.6 2	.817 N		P 3	NP NP	N/A (1.000)	N/A (1.000)	N/A (1.000)	-	2.20	0.332	0.592	2.12	0.08	0.7	1.41	0.7	1.98	0.3	0.67	0.7	0.94	1.0	2.07	0.7	2.92
14	Slater Rd	Haxton Way to Elder Rd	Lummi Nation	1.5	2,177	11 6	Paved	6	Paved	N/A	N/A NP	0	1.4 0	.667 N		P 3	NP NP	N/A (1.000)	N/A (1.000)	N/A (1.000)	-	1.40	0.157	0.876	0.96	0.44	0.7	0.61	1.5	0.41	0.3	0.29	1.5	0.19	1.0	0.90	1.5	0.60
15	Slater Rd	Elder Rd to Lake Terrell Rd	Lummi Nation	1.0	2,177	11 6	Paved	6	Paved	N/A	N/A NP	0	3.9	0.25 N	IP NP N	P 3	NP NP	N/A (1.000)	N/A (1.000)	N/A (1.000)	1	2.40	0.236	0.866	0.89	1.51	0.7	0.45	1.0	0.45	0.3	0.21	1.0	0.21	1.0	0.66	1.0	0.66
16	Slater Rd	Lake Terrell Rd to Curve	Lummi Nation	1.0	2,177	11 0	Turf	0	Turf	N/A	N/A NP	0	2.2	ZN	IP NP N	IP 3	NP NP	N/A (1.000)	N/A (1.000)	N/A (1.000)		1,00	0.234	0.846	0.81	0.19	0.7	0.53	1.0	0.52	0.3	0.25	1.0	0.25	1.0	0.78	1.0	0.77
17	Curve	Slater Rd to Beach Way	Lummi Nation	0.1	2,014	12 2	Gravel	2	Gravel	0.05	120.39 NP	0	0.3	0 N	IP NP N	P 5	NP NP	N/A (1.000)	N/A (1.000)	N/A (1.000)	2	0.80	2.360	0.378	0.76	0.04	0.7	0.47	0.1	4.73	0.3	0.22	0.1	2.23	1.0	0.70	0.1	6.96
18	Beach Way	Curve to Curve	Lummi Nation	0.2	2,014	10 0	Turf	0	Turf	N/A	N/A NP	0	5.6 6	6.67 N	IP NP N	P 4	NP NP	N/A (1.000)	N/A (1.000)	N/A (1.000)	-	0.20	1.311	0.602	0.38	-0.18	0.7	0.34	0.2	1.90	0.3	0.16	0.2	0.90	1.0	0.50	0.2	2.80
19	Curve Reach Way	Beach Way to Beach Way	Lummi Nation	0.1	2,014	11 0	Turf	0	Turf	0.05	106.76 NP	0	0.3	30 N		P 4	NP NP	N/A (1.000)	N/A (1.000)	N/A (1.000)	-	0.00	4.720	0.342	0.00	0.00	0.7	0.28	0.1	5.55	0.5	0.13	0.1	2.61	1.0	0.41	0.1	8.14
20	Curve	Beach Way to Sucia Dr	Lummi Nation	0.0	2,014	11 0	Turf	0	Turf	0.04	99 NP	0	0.2	0 1		P 4	NP NP	N/A (1.000)	N/A (1.000)	N/A (1 000)	-	0.00	5 900	0.732	0.00	0.00	0.7	0.29	0.0	7.21	0.3	0.14	0.0	3.41	1.0	0.42	0.0	10.61
22	Sucia Dr	Curve to Germaine Dr	Lummi Nation	0.1	2.014	10 0	Turf	õ	Turf	N/A	N/A NP	0	0.1	130 N		P 3	NP NP	N/A (1.000)	N/A (1.000)	N/A (1.000)		0.20	2.360	0.515	0.30	-0.10	0.7	0.27	0.1	2.71	0.3	0.13	0.1	1.28	1.0	0.40	0.1	3.99
23	Sucia Dr	Germaine Dr to Cleo Rose Ln	Lummi Nation	0.4	1,752	10 0	Turf	0	Turf	N/A	N/A NP	0	1.9 3	3.33 N		P 3	NP NP	N/A (1.000)	N/A (1.000)	N/A (1.000)		0.00	0.656	0.766	0.00	0.00	0.7	0.32	0.4	0.88	0.3	0.15	0.4	0.42	1.0	0.47	0.4	1.30
24	Sucia Dr	Cleo Rose Ln to End	Lummi Nation	1.4	1,591	10 0	Turf	0	Turf	N/A	N/A NP	0	0.7 8	7.32 N		P 3	NP NP	N/A (1.000)	N/A (1.000)	N/A (1.000)		0.00	0.166	0.654	0.00	0.00	0.7	2.16	1.4	1.52	0.3	1.02	1.4	0.72	1.0	3.18	1.4	2.24
