



Cape Cod Bridges Program

Bourne, Massachusetts

Appendix 3.1
Alternatives Assessments Technical Report

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Acronyms and Abbreviations

Acronym/Abbreviation	Definition
FHWA	Federal Highway Administration
MassDOT	Massachusetts Department of Transportation
MRER/EA	Major Rehabilitation Evaluation Report/Environmental Assessment
Program	Cape Cod Bridges Program
USACE	U.S. Army Corps of Engineers

1 Introduction

Documentation of the Massachusetts Department of Transportation's (MassDOT) extensive alternatives assessment process is provided in support of the Draft Environmental Impact Report and Draft Section 4(f) Evaluation for the Cape Cod Bridges Program (Program), in accordance with the following federal and state statutes, regulations, and guidance:

- Federal Highway Administration's (FHWA) regulations implementing the National Environmental Policy Act, *Environmental Impact and Related Procedures* (23 Code of Federal Regulations [CFR] 771), and corresponding guidance, Technical Advisory (T 6640.8A): *Guidance for Preparing and Processing Environmental and Section 4(f) Documents* (October 30, 1987).
- Section 4(f) of the U.S. Department of Transportation Act of 1966 and its implementing regulations, 49 United States Code 303, 23 CFR 774.
- Certificate of the Secretary of the Office of Energy and Environmental Affairs on the Environmental Notification Form for the Cape Cod Bridges Program (July 7, 2023).
- Massachusetts Environmental Policy Act regulations, 301 Code of Massachusetts Regulation 11.00 (as amended, January 6, 2023).

2 Summary of Program's Alternatives Analysis Process

In coordination with the U.S. Army Corps of Engineers (USACE) and the FHWA, and incorporating input from stakeholders and the public, the Massachusetts Department of Transportation (MassDOT) developed a multi-step filtering process for identifying and evaluating alternatives for the Cape Cod Bridges Program. MassDOT documented its alternatives assessment process in the following reports:

- **Attachment 1, Cape Cod Bridges Program Alternatives Analysis Report** (July 2025), which provides the following analyses conducted through 2023:
  - Details of the screening of the USACE's Major Rehabilitation Evaluation Report/Environmental Assessment (MRER/EA) alternatives and recommendation for in-kind bridge replacement
  - Assessments and identification of the recommended bridge highway cross-section and shared used path, bridge vertical and horizontal clearance, main span length and bridge pier location, bridge deck configuration, mainline alignment location, and bridge type
  - Initial assessment of highway interchange approach options resulting in advancement of 10 options for a detailed evaluation
- **Attachment 2, Cape Cod Bridges Program Highway Interchange Approaches Detailed Assessment Report** (July 2025), which provides details of the secondary evaluation of 10 interchange approach

options that passed the initial assessment and resulted in a single pairing of options for each replacement bridge crossing. This assessment was conducted through 2024.

3 Summary of Alternatives Analysis Report

Section 3 summarizes the eight engineering assessments that comprise **Attachment 1**. For some Program design parameters, MassDOT's analyses consisted of a single evaluation; for other parameters, an initial assessment followed by a detailed evaluation was required to arrive at the final recommendation.

3.1 Screening of Alternatives Considered in USACE's Major Rehabilitation Evaluation Report/Environmental Assessment (MRER/EA)

Pursuant to 23 United States Code 139(f)(4)(E)(ii), the Program builds upon and references prior, multi-year foundational studies, including the USACE's MRER/EA of the Cape Cod Canal highway bridges.

In coordination with FHWA, MassDOT conducted an independent conceptual screening of 12 alternatives presented by the USACE in the MRER/EA. The 12 alternatives comprised the "Universe of Alternatives" for addressing the deteriorating Sagamore and Bourne Highway Bridges.

MassDOT evaluated the alternatives in accordance with FHWA's regulations, National Environmental Policy Act implementing regulations, 23 CFR 771, and its Technical Advisory (T 6640.8A): Guidance for Preparing and Processing Environmental and Section 4(f) Documents. MassDOT reviewed the USACE MRER/EA alternatives relative to the Program's Purpose and Need Statement and National Environmental Policy Act guidance for evaluating alternatives for reasonableness.

MassDOT determined that replacing both bridges with two new adjacent bridges at each crossing location, each providing two through-traffic lanes and an auxiliary lane in each direction and built to current design standards, would meet the identified Program needs to address the escalating bridge maintenance demands and improve traffic operations and accommodations for pedestrians and bicyclists. Based on its ability to fully meet the Program needs, while minimizing the approach road modifications necessary to connect the replacement bridges to the regional and local transportation system, MassDOT recommended advancing the Four Travel Lanes and Two Auxiliary Lanes Replacement Alternative (Replacement Highway Bridges Built to Modern Design Standards) as presented in the MRER/EA for further consideration. MassDOT's recommendation for Replacement Highway Bridges Built to Modern Design Standards, which concurs with the USACE's Preferred Alternative, was the basis for assessing the Cape Cod Bridges Program design parameters.

MassDOT determined that the 11 remaining alternatives from the MRER/EA's Universe of Alternatives were not reasonable alternatives.

3.2 Assessment of Bridge Highway Cross-Section and Shared-Use Path

In accordance with MassDOT and FWHA design criteria, as well as American Association of State Highway and Transportation Officials (AASHTO) guidelines, MassDOT evaluated proposed bridge highway cross-section and the maximum profile grades relative to the MRER/EA's recommendations that each new bridge would include four 12-foot-wide through travel lanes, two in each direction; two 12-foot-wide auxiliary lanes, one in each direction; a shoulder; a separation median; and approach grades. MassDOT determined that the proposed shared-use path at each canal crossing would be designed in accordance with MassDOT, AASHTO, and FHWA design criteria, as well as the guidance of the Americans with Disabilities Act and the Architectural Access Board.

3.3 Assessment of Bridge Vertical and Horizontal Clearances

MassDOT evaluated the vertical and horizontal clearances for the replacement bridges relative to the recommendations presented in the USACE's MRER/EA. The MRER/EA indicated that to maintain the existing vertical clearance of 135 feet above mean high water, the height of the new bridges should be increased to accommodate anticipated sea level rise. Additionally, the USACE indicated that horizontal clearance for navigation must be considered with the replacement bridge design.

Based on its evaluations of sea level rise projections from the National Oceanic and Atmospheric Administration and the Massachusetts Climate Change Projections, issued by the Massachusetts Executive Office of Energy and Environmental Affairs, MassDOT recommended an increase in bridge height by three feet, which would maintain the existing vertical clearance at 135 feet above mean high water in a future sea level rise condition. Incorporating the USACE's recommendation regarding navigation, MassDOT recommended that the replacement bridge structures provide a minimum of 500 feet of horizontal navigational width, to be consistent with existing conditions.

3.4 Assessment of Main Span Length and Bridge Pier Location

The bridge piers for the existing Sagamore and Bourne Bridges are within Cape Cod Canal and outside the navigation channel and support a mainline center span length of 616 feet. MassDOT evaluated the USACE's preference for locating the proposed bridge piers outside of the canal cut to improve navigation, operations, and maintenance, as indicated in the MRER/EA.

MassDOT conducted an initial assessment of the main span length and bridge pier location against the applicable bridge design evaluation criteria of costs, main span footings and construction. This initial assessment resulted in a recommendation for an out-of-water pier location with two potential main span lengths of approximately 700 feet and 820 feet. MassDOT further evaluated the two main span lengths as part of a detailed bridge fabrication and erection methodology analysis for the bridge type. This second assessment contributed to a final recommendation for an approximate 700-foot main span with the bridge piers located within the rip-rap slope and above the low tide line.

3.5 Assessment of Bridge Deck Configuration

As a variation of the single bridge deck configuration presented in the MRER/EA, MassDOT investigated constructing two separate deck structures for each replacement highway bridge, consisting of two parallel separate northbound and southbound decks (barrels). MassDOT's qualitative assessment focused on the constructability aspects of the bridge deck configuration, including duration of construction, construction complexity, and potential for construction phasing. MassDOT also evaluated the durability and structural redundancy aspects of the bridge deck configurations.

Based on its initial assessment, MassDOT determined that both bridge deck configurations would be feasible depending on the bridge type and advanced the single deck and two separate deck options for further evaluation. After a secondary evaluation that assessed the bridge deck configuration relative to a short list of bridge types, MassDOT recommended advancing the two separate deck configurations as part of the final bridge type recommendation.

3.6 Assessment of Mainline Alignment Location

MassDOT assessed the MRER/EA's recommendation that the two new highway bridges be constructed parallel to and immediately in-shore of the existing Sagamore and Bourne Bridges (offline and inboard). MassDOT identified five optional locations for each highway bridge mainline alignment over Cape Cod Canal and evaluated the locations based on their performance in meeting the Program needs to address the substandard design elements of the bridges relative to the mainline approaches and their adjacent interchanges and intersections, improve vehicular traffic operations, and improve accommodations for pedestrians and bicyclists. Additional objectives included minimizing temporary and permanent environmental impacts, including right-of-way impacts and impacts to the traveling public.

Based on the results of its performance relative to meeting the Program's highway design evaluation criteria, the Fully Offline Inboard Option for both the Sagamore Bridge and Bourne Bridge locations had an overall higher rating than the other mainline alignment location options. As a result, MassDOT recommended advancing the Fully Offline Inboard Option for both canal crossings as the mainline alignment location retained for detailed study.

3.7 Assessment of Bridge Types

MassDOT's assessments of bridge types for the replacement highway bridges consisted of a conceptual screening of a Universe of Concepts, followed by initial and detailed evaluations.

Incorporating the USACE's Preferred Alternative for In-Kind Bridge Replacements, and in collaboration with FHWA and USACE, MassDOT conceptually screened a wide range of bridge types and design parameters to identify feasible bridge types and configurations for further analysis. In this conceptual screening, MassDOT identified the decision drivers for bridge type selection, advanced favorable design features, and eliminated unfavorable bridge types.

MassDOT then conducted an initial assessment of a short list of bridge types relative to the Program's bridge design evaluation criteria. MassDOT placed highest priority on bridge types that would be

practical and feasible to construct and maintain; bridge types that would not be practical and feasible were not advanced for further evaluation. Additionally, MassDOT placed high priority on a bridge construction method that would minimize Cape Cod Canal navigation impacts. As a result of this initial assessment, MassDOT recommended the advancement of three bridge types with various configurations for a secondary evaluation.

MassDOT's detailed analysis incorporated MassDOT's highway geometric assessments, additional constructability assessments of the feasible bridge types (including a detailed bridge deck configuration assessment), and the public's review of the feasible bridge types relative to community considerations and bridge aesthetics. As a result of the detailed bridge type assessment, including public input, MassDOT recommended the following bridge type to be retained for detailed study: parallel, twin tied-arch bridge structures supported on Delta frames with an approximate 700-foot main span length. As design advances, MassDOT will determine exact span length, arch rib configuration, tie-in with approach ramps, and other parameters for the Tied-Arch Bridge with Delta Frame, which will be included in the Program Bridge Type Study.

3.8 Assessment of Highway Interchange Approach Options

MassDOT conducted the assessments of the highway interchange approach options in two detailed evaluations. The first detailed evaluation is documented in **Attachment 1, Cape Cod Bridges Program Alternatives Analysis Report**.

Using the alternatives identified in its 2017 Cape Cod Canal Area Transportation Study as its starting point, MassDOT conceptually identified and screened a total of 97 highway interchange approach concepts (the Universe of Concepts) according to feasibility and reasonability. From the screening of the Universe of Concepts, MassDOT identified 22 active concepts, where the concept was deemed to be a viable option to be further refined, for the highway interchange approaches at the four quadrants of the canal crossings: Bourne North, Bourne South, Sagamore North, and Sagamore South.

Incorporating the USACE's MRER/EA Preferred Alternative of In-Kind Bridge Replacement, and its recommendation for a Fully Offline Inboard location for the mainline alignment, MassDOT assessed the 22 highway interchange approach options relative to the Program's highway design evaluation criteria developed in collaboration with FHWA. Based on 2050 No Build Alternative condition traffic volumes, MassDOT assessed future traffic operations using several traffic analysis and modeling programs and conducted engineering assessments consistent with AASHTO's Highway Safety Manual. Highway interchange approach options were rated based on their performance relative to meeting the Program's highway design evaluation criteria; the ratings were then compared to identify options that MassDOT would recommend for a detailed, secondary level of assessment. Based on its initial assessment, MassDOT recommended a secondary evaluation of 10 highway interchange approach options for the four quadrants of the canal crossings.

4 Summary of Highway Interchange Approach Detailed Assessment Report

4.1 Overview

Attachment 2, Cape Cod Bridges Program - Highway Interchange Approaches Detailed Assessment Report provides the secondary evaluation of the ten highway interchange options that passed the initial evaluations (described in **Section 3.8**). MassDOT prepared this report to document the detailed assessment of the highway interchange approach options that were considered for the Bourne and Sagamore replacement bridges, and then either not carried forward or advanced for incorporation into the Build Alternative Retained for Detailed Study in the Program's National Environmental Policy Act/Massachusetts Environmental Policy Act environmental reviews. The following summarizes the two-step approach MassDOT used to conduct detailed assessments of the highway interchange approach options.

4.2 Regional Traffic Operations Assessment

In Step 1, MassDOT focused on network (regional)-wide transportation performance measures. Based on the pairing of one option each for the Bourne North, Bourne South, Sagamore North, and Sagamore South quadrant, MassDOT identified 36 possible permutations of options. MassDOT then narrowed the number of permutations to eliminate pairings that performed similarly and conducted multiple analyses of the remaining permutations. The purpose of these multiple analyses was:

1. To determine if there were options in one area of the network that could adversely impact the performance of options in other areas of the network
2. To identify options with fatal flaws that could adversely impact regional traffic operations.

MassDOT determined that options that would adversely impact overall network performance would be considered fatally flawed and would be eliminated from further analysis. MassDOT determined that highway interchange options that scored well regarding regional traffic operations would advance to further evaluation (Step 2) based on the Program Purpose and Need Statement evaluation criteria and the Program's goals and objectives.

4.3 Program Needs and Goals Performance Assessment

In the second step, MassDOT advanced highway interchange options that passed Step 1 to a Step 2 evaluation. MassDOT identified transportation performance measures and contextual performance measures and then evaluated the options relative to the Program needs and the Program goals and objectives. Transportation performance measures addressed the four overall Program needs identified in the Purpose and Need Statement:

- **Operations**, focusing on poor vehicular traffic operations, including high traffic volumes and congestion resulting in poor levels of service.

- **Geometrics and Safety**, focusing on the substandard design elements of the Cape Cod Canal highway bridges, the immediate mainline approaches, and their adjacent interchanges and intersections, including abrupt and steep connections to surface roads and nonconforming traffic safety features.
- **Multimodal Accommodations**, focusing on the lack of accessible bicycle and pedestrian accommodations and connections between existing facilities, including gaps and unsafe conditions across the canal and between local area roadways.
- **Structural and Maintenance**, focusing on the deteriorating structural condition and escalating maintenance demands of the existing Cape Cod Canal highway bridges, including the needed major rehabilitation programs identified by the USACE in the MRER/EA.

Contextual performance measures address the Program goals and objectives:

- Maintain and improve the socioeconomic fabric of the surrounding community (Socioeconomics).
- Preserve and protect natural resources (Natural Resources).
- Enhance the resiliency and sustainability of the built environment (Resiliency and Sustainability).
- Maximize constructability (Constructability).
- Facilitate emergency response (Emergency Response).
- Maximize cost effectiveness (Cost Effectiveness).

4.4 Summary of Evaluation

MassDOT developed a scoring system for evaluating the highway interchange approach options based on their quantitative and qualitative performance. Relative to meeting Program needs, an option was rated according to the benefits it would provide compared to other options or the No Build Alternative condition; benefit ratings were determined to be *substantial, marginal/some*, or *insufficient/negligible*. Regarding meeting Program goals and objectives, an option was rated in one of two ways: 1) based on the impacts it would incur compared to the other options, ranging from *more or most impacts* to *less or least impacts*; or 2) based on the opportunities it would provide in meeting Program objectives compared to the other options, ranging from *more or most opportunity* to *less or least opportunity*.

Based on the results of the two-step evaluation process, MassDOT identified the highest-ranking interchange approach options, two per crossing, as the recommended interchange pairings to be incorporated into the Build Alternative to be retained for detailed study in the DEIR.

The detailed evaluation criteria performance measures scoring matrices for the Sagamore and Bourne highway interchange options, including quantitative comparisons of environmental impacts, are provided in **Table 3-1** and **Table 3-2**, appended to **Attachment 2**.

5 Attachments

- Attachment 1, Cape Cod Bridges Program Alternatives Analysis Report (February 20, 2024; updated June 2025)
- Attachment 2, Cape Cod Bridges Program - Highway Interchange Approaches Detailed Assessment Report (June 2025)

Attachment 1 – Alternatives Analysis Report









Cape Cod Bridges Program

Bourne, Massachusetts

Alternatives Analysis Report

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Appendices

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Appendix B. Cape Cod Bridge Replacements Constructability Assessment

Appendix C. Cape Cod Bridges Replacements Phase II Screening Report

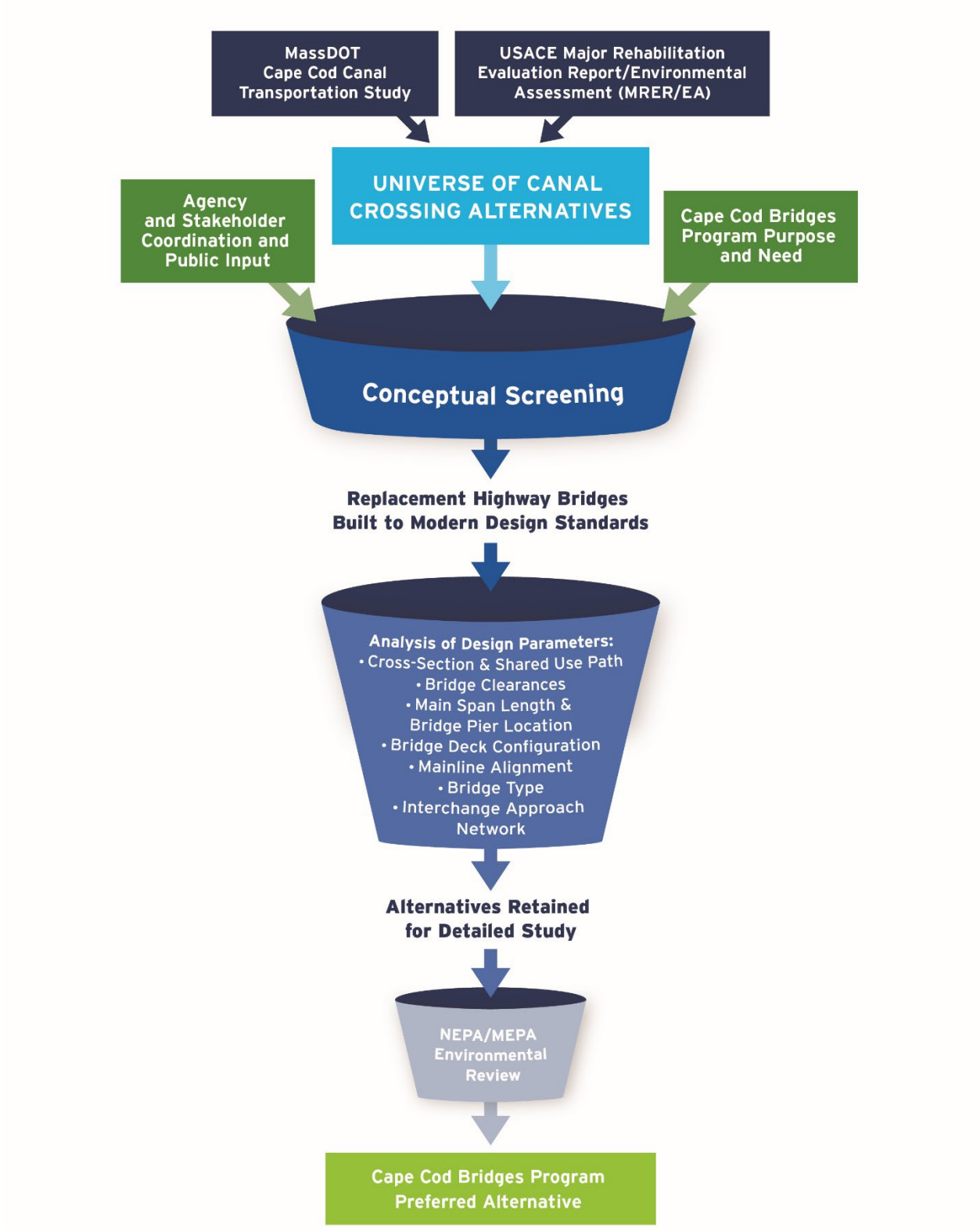
Appendix D. Cape Cod Bridges Program Screening of Highway Interchange Approach Concepts

Executive Summary

The Massachusetts Department of Transportation (MassDOT), in coordination with the Federal Highway Administration (FHWA) as the lead federal agency and the New England District of the U.S. Army Corps of Engineers (USACE) as a cooperating agency, is preparing environmental analyses and documentation for the Cape Cod Bridges Program (Program) in compliance with the National Environmental Policy Act (NEPA) of 1969, as amended (42 United States Code [U.S.C.] 4321, et seq.); 23 USC 139, *Efficient Environmental Reviews for Project Decisionmaking and One Federal Decision*; FHWA's regulations implementing NEPA, *Environmental Impacts and Related Procedures* (23 CFR 771); and with the Massachusetts Environmental Policy Act (MEPA; Massachusetts General Law [MGL] Chapter 30, Sections 61 through 62I, and its implementing regulations, 301 Code of Massachusetts Regulations [CMR] 11.00, as amended January 6, 2023). The purpose of the Program is to improve cross-canal mobility and accessibility between Cape Cod and mainland Massachusetts for all road users and to address the increasing maintenance needs and functional obsolescence of the aging Cape Cod Canal highway bridges.

As required by NEPA and MEPA, MassDOT prepared this Alternatives Analysis Report to document and disclose the bridge type design alternatives, mainline alignment options, and highway interchange approach options that were considered for the Program, including those that were recommended to be carried forward for further evaluation in the NEPA and MEPA environmental documents as Alternatives Retained for Detailed Study. This Alternatives Analysis Report summarizes MassDOT's evaluation processes conducted through 2023. It comprises eight engineering assessments; seven of these assessments established the bridge design parameters, and the eighth assessment consisted of the intial evaluations of the interchange approach networks. For some Program design parameters, MassDOT's analyses consisted of a single evaluation; for other parameters, an initial assessment was followed by a secondary, more detailed evaluation.

Figure ES-1 presents a graphic of MassDOT's alternatives analysis process conducted for the Cape Cod Bridges Program. The Program's multi-tiered alternative screening and evaluation process is similar to a funnel. MassDOT used its 2019 Cape Cod Canal Transportation Study and the USACE's Major Rehabilitation Evaluation Report/Environmental Assessment (MRER/EA) as the foundational planning documents which identified a broad range of alternatives for the Program. In coordination with FHWA and USACE, and incorporating input from stakeholders and the public, MassDOT developed a multi-step filtering process for identifying and evaluating alternatives and options for the Program. MassDOT conducted engineering assessments at the conceptual (approximately 5 percent) level and the preliminary (approximately 10 percent) design stages to further define Program design parameters. MassDOT's assessments consisted of qualitative and quantitative evaluations of the Program design parameters relative to design evaluation criteria and other factors established in coordination with FHWA and USACE.



ES-1. Summary Graphic of Cape Cod Bridges Program Alternatives Analysis Process

ES-1 Screening of Alternatives Considered in USACE's Major Rehabilitation Evaluation Report/Environmental Assessment (MRER/EA)

MassDOT's screening of alternatives considered in USACE's Major Rehabilitation Evaluation Report/Environmental Assessment (MRER/EA) is presented in Section 4.

In coordination with FHWA, MassDOT conducted an independent conceptual screening of twelve alternatives presented by the USACE in the MRER/EA. The twelve alternatives comprised the "Universe of Alternatives" for addressing the deteriorating Sagamore and Bourne Highway Bridges. MassDOT evaluated the alternatives in accordance with the National Environmental Policy Act (NEPA) (42 USC 4321 et. seq.) and FHWA's regulations NEPA implementing regulations, 23 CFR 771, and its Technical Advisory (T 6640.8A): *Guidance for Preparing and Processing Environmental and Section 4(f) Documents*. MassDOT determined that replacing both bridges with two new adjacent bridges at each crossing location, each providing two through traffic lanes and an auxiliary lane in each direction and built to current design standards, would meet the identified Program Needs to address the escalating bridge maintenance demands and improve traffic operations and accommodations for pedestrians and bicyclists. Based on its ability to fully meet the Program Needs, while minimizing the approach road modifications necessary to connect the replacement bridges to the regional and local transportation system, MassDOT recommended advancing the Four Travel Lanes and Two Auxiliary Lanes Replacement Alternative (Replacement Highway Bridges Built to Modern Design Standards) as presented in the MRER for further consideration. MassDOT's recommendation for Replacement Highway Bridges Built to Modern Design Standards, which concurs with the USACE's Preferred Alternative, was the basis for assessing the Cape Cod Bridges Program design parameters.

ES-2 Assessment of Bridge Highway Cross-Section and Shared Use Path

MassDOT's assessment of bridge highway cross-section and shared use path is presented in Section 5.

In accordance with MassDOT and FWHA design criteria, as well as American Association of State Highway and Transportation Officials (AASHTO) guidelines, MassDOT evaluated proposed bridge highway cross-section and the maximum profile grades relative to the MRER/EA's recommendations that each new bridge would include four 12-foot-wide through travel lanes, two in each direction; two 12-foot-wide auxiliary lanes, one in each direction; a shoulder; a separation median; and approach grades. MassDOT determined that the proposed shared use path at each canal crossing would be designed in accordance with MassDOT, AASHTO, and FHWA design criteria, as well as the guidance of the Americans with Disabilities Act (ADA) and the Architectural Access Board (AAB). As design advances, MassDOT will determine the width of the shared use path, which will be presented in the MEPA document.

ES-3 Assessment of Bridge Vertical and Horizontal Clearances

MassDOT's assessment of bridge vertical and horizontal clearances is presented in Section 6.

MassDOT evaluated the vertical and horizontal clearances for the replacement bridges relative to the recommendations presented in the USACE's MRER/EA. The MRER/EA indicated that to maintain the existing vertical clearance of 135 feet above mean high water (MHW), the height of the new bridges should be increased to accommodate fluctuations in relative sea level elevation. Additionally, the USACE indicated that horizontal clearance for navigation must be considered with the replacement bridge design.

Accordingly, MassDOT recommended an increase in bridge height by approximately three feet, which would maintain the existing vertical clearance at 135 feet above MHW with accommodations for fluctuations in relative sea level elevation. Incorporating the USACE's recommendation regarding navigation, MassDOT recommended that the replacement bridge structures provide a minimum of 500 feet of horizontal navigational width, to be consistent with existing conditions.

ES-4 Assessment of Main Span Length and Bridge Pier Location

The bridge piers for the existing Bourne and Sagamore bridges are located within the canal and outside the navigation channel and support a mainline center span length of 616 feet. MassDOT evaluated the USACE's preference for locating the proposed bridge piers outside of the canal cut to improve navigation, operations, and maintenance, as indicated in the MRER/EA.

MassDOT conducted an initial assessment of the main span length and bridge pier location against the applicable bridge design evaluation criteria of costs, main span footings and construction, presented in Section 7. This initial assessment resulted in a recommendation for an out-of-water pier location with two potential main span lengths of approximately 700-feet and 820-feet. MassDOT further evaluated the two main span lengths as part of a detailed bridge fabrication and erection methodology analysis for the bridge type, presented in Section 11. This second assessment contributed to a final recommendation for an approximate 700-foot main span with the bridge piers located within the rip rap slope and above the low tide line.

ES-5 Assessment of Bridge Deck Configuration

As a variation of the single bridge deck configuration presented in the MRER/EA, MassDOT investigated constructing two separate deck structures for each replacement highway bridge, consisting of two parallel separate northbound and southbound decks (barrels), presented in Section 8. MassDOT's qualitative assessment focused on the constructability aspects of the bridge deck configuration, including duration of construction, construction complexity, and potential for construction phasing. MassDOT also evaluated the durability and structural redundancy aspects of the bridge deck configurations.

Based on its initial assessment, MassDOT determined that both bridge deck configurations would be feasible depending on the bridge type and advanced the single deck and two separate deck options for further evaluation. After a secondary evaluation that assessed the bridge deck configuration relative to a

short list of bridge types, presented in Section 11, MassDOT recommended advancing the two separate deck configurations as part of the final bridge type recommendation.

ES-6 Assessment of Mainline Alignment Location

MassDOT's assessment of the mainline alignment locations consisted of an initial and detailed evaluation and is located in Section 9.

MassDOT assessed the MRER/EA's recommendation that the two new highway bridges be constructed parallel to and immediately inshore of the existing Bourne and Sagamore Bridges (offline and inboard). MassDOT identified five optional locations for each highway bridge mainline alignment over Cape Cod Canal and evaluated the locations based on their performance in meeting the Program needs to address the substandard design elements of the bridges relative to the mainline approaches and their adjacent interchanges and intersections, improve vehicular traffic operations, and improve accommodations for pedestrians and bicyclists. Additional objectives included minimizing temporary and permanent environmental impacts, including right-of-way impacts and impacts to the traveling public.

Based on the results of its performance relative to meeting the Program's highway design evaluation criteria, the Fully Offline Inboard Option for both the Bourne and Sagamore locations had an overall higher rating than the other mainline alignment location options. As a result, MassDOT recommended advancing the Fully Offline Inboard Option for both canal crossings as the mainline alignment location retained for detailed study.

ES-7 Assessment of Bridge Types

MassDOT's assessments of bridge types for the replacement highway bridges, located in Sections 10 and 11, consisted of a conceptual screening of a Universe of Concepts, followed by initial and detailed evaluations.

Incorporating the USACE's Preferred Alternative for In-Kind Bridge Replacements, and in collaboration with FHWA and USACE, MassDOT conceptually screened a wide range of bridge types and design parameters to identify feasible bridge types and configurations for further analysis. In this conceptual screening, MassDOT identified the decision drivers for bridge type selection, advanced favorable design features, and eliminated unfavorable bridge types.
MassDOT then conducted an initial assessment of a short list of bridge types relative to the Program's bridge design evaluation criteria. MassDOT placed highest priority on bridge types that would be practical and feasible to construct and maintain; bridge types that would not be practical and feasible were not advanced for further evaluation. Additionally, MassDOT placed high priority on a bridge construction method that would minimize Cape Cod Canal navigation impacts. As a result of this initial assessment, MassDOT recommended the advancement of three bridge types with various configurations for a secondary evaluation.

MassDOT's detailed analysis incorporated MassDOT's highway geometric assessments, additional constructability assessments of the feasible bridge types (including a detailed bridge deck configuration

assessment), and the public's review of the feasible bridge types relative to community considerations and bridge aesthetics. As a result of the detailed bridge type assessment, including public input, MassDOT recommended the following bridge type to be retained for detailed study: parallel, twin tied-arch bridge structures supported on Delta frames with an approximate 700-foot main span length. As design advances, MassDOT will determine exact span length, arch rib configuration, tie-in with approach ramps, and other parameters for the Tied-Arch Bridge with Delta Frame, which will be included in the Program Bridge Type Study.

ES-8 Initial Assessments of Highway Interchange Approach Options

MassDOT's initial assessments of options for the highway interchange approach network, located in Section 12, consisted of a conceptual screening of a Universe of Concepts, followed by a preliminary (10 percent design level) assessment and identification of options to advance to a more detailed assessment.

Using the alternatives identified in its 2017 Cape Cod Canal Area Transportation Study as its starting point, MassDOT conceptually identified and screened a total of 97 highway interchange approach concepts (the Universe of Concepts) according to feasibility and reasonability. From the screening of the Universe of Concepts, MassDOT identified 22 active concepts, where the concept was deemed to be a viable option to be further refined, for the highway interchange approaches at the four quadrants of the canal crossings, identified as Bourne North, Bourne South, Sagamore North, and Sagamore South.

Incorporating the USACE's MRER/EA Preferred Alternative of In-Kind Bridge Replacement, and its recommendation for a Fully Offline Inboard location for the mainline alignment, MassDOT assessed the 22 highway interchange approach options relative to the Program's highway design evaluation criteria developed in collaboration with FHWA. Based on 2050 No-Build condition traffic volumes, MassDOT assessed future traffic operations using several traffic analysis and modeling programs and conducted engineering assessments consistent with AASHTO's Highway Safety Manual. Highway interchange approach options were rated based on their performance relative to meeting the Program's highway design evaluation criteria; the ratings were then compared to identify options that MassDOT would recommend for a detailed, secondary level of assessment. Based on its initial assessment, MassDOT recommended a secondary evaluation of ten highway interchange approach options for the four quadrants of the canal crossings.

MassDOT then conducted a secondary assessment of the ten highway interchange options, completed in 2024. The secondary, detailed assessment consisted of quantitative and qualitative analyses of evaluation criteria related to the following Program Needs identified in the Purpose and Need Statement – operations, geometrics and safety, multi-modal accommodations, and maintenance and structural – and Program goals and objectives. The results of the secondary assessment are reported in the Program's Highway Interchange Approaches Detailed Assessment Report (June 2025). The Sagamore and Bourne highway interchange approach options that passed the detailed evaluation are identified as MassDOT's recommended Options Retained for Detailed Study, which are further evaluated in the NEPA and MEPA documents.

1 Introduction

The Massachusetts Department of Transportation (MassDOT), in coordination with the Federal Highway Administration (FHWA) as the lead federal agency and the New England District of the U.S. Army Corps of Engineers (USACE) as a cooperating agency, is preparing environmental analyses and documentation for the Cape Cod Bridges Program in compliance with the National Environmental Policy Act (NEPA) of 1969, as amended (42 United States Code [U.S.C.] 4321, et seq.); 23 USC 139, *Efficient Environmental Reviews for Project Decisionmaking and One Federal Decision*; FHWA's regulations implementing NEPA, *Environmental Impacts and Related Procedures* (23 CFR 771); and with the Massachusetts Environmental Policy Act (MEPA; Massachusetts General Law [MGL] Chapter 30, Sections 61 through 62I, and its implementing regulations, 301 Code of Massachusetts Regulations [CMR] 11.00, as amended January 6, 2023). As required by MEPA and NEPA, MassDOT prepared this Alternatives Analysis Report to document and disclose the bridge type design alternatives, mainline alignment options, and highway interchange approach options that were considered for the Program, including those that were recommended to be carried forward for further evaluation in the NEPA and MEPA environmental documents as Alternatives Retained for Detailed Study.

The Sagamore and Bourne highway bridges span Cape Cod Canal and are located in the town of Bourne, Barnstable County, Massachusetts (Figure 1-1). Cape Cod Canal, which connects Cape Cod Bay and Buzzards Bay, was privately owned, and built during the early 1900s. In 1919, Congress authorized the purchase of the canal and in 1927, Congress directed the U.S. Army Corps of Engineers (USACE) to operate and improve the canal under the authority of the Rivers and Harbors Act of 1927. The Rivers and Harbors Act of 1935 gave the authority for the USACE to operate and maintain the Bourne and Sagamore highway bridges, as part of the Cape Cod Canal Federal Navigation Project (FNP). The two highway bridges continue to be managed by the New England District of the USACE.

The current bridges were constructed beginning in 1933 and opened to traffic in 1935. At nearly 90 years old, the Bourne and Sagamore bridges are in deteriorated condition and are determined to be functionally obsolete. Both highway bridge crossings over Cape Cod Canal are vital components of the local and regional transportation network, as they provide the only vehicular access on and off Cape Cod for the 230,000 year-round residents of Barnstable County, and millions of visitors to the Cape each year during the height of the summer tourist season from Memorial Day through Labor Day. The bridges and their approach roadway network no longer meet the needs of the traveling public. The combination of today's high traffic volumes and substandard design features of the Bourne and Sagamore bridges and their approach roadway network substantially impairs traffic operations and safety within vicinity of the Cape Cod Canal.

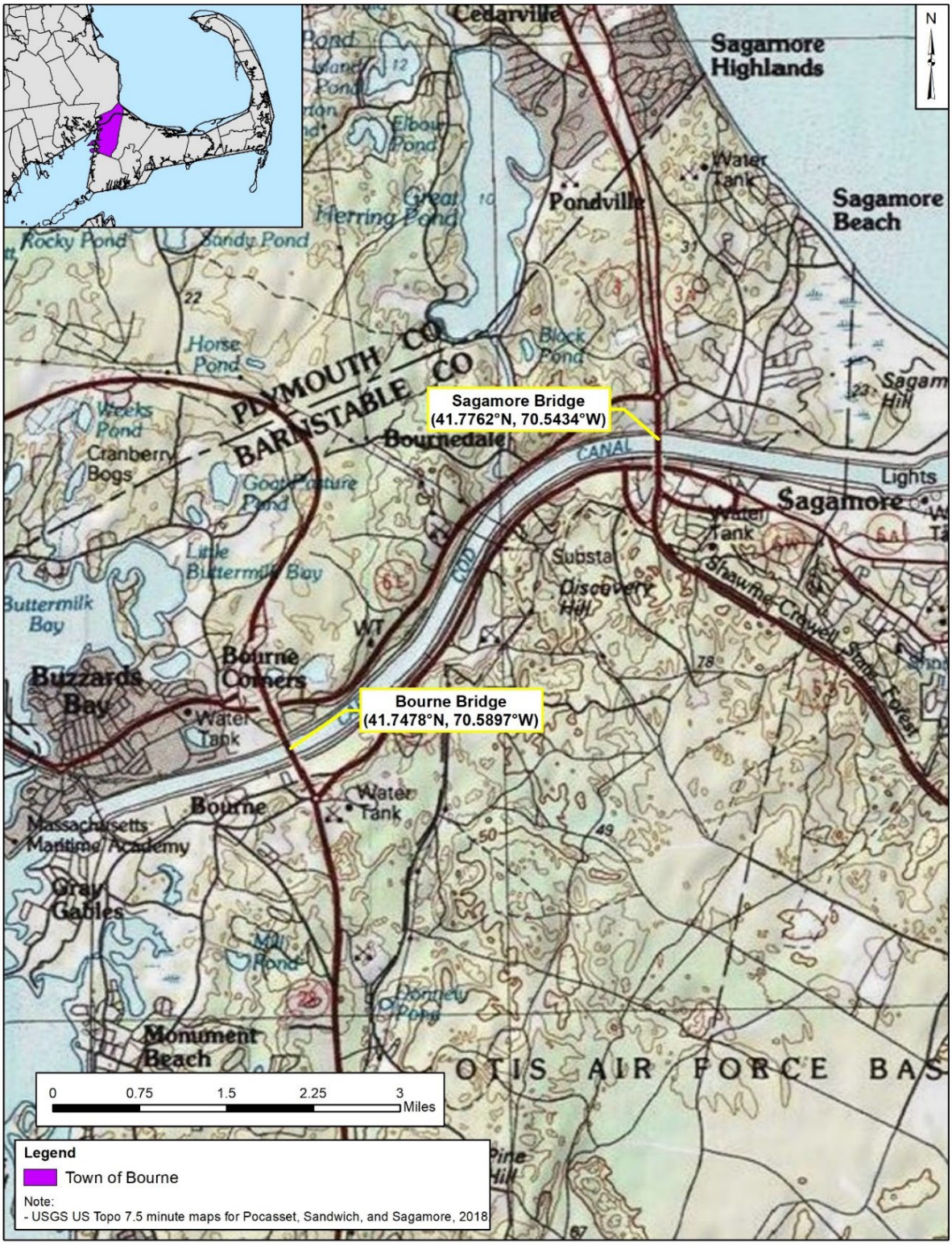


Figure 1-1. Sagamore and Bourne Highway Bridges Location Map

1.1 Program Background

In accordance with 23 CFR 771.111(a) and consistent with 23 United States Code (USC) 139(f)(4)(E)(ii), the Cape Cod Bridges Program builds upon and references foundational studies that evaluated alternatives for addressing the deteriorating performance of the aging Bourne and Sagamore Highway Bridges and the multimodal transportation deficiencies of the surrounding approach roadway networks.

1.1.1 MASSDOT OFFICE OF TRANSPORTATION PLANNING CAPE COD CANAL TRANSPORTATION STUDY

In collaboration with FHWA, MassDOT launched the Cape Cod Canal Transportation Study in 2015 to identify and evaluate existing and future multimodal transportation deficiencies and needs around the Cape Cod Canal area.[1] The study area for the Cape Cod Canal Transportation Planning Study included land up to four miles on either side of the canal, extending farther at certain points to include major highway interchanges. The Cape Cod Transportation Study involved a Study Working Group, including local and state elected officials, federal agencies including the USACE, state agencies, area municipalities, metropolitan planning organizations, chambers of commerce, key businesses, and other interested parties, and an extensive public outreach program. At the conclusion of the Cape Cod Canal Transportation Study in 2019, MassDOT, in coordination with the Study Working Group, provided recommendations for addressing multimodal deficiencies within the Cape Cod Canal area including:

- Improvements to pedestrian and bicycle accommodations and connections proximate to and from local roadways over Cape Cod Canal via the Bourne and Sagamore Bridges; and
- Implementation of major transportation system improvements at roadway approaches to the Bourne and Sagamore Bridges, including adjacent interchanges and intersections.

1.1.2 USACE MAJOR REHABILITATION EVALUATION REPORT/ENVIRONMENTAL ASSESSMENT (MRER/EA) OF THE CAPE COD CANAL HIGHWAY BRIDGES

In March 2020, the USACE completed a multi-year Major Rehabilitation Evaluation (MRE) of the Bourne and Sagamore highway bridges.[2] The USACE is required to complete an MRE whenever infrastructure maintenance construction costs are expected to exceed $20 million and would take more than two years of construction to complete. The MRE is a four-part evaluation: a structural engineering risk and reliability analysis of the current structures, cost engineering, economic analysis, and environmental evaluation of all feasible alternatives.

The USACE conducted the MRE to identify and evaluate conceptual alternatives to determine whether major rehabilitation or bridge replacement would provide the most cost effective, safe, efficient, and reliable means of providing long-term vehicular crossings of Cape Cod Canal. The USACE examined bridge performance, benefits, costs, and impacts in the context of continued rehabilitation versus replacement over a 50-year period of analysis, per USACE regulation and policy. The alternatives were measured against a common Base Condition of continued maintenance and repair of the bridges as needed, but without major rehabilitation, as well as eleven other alternatives for crossing Cape Cod Canal. The study resulted in publication of the MRE Report (MRER), which evaluated the risk and

[1] https://www.mass.gov/lists/cape-cod-canal-study-documents

[2] https://www.nae.usace.army.mil/Missions/Projects-Topics/Cape-Cod-Canal-Bridges-Major-Rehabilitation-Study

reliability of the Bourne and Sagamore bridges, as well as the economic impacts and benefits of the numerous alternatives.

A decision was made by the USACE and the Assistant Secretary of the Army for Civil Works on April 3, 2020, to replace the current Bourne and Sagamore Bridges with two new bridges built to modern-day standards. In its decision, the USACE noted that this solution would provide the federal government with the best long-term investment for safe access to Cape Cod for the traveling public over the next 50 plus years. The USACE indicated that the MRER represented an initial assessment of the replacement of the Cape Cod Canal highway bridges, as a concept level plan for the bridge replacement project. The USACE indicated that the concept level plan would be carried forward into detailed analysis, including design and construction.

To support the MRER decision document, the USACE completed an Environmental Assessment (EA) pursuant to the requirements of NEPA. The USACE determined that the purpose of the USACE's Cape Cod Canal Bourne and Sagamore Bridges Project was to restore or replace the existing deteriorated bridges to provide structures which will maintain reliability of service, improve safety and ease of maintenance, and provide safe, secure, and cost-effective access across the Cape Cod Canal. FHWA and MassDOT participated in the MRER/EA as cooperating agencies. The MRER/EA developed and assessed the alternatives at a conceptual level only; the USACE considered the MRER and the EA to be the first phase in examining the future of the Cape Cod Canal highway bridges. In its MRER/EA, the USACE noted that a supplemental NEPA document (Phase II) would be required for the design and construction of the replacement bridges.

Based on a detailed evaluation of costs and benefits of all feasible alternatives presented in the MRER/EA, the USACE determined that replacement of both bridges with new bridges that conform to modern highway design standards would be the most cost-effective practicable alternative for providing critical public transportation access across Cape Cod Canal. This recommendation considered the safety and reliability of the bridges and Cape Cod Canal for both vehicular and maritime transportation. Based on the findings of the MRER/EA and receipt of public comments, the USACE determined that the replacement of both highway bridges with new bridges would not have significant adverse impact on the environment. On March 29, 2022, the USACE formally issued a Finding of No Significant Impact (FONSI) for the proposed action to replace the Bourne and Sagamore bridges.[3]

1.1.3 MEMORANDUM OF UNDERSTANDING BETWEEN USACE AND MASSDOT

In July 2020 during the preparation of the USACE's MRER/EA, a Memorandum of Understanding (MOU) was executed between the USACE and MassDOT regarding the future ownership, operations, and maintenance of the Bourne and Sagamore highway bridges.[4] According to the terms of the

[3] https://www.nae.usace.army.mil/Portals/74/docs/Topics/Cape%20Cod%20Canal%20Bridges/Reports/MRER-Env-Assessment-March2022-FONSI-FINAL.pdf

[4] https://www.nae.usace.army.mil/Portals/74/docs/Topics/Cape%20Cod%20Canal%20Bridges/Agreements/Cape-Cod-Canal-Bridges-MOU-7JUL2020.pdf

agreement, the USACE continues to be responsible for the ownership, operation, and maintenance of the two existing bridges until replacement bridges are built and operational. MassDOT is responsible for leading the Cape Cod Bridges Program delivery (including the feasibility study, alternatives analysis, preliminary design, and environmental permitting processes), as well as overseeing procurement and construction of the new bridges. MassDOT will then own, operate, and maintain the completed bridges and approaches as part of the system of state highways to be maintained by MassDOT.

1.1.4 FHWA'S ROLE AS CAPE COD BRIDGES PROGRAM LEAD FEDERAL AGENCY

On January 20, 2023, in response to a request from MassDOT, FHWA agreed to serve as the lead federal agency for the Cape Cod Bridges Program. FHWA committed to working closely with the USACE as the Program design advances, including requesting the USACE to serve as a Cooperating Agency on the Program. In August 2023, FHWA determined that the Program would require the preparation of an Environmental Impact Statement (EIS), to ensure that "full and fair discussion of significant environmental impacts are disclosed to decision makers and the public, and to ensure all reasonable alternatives that would avoid or minimize adverse impacts or enhance the quality of the environment are considered."

1.2 Cape Cod Bridges Program Study Area

Figures 1-2 and 1-3 present the Cape Cod Bridges Program Study Area that was used for the analyses presented in this report. The Study Area, shown in as two distinct study areas, includes the areas of the existing bridges and highway approach interchanges for each canal crossing.

The Bourne Program Study Area includes the Route 25 and Route 28 approaches to the bridge. North of Cape Cod Canal, roadways include Route 6 (Scenic Highway) and the roadways approaching Belmont Circle, including the Route 25 exit- and entrance-ramps and portions of the Head of the Bay Road, Main Street, and the Buzzards Bay Bypass. South of the canal, roadways include the Bourne Rotary and approach roadways including Route 28, Sandwich Road, and Trowbridge Road, Veterans Way, and the Bourne Rotary Connector. The Sagamore Program Study Area includes the Route 3 and Route 6 approaches to the bridge. North of Cape Cod Canal, roadways include the Scenic Highway and Meetinghouse Road approaches, the Route 3/Scenic Highway interchange, and portions of Canal Street and State Road. South of the canal, roadways include Cranberry Highway and Sandwich Road and Route 6 itself extending south of the Mid-Cape Connector ramps to Route 6.

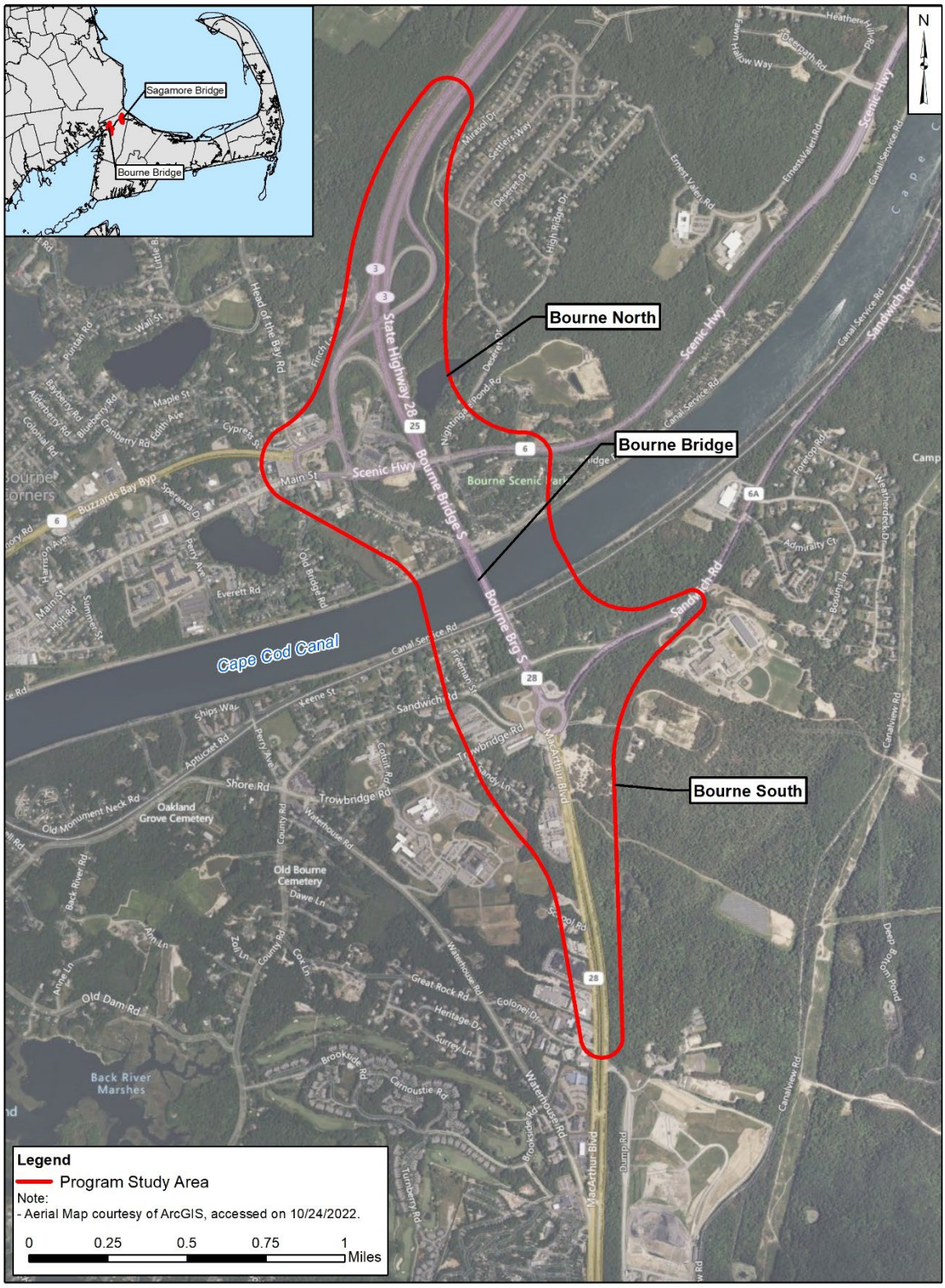


Figure 1-2. Cape Cod Bridges Program - Bourne Program Study Area

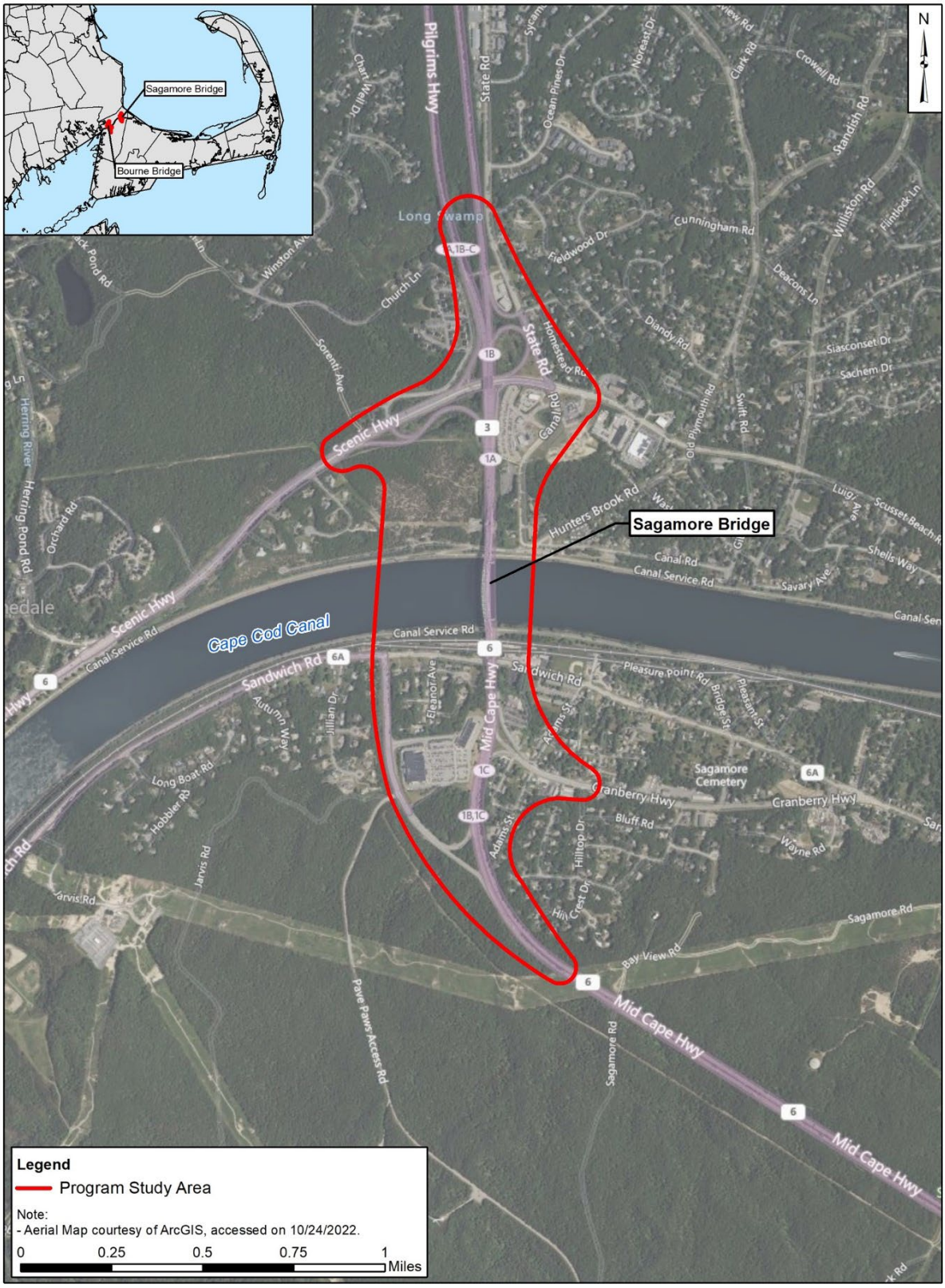


Figure 1-3. Cape Cod Bridges Program — Sagamore Program Study Area

1.3 Program Purpose and Need

1.3.1 PROGRAM PURPOSE

The purpose of the Cape Cod Bridges Program is to improve cross-canal mobility and accessibility between Cape Cod and mainland Massachusetts for all road users and to address the increasing maintenance needs and functional obsolescence of the aging Cape Cod Canal highway bridges.

1.3.2 PROGRAM NEEDS

The needs for the Cape Cod Bridges Program are as follows:

- Address the deteriorating structural condition and escalating maintenance demands of the Cape Cod Canal highway bridges,
- Address the substandard design elements of the Cape Cod Canal highway bridges, the immediate mainline approaches and their adjacent interchanges and intersections,
- Improve vehicular traffic operations, and
- Improve accommodations for pedestrians and bicyclists.

2 Overview of the Alternatives Analysis Process

In coordination with USACE and FHWA, and incorporating input from stakeholders and the public, MassDOT developed a multi-step filtering process for identifying and evaluating alternatives for the Program. This Alternatives Analysis Report summarizes MassDOT's evaluation processes conducted through 2023. It comprises eight engineering assessments; seven of these assessments established the bridge design parameters, and the eighth assessment consisted of the intial evaluations of the interchange approach networks. For some Program design parameters, MassDOT's analyses consisted of a single evaluation; for other parameters, an initial assessment was followed by a secondary, more detailed evaluation.

Figure 2-1 presents a summary graphic of MassDOT's alternatives analysis process conducted for the Cape Cod Bridges Program. The Program's multi-tiered screening and evaluation process is similar to a funnel. Utilizing the Cape Cod Canal Transportation Study and the USACE's MRER/EA as the foundational planning documents, in accordance with 23 CFR 771.111(a) and consistent with 23 USC 139 (f)(4)(E)(ii), MassDOT screened the Universe of Cape Cod Canal Crossing Alternatives presented in the MRER/EA and confirmed the USACE's recommended Preferred Alternative of replacing the highway bridges with new bridges built to modern highway design standards.

Incorporating the USACE's Preferred Alternative, MassDOT conducted an analysis of multiple Program design parameters, including additional MRER/EA bridge recommendations, at the conceptual (approximately 5 percent) level and the preliminary (approximately 10 percent) design stages. MassDOT's assessments consisted of qualitative and quantitative evaluations of the Program design parameters relative to design evaluation criteria and other factors established in coordination with FHWA and USACE. MassDOT reviewed the results of its analyses with agencies and Program stakeholders and the public.

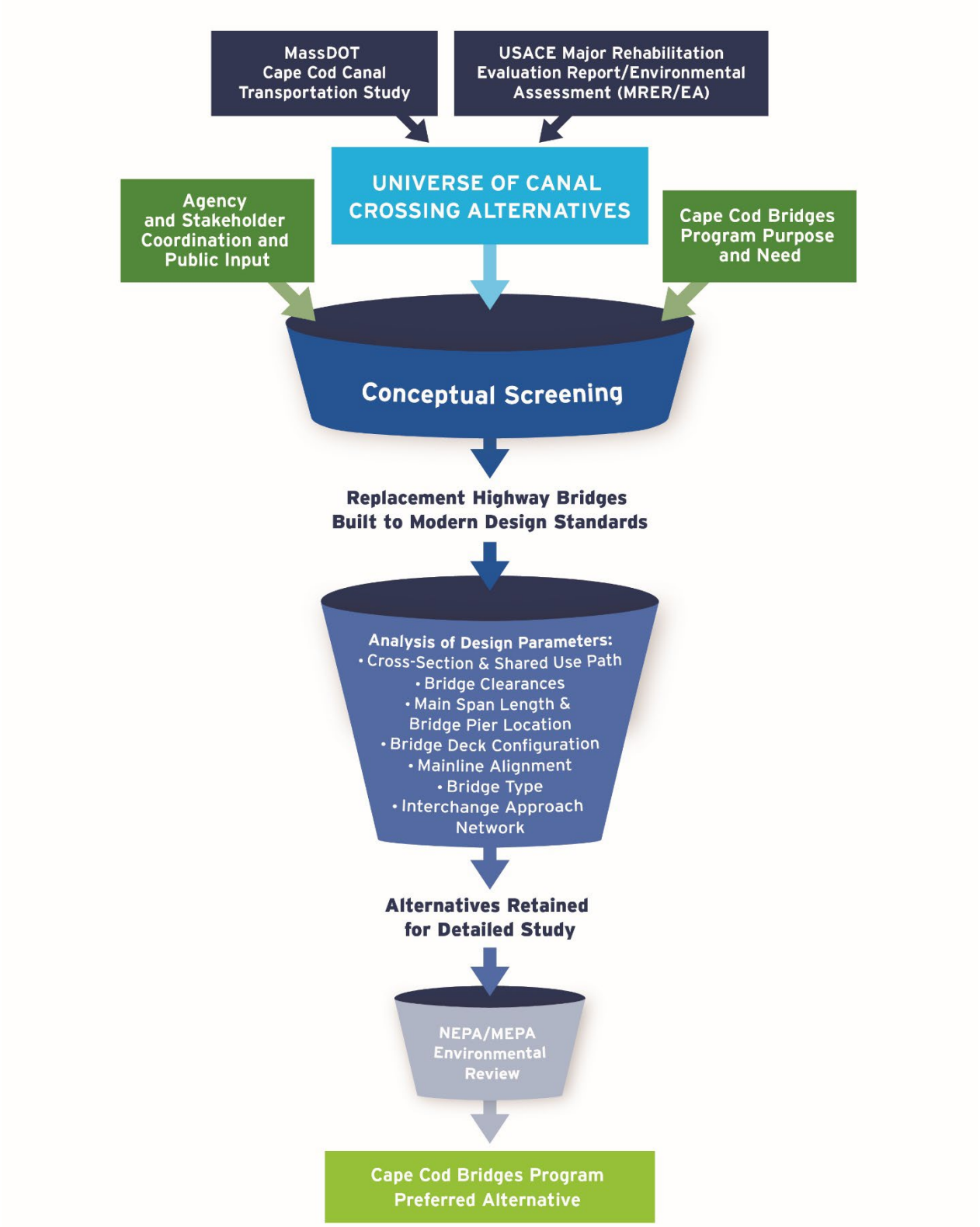


Figure 2-1. Summary Graphic of the Cape Cod Bridges Program Alternatives Analysis Process

As a result of the progressively refined alternatives analysis process, and with agency and stakeholder input and public review, MassDOT recommended advancing a replacement highway bridge alternative and highway interchange approach options for further consideration. The results of the multiple analyses are identified as the Alternatives Retained for Detailed Study, which are presented in Section 3 of this Alternatives Analysis Report. MassDOT committed to further evaluating the Alternatives Retained for Detailed Study in the Environmental Impact Reports (DEIR and FEIR), prepared in compliance with the Massachusetts Environmental Policy Act (MEPA).

MassDOT's analyses of the Cape Cod Bridges Program design parameters, described in Sections 4 through 12 of this Alternatives Analysis Report, include the following:

- Screening of Alternatives Considered in USACE's Major Rehabilitation Evaluation Report/Environmental Assessment (MRER/EA) (Section 4);
- Assessment of Bridge Highway Cross-Section and Shared Use Path (Section 5);
- Assessment of Bridge Vertical and Horizontal Clearances (Section 6);
- Assessment of Main Span Length and Bridge Pier Location (Sections 7 and 11.3.2);
- Assessment of Bridge Deck Configuration (Sections 8 and 11.3.1);
- Assessment of Mainline Alignment Location (Section 9);
- Assessment of Bridge Types (Sections 10 and 11);
- Assessment of Conceptual and Initial Highway Interchange Approach Options (Section 12).

The Alternatives Analysis Report is supported by four appendices that document the decisions presented in Sections 4 through 12:

- Appendix A provides the Cape Cod Bridge Replacements Initial Screening Report (HNTB, 2021), which documents the multiple program design parameters that MassDOT evaluated in the assessment of bridge types.
- Appendix B provides the Cape Cod Bridge Replacements Constructability Assessment (HNTB, 2021), which evaluates the favorable bridge types for various aspects of constructability, including fabrication, material transport, erection methodology, and impacts to canal and canal-side traffic.
- Appendix C provides the Cape Cod Bridge Replacements Phase II Screening Report (HNTB, 2022), which documents the detailed analysis that resulted in a recommended bridge type for the replacement of the Bourne and Sagamore highway bridges.
- Appendix D provides the conceptual identification and screening a wide range of highway interchange approach configurations that resulted in an assessment of 22 highway interchange approach options for the Bourne and Sagamore crossings.

3 Alternatives Retained for Detailed Study

This section describes the No Build Alternative and the Build Alternative that are recommended to be retained for detailed study in the NEPA and MEPA environmental review documents.

3.1 No Build Alternative

The Sagamore and Bourne highway bridges, as components of the Cape Cod Canal Federal Navigation Project (FNP), are federal assets that are currently managed by the USACE's New England District. The Commonwealth of Massachusetts owns the connecting major highway corridors in the Program Study Areas at the bridges, consisting of the Route 3/Route 6 corridor at Sagamore Bridge and the Route 25/Route 28 corridor at Bourne Bridge.

In the No Build Alternative, the Sagamore and Bourne highway bridges would retain their current configuration of four 10-foot-wide travel lanes, two in each direction, with one 6-foot sidewalk and a 2-foot safety curb. The No Build Alternative would nullify the 2020 MOU between USACE and MassDOT. USACE would continue to own the Bourne and Sagamore Bridges and would implement a maintenance and repair program as needed to maintain bridge operations and public safety. MassDOT would continue to own, operate, and maintain the State highway networks at the two bridges.

The No Build Alternative would include recently completed and proposed State-sponsored and local transportation improvements projects in and near the Program Study Areas as indicated in the Federal Fiscal Year (FFY) 2025-2029 Transportation Improvement Program (TIP) for the Cape Cod Metropolitan Planning Organization.[5] Table 3-1 identifies the TIP projects in and near the Program Study Areas to be incorporated in the No Build Alternative.

Table 3-1. Transportation Improvement Program Projects, 2025–2029, in the Cape Cod Bridges Program Study Area

Project Number	Year	Transportation Project	Project Description	Status
606900	2020	Belmont Circle Traffic and Multimodal Improvements	Traffic and multimodal improvements at Belmont Circle at U.S. Route 6 and State Route 25 and State Route 28	Completed
608422	2022	Trail Improvements – Sandwich	Shared-use path on Service Road (State Route 130 to Chase Road)	Underway

[5] The TIP was endorsed on May 20, 2024, with subsequent amendments on November 18, 2024; December 16, 2024; February 24, 2025; and an adjustment on March 24, 2025.

Project Number	Year	Transportation Project	Project Description	Status
610542	2023	Bourne Rotary Improvements	• Restriping Bourne Rotary to two lanes and adding a channelized right-turn lane from State Route 28 northbound to Sandwich Road eastbound • Adding signs at Bourne Rotary • Installing flashing beacons at the Bourne Rotary approaches	Underway
613195	2024	Bridge Systematic Maintenance	Bridge deck replacement of the Quaker Meetinghouse Road Bridge over U.S. Route 6/Mid-Cape Highway as part of an overall bridge preservation strategy	Programmed
609262	2025	Bourne Rail Trail, Phase 1	First phase of four planned phases of the Bourne Rail Trail connection to the Shining Sea Bikeway to the south in Falmouth and to the Cape Cod Canal path (Canal Service Road) in the town of Bourne; Phase 1 is approximately one-half mile long within the existing right-of-way of the Old Colony Railroad (Woods Hole branch line) from the Canal Service Road to Monument Neck Road.	Programmed
610673	—	Bourne Rail Trail, Phase 2	Phase 2 of four planned phases of the Bourne Rail Trail connection to Shining Sea Bikeway to the south in Falmouth and to the Cape Cod Canal path (Canal Service Road) in the town of Bourne; Phase 2 is approximately 2 miles long from Monument Neck Road to Monk's Park/ Valley Bars Road.	Not Programmed
	—	Bourne Rail Trail, Phase 3 and Phase 4A	Phase 3 and Phase 4A of four planned phases of the Bourne Rail Trail connection to Shining Sea Bikeway to the south in Falmouth	Not Programmed
607394/ 611998	—	Bourne Rail Trail, Phase 4B	Phase 4B of four planned phases of the Bourne Rail Trail connection to the Shining Sea Bikeway to the south in Falmouth and to the Cape Cod Canal path (Canal Service Road) in the town of Bourne; Phase 4B is approximately 1 mile long, extending the Shining Sea Bikeway from its current terminus in North Falmouth into the town of Bourne.	Not Programmed

Project Number	Year	Transportation Project	Project Description	Status
606082	2025–2028	U.S. Route 6 Scenic Highway Median Installation	• Resurfacing • Safety improvements, including a raised center median and expanded shoulders to separate eastbound and westbound travel lanes • Drainage improvements • Traffic signal improvements at two intersections • Shared-use path	Programmed
612053	2025	Bourne/Sandwich, Resurfacing and Related Work on U.S. Route 6	Improvements to pavement serviceability, condition, and roadway safety on U.S. Route 6 from Sagamore Bridge to the Sandwich town line (8.55 miles)	Programmed
613200	2026	Chase Road over U.S. Route 6 Bridge	Bridge deck replacement of Chase Road over U.S. Route 6 (Mid-Cape Highway) bridge structure in the town of Sandwich	Programmed
612063	2028	State Route 28 Resurfacing and Related Work	Improvements to pavement serviceability, condition, and roadway safety on MacArthur Boulevard (State Route 28) from Bourne Rotary to Otis Rotary	Programmed
613199	2028	U.S. Route 6 over State Route 130 Bridge	Bridge deck replacement of U.S. Route 6 (Mid-Cape Highway) bridge structure over State Route 130 in the town of Sandwich	Programmed
613271	—	Shared-use path, State Route 130 to Canal Service Road	Shared-use path from State Route 130 to Canal Service Road in the town of Sandwich	Not Programmed

Note: Table 3-1 includes only those projects in the Study Area that are part of the No Build Alternative. It does not include Project S13144, the replacement of the Sagamore Bridge, which was added to the FFY 2025-2029 TIP as Amendment #2, December 9, 2024.

The No Build Alternative represents the "Fix as Fails" Base Condition of the USACE's MRER/EA. In the No Build Alternative, the USACE would implement an ongoing program of continued inspections and maintenance and repair of both existing bridges as needed to maintain safety. No major rehabilitation efforts involving extensive repairs and replacement of major bridge components would occur. Structural components would be repaired, and critical elements would be replaced only when inspections indicate unsatisfactory reliability ratings. The MRER/EA indicated that both highway bridges are in deteriorated condition, well beyond the state in which actions and funding from the USACE's operations and maintenance program could correct the deficiencies and restore and sustain reliability. The USACE indicated that as the bridges continue to age, routine maintenance and minor component replacement would result in an unacceptable structural condition. As a result, it is likely that lower vehicle weights, traffic volume restrictions, and speed limits would be required and posted to maintain continued bridge safety.

The No Build Alternative would not meet any of the identified needs of the Cape Cod Bridges Program: it would not address the deteriorating structural condition and escalating maintenance demands of the existing bridges; it would not address the substandard design elements of the bridges, the immediate mainline approaches, and their adjacent interchanges and intersections; it would not improve vehicular traffic operations; and it would not improve accommodations for pedestrians and bicyclists.

Although the No Build Alternative would not meet the identified Program Purpose and Need, NEPA requires that an EIS consider a no build/no action alternative. FHWA and MassDOT retained the No Build Alternative in the EIS/EIR as the base condition against which the Build Alternative is compared and evaluated.

3.2 Build Alternative

The Cape Cod Bridges Program Build Alternative incorporates the USACE's MRER/EA Preferred Alternative of In-Kind Bridge Replacement updated to comply with federal and state highway and design safety standards. The Cape Cod Bridges Program proposes to replace the Bourne and Sagamore highway bridges with parallel, twin tied-arch bridge structures supported on Delta frames with an approximate 700-foot mainline span length. At both the Bourne and Sagamore crossings, the replacement bridge mainline alignment location will be fully offline and inboard of the existing highway bridges, on the side of the canal between the existing Bourne Bridge and Sagamore Bridge. Additionally, at both canal crossings, the Cape Cod Bridges Program will include a reconfiguration of the highway interchange approach networks north and south of Cape Cod Canal to align with the replacement highway bridges.

Table 3-2 presents the recommended design elements of the Program's Build Alternative Retained for Detailed Study, based on the USACE's MRER/EA and Cape Cod Canal Transportation Study foundational documents and MassDOT's assessments conducted through 2023. MassDOT's further evaluation of the Alternative Retained for Detailed Study, included in the NEPA and MEPA documents, identify avoidance, minimization, and mitigation measures as needed.

Table 3-2. Summary of Recommended Alternative Retained for Detailed Study

Program Element/ Program Design Parameter	MassDOT Analysis through 2023	Description
Replacement Highway Bridges	Screening of USACE MRER/EA Universe of Alternatives	Replacement of Both Highway Bridges with New Bridges with Four Through-Traffic Lanes and Two Auxiliary Lanes (In-Kind Bridge Replacement, updated to comply with federal and state highway and design safety standards).
Bridge Highway Cross-Section and Shared Use Path	Assessment of Bridge Highway Cross-Section and Shared Use Path	Each replacement highway bridge would provide four 12-foot-wide through travel lanes (two in each direction), two 12-foot-wide entrance/exit (auxiliary) lanes, a 4-foot-wide left shoulder, and a 10-foot-wide right shoulder. Right and left barriers would be offset an additional 2 feet beyond the limits of the shoulders.
		Each crossing location would include one bi-directional pedestrian and bicycle shared-use path (SUP), separated from vehicular traffic by the shoulder and barrier; the width of SUP to be determined as design advances.
Bridge Clearances	Assessment of Bridge Vertical and Horizontal Clearances	The replacement bridges would maintain the existing vertical clearance of 135 feet above mean high water (MHW) and account for fluctuations in relative sea level elevation.
		The replacement bridges would provide a minimum of 500 feet of horizontal channel width to be consistent with existing conditions.
Main Span Length and Bridge Pier Location	Assessment of Main Span Length and Bridge Pier Location	The replacement bridges would have a main span length of approximately 700 feet, which would locate the bridge piers at the waterline adjacent to the service road (shoreline piers), into the rip rap slope but above the low tide line.
Bridge Deck Configuration	Assessment of Bridge Deck Configuration	Each crossing (Bourne and Sagamore) would have two separate decks (twin structures).

Program Element/ Program Design Parameter	MassDOT Analysis through 2023	Description
Mainline Alignment	Assessment of Mainline Alignment Location	The mainline alignment locations at both crossings would be Fully Offline Inboard. Both barrels of the replacement highway bridge would be located fully outside the footprint of the existing bridge, approximately 10 feet apart and parallel to each other, and on the side of the canal between the existing Bourne Bridge and Sagamore Bridge. At the Bourne crossing, both barrels of the replacement highway bridge would be located east of the existing Bourne Bridge, towards Cape Cod Bay. At the Sagamore crossing, both barrels of the replacement highway bridge would be located west of the existing Sagamore Bridge, toward Buzzards Bay.
Bridge Type	Assessment of Bridge Types	The replacement bridges would be twin Tied-Arch Bridges with Delta Frames supporting an approximate 700-foot mainline span.
Interchange Approach Network	Conceptual and Initial Assessments of Highway Interchange Approach Options	Based on the conceptual and initial assessments of highway interchange approaches, ten options advanced to a secondary, more detailed assessment, reported in the Interchange Approaches Detailed Assessment Report (June 2025), resulting in one Sagamore Crossing North and South interchange pairing and one Bourne Crossing North and South interchange pairing (recommended options as part of the Build Alternative Retained for Detailed Study).

4 Screening of Alternatives Considered in USACE's Major Rehabilitation Evaluation Report/Environmental Assessment

4.1 Introduction

The Title 23 U.S.C. 139 regulations allow for the efficient review of environmental processes and encourage past studies, analyses, information, and decisions to be included in environmental and planning documents to the extent practicable to avoid duplication of efforts. Pursuant to 23 U.S.C. the Program builds upon and references prior, multi-year foundational studies, including the USACE's Major Rehabilitation Evaluation Report/Environmental Assessment (MRER) of the Cape Cod Canal highway bridges.

In accordance NEPA, FHWA's regulations NEPA implementing regulations, 23 CFR 771, and its Technical Advisory (T 6640.8A): *Guidance for Preparing and Processing Environmental and Section 4(f) Documents,* and in coordination with FHWA, MassDOT conducted an independent screening of the Universe of Alternatives presented in the USACE's MRER/EA.

Section 4 summarizes the alternatives identified in the USACE's MRER/EA and MassDOT's recommendations to advance or not carry forward the alternative for further design and analysis relative to the approved Cape Cod Bridges Program Purpose and Need Statement and its assessment of whether the alternatives are reasonable in accordance with federal regulations and established guidance.

4.2 Overview of MRER/EA's Universe of Canal Crossing Alternatives

Per NEPA, federal agencies are required to identify a reasonable range of alternatives that meet the project purpose, including those that are practical or feasible from a technical and economic standpoint. In addition to the Base Condition, USACE initially identified and screened a "universe of alternatives" for crossing Cape Cod Canal. The USACE reported that many of these initial alternatives presented in the MRER/EA were introduced during a series of five public information sessions held in December 2018 to discuss the future of the bridges. The alternatives were evaluated and screened to reduce the alternatives to those which would be implementable with respect to the following:

- Functionality (Project Purpose), considering whether the alternative would provide safe, reliable, long-term vehicular access connecting Cape Cod with the mainland;
- Cost, considering whether the alternative could be implemented at a reasonable cost, measured over the USACE's 50-year period of analysis;
- Impacts, considering whether the alternative could be implemented without significant environmental, social, and cultural resource impacts;
- Navigability, considering whether the alternative would allow for continued maritime use of Cape Cod Canal as a safe passage for deep-draft and shallow-draft vessels, consistent with the Congressional authorization for the Cape Cod Canal Federal Navigation Project (FNP);[6]
- Authority, considering whether the alternative would be within the USACE's existing authorization for operating and maintaining the existing highway bridges, as well as the of features of the Cape Cod Canal FNP, in accordance with the Rivers and Harbors Act of 1935.

Table 4-1 lists the Universe of Canal Crossing Alternatives presented in the USACE's MRER/EA and the USACE's initial evaluation results. The USACE did not advance alternatives that failed more than one of the screening measures or those alternatives that were not within the USACE's existing authorization.

[6] In addition to the two highway bridges, the FNP consists of Cape Cod Canal, a 32-foot deep channel linking Buzzards Bay to Cape Cod Bay; dikes, revetments, jetties and other features that keep the channel open; mooring areas and small boat harbors in Sandwich and Bourne; the Buzzards Bay Railroad Bridge; access and recreation areas surrounding the canal; and the Cape Cod Canal Visitor Center, headquarters, traffic control and other operation and maintenance facilities.

NEPA requires that a No Action (No Build) alternative be carried forward as a base condition against which all other alternatives will be compared and evaluated.

Table 4-1 USACE MRER/EA Identification and Evaluation of Universe of Canal Crossing Alternatives

Initial Alternative	Summary Description	Advanced for Detailed Analysis in MRER/EA?
A. Base Condition (No Action)	Maintaining and repairing both bridges would continue without any major rehabilitation. Bridge components would be repaired or replaced when inspections yield unsatisfactory reliability ratings.	Yes
B. Major Rehabilitation of Both Bridges	Implementing repairs and major rehabilitation of both bridges. All known structural, mechanical, and electrical deficiencies would be addressed and obsolete components replaced on both bridges to maintain safety and avoid future postings of bridge weight restrictions.	Yes
C. Replacement of One or Both Bridges – Four Lanes Each	Constructing two new high-level bridges located adjacent to and in similar alignment to existing bridges. The new bridges would maintain the roadway configuration of the existing bridges, with four travel lanes and a single pedestrian/bicycle lane.	No
D. Replacement of One or Both Bridges– Four Through Lanes Each and Two Auxiliary Lanes Each	Constructing two new high-level bridges located adjacent to and in similar alignment to existing bridges. Each new bridge would include four vehicle travel lanes and two auxiliary lanes to facilitate safe exit and entrance from the connecting surface roads. Includes a pedestrian/bicycle lane.	Yes
E. Replacement of One or Both Bridges– Additional Through Lanes	Constructing two new high-level bridges located adjacent to and in similar alignment to existing bridges. Each new bridge would include four vehicle travel lanes; two auxiliary lanes; and additional through-traffic lanes in one or more directions. Includes a pedestrian/bicycle lane.	No
F. Replacement – Single New Bridge	Replacing existing bridges with a new single high-level fixed span highway bridge more centrally located along the canal, with at least four vehicles travel lanes in each direction.	No
G. Construction of Third Highway Bridge	Constructing a third highway bridge with either an ongoing system of maintenance and repairs of existing bridges (Alternative A), or major rehabilitation or replacement of the existing bridges (Alternatives B and C).	No
H. Replacement - Two Tunnels	Replacing one or both existing bridges with highway tunnels beneath Cape Cod Canal, with at least four vehicle travel lanes in each direction.	No

Initial Alternative	Summary Description	Advanced for Detailed Analysis in MRER/EA?
I. Replacement – Single Tunnel	Replacing both highway bridges with a single highway tunnel beneath Cape Cod Canal that meets the traffic demands of the two existing crossings (including at least four vehicle travel lanes in each direction). As a result, more than one tunnel tube could be required.	No
J. Replacement - Low Level Draw Spans	Replacing one or both existing highway bridges with low-level draw spans, consisting of either bascule bridges or vertical lift spans; thereby eliminating Cape Cod Canal as a deep draft commercial waterway. An option would be constructing low-level fixed bridges.	No
K. Replacement - Causeways	Replacing both existing highway bridges with low-level causeways to provide access across the canal, converting Cape Cod Canal to an estuary. On option to large culverts would be constructing low-level fixed bridges.	No
L. Deauthorization and Closure of Cape Cod Canal	Deauthorizing and closing Cape Cod Canal, eliminating the canal as a navigable waterway in its entirety and requiring extensive fill in the canal land cut to restore natural drainage and estuarine and coastal ecosystem, and for highway construction.	No

Based on the results of this initial screening, the USACE advanced three alternatives for further consideration. Each of the alternatives would be within the USACE's existing authority for operation, maintenance, repair, rehabilitation, and replacement of the Cape Cod Canal FNP project features. The USACE conducted an extensive engineering and economic analysis of the existing highway bridges, their rehabilitation, and alternatives to major rehabilitation. The USACE developed a rough order of magnitude cost estimate for a program of major rehabilitation for each of the two bridges. The USACE also assessed the impacts of service disruptions due to emergency repairs, including vehicular and navigation traffic management during major rehabilitation.

In evaluating the alternatives to major rehabilitation of the two highway bridges, the USACE considered the expected performance, reliability and engineering risk of each alternative and compared the alternatives to the base condition to determine their relative effectiveness, cost and impacts toward the goal of providing safe and reliable long-term vehicular access across Cape Cod Canal. In calculating bridge replacement costs, the USACE considered the following: 1) bridge costs, including new bridge construction costs, associated state highway modifications, real estate interests, and utility relocation costs; 2) traffic management during bridge replacement, including vehicular and marine traffic management; and 3) future operation, maintenance, and repair costs for the replacement bridges.

The USACE determined that Alternative D, the bridge replacement alternative, had higher net benefits and a higher benefit-cost-ratio than the Major Rehabilitation alternative (Alternative B) and the Base

Condition (Alternative A). One disadvantage of the new bridges would be the high initial construction cost. However, the USACE determined that the Bridge Replacement Alternative would result in more reliable bridges that meet current engineering design and safety standards and regulations. The improved reliability would substantially decrease the probability of bridge failure and resulting costs associated with emergency repair and associated time value costs from lane closures. Additionally, there would be lower annual operation and maintenance (O&M) costs after the erection of the replacement bridges. Because the existing bridges would remain in service until the new bridges opened to traffic, lane and bridge closures would not be required during their construction. There would be limited impacts to vehicular traffic and impacts to navigation during construction. Finally, during minor repairs and inspections, bridges with auxiliary lanes would result in less traffic delays as two lanes in each direction could remain open in many circumstances.

The USACE noted that its economic analysis was performed under the assumption that the infrastructure and surrounding roadways to the bridges would remain in their current conditions and would not be upgraded by the Commonwealth of Massachusetts. The USACE determined that if the State chose to improve the road network surrounding the bridges as proposed in MassDOT's Cape Cod Transportation Study, particularly near the Bourne Rotary, then the Bridge Replacement Alternative would provide additional efficiency benefits. This alternative would improve travel time by allowing the left-hand travel lanes to be fully used by through traffic, since exiting and entering traffic would use the acceleration/ deceleration lanes. The benefits of improved travel time could increase the net annual benefits and benefit-cost-ratios. Further, shifting the exiting and entering traffic out of the right-hand through traffic lanes also would have traffic safety benefits, as conflicts between fast-moving and slow-moving vehicles would be minimized. Additionally, the USACE determined that Alternative D could reduce impacts to the traveling public when future maintenance on the bridges is performed.

In the MRER/EA and FONSI, the USACE determined that its Preferred Alternative for the Bourne and Sagamore highway bridges would be replacement of both highway bridges with new bridges having four through-traffic lanes and two acceleration/deceleration (auxiliary) lanes (Replacement Highway Bridges Built to Modern Design Standards). The USACE indicated that final design would conform to American Association of State Highway and Transportation Officials (AASHTO), FHWA, and MassDOT design standards current at that time.

4.3 Determining Reasonable Alternatives

MassDOT reviewed the USACE MRER/EA alternatives relative to the Cape Cod Bridges Program's Purpose and Need and guidance for determining a range of reasonable alternatives. NEPA as amended requires that Environmental Impact Statements consider a reasonable range of alternatives that are technically and economically feasible and meet the purpose and need of the proposal. As described in 23 CFR 771.105, it is the U.S. Department of Transportation's policy to evaluate alternative courses of action and determine the proposed action that is in the "best overall public interest based upon a balanced consideration of the need for safe and efficient transportation; of the social, economic, and

environmental impacts of the proposed transportation improvement; and of national, State and local environmental protection goals."[7]

Based on guidance provided in AASHTO's Practitioner's Handbook 07 *Defining Purpose and Need and Determining the Range of Alternatives for Transportation Projects*, an alternative can be eliminated in the screening process based on factors related to reasonableness, including but not limited to its inability to meet the purpose and need.[8] Further, AASHTO identified the following:

- An alternative that does not meet the purpose and need is, by definition, unreasonable, and for that reason, it can be eliminated in the screening process.
- Even if an alternative meets or potentially meets the purpose and need, it can still be rejected as unreasonable based on one or more other factors, including environmental impacts, engineering, and cost, and limited ability to meet purpose and need.

4.4 Canal Crossing Alternatives Not Recommended for Further Evaluation

4.4.1 BASE CONDITION (ALTERNATIVE A)

In the MRER/EA's Base Condition (No Action Alternative), the USACE would continue to repair and maintain the Bourne and Sagamore Bridges as needed to maintain public safety. The USACE determined that the Base Condition of a continued program of maintenance and repairs, or the "Fix as Fails" approach, is not a reasonable alternative as it would fail to satisfy the identified Program needs for addressing the underlying structural and roadway design deficiencies of the Bourne and Sagamore Bridges. The USACE indicated that it is likely that as the Bourne and Sagamore bridges continue to age, the repairs would not fully address the safety, efficiency, and effectiveness of the bridges. As a result, lower vehicle weights, traffic volume restrictions, and speed limit postings likely would be required on both bridges to maintain continued bridge safety. Per NEPA requirements, however, the USACE retained the Base Condition (No Action Alternative) in the MRER/EA as the condition against which all other alternatives were measured.

MassDOT evaluated the USACE MRER/EA Base Condition (No Action Alternative) against the Cape Cod Bridges Program Purpose and Need and determined that the Base Condition is not a reasonable alternative as it would not meet the Cape Cod Bridges Program's Purpose and Need. The component deficiencies of the approaching 90-year-old bridges and their increasingly frequent maintenance needs would continue to impede mobility and accessibility for road users crossing Cape Cod Canal. Further, the Base Condition would result in unacceptable safety or operational problems.

As indicated in Section 3.1, the No Build Alternative for the Cape Cod Bridges Program incorporates the MRER/EA's Base Condition. In the Program's No Build Alternative, the Sagamore and Bourne highway bridges would remain federal assets, and USACE would continue to operate, maintain, and repair the bridges under a "Fix as Fails" scenario. Although the No Build Alternative would not meet the identified

[7] https://www.ecfr.gov/current/title-23/chapter-I/subchapter-H/part-771
[8] https://environment.transportation.org/wp-content/uploads/2021/05/ph07-2.pdf

Purpose and Need for the Cape Cod Bridges Program, MassDOT will retain the No Build Alternative in the EIS as the base condition against which all other alternatives will be compared and evaluated.

4.4.2 MAJOR REHABILITATION OF BOTH BRIDGES (ALTERNATIVE B)

This Major Rehabilitation Alternative would involve a major rehabilitation of the Sagamore and Bourne Bridges, consisting of significant repairs and replacement of major bridge components such as connections between the spans and the piers/abutments, hangers that connect deck and truss sections, fracture-critical gusset plates that tie truss members together, and substructure members of the decks. Each major bridge rehabilitation would be expected to take approximately 3.5 years to complete with partial or full closure of the bridges required during construction. The ongoing program of continual inspection, maintenance, and repairs would also continue throughout the remaining life of the bridges.

In the MRER/EA, the USACE indicated that major rehabilitation of both the Sagamore and Bourne bridges would improve the reliability of the bridges and reduce the likelihood of component failure. However, while the Major Rehabilitation Alternative would have a lower initial construction cost compared to replacing the bridges, MassDOT determined that the Major Rehabilitation Alternative would not be acceptable. First, this alternative would an adverse impact on traffic patterns during construction due to lane and full bridge closures. The USACE estimated that major rehabilitation of each bridge would take approximately 3.5 years to complete. With the need to divert traffic between the two bridges during rehabilitation, maintain sufficient traffic capacity, and lessen adverse impacts to traffic throughout the rehabilitation duration, the USACE determined that only one bridge would be worked on at a time. Lane and bridge closures would not occur Memorial Day through Columbus Day, nor on Patriots Day or Thanksgiving weekends, to avoid impacting the tourist travel season. Further, construction would be limited during the winter months. This construction schedule would result in an overall six to eight-year construction period for the rehabilitation of both bridges, with prolonged single and double lane closures on both bridges. Secondly, in the Major Rehabilitation Alternative, the bridges would not be brought up to current engineering standards and regulations. As a result, this alternative would present higher risks, as continued deterioration over time and escalating frequency of future repairs and additional rehabilitation could warrant the need for replacement in the future.

MassDOT determined that the Major Rehabilitation Alternative is not a reasonable alternative as it would not meet the identified needs of the Cape Cod Bridges Program for addressing the underlying structural and roadway design deficiencies of the Bourne and Sagamore bridges and improving accommodations for pedestrians and bicyclists. The component deficiencies of the bridges, combined with prolonged construction period bridge closures and ongoing maintenance requirements throughout the remaining life of the bridges, would continue to impede mobility and accessibility for road users crossing Cape Cod Canal. Further, MassDOT determined that the ongoing deterioration would result in unacceptable safety or operational problems, and the extended construction period with partial and/or full closures of the bridges would result in severe disruption to the town of Bourne and surrounding communities on- and off-Cape. For these reasons, MassDOT did not recommend further consideration of the Major Rehabilitation Alternative.

4.4.3 REPLACEMENT OF ONE OR BOTH HIGHWAY BRIDGES WITH NEW BRIDGES, EACH LIMITED TO FOUR THROUGH TRAFFIC LANES (ALTERNATIVE C)

The Four Travel Lanes Replacement Alternative would involve replacement of one or both existing highway bridges; however, it would not provide auxiliary lanes. Each new bridge would be located along approximately the same alignment as the existing bridges, parallel to them, and offset by the width of the new bridge. The existing bridges would remain in service until the new bridges were in completed and open to traffic.

This Four Travel Lanes Replacement Alternative would, at a minimum, maintain the roadway configuration of the existing highway bridges, consisting of four travel lanes, two in each direction, and a single pedestrian/bicycle lane. The width of the existing 10-foot travel lanes would be increased to 12 feet. Additional improvements would include providing a separated and wider pedestrian and bicycle lane, limiting the bridge grades to approximately four percent, and adding shoulders to accommodate vehicle breakdowns. Additionally, the USACE noted that a secondary evaluation would be conducted to assess and update the existing vertical clearance of 135 feet above mean high water (MHW) to account for fluctuations in relative sea level elevation.

Based on the proximity of the existing interchanges and intersections at the end of each bridge, current FHWA and MassDOT highway design standards require that these types of bridge facilities include acceleration and deceleration lanes (auxiliary lanes) for entering and exiting vehicles to safely transition into or out of through traffic.

MassDOT determined that the Four Travel Lanes Replacement Alternative, consisting of replacing one or two of the existing bridges without providing the needed auxiliary lanes, is not a reasonable alternative. This alternative would not fully meet current FHWA and MassDOT highway design standards, nor would it meet the identified Program Needs to address the substandard design elements of the Cape Cod Canal highway bridges and improve vehicular traffic operations. This alternative would not resolve existing safety and operational problems. For these reasons, MassDOT did not recommend further consideration of the Four Travel Lanes Replacement Alternative.

