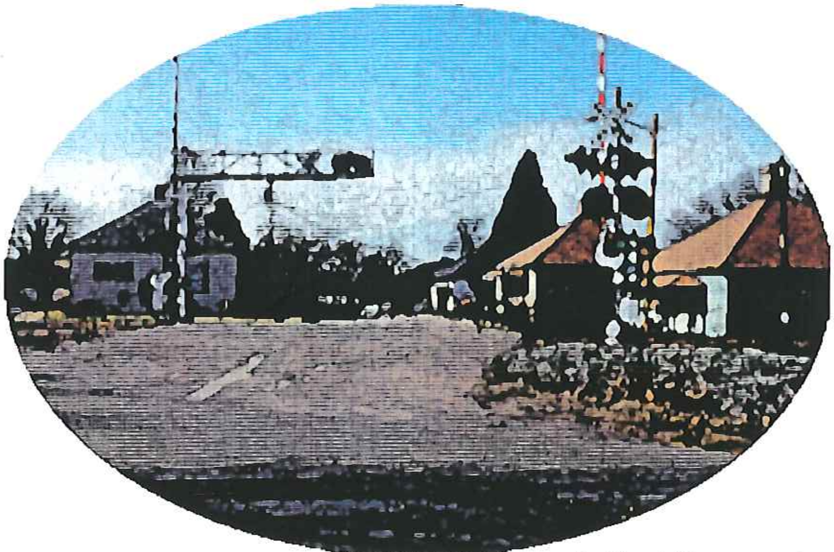
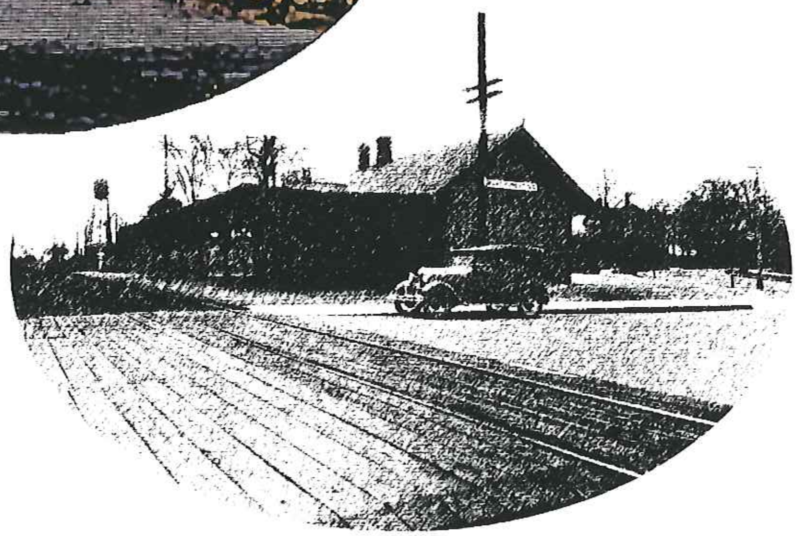
TRAFFIC SEPARATION STUDY

FOR THE

TOWN OF WAKE FOREST





prepared by

PARSONS TRANSPORTATION GROUP

prepared for the

NORTH CAROLINA DEPARTMENT OF TRANSPORTATION

RAIL DIVISION

ENGINEERING AND SAFETY BRANCH

November 1999

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To improve safety at highway-rail crossings in northern Wake County, the Town of Wake Forest and the North Carolina Department of Transportation (NCDOT) agreed to evaluate the public highway-rail crossings of the CSX Railway in Wake Forest. The purpose of this evaluation is to determine if any of the public crossings should be closed or grade-separated (bridged) to improve safety. The study also examines other possible safety enhancements to local streets and crossings that would further improve public safety, while accommodating current and projected highway, school bus and emergency response traffic. Recommendations are made for near-term (0-2 years), mid-term (2-5 years) and long-term (5-10 years).

FINDINGS

Growth Rates

Increases in population and employment generate traffic growth, and all indications are that Wake Forest will experience considerable growth over the next 10-20 years, as development extends north from Raleigh along the US-1 corridor. The projected increases in traffic volumes at the subject rail crossings will have a far more substantial effect on safety and delay than will any anticipated increases in rail operations.

Transportation Improvement Program (TIP) and Long-Range Plans

Several planned or programmed roadway improvement projects will significantly alter traffic patterns in Wake Forest, reducing traffic volumes at several crossings, and providing opportunities for crossing consolidation and elimination.

Key projects include:

- NC-98 Wake Forest Bypass (NC TIP Project Number R-2809),
- Extension of Rogers Road west to South Main Street,
- Extension of Franklin Street south to Forestville (Rogers) Road.

Only the extension of Rogers Road was explicitly considered in the analysis conducted for this study, since it is the only one involving a potential at-grade rail crossing. However, the long-term implications of the other two projects are discussed qualitatively in terms of their traffic impacts, along with additional alternatives that may become feasible upon their completion.

Development of the Ammons Property

The mixed-used development proposed for the Ammons property east of Main Street provides an opportunity to improve crossing conditions in the study area. Current policy dictates that no new at-grade crossings be allowed along this rail corridor without the elimination of one or more existing public crossings. The proposed extension of Rogers Road as part of the Ammons development would facilitate the elimination of the Forestville Road crossing. Furthermore, while the initial Rogers Road rail crossing would be at-grade, adjacent sites are being planned in anticipation of an eventual grade separation, with adequate building and access setbacks.

Future Passenger Rail Service

Two possible changes in rail service could have major impacts on grade crossing conditions in the study area. Although neither was directly analyzed in this study, their potential implications were considered in developing the study's overall recommendations.

The CSX "S" line is on the federally designated *Southeast High Speed Rail Corridor (SEHSR).* This designation could necessitate more positive warning measures, and even grade separation, at most of the crossings studied. Until HSR planning has progressed to the point of identifying alignments and operational characteristics, expensive long-term solutions (especially grade-separations) should be considered carefully. The potential impacts of higher-speed passenger rail services are identified as long-term (5-10 year) recommendations.

The potential extension of TTA regional rail service along this corridor should also be considered carefully in recommending major crossing improvements. Although train speeds would be much lower than HSR (comparable, in fact, to existing train speeds), their frequency would be much higher, especially during the peak hours of roadway travel. The resulting increase in train–vehicle conflicts could dramatically worsen traffic delays at crossings. However, more detailed information on train operations and rail alignments is needed before specific recommendations can be made.

RECOMMENDATIONS

Near-Term (0-2 years)

• Seawell Road	
– Enhance crossing grade surfaces and pavement markings.	$5,000
• Proposed Rogers Road Extension	
– Install flashing lights, cantilever signals, gates, and monolithic concrete median barriers. (Responsibility for funding to be determined by negotiations among NCDOT, Town of Wake Forest, and developer.)	$150,000
• Forestville Road (NCDOT responsibility)	
– Remove crossing and warning devices.	$9,000
– Remove pavement; install barricades; landscape.	$4,000
– Construct turnaround.	$27,000
• Friendship Chapel Road	
– Enhance pavement markings.	$1,200
• East Holding Avenue	
– Install more durable crossing surface (rubber or concrete).	$35,000
• Sycamore Street (Town of Wake Forest responsibility)	
– Remove crossing and warning devices.	$8,000
– Install barricades and landscaping.	$4,000
– Construct turnaround.	$24,000
• East Elm Street	
– CSX to remove abandoned tracks and modify approach grades.	$9,000
– CSX to relocate existing railroad safety devices closer to active track.	$25,000
– NCDOT to install more durable crossing surface (rubber or concrete) upon completion of removal and relocation work by CSX.	$35,000
• Brick Street	
– Modify approach grades.	$8,000
TOTAL	$344,200

Mid-Term (2-5 years)

• Seawell Road	
– Install flashing light signals and long gate arms.	$75,000
• Friendship Chapel Road	
– Install flashing light signals and long gate arms.	$75,000
TOTAL	$150,000

Long-Term (5-10 years)

• Ligon Mill Road	
– Install four-quadrant gates.	$140,000
– Construct monolithic concrete median barriers.	$15,000
• East Holding Avenue	
– Install four-quadrant gates.	$140,000
• East Elm Street	
– Install four-quadrant gates.	$140,000
• Brick Street	
– Add turn lanes to North White Street.	$180,000
– Install four-quadrant gates.	$140,000
TOTAL	$755,000

In addition, several long-term recommendations are contingent upon long-range highway and/or rail projects. At this time, there is not enough information to provide accurate cost estimates. Based on experience, however, the following general estimates are provided:

- Proposed Rogers Road Extension
  - Construct grade-separation. — $2-3 million

    Note: NCDOT, the Town of Wake Forest, and the developer are working to establish the feasibility of an underpass vs. an overpass, and to identify cut/slope lines defining encroachment limits. As soon as a preliminary plan is available, it will be possible to develop accurate cost estimates, and plans for staging implementation.

- Friendship Chapel Road
  - Close crossing if Friendship Chapel Road is connected to the extension of South Franklin Street. — $40,000

1. INTRODUCTION

STUDY OBJECTIVES

To improve safety at highway-rail crossings in northern Wake County, the Town of Wake Forest and the North Carolina Department of Transportation (NCDOT) agreed to evaluate the public highway-rail crossings of the CSX Railway in Wake Forest. The purpose of this evaluation is to determine if any of the public crossings should be closed or grade-separated (bridged) to improve safety. The study also examines other possible safety enhancements to local streets and crossings that would further improve public safety, while accommodating current and projected highway, school bus and emergency response traffic. Recommendations are made for near-term (0-2 years), mid-term (2-5 years) and long-term (5-10 years).

PREAMBLE

Across America, several hundred people are killed each year in collisions at highway-rail crossings. Collisions between trains and highway vehicles are the principal cause of death in the railroad industry. In 1998, there were 109 highway/rail crossing collisions in North Carolina, resulting in 15 deaths and 48 injuries. North Carolina ranks 14th in the nation for such collisions. As the number of freight and passenger trains increases and highway traffic grows, the need to identify and prioritize safety enhancements will become even more critical.

Since the late 1970's aggressive safety programs have lead to steady reductions in deaths and injuries due to train-vehicle collisions. The NCDOT Rail Division administers a comprehensive program to improve rail-crossing safety. The Federal Railroad Administration, Federal Highway Administration, and affected railroad operators all support and participate in this program.

EXISTING CONDITIONS AND ASSUMPTIONS

Train Operations

The CSX "S" line traverses the Town of Wake Forest in a north-south direction, roughly paralleling the original alignment of US 1 (Figure 1). The railway currently connects Raleigh and Norlina. The number of daily freight trains crossing at each location in the study varies by day of the week:

- A southbound rock train of about 50 cars passes through Wake Forest between 7:00 AM and 7:30 AM on Tuesdays and Fridays. It returns northbound on Wednesdays and Fridays, between 6:00 PM and 6:30 PM.
- On weekdays, a 30-car to 70-car road switcher passes northbound at about 11:00 AM, returning southbound between 6:00 PM and 6:30 PM.
- Another road switcher passes through in mid-afternoon, three days a week. It returns in late afternoon, and is typically 15-20 cars long.

For analysis purposes, it is assumed that each crossing is traversed by five daily freight trains, with an average length of 4,500 feet and a maximum speed of 40 mph. For the 2015 design year, train operations are assumed to double (to 10 daily freight trains). The assumed average train length increases to 5,280 feet, with maximum train speed remaining at 40 mph. *(During the analysis, a wide range of train speeds and frequencies were evaluated, from existing values to speeds as high as 79 mph and frequencies of 50 trains/day. Variations in these assumptions did not significantly affect the ultimate findings and recommendations of the study, which were found to be far more sensitive to growth in vehicular traffic and changes in the roadway network.)*

Traffic Volumes and Conditions

Traffic counts were collected in May of 1998 and January of 1999. Vehicular crossing volumes range from 115 vehicles per day to 4,550 vehicles per day. Peak period turning movement counts were conducted at four locations in January of 1999.

Due to the amount of new development anticipated in this area, an annual growth rate of 3% was used to derive future traffic volumes. This rate was confirmed by the NCDOT Statewide Planning Branch. Future traffic associated with the Ammons development (at Rogers Rd. extension and Forestville Rd.) was obtained from a traffic impact analysis of the project conducted by the engineering firm of Kimley-Horn Associates.

Only two crossings have experienced accidents in the last ten years. One at Brick Street resulted in an injury, and two at East Holding Avenue resulted in a fatality and an injury.

Crossing Locations

This study evaluates eight (8) existing public at-grade crossings and one (1) proposed interim at-grade crossing between Ligon-Mill Road (SR-2044) and Brick Street.

1. **Ligon Mill Road** (SR-2044) is a two-lane thoroughfare serving low-density rural/suburban residential development. Current average daily traffic (ADT) is 1,937 vehicles, and warning devices consist of advance warning signs, crossbucks, bells, flashers, and gates.
   CSX RR Mile Post S 0143.75, Crossing #630 598S.

2. **Seawell Road** (SR-2046) is a narrow, two-lane, dead end road providing the only access to several private properties. The ADT on Seawell Road is less than 120 vehicles per day. The road is unpaved east of the railroad crossing, which is marked with advance warning signs, crossbucks, and stop signs.
   CSX RR Mile Post S 0143.15, Crossing #630 597K.

3. **Rogers Road Extension** is a proposed facility to be constructed by as part of a major mixed-use development. This major thoroughfare would initially be constructed as a two- or three-lane facility, with an ultimate cross-section of five lanes.

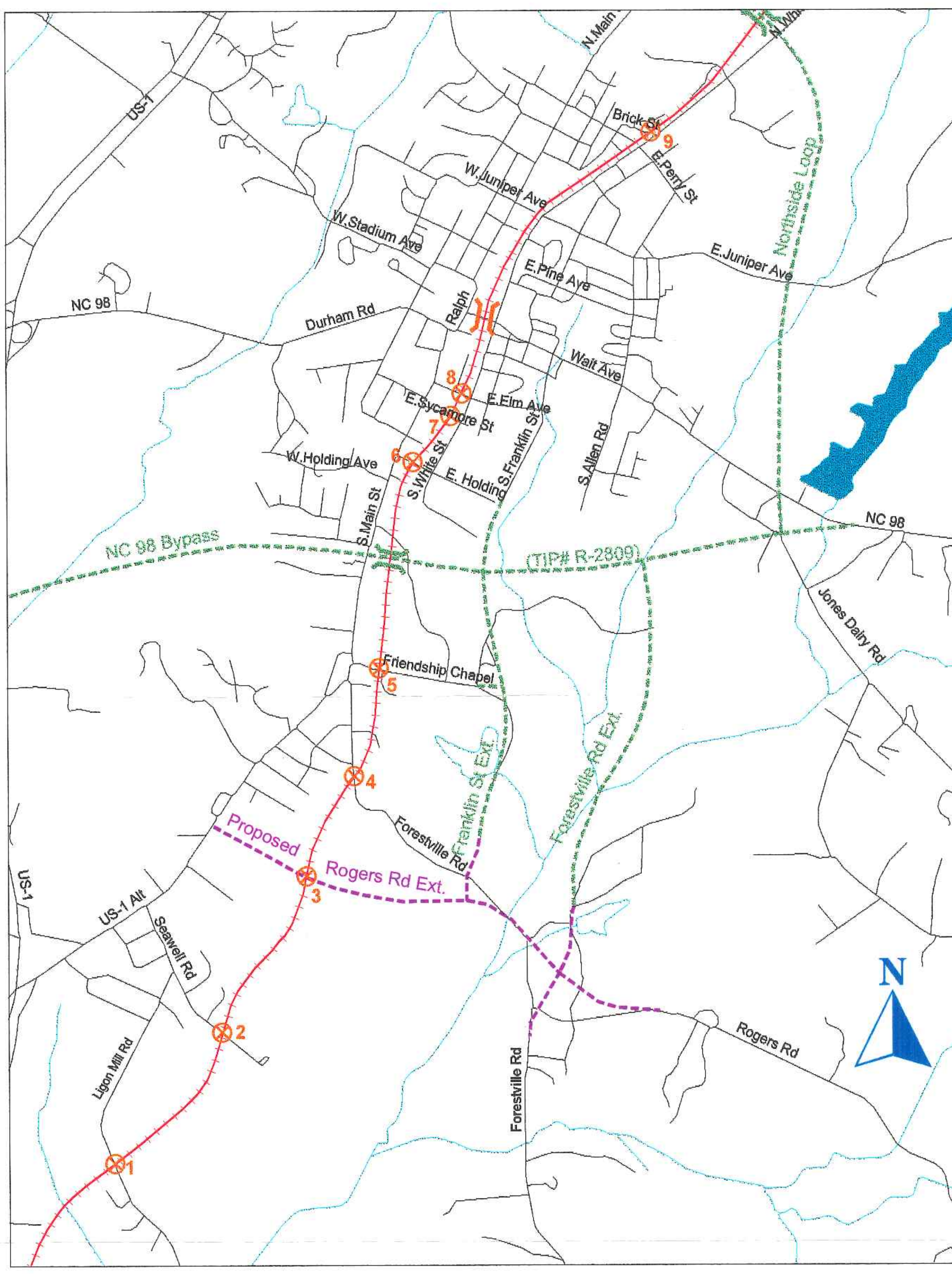
4. **Forestville Road** (SR-2049) provides access to an industrial site, some residential development, and farmland. It is a two-lane road designated as a major thoroughfare, with an ADT of 2,581. Warning devices consist of advance warning signs, crossbucks, flashing lights (cantilevered overhead and pole-mounted roadside), and automated gates.
   CSX RR-Mile Post S 0142.15, Crossing #630 596D.