25	Patos Dr	Sucia Rd to End	Lummi Nation	0.2	262	9 0	Turf	0	Turf	N/A	N/A NP	0	2.5 6	6.67 N	IP NP N	P 3	NP NP	N/A (1.000)	N/A (1.000)	N/A (1.000)	1	0.00	1.124	0.930	0.00	0.00	0.7	0.05	0.2	0.21	0.3	0.02	0.2	0.10	1.0	0.07	0.2	0.32
2.6	Lake Terrell Rd	Slater Rd to Curve	Lummi Nation	1.0	1,397	9 0	Turf	0	Turf	N/A	N/A NP	0	10.1 1	6.84 N	IP NP N	P 4	NP NP	N/A (1.000)	N/A (1.000)	N/A (1.000)		0.00	0.248	0.819	0.00	0.00	0.7	0.60	1.0	0.64	0.3	0.29	1.0	0.30	1.0	0.89	1.0	0.94
.27	Curve	Lake Terrell Rd to N Red River Rd	Lummi Nation	0.1	900	10 0	Turf	0	Turf	0.05	94.24 NP	0	0.3	0 N	IP NP N	P 4	P NP	N/A (1.000)	N/A (1.000)	N/A (1.000)	2	0.00	4.720	0.568	0.00	0.00	0.7	0.11	0.1	2.19	0.3	0.05	0.1	1.03	1.0	0.16	0.1	3.22
2.8	IN Red River Rd	Curve to Hillaire Rd	Lummi Nation	1.6	600	9 0	Turf	0	Turf	0.16	603.61 NP	0	2.7	12.5 N	IP NP N	P 4	PNP	N/A (1.000)	N/A (1.000)	N/A (1.000)	-	0.80	0.148	0.919	0.61	0.19	0.7	0.40	1.6	0.25	0.3	0.19	1.6	0.12	1.0	0.59	1.6	0.37
29	S Red River Rd	Hillaire Rd to Haxton Way	Lummi Nation	1.1	24/	9 0	Turf	0	Turf	0.18	605 16 NP	0	1.4	O N	IP NP N	P 4	NP NP	N/A (1.000)	N/A (1.000)	N/A (1.000)	-	0.40	0.211	0.972	0.14	0.26	0.7	0.09	11	0.08	0.5	0.04	11	0.04	1.0	0.13	11	0.12
31	S Red River Rd	Haxton Way to Slater Dr	Lummi Nation	1.2	225	9 0	Turf	0	Turf	0.28	557.66 NP	0	2.3 4	167 N	P NP N	P 4	NP NP	N/A (1.000)	N/A (1.000)	N/A (1.000)		0.60	0.197	0.979	0.12	0.48	0.7	0.08	12	0.05	0.3	0.04	12	0.03	1.0	0.11	12	0.09
32	Haxton Way	Slater Rd to N Red River Rd	Lummi Nation	0.6	5,482	10 4	Turf	4	Turf	N/A	N/A NP	0	0.5 6	557 N		P 3	NP P	N/A (1.000)	N/A (1.000)	N/A (1.000)		0.80	0.387	0.697	1.03	-0.23	0.7	0.76	0.6	1.25	0.3	0.36	0.6	0.59	1.0	1.12	0.6	1.84
33	Haxton Way	N Red River Rd to Lummi Shore Dr	Lummi Nation	0.4	5,184	10 2	Turf	2	Turf	N/A	N/A NP	0	1.6 1	4.29 N		P 3	NP NP	N/A (1.000)	N/A (1.000)	N/A (1.000)		0.60	0.674	0.648	0.73	-0.13	0.7	0.55	0.4	1.56	0.3	0.26	0.4	0.74	1.0	0.81	0.4	2.30
34	Haxton Way	Lummi Shore Dr to Kwina Rd	Lummi Nation	0.9	4,000	10 2	Turf	2	Turf	0.14	1235.62 NP	0	1.8 4	.598 N	P NP N	P 3	NP NP	N/A (1.000)	N/A (1.000)	N/A (1.000)		1.00	0.271	0.685	1.47	-0,47	0.7	1.15	0.9	1.32	0.3	0.54	0.9	0.62	1.0	1.69	0.9	1.94
35	Haxton Way	Kwina Rd to Boynton Rd	Lummi Nation	1.9	5,187	10 6	Paved	6	Paved	N/A	N/A NP	0	4.7 4	.301 N	IP NP N	P 3	NP P	N/A (1.000)	N/A (1.000)	N/A (1.000)	1	1.60	0.127	0.718	2.67	-1.07	0.7	2.10	1.9	1.13	0.3	0.99	1.9	0.53	1.0	3.09	1.9	1.66
