

# **Hazard Elimination Project Evaluation**

Order # 41000017636

Hazard Elimination Project W-4823

**Evaluation of the Rumble Strip Installation  
on I-40 Business / US-421**

**Forsyth / Guilford Counties**

Documents Prepared By:

Safety Evaluation Group  
Traffic Safety Systems Management Section  
Transportation Mobility and Safety Division  
North Carolina Department of Transportation

**Principal Investigator**



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Traffic Safety Project Engineer

10-22-2012  
Date

# *Hazard Elimination Project Evaluation Documentation*

## **Subject Location**

Evaluation of Hazard Elimination Project Number W-4823 located along five different segments in Forsyth/Guilford Counties, around the City of Winston-Salem:

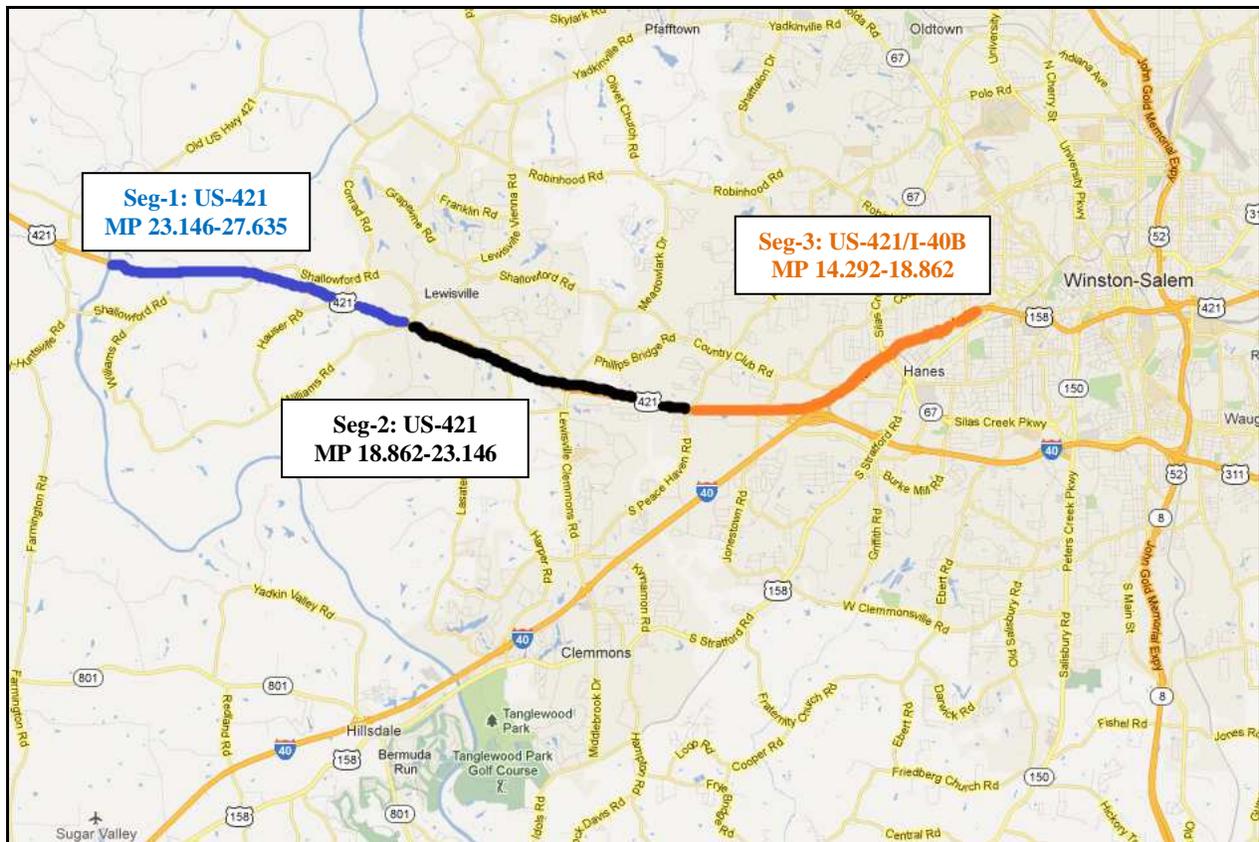
Segment 1 – US-421 in Forsyth County from SR 1171 (Concord Church Road) northward to Yadkin County Line - Forsyth MP 23.146 to 27.635 – *Total Length 4.489 miles*

Segment 2 – US-421 in Forsyth County from SR 1891 (Peace Haven Road) northward to SR 1171 (Concord Church Road) - Forsyth MP 18.862 to 23.146 – *Total Length 4.284 miles*

Segment 3 – US-421 (partially I-40 Business) in Forsyth County from SR 1891 (Peace Haven Road) southward to 0.25 mile north of US-158 (Stratford Road) – Forsyth I-40 Bus WB Couplet MP 14.292 to 16.782 and US-421 MP 16.782 to 18.862 – *Total Length 4.57 miles*

Segment 4 – I-40 Business in Forsyth County from 2.3 miles south to 4.1 miles south of US-52 – Forsyth I-40 Bus WB Couplet MP 7.20 to 9.00 - Northbound Lanes Only – *Total Length 1.80 miles*

Segment 5 – I-40 Business in Forsyth County from 4.1 miles south of US-52 to I-40 in Guilford County (analysis stopped at SR 2007 Bunker Hill overpass) - Forsyth MP 0.00 to 7.186 and Guilford MP 0.40 to 1.72 – *Total Length 8.506 miles*





## Project Information and Background from the Project File Folder

The hazard elimination project improvement chosen for the subject locations were the installation of milled rumble strips along the inside and outside shoulders of these access freeway controlled roadway segments.