5. **Friendship Chapel Road** (SR-2047) is a two-lane local street providing the only access to residences, a church, and limited industrial development. The ADT is about 450 vehicles, and warning treatments consist of stop signs and crossbucks.
   CSX RR Mile Post S 0141.73, Crossing #630 595W.

6. **East Holding Avenue** is a wide, two-lane, minor urban thoroughfare connecting Main Street and White Street through a mixed commercial, institutional, and residential area. The ADT is 4,550, and the crossing includes advance warning signs, crossbucks, bells, cantilevered and mast-mounted flashing lights, and automated gate arms.
   CSX RR Mile Post S 0140.99, Crossing #630 591U.

7. **Sycamore Street** is an unpaved local street serving a combined residential and commercial area between Main Street and White Street. The ADT is less than 170 vehicles, and the crossing is marked with crossbucks and advance warning signs.
   CSX RR Mile Post S 0140.79, Crossing #630 590M.

Figure 1
Wake Forest Study Area with Crossing Locations



ID [Road Name]	[RR Mile Post]	[RR Cross ID]
1 Ligon Mill Rd (SR-2044)	S 0143.75	630 598S
2 Seawell Rd (SR-2046)	S 0143.15	630 597K
3 Rogers Rd Ext.		
4 Forestville Rd (SR-2049)	S 0142.15	630 596D
5 Friendship Chapel Rd (SR-2047)	S 0141.73	630 595W
6 E.Holding Ave	S 0140.99	630 591U
7 Sycamore St	S 0140.79	630 590M
8 E.Elm St	S 0140.70	630 589T
9 Brick St	S 0139.53	630 582V

New Projects
Ammons Development
Thoroughfare Plan Project
RR Crossings
Studied
0 .20 .40 .60
Miles

8. **East Elm Street** is a 2-lane major thoroughfare serving the central business district. The ADT is approximately 4,520, and the crossing is on a severe hump, with a set of abandoned tracks on either side of the active line. A steep grade descends to the intersection with White Street, only 80 feet away. Warning devices include crossbucks, flashing lights, bells, and gate arms.
   CSX RR Mile Post S 0140.70, Crossing #630 589T.

9. **Brick Street** is a narrow local street connecting an older, suburban neighborhood with North White Street, which intersects Brick Street less than 50 feet from the crossing. The current ADT on Brick Street is about 1,320 vehicles, and the crossing is at the top of a short, steep approach. Warning devices consist of crossbucks, bells, cantilevered and mast-mounted flashing lights, and gates.
   CSX RR Mile Post S 0139.53, Crossing #630 582V.

OTHER CONSIDERATIONS

Future passenger rail service rail

The CSX "S" line is on the federally designated *Southeast High Speed Rail Corridor (SEHSR)*. The potential impacts of higher-speed passenger rail services are identified as long-term (5-10 year) recommendations. The potential extension of TTA regional rail service to Wake Forest from Raleigh is also considered.

Future highway projects

Several major planned or programmed roadway projects are relevant to this study. The NC 98 Wake Forest Bypass will provide a grade-separated rail crossing, and, in combination with the extension of Rogers Road, improvement of southern US 1A, and the extension of Franklin Street, will significantly change travel patterns crossing the CSX "S" line. Upon completion, these projects will also provide opportunities for elimination of redundant crossings. Crossings that connect to the same street network and are less than a quarter-mile (+/- 1500 feet) apart are considered to be redundant.

2. EVALUATION CRITERIA/METHODOLOGY

A variety of techniques were used to evaluate the crossing conditions in terms of safety and traffic delay. This section describes the techniques employed in this study. Table 1 summarizes the sources of the data used in these analyses.

Table 1. Summary of Data Collected for Grade Crossing Evaluations

Data Item	Source
Crossing Volumes (ADT)	NCDOT
Turning Movement Counts - Adjacent Intersections	NCDOT
Lane Configurations - Adjacent Intersections	Field Visits
Freight Train Volumes, Speeds, & Lengths	CSX, NCDOT Rail Division
Inventory of Railroad Crossing Control Types	Field Visits
School Bus Routes	Wake Forest-Rolesville School Dist.
Emergency Vehicle Routes	Town of Wake Forest
Observations	Field Visits

EVALUATION CRITERIA

The following standard criteria developed for the NCDOT rail crossing closure program were used in evaluating the Wake Forest crossings:

- Accident history
- Vehicle traffic
- Train traffic
- Truck traffic/Truck route
- Hazardous Materials
- Type roadway (thoroughfare, collector, local access, etc.)
- Type of property being served (residential, industrial, commercial)
- School bus route
- Emergency route
- Type of warning devices present
- Redundant crossing (yes/no)
- Potential for grade separation (high, medium, low)
- Feasibility of implementing roadway improvements (high, medium, low)
- Economic impact if crossing closed (high, medium, low)

Findings for each crossing relative to each of these criteria are summarized in Table 2.

SAFETY

Accident History

Vehicle-train collisions have occurred at two crossings since 1989:

- Brick Avenue - one accident occurred resulting in one injury.
- East Holding Avenue - two accidents occurred at the crossing, one resulting in a fatality, the other in an injury.

No accidents have occurred at either of these locations since additional warning devices were installed in 1997and 1998 respectively.

Table 2. Evaluation of At-Grade Highway/Railroad Crossings in Wake Forest, NC

Crossing #	Railroad	Municipality or County	Street Name	Maintenance Responsibility (City/NCDOT)	Street Classification	Warning Devices (Type)[1]	24-Hour ADT	2015 ADT (Projected)	24-Hour Train Volume	Accident History[2] 1989-1998	School Bus Route (Y/N)	Emergency Route (Y/N)	Designated Truck Route (Y/N)	Percent Trucks[3]
630 598S	CSX	Wake County	SR 2044 (Ligon Mill Rd)	NCDOT	Minor Thoroughfare	4	1,937	3,202	5	0	Y	Y	Y	(0.3)
630 597K	CSX	Wake County	SR 2046 (Seawell Rd)	NCDOT	Local	2	112	185	5	0	Y	Y	Y	(0.2)
--[4]	*CSX*	*Wake Forest*	*Rogers Road Extension*	*NCDOT*	*Major Thoroughfare*	*5*	--	*26,300*	*5*	--	*Y*	*Y*	*Y*	*(0.6)*
630 596D	CSX	Wake Forest	SR 2049 (Forestville Rd)	NCDOT	Major Thoroughfare	5	2,581	200	5	0	Y	Y	Y	(0.5)
630 595W	CSX	Wake Forest	SR 2047 (Friendship Chapel)	NCDOT	Local	2	446	737	5	0	Y	Y	Y	(0.4)
630 591U	CSX	Wake Forest	E. Holding Ave	City	Minor Thoroughfare	5	4,548	7,517	5	2 (1k/1i)*	N	Y	N	(0.5)
630 590M	CSX	Wake Forest	Sycamore St	City	Local	2	166	274	5	0	N	Y	Y	(0.2)
630 589T	CSX	Wake Forest	E. Elm St	City	Major Thoroughfare	4	4,517	7,466	5	0	N	Y	N	0.6
630 582V	CSX	Wake Forest	Brick Ave	City	Local	5	1,323	2,187	5	1 (0k/1i)*	N	Y	Y	(0.2)

NOTES:

1. Warning device types defined as follows: 1 = unmarked; 2 = crossbucks only; 3 = flashers only (no gates); 4 = flashers and gates; 5 = flashers, cantilever signals, and gates.
2. Accident History [N(k/i)]: N = number of accidents; k = number of fatal accidents; i = number of injury accidents.
   *Accidents occurred prior to installation of existing warning devices.
3. Estimated truck percentages are indicated with parentheses.
4. *Italics indicate assumptions for proposed crossing.*

Table 2 (cont.): **Evaluation of At-Grade Highway/Railroad Crossings in Wake Forest, NC**

Street Name	Hazardous Materials (Y/N)	Crossing Condition (Good, Fair, Poor)		Redundant Crossing (Y/N)	Adequate Storage (Y/N)	Property Served	Economic Impact if Closed (High, Med, Low)	Need for Enhanced Warning Devices[5]	Need for Roadway Improvements (High, Med, Low)	Feasibility of Implementing Roadway Improvements (High, Med, Low)	Potential for Grade Separation (High, Med, Low)
		Geometry	Sight Distance								
SR 2044 (Ligon Mill Rd)	N	Good	Fair	N	Y	Res	Med	--	Low	High	Med
SR 2046 (Seawell Rd)	N	Fair	Poor	N	Y	Res	Low	S, S&M	High	High	Low
Rogers Road Extension[4]	*N*	*Good*	*Good*	--	--	Res/Comm/Ind	--	*S, S&M*	--	--	*High*
SR 2049 (Forestville Rd)	N	Poor	Poor	N	Y	Res/Ind	High *(Low)*	(close)	Med	Low	Low
SR 2047 (Friendship Chapel Rd)	N	Good	Fair	N	Y	Res/Ind/Inst	High	S, S&M	Low	High	Low
E. Holding Ave	N	Fair	Fair	N	Y	Inst/Res/Comm	Med	--	Med	High	Low
Sycamore St	N	Fair	Fair	Y	Y	Res/Comm	Low	(close)	High	High	Med
E. Elm St	N	Poor	Fair	N	Y	Comm	High	--	High	Med	Med
Brick Ave	N	Good	Fair	N	Y	Res	Low	--	High	Low	Low

<u>NOTES:</u>

4. *Italics indicate assumptions for proposed crossing.*
5. S, S&M - Signs, signals (12" lenses) & markings

Exposure Index

A key element of the safety assessment is the *exposure index*, the basis of NCDOT Rail Division's Rail Grade Separation Guidelines. The guidelines state the following:

- Separations should be used in RURAL areas when the exposure index is 15,000 or more.
- Separations should be used in URBAN areas when the exposure index is 30,000 or more.

The exposure index is defined as the "product of the number of trains per day and the projected average daily highway traffic at the end of the design period." The formula is shown below:

$$EI = N \times ADT$$

where:

EI	=	NCDOT Rail Division's Exposure Index.
N	=	Number of trains per day.
ADT	=	Average daily traffic volume at highway/rail at-grade crossing.

Recommendations for grade separations consider the results calculated using this formula, which are summarized in Table 3.

Table 3. Exposure Indices

Crossing	1998 (5 trains/day)	2015 (10 trains/day)
Ligon Mill	9,685	***32,020***
Seawell	560	1,850
Rogers Road Ext	NA	***263,000***
Forestville	12,905	2,000
Friendship Chapel	2,230	7,370
East Holding	22,740	***75,170***
Sycamore	830	2,740
East Elm	22,585	***74,660***
Brick	6,615	***21,870***

NOTE: ***Bold Italics*** indicate values exceeding relevant thresholds.

DELAY ANALYSIS

Level of service (LOS) is a measure of the operational efficiency of the at-grade crossing. It is determined using procedures from the *Highway Capacity Manual* procedures. Level of service is expressed as a letter ranging from A (free flowing) to F (severely congested) and is determined using the average delay for all vehicles. Table 4 summarizes the relationships between average delay and level of service.

Crossing Delay

Traffic delay at railroad crossing is a function of a number of factors. To quantify the average delay at each crossing under existing and various future conditions, several values were calculated for each at-grade crossing. The calculations are based on methodology developed for the *Proposed*

Table 4. Highway Capacity Manual LOS Thresholds for Average Delay

Level of Service	Average Delay/Vehicle (seconds)
A	≤ 5.0
B	> 5.0 to ≤ 15.0
C	> 15.0 to ≤ 25.0
D	> 25.0 to ≤ 40.0
E	> 40.0 to ≤ 60.0
F	> 60.0

Conrail Acquisition Draft Environmental Impact Statement (DEIS)[1]. This methodology was developed by the Surface Transportation Board's Section of Environmental Analysis (SEA). Parsons Transportation Group modified the formulas as needed for this project. Appendix B contains a detailed description of this methodology.

The following values were calculated for existing and future conditions:

- Blocked crossing time per train.
- Event time.
- Average delay per stopped vehicle.
- Number of vehicles delayed per day.
- Maximum vehicle queue.
- Total stopped vehicle delay per day.
- Average delay for all vehicles.
- Traffic level of service (LOS).

Tables 5 and 6 summarize the results of the traffic delay analyses.

[1] Surface Transportation Board Section of Environmental Analysis. *Proposed Conrail Acquisition Draft Environmental Impact Statement.* December 1997, Volume 1, Chapter 3, pp. 3-16 to 3-18 and Volume 5A, Appendix C, pp. C-10 to C-16.

Table 5. 1998 Vehicle-Delay due to Train Crossings

Roadway Name	No. Road Lanes	ADT	Arrival Rate (veh/min) 2x uniform	Departure Rate (veh/hr)	Trains per day	Train Speed (miles/hr)	Train Length (feet)	Crossing Blockage Time (min)	Event (Queue) Time (min)	Exposure Ratio	Number of Veh. Delayed/Day	Max. Peak Hr. Queue (veh/ln)	Avg. Delay/ Stopped Veh. (mins)	Avg. Delay /Veh. (All vehicles)	LOS
Ligon Mill	2	1,937	2.69	46.67	5	40	4,500	1.78	1.89	0.012	12	3	0.94	0.70	A
Seawell	2	112	0.16	46.67	5	40	4,500	1.48	1.48	0.010	1	0	0.74	0.46	A
Forestville	2	2,581	3.58	46.67	5	40	4,500	1.80	1.9	0.012	16	5	0.96	0.71	A
Friendship Chapel	2	446	0.62	46.67	5	40	4,500	1.50	1.5	0.010	2	1	0.75	0.46	A
Holding	2	4,548	6.32	46.67	5	40	4,500	1.80	2.1	0.012	28	8	1.03	0.76	A
Sycamore	2	166	0.23	46.67	5	40	4,500	1.50	1.5	0.010	1	0	0.74	0.46	A
Elm	2	4,517	6.27	46.67	5	40	4,500	1.80	2.1	0.012	28	8	1.03	0.76	A
Brick	2	1,323	1.84	46.67	5	40	4,500	1.78	1.85	0.012	8	2	0.93	0.69	A

Table 6. 2015 Vehicle-Delay due to Train Crossings

Roadway Name	No. Road Lanes	ADT	Arrival Rate (veh/min) 2x uniform	Departure Rate (veh/hr)	Trains per day	Train Speed (miles/hr)	Train Length (feet)	Crossing Blockage Time (min)	Event (Queue) Time (min)	Exposure Ratio	Number of Veh. Delayed/Day	Max. Peak Hr. Queue (veh/ln)	Avg. Delay/ Stopped Veh. (mins)	Avg. Delay /Veh. (All vehicles)	LOS
Ligon Mill	2	3,202	4.45	46.67	10	40	5,280	2.00	2.21	0.028	44	6	1.11	1.84	A
Seawell	2	185	0.26	46.67	10	40	5,280	2.00	2.01	0.028	3	0	1.01	1.68	A
Rogers Rd. Ext.	4	26,300	36.53	93.33	10	40	5,280	2.00	3.29	0.028	365	26	1.64	2.74	A
**Forestville*	*2*	*200*	*0.28*	*46.67*	*10*	*40*	*5,280*	*2.00*	*2.01*	*0.028*	*3*	*0*	*1.01*	*1.68*	*A*
Friendship Chapel	2	737	1.02	46.67	10	40	5,280	2.00	2.04	0.028	10	1	1.02	1.70	A
Holding	2	7,517	10.44	46.67	10	40	5,280	2.00	2.58	0.028	104	15	1.29	2.15	A
Sycamore	2	274	0.38	46.67	10	40	5,280	2.00	2.02	0.028	4	1	1.01	1.68	A
Elm	2	7,466	10.37	46.67	10	40	5,280	2.00	2.57	0.028	104	15	1.29	2.14	A
Brick	2	2,187	3.04	46.67	10	40	5,280	2.00	2.14	0.028	30	4	1.07	1.78	A

**Forestville Rd. crossing is to be closed upon completion of proposed Rogers Rd. extension. Figures shown represent conditions if Forestville Rd. remained open.*

Adjacent Signalized Intersections

No signalized intersections are close enough to existing at-grade rail crossings to affect their operations, or to be affected by train crossings and subsequent vehicle queues. No future signalized intersections with potential for such interactions were identified.

Adjacent Unsignalized Intersections

Two unsignalized intersections are close enough to at-grade crossings to create potential delays due to interference between train operations and traffic control devices.

East Elm Street and White Street

This intersection is unsignalized with all single-lane approaches, and stop signs on White Street. The existing LOS is "A" in the AM peak, and "A" in the PM peak. In 2015, the AM LOS is forecast to be "A," and the PM, "D."

During a train crossing, no more than three or four automobiles can safely queue in the westbound lane of East Elm Street between the railroad tracks and White Street. This is less than both the 1998 and 2015 predicted maximum queues of 8 and 15 vehicles, respectively. Due to the single-lane approaches, a long train can potentially "lock up" the entire intersection.

Brick Street and North White Street

Brick Street "tees" into North White Street less than 50 feet from the crossing. Traffic control consists of a "STOP" sign on Brick Street. Traffic volumes are relatively low, and do not appear likely to warrant a traffic signal. However, the limited distance between the crossing and the "STOP" sign at North White Street could lead to vehicles queuing back onto the tracks.

VEHICLES QUEUEING ACROSS RAILROAD TRACKS

The presence of nearby traffic signals, intersections, or parallel roadways can result in queues of stopped vehicles extending onto or across a railroad crossing. The only location with the potential for this problem is Brick Street, where there is room for no more than a single vehicle to safely wait before turning onto North White Street. This was the cause of two accidents, in 1977 and 1984. The enhancement of warning signs, signals, and markings appears to have reduced the risk of this type of accident.