36	Haxton Way	Boynton Rd to Cagey Rd	Lummi Nation	0.9	5,187	10 6	Paved	6	Paved	N/A	N/A NP	0	7.8	0 N	IP NP N	IP 3	NP P	N/A (1.000)	N/A (1.000)	N/A (1.000)	-	0.40	0.278	0.707	1.17	-0,77	0.7	1.01	0.9	1.19	0.3	0.48	0.9	0.56	1.0	1.49	0.9	1.75
37	Haxton Way	Cagey Rd to Sunset Way	Lummi Nation	0.3	4,553	10 6	Paved	6	Paved	N/A	N/A NP	0	7.2	0 N	IP NP N	P 3	NP NP	N/A (1.000)	N/A (1.000)	N/A (1.000)	-	0.00	0.843	0.719	0.00	0.00	0.7	0.31	0.3	1.12	0.3	0.15	0.3	0.53	1.0	0.46	0.3	1.65
38	Haxton Way	Sunset Way to Baich Rd	Lummi Nation	0.3	4,553	10 6	Paved	6	Paved	N/A	N/A NP	0	15.6 3	.448 N	IP NP N	P 3	NP NP	N/A (1.000)	N/A (1.000)	N/A (1.000)	-	0.00	0.814	0.719	0.00	0,00	0.7	0.33	0.3	1.12	0.3	0.15	0.3	0.53	1.0	0.48	0.3	1.65
39	Haxton Way	Smokehouse Rd to Southeate Rd	Lummi Nation	0.3	2 294	10 0	Paved	0	Paved	N/A	N/A NP	0	3.7 4	8 28 M		P 3	PNP	N/A (1.000)	N/A (1.000)	N/A (1 000)	-	0.40	0.845	0.735	0.42	-0.12	0.7	0.29	0.5	1.04	0.3	0.14	0.5	0.49	1.0	0.45	0.3	1.95
41	Haxton Way	Southeate Rd to MacKenzie Rd	Lummi Nation	0.5	2,294	10 4	Paved	0	Paved	N/A	N/A NP	0	83 3	4 71 N	IP NP N	P 3	NP NP	N/A (1 000)	N/A (1.000)	N/A (1.000)		0.60	0.621	0.695	0.52	-0.07	0.7	0.48	0.4	1.35	0.5	0.10	0.5	0.59	1.0	0.70	0.4	1.85
42	Lummi View Dr	MacKenzie Rd to Grove Rd	Lummi Nation	0.3	3,967	10 4	Paved	0	Paved	N/A	N/A NP	0	2.5 7	4.19 N	P NP N	P 3	PNP	N/A (1.000)	N/A (1.000)	N/A (1.000)		0.40	0.761	0.543	0.78	-0.38	0.7	0.75	0.3	2.42	0.3	0.35	0.3	1.14	1.0	1.11	0.3	3.57
43	Curve	Lummi View Dr to Finkbonner Rd	Lummi Nation	0.2	3,967	10 4	Paved	0	Paved	0.23	561.77 NP	0	3.2	35.5 N		P 3	P NP	N/A (1.000)	N/A (1.000)	N/A (1.000)	1	0.00	1.047	0.541	0.00	0.00	0.7	0.55	0.2	2.44	0.3	0.26	0.2	1.15	1.0	0.81	0.2	3.59
44	Lummi View Dr	Finkbonner Rd to Lena Rd	Lummi Nation	0.3	3,967	9 0	Turf	0	Turf	0.11	874.34 NP	0	4	24 N	P NP N	P 3	P NP	N/A (1.000)	N/A (1.000)	N/A (1.000)		0.20	0.944	0.517	0.61	-0.41	0.7	0.67	0.3	2.69	0.3	0.32	0.3	1.27	1.0	0.99	0.3	3.96
45	Curve	Lummi View Dr to MacKenzie Rd	Lummi Nation	0.1	3,967	9 0	Turf	0	Turf	0.09	391.53 NP	0	6	0 N	P NP N	P 3	P NP	N/A (1.000)	N/A (1.000)	N/A (1.000)	-	0.20	4.720	0.491	0.21	-0.01	0.7	0.15	0.1	2.98	0.3	0.07	0.1	1.41	1.0	0.22	0.1	4.39
46	Lummi View Dr	MacKenzie Rd to Blackhawk Way	Lummi Nation	0.5	1,124	10 0	Turf	0	Turf	0.21	883.35 NP	0	2.9 2	5.53 N	P NP N	P 3	PP	N/A (1.000)	N/A (1.000)	N/A (1.000)	4	0.40	0.502	0.852	0.35	0.05	0.7	0.23	0.5	0.50	0.3	0.11	0.5	0.24	1.0	0.34	0.5	0.73

		Worksheet 1A General Information and Input Data for Rural Two-Lane Two-Way Roadway Segments Right Shoulder Left Shoulder															E	mpirica	I Bayes	s Analysi	s	Worl	ksheet 1	E – Su	mmary F	Results	for Rura	al Two-l	Lane Tw	o-Way R	oadway	Segmen	its						
