CORRIDOR REPORT

Route 2 Corridor Study

District 3 and District 4

PREPARED FOR

Massachusetts Department of Transportation
10 Park Plaza
Boston, MA 02114

PREPARED BY

260 Arsenal Place
PO Box 9151
Watertown, MA 02471
617.924.1770

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Executive Summary

The Route 2 Corridor Study (the study) evaluates the existing and future transportation conditions along the Route 2 corridor in Districts 3 and 4 in Massachusetts and the effects of/to adjacent municipalities. The study develops and analyzes alternatives that are intended to improve transportation conditions, *with a primary focus on the safety and operations along Route 2*. Alternatives are evaluated in the context of the overall traffic network, with impact on vehicular, bicycle and pedestrian use, land use, and natural resource areas.

The study examined and analyzed mobility under existing conditions and under year 2039 conditions. Near-term and long-term recommendations have been developed using both quantitative information from analyses and qualitative feedback provided by MassDOT. In some cases, MassDOT has been proactive in starting to address identified issues and carry out immediate-term recommendations. The study includes an "Action Plan" for implementation of the near- and long-term study recommendations. All alternatives/recommendations identified and developed herein are conceptual in nature. In some instances, multiple concept alternatives were developed for consideration. All concept alternatives will require further design development, public engagement and more detailed evaluation of potential permitting/right-of-way implications to prioritize and select improvements for actual implementation.

This report is organized into five chapters that generally correspond to the major work tasks. Highlights from each chapter are discussed below.

Study Acknowledgements & Scope

During the initial months of the study, preliminary goals, objectives, and evaluation criteria were developed and refined in conjunction with the Traffic and Safety Section and Districts 3 and 4. The study's *Purpose & Need* was primarily focused on addressing current concerns related to traffic safety as well as operations, delay, and congestion for vehicles, bicycles and pedestrians (see study goals below and in Chapter 1). Due to the scope that was initially identified, this study did not include a significant evaluation of MassDOT's larger transportation issues and goals along this corridor such as mode shift/transit service, sustainability, resiliency and climate change. MassDOT is proactively addressing those items through separate, parallel initiatives outside of this study. To that end, The Route 2 Study:

- did not include evaluation of electrification, E-lanes, climate goals, and resiliency elements;

- did not include detailed transit analyses and related mode shift potential;

- did not evaluate mode shift potential related to bicycle use adjacent to, or on Route 2. The study identified area bike facilities and opportunities for enhanced north-south bicycle movement along the eastern portion of the corridor.

The study scope also had additional limitations in development of alternatives for consideration, including:

- at the time the study was completed as a DRAFT, it did not reflect the pending MCI-Concord closure or any additional future MassDOT related Concord Rotary planning initiatives;

- did not include grade-separated solutions in the eastern study area (east of Concord Rotary);

- No traffic demand modeling was completed to identify potential modifications to traffic demand or patterns associated with the conceptual level improvement alternatives contained in the study. As such, the scope did not include an evaluation of how the implementation of the recommendations could impact the potential for new trips or trips diverted onto Route 2 (outside of planned development or normal background growth).

- did not prioritize projects/locations. The study provides a menu of improvement alternatives for consideration (see Recommended Action Plan below, and in Chapter 5). The Action Plan does indicate projects that have interdependency/reliance with one another;

- did not provide preliminary or final design details. The study developed concept level alternatives only for consideration;

- did not include every interchange/intersection/driveway along Route 2 (or adjacent communities) within the limits of the study area.

It is anticipated that as projects are identified and prioritized for advancement, many of the limitations above would be addressed through required planning/permitting efforts and/or in advancement of preliminary/final design, or as part of separate MassDOT initiatives.

ES.1 Chapter 1: Study Process and Framework

Chapter 1 outlines the study process and background, study area, goals and objectives, and the evaluation criteria developed to test the feasibility of alternatives. The following are the listed goals for the Route 2 Corridor Study:

› Improve traffic flow on highways, ramps, and local streets in the study area;
› Improve safety for all modes of transportation within the study area;
› Enhance mobility while minimizing impacts to the quality of life for area communities and adjacent natural resource areas; and
› Develop recommendations that are feasible and meet MassDOT Criteria.

The study area for the Route 2 Corridor Study includes Route 2 from approximately Oak Hill Road in Fitchburg in the west, to Tracey's Corner (Bedford Road) in Lincoln to the east. The study area encompasses sections of MassDOT District 3 and District 4 and was delineated into an Eastern and Western study areas as depicted in Figure ES-1.

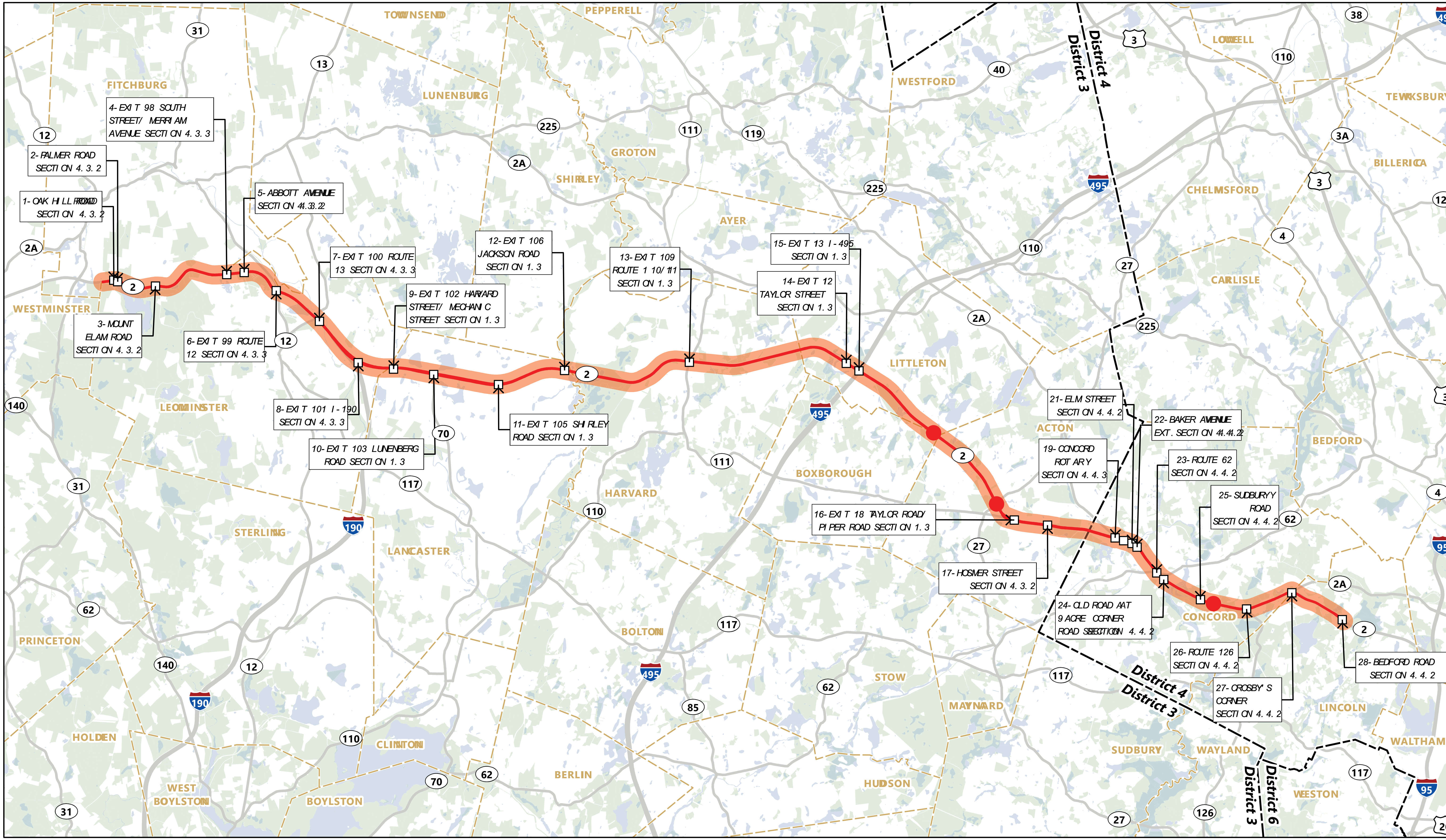
There has been an initial outreach effort that includes informational briefings with legislators, local officials, and the public. From this outreach, comments were provided which have helped to inform the study and next steps. To date there has been an extensive stakeholder outreach and engagement process. The process began with outreach to regional legislators and then expanded to local legislators/municipal officials from adjacent corridor communities. Two additional presentations were conducted that were open to the general public. The outreach program to date included:

- Legislative Briefing – 11/27/2023
- Western Area Municipal Officials Brief– 1/30/2024
- Eastern Area Municipal Officials Brief – 2/1/2024
- Public Information Meetings – 2/13/2024 and 2/20/2024

ES.2 Chapter 2: Existing Conditions

Chapter 2 describes the existing (2019) conditions (pre-pandemic) in the study area, including discussions of demographics, environmental resources, land use and economic development, a safety evaluation, and a summary of the transportation infrastructure and operations within the study area. The following summarize the findings of the Existing Conditions for the corridor:

- Route 2 is a diverse corridor
  - Eastern study area (District 4) is governed by signalized intersections and the Concord Rotary
  - Western study area (District 3) is primarily comprised of limited access interchanges
- Significant bottlenecks are present, including:
  - Tracey’s Corner (Bedford Road);
  - Concord Rotary; and
  - I-190 Interchange.
- Traffic demand exceeds capacity during many hours of the day
- Significant crash experience – many locations exceed statewide averages; HSIP locations include Tracey’s Corner (Bedford Road), Taylor Road & Piper Road, and Baker Avenue Extension & Elm Street.
- Significant and notable sensitive environmental and natural resource areas along length of corridor
- Limited current multi-modal accommodation
- Traffic conditions in 2022 have reflected some level of rebound as compared to pre-pandemic conditions (approximately 10% lower daily volume). Pre-pandemic conditions were used conservatively in this evaluation.



Route 2 Corridor Study

Study Area Location

0 1 2 Miles

Study Area Map
Route 2 Corridor Study

Figure ES-1

ES.3 Chapter 3: Future Conditions (Year 2039)

Chapter 3 assesses the 2039 Future Conditions, including land use forecasts, planned infrastructure improvements, future traffic demand forecasts, and future traffic operations within the study area. Issues, opportunities, and constraints that evolved from a thorough review of data are also discussed. The analysis of existing and future transportation conditions and development of issues, opportunities and constraints in the study area identified areas of the transportation network that require improvements and guided the development of study alternatives. The following summarize the findings of the Future Conditions for the corridor:

› Normal background growth in traffic volumes expected along the corridor
› Site-specific development is heavily focused around Devens
› Outside of this study, other operational and safety improvement projects have been implemented along the corridor

ES.4 Chapter 4: Recommended Improvement Alternatives

Chapter 4 outlines the alternatives developed for the study. A range of transportation improvements (operations and safety) were identified. These alternatives were organized into corridor wide or site-specific categories and defined for near-term (0-10yrs) or long-term (10+ years) implementation. In general, the alternatives were developed in the following categories:

1) Corridor-wide considerations:

› Capacity expansion of Route 2 to 6 lanes (3 per direction) (eastern and western study areas)

2) Western study area:

› Improvement alternatives for the Right-in/right-out locations
› Various Interchange alternatives
  - Weaving/acceleration/deceleration considerations
  - Partial or full reconstruction concepts
  - Peer review of concepts developed by others

3) Eastern study area:

› Signalized improvement alternatives
  - Operational improvements – capacity/signal timing/phasing/lane configurations
  - Pedestrian and bicyclist accommodations
  - Equipment upgrades
› Concord Rotary alternatives
  - Presentation of grade-separated alternatives (by others)
  - Evaluation of at-grade alternatives

The project goals were used as an abbreviated list of criteria against which to measure the alternatives. Any alternative showing merit was retained for consideration and will be subject to a more detailed technical analysis (i.e., advanced design development and permitting) to determine the transportation benefit versus the associated impacts to the environment, economic development in the area, and other factors. The chapter also identifies which alternatives were considered, but dismissed, prior to detailed analysis.

Chapter 4 presents a detailed evaluation of each alternative carried forward for technical analysis.

ES.5 Chapter 5: Implementation Plan

Chapter 5 summarizes the benefits of each recommended alternative and presents an “Action Plan” for the study recommendations. Table ES-1 presents the details of the Action Plan for the recommended improvements, including potential right-of-way and resource area impacts, order of magnitude construction cost estimates, the implementation timeframe, other ancillary features and specific next steps.

Table ES-1 Recommended Action Plan – Alternatives Matrix and Implementation Timeframe

Study Area Map #	Location	Municipality	Alternative	Construction Cost [1]	Implementation Timeframe (Years) Near-Term 0 - 10	Long-Term[2] 10+	Notes	Impacts[3] Environ-mental	ROW	Prioritization/ Sequencing	Figure No.	Diversion potential	Traffic pattern changes
	Western (District 3) Study Area												
	Right-In/Right-Out												
1	Oak Hill Road (N)	Fitchburg	Improve Accel/ Decel lanes	$600,000-$700,000	x						4-1		
2	Palmer Road (S)	Leominster	Improve Decel lane	$300,000-$400,000	x			x			4-1		
5	Abbott Ave (N)	Leominster	Improve Accel/ Decel lanes	$300,000-$400,000	x						4-2		
5	Abbott Ave (S)	Leominster	Close ramp	$300,000-$400,000	x					Dependent on improvements to Route 2 at Merriam Avenue intersection	4-2	x	x
17	Hosmer Street (N)	Acton	Improve Decel lane	$400,000-$500,000	x						4-3		
17	Hosmer Street (S)	Acton	Improve Accel/ Decel lanes	$300,000-$400,000	x						4-3		
18	Wetherbee Street (N)	Acton	Improve Accel/ Decel lanes	$400,000-$500,000	x						4-4		
18	School Street (S)	Acton	Improve Accel/ Decel lanes	$400,000-$500,000	x						4-4		
	District Wide												
	Western (District 3)	Fitchburg to Acton	6-lane Cross-section (~18 miles)	$650,000,000-$750,000,000		x	Multiple Bridge Reconstructions	x	x	Consider resetting bridge supports as useful life of each bridge is met/ exceeded		x	x

Table ES-1 Recommended Action Plan – Alternatives Matrix and Implementation Timeframe

Study Area Map #	*Location*	*Municipality*	*Alternative*	*Construction Cost* [1]	*Implementation Timeframe (Years)* Near-Term 0 - 10	*Implementation Timeframe (Years)* Long-Term[2] 10+	*Notes*	*Impacts*[3] Environ-mental	*Impacts*[3] ROW	*Prioritization/ Sequencing*	*Figure No.*	*Diversion potential*	*Traffic pattern changes*
	Interchange Alternatives												
3	Route 2 at Mt Elam Road	Leominster/ Fitchburg	Increase eastbound / westbound deceleration lanes and westbound acceleration lanes	$6,000,000-$6,500,000	x						4-5		
		Leominster/ Fitchburg	Modifies geometry of Mt Elam Road (north)	$7,000,000-$7,500,000	x						4-6		
		Leominster/ Fitchburg	Shifts Route 2 to the north for a longer eastbound acceleration lane	$9,000,000-$10,000,000		x		x			4-7	x	
		Leominster/ Fitchburg	Close Mt Elam Road (south)	$500,000-$600,000					x		N/A	x	x
4	Route 2 at Merriam Avenue	Leominster/ Fitchburg	Improve Accel/ Decel lanes	$500,000-$600,000	x						4-8		
		Leominster/ Fitchburg	Upgrade eastbound intersection and close Abbott Avenue (south)	$2,000,000-$2,500,000		x				Consider closing Abbott Ave (S) access if improved	4-9	x	x
6	Route 2 at North Main Street (Route 12)	Leominster/ Fitchburg	Close redundant ramps and upgrade intersections	$4,500,000-$5,000,000		x	Bridge replacement / ramp project recently completed				4-10		x
7	Route 2 at Main Street (Route 13)	Leominster	Improve Accel/ Decel lanes	$400,000-$500,000	x						4-11		
		Leominster	Develop full diamond interchange	$55,000,000-$60,000,000		x	Adjacent to State Police barracks. Signal currently being provided at Westbound off-ramp intersection	x	x		4-12	x	x
8	Route 2 at I-190	Leominster	Widen Route 2 bridge over Nashua River and lane reconfiguration between I-190 and Route 13	$80,000,000-$90,000,000		x		x			4-13		
12	Route 2 at Jackson Road	Devens	Close redundant ramps	$1,000,000-$1,500,000	x						4-14		x
		Devens	Dual-lane ramps	$6,500,000-$7,500,000		x		x			N/A		
14/15	Route 2 at I-495 / Taylor Street	Littleton	Collector-Distributor Lanes	$19,500,000-$21,000,000		x	I-495 Bridge over Route 2 recently upgraded				4-15		

Table ES-1 Recommended Action Plan – Alternatives Matrix and Implementation Timeframe

Study Area Map #	Location	Municipality	Alternative	Construction Cost [1]	Implementation Timeframe (Years) Near-Term 0 - 10	Long-Term[2] 10+	Notes	Impacts[3] Environ-mental	ROW	Prioritization/ Sequencing	Figure No.	Diversion potential	Traffic pattern changes
	Eastern (District 4) Study Area												
	District Wide												
	Eastern (District 4)	Concord to Lincoln	6-lane Cross-section (~8 miles)	\$250,000,000-\$300,000,000		x	Multiple Bridge Reconstructions	x	x	Consider resetting bridge supports as useful life of each bridge is met/ exceeded			
	Intersection Alternatives												
22	Route 2 at Baker Avenue/Elm Street	Concord	Remove jughandle and Elm Street to Route 2 westbound access	\$5,000,000-\$5,500,000	x	Identified as Near-Term, however, Environmental requirements could push project into Long-Term		x			4-18		x
		Concord	3rd lane westbound including Concept 1 improvements	\$7,000,000-\$7,500,000	x	Identified as Near-Term, however, Environmental requirements could push project into Long-Term		x			4-19		x
23	Route 2 at Main Street (Route 62)	Concord	3rd lane eastbound, pedestrian & bicycle enhancements	\$3,000,000-\$3,500,000	x	Identified as Near-Term, however, ROW requirements could push project into Long-Term			x		4-20		
		Concord	Dual left-turn westbound	\$4,000,000-\$4,500,000	x					Improvements at Rotary might deem this improvement unnecessary	4-21		x
		Concord	3rd lane westbound	\$3,000,000-\$3,500,000	x	Identified as Near-Term, however, ROW/ Environmental requirements could push project into Long-Term		x	x		4-22		

Table ES-1 Recommended Action Plan – Alternatives Matrix and Implementation Timeframe

Study Area Map #	Location	Municipality	Alternative	Construction Cost [1]	Implementation Timeframe (Years) Near-Term 0 - 10	Long-Term[2] 10+	Notes	Impacts[3] Environ-mental	ROW	Prioritization/ Sequencing	Figure No.	Diversion potential	Traffic pattern changes
24	Route 2 at Old Road to 9 Acre Corner Road	Concord	3rd lane eastbound, pedestrian & bicycle enhancements	$3,000,000-$3,500,000	x	Identified as Near-Term, however, ROW requirements could push project into Long-Term			x		4-23		
		Concord	3rd lane westbound	$3,500,000-$4,000,000	x	Identified as Near-Term, however, ROW requirements could push project into Long-Term			x		4-24		
25	Route 2 at Sudbury Road	Concord	3rd lane both directions, pedestrian and bicycle enhancements	$4,500,000-$5,000,000	x						4-25		
		Concord	3rd lane eastbound, dual left-turn westbound	$5,000,000-$5,500,000	x						4-26		x
26	Route 2 at Walden Street (Route 126)	Concord	3rd lane eastbound, pedestrian & bicycle enhancements	$6,000,000-$6,500,000	x						4-27		
		Concord	3rd lane eastbound (no eastbound left-turn)	$6,000,000-$6,500,000	x						4-28	x	x
		Concord	3rd lane eastbound, dual left-turn southbound	$6,500,000-$7,000,000	x						N/A		
28	Route 2 at Bedford Road	Lincoln	Extend and formalize 3rd lane both directions	$2,000,000-$2,500,000	x			x			4-29		
		Lincoln	3rd lane both directions, dual left-turn southbound	$3,000,000-$3,500,000	x			x			N/A		

Table ES-1 Recommended Action Plan – Alternatives Matrix and Implementation Timeframe

Study Area Map #	Location	Municipality	Alternative	Construction Cost [1]	Implementation Timeframe (Years)		Notes	Impacts[3]		Prioritization/ Sequencing	Figure No.	Diversion potential	Traffic pattern changes
					Near-Term 0 - 10	Long-Term[2] 10+		Environ-mental	ROW				
	Rotary Alternatives												
19	Concord Rotary	Concord	Grade-Separated Alternatives	$100,000,000		x	Concept done by others. [4] Major traffic impacts during construction	x	x	Rotary improvements should precede any other location improvements for Eastern (District 4) Study Area	4-30 and 4-31		x
		Concord	Thru-About	$7,000,000-$8,000,000	x			x			4-32		x
		Concord	Signal Option A	$14,500,000-$16,500,000	x			x	x		4-33		x
		Concord	Signal Option B	$15,500,000-$18,000,000	x			x	x		4-34		x
		Concord	Signal Option C with Jughandle	$16,000,000-$18,500,000	x			x	x		4-35		x
		Concord	One-way Coupling	$16,000,000-$18,500,000		x		x	x		4-36		x
		Concord	Continuous Flow Intersection	$16,000,000-$18,500,000		x		x	x		4-37		x

1 Does not include costs associated with right of way, design, construction services, permitting. All based on current available cost information. No escalation for long-term implementations
2 Any alternative indicated as Near-Term with ROW/Environmental impacts could extend beyond 10 yrs (i.e., Long-Term project)
3 Impacts noted are from a high-level review of publicly available GIS data. An in-depth review is expected during further design development.
4 Concord Rotary Grade-Separated alternatives were done by others. Construction costs are from ProjectInfo website.

1

Study Process and Framework

The Route 2 Corridor Study was sponsored by the Massachusetts Department of Transportation (MassDOT). It represents a comprehensive effort to study the transportation network and conditions along the Route 2 corridor in both Districts 3 and 4. The project limits are presented in Figure 1-1 and extended along Route 2, from Oak Hill Road in Fitchburg in the west, to Tracey's Corner (Bedford Road) in Lincoln to the east.

1.1 Introduction

This study evaluates the existing and projected future traffic operations, safety and geometric conditions within the project limits and provides recommendations for short and long-term improvements along the corridor. The study examined and analyzed mobility conditions under existing (2019) conditions and under future year 2039 conditions. Short-term (0-10yrs) and long-term (>10yrs) mobility recommendations have been developed based on qualitative and quantitative information and analyses.

Over the course of the study, there was coordination with MassDOT-Highway Division's Traffic & Safety section, as well as representatives from Districts 3 and 4. The study commenced in 2019 prior to the COVID-19 pandemic. All data and analyses included herein are based on pre-pandemic conditions. The pandemic also limited planned stakeholder engagement proposed in development of alternatives during 2020-2021. Robust and transparent engagement will be included in subsequent advancement of improvement alternatives to be considered for implementation.

This report documents all phases of the work efforts for this study and is organized as follows:

› Chapter 1 – Study Process and Framework
› Chapter 2 – Existing Conditions
› Chapter 3 – Future Conditions (Year 2039)
› Chapter 4 – Recommended Improvement Alternatives
› Chapter 5 – Implementation Plan

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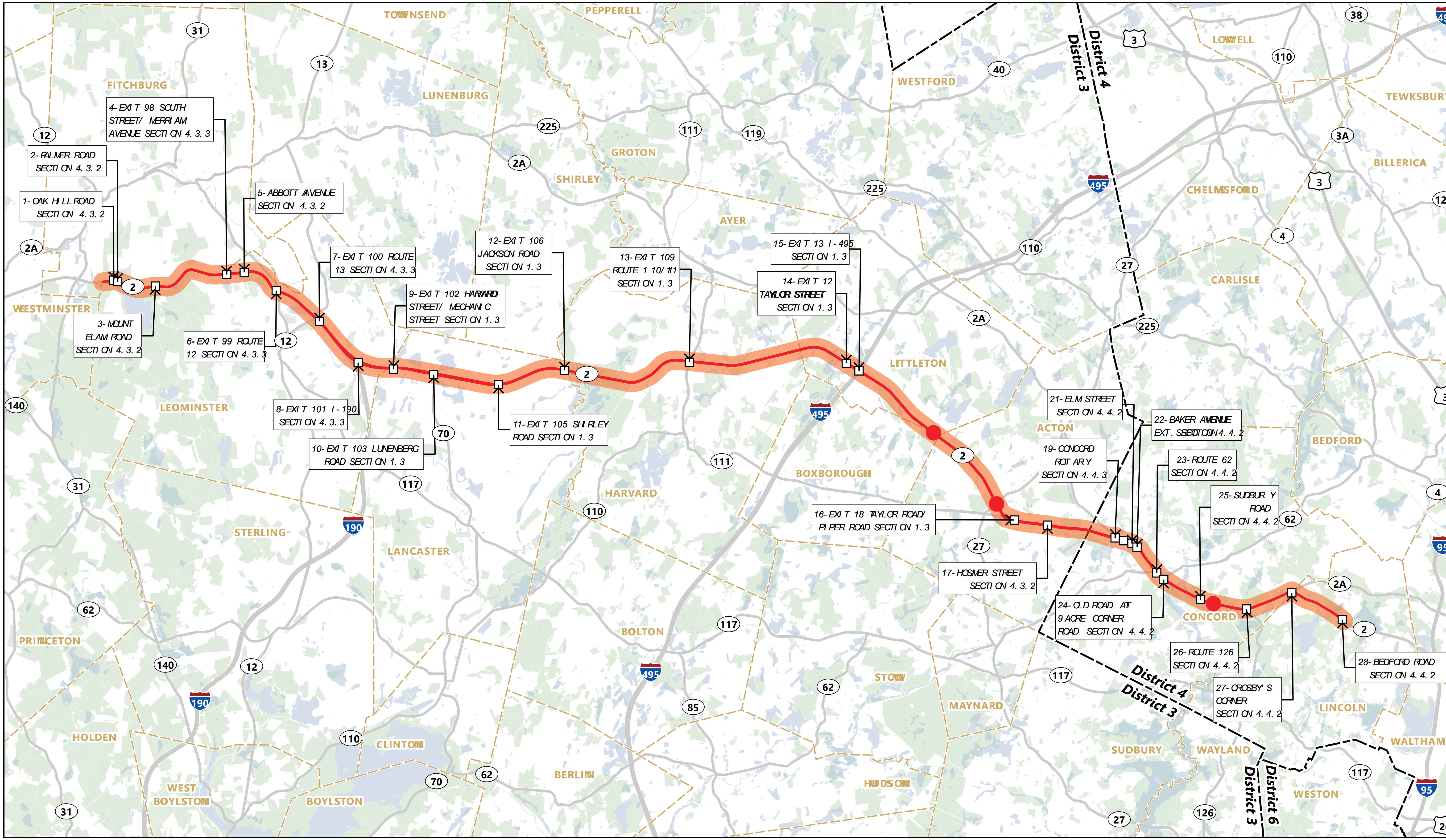


Route 2 Corridor Study

Study Area Location

0 1 2 Miles

Study Area Map
Route 2 Corridor Study

Figure 1-1

1.1.1 Study Purpose and Need

During the initial months of the study, preliminary goals, objectives, and evaluation criteria were developed and refined in conjunction with the Traffic and Safety Section and Districts 3 and 4. The Project Goals and Objectives define the general intent and purpose for conducting the study based on the issues, as well as the intended outcomes related to implementation of improvement alternatives. Evaluation criteria were established as the metric for success and were used to measure how well qualitatively and quantitatively each alternative meets the stated goal and associated objectives.

Through coordination with MassDOT, the following goals for the study were developed:

- Improve traffic flow on roadways, ramps, and local streets within the study area.
- Improve safety for all modes of transportation within the study area.
- Enhance mobility while minimizing impacts to the quality of life for area communities and adjacent natural resource areas.
- Develop recommendations that are feasible and meet MassDOT criteria.

It should be noted that the goal of this study did not focus on the conversion of Route 2 into a 6-lane freeway, but instead, provides localized recommendations to address safety and congestions concerns throughout the corridor. In addition, by focusing on short-term proposed recommendations throughout the study area, this helps to avoid extensive construction activities, costly right-of-way takings, and lengthy environmental processes that typical longer-term recommendations would entail. A high-level evaluation of the potential benefits and impacts related to conversion of route 2 to a 6-lane freeway, while not the focus, was provided as part of the study. In addition, this study did not look to encourage new or divert traffic to Route 2 (outside of that anticipated as part of planned development or normal background growth along the corridor), but rather, to address existing traffic demand and reduce diversions to local roadways. No traffic demand modeling was completed to identify potential modifications to traffic demand or patterns associated with the conceptual level improvement alternatives contained in the study.

Table 1-1 summarizes the Goals, Objectives and Evaluation Criteria established for the study.

Table 1-1 Study Specific Goals, Objectives, and Evaluation Criteria

Goal/Objective	Evaluation Criteria
GOAL: Improve Traffic Flow on highways, ramps, and local streets in the study area	
Decrease congestion and reduce delays	Average speeds
	Queue lengths at key intersections
	Level of service (LOS) at key intersections and links
Improve system reliability	Number of lane changes
	Flow rate
	Duration and extent of congestion
Minimize local street impacts and relieve impacts of cut through traffic	Changes in forecast traffic volumes on key local streets
GOAL: Improve safety for all modes of transportation within the study area.	
Eliminate/improve locations and situations that pose hazards	Evaluate existing intersection/interchange geometry vs. current design standards
	Focus on hot spots from crash records – changes in contributing factors to safety hazards
Ensure that the transportation infrastructure meets current safe design standards	Number of deviations from AASHTO and MassDOT guidelines
GOAL: Enhance Mobility while minimizing impacts to the quality of life for area communities and adjacent natural resource areas.	
Relieve impacts of cut through traffic on neighborhoods and business districts	Qualitative indirect effects of property values
	Qualitative indirect effects of revenue & jobs
Minimize residential and business property takings	Number of full and partial takings
Protect wetlands and water bodies	Number of wetlands affected and square feet of encroachment
Protect wildlife habitats, particularly habitats that support threatened or endangered species	Number of habitats affected and square feet of encroachment
Protect historic/archeological resources	Positive or negative impact to historical/archeological resources
If impacts cannot be avoided, minimize them to the greatest extent possible	Mitigation measures for selected alternative(s)
GOAL: Develop recommendations that are feasible and meet MassDOT Criteria.	
Minimize construction impacts (to traffic flow, the surrounding quality of life and natural environment)	Description, severity, and duration of construction impacts and measures to mitigate
Identify solutions that are cost-effective in the context of state transportation planning	Conceptual cost estimates
Identify solutions that meet the MassDOT Design Manual Criteria	Number of deviations from AASHTO and MassDOT guidelines
Identify solutions that meet criteria for federal funding	Number of deviations from AASHTO and MassDOT guidelines
Identify solutions that include both short-term and long-term actions to improve traffic flow and safety	Improved level of service, and queuing (minimizing/avoiding queue backups on the mainline)
Identify opportunities for bicycle and pedestrian access across Route 2 in the Eastern study area	Improved pedestrian and bicycle access

1.2 Study Area

The first step in the study framework development involved defining the study area. The project limits are presented in Figure 1-1 and extended along Route 2, from Oak Hill Road in Fitchburg in the west, to Tracey's Corner (Bedford Road) in Lincoln to the east.

The study area boundary was finalized with input from MassDOT. The nine municipalities within the study area include Fitchburg, Leominster, Lancaster, Devens[1], Harvard, Littleton, Acton, Concord, and Lincoln. The study includes 21 "full study" locations, 7 "review study" locations and 2 Road Safety Audit Locations. The specific study locations and scope is summarized in Table 1-2.

The Route 2 study area includes mainline sections, signalized intersections, the Concord Rotary, and interchange locations (including the ramps and the intersecting surface roadways). For organizational purposes and due to the differing characteristics of Route 2, discussions in this report include an eastern (District 4) study area and a western (District 3) study area. The western (District 3) study area includes all of the District 3 locations along Route 2 from Oak Hill Road in Fitchburg to School/Wetherbee Street in Acton. The eastern (District 4) study area includes all of the District 4 locations along Route 2 from the Concord Rotary to Tracey's Corner (Bedford Road)

1.3 Peer Reviews

There were 7 study area locations for which previous studies/concept designs were completed by others. These studies/ concept designs were peer reviewed as part of this study to identify any recommended modifications or additional enhancements that could be considered as those project advance, with an emphasis on interchange/intersection geometrics. The following locations were peer reviewed as part of this effort:

- **Interchange 34 (Exit 102):** Route 2 North Harvard Street and Mechanic Street (including potential ramp consolidation)
- **Interchange 35 (Exit 103):** Lunenburg Road (Route 70) (including potential ramp consolidation)
- **Interchange 36 (Exit 105):** Route 2 at Shirley Road (including potential ramp consolidation)
- **Interchange 38 (Exit 109):** Route 2 at Ayer Road
- **Interchange 39 (Exit 112):** Route 2 at Taylor Street[2]
- **Interchange 40 (Exit 113):** Route 2 at Interstate 495[2]
- **Interchange 43 (Exit 118):** Route 2/ Route 111/ Taylor Road and Piper Road

Where appropriate, memorandums were prepared documenting the results of the peer review and were provided to MassDOT and are included in the appendix. Some additional details related to improvement alternatives at Route 2 and I-495 are provided herein.

1 Devens is a regional enterprise zone and census-designated place in the towns of Ayer, Shirley, and Harvard.

2 The Taylor Street and I-495 interchanges were recently reconstructed. As such, the scope for these locations were limited.

Table 1-2 Study Area Locations and Scope

Intersection No.	Study Location	City/Town	Study Type
District 3 Locations			
1	Route 2 at Oak Hill Road	Fitchburg	Full Study
2	Route 2 at Palmer Road	Fitchburg	Full Study
3	Route 2 at Mt Elam Road	Fitchburg	Full Study
4	Interchange 30: Route 2 at Merriam Avenue and South Street – Exit 98	Fitchburg / Leominster	Full Study
5	Route 2 at Abbott Avenue	Leominster	Full Study
6	Interchange 31: Route 2 at N. Main Street (Route 12) – Exit 99	Leominster	Full Study
7	Interchange 32: Route 2 at Main Street (Route 13) – includes merge/diverge with IC 33 – Exit 100	Leominster	Full Study
8	Interchange 33: Route 2 at Interstate 190 (including westbound weave with IC 32) – Exit 101	Leominster	Full Study
9	Interchange 34: Route 2 at North Harvard Street and Mechanic Street (including potential ramp consolidation) – Exit 102	Lancaster	Review Study
10	Interchange 35: Lunenburg Road (Route 70) (including potential ramp consolidation) – Exit 103	Lancaster	Review Study
11	Interchange 36: Route 2 at Shirley Road (including potential ramp consolidation) – Exit 105	Lancaster	Review Study
12	Interchange 37: Route 2 at Jackson Road – focus on merge onto Route 2 WB from Jackson Road) – Exit 106	Lancaster/ Devens/ Harvard	Full Study
13	Interchange 38: Route 2 at Ayer Road – Exit 109	Harvard	Review Study
14	Interchange 39: Route 2 at Taylor Street – Exit 112	Littleton	Review Study
15	Interchange 40: Route 2 at Interstate 495 – Exit 113	Littleton	Review Study
16	Interchange 43: Route 2/ Route 111/ Taylor Road and Piper Road – Exit 118	Acton	Review Study
17	Route 2 at Hosmer Street	Acton	Full Study
18	Route 2 at School Street and Wetherbee Street	Acton	Full Study
District 4 Locations			
19	Route 2 at Concord Rotary	Concord	Full Study
20	Route 2 at (State Police) Emergency Signal	Concord	Full Study
21	Route 2 at Elm Street	Concord	Full Study
22	Route 2 at Baker Avenue Extension	Concord	Full Study/ RSA
23	Route 2 at Main Street (Route 62)	Concord	Full Study
24	Route 2 at Old Road to 9 Acre Corner Road	Concord	Full Study
25	Route 2 at Sudbury Road	Concord	Full Study
26	Route 2 at Walden Street (Route 126)	Concord	Full Study
27	Interchange 50: Cambridge Turnpike (Crosby's Corner) – Exit 125	Concord/ Lincoln	Full Study
28	Route 2 at Bedford Road (Tracey's Corner)	Lincoln	Full Study/ RSA

1.4 Outreach

To date there has been an extensive stakeholder outreach and engagement process. The process began with outreach to regional legislators and then expanded to local legislators/municipal officials from adjacent corridor communities. Two additional presentations were conducted that were open to the general public. The outreach program to date included:

- Legislative Briefing – 11/27/2023
- Western Area Municipal Officials Brief– 1/30/2024
- Eastern Area Municipal Officials Brief – 2/1/2024
- Public Information Meetings – 2/13/2024 and 2/20/2024

2

Existing Conditions

This chapter describes the existing conditions within the study area. Various sections of this chapter present traffic volumes and operations, pedestrian and bicycle accommodations, environmental resources, land use, transit services, safety, travel patterns, and a summary of the current transportation infrastructure deficiencies and needs.

The primary purpose of this study is to identify transportation issues along the Route 2 corridor and to recommend improvement alternatives. This chapter documents many of the current design, safety and operational deficiencies for the corridor and presents the framework for assessing expected future conditions with and without improvements addressing these deficiencies.

2.1 Roadway and Intersection Description

This section summarizes the roadway characteristics of each study area location. Descriptions of the study area roadways and intersections are provided below, including descriptions of the existing lane configurations and traffic control at the study locations.

2.1.1 Western Study Area

Route 2, in the western study area, is primarily a limited access highway (no pedestrians, bicyclists, or horses) that provides two primary types of access control with right-in/right-out access and grade-separated interchange access. Encompassing the western study area, there is one signalized location (Mt. Elam Road). From Oak Hill Road/Palmer Road to I-495, eastbound and westbound are typically separated by a concrete median barrier. East of I-495, Route 2 is separated by a variable width grass median.

The posted speed limit for the majority of Route 2 is 55 mph. There are lower posted speed limits near the interchange of Route 12 (50 mph), near Mt Elam Road (45 mph), and between Route 27 and the Concord Rotary (45 mph).

1. & 2. Route 2 at Oak Hill Road/Palmer Road (Fitchburg)

Oak Hill Road is serviced by Route 2 westbound with right-in/right-out access. The Oak Hill Road approach is stop-controlled. Acceleration and deceleration ramps are provided for Oak Hill Road access.

Palmer Road is serviced by Route 2 eastbound with right-in/right-out access. The Palmer Road approach is stop-controlled. A deceleration ramp is provided for Palmer Road access; however, an acceleration ramp is not provided due to the Notown Reservoir located southeast of the intersection.

3. Route 2 at Mt. Elam Road (Fitchburg)

Mt. Elam Road south of Route 2 is accessed by an eastbound Route 2 off-ramp. The Mt. Elam Road northbound approach is controlled by a signal. The eastbound acceleration area is limited by the Goodfellow Pond located southeast of the intersection.

Mt. Elam Road north of Route 2 is accessed by a westbound Route 2 off-ramp. The Mt. Elam Road southbound approach is stop-controlled. The intersection also provides an intersection control beacon, yellow-flash for Route 2 and red-flash for Mt. Elam Road. Approximately 100 feet north of the Route 2 westbound intersection is a four-legged unsignalized intersection, with stop-control for both the eastbound and westbound approaches.

4. Route 2 at Interchange 30 (Exit 98) – Merriam Avenue/South Street (Fitchburg/Leominster)

Interchange 30 is a partial cloverleaf service interchange that provides access to Merriam Avenue south of Route 2 and access to South Street north or Route 2. Deceleration and acceleration ramps are provided for both directions. The eastbound acceleration ramp extends into an auxiliary lane with Abbott Avenue. The ramp termini at South Street and Merriam Avenue are both stop-controlled.

5. Route 2 at Abbott Avenue (Leominster)

Abbott Avenue south is serviced by Route 2 eastbound with right-in/right-out access. The Abbott Avenue northbound approach is stop-controlled. The eastbound off-ramp is an auxiliary lane with the eastbound on-ramp from Interchange 30.

Abbott Avenue north is serviced by Route 2 westbound with right-in/right-out access. The Abbott Avenue southbound approach is stop-controlled.

6. Route 2 at Interchange 31 (Exit 99) – North Main Street (Route 12) (Leominster)

Interchange 31 is a partial cloverleaf service interchange that provides access to North Main Street (Route 12) from both sides of Route 2. This location was recently (within the last ten years) reconstructed from a full cloverleaf design.

A single off-ramp and two on-ramps are provided for the eastbound direction, while two off-ramps and a single on-ramp is provided for the westbound direction. The ramp termini for North Main Street (Route 12) in both eastbound and westbound ramps are signalized.

7. Route 2 at Interchange 32 (Exit 100) – Main Street (Route 13) (Leominser)

Interchange 32 is a service interchange that provides access to Main Street (Route 13) via Commercial Road/Haws Street for the eastbound direction, and via Mead Street for the westbound direction. Each direction provides a single off-ramp and on-ramp. The westbound ramp system has private driveway access along Mead Street.

The Route 2 eastbound ramps at Haws Street is signalized. The Route 2 westbound ramp is under stop control at Main Street (Route 13), however, there is currently an intersection project for Mead Street at Main Street (Route 13) that is expected to signalize the intersection.

8. Route 2 at Interchange 33 (Exit 101) – Interstate 190 (Leominster)

Interchange 33 is a system interchange that provides access to Interstate 190. The eastbound direction provides a dual-lane ramp to I-190. The westbound provides a single lane ramp from I-190 on the left side of Route 2.

12. Route 2 at Interchange 37 (Exit 102) – Jackson Road (Lancaster/Devens/Harvard)

Interchange 37 is a partial cloverleaf service interchange that provides access to Jackson Road both sides of Route 2. A single off-ramp and on-ramp are provided for the eastbound direction, while two off-ramps and two on-ramps are provided for the westbound direction. This location was previously a full cloverleaf, but the southeast ramps were removed. The ramp termini for both directions are unsignalized.

14/15. Interchange 39 & Interchange 40 (Exit 112 & Exit 113) – Taylor Street and Interstate 495 (Littleton)

Interchange 39 is a partial cloverleaf service interchange that provides access to Taylor Street on both sides of Route 2. A single off-ramp and on-ramp are provided for both directions. The ramp termini for both directions are unsignalized.

Interchange 40 is a full cloverleaf system interchange that provides access to Interstate 495. Two on-ramps and two off-ramps are provided for both directions. There are weaving segments between the connections the I-495 ramps as well as between the I-495 southbound ramps and the Taylor Street ramps.

17. Hosmer Street (Acton)

Hosmer Street south is serviced by Route 2 eastbound with right-in/right-out access. The Hosmer Street northbound approach is stop-controlled. Acceleration and deceleration ramps are provided for Route 2 eastbound.

Hosmer Street north is serviced by Route 2 westbound with right-in/right-out access. The Hosmer Street southbound approach is stop-controlled. Acceleration and deceleration ramps are not provided for Route 2 westbound.

18. School Street/Wetherbee Street (Acton)

School Street south is serviced by Route 2 eastbound with right-in/right-out access. The School Street approach is stop-controlled. Acceleration and deceleration ramps are not provided for Route 2 eastbound.

Wetherbee Street is serviced by Route 2 westbound with a right-in/right-out access. The Wetherbee Street approach is stop-controlled. Acceleration and deceleration ramps are not provided for Route 2 westbound.

2.1.2 Eastern Study Area

Route 2, in the eastern study area, is a limited access highway that typically provides access with signalized intersections. The posted speed limit for the majority of Route 2 is 45 mph, however, some areas have different posted speed limits with: 25 mph near Concord Rotary, 40 mph near Elm Street and Baker Avenue Ext, and 55 near Crosby's Corner. From Elm Street to Bedford Road, eastbound and westbound are typically separated by a concrete median barrier.

19. Route 2 at Concord Rotary (Concord)

The Concord Rotary is a two-lane rotary that provides access for Route 2 eastbound and westbound, Commonwealth Avenue to the south, Barretts Mill Road to the northeast, and Elm Street (Route 2A/119) to the northwest.

Over the course of this study, geometric modifications were completed at the rotary. The improvements included: improved delineation and wayfinding, geometric improvements to the Commonwealth Avenue exit and limiting circulating lanes to a single lane between the Route 2 exits and entrances.

21/22. Route 2 at Baker Avenue Extension at Elm Street (Concord)

Route 2 eastbound provides an exclusive left-turn lane, two through lanes and a short, channelized right-turn lane. Route 2 westbound provides two through lanes, and a channelized right-turn lane that leads to an atypical "jughandle" type movement at Elm Street, which facilitates a southbound movement.

Baker Avenue Extension northbound provides an exclusive left-turn lane, a through lane, and an exclusive right-turn lane. Baker Avenue Extension southbound provides an exclusive left-turn lane and a through lane. Elm Street westbound merges with Route 2 approximately 700 feet west of the Route 2 and Baker Avenue extension intersection.

The signal has a 3-phase operation with a protected Route 2 eastbound left-turn phase, a Route 2 eastbound-westbound through phase, and a permissive Baker Ave Extension and Elm Street northbound-southbound phase. Pedestrian and bicyclist accommodations are not provided at the intersection.

23. Route 2 at Main Street (Route 62) (Concord)

Route 2 eastbound provides two through lanes and a channelized right-turn lane. Route 2 westbound provides an exclusive left-turn lane, two through lanes, and a channelized right-turn lane. Main Street northbound provides a general-purpose lane with the right-turn channelized at the intersection. Main Street southbound provides a general-purpose lane.

The signal has a 3-phase operation with a protected Route 2 westbound left-turn phase, a Route 2 eastbound-westbound through phase, and a permissive Main Street northbound-southbound phase. A crosswalk is provided across the Route 2 western leg of the intersection with concurrent phasing and sidewalks extended along the western side of Main Street with pedestrian priority installed across Route 2. Bicyclist accommodations are not provided at the intersection.

24. Route 2 at Old Road to 9 Acre Corner (Concord)

Route 2 eastbound provides and exclusive left-turn lane, two through lanes and an exclusive right-turn lane. Route 2 westbound provides an exclusive left-turn lane, two through lanes and an exclusive right-turn lane. Old Road to 9 Acre Corner Road northbound provides an exclusive left-turn lane, a through lane, and an exclusive right-turn lane. Old Road to 9 Acre Corner Road southbound provides an exclusive left-turn lane, and a shared through/right-turn lane.

The signal operates with protected Route 2 eastbound-westbound left-turn phases (and northbound right-turn overlap), a Route 2 eastbound-westbound through phases, and a permissive Old Road to 9 Acre Corner northbound-southbound phase.

Crosswalks are provided across the Route 2 eastern leg of the intersection and across the Old Road to 9 Acre Corner southern leg of the intersection, both with concurrent phasing with pedestrian priority installed across Route 2. Sidewalks extend along the eastern side of Old Road to 9 Acre Corner Road and along the western side of Old Road to 9 Acre Corner Road between Route 2 and Old Marlboro Road. Bicyclist accommodations are not provided at the intersection.

25. Route 2 at Sudbury Road (Concord)

Route 2 eastbound provides and exclusive left-turn lane, two through lanes and an exclusive right-turn lane. Route 2 westbound provides an exclusive left-turn lane, two through lanes and an exclusive right-turn lane. Sudbury Road northbound provides a shared left/through lane and a short undefined exclusive right-turn lane. Sudbury Road southbound provides a general purpose-lane.

The signal operates with protected Route 2 eastbound-westbound left-turn phases (and northbound right-turn overlap), a Route 2 eastbound-westbound through phases, and a permissive Sudbury Road northbound-southbound phase.

Crosswalks are provided across the southern and western legs of the intersection with concurrent phasing and sidewalks extend along the western side of Sudbury Road. Bicyclist accommodations are not provided at the intersection.

26. Route 2 at Walden Street (Route 126) (Concord)

Route 2 eastbound provides and exclusive left-turn lane, two through lanes and an exclusive right-turn lane. Route 2 westbound provides an exclusive left-turn lane, two through lanes and an exclusive right-turn lane. Both Walden Street northbound and southbound provide exclusive left-turn lanes, through lanes, and channelized right-turn lanes.

The signal operates with protected Route 2 eastbound-westbound left-turn phases (and northbound right-turn overlap), a Route 2 eastbound-westbound through phases, and a split-phase for the Walden Street northbound and southbound movements.

A crosswalk is provided across the western leg of the intersection with concurrent phasing with pedestrian priority installed across Route 2. Sidewalks extend along the western side of Walden Street but terminate shortly after the intersection. Bicyclist accommodations are not provided at the intersection.

28. Route 2 at Bedford Road (Tracey's Corner) (Lincoln)

Route 2 eastbound and westbound provide two through lanes and shared through/right-turn lanes, with at-grade cloverleaf loops. Both Bedford Road (Tracey's Corner) northbound and southbound provide general-purpose lanes with channelized right-turns, however from observations the general-purpose lanes can at times operate as two lanes with an exclusive left-turn lane and through lane.

The signal operates with a Route 2 eastbound-westbound through phase, an exclusive pedestrian phase, a lead Bedford Road southbound left-turn/through phase and a permissive Bedford Road northbound-southbound phase.

A crosswalk is provided across the eastern leg of the intersection. Beyond the intersection sidewalk is provided along the western side of Bedford Road, however at the intersection the sidewalk is provided along the eastern side of Bedford Road. Bicyclist accommodations are not provided at the intersection.

2.2 Existing Traffic Volumes

This section quantifies the traffic volumes on the Route 2 corridor, as well as other key intersecting roadways serving the corridor. Annual average traffic data, along with typical weekly and daily data, are presented to compare traffic trends and characteristics by year, by day-of-week, and by hour of the day.

The traffic volumes presented in this section were collected in either May 2019 or December 2019 (pre-COVID). At the onset of the study, Cambridge Turnpike, a significant local roadway that intersects Route 2 at Crosby's Corner, was closed to all traffic as part of a roadway reconstruction project. As a result, the traffic volumes at this location and adjacent locations were impacted. Traffic volumes presented herein, and specifically at those locations impacted by the closure of Cambridge Turnpike, were established and supplemented with historic counts collected from previous studies along the corridor.

The source and date of traffic volumes are depicted in Table 2-1. As presented in the following section a series of figures which provide summary graphics indicating both existing peak hour traffic volumes during the morning and evening peak commuting hours, traffic operations in the form of traditional Level of Service (LOS) discussions, as well as a comparison of volume-to-capacity (v/c) ratios for specific links within the corridor.

Table 2-1 Traffic Volume Source and Date

Intersection No.	Study Location	Source/Date
1	Route 2 at Oak Hill Road	December 2019
2	Route 2 at Palmer Road	December 2019
3	Route 2 at Mt Elam Road	May 2019
4	Interchange 30: Route 2 at Merriam Avenue and South Street – Exit 98	May 2019
5	Route 2 at Abbott Avenue	December 2019
6	Interchange 31: Route 2 at N. Main Street (Route 12) – Exit 99	**GPI FDR – January 2019**
7	Interchange 32: Route 2 at Main Street (Route 13) – includes merge/diverge with IC 33 – Exit 100	December 2019 **Tetra Tech FDR – May 2014**
8	Interchange 33: Route 2 at Interstate 190 (including westbound weave with IC 32) – Exit 101	December 2019 **MassDOT Database 2016/2017**
9	Interchange 34: Route 2 North Harvard Street and Mechanic Street (including potential ramp consolidation) – Exit 102	**Transystems 2014**
10	Interchange 35: Lunenburg Road (Route 70) (including potential ramp consolidation) – Exit 103	**Transystems 2014**
11	Interchange 36: Route 2 at Shirley Road (including potential ramp consolidation) – Exit 105	**Transystems 2014**
12	Interchange 37: Route 2 at Jackson Road – focus on merge onto Route 2 WB from Jackson Road) – Exit 106	December 2019
13	Interchange 38: Route 2 at Ayer Road – Exit 109	**Transystems 2014**
14	Interchange 39: Route 2 at Taylor Street – Exit 112	September 2017 **MassDOT Database 2019**
15	Interchange 40: Route 2 at Interstate 495 – Exit 113	September 2019 **MassDOT Database 2019**
16	Interchange 43: Route 2/ Route 111/ Taylor Road and Piper Road – Exit 118	**Tetra Tech FDR – January 2019**
17	Route 2 at Hosmer Street	December 2019
18	Route 2 at School Street and Wetherbee Street	December 2019
19	Route 2 at Concord Rotary	May 2019
20	Route 2 at (State Police) Emergency Signal	May 2019
21	Route 2 at Elm Street	May 2019
22	Route 2 at Baker Avenue Ext	May 2019
23	Route 2 at Main Street (Route 62)	May 2019
24	Route 2 at Old Road to 9 Acre Corner	May 2019
25	Route 2 at Sudbury Road	**MPO Study 2012**
26	Route 2 at Walden Street (Route 126)	**MPO Study 2012**
27	Interchange 50: Cambridge Turnpike (Crosby's Corner) – Exit 125	**
28	Route 2 at Bedford Road (Tracey's Corner)	May 2019

**Not included due to the Cambridge turnpike closure impacting traffic volumes.

2.2.1 Average Annual Daily Traffic

Traffic data within the study were obtained and reviewed to quantify the magnitude of traffic volumes along the various study area roadways and to identify trends that have occurred over the years. Average annual daily traffic (AADT) for the corridor was collected by MassDOT via permanent counting stations. AADT is expressed in the terms of vehicles per day and is adjusted by MassDOT for month-to-month seasonal fluctuations so that the data is representative of an annual average condition and not one particular month. Comparing historical AADTs at one location helps determine trends without the influence of seasonal bias. Comparing AADTs at several locations helps to provide a more accurate comparison of traffic volumes along the corridor as a whole.

2.2.1.1 Historical Traffic Volumes

Historical traffic volume information dating back to 2011 was reviewed for the Route 2 corridor. Figure 2-1 and Figure 2-2 graphically indicates the rates of growth along the Route 2 corridor at two continuous count stations for the eastern and western study areas.

Table 2-2 summarizes the historical growth in traffic volumes in the study area over the approximate twenty three-year period studied. The results of this traffic growth research indicate that the segment of Route 2 east of Rt 140 has seen an average of approximately 3.9 percent per year over a 5-year period. Route 2 east of the Concord Rotary has seen traffic volume growth at an average rate of 1.2 percent per year over an 8-year period.

Table 2-2 Traffic Volume Historical Growth

Location	Count Station	Date of Count		Average Annual Traffic Volume		Average Traffic Growth per Year
		First Count	Last Count	First Count	Last Count	
Rt 2, west of Rt 70	34	2011	2018	49,475	59,761	2.74%
Rt 2, east of Rt 140	3008	2011	2016	42,087	50,872	3.86%
Rt 2, west of Taylor Street	3072	2011	2016	45,278	53,207	3.28%
Rt 2, west of Route 27	4172	2011	2019	35,171	44,803	3.86%
Rt 2, between Sudbury Rd and Walden Rd	4950	2011	2015	45,743	46,889	0.62%
Rt 2, east of Concord Rotary	403	2011	2019	43,434	47,823	1.21%

Source: MassDOT Count Data

Figure 2-1 Historical Traffic Volume Growth (Western Study Area)

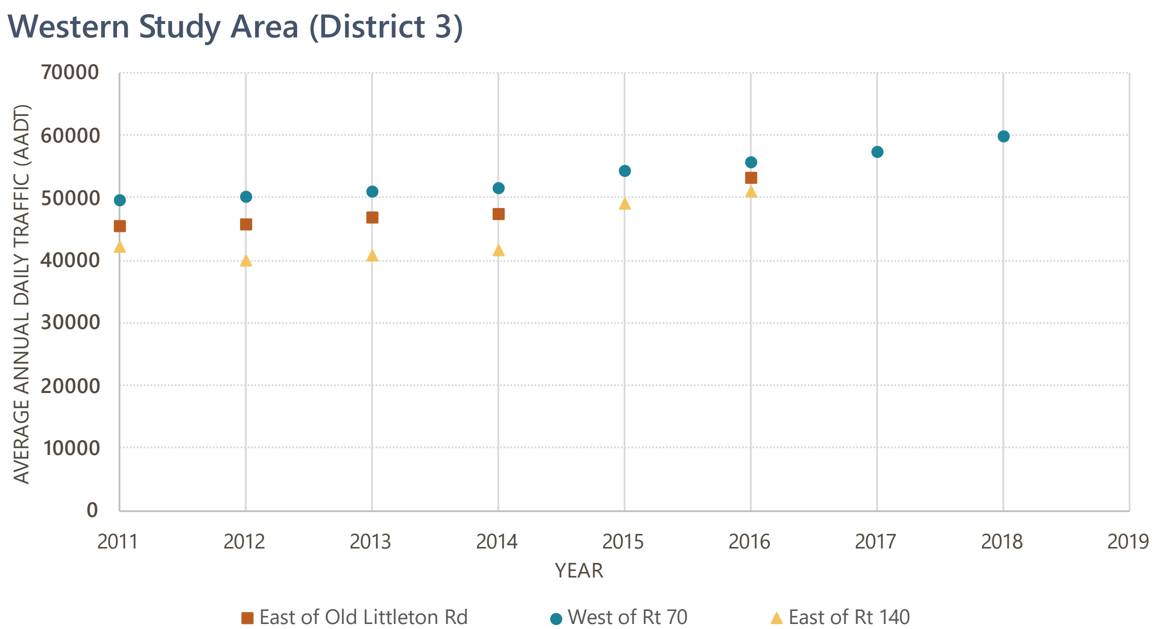
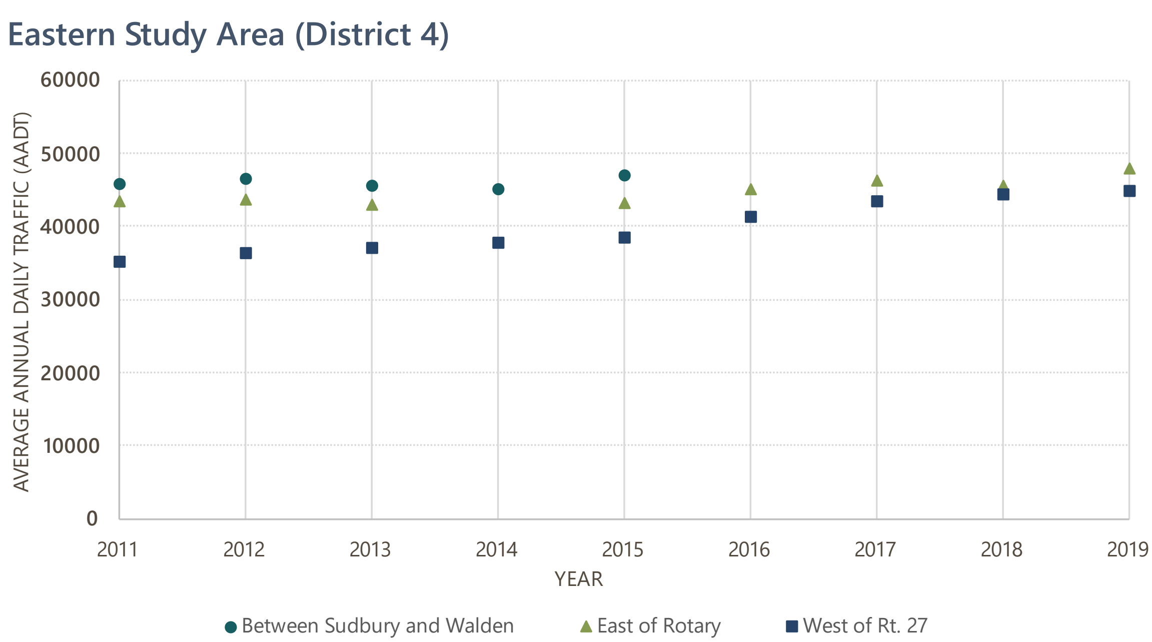


Figure 2-2 Historical Traffic Volume Growth (Eastern Study Area)



2.2.2 Observed Traffic Volumes

2.2.2.1 Route 2 Mainline Traffic Volumes

To identify current traffic flow characteristics, daily and hourly traffic volume data were collected in May 2019 using automatic traffic recorders (ATRs) along the Route 2 corridor. One focus of this study is to evaluate Route 2's ability to accommodate the fluctuations in daily traffic demands. Identifying hourly fluctuations in daily traffic volumes helps to identify the degree of commuting traffic and the periods of peak usage along the corridor. Figure 2-3 through Figure 2-6 present hourly traffic volume profiles for representative segments of Route 2. Table 2-3 summarizes the daily and peak hour traffic volumes along the corridor.

Figure 2-3 Mainline Hourly Traffic Demand Profile (A)

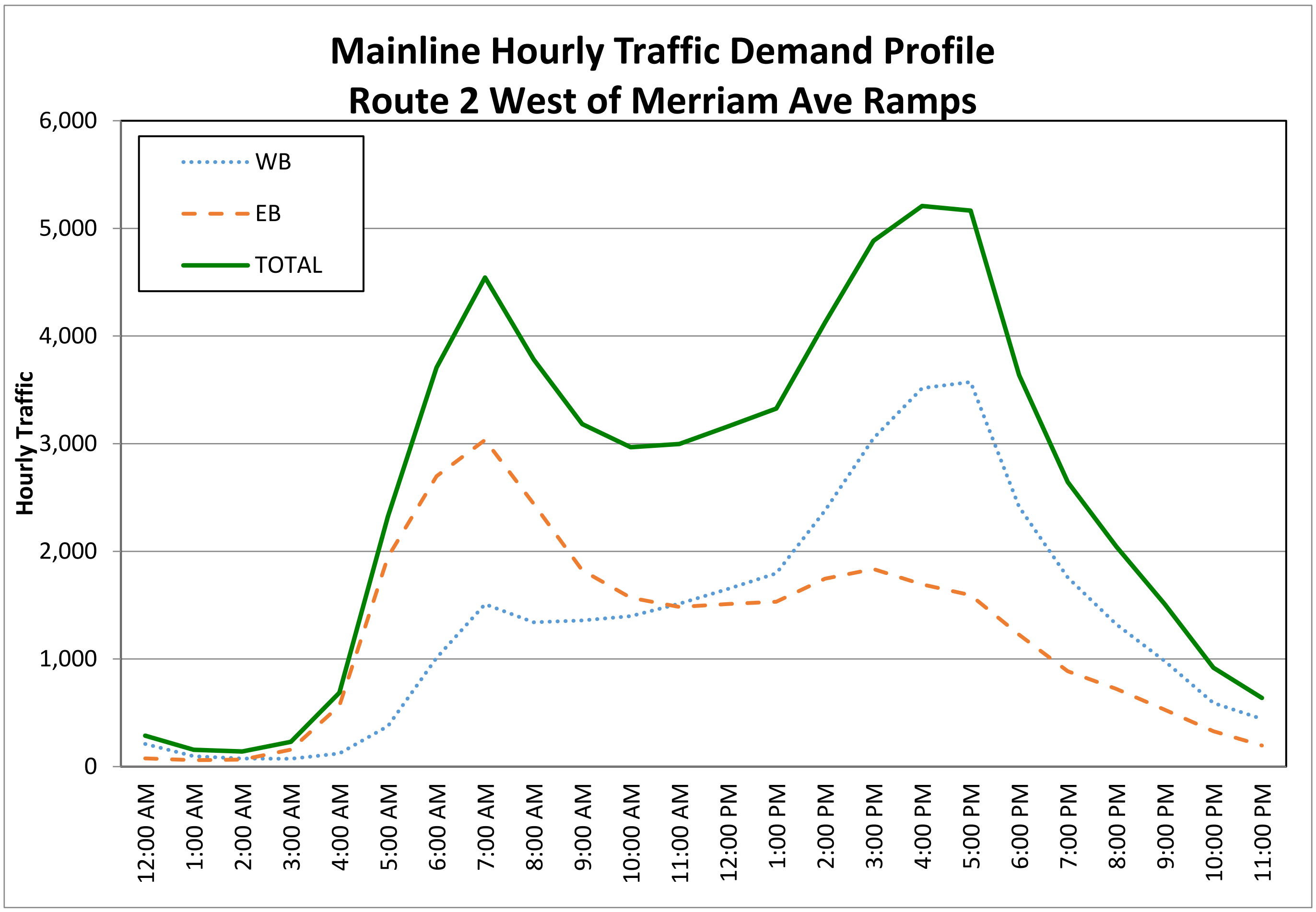


Figure 2-4 Mainline Hourly Traffic Demand Profile (B)

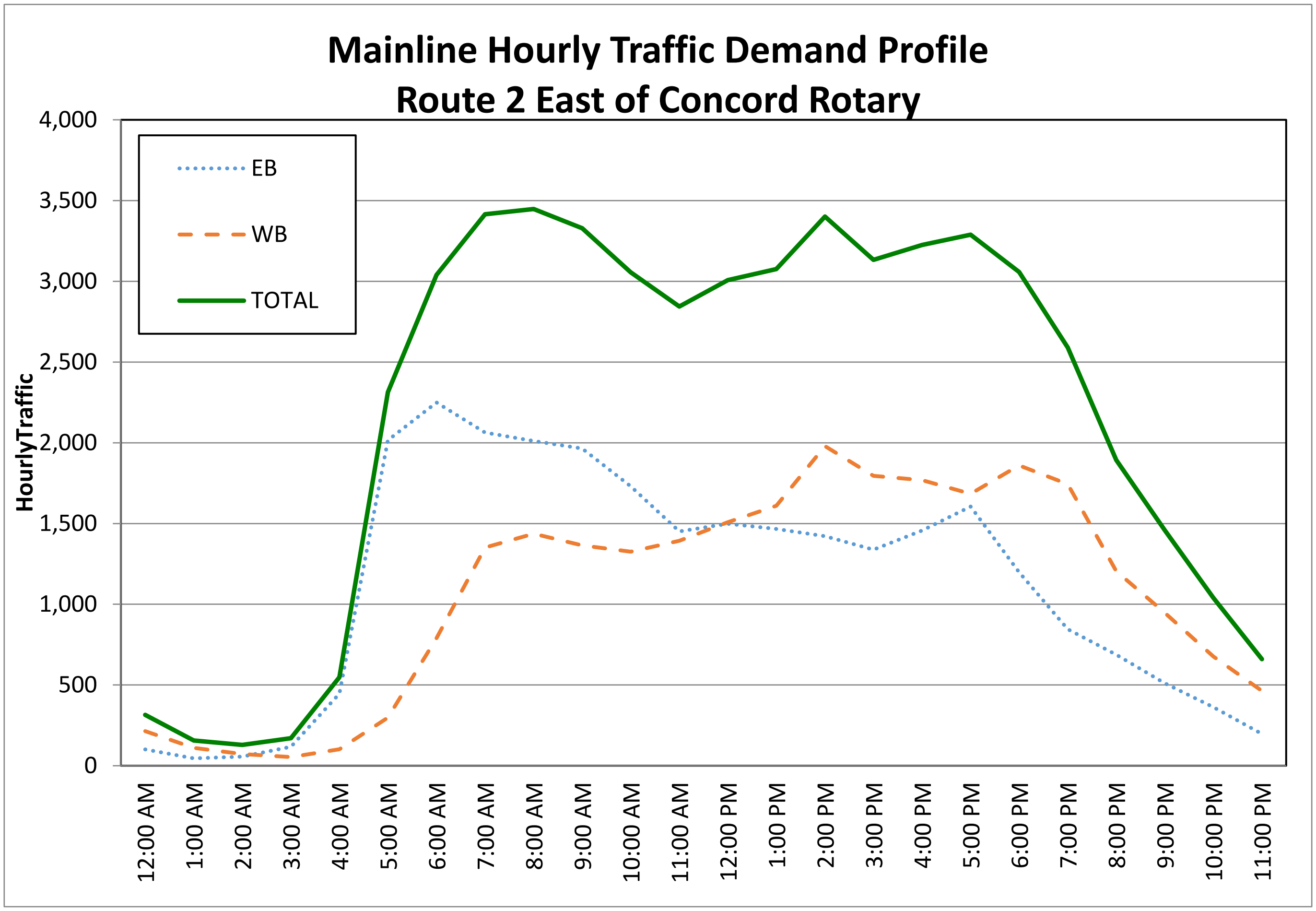


Figure 2-5 Mainline Hourly Traffic Demand Profile (C)

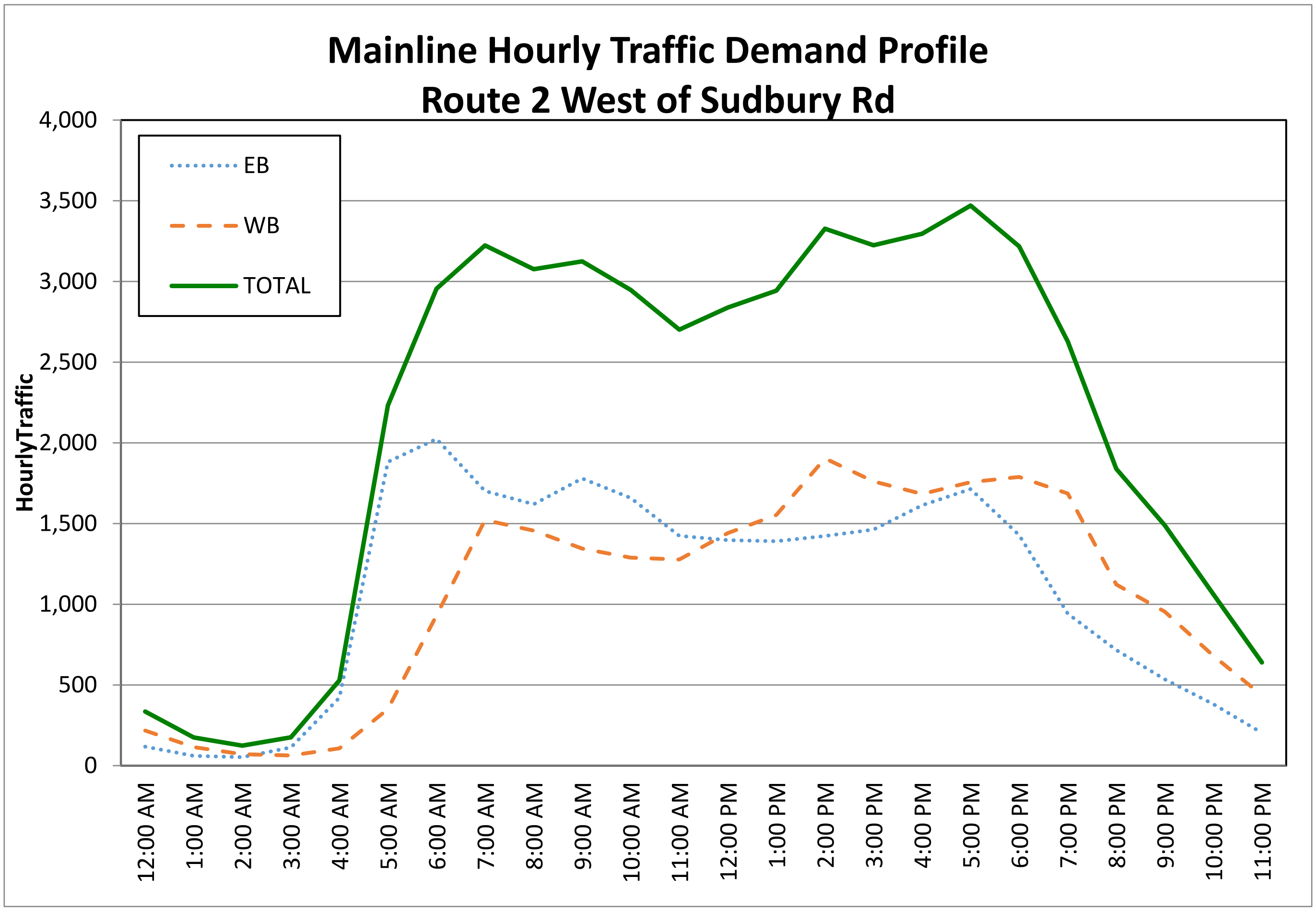


Figure 2-6 Mainline Hourly Traffic Demand Profile (D)

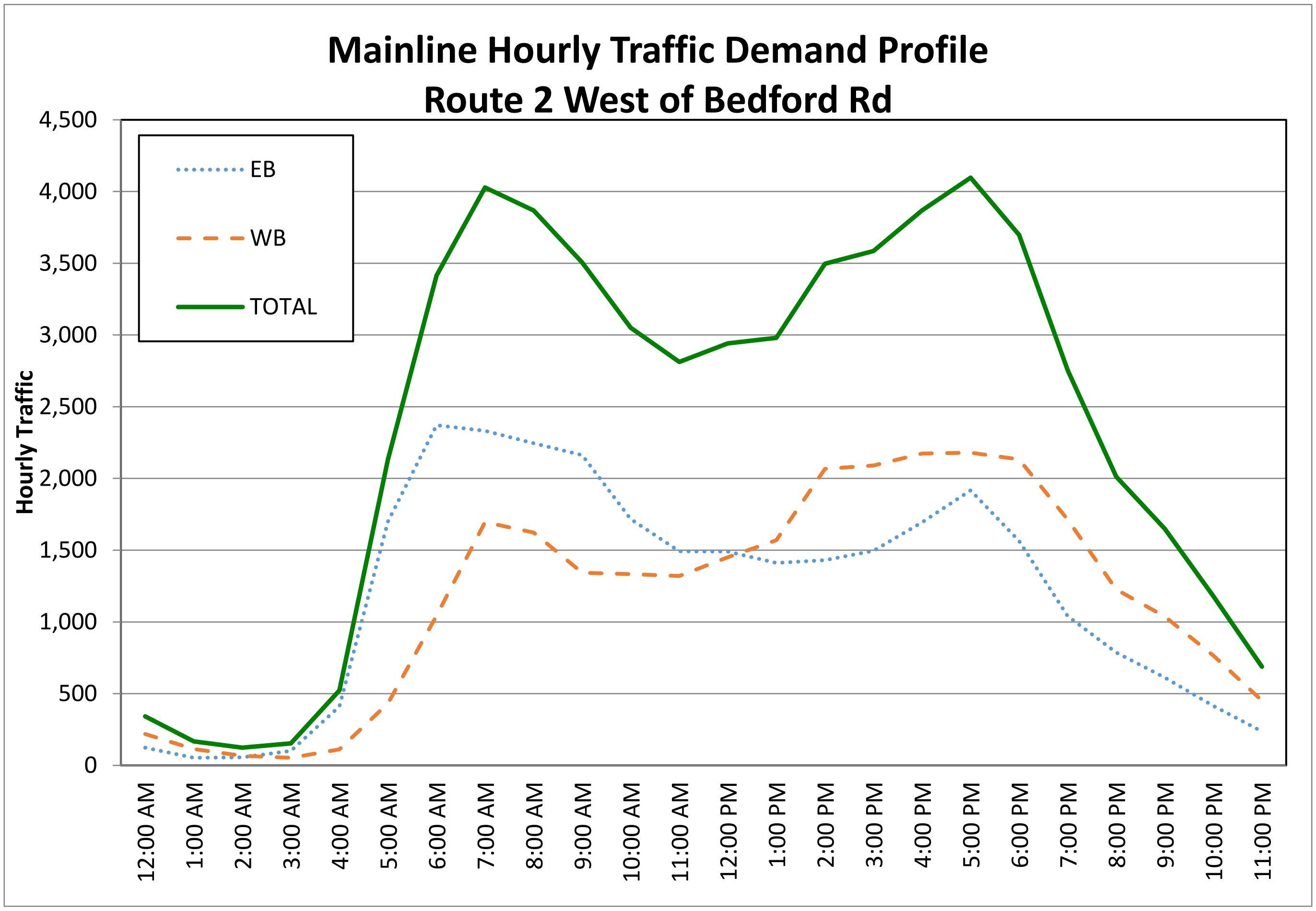


Table 2-3 Observed Traffic Volume Summary

	Daily [a]	Weekday Morning Peak Hour			Weekday Evening Peak Hour		
Location	**Weekday**	**Volume [b]**	**K Factor [c]**	**Dir. Dist. [d]**	**Volume**	**K Factor**	**Dir. Dist.**
Route 2, west of Merriam Ave ramps	62,300	4,545	7.3%	**EB** 67%	5,210	8.4%	**WB** 67%
Route 2, east of Concord Rotary	52,600	3,450	6.6%	**EB** 58%	3400	6.5%	**WB** 58%
Route 2, west of Sudbury Rd	51,600	3,225	6.3%	**EB** 53%	3,470	6.7%	**WB** 51%
Route 2, west of Bedford Rd (Tracey's Corner)	57,100	4,030	7.1%	**EB** 58%	4,095	7.2%	**WB** 53%

Source: Vanasse Hangen Brustlin, Inc.
Based on automatic traffic recorder (ATR) counts conducted in May 2019.
a average daily traffic (ADT) volume expressed in vehicles per day
b peak period traffic volumes expressed in vehicles per hour
c percent of daily traffic that occurs during the peak period
d directional distribution of peak period traffic

As Figure 2-3 through Figure 2-6 and Table 2-3 indicate, the morning and evening peak hour traffic volumes represent between six and eight percent of the daily traffic along Route 2. The peak directional flow of traffic is eastbound during the morning peak hour and westbound during the evening peak hour along all segments of Route 2.

