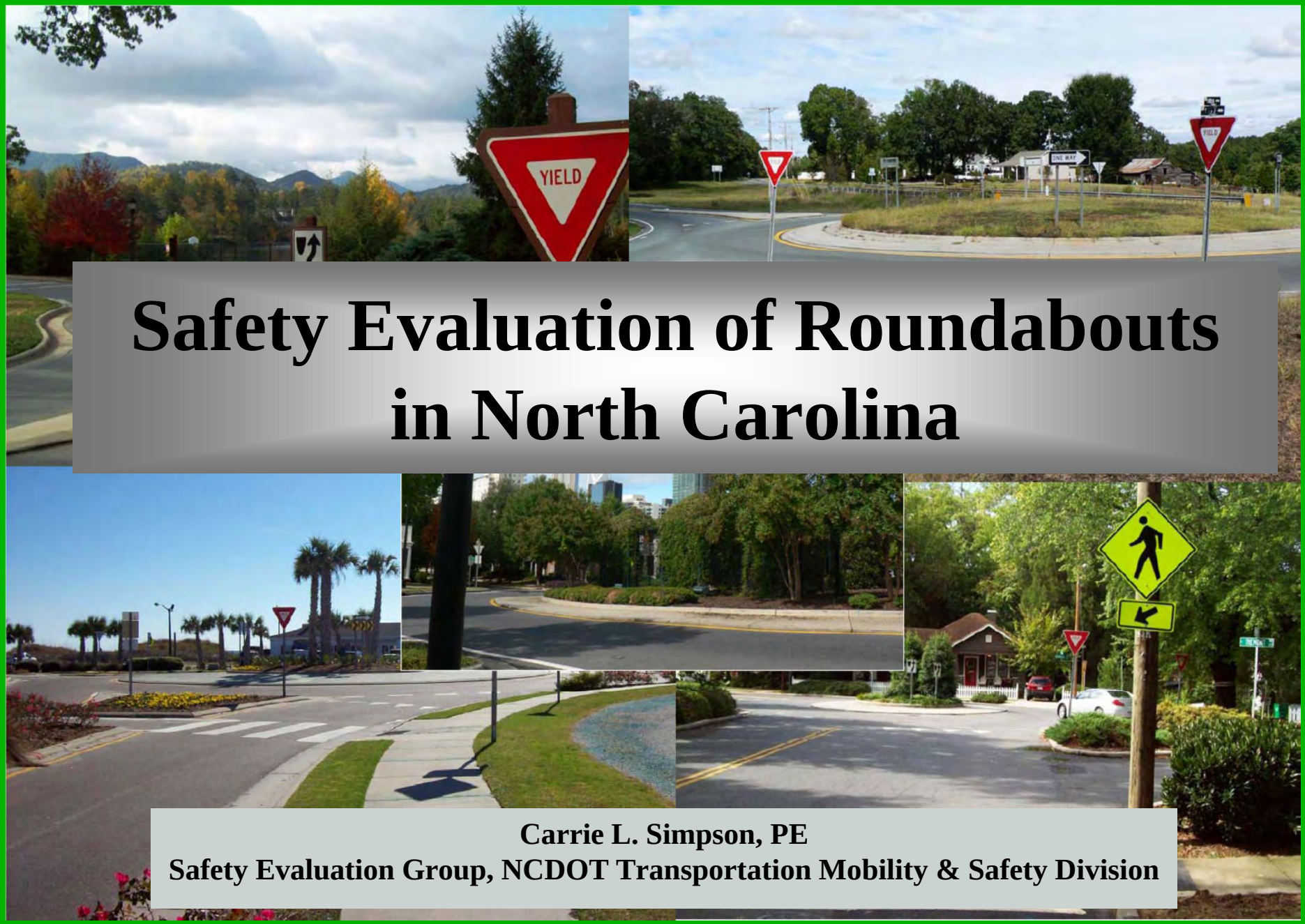

Safety Evaluation of Roundabouts in North Carolina

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Safety Evaluation Group, NCDOT Transportation Mobility & Safety Division

NCDOT Transportation Mobility & Safety Division

JUNE 2011

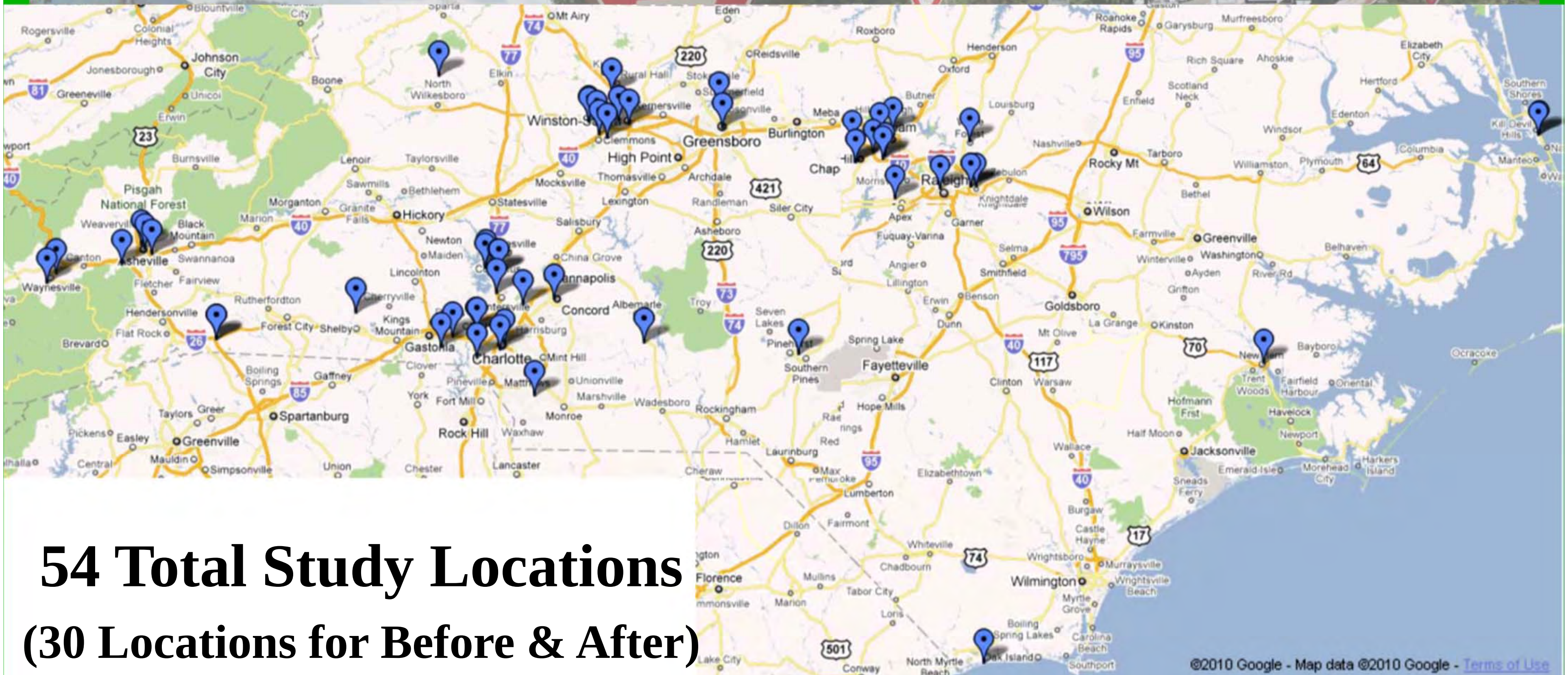
Introduction

Evaluation Objectives:

The Purpose of this Evaluation is to Determine the Safety Effectiveness of Roundabouts Installations Statewide

- Crash Frequency
- Severity
- Crash Types
- Night Crashes & Lighting Conditions
- Relationships between Intersection Geometry & Crashes
- Relationships between Entering Volume & Crashes
- Vehicle Speeds
- Signing and Marking Practices

Roundabout Study Locations

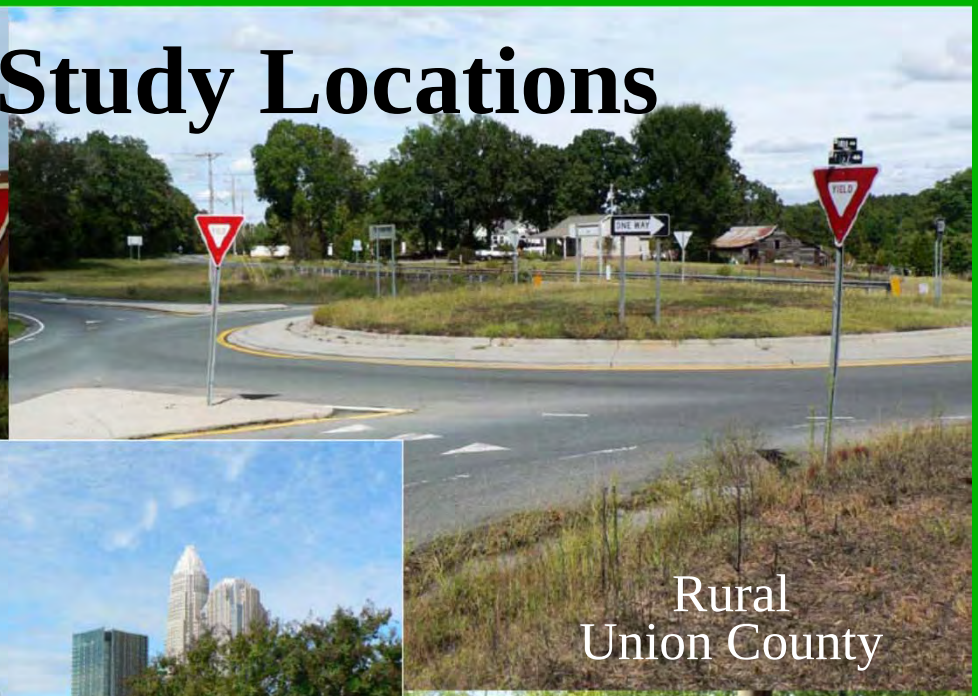


54 Total Study Locations

(30 Locations for Before & After)

Roundabout Study Locations

Suburban
Buncombe County



Rural
Union County

Urban
Mecklenburg County

Brunswick County

Mecklenburg County

NCDOT Transportation Mobility & Safety Division

Roundabout Study Locations

NCDOT Transportation Mobility & Safety Division

Crash Analysis Results

NCDOT Transportation Mobility & Safety Division

North Carolina Crash Analysis Results

Percent Crash Reductions at NC Roundabouts
(Naïve Before & After with Linear Traffic Factor)

	All 30 Sites
Total Crashes	**46.2% (5.2)**
Injury Crashes - All Types	75.3% (4.9)
Injury Crashes - KAB	85.0% (6.5)
Frontal Impact Crashes*	75.6% (3.9)
Rear End Crashes*	29.9% (13.2)
Sideswipe Crashes*	20.1% (28.9)
Day	56.0% (5.0)
Night	2.8% (18.2)

* As crash classified in DMV 349

( ) = standard deviation of an estimated value

NCDOT Transportation Mobility & Safety Division

National Roundabout Safety Statistics

SOURCE: NCHRP 672 (2010)

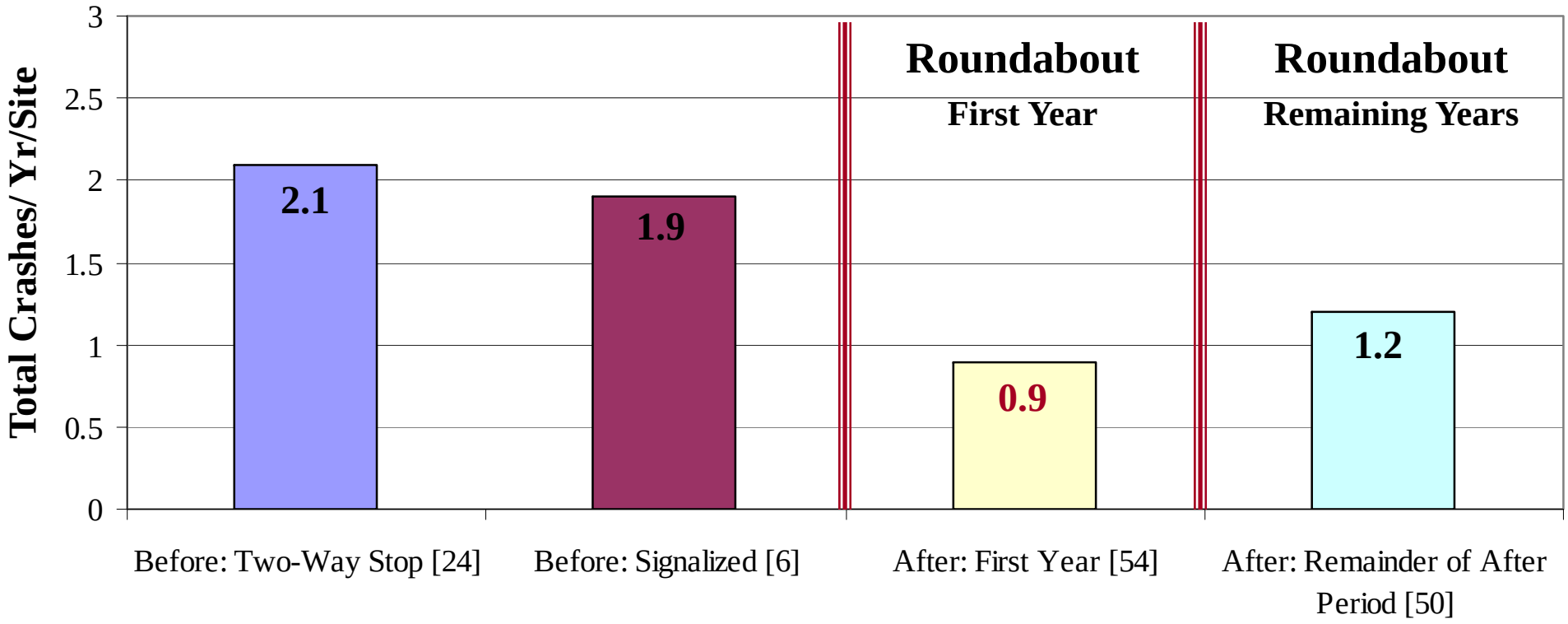
Exhibit 5-9
Comparisons to Previous Intersection Treatments in the United States

Control Before	Sites	Setting	Lanes	Estimate of the Percent Reduction in Crashes (and Standard Error)	
				All	Injury + Fatal
All Sites	55	All	All	35.4% (3.4)	75.8% (3.2)
Signalized	9	All	All	47.8% (4.9)	77.7% (6.0)
	4	Suburban	2	66.7% (4.4)	Sample too small to analyze
	5	Urban	All	Effects insignificant	60.1% (11.6)
All-way stop	10	All	All	Effects insignificant	Effects insignificant
Two-way stop	36	All	All	44.2% (3.8)	81.8% (3.2)
	9	Rural	1	71.5% (4.0)	87.3% (3.4)
	17	Urban	All	29.0% (9.0)	81.2% (7.9)
	12		1	39.8% (10.1)	80.3% (10.0)
	5		2	Sample too small to analyze	Sample too small to analyze
	10	Suburban	All	31.8% (6.7)	71.0% (8.3)
	4		1	78.2% (5.7)	77.6% (10.4)
	6		2	19.3% (9.1)	68.0% (11.6)
	27	Urban/ Suburban	All	30.8% (5.5)	74.4% (6.0)
	16		1	56.3% (6.0)	77.7% (7.4)
	11		2	17.9% (8.2)	71.8% (9.3)

Overall, there is an observed reduction of 35% and 76% in total and injury crashes, respectively, following conversion to a roundabout. These values are consistent with results from international studies, as shown in Exhibit 5-10.