TRAFFIC SIGNAL PREEMPTION

Standard practice (based of *The Manual on Uniform Traffic Control Devices*) requires that traffic signals located within 200 feet of a railroad crossing be coordinated with the crossings train detection and warning system to preempt normal operations of the traffic signal. There are no traffic signals within 200 feet of any of the crossings in this study. Should a traffic signal become warranted at the intersection of East Elm and White Streets, however, preemption would be needed.

HUMPED CROSSINGS

A "humped" crossing exists where the elevation of the railroad is significantly higher than the crossing roadway, causing vehicles to ascend on one side of the tracks and descend on the other. The severity of this condition can range from discomfort at normal speeds, to "bottoming out" of vehicles with long wheelbases or low clearances. This dragging can damage vehicles, or cause them to become stuck on the crossing, creating a serious hazard. Routine track maintenance tends to exacerbate the problem over time, as track ballast work typically adds about 3" per occurrence. Over a ten year period, the railroad will rise about one foot as a result of this routine maintenance.

As the **Findings and Recommendations** section of this report discusses in more detail, several of the crossings have humped profiles. East Elm Street is the most severe, followed by Brick Street. Sycamore Street, Forestville Road and East Holding Street have slight humps.

GRADE CROSSING CONDITION

A poor grade crossing surface can result in a rough, uneven ride. This can increase wear and tear on vehicles, create a traffic safety hazard, and cause congestion by reducing travel speeds.

The Sycamore Street and Seawell Road crossing are in poor condition, but these are low-volume, low speed facilities. Conditions at East Elm Street and Brick Street are less than desirable, due mainly to the hump condition described above. In addition, the two sets of abandoned rails at East Elm Street degrade the quality of that crossing.

VEHICLES DRIVING AROUND AUTOMATED GATES

Several situations can lead to the circumvention of automated gates by motorists:

- Gates are lowered, but no train is visible
- Gates fail, and remain in the lowered position
- Gates are lowered and train is visible, but motorist is too impatient to wait

There is no evidence suggesting this is a significant problem at the crossings studied.

IMPROVED SIGNS AND MARKINGS

The effectiveness of required warning signs, markings, signals, and other devices depends heavily on proper installation and maintenance by state and municipal transportation departments and the railroads. Signs and markings at the Seawell Road and Friendship Chapel Road crossings could be enhanced.

ROADWAY IMPROVEMENTS

Improvements and additions to the roadway system in the Wake Forest area are critical factors in this study's recommendations. Several key recommendations are contingent on completion of planned highway projects, both public and private:

- The proposed Rogers Road extension directly affects the Forestville Road crossing.
- Both traffic conditions and potential alternatives at Friendship Chapel Road depend on a connection with the planned extension of Franklin Street.
- TIP Project Number R-2809 (NC-98 Wake Forest Bypass) will provide a new grade-separated railroad crossing just north of Friendship Chapel Road, and will affect traffic volumes at the Holding Avenue and East Elm Street crossings.

ROADWAY GRADE SEPARATION

To fully eliminate the potential for train/vehicle collisions while still maintaining access across the tracks, construction of a grade separation should be evaluated. However, modifications to mainline railway grades or profiles are severely constrained by strict design standards. Highway overpasses of railroads require a vertical clearance of 23 feet, while railroad overpasses of highways typically require 16 to 17 feet. Due to sight distance requirements for safe stopping, a "crest" curve on a roadway overpass is longer than a "sag" curve at a comparable underpass, thereby involving a longer approach distance. This can have important implications with respect to property access and street network connectivity. Other considerations include visual and noise impacts of roadway overpasses, especially in neighborhoods, downtowns, or historic areas.

Historically, the grade separation of railroad crossings has played an important role in shaping the Town of Wake Forest. Figures 2-4 (from the collection of Frank Moore, Charleston, SC) depict the at-grade crossing at Wait Avenue (NC-98) as it existed prior to construction of a railroad overpass in 1936. Not only do these photographs reflect the physical changes involved in retrofitting a grade-separation, they also illustrate the evolution of the signs, signals, markings, and other devices used to warn motorists at railroad crossings. Figure 5 shows the grade separation as it exists today. The structure, while functional, obviously provides less vertical and horizontal clearance than would be expected in a modern design.

OTHER MOBILITY FACTORS

The completion of several major roadway projects will significantly alter travel patterns in the Wake Forest area. The NC-98 Wake Forest Bypass (NC TIP Project Number R-2809) will provide a grade-separated railroad crossing. It is expected that soon after construction of the eastern portion of the NC-98 Bypass, Franklin Street will be extended southward, at least as far as the Bypass. Eventually, the Franklin Street Extension should tie into the road network associated with the proposed, Ammons development. This would provide alternative access, permitting closure of the Friendship Chapel crossing. Completion of these projects could also reduce traffic volumes at the East Elm Street and Holding Avenue crossings. The extension of Rogers Road to Main Street (also part of the

Figure 2. Wait Avenue Crossing – View Looking South, 1932.

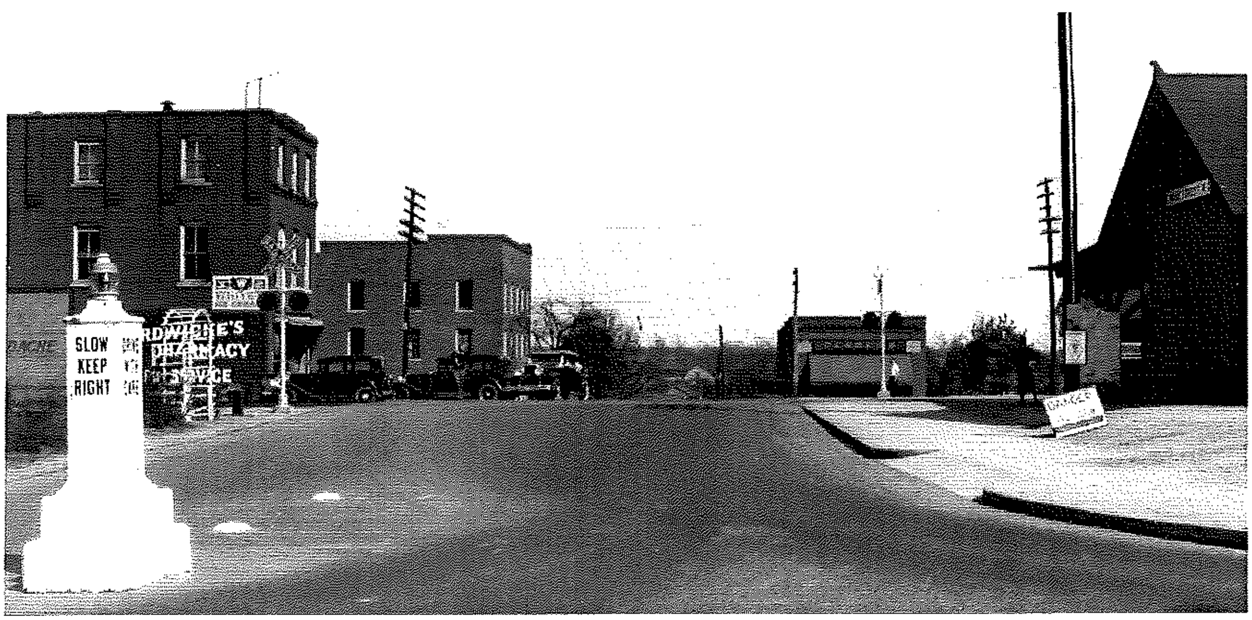


Figure 3. Wait Avenue Crossing – View Looking East, 1932.

Figure 4. Wait Avenue Crossing – View from Northwest, 1932.

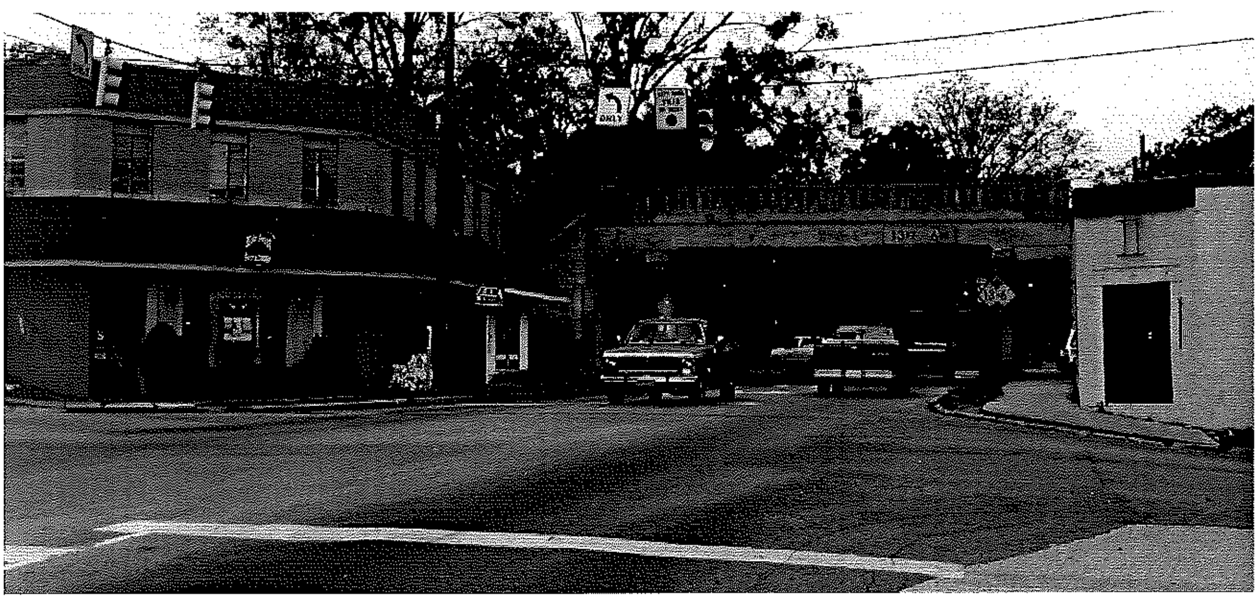


Figure 5. Wait Avenue Grade Separation – View Looking West, 1998.

Ammons development) will add an interim at-grade railroad crossing, but will allow elimination of the Forestville Road crossing.

Rapid growth along the US-1 corridor north of Raleigh is expected to continue over the next twenty years, and beyond. The Town of Wake Forest represents a major concentration for new development, and substantial traffic growth is expected during this period. With the increased traffic will come increased accident potential and traffic delays at existing grade crossings.

Long-term changes in train operations could exacerbate the situation. Increases in freight activity are likely, and the potential extension of TTA regional rail service to Wake Forest is being discussed. Furthermore, the CSX "S" line is on the federally-designated *Southeast High Speed Rail* corridor.

Clearly, both the need and the opportunity exist for enhancing rail crossings in the study area. A number of options available for consideration are discussed below.

GRADE SEPARATION STRUCTURES

Many factors must be considered before suggesting grade separation, including:

- Traffic volumes (both vehicle and train)
- Accident history
- Topography
- Construction impacts
- Costs

Traffic Volumes

The threshold for considering grade separation of local streets is generally considered to be above the range of 15,000 to 30,000 vehicles per day. With low train volumes (as are currently exhibited in Wake Forest), multi-lane roadways can accommodate daily volumes of over 30,000 vehicles without creating unacceptable delays.

An ***exposure index*** is employed by NCDOT as a guideline in determining whether or not grade separation is justified at proposed highway/rail crossings. This index is calculated by multiplying the number of trains per day by the number of crossing vehicles per day, in the design year. Current policy identifies an exposure index of 15,000 as the threshold for considering grade separation in rural areas. In urban areas, an exposure index of 30,000 or greater identifies a potential grade separation.

Accident History

In some cases, the accident history of a low-volume crossing may justify grade separation, even with a low exposure index. If the crossing cannot be closed, or other safety provisions made, a physical separation between the road and tracks may be the only feasible solution.

Topography

The relationship between elevations and slopes in the vicinity of the crossing greatly influence the viability of constructing a grade-separation. Where existing topography facilitates a highway overpass, minimizing earthwork and ROW requirements, the cost of grade separation can be significantly reduced. When topography is relatively flat, costs (and other impacts) can escalate significantly.

Construction Impacts

While the impacts of constructing a new grade separation can be significant, retrofitting a grade separation to comply with current design criteria is typically more disruptive during and after construction. Visual, noise, and access degradation can be severe, and the separation may require the relocation of businesses or dwellings. Other potential impacts can involve wetlands/woodlands, historic/archaeological sites, and hazardous materials.

Costs

Grade separation structures represent substantial, long-term infrastructure investments, often exceeding several million dollars. Careful analysis and planning is required to insure that this alternative is the most cost-effective and beneficial solution.

CROSSING PROTECTION DEVICE UPGRADES

The most common, and cost-effective, way to increase the safety at a railway crossing is to upgrade existing warning devices at the crossing. Typical warning devices include signs, gate arms, flashing lights and bells. *Passive* devices, such as advanced warning signs and crossbucks, merely warn the motorist of the existence of a railroad crossing. These devices are most suitable where train and traffic volumes and speeds are low, and where sight distance is adequate. *Active* devices that warn motorists of approaching trains include flashing lights, bells, and automated gates. Such devices are usually employed at locations exhibiting higher volumes or speeds, or greater potential for accidents. The hierarchy of standard warning treatments, from least to most positive is:

1. Unmarked;
2. Railroad crossbucks;
3. Standard STOP signs (limited sight distance) and crossbucks;
4. Flashing signals and bells;
5. Flashing signals, bells and gates.

ADVANCED CROSSING PROTECTION DEVICES

The NCDOT Rail Division and Norfolk Southern Railway have been testing advanced crossing protection devices on the main line from Raleigh to Charlotte since 1995. These devices are most appropriate where high-volume multilane roadways cross railroad main lines, and where significant numbers of motorists are ignoring or circumventing existing warning devices. The advanced warning devices being considered are described below, along with some initial NCDOT Rail Division test results from Charlotte, NC.

Median Barriers

Median barriers consist of markers mounted on raised islands along the roadway centerline to discourage motorists from driving in opposing travel lanes to "go around" around lowered gate arms. Median treatments typically extend 70' to 100' back from the gates, but may be precluded by driveways or intersecting roads within this distance. Typical costs are about $15,000 per location. Installation of median barriers at Sugar Creek Road in Charlotte reduced crossing violations by 77%.

Four-Quadrant Gates

This crossing treatment requires an additional gate on each approach, completely "sealing" the crossing. Several measures are employed to prevent vehicles from becoming "trapped" inside the gates, including careful timing of the gates to allow traffic to clear; providing 16 feet of clearance between track center and gates; leaving adequate space between gate tips for a vehicle to "squeeze" out; and use of breakaway arms. In tests at the Sugar Creek Rd. crossing in Charlotte, four-quadrant gates alone reduced violations by 86%; in combination with median barriers, the reduction in violations rose to 98%. The cost of four-quadrant gates is site specific, but $140,000 is typical.

Long Gate Arms

Extra-long arms cover at least ¾ of the crossing width. When tested at the Orr Road crossing in Charlotte, the installation of long gate arms reduced crossing violations by 67%. A cost of $20,000 is typical.

Articulated Gates

Articulated gates are hinged arms that unfold to cover at least ¾ of crossing width. They are typically warranted where overhead obstructions prevent the use of long gate arms. Articulated gates installed at Orr Road in Charlotte reduced crossing violations by 78%.

Remote Video Detection

The Crossing Law Enforcement and Research of (CLEAR) Violations program employs video cameras to monitor selected crossings. The recorded provide information on crossing operations, violations, and accidents for both enforcement and research purposes.

CROSSING CONSOLIDATION & ELIMINATION

Many low-volume crossings are unnecessary due to the availability of alternative access across the tracks. These alternative crossings can often be made safer, since many low-volume crossings lack adequate warning devices. Resources are not available to upgrade warning devices on all existing crossings, and grade separation would be even less feasible. Therefore, consolidation and closure of these minor crossings is an effective strategy in terms of both costs and safety benefits. Typically, a crossing is considered redundant (and therefore a candidate for elimination) if it is within ¼-mile of another crossing connected to the same street network.

Crossing consolidations eliminate the potential for train/vehicle collisions. Crossing-related installation and maintenance costs are reduced, and by concentrating traffic at fewer, higher-volume crossings, more expensive active warning treatments and roadway improvements can be justified.

Crossings with high potential for elimination include:

- Redundant crossings near parallel crossings or grade separations, or where traffic can be safely and efficiently diverted to another crossing;
- Skewed crossings, or those where sight distance is limited by horizontal/vertical curvature, vegetation, or permanent obstructions;
- Crossings with a history of frequent accidents;
- Crossings adjacent to a newly constructed crossing or grade separation;
- Private crossings with no identifiable owner, or where the owner is unwilling or unable to fund crossing upgrades (and where alternative access is reasonably available);
- Complex crossings that cannot be effectively served by warning devices due to multiple tracks, extensive switching operations, etc.

ROADWAY IMPROVEMENTS

Roadway improvements can reduce both accident potential and traffic delay at railroad crossings. Realignment and re-grading can improve visibility and reduce the time required to traverse a crossing. Additional lanes significantly increase capacity, reducing the residual delay following a crossing event. New roadways can provide alternative routes, allowing crossings to occur at more desirable locations, and potentially eliminating some crossing trips.