1			ht Shoulder	Left	Shoulder													21				11		Prope	rty Dama	ige Only	(PDO)	F	atal and	Injury (F	FI)		Total						
	oadway	cadway Section	uńsdiction	ength of segment, L (miles)	ADT (vehicles/day)	ane width (feet) Vidth	ype	Vidth	ype	ength of horizontal curve (miles)	adius of curvature (feet)	piral transition curve (presenting present)	stade (%)	ntiveway density (driveways/mile)	enterline rumble strips (present/not present) assing lanes (present (1 lane) / mesont (2 lane) / nor mesont))	wo-way left-turn lane (present/hot present)	(badside hazard rating (1-7 scale)	regreek enforcement (present/not present)	ddtional CMF - 1	ddtlonal CMF - 2	dditional CMF - 3	dditional CMF - Numeric	bserved Crashes N operate (crashes/year)	ivedispersion Parameter, k	vegmed Adjustment, w Equation A-5 from Part C Appendix)	xpected Average Crash Frequency, N ∞eete Equation A-4 from Part C Appendix)	xcess Expected Crashes downed Nepedee	rash Severity Distribution (proportion)	redicted average crash frequency crashes/year)	(oadway segment length (miles)	tash rate (crashes/mile/year)	rash Severity Distribution (proportion)	redicted average crash frequency crashes/year/	(badway segment length (miles)	tash rate (crashes/mile/year)	ash Severity Distribution (proportion)	reoxed average crash irequency crashes/year)	(sadway segment lengin (miles)	itash rate (crashes/mieryear)
11	1 Lummi Shore Rd	Smokehouse Rd to Shorewood Ln	Lummi Nation	0.5	1.500	10 5	Paved	5	Paved	N/A	N/A	NP U	0 7.7	11.1	INP NP	NP	3 N	P NP 1	< 10001	N/A (1.000)	N/A (1.000)	4	0.20 0	0.524	0.867	0.28	-0.08	0.7	0.20	0.5	0.44	0.3	0.09	0.5	0.21	1.0	0.29	0.5	0.65
5	2 Lummi Shore Rd	Shorewood Ln to Beach Pl	Lummi Nation	0.2	1,500	10 5	Paved	5	Paved	N/A	N/A	NP	0 5.3	26.0	NP NP	NP	3 F	P NP I	N/A (1.000)	N/A (1.000)	N/A (1.000)		0.40 1	1.026	0.839	0.22	0.18	0.7	0.13	0.2	0.55	0.3	0.06	0.2	0.26	1.0	0.19	0.2	0.81
5	3 Lummi Shore Rd	Beach Pl to Cagey Rd	Lummi Nation	0.4	1,500	10 5	Paved	5	Paved	N/A	N/A	NP	0 6.1	14.6	NP NP	NP	3 N	PNP	N/A (1.000)	N/A (1.000)	N/A (1.000)		0.40 0	0.576	0.855	0.31	0.09	0.7	0.20	0.4	0.49	0.3	0.09	0.4	0.23	1.0	0.29	0.4	0.72
5	4 Lummi Shore Rd	Cagey Rd to Curve	Lummi Nation	0.6	2,270	9 0	Turf	0	Turf	0.17	746.25	NP	0 4.1	8.77	NP NP	NP	4 N	P NP	N/A (1.000)	N/A (1.000)	N/A (1.000)	-	0.40 0	0.414	0.696	0.86	-0.46	0.7	0.72	0.6	1.26	0.3	0.34	0.6	0.59	1.0	1.06	0.6	1.85