Crash Analysis Results - Immediately After

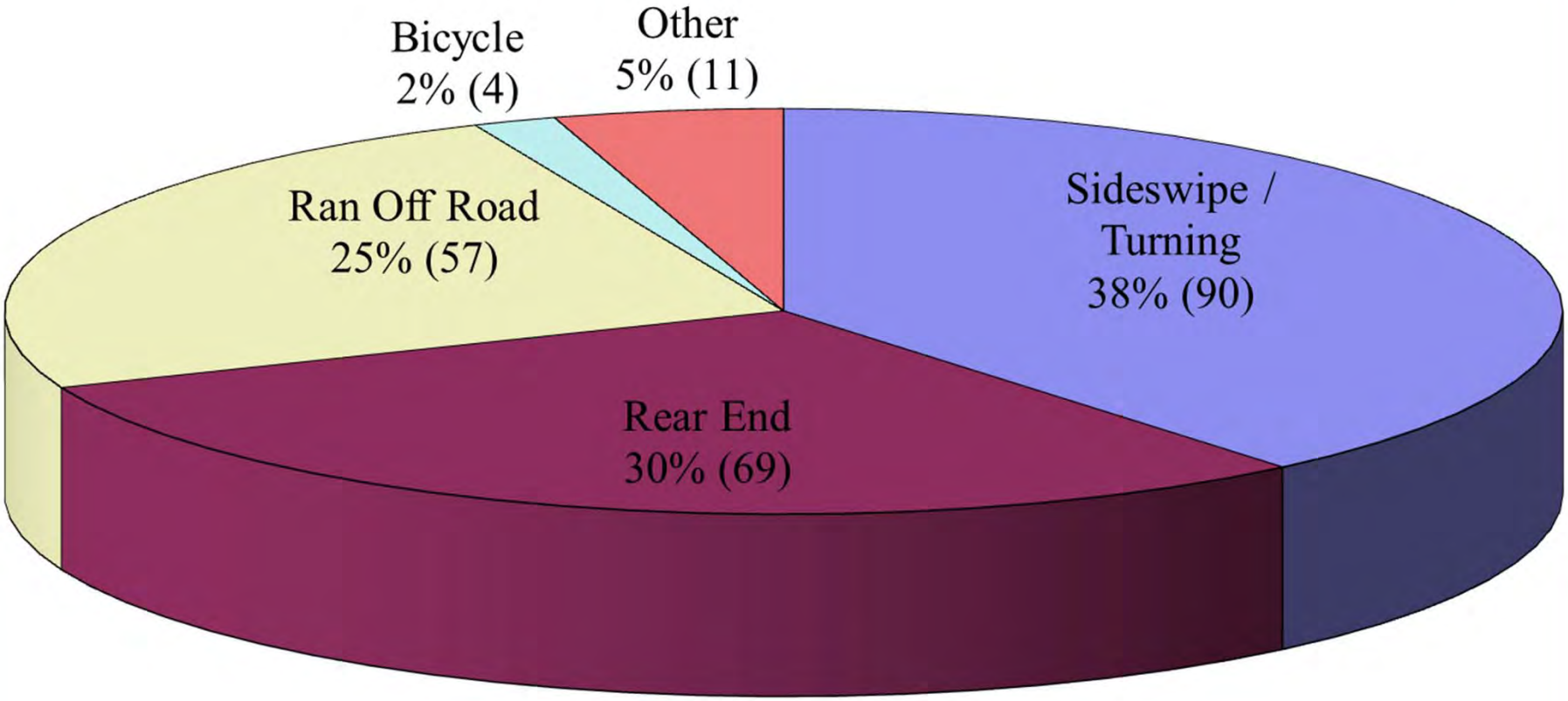
Safety Performance First Year After Installation



Crash Analysis Results: Crash Types

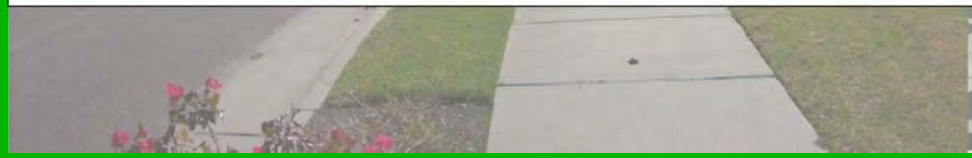
NCDOT Transportation Mobility & Safety Division

Roundabout Crash Types



0 Pedestrian Crashes

( ) = Crash Frequency



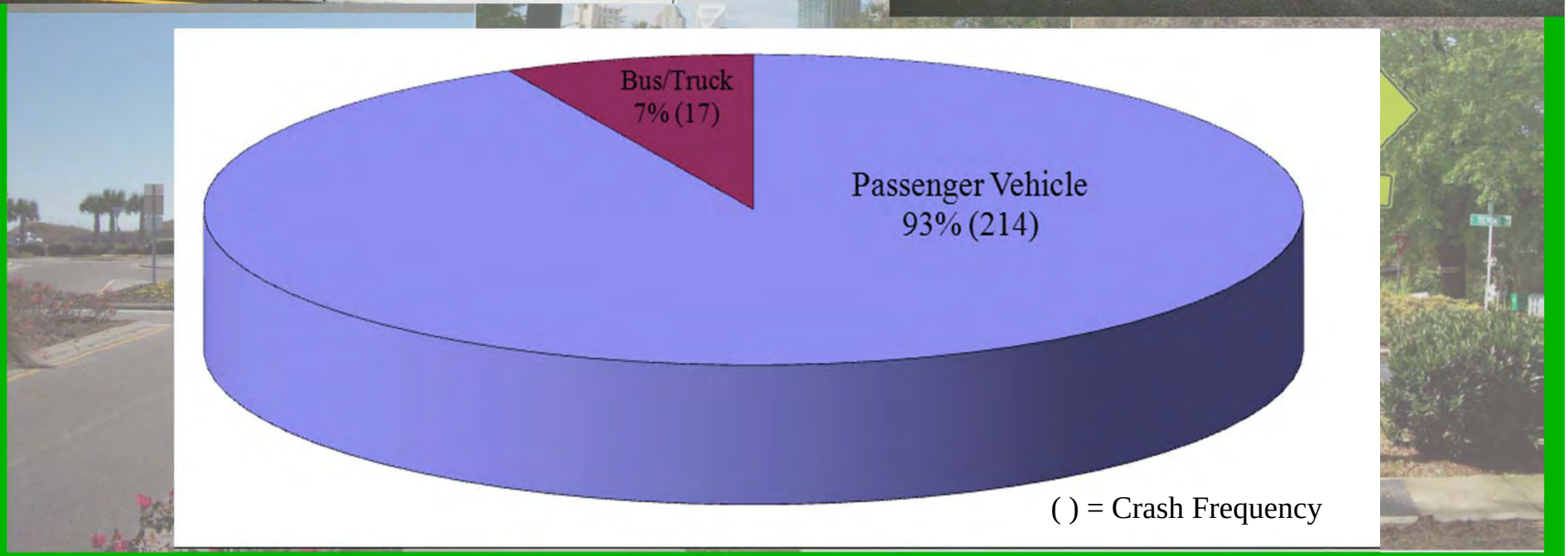
Bicycle and Pedestrian Involved Crashes

		Bicycle Crashes							
		Before (30 Sites)				After (54 Sites)			
Sites with Bicycle Crashes	Study Years	#	Injury Type	Vehicle Impact Speed	Location	#	Injury Type	Vehicle Impact Speed	Location
WT Weaver @ University Heights	7	1	B	10 mph	inside	0	---	---	---
US 421 NB Ramp @ Williams	6	0	---	---	---	1	B	5 mph	entry
US 421 SB Ramp @ Williams	9	0	---	---	---	1	C	15 mph	inside
Ninth @ Davidson	8	1	B	5 mph	xwalk	0	---	---	---
Voit Gilmore @ Knoll	4	0	---	---	---	1	B	20 mph	xwalk
Pullen @ Stinson	6	1	C	5 mph	xwalk	1	C	5 mph	entry
	SUM	**3**				**4**			

No Pedestrian Crashes (Before or After)

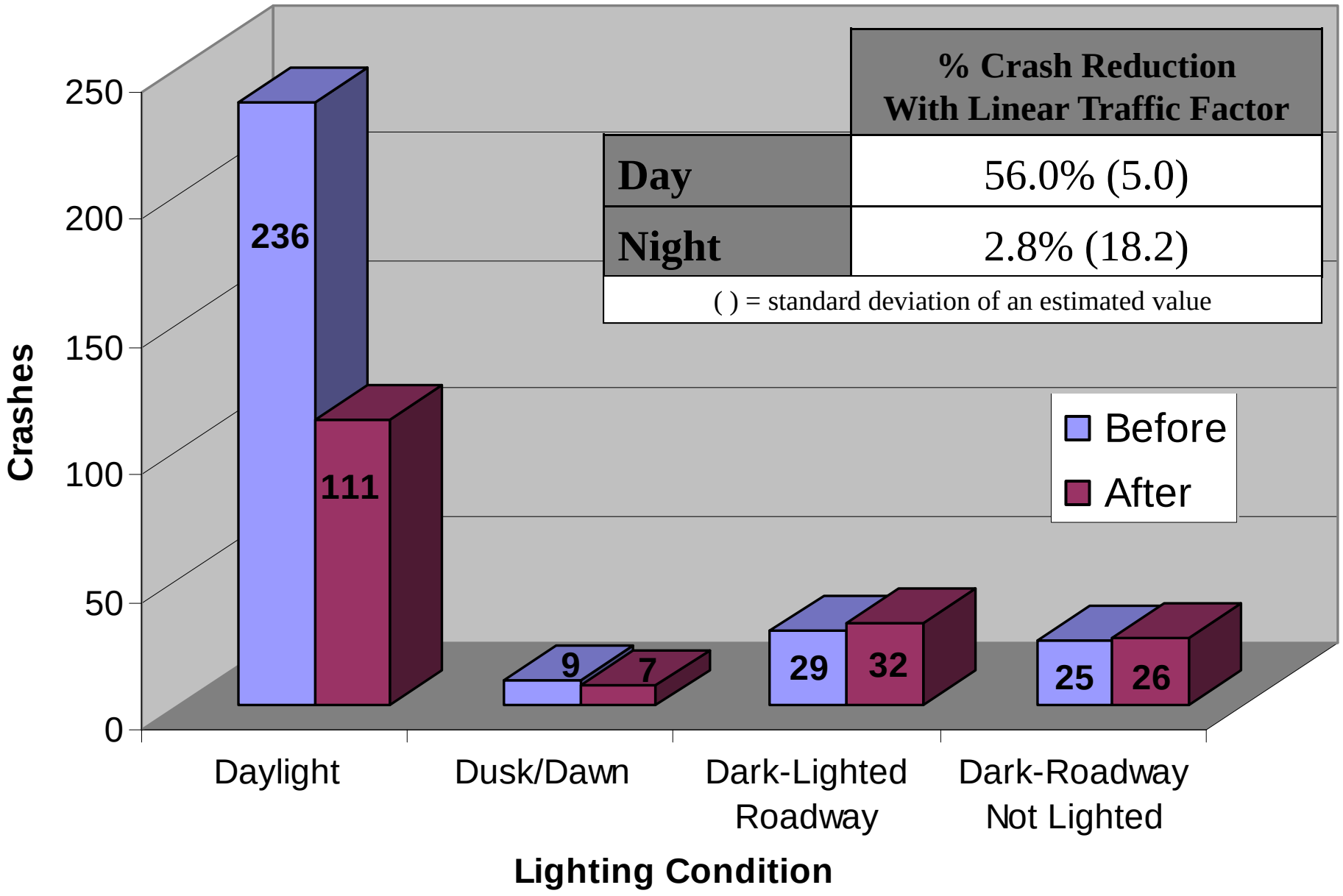
NCDOT Transportation Mobility & Safety Division

Heavy Vehicle Involvement



NCDOT Transportation Mobility & Safety Division

Day Vs. Night Crashes



Crash Analysis Results: Intersection Features & Crashes

NCDOT Transportation Mobility & Safety Division

Crash Analysis Results – Size Categories

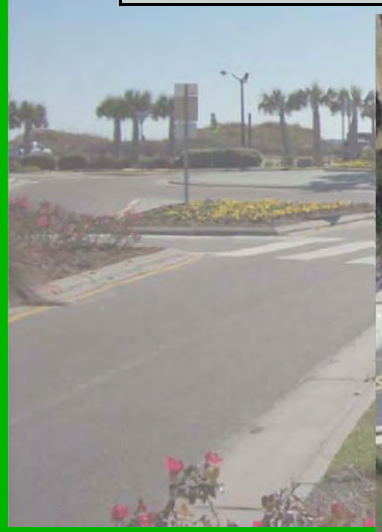
Percent Crash Reductions at NC Roundabouts
(Naïve Before & After with Linear Traffic Factor)

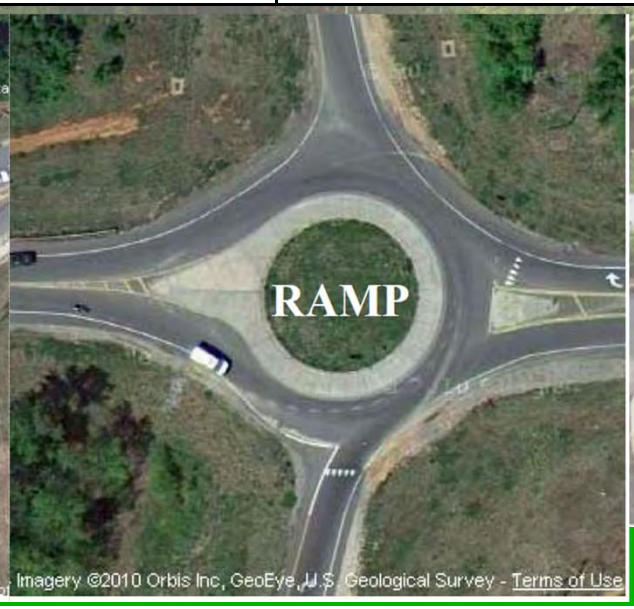
SINGLE LANE	**Sites**	**Total Crashes**	**KAB Injury Crashes**
Mini & Compact	**9**	**60.7% (7.5)**	**100%**
Mini	4	57.7% (17.1)	100%
Compact	5	61.9% (8.1)	100%
Standard & Large	**14**	**56.3% (6.3)**	**84.8% (9.0)**
Standard	10	58.9% (7.3)	90.5% (9.0)
Large	4	51.4% (12.1)	80.7% (13.6)

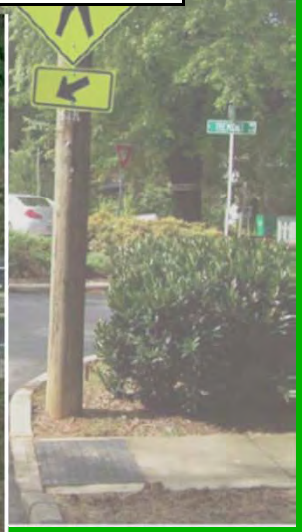
Crash Analysis Results – Size Categories

Percent Crash Reductions at NC Roundabouts
(Naïve Before & After with Linear Traffic Factor)

	Sites	Total Crashes	KAB Injury Crashes
Single Lane (All, Non-Ramp)	23	57.8% (4.9)	89.6% (6.1)
Double Lane	1	-11.2% (42.1)	N/A
Ramp	6	2.5% (19.8)	75.8% (14.5)







Crash Analysis Results – Prior Control

Percent Crash Reductions at NC Roundabouts
(Naïve Before & After with Linear Traffic Factor)

Before Period Control Type	**Sites**	**Total Crashes**	**KAB Injury Crashes**
Two-Way Stop	24	47.7% (5.7)	78.1% (9.6)
Signalized	6	41.2% (11.8)	100%

Crash Analysis Results – Number of Legs

Percent Crash Reductions at NC Roundabouts
(Naïve Before & After with Linear Traffic Factor)

Number of Legs	Sites*	Total Crashes	KAB Injury Crashes
3 Leg	8	57.1% (9.7)	89.3% (10.1)
4 Leg	15	58.2% (5.6)	90.2% (6.9)