4.4.4 REPLACEMENT OF ONE OR BOTH HIGHWAY BRIDGES WITH NEW BRIDGES WITH ADDITIONAL (MORE THAN FOUR) NON-FEDERALLY FUNDED THROUGH TRAFFIC LANES, AND TWO AUXILIARY LANES (ALTERNATIVE E)

The Additional Through-Travel Lanes Replacement Alternative would replace one or both existing highway bridges with new bridges that would include additional through traffic lanes beyond the four travel lanes and two auxiliary lanes provided in Alternative D. The existing bridges would remain in service until the new bridges were in completed and open to traffic.

MassDOT determined that this alternative is not reasonable. Providing for additional traffic capacity across one or both replacement highway bridges would require considerable traffic capacity upgrades to the regional highway network on both sides of Cape Cod Canal. These upgrades likely would carry substantially high construction costs and extensive environmental, land use and community impacts. Further, this alternative would be outside the scope of the Cape Cod Bridges Program, as the purpose of

the Program is not to increase capacity. For these reasons, MassDOT did not recommend further consideration of the Additional Through-Travel Lanes Replacement Alternative.

4.4.5 REPLACEMENT OF BOTH HIGHWAY BRIDGES WITH A SINGLE NEW BRIDGE (ALTERNATIVE F)

The Single New Bridge Alternative would replace both existing bridges with a new mid-canal, high-level fixed span highway bridge more centrally located along the canal. The single replacement highway bridge would need to meet the traffic demands of the existing bridges, which would require at least four lanes in each direction (eight lanes total). In this alternative, the existing bridges would remain in service until the new bridge was completed and open to traffic.

MassDOT determined that the Single New Bridge Alternative is not a reasonable alternative as it would fail to meet the identified Program purpose of improving cross-canal mobility and accessibility between the Cape Cod and the mainland for all road users. One mid-canal bridge crossing would decrease road user accessibility for cross-Canal trips, as the replacement bridge would be located farther from developed residential and commercial areas on both the Cape and mainland sides of the canal in the town of Bourne.

MassDOT determined that construction of a new single highway bridge in a central location along the canal would require extensive redesign and realignment of the transportation network on both sides of the canal, including utility corridor relocations. On the Cape side, Routes 28, 6 and 6A, and other local surface roads would require major realignments to route around or connect to a new mid-canal crossing. On the mainland side, Routes 3 and 25 from the east and west, respectively, would need to be realigned and extended to connect to a new mid-canal crossing.

The roadway infrastructure necessary to accommodate a new mid-canal crossing would result in extensive impacts to residential and commercial land uses, Joint Base Cape Cod, as well as sensitive environmental resources including wetlands, open space, and rare species habitat. MassDOT determined that based on the substantial costs, adverse natural resource impacts, and extensive land acquisition, the Single New Bridge Alternative would not be reasonable.

Further, in comparison to the existing two Cape Cod Canal bridge crossings, MassDOT determined that the Single New Bridge Alternative would introduce a level of risk associated with emergency evacuation, access to national defense facilities, and emergency response. If a single highway bridge were fully or partly closed for repairs or otherwise unavailable, there would be no other options for vehicle or pedestrian access across the canal.

Based on its inability to meet the Program Purpose and Need, anticipated high costs, substantial environmental impacts, and public safety considerations, MassDOT determined that the Single New Bridge Alternative is not a reasonable alternative and did not recommend further consideration of this alternative.

4.4.6 CONSTRUCTION OF A NEW THIRD HIGHWAY BRIDGE (ALTERNATIVE G)

The Third Highway Bridge Alternative would involve construction of a third highway bridge that could occur with either an ongoing system of maintenance and repairs of existing bridges (Base Condition, Alternative A), with major rehabilitation of the existing bridges (Major Rehabilitation, Alternative B), or

with replacement of the existing bridges (Bridge Replacement, Alternatives C, D, or E). In all scenarios, construction of a third highway bridge would reduce demand and load on the two existing bridges. Additionally, in all scenarios, the Third Highway Bridge Alternative would require extensive redesign and realignment of the transportation network on both the Cape and mainland sides of the canal to accommodate the new canal crossing, including utility corridors.

MassDOT evaluated the concept of a third highway bridge crossing of Cape Cod Canal in the 2019 Cape Cod Canal Transportation Study. This concept involved construction of a new mid-canal bridge crossing extending from Route 25 north of the Canal to Route 6 south of the Canal. In this alternative that MassDOT considered in the Study, the ongoing program of continual inspection, maintenance, and repairs of the existing Bourne and Sagamore Bridges by the USACE would continue through their remaining life (Base Condition, Alternative A).

Based on conceptual level design, MassDOT estimated that the Third Highway Bridge Alternative would require major infrastructure construction, as well as extensive redesign and realignment of regional highways and local roadways on both the Cape and mainland sides of the canal. The roadway infrastructure necessary to accommodate a new mid-canal crossing would result in extensive impacts to residential and commercial land uses, Joint Base Cape Cod, as well as sensitive environmental resources including wetlands, protected open space, and rare species habitat. MassDOT determined that based on the substantial costs, adverse natural resource impacts, and extensive land acquisition, including that from Joint Base Cape Cod, the Third Highway Bridge Alternative would not be reasonable.

Further, MassDOT determined that the Third Highway Bridge Alternative, in combination with either the Base Condition (Alternative A) or Rehabilitation (Alternative B), would fail to meet the identified Program needs for addressing the underlying structural and roadway design deficiencies of the existing Bourne and Sagamore bridges and would result in unacceptable safety or operational problems. These component deficiencies, combined with ongoing maintenance requirements throughout the remaining life of the existing Bourne and Sagamore bridges, would continue to impede mobility and accessibility for road users crossing the Cape Cod Canal. Additionally, the Third Highway Bridge Alternative with the Rehabilitation Alternative would result in severe disruption to the town of Bourne and surrounding communities on- and off-Cape over a lengthy construction period.

MassDOT determined that the Third Highway Bridge Alternative with a bridge replacement scenario is not a reasonable alternative. While this alternative could meet the Program needs for addressing the underlying structural and roadway design deficiencies of the Bourne and Sagamore bridges through bridge replacement (depending upon the replacement alternative), MassDOT determined that the substantial engineering costs and adverse natural resource impacts of a third highway bridge would make this alternative unacceptable.

Based on these reasons, as well as the findings of MassDOT's 2019 Cape Cod Canal Transportation Study, MassDOT did not recommended further consideration of the New Third Highway Bridge Alternative.

4.4.7 REPLACEMENT OF ONE OR BOTH HIGHWAY BRIDGES WITH A SINGLE TUNNEL OR TUNNELS (ALTERNATIVE H AND ALTERNATIVE I)

The Tunnel Alternative would replace one or both Cape Cod Canal highway bridges with one or more highway tunnels beneath Cape Cod Canal. This alternative would include all required functional systems such as ventilation, fire suppression, drainage, electrical and communication. In this alternative, the existing bridges would remain in service until completion of the tunnel(s).

MassDOT determined that replacing one of the highway bridges with a tunnel is not reasonable as it fails to meet the identified Program needs for addressing the underlying structural and roadway design deficiencies of the existing Bourne and Sagamore bridges. These component deficiencies, combined with ongoing maintenance requirements throughout the remaining life of the existing Bourne and Sagamore bridges, would continue to impede mobility and accessibility for road users crossing Cape Cod Canal. Further, the ongoing deterioration of the remaining bridge would result in unacceptable safety or operational problems.

A second option in the Tunnel Alternative would be replacing both of the highway bridges with a single tunnel or tunnels. This alternative would require that the replacement tunnel or tunnels meet the traffic demands of the existing bridges, which would require at least four lanes in each direction. As a result, replacement of both bridges likely would require more than one tunnel tube (of two lanes in each direction).

MassDOT determined that the Tunnel Alternative is not a reasonable alternative as it would not meet the Program purpose of improving cross-canal mobility and accessibility for all road users. Pedestrians and bicyclists would need to be accommodated by other means as they would be prohibited from traveling within the tunnels due to air quality and safety concerns. Tunnels also have substantial vertical clearance restrictions, which would impede mobility for oversized commercial vehicles crossing Cape Cod Canal.

Further, MassDOT determined that the Tunnel Alternative would require extensive reconfiguration of existing approach highways to meet the required tunnel entrance and exit elevations, as well as existing land elevations on either side of Cape Cod Canal. Due to the depth of the tunnel and the four percent grade needed to meet the roadway network approach, the tunnel length would exceed one mile, with the tunnel portals positioned substantially farther from the canal than the existing bridge approaches. The relocation and realignment of the state and local road systems needed to accommodate the tunnel routes and their portals would make accessibility for cross-canal travel more difficult for Bourne residents proximate to the canal. Additionally, the relocation and realignment could result in extensive impacts to wetlands, recreational facilities, residences, businesses, and Joint Base Cape Cod. For these reasons, MassDOT did not recommend further consideration of the Tunnel Alternative.

4.4.8 REPLACEMENT OF ONE OR BOTH BRIDGES WITH LOW-LEVEL DRAW SPANS (ALTERNATIVE J)

The Low-Level Draw Span Alternative would replace one or both existing highway bridges with low-level draw spans (either bascule bridges or vertical lift spans). The replacement bridges would be constructed in similar alignments to the existing Bourne and Sagamore Bridges. In this alternative, the existing bridges would remain in service until completion of the new bridges.

MassDOT determined that the Low-Level Draw Span Alternative is not a reasonable alternative as it would not meet the identified Program purpose of improving cross-canal mobility and accessibility between Cape Cod and the mainland for all road users. According to the USACE, on an annual basis, Cape Cod Canal is used by more than 3,000 cargo vessels, at least 750 fishing vessels, approximately 150 to 200 military vessels, and more than 4,000 recreational vessels. Frequent draw span openings for passage of marine vessels would result in substantial traffic disruptions and delays to road users crossing Cape Cod Canal. These disruptions and delays would be compounded during the summer months due to high traffic volumes crossing the canal. The traffic disruptions and delays would be overly burdensome to Bourne residents who rely on the bridges for their daily activities and livelihood.

Further, MassDOT determined that replacing one of the existing highway bridges with a low-level span is not a reasonable alternative as it would not meet the identified Program need for addressing the ongoing maintenance requirements of the existing Bourne and Sagamore bridges. Additionally, low-level draw spans require increased maintenance compared to high level bridges and are susceptible to operational issues as they age, which would be highly disruptive to traffic crossing the Cape Cod Canal. The ongoing deterioration of the remaining bridge, as well as the maintenance needs of the replacement low-level draw span, could result in unacceptable safety or operational problems. For these reasons, MassDOT did not recommend further consideration of the Low-Level Draw Span Alternative.

4.4.9 REPLACEMENT OF BOTH BRIDGES WITH LOW-LEVEL CAUSEWAYS (ALTERNATIVE K)

The Low-Level Causeways Alternative would replace both existing highway bridges with low-elevation roadways to provide access across Cape Cod Canal. Tidal flow in the canal would be preserved by including large culverts that would permit tidal exchange, effectively converting the canal to an estuary.

MassDOT determined that the Low-Level Causeways Alternative is not a reasonable alternative. Constructing low-elevation roadways across Cape Cod Canal would require extensive profile modifications to local roads and regional highway connections on both the Cape and mainland sides of the canal, which would carry high infrastructure costs as well as major traffic disruptions. Further, Cape Cod Canal and the areas surrounding the Bourne Bridge are mapped within high-risk flood zones; low-level causeways would increasingly be vulnerable to flooding due to fluctuations in relative sea level elevation and coastal storm surge. Flooding issues along these low-elevation causeways would impair mobility and create unsafe conditions for road users, which threaten efficient and effective response to public health emergencies and disasters. Due to the potential risks associated with the Low-Level Causeways Alternative, this alternative would not meet the identified Program purpose of improving cross-canal mobility and accessibility between Cape Cod and the mainland for all road users.

Based on its inability to meet the Program Purpose and Need, the potential for adverse socio-economic impacts, and increased vulnerability to flooding, and MassDOT determined that the Low-Level Causeways Alternative is not a reasonable alternative and did not recommend further consideration of this alternative.

4.4.10 DEAUTHORIZATION AND CLOSURE OF CAPE COD CANAL (ALTERNATIVE L)

The Canal Deauthorization Alternative would fill Cape Cod Canal and construct surface roadways to provide access across the former canal. The Canal Deauthorization Alternative would eliminate the canal as a navigable waterway in its entirety.

MassDOT determined that the Canal Deauthorization Alternative is not a reasonable alternative based on the high costs and the extent of adverse impacts to the coastal environment. As reported in the USACE's MRER/EA, filling in the canal would require the purchase of approximately three million cubic yards of fill material per mile, as well as additional material for crossings to meet grade levels at existing banks. The material would need to be transported, placed, and spread, graded and the areas reclaimed. The USACE estimated that the cost for such actions would likely be several hundred million dollars. This alternative would result in substantial adverse socio-economic and environmental impacts.

The Cape Cod Canal provides important spawning grounds and habitat for a variety marine species and wildlife populations protected under federal laws and regulations. Filling in Cape Cod Canal would severely impact environmental resources protected under other federal statutes, including the Essential Fish Habitat of multiple species protected under the Magnuson Stevens Fishery Conservation and Management Act; the endangered North Atlantic Right Whale, protected under the Endangered Species Act (ESA); and non-ESA listed whales, dolphins, porpoises, and seals protected under the Marine Mammal Protection Act.

Further, the Cape Cod Canal is a federally authorized Civil Works Project; as such, the Canal Deauthorization Alternative is not within MassDOT's authorization.

The Canal Deauthorization Alternative would result in substantial adverse impacts to Cape Cod residents and visitors who utilize the canal facilities for recreation. In addition to the two Canal Service Roads and the waterway, most of the land surrounding the canal at and near the existing bridge sites consists of land managed or leased by the USACE for recreation and identified as Section 4(f) resources. At the Bourne Bridge crossing, these recreation lands include the Bourne Recreation Area, Bourne Bridge Area, and the 112-acre Bourne Scenic Park, leased to the Bourne Recreation Authority for camping. At the Sagamore Bridge crossing, these recreation lands include the Sagamore Recreation Area and the Sagamore Bridge Area.

Based on the high construction costs, as well as the anticipated substantial adverse socio-economic and environmental impacts, MassDOT did not recommend further consideration of the Canal Deauthorization Alternative.

4.5 Canal Crossing Alternative Recommended for Further Evaluation

4.5.1 REPLACEMENT OF ONE OR BOTH HIGHWAY BRIDGES WITH NEW BRIDGES EACH LIMITED TO FOUR THROUGH LANES AND TWO AUXILIARY LANES (ALTERNATIVE D)

The Four Travel Lanes and Two Auxiliary Lanes Replacement Alternative would replace the existing highway bridges with four travel lanes, two in each direction, as proposed in Alternative C. In addition, this alternative would include construction of two auxiliary lanes, one in each direction, to comply with current MassDOT and FHWA standards and guidelines for highway and bridge design. Including acceleration/deceleration lanes on the bridge deck would allow for two through lanes of traffic in each direction, while improving safety for exiting and merging vehicles and avoiding back-up of exiting vehicles onto the through travel portions of the bridge deck. The existing bridges would remain in service until the new bridges were completed and opened to traffic.

MassDOT determined that replacement of only one bridge in this alternative is not reasonable for further evaluation based on its limited ability to meet the Program Purpose and Need. In the event that only one of the bridges were replaced and built to modern design standards, the other bridge would still require an ongoing program of continual inspection, maintenance, and repairs by the USACE. The underlying roadway design deficiencies would persist, and the ongoing deterioration of the remaining bridge would result in unacceptable safety or operational problems.

MassDOT determined that replacing both bridges with new adjacent bridges, each providing two through traffic lanes and an auxiliary lane in each direction and built to current design standards, would meet the identified Program Needs to address the escalating bridge maintenance demands and improve traffic operations and accommodations for pedestrians and bicyclists. Based on its ability to fully meet the Program Needs, while minimizing the approach road modifications necessary to connect the replacement bridges to the regional and local transportation system, MassDOT recommended the advancement of this alternative for further consideration.

Based on a review of the USACE MRER/EA alternatives in light the Cape Cod Bridges Program's Purpose and Need, as well as other factors including environmental impacts, public safety, and cost, FHWA and MassDOT recommended that replacement highway bridges built to modern design standards is the only reasonable alternative to be advanced for further study in the EIS. This recommendation for the Build Alternative Retained for Detailed Study is consistent with the findings of the USACE's MRER/EA. MassDOT reviewed the results of this initial screening and its recommendation with the public through virtual public meetings in June 2021.

4.6 Assessments of USACE Recommended Conceptual Design Parameters

In its description of its Preferred Alternative of Replacement Highway Bridges Built to Modern Design Standards, the USACE identified bridge design parameters as well as its understanding of the construction process. While the USACE indicated that it would defer development of actual bridge type and other design parameters until further advancement of the program to replace the highway bridges, the MRER/EA identified design parameters at the conceptual design level for the bridge highway cross

section, bridge clearances, bridge deck configuration, and mainline alignment location. The MRER/EA also included recommendations for the location of the bridge piers. Figure 4-1 shows the USACE's Preferred Alternative concept for the replacement bridges presented in the MRER/EA.

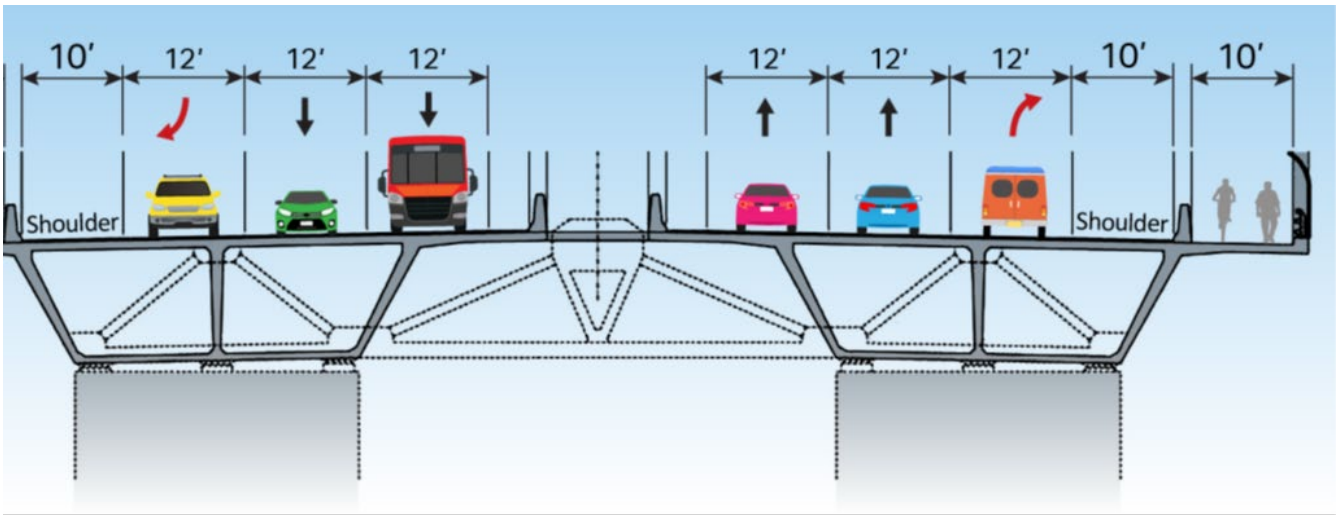


Figure 4-1. MRER/EA Preferred Alternative: Replacement Highway Bridges Built to Modern Design Standards

The MRER/EA presented the USACE's understanding of the replacement bridge construction sequencing. The USACE recommended that the existing bridges remain in service with operation, maintenance, and repaired as needed, until the new bridges are opened to traffic. The existing bridges would be demolished upon the opening of the new bridges.

In considering the USACE's Preferred Alternative for Replacement Highway Bridges Built to Modern Design Standards, MassDOT conducted independent assessments of the USACE's conceptual bridge design parameters and recommendations. Sections 4.6.1 through 4.6.5 summarize present the USACE's concepts of the bridge design parameters as presented in the MRER/EA. MassDOT's assessments of the USACE's recommendations are provided in Sections 5 through 9 of the Alternatives Analysis Report.

4.6.1 BRIDGE HIGHWAY CROSS SECTION

The MRER/EA indicated that each new bridge would include four 12-foot-wide through travel lanes, two in each direction. Each new bridge would have two 12-foot-wide auxiliary lanes for entrance and exit, one in each direction. Each new bridge would include one non-vehicular lane for pedestrian and bicycle traffic (shared use path) with separation between the non-vehicular lane and the vehicle traffic lanes. Each new bridge would include shoulder width on the vehicle deck. Each new bridge would include a median to separate northbound and southbound vehicular traffic. Each new bridge would have deck and approach grades no steeper than 4 percent. Section 5 presents MassDOT's assessments of the USACE's recommendations for the bridge highway cross section and shared use path.

4.6.2 BRIDGE CLEARANCES

The MRER/EA indicated that each new bridge would have a minimum vertical clearance for navigation of 135 feet above mean high water (MHW) over the width of the navigation channel, increased by 7.8 feet to accommodate fluctuations in relative sea level elevation. Additionally, the USACE indicated that horizontal clearance for navigation must be considered with the replacement bridge design. Section 6 presents MassDOT's independent evaluation of the bridge clearances.

4.6.3 MAIN SPAN LENGTH AND BRIDGE PIER LOCATION

As the operator of the Cape Cod Canal, the USACE noted its preference for bridge piers located outside of the canal channel. The MRER/EA indicated that locating the replacement bridge piers outside of the water would open the horizontal clearance, improve navigational safety, and provide easier access to the piers for inspection and maintenance. Section 7 presents MassDOT's assessment of the main span length and bridge pier location.

4.6.4 BRIDGE DECK CONFIGURATION

As shown in Figure 4-1, the MRER/EA's concept for each replacement highway bridge consisted of a single deck that would accommodate the increased width of the through travel lanes, two auxiliary lanes, a shared use path and shoulders. Section 8 presents MassDOT's assessment of the conceptual bridge deck configuration presented by the USACE.

4.6.5 MAINLINE ALIGNMENT LOCATION

The MRER/EA indicated that for the USACE's Preferred Alternative**,** the two new highway bridges would be constructed parallel to and immediately inshore of the existing Bourne and Sagamore Bridges. Section 9 presents MassDOT's assessment of the USACE's recommendation for an inboard location for the mainline alignment, including consideration of the proposed construction sequencing presented in the MRER/EA.

5 Assessment of Bridge Highway Cross Section and Shared Use Path

5.1 Introduction

Section 5 describes MassDOT's evaluation and confirmation of the proposed bridge highway cross-section, including the highway travel and auxiliary lanes and shared-use path, as presented in the MRER/EA's description of the USACE's Preferred Alternative (Section 4.6).

5.2 Bridge Highway Cross-Section

MassDOT evaluated the composition and dimensions of the proposed bridge highway cross-section and the maximum profile grades relative to the MRER/EA's recommendations that each new bridge would include four 12-foot-wide through travel lanes, two in each direction; two 12-foot-wide auxiliary lanes, one in each direction; a shoulder; a separation median; and maximum grades. The design of the proposed cross section composition and dimensions would be consistent with MassDOT and AASHTO design criteria.

The Program mainlines consist of Route 3 and Route 6 at the Bourne crossing, and Route 25 and Route 28 at the Sagamore crossing. According to MassDOT's Road Inventory File, the federal functional classification for Route 3, Route 6, Route 25, and Route 28 (except for Route 28 south of and including the Bourne Rotary) is identified as "Principal Arterial – Other Freeways." Route 28 has a federal functional class of "Principal Arterial – Other" from the Bourne Rotary to the Otis Rotary, approximately four miles south of the Bourne Rotary. To align with the roadway type and context, including roadway users' expectations regarding approach speeds and average running speeds, the mainline at the Bourne replacement bridge (Route 28) would have a design speed of 55 miles per hour (MPH) and the mainline at the Sagamore replacement bridge (Route 6) would have a design speed of 60 MPH.

To confirm the USACE's decision to include auxiliary lanes in the replacement highway bridge roadway design, MassDOT evaluated design criteria that would warrant a continuous auxiliary lane over the bridge structures, including interchange spacing, traffic operations under future No Build conditions, geometric guidelines, and constructability. Per AASHTO highway design standards for adequate acceleration lane, deceleration lane, and taper lengths for interchange access to the bridges north and south of the canal crossings, a continuous auxiliary lane in each direction for the full length of the Sagamore Bridge and the southbound direction of the Bourne Bridge is required. For the northbound Bourne Bridge crossing, the constructability of the bridge and the need to accommodate users during construction necessitates the additional structure width.

Considering the functional classification and the rolling terrain at both bridge sites, MassDOT evaluated the appropriate profile grade for each highway bridge. MassDOT proposes a maximum grade of 4.5 percent for the Bourne replacement bridge and a maximum grade of 4 percent for the Sagamore replacement bridge. The proposed grades would be considerably flatter than the existing bridge grades of 6 percent. The flatter grades would improve safety by reducing the effect of the speed differential for trucks approaching the crest of the bridges, and they would reduce the likelihood of trucks and other vehicles becoming stuck during snow and ice events.

5.3 Shared Use Path

The conceptual design for the MRER/EA's Preferred Alternative included a single dedicated 10-foot-wide shared use path for pedestrians and bicyclists for each crossing. The proposed shared use paths would be designed in accordance with MassDOT, AASHTO, and FHWA design criteria, as well as the guidance of the Americans with Disabilities Act (ADA) and the Architectural Access Board (AAB). The shared use paths on the Bourne and Sagamore Bridges would follow the proposed mainline roadway profiles and, where possible, the grades would be reduced on the approaches to the bridges. MassDOT is continuing to evaluate options for the width of the shared use path, to be determined as design advances.

Figure 5-1 presents a schematic of the bridge highway cross-section at the Bourne and Sagamore crossings.[9]

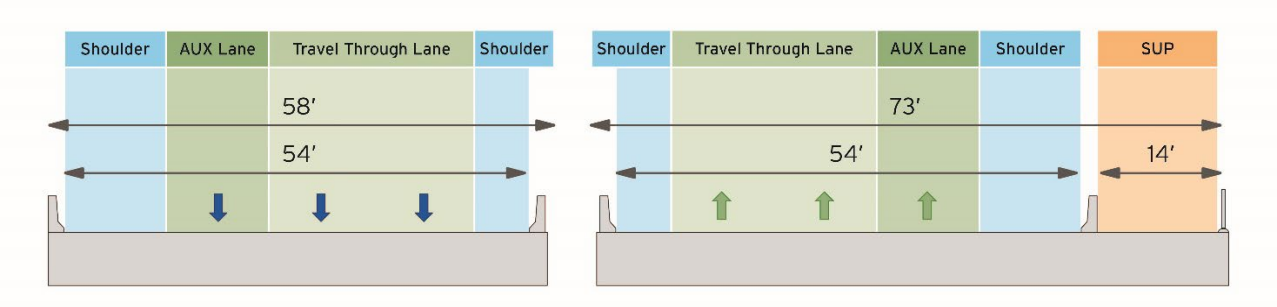


Figure 5-1. Replacement Bridge Highway Cross-Section

In accordance with AASHTO and FHWA design criteria and ADA guidance, MassDOT recommendations for the highway deck cross-section consisted of two 12-foot-wide through travel lanes, a 12-foot-wide entrance/exit (auxiliary) lane, a 4-foot-wide left shoulder, and a 10-foot-wide right shoulder. Right and left barriers would be offset an additional 2 feet beyond the limits of the shoulders, for a total structure width of 54 feet curb to curb. Additionally, each bridge crossing would include one bi-directional pedestrian and bicycle shared use path (SUP), separated from vehicular traffic by the shoulder and barrier.

6 Assessment of Bridge Vertical and Horizontal Clearances

6.1 Introduction

Section 6 describes MassDOT's assessment and determination of the proposed bridge vertical and horizontal clearances, incorporating the USACE's Preferred Alternative of Replacement Highway Bridges Built to Modern Design Standards, relative to the recommendations presented in the USACE's MRER/EA (Section 4.6). The results of the assessment are incorporated into the Program's bridge type assessments presented in Sections 10 and 11.

6.2 Bridge Vertical Clearance

The existing Bourne and Sagamore bridges each provide a vertical clearance of 135 feet above mean high water (MHW). In the MRER/EA, the USACE determined that the new bridge vertical clearances should account for fluctuations in relative sea level, provided the 135-foot clearance of the existing bridges were to remain as a goal for navigable transit of Cape Cod Canal by auto carriers and cruise ships, the largest ships currently using the canal.

[9] MassDOT has not determined the total width of the shared use path. A 14-foot-wide shared use path is shown for illustrative purposes only.

Accordingly, MassDOT recommended an increase in bridge height by approximately three feet, which would maintain the existing vertical clearance at 135 feet above MHW with accommodations for fluctuations in relative sea level. The effective vertical clearance of both replacement bridges would match existing conditions at 135 feet above MHW.

6.3 Bridge Horizontal Clearance

The existing Bourne and Sagamore bridges each provide a 500-foot horizontal clearance over Cape Cod Canal. The existing bridges have piers located within the canal cut, seaward of the slope protection but outside of the channel limits. The channel has a bottom cut width of 480 feet within the land cut reaches, including between the bridges. In the MRER/EA, the USACE indicated that increasing the effective horizontal clearance for navigation should be considered with the replacement bridges.

Incorporating the USACE's recommendation, MassDOT recommended that the replacement bridge structures provide a minimum of 500 feet of horizontal navigational width, to be consistent with existing conditions.

7 Assessment of Main Span Length and Bridge Pier Location

7.1 Introduction

Section 7 presents the results of the main span length and bridge pier location assessment, wherein MassDOT identified and assessed options for the main span length and location of bridge piers for the replacement bridges. The results of the assessment are incorporated into the Program's bridge type assessment presented in Section 10. Appendix A, the Cape Cod Bridge Replacements Initial Screening Report, provides more details on the main span length and bridge pier location analysis.

7.2 Main Span Length and Pier Location Options

The bridge piers for the existing Bourne and Sagamore bridges are located within the canal and outside the navigation channel and support a mainline center span length of 616 feet. In the MRER/EA, the USACE noted that locating any new piers on land outside of the canal cut would require moving the pier locations landward by about 50 feet on each shore. It also would require lengthening the main span over the waterway. As indicated in Section 4.6, the USACE indicated its preference for bridge piers located outside of the canal cut as a means to improve navigation as well as operations and maintenance.

Incorporating the USACE's Preferred Alternative for Replacement Highway Bridges Built to Modern Design Standards, and in coordination with the USACE and FHWA, MassDOT identified two options for the replacement bridge pier locations: In-Water and Out-of-Water. The In-Water Option includes two variations for the approximate main span lengths: 525 feet and 616 feet. The shortest possible span length of 525 feet would be dictated by the minimum required horizontal clearance of 480 feet between

the edges of the footings.[10] The 616-foot span length would equal the span length of the existing bridges, thereby maintaining the status quo for channel operations. The Out-of-Water Option also includes two variations for the approximate main span lengths: 700 feet and 820 feet. A medium span length of approximately 700 feet would locate the piers within the rip rap slope and above the low tide line. A longer span length of approximately 820 feet would locate the piers entirely on land.

7.3 Design Evaluation Criteria and Assessment Methodology

Through a collaborative process with the USACE and FHWA at the onset of the Cape Cod Bridges Program, MassDOT developed design evaluation criteria to assess the Program's bridge design parameters. Table 7-1 lists the ten major categories of evaluation criteria, including their subcategories.

Table 7-1. MassDOT Bridge Design Parameter Evaluation Criteria

Design Evaluation Category	Subcategories
Initial Cost	Main Span Structure
	Main Span Foundations
	Overall
Highway Geometrics	Grade/Length
	Footprint
	Horizontal Tangent Length
Main Span Footings	Vessel Impact
	Scour
Construction	Phasing
	Duration
	Constructability
	Impact on Canal Traffic
	Environmental Impact
Structural Redundancy	Fracture-Critical Members
	Failure-Critical Members
Inspection & Maintenance	Access
	Frequency
Durability	Protection
	Replacement
	Monitoring
Wind Response	Structural Efficiency
	Dynamic Effects
Snow & Ice Response	Bridge Closures
	Monitoring/Deicing
Community Considerations	Aesthetics/Signature

[10] Early coordination with the USACE identified a 480-foot horizontal channel width requirement. In later discussions with the USACE, MassDOT confirmed a 500-foot horizontal channel width requirement.

For the main span and bridge pier location assessment, MassDOT focused on the following three design evaluation criteria as they are the only criteria from Table 7-1 that are applicable to this bridge design parameter:

- Initial Costs, consisting of a qualitative assessment of main span structure and main span foundation costs.
- Main Span Footings, including potential for vessel impact and scour.
- Construction, including duration of construction, constructability, impact on ongoing canal traffic, and environmental impact.

MassDOT used an unscaled, qualitative rating scheme to facilitate the assessment. Of particular importance are the triple-green (●●●) and triple-red (●●●) ratings, indicating pier location options and variations that MassDOT recommended for further consideration, or the pier location options and variations that MassDOT did not recommend for further consideration.

7.4 Main Span and Bridge Pier Location Assessment Results

Table 7-2 presents the results of the main span and bridge pier location assessment. Based on its easier constructability by land, its substantially reduced impacts to environmental resources and navigation, and the preferences of the USACE as the operator of Cape Cod Canal, MassDOT recommended that the Out-of-Water location for the bridge piers, including both medium main span and long main span variations, be carried forward for further evaluation. In January 2023, MassDOT conducted virtual public meetings to review its recommendations resulting from the main span length and bridge pier location assessment.

Table 7-2. Summary of Main Span Length and Bridge Pier Location Assessment

Bridge Design Evaluation Criteria [a]	Pier Locations/Main Span Lengths			
	In-Water Option		Out-of-Water Option	
	Minimum/525 feet	Existing/616 feet	Shore Line Piers/700 feet	Land Piers/820 feet
Cost				
• Main Span Structure	●●	●	●	●●
• Main Span Foundation	●●	●●	●	●●
Main Span Footings				
• Vessel Impact	●●●	●●	●●●	●●●
• Scour	●●	●●	●●	●●●
Construction				
• Duration	●	●	●	●
• Constructability	●●	●	●●	●●
• Impact on Canal Traffic	●●	●	●●	●●●
• Environmental Impact	●●	●●	●	●●

a. ●●● Most favorable; ●● Favorable; ● Neutral; ●● Less Favorable; ●●● Unfavorable; ●● Not Rated

7.5 Details of the Main Span and Bridge Pier Location Assessment

Section 7.5 presents a detailed discussion of Table 7-2 ratings and MassDOT's recommendations on advancing or not carrying forward bridge pier locations for further design and evaluation.

7.5.1 OPTION RECOMMENDED FOR FURTHER EVALUATION: OUT-OF-WATER PIERS

Both spans of the Out-of-Water Option were recommended for further evaluation, as described in Sections 7.5.1.1 and 7.5.1.2.

7.5.1.1 700-Foot Span

A medium main span length of approximately 700 feet would locate the replacement bridge piers at the waterline adjacent to the service road (shoreline piers), into the rip rap slope but above the low tide line, as shown in Figure 7-1.

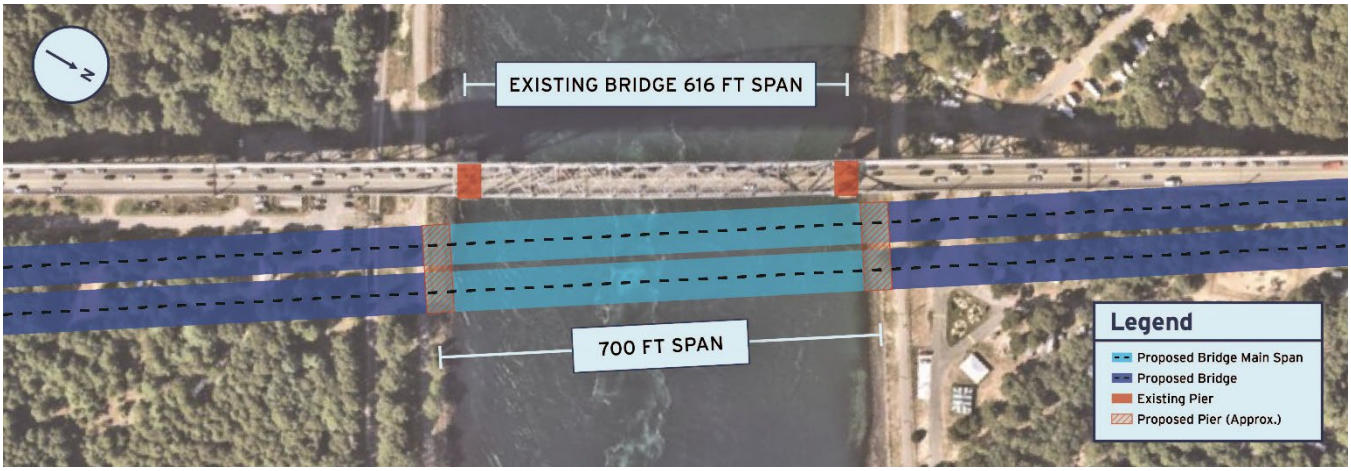


Figure 7-1. Main Span and Pier Location Out-of-Water Option: Approximate 700-Foot Span Length

Initial Costs Rating: Neutral

The pier construction would be from the land, which would be easier than construction from the water; however, the foundation installation would require some land-based installation of sheeting for work in the tidal zone.

Main Span Footing Rating: Favorable to Most Favorable

With an approximate 700-foot span, the piers would be located outside the waterway and in the rip rap, and the potential for off-course vessels to impact the piers would be substantially reduced. With an armored slope, the 700-foot span receives a favorable rating regarding the potential for scour. Because the longer spans would effectively improve navigation conditions, the USACE indicated a preference for medium to long mainline span lengths.

Construction Rating: Neutral to Favorable

In the 700-foot span of the Out-of-Water Option, there would be no channel fouling. Pier construction would be from the land; however, the installation of sheeting would require work in the water and impact water quality.

7.5.1.2 820-Foot Span

A long main span length of approximately 820 feet would locate the replacement bridge piers entirely on land (land piers), as shown in Figure 7-2.

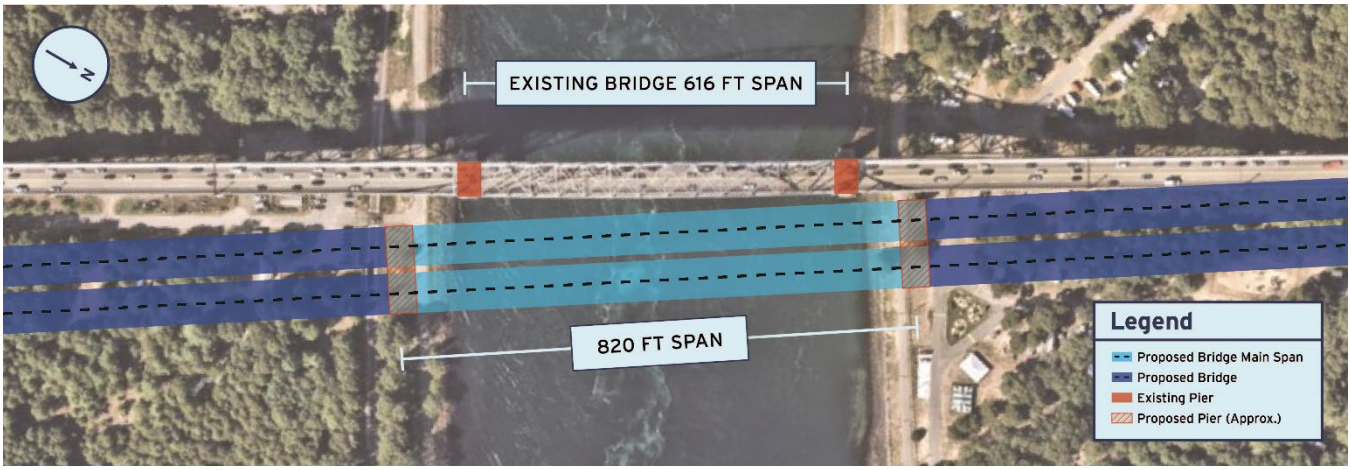


Figure 7-2. Main Span Out-of-Water Option: Approximate 820-Foot Span Length

Initial Costs Rating: Less Favorable to Favorable

The longest span length would have the highest superstructure costs relative to the other span lengths. Because it would provide the best accessibility for foundation construction, via the land, the 820-foot span length receives a favorable rating for the main span foundation costs.

Main Span Footing Rating: Most Favorable

There would be no impact to vessels or canal traffic and no potential for scour with an approximate 820-foot main span length. Because the longer spans would effectively improve navigation conditions, the USACE indicated a preference for medium to long mainline span lengths.

Construction Rating: Neutral to Most Favorable

The longest span of the Out-of-Water Option would involve a more difficult superstructure. With an 820-foot span, there would be no channel fouling. With construction only on land, there would be no impacts to the waterway, but the land location would impact the USACE's existing service roads along each bank.

7.5.2 OPTION NOT RECOMMENDED FOR FURTHER EVALUATION: IN-WATER PIERS

Neither span of the In-Water Option was recommended to be carried forward for further evaluation, as described in Sections 7.5.2.1 and 7.5.2.2.

7.5.2.1 525-Foot Span

A main span of approximately 525 feet would locate the bridge piers just outside the navigational limits, as shown in Figure 7-3.

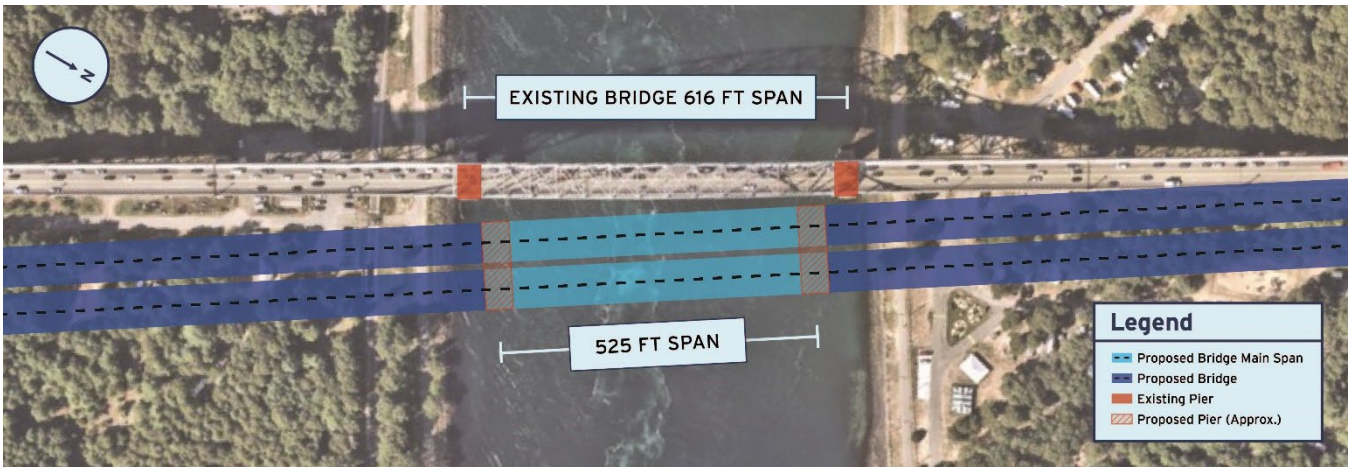


Figure 7-3. Main Span In-Water Option: Approximate 525-Foot Span

Initial Costs Rating: Less Favorable to Favorable

The shortest span of the In-Water Option would have the lowest superstructure cost in comparison to the other main span lengths, but it would have the highest foundation costs relative to the other span lengths. Due to their location just outside the navigation channel limits, the piers would be designed and constructed to withstand vessel impacts, which would increase construction costs. Additionally, this option would require a full marine cofferdam for construction, increasing costs.

Main Span Footing Rating: Less Favorable to Unfavorable

The USACE indicated that the shortest span of 525-feet would not be acceptable for canal navigation operations; locating the main span footings at the channel limits would increase the potential for vessel impacts and would adversely impact existing navigation conditions.

Construction Rating: Neutral to Most Favorable

The piers would be constructed from the water using a cofferdam, with access from the water via a construction trestle (work platform). Construction and operation of this main span length would impact environmental resources, including water quality, with a potential for scour and a high propensity for channel fouling.

7.5.2.2 616-Foot Span

A mainline center span length of approximately 616 feet would locate the replacement bridge spans outside the navigation channel and closer to the shoreline, as shown in Figure 7-4.

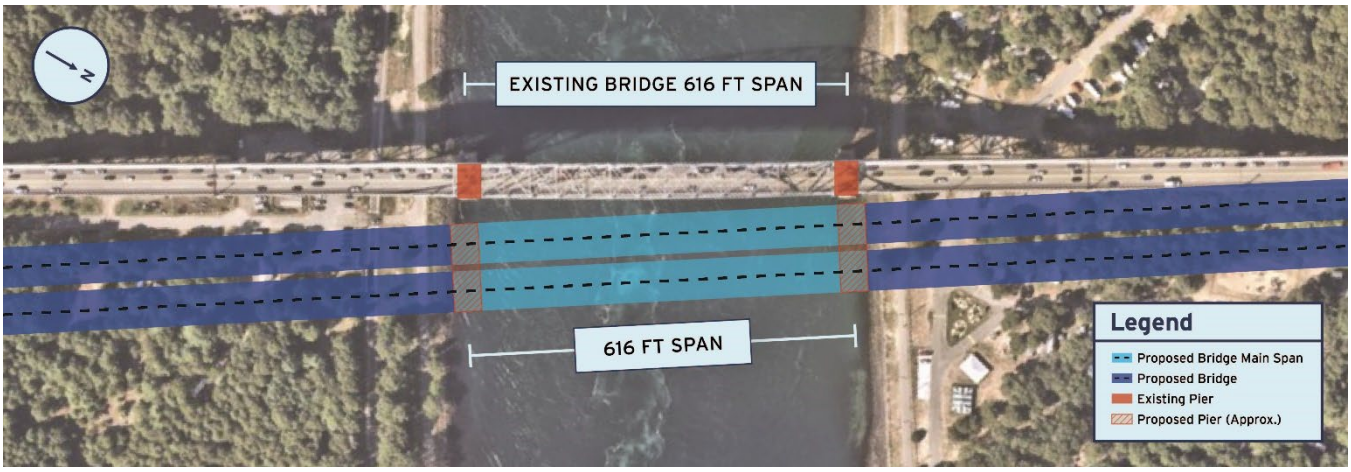


Figure 7-4. Main Span In-Water Option: Approximate 616-Foot Span Length

Initial Costs Rating: Less Favorable to Neutral

Like the 525-foot short span, the 616-foot main span would incur high foundation costs relative to the Out-of-Water Option; it would require construction from the waterway via a construction trestle with a cofferdam in the waterway.

Main Span Footing Rating: Less Favorable

While this span length would not alter existing navigation conditions, the USACE indicated that longer bridge spans would be preferred. This option would have a potential for impacts to the pier foundations by small vessels and shallow draft barges. Currently, the footings do not have substantial scour, therefore scour in this option would not be likely.

Construction Rating: Less Favorable to Neutral

The piers would be constructed from the water using a cofferdam, with access from the water via a construction trestle (work platform). Construction and operation of this mainline span length would impact environmental resources, including water quality.

8 Assessment of Bridge Deck Configuration

8.1 Introduction

Section 8 presents the results of MassDOT's assessment of the conceptual bridge deck configuration presented as a bridge design parameter of the USACE's Preferred Alternative (Section 4.6). Appendix A, the Cape Cod Bridge Replacements Initial Screening Report, provides additional information on the bridge deck configuration assessment.

8.2 Design Evaluation Criteria and Assessment

Of the bridge parameter design evaluation criteria listed in Table 7-1, MassDOT focused its qualitative assessment on the constructability aspects of the bridge deck configurations, including duration of construction, construction complexity, and potential for construction phasing. MassDOT also evaluated the durability and structural redundancy aspects of the bridge deck configurations.

To accommodate the roadways, shoulders, and pedestrian/bicycle path, the required roadway width of a single deck for the highway bridges would be substantial (approximately 129 feet), necessitating a roadway deck with large floor beams. Constructing a single wide deck would add a level of complexity associated with transportability, potentially resulting in larger float-in weights and sizes, larger crane requirements for erection, and interim stability. Additionally, a single deck configuration would have a greater structure depth, requiring a steeper or longer approach on both sides of the canal. The constructability challenges of a single roadway deck would increase overall project costs.

As a variation of the single deck configuration for the highway bridge presented in the MRER/EA, MassDOT investigated constructing separate deck structures for each replacement highway bridge, consisting of two parallel separate northbound and southbound decks (barrels). Separate structures would use cost-effective, smaller construction elements with a shallower floor beam depth, which would simplify fabrication and erection.

Additionally, MassDOT determined that separate structures would allow for phased construction of parallel bridge structures, facilitating an earlier decommissioning and demolition of the existing highway bridges than with a single deck. In a two-deck approach, one replacement highway bridge span would be erected first and carry two-way traffic in a temporary configuration, providing the same number of travel lanes as the existing highway bridge. The next phases would be to demolish the existing bridge and construct the second bridge. The last phases would be to route traffic onto separate northbound and southbound structures and reconfigure the first highway bridge for one-way traffic. This construction method reinforced the USACE's construction preferences indicated in the MRER/EA. Figures 8-1 and 8-2 show a schematic comparison of the single deck and two separate deck configurations.[11]

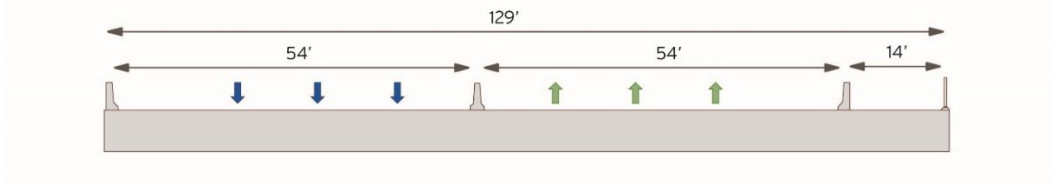


Figure 8-1. Bridge Structure Configuration with a Single Deck

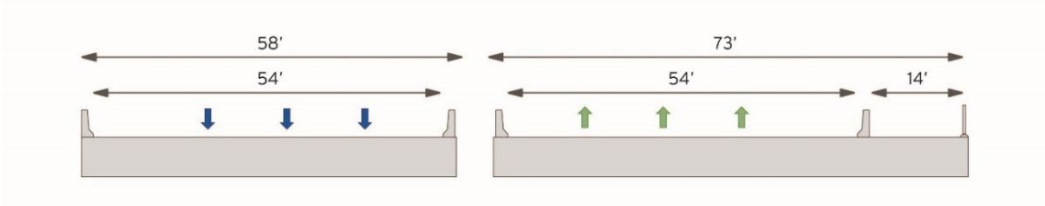


Figure 8-2. Bridge Structure Configuration with Two Separate Decks

[11] MassDOT has not determined the width of the shared use path; the 14-foot-wide path is shown for illustrative purposes only.

In a phased construction approach, a new structure, albeit in a temporary configuration, would be available more quickly than with single-stage construction; however, the overall construction time might be longer. Single-phase construction might shorten the overall schedule; however, the existing highway bridges would need to remain in service longer than in a phased construction approach. Extending the service period of the existing Bourne and Sagamore bridges not only would require a continued maintenance and repair program of the functionally obsolete and deteriorating bridges, but also could trigger an extensive rehabilitation of bridge components to extend their useful life and to avoid weight restrictions, lane reductions, and/or lane closures.

A replacement highway bridge with two separate deck structures would have a larger footprint than one with a single deck structure due to the need to provide adequate spacing, approximately 10 feet, between the individual structures.

Two separate deck structures would provide long-term benefits relative to the life of the bridge that the single deck span would not offer. The two individual roadway deck structures would provide structural redundancy and would facilitate inspection, maintenance, and replacement, as each structure could operate independently. Further, two separate bridge structures at each crossing would provide advantages in case of an emergency evacuation or a compromising event impacting a single bridge structure.

8.3 Results of Bridge Deck Configuration Assessment

Based on its assessment of proposed bridge deck configurations, which identified advantages and disadvantages of each option, MassDOT determined that both bridge deck configurations would be feasible depending on the bridge type and advanced the single deck and separate deck options for further evaluation. The result of this assessment of the bridge deck configuration is incorporated into MassDOT's bridge type assessment, presented in Section 10.

9 Assessment of Mainline Alignment Location

9.1 Introduction

Section 9 presents MassDOT's assessment of the mainline alignment location presented as a bridge design parameter of the USACE's Preferred Alternative: parallel to and immediately inshore of the existing Bourne and Sagamore Bridges (Section 4.6). Incorporating the USACE's Preferred Alternative of Replacement Highway Bridges Built to Modern Design Standards, MassDOT's assessment of the mainline alignment location also included consideration of the proposed construction sequencing as presented in the MRER/EA.

9.2 Mainline Alignment Location Options

In coordination with FHWA and USACE, MassDOT developed five optional locations for the highway bridge mainline alignment over Cape Cod Canal. These mainline alignment locations, consisting of the Fully Offline Inboard, Partially Offline Inboard, Partially Offline Outboard, Fully Offline Outboard and Split, are defined as follows:

- Fully Offline, where both barrels of the replacement highway bridge are located outside the footprint of the existing bridge.
- Partially Offline, where portions of the replacement highway bridge are located within the footprint of the existing bridge and portions of the replacement highway bridge are located outside the footprint of the existing bridge.
- Inboard, where the replacement highway bridge is located on the side of the canal between the existing Bourne Bridge and Sagamore Bridge. For Bourne, the replacement bridge would be east of the existing bridge closer to Cape Cod Bay. For Sagamore, the replacement bridge would be west of the existing bridge closer to Buzzards Bay.
- Outboard, where the replacement highway bridge is located on the bay side of the existing bridge. For Bourne, the replacement bridge would be west of the existing bridge closer to Buzzards Bay. For Sagamore, the replacement bridge would be east of the existing bridge closer to Cape Cod Bay.
- Split, where the traffic heading on-Cape would be located on one side of the existing bridge and the traffic heading off-Cape would be located on the other side of the existing bridge.

Except for the Split location, the barrels of the replacement bridges would be constructed parallel to and approximately 10-feet apart from each other.

9.3 Design Evaluation and Assessment Methodology

In collaboration with FHWA, MassDOT established Program highway design criteria to evaluate the five optional highway bridge mainline alignment locations, based on the Cape Cod Bridges Program needs to address the substandard design elements of the bridges relative to the mainline approaches and their adjacent interchanges and intersections, improve vehicular traffic operations, and improve accommodations for pedestrians and bicyclists. Additional objectives included minimizing temporary and permanent environmental impacts, including right-of-way impacts and impacts to the traveling public. Table 9-1 lists the Program's highway design evaluation criteria and applicable performance measures.

Table 9-1. Cape Cod Bridges Program Highway Design Evaluation Criteria and Goals

Highway Design Evaluation Criteria	Evaluation Criteria Performance Measure
Operations	Ability to improve existing traffic operations Compared to the existing operations. This analysis takes into consideration the proposed cross section dimensions, the introductions of auxiliary lanes and other features that affect operations. Improving traffic operations and cross canal mobility is included in the Purpose and Need.
Connectivity	Ability to maintain or improve existing roadway connections
Geometrics	Evaluation of the geometry of each option relative to the existing geometry and the ability to meet or exceed current MassDOT and FHWA design standards, without design exceptions, including but not limited to mainline

Highway Design Evaluation Criteria	Evaluation Criteria Performance Measure
	curve lengths, stopping sight distances, and grade profiles for connecting to the interchange approach networks.
Safety	Ability to improve existing safety conditions by reducing predicted crash frequency, crash rate, crash type, and/or crash severity.
Constructability	Ability to maximize constructability and construction efficiency, including maintaining two traffic lanes in each direction at each crossing during construction, maintaining all connections to the local roadway network at locations like the existing condition during construction, maintaining and/or improving schedule and costs, minimizing impacts to the traveling public, and reducing complexity relative to staging and need for temporary structures.
Multi-Modal Connections	Evaluation of how well each mainline option will accommodate bicyclists and pedestrians, including ability to provide for multi-modal uses through separated bicycle and pedestrian accommodations on the bridge structure and to the interchange approach network. Includes consideration of safety and the user experience.
Utility Impacts	Ability to minimize direct and indirect impacts to existing utilities within the footprints of the existing and/or replacement bridges, including relocations.
Environmental Impacts	Ability to minimize impacts to protected resources.
Right-of-Way Impacts	Ability to minimize impacts to properties, including full acquisitions and partial acquisitions, potential displacement, in consideration of the uses of the properties and the magnitude of the impact (acquisition of entire parcel, partial acquisition, vacant lots, active businesses, etc.) and adverse impacts to Environmental Justice (EJ) communities.

The mainline alignment locations were rated based on their performance relative to meeting the Program design evaluation criteria. MassDOT placed high priority on advancing highway bridge mainline alignment location options that would be practical and feasible to construct and maintain. While the evaluation associated with some of the Categories did not result in a differentiation among the options for the mainline alignment locations. MassDOT included these categories in anticipation that they would be critical criteria in evaluating the highway interchange approach options. While this analysis focused on the mainline alignment location options, the evaluation also accounted for the benefits and the impacts associated with establishing the connections from the mainline roadways to the local roadway network.

MassDOT recommended that options that would be impractical and/or infeasible not advance for further evaluation. MassDOT used an unscaled, qualitative rating scheme to facilitate the screening. Of particular importance are the triple-green (●●●) ratings and triple-red (●●●) ratings, indicating options that MassDOT recommended advancing for further design or options that MassDOT did not recommend advancing for further consideration.

In January 2023, MassDOT conducted virtual public meetings to review the assessment results and to present its recommendation for the Fully Offline Inboard location for the Bourne and Sagamore crossings. In May 2023, MassDOT also hosted an in-person Open House in Bourne to solicit public feedback on its recommendations, including the mainline alignment locations.

9.4 Summary of Bourne Bridge Mainline Alignment Location Assessment

Table 9-2 presents the results of the Bourne Bridge mainline alignment location assessment. The most favorable mainline location for replacement of the Bourne Bridge was recommended to be the Fully Offline Inboard Option, where both barrels of the replacement highway bridge would be located outside the footprint of the existing bridge, approximately 10 feet apart and parallel to each other, on the side of the canal between Bourne Bridge and Sagamore Bridge. The replacement structures for the Bourne Bridge would be east of the existing bridge, closer to Cape Cod Bay.

Table 9-2. Results of Bourne Bridge Mainline Alignment Location Assessment

Highway Design Evaluation Criteria (1), (2)	Fully Offline Inboard	Partially Offline Inboard	Partially Offline Outboard	Fully Offline Outboard	Split
Operations	●●	●●	●●	●●	●●
Connectivity	●	●	●	●	●
Geometrics	●●●	●●●	●●●	●●●	●●●
Safety	●●	●●	●●	●●	●●
Constructability	●●●	●●	●●	●	●
Multi-Modal	●●	●●	●●	●●	●●
Utilities	●	●	●	●●	●
Environmental	■ ■	■ ■	■ ■	■ ■	■ ■
Right-of-Way	■ ■ ■ ■	■ ■ ■	■	■ ■	■ ■

(1) ●●● Most favorable; ●● Favorable; ● Neutral; ●● Less Favorable; ●●● Unfavorable; ●● Not Rated

(2) Range of Least to Less Impacts= ■ ■ ■ ■, ■ ■ ■, ■ ■, ■; Medium Impacts= ❖ ; Range of More to Most Impacts= ■, ■ ■, ■ ■ ■, ■ ■ ■ ■

The mainline alignment location options showed generally consistent performance ratings regarding traffic operations, connectivity, geometrics, safety, and multi-modal connections. Additionally, impacts to existing utilities and the environment would be similar among the options.

Operations Rating: Favorable

The inclusion of auxiliary lanes in all options would improve traffic operations relative to existing conditions, including traffic merging/diverging and weaving.

Connectivity Rating: Neutral

All options would maintain the four existing roadway connections.

Geometrics Rating: Most Favorable

All options would meet current MassDOT and FHWA design standards without design exceptions.[12] In all options, geometric improvements to the vertical profile curves would improve stopping sight distances.

Safety Rating: Favorable

With the addition of acceleration and deceleration lanes, increased lane widths, increased shoulder widths, geometric improvements to the vertical profile curves, and addition of a median barrier, safety conditions would improve in all options, resulting in reduced predicted crashes and a favorable safety rating.

Multi-Modal Connections Rating: Favorable

All options would include a separated pedestrian and bicycle shared use path in the final condition and a sidewalk in the construction phase. Additionally, all options would provide the same level of regional and local connections to the shared use path.

Environmental Impacts Rating: Less Impactful

Due to the replacement of the existing bridges, all options would result in an adverse effect to the NRHP-eligible Bourne Bridge under Section 106 of the NHPA. No direct impacts to Massachusetts Wetlands Protection Act (WPA)-protected resources are anticipated with any of the options. However, in all options, the ramp connections would be within the 100-foot buffer zone of Nightingale Pond.

Section 9.5 presents details of the Bourne Bridge mainline alignment location assessment, focusing on the differentiators among the options.

9.5 Details of Bourne Bridge Mainline Alignment Location Assessment

Section 9.5 discusses the major evaluation criteria of constructability, utility impacts, and right-of-way impacts that are differentiators among the mainline alignment location options, as shown in Table 9-2.[13] It then presents MassDOT's recommendations to advance or not carry forward the Bourne Bridge mainline alignment location options for further design and evaluation.

9.5.1 OPTION RECOMMENDED FOR FURTHER EVALUATION: FULLY OFFLINE INBOARD

In the Fully Offline Inboard Option, both barrels of the replacement highway bridge would be located east of and outside the footprint of the existing Bourne Bridge, closer to Cape Cod Bay. Figure 9-1 shows a sketch of the Fully Offline Inboard Option.

[12] Design standards include AASHTO's 2018 "Policy on Geometric Design of Highways and Streets" Manual (Green Book) and MassDOT's 2006 Project Development and Design Guide.

[13] Note that additional right-of-way impacts would occur when the favorable Bourne mainline location alternative is paired with the interchange approach options, as presented in Section 12.

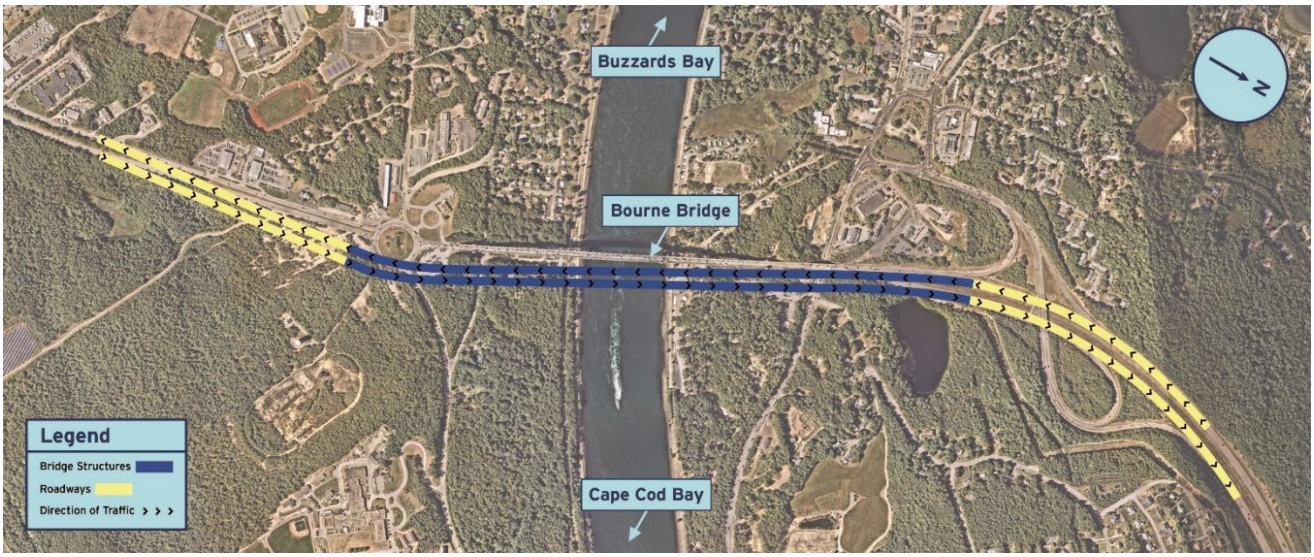


Figure 9-1. Bourne Bridge Fully Offline Inboard Option

Constructability Rating: Most Favorable

In the Fully Offline Inboard Option, MassDOT would be able to construct the new southbound bridge structure and the new northbound bridge structure without impacting the existing Bourne Bridge. In this option, the mainline would be located far enough to the east so that there would be no overlap with the existing Bourne Bridge and there would be available space for work zones at construction start. With full offline construction, this option would provide for the largest construction laydown area east of existing Bourne Bridge which would facilitate construction of both barrels of the replacement bridge. The first replacement barrel could be constructed away from the Bourne Rotary, which would facilitate construction staging more easily. Further, this option would maintain existing traffic flows and would minimally impact existing traffic patterns. All existing traffic could be relocated from the existing bridge to the first replacement bridge structure, thereby lessening the risk that major repairs and/or rehabilitation of the existing bridges would need to be performed.

Utility Impacts Rating: Neutral

This option would directly impact the Enbridge Gas Metering Station and would encroach on the gas transmission easement. This option would result in multiple minor impacts to water, sewer, telecommunications (cable television/fiber optics), and electric utilities, as well as multiple drainage system impacts.

Right-of-Way Impacts: Least Impactful

Based upon preliminary design, this option would have the least impactful right-of-way impacts compared to the other options. This option would not require any full residential property acquisitions. It would result in one residential partial property acquisition, two commercial partial property acquisitions, and five commercial full property acquisitions. Of the five commercial full property acquisitions, four of the parcels are vacant and zoned for commercial use and one parcel consists of an active business. None of the impacts would directly affect Environmental Justice (EJ) communities or populations.

Construction of this option would impact Bourne Scenic Park, a resource protected under Section 4(f) of the Transportation Act of 1966 [Section 4(f)]. The Bourne Scenic Park is located on USACE property leased to the Bourne Recreation Authority (BRA) and on Town of Bourne/BRA-owned property. Impacts to USACE-leased property would consist of approximately 333,000 square feet (sf) of permanent impacts and approximately 744,000 sf of construction impacts. Impacts to the BRA-owned property would consist of approximately 118,000 sf of construction impacts. In addition to park impacts, this option could require infrastructure relocation at Bourne Scenic Park.

9.5.2 OPTION NOT RECOMMENDED FOR FURTHER EVALUATION: PARTIALLY OFFLINE INBOARD

In the Partially Offline Inboard Option, the replacement highway bridge would be located east of and partially within the footprint of the existing Bourne Bridge, toward Cape Cod Bay. Figure 9-2 shows a sketch of the Partially Offline Inboard Option.

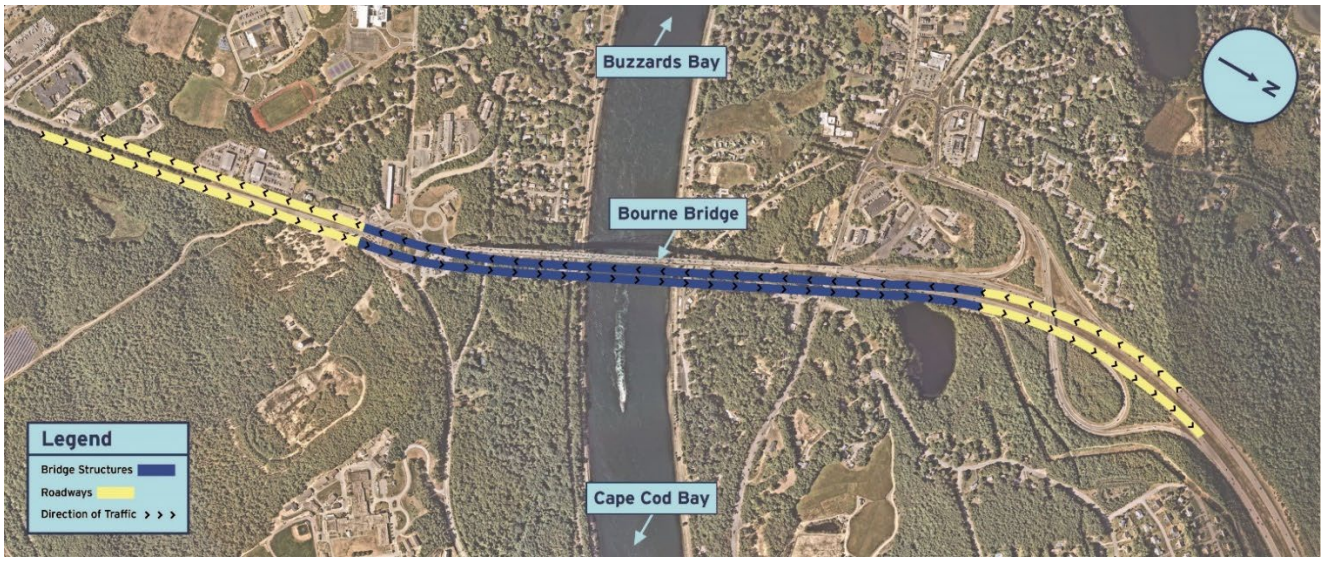


Figure 9-2. Bourne Bridge Partially Offline Inboard Option

Constructability Rating: Less Favorable

In the Partially Offline Inboard Option, the northbound barrel would be much closer to existing traffic on the Bourne Bridge; this condition would force demolition of the existing Bourne Bridge prior to beginning construction of the replacement southbound barrel. While the existing ramp connections could potentially be maintained in this alternative, this construction sequencing would extend the construction schedule by at least one year in comparison to the Fully Offline Inboard Option. There would be additional difficulties in maintaining ramp access to the mainline, involving complex construction staging with more stages, including requiring temporary structures. The multiple traffic pattern changes of this option would disrupt the existing flow of traffic. Additionally, this option would require construction over the active Bourne Rotary, resulting in extensive access issues to existing businesses south of the rotary. Further, there would be constrained laydown areas in this option, creating mobilization inefficiencies for the contractor.

Utility Impacts Rating: Neutral

This option would directly impact the Enbridge Gas Metering Station and would encroach on the gas transmission easement. This option would result in multiple minor impacts to water, sewer, telecommunication, and electric utilities, as well as multiple drainage system impacts.

Right-of-Way Impacts Rating: Less Impactful

Based on preliminary design, this option would result in five commercial partial property acquisitions and two commercial full property acquisitions, both of which consist of two active businesses. The impacts would not directly affect EJ communities or populations.

Construction of this option would impact Bourne Scenic Park, a Section 4(f) resource. Impacts to USACE-leased property would consist of approximately 329,500 sf of permanent impacts and approximately 667,000 sf of construction impacts. Impacts to the BRA-owned property would consist of approximately 68,200 sf of construction impacts.

9.5.3 OPTION NOT RECOMMENDED FOR FURTHER EVALUATION: PARTIALLY OFFLINE OUTBOARD

In the Partially Offline Outboard Option, the replacement highway bridge would be located west of and partially within the footprint of the existing Bourne Bridge, toward Buzzards Bay. Figure 9-3 shows a sketch of the Partially Offline Outboard Option.

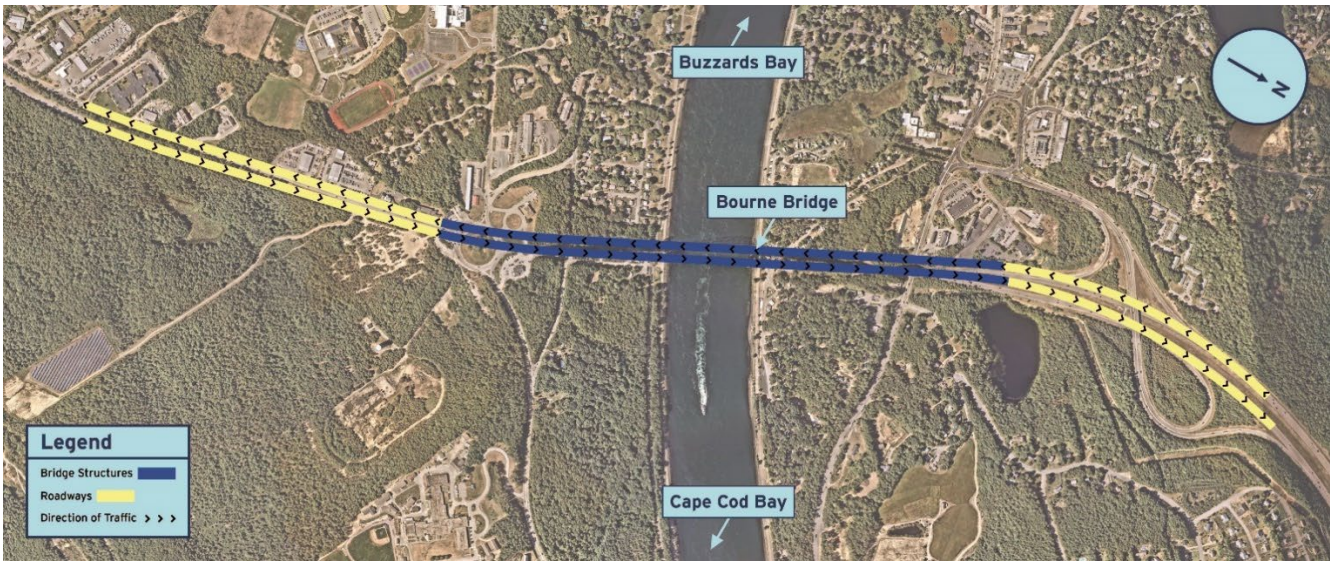


Figure 9-3. Bourne Bridge Partially Offline Outboard Option

Constructability Rating: Less Favorable

In the Partially Offline Outboard Option, demolition of the existing bridge would be required prior to beginning construction of the replacement northbound barrel. As a result, the construction schedule for the Partially Offline Outboard Option would be extended by at least one year in comparison to the Fully Offline Inboard Option. This option would involve complex construction staging with more stages, including requiring temporary structures. The multiple traffic pattern changes of the Partially Offline

Outboard Option would disrupt the existing flow of traffic. Additionally, this option would result in extensive access issues to existing businesses south of the rotary and would require construction over the active Bourne Rotary. Further, there would be constrained laydown areas in the Partially Offline Outboard Option, creating mobilization inefficiencies.

Utility Impacts Rating: Neutral

This option would indirectly impact the Enbridge Gas Metering Station. The bridge would not be directly over the metering station; however, the metering station would still need to be relocated for the construction of the new bridge. This option would result in multiple minor impacts to water, sewer, telecommunication, and electric utilities. Additionally, due to conflicts with the proposed main span bridge piers and abutments, this option would involve multiple drainage system impacts, including relocation of the twin 43-inch by 68-inch elliptical outfall pipes, as well as portions of the connecting upstream Route 28 drainage.

Right-of-Way Impacts Rating: Less Impactful

Based on preliminary design, the Partially Offline Outboard Option would result in one residential partial property acquisition, one residential full property acquisition, six commercial partial property acquisitions, and seven commercial full property acquisitions consisting of five active businesses, including a new 180,000 sf commercial development and a vacant building for three businesses. Additionally, this option would displace the existing shopping plaza and the Massachusetts State Police Barracks, a community resource. The impacts would not directly affect EJ communities or populations.

Like the Fully Offline Inboard Option, this option would impact Bourne Scenic Park, a Section 4(f) resource. Impacts to USACE-leased property would consist of approximately 318, 500 sf of permanent impacts and approximately 660,000 sf of construction impacts. Impacts to the BRA-owned property would consist of approximately 5,000 sf of construction impacts.

Compared to the Fully Offline Inboard and Partially Offline Inboard options, the right-of-way impacts of the Partially Offline Outboard Option would be less impactful.

9.5.4 OPTION NOT RECOMMENDED FOR FURTHER EVALUATION: FULLY OFFLINE OUTBOARD

In the Fully Offline Outboard Option, both barrels of the replacement highway bridge would be located west of and outside the footprint of the existing Bourne Bridge, closer to Buzzards Bay. Figure 9-4 shows a sketch of the Fully Offline Outboard Option.

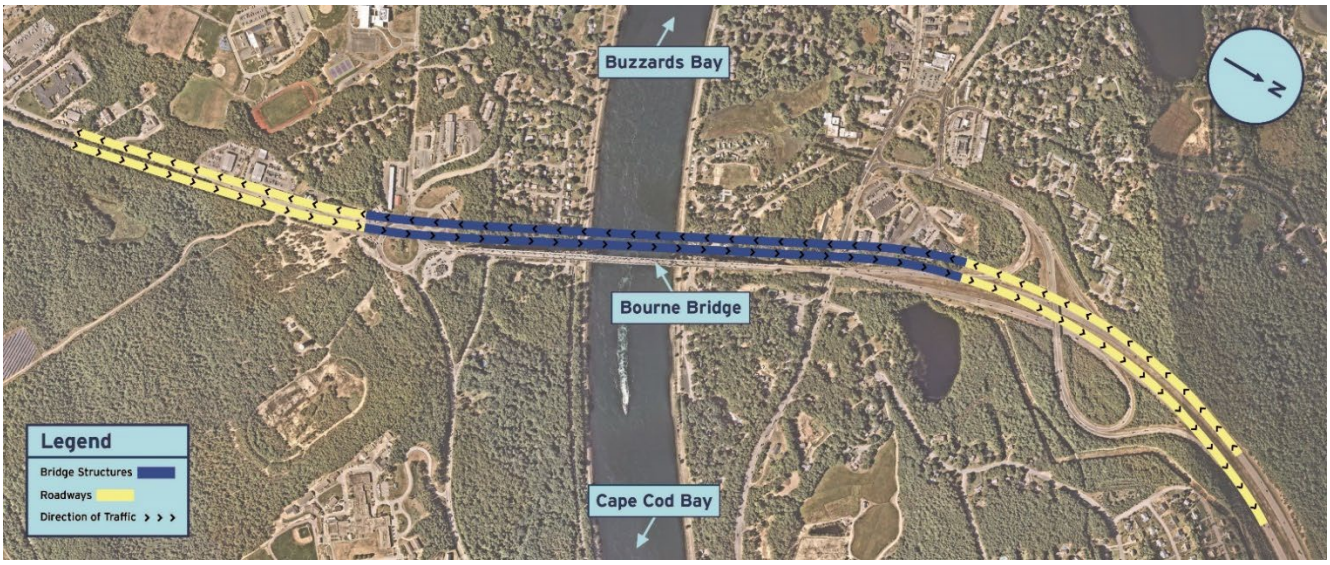


Figure 9-4. Bourne Bridge Fully Offline Outboard Option

Constructability Rating: Neutral

The Fully Offline Outboard Option would involve construction of the southbound barrel first, which would maintain existing ramp connections. Due to constrained right-of-way availability on the west side of the existing highway bridge, this option would have limited construction laydown areas, resulting in complex construction staging with more stages. The multiple traffic pattern changes of the Fully Offline Outboard Option would disrupt the existing flow of traffic. Like the Partially Offline Inboard and Partially Offline Outboard options, construction impacts of this option would include extensive access issues to existing businesses north and south of the Bourne Rotary.

Utility Impacts Rating: Favorable

Because it would not directly impact the Enbridge Gas Metering Station, early relocation of the gas line would not be critical in the Fully Offline Outboard Option. This option would result in multiple minor impacts to water, sewer, telecommunication, and electric utilities. Additionally, due to conflicts with the proposed main span bridge piers and abutments, this option would involve multiple drainage system impacts, including relocation of the twin 43-inch by 68-inch elliptical outfall pipes, as well as portions of the connecting upstream Route 28 drainage system.

Right-of-Way Impacts Rating: More Impactful

Based on preliminary design, the Fully Offline Outboard Option would result in three residential partial property acquisitions, three residential full property acquisitions, three commercial partial property acquisitions, and 11 commercial full property acquisitions consisting of 11 active businesses, including three gas stations, two motels, six businesses, and a vacant building for three businesses. Additionally, this option would displace the existing shopping plaza and the State Police Barracks. The impacts would not directly affect EJ communities or populations.

This option would impact Bourne Scenic Park, a Section 4(f) resource. Impacts to USACE-leased property would consist of approximately 320, 000 sf of permanent impacts and approximately 674,000 sf

of construction impacts. The Fully Offline Outboard Option is the only option that would not impact BRA-owned property.

9.5.5 OPTION NOT RECOMMENDED FOR FURTHER EVALUATION: SPLIT

In the Split Option, the two barrels of the replacement highway bridge would be located on either side of existing Bourne Bridge; the southbound barrel of the replacement highway bridge would be west of existing Bourne Bridge (closer to Buzzards Bay) and the northbound barrel of the replacement highway bridge would be east of existing Bourne Bridge (closer to Cape Cod Bay). Figure 9-5 presents a sketch of the Split Option.

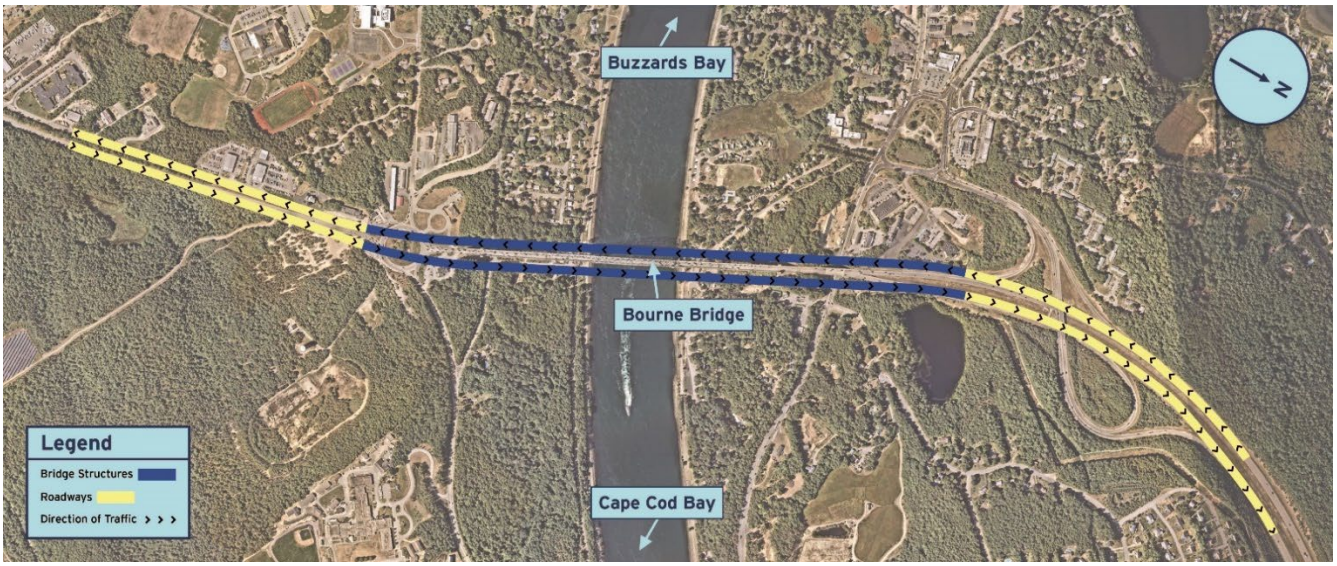


Figure 9-5. Bourne Bridge Split Option

Constructability Rating: Neutral

The Split Option would allow for full offline construction of the replacement highway bridge, benefiting the construction schedule while providing the contractor with flexibility regarding the construction phasing. However, there would be adverse constructability issues with this option: this option would involve construction over the Bourne Rotary and extensive access issues to existing businesses south of the rotary. In this option, existing ramp connections would be maintained during construction.

Utility Impacts Rating: Neutral

The Split Option would indirectly impact the Enbridge Gas Metering Station. The bridge would not be directly over the metering station; however, the metering station would still need to be relocated for the construction of the new bridge. This option would result in multiple minor impacts to water, sewer, telecommunication, and electric utilities. Additionally, due to conflicts with the proposed main span bridge piers and abutments, this option would involve multiple drainage system impacts, including relocation of the twin 43-inch by 68-inch elliptical outfall pipes, as well as portions of the connecting upstream Route 28 drainage system.

Right-of-Way Impacts Rating: Less Impactful

The Split Option is the only option that would increase the transportation corridor width and State right-of-way. Based on preliminary design, this option would require one residential full property acquisition, four commercial partial property acquisitions, and six commercial full property acquisitions consisting of three service stations and three other businesses. None of the impacts would directly affect EJ populations or communities.

Like the other options, the Split Option would impact Bourne Scenic Park, a Section 4(f) resource. Impacts to USACE-leased property would consist of approximately 382,000 sf of permanent impacts and approximately 696,000 sf of construction impacts. Impacts to the BRA-owned property would consist of approximately 35,000 sf of construction impacts.

9.6 Summary of Sagamore Bridge Mainline Alignment Location Assessment

Table 9-3 presents the results of the Sagamore Bridge mainline alignment location assessment. The most favorable mainline location for replacement of the Sagamore Bridge was recommended to be the Fully Offline Inboard Option, where both barrels of the replacement highway bridge would be located outside the footprint of the existing bridge, approximately 10 feet apart and parallel to each other, on the on the side of the canal between the existing Bourne Bridge and Sagamore Bridge. The replacement structures for the Sagamore Bridge would be west of the existing bridge, closer to Buzzards Bay.

Table 9-3. Results of Sagamore Bridge Mainline Alignment Location Assessment

Highway Design Evaluation Criteria (1), (2)	Fully Offline Inboard	Partially Offline Inboard	Partially Offline Outboard	Fully Offline Outboard	Split
Operations	●●	●●	●●	●●	●●
Connectivity	●	●	●	●	●
Geometrics	●●	●●	●	●	●
Safety	●●	●●	●●	●●	●●
Constructability	●	●●	●●●	●●●	●●●
Multi-Modal	●●	●	●	●	●
Utilities	●	●	●	●	●
Environmental	■ ■	■ ■	■ ■ ■	■ ■ ■	■ ■
Right-of-Way	❖	■	■ ■ ■	■ ■ ■ ■	■ ■ ■

(1) ●●● Most favorable; ●● Favorable; ● Neutral; ●● Less Favorable; ●●● Unfavorable; ●● Not Rated

(2) Range of Least to Less Impacts= ■ ■ ■ ■, ■ ■ ■, ■ ■, ■; Medium Impacts= ❖ ; Range of More to Most Impacts= ■, ■ ■, ■ ■ ■, ■ ■ ■ ■

The five alignment location options showed generally consistent ratings regarding traffic operations, connectivity, safety, and multi-modal connections. Impacts to existing utilities would be similar among the options. Further, all five options would require land on-Cape directly west of existing Sagamore Bridge (the Round Hill neighborhood) for construction of the replacement bridges and demolition of the existing bridges.

Operations Rating: Favorable

The location of the replacement bridge would not affect traffic operations capacity of the mainline over Cape Cod Canal. In all options, the improvements to lane and shoulder widths along with inclusion of auxiliary lanes would improve traffic operations relative to existing conditions, including traffic merging/diverging and weaving. All options would remove the Route 3 southbound lane drop.

Connectivity Rating: Neutral

All options would maintain existing roadway connections.

Safety Rating: Favorable

With the addition of acceleration and deceleration lanes, increased lane widths, increased shoulder widths, geometric improvements to the vertical profile curves, improved ramp acceleration and deceleration areas, and addition of a median barrier, safety conditions would improve in all options, resulting in a reduction in predicted crashes and a favorable safety rating. In all options, geometric improvements to the vertical profile curves would improve stopping sight distances.

Utility Impacts Rating: Neutral

Regarding potential utility impacts, the options received a neutral rating relative to each other. All options would displace the Enbridge Gas metering station, and each option would involve some direct and/or indirect impacts to existing utilities, consisting of gas, water, telecommunications, and electrical.

Section 9.7 present details of the Sagamore Bridge mainline alignment location assessment, focusing on the differentiators among the options.

9.7 Details of Sagamore Bridge Mainline Location Assessment

Section 9.7 discusses the major evaluation criteria of geometrics, constructability, multi-modal connections, environmental impacts, and right-of-way impacts that are differentiators among the mainline alignment location options, as shown in Table 9-3.[14] It then presents MassDOT's recommendations to advance or not carry forward the Sagamore Bridge mainline alignment location options for further design and evaluation.

9.7.1 OPTION RECOMMENDED FOR FURTHER EVALUATION: FULLY OFFLINE INBOARD

In the Fully Offline Inboard Option, both barrels of the replacement highway bridge would be located west of and outside the footprint of the existing Sagamore Bridge, closer to Buzzards Bay. Figure 9-6 presents a sketch of the Fully Offline Inboard Option.

[14] Note that additional right-of-way impacts would occur when the favorable Sagamore mainline location alternative is paired with the interchange approach options, as presented in Section 12.

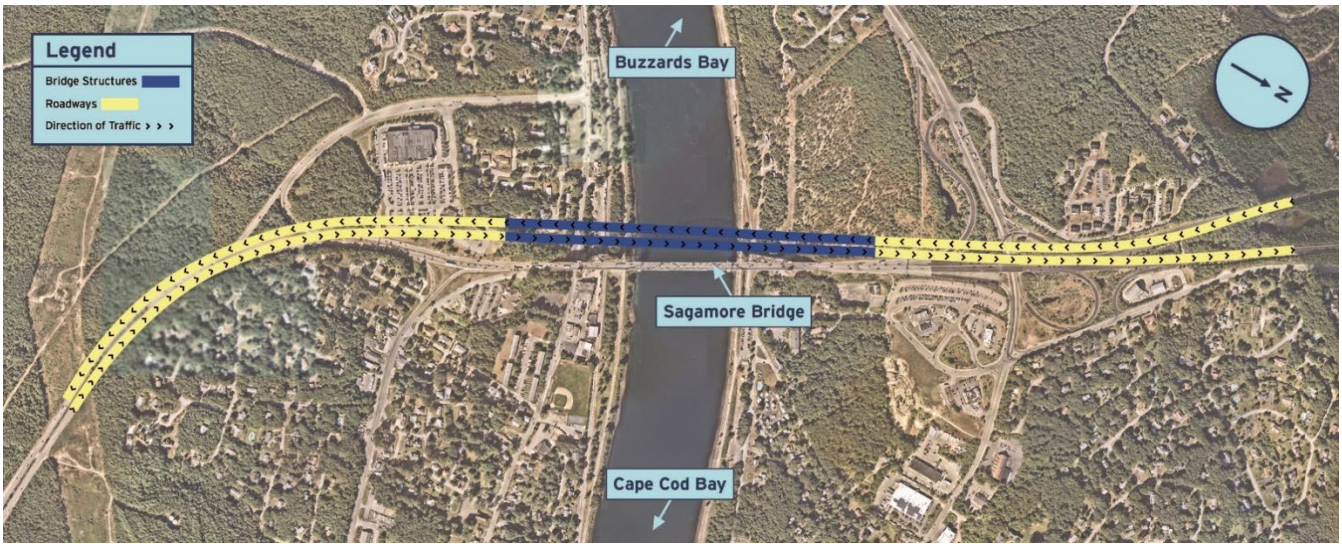


Figure 9-6. Sagamore Bridge Fully Offline Inboard Option

Geometrics Rating: Favorable

The Fully Offline Inboard Option would eliminate the reverse curve in the roadway alignment south of the existing bridge by replacing it with a long tangent connecting to existing curves at the southern and northern end of the bridge. By shifting the mainline west of and outside the footprint of the existing Sagamore Bridge, this option would provide space to add bicycle and pedestrian accommodations along State Road. This option would better accommodate connections to the approach road network that provides an on-ramp near the Christmas Tree Shop and an off-ramp near the Park & Ride lot. In this option, the Route 6 eastbound and Route 3 northbound mainline curve lengths north of the canal would meet the minimum MassDOT design requirements.

Constructability Rating: Neutral

With a fully offline construction, this option would have the largest construction laydown area west of existing Sagamore Bridge, which would facilitate construction of both barrels of the replacement bridge. MassDOT is evaluating two construction approaches in the Fully Offline Inboard Option. In the first approach, MassDOT would keep the existing bridge in service through construction of both replacement bridges; however, this approach would require ongoing inspections of the existing bridge and existing bridge rehabilitation could be necessary. In the second approach, MassDOT would construct the first bridge and transfer existing traffic (providing bi-directional traffic) following its construction; however, this approach would require difficult temporary ramp connections. In this option, the southbound Route 3 bridge and approaches over Scenic Highway could be built without affecting the existing on-Cape traffic. The Route 3 northbound bridge and approaches would be built in two phases.