TRAFFIC SIGNALS

Traffic signals are not specifically intended as warning devices at railroad crossings. However, when an at-grade railroad crossing is located near a signalized intersection (typically within 200'), special steps should be taken to insure that vehicles do not get trapped on the tracks due to queues resulting from a red signal. The normal sequence of traffic signal indications should be preempted by the approach of a train, eliminating the possibility of entrapment due to conflicting traffic and railroad crossing signals. Ideally, the preempted signal phasing should be designed to allow non-conflicting movements to proceed during a train crossing, thereby minimizing overall traffic delay.

KEY FINDINGS

In the course of this study, several critical issues emerged. The findings and recommendations of this study are highly dependent on these factors, and on related assumptions. Four of the most critical factors are discussed below.

Growth Rates

Increases in population and employment generate traffic growth, and all indications are that Wake Forest will experience considerable growth over the next 10-20 years, as development extends north from Raleigh along the US-1 corridor. The proposed Wakefield development is a prime example of what is expected. The projected increases in traffic volumes at the subject rail crossings will have a far more substantial effect on safety and delay than will any anticipated increases in rail operations.

Transportation Improvement Program (TIP) & Long-Range Plans

Most of the recommendations resulting from this study are relatively low-cost, near-term solutions. They depend more on existing conditions than on long-range expectations of traffic volumes and highway improvements. However, several pending roadway improvement projects will significantly alter traffic patterns in Wake Forest, reducing traffic volumes at several crossings, and providing opportunities for crossing consolidation and elimination. Additional development triggered by improved accessibility may add traffic at some locations, but careful planning should allow new facilities to offset this increase by diverting traffic to more desirable routes.

Key projects include:

- NC-98 Wake Forest Bypass (NC TIP Project Number R-2809),
- Extension of Rogers Road west to South Main Street,
- Extension of Franklin Street south to Forestville (Rogers) Road.

These projects all have some degree of commitment behind them, and are either in the state TIP (Transportation Improvement Program) or CAMPO (Capital Area Metropolitan Planning Organization) long-range transportation plan, or have been recently proposed for inclusion. Only the extension of Rogers Road was explicitly considered in the analysis conducted for this study, since it is the only one that involves a potential at-grade crossing. However, the long-term implications of the other two projects are discussed qualitatively in terms of their traffic impacts, along with additional alternatives that may become feasible upon their completion.

Private developers have made progress on portions of another facility proposed in the thoroughfare plan, the Northside Loop. However, there is no state or local funding committed to this project, nor is it programmed for completion. It seems unlikely that private development will result in completion of the critical segment across the rail corridor, given topographic constraints that limit development potential and escalate roadway construction costs. Therefore, this study assumes that the Northside Loop will not be completed by 2015.

Development of the Ammons Property

The mixed-used development proposed for the Ammons property east of Main Street in southern Wake Forest provides a timely opportunity to improve crossing conditions in the study area. Current policy dictates that no new at-grade crossings be allowed along this rail corridor unless one or more existing public crossings is eliminated. The proposed extension of Rogers Road as part of the Ammons development would facilitate the elimination of the Forestville Road crossing. Furthermore, while the initial Rogers Road rail crossing would be at-grade, adjacent sites are being planned in anticipation of an eventual grade separation. In addition to building setbacks and driveway restrictions, consideration should be given to preserving a parallel roadway corridor for vehiclular traffic during construction of a grade separation. Should a highway underpass be recommended, right-of-way for a railroad detour track should be reserved.

The traffic effects of the Ammons development (both in terms of new trips generated and the diversion of trips onto the extension of Rogers Road) were obtained from preliminary traffic impact studies conducted for the developer by Kimley-Horn Associates. This information was factored into the traffic forecasts for the Rogers Rd. and Forestville Rd. crossings.

Future Passenger Rail Service

Two possible changes in rail service could have major impacts on grade crossing conditions in the study area. Although neither was directly analyzed in this study, their potential implications were considered in developing the study's overall recommendations.

In the future, the federal high-speed rail (HSR) designation of the CSX "S" corridor could necessitate installation of additional safety devices, and future construction grade separations. Until HSR planning has progressed to the point of identifying alignments and operational characteristics, expensive long-term solutions (especially grade-separations) should be considered carefully.

The potential extension of TTA regional rail service along this corridor should also be considered carefully in recommending major crossing improvements. Although train speeds would be much lower than HSR (comparable, in fact, to existing train speeds), their frequency would be much higher, especially during the peak hours of roadway travel. The resulting increase in train–vehicle conflicts could dramatically worsen traffic delays at crossings. Once again, however, more detailed information on train operations and rail alignments is needed before specific recommendations can be made.

SPECIFIC RECOMMENDATIONS

The following section of the report describes the recommendations on a crossing-by-crossing basis. Relevant findings, forecasts, and supporting data are included for every crossing, along with photographs of each approach and a plan view of the crossing indicating existing conditions and proposed improvements.

For the purposes of this report, recommendations are classified as follows:

- Near-term (0-2 years)
- Mid-term (2-5 years)
- Long-term (5-10 years)

Costs are estimated for individual improvement recommendations, and for the crossing as a whole.

1. LIGON MILL ROAD (SR-2044) *CSX RR MILE POST S 0143.75, CROSSING #630 598S*

Ligon Mill Road is essentially a two-lane thoroughfare serving low-density rural/suburban residential development. The current average daily traffic (ADT) is 1,937 vehicles per day, with an ADT of about 3,200 expected by 2015. New residential development is occurring in the northeast quadrant of the crossing, and the north side of Ligon Mill Road has been widened (with sidewalk) along the subdivision frontage up to the railroad crossing.

The existing crossing gives no indication of any significant safety or capacity problems, and appears to be adequate for the anticipated growth in traffic and train activity, even considering the a proposal to revise the thoroughfare plan to extend Ligon Mill Road northward. Four-quadrant, articulated, or long-arm gates could be considered if train speeds or frequencies increase dramatically, or if the remaining widening of Ligon Mill Road is carried out.

This crossing is not a good candidate for grade-separation, due to topography and the proximity of residences. Should higher-speed rail service be implemented along this corridor, it is likely that the track alignment in this area would shift southeast to reduce curvature. The existing crossing would then be replaced by a roadway overpass at the new location.

Recommendations

Long-Term (5-10 years)

Install four-quadrant automated gates. Install median barriers if feasible.

Estimated Cost of Recommendations

Install four-quadrant automated gates		$140,000
Construct monolithic concrete median barriers		$15,000
	TOTAL	$155,000

Impacts of Recommendations

Implementing these recommendations should result in safety benefits.

TABLE 7. Ligon Mill Road Crossing Characteristics

Measure	Existing	2015	Improved 2015
Exposure Index	9,685	32,020	32,020
Maximum Queue	3	6	6
Vehicles Delayed / Day	12	44	44
Minutes Delay / Stopped Vehicle	0.9	1.1	1.1
LOS	A	A	A

Figure 6. Ligon Mill Road Crossing – View Looking East

Figure 7. Ligon Mill Road Crossing – View Looking West

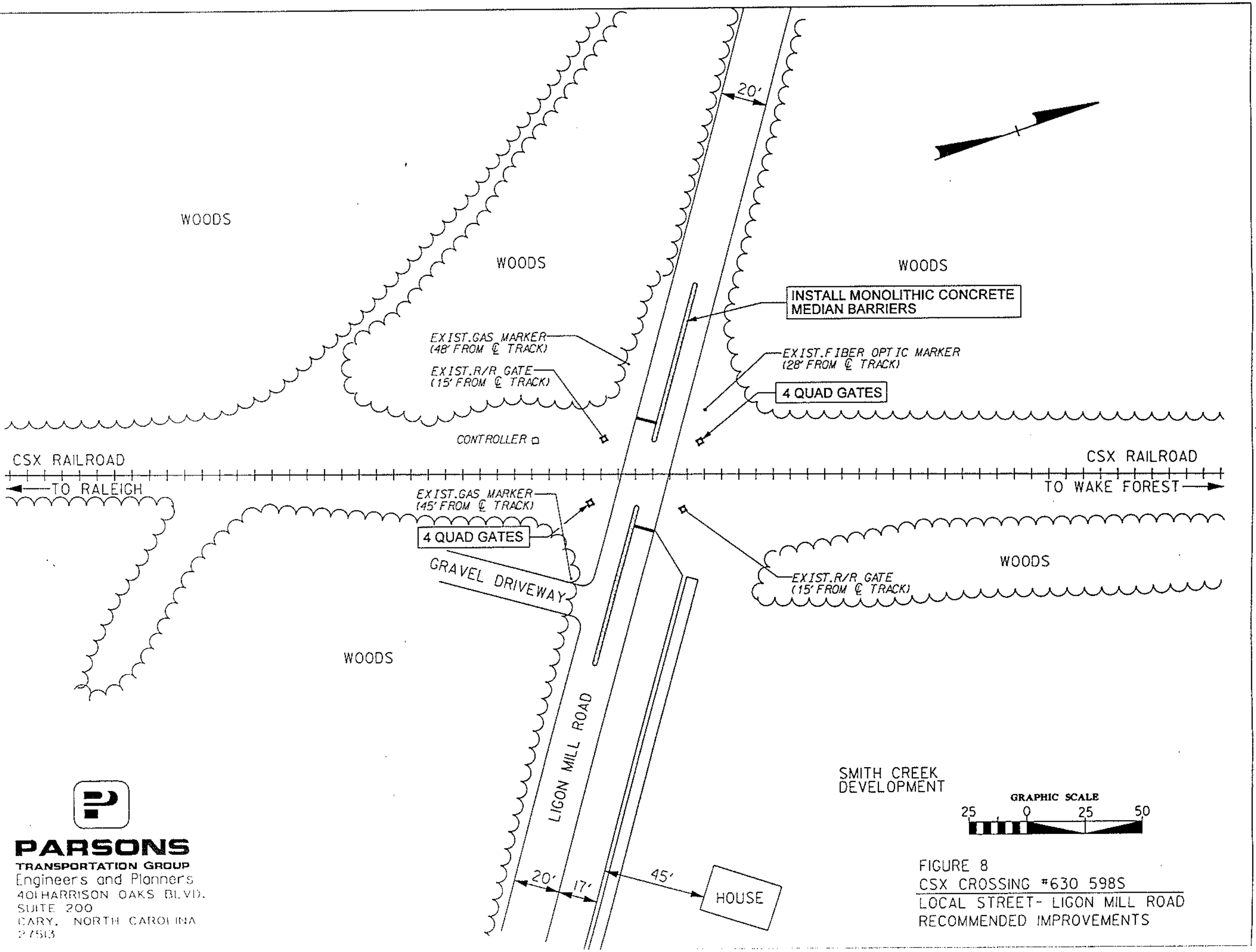


FIGURE 8
CSX CROSSING #630 598S
LOCAL STREET- LIGON MILL ROAD
RECOMMENDED IMPROVEMENTS

PARSONS
TRANSPORTATION GROUP
Engineers and Planners
401 HARRISON OAKS BLVD.
SUITE 200
CARY, NORTH CAROLINA
27513

2. SEAWELL ROAD (SR-2046) *CSX RR MILE POST S 0143.15, CROSSING #630 597K*

Seawell Road is a local dead end road serving a primarily residential area, providing the only access to several private properties. This narrow, two-lane roadway is unpaved east of the railroad crossing. The ADT on Seawell Road is less than 120 vehicles per day. In 2015, the ADT is projected to reach 185 vehicles per day.

Although there are no geometric problems significantly reducing safety or capacity, the crossing is rough, and should be improved to offer a smoother crossing. Lights and gates should be considered, especially if higher-speed rail or commuter rail service is instituted. However, higher-speed rail operations would probably require shifting the tracks westward slightly, to reduce curvature.

Recommendations

Near-Term (0-2 years)

Modify approach and crossing grade surfaces. Enhance pavement markings.

Mid-Term (2-5 years)

Install flashing lights and gate arms. Median barriers do not appear warranted.

Estimated Cost of Recommendations

Enhance pavement markings and grading of crossing pavement	$5,000
Install flashing light signals and long automated gate arms	$75,000
TOTAL	$80,000

Impacts of Recommendations

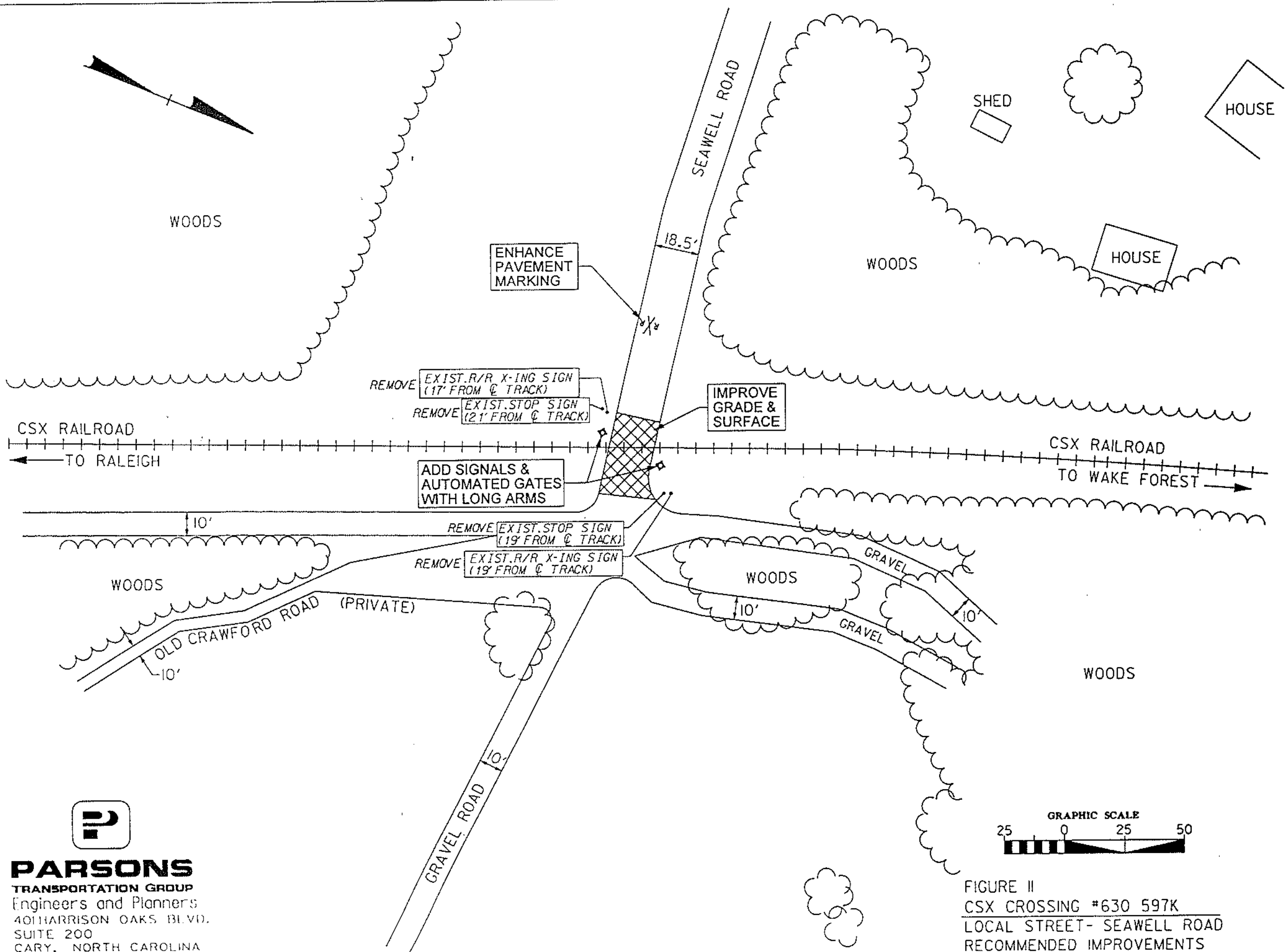
The effects of implementing these recommendations should be entirely positive. Access to properties depending on this crossing will be safer.

TABLE 8. Seawell Road Crossing Characteristics

MEASURE	EXISTING	2015	IMPROVED 2015
Exposure Index	560	1,850	1,850
Maximum Queue	0	0	0
Vehicles Delayed / Day	1	2	3
Minutes Delay / Stopped Vehicle	0.7	0.9	1.0
LOS	A	A	A

Figure 9. Seawell Road Crossing – View Looking East

Figure 10. Seawell Road Crossing – View Looking West



PARSONS
TRANSPORTATION GROUP
Engineers and Planners
4011 HARRISON OAKS BLVD.
SUITE 200
CARY, NORTH CAROLINA
27513

FIGURE II
CSX CROSSING #630 597K
LOCAL STREET- SEAWELL ROAD
RECOMMENDED IMPROVEMENTS

3. ROGERS ROAD EXTENSION

The extension of Rogers Road west to US-1A (South Main Street) is proposed as part of a major new mixed-use development southeast of central Wake Forest. Although this major thoroughfare would be initially constructed as a two- or three-lane facility (depending on negotiations with NCDOT and CSX), a five-lane cross-section will ultimately be needed to carry the 26,300 vehicles/day forecast by 2015.

Given the volume of traffic, and the potential for regional and higher-speed rail service in this corridor, long-term provisions for grade separation are prudent. The 2015 design year exposure index of 263,000 for the proposed Rogers Road extension is approximately ten times greater than the index at which a grade separation should be constructed. Due to uncertainty regarding the eventual alignment of Southeast High Speed Rail corridor (SEHSR), and whether a highway overpass or underpass would be more feasible, it is premature to propose a specific grade separation design at this time. Instead, adequate building setbacks and access restrictions should be required, so high right-of-way and relocation costs do not become unnecessary obstacles to future grade separation. At least a preliminary design would be required to determine the most feasible configuration for a grade separation structure, and to identify right-of-way requirements, building setbacks, and driveway limitations.