In general, traffic volumes in the western part of the study area are more concentrated during the evening peak hour compared to the morning peak hour. However, in the eastern part of the study area the peaks are less pronounced.

In the western study area of Route 2 the weekday morning and weekday evening peak hours follow a traditional 6:00 AM to 8:00 AM and 4:00 PM to 6:00 PM peak period as presented in Figure 2-3. However, In the eastern study area of Route 2 the data reflects that an early peaking before traditional peak periods (as early as 5:00 AM eastbound and 2:00 PM westbound) as presented in Figure 2-4.

The nontraditional peaking in the eastern study area may be an anomaly of the data, the road may peak early however, as intersecting street volumes increase, and congestion builds up the traffic signals are not able to maintain the Route 2 mainline volume. Peaking anomalies may also reflect people heading to the Boston core using commuter rail, with people heading to inner suburbs or the Route 128 area preferring to drive due to lack of high-frequency transit options. The traffic data collection equipment can only register the volume passing a point within the hour and does not account for additional queued up latent demand (e.g., traffic queued up across multiple signalized intersections and the Concord Rotary).

2.2.2.2 Peak Hour Volumes

Turning movement volume counts were collected at the signalized intersections along Route 2 and the intersections of the ramp termini with local streets during the weekday morning and evening peak hour (6:00 AM – 10:00 AM; 3:00 PM – 7:00 PM). These data were collected using manual turning movement/classification counts (TMCs) to identify current traffic volumes traveling through the key intersections in the region. As part of this TMC data collection, origin destination (OD) data was collected at the Concord Rotary and at the weaving maneuver along Route 2 between I-190 and Route 13.

The overall morning and evening peak hours along the Route 2 mainline generally occurred from 7:30 AM – 8:30 AM and from 5:00 PM – 6:00 PM. Peak hours of total traffic at individual study area intersections tended to occur at slightly different times. This is because traffic volumes on the streets that intersect with Route 2 tend to peak later in the morning and the later in the evening than does the Route 2 mainline volume. These 2019 data were used to establish the baseline traffic conditions in the peak hour traffic analysis of the basic freeway segments; merge/diverge ramps, weaving segments, and study area intersections.

2.2.3 Seasonal Variation

Traffic counts for this project were conducted in May and December of 2019. MassDOT continuous count station data within the study area along Route 2 were reviewed. Traffic volumes collected in May generally were found to be higher than the average month. For a more conservative analysis, no seasonal adjustments were applied to the data as the May count data were found to be higher than the average conditions. Traffic volumes collected in December were found to be generally equal to or slightly below the average month. As such, the data for December were increased by one percent.

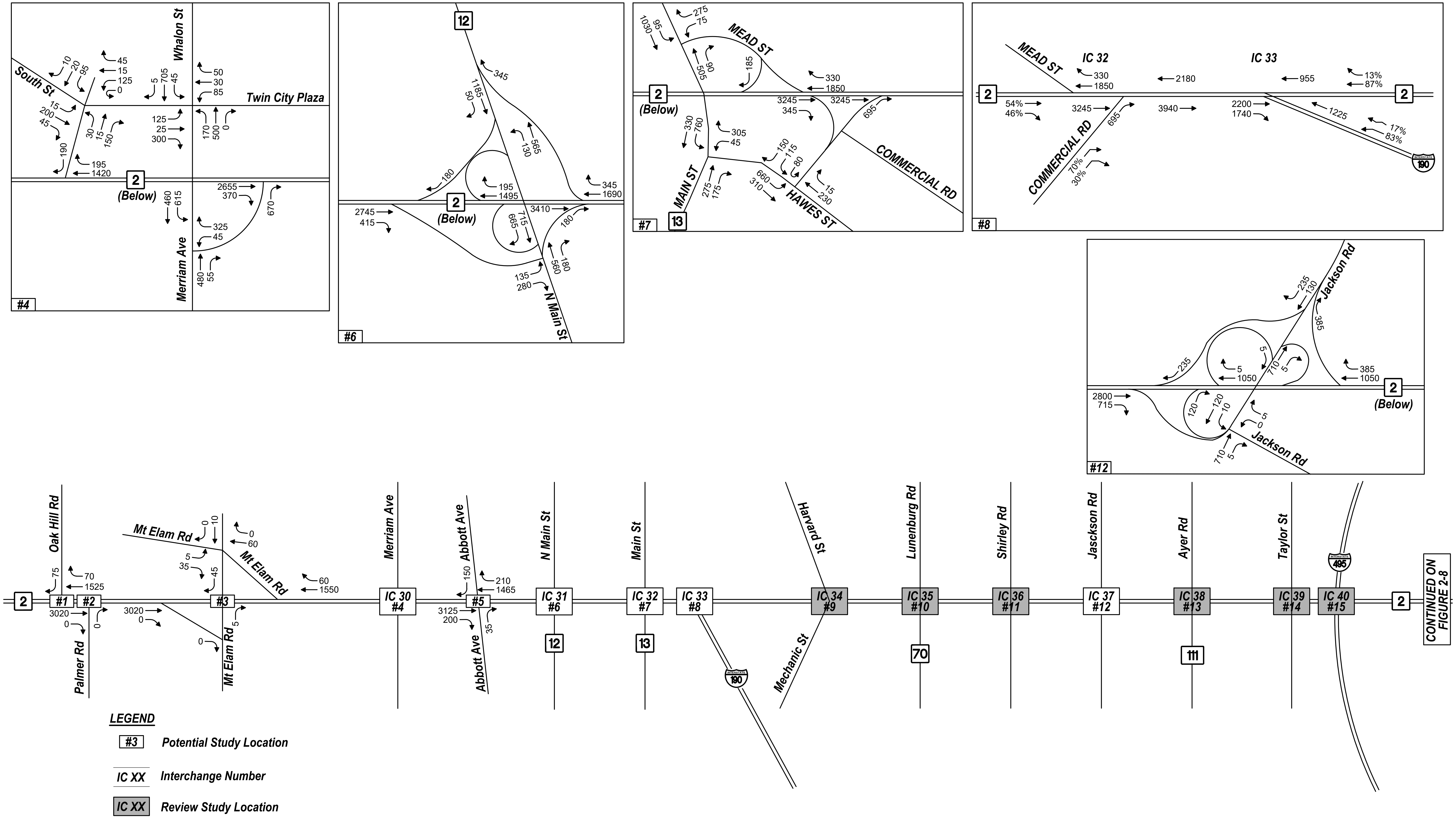
2.2.4 Network Balancing

To account for variations in volumes from different years, seasons, and peak hours, volume networks were balanced. This effort also adjusted for the early peaking reflected in the data (and discussed above) within the more easterly sections of Route 2 due to peak hour congestion. Two balanced networks were developed for each portion of the study area, Oak Hill to I-190 for the western section of the study area, and the Concord Rotary to Tracey’s Corner (Bedford Road) for the eastern section of the study area.

The existing conditions weekday morning and weekday evening peak hour intersection traffic volumes are shown graphically for each of the study area locations along Route 2 in the attached Figure 2-7 through Figure 2-10.

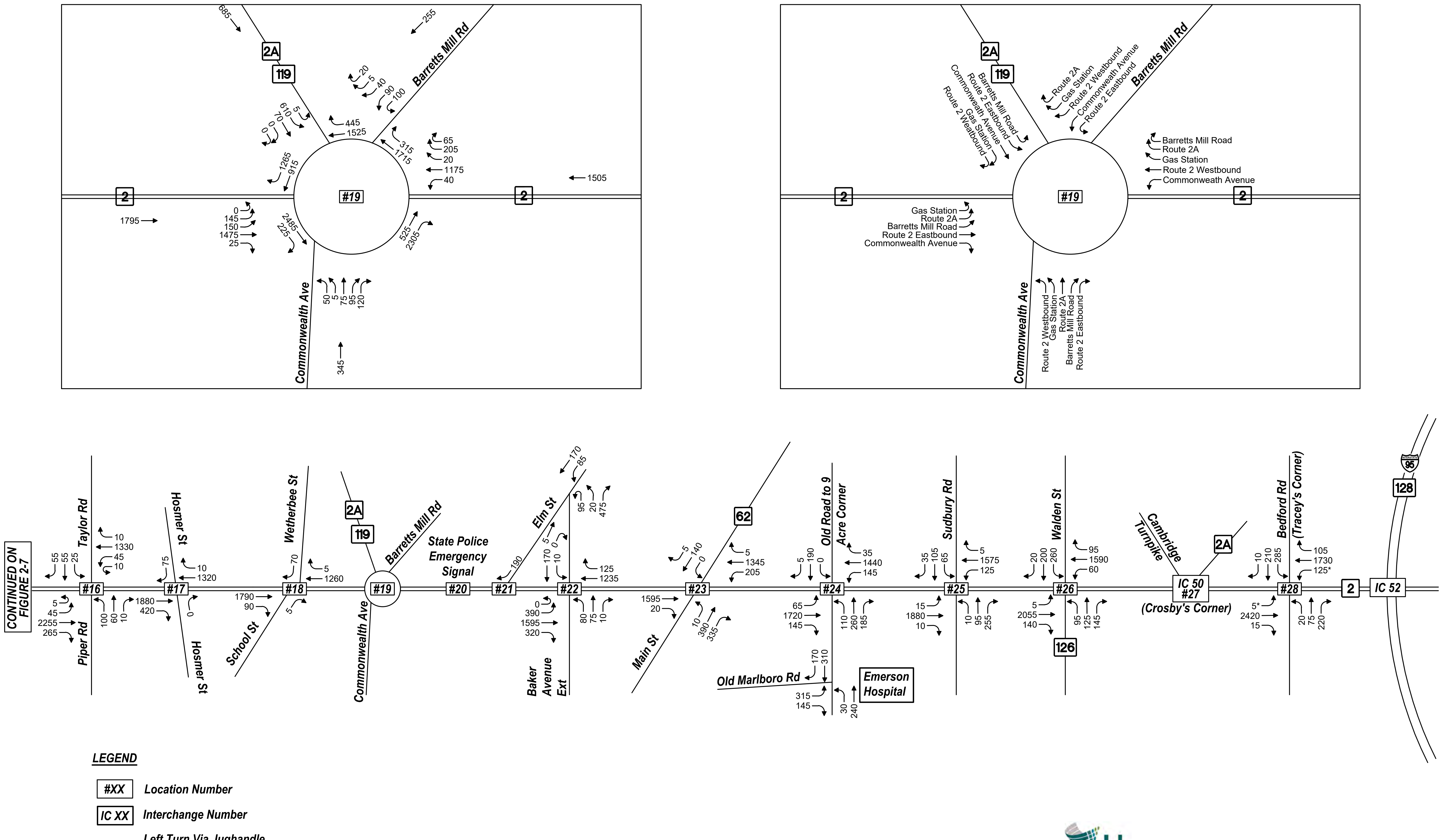
2.2.5 Pedestrian and Bicycle Volumes

Pedestrian and Bicycle volume counts were included as part of the turning movement/ classification counts (TMCs) in the eastern study area. The pedestrian and bicycle volumes are presented in Figure 2-11 and Figure 2-12 respectively.



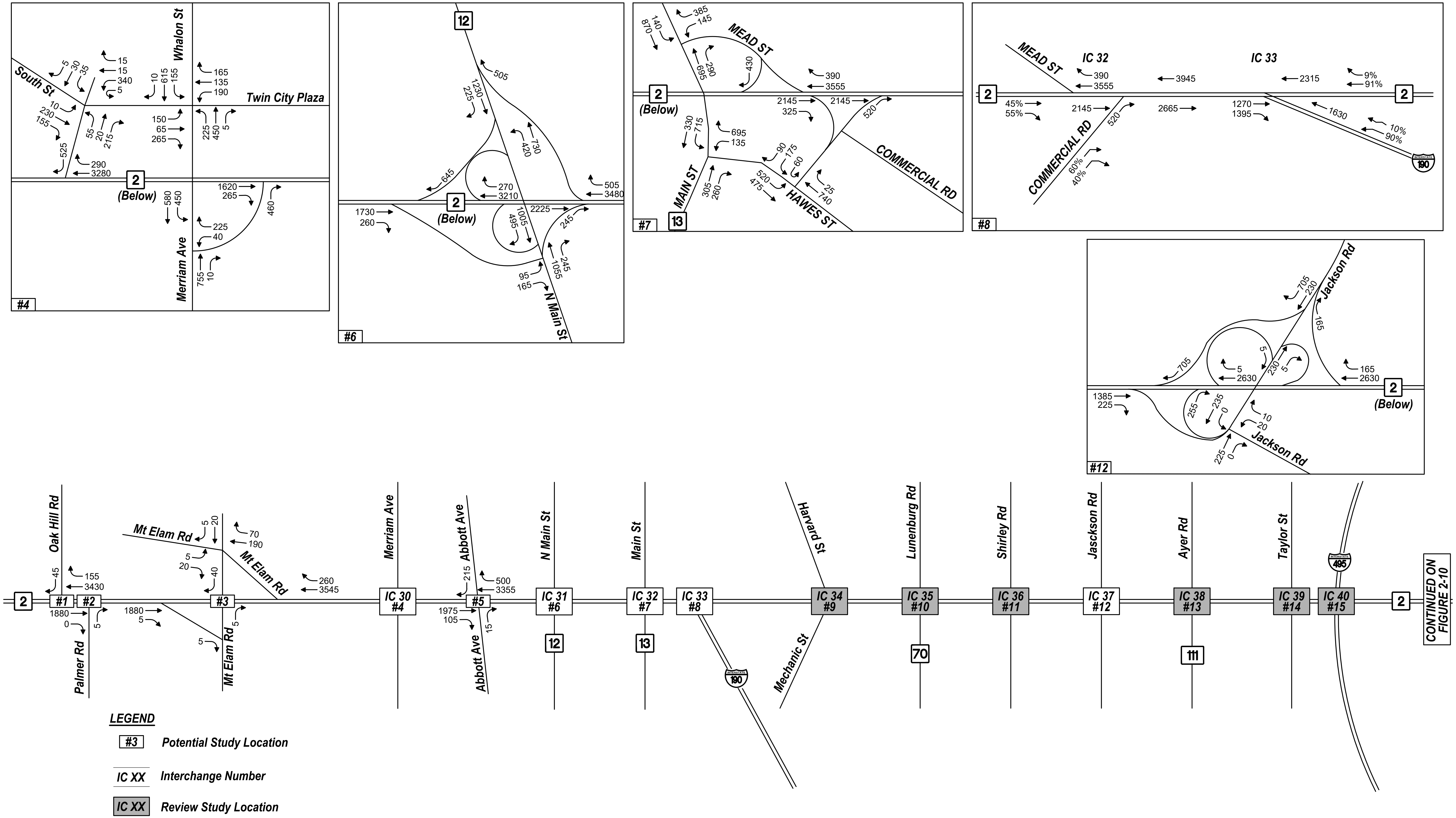
2019 Existing Traffic Volumes
Weekday Morning Peak Hour
Western Study Area
Route 2 Corridor Study

Figure 2-7



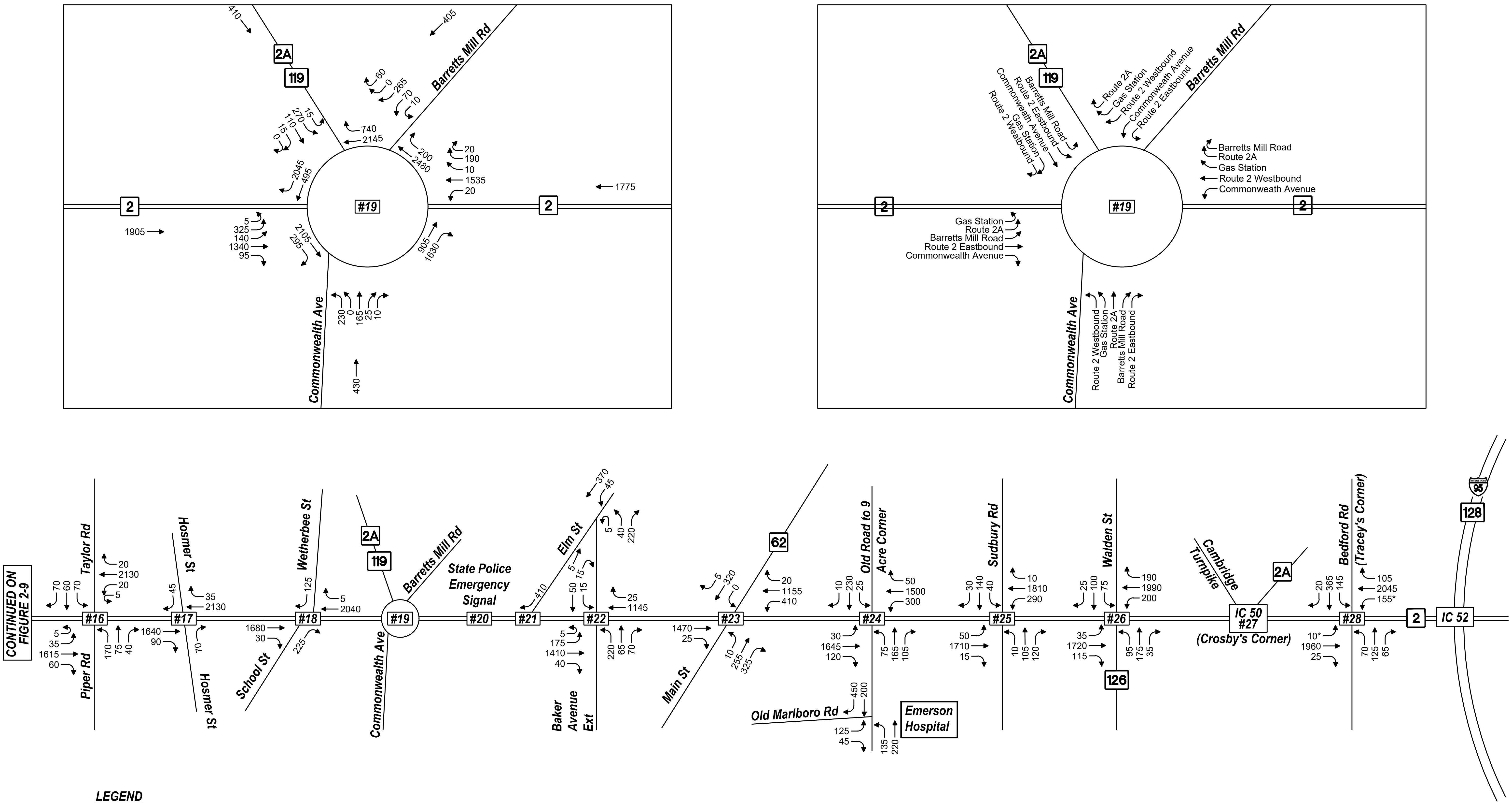
2019 Existing Traffic Volumes
Weekday Morning Peak Hour
Eastern Study Area
Route 2 Corridor Study

Figure 2-8



2019 Existing Traffic Volumes
Weekday Evening Peak Hour
Western Study Area
Route 2 Corridor Study

Figure 2-9



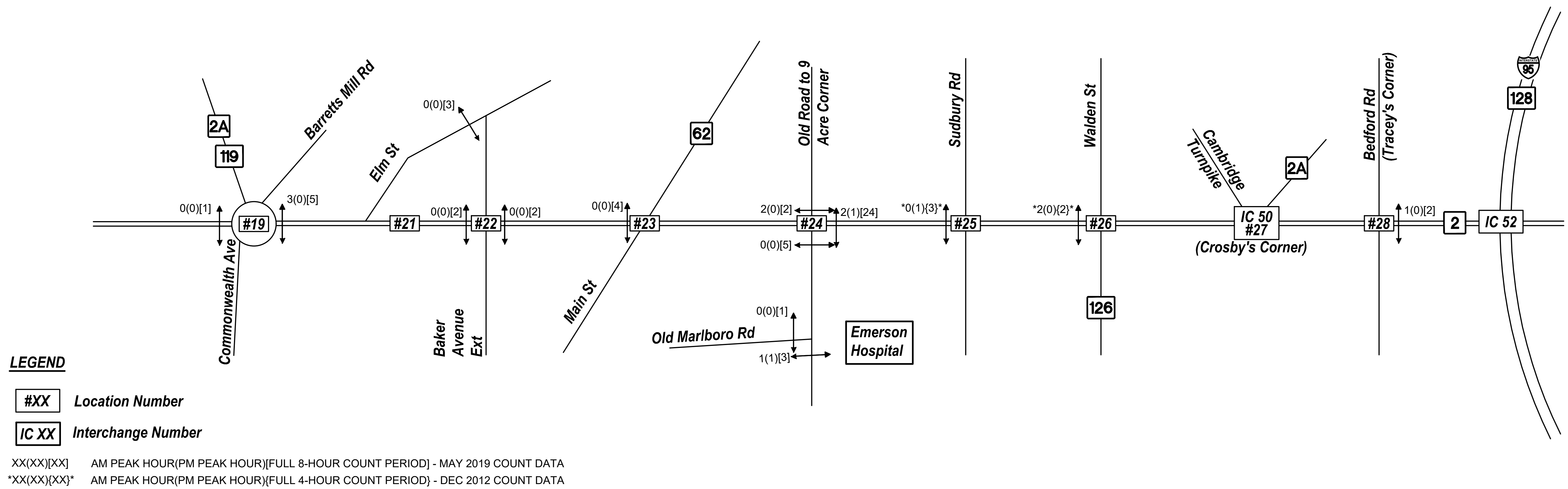
LEGEND

#XX	*Location Number*
IC XX	*Interchange Number*
...	*Left Turn Via Jughandle*

2019 Existing Traffic Volumes
Weekday Evening Peak Hour
Eastern Study Area
Route 2 Corridor Study

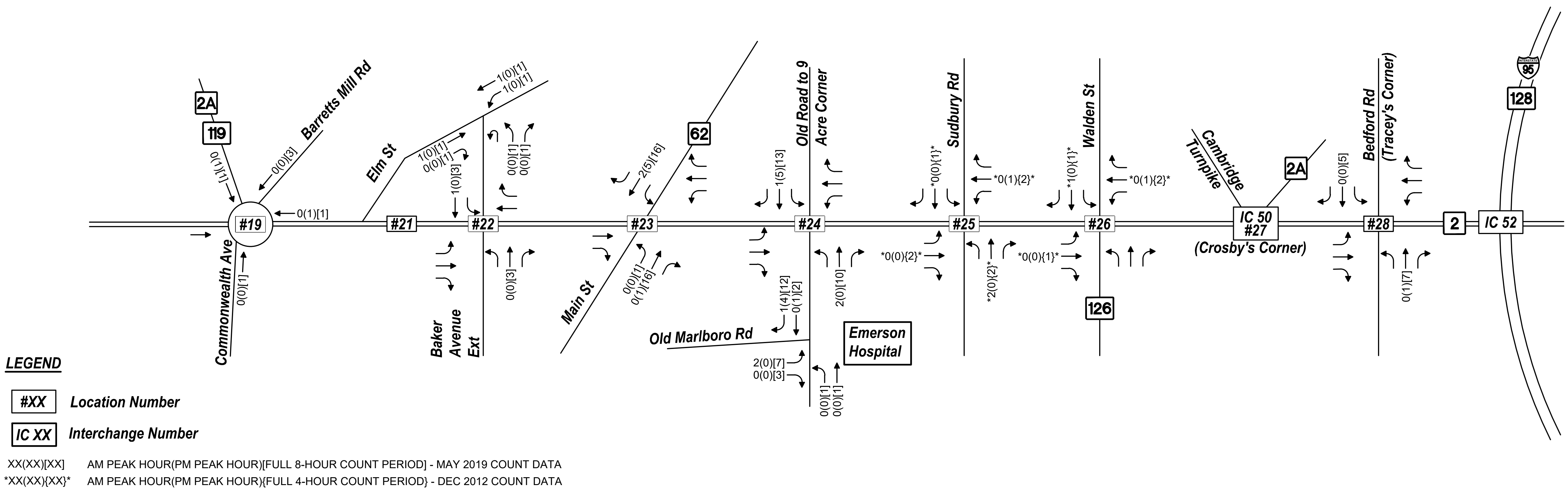
Figure 2-10

\\vhb\gbl\proj\Wat-TE\12529.70 Rt 2 Traffic Safety\graphics\FIGURES\Volume Graphics\Volume Graphics Stick Figure Version.dwg



2019 Pedestrian Volumes
Weekday Peak Hour
Eastern Study Area
Route 2 Corridor Study

Figure 2-11



2019 Bicycle Volumes
Weekday Peak Hour
Eastern Study Area
Route 2 Corridor Study

Figure 2-12

2.3 Safety Assessment

A safety analysis was conducted for the Route 2 corridor within the study area limits to determine if the traffic demands combined with the geometric conditions and existing traffic control have contributed to potential safety trends and/or concerns.

2.3.1 Methodology

To identify crash rates and trends potentially related to volumes/geometrics/traffic control at study area intersections, the most current vehicle crash data was obtained from MassDOT for the years 2013 to 2019. Crash data is included in the Technical Appendix.

For the study area intersections, crash rates were calculated and compared to average crash rates for each District. Using the traffic volumes combined with the number of crashes in the five-year total allows for the calculation of a crash rate at a given intersection. The calculation of an intersection's crash rate is an effective tool to measure and compare the relative safety of an intersection to others. The crash rate calculation is expressed as crashes per million entering vehicles (MEV), which is a standard in the traffic engineering profession and reflects how many crashes were recorded per one million vehicles that pass through the intersection. While each study area intersections crash experience and rate is evaluated individually, crash rates that exceed MassDOT's average at intersections in the district in which the town or city is located (District 3 or District 4 for Route 2 study area intersections) could indicate safety, geometric or traffic control issues and warrant further examination.

The latest published average crash rates[3] by MassDOT are 0.89 for signalized intersections and 0.61 for unsignalized intersections in District 3, while crash rates for District 4 are 0.73 for signalized intersections and 0.57 for unsignalized intersections. These rates imply that, on average, 0.89 and 0.73 crashes occurred per million vehicles entering signalized intersections, and 0.61 or 0.57 crashes occurred per million vehicles entering unsignalized intersections in District 3 and District 4 respectively. Crash rate calculations are included in the Technical Appendix. It should be noted that the location for some crashes cannot be precisely determined from the database. These locations typically involve interchange and/or rotary locations. Additionally, some crashes may have occurred but were either not reported or not included in the database, and therefore not considered. A summary of the study intersections' vehicle crash history is presented in Table 2-4 through Table 2-6. Unless otherwise noted, all crash rates presented herein are at intersections/interchanges with Route 2. Additional crashes recorded at local intersections adjacent to Route 2 interchanges within the western portions of the study area are not included in this report's table but are included in the Appendix for reference purposes.

3 https://www.mass.gov/service-details/intersection-and-roadway-crash-rate-data-for-analysis, June 26, 2018.

Table 2-4 Vehicular Crash Summary (2013-2019)

	Oak Hill Road	Palmer Road	Mt. Elam Road (EB)	Mt. Elam Road (WB)	Merriam Ave at Rt 2 EB Ramp	South Street at Rt 2 WB Ramp	Whalon Street at South Street/ Merriam Avenue	Rt 2 EB Off/On-Ramp to/from Merriam Avenue	Rt 2 WB Off/On-Ramp to/from South Street	Abbott Avenue (Route 2 EB)	Abbott Avenue (Route 2 WB)	Rt 12 (N Main St) at Rt 2 EB Ramps	Rt 12 (N. Main Street) at Rt 2 WB Ramps
Location # (Interchange #)	**1**	**2**	**3a**	**3b**	**4a**	**4b**	**4c (IC 30)**	**4d (IC 30)**	**4f (IC 30)**	**5a**	**5b**	**6e (IC 31)**	**6f (IC 31)**
Signalized or Facility Type?	No	No	Yes	No	No	No	Yes	No	No	No	No	Yes	Yes
MassDOT Average Crash Rate	0.61	0.61	0.89	0.61	0.61	0.61	0.89	0.61	0.61	0.61	0.61	0.89	0.89
Calculated Crash Rate	0.27	0.06	0.49	0.32	1.18	0.40	0.32	0.38	0.43	0.17	0.34	0.29	0.25
Exceeds Average?	No	No	No	No	Yes	No	No	No	No	No	No	No	No
Year													
2013	2	0	1	4	7	1	0	6	5	0	4	3	2
2014	2	1	1	11	12	1	3	8	5	0	6	2	4
2015	6	2	5	9	17	3	5	4	3	2	6	7	0
2016	5	1	2	1	12	2	6	5	8	3	4	3	5
2017	4	0	10	6	14	3	2	8	15	3	5	7	7
2018	2	0	15	1	4	1	2	5	13	5	4	1	0
2019	7	1	8	3	3	2	4	4	1	3	10	0	0
Total	28	5	42	35	69	13	22	40	50	16	39	23	18
Average	4.00	0.71	6.00	5.00	9.86	1.86	3.14	5.71	7.14	2.29	5.57	3.29	2.57
Collision Type													
Angle	0	0	0	3	21	8	5	0	0	1	4	5	3
Head-on	0	0	0	0	0	0	0	0	1	0	1	1	0
Rear-end	7	3	33	13	39	0	15	16	23	6	10	12	12
Rear-to-Rear	0	0	1	0	0	0	0	0	0	0	0	0	0
Sideswipe, opposite direction	0	0	0	1	1	1	0	1	1	0	2	0	0
Sideswipe, same direction	5	1	3	3	2	4	1	5	9	0	6	2	3
Single vehicle crash	16	1	5	14	6	0	1	17	16	9	16	3	0
Unknown	0	0	0	1	0	0	0	1	0	0	0	0	0
Not reported	0	0	0	0	0	0	0	1	0	0	0	0	0
Crash Severity													
Fatal injury	0	0	0	0	0	0	0	0	0	0	0	0	0
Non-fatal injury	2	0	14	11	9	1	5	8	10	5	4	6	1
Property damage only (none injured)	26	5	28	24	60	12	17	32	39	11	35	17	17
Not Reported	0	0	0	0	0	0	0	0	1	0	0	0	0
Unknown	0	0	0	0	0	0	0	0	0	0	0	0	0
Time of Day													
Weekday, 7:00 AM - 9:00 AM	3	1	9	3	3	1	3	10	5	4	3	4	1
Weekday, 4:00 PM - 6:00 PM	1	0	3	8	21	4	1	2	13	2	6	1	1
Saturday, 11:00 AM - 2:00 PM	0	0	2	0	0	0	3	1	1	0	1	1	0
Weekday, other time	14	3	21	21	36	7	13	17	22	6	16	13	14
Weekend, other time	10	1	7	3	9	1	2	10	9	4	13	4	2
Pavement Conditions													
Dry	20	5	34	26	53	10	14	24	36	9	28	19	13
Wet	4	0	4	2	14	1	6	6	7	6	10	4	5
Snow	1	0	0	3	1	2	2	5	3	0	0	0	0
Ice	1	0	1	3	0	0	0	2	1	1	0	0	0
Sand, mud, dirt, oil, gravel	1	0	2	0	0	0	0	0	0	0	0	0	0
Water (standing, Moving)	0	0	0	1	0	0	0	1	0	0	0	0	0
Slush	1	0	1	0	1	0	0	1	2	0	0	0	0
Other	0	0	0	0	0	0	0	0	1	0	0	0	0
Unknown/Not reported	0	0	0	0	0	0	0	1	0	0	1	0	0
Non-Motorist (Bike, Pedestrian)	0	0	0	0	0	0	0	0	0	0	0	0	0

Source: MassDOT crash portal, accessed October 2022. Crash rates are based on District Crash Rates published by MassDOT on June 26, 2018. Actual crash reports were not analyzed for this project and the geolocation of crashes has not been verified.

Table 2-5 Vehicular Crash Summary (2013-2019) - Continued

	Rt 2 EB Off/On-Ramps to/from Rt 12 (N Main St)	Rt 2 WB Off/On-Ramp to/from Rt 12 (N Main St)	Rt 2 EB Off/On-Ramp to/from Haws Street	Rt 2 WB Off/On-Ramp to/from Rt 13 (Main St)	Rt 2 EB at I-190	Rt 2 WB at I-190	Jackson Road at Rt 2 WB Ramps	Rt 2 EB Off/On-Ramp to/from Jackson Road	Rt 2 WB Off/On-Ramps to/from Jackson Road
Location # (Interchange #)	**6g (IC 31)**	**6i (IC 31)**	**7g (IC 32)**	**7i (IC 32)**	**8a (IC 33)**	**8b (IC 33)**	**12a (IC 37)**	**12b (IC 37)**	**12d (IC 37)**
Signalized?	No	No	No	No	No	No	No	No	No
MassDOT Average Crash Rate	0.61	0.61	0.89	0.61	0.61	0.61	0.61	0.61	0.61
Calculated Crash Rate	1.89	0.53	0.87	1.20	0.35	0.44	0.13	0.10	0.79
Exceeds Average?	Yes	No	No	Yes	No	No	No	No	Yes
Year									
2013	26	15	7	17	1	6	0	2	10
2014	19	12	5	22	5	4	0	1	15
2015	36	13	9	19	5	7	0	1	8
2016	21	5	8	23	4	7	3	1	13
2017	24	3	17	17	6	7	2	3	10
2018	47	8	8	25	4	4	0	1	15
2019	40	16	5	20	11	13	0	1	8
Total	213	72	59	143	36	48	5	10	79
Average	30.43	10.29	8.43	20.43	5.14	6.86	0.71	1.43	11.29
Collision Type									
Angle	17	3	11	1	1	1	0	1	2
Head-on	1	1	2	1	0	0	0	0	0
Rear-end	120	38	35	86	13	29	2	1	34
Rear-to-Rear	0	1	0	3	0	1	0	0	0
Sideswipe, opposite direction	0	0	0	0	0	0	0	0	0
Sideswipe, same direction	37	13	7	11	3	7	1	1	10
Single vehicle crash	37	16	4	40	19	10	2	7	33
Unknown	1	0	0	0	0	0	0	0	0
Not reported	0	0	0	1	0	0	0	0	0
Crash Severity									
Fatal injury	0	0	0	1	0	0	0	0	0
Non-fatal injury	50	21	16	36	12	8	1	1	18
Property damage only (none injured)	162	50	43	105	22	39	4	8	58
Not Reported	1	1	0	0	2	1	0	0	3
Unknown	0	0	0	1	0	0	0	1	0
Time of Day									
Weekday, 7:00 AM - 9:00 AM	48	2	3	6	4	6	0	2	2
Weekday, 4:00 PM - 6:00 PM	16	22	10	48	1	26	1	0	25
Saturday, 11:00 AM - 2:00 PM	1	1	2	3	2	0	0	0	1
Weekday, other time	115	38	32	70	23	11	3	4	34
Weekend, other time	33	9	12	16	6	5	1	4	17
Pavement Conditions									
Dry	159	59	48	114	23	36	4	4	62
Wet	38	8	8	12	6	6	1	0	8
Snow	6	2	1	11	5	1	0	3	7
Ice	6	2	1	3	2	1	0	2	2
Sand, mud, dirt, oil, gravel	0	0	0	1	0	0	0	0	0
Water (standing, Moving)	0	0	0	0	0	1	0	0	0
Slush	4	1	1	1	0	1	0	1	0
Other	0	0	0	0	0	0	0	0	0
Unknown/Not reported	0	0	0	1	0	2	0	0	0
Non-Motorist (Bike, Pedestrian)	0	0	1	1	0	0	0	0	1

Source: MassDOT crash portal, accessed October 2022. Crash rates are based on District Crash Rates published by MassDOT on June 26, 2018. Actual crash reports were not analyzed for this project and the geolocation of crashes has not been verified.

Table 2-6 Vehicular Crash Summary (2013-2019) – Continued

	Hosmer Street (Route 2 EB)	Hosmer Street (Route 2 WB)	School Street	Wetherbee Street	District 3 / District 4 Break	Concord Rotary	Elm Street & Baker Avenue Extension[1]	Main Street (Route 62) Concord	Old Road to 9 Acre Road at Old Marlboro Road	Old Road to 9 Acre Road	Sudbury Road	Walden Street (Route 126)	Bedford Road (Tracey's Corner)[1]
Location # (Interchange #)	**17a**	**17b**	**18a**	**18b**		**19**	**21/22**	**23**	**24a**	**24b**	**25**	**26**	**28**
Signalized?	No	No	No	No		No	Yes	Yes	No	Yes	Yes	Yes	Yes
MassDOT Average Crash Rate	0.61	0.61	0.61	0.61		0.57	0.73	0.73	0.57	0.73	0.73	0.73	0.73
Calculated Crash Rate	0.13	0.18	0.12	0.03		2.73	0.82	0.79	0.60	0.36	0.56	0.48	0.64
Exceeds Average?	No	No	No	No		Yes	Yes	Yes	Yes	No	No	No	No
Year													
2013	1	3	0	0		35	11	9	2	9	7	13	11
2014	0	1	2	0		35	8	14	2	2	5	16	13
2015	1	1	0	1		54	15	6	5	7	6	3	16
2016	0	3	0	0		55	8	14	6	4	15	8	11
2017	0	2	2	0		49	20	14	3	3	8	9	4
2018	3	1	1	1		57	13	15	1	11	14	8	23
2019	0	0	0	0		75	14	16	1	6	15	11	14
Total	5	11	5	2		360	89	88	20	42	70	68	92
Average	0.71	1.57	0.71	0.29		51.43	12.71	12.57	2.86	6.00	10.00	9.71	13.14
Collision Type													
Angle	0	2	1	0		80	23	11	11	5	6	1	11
Head-on	0	0	0	0		1	2	3	0	1	1	1	4
Rear-end	2	2	3	1		124	43	67	1	24	53	55	51
Rear-to-Rear	0	0	0	0		1	1	0	0	0	0	0	0
Sideswipe, opposite direction	0	0	0	0		3	4	0	4	0	1	0	5
Sideswipe, same direction	1	0	0	0		124	10	3	3	6	1	5	7
Single vehicle crash	2	7	1	1		27	6	4	1	6	8	5	14
Unknown	0	0	0	0		0	0	0	0	0	0	1	0
Not reported	0	0	0	0		0	0	0	0	0	0	0	0
Crash Severity													
Fatal injury	0	0	0	0		0	0	0	0	0	0	0	0
Non-fatal injury	0	5	1	0		61	33	25	1	15	15	20	29
Property damage only (none injured)	5	5	4	2		298	56	63	18	27	55	48	62
Not Reported	0	1	0	0		1	0	0	0	0	0	0	1
Unknown	0	0	0	0		0	0	0	1	0	0	0	0
Time of Day													
Weekday, 7:00 AM - 9:00 AM	1	2	0	0		44	9	7	4	4	13	11	11
Weekday, 4:00 PM - 6:00 PM	0	2	2	0		45	17	12	3	4	12	9	14
Saturday, 11:00 AM - 2:00 PM	0	0	0	0		2	0	2	0	0	2	1	3
Weekday, other time	4	2	2	2		205	58	47	12	24	33	36	46
Weekend, other time	0	5	1	0		64	5	20	1	10	10	11	18
Pavement Conditions													
Dry	5	8	4	1		306	77	76	19	37	54	54	80
Wet	0	2	1	0		45	8	9	0	5	10	11	9
Snow	0	1	0	0		4	2	2	0	0	4	0	1
Ice	0	0	0	0		0	0	0	0	0	1	1	1
Sand, mud, dirt, oil, gravel	0	0	0	0		1	0	0	0	0	0	0	0
Water (standing, Moving)	0	0	0	1		0	0	0	0	0	0	0	0
Slush	0	0	0	0		0	0	0	1	0	0	0	0
Other	0	0	0	0		0	0	0	0	0	0	0	0
Unknown/Not reported	0	0	0	0		4	2	1	0	0	1	2	1
Non-Motorist (Bike, Pedestrian)	0	0	0	0		2	0	0	0	0	0	1	2

Source: MassDOT crash portal, accessed October 2022. Crash rates are based on District Crash Rates published by MassDOT on June 26, 2018. Actual crash reports were not analyzed for this project and the geolocation of crashes has not been verified.

1 Road Safety Audit conducted as part of corridor study.

2.3.2 Vehicular Crash History

As shown in Table 2-4 through Table 2-6, calculated crash rates for 7 study area intersections are equal to or greater than their respective MassDOT district average crash rate values including: 1) Merriam Avenue at Route 2 Ramps, 2) Route 2 eastbound off/on-ramps from Route 12, 4) Rt 2 EB Off/On-Ramp to/from Haws Street, 5) Rt 2 WB Off/On-Ramp to/from Rt 13 (Main St), 6) Concord Rotary, 7) Route 2 at Baker Avenue Ext. One fatal injury occurred across the study area during the study period, which occurred at the Route 2 westbound at Route 13 interchange, and 21 non-motorist (bike, pedestrian) crashes occurred in the study area. Key results include:

2.3.2.1 Western Study Area

- Mt. Elam Road (Route 2 eastbound) – 14 of the 42 total crashes were injury crashes. 33 of the crashes were rear-end type.
- Mt. Elam Road (Route 2 westbound) – 11 of the 35 total crashes were injury crashes. 14 of the crashes involved single vehicles.
- Merriam Avenue at Route 2 eastbound ramps – Crash rate (1.18) higher than District 3 average (0.61) for unsignalized intersections. 21 of the 69 crashes occurred during the weekday evening peak period and 14 crashes occurred with wet pavement conditions.
- Route 2 eastbound off/on-ramps to/from Merriam Avenue – 17 of the 40 total crashes involved single vehicles. Five of the crashes occurred with snowy pavement conditions.
- Route 2 westbound off/on-ramps to/from South Street – 17 of the 50 total crashes involved single vehicles.
- Abbott Avenue (Route 2 westbound) – 16 of the 39 total crashes involved single vehicles.
- Route 2 eastbound off/on-ramps to/from Route 12 – Crash rate (1.89) higher than District 3 average (0.61) for unsignalized intersections. There are a total of 213 crashes with 120 reported as rear-end.
- Route 2 westbound off/on-ramp to/from Route 12 – 22 of the 72 crashes occurred during the evening weekday peak period.
- Route 2 westbound off/on-ramp to/from Route 13 – 80 of the 169 total crashes involved an angle crash. 37 of the crashes occurred during the evening weekday peak period.
- Route 2 westbound off/on-ramps to/from Jackson Road – 33 of the 79 total crashes involved a single vehicle.
- Hosmer Street (Route 2 westbound) – 5 of the 11 total crashes involved an injury.

2.3.2.2 Eastern Study Area

- Concord Rotary - Crash rate (2.73) higher than District 4 average (0.57) for unsignalized intersections. There are a total of 360 crashes with 269 occurring during off-peak hours. There are 2 pedestrian/bike-related crashes.
- Baker Avenue Extension and Elm Street – Crash rate (0.82) higher than District 4 average (0.73) for signalized intersections. 33 of the 89 total crashes involved an injury.
- Main Street (Route 62) – 67 of the 89 total crashes are rear-end type.
- Sudbury Road – 53 of the 70 total crashes are rear-end type.

- Walden Street (Route 126) – 1 crash involved a bicyclist/pedestrian. 55 of the 68 total crashes are rear-end type.
- Bedford Road (Tracey's Corner) – 29 of the 92 total crashes involved an injury.

A figure showing the crash clusters from 2013 to 2019 along the Route 2 corridor study area are shown in the Appendix.

2.3.3 Highway Safety Improvement Program (HSIP)

The Highway Safety Improvement Program (HSIP) was established under the 'Moving Ahead for Progress in the 21st Century Act' (MAP-21) as a Federal-aid funding program to achieve significant reduction in fatalities and serious injuries on all public roads. Projects using HSIP funding are selected based the top five percent regional crash location list and identified in the Strategic Highway Safety Plan (SHSP). An HSIP-eligible cluster is one in which the total number of "equivalent property damage only [4]"crashes in the area is within the top 5 percent of all clusters in that region. Being HSIP-eligible makes the location eligible for FHWA and MassDOT funds to address the identified safety issues at these locations.

Four study area intersections are on the most recent Top Crash Locations GIS-based website (https://gis.massdot.state.ma.us/topcrashlocations/). The crash clusters that are identified in the study area show both Top 200 intersections and HSIP intersections (2014-2016), as well as Bicycle and Pedestrian Clusters (2007-2016). This website is hosted by MassDOT under the authority of United States Code Title 23, Section 148, Highway Safety Improvement Program, sponsored by the Federal Highway Administration. Table 2-7 presents the list of study area intersections on the statewide HSIP intersection crash list and their respective EPDO.

Table 2-7 HSIP Locations

Location	Cluster Type	EPDO
Hawes Street at Commercial Road (Route 2 at Main Street – Route 13)	HSIP	143
Route 2/Route 111/ Taylor Road and Piper Road	Top 200	294
Route 2 at Baker Avenue Ext/Elm Street	HSIP	129
Route 2 at Bedford Road (Tracey's Corner)	HSIP	152

Source: MassDOT – Top Crash Locations website, 2020.

2.3.4 Road Safety Audit

The Federal Highway Administration (FHWA) defines a Road Safety Audit (RSA) as "the formal safety examination of an existing or future road or intersection by an independent, multidisciplinary team". The purpose of an RSA is to identify elements of a roadway or intersection that may present safety concerns and possible opportunities to mitigate these issues for all roadway users. As part of the Route 2 Corridor Study, RSAs were conducted in January 2020 at the intersections of Route 2 at Baker Avenue Extension & Elm Street in Concord and Route 2 at Bedford Road in Lincoln to identify potential short, mid, and long-term improvements. The RSA reports are included in the Technical Appendix.

4 "Equivalent property damage only" is a method of combining the numbers of crashes with the severity of the crashes based on a weighted scale. Crashes involving property damage only are reported at a minimal level of importance, while collisions involving personal injury (or fatalities) are weighted more heavily.

Prior to the commencement of the Route 2 Corridor Study, RSAs were conducted (by others) at the following additional study area locations:

- Concord Rotary
- Route 2 at Taylor Road and Piper Road
- Route 2 at Lunenburg Road (Route 70)
- Route 2 at I-495
- Route 2 at Main Street (Route 13)

A review of each additional RSA was completed as part of this study to identify if potential safety enhancements from the RSA should be considered. MassDOT compiles all RSAs that are conducted in the commonwealth at (https://gis.massdot.state.ma.us/roadsafetyaudits/).

The RSAs discussed a series of issues at each intersection from a safety perspective. Among others, these issues include significant traffic congestion, faded pavement markings, substandard pedestrian accommodations, limited signal head visibility, sight distance issues, and lack of emergency vehicle preemption. Recommended improvements include signal timing/phasing adjustments, signage and pavement marking updates/installation, pedestrian signal equipment/replacement and wheelchair ramp realignment, as well as emergency vehicle preemption. Below details some of the issues and enhancements that were discussed at each RSA.

2.3.4.1 Route 2 at Baker Avenue Extension at Elm Street

A major theme from the RSA included the non-standard geometry (jughandle and merging Elm Street) of the intersection. Audit participants mentioned that jughandles can be confusing for drivers and that a redesign to a more standard intersection that allowed left-turns for each approach could be an enhancement. It was also mentioned that the Elm Street merge could be redesigned with a more perpendicular approach to Route 2 traffic which could provide better sightlines for Elm Street drivers.

2.3.4.2 Route 2 at Bedford Road (Tracey's Corner)

Similar to Baker Avenue Extension, audit participants noted the non-standard use of jughandles for the intersection. While jughandles weren't necessarily suggested to be removed, enhancements to the jughandles with more clear signage and updated geometry were noted as potential enhancements.

It should be noted that both locations had a prevalence of rear-end crashes, specifically for the Route 2 approaches. A potential enhancement for this type of crash are advance warning signs, specifically "Red Signal Ahead" signs that provide early indication of a potential red light. In addition, both locations were noted as having limited pedestrian and bicyclist accommodations and that sidewalks, crosswalk locations, and bicyclist facilities should be considered. Finally, outdated signal equipment should be updated with high-visibility backplates.

2.4 Transportation Infrastructure Review

A detailed review of current roadway, intersection, and interchange geometrics, as well as inventory of traffic control was completed to facilitate establishment of existing conditions.

This information is intended to identify current roadway design and traffic control deficiencies and which roadway segments and intersections should be more closely examined as part of the development of future recommendations for the corridor.

2.4.1 Roadway Geometry & Traffic Control Inventory

Record construction plans for the Route 2 corridor were obtained from MassDOT. Where record plan information was not available, base plans were developed using aerials and supplemented with MassGIS data and field visits.

Two primary types of access control were evaluated within the western (District 3) study area: right-in/right out access and grade-separated interchange access. Table 2-8 and Table 2-9 list the right-in/right-out and interchange design criteria, respectively, as presented in the AASHTO's *A Policy on Geometric Design of Highways and Streets*, 2018. E-20-001 refers to the FHWA Standard/ Controlling Criteria.

All study area locations within the eastern (District 4) study area, excepting the Concord Rotary, are at-grade signalized intersections, which were inventoried, and included the intersection of Route 2 with Taylor/Piper Road in District 3.

2.4.1.1 Right-in/Right-out Only Locations

Right-in/right-out only intersections exist along the Route 2 corridor in the western (District 3) study area. The following presents design criteria/standards (Table 2-8), as well as a geometric review of the current acceleration and deceleration conditions at these locations (Table 2-9).

Table 2-8 Right-in/Right-out Design Criteria

Design Element	Criteria (55 MPH)[1]	Criteria (65 MPH)[2]	Reference[3]
Deceleration Length	455 ft	540 ft	Table 10-5 & 10-6 (p. 10-133 & 10-138)
Deceleration Taper	180 ft	180 ft	AASHTO 10.9.6.6.2 (p 10-139)
Acceleration Length	900 ft	1350 ft	Table 10-4 & 10-5 (p. 10-132 & 10-133)
Acceleration Taper	300 ft	300 ft	AASHTO 10.9.6.5 (p 10-128)
Minimum Ramp Design Speed	15 mph	15 mph	Table 10-1 (p. 10-105)

Source: A Policy on Geometric Design of Highways and Streets, AASHTO, 2018. (2018 Green Book)

1 Design criteria assume 45 mph mainline posted speed, single-lane, and flat grade. (45 mph for 1.25 miles in Fitchburg – SSR #7490)

2 Design criteria assume 55 mph mainline posted speed, single-lane, and flat grade.

3 Figure and page numbers refer to the 2018 Green Book.

Table 2-9 Right-in/Right-out Existing Conditions

Right-in/Right out Location	Existing Deceleration		Existing Acceleration	
	Measured Length	Meets Standards	Measured Length	Meets Standards
Eastbound				
Palmer Road	495′	No	0′	No
Mt Elam Road	0′ (Ramp 420′)	No	N/A (Signalized)	N/A (Signalized)
Abbott Avenue	N/A (Weave)	N/A (Weave)	590′	No
Hosmer Street	465′	No	435′	No
School Street	225′	No	285′	No
Westbound				
Wetherbee Street	0′	No	0′	No
Hosmer Street	485′	No	345′	No
Abbott Avenue	470′	No	530′	No
Mt Elam Road	0′ (400′ Ramp)	No	0′	No
Oak Hill Road	490′	No	700′	No

Note: Lengths measured from aerial and include taper lengths.

2.4.1.2 Interchange Locations

Grade-separated interchange locations exist along the Route 2 corridor in the western (District 3) study area. The following presents design criteria/standards, as well as a geometric review of the current conditions at these locations.

A review of the roadway geometry indicated that the majority of the currently provided acceleration lanes, deceleration lanes, and ramps at study area locations do not meet segment length standards. The following presents design criteria/standards (Table 2-10), as well as a geometric review of the current interchange conditions at these locations (Tables 2-11 and 2-12).

Table 2-10 Service Interchange Design Criteria

Design Element	Criteria[1]	Reference[2]
Deceleration Length	540 ft	Table 10-5 & 10-6 (p. 10-133 & 10-138)
Acceleration Length	1,350 ft	Table 10-4 & 10-5 (p. 10-132 & 10-133)
Distance between ramp terminals	500-2,000 ft	Figure 10-70 (p. 10-127)[3]
Minimum Ramp Design Speed	30 mph	Table 10-1 (p. 10-105)
Ramp Width	22 ft	Table 3-27 (p. 3-109)
Ramp Length	1,000 ft	Engineering Directive E-20-001

Source: A Policy on Geometric Design of Highways and Streets, AASHTO, 2018. (2018 Green Book)

1 Design criteria assume 65 mph mainline design speed, single-lane ramps, and flat grade.

2 Figure and page numbers refer to the 2018 Green Book.

3 EN-EX condition is controlled by the weaving section distance.

Table 2-11 Interchange Existing Conditions (Off-Ramps)

Right-in/Right out Location	Existing Deceleration		Existing Ramp	
	Measured Length	Meets Standards	Measured Length	Meets Standards
Eastbound				
Merriam Avenue	530′	No	700′	No
N. Main Street (Route 12)	545′	No	730′	No
Main Street (Route 13)	500′	No	700′[1]	No[1]
Jackson Road	1,150′	Yes	1,670′	Yes
Westbound				
Jackson Road (To NB)	1000	Yes	1,500′	Yes
Jackson Road (To SB)	NA (Weave)	NA (Weave)	1,100′	Yes
Main Street (Route 13)	500′	No	1,000′[1]	No[1]
N. Main Street (To Route 12 NB)	580	No	410′	No
N. Main Street (To Route 12 SB)	400	No	250′	No
Merriam Avenue	450′	No	655′	No

Note: Lengths measured from aerial and include taper lengths.
1 Not a proper ramp with driveway access points along ramp.

Table 2-12 Interchange Existing Conditions (On-Ramps)

Right-in/Right out Location	Existing Acceleration		Existing Ramp Length	
	Measured Length	Meets Standards	Measured Length	Meets Standards
Eastbound				
Merriam Avenue	NA (Weave)	NA (Weave)	720′	No
N. Main Street (Route 12 - From SB)	340′	No	385′	No
N. Main Street (Route 12 - From NB)	720′	No	270′	No
Main Street (Route 13)	650′	No	500′	No
Jackson Road	1,300′	No	950′	No
Westbound				
Jackson Road (From NB)	N/A (Weave)	N/A (Weave)	380	No
Jackson Road (From SB)	1800′	Yes	1160′	Yes
Main Street (Route 13)	720′	No	1000′[1]	No[1]
N. Main Street (Route 12)	1,500′	No	280′	No
Merriam Avenue	610′	No	480′	No

Note: Lengths measured from aerial and include taper lengths.
1 Not a proper ramp with driveway access points along ramp.

2.4.1.3 Signalized Locations

Signal inventories were conducted from December 2019 to January 2020 that involved reviewing sequence/timing data, inventorying existing signal hardware, conditions, and operations. A summary was submitted for each District that identified deficiencies and recommended upgrades at each location. The majority of the issues identified included vehicle detection, pedestrian button, GPS (clock), and emergency strobe operations (pre-emption). The signal sequence and timing data identified from the inventory were used as inputs to model the existing traffic operations. The inventory notes are included in the Technical Appendix.

2.5 Existing Traffic Operations

The next step in the study process was to evaluate the current operations provided by the study area roadway, interchanges, and intersections. This analysis provides a technical assessment of the existing operational qualities of the highway segments, interchange ramps, weaving segments, signalized intersections, and the Concord Rotary using the procedures outlined in the Highway Capacity Manual 6th Edition (HCM 6)[5]. The traffic analysis was conducted using the existing (2019) weekday morning and weekday evening peak hour traffic volumes, traffic control and the geometric design conditions as they currently exist along the corridor.

The traffic engineering profession uses "level-of-service" as the qualitative measurement denoting the different operating conditions that occur under various traffic volume loadings. Level-of-service incorporates a number of factors including roadway geometrics, vehicular speeds, delay, freedom to maneuver, and safety. Level-of-service (LOS) designations are assigned to specific locations and range from A to F. LOS A represents the best operating condition with free flow and minimal delay. LOS F represents the worst condition with congestion and long delays. LOS A through D are typically considered desirable conditions for urban intersections by state and local transportation agencies. LOS E and F conditions are often considered to be undesirable, although frequently encountered in urban settings.

2.5.1 Western (District 3) Study Area

The Western portion of Route 2 (District 3) primarily consist of a limited access highway with interchanges. This section was evaluated using basic freeway, diverge, merge, and weaving segment analyses.

2.5.1.1 Basic Freeway (Limited Access Highway) Segment Operations

The capacity of Route 2 limited access mainline segments in District 3 were analyzed using procedures outlined in Chapter 12, Basic Freeway Segments, of the HCM 6. According to the HCM 6, a four-lane limited access highway can process approximately 2,400 passenger vehicles per lane per hour under optimal operating conditions. This optimal capacity is influenced by a number of factors including the number of heavy vehicles such as trucks or buses within the traffic stream, the terrain, lane widths, the presence of obstructions adjacent to the roadway, the composition of the driver population

5 Highway Capacity Manual, 6th Edition: A Guide for Multimodal Mobility Analysis, Transportation Research Board, National Research Council, Washington, D.C., 2016.

(commuters who are familiar with the roadway or infrequent users), and the prevailing speed of the traffic flow.

Three measures provide an indication of how well traffic flow is accommodated by a limited access highway segment. These measures include density of passenger cars per mile per lane of roadway, average speed of passenger cars, and volume to capacity ratio. These measures are interrelated, but the primary measure used to provide an estimate of level of service is density. As the density of vehicles per mile of roadway increases, the speed and flow rate tend to decrease while the level of service declines. The term level-of-service is used to define the operational characteristics of traffic flow along a given roadway. A letter grade from LOS A (representing free-flow traffic conditions) to LOS F (representing an unacceptable level of congestion) is assigned to a specific segment of the roadway. Table 2-13 present the criteria for freeway segment level of service.

Table 2-13 Freeway (Limited Access Highway) Level of Service Criteria

Level of Service	Freeway Density[1]
A	0 to 11
B	> 11 to 18
C	> 18 to 26
D	> 26 to 35
E	> 35 to 45
F	> 45

Source: Transportation Research Board, Highway Capacity Manual (HCM 6), (Washington, DC).
1 Density is expressed in passenger cars per mile per lane

The results of the basic freeway segment analysis for Route 2 under morning and evening peak hour conditions are summarized in Table 2-14. Capacity analysis worksheets for basic freeway segments are included in the Appendix. Key results include:

- Route 2 Eastbound – During the morning peak hour, eight of the nine segments in District 3 operate under congested conditions (LOS E). During the evening peak hour, the eastbound direction of Route 2 is generally operating at acceptable levels within the study area (seven of the nine segments operate LOS C).
- Route 2 Westbound – During the morning peak hour, eight of the nine segments in District 3 operate near free-flow conditions (LOS C or better). During the evening peak hour, the westbound direction of Route 2 is generally operating under congested levels within the study area (seven of the nine segments operate LOS E or worse).

Table 2-14 Route 2 Freeway Segment Capacity Analyses Summary — 2019 Existing Conditions

Freeway Segment Description		Weekday Morning Peak Hour			Weekday Evening Peak Hour		
From	To	Volume1	Density2	LOS3	Volume	Density	LOS
Eastbound							
Princeton Road (Route 31)	Palmer Road	3,020	36.1	E	1,880	22.4	C
Palmer Road	Mt. Elam Road	3,020	38.1	E	1,885	21.6	C
Mt. Elam Road	Merriam Avenue	3,025	41.8	E	1,885	24.8	C
Merriam Avenue	Abbott Avenue	3,325	40.2	E	2,080	25.1	C
Abbott Avenue	N. Main Street (Route 12)	3,160	37.6	E	1,990	23.7	C
N. Main Street (Route 12)	Main Street (Route 13)	3,590	40.2	E	2,470	29.1	D
Main Street (Route 13)	I-190	3,940	44.8	E	2,665	32.1	D
Shirley Road	Jackson Road	3,515	40.4	E	1,610	18.4	C
Jackson Road	Ayer Road (Route 110/111)	2,920	33.6	D	1,640	18.9	C
Westbound							
Ayer Road (Route 110/111)	Jackson Road	1,435	16.5	B	2,795	32.1	D
Jackson Road	Shirley Road	1,285	14.9	B	3,335	38.6	E
I-190	Main Street (Route 13)	2,180	27.7	D	3,945	44.6	E
Main Street (Route 13)	N. Main Street (Route 12)	2,035	25.9	C	3,985	45.0	E
N. Main Street (Route 12)	Abbott Avenue	1,675	19.9	C	3,855	46.4	F
Abbott Avenue	Merriam Avenue	1,615	19.4	C	3,570	42.8	E
Merriam Avenue	Mt Elam Rd	1,610	16.3	B	3,805	31.2	D
Mt. Elam Road	Oak Hill Rd	1,595	20.5	C	3,585	40.4	E
Oak Hill Road	Princeton Road (Route 31)	1,600	18.9	C	3,475	41.1	E

Source: VHB, Inc. using HCM 6 methodologies.
Note: Shaded cells denote LOS E or LOS F conditions.
1 Volume – Volume in vehicles per hour on the freeway segment.
2 Density – Expressed in passenger cars per mile per lane.
3 LOS – Level of service rating for the freeway segment, ranging from LOS A (best) to LOS F (worst).

2.5.1.2 Ramp Operations

The analysis of merge and diverge operations at ramps is based on procedures presented in Chapter 14, Freeway Merge and Diverge Segments, of the HCM 6. The procedures focus on the interaction between freeway mainline through traffic and traffic merging from or diverging to ramps. The analysis considers geometric and operational factors such as the length and taper of the acceleration/deceleration lanes, free-flow vehicle speed along the freeway/limited access highway and on the ramps themselves, and the number of vehicles in the right-most (or left-most for left exits) two lanes of the freeway. The focus of the analysis is at the ramp junction with the mainline where entering vehicles attempt to find gaps in the adjacent traffic stream. The action of this merging traffic creates vehicle turbulence along the mainline which can affect operations. The converse of this action is the diverge movement which forces exiting vehicles to shift in advance and occupy the right travel lane in order to exit the mainline causing temporary instability as the vehicles shift lanes and decelerate. According to the HCM, the influence area for these movements is approximately 1,500 feet before the diverge areas and beyond the merge areas (including acceleration and deceleration lanes). Table 2-15 presents the LOS criteria.