Multi-Modal Connections Rating: Favorable

The Fully Offline Inboard Option is the only option that could accommodate bicycle and pedestrian access along State Road through a shared-use path without altering the state highway layout.

Environmental Impacts Rating: Less Impactful

In this option, no direct wetland impacts are anticipated. The Fully Offline Inboard Option would be within previously disturbed portions of the Herring River Watershed Area of Critical Environmental Concern (ACEC) within the State highway layout. Due to replacement of the existing bridge, this option would result in an Adverse Effect to the NRHP-eligible Sagamore Bridge under Section 106 of the NHPA.

Right-of-Way Impacts Rating: Medium

Based on preliminary design, the Fully Offline Inboard Option would result in 11 residential full property acquisitions, consisting of ten occupied units and one undeveloped parcel; one commercial partial property acquisition, consisting of one building with three active businesses and four vacancies; and two commercial full property acquisitions, consisting of one vacant parcel and one construction yard. The proposed residential full property acquisitions within the Round Hill neighborhood would be due to the construction zone required for construction of the replacement of Sagamore Bridge and demolition of the existing bridge. None of the impacts would directly affect EJ populations or communities.

While the Fully Offline Inboard Option would impact the Round Hill neighborhood, MassDOT determined that shifting the mainline alignment further east, particularly with the Partial Inboard and Outboard Options and the Full Offline Outboard Option, would significantly increase right-of-way impacts when combined with the interchange approach options. These impacts would be most pronounced in the Marconi Street and Adams Street neighborhood on the on-Cape side and along State Road on the off-Cape side. In addition to the impacts directly related to the mainline, all options, except for the Fully Inboard Offline option, would necessitate additional residential property acquisitions to connect the mainline to Cranberry Highway.

Compared to the other Sagamore Bridge mainline alignment options, the Fully Offline Inboard Option would result in a comparable number of impacts (through full or partial property acquisitions) to the Partially Offline Inboard Option and slightly more impacts than the Partially Offline Outboard Option. However, when paired with the highway interchange approach options, MassDOT determined that the two partially offline options ultimately would result in greater overall property impacts, particularly to residential properties, than would the Fully Offline Inboard Option. As a result, MassDOT assigned the Fully Offline Inboard Option a "medium" right-of-way impacts rating.

Construction of the Fully Offline Inboard Option would temporarily impact approximately 43,100 sf of Town of Bourne-owned property. This option also would impact USACE-owned property (the Cape Cod Canal Federal Navigation Project), involving approximately 369,500 sf of construction impacts due to the construction laydown area and approximately 304,000 sf of permanent impacts.

9.7.2 OPTION NOT RECOMMENDED FOR FURTHER EVALUATION: PARTIALLY OFFLINE INBOARD

In the Partially Offline Inboard Option, the replacement highway bridge would be located west of and partially within the footprint of the existing Sagamore Bridge, toward Buzzards Bay. Figure 9-7 presents a sketch of the Partially Offline Inboard Option.

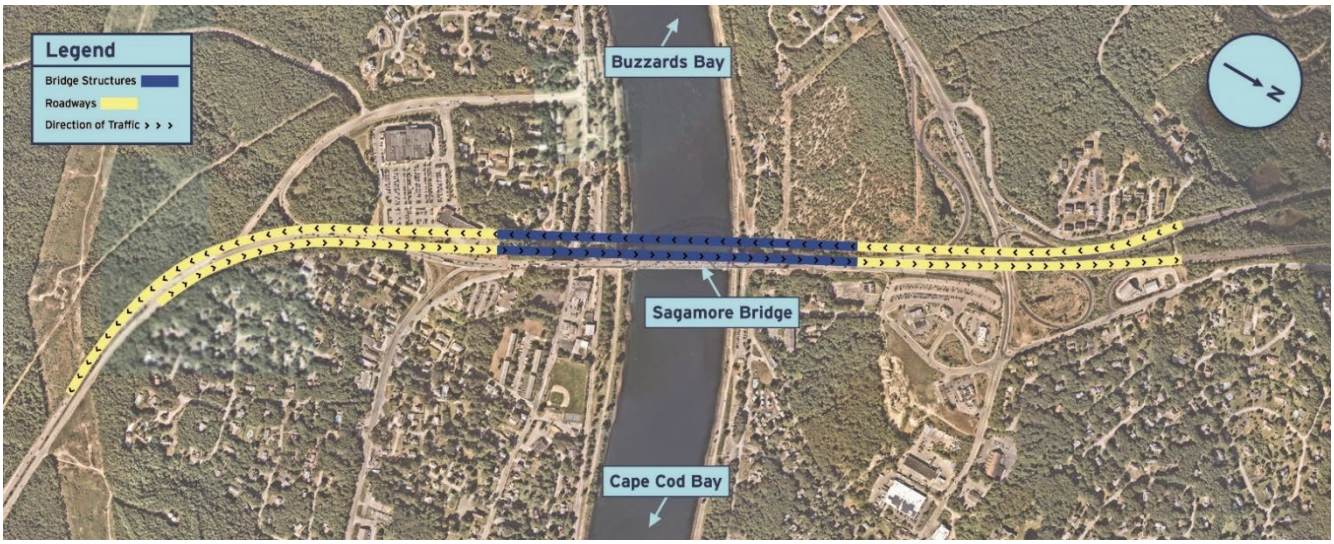


Figure 9-7. Sagamore Bridge Partially Offline Inboard Option

Geometrics Rating: Favorable

In the Partially Offline Inboard Option, the mainline curve lengths would be less than the desired lengths per MassDOT's Project Development and Design Guide, but most curve lengths would meet the minimum mainline curve lengths. By locating the proposed mainline alignment close to the existing Sagamore Bridge, this option would result in steeper ramp profile grades for the approaching road network that provides an on-ramp near the Christmas Tree Shop south of the canal and an off-ramp near the Park & Ride lot north of the canal.

Constructability Rating: Less Favorable

In the Partially Offline Inboard Option, MassDOT would first construct the eastbound replacement bridge, transfer the existing traffic (providing bi-directional traffic) to the new eastbound bridge, demolish the existing bridge, and then construct the westbound replacement bridge. This construction approach would require construction of a temporary Route 3 southbound structure and a temporary structure over Scenic Highway. The required temporary ramp connections, especially the on-Cape westbound on-ramp and the off-Cape westbound off-ramp, would be difficult with this option's alignment shift to the east. Additionally, some existing ramp connections would not be maintained during construction and multiple short term ramp closures could be required. Compared to the Fully Offline Inboard Option, the Partially Offline Inboard Option would involve a substantial construction duration due to complex construction staging with multiple construction stages, mobilization inefficiencies due to constrained laydown areas, and major multiple traffic pattern changes/diversions which would disrupt existing traffic flows.

Multi-Modal Connections Rating: Neutral

Utilizing the existing easterly State Road Layout line, the Partially Offline Inboard Option would not be able to accommodate bicycle and pedestrian access along State Road without also incurring right-of-way impacts to the neighborhood to the east.

Environmental Impacts Rating: Less Impactful

Like the Fully Offline Inboard Option, in this option, no direct wetland impacts are anticipated. This option would be within previously disturbed portions of the Herring River Watershed ACEC within the State highway layout.

Right-of-Way Impacts Rating: More Impactful

Based on preliminary design, the Partially Offline Inboard Option would result in two residential partial property acquisitions; seven residential full property acquisitions, including two undeveloped parcels; two commercial partial property acquisitions, including an undeveloped parcel and one building with three active businesses and four vacancies; and three commercial full property acquisitions, including one active business, one vacant parcel and one construction yard. None of the impacts would directly affect EJ populations or communities. MassDOT also determined that the Partially Offline Inboard Option, combined with the proposed interchange approach options, would notably increase total impacts to the Marconi Street and Adams Street neighborhoods.

Compared to the other Sagamore Bridge mainline alignment options, the Partially Offline Inboard Option would result in a comparable number of impacts (through full or partial property acquisitions) to the Fully Offline Inboard Option and more impacts than the Partially Offline Outboard Option. As noted in Section 9.7.1, however, MassDOT determined that as the mainline alignment is shifted to the east (the case with both partial options), right-of-way impacts increase when combined with the interchange approach options. As a result, the Partially Offline Inboard Option would have greater overall property impacts than the Fully Offline Inboard Option, particularly to residential properties. MassDOT therefore assigned the Partially Offline Inboard Option a "more impactful" right-of-way impacts rating.

Construction of this option would impact approximately 43,100 sf of Town of Bourne-owned property. This option also would impact USACE-owned property, involving approximately 386,500 sf of construction impacts due to the construction laydown area and approximately 304,900 sf of permanent impacts.

9.7.3 OPTION NOT RECOMMENDED FOR FURTHER EVALUATION: PARTIALLY OFFLINE OUTBOARD

In the Partially Offline Outboard Option, the replacement highway bridge would be located east of and partially within the footprint of the existing Sagamore Bridge, toward Cape Cod Bay. Figure 9-8 presents a sketch of the Partially Offline Outboard Option.

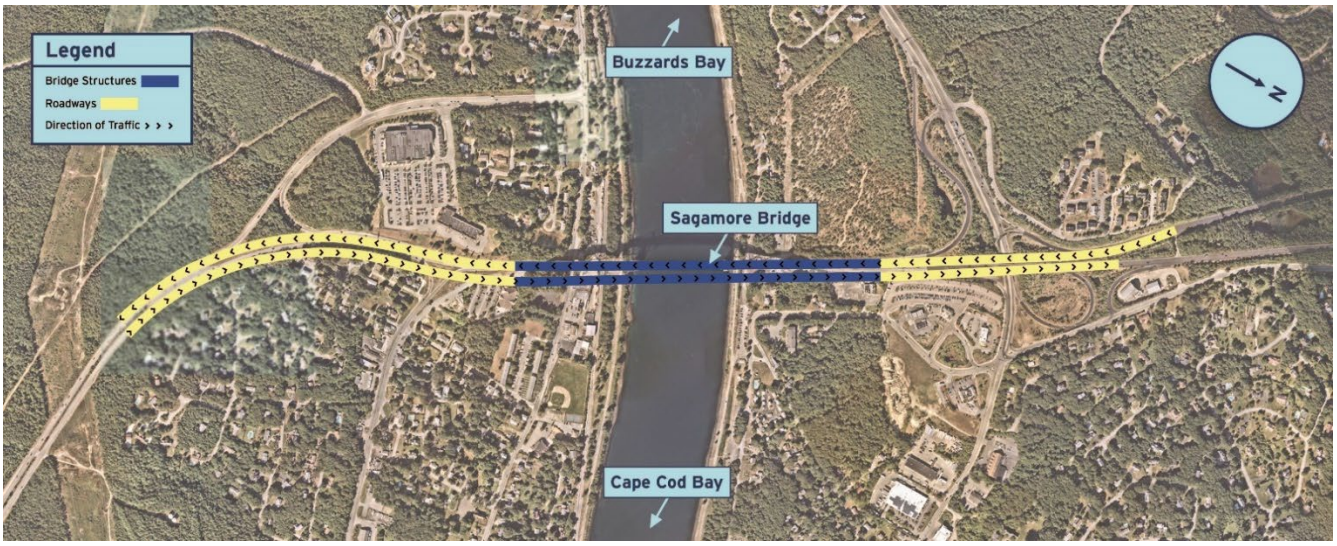


Figure 9-8. Sagamore Bridge Partially Offline Outboard Option

Geometrics Rating: Neutral

In the Partially Offline Outboard Option, Route 6 eastbound and Route 6 westbound mainline curve lengths north and south of the canal would be less than the both the desired and minimum lengths per MassDOT's Project Development and Design Guide (PDDG). Additionally, this option would require an additional six feet of inside shoulder to meet the sight stopping distance for a 60 miles per hour (MPH) design speed.

Constructability Rating: Unfavorable

In the Partially Offline Outboard Option, MassDOT would first construct the westbound replacement bridge, transfer the existing traffic (providing bi-directional traffic) to the new westbound bridge, demolish the existing bridge, and then construct the eastbound replacement bridge. This construction approach would require temporary ramp connections which would be difficult with this option's alignment shift to the east, especially the on-Cape westbound on-ramp and the off-Cape westbound off-ramp. Additionally, some existing ramp connections would not be maintained during construction, requiring multiple short term ramp closures and temporary ramp connections. For example, the eastbound on-ramp from Scenic Highway and the eastbound off-ramp to the Mid-Cape Connector would be closed for extended periods while the existing bridge is demolished, and the temporary ramp connections are constructed. In comparison to the Fully Offline Inboard Option, the Partially Offline Outboard Option would involve a substantial construction duration due to complex construction staging with multiple construction stages, mobilization inefficiencies due to constrained laydown areas, and major multiple traffic pattern changes/diversions which would disrupt existing traffic flows.

Multi-Modal Connections Rating: Neutral

Utilizing the existing easterly State Road Layout line, the Partially Offline Outboard Option would not accommodate the addition of bicycle and pedestrian access along State Road without right-of-way impacts to the neighborhood to the east.

Environmental Impacts Rating: Less Impactful

In the Partially Offline Outboard Option, no direct wetland impacts are anticipated. Additionally, this alternative has no anticipated impacts to the Herring River Watershed ACEC. Compared to the Fully Offline and Partially Offline Inboard options, this option would be less impactful.

Right-of-Way Impacts Rating: More Impactful

Based on preliminary design, the Partially Offline Outboard Option would result in four residential full property acquisitions, including one undeveloped parcel; one commercial partial property acquisition, including an undeveloped parcel and one building with three active businesses and four vacancies; and seven commercial full property acquisitions, consisting of a service station, two other active businesses, two undeveloped parcels, a warehouse, and a construction yard. None of the impacts would directly affect EJ populations or communities. MassDOT also determined that the Partially Offline Outboard Options, combined with the proposed interchange approach options, would notably increase total impacts to the Marconi Street and Adams Street neighborhoods.

Compared to the other Sagamore Bridge mainline alignment options, the Partially Offline Outboard Option would result in fewer impacts (through full or partial property acquisitions) than both the Fully Offline Inboard Option and the Partially Offline Inboard Option. As noted in Section 9.7.1, however, MassDOT determined that as the mainline alignment is shifted to the east, right-of-way impacts increase when combined with the interchange approach options. As a result, the Partially Offline Outboard Option would have greater overall property impacts than both the Fully Offline Inboard Option and the Partially Offline Inboard Option, particularly to residential properties. MassDOT therefore assigned the Partially Offline Inboard Option a "more impactful" right-of-way impacts rating.

Construction of the Partially Offline Outboard Option would impact approximately 43,100 sf of Town of Bourne-owned property. This option also would impact USACE-owned property, involving approximately 358,400 sf of construction impacts due to the construction laydown area and approximately 213,500 sf of permanent impacts. Compared to the Partially Offline Inboard Option, the Partially Offline Outboard Option would be more impactful.

9.7.4 OPTION NOT RECOMMENDED FOR FURTHER EVALUATION: FULLY OFFLINE OUTBOARD

In the Fully Offline Outboard Option, both barrels of the replacement highway bridge would be located east of and outside the footprint of the existing Sagamore Bridge, closer to Cape Cod Bay. Figure 9-9 presents a sketch of the Fully Offline Outboard Option.

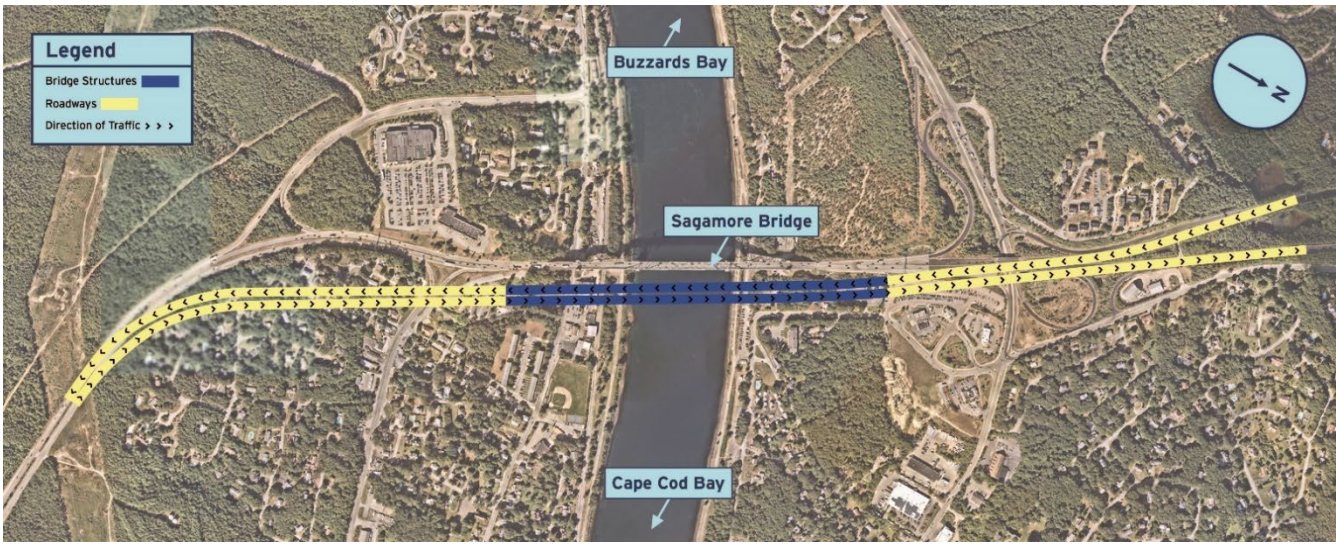


Figure 9-9. Sagamore Bridge Fully Offline Outboard Option

Geometrics Rating: Neutral

In the Fully Offline Outboard Option, Route 6 eastbound and Route 6 westbound mainline curve lengths north of the canal would be less than both the desired and minimum lengths per MassDOT's PDDG. Route 6 eastbound and Route 6 westbound mainline curve lengths south of the canal would be less than the desired lengths but would meet the minimum lengths per MassDOT's PDDG.

Constructability Rating: Unfavorable

In the Fully Offline Outboard Option, MassDOT would need to construct both the eastbound and westbound replacement structures, then transfer the existing traffic to the new structures, and then demolish the existing bridge. MassDOT would construct the Route 3 bridges over Scenic Highway in multiple phases. While both the westbound and eastbound bridges could be built without affecting the existing bridge, this option would require extended durations of multiple closed ramp connections to the mainline. Additionally, the required temporary ramp connections would be difficult with this option's alignment shift to the east, especially the on-Cape westbound on-ramp and the off-Cape westbound off-ramp. In comparison to the Fully Offline Inboard Option, the Fully Offline Outboard Option would involve complex construction staging with multiple construction stages, mobilization inefficiencies due to constrained laydown areas, and major multiple traffic pattern changes/diversions which would disrupt existing traffic flows.

Multi-Modal Connections Rating: Neutral

Utilizing the existing easterly State Road Layout line, the Fully Offline Outboard Option would not accommodate the addition of bicycle and pedestrian access along State Road without right-of-way impacts to the neighborhood to the east.

Environmental Impacts Rating: Less Impactful

Like the Partially Offline Outboard Option, no direct wetland impacts or impacts to the Herring River Watershed ACEC are anticipated. Compared to the Fully Offline and Partially Offline Inboard options, the Fully Offline Outboard Option would be less impactful.

Right-of-Way Impacts Rating: Most Impactful

Based upon preliminary design, the Fully Offline Outboard Option would have the most impactful right-of-way impacts compared to other alternatives. This option would result in the most substantial disruption to the community and would require five residential partial property acquisitions; 30 residential full property acquisitions; two commercial partial property acquisitions, including an undeveloped parcel and one building with three active businesses and four vacancies; and eight commercial full property acquisitions, consisting of five active businesses, two undeveloped parcels, and a warehouse. None of the impacts would directly impact EJ populations or communities.

In the Fully Offline Outboard Option, additional impacts to the neighborhood to the east would be anticipated with realigning the loop ramp, State Road, and providing bicycle and pedestrian accommodations. Further, as noted in Section 9.7.1, as the mainline alignment is shifted to the east, right-of-way impacts increase when combined with the interchange approach options. The Fully Offline Outboard Option, when combined with the proposed interchange approach options, would result in substantially increased total impacts to the Marconi Street and Adams Street neighborhoods. As a result, MassDOT assigned the Fully Offline Outboard Option a "most impactful" rating compared to the other four mainline alignment options.

Construction of the Fully Offline Outboard Option would impact approximately 43,100 sf of Town of Bourne-owned property. This option would impact USACE-owned property, involving approximately 264,000 sf of construction impacts due to the construction laydown area and approximately 253,700 sf of permanent impacts. Additionally, the Fully Offline Outboard Option would displace MassDOT's Park and Ride Lot.

9.7.5 OPTION NOT RECOMMENDED FOR FURTHER EVALUATION: SPLIT

In the Split Option, the two barrels of the replacement highway bridge would be located on either side of existing Sagamore Bridge; the westbound barrel of the replacement highway bridge would be east of existing Sagamore Bridge, closer to Cape Cod Bay, and the eastbound barrel of the replacement highway bridge would be west of existing Sagamore Bridge, closer to Buzzards Bay. Figure 9-10 presents a sketch of the Split Option.

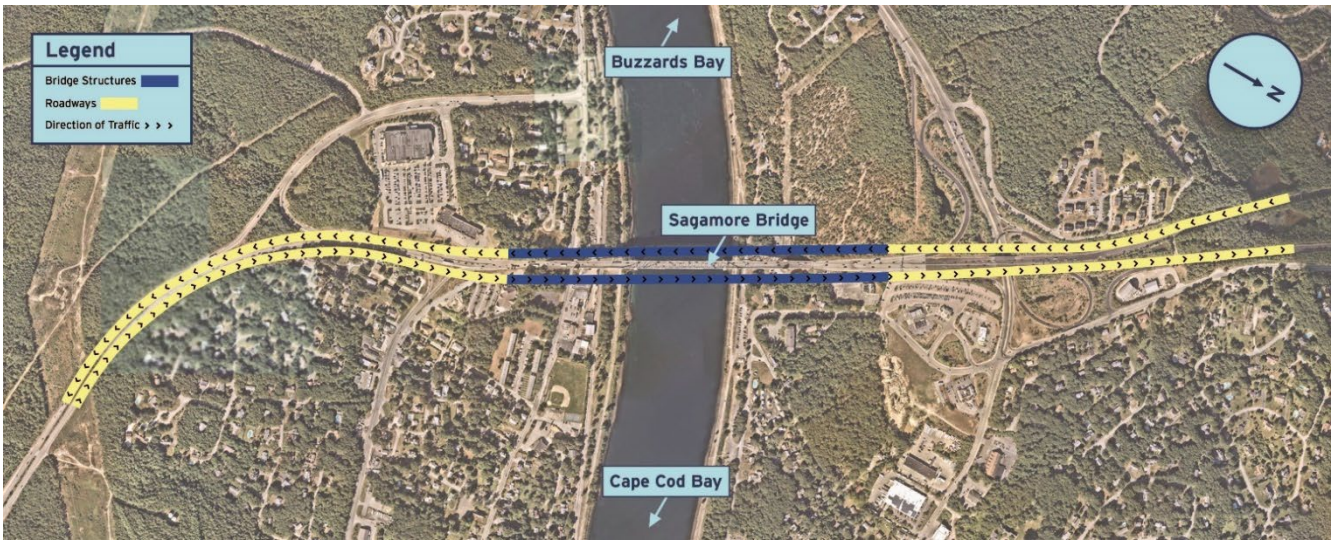


Figure 9-10. Sagamore Bridge Split Option

Geometrics Rating: Neutral

Like the Partially Offline Outboard Option, in the Split Option, Route 6 eastbound and Route 6 westbound mainline curve lengths north and south of the canal would be less than the both the desired and minimum lengths per MassDOT's PDDG.

Constructability Rating: Unfavorable

In the Split Option, MassDOT would construct the westbound replacement structure, transfer the existing traffic (providing bi-directional traffic) to the new westbound bridge, construct the eastbound structure, transfer the existing traffic to the replacement structures, and then demolish the existing bridge. A temporary Route 3 southbound structure and a temporary structure over Scenic Highway would be needed. The required temporary ramp connections would be difficult with this option's alignment shift to the east, especially the on-Cape westbound on-ramp and the off Cape westbound off-ramp. In comparison to the Fully Offline Outboard Option, the Split Option would involve substantially more construction time due to the demolition of the existing bridge after construction of the replacement bridge structures. Additional challenges of this option would include complex construction staging with multiple construction stages, especially related to the construction of the Route 3 northbound and southbound bridges over the Scenic Highway.

Multi-Modal Connections Rating: Neutral

Utilizing the existing easterly State Road Layout line, the Split Option would not accommodate the addition of bicycle and pedestrian access along State Road without right-of-way impacts to the neighborhood to the east.

Environmental Impacts Rating: Less Impactful

In the Split Option, no direct wetland impacts are anticipated. Like the two Inboard options, the Split Option would disturb portions of the Herring River Watershed ACEC within the State highway layout. The less impactful environmental impact rating of the Split Option is comparable to the ratings of the Fully Offline Inboard Option and Partially Offline Inboard Option.

Right-of-Way Impacts Rating: More Impactful

Based on preliminary design, the Split Option would result in nine residential full property acquisitions, including three undeveloped lots; one commercial partial property acquisitions, including an undeveloped parcel and one building with three active businesses and four vacancies; and seven commercial full property acquisitions, consisting of three active businesses, two undeveloped parcels, a warehouse, and a construction yard. None of the impacts would directly affect EJ populations or communities.

In the Split Option, additional impacts to the neighborhood to the east would be anticipated with realigning the loop ramp, State Road, and providing bicycle and pedestrian accommodations. Further, MassDOT also determined that the Split Option, combined with the proposed interchange approach options, would increase total impacts to the Marconi Street and Adams Street neighborhoods.

Construction of the Split Option would impact approximately 43,100 sf of Town of Bourne-owned property. This option would impact USACE-owned property, involving approximately 442,300 sf of construction impacts and approximately 273,100 sf of permanent impacts. Additionally, the Split Option would displace MassDOT's Park and Ride Lot.

9.8 Mainline Alignment Location Recommended for Detailed Study

Based on the results of its performance relative to meeting the Program's highway design evaluation criteria, the Fully Offline Inboard Option for both the Bourne and Sagamore locations had an overall higher rating than the other mainline alignment location options, as shown in Tables 9-2 and 9-3.

For the Bourne mainline alignment evaluation (Table 9-2), the ratings among the five options were fairly consistent, with no option scoring an unfavorable rating. The differentiating factors among the options were geometrics, constructability, and right-of-way, where the Fully Offline Inboard Option received two most favorable ratings and one least impact rating. For the Sagamore mainline evaluation (Table 9-3), the ratings among the options substantially differed regarding constructability and right-of-way impacts. In comparison to the neutral constructability rating of the Fully Offline Inboard Option, the ratings of the other options ranged from less favorable to unfavorable. Additionally, in comparison to the right-of-way "medium" impact rating assigned to the Fully Offline Inboard Option, the ratings of the other options ranged from more impacts to the most impacts, particularly when combined with the interchange approach options.

Because it rated the highest among all five mainline alignment location options, MassDOT recommended advancing the Fully Offline Inboard Option for both canal crossings as the mainline alignment location retained for detailed study.

10 Initial Bridge Type Assessment

10.1 Introduction

Section 10 presents the results of MassDOT's conceptual screening and initial assessment of the replacement bridge type. The initial bridge type assessment incorporates the results of the main span length and bridge pier location assessment, presented in Section 7, and MassDOT's assessment for the bridge deck configuration, presented in Section 8.

10.2 Conceptual Screening: Bridge Type Selection

Incorporating the USACE's Preferred Alternative for In-Kind Bridge Replacements, and in collaboration with FHWA and USACE, MassDOT conducted a conceptual screening of a wide range of bridge types and design parameters to identify feasible bridge types and configurations for further analysis. In this initial screening, MassDOT identified the decision drivers for bridge type selection, advanced favorable design features, and eliminated unfavorable bridge types.

As illustrated in Figure 10-1, main span length is a critical parameter that affects bridge type selection and bridge cost.[15] The vertical blue lines in Figure 10-1 indicate the possible bridge types appropriate for the full range of potential Cape Cod Canal main span crossings of 525 to 820 feet. Additionally, Figure 10-1 indicates that the unit cost per deck area increases with main span length. In general, for structural efficiency, the center span length should be limited to the minimum needed to meet functional and aesthetic requirements.

Considering the most cost-effective bridge types that would meet the applicable main center span range, MassDOT initially identified the tied-arch bridge, the box girder bridge, and the cable-stayed bridge as the most efficient structure bridge types and potential replacement bridge types for the Bourne and Sagamore highway bridges. A truss bridge type was also considered as potentially feasible. Because they would not be cost-effective, the suspension bridge type, the constant-depth box girder type, the T-Beam bridge type, and the solid slab bridge type were not carried forward further consideration.

[15] *Adapted from Svensson, H., Cable-Stayed Bridges – 40 Years of Experience Worldwide, Ernst & Sohn, 2011.*

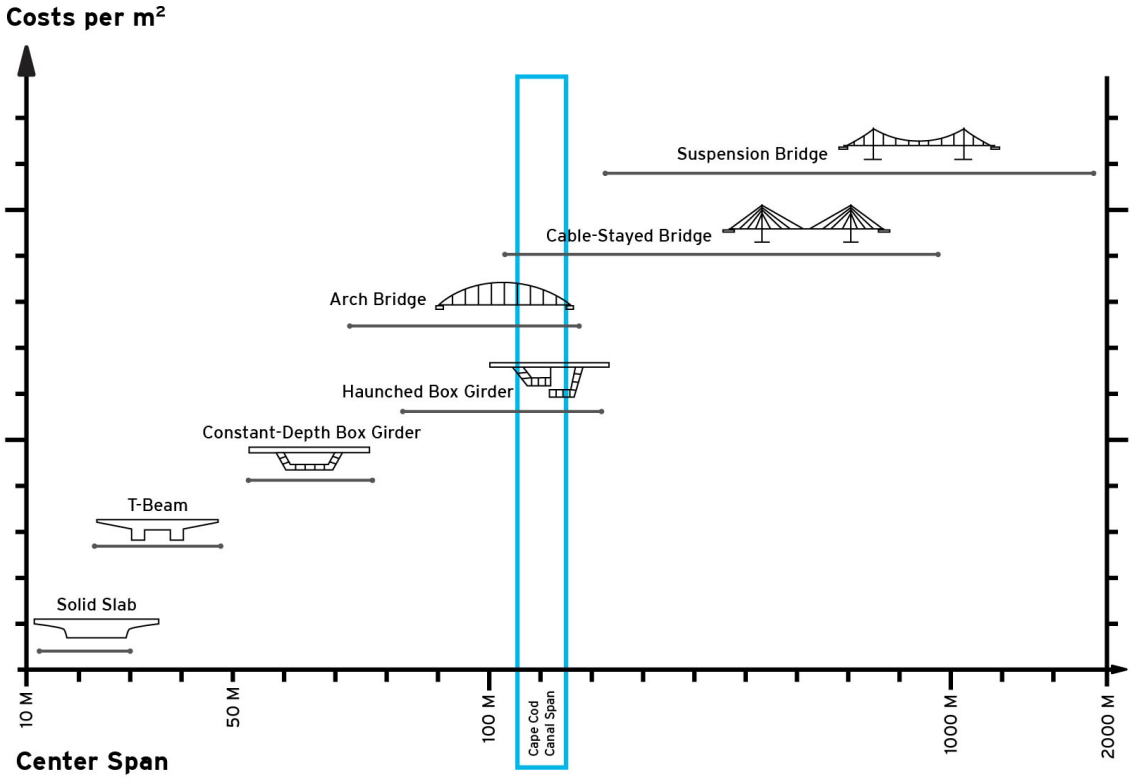


Figure 10-1. Bridge Type by Cost and Span Length

Sections 10.2.1 through 10.2.4 describe the four bridge types and multiple design options that resulted from MassDOT's initial screening.

10.2.1 TRUSS BRIDGE

The existing Bourne and Sagamore highway bridges are steel truss bridges, with a truss arch span over the canal. Truss bridges are load-bearing structures composed of a series of interconnected triangles, known as trusses, providing a stable form that can support considerable loads over a large span.

In the initial screening, MassDOT identified two variations consisting of a constant depth truss for span lengths up to approximately 700 feet and a variable depth truss for the long span of 820 feet. Figure 10-2 shows an elevation view schematic drawing of a constant depth truss bridge.

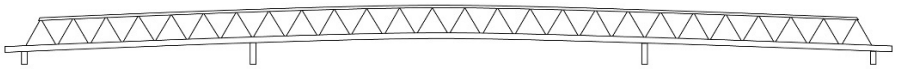


Figure 10-2. Schematic of Truss Bridge Type

For this bridge type, a substantial portion of a truss bridge would be "stick-built" in place, requiring temporary falsework (piers or high towers) in the canal during erection to support a structure until it becomes self-supporting. Alternatively, the center span could potentially be constructed in an off-site fabrication yard, transported to the site via an ocean-going barge, and lifted into place.

10.2.2 TIED-ARCH BRIDGE

In a tied-arch bridge, the arch is positioned above the bridge deck and attached cables support the deck. Traditional tied-arch bridges use vertical bridge piers with the arches located on top of the piers. As a variation, MassDOT also identified a tied-arch configuration on a Delta frame, where the approach spans cantilever into the main span, thereby shortening the length of the tied arch but adding some approach complexity with the Delta frame. Figures 10-3 and 10-4 show schematic drawings of a tied-arch bridge (non-Delta frame) and a tied-arch bridge with a Delta frame.

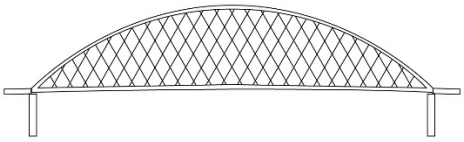


Figure 10-3. Schematic of Tied-Arch Bridge Type – Longer Arch (Non-Delta Frame)

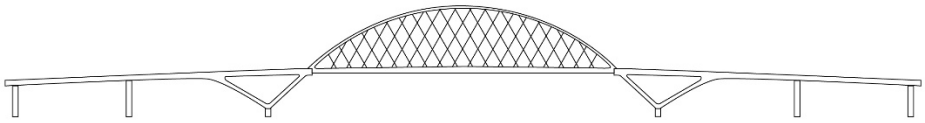


Figure 10-4. Schematic Of Tied-Arch Bridge Type – Delta Frame

10.2.3 CABLE-STAYED BRIDGE

In a cable-stayed bridge, the weight of the steel deck is supported by multiple diagonal cables in tension running directly to one or more towers. For this bridge type, MassDOT identified two configurations, with either a single tower or two towers. Of the two configurations, the single-tower results in the taller

structure with a tower height above deck between 30 percent and 40 percent of the span length, or approximately 250 feet. Two-tower configurations tend to be more efficient, with tower heights in the range of 20 percent to 25 percent of the main span length, or approximately 154 feet. Figures 10-5 and 10-6 show schematic drawings of a cable-stayed bridge type with a single-tower and with two-towers.

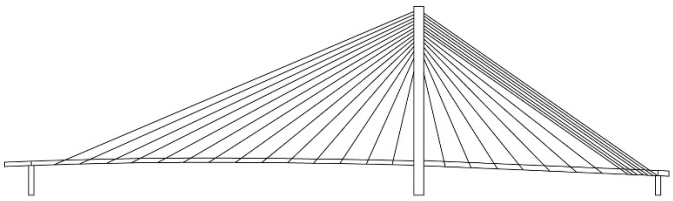


Figure 10-5. Schematic of Cable-Stayed Bridge Type — Single-Tower

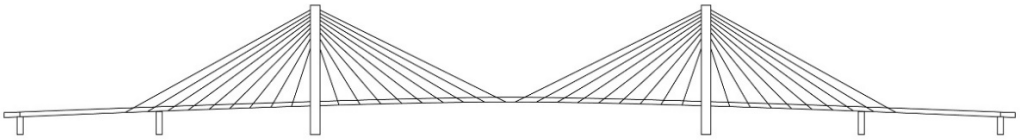


Figure 10-6. Schematic of Cable-Stayed Bridge Type — Two-Towers

A cable-stayed bridge would be constructed either from short, prefabricated elements delivered by barge or on-site using tower cranes. Erection of the cable-stayed bridge towers on-site would be as a balanced-cantilever erection, with the deck advanced symmetrically from each tower, or as a progressive cantilever construction, with the back span erected on shoring towers, followed by successive installation of shorter main span segments that cantilever over the canal span.

10.2.4 BOX GIRDER BRIDGE

In a box girder bridge, the deck is built on top of girders, rigid horizontal support beams, which are bound together in a hollow box shape. Supporting structures, such as cables, are not required above the deck level to support the bridge. MassDOT initially investigated variations for the box girder bridge consisting of steel boxes or post-tensioned concrete boxes. However, because there is no recent experience in the United States for construction of a steel box variation in the proposed 700-foot or 820-foot mainline span lengths, MassDOT did not carry forward the steel box variation as a viable option and evaluated only the post-tensioned concrete box. Figure 10-7 shows a schematic drawing of the concrete box-girder bridge type.



Figure 10-7. Schematic of Concrete Box Girder Bridge Type

A concrete box girder bridge would be constructed as balanced cantilevers with cast-in-place concrete placed into form travelers.

10.3 Design Evaluation Criteria and Assessment Methodology

MassDOT performed a rigorous preliminary engineering assessment of the four bridge types according to the bridge design evaluation criteria shown in Table 7-1 and described as follows:

- Initial costs, consisting of a qualitative evaluation of costs of the main span superstructure, main span foundations (substructure), and approaches.
- Ability to meet or exceed highway geometric design standards, consisting of the following:
    - Required highway elevation, and corresponding grade and length of the approach spans and ramps (horizontal tangent length), to meet the bridge's vertical clearance of 138 feet over the navigation channel, and
    - Required tie-in of vehicular and pedestrian ramps to the highway bridge mainline.
- Construction, including duration of construction, constructability, potential for phasing, difficulty of construction, and impact on canal traffic.
- Structural redundancy of fracture-critical and failure-critical members.
- Inspection and maintenance requirements, including accessibility to bridge components, exposure to the elements, and frequency of required inspection and maintenance.
- Durability, consisting of protection, replacement, and monitoring of structure members.
- Response to adverse weather conditions, including snow, ice, and wind.
- Community considerations, including aesthetics.

MassDOT placed highest priority on bridge types that would be practical and feasible to construct and maintain; bridge types that would not be practical and feasible were not advanced for further evaluation.

Additionally, MassDOT placed high priority on a bridge construction method that would minimize Cape Cod Canal navigation impacts. Cape Cod Canal supports substantial vessel traffic in both directions, such that barges, temporary construction supports (falsework), and/or any in-water equipment in the canal, both within and adjacent to the navigation channel, would be at risk for vessel impact. Long-term obstruction of the canal would amplify this risk. Based on consultation with the USACE, construction methods that would require falsework in the canal or frequent construction

activities from the canal would be unacceptable. The USACE indicated that short-term planned canal closures would be preferable over long-term operational restrictions in the channel.

MassDOT used an unscaled, qualitative rating scheme to facilitate the initial assessment of bridge types. Of particular importance are the triple-green (●●●) and triple-red (●●●) ratings, indicating bridge types and options that MassDOT advanced to the next evaluation (detailed assessment) or bridge types and options that MassDOT removed from further consideration.

Appendix A, the Cape Cod Bridge Replacements Initial Screening Report, documents the multiple bridge parameters that MassDOT conceptually screened and the results of the initial bridge type assessment.

10.4 Initial Bridge Type Assessment Results

Tables 10-1 and 10-2 present the results of the initial assessment of bridge types with piers located out-of-water, with either an approximate 700-foot or 820-foot main span length.

Table 10-1. Summary of Initial Bridge Type Assessment – 700-Foot Main Span

Bridge Design Evaluation Criteria [a]	Truss	Tied Arch		Cable Stayed		Concrete Box Girder
		Without Delta Frame	With Delta Frame	Two-Tower	Single-Tower	
Initial Costs						
• Main Span Structure	●	●●	●●	●●	●●●	●●
• Main Span Foundation	●●	●●	●●	●●	●●	●●
• Overall	●●	●●	●●	●●	●●	●●
Highway Geometrics						
• Grade/Length	●●	●●	●●	●	●	●●
• Horizontal Tangent Length	●●	●●	●●	●●	●●	●●
Construction						
• Duration	●●	●●●	●●●	●	●●	●
• Constructability	●●	●●	●●●	●●	●	●
• Impact on Canal Traffic	●	●●●	●●●	●	●	●●●
Structural Redundancy						
• Fracture-Critical Members	●●●	●●	●●	●●	●●	●●●
• Failure-Critical Members	●●	●●	●●	●●	●●	●●

Bridge Design Evaluation Criteria [a]	Truss	Tied Arch		Cable Stayed		Concrete Box Girder
		Without Delta Frame	With Delta Frame	Two-Tower	Single-Tower	
Inspection & Maintenance						
• Access	●●	●●	●●	●	●	●●
• Frequency	●●	●	●	●	●	●●●
Durability						
• Protection	●	●	●	●	●	●●
• Replacement	●	●●	●●	●	●	●●
• Monitoring	●	●	●	●	●	●
Wind Response						
• Structural Efficiency	●●	●●	●●	●●	●●	●●
• Dynamic Effects	●	●	●	●●	●●	●●
Snow & Ice Response						
• Bridge Closures	●	●	●	●●	●●	●●
• Monitoring/Deicing	●	●	●	●●	●●	●●
Community Considerations						
• Aesthetics	●●	●●	●●	●●	●●	●●

a. ●●● Most favorable; ●● Favorable; ● Neutral; ●● Less Favorable; ●●● Unfavorable; ●● Not Rated

Table 10-2. Summary of Initial Bridge Type Assessment – 820-Foot Main Span

Bridge Design Evaluation Criteria [a]	Truss	Tied Arch		Cable Stayed		Concrete Box Girder
		Without Delta Frame	With Delta Frame	Two-Tower	Single-Tower	
Initial Costs						
• Main Span Structure	●●	●●	●●	●●	●●●	●
• Main Span Foundation	●●	●●	●●	●●	●●	●●
• Overall	●●	●●	●●	●●	●●	●●
Highway Geometrics						
• Grade/Length	●●	●●	●●	●	●	●●
• Horizontal Tangent Length	●●	●●	●●	●●	●●	●●
Construction						
• Duration	●●	●●●	●●●	●●	●●	●
• Constructability	●●	●●	●●●	●●	●	●
• Impact on Canal Traffic	●●	●●	●●	●	●	●●●
Structural Redundancy						

Bridge Design Evaluation Criteria [a]	Truss	Tied Arch		Cable Stayed		Concrete Box Girder
		Without Delta Frame	With Delta Frame	Two-Tower	Single-Tower	
• Fracture-Critical Members	●●●	●●	●●	●●	●●	●●●
• Failure-Critical Members	●●	●●	●●	●●	●●	●●
Inspection & Maintenance						
• Access	●●	●●	●●	●	●	●●
• Frequency	●●	●	●	●	●	●●●
Durability						
• Protection	●	●	●	●	●	●●
• Replacement	●	●●	●●	●	●	●●
• Monitoring	●	●	●	●	●	●
Wind Response						
• Structural Efficiency	●	●	●	●●	●	●
• Dynamic Effects	●	●●	●●	●●	●●	●●
Snow & Ice Response						
• Bridge Closures	●	●	●	●●	●●	●●
• Monitoring/Deicing	●	●	●	●●	●●	●●
Community Considerations						
• Aesthetics	●●	●●	●●	●●	●●	●●

a. ●●● Most favorable; ●● Favorable; ● Neutral; ●● Less Favorable; ●●● Unfavorable; ●● Not Rated

Based on their performance relative to the bridge design evaluation criteria, and incorporating either a single deck or two-deck configuration, MassDOT advanced the tied-arch bridge type, the cable-stayed bridge type, and the box girder bridge type for a detailed bridge type assessment in the following configurations:

- Tied-Arch Bridge Type, either with traditional piers (without Delta frame) supporting a 700-foot main span or with a Delta-frame configuration supporting a 700-foot or 820-foot main span;
- Two-Tower Cable-Stayed Bridge Type supporting a 700-foot or 820-foot main span; and
- Concrete Box Girder Bridge Type supporting a 700-foot main span.

The initial bridge type assessment also identified specific detailed analyses needed to confirm the qualitative assessments presented in Tables 10-1 and 10-2. For example, MassDOT identified the need for wind tunnel studies to confirm the dynamic effects of the bridge types relative to wind force. Additionally, MassDOT identified an option to provide two separate bridge structures (barrels) at each crossing to facilitate phased construction (as described in Section 8).

10.5 Details of the Initial Bridge Type Assessment

Section 10.5 presents a detailed discussion of the major evaluation criteria differentiators shown in Tables 10-1 and 10-2, and MassDOT's recommendations to advance or not carry forward bridge types and their options for a secondary evaluation.

10.5.1 BRIDGE TYPES AND OPTIONS RECOMMENDED FOR FURTHER EVALUATION

10.5.1.1 Tied-Arch Bridge with Delta Frame, 700-foot, or 820-Foot Main Span; Tied- Arch Bridge without Delta Frame, 700-foot Main Span

Initial Costs Rating: Favorable

The Tied-Arch Bridge Type offers the potential for accelerated bridge construction, with the steel arch structure fabricated offsite while on-site foundation and substructure construction progress simultaneously. With off-site construction, the tied arch could be delivered by barge as a complete unit and lifted into position during a short, single (approximate 48-hour long) closure of the canal. This bridge type also receives a favorable rating regarding initial costs of the main span structure.

Geometrics Rating: Less Favorable to Favorable

The Tied-Arch Bridge Type has the least main span girder depth, giving it a favorable highway geometrics rating regarding the required vertical grade and length of the approaches to meet the bridge. For both variations, only the design of the main span over the canal would need to be straight; the approach span design could accommodate highway design plan curvature, increasing flexibility for the approach highway networks.

Construction Rating: Favorable to Most Favorable

Due to the opportunity for accelerated bridge construction, with the steel arch structure fabricated offsite concurrent with on-site foundation and substructure construction, this bridge type receives a most favorable rating regarding construction duration. Due to an anticipated short, scheduled canal closure for the tied arch installation, this bridge type receives a most favorable rating regarding impact on canal operations. The Delta frame variation, with a shortened arch length, could be positioned between the piers in its low position, allowing for a relatively quick and stable lifting operation. Because it would avoid interference between arch and piers during the lifting operation, the Tied-Arch Bridge Type - Delta frame receives a most favorable constructability rating in comparison to a favorable rating for the Tied-Arch without Delta frame.

Structural Redundancy Rating: Favorable

In the Tied-Arch Bridge Type, the tie girders, hangers, and floor beams are designed for system redundancy for fracture-critical and failure-critical members. This bridge type would use inclined cables arranged in a network pattern as opposed to the traditional vertical cable arrangement. The arch's closely spaced cables in a network pattern arrangement would provide structural redundancy and improved rib stability for these failure-critical members; the loss of one or several cables could be easily accommodated by the structure. Additionally, the tie girders and ribs would be accessible for inspection, maintenance, and replacement, resulting in a favorable rating.

10.5.1.2 Two-Tower Cable-Stayed Bridge, 700-Foot, or 820-Foot Main Span

Initial Costs Rating: Favorable

The two-tower supported Cable-Stayed Bridge Type, at the lower end of an efficient main span structure range for this type of bridge (as shown on Figure 10-1), receives a favorable rating.

Geometrics Rating: Less Favorable to Neutral

This bridge type receives a less favorable rating regarding main and side spans and horizontal tangent length in both span lengths: neither the main span nor the side span design could accommodate any highway design plan curvature, reducing flexibility for the approach highway networks.

Construction Rating: Favorable

For this bridge type, cantilever superstructure construction using prefabricated steel or concrete elements would have short-term impacts on canal traffic: navigation would be impacted by the periodic, partial obstructions of the canal for the approximate 40 segment lifts required for each bridge construction. A repetitive construction cycle could benefit the construction schedule.

Structural Redundancy Rating: Favorable

The crossing hanger cables and floor beams, determined to be fracture-critical members, would be designed for system redundancy; due to their close spacing, the loss of one or several cables could be accommodated by the overall structure.

Wind, Snow, and Ice Rating: Less Favorable

This bridge type receives a less favorable rating with respect to adverse weather conditions, including response to wind, snow, and ice. Wind tunnel studies would be needed for further assessment.

10.5.1.3 Concrete Box Girder Bridge, 700-foot Main Span

Initial Costs Rating: Less Favorable to Favorable

Due to the simplicity of the structure, the Concrete Box Girder Bridge Type receives a favorable rating regarding the initial costs of the main span structure. However, the Box Girder Bridge Type would require a girder depth of 10 to 20 feet greater than that required for the other bridge types; the deeper substructure would require longer or steep approaches, resulting in higher main span foundation and overall costs and a less favorable rating.

Geometrics Rating: Less Favorable to Favorable

Due to the required main span girder depth, this bridge type would require length or grade, resulting in a less favorable rating. However, this bridge type could accommodate a moderate highway plan curvature, increasing flexibility for the approach highway networks.

Construction Rating: Neutral to Most Favorable

A post-tensioned concrete box variation would be constructed as balanced cantilevers with cast-in-place concrete placed into form travelers. This method would present the opportunity for accelerated construction by working from two piers simultaneously; due to the repetitive construction cycle, the concrete box variation receives a favorable constructability rating. Further, balanced cantilever construction would take place entirely from above and would not affect navigation, resulting in a most favorable rating regarding construction impacts to canal traffic.

Structural Redundancy, Inspection and Maintenance Rating: Less Favorable to Most Favorable

With no fracture-critical members and with the fewest elements to maintain and inspect, the Concrete Box Girder Bridge Type is rated most favorable regarding structural redundancy and frequency of inspection and maintenance in comparison with other bridge types. But due to the post-tensioning tendons, failure-critical members, this bridge type receives a less favorable rating. In addition, deck replacement would not be possible with this bridge type, should it be required in the future.

Durability, Snow, and Ice Rating: Less Favorable to Favorable

This bridge type would not require supporting structures above the deck level. Unlike the other bridge types, the Concrete Box Girder Bridge Type would have the fewest exposed and vulnerable elements. As a result, impacts due to adverse weather conditions would be uncommon or negligible.

10.5.2 BRIDGE TYPES AND OPTIONS NOT RECOMMENDED FOR FURTHER EVALUATION

10.5.2.1 Truss Bridge, 700-Foot, or 820-Foot Main Span

Construction Rating: Neutral to Less Favorable

Constructing the Truss Bridge Type would be slower than the other bridge types. Falsework for stick-building would reduce the horizontal clearance at the bridge site for the entire duration of superstructure construction. Further, temporary fendering or other means of pier protection around the falsework during construction would introduce additional expense and complexity.

Structural Redundancy Rating: Less Favorable to Unfavorable

Tension elements in truss bridges, such as the tension diagonals and chords, are considered fracture-critical and any truss member is considered failure-critical. These members are subject to special fabrication and material quality and testing requirements: fracture-critical members must be inspected at arm's length every other year.

10.5.2.2 Tied-Arch Bridge without Delta Frame, 820-Foot Main Span

Initial Cost Rating: Less Favorable

The longer arch of the Tied-Arch Bridge Type without Delta frame represents the upper end of the economical span range; as a result, it receives a lower cost rating.

Construction Rating: Less Favorable to Unfavorable

On-site stick building of this bridge type would involve a long construction phase, resulting in an unfavorable construction duration. Additionally, the temporary falsework required during arch construction and erection would impact canal operations for approximately one year. Consultation with USACE as well as review of construction risks eliminated construction methods that that would require falsework or frequent construction activities in and from the canal from the canal.

10.5.2.3 Single-Tower Cable Stayed Bridge, 700-Foot, and 820-Foot Main Span

Initial Cost Rating: Unfavorable

Although the Single-Tower Cable Stayed Bridge variation's rankings are like the two-tower variation, due to its inefficient structural system leading to substantially higher costs for the main span structure, the Single-Tower Cable Stayed Bridge structure receives unfavorable ratings in both the 700-foot and 820-foot mainline span length.

10.5.2.4 Concrete Box Girder Bridge, 820-Foot Main Span

Initial Cost Rating: Less Favorable to Neutral

While this bridge type would have an efficient and simple structural system, there would be higher overall costs due to the heavy foundation and deeper superstructure.

Construction Rating: Neutral to Most Favorable

Construction of this bridge type would have no impact on canal operations, resulting in a most favorable rating. However, the current main span length record for a concrete box girder bridge in the United States is 760 feet. While construction of the 820-foot span may be feasible, it would not be practicable for the Program.

11 Detailed Bridge Type Assessment

11.1 Introduction

Based on the results of the initial bridge type assessment, MassDOT determined that the following bridge types and configurations would be further evaluated in a detailed bridge type assessment:

- Tied-Arch Bridge with Delta frame supporting a 700-foot main span on a single deck, or supporting a 700-foot or 820-foot main span on separate decks;
- Tied-Arch Bridge without Delta frame supporting a 700-foot main span on separate decks;
- Two-Tower Cable Stayed Bridge supporting a 700-foot or 820-foot main span on separate decks, or supporting an 820-foot main span on a single deck; and
- Concrete Box Girder Bridge supporting a 700-foot main span on separate decks.

Sections 11.2 and 11.3 describe the detailed bridge type assessments MassDOT conducted, consisting of additional highway geometrics assessments and a detailed and comprehensive constructability assessment of the bride types selected as feasible by the initial bridge type assessment. The constructability assessments included a detailed assessment of the bridge deck configuration and a screening of bridge fabrication and erection methodologies.

Appendix B provides the Cape Cod Bridge Replacements Constructability Assessment (HNTB, 2021), which evaluates the initial favorable bridge configurations for various aspects of constructability, including fabrication, material transport, erection methodology, and impacts to canal and canal-side traffic. Appendix C provides the Cape Cod Bridge Replacements Phase II Screening Report (HNTB, 2022), which documents the secondary evaluation process that resulted in a recommended bridge type for the replacement of the Bourne and Sagamore highway bridges.

MassDOT then presented the preliminary recommendations for the favorable bridge types to the public. Section 11.4 describes the public's review of MassDOT's preliminary recommendations, including an assessment of community considerations and bridge aesthetics, which confirmed the recommended bridge type as the Alternative Retained for Detailed Study.

11.2 Highway Geometrics Assessments

In its further highway and interchange design following the initial bridge type assessment, MassDOT confirmed that there are feasible geometric solutions for bridges with structure depths in the 8-foot range, such as the Tied-Arch and Cable Stayed bridge types.

The Tied-Arch Bridge with Delta Frame would have the least main span girder depth, which would facilitate the grade and length of the highway approach spans and ramps needed to maintain the required vertical clearance of 135 above MHW. Additionally, this bridge type would provide the flexibility to tie in interchange approach ramps closer to the main span.

The Two-Tower Cable Stayed Bridge was shown to be feasible from a highway geometrics aspect, but it would limit or eliminate some approach configurations and steepen ramp grades, resulting in a less favorable highway geometrics rating.

An analysis of ramp tie-in grades indicated that the deeper structure depth required for the Concrete Box Girder Bridge Type would not meet highway or ADA design criteria and codes. Further, this bridge type would require an approach length and grade that could not be accommodated in highway design and construction without substantial right-of-way impacts.

11.3 Advanced Constructability Assessments

11.3.1 BRIDGE DECK CONFIGURATION SECONDARY ASSESSMENT

An advanced constructability review of the project site and the bridge configurations identified that a bridge structure configuration with a single deck would present a constructability risk. MassDOT determined that the width of the single deck configuration, at approximately 129-feet, would be at the limit of being transportable, being erectable, and maintaining interim stability. Wide decks would necessitate large floor beams and require increased crane capacity. Additionally, wide decks would increase the complexity of geometry control.

In contrast, the constructability review indicated that a two-deck configuration would offer constructability and phasing benefits over single structures due to smaller member sizes, simplified geometry control, and ability to sequence construction of new spans with demolition of existing spans. With separate bridge structure decks, the new bridge would be built parallel to the existing structure. It would then carry traffic in a temporary configuration, while the old bridge would be demolished, and a new second-phase bridge would be erected in its place.

MassDOT determined that incorporating a two separate deck configuration (twin structures for each crossing) would provide flexibility during construction. While a two-deck configuration could potentially increase total construction time, it also would accelerate the schedule for decommissioning of the existing bridges. An accelerated schedule for demolishing the existing bridges would be highly advantageous in view of the high cost of maintaining the existing bridges and considering the risk and high user costs of a loss of service. For these reasons, MassDOT recommended the incorporation of the

bridge structure configuration with separate parallel decks into the bridge type. MassDOT recommended that the single-deck configuration not advance for further analysis.

11.3.2 BRIDGE FABRICATION AND ERECTION METHODOLOGY ASSESSMENTS

MassDOT's assessment of the bridge fabrication and erection methodology incorporates a detailed constructability evaluation of the two optional main span lengths of approximately 700-feet and 820-feet (presented in Section 7).

As an alternative to in-situ piecewise erection ("stick building"), a traditional methodology for arch construction which relies on falsework to temporarily support arch members until the full span is complete, MassDOT investigated the potential to fabricate the replacement bridge arch span offline of the permanent alignment, then transport it to the final installed position. Due to existing site condition constraints, MassDOT determined that no suitable arch fabrication sites exist along canal, however offsite fabrication and open-water transport would be feasible. The constructability assessment indicated that for spans in the 700-foot range, twin Tied-arch Bridges on Delta piers lifted using strand jacks would be very well suited to site conditions; the vertical clearances of the existing Bourne and Sagamore bridges and barge operations favor the 700-foot span.

With a tied-arch bridge, the steel structure could be assembled in a remote fabrication yard, transported to the site on an ocean-going barge, and lifted into place. This construction scheme would minimize impacts to canal traffic, requiring a short closure only during the lifting operation. With a Tied-Arch Bridge, the arch would be self-supporting and stable for transport once constructed on land and transferred to a barge for transport. In contrast to a cable-stayed bridge erection, float-in construction of a tied-arch bridge would enable the structure to be installed as a complete, stable unit. Duration of the critical lifting operation would be minimal and could be scheduled to take advantage of favorable weather conditions.

Positioning the longer arch (non-Delta frame) into place would require lifting the arch approximately 140 feet from a barge in an off-line position to avoid the vertical piers. This construction requirement would be risky from a practicality, schedule, and cost perspective, resulting in an unfavorable construction rating. The shorter arch of the Delta frame, as opposed to the longer span of the non-Delta variation, would be beneficial regarding barge size and the limited vertical clearance of the existing bridges. Further, the tied-arch bridge on delta piers would be beneficial over straight piers (non-Delta variation), as the simplified lifting operations would avoid the challenge of maintaining barge stability while lifting the arch to the elevation required for installation on straight piers. The Tied-Arch Bridge with Delta frame supporting a 700-foot main span receives most favorable construction ratings for duration of construction and constructability.

Over the past decade, sustained wind speeds of 20 miles per hour (mph) or greater have been recorded on approximately 10 percent of days during the winter months (October through April). Gusts exceeding 40 mph occur regularly. Extreme weather and/or wind events can be expected to occur during construction while the structure is in a vulnerable state. To mitigate the risk associated with extreme

weather or wind events, MassDOT determined that a design and erection strategy which minimizes the time the structure is vulnerable during erection would be the most advantageous.

While twin cable stayed bridge configurations in the 820-foot range would be well suited to the site conditions, MassDOT determined that the Cable-Stayed Bridge Type in both the 700-foot and 820-foot span length would be vulnerable to high winds events during construction relative to tied arch bridges on delta piers. Erection of cable-stayed bridge towers requires the use of tower cranes. Wind tunnel testing of the Cable-Stayed Bridge type indicates that the use of tower cranes would be subject to severe operational restrictions in windy conditions, whether they are operated from land or a barge, or if they are tower-based. Tower cranes generally have a safe operational wind ceiling of 25 mph. Given the exposed site, this limitation would present a considerable construction schedule risk. Wind tunnel testing indicates that the Cable-Stayed Bridge Type would be vulnerable to wind loads during certain construction stages and cable-stayed construction operations would be more affected by high-wind conditions. The cables would be vulnerable to wind and wind-rain induced vibrations, and the light structure itself would be more susceptible to dynamic effects. The cable force and geometry control requirements would present considerable schedule and cost risks.

11.4 Public Review of Preliminary Recommendations

In November 2022, MassDOT conducted virtual public meetings to review preliminary recommendations of the feasible bridge types, obtain public sentiment on the bridge types, and confirm the bridge type to be advanced for further design.

11.4.1 COMMUNITY CONSIDERATIONS AND BRIDGE AESTHETICS

MassDOT reviewed three feasible bridge types relative to community considerations, including consistency with the Context Sensitive Design principal to be "in harmony with the community" and preserve the scenic, aesthetic, historic, and built resources of the area.

Figures 11-1 and 11-2 show renderings of the existing bridges from the viewpoints of the Cape Cod Canal and the motor vehicle driver crossing the bridge.[16] The arched main span, which is visually consistent with the surrounding terrain, emphasizes the crossing of the canal. While the initial construction of the Cape Cod Canal dates to 1916, the current bridges were constructed in 1935 in the same period as the USACE's reconstruction of the canal throughout the 1930s. The existing Bourne and Sagamore bridges are contributing resources to and consistent with the character of the Cape Cod Canal Historic District, which was determined by the Massachusetts Historical Commission (MHC) to be eligible for individual listing in the National Register of Historic Places (NRHP). The bridges are recognized as the "Gateway to Cape Cod." The Bourne Comprehensive Plan cites the importance that the bridge replacements "respect the iconic natures of these bridges to the Cape's image," noting that the bridges are integral to the local heritage of Cape Cod. The Cape Cod Commission's Regional Policy Plan includes two policy goals applicable to the existing bridges and their replacements: Community Design, to "protect and enhance the unique character of the region's built and natural environment based on the

[16] The singular rendering represents views from either the Bourne or Sagamore Bridge. As steel truss bridges with concrete column piers and abutments, the bridges are almost identical.

local context;" and Cultural Heritage, to "protect and preserve the significant cultural, historic, and archaeological values and resources of Cape Cod." Further, the Policy Plan's vision for Historic Areas, including local and/or NRHP districts, is to protect historic resources and to support development that respects the form, scale, and character of existing historic areas.



Figure 11-1. Rendering of Existing Bridge — Cape Cod Canal Viewpoint



Figure 11-2. Rendering of Existing Bridge — Driver Viewpoint

Figures 11-3 and 11-4 show renderings of the Tied-Arch Bridge Type with Delta frame from the viewpoints of the Cape Cod Canal and the motor vehicle driver crossing the bridge. The Tied-Arch Bridge Type provides an iconic portal, like the existing bridges, and is consistent with the surrounding terrain. Because it would echo the appearance of the existing Bourne and Sagamore bridges and it provides a continuity of style and aesthetic, the Delta frame variation maintains a consistent visual linkage with the NRHP-eligible Cape Cod Canal Historic District. MassDOT determined that it is likely that the Tied-Arch Bridge Type - Delta frame would avoid an adverse visual effect on the NRHP-potentially eligible Cape Cod Canal Historic District.

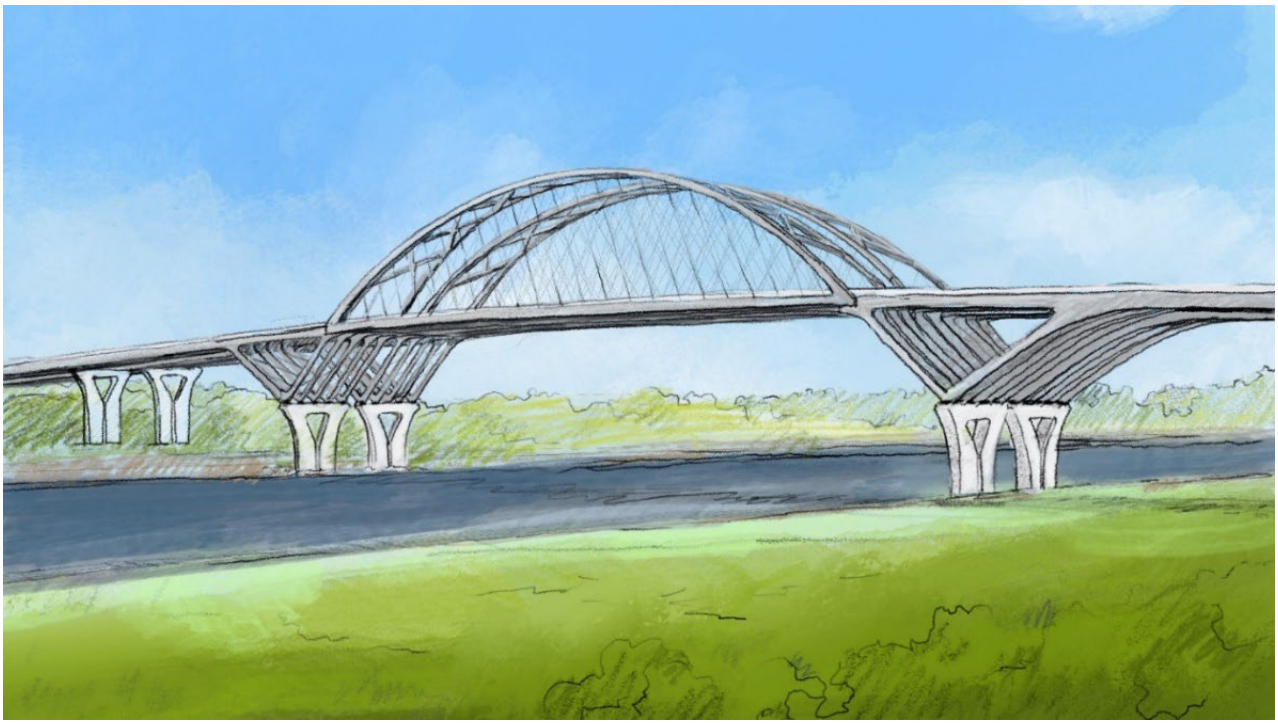


Figure 11-3. Rendering of Tied Arch Bridge with Delta Frame – Cape Cod Canal Viewpoint



Figure 11-4. Rendering of Tied Arch Bridge with Delta Frame – Driver Viewpoint

Figures 11-5 and 11-6 show renderings of the Two-Tower Cable Stayed Bridge Type from the viewpoints of the Cape Cod Canal and the motor vehicle driver crossing the bridge. The bridge form represents a substantial departure from the visual character of the existing structure. Due to its dissimilarity to the existing historic structures, the introduction of modern element in its viewshed, and the inconsistency with the existing context, the Two-Tower Cable-Stayed Bridge Type potentially could have an adverse visual effect on the NRHP-potentially eligible Cape Cod Canal Historic District.



Figure 11-5. Rendering of Two-Tower Cable Stayed Bridge – Cape Cod Canal Viewpoint



Figure 11-6. Rendering Of Two-Tower Cable Stayed Bridge – Driver Viewpoint

Figures 11-7 and 11-8 show renderings of the Concrete Box Girder Bridge Type from the viewpoints of the Cape Cod Canal and the motor vehicle driver crossing the bridge. This bridge type does not provide a gateway experience for the driver, and the massive concrete structure represents a departure from the gracefulness of the existing steel bridges. Due to its dissimilarity to the existing historic structures, the introduction of a modern element in its viewshed, and the inconsistency with the existing context, the Box Girder Bridge Type potentially could have an adverse visual effect on the NRHP- eligible Cape Cod Canal Historic District.



Figure 11-7. Rendering of Concrete Box Girder Bridge — Cape Cod Canal Viewpoint



Figure 11-8. Rendering Of Concrete Box Girder Bridge — Driver Viewpoint

11.4.2 PUBLIC POLLING RESULTS

MassDOT received a total of 2,214 responses during and following the November 2022 public meetings. Tables 11-1 and 11-2 present the results of the public opinion polls. As shown in Table 10-2, with an average rating of 4.5 out of 5, the Tied-Arch Bridge with Delta Frame received the most favorable public review rating.

Table 11-1. Public Review: Bridge Replacement Considerations

Polling Questions/Rankings	How important is that the new Cape Cod Bridges resemble the current Bourne and Sagamore Bridges?		The existing bridges are iconic as portals into Cape Cod. How important is it to replace the existing bridges with landmark structures?	
	Count	Percentage	Count	Percentage
Very Important	882	40	1,245	56
Somewhat Important	700	32	653	30
Not that Important	366	16	210	9
Not at all Important	263	12	100	5
Total Responses	2,211	100	2,208	100

Note: Percentages are rounded.

Table 11-2. Public Review: Bridge Types

Rate the Bridge Type According to Your Preference *	Tied Arch Bridge with Delta Frame		Two-Tower Cable-Stayed Bridge		Concrete Box Girder Bridge	
	Count	Percentage	Count	Percentage	Count	Percentage
☆	64	2.9	510	23.0	1,479	66.8
☆☆	52	2.4	307	13.9	278	12.6
☆☆☆	209	9.4	608	27.5	250	11.3
☆☆☆☆	328	14.8	416	18.8	100	4.5
☆☆☆☆☆	1,561	70.5	373	16.8	107	4.8
Total Responses	2,214	100.0	2,214	100.0	2,214	100.0
Average Rating	4.5		2.9		1.7	
☆= least preferred; ☆☆☆☆☆= most preferred						

11.5 Detailed Bridge Type Assessment Results

Tables 11-3 and 11-4 present the results of the detailed assessment of the three bridge types. The detailed analysis incorporates MassDOT's highway geometric assessments, additional constructability assessments of the feasible bridge types (including the detailed bridge deck configuration assessment), and the public's review of the feasible bridge types relative to community considerations and bridge aesthetics.

The Tied-Arch Bridge with Delta Frame supporting an approximate 700-foot main span received four favorable or more ratings out of six engineering criteria further evaluated during the detailed bridge type assessment. Additionally, the Tied-Arch Bridge with Delta Frame on a 700-foot main span received the highest public review rating.

Table 11-3. Summary of Detailed Bridge Type Assessment – 700-Foot Main Span Length

Bridge Design Evaluation Criteria [a]	Tied-Arch Bridge		Two-Tower Cable Stayed Bridge	Concrete Box Girder Bridge
	Without Delta Frame	With Delta Frame		
Highway Geometrics				
• Grade/Length	●●	●●	●●	●●●
• Horizontal Tangent Length	●●	●●●	●●	●●
Construction				
• Duration	●●●	●●●	●●	●
• Constructability	●●●	●●●	●●	●●
Wind Response				
• Structural Efficiency	●●	●●	●●	●●
• Dynamic Effects	●	●	●●	●●
Community Considerations [b]				
• Aesthetics/Signature	●●	★★★★½	●●	★½

a. ●●● Most favorable; ●● Favorable; ● Neutral; ●● Less Favorable; ●●●Unfavorable; ●●Not Rated

b. ★★★★½ = 4.5 stars, ★★½ = 2.9, ★½ = 1.7

Table 11-4. Summary Of Detailed Bridge Type Assessment – 820-Foot Main Span Length

Bridge Design Evaluation Criteria [a]	Tied-Arch Bridge with Delta Frame	Two-Tower Cable Stayed Bridge
Highway Geometrics		
• Grade/Length	●●	●●
• Horizontal Tangent Length	●●	●●
Construction		
• Duration	●●●	●●
• Constructability	●●●	●●
Wind Response		
• Structural Efficiency	●	●●
• Dynamic Effects	●●	●●
Community Considerations [b]		
• Aesthetics/Signature	●●	★★½

a. ●●● Most favorable; ●● Favorable; ● Neutral; ●● Less Favorable; ●●●Unfavorable; ●●Not Rated

b. ★★★★½ = 4.5 stars, ★★½ = 2.9 stars, ★½ = 1.7

As a result of the detailed bridge type assessment, incorporating the highway geometric and constructability assessments and public input, MassDOT recommended the following bridge type to be retained for detailed study: parallel, twin tied-arch bridge structures supported on Delta frames with an approximate 700-foot main span length. As design advances, MassDOT will determine exact span length, arch rib configuration, tie-in with approach ramps, and other parameters for the Tied-Arch Bridge with Delta Frame, which will be included in the Program Bridge Type Study.

12Initial Assessment of Highway Interchange Approach Options

12.1 Introduction

Section 12 summarizes MassDOT's initial series of evaluations conducted through 2023of highway interchange approach options for the four quadrants of the canal crossings, two each at the Bourne and Sagamore crossings. The four quadrants, referenced as Bourne North, Bourne South, Sagamore North, and Sagamore South, are shown in Figure 12-1.

12.2 Conceptual Screening of Universe of Concepts

Using the alternatives identified in its 2017 Cape Cod Canal Area Transportation Study as its starting point, MassDOT initially identified and screened a total of 80 highway interchange approach concepts, consisting of 29 concepts for Bourne North, 17 concepts for Bourne South, 18 concepts for Sagamore North, and 16 concepts for Sagamore South. The conceptual screening consisted of defining highway interchange approach concepts according to three status levels:

- Active, where the concept was deemed to be a viable option to be further refined;
- Incorporated Elsewhere, where portions of the concept were viable and incorporated into another concept;
- Not Being Further Developed (NBFD), where the concept demonstrated fatal flaws and was not carried forward for further design or where a similar concept provided the same connections with less environmental or right-of-way impacts.

MassDOT screened the Universe of Concepts according to feasibility and reasonability. At this level of evaluation, feasibility was based on aerial images for the horizontal alignment and U.S. Geological Survey (USGS) approximate elevations for the vertical alignment. Concepts that were deemed to be viable but were like other more favorable concepts were incorporated into those concepts, either wholly or partially, and were labeled as "Incorporated Elsewhere." Concepts that presented significant geometric or safety challenges, did not provide all necessary connections, or posed infeasible constructability issues were identified as fatally flawed, labeled as "NBFD," and were not carried forward for further design and evaluation. Other NBFD concepts included those concepts that provided the same connections as other concepts but involved more environmental or right-of-way impacts.

MassDOT also identified two other categories for discrete design elements specific to Program Study Area quadrants. MassDOT identified a category of "Paused/Pending Future Need" concepts specific to Bourne North. These discrete design elements were related to Belmont Circle improvements. MassDOT paused the development of these design elements pending the need for improvements to Belmont Circle. MassDOT identified a category of "Deferred/Design Development" concepts specific to Sagamore North. These discrete design elements were deemed to be potentially viable; however, MassDOT opted to defer the advancement of these specific design elements until further design.

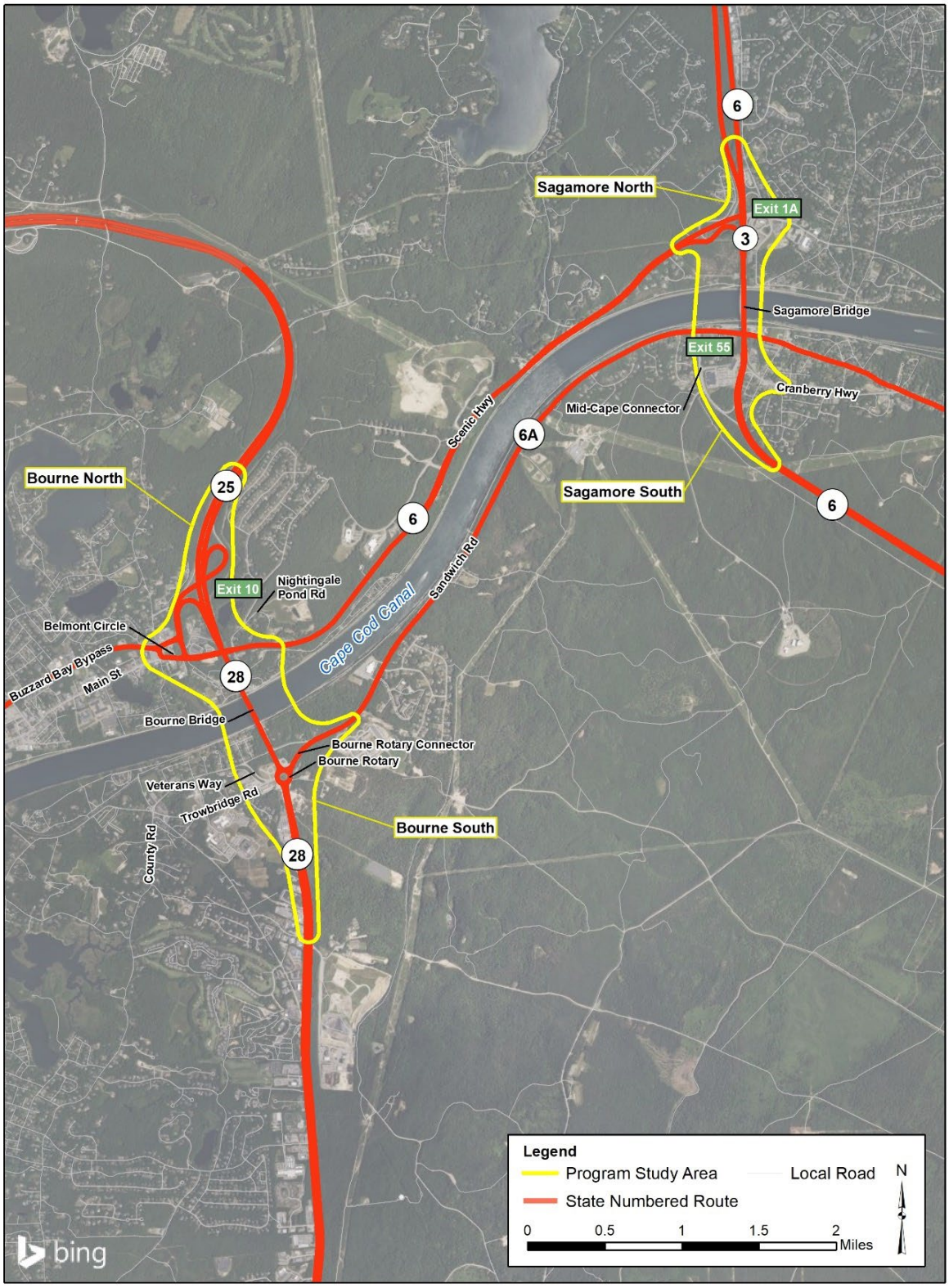


Figure 12-1. Bourne and Sagamore Program Study Area Quadrants

Of the 46 concepts MassDOT initially developed for the Bourne Program Study Area, nine concepts were defined as active options to advance for further evaluation, seven concepts were incorporated elsewhere, 26 concepts were defined as NBFD, and four concepts were paused. Of the 34 concepts MassDOT initially developed for the Sagamore Program Study Area, 13 concepts were defined as active options to advance for further evaluation, two concepts were incorporated elsewhere, 12 concepts were defined as NBFD, and seven concepts were deferred. Appendix D provides the conceptual identification and screening assessment of the wide range of highway interchange approach configurations (Universe of Concepts) that resulted in 22 interchange approach options for the Bourne and Sagamore crossings.

12.3 Design Evaluation Criteria and Assessment Methodology

From the screening of the Universe of Concepts, MassDOT identified 22 highway interchange approach options for the four quadrants of the canal crossings that advanced to an initial assessment. Utilizing the USACE's MRER/EA Preferred Alternative of In-Kind Bridge Replacement, and incorporating its recommended Fully Offline Inboard location for the mainline alignment, MassDOT identified the following active options:

- Bourne Crossing: four Bourne North (BN) options and five Bourne South (BS) options; and
- Sagamore Crossing: four Sagamore North (SN) options and nine Sagamore South (SS) options.

MassDOT assessed the 22 highway interchange approach options relative to the Program's highway design evaluation criteria listed in Table 8-1 and summarized below:

- Operations – Ability to improve existing traffic operations.
- Connectivity – Ability to maintain or improve existing roadway connections.
- Geometrics – Ability to meet or exceed current MassDOT and FHWA design standards, without design exceptions, including but not limited to curve lengths, stopping sight distances, and desired profile grades for roadway-bridge connections. The desired profile grades are 4.5 percent for the Bourne crossing and 4 percent for the Sagamore crossing.
- Safety – Ability to improve safety conditions by reducing predicted crash frequency, crash rate, crash type, and/or crash severity.
- Constructability – Ability to maximize constructability and construction efficiency, including maintaining two traffic lanes in each direction at each crossing during construction, maintaining all connections to the local roadway network at locations like the existing condition during construction, maintaining and/or improving schedule and costs, minimizing impacts to the traveling public, and reducing complexity relative to staging and need for temporary structures.
- Multi-Modal Connections- Ability to provide for multi-modal connections through barrier separated bicycle and pedestrian accommodations on the bridge structure and to the interchange approach network.
- Utility Impacts – Ability to minimize direct and indirect impacts to existing utilities, including relocations.
- Environmental Impacts- Ability to minimize impacts to protected resources.

- Right-of-Way Impacts – Ability to minimize impacts to properties, including full acquisitions and partial impacts, potential displacement, and adverse effects to Environmental Justice (EJ) communities.

Based on 2050 No-Build condition traffic volumes, MassDOT assessed future traffic operations using several traffic analysis and modeling programs.[17] To assess safety conditions of the options relative to the 2050 No-Build traffic volumes, MassDOT conducted engineering assessments consistent with AASHTO's Highway Safety Manual. MassDOT estimated utility, environmental, and right-of-way impacts using the interchange conceptual footprints.

Highway interchange approach options were rated based on their performance relative to meeting the Program's highway design evaluation criteria; the ratings were then compared to identify options that MassDOT would recommend for a detailed, secondary level of assessment. MassDOT placed high priority on interchange approach options that would be practical and feasible to construct and maintain; options that would not be practical and feasible were not recommended to be carried forward for further evaluation. MassDOT used an unscaled, qualitative rating scheme to facilitate the screening.

MassDOT used an unscaled, qualitative rating scheme to facilitate the screening. Of particular importance are the triple-green (●●●) and triple-red (●●●) ratings, indicating highway interchange approach options that MassDOT recommended to advance to a detailed assessment, or highway interchange approach options that presented considerable drawbacks and which MassDOT did not recommend for further consideration.

Sections 12.4 through 12.11 present the findings of the initial assessment of highway interchange approach options for the Bourne North and South and Sagamore North and South crossings. The assessment results are conceptual, particularly regarding environmental and right-of-way impacts. It is important to note that the right-of-way impacts identified for the Bourne and Sagamore crossing interchange approach options would be added to the anticipated right-of-way impacts associated with MassDOT's recommended Fully Offline Inboard location for the mainline alignment at both crossings.

In March 2023, MassDOT conducted virtual public meetings to review the results of the initial highway interchange approach and present the short list of options recommended for a detailed assessment. Additionally, in May 2023, MassDOT hosted an in-person Open House in Bourne to solicit public feedback on the Program's recommendations, including the ten highway interchange approach options proposed for a further evaluation.

[17] Traffic analysis and modeling software included Synchro, Highway Capacity Software, SIDRA Software, and VISSIM.

12.4 Summary of Bourne North Crossing Interchange Approach Initial Assessment

MassDOT identified four interchange approach options for the Bourne North crossing and conducted an initial assessment relative to the highway design criteria. All four approach options would meet current MassDOT and FWHA design standards. The northbound and southbound ramps would be designed for a minimum speed of 30 MPH. The four options received a consistent neutral or better safety impacts rating and a favorable or better connectivity rating. All four options received a favorable multi-modal connections rating; each would include an independent shared use path on the bridge that would provide a 4.50 percent longitudinal profile grade off the mainline structure. It is anticipated that path routing would be fairly circuitous to provide the length necessary to allow the path to descend from the bridge structure elevation to the elevation of the path termini. The four approach options largely differed regarding operations, constructability, and environmental and right-of-way impacts.

Table 12-1 presents the results of the initial assessment of Bourne North crossing interchange approach options. Based on the initial assessment, MassDOT advanced Options BN-6.1, BN-13.1, and BN-14.4b as Bourne North crossing interchange approach alternatives for further evaluation.

Table 12-1. Initial Assessment Results of Bourne North Crossing Interchange Approach Options

Highway Design Evaluation Criteria (1), (2)	BN-6.1	BN-10	BN-13.1	BN-14.4b
Operations	●●	●	●●	●●●
Connectivity	●●	●●●	●●	●●●
Geometrics	●●	●	●●	●●
Safety	●	●	●	●●
Constructability	●●●	●	●	●
Multi-Modal	●●	●●	●●	●●●
Utilities	●●	●●	●●	●●
Environmental	■ ■	■ ■ ■ ■	■ ■	■ ■
Right-of-Way	■ ■ ■	■	■	■ ■

(1): ●●● Most favorable; ●● Favorable; ● Neutral; ●● Less Favorable; ●●● Unfavorable; ●● Not Rated

(2) Range of Least to Less Impacts= ■ ■ ■ ■, ■ ■ ■, ■ ■, ■; Medium Impacts= ❖ ; Range of More to Most Impacts= ■, ■ ■, ■ ■ ■, ■ ■ ■ ■

Section 12.5 presents details of the initial assessment of the Bourne North crossing highway interchange approach options and MassDOT's recommendations to advance or not carry forward options for a more detailed evaluation.

12.5 Details of Bourne North Crossing Interchange Approach Initial Assessment

12.5.1 OPTIONS RECOMMENDED FOR FURTHER EVALUATION

12.5.1.1 Option BN-6.1

Option BN-6.1 would largely mimic the existing interchange configuration. All entering and exiting movements would utilize existing ramp configurations with minor modifications to meet the offset

mainline while adding a new northbound on-ramp directly from Scenic Highway east of the mainline. Like existing conditions, the termini of the ramps would be in the northeast quadrant of Belmont Circle. In addition to maintaining the existing ramp configurations, Option BN-6.1 would add a second northbound access point from Route 6 (Scenic Highway) to Route 25. Access to this ramp would be located along Scenic Highway between the relocated mainline and the existing intersection with Nightingale Road. The new ramp alignment would closely follow the relocated mainline alignment before curving east, away from the mainline, to reconnect with the curvature of the existing northbound on/off loop ramp. The new ramp would merge with the existing northbound on-ramp before merging with the Route 25 mainline highway. Figure 12-2 shows a conceptual layout of Option BN-6.1.

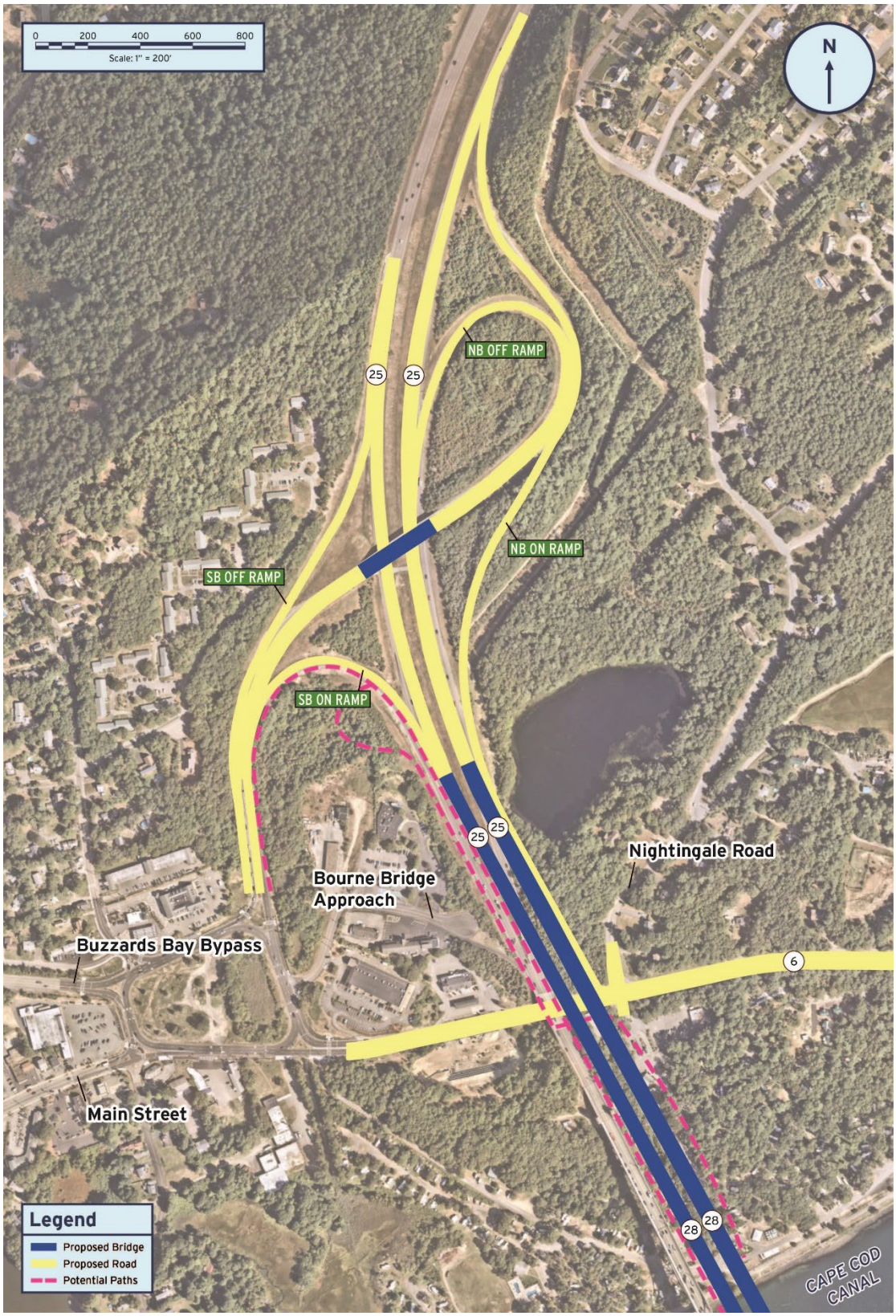


Figure 12-2. Bourne North Crossing Interchange Approach Option BN-6.1

Operations, Connectivity, and Geometrics Ratings: Favorable

This option would largely mimic existing connections. The new Route 25 northbound on-ramp would provide an additional access route to Route 25 northbound and would reduce westbound traffic at Belmont Circle. This option would not add southbound connections, however; therefore, it would not improve any southbound movements at the interchange approach. This option would meet current MassDOT and FHWA design standards, with the northbound off-ramp and the southbound on-ramp designed to meet a minimum design speed of 30 MPH.

Safety Rating: Neutral

Due to improved geometric and cross-sectional features of the new ramp facility, engineering assessments and safety modeling indicate that the overall highway and ramp segment crash rates are predicted to be slightly reduced in comparison to the base condition. However, the interaction between vehicles exiting Nightingale Road and entering the new northbound on-ramp could contribute to crashes, negating some of the projected safety improvements. Methods of improving the safety operations of this potential conflict area would require further investigation as design progresses.

Constructability Rating: Most Favorable

Besides the new northbound on-ramp connection, there would be no other additional structures, resulting in minimal impacts to the traveling public and no additional construction complexity. Compared to the other Bourne North crossing interchange approach options, Option BN-6.1 would result in a one-year schedule reduction.

Multi-Modal Connections Rating: Favorable

It is anticipated that connections to the local road network would be provided by shared use path direct connections to Belmont Circle and the USACE Canal Service Road (bike path).

Utility Impacts Rating: Favorable

Utility impacts would be limited to some minor water main impacts; relocation of 18 utility poles, overhead wires, and other minor electrical impacts; and minor drainage impacts. This option would not involve notable telecommunications or sewer impacts. Impacts to gas infrastructure would not notably increase over those impacts anticipated due to the relocated mainline (Route 25) construction.

Environmental Impacts Rating: Less Impactful

Option BN-6.1 would not involve direct impacts to environmental resources. However, the ramp connection would be within five feet of Nightingale Pond and the proposed shared use path over wetlands could create indirect (shading) impacts to approximately 2,000 sf of wetlands.

Right-of-Way Impacts Rating: Less Impactful

Based on conceptual design, this option would involve right-of-way impacts in addition to those previously identified for MassDOT's recommended mainline alignment alternative: Fully Offline Inboard. Option BN-6.1 would result in three residential partial property acquisitions and two commercial property partial acquisitions, including minor property impacts to the 4-acre, Sav-On Mart mixed use development and a 10-pump gasoline station. The impacts would not directly affect EJ communities or populations.

12.5.1.2 Option BN-13.1

Option BN-13.1 would build upon the concepts introduced in Option BN-6.1, where all entering and exiting movements would utilize existing ramp configurations with minor modifications to meet the proposed offset mainline and to improve acceleration and deceleration distances. Option BN-13.1 also would add a connection from Route 25 southbound off-ramp directly to Scenic Highway. The new direct connection from Route 25 southbound to Route 6 (Scenic Highway) would be possible via a division of the existing southbound off-ramp that continues south parallel to the relocated mainline. This alignment would require the Route 25 southbound off-ramp to pass under the Route 25 southbound on-ramp in a braided ramp configuration. After passing under the southbound on-ramp, the off-ramp would continue south until it intersects with Scenic Highway at an at-grade intersection. The Route 25 connection with Scenic Highway eastbound would be west of the Nightingale Road intersection and controlled by a signal. Figure 12-3 shows a conceptual layout of Option BN-13.1.