I-40 Business and US-421 are both access controlled multi-lane routes with paved shoulder widths varying between 4 feet and 10 feet. There is one spot on Segment-2 where thermo pavement markings were installed instead of rumble strips due to the lack of a paved shoulder. The speed limit on all sections varies between 55-mph and 65-mph; and all roadway sections have consistent median barrier. The total countermeasure improvement distance over all routes is 23.649 miles.

Multiple construction projects were listed in the background information as being active during the analysis periods including TIP U-2728 and U-3119 on US-421 and TIP U-2827 and R-952 on I-40 Business through Winston-Salem.

The original statement of problem mentioned that vehicles were running off the road resulting in fatalities, serious injuries, and property damage. Lane departure crashes often result from fatigued or inattentive drivers. Rumble strips provide both noise and vibration as a warning to motorists that they are leaving the travel lane.

The initial crash analysis was completed from August 1, 2000 to August 1, 2003 with 226 reported correctable Ran-Off Road collisions. The improvement was completed on June 30, 2006 with a total cost of \$200,000. The projected B/C Ratio was 134.08.

## Naive Before and After Analysis

After reviewing the project file folder along with all the crashes along the subject segment, the crash data omitted from this analysis to consider for an adequate construction period were the months of April through June 2006. The before period consisted of reported crashes from June 1, 2000 through March 31, 2006 (5 years, 10 months); and the after period consisted of reported crashes from July 1, 2006 through April 30, 2012 (5 years, 10 months). The ending date for this analysis was determined by the date of available crash data at the time of analysis.

The treatment data consisted of all crashes along these segments with a zero (0) foot y-line (No Ramps). *Please see attached location map for further details.*

The following data table depicts the Naive Before and After Analysis for the treatment location. Please note that Freeway Lane Departure Crashes were the target crashes for the applied countermeasure. The Freeway Lane Departure Crash types considered are as follows: Angle; Fixed Object; Head-On; Jackknife; Overturn/Rollover; Parked Motor Vehicle; Ran-Off Roadway (Right, Left, Straight); and Sideswipe (Same and Opposite Direction). All lane departure crashes were independently verified.

<b><u>Segments B/D/E Combined</u></b>	<b>Before</b>	<b>After</b>	<b>Percent Reduction (-) Percent Increase (+)</b>
Total Crashes	1516	1370	- 9.6 %
Total Severity Index	5.01	4.00	- 20.2 %
Target Crashes – Lane Departure	876	675	- 22.9 %
Target Crash Severity Index	5.63	4.68	- 16.9 %

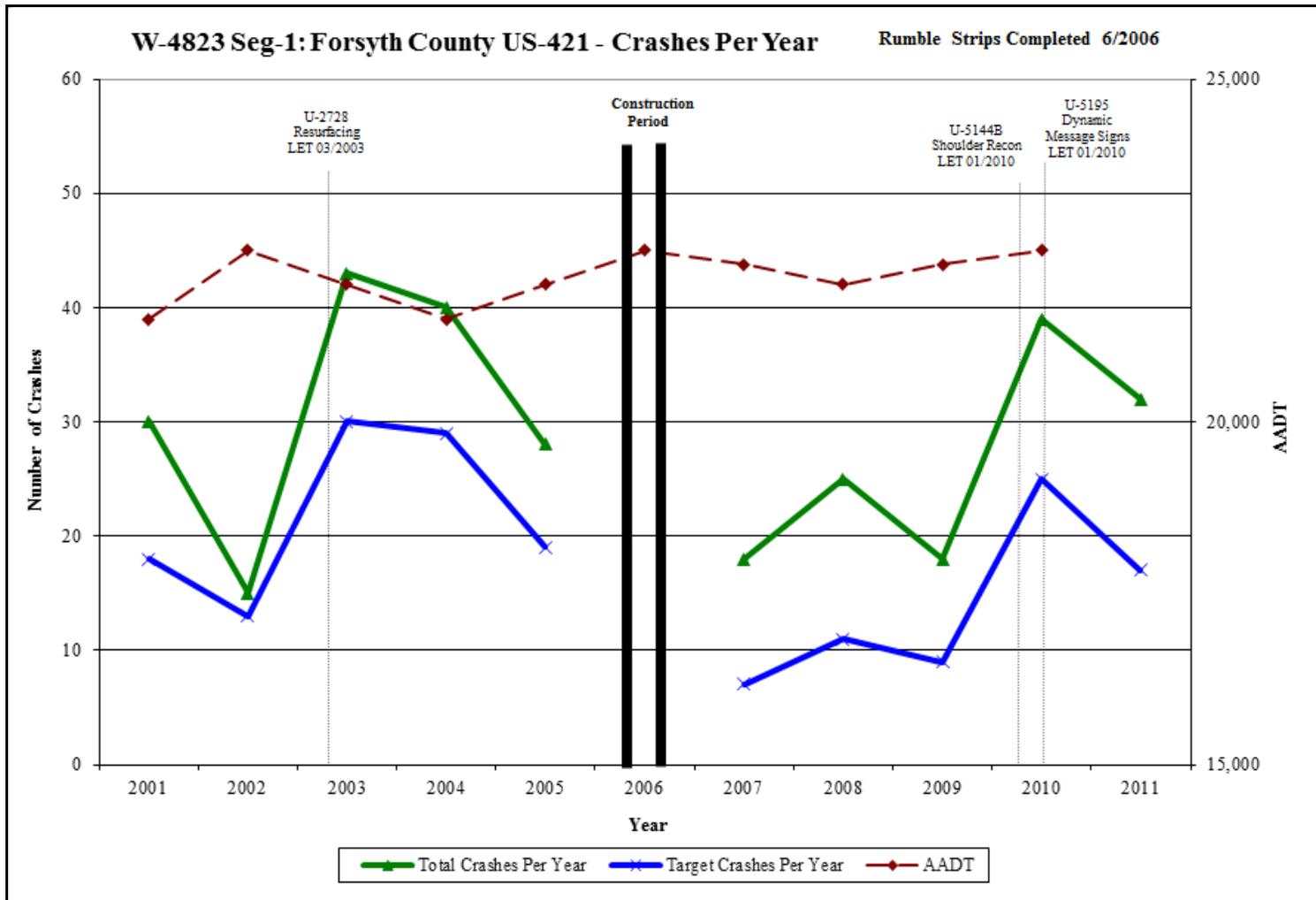
The data is further explored per segment and by direction in the tables that follow:

<b><u>S1: US-421 (MP 23.146 to 27.635)</u></b>	<b>Before</b>	<b>After</b>	<b>Percent Reduction (-)/ Percent Increase (+)</b>
Total Crashes – Both Directions	181	152	- 16.0 %
Total Severity Index	4.59	4.81	4.8 %
LD Crashes – Both Directions	121	83	- 31.4 %
Lane Departure Severity Index	4.88	6.44	32.0 %
Volume (2003, 2009)	22,500	22,000	- 2.2 %
Total Crash Rate (100 Million Vehicle Miles)	83.93	72.05	- 14.2 %
<b>Injury Crashes</b>			
Fatal Injury Crashes	2	4	100.0 %
Class-A Injury Crashes	1	1	0.0 %
Class-B Injury Crashes	17	12	- 29.4 %
Class-C Injury Crashes	40	15	- 62.5 %
Property Damage Only Crashes	121	120	- 0.8 %
<b>Contributing Factors</b>			
Night Crashes	70	60	- 14.3 %
Animal Crashes	24	42	75.0 %
Wet Road Crashes	32	32	0.0 %
Alcohol / Drug Related	11	3	- 72.7 %

<b><u>Seg-1: US-421 Northbound Only</u></b>	<b>Before</b>	<b>After</b>	<b>Percent Reduction (-)/ Percent Increase (+)</b>
NB Total Crashes	90	76	- 15.6 %
NB Total Severity Index	3.49	7.25	107.8 %
NB Lane Departure Crashes	53	37	- 30.2 %
NB Lane Departure Severity Index	3.09	11.39	268.6 %

<b><u>Seg-1: US-421 Southbound Only</u></b>	<b>Before</b>	<b>After</b>	<b>Percent Reduction (-)/ Percent Increase (+)</b>
SB Total Crashes	91	76	-16.5 %
SB Total Severity Index	5.67	2.36	- 58.4 %
SB Lane Departure Crashes	68	46	- 32.4 %
SB Lane Departure Severity Index	6.28	2.45	- 61.0 %

Segment-1 experienced a reduction of 16 percent in Total Crashes with a 31 percent reduction in Lane Departure Crashes. In addition, the Total Severity Index saw a 5 percent increase with Severe Injury Crashes (Fatal and A-injury) increased from three (3) to five (5) from the before to the after period. Contributing factors include a 75 percent increase in Animal crashes with a zero percent change in Wet Road Crashes at thirty-two (32) through the evaluation.



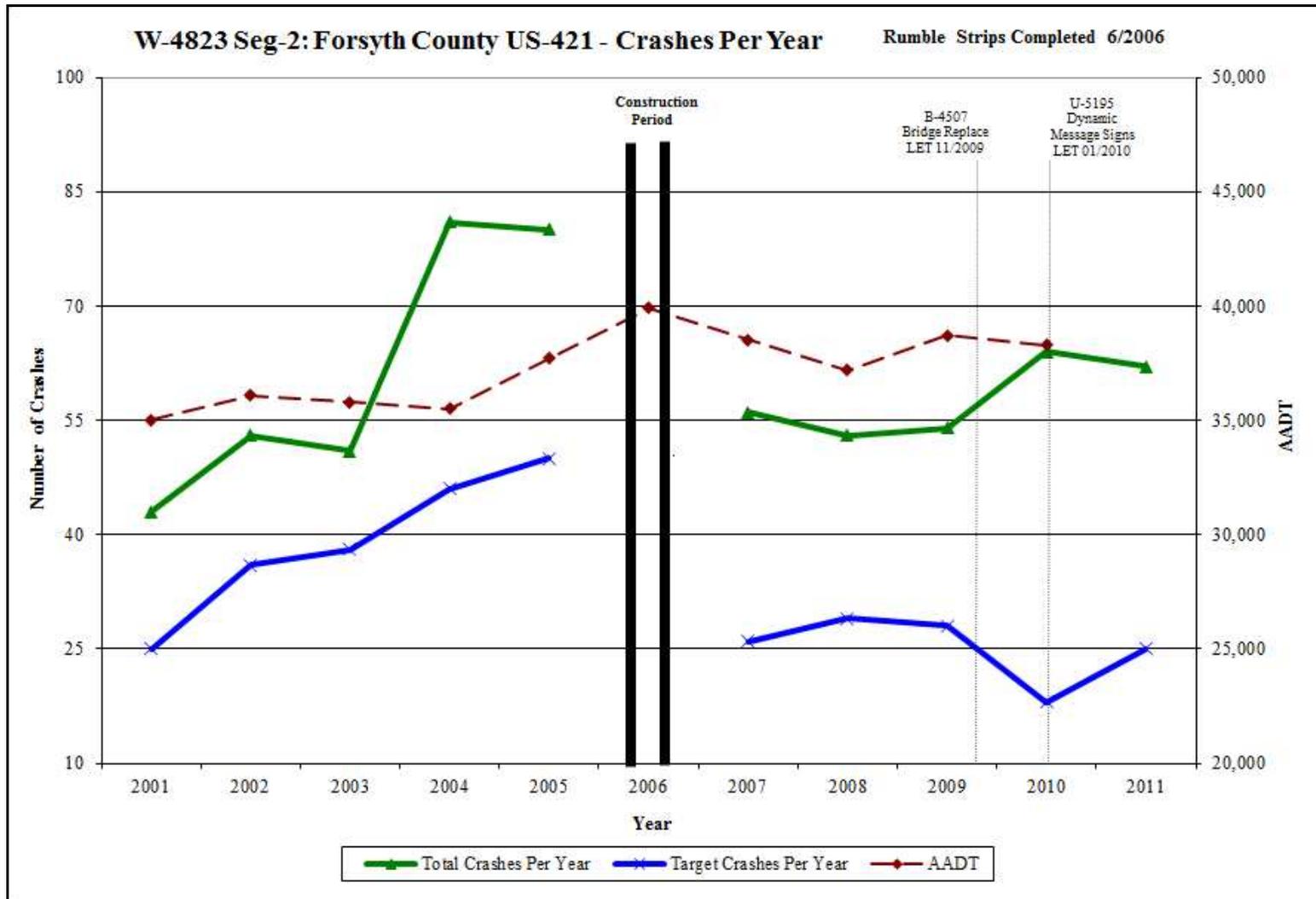
The previous chart depicts the number of Total and Target Crashes per year plotted in the before and after period for Segment-1, along with the AADT. Segment-1 lane departure crashes per year appear to have spiked in 2010 for an unknown conclusive reason. The TIP Letting website was searched for projects that were completed along these routes and three are listed above. However, the Safety Evaluation Group cannot conclude that other funds may have been used to complete construction, safety, or resurfacing projects along these roadway segments that may have affected crashes in the after period.