* All Sizes of Single Lane, Non-Ramp Roundabouts

Crash Analysis Results – Bypass Lanes

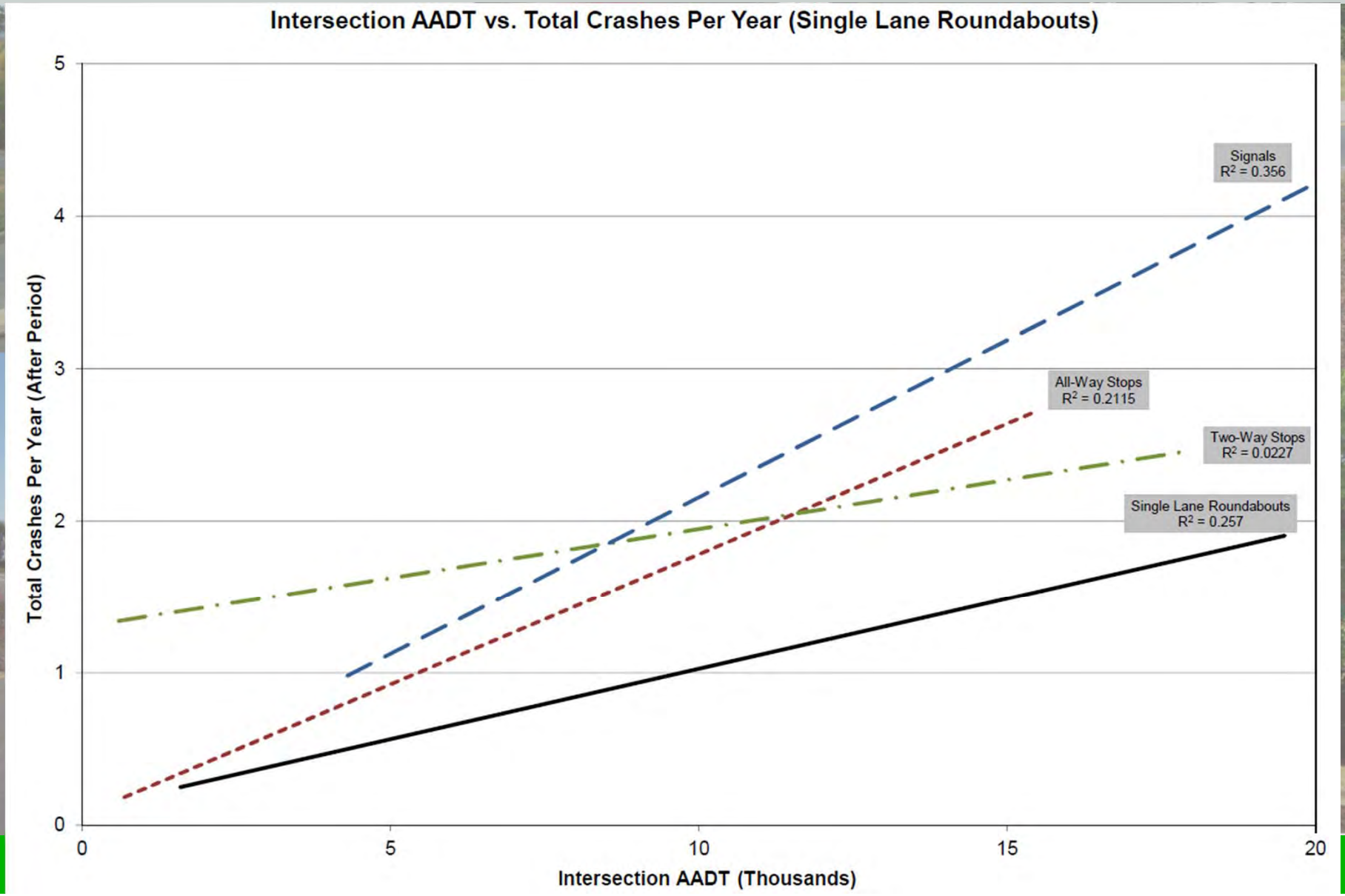
Avg. Sideswipe Crashes/Yr/Site	Sites	Before	After	Avg. AADT (Excluding Ramps)
Bypass Lane	5	0.2	0.1	10,800
No Bypass Lane	25	0.1	0.1	8,000

Crash Analysis Results: Entering Volume & Crashes

NCDOT Transportation Mobility & Safety Division

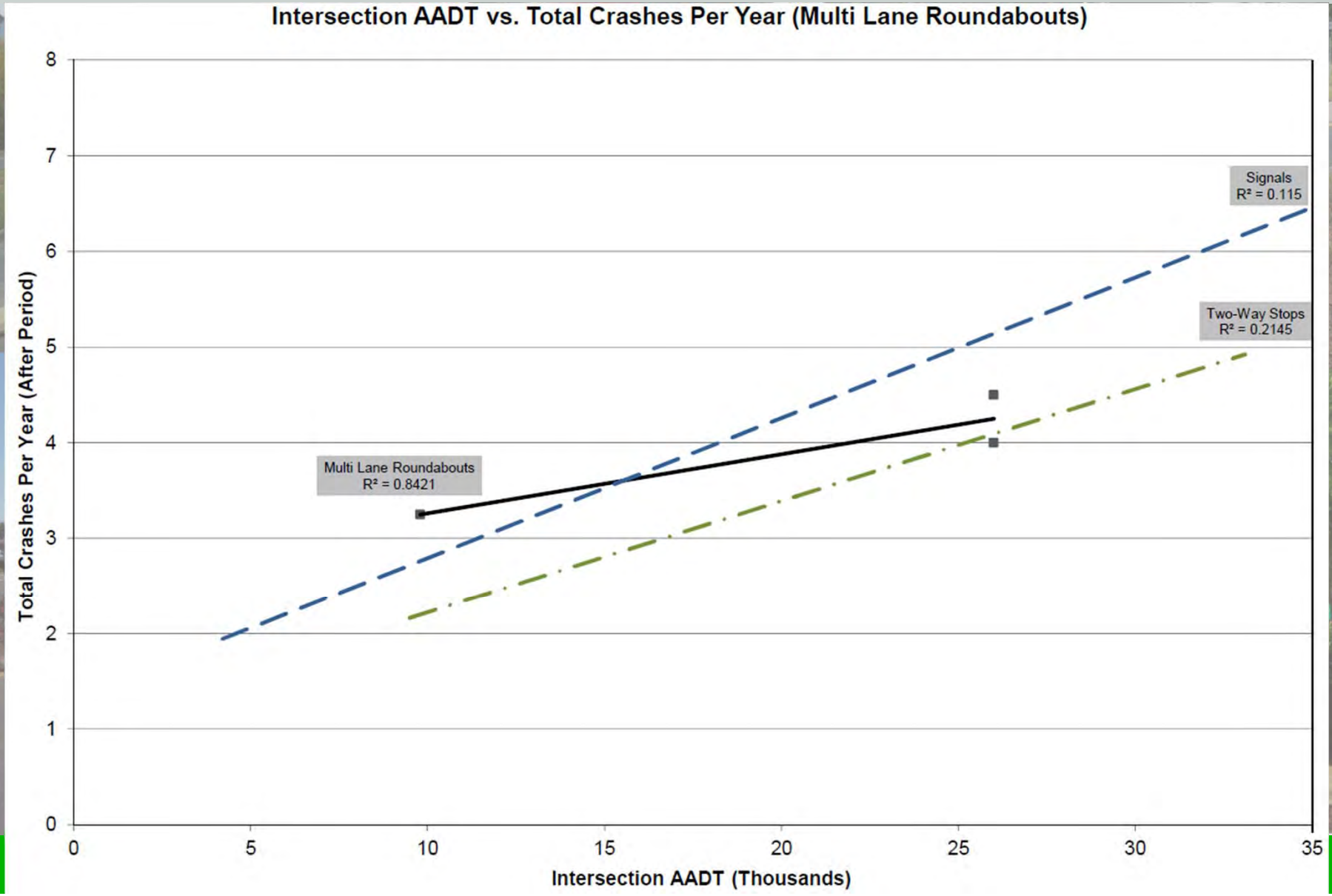
Entering Volume vs. Crashes/Yr

Comparison of Single Lane Roundabouts, All-Way Stops, Two-Way Stops & Signals



Entering Volume vs. Crashes/Yr

Comparison of Multi Lane Roundabouts, 2-Way Stops & Signals



Crash Analysis Results: Speed Related Data

NCDOT Transportation Mobility & Safety Division

Crash Analysis Results - Speed Limits

Percent Crash Reductions at NC Roundabouts
(Naïve Before & After with Linear Traffic Factor)

Approach Speed Limits	Sites	Total Crashes	KAB Injury Crashes
Low Speed (< 45 mph)	19	39.9% (7.9)	90.9% (6.4)
High Speed (≥ 45 mph)	11	52.6% (6.7)	79.0% (11.1)

Speeds at Impact (mph)

Estimated Speeds at Crash Impact (30 Sites)	Before	After	% Difference
Average Speed	18.2	15.1	-17%
Average Speed: Vehicle 1	16.8	16.4	-2%
Average Speed: Vehicle 2	19.7	13.3	-32%

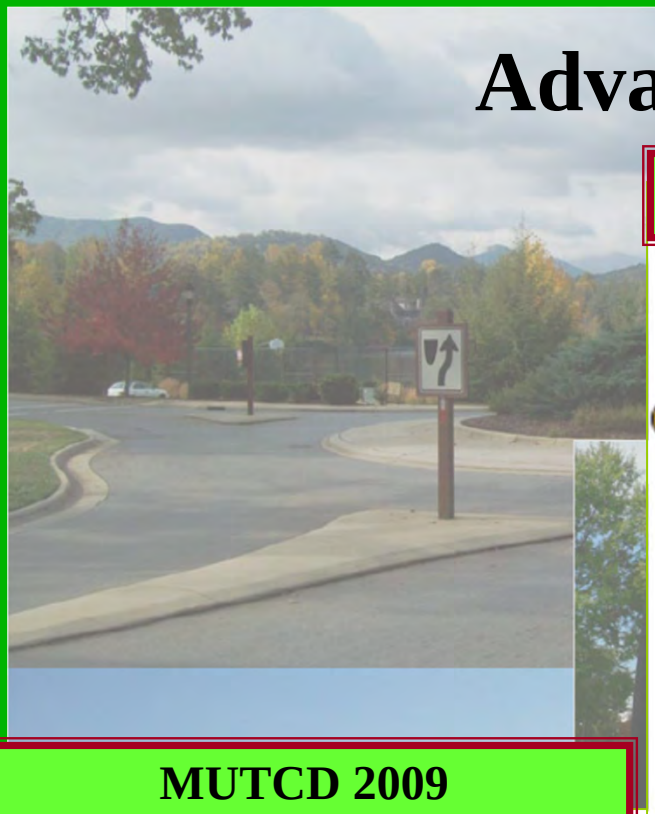
Max Speed	70	55
Interquartile Range (IQR)*	5-30 [25]	5-20 [15]

***IQR is the range of the middle 50% of data.**

Signing & Marking Practices

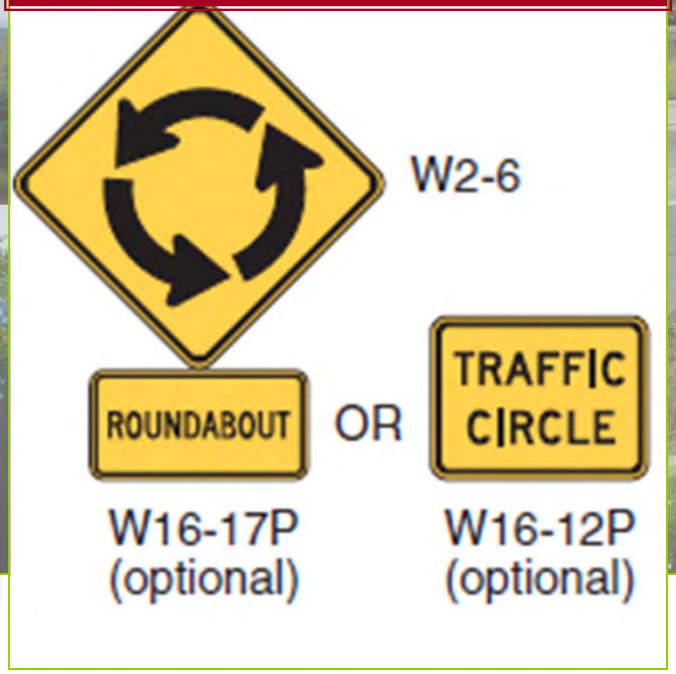
NCDOT Transportation Mobility & Safety Division

Advanced Warning Signs



MUTCD 2009

MUTCD 2009



02 The Circular Intersection (W2-6) symbol sign (see Figure 2C-9) may be installed in advance of a circular intersection (see Figures 2B-21 through 2B-23).

Guidance:

03 *If an approach to a roundabout has a statutory or posted speed limit of 40 mph or higher, the Circular Intersection (W2-6) symbol sign should be installed in advance of the circular intersection.*

Option:

04 An educational plaque (see Figure 2C-9) with a legend such as ROUNDABOUT (W16-17P) or TRAFFIC CIRCLE (W16-12P) may be mounted below a Circular Intersection symbol sign.

NC Advanced Warning Sign Practices

NCDOT Transportation Mobility & Safety Division

NC Advanced Warning Sign Practices

NCDOT Transportati

Advisory Speed Limits

2009 MUTCD

Section 2C.08 Advisory Speed Plaque (W13-1P)

Option:

01 The Advisory Speed (W13-1P) plaque (see Figure 2C-1) may be used to supplement any warning sign to indicate the advisory speed for a condition.

Standard:

02 **The use of the Advisory Speed plaque for horizontal curves shall be in accordance with the information shown in Table 2C-5. The Advisory Speed plaque shall also be used where an engineering study indicates a need to advise road users of the advisory speed for other roadway conditions.**

03 **If used, the Advisory Speed plaque shall carry the message XX MPH. The speed displayed shall be a multiple of 5 mph.**

04 **Except in emergencies or when the condition is temporary, an Advisory Speed plaque shall not be installed until the advisory speed has been determined by an engineering study.**

05 **The Advisory Speed plaque shall only be used to supplement a warning sign and shall not be installed as a separate sign installation.**