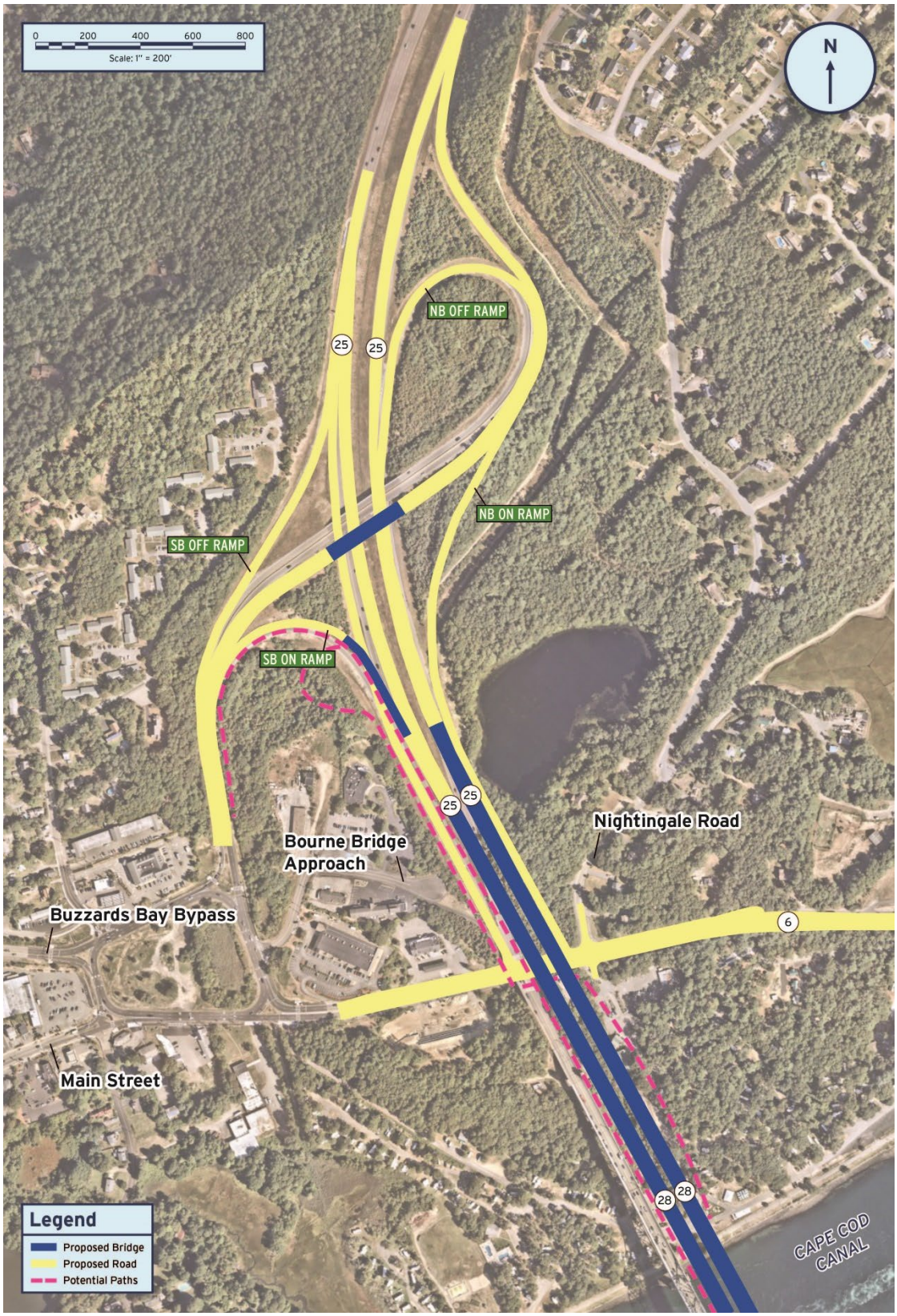


Figure 12-3. Bourne North Crossing Interchange Approach Option BN-13.1

Operations, Connectivity, and Geometrics Ratings: Favorable

In comparison to existing conditions, this option would provide two additional direct access routes to and from Route 25: from Scenic Highway westbound to Route 25 northbound and from Route 25 southbound to Scenic Highway eastbound. Both new access routes would reduce westbound and southbound traffic at Belmont Circle. Furthermore, additional design would be needed to ensure that the westbound traffic queue at the new signalized intersection west of Nightingale Road would avoid queue blockage at the Nightingale Road intersection. This option would meet current MassDOT and FHWA design standards, with the northbound off-ramp and the southbound on-ramp designed to meet a minimum design speed of 30 MPH.

Constructability Rating: Neutral

Due to the construction of the Route 25 bridge and southbound on-ramp over the southbound off-ramp, this option would add an additional year of construction compared to Option BN-6.1. While there would be minimal impacts to the traveling public, the construction of the skewed Route 25 southbound on-ramp over the Route 25 off-ramp would create a complex abutment/pier arrangement.

Safety Rating: Neutral

While the additional ramp facilities connecting Route 25 and Scenic Highway would remove major vehicle movements from Belmont Circle, engineering assessments and safety modeling predict similar highway and ramp segment crash rates in this option compared to the future no-build conditions.

Multi-Modal Connections Rating: Favorable

It is anticipated that connections to the local road network would be provided by shared use path direct connections to Belmont Circle and the USACE Canal Service Road (bike path).

Utility Impacts Rating: Favorable

Like Option BN-6.1, utility impacts in Option BN-13.1 would be limited to minor impacts relative to water; electrical, with relocation of 18 utility poles and overhead wires; and drainage. There would be no notable telecommunications or sewer impacts resulting from this option. Impacts to gas infrastructure would not notably increase over those impacts anticipated due to the relocated mainline construction.

Environmental Impacts Rating: Less Impactful

No direct environmental impacts are anticipated in this option. However, the Route 25 northbound on-ramp connection would be within five feet of Nightingale Pond.

Right-of-Way Impacts Rating: Least Impactful

Based on conceptual design, this option would involve right-of-way impacts in addition to those previously identified for MassDOT's recommended mainline alignment: Fully Offline Inboard. Option BN-13.1 would result in four residential partial property acquisitions and three commercial partial property acquisitions, including minor property impacts to the 4-acre Sav-On Mart new development. The impacts would not directly affect EJ communities or populations.

12.5.1.3 Option BN-14.4b

Option BN-14.4b would address the high travel demand movements from Route 25 to Route 6 (Scenic Highway) by providing a combination of direct connection ramps. Option BN-14.4b would provide a connection between Route 6 westbound and Route 25 northbound with an exit ramp from Route 6 westbound prior to the Nightingale Road intersection. The ramp would pass over Nightingale Road before turning northerly to continue parallel to the relocated Route 25 mainline, like the ramp alignments proposed in Options BN-6.1 and BN-13.1. Option BN-14.4b would provide a connection between Route 25 southbound and Route 6 eastbound with an off-ramp, following a similar alignment to the ramp proposed in Option BN-13.1. However, rather than the ramp terminating at the at-grade intersection proposed in Option BN-13.1, in Option BN-14.4b, the ramp would remain elevated and span over Route 6 while curving easterly. It would then cross under the relocated Route 25 mainline before merging with Route 6 eastbound after the Nightingale Road intersection. All other movements in Option BN-14.4b would maintain the existing ramp configurations with termini in the northeast quadrant of Belmont Circle. Figure 12-4 shows a conceptual layout of Option BN-14.4b.

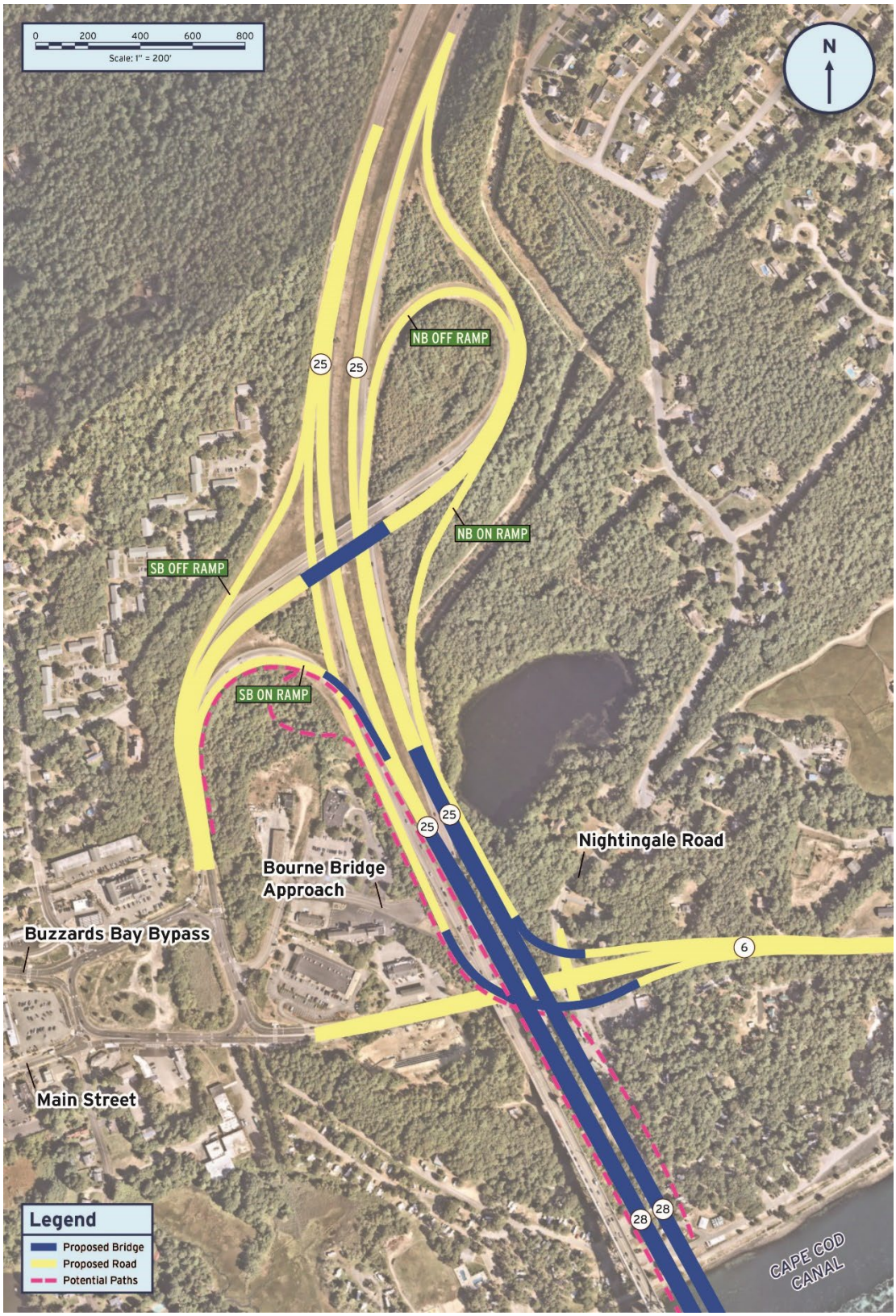


Figure 12-4. Bourne North Crossing Interchange Approach Option BN-14.4b

Operations and Connectivity Ratings: Most Favorable

In comparison to existing conditions and like Option BN-13.1, this option would provide two additional direct access routes to and from Route 25: the Scenic Highway westbound to Route 25 northbound on-ramp and the Route 25 southbound to Scenic Highway eastbound off-ramp. Both new access routes would reduce westbound and southbound traffic at Belmont Circle. Additionally, since both the on-ramp and off-ramp connections would merge and diverge east of the Nightingale Road intersection, the ramp connections would reduce the westbound and eastbound traffic at the Nightingale Road intersection.

Geometrics Rating: Favorable

This option would meet current MassDOT and FHWA design standards, with the northbound off-ramp and the southbound on-ramp designed to meet a minimum design speed of 30 MPH.

Constructability Rating: Neutral

Due to the construction of the Route 25 bridge and southbound on-ramp over the southbound off-ramp, this option would add an additional year of construction as compared to Option BN-6.1. Like Option BN-13.1, there would be minimal impacts to the traveling public in Option BN-14.4b. However, the construction of the skewed Route 25 southbound on-ramp over the Route 25 off-ramp would create a complex abutment/pier arrangement.

Safety Rating: Favorable

While engineering assessments and safety modeling predict that the merge of eastbound Scenic Highway lanes west of the on-ramp merge may contribute to additional crashes on this portion of roadway, the additional ramp facilities connecting Route 25 and Scenic Highway would remove major vehicle movements from Belmont Circle. This reduction in vehicle movements would considerably improve safety through the Belmont Circle area. There would be similar highway and ramp segment crash rates in this option as compared to the future no-build conditions.

Multi-Modal Connections Rating: Favorable

It is anticipated that connections to the local road network would be provided by shared use path direct connections to Belmont Circle, the USACE Canal Service Road (bike path), and Scenic Highway.

Utility Impacts Rating: Favorable

Utility impacts in Option BN-14.4b would involve multiple minor water impacts; electrical impacts, with relocation of 19 utility poles and overhead wires; minor telecommunication impacts, and minor drainage impacts. Impacts to gas infrastructure would not notably increase over those impacts anticipated due to the relocated mainline construction.

Environmental Impacts Rating: Less Impactful

No direct environmental impacts are anticipated in this option. However, the Route 25 northbound on-ramp connection would be within five feet of Nightingale Pond.

Right-of-Way Impacts Rating: Less Impactful

Based on conceptual design, this option would involve right-of-way impacts in addition to those previously identified for MassDOT's recommended mainline alignment alternative: Fully Offline Inboard. Option BN-14.4b would result in one residential full parcel acquisition, three residential partial property acquisitions, and two commercial partial property acquisitions, including minor property

impacts to the 4-acre Sav-On Mart new development. The impacts would not directly affect EJ communities or populations.

12.5.2 OPTION NOT RECOMMENDED FOR FURTHER EVALUATION: OPTION BN-10

Option BN-10 would maintain the existing exit and entrance points along Route 25 with minor modifications to the ramp configurations to accommodate the relocated Route 25 mainline roadway. Once exiting the highway, however, the Route 25 southbound to Route 6 (Scenic Highway) eastbound movement would break away from the existing off ramp onto a separate ramp flyover that would cross over Belmont Circle while curving easterly. From there, the ramp would descend and cross under the relocated Route 25 mainline before merging with Route 6 (Scenic Highway) eastbound after the Nightingale Road intersection. Additionally, this option would provide a direct connection ramp from Route 6 (Scenic Highway) westbound to Route 25 northbound while avoiding entry into Belmont Circle. Inclusion of this ramp would require the reconfiguration of the Bourne Bridge approach road to connect with Route 6 (Scenic Highway) east of the relocated Route 25 mainlines. Inclusion of the Route 25 SB to Route 6 eastbound flyover ramp would require the relocation of the Campground Access Road. Figure 12-5 shows a conceptual layout of Option BN-10.

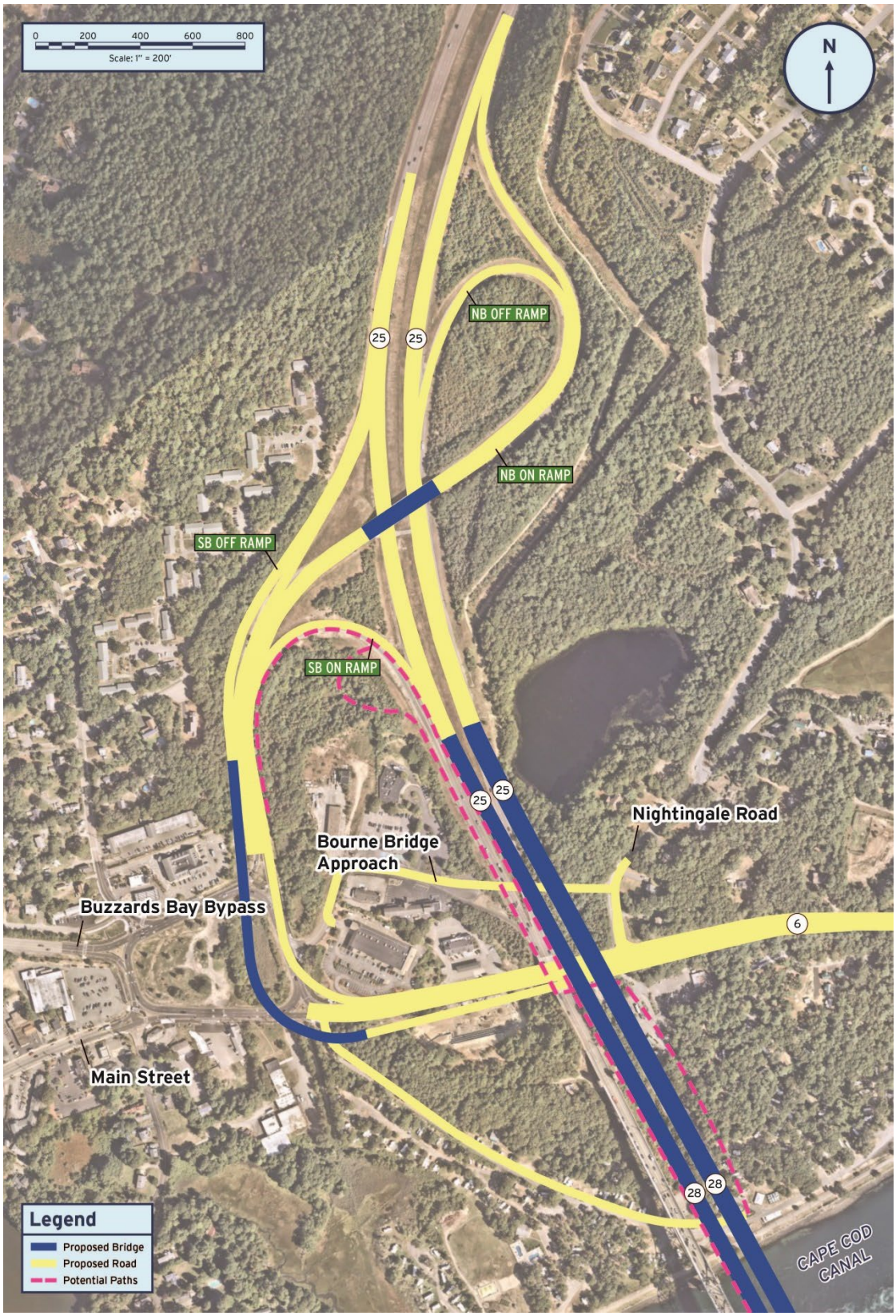


Figure 12-5. Bourne North Crossing Interchange Approach Option BN-10

Operations and Geometrics Ratings: Neutral

This option would reduce traffic at Belmont Circle. The Scenic Highway (Route 6) westbound to Route 25 northbound and Bourne Bridge southbound on-ramp connection would reduce westbound traffic at Belmont Circle, and the Route 25 southbound to Scenic Highway eastbound connection would reduce southbound traffic at Belmont Circle. However, the direct connections from Scenic Highway westbound to Route 25 northbound and the Bourne Bridge southbound could cause weaving issues due to the location of the merge and the weaving segment length. This option would meet current MassDOT and FHWA design standards, with the northbound off-ramp and the southbound on-ramp designed to meet a design speed of 30 MPH. However, Option BN-10 would include a substandard merge condition at the southbound on-ramp approach at Belmont Circle, providing less than 130-feet of merge (from a minimum requirement of 300-feet).

Connectivity Rating: Most Favorable

This option would provide direct access from Scenic Highway (Route 6) westbound to Route 25 northbound and Bourne Bridge southbound, and from Route 25 southbound to Scenic Highway eastbound; resulting in three additional direct access routes to and from Routes 25/28 compared to existing conditions. Additionally, this option would provide indirect access to local businesses at Belmont Circle.

Safety Rating: Neutral

Engineering assessments and safety modeling indicate that the ramp merge connection along Scenic Highway could contribute to additional crashes compared to ramps at signal or stop-controlled intersections. Further, the weave section along on-ramps in the Belmont Circle area could contribute to rear-end or side-side collisions that would not be expected with the other Bourne North interchange approach options.

Constructability Rating: Neutral

Due to the construction of the Route 25 bridge and southbound off-ramp flyover, it is anticipated that compared to Option BN-6.1, this option would add an additional year of construction. While there would be minimal impacts to the traveling public, constructing the Route 25 southbound off-ramp flyover under the relocated Route 25 mainline would increase construction complexity and staging challenges.

Multi-Modal Connections Rating: Favorable

It is anticipated that connections to the local road network would be provided by shared use path direct connections to Belmont Circle and the Canal Service Road (bike path).

Utility Impacts Rating: Less Favorable

Utility impacts would include multiple minor gas and water main impacts; minor telecommunication and sewer impacts; relocation of 25 utility poles, overhead wires, and other multiple minor electrical impacts. This option also has an increased likelihood of substantial impacts to the existing 72-inch drainage conduit that leads to the outfall of the Route 28 drainage system, as well as other minor drainage impacts.

Environmental Impacts Rating: Most Impactful

The construction of the Route 25 interchange would directly impact approximately 4,600 sf of existing wetlands; additionally, indirect wetland impacts, due to shading, would be expected. The substantial wetland impact could trigger the requirement for variance under the WPA.

Right-of-Way Impacts Rating: Less Impactful

Based on conceptual design, this option would involve right-of-way impacts in addition to those previously identified for MassDOT's recommended mainline alignment alternative: Fully Offline Inboard. Option BN-10 would result in one residential full acquisition; two residential partial impacts; one commercial full acquisition consisting of the 4-acre Sav-On Mart new development; and one commercial partial impact. The impacts would not directly affect EJ communities or populations.

12.6 Summary of Bourne South Crossing Interchange Approach Initial Assessment

MassDOT identified five interchange approach options for the Bourne South crossing and conducted an initial assessment relative to the highway interchange design criteria. The five approach options would meet current MassDOT and FWHA design standards. All five options would include an independent shared use path on the bridge that would provide a 4.50 percent maximum profile grade off the mainline structure. It is anticipated that path routing would be fairly circuitous to provide the length necessary to allow the path to descend from the bridge structure elevation to the elevation of the path termini. The five options receive a consistent neutral utility impacts rating. All five options receive less impactful environmental and right-of-way impacts ratings. The five approach options differ regarding operations, connectivity, geometrics, safety, and constructability.

Table 12-2 presents the results of the initial assessment of Bourne South crossing interchange approach options. Based on the initial assessment, MassDOT recommended advancing Options BS-2 and BS-2.2 for further evaluation.

Table 12-2. Initial Assessment Results of Bourne South Crossing Interchange Approach Options

Highway Design Evaluation Criteria (1), (2)	BS-2	BS-2.2	BS-6.1	BS-9	BS-9.1
Operations	●●●	●●●	●	●●	●●
Connectivity	●●●	●●	●	●●	●
Geometrics	●●	●●	●	●	●●
Safety	●●●	●●●	●●	●	●
Constructability	●●	●●	●●	●●●	●●●
Multi-Modal	●●	●●	●	●	●●
Utilities	●	●	●	●	●
Environmental	■■	■■	■■	■■	■■
Right-of-Way	■■	■■	■	■	■

(1): ●●● Most favorable; ●● Favorable; ● Neutral; ●● Less Favorable; ●●● Unfavorable; ●● Not Rated

(2) Range of Least to Less Impacts= ■■■■, ■■■, ■■, ■; Medium Impacts= ❖ ; Range of More to Most Impacts= ■, ■■, ■■■, ■■■■

Section 12.7 presents details of the initial assessment of the Bourne South crossing highway interchange approach options and MassDOT's recommendations to advance or not carry forward options for a more detailed evaluation.

12.7 Details of Bourne South Crossing Interchange Approach Initial Assessment

12.7.1 OPTIONS RECOMMENDED FOR FURTHER EVALUATION

12.7.1.1 Option BS-2

Option BS-2 would replace the existing Bourne Rotary with a grade separated diamond interchange. The relocated Route 25/Route 28 would span over the reconfigured Trowbridge Road. Local connections from Route 25/Route 28 would be made via slip ramps connecting to Trowbridge Road. Option BS-2 would provide a two-way frontage road west of Route 28 southbound at an intersection with Trowbridge Road, providing local access to businesses that are currently accessed only from existing Route 28 southbound. Figure 12-6 shows a conceptual layout of Option BS-2.

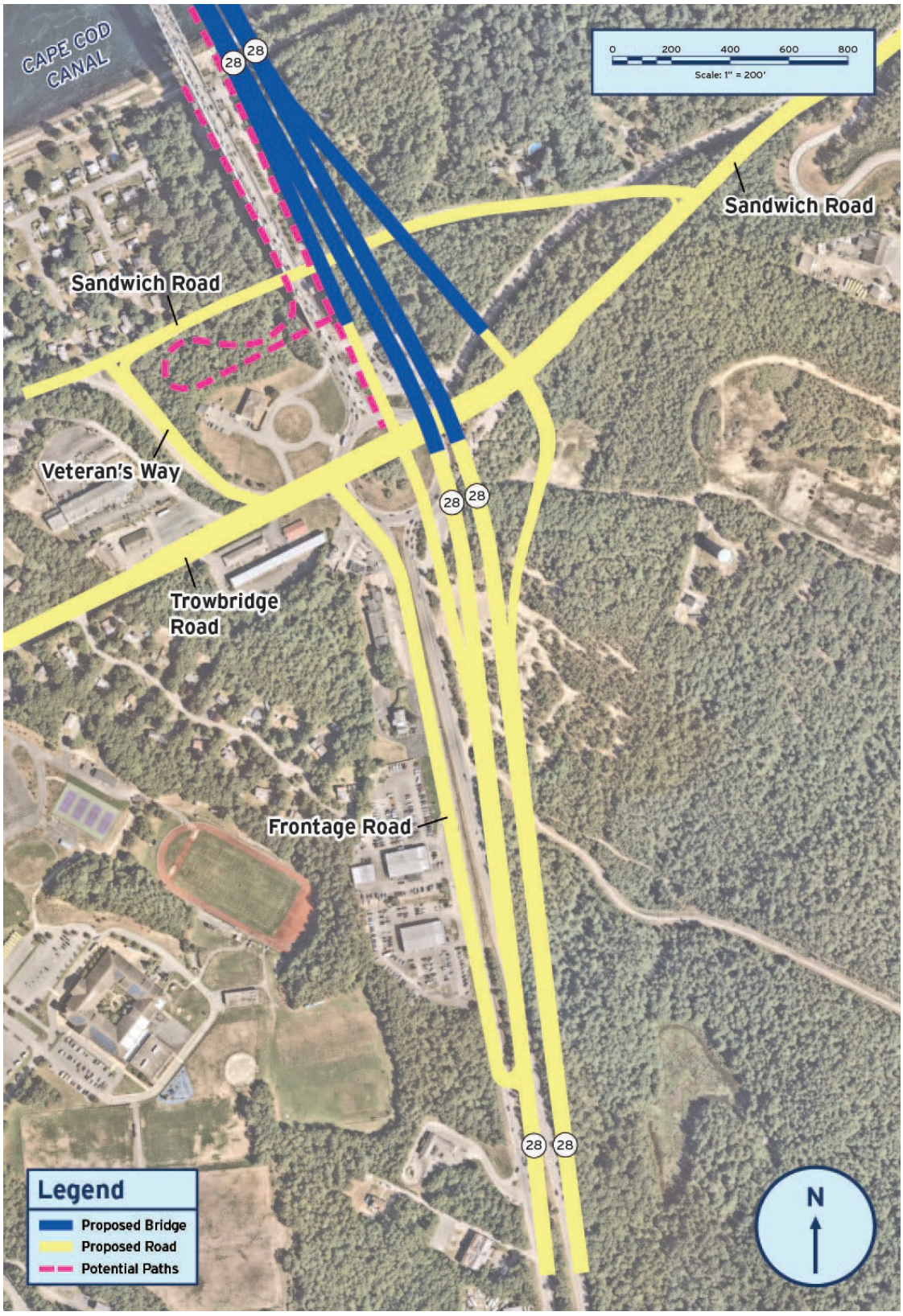


Figure 12-6. Bourne South Crossing Interchange Approach Option BS-2

Operations, Connectivity and Safety Ratings: Most Favorable

By providing direct access to and from Route 25/28 in both the northbound and southbound directions, it would improve the quality and number of existing connections. Additionally, this option would maintain local traffic connections to and from Sandwich Road and Trowbridge Road. Option BS-2 would provide improved operations for all major movements within the Program Study Area. Additionally, engineering assessments and safety modeling indicate that there would be a substantial reduction in predicted crashes primarily due to the elimination of the Bourne Rotary.

Geometrics Rating: Favorable

This option would meet current MassDOT and FHWA design standards. It would allow for bi-directional flow on Frontage Road for access to and from Trowbridge Road. However, the northbound off-ramp would require a 15-foot excavation to meet the proposed relocated Trowbridge Road grade.

Constructability Rating: Favorable

Because of the relative simplicity of this proposed interchange configuration and the ability to construct much of it outside of the existing roadway footprints, the complexity of construction would be minimized. Further, there would be minimal impacts to the traveling public during construction.

Multi-Modal Connections Rating: Favorable

It is anticipated that connections to the local road network would be provided by shared use path direct connections to Trowbridge Road westbound and the Canal Service Road (bike path).

Utility Impacts Rating: Neutral

Utility impacts would include gas impacts consisting of one 12-inch HP impact and multiple minor impacts; multiple minor water main impacts; telecommunication impacts including several impacts to a duct bank and other minor impacts; relocation of 31 utility poles, overhead wires, and other multiple minor electrical impacts; and minor drainage impacts.

Environmental Impacts Rating: Less Impactful

Based on conceptual level development, this option would result in minor to no areas of wetland impacts.

Right-of-Way Impacts Rating: Least Impactful

Based on conceptual design, this option would involve right-of-way impacts in addition to those previously identified for MassDOT's recommended Fully Offline Inboard Option for the mainline alignment. Option BS-2 would result in one commercial partial impact. The impacts would not directly affect EJ communities or populations.

12.7.1.2 Option BS-2.2

Option BS-2.2 would replace the existing Bourne Rotary with a grade separated single point interchange configuration. Like Option BS-2, in Option BS-2.2, the relocated Route 25/Route 28 would span over a reconfigured Trowbridge Road. The on and off slip ramps would terminate at Trowbridge Road with a central intersection located beneath the relocated Route 25/Route 28 bridge. Like Option BS-2, Option BS-2.2 would include a two-way frontage road west of Route 28 southbound to provide access to local businesses that are currently accessed from existing Route 28 southbound. However, due to the geometry of the turning lanes associated with the central intersection, access to the frontage road from Trowbridge Road may not be feasible. To provide access to this frontage road, a connecting roadway from the southbound on-ramp would be provided. Figure 12-7 shows a conceptual layout of Option BS-2.2.

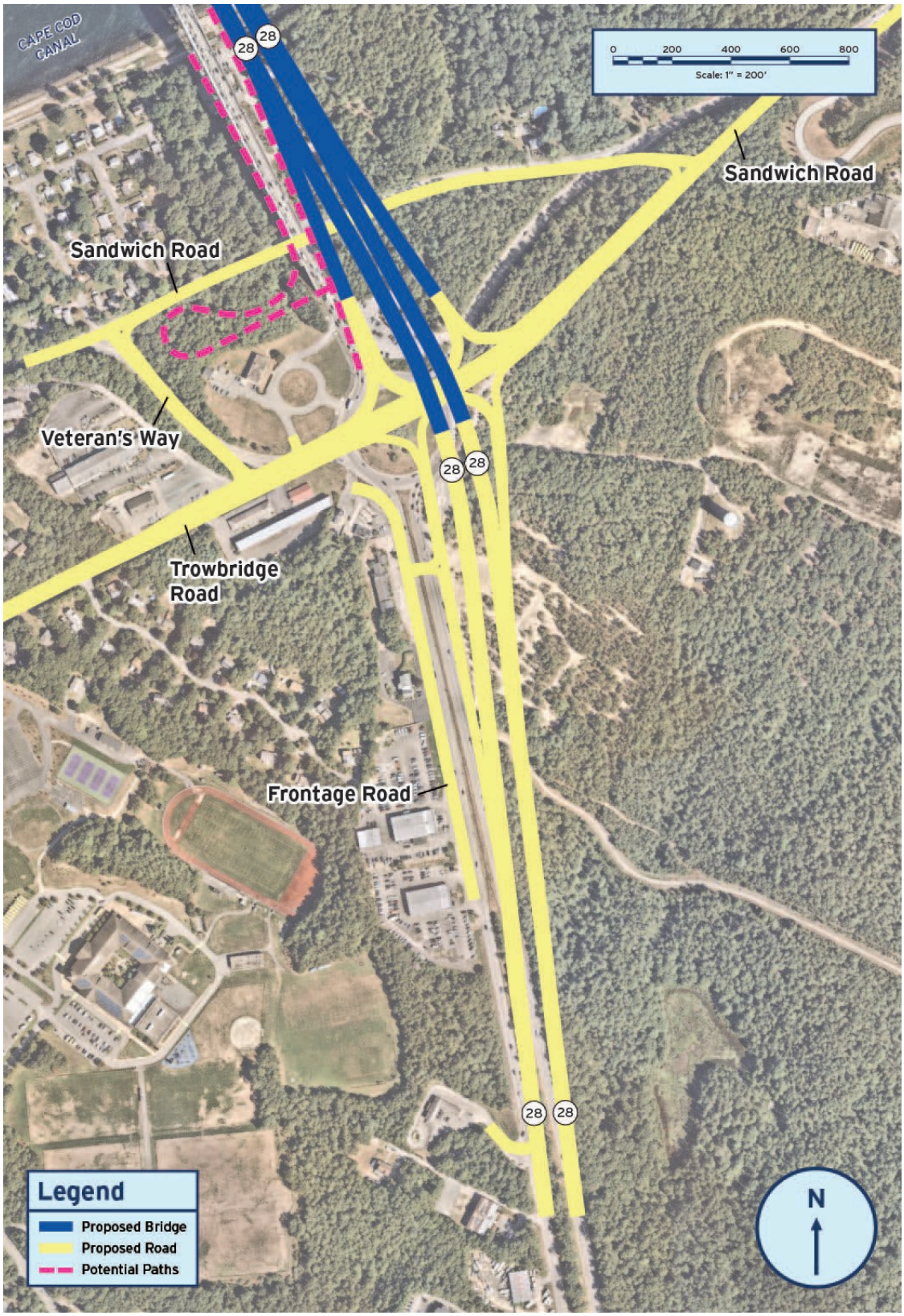


Figure 12-7. Bourne South Crossing Interchange Approach Option BS-2.2

Operations and Safety Ratings: Most Favorable

Option BS-2.2 would provide improved operations for all major movements within the Program Study Area. Preliminary modeling indicates that the single point interchange would reach near capacity in the future build condition; however, this result is expected to improve as more advanced modeling and traffic analysis are completed. Additionally, future design of this option should evaluate the weave section along the access to Route 25 southbound on-ramp and Frontage Road for additional modifications. Engineering assessments and safety modeling indicate that in Option BS-2.2, there would be a substantial reduction in predicted crashes primarily due to elimination of the Bourne Rotary. Option BS-2.2 would consolidate interchange terminus movements at one signal-controlled intersection vs. two signal-controlled intersections provided in Option BS-2; and the off-ramp curvature would constrain speeds for vehicles merging onto eastbound Sandwich Road.

Connectivity and Geometrics Rating: Favorable

By providing direct access to and from Route 25/28 in both the northbound and southbound directions, it would improve the quality and number of existing connections. Additionally, this option would maintain local traffic connections to and from Sandwich Road and Trowbridge Road. This option would meet current MassDOT and FHWA design standards. It would maintain the existing access points to Frontage Road. However, the northbound off-ramp would require a 15-foot excavation to meet the proposed grade of relocated Trowbridge Road.

Constructability Rating: Favorable

Because of the relative simplicity of this proposed interchange configuration and the ability to construct much of it outside of the existing roadway footprints, the complexity of construction would be minimized. Further, there would be minimal impacts to the traveling public during construction.

Multi-Modal Connections Rating: Favorable

It is anticipated that connections to the local road network would be provided by shared use path direct connections to Trowbridge Road westbound and the Canal Service Road (bike path).

Utility Impacts Rating: Neutral

This option would incur the same impacts as Option BS-2. Utility impacts would include multiple minor gas and water main impacts; telecommunication impacts including several impacts to a 12-foot-4-inch duct bank and other minor impacts; relocation of 31 utility poles, overhead wires, and other multiple minor electrical impacts; and minor drainage impacts.

Environmental Impacts Rating: Less Impactful

Based on conceptual level development, this option would result in minor to no areas of wetland impacts.

Right-of-Way Impacts Rating: Least Impactful

Based on conceptual design, this option would involve right-of-way impacts in addition to those previously identified for MassDOT's recommended Fully Offline Inboard Option for the mainline alignment. Option BS-2.2 would result in one commercial partial impact. The impact would not directly affect EJ communities or populations.

12.7.2 OPTIONS NOT RECOMMENDED FOR FURTHER EVALUATION

12.7.2.1 Option BS-6.1

Option BS-6.1 is based upon a partial cloverleaf configuration with most ramps relocated south of the relocated Trowbridge Road. In this option, the southbound off-ramp would exit from the relocated Route 25/28 before crossing the relocated Trowbridge Road on an independent structure. Once across Trowbridge Road, it would enter a compact loop before terminating at a "peanut" roundabout intersection. The northbound on-ramp would use a similar loop configuration located south of Trowbridge Road before crossing over Trowbridge Road and merging with the Route 25/28 roadway. In addition to an eastbound to northbound exit from Trowbridge Road, Option BS-6.1 would provide direct access to the northbound off-ramp from Sandwich Road. This access would intersect with the northbound off-ramp at an at-grade intersection after passing over a depressed Trowbridge Road. Frontage Road also would serve as the southbound on-ramp with a merge condition at the southern end of Frontage Road. Figure 12-8 shows a conceptual layout of Option BS-6.1.



Figure 12-8. Bourne South Crossing Interchange Approach Option BS-6.1

Operations, Connectivity and Geometrics Ratings: Neutral

While it would provide good connections to the relocated Bourne Bridge for both Route 28 northbound and southbound traffic and bi-directional access to Frontage Road via the peanut roundabout, this option would require revising Sandwich Road to a partial one-way roadway, resulting in less connectivity for local eastbound traffic. Regarding operations, Option BS-6.1 would have acceptable levels of service at all intersections/ roundabouts except for the Route 25 southbound off-ramp; modeling indicates that the southbound off-ramp would experience substantial queues at the approach to the peanut roundabout. Future design of the option would need to evaluate the necessity of an additional lane along the approach which would impact Frontage Road. While Option BS-6.1 would meet current MassDOT and FHWA design standards, there are two caveats regarding geometrics. The direct connection ramps would create wayfinding issues for both local and regional traffic. Additionally, the southbound off-ramp geometry could require a two-lane off-ramp: entering the peanut roundabout with two lanes would not provide the adequate decision sight distance and could cause queuing problems due to gap acceptance issues within the peanut roundabout.

Safety Rating: Favorable

Engineering assessments and safety modeling indicate that there would be a substantial reduction in predicted crashes primarily due to elimination of the Bourne Rotary. Additionally, the roundabout would contribute to reductions in predicted crashes. However, the complicated wayfinding and multiple decision points in a small area could contribute to additional crashes. Further, the traffic signal-controlled ramp intersection located east of Route 28 would likely contribute to additional crashes.

Constructability Rating: Unfavorable

Multiple construction stages would be required to construct the proposed northbound on- and off-ramp structures, creating a level of construction complexity. Additionally, substantial impacts to traveling public would be expected in Option BS-6.1 due to multiple detours required for eastbound and westbound movements to avoid the peanut roundabout construction. Compared to Options BS-2 and BS-2.2, Option BS-6.1 would incur an additional construction duration of at least one year.

Multi-Modal Connections Rating: Neutral

It is anticipated that connections to the local road network would be provided by shared use path direct connections to Trowbridge Road and the USACE Canal Service Roads (bike path). A drawback of this configuration would be the likelihood that the shared use path would follow the interior of the loop ramp configuration, requiring the path to cross through the intersection of the ramp and the local road.

Utility Impacts Rating: Neutral

This option would incur approximately the same impacts as Options BS-2 and BS-2.2. Utility impacts would include multiple minor gas impacts; minor water main impacts; telecommunication impacts including several impacts to a 12-foot-4-inch duct bank and other minor impacts; relocation of 31 utility poles, overhead wires, and other multiple minor electrical impacts; and minor drainage impacts.

Environmental Impacts Rating: Less Impactful

Based on conceptual level development, this option would result in minor to no areas of wetland impacts.

Right-of-Way Impacts Rating: Less Impactful

Based on conceptual design, this option would involve right-of-way impacts in addition to those previously identified for MassDOT's recommended Fully Offline Inboard Option for the mainline alignment. Option BS-6.1 would result in one commercial property full acquisition and three commercial partial property acquisitions. The impacts would not directly affect EJ communities or populations. Additionally, this option would substantially impact driveway access to the State Police Barracks.

12.7.2.2 Option BS-9

Option BS-9 would replace the existing Bourne Rotary with a roundabout, where northbound and southbound Route 25 intersect with Trowbridge Road at a two-lane roundabout. Option BS-9 would provide a separate southbound off-ramp for vehicles continuing eastbound on Sandwich Road. This ramp would loop around the existing State Police Barracks property before merging into Sandwich Road. Eastbound Sandwich Road would split after it passes under the relocated Route 25/28 mainlines; one lane would connect with Trowbridge Road at an-grade signalized intersection, while the other lane would cross under Trowbridge Road before merging with Sandwich Road prior to the Technical High School driveway. Option BS-9 would provide a frontage road near the existing Route 28 southbound roadway alignment to provide access to local businesses. Figure 12-9 shows a conceptual layout of Option BS-9.

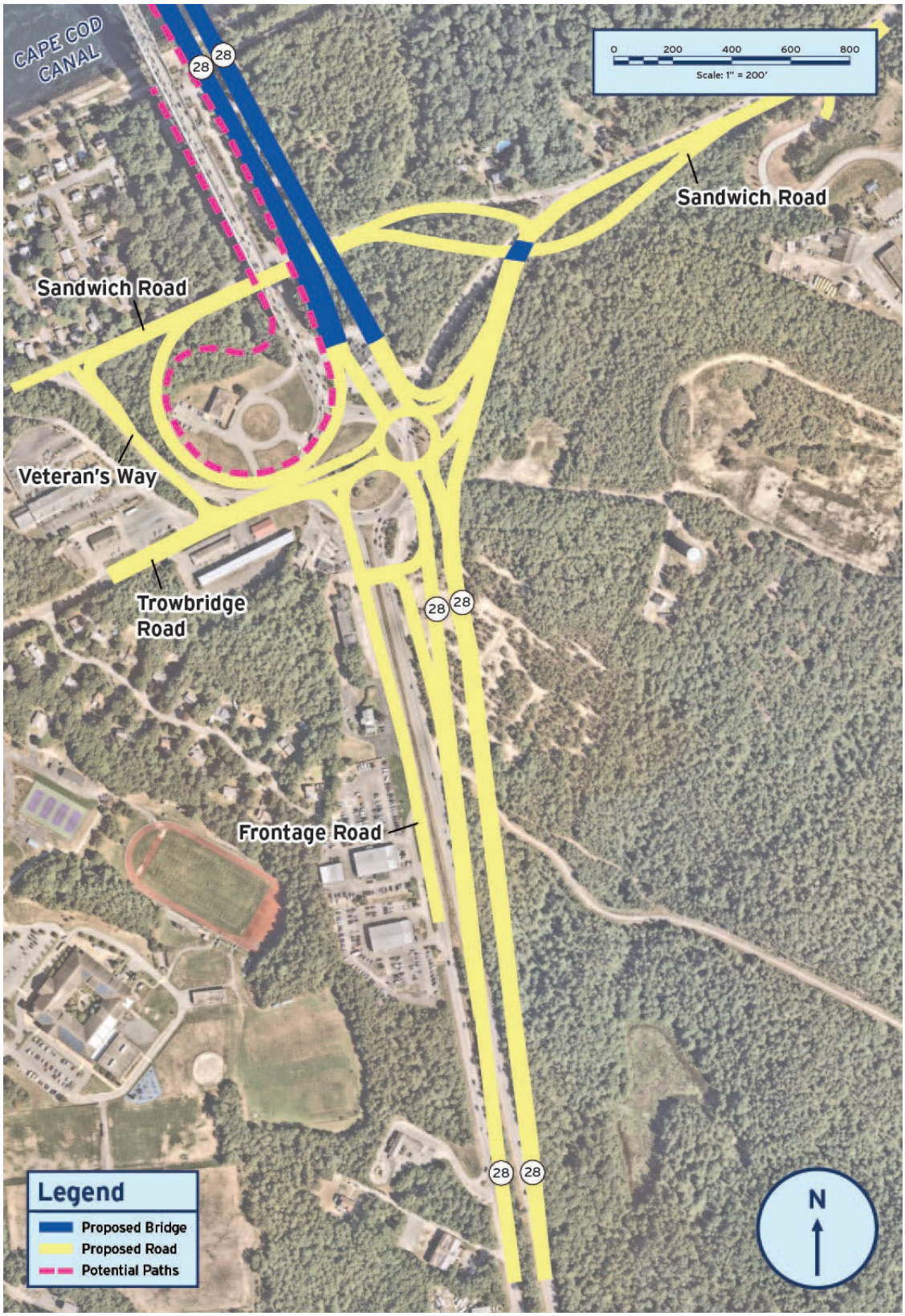


Figure 12-9. Bourne South Crossing Interchange Approach Option BS-9

Operations Rating: Less Favorable

Operations modeling indicates that the roundabout would operate above capacity mainly due to substantial northbound and southbound through movements that do not bypass the roundabout.

Connectivity Rating: Favorable

This option would provide good connections to the relocated Bourne Bridge with circulation via a roundabout. Additionally, it would provide eastbound and westbound local traffic connectivity using either Sandwich Road or Trowbridge Road, and the Route 25 southbound off-ramp movement to Sandwich Road eastbound would bypass the terminus roundabout.

Geometrics Rating: Neutral

This option would meet current MassDOT and FHWA design standards. The southbound off-ramp would be designed to meet a minimum design speed of 30 MPH. However, the Sandwich Road connector would create a depressed "boat" section as it approaches and crosses under Trowbridge Road. This "boat" section of roadway would be well below existing grades, thereby likely requiring retaining walls on both sides of the roadway. Additionally, this depressed section of roadway would prove problematic for drainage and would potentially require a pump station to allow the roadway to drain properly. It should also be noted that constructing the roundabout to meet Route 25/28 at-grade would require raising the roundabout approximately twenty to thirty feet over the existing roadway.

Safety Rating: Neutral

Engineering assessments and safety modeling indicate that slower speeds at a modern roundabout should reduce crashes compared to future conditions at the existing Bourne Rotary (No Build condition). However, traffic volumes are forecasted to exceed roundabout capacity, thereby negating the crash reduction effects of a well- functioning roundabout. Congestion-related crashes along Route 25/28, Sandwich Road, and Trowbridge Road were not assessed.

Constructability Rating: Unfavorable

Multiple construction stages would be required to raise the roundabout grade while maintaining all ramp connections as well as raising Sandwich Road/Trowbridge Road intersection. The temporary sheeting and fill amounts would add construction complexity to this option. Substantial impacts to traveling public would be expected in Option BS-9 due to multiple detours required for eastbound and westbound movements to avoid the roundabout construction. Compared to Options BS-2 and BS-2.2, Option BS-9 would incur an additional construction duration of at least one year due to complexities with roundabout construction and the Sandwich Road underpass depressed boat section construction.

Multi-Modal Connections Rating: Neutral

It is anticipated that connections to the local road network would be provided by a shared use path to the Canal Service Road. It is anticipated that path routing would be fairly circuitous to provide the length necessary to allow the path to descend from the elevation of the canal crossing to the elevation of the path termini.

Utility Impacts Rating: Neutral

Utility impacts would include multiple minor gas impacts; minor water main and sewer impacts; telecommunication impacts including several impacts to a 12-foot-4-inch duct bank and other minor impacts; relocation of 20 utility poles and multiple overhead wires; and minor drainage impacts.

Environmental Impacts Rating: Less Impactful

Based on conceptual level development, this option would result in minor to no areas of wetland impacts.

Right-of-Way Impacts Rating: Less Impactful

Based on conceptual design, this option would involve right-of-way impacts in addition to those previously identified for MassDOT's recommended Fully Offline Inboard Option for the mainline alignment. Option BS-9 would result in one residential partial property acquisition, one commercial full property acquisition consisting of an active business, and one commercial partial property acquisition. The impacts would not directly affect EJ communities or populations.

12.7.2.3 Option BS-9.1

Option BS-9.1 proposes the same roundabout configuration as Option BS-9, but it would remove the southbound to eastbound loop ramp. In this option, this ramp would be replaced with a standard bypass lane. All other movements in Option BS-9.1 would be the same as Option BS-9. Figure 12-10 shows a conceptual layout of Option BS-9.1.

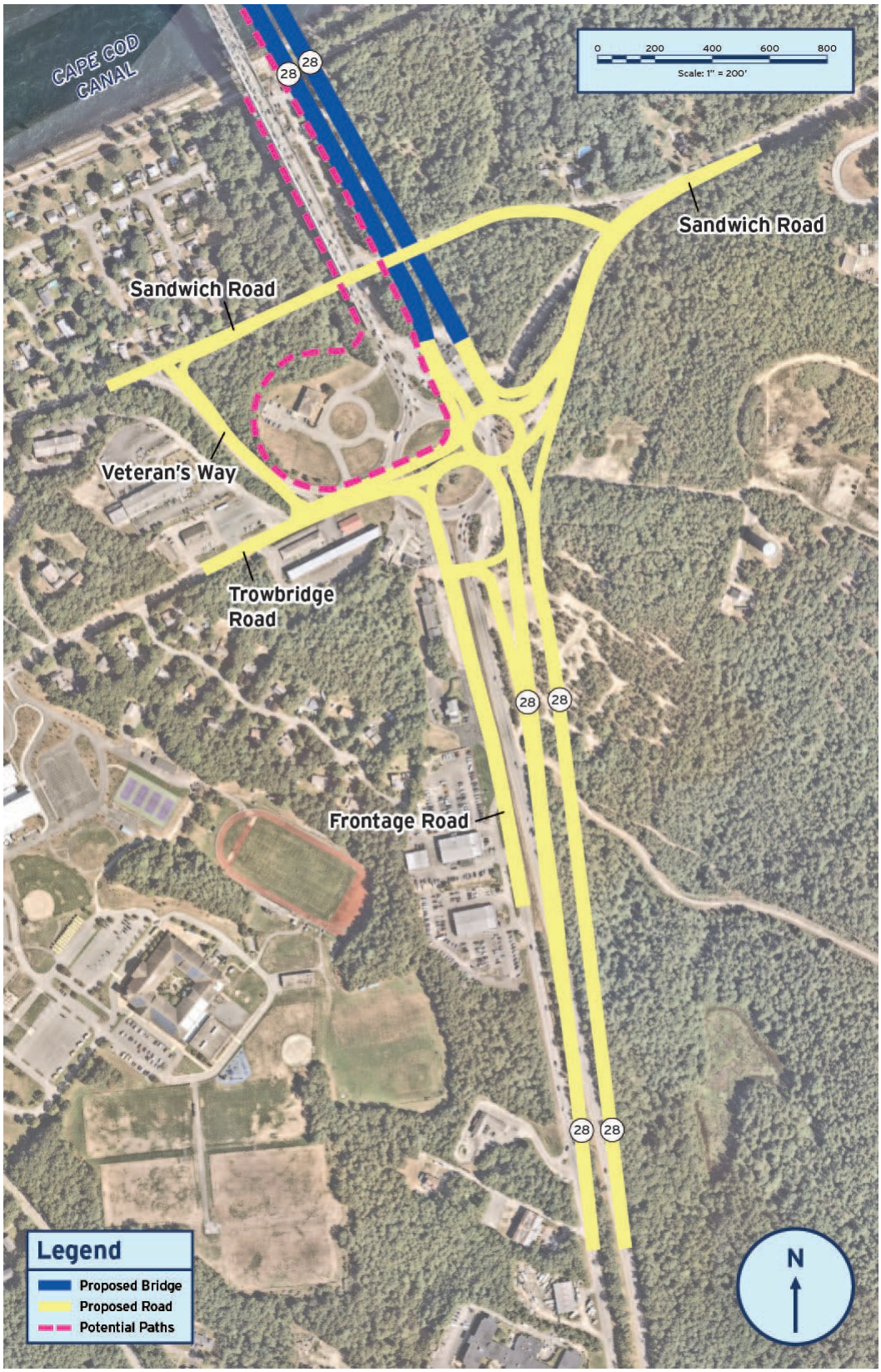


Figure 12-10. Bourne South Crossing Interchange Approach Option BS-9.1

Operations Rating: Less Favorable

Operations modeling indicates that the roundabout is expected to operate above capacity mainly due to substantial northbound and southbound through movements which do not bypass the roundabout. Further, traffic from the Route 25 southbound off-ramp movement to Sandwich Road eastbound would circulate through the terminus roundabout which would impede eastbound Trowbridge Road and northbound Route 28 traffic entry into the roundabout.

Connectivity Rating: Neutral

Like Option BS-9, Option BS-9.1 would provide good connections to the relocated Bourne Bridge with circulation via a roundabout and eastbound and westbound local traffic has connectivity using either Sandwich Road or Trowbridge Road. However, in Option BS-9.1, the Route 25 southbound off-ramp movement to Sandwich Road eastbound would circulate through the terminus roundabout.

Geometrics Rating: Favorable

This option would provide bi-directional flow on Frontage Road for access to and from Trowbridge Road. However, Option BS-9.1 would require raising the elevation of the roundabout by approximately 30 feet over the existing elevation of the rotary.

Safety Rating: Neutral

Engineering assessments and safety modeling indicate that slower speeds at a modern roundabout should reduce crashes compared to future conditions at the existing Bourne Rotary (No Build condition). However, traffic volumes are forecasted to exceed roundabout capacity, thereby negating the typical safety benefits of a well-functioning roundabout. Congestion-related crashes along Route 25/28, Sandwich Road, or Trowbridge Road were not assessed.

Constructability Rating: Unfavorable

Multiple construction stages would be required to raise the roundabout grade while maintaining all ramp connections as well as raising Sandwich Road/Trowbridge Road intersection. The temporary sheeting and fill amounts would add construction complexity to this option. Substantial impacts to traveling public would be expected in Option BS-9 due to multiple detours required for eastbound and westbound movements to avoid the roundabout construction. Compared to Options BS-2 and BS-2.2, Option BS-9 would incur an additional construction duration of at least one year due to complexities with elevating grades while maintaining ramp connections as well as raising the Sandwich Road/Trowbridge Road intersection.

Multi-Modal Connections Rating: Favorable

It is anticipated that connections to the local road network would be provided by shared use path direct connections to Trowbridge Road and the Canal Service Road (bike path).

Utility Impacts Rating: Neutral

Utility impacts would include multiple minor gas impacts; minor water main and sewer impacts; telecommunication impacts including several impacts to a 12-foot-4-inch duct bank and other minor impacts; relocation of 17 utility poles and multiple overhead wires; and minor drainage impacts.

Environmental Impacts Rating: Less Impactful

Based on conceptual level development, this option would result in minor to no areas of wetland impacts.

Right-of-Way Impacts Rating: Less Impactful

Based on conceptual design, this option would involve right-of-way impacts in addition to those previously identified for MassDOT's recommended Fully Offline Inboard Option for the mainline alignment. Option BS-9.1 would result in one residential partial property acquisition and two commercial partial property acquisitions. The impacts would not directly affect EJ communities or populations.

12.8 Summary of Sagamore North Crossing Interchange Approach Initial Assessment

For the Sagamore North crossing, MassDOT identified four interchange approach options for modifying the Route 6 westbound/Route 3 northbound off-ramp and conducted a preliminary assessment relative to the highway design evaluation criteria. Modifications largely would consist of the realignment of existing ramps to meet the relocated Route 3 alignment. Modifications to the Route 6 eastbound on-ramp and the Route 3 southbound off-ramp and the local roadway network would be developed further as design progresses.

The four approach options would meet current MassDOT and FHWA design standards. At a minimum, the four options received a favorable safety rating, as all would reduce the predicted crashes and crash rates. The four options received a favorable utility impacts rating; all options would involve minimal utility impacts limited to relocation of ramp light poles. It is anticipated that none of the four options would involve additional right-of-way impacts other than those impacts previously identified for MassDOT's recommended Fully Offline Inboard Option for the mainline alignment, as cited in Section 8. Based on conceptual design, the right-of-way impacts for the four options received a medium impact rating. The four approach options would differ regarding operations, connectivity, geometrics, constructability, multi-modal connections, and environmental impacts.

Table 12-3 presents the results of the initial assessment of Sagamore North crossing interchange approach options. Based on the initial assessment, MassDOT recommended advancing Options SN-1A and SN-8A for a detailed assessment.

Table 12-3. Initial Assessment Results of Sagamore North Crossing Interchange Approach Options

Highway Design Evaluation Criteria (1), (2)	SN-1A	SN-3A	SN-4A	SN-8A
Operations	●	●●	●●	●●
Connectivity	●	●●	●●	●●
Geometrics	●	●●	●●	●●
Safety	●●	●●●	●●	●●●
Constructability	●	●●	●●	●
Multi-Modal	●●	●●	●●	●●
Utilities	●●	●●	●●	●●
Environmental	■ ■	■ ■ ■	■ ■ ■	■ ■ ■
Right-of-Way	❖	❖	❖	❖

(1) ●●● Most favorable; ●● Favorable; ● Neutral; ●● Less Favorable; ●●●Unfavorable; ●● Not Rated

(2) Range of Least to Less Impacts= ■ ■ ■ ■, ■ ■ ■, ■ ■, ■; Medium Impacts= ❖ ; Range of More to Most Impacts= ■, ■ ■, ■ ■ ■, ■ ■ ■ ■

Section 12.9 presents details of the initial assessment of the Sagamore North crossing highway interchange options and MassDOT's recommendations to advance or not carry forward options for further evaluation.

12.9 Details of Sagamore North Crossing Interchange Approach Initial Assessment

12.9.1 OPTIONS RECOMMENDED FOR FURTHER EVALUATION

12.9.1.1 Option SN-1A

Option SN-1A would mimic the existing interchange ramp configurations and would include the modifications necessary to support the relocated Route 3 alignment. In this option, acceleration and deceleration lane lengths would increase to meet current design standards and improve user safety and operations. In Option SN-1A, State Road would not be modified and there would be no change to the Route 6 westbound off-ramp loop to Scenic Highway. Figure 12-11 shows a conceptual layout of Option SN-1A.

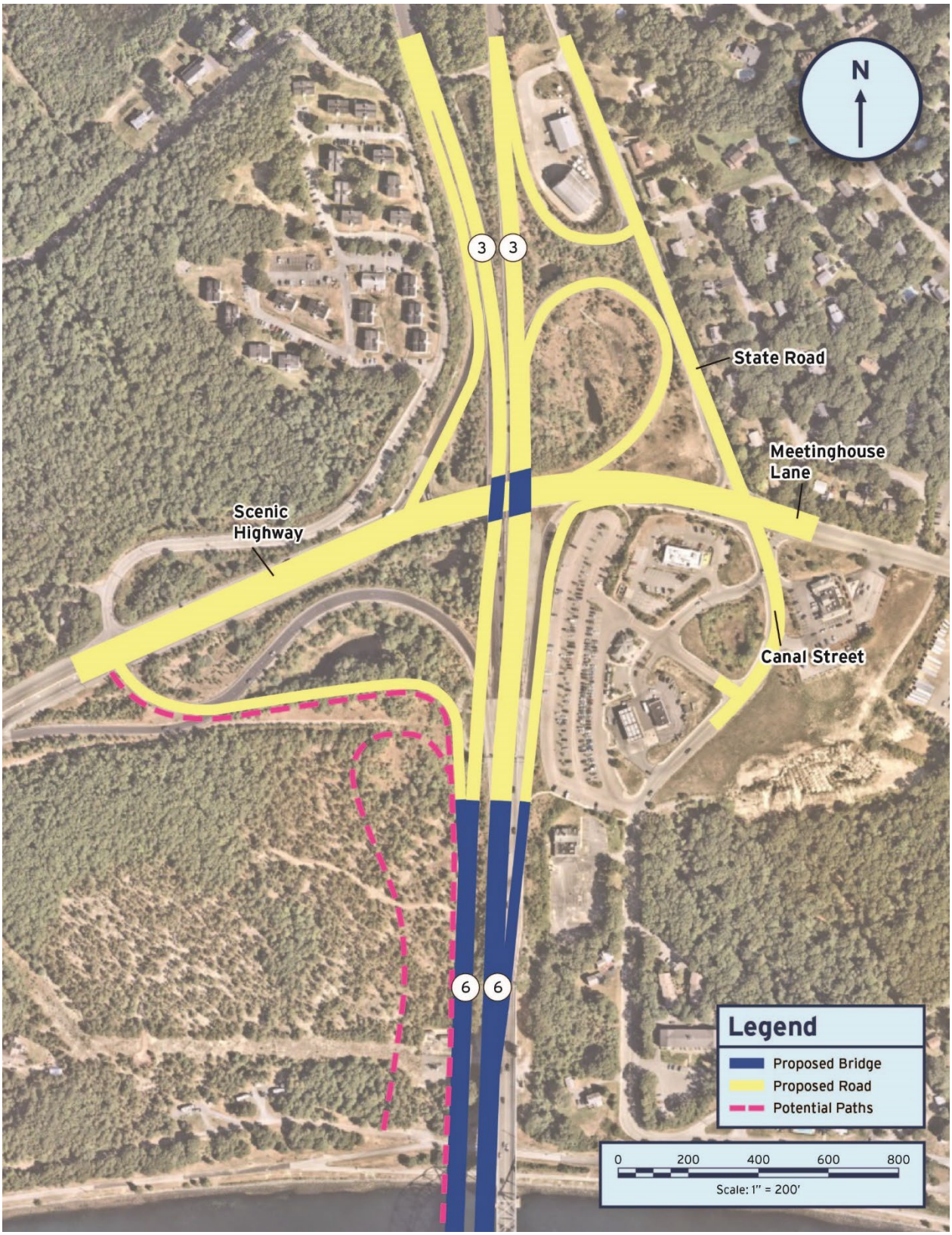


Figure 12-11. Sagamore North Crossing Interchange Approach Option SN-1A

Operations, Connectivity and Geometrics Rating: Neutral

In this option, operations would be like the No Build condition, and existing ramp connections would be maintained. The Route 6 westbound to Scenic Highway westbound loop ramp would be designed to meet a minimum design speed of 25 MPH.

Safety Rating: Favorable

Engineering assessments and safety modeling indicate that due to the geometric and cross-section improvements, there would be a moderate reduction in both the predicted number of crashes and the predicted crash rates in the areas of the Route 3 acceleration/deceleration lanes.

Constructability Rating: Neutral

This option would substantially increase the construction duration compared to other options: the Route 6 westbound off-ramp to Meetinghouse Lane could not be completed until both barrels of the replacement are completed, and the existing Sagamore Bridge could not be demolished until new off-ramp is completed. The required construction sequence could add a scheduling complication to this option. Option SN-1A would involve minor impacts to existing traffic. Except for the Route 6 westbound off-ramp to Meetinghouse Lane, which would be difficult to construct since it would cross existing Route 6 traffic, this option would not have construction complexities. A temporary connection to State Road could be required for a short duration.

Multi-Modal Connections Rating: Less Favorable

It is anticipated that connections to the local road network would be provided by a shared use path connection to the USACE Canal Service Road bike path). Based on conceptual design, this option would not allow for additional bicycle/pedestrian accommodations along State Road without substantial right-of-way impacts.

Utility Impacts Rating: Favorable

This option would involve minimal utility impacts limited to relocation of multiple ramp light poles.

Environmental Impacts Rating: Neutral

In this option, the relocation of the Route 3 southbound off-ramp would extend into the Herring River Watershed ACEC within the highway layout and in areas previously disturbed by highway construction. Additionally, Option SN-1A would impact non-jurisdictional storm water basins.

Right-of-Way Impacts Rating: Medium

This option would not involve additional right-of-way impacts other than those impacts previously identified for MassDOT's recommended Fully Offline Inboard Option for the mainline alignment.

12.9.1.2 Option SN-8A

Option SN-8A is like the configurations of Options SN-1A and SN-3A. Option SN-8A would introduce a variation to the existing interchange by providing a single exit point from a relocated Route 3. Option SN-8A would relocate the northbound to eastbound off-ramp movement and eliminate the northbound to eastbound slip ramp. In Option SN-8A, vehicles exiting Route 3 northbound and continuing to State Road or Meetinghouse Lane would cross over Scenic Highway/Meetinghouse Lane before turning easterly to connect directly to State Road. In Option SN-8A, State Road would be widened to the west, which would allow for further improvements to the ramp geometry and State Road. Figure 12-12 shows a conceptual layout of Option SN-8A.

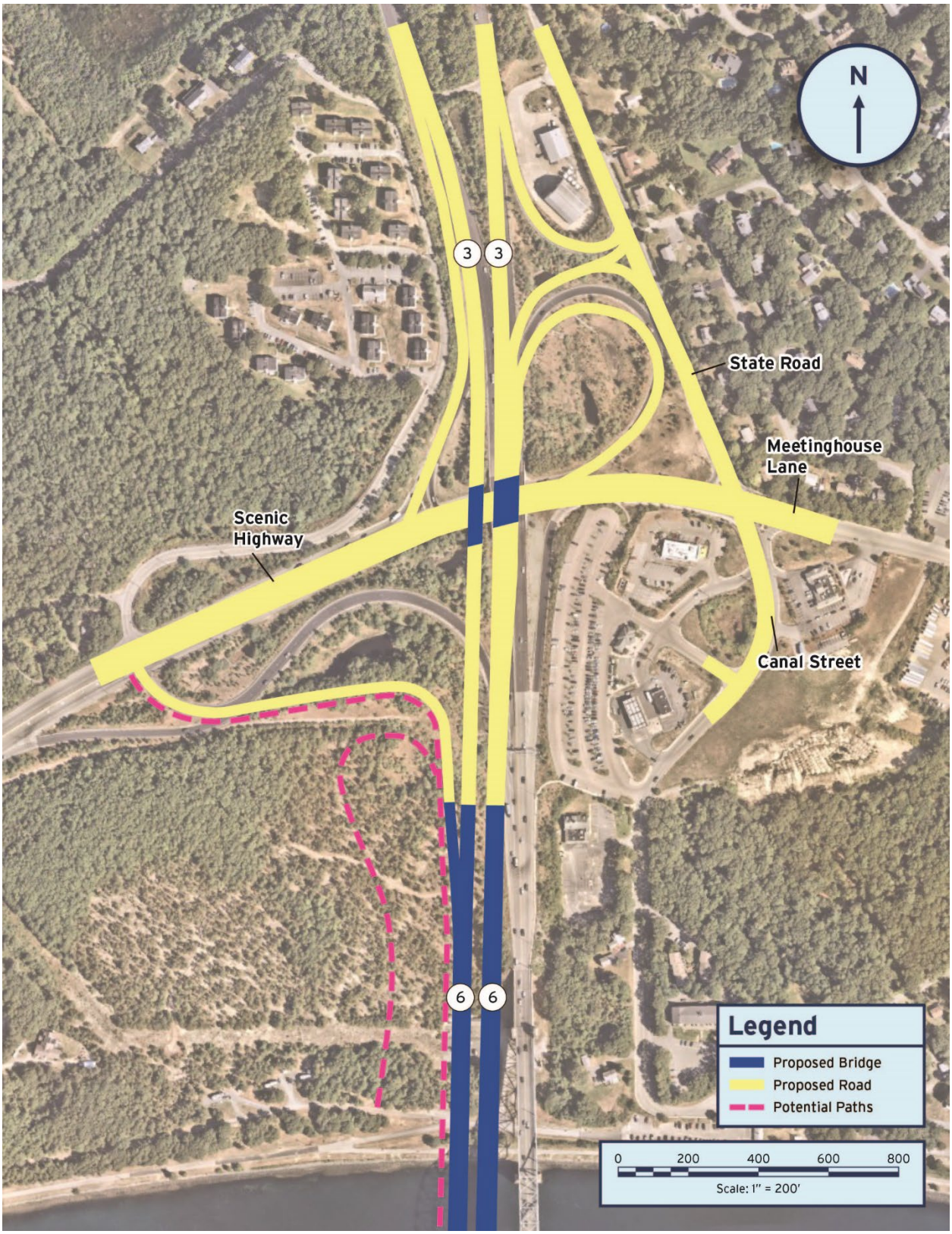


Figure 12-12. Sagamore North Crossing Interchange Approach Option SN-8A

Operations, Connectivity and Geometrics Rating: Favorable

By eliminating the Route 6 westbound off-ramp to Scenic Highway eastbound connection, Option SN-8A would provide a more direct connection for local State Road traffic, and it would eliminate the weave for Route 3 northbound off-ramp traffic destined for State Road northbound. Additionally, Option SN-8A would maintain the loop ramp for Route 6 westbound to Scenic Highway westbound traffic. Operations modeling indicates that Option SN-8A would result in acceptable operations at the State Road/Route 3 northbound ramps intersection with minimal queueing on the off-ramp. In Option SN-8A, there would be reduced demand at the Meetinghouse Lane/Canal Street/State Road intersection. While Option SN-8A would meet current MassDOT and FHWA design standards, it would have a tight loop ramp geometry for the Route 6 westbound to Scenic Highway westbound traffic. Additionally, to achieve the minimum 1,000-foot ramp length, a barrier separation between the ramp and Route 6 westbound would be required.

Safety Rating: Favorable

Engineering assessments and safety modeling indicate that due to the geometric and cross-section improvements, there would be a moderate reduction in both the predicted number of crashes and the predicted crash rates in the areas of the Route 3 acceleration/deceleration lanes. Additionally, there would be a minimal reduction in the predicted crash rate on ramp roadways and a reduction in the predicted number of crashes on Scenic Highway.

Constructability Rating: Neutral

This option would add construction complexity: it would require the initial construction of the new Route 6 westbound off-ramp adjacent to the existing ramp, with a new signalized intersection and channelized lanes where the ramps meet State Road. Additionally, widening State Road to the west would require construction of a retaining wall. Construction of the new Route 6 westbound off-ramp and the retaining wall would extend the construction schedule. While existing ramp connections could be maintained during construction, there would minor impacts to existing ramp traffic and State Road traffic due to minor lane shifts during widening and retaining wall construction.

Multi-Modal Connections Rating: Favorable

It is anticipated that connections to the local road network would be provided by a shared use path connection to the USACE Canal Service Road (bike path) and on the east side of State Road.

Utility Impacts Rating: Favorable

This option would involve minimal utility impacts limited to relocation of utility poles and multiple ramp light poles.

Environmental Impacts Rating: Less Impactful

In this option, no direct wetland impacts are anticipated.

Right-of-Way Impacts Rating: Least Impactful

This option would not involve additional right-of-way impacts other than those impacts previously identified for MassDOT's recommended Fully Offline Inboard Option for the mainline alignment.

12.9.2 OPTIONS NOT RECOMMENDED FOR FURTHER EVALUATION

12.9.2.1 Option SN-3A

Option SN-3A would relocate the Route 3 northbound to the Scenic Highway eastbound off-ramp movement and eliminate the northbound to eastbound slip ramp. Like Option SN-8A, Option SN-3A would reconfigure the existing interchange to provide a single exit point from a relocated Route 3. In contrast to Option SN-8A, Option 3N-3A would not include changes to State Road and therefore would not include pedestrian or bicyclist improvements to State Road. The movements on the westbound off-ramp to Meetinghouse Lane would be accommodated on the new direct connection to State Road. In this option, vehicles exiting Route 3 northbound and continuing to State Road or Meetinghouse Lane would cross over Scenic Highway/Meetinghouse Lane before turning easterly to connect directly to State Road. Figure 12-13 shows a conceptual layout of Option SN-3A.

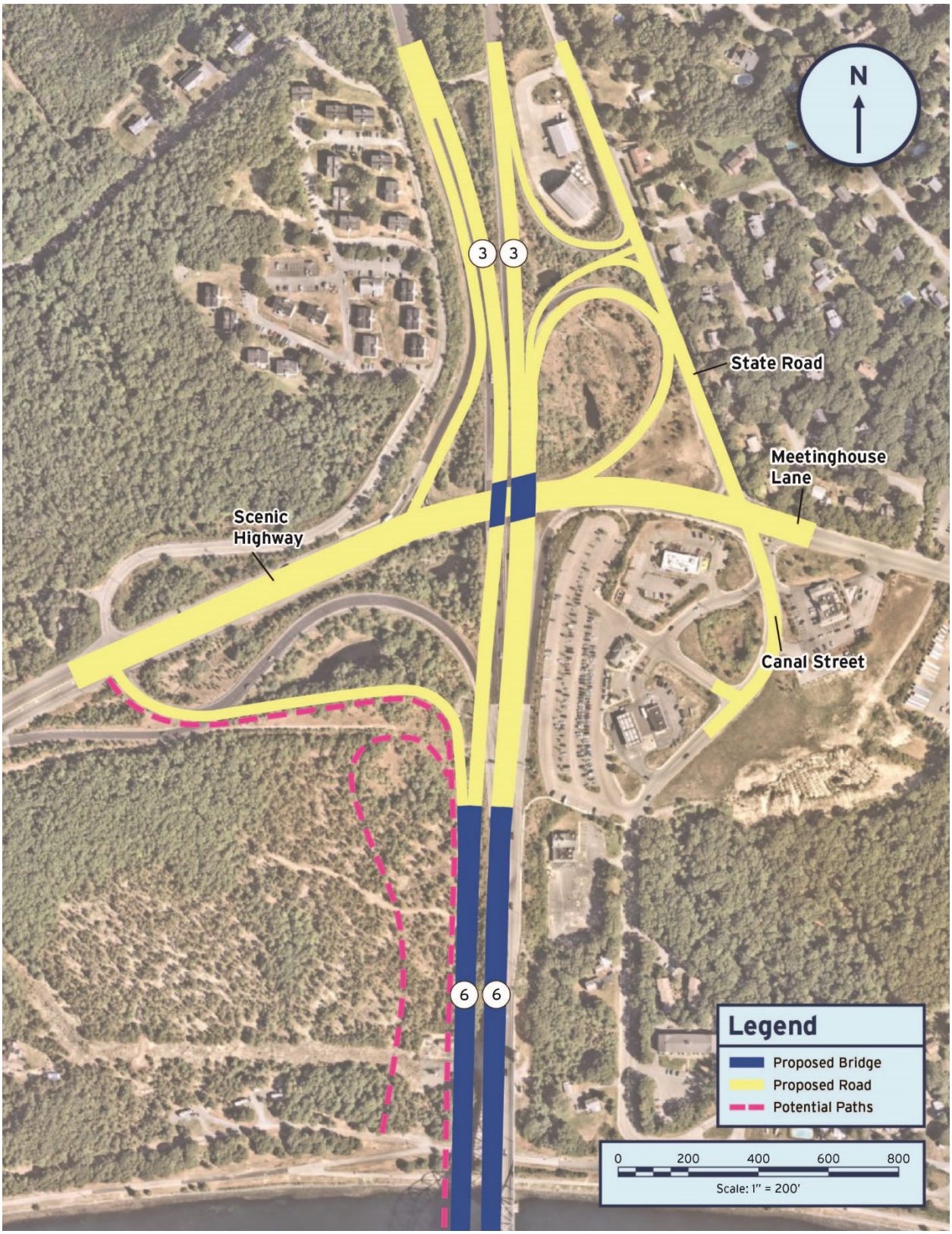


Figure 12-13. Sagamore North Crossing Interchange Approach Option SN-3A

Operations, Connectivity and Geometrics Rating: Favorable

By eliminating the Route 6 westbound off-ramp to Scenic Highway eastbound connection, Option SN-3A provides a more direct connection for local State Road northbound traffic, eliminating the weave for Route 6 westbound off-ramp traffic destined for State Road northbound. Additionally, Option SN-3A maintains the loop ramp for Route 6 westbound to Scenic Highway westbound traffic. Operations modeling indicates that Option SN-3A would result in acceptable operations at the State Road/Route 3 northbound ramps intersection with minimal queueing on the off-ramp. In Option SN-3A, there would be reduced demand at the Meetinghouse Lane/Canal Street/State Road intersection. While Option SN-3A would meet current MassDOT and FHWA design standards, it would have a tight loop ramp geometry for the Route 6 westbound to Scenic Highway westbound traffic. Additionally, to achieve the minimum 1,000-foot ramp length, a barrier separation between the ramp and Route 6 westbound would be required.

Safety Rating: Most Favorable

Engineering assessments and safety modeling indicate that due to the geometric and cross-section improvements, there would be a moderate reduction in both the predicted number of crashes and the predicted crash rates in the areas of the Route 3 acceleration/deceleration lanes. Additionally, there would be a minimal reduction in the predicted crash rate on ramp roadways and a reduction in the predicted number of crashes on Scenic Highway.

Constructability Rating: Favorable

Because the existing Route 6 westbound off-ramp connections could be maintained during construction, Option SN-3A would have an improved ramp construction schedule. Option SN-3A would have minor impacts to existing traffic. However, Option SN-3A would introduce construction complexity: the new Route 6 westbound off-ramps and retaining walls would be constructed adjacent to the existing ramp, and a new signalized intersection and channelized lanes would be constructed where the ramps meet State Road.

Multi-Modal Connections Rating: Less Favorable

It is anticipated that connections to the local road network would be provided by a shared use path connection to the USACE Canal Service Road (bike path). Due to space constraints associated with a reduced mainline highway shift compared to other options, it is anticipated that Option SN-3A would not provide additional bicycle and pedestrian accommodations along State Road without substantial right-of-way impacts.

Utility Impacts Rating: Favorable

This option would involve minimal utility impacts limited to relocation of multiple ramp light poles.

Environmental Impacts Rating: Less Impactful

In this option, no direct wetland impacts are anticipated.

Right-of-Way Impacts Rating: Medium

This option would not involve additional right-of-way impacts other than those impacts previously identified for MassDOT's recommended Fully Offline Inboard Option for the mainline alignment.

12.9.2.2 Option SN-4A

Like Option SN-8A, Option SN-4A would reconfigure the existing interchange to provide a single exit point from a relocated Route 3. Option SN-4A would eliminate the existing northbound to eastbound slip ramp and relocate the movements to a direct connection to State Road. In this option, the ramp would intersect State Road at a roundabout which also would provide access to the northbound on-ramp. The northbound off-ramp also would provide a loop ramp that bypasses the roundabout with a direct connection to State Road and Scenic Highway/ Meetinghouse Lane. Figure 12-14 shows a conceptual layout of Option SN-4A.

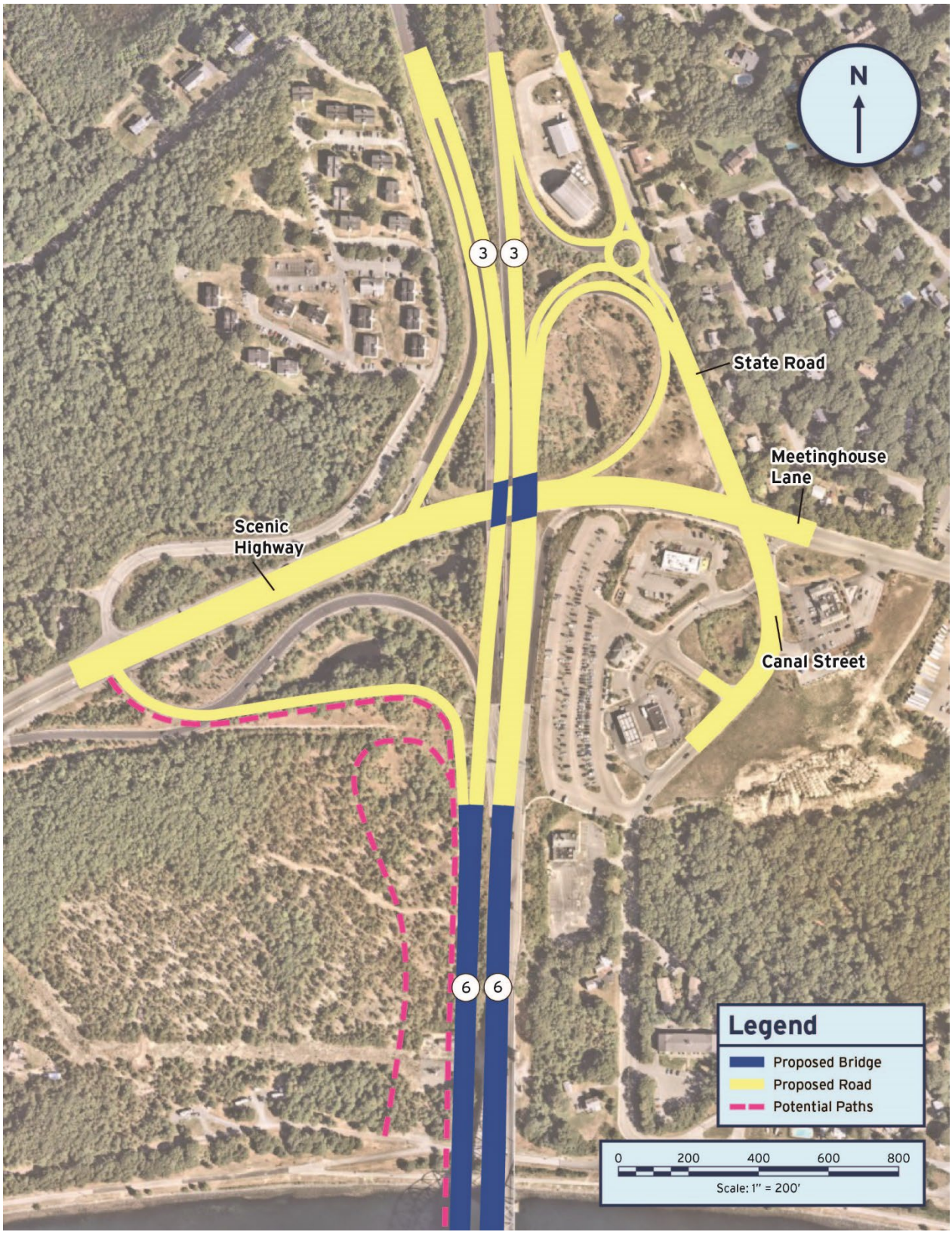


Figure 12-14. Sagamore North Crossing Interchange Approach Option SN-4A

Operations and Geometrics Rating: Less Favorable

Operations modeling indicates that the roundabout on State Road at Route 3 northbound ramps would operate acceptably with minimal queues on the off-ramp. However, combining loop ramp traffic with State Road traffic would create a short 200-foot southbound weaving section with high volumes destined for Scenic Highway westbound. The southbound queues on State Road could extend into the weaving section. While Option SN-4A would meet current MassDOT and FHWA design standards, it would have a tight loop ramp geometry for the Route 6 westbound to Scenic Highway westbound traffic. Additionally, to achieve the minimum 1,000-foot ramp length, a barrier separation between the ramp and Route 6 westbound would be required. Further, approximately 400 feet would be available for decision sight distance between the loop ramp and roundabout traffic and the Canal Street intersection, considerably less than the required 720 feet, requiring drivers to make multiple decision points in a limited distance.

Connectivity Rating: Favorable

By eliminating the Route 6 westbound off-ramp to Scenic Highway eastbound connection, Option SN-4A would direct all traffic to State Road, including the Route 6 westbound to Scenic Highway eastbound traffic.

Safety Rating: Favorable

Engineering assessments and safety modeling indicate that due to the geometric and cross-section improvements, there would be a moderate reduction in both the predicted number of crashes and the predicted crash rates in the areas of the Route 3 acceleration/ deceleration lanes. Additionally, there would be a minimal reduction in the predicted crash rate on ramp roadways and a reduction in the predicted number of crashes on Scenic Highway. However, the weaving section on State Road would contribute to additional rear-end/sideswipe crashes.

Constructability Rating: Less Favorable

The Route 6 westbound off-ramps and State Road widening would involve extensive retaining wall construction and would be difficult to construct since it would be in the same alignment with the existing off-ramp with major elevation changes. This option would require construction of a temporary Route 6 westbound off-ramp, adding approximately 6 to 12 months to the schedule. Further, the temporary ramp would be needed for an extended duration; the reduced speeds on this high-volume ramp would adversely impact local traffic.

Multi-Modal Connections Rating: Favorable

It is anticipated that connections to the local road network would be provided by a shared use path connection to the USACE Canal Service Road (bike path) and on the east side of State Road.

Utility Impacts Rating: Favorable

This option would involve minimal utility impacts limited to relocation of utility poles and multiple ramp light poles.

Environmental Impacts Rating: Less Impactful

In this option, no direct wetland impacts are anticipated.

Right-of-Way Impacts Rating: Medium

This option would not involve additional right-of-way impacts other than those impacts previously identified for MassDOT's recommended Fully Offline Inboard Option for the mainline alignment.

12.10 Summary of Sagamore South Crossing Interchange Approach Initial Assessment

MassDOT identified nine interchange approach options for the Sagamore South crossing and conducted an initial assessment relative to the highway design evaluation criteria. All nine approach options would provide favorable to most favorable multi-modal connections. All options would involve right-of-way impacts in addition to those previously identified for MassDOT's recommended mainline alignment, the Fully Offline Inboard Option, resulting in more impactful ratings. With these exceptions, the approach options would differ substantially relative to meeting the highway design evaluation criteria.

Table 12-4 presents the results of the initial assessment of Sagamore South crossing interchange approach options. Based on the initial assessment, MassDOT recommended advancing Options SS-1, SS-1.1, and SS-3.1A for a more detailed assessment.

Table 12-4. Initial Assessment Results of Sagamore South Crossing Interchange Approach Options

Highway Design Evaluation Criteria (1), (2)	SS-1	SS-1.1	SS-3	SS-3.1	SS-3.1A	SS-3.2	SS-9	SS-9.1	SS-9.1A
Operations	●●	●●	●●	●●	●●	●	●●	●●	●●
Connectivity	●●	●	●●	●	●●	●●	●●●	●●	●●
Geometrics	●	●	●	●●	●●	●	●	●●●	●●
Safety	●●	●●	●●	●●	●●	●●	●●	●●	●●
Constructability	●●	●●	●●	●●●	●●	●●●	●●	●●	●●
Multi-Modal	●●●	●●	●●●	●●●	●●●	●●	●●●	●●	●●
Utilities	●●	●●	●●	●●	●●	●●	●●	●●	●●
Environmental	■■	■■■	■■■	■■■	■■■	■■	■■■■	■■■■	■■■■
Right-of-Way	■■■	■■■	■■■	■■■	■■■	■■	■■■■	■■■■	■■■■

(1) ●●● Most favorable; ●● Favorable; ● Neutral; ●● Less Favorable; ●●● Unfavorable; ●● Not Rated

(2) Range of Least to Less Impacts= ■■■■, ■■■, ■■; Medium Impacts= ❖ ; Range of More to Most Impacts= ■, ■■, ■■■, ■■■■

Sections 12-11 presents details of the initial assessment of the Sagamore South crossing highway interchange options and MassDOT's recommendations to advance or not carry forward options for further evaluation.

12.11 Details of Sagamore South Crossing Interchange Approach Initial Assessment

12.11.1 OPTIONS RECOMMENDED FOR FURTHER EVALUATION

12.11.1.1 Option SS-1

Option SS-1 would modify ramp alignments to accommodate the relocated Route 6 mainline while largely maintaining the existing ramp configurations. The westbound on-ramp and off-ramp movements would utilize a diamond type configuration to meet a modified Cranberry Highway. Acceleration and deceleration lanes would lengthen to improve safety and operations along the Route 6 mainline and ramps. The eastbound on-ramp would maintain its existing configuration but would feature a lengthened acceleration lane to meet current design standards and improve operations and safety. While the eastbound off-ramp would maintain the same general configuration as the existing off-ramp, it would shift approximately 400 feet toward the existing infield area to meet the relocated Route 6 roadway. Option SS-1 would extend Cranberry Highway under Route 6 and continue to the intersection with the Mid-Cape Connector. Figure 12-15 shows a conceptual layout of Option SS-1.

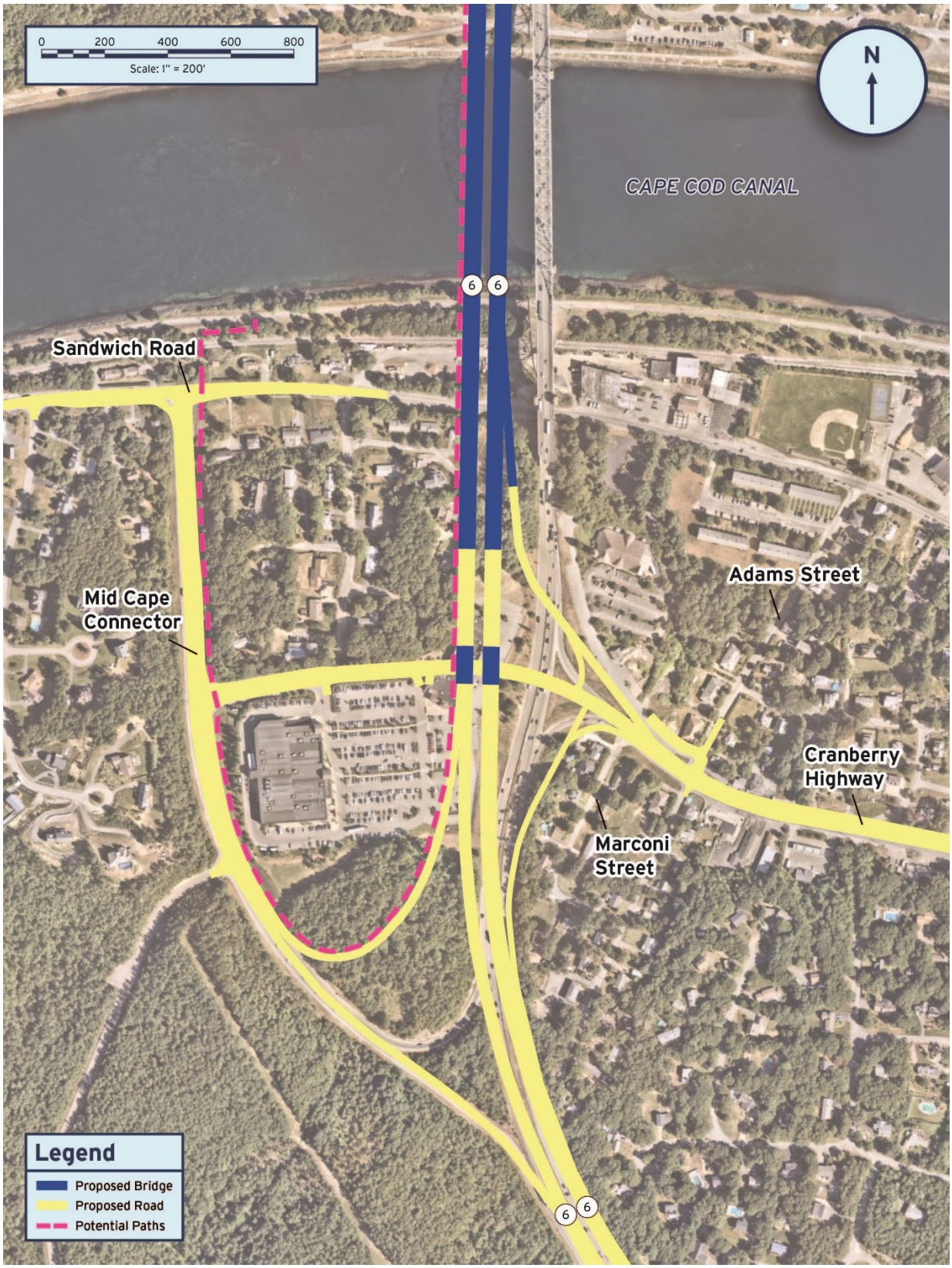


Figure 12-15. Sagamore South Crossing Interchange Approach Option SS-1

Operations and Connectivity Rating: Favorable

Operations modeling indicates that this option would improve operations at the ramp junctions on Route 6. Additionally, the signalized intersections on the Mid-Cape Connector and Cranberry Highway at the Route 6 westbound ramps would operate acceptably. However, should future build volumes show a large increase in Route 6 westbound ramp traffic, the need for additional turn lanes would need to be evaluated. Option SS-1 would maintain existing ramp connections and the Cranberry Highway Extension (old Factory Outlet Way) would improve access between properties east and west of Route 6.