<b><u>S2: US-421 (MP 18.862 to 23.146)</u></b>	<b>Before</b>	<b>After</b>	<b>Percent Reduction (-)/ Percent Increase (+)</b>
Total Crashes – Both Directions	361	344	- 4.7 %
Total Severity Index	7.00	3.75	- 46.4 %
LD Crashes – Both Directions	220	151	- 31.4 %
Lane Departure Severity Index	8.44	4.45	- 47.3 %
Volume (2003, 2009)	36,100	37,200	3.0 %
Total Crash Rate (100 Million Vehicle Miles)	109.59	101.29	- 7.6 %
<b>Injury Crashes</b>			
Fatal Injury Crashes	4	1	- 75.0 %
Class-A Injury Crashes	12	2	- 83.3 %
Class-B Injury Crashes	48	31	- 35.4 %
Class-C Injury Crashes	81	66	- 18.5 %
Property Damage Only Crashes	216	244	13.0 %
<b>Contributing Factors</b>			
Night Crashes	106	81	- 23.6 %
Animal Crashes	29	35	20.7 %
Wet Road Crashes	51	49	- 3.9 %
Alcohol / Drug Related	22	11	- 50.0 %

<b><u>Seg-2: US-421 Northbound Only</u></b>	<b>Before</b>	<b>After</b>	<b>Percent Reduction (-)/ Percent Increase (+)</b>
NB Total Crashes	152	162	6.6 %
NB Total Severity Index	7.22	4.32	- 40.2 %
NB Lane Departure Crashes	97	73	- 24.7 %
NB Lane Departure Severity Index	8.34	5.41	- 35.1 %

<b><u>Seg-2: US-421 Southbound Only</u></b>	<b>Before</b>	<b>After</b>	<b>Percent Reduction (-)/ Percent Increase (+)</b>
SB Total Crashes	209	182	- 12.9 %
SB Total Severity Index	6.85	3.24	- 52.7 %
SB Lane Departure Crashes	123	78	- 36.6 %
SB Lane Departure Severity Index	8.52	3.56	- 58.2 %

Segment-2 experienced a reduction of 5 percent in Total Crashes with a 31 percent reduction in Lane Departure Crashes. In addition, the Total Severity Index saw a 46 percent reduction with Severe Injury Crashes (Fatal and A-injury) reduced significantly from sixteen (16) to three (3) from the before to the after period. Contributing factors include a 21 percent increase in Animal crashes with a slight decrease in wet road crashes from fifty-one (51) to forty-nine (49) through the evaluation.