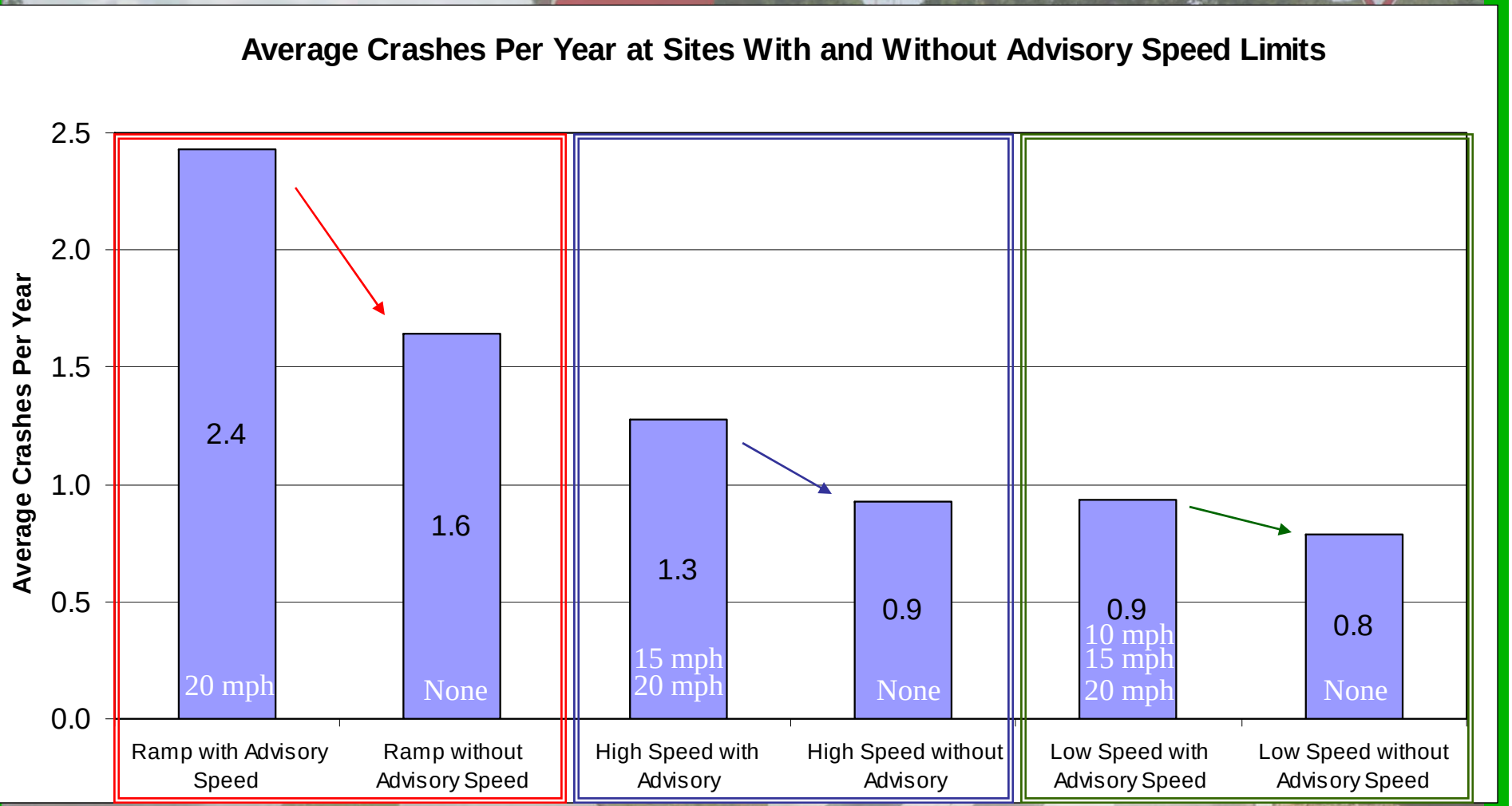
06 **The advisory speed shall be determined by an engineering study that follows established engineering practices.**

Advisory Speed Limits

NCHRP 672 Roundabout Guide (2010):

MUTCD. In practice it is difficult to define an appropriate advisory speed: Should it be related to the slowest speed for through traffic (V2), the slowest speed of all movements (typically V4), or another speed (such as zero for potentially coming to a stop at the yield sign)? In addition, advisory speed plaques are usually only used for turns and curves, not intersections.

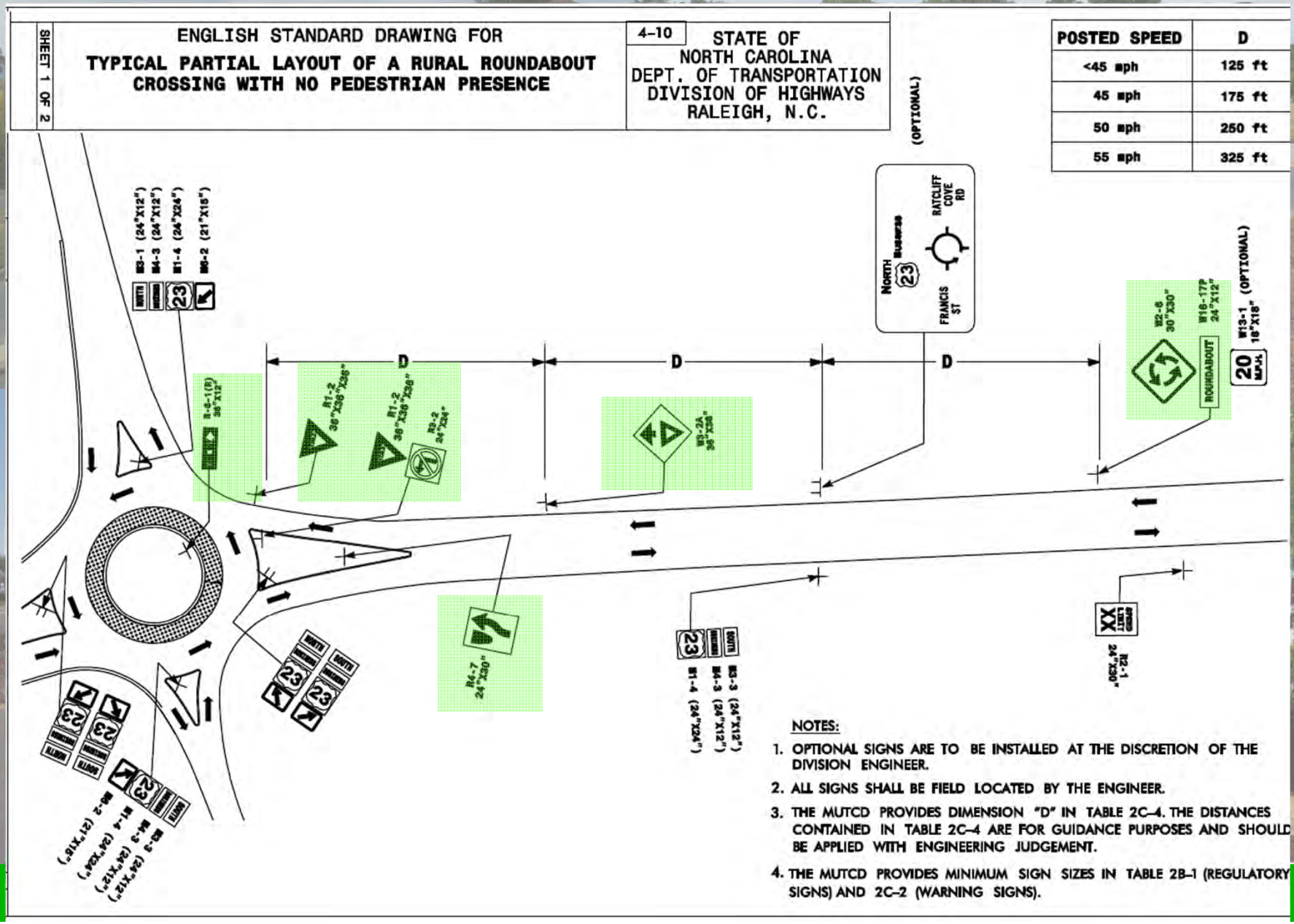
Advisory Speed Limits & Crashes/Yr



NCDOT Transportation Mobility & Safety Division

Number of Signs Per Approach

NCDOT Signing Layout - RURAL



Rural Signing & Marking Examples

NCDOT Signing Layouts - URBAN

SHEET 2 OF 2

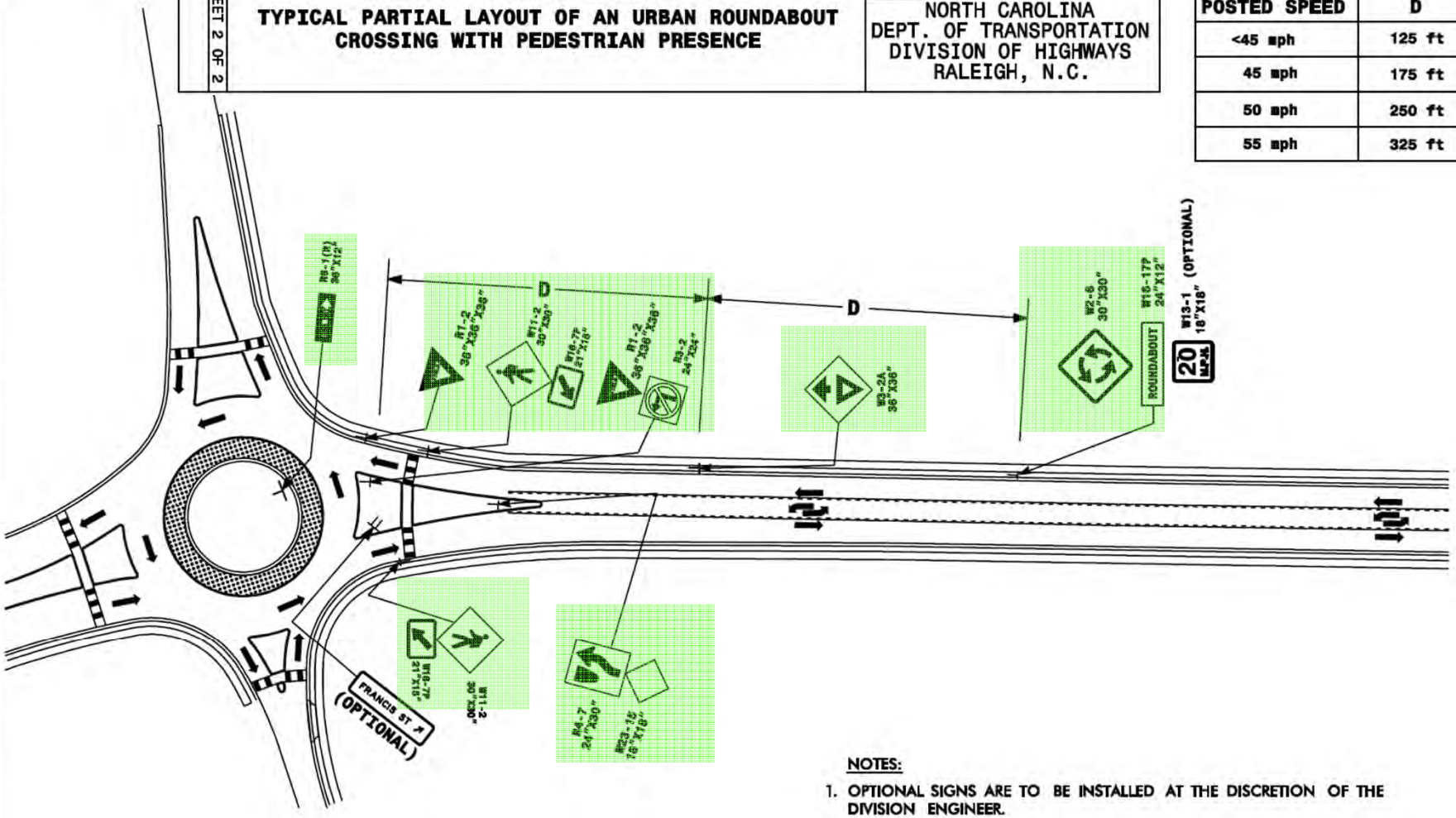
ENGLISH STANDARD DRAWING FOR

TYPICAL PARTIAL LAYOUT OF AN URBAN ROUNDABOUT CROSSING WITH PEDESTRIAN PRESENCE

4-10

STATE OF
NORTH CAROLINA
DEPT. OF TRANSPORTATION
DIVISION OF HIGHWAYS
RALEIGH, N.C.

POSTED SPEED	D
<45 mph	125 ft
45 mph	175 ft
50 mph	250 ft
55 mph	325 ft

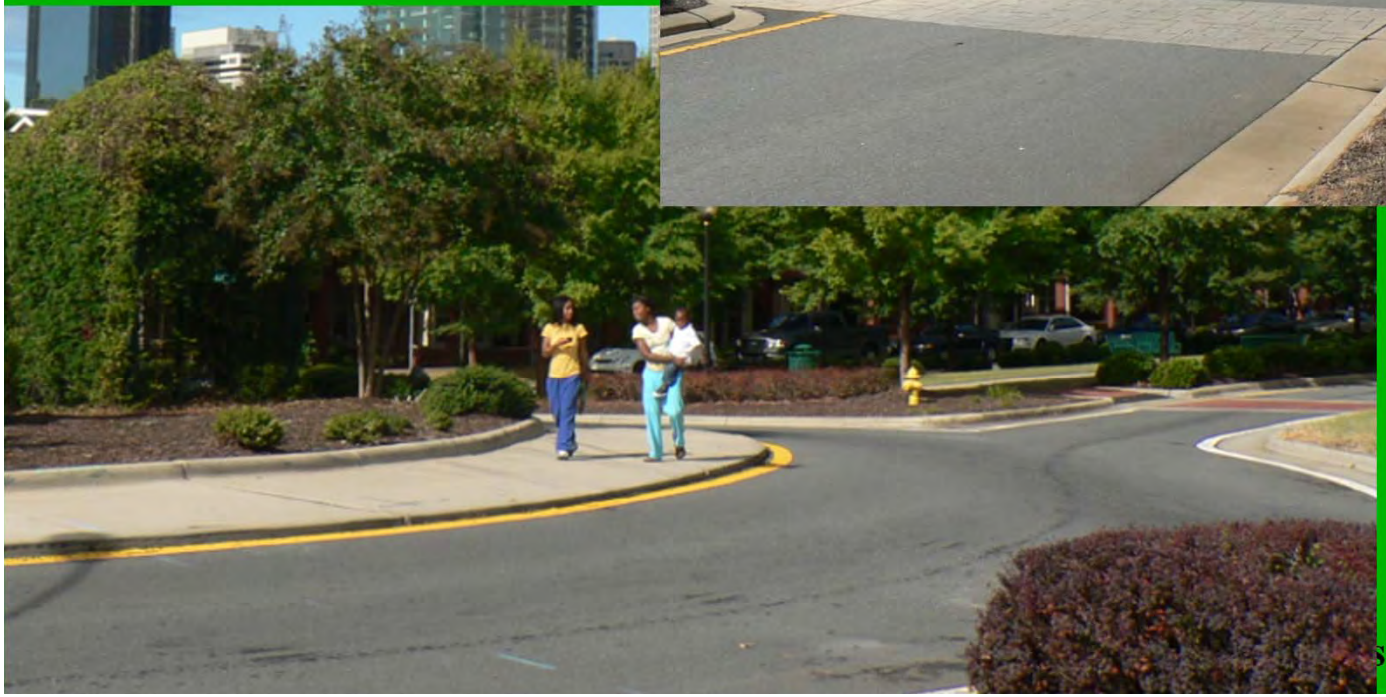


NOTES:

1. OPTIONAL SIGNS ARE TO BE INSTALLED AT THE DISCRETION OF THE DIVISION ENGINEER.
2. ALL SIGNS SHALL BE FIELD LOCATED BY THE ENGINEER.
3. THE MUTCD PROVIDES DIMENSION "D" IN TABLE 2C-4. THE DISTANCES CONTAINED IN TABLE 2C-4 ARE FOR GUIDANCE PURPOSES AND SHOULD BE APPLIED WITH ENGINEERING JUDGEMENT.
4. THE MUTCD PROVIDES MINIMUM SIGN SIZES IN TABLE 2B-1 (REGULATORY SIGNS) AND 2C-2 (WARNING SIGNS).