5	5 Curve	Lummi Shore Rd to Lummi Shore Rd	Lummi Nation	0.9	2,270	9 0	Turf	0	Turf	0.89	2316.23	NP	0 2.7	8.98	NP NP	NP	4 N	P NP	N/A (1.000)	N/A (1.000)	N/A (1.000)	_	1.00 0	0.265	0.775	1.08	-0.08	0.7	0.74	0.9	0.84	0.3	0.35	0.9	0.40	1.0	1.10	0.9	1.23
5	5 Lummi Shore Rd	Curve to Scott Rd	Lummi Nation	0.6	2,270	9 0	Turf	0	Turf	N/A	N/A	NP	0 3.6	1.66	7 NP NP	NP	4 N	P NP	N/A (1.000)	N/A (1.000)	N/A (1.000)		0.20 0	0.393	0.782	0.60	-0,40	0.7	0.48	0.6	0.80	0.3	0.23	0.6	0.38	1.0	0.71	0.6	1.18
5	7 Lummi Shore Rd	Scott Rd to Kwina Rd	Lummi Nation	0.8	2,916	9 0	Turf	0	Turf	N/A	N/A	NP	0 6.3	5 17.1	I NP NP	NP	4 N	P NP 1	N/A (1.000)	N/A (1.000)	N/A (1.000)		1.20 0	0.311	0.666	1.48	-0.28	0.7	1.10	0.8	1.44	0.3	0.52	0.8	0.68	1.0	1.62	0.8	2.13
5	B Lummi Shore Dr	Kwina Rd to Haxton Way	Lummi Nation	1.1	1,039	9 0	Turf	0	Turf	N/A	N/A	NP	0 2.1	12.9	5 NP NP	NP	3 N	PNP	N/A [1.000]	N/A (1.000)	N/A (1.000)		0.40 0	0.219	0.900	0.50	-0,10	0.7	0.35	1.1	0.32	0.3	0.16	1.1	0.15	1.0	0.51	1.1	0.47
59	9 Smokehouse Rd	Haxton Way to Kinley Way	Lummi Nation	0.8	937	10 0	Turf	0	Turf	N/A	N/A	NP	0 3.7	13.7	S NP NP	NP	4 N	PNP	N/A [1.000]	N/A (1.000)	N/A (1.000)		0.40 0	0.295	0.899	0.38	0.02	0.7	0.26	0.8	0.32	0.3	0.12	0.8	0.15	1.0	0.38	0.8	0.48
6	Smokehouse Rd	Kinley Way to Lummi Shore Rd	Lummi Nation	1.0	937	10 0	Turf	0	Turf	N/A	N/A	NP	0 5.8	17.5	NP NP	NP	4 N	P NP	N/A (1.000)	N/A (1.000)	N/A (1.000)		0.00 0	0.243	0.889	0.00	0.00	0.7	0.35	1.0	0.36	0.3	0.17	1.0	0.17	1.0	0.52	1.0	0.53
6	1 Cagey Rd	Haxton Way to Chief Martin Rd	Lummi Nation	1.2	150	9 0	Turf	0	Turf	N/A	N/A	NP	0 5.1	1 17.7	A NP NP	NP	4 N	PNP	N/A (1.000)	N/A (1.000)	N/A (1.000)		0.00	0.190	0.980	0.00	0.00	0.7	0.07	1.2	0.06	0.3	0.03	1.2	0.03	1.0	0.11	1.2	0.09
6	2 Cagey Rd	Chief Martin Rd to Lummi Shore Rd	Lummi Nation	0.8	150	9 0	Turf	0	Turf	N/A	N/A	NP	0 7	15.1	9 NP NP	NP	4 N	P NP	N/A [1.000]	N/A (1.000)	N/A (1.000)		0.00 0	0.299	0.980	0.00	0.00	0.7	0.05	0.8	0.06	0.3	0.02	0.8	0.03	1.0	.0.07	0.8	0.08
6	3 Chief Martin Rd	Kwina Rd to Scott Rd	Lummi Nation	0.8	252	9 0	Turf	0	Turf	N/A	N/A	NP	0 3.5	5 2.59	7 NP NP	NP	4 N	PNP	N/A (1.000)	N/A (1.000)	N/A (1.000)		0.20 0	0.306	0.980	0.07	0.13	0.7	0.05	0.8	0.06	0.3	0.02	0.8	0.03	1.0	0.07	0.8	0.09
6	4 Chief Martin Rd	Scott Rd to Cagey Rd	Lummi Nation	1.8	150	9 0	Turf	0	Turf	N/A	N/A	NP	0 5.7	0.56	B NP NP	NP	4 N	PNP	N/A [1.000]	N/A (1.000)	N/A (1.000)		0.20 0	0.134	0.988	0.09	0.11	0.7	0.06	1.8	0.03	0.3	0.03	1.8	0.02	1.0	0.09	1.8	0.05