Table 2-15 Ramp Level of Service Criteria

Level of Service	Ramp Density[1]
A	0 to 10
B	> 10 to 20
C	> 20 to 28
D	> 28 to 35
E	> 35
F	Demand exceeds capacity

Source: Transportation Research Board, Highway Capacity Manual (HCM 6), (Washington, DC).
1 Density is expressed in passenger cars per mile per lane

The results of the merge and diverge analyses for Route 2 are presented in Tables 2-16 and 2-17, respectively. Capacity analysis worksheets for ramp merges and diverges are included in the Appendix.

Key results of the merge analyses (Table 2-16) include:

› Route 2 Eastbound – During the morning peak hour, three of the eight on-ramps to Route 2 eastbound operate under congested conditions (LOS E/F). During the evening peak hour, all eight eastbound on-ramps operate at LOS C or better.

› Route 2 Westbound – During the morning peak hour, all nine westbound on-ramps operate near free-flow conditions (LOS C or better). During the evening peak hour, four of the nine on-ramps operate under congested levels within the study area (LOS E/F).

Key results of the diverge analyses (Table 2-17) include:

› Route 2 Eastbound – During the morning peak hour, all off-ramps operate at LOS D or better, with the exception of the I-190 off-ramp (Exit 33) which operates at LOS F. Similarly, all off-ramps operate at LOS C or better during the evening peak hours.

› Route 2 Westbound – During the morning peak hour, all nine westbound off-ramps operate at LOS C or better. In the evening peak hour, five of the nine westbound off-ramps operate under congested conditions (LOS E).

Poor operations at these locations are influenced by heavy mainline volumes, heavy ramp volumes and the presence of nearby upstream and downstream off-ramps.

Table 2-16 Route 2 Ramp Capacity Analyses (Merge) Summary — 2019 Existing Conditions

	Weekday Morning Peak Hour			Weekday Evening Peak Hour		
Ramp Location	**Volume[1]**	**Density[2]**	**LOS[3]**	**Volume**	**Density**	**LOS**
Eastbound						
Palmer Road	0	33.0	D	5	22.7	C
Mt Elam Road	5	34.4	D	5	21.9	C
Merriam Avenue	670	35.4	E	460	23.1	C
Abbott Avenue	35	30.3	D	15	19.6	B
N. Main Street (Route 12)	665	34.5	D	495	23.5	C
	180	35.2	E	245	24.5	C
Main Street (Route 13)	695	38.5	F[4]	520	26.6	C
Jackson Road	120	23.6	C	255	11.6	B
Westbound						
Jackson Road	5	13.6	B	5	25.5	C
	235	13.4	B	705	29.5	D
I-190	1,225	17.2	B	1,630	30.4	F[4]
Main Street (Route 13)	185	21.4	C	430	35.6	E
N. Main Street (Route 12)	180	12.0	B	645	31.1	D
Abbott Avenue	150	17.6	B	215	35.3	E
Merriam Avenue	190	17.5	B	525	33.3	D
Mt Elam Road	45	19.2	B	40	36.1	E
Oak Hill Road	75	17.4	B	45	34.6	D

Source: VHB, Inc. using HCM 6 methodologies.
Note: Shaded cells denote LOS E or LOS F conditions.
1 Volume – Volume in vehicles per hour on the ramp segment.
2 Density – Expressed in passenger cars per mile per lane.
3 LOS – Level of service rating for the freeway segment, ranging from LOS A (best) to LOS F (worst).
4 LOS F due to demand greater than capacity.

Table 2-17 Route 2 Ramp Capacity Analyses (Diverge) Summary — 2019 Existing Conditions

Ramp Location	Weekday Morning Peak Hour			Weekday Evening Peak Hour		
	Volume[1]	Density[2]	LOS[3]	Volume	Density	LOS
Eastbound						
Palmer Road	0	30.1	D	0	18.7	B
Mt Elam Road	0	34.6	D	5	20.7	C
Merriam Avenue	370	31.3	D	265	18.4	B
Abbott Avenue	200	34.1	D	105	21.6	C
N. Main Street (Route 12)	415	31.3	D	260	19.6	B
Main Street (Route 13)	345	34.8	D	325	23.5	C
I-190	1,740	33.9	F[4]	1,395	21.1	C
Jackson Road	715	32.8	D	225	13.8	B
Westbound						
Jackson Road	385	14.2	B	165	25.2	C
	5	11.9	B	5	25.4	C
Main Street (Route 13)	330	23.5	C	390	37.7	E
N. Main Street (Route 12)	345	21.9	C	505	37.8	E
	195	19.1	B	270	33.9	D
Abbott Avenue	210	17.5	B	500	39.4	F[4]
Merriam Avenue	195	16.8	B	290	31.7	D
Mt Elam Road	60	17.6	B	260	38.3	E
Oak Hill Road	70	16.5	B	155	36.5	E

Source: VHB, Inc. using HCM 6 methodologies.
Note: Shaded cells denote LOS E or LOS F conditions.
1 Volume – Volume in vehicles per hour on the ramp segment.
2 Density – Expressed in passenger cars per mile per lane.
3 LOS – Level of service rating for the freeway segment, ranging from LOS A (best) to LOS F (worst).
4 LOS F due to demand greater than capacity.

2.5.1.3 Weaving Segment Operations

The analysis of weaving operations at interchange ramps is based on procedures presented in Chapter 13, Freeway Weaving Segments, of the HCM 6. A weaving movement is defined as the interaction between the crossings of two or more traffic streams traveling in the same direction without the aid of traffic control devices. The measure of effectiveness to determine the level of service is based on many parameters, including density and the speed of both the weaving and non-weaving vehicles. The higher the speeds and lower the density, the better the operations of the weaving segment. Similar to ramp merge and diverge areas, LOS D (as defined in the Highway Capacity Manual) is considered to be the acceptable limit and LOS E or F conditions are typically considered unacceptable.

Table 2-18 summarizes the LOS criteria for weaving segments.

Table 2-18 Weave Level of Service Criteria

Level of Service	Weave Density[1]
A	0 to 10
B	> 10 to 20
C	> 20 to 28
D	> 28 to 35
E	> 35 to 43
F	> 43, or demand exceeds capacity

Source: Transportation Research Board, Highway Capacity Manual (HCM 6), (Washington, DC).
1 Density is expressed in passenger cars per mile per lane

The results of the weaving segment analysis for Route 2 under morning and evening peak hour conditions are summarized in Table 2-19. Capacity analysis worksheets for weaving segments are included in the Appendix. Key results include:

- Route 2 Eastbound – During the morning peak hour, three weaving segments operate at LOS F due to demand greater than capacity. In the evening peak hour, only one of the weaving segments operates under congested conditions (LOS E), with the other segments operating LOS C or better.
- Route 2 Westbound – During the morning peak hour, all weaving segments operate at LOS C or better. During the evening peak hour, the I-190 to Route 13 weaving segment operates under congested conditions (LOS F), while the remaining segments operate at LOS D or better.

Table 2-19 Route 2 Weaving Segments Capacity Analyses Summary — 2019 Existing Conditions

	Weekday Morning Peak Hour			Weekday Evening Peak Hour		
Weave Segment Description	Demand[1]	Density[2]	LOS[3]	Demand	Density	LOS
Eastbound						
Merriam Avenue to Abbott Avenue	3,325	N/A[4]	F	2,080	26.1	C
Route 13 to I-190	3,690	N/A[4]	F	2,655	37.5	E
Taylor Street to I-495 SB	3,086	30.2	D	1,435	12.9	B
I-495 SB to I-495 NB	3,566	N/A[4]	F	1,985	21.5	C
Westbound						
I-495 NB to I-495 SB	1,260	10.9	B	2,768	26.6	C
I-495 SB to Taylor Street	1,720	16.1	B	2,918	26.2	C
Jackson Rd NB to Jackson Rd SB	1,065	11.3	B	2,635	30.8	D
I-190 to Route 13	2,010	24.1	C	3,825	N/A[4]	F

Source: VHB, Inc. using HCM 6 methodologies.
Note: Shaded cells denote LOS E or LOS F conditions.
1 Demand – Weave segment demand in vehicles per hour.
2 Density – Expressed in passenger cars per mile per lane.
3 LOS – Level of service rating for the freeway segment, ranging from LOS A (best) to LOS F (worst).
4 Density not available when LOS F.
5 Volumes from Taylor Street Overpass and I-495 Bridge Replacement FDR.

2.5.2 Eastern (District 4) Study Area

The Eastern portion of Route 2 (District 4) primarily consists of a limited access highway with at-grade intersections. This section was completed using signalized and unsignalized (Concord Rotary) analyses. The number and proximity of signalized intersections along the segments of Route 2, east of the rotary, essentially govern the capacity and operations (i.e., LOS) experienced along this portion of the corridor. Often during peak hours of congestion, queue spillback from adjacent intersections further degrades mainline Route 2 operations beyond those presented herein. In addition, the currently poor operations experienced at the Concord Rotary have a cascading effect on operations on Route 2, most notably on the westbound approaches to the rotary and adjacent intersections during the evening peak periods.

2.5.2.1 Re-establishing Coordination Cycle/Split/Offset (CSO)

A review of the existing traffic signal timing within the District 4 sections of Route 2 was conducted. It was found that existing coordination along the corridor was not operating properly due to malfunctioning GPS time synch units and intersections that were manually set to run free.

As a short-term improvement, a new timing plan along with a list of necessary infrastructure repairs was developed to re-establish coordination along the corridor. Development of this timing plan involved evaluation of signal grouping, cycle length, corridor progression, dynamic max considerations, and a review of clearance intervals. This task included an evaluation of the following intersections:

1. Route 2 at Baker Avenue Extension
2. Route 2 at Main Street (Route 62)
3. Route 2 at Old Road to 9 Acre Corner
4. Route 2 at Sudbury Road
5. Route 2 at Walden Street (Route 126)
6. Route 2 at Bedford Road (Tracey's Corner)

In order to determine which intersections in the study area should be coordinated, the speed, distance between intersections, traffic volumes, and natural cycle lengths were considered. Various tools were used to evaluate the applicability of coordination, including the coupling index, time-space diagrams, and Synchro modeling. A series of alternative systems/subsystems and cycle lengths were evaluated. Ultimately, a single coordinated system between Main Street (Route 62) and Walden Street (Route 126) was selected. This option enhances the primary goal of improving progression along the corridor.

The intersection of Baker Avenue was not included in the coordinated system because the desired cycle length was shorter than the optimal cycle length of the coordinated system. However, at this location, timing adjustments were made to address an existing operational challenge for the weekday morning eastbound left-turn lane, which often involved queueing past the available storage. With the intersection operating in isolation, a dynamic maximum (dynamic max) operation was proposed for the left turn protected phase during the weekday mornings which would dynamically extend the associated phase timing for each subsequent cycle to accommodate the variable, but high left-turning volumes.

The intersection of Bedford Road was not included in the coordinated system because of the distance between the nearest adjacent signalized intersection (more than two miles from Walden Street). With the intersection operating under free operation, a dynamic max operation was also proposed at this location for the mainline movements.

These timing changes were implemented in the Spring of 2021 and serve as the existing conditions of this report. Timing changes also included updating the clearance times (red/yellow/pedestrian) to be in accordance with the latest MassDOT guidance.

2.5.2.2 Signalized Intersection Operations

Capacity analyses were conducted for the signalized intersections within the study area to assess the quality of traffic flow. These analyses provide an indication of how well the existing transportation infrastructure handles the existing traffic volumes and provides a basis for assessing operations with forecasted traffic demands. The capacity analyses were conducted using Synchro software (Version 10), which is based on the Highway Capacity Manual, 6th Edition.

Level-of-service for signalized intersections is based on average delay for all vehicles entering the intersection, including initial deceleration delay, queue move-up time, stopped delay, and final acceleration delay. The level-of-service criteria for signalized intersections are presented in Table 2-20.

Table 2-20 Level-of-Service Criteria for Signalized Intersections

Level of Service	Stopped Delay per Vehicle (seconds)
A	<10.0
B	10.1 to 20.0
C	20.1 to 35.0
D	35.1 to 55.0
E	55.1 to 80.0
F	>80.0

Source: Transportation Research Board, Highway Capacity Manual (HCM 6), (Washington, DC).

Capacity analyses were conducted at all intersections along Route 2 within the study area. In addition, capacity analyses were conducted at several predefined intersections within the study area that are adjacent to the Route 2 mainlines and are potentially impacted by traffic entering onto or exiting from Route 2.

The results of signalized intersection capacity analysis for Route 2 intersections in District 4 under existing morning and evening peak hour conditions are summarized in Table 2-21. Capacity analysis worksheets are included in the Appendix.

Key results at signalized intersections include:

- Baker Avenue Extension – The eastbound left queue during the morning peak hour is longer than storage length with operations at LOS E. Operations at this intersection are predominantly impacted by the operations of the Concord Rotary which is located 0.5-mile to the west.
- Main Street (Route 62) – The eastbound through movement experiences high delays and long queues during both peak periods, with LOS E and F during the morning and evening peak hour, respectively. Similarly, the westbound left-turn movement during the morning and evening peak hour experiences long delays and queues, furthermore, during the evening peak hour the queues

exceed the provided storage length. The northbound approach experiences long delays and operates at LOS F during both peak periods, while the southbound approach operates at LOS F during the evening peak hour.

- Old Road to 9 Acre Corner – The eastbound through movement operates at LOS E in the evening peak hour. Both eastbound and westbound left-turn movements operate at LOS E during both peak periods, however, the westbound left-turn movement during the evening peak hour has occasional queueing extending past the storage area. A few of the side street movements operate at LOS E or worse but the queuing is manageable.
- Sudbury Road – The eastbound through movement operates at LOS E in the evening peak hour. The westbound left-turn movement operates at LOS F during both peak periods. The northbound approach operates at LOS E while the southbound approach operates at LOS F during both peak periods. The intersection operates overall at LOS D during both peak periods.
- Walden Street – The eastbound through movement operates at LOS F and E during the morning and evening peak periods, respectively. Five of the six side street movements operate at LOS E or F during the morning peak period, while four of the six movements operate at LOS E or F during the evening peak period. The intersection operates overall at LOS E during both peak periods.
- Bedford Road – The intersection operates at overall LOS F with 91 seconds of delay during both peak periods. The eastbound movement operates at LOS F during the morning peak period and LOS E during the evening peak period. The westbound through movement operates at LOS F during the evening peak period. The southbound left movement operates at LOS F during the morning peak period. The northbound left and through movements operate at LOS E or F during both peak periods.

Table 2-21 Signalized Intersection Capacity Analysis – 2019 Existing Conditions

	Weekday Morning Peak Hour					Weekday Evening Peak Hour				
Location/Movement	v/c [a, f]	Del [b]	LOS [c]	50 Q [d]	95 Q [e]	v/c	Del	LOS	50 Q	95 Q
Route 2 at Baker Avenue Extension										
EB L	0.92	60	E	248	#425	0.71	42	D	100	#198
EB T/R	0.83	12	B	398	524	0.72	12	B	273	351
WB T	0.97	45	D	436	#599	0.85	28	C	297	382
WB R	0.09	18	B	0	37	0.02	16	B	0	0
NB L	0.72	60	E	51	#124	0.82	46	D	126	#257
NB T	0.31	38	D	45	89	0.17	25	C	31	68
NB R	0.01	36	D	0	0	0.05	24	C	0	13
SB L	0.06	36	D	6	22	0.06	24	C	7	24
SB T	0.73	49	D	117	187	0.14	25	C	25	55
Overall	**0.92**	**30**	**C**			**0.86**	**22**	**C**		

Table 2-21 Signalized Intersection Capacity Analysis – 2019 Existing Conditions

	Weekday Morning Peak Hour					Weekday Evening Peak Hour				
Location/Movement	v/c [a, f]	Del [b]	LOS [c]	50 Q [d]	95 Q [e]	v/c	Del	LOS	50 Q	95 Q
Route 2 at Main Street (Route 62)										
EB T	1.00	56	E	~748	#932	1.08	88	F	~766	#905
EB R	0.01	0	A	0	0	0.02	0	A	0	0
WB L	0.95	97	F	189	m#278	1.06	120	F	~430	m#647
WB T	0.60	12	B	205	m238	0.52	8	A	159	252
WB R	0.00	7	A	0	m0	0.01	13	B	1	m4
NB T	0.97	84	F	362	#572	1.01	107	F	~254	#442
NB R	0.53	46	D	116	230	0.59	49	D	143	258
SB T	0.40	44	D	133	175	0.79	58	E	284	#421
Overall	**0.99**	**45**	**D**			**1.06**	**63**	**E**		
Route 2 at Old Rd to 9 Acre Corner										
EB L	0.69	68	E	61	m66	0.57	64	E	28	m29
EB T	0.99	28	C	~497	m#848	1.10	61	E	~864	m#794
EB R	0.13	12	B	11	m12	0.09	2	A	0	m0
WB L	0.86	79	E	134	m#184	0.92	67	E	252	m#409
WB T/R	0.80	23	C	486	326	0.76	24	C	765	840
NB L	1.01	>120	F	100	#225	0.91	118	F	67	#163
NB T	0.79	60	E	225	329	0.56	50	D	136	211
NB R	0.39	35	D	100	166	0.16	26	C	40	80
SB L	N/A	N/A	N/A	N/A	N/A	0.17	45	D	20	47
SB T/R	0.79	60	E	215	236	0.85	70	E	219	#316
Overall	**1.00**	**35**	**C**			**1.02**	**46**	**D**		
Route 2 at Sudbury Road										
EB L	0.62	108	F	14	m16	0.80	49	D	41	m41
EB T	1.08	54	D	~988	m#1020	1.03	78	E	~821	m705
EB R	0.01	15	B	0	m0	0.01	17	B	0	m0
WB L	0.87	89	F	126	m#177	0.97	87	F	~289	m#312
WB T	0.83	18	B	212	485	0.83	14	B	306	m314
WB R	0.00	10	B	0	m0	0.01	9	A	0	m0
NB L/T/R	0.82	62	E	251	#386	0.74	61	E	174	230
SB L/T/R	0.97	98	F	192	#338	0.89	81	F	194	#319
Overall	**1.05**	**43**	**D**			**0.99**	**50**	**D**		

Table 2-21 Signalized Intersection Capacity Analysis – 2019 Existing Conditions

	Weekday Morning Peak Hour					Weekday Evening Peak Hour				
Location/Movement	v/c [a, f]	Del [b]	LOS [c]	50 Q [d]	95 Q [e]	v/c	Del	LOS	50 Q	95 Q
Route 2 at Walden Street										
EB L	0.31	81	F	4	m5	0.75	78	E	33	m33
EB T	1.19	100	F	~1142	m#1041	1.11	75	E	~916	m#879
EB R	0.12	1	A	1	m0	0.08	31	C	6	m6
WB L	0.75	92	F	53	#134	0.82	74	E	167	#281
WB T	0.86	29	C	501	#776	1.02	53	D	~989	#1125
WB R	0.06	6	A	0	14	0.13	9	A	11	35
NB L	0.86	102	F	92	#195	0.52	56	E	87	148
NB T	1.06	>120	F	~131	#260	0.90	92	F	167	#314
NB R	0.22	58	E	11	79	0.03	51	D	0	0
SB L	1.05	>120	F	~256	#437	0.54	60	E	68	122
SB T	0.77	65	E	176	#293	0.67	68	E	92	156
SB R	0.02	0	A	0	0	0.02	0	A	0	0
Overall	**1.14**	**72**	**E**			**1.02**	**61**	**E**		
Route 2 at Bedford Road										
EB T	1.20	120	F	~1164	#1845	1.08	70	E	~737	#1433
EB R	0.02	10	B	4	20	0.03	11	B	7	31
WB T	0.95	36	D	604	#1278	1.19	117	F	~996	#1653
WB R	0.12	11	B	30	92	0.13	12	B	31	97
NB L	0.39	59	E	16	#61	1.11	>120	F	~66	#188
NB T	0.83	99	F	63	#198	0.88	86	F	108	#253
NB R	0.18	57	E	0	#127	0.06	47	D	0	7
SB L	>1.20	>120	F	~229	#416	0.75	52	D	88	#259
SB T	0.72	52	D	170	291	0.99	87	F	262	#622
SB R	0.01	39	D	0	0	0.02	34	C	0	0
Overall	**>1.20**	**91**	**F**			**1.15**	**91**	**F**		

Source: VHB, Inc. using Synchro 9/10 software
Note: Shaded cells denote LOS E or LOS F conditions.
a Volume to capacity ratio.
b Average total delay, in seconds per vehicle.
c Level-of-service.
d 50th percentile queue, in feet.
e 95th percentile queue, in feet.
f Overall v/c is noted as Intersection Capacity Utilization (ICU).
~ Volume exceeds capacity, queue is theoretically infinite.
# 95th percentile volume exceeds capacity; queue may be longer.
m Volume for 95th percentile queue is metered by upstream signal.

2.5.2.3 Concord Rotary Operations

The majority of the intersections in the Report are analyzed using software packages imploring the Highway Capacity Manual (HCM) methodologies. Operations for the unique nature of the Concord Rotary could not be accurately reflected by those methods, therefore VISSIM has been used to analyze Concord Rotary in all analysis scenarios. For the 2019 Existing and 2039 No-Build Conditions, the Concord Rotary was analyzed as an unsignalized intersection. For unsignalized intersections, level-of-service is based on stopped delay for vehicles on the side street approaches since the main street traffic is not affected by side street traffic. The level-of-service criteria for unsignalized intersections are presented in Table 2-21.

Table 2-22 Level-of-Service Criteria for Unsignalized Intersections

Level of Service	Stopped Delay per Vehicle (seconds)
A	<10.0
B	10.1 to 15.0
C	15.1 to 25.0
D	25.1 to 35.0
E	35.1 to 50.0
F	>50.0

Source: Transportation Research Board, Highway Capacity Manual (HCM 6), (Washington, DC).

VISSIM Methodology

VISSIM is a transportation planning and operations software package designed to provide a sophisticated visual and analytical representation of traffic operations on a full range of functionally classified roadways. A VISSIM simulation includes a coded network that relies on driver behavior and a calibrated model for evaluation. A write-up regarding the simulation methodology, network set-up, model calibration and application, and driver behavior settings are included in the Appendix.

During the corridor study, "Retrofit" conditions were provided for the Concord Rotary. The improvements included deflection angle changes to the approaches and reduced the circulating roadway to a single lane at the entry point for Route 2 eastbound and westbound, while maintaining two lanes for the other approaches. Similar to Existing Conditions, Vissim analyses were conducted for the Retrofit Conditions utilizing 2019 Existing Volumes. Table 2-23 presents a summary of the VISSIM analyses under Existing Conditions, while Table 2-24 presents a summary of the Retrofit Conditions using existing volumes.

Table 2-23 Concord Rotary Capacity Analysis – 2019 Existing Conditions

	Weekday Morning Peak Hour					Weekday Evening Peak Hour				
Location/Movement	Dem [a]	Del [b]	LOS [c]	Avg Q [d]	Max Q [e]	Dem	Del	LOS	Avg Q	Max Q
21: Route 2 at Concord Rotary										
Route 2 EB	1,540	>120	F	2,437	4,448	1,900	104	F	1,036	2,789
Route 2 WB	1,480	21	C	98	559	1,765	>120	F	3,566	5,033
Commonwealth Ave NB	235	>120	F	1,108	2,264	465	>120	F	2,125	3,065
Route 2A SWB	545	>120	F	2,339	4,602	410	26	D	37	294
Barretts Mill Rd SEB	235	28	D	32	221	405	>120	F	1,805	2,185
Overall		**>120**	**F**				**>120**	**F**		

Source: VHB, Inc. using Vissim 11 software
Note: Shaded cells denote LOS E or LOS F conditions.
A Volume
b Average total delay, in seconds per vehicle.
c Level-of-service.
d Average queue, in feet.
e Maximum queue, in feet.

Table 2-24 Concord Rotary Capacity Analysis – 2019 Retrofit Conditions

	Weekday Morning Peak Hour					Weekday Evening Peak Hour				
Location/Movement	Dem [a]	Del [b]	LOS [c]	Avg Q [d]	Max Q [e]	Dem	Del	LOS	Avg Q	Max Q
21: Route 2 at Concord Rotary										
Route 2 EB	1,540	103	F	1,413	1,674	1,900	69	F	1,356	1,674
Route 2 WB	1,480	19	C	91	569	1,765	>120	F	1,590	1,674
Commonwealth Ave NB	235	35	D	68	359	465	96	F	362	865
Route 2A SWB	545	>120	F	1,353	1,674	410	73	F	218	565
Barretts Mill Rd SEB	235	29	D	34	250	405	>120	F	1,089	1,169
Overall		**68**	**F**				**108**	**F**		

Source: VHB, Inc. using Vissim 11 software
Note: Shaded cells denote LOS E or LOS F conditions.
A Volume
b Average total delay, in seconds per vehicle.
c Level-of-service.
d Average queue, in feet.
e Maximum queue, in feet.

As shown in Table 2-24, the Retrofit conditions appear to provide an overall delay benefit for both morning and evening peak periods, however, the overall operations are maintained at LOS F.

2.6 Multimodal Conditions

The following section summarizes the bicycle, pedestrian, and transit accommodations within the study area.

2.6.1 Bicycle and Pedestrian Mobility

Bicycle and Pedestrian mobility and accommodation is an important component of the transportation system throughout Massachusetts, including in and around the study area. Walking and bicycling are especially useful for shorter trips (less than five miles). They can be use used for commuting, errands, and recreational purposes. Currently a significant portion of the study area related to the Route 2 mainline has little to no bicycle accommodations. However, local intersecting streets and recreational trails currently provide some options for bicyclists and should be evaluated for increased bicycle accommodation. Similarly, there is some accommodation for pedestrians with regards to sidewalks and at traffic signals, however, it is inconsistent and sporadic throughout the study area.

The Statewide Bicycle Transportation Plan, completed in May 2019, is the statewide resource for bicycle planning in Massachusetts. This plan does not highlight any specific future projects or improvements directly along the Route 2 corridor. However, according to MassDOT's statewide database of existing and planned bikeways, there are 3 planned paths that will cross Route 2 within the study area: quarter mile east of the Concord Rotary; half mile west of the Concord Rotary; and directly east of Route 12 interchange. The existing and planned pedestrian and bicycle facilities in the eastern (District 4) study area are shown in Figure 2-13.

Some form of pedestrian accommodation (crosswalks, signalization, and ADA facilities) is provided for crossing the mainline/intersecting streets at the majority of signalized intersections along Route 2 within the study area. However, these locations are highlighted with limited (many times only a single crossing), long crosswalks accompanied with long cycle lengths that could hinder pedestrian operations and mobility. Pedestrian facilities are limited along the westerly (District 3) segments of the study area given its limited access nature. The signalized locations were analyzed and updated to increase allotted (clearance) time for pedestrians as part of the retiming and re-establishing coordination effort discussed previously.

2.6.2 Transit Services

The MBTA provides commuter rail and bus service into and out of the greater Boston area. There is one commuter rail line that traverses/parallels the study area, the Fitchburg Line, which has stops in 8 of the communities in the study area. In addition to the MBTA, the Montachusett Regional Transit Authority (MART) operates local fixed route bus services in Fitchburg, Leominster, and Lunenburg. MART also provides a Devens shuttle from Leominster.

Figure 2-14 displays the current transit service routes within the Route 2 area at the time of this reports publishing.

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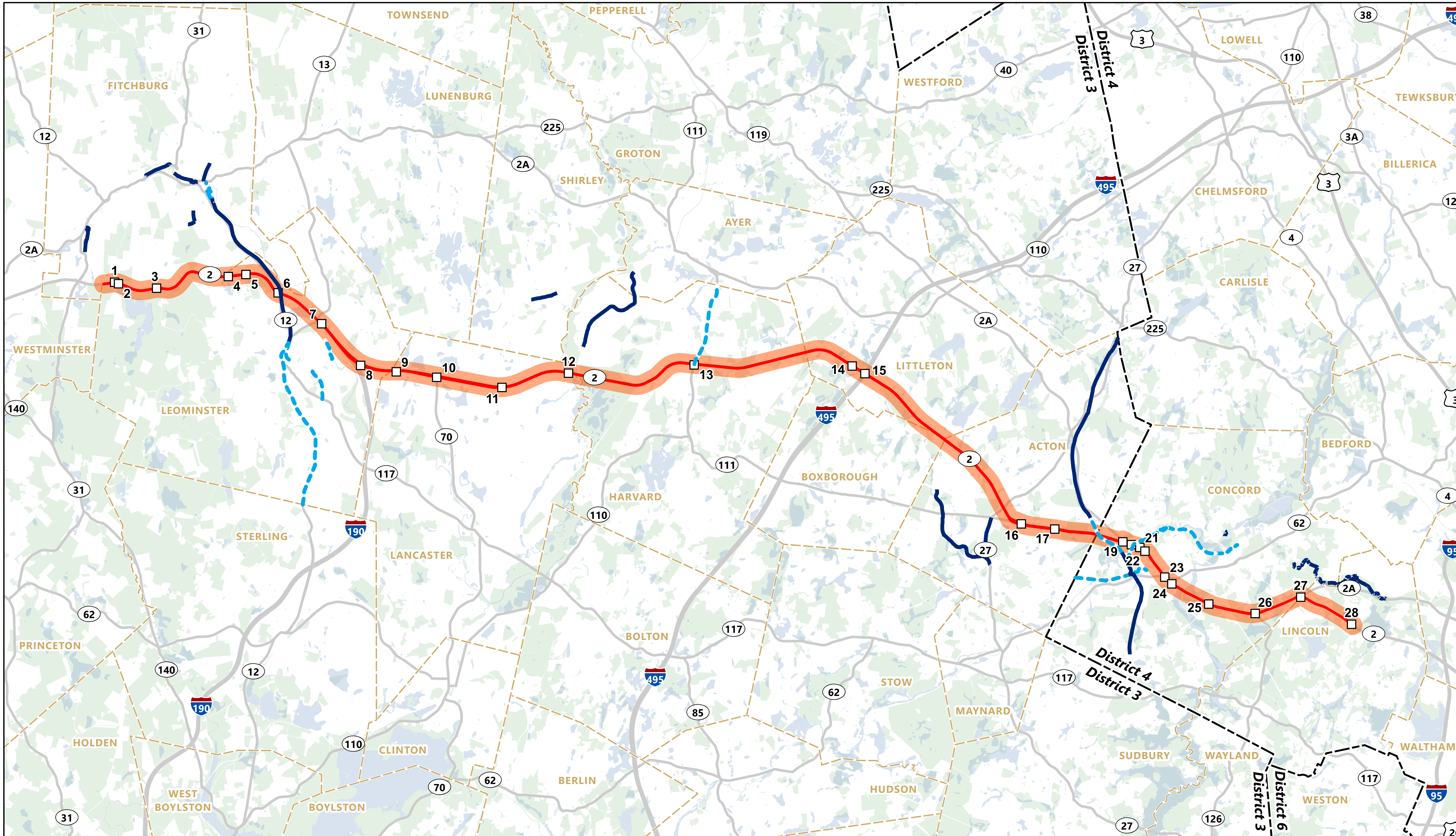

Route 2 Corridor Study
Study Area Location
Existing Bike Facility
Planned Bike Facility
MassDOT Districts

0 1 2 Miles

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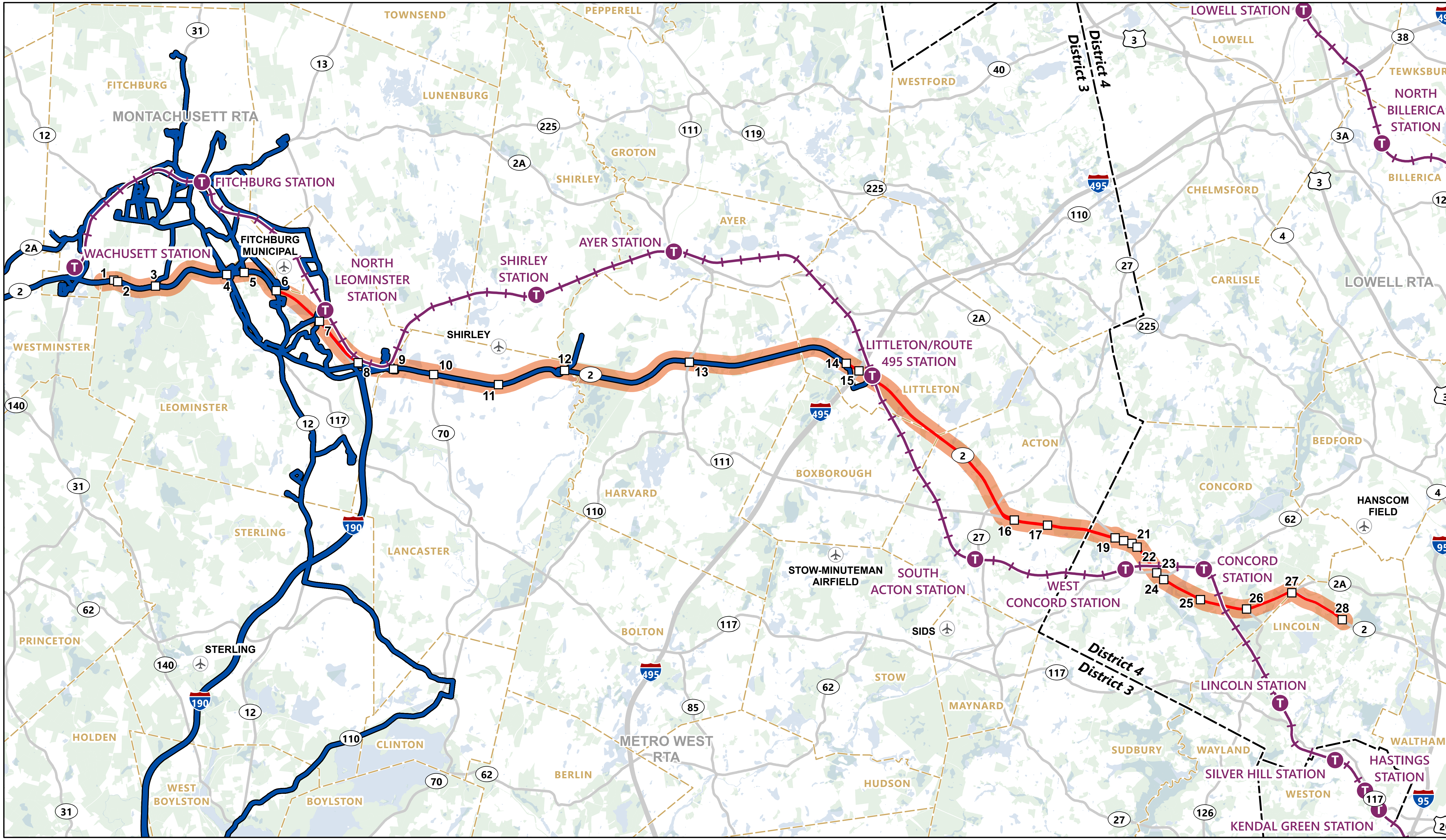
Pedestrian and Bicycle Summary
Route 2 Corridor Study

Figure 2-13



Route 2 Corridor Study

Study Area Location

MBTA Commuter Rail Stations

MBTA Commuter Rail Lines

Airports

Montachusett RTA

MassDOT Districts

0 1 2 Miles

Transit Summary
Route 2 Corridor Study

Figure 2-14

2.7 Environmental Resources

Any consideration for physical improvements along the Route 2 corridor needs to include an understanding and sensitivity to the existing natural resource areas. The environmental resources identified and discussed in this section will help guide the development of alternatives so that impacts to the environment are avoided, minimized, or appropriately mitigated.

Environmental resource mapping for the Route 2 Study area was developed primarily using Massachusetts Geographic Information System (MassGIS) data (http://www.state.ma/us/mgis/massgis.htm). Historical resources along the Project limits were determined based on the latest available data from the Massachusetts Cultural Resource Information System (MACRIS) maintained by the Massachusetts Historical Commission (MHC). Environmental resources along the Route 2 study area are described below. Zoomed in maps of environmental resources of the Route 2 study area are included in the Appendix.

2.7.1 State and Federal Jurisdictional Wetlands

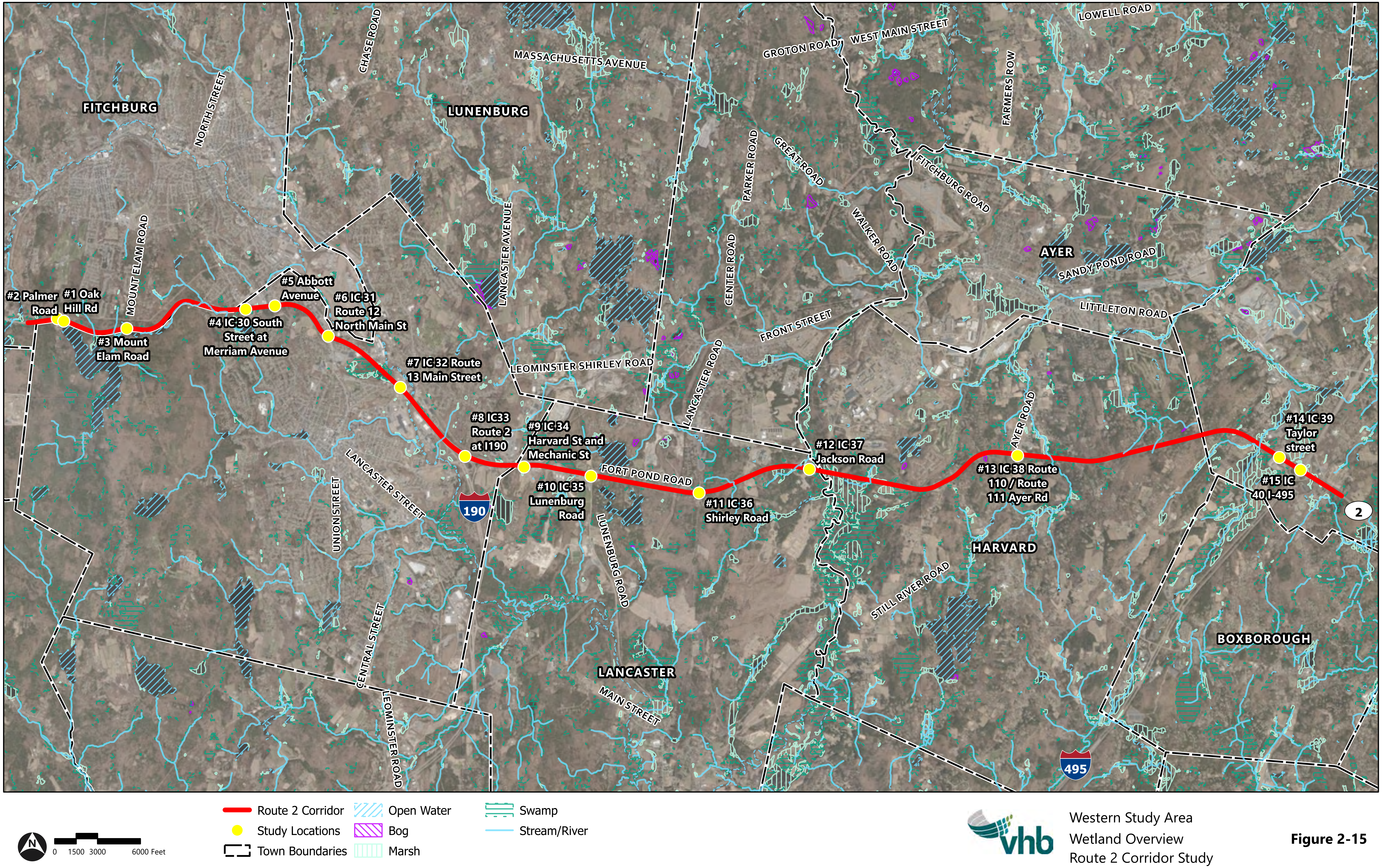
A number of wetlands and waterways are present in the study area and are regulated under a number of regulatory programs including:

- The Massachusetts Wetlands Protection Act (WPA), MGL Chapter 131, Section 40 and its implementing regulations, 310 CMR 10.00;
- Section 401 of the Clean Water Act (CWA) and its implementing regulations, 314 CMR 9.00;
- Sections 10 and 404 of the CWA; and
- Any local bylaws of the towns within the study area.

Resource Areas jurisdictional under the WPA along the corridor include: Land Under Water Bodies and Waterways (LUWW), Bank, Bordering Vegetated Wetland (BVW), Bordering Land Subject to Flooding (BLSF), Isolated Land Subject to Flooding (ILSF) and Riverfront Area. The WPA establishes a 100-foot buffer zone from the limit of Bank (if not bordered by wetland) and/or BVW associated with these wetland systems. A 200-foot Riverfront Area is established from the limits of Mean-annual high-water associated with perennial streams. Additionally, local bylaws may set additional buffer zones extending from wetland limits. Wetlands within the study aera are shown on Figure 2-15 and Figure 2-16.

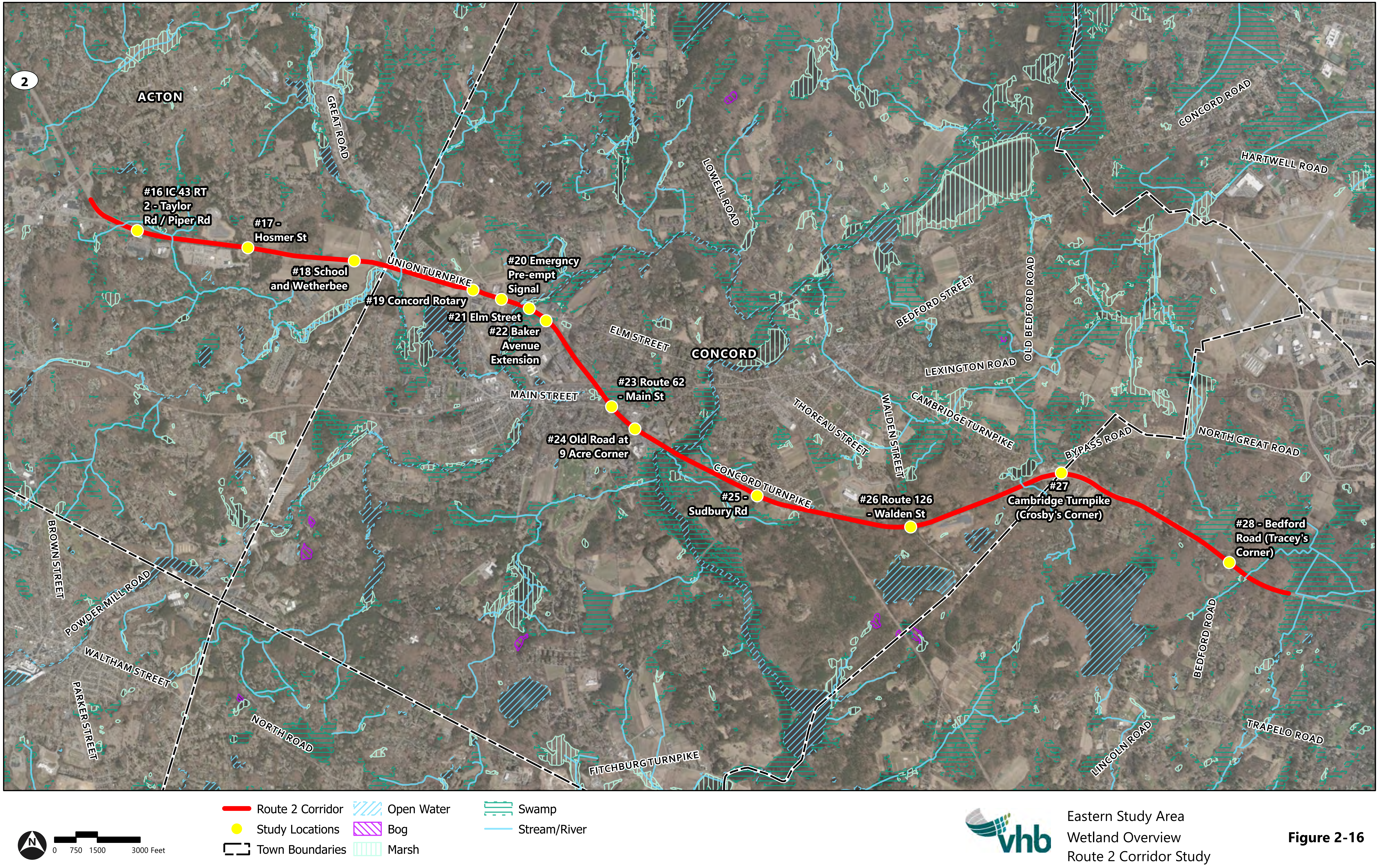
Note that the MassGIS data layer for wetlands is not inclusive of all potentially jurisdictional areas, and field delineations should be conducted wherever alternatives may require new land alterations. Should future alternatives require work or new infrastructure within WPA jurisdictional resource areas or their associated buffer zones coordination with local Conservation Commissions would be necessary. Alternatives within WPA jurisdiction would need to receive a Negative Determination or an Order of Conditions (OOC) to allow the proposed work. If permanent impacts to wetlands exceed 5,000 square feet of permanent impact, the Project may require a Variance from the WPA from DEP.

For the purposes of this desk top analysis, all wetlands indicated on the MassGIS data layer as DEP wetlands are presumed to also meet the definition of Waters of the US under the clean water act. Any alternative requiring work within areas regulated as Waters of the US would require permitting pursuant to Sections 401 or 404 of the CWA.



Western Study Area
Wetland Overview
Route 2 Corridor Study

Figure 2-15



Eastern Study Area
Wetland Overview
Route 2 Corridor Study

Figure 2-16

2.7.2 Threatened and Endangered Species

- **Natural Heritage and Endangered Species Program (NHESP)** – The study area is located within or adjacent to areas designated as Priority Habitat of Rare Species (PH) and Estimated Habitat of Rare Wildlife (EH). Figure 2-17 and Figure 2-18 show the limits of the rare species habitats mapped by NHESP. Any alternative that will involve work within either PH or EH will require coordination with the NHESP pursuant to the Massachusetts Endangered Species Act (MESA).
- **Vernal Pools** – According to data from NHESP, some of the study locations along the corridor are located in the vicinity of Potential and Certified Vernal Pools. These areas have not been inspected to determine their ability to provide successful amphibian breeding habitat but are shown to identify the potential location of breeding habitats. Should future alternatives encroach upon Vernal Pool resources, additional studies may be needed, and avoidance and mitigation measures will need to be incorporated into the design. Figure 2-17 and Figure 2-18 show the approximate locations of known vernal pools
- **Section 7 of the US Endangered Species Act** – According to the United States Fish and Wildlife Service (USFWS) Information for Planning and Conservation (IPaC) online Mapping tool, the study area is within potential habitat of the federally listed Northern Long-eared bat (Myotis septentrionalis). Coordination with USFWS pursuant to Section 7 will be required. Should future alternatives require tree clearing activities during construction time of year restrictions may need to be implemented.

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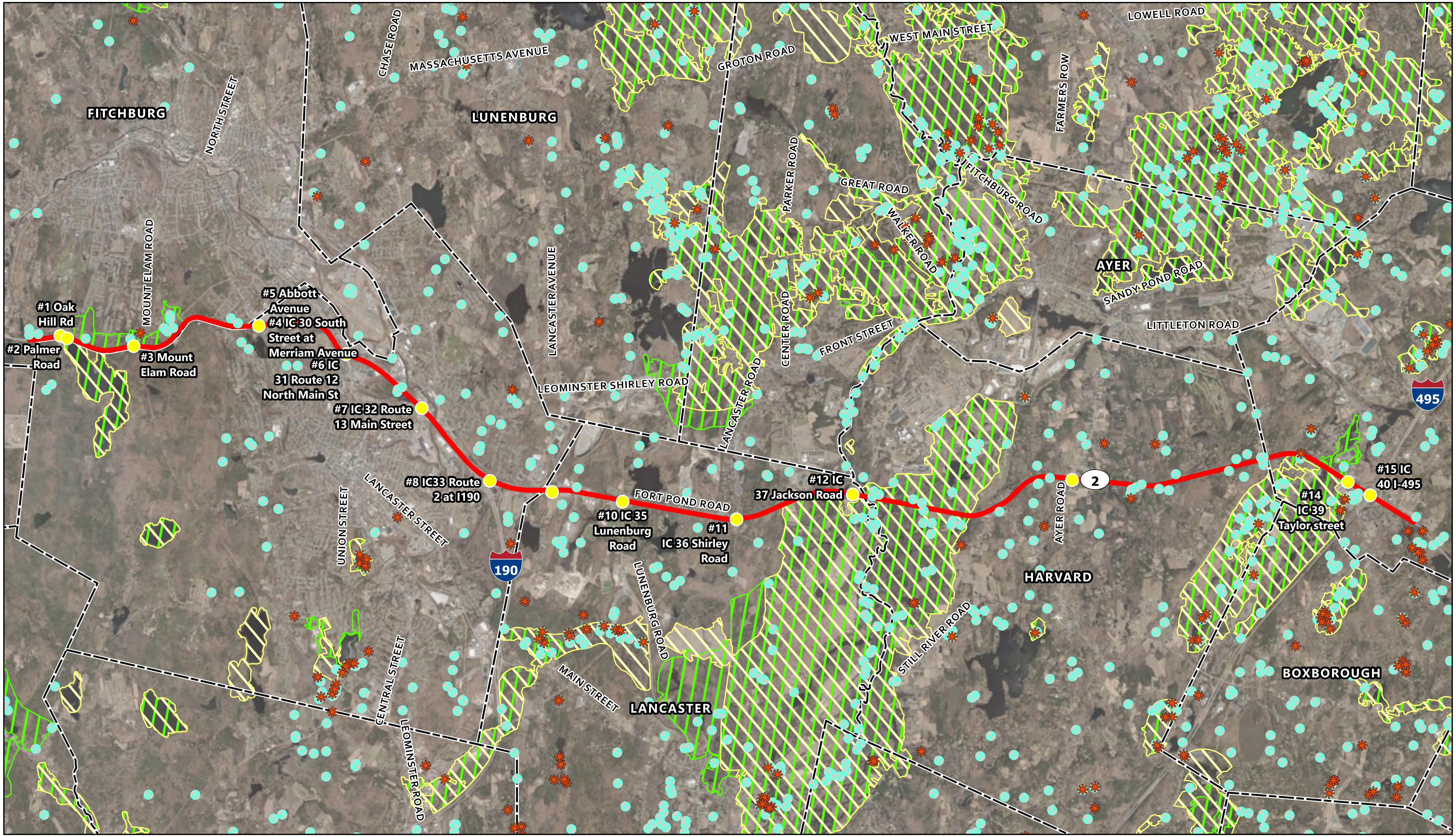
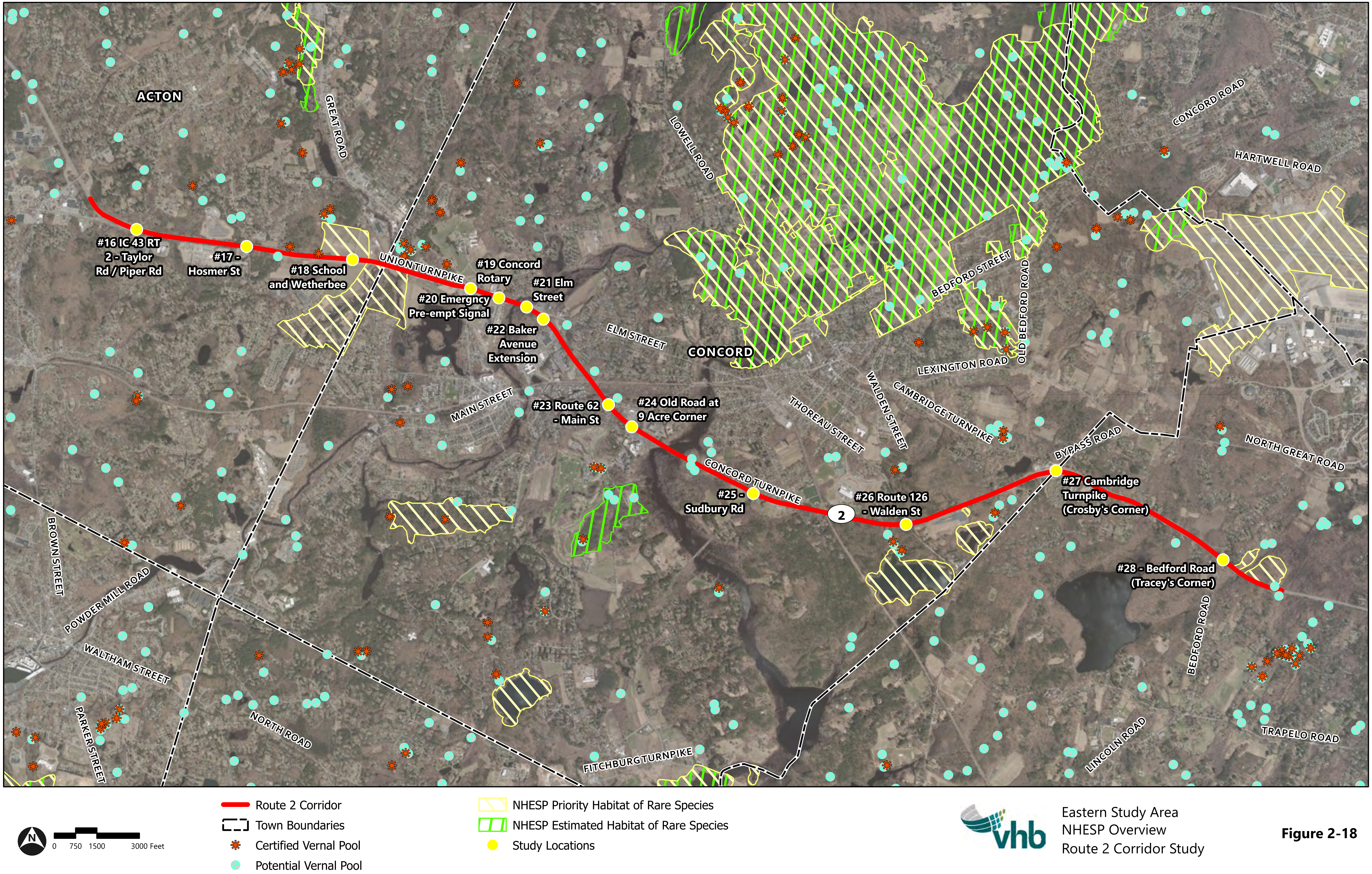


Route 2 Corridor
Town Boundaries
Certified Vernal Pool
Potential Vernal Pool
NHESP Priority Habitat of Rare Species
NHESP Estimated Habitat of Rare Species
Study Locations

0 1500 3000 6000 Feet

Western Study Area
NHESP Overview
Route 2 Corridor Study

Figure 2-17



Eastern Study Area
NHESP Overview
Route 2 Corridor Study

Figure 2-18

2.7.3 Outstanding Resource Waters

Based on mapping maintained by MassGIS and a published atlas, two locations are located within areas designated as Outstanding Resource Waters that are critical to public water supply protection (Figure 2-19 and Figure 2-20):

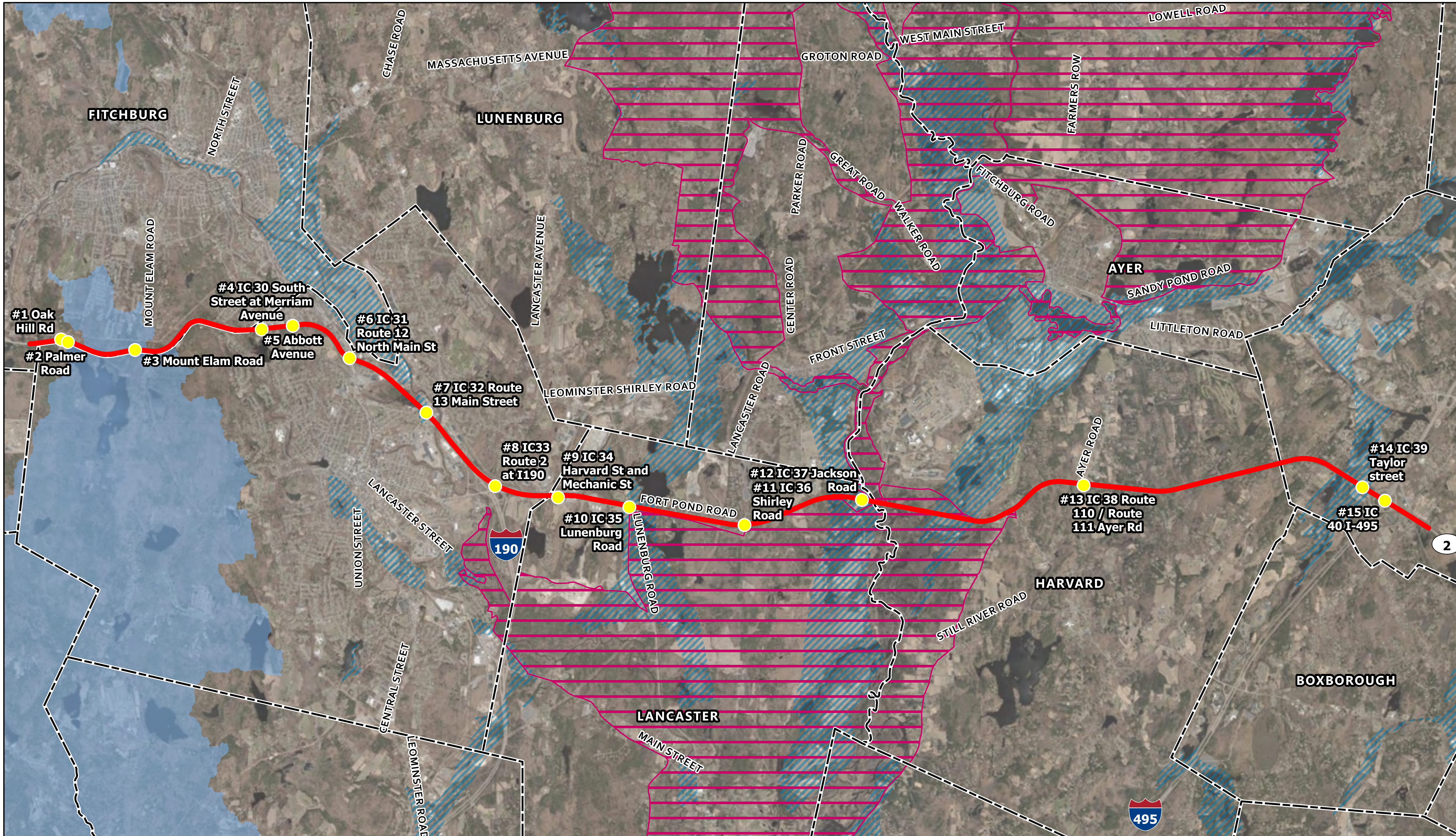
- Route 2 at Mount Elam Road in Fitchburg and Leominster
- Tracey's Corner (Route 2 at Bedford Road) in Lincoln

Should future Alternatives result in alteration of wetland resource areas that contribute to these ORW, an individual Water Quality Certification pursuant to Section 401 of the CWA would be required.

2.7.4 Areas of Critical Environmental Concern (ACEC)

The study area traverses the Central Nashua River Valley Area of Critical Environmental Concern in the towns of Harvard and Lancaster Massachusetts. https://www.mass.gov/service-details/central-nashua-river-valley-acec

The ACEC includes a network of publicly and privately held open space, including the Oxbow National Wildlife Refuge (Figure 2-19).



0 1500 3000 6000 Feet

- Route 2 Corridor
- Study Locations
- Town Boundaries
- Areas of Critical Environmental Concern (ACEC)
- MassDEP Approved Wellhead Protection Areas (Zone II)
- Aquifers
- Outstanding Resource Water

Western Study Area
Critical Resource Overview
Route 2 Corridor Study

Figure 2-19

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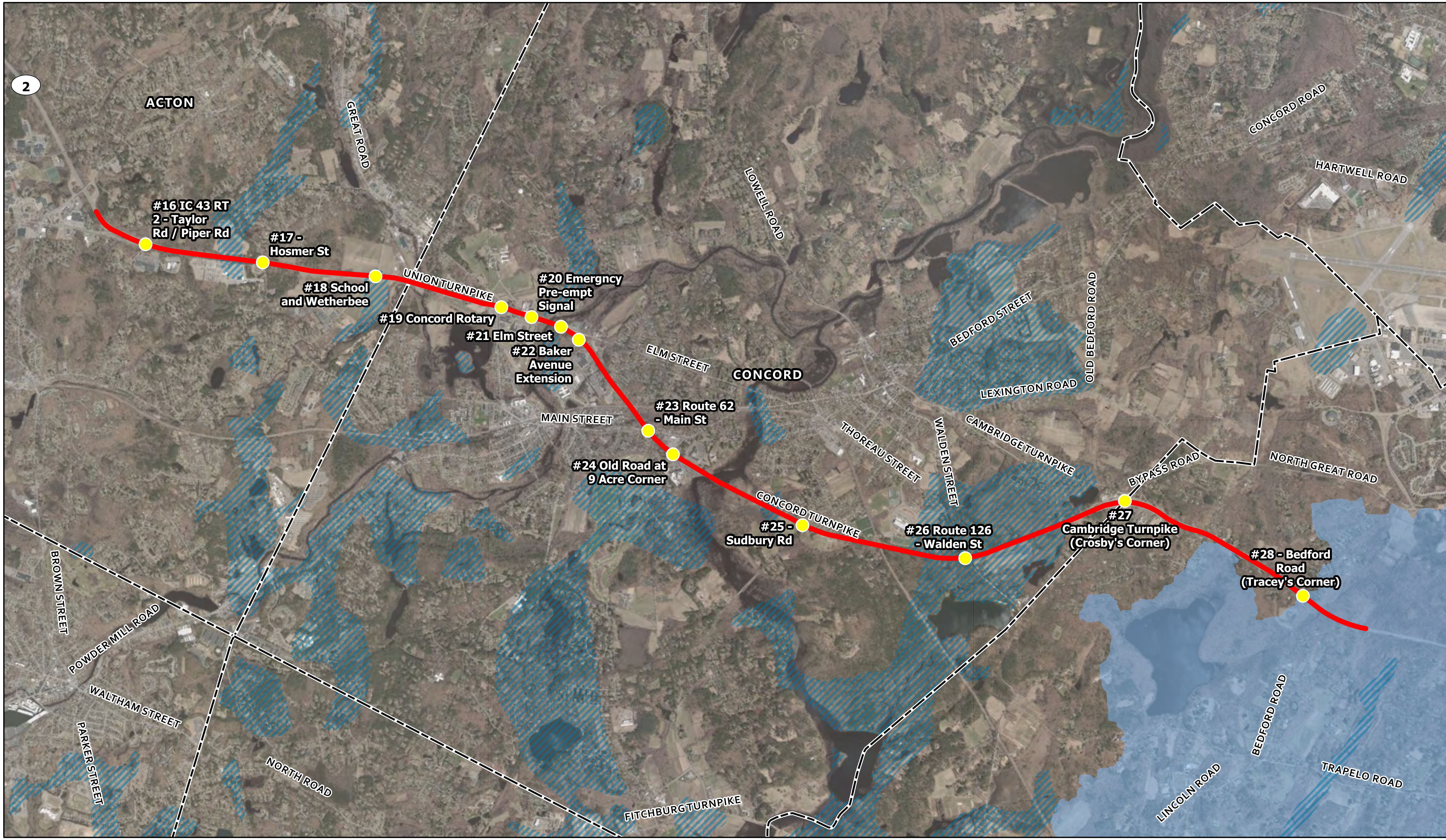

N
0 750 1500 3000 Feet

Route 2 Corridor
Study Locations
Town Boundaries
Areas of Critical Environmental Concern (ACEC)
MassDEP Approved Wellhead Protection Areas (Zone II)
Aquifers
Outstanding Resource Water

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Eastern Study Area
Critical Resource Overview
Route 2 Corridor Study

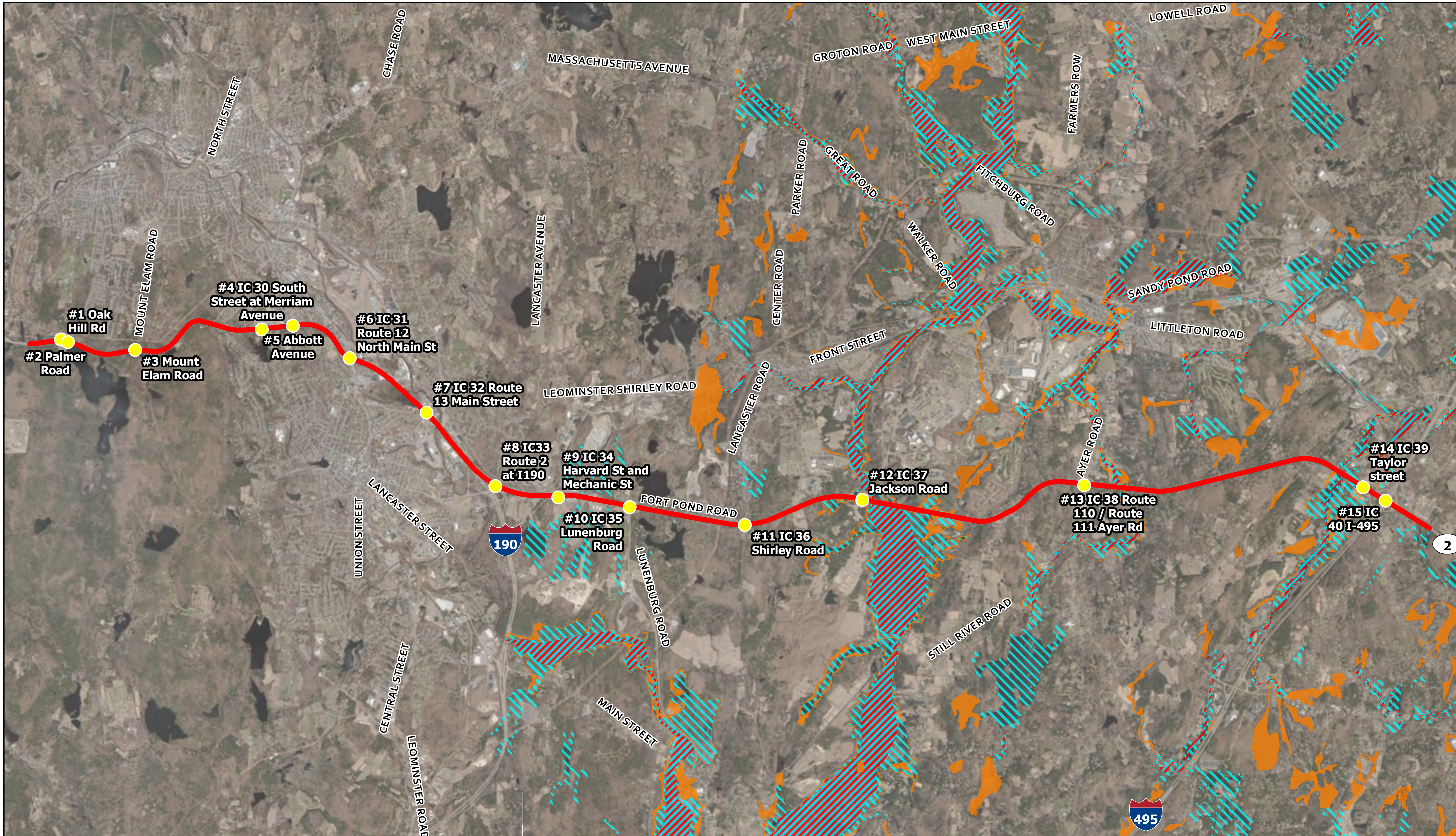
Figure 2-20

2.7.5 Federal Emergency Management Agency (FEMA) Floodplains and Floodways

The Route 2 study corridor crosses tributaries to the Nashua River, including areas of adjacent floodplain as mapped by the Federal Emergency management Agency. Figure 2-20 and Figure 2-21 present the FEMA floodplain overview.

2.7.6 Open space parcels subject to protection under Section 4(f) of the DOT Act and Article 97 of the Massachusetts Constitution

Recreational and Open Space – Publicly and privately owned open space parcels including parks, conservation land, libraries, recreational areas, and cemeteries are located along the study area. Publicly owned open space may be protected at the federal level through Section 4(f) of the Department of Transportation Act or Section 6(f) of the Land and Water Conservation Fund Act. Several Open space parcels along the corridor are subject to protection under Article 97 of the Amendments to the Constitution of the Commonwealth of Massachusetts. Parcels of private land are primarily protected as open space through conservation or agricultural restrictions. A conservation restriction is a legally binding agreement between the landowner and a holder – usually a public agency or a private land trust; whereby the landowner agrees to limit the use of their property for the purpose of protecting certain conservation values. The conservation restriction may run for a period of years or in perpetuity. Figure 2-22 and Figure 2-23 show the locations of known parkland and open space parcels along the corridor.