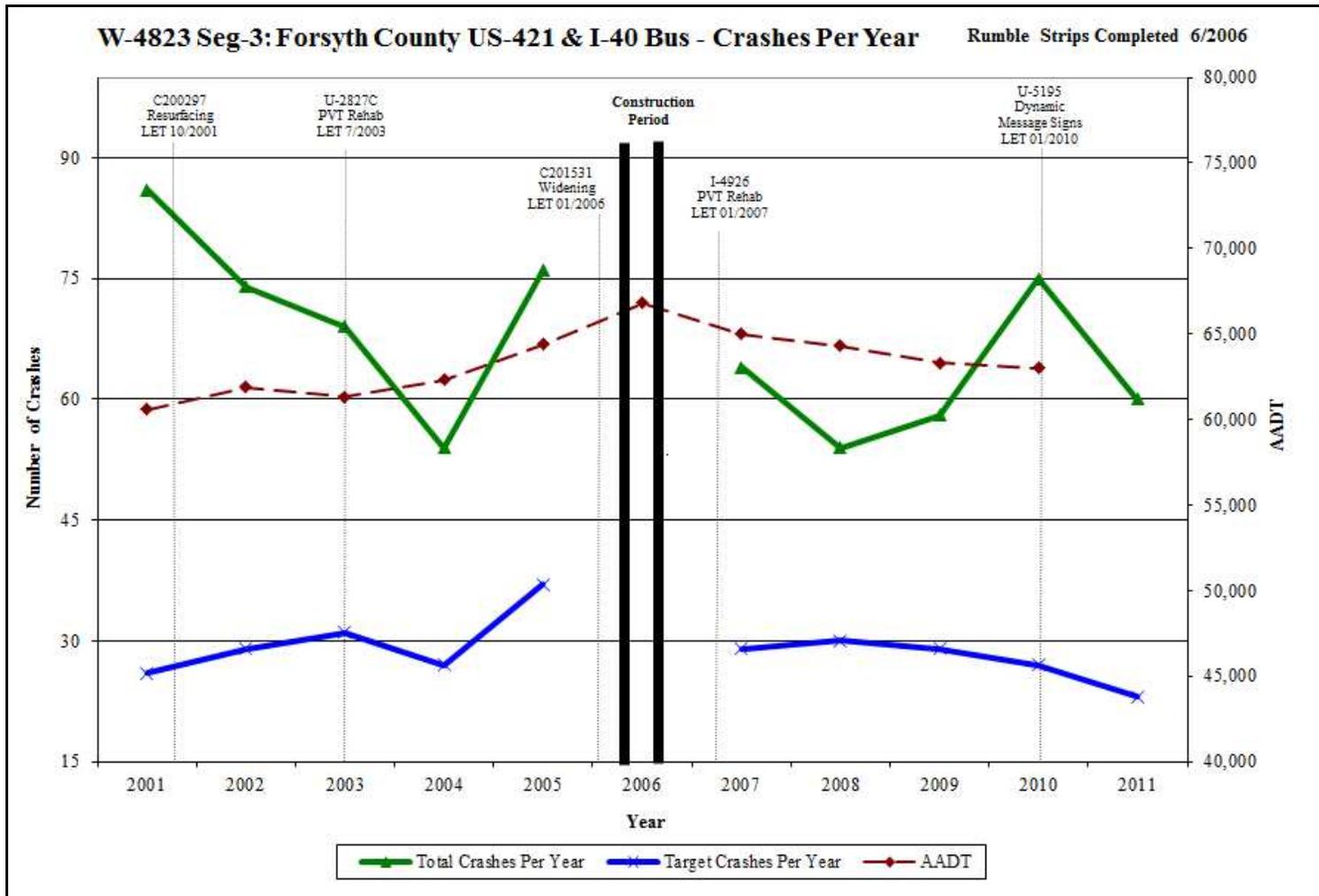
The previous chart depicts the number of Total and Target Crashes per year plotted in the before and after period for Segment-2, along with the AADT. Segment-2 total and lane departure crashes per year appear to have dropped and started a downward trend in the after period. The TIP Letting website was searched for projects that were completed along these routes and two are listed above. However, the Safety Evaluation Group cannot conclude that other funds may have been used to complete construction, safety, or resurfacing projects along these roadway segments that may have affected crashes in the after period.

<b><u>S3: I-40B/US-421 (MP 14.292-18.862)</u></b>	<b>Before</b>	<b>After</b>	<b>Percent Reduction (-)/ Percent Increase (+)</b>
Total Crashes – Both Directions	429	369	- 14.0 %
Total Severity Index	3.70	3.64	- 1.6 %
<b>LD Crashes – Both Directions</b>			
LD Crashes – Both Directions	185	155	- 16.2 %
Lane Departure Severity Index	3.53	2.77	- 21.5 %
<b>Volume (2003, 2009)</b>			
Volume (2003, 2009)	61,900	64,300	3.9 %
Total Crash Rate (100 Million Vehicle Miles)	71.20	58.93	- 17.2 %
<b>Injury Crashes</b>			
Fatal Injury Crashes	1	1	0.0 %
Class-A Injury Crashes	1	1	0.0 %
Class-B Injury Crashes	30	27	- 10.0 %
Class-C Injury Crashes	106	84	- 20.7 %
Property Damage Only Crashes	291	256	- 12.0 %
<b>Contributing Factors</b>			
Night Crashes	106	80	- 24.5 %
Animal Crashes	7	15	114.3 %
Wet Road Crashes	85	76	- 10.6 %
Alcohol / Drug Related	14	14	0.0 %

<b><u>Seg-3: I-40B/US-421 Northbound</u></b>	<b>Before</b>	<b>After</b>	<b>Percent Reduction (-)/ Percent Increase (+)</b>
NB Total Crashes	245	168	- 31.4 %
NB Total Severity Index	4.07	4.33	6.4 %
<b>NB Lane Departure Crashes</b>			
NB Lane Departure Crashes	106	78	- 26.4 %
NB Lane Departure Severity Index	3.95	2.61	- 33.9 %

<b><u>Seg-3: I-40B/US-421 Southbound</u></b>	<b>Before</b>	<b>After</b>	<b>Percent Reduction (-)/ Percent Increase (+)</b>
SB Total Crashes	184	201	9.2 %
SB Total Severity Index	3.21	3.06	- 4.7 %
<b>SB Lane Departure Crashes</b>			
SB Lane Departure Crashes	79	77	- 2.5 %
SB Lane Departure Severity Index	2.97	2.92	- 1.7 %

Segment-3 experienced a 14 percent reduction in Total Crashes and a 16 percent reduction in Lane Departure Crashes through the evaluation periods. The Total Severity Index reduced by 1.6 percent with same number of Severe Injury Crashes (Fataals and A-injury) at two (2) per evaluation period. There was a contributing factor increase in Animal Crashes of 114 percent but a reduction of 24.5 percent in Night Crashes.