These setbacks and rights-of-way requirements should consider the implications of constructing a highway underpass or overpass while maintaining vehicular traffic on Rogers Road, or detouring traffic during construction. If preliminary plans indicate it is more feasible to grade-separate Rogers Road with a highway underpass, property for a temporary or permanent railroad detour track should be identified and preserved. This would allow CSX freight traffic to maintain operations throughout construction. In the near-term, the NCDOT Rail Division will coordinate negotiations among the developer, the NCDOT, and the Town of Wake Forest to establish responsibilities for each party in the provision and maintenance of adequate signs, signals, markings, and other warning devices.

Recommendations

Near-Term (0-2 years)

Install flashing lights, cantilevered signals, gates, and concrete median barriers. Preserve adequate building setbacks, and limit intersection locations to facilitate future grade separation. Reserve adequate ROW for maintaining vehicular traffic during construction. If a highway underpass is recommended, preserve ROW for a railroad detour track.

Long-Term (5-10 years)

Consider grade-separation, with or without SEHSR track realignment.

Estimated Cost of Recommendations

Install flashing lights, cantilevered signals, gates, and concrete median barriers.	$150,000
TOTAL	$150,000

Grade separation costs vary considerably, and an accurate estimate requires more detailed analysis. However, such projects typically range from $2-3 million.

Impacts of Recommendations

TABLE 9. Rogers Road Extension Crossing Characteristics

MEASURE	EXISTING	2015	IMPROVED 2015*
Exposure Index			**263,000**
Maximum Queue			26
Vehicles Delayed / Day			365
Minutes Delay / Stopped Vehicle			1.6
LOS			A

* If at-grade crossing remains.

NOTE:
IT IS ANTICIPATED THAT ROGERS ROAD EXT. WILL EVENTUALLY BE GRADE-SEPARATED. PRESERVE ADEQUATE BUILDING SETBACKS, AND LIMIT INTERSECTION LOCATIONS TO FACILITATE FUTURE GRADE SEPARATION. RESERVE ADEQUATE R.O.W. FOR MAINTAINING VEHICULAR TRAFFIC DURING CONSTRUCTION. IF A HIGHWAY UNDERPASS IS RECOMMENDED, PRESERVE R.O.W. FOR A RAILROAD DETOUR TRACK.

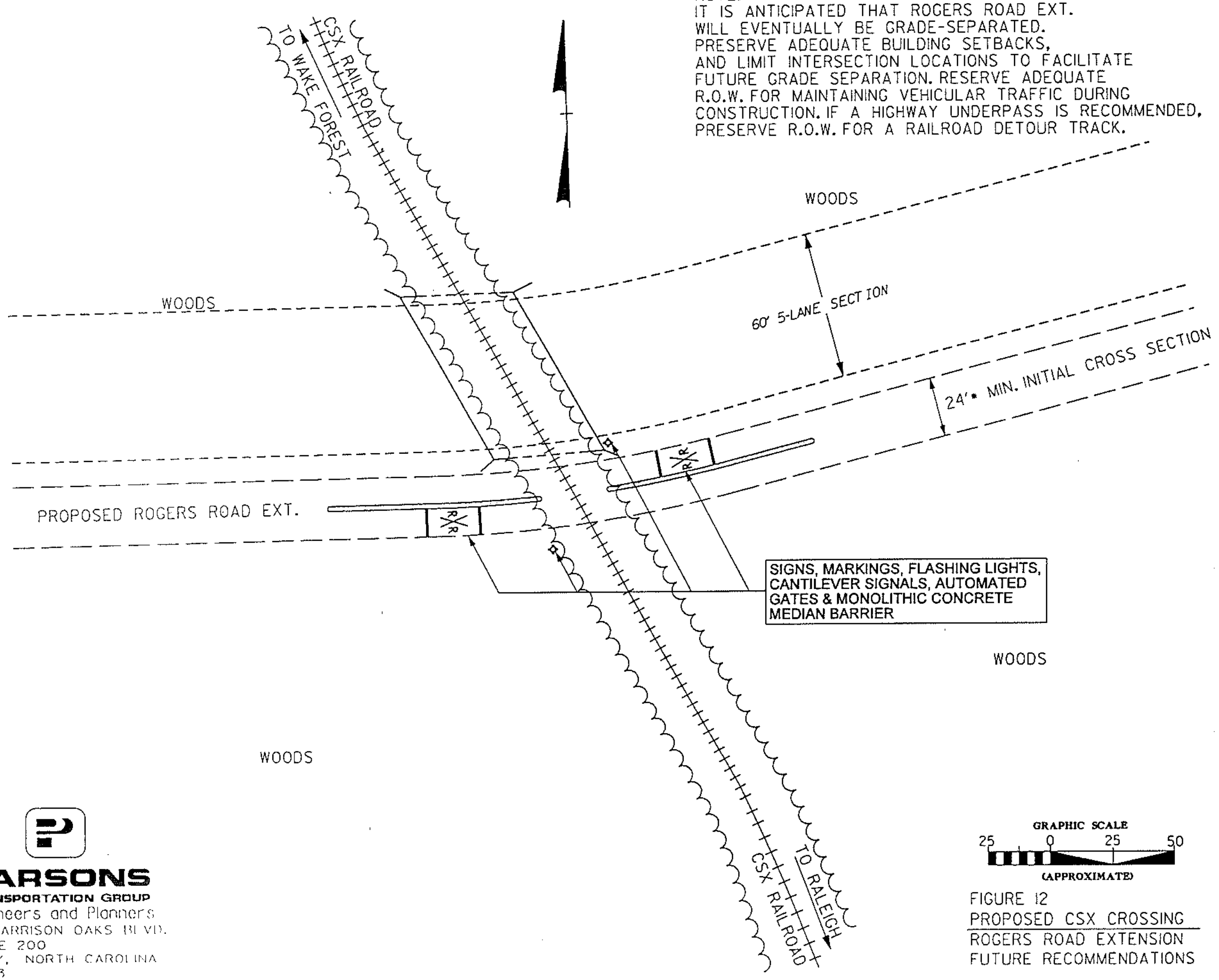


FIGURE 12
PROPOSED CSX CROSSING
ROGERS ROAD EXTENSION
FUTURE RECOMMENDATIONS

PARSONS
TRANSPORTATION GROUP
Engineers and Planners
401 HARRISON OAKS BLVD.
SUITE 200
CARY, NORTH CAROLINA
27513

4. FORESTVILLE ROAD (SR-2049) *CSX RR MILE POST S 0142.15, CROSSING #630 596D*

Forestville Road provides access to an industrial site, some residential development, and farmland. It is a two-lane road designated as a major thoroughfare. The crossing is skewed and slightly humped, with a sharply curved, uphill approach from the plant entrance to the east

The current ADT at the Forestville Road crossing is 2,581 vehicles per day. Without considering the proposed extension of Rogers Road (and associated new development), the estimated ADT in 2015 is almost 4,270 vehicles per day. If the proposed development and road extension are assumed in place, 2015 traffic projections for Forestville Road drop to around 200 vehicles/day, as traffic diverts to the more attractive route.

Recommendations

Near-Term (0-2 years)

Close the Forestville Road crossing upon the completion of proposed Rogers Road extension.

Estimated Cost of Recommendations

Remove crossing and warning devices		$9,000
Remove pavement; install barricades; landscape		$4,000
Construct turnarounds		$27,000
	TOTAL	$40,000

Impacts of Recommendations

West of the railroad tracks, the impacts of closing the crossing should be predominantly positive. Traffic through the residential neighborhood will decrease, and truck traffic will be virtually eliminated. Potential safety and congestion problems at the intersection of Forestville Road and South Main Street will be significantly reduced. Emergency response time and access for municipal services should not be affected.

To the east, the major negative impact will be a reduction in accessibility to the industrial site located adjacent to the tracks. Although Rogers Road will provide a safer route for crossing the tracks and accessing US-1A, it increases trip lengths. Less than two-tenths of a mile is added to trips using the southern part of US-1A, but the length of trips to and from the north increases by about 1-1/2 miles. The possible extension of Franklin Street south to Rogers Road would effectively eliminate this problem, however.

TABLE 10. Forestville Road Crossing Characteristics

MEASURE	EXISTING	2015	IMPROVED 2015
Exposure Index	12,905	2,000	NA
Maximum Queue	5	0	NA
Vehicles Delayed / Day	16	3	NA
Minutes Delay / Stopped Vehicle	1.0	1.0	NA
LOS	A	A	NA

Figure 13. Forestville Road Crossing – View Looking East

Figure 14. Forestville Road Crossing – View Looking West

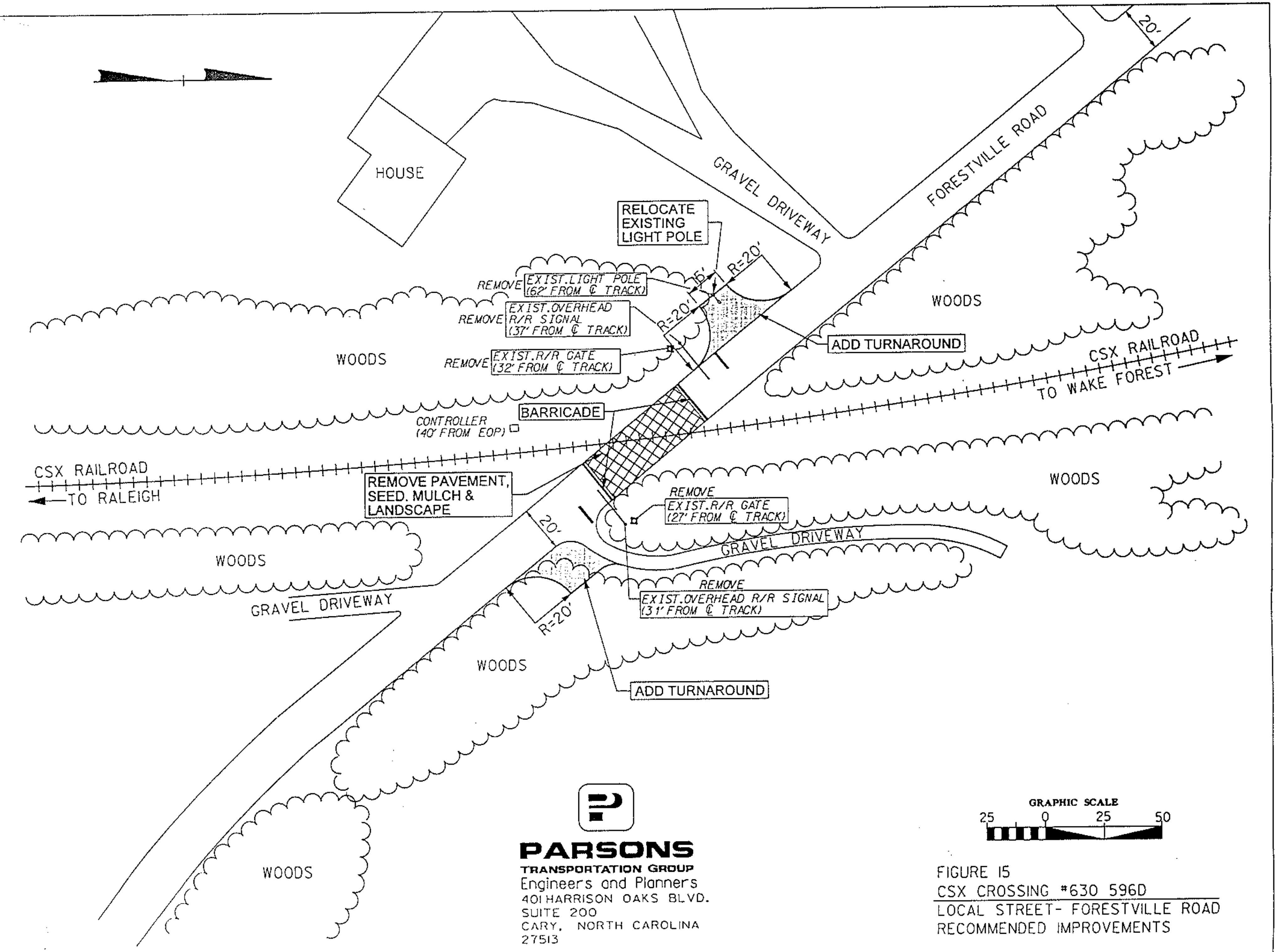


FIGURE 15
CSX CROSSING #630 596D
LOCAL STREET- FORESTVILLE ROAD
RECOMMENDED IMPROVEMENTS

6. FRIENDSHIP CHAPEL ROAD (SR-2047)

CSX RR MILE POST S 0141.73, CROSSING #630 595W

Friendship Chapel Road is a two-lane local street providing the only access to residences, a church, and limited industrial development east of the railroad crossing. There are no apparent safety or capacity problems related to the condition or geometry of the crossing itself. Warning devices are minimal, consisting of stop signs and crossbucks.

About 450 vehicles per day currently use Friendship Chapel Road, and by 2015 that volume is expected to grow to about 740 vehicles per day. Eventually, Friendship Chapel Road may be connected to a southern extension of Franklin Street to Rogers Road, resulting in significantly higher traffic volumes, due to both traffic diversion and new development. Should this connection occur, however, the additional access may permit closing of the Friendship Chapel Road crossing. This would probably be more cost-effective than a grade-separation. While appearing feasible, a roadway overpass may be complicated by the relatively short distance between the rail corridor and South Main Street. Furthermore, the NC 98 Wake Forest Bypass (NC TIP Project #R-2809) will intersect South Main Street in the vicinity of Friendship Chapel Road, and will pass over the railroad tracks. This facility will carry most new and diverted traffic that might otherwise use Friendship Chapel Road, and it is unlikely that two grade separations would be built so close together.

Recommendations

Near-Term (0-2 years)

Enhance pavement markings.

Mid-Term (2-5 years)

Install flashing light signals and long-arm automated gates.

Long-Term (Conditional, 5-10 years)

Remove the crossing if Friendship Chapel Road is connected to the extension of South Franklin Street.

Estimated Cost of Recommendations

Enhance pavement markings		$1,200
Install flashing light signals and long-arm automated gates		$75,000
	TOTAL	$76,200

Remove crossing and warning devices		*$9,000*
Remove pavement; install barricades; landscape		*$4,000*
Construct turnarounds		*$27,000*
	TOTAL	*$40,000*

Impacts of Recommendations

All of the recommended improvements would improve the safety of the crossing. Closing the crossing under the conditions described would have minimal impact on local accessibility, and would potentially improve traffic congestion/operations and safety at the intersection with South Main Street.

TABLE 11. Friendship Chapel Road Crossing Characteristics

Measure	Existing	2015	Improved 2015*
Exposure Index	2,230	7,370	7,370
Maximum Queue	1	1	1
Vehicles Delayed / Day	2	9	10
Minutes Delay / Stopped Vehicle	0.7	0.9	1.0
LOS	A	A	A

* If at-grade crossing remains.

Figure 16. Friendship Chapel Road Crossing – View Looking East

Figure 17. Friendship Chapel Road Crossing – View Looking West

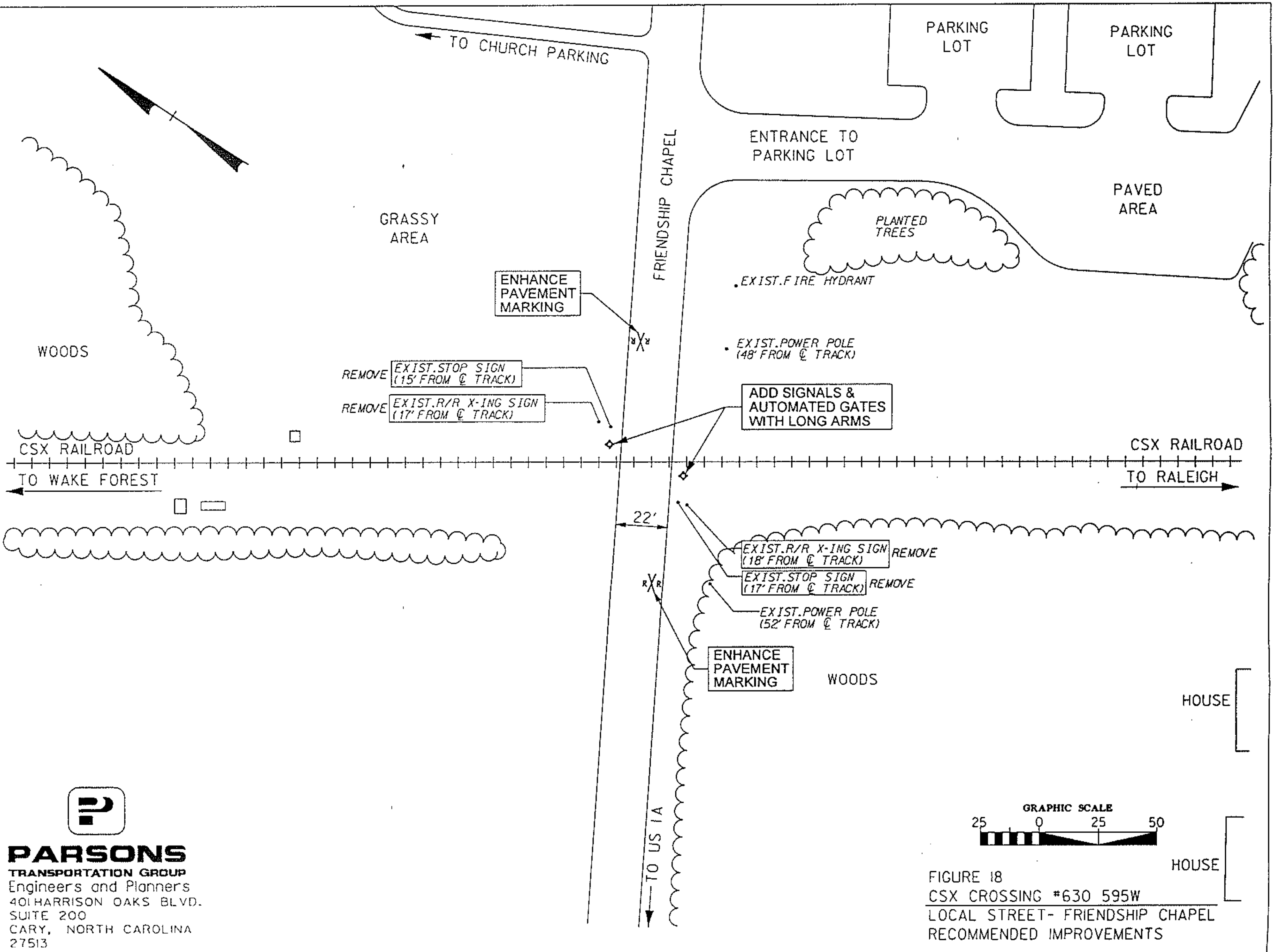


FIGURE 18
CSX CROSSING #630 595W
LOCAL STREET- FRIENDSHIP CHAPEL
RECOMMENDED IMPROVEMENTS

PARSONS
TRANSPORTATION GROUP
Engineers and Planners
401 HARRISON OAKS BLVD.
SUITE 200
CARY, NORTH CAROLINA
27513

6. EAST HOLDING AVENUE *CSX RR MILE POST 0140.99, CROSSING #630 591U*

East Holding Avenue is a relatively wide, two-lane urban street classified as a minor thoroughfare. The railroad crossing is on a section connecting Main Street and White Street through a mixed commercial, institutional, and residential area. The current ADT on Holding Avenue is about 4,550 vehicles daily, with an estimated ADT in 2015 of about 7,520 vehicles.