6	5 Boynton Rd	Robertson Rd to Haxton Way	Lummi Nation	0.1	200	9 0	Turf	0	Turf	N/A	N/A	NP	0 0.4	1	NP NP	NP	4 N	P NP 1	N/A (1.000)	N/A (1.000)	N/A (1.000)	1	0.00 1	1.967	0.986	0.00	0.00	0.7	0.01	0.1	0.04	0.3	0.00	0.1	0.02	1.0	0.01	0.1	0.06
6	6 Robertson Rd	Boynton Rd to Cagey Rd	Lummi Nation	0.9	350	9 0	Turf	0	Turf	N/A	N/A	NP	0 4.3	43.1	8 NP NP	NP	3 F	P NP 1	N/A (1.000)	N/A (1.000)	N/A (1.000)		0.00 0	0.268	0.935	0.00	0.00	0.7	0.18	0.9	0.20	0.3	80.0	0.9	0.09	1.0	0.26	0.9	0.29
6	7 Sunset Way	Cagey Rd to Haxton Way	Lummi Nation	0.4	150	9 0	Turf	0	Turf	N/A	N/A	NP	0 11.7	51.4	NP NP	NP	4 F	P NP 1	N/A (1.000)	N/A (1.000)	N/A (1.000)	_	0.00	0.674	0.959	0.00	0.00	0.7	0.04	0.4	0.12	0.3	0.02	0.4	0.06	1.0	0.05	0.4	0.18
5	8 MacKenzie Rd	Lummi View Dr to Lummi View Dr	Lummi Nation	0.7	150	9 0	Turf	0	Turf	N/A	N/A	NP	0 3.5	78.4	6 NP NP	NP	4 N	P NP 1	N/A [1.000]	N/A (1.000)	N/A (1.000)		0.40 0	0.363	0.942	0.18	0,22	0.7	0.12	0.7	0.18	0.3	0.05	0.7	0.08	1.0	0.17	0.7	0.26
6	9 Finkbonner Rd	MacKenzie Rd to Lummi View Dr	Lummi Nation	0.2	75	9 0	Turf	0	Turf	N/A	N/A	NP	0 3.1	43.4	8 NP NP	NP	4 N	P NP 1	N/A (1.000)	N/A (1.000)	N/A (1.000)		0.20 1	1.026	0.980	0.02	0.18	0.7	0.01	0.2	0.06	0.3	0.01	0.2	0.03	1.0	0.02	0.2	0.09
70	Scott Rd	Chief Martin Rd to Lummi Shore Rd	Lummi Nation	0.8	303	9 0	Turf	0	Turf	N/A	N/A	NP	0 4.6	5	NP NP	NP	4 N	P NP	N/A (1.000)	N/A (1.000)	N/A (1.000)		0.00 0	0.303	0.976	0.00	0.00	0.7	0.05	8.0	0.07	0.3	0.03	0.8	0.03	1.0	0.08	0.8	0.10

Intersections

	Worksheet 2A General Information and Input Data for Rural Two-Lane Two-Way Roadway Intersections														1	Empirica	al Bayes	Analysis		Worksheet	2E Sum	nary Result Road Inter	s for Rural sections	Two-Lane	Two-Way	
						_															Crash S	everity Dist	ribution	Predicte frequenc	id average y (crashes	crash / year)
	Major Roadway	Minor Roadway	Jurisdiction	Intersection Type	AADT major (vehicles/day)	AADT minor (vehicles/day)	[It 4ST, does skew differ for minor legs?]	Shew for Leg 1 (All):	Skew for Leg 2 (4ST orly):	Number of signalized or uncontrolled approaches with a left-turn lane (0, 1, 2, 3, 4)	Number of signalized or uncortrolled approaches with a right-turn lane (0, 1, 2, 3, 4)	Intersection lighting Additional CMF - 1	Additional CMF - 2	Additional CMF - 3	Additional CMF - Numeric	Observed Crashes N _{ctearved} (crashes/year)	Ovedispersion Parameter, k	Weighted Adjustment, w (Equation A 5 from Part C Appendix)	Expected Average Crash Frequency, N _{scheded} (Equation A-4 from Part CAppendix)	Excess Expected Grashes Naterved - Necession	Total	Fatal and hjury (FI)	Property Damage Orly (PDO)	Property Damage Orly (PDO)	Fatal and hjury (FI)	Total