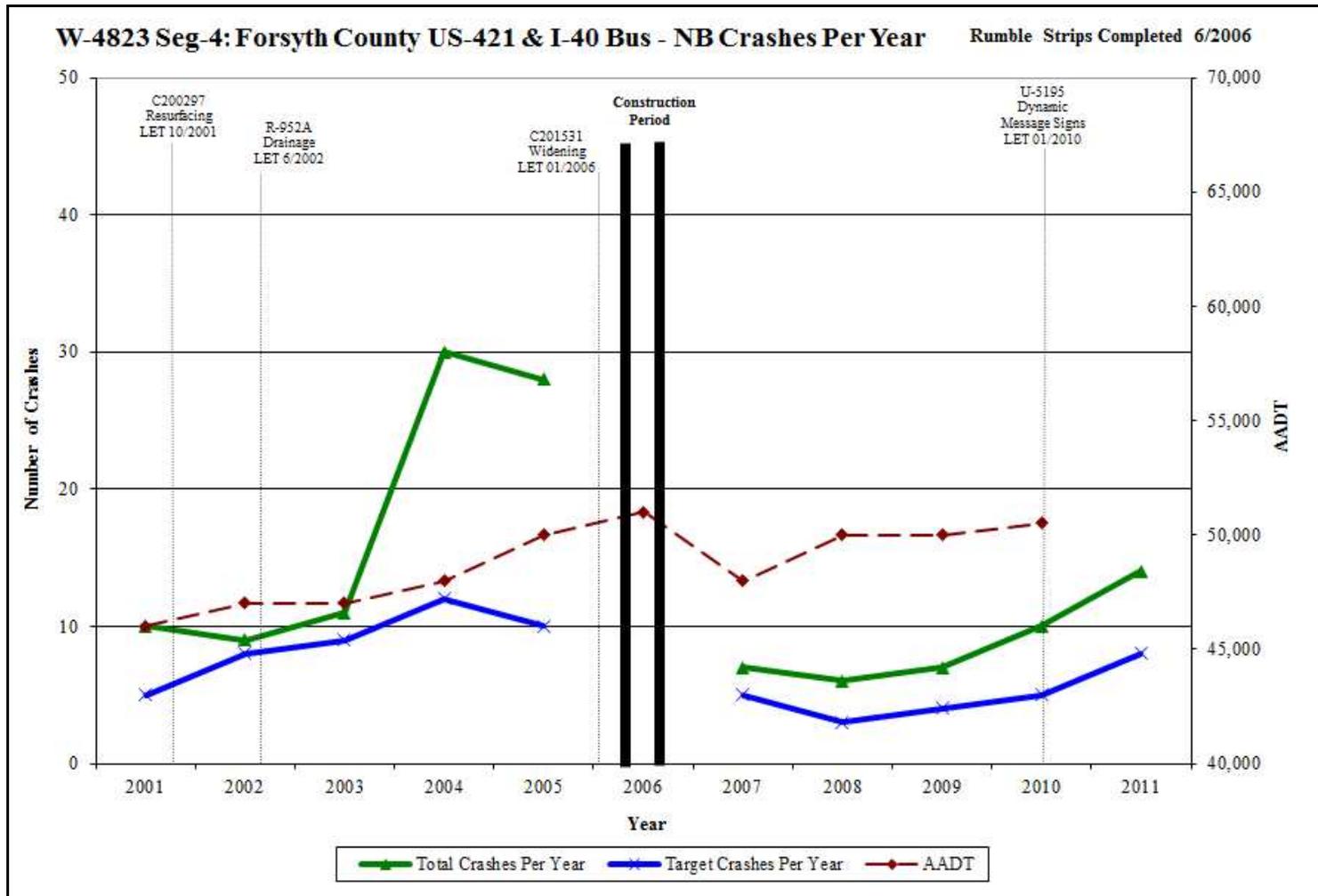


The previous chart depicts the number of Total and Target Crashes per year plotted in the before and after period for Segment-3, along with the AADT. Segment-3 lane departure crashes per year appear to be on a downward trend in the after period following a spike in 2005. The TIP Letting website was searched for projects that were completed along these routes and five (5) are listed above. However, the Safety Evaluation Group cannot conclude that other funds may have been used to complete construction, safety, or resurfacing projects along these roadway segments that may have affected crashes in the after period.

Per the project background information, Segment 4 was only treated for the northbound travel lanes of US-421 (or the Westbound Lanes of I-40 Business) from 2.3 mile south of US-52 southward to 4.1 miles south of US-52 for a total length of 1.8 miles. The following chart and data analysis is for the northbound lanes only; therefore a by direction analysis is not fully detailed here.

<b><u>S4: I-40 Bus (MP 7.20 to 9.00)</u></b>	<b>Before</b>	<b>After</b>	<b>Percent Reduction (-)/ Percent Increase (+)</b>
Total Crashes – Northbound Only	98	50	- 49.0 %
Total Severity Index	4.74	3.66	- 22.8 %
LD Crashes – Northbound Only	51	28	- 45.1 %
Lane Departure Severity Index	4.37	3.91	- 10.5 %
Volume (2003, 2009) – Both Directions	47,000	50,000	6.4 %
Total Crash Rate (100 Million Vehicle Miles)	54.38	26.07	- 52.1 %
<b>Injury Crashes</b>			
Fatal Injury Crashes	0	0	N/A
Class-A Injury Crashes	2	0	- 100.0 %
Class-B Injury Crashes	7	4	- 42.9 %
Class-C Injury Crashes	22	14	- 36.4 %
Property Damage Only Crashes	67	32	- 52.2 %
<b>Contributing Factors</b>			
Night Crashes	17	13	- 23.5 %
Animal Crashes	3	5	66.7 %
Wet Road Crashes	26	12	- 53.8 %
Alcohol / Drug Related	5	5	0.0 %

Segment-4 experienced a 49 percent reduction in Total Northbound Crashes and a 45 percent reduction in Lane Departure Crashes through the evaluation periods. The Total Severity Index reduced by 23 percent with a reduction in Severe Injury Crashes (Fatales and A-injury) from two (2) to zero (0) from the before to the after periods. The northbound segment also experienced a 54 percent reduction in Wet Road Crashes during the evaluation periods.