Geometrics Rating: Neutral

The eastbound and westbound off-ramps to Cranberry Highway would be designed to meet the maximum desired profile of 6 percent. The westbound off-ramp to Cranberry Highway would be shifted east; however, it would be closer to the Marconi Street neighborhood. Further, the right turn movement for delivery vehicles exiting the Christmas Tree Shop driveway to Cranberry Highway would mimic existing conditions and encroach into the opposite lane of travel on Cranberry Highway.

Safety Rating: Favorable

Engineering assessments and safety modeling indicate that there would be a moderate reduction in overall predicted crashes and crash rate compared to the No Build condition. Due to the geometric and cross-section improvements, there would be a moderate reduction in both the predicted number of crashes and the predicted crash rates in the areas of the Route 6 acceleration/ deceleration lanes and ramps. This option would result negligible differences on Sandwich Road and the Mid-Cape Connector.

Constructability Rating: Less Favorable

In Option SS-1, the construction of ramps and connector roads would consist of a combination of new alignments away from existing traffic and minor widening of existing roadways. This would increase construction complexity. The Route 6 eastbound off-ramp would require a temporary connection to a portion of the Cranberry Highway Extension, but this option would not change the Route 6 westbound off-ramp to Cranberry Highway. Only minor traffic impacts would result from the widening of Sandwich Road, the Mid-Cape Connector and Cranberry Highway Extension. This option would substantially increase the construction duration compared to other options: construction of the Route 6 westbound on-ramp from Cranberry Highway and the Cranberry Highway Extension could not be completed until barrels of the replacement bridge are completed, and the existing Sagamore Bridge could not be demolished until the new Route 6 westbound on-ramp is completed. The required construction sequence could add a scheduling complication to this option.

Multi-Modal Connections Rating: Most Favorable

It is anticipated that connections to the local road network would be provided by shared use path direct connections to Cranberry Highway, Sandwich Road and the Canal Service Road, including bicycle and pedestrian accommodations along Cranberry Highway and Cranberry Highway Extension.

Utility Impacts Rating: Favorable

In the option, utility impacts would be limited to the relocation of multiple utility poles, light poles, and overhead wire.

Environmental Impacts Rating: Less Impactful

In this option, no direct wetland impacts are anticipated.

Right-of-Way Impacts Rating: More Impactful

Based on conceptual design, this option would result in right-of-way impacts in addition to those impacts previously identified for MassDOT's recommended Fully Offline Inboard Option for the mainline alignment. Option SS-1 would result in two residential full property acquisitions, including two vacant parcels; ten residential partial property acquisitions, including one vacant parcel; one commercial full property acquisition, consisting of a vacant parcel; and nine commercial partial property acquisitions. The impacts would not directly affect EJ communities or populations.

12.11.1.2 Option SS-1.1

Option SS-1.1 would provide the same interchange configuration as Option SS-1, but Option SS-1.1 would eliminate the Cranberry Highway Extension. This elimination would result in an option that largely would mimic the existing interchange configuration with modifications limited to those necessary to match the relocated Route 6 mainline and to provide lengthened acceleration and deceleration lanes. Figure 12-16 shows a conceptual layout of Option SS-1.1.

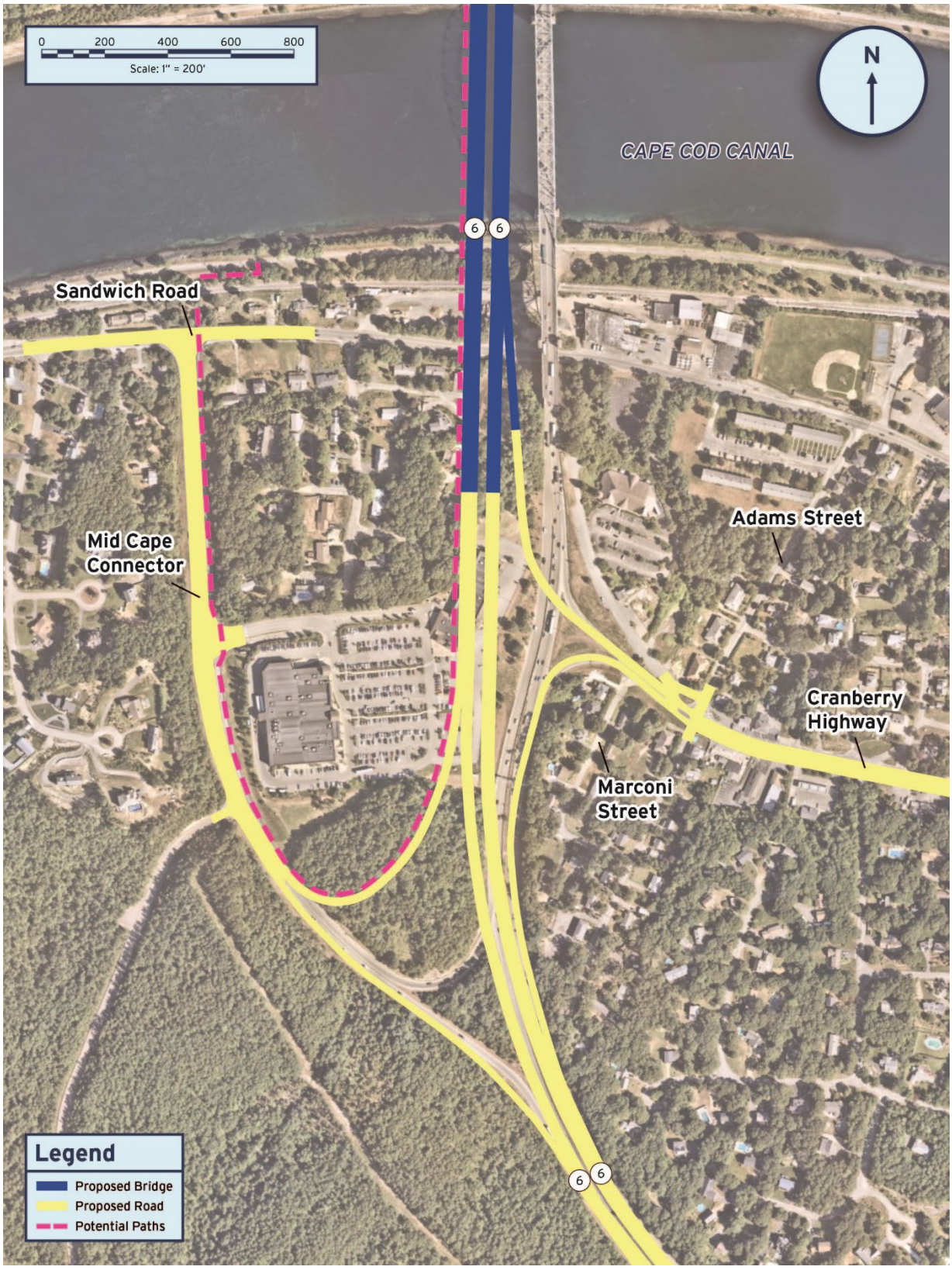


Figure 12-16. Sagamore South Crossing Interchange Approach Option SS-1.1

Operations Rating: Favorable

Operations modeling indicates that this option would improve operations at the ramp junctions on Route 6. Additionally, this option would result in acceptable operations at existing intersections with no or minimal changes to lane arrangements.

Connectivity and Geometrics Rating: Neutral

Option SS-1.1 would maintain existing ramp connections. The geometric conditions of Option SS-1.1 would be like those of Option SS-1. The eastbound and westbound off-ramps to Cranberry Highway would be designed to meet the maximum desired profile of 6 percent. Additionally, the westbound off-ramp to Cranberry Highway would be shifted east, closer to the Marconi Street neighborhood. Further, the right turn movement for delivery vehicles exiting the Christmas Tree Shop driveway to Cranberry Highway would mimic existing conditions and encroach into the opposite lane of travel on Cranberry Highway.

Safety Rating: Favorable

Engineering assessments and safety modeling indicate that due to the geometric and cross-section improvements, there would be a moderate reduction in both the predicted number of crashes and the predicted crash rates in the areas of the Route 6 acceleration/ deceleration lanes and ramps compared to No Build condition. Additionally, crash rates would be reduced slightly on the ramp roadways. This option would result negligible differences on Sandwich Road and the Mid-Cape Connector.

Constructability Rating: Less Favorable

In Option SS-1.1, the construction of ramps and connector roads would consist of a combination of new alignments away from existing traffic and minor widening of existing roadways. This option would substantially increase the construction duration compared to other options: construction of the Route 6 westbound on-ramp from Cranberry Highway and the Cranberry Highway Extension could not be completed until barrels of the replacement bridge are completed, and the existing Sagamore Bridge could not be demolished until the new Route 6 westbound on-ramp is completed. The required construction sequence could add a scheduling complication to this option. Unlike Option SS-1, which would involve a temporary Route 6 eastbound off-ramp connection to the Cranberry Highway Extension, Option SS-1.1 would not include the Cranberry Highway Extension, eliminating the potential for a temporary Route 6 eastbound off-ramp connection. However, Option SS-1.1 would not be possible without a temporary connection. Like Option SS-1, this option would not change the Route 6 westbound off-ramp to Cranberry Highway. Option SS-1.1 would incur only minor traffic impacts due to the widening of Sandwich Road, the Mid-Cape Connector and Factory Outlet Way.

Multi-Modal Connections Rating: Favorable

It is anticipated that connections to the local road network would be provided by shared use path direct connections to Sandwich Road and the Canal Service Road, including bicycle and pedestrian accommodations along Cranberry Highway.

Utility Impacts Rating: Favorable

In this option, utility impacts would be limited to the relocation of multiple utility poles, light poles, and overhead wire.

Environmental Impacts Rating: Less Impactful

In this option, no direct wetland impacts are anticipated.

Right-of-Way Impacts Rating: Impactful

Based on conceptual design, this option would result in right-of-way impacts in addition to those impacts previously identified for MassDOT's recommended Fully Offline Inboard Option for the mainline alignment. Option SS-1 would result in two residential full property acquisitions; nine residential partial property acquisitions, including a vacant parcel; one commercial full property acquisition, consisting of a vacant parcel; and nine commercial partial property acquisitions. The impacts would not directly affect EJ communities or populations.

12.11.1.3 Option SS-3.1A

Option SS-3.1A would closely resemble Option SS-1 with one major difference. In Option SS-3.1A, the northbound on-ramp would be relocated to begin off the Mid-Cape Connector, so it would share the same entrance point as the southbound on-ramp. From this location, the ramp would curve northerly and cross under Route 6 before merging with the Route 6 northbound roadway. The merge would occur as the northbound on-ramp and Route 6 cross over the Cranberry Highway Extension. Figure 12-17 shows a conceptual layout of Option SS-3.1A.

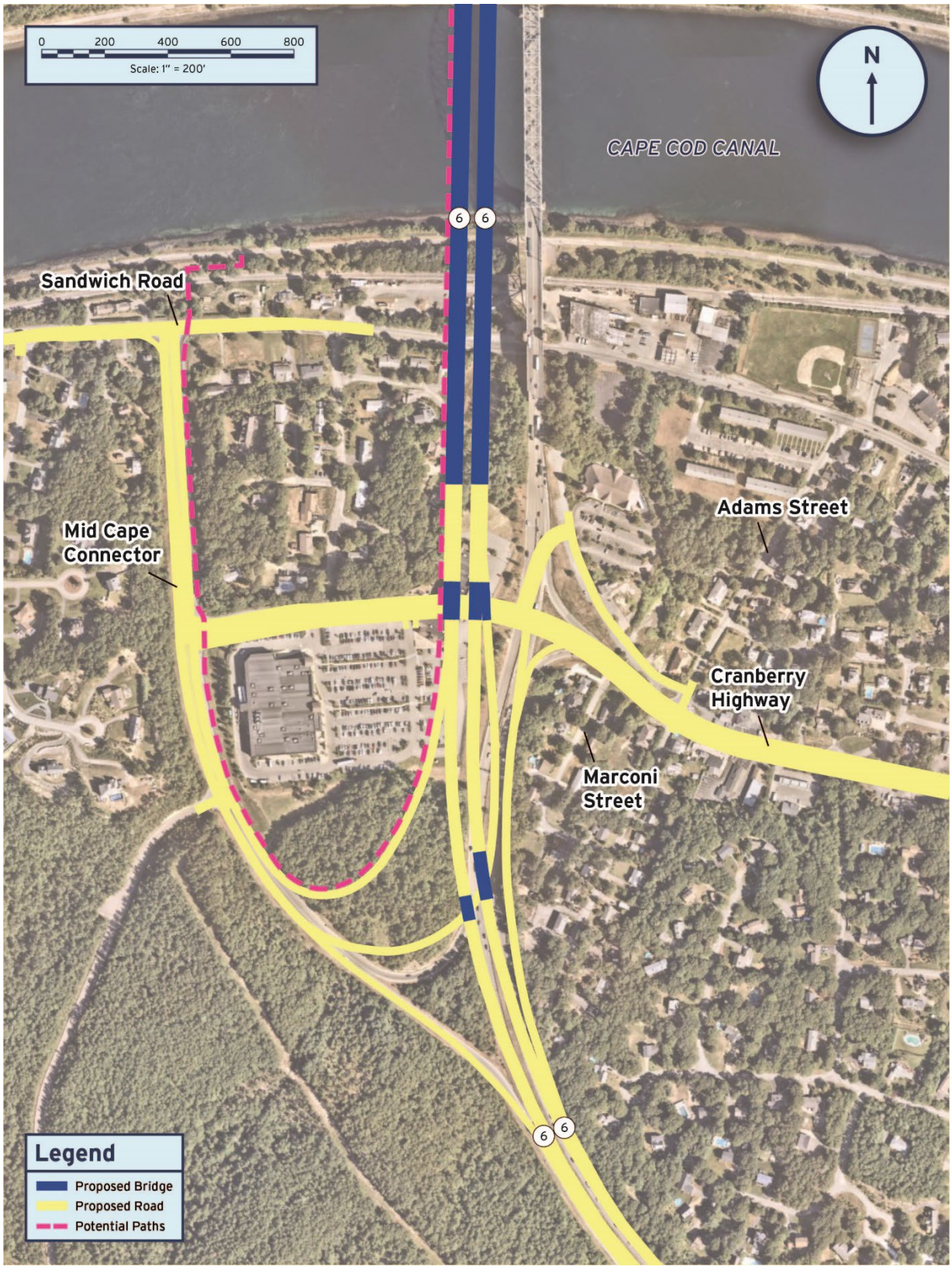


Figure 12-17. Sagamore South Crossing Interchange Approach Option SS-3.1A

Operations, Connectivity and Geometrics Rating: Favorable

In Option SS-3.1A, the Cranberry Highway Extension would improve access between properties east and west of Route 6. Additionally, shifting access to Route 6 westbound from east of the roadway to the Mid-Cape Connector would be offset by the Cranberry Highway Extension. This option would reduce the length for trips to and from Route 6 eastbound and Route 6A, east of Cranberry Highway. The trip length from Route 6 westbound to Sandwich Road, west of the Mid-Cape Connector, would be reduced by a mile. However, the trip length from Route 6A, east of Cranberry Highway, to Route 6 westbound would increase by over one-half-mile. Operations modeling indicates that Option SS-3.1A would improve operations at the ramp junctions on Route 6. Additionally, the signalized intersections on the Mid-Cape Connector and Cranberry Highway at the Route 6 westbound ramps would operate acceptably.

However, should future build volumes show a substantial increase in Route 6 westbound ramp traffic, the need for additional turn lanes would need to be evaluated. Option SS-3.1A would meet current MassDOT and FHWA design standards. The eastbound off-ramp would be designed at the maximum desired 6 percent profile grade. Additionally, this option would provide better egress to Cranberry Highway for Christmas Tree Shop delivery vehicles. Further, Option SS-3.1A would eliminate the need for a substantial excavation adjacent to Route 6 westbound.

Safety Rating: Favorable

Engineering assessments and safety modeling indicate that due to the geometric and cross-section improvements, there would be a moderate reduction in both the predicted number of crashes and the predicted crash rates in the areas of the Route 6 acceleration/ deceleration lanes and ramps. Additionally, due to the proposed ramp geometry, there would be a moderate reduction in predicted crash rate on ramp segments. This option would result negligible differences on Sandwich Road and the Mid-Cape Connector.

Constructability Rating: Less Favorable

The construction of ramps and connector roads would consist of a combination of new alignments away from existing traffic and minor widening to existing roadways. A major portion of the new ramps could be constructed without affecting existing roadways. Unlike Option SS-3.1 (described in Section 8.6.2.2), in Option SS-3.1A, construction of the new Route 6 eastbound off-ramp would not involve deep excavation or construction complexity. The Route 6 eastbound off-ramp would require a temporary connection to a portion of the Cranberry Highway Extension. In Option SS-3.1A, the Cranberry Highway Extension could not be completed until both barrels of the replacement bridge are completed.

Additionally, Cranberry Highway and the signalized intersection for the Christmas Tree Shop could not be built until all Route 6 traffic is relocated on the new bridge structures. The required construction sequence could add a scheduling complication to this option. In this option, only minor traffic impacts would be expected due to the widening of Sandwich Road, the Mid-Cape Connector, and the Cranberry Highway Extension (old Factory Outlet Way).

Multi-Modal Connections Rating: Most Favorable

It is anticipated that connections to the local road network would be provided by shared use path direct connections to Cranberry Highway, Sandwich Road and the Canal Service Road, including bicycle and pedestrian accommodations along Cranberry Highway and Cranberry Highway Extension.

Utility Impacts Rating: Favorable

In this option, utility impacts would be limited to the relocation of multiple utility poles, light poles, and overhead wire.

Environmental Impacts Rating: Less Impactful

In this option, no direct wetland impacts are anticipated.

Right-of-Way Impacts Rating: More Impactful

Based on conceptual design, this option would result in right-of-way impacts in addition to those impacts previously identified for MassDOT's recommended Fully Offline Inboard Option for the mainline alignment. Option SS-3.1A would result in two residential full property acquisitions, including two vacant parcels; ten residential partial property acquisitions, including one vacant parcel; one commercial full property acquisition, consisting of a vacant parcel; and eight commercial partial property acquisitions. The impacts would not directly affect EJ communities or populations.

12.11.2 OPTIONS NOT RECOMMENDED FOR FURTHER EVALUATION

12.11.2.1 Option SS-3

Option SS-3 generally would maintain three of the four existing ramp configurations, consisting of the eastbound off-ramp, the eastbound on-ramp, and the westbound off-ramp, with minor modifications to meet current design standards. Option SS-3 would shift the eastbound off-ramp approximately 400 feet into the existing infield area. Option SS-3 would relocate the westbound on-ramp to begin off the Mid-Cape Connector. From there, the westbound on-ramp would curve northerly as it crosses over the relocated Route 6 mainlines and then continue north before merging with Route 6 westbound. Additionally, Option SS-3 would extend Cranberry Highway under Route 6 with its terminus at the Mid-Cape Connector. All ramps would provide lengthened acceleration and deceleration lanes to meet current design standards and improve operations and safety. Figure 12-18 shows a conceptual layout of Option SS-3.

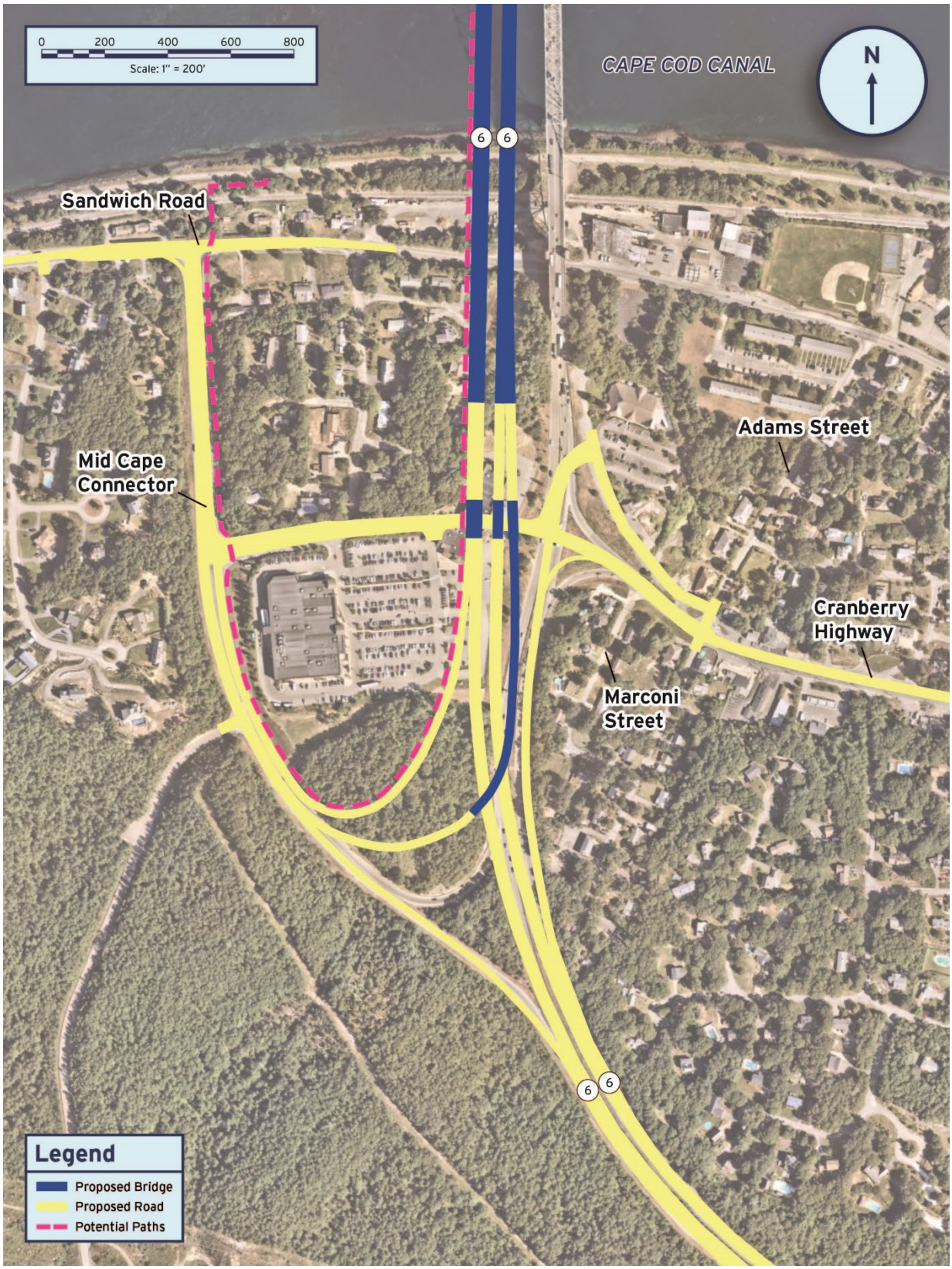


Figure 12-18. Sagamore South Crossing Interchange Approach Option SS-3

Operations and Connectivity Rating: Favorable

In Option SS-3, all access to and from Route 6 eastbound to Route 6 westbound would be provided from the Mid-Cape Connector, reducing the length for trips to and from Route 6 eastbound and Route 6A, east of Cranberry Highway. The trip length from Route 6 westbound to Sandwich Road, west of Mid-Cape Connector, would be reduced by over one-half-mile. However, Option SS-3 would increase the length for trips to Route 6 westbound from Route 6A, east of Cranberry Highway. Access to and from neighborhoods east of Route 6 would be offset by the Cranberry Highway Extension. Operations modeling indicates that Option SS-3 would improve operations at the ramp junctions on Route 6. Additionally, the signalized intersections on the Mid-Cape Connector and Cranberry Highway at the Route 6 westbound ramps would operate acceptably. However, should future build volumes show a large increase in Route 6 westbound ramp traffic, the need for additional turn lanes would need to be evaluated.

Geometrics Rating: Neutral

Option SS-3 would meet current MassDOT and FHWA design standards. Both the eastbound off-ramp and the westbound on-ramp would be designed at the desired 6 percent profile grade. Additionally, Option SS-3 would provide better egress to Cranberry Highway for Christmas Tree Shop delivery vehicles compared to other options. However, Option SS-3 would require an elevated ramp structure: the Mid-Cape Connector to Route 6 westbound. The structure's profile grade would approach the maximum desirable grade of 6 percent and span over Route 6, resulting in a high ramp structure adjacent to the Marconi Street neighborhood.

Safety Rating: Favorable

Engineering assessments and safety modeling indicate that due to the geometric and cross-section improvements, there would be a moderate reduction in both the predicted number of crashes and the predicted crash rates in the areas of the Route 6 acceleration/ deceleration lanes and ramps compared to No Build conditions. Additionally, crash rates would be reduced slightly on the ramp roadways. This option would result negligible differences on Sandwich Road and the Mid-Cape Connector.

Constructability Rating: Favorable

In Option SS-3, the construction of ramps and connector roads would consist of a combination of new alignments away from existing traffic and minor widening of existing roadways. A major portion of the new ramps could be constructed without affecting existing roadways. In Option SS-3, completion of the Cranberry Highway Extension would require completion of both barrels of the replacement bridge, potentially adding a scheduling complication to this option.

Multi-Modal Connections Rating: Most Favorable

It is anticipated that connections to the local road network would be provided by shared use path direct connections to Cranberry Highway, Sandwich Road, and the Canal Service Road, including bicycle and pedestrian accommodations along Cranberry Highway and Cranberry Highway Extension.

Utility Impacts Rating: Favorable

In this option, utility impacts would be limited to the relocation of multiple utility poles, light poles, and overhead wire.

Environmental Impacts Rating: Less Impactful

In this option, no direct wetland impacts are anticipated.

Right-of-Way Impacts Rating: More Impactful

Based on conceptual design, this option would result in right-of-way impacts in addition to those impacts previously identified for MassDOT's recommended Fully Offline Inboard Option for the mainline alignment. Option SS-3 would result in two residential full property acquisitions, including one vacant parcel; ten residential partial property acquisitions, including one vacant parcel; one commercial full property acquisition, consisting of a vacant parcel; and nine commercial partial property acquisitions. The impacts would not directly affect EJ communities or populations.

12.11.2.2 Option SS-3.1

Option SS-3.1 would concentrate all ramp movements to begin and end at the Mid-Cape Connector. The eastbound off-ramp and on-ramp would be like the existing ramp configurations, with a 400-foot shift into the infield area to accommodate the relocated Route 6 mainline alignments. However, in Option SS-3, the westbound off-ramp and on-ramp termini would be substantially changed from their existing ramp configurations. The westbound on-ramp would begin at the terminus of the Mid-Cape Connector and curve northerly as it spans over the westbound off-ramp; it would then cross under the relocated Route 6 mainline before merging with Route 6 westbound. The westbound off-ramp would exit Route 6 in advance of the interchange and then descend to cross under the Route 6 mainline while curving westerly. The off-ramp would cross under the westbound on-ramp before terminating at the Mid-Cape Connector. In Option SS-3.1, all ramps would lengthen acceleration and deceleration lanes to meet current design standards and improve operations and safety. Option SS-3.1 would extend Cranberry Highway to the Mid-Cape Connector by crossing under the relocated Route 6 mainlines. Figure 12-19 shows a conceptual layout of Option SS-3.1.

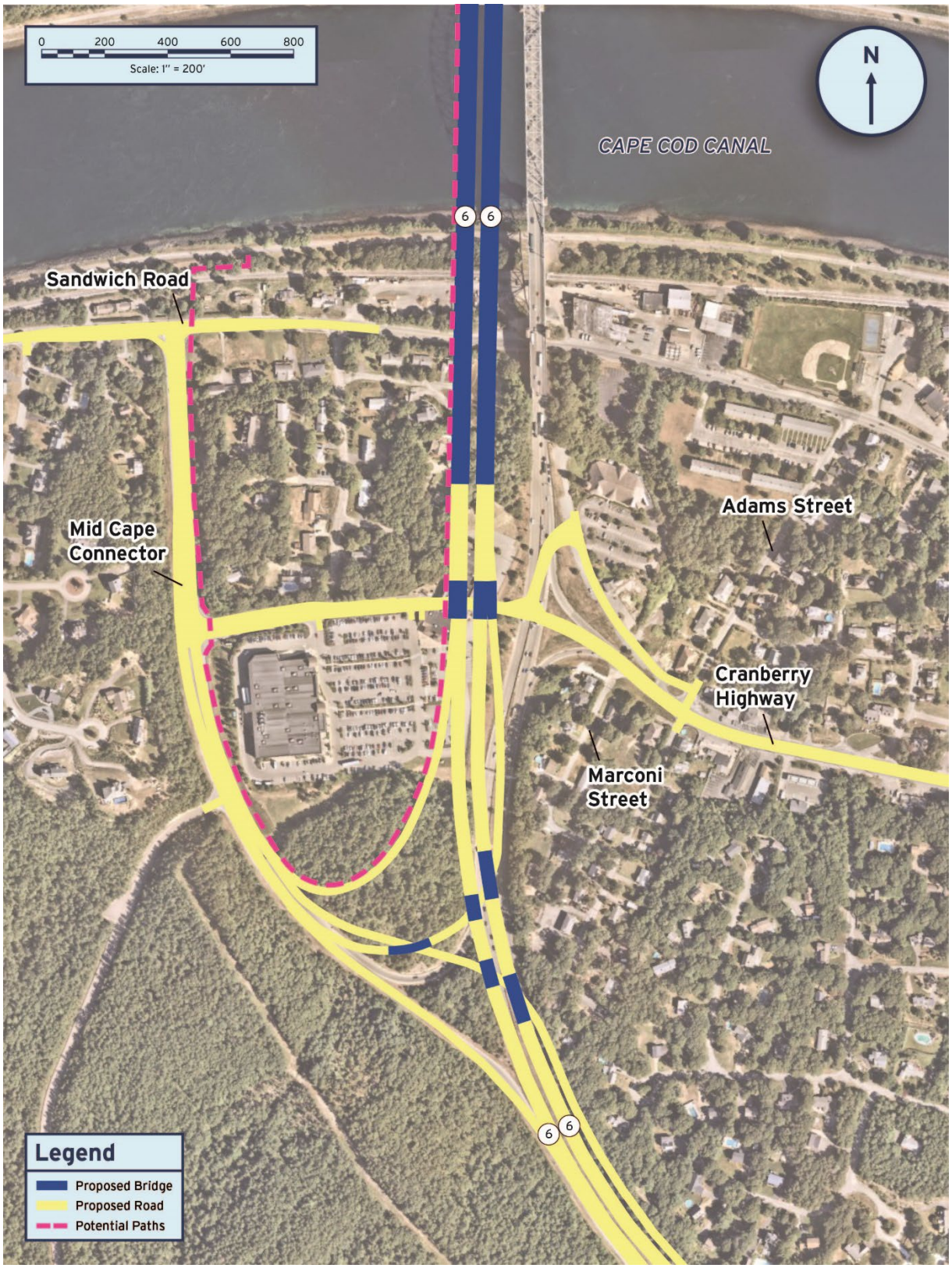


Figure 12-19. Sagamore South Crossing Interchange Approach Option SS-3.1

Operations and Geometrics Rating: Favorable

Operations modeling indicates that Option SS-3.1 would improve operations at the ramp junctions on Route 6. Additionally, the signalized intersections on the Mid-Cape Connector would operate acceptably. However, should future build volumes show a large increase in Route 6 westbound ramp traffic, the need for additional turn lanes would need to be evaluated. Additionally, further development of this option would require an evaluation of the Route 6 eastbound and westbound off-ramp traffic weave on the Mid-Cape Connector prior to the Cranberry Highway Extension intersection. Option SS-3.1 would meet current MassDOT and FHWA design standards. The eastbound off-ramp would be designed at the desired 6 percent profile grade. Option SS-3.1 would provide better egress to Cranberry Highway for Christmas Tree Shop delivery vehicles compared to other options. However, construction of the new Route 6 westbound off-ramp to the Mid Cape Connector, located between Route 6 westbound and the existing Route 6 westbound off-ramp, would involve a substantial excavation of up to 35 feet along Route 6.

Connectivity Rating: Neutral

In Option SS-3.1, all access to and from Route 6 would be provided from the Mid-Cape Connector. This option would reduce the length for trips to and from Route 6 eastbound and Route 6A, east of Cranberry Highway. The trip length from Route 6 westbound to Sandwich Road, west of Mid-Cape Connector, would be reduced by a mile. However, Option SS-3.1 would increase the length for trips to and from Route 6 westbound and Route 6A, east of Cranberry Highway. Access to and from neighborhoods east of Route 6 would be offset by the Cranberry Highway Extension.

Safety Rating: Favorable

Engineering assessments and safety modeling indicate that due to the geometric and cross-section improvements, there would be a moderate reduction in both the predicted number of crashes and the predicted crash rates in the areas of the Route 6 acceleration/ deceleration lanes and ramps compared to No Build conditions. Additionally, crash rates would be reduced slightly on the ramp roadways. This option would result negligible differences on Sandwich Road and the Mid-Cape Connector.

Constructability Rating: Unfavorable

The construction of ramps and connector roads would consist of a combination of new alignments away from existing traffic and minor widening to existing roadways. A major portion of the new ramps could be constructed without affecting existing roadways. The Route 6 eastbound off-ramp would require a temporary connection to a portion of the Cranberry Highway Extension. With a deep cut boat section and deep drainage excavation, the new Route 6 westbound off-ramp would require extensive sheeting, adding construction complexity. Further, the Cranberry Highway Extension and the Route 6 westbound off-ramp could not be completed until both barrels of the replacement bridge are completed. The required construction sequence would add a scheduling complication to this option, adding a minimum of a year to the construction schedule. Only minor traffic impacts would result from the widening of Sandwich Road, the Mid-Cape Connector, and Cranberry Highway Extension (old Factory Outlet Way).

Multi-Modal Connections Rating: Most Favorable

It is anticipated that connections to the local road network would be provided by shared use path direct connections to Cranberry Highway, Sandwich Road and the Canal Service Road, including bicycle and pedestrian accommodations along Cranberry Highway and Cranberry Highway Extension.

Utility Impacts Rating: Less Favorable

In addition to the relocation of multiple utility poles, light poles, and overhead wire, in Option SS-3.1, a drainage pump station or deep drainage pipes could be required for the Route 6 westbound on- and off-ramp areas.

Environmental Impacts Rating: Less Impactful

In this option, no direct wetland impacts are anticipated. However, the deep excavation required for the Route 6 westbound ramp to the Mid-Cape Connector would extend well past the utility corridor.[18] As a result, this alternative would likely have temporary and permanent impacts to the Shawme Crowell State Park and could require relocation of one or more utility towers within the utility corridor. The Shawme Crowell State Park is protected under Article 97[19] and Section 4(f) of the Department of Transportation Act of 1966.[20]

Right-of-Way Impacts Rating: More Impactful

Based on conceptual design, this option would result in right-of-way impacts in addition to those impacts previously identified for MassDOT's recommended Fully Offline Inboard Option for the mainline alignment. Option SS-3.1 would result in two residential full property acquisitions, including two vacant parcels; ten residential partial property acquisitions, including one vacant parcel; one commercial full property acquisition, consisting of a vacant parcel; and eight commercial partial property acquisitions. The impacts would not directly affect EJ communities or populations.

12.11.2.3 Option SS-3.2

Option SS-3.2 would have most of the same features as Option SS-3.1; however, Option SS-3.2 would eliminate the Cranberry Highway Extension. Figure 12-20 shows a conceptual layout of Option SS-3.2.

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[18] The utility corridor carries the high-tension electrical power on three sets of parallel towers from east to west. The open cut area is owned by the Massachusetts Department of Conservation and Recreation (DCR) and leased to the power companies (NGRID). Note that because the utility corridor is kept free of trees, the area provides unique habitat for several state listed species.

[19] Article 97 protection applies to lands acquired by State agencies under the Executive Office of Energy and Environmental Affairs in fee simple or by a Conservation Restriction; these lands are protected under Article 97 of the Amendments to the Massachusetts Constitution and require a two-thirds vote of the State Legislature before they can be disposed of.

[20] Section 4(f) requires the consideration of park and recreation lands, wildlife and waterfowl refuges, and historic sites during U.S. Department of Transportation project development. Before approving a project that uses Section 4(f) property, FHWA must determine that there is no feasible and prudent alternative that avoids the Section 4(f) properties and that the project includes all possible planning to minimize harm to the Section 4(f) properties; or FHWA makes a finding that the project has a de minimis impact on the Section 4(f) property.



Figure 12-20. Sagamore South Crossing Interchange Approach Option SS-3.2

Operations and Geometrics Rating: Neutral

Operations modeling indicates that Option SS-3.2 would improve operations at the ramp junctions on Route 6. However, additional delays/queues would be expected at Sandwich Road and the Mid-Cape Connector with this now being sole access point to/from Route 6. Should future build volumes show a large increase in Route 6 westbound ramp traffic, the need for additional turn lanes would need to be evaluated. Additionally, further development of this option would require an evaluation of the Route 6 eastbound and westbound off-ramp traffic weave on the Mid-Cape Connector prior to the Market Basket intersection. Option SS-3.2 would meet current MassDOT and FHWA design standards. The eastbound off-ramp would be designed at the desired 6 percent profile grade. However, construction of the new Route 6 westbound off-ramp to the Mid Cape Connector, located between Route 6 westbound and the existing Route 6 westbound off-ramp, would involve a substantial excavation of up to 35 feet along Route 6.

Connectivity Rating: Less Favorable

In Option SS-3,2, all access to and from Route 6 would be provided from the Mid-Cape Connector, impacting access to neighborhoods to the east. This option would increase trip lengths to and from Route 6 westbound and Route 6A, east of Cranberry Highway. However, this option would reduce the trip length for Route 6 westbound to Sandwich Road, west of the Mid-Cape Connector, by a mile.

Safety Rating: Favorable

Engineering assessments and safety modeling indicate that due to the geometric and cross-section improvements, there would be a moderate reduction in both the predicted number of crashes and the predicted crash rates on Route 6. Additionally, crash rates would be reduced slightly on the ramp segments. This option would result negligible differences on Sandwich Road and the Mid-Cape Connector.

Constructability Rating: Unfavorable

from existing traffic and minor widening to existing roadways. A major portion of the new ramps could be constructed without affecting existing roadways. Without the Cranberry Highway Extension, a temporary Route 6 eastbound off-ramp would not be possible, however, Option SS-3.2 would require some type of connection. With a deep cut boat section and deep drainage excavation, the new Route 6 westbound off-ramp would require extensive sheeting, adding construction complexity. Additionally, the Route 6 westbound off-ramp could not be completed until both barrels of the replacement bridge are completed. The required construction sequence would add a scheduling complication to this option, adding more than a year to the construction schedule. Only minor traffic impacts would result from the widening of Sandwich Road and the Mid-Cape Connector.

Multi-Modal Connections Rating: Favorable

It is anticipated that connections to the local road network would be provided by shared use path direct connections to Sandwich Road and the Canal Service Road, including bicycle and pedestrian accommodations along Cranberry Highway.

Utility Impacts Rating: Less Favorable

Like Option SS-3.1, in addition to the relocation of multiple utility poles, light poles, and overhead wire, in Option SS-3.2, a drainage pump station or deep drainage pipes could be required for the Route 6 westbound on- and of-ramp areas.

Environmental Impacts Rating: Impactful

In this option, no direct wetland impacts are anticipated. However, the construction of the Route 6 westbound ramp to the Mid-Cape connector would result in permanent and temporary impacts to the Shawme Crowell State Park. This property is protected under Article 97.

Right-of-Way Impacts Rating: Impactful

Based on conceptual design, this option would result in right-of-way impacts in addition to those previously identified for MassDOT's recommended Fully Offline Inboard Option for the mainline alignment. Option SS-3.2 would result in two residential full property acquisitions; seven residential partial property acquisition, including a vacant parcel; one commercial full property acquisition, consisting of a vacant parcel; and one commercial partial property acquisition. The impacts would not directly affect EJ communities or populations.

12.11.2.4 Option SS-9

Option SS-9 would use an elongated modified diamond type configuration to provide westbound off and on-ramp movements as well as the eastbound on-ramp. This option would provide a cross-highway connection under Route 6 in the existing overhead utility corridor. In Option SS-9, the westbound off-ramp and on-ramps would assume a standard diamond configuration with an intersection at the end of the ramps at a partial roundabout. This roundabout would connect to a partial roundabout on the west side of Route 6 via an underpass connecting roadway. The eastbound on-ramp would begin at this roundabout and merge with Route 6 eastbound in a standard diamond configuration. The unique aspect of this arrangement is that all access to the diamond portion of the interchange would be provided by a two-way frontage road on the west side of Route 6. This frontage road would connect to the Mid-Cape Connector Road. The eastbound off-ramp would maintain a similar configuration to the existing ramp with an approximate 400-foot shift into the infield area to accommodate the relocated Route 6 mainline alignment. Option SS-9 also would extend Cranberry Highway under Route 6, intersecting with the Mid-Cape Connector. Figure 12-21 shows a conceptual layout of Option SS-9.

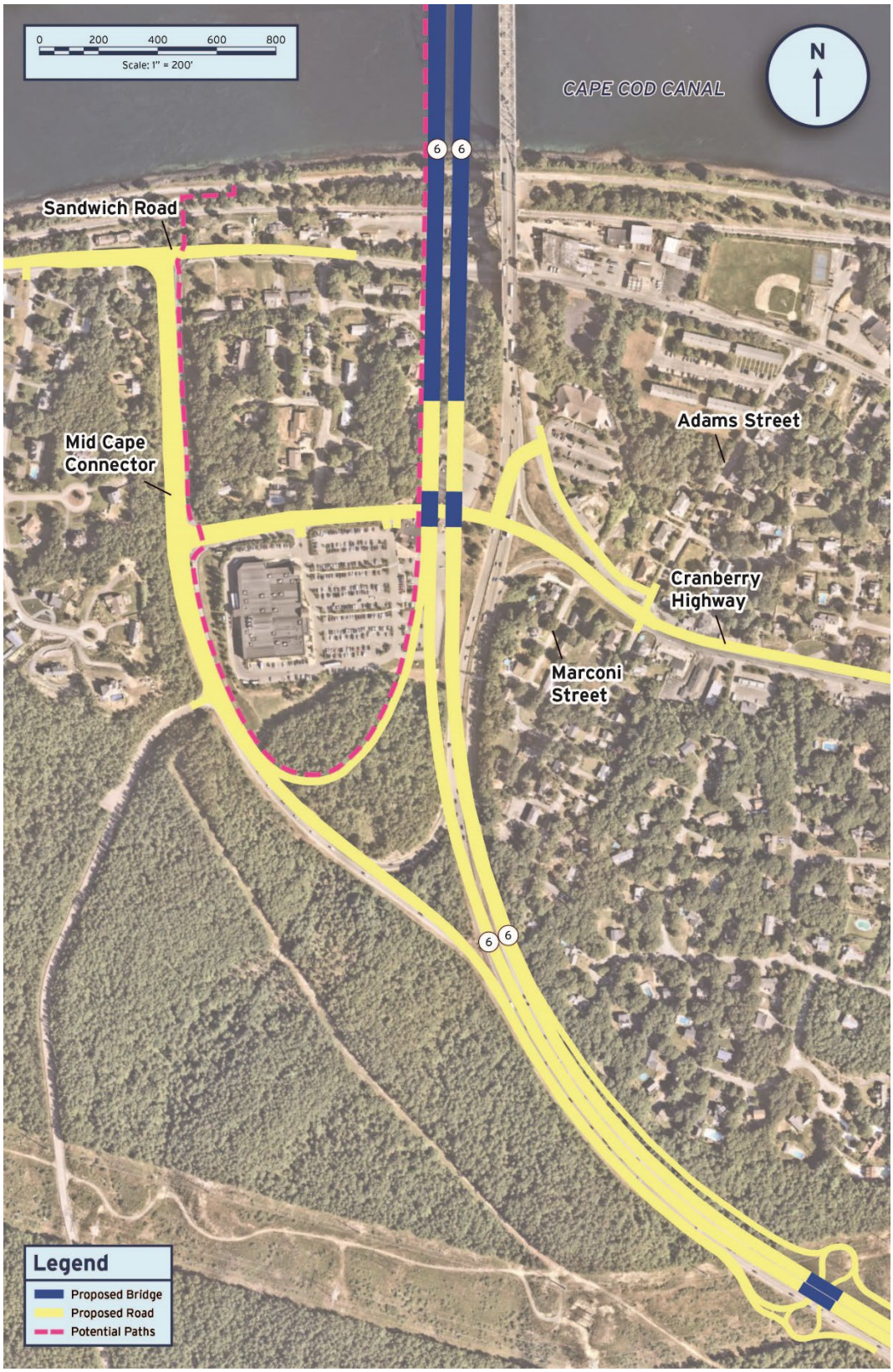


Figure 12-21. Sagamore South Crossing Interchange Approach Option SS-9

Operations Rating: Less Favorable

Operations modeling indicates that Option SS-9 would improve operations at the ramp junctions on Route 6 and the signalized intersections on the Mid-Cape Connector would operate acceptably. However, high conflicting volumes for traffic entering and exiting Route 6 westbound would result in poor operations at the bottom of the ramps with long queues on the Route 6 westbound off-ramp. Additionally, further development of this option would require an evaluation of the Route 6 eastbound and westbound off-ramp traffic weave on the Mid-Cape Connector prior to the Cranberry Highway Extension intersection.

Connectivity Rating: Unfavorable

In this option, the Cranberry Highway Extension would improve access to and from Route 6 eastbound and properties east of Route 6. However, the trip length for traffic destined for Route 6 westbound from Route 6A, east of Cranberry Highway would increase by just over 1.5 miles. This option would reduce the lengths of trips to and from Sandwich Road, west of the Mid-Cape Connector and Route 6 westbound, and to and from Route 6A, east of Cranberry Highway and Route 6 eastbound.

Geometrics Rating: Neutral

Option SS-9 would meet current MassDOT and FHWA design standards. The eastbound off-ramp would be designed at the desired 6 percent profile grade. Additionally, this option would provide better egress to Cranberry Highway for Christmas Tree Shop delivery vehicles. However, construction of the new Route 6 westbound off-ramp to the Mid Cape Connector, located between Route 6 westbound and the existing Route 6 westbound off-ramp, would involve a substantial excavation of up to 35 feet along Route 6.

Safety Rating: Less Favorable

Engineering assessments and safety modeling indicate that due to the geometric and cross-section improvements, there would be a moderate reduction in both the predicted number of crashes and the predicted crash rates on Route 6. However, the long straight frontage road could encourage faster speeds heading north where the Route 6 eastbound off-ramp meets the Mid-Cape Connector. This option would result a negligible change in predicted crash rates on ramp roadways and negligible differences on Sandwich Road and the Mid-Cape Connector.

Constructability Rating: Less Favorable

The construction of ramps and connector roads would consist of a combination of new alignments away from existing traffic and minor widening to existing roadways. A major portion of the new ramps could be constructed without affecting existing roadways. The new Route 6 westbound off-ramp and the Route 6 eastbound on-ramp at the utility corridor would require temporary roadways in each direction while both barrels of the replacement bridges are built. The Route 6 eastbound off-ramp would require a temporary connection to a portion of the Cranberry Highway Extension. The Cranberry Highway Extension could not be completed until both barrels of the replacement bridge are completed. Further, the access into the Christmas Tree Shop could not be built until all Route 6 traffic is relocated to the new bridge. The required construction sequence would add a scheduling complication to this option. Option SS-9 would impact local traffic; Route 6 eastbound and westbound in the vicinity of the utility corridor would require multiple traffic shifts for the Route 6 bridges and the on- and off-ramps.

Multi-Modal Connections Rating: Most Favorable

It is anticipated that connections to the local road network would be provided by shared use path direct connections to Cranberry Highway, Sandwich Road, and the Canal Service Road, including bicycle and pedestrian accommodations along Cranberry Highway and Cranberry Highway Extension.

Utility Impacts Rating: Less Favorable

In addition to the relocation of multiple utility poles, light poles, and overhead wire, Option SS-9 would interrupt the natural drainage patterns of the existing utility corridor. This option could require a drainage pump station or an outfall on Joint Base Cape Cod (JBCC) property. Additionally, three of the high voltage utility towers would be impacted by the roundabouts.

Environmental Impacts Rating: Most Impactful

This option would result in impacts to both the Joint Base Cape Cod (JBCC) Upper Cape Water Supply Reserve to the west and Massachusetts Department of Conservation and Recreation (DCR) property to the east. Both properties are protected under Article 97 and the DCR property also is protected under Section 4(f). Additionally, property impacts could involve a take of State-listed endangered species.

Right-of-Way Impacts Rating: Most Impactful

Based on conceptual design, this option would result in right-of-way impacts in addition to those impacts previously identified for MassDOT's recommended Fully Offline Inboard Option for the mainline alignment. Option SS-9 would result in two residential full property acquisitions; 14 residential partial property acquisitions, including a vacant parcel; one commercial full property acquisition, consisting of a vacant parcel; and eight commercial partial property acquisitions. The right-of-way impacts would not directly affect EJ communities or populations.

12.11.2.5 Option SS-9.1

Option SS-9.1 would provide a variation of Option SS-9 while maintaining the shift of the mainline merge and diverge points for several ramps easterly along Route 6. In Option SS-9.1, however, the new westbound on-ramp would be near its existing location at the end of Cranberry Highway. This would allow for a slight simplification of the connecting movements in the vicinity of the overhead utility corridor. This option would not extend Cranberry Highway. Figure 12-22 shows a conceptual layout of Option SS-9.1.

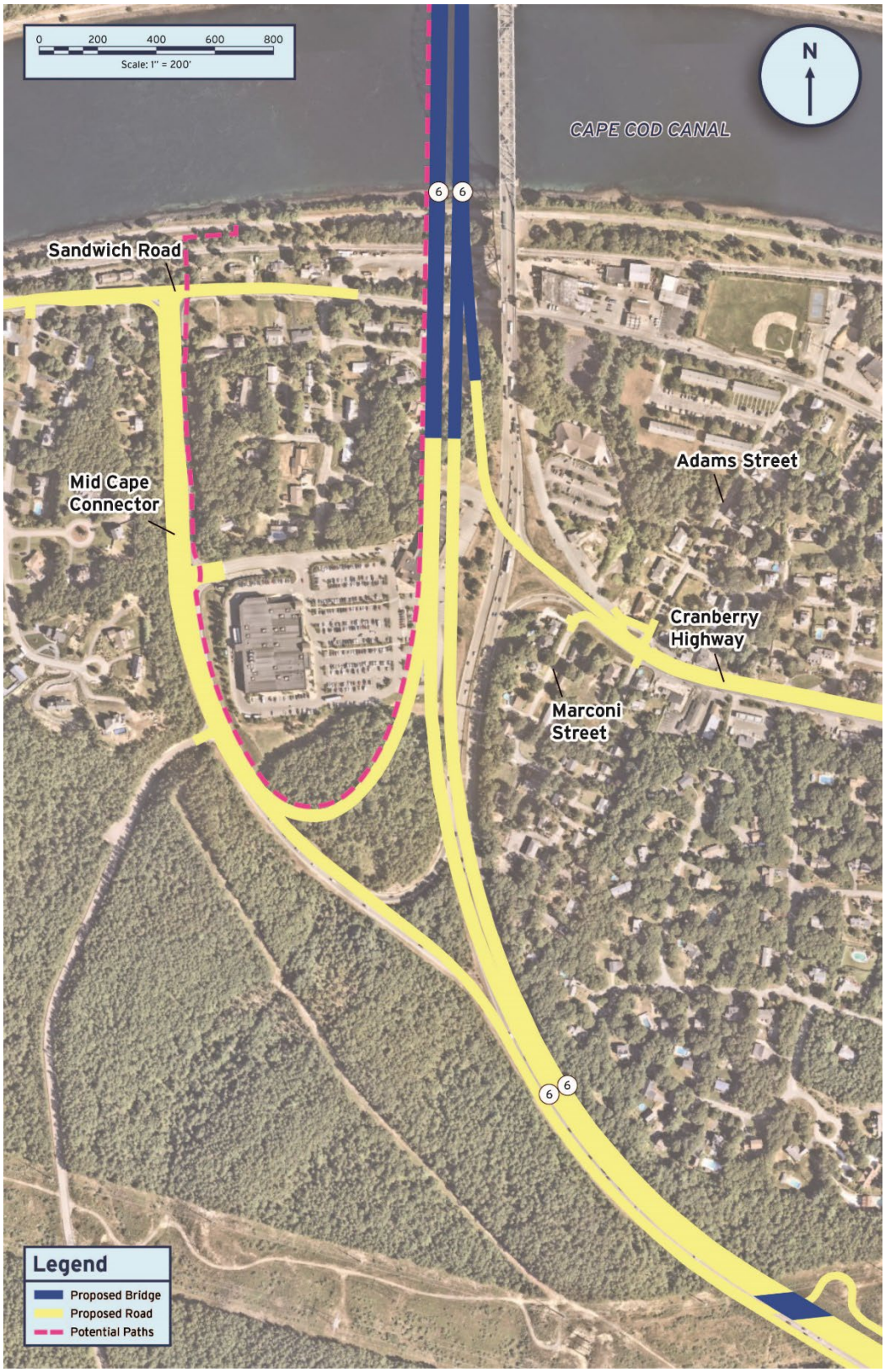


Figure 12-22. Sagamore South Crossing Interchange Approach Option SS-9.1

Operations Rating: Favorable

Operations modeling indicates that Option SS-9.1 would improve operations at the ramp junctions on Route 6. Additionally, this option would provide acceptable operations with the addition of a third approach lane on the Mid-Cape Connector at Sandwich Road. Further development of this option would require an evaluation of the Route 6 eastbound and westbound off-ramp traffic weave on the Mid-Cape Connector prior to the Market Basket intersection.

Connectivity Rating: Less Favorable

This option generally would maintain existing connections. However, in Option SS-9.1, traffic exiting Route 6 westbound onto the Mid-Cape Connector on the west rather than on the east would have reduced connectivity to properties along Cranberry Highway. In this option, the trip length from Route 6 westbound to Sandwich Road, west of the Mid-Cape Connector, would be reduced by a mile; and the trip length from Route 6 westbound to Route 6A, east of Cranberry Highway, would be increased by one-half-mile.

Geometrics Rating: Unfavorable

While the eastbound off-ramp would be designed at the desired 6 percent profile grade, the westbound on-ramp profile grade would be less than 6 percent. Additionally, the westbound off-ramp would introduce a sharp reverse curve geometry at the end of a downgrade prior to going under Route 6; this design would not meet horizontal design standards. Construction of the new Route 6 westbound off-ramp would involve a substantial excavation of up to 35 feet adjacent to the proposed hook turn (partial roundabout) within the utility corridor, east of Route 6. Further, the right turn movement for delivery vehicles exiting the Christmas Tree Shop driveway to Cranberry Highway would mimic existing conditions and encroach into the opposite lane of travel on Cranberry Highway.

Safety Rating: Less Favorable

Engineering assessments and safety modeling indicate that due to the geometric and cross-section improvements and ramp geometry, there would be a slight reduction in both the predicted number of crashes and the predicted crash rates on Route 6 and ramp segments. However, the long straight frontage road could encourage faster speeds heading north where the Route 6 eastbound off-ramp meets the Mid-Cape Connector. This option would result a negligible change in predicted crash rates on ramp roadways and negligible differences on Sandwich Road and the Mid-Cape Connector.

Constructability Rating: Less Favorable

The construction of ramps and connector roads would consist of a combination of new alignments adjacent to existing roadways. The new Route 6 westbound off-ramp and Route 6 eastbound on-ramp at the utility corridor would require temporary roadways in each direction while the while the barrels of the replacement bridges are built. Option SS-9.1 would not include the Cranberry Highway Extension, therefore a temporary Route 6 eastbound off-ramp would not be possible; however, this option would require some type of connection. This option would substantially increase the construction duration compared to other options: construction of the Route 6 westbound on-ramp from Cranberry Highway could not be completed until barrels of the replacement bridge are completed, and the existing Sagamore Bridge could not be demolished until the new Route 6 westbound on-ramp is completed. The required construction sequence could add a scheduling complication to this option. Route 6 eastbound and

westbound in the vicinity of the utility corridor would require multiple traffic shifts for the Route 6 Bridges and on- and off- ramps.

Multi-Modal Connections Rating: Favorable

It is anticipated that connections to the local road network would be provided by shared use path direct connections to Sandwich Road and the Canal Service Road, including bicycle and pedestrian accommodations along Cranberry Highway.

Utility Impacts Rating: Less Favorable

In addition to the relocation of multiple utility poles, light poles, and overhead wire, Option SS-9.1 would interrupt the natural drainage patterns of the existing utility corridor. This option could require a drainage pump station or an outfall on JBCC property. Additionally, three of the high voltage utility towers would be impacted by the roundabouts.

Environmental Impacts Rating: Most Impactful

This option would result in impacts to the DCR property to the east and, at a minimum, a permanent easement on the JBCC property. Both properties are protected under Article 97 and the DCR property also is protected under Section 4(f). Additionally, property takings could involve a take of State-listed endangered species.

Right-of-Way Impacts Rating: More Impactful

Based on conceptual design, this option would result in right-of-way takings in addition to those previously identified for MassDOT's recommended Fully Offline Inboard Option for the mainline alignment. Option SS-9.1 would result in two residential full property acquisitions; ten residential partial property acquisitions, including a vacant parcel; one commercial full property acquisition, consisting of a vacant parcel; and nine commercial partial property acquisitions. The takings would not adversely impact EJ communities or populations.

12.11.2.6 Option SS-9.1A

Option SS-9.1A would be very similar to Option SS-9.1. The key difference between the two options would be the Route 6 westbound off-ramp alignment. In Option SS-9.1A, the westbound off-ramp alignment would cross under the relocated Route 6 mainlines at a more gradual taper and require a longer bridge. All other ramp configurations would match those proposed in Option SS-9.1.
Figure 12-23 shows a conceptual layout of Option SS-9.1A.

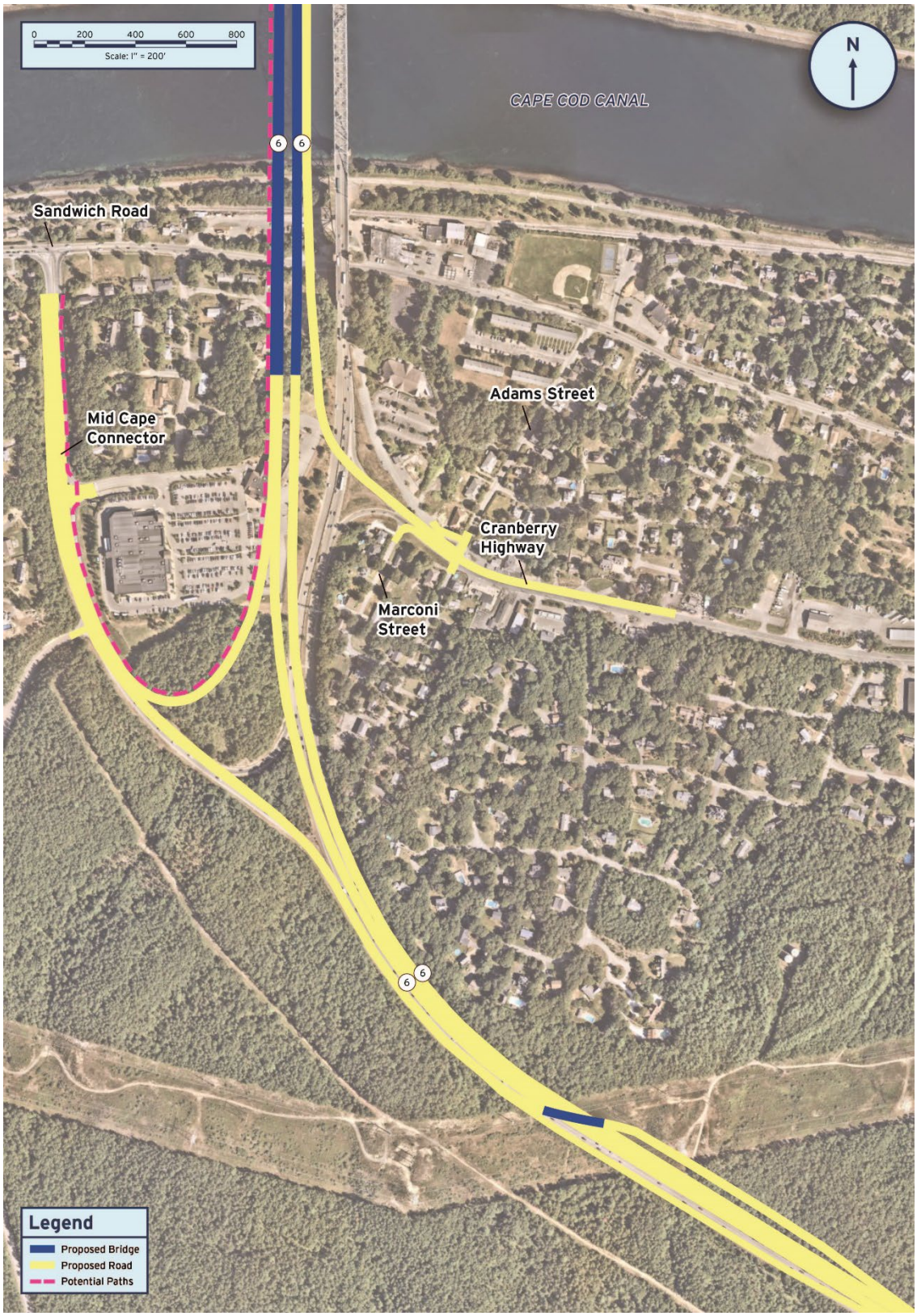


Figure 12-23. Sagamore South Crossing Interchange Approach Option SS-9.1A

Operations Rating: Favorable

Operations modeling indicates that Option SS-9.1A would improve operations at the ramp junctions on Route 6. Additionally, this option would provide acceptable operations with the addition of a third approach lane on the Mid-Cape Connector at Sandwich Road. Further development of this option would require an evaluation of the Route 6 eastbound and westbound off-ramp traffic weave on the Mid-Cape Connector prior to the Market Basket intersection.

Connectivity and Geometrics Rating: Less Favorable

This option generally would maintain existing connections. However, like Option SS-9.1, in Option SS-9.1A, traffic exiting Route 6 westbound onto the Mid-Cape Connector on the west rather than on the east would have reduced connectivity to properties along Cranberry Highway. In this option, the trip length from Route 6 westbound to Sandwich Road, west of the Mid-Cape Connector, would be reduced by a mile; and the trip length from Route 6 westbound to Route 6A, east of Cranberry Highway, would be increased by one-half-mile. While the eastbound off-ramp would be designed at the desired 6 percent profile grade, the westbound on-ramp profile grade would be less than 6 percent. Construction of the new Route 6 westbound off-ramp would involve a substantial excavation of 45 feet or more adjacent to the proposed reverse curve alignment passing under the mainline within the utility corridor, east of Route 6. Further, the right turn movement for delivery vehicles exiting the Christmas Tree Shop driveway to Cranberry Highway would mimic existing conditions and encroach into the opposite lane of travel on Cranberry Highway. The Cranberry Highway Extension (Option SS-1) could be incorporated into Option SS-9.1A.

Safety Rating: Less Favorable

Engineering assessments and safety modeling indicate that due to the geometric and cross-section improvements and ramp geometry, there would be a slight reduction in both the predicted number of crashes and the predicted crash rates on Route 6 and ramp segments. However, the long straight frontage road could encourage faster speeds heading north where the Route 6 eastbound off-ramp meets the Mid-Cape Connector. This option would result a negligible change in predicted crash rates on ramp roadways and negligible differences on Sandwich Road and the Mid-Cape Connector.

Constructability Rating: Less Favorable

The construction of ramps and connector roads would consist of a combination of new alignments adjacent to existing roadways. The new Route 6 westbound off-ramp and Route 6 eastbound on-ramp at the utility corridor would require temporary roadways in each direction while the while the barrels of the replacement bridges are built. Option SS-9.1A would not include the Cranberry Highway Extension, therefore a temporary Route 6 eastbound off-ramp would not be possible; however, this option would require some type of connection. This option would substantially increase the construction duration compared to other options: construction of the Route 6 westbound on-ramp from Cranberry Highway could not be completed until both barrels of the replacement bridge are completed, and the existing Sagamore Bridge could not be demolished until the new Route 6 westbound on-ramp is completed. The required construction sequence could add a scheduling complication to this option. Route 6 eastbound and westbound in the vicinity of the utility corridor would require multiple traffic shifts for the Route 6 Bridges and on- and off-ramps.

Multi-Modal Connections Rating: Favorable

It is anticipated that connections to the local road network would be provided by shared use path direct connections to Sandwich Road and the Canal Service Road, including bicycle and pedestrian accommodations along Cranberry Highway.

Utility Impacts Rating: Less Favorable

In addition to the relocation of multiple utility poles, light poles, and overhead wire, Option SS-9.1A would interrupt the natural drainage patterns of the existing utility corridor. This option could require a drainage pump station or an outfall on JBCC property. Additionally, one high voltage utility tower would be impacted by the Route 6 westbound off-ramp (retaining wall).

Environmental Impacts Rating: Most Impactful

Option SS-9.1A would not include the Cranberry Highway Extension, which would provide more direct vehicular, pedestrian and bicycle access to Market Basket. This option could result in impacts to the DCR property to the east, a minimum permanent easement on JBCC property for the retaining wall and drain outlet, and a permanent easement on State property for the retaining wall. The properties are protected under Article 97 and the DCR property also is protected under Section 4(f). Additionally, the DCR property impacts could involve a take of State-listed endangered species.

Right-of-Way Impacts Rating: More Impactful

Based on conceptual design, this option would result in right-of-way impacts in addition to those impacts previously identified for MassDOT's recommended Fully Offline Inboard Option for the mainline alignment. Option SS-9.1A would result in two residential full property acquisitions; ten residential partial property acquisitions, including a vacant parcel; one commercial full property acquisition, consisting of a vacant parcel; and nine commercial partial property acquisitions. The takings would not adversely impact EJ communities or populations.

12.12 Summary of Program Interchange Approach Initial Assessments

Table 12-5 identifies the highway interchange approach options for the Bourne and Sagamore crossings that were advanced for a more detailed evaluation. Cumulative impacts, including utility, environmental, and right-of-way impacts, would result when pairing the interchange approach options with MassDOT's recommended Fully Offline Inboard location for the mainline alignment.

Table 12-5. Summary of Bourne and Sagamore Crossing Highway Interchange Approach Options Advanced for Further Evaluation

Program Study Area	Option	Summary Description
Bourne North	BN-6.1	Like the existing interchange configuration, modified to meet the offset mainline while adding a new northbound on-ramp directly from Scenic Highway east of the mainline.
	BN-13.1	Builds upon Alternative BN-6.1 and adds a connection from Route 25 southbound off-ramp directly to Scenic Highway.
	BN-14.4b	Like Alternative BN-13.1 and provides a combination of direct connection ramps between Route 25 and Route 6.

Program Study Area	Option	Summary Description
Bourne South	BS-2	Replaces the existing Bourne Rotary with a grade separated diamond interchange.
	BS-2.2	Replaces the existing Bourne Rotary with a grade separated single point interchange configuration.
Sagamore North	SN-1A	Like the existing interchange ramp configurations with modifications to support the relocated Route 3 alignment.
	SN-8A	Like Alternative SN-1A but provides a single exit point from a relocated Route 3.
Sagamore South	SS-1	Modifies ramp alignments to accommodate the relocated Route 6 mainline while largely maintaining the existing ramp configurations. Extends Cranberry Highway under Route 6 to provide a connection to Mid-Cape Connector.
	SS-1.1	Provides the same interchange configuration as Alternative SS-1 but eliminates the Cranberry Highway Extension.
	SS-3.1A	Like Alternative SS-1 but relocates the northbound on-ramp so it shares the same entrance point as the southbound on-ramp off the Mid-Cape Connector.

12.13 Secondary Assessment of Highway Interchange Approach Options

In 2024, MassDOT conducted a secondary evaluation of the ten highway interchange approach options for the four quadrants of the canal crossings. The more detailed assessment consisted of a primarily quantitative analysis, along with qualitative assessments, of evaluation criteria related to the following Program Needs identified in the Purpose and Need Statement:

- Operations;
- Geometrics and Safety;
- Multi-Modal Accommodations; and
- Maintenance and Structural.

Additionally, the options were evaluated both quantitatively and qualitatively relative to the Program goals and objectives.

The Sagamore and Bourne highway interchange approach options that passed the detailed evaluation are described in the Program's Highway Interchange Approaches Detailed Assessment Report (June 2025), which identifies y MassDOT's recommended Options Retained for Detailed Study. These recommended option are incorporated into the recommended Build Alternative, which is further evaluated in the MEPA document.

Appendix A Cape Cod Bridge Replacements Initial Screening Report



CAPE COD BRIDGE REPLACEMENTS

Initial Screening Report

PREPARED BY HNTB FOR massDOT Massachusetts Department of Transportation 2021

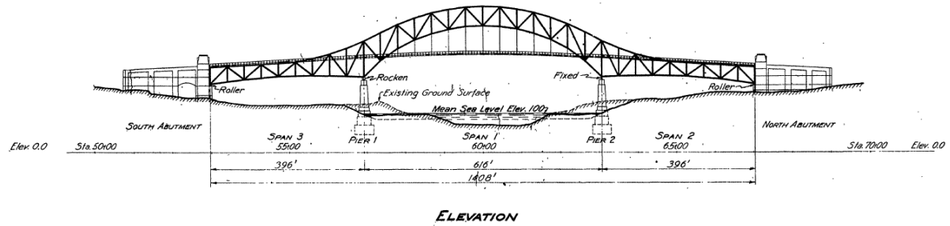
Cape Cod Bridges - Initial Screening Report

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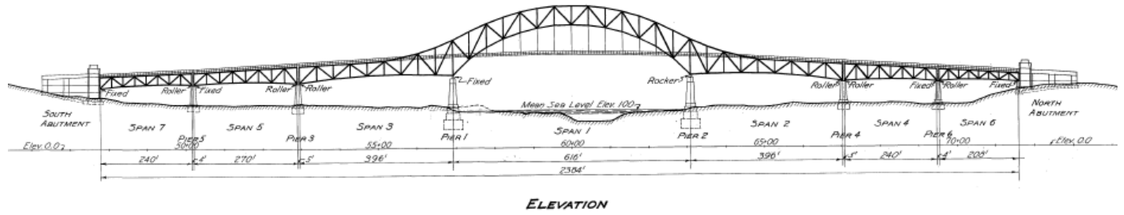
1 INTRODUCTION

The existing Cape Cod Bridges, comprising Sagamore Bridge to the east and Bourne Bridge to the west, cross the Cape Cod Canal to link Cape Cod with the mainland (Fig. 1.1). The bridges were opened in 1935 and have reached the end of their useful economic life. In a Major Rehabilitation Evaluation Report (MRER) completed in March, 2020, the US Army Corps of Engineers recommended construction of new bridges located parallel to and immediately inshore of the existing bridges. The MRER envisions that the new bridges accommodate two through-travel lanes, one auxiliary on/off lane, a 10-ft inside shoulder and a 4-ft outside shoulder for each direction. In addition, a shared-use path for dedicated pedestrian and bicycle traffic would be provided.



ELEVATION

a) Sagamore Bridge



ELEVATION

b) Bourne Bridge

Fig. 1.1 – Existing Cape Cod Bridges

This report summarizes the results of an initial screening study performed to identify feasible bridge types and configurations for further evaluation. This is the first of three phases which will ultimately lead to a Type, Size, and Location Study and support the development of MassDOT's Bridge Type Selection Worksheet. For the purposes of this initial screening, no distinction was made between the Sagamore and Bourne bridges; the analysis presented here at this level of conceptual design applies to both.

For the initial assessment a wide range of bridge types and design parameters were considered and screened by a set of criteria. For the sake of clarity each parameter was initially evaluated separately. This pre-screening allowed the team to quickly identify the decision drivers for bridge type selection, to advance favorable design features, and to eliminate unfavorable alternatives. The process was collaborative, taking place through a series of virtual meetings attended by MassDOT, the US Army Corps of Engineers, FHWA, and HNTB. The final product of this phase is a matrix of potential bridge types and configurations to be further evaluated in the next phase of conceptual design in conjunction with highway design considerations. Possible foundation types for main span and approaches will be screened separately based on the results of geotechnical explorations that are currently ongoing. Important bridge design parameters and evaluation criteria are depicted in Figure 1.2 and are discussed in the following

Sections 2 and 3. The completed evaluation matrices and the proposed bridge type matrix are presented in Sections 4 and 5 of this report and in two appendices.

PARAMETERS
Navigational Clearances
Roadway Widths
Main Span Length
Deck Arrangement
Main Span Bridge Type
Cable-Stayed Bridge Tower Configuration
Tied Arch Bridge Rib Configurations
Main Span Girder Type
Approach Bridge Type



Fig. 1.2 – Bridge Design Parameters and Screening Criteria

2 BRIDGE DESIGN PARAMETERS

2.1 Navigational Clearances

The minimum navigational clearances are controlled by the width of the existing channel of 480 feet and the requirement to maintain a vertical clearance above mean high water of 135 feet. The MRER follows the US Army Corps of Engineers' protocol in considering rates of sea level rise that are higher than historical rates to account for the potential impacts of climate change. It took a conservative approach recommending the "high sea level rise" estimate as a starting point for conceptual design. This resulted in an increase to the clearance requirement above mean high water by 7.8 feet to approximately 143 feet as indicated by the minimum clearance box shown in Figure 2.1. As conceptual design of the bridges and approaches progresses, there will be further evaluation of the most appropriate scenario of sea level rise to include in the final design elevation.

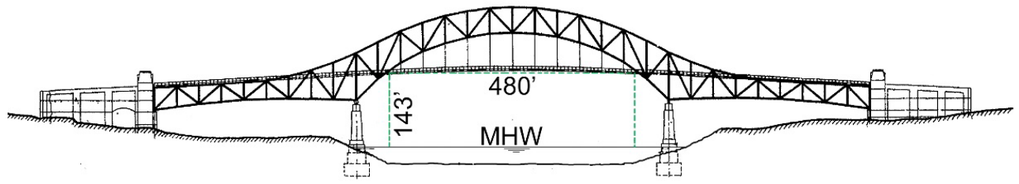


Fig. 2.1 – Navigational Clearance Requirements

2.2 Roadway Width

With the preliminary lane and shoulder configuration described in Section 1 the minimum roadway width is 54 feet per direction (Fig. 2.2). This includes two 12-foot through lanes, a 12-foot auxiliary on/off lane, and 10-foot and 4-ft shoulders each with two-foot offsets from the adjacent barriers. The shared use path width is 14 feet, accounting for a 10-foot path and two two-foot offsets to each barrier.

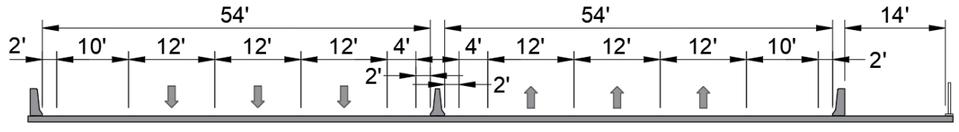


Fig. 2.2 – Roadway Widths

2.3 Main Span Length

The main span length is a critical parameter that affects bridge type selection and bridge cost. This relationship is shown schematically in Figure 2.3. The vertical dashed lines indicate the range of possible spans appropriate for this crossing. This chart suggests that for the applicable span range (525 to 820 feet) the most efficient structure types include haunched box girder, arch bridge, and cable-stayed bridge. A range for truss bridges is not shown but it is similar to that for arch bridges.

Another observation from the chart is that unit cost per deck area increases with span length. This is a consequence of the fact that the demand on the structure indicated by the maximum bending moment increases with the square of the span length, while resistance in the form of structure depth increases only linearly. This relationship is tempered if there is a clear advantage for foundation construction with a longer span. In general, for structural efficiency, span length should be limited to the minimum needed to meet functional and aesthetic requirements.

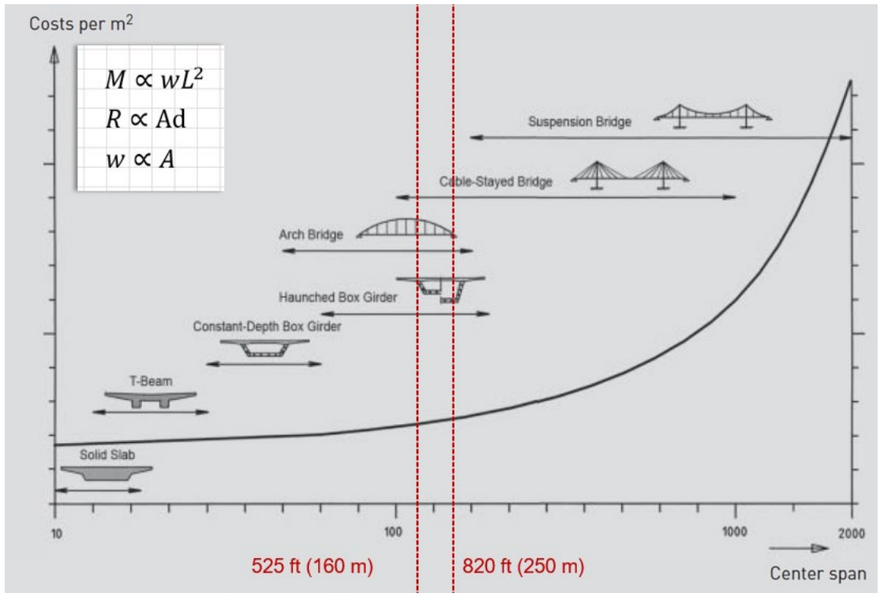


Fig. 2.3 – Bridge Type and Cost vs. Span Length
(Adapted from Svensson, H., *Cable-Stayed Bridges – 40 Years of Experience Worldwide*, Ernst & Sohn, 2011)

2.4 Deck Arrangement

2.4.1 Number of Bridges

To accommodate two 54-ft wide roadways in each direction, a 14-ft shared use path, and traffic barriers the required width of a single deck is approximately 129 feet (Fig. 2.4a). This results in very long floorbeam spans which increases cost and complexity of construction. Therefore, a configuration using two separate bridges can be cost-effective (Fig. 2.4b). This option also has the advantage that it allows phased construction, where one of the bridges is erected first and then carries all traffic in a temporary configuration while the old bridge is demolished and replaced by the second-phase new bridge. The phased construction scheme is discussed in more detail in Section 3.5.1.

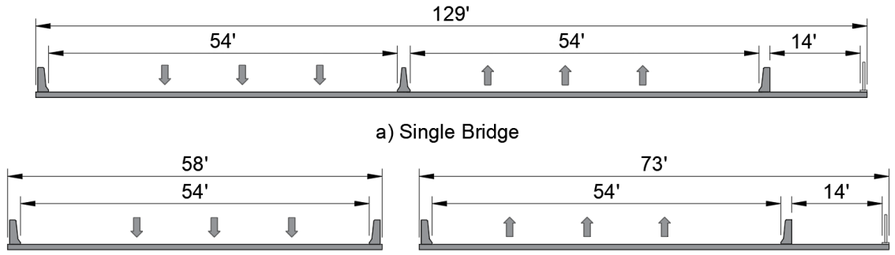


Fig. 2.4 - Deck Configurations with Single Shared-Use Path

A potential concern with a single shared-use path is the safety of pedestrians and bicyclists with critical traffic densities. The situation is exacerbated by the steep grades of the approach bridges which will amplify the speed difference between descending bicyclists and pedestrians. For this reason deck configurations with separate paths for cyclists and pedestrians were added to the evaluation matrix (Fig. 2.5). Besides the improvements for non-vehicular use, the resulting symmetric geometry also has advantages for construction since it simplifies details and maximizes repetition. The goal at this conceptual stage is only to evaluate the effect of the various shared-use path arrangements on bridge types.

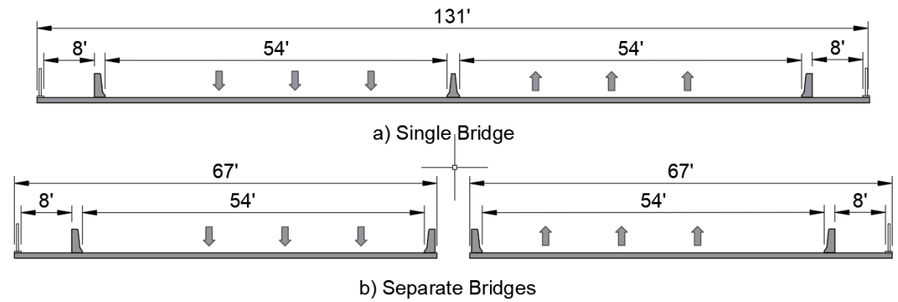


Fig. 2.5 – Deck Configurations with Separate Non-Vehicular Paths

2.4.2 Single Bridge

Among the single bridge deck alternatives a distinction can be made with regard to where the supporting elements – cables or truss members - are located relative to the deck width. In Figure 2.6a the floorbeams span over the full width. Figure 2.6b shows a configuration where one of the cable planes is located between roadway and shared-use path. This arrangement achieves structural efficiencies because it reduces floorbeam span length and it also creates a visual and physical barrier that would enhance the user experience for pedestrians and bicyclists.

In Figure 2.6c separation between non-vehicular and vehicular traffic is taken a step further by moving the shared-use path to its own level. This arrangement can accommodate different gradients for roadway and path by varying the height of the support columns. A disadvantage is the unfavorable loading for the floorbeams due to the introduction of a concentrated load in mid span. Figure 2.6d shows an arrangement with a single cable plane. This configuration results in the greatest deck width because the roadways must be sufficiently separated for a central tower to pass between them.

2.4.3 Separate Bridges

Figures 2.7a and b depict the analogous configurations to the single-deck options where one of the cable planes can be arranged either outside the shared-use path or between path and roadway. The arrangement shown in Figure 2.7c envisions two identical structures carrying the roadways with a link slab carrying the path which would be constructed at a later stage.

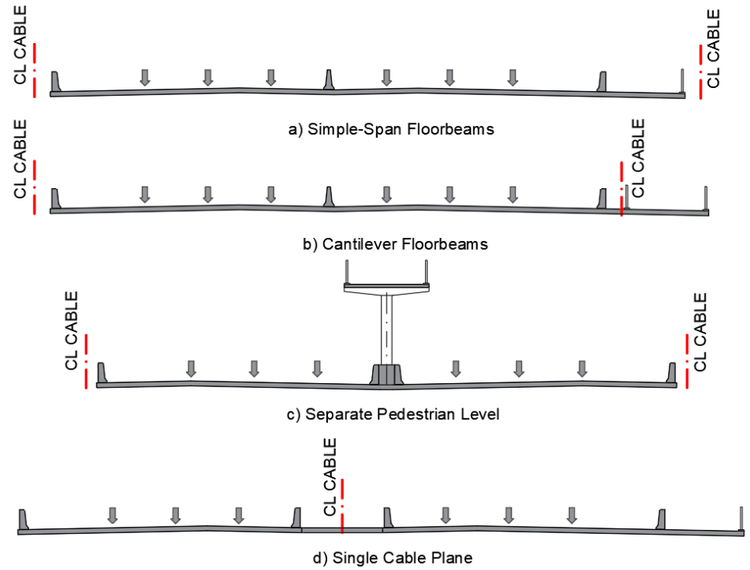


Fig. 2.6 – Single Bridge Deck Configurations

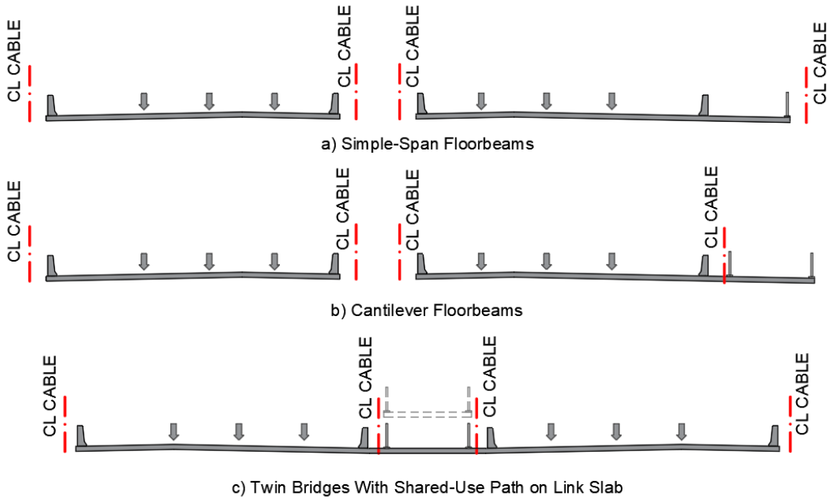


Fig. 2.7 – Separate Bridge Deck Configurations

2.5 Main Span Bridge Type

Figures 2.9 and 2.10 show preliminary elevation views of the various main span bridge options. For the Cape Cod Canal bridge sites, the potential span lengths vary from approximately 525 feet to 820 feet (see Section 3.1). The first figure is representative of spans in the range of 525 to 700 feet, the second figure has been developed assuming an 820-foot span.

For the tied arch options there are two configurations. The traditional system uses vertical piers with the arches supported on top of these piers (Figures 2.9a and 2.10a). Alternatively, with the Delta-frame arrangement the approach spans cantilever into the main span, thus shortening the length of the actual tied arch, albeit at the expense of a more complex approach span structure (Figures 2.9b and 2.10b). Visually this scheme echoes the appearance of the existing through-arch bridges. It also offers advantages for construction if the tied arch span is fabricated off-site, delivered by barge, and lifted into its final position.

Both arch configurations use inclined cables arranged in a network pattern. This simple change from the traditional arrangement with vertical cables creates significant advantages for structure behavior and structure redundancy. The rise of the arches ranges from 1/5th to 1/6th of the span length.

For the truss options (Figures 2.9c and 2.10c) a constant depth truss is envisioned for the medium-long span ranges with a span-to-depth ratio of approximately 12 to 15. For the 820-ft span Figure 2.10c shows a variable depth truss with tentative structure depths of 110 feet at the supports and 50 feet at midspan.

For the cable-stayed bridge alternatives, configurations with a single tower or two towers were developed (Figures 2.9d, e, 2.10d, e). The single-tower option results in the tallest structure with a tower height above deck between 30% and 40% of the span length (i.e. approximately 250 feet). If geological and other constraints permit, two-tower configurations tend to be more efficient, with tower heights in the range of 20% to 25% of the main span length.

For the 820-ft span a suspension bridge option is included as shown in Figure 2.10g, although this length falls short of the typical span range where such an alternative would normally be considered. Suspension bridges allow the use of a very slender and light deck at the expense of large gravity blocks at each end needed to anchor the main cables.

The haunched girder alternatives, either in the form of a steel box or a post-tensioned concrete box, do not require supporting structure above the deck level (Fig. 2.9f, g, 2.10f). However, at the controlling location at the edges of the navigational clearance box their girder depth is 10 to 20 feet greater than for the other alternatives. As illustrated in Figure 2.8 by using the example of arch and concrete box girder alternatives for a 700-ft main span, this greater depth has an unfavorable impact on length and grade of the approach bridges.

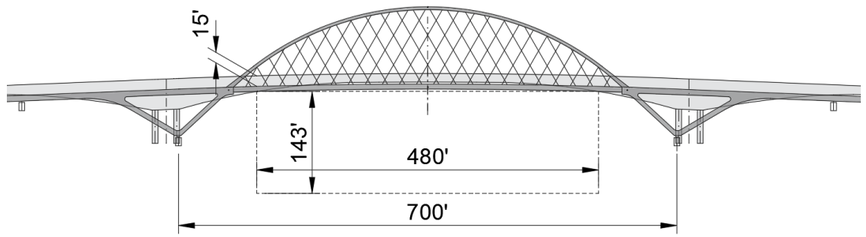


Fig. 2.8 – Influence of Girder Depth on Highway Profile

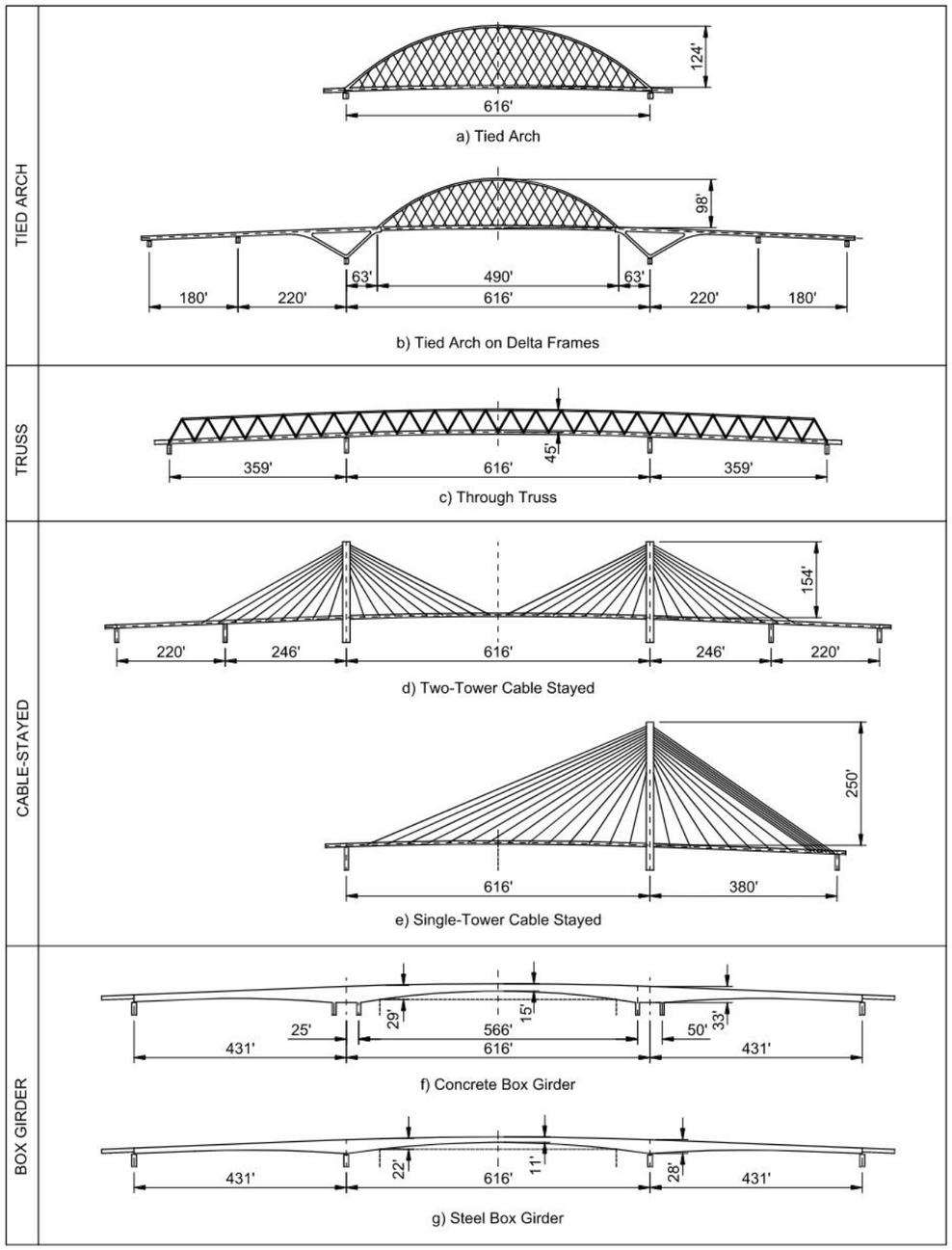


Fig. 2.9 – 525-ft to700-ft Span Options (616-ft foot span shown, 525-ft & 700-ft Spans Similar)

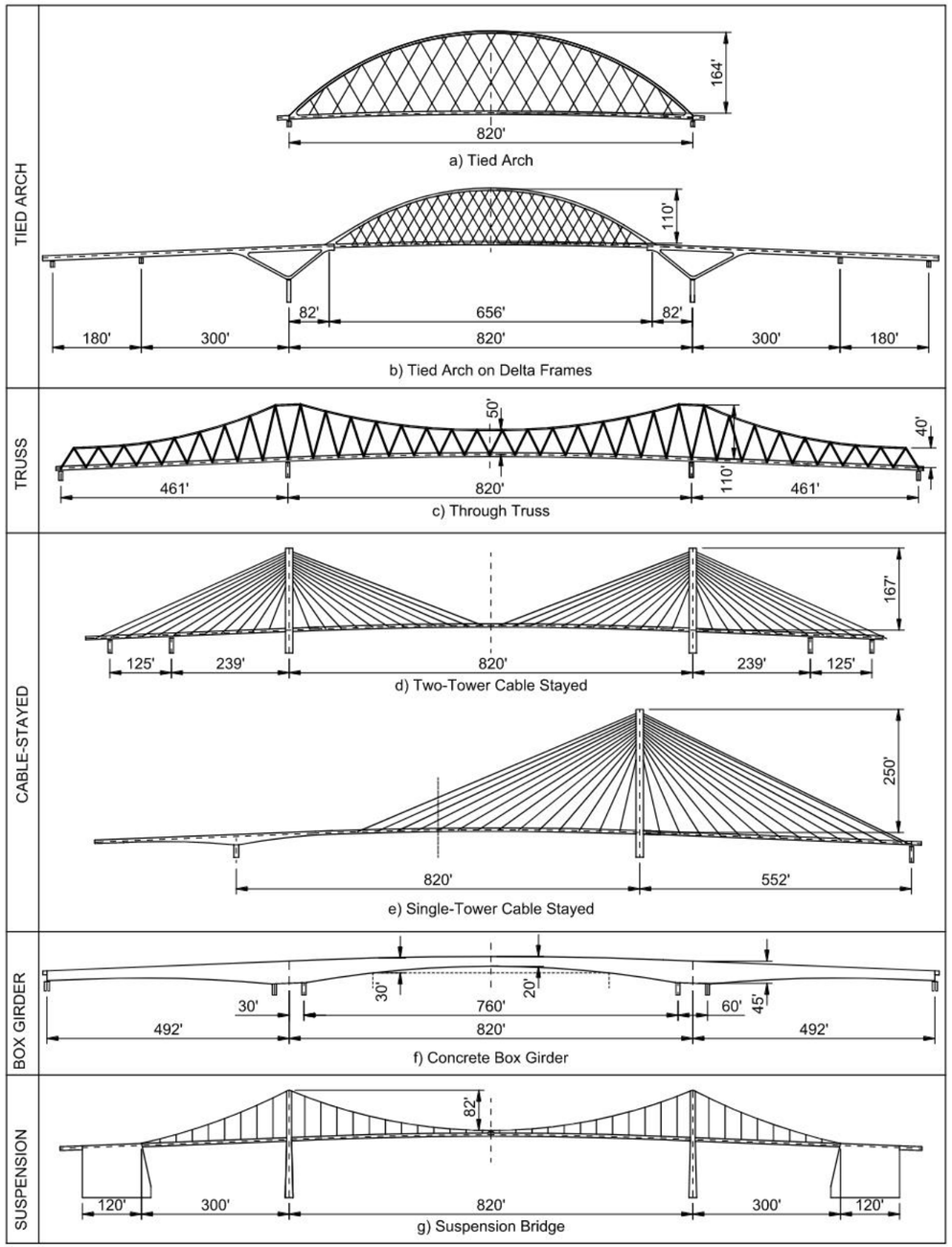


Fig. 2.10 – 820-ft Span Bridge Options

2.6 Cable-Stayed Bridge Tower Configuration

For the cable-stayed bridge alternatives, a number of tower configurations are feasible, identified as H, A, and inverted-Y tower and central pylon in Figure 2.11. Figure 2.12 shows representative examples in completed bridge structures. Under high wind-load conditions A-towers or H-towers with upper cross bracing are more efficient than single-leg towers or free-standing H (or V)-towers.

