

Hazard Elimination Project Evaluation

Project Log # 200608058

Hazard Elimination Project W-4402

Evaluation of the Shoulder Guardrail Installations on US 221 at the Bridge Approaches and Bridge Rails to Bridge # 30, 55, and 74, Rutherford County

Documents Prepared By:

Safety Evaluation Group
Traffic Safety Systems Management Section
Traffic Engineering and Safety Systems Branch
North Carolina Department of Transportation

Principal Investigator



Carrie L. Simpson, PE

1/3/08

Date

Traffic Safety Project Engineer

Hazard Elimination Project Evaluation Documentation

Subject Location

Evaluation of Hazard Elimination Project W-4402 – Installation of shoulder guardrail on US 221 at the bridge approaches and bridge rails of Bridge # 30, 55, and 74 in Rutherford County

Project Information and Background from the Project File Folder

The safety countermeasure chosen for the subject location was the installation of approximately 6900 linear feet of shoulder guardrail in the vicinity of Bridges 30, 55, and 74 on US 221. Prior to the improvements, Bridges 30 and 55 did not have approach guardrail or bridge-end protection. Bridge 74 did have approach guardrail on all four approaches; however, the guardrail was connected to the bridge rail only at the southwest corner. The Bridge 74 guardrail was replaced and upgraded as part of the countermeasure.

US 221 is a two-lane highway with varying shoulder widths of 6-10 feet and speed limit of 55 miles per hour. According to the project file, the unprotected bridge ends and steep fill sections were contributing factors in the severity of Ran Off Road crashes.

The initial crash analysis for this location was completed from July 1, 1996 through June 30, 1999 with a total of six reported crashes. Five of these were Ran Off Road crashes, and one was a Fixed Object crash that resulted in a fatality. Five of the six crashes involved injuries. W-4402 was completed in August of 2001 at an estimated cost of \$200,000.

Naïve Before and After Analysis

After reviewing the hazard elimination project file folder along with all the crashes at the subject locations, the crash data omitted from this analysis to consider for an adequate construction period was from July 1, 2001 through October 31, 2001. The before period consisted of reported crashes from November 1, 1995 through June 30, 2001 (5 Years, 8 Months) and the after period consisted of reported crashes from November 1, 2001 through June 30, 2007 (5 Years, 8 Months). The ending date for this analysis was determined by the available crash data at the time the crash analysis was completed.

The treatment data consisted of all crashes on US 221 from MP 1.45-1.85 (vicinity of Bridge 30) and MP 5.02-5.64 (vicinity of Bridges 55 & 74). A total of 1.02 miles was analyzed. The study limits include the entire length of the bridges and approach guardrail, plus extends approximately 500' beyond the guardrail terminals. A 0 feet Y-line was used in the analysis. Please see the attached *Location Map* and *Aerial Photos* for further detail.

The following tables depict the Naïve Before and After Analysis for the Total Crashes and Target Crashes at the aggregated treatment locations. Please note that Ran Off Road crash types were the target crashes for the applied countermeasure. Ran Off Road crash types considered are as follows: Ran Off Road – Left, Ran Off Road – Right, Ran Off Road – Straight, Fixed Object, Head-on, Sideswipe – Same Direction, Sideswipe – Opposite Direction, and Overturn / Rollover.

<u>Total Treatment Information</u>	Before	After	Percent Reduction (-)/ Percent Increase (+)
Total Crashes	24	22	-8.3%
Total Severity Index	10.40	7.47	-28.2%
Target Crashes	16	11	-31.3%
Target Severity Index	14.64	11.93	-18.5%
Volume	6200	7100	14.5%

<u>Target Crash Information</u>	Before	After	Percent Reduction (-)/ Percent Increase (+)
<i>Target Crashes - Injuries</i>			
Fatal Injury Crashes	1	0	-100.0%
Non-Fatal Injury Crashes	10	7	-30.0%
Total Injury Crashes	11	7	-36.4%
<i>Target Crashes - Contributing Factors</i>			
Night Crashes	8	4	-50.0%
Wet / Icy Crashes	6	4	-33.3%
<i>Target Crashes - Crash Types</i>			
Ran Off Road	10	0	-100.0%
Fixed Object	3	6	100.0%
Head On	0	1	N/A
Sideswipe, Opposite Direction	2	3	50.0%
Sideswipe, Same Direction	1	1	0.0%

The naïve before and after analysis at the treatment location resulted in an 8 percent decrease in Total Crashes, a 31 percent decrease in Target Crashes, and a 15 percent increase in Average Daily Traffic (ADT). Further investigation shows there was a 28 percent decrease in the Severity Index for Total Crashes and a 19 percent decrease in the Severity Index for Target Crashes. The before period ADT year was 1998 and the after period ADT year was 2004.

Because we had specific information as to exactly where each run of guardrail was placed in this project, specific crash information for each run of guardrail could be analyzed. In the following tables, the data is provided separately for Bridges 30 and 55/74.

Treatment Information - Bridge 30

	Before	After	Percent Reduction (-)/ Percent Increase (+)
Total Crashes	12	6	-50.0%
Total Severity Index	10.40	2.23	-78.6%
Target Crashes			
Target Crashes	9	2	-77.8%
Target Severity Index	13.53	4.70	-65.3%
Volume			
Volume	6900	8000	15.9%

Target Crash Information - Bridge 30

	Before	After	Percent Reduction (-)/ Percent Increase (+)
Target Crashes - Injuries			
Fatal Injury Crashes	0	0	N/A
Non-Fatal Injury Crashes	6	1	-83.3%
Total Injury Crashes	6	1	-83.3%
Target Crashes - Contributing Factors			
Night Crashes	3	0	-100.0%
Wet / Icy Crashes	5	1	-80.0%
Target Crashes - Crash Types			
Ran Off Road	6	0	-100.0%
Fixed Object	1	0	-100.0%
Sideswipe, Opposite Direction	2	2	0.0%

The naïve before and after analysis at the Bridge 30 location resulted in a 50 percent decrease in Total Crashes, a 78 percent decrease in Target Crashes, and a 16 percent increase in Average Daily Traffic (ADT).

Treatment Information - Bridges 55 & 74

	Before	After	Percent Reduction (-)/ Percent Increase (+)
Total Crashes	12	16	33.3%
Total Severity Index	10.40	9.44	-9.2%
Target Crashes			
Target Crashes	7	9	28.6%
Target Severity Index	16.06	13.53	-15.8%
Volume			
Volume	5800	6600	13.8%

Target Crash Information - Bridges 55 & 74

	Before	After	Percent Reduction (-)/ Percent Increase (+)
Target Crashes - Injuries			
Fatal Injury Crashes	1	0	-100.0%
Non-Fatal Injury Crashes	4	6	50.0%
Total Injury Crashes	5	6	20.0%
Target Crashes - Contributing Factors			
Night Crashes	5	4	-20.0%
Wet / Icy Crashes	1	3	200.0%
Target Crashes - Crash Types			
Ran Off Road	4	0	-100.0%
Fixed Object	2	6	200.0%
Head On	0	1	N/A
Sideswipe, Opposite Direction	1	1	0.0%
Sideswipe, Same Direction	0	1	N/A

The naïve before and after analysis at the Bridge 55/74 location resulted in a 33 percent increase in Total Crashes, a 29 percent increase in Target Crashes, and a 14 percent increase in Average Daily Traffic (ADT).

Results and Discussion

The naïve before and after analysis involving the comparison of treatment actual before data versus treatment actual after data resulted in an 8 percent decrease in Total Crashes and a 31 percent decrease in Target Crashes. Further investigation shows that the Severity Index of Total Crashes and Target Crashes appear to have decreased 28 and 19 percent respectively using naïve methodologies. The summary results above demonstrate that overall the treatment locations appear to have had a decrease in Total Crashes, Target Crashes, and the Severity Index from the before to the after period.

The calculated benefit to cost ratio for this project is 2.99 considering total crashes. The benefit to cost ratio considering only target crashes is 3.22. 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 costs.

Typically, one would expect guardrail installation projects to result in an increased number of Ran Off Road crash types and a decrease in the severity of Ran Off Road crash types. The increase in Ran Off Road crash types is expected due to the placement of a fixed object (guardrail) near the travel way. The decrease in the severity of Ran Off Road crash types is expected due to the guardrail being more forgiving than the object it is protecting. The results from this project seem to be in concurrence with the above-mentioned expectations except for the decrease in the number of Ran Off Road crash types.

There were two predominant contributing factors associated with Target Crashes in both the before and after period. Wet / Icy conditions were a contributing factor in 38 percent of Target Crashes (6 of 16) in the before period and 36 percent of crashes in the after period (4 of 11). Also, Night Crashes accounted for 50 percent of Target Crashes (8 of 16) in the before period and 36 percent of crashes in the after period (4 of 11). With four fewer Target Night Crashes in the after period, the reduction in Target Night Crashes played a considerable role in the reduction of Target Crashes. The decrease in Target Night Crashes may be attributed to the improved delineation provided by the markers and end treatments on the upgraded guardrail.

Because we had specific information as to exactly where each run of guardrail was placed in this project and because each location experienced differing results, specific crash information for each run of guardrail was analyzed. To supplement the discussion below, please see the *Collision Diagrams* provided for each Bridge Location.