1	Slater Rd	Ferndale Rd	Lummi Nation	4ST	10,621	1,000	N	0	0	2	0	P N/A (1.000)	N/A (1.000)	N/A (1.000)		2.00	0.240	0.724	1.70	0,30	1.000	0.431	0.6	0.91	0.69	1.59
2	Slater Rd	Imhoff Rd	Lummi Nation	3ST	10,621	750	N	0	0	1	0	P N/A (1.000)	N/A (1.000)	N/A (1.000)	_	1.20	0.540	0.644	1.09	0.11	1.000	0.415	0.6	0.60	0.42	1.02
3	Slater Rd	IS Red River Rd	Lummi Nation	3ST	10,621	225	N	0	0	0	0	NP N/A (1.000)	N/A (1.000)	N/A (1.000)		0.40	0.540	0.622	0.85	-0.45	1.000	0.415	0.6	0.66	0.47	1.12
4	Slater Rd	Haxton Way	Lummi Nation	4SG	8,000	5,482	N	0	0	2	1	P N/A (1000)	N/A (1.000)	N/A (1.000)	_	3.40	0.110	0.686	3.93	-0.53	1.000	0.340	0.7	2,75	1,42	4,17
5	Slater Rd	Elder Ko	Lummi Nation	551	8,000	500	N	0	0	- 0	0	NP N/A (1000)	N/A (1.000)	N/A (1.000)	-	0.60	0.540	0.582	1.02	-0.42	1.000	0.415	0.6	0.78	0.55	1.55
0	Slater RD Hilloire Rd	Lake Lerrell RO	Lummi Nation	451	2,1//	1,397	N	10	0		0	NP N/A (1.000)	N/A (1.000)	N/A (1.000)	-	0.80	0.240	0.725	1.58	-0.58	1.000	0.431	0.6	0.91	0.69	1.60
	Hillaire Ru	F Red River Rd	Cummi Nation	201	500	24/	N N	10	0			NP N/A (1000)	N/A (1.000)	N/A (1.000)	-	0.20	0.540	0.944	0.11	0.09	1.000	0.415	0.6	0.06	0.05	0.11
0	Hinaire Ku	N Red River Rd	Lummi Nation	457	500	245	N.	10	60		0	NP N/A (1000)	N/A (1.000)	N/A (1.000)	-	0.00	0.540	0.940	0.00	0.00	1.000	0.415	0.6	0.06	0.04	1.17
10	Haxton Way	5 Pad Piver Pd	Lummi Nation	451	5,104	24/	N V	45	60		0	P N/A (1000)	N/A (1.000)	N/A (1.000)		0.20	0.240	0.700	0.90	-0.70	1.000	0.451	0.6	0.67	0.51	1.1/
11	Hayton Way	Lummi Shore Rd	Lummi Nation	357	5 184	1 030	N	60	0			P N/A (1.000)	N/A (1.000)	N/A (1.000)	-	0.00	0.540	0.545	0.00	0.00	1.000	0.415	0.6	0.01	0.40	1.55
17	Ywina Dd	Hillaire Pd	Lummi Nation	351	571	500	N	0	0		0		N/s (1.000)	N/A (1.000)	-	0.00	0.540	0.043	0.00	0.00	1.000	0.415	0.6	0.10	0.04	0.17
13	Haxton Way	Kwina Rd	Lummi Nation	4SG	5.187	3.893	N	30	0	- o	ō	P Losent to conditional like	N/A (1.000)	N/A (1.000)		0.80	0.110	0.855	1.43	-0.63	1.000	0.340	0.7	1.02	0.52	1.54
14	Kwina Rd	Chief Martin Rd	Lummi Nation	3ST	3,893	252	N	0	0	0	0	P N/A (1000)	N/A (1.000)	N/A (1.000)		0.20	0.540	0.792	0.43	-0.23	1.000	0.415	0.6	0.28	0.20	0.48
15	Kwina Rd	Lummi Shore Dr	Lummi Nation	3ST	3.893	2,916	N	0	0	0	0	P N/A (1000)	N/A (1.000)	N/A (1.000)		0.40	0.540	0.535	1.05	-0.65	1.000	0.415	0.6	0.94	0.67	1.61
16	Marine Dr	Lummi Shore Dr	Lummi Nation	3ST	3,906	2,916	N	45	0	0	0	NP N/A (1000)	N/A (1.000)	N/A (1.000)		0.00	0.540	0.463	0.00	0.00	1.000	0.415	0.6	1.25	0.89	2.14