The crossing occurs on a slight hump. There have been two accidents at this crossing in the last ten years, including one fatality. However, no accidents have occurred since 1997, when bells, cantilevered flashing lights, and automated gate arms were installed. This crossing is not a good candidate for closure, due to economic and accessibility impacts.

The Wake Forest Thoroughfare Plan calls for the extension of East Holding Avenue eastward, to tie in with South Allen Road and the Wake Forest Bypass. While the Bypass could divert traffic from East Holding, it could also generate new development, and increased traffic. Should grade separation be warranted by higher-speed and/or regional rail services in the corridor, a railroad overpass appears most feasible, given the location's topography. Maintaining access to adjacent properties could be problematic, however.

Recommendations

Near-Term (0-2 years)

Install more durable (rubber or concrete) crossing surface.

Long-Term (5-10 years)

Upgrade to four-quadrant automated crossing arms. Median barriers are not recommended due to driveway locations.

Estimated Cost of Recommendations

Install more durable (rubber or concrete) crossing surface		$35,000
Install four-quadrant automated crossing arms		$140,000
	TOTAL	$175,000

Impacts of Recommendations

Implementing these recommendations should result in safety benefits.

TABLE 12. East Holding Avenue Crossing Characteristics

MEASURE	EXISTING	2015	IMPROVED 2015
Exposure Index	22,740	**75,170**	**75,170**
Maximum Queue	8	15	15
Vehicles Delayed / Day	28	104	104
Minutes Delay / Stopped Vehicle	1.0	1.3	1.3
LOS	A	A	A

Figure 19. East Holding Avenue Crossing – View Looking East

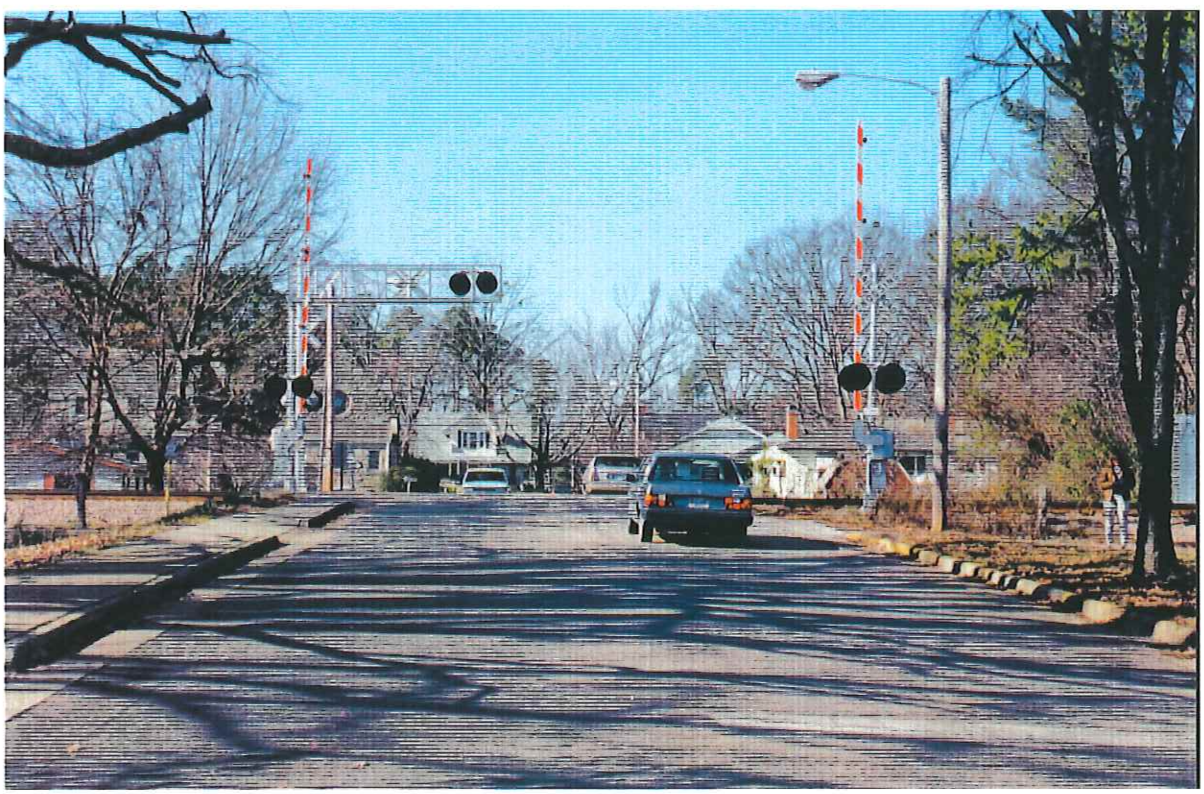


Figure 20. East Holding Avenue Crossing – View Looking West

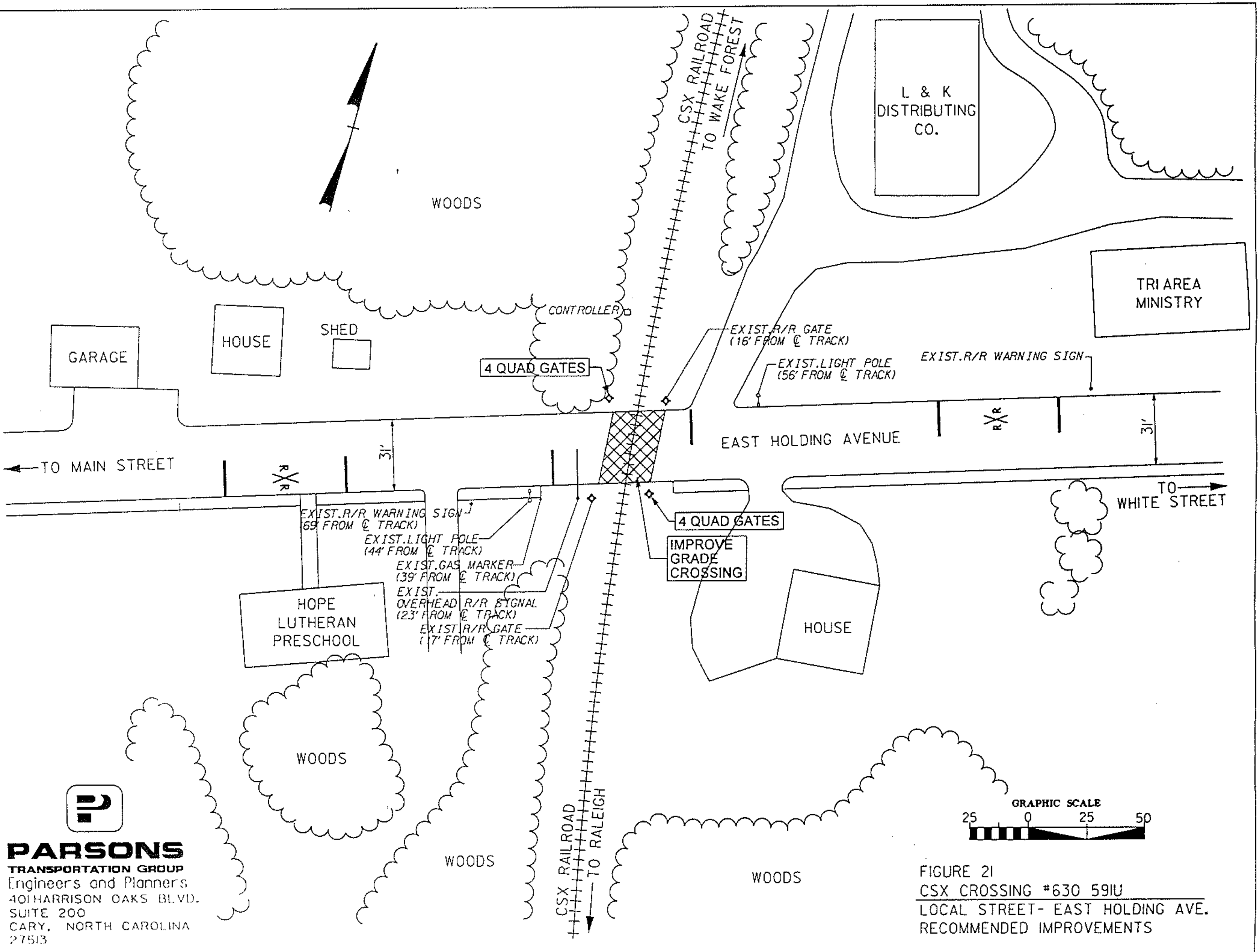


FIGURE 21
CSX CROSSING #630 591U
LOCAL STREET- EAST HOLDING AVE.
RECOMMENDED IMPROVEMENTS

PARSONS
TRANSPORTATION GROUP
Engineers and Planners
401 HARRISON OAKS BLVD.
SUITE 200
CARY, NORTH CAROLINA
27513

7. SYCAMORE STREET *CSX RR MILE POST S 0140.79, CROSSING #630 590M*

Sycamore Street is an unpaved local street serving a combined residential and commercial area between Main Street and White Street (the portion east of the tracks is commercial, the portion to the west is essentially residential). Currently, the ADT on Sycamore Street is less than 170 vehicles per day. The 2015 ADT is expected to increase to 275 vehicles per day.

Recommendations

Near-Term (0-2 years)

Eliminate this crossing. Abandon street ROW between the tracks and White Street. Add a turnaround west of the tracks.

Estimated Cost of Recommendations

Remove crossing and warning devices	$8,000
Install barricades and landscaping	$4,000
Construct turnaround	$24,000
TOTAL	$36,000

Impacts of Recommendations

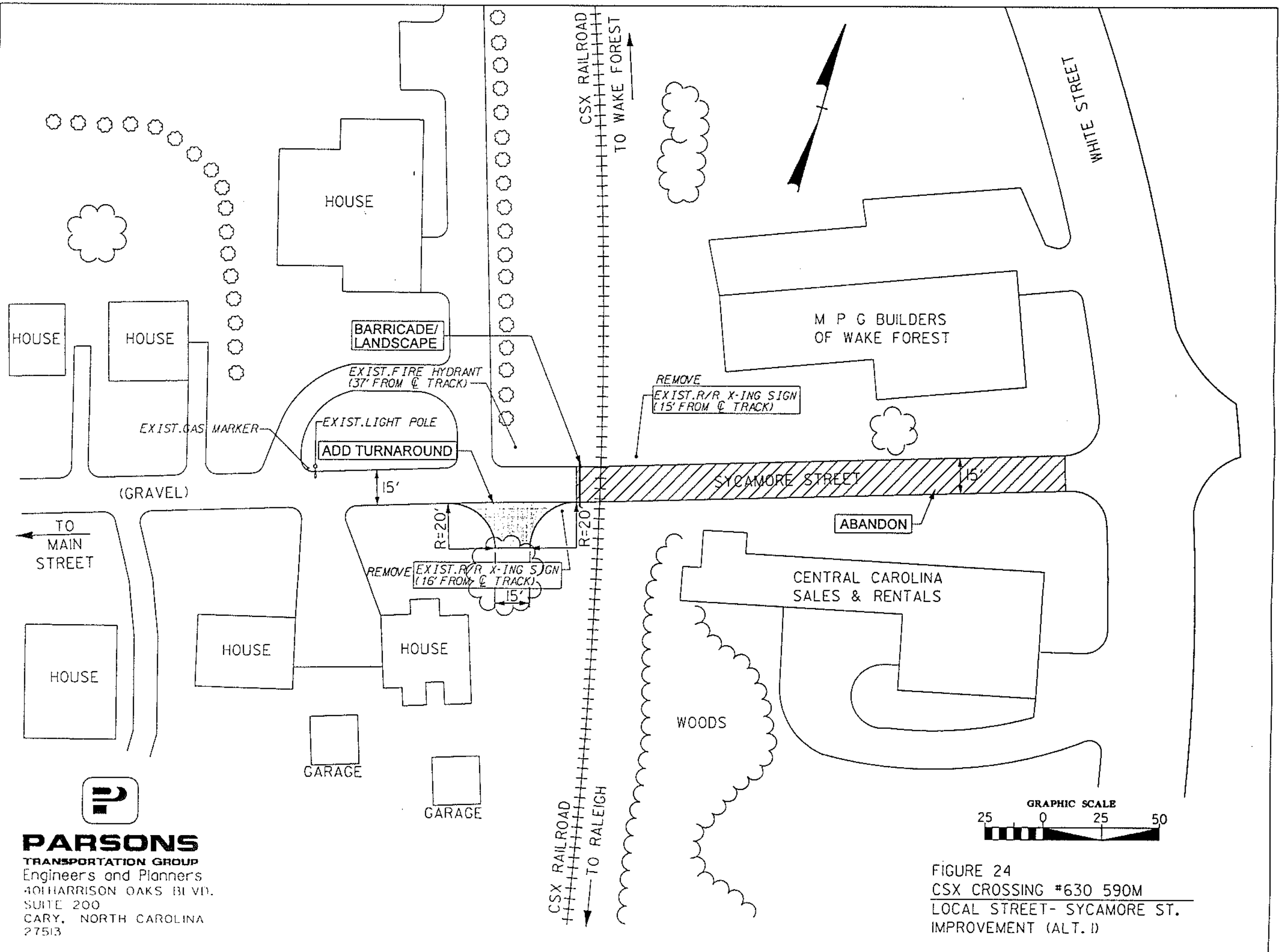
Since Sycamore Street is not needed for access to any properties east of the railroad tracks, the ROW could be abandoned, relieving the Town of maintenance responsibilities. A turnaround will be needed on the west side of the tracks, to accommodate sanitation trucks and other large vehicles. Encroachment on existing residential properties will probably be necessary, with complications presented by large trees, a fire hydrant, and drainage ditches. Two turnaround designs were evaluated, with the symmetrical "T" design (Alternative 2) appearing to minimize impacts on residential property. This design is recommended.