N
0 1500 3000 6000 Feet

- Route 2 Corridor
- Study Locations
- Town Boundaries
- FEMA 100-year Floodplain
- FEMA Regulatory Floodway
- VE: High Risk Coastal Area
- D: Possible But Undetermined Hazard
- FEMA 500-year Floodplain
- X: Reduced Flood Risk due to Levee

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Western Study Area
FEMA Floodplain Overview
Route 2 Corridor Study

Figure 2-21

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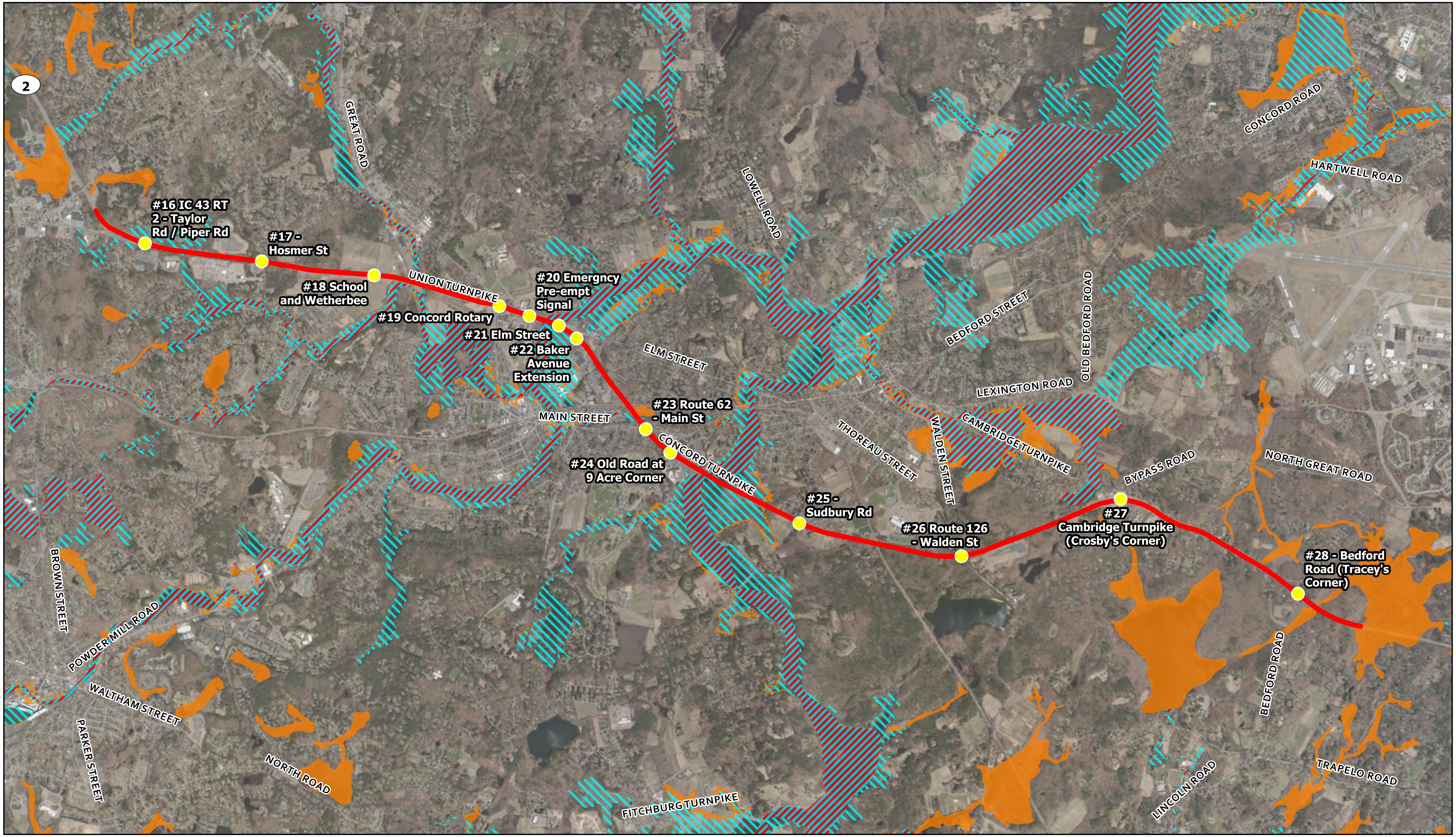

N

0 750 1500 3000 Feet

- Route 2 Corridor
- Study Locations
- Town Boundaries
- FEMA 100-year Floodplain
- FEMA Regulatory Floodway
- VE: High Risk Coastal Area
- D: Possible But Undetermined Hazard
- FEMA 500-year Floodplain
- X: Reduced Flood Risk due to Levee

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Eastern Study Area
FEMA Floodplain Overview
Route 2 Corridor Study

Figure 2-22

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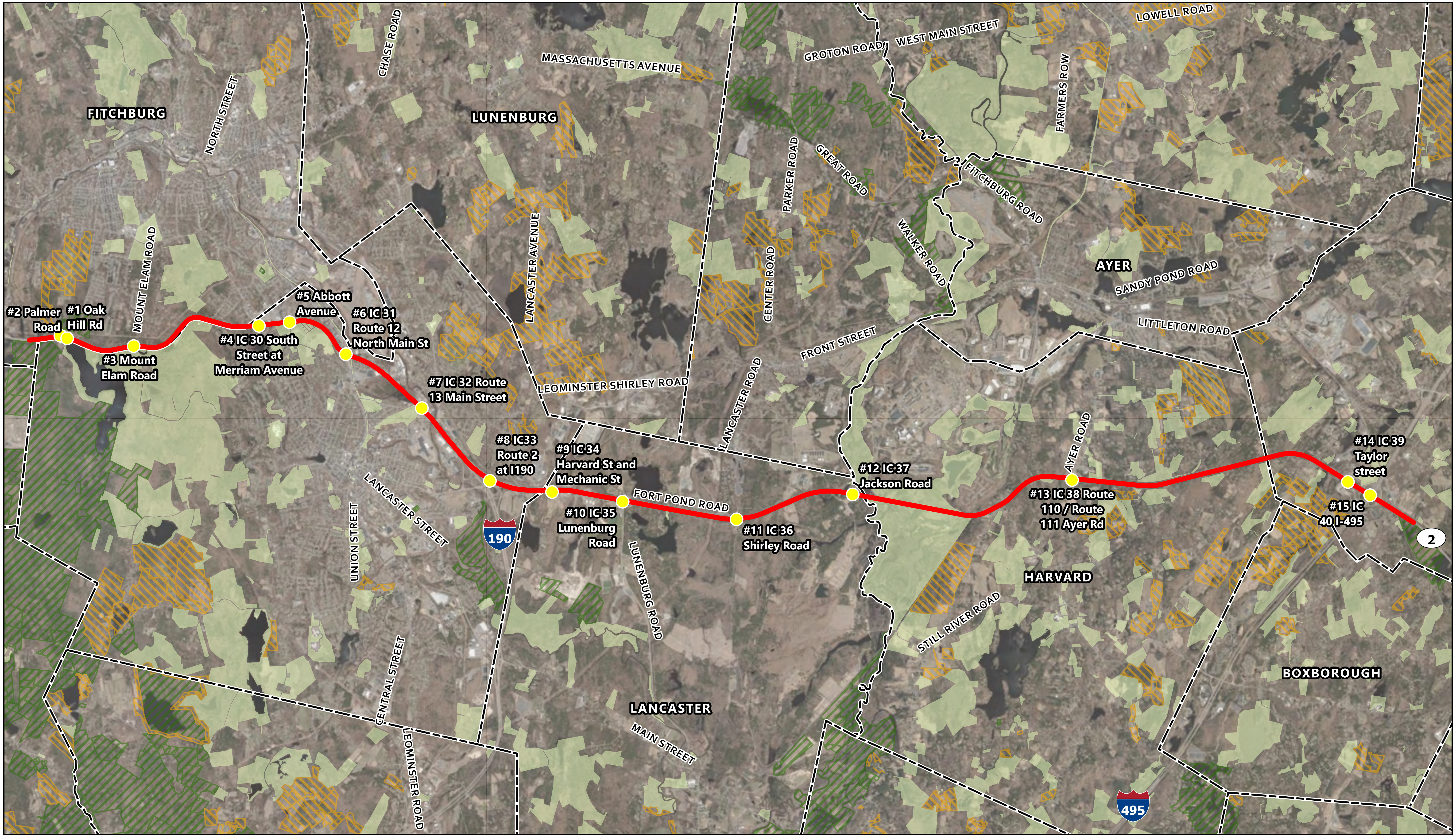

Route 2 Corridor
Study Locations
Town Boundaries
Public
Park
Private

0 1500 3000 6000 Feet

Western Study Area
Protected and Recreational
Open Space Overview
Route 2 Corridor Study

Figure 2-23

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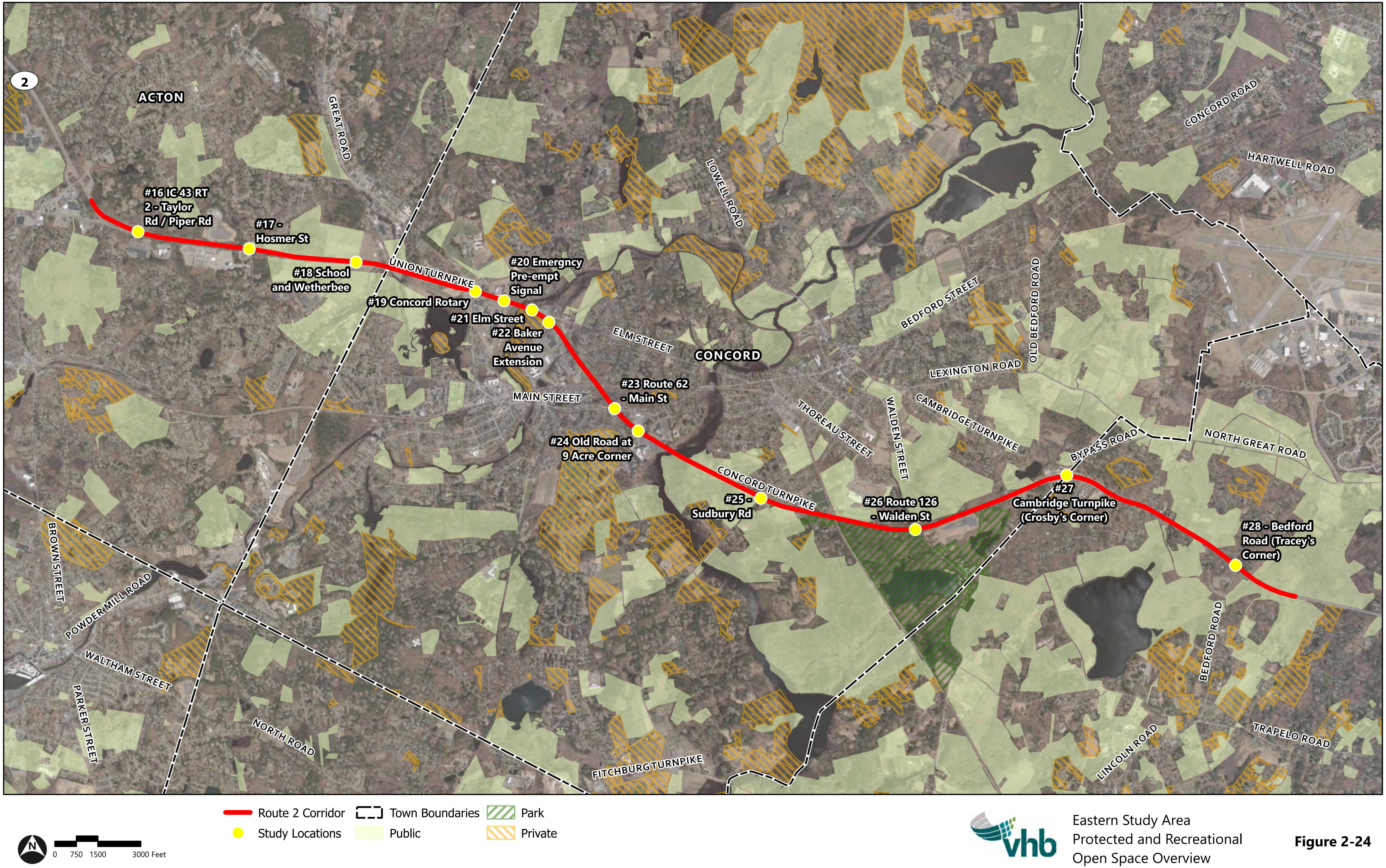


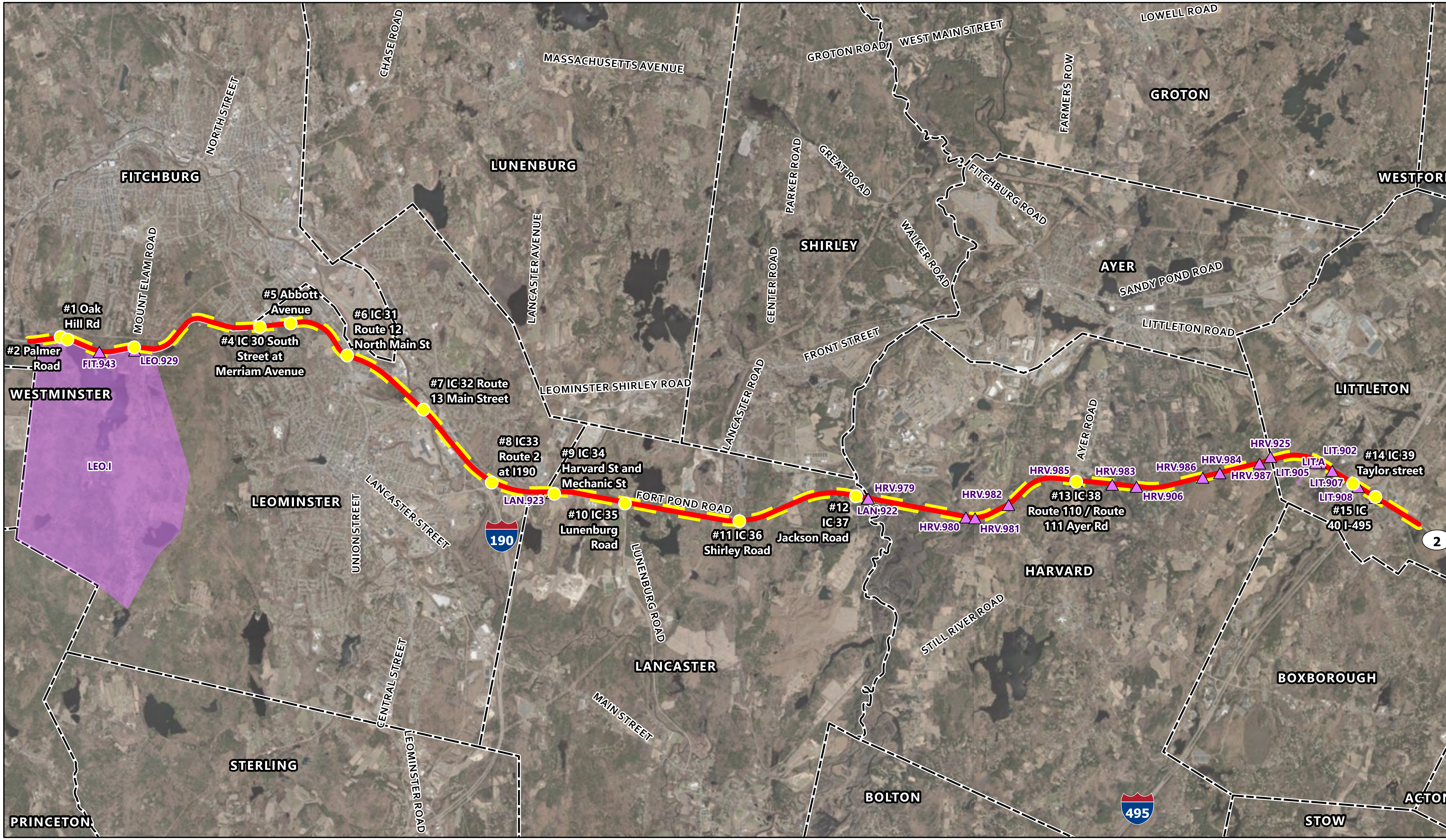
Eastern Study Area
Protected and Recreational
Open Space Overview
Route 2 Corridor Study

Figure 2-24

2.7.7 Massachusetts Cultural Resource Information System (MACRIS) for Historic Districts and Sites subject to protection under Section 106 of the Nation Historic Preservation Act

Federal policy set forth in the National Historic Preservation Act (NHPA) of 1966, as amended (16 USC 470 et seq.) includes preserving *"the historical and cultural foundations of the Nation"* and preserving irreplaceable examples important to our national heritage to maintain *"cultural, educational, aesthetic, inspirational, economic, and energy benefits"*. As specific recommendations are made and alternatives are developed for this project, permits from the Federal and Massachusetts state agencies will be subject to compliance with the above noted regulations.

As part of this research, a detailed desktop review of the Massachusetts Cultural Resource Information System (MACRIS) online database and geographic information systems (GIS) mapping tool, which serves as the repository for the Inventory of the Historic and Archaeological Assets of the Commonwealth (the "Inventory") and is maintained by the Massachusetts Historical Commission (MHC was conducted to identify aboveground and archeological resources within a 250 foot buffer area of the study area roadways. In summary, 62 individual properties and areas were identified in MACRIS. Of these, there is one National Register Historic District, three individually listed National Register properties, 10 inventoried areas, and 48 inventoried individual properties. As alternatives are developed that have the potential to impact these locations, additional research will need to be conducted to determine the exact nature of these historical resources as well as the possible outcomes of any direct or indirect impact to them. Results of the historical review are shown on Figure 2-25 and 2-26.



- Study Locations
- Route 2 Corridor
- Town Boundaries
- 250-ft Route 2 Corridor Buffer
- Inventoried Historic Property
- National Register Listed Historic Property
- Inventoried Historic Area
- National Register Listed Historic District

N 0 1500 3000 6000 Feet

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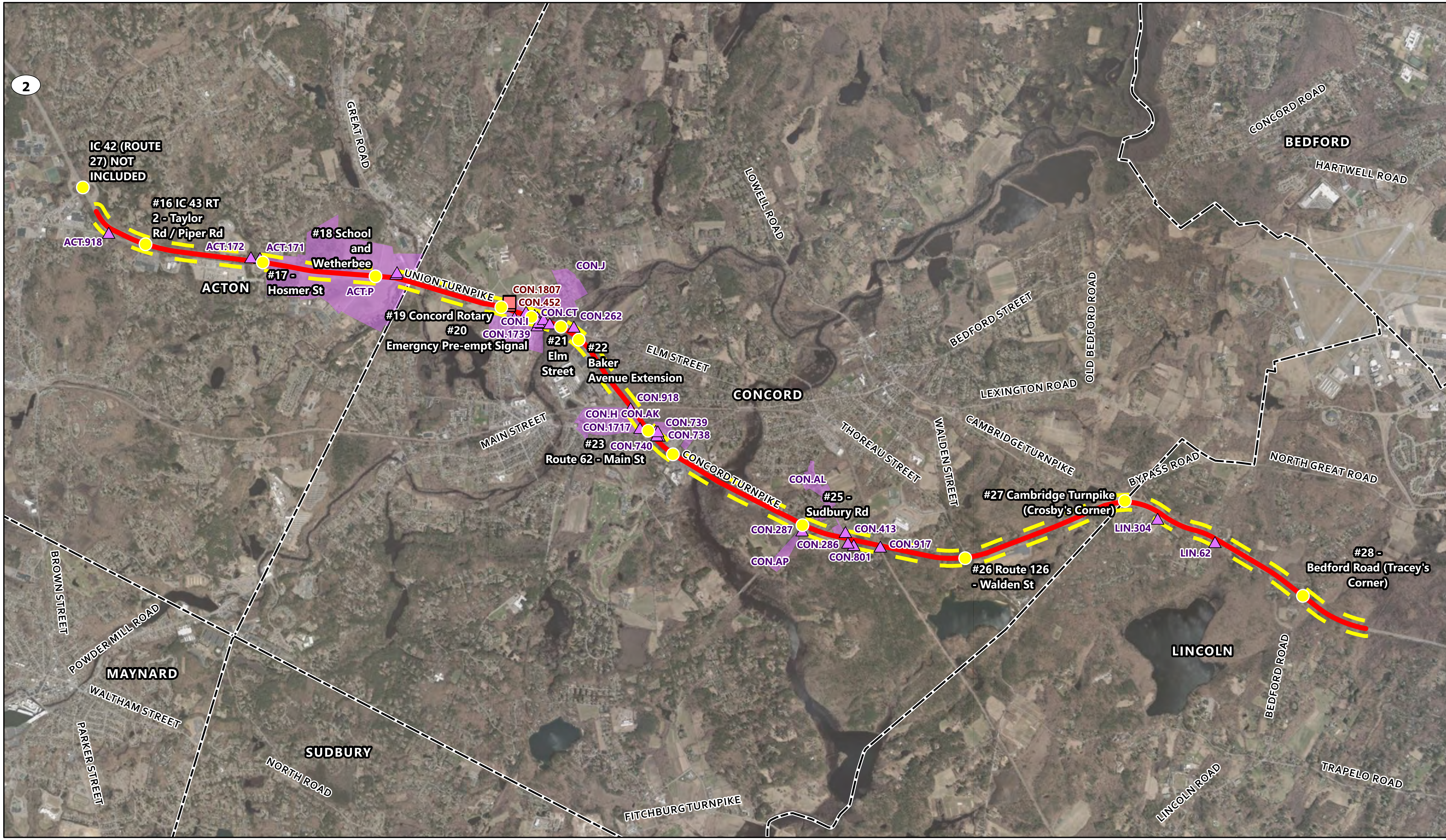
Western Study Area
Historical Resources Overview
Route 2 Corridor Study

Figure 2-25



N 0 750 1500 3000 Feet

- Study Locations
- Route 2 Corridor
- Town Boundaries
- 250-ft Route 2 Corridor Buffer
- Inventoried Historic Property
- National Register Listed Historic Property
- Inventoried Historic Area
- National Register Listed Historic District

Eastern Study Area
Historical Resources Overview
Route 2 Corridor Study

Figure 2-26

3

Future Conditions (Year 2039)

This chapter describes the future transportation conditions within the study area. Sections of this chapter present an overview of the travel demand forecasting process, identification of known roadway and infrastructure improvements planned for the study area, study area demographic projections, the future traffic demands and operations, the impacts of these demands on the infrastructure capacity, and a summary of the future deficiencies/needs of the corridor.

Background information about this project, and the existing conditions were presented in Chapters 1 and 2. Subsequent chapters will present the improvement alternatives, the final recommendations, and the plan of action for the corridor.

The nature of this study requires forecasting travel demands and patterns to define recommended improvements that provide sustaining benefits to the traveling public. Given the COVID-19 Pandemic, traffic volumes from 2019 have been utilized as the base, existing condition. This study will use a twenty-year (2039) planning horizon to ensure that proposed improvements are "visionary" providing long-term benefits for the Route 2 corridor and the region. Improvement alternatives will be developed understanding that future 2039 conditions will be a projection and development of enhancements to address all deficiencies may not be feasible from a financial, physical infrastructure or impact to natural resource areas perspective.

3.1 2039 Future Traffic Demand

Background growth projections for the Route 2 corridor were established based on travel demand model projections (developed by the Central Transportation Planning Staff (CTPS) for the Boston Region Metropolitan Planning Organization (MPO)). The CTPS model is a statewide travel demand model that projects future volumes based on household and employment growth assumptions. Table 3-1 displays household, population, and employment by jurisdiction and compares 2016 and 2040 CTPS travel demand model projections to show expected regional growth patterns within the study area. Projected background growth rates from the model were developed and applied to the existing morning and evening peak hour volumes. The total background growth in traffic volumes was developed for the mainline segments, ramps, weaving segments, and key intersections in the study area. Table 3-2 presents a comparison of the 2016 and 2040 weekday morning, evening peak hour, and daily traffic volumes for Route 2 mainline segments based on CTPS growth factors.

In addition to the projected background growth identified in the CTPS model, additional site-specific traffic growth associated with the significant planned developments, was added to the traffic volume projections (based on information provided in their MEPA/permit filings). Outreach was performed with communities along the Route 2 study area corridor to identify future projects that may want to be included in traffic projections. Devens was the sole location that is expected to have substantial and planned growth during the twenty-year horizon that would not fully be captured as normal background growth in the CTPS model.

Table 3-1 Household, Population, and Employment Growth by Jurisdiction

	Household			Population			Employment		
Community	**2016**	**2040**	**Percent Growth**	**2016**	**2040**	**Percent Growth**	**2016**	**2040**	**Percent Growth**
Gardner	8,876	9,843	10.9%	21,008	21,204	0.9%	8,268	8,230	-0.5%
Westminster	2,852	3,108	9.0%	7,384	7,420	0.5%	2,588	2,576	-0.5%
Fitchburg	16,175	17,861	10.4%	41,791	43,008	2.9%	13,045	12,980	-0.5%
Lunenburg	4,041	4,521	11.9%	10,199	10,364	1.6%	2,275	2,265	-0.4%
Leominster	17,303	18,846	8.9%	40,620	40,299	-0.8%	18,031	17,942	-0.5%
Shirley[1]	2,366	2,857	20.8%	7,155	7,127	-0.4%	2,338	2,327	-0.5%
Lancaster[1]	2,534	2,853	12.6%	8,099	8,095	0.0%	2,033	2,022	-0.5%
Ayer[1]	3,289	3,896	18.5%	7,601	8,257	8.6%	4,961	4,940	-0.4%
Harvard[1]	2,161	3,305	52.9%	6,878	9,175	33.4%	2,804	2,789	-0.5%
Littleton	3,817	4,408	15.5%	9,761	10,658	9.2%	5,417	5,742	6.0%
Boxborough	2,139	2,560	19.7%	5,243	5,762	9.9%	2,067	2,175	5.2%
Acton	8,689	10,062	15.8%	22,375	24,612	10.0%	10,890	10,918	0.3%
Concord	7,051	8,207	16.4%	18,624	20,713	11.2%	13,992	14,674	4.9%
Lincoln	2,502	2,895	15.7%	6,809	7,748	13.8%	2,790	2,783	-0.3%
Lexington	11,969	13,864	15.8%	31,189	34,677	11.2%	19,242	21,413	11.3%
Waltham	25,028	28,991	15.8%	61,290	67,296	9.8%	57,150	60,583	6.0%
Total	**122,808**	**140,117**	**14.1%**	**308,042**	**328,455**	**6.6%**	**169,907**	**176,399**	**3.8%**

Source: CTPS 2040 model

1 Does not include expected Devens area growth.

Table 3-2 Route 2 Mainline Peak Hour Volume Comparison 2016-2040

	Weekday Morning Traffic Volumes			Weekday Evening Traffic Volumes			Daily Traffic Volumes		
Segment	2016 Existing	Percent Growth	2040 Future	2016 Existing	Percent Growth	2040 Future	2016 Existing	Percent Growth	2040 Future
Route 2 Eastbound									
West of I-190	6,012	5%	6,290	5,274	7%	5,641	31,658	7%	33,989
West of I-495	6,021	6%	6,376	4,273	7%	4,589	25,626	11%	28,402
West of Rte 27	5,524	-7%	5,118	4,045	0%	4,030	24,341	1%	24,517
West of Rte 62	3,631	1%	3,678	3,043	5%	3,208	18,645	10%	20,593
West of I-95	7,324	4%	7,615	6,310	4%	6,544	35,328	5%	36,970
East of I-95	12,002	4%	12,423	11,122	3%	11,508	56,607	4%	59,079
Route 2 Westbound									
East of I-95	9,394	7%	10,046	11,090	5%	11,635	52,600	6%	55,945
West of I-95	5,514	9%	6,016	7,135	4%	7,450	33,835	8%	36,547
West of Rte 62	3,043	15%	3,497	3,763	-1%	3,741	19,438	11%	21,504
West of Rte 27	3,244	9%	3,542	5,342	-6%	5,032	22,417	5%	23,431
West of I-495	4,065	10%	4,461	6,088	4%	6,342	26,975	11%	29,833
West of I-190	5,094	12%	5,714	6,434	5%	6,760	32,331	12%	36,093

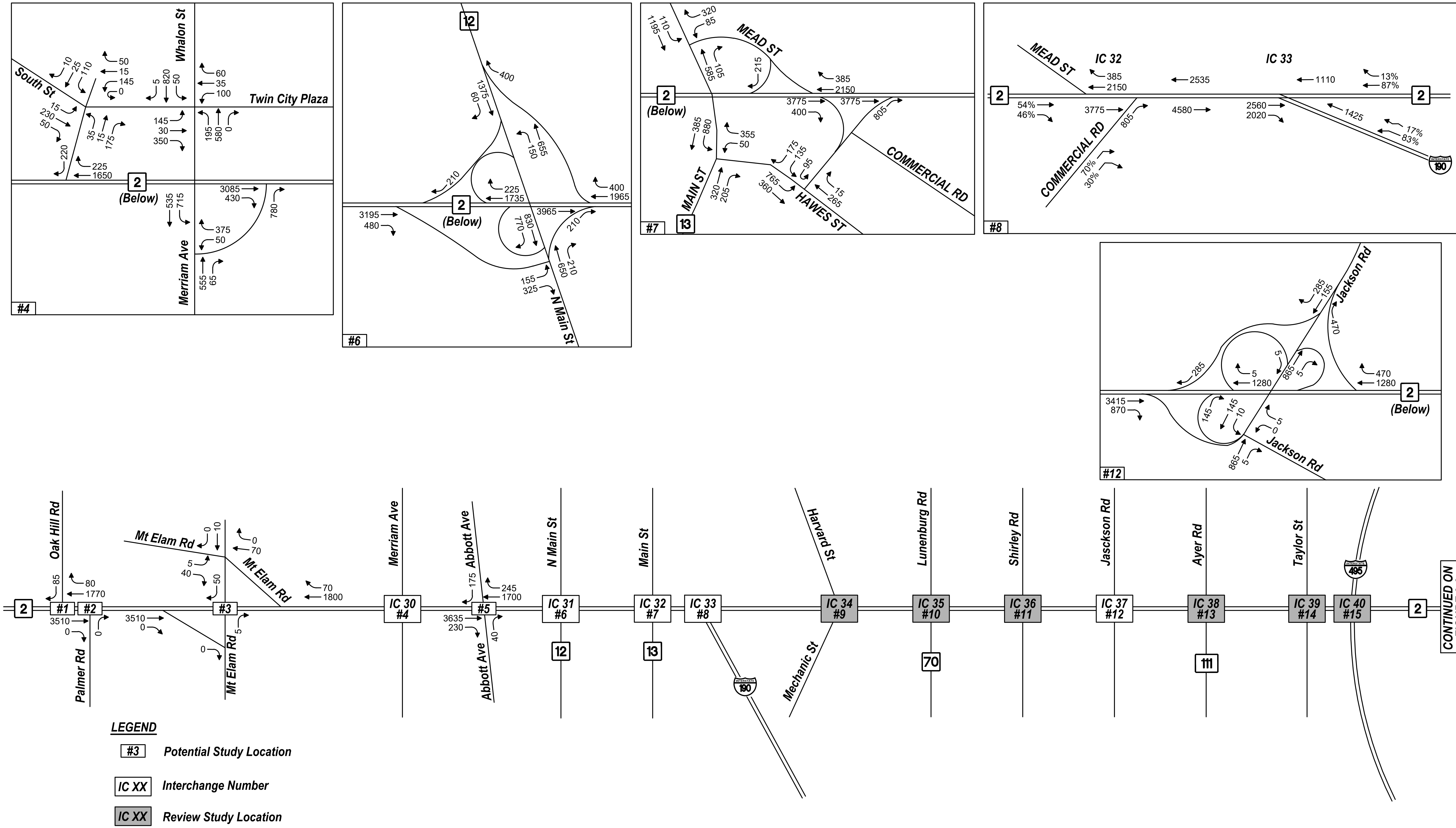
Source: CTPS 2040 model

Note: Does not include expected Devens area growth.

Devens is a regional enterprise zone comprised of parts of Ayer, Shirley, Harvard, and Lancaster. A 1995 Final Environmental Impact Reported allowed the redevelopment of Fort Devens into a mixed used planned community with up to 8.5 million square feet and a threshold of 59,625 daily vehicle trips. A report is issued every five years regarding the status of Devens. The 2015 report, the last publicly available report, specifies that continued growth is expected for Devens. The report assumptions were factored into regional growth for 2039 in addition to the CTPS-based growth assumptions. Based on the report’s distribution model it is expected that the Devens-specific growth would more heavily affect the western portion of the study area.

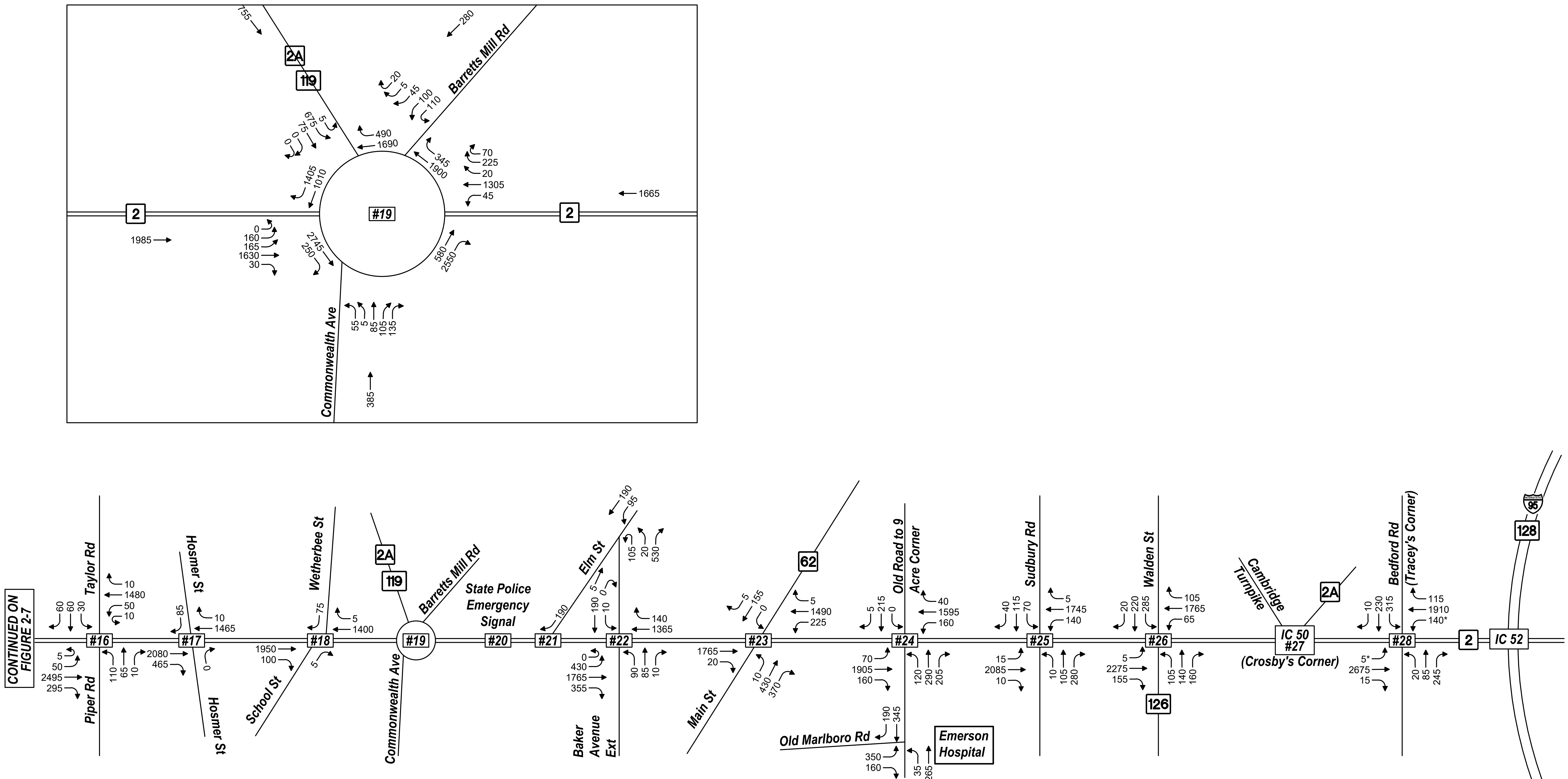
Considering the CTPS model background growth and the planned Devens development, it was determined that the following regional annual growth rates would be applied: 0.75 percent per year west of I-190, 1 percent per year between I-190 and I-495, and 0.5 percent east of I-495. The projected growth rates were discussed and agreed upon by MassDOT.

There rates were applied for a 20-year study horizon on the 2019 Existing Conditions peak hour traffic volumes to establish the 2039 Baseline peak hour traffic volumes. The 2039 Baseline peak hour traffic volumes are shown in Figure 3-1 through Figure 3-4.



2039 Baseline Traffic Volumes
Weekday Morning Peak Hour
Western Study Area
Route 2 Corridor Study

Figure 3-1

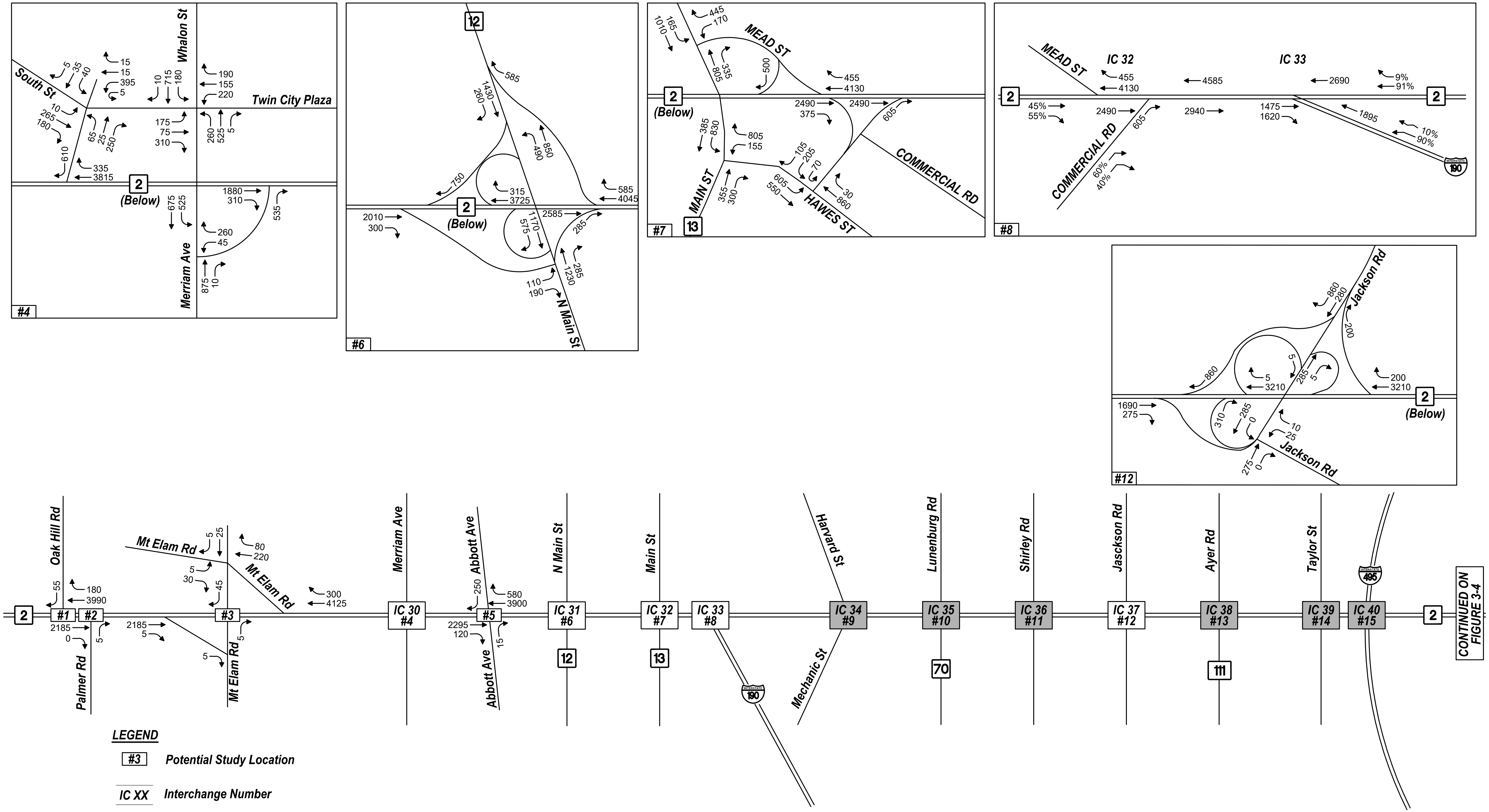


LEGEND

#XX	Location Number
IC XX	Interchange Number
*	Left Turn Via Jughandle

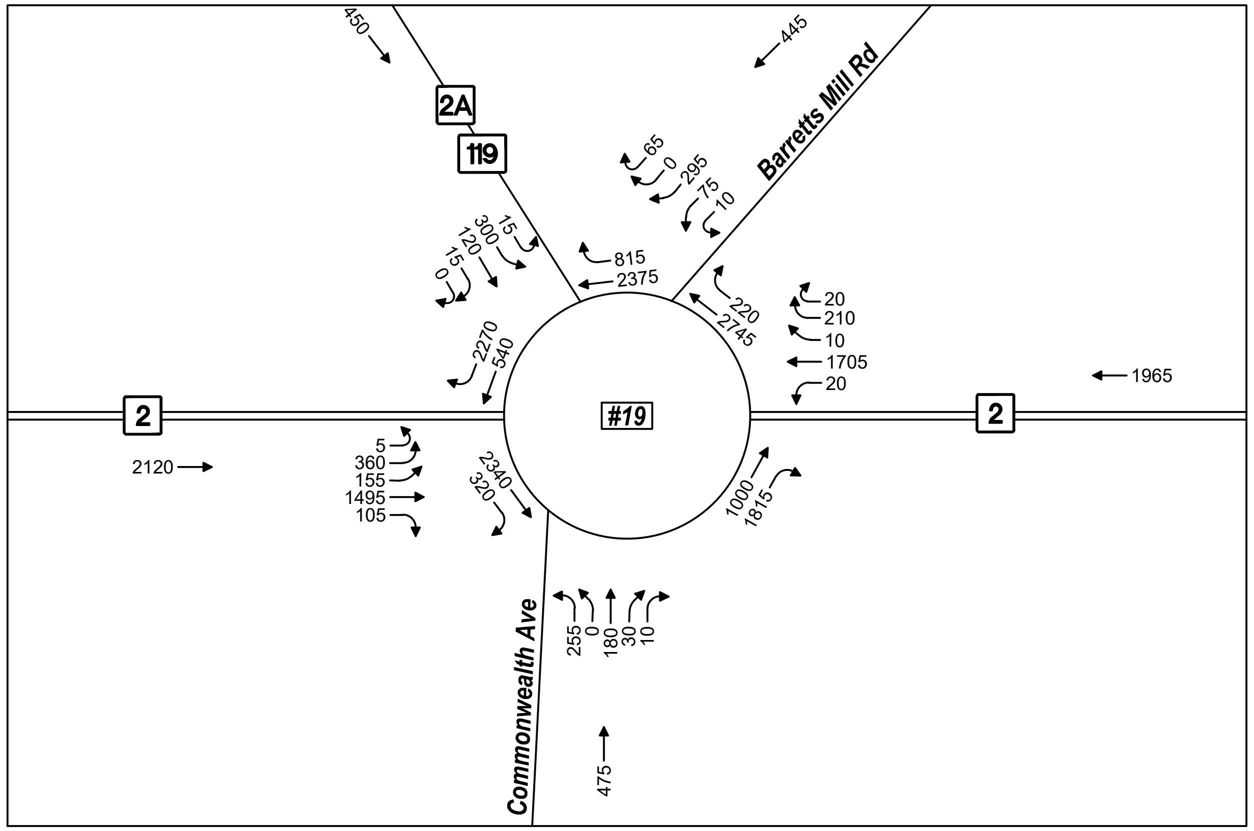
2039 Baseline Traffic Volumes
Weekday Morning Peak Hour
Eastern Study Area
Route 2 Corridor Study

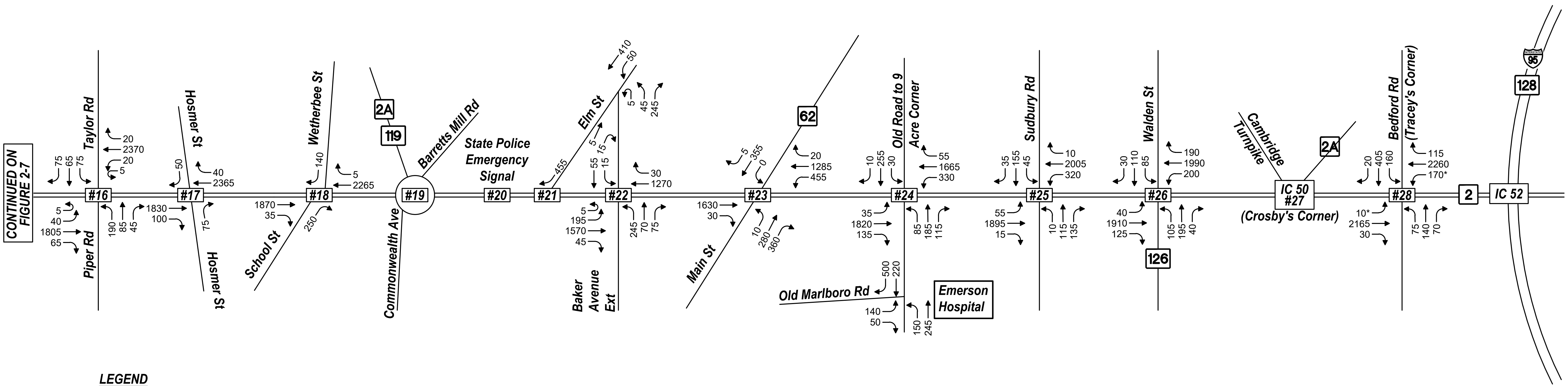
Figure 3-2



2039 Baseline Traffic Volumes
Weekday Evening Peak Hour
Western Study Area
Route 2 Corridor Study

Figure 3-3





LEGEND

#XX	Location Number
IC XX	Interchange Number
...	Left Turn Via Jughandle

2039 Baseline Traffic Volumes
Weekday Evening Peak Hour
Eastern Study Area
Route 2 Corridor Study

Figure 3-4

3.2 Planned Roadway Improvement Projects

Based on a review of previously submitted traffic studies and discussions with MassDOT Highway Division, several specific roadway improvement projects are planned in the study area and are described in detail below. The potential benefit/impact of these projects were included in future (2039) traffic operations analyses. Below is a list of MassDOT projects included that are under design/construction in the study area:

- 608478 – Concord – Resurfacing and related work on Route 2
- 605651 – Leominster – Reconstruction on Route 13, from Hawes Street to Prospect Street
- 607748 - Acton – Intersection & signal improvements on SR 2 & SR 111 (Massachusetts Avenue) at Piper Road & Taylor Road
- 608495 – Concord/Lexington/Lincoln – Resurfacing and related work on Route 2A
- 606223 – Acton/Concord – Bruce Freeman Rail Trail Construction
- 608475 – Lancaster/Harvard/Littleton – Resurfacing and related work on Route 2
- 607993 – Ayer/Lancaster/Leominster – Stormwater Improvements along Route 2
- 608832 – Lancaster – Interchange Improvements at Rt 2 (Old Exit 34) Old Union Turnpike
- 609411 – Fitchburg/Leominster – Twin Cities Rail Trail Construction (Phase 2)

3.3 2039 Future Traffic Operations

The next step in the study process was to evaluate the projected future operations of the study area roadway and traffic control system under increased traffic demand. This analysis provides a technical assessment of the projected future operational qualities of the Route 2 limited access highway segments, ramps, weaving segments, and intersections using the procedures outlined in the Highway Capacity Manual 6th Edition (HCM6). As noted, analysis of the Concord Rotary was completed using VISSIM and its procedures/methodologies. The capacity analysis was conducted using the 2039 Baseline weekday morning and weekday evening peak hour traffic volumes and the planned future geometric design conditions (without additional improvements) within the study area. All planned roadway/geometric design improvements from the existing conditions that have been incorporated into the 2039 Baseline condition were detailed above.

3.3.1 Western (District 3) Study Area

The Western portion of Route 2 (District 3) primarily consists of a limited access highway with interchanges. This section was evaluated using basic freeway, diverge, merge, and weaving segment analyses.

3.3.1.1 Basic Freeway Segment Operations

The capacity of basic freeway segments was analyzed using procedures outlined in Chapter 12, Basic Freeway Segments, of the HCM 6. The results of the Route 2 limited access mainline segment analysis under projected 2039 No-Build morning and evening peak hour conditions are summarized in Table 3-3. Capacity analysis worksheets for Route2 mainline segments are included in the Appendix. Key results include:

- Route 2 Eastbound – During the morning peak hour, all nine segments operate under congested conditions (LOS E or F). Previously under 2019 Existing Conditions, eight of the nine segments operated at LOS E. During the evening peak hour, the eastbound direction of Route 2 continues to generally operate at acceptable levels within the study area (eight of the nine segments operate at LOS D or better).
- Route 2 Westbound – During the morning peak hour, seven of the nine segments operate near free-flow conditions (LOS C or better). During the evening peak hour, the westbound direction of Route 2 is generally operating under congested levels within the study area (all nine segments operate LOS E or worse). Previously under 2019 Existing Conditions, seven of the nine segments operated at LOS E.

Table 3-3 Route 2 Mainline Segment Capacity Analyses Summary — 2039 Baseline Conditions

Freeway Segment Description		Weekday Morning Peak Hour			Weekday Evening Peak Hour		
From	To	Volume[1]	Density[2]	LOS[3]	Volume	Density	LOS
Eastbound							
Princeton Road (Route 31)	Palmer Road	3,505	41.9	E	2,185	26.1	**[D]**
Palmer Road	Mt. Elam Road	3,505	41.4	E	2,190	25.9	C
Mt. Elam Road	Merriam Avenue	3,515	>45.0	**[F]**	2,190	28.8	**[D]**
Merriam Avenue	Abbott Avenue	3,860	>45.0	**[F]**	2,415	29.2	**[D]**
Abbott Avenue	N. Main Street (Route 12)	3,670	43.8	E	2,310	27.5	**[D]**
N. Main Street (Route 12)	Main Street (Route 13)	4,170	>45.0	**[F]**	2,870	34.1	D
Main Street (Route 13)	I-190	4,575	>45.0	**[F]**[4]	3,095	37.7	**[E]**
Shirley Road	Jackson Road	4,290	>45.0	**[F]**	1,965	22.4	C
Jackson Road	Ayer Road (Route 110/111)	3,565	41.3	**[E]**	2,000	23.0	C
Westbound							
Ayer Road (Route 110/111)	Jackson Road	1,750	20.1	**[C]**	3,410	39.2	**[E]**
Jackson Road	Shirley Road	1,570	18.2	**[C]**	4,070	>45.0	**[F]**
I-190	Main Street (Route 13)	2,530	32.5	D	4,580	>45.0	**[F]**
Main Street (Route 13)	N. Main Street (Route 12)	2,365	30.4	**[D]**	4,625	>45.0	**[F]**
N. Main Street (Route 12)	Abbott Avenue	1,945	23.1	C	4,475	>45.0	F
Abbott Avenue	Merriam Avenue	1,875	22.5	C	4,145	>45.0	**[F]**
Merriam Avenue	Mt Elam Rd	1,870	17.6	B	4,420	38.2	**[E]**
Mt. Elam Road	Oak Hill Rd	1,850	24.3	C	4,165	>45.0	**[F]**
Oak Hill Road	Princeton Road (Route 31)	1,860	22.0	C	4,035	>45.0	**[F]**

Source: VHB, Inc. using HCM 6 methodologies.

Note: Shaded cells denote LOS E or LOS F conditions. **[BOLD RED]** letters indicate a LOS degradation from 2019 conditions.

1 Volume – Volume in vehicles per hour on the freeway segment.

2 Density – Expressed in passenger cars per mile per lane.

3 LOS – Level of service rating for the freeway segment, ranging from LOS A (best) to LOS F (worst).

4 LOS F due to demand greater than capacity.

3.3.1.2 Ramp Operations

The analysis of merge and diverge operations at ramps is based on procedures presented in Chapter 14, Freeway Merge and Diverge Segments, of the HCM 6. The projected 2039 No-Build results of the merge and diverge analyses for Route 2 are presented in Table 3-4 and Table 3-5, respectively. Capacity analysis worksheets for ramp merges and diverges are included in the Appendix.

Key results of the merge analyses (Table 3-4) include:

› Route 2 Eastbound – During the morning peak hour, six of the eight on-ramps to Route 2 eastbound operate under congested conditions (LOS E/F), compared to 2019 Existing Conditions when three ramps operated at LOS E or F. During the evening peak hour, all eight eastbound on-ramps operate at LOS D or better.

› Route 2 Westbound – During the morning peak hour, all nine westbound on-ramps operate near free-flow conditions (LOS C or better). During the evening peak hour, eight of the nine on-ramps operate under congested levels within the study area (LOS E/F). Previously under 2019 Existing Conditions, four of the nine on-ramps operated at LOS E or F.

Key results of the diverge analyses (Table 3-5) include:

› Route 2 Eastbound – During the morning peak hour, seven of the eight off-ramps operate under congested (LOS E/F) compared to 2019 Existing Conditions when one off-ramp operated at LOS F. Conversely, all off-ramps operate at LOS C or better during the evening peak hours.

› Route 2 Westbound – During the morning peak hour, all nine westbound off-ramps operate at LOS C or better. In the evening peak hour, seven of the nine westbound off-ramps operate under congested conditions (LOS F) with demand being greater than capacity. Previously under 2019 Existing Conditions, five of the off-ramps operated at LOS E or F.

Similar to Existing Conditions, poor operations at these locations are influenced by even heavier mainline and ramp volumes, and the presence of nearby upstream and downstream off-ramps.

Table 3-4 Route 2 Ramp Capacity Analyses (Merge) Summary — 2039 No-Build Conditions

	Weekday Morning Peak Hour			Weekday Evening Peak Hour		
Ramp Location	Volume[1]	Density[2]	LOS[3]	Volume	Density	LOS
Eastbound						
Palmer Road	0	37.5	**[E]**	5	25.5	C
Mt Elam Road	5	37.5	**[E]**	5	25.5	C
Merriam Avenue	780	40.0	**[F[4]]**	535	26.9	C
Abbott Avenue	40	34.9	D	15	22.5	**[C]**
N. Main Street (Route 12)	770	39.0	**[F[4]]**	575	26.6	C
	210	40.1	**[F[4]]**	285	28.2	**[D]**
Main Street (Route 13)	805	44.0	F[4]	605	30.6	**[D]**
Jackson Road	145	29.1	**[D]**	310	14.8	B
Westbound						
Jackson Road	5	14.5	B	5	32.2	**[D]**
	285	14.9	B	860	37.5	**[F[4]]**
I-190	1,420	16.5	B	1,895	35.0	F[4]
Main Street (Route 13)	215	23.0	C	500	43.5	**[F[4]]**
N. Main Street (Route 12)	210	14.2	B	750	37.0	**[F[4]]**
Abbott Avenue	175	19.7	B	250	40.4	**[F[4]]**
Merriam Avenue	220	18.7	B	610	41.7	**[F[4]]**
Mt Elam Road	50	22.3	**[C]**	45	43.4	**[F[4]]**
Oak Hill Road	85	19.7	B	50	39.6	**[F[4]]**

Source: VHB, Inc. using HCM 6 methodologies.
Note: Shaded cells denote LOS E or LOS F conditions. **[BOLD RED]** letters indicate a LOS degradation from 2019 conditions.
1 Volume – Volume in vehicles per hour on the ramp segment.
2 Density – Expressed in passenger cars per mile per lane.
3 LOS – Level of service rating for the freeway segment, ranging from LOS A (best) to LOS F (worst).
4 LOS F due to demand greater than capacity.

Table 3-5 Route 2 Ramp Capacity Analyses (Diverge) Summary — 2039 No-Build Conditions

	Weekday Morning Peak Hour			Weekday Evening Peak Hour		
Ramp Location	Volume[1]	Density[2]	LOS[3]	Volume	Density	LOS
Eastbound						
Palmer Road	0	35.0	D	0	21.7	**[C]**
Mt Elam Road	0	38.0	**[E]**	5	24.7	C
Merriam Avenue	430	35.4	**[E]**	310	22.0	**[C]**
Abbott Avenue	230	39.5	**[F[4]]**	120	25.0	C
N. Main Street (Route 12)	480	36.5	**[E]**	300	22.8	**[C]**
Main Street (Route 13)	400	40.6	**[F[4]]**	375	27.5	C
I-190	2,020	41.1	F[4]	1,620	26.2	C
Jackson Road	870	40.5	**[F[4]]**	275	17.1	B
Westbound						
Jackson Road	470	16.2	B	200	32.9	**[D]**
	5	13.4	B	5	32.8	**[D]**
Main Street (Route 13)	385	25.7	C	455	>45.0	**[F[4]]**
N. Main Street (Route 12)	400	23.8	C	585	>45.0	**[F[4]]**
	225	20.6	**[C]**	315	41.5	**[F[4]]**
Abbott Avenue	245	20.2	**[C]**	580	>45.0	F[4]
Merriam Avenue	225	17.9	B	335	40.8	**[F[4]]**
Mt Elam Road	70	21.3	**[C]**	300	>45.0	**[F[4]]**
Oak Hill Road	80	19.0	B	180	42.3	**[F[4]]**

Source: VHB, Inc. using HCM 6 methodologies.
Note: Shaded cells denote LOS E or LOS F conditions. **[BOLD RED]** letters indicate a LOS degradation from 2019 conditions.
1 Volume – Volume in vehicles per hour on the ramp segment.
2 Density – Expressed in passenger cars per mile per lane.
3 LOS – Level of service rating for the freeway segment, ranging from LOS A (best) to LOS F (worst).
4 LOS F due to demand greater than capacity.

3.3.1.3 Weaving Segment Operations

The analysis of weaving operations at interchange ramps is based on procedures presented in Chapter 13, Freeway Weaving Segments, of the HCM 6. The results of the weaving segment analysis for Route 2 under projected 2039 No-Build morning and evening peak hour conditions are summarized in Table 3-6. Capacity analysis worksheets for weaving segments are included in the Appendix. Key results include:

› Route 2 Eastbound – During the morning peak hour, the same three weaving segments that operated at LOS F during Existing Conditions will continue to operate at LOS F due to demand greater than capacity. In the evening peak hour, only one of the weaving segments operates under congested conditions (LOS E), with the other segments operating LOS D or better.

› Route 2 Westbound – During the morning peak hour, all weaving segments operate at LOS B or better with the I-190 to Route 13 segment operating at LOS D. During the evening peak hour, the I-190 to Route 13 and Jackson Road weaving segments operate under congested conditions (LOS

E or F), while the remaining segments operate at LOS D or better. Previously under 2019 Existing Conditions, only one weaving segment operated at LOS F (I-190 to Route 13).

Table 3-6 Route 2 Weaving Segments Capacity Analyses Summary — 2039 No-Build Conditions

Weave Segment Description	Weekday Morning Peak Hour			Weekday Evening Peak Hour		
	Demand[1]	Density[2]	LOS[3]	Demand	Density	LOS
Eastbound						
Merriam Avenue to Abbott Avenue	3,675	N/A[4]	F	2,300	29.5	**[D]**
Route 13 to I-190	4,360	N/A[4]	F	2,945	N/A[4]	**[F]**
Taylor Street to I-495 SB	3,631	34.2	D	1,586	14.4	B
I-495 SB to I-495 NB	3,940	N/A[4]	F	2,193	24.3	C
Westbound						
I-495 NB to I-495 SB	1,392	12.3	B	3,058	30.2	**[D]**
I-495 SB to Taylor Street	1,900	18.1	B	2,918	29.5	**[D]**
Jackson Rd NB to Jackson Rd SB	1,285	14.0	B	3,215	38.8	**[E]**
I-190 to Route 13	2,410	29.7	**[D]**	4,360	N/A[4]	F

Source: VHB, Inc. using HCM 6 methodologies.
Note: Shaded cells denote LOS E or LOS F conditions. **[BOLD RED]** letters indicate a LOS degradation from 2019 conditions.
1 Demand – Weave segment demand in vehicles per hour.
2 Density – Expressed in passenger cars per mile per lane.
3 LOS – Level of service rating for the freeway segment, ranging from LOS A (best) to LOS F (worst).
4 Density not available when LOS F.
5 Volumes from Taylor Street Overpass and I-495 Bridge Replacement FDR.

3.3.2 Eastern (District 4) Study Area

The Eastern portion of Route 2 (District 4) primarily consists of the Route 2 mainline intersected by local streets at signalized intersections. The Concord Rotary is an exception to the signalized locations along this portion of the easterly study area and will be covered in subsequent sections. Capacity analyses for this segment was completed using HCM signalized and unsignalized (Concord Rotary) analyses.

3.3.2.1 Signalized Intersection Operations

Capacity analyses were conducted for the signalized intersections within the study area to assess the quality of traffic flow under projected 2039 conditions. The results of signalized intersection capacity analysis for Route 2 under projected 2039 morning and evening peak hour conditions are summarized in Table 3-7. Key results at signalized intersections include:

› Baker Avenue Extension – The overall intersection operations for the morning peak hour period degrades from LOS C to E, while the evening peak hour period maintains LOS C. The westbound through movement degrades from LOS D to LOS F during the morning peak hour. The northbound left-turn movement degrades from LOS E and D to LOS F and E, for the morning and evening peak periods, respectively. Operations at this intersection are significantly impacted by the operations of the Concord Rotary, located 0.5-mile to the west, and not fully reflected in the capacity analyses presented herein.

- Main Street (Route 62) – The overall intersections operations degrade from LOS D and E to LOS E and F, for the morning and evening peak periods, respectively. The eastbound through movement degrades from LOS E to LOS F during the morning peak period. The eastbound through movement increases in delay from 88 seconds to more than 2 minutes for the evening peak period.
- Old Road to 9 Acre Corner – The overall intersection operations degrade to LOS E for both peak periods. The eastbound through movement degrades from LOS E to LOS F during the evening peak period. The westbound left-turn movement degrades from LOS E to F during both peak periods.
- Sudbury Road – The overall intersection operations degrade to LOS F from LOS D for both peak periods. The eastbound through movement degrades from LOS D to LOS F during the morning peak period, and from LOS E to LOS F in the evening peak period.
- Walden Street – The overall intersection operations degrade from LOS E to LOS F with over 100 seconds of delay for both peak periods. The westbound through movement degrades from LOS D to LOS F during the evening peak period.
- Bedford Road – The overall intersection operations degrade from 91 seconds to over 2 minutes of delay for both peak periods. A majority of movements operate at LOS E/F during under 2039 conditions.

Table 3-7 Signalized Intersection Capacity Analysis – 2039 No-Build Conditions

Location/ Movement	Weekday Morning Peak Hour					Weekday Evening Peak Hour				
	v/c [a]	Del [b]	LOS [c]	50 Q [d]	95 Q [e]	v/c	Del	LOS	50 Q	95 Q
Route 2 at Baker Avenue Extension										
EB L	0.92	57	E	270	#453	0.81	52	D	116	#229
EB T/R	0.93	19	B	535	#847	0.80	14	B	334	432
WB T	1.16	114	F	~600	#735	0.91	33	C	348	#483
WB R	0.11	21	C	4	45	0.02	16	B	0	0
NB L	0.88	91	F	59	#154	0.91	62	E	149	#297
NB T	0.33	38	D	51	98	0.19	27	C	35	72
NB R	0.01	35	D	0	0	0.05	26	C	0	17
SB L	0.06	36	D	6	22	0.06	26	C	8	24
SB T	0.77	52	D	133	#228	0.15	27	C	29	59
Overall	**1.07**	**56**	**E**			**0.93**	**27**	**C**		
Route 2 at Main Street (Route 62)										
EB T	1.13	100	F	~973	#1112	1.20	>120	F	~922	#1062
EB R	0.01	0	A	0	0	0.02	0	A	0	0
WB L	0.99	97	F	207	m#245	1.17	>120	F	~518	m#649
WB T	0.66	12	B	213	m274	0.58	11	B	227	m302
WB R	0.00	7	A	0	m0	0.01	14	B	2	m3
NB T	1.07	112	F	~439	#653	>1.20	>120	F	~355	#543
NB R	0.63	49	D	151	277	0.69	53	D	180	#307
SB T	0.45	44	D	149	193	0.88	67	E	322	#495
Overall	**1.09**	**65**	**E**			**>1.20**	**94**	**F**		
Route 2 at Old Rd to 9 Acre Corner										
EB L	0.74	64	E	66	m62	0.53	61	E	33	m31
EB T	1.14	80	F	~1005	m#858	>1.20	112	F	~1037	m#825
EB R	0.15	13	B	11	m10	0.10	2	A	0	m0
WB L	0.96	94	F	148	m#176	1.13	>120	F	~338	m#386
WB T/R	0.91	28	C	591	m#371	0.89	32	C	853	m923
NB L	1.14	>120	F	~129	#262	0.99	>120	F	78	#193
NB T	0.82	60	E	256	#405	0.56	49	D	153	236
NB R	0.39	35	D	100	166	0.18	27	C	46	89
SB L	N/A	N/A	N/A	N/A	N/A	0.2	44	D	24	55
SB T/R	0.82	60	E	249	267	0.85	67	E	245	#380
Overall	**1.14**	**59**	**E**			**1.14**	**73**	**E**		

Table 3-7 Signalized Intersection Capacity Analysis – 2039 No-Build Conditions

Location/ Movement	Weekday Morning Peak Hour					Weekday Evening Peak Hour				
	v/c [a]	Del [b]	LOS [c]	50 Q [d]	95 Q [e]	v/c	Del	LOS	50 Q	95 Q
Route 2 at Sudbury Road										
EB L	0.62	96	F	14	m14	0.95	66	E	45	m41
EB T	>1.20	117	F	~1188	m#990	1.15	>120	F	~1001	m713
EB R	0.01	16	B	0	m0	0.01	17	B	0	m0
WB L	0.99	111	F	141	m#181	1.16	>120	F	~346	m#294
WB T	0.94	25	C	284	m#1000	0.94	17	B	353	m305
WB R	0.00	11	B	0	m0	0.01	9	A	0	m0
NB L/T/R	1.05	108	F	~389	#596	1.03	112	F	~294	#399
SB L/T/R	>1.20	>120	F	~276	#437	>1.20	>120	F	~274	#435
Overall	**>1.20**	**85**	**F**			**1.17**	**83**	**F**		
Route 2 at Walden Street (Route 126)										
EB L	0.31	82	F	4	m4	0.66	62	E	37	m33
EB T	>1.20	>120	F	~1357	m#988	>1.20	>120	F	~1101	m#878
EB R	0.14	2	A	1	m0	0.08	24	C	6	m4
WB L	0.81	103	F	58	#145	0.82	74	E	167	#281
WB T	0.95	39	D	617	#1000	1.15	105	F	~1186	#1320
WB R	0.07	6	A	1	16	0.15	9	A	17	42
NB L	0.95	>120	F	102	#217	0.55	57	E	96	161
NB T	1.19	>120	F	~160	#295	0.98	110	F	~200	#357
NB R	0.38	60	E	25	#113	0.03	51	D	0	0
SB L	1.15	>120	F	~302	#486	0.60	63	E	78	137
SB T	0.84	74	E	197	#337	0.73	72	E	103	#182
SB R	0.02	0	A	0	0	0.02	0	A	0	0
Overall	**>1.20**	**103**	**F**			**1.12**	**106**	**F**		

Table 3-7 Signalized Intersection Capacity Analysis – 2039 No-Build Conditions

Location/ Movement	Weekday Morning Peak Hour					Weekday Evening Peak Hour				
	v/c [a]	Del [b]	LOS [c]	50 Q [d]	95 Q [e]	v/c	Del	LOS	50 Q	95 Q
Route 2 at Bedford Road										
EB T	>1.20	>120	F	~1385	#2117	1.19	116	F	~994	#1651
EB R	0.02	10	B	4	20	0.04	11	B	9	36
WB T	1.05	62	E	778	#1491	>1.20	>120	F	~1185	#1892
WB R	0.13	11	B	33	100	0.14	12	B	34	105
NB L	0.40	60	E	16	#62	>1.20	>120	F	~94	#221
NB T	0.93	>120	F	71	#223	0.98	115	F	123	#291
NB R	0.33	58	E	9	#157	0.07	47	D	0	14
SB L	>1.20	>120	F	~284	#478	0.88	74	E	98	#316
SB T	0.79	58	E	189	#342	1.10	119	F	~308	#709
SB R	0.01	39	D	0	0	0.02	34	C	0	0
Overall	**>1.20**	**>120**	**F**			**>1.20**	**>120**	**F**		

Source: VHB, Inc. using Synchro 9/10 software
Note: Shaded cells denote LOS E or LOS F conditions.
a Volume to capacity ratio.
b Average total delay, in seconds per vehicle.
c Level-of-service.
d 50th percentile queue, in feet.
e 95th percentile queue, in feet.
~ Volume exceeds capacity, queue is theoretically infinite.
# 95th percentile volume exceeds capacity; queue may be longer.
m Volume for 95th percentile queue is metered by upstream signal.

3.3.2.2 Concord Rotary Operations

Capacity analysis was conducted for the Concord Rotary (unsignalized analysis) under projected 2039 conditions. The results of capacity analysis for the Concord Rotary under projected 2039 morning and evening peak hour conditions are summarized in Table 3-8.