The number of Total Crashes at the Bridge 30 location decreased by 50 percent, from 12 crashes in the before period to 6 crashes in the after period. Also, the number of Target Crashes at the Bridge 30 location decreased by 78 percent, from 9 crashes in the before period to 2 crashes in the after period. The severity of Total and Target Crashes also decreased substantially at the Bridge 30 location. The number of Target Injury Crashes decreased by 83 percent, from 6 crashes in the before period to 1 crash in the after period.

The number of Total Crashes at the Bridge 55/74 location increased by 33 percent, from 12 crashes in the before period to 16 crashes in the after period. Also, the number of Target Crashes at the Bridge 55/74 location increased by 29 percent, from 7 crashes in the before period to 9 crashes in the after period. One Fatal Target Crash occurred in the before period (see Crash #5 in the Bridge 55/74 Before Period Collision Diagram), where wet and dark conditions were contributing factors. In this crash, the vehicle hydroplaned and ran off the road striking the Bridge 55 rail end. In the after period, 5 of the 9 Target Crashes at the Bridge 55/74 location occurred at night, in wet/icy conditions, or under both conditions.

Please see the attached *Aerial Photos* and *Treatment Site Photos* for additional visual information. As the Safety Evaluation Group completes additional reviews for this type of countermeasure, we will be able to provide more objective and definite information regarding actual crash reduction factors.

TOTAL BENEFIT-COST ANALYSIS WORKSHEET

LOCATION: US 221 at Bridges 30, 55, 74
 COUNTY: Rutherford
 FILE NO.: W-4402

BY: CLS
 DATE: 12/11/2007

DETAILED COST: TYPE IMPROVEMENT - **Guardrail**

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 = \$760
 ESTIMATED INCREASE IN ANNUAL UTILITY COST = \$0
 TOTAL ANNUAL COST= \$30,566
 TOTAL COST OF PROJECT= \$200,000

COMPREHENSIVE COST REDUCTION:

TIME PERIOD	YEARS	ESTIMATED NUMBER OF ANNUAL ACCIDENT DECREASES						ANNUAL COSTS
		K & A CRASHES	K & A CRASHES PER YR	B & C CRASHES	B & C CRASHES PER YR	PDO CRASHES	PDO CRASHES PER YR	
BEFORE	5.66	2	0.35	10	1.77	12	2.12	\$216,749
AFTER	5.66	1	0.18	9	1.59	12	2.12	\$125,230

Annual Benefits from Crash Cost Savings \$91,519

NET AVG. ANNUAL BENEFITS = AVG. ANNUAL BENEFITS - TOTAL ANNUAL COST = \$60,954

BENEFIT-COST RATIO = AVG ANNUAL BENEFITS/TOTAL ANNUAL COST = 2.99

TOTAL COST OF PROJECT - \$200,000 COMPREHENSIVE B/C RATIO - 2.99

TREATMENT BENEFIT-COST ANALYSIS WORKSHEET

LOCATION: US 221 at Bridges 30, 55, 74
 COUNTY: Rutherford
 FILE NO.: W-4402

BY: CLS
 DATE: 12/11/2007

DETAILED COST: TYPE IMPROVEMENT - **Guardrail**

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 = \$760
 ESTIMATED INCREASE IN ANNUAL UTILITY COST = \$0
 TOTAL ANNUAL COST= \$30,566
 TOTAL COST OF PROJECT= \$200,000

COMPREHENSIVE COST REDUCTION:

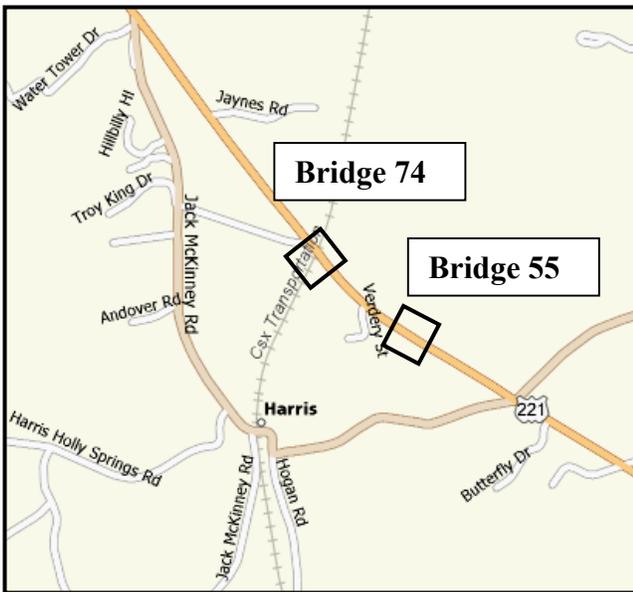
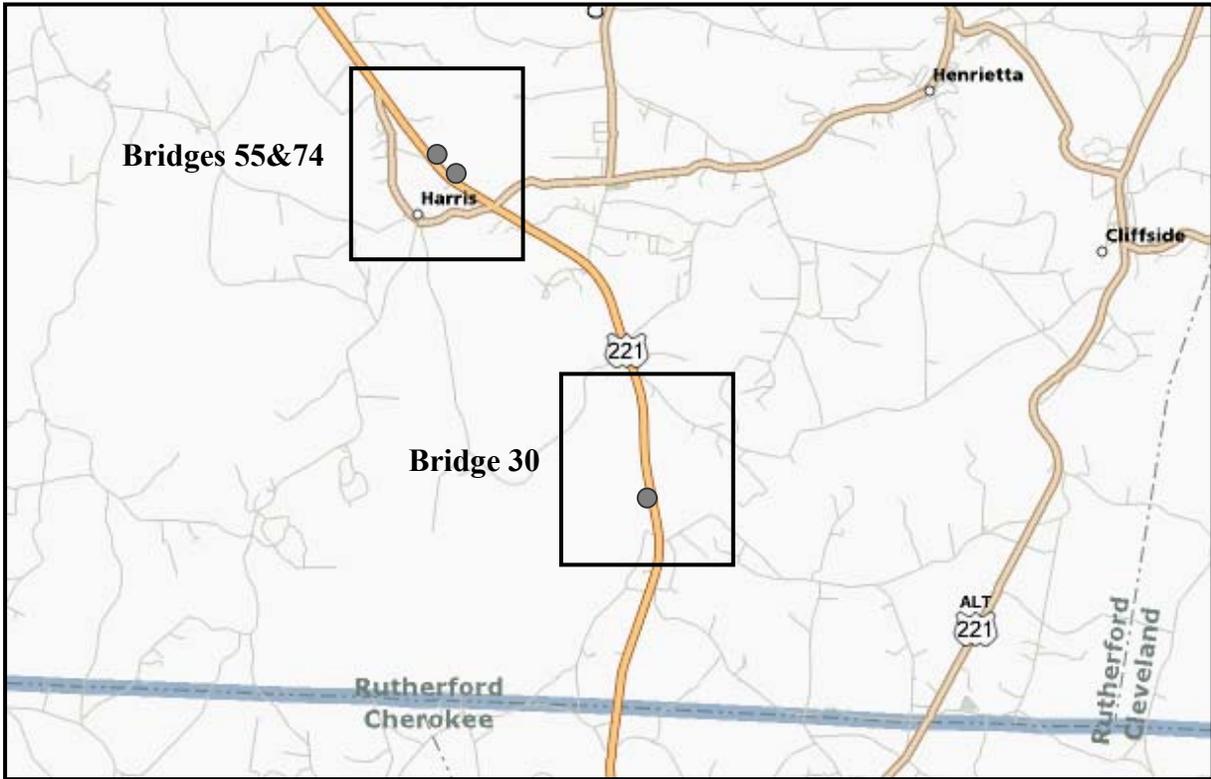
TIME PERIOD	YEARS	ESTIMATED NUMBER OF ANNUAL ACCIDENT DECREASES						ANNUAL COSTS
		K & A CRASHES	K & A CRASHES PER YR	B & C CRASHES	B & C CRASHES PER YR	PDO CRASHES	PDO CRASHES PER YR	
BEFORE	5.66	2	0.35	9	1.59	5	0.88	\$208,746
AFTER	5.66	1	0.18	6	1.06	4	0.71	\$110,177