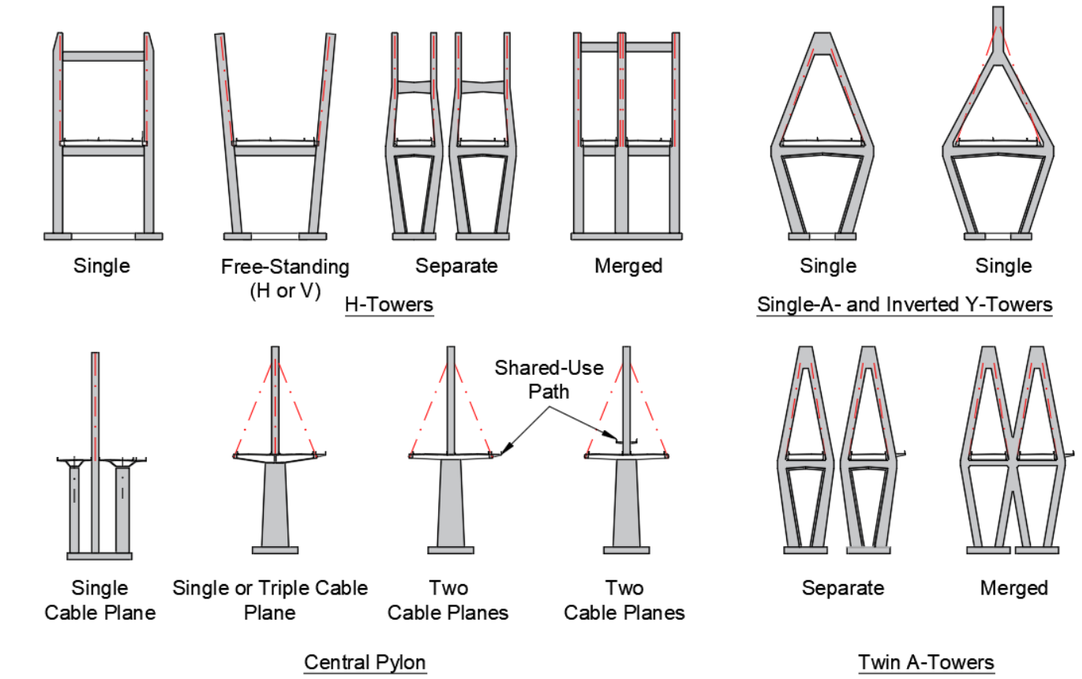


Fig. 2.11 – Cable-Stayed Bridge Tower Configurations

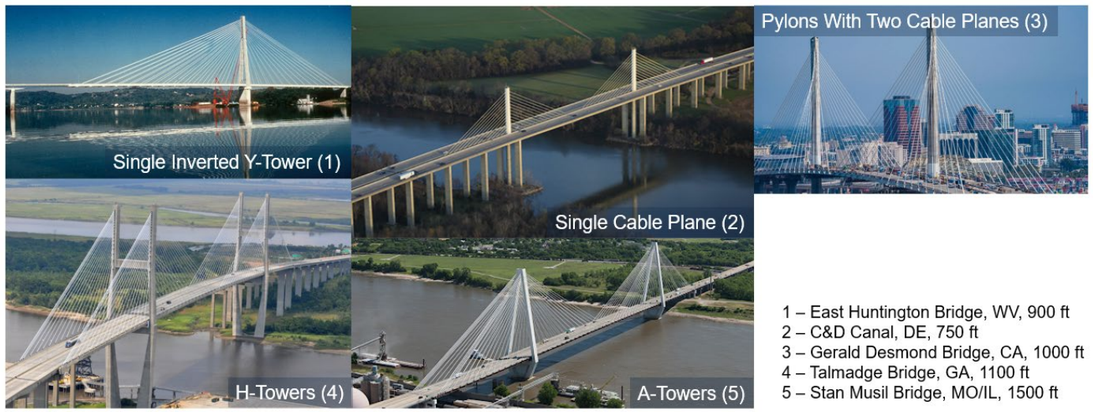


Fig. 2.12 – Representative Examples for Cable-Stayed Bridge Options

2.7 Tied Arch Bridge Rib Configurations

For the tied arch options Figure 2.13 shows configurations with braced vertical ribs, with inclined ribs to create a basket handle arrangement, and with free-standing vertical ribs. Figure 2.14 illustrates these structure types with photographs of representative examples.

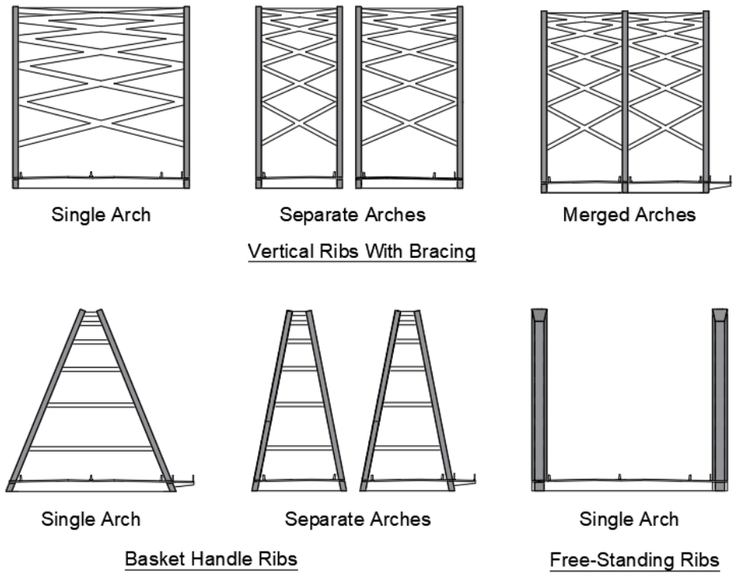


Fig. 2.13 – Tied Arch Rib Configurations



Fig. 2.14 – Representative Examples for Network Tied Arch Options

With the free-standing ribs the upper lateral bracing is eliminated. Arch rib stability is ensured by making these members significantly wider and by fixing them into the end floorbeams. Basket handle arches are visually attractive and reduce upper lateral bracing demands, but they are more difficult to construct than vertical arch ribs. Also, there is a potential conflict between traffic clearance requirements and the inclined ribs as they lean over the roadway. This concern becomes particularly acute with wide bridge decks and low arch rib rise and can make this option infeasible under those circumstances.

2.8 Main Span Girder Type

2.8.1 Haunched Box Girder Bridges

Haunched box girder bridges may be of either post-tensioned concrete, composite steel with concrete deck, or steel with orthotropic deck (Fig. 2.15, 2.16). There is no recent experience in the US with steel box girder bridges for this span range. The current span length record for a concrete box girder bridge is held by the I-64 Kanawha River crossing in Charleston, West Virginia with a main span length of 760 feet. However, span lengths in excess of 900 feet are feasible with this type of structure.

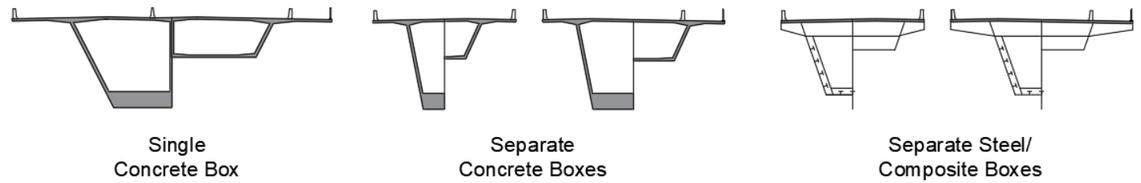


Fig. 2.15 – Haunched Girder Cross Sections

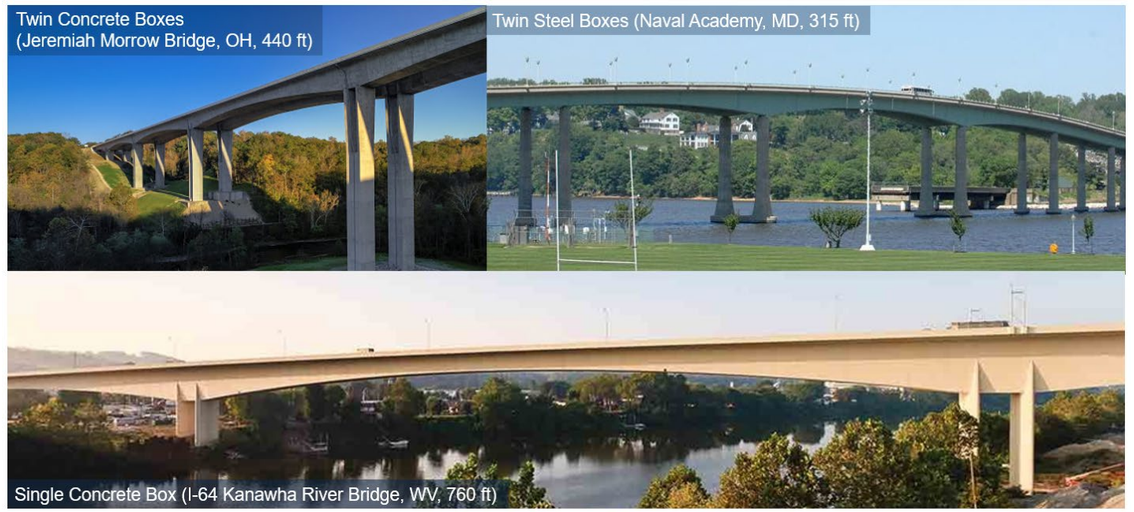


Fig. 2.16 – Representative Examples for Haunched Box Girder Bridge Options

2.8.2 Cable Supported Bridges – Deck Systems

A typical and efficient deck system for cable supported bridges, cable-stayed or arch, comprises longitudinal edge girders and closely spaced transverse floorbeams (Fig. 2.17a-d). With tied arches or trusses it is advantageous to configure the edge girder as a closed box (Fig. 2.17a). The box can be designed to tolerate partial loss of the cross section and thus provides internal member redundancy. In addition it allows for the cables to be anchored inside the box for better protection from the elements and for ease of inspection.

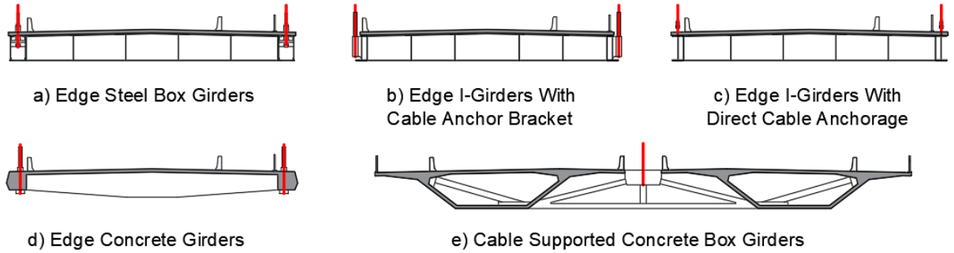


Fig. 2.17 – Cable Supported Bridges

For cable-stayed bridges steel I-girders are commonly used. The cables are anchored either in brackets with anchor pipes ("rocket launchers") attached to the side of the edge girders (Fig. 2.17b) or in fin plates that are in line with the web of the edge girder (Fig. 2.17c). With an all-concrete deck cables are anchored below the post-tensioned edge girder (Fig. 2.17d). Deck segments would be either cast-in-place on form travelers or would use precast elements to reduce on-site work and to increase the rate of construction.

With a single cable plane a torsionally stiff deck is needed to prevent excessive twisting of the cross section under asymmetric loading. This requires a deep, closed box section, either in the form of two linked parallel boxes (Fig. 2.17e) or as a single box (not shown).

2.9 Approach Bridge Type

The approach bridges would most efficiently use a standard bridge type, i.e. steel or prestressed concrete stringer bridges (Figures 2.18a, b). The concrete option is feasible for spans of up to about 160 feet, while a typical steel plate girder is suitable for spans of up to 300 feet and even greater. Steel tub girders would be used if the aesthetically cleaner lines of a closed box are desired or if plan curvature of the bridge requires greater torsional stiffness (Fig. 2.18c). The concrete box girder option would be advantageous in the context of precast segmental construction if similar concrete boxes are also used for the main span (2.18d).

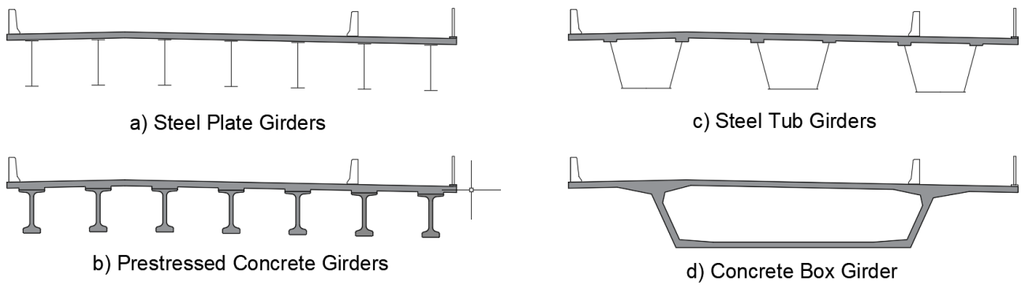


Fig. 2.18 – Approach Bridge Types

3 SCREENING CRITERIA

3.1 Introduction

Figure 3.1 lists the evaluation criteria used for initial screening of the bridge design parameters. The criteria have been divided into ten major groups with subgroups for each category.

EVALUATION CRITERIA	
INITIAL COST	Main Span Structure
	Main Span Foundations
	Overall
HIGHWAY GEOMETRICS	Grade/Length
	Footprint
	Horizontal Tangent Length
MAINSPAN FOOTINGS	Vessel Impact
	Scour
CONSTRUCTION	Phasing
	Duration
	Constructability
	Impact on Canal Traffic
	Maintenance of Traffic
	Environmental Impact

STRUCTURAL REDUNDANCY	Fracture-Critical Members
	Failure-Critical Members
INSPECTION & MAINTENANCE	Access
	Frequency
DURABILITY	Protection
	Replacement
	Monitoring
WIND RESPONSE	Structural Efficiency
	Dynamic Effects
SNOW & ICE RESPONSE	Bridge closures
	Monitoring/Deicing
COMMUNITY	Appearance/Signature
	Bike/Pedestrian Path

Fig. 3.1 – Screening Criteria

3.2 Initial Cost

Initial cost represents a qualitative evaluation of costs for main-span superstructure, main span foundations, and approaches. It is informed by the understanding that longer span length translates into greater superstructure cost, but that this is tempered by easier foundation and substructure construction if it can be performed from land. Approach span costs are affected by the footprint of the structure and the associated Right of Way impacts, span lengths, and total structure length and grade.

3.3 Highway Geometrics

3.3.1 Grade and Length

The main span girder depth affects the vertical profile of the new bridges due to the need for relatively steep climbs to achieve the desired clearance over the canal. Figure 3.2 illustrates schematically how additional girder depth necessitates either longer or steeper approaches. For example, assuming L = 800 ft and α = 4%, a difference of 12 foot in girder depth translates to either 300 foot longer approaches on both sides or 1.5% steeper approach grades.

Of the bridge types considered, the cable supported options with two cable planes (arch, cable-stayed, suspension) and the truss offer the least girder depth, controlled by the depth needed for the floorbeams. A single-plane cable-stayed bridge and in particular the box girder options require significantly deeper girders.

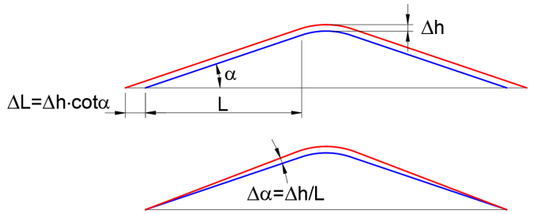


Fig. 3.2 – Influence of Girder Depth on Highway Alignment

3.3.2 Footprint

Alternatives with two separate bridges will have a larger footprint than a single bridge due to the need for an adequate gap between the individual structures. However, with two separate bridges and phased construction it is possible to overlap the footprint for the existing structure, thereby minimizing additional Right of Way impacts.

3.3.3 Horizontal Tangent Length

A horizontal tangent highway alignment is required over the length of the main span and any side or anchor spans. The exception are box girder bridges which can accommodate a moderate plan curvature (R>2500 ft) due to their great torsional stiffness. The length of the side spans is typically set to avoid uplift on the anchor piers under dead load and under live-load concentrated on the main span. Alternatively, with shorter side spans a tie-down mechanism in the form of vertical cables, inverted bearings, or ballast can be employed to resist uplift. With these considerations typical side span lengths range from 40% to 60% of the main span length. The arch option with traditional piers does not require anchor spans. The requirement for longer horizontal tangent lengths on some bridge types may preclude certain desirable highway alignments.

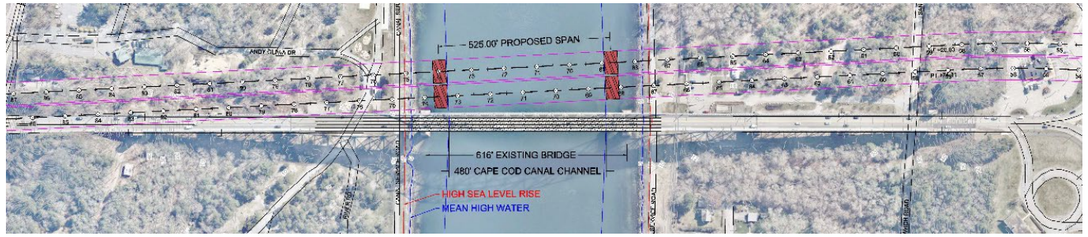
3.4 Main Span Footings

Four different main span lengths were considered as shown in Figure 3.3. The shortest possible span is 525 feet, dictated by the minimum required horizontal clearance of 480 feet between the edges of the footings (Fig. 3.3a). The 616-foot span option equals the span length of the existing bridges, thereby maintaining the status quo for channel operations (b). With an 820-ft span the new piers are located entirely on land with room to reroute the service roads between channel banks and piers (d). The 700-ft span alternative locates the piers between the service road and the canal, into the rip rap slope but above the low tide line (c). The footing location is evaluated with respect to impact on canal traffic and the potential for scour in this category and with respect to constructability in the Construction category. Bridge and approach roadway locations and alignments shown in the figure are for discussion purposes only. No determination has been made regarding future roadway alignment and bridge locations.

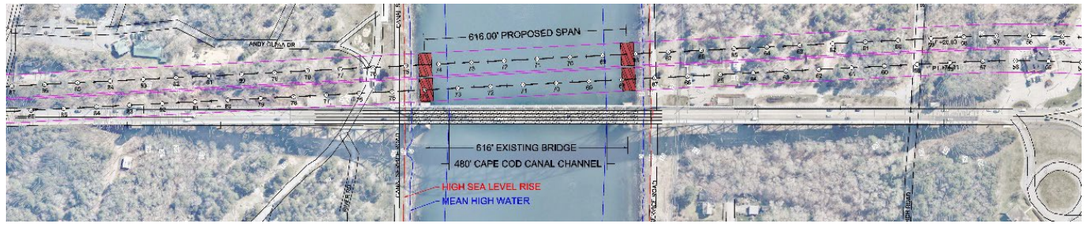
3.5 Construction

3.5.1 Phasing

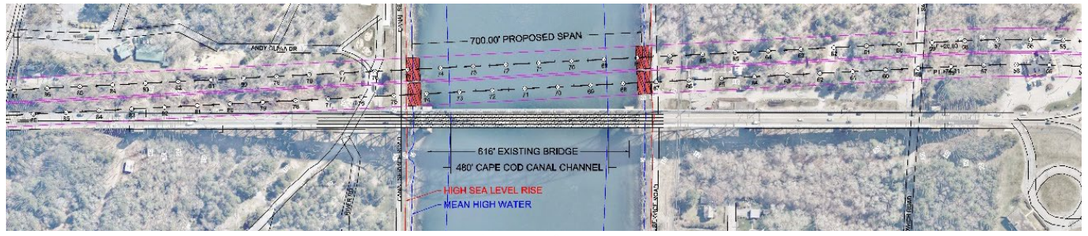
A single bridge accommodating both northbound and southbound traffic and the shared-use path becomes quite wide. Therefore, an alternative with separate structures for each direction is advantageous because it uses smaller construction elements and in addition gives the possibility of erecting northbound and southbound structures in separate phases (Fig. 3.4). With this approach during Phase 1 a new bridge is constructed parallel to the existing structure. Upon completion of Phase 1 all traffic is shifted to the new bridge with a temporary lane configuration. During Phase 2 the old bridge is dismantled and the second structure is erected in its place. The last step is to route traffic onto separate northbound and southbound structures and to configure the Phase 1 bridge for one-way traffic.



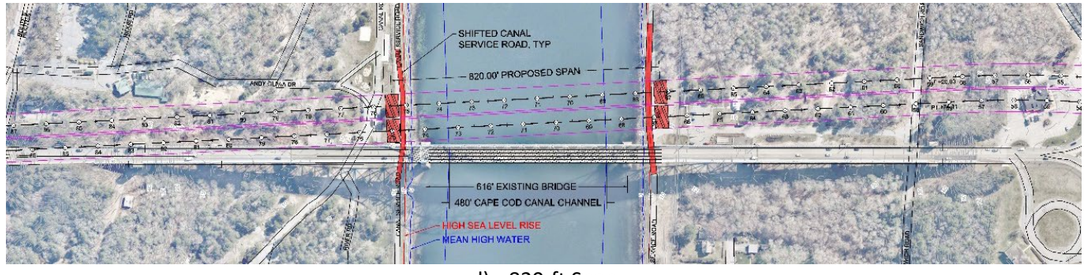
a) 525-ft Span



b) 616-ft Span



c) 700-ft Span



d) 820-ft Span

Fig. 3.3 – Main Span Footing Location Alternatives

3.5.2 Duration

When evaluating the impact of construction schedule, a distinction must be made between time required to take the existing bridge off line and time required for overall completion of the project. With phased construction a new structure, albeit in temporary configuration, would be available more quickly than with single-stage construction, however, overall construction time might be longer. Conversely, single-phase construction might shorten the overall schedule, but the existing bridge would need to remain in service longer.

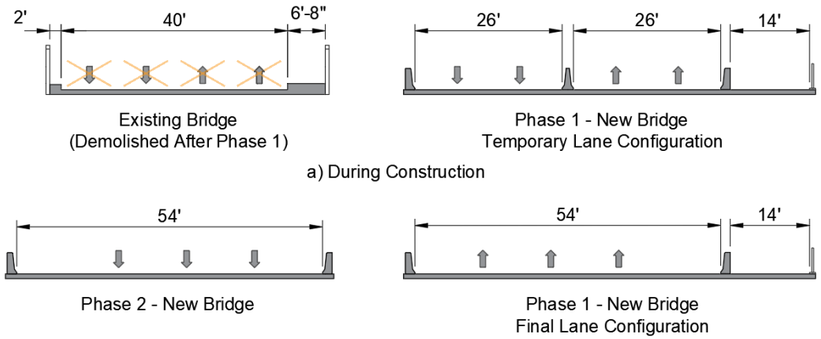


Fig. 3.4 – Phased Construction

3.5.3 Constructability

The main span superstructure construction method is dictated by the bridge type (Fig. 3.5). A post-tensioned concrete box girder would be constructed as balanced cantilevers with cast-in-place concrete placed into form travelers. A cable-stayed bridge would be constructed from short prefabricated elements delivered by barge or over the previously erected bridge. A tied arch can be prefabricated on shore as a complete unit, delivered by barge, and lifted into position during a short (approximately 48 hours long) closure of the canal. The Delta frame configuration is advantageous with this scheme, because it avoids interference between arch and piers during the lifting operation and greatly shortens the length of the arch for float-in and lifting. Alternatively, tied arches and trusses can be stick-built on site. This option requires temporary falsework in the canal during erection until the structure has become self-supporting. The opening between falsework towers cannot exceed approximately half the span length, i.e. 350 to 400 feet for the longer span alternatives.

Foundation construction in the canal requires a temporary trestle bridge or a causeway (Fig. 3.6). To avoid these elements the foundations can be placed entirely on land or just at the edge of the canal. Except for the land option, all of these alternatives require a braced cofferdam with a tremie seal to provide a dry work area for foundation construction.

3.5.4 Impact on Canal Traffic

All alternatives maintain the minimum required navigational clearances. Therefore, fixed structures needed to facilitate foundation construction, e.g. a trestle bridge, would have minimal impact on canal traffic. Some coordination would be required to accommodate material barges and barge-mounted cranes needed during this stage.

Cantilever superstructure construction (cable-stayed or box girder bridge) using prefabricated steel or concrete elements would have short-term impacts at the work front as segments are lifted off the delivery barge, at a frequency of typically once a week or every other week. Lifting an entire arch span would require closure of the complete channel for the duration of the operation, approximately 48 hours per bridge. Falsework for stick-building would reduce the horizontal clearance at the bridge site for the entire duration of superstructure construction. On the other hand, balanced cantilever construction of the post-tensioned concrete box girder option takes place entirely from above and does not affect canal traffic.



Fig. 3.5 – Main Span Superstructure Construction Methods



Fig. 3.6 – Foundation Construction

3.5.5 Maintenance of Traffic

With phased construction a new bridge would come on line quickly and provide about the same level of service as the existing structure. This stage would persist for about two years while the old bridge is dismantled and a new structure erected in its place. With single-stage construction the existing bridge needs to remain in service until the new structure is completed in its entirety.

3.5.6 Environmental Impact

This assessment favors alternatives that minimize impact to the waterway (i.e. the longer span options) and the ROW needs (i.e. phased construction with the second phase located within the alignment of the existing bridge).

3.6 Structural Redundancy

The AASHTO Bridge Design Specifications define a fracture-critical member as *a steel primary member or portion thereof subject to tension whose failure would probably cause a portion of or the entire bridge to collapse*. Typically, truss chords and diagonals in tension, tie girders of tied arches, and floorbeams spaced greater than 12 feet would be classified as fracture-critical (Fig. 3.7). Such members are subject to special fabrication and material quality and testing requirements. Most importantly, when in service fracture-critical members must be inspected at arm's length every other year.

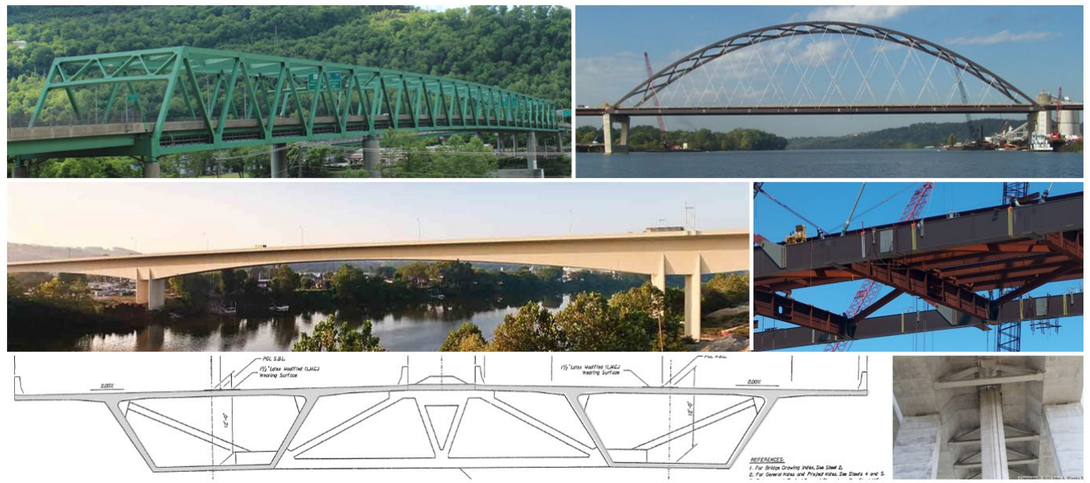


Fig. 3.7 – Structural Redundancy

With network tied arches the tie girders can tolerate loss of moment capacity due to the beneficial truss-like effect of the crossing hanger cables. Furthermore, with closely spaced cables loss of one or several cables can be easily accommodated by the structure. To achieve tie girder redundancy for axial load, typically the tie girder is built up of four individual plates bolted together at the corners and designed to withstand loss of any one of these plates. Currently the FHWA does not recognize such internal redundancy as effective, but there is a large and increasing body of research suggesting that this detail is indeed a valid approach to prevent complete failure of the member.

Even though not defined in the current bridge design specifications, members in compression and made of concrete can be just as critical as tension members in steel. Examples of such failure-critical components include the concrete truss system linking individual boxes for certain single-plane cable-stayed bridge types (Fig. 3.7, bottom panels) and the prestressing tendons in post-tensioned concrete box girders.

3.7 Inspection & Maintenance

Inspection and maintenance considerations favor the simpler box girder alternative which avoids structural components above deck that are exposed to the elements and difficult to reach for inspection (Fig. 3.8). For tied arch bridges the accessible box section typically used for the tie girders ensures good inspectability of the lower anchorages and of the interior of the girders (Fig. 3.8, left picture).

The maintenance and redundancy criteria also lead to a more favorable assessment of the options with two separate structures, and particularly those where northbound and southbound bridges are identical (Fig. 2.5b). This arrangement allows for complete closure of one of the bridges while still accommodating four travel lanes and a shared-use path on the second bridge if the barriers are reconfigured accordingly.



Fig. 3.8 – Inspection and Maintenance

3.8 Durability

Hangers and stay-cables are exposed and highly stressed elements. Normally cable replacement is anticipated to be required at least once during the life of the bridge. Modern cable-supported bridges are designed to facilitate such cable replacement using light equipment while maintaining the full traffic capacity. Post-tensioning tendons are better protected than stay cables, either as external tendons running inside the box, or as internal tendons embedded in the concrete cross section. With balanced cantilever construction most of the tendons would be internal to deck and bottom slab and grouted and, therefore, would not be replaceable. However, some states are experimenting with substituting a flexible wax filler for the cement grout to allow for tendon replacement. In addition, it is standard practice to make provisions for the installation and anchorage of future tendons. A concern

about durability issues resulting from poor tendon grouting has emerged over the past two decades and has been addressed by industry through the development of stringent installation and material testing requirements and a certification program for grouting technicians. An advantage of balanced cantilever construction is that it requires a large number of short tendons, in excess of one hundred for the present case, so that the post-tensioning system has significant redundancy.

For conventional stringer bridges it is sometimes necessary to replace the bridge deck while the girders can be reused. This is relatively straight forward because the girders are typically designed to support the weight of the deck in their non-composite condition. Similarly, deck replacement is also possible for the truss alternative and for the network tied arch options described above. It is more difficult and less economical for cable-stayed bridges, because most efficiently in this application the concrete deck would be designed to participate in the transfer of the large axial forces introduced into the girder by the horizontal component of the cable forces. For the box girder alternative the deck is an integral part of the cross section and cannot be replaced. Prestressing the deck in both directions to limit crack widths under service loads, use of corrosion-resistant reinforcement, provision of additional cover and allowance for a future wearing surface, and installation of a wearing surface and waterproofing membrane during initial construction are all effective means to achieve a service life of the bridge deck compatible with the rest of the structure and thus eliminates the need to provide for future bridge deck replacement.

3.9 Wind Response

The Cape Cod Canal is located at a site subject to high wind loads with design three-second wind gusts of 130 mph (Fig. 3.9). Wind pressure is proportional to the square of the wind speed and increases with height above ground. Some tower shapes and configurations are more efficient to resist these wind forces than others. The cables themselves are vulnerable to wind and wind-rain induced vibrations, and with light structures the entire deck can experience vibrations ranging from the annoying to the catastrophic. With parallel structures there are also down-wind effects where the wake of the windward structure affects the leeward structure. The stiffer a structure the less susceptible it is to dynamic effects. For the alternatives considered here this means that a concrete box girder bridge will have superior performance to a truss, followed by the tied arch options, cable-stayed bridges, and finally the suspension bridge. Steel box girder bridges are less favorable than concrete boxes due to their sensitivity to vortex-shedding-induced oscillations.

All alternatives will be subject to wind tunnel studies to verify their performance and to determine wind force coefficients for drag and uplift. With a cable-stayed bridge dampers will likely be required to suppress stay-cable vibrations. Network tied arches have steeper and shorter cables which typically are less vulnerable to excitation and rarely require dampers. For flexible bridge decks it may be necessary to make aerodynamic improvements along the edge girders over part of the bridge length to improve the wind flow around the deck.

3.10 Snow and Ice response

For alternatives with structure above the deck, under certain weather conditions ice drop onto the roadway below has been an issue for a number of recently completed bridges (Fig. 3.10). This is particularly true for cable-stayed bridges with ice falling off the cables. It has been less of a problem with more rigid components, i.e. upper lateral bracing or arch ribs. The weather conditions causing ice drop are predictable and can be monitored via a weather station installed at the bridge site, making it possible to close exposed lanes as needed prior to the event. Alternatively, active measures are under development, e.g. rotating stay pipes to reduce excessive ice build-up on stay cables.



Fig. 3.9 – Wind Response



Fig. 3.10 – Ice Drop

3.11 Community

Screening criterion “Community” evaluates the potential of the bridge type to become a signature bridge for the site and the experience for pedestrians and bicyclists. Fig. 3.11 contrasts a number of representative bridge types. While all of them can be shaped and detailed with aesthetic appeal in mind, some of these structure forms are more visible and dominant than others. For example, a box girder bridge may appeal with its understated elegance, while a cable-stayed bridge with its tall towers would be visible from a great distance. The evolution of LED lighting facilitates illumination that can even be programmed to display varying light patterns.



Fig. 3.11 – Bridge Aesthetics

Pedestrian and bicyclist experience is influenced by the separation from vehicular traffic, access to the bridge, and by the flow of both bicyclists and pedestrians in the paths provided. The option to provide two dedicated paths instead of a single shared-use path in anticipation of heavy use and concerns about cyclist speed with the steep grades has been discussed in Section 2.4. The parameters for design of the shared-use path are under development in conjunction with the highway design.

Separation from vehicular traffic can be enhanced by placing the path outside a cable plane or on a separate elevated structure (Fig. 2.6). An ancillary consideration, which does not affect bridge type selection, is access to the bridge structure from the canal service roads below and the street network further in from shore. These access considerations will be considered in the next design phase, in conjunction with preliminary highway design alternative analysis.

4 SCREENING MATRICES

4.1 Introduction

Evaluation of the bridge design parameters employed an unscaled, qualitative rating scheme to facilitate initial screening. The ranking is based on a simple color code as depicted in Figure 4.1. This gives a quick visual indication of the desirability of a certain feature. Of particular importance are the triple-red and triple-green ratings, indicating options that are removed from further consideration or that are conclusively carried to the next evaluation phase, respectively. The evaluation matrices were completed in consultation with representatives of MassDOT, Army Corps of Engineers, and FHWA and they are included in Appendix A of this report. The matrices contain notes briefly explaining the particular ratings. The following sections expand on these notes with additional information supporting the "most favorable" and the "unfavorable" assessments. These same criteria will be used to perform more detailed, quantitative and scaled ranking of bridge alternatives in future phases of preliminary design.

CRITERIA	ALT. 1	ALT. 2	
INITIAL COST	🟢🟢	🟢🟢🟢	
HIGHWAY GEOMETRICS	⚪	🟡🟡	
MAINSPAN FOOTINGS	🔴🔴🔴	🟡🟡	
CONSTRUCTION	🟡🟡	⚪	
STRUCTURAL REDUNDANCY	🟡🟡	🟢🟢	
INSPECTION & MAINTENANCE	🟢🟢	🟢🟢🟢	
DURABILITY	🟢🟢	🟢🟢🟢	
WIND RESPONSE	⚪	🟢🟢	
SNOW & ICE RESPONSE	🟡🟡	🟢🟢	
COMMUNITY	🟢🟢	🟡🟡	

🟢🟢🟢 Most Favorable
🟢🟢 Favorable
⚪ Neutral
🟡🟡 Less Favorable
🔴🔴🔴 Unfavorable
•• Not Rated

Fig. 4.1 – Rating Scheme Format

4.2 Main Span Length

The discussions with the Army Corps of Engineers revealed that the shortest-span option (525 feet) is not acceptable and that the longer-span options (700 feet and 820 feet) are favored. The higher superstructure cost with the longer spans was judged to be partially compensated for by the easier access for foundation construction.

4.3 Deck Configuration

A clear preference for two separate structures emerged from the evaluation due to the opportunity for phased construction, the shortest time to decommissioning of the existing bridge, the possibility to overlap the new bridge alignment with the existing bridge footprint, and the operational flexibility during the service life of the new bridge. The preference was not strong enough, however, to completely eliminate single-bridge options from further consideration.

4.4 Single Bridge

Amongst the single-bridge options a cable-stayed alternative with a single, central cable plane was rated "unfavorable". This assessment was based on concerns about the exceptionally great width (approximately 145 feet) of the deck required with this arrangement and about the asymmetric loading from a one-sided shared-use path.

4.5 Separate Bridges

Amongst the parallel-bridge options an alternative with a link slab connecting two independent structures and carrying the shared-use path was eliminated from further considerations. This decision was driven by an assessment that the link slab would perform poorly during service and that this arrangement would not allow for pedestrian access during phased construction.

4.6 Medium-Long-Span Bridge Types

This matrix groups the 525, 616, and 700-ft span options together, as they all have similar characteristics. Only the latter two are relevant, however, since the 525-ft span option is eliminated by channel operation considerations. Amongst the bridge type alternatives presented here, tied arches and tied arches with Delta frames are rated very favorably due to the possibility of accelerated bridge construction with the arch being fabricated offsite while construction of foundations and substructure progresses simultaneously. The haunched concrete box girder option was rated favorably due to the simplicity of the structure with the fewest items to maintain and inspect.

The truss option was eliminated from further consideration because tension elements in trusses are considered fracture-critical, which triggers a requirement for costly biennial inspections. The single-tower cable-stayed bridge option was eliminated because the site conditions permit construction of two towers, resulting in a much more efficient structural system.

4.7 Long-Span Bridge Types

Bridge types considered for the 820-ft span alternative are similar to the medium-long-span bridge types with the addition of a suspension bridge option and the modification of the truss option from constant to variable depth. As for the shorter spans and for the same reasons, the truss bridge and the single-tower cable-stayed bridge alternatives were rated “unfavorable”. The suspension bridge option was also eliminated from further consideration since it is better suited for much longer spans.

Among the tied arch options only the arrangement with Delta frames was advanced for the long-span range, since this alternative reduces the length of the arch span and thus retains the feasibility to float in the prefabricated arch structure. With a longer arch, the limited channel width cannot accommodate the float-in operation and construction on site with falsework in the canal would be required, which was deemed unacceptable.

4.8 Cable-Stayed Bridge Towers

The matrix evaluating cable-stayed bridge towers comprises arrangements with two tower legs either in the form of an H (or V), an A, or an inverted Y. All of these configurations were deemed feasible and the prescreening process did not eliminate any of them.

4.9 Cable-Stayed Bridge Pylons

The matrix evaluating cable-stayed bridge pylons comprises arrangements with a single tower leg and one, two, or three cable planes. Only the alternative with three cable planes was eliminated due to the associated challenges of controlling the cable forces with this indeterminate floorbeam support system. It is noted that the pylon configurations only work in conjunction with a single bridge structure.

4.10 Arch Rib Configurations

The arch rib configurations include vertical ribs with upper lateral bracing, free-standing vertical ribs, and basket handle rib arrangements. Considering the high wind forces at this site, free-standing ribs were ruled out. In addition, an alternative with three ribs and three cable planes was rated “unfavorable” due to the expected difficulties of apportioning the cable forces with the resulting indeterminate floorbeam support.

4.11 Haunched Box Girder Bridges

For the haunched girder alternatives only the solution with two separate post-tensioned concrete box girders was advanced. A single concrete box, either with a single cell or two cells, was considered not feasible due to the great deck width (approximately 129 feet) required to accommodate both roadways and the shared-use path. An alternative using two separate steel boxes was also rated “unfavorable” in view of expected high fabrication costs and lack of recent US experience with this type of structure at the span ranges considered.

4.12 Deck Girder Types

The matrix evaluating deck girder options is primarily concerned with deck materials, edge girder configurations, and box girder configurations. None of the criteria were rated strongly enough to become decision drivers (i.e. received a triple-red or triple-green rating), however, a preference emerged for closed steel box edge girders with the tied arch alternatives and an open steel edge girder with the cable-stayed bridge alternatives.

4.13 Approach Bridge Types

For the approach bridge type assessment the ratings in the corresponding decision matrix reflects the expectation that a traditional steel-plate, multi-girder arrangement can best meet the span length requirements for the approaches and provide the necessary flexibility to tie in ramps. An alternative with steel tub girders was also rated highly mostly for aesthetic reasons in view of its cleaner lines.

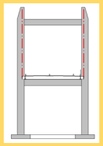
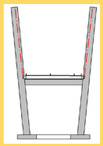
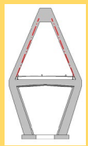
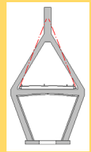
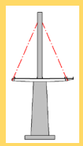
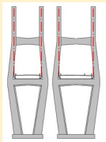
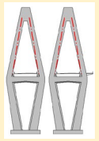
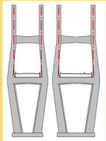
5 PROPOSED CONFIGURATIONS

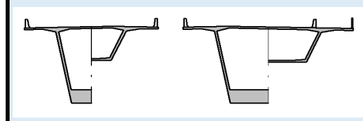
Informed by the rating matrices a set of bridge options comprising the most promising and favorable features was selected as follows:

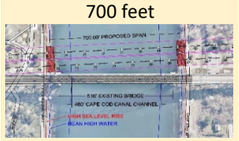
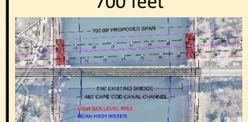
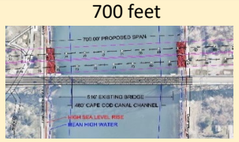
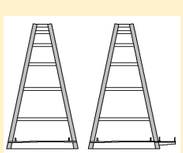
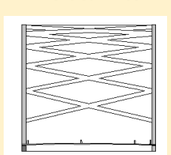
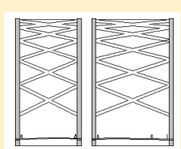
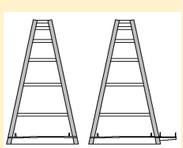
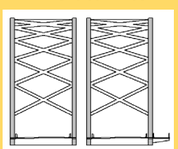
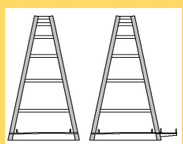
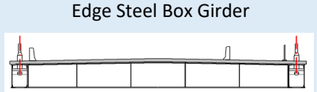
- Cable-stayed bridge alternatives with a single deck and a 820-ft span and with separate decks at 700 feet and 820 feet, all with various tower configurations.
- A post-tensioned concrete box girder alternative comprising twin bridges with a 700-ft span.
- Network tied arch options, either with traditional piers supporting a 700-ft span or with Delta-frame configuration for 700 and 820-ft main spans with various rib and deck configurations.

Table 5.1 shows summary information for each alternative and preliminary renderings are included in Appendix A. Table entry and corresponding rendering are identified by the matching label (e.g. “CS1” for Cable-Stayed Bridge Alternative 1). It is noted that these renderings have the character of massing studies and depict preliminary and tentative proportions. Further sharpening of the bridge type screening will occur during the next phase of the study in conjunction with the evolving highway design.

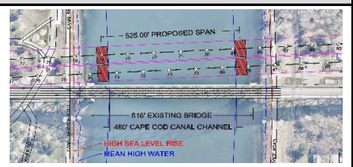
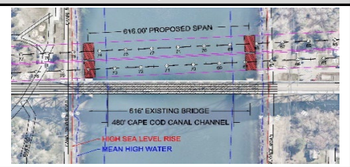
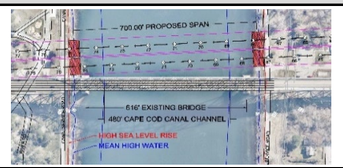
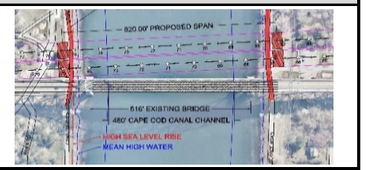
TABLE 5.1 - PROPOSED BRIDGE TYPES AND CONFIGURATIONS FOR FURTHER EVALUATION

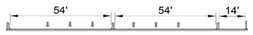
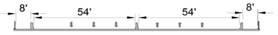
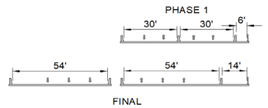
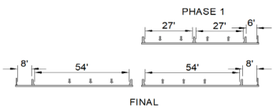
Type	Two-Tower Cable Stayed with Two Cable-Planes 										
Label	CS1	CS2	CS3	CS4	CS5	CS6	CS7	CS8	CS9	CS10	CS11
Deck	Single Deck					Separate Decks					
Span	820 feet 					700 feet 			820 feet 		
Tower	H 	V 	Single A 	Single Y 	Pylon 	Separate H's 	Separate A's 	Merged A's 	Separate H's 	Separate A's 	Merged A's 
Girder	Edge Steel I-Girder 										

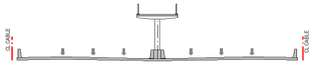
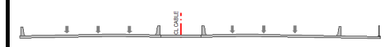
Type	Box Girder 					
Lable	BG1					
Deck	Separate Decks					
Span	>700 feet 					
Girder	Post-Tensioned Concrete 					

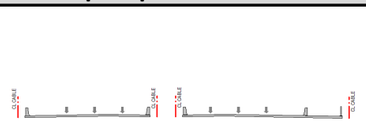
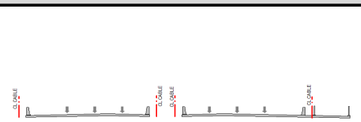
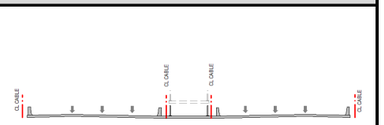
Type	Tied Arch 	Tied Arch with Delta Frames 				
	TA1	TA2	TA3	TA4	TA5	TA6
Deck	Separate Decks	Single Deck	Separate Decks			
Span	700 feet 	700 feet 	700 feet 		820 feet 	
Rib	Basket Handle Ribs 	Vertical Ribs 	Vertical Ribs 	Basket Handle Ribs 	Vertical Ribs 	Basket Handle Ribs 
Girder	Edge Steel Box Girder 					

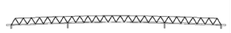
APPENDIX A – SCREENING MATRICES

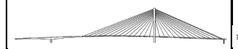
MAIN SPAN LENGTH		Minimum - 525 ft		Status-Quo - 616 ft		Shore Line Piers - 700 ft		Land Piers - 820 ft	
Most Favorable Favorable Neutral Less Favorable Unfavorable Not Rated									
EVALUATION CRITERIA		Rating	Notes	Rating	Notes	Rating	Notes	Rating	Notes
INITIAL COST	Main Span Structure	●●	Lowest superstructure cost.	●	Intermediate superstructure and foundation costs.	●	Intermediate superstructure and foundation costs.	●●	Highest superstructure cost.
	Main Span Foundations	●●	Highest foundation cost, designed for vessel impact, construction access, requires cofferdam.	●●	High foundation cost - accesss, cofferdam.	●	Close to land, but still requires cofferdam in tidal zone.	●●	Best accessibility for foundation cosntruction.
	Overall	••		••		••		••	
HIGHWAY GEOMETRICS	Grade/Length	••		••		••		••	
	Footprint	••		••		••		••	
	Horizontal Tangent Length	••		••		••		••	
MAINSPAN FOOTINGS	Vessel Impact	●●●	Not acceptable for canal operations.	●●	Small vessels and shallow draft barges.	●●●	Large vessels ground out, small vessels only.	●●●	Not possible.
	Scour	●●		●●	No significant scour with existing structure.	●●	Armored slope.	●●●	Not possible.
CONSTRUCTION	Phasing	••		••		••		••	
	Duration	●	Pier construction from water.	●	Pier construction from water.	●	Pier construction from water.	●	More difficult superstructure.
	Constructability	●●	Pier construction from trestle bridge.	●	Trestle bridge or causeway.	●●	Pier construction from land.	●●	Pier construction on land.
	Impact on Canal Traffic	●●	Most channel fouling.	●		●●	No channel fouling.	●●●	No channel fouling.
	Maintenance of Traffic	••		••		••		••	
	Environmental Impact	●●	Pier footing in water.	●●	Pier footing in water.	●	Pier footing tucked into shore line.	●●	Pier footing on land.
STRUCTURAL REDUNDANCY	Fracture-Critical Members	••		••		••		••	
	Failure-Critical Members	••		••		••		••	
INSPECTION & MAINTENANCE	Access	••		••		••		••	
	Frequency	••		••		••		••	
DURABILITY	Protection	••		••		••		••	
	Replacement	••		••		••		••	
	Monitoring	••		••		••		••	
WIND RESPONSE	Structural Efficiency	••		••		••		••	
	Dynamic Effects	••		••		••		••	
SNOW & ICE RESPONSE	Bridge closures	••		••		••		••	
	Monitoring/Deicing	••		••		••		••	
COMMUNITY	Appearance/Signature	••		••		••		••	
	Bike/Pedestrian Path	••		••		••		••	

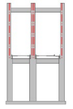
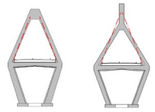
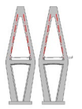
DECK CONFIGURATION		Single Deck/Single Path		Single Deck/Two Paths		Separate Decks/Single Path		Separate Decks/Two Paths	
	Most Favorable Favorable Neutral Less Favorable Unfavorable Not Rated								
EVALUATION CRITERIA		Rating	Notes	Rating	Notes	Rating	Notes	Rating	Notes
INITIAL COST	Main Span Structure	●	Highest floorbeam cost, but least number of ribs or cable planes.	●	Highest floorbeam cost, but lest number of ribs or cable planes.	●	Least floorbeam costs, but requires more ribs or cable planes.	●	Least floorbeam costs, but requires more ribs or cable planes.
	Main Span Foundations	••		••		••		••	
	Overall	••		••		••		••	
HIGHWAY GEOMETRICS	Grade/Length	●●	Greater structure depth requires steeper or longer approach.	●●	Greater structure depth requires steeper or longer approach.	●●	Least floorbeam depth.	●●	Least floorbeam depth.
	Footprint	●	Smaller constructed footprint, but may require more takings.	●	Smaller constructed footprint, but may require more takings.	●●	Greatest flexibility for overlap with existing alignment.	●●	Greatest flexibility for overlap with existing alignment.
	Horizontal Tangent Length	••		••		••		••	
MAINSPAN FOOTINGS	Vessel Impact	••		••		••		••	
	Scour	••		••		••		••	
CONSTRUCTION	Phasing	●●	Not an option.	●●	Not an option.	●●●	Phase 1: 2 x 30-ft roadways	●●●	Phase 1: 2 x 27-ft roadways
	Duration	●		●		●●	Old bridge decommissioned soonest.	●●	Old bridge decommissioned soonest.
	Constructability	●●		●●		●●	More repetitive, smaller pieces.	●●	More repetitive, smaller pieces.
	Impact on Canal Traffic	••		••		••		••	
	Maintenance of Traffic	●	Staged tie-in to existing highway more difficult.	●	Staged tie-in to existing highway more difficult.	●●	Allows phased construction.	●●●	Most flexible-either structure can be configured for two-way traffic during construction and during life of structure.
	Environmental Impact	●	Smaller constructed footprint, but may require more takings.	●	Smaller constructed footprint, but may require more takings.	●●	Greatest flexibility for overlap with existing alignment.	●●	Greatest flexibility for overlap with existing alignment.
STRUCTURAL REDUNDANCY	Fracture-Critical Members	••		••		••		••	
	Failure-Critical Members	●		●		●●	Each structure can operate independently and carry two-way traffic, but no path.	●●●	Each structure can operate independently and carry two-way traffic and a path.
INSPECTION & MAINTENANCE	Access	••		••		••		••	
	Frequency	••		••		••		••	
DURABILITY	Protection	••		••		••		••	
	Replacement	••		••		●●	Each structure can operate independently and carry two-way traffic, but no path.	●●●	Most flexible-either structure can be configured for two-way traffic during construction and during life of structure.
	Monitoring	••		••		••		••	
WIND RESPONSE	Structural Efficiency	••		••		••		••	
	Dynamic Effects	●●	Better wind stability.	●●	Better wind stability.	●●	Need to adress wake effects.	●●	Need to adress wake effects.
SNOW & ICE RESPONSE	Bridge closures	••		••		••		••	
	Monitoring/Deicing	••		••		••		••	
COMMUNITY	Appearance/Signature	••		••		••		••	
	Bike/Pedestrian Path	••		••		••		••	

SINGLE BRIDGE DECK		Simple Span Floorbeam		Cantilever Floorbeam		Separate Pedestrian Level		Single Cable Plane	
Most Favorable Favorable Neutral Less Favorable Unfavorable Not Rated									
EVALUATION CRITERIA		Rating	Notes	Rating	Notes	Rating	Notes	Rating	Notes
INITIAL COST	Main Span Structure	●	Largest floorbeam span.	●●	Reduced floorbeam span length.	●●	Additional cost for walkway support, transverse flyovers, and screens.	●●●	Requires torsionally stiff and deep deck girder to address eccentricty.
	Main Span Foundations	●		●		●●	Additional cost for walkway support and screens.	●	
	Overall	••		••		••		••	
HIGHWAY GEOMETRICS	Grade/Length	●		●		●●	Allows different grades for roadway and path.	●●	Deep structure increases approach length or grade.
	Footprint	●		●		●●	Smallest footprint.	●●	Closure strip/tower increases deck width.
	Horizontal Tangent Length	••		••		••		••	
MAINSPAN FOOTINGS	Vessel Impact	••		••		••		••	
	Scour	••		••		••		••	
CONSTRUCTION	Phasing	••		••		••		••	
	Duration	••		••		••		••	
	Constructability	••		••		••		••	
	Impact on Canal Traffic	••		••		••		••	
	Maintenance of Traffic	••		••		••		••	
	Environmental Impact	••		••		••		••	
STRUCTURAL REDUNDANCY	Fracture-Critical Members	••		••		••		••	
	Failure-Critical Members	••		••		••		••	
INSPECTION & MAINTENANCE	Access	••		••		••		••	
	Frequency	••		••		••		••	
DURABILITY	Protection	••		••		••		••	
	Replacement	••		••		••		••	
	Monitoring	••		••		••		••	
WIND RESPONSE	Structural Efficiency	••		••		••		••	
	Dynamic Effects	••		••		••		••	
SNOW & ICE RESPONSE	Bridge closures	••		••		••		••	
	Monitoring/Deicing	••		••		••		••	
COMMUNITY	Appearance/Signature	••		••		••		••	
	Bike/Pedestrian Path	●		●●	Cable plane creates barrier effect.	●●	Path offset from traffic.	●	

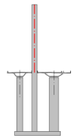
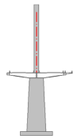
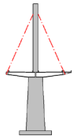
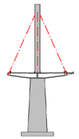
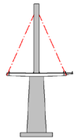
SEPARATE BRIDGE DECKS		Simple Span Floorbeams		Cantilever Floorbeam		Twins With Link Slab	
Most Favorable Favorable Neutral Less Favorable Unfavorable Not Rated							
EVALUATION CRITERIA		Rating	Notes	Rating	Notes	Rating	Notes
INITIAL COST	Main Span Structure	●		●●	Reduced floorbeam span.	●●	Reduced floorbeam span.
	Main Span Foundations	••		••		••	
	Overall	••		••		••	
HIGHWAY GEOMETRICS	Grade/Length	••		••		••	
	Footprint	••		••		••	
	Horizontal Tangent Length	••		••		••	
MAINSPAN FOOTINGS	Vessel Impact	••		••		••	
	Scour	••		••		••	
CONSTRUCTION	Phasing	●●	2x30-ft roadways and 6-ft path in temporary configuration.	●	2x26-ft roadways and 14-ft path in temporary configuration.	●●●	2x26-ft roadways but no path in temporary configuration.
	Duration	••		••		••	
	Constructability	●		●●	Path eccentricity complicates construction.	●●	Path adds another construction phase, durability of deck construction joints.
	Impact on Canal Traffic	••		••		••	
	Maintenance of Traffic	••		••		••	
	Environmental Impact	••		••		••	
STRUCTURAL REDUNDANCY	Fracture-Critical Members	••		••		••	
	Failure-Critical Members	••		••		••	
INSPECTION & MAINTENANCE	Access	••		••		••	
	Frequency	••		••		••	
DURABILITY	Protection	●		●		●●	Complex behavior of link slab as it spans between twin superstructures.
	Replacement	••		••		••	
	Monitoring	••		••		••	
WIND RESPONSE	Structural Efficiency	••		••		••	
	Dynamic Effects	••		••		••	
SNOW & ICE RESPONSE	Bridge closures	••		••		••	
	Monitoring/Deicing	••		••		••	
COMMUNITY	Appearance/Signature	••		••		••	
	Bike/Pedestrian Path	●		●●	Cable plane creates barrier effect.	●●	Path surrounded by traffic on both sides.

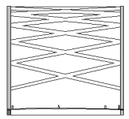
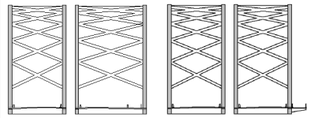
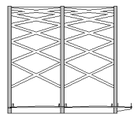
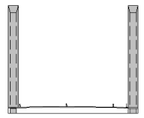
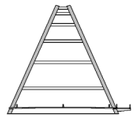
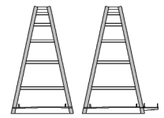
BRIDGE TYPE (525/616/700-FT)		Tied Arch		Tied Arch With Delta Frame		Truss		Two-Tower Cable Stayed		Single-Tower Cable Stayed		Box Girder	
Most Favorable Favorable Neutral Less Favorable Unfavorable Not Rated													
EVALUATION CRITERIA		Rating	Notes	Rating	Notes	Rating	Notes	Rating	Notes	Rating	Notes	Rating	Notes
INITIAL COST	Main Span Structure	●●	Efficient off-site construction, least length of main span structure.	●●	Efficient off-site construction, but added complexity from Delta frames.	●	Slower construction.	●●	Lower end of efficient span range for this type of structure.	●●●	Inefficient structural system.	●●	Efficient and simple structural system.
	Main Span Foundations	••		••		••		••		••		●●	Heavy foundation.
	Overall	••		••		••		••		••		●●	Deeper superstructure requires longer or taller approaches.
HIGHWAY GEOMETRICS	Grade/Length	●●	Least main span girder depth. Shortest main span creates more flexibility for curved approaches.	●●	Least main span girder depth.	●●	Least main span girder depth.	●	Similar to arches and truss with two cable planes, similar to box girder with single cable plane.	●	Similar to arches and truss with two cable planes, similar to box girder with single cable plane.	●●	Extra approach structure length or grade due to main span girder depth.
	Footprint	••		••		••		••		••		••	
	Horizontal Tangent Length	●●	Main span only.	●●	Arch and Delta frame spans.	●●	Main and side spans.	●●	Main and side spans.	●●	Main and side span.	●●	Can accommodate moderate plan curvature.
MAINSPAN FOOTINGS	Vessel Impact	••		••		••		••		••		••	
	Scour	••		••		••		••		••		••	
CONSTRUCTION	Phasing	••		••		••		••		••		••	
	Duration	●●●	Accelerated bridge construction with arch fabricated off-site and floated in.	●●●	Accelerated bridge construction with arch fabricated off-site and floated in.	●●	Significant portion of structure erected by stick building.	●	Accelerated construction by working from two towers simultaneosuly.	●●	Single work front and linear construction process.	●	Accelerated construction by working from two piers simultaneously.
	Constructability	●●	Arch floated in, complex lifting operation.	●●●	Arch floated in, Delta piers simplify lifting operation.	●●	Stick building with floated in drop-in span.	●	Repetitive construction cycle, but requires careful cable force and geometyry control, tower construction.	●	Repetitive construction cycle, but requires careful cable force and geometyry control, tower construction.	●●	Repetitive construction cycle.
	Impact on Canal Traffic	●●●	Single closure for each span lift.	●●●	Single closure for each span lift.	●	Barge operations near pier, one extended closure for drop-in lift	●	Periodic, partial obstructions for segment lift from barge (approximately 40 lifts/bridge)	●	Periodic, partial obstructions for segment lift from barge (approximately 40 lifts/bridge)	●●●	None.
	Maintenance of Traffic	••		••		••		••		••		••	
	Environmental Impact	••		••		••		••		••		••	
STRUCTURAL REDUNDANCY	Fracture-Critical Members	●●	Fracture critical elements (ties, hangers, floorbeams) designed for system or internal redundancy.	●●	Fracture critical elements (ties, hangers, floorbeams) designed for system or internal redundancy.	●●●	Tension diagonals, tension chords designated as fracture-critical members.	●●	Hangers, floorbeams - designed for system or internal redundancy.	●●	Hangers, floorbeams - designed for system or internal redundancy.	●●●	No fracture critical members.
	Failure-Critical Members	●●	Improved rib stability due to network hanger arrangement.	●●	Improved rib stability due to network hanger arrangement.	●●	Any truss member.	●●	Stiffening girder.	●●	Stiffening girder.	●●	Post-tensioning tendons.
INSPECTION & MAINTENANCE	Access	●●	Accessible tie girders and ribs, snooper for under-deck, cherry picker for cables.	●●	Accessible tie girders and ribs, snooper for under-deck, cherry picker for cables.	●●	Snooper and cherry picker.	●	Accessible towers, snooper for under-deck, rope access for cables	●	Accessible towers, snooper for under-deck, rope access for cables	●●	Accessible box girder, snooper for under-deck, but cannot inspect internal tendons.
	Frequency	●	Typical cycle.	●	Typical cycle.	●●	Hands-on inspection of fracture-critical items at two-year intervals.	●	Typical cycle.	●	Typical cycle.	●●●	Typical cycle, fewest elements to inspect.
DURABILITY	Protection	●	Has vulnerable elements above deck. Metallized steel, partially prestressed precast deck panels.	●	Has vulnerable elements above deck. Metallized steel, partially prestressed precast deck panels.	●	Has vulnerable elements above deck. Metallized steel, concrete cover and corrosion resistant reinforcement.	●	Has vulnerable elements above deck. Metallized steel, partially prestressed precast deck panels.	●	Has vulnerable elements above deck. Metallized steel, partially prestressed precast deck panels.	●●	Fewest exposed elements, deck fully prestressed longitudinally and transversely, concrete cover and corrosion resistant reinforcement.
	Replacement	●●	Cables, deck overlay system, deck.	●●	Cables, deck overlay system, deck.	●	Deck overlay system, deck.	●	Cables, deck overlay system, typically not designed for deck replacement.	●	Cables, deck overlay system, typically not designed for deck replacement.	●●	Deck overlay system, deck replacement not possible.
	Monitoring	●	Cables.	●	Cables.	●	None required.	●	Cables.	●	Cables	●	None required.
WIND RESPONSE	Structural Efficiency	••		••		••		••		●●	Poor wind performance (effectively twice the span length)	••	
	Dynamic Effects	●	Requires wind tunnel studies.	●	Requires wind tunnel studies.	●	Potential for truss member vibrations.	●●	Requires wind tunnel studies.	●●	Requires wind tunnel studies.	●●	Negligible.
SNOW & ICE RESPONSE	Bridge closures	●	Uncommon.	●	Uncommon.	●	Uncommon.	●●	During critical climatic conditions.	●●	During critical climatic conditions.	●●	Uncommon.
	Monitoring/Deicing	●	Ice drop from rib-bracing.	●	Ice drop from rib-bacing.	●	Ice drop from top chord bracing.	●●	Ice drop from cables.	●●	Ice drop from cables.	●●	Uncommon.
COMMUNITY	Appearance/Signature	●●	Efficient, less height.	●●	Echoes appearance of existing structure.	●●	Utilitarian.	●●	Iconic.	●●	Iconic.	●	Understated elegance.
	Bike/Pedestrian Path	••		••		••		••		••		••	

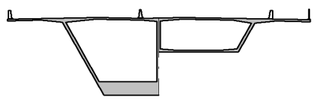
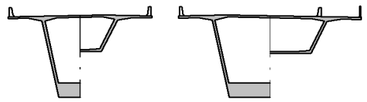
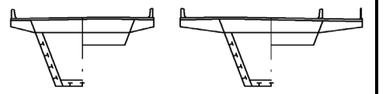
BRIDGE TYPE (820-FT SPAN)		Tied Arch		Tied Arch With Delta Frame		Truss		Two-Tower Cable Stayed		Single-Tower Cable Stayed		Box Girder		Suspension Bridge	
Most Favorable Favorable Neutral Less Favorable Unfavorable Not Rated															
EVALUATION CRITERIA		Rating	Notes	Rating	Notes	Rating	Notes	Rating	Notes	Rating	Notes	Rating	Notes	Rating	Notes
INITIAL COST	Main Span Structure	●●	Upper end of economical span range for this type of structure.	●●	Efficient off-site construction, but added complexity from Delta frames.	●●	Slow construction.	●●	Very efficient span range for this type of structure.	●●●	Inefficient structural system.	●	Efficient and simple structural system, but US record at this span range.	●●●	Not common/not economical for this span range.
	Main Span Foundations	••		••		••		••		••		●●	Heavy foundation.	••	
	Overall	••		••		••		••		••		●●	Deeper superstructure requires longer or taller approaches.	••	
HIGHWAY GEOMETRICS	Grade/Length	●●	Least main span girder depth. Shortest main span creates more flexibility for curved approaches.	●●	Least main span girder depth.	●●	Least main span girder depth.	●	Similar to arches and truss with two cable planes, similar to box girder with single cable plane.	●	Similar to arches and truss with two cable planes, similar to box girder with single cable plane.	●●	Extra approach structure length or grade due to main span girder depth.	●●	Least main span girder depth.
	Footprint	••		••		••		••		••		••		••	
	Horizontal Tangent Length	●●	Main span only.	●●	Arch and Delta frame spans.	●●	Main and side spans.	●●	Main and side spans.	●●	Main and side span.	●●	Can accommodate moderate plan curvature.	●●	Main and side spans.
MAINSPAN FOOTINGS	Vessel Impact	••		••		••		••		••		••		••	
	Scour	••		••		••		••		••		••		••	
CONSTRUCTION	Phasing	••		••		••		••		••		••		••	
	Duration	●●●	Slow construction (stick building)	●●●	Accelerated bridge construction with arch fabricated off-site and floated in.	●●	Significant portion of structure erected by stick building.	●	Accelerated construction by working from two towers simultaneosuly.	●●	Single work front and linear construction process.	●	Accelerated construction by working from two piers simultaneously, pier segments are time consuming.	●●	Slow construction (cable spinning)
	Constructability	●●	Record-span float-in or stick building, float-in requires fabrication yard on shore between existing bridges due to height of structure.	●●●	Arch floated in, Delta piers simplify lifting operation.	●●	Stick building with floated in drop-in span.	●●	Repetitive construction cycle, but requires careful cable force and geometyry control, tower construction.	●	Repetitive construction cycle, but requires careful cable force and geometyry control, tower construction.	●	Record span for USA. Repetitive construction cycle.	●●	Uncommon type of structure.
	Impact on Canal Traffic	●●	Reduced channel width (~380 ft) due to falsework required during arch erection (~ 1 year).	●●	Barge operations near shore line, one 24 hr closure for drop-in lift.	●●	Barge operations near shore line, one 24 hr closure for drop-in lift.	●	Periodic, partial obstructions for segment lift from barge (approximately 40 lifts).	●	Periodic, partial obstructions for segment lift from barge (approximately 40 lifts).	●●●	None.	●	Periodic, partial obstructions for segment lift from barge (approximately 40 lifts).
	Maintenance of Traffic	••		••		••		••		••		••		••	
	Environmental Impact	••		••		••		••		••		••		••	
STRUCTURAL REDUNDANCY	Fracture-Critical Members	●●	Fracture critical elements (ties, hangers, floorbeams) designed for system or internal redundancy.	●●	Fracture critical elements (ties, hangers, floorbeams) designed for system or internal redundancy.	●●●	Tension diagonals, tension chords designated as fracture-critical members.	●●	Hangers, floorbeams - designed for system or internal redundancy.	●●	Hangers, floorbeams - designed for system or internal redundancy.	●●●	No fracture critical members.	●●	Main cables. Floorbams and hangers designed for system redundancy.
	Failure-Critical Members	●●	Arch ribs.	●●	Arch ribs.	●●	Any truss member.	●●	Stiffening girder.	●●	Stiffening girder.	●●	Post-tensioning tendons.	●	Saddles.
INSPECTION & MAINTENANCE	Access	●●	Accessible tie girders and ribs, snooper for under-deck, cherry picker for cables.	●●	Accessible tie girders and ribs, snooper for under-deck, cherry picker for cables.	●●	Snooper and cherry picker.	●	Accessible towers, snooper or traveler platform for under-deck, rope access for cables.	●	Accessible towers, snooper or traveler for under-deck, rope access for cables.	●●	Accessible box girder, snooper for under-deck, but cannot inspect internal tendons.	●●	Accessible tower, walkable main cable, snooper or traveler for under-deck.
	Frequency	●	Typical cycle.	●	Typical cycle.	●●	Hands-on inspection of fracture-critical items at two-year intervals.	●	Typical cycle.	●	Typical cycle.	●●●	Typical cycle, fewest inspection items.	●	Typical cycle.
DURABILITY	Protection	●	Has vulnerable elements above deck. Metallized steel, partially prestressed precast deck panels.	●	Has vulnerable elements above deck. Metallized steel, partially prestressed precast deck panels.	●	Has vulnerable elements above deck. Metallized steel, concrete cover and corrosion resistant reinforcement.	●	Has vulnerable elements above deck. Metallized steel, partially prestressed precast deck panels.	●	Has vulnerable elements above deck. Metallized steel, partially prestressed precast deck panels.	●●	Fewest exposed elements, deck fully prestressed longitudinally and transversely, concrete cover and corrosion resistant reinforcement.	●●	Has vulnerable elements above deck. Metallized steel, concrete cover and corrosion resistant reinforcement.
	Replacement	●	Cables, deck overlay system, deck.	●	Cables, deck overlay system, deck.	●	Deck overlay system, deck.	●	Cables, deck overlay system, typically not designed for deck replacement.	●	Cables, deck overlay system, typically not designed for deck replacement.	●●	Deck overlay system, deck replacement not possible.	●●	Cables, deck overlay system. Main cable is not replaceable.
	Monitoring	●	Cables.	●	Cables.	●	None required.	●	Cables.	●	Cables.	●	None required.	●	Cables.
WIND RESPONSE	Structural Efficiency	●		●		●		●		●●	Poor wind performance (effectively twice the span length)	●	Large depth for wind catching area - larger foundation loads.	●	
	Dynamic Effects	●●	Requires wind tunnel studies.	●●	Requires wind tunnel studies.	●	Potential for truss member vibrations.	●●	Requires wind tunnel studies.	●●	Requires wind tunnel studies.	●●	Negligible.	●●	Requires wind tunnel studies.
SNOW & ICE RESPONSE	Bridge closures	●	Uncommon.	●	Uncommon.	●	Uncommon.	●●	During critical climatic conditions.	●●	During critical climatic conditions.	●●	Uncommon.	●●	Uncommon.
	Monitoring/Deicing	●	Ice drop from rib-bracing.	●	Ice drop from rib-bacing.	●	Ice drop from top chord bracing.	●●	Ice drop from cables.	●●	Ice drop from cables.	●●	Uncommon.	●●	Uncommon.
COMMUNITY	Appearance/Signature	●●	Iconic.	●●	Echoes appearance of existing structure.	●●	Utilitarian.	●●	Iconic.	●●	Iconic.	●●	Understated elegance.	●●	Iconic.
	Bike/Pedestrian Path	••		••		••		••		••		••			

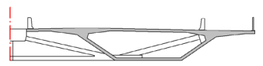
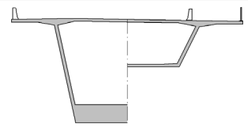
CABLE STAYED BRIDGE TOWERS		Single H		Free-Standing H		Separate H's		Merged H's		Single A/Inverted Y		Separate A's		Merged A's	
															
EVALUATION CRITERIA		Rating	Notes	Rating	Notes	Rating	Notes	Rating	Notes	Rating	Notes	Rating	Notes	Rating	Notes
INITIAL COST	Main Span Structure	●●	Simplest tower shape.	●●	Inefficient structural system.	●	More complex formwork and bracing for inclined legs.	●●	Simple shape, efficient structure.	●	More complex formwork and bracing for inclined legs, inefficient structural system.	●	More complex formwork and bracing for inclined legs.	●	Most complex tower shape.
	Main Span Foundations	••		••		••		••		••		••		••	
	Overall	••		••		••		••		••		••		••	
HIGHWAY GEOMETRICS	Grade/Length	••		••		••		••		••		••		••	
	Footprint	••		••		••		••		••		••		••	
	Horizontal Tangent Length	••		••		••		••		••		••		••	
MAINSPAN FOOTINGS	Vessel Impact	••		••		••		••		••		••		••	
	Scour	••		••		••		••		••		••		••	
CONSTRUCTION	Phasing	●●	Not an option.	●●	Not an option.	●●	Easily accommodates phased construction.	●	Possible, with extra considerations for tower construction.	●●	Not an option.	●●	Easily accommodates phased construction.	●	Possible, with extra considerations for tower construction.
	Duration	••		••		••		••		••		••		••	
	Constructability	●●	Simplest tower shape.	●		●		●●	Simple tower shape.	●●	Inclined tower legs.	●●	Inclined tower legs.	●●	Inclined and intersecting tower legs.
	Impact on Canal Traffic	••		••		••		••		••		••		••	
	Maintenance of Traffic	••		••		••		••		••		••		••	
	Environmental Impact	••	FAA Part 77	••	FAA Part 77	••	FAA Part 77	••	FAA Part 77	••	FAA Part 77	••	FAA Part 77	••	FAA Part 77
STRUCTURAL REDUNDANCY	Fracture-Critical Members	••		••		••		••		••		••		••	
	Failure-Critical Members	••		••		••		••		••		••		••	
INSPECTION & MAINTENANCE	Access	••		••		••		••		••		••		••	
	Frequency	••		••		••		••		••		••		••	
DURABILITY	Protection	••		••		••		••		••		••		••	
	Replacement	••		••		••		••		••		••		••	
	Monitoring	••		••		••		••		••		••		••	
WIND RESPONSE	Structural Efficiency	●	Frame action.	●●	Flagpoles.	●	Frame action.	●●	Frame action.	●●	Truss action.	●●	Truss action.	●●	Truss action.
	Dynamic Effects	●●	Good flutter resistance due to great deck width.	●	Flexible tower legs.	●●	Wake effects, upstream/downstream wind flow interactions, poor deck flutter resistance.	●●	Wake effects, upstream/downstream wind flow interactions, poor deck flutter resistance.	●●	Best deck flutter resistance.	●●	Improved deck flutter resistance.	●●	Improved deck flutter resistance.
SNOW & ICE RESPONSE	Bridge closures	●	During critical climatic conditions.	●●	During critical climatic conditions.	●	During critical climatic conditions.	●	During critical climatic conditions.	●●	During critical climatic conditions.	●●	During critical climatic conditions.	●●	During critical climatic conditions.
	Monitoring/Deicing	●	Ice drop from cables.	●●	Ice drop from cables.	●	Ice drop from cables.	●	Ice drop from cables.	●●	Ice drop from cables.	●●	Ice drop from cables.	●●	Ice drop from cables.
COMMUNITY	Appearance/Signature	●●	Simple.	●●	Uneasy.	●	Busy.	●	Simple.	●●	Odd proportions.	●●	Elegant.	●●	Iconic.
	Bike/Pedestrian Path	••		••		••		••		••		••		••	

●● Most Favorable
●● Favorable
● Neutral
●● Less Favorable
●●● Unfavorable
•• Not Rated

CABLE-STAYED BRIDGE PYLONS		Single Cable Plane/Two Boxes		Single Cable Plane/Single Box		Two Cable Planes/Single Box		Three C. Planes/Single Box		Two C. Planes/Edge Girders	
Most Favorable Favorable Neutral Less Favorable Unfavorable Not Rated											
EVALUATION CRITERIA		Rating	Notes	Rating	Notes	Rating	Notes	Rating	Notes	Rating	Notes
INITIAL COST	Main Span Structure	●	Greatest structure weight.	●	Slow deck construction.	●	Slow deck construction.	●	Slow deck construction.	●	Simplest tower.
	Main Span Foundations	••		••		••		••		••	
	Overall	••		••		••		••		••	
HIGHWAY GEOMETRICS	Grade/Length	••		••		••		••		••	
	Footprint	••		••		••		••		••	
	Horizontal Tangent Length	••		••		••		••		••	
MAINSPAN FOOTINGS	Vessel Impact	••		••		••		••		••	
	Scour	••		••		••		••		••	
CONSTRUCTION	Phasing	●●	Not an option.	●●	Not an option.	●●	Not an option.	●●	Not an option.	●●	Not an option.
	Duration	••		••		••		••		••	
	Constructability	●	Precast concrete segments for deck.	●●	Cast-in-place concrete for deck.	●●	Cast-in-place concrete for deck.	●●●	Cast-in-place concrete for deck, interacton between three cable planes.	●●	Simplest deck system.
	Impact on Canal Traffic	••		••		••		••		••	
	Maintenance of Traffic	••		••		••		••		••	
	Environmental Impact	••		••		••		••		••	
STRUCTURAL REDUNDANCY	Fracture-Critical Members	••		••		••		••		••	
	Failure-Critical Members	••		••		••		••		••	
INSPECTION & MAINTENANCE	Access	••		••		••		••		••	
	Frequency	••		••		••		••		••	
DURABILITY	Protection	••		••		••		••		••	
	Replacement	••		••		••		••		••	
	Monitoring	••		••		••		••		••	
WIND RESPONSE	Structural Efficiency	●●	Flagpole.	●●	Flagpole.	●●	Tower and deck stabilize each other.	●●	Tower and deck stabilize each other.	●	More flexible deck, small torsional stiffness.
	Dynamic Effects	●	Flexible tower.	●	Flexible tower.	●●	Very stable system.	●●	Very stable system.	●	
SNOW & ICE RESPONSE	Bridge closures	●	During critical climatic conditions.	●	During critical climatic conditions.	●●	During critical climatic conditions.	●●	During critical climatic conditions.	●●	During critical climatic conditions.
	Monitoring/Deicing	●	Ice drop from cables.	●	Ice drop from cables.	●●	Ice drop from cables.	●●	Ice drop from cables.	●●	Ice drop from cables.
COMMUNITY	Appearance/Signature	●●	Clean lines due to single cable plane.	●●	Single cable plane, closed box for deck.	●	Closed box for deck.	●●	Closed box for deck, busy with cables.	●●	Visible deck grillage.
	Bike/Pedestrian Path	••		••		••		••		••	

ARCH RIBS		Single/Vertical Ribs		Separate/Vertical Ribs		Merged/Vertical Ribs		Single/Freestanding		Single/Basket Handle		Separate/Basket Handle	
	Most Favorable Favorable Neutral Less Favorable Unfavorable Not Rated												
EVALUATION CRITERIA		Rating	Notes	Rating	Notes	Rating	Notes	Rating	Notes	Rating	Notes	Rating	Notes
INITIAL COST	Main Span Structure	●		●		●		●	Higher rib quantity and complexity, but no upper lateral bracing.	●		●●	Least rib bracing quantity.
	Main Span Foundations	••		••		••		••		••		••	
	Overall	••		••		••		••		••		••	
HIGHWAY GEOMETRICS	Grade/Length	••		••		••		••		••		••	
	Footprint	••		••		••		••		••		••	
	Horizontal Tangent Length	••		••		••		••		••		••	
MAINSPAN FOOTINGS	Vessel Impact	••		••		••		••		••		••	
	Scour	••		••		••		••		••		••	
CONSTRUCTION	Phasing	●●	Not an option.	●●	Easily accommodates phased construction.	●●	Not an option.	●●	Not an option.	●●	Not an option.	●	2x24-ft roadways but no path in temporary configuration.
	Duration	••		••		••		••		••		••	
	Constructability	●●	Fewer, larger pieces to handle.	●●	Smaller, but more pieces to handle.	●●●	Three cable planes makes hangerforces and floorbam moments difficult to control.	●●	Demanding geometry control for ribs.	●	More complex rib shoring.	●●	Smaller pieces to handle.
	Impact on Canal Traffic	••		••		••		••		••		••	
	Maintenance of Traffic	••		••		••		••		••		••	
	Environmental Impact	••		••		••		••		••		••	
STRUCTURAL REDUNDANCY	Fracture-Critical Members	••		••		••		••		••		••	
	Failure-Critical Members	••		••		••		••		••		••	
INSPECTION & MAINTENANCE	Access	••		••		••		••		••		••	
	Frequency	••		••		••		••		••		••	
DURABILITY	Protection	••		••		••		••		••		••	
	Replacement	••		••		••		••		••		••	
	Monitoring	••		••		••		••		••		••	
WIND RESPONSE	Structural Efficiency	●	Truss action, but high moment demans at portal frame.	●	Truss action, but high moment demans at portal frame.	●	Truss action, but high moment demans at portal frame.	●●●	Structural system not appropriate for this site.	●●	A-shape helps with wind resistance.	●●	A-shape helps with wind resistance.
	Dynamic Effects	●	More susceptible	●●	Wake galloping of cables.	●	More susceptible.	●●	Most susceptible.	●●	Less susceptible.	●●	Less susceptible.
SNOW & ICE RESPONSE	Bridge closures	●	Uncommon.	●	Uncommon.	●	Uncommon.	●	Uncommon	●	Uncommon.	●	Uncommon.
	Monitoring/Deicing	●	Ice drop from rib bracing.	●	Ice drop from rib bracing.	●	Ice drop from rib bracing.	●●	No bracing members.	●●	Ice drop from ribs and rib bracing.	●●	Ice drop from ribs and rib bracing.
COMMUNITY	Appearance/Signature	●●	More rib bracing.	●●	More rib bracing.	●●	More rib bracing.	●●	Clean lines.	●●	Odd proportions.	●●	Less bracing.
	Bike/Pedestrian Path	••		••		••		••		••		••	

BOX GIRDERS		Single Concrete Box		Separate Concrete Boxes		Separate Steel Boxes	
Most Favorable Favorable Neutral Less Favorable Unfavorable Not Rated							
EVALUATION CRITERIA		Rating	Notes	Rating	Notes	Rating	Notes
INITIAL COST	Main Span Structure	●●●	Very complex and heavy form traveler.	●●	Good repetition and rhythm.	●●●	Not competitive due to complex fabrication.
	Main Span Foundations	••		••		••	
	Overall	••		••		••	
HIGHWAY GEOMETRICS	Grade/Length	••		••		••	
	Footprint	••		••		••	
	Horizontal Tangent Length	••		••		••	
MAINSPAN FOOTINGS	Vessel Impact	••		••		••	
	Scour	••		••		••	
CONSTRUCTION	Phasing	●●	Not an option.	●●	Easily accommodates phased construction.	●●	Easily accommodates phased construction.
	Duration	••		••		••	
	Constructability	●●	Complex and heavy form traveler.	●●	Routine.	●●	Unusual system.
	Impact on Canal Traffic	••		••		••	
	Maintenance of Traffic	••		••		••	
	Environmental Impact	••		••		••	
STRUCTURAL REDUNDANCY	Fracture-Critical Members	●●	No.	●●	No.	●●	Tension flanges and webs.
	Failure-Critical Members	••		••		••	
INSPECTION & MAINTENANCE	Access	••		••		••	
	Frequency	••		••		••	
DURABILITY	Protection	••		••		••	
	Replacement	••		••		••	
	Monitoring	••		••		••	
WIND RESPONSE	Structural Efficiency	••		••		••	
	Dynamic Effects	●	Insensitive to dynamic effects.	●	Insensitive to dynamic effects.	●●	Sensitive to vortex-shedding induced oscillations.
SNOW & ICE RESPONSE	Bridge closures	••		••		••	
	Monitoring/Deicing	••		••		••	
COMMUNITY	Tensioned	●●	Understated elegance, closed box gives clean lines.	●●	Understated elegance, closed box gives clean lines.	●	Splices detract from otherwise elegant appearance.
	Bike/Pedestrian Path	••		••		••	

DECK GIRDERS		Edge Steel Box (Arch)		Edge I-Girder W/Bracket (C.S.)		Edge I-Girder W/Fin (C.S.)		Edge Concrete Girders (C.S.)		Cable-Supported Box Girder		Self-Supporting Box Girder	
Most Favorable Favorable Neutral Less Favorable Unfavorable Not Rated													
EVALUATION CRITERIA		Rating	Notes	Rating	Notes	Rating	Notes	Rating	Notes	Rating	Notes	Rating	Notes
INITIAL COST	Main Span Structure	••		••		••		••		••		••	
	Main Span Foundations	••		••		••		••		••		••	
	Overall	••		••		••		••		••		••	
HIGHWAY GEOMETRICS	Grade/Length	••		••		••		••		••		••	
	Footprint	••		••		••		••		••		••	
	Horizontal Tangent Length	••		••		••		••		••		••	
MAINSPAN FOOTINGS	Vessel Impact	••		••		••		••		••		••	
	Scour	••		••		••		••		••		••	
CONSTRUCTION	Phasing	••		••		••		••		••		••	
	Duration	••		••		••		••		••		••	
	Constructability	●●	Simple system, much repetition.	●●	Simple system, much repetition.	●	Simple system, much repetition, but fin plate connection to edge girder is challenging.	●●	Precast or cast-in-place deck, difficult erection control.	●	Numerous heavy precast elements.	●●	Simplest system.
	Impact on Canal Traffic	••		••		••		••		••		••	
	Maintenance of Traffic	••		••		••		••		••		••	
	Environmental Impact	••		••		••		••		••		••	
STRUCTURAL REDUNDANCY	Fracture-Critical Members	●●	Edge boxes designed for internal redundancy.	●●	Floorbeam spacing < 12 feet or > 15 feet with redundancy girders.	●●	Floorbeam spacing < 12 feet or additional redundancy girders.	●●	None.	●●	None.	●●	None.
	Failure-Critical Members	●		●		●		●	Floorbeam post-tensioning tendons.	●●	Delta frames are critical component of system.	●	Longtudinal post-tensioning tendons.
INSPECTION & MAINTENANCE	Access	●●	Accessible edge box girder, snooper.	●●	Snooper or inspection traveler.	●●	Snooper or inspection traveler.	●●	Snooper or inspection traveler.	●●	Accessible box girders, snooper.	●●	Accessible box girders, snooper.
	Frequency	••		••		••		••		••		••	
DURABILITY	Protection	●●	Cable anchorages inside box.	●	Cable anchorages below deck level.	●●	Cable anchorages at deck level.	●●	Cable anchorages underneath edge girders.	●●	Cable anchorages and Delta frames below deck.	●●	Very few exposed elements.
	Replacement	••		••		••		••		••		••	
	Monitoring	••		••		••		••		••		••	
WIND RESPONSE	Structural Efficiency	••											
	Dynamic Effects	••											
SNOW & ICE RESPONSE	Bridge closures	••											
	Monitoring/Deicing	••											
COMMUNITY	Appearance/Signature	●	Visible deck grillage and bracing, numerous splices.	●	Visible deck grillage, numerous splices.	●	Visible deck grillage.	●●	Cleaner lines, no splices.	●●	Closed box, cleaner lines.	●●	Closed box, cleaner lines.
	Bike/Pedestrian Path	••											

APPROACHES		Steel Plate Girders		Concrete Bulb Tees		Single-Cell Concrete Box		Steel Tub Girders	
		Most Favorable Favorable Neutral Less Favorable Unfavorable Not Rated							
EVALUATION CRITERIA		Rating	Notes	Rating	Notes	Rating	Notes	Rating	Notes
INITIAL COST	Main Span Structure	●●●	Common bridge type, longer spans available.	●●	Less efficient system, shorter spans (125-ft).	●	Only economical in conjunction with segmental main box	●●	More complex fabrication, but cost competitive for straight highway alignment.
	Main Span Foundations	●●		●●	More foundations.	●	Heavy foundations.	●●	
	Overall	••		••		••		••	
HIGHWAY GEOMETRICS	Grade/Length	••		••		••		••	
	Footprint	••		••		••		••	
	Horizontal Tangent Length	••		••		••		••	
MAINSPAN FOOTINGS	Vessel Impact	••		••		••		••	
	Scour	••		••		••		••	
CONSTRUCTION	Phasing	●●	Can be easily accommodated.	●●	Can be easily accommodated.	●●	With two boxes.	●●	Can be easily accommodated.
	Duration	••		••		••		••	
	Constructability	●●	Typical system.	●	Typical system, transportation becomes limiting factor.	●●	Requires complex erection gantry or falsework.	●●	Typical system.
	Impact on Canal Traffic	••		••		••		••	
	Maintenance of Traffic	••		••		••		••	
	Environmental Impact	••		••		••		••	
STRUCTURAL REDUNDANCY	Fracture-Critical Members	••		••		••		••	
	Failure-Critical Members	••		••		••		••	
INSPECTION & MAINTENANCE	Access	••		••		••		••	
	Frequency	••		••		••		••	
DURABILITY	Protection	●●	Weathering steel, deck protection system.	●●	Fully prestressed girders, deck protection system.	●●	Deck prestressed in two directions, deck protection system.	●●	Weathering steel, deck protection system.
	Replacement	●●	Deck is replaceable.	●●	Deck is replaceable.	●	Sacrificial deck thickness, deck not replaceable.	●●	Deck is replaceable.
	Monitoring	••		••		••		••	
WIND RESPONSE	Structural Efficiency	••		••		••		••	
	Dynamic Effects	••		••		••		••	
SNOW & ICE RESPONSE	Bridge closures	••		••		••		••	
	Monitoring/Deicing	••		••		••		••	
COMMUNITY	Appearance/Signature	●	Utilitarian.	●	Utilitarian.	●●	Clean lines.	●●	Clean lines.
	Bike/Pedestrian Path	••		••		••		••	

APPENDIX B – MASSING STUDIES OF PROPOSED BRIDGE TYPES AND CONFIGURATIONS

The renderings show preliminary and conceptual geometry and proportions of bridge alternatives proposed for further evaluation. Further refinement and revisions will take place as the type studies progress.