Table 3-8 Concord Rotary Capacity Analysis – 2039 No-Build Conditions

	Weekday Morning Peak Hour					Weekday Evening Peak Hour				
Location/Movement	**Dem [a]**	**Del [b]**	**LOS [c]**	**Avg Q [d]**	**Max Q [e]**	**Dem**	**Del**	**LOS**	**Avg Q**	**Max Q**
21: Route 2 at Concord Rotary										
Route 2 EB	1,985	>120	F	3,457	5,031	2,105	>120	F	2,919	5,032
Route 2 WB	1,665	60	F	476	1,478	1,960	>120	F	4,222	5,033
Commonwealth Ave NB	380	>120	F	1,623	2,347	475	>120	F	2,402	3,062
Route 2A SWB	755	>120	F	3,188	4,608	455	27	D	47	347
Barretts Mill Rd SEB	280	55	F	84	346	450	>120	F	2,044	2,185
Overall		**>120**	**F**				**>120**	**F**		

Source: VHB, Inc. using Vissim 11 software
Note: Shaded cells denote LOS E or LOS F conditions.
A Volume
b Average total delay, in seconds per vehicle.
c Level-of-service.
d Average queue, in feet.
e Maximum queue, in feet.

As indicated by the 2019 Existing Conditions analysis for the Concord Rotary, additional volume would not be able to be processed, specifically for the evening peak period. As shown in Table 3-8, delays and queues at the Concord Rotary are expected to remain high with most of the movements during both peak periods operating at LOS F.

3.4 Issues Definition and Evaluation

Chapter 3 has presented the future transportation conditions within the study area. As would be expected, many of the existing deficiencies/needs that were presented in Chapter 2 are negatively impacted and further degraded as traffic demands increase to projected 2039 conditions. Several mainline segments, ramps, and study area intersections degrade to "over capacity" levels (LOS F) in the 2039 Baseline Condition, or currently poor (LOS F) operations experience increases in delay and associated queuing. A summary of the existing and future traffic demands, safety assessment, traffic operations, and geometric deficiencies is presented below.

3.4.1.1 Traffic Demands

From 2019 to 2039, daily traffic volumes on Route 2 are expected to increase by an average of 10-20 percent - about 0.5-1.0 percent per year. In general, higher growth is expected near the Devens Enterprise Region closer to the I-190 split in the western (District 3) study area. This higher growth can be attributed to continued planned development in the near/long-term.

Although the magnitude of traffic demand is expected to increase from 2019 to 2039, the origin-destination patterns expected in 2039 are generally unchanged from 2019. Traffic flow will continue to be distributed toward Boston (eastbound) in the morning and from Boston (westbound) in the evening.

3.4.1.2 Safety Assessment

A detailed safety analysis was conducted for the Route 2 corridor within the study area limits and is summarized in the Safety Assessment section of Chapter 2. This review was conducted to determine if the traffic demands being placed on the roadways combined with the geometric conditions/traffic control of the roadways or ramps have resulted in potential safety concerns, specifically the 7 study area locations with higher than District and Statewide average crash rates. It could be expected that, in lieu of any changes to the current geometric conditions/traffic control, crash rates would remain static or potentially increase moving into the future.

Vehicular Crash History

To identify potential vehicle crash trends in the region, reported vehicular crash data for the study area roadways and intersections was obtained from MassDOT for the years 2013 through 2019. For the mainline segments and interchanges, these data were summarized, and crash trends were identified.

The results of this effort indicate that the following occurred between 2013 and 2019 within the study area:

- There were more than 1,900 reported crashes at the Route 2 study area intersections/interchanges, including 1 fatality
- 8 out of 36 Route 2 study area intersections/interchanges had crash rates that exceeded the statewide average for the area
- 3 study area intersections are on the 2013-2017 Statewide HSIP crash list

Background Project Improvements

The Leominster – Route 13 project is expected to address some of the safety issues that currently exist. The project is proposed to include a signal at the Route 2 westbound ramps at Main Street intersection, which is expected to reduce the number of angle crashes that occur at the HSIP location.

3.4.1.3 Geometric Deficiencies

A detailed evaluation of access control (right-in/right-out and interchange access) along Route 2 (primarily in the western segment/District 3) was completed and has been summarized in the Transportation Infrastructure Review section of Chapter 2. The review identified that majority of access control points along Route 2 have some form of geometric deficiency (i.e., deficient ramp lengths, acceleration lane and taper lengths, and deceleration lane and taper lengths). The deficiencies are further identified and addressed in improvement alternative concepts presented in Chapter 4.

3.5 Peer Review Locations

As part of the Route 2 Corridor Study, VHB conducted a peer review of study area locations. The peer review consisted of multiple interchanges/intersections in the District 3 study area. These locations include:

- **Interchange 34 (Exit 102):** Route 2 North Harvard Street and Mechanic Street (including potential ramp consolidation)[6]
- **Interchange 35 (Exit 103):** Lunenburg Road (Route 70) (including potential ramp consolidation)[6]
- **Interchange 36 (Exit 105):** Route 2 at Shirley Road (including potential ramp consolidation)[6]
- **Interchange 38 (Exit 109):** Route 2 at Ayer Road[6]
- **Interchange 39 (Exit 112):** Route 2 at Taylor Street[7]
- **Interchange 40 (Exit 113):** Route 2 at Interstate 495[7]
- **Interchange 43 (Exit 118):** Route 2/ Route 111/ Taylor Road and Piper Road

The following section provides a summary of each peer review. Where appropriate, memorandums were prepared documenting the results of the peer review and were provided to MassDOT and are included in the appendix. It should be noted that the Route 2/ Route 111/ Taylor Road and Piper Road peer review is still in progress. The initial 25% design was reviewed. However, the initial design was not progressed after feedback from the community. MassDOT then considered alternative intersection concepts at this location which also progressed to 25% design, which were also peer reviewed. Both reviews are included in the attachments.

3.5.1 Interchange 34 (Exit 102) – Route 2 North Harvard Street and Mechanic Street

Two alternatives were presented as part of the study and Alternative 1 was the recommended alternative. Alternative 1 improves the deficient geometry and addresses sight distance concerns of the eastbound ramp at Mechanic Street. Operations are improved with the proposed signalized intersection of the eastbound ramps and Old Union Turnpike. As part of the peer review, the recommended alternative is appropriate at this location. Additional considerations are included in the attachments.

3.5.2 Interchange 35 (Exit 103) – Lunenburg Road (Route 70)

Five Alternatives were presented at Exit 35 Route 70 as part of the study and Alternative 5 was the recommended alternative from the study. The alternative addresses the geometric deficiencies of the eastbound ramps and the westbound off-ramps. With the proposed traffic signal and ramp configuration the current operational deficiencies have been addressed at the intersections of Route 70 at Fort Pond Road and the Westbound off-ramp at Fort Pond Road. As part of the peer review, the recommended alternative is appropriate at this location. Additional considerations are included in the attachments.

6 *Route 2 Interchange Improvements Alternatives Analysis, Harvard/Lancaster, MA*. Transystems, February 2016. Interchanges 34 through 38.

7 The Taylor Street and I-495 interchanges were recently reconstructed. As such, the scope for these locations were limited.

3.5.3 Interchange 36 (Exit 105) – Route 2 at Shirley Road

Four alternatives were presented at Exit 36 Shirley Road as part of the study and Alternative 3 was the recommended alternative. The alternative addresses the geometric deficiencies of the eastbound and westbound ramps. The proposed ramp configuration has acceptable operations and addresses the operational deficiencies of Fort Pond Road at Shirley Road. As part of the peer review, the recommended alternative is appropriate at this location. Additional considerations are included in the attachments.

3.5.4 Interchange 38 (Exit 109) – Route 2 at Ayer Road

Four alternatives were presented at Exit 38 Route 110/111 as part of the study and Alternative 2 was the recommended alternative. The alternative addresses the geometric deficiencies and weave related safety concerns. The proposed ramp configuration has acceptable operations. As part of the peer review, the recommended alternative is appropriate at this location. Additional considerations are included in the attachments.

3.5.5 Interchange 39 (Exit 112): Route 2 at Taylor Street and Interchange 40 (Exit 113) Route 2 at I-495

See section 4.3.3.7 for information regarding potential improvements at this location.

3.5.6 Interchange 43 (Exit 118): Route 2/ Route 111/ Taylor Road and Piper Road

MassDOT initiated a project at the Route 2 / Route 111 / Taylor Road and Piper Road intersection to address existing safety concerns due to the unique intersection layout and older traffic signal equipment. An initial design was prepared which proposed the removal of the left turns from the Route 2 eastbound approach, however this design was not progressed due to concerns with the diversion of this traffic through local roadways. MassDOT is evaluating alternative intersection designs that will improve safety for all users, and it is expected that a preferred alternative will be identified later this year (2024). Reviews of these designs are included in the attachments.

4

Recommended Improvement Alternatives

This chapter presents conceptual improvement alternatives within the study area based on the operational, safety and environmental resource analyses and evaluation completed in chapters 1, 2 and 3. This chapter is organized in two main sections with concept improvement alternatives presented for (1) the western (District 3) study area (including right-in right-out locations, mainline Route 2, and interchanges) and (2) the eastern (District 4) study area (Route 2 signalized intersections and the Concord Rotary).

4.1 Existing and Future Conditions Summary

The following summarize the findings of the Existing Conditions for the corridor:

› Route 2 is a diverse corridor
  - Eastern study area (District 4) is governed by signalized intersections and the Concord Rotary
  - Western study area (District 3) is primarily comprised of limited access interchanges

› Significant bottlenecks are present, including:
  - Tracey's Corner (Bedford Road);
  - Concord Rotary; and
  - I-190 Interchange.

› Traffic demand exceeds capacity during many hours of the day

› Significant crash experience – many locations exceed statewide averages; HSIP locations include Tracey's Corner (Bedford Road), Taylor Road & Piper Road, and Baker Avenue Extension & Elm Street.

› Significant and notable sensitive environmental and natural resource areas along length of corridor

- Limited current multi-modal accommodation
- Traffic conditions in 2022 have reflected some level of rebound as compared to pre-pandemic conditions (approximately 10% lower daily volume). Pre-pandemic conditions were used conservatively in this evaluation.

The following summarize the findings of the Future Conditions for the corridor:

- Normal background growth in traffic volumes expected along the corridor
- Site-specific development is heavily focused around Devens
- Outside of this study, other operational and safety improvement projects have been implemented along the corridor

4.2 Conceptual Improvement Alternative(s) Development

Conceptual level improvement alternatives have been developed for study area locations and are presented herein. Order of magnitude construction cost estimates have been developed and provided, as well as an initial categorization regarding implementation timeframes. Improvement alternatives are presented as:

- Near-term (0-10 years) – Alternatives range from shorter-term safety improvements, signal operation modifications, equipment upgrades (including adaptive signal systems, battery back-up systems and system/video monitoring), minor geometric modifications, accessibility improvements, pedestrians and bicycle enhancements (safe crossings and detection - where applicable) to more significant geometric modifications, ramp consolidations, access modifications, and safety improvements based on mainline crash history, geometric deficiencies, cross sectional and drainage improvements
- Long-term (10+ years) – Alternatives include major geometric modifications and interchange/intersection re-configurations that could involve environmental permitting, land acquisition and/or larger construction costs

4.3 Western (District 3) Study Area

The following section summarizes conceptual improvement alternatives for the western (District 3) study area. This section includes a high-level review of the impacts and benefits of developing a third lane in each direction, an evaluation of the existing right-in/right-out only locations and an assessment of interchange access/egress points.

4.3.1 Capacity Expansion of Route 2 to 6 lane Cross-section (Long-Term)

Route 2 primarily provides a four-lane (two-lanes per direction), median divided limited access roadway within the western study area. The current and project future capacity analyses indicate significant portions of the roadway that currently are (or are projected to be) over capacity during peak periods of operation. The following presents a high-level analysis of benefits and challenges to widening Route 2 to provide a third lane in each direction, including an overview of the magnitude of potential associated impacts and costs, as well as a summary of the potential operational benefits.

4.3.1.1 Infrastructure, Right-of-Way, Environmental and Cost Constraints

An evaluation of the constraints of adding a 3rd lane in each direction revealed multiple structures (bridges, culverts, abutments) along Route 2 within the western (District 3) study area that would need to be widened/modified (in excess of 20 structures). As these structures reach the end of their design life, widening the bridge abutments and decks should be considered as a corridor-wide recommendation rather than simple rehabilitation projects. Similarly, in order to accommodate the additional lane and a shoulder that meets design criteria, permanent takings would be required to widen the roadway's layout. There are several bodies of water and associated environmental resource area (rivers, ponds, marshes) that would involve environmental permitting associated with the widening. Finally, the approximate cost associated with constructing a 3rd lane within the western (District 3) study area is expected to be $650,000,000 to 750,000,000[8].

4.3.1.2 Operations

As shown in the Existing and No-build condition chapters, the mainline and ramp segments within the western study area are near or overcapacity with operations at LOS E or F for all movements in the peak hour direction (eastbound in the morning and westbound in the evening). Table 4-1 shows the operational benefits to the Route 2 mainline segments with an added 3rd lane. Key results include:

- Route 2 Eastbound – During the morning peak hour, all segments are expected to improve to operate at an acceptable LOS D (projected 2039). During the evening peak hour, the eastbound direction of Route 2 continues to operate at acceptable levels within the western (District 3) study area (all nine segments operate at LOS C or better).
- Route 2 Westbound – During the morning peak hour, all nine segments will continue to operate near free-flow conditions (LOS C or better) (projected 2039). During the evening peak hour, six of the nine segments analyzed improve to acceptable LOS, while three of the nine segments are still expected to operate under congested conditions (LOS E) even with an additional (3rd) lane.

8 Based on current available cost information. Does not include costs associated with right of way, design, construction services, permitting, or long-term escalation.

Table 4-1 Route 2 Freeway Segment Capacity Analyses Summary — 2039 Conditions – Add 3rd Lane

Freeway Segment Description		Weekday Morning Peak Hour			Weekday Evening Peak Hour		
From	To	Volume[1]	Density[2]	LOS[3]	Volume	Density	LOS
Eastbound							
Princeton Road (Route 31)	Palmer Road	3,505	27.8	D	2,185	17.3	B
Palmer Road	Mt. Elam Road	3,505	27.5	D	2,190	17.2	B
Mt. Elam Road	Merriam Avenue	3,515	31.0	D	2,190	19.2	C
Merriam Avenue	Abbott Avenue	3,860	31.1	D	2,415	19.5	C
Abbott Avenue	N. Main Street (Route 12)	3,670	29.1	D	2,310	18.3	C
N. Main Street (Route 12)	Main Street (Route 13)	4,170	32.5	D	2,870	22.8	C
Main Street (Route 13)	I-190	4,580	30.7	D	3,095	21.0	C
Shirley Road	Jackson Road	4,290	32.6	D	1,965	14.9	B
Jackson Road	Ayer Road (Route 110/111)	3,565	27.3	D	2,000	15.3	B
Westbound							
Ayer Road (Route 110/111)	Jackson Road	1,750	13.4	B	3,410	26.1	D
Jackson Road	Shirley Road	1,570	12.1	B	4,070	31.4	D
I-190	Main Street (Route 13)	2,535	16.8	B	4,585	30.4	D
Main Street (Route 13)	N. Main Street (Route 12)	2,365	20.3	C	4,625	35.6	**E**
N. Main Street (Route 12)	Abbott Avenue	1,945	15.4	B	4,475	35.5	**E**
Abbott Avenue	Merriam Avenue	1,875	15.0	B	4,145	33.1	D
Merriam Avenue	Mt Elam Rd	1,870	17.6	B	4,420	38.2	**E**
Mt. Elam Road	Oak Hill Rd	1,850	16.1	B	4,165	31.5	D
Oak Hill Road	Princeton Road (Route 31)	1,860	14.6	B	4,035	31.7	D

Source: VHB, Inc. using HCM 6 methodologies.
Note: Shaded cells denote LOS E or LOS F conditions.
1 Volume – Volume in vehicles per hour on the freeway segment.
2 Density – Expressed in passenger cars per mile per lane.
3 LOS – Level of service rating for the freeway segment, ranging from LOS A (best) to LOS F (worst).

Similar to the improved mainline operations, the ramp segments (both diverge and merge) are expected to improve with the added 3rd lane along Route 2 within the western (District 3) study area. Key results of the merge analyses (Table 4-2) include:

› Route 2 Eastbound – In contrast to the 2039 Baseline Conditions, all merge locations are expected to improve to operate near-free flow conditions (LOS D or better) during both peak hours.

- Route 2 Westbound – Similar to eastbound, all westbound merge locations are expected to improve to operate near-free flow conditions (LOS D or better) during both peak hours.

Table 4-2 Route 2 Ramp Capacity Analyses (Merge) Summary — 2039 Add 3rd Lane

	Weekday Morning Peak Hour			Weekday Evening Peak Hour		
Ramp Location	**Volume[1]**	**Density[2]**	**LOS[3]**	**Volume**	**Density**	**LOS**
Eastbound						
Palmer Road	0	24.0	C	5	17.0	B
Mt Elam Road	5	24.0	C	5	17.0	B
Merriam Avenue	780	28.2	D	535	19.7	B
Abbott Avenue	40	21.5	C	15	14.0	B
N. Main Street (Route 12)	770	27.0	C	575	19.0	B
	210	25.4	C	285	18.6	B
Main Street (Route 13)	805	29.9	D	605	21.3	C
Jackson Road	145	17.2	B	310	8.9	A
Westbound						
Jackson Road	5	9.7	A	5	20.1	C
	285	10.2	B	860	25.7	C
I-190	1,420	12.7	B	1,895	25.9	C
Main Street (Route 13)	215	15.1	B	500	28.3	D
N. Main Street (Route 12)	210	8.1	A	750	24.0	C
Abbott Avenue	175	13.3	B	250	25.8	C
Merriam Avenue	220	12.6	B	610	27.6	C
Mt Elam Road	50	15.4	B	45	27.6	C
Oak Hill Road	85	13.1	B	50	24.7	C

Source: VHB, Inc. using HCM 6 methodologies.
Note: Red values denote LOS E or LOS F conditions.
1 Volume – Volume in vehicles per hour on the ramp segment.
2 Density – Expressed in passenger cars per mile per lane.
3 LOS – Level of service rating for the freeway segment, ranging from LOS A (best) to LOS F (worst).
4 LOS F due to demand greater than capacity.

Key results of the diverge analyses (Table 4-3) include:

- Route 2 Eastbound – During the morning peak hour, seven of the eight off-ramps improve to operate at acceptable conditions (LOS D or better) (projected 2039). The lone diverge location that will operate under congested conditions is the I-190 split. Similarly, all off-ramps improve to operate at LOS C or better during the evening peak hours given the added 3rd lane.
- Route 2 Westbound – During the morning peak hour, all nine westbound off-ramps improve to operate at LOS B or better (projected 2039). In the evening peak hour, all nine westbound off-ramps improve to operate at LOS D or better given the added 3rd lane.

Table 4-3 Route 2 Ramp Capacity Analyses (Diverge) Summary — 2039 Add 3rd Lane

	Weekday Morning Peak Hour			Weekday Evening Peak Hour		
Ramp Location	Volume[1]	Density[2]	LOS[3]	Volume	Density	LOS
Eastbound						
Palmer Road	0	22.9	C	0	14.9	B
Mt Elam Road	0	25.9	C	5	17.9	B
Merriam Avenue	430	24.0	C	310	16.2	B
Abbott Avenue	230	26.2	C	120	18.1	B
N. Main Street (Route 12)	480	24.5	C	300	16.7	B
Main Street (Route 13)	400	31.5	D	375	19.9	B
I-190	2,020	34.2	C	1,620	22.9	C
Jackson Road	870	28.7	D	275	11.6	B
Westbound						
Jackson Road	470	11.5	B	200	22.9	C
	5	8.7	A	5	21.5	C
Main Street (Route 13)	385	17.4	B	455	29.8	D
N. Main Street (Route 12)	400	14.2	B	585	30.0	D
	225	13.4	B	315	27.5	C
Abbott Avenue	245	14.8	B	580	29.9	D
Merriam Avenue	225	13.3	B	335	26.2	C
Mt Elam Road	70	15.2	B	300	31.0	D
Oak Hill Road	80	13.2	B	180	27.4	C

Source: VHB, Inc. using HCM 6 methodologies.
Note: Red values denote LOS E or LOS F conditions.
1 Volume – Volume in vehicles per hour on the ramp segment.
2 Density – Expressed in passenger cars per mile per lane.
3 LOS – Level of service rating for the freeway segment, ranging from LOS A (best) to LOS F (worst).
4 LOS F due to demand greater than capacity.

Summary

As shown in Tables 4-2 and 4-3, mainline, merge, and diverge operations are expected to improve with the implementation of a 3rd lane/direction when compared to the 2039 Baseline Conditions. With the addition of the 3rd lane, all mainline segments are expected to operate at LOS D or better during both peak periods, except for three westbound segments during the evening peak period under 2039

Conditions. This is in contrast with the 2039 Baseline Conditions when all nine eastbound segments will operate at LOS E or F during the morning peak period and all nine westbound segments will operate at LOS E or F during the evening peak period. The merge and diverge analyses indicate an acceptable level of service for each of the ramps when implementing a 3rd lane/direction, excepting the diverge at the I-190 split, which is projected to be at or near capacity during the morning (AM) peak period (see specific I-190 section below). However, the improvement in mainline and interchange ramp peak period operations will require significant infrastructure modifications, right-of-way acquisition, environmental permitting/mitigation, and construction costs. It is not recommended that a corridor-wide capacity expansion project be undertaken due to the significant cost and impacts, and instead localized improvements should be pursued along the corridor. These localized improvements are discussed in more detail in the following sections.

4.3.2 Right-In/Right-Out Only Conceptual Alternatives (Near-Term)

The following section summarizes conceptual improvement alternatives at the right in/ right out only locations. It includes a review of the current geometry, volumes, and crash experience, as well as impacts related to closure considerations and detour options for the following Right-In/Right-out only locations along Route 2:

- Oak Hill Road (North)
- Palmer Road (South)
- Abbott Avenue (North and South)
- Hosmer Street (North and South)
- Wetherbee Street (North)
- School Street (South)

4.3.2.1 Traffic Volumes, Crash Evaluation, and Geometrics

Existing peak hour traffic volumes at each location are shown in Figure 2-7 through Figure 2-10 and reflect various levels of usage at these locations. At the low-end of peak hour volumes, right-in/right-out movements were observed to have less than 5 vehicles per hour (Route 2 at Palmer Road), while on the high-end, movements were observed to have more than 400 vehicles per hour (Hosmer Street (south) and Abbott Avenue (north)).

The safety analysis presented in Chapter 2 included the right-in/right-out only locations. The safety analysis found that none of the locations had high crash rates, however, there are locations that had a higher instance of injury crashes. Specifically, the Abbott Avenue (north) location had 25 crashes, including 4 injury crashes, and the Hosmer Street (north) location had 5 injury crashes out of 10 total crashes.

As also presented in Chapter 2, all existing right-in/right-out only locations have acceleration and deceleration lanes that do not meet current design standards based on mainline operating speeds.

4.3.2.2 Closure Evaluation/Recommended Improvements

Each current right-in/right-out only location was evaluated for potential closure and the related impact of diverting current users to alternate access/egress points along Route 2. Table 4-4 shows the most likely access/egress diversion route if the current right-in/right-out only location was closed.

Table 4-4 Route 2 Right-In/Right-Out Diversion Potential

Ramp Location	Upstream Alternative	Downstream Alternative
Oak Hill Road (North) at Route 2 WB	Mt Elam Road (3.2 miles)	Exit 28 (1.7 miles)
Palmer Road (South) at Route 2 EB	N/A – Dead-End Road	
Abbott Ave (North) at Route 2 WB	Exit 31 Route 12 (1.6 miles)	Exit 30 Merriam (0.9 miles)
Abbott Ave (South) at Route 2 EB	Exit 30 Merriam (1.1 miles)	Exit 31 Route 12 (2 miles)
Hosmer Street (North) at Route 2 WB	Wetherbee Street (1.8 miles)	Taylor Road (1.8 miles)
Hosmer Street (South) at Route 2 EB	Piper Road (1.8 miles)	School Street (1.9 miles)
Wetherbee St (North) at Route 2 WB	Route 2A (1.3 miles)	Hosmer Street (2.5 miles)
School Street (South) at Route 2 EB	Hosmer Street (1.3 miles)	Commonwealth Ave (3.4 miles)

As shown in Table 4-4, the majority of closures would require a diversion of at least 1 mile in order for drivers to complete their existing trips. Further, while some closures would divert relatively minor volumes (less than 100 peak hour trips), a number would divert larger volumes, including Abbott Avenue (North) which would divert over 700 vehicles (total right-in and out) in the evening peak hour.

The crash history at the current locations does not indicate a significant problem, however, substandard acceleration/deceleration geometry is most likely contributing to the crashes that have occurred. Closure considerations would result in diversion of current traffic volumes (sometimes significant) to adjacent, less convenient Route 2 access/egress points.

The potential for closure was considered at each of the right-in/right-out only locations. The following summarizes the results of this evaluation:

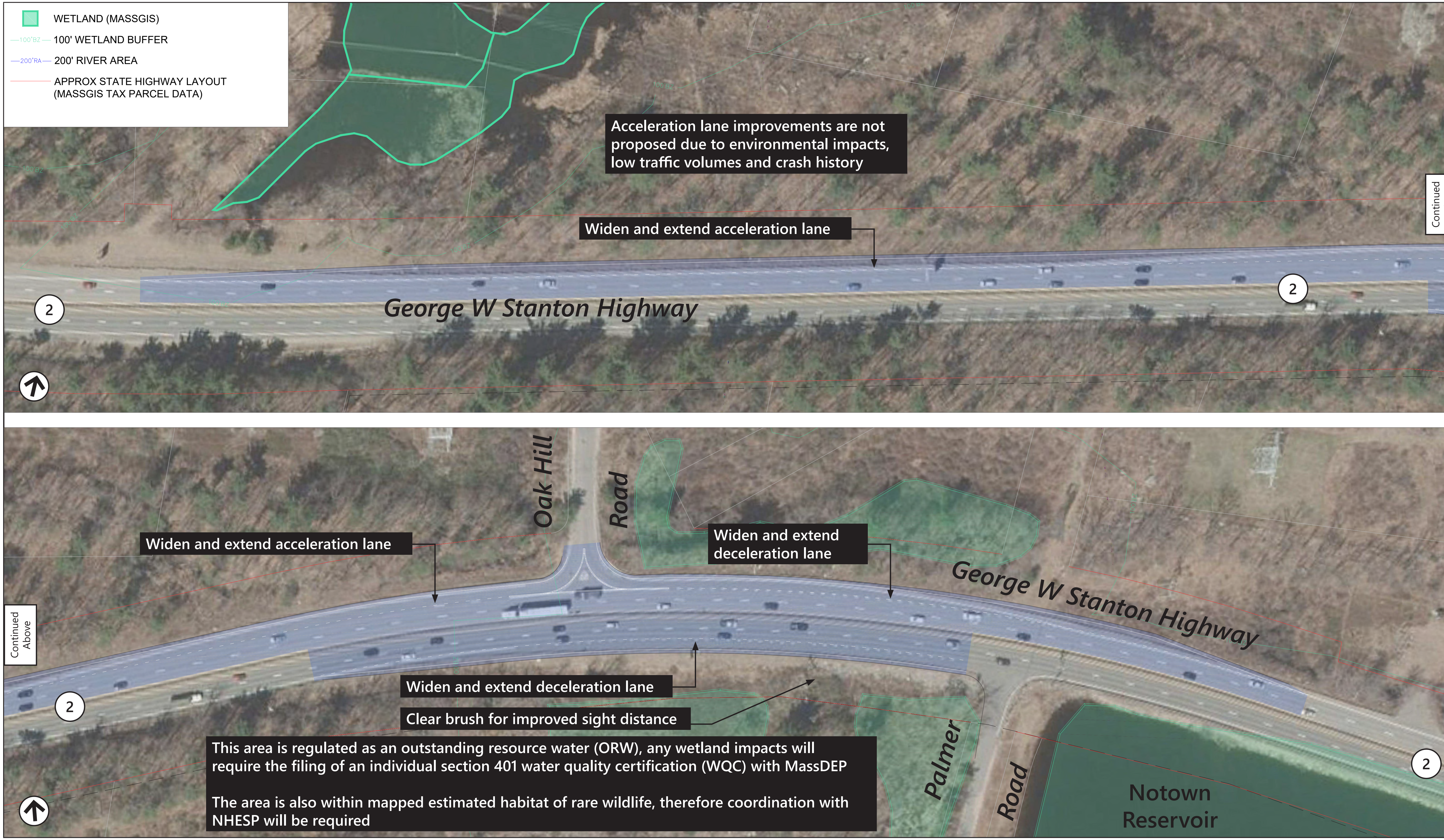
- Oak Hill Road (North) – Closure is not recommended since the roadway services moderate traffic volumes with 150-200 vehicles during the peak hours and the alternative diversion routes are greater than 3 miles or could encourage traffic to cut through neighborhood roadways. This location also has a limited crash experience and there are opportunities to improve the current acceleration and deceleration lanes with limited impacts/costs. The downstream Princeton Road ramp, while not in the study area, is approximately 3,200 feet to the west of the ramp. The spacing of the two ramps may increase delay for the entry of vehicles from Oak Hill Road. **Recommendation: if Closure is not acceptable, Increase Acceleration and Deceleration Lanes**
- Palmer Road (South) – While serving a low volume (peak hour traffic volumes are 5 vehicles or less) with limited crash experience, closure of Palmer Road is not a realistic consideration given it currently services a dead-end roadway and there is not a feasible alternative for accessing the properties. **Recommendation: Increase Deceleration Lane**
- Abbott Avenue (North) – Closure is not recommended since Abbott Avenue (North) services over 700 vehicles in the evening peak hour. The diverted volume would be expected to travel through the Route 2 at South Street/Merriam Avenue interchange or the Route 2 at Route 12 exit, which are already at, or near capacity during peak periods. **Recommendation: Remain Open**
- Abbott Avenue (South) - Moderate volumes turn right onto Abbott Avenue from Route 2 eastbound with 200 vehicles during the morning peak hour and 105 vehicles during the evening peak hour. However, the volumes turning right onto Route 2 from Abbott Avenue (south) are relatively low, ranging from 15-35 vehicles per hour. Full or partial (i.e., access to Route 2 eastbound) closure should be considered if improvements along the likely diversion routes (i.e., signalizing the intersection of the Route 2 eastbound ramps at Merriam Avenue) are completed.

Recommendation: Closure (Requires intersection improvements at Merriam Avenue at Ramps as well as public outreach)

- Hosmer Street, Wetherbee Street and School Street – these intersections are closely spaced and could be further evaluated for full or partial closure with public engagement with the community and affected neighborhoods. Partial closure (i.e., right-out from Hosmer Street (south), right-in to Wetherbee Street) could be considered based on current volumes and crash experience. Moreover, any improvements completed at the Concord Rotary (discussed later) would be expected to have impacts on the usage of these locations, as much of the current use can be tied to attempt to avoid congestion at the rotary.
  - Hosmer Street (North) – Relatively low volume with less than 100 vehicles in and out during the peak hours. Right out onto Route 2 westbound could be considered for partial closure given the proximity to the transfer station access/egress. This location experienced 10 reported crashes during the 5-year safety analysis period, with 5 of those crashes involving an injury. **Recommendation: Remain Open**
  - Hosmer Street (South) – A partial closure for Hosmer Street (South) could be considered as the volumes are relatively low for the move onto Route 2 eastbound (0 vehicles during the morning peak hour and 70 vehicles during the evening peak hour). If partial closure is pursued, it is expected that School Street would remain open and would be used as the alternate Route 2 access point. A significant volume (420 vehicles per hour) was observed during the weekday morning turning right onto Hosmer Street (South); however, this movement reflects morning commuters attempting to avoid congestion at the rotary. Similarly, access to the ADESA facility is provided via Hosmer Street (South). Car carriers accessing the facility would be forced onto the local road network if Hosmer Street (South) is closed. **Recommendation: Remain Open**
  - Wetherbee Street (North) – Potential for partial closure as there are very low volumes accessing Wetherbee Street (North) from Route 2 westbound (5 right-in vehicles per hour, both morning and evening). This low volume could be diverted up/downstream through Concord Rotary or Hosmer Street (North) / Taylor Road. Volumes turning right on to Route 2 westbound from Wetherbee Street are also relatively low (70 vehicles during the morning peak hour and 125 vehicles during the evening peak hour). However, restriction of this movement onto Route 2 would depend on the potential closure of Hosmer Street (North) to avoid possible diversion of traffic through neighborhood roads. There is a minimal crash experience at this location (1 crash). **Recommendation: Partial Closure (Requires Discussion with Town)**
  - School Street (South) – Potential for partial closure of the relatively low volume movement from Route 2 eastbound onto School Street (90 and 30 vehicles per hour, morning and evening, respectively) as this volume could be processed at Hosmer Street (South). There is a minimal crash experience at this location (4 crashes). **Recommendation: Partial Closure (Requires Discussion with Town)**

Any further consideration of closure at these locations would require close coordination with the communities and neighborhoods proximate to the right-in/right-out only locations in question.

As part of the evaluation completed herein, Figures 4-1 through Figure 4-4 present the near-term conceptual-level geometric acceleration and deceleration improvements recommended for the right-in/right-out only study locations if they are to remain open. In general, the concepts developed were within the existing right-of-way and avoid direct impacts to environmental resource areas, unless otherwise noted (a number of the concepts are within a wetland buffer which is represented graphicly on the concepts).



City of Fitchburg **INSET A**

SCALE: 1" = 100'

0 50 100 Feet

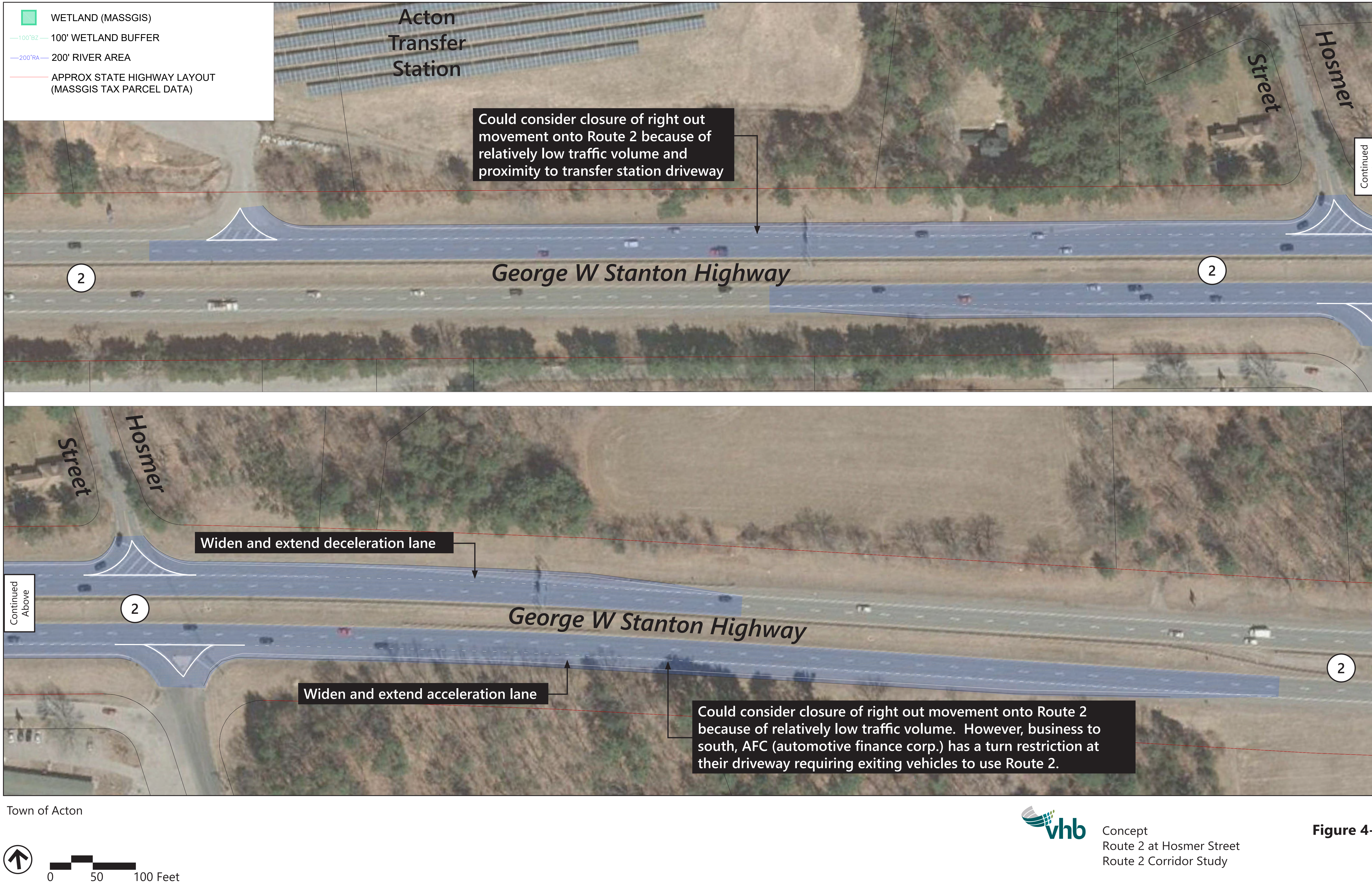
Concept
Route 2 at Oak Hill Road/
Palmer Road
Route 2 Corridor Study

Figure 4-1

Town of Leominster

Concept
Route 2 at Abbott Avenue
Route 2 Corridor Study

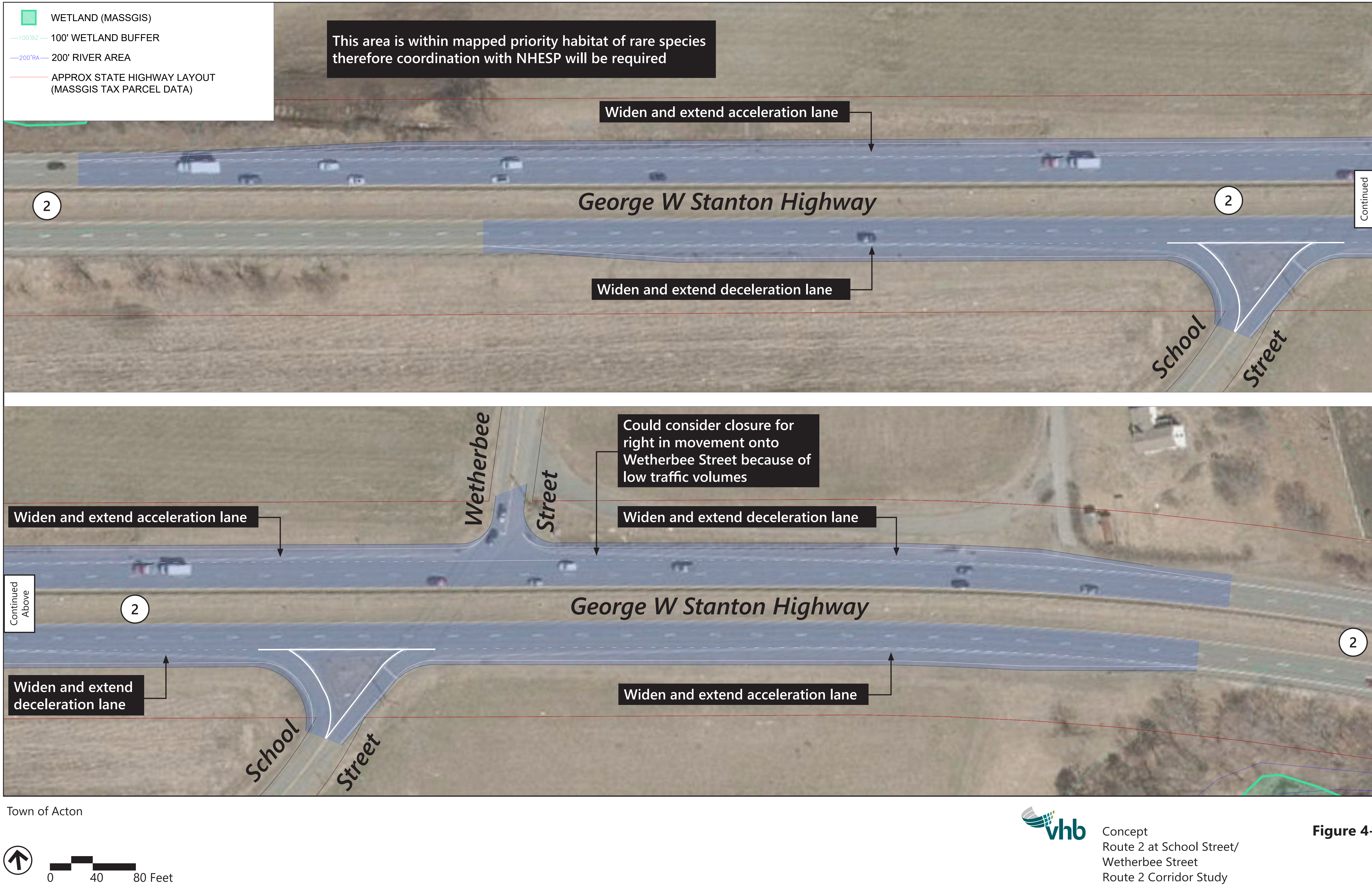
Figure 4-2



Town of Acton

Concept
Route 2 at Hosmer Street
Route 2 Corridor Study

Figure 4-3



Town of Acton

Concept
Route 2 at School Street/
Wetherbee Street
Route 2 Corridor Study

Figure 4-4

4.3.3 Interchange Alternatives

Conceptual improvement alternatives were developed within the western (District 3) study area to improve operations and safety by modification of overall interchange geometry, including ramp layout and design, weaving areas, and acceleration/deceleration lane lengths. Concepts include the removal of redundant ramps and the potential impacts of redirected traffic at select locations. Operational results are presented at key locations impacted by the conceptual design modifications. In general, the concepts developed were within the existing right-of-way and avoid direct impacts to environmental resource areas, unless otherwise noted (a number of the concepts are within a wetland buffer which is represented graphicly on the concepts).

Any intersection modification would require an Intersection Control Evaluation (ICE)[9], as part of MassDOT's guidelines. While certain conceptual plans may show a signal or roundabout, a specific treatment shown on the concepts is not meant to indicate a preference for the intersection at this stage. Further analysis will be required as part of any 25%-design development.

4.3.3.1 Route 2 at Mt Elam Road

Operational and/or safety issues identified at this location included: insufficient acceleration and deceleration lane lengths, unexpected traffic signal at a high-speed location (moderate number of crashes related to relatively low side-street volumes), and irregular intersection geometry at Mt Elam Road. All of the concepts within this area are within a 100-foot buffer zone of wetlands including the Goodfellow Pond which is regulated as an Outstanding Resource Water.

Concept 1 – Increase eastbound/westbound deceleration lanes and westbound acceleration lane (Near-Term)

As presented if Figure 4-5, the improvement alternative includes increasing the deceleration and acceleration lane lengths, as shown, to meet current MassDOT design criteria. Increasing the eastbound acceleration lane length onto Route 2 in its current alignment was not feasible due to the proximity of Goodfellow Pond and associated significant environmental impacts. Extension of the Route 2 westbound deceleration and acceleration lanes could allow for the removal of the current flashing signal indication on the westbound Route 2 approach. Improvements to the signal equipment involve upgrading to current MassDOT standards.

Concept 2 – Includes improvements from Concept 1 and modifies the geometry of Mt Elam Road (north) (Near-Term)

As presented in Figure 4-6, the concept builds on the improvement from Concept 1 and addresses the current irregular intersection geometry of the westbound off-ramp's intersection with Mt Elam Road, potentially reducing the risk of wrong way driving (vehicles entering the Route 2 westbound off-ramp from Mt Elam Road). Record right-of-way information in this area associated with the Mt Elam Road reconfiguration was limited and will need further review to understand potential impacts.

9 *Intersection Control Evaluation (ICE) Procedure Requirements*. MassDOT, 9/8/2022

Concept 3 – Includes improvements form Concepts 1 and 2, and shifts Route 2 to the north to develop a lengthened eastbound acceleration lane (Long-Term).

As presented in Figure 4-7, the concept builds on the improvements from Concepts 1 and 2 and allows for an extended acceleration lane onto Route 2 eastbound by shifting the current Route 2 alignment to the north. With proper acceleration and deceleration to/from Mt Elam Road along Route 2 eastbound, removal of the current stop-and-go traffic signal can be considered to address any safety concerns associated with a traffic signal along a high-speed roadway. While the number of crashes at this location (Route 2 Eastbound at Mt. Elam Road) is not necessarily high (23 reported crashes in 5 years) seven of the crashes involved an injury. Similarly, 18 of the 23 crashes were rear-end type crashes, which are typically associated with a poor sight line and/or an unexpected traffic signal.

Additional Considerations – Property Acquisitions

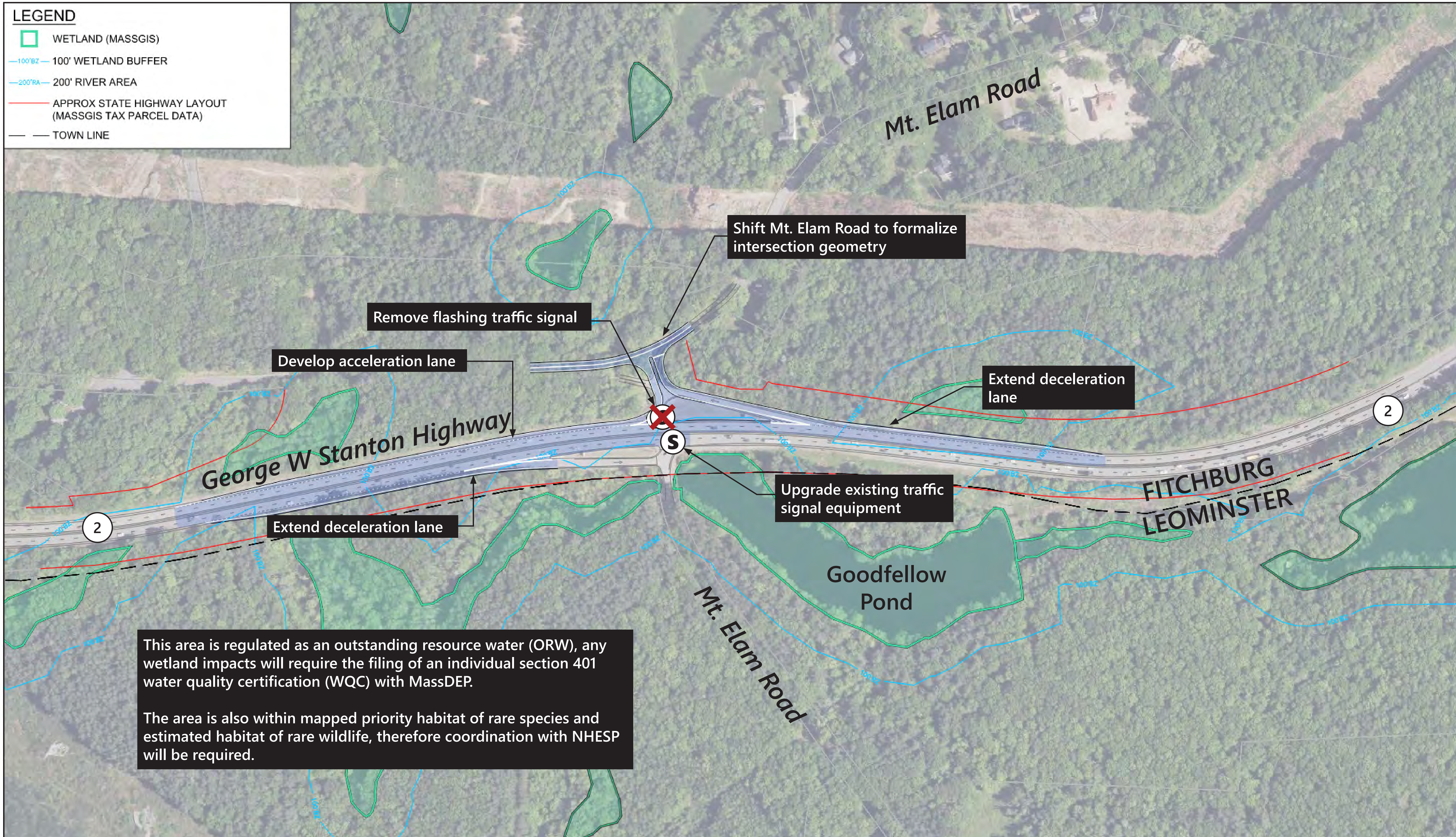
Mt Elam Road (south) provides access to only a few properties. Similarly, the traffic volume generated by these properties is very low (~5 per peak hour). As such, consideration should be given to acquiring the properties along Mt Elam Road (South). This would allow for a closure of the roadway and removal of the signal.

City of Fitchburg / Town of Leominster

0 125 250 Feet

Concept 1
Route 2 at Mt. Elam Road
Route 2 Corridor Study

Figure 4-5

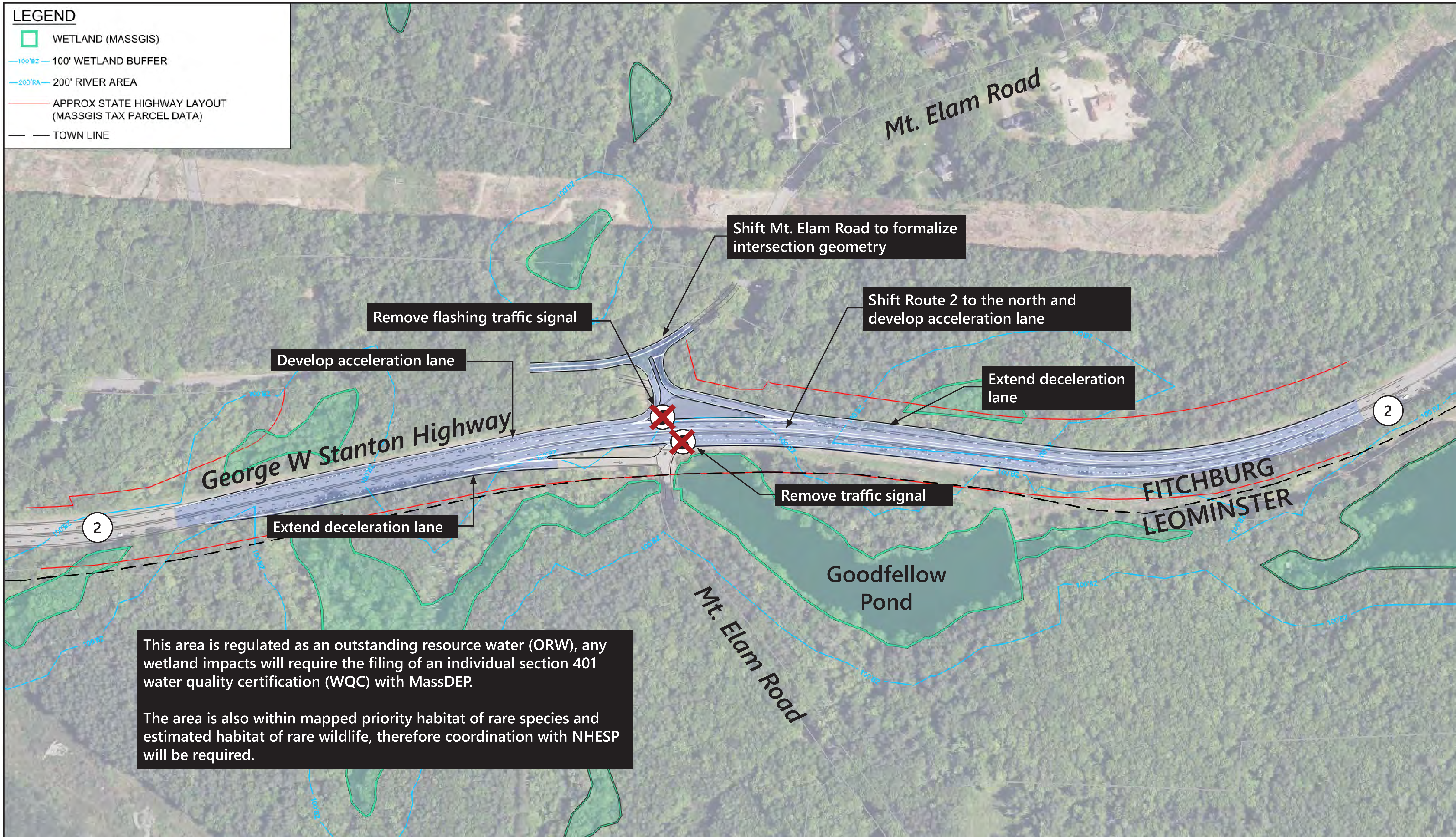


City of Fitchburg / Town of Leominster

0 125 250 Feet

Concept 2
Route 2 at Mt. Elam Road
Route 2 Corridor Study

Figure 4-6



City of Fitchburg / Town of Leominster

Concept 3
Route 2 at Mt. Elam Road
Route 2 Corridor Study

Figure 4-7

4.3.3.2 Route 2 at Merriam Avenue

Operational and/or safety issues identified at this location include a weaving section created by the current westbound off-ramp and vehicles entering from Abbott Avenue (to the east), insufficient acceleration and deceleration lengths, and operations/crash experience at the Merriam Avenue intersection at the Route 2 eastbound ramps.

Concept 1 – Improve acceleration and deceleration lane lengths (Near-Term)

As presented in Figure 4-8, this concept increases the eastbound off-ramp's deceleration lane, develops an auxiliary lane between Abbott Avenue (North) and the westbound off-ramp's deceleration lane, extends the length of the westbound on-ramp's acceleration lane, and maintains the existing eastbound auxiliary lane between the on-ramp and Abbott Avenue (South). The current bridge abutment are the limits of deceleration lanes. A long-term consideration should be to reset the bridge abutments to provide proper length deceleration lanes.

Concept 2 – Improve all acceleration and deceleration lanes, signalize eastbound ramps and close Abbott Avenue (South) (Long-Term)

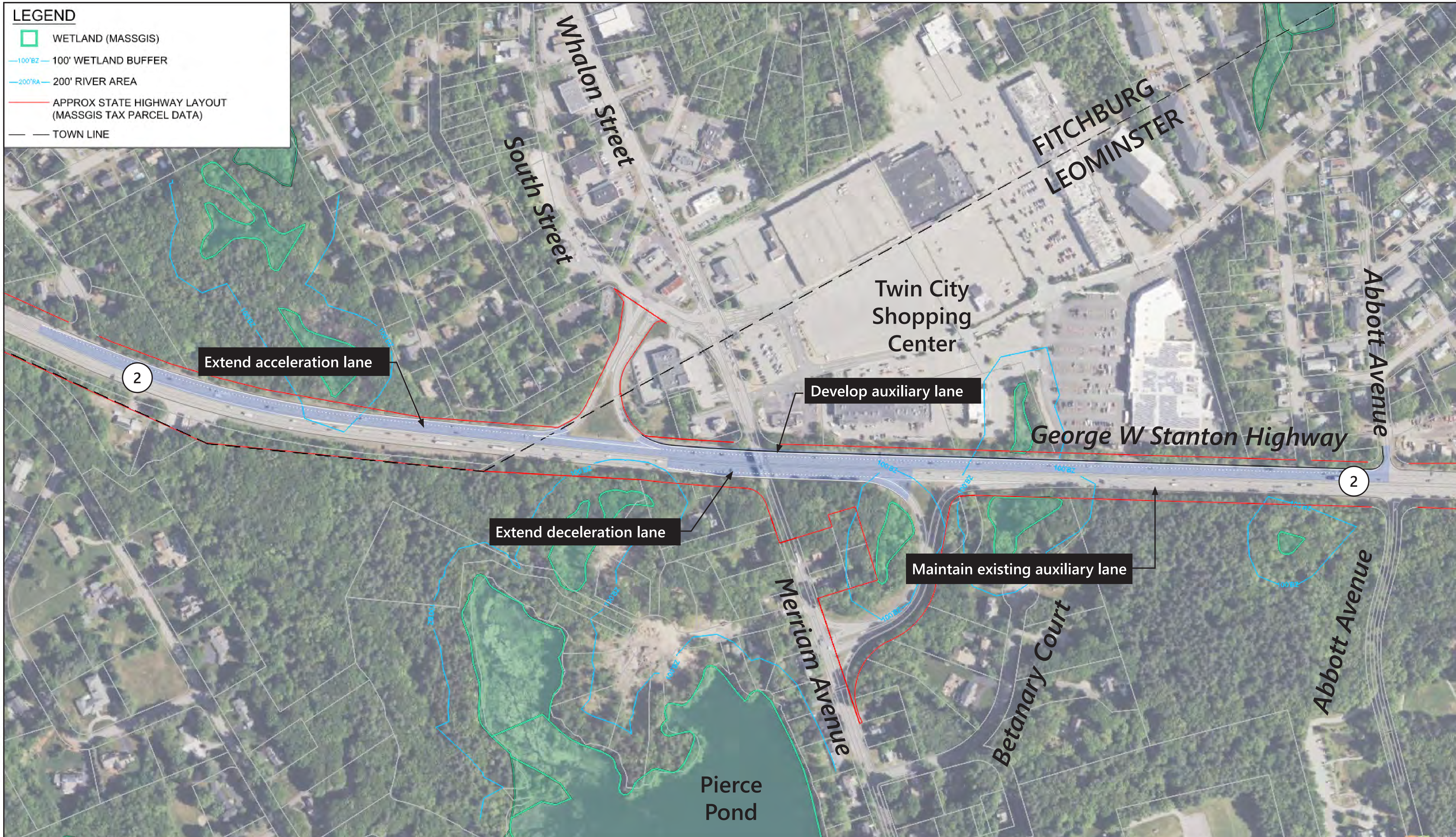
As presented in Figure 4-9, this concept carried forward the geometric improvements of Concept 1, but also proposes to close Abbott Avenue (South). This concept also proposes a new traffic signal at the eastbound ramps to address existing safety concerns and to better accommodate the diverted traffic volumes associated with the closure of Abbott Avenue (South). It should be noted that a roundabout is also a consideration in lieu of signalization at the intersection. As noted in the right-in/right-out only evaluation, if the Abbott Avenue (South) location is closed, vehicles would be most likely to divert to the Route 2 eastbound ramps at Merriam Avenue. The closure of the Abbott Avenue allows for the development of a proper acceleration lane for the Route 2 eastbound on-ramp.

Table 4-5 presents the capacity analysis of the Route 2 eastbound ramps/Merriam Avenue intersection with signalization and the closure of Abbott Avenue (South). The intersection is projected to operate with less queuing than under 2039 No-Build Conditions, specifically the off-ramp segment, even with the additional diverted Abbott Avenue (South) volume. The proposed signal may also reduce the number of angle crashes at the currently unsignalized intersection. The new signal has negative operational impacts for currently unsignalized movements along Merriam Avenue, with a LOS E in the northbound direction during the weekday morning and evening peak hours and a LOS E for the southbound left turn movement during the weekday morning peak hour and a LOS F during the weekday evening peak hour.

Table 4-5 Intersection Capacity Analysis – Merriam Avenue at Route 2 Eastbound Ramps

	2039 No-Build *(Unsignalized)*					2039 Concept 2 *(Signalized)*				
Location/Movement	Dem[a]	v/c	Del	LOS	95 Q	v/c [b]	Del [c]	LOS [d]	50 Q [e]	95 Q [f]
Morning Peak Hour										
WB L	370	>1.20	>120	F	1495	0.93	76	E	234	#366
WB R	N/A					0.25	40	D	0	63
NB T	N/A					1.02	77	E	~497	#741
SB L	615	0.74	18	C	173	1.08	82	F	~525	m#629
SB T	N/A					0.40	3	A	63	m99
Overall						**1.08**	**57**	**E**		
Evening Peak Hour										
WB L	265	>1.20	>120	F	983	0.69	58	E	131	202
WB R	N/A					0.15	47	D	0	76
NB T	N/A					1.02	68	E	~791	#1047
SB L	450	0.76	23	C	178	0.96	62	E	380	#652
SB T	N/A					0.49	5	A	154	246
Overall						**0.95**	**47**	**D**		

Source: VHB, Inc. using Synchro 9/10 software
Note: Shaded cells denote LOS E or LOS F conditions.
a Demand (vehicles).
b Volume to capacity ratio.
c Average total delay, in seconds per vehicle.
d Level-of-service.
e 50th percentile queue, in feet.
f 95th percentile queue, in feet.
~ Volume exceeds capacity, queue is theoretically infinite.
# 95th percentile volume exceeds capacity; queue may be longer.
m Volume for 95th percentile queue is metered by upstream signal.



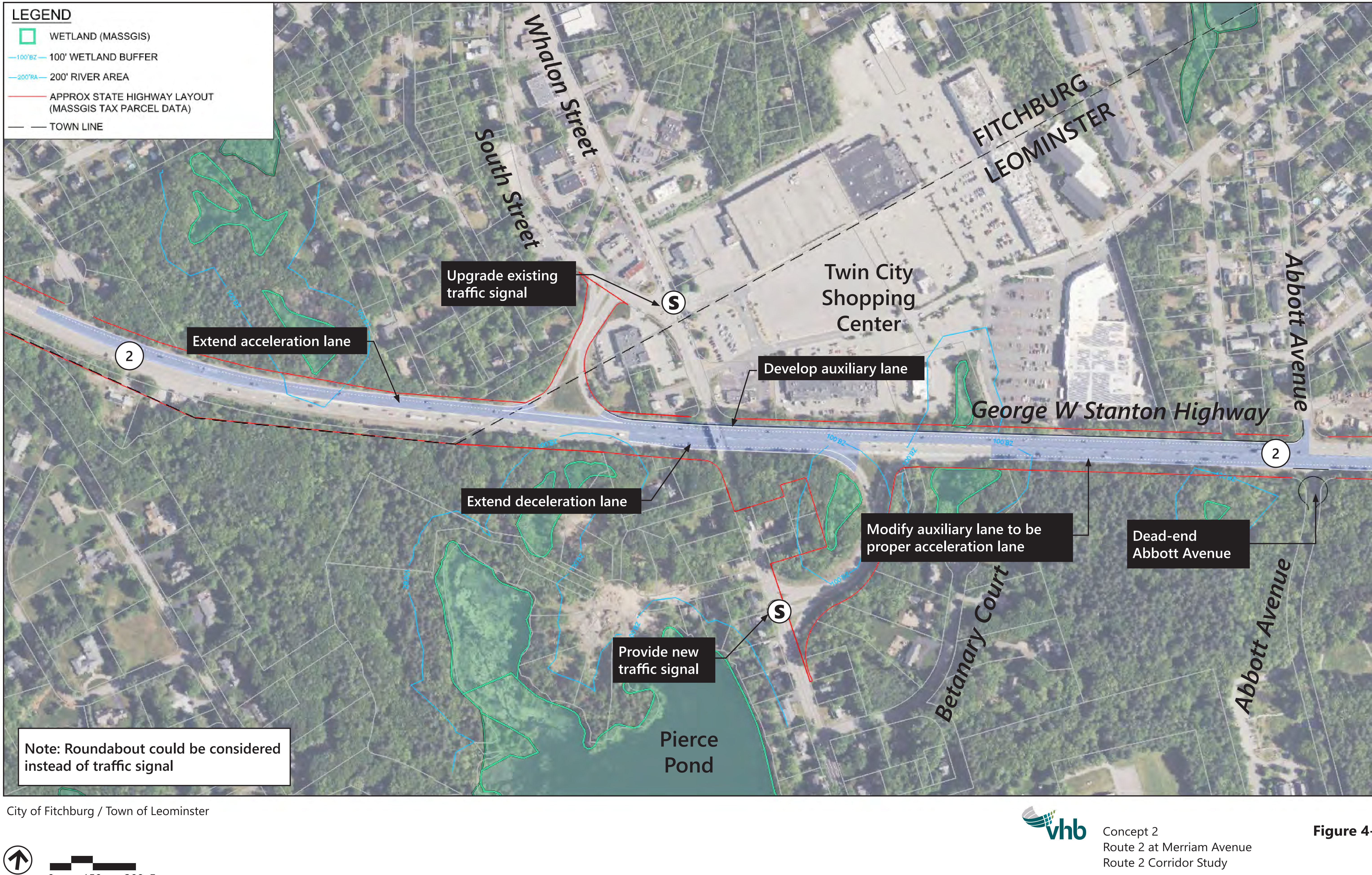
City of Fitchburg / Town of Leominster

0 150 300 Feet

vhb

Concept 1
Route 2 at Merriam Avenue
Route 2 Corridor Study

Figure 4-8



City of Fitchburg / Town of Leominster

Concept 2
Route 2 at Merriam Avenue
Route 2 Corridor Study

Figure 4-9

4.3.3.3 Route 2 at North Main Street (Route 12)

Operational and/or safety issues identified at this location include insufficient acceleration and deceleration lane lengths due to current interchange geometry, as well as closely spaced, redundant eastbound on-ramps and westbound off-ramps.

Concept – Close redundant ramps (Long-Term)

As presented in Figure 4-10, the concept for the Route 12 interchange proposes to close the redundant Route 2 ramps (eastbound second on-ramp and westbound second off-ramp). Closing the second eastbound on-ramp allows for an extension of the acceleration lane length of the first eastbound on-ramp. Traffic signal modifications are needed at the Route 2 eastbound ramps/Route 12 intersection to accommodate the ramps closure to allow for a Route 12 northbound left-turn onto the Route 2 eastbound on-ramp.

Closing the second westbound off-ramp eliminates the short, deficient deceleration distance between the two current off-ramps. The improvement alternative proposes to realign the remaining westbound off-ramp geometry to align perpendicular to Route 12 to allow for a signalized westbound left turn movement onto Route 12 southbound. Dual left turn lanes are proposed for the northbound and westbound approaches to the modified Route 2 westbound ramps/Route 12 intersection. To accommodate the changes shown further structural evaluation will need to be conducted to determine feasibility of modifying the median on the Route 12 bridge over Route 2. The bridge abutments of the adjacent old railroad crossing (now rail trail) are potentially limiting the ability to extend both the eastbound deceleration lane and westbound acceleration lane.

Table 4-6 and Table 4-7 show the capacity analysis the conceptual improvements at the eastbound and westbound ramps, respectively. With the proposed ramp reconfigurations both intersections are expected to provide acceptable 2039 operations.

Table 4-6 Intersection Capacity Analysis – N Main Street (Rt 12) at Route 2 Eastbound Ramps

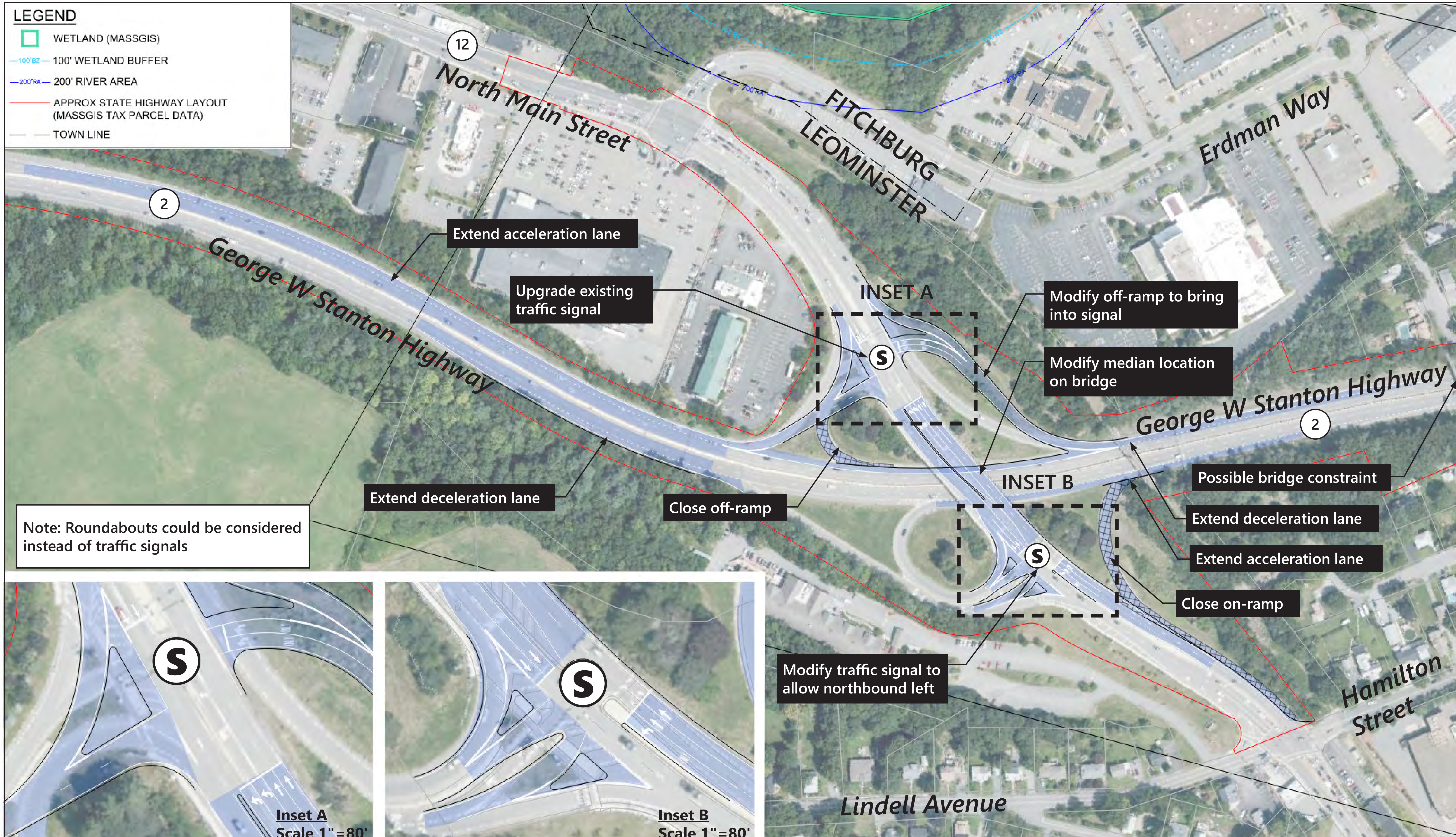
	2039 No-Build					2039 Concept				
Location/Movement	v/c [a]	Del [b]	LOS [c]	50 Q [d]	95 Q [e]	v/c	Del	LOS	50 Q	95 Q
Morning Peak Hour										
EB L	0.39	15	B	51	113	0.67	30	C	86	132
EB R	0.71	21	C	80	173	0.53	26	C	32	66
NB L	N/A					0.68	31	C	90	#206
NB T	0.41	9	A	64	148	0.31	5	A	54	91
SB T	0.55	10	A	96	210	0.67	17	B	166	241
SB R	0.60	11	B	0	50	0.76	22	C	50	#364
Overall	**0.64**	**12**	**B**			**0.72**	**19**	**B**		
Evening Peak Hour										
EB L	0.34	17	B	33	86	0.58	34	C	70	117
EB R	0.50	17	B	42	111	0.15	30	C	0	45
NB L	N/A					0.74	35	D	146	#243
NB T	0.64	8	A	107	227	0.50	4	A	110	155
SB T	0.63	8	A	103	220	0.79	21	C	273	383
SB R	0.40	6	A	0	36	0.45	15	B	19	98
Overall	**0.60**	**9**	**A**			**0.74**	**16**	**B**		

Source: VHB, Inc. using Synchro 9/10 software
Note: Shaded cells denote LOS E or LOS F conditions.
a Volume to capacity ratio.
b Average total delay, in seconds per vehicle.
c Level-of-service.
d 50th percentile queue, in feet.
e 95th percentile queue, in feet.
~ Volume exceeds capacity, queue is theoretically infinite.
# 95th percentile volume exceeds capacity; queue may be longer.
m Volume for 95th percentile queue is metered by upstream signal.