Annual Benefits from Crash Cost Savings \$98,569

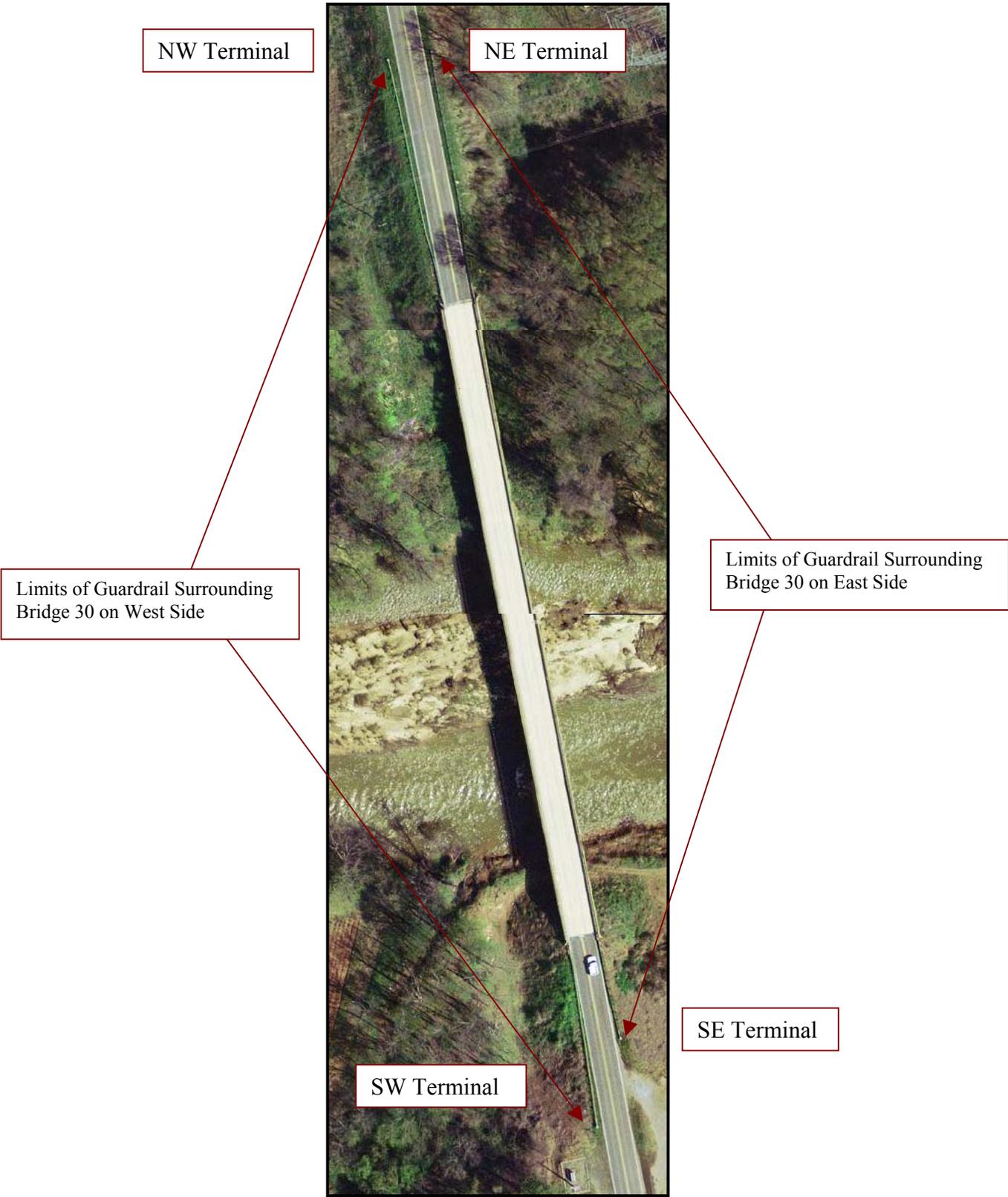
NET AVG. ANNUAL BENEFITS = AVG. ANNUAL BENEFITS - TOTAL ANNUAL COST = \$68,003
 BENEFIT-COST RATIO = AVG ANNUAL BENEFITS/TOTAL ANNUAL COST = 3.22

TOTAL COST OF PROJECT - \$200,000 COMPREHENSIVE B/C RATIO - 3.22

W-4402 LOCATION MAP



AERIAL PHOTOGRAPH OF BRIDGE 30



NW Terminal

NE Terminal

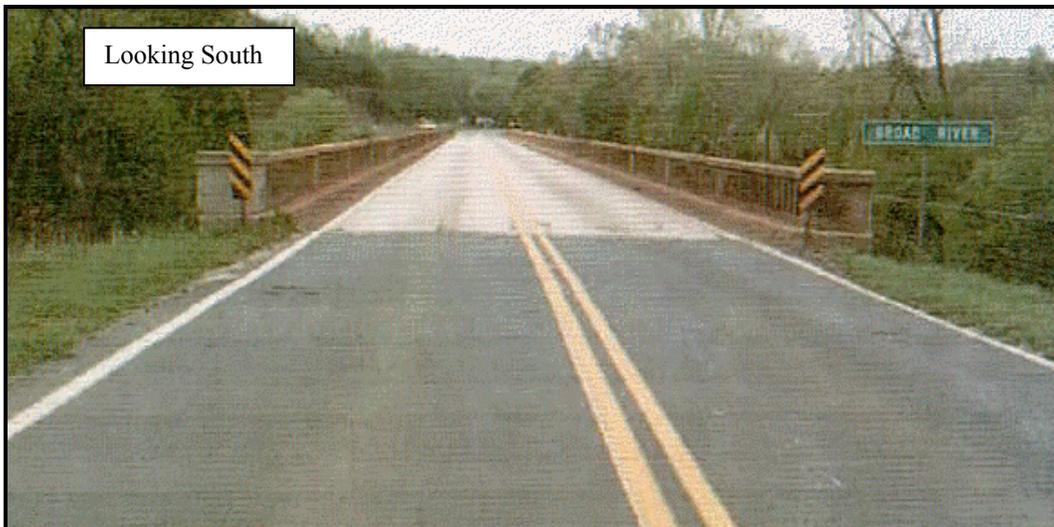
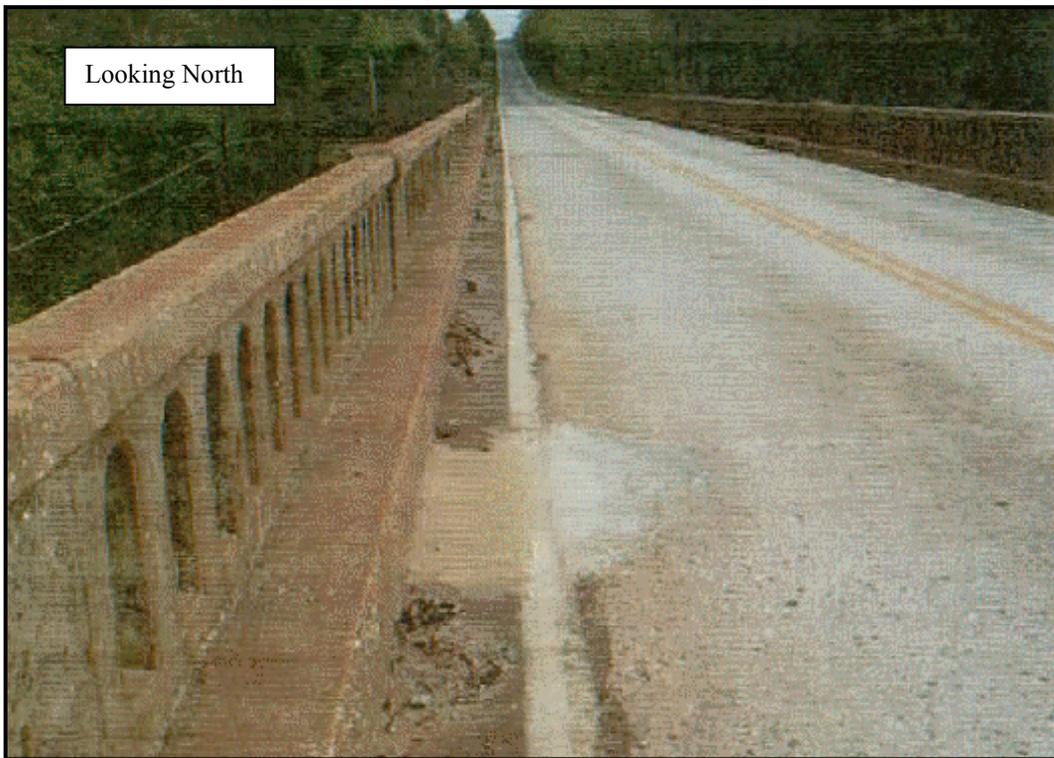
Limits of Guardrail Surrounding Bridge 30 on West Side