PRE-DECISIONAL & DELIBERATIVE
CS1 - CABLE-STAYED
SINGLE BRIDGE - 820' SPAN
H-TOWERS


PRE-DECISIONAL & DELIBERATIVE
CS2 - CABLE-STAYED
SINGLE BRIDGE - 820' SPAN
V-TOWERS


PRE-DECISIONAL & DELIBERATIVE
CS3 - CABLE-STAYED
SINGLE BRIDGE - 820' SPAN
A-TOWERS


PRE-DECISIONAL & DELIBERATIVE
CS4 - CABLE-STAYED
SINGLE BRIDGE - 820' SPAN
Y-TOWERS


PRE-DECISIONAL & DELIBERATIVE
CS5 - CABLE-STAYED
SINGLE BRIDGE - 820' SPAN
PYLONS


PRE-DECISIONAL & DELIBERATIVE
CS6 - CABLE-STAYED
TWIN BRIDGES - 700' SPAN
H-TOWERS


PRE-DECISIONAL & DELIBERATIVE
CS7 - CABLE-STAYED
TWIN BRIDGES - 700' SPAN
A-TOWERS


PRE-DECISIONAL & DELIBERATIVE
CS8 - CABLE-STAYED
TWIN BRIDGES - 700' SPAN
MERGED A-TOWERS


PRE-DECISIONAL & DELIBERATIVE
CS9 - CABLE-STAYED
TWIN BRIDGES - 820' SPAN
H-TOWERS


PRE-DECISIONAL & DELIBERATIVE
CS10 - CABLE-STAYED
TWIN BRIDGES - 820' SPAN
A-TOWERS


PRE-DECISIONAL & DELIBERATIVE
CS11 - CABLE-STAYED
TWIN BRIDGES - 820' SPAN
MERGED A-TOWERS


PRE-DECISIONAL & DELIBERATIVE
BG1 - POST - TENSIONED BOX GIRDER
TWIN BRIDGES - 734' SPAN
VARIABLE SOFFIT


PRE-DECISIONAL & DELIBERATIVE
TA1 - TIED ARCH
TWIN BRIDGES - 700' SPAN
BASKET HANDLE RIBS


PRE-DECISIONAL & DELIBERATIVE
TA2 - TIED ARCH WITH DELTA FRAME
SINGLE BRIDGE - 700' SPAN
VERTICAL RIBS


PRE-DECISIONAL & DELIBERATIVE
TA3 - TIED ARCH WITH DELTA FRAME
TWIN BRIDGES - 700' SPAN
VERTICAL RIBS


PRE-DECISIONAL & DELIBERATIVE
TA4 - TIED ARCH WITH DELTA FRAME
TWIN BRIDGES - 700' SPAN
BASKET HANDLE RIBS


PRE-DECISIONAL & DELIBERATIVE
TA5 - TIED ARCH WITH DELTA FRAME
TWIN BRIDGES - 820' SPAN
VERTICAL RIBS


PRE-DECISIONAL & DELIBERATIVE
TA6 - TIED ARCH WITH DELTA FRAME
TWIN BRIDGES - 820' SPAN
BASKET HANDLE RIBS

Appendix B Cape Cod Bridge Replacements Constructability Assessment



CAPE COD BRIDGE REPLACEMENTS

Constructability Assessment

PREPARED BY HNTB FOR massDOT Massachusetts Department of Transportation 2021

Cape Cod Bridges – Constructability Assessment

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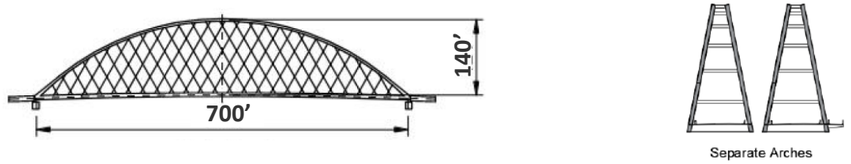
Appendix A – Fabrication Site Screening
Appendix B – Site Visit Memo

1 INTRODUCTION

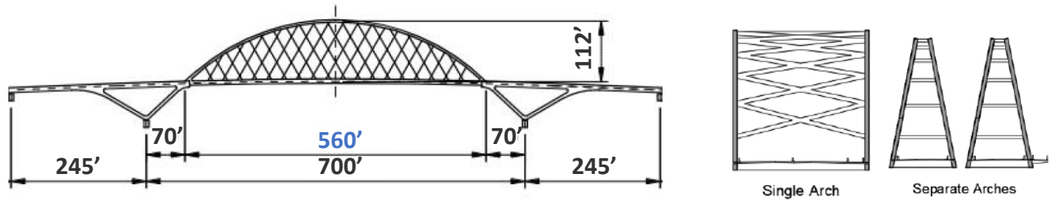
The existing Cape Cod Bridges have reached the end of their useful economic life and need replacement. In an initial screening study, documented in a separate report, a large number of bridge design parameters and bridge types were evaluated systematically in order to arrive at a selection of feasible and favorable options for replacement bridges. The initial selection included cable-stayed, haunched concrete box girder, and tied arch bridges. As part of a second phase of screening, the initially recommended alternatives were tested against highway design constraints which disfavored the haunched concrete box girder type. The remaining feasible alternatives were then evaluated in greater depth for constructability, as documented in the present report.

2 REPRESENTATIVE CONFIGURATIONS

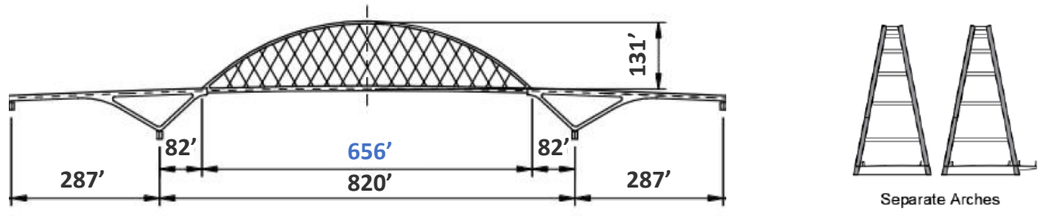
To focus the scope of the constructability review, several configurations were identified which collectively represent the range of parameters across the feasible alternatives.



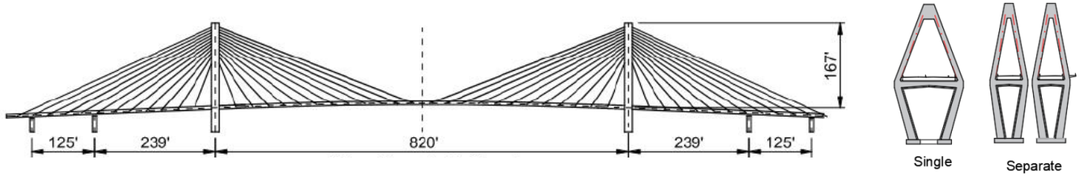
a) Tied Arch on Straight Piers; Twin Arches; 700' Main Span



b, c) Tied Arch on Delta Frame Piers; Single or Twin Arches; 700' Main Span (560' Arch Span)



d) Tied Arch on Delta Frame Piers; Twin Arches; 820' Main Span (656' Arch Span)



e, f) Two-Tower Cable Stayed; Single or Twin Towers; 820' Main Span

Fig. 2.1 – Representative configurations for constructability evaluation

This report evaluates the six configurations shown in Figure 2.1 for various aspects of constructability, including: fabrication, material transport, erection methodology, and impacts to canal and canal-side traffic. Additional discussion of site conditions and demolition approach is also included. For the purposes of this evaluation, no distinction was made between the Sagamore and Bourne bridges; the analysis presented here at this level of conceptual design applies to both except for specific site conditions as noted.

For the tied arch options, there are two configurations. The traditional system uses vertical piers with the arches supported on top of these piers (Figure 2.1a). Alternatively, with the delta-frame arrangement the approach spans cantilever into the main span, thus shortening the length of the actual tied arch, albeit at the expense of a more complex approach span structure (Figures 2.1b-d).

3 SITE CONDITIONS

3.1 Location and Access

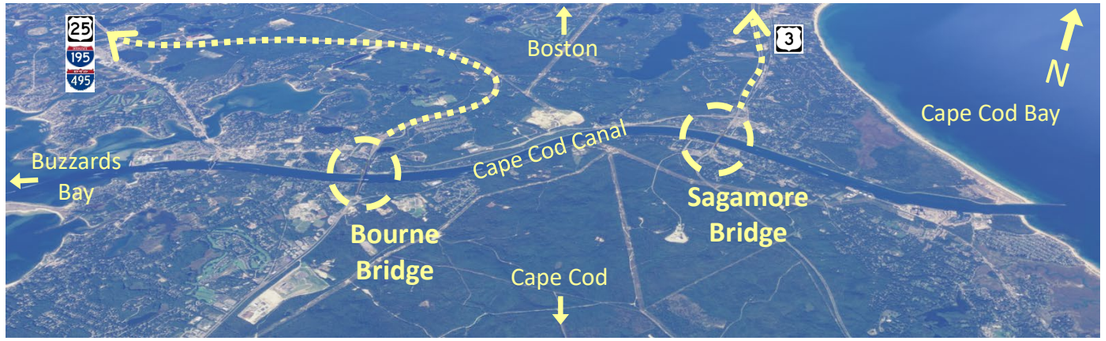


Fig. 3.1 – Site location

The Cape Cod Bridges span the Cape Cod Canal which connects Cape Cod Bay on the east with Buzzards Bay on the west. Both crossings service state routes with accessible connections to Interstates I-195 and I-495. The approaches on each shore are connected by service roads: Route 6 on the north, and Sandwich Road on the south. Existing approach ramps and local roads can accommodate typical truck traffic for material deliveries. Over-length permit vehicles may be restricted from specific movements due to tight radius and/or grade changes, however the combination of twin spans and service roads generally provides an alternate movement which is less restrictive.

The Bourne and Sagamore bridges provide the only vehicular access from mainland Massachusetts to Cape Cod. The crossings are utilized by nearly 215,000 year-round residents, as well as a 300% population increase at the peak of summer tourism between Memorial Day and Labor Day. Traffic during the summer months can be severe including multi-hour backups, and any lane closures or work zone restrictions will exacerbate conditions. Concrete deliveries to site will need to account for potentially significant traffic delays.

3.2 Canal

The Cape Cod Canal is a seven-mile-long artificial waterway originally constructed in 1914 and maintained and operated by the US Army Corps of Engineers (USACE). The canal navigational channel is 480’ wide with a nominal draft depth of 32’ at mean low water maintained by regular dredging. The canal features a strong 6-knot tidal current which reverses direction every 6 hours with only 15 minutes of slack tide in-between (see Figure 3.2). The canal is utilized year-round by over 21,000 recreational and commercial vessels, of which over a quarter were ships of more than 65’ in length carrying almost 7 million tons of cargo. There are three spans crossing the canal: the Bourne and Sagamore vehicular bridges, and the Cape Cod Canal Railroad Bridge at the west end. All three existing bridges maintain 135’ of vertical clearance at MHW (mean high water). Design criteria for the new bridges will require maintaining the existing horizontal and vertical clearances, as well as accommodating future sea rise.

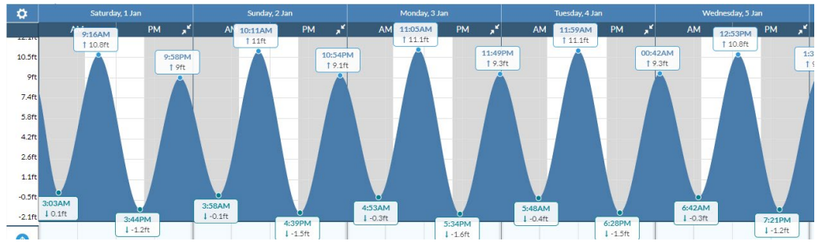


Fig. 3.2 – Sample tide chart for Cape Cod Canal

Canal traffic operates in both directions. Reductions in navigable width due to construction activities may require the canal to institute alternate one-way operation at the construction sites. USACE prefers short-term canal closures over long-term operational restrictions in the channel. Traffic conditions on the canal present a risk of impact to any in-water equipment or falsework within or adjacent to the navigable channel. Long-term obstruction of the canal will amplify this risk.

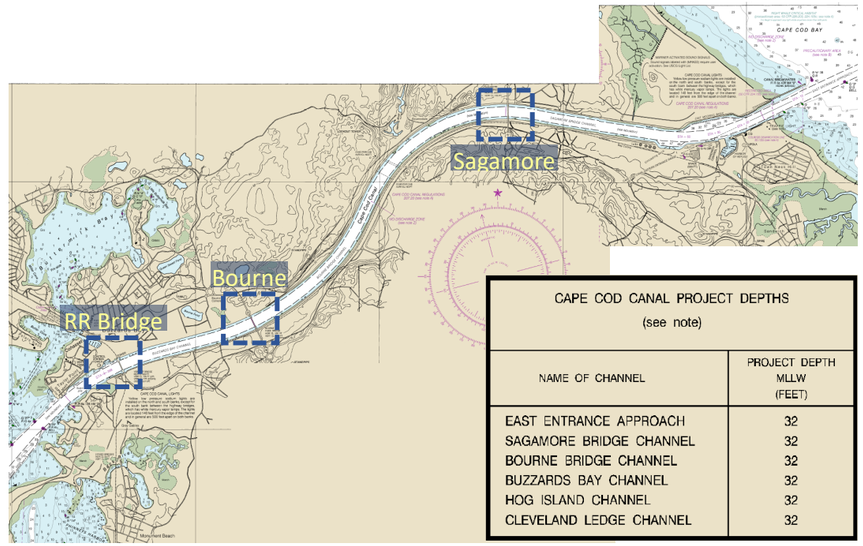
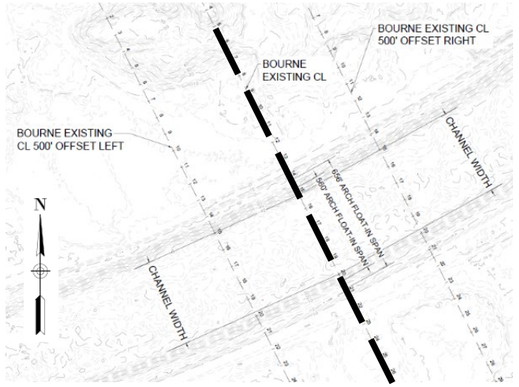
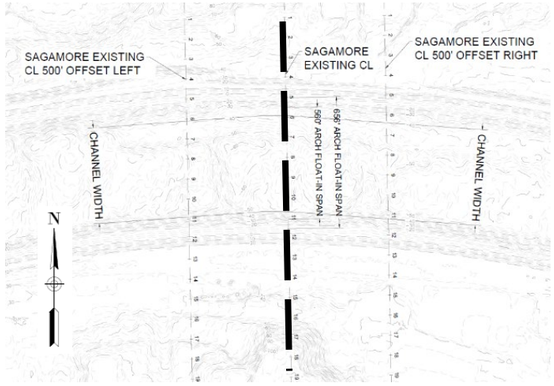
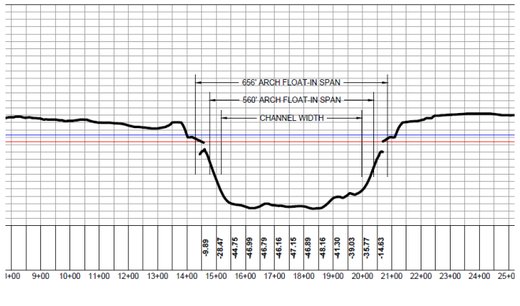


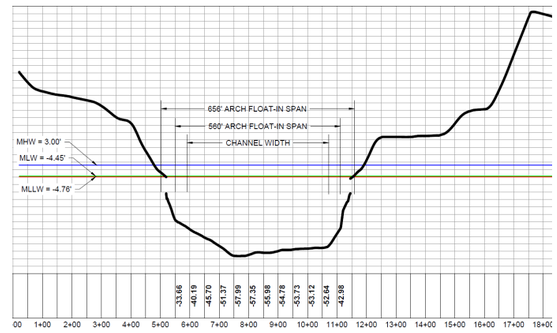
Fig. 3.3 – NOAA soundings chart for Cape Cod Canal







a) Bourne Bridge existing alignment



b) Sagamore Bridge existing alignment

Fig. 3.4 – Canal Bathymetry

3.3 Shore

Both shores of the canal feature significant residential and commercial utilization, with remaining undeveloped parcels held as preserve land by a combination of state parks, conservation trusts, and federal agencies. USACE holds a right-of-way full length of the canal and maintains service roads on both sides of the canal to facilitate riprap maintenance. The service roads are open to public access and there is significant use by local residents and visitors for walking, running, fishing, and biking. Multiple canal access points have been developed into recreation areas, including one at each existing bridge, and there is a campground east of the Bourne bridge.



Fig. 3.5 – Mass Coastal Railroad

Topographically, the north bank features a significant bluff which rises just past the service road. On the south bank, the Mass Coastal Railroad runs full length of the canal from the Cape Cod Railroad Bridge on the west end to the Sandwich Marina on the east end. The railroad operates daily refuse trains on the tracks and passenger rail service on the weekends, including service to the Bourne station located at the Bourne Recreational Area below the bridge.

The shoreline of the canal is protected by roughly 50’ of riprap outside the navigation channel. There are no existing bulkhead or mooring facilities along the canal in the vicinity of the bridges. It will be challenging for a land-based crawler crane to reach across this region to receive material deliveries via water without modifying the shore to facilitate access (e.g. finger piers or dredging).

At the existing Bourne bridge, there is a drainage outfall on the north shore. It is anticipated this outfall will require reconstruction or relocation as part of the revised drainage scheme.



Fig. 3.6 – Existing drainage outfall and riprap

3.4 Wind

The siting of the Canal between Cape Cod Bay and Buzzards Bay combines with the topography to generate significant wind conditions at the project site. Cape Cod is subject to significant coastal storms including hurricanes (e.g. Henri in Aug 2021) and Nor’easters (typically 2-5 per winter). To mitigate the risk associated with extreme weather or wind events, a design and erection strategy which minimizes the time the structure is vulnerable during erection is preferred.

Over the past decade, sustained wind speeds of 20mph or greater have been recorded on approximately 10% of days during the winter months (October through April). Gusts exceeding 40mph occur regularly. These wind conditions may present a challenge for the use of tall cranes—whether ground, barge, or tower based. These cranes generally have a safe operational wind ceiling of 25mph, implying frequent loss of use would be expected at this site. A site-specific meteorological study is strongly recommended to establish wind parameters for both permanent design and construction loading at bridge height.

Wind interaction between adjacent structures is also a consideration, either between a new structure and the existing bridge, or between two new twin structures. Vortex shedding and other aeroelastic effects should be carefully evaluated for both the permanent condition and for all intermediate stages of construction.

4 FOUNDATIONS

4.1 Layout and Service Road Impacts

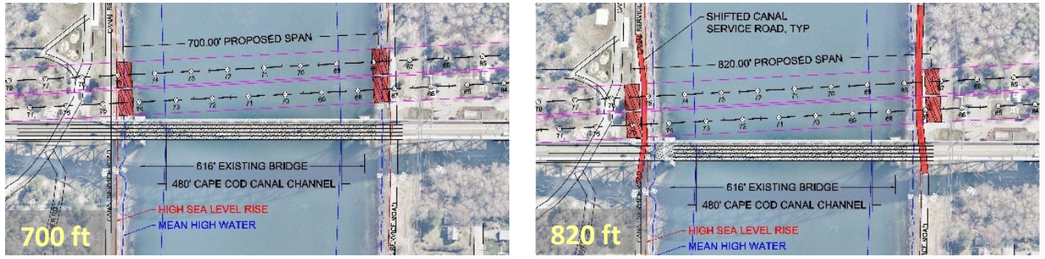


Fig. 4.1 – Footing Layout for 700’ and 820’ Spans

The initial selection process identified 700’ and 820’ span lengths as preferred for footing placement as these layouts do not impact navigational clearance of the canal. A 700’ span places footings at the waterline adjacent to the service road. The longer 820’ span extends the footings outward and requires shifting the service road to fall

between the new footings and the waterline. Construction will require temporary closure of public access to the existing canal service roads along each bank. Access will be maintained for USACE to perform riprap and lighting maintenance.

4.2 Deep Foundations

The new crossings will require deep foundations. Information from the area's Geology, visual record of the Cape Cod Canal's construction, and the 1934 USCOE plans of the existing Cape Cod bridges, show the probable existence of very large boulders at various locations and different depths at the site.

Consequently, a Pilot Geophysical Survey was conducted at the existing bridges' canal-piers and abutments to uncover the subsurface soil and bedrock profile, and to detect and locate possible boulders and boulder layers that could impact the construction of the new bridge's sub-structures. The Geophysical exploration, using Ground Penetrating Radar (GPR), determined that Boulders are present in the subsurface at depths of 2 to 35 feet below ground surface and that Boulder layers could be present at depths greater than 35 feet. The exploration concluded that the depth of competent bedrock varies between 87 and 196 feet below ground surface. The overburden is composed of surficial fill above thick layer of Sand and Gravel.

The next phase consists of conducting a Pilot Subsurface Exploration program with the intent to gain a more detailed outline of the underground elements (such as soils type / profile, groundwater levels, bedrock's type / condition) as well as to confirm the existence, location, depth, and configuration of boulders as detected by the Geophysical Survey. This information is critical for the conceptual design of the foundation, as boulders would be an obstacle to the installation of cofferdams and deep foundation. While Drilled Shafts and drilled Micro Piles can be installed through boulders with special tools, boulders are an impediment to Driven Piles unless an extensive pre-drilling system is used.

Later, at the Sketch Plan phase, there will be a more typical full boring program once final locations of structures and roadways have been determined. Also, MassDOT Geotechnical had suggested to initiate, during the pre-construction phase, a "Pilot Load-testing Program" to check applicable type and length of driven piles, thus providing data for Contractors, mitigating potential extra-work orders, and saving both schedule and cost for the final project.

4.3 Footing Construction

Based on the water table and preliminary stratigraphy, a perched footing on land is not viable. As such, a cofferdam will be required for footing construction regardless of whether the footing is located on land or at the shore. Due to the existing riprap along both banks of the canal, minimal environmental impacts are anticipated in the benthic zone.

5 ARCH CONSTRUCTION

The initial screening study identified arches, and specifically tied-arch spans, as well suited to the site conditions at Bourne and Sagamore. As such, they are well represented in this report with tied arches comprising four of six concepts evaluated. Tied-arch bridges are generally constructed via one of two methodologies: in-situ piecewise erection utilizing temporary supports, or off-site fabrication of a complete arch span followed by transport and heavy lifting to install the structure in the permanent location. The following parameters are evaluated for both scenarios:

- **Navigational impacts**: Short and long-term impacts to canal operations due to temporary supports or equipment (e.g. crane barges) located in the navigable waterway. Also consider closures required for transport and lifting operations.
- **Crane requirements:** Crane reach, lifting capacity, and placement.
- **Arch aspect ratio:** Design considerations of limited arch height to span length ratio (typically 1:5 to 1:6). Arch efficiency decreases with height-to-span ratio, constraining arch rise adds cost and complexity to the design.
- **Arch rib orientation:** Vertical versus inclined (see initial screening study for additional discussion).
- **Structure width:** Floorbeam pick weight, geometry control, and transport considerations. Single versus twin structures.

Additionally, several parameters specific to off-site fabrication are considered:

- **Fabrication site:** Suitability of various local, regional, and national locations for arch fabrication.
- **Clearance envelope:** Bounding box for transport to verify vertical and horizontal navigational clearances.
- **Lifting weight:** Steel only erection weight for heavy lifting activities.

5.1 In-Situ Erection

In-situ piecewise erection, referred to as 'stick building', is a traditional methodology for arch construction which relies on falsework to temporarily support arch members until the full span is complete. Historically, stick building has been the primary method used for steel deck and truss arches, and is still the preferred strategy for erecting tied arches with span and width configurations not amenable to a float-in approach. Falsework can be implemented as temporary piers supporting the arch tie from below, or as high towers with cable stays supporting the arch rib from above.



a) Temporary Piers **b) Cable Stay Towers**

Fig. 5.1 – Two schemes for temporary support during arch erection

Temporary piers are typically located at quarter-span points to support temporary struts holding the arch ribs, which would reduce navigational clearance from 480' to 410' for an 820' span. These piers and struts are required for a significant portion of arch span erection, and as such, would represent a long-term impact to navigational clearance. Spacing of temporary piers can reasonably be increased to maintain the existing 480' navigational clearance, however this increases the strut angle and may result in uplift requiring hold-downs during erection. It is important

to recognize that the risk of vessel impact remains if temporary piers are just outside the navigation channel. Temporary fendering or other means of pier protection would introduce significant expense and complexity.

Cable-stayed high tower falsework utilizes tall temporary towers located at each end of the span to support the arch rib and, via hangers, the arch tie segments below. Towers are typically restrained with adjustable guys which counterbalance the increasing weight of the arch during erection. High towers have the advantage of eliminating the need for temporary piers in the channel but at the tradeoff of increased wind exposure, adding design cost and complexity and increasing risk throughout the duration of arch erection. Vertical arch ribs are strongly preferred with a high tower erection scheme as inclined 'basket-handle' ribs result in challenging cable geometry.

For all stick-building schemes, single full-width arches will be more challenging to erect than twin independent structures: a single arch will require large floorbeams with considerable pick weights and in general it will be more challenging to control geometry on the larger structure. Both single and twin structures will require very large cranes or dual crane picks due to the required boom extension to set upper arch segments. High winds may restrict operation of tall cranes. Crane and service barges will present an ongoing navigation obstruction and impact risk throughout the duration of arch erection.

5.2 Float-in Erection

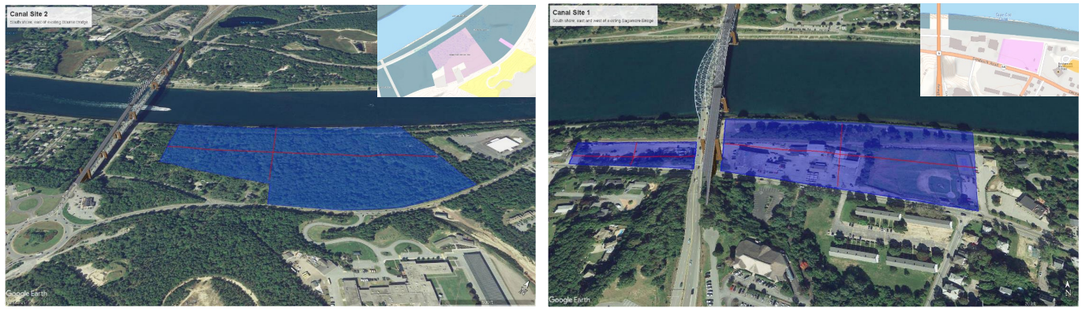
An alternate approach to in-situ construction is to fabricate the arch span offline of the permanent alignment, then transport it to the final installed position. Where site conditions permit arch construction adjacent to the final alignment, transport may be achieved by launching on rollers or via self-propelled modular transports (SPMTs), however most offsite construction strategies for water crossings require at least a short-distance transport over water via barge.

Tied arches are well suited to float-in strategies as the arch is self-supporting and stable for transport once assembled. To minimize transport and lifting weight, arches are transported as steel-only with a precast or cast-in-place concrete deck placed after the arch is installed. Arches can be constructed directly on a moored barge or constructed on land and transferred to a barge via SPMT for transport. Loading or constructing an arch on a barge requires a suitable slip or bulkhead with sufficient length, draft, and load capacity to support heavy equipment. Temporary mooring facilities can be constructed if no suitable facilities exist, however the cost and environmental impacts of in-water construction required to construct a temporary mooring facility should be carefully considered when evaluating a site.

5.2.1 Fabrication Sites

In assessing potential arch fabrication sites, the first locations evaluated are those directly adjacent to the proposed bridge alignment. These locations do not require complex open-water transport and offer the benefit of concentrating work activities local to each structure. An evaluation of various strategies for fabrication local to the sites found the following:

- A longitudinal construction and launch strategy along or parallel to the existing alignment is precluded or cost prohibitive due to site topography.
- Construction adjacent to each alignment is constrained by topography on the north shore. Two potential fabrication areas were explored on the south shore (see Figure 5.2), but they were found to be impractical due to extensive residential and commercial development and extensive conservation land. Additionally, the Mass Coastal Railroad track runs parallel to the south shore approximately 100' inland, which would bisect any likely work sites presenting logistical and safety challenges.
- Construction on the canal shore adjacent to the alignment requires a bulkhead or other mooring facility which does not currently exist along the canal. The canal bathymetry features a shallow zone along the shore lined with riprap. Mooring facilities would require either dredging or extension of a pier into the canal to provide sufficient draft for barge operations. Construction of these facilities at Borne and Sagamore would be costly, create a long-term reduction in navigational width for the canal, and is not recommended within the environmentally sensitive region of the canal and shoreline.



a) Bourne Bridge Area **b) Sagamore Bridge Area**

Fig. 5.2 – Potential local fabrication sites along canal

With no viable candidates for fabrication sites found along the canal, we next explore regional opportunities along the Massachusetts coastline and connected waterways. Regional sites will require transport of the assembled arch across open water via barge. This report does not seek to make a specific recommendation for selection of a construction yard, but rather to demonstrate that suitable regional sites exist. Screening of potential construction yards considers the following parameters:

- Distance from the canal
- Horizontal and vertical clearances of existing bridges and structures along travel route
- Availability of bulkhead with deep draft for barge access
- Access to rail and interstate for material delivery
- Commercial availability
- Site conditions and required improvements

Three candidates were identified within 75 NM (nautical miles) of the canal which satisfy the screening parameters: an existing commercial heavy-lift construction facility inside the New Bedford hurricane protection barrier, the decommissioned Somerset Power plant on the Taunton River, and mooring slips on the Weymouth Fore River attached to the Jay Cashman Corporation Marine Facility and to a commercial auto lot.



Location		Distance	Horizontal Clearance		Vertical Clearance	
			Width	Feature	Height	Feature
A	New Bedford Heavy Lift Construction Facility	21 NM	150‘	New Bedford Hurricane Barrier	135‘	Canal Bridges
B	Somerset Power LLC (Decommissioned)	64 NM	98‘	Brightman St Bridge (Decommissioned)	135‘	Charles M Braga Jr Bridge
C	Weymouth Fore River Slips	50 NM	250‘	Fore River Lift Bridge	135‘	Canal Bridges

Fig. 5.3 – Regional fabrication sites and controlling navigational clearances

The table above lists the controlling horizontal and vertical clearances (at MHW) for features along the anticipated travel route for each location. Vertical clearance at the existing canal bridges, including the railroad lift bridge, is 135’. As discussed in the section below on barges, freeboard requirements for operations in the canal differ from open water operations, and accordingly total transport height should be evaluated independently for each feature. For detailed screening information on these sites and others evaluated, see Appendix A.

While viable regional candidates for fabrication sites were identified, we also consider options further afield in the interest of encouraging competitive bidding by experienced fabricators and erectors. Further north along the coast there are promising sites in Portsmouth, NH and Portland, ME. At a national level, it is feasible to fabricate the arch spans at a specialty construction yard anywhere in the country accessible via commercial shipping. Past projects in the region have utilized structural steel from yards sited along the east coast, inland waterways, or even the west coast with navigation via the Panama Canal.

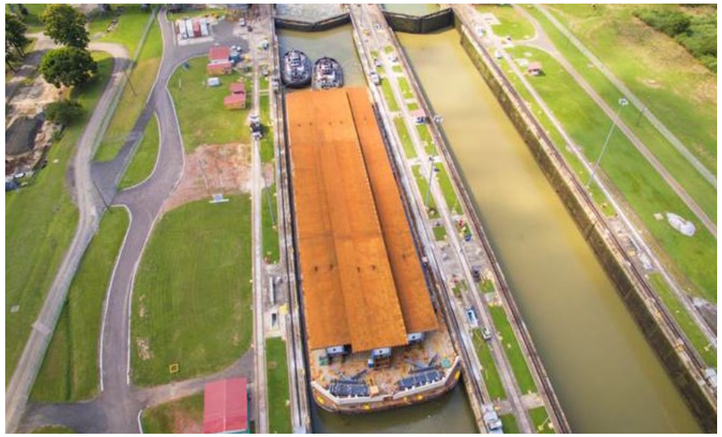


Fig. 5.4 – Wittpenn Bridge girders in the Panama Canal

As an example: the recently completed Wittpenn Bridge in Jersey City, NJ was fabricated in Portland, OR and shipped as five large pieces via barge through the Panama Canal. Consideration of faraway fabrication sites should balance the economic and technical benefits offered by these locations against increased cost and risk of long-distance open-water transport.

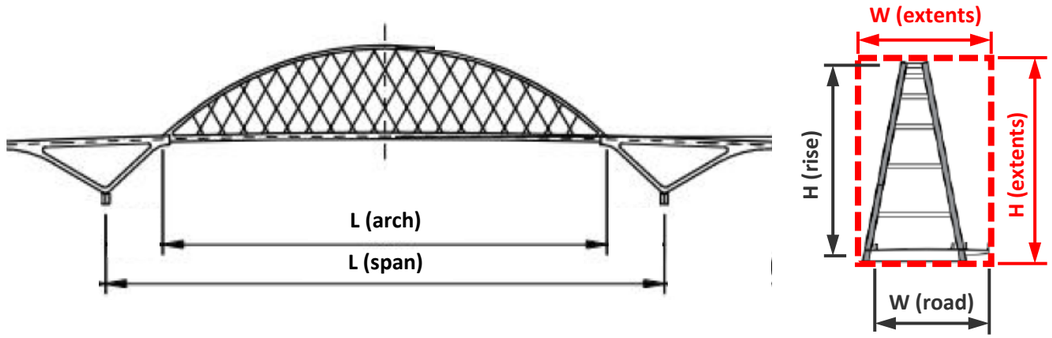
5.2.2 Transport Considerations

The following considerations on arch transport via barge are provided for informational purposes and should be considered neither complete nor authoritative. An experienced erection and marine transport engineer shall be engaged for all aspects of design related to marine transport.

To assess barge sizing and evaluate horizontal and vertical clearances along proposed navigational routes, the height, width, and weight parameters in Fig 5.5 are used. Key assumptions include a ratio of arch span to rise between 5:1 and 6:1, out-to-out limit for structure height 7’ greater than the nominal rise (from centerline of arch and rib), out-to-out limit for structure width 12’ greater than the nominal roadway width, and lift weight represents steel only approximated by multiplying the deck area (excluding sidewalks) by 120psf.

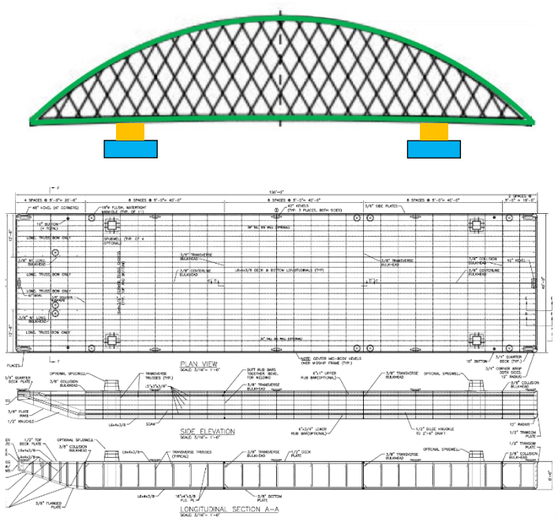
For structure configurations with the shared use path located outside the cable plane, transport width can be reduced by erecting cantilevered walkway floorbeams after the arch has been delivered to site.

Barge selection and layout requires balancing various parameters including load, required freeboard (height between waterline and deck), and stability against overturning. Barges can be oriented parallel or orthogonal to the longitudinal axis of the arch, and multiple barges can be ganged together with struts to carry large loads or improve handling characteristics. Some barges are designed with raked (inclined) bows for hydrodynamic efficiency or include spudwells for mooring against movement due to currents. Barges in the size range of 240’-300’ long by 70’-100’ wide are widely used and generally available. Large ocean-going barges up to 360’ x 120’ are also available. See figure 5.6 for example barge sizes and configurations.

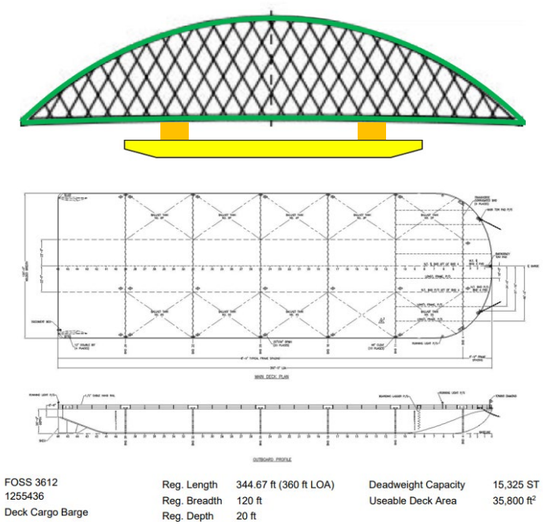


Configuration	Arrangement	Span Length	Arch Length	Arch Rise	Road Width	Height	Width	Lift Weight
Tied Arch on Straight Piers	Twin Arches	700'	700'	117'-140'	73'	124'-147'	85'	5,000 kips
Tied Arch on Delta Frame Piers	Single Arch	700'	560'	93'-112'	129'	100'-119'	141'	8,500 kips
Tied Arch on Delta Frame Piers	Twin Arches	700'	560'	93'-112'	73'	100'-119'	85'	4,000 kips
Tied Arch on Delta Frame Piers	Twin Arches	820'	656'	109'-131'	73'	116'-138'	85'	4,500 kips

Fig. 5.5 – Clearance parameters and lift weights for representative arch configurations (delta frame shown)



a) Twin 150’ x 40’ deck barge with spudwells oriented transversely to span for canal operations



b) Single 360’ x 120’ deck barge oriented parallel to span for deep water operations

Fig. 5.6 – Example barge sizes and configurations

Freeboard requirements change based on operating environment: 2’-3’ is recommended in the canal depending on speed and traffic conditions, while open-water operations require 6’-7’. As a rule, barge capacity decreases as freeboard increases. Arches will require cribbing to distribute the load and facilitate loading and unloading, typically a minimum of 6’-8’ in depth. Freeboard requirements and cribbing depth must be considered when establishing the total transport height for vertical clearance checks.

Barge stability is a function of the relationship between the center of gravity, the center of buoyancy, and the metacentric height relating the two as a barge rolls. Practically this signifies that as the height of the arch’s center of gravity above the waterline is increased, barge stability decreases, and a larger barge is required to safely carry the load.

Tied arches are designed to be vertically supported at the ends of each span where the arch forces naturally resolve. Transport via barge generally requires arches to be temporarily supported elsewhere along the tie (e.g. at quarter points), which forces the tie to carry the rib in bending as a cantilever. Compression struts installed between rib and tie over the intermediate point of support provide an alternate load path during the temporary condition (see Figure 5.7). Strut placement and orientation should be optimized to both minimize rib and tie bending, and to ensure load is not relieved from the suspenders.

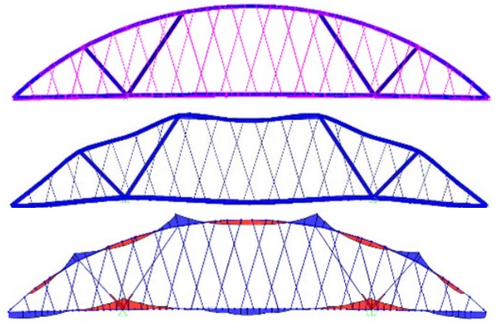


Fig. 5.7 – Temporary strut optimization

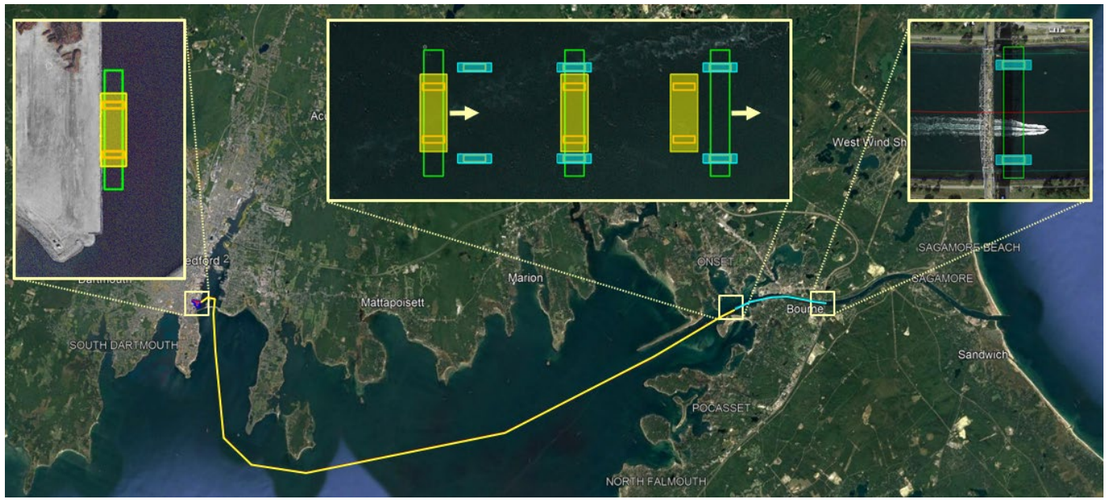


Fig. 5.8 – Conceptual barge transfer between ocean-going (yellow) and canal operations (blue)

The significant 6-knot current which reverses every 6 hours will present a challenge to barge handling in the canal. If a large barge oriented longitudinally to the structure is used for deep-water transport, rotating that same barge across the canal to position the arch for erection will present a large cross section to the canal flow. Fine positioning control in these circumstances may be difficult to achieve with tugs alone. Use of smaller barges ganged together

and oriented transversely to the arch span could mitigate this risk by aligning the barges with the current during erection to improve hydrodynamic performance. It is also feasible to utilize a large barge oriented parallel for open-water transport, then transfer the arch to smaller orthogonal barges to facilitate precision handling within the canal (see Figure 5.8). It is anticipated that any transfer operations would be conducted within sheltered waters and off the main navigational channel. Alternately, a strategy employing winches anchored to dolphins on either side of the canal and span could provide external reaction points to permit fine geometry control.

5.2.3 Erection Considerations

There are a variety of established lifting approaches available to erect a tied arch which has been floated-in, however not all are suitable for the site conditions at Bourne and Sagamore. In particular, the significant height of the final alignment over the water to provide the required vertical clearance will necessitate lifting the arch over 140'. Pier type is a second consideration for lifting strategy, as straight piers require the arch to be lifted offset from the final alignment to a sufficient height to clear the pier caps before it can be translated into position and set in place. In contrast, delta frame girders which cantilever from the piers over the channel permit direct vertical lifting to the final position as there are no interfering elements (see Figure 5.11 and additional discussion below).

Looking at lifting strategies for non-delta frame piers, the question becomes how lifting and transport of the arch span are sequenced. One approach is to construct the arch on fixed shoring towers at the elevation of the final alignment. This has the advantage of simplifying jacking procedures as only a few feet of travel are required to lower the structure onto the pier caps. However, the high elevation of the arch metacenter above the waterline limits transport to very short distances due to barge stability limits. This requires the arch to be constructed along the canal directly adjacent to the final alignment which precludes a high tower strategy at Bourne and Sagamore.





Fig. 5.9 – Broadway Bridge in Little Rock, AK being floated-in on high shoring towers from adjacent erection site

A second lifting strategy utilizes self-erecting jacking towers to raise the structure from below. This approach enables the arch metacenter to remain much closer to the water during transport improving barge stability characteristics and enabling longer distance and open-water operations. Once the arch is in position adjacent to the final alignment, progressive lift jacking towers are used to sequentially raise the arch in small increments, adding segments to the shoring towers as the height increases. The progressive lift systems are complex custom machines which are currently only available from providers in the EU (e.g. Mammoet, Fagioli). The exclusiveness and complexity of these systems can result in high cost and difficulty obtaining schedule commitments for availability. Additionally, based on past projects, the required lift height is anticipated to be at the extreme range of stability for currently available jacking systems and would likely require multiple towers per corner to ensure adequate factors of safety. As such, progressive lift is not a recommended strategy for arch erection at this site.





Fig. 5.10 – Wellsburg Bridge in Wellsburg, WV being raised on progressive lift jacking towers

Cranes and hydraulic strand jacks on gantries have also been utilized for lifting of arches onto non-delta piers from above, however the span length and required lift height at Bourne and Sagamore would require large and expensive falsework towers or a complex coordinated pick with up to four cranes simultaneously. These approaches are not recommended due to the cost and associated risk.

With delta frame girders, the support point for the tied-arch span is located over the navigable channel enabling use of a direct lift approach with hydraulic strand jacks. Strand jacks are a type of linear winch where a bundle of cables is guided through a hydraulic cylinder and gripped above and below with anchor wedges. Stroking the cylinder while grips are alternately engaged achieves a sequential lifting or lowering motion with essentially no limits on total lift height. This lifting strategy is well established in industry and utilizes hardware developed for post-tensioning and stay cable stressing.





Fig. 5.11 – Lake Champlain Bridge in Crown Point, NY being lifted by hydraulic strand jacks from delta frames

Strand jacks typically enable lifting at a rate of 10'-20' per hour, with the considerable advantage that once lifting begins, load is immediately transferred to the permanent structure and the erection procedure no longer requires

barges for support or stability. Speed of erection aligns with USACE preference for short-term canal closures over long-term operational impacts. It also mitigates the time-dependent risk of high winds during vulnerable construction stages. As an example, the Lake Champlain Bridge between NY and VT was erected using strand jacks on August 26, 2011, the day before hurricane Irene struck the region. Lifting was completed in 16 hours, at which point the arch was secure in the final stable configuration and able to safely weather the storm.

Design of the delta frames should be sensitive to barge sizing and placement limitations to facilitate transfer and lifting. Due to the need for the end floorbeam and knuckle of the arch to pass through the delta frame, attention must be paid to detailing of the interface between the two components. A strategy successfully utilized on previous delta girder arches holds back segments of the delta girder end beam to leave openings for arch passage. The missing end beam segments are then lifted with the arch span and spliced before the arch is released from the jacks onto permanent bearings.

For the specific site conditions at the Bourne and Sagamore Bridges, all approaches evaluated for lifting of tied arches onto straight piers have substantial drawbacks. In contrast, a cable lifting strategy from delta frame girders appears well suited to the site constraints.

6 CABLE STAY CONSTRUCTION

In addition to arches, the initial screening study determined that a cable-stayed bridge is also suited to the site conditions at Bourne and Sagamore. It is anticipated that construction of a cable-stayed bridge would be performed either as balanced-cantilever erection (deck advanced symmetrically from each tower) or as progressive construction (back span on shoring, main span as cantilever).

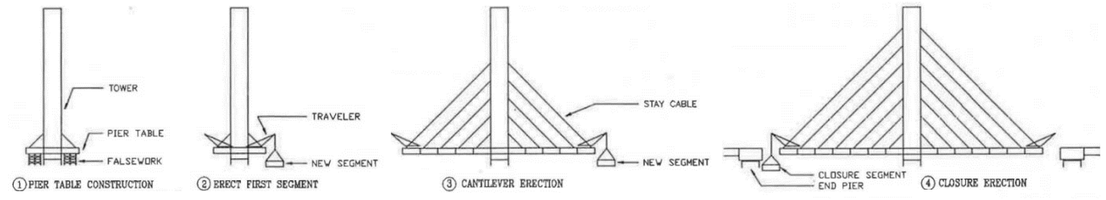


Fig. 6.1 – Typical stages of balanced-cantilever erection

This balanced-cantilever approach (see Figure 6.1) begins with construction of the permanent towers, followed by erection of tower deck segments on ground-supported or pier-supported falsework, commonly referred to as the pier table. There is a preference for span lengths which enable pier table construction from land. From the pier table, the deck is erected segmentally on each side of the tower in a balanced sequence which minimizes load unbalance and longitudinal bending in piers and foundations. Stays are installed as the deck is progressed, resulting in a structure that is self-supporting and can also support erection equipment and construction materials on the cantilever. Balanced cantilever construction is suitable for both precast concrete segmental and steel edge girder superstructures, however the initial screening study identified a preference for open steel edge girders.

With progressive construction, first the back spans are erected on shoring towers, followed by successive installation of shorter main span segments that cantilever over the river span. This method is advantageous if it is desired to deliver materials via the approach and along the previously erected bridge.

Material delivery and handling is a key consideration for balanced cantilever erection. Deck girders and floorbeams are traditionally picked and set from directly below the tip of each cantilever by either deck-mounted derricks or large ground and barge-mounted cranes. Use of large barge-mounted cranes is not preferred as they will present an ongoing navigation obstruction and impact risk throughout a significant portion of the construction duration. Deck-mounted derricks also require service barges to deliver material which will intermittently obstruct the channel.



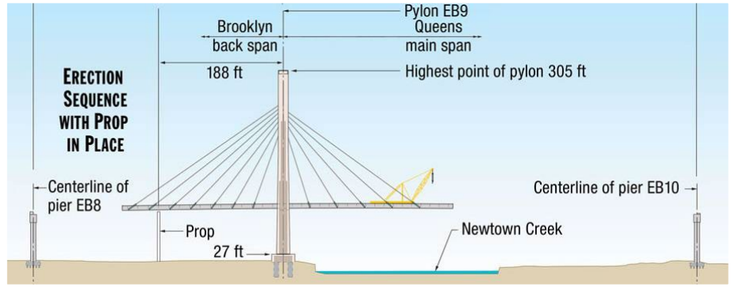


Fig. 6.2 – Construction of the Kosciuszko Bridge in Brooklyn, NY using a stiff-leg derrick to transport materials across the deck

An alternate strategy is to feed all materials from the shore-side cantilever using a truck or stiff-leg derrick on deck to transport materials to the water-side cantilever. This approach eliminates the need for crane and service barges in the channel, however it requires installation of a temporary or permanent prop in the back span to control deflections and stresses resulting from the moving loads. As an ancillary benefit, a back span prop also provides an alternate load path which can improve stability and resist wind loads during erection.

Cable-stay structures are more susceptible than arches to wind loading during construction due to the unstable double-cantilever condition that exists until closure segments anchor the spans to the approaches at each end. This intermediate erection condition often represents a controlling design case for main structural components. Tower cranes typically used for pylon erection are subject to possible frequent loss of use due to wind conditions at the site. As such, tall pylons extending above the deck may not be preferred due to the risk of delay and associated expense.

One common strategy for mitigating risk in high-wind regions is to develop contingency measures for securing the structure in the event of a hurricane or other major storm. Given the anticipated multi-year project duration required to construct two or four new crossings, it is credible to expect extreme events will occur during construction and develop mitigation measures integral with the design to maximize performance and reliability.

Finally, as with arches, single full-width cable-stay structures will be more challenging to erect than twin independent structures: a single deck will require large floorbeams with considerable pick weights and in general it will be more challenging to control geometry on the larger structure.

7 DEMOLITION

7.1 Existing Bridges

The existing Bourne and Sagamore Bridges were completed in 1935 and underwent a major rehabilitation program in the 1980s. The center spans are through arch truss suspended spans with cables suspending the roadway deck from the arch. Decks are steel grids filled with five inches of concrete and topped with a two-inch bituminous concrete surface. Channel piers are pairs of hollow concrete columns sitting on footing pedestals in the canal. Columns are tapered and joined at the top by a concrete strut.

Both bridges are functionally obsolete and rated as structurally deficient with recent inspections noting continuing deterioration of the deck, fatigue sensitive details on fracture critical members, and truss joint gusset plates with significant section loss. Existing conditions and deterioration will have to be taken into careful account in the preparation of the demolition scheme.

A review of historic photographs documenting the original erection of the canal bridges yields several insights which may inform demolition:

- Unlike many arches, the arch truss main span is largely self-supporting under selfweight. It does appear a set of props in the back spans were utilized as hold-downs based on their placement at the line of action where the upper cord projects through the back span deck truss.
- Arch truss and deck steel was erected using travelling derricks riding on the top cord of each truss plane.
- Temporary props were utilized to erect the back span deck trusses.

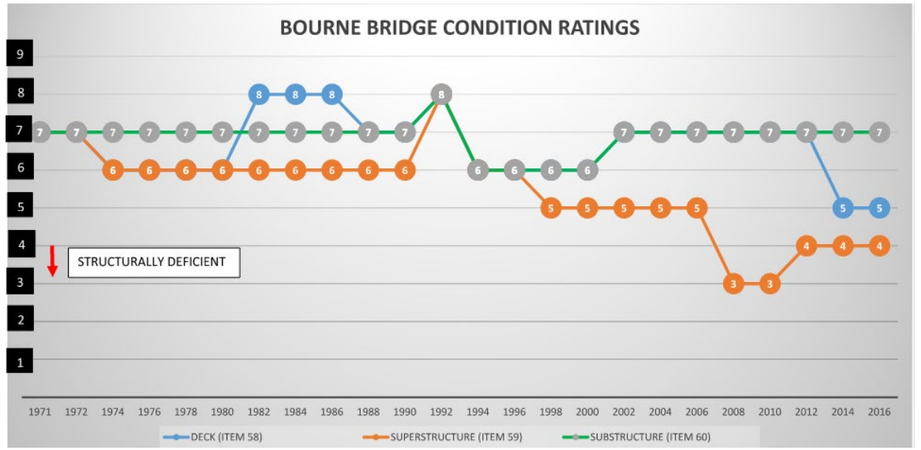


Fig. 7.1 – History of condition ratings for Bourne Bridge (FHWA)

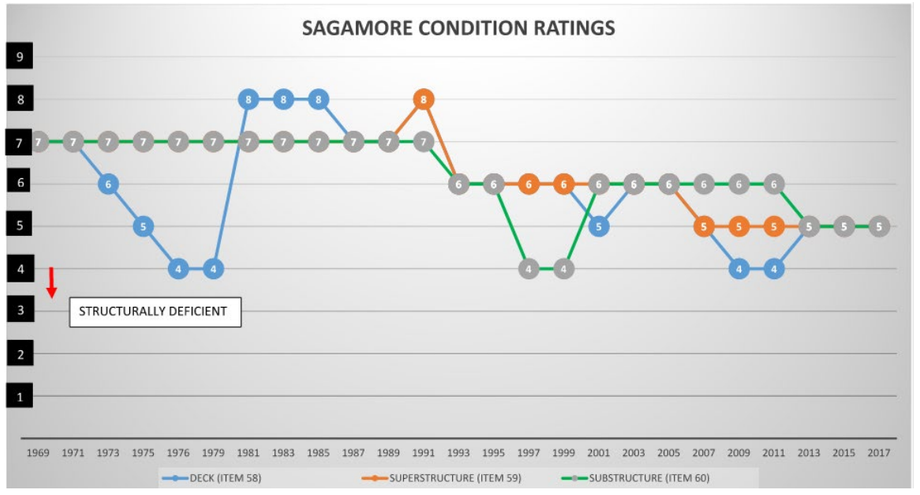


Fig. 7.2 – History of condition ratings for Sagamore Bridge (FHWA)



Fig. 7.3 – Historic photos showing erection of Bourne and Sagamore Bridges (c. 1934)

7.2 Methodology

The following considerations on demolition are provided for informational purposes and should be considered neither complete nor authoritative. An experienced demolition engineer shall be engaged for all aspects of design and planning.

It is assumed that all demolition strategies will first remove the steel grid deck and concrete infill. It may be possible to lower entire segments of the floor system to barges for removal, however deck deterioration may make this challenging. Cutting and percussive concrete removal will require shielding below the deck to capture debris and protect the navigation channel.

Demolition of the back span truss and approach deck trusses are less constrained so it is anticipated that any number of traditional demolition approaches would be suitable for these spans. Existing piers and footings should be demolished to below the mud line to remove potential navigation hazards.

Several demolition approaches for the steel arch trusses are presented below for discussion purposes:

7.2.1 Reverse Cantilever Deconstruction

Given observations regarding the original erection scheme, it appears piece-wise deconstruction of the arch trusses is feasible. This approach would essentially reverse the construction process. First, any deck framing remaining after concrete removal would be lowered onto barges, in larger segments where feasible. Next, temporary hold-downs and props would be engaged in the back spans as required to maintain stability. The arch truss would be separated into twin cantilevers and deconstructed member-by-member starting at mid-span and working toward the shore. Demolished steel would be lowered onto barges below.

Careful evaluation of the existing structure is required to establish whether it can support modern derricks on top of the arch in its current condition. If not, a large barge-mounted crane would be required to support demolition. This approach enables a high degree of control over the demolition process, but at the tradeoff of a significant duration where the structure is vulnerable, and the wind risk is amplified. Significant numbers of support barges would be required during demolition of the main span to receive deck and truss members. Additionally, attempting to reverse-engineer the construction process without plans detailing the original erection sequence adds risk. Built-up sections and gussets can hide unexpected detailing and unanticipated conditions from even a detailed visual observation.

7.2.2 Float-out

Instead of deconstructing the arch member-by-member, it should be evaluated whether a large portion of the arch truss can be removed as a single unit. This approach would require cutting the truss arch inside of the main span piers and lowering it onto barges using strand jacks or tandem cranes. The major benefit to this strategy is that it minimizes disruption to the navigational channel. Care is required when establishing cut locations to ensure the removed section remains stable as it is lowered to the barge and during transport. As with piece-wise deconstruction, the remaining cantilever portions of the arch truss would require use of temporary props in the back spans for stability.

7.2.3 Controlled Explosive Demolition

It is expected that use of explosives to drop the existing main and back spans will cause extensive and long-tern disruption of canal traffic, adverse ecological impacts, and potential damage to the canal bed. The proximity of approach spans to residential and commercial properties presents an unacceptable risk to the public. As such, explosive demolition of the Bourne and Sagamore bridges is not recommended.

8 CONSTRUCTABILITY TAKEAWAYS

8.1 Risks

Constructability review of the project site and representative configurations identified the following key risks:

- Extreme weather/wind events can reasonably be expected to occur during construction while the structure is in a vulnerable state.
- Wind interaction between structures may produce adverse aeroelastic behaviors during both temporary (new + existing) and permanent (new + new) span configurations. Cable-stayed structures are more susceptible to these effects than arches.
- Cable-stayed structures are vulnerable to wind loads during certain construction stages and cable-stayed construction operations are more affected by high-wind conditions.
- Cranes, whether tower, land, or water based, will be subject to operational limitations and impacted by frequent winds exceeding safe operational parameters.
- The canal supports sufficient vessel traffic such that barges and temporary supports in the canal are at risk for vessel impact. Objects both within and adjacent to the navigational channel are subject to this risk.
- Canal tidal currents create a challenging environment for barge operations.
- Elevation of the proposed alignment is at the limit of barge-based lifting capacity for stability.
- Cape Cod Railroad operations will constrain construction activities along south shoreline
- Deep foundations are necessary and there is a risk of encountering boulders at depth, complicating installation of piles, drilled shafts, or other deep foundation elements.
- Single deck configurations are at the limit of transportability, erectability, and interim stability. Wide decks necessitate large floorbeams, require increased crane capacity, and enhance complexity of geometry control as rotation makes field connections difficult.

8.2 Recommendations

Based on the findings of this report, the following recommendations are presented:

- Erection strategies are preferred which avoid the need for temporary piers in the water and, in general, minimize in-water work. This risk is time dependent: if barge operations or temporary piers are required, duration of navigational obstruction should be minimized to reduce the likelihood of ship impact.
- USACE prefers short-term canal closures over long-term operational restrictions in the channel.
- Material delivery via water is not recommended due to lack of existing bulkheads local to the alignments. Barges cannot moor close enough to shore for land-based crawler cranes to hoist materials without construction of in-water facilities within an environmentally sensitive area.
- Risk associated with extreme weather and wind is time dependent: bridge configurations and construction strategies which minimize the duration a structure is vulnerable during erection are preferred. A site-specific meteorological study is strongly recommended to establish wind parameters for both permanent design and construction loading.
- In contrast with cable-stayed bridge erection, float-in construction of a tied arch enables the structure to be installed as a complete, stable unit. Duration of the critical lifting operation is minimal and can easily be scheduled to take advantage of favorable weather conditions.
- No suitable arch fabrication sites exist along canal, however offsite fabrication and open-water transport is feasible.
- Twin structures offer constructability and phasing benefits over single structures due to smaller member sizes, simplified geometry control, and ability to sequence construction of new spans with demolition of existing spans.
- Tied arches on delta piers are preferred over straight piers due to simplified lifting operations and to avoid the challenge of maintaining barge stability while lifting the arch to the elevation required for installation on straight piers.
- Demolition of the existing bridges via reverse cantilever deconstruction appears feasible based on historic information.

Key takeaways:

- **For spans in the range of 700', twin tied arches on delta piers lifted using strand jacks is a configuration and erection methodology well suited to site conditions.**
- **For spans in the range of 820', twin cable-stayed bridges configurations are also well suited to site conditions but are subject to increased wind risk during construction relative to tied arches on delta piers.**

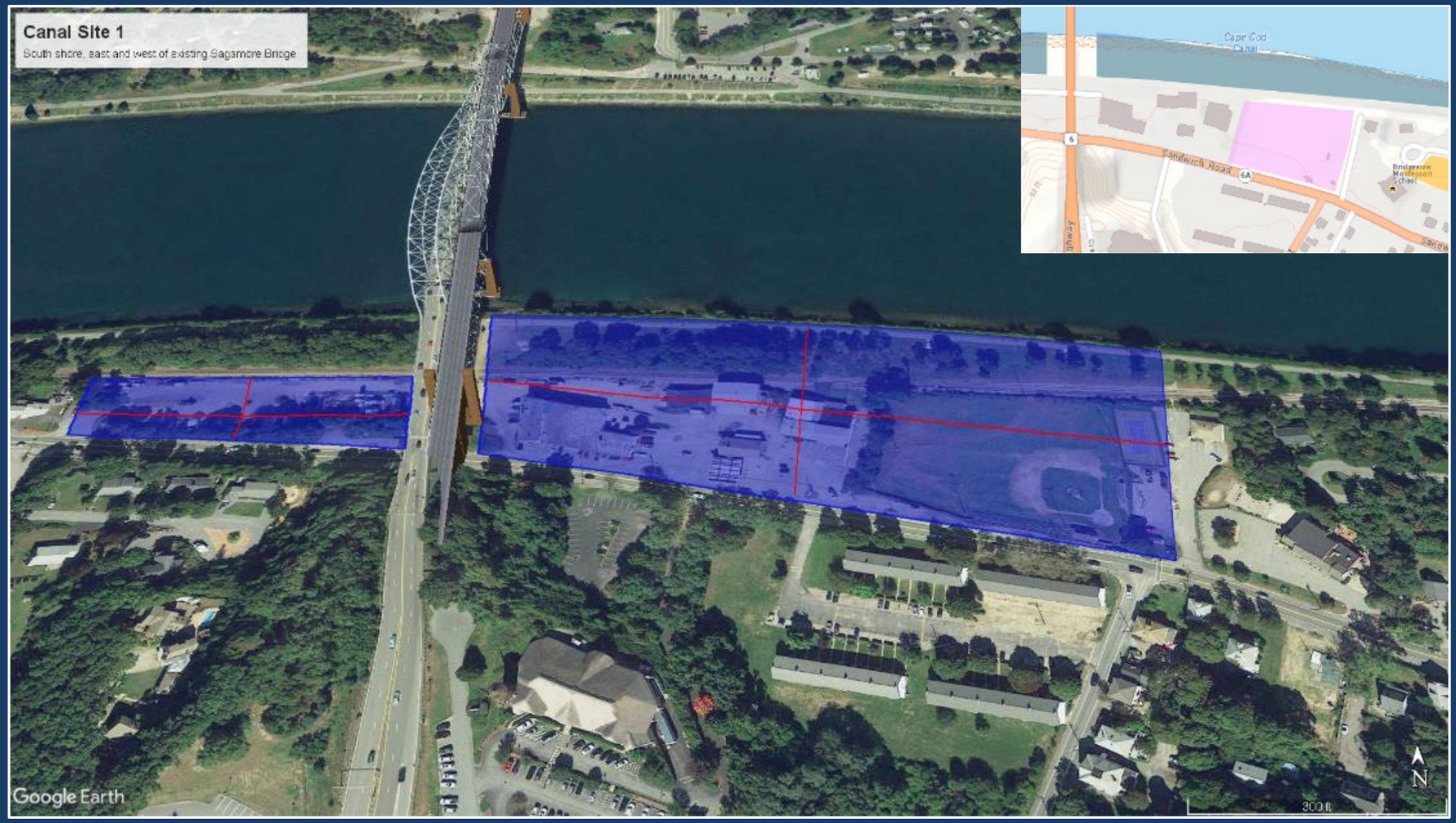
Appendix A
Fabrication Site Screening

PRE-DECISIONAL AND DELIBERATIVE

Construction Sites - Canal - Sagamore Bridge

Site Details (east + west)

- Length = 1000’ + 500’
- Width = 400’ + 150’
- Area = 10 acres + 2 acres
- Distance = 0 NM
- Owners / Stakeholders:
  - Mixed commercial
  - Keith Field Recreation Area (municipal, Town of Bourne)
  - Cape Cod Canal Access (federal, USACE)



Pro

- Commercial property may be available for use as laydown/fabrication area
- Proximity to site
- Canal water access

Con

- Mass Coastal Railroad runs through site
- Size constrained by surrounding residential
- Eastern 400’ section requires taking/restoring municipal recreation area (baseball field, tennis court, etc.)
- No existing bulkhead or dock

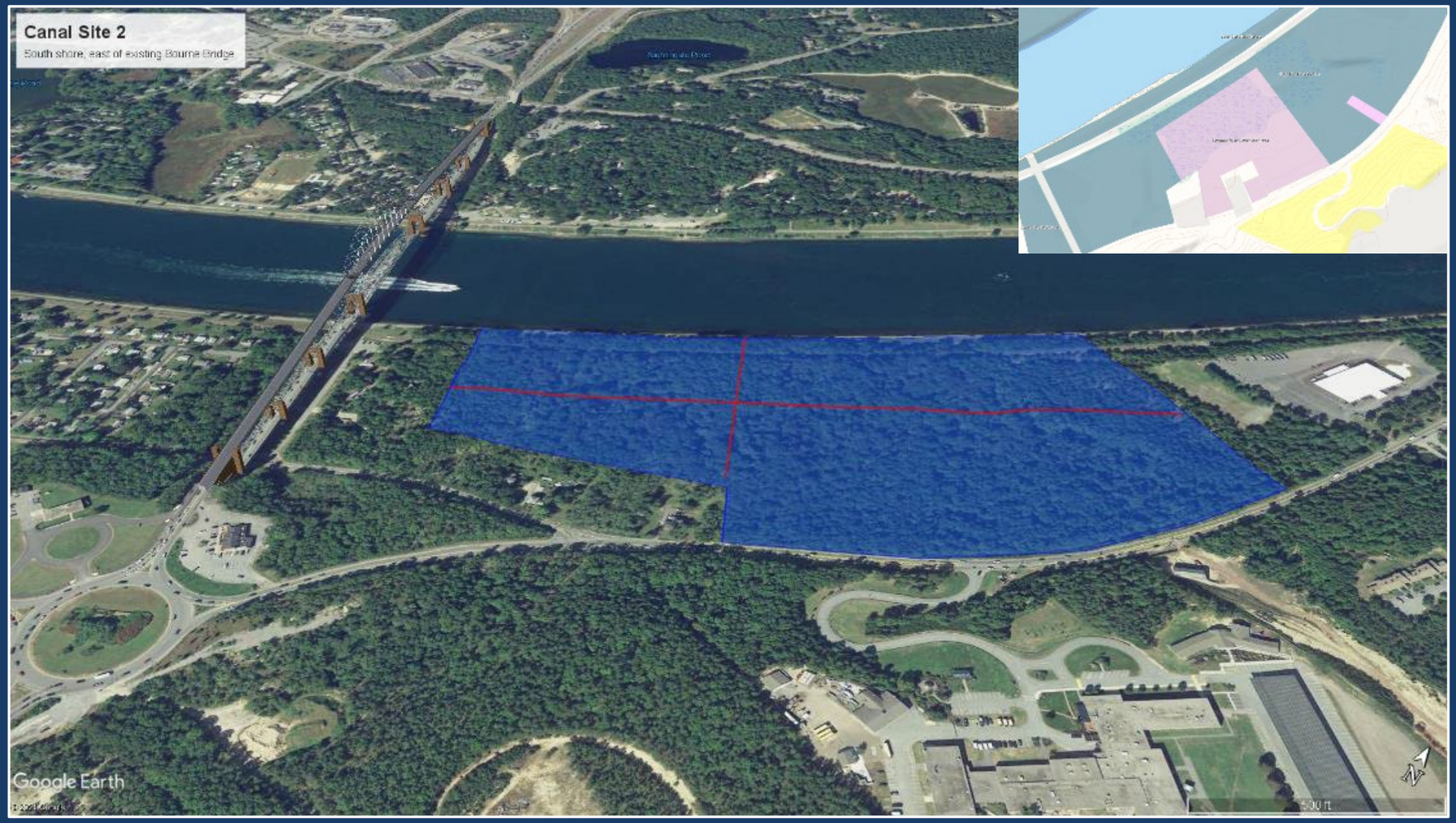
PRELIMINARY

PRE-DECISIONAL AND DELIBERATIVE

Construction Sites - Canal - Bourne Bridge

Site Details

- Length = 2100’
- Width = 750’
- Area = 46 acres
- Distance = 0 NM
- Owners / Stakeholders:
  - Sandwich Road Conservation Area, aka “Labretto Property” (municipal, Town of Bourne)
  - Cape Cod Canal Access (federal, USACE?)



Pro

- Proximity to site
- Canal water access

Con

- SRCA (pink inset) is undeveloped conservation land
- Upper Cape Regional Tech School seeking to obtain access and management rights (2019)
- No existing bulkhead or dock

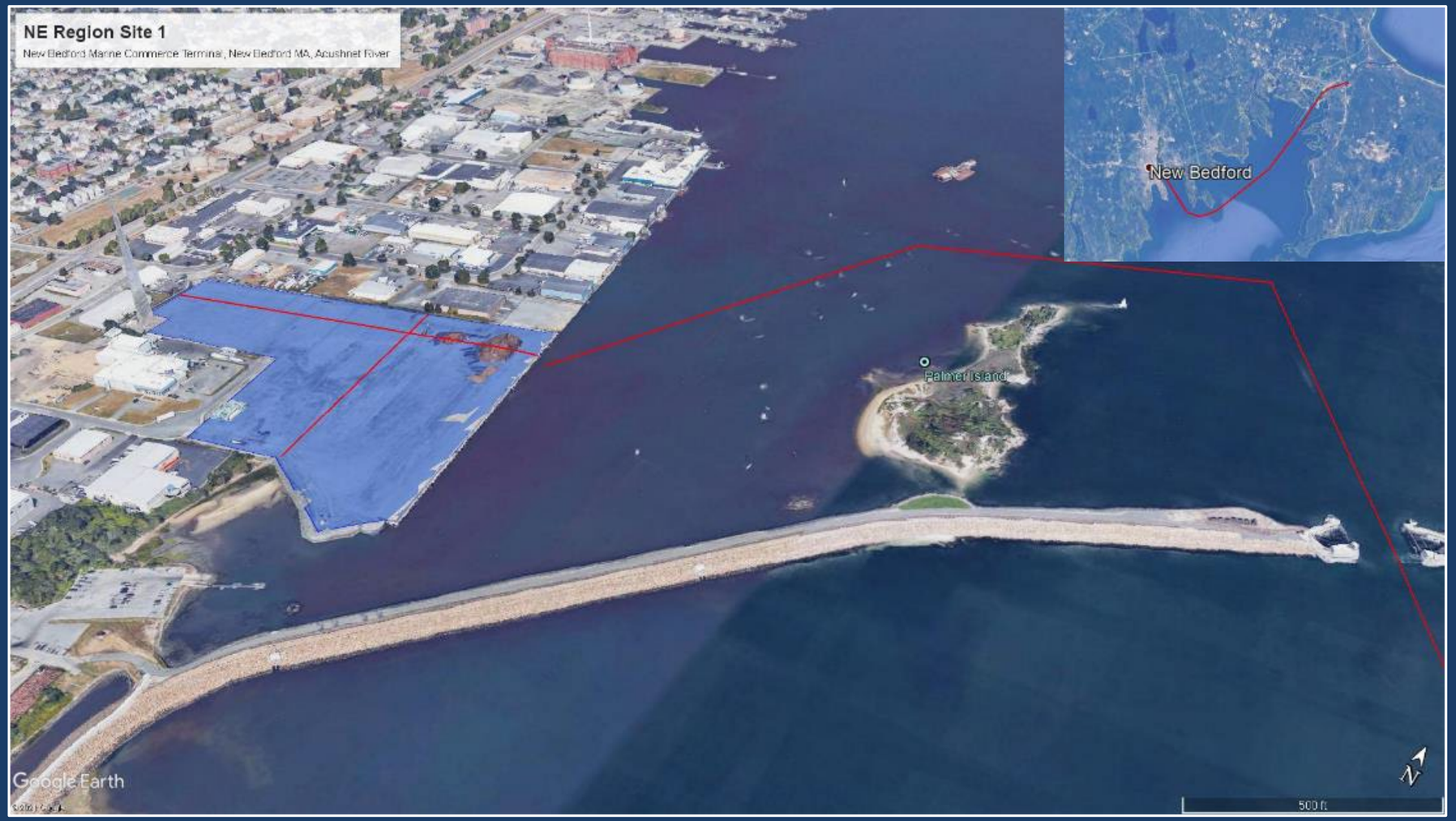
PRELIMINARY

PRE-DECISIONAL AND DELIBERATIVE

Construction Sites - Northeast Region - New Bedford

Site Details

- Length = 1250’
- Width = 825’
- Area = 20 acres
- Distance = 21 NM
- Owners / Stakeholders:
  - New Bedford Marine Commerce Terminal (commercial)



Pro

- Commercial heavy-lift construction facility (offshore wind)
- 1000’ of bulkhead (35’+ draft access)
- High uniform load capacity yard/quay
- Nearby rail and interstate access (I-95 / I-495)

Con

- New Bedford Hurricane Protection Barrier horizontal clearance = 150’

PRELIMINARY

PRE-DECISIONAL AND DELIBERATIVE

Construction Sites - Northeast Region - Acushnet River

Site Details

- Length = 850’
- Width = 350’
- Area = 7.5 acres
- Distance = 24 NM
- Owners / Stakeholders:
  - City of New Bedford



Pro

- None

Con

- No existing bulkhead
- I-195 & Coggeshall Street fixed span roadway bridges restrict access to Buzzards Bay
- New Bedford-Fairhaven Swing Bridge horizontal clearance = 95’

PRELIMINARY

PRE-DECISIONAL AND DELIBERATIVE

Construction Sites - Northeast Region - Taunton River

Site Details

- Length = 900’
- Width = 400’
- Area = 8 acres
- Distance = 64 NM
- Owners / Stakeholders:
  - Somerset Power LLC, decommissioned (commercial)



Pro

- Decommissioned plant and property available
- 600’ of bulkhead (35’ draft depth)
- Nearby interstate access (I-195)

Con

- Veterans Memorial Bascule Bridge horizontal clearance = 200’
- Brightman St Bascule Bridge horizontal clearance = 98’ (bridge decommissioned but not demolished)
- Charles M Braga Jr Fixed Bridge vertical clearance = 135’
- Existing bulkhead and yard require rehabilitation

PRELIMINARY

PRE-DECISIONAL AND DELIBERATIVE

Construction Sites - Northeast Region - Weymouth Fore River

Site Details

- Area = 16 acres
- Distance = 50 NM
- Owners / Stakeholders:
  - Cashman Dredging & Marine Construction



Pro

- Construction yard
- Multiple slips/bulkheads
- Nearby rail and interstate access (I-93)
- Fore River Lift Bridge horizontal clearance = 250’; vertical clearance = 220’

Con

- Dependent on engagement/availability of Cashman

PRELIMINARY

PRE-DECISIONAL AND DELIBERATIVE

Construction Sites - Northeast Region - Weymouth Fore River

Site Details

- Length = 1000’
- Width = 175’ / 250’
- Area = 12 acres
- Distance = 50 NM
- Owners / Stakeholders:
  - Quirk Auto Dealers (commercial)
  - ABC Supply Co. Inc. (commercial)



Pro

- 800’x150’ slip (28’ draft depth)
- Nearby rail and interstate access (I-93)
- Fore River Lift Bridge horizontal clearance = 250’; vertical clearance = 220’

Con

- Site not advertised as available
- Portion of yard constructed over old slip; load capacity may be reduced

PRELIMINARY

PRE-DECISIONAL AND DELIBERATIVE

Construction Sites - Northeast Region – Portland ME

Site Details

- Area = 28 acres
- Distance = 121 NM
- Owners / Stakeholders:
  - Cianbro Deepwater Marine Facility



Pro

- Construction yard
- 600’ deepwater bulkhead
- Nearby rail and interstate access (I-295)
- Casco Bay Bridge horizontal clearance = 196’

Con

- Dependent on engagement/availability of Cianbro

PRELIMINARY

PRE-DECISIONAL AND DELIBERATIVE

Construction Sites - Northeast Region – Portsmouth NH

Site Details

- Area = 9 acres
- Distance = 85 NM
- Owners / Stakeholders:
  - Pease International Division of Ports & Harbors (NH State Port Authority)



Pro

- Construction yard
- 600’ deepwater bulkhead
- Onsite rail and nearby interstate access (I-95)
- Memorial Bridge horizontal clearance = 260’; vertical clearance = 129’

Con

- Marine terminal availability for construction
- Upcoming major rehabilitation of main wharf

PRELIMINARY

Appendix B
Site Visit Memo

TECHNICAL MEMORANDA

To
John Smith, Ted Zoli

From
Tom DeHaven

Cc
Justin Steinhouse, Gregor Wollman

Project
Cape Cod Bridges Replacement

Subject
Cape Cod Bridge Site Visit on November 19, 2021

Date
November 19, 2021

Today, Tom DeHaven visited the site of the two Cape Cod Bridge with John Smith and Mike Beintum.

We went to the Sagamore and Bourne Bridge sites. The purpose was to compare and contrast these sites with each other and with the C&D Canal Bridge site in Delaware. Tom DeHaven spent 5 years as the Resident Engineer during the new construction of the C&D Canal Bridge across a canal that is managed by the USACOE. Were any of the lessons learned during the C&D Canal construction applicable to the decision-making matrix and risk matrix for the new bridges in Cape Cod?

The C&D Canal bridge at first glance is very similar to the Cape Cod Canal. Both at about 625' wide, with similar depth and rip rap along the shores. Both have large ships and barges using the canal frequently. Both have canal access roads on each side for use by the USACOE. Both have 135' vertical clearance and will require long approach spans to get the roadway down to roadway level at a 4-5% grade.

There are some noted differences. Especially for the Sagamore Bridge where there is a lot of residential development very close to the bridge and its approaches. This significant amount of residences in close proximity to the bridge results in a substantial number of pedestrians walking along the canal access. The C&D Canal was rather remote, unpaved, and not utilized much by pedestrians or cyclists. Another major difference is the wind. The wind at both Cape Cod sites was noticeable at ground level and then especially while driving over the bridges. It is noted that this was considered by locals to be a calm day and we were told that most days the wind blows much harder. The final noted difference is the canal flow. The Cape Cod flow is strong and

changes with the tide. It is ripping along and with little slack tide. The C&D flow was very gentle and was easily managed by construction boats and barges.

Some constructability considerations include:

- **Construction access from barges.** On C&D it was assumed that most materials could easily be delivered by barge and off loaded by land-based crawler cranes. During construction it quickly became evident that the land-based cranes could barely reach a barge over the rip rap and shallow areas. Even if they could reach the barges, they had very limited capacity at that radius. Also securing a barge to off load was not easy without installing piling for anchor points. The C&D contractor eventually installed a stiff-legged derrick to lift heavy loads off barges that were anchored close to shore. This was a slow process, and the stiff-leg derrick was founded on piling in the rip rap and it still conflicted with the canal access road. On C&D, all typical construction materials were delivered over land. The point is that the new Cape Cod Bridges should not be based on canal delivery except in limited circumstances.
- **Wind on Tower Cranes –** On C&D Canal, tower cranes were sued to construct the pylon towers that went up to about 300'. There were days when the tower crane was not used to high winds but they were the exception. In my experience, (tower cranes on three cable-stayed bridges where I was on site) tower cranes cannot be utilized when the winds exceed 25 mph. Pylon construction has always been a Critical Path element on every project schedule and this would need to be factored into a project construction schedule.
  An example of this impact is the Ironton-Russell Bridge in Ohio. It is a cable-stayed bridge across the Ohio River between Ohio and Kentucky along a river gorge. This gorge experience high winds especially above 100'. ODOT bid the project and all of the bids were in excess of 120% of the estimate. ODOT performed interviews with the bidders and found that all of them were bidding an extra year of construction and including the Liquidated Damage and overhead for that year. The reason given for the extra year was that their analysis of the winds that the tower cranes would experience severely limited the number of days where the tower could work due to high winds. ODOT had to redesign the bridge to have two pylons instead of one to lower the pylon height and modify the project schedule to allow for more time and then re bid the project after a delay of over a year.



New Ironton-Russell Bridge

Based on the site visit today, it is imperative to perform a meteorological study to review the impact of high winds on construction with special consideration on tower cranes or cranes above deck level. From my C&D Canal experience, it is not clear that we could have built that bridge in the same schedule at Cape Cod due to the stronger wind forces.

- **Extreme Weather event-** Many long span bridges have the design controlled by a construction case where the bridge is in long cantilever but not connected to the approaches. An extreme wind event in that condition would be challenging for a bridge to withstand without taking extreme measures to tie-down the bridge. Contractors, especially along coastal areas, often have plans to secure the structure in the event of major storms like hurricanes. From the site visit, it appears that this area could very easily experience a major wind event where the bridge under construction is taxed to its limits. If the bridge were in pure cantilever and collapsed then it could either damage the existing bridge and/or foul the canal. Again, strongly recommend studying the possible wind events that might impact these sites and consider that strongly in the Risk Analysis. Many of these extreme wind events occur during the warmer times of the year when the contractor is actively working and for a multi-year projects with four canal crossings, it is very conceivable that there will be extreme wind events during construction and this major Risk should be mitigated however possible. This is not just a concern for delays or claims, there potential risk of damaging the existing bridges or fouling the canal.
- **Another constructability consideration is public access through the project site-** While there is always a desire to allow the public to keep the typical access for walking and cycling, it is simply unsafe and unwise to mix the public and active construction. The Contractor is placed in an unfair position of having the general public accessing a construction site. This is an unwarranted risk to the public and to the Contractor. On the Bourne Bridge, there is a campground to the east and it would be unwise to allow that to be access from the west across the new construction site. Strongly recommend finding alternate egresses; shutting off this access and begin a PR campaign to alert the stakeholders why this access will be limited for public safety. Consider Denial of Access Fencing and locked gates across the access road during the construction project.
- **Another constructability issue is the access for beams for the approach spans-** The approach spans will be either steel or concrete beams with a cast-in-place deck. Access for delivery of the spans looks feasible by land delivery. Delivery by barge does not seem practical. One potential option to be explored is the use of the rail line on the east side of the canal for delivery of project materials and possibly even beams. For the beam delivery the existing bridges and their capacity need to be reviewed and delivery limitations established. Special attention needs to be paid to the capacity of the concrete deck beams in the hollow abutments.
- **Another constructability issue to consider is the availability of concrete for the project-** The project will require large volumes of concrete for the footings, piers and bridge decks. The area has very challenging traffic flow during large portions of the year. Will the contractor be able to ensure consistent and timely delivery of concrete from off project batch plants? Should the contractor be required to establish an on-site batch plant specifically for this project? The location for such a plant and the waste from such a plant need to be considered.

Appendix C Cape Cod Bridge Replacements Phase II Screening Report



CAPE COD BRIDGE REPLACEMENTS

Phase II Screening Report

PREPARED BY HNTB FOR massDOT Massachusetts Department of Transportation 2022

Cape Cod Bridges – Phase II Screening Report

1 INTRODUCTION

The existing Cape Cod bridges have reached the end of their useful economic life and need replacement. In an initial screening study, documented in a separate report, a large number of bridge design parameters and bridge types were evaluated systematically in order to arrive at a selection of feasible and favorable options for replacement bridges. The initial selection included cable-stayed, haunched concrete box girder, and tied arch bridges (Table 1). During the second phase of the screening, documented in the present report, the initially recommended alternatives were tested against highway design constraints and were evaluated in greater depth for constructability. For the most promising bridge types (tied arch and cable-stayed bridge) their performance under wind loads was investigated in wind tunnel tests. Based on feedback from these studies it was possible to further refine and reduce the initial selection of feasible bridge types.

2 HIGHWAY GEOMETRICS

A particular challenge for the site is the bridge height needed to accommodate the required vertical clearance over the navigation channel. Gaining the necessary highway elevation places great demands on grade and length of the approach spans and ramps. This constraint significantly penalizes the alternatives requiring more structure depth below the roadway, i.e. the box girder option. On the other hand, it favors the cable supported options (arch or cable-stayed) which require only a relatively shallow deck girder. For the same reason a side by side two-deck configuration is preferable to a single, wide deck because floorbeams have to span a shorter distance and, therefore, can be made more slender.

Another assessment criterion that evolved from the highway design studies is the tie-in of vehicular and pedestrian ramps into the main line. Options with two separate shared-use paths turned out to be infeasible and were eliminated from further development. In addition, this consideration favors the tied-arch options because the lack of a cable-supported back span provides the flexibility to tie in any ramps closer to the canal.

3 CONSTRUCTION

The complete constructability assessment is documented in a separate report. Following below is a brief highlight of the findings obtained during that study which allowed for further narrowing of the recommended bridge types.

3.1 Impact on Canal traffic:

Feedback from the Army Corps of Engineers and from a constructability and risk assessment ruled out alternatives that require falsework in the canal or frequent construction activities from the canal. This constraint eliminated tied arch construction on shoring. For cable-stayed bridges it dictates that the bridge be erected in balanced cantilever or progressive cantilever with new segments fed via the shored back span on land to the work front over the canal.

3.2 Float-In Option:

With a tied arch alternative there is the option to assemble the steel structure in a remote fabrication yard, transport it to site on an ocean-going barge, and lift it into place. This construction scheme minimizes impact to canal traffic, requiring a short closure (12 to 24 hours) only during the lifting operation. To keep barge sizes reasonable and considering the limited vertical clearance underneath the existing canal bridges, this option favors the 700-ft span arches with two decks and supported on Delta frames. With the Delta frames, the new arch can be positioned between the piers in its low position allowing for quick and stable lifting operation using strand jacks. Vertical piers would require raising of the arch on the barge in an off-line position so that it clears the piers as it is moved into place. The required lifting height of some 140 feet on barge is at the edge of feasibility and was deemed undesirable, leading to elimination of the vertical pier options.

3.3 Cable-Stayed Bridge Tower Construction:

Erection of cable-stayed bridge towers requires the use of tower cranes, which are subject to severe operation restrictions in windy conditions. Given the exposed site, this limitation creates a considerable schedule risk. The 820-foot cable stayed bridge has constructability advantages over the 700-foot span length as the towers are fully on land.

3.4 Phased Construction:

Alternatives using the two-deck configuration also emerged as favorable because they afford the opportunity for phased construction. With this scheme a new bridge is built parallel to the existing structure. It then carries traffic in a temporary configuration, while the old bridge is demolished, and a new second-phase bridge is erected. This approach provides flexibility during construction and, while potentially increasing total construction time, will accelerate the schedule to decommissioning of the existing bridges. This latter advantage is significant in view of the high cost of maintaining the existing bridges and considering the risk and high user cost of loss of service.

4 UPDATED SCREENING MATRICES

Appendix A includes the updates to the screening matrices. Alternatives eliminated after the initial screening are indicated by the grey underlay and alternatives no longer recommended in this second stage screening are high-lighted in orange. Where ratings or notes have changed, notes are shown in red. Following below is a summary of the changes to the screening matrices:

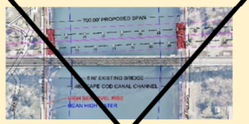
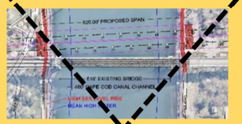
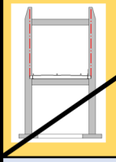
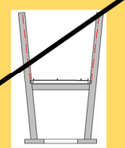
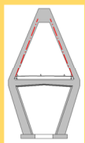
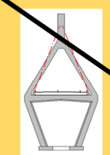
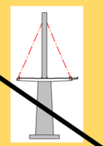
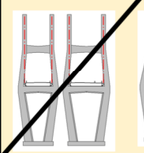
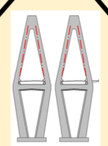
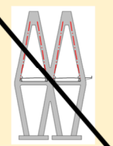
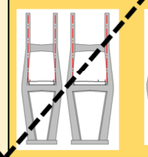
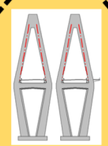
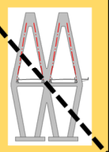
- Main Span Length: No changes.
- Deck Configuration: Only the option with separate decks and single shared-use path was retained.
- Single Bridge: No longer considered.
- Separate Bridges: No changes.
- Bridge Types with 700-ft Span: Box girder option is feasible, but not recommended. Cable-stayed option was removed from further consideration in favor of the 820-foot span.
- Bridge Types with 820-ft Span: Box girder option is no longer being considered. Cable stayed option is feasible, but not recommended.
- Cable-Stayed Bridge Towers: Cable-stayed bridge type no longer being considered.
- Cable-Stayed Bridge Pylons: Cable-stayed bridge type no longer being considered.
- Arch Ribs: Tied arches with vertical piers and all alternatives associated with single deck were eliminated.
- Box Girders: No longer being considered.
- Deck Girders: Box girder options, either cable-supported or self-supporting, no longer recommended due to structure depth.
- Approaches: Only the alternative using steel plate girders was retained. The other options (steel box girder, precast concrete girder, concrete box girder) were deemed to be not feasible with the required span lengths and limited access for the approach spans.

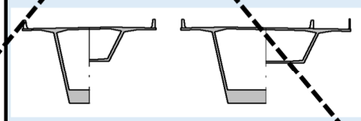
5 UPDATED PROPOSED CONFIGURATIONS

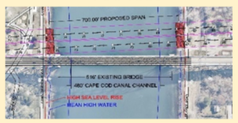
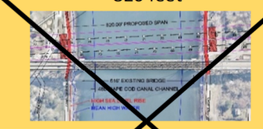
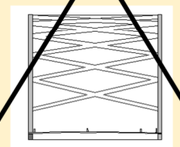
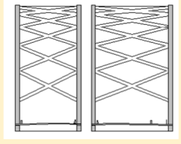
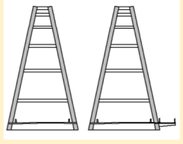
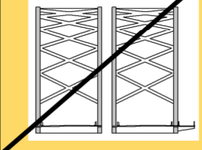
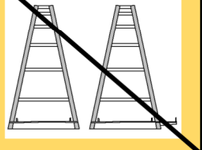
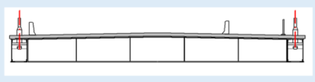
Based on the feedback from highway design, constructability assessment and wind tunnel studies, the most favorable main span bridge option was found to be parallel network tied-arch bridges supported on Delta frames

with a main span of about 700 feet. 820-foot cable-stayed and 700-foot concrete box girder options are feasible, but not recommended. This preliminary recommendation will be presented at the Round 4 public meetings in November 2022 to receive public feedback on the recommended option from stakeholders and the public. Exact span length, deck configuration, arch rib configuration, tie-in with approach ramps and other parameters would be determined in the bridge type study. Table 1 summarizes the proposed bridge types and configurations; alternatives no longer being considered are crossed out; alternatives feasible but no longer recommended have been crossed out with a dashed X.