Pedestrian Accommodations

Pedestrian Accommodations



sion

Pedestrian Accommodations

NCDOT Transportation Mobility & Safety Division

Bicycle Accommodations

Pavement Marking Practices

Marking Type		% of Roundabouts [#]
Yield Entry Lines		72% [39]
Dashed Entry Lines		72% [39]
“Yield” Markings		6% [3]
Advance Arrow Markings		13% [7]
In Circle Arrow Markings		19% [10]
Marked Crosswalks		59% [32]

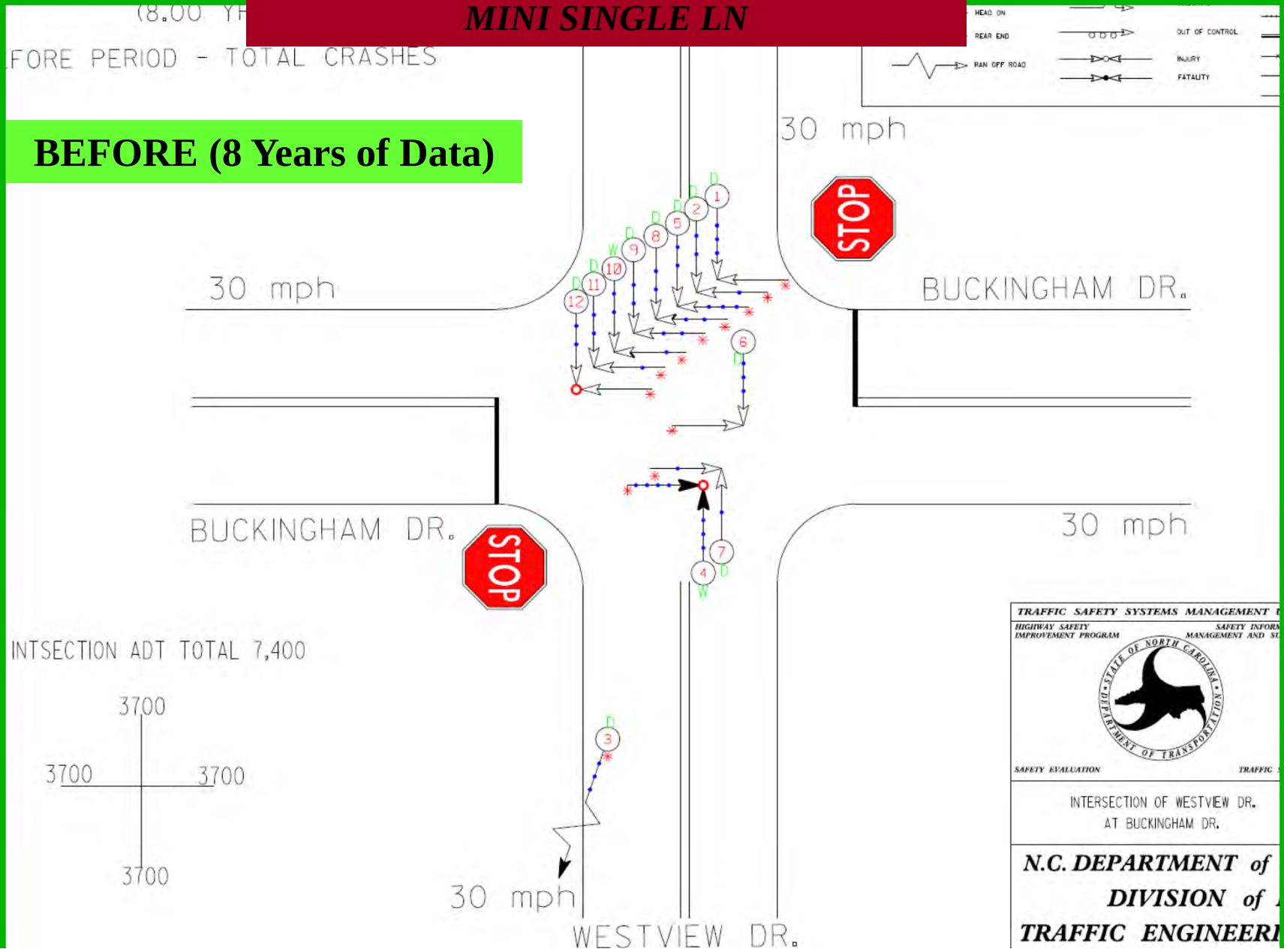
Collision Diagrams

NCDOT Transportation Mobility & Safety Division

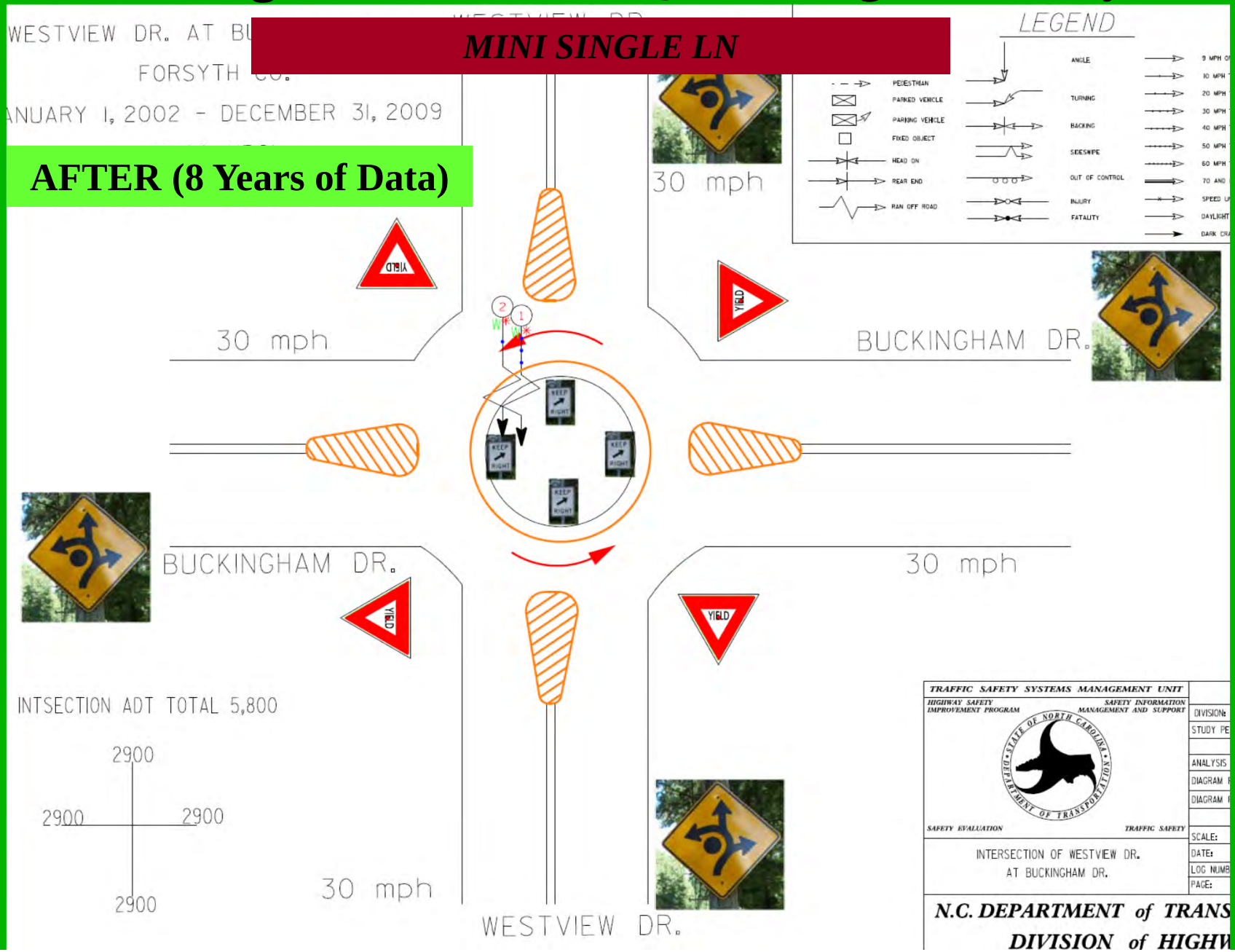
Crash Diagrams: Westview @ Buckingham, Forsyth Co.

MINI SINGLE LN

BEFORE (8 Years of Data)

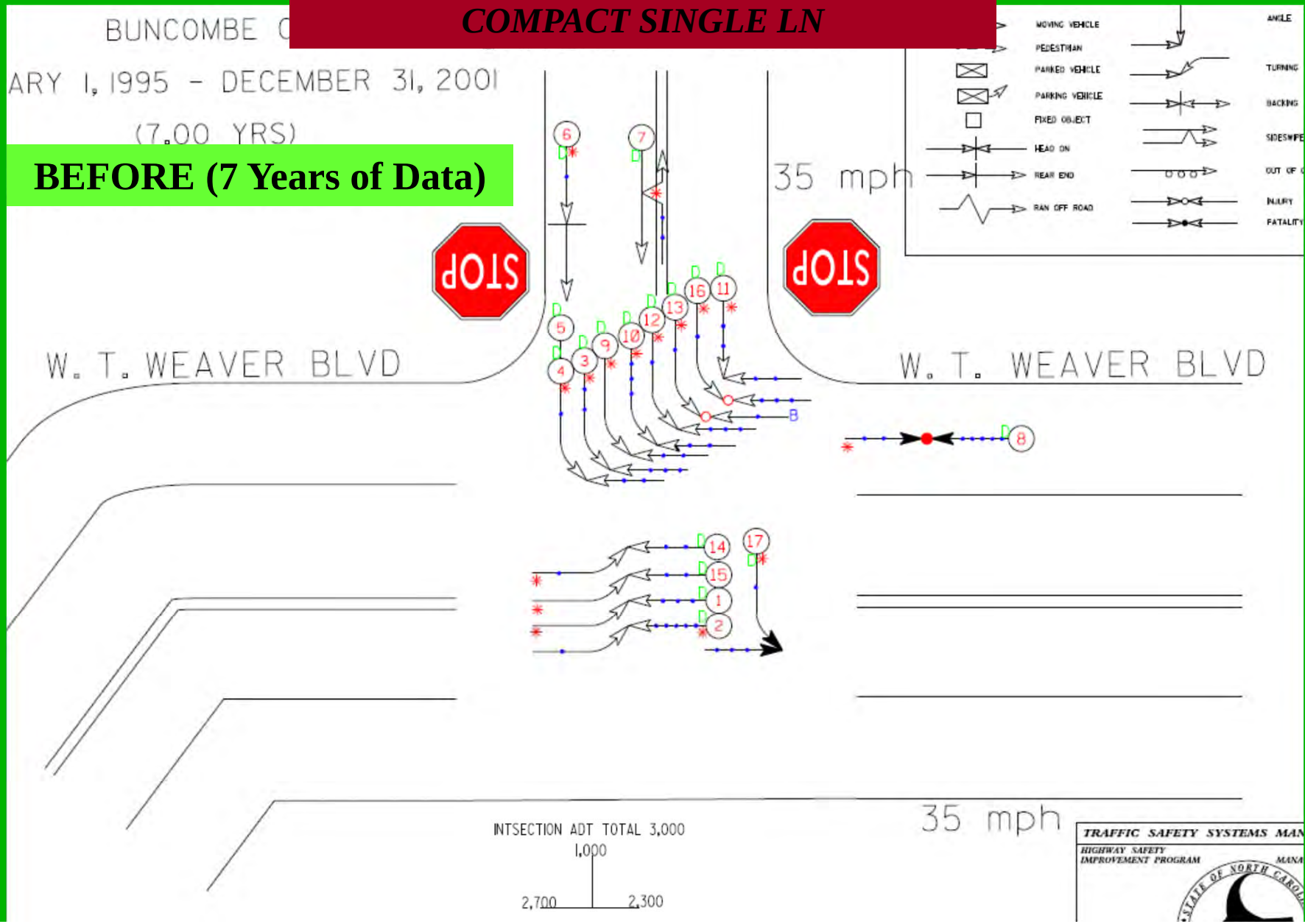


Crash Diagrams: Westview @ Buckingham, Forsyth Co.



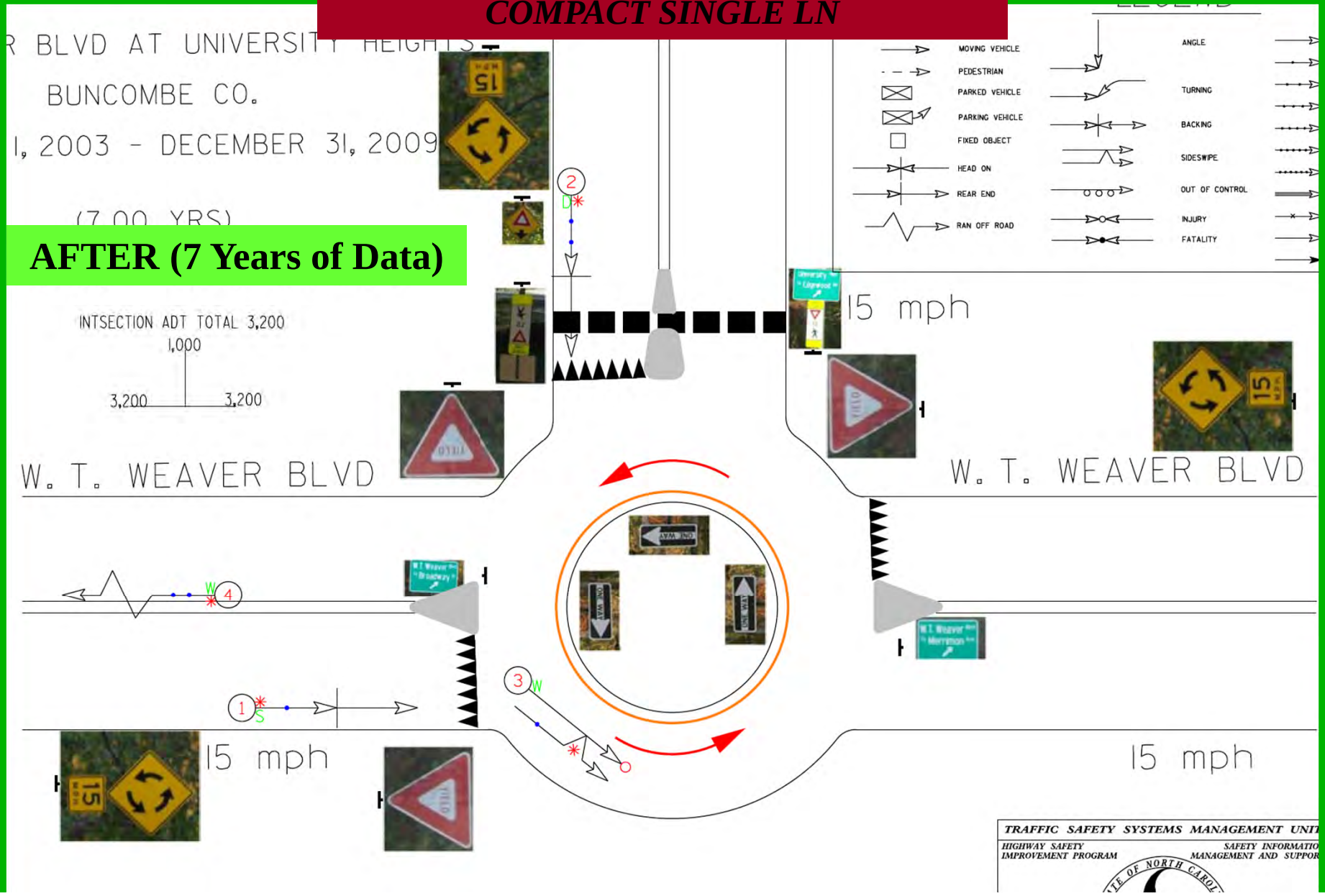
Crash Diagrams: WT Weaver @ University Heights, Buncombe Co.

COMPACT SINGLE LN



Crash Diagrams: WT Weaver @ University Heights, Buncombe Co.