Table 4-7 Intersection Capacity Analysis – N Main Street (Rt 12) at Route 2 Westbound Ramps

	2039 No-Build					2039 Concept				
Location/Movement	v/c [a]	Del [b]	LOS [c]	50 Q [d]	95 Q [e]	v/c	Del	LOS	50 Q	95 Q
Morning Peak Hour										
EB R	0.00	31	C	0	0	N/A				
WB L	N/A					0.48	29	C	55	92
WB R						0.27	0	A	0	0
NB L	0.47	22	C	51	137	0.43	30	C	36	67
NB T	0.22	0	A	0	0	0.28	3	A	43	73
SB T	0.70	8	A	157	314	0.83	17	B	270	437
Overall	**0.64**	**9**	**A**			**0.71**	**13**	**B**		
Evening Peak Hour										
EB R	0.00	48	D	0	#116	N/A				
WB L	N/A					0.70	41	D	95	140
WB R						0.40	1	A	0	0
NB L	0.95	58	E	316	#528	0.87	48	D	145	#225
NB T	0.26	0	A	0	0	0.33	3	A	69	91
SB T	0.86	20	C	430	545	0.98	37	D	508	#704
Overall	**0.89**	**23**	**C**			**0.91**	**26**	**C**		

Source: VHB, Inc. using Synchro 9/10 software
Note: Shaded cells denote LOS E or LOS F conditions.
a Volume to capacity ratio.
b Average total delay, in seconds per vehicle.
c Level-of-service.
d 50th percentile queue, in feet.
e 95th percentile queue, in feet.
~ Volume exceeds capacity, queue is theoretically infinite.
# 95th percentile volume exceeds capacity; queue may be longer.
m Volume for 95th percentile queue is metered by upstream signal.



City of Fitchburg / Town of Leominster

0 100 200 Feet

Concept 1
Route 2 at North Main Street (Route 12)
Route 2 Corridor Study

Figure 4-10

4.3.3.4 Route 2 at Main Street (Route 13)

Operational and/or safety issues identified at this location includes insufficient acceleration and deceleration lane lengths. There were a reported 66 and 93 crashes for the eastbound and westbound ramp locations, respectively. The westbound ramps are highlighted with 28 injury crashes, including 1 fatal crash. The current on/off-ramps also atypically provide direct access to various site driveways along the ramps' length prior to its intersection with Route 13. There is currently a project at this location that involves signalizing the westbound on/off ramp intersection with Route 113. The improvements currently being pursued are expected to address some of the safety issues at this location.

Concept 1 – Improve acceleration and deceleration lane lengths (Near-Term)

As presented in Figure 4-11, Concept 1 proposes extended deceleration lane lengths for both eastbound and westbound off-ramps to Route 13. Extension of acceleration lane lengths are proposed for the on-ramp to Route 2 westbound. However, acceleration lane improvements are not proposed in the near-term for the on-ramp to Route 2 eastbound because it would require bridge widening over the Nashua River.

Concept 2 – Develop full diamond interchange (Long-Term)

As presented in Figure 4-12, Concept 2 considers developing a full diamond interchange, with signalization, that connects the on/off-ramps proximate to the Route 13 bridge over Route 2. Developing the full diamond Interchange facilitates more typical and standard off/on-ramps and eliminates breaks in access for private property. This concept involves a widening of the Route 13 bridge over Route 2, environmental impacts/permitting and permanent right of way impacts and modifications.

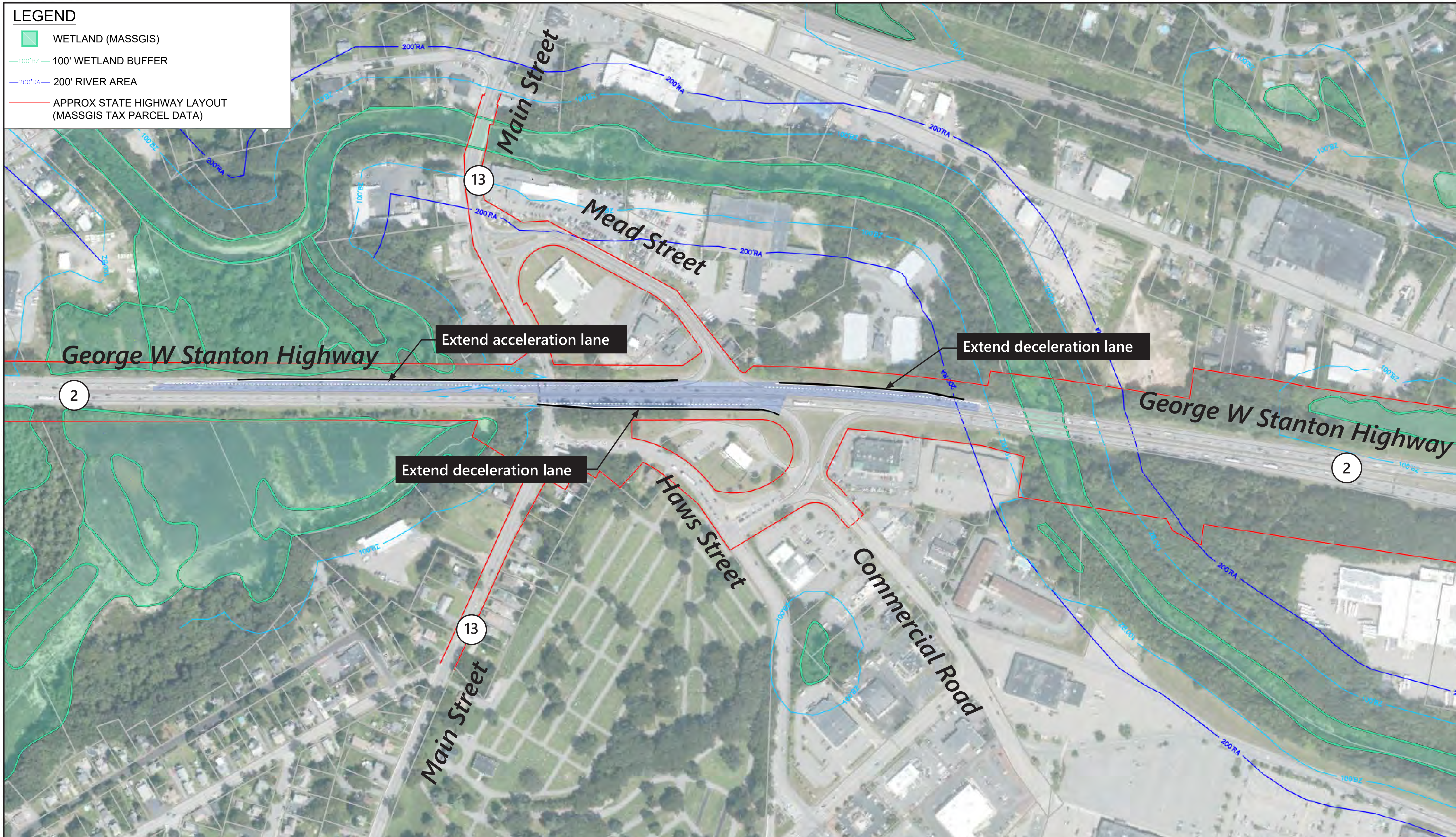
As shown in Table 4-8, the two signals adjacent to the proposed widened Route 13 bridge are expected to operate at LOS C or better for both (projected 2039) peak periods.

Table 4-8 Intersection Capacity Analysis – Main Street (Rt 13) at Route 2 Ramps (2039 Concept 2)

Location/Movement	Morning Peak Hour					Evening Peak Hour				
	v/c [a]	Del [b]	LOS [c]	50 Q [d]	95 Q [e]	v/c	Del	LOS	50 Q	95 Q
Route 13 at Route 2 EB Off-Ramp & Haws Street										
EB L	0.67	42	D	88	#158	0.48	38	D	52	100
EB T	0.54	37	D	72	113	0.80	49	D	91	#157
WB L	0.33	24	C	18	45	0.67	30	C	82	#145
WB R	0.15	41	D	64	98	0.54	54	D	238	302
NB T	0.76	43	D	110	146	0.77	43	D	109	#174
NB R	0.17	34	C	0	47	0.47	36	D	31	#147
SB L	0.66	15	B	238	289	0.76	11	B	56	m64
SB T	0.35	6	A	154	139	0.39	2	A	11	m14
Overall	0.66	26	C			0.75	31	C		
Route 13 at Route 2 WB Off-Ramp & Haws Street										
WB L	0.39	36	D	51	84	0.39	27	C	82	141
WB R	0.54	39	D	38	120	0.93	59	E	185	#379
NE L	0.43	8	A	2	m26	0.87	37	D	124	m267
NE T	0.21	3	A	6	135	0.35	6	A	107	125
SW T	0.58	10	B	207	407	0.90	36	D	365	#591
Overall	**0.56**	**13**	**B**			**0.92**	**31**	**C**		

Source: VHB, Inc. using Synchro 9/10 software
Note: Shaded cells denote LOS E or LOS F conditions.
a Volume to capacity ratio.
b Average total delay, in seconds per vehicle.
c Level-of-service.
d 50th percentile queue, in feet.
e 95th percentile queue, in feet.
~ Volume exceeds capacity, queue is theoretically infinite.
# 95th percentile volume exceeds capacity; queue may be longer.
m Volume for 95th percentile queue is metered by upstream signal.

\\vhb\gbl\proj\Wat-TE\12529.70 Rt 2 Traffic Safety\graphics\FIGURES\2023.01.31 Concept Plans\Route 2 Graphics v2.indd p14 02/23/23



Town of Leominster

0 150 300 Feet

vhb

Concept 2
Route 2 at Main Street (Route 13)
Route 2 Corridor Study

Figure 4-12

Town of Leominster INSET A

0 100 200 Feet

Concept 1 Route 2 between Main Street (Route 13) and I-190
Route 2 Corridor Study

Figure 4-13

4.3.3.5 Route 2 at I-190 Connection

Congestion and safety issues were reviewed at the Route 2 at I-190 interchange. In summary, the mainline segments adjacent to the interchange operate at LOS E during Existing Conditions for the eastbound morning peak and westbound evening peak and are expected to degrade to LOS F during 2039 Baseline Conditions for the same peak hours. Similarly, the merge and diverge ramp segments currently operate at LOS F under Existing Conditions.

Concept 1 – Proposed widened Route 2 bridge over Nashua River and lane reconfiguration between I-190 and Route 13 (Long-Term)

As presented in Figure 4-13, the concept proposes a replacement and widening of the Route 2 bridge over the Nashua River. The concept utilizes the widened bridge, as well as available roadway width to modify the lane configuration between Exits 32 (Route 13) and 33 (I-190). The concept proposes a six-lane cross section over the river (3 lanes per direction). This will allow for an improved acceleration length and add-a-lane condition for the on-ramp from Route 13 to Route 2 eastbound.

The widened bridge also allows for Route 2 eastbound to be widened from 3-lanes to 4-lanes (east of the river) on its approach to I-190, with 2 lanes continuing onto Route 2 eastbound and 2 lanes continuing onto Route I-190. In the westbound direction, the concept proposes to maintain the current 2 lanes from Route 2 and use existing roadway width to provide 2 lanes from I-190 (currently a lane drop) to join into a 4-lane section for a portion of Route 2 westbound prior to a lane drop to 3-lanes over the Nashua River. The three-lane westbound section would be carried beyond the Route 13 off-ramp where it is then dropped back to a two-lane section. To develop the concept, lane modifications are required at the Route 2 at Main Street (Route 13) interchange to reposition the westbound on-ramp away from the lane drop (i.e., similar to what was presented in Figure 4-12). These modifications would require bridge reconstruction over the Nashua River to provide adequate width along Route 2. However, the existing structure of I-190 over Route 2 eastbound and Route 2 westbound over Nashua Street has adequate width to accommodate the lane reconfiguration. Additional design development is required to understand how to conduct the 4 to 3 lane drop. Based on existing evening peak volumes, 59% of westbound volumes are coming from the Route 2 connection, compared to 41% from I-190. As such, operations could be improved by conducting a left-side lane drop, rather than the typical right-side lane drop.

As shown in Table 4-9, the proposed concept improves operations to acceptable levels (LOS "D" or better) for a number of movements in 2039, excepting eastbound morning and westbound evening peak hour weave segments. It should be noted that both the eastbound and westbound weave analyses indicated that the short length between the on- and off-ramps (Route 13 and I-190), in conjunction with the high volumes, are resulting in current and projected poor conditions (i.e., unless additional spacing can be achieved between Route 13 and I-190, weave operations under the current and future volume demand will suffer).

Table 4-9 Route 2 at I-190 Ramps Capacity Analyses Summary — 2039 Concept

Analysis Type	Location	Weekday Morning Peak Hour			Weekday Evening Peak Hour		
		Volume[1]	Density[2]	LOS[3]	Volume	Density	LOS
2039 Baseline Conditions							
Eastbound							
Basic	Route 2	4,580	N/A[4]	F	3,095	37.7	E
Merge	Exit 32	805	N/A[4]	F	605	30.6	D
Diverge	Exit 33	2,020	N/A[4]	F	1,620	26.2	C
Weave	Exit 32 to Exit 33	4,580	N/A[4]	F	3,095	N/A[4]	F
Westbound							
Basic	Route 2	2,535	32.5	D	4,585	N/A[4]	F
Merge	Exit 33	1,425	16.5	B	1,895	N/A[4]	F
Diverge	Exit 32	385	25.7	C	455	N/A[4]	F
Weave	Exit 33 to Exit 32	2,535	29.7	D	4,585	N/A[4]	F
2039 Concept							
Eastbound							
Basic	Route 2	4,580	30.7	D	3,095	21.0	C
Merge	Exit 32	805	29.9	D	605	21.3	C
Diverge	Exit 33	2,020	22.7	C	1,620	18.2	B
Weave	Exit 32 to Exit 33	4,580	N/A[4]	F	3,095	29.5	D
Westbound							
Basic	Route 2	2,535	16.8	B	4,585	30.4	D
Merge	Exit 33	1,425	14.6	B	1,895	27.7	C
Diverge	Exit 32	385	17.4	B	455	29.8	D
Weave	Exit 33 to Exit 32	2,535	20.9	C	4,585	40.0	E

Source: VHB, Inc. using HCM 6 methodologies.

Note: A 3rd lane mainline is considered for all concept analyses. Shaded cells denote LOS E or LOS F conditions.

1 Demand – Weave segment demand in vehicles per hour.

2 Density – Expressed in passenger cars per mile per lane.

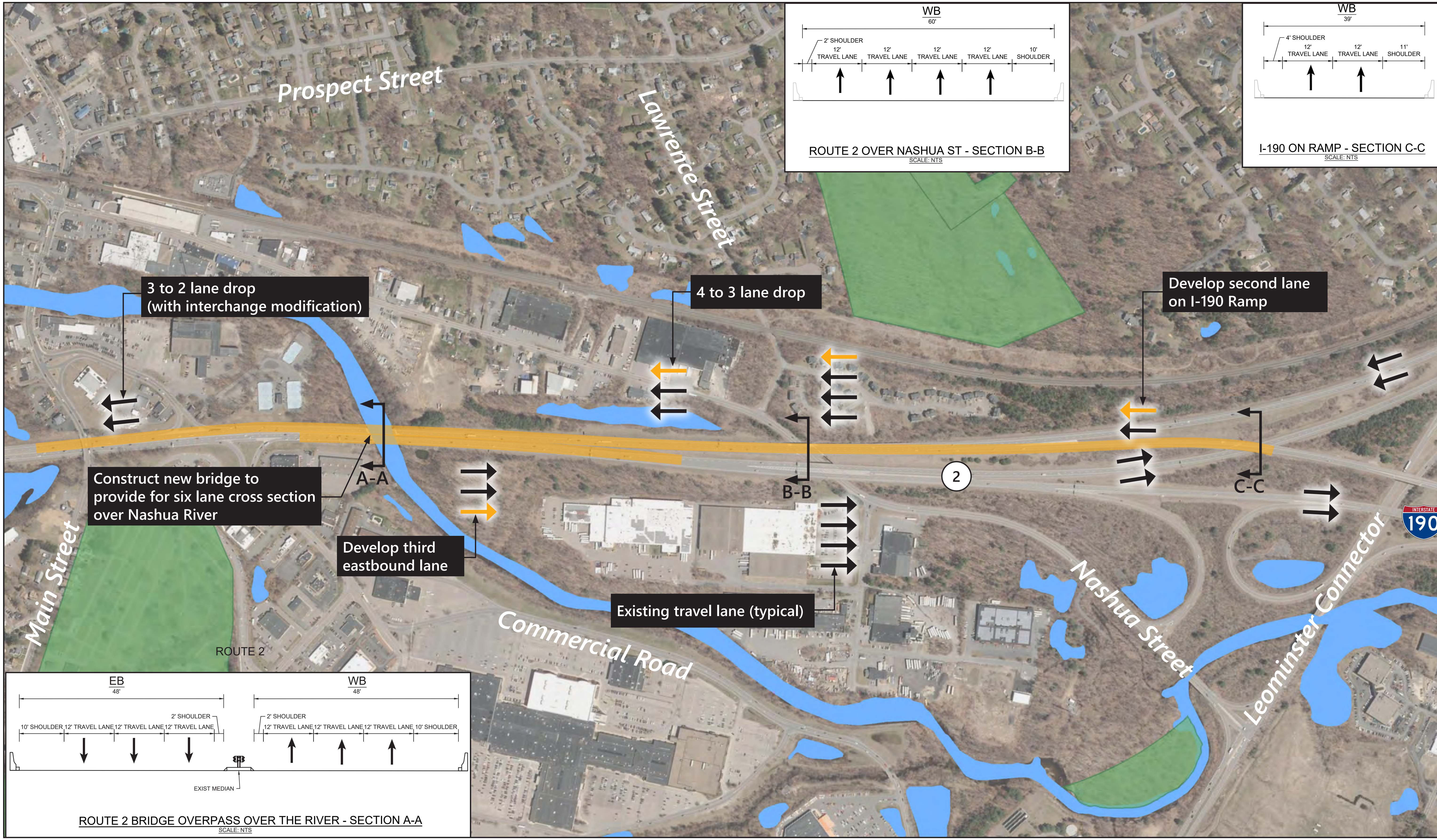
3 LOS – Level of service rating for the freeway segment, ranging from LOS A (best) to LOS F (worst).

4 LOS F due to demand greater than capacity.

5 Density not available when LOS F.

ROUTE 2 WESTBOUND

I-190



Town of Leominster

Protected and Recreational OpenSpace

DEP Wetlands (2005)

0 250 500 Feet

vhb

Concept 1 Route 2 between
Main Street (Route 13) & I-190
Route 2 Corridor Study

Figure 4-13

4.3.3.6 Route 2 at Jackson Road

Operational and/or safety issues identified at this location include the partial cloverleaf geometric design of the westbound ramps at the Jackson Road interchange, which introduces a short weaving segment along Route 2 westbound at the on/off-ramps for Jackson Road south traffic.

Concept 1 – Close redundant ramps (Near-Term)

As presented in Figure 4-14, the concept proposes removing the redundant westbound on- and off-ramps, and thereby the elimination of the Route 2 westbound weaving segment. The elimination of the redundant westbound off-ramp would require associated geometric modifications to "tee" up the remaining westbound off-ramp to allow movements to both Jackson Road southbound and northbound (with potential future signalization based on demand). The elimination of one of the westbound on-ramps would require geometric modifications to allow Jackson Road northbound left-turns to Route 2 westbound at the remaining on-ramp (with potential future signalization based on demand). No capacity analysis was conducted given the current low traffic volumes on the ramps proposed for elimination (5 vehicles during the peak hours).

Additional consideration should be given to closing just one of the ramps in the loop instead of closing both ramps. Closing either the off- or on-ramp would provide the recommended acceleration (on-ramp) or deceleration (off-ramp).

Future Considerations (Long-Term)

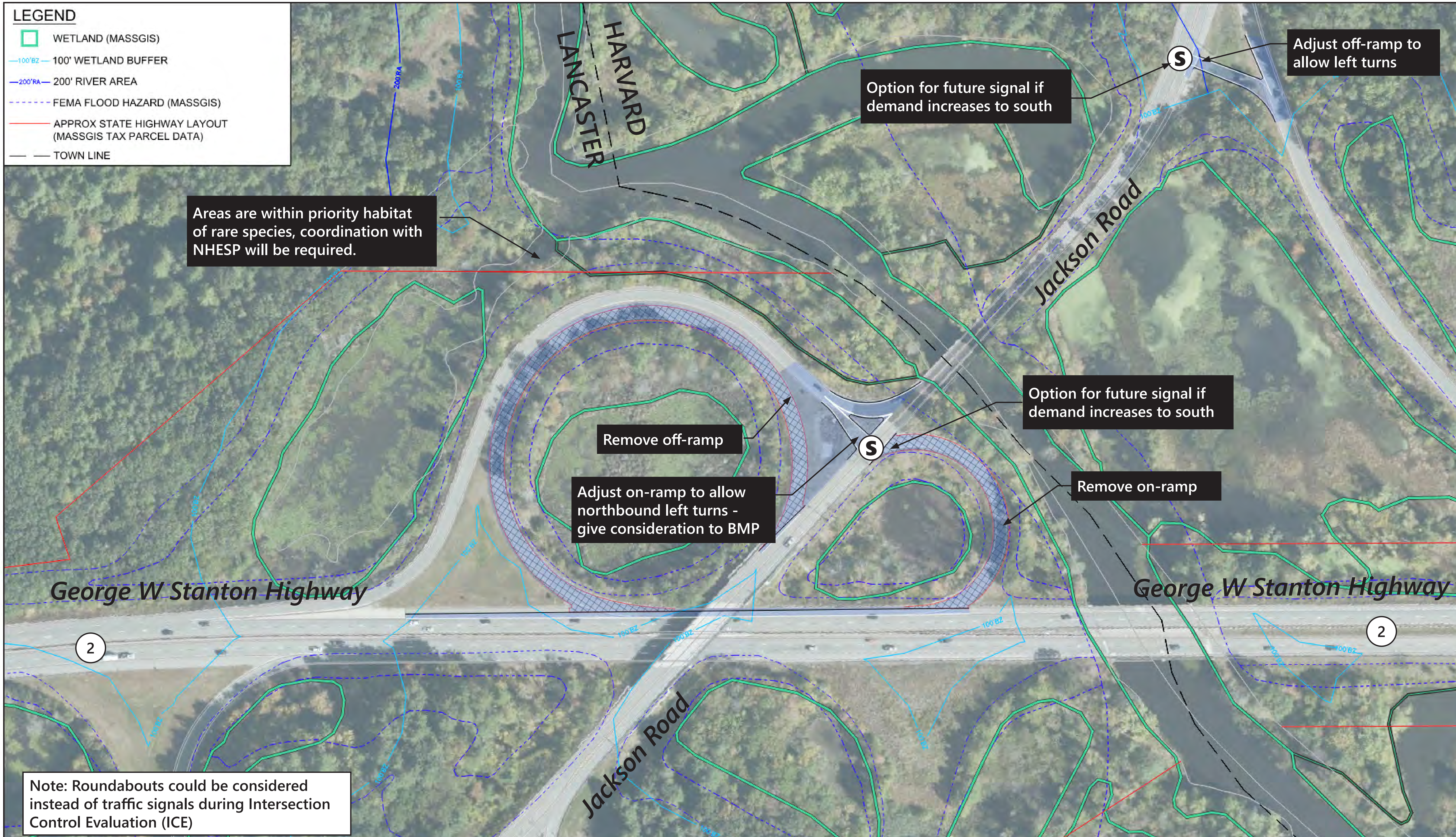
Additional future Devens development is expected to increase traffic volume at the interchange, potentially significantly. A significant percentage of the current traffic that travels to/from Devens utilizes Jackson Road and this interchange. As such, further monitoring should be conducted to determine if signalization, dual-lane ramps (eastbound off-ramp/westbound on-ramp), etc. are necessary. However, geometric modifications to accomplish widening to develop dual-lane ramps could involve significant environmental (e.g., wetland, priority habitat of rare species, and areas of critical environmental concern (ACEC)) challenges in this area.

4.3.3.7 Route 2 at I-495 and Taylor Street

Operational and/or safety issues identified at this location include the weaving movements and the high number of crashes that occur along Route 2 with between the I-495 and Taylor Street ramps given their proximity.

Concept 1 – Collector-Distributor (CD) Roads (Long-Term)

As presented in Figure 4-15, the concept considers development of a collector-distributor (C-D) road system along Route 2 eastbound and westbound, between the Taylor Street ramps and the I-495 ramps. This modification mitigates the high-speed weaving conflicts that currently exist. The concept requires geometric/physical modifications to the bridge abutment slopes to provide the width needed to develop the CD roadways. Consideration should be given to widening of Route 2 over Foster Street. Based on 2019 ramp volumes, the single lane CD lane volume for eastbound or westbound does not exceed 1,400 vehicles during either morning or evening peak period. Additional considerations regarding acceleration/deceleration distance for the loop ramps is required.

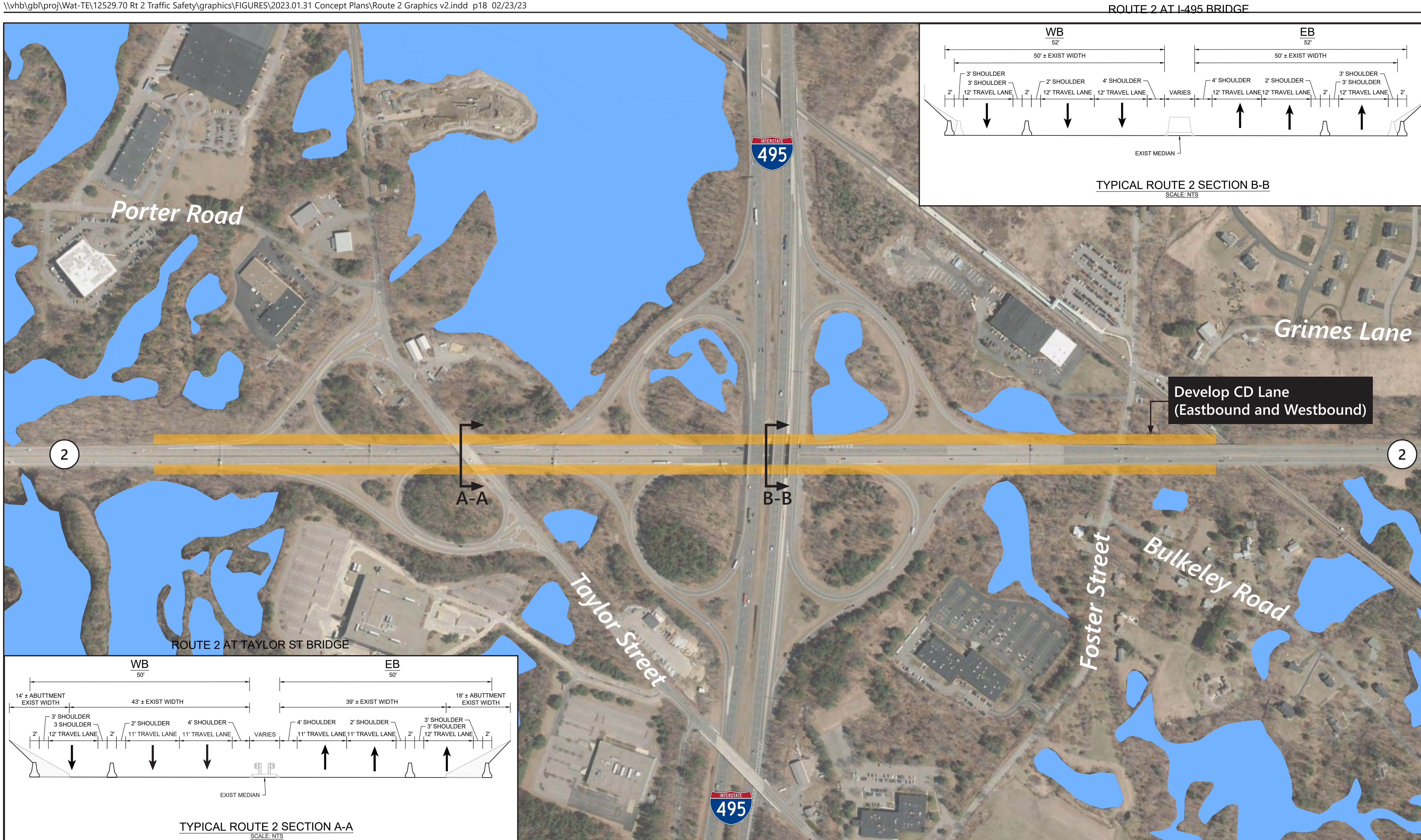


Town of Harvard / Town of Lancaster

0 150 300 Feet

Concept 1
Route 2 at Jackson Road
Route 2 Corridor Study

Figure 4-14



Town of Littleton

0 200 400 Feet

vhb

Concept 1 Route 2 at
I-495 and Taylor Street
Route 2 Corridor Study

Figure 4-15

4.4 Eastern (District 4) Study Area

The following section summarizes conceptual improvements for the eastern (District 4) study area. This section details corridor-wide considerations, such as mainline capacity and bottleneck locations and includes a high-level review of the impacts and benefits of developing a third lane in each direction along the Route 2 mainline. Subsequent sections detail an assessment and development of conceptual improvement alternatives at each of the signalized intersections within District 4 and the Concord Rotary.

4.4.1 Capacity Expansion of Route 2 to 6 lane Cross-section (Long-Term)

The capacity of the mainline section of Route 2, between Tracey's Corner (Bedford Road) and the Concord Rotary, is essentially governed by the proximity of signalized intersections and the rotary. The existing and projected operational analyses along this section of Route 2 reveals capacity constraints, especially during peak periods of traffic volume.

Route 2's capacity is constrained by signal operations along its length but is also metered by significant bottlenecks at each end of the District 4 corridor, namely, the Concord Rotary and Tracey's Corner (Bedford Road). Poor eastbound morning peak period operations at the Concord Rotary and at Tracey's Corner (Bedford Road) result in significant delays and vehicle queuing. Similarly, westbound evening peak period motorists experience similar problems at these locations, most notably at the rotary where queue spillback often impacts operations at adjacent intersections (Baker Avenue extension, Main Street (Route 62), Old Road to 9 Acre Corner, etc.). These locations constrain the volume of traffic that can enter and exit the corridor. The poor operations at these locations result in a significant volume of peak period traffic that diverts from the corridor to adjacent area roadways.

As completed for the western (District 3) study area, a high-level analysis of constructing a third lane in each direction was conducted for the eastern (District 4) study area. The following provides an overview of the challenges to widening (physical infrastructure, right-of-way, environmental impacts, construction costs, etc.).

4.4.1.1 Infrastructure, Right-of-Way, Environmental and Cost Overview

Figure 4-16 presents an overview of potential constraints to widening along the Route 2 corridor in the eastern (District 4) section. Widening to add a 3rd lane in each direction would require modification to at least 6 structures. In order to accommodate a 3rd lane and shoulder that meet design criteria, permanent takings would be required to provide adequate right-of-way. Further, there are several bodies of water (e.g., Assabet and Sudbury Rivers and Hobbs Brook) and other environmental resource areas (i.e., wetland, rare and endangered species, open space, and outstanding resource waters) that would involve environmental permitting. Finally, the cost associated with constructing a 3rd lane/direction within the eastern (District 4) study area is expected to be $250,000,000 to $300,000,000.

The physical, environmental, and right-of-way constraints to adding a 3rd lane for the entirety of the study area are significant, saying nothing of the ultimate construction cost. Any such consideration would be expected to take potentially decades to realize. In the near-term, each signalized location along the eastern (District 4) study area was evaluated for the potential to use existing roadway width (and/or minor widening) to provide a 3rd lane eastbound and/or westbound on the approach and departure of signalized intersections (not continuous for the length of the corridor). The conceptual level improvement alternatives evaluated provision of relatively short 3rd lanes (up to 1,500 feet total approach and departure) for additional processing and queue storage. The third lane through lane, where proposed at selective locations along the corridor, can generally be done through repurposing of existing exclusive right turn lanes or shoulders (with limited widening). A goal for implementation is to not notably increase total width of Route 2 or overall pedestrian crossing distances. It is important to note that while these lane additions, for example at Baker Avenue, Main Street (Route 62), and Old Road to 9 Acre Corner, may result in intersection delay reductions for the westbound evening movements it does not necessarily increase corridor capacity due to the metering effect of the Concord Rotary downstream.

Figure 4-17 provides a corridor-wide summary of where development of an intersection-specific 3rd lane (eastbound and/or westbound) is proposed for consideration. A more detailed discussion of the benefits and challenges to the addition of a third lane at each location is provided in the signalized intersection conceptual improvement alternatives section that follows.

4.4.1.2 Westbound Left Turn Considerations

A project to address the overall mainline capacity issues along Route 2 within District 4 would be costly and take years, if it were feasible at all given the constraints detailed above. In addition, to fully address operational conditions, the additional capacity afforded would need to be carried through the Concord Rotary and Tracey's Corner (Bedford Road) to address these bottlenecks.

As noted, there is substantial diversion from the corridor during peak periods given the capacity constraints/bottlenecks and associated delay and queuing. This is particularly noted during the evening peak period in the westbound direction as a result of the bottleneck created by the Concord Rotary, resulting in significant left-turning volume at adjacent intersections in an attempt to avoid the rotary. As can be seen in Figure 4-18, at Sudbury Road, Old Road to 9 Acre Corner, and Main Street, approximately 300 or more vehicles make left turns at each location during the weekday evening peak hour to avoid spillback from the rotary. In total, approximately 1,000 left-turning vehicles per hour are distributed over the three locations, resulting in delay and queuing that impact mainline movements (as well as West Concord neighborhoods). The ultimate solution to minimize this diversion/cut-through movement is Route 2 capacity expansion and/or significant improvements at the Concord Rotary. In the near-term, development of westbound dual-left turn lanes were evaluated at each of these locations in the signalized intersection conceptual improvement alternatives section that follows. In summary, concept alternatives including dual-left turn lanes westbound are presented for Main Street (Route 62) and Sudbury Road for consideration. While there are geometric challenges at each of these locations, the proximity and volume distribution to Old Marlboro Road preclude consideration of dual westbound left-turn lanes at Old Road to 9 Acre Corner.

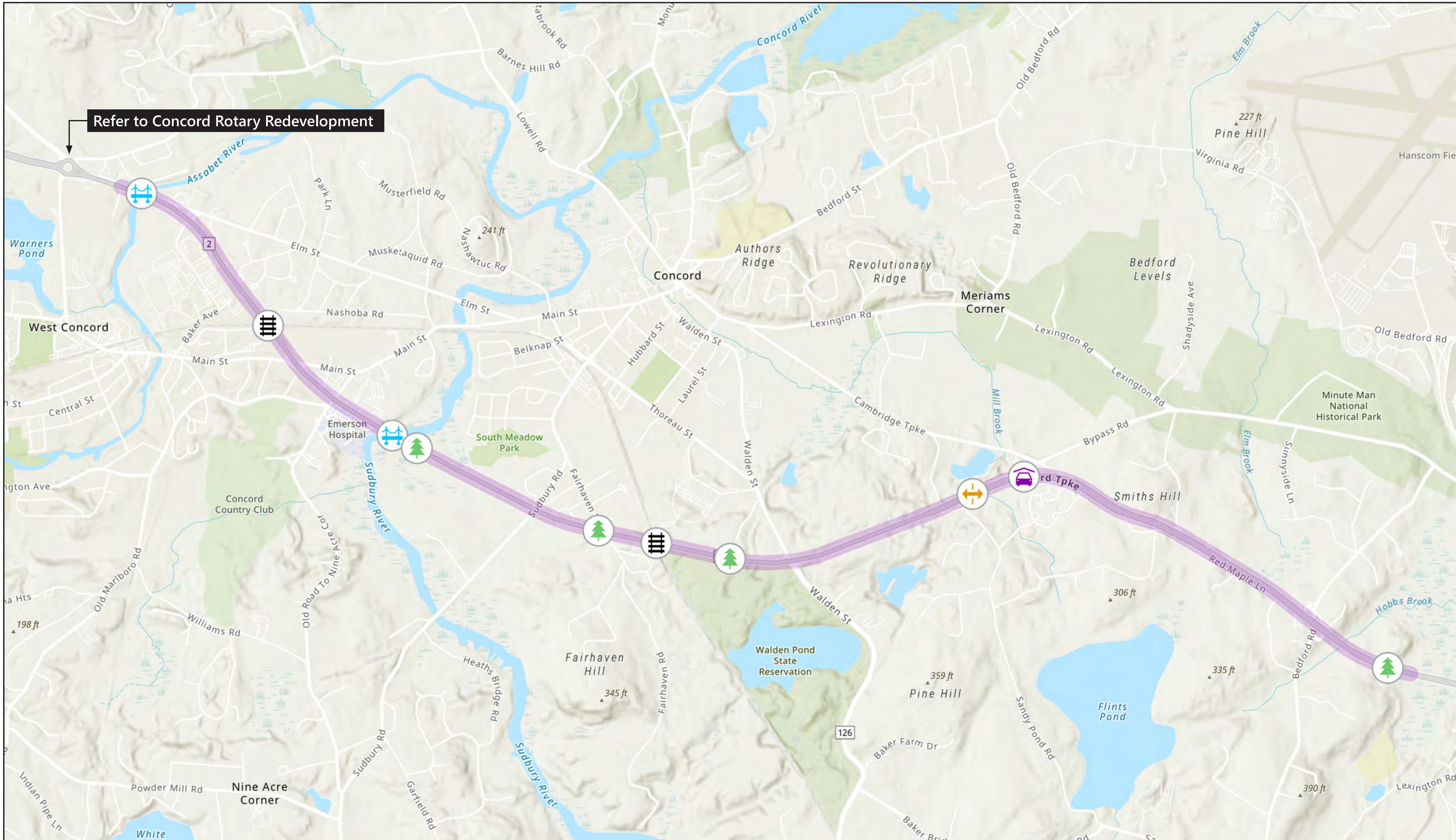
The westbound dual left-turn lanes that are presented at Main Street and Sudbury Road were proposed primarily to better accommodate queue storage and are not to facilitate current or additional cut-through traffic on to local roads. Currently, left-turn queues spill back through available storage lengths into the through travel lanes and impede mainline traffic, resulting in both a safety and operational concern. The analysis does not assume additional cut through traffic as a result of provision of dual left-turn lanes at these locations, but rather analyzes the existing volumes that are currently destined to the local roadway network. Further discussion is needed with local officials to consider implementing protocols to discourage cut-through traffic (i.e., signal timing adjustments for left-turns) while still better accommodating current left-turn queue spillback.

4.4.1.3 Travel Demand Analysis

The analysis that was conducted/presented herein did not involve rerouting volumes along Route 2. It should be noted that with lane modifications/alterations, there could be an expected change in travel patterns. The scope of the Route 2 Corridor Study did not include travel demand modeling or related redistribution of traffic volumes, and as such, only considered the existing travel patterns through the study area. If a specific project is advanced that involves capacity expansion/alterations, potential impacts to traffic patterns and routes should be considered at an intersection, interchange, and/or along the extended lengths of the Route 2 corridor.

4.4.1.4 Grade-Separated Alternatives

The scope of work for the Study did not consider any grade-separated alternatives east of the Concord Rotary. These types of significant infrastructure projects require extensive planning, substantial permitting and potential right-of-way acquisition that were beyond the scope of this study.



Town of Concord

0 1/4 1/2 Mile

Rail Crossing

River Crossing

Grade Separated Intersection

Animal Crossing

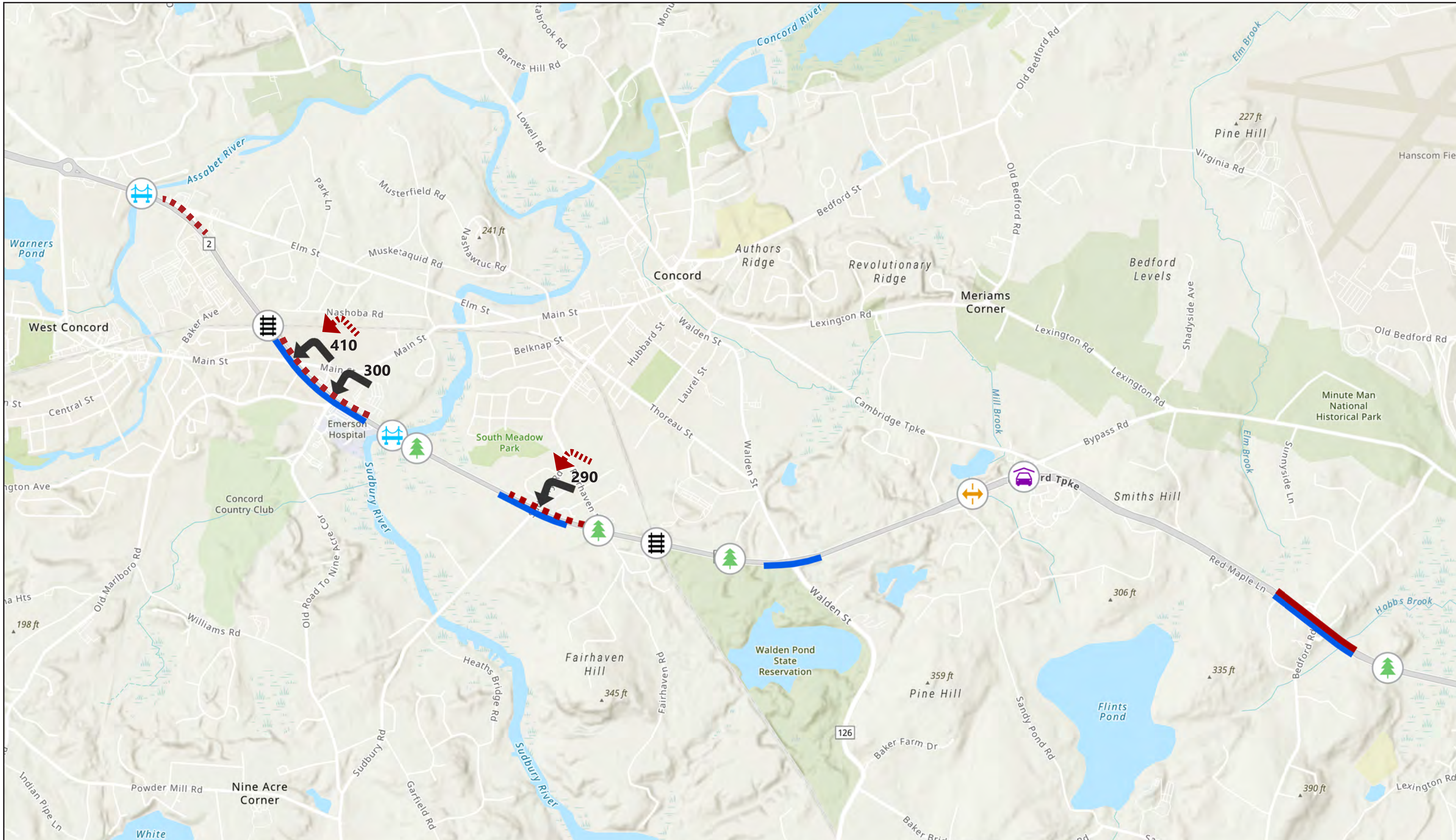
Environmental/ Cultural Resources

3rd Lane Review Area

vhb

Third Lane Constraints
Eastern (District 4) Study Area
Route 2 Corridor Study

Figure 4-16



Town of Concord

0 1/4 1/2 Mile

Rail Crossing
River Crossing
Grade Separated Intersection
Animal Crossing
Environmental/ Cultural Resources
Dual Left WB Alternative
3rd Lane EB
3rd Lane WB
3rd Lane WB Alternative

Third Lane Proposed Area
Eastern (District 4) Study Area
Route 2 Corridor Study

Figure 4-17

4.4.2 Signalized Intersection Alternatives

Conceptual intersection improvement alternatives were developed to address existing (and/or projected) safety and operational concerns identified along the corridor. Further, additional bicycle and pedestrian enhancements have been developed to improve access across Route 2 at key and high demand locations. Conceptual level improvement alternatives for the Concord Rotary are presented in Section 4.4.3. The improvement concepts assume a full traffic signal upgrade at each location and given the speeds and high rear-end crash history on Route 2, an evaluation of enhancing set back/dilemma zone detection and "red signal ahead" advance warning signs. In general, the concepts developed were within the existing right-of-way and avoid direct impacts to environmental resource areas, unless otherwise noted (a number of the concepts are within a wetland buffer which is represented graphicly on the concepts).

4.4.2.1 Route 2 at Baker Avenue Extension/Elm Street

Conceptual improvement alternatives were developed to address current (and/or projected) safety and operational concerns. A goal of the improvement concept was to incorporate safety enhancements, where possible, from the Road Safety Audit without increasing delays and queues for Route 2 and side street traffic. Additional considerations were made for the higher volume movements (i.e., eastbound left-turn and Elm Street westbound/southbound right-turn), as well as the poor operations and extensive queuing experienced where Elm Street merges with Route 2 westbound, especially during the evening peak period.

Concept 1 – Remove Jughandle & Elm Street to Route 2 Westbound Access (Near-Term)

As presented in Figure 4-18, Concept 1 proposes removal of the jughandle on the north side of the intersection, provision of a westbound Route 2 left-turn lane, development of a dual left-turn movement for the eastbound approach, and bringing the current Elm Street to Route 2 westbound merging volume into the signal operations as a southbound dual right-turn movement. Given the proposed geometry, the eastbound and westbound traffic signal phases may need to operate separately. Additionally, the southbound dual right-turn movement would most likely operate as an overlap phase with the eastbound left turn and not during the northbound and southbound concurrent movement. New pedestrian accommodations are proposed along the western side of Elm Street and Baker Avenue Extension, which requires accommodating a new pedestrian signal phase within the signal cycle. Bicycle lanes are provided along Elm Street and Baker Avenue Extension. Extending pedestrian and bicycle enhancements along Baker Avenue Extension, south of the intersection, would require significant grading and involve environmental impacts. Additional widening/permitting along Baker Avenue Extension would be needed to extend the pedestrian and bicycle accommodations further south of the immediate intersection.

The concept incorporates safety improvements identified in the road safety audit with the elimination of the jughandle and brings the westbound Elm Street merge into the intersection operations. The concept also details the lack of pedestrian accommodations that were identified as a safety issue in the road safety audit. For the newly proposed crosswalk, the analysis assumes use of an exclusive pedestrian phase to avoid unnecessarily increasing the length of the NB-SB Baker Avenue Extension/Elm Street phase to accommodate the long pedestrian clearance times required. Use of an exclusive pedestrian phase typically results in increased delays, but the low to non-existent pedestrian volumes should have limited actuations and impact to overall vehicle delays and queuing. There have also been attempts in the past to increase the storage length for the eastbound left-turn. By providing a dual left-turn eastbound, the eastbound spillback concern should be decreased. The concept addresses many of the current safety and accommodation concerns at the intersection while not significantly impacting operations. As shown in Table 4-10, the concept slightly improves overall projected 2039 future intersection operations from LOS E to LOS D in the morning peak hour and in the evening peak period operations slightly degrade from LOS C to LOS E. Most movements see either slight improvements in queueing or increases in queue length by only a few vehicles, but the eastbound through queue in the morning peak hour increases significantly from an average of just over 500 feet to just under 900 feet.

Concept 2 – 3rd Lane Westbound including Concept 1 improvements (Near-Term)

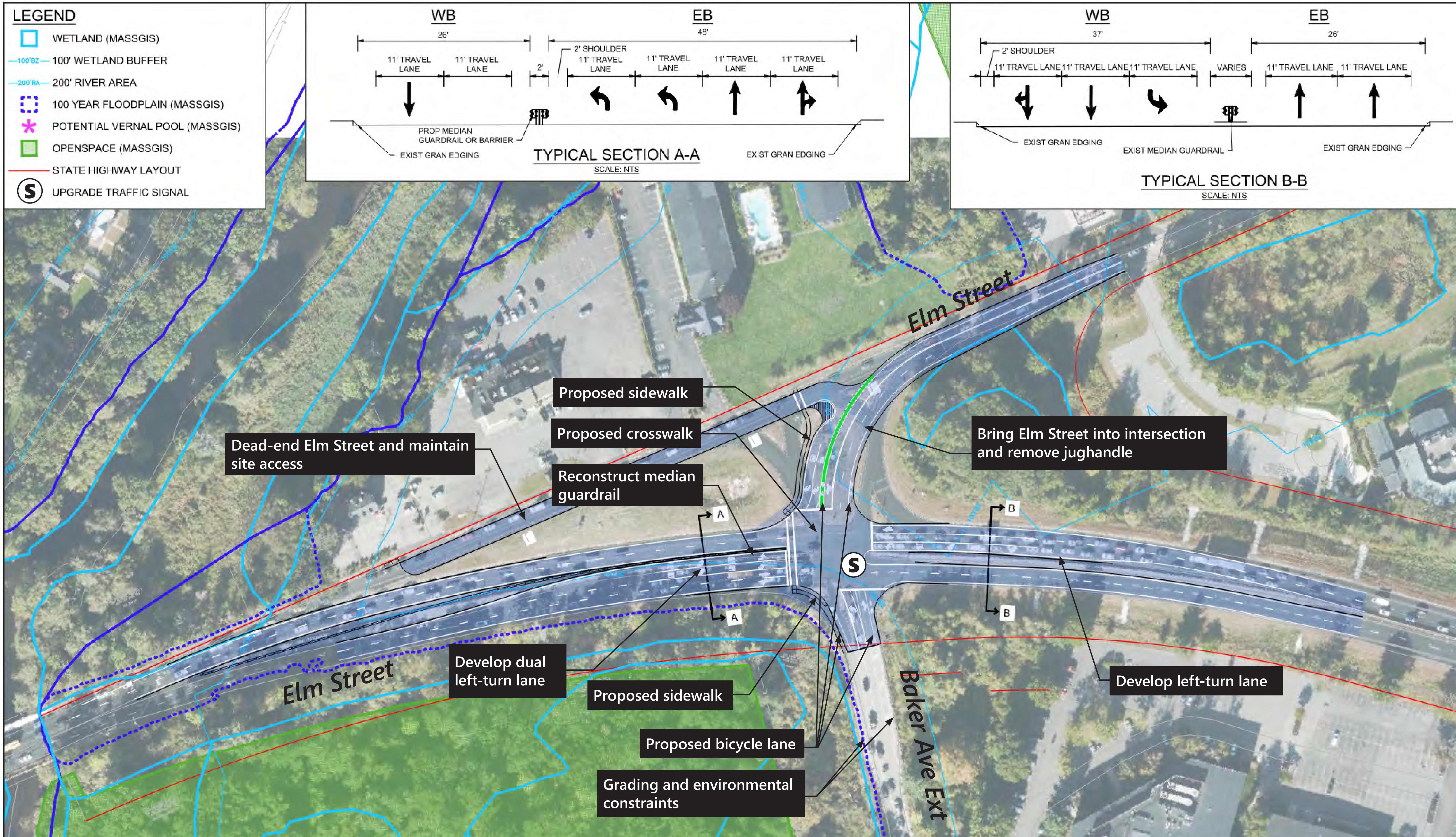
As presented in Figure 4-19, Concept 2 builds on the improvements proposed in Concept 1 and also includes a third general purpose (TH-RT) lane in the westbound direction to be consistent with proposals at its adjacent signalized location at Main Street. This additional westbound lane would require widening the roadway on the approach and departure to/from Baker Avenue Extension/Elm Street. The required roadway widening should not impact right-of-way or environmental resource areas, but segments of the new lane would fall within the 100’ wetland buffer.

As shown in Table 4-10, the concept improves overall projected 2039 future intersection operations from LOS E to LOS D in the morning peak hour while the evening peak period operations decrease slightly from LOS C to LOS D. Again, most movements see either slight improvements in queueing or increases in queue length by only a few vehicles, but the eastbound through queue in the morning peak hour increases significantly from an average of just over 500 feet to just under 900 feet.

Table 4-10 Signalized Intersection Capacity Analysis – Route 2 at Baker Ave Ext. 2039 Concepts

Location/Movement	2039 No-Build					2039 Concept 1 EB Dual-Left/ SB Dual-Right (No Split)					2039 Concept 2 Concept 1 Improvements/3rd Lane WB				
	v/c[a]	Del[b]	LOS[c]	50 Q[d]	95 Q[e]	v/c	Del	LOS	50 Q	95 Q	v/c	Del	LOS	50 Q	95 Q
22: Route 2 at Baker Avenue Extension															
Weekday Morning															
EB L	0.92	57.4	E	270	#453	0.76	48	D	153	209	0.76	48	D	153	209
EB T/R	0.93	19.1	B	535	#847	1.06	60	E	~896	#1036	1.06	60	E	~896	#1036
WB L	-	-	-	-	-	0.76	68	E	80	#174	0.76	68	E	80	#174
WB T	1.16	114	F	~600	#735	0.83	25	C	455	560	0.58	18	B	255	301
WB R	0.11	21	C	4	45	-	-	-	-	-	-	-	-	-	-
NB L	0.88	91	F	59	#154	0.70	60	E	66	#148	0.70	60	E	66	#148
NB T	0.33	38	D	51	98	0.50	47	D	65	122	0.50	47	D	65	122
NB R	0.01	35	D	0	0	-	-	-	-	-	-	-	-	-	-
SB L	0.06	36	D	6	22	-	-	-	-	-	-	-	-	-	-
SB T	0.77	52	D	133	#228	0.54	49	D	73	128	0.54	49	D	73	128
SB R	-	-	-	-	-	0.49	41	D	86	127	0.49	41	D	86	127
Overall	**1.07**	**56**	**E**			**1.09**	**46**	**D**			**1.06**	**44**	**D**		
Weekday Evening															
EB L	0.81	52	D	116	#229	>1.20	>120	F	~94	#168	>1.20	>120	F	~81	#168
EB T/R	0.80	14	B	334	432	0.84	20	C	359	#694	0.88	23	C	359	#694
WB L	-	-	-	-	-	0.25	58	E	3	15	0.25	54	D	3	15
WB T	0.91	33	C	348	#483	0.89	36	D	420	#574	0.69	27	C	247	299
WB R	0.02	16	B	0	0	-	-	-	-	-	-	-	-	-	-
NB L	0.91	62	E	149	#297	1.00	97	F	170	#330	0.93	72	E	151	#330
NB T	0.19	27	C	35	72	0.38	35	D	67	128	0.35	32	C	59	128
NB R	0.05	26	C	0	17	-	-	-	-	-	-	-	-	-	-
SB L	0.06	26	C	8	24	-	-	-	-	-	-	-	-	-	-
SB T	0.15	27	C	29	59	0.21	33	C	41	77	0.20	29	C	36	77
SB R	-	-	-	-	-	1.05	97	F	~194	#292	0.98	73	E	172	#292
Overall	**0.93**	**27**	**C**			**1.15**	**55**	**E**			**1.09**	**47**	**D**		

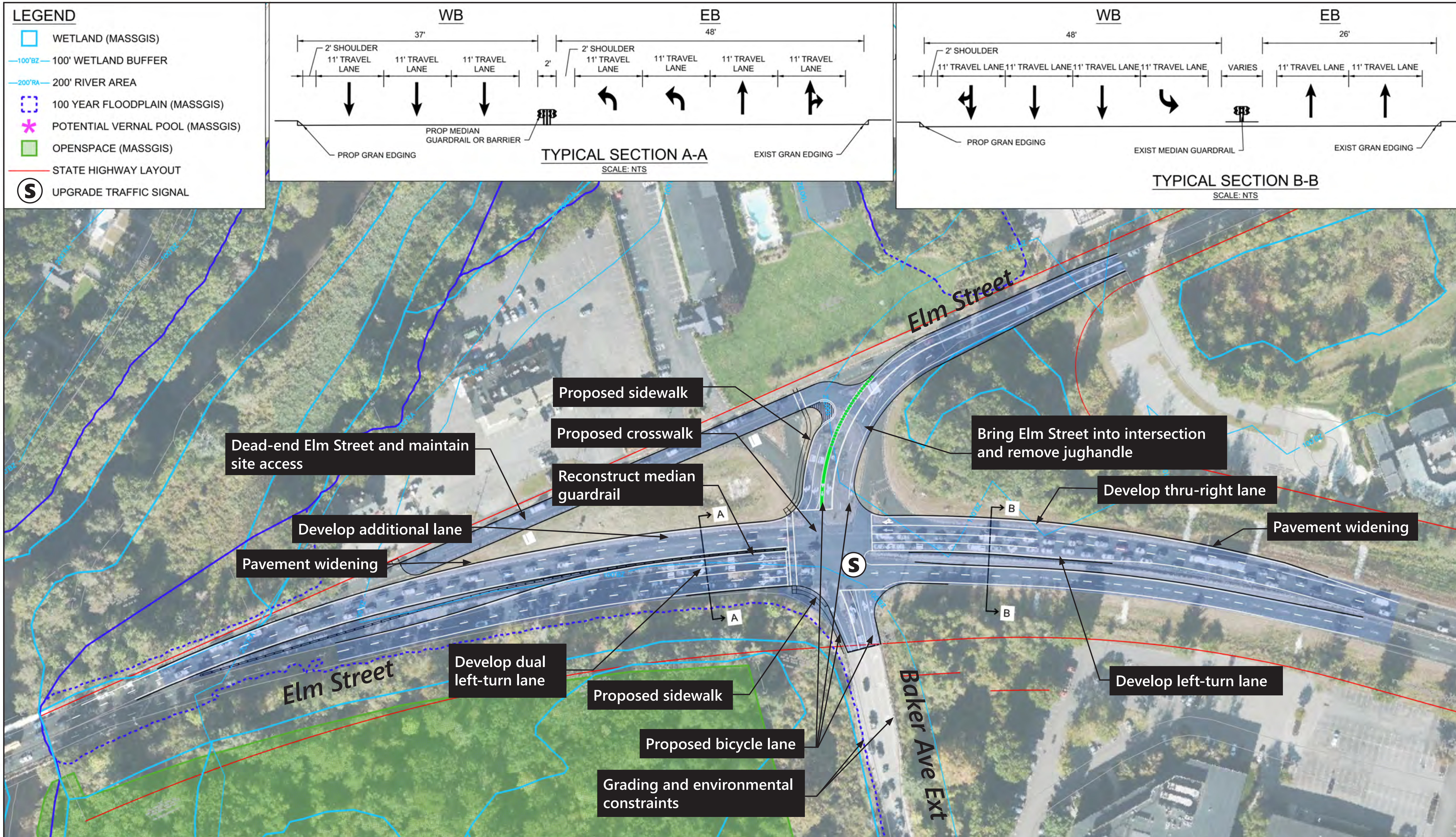
Source: VHB, Inc. using Synchro 9/10 software
Note: Shaded cells denote LOS E or LOS F conditions.
a Volume to capacity ratio.
b Average total delay, in seconds per vehicle.
c Level-of-service.
d 50th percentile queue, in feet.
e 95th percentile queue, in feet.
~ Volume exceeds capacity, queue is theoretically infinite.
# 95th percentile volume exceeds capacity; queue may be longer.
m Volume for 95th percentile queue is metered by upstream signal.



Town of Concord

0 60 120 Feet

Concept 1
Route 2 at Baker Ave Extension/Elm Street
Route 2 Corridor Study



Town of Concord

0 60 120 Feet

Concept 2
Route 2 at Baker Ave Extension/Elm Street
Route 2 Corridor Study

Figure 4-19

4.4.2.2 Route 2 at Main Street (Route 62)

Conceptual improvement alternatives were developed to address current (and/or projected) safety and operational concerns, as well as pedestrian and bicycle accommodation. Additional considerations (Concept 2) were made for the westbound left-turn movement due to the significant weekday evening peak hour left-turn demand (over 400 vehicles per hour).

Concept 1 – 3rd Lane Eastbound, Pedestrian & Bicycle Enhancements (Near-Term)

As presented in Figure 4-20, Concept 1 proposes adding a third general purpose (TH-RT) lane in the eastbound direction. The eastbound movement has significant volume and experiences significant delay/queuing (especially during the morning peak period). Concept 1 would repurpose existing roadway and shoulder width to develop the third lane approaching Main Street (Route 62) and extend to Old Road to Nine Acre Corner (discussed in the following section and presented in Figure 4-22). New pedestrian accommodations (crosswalk/signal) are proposed along the easterly side of the intersection to provide an additional Route 2 crossing and new bicycle accommodations (bicycle lanes) are provided along Main Street (Route 62).

As shown in Table 4-11, Concept 1 provides an improvement in overall projected 2039 future intersection operations from LOS E to LOS D in the morning peak hour and LOS F to LOS D in the evening peak hour. Average queues for the eastbound through movement will decrease from over 900 feet to under 500 feet per lane for both peak periods.

Concept 2 – 3rd Lane Eastbound and dual left-turn Westbound (Near-Term)

As presented in Figure 4-21, the second concept builds on Concept 1 and develops a dual-left turn for the westbound approach. The westbound left-turn is forecasted to have a future 2039 volume of 455 vehicles in the evening peak period (without substantial enhancements to the Concord Rotary). The dual left-turn lane is proposed to minimize queue spill back into mainline through lanes and can be developed by use of the current roadway/shoulder width available on the westbound approach. However, developing the receiving geometry along Main Street has challenges with limited right-of-way and the proximity to the marked crosswalk that will need to be worked out in further design development.

As shown in Table 4-11, the projected 2039 future overall intersection operations will improve to LOS C in both peak periods, from LOS E and LOS F, in the morning and evening peak periods, respectively. This is also an improvement from Concept 1 where overall operations are expected to be LOS D for both peak periods. The average queues for the westbound left-turn movement are expected to decrease from over 500 feet to roughly 200 feet per lane in the evening peak period.

Concept 3 – 3rd Lane Eastbound and Westbound (Near-Term)

As presented in Figure 4-22, the third concept also builds on Concept 1 and includes a third general purpose (TH-RT) lane in the westbound direction in addition to a third general purpose (TH-RT) lane in the eastbound direction. The third westbound lane would be developed on the approach to Main Street (Route 62) from the existing exclusive right-turn lane and shoulder beginning at Old Road to 9 Acre Corner as provided by Concept 2 in Section 4.4.2.3. On the departure from the intersection, the third westbound lane would be developed using existing width of roadway/shoulder with some minor widening required within a wetland buffer zone. As in Concept 1, new pedestrian accommodations (crosswalk/signal) are proposed along the easterly side of the intersection to provide an additional

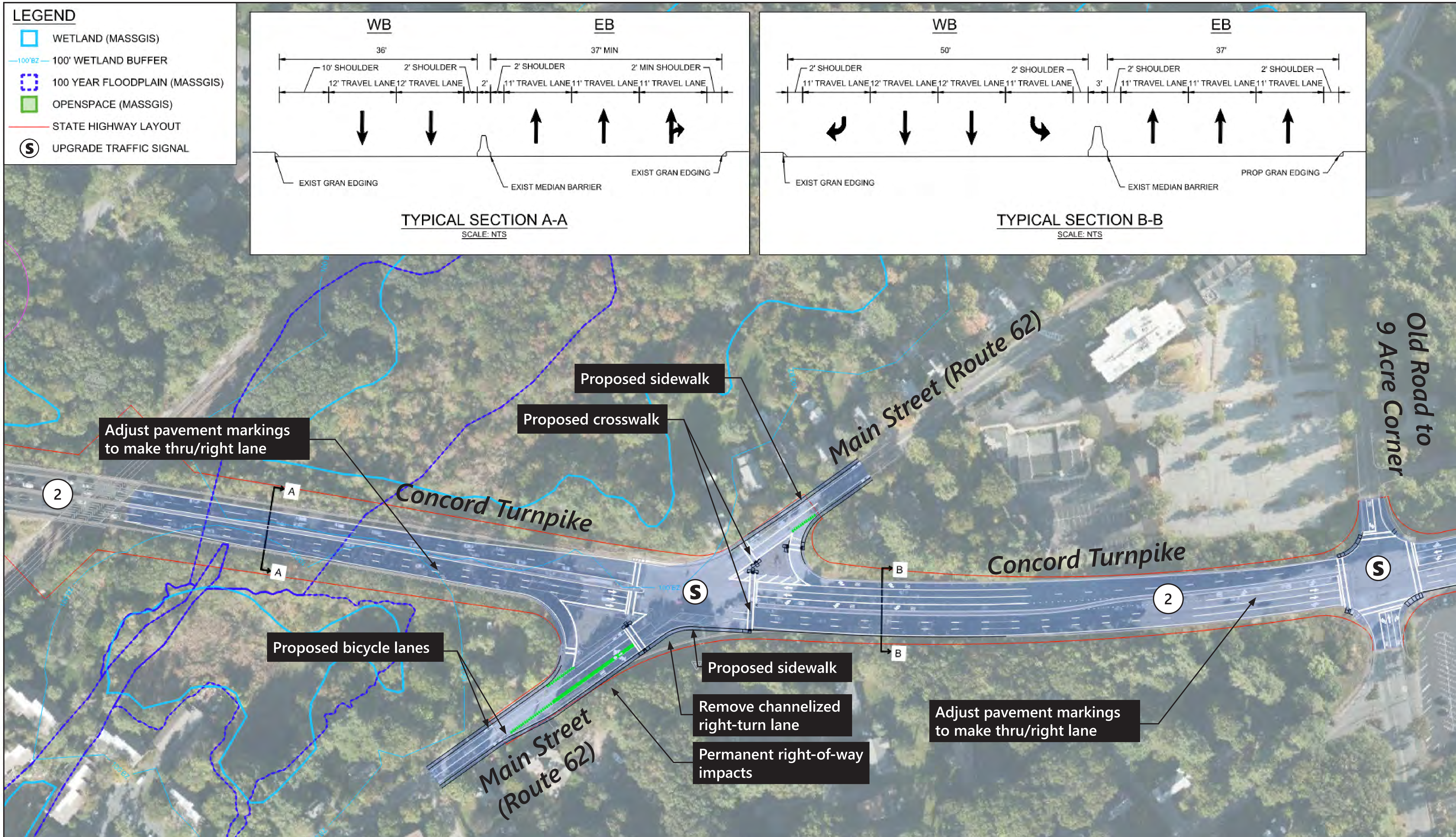
Route 2 crossing (similar curb to curb length as exists) and new bicycle accommodations (bicycle lanes) are provided along Main Street (Route 62).

As shown in Table 4-11, Concept 3 provides an improvement in overall projected 2039 future intersection operations from LOS E to LOS D in the morning peak hour and LOS F to LOS D in the evening peak hour. Average queues for the eastbound through movement will decrease from over 900 feet to under 500 feet per lane for both peak periods. Average queues for the westbound through movement remain approximately unchanged at just over 200 feet per lane in the morning peak hour and decrease slightly from approximately 225 feet to 130 feet per lane in the evening peak hour. Note that projected operations for the westbound left turn movement with the addition of the third westbound through lane in Concept 3 (LOS E) appear worse than if the third westbound through lane is not provided in Concept 1 (LOS D). This results from the concept being evaluated together with a third westbound lane at Old Road to 9 Acre Corner (Section 4.4.2.3, Concept 2), which results in a higher number of left-turning vehicles arriving at Main Street during a red light.