TABLE 13. Sycamore Street Crossing Characteristics

MEASURE	EXISTING	2015	IMPROVED 2015
Exposure Index	830	2,740	NA
Maximum Queue	0	0	NA
Vehicles Delayed / Day	1	3	NA
Minutes Delay / Stopped Vehicle	0.7	0.9	NA
LOS	A	A	NA

Figure 22. Sycamore Street Crossing – View Looking East

Figure 23. Sycamore Street Crossing – View Looking West



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Engineers and Planners
401 HARRISON OAKS BLVD.
SUITE 200
CARY, NORTH CAROLINA
27513

FIGURE 24
CSX CROSSING #630 590M
LOCAL STREET- SYCAMORE ST.
IMPROVEMENT (ALT. I)

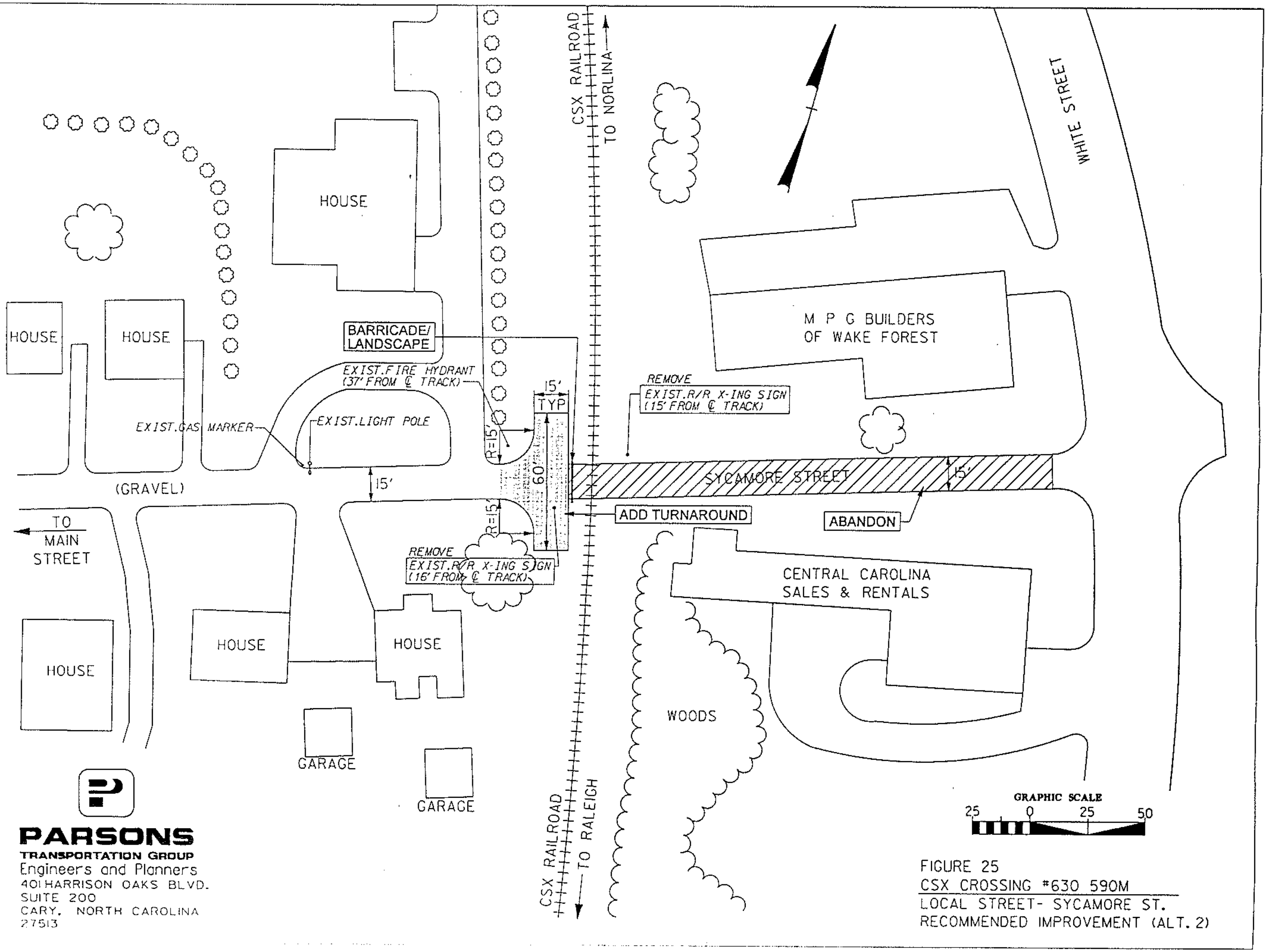

FIGURE 25
CSX CROSSING #630 590M
LOCAL STREET- SYCAMORE ST.
RECOMMENDED IMPROVEMENT (ALT. 2)

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8. EAST ELM STREET *CSX RR MILE POST S 0140.70, CROSSING #630 589T*

East Elm Street provides access to several commercial businesses while connecting Main Street and White Street. This two-lane urban facility is classified as a major thoroughfare. Approximately 4,520 vehicles per day cross the railroad tracks using East Elm Street. In 2015, the volume is estimated to reach about 7,470 vehicles per day.

The crossing is on a severe hump, as evidenced by the numerous gouges in the pavement of the westbound lane, immediately west of the crossing. Two sets of abandoned tracks remain embedded in the pavement, one on either side of the active line. To the east, a steep grade descends to the intersection with White Street, approximately 80 feet away.

This intersection is unsignalized with all single-lane approaches, and stop signs on White Street. The existing LOS is "A" in the AM peak, and "A" in the PM peak. In 2015, the AM LOS is forecast to be "A," and the PM, "D."

During a train crossing, no more than three or four automobiles can safely queue in the westbound lane of East Elm Street between the railroad tracks and White Street. This is less than both the 1998 and 2015 predicted maximum queues of 8 and 15 vehicles, respectively. Due to the single-lane approaches, a long train can potentially "lock up" the entire intersection.

A preemptive traffic signal will not help unless additional turn lanes are added to the White Street and westbound East Elm Street approaches. Existing pavement width appears adequate to permit the addition or modification of current lane designations, although some curb radii may need to be increased. Even so, substantial benefits may not be realized due to the large proportion of westbound movements in the peak periods. Traffic patterns may shift, however, upon completion of the Franklin Street extension and the Wake Forest Bypass.

The grades on East Elm Street strongly favor a railroad overpass as the most feasible means of grade separation, should such a step be deemed necessary. Maintaining access to adjoining properties may prove difficult, however.

Recommendations

Near-Term (0-2 years)

CSX to remove abandoned tracks, relocate safety devices closer to active track, and modify approach grades to reduce "hump." Install more durable crossing surface (rubber or concrete).

Long-Term (5-10 years)

Upgrade to four-quadrant automated crossing arms. Median barriers are not recommended due to driveway locations.

Estimated Cost of Recommendations

Remove abandoned tracks and modify approach grades	$9,000
Relocate safety devices closer to active track	$25,000
Install more durable crossing surface (rubber or concrete)	$35,000
Install four-quadrant automated crossing arms	$140,000
TOTAL	$209,000

Impacts of Recommendations

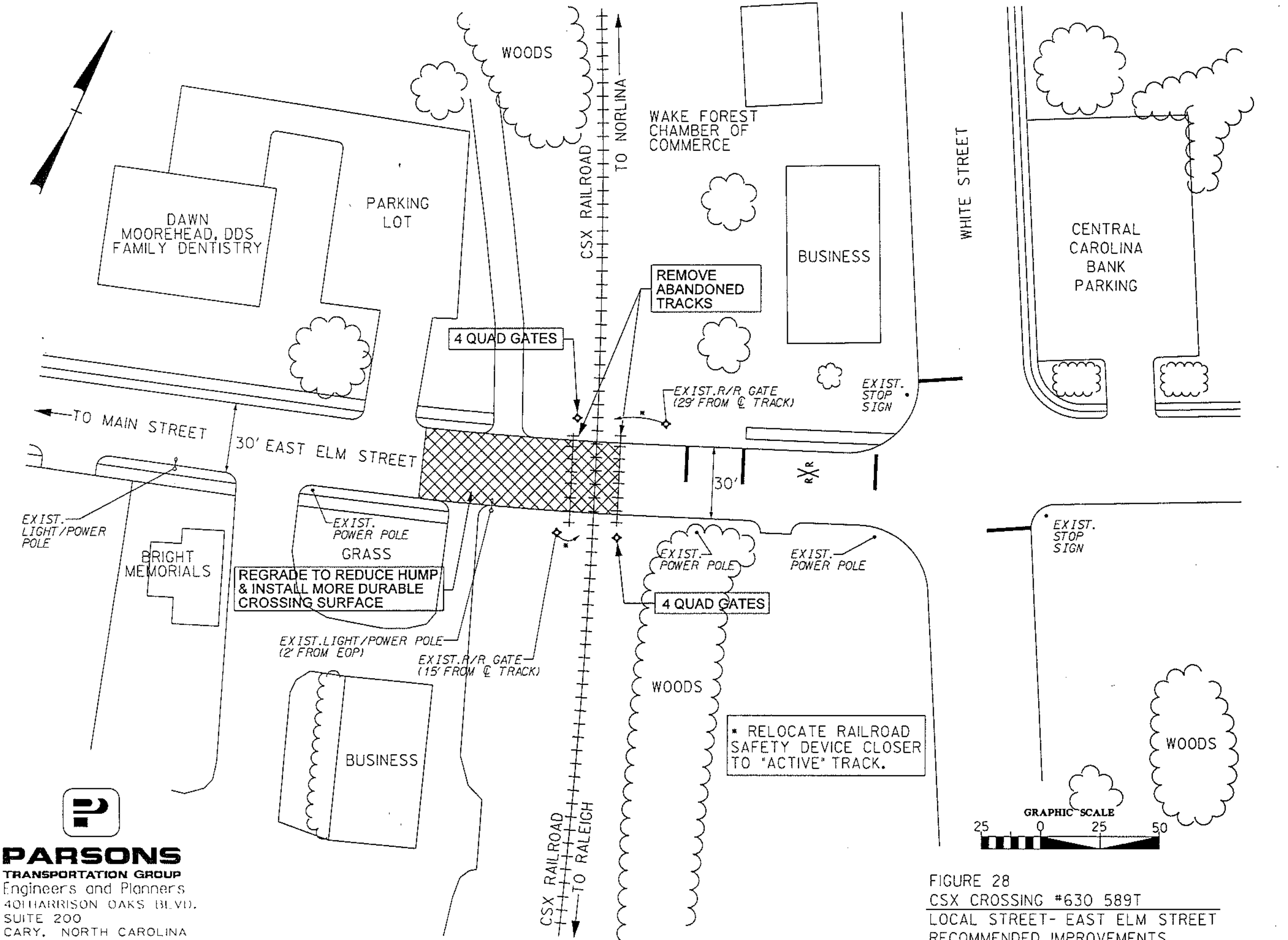
Implementing these recommendations should result in safety benefits.

TABLE 14. East Elm Street Crossing Characteristics

MEASURE	EXISTING	2015	IMPROVED 2015
Exposure Index	22,585	**74,660**	**74,660**
Maximum Queue	8	15	15
Vehicles Delayed / Day	28	104	104
Minutes Delay / Stopped Vehicle	1.0	1.3	1.3
LOS	A	A	A

Figure 26. East Elm Street Crossing – View Looking East

Figure 27. East Elm Street Crossing – View Looking West



PARSONS
TRANSPORTATION GROUP
Engineers and Planners
401 HARRISON OAKS BLVD.
SUITE 200
CARY, NORTH CAROLINA
27513

FIGURE 28
CSX CROSSING #630 589T
LOCAL STREET- EAST ELM STREET
RECOMMENDED IMPROVEMENTS

9. BRICK STREET *CSX RR MILE POST S 0139.53, CROSSING #630 582V*

Brick Street is a narrow local street connecting the northern end of an older, suburban neighborhood with North White Street. Brick Street curves as it crosses the railroad less than 50 feet west of its "T" intersection with North White Street, at the top of a short, steep approach. The current ADT on Brick Street is about 1,320 vehicles per day, with an ADT of about 2,190 vehicles forecast for 2015.

There has been one automobile-train accident at this crossing in the last ten years, resulting in an injury. However, no accidents have occurred since 1998, when cantilevered flashing lights and automated gate arms were installed. The limited distance between the crossing and the "STOP" sign at North White Street could lead to vehicles queuing back onto the tracks, although this was not the cause of the accident. Projected volumes do not appear to warrant a traffic signal. This crossing is not a good candidate for closure, due to economic and accessibility impacts, and geometric constraints make grade separation impractical.

Since North White St. is only two lanes wide, a vehicle waiting to turn onto Brick St. during a long train crossing could block through traffic for an extended period. The addition of turn bays to North White Street (southbound right and northbound left) would provide storage for several vehicles, allowing through traffic to continue unimpeded. This widening would impact residential property along the eastern side of North White Street. This project could be an initial stage in improving North White Street, although such improvements are not currently programmed.

Recommendations

Near-Term (0-2 years)

Modify approach grades to reduce "hump."

Long-Term (5-10 years)

Upgrade to four-quadrant automated crossing arms.

Adding turn lanes to North White Street.

Estimated Cost of Recommendations

Modify approach grades		$8,000
Install four-quadrant automated crossing arms		$140,000
Add turn lanes to North White St.		$180,000
	TOTAL	$328,000

Impacts of Recommendations

Implementing these recommendations should result in safety benefits.

TABLE 15. Brick Street Crossing Characteristics

Measure	Existing	2015	Improved 2015
Exposure Index	6,615	**21,870**	**21,870**
Maximum Queue	2	4	4
Vehicles Delayed / Day	8	30	30
Minutes Delay / Stopped Vehicle	0.9	1.1	1.1
LOS	A	A	A

Figure 29. Brick Street Crossing – View Looking East

Figure 30. Brick Street Crossing – View Looking West

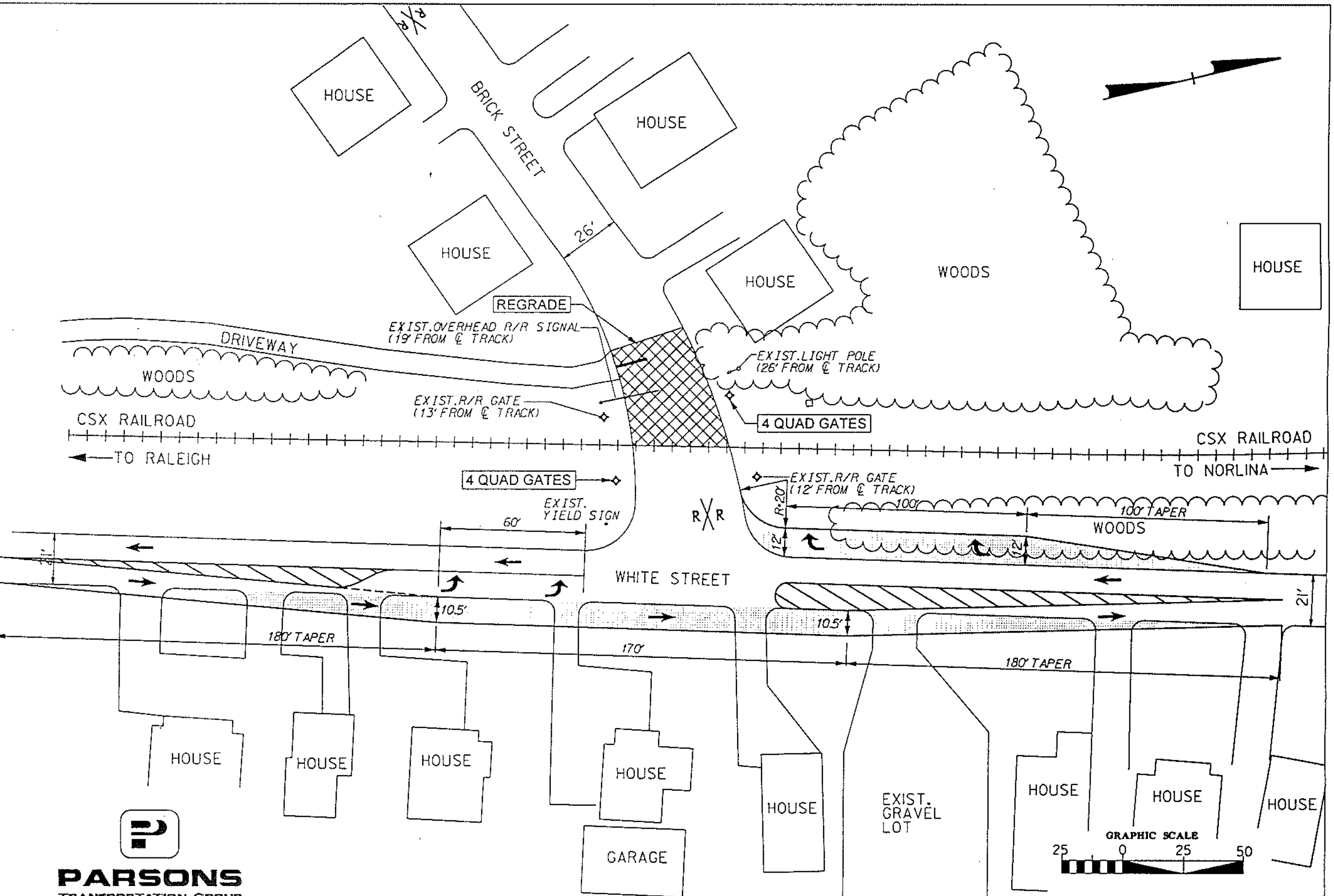


FIGURE 31
CSX CROSSING #630 582V
LOCAL STREET- BRICK STREET
RECOMMENDED IMPROVEMENTS

DELAY ANALYSIS

To quantify changes in traffic delays, several values were calculated for each of the at-grade crossings. The calculations are based on methodology developed for the Proposed Conrail Acquisition Draft Environmental Impact Statement (DEIS)[1]. This methodology was developed by the Surface Transportation Board's Section of Environmental Analysis (SEA). Barton-Aschman Associates modified the formulas as needed for this project.

The following values were calculated for existing and future conditions:

- Blocked crossing time per train.
- Event time.
- Average delay per stopped vehicle.
- Number of vehicles delayed per day.
- Maximum vehicle queue.
- Total stopped vehicle delay per day.
- Average delay for all vehicles.
- Traffic level of service (LOS).

Blocked Crossing Time per Train

This value is the time required for a train to pass by the intersecting roadway. Blocked crossing time is a function of the length and speed of the train. It is used to calculate other values such as the length of time drivers must wait for a train to pass. The formula, developed by the Stanford Research Institute (SRI), is shown below (*1*).

$$T_c = \frac{L}{V \times 88} + 0.50$$

where:

T_c	=	Time required for the train to pass the at-grade crossing. This value, expressed in minutes, includes time required for the signal flashers activate and the gate to close and open (if gates are present).
L	=	Length of the train expressed in feet.
V	=	Train speed in miles per hour
88	=	Factor to convert from miles per hour to feet per minute.
0.50	=	Time in minutes for the signal flashers to activate and the gate to close and open prior to and after the arrival of a train. If gates and/or flashers are not present, this value will not be added.