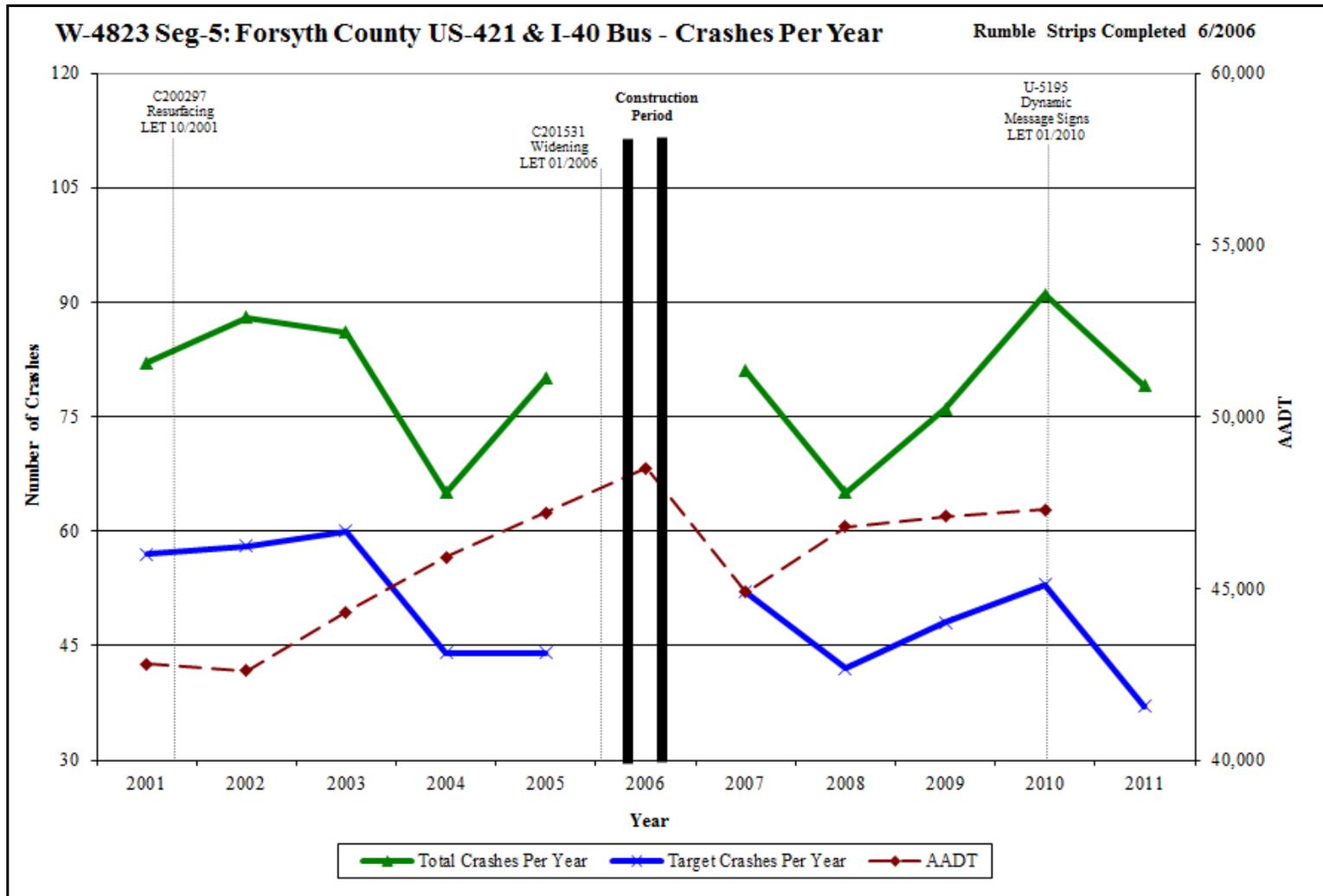
The previous chart depicts the number of Total and Target Crashes per year plotted in the before and after period for Northbound Segment-4, along with the AADT. Northbound Segment-4 total and lane departure crashes per year appear to have both dropped significantly immediately after the project and started to develop a small increasing trend. There was a spike in Total Crashes during 2004 for an unknown conclusive reason. The TIP Letting website was searched for projects that were completed along these routes and four are listed above. However, the Safety Evaluation Group cannot conclude that other funds may have been used to complete construction, safety, or resurfacing projects along these roadway segments that may have affected crashes in the study periods.

<b><u>S5: I-40 Bus (MP 0.40 to 8.906)</u></b>	<b>Before</b>	<b>After</b>	<b>Percent Reduction (-)/ Percent Increase (+)</b>
Total Crashes – Both Directions & Counties	447	455	1.8 %
Total Severity Index	4.89	4.24	- 13.3 %
<b>LD Crashes – Both Directions &amp; Counties</b>			
LD Crashes – Both Directions & Counties	299	258	- 13.7 %
Lane Departure Severity Index	5.37	5.48	2.0 %
<b>Volume (2003, 2009)</b>			
Volume (2003, 2009)	42,600	46,800	9.9 %
Total Crash Rate (100 Million Vehicle Miles)	57.92	53.64	- 7.4 %
<b>Injury Crashes</b>			
Fatal Injury Crashes	3	5	66.7 %
Class-A Injury Crashes	6	0	- 100.0 %
Class-B Injury Crashes	46	40	- 13.0 %
Class-C Injury Crashes	97	108	11.3 %
Property Damage Only Crashes	295	302	2.4 %
<b>Contributing Factors</b>			
Night Crashes	177	168	- 5.1 %
Animal Crashes	39	51	30.8 %
Wet Road Crashes	115	110	- 4.3 %
Alcohol / Drug Related	28	22	- 21.4 %

<b><u>Seg-5: I-40B Eastbound Only</u></b>	<b>Before</b>	<b>After</b>	<b>Percent Reduction (-)/ Percent Increase (+)</b>
EB (SB) Total Crashes	221	231	4.5 %
EB (SB) Total Severity Index	4.68	4.28	- 8.5 %
<b>EB (SB) Lane Departure Crashes</b>			
EB (SB) Lane Departure Crashes	148	132	- 10.8 %
EB (SB) Lane Departure Severity Index	5.14	5.57	8.4 %

<b><u>Seg-5: I-40B Westbound Only</u></b>	<b>Before</b>	<b>After</b>	<b>Percent Reduction (-)/ Percent Increase (+)</b>
WB (NB) Total Crashes	226	224	- 0.9 %
WB (NB) Total Severity Index	5.10	4.20	- 17.6 %
<b>WB (NB) Lane Departure Crashes</b>			
WB (NB) Lane Departure Crashes	151	126	- 16.6 %
WB (NB) Lane Departure Severity Index	5.61	5.39	- 3.9 %

Segment-5 experienced a 2 percent increase in Total Crashes but a 14 percent reduction in Lane Departure Crashes through the evaluation periods. The Total Severity Index reduced by 13 percent with a decrease in Severe Injury Crashes (Fatals and A-injury) from nine (9) to five (5) from the before to the after periods.