17	Marine Dr	Lummi Shore Rd	Lummi Nation	3ST	3,906	2,915	N	60	0	0	0	NP N/A (1000)	N/A (1.000)	N/A (1.000)		0.60	0.540	0.449	1.35	-0.75	1.000	0.415	0.6	1.33	0.94	2.28
18	Marine Dr	Ferndale Rd	Lummi Nation	3ST	3,906	1,000	N	0	0	0	0	NP N/A (1.000)	N/A (1.000)	N/A (1.000)		0.00	0.540	0.636	0.00	0.00	1.000	0.415	0.6	0.62	0.44	1.06
19	Chief Martin Rd	Scott Rd	Lummi Nation	3ST	252	303	N	0	0	0	0	NP N/A (1.000)	N/A (1.000)	N/A (1.000)		0.20	0.540	0.965	0.07	0.13	1.000	0.415	0.6	0.04	0.03	0.07
20	Lummi Shore Rd	Scott Rd	Lummi Nation	3ST	2,915	303	N	10	0	0	0	NP N/A (1000)	N/A (1.000)	N/A (1.000)		0.00	0.540	0.791	0.00	0.00	1.000	0.415	0.6	0.29	0.20	0,49
21	Cagey Rd	Chief Martin Rd	Lummi Nation	3ST	330	252	N	0	0	0	0	NP N/A (1.000)	N/A (1.000)	N/A (1.000)	-	0.40	0.540	0.960	0.09	0,31	1.000	0.415	0.6	0.04	0.03	0.05
22	Haxton Way	Cagey Rd	Lummi Nation	4ST	4,300	330	N	50	50	0	0	P N/A (1.000)	N/A (1.000)	N/A (1.000)		0.00	0.240	0.779	0.00	0.00	1.000	0.431	0.6	0.67	0.51	1.19
23	Lummi Shore Rd	Cagey Rd	Lummi Nation	3ST	2,270	330	N	10	0	0	0	NP N/A (1.000)	N/A (1.000)	N/A (1.000)	_	0.00	0.540	0.816	0.00	0.00	1.000	0.415	0.6	0.24	0.17	0,42
24	Haxton Way	Smokehouse Rd	Lummi Nation	4ST	4,553	937	N	45	45	0	0	P convert to youndedout (12)	N/A (1.000)	N/A (1.000)	_	0.20	0.240	0.848	0.66	-0.46	1.000	0.431	0.6	0.42	0.32	0.74
25	Lummi Shore Rd	Smokehouse Rd	Lummi Nation	3ST	2,270	937	N	45	0	0	0	NP N/A (1.000)	N/A (1.000)	N/A (1.000)	_	0.00	0.540	0.698	0.00	0.00	1.000	0.415	0.6	0.47	0.33	0.80
26	Haxton Way	MacKenzie Rd	Lummi Nation	3ST	2,294	550	N	60	0	0	0	P N/A (1.000)	N/A (1.000)	N/A (1.000)	_	0.60	0.540	0.757	0.60	0.00	1.000	0.415	0.6	0.35	0.25	0,60
27	Mackenzie Rd	Finkbonner Rd	Lummi Nation	- 3ST	550	100	N	15	0	0	0	NP N/A (1.000)	N/A (1.000)	N/A (1.000)	-	0.00	0.540	0.960	0.00	0.00	1.000	0.415	0.6	0.05	0.03	0.08
28	Lummi View Dr	Finkbonner Rd	Lummi Nation	- 3ST	3,967	100	N	10	0	- 0	0	NP N/A (1.000)	N/A (1.000)	N/A (1.000)	_	0.00	0.540	0.837	0.00	0.00	1.000	0.415	0.6	0.21	0.15	0.36
29	Lummi view Dr	Mackenzie Rd	Lummi Nation	- 351	3,967	550	N	0	0	0	0	NP N/A (1000)	N/A (1.000)	N/A (1.000)	-	0.00	0.540	0.698	0.00	0.00	1.000	0.415	0.6	0.47	0.33	0.80
30	Marine Dr	Imarine or spur	Lummi Nation	351	3,906	500	N	45	0	1 0	0	N/A (1000)	N/A (1.000)	N/A (1.000)		0.20	0.540	0.672	0.67	-0.47	1.000	0.415	0.6	0.53	0.38	0.90



Opus International Consultants Inc. 27333 Meadowbrook Road, Suite 210 Novi, MI 48377 USA

t: +1 248 539 2222 f: +1 248 349 6862 w: www.opusinternational.com