Limits of Guardrail Surrounding Bridge 30 on East Side

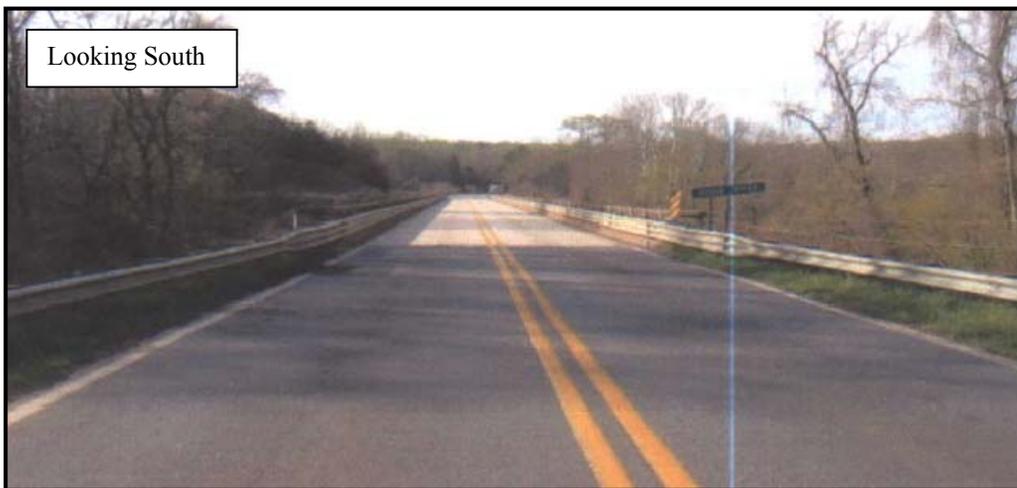
SE Terminal

SW Terminal

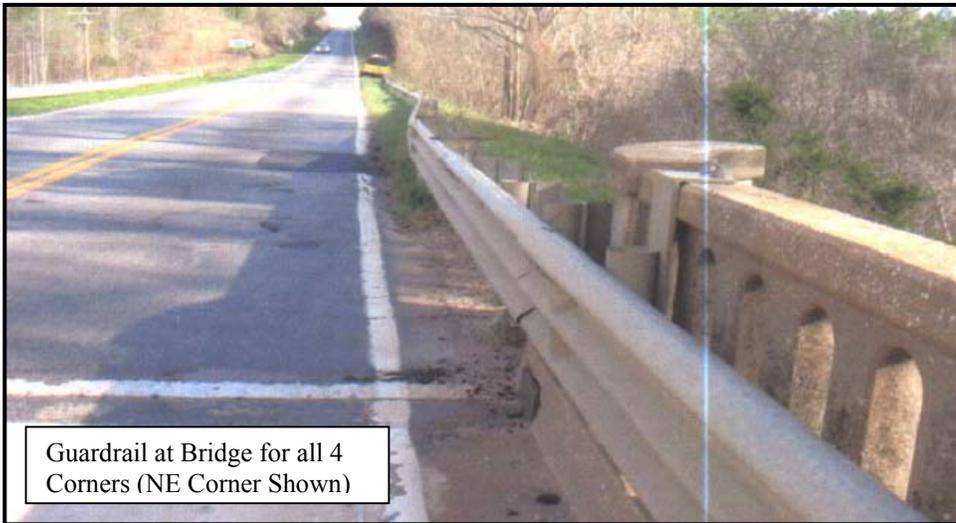
Bridge 30 Location Photos – Before Period (Taken 4/20/2001)



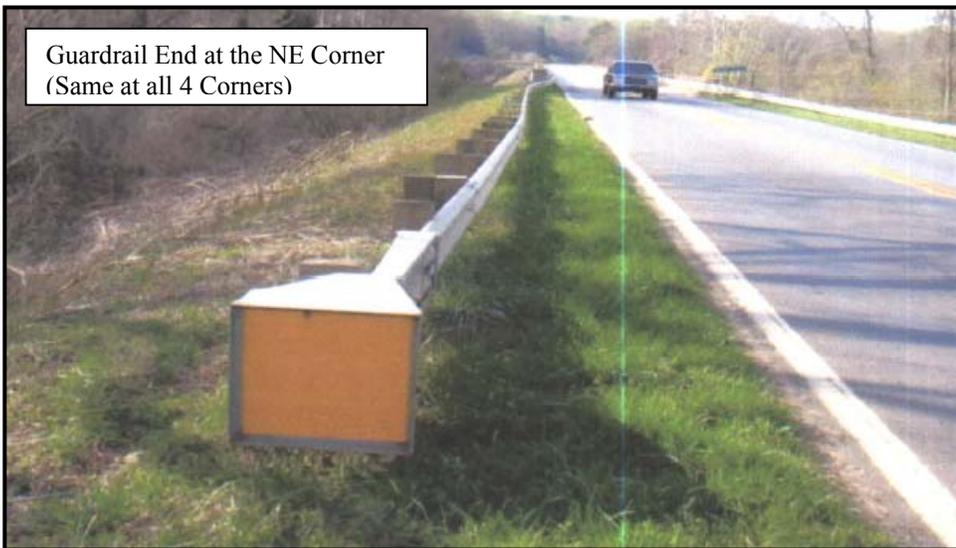
Bridge 30 Location Photos – After Period (Taken 4/5/2005)



Bridge 30 Location Photos – After Period Cont'd (Taken 4/5/2005)



Guardrail at Bridge for all 4
Corners (NE Corner Shown)

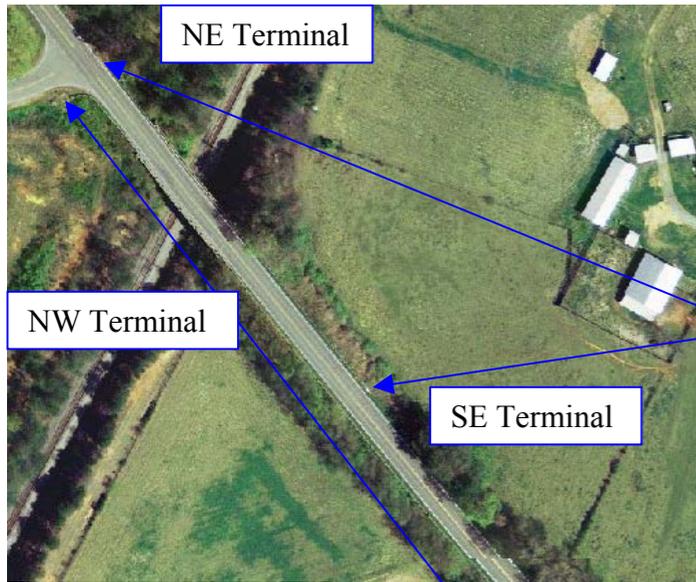


Guardrail End at the NE Corner
(Same at all 4 Corners)



Retrofit Rail Along Bridge Rails

AERIAL PHOTOGRAPH OF BRIDGES 55 AND 74



NE Terminal

NW Terminal

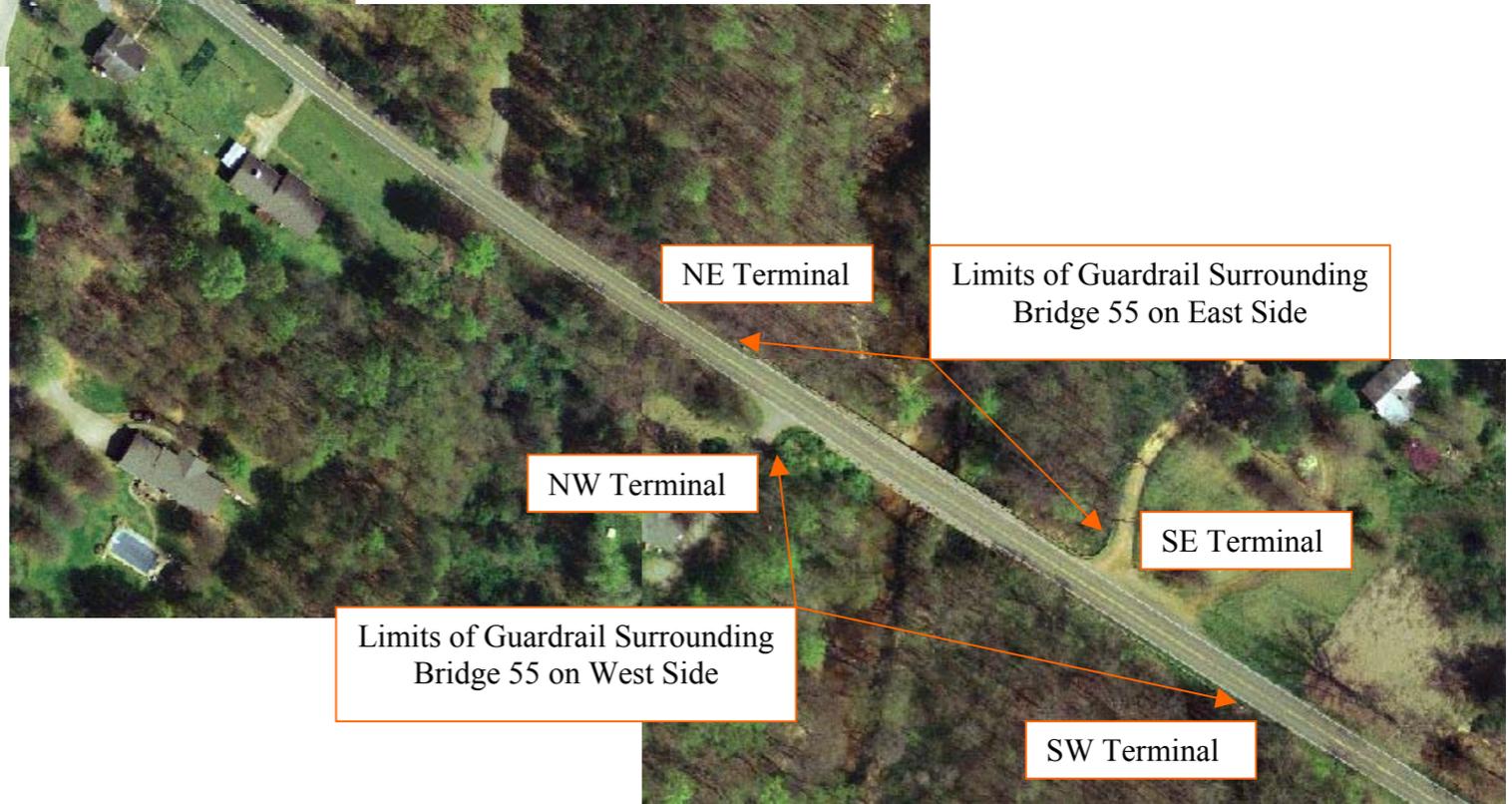
SE Terminal

Limits of Guardrail Surrounding Bridge 74 on East Side

Limits of Guardrail Surrounding Bridge 74 on West Side



SW Terminal



NE Terminal

Limits of Guardrail Surrounding Bridge 55 on East Side

NW Terminal

SE Terminal

Limits of Guardrail Surrounding Bridge 55 on West Side

SW Terminal

Bridge 55 Location Photos – Before Period (Taken 4/20/2001)