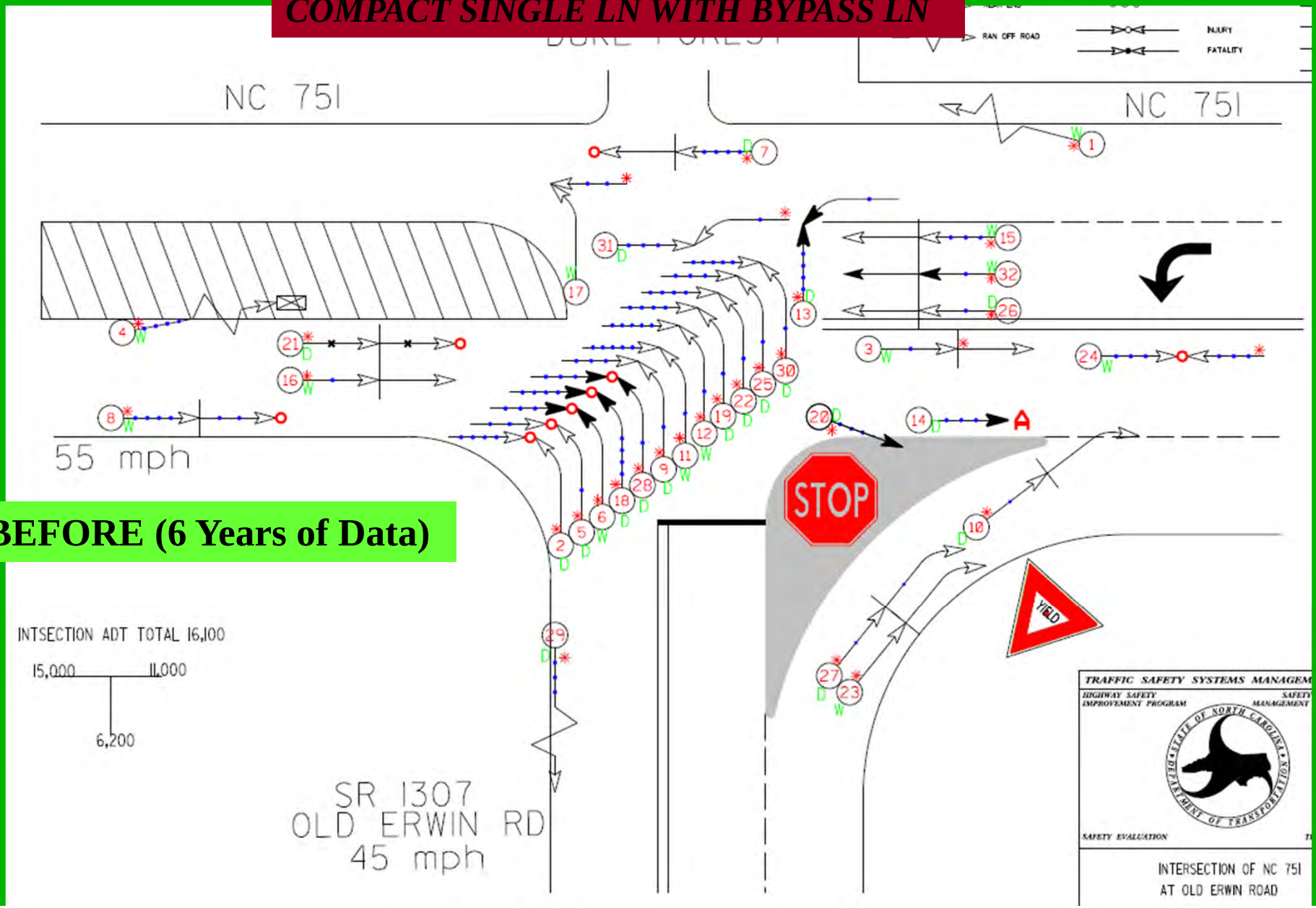
COMPACT SINGLE LN



AFTER (7 Years of Data)

Crash Diagrams: NC 751 @ Erwin Rd, Durham Co.

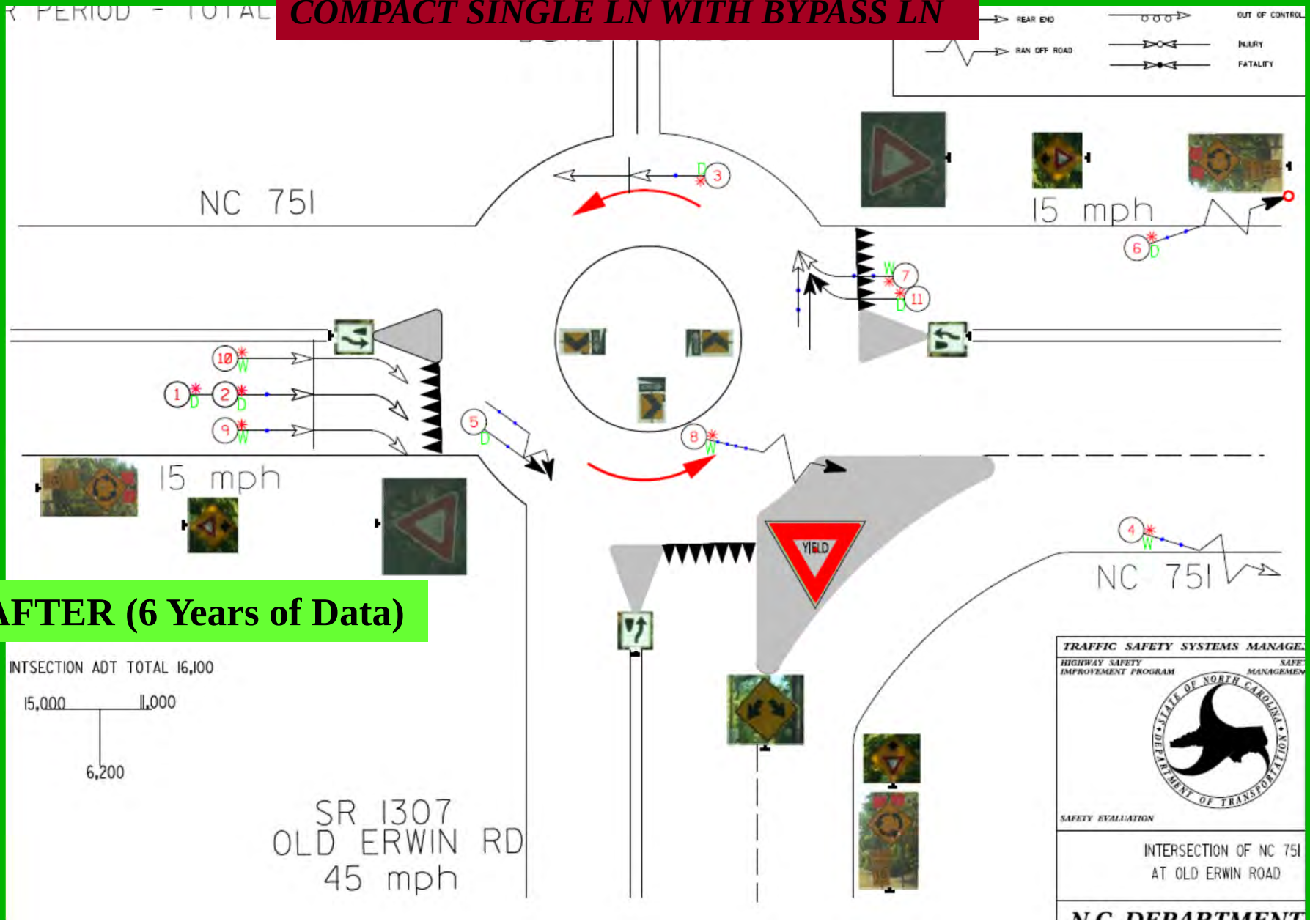
COMPACT SINGLE LN WITH BYPASS LN



BEFORE (6 Years of Data)

Crash Diagrams: NC 751 @ Erwin Rd, Durham Co.

COMPACT SINGLE LN WITH BYPASS LN

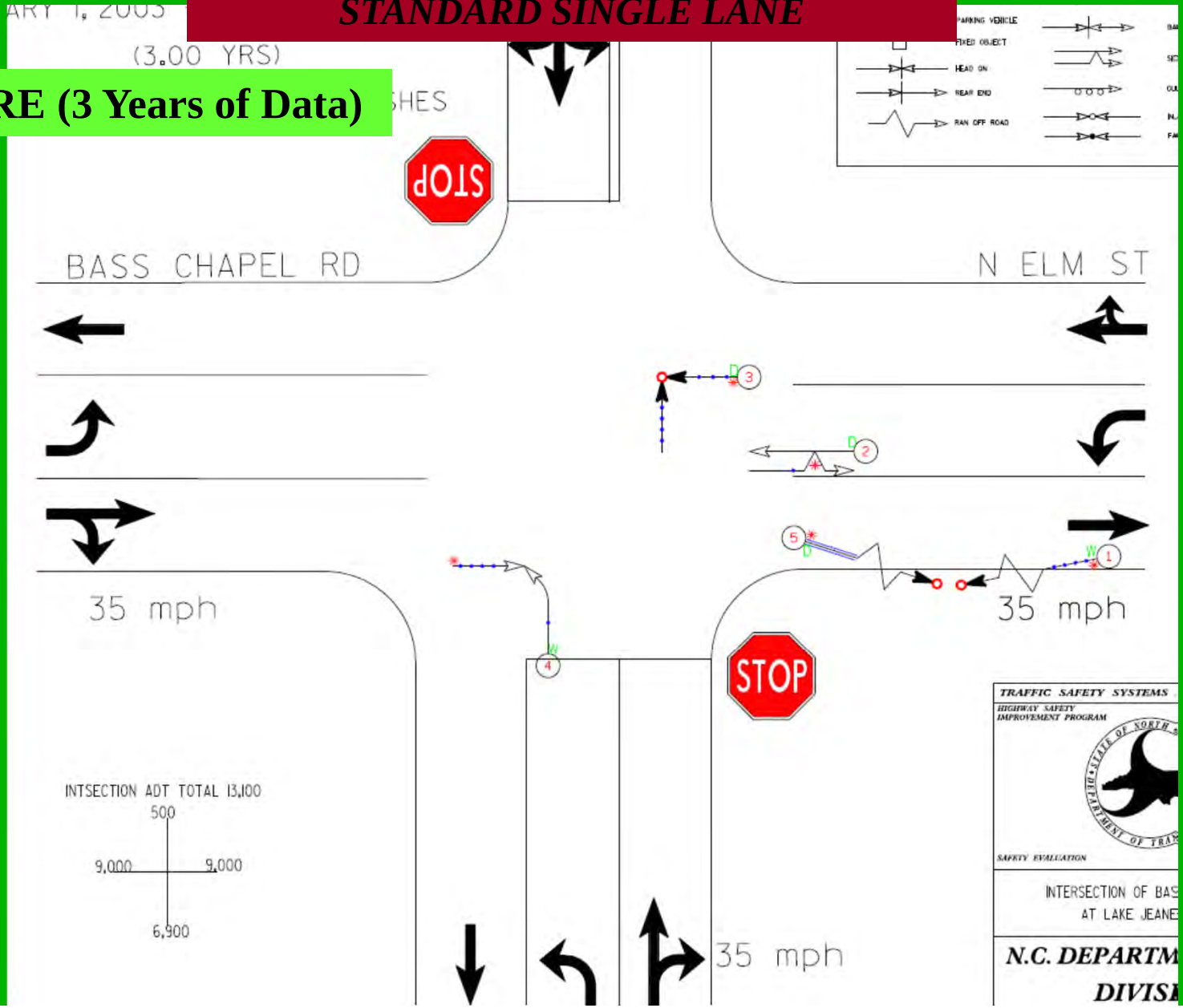


AFTER (6 Years of Data)

Crash Diagrams: Lake Jeanette @ Elm, Guilford Co.

STANDARD SINGLE LANE

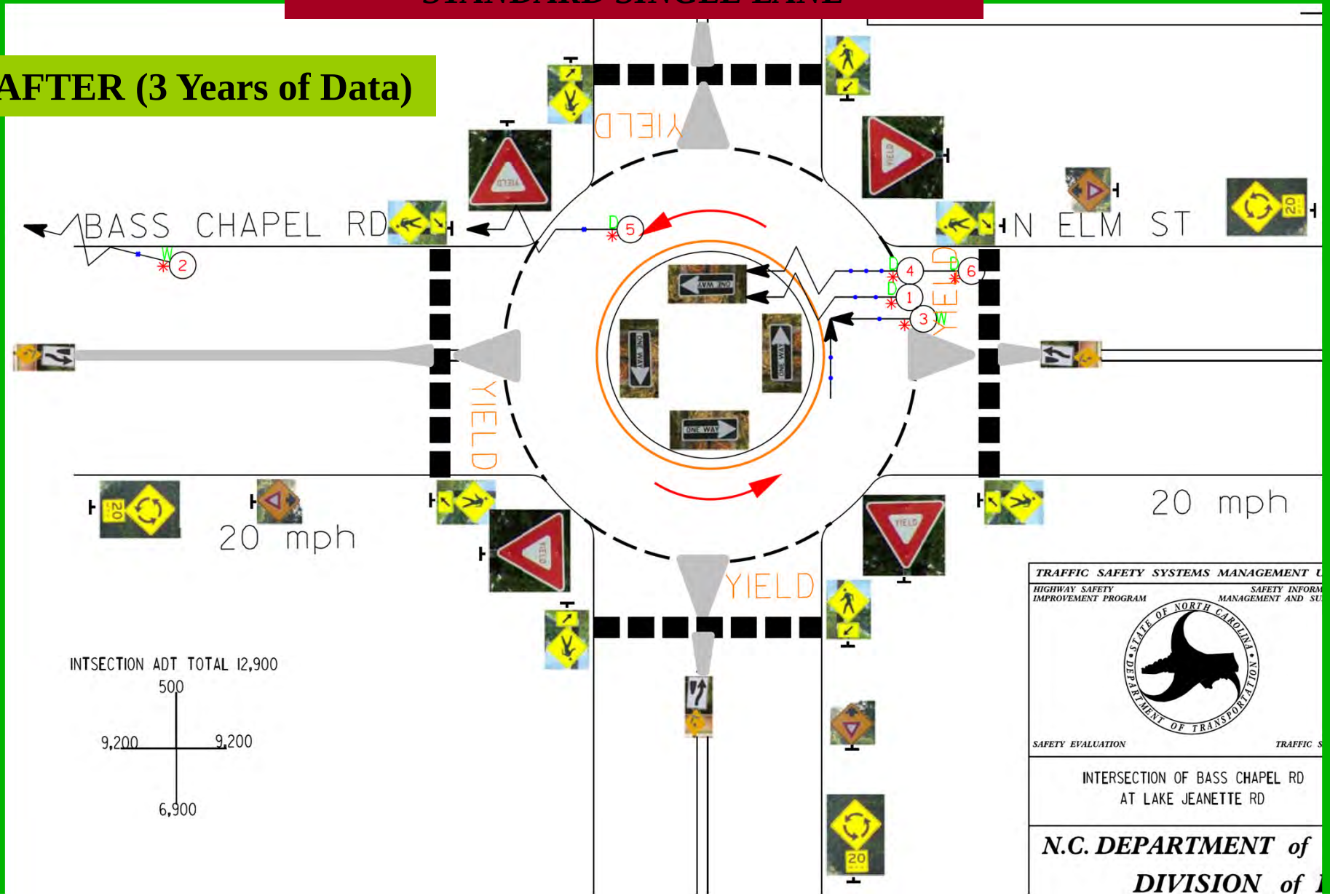
BEFORE (3 Years of Data)



Crash Diagrams: Lake Jeanette @ Elm, Guilford Co.