The following chart depicts the number of Total and Target Crashes per year plotted in the before and after period for Segment-5, along with the AADT. Segment-5 total and lane departure crashes per year appear to have spiked in 2010 for an unknown conclusive reason. The TIP Letting website was searched for projects that were completed along these routes and three are listed above. However, the Safety Evaluation Group cannot conclude that other funds may have been used to complete construction, safety, or resurfacing projects along these roadway segments that may have affected crashes in the study periods.

## Results and Discussion

Overall, the combined totals of each segment resulted in a 9.6 percent reduction in Total Crashes and a 23 percent reduction in Lane Departure Crashes. The severity indexes were impacted with a reduction between 15 and 20 percent for the both the Total and Target Crashes.

Four out of the five segments experienced a reduction in Total crashes with Segment-5 experiencing a slight increase of 1.8 percent. Segment-4 (northbound lanes only) experienced the greatest benefit with a 49 percent reduction in Total Crashes and a 45 percent reduction in Lane Departure Crashes.

The calculated benefit to cost ratio for this project is **73.10 considering total crashes**. The benefit to cost ratio **considering only target crashes is 58.82**. The benefits are calculated using the change in annual crash costs from the before to the after period. Operational and other benefits related to the project are not considered in this analysis. The costs of the project include the actual construction costs as well as the increase in annual maintenance and utility costs.

As the Safety Evaluation Group completes additional spot safety reviews for this type of countermeasure, we will be able to provide objective and definite information regarding actual crash reduction factors for this type of intersection.

**BENEFIT-COST ANALYSIS WORKSHEET - Total Crashes**

LOCATION: 5 Segments of US-421		BY: JBS						
COUNTY: Forsyth / Guilford		DATE: 10/4/2012						
FILE NO.: W-4823								
DETAILED COST:	TYPE IMPROVEMENT - Rumblestrips							
	ITEMS	TOTAL	SERVICE	CRF	ANNUAL COST			
	Construction	\$200,000	10	0.149	\$29,806			
		\$0	0	0.000	\$0			
	Right-of-Way	\$0	0	0.000	\$0			
	TOTALS	\$200,000	10	0.149	\$29,806			
	ESTIMATED INCREASE IN ANNUAL MAINT. COST =				\$0			
	ESTIMATED INCREASE IN ANNUAL UTILITY COST =				\$0			
	TOTAL ANNUAL COST=				\$29,806			
	TOTAL COST OF PROJECT=				\$200,000			
COMPREHENSIVE COST REDUCTION:								
ESTIMATED NUMBER OF ANNUAL ACCIDENT DECREASES								
TIME PERIOD	YEARS	K & A CRASHES	K & A CRASHES PER YR	B & C CRASHES	B & C CRASHES PER YR	PDO CRASHES	PDO CRASHES PER YR	ANNUAL COSTS
BEFORE	5.84	32	5.48	494	84.59	990	169.52	\$5,872,774
AFTER	5.84	15	2.57	401	68.66	954	163.36	\$3,693,870
							Annual Benefits from Crash Cost Savings	\$2,178,904
	NET AVG. ANNUAL BENEFITS = AVG. ANNUAL BENEFITS - TOTAL ANNUAL COST				=	\$2,149,098		
	BENEFIT-COST RATIO = AVG ANNUAL BENEFITS/TOTAL ANNUAL COST				=	73.10		
	TOTAL COST OF PROJECT	-	\$200,000		COMPREHENSIVE B/C RATIO	-		73.10

**BENEFIT-COST ANALYSIS WORKSHEET - Target Crashes**

LOCATION: 5 Segments of US-421		BY: JBS						
COUNTY: Forsyth / Guilford		DATE: 10/4/2012						
FILE NO.: W-4823		Target - Lane Departure						
DETAILED COST:	TYPE IMPROVEMENT - Rumblestrips							
	ITEMS	TOTAL	SERVICE	CRF	ANNUAL COST			
	Construction	\$200,000	10	0.149	\$29,806			
		\$0	0	0.000	\$0			
	Right-of-Way	\$0	0	0.000	\$0			
	TOTALS	\$200,000	10	0.149	\$29,806			
	ESTIMATED INCREASE IN ANNUAL MAINT. COST =				\$0			
	ESTIMATED INCREASE IN ANNUAL UTILITY COST =				\$0			
	TOTAL ANNUAL COST=				\$29,806			
	TOTAL COST OF PROJECT=				\$200,000			
COMPREHENSIVE COST REDUCTION:								
ESTIMATED NUMBER OF ANNUAL ACCIDENT DECREASES								
TIME PERIOD	YEARS	K & A CRASHES	K & A CRASHES PER YR	B & C CRASHES	B & C CRASHES PER YR	PDO CRASHES	PDO CRASHES PER YR	ANNUAL COSTS
BEFORE	5.84	24	4.11	302	51.71	550	94.18	\$4,028,253
AFTER	5.84	11	1.88	223	38.18	441	75.51	\$2,275,051
							Annual Benefits from Crash Cost Savings	\$1,753,202
	NET AVG. ANNUAL BENEFITS = AVG. ANNUAL BENEFITS - TOTAL ANNUAL COST				=	\$1,723,396		
	BENEFIT-COST RATIO = AVG ANNUAL BENEFITS/TOTAL ANNUAL COST				=	58.82		
	TOTAL COST OF PROJECT	-	\$200,000		COMPREHENSIVE B/C RATIO	-		58.82