Bridge 55 Location Photos – After Period (Taken 4/6/2005)

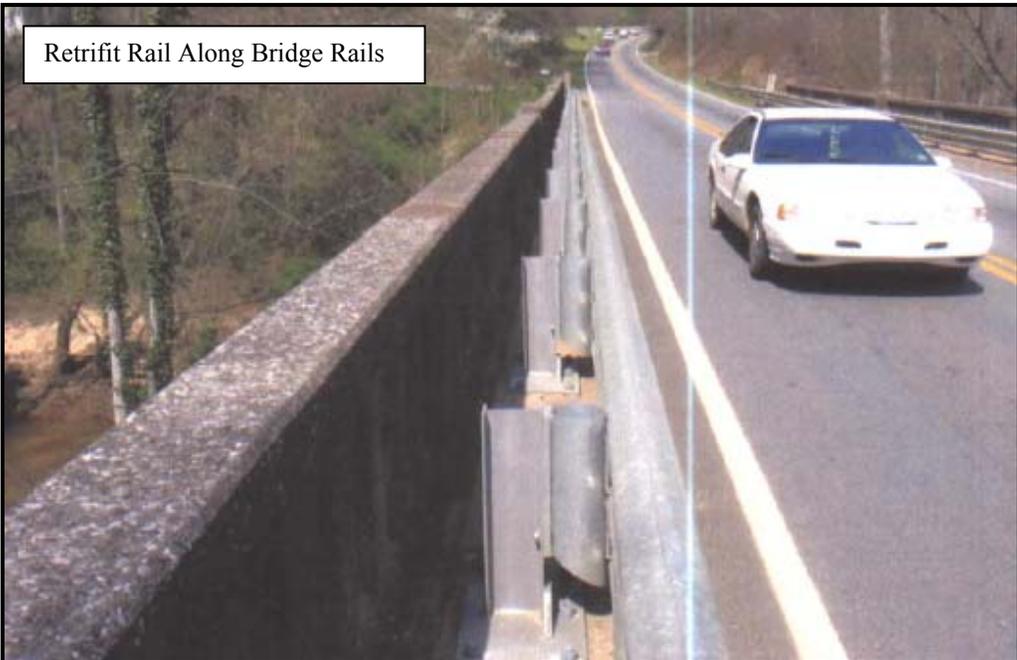
Looking North



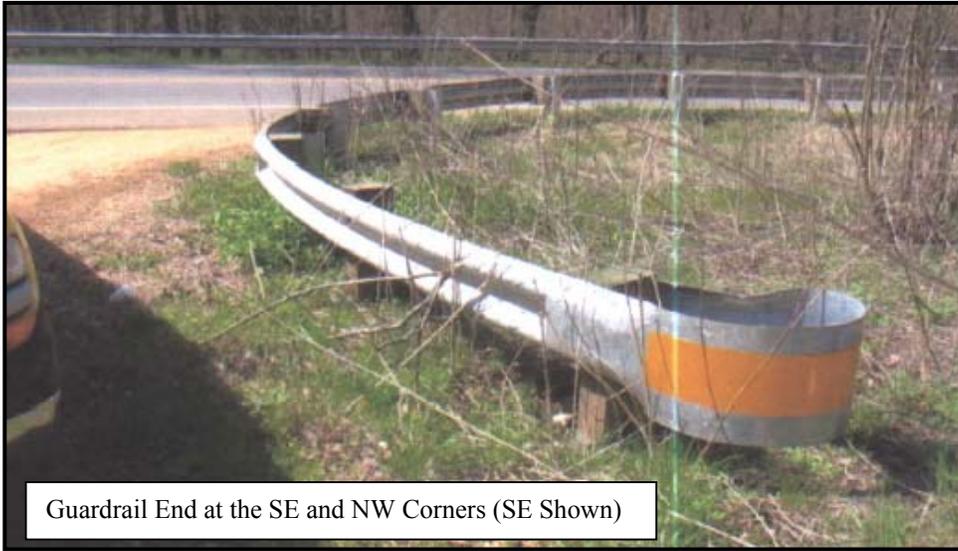
Looking South



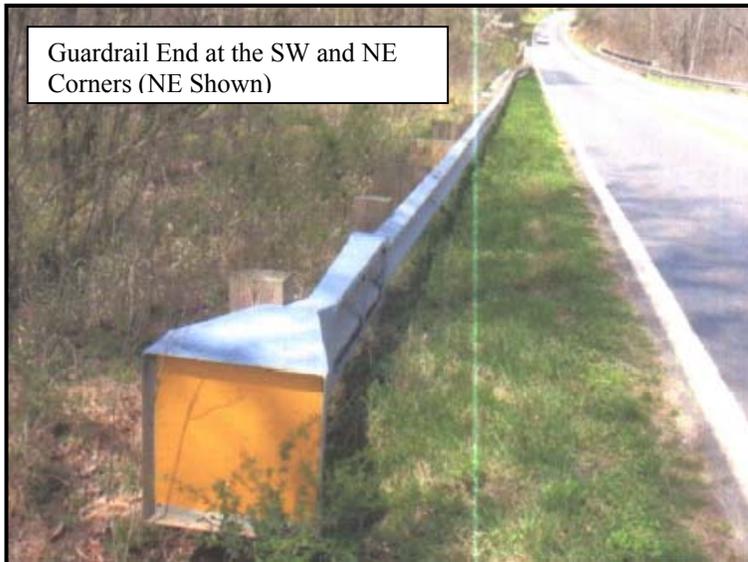
Retrfit Rail Along Bridge Rails



Bridge 55 Location Photos – After Period Cont'd (Taken 4/6/2005)



Guardrail End at the SE and NW Corners (SE Shown)

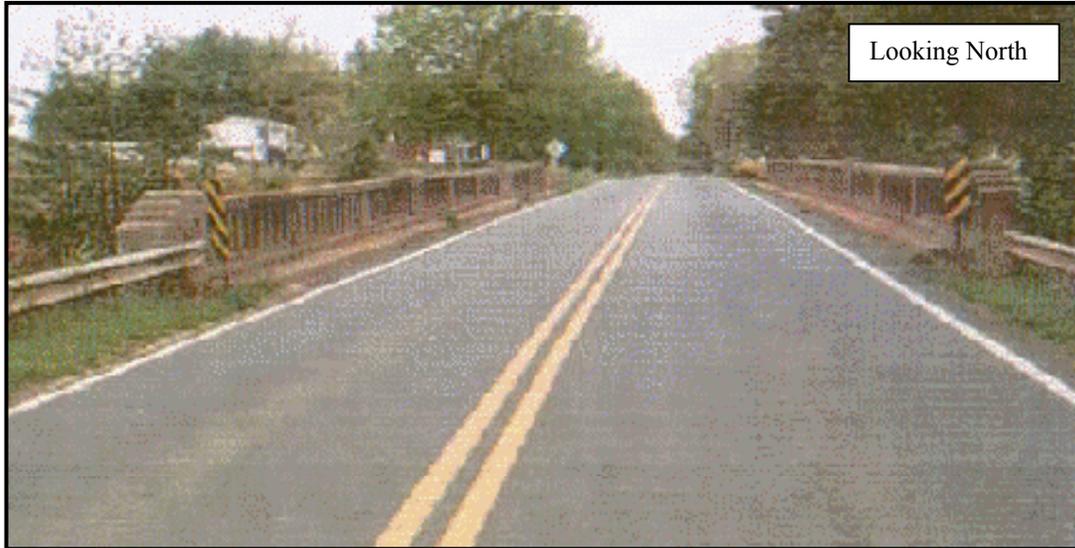


Guardrail End at the SW and NE Corners (NE Shown)

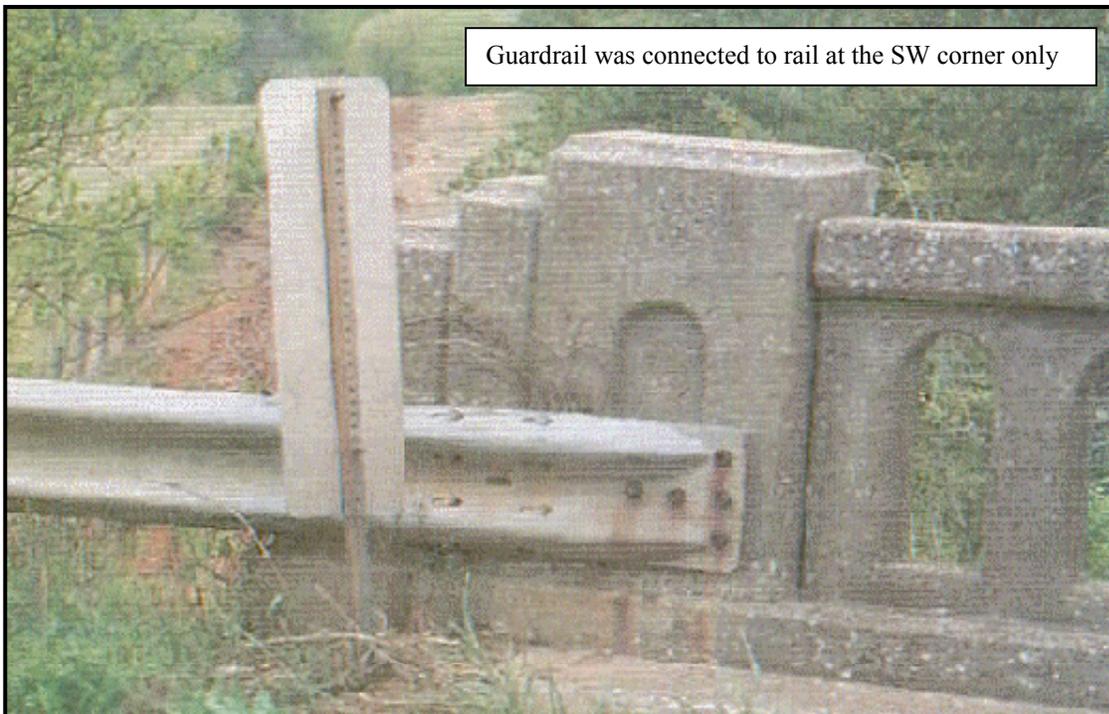


Guardrail transition from bridge (SW corner shown)