STANDARD SINGLE LANE

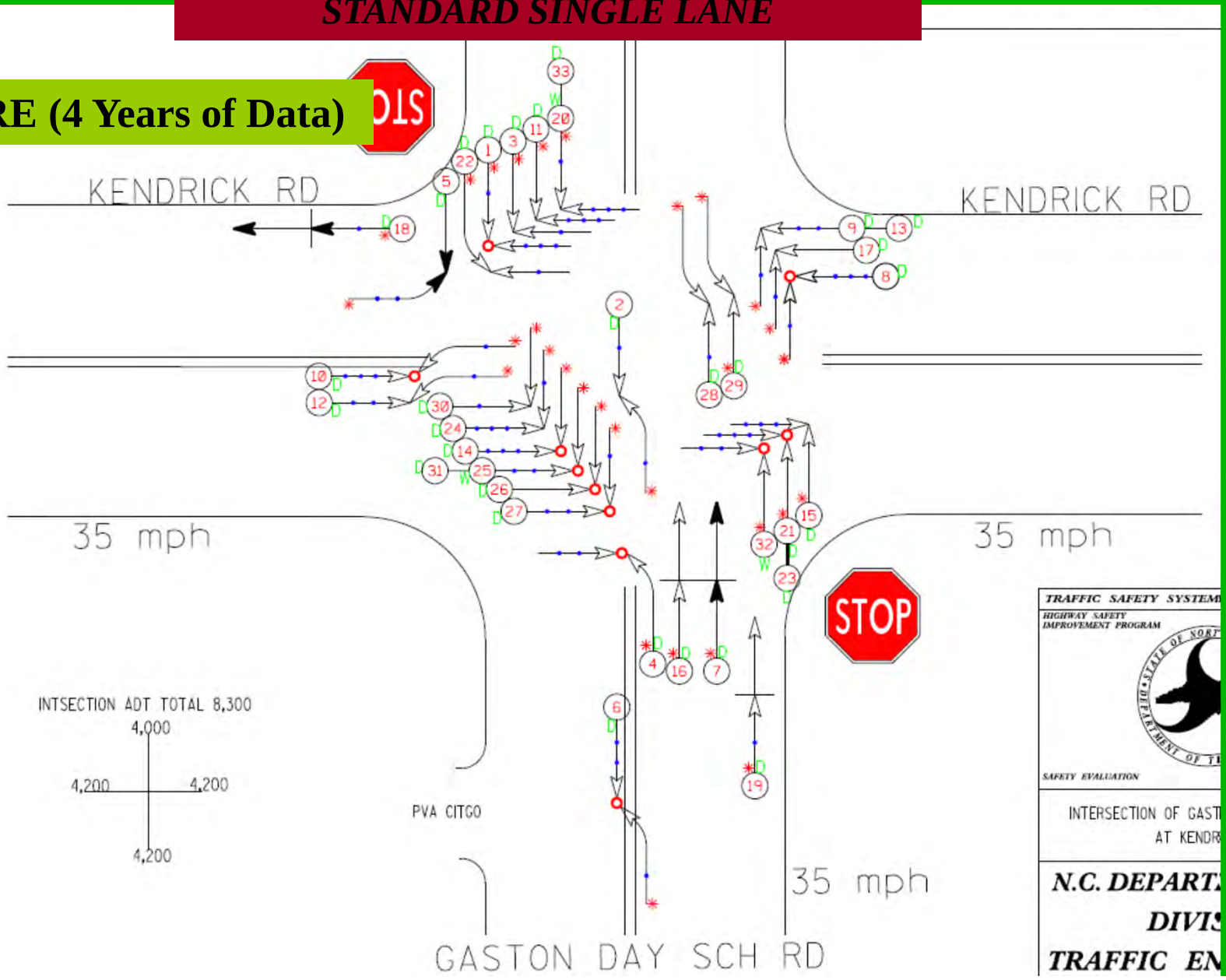
AFTER (3 Years of Data)



Crash Diagrams: Gaston Day School @ Kendrick, Gaston Co.

STANDARD SINGLE LANE

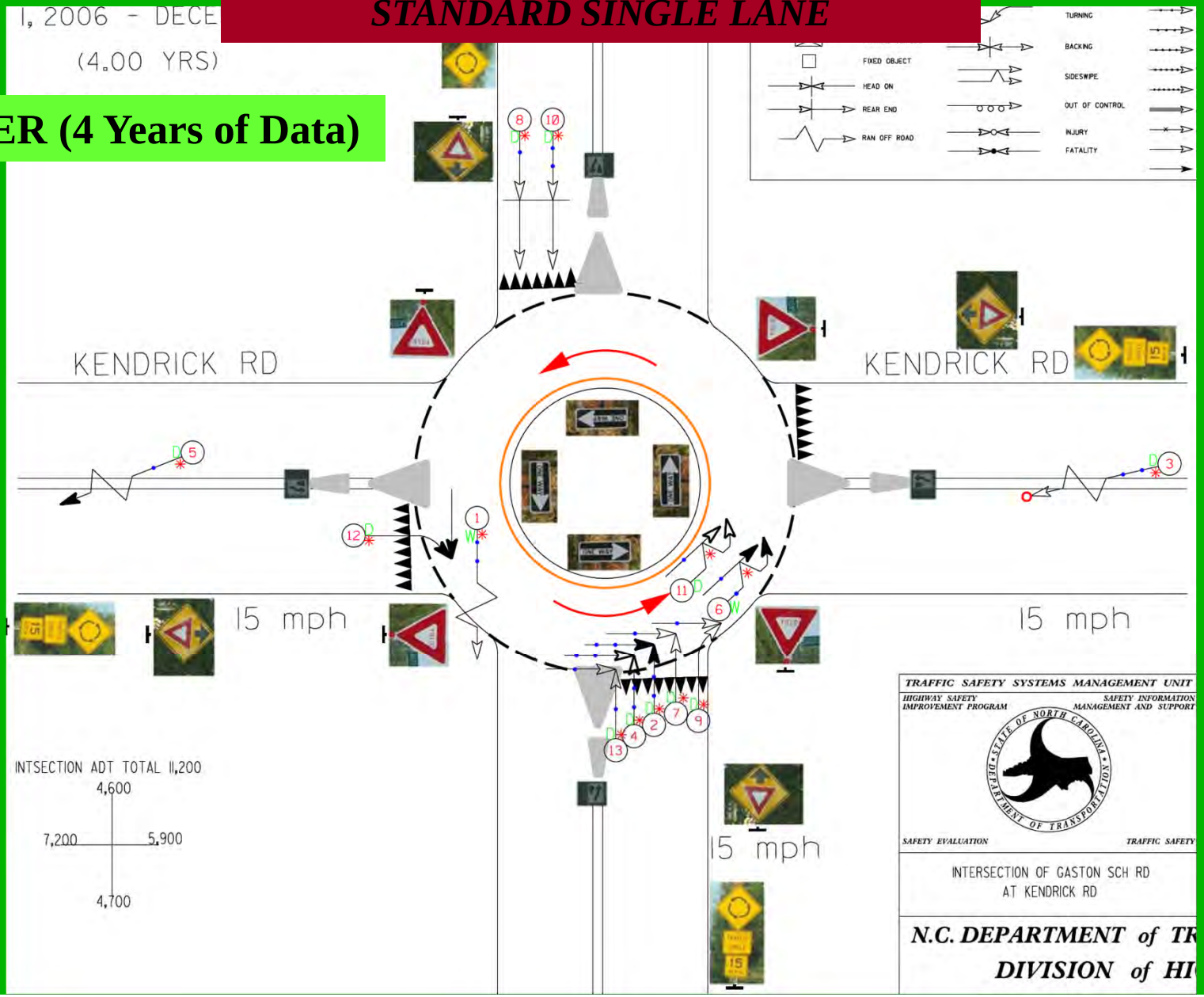
BEFORE (4 Years of Data)



Crash Diagrams: Gaston Day School @ Kendrick, Gaston Co.

STANDARD SINGLE LANE

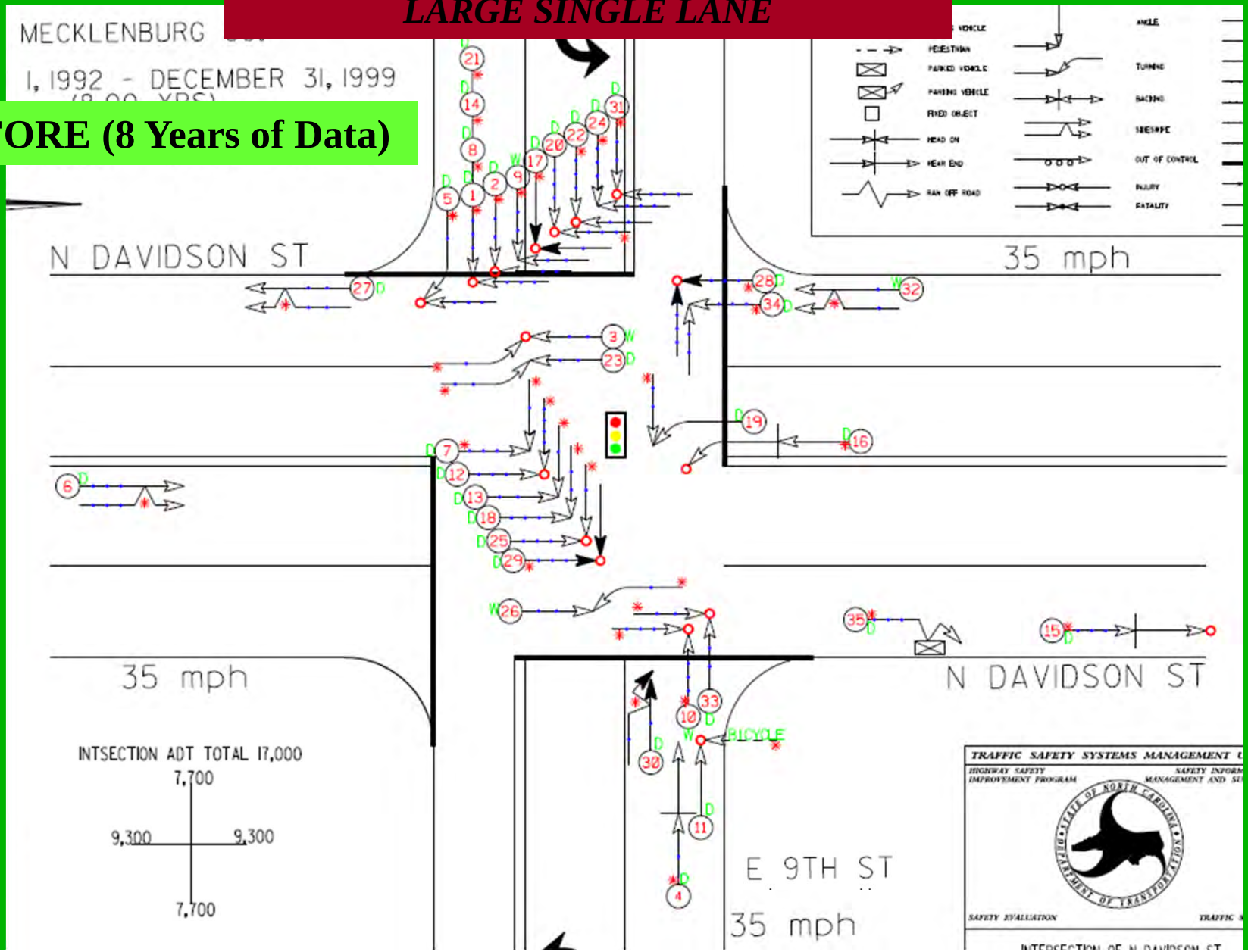
AFTER (4 Years of Data)



Crash Diagrams: Ninth @ Davidson, Mecklenburg Co.

LARGE SINGLE LANE

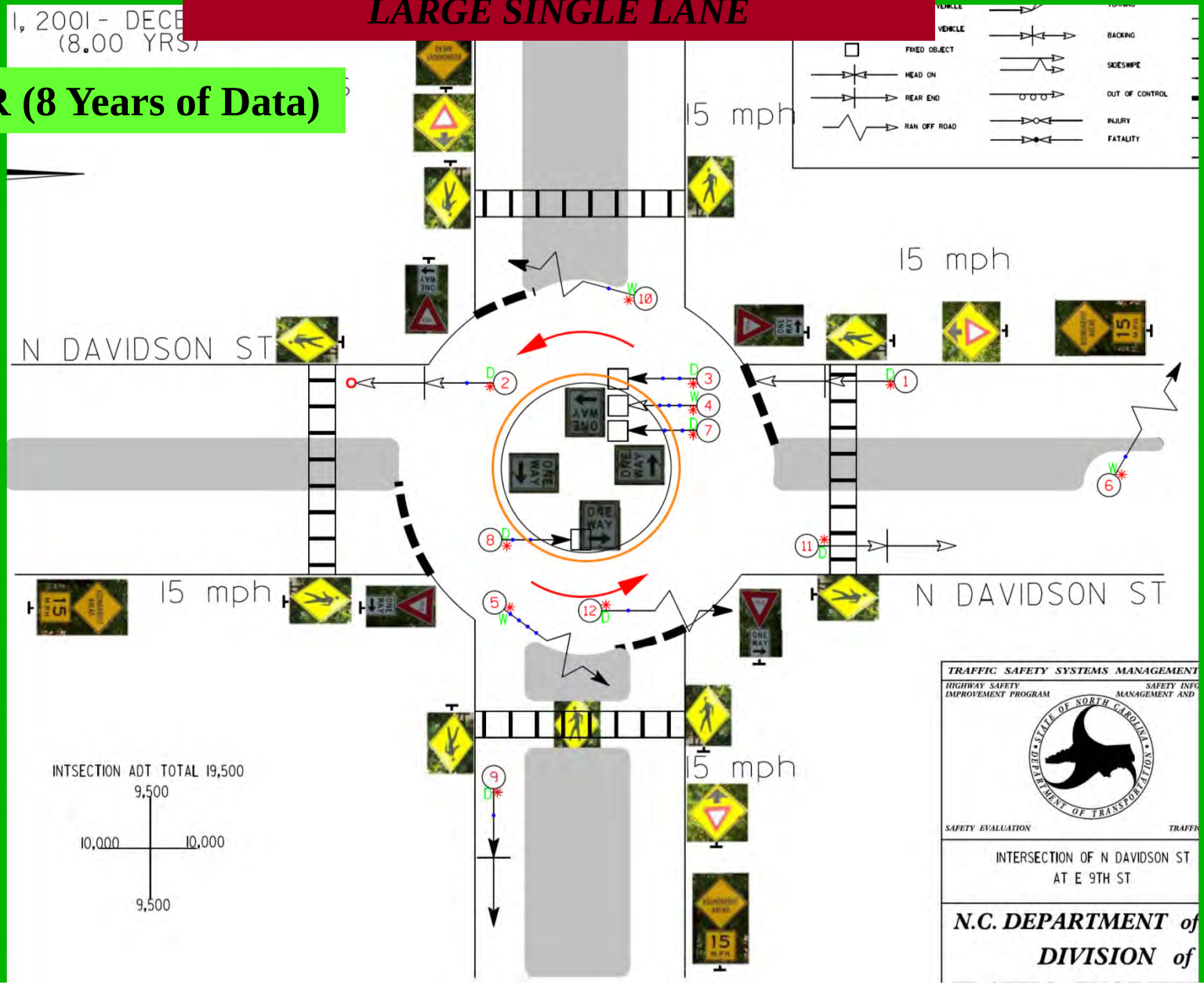
BEFORE (8 Years of Data)



Crash Diagrams: Ninth @ Davidson, Mecklenburg Co.