Table 4-11 Signalized Intersection Capacity Analysis – Route 2 at Main Street 2039 Concepts

Location/ Movement	2039 No-Build					2039 Concept 1 3rd Lane EB					2039 Concept 2 3rd Lane EB w/ WB Dual-Left					2039 Concept 3 3rd Lane EB & WB				
	v/c[a]	Del[b]	LOS[c]	50 Q[d]	95 Q[e]	v/c	Del	LOS	50 Q	95 Q	v/c	Del	LOS	50 Q	95 Q	v/c	Del	LOS	50 Q	95 Q
23: Route 2 at Main Street																				
Weekday Morning																				
EB T	1.13	100	F	~973	#1112	0.99	49	D	~456	#573	0.91	31	C	365	#453	0.99	49	D	~456	#573
EB R	0.01	0	A	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
WB L	0.99	97	F	207	m#245	0.88	48	D	156	m162	0.77	52	D	68	#125	0.88	63	E	157	m#268
WB T	0.66	12	B	213	m274	0.73	23	C	404	m414	0.75	16	B	316	405	0.51	18	B	221	302
WB R	0	7	A	0	m0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
NB T	1.07	112	F	~439	#653	0.93	59	E	293	#480	0.91	52	D	258	#434	0.93	59	E	293	#480
NB R	0.63	49	D	151	277	0.43	32	C	56	156	0.59	31	C	103	207	0.43	32	C	56	156
SB T	0.45	44	D	149	193	0.39	31	C	107	146	0.38	28	C	94	132	0.39	31	C	107	146
Overall	**1.09**	**65**	**E**			**0.96**	**39**	**D**			**0.94**	**29**	**C**			**0.95**	**38**	**D**		
Weekday Evening																				
EB T	1.2	>120	F	~922	#1062	0.99	54	D	444	#563	0.84	29	C	310	372	0.99	54	D	444	#563
EB R	0.02	0	A	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
WB L	1.17	>120	F	~518	m#649	1.16	>120	F	~440	m#537	1.11	115	F	~212	#311	1.16	>120	F	~441	#648
WB T	0.58	11	B	227	m302	0.62	16	B	342	m388	0.66	13	B	273	348	0.43	12	B	130	230
WB R	0.01	14	B	2	m3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
NB T	>1.20	>120	F	~355	#543	0.94	76	E	223	#394	0.8	43	D	167	#283	0.94	76	E	223	#394
NB R	0.69	53	D	180	#307	0.27	35	D	15	98	0.59	32	C	101	201	0.27	35	D	15	98
SB T	0.88	67	E	322	#495	0.79	48	D	258	#390	0.75	38	D	199	298	0.79	48	D	258	#390
Overall	**>1.20**	**94**	**F**			**1.03**	**51**	**D**			**0.87**	**35**	**C**			**1.03**	**50**	**D**		

Source: VHB, Inc. using Synchro 9/10 software
Note: Shaded cells denote LOS E or LOS F conditions.
a Volume to capacity ratio.
b Average total delay, in seconds per vehicle.
c Level-of-service.
d 50th percentile queue, in feet.
e 95th percentile queue, in feet.
~ Volume exceeds capacity, queue is theoretically infinite.
# 95th percentile volume exceeds capacity; queue may be longer.
m Volume for 95th percentile queue is metered by upstream signal

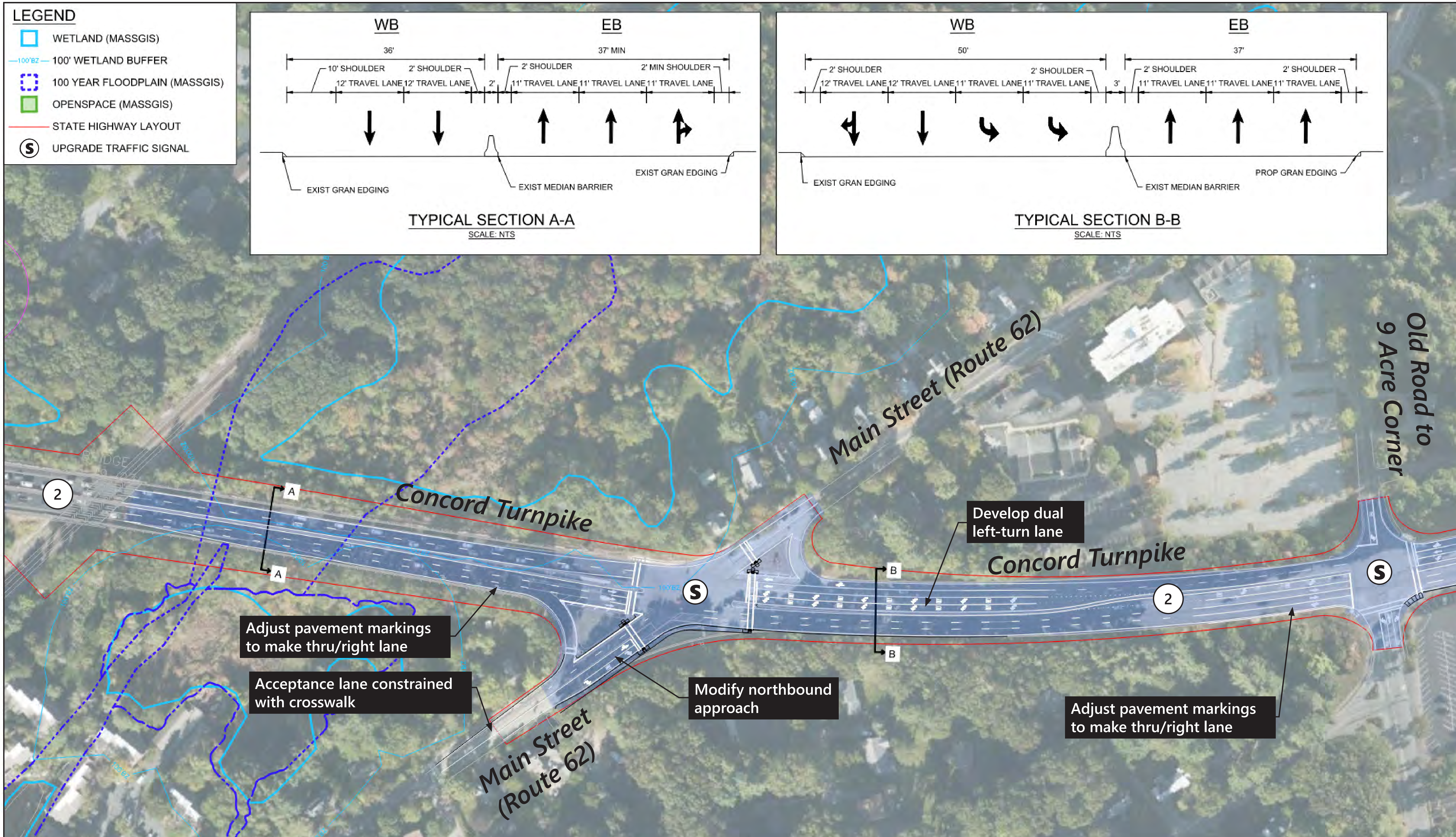


Town of Concord

0 75 150 Feet

Concept 1
Route 2 at Main Street (Route 62)
Route 2 Corridor Study

Figure 4-20

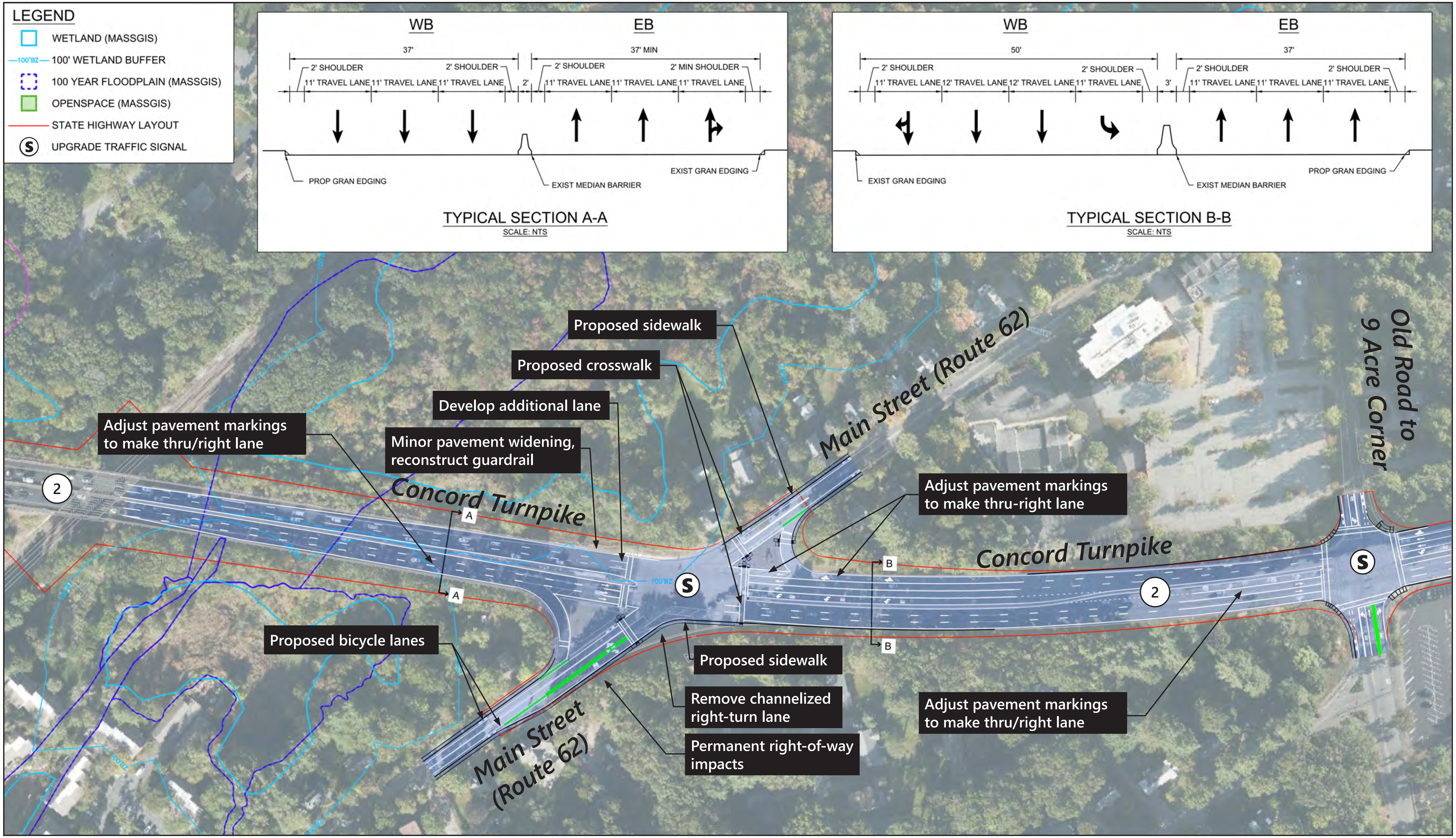


Town of Concord

0 75 150 Feet

Concept 2
Route 2 at Main Street (Route 62)
Route 2 Corridor Study

Figure 4-21



Town of Concord

0 75 150 Feet

vhb

Concept 3
Route 2 at Main Street (Route 62)
Route 2 Corridor Study

Figure 4-22

4.4.2.3 Route 2 at Old Road to 9 Acre Corner Road

Conceptual improvement alternatives were developed to address current (and/or projected) safety and operational concerns, as well as pedestrian and bicycle accommodation. Additional considerations were made regarding development of a dual westbound left-turn to address the heavy westbound left-turn movement (see Section 4.4.1.2). However, the proximity of Old Marlboro Road on the departure and the current volume distribution (and potential left-turn lane use imbalance) eliminated this location from consideration of a dual westbound left-turn.

Concept 1 – 3rd Lane Eastbound, Pedestrian & Bicycle Enhancements (Near-Term)

As presented in Figure 4-23, Concept 1 proposes development of a third general purpose (TH-RT) lane in the eastbound direction. The eastbound through movement has significant volume and experiences significant delay/queuing (especially during the morning peak period). The concept would repurpose existing roadway and shoulder width, with minor widening, to develop the third lane approaching Old Road to 9 Acre Corner and extend on the departure to an eventual transition back to two-lanes eastbound. For this improvement the widening is minor and should not impact right-of-way or environmental resource areas. New pedestrian accommodations (crosswalk/signal) are added along the westerly and northerly sides of the intersection and new bicycle accommodations (bicycle lanes) are provided along Old Road to 9 Acre Corner. However, providing these bicycle accommodations will require permanent right-of-way impacts along Old Road to 9 Acre Corner.

As shown in Table 4-12, the concept provides improvement in overall projected 2039 future intersection operations from LOS E to LOS D in the morning peak hour and LOS E to LOS D in the evening peak hour. Average queues (projected 2039) for the eastbound through movement will decrease from over 1,000 feet to under 600 feet per lane for both peak periods.

Concept 2 – 3rd Lane Eastbound & Westbound, Pedestrian & Bicycle Enhancements (Near-Term)

As presented in Figure 4-24, Concept 2 builds on the improvements proposed in Concept 1 and also provides a third general purpose (TH-RT) lane in the westbound direction. The additional westbound lane would repurpose the existing shoulder and require minor widening on both the approach and departure to/from Old Road to 9 Acre Corner. Widening on both the approach and departure to/from Old Road to 9 Acre Corner potentially requires permanent right-of-way impacts with the proposed curb line falling along or just beyond the existing layout.

As shown in Table 4-12, the concept provides improvement in overall projected 2039 future intersection operations from LOS E to LOS C in the morning peak hour and LOS E to LOS E with reduced delay in the evening peak hour. Average queues (projected 2039) for the eastbound through movement will decrease from over 1,000 feet to 600 feet or under per lane for both peak periods. Average westbound queues (projected 2039) for the westbound through movement will decrease from nearly 600 feet to under 400 feet in the morning peak hour, and from over 800 feet to under 400 feet in the evening peak hour.

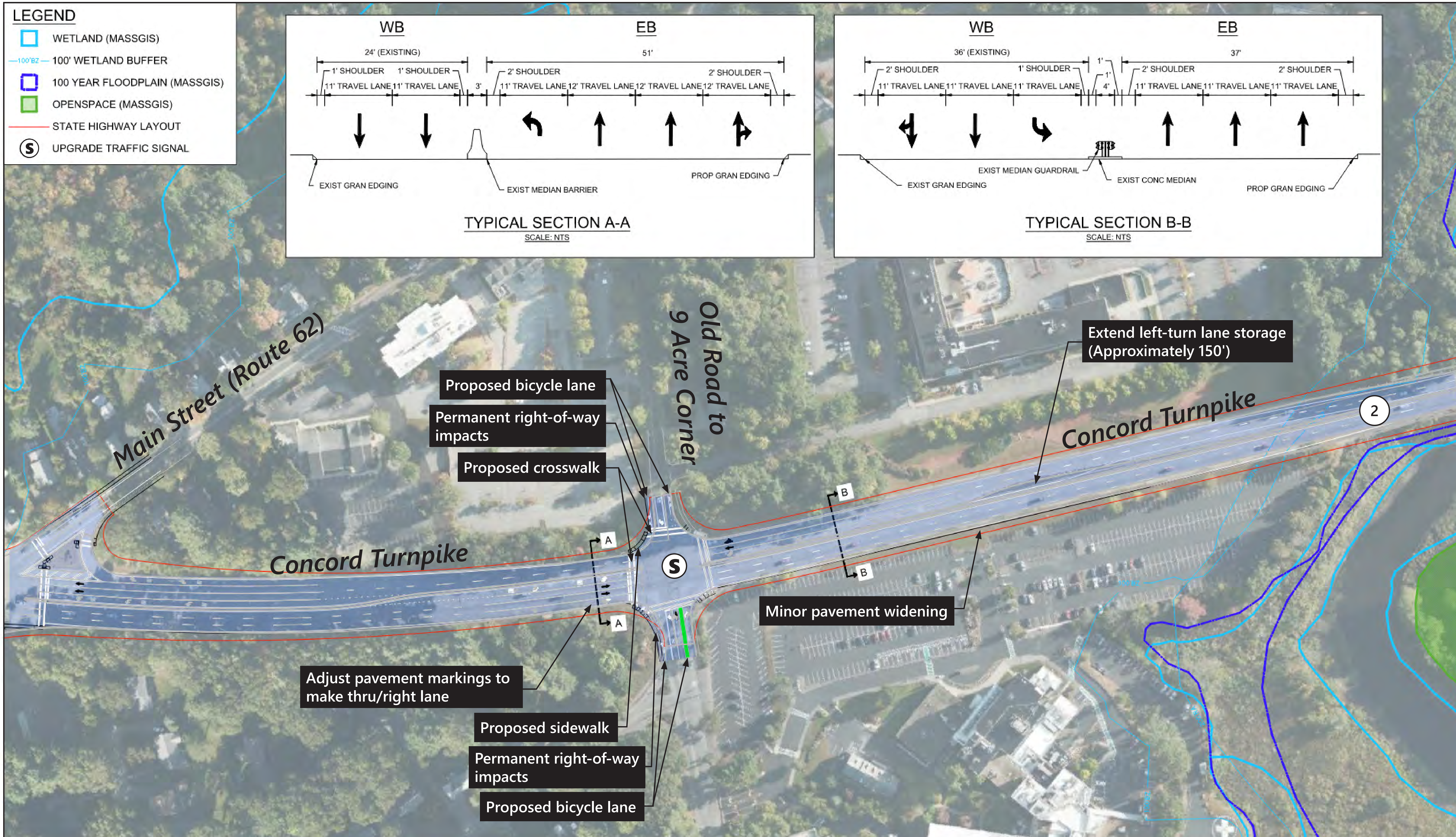
Other Considerations

An additional consideration for this location was developing a dual-left turn for the westbound approach as the projected future turning volume was forecasted to be approximately 330 vehicles in the evening peak period. An investigation of the current left-turn volume distribution showed that roughly 80% of current westbound left turns from Route 2 turn right onto Old Marlboro Road. This would result in either a significant volume imbalance in a dual lane scenario, or last-minute merging/weaving on the departure, both notable safety concerns. However, the concept does propose to extend the current westbound left-turn storage length to better accommodate vehicle queuing.

Table 4-12 Signalized Intersection Capacity Analysis – Route 2 at Old Rd to 9 Acre Corner 2039 Concept

Location/Movement	2039 No-Build					2039 Concept 1 3rd Lane EB					2039 Concept 2 3rd Lane EB & WB				
	v/c [a]	Del [b]	LOS [c]	50 Q [d]	95 Q [e]	v/c	Del	LOS	50 Q	95 Q	v/c	Del	LOS	50 Q	95 Q
24: Route 2 at Old Rd to 9 Acre Corner															
Weekday Morning															
EB L	0.74	64	E	66	m62	0.68	64	E	50	m56	0.66	62	E	50	m56
EB T	1.14	80	F	~1005	m#858	1.04	30	C	~542	m#567	1.05	37	D	~554	m#579
EB R	0.15	13	B	11	m10	-	-	-	-	-	-	-	-	-	-
WB L	0.96	94	F	148	m#176	0.76	56	E	101	#237	0.73	53	D	99	#237
WB T/R	0.91	28	C	591	m#371	1.02	52	D	~656	#806	0.71	21	C	316	397
NB L	1.14	>120	F	~129	#262	0.94	96	F	82	#181	0.93	91	F	83	#176
NB T	0.82	60	E	256	#405	0.79	45	D	189	273	0.78	45	D	191	269
NB R	0.41	34	C	116	188	0.36	24	C	70	126	0.36	23	C	69	124
SB L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SB L/T/R	0.82	60	E	249	267	0.79	46	D	183	196	0.78	45	D	185	193
Overall	**1.14**	**59**	**E**			**1.03**	**42**	**D**			**0.98**	**34**	**C**		
Weekday Evening															
EB L	0.53	61	E	33	m31	0.57	65	E	28	m34	0.51	61	E	28	m34
EB T	>1.20	112	F	~1037	m#825	1.12	64	E	~602	m#628	1.19	100	F	~632	m#664
EB R	0.1	2	A	0	m0	-	-	-	-	-	-	-	-	-	-
WB L	1.13	>120	F	~338	m#386	0.9	64	E	242	#452	0.83	53	D	233	#452
WB T/R	0.89	32	C	853	m923	0.93	31	C	~655	#867	0.66	18	B	332	428
NB L	0.99	>120	F	78	#193	0.85	86	F	62	#148	0.79	71	E	62	#133
NB T	0.56	49	D	153	236	0.55	41	D	126	195	0.53	40	D	126	187
NB R	0.18	27	C	46	89	0.16	19	B	31	66	0.15	17	B	29	61
SB L	0.2	44	D	24	55	0.18	36	D	20	46	0.18	36	D	20	44
SB T/R	0.85	67	E	245	#380	0.82	56	E	201	284	0.80	53	D	201	273
Overall	**1.14**	**73**	**E**			**1.02**	**50**	**D**			**0.98**	**59**	**E**		

Source: VHB, Inc. using Synchro 9/10 software
Note: Shaded cells denote LOS E or LOS F conditions.
a Volume to capacity ratio.
b Average total delay, in seconds per vehicle.
c Level-of-service.
d 50th percentile queue, in feet.
e 95th percentile queue, in feet.
~ Volume exceeds capacity, queue is theoretically infinite.
# 95th percentile volume exceeds capacity; queue may be longer.
m Volume for 95th percentile queue is metered by upstream signal

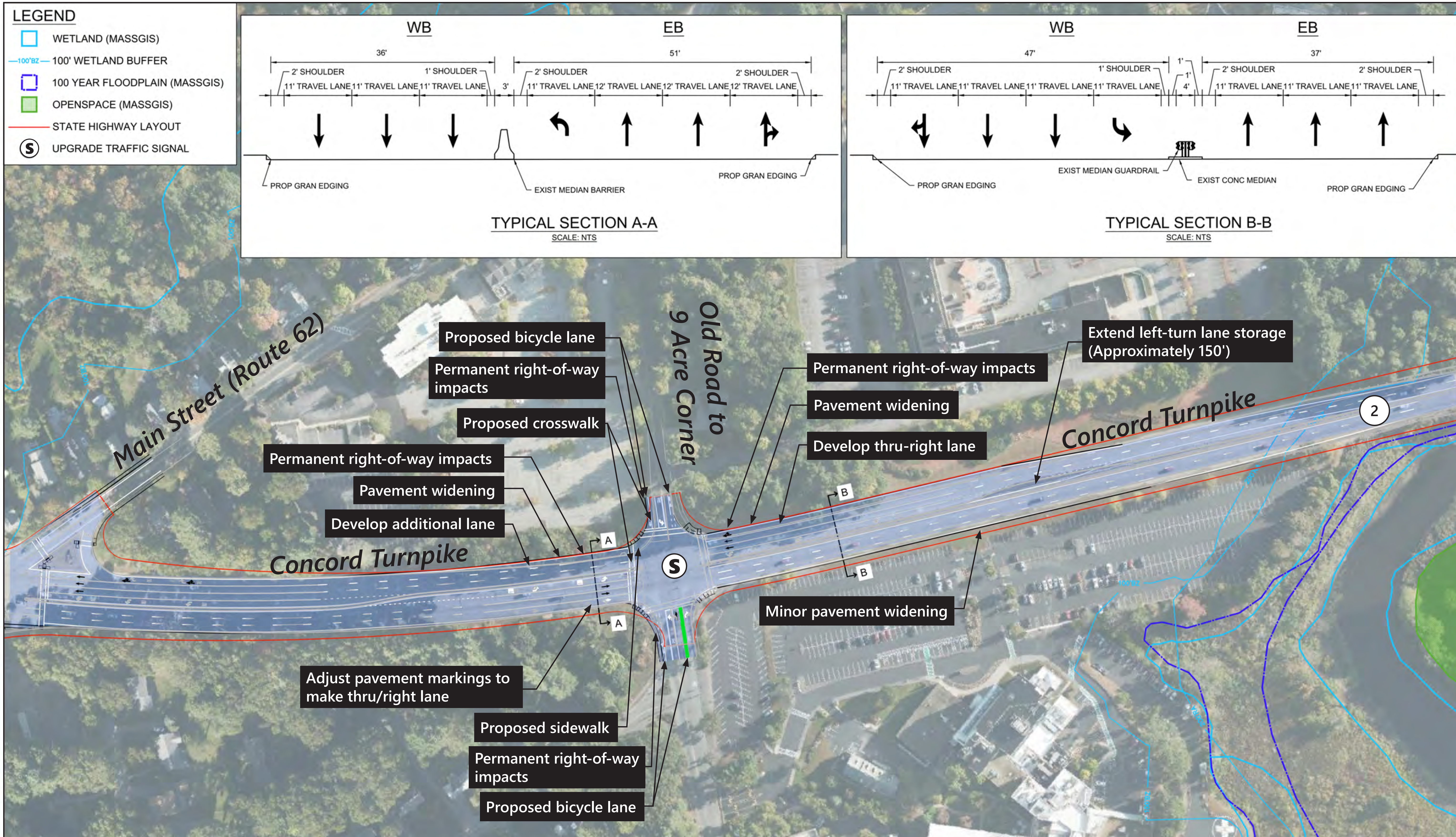


Town of Concord

0 75 150 Feet

Concept 1
Route 2 at Old Road to 9 Acre Corner
Route 2 Corridor Study

Figure 4-23



Town of Concord

0 75 150 Feet

Concept 2
Route 2 at Old Road to 9 Acre Corner
Route 2 Corridor Study

Figure 4-24

4.4.2.4 Route 2 at Sudbury Road

Conceptual improvement alternatives were developed to address current (and/or projected) safety and operational concerns, as well as pedestrian and bicycle accommodation. Additional considerations (Concept 2) were made for the westbound left-turn movement due to the significant weekday evening peak hour demand (approximately 300 vehicles per hour). Additionally, the northbound right-turn movement currently has an existing overlapping signal phase without a formal right-turn lane.

Concept 1 – 3rd Lane Eastbound & Westbound, Pedestrian & Bicycle Enhancements (Near-Term)

As presented in Figure 4-25, Concept 1 proposes adding a third general purpose lane for Route 2 in both directions. Concept 1 would repurpose existing roadway and shoulder width (with minor roadway widening along Route 2 westbound that may require right-of-way modifications) to provide the third lane on the approach and departure in each direction. The Route 2 eastbound departure is constrained by the proximity to Fairhaven Road and in this concept the length is restricted to avoid right-of-way impacts that would be required for extending the 3rd lane beyond Fairhaven Road. The concept would propose to extend the current westbound left-turn storage length to better accommodate vehicle queuing. Minor widening (and potential right-of-way impacts) is proposed to formalize a northbound exclusive right-turn lane in conjunction with the current overlap signal phasing.

Existing pedestrian crosswalks are maintained; however, the concept removes the current apex ramp on the southwest corner and would provide pedestrian signal heads and phasing crossing the southern Sudbury Road Leg. New bicycle accommodations (bicycle lanes) are proposed along Sudbury Road. There may be additional right-of-way impacts to provide for bicycle accommodation along Sudbury Road depending upon the limits of the intersection improvements.

As shown in Table 4-13, Concept 1 provides an improvement in projected 2039 future overall intersection operations from LOS F to LOS D in both morning and evening peak hour periods. The heavy eastbound through movement improves from a LOS F to LOS D in both peak periods with average queues reduced from over 1000 feet to less than 500 feet per lane in both peak periods.

Concept 2 – 3rd lane Eastbound, dual left-turn Westbound (Near-Term)

As presented in Figure 4-26, Concept 2 considers providing a dual westbound left-turn (in lieu of a 3rd westbound through lane), in conjunction with an eastbound 3rd (TH-RT) lane. Under 2039 conditions, the left-turn movement in the evening is projected to exceed 300 vehicles per hour. The development of the dual westbound left-turn lane will repurpose the existing westbound right-turn only lane and is proposed to minimize queue spill back into mainline through lanes. The development of the dual-left turn lane may impact right-of-way along the Route 2 westbound approach and may also require right-of-way modifications along the Sudbury Road southbound departure to accommodate the dual westbound left-turn movement.

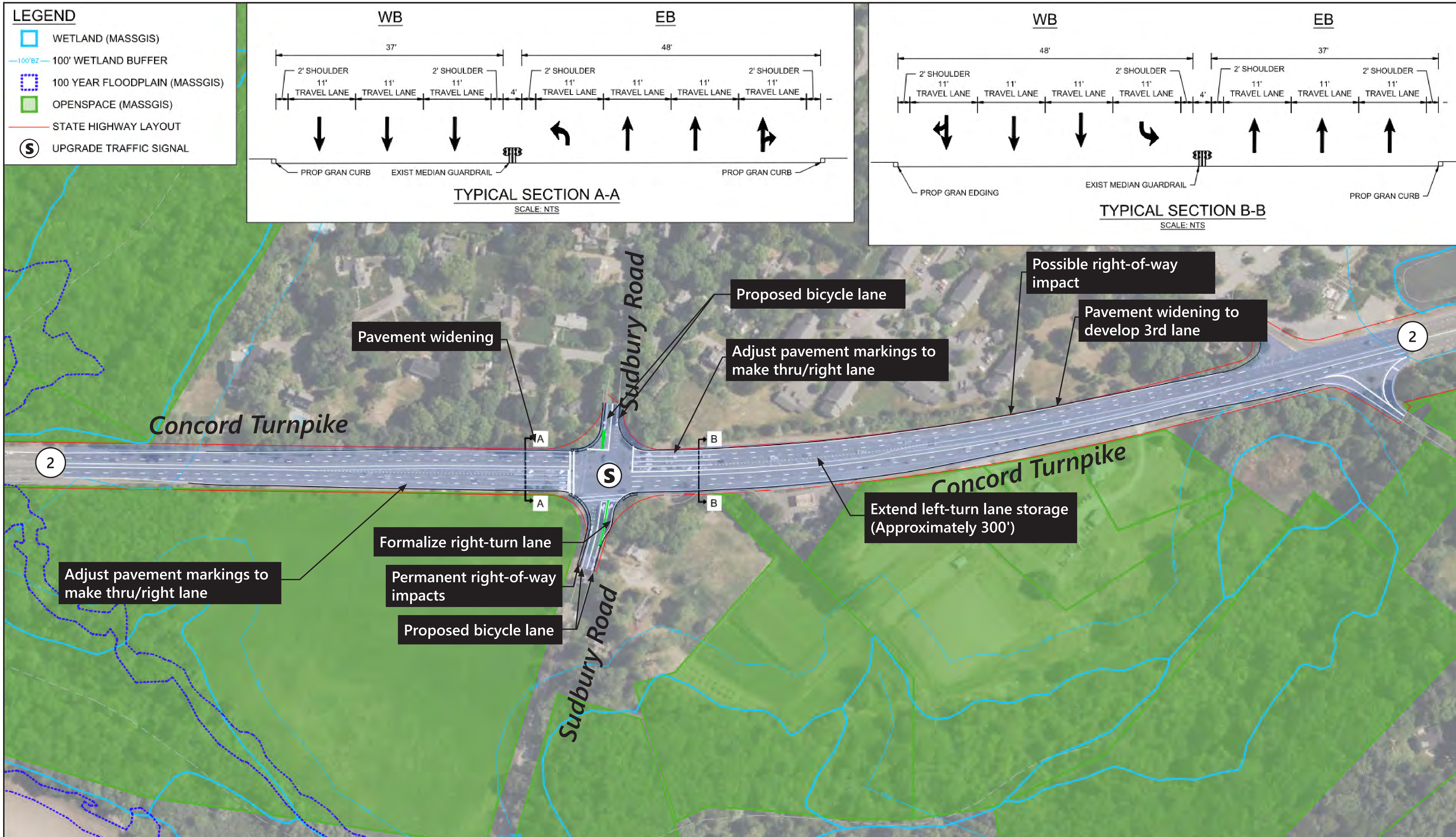
As shown in Table 4-13, Concept 2 improves overall projected 2039 intersection operations from LOS F to LOS D in the morning peak hour, and LOS F to LOS E in the evening peak hour. The eastbound through movement operations are reduced from LOS F to LOS C in both future peak periods. Similarly, the westbound left-turn LOS is improved from LOS F to LOS E and LOS D in the morning and evening peak periods, respectively. While Concept 2 does show an improvement to 2039 No-Build Conditions, Concept 1's overall operations are better, with 10 and 15 seconds of delay improvement for morning and evening peak periods, respectively. Based on operational analyses, it appears the provision of a

3rd westbound general-purpose lane has more benefit than the development of a westbound dual left-turn lane.

Table 4-13 Signalized Intersection Capacity Analysis – Route 2 at Sudbury Road 2039 Concepts

Location/Movement	2039 No-Build					2039 Concept 1 3rd Lane EB and WB					2039 Concept 2 3rd Lane EB and WB Dual-Left				
	v/c [a]	Del [b]	LOS [c]	50 Q [d]	95 Q [e]	v/c	Del	LOS	50 Q	95 Q	v/c	Del	LOS	50 Q	95 Q
25: Route 2 at Sudbury Road															
Weekday Morning															
EB L	0.62	96	F	14	m14	0.50	60	E	9	30	0.50	60	E	9	30
EB T	>1.20	117	F	~1188	m#990	0.96	40	D	~495	#698	0.92	30	C	446	#645
EB R	0.01	16	B	0	m0	-	-	-	-	-	-	-	-	-	-
WB L	0.99	111	F	141	m#181	0.98	110	F	94	#231	0.74	58	E	47	#101
WB T**	0.94	25	C	284	m#1000	0.79	21	C	289	#628	1.07	64	E	513	#977
WB R	0.00	11	B	0	m0	-	-	-	-	-	-	-	-	-	-
NB L/T/R*	1.05	108	F	~389	#596	0.83	48	D	195	298	0.83	48	D	195	298
SB L/T/R	>1.20	>120	F	~276	#437	0.88	60	E	143	#235	0.88	60	E	143	#235
Overall	**>1.20**	**85**	**F**			**0.96**	**38**	**D**			**1.05**	**48**	**D**		
Weekday Evening															
EB L	0.95	66	E	45	m41	0.78	90	F	38	#103	0.79	92	F	38	#103
EB T	1.15	>120	F	~1001	m713	0.97	49	D	445	#664	0.90	33	C	447	#620
EB R	0.01	17	B	0	m0	-	-	-	-	-					
WB L	1.16	>120	F	~346	m#294	1.03	99	F	~233	#446	0.78	52	D	112	#185
WB T**	0.94	17	B	353	m305	0.87	26	C	504	#751	1.12	87	F	~886	#1120
WB R	0.01	9	A	0	m0	-	-	-	-	-					
NB L/T/R*	1.03	112	F	~294	#399	0.80	49	D	203	260	0.79	48	D	203	260
SB L/T/R	>1.20	>120	F	~274	#435	0.73	45	D	162	246	0.72	43	D	162	245
Overall	**1.17**	**83**	**F**			**0.94**	**44**	**D**			**1.05**	**59**	**E**		

Source: VHB, Inc. using Synchro 9/10 software
Note: Shaded cells denote LOS E or LOS F conditions.
* NB R modeled using short lane analysis.
** WB T Concept 1 and Concept 2 modeled using short lane analysis.
a Volume to capacity ratio.
b Average total delay, in seconds per vehicle.
c Level-of-service.
d 50th percentile queue, in feet.
e 95th percentile queue, in feet.
~ Volume exceeds capacity, queue is theoretically infinite.
# 95th percentile volume exceeds capacity; queue may be longer.
m Volume for 95th percentile queue is metered by upstream signal

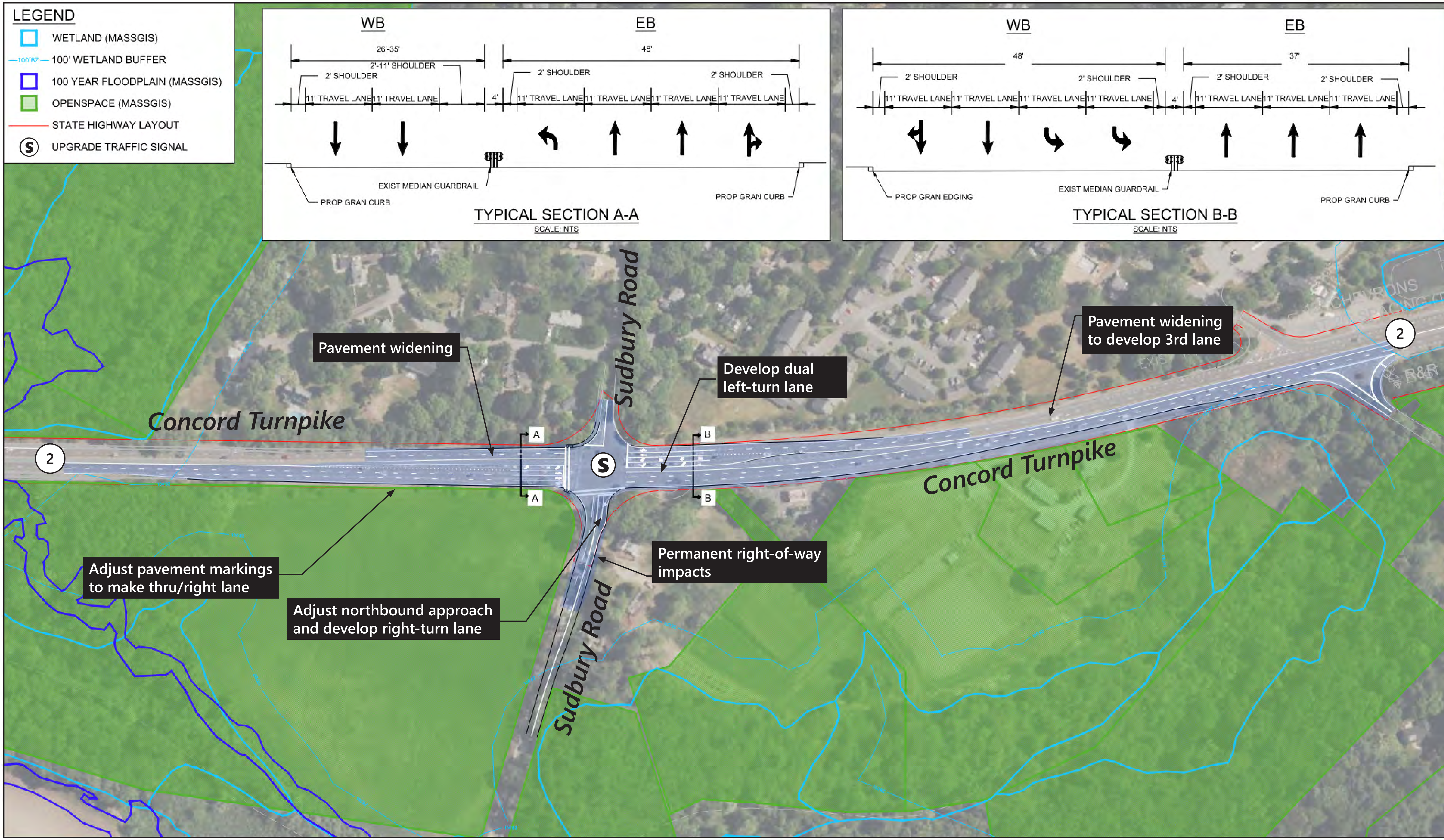


Town of Concord

0 100 200 Feet

Concept 1
Route 2 at Sudbury Road
Route 2 Corridor Study

Figure 4-25



Town of Concord

0 100 200 Feet

Concept 2
Route 2 at Sudbury Road
Route 2 Corridor Study

Figure 4-26

4.4.2.5 Route 2 at Walden Street (Route 126)

Conceptual improvement alternatives were developed to address current (and/or projected) safety and operational concerns, as well as pedestrian and bicycle accommodation. Pedestrian and bicycle activity at this intersection is relatively higher than most locations along Route 2 (Walden Pond as a destination), especially during summer months, and concept alternatives reflect choices made in favor of improved accommodation and safety (versus vehicle operations).

Concept 1 – Pedestrian & Bicycle Enhancements, 3rd Lane Eastbound (Near-Term)

As presented in Figure 4-27, Concept 1 proposes a series of pedestrian and bicycle enhancements, as well as development of a 3rd general purpose lane eastbound.

Pedestrian enhancements include expansion of the delta island in the northwest corner of the intersection to increase pedestrian refuge areas and shorten crossing distances. A new pedestrian crosswalk is proposed across the southbound Walden Street approach to the intersection and a new sidewalk along the easterly side of Walden Street is proposed for connectivity. A proposed buffered bike lane is proposed along both sides of Walden Street, north and south of Route 2.

Concept 1 would repurpose existing roadway and shoulder width, with minor widening, to provide the third lane on the approach and departure of Route 2 eastbound. For this improvement the widening is minor and should not impact right-of-way or environmental resource areas. The potential to repurpose the westbound exclusive right-tune lane to a general (TH-RT) lane was considered. However, the existing westbound right-turn volume (190 vehicles per hour in the weekday evening) to Walden Street is noticeably higher than right-turn volumes at other locations along the corridor, and the repurposing would negate the island expansion/crosswalk shortened pedestrian improvements detailed above. Concept 1 proposes to extend the exclusive westbound left-turn lane to better accommodate peak period vehicle queuing.

As shown in Table 4-14, Concept 1 provides an improvement in overall projected 2039 future intersection operations from LOS F to LOS E in the evening peak period and an improvement of delay by 10 seconds per vehicle (103 seconds to 93 seconds) in the morning peak period. Similarly, the average queue for the heavy eastbound movement is reduced from over 1350 feet to around 950 feet per lane during the morning peak period.

Concept 2 – 3rd Lane Eastbound (No Eastbound Left)

As presented in Figure 4-28, Concept 2 considers elimination of the low volume (5 to 35 vehicles per hour) eastbound left-turn movement and widens the center median for increased refuge area for pedestrians/bicycles. Concept 2 also incorporates the 3rd lane for the eastbound approach/departure, similar to Concept 1.

As shown in Table 4-14, Concept 2 provides an improvement in projected 2039 future overall intersection operations from LOS F to LOS D in the evening peak period and an improvement of delay by 20 seconds per vehicle (103 seconds to 82 seconds) in the morning peak period. Similar to Concept 1, the average queues are improved for the heavy eastbound movement from over 1350 feet per lane to around 950 feet per lane during the morning peak period. Compared to existing conditions and Concept 1 this concept reduced the average queues in the westbound direction during the weekday evening peak period from 1200 feet per lane to around 800 feet per lane.

Concept 3 – 3rd Lane Eastbound, Dual-left turn Southbound (Analysis Only)

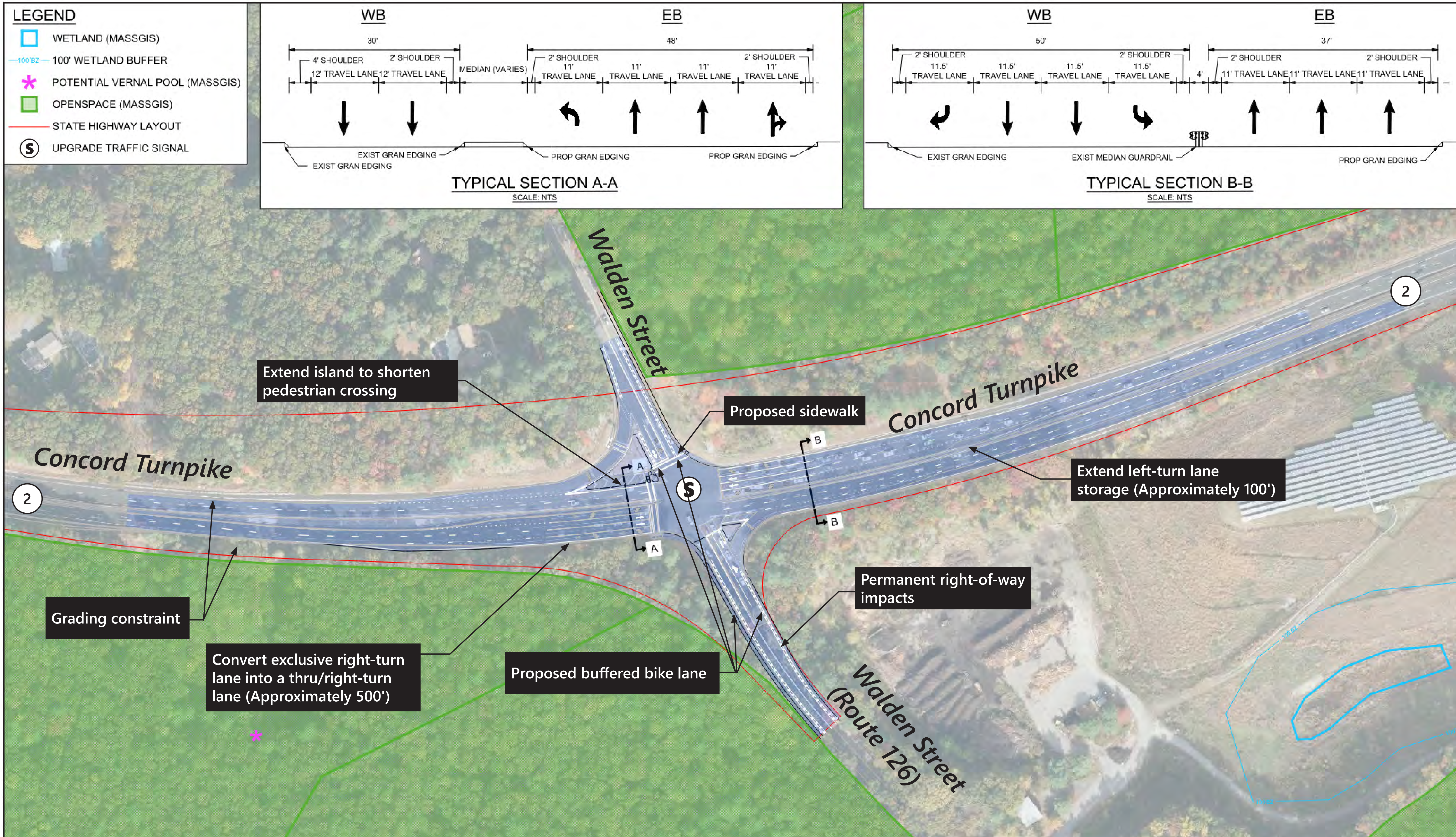
Concept 3 includes the improvements proposed in Concept 1 and modifies the southbound Walden Street approach to provide a dual-left turn (a significant movement, specifically for the morning peak period), as well as a shared TH-RT lane. This is in contrast to the existing condition (and Concept 1 configuration) where the southbound approach provides an exclusive left-turn lane and a through lane with a channelized right-turn lane. All concepts maintain the existing northbound and southbound split phase operation.

As shown in Table 4-14, Concept 3 provides an improvement in projected 2039 future overall intersection operations from 106 to 82 seconds of delay in the evening peak period, and 103 to 77 seconds of delay for the morning peak period. During the morning peak period, Concept 3 experiences less delay than both Concepts 1 and 2 (from 93 and 82 seconds to 77 seconds), however, Concept 3 does not show an improvement when compared with Concept 1 or Concept 2 in the evening peak periods. The 95th percentile queue for the southbound left-turn is reduced from over 475 feet to around 175 feet per lane for the morning peak period.

Table 4-14 Signalized Intersection Capacity Analysis – Route 2 at Walden Street 2039 Concepts

	2039 No-Build					2039 Concept 1 3rd Lane EB					2039 Concept 2 3rd Lane EB, Remove EB Left					2039 Concept 3 3rd Lane EB, SB Dual Left				
Location/Movement	v/c [a]	Del [b]	LOS [c]	50 Q [d]	95 Q [e]	v/c	Del	LOS	50 Q	95 Q	v/c	Del	LOS	50 Q	95 Q	v/c	Del	LOS	50 Q	95 Q
26: Route 2 at Walden Street																				
Weekday Morning																				
EB L	0.31	82	F	4	m4	0.29	68	E	4	18	-	-	-	-	-	0.29	68	E	4	18
EB T*	>1.20	>120	F	~1357	m#988	1.20	>120	F	~962	#1104	1.20	>120	F	~962	#1104	1.15	107	F	~937	#1078
EB R	0.14	2	A	1	m0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
WB L	0.81	103	F	58	#145	0.75	84	F	53	#132	0.75	84	F	53	#132	0.75	84	F	53	#132
WB T	0.95	39	D	617	#1000	1.03	60	E	632	#1003	0.91	30	C	632	767	1.00	50	D	604	#978
WB R	0.07	6	A	1	16	0.07	7	A	1	19	0.07	4	A	3	13	0.07	5	A	1	19
NB L	0.95	>120	F	102	#217	0.83	86	F	92	#192	0.83	86	F	92	#192	0.76	72	E	92	#181
NB T	1.19	>120	F	~160	#295	1.04	>120	F	~132	#263	1.04	>120	F	~132	#263	0.94	106	F	124	#251
NB R	0.38	60	E	25	#113	0.25	53	D	13	83	0.28	53	D	17	87	0.23	51	D	13	82
SB L	1.15	>120	F	~302	#486	1.12	>120	F	~272	#452	1.12	>120	F	~272	#452	0.68	54	D	118	167
SB T	0.84	74	E	197	#337	0.82	66	E	180	#312	0.82	66	E	180	#312	0.98	102	F	185	#348
SB R	0.02	0	A	0	0	0.02	0	A	0	0	0.02	0	A	0	0	0.02	45	D	0	0
Overall	**>1.20**	**103**	**F**			**1.15**	**93**	**F**			**1.18**	**82**	**F**			**1.09**	**77**	**E**		
Weekday Evening																				
EB L	0.66	62	E	37	m33	0.66	53	D	36	m35	-	-	-	-	-	0.61	71	E	32	#75
EB T*	>1.20	>120	F	~1101	m#878	0.96	40	D	428	m382	1.00	54	D	~563	#731	0.91	38	D	553	#680
EB R	0.08	24	C	6	m4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
WB L	0.82	74	E	167	#281	0.82	74	E	167	#281	0.84	68	E	142	#261	1.09	>120	F	~178	#333
WB T	1.15	105	F	~1186	#1320	1.15	105	F	~1186	#1320	1.01	41	D	~794	#1013	1.18	115	F	~1112	#1248
WB R	0.15	9	A	17	42	0.15	7	A	17	42	0.16	3	A	19	36	0.15	7	A	17	42
NB L	0.55	57	E	96	161	0.55	57	E	96	161	0.58	51	D	80	140	0.54	52	D	87	149
NB T	0.98	110	F	~200	#357	0.98	110	F	~200	#357	1.03	118	F	~165	#312	0.96	101	F	171	#321
NB R	0.03	51	D	0	0	0.03	51	D	0	0	0.03	43	D	0	0	0.03	47	D	0	0
SB L	0.60	63	E	78	137	0.60	63	E	78	137	0.67	61	E	67	#140	0.34	53	D	36	63
SB T	0.73	72	E	103	#182	0.73	72	E	103	#182	0.82	78	E	88	#189	0.82	82	F	96	#197
SB R	0.02	0	A	0	0	0.02	0	A	0	0	0.02	0	A	0	0	0.02	51	D	0	0
Overall	**1.12**	**106**	**F**			**1.10**	**75**	**E**			**1.07**	**49**	**D**			**1.15**	**82**	**F**		

Source: VHB, Inc. using Synchro 9/10 software
Note: Shaded cells denote LOS E or LOS F conditions.
* EB T Concept 1 and Concept 2 modeled using short lane analysis.
a Volume to capacity ratio.
b Average total delay, in seconds per vehicle.
c Level-of-service.
d 50th percentile queue, in feet.
e 95th percentile queue, in feet.
~ Volume exceeds capacity, queue is theoretically infinite.
\# 95th percentile volume exceeds capacity; queue may be longer.
m Volume for 95th percentile queue is metered by upstream signal

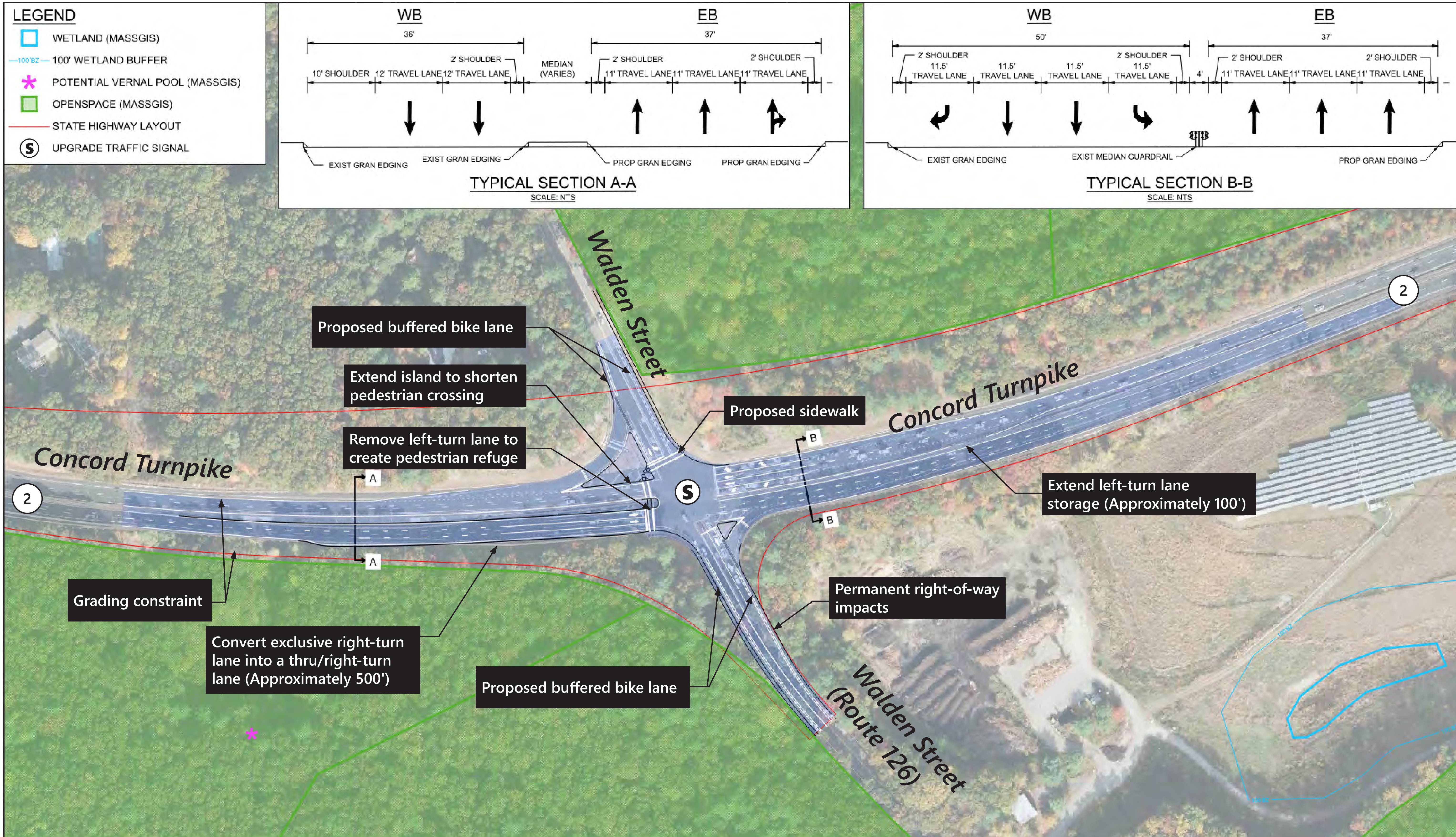


Town of Concord

0 75 150 Feet

Concept 1
Route 2 at Walden Street
Route 2 Corridor Study

Figure 4-27



Town of Concord

0 75 150 Feet

vhb

Concept 2
Route 2 at Walden Street
Route 2 Corridor Study

Figure 4-28

4.4.2.6 Route 2 at Bedford Road (Tracey's Corner)

Conceptual improvement alternatives were developed to address current (and/or projected) safety and operational concerns, as well as pedestrian and bicycle accommodation. A primary focus involved incorporation, where possible, of safety measures identified in the Road Safety Audit. Additional considerations (Concept 2) were made for the heavy southbound through and left-turn movements.

Concept 1 – Extend and Formalize 3rd Lane Eastbound & Westbound

As presented in Figure 4-29, Concept 1 proposes extending and formalizing three through travel lanes (6-lane cross-section) in each direction on Route 2 in the vicinity of Bedford Road. At this location there is currently an existing 3rd through lane in both the eastbound and westbound directions, however they are not well signed, are relatively short in length and primarily serve as an exclusive right-turn lane to the loop ramps to Bedford Road. Existing traffic volume data indicate they are extremely underutilized for through movements. Concept 1 is designed to get better utilization out of these third lanes for through movements by extending their length (approach and departure), enhanced lane use signage and signal indications. The 3rd lane eastbound and westbound will be enhanced using existing roadway and shoulder width with minor widening. Concept 1 also formalizes Bedford Road, including minor widening into the loop ramp areas, to provide for 2-lane approaches, consisting of an exclusive left-turn lane and a shared through-right lane. A new pedestrian crosswalk/signal is proposed across the northbound Bedford Road approach. Buffered bicycle lanes are proposed on each side of Bedford Road, north and south of Route 2.

As shown in Table 4-15, Concept 1 provides an improvement in projected 2039 future overall intersection operations from LOS F to LOS E in the morning peak hour and LOS F to LOS D in the evening peak hour. The average queue length for the eastbound through movement is reduced from nearly 1400 feet to 850 feet per lane in the morning peak period and from 1000 feet to approximately 525 feet per lane in the evening peak period. Similarly for the westbound through movement, the average queue length is reduced from nearly 775 feet to approximately 525 feet per lane in the morning peak period and is reduced 1200 feet to approximately 700 feet per lane in the evening peak period.

Concept 2 – 3rd lane Eastbound & Westbound, dual left-turn Southbound (Analysis Only)

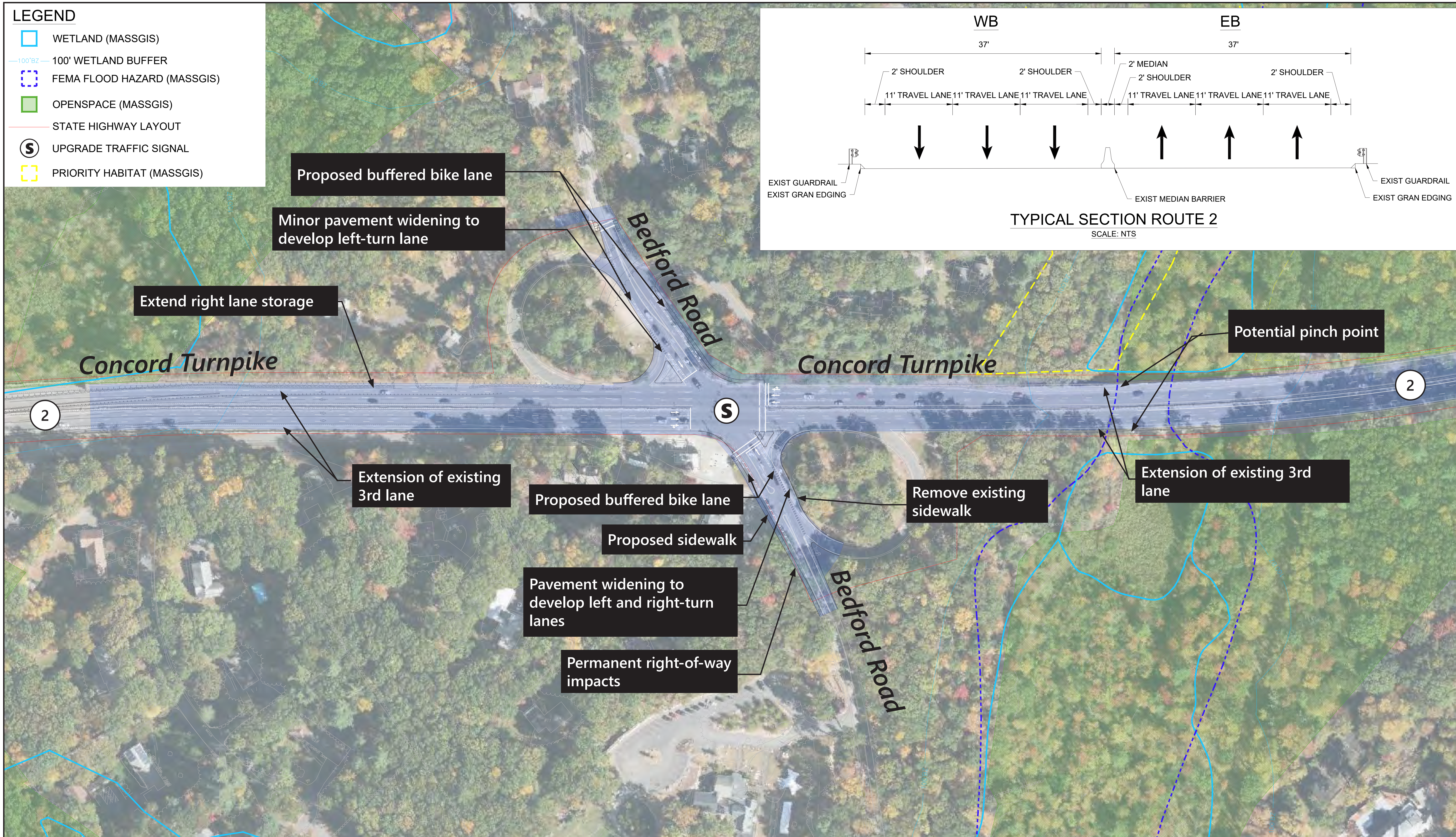
Additional analysis was conducted for Concept 2 which considers providing a southbound dual left-turn, in conjunction with the Concept 1 improvements (extending and formalizing the 3rd lane eastbound and westbound). In the 2039 conditions, the southbound left-turn movement in the morning is projected to have as many as 315 vehicles per hour. Further, potential future redevelopment at Hanscom Air Base could increase the volumes on Bedford Road. The widening along Bedford Road proposed in Concept 2, in conjunction with the bicycle improvements, would result in permanent Right of Way impacts.

As shown in Table 4-15, Concept 2 improves overall projected 2039 intersection operations from LOS F to LOS E in both peak periods. The southbound left-turn movement 95th percentile queue is reduced from approximately 475 feet to 200 feet per lane in the morning and approximately 325 feet to 175 feet per lane in the evening peak period. The overall intersection under Concept 2 is expected to operate at 61 seconds of delay during the morning peak period, compared to 69 seconds of delay under Concept 1, however, during the evening peak period the overall intersection under Concept 2 will operate with 59 seconds of delay compared to 46 seconds under Concept 1.

Table 4-15 Signalized Intersection Capacity Analysis – Route 2 at Bedford Road (Tracey's Corner) 2039 Concepts

	2039 No-Build					2039 Concept 1 – 3rd Lane EB and WB NB (L|T|R) – SB (L|T|R)					2039 Concept 2 – 3rd Lane EB and WB NB (L|T|R) – SB (L|L|T|R)				
Location/Movement	v/c [a]	Del [b]	LOS [c]	50 Q [d]	95 Q [e]	v/c	Del	LOS	50 Q	95 Q	v/c	Del	LOS	50 Q	95 Q
28: Route 2 at Bedford Road															
Weekday Morning															
EB T	>1.20	>120	F	~1385	#2117	1.12	92	F	~847	#1358	1.11	85	F	~754	#1409
EB R	0.02	10	B	4	20	-	-	-	-	-	-	-	-	-	-
WB T*	1.05	62	E	778	#1491	0.94	39	D	534	#1007	0.93	36	D	468	#1058
WB R	0.13	11	B	33	100	-	-	-	-	-	-	-	-	-	-
NB L	0.40	60	E	16	#62	0.21	52	D	15	52	-	-	-	-	-
NB T	0.93	>120	F	71	#223	0.49	54	D	66	151	0.61	55	D	40	114
NB R	0.33	58	E	9	#157	0.83	83	F	90	#311	-	-	-	-	-
SB L	>1.20	>120	F	~284	#478	1.02	93	F	221	#411	0.80	57	E	116	188
SB T	0.79	58	E	189	#342	0.54	36	D	160	284	0.59	36	D	157	283
SB R	0.01	39	D	0	0	0.01	30	C	0	0	-	-	-	-	-
Overall	**>1.20**	**>120**	**F**			**1.08**	**69**	**E**			**0.95**	**61**	**E**		
Weekday Evening															
EB T	1.19	116	F	~994	#1651	0.89	31	C	519	#1014	0.94	36	D	507	#1008
EB R	0.04	11	B	9	36	-	-	-	-	-	-	-	-	-	-
WB T*	>1.20	>120	F	~1185	#1892	1.02	52	D	686	#1265	1.08	73	E	~677	#1242
WB R	0.14	12	B	34	105	-	-	-	-	-	-	-	-	-	-
NB L	>1.20	>120	F	~94	#221	0.98	>120	F	71	#197	-	-	-	-	-
NB T	0.98	115	F	123	#291	0.61	51	D	123	221	0.99	96	F	121	#248
NB R	0.07	47	D	0	14	0.07	44	D	0	27	-	-	-	-	-
SB L	0.88	74	E	98	#316	0.72	50	D	100	#269	0.88	87	F	60	#163
SB T	1.10	119	F	~308	#709	0.93	69	E	308	#684	0.92	63	E	290	#679
SB R	0.02	34	C	0	0	0.02	33	C	0	0	-	-	-	-	-
Overall	**>1.20**	**>120**	**F**			**1.01**	**46**	**D**			**1.04**	**59**	**E**		

Source: VHB, Inc. using Synchro 9/10 software
Note: Shaded cells denote LOS E or LOS F conditions.
* WB TR in concepts 1 and 2 assume reduced lane utilization due to right-turn volumes
a Volume to capacity ratio.
b Average total delay, in seconds per vehicle.
c Level-of-service.
d 50th percentile queue, in feet.
e 95th percentile queue, in feet.
~ Volume exceeds capacity, queue is theoretically infinite.
\# 95th percentile volume exceeds capacity; queue may be longer.



Town of Lincoln

0 75 150 Feet

Concept 1
Route 2 at Bedford Road (Tracey's Corner)
Route 2 Corridor Study

Figure 4-29

4.4.3 Concord Rotary Alternatives

The Concord Rotary represents a major bottleneck along the Route 2 corridor. It has experienced significant peak period delays and queuing for years. The Concord Rotary has been identified as a high crash location by MassDOT and an RSA was conducted June 21, 2017. The most recent crash data available (2013-2017) showed that there were 228 reported crashes over the 5-year period, with most of the crashes comprising of rear-end type, sideswipe, or an angle crash. MassDOT recently (Summer 2020) implemented minor geometric/restriping modifications to provide better delineation of movements based on findings of the RSA report. MassDOT has previously evaluated the Concord Rotary, including the development of concept-level grade separated proposals (see below). As an alternative, and in addition to grade separated design alternatives, this study developed and evaluated at-grade signalized intersection alternatives for consideration.

Capacity analysis tables (Tables 4-16 through 4-29) are included summarizing projected 2039 traffic operations under the various at-grade signalized alternatives presented herein. Table 4-29, at the end of this section, compares all at-grade alternatives at the Concord Rotary for overall operations and highlights the differences in projected Route 2 eastbound and westbound queues. From a multimodal standpoint, the Concord Rotary has historically been difficult to traverse through. As the Bruce Freeman Rail Trail project (to the east) is constructed, it is expected that an increase in pedestrian and bicyclists will be present at the rotary. For any improvements, pedestrians are projected to be accommodated with exclusive phasing and associated signals. Bicycle lanes and phasing for any future project should be a consideration as demand increases. However, the mobility of pedestrians/bicyclists for east-west movements along Route 2 is currently not being consider and would be part of a longer-term initiative that is outside the scope of this study.

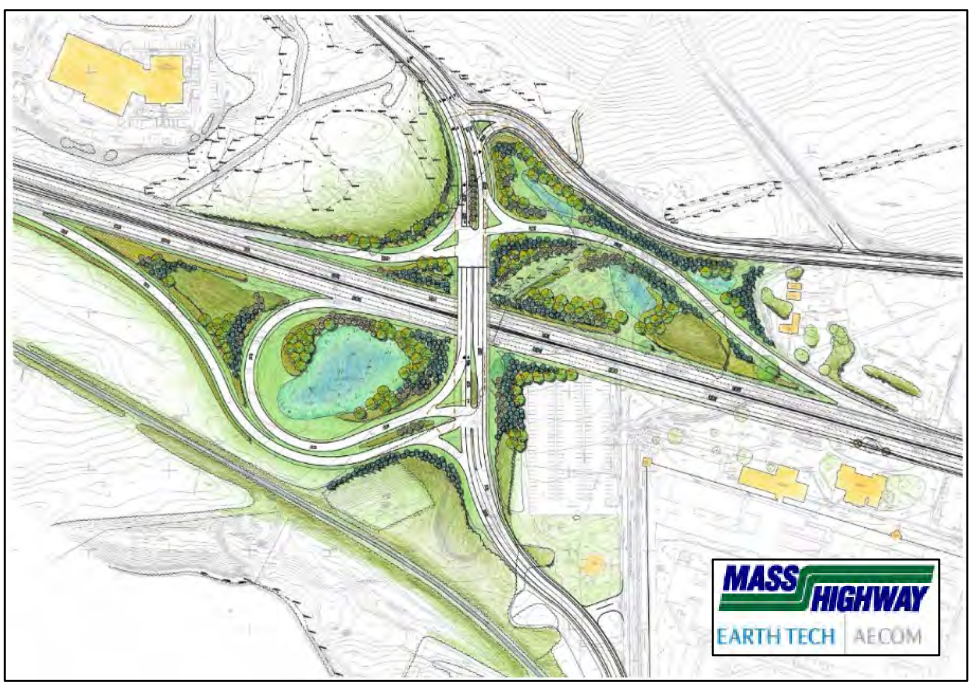
At the time the study was completed as a DRAFT, it did not reflect the pending MCI-Concord closure or any additional upcoming MassDOT related Concord Rotary planning initiatives.