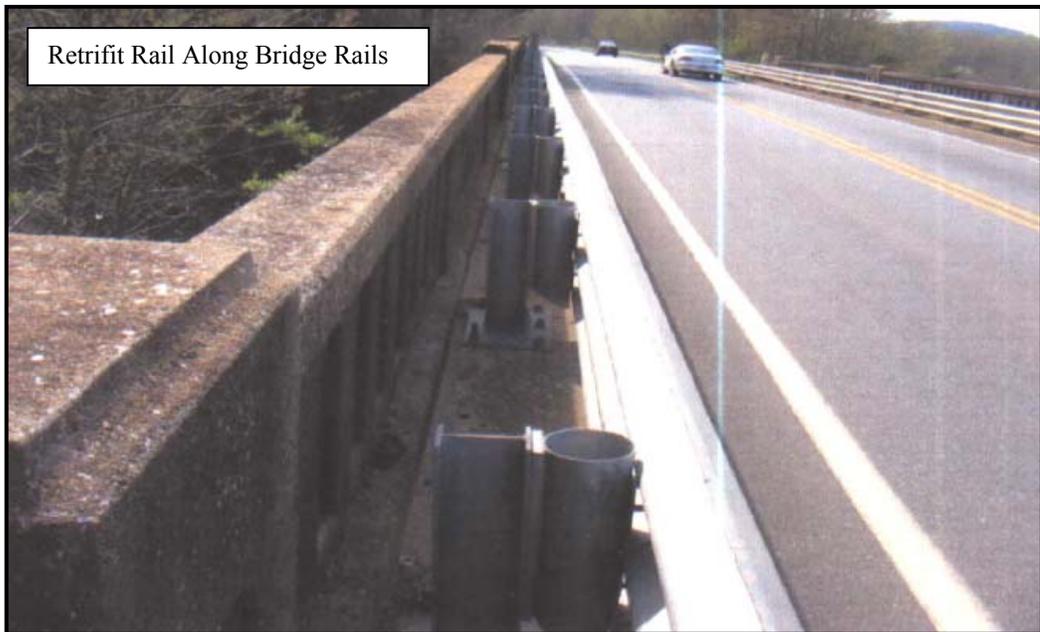
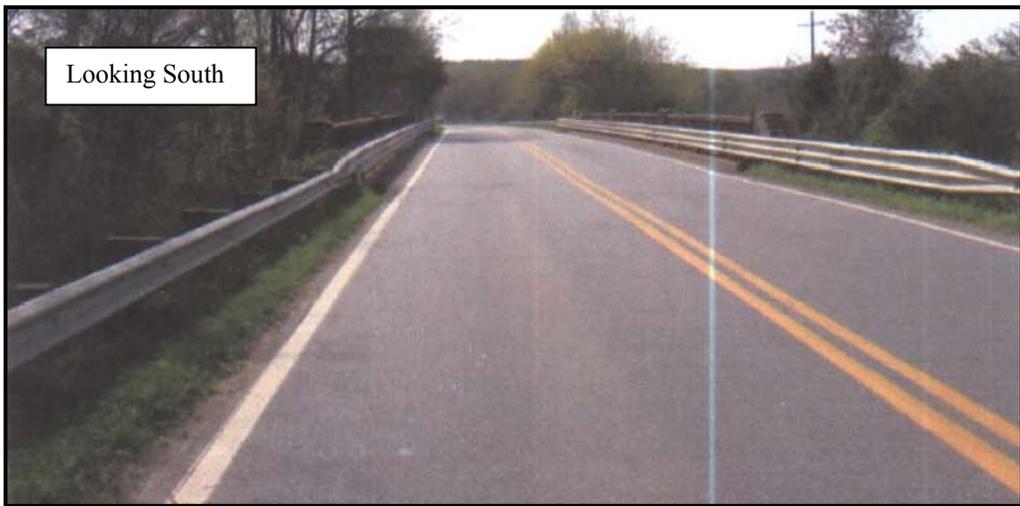
Bridge 74 Location Photos – Before Period (Taken 4/20/2001)



Bridge 74 Location Photos – Before Period Cont'd (Taken 4/20/2001)



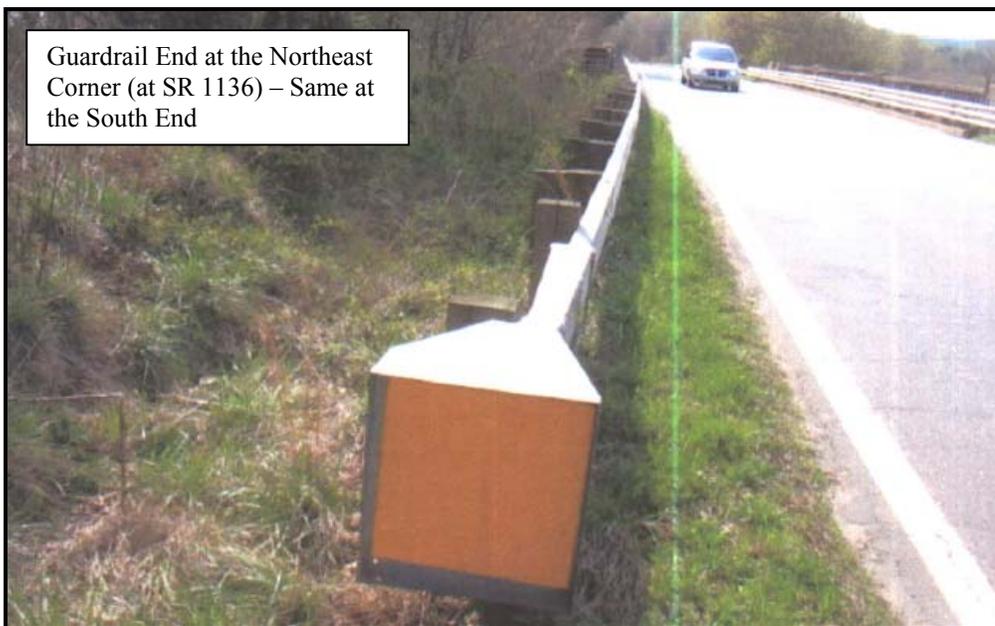
Bridge 74 Location Photos – After Period (Taken 4/6/2005)



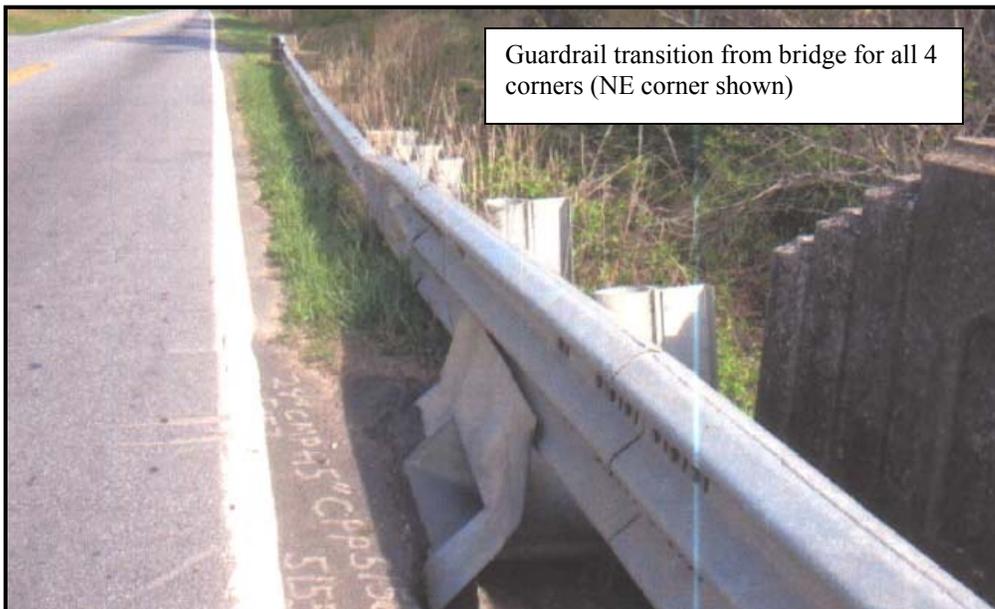
Bridge 74 Location Photos – After Period Cont'd (Taken 4/6/2005)



Guardrail End at the Northwest Corner (at SR 1136)