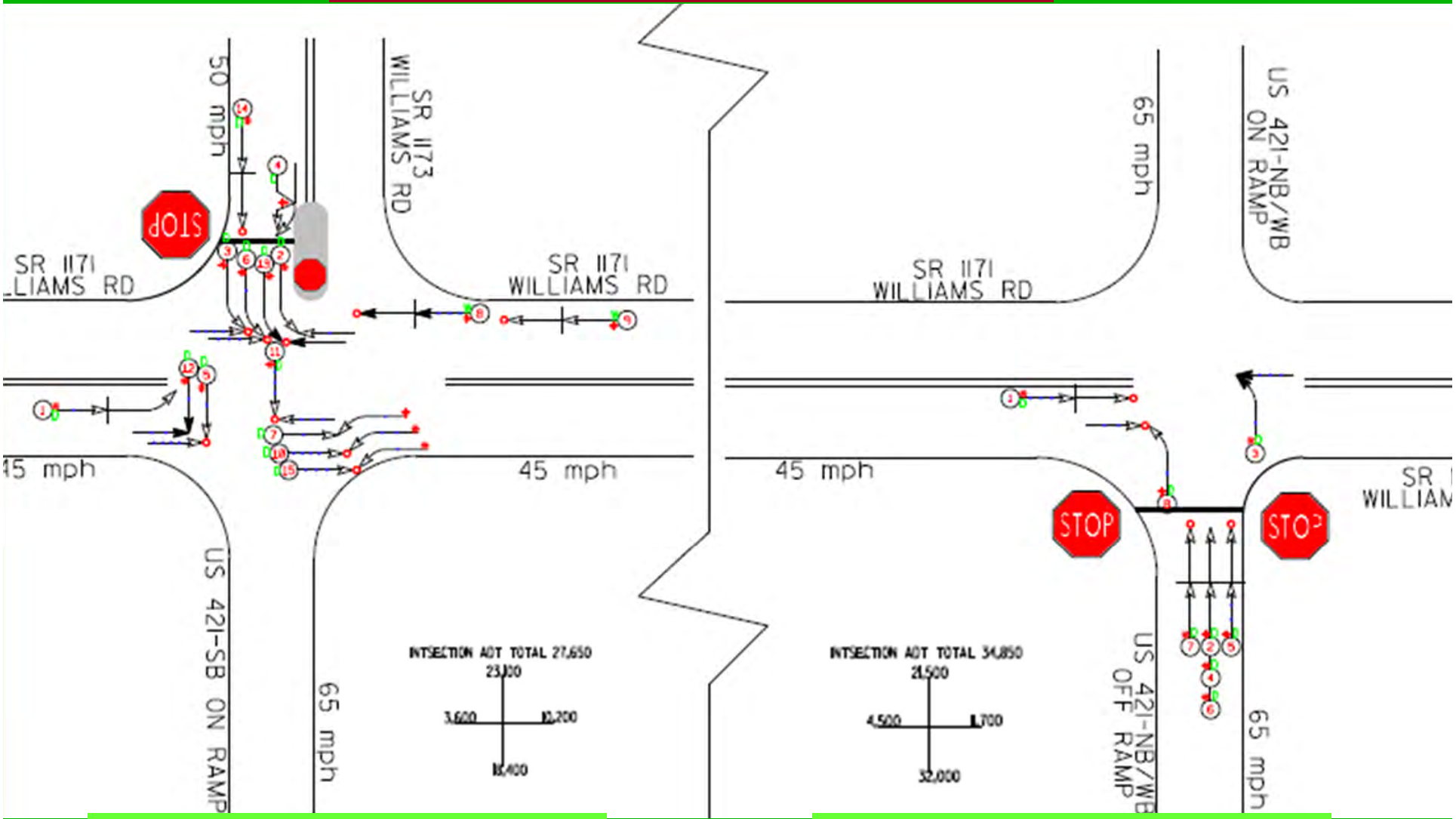
LARGE SINGLE LANE

AFTER (8 Years of Data)



Crash Diagrams: US 421 @ Williams Rd, Forsyth Co.

INTERCHANGE

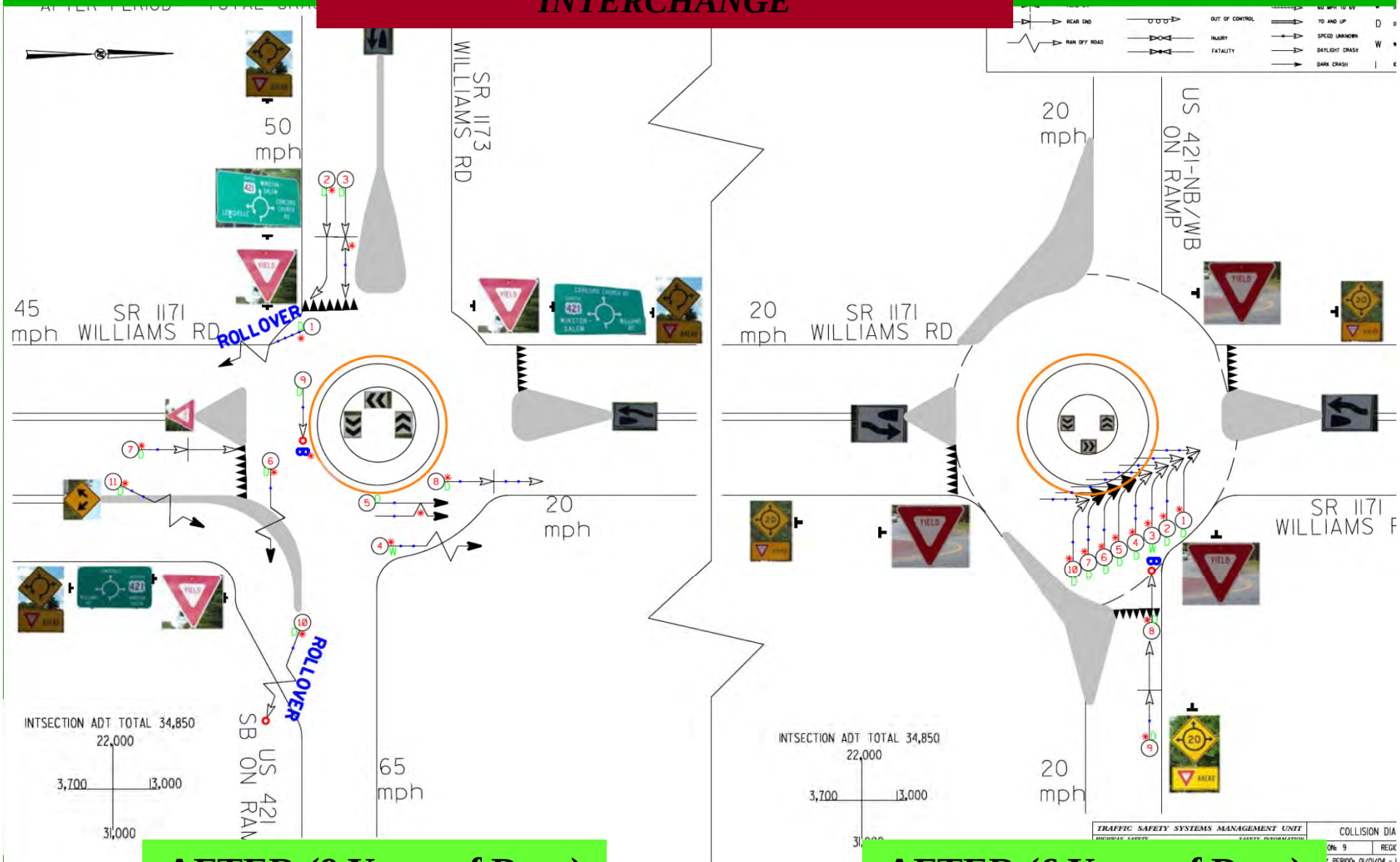


BEFORE (9 Years of Data)

BEFORE (6 Years of Data)

Crash Diagrams: US 421 @ Williams Rd, Forsyth Co.

INTERCHANGE



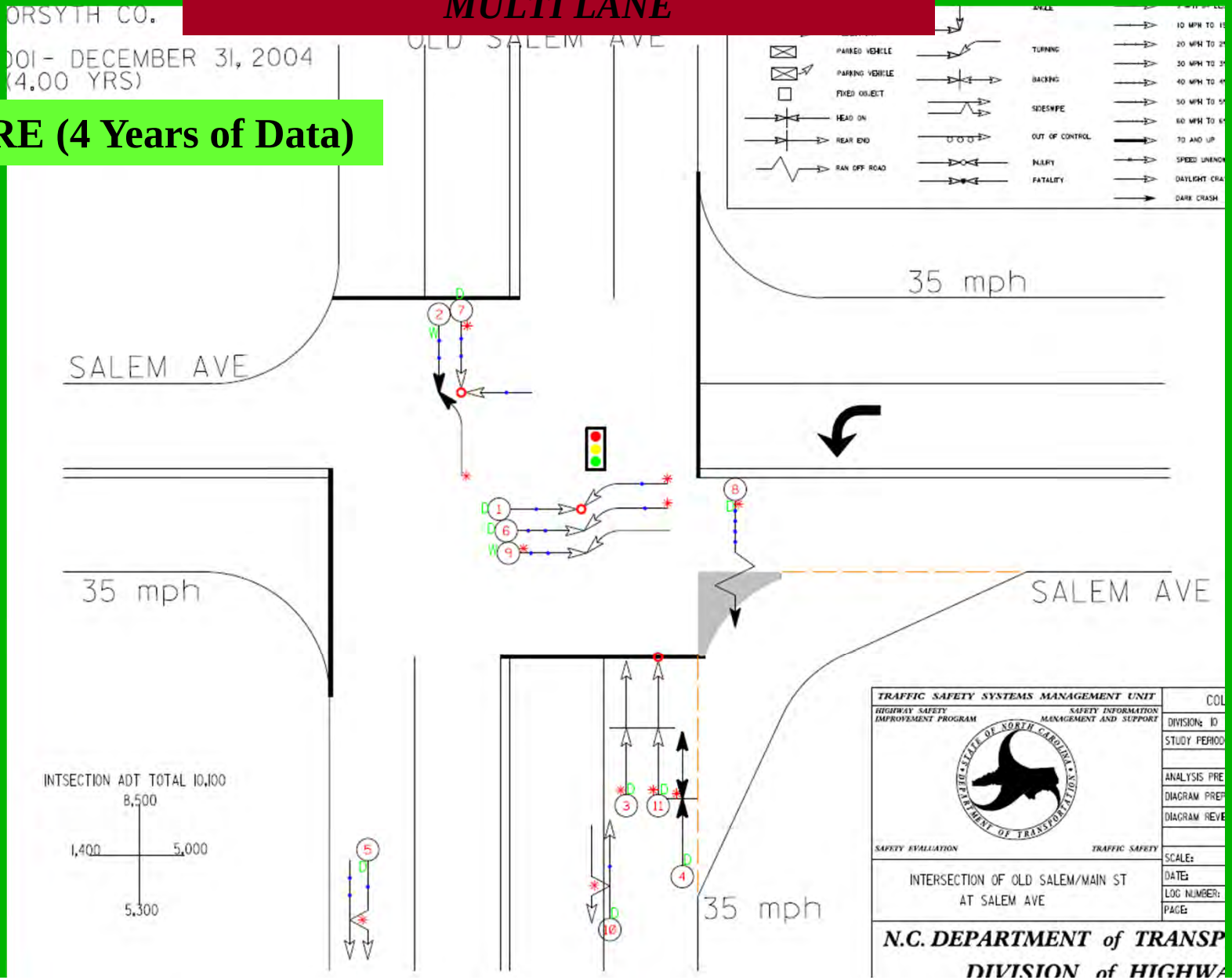
AFTER (9 Years of Data)

AFTER (6 Years of Data)

Crash Diagrams: Main @ Salem, Forsyth Co.

MULTI LANE

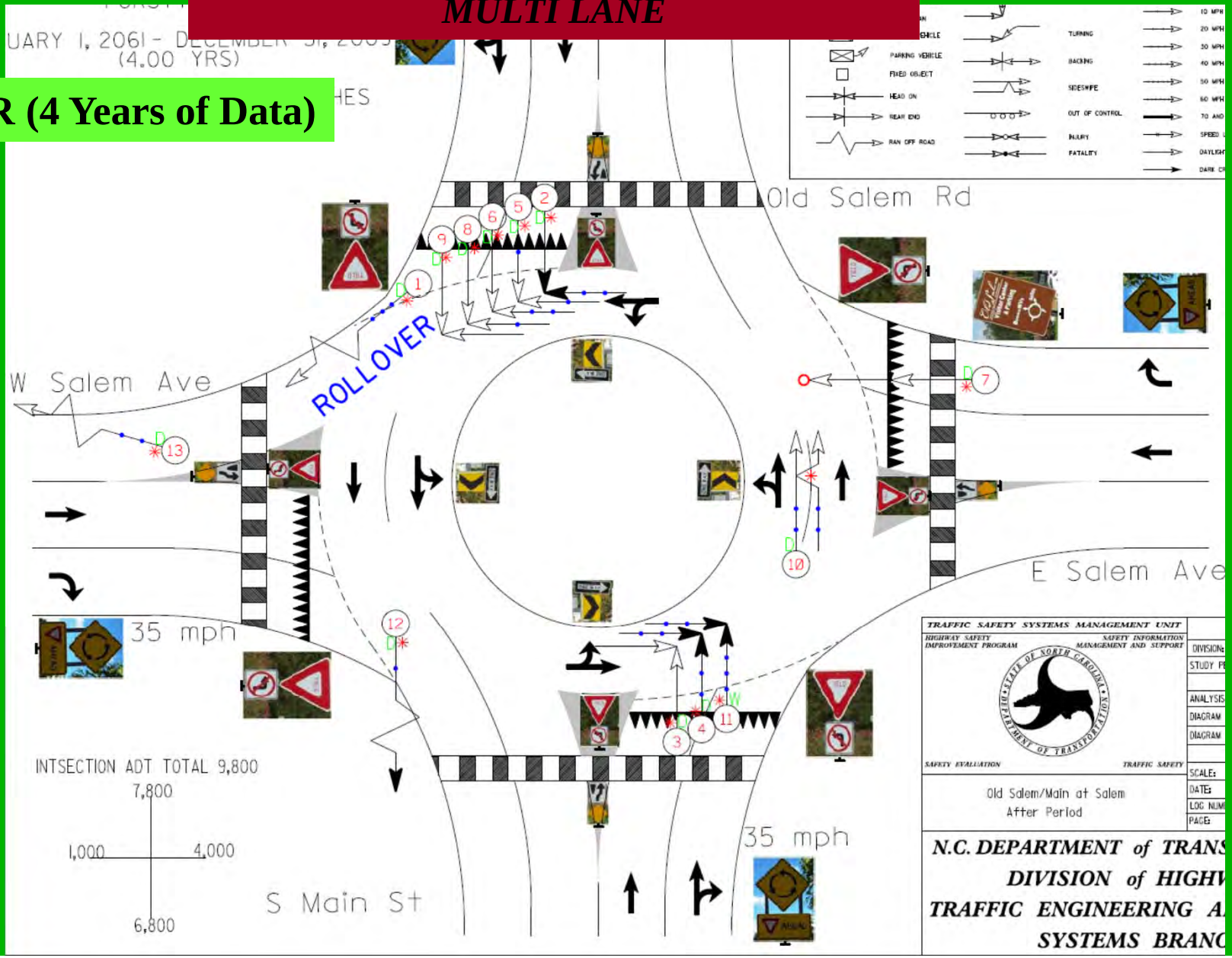
BEFORE (4 Years of Data)

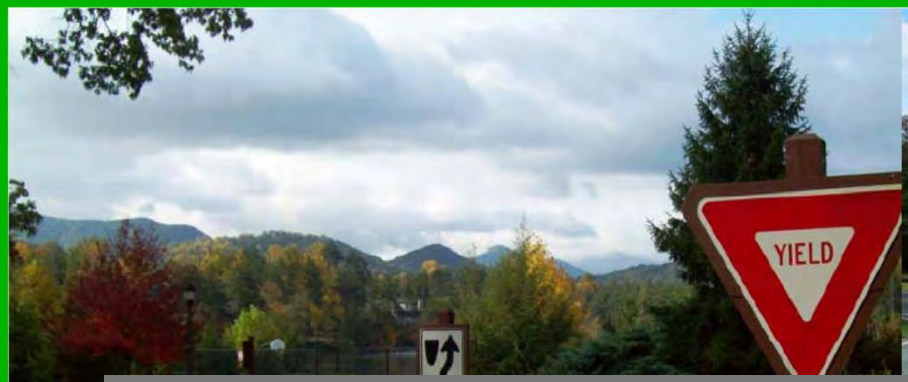


Crash Diagrams: Main @ Salem, Forsyth Co.

MULTI LANE

AFTER (4 Years of Data)

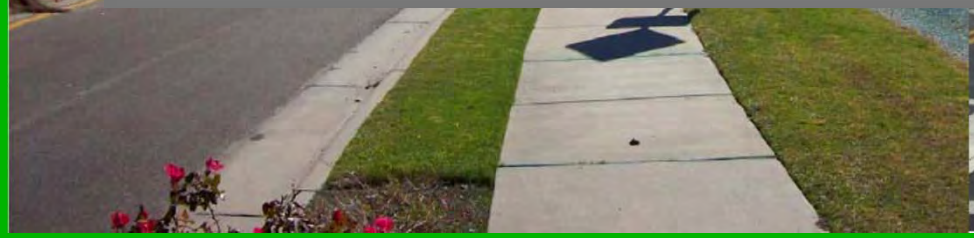




CONCLUSION

Recommended Crash Reduction Factors:

Total Crashes	**-46%**
Injury Crashes	**-75%**
Frontal Impact Crashes	**-76%**



QUESTIONS?

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