[1] Surface Transportation Board Section of Environmental Analysis. *Proposed Conrail Acquisition Draft Environmental Impact Statement.* December 1997, Volume 1, Chapter 3, pp. 3-16 to 3-18 and Volume 5A, Appendix C, pp. C-10 to C-16.

Event Time

The event time includes the blockage time and the time required to dissipate the queue formed during the passage of the train. This value, expressed in minutes, is calculated using the following formula from the *Transportation and Traffic Engineering Handbook*[2]:

$$T_e = T_c \times \frac{S_c}{S_c - S_q}$$

where:

T_e	=	Event time expressed in minutes. The event time includes the blockage time plus the time required to dissipate the queue.
T_c	=	Time required for the train to pass the at-grade crossing, expressed in minutes.
S_c	=	Capacity of uninterrupted flow, in vehicles per minute.
S_q	=	Arrival rate of traffic, in vehicles per minute.

Average Delay Per Stopped Vehicle

The average delay per stopped vehicle is the average amount of time a driver waits at an at-grade crossing during the passing of a train. A uniform traffic arrival distribution is assumed.

$$D_{avg} = \frac{T_e}{2}$$

where:

D_{avg}	=	Average time a driver is delayed by a passing train, in minutes/vehicle.
T_e	=	Event time expressed in minutes. The event time includes the blockage time plus the time required to dissipate the queue.
2	=	Factor applied to the total event time. With uniform arrivals, it can be assumed that the average delay for stopped vehicles is one-half the total event time.

Number of Vehicles Delayed Per Day

The number of vehicles delayed per day represents the number of drivers in a 24-hour period that would be stopped by the passing of a train at an at-grade crossing.

$$V_D = \frac{ADT}{1440} \times T_e \times N$$

where:

V_D	=	Number of vehicles delayed per day.
ADT	=	Average daily traffic volume, in vehicles/day.
1440	=	Factor to convert vehicles per hour to vehicles per minute.
T_e	=	Event time expressed in minutes. The event time includes the blockage time plus the time required for the queue to dissipate.
N	=	Number of trains per day.

[2] Institute of Transportation Engineers. *Transportation and Traffic Engineering Handbook*. Second Edition, 1982.

Maximum Vehicle Queue

The maximum vehicle queue is the estimated longest line of autos, trucks, and buses forming during the passage of a train at the peak hour of roadway traffic. Because hourly volume data for crossing traffic were unavailable, peak hour and directional split percentages were assumed. The following equation was used:

$$Q = ADT \times 0.1 \times \frac{0.6}{60} \times \frac{T_c}{NL/2}$$

where:

Q	=	Maximum vehicle queue in peak hour, expressed in number of vehicles.
ADT	=	Average daily traffic volume, in vehicles/day.
0.1	=	Ten percent factor to convert ADT to peak-hour traffic.
0.6	=	Sixty percent factor to convert two-way traffic to peak-direction traffic.
60	=	Factor to convert traffic volume per hour to traffic volume per minute.
T_c	=	Time required for the train to pass the at-grade crossing, expressed in minutes.
NL	=	Number of highway lanes at the highway/rail at-grade crossing as reported by the FRA database (or field investigation or other source).
2	=	Factor to convert total number of roadway lanes to number of lanes in peak direction.

Total Stopped Vehicle Delay Per Day

This value represents the aggregate delay experienced by vehicles stopping for, or delayed by, passing trains over a 24-hour period.

$$D_T = V_D \times D_{avg}$$

where:

D_T	=	Total time drivers are delayed by passing trains over a 24-hour period, expressed in minutes/day.
V_D	=	Number of vehicles delayed per day.
D_{avg}	=	Average time a driver is delayed by a passing train, in minutes/vehicle.

Average Delay for All Vehicles

The average delay for all vehicles is the estimated delay experienced by all drivers that cross a particular at-grade crossing. This value includes both drivers who would and would not be delayed by trains. It is estimated using the following equation:

$$D_v = \frac{D_T}{ADT}$$

Traffic Level of Service

Level of service (LOS) is a measure of the operational efficiency of the at-grade crossing. It is determined using *Highway Capacity Manual*[3] procedures. Level of service is expressed as a letter ranging from A (free flowing) to F (severely congested) and is determined using the average delay for all vehicles. **Table -** summarizes the relationships between average delay and level of service.

Table -. Highway Capacity Manual LOS Thresholds for Average Delay

Level of Service	Average Delay per Vehicle (seconds)
A	≤ 5.0
B	> 5.0 to ≤ 15.0
C	> 15.0 to ≤ 25.0
D	> 25.0 to ≤ 40.0
E	> 40.0 to ≤ 60.0
F	> 60.0

[3] Transportation Research Board. *Highway Capacity Manual: Special Report 209, Third Edition (Updated 1994).*

APPENDIX B

INTERSECTION ANALYSIS

HCS: Unsignalized Intersections   Release 2.1g   WHELM99P.HC0   Page 1

Center For Microcomputers In Transportation
University of Florida
512 Weil Hall
Gainesville, FL   32611-2083
Ph: (904) 392-0378

Streets: (N-S) White Street   (E-W) Elm Street
Major Street Direction.... EW
Length of Time Analyzed... 15 (min)
Analyst.................. Scott Beasley
Date of Analysis.......... 1/14/99
Other Information.........PM Peak
Two-way Stop-controlled Intersection

	Eastbound			Westbound			Northbound			Southbound		
	L	T	R	L	T	R	L	T	R	L	T	R
No. Lanes	0	> 1 <	0	0	> 1 <	0	0	> 1 <	0	0	> 1 <	0
Stop/Yield			N			N						
Volumes	108	194	17	40	126	72	7	84	63	34	52	67
PHF	.95	.95	.95	.95	.95	.95	.95	.95	.95	.95	.95	.95
Grade		0			0			0			0	
MC's (%)	0			0			0	0	0	0	0	0
SU/RV's (%)	0			0			0	0	0	0	0	0
CV's (%)	2			2			2	2	2	2	2	2
PCE's	1.02			1.02			1.02	1.02	1.02	1.02	1.02	1.02

Adjustment Factors

Vehicle Maneuver	Critical Gap (tg)	Follow-up Time (tf)
Left Turn Major Road	5.00	2.10
Right Turn Minor Road	5.50	2.60
Through Traffic Minor Road	6.00	3.30
Left Turn Minor Road	6.50	3.40

Worksheet for TWSC Intersection

Step 1: RT from Minor Street	NB	SB
Conflicting Flows: (vph)	213	171
Potential Capacity: (pcph)	1080	1134
Movement Capacity: (pcph)	1080	1134
Prob. of Queue-Free State:	0.94	0.94

Step 2: LT from Major Street	WB	EB
Conflicting Flows: (vph)	222	209
Potential Capacity: (pcph)	1344	1363
Movement Capacity: (pcph)	1344	1363
Prob. of Queue-Free State:	0.97	0.91
TH Saturation Flow Rate: (pcphpl)	1700	1700
RT Saturation Flow Rate: (pcphpl)	1700	1700
Major LT Shared Lane Prob. of Queue-Free State:	0.96	0.90

Step 3: TH from Minor Street	NB	SB
Conflicting Flows: (vph)	578	549
Potential Capacity: (pcph)	543	562
Capacity Adjustment Factor due to Impeding Movements	0.87	0.87
Movement Capacity: (pcph)	472	488
Prob. of Queue-Free State:	0.81	0.89

Step 4: LT from Minor Street	NB	SB
Conflicting Flows: (vph)	603	617
Potential Capacity: (pcph)	474	465
Major LT, Minor TH Impedance Factor:	0.77	0.70
Adjusted Impedance Factor:	0.82	0.77
Capacity Adjustment Factor due to Impeding Movements	0.77	0.72
Movement Capacity: (pcph)	365	336

Intersection Performance Summary

Movement	Flow Rate (pcph)	Move Cap (pcph)	Shared Cap (pcph)	Avg. Total Delay (sec/veh)	95% Queue Length (veh)	LOS	Approach Delay (sec/veh)
NB L	7	365 >					
NB T	90	472 >	603	8.2	1.2	B	8.2
NB R	67	1080 >					
SB L	37	336 >					
SB T	56	488 >	572	8.8	1.3	B	8.8
SB R	72	1134 >					
EB L	116	1363		2.9	0.2	A	1.0
WB L	43	1344		2.8	0.0	A	0.5

Intersection Delay = 3.5 sec/veh

ısignalized Intersections   Release 2.1g   WHELM99A.HC0   Page 1

LM99A.HC0

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ville, FL   32611-2083
4) 392-0378

s: (N-S) White Street   (E-W) Elm Street
Street Direction.... EW
of Time Analyzed... 15 (min)
t.................... Scott Beasley
f Analysis.......... 1/14/99
nformation.........AM Peak
, Stop-controlled Intersection

	Eastbound L	Eastbound T	Eastbound R	Westbound L	Westbound T	Westbound R	Northbound L	Northbound T	Northbound R	Southbound L	Southbound T	Southbound R
nes	0	> 1	< 0	0	> 1	< 0	0	> 1	< 0	0	> 1	< 0
eld			N			N						
	60	91	13	24	159	25	9	54	37	17	30	50
	.95	.95	.95	.95	.95	.95	.95	.95	.95	.95	.95	.95
		0			0			0			0	
)	0			0			0	0	0	0	0	0
s (%)	0			0			0	0	0	0	0	0
)	2			2			2	2	2	2	2	2
	1.02			1.02			1.02	1.02	1.02	1.02	1.02	1.02

Adjustment Factors

er	Critical Gap (tg)	Follow-up Time (tf)
rn Major Road	5.00	2.10
urn Minor Road	5.50	2.60
Traffic Minor Road	6.00	3.30
rn Minor Road	6.50	3.40

SB

180
122
.122
.95

EB

193
.387
.387
).95
1700
1700

).95

SB

378
691

0.93
645
0.95

SB

419
606

0.85
0.88

0.85
518

Worksheet for TWSC Intersection

Step 1: RT from Minor Street	NB	SB
Conflicting Flows: (vph)	103	180
Potential Capacity: (pcph)	1228	1122
Movement Capacity: (pcph)	1228	1122
Prob. of Queue-Free State:	0.97	0.95

Step 2: LT from Major Street	WB	EB
Conflicting Flows: (vph)	110	193
Potential Capacity: (pcph)	1519	1387
Movement Capacity: (pcph)	1519	1387
Prob. of Queue-Free State:	0.98	0.95
TH Saturation Flow Rate: (pcphpl)	1700	1700
RT Saturation Flow Rate: (pcphpl)	1700	1700
Major LT Shared Lane Prob. of Queue-Free State:	0.98	0.95

Step 3: TH from Minor Street	NB	SB
Conflicting Flows: (vph)	384	378
Potential Capacity: (pcph)	686	691
Capacity Adjustment Factor due to Impeding Movements	0.93	0.93
Movement Capacity: (pcph)	640	645
Prob. of Queue-Free State:	0.91	0.95

Step 4: LT from Minor Street	NB	SB
Conflicting Flows: (vph)	414	419
Potential Capacity: (pcph)	610	606
Major LT, Minor TH Impedance Factor:	0.89	0.85
Adjusted Impedance Factor:	0.91	0.88
Capacity Adjustment Factor due to Impeding Movements	0.87	0.85
Movement Capacity: (pcph)	530	518

Intersection Performance Summary

Movement	Flow Rate (pcph)	Move Cap (pcph)	Shared Cap (pcph)	Avg. Total Delay (sec/veh)	95% Queue Length (veh)	LOS	Approach Delay (sec/veh)
NB L	9	530 >					
NB T	58	640 >	763	5.5	0.5	B	5.5
NB R	40	1228 >					
SB L	18	518 >					
SB T	33	645 >	783	5.3	0.5	B	5.3
SB R	54	1122 >					
EB L	64	1387		2.7	0.0	A	1.0
WB L	25	1519		2.4	0.0	A	0.3

Intersection Delay = 2.3 sec/veh

HCS: Unsignalized Intersections Release 2.1g WHELM15A.HC0 Page 1

Center For Microcomputers In Transportation
University of Florida
512 Weil Hall
Gainesville, FL 32611-2083
Ph: (904) 392-0378

Streets: (N-S) White Street (E-W) Elm Street
Major Street Direction.... EW
Length of Time Analyzed... 15 (min)
Analyst................... Scott Beasley
Date of Analysis.......... 1/14/99
Other Information.........2015 AM Peak
Two-way Stop-controlled Intersection

	Eastbound			Westbound			Northbound			Southbound		
	L	T	R	L	T	R	L	T	R	L	T	R
No. Lanes	0	> 1	< 0	0	> 1	< 0	0	> 1	< 0	0	> 1	< 0
Stop/Yield			N			N						
Volumes	99	150	21	40	263	41	15	89	61	28	50	83
PHF	.95	.95	.95	.95	.95	.95	.95	.95	.95	.95	.95	.95
Grade		0			0			0			0	
MC's (%)	0			0			0	0	0	0	0	0
SU/RV's (%)	0			0			0	0	0	0	0	0
CV's (%)	2			2			2	2	2	2	2	2
PCE's	1.02			1.02			1.02	1.02	1.02	1.02	1.02	1.02

Adjustment Factors

Vehicle Maneuver	Critical Gap (tg)	Follow-up Time (tf)
Left Turn Major Road	5.00	2.10
Right Turn Minor Road	5.50	2.60
Through Traffic Minor Road	6.00	3.30
Left Turn Minor Road	6.50	3.40

Worksheet for TWSC Intersection

Step 1: RT from Minor Street	NB	SB
Conflicting Flows: (vph)	169	298
Potential Capacity: (pcph)	1137	978
Movement Capacity: (pcph)	1137	978
Prob. of Queue-Free State:	0.94	0.91

Step 2: LT from Major Street	WB	EB
Conflicting Flows: (vph)	180	320
Potential Capacity: (pcph)	1407	1207
Movement Capacity: (pcph)	1407	1207
Prob. of Queue-Free State:	0.97	0.91
TH Saturation Flow Rate: (pcphpl)	1700	1700
RT Saturation Flow Rate: (pcphpl)	1700	1700
Major LT Shared Lane Prob. of Queue-Free State:	0.96	0.90

Step 3: TH from Minor Street	NB	SB
Conflicting Flows: (vph)	635	624
Potential Capacity: (pcph)	506	513
Capacity Adjustment Factor due to Impeding Movements	0.87	0.87
Movement Capacity: (pcph)	439	445
Prob. of Queue-Free State:	0.78	0.88

Step 4: LT from Minor Street	NB	SB
Conflicting Flows: (vph)	684	692
Potential Capacity: (pcph)	425	421
Major LT, Minor TH Impedance Factor:	0.76	0.68
Adjusted Impedance Factor:	0.82	0.75
Capacity Adjustment Factor due to Impeding Movements	0.74	0.71
Movement Capacity: (pcph)	316	298

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Streets: (N-S) White Street (E-W) Elm Street
Major Street Direction.... EW
Length of Time Analyzed... 15 (min)
Analyst................... Scott Beasley
Date of Analysis.......... 1/14/99
Other Information.........2015 PM Peak
Two-way Stop-controlled Intersection

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	Eastbound			Westbound			Northbound			Southbound		
	L	T	R	L	T	R	L	T	R	L	T	R
No. Lanes	0	> 1	< 0	0	> 1	< 0	0	> 1	< 0	0	> 1	< 0
Stop/Yield			N			N						
Volumes	179	321	28	66	208	119	12	139	104	56	86	111
PHF	.95	.95	.95	.95	.95	.95	.95	.95	.95	.95	.95	.95
Grade		0			0			0			0	
MC's (%)	0			0								
SU/RV's (%)	0			0			0	0	0	0	0	0
CV's (%)	2			2			0	0	0	0	0	0
PCE's	1.02			1.02			2	2	2	2	2	2
							1.02	1.02	1.02	1.02	1.02	1.02

Adjustment Factors

Vehicle Maneuver	Critical Gap (tg)	Follow-up Time (tf)
Left Turn Major Road	5.00	2.10
Right Turn Minor Road	5.50	2.60
Through Traffic Minor Road	6.00	3.30
Left Turn Minor Road	6.50	3.40

Worksheet for TWSC Intersection

Step 1: RT from Minor Street	NB	SB
Conflicting Flows: (vph)	352	282
Potential Capacity: (pcph)	918	996
Movement Capacity: (pcph)	918	996
Prob. of Queue-Free State:	0.88	0.88

Step 2: LT from Major Street	WB	EB
Conflicting Flows: (vph)	367	344
Potential Capacity: (pcph)	1146	1175
Movement Capacity: (pcph)	1146	1175
Prob. of Queue-Free State:	0.94	0.84
TH Saturation Flow Rate: (pcphpl)	1700	1700
RT Saturation Flow Rate: (pcphpl)	1700	1700
Major LT Shared Lane Prob. of Queue-Free State:	0.92	0.79

Step 3: TH from Minor Street	NB	SB
Conflicting Flows: (vph)	954	906
Potential Capacity: (pcph)	344	365
Capacity Adjustment Factor due to Impeding Movements	0.73	0.73
Movement Capacity: (pcph)	251	267
Prob. of Queue-Free State:	0.41	0.65

Step 4: LT from Minor Street	NB	SB
Conflicting Flows: (vph)	995	1018
Potential Capacity: (pcph)	281	272
Major LT, Minor TH Impedance Factor:	0.48	0.30
Adjusted Impedance Factor:	0.59	0.43
Capacity Adjustment Factor due to Impeding Movements	0.52	0.38
Movement Capacity: (pcph)	145	103