Guardrail End at the Northeast Corner (at SR 1136) – Same at the South End



Guardrail transition from bridge for all 4 corners (NE corner shown)

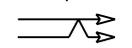
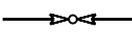
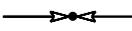
US 221 at Bridge # 30 in Rutherford County

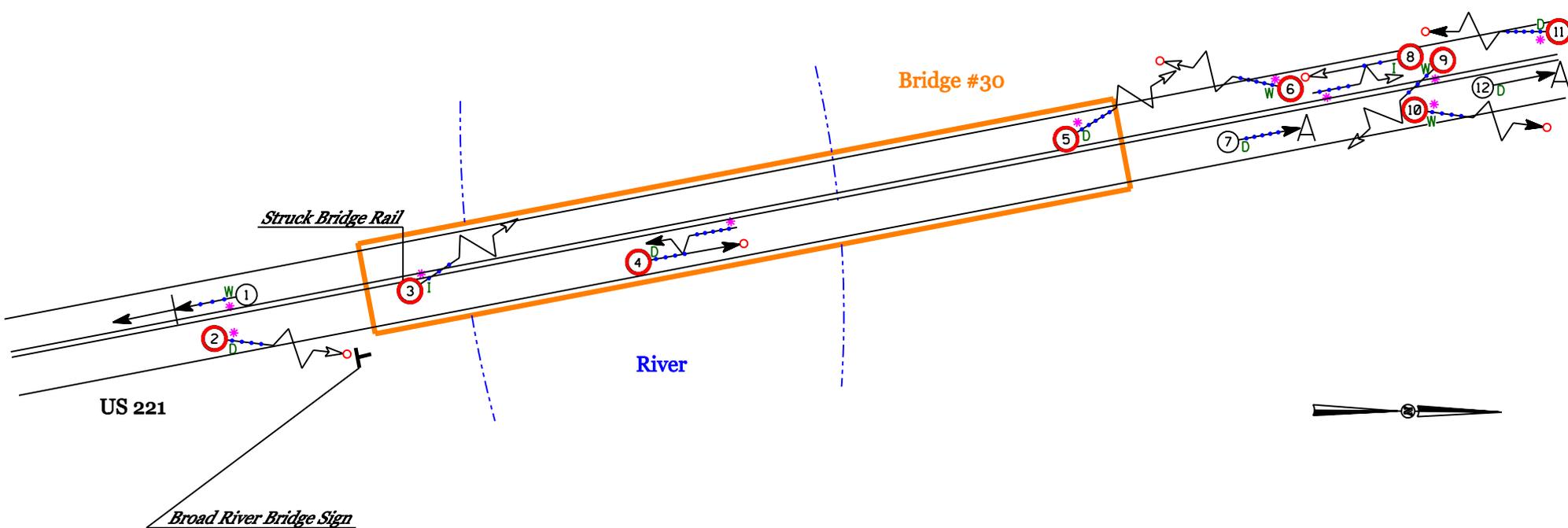
Before Period

November 1, 1995 - June 30, 2001

(5.66 Years)

LEGEND

	MOVING VEHICLE		ANGLE		9 MPH OR LESS		PEDESTRIAN
	PEDESTRIAN		TURNING		10 MPH TO 19		BICYCLE
	PARKED VEHICLE		BACKING		20 MPH TO 29		TRAIN
	PARKING VEHICLE		SIDESWIPE		30 MPH TO 39		ANIMAL
	FIXED OBJECT		OUT OF CONTROL		40 MPH TO 49		DRIVER AT FAULT
	HEAD ON		INJURY		50 MPH TO 59		DRY
	REAR END		FATALITY		60 MPH TO 69		WET
	RAN OFF ROAD		70 AND UP		DAYLIGHT CRASH		ICY OR SNOWY



	Target Crashes
	Guardrail
	Bridge

TRAFFIC SAFETY SYSTEMS MANAGEMENT UNIT <small>HIGHWAY SAFETY IMPROVEMENT PROGRAM</small> <small>SAFETY INFORMATION MANAGEMENT AND SUPPORT</small>		COLLISION DIAGRAM	
		DIVISION: 13 AREA: ..	STUDY PERIOD: 8/2/95.. TO 6/30/01.
		DISTANCE: 0.40 M. Y-LINE: .0 FT	ANALYSIS PREPARED BY: CLS.....
<small>SAFETY EVALUATION</small> <small>TRAFFIC SAFETY</small>		DIAGRAM PREPARED BY: CLS.....	DIAGRAM REVIEWED BY:
BRIDGE..30..		SCALE: NOT TO SCALE	DATE: 12/6/01.....
		LOG NUMBER: 200608058	
N.C. DEPARTMENT of TRANSPORTATION DIVISION of HIGHWAYS TRAFFIC ENGINEERING AND SAFETY SYSTEMS BRANCH			

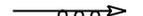
US 221 at Bridge # 30 in Rutherford County

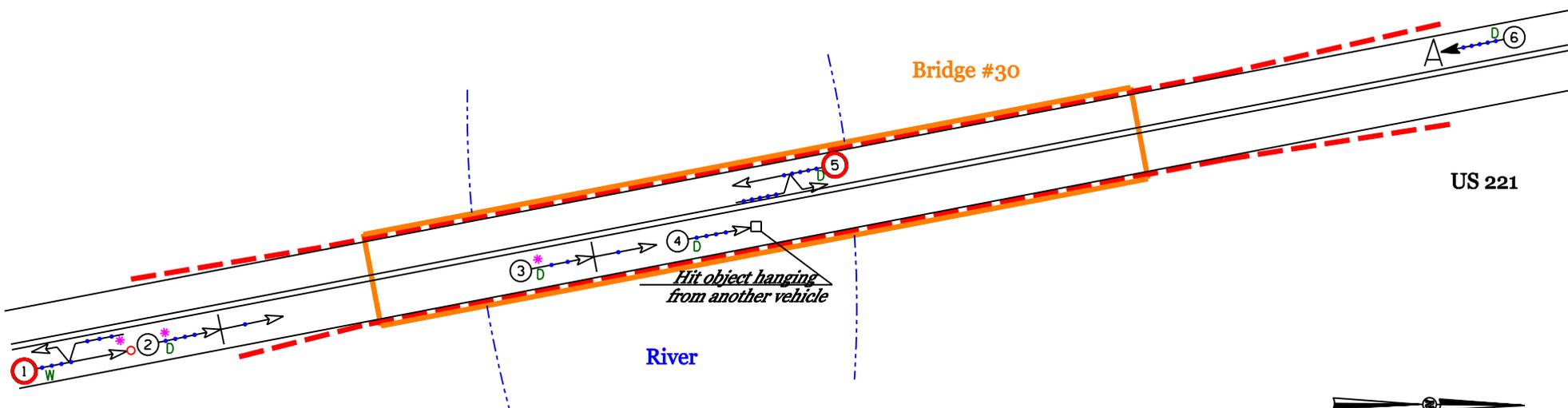
After Period

November 1, 2001 - June 30, 2007

(5.66 Years)

LEGEND

	MOVING VEHICLE		ANGLE		9 MPH OR LESS	P	PEDESTRIAN
	PEDESTRIAN		TURNING		10 MPH TO 19	B	BICYCLE
	PARKED VEHICLE		BACKING		20 MPH TO 29	T	TRAIN
	PARKING VEHICLE		SIDESWIPE		30 MPH TO 39	A	ANIMAL
	FIXED OBJECT		OUT OF CONTROL		40 MPH TO 49	*	DRIVER AT FAULT
	HEAD ON		INJURY		50 MPH TO 59	D	DRY
	REAR END		FATALITY		60 MPH TO 69	W	WET
	RAN OFF ROAD		DAYLIGHT CRASH		70 AND UP	I	ICY OR SNOWY



	Target Crashes
	Guardrail
	Bridge

TRAFFIC SAFETY SYSTEMS MANAGEMENT UNIT <small>HIGHWAY SAFETY IMPROVEMENT PROGRAM</small> <small>SAFETY INFORMATION MANAGEMENT AND SUPPORT</small>		COLLISION DIAGRAM	
		DIVISION: 13 AREA: ..	STUDY PERIOD: 11/01/01 TO 6/30/07
		DISTANCE: 0.90 MI. Y-LINE: .0 FT	ANALYSIS PREPARED BY: CLS
<small>SAFETY EVALUATION</small> <small>TRAFFIC SAFETY</small>		BRIDGE: 30	SCALE: NOT TO SCALE
		DATE: 12/6/07	LOG NUMBER: 200608058
N.C. DEPARTMENT of TRANSPORTATION DIVISION of HIGHWAYS TRAFFIC ENGINEERING AND SAFETY SYSTEMS BRANCH			

SR 1136

(New Bethel Church Rd)