4.4.3.1 Grade Separated Alternatives (By Others)

Grade separated alternatives at the Concord Rotary were explored by MassDOT in previous studies/projects/reports. Two design alternatives were previously presented as refined alternatives (Alternative 3 and Alternative 5) and are presented in Figure 4-30 and Figure 4-31. Each of the alternatives realign Commonwealth Avenue and Route 2A/119 to intersect Route 2 to the west of the current rotary/prison employee parking lot. Each alternative provides full access/egress to and from Route 2 eastbound and westbound to Commonwealth Avenue and Route 2A/119. Alternative 3 provides a full diamond-type interchange west of the existing Rotary. Alternative 5 maintains the diamond-type configuration for the Route 2 westbound ramps and proposes a partial cloverleaf for Route 2 eastbound ramps. As a result of the previous work by MassDOT and others, grade separated alternatives at the Concord Rotary were not further evaluated as part of this study.

Figure 4-30 Concord Rotary Refined Alternative 3 (By Others)

Figure 4-31 Concord Rotary Refined Alternative 5 (By Others)



At-Grade Signalized Alternatives

As an option to grade separated options, several at-grade signalized alternatives were evaluated as part of this study. These represent lower cost, less impactful options (e.g., environmental resource areas, right-of-way, as well as impacts to traffic during construction) as compared to the grade separated alternatives detailed above. A series of conceptual-level intersection alternatives were considered for reconfiguring the rotary to remain at-grade and be under signalized control. Five concepts are presented graphicly in Figure 4-32 through Figure 4-36 and described below. An additional concept evaluating a continuous flow intersection was analyzed and preliminarily evaluated from a geometric perspective. All alternatives were analyzed with Synchro while the Thru-about alternative was analyzed with both Synchro and Vissim. A comparison to Concord Rotary No-Build queues is presented for each alternative to show the drastic improvements for Route 2 mainline operations.

Concept 1 – Thru-About

As presented in Figure 4-32, the concept essentially maintains the existing rotary footprint but allows for the Route 2 eastbound and westbound through movements a direct connection straight through the rotary. This concept would include signalized control on the eastern and western sides of the existing circle. The design allows for a simple two-phase signal operation (not including potential accommodation for pedestrian movements) at each location with all turning movements circulating the rotary as they do currently.

From a review of current traffic volumes and origin-destination at the rotary, it was determined that more than 80% of approach volumes for Route 2 eastbound during the morning peak hour and Route 2 westbound during the evening peak hour at the rotary wish to continue straight on Route 2. The Thru-about concept allows for that movement to take place without mixing with traffic from Route 2A/119, Commonwealth Avenue and Barretts Mill Road. The simplified phasing at each signalized location (i.e., 2 phase without pedestrians) allows for the mainline of Route 2 to remain a four-lane cross section, although exclusive right-turn lanes are proposed on the approach to the rotary in both the eastbound and westbound directions. Development of a six-lane cross-section on Route 2 could be considered and would further reduce delay and queuing on the eastbound and westbound approaches. Development of a six-lane cross-section on Route 2 may need to be considered with the potential return of current cut-thru traffic back to Route 2 if the current poor Route 2 mainline operations are addressed at the rotary.

Both Synchro and Vissim were utilized to analyze the Thru-About alternative. Capacity analysis is shown in Table 4-16 (Vissim) and Table 4-17 (Synchro).

As shown in Table 4-16, the analysis shows that while the overall delays are still expected to be high (under Vissim), most of the average and 95th percentile queues will be reduced. Eastbound queues during the morning peak hour will be reduced from ~3500/5000 feet to ~500/1400 feet, (average/95th, respectively) and westbound queues during the evening peak hour will be reduced from ~4200/5000 feet to ~450/1500 feet (average/95th, respectively).

Table 4-16 Signalized Intersection Capacity Analysis – 2039 Concept 1 – Thru-About (Vissim)

Location/Movement	2039 No Build					2039 Thru-About				
	Dem [a]	Del [b]	LOS [c]	Avg Q [d]	Max Q [e]	Dem	Del	LOS	Avg Q	Max Q
Morning Peak Hour										
Route 2 EB	1985	>120	F	3457	5031	1985	50	D	478	1373
Route 2 WB	1665	60	F	476	1478	1665	27	C	58	474
Commonwealth Ave NB	380	>120	F	1623	2347	380	>120	F	1544	1674
Route 2A SEB	755	>120	F	3188	4608	755	>120	F	1342	1674
Barretts Mill Rd SWB	280	55	F	84	346	280	32	C	4	137
Overall		**>120**	**F**				**73**	**E**		
Evening Peak Hour										
Route 2 EB	2105	>120	F	2919	5032	2105	74	E	973	1670
Route 2 WB	1960	>120	F	4222	5033	1960	25	C	36	562
Commonwealth Ave NB	475	>120	F	2402	3062	475	>120	F	1429	1668
Route 2A SEB	455	27	D	47	347	455	>120	F	1512	1672
Barretts Mill Rd SWB	450	>120	F	2044	2185	450	76	F	236	847
Overall		**>120**	**F**				**92**	**F**		

Source: VHB, Inc. using Vissim software
Note: Shaded cells denote LOS E or LOS F conditions.
a Demand, in vehicles.
b Average total delay, in seconds per vehicle.
c Level-of-service.
d Average queue, in feet.
e 95th percentile queue, in feet.

As shown in Table 4-17, using Synchro, the Thru-about signalized intersections with 2-phase signal operations are expected to operate at LOS C or better for all intersections during both peak periods. Specifically, the eastbound approaches during the morning peak period will operate at LOS D or better with a 95th percentile queue less than 700 feet (~5000 feet during 2039 No-Build). Similarly, the westbound approach during the evening peak period is expected to operate at LOS D with a 95th percentile queue of approximately 700 feet (~5000 feet during 2039 No-Build). The delays and queues are much less than what is experienced today, as well as what would be expected during the 2039 No-Build Condition.

Analyzing the thru-about alternative with Synchro tells a different story with regards to improvements in operations and queuing. Vissim analyzes all vehicles entering the study area and the total delay experienced through the specified node, in this case, all approaches leading up to the Concord Rotary. Synchro analyzes each individual intersection, in this case, the two proposed signals that are located at the eastern and western portions of the rotary. Vissim reports the entire delay each vehicle experiences going through the network, while Synchro only reports the delay of each vehicle at each individual intersection. As such, an exercise of combining and weighing the individual delays that are reported in Synchro was completed to have a fair comparison between the delays that are reported in Vissim and the delays that are reported in Synchro. The weighted average delay exercise shows a delay of 75 seconds for the morning and 53 seconds for the evening peak period. The morning delay is similar to the reported delay for Vissim (73 seconds), while the evening delay is much lower than the Vissim delay of 92 seconds. In summary, while delay and queue estimation differs somewhat between Synchro and Vissim, they both project improvements over the current rotary configuration.

Table 4-17 Signalized Intersection Capacity Analysis – 2039 Concept 1– Thru-About

	2039 Thru-about (2 phase no lefts)[1]				
Location/Movement	v/c [a]	Del [b]	LOS [c]	50 Q [d]	95 Q [e]
Route 2 at Western Signal					
Weekday Morning					
EBT	0.98	40	D	490	#681
EBR	0.47	16	B	131	206
WBT	0.77	4	A	21	27
SBT	0.96	49	D	320	m#456
SBR	0.19	15	B	25	m57
Overall		**29**	**C**		
Weekday Evening					
EBT	0.88	25	C	353	#477
EBR	0.83	27	C	266	#480
WBT	0.99	11	B	60	m54
SBT	0.74	28	C	169	m209
SBR	0.71	30	C	132	m192
Overall		**21**	**C**		
Route 2 at Eastern Signal					
Weekday Morning					
EBT	0.95	10	B	42	m52
WBT	0.79	22	C	323	416
WBR	0.45	16	B	125	197
NBT	1.02	56	E	~270	m#429
NBR	0.99	59	E	182	m#409
Overall		**28**	**C**		
Weekday Evening					
EBT	0.86	6	A	24	m54
WBT	1.01	45	D	~472	#650
WBR	0.34	13	B	76	128
NBT	0.96	42	D	248	#427
NBR	0.61	23	C	109	m172
Overall		**29**	**C**		

Source: VHB, Inc. using Synchro 9/10 software and Vissim.
Note: Shaded cells denote LOS E or LOS F conditions.
A Volume to capacity ratio.
B Average total delay, in seconds per vehicle.
C Level-of-service.
D 50th percentile queue, in feet.
E 95th percentile queue, in feet.
~ Volume exceeds capacity, queue is theoretically infinite.
# 95th percentile volume exceeds capacity; queue may be longer.
M Volume for 95th percentile queue is metered by upstream signal.
1 Thru-about (2 phase no lefts): 2 thru lanes EB/WB.

TYPICAL SECTION B-B
SCALE: NTS

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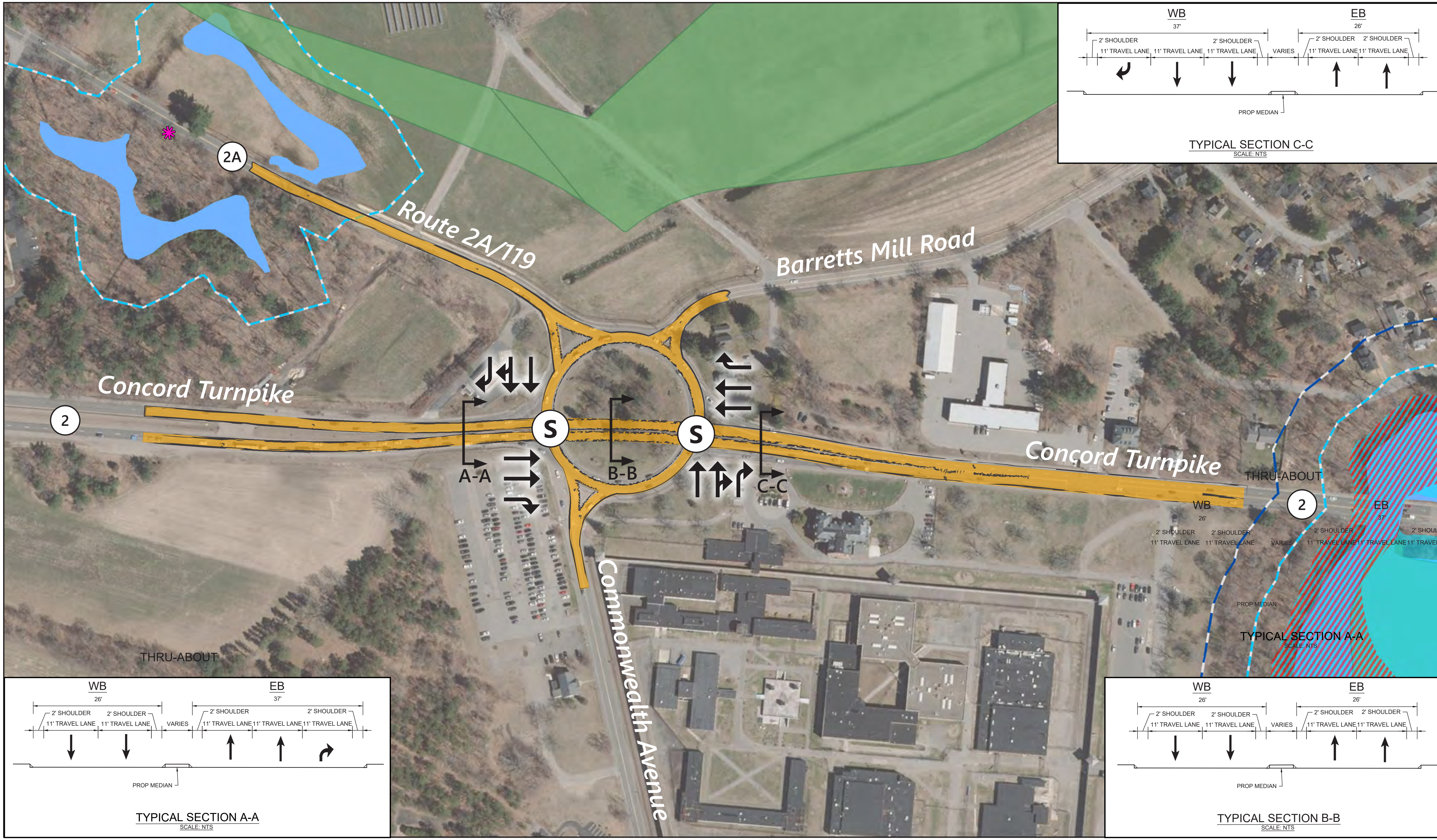


Town of Concord

0 100 200 Feet

NHESP Certified Vernal Pool
AE: 1% Annual Chance of Flooding, with BFE
AE: Regulatory Floodway
DEP Wetland Buffer 100'
River Buffer 200'
Protected and Recreational OpenSpace
DEP Wetlands (2005)

vhb

Concord Rotary Concept 1
Thru-About
Route 2 Corridor Study

Figure 4-32

Concept 2 – Signal Option A

As presented in Figure 4-33, this concept aligns Commonwealth Avenue and Route 2A/119 to form a large four-legged signalized intersection with Route 2. Barretts Mill Road would connect with Route 2A/119 just north of the large intersection. Due to the close spacing of the two intersections, both locations would most likely run off a single controller to prevent queue storage and blocking problems. As compared to the Thru-about, the signal operation (i.e., phasing and interconnection with Barretts Mill Road) would be more complicated and allow for less green time to be allocated to Route 2 eastbound and westbound. As a result, Concept 2 proposes a six-lane cross-section on Route 2 for mainline movements to better manage delays and queuing, along with additional exclusive turning lanes as detailed on Figure 4-30.

As shown in Table 4-18, the major intersection for Concept 2 is expected to operate at LOS D and E in the morning and evening peak periods, respectively. For some context, the overall operations would be similar to the rest of the Route 2 intersections (with improvements presented in section 4.4.2) in the Eastern study area for projected 2039 levels. The eastbound through movement during the critical morning peak period is expected to operate at LOS D with a 95th percentile queue of approximately 625 feet, compared to over 5,00 feet for 2039 No-Build Condition. While the westbound through movement during the critical evening peak period is expected to operate at LOS F, the 95th percentile queue of approximately 725 feet is still an improvement from the 2039 No-Build average queue of over 5,000 feet. As seen in the following table (Table 4-19), the Barretts Mill Road intersection with Route 2A/119 is expected operate at LOS D for both peak periods.

Concept 2 represents a typical signalized intersection setup, which should provide less confusion for drivers. However, when compared to other concepts, Concept 2 is expected to experience the largest delays with some of the longer queues. Even with the longer delays and queuing, Concept 2 has much better operations than 2039 No-Build Condition.

Pedestrians are projected to be accommodated with exclusive phasing and associated signals. Bicycle lanes and phasing should be a future consideration as demand increases.

Table 4-18 Signalized Intersection Capacity Analysis – 2039 Concept 2 – Signal Option A (Main Intersection)

	2039 Build Conditions Signal Option A Concept 2				
Location/Movement	v/c [a]	Del [b]	LOS [c]	50 Q [d]	95 Q [e]
Route 2 at Commonwealth Ave/Route 2A/119					
Weekday Morning					
EB L	0.91	78	E	141	#227
EB T [f]	0.95	48	D	501	#623
WB L	0.71	86	F	37	#90
WB T	0.94	52	D	391	#493
WB R	0.29	13	B	53	99
NB L	0.41	55	D	45	90
NB T	0.98	104	F	105	#205
SB L	0.88	17	B	97	m120
SB T	0.37	10	B	42	m56
SB R	0.03	22	C	0	m0
Overall	**0.98**	**46**	**D**		
Weekday Evening					
EB L	1.13	>120	F	~275	#390
EB T [f]	0.73	30	C	440	503
WB L	0.50	72	E	20	50
WB T	1.03	72	E	~624	#721
WB R	0.23	17	B	45	91
NB L	1.15	>120	F	~267	#445
NB T	0.50	54	D	97	142
SB L	0.56	21	C	80	m92
SB T	0.67	23	C	101	m120
SB R	0.55	51	D	116	m153
Overall	**1.01**	**61**	**E**		

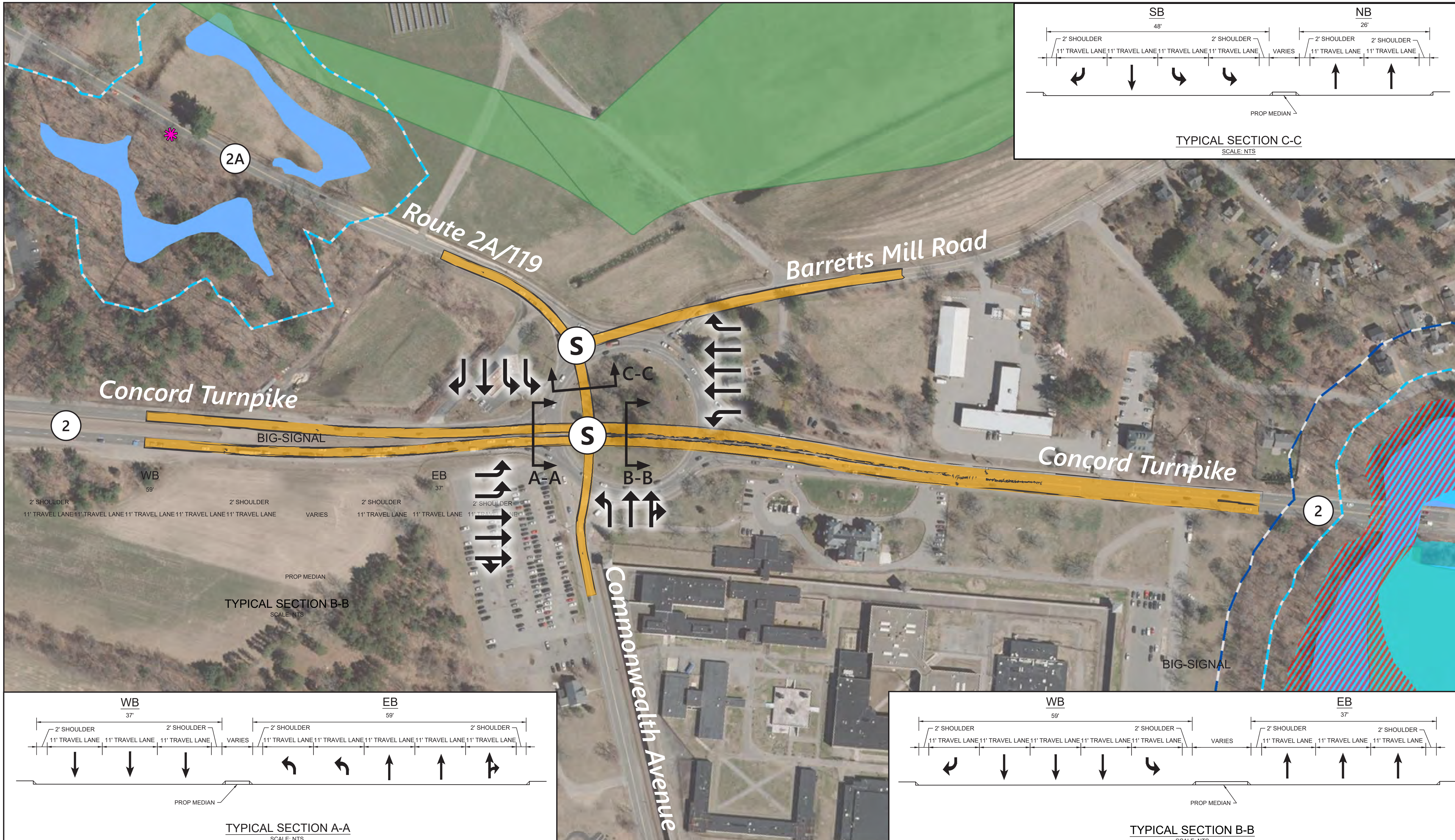
Source: VHB, Inc. using Synchro 9/10 software.
Note: Shaded cells denote LOS E or LOS F conditions.
a Volume to capacity ratio.
b Average total delay, in seconds per vehicle.
c Level-of-service.
d 50th percentile queue, in feet.
e 95th percentile queue, in feet.
f short-lane analysis operates comparable or better than full length lane analysis

~ Volume exceeds capacity, queue is theoretically infinite.
# 95th percentile volume exceeds capacity; queue may be longer.
m Volume for 95th percentile queue is metered by upstream signal.

Table 4-19 Signalized Intersection Capacity Analysis – 2039 Concept 2 – Signal Option A (Barretts Mill Road at Route 2A/119)

	2039 Build Conditions Signal Option A Concept 2				
Location/Movement	v/c [a]	Del [b]	LOS [c]	50 Q [d]	95 Q [e]
Route 2A/119 (Route 2A at Barretts Mill)					
Weekday Morning					
WB L	0.52	35	D	177	265
WB R	0.02	29	C	0	21
NB T	0.47	24	C	84	m121
SB T	0.95	63	E	327	#451
Overall	**0.65**	**42**	**D**		
Weekday Evening					
WB L	0.67	39	D	299	421
WB R	0.05	28	C	0	34
NB T	0.65	28	C	154	m164
SB T	1.04	107	F	~230	#344
Overall	**0.73**	**50**	**D**		

Source: VHB, Inc. using Synchro 9/10 software
Note: Shaded cells denote LOS E or LOS F conditions.
a Volume to capacity ratio.
b Average total delay, in seconds per vehicle.
c Level-of-service.
d 50th percentile queue, in feet.
e 95th percentile queue, in feet.
~ Volume exceeds capacity, queue is theoretically infinite.
# 95th percentile volume exceeds capacity; queue may be longer
m Volume for 95th percentile queue is metered by upstream signal.



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AE: Regulatory Floodway
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River Buffer 200'
Protected and Recreational OpenSpace
DEP Wetlands (2005)

0 100 200 Feet

Concord Rotary Concept 2
Signal Option A
Route 2 Corridor Study

Figure 4-33

Concept 3 – Signal Option B

As presented in Figure 4-34, Concept 3 is similar to Concept 2 but pushes the connection with Barretts Mill Road further north to form a modified three-legged signalized intersection. The increased spacing between the intersections provides for additional queue storage but may still require interconnection between the two signals. The benefits of the additional spacing between the main signal on Route 2 and proposed signalization at Barretts Mill Road may come at the costs of additional environmental permitting efforts related to the Article 97 designated land at the prison farm. Further investigations into the limits of the Article 97 property should be conducted as part of further design development.

Increasing the spacing between the two intersections has a negligible effect on the major intersection operations. However, increasing the distance between the major and minor intersections helps the operations for Barretts Mill Road and Route 2A/119 intersection. As shown in Table 4-20, the Barretts Mill Road intersection is expected operate at LOS B or better for both peak periods (compared to LOS D in Concept 2).

Roundabout Variation

An additional consideration for Concept 3 is to provide a roundabout (versus signal) at the intersection of Route 2A/119 and Barretts Mill Road. This variation provides an opportunity to simplify operations at the main Route 2 intersection by eliminating the Route 2 westbound left turn to Commonwealth Avenue at the signal. The variation proposes this low volume movement (40 vehicles or less during the weekday evening and weekday morning peak hours) be processed as a right-turn from Route 2 westbound and utilize the roundabout to reverse direction and access Commonwealth Avenue to the south. Note, similar concerns with regard to the Article 97 property at the prison farm could be realized depending upon the location of the roundabout in relation to the proposed signal on Route 2.

As shown in Table 4-21, the roundabout to the north of the intersection is expected to operate at LOS C during both peak periods. The 95th percentile queue for the Route 2A/119 approach during the morning peak hour is expected to be nearly 700 feet. All other 95th percentile queues are expected to be less than 400 feet for both peak periods.

Table 4-20 Signalized Intersection Capacity Analysis – 2039 Concept 3 – Signal Option B (Barretts Mill Road at Route 2A/119)

	2039 Build Conditions Signal Option B Concept 3				
Location/Movement	**v/c** [a]	**Del** [b]	**LOS** [c]	**50 Q** [d]	**95 Q** [e]
Route 2A/119 (Route 2A at Barretts Mill)					
Weekday Morning					
WB L	0.49	12	B	47	122
WB R	0.02	9	A	0	12
NB T	0.47	8	A	34	84
SB T	0.58	9	A	62	131
Overall	**0.54**	**9**	**A**		
Weekday Evening					
WB L	0.66	15	B	98	185
WB R	0.05	10	B	0	19
NB T	0.67	12	B	103	207
SB T	0.35	9	A	44	94
Overall	**0.66**	**12**	**B**		

Source: VHB, Inc. using Synchro 9/10 software.
Note: Shaded cells denote LOS E or LOS F conditions.
a Volume to capacity ratio.
b Average total delay, in seconds per vehicle.
c Level-of-service.
d 50th percentile queue, in feet.
e 95th percentile queue, in feet.

Table 4-21 Roundabout Capacity Analysis – 2039 Concept 3 - Signal Option B – Roundabout Variation (Barretts Mill Road at Route 2A/119)

	2039 Build Conditions Signal Option B Roundabout Variation Concept 3				
Location/Movement	**Dem [a]**	**v/c [b]**	**Delay [c]**	**LOS [d]**	**95 Q [e]**
Elm Street at Barretts Mill Road					
Weekday Morning					
EB	755	0.89	30	D	657
WB	275	0.41	11	B	58
NB	860	0.72	13	B	230
Overall	**1,890**		**19**	**C**	
Weekday Evening					
EB	450	0.60	14	B	141
WB	445	0.91	47	E	336
NB	975	0.83	19	C	368
Overall	**1,870**		**24**	**C**	

Source: VHB, Inc. using Sidra 7 software

Note: Shaded cells denote LOS E or LOS F conditions. This variation could also be used for Concepts 4 or 5.

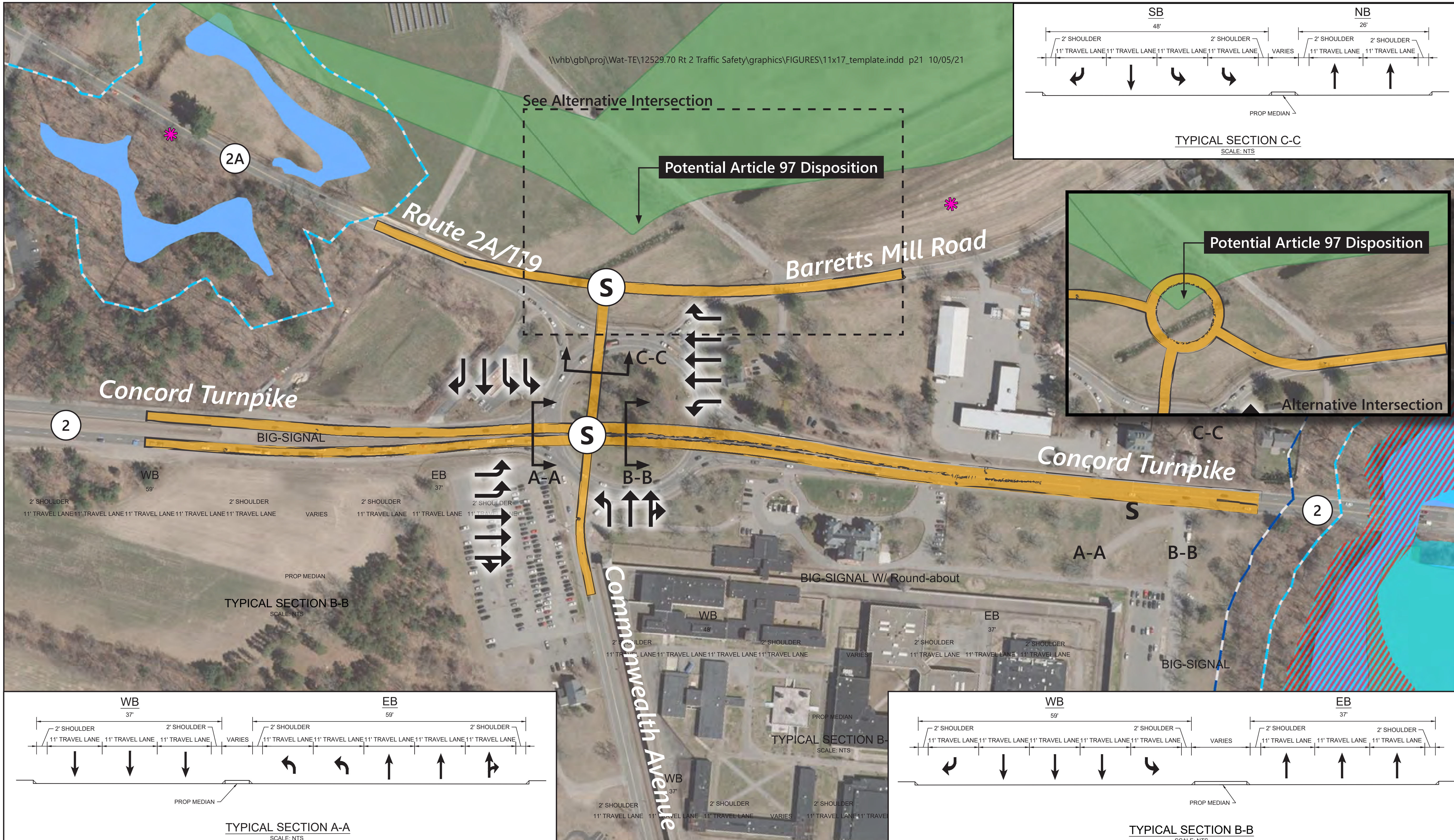
a Demand, in vehicles per hour.

b Volume to capacity ratio.

c Average total delay, in seconds per vehicle.

d Level-of-service.

e 95th percentile queue, in feet.



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DEP Wetlands (2005)

0 100 200 Feet

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Concord Rotary Concept 3
Signal Option B
Route 2 Corridor Study

Figure 4-34

Concept 4 – Signal Option C with Jughandle

As presented in Figure 4-35, Concept 4 builds on Concept 3 (eliminated westbound left-turns at the signal) by further simplifying the traffic signal phasing at the main intersection on Route 2 in eliminating eastbound turning movements. The eastbound left and right-turn movements are processed via a proposed one-way jughandle located behind the prison employee parking lot and (as in Concept 4) the westbound left turn is processed as a right-turn from Route 2 and the proposed roundabout located to the north.

As shown in Table 4-22, the major intersection for Concept 4 is expected to operate at LOS D for both morning and evening peak periods. Removing left-turns from the major intersection along Route 2 allows for more capacity for the major eastbound-westbound through movements. The eastbound through movement during the morning peak period is expected to operate at LOS E with an average queue of approximately 450 feet (compared to 2039 No-Build of 3,500 feet), while the westbound through movement during the evening peak period is expected to operate at LOS D with an average queue of approximately 375 feet (compared to 2039 No-Build of 4,200 feet). As seen in the preceding table (Table 4-23), the jughandle intersection south of the prison parking lot is expected to operate at LOS B during both peak periods.

The footprint of potential improvement related to Concept 4 is a consideration in that an additional link (and possible right-of-way implications) would be required behind the parking lot of the adjacent prison in order to accommodate the jughandle. Moreover, it is expected that the jughandle would need to be signalized at its intersection with Commonwealth Avenue. Concept 4 does provide improvements to operation at the major Route 2 intersection when compared to the other typical signalized options (Concepts 2 and 3).

Table 4-22 Signalized Intersection Capacity Analysis – 2039 Concept 4 – Signal Option C with Jughandle (Major Intersection)

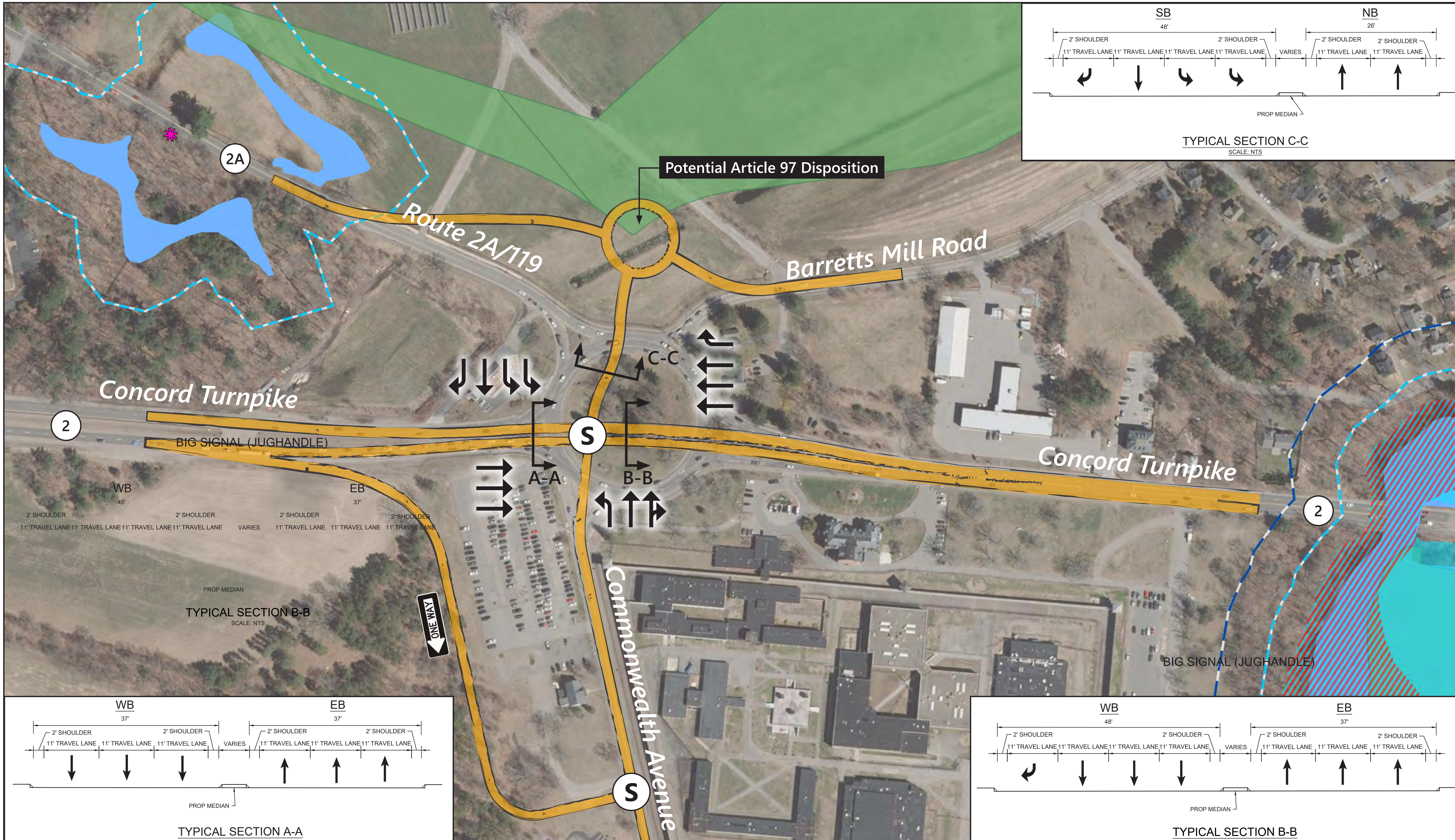
	2039 Build Conditions Signal Option C with Jughandle Concept 4				
Location/Movement	**v/c [a]**	**Del [b]**	**LOS [c]**	**50 Q [d]**	**95 Q [e]**
Route 2 at Comm Ave/Route 2A/119					
Weekday Morning					
EB T	1.05	70	E	~451	#547
WB T	0.84	35	C	300	362
WB R	0.39	11	B	84	135
NB L	0.16	33	C	32	66
NB T	0.99	70	E	233	#358
SB L	0.99	65	E	278	#408
SB T	0.51	33	C	131	209
SB R	0.03	28	C	0	0
Overall	**1.01**	**54**	**D**		
Weekday Evening					
EB T	0.83	29	C	297	359
WB T	0.95	39	D	365	#478
WB R	0.29	11	B	53	93
NB L	0.67	35	D	142	229
NB T	0.96	56	E	235	#357
SB L	0.59	36	D	91	135
SB T	0.78	48	D	131	#245
SB R	0.90	67	E	124	#287
Overall	**0.94**	**39**	**D**		

Source: VHB, Inc. using Synchro 9/10 software.
Note: Shaded cells denote LOS E or LOS F conditions.
a Volume to capacity ratio.
b Average total delay, in seconds per vehicle.
c Level-of-service.
d 50th percentile queue, in feet.
e 95th percentile queue, in feet.
~ Volume exceeds capacity, queue is theoretically infinite.
# 95th percentile volume exceeds capacity; queue may be longer.
m Volume for 95th percentile queue is metered by upstream signal.

Table 4-23 Signalized Intersection Capacity Analysis – 2039 Concept 4 – Signal Option C with Jughandle (Barretts Mill Road at Route 2A/119 and Commonwealth Avenue at Jughandle)

	2039 Build Conditions Signal Option C with Jughandle Concept 4				
Location/Movement	**v/c [a]**	**Del [b]**	**LOS [c]**	**50 Q [d]**	**95 Q [e]**
Route 2A/119 (Route 2A at Barretts Mill)					
Weekday Morning					
WB L	0.49	12	B	47	122
WB R	0.02	9	A	0	12
NB T	0.52	9	A	42	101
SB T	0.58	9	A	62	131
Overall	**0.54**	**9**	**A**		
Weekday Evening					
WB L	0.66	16	B	100	185
WB R	0.05	10	B	0	19
NB T	0.35	9	A	44	94
SB T	0.68	12	B	107	214
Overall	**0.67**	**12**	**B**		
Commonwealth Ave at Jughandle					
Weekday Morning					
EB L	0.57	11	B	48	140
EB R	0.02	8	A	0	12
NB T	0.54	9	A	55	154
SB T	0.32	8	A	29	87
Overall	0.55	9	A		
Weekday Evening					
EB L	0.76	16	B	127	#281
EB R	0.07	8	A	0	24
NB T	0.70	15	B	117	234
SB T	0.33	10	B	45	98
Overall	**0.73**	**14**	**B**		

Source: VHB, Inc. using Synchro 9/10 software.
Note: Shaded cells denote LOS E or LOS F conditions.
a Volume to capacity ratio.
b Average total delay, in seconds per vehicle.
c Level-of-service.
d 50th percentile queue, in feet.
e 95th percentile queue, in feet.
~ Volume exceeds capacity, queue is theoretically infinite.
# 95th percentile volume exceeds capacity; queue may be longer.
m Volume for 95th percentile queue is metered by upstream signal.



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0 100 200 Feet

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Concord Rotary Concept 4
Signal Option C with Jughandle
Route 2 Corridor Study

Figure 4-35

Concept 5 – One-way Coupling

As presented in Figure 4-36, Concept 5 builds on Concept 4 and is designed to further simplify the signal phasing and reduce conflict points at Route 2. The concept separates the northbound and southbound movements into a one-way couplet, including a new one-way connection from Route 2A/119 and Barret's Mill Road southbound, and one-way Commonwealth Avenue northbound. This will allow the elimination of eastbound and westbound left-turn movements at the proposed signalized locations along Route 2 and will allow for protected northbound and southbound left-turn movements. With a simplified two-phase operation this concept allows for a smaller Route 2 cross section compared to Concepts 2, 3 and 4. The concept presents two through lanes in the westbound direction and three through lanes in the eastbound direction (additional eastbound lane is necessary to accommodate the large eastbound through plus the large southbound left movements during the weekday morning peak hours).

As shown in Table 4-24, the one-way coupling set of intersections are expected to operate at LOS C or better during both peak periods. The longest average queue for the eastbound through movement is expected to be approximately 450 feet in the morning peak period, while the longest average queue for the westbound through movement is expected to be approximately 425 feet, much less than the 2039 No-Build Conditions of 3,500 and 4,200 for eastbound and westbound, respectively. All movements at both intersections are expected to operate at LOS D or better during both peak periods.

Similar to Concept 4, the footprint of improvements for Concept 5 is a consideration as the one-way couplet would require acquiring property. The projected operations related to Concept 5 are improved as compared to the other alternatives at the signalized Route 2 locations.

Table 4-24 Signalized Intersection Capacity Analysis – 2039 Concept 5 – One-Way Coupling

	2039 Build Conditions One-Way Coupling Concept 5				
Location/Movement	v/c [a]	Del [b]	LOS [c]	50 Q [d]	95 Q [e]
Route 2 at Commonwealth Ave SB/Route 2A/119 SB					
Weekday Morning					
EB T	0.83	21	C	347	418
WB T	0.73	2	A	27	32
SB L	0.92	49	D	247	#357
SB T	0.47	31	C	118	m188
SB R	0.03	24	C	0	m2
Overall	**0.86**	**21**	**C**		
Weekday Evening					
EB T	0.83	18	B	300	372
WB T	0.97	10	A	92	m#119
SB L	0.43	32	C	83	m115
SB T	0.54	33	C	113	m170
SB R	0.64	40	D	107	m180
Overall	**0.97**	**18**	**B**		
Route 2 at Commonwealth Ave NB/Route 2A/119 NB					
Weekday Morning					
EB T	0.89	14	B	449	435
WB T	0.79	20	B	323	416
WB R	0.41	13	B	95	163
NB L	0.12	25	C	26	56
NB T	0.74	33	C	189	254
Overall	**0.91**	**18**	**B**		
Weekday Evening					
EB T	0.63	4	A	83	91
WB T	0.96	31	C	432	#625
WB R	0.30	10	B	59	106
NB L	0.65	31	C	124	205
NB T	0.95	49	D	205	#321
Overall	**0.96**	**23**	**C**		

Source: VHB, Inc. using Synchro 9/10 software.
Note: Shaded cells denote LOS E or LOS F conditions.
a Volume to capacity ratio.
b Average total delay, in seconds per vehicle.
c Level-of-service.
d 50th percentile queue, in feet.
e 95th percentile queue, in feet.
~ Volume exceeds capacity, queue is theoretically infinite.
# 95th percentile volume exceeds capacity; queue may be longer.
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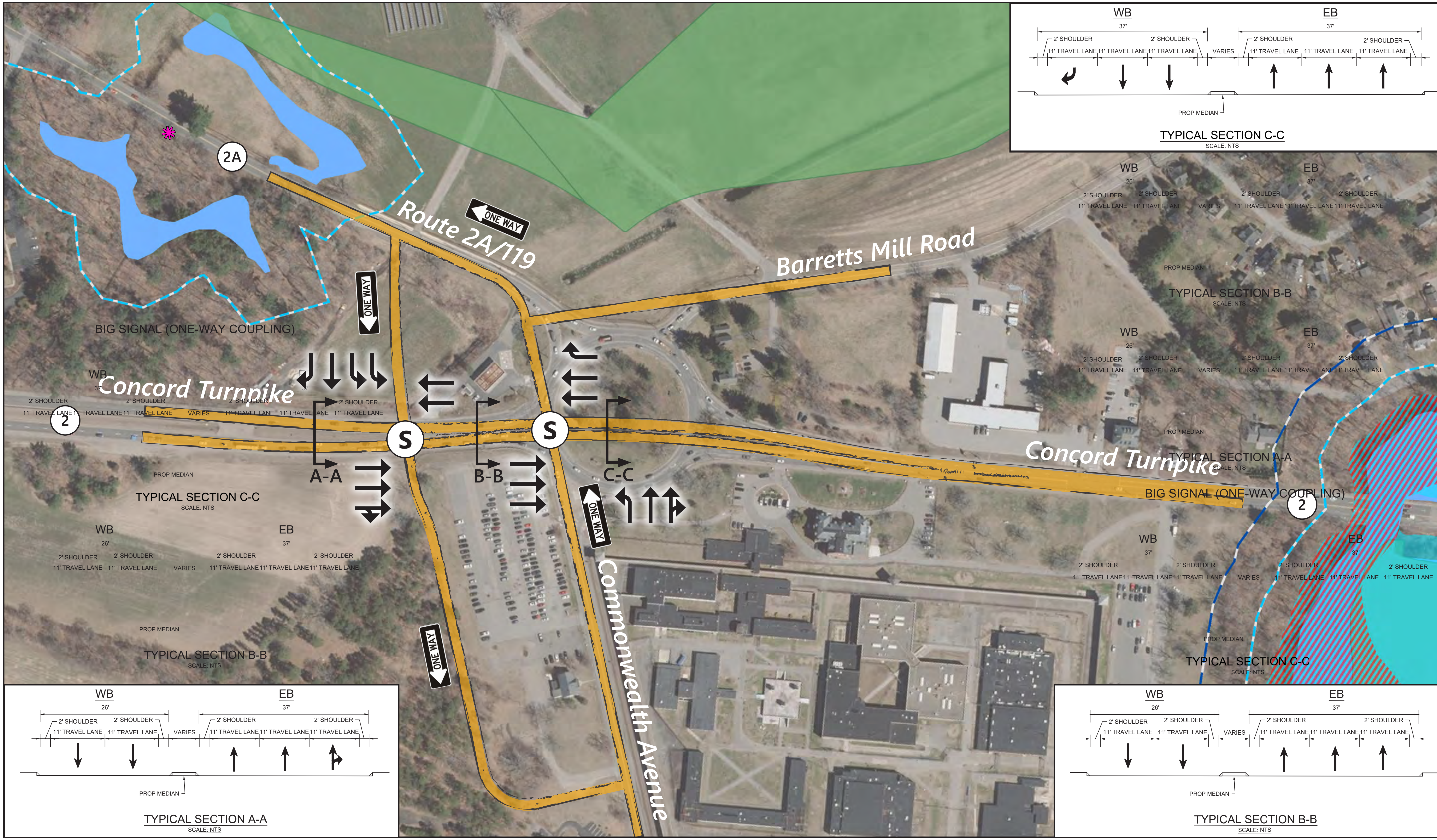

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- DEP Wetlands (2005)

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Concord Rotary Concept 5
One-way Coupling
Route 2 Corridor Study

Figure 4-36

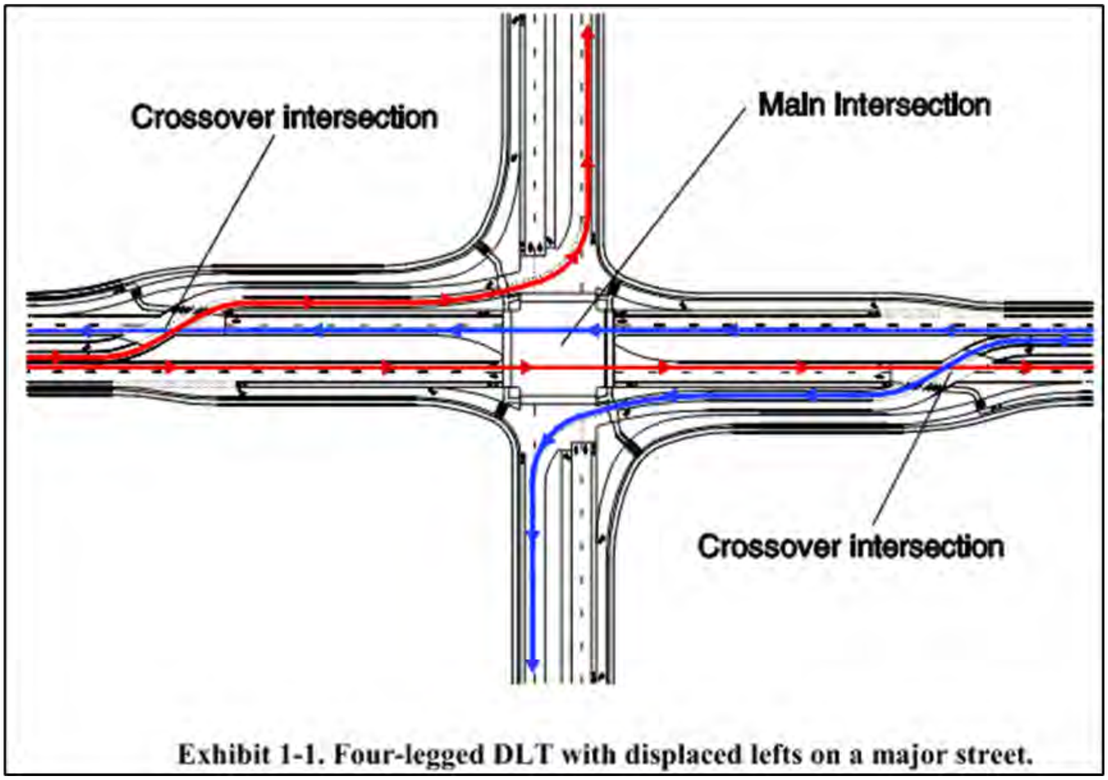
Concept 6 – Continuous flow Intersection

Concept 6 includes consideration of a continuous flow type intersection/signal along the Route 2 mainline. A continuous flow intersection is an alternative design for an at-grade intersection (presented graphically from FWHA information guide on displaced left turn intersection in Figure 4-37). In this instance, the heavy eastbound Route 2 left-turn movement would cross Route 2 westbound before the proposed intersection. This will allow eastbound left-turn and through movements to be processed at the signal concurrently, and not in conflict with westbound through movements. Concept 6 would propose to eliminate westbound left-turn movements at the signal (similar to Concept 4) processing them as right-turns that would use a proposed roundabout (again similar to Concept 4) to access Commonwealth Avenue to the south. The major challenge to developing a continuous flow intersection at this location would be the significant cross-section required, in this instance, on the eastbound Route 2 approach which could involve right-of way modification and property acquisitions. There could be similar concerns with regard to the Article 97 property at the prison farm depending upon the location of the roundabout in relation to the proposed signal on Route 2. The westbound approach is not considered for a continuous flow treatment as the westbound left-turn movement is minimal.

As shown in Table 4-25, the continuous flow intersection is expected to operate at LOS D and C in the morning and evening peak periods, respectively. Both the eastbound and westbound through movements are expected to operate at LOS D with approximately 400 feet of queue during the morning and evening peak periods, respectively. Similarly, all movements for both peak periods are expected to operate at LOS D or better. As shown in Table 4-26, the Barretts Mill Road and Route 2A/119 connection is expected to operate at LOS B or better for both peak periods.

Concept 6 represents an alternative design (none constructed in Massachusetts) intersection setup, which might be more confusing for drivers. However, when compared to other concepts, Concept 6 is expected to provide better operations with both shorter delays and less queuing along Route 2 as compared to most of the other alternatives. Most of the expected property acquisitions required for this concept are immediately adjacent to the intersection.

Figure 4-37 Continuous Flow Intersection



Source: FHWA Displaced Left Turn Intersection Information Guide (August 2014)

Table 4-25 Signalized Intersection Capacity Analysis – 2039 Concept 6 – Continuous Flow Intersection

	2039 Build Conditions Continuous Flow Intersection Concept 6				
Location/Movement	**v/c [a]**	**Del [b]**	**LOS [c]**	**50 Q [d]**	**95 Q [e]**
Route 2 at Commonwealth Ave/Route 2A/119 at Route 2					
Weekday Morning					
EB T	0.93	37	D	394	#503
WB T	0.73	27	C	275	331
WB R	0.24	20	C	0	56
NB L	0.25	39	D	35	73
NB T	0.77	50	D	111	#172
SB L	0.92	49	D	270	#384
SB T	0.38	30	C	99	162
SB R	0.03	27	C	0	0
Overall	**0.90**	**36**	**D**		
Weekday Evening					
EB T	0.85	29	C	364	436
WB T	0.90	33	C	405	#520
WB R	0.17	19	B	0	51
NB L	0.79	48	D	163	#259
NB T	0.34	33	C	65	101
SB L	0.51	35	D	97	142
SB T	0.67	41	D	140	224
SB R	0.82	53	D	141	#291
Overall	**0.85**	**33**	**C**		

Source: VHB, Inc. using Synchro 9/10 software.
Note: Shaded cells denote LOS E or LOS F conditions.
a Volume to capacity ratio.
b Average total delay, in seconds per vehicle.
c Level-of-service.
d 50th percentile queue, in feet.
e 95th percentile queue, in feet.
~ Volume exceeds capacity, queue is theoretically infinite.
# 95th percentile volume exceeds capacity; queue may be longer.
m Volume for 95th percentile queue is metered by upstream signal.

Table 4-26 Signalized Intersection Capacity Analysis – 2039 Concept 6 – Continuous Flow (Barretts Mill Road at Route 2A/119)

Location/Movement	2039 Build Conditions Continuous Flow Intersection Concept 6				
	v/c [a]	Del [b]	LOS [c]	50 Q [d]	95 Q [e]
Route 2					
Weekday Morning					
EB L	0.67	22	C	107	252
EB T	0.51	0	A	0	0
WB T	0.54	9	A	111	216
Overall	**0.61**	**6**	**A**		
Weekday Evening					
EB L	0.89	42	D	279	#456
EB T	0.48	0	A	0	0
WB T	0.88	21	C	435	#549
Overall	**0.89**	**16**	**B**		

Source: VHB, Inc. using Synchro 9/10 software.
Note: Shaded cells denote LOS E or LOS F conditions.
a Volume to capacity ratio.
b Average total delay, in seconds per vehicle.
c Level-of-service.
d 50th percentile queue, in feet.
e 95th percentile queue, in feet.
~ Volume exceeds capacity, queue is theoretically infinite.
\# 95th percentile volume exceeds capacity; queue may be longer.
m Volume for 95th percentile queue is metered by upstream signal.

Summary

All concepts for the Concord Rotary show improved operations based on 2039 projected volumes as compared to the No-Build Condition. All concept alternatives were developed with a focus on reducing delay and improving Route 2 queuing on the eastbound approach during the morning peak hour and westbound approach during the evening peak hour. Operations for the Concord Rotary concepts are summarized in Table 4-27.

While all concepts improve overall operations when compared to 2039 No-Build Conditions, some alternatives might be more costly and timely to construct (i.e., Concept 6), as well as have more impacts to right-of-way (i.e., Concept 5) or environmental resource areas. With this in mind, from a feasibility standpoint, while funding is being secured for a larger grade-separated project for the Concord Rotary, the concept that may provide the best benefit-cost ratio as an interim solution would be the Thru-About alternative.

Table 4-27 Signalized Intersection Capacity Analysis – 2039 Build Summary

Condition		Location	Period	Overall			Route 2 Mainline	
				v/c	Del	LOS	EB 95th Q	WB 95th Q
2039 No-Build	Rotary	Major Intersection	AM		**>120**	**F**	**5031**	**1478**
			PM		**>120**	**F**	**5032**	**5033**
Concept 1 (Vissim)	Thru-About	Major Intersection	AM		**73**	**E**	**1373**	**474**
			PM		**92**	**F**	**1670**	**562**
Concept 1 (Synchro Weighted Average)	Thru-About	Major Intersection	AM		**75**	**E**		
			PM		**53**	**D**		
Concept 1 (Synchro)	Thru-about	Western Intersection	AM	**0.97**	**29**	**C**	**#681**	27
			PM	**0.91**	**21**	**C**	**#477**	m54
		Eastern Intersection	AM	**0.99**	**28**	**C**	m52	**416**
			PM	**0.99**	**29**	**C**	m54	**#650**
Concept 2	Signal Option A	Major Intersection	AM	**0.98**	**46**	**D**	**#623**	**#493**
			PM	**1.01**	**61**	**E**	**503**	**#721**
		Minor Intersection	*AM*	*0.65*	*42*	*D*		
			PM	*0.73*	*50*	*D*		
Concept 3	Signal Option B	*Minor Intersection*	*AM*	*0.54*	*9*	*A*		
			PM	*0.66*	*12*	*B*		
Concept 4	Signal Option C with Jughandle	Major Intersection	AM	**1.01**	**54**	**D**	**#547**	**362**
			PM	**0.94**	**39**	**D**	**359**	**#478**
		Minor Intersection (North)	*AM*	*0.54*	*9*	*A*		
			PM	*0.67*	*12*	*B*		
		Minor Intersection (South)	*AM*	*0.55*	*9*	*A*		
			PM	*0.73*	*14*	*B*		
Concept 5	One-Way Coupling	Western Intersection	**AM**	**0.86**	**21**	**C**	**418**	**32**
			PM	**0.97**	**18**	**B**	**372**	**m#119**
		Eastern Intersection	**AM**	**0.91**	**18**	**B**	**435**	**416**
			PM	**0.96**	**23**	**C**	**91**	**#625**
Concept 6	Continuous Flow	Major Intersection	**AM**	**0.90**	**36**	**D**	**#503**	**331**
			PM	**0.85**	**33**	**C**	**436**	**#520**
		Minor Intersection	*AM*	*0.61*	*6*	*A*		
			PM	*0.89*	*16*	*B*		

Source: VHB, Inc. using Synchro 9/10 software.
Note: Shaded cells denote LOS E or LOS F conditions.
a Volume to capacity ratio.
b Average total delay, in seconds per vehicle.
c Level-of-service.
e 95th percentile queue, in feet.
~ Volume exceeds capacity, queue is theoretically infinite.
# 95th percentile volume exceeds capacity; queue may be longer.
m Volume for 95th percentile queue is metered by upstream signal.

5

Implementation Plan

Chapter 4 developed, screened, and analyzed potential transportation, safety and mobility, improvements for the Route 2 corridor for both Western (District 3) and Eastern (District 4) study areas. The alternatives analysis was combined with input from MassDOT Districts 3 and 4. These efforts resulted in the identification of recommended improvement projects to be considered for further consideration. This chapter presents an "Action Plan" for potential implementation of the study recommendations.

5.1 Overview

The study took a multi-faceted approach to transportation infrastructure needs and recommends a program of potential near-term actions (1 to 10 years) and long-term actions (over 10 years). Immediate actions (under 1 year) were identified and presented in Chapter 2 and consist of RSAs, traffic signal inventories and signal timing and equipment improvements. All alternatives identified and developed herein are conceptual in nature. In some instances, multiple concept alternatives were developed for consideration. All concept recommendations will require further design development, public engagement and more detailed evaluation of potential permitting/right-of-way implications to prioritize and select improvements for implementation.

Improved mobility and safety were the primary drivers that guided the development of the recommended Action Plan. This study does not identify specific funding sources for each recommendation because of the many variables and the uncertainty associated with funding sources and schedules for projects. While funding is always a consideration and was factored into the evaluation criteria, funding availability was not a primary driver for the development of the study recommendations.

It is acknowledged that the recommendations presented herein represent a significant investment in potential transportation-related infrastructure. These projects represent an investment in total that currently far exceeds available funding as presently programmed. The advancement of the recommendations developed as part of this study will require prioritization by (and coordination between) MassDOT, District 3, District 4, municipalities, and other stakeholders to address current fiscal constraints as related to transportation improvements. Besides prioritization, identification of potential funding sources and availability to leverage funding could alter priorities.

5.2 Recommended Action Plan

Table 5-1 presents the details of this Action Plan, including order of magnitude construction cost estimates, potential funding sources, the responsible facilitating organizations, the implementation timeframe, other ancillary features and specific next steps. Figure 6-1 presents an overview of the recommended projects that comprise the Action Plan.

Each of the improvement concepts herein will need to follow a multi-step process as shown below. Depending on the project, some of the early steps may have already been completed either as part of this study or in other studies.

- Step 1: Problem/Need/Opportunity Identification
- Step 2: Project Planning
- Step 3: Project Initiation
- Step 4: Environmental Review and Permitting /Design/Right-of-way Acquisition
- Step 5: Funding/Programming on the Regional and State Transportation Improvement Programs
- Step 6: Advertise/Bid and Contract Award
- Step 7: Construction

As noted in Table 5-1, some recommendations are not anticipated to require environmental review and permitting. More complex recommendations, such as interchange reconstruction and bridge replacements, will likely require more in-depth design, permitting, and environmental documentation. These initial steps would begin in the near-term timeframe. Right-of-way acquisition is anticipated for some of the recommendations, as noted in Table 5-1.

Table 5-1 Recommended Action Plan – Alternatives Matrix and Implementation Timeframe

Study Area Map #	Location	Municipality	Alternative	Construction Cost [1]	Implementation Timeframe (Years)		Notes	Impacts[3]		Prioritization/ Sequencing	Figure No.	Diversion potential	Traffic pattern changes
					Near-Term 0 - 10	Long-Term[2] 10+		Environ-mental	ROW				
	Western (District 3) Study Area												
	Right-In/Right-Out												
1	Oak Hill Road (N)	Fitchburg	Improve Accel/ Decel lanes	$600,000-$700,000	x						4-1		
2	Palmer Road (S)	Leominster	Improve Decel lane	$300,000-$400,000	x			x			4-1		
5	Abbott Ave (N)	Leominster	Improve Accel/ Decel lanes	$300,000-$400,000	x						4-2		
5	Abbott Ave (S)	Leominster	Close ramp	$300,000-$400,000	x					Dependent on improvements to Route 2 at Merriam Avenue intersection	4-2	x	x
17	Hosmer Street (N)	Acton	Improve Decel lane	$400,000-$500,000	x						4-3		
17	Hosmer Street (S)	Acton	Improve Accel/ Decel lanes	$300,000-$400,000	x						4-3		
18	Wetherbee Street (N)	Acton	Improve Accel/ Decel lanes	$400,000-$500,000	x						4-4		
18	School Street (S)	Acton	Improve Accel/ Decel lanes	$400,000-$500,000	x						4-4		
	District Wide												
	Western (District 3)	Fitchburg to Acton	6-lane Cross-section (~18 miles)	$650,000,000-$750,000,000		x	Multiple Bridge Reconstructions	x	x	Consider resetting bridge supports as useful life of each bridge is met/ exceeded		x	x

Table 5-1 Recommended Action Plan – Alternatives Matrix and Implementation Timeframe

					Implementation Timeframe (Years)			***Impacts***[3]					
Study Area Map #	***Location***	***Municipality***	***Alternative***	***Construction Cost***[1]	*Near-Term 0 - 10*	*Long-Term*[2] *10+*	***Notes***	*Environ-mental*	*ROW*	***Prioritization/ Sequencing***	***Figure No.***	***Diversion potential***	***Traffic pattern changes***
	Interchange Alternatives												
3	Route 2 at Mt Elam Road	Leominster/ Fitchburg	Increase eastbound / westbound deceleration lanes and westbound acceleration lanes	$6,000,000- $6,500,000	x						4-5		
		Leominster/ Fitchburg	Modifies geometry of Mt Elam Road (north)	$7,000,000- $7,500,000	x						4-6		
		Leominster/ Fitchburg	Shifts Route 2 to the north for a longer eastbound acceleration lane	$9,000,000- $10,000,000		x		x			4-7	x	
		Leominster/ Fitchburg	Close Mt Elam Road (south)	$500,000- $600,000					x		N/A	x	x
4	Route 2 at Merriam Avenue	Leominster/ Fitchburg	Improve Accel/ Decel lanes	$500,000- $600,000	x						4-8		
		Leominster/ Fitchburg	Upgrade eastbound intersection and close Abbott Avenue (south)	$2,000,000- $2,500,000		x				Consider closing Abbott Ave (S) access if improved	4-9	x	x
6	Route 2 at North Main Street (Route 12)	Leominster/ Fitchburg	Close redundant ramps and upgrade intersections	$4,500,000- $5,000,000		x	Bridge replacement / ramp project recently completed				4-10		x
7	Route 2 at Main Street (Route 13)	Leominster	Improve Accel/ Decel lanes	$400,000- $500,000	x						4-11		
		Leominster	Develop full diamond interchange	$55,000,000- $60,000,000		x	Adjacent to State Police barracks. Signal currently being provided at Westbound off-ramp intersection	x	x		4-12	x	x
8	Route 2 at I-190	Leominster	Widen Route 2 bridge over Nashua River and lane reconfiguration between I-190 and Route 13	$80,000,000- $90,000,000		x		x			4-13		
12	Route 2 at Jackson Road	Devens	Close redundant ramps	$1,000,000- $1,500,000	x						4-14		x
		Devens	Dual-lane ramps	$6,500,000- $7,500,000		x		x			N/A		
14/15	Route 2 at I-495 / Taylor Street	Littleton	Collector-Distributor Lanes	$19,500,000- $21,000,000		x	I-495 Bridge over Route 2 recently upgraded				4-15		

Table 5-1 Recommended Action Plan – Alternatives Matrix and Implementation Timeframe

Study Area Map #	Location	Municipality	Alternative	Construction Cost [1]	*Implementation Timeframe (Years)* Near-Term 0 - 10	Long-Term[2] 10+	Notes	*Impacts*[3] Environ-mental	ROW	Prioritization/ Sequencing	Figure No.	Diversion potential	Traffic pattern changes
	Eastern (District 4) Study Area												
	District Wide												
	Eastern (District 4)	Concord to Lincoln	6-lane Cross-section (~8 miles)	$250,000,000-$300,000,000		x	Multiple Bridge Reconstructions	x	x	Consider resetting bridge supports as useful life of each bridge is met/ exceeded			
	Intersection Alternatives												
22	Route 2 at Baker Avenue/Elm Street	Concord	Remove jughandle and Elm Street to Route 2 westbound access	$5,000,000-$5,500,000	x	Identified as Near-Term, however, Environmental requirements could push project into Long-Term		x			4-18		x
		Concord	3rd lane westbound including Concept 1 improvements	$7,000,000-$7,500,000	x	Identified as Near-Term, however, Environmental requirements could push project into Long-Term		x			4-19		x
23	Route 2 at Main Street (Route 62)	Concord	3rd lane eastbound, pedestrian & bicycle enhancements	$3,000,000-$3,500,000	x	Identified as Near-Term, however, ROW requirements could push project into Long-Term			x		4-20		
		Concord	Dual left-turn westbound	$4,000,000-$4,500,000	x					Improvements at Rotary might deem this improvement unnecessary	4-21		x
		Concord	3rd lane westbound	$3,000,000-$3,500,000	x	Identified as Near-Term, however, ROW/ Environmental requirements could push project into Long-Term		x	x		4-22		

Table 5-1 Recommended Action Plan – Alternatives Matrix and Implementation Timeframe

Study Area Map #	Location	Municipality	Alternative	Construction Cost [1]	***Implementation Timeframe (Years)*** Near-Term 0 - 10	Long-Term[2] 10+	Notes	***Impacts[3]*** Environ-mental	ROW	Prioritization/ Sequencing	Figure No.	Diversion potential	Traffic pattern changes
24	Route 2 at Old Road to 9 Acre Corner Road	Concord	3rd lane eastbound, pedestrian & bicycle enhancements	\$3,000,000-\$3,500,000	x	Identified as Near-Term, however, ROW requirements could push project into Long-Term			x		4-23		
		Concord	3rd lane westbound	\$3,500,000-\$4,000,000	x	Identified as Near-Term, however, ROW requirements could push project into Long-Term			x		4-24		
25	Route 2 at Sudbury Road	Concord	3rd lane both directions, pedestrian and bicycle enhancements	\$4,500,000-\$5,000,000	x						4-25		
		Concord	3rd lane eastbound, dual left-turn westbound	\$5,000,000-\$5,500,000	x						4-26		x
26	Route 2 at Walden Street (Route 126)	Concord	3rd lane eastbound, pedestrian & bicycle enhancements	\$6,000,000-\$6,500,000	x						4-27		
		Concord	3rd lane eastbound (no eastbound left-turn)	\$6,000,000-\$6,500,000	x						4-28	x	x
		Concord	3rd lane eastbound, dual left-turn southbound	\$6,500,000-\$7,000,000	x						N/A		
28	Route 2 at Bedford Road	Lincoln	Extend and formalize 3rd lane both directions	\$2,000,000-\$2,500,000	x			x			4-29		
		Lincoln	3rd lane both directions, dual left-turn southbound	\$3,000,000-\$3,500,000	x			x			N/A		

Table 5-1 Recommended Action Plan – Alternatives Matrix and Implementation Timeframe

Study Area Map #	Location	Municipality	Alternative	Construction Cost [1]	Implementation Timeframe (Years) Near-Term 0 - 10	Long-Term[2] 10+	Notes	Impacts[3] Environ-mental	ROW	Prioritization/ Sequencing	Figure No.	Diversion potential	Traffic pattern changes
	Rotary Alternatives												
19	Concord Rotary	Concord	Grade-Separated Alternatives	$100,000,000		x	Concept done by others. [4] Major traffic impacts during construction	x	x	Rotary improvements should precede any other location improvements for Eastern (District 4) Study Area	4-30 and 4-31		x
		Concord	Thru-About	$7,000,000-$8,000,000	x			x			4-32		x
		Concord	Signal Option A	$14,500,000-$16,500,000	x			x	x		4-33		x
		Concord	Signal Option B	$15,500,000-$18,000,000	x			x	x		4-34		x
		Concord	Signal Option C with Jughandle	$16,000,000-$18,500,000	x			x	x		4-35		x
		Concord	One-way Coupling	$16,000,000-$18,500,000		x		x	x		4-36		x
		Concord	Continuous Flow Intersection	$16,000,000-$18,500,000		x		x	x		4-37		x

1 Does not include costs associated with right of way, design, construction services, permitting. All based on current available cost information. No escalation for long-term implementations
2 Any alternative indicated as Near-Term with ROW/Environmental impacts could extend beyond 10 yrs (i.e., Long-Term project)
3 Impacts noted are from a high-level review of publicly available GIS data. An in-depth review is expected during further design development.
4 Concord Rotary Grade-Separated alternatives were done by others. Construction costs are from ProjectInfo website.