Bridge #74

Struck Guardrail

RxR

US 221

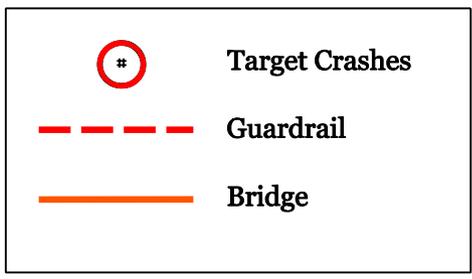
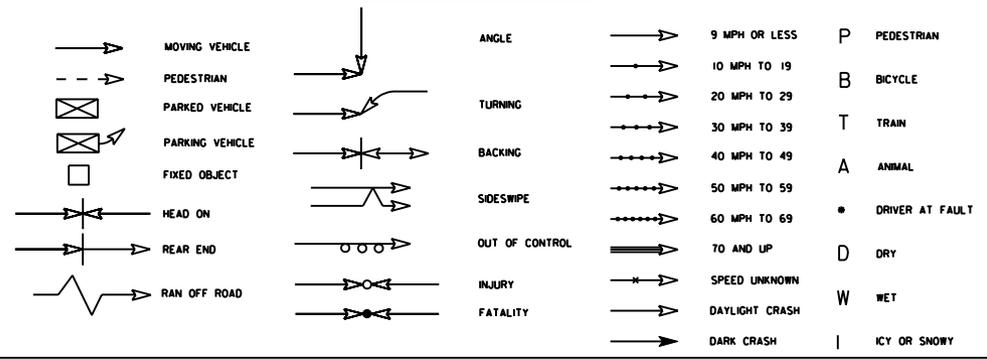
US 221 at Bridges # 55 & 74 in Rutherford County

Before Period

November 1, 1995 - June 30, 2001

(5.66 Years)

LEGEND



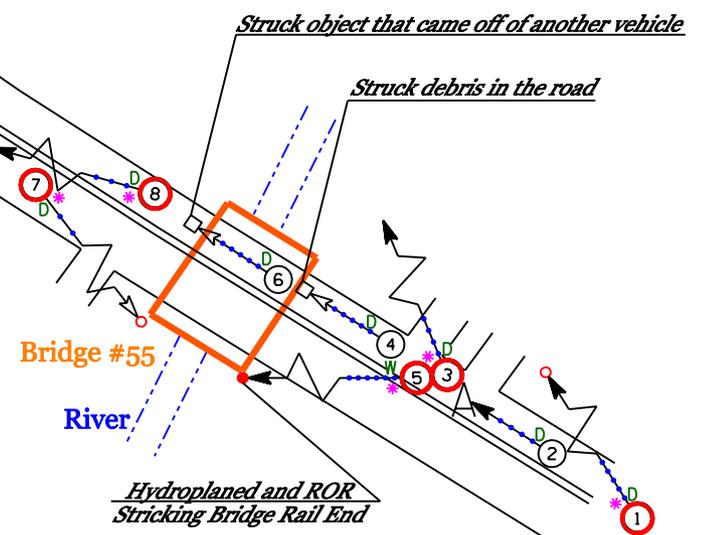
TRAFFIC SAFETY SYSTEMS MANAGEMENT UNIT
ROADWAY SAFETY IMPROVEMENT PROGRAM SAFETY INFORMATION MANAGEMENT AND SUPPORT

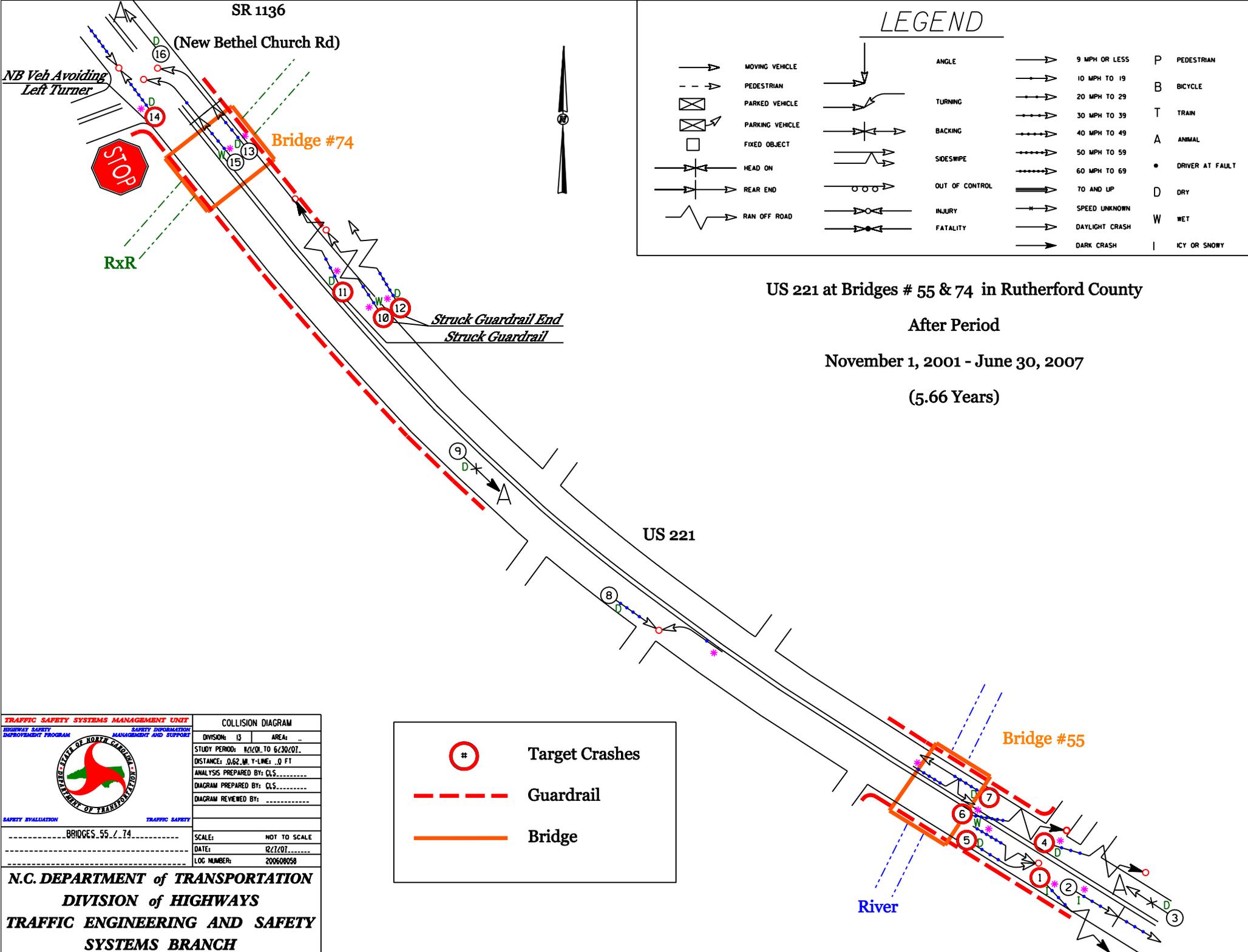
COLLISION DIAGRAM

DIVISION: 13	AREA: ..
STUDY PERIOD: 8/1/95.. TO 6/30/01	
DISTANCE: 0.62 MI. Y-LINE: 0 FT	
ANALYSIS PREPARED BY: CLS.....	
DIAGRAM PREPARED BY: CLS.....	
DIAGRAM REVIEWED BY:	

SCALE: NOT TO SCALE
 DATE: 8/1/07
 LOG NUMBER: 200608058

N.C. DEPARTMENT of TRANSPORTATION
DIVISION of HIGHWAYS
TRAFFIC ENGINEERING AND SAFETY
SYSTEMS BRANCH





LEGEND

→	MOVING VEHICLE	↘	ANGLE	→	9 MPH OR LESS	P	PEDESTRIAN
- - - →	PEDESTRIAN	↙	TURNING	→	10 MPH TO 19	B	BICYCLE
⊠	PARKED VEHICLE	↔	BACKING	→	20 MPH TO 29	T	TRAIN
⊠ ↘	PARKING VEHICLE	↔	SIDESWIPE	→	30 MPH TO 39	A	ANIMAL
□	FIXED OBJECT	↔	OUT OF CONTROL	→	40 MPH TO 49	*	DRIVER AT FAULT
→	HEAD ON	↔	INJURY	→	50 MPH TO 59	•	DRIVER AT FAULT
→	REAR END	↔	FATALITY	→	60 MPH TO 69	D	DRY
↘	RAN OFF ROAD	↔	SPEED UNKNOWN	→	70 AND UP	W	WET
		↔	DAYLIGHT CRASH	→	70 AND UP	I	ICY OR SNOWY
		↔	DARK CRASH				

US 221 at Bridges # 55 & 74 in Rutherford County
 After Period
 November 1, 2001 - June 30, 2007
 (5.66 Years)

TRAFFIC SAFETY SYSTEMS MANAGEMENT UNIT <small>HIGHWAY SAFETY IMPROVEMENT PROGRAM SAFETY INFORMATION MANAGEMENT AND SUPPORT</small>	
	
COLLISION DIAGRAM DIVISION: 13 AREA: .. STUDY PERIOD: 8/1/01 TO 6/30/07 DISTANCE: 0.62 MI. Y-LINE: 0 FT ANALYSIS PREPARED BY: CLS DIAGRAM PREPARED BY: CLS DIAGRAM REVIEWED BY:	
<small>SAFETY EVALUATION</small> BRIDGES 55 & 74	<small>TRAFFIC SAFETY</small> SCALE: NOT TO SCALE DATE: 8/1/07 LOG NUMBER: 200608058
N.C. DEPARTMENT of TRANSPORTATION DIVISION of HIGHWAYS TRAFFIC ENGINEERING AND SAFETY SYSTEMS BRANCH	

⊛	Target Crashes
- - -	Guardrail
—	Bridge