TABLE 1 - PROPOSED BRIDGE TYPES AND CONFIGURATIONS FOR FURTHER EVALUATION

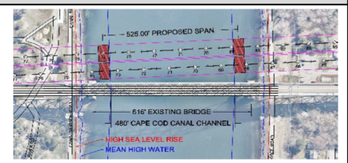
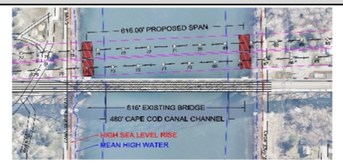
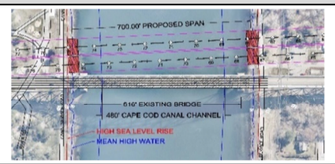
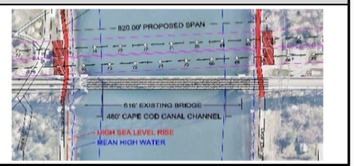
Type	Two-Tower Cable Stayed with Two Cable-Planes 											
Label	CS1	CS2	CS3	CS4	CS5	CS6	CS7	CS8	CS9	CS10	CS11	
Deck	Single Deck					Separate Decks						
Span	820 feet 					700 feet 			820 feet 			
Tower	H 	V 	Single A 	Single Y 	Pylon 	Separate H's 	Separate A's 	Merged A's 	Separate H's 	Separate A's 	Merged A's 	
Girder	Edge Steel I-Girder 											

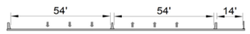
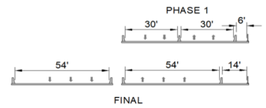
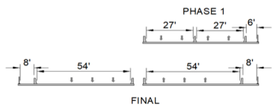
Type	Box Girder 					
Lable	BG1					
Deck	Separate Decks					
Span	>700 feet 					
Girder	Post-Tensioned Concrete 					

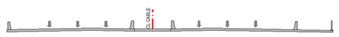
Type	Tied Arch 	Tied Arch with Delta Frames 				
	TA1	TA2	TA3	TA4	TA5	TA6
Deck	Separate Decks	Single Deck	Separate Decks			
Span	700 feet 	700 feet 	700 feet 		820 feet 	
Rib	Basket Handle Ribs 	Vertical Ribs 	Vertical Ribs 	Basket Handle Ribs 	Vertical Ribs 	Basket Handle Ribs 
Girder	Edge Steel Box Girder 					

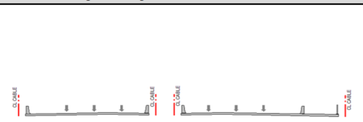
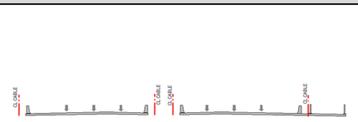
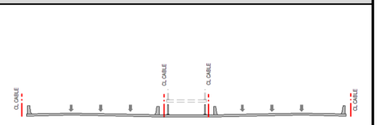
- X — No longer being considered
- X — Feasible but not recommended

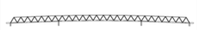
APPENDIX A – UPDATED SCREENING MATRICES

MAIN SPAN LENGTH		Minimum - 525 ft		Status-Quo - 616 ft		Shore Line Piers - 700 ft		Land Piers - 820 ft	
Most Favorable Favorable Neutral Less Favorable Unfavorable Not Rated									
EVALUATION CRITERIA		Rating	Notes	Rating	Notes	Rating	Notes	Rating	Notes
INITIAL COST	**Main Span Structure**	●●	Lowest superstructure cost.	●	Intermediate superstructure and foundation costs.	3 ●	**Intermediate superstructure and foundation costs.**	2. ●●	**Highest superstructure cost.**
	Main Span Foundations	●●	Highest foundation cost, designed for vessel impact, construction access, requires cofferdam.	●●	High foundation cost - access, cofferdam.	3 ●	**Close to land, but still requires cofferdam in tidal zone.**	4. ●●	**Best accessibility for foundation construction.**
	Overall	••		••		x ••		x ••	
HIGHWAY GEOMETRICS	**Grade/Length**	••		••		x ••		x ••	
	Footprint	••		••		x ••		x ••	
	Horizontal Tangent Length	••		••		x ••		x ••	
MAINSPAN FOOTINGS	**Vessel Impact**	●●●	Not acceptable for canal operations.	●●	Small vessels and shallow draft barges.	5 ●●●	**Large vessels ground out, small vessels only.**	5 ●●●	**Not possible.**
	Scour	●●		●●	No significant scour with existing structure.	4 ●●	**Armored slope.**	5 ●●●	**Not possible.**
CONSTRUCTION	**Phasing**	••		••		x ••		x ••	
	Duration	●●	Construction from water.	●		3 ●		3 ●	
	Constructability	●●	Pier construction from trestle bridge.	●	Trestle bridge or causeway.	4 ●●	**Pier construction from land.**	4 ●●	**Pier construction on land.**
	Impact on Canal Traffic	●●	Most channel fouling.	●		4 ●●	**No channel fouling.**	5 ●●●	**No channel fouling.**
	Maintenance of Traffic	••		••		x ••		x ••	
	Environmental Impact	●●	Pier footing in water.	●●	Pier footing in water.	3 ●	**Pier footing tucked into shore line.**	4 ●●	**Pier footing on land.**
STRUCTURAL REDUNDANCY	**Fracture-Critical Members**	••		••		x ••		x ••	
	Failure-Critical Members	••		••		x ••		x ••	
INSPECTION & MAINTENANCE	**Access**	••		••		x ••		x ••	
	Frequency	••		••		x ••		x ••	
DURABILITY	**Protection**	••		••		x ••		x ••	
	Replacement	••		••		x ••		x ••	
	Monitoring	••		••		x ••		x ••	
WIND RESPONSE	**Structural Efficiency**	••		••		x ••		x ••	
	Dynamic Effects	●●	Shorter spans are less sensitive to wind effects.	●●	Shorter spans are less sensitive to wind effects.	3 ●	**Medium sensitivity to wind effects.**	2. ●●	**Most sensitive to wind effects.**
SNOW & ICE RESPONSE	**Bridge closures**	••		••		x ••		x ••	
	Monitoring/Deicing	••		••		x ••		x ••	
COMMUNITY CONSIDERATIONS	**Appearance/Signature**	••		••		x ••		x ••	
	Bike/Pedestrian Path	••		••		x ••		x ••	

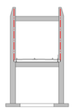
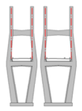
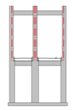
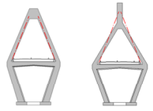
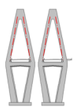
DECK CONFIGURATION		Single Deck/Single Path		Single Deck/Two Paths		Separate Decks/Single Path		Separate Decks/Two Paths	
Most Favorable Favorable Neutral Less Favorable Unfavorable Not Rated									
EVALUATION CRITERIA		Rating	Notes	Rating	Notes	Rating	Notes	Rating	Notes
INITIAL COST	**Main Span Structure**	●	Highest floorbeam cost, but least number of ribs or cable planes.	●	Highest floorbeam cost, but least number of ribs or cable planes.	● 3	**Least floorbeam costs, but requires more ribs or cable planes.**	●	Least floorbeam costs, but requires more ribs or cable planes.
	Main Span Foundations	••		••		•• x		••	
	Overall	••		••		•• x		••	
HIGHWAY GEOMETRICS	**Grade/Length**	●●	Greater structure depth requires steeper or longer approach.	●●	Greater structure depth requires steeper or longer approach.	●● 4	**Least floorbeam depth.**	●●	Least floorbeam depth.
	Footprint	●	Smaller constructed footprint, but may require more takings.	●	Smaller constructed footprint, but may require more takings.	●● 4	**Greatest flexibility for overlap with existing alignment.**	●●	Greatest flexibility for overlap with existing alignment.
	Horizontal Tangent Length/ Ramp Tie-Ins	•• x		●●●	Highway design constraints preclude two shared-use paths.	•• x		●●●	Highway design constraints preclude two shared-use paths.
MAINSPAN FOOTINGS	**Vessel Impact**	••		••		•• x		••	
	Scour	••		••		•• x		••	
CONSTRUCTION	**Phasing**	●●	Not an option.	●●	Not an option.	●●● 5	**Phase 1: 2 x 30-ft roadways**	●●●	Phase 1: 2 x 27-ft roadways
	Duration	●●	Old bridge decommissioned later.	●●	Old bridge decommissioned later.	●● 4	**Old bridge decommissioned soonest.**	●●	Old bridge decommissioned soonest.
	Constructability	●●	Requires handling of large floorbeams, larger float-in weight and size.	●●	Requires handling of large floorbeams, larger float-in weight and size.	●● 4	**More repetitive, smaller pieces.**	●●	More repetitive, smaller pieces.
	Impact on Canal Traffic	••		••		•• x		••	
	Maintenance of Traffic	●	Staged tie-in to existing highway more difficult.	●	Staged tie-in to existing highway more difficult.	●● 4	**Allows phased construction.**	●●	Allows phased construction.
	Environmental Impact	●	Smaller constructed footprint, but may require more takings.	●	Smaller constructed footprint, but may require more takings.	●● 4	**Greatest flexibility for overlap with existing alignment.**	●●	Greatest flexibility for overlap with existing alignment.
STRUCTURAL REDUNDANCY	**Fracture-Critical Members**	••		••		•• x		••	
	Failure-Critical Members	●		●		●●● 5	**Each structure can operate independently and carry two-way traffic and a path.**	●●●	Each structure can operate independently and carry two-way traffic and a path.
INSPECTION & MAINTENANCE	**Access**	••		••		•• x		••	
	Frequency	••		••		•• x		••	
DURABILITY	**Protection**	••		••		•• x		••	
	Replacement	••		••		●●● 5	**Each structure can operate independently and carry two-way traffic and a path.**	●●●	Each structure can operate independently and carry two-way traffic and a path.
	Monitoring	••		••		•• x		••	
WIND RESPONSE	**Structural Efficiency**	••		••		•• x		••	
	Dynamic Effects	●●●	Better wind stability.	●●●	Better wind stability.	●● 4	**Sensitive to deck spacing. Wind tunnel tests demonstrated good behavior.**	●●	Sensitive to deck spacing. Wind tunnel tests demonstrated good behavior.
SNOW & ICE RESPONSE	**Bridge closures**	••		••		•• x		••	
	Monitoring/Deicing	••		••		•• x		••	
COMMUNITY CONSIDERATIONS	**Appearance/Signature**	••		••		•• x		••	
	Bike/Pedestrian Path	••		••		•• x		••	

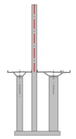
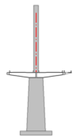
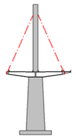
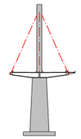
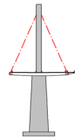
SINGLE BRIDGE DECK		Simple Span Floorbeam		Cantilever Floorbeam		Separate Pedestrian Level		Single Cable Plane	
Most Favorable Favorable Neutral Less Favorable Unfavorable Not Rated									
EVALUATION CRITERIA		Rating	Notes	Rating	Notes	Rating	Notes	Rating	Notes
INITIAL COST	**Main Span Structure**	●	Largest floorbeam span.	●●	Reduced floorbeam span length.	●●	Additional cost for walkway support, transverse flyovers, and screens.	●●●	Requires torsionally stiff and deep deck girder to address eccentricity.
	Main Span Foundations	●		●		●●	Additional cost for walkway support and screens.	●	
	Overall	••		••		••		••	
HIGHWAY GEOMETRICS	**Grade/Length**	●●	Greater floorbeam depth requires steeper or longer approach.	●●	Greater floorbeam depth requires steeper or longer approach.	●●	Allows different grades for roadway and path.	●●	Deep structure increases approach length or grade.
	Footprint	●		●		●●	Smallest footprint.	●●	Closure strip/tower increases deck width.
	Horizontal Tangent Length/Ramp Tie-Ins	••		••		●●●	Highway design constraints preclude raised median path.	••	
MAINSPAN FOOTINGS	**Vessel Impact**	••		••		••		••	
	Scour	••		••		••		••	
CONSTRUCTION	**Phasing**	••		••		••		••	
	Duration	••		••		••		••	
	Constructability	●●	Requires handling of large floorbeams, larger float-in weight and size.	●●	Requires handling of large floorbeams, larger float-in weight and size.	••		••	
	Impact on Canal Traffic	••		••		••		••	
	Maintenance of Traffic	••		••		••		••	
	Environmental Impact	••		••		••		••	
STRUCTURAL REDUNDANCY	**Fracture-Critical Members**	••		••		••		••	
	Failure-Critical Members	••		••		••		••	
INSPECTION & MAINTENANCE	**Access**	••		••		••		••	
	Frequency	••		••		••		••	
DURABILITY	**Protection**	••		••		••		••	
	Replacement	••		••		••		••	
	Monitoring	••		••		••		••	
WIND RESPONSE	**Structural Efficiency**	••		••		••		••	
	Dynamic Effects	••		••		••		••	
SNOW & ICE RESPONSE	**Bridge closures**	••		••		••		••	
	Monitoring/Deicing	••		••		••		••	
COMMUNITY CONSIDERATIONS	**Appearance/Signature**	••		••		••		••	
	Bike/Pedestrian Path	●		●●	Cable plane creates barrier effect.	●●	Path offset from traffic.	●	

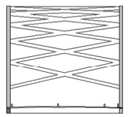
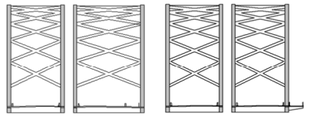
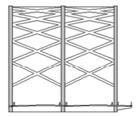
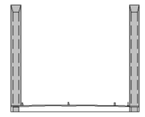
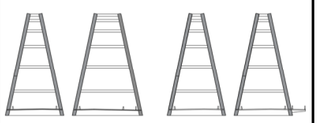
SEPARATE BRIDGE DECKS		Most Favorable Favorable Neutral Less Favorable Unfavorable Not Rated	Simple Span Floorbeams	Cantilever Floorbeam	Twins With Link Slab
					
EVALUATION CRITERIA			Rating / Notes	Rating / Notes	Rating / Notes
INITIAL COST	**Main Span Structure**		3 ● —	4 ●● **Reduced floorbeam span.**	●● Reduced floorbeam span.
	Main Span Foundations		×2 ••	×2 ••	••
	Overall		×2 ••	×2 ••	••
HIGHWAY GEOMETRICS	**Grade/Length**		×2 ••	×2 ••	••
	Footprint		×2 ••	×2 ••	••
	Horizontal Tangent Length		×2 ••	×2 ••	••
MAINSPAN FOOTINGS	**Vessel Impact**		×2 ••	×2 ••	••
	Scour		×2 ••	×2 ••	••
CONSTRUCTION	**Phasing**		4 ●● **2x30-ft roadways and 6-ft path in temporary configuration.**	3 ● **2x26-ft roadways and 14-ft path in temporary configuration.**	●●● 2x26-ft roadways but no path in temporary configuration.
	Duration		×2 ••	×2 ••	••
	Constructability		3 ●	3 ●	●● Path adds another construction phase, durability of deck construction joints.
	Impact on Canal Traffic		×2 ••	×2 ••	••
	Maintenance of Traffic		×2 ••	×2 ••	••
	Environmental Impact		×2 ••	×2 ••	••
STRUCTURAL REDUNDANCY	**Fracture-Critical Members**		×2 ••	×2 ••	••
	Failure-Critical Members		×2 ••	×2 ••	••
INSPECTION & MAINTENANCE	**Access**		×2 ••	×2 ••	••
	Frequency		×2 ••	×2 ••	••
DURABILITY	**Protection**		3 ●	3 ●	●● Complex behavior of link slab as it spans between twin superstructures.
	Replacement		×2 ••	×2 ••	••
	Monitoring		×2 ••	×2 ••	••
WIND RESPONSE	**Structural Efficiency**		×2 ••	×2 ••	••
	Dynamic Effects		3 ●	4 ●● **Improved wind response.**	●
SNOW & ICE RESPONSE	**Bridge closures**		×2 ••	×2 ••	••
	Monitoring/Deicing		×2 ••	×2 ••	••
COMMUNITY CONSIDERATIONS	**Appearance/Signature**		×2 ••	×2 ••	••
	Bike/Pedestrian Path		3 ●	4 ●● **Cable plane creates barrier effect.**	●● Path surrounded by traffic on both sides.

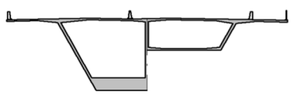
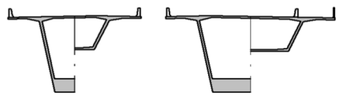
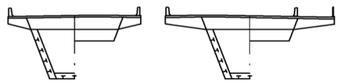
BRIDGE TYPE (700-FT SPAN)		Tied Arch		Tied Arch With Delta Frame		Truss		Two-Tower Cable Stayed		Single-Tower Cable Stayed		Box Girder	
Most Favorable Favorable Neutral Less Favorable Unfavorable Not Rated													
EVALUATION CRITERIA		Rating	Notes	Rating	Notes	Rating	Notes	Rating	Notes	Rating	Notes	Rating	Notes
INITIAL COST	**Main Span Structure**	●●	Efficient off-site construction, least length of main span structure.	●●	**Efficient off-site construction, but added complexity from Delta frames.**	●	Slower construction.	●●	Lower end of efficient span range for this type of structure.	●●●	Inefficient structural system.	●●	Efficient and simple structural system.
	Main Span Foundations	··		··		··		··		··		●●	Heavy foundation.
	Overall	··		··		··		··		··		●●	Deeper superstructure requires longer or taller approaches.
HIGHWAY GEOMETRICS	**Grade/Length**	●●	Least main span girder depth. Shortest main span creates more flexibility for curved approaches.	●●	**Least main span girder depth.**	●●	Least main span girder depth.	●●	Limits or eliminates some approach bridge configurations, steepens ramp grades.	●●	Limits or eliminates some approach bridge configurations, steepens ramp grades.	●●●	Highway design cannot accommodate extra approach structure length or grade required by increased main span girder depth.
	Footprint	··		··		··		··		··		··	
	Horizontal Tangent Length	●●	Main span only.	●●●	**Main span only.**	●●	Main and side spans.	●●	Main and side spans.	●●	Main and side span.	●●	Can accommodate moderate plan curvature.
MAINSPAN FOOTINGS	**Vessel Impact**	··		··		··		··		··		··	
	Scour	··		··		··		··		··		··	
CONSTRUCTION	**Phasing**	··		··		··		··		··		··	
	Duration	●●●	Accelerated bridge construction with arch fabricated off-site and floated in.	●●●	**Accelerated bridge construction with arch fabricated off-site and floated in.**	●●	Significant portion of structure erected by stick building.	●●	Requires tower cranes which have limited operation window during wind.	●●	Requires tower cranes which have limited operation window during wind.	●	Accelerated construction by working from two piers simultaneously. Cold weather impacts construction rates.
	Constructability	●●●	Complex and risky arch lifting operation on barge.	●●●	**Arch floated in, Delta piers simplify lifting operation.**	●●	Stick building with floated in drop-in span.	●●	Repetitive construction cycle, but requires careful cable force and geometry control, tower construction. Vulnerable to high wind events during construction.	●●	Repetitive construction cycle, but requires careful cable force and geometry control, tower construction. Vulnerable to high wind events during construction.	●●	Repetitive construction cycle.
	Impact on Canal Traffic	●●●	Single closure for each span lift.	●●●	**Single closure for each span lift.**	●	Barge operations near pier, one extended closure for drop-in lift.	●	Periodic, partial obstructions for segment lift from barge (approximately 40 lifts/bridge).	●	Periodic, partial obstructions for segment lift from barge (approximately 40 lifts/bridge).	●●●	None.
	Maintenance of Traffic	··		··		··		··		··		··	
	Environmental Impact	··		··		··		··		··		··	
STRUCTURAL REDUNDANCY	**Fracture-Critical Members**	●●	Fracture critical elements (ties, hangers, floorbeams) designed for system or internal redundancy.	●●	**Fracture critical elements (ties, hangers, floorbeams) designed for system or internal redundancy.**	●●●	Tension diagonals, tension chords designated as fracture-critical members.	●●	Hangers, floorbeams - designed for system or internal redundancy.	●●	Hangers, floorbeams - designed for system or internal redundancy.	●●●	No fracture critical members.
	Failure-Critical Members	●●	Improved rib stability due to network hanger arrangement.	●●	**Improved rib stability due to network hanger arrangement.**	●●	Any truss member.	●●	Stiffening girder.	●●	Stiffening girder.	●●	Post-tensioning tendons.
INSPECTION & MAINTENANCE	**Access**	●●	Accessible tie girders and ribs, snooper for under-deck, cherry picker for cables.	●●	**Accessible tie girders and ribs, snooper for under-deck, cherry picker for cables.**	●●	Snooper and cherry picker.	●	Accessible towers, snooper for under-deck, rope access for cables	●	Accessible towers, snooper for under-deck, rope access for cables	●●	Accessible box girder, snooper for under-deck, but cannot inspect internal tendons.
	Frequency	●	Typical cycle.	●	**Typical cycle.**	●●	Hands-on inspection of fracture-critical items at two-year intervals.	●	Typical cycle.	●	Typical cycle.	●●●	Typical cycle, fewest elements to inspect.
DURABILITY	**Protection**	●	Has vulnerable elements above deck. Metallized steel, partially prestressed precast deck panels.	●	**Has vulnerable elements above deck. Metallized steel, partially prestressed precast deck panels.**	●	Has vulnerable elements above deck. Metallized steel, concrete cover and corrosion resistant reinforcement.	●	Has vulnerable elements above deck. Metallized steel, partially prestressed precast deck panels.	●	Has vulnerable elements above deck. Metallized steel, partially prestressed precast deck panels.	●●	Fewest exposed elements, deck fully prestressed longitudinally and transversely, concrete cover and corrosion resistant reinforcement.
	Replacement	●●	Cables, deck overlay system, deck.	●●	**Cables, deck overlay system, deck.**	●	Deck overlay system, deck.	●	Cables, deck overlay system, typically not designed for deck replacement.	●	Cables, deck overlay system, typically not designed for deck replacement.	●●	Deck overlay system, deck replacement not possible.
	Monitoring	●	Cables.	●	**Cables.**	●	None required.	●	Cables.	●	Cables	●	None required.
WIND RESPONSE	**Structural Efficiency**	··		··		··		●●	Wind response during construction governs pylon and foundation design.	●●	Poor wind performance (effectively twice the span length).	··	
	Dynamic Effects	●	Requires wind tunnel studies.	●	**Requires wind tunnel studies.**	●	Potential for truss member vibrations.	●●	Requires wind tunnel studies for construction phases.	●●	Requires wind tunnel studies.	●●	Negligible.
SNOW & ICE RESPONSE	**Bridge closures**	●	Uncommon.	●	**Uncommon.**	●	Uncommon.	●●	During critical climate conditions.	●●	During critical climate conditions.	●●	Uncommon.
	Monitoring/Deicing	●	Ice drop from rib-bracing.	●	**Ice drop from rib-bracing.**	●	Ice drop from top chord bracing.	●●	Ice drop from cables.	●●	Ice drop from cables.	●●	Uncommon.
COMMUNITY CONSIDERATIONS	**Appearance/Signature**	●●	Efficient, less height.	●●●	**Echoes appearance of existing structure.**	●●	Dissimilarity to historic structure likely has adverse impact on Cape Cod Historic District.	●●	Dissimilarity to historic structure likely has adverse impact on Cape Cod Historic District.	●●	Dissimilarity to historic structure likely has adverse impact on Cape Cod Historic District.	●●	Dissimilarity to historic structure likely has adverse impact on Cape Cod Historic District.
	Bike/Pedestrian Path	··		··		··		··		··		··	

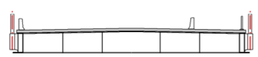
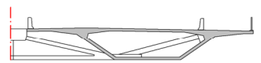
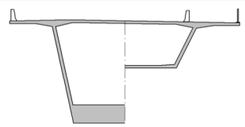
BRIDGE TYPE (820-FT SPAN)		Tied Arch		Tied Arch With Delta Frame		Truss		Two-Tower Cable Stayed		Single-Tower Cable Stayed		Box Girder		Suspension Bridge	
Most Favorable Favorable Neutral Less Favorable Unfavorable Not Rated															
EVALUATION CRITERIA		Rating	Notes	Rating	Notes	Rating	Notes	Rating	Notes	Rating	Notes	Rating	Notes	Rating	Notes
INITIAL COST	**Main Span Structure**	●●	Upper end of economical span range for this type of structure.	●●	Efficient off-site construction, but added complexity from Delta frames.	●●	Slow construction.	●●	Very efficient span range for this type of structure.	●●●	Inefficient structural system.	●	Efficient and simple structural system, but US record at this span range.	●●●	Not common/not economical for this span range.
	Main Span Foundations	··		··		··		··		··		●●	Heavy foundation.	··	
	Overall	··		··		··		··		··		●●	Deeper superstructure requires longer or taller approaches.	··	
HIGHWAY GEOMETRICS	**Grade/Length**	●●	Least main span girder depth. Shortest main span creates more flexibility for curved approaches.	●●	Least main span girder depth.	●●	Limits or eliminates some approach bridge configurations, steepens ramp grades.	●●	Limits or eliminates some approach bridge configurations, steepens ramp grades.	●●	Limits or eliminates some approach bridge configurations, steepens ramp grades.	●●●	Highway design cannot accommodate extra approach structure length or grade required by increased main span girder depth.	●●	Limits or eliminates some approach bridge configurations, steepens ramp grades.
	Footprint	··		··		··		··		··		··		··	
	Horizontal Tangent Length	●●	Main span only.	●●	Main span only.	●●	Main and side spans.	●●	Main and side spans.	●●	Main and side span.	●●	Can accommodate moderate plan curvature.	●●	Main and side spans.
MAINSPAN FOOTINGS	**Vessel Impact**	··		··		··		··		··		··		··	
	Scour	··		··		··		··		··		··		··	
CONSTRUCTION	**Phasing**	··		··		··		··		··		··		··	
	Duration	●●●	Slow construction (stick building)	●●●	Accelerated bridge construction with arch fabricated off-site and floated in.	●●	Significant portion of structure erected by stick building.	●●	Requires tower cranes which have limited operation window during wind.	●●	Requires tower cranes which have limited operation window during wind.	●	Accelerated construction by working from two piers simultaneously, pier segments are time consuming.	●●	Slow construction (cable spinning)
	Constructability	●●	Record-span float-in or stick building, float-in requires fabrication yard on shore between existing bridges due to height of structure.	●●●	Vertical clearance restrictions and barging operations favor shorter span.	●●	Stick building with floated in drop-in span.	●●	Repetitive construction cycle, but requires careful cable force and geometry control, tower construction. Vulnerable to high wind events during construction.	●●	Repetitive construction cycle, but requires careful cable force and geometry control, tower construction. Vulnerable to high wind events during construction.	●	Record span for USA. Repetitive construction cycle.	●●	Uncommon type of structure.
	Impact on Canal Traffic	●●	Reduced channel width (~380 ft) due to falsework required during arch erection (~ 1 year).	●●	Barge operations near shore line, one 24 hr closure for drop-in lift.	●●	Barge operations near shore line, one 24 hr closure for drop-in lift.	●	Periodic, partial obstructions for segment lift from barge (approximately 40 lifts).	●	Periodic, partial obstructions for segment lift from barge (approximately 40 lifts).	●●●	None.	●	Periodic, partial obstructions for segment lift from barge (approximately 40 lifts).
	Maintenance of Traffic	··		··		··		··		··		··		··	
	Environmental Impact	··		··		··		··		··		··		··	
STRUCTURAL REDUNDANCY	**Fracture-Critical Members**	●●	Fracture critical elements (ties, hangers, floorbeams) designed for system or internal redundancy.	●●	Fracture critical elements (ties, hangers, floorbeams) designed for system or internal redundancy.	●●●	Tension diagonals, tension chords designated as fracture-critical members.	●●	Hangers, floorbeams - designed for system or internal redundancy.	●●	Hangers, floorbeams - designed for system or internal redundancy.	●●●	No fracture critical members.	●●	Main cables. Floorbeams and hangers designed for system redundancy.
	Failure-Critical Members	●●	Arch ribs.	●●	Arch ribs.	●●	Any truss member.	●●	Stiffening girder.	●●	Stiffening girder.	●●	Post-tensioning tendons.	●	Saddles.
INSPECTION & MAINTENANCE	**Access**	●●	Accessible tie girders and ribs, snooper for under-deck, cherry picker for cables.	●●	Accessible tie girders and ribs, snooper for under-deck, cherry picker for cables.	●●	Snooper and cherry picker.	●	Accessible towers, snooper or traveler platform for under-deck, rope access for cables.	●	Accessible towers, snooper or traveler for under-deck, rope access for cables.	●●	Accessible box girder, snooper for under-deck, but cannot inspect internal tendons.	●●	Accessible tower, walkable main cable, snooper or traveler for under-deck.
	Frequency	●	Typical cycle.	●	Typical cycle.	●●	Hands-on inspection of fracture-critical items at two-year intervals.	●	Typical cycle.	●	Typical cycle.	●●●	Typical cycle, fewest inspection items.	●	Typical cycle.
DURABILITY	**Protection**	●	Has vulnerable elements above deck. Metallized steel, partially prestressed precast deck panels.	●	Has vulnerable elements above deck. Metallized steel, partially prestressed precast deck panels.	●	Has vulnerable elements above deck. Metallized steel, concrete cover and corrosion resistant reinforcement.	●	Has vulnerable elements above deck. Metallized steel, partially prestressed precast deck panels.	●	Has vulnerable elements above deck. Metallized steel, partially prestressed precast deck panels.	●●	Fewest exposed elements, deck fully prestressed longitudinally and transversely, concrete cover and corrosion resistant reinforcement.	●●	Has vulnerable elements above deck. Metallized steel, concrete cover and corrosion resistant reinforcement.
	Replacement	●	Cables, deck overlay system, deck.	●	Cables, deck overlay system, deck.	●	Deck overlay system, deck.	●	Cables, deck overlay system, typically not designed for deck replacement.	●	Cables, deck overlay system, typically not designed for deck replacement.	●●	Deck overlay system, deck replacement not possible.	●●	Cables, deck overlay system. Main cable is not replaceable.
	Monitoring	●	Cables.	●	Cables.	●	None required.	●	Cables.	●	Cables.	●	None required.	●	Cables.
WIND RESPONSE	**Structural Efficiency**	●		●		●		●●	Wind response during construction governs pylon and foundation design.	●●	Poor wind performance (effectively twice the span length)	●	Large depth for wind catching area - larger foundation loads.	●	
	Dynamic Effects	●●	Requires wind tunnel studies.	●●	Requires wind tunnel studies.	●	Potential for truss member vibrations.	●●	Requires wind tunnel studies.	●●	Requires wind tunnel studies.	●●	Negligible.	●●	Requires wind tunnel studies.
SNOW & ICE RESPONSE	**Bridge closures**	●	Uncommon.	●	Uncommon.	●	Uncommon.	●●	During critical climate conditions.	●●	During critical climate conditions.	●●	Uncommon.	●●	Uncommon.
	Monitoring/Deicing	●	Ice drop from rib-bracing.	●	Ice drop from rib-bracing.	●	Ice drop from top chord bracing.	●●	Ice drop from cables.	●●	Ice drop from cables.	●●	Uncommon.	●●	Uncommon.
COMMUNITY CONSIDERATIONS	**Appearance/Signature**	●●	Iconic.	●●●	Echoes appearance of existing structure.	●●	Dissimilarity to historic structure likely has adverse impact on Cape Cod Historic District.	●●	Dissimilarity to historic structure likely has adverse impact on Cape Cod Historic District.	●●	Dissimilarity to historic structure likely has adverse impact on Cape Cod Historic District.	●●	Dissimilarity to historic structure likely has adverse impact on Cape Cod Historic District.	●●	Dissimilarity to historic structure likely has adverse impact on Cape Cod Historic District.
	Bike/Pedestrian Path	··		··		··		··		··		··			

CABLE STAYED BRIDGE TOWERS		Single H		Free-Standing H		Separate H's		Merged H's		Single A/Inverted Y		Separate A's		Merged A's	
Most Favorable Favorable Neutral Less Favorable Unfavorable Not Rated															
EVALUATION CRITERIA		Rating	Notes	Rating	Notes	Rating	Notes	Rating	Notes	Rating	Notes	Rating	Notes	Rating	Notes
INITIAL COST	**Main Span Structure**	●●	Simplest tower shape.	●●	Inefficient structural system.	●	More complex formwork and bracing for inclined legs.	●●	Simple shape, efficient structure.	●	More complex formwork and bracing for inclined legs, inefficient structural system.	●	More complex formwork and bracing for inclined legs.	●	Most complex tower shape.
	Main Span Foundations	••		••		••		••		••		••		••	
	Overall	••		••		••		••		••		••		••	
HIGHWAY GEOMETRICS	**Grade/Length**	••		••		••		••		••		••		••	
	Footprint	••		••		••		••		••		••		••	
	Horizontal Tangent Length	••		••		••		••		••		••		••	
MAINSPAN FOOTINGS	**Vessel Impact**	••		••		••		••		••		••		••	
	Scour	••		••		••		••		••		••		••	
CONSTRUCTION	**Phasing**	●●	Not an option.	●●	Not an option.	●●	Easily accommodates phased construction.	●	Possible, with extra considerations for tower construction.	●●	Not an option.	●●	Easily accommodates phased construction.	●	Possible, with extra considerations for tower construction.
	Duration	••		••		••		••		••		••		••	
	Constructability	●●	Simplest tower shape.	●		●		●●	Simple tower shape.	●●	Inclined tower legs.	●●	Inclined tower legs.	●●	Inclined and intersecting tower legs.
	Impact on Canal Traffic	••		••		••		••		••		••		••	
	Maintenance of Traffic	••		••		••		••		••		••		••	
	Environmental Impact	••		••		••		••		••		••		••	
STRUCTURAL REDUNDANCY	**Fracture-Critical Members**	••		••		••		••		••		••		••	
	Failure-Critical Members	••		••		••		••		••		••		••	
INSPECTION & MAINTENANCE	**Access**	••		••		••		••		••		••		••	
	Frequency	••		••		••		••		••		••		••	
DURABILITY	**Protection**	••		••		••		••		••		••		••	
	Replacement	••		••		••		••		••		••		••	
	Monitoring	••		••		••		••		••		••		••	
WIND RESPONSE	**Structural Efficiency**	●	Frame action.	●●	Flagpoles.	●	Frame action.	●●	Frame action.	●●	Truss action.	●●	Truss action.	●●	Truss action.
	Dynamic Effects	●●	Good flutter resistance due to great deck width.	●	Flexible tower legs.	●●	Wake effects, upstream/downstream wind flow interactions, poor deck flutter resistance.	●●	Wake effects, upstream/downstream wind flow interactions, poor deck flutter resistance.	●●	Best deck flutter resistance.	●●	Improved deck flutter resistance.	●●	Improved deck flutter resistance.
SNOW & ICE RESPONSE	**Bridge closures**	●	During critical climate conditions.	●●	During critical climate conditions.	●	During critical climate conditions.	●	During critical climate conditions.	●●	During critical climate conditions.	●●	During critical climate conditions.	●●	During critical climate conditions.
	Monitoring/Deicing	●	Ice drop from cables.	●●	Ice drop from cables.	●	Ice drop from cables.	●	Ice drop from cables.	●●	Ice drop from cables.	●●	Ice drop from cables.	●●	Ice drop from cables.
COMMUNITY CONSIDERATIONS	**Appearance/Signature**	●●	Simple.	●●	Less stable appearance.	●	Busy.	●	Simple.	●●	Odd proportions.	●●	Elegant.	●●	Iconic.
	Bike/Pedestrian Path	••		••		••		••		••		••		••	

CABLE-STAYED BRIDGE PYLONS		Single Cable Plane/Two Boxes		Single Cable Plane/Single Box		Two Cable Planes/Single Box		Three C. Planes/Single Box		Two C. Planes/Edge Girders	
Most Favorable Favorable Neutral Less Favorable Unfavorable Not Rated											
EVALUATION CRITERIA		Rating	Notes	Rating	Notes	Rating	Notes	Rating	Notes	Rating	Notes
INITIAL COST	Main Span Structure	●	Greatest structure weight.	●	Slow deck construction.	●	Slow deck construction.	●	Slow deck construction.	●	Simplest tower.
	Main Span Foundations	••		••		••		••		••	
	Overall	••		••		••		••		••	
HIGHWAY GEOMETRICS	Grade/Length	••		••		••		••		••	
	Footprint	••		••		••		••		••	
	Horizontal Tangent Length	••		••		••		••		••	
MAINSPAN FOOTINGS	Vessel Impact	••		••		••		••		••	
	Scour	••		••		••		••		••	
CONSTRUCTION	Phasing	●●	Not an option.	●●	Not an option.	●●	Not an option.	●●	Not an option.	●●	Not an option.
	Duration	••		••		••		••		••	
	Constructability	●	Precast concrete segments for deck.	●●	Cast-in-place concrete for deck.	●●	Cast-in-place concrete for deck.	●●●	Cast-in-place concrete for deck, interaction between three cable planes.	●●	Simplest deck system.
	Impact on Canal Traffic	••		••		••		••		••	
	Maintenance of Traffic	••		••		••		••		••	
	Environmental Impact	••		••		••		••		••	
STRUCTURAL REDUNDANCY	Fracture-Critical Members	••		••		••		••		••	
	Failure-Critical Members	••		••		••		••		••	
INSPECTION & MAINTENANCE	Access	••		••		••		••		••	
	Frequency	••		••		••		••		••	
DURABILITY	Protection	••		••		••		••		••	
	Replacement	••		••		••		••		••	
	Monitoring	••		••		••		••		••	
WIND RESPONSE	Structural Efficiency	●●	Flagpole.	●●	Flagpole.	●●	Tower and deck stabilize each other.	●●	Tower and deck stabilize each other.	●	More flexible deck, small torsional stiffness.
	Dynamic Effects	●	Flexible tower.	●	Flexible tower.	●●	Very stable system.	●●	Very stable system.	●	
SNOW & ICE RESPONSE	Bridge closures	●	During critical climate conditions.	●	During critical climate conditions.	●●	During critical climate conditions.	●●	During critical climate conditions.	●●	During critical climate conditions.
	Monitoring/Deicing	●	Ice drop from cables.	●	Ice drop from cables.	●●	Ice drop from cables.	●●	Ice drop from cables.	●●	Ice drop from cables.
COMMUNITY CONSIDERATIONS	Appearance/Signature	●●	Clean lines due to single cable plane.	●●	Single cable plane, closed box for deck.	●	Closed box for deck.	●●	Closed box for deck, busy with cables.	●●	Visible deck grillage.
	Bike/Pedestrian Path	••		••		••		••		••	

ARCH RIBS		Single/Vertical Ribs		Separate/Vertical Ribs		Merged/Vertical Ribs		Single/Freestanding		Single/Basket Handle		Separate/Basket Handle	
●●● Most Favorable ●● Favorable ● Neutral ●● Less Favorable ●●● Unfavorable •• Not Rated													
EVALUATION CRITERIA		Rating	Notes	Rating	Notes	Rating	Notes	Rating	Notes	Rating	Notes	Rating	Notes
INITIAL COST	**Main Span Structure**	●		●		●		●	Higher rib quantity and complexity, but no upper lateral bracing.	●		●●	**Least rib bracing quantity.**
	Main Span Foundations	••		••		••		••		••		••	
	Overall	••		••		••		••		••		••	
HIGHWAY GEOMETRICS	**Grade/Length**	••		••		••		••		••		••	
	Footprint	••		••		••		••		••		••	
	Horizontal Tangent Length	••		••		••		••		••		••	
MAINSPAN FOOTINGS	**Vessel Impact**	••		••		••		••		••		••	
	Scour	••		••		••		••		••		••	
CONSTRUCTION	**Phasing**	●●	Not an option.	●●	**Easily accommodates phased construction.**	●●	Not an option.	●●	Not an option.	●●	Not an option.	●	**2x24-ft roadways but no path in temporary configuration.**
	Duration	••		••		••		••		••		••	
	Constructability	●	Fewer, larger pieces to handle. More difficult to float in.	●●	**Smaller, but more pieces to handle.**	●●●	Three cable planes makes hanger forces and floorbeam moments difficult to control.	●●	Demanding geometry control for ribs.	●	More complex rib shoring.	●●	**Smaller pieces to handle.**
	Impact on Canal Traffic	••		••		••		••		••		••	
	Maintenance of Traffic	••		••		••		••		••		••	
	Environmental Impact	••		••		••		••		••		••	
STRUCTURAL REDUNDANCY	**Fracture-Critical Members**	••		••		••		••		••		••	
	Failure-Critical Members	••		••		••		••		••		••	
INSPECTION & MAINTENANCE	**Access**	••		••		••		••		••		••	
	Frequency	••		••		••		••		••		••	
DURABILITY	**Protection**	••		••		••		••		••		••	
	Replacement	••		••		••		••		••		••	
	Monitoring	••		••		••		••		••		••	
WIND RESPONSE	**Structural Efficiency**	●	Truss action, but high moment demands at portal frame.	●	**Truss action, but high moment demands at portal frame.**	●	Truss action, but high moment demands at portal frame.	●●●	Structural system not appropriate for this site.	●●	A-shape helps with wind resistance.	●●	**A-shape helps with wind resistance.**
	Dynamic Effects	●	More susceptible.	●	**Potential for wake effects with closely spaced arch ribs.**	●	More susceptible.	●●	Most susceptible.	●●	Less susceptible.	●●	**Less susceptible.**
SNOW & ICE RESPONSE	**Bridge closures**	●	Uncommon.	●	**Uncommon.**	●	Uncommon.	●	Uncommon.	●	Uncommon.	●	**Uncommon.**
	Monitoring/Deicing	●	Ice drop from rib bracing.	●	**Ice drop from rib bracing.**	●	Ice drop from rib bracing.	●●	No bracing members.	●●	Ice drop from ribs and rib bracing.	●●	**Ice drop from ribs and rib bracing.**
COMMUNITY CONSIDERATIONS	**Appearance/Signature**	●●	More rib bracing.	●●	**More rib bracing.**	●●	More rib bracing.	●●	Clean lines.	●●	Odd proportions.	●●	**Less bracing.**
	Bike/Pedestrian Path	••		••		••		••		••		••	

BOX GIRDERS		Single Concrete Box		Separate Concrete Boxes		Separate Steel Boxes	
Most Favorable Favorable Neutral Less Favorable Unfavorable Not Rated							
EVALUATION CRITERIA		Rating	Notes	Rating	Notes	Rating	Notes
INITIAL COST	**Main Span Structure**	●●●	Very complex and heavy form traveler.	●●	Good repetition and rhythm.	●●●	Not competitive due to complex fabrication.
	Main Span Foundations	••		••		••	
	Overall	••		••		••	
HIGHWAY GEOMETRICS	**Grade/Length**	••		●●●	Highway design constraints require minimizing structure depth.	••	
	Footprint	••		••		••	
	Horizontal Tangent Length	••		••		••	
MAINSPAN FOOTINGS	**Vessel Impact**	••		••		••	
	Scour	••		••		••	
CONSTRUCTION	**Phasing**	●●	Not an option.	●●	Easily accommodates phased construction.	●●	Easily accommodates phased construction.
	Duration	••		••		••	
	Constructability	●●	Complex and heavy form traveler.	●●	Routine.	●●	Unusual system.
	Impact on Canal Traffic	••		••		••	
	Maintenance of Traffic	••		••		••	
	Environmental Impact	••		••		••	
STRUCTURAL REDUNDANCY	**Fracture-Critical Members**	●●	No.	●●	No.	●●	Tension flanges and webs.
	Failure-Critical Members	••		••		••	
INSPECTION & MAINTENANCE	**Access**	••		••		••	
	Frequency	••		••		••	
DURABILITY	**Protection**	••		••		••	
	Replacement	••		••		••	
	Monitoring	••		••		••	
WIND RESPONSE	**Structural Efficiency**	••		••		••	
	Dynamic Effects	●	Insensitive to dynamic effects.	●	Insensitive to dynamic effects.	●●	Sensitive to vortex-shedding induced oscillations.
SNOW & ICE RESPONSE	**Bridge closures**	••		••		••	
	Monitoring/Deicing	••		••		••	
COMMUNITY CONSIDERATIONS	**Tensioned**	●●	Understated elegance, closed box gives clean lines.	●●	Understated elegance, closed box gives clean lines.	●	Splices detract from otherwise elegant appearance.
	Bike/Pedestrian Path	••		••		••	

DECK GIRDERS		Edge Steel Box (Arch)		Edge I-Girder W/Bracket (C.S.)		Edge I-Girder W/Fin (C.S.)		Edge Concrete Girders (C.S.)		Cable-Supported Box Girder		Self-Supporting Box Girder	
●●● Most Favorable ●● Favorable ● Neutral ●● Less Favorable ●●● Unfavorable •• Not Rated													
EVALUATION CRITERIA		Rating	Notes	Rating	Notes	Rating	Notes	Rating	Notes	Rating	Notes	Rating	Notes
INITIAL COST	**Main Span Structure**	••		••		••		••		••		••	
	Main Span Foundations	••		••		••		••		••		••	
	Overall	••		••		••		••		••		••	
HIGHWAY GEOMETRICS	**Grade/Length**	••		••		••		••		●●●	Highway design constraints require minimizing structure depth.	●●●	Highway design constraints require minimizing structure depth.
	Footprint	••		••		••		••		••		••	
	Horizontal Tangent Length	••		••		••		••		••		••	
MAINSPAN FOOTINGS	**Vessel Impact**	••		••		••		••		••		••	
	Scour	••		••		••		••		••		••	
CONSTRUCTION	**Phasing**	••		••		••		••		••		••	
	Duration	••		••		••		••		••		••	
	Constructability	●● 4	**Simple system, much repetition.**	●● 4	**Simple system, much repetition.**	● 3	**Simple system, much repetition, but fin plate connection to edge girder is challenging.**	●●●	Precast or cast-in-place deck, difficult erection control.	●	Numerous heavy precast elements.	●●	Simplest system.
	Impact on Canal Traffic	••		••		••		••		••		••	
	Maintenance of Traffic	••		••		••		••		••		••	
	Environmental Impact	••		••		••		••		••		••	
STRUCTURAL REDUNDANCY	**Fracture-Critical Members**	●● 4	**Edge boxes designed for internal redundancy.**	●● 4	**Floorbeam spacing < 12 feet or > 15 feet with redundancy girders.**	●● 4	**Floorbeam spacing < 12 feet or additional redundancy girders.**	●●	None.	●●	None.	●●	None.
	Failure-Critical Members	● 3		● 3		● 3		●	Floorbeam post-tensioning tendons.	●●	Delta frames are critical component of system.	●	Longitudinal post-tensioning tendons.
INSPECTION & MAINTENANCE	**Access**	●● 4	**Accessible edge box girder, snooper.**	●● 4	**Snooper or inspection traveler.**	●● 4	**Snooper or inspection traveler.**	●●	Snooper or inspection traveler.	●●	Accessible box girders, snooper.	●●	Accessible box girders, snooper.
	Frequency	••		••		••		••		••		••	
DURABILITY	**Protection**	●● 4	**Cable anchorages inside box.**	● 3	**Cable anchorages below deck level.**	●● 2	**Cable anchorages at deck level.**	●●	Cable anchorages underneath edge girders.	●●	Cable anchorages and Delta frames below deck.	●●	Very few exposed elements.
	Replacement	••		••		••		••		••		••	
	Monitoring	••		••		••		••		••		••	
WIND RESPONSE	**Structural Efficiency**	••											
	Dynamic Effects	●● 4	**Box edge girder is less susceptible.**	●● 2	**Relatively poor wind performance.**	●● 2	**Relatively poor wind performance.**						
SNOW & ICE RESPONSE	**Bridge closures**	••											
	Monitoring/Deicing	••											
COMMUNITY CONSIDERATIONS	**Appearance/Signature**	● 3	**Visible deck grillage and bracing, numerous splices.**	● 3	**Visible deck grillage, numerous splices.**	● 3	**Visible deck grillage.**	●●	Cleaner lines, no splices.	●●	Closed box, cleaner lines.	●●	Closed box, cleaner lines.
	Bike/Pedestrian Path	••											

APPROACHES		Steel Plate Girders		Concrete Bulb Tees		Single-Cell Concrete Box		Steel Tub Girders	
		Most Favorable Favorable Neutral Less Favorable Unfavorable Not Rated							
EVALUATION CRITERIA		Rating	Notes	Rating	Notes	Rating	Notes	Rating	Notes
INITIAL COST	**Main Span Structure**	5 ●●●	**Common bridge type, longer spans available.**	2 ●●	Less efficient system, shorter spans (125-ft).	1 ●●●	Only economical in conjunction with segmental main box.	4 ●●	More complex fabrication, but cost competitive for straight highway alignment.
	Main Span Foundations	4 ●●		2 ●●	More foundations.	1 ●	Heavy foundations.	4 ●●	
	Overall	x ••		x ••		x ••		x ••	
HIGHWAY GEOMETRICS	**Grade/Length**	x ••		x ••		x ••		x ••	
	Footprint	x ••		x ••		x ••		x ••	
	Horizontal Tangent Length	x ••		x ••		x ••		x ••	
MAINSPAN FOOTINGS	**Vessel Impact**	x ••		x ••		x ••		x ••	
	Scour	x ••		x ••		x ••		x ••	
CONSTRUCTION	**Phasing**	4 ●●	**Can be easily accommodated.**	4 ●●	Can be easily accommodated.	4 ●●	With two boxes.	4 ●●	Can be easily accommodated.
	Duration	x ••		x ••		x ••		x ••	
	Constructability	4 ●●	**Typical system.**	1 ●●●	Inappropriate for long spans. Using spliced girders introduces complex construction logistics.	2 ●●	Requires complex erection gantry or falsework.	1 ●●●	Difficult crane access and high pick weight.
	Impact on Canal Traffic	x ••		x ••		x ••		x ••	
	Maintenance of Traffic	x ••		x ••		x ••		x ••	
	Environmental Impact	x ••		x ••		x ••		x ••	
STRUCTURAL REDUNDANCY	**Fracture-Critical Members**	x ••		x ••		x ••		x ••	
	Failure-Critical Members	x ••		x ••		x ••		x ••	
INSPECTION & MAINTENANCE	**Access**	x ••		x ••		x ••		x ••	
	Frequency	x ••		x ••		x ••		x ••	
DURABILITY	**Protection**	4 ●●	**Weathering steel, deck protection system.**	4 ●●	Fully prestressed girders, deck protection system.	4 ●●	Deck prestressed in two directions, deck protection system.	4 ●●	Weathering steel, deck protection system.
	Replacement	4 ●●	**Deck is replaceable.**	4 ●●	Deck is replaceable.	1 ●	Sacrificial deck thickness, deck not replaceable.	4 ●●	Deck is replaceable.
	Monitoring	x ••		x ••		x ••		x ••	
WIND RESPONSE	**Structural Efficiency**	x ••		x ••		x ••		x ••	
	Dynamic Effects	x ••		x ••		x ••		x ••	
SNOW & ICE RESPONSE	**Bridge closures**	x ••		x ••		x ••		x ••	
	Monitoring/Deicing	x ••		x ••		x ••		x ••	
COMMUNITY CONSIDERATIONS	**Appearance/Signature**	3 ●	**Utilitarian.**	3 ●	Utilitarian.	4 ●●	Clean lines.	4 ●●	Clean lines.
	Bike/Pedestrian Path	x ••		x ••		x ••		x ••	

Appendix D Cape Cod Bridges Program Screening of Highway Interchange Approach Concepts

PRE-DECISIONAL AND DELIBERATIVE



CAPE COD BRIDGE REPLACEMENTS

Screening of Highway Interchange Approach Concepts

PREPARED BY HNTB FOR massDOT Massachusetts Department of Transportation

CAPE COD BRIDGES PROGRAM: SCREENING OF HIGHWAY INTERCHANGE APPROACH CONCEPTS

Introduction

In 2020, the Massachusetts Department of Transportation (MassDOT) began highway interchange approach concepts for the Cape Cod Canal Bridges Program in coordination with the Federal Highway Administration (FHWA) and the U.S. Army Corps of Engineers (USACE). This work started by exploring the broadest range of concepts possible, including solutions that were evaluated as part of its Cape Cod Canal Area Transportation Study, which was prepared in collaboration with the FHWA.

This report presents a table of the 80 highway interchange approach concepts, including discrete design elements, that MassDOT initially developed for the Bourne and Sagamore Program Study Area quadrants as shown on Figure 1: Bourne North, Bourne South, Sagamore North, and Sagamore South. These initial highway interchange approach concepts included 29 concepts for Bourne North, 17 concepts for Bourne South, 18 concepts for Sagamore North, and 16 concepts for Sagamore South.

The initial screening consisted of defining highway interchange approach concepts according to three status levels:

- Active, where the concept was deemed to be a viable option to be further refined;
- Incorporated Elsewhere, where portions of the concept were viable and incorporated into another concept;
- Not Being Further Developed (NBFD), where the concept demonstrated fatal flaws and was not carried forward for further design or where a similar concept provided the same connections with less environmental or right-of-way impacts.

The highway interchange approach concepts were screened according to feasibility and reasonability. At this level of evaluation, feasibility was based on aerial images for the horizontal alignment and USGS approximate elevations for the vertical alignment. Concepts that were deemed to be viable but were like other more favorable concepts were incorporated into those concepts, either wholly or partially, and were labeled as "Incorporated Elsewhere." Concepts that presented significant geometric or safety challenges, did not provide all necessary connections, or posed infeasible constructability issues were identified as fatally flawed, labeled as "NBFD," and were not carried forward for further design and evaluation. Other NBFD concepts included those concepts that provided the same connections as other concepts but involved more environmental or right-of-way impacts.

MassDOT identified a category of "Paused/Pending Future Need" concepts specific to the Bourne North Program Study Area quadrant. These discrete design elements were related to Belmont Circle improvements. MassDOT paused the development of these design elements pending the need for improvements to Belmont Circle.

MassDOT identified a category of "Deferred/Design Development" concepts specific to the Sagamore North Program Study Area quadrant. These discrete design elements were deemed to be potentially viable; however, MassDOT opted to defer the advancement of these specific design elements until further design.

Of the 46 concepts initially developed for the Bourne Program Study Area, nine concepts were defined as active options to advance for further evaluation, seven concepts were incorporated elsewhere, 26 concepts were defined as NBFD, and four concepts were paused. Of the 34 concepts MassDOT initially developed for the Sagamore Program Study Area, 13 concepts were defined as active options to advance for further evaluation, two concepts were incorporated elsewhere, 12 concepts were defined as NBFD, and seven concepts were deferred.

In sum, from the 80 highway interchange approach concepts that MassDOT initially developed, a total of 22 active options were advanced for further design and evaluation.

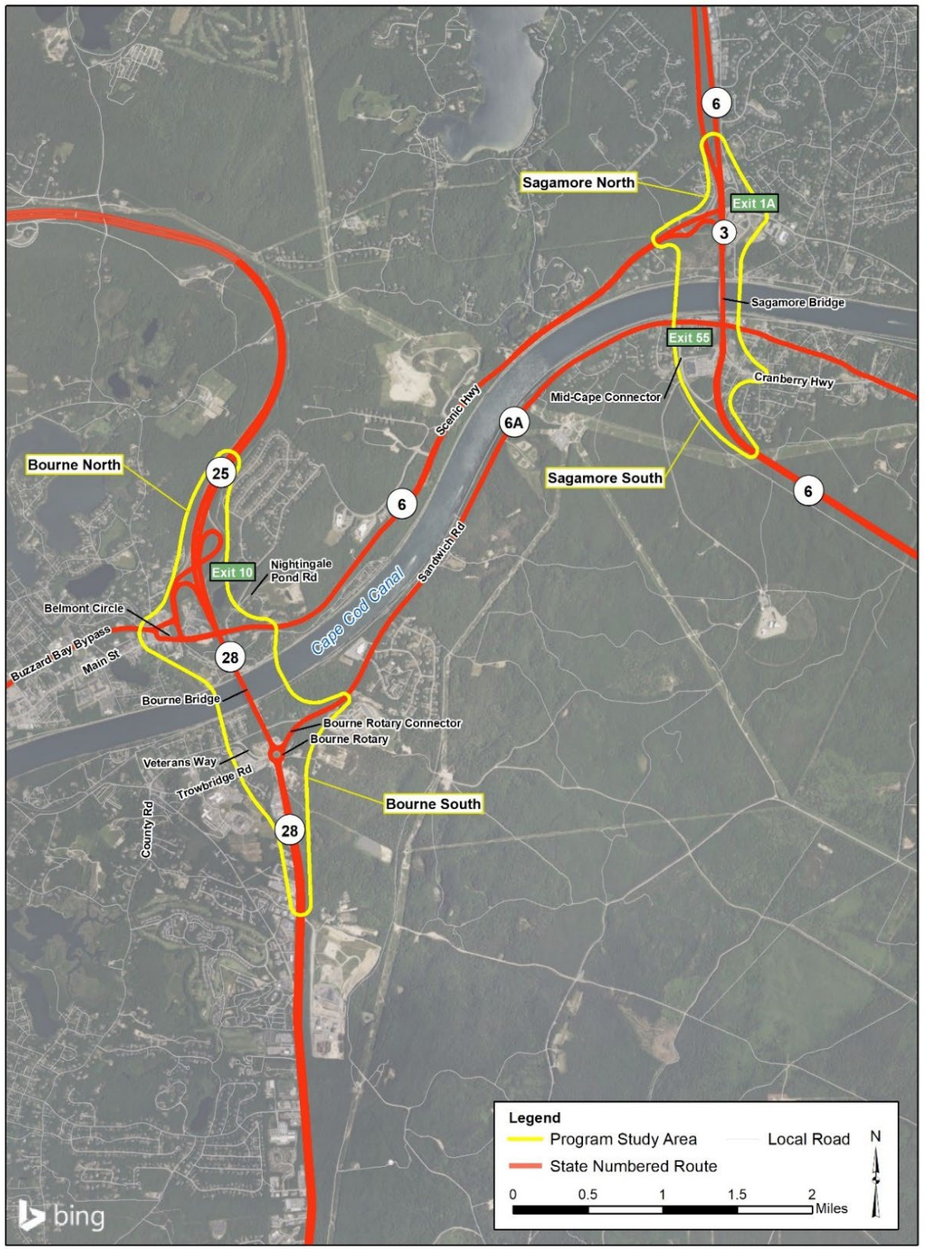


Figure 1. Bourne and Sagamore Program Study Area Quadrants

Alt ID	Name	Alternative Description or Sub-Alternative Modification	Status	Reason for Non-Active Status	Date of Initial Development	Date of Modification	Date of Pause for advancement	Date of Elimination
Bourne North Interchanges								
BN-1	Belmont Circle T	Reconfiguration of Belmont Circle into a T intersection	Not Being Developed Further	due to traffic analysis poor ops - replaced with 1.2	February 2021		October 2021	November 2021
BN-1.1	Belmont Circle Florida T	Reconfiguration of Belmont Circle into a Florida T intersection	Not Being Developed Further	due to traffic analysis poor ops - replaced with 1.2	July 2021		October 2021	November 2022
BN-1.2	Main St & Scenic Highway Alginment - Belmont Circle	Reconfiguration of Belmont Circle to the South Side of the circle so that Main St to Rt 6 (heavier movement) can be the through movement	Paused/Pending Future Need	Related to Belmont Circle improvements; development of the design element was put on hold pending the need for improvements to Belmont Circle.	October 2021			
BN-2	Belmont Circle 4 Legged	Reconfiguration of Belmont Circle into a 4 legged intersection	Paused/Pending Future Need	Related to Belmont Circle improvements; development of the design element was put on hold pending the need for improvements to Belmont Circle.	April 2020	October 2021		
BN-2.1	Belmont Circle Roundabout	4 legged intersection with roundabout and bypass lanes	Paused/Pending Future Need	Related to Belmont Circle improvements; development of the design element was put on hold pending the need for improvements to Belmont Circle.	October 2021	October 2021		
BN-3	Realigned Route 6	Realignment of Route 6 with Buzzards bay via old bridge approach roadway	Paused/Pending Future Need	Related to Belmont Circle improvements; development of the design element was put on hold pending the need for improvements to Belmont Circle.	April 2020	October 2021	January 2022	
BN-3.1	Realigned Route 6 with Florida T	Realignment of Route 6 with at-grade Florida T intersection with ramps	Not Being Developed Further	This intersection option requires realignment of Scenic Highway through the businesses on the Bourne Bridge Approach roadway. The impacts to local businesses and residential houses on the east side of the bridge are severe and this option is seen as undesirable.	July 2021			December 2021
BN-4	Northbound Diamond	Half diamond (NB)	Not Being Developed Further	NB off-ramp grade over 7%	April 2020			February 2021
BN-5	NB Frontage Road	NB on-ramp to frontage road	Not Being Developed Further	connection from 6 WB to existing loop ramp option more desirable (BN-6.1)	April 2020			September 2021
BN-6	NB Separated Off Ramp	NB on-ramp separated from Off ramp	Not Being Developed Further	connection from 6 WB to existing loop ramp option more desirable (BN-6.1)	April 2020			September 2021
BN-6.1	NB Separated Off Ramp	NB on-ramp to connect to existing outer loop on ramp	Active		September 2021			
BN-7	Diverging Diamond	Diverging diamond interchange at Route 6 (Scenic Hwy)	Not Being Developed Further	NB off-ramp and SB on-ramp grade over 7%	April 2020			February 2021
BN-8	Big Diverging Diamond	Diverging diamond with split Route 6 (Scenic Hwy)	Not Being Developed Further	NB off-ramp and SB on-ramp grade over 7%	April 2020			February 2021
BN-9	Underpass	Underpass at Belmont Circle	Not Being Developed Further	utiltiy and grounder issues preculde this alaternative	April 2020			September 2021

Alt ID	Name	Alternative Description or Sub-Alternative Modification	Status	Reason for Non-Active Status	Date of Initial Development	Date of Modification	Date of Pause for advancement	Date of Elimination
BN-10	Overpass	Overpass at Belmont Circle	Active		May 2021			
BN-10.1	Overpass with WB to NB slip lane	Overpass at Belmont Circle Belmont Circle intersection shifted WB Removed Route 6 WB to NB ramp, replaced with slip lane at intersection	Not Being Developed Further	too much fill required, is undesireable compared to BN-10	September 2021	October 2021		
BN-11	Continuous Flow Green T	Continuous flow intersection on Scenic Hwy with NB on-ramp	Not Being Developed Further	new loop ramp option more desirable (BN-11.1)	April 2020	October 2021		September 2021
BN-11.1	Continuous Flow Green T	Continuous flow intersection on Scenic Hwy with NB on-ramp to existing outer loop on ramp	Not Being Developed Further	-other design alternative carry same movements in simpler alignemnts. Retained for poxxible inclusion of some of the elements in this alternative for others	September 2021		October 2021	
BN-12	Belmont Circle T with roundabout	Belmont Circle replaced with roundabout, NB on-ramp merges or stays separated from off ramp	Incorporated Elsewhere	roundabout moved to BN 2.1	July 2021	October 2021		
BN-13	Modified Diamond 1	SB off ramp to Rt 6 and Rt 6 to NB on ramp direct connection, bypassing Belmont Circle	Not Being Developed Further	connection from 6 WB to existing loop ramp option more desirable (BN-13.1)	July 2021			September 2021
BN-13.1	Modified Diamond 1	SB off ramp to Rt 6 and Rt 6 to NB on ramp direct connection, bypassing Belmont Circle NB on-ramp to connect to existing outer loop on ramp	Active		September 2021			
BN-14	Modified Diamond 2 - Option 1	SB off ramp to Rt 6 and Rt 6 to NB on ramp direct connection, bypassing Belmont Circle Realigned neighborhood access to High Ridge Drive and new campground entrance	Not Being Developed Further	connection from 6 WB to existing loop ramp option more desirable (BN-14.2)	July 2021			September 2021
BN-14	Modified Diamond 2 - Option 2	SB off ramp to Rt 6 and Rt 6 to NB on ramp direct connection, bypassing Belmont Circle Realigned neighborhood access to Desert Drive and new campground entrance	Not Being Developed Further	connection from 6 WB to existing loop ramp option more desirable (BN-14.3)	July 2021			September 2021
BN-14.1	Modified Diamond 3	SB off ramp to Rt 6 and Rt 6 to NB on ramp direct connection, bypassing Belmont Circle	Not Being Developed Further	connection from 6 WB to existing loop ramp option more desirable (BN-14.4)	July 2021			September 2021
BN-14.2	Modified Diamond 2 - Option 1	SB off ramp to Rt 6 and Rt 6 to NB on ramp direct connection, bypassing Belmont Circle NB on-ramp to connect to existing outer loop on ramp Realigned neighborhood access to High Ridge Drive and new campground entrance	Not Being Developed Further	Alternative required closure of Nightingale ROad at Scenic Highway. Reconnection to maintain residential access required long and roundabout route around the cranberry bog and new full signalized intersection on Scenic Highway. Option was removed as BN-14.4b accomplished the same connections.	September 2021			January 2022
BN-14.3	Modified Diamond 2 - Option 2	SB off ramp to Rt 6 and Rt 6 to NB on ramp direct connection, bypassing Belmont Circle NB on-ramp to connect to existing outer loop on ramp Realigned neighborhood access to Desert Drive and new campground entrance	Incorporated Elsewhere	- provided as sub alternative to 14.2	September 2021			
BN-14.4	Modified Diamond 3	SB off ramp to Rt 6 and Rt 6 to NB on ramp direct connection, bypassing Belmont Circle NB on-ramp to connect to existing outer loop on ramp	Incorporated Elsewhere	- provided as sub alternative to 14.2	September 2021			
BN-14.4a	Modified Diamond 3 With at Grade Intersection at Nightingale	SB off ramp to Rt 6 and Rt 6 to NB on ramp at intersection at Nightingale Road, bypassing Belmont Circle NB on-ramp to connect to existing outer loop on ramp	Incorporated Elsewhere	- provided as sub alternative to 14.2	October 2021			
BN-14.4b	Modified Diamond 3 With at Grade Intersection at Nightingale	SB off ramp to Rt 6 and Rt 6 to NB on ramp at intersection at Nightingale Road, bypassing Belmont Circle NB on-ramp to connect to existing outer loop on ramp with structure over Nighingale Road	Active	- provided as sub alternative to 14.2	October 2021			

Alt ID	Name	Alternative Description or Sub-Alternative Modification	Status	Reason for Non-Active Status	Date of Initial Development	Date of Modification	Date of Pause for advancement	Date of Elimination
Bourne South Interchanges								
BS-1	At-Grade Intersection	At-grade 4 legged intersection	Not Being Developed Further	traffic analysis showed 3 left turn lanes on SB 28 - direction from massdot to not continue and move intersection to BS-9	Feb 2021			Sep-21
BS-2	Diamond	Diamond interchange	Active		April 2020			
BS-2.2	Diamond	Diamond interchange with Single Point Urban Interchange	Active		April 2020			
BS-3	Diverging Diamond	Diverging diamond interchange on Sandwich Rd/Trowbridge	Incorporated Elsewhere	provided as sub alternative to BS-2	April 2020		October 2021	February 2021
BS-4	Semi-Direct	Variation of Planning Study Alternative	Not Being Developed Further	SB Off ramp is expected to have impacts to the Police Barracks. Expectation for increased wayfinding signs necessary to clarify direct connection directions.	May 2021	October 2021		December 2021
BS-4.1	Modified Semi-Direct	Modified Study Alt with Rdbt.	Not Being Developed Further	no advantage with roundabout - design abandoned	April 2020			August 2021
BS-5	Modified No Cut Through	Partial cloverleaf with discontinued through route	Not Being Developed Further	No Trowbridge/Sandwich through for EB or WB was not considered viable	April 2020			February 2021
BS-6	Partial Clover 1	Partial cloverleaf with loops in SW & SE quadrants	Incorporated Elsewhere	Incorporated into BS-6.1.	February 2021			
BS-6.1	Partial Clover 1	Partial cloverleaf with loops in SW & SE quadrants Peanut roundabout in NW quadrant	Active		January 2022			
BS-7	Partial Clover 2	Partial cloverleaf with loops in SE quadrants	Not Being Developed Further	Alternatives requires very steep ramp profile grades. Elimination of Veteran's Road negatively impacts local traffic movements.	February 2021		October 2021	
BS-8	Split with Direct Connects	Trowbridge Rd E/W split with direct connects between	Not Being Developed Further	Alternative has poor merge/weave distances and excessive abutter impacts. Safety concerns with the proposed NB On-Ramp access through jug-handle.	February 2021		October 2021	
BS-9	Bourne Rotary Replaced with Roundabout	Bourne rotary replaced with roundabout and no Trowbridge Road through	Active		July 2021			
BS-9.1	Bourne Rotary Replaced with Roundabout	Bourne rotary replaced with roundabout and no Trowbridge Road through	Active		February 2022			
BS-10	Partial Clover 3	Partial cloverleaf with loops in SW & SE quadrants	Not Being Developed Further	Concerns about maintaining all the structures proposed in the hybrid alternatives "spaghetti ramps".	July 2021		October 2021	
BS-10.1	Partial Clover 3 Modified	Partial cloverleaf with loops in SW & SE quadrants. Differs from BS-10 with Sandwich Road cul-de-sac	Not Being Developed Further	Creates cul-de-sac of residential Sandwich Road Underpass. Concerns about maintaining all the structures proposed in the hybrid alternatives "spaghetti ramps".	July 2021		October 2021	
BS-11	Partial Clover 4	Partial cloverleaf with loops in SE quadrant	Not Being Developed Further	Requires a 50' tall structure over the mainline roadways. Concern about required maintenance on all hybrid options.	July 2021			October 2021
BS-12	Partial Clover 5	Partial cloverleaf with loops in SE quadrant	Incorporated Elsewhere	Alternative was combined with BS-6	August 2021		October 2021	

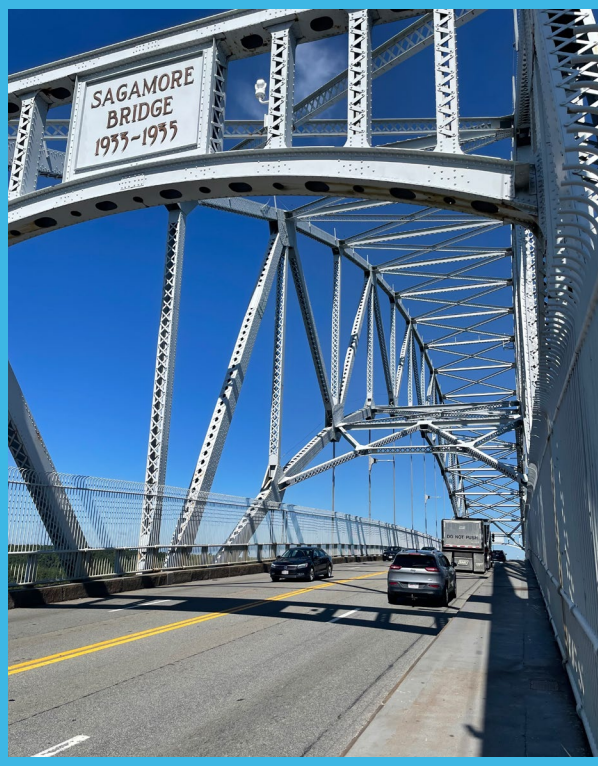
Alt ID	Name	Alternative Description or Sub-Alternative Modification	Status	Reason Alternative Is Not Being Developed Further	Date of Initial Development	Date of Modification	Date Development Held
Sagamore North Interchanges							
SN-1A (formerly SN-1)	Existing Configuration	Maintains existing ramp configurations	Active		April 2020		
SN-1B	Route 6 EB On Ramp - Existing Configuration	Maintains the idea of the existing geometry for the Route 6 EB On Ramp. Maintains free flow ramp condition and S curve geometry.	Incorporated Elsewhere	Incorporated elsewhere for future deisgn consideration	February 2022		
SN-1C	Route 3 SB Off Ramp with M-SF-3 Mainline Alignment	Maintains existing ramp geometry with adjustments to meet the SF-3 mainline alignment.	Not Being Developed Further	This alternative was eliminated when the M-SF-3 Mainline Alignment was eliminated. Note, the geometry for the Route 3 SB off ramp is the same as the geometry for SN-8D. The difference is the mainline that is being used for these alternatives.	February 2022		May 2022 (Mainline Matrix Development Process)
SN-2	NB Off-Ramp to Scenic Hwy	NB to EB movement to signalized T intersection with Meetinghouse Lane	Not Being Developed Further	Likely operational issues (replaced with SN-3)	February 2021		March 2021 (After MassDOT Mtg)
SN-3A (formerly SN-3)	NB Off-Ramp to State Road	NB to State Rd/Meetinghouse Lane movement to signalized T intersection with State Road. NB to WB movement remains on loop ramp.	Active		March 2021		May 2022 (Mainline Matrix Development Process)
SN-4A (formerly SN-4)	NB Off-Ramp to State Road	Single NB exit to roundabout at State Road.	Active		July 2021		
SN-4.1	NB Off-Ramp to State Road	Single NB exit to roundabout at State Road. Roundabout at State Road / Scenic Highway / Meetinghouse Lane intersection.	Not Being Developed Further	This alternative is similar to SN-4A except that it provides a roundabout (verses signalized intersection) at the Canal St/Meetinghouse Ln/State Rd/Scenic Highway intersection. This alternative will have significant impacts on the McDonald's property and will likely impact drive through operations. For this reason, this alternative is no longer being developed.	July 2021		December 2, 2021 (FHWA & MassDOT Mtg)

Alt ID	Name	Alternative Description or Sub-Alternative Modification	Status	Reason Alternative Is Not Being Developed Further	Date of Initial Development	Date of Modification	Date Development Held
SN-5	NB Off-Ramp to State Road	NB free flow movement to peanut roundabout at State Road / Scenic Highway / Meetinghouse Lane intersection. No direct left turn to State Road NB (U-turn within peanut roundabout)	Not Being Developed Further	The elimination of left turns onto State Road has a negative impacts at the Meetinghouse Lane/Canal St/Scenic Highway intersection. This alternative would require a double lane peanut roundabout which would increase impacts to McDonalds and Dunkin Donuts at this intersection. For these reasons, this alternative is no longer being developed.	July 2021		December 2, 2021 (FHWA & MassDOT Mtg)
SN-5A (formerly SN-7)	Route 3/ 6 EB On-Ramp Alteration to Diamond On-Ramp	Moves both Route 3 / 6 EB on-ramps from the Church Lane intersection to a signalized intersection at the existing Route 3 SB off-ramp location.	Not Being Developed Further	Eliminated from the alternatives list due to excessive grades for the Route 6 EB On Ramp.	July 2021		
SN-6A (formerly SN-6)	Route 3/ 6 EB On-Ramp Alteration	Brings traffic on Scenic Highway EB destined for Route 6 On-Ramp to signalized intersection at Church Lane. Removes existing free flow on-ramp. Maintains S curve on ramp.	Incorporated Elsewhere	Incorporated elsewhere for future deisgn consideration	July 2021		
SN-8A (formerly SN-8)	SN-3 & SN-5 Hybrid with revised Route 3 SB On-Ramp	Includes bike/ped accommodations along State Rd. Utilizes M-SF-4 mainline to provide additional space for reconstructed loop ramp with wider State Rd. Includes new signalized intersection at State Rd.	Active		August 2021		
SN-8B	Simple, Free Flow Route 6 EB On Ramp with Roundabout at Church Lane	Assumes a roundabout at Church Lane. Maintains the existing free flow ramp for Scenic Highway to Route 6 EB traffic. Provides a long tangent and simple curve for the ramp geometry.	Deferred/Design Development	Discrete design element deferred pending further design.	February 2022		
SN-8C	Simple, Free Flow Route 6 EB On Ramp with signal at Church Lane	Assumes a signal at Church Lane. Maintains the existing free flow ramp for Scenic Highway to Route 6 EB traffic. Provides a long tangent and simple curve for the ramp geometry.	Deferred/Design Development	Discrete design element deferred pending further design.	February 2022		
SN-8D	Route 3 SB Off Ramp with SF-4 Mainline Alignment	Maintains existing ramp geometry but is shifted to the west to accommodate the M-SF-4 Mainline Alignment.	Deferred/Design Development	Discrete design element deferred pending further design.	February 2022		
SN-8E	Simple, Channelized Right Route 6 EB On Ramp with signal at Church Lane	Assumes a signal at Church Lane. Creates a channelized right turn for Scenic Highway EB to Route 6 EB traffic. Provides a long tangent and simple curve for the ramp geometry.	Deferred/Design Development	Discrete design element deferred pending further design.	April 2022		
Scenic Highway - Option 1	Three signalized intersections along Scenic Highway.	Provides signalized intersections at Church Lane, the Route 3 SB Off Ramp, and State Road.	Deferred/Design Development	Discrete design element deferred pending further design.	February 2022		
Scenic Highway - Option 2	Two signalized intersections along Scenic Highway and a Peanut Roundabout at the State Road Intersection	Provides signalized intersections at Church Lane and the Route 3 SB Off Ramp. Provides a peanut roundabout at State Road.	Deferred/Design Development	Discrete design element deferred pending further design.	February 2022		
Scenic Highway - Option 3	Three Roundabouts along Scenic Highway.	Provides roundabouts at Church Lane, the Route 3 SB Off Ramp, and State Road.	Deferred/Design Development	Discrete design element deferred pending further design.	February 2022		
Sagamore South Interchanges							
SS-1	Existing Configuration: Partial Diamond with Cranberry Hwy Extension	Maintains existing ramp configurations; Adds Cranberry Highway Extension to Connect to Mid Cape Connector via the Market Basket Driveway	Active		April 2020		
SS-1.1	Existing Configuration: Partial Diamond	Same as SS-1 but does not include the Cranberry Highway Extension	Active		September 2021		
SS-2	Existing Configuration: Partial Diamond with South Cranberry Hwy Extension	Maintains existing ramp configurations; Adds Cranberry Highway Extension to Connect to Mid Cape Connector south of Market Basket	Not Being Developed Further	Development held due to significant residential impacts to the Marconi Street neighborhood and steep (7% +/-) grades for the Route 6 WB on and off ramps.	April 2020		December 2, 2021 (FHWA & MassDOT Mtg)
SS-3	Route 6 WB On Ramp Flyover	Flyover from Mid-Cape Connector to Route 6 WB with north Cranberry Hwy Extension	Active		April 2020		
SS-3.1	WB On and Off Ramp Underpass to Mid Cape Connector w/ Cranberry Highway Extension	Fly under from Mid-Cape Connector to Route 6 WB, Fly under from Route 6 WB to Mid-Cape Connector with north Cranberry Hwy Extension	Active		August 2021		

Alt ID	Name	Alternative Description or Sub-Alternative Modification	Status	Reason Alternative Is Not Being Developed Further	Date of Initial Development	Date of Modification	Date Development Held
SS-3.1A	Route 6 WB On Ramp Under Route 6	Relocated the Route 6 WB On ramp to come off of Mid Cape Connector. All other ramps and generally where the existing ramps are.	Active		April 2020		
SS-3.2	WB On and Off Ramp Underpass	Same as SS-3.1 but does not include the Cranberry Highway Extension	Active		September 2021		
SS-4	Utility Corridor off Sandwich Road	Route 6 WB On and Off ramps using utility corridor (Study Alt); Access is off of Sandwich Road (Route 6A)	Not Being Developed Further	Not being developed further due to environmental impacts to endangered species (box turtle).	February 2021		December 2, 2021 (FHWA & MassDOT Mtg)
SS-4.1	Utility Corridor off Cranberry Highway	Route 6 WB On and Off ramps using utility corridor (Study Alt); Access is off Cranberry Highway	Not Being Developed Further	Development held due to steep grade (8% for 1,000 ft) and impacts to Protect Article 97/4f Land (state forest).	March 2021		Sept 9, 2021 (During MassDOT Mtg)
SS-5	Roundabout Interchange at Utility Corridor	West side frontage road to roundabout/peanut interchange at utility corridor	Not Being Developed Further	Development held due to impacts to JBCC and Protected Article 97 Land	April 2020		Feb 2021
SS-6	Cranberry Highway Roundabouts	Evaluated Roundabouts along Cranberry Highway and extending the on ramp along Cranberry Highway to try to lessen grades for the Route 6 on ramp near the Christmas Tree Shop.	Not Being Developed Further	Development held due to steep grades still found on the ramp and significant impacts with the roundabouts to adjacent properties.	February 2021		March 2021 (Pre MassDOT Mtg)
SS-7	Full Diamond	Full diamond with north Cranberry Hwy Extension	Not Being Developed Further	Development held due to NB on and off and SB off ramps being too steep	April 2020		Feb 2021
SS-8	Utility Corridor Partial Roundabout	Study Alt with NB and SB connections using roundabout	Not Being Developed Further	Duplicate with limited additional benefit and impacts to Article 97 land.	April 2020		Feb 2021
SS-9	Utility Corridor Peanut Roundabout	Frontage road parallel to Route 6 EB. Peanut roundabout underneath new Route 6 bridge structure. All ramps except Route 6 EB off-ramp moved to utility corridor.	Active		July 2021		
SS-9.1	Utility Corridor Partial Roundabout	Similar to SS-9 except Route 6 WB On-Ramp remains in existing location at Cranberry Highway.	Active		July 2021		
SS-9.1A	Utility Corridor Flattened Route 6 WB Off Ramp	Modified SS-9.1 Route 6 WB Off Ramp to improve ramp geometry.	Active		May 2022		

Attachment 2 – Highway Interchange Approaches Detailed Assessment Report









Cape Cod Bridges Program

Bourne, Massachusetts

Highway Interchange Approaches Detailed Assessment Report

massDOT
Massachusetts Department of Transportation

SUBMITTED TO:
Federal Highway Administration
Massachusetts Division

220 Binney Street, 9th Floor
Cambridge, MA 02142

PROPONENT:
The Massachusetts Department of Transportation
Highway Division
10 Park Plaza
Boston, MA 02116

July 2025

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1 Introduction

The Massachusetts Department of Transportation (MassDOT), in coordination with the Federal Highway Administration (FHWA) as the lead federal agency and the New England District of the U.S. Army Corps of Engineers (USACE) as a cooperating agency, is preparing environmental analyses and documentation for the Cape Cod Bridges Program (Program) in compliance with the National Environmental Policy Act (NEPA) of 1969, as amended (42 United States Code [USC] 4321, et seq.); 23 USC 139, *Efficient Environmental Reviews for Project Decision making and One Federal Decision*; FHWA's regulations implementing NEPA, *Environmental Impacts and Related Procedures* (23 CFR 771); and with the Massachusetts Environmental Policy Act (MEPA; Massachusetts General Law [MGL] Chapter 30, Sections 61 through 62I, and its implementing regulations, 301 Code of Massachusetts Regulations [CMR] 11.00, as amended January 6, 2023).

This *Highway Interchange Approach Detailed Assessment Report* is a continuation of the *Cape Cod Bridges Program Alternatives Analysis Report* (February 20, 2024; updated June 2025). MassDOT has prepared this report to document the secondary evaluation of ten interchange approach options that passed the initial assessment and resulted in a single pairing of options for each replacement bridge crossing. This single pairing of options for each replacement bridge crossing was then incorporated into the Build Alternative Retained for Detailed Study in the Program's NEPA and MEPA environmental review documents. The highway interchange approach detailed assessment was conducted through 2024.

1.1 Program Areas

The Sagamore and Bourne highway bridges span Cape Cod Canal, located in the town of Bourne, Barnstable County, Massachusetts. As part of the Cape Cod Canal Federal Navigation Project (FNP), the bridges are federally owned and managed by the New England District of the U.S. Army Corps of Engineers (USACE). The Program Areas are defined as the areas of the existing bridges and highway approach intersections, including pedestrian-bicycle accommodations, for each crossing. Figure 1-1 presents the location of the Bourne and Sagamore Bridges and their approximate project limits.

1.1.1 Bourne Program Area

The Bourne Program Area includes the Route 25 and Route 28 approaches to the Bourne Bridge. North of Cape Cod Canal (Bourne North), roadways include Route 6 (Scenic Highway) and the roadways approaching Belmont Circle, including the Route 25 exit- and entrance-ramps and portions of the Head of the Bay Road, Main Street, and the Buzzards Bay Bypass. South of the canal (Bourne South), roadways include the Bourne Rotary and approach roadways including Route 28, Sandwich Road, and Trowbridge Road, Veterans Way, and the Bourne Rotary Connector. The Bourne Program Area also includes the existing pedestrian/bicycle network, provided as off-road trails or on-road accommodations at the bridge site and along the roadways north and south of the canal.

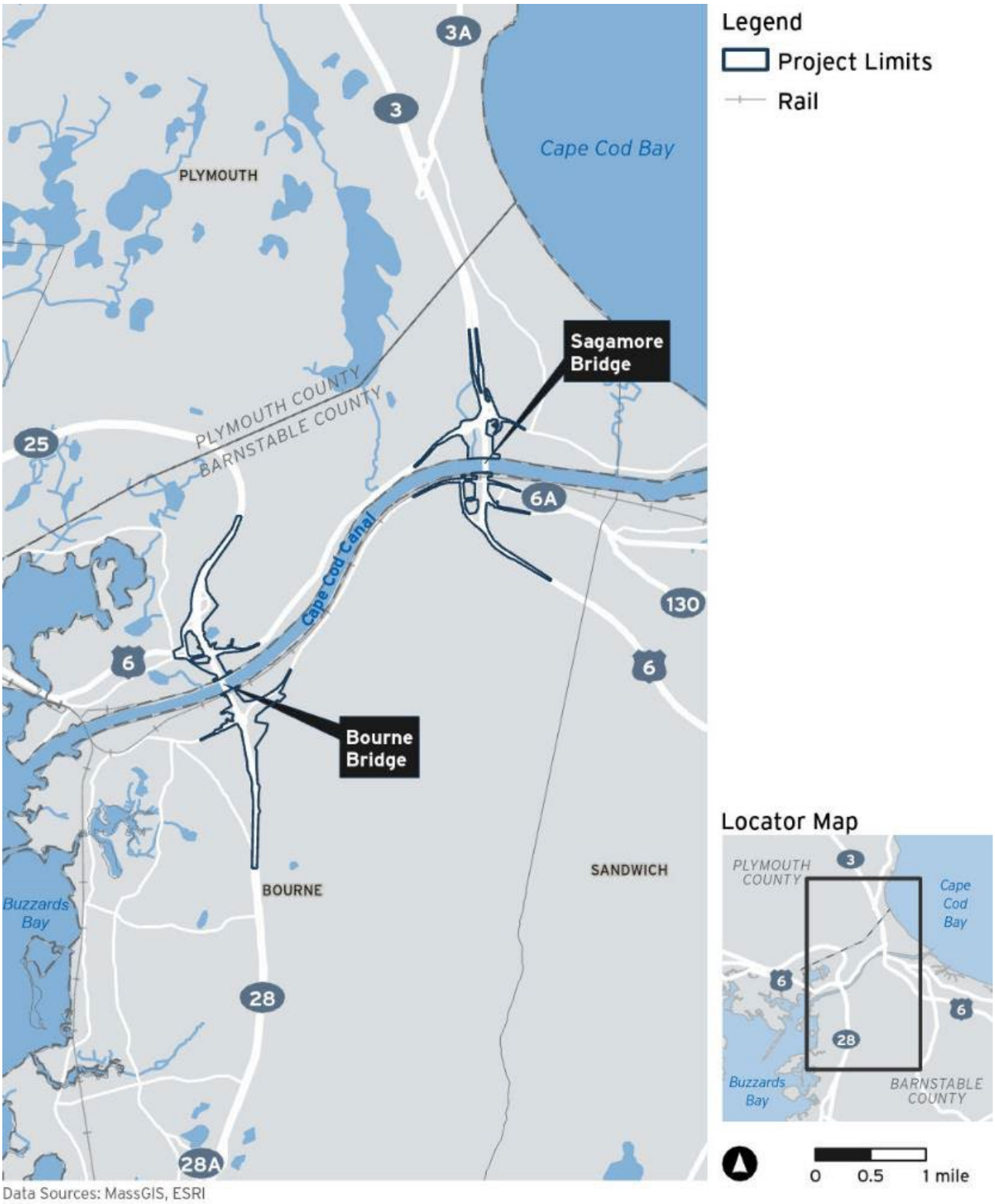


Figure 1-1. Location of Bourne and Sagamore Bridges and Program Limits

1.1.2 Sagamore Program Area

The Sagamore Program Study Area includes the Route 3 and Route 6 approaches to the Sagamore Bridge. North of Cape Cod Canal (Sagamore North), roadways include the Scenic Highway and Meetinghouse Road approaches, the Route 3/Scenic Highway interchange, and portions of Canal Street and State Road. South of the canal (Sagamore South), roadways include Cranberry Highway, Mid-Cape Connector, Sandwich Road, and Route 6 itself extending south of the Mid-Cape Connector ramps to Route 6. The Sagamore Program Study Area also includes the existing pedestrian/bicycle network, provided as off-road trails or on-road accommodations at the bridge site and along the roadways north and south of the canal.

1.2 Program Background

1.2.1 Program Purpose and Need

The purpose of the Program is to improve cross-canal mobility and accessibility between Cape Cod and mainland Massachusetts for all road users and to address the increasing maintenance needs and functional obsolescence of the aging Cape Cod Canal highway bridges. The Program is needed to address the following transportation deficiencies within the Program Study Areas:

- Deteriorating structural condition and escalating maintenance demands of the Cape Cod Canal highway bridges;
- Substandard design elements of the Cape Cod Canal highway bridges, the immediate mainline approaches, and their adjacent interchanges and intersections;
- Poor vehicular traffic operations; and
- Lack of accessible bicycle and pedestrian accommodations and connections between existing facilities.

1.2.2 Program Foundational Studies

In accordance with 23 U.S.C. 139(f)(4)(E)(ii), the Program builds upon and references prior, multi-year foundational studies, including:

1) the U.S. Army Corps of Engineers (USACE) Cape Cod Canal Highway Bridges Major Rehabilitation Evaluation (MRE), and subsequent MRE Report/Environmental Assessment (MRER/EA), which were completed to evaluate the current condition of the bridges and determine whether standard operation and maintenance, major rehabilitation, or replacement of either or both bridges would provide the most reliable, fiscally responsible solution for providing long-term vehicular access across Cape Cod Canal; and

2) the MassDOT Office of Transportation Planning (OTP) Cape Cod Canal Transportation Study, which was completed to identify and evaluate existing and future multimodal transportation deficiencies and needs of the existing roadway network around the Cape Cod Canal area.

2 Overview of Alternative Analysis Process

2.1 Introduction

As required by NEPA and MEPA, MassDOT conducted an extensive alternatives evaluation process for the Cape Cod Bridges Program, documented in the *Cape Cod Bridges Program Alternatives Analysis Report* (April 28, 2023, updated February 2, 2024). MassDOT included the *Cape Cod Bridges Program Alternatives Analysis Report* in its Environmental Notification Form (ENF), which was filed with the MEPA Office on April 28, 2023, and noticed in the Environmental Monitor on May 10, 2023. MassDOT included the *Cape Cod Bridges Program Alternatives Analysis Report,* updated per FHWA, in the Notice of Intent to Prepare an Environmental Impact Statement (EIS), published in the Federal Register on February 29, 2024. The alternative evaluation process included multiple opportunities for agency and public review.[1]

Figure 2-1 presents a summary graphic of MassDOT's alternatives analysis process for the Cape Cod Bridges Program. The Program's multi-tiered screening and evaluation process is similar to a funnel. Utilizing the Cape Cod Canal Transportation Study and the USACE's MRER/EA as the foundational planning documents, in accordance with 23 CFR 771.111(a) and consistent with 23 USC 139 (f)(4)(E)(ii), MassDOT screened the Universe of Cape Cod Canal Crossing Alternatives presented in the MRER/EA and confirmed the USACE's recommended Preferred Alternative of replacing the highway bridges with new bridges built to modern highway design standards.

Incorporating the USACE's Preferred Alternative of Replacement of Both Highway Bridges with New Bridges with Four Through-Traffic Lanes and Two Auxiliary Lanes, MassDOT conducted an analysis of Program design parameters at the conceptual (approximately 5 percent design) level and the preliminary (approximately 10 percent) design stages to further define Program design parameters. MassDOT's multiple assessments consisted of qualitative and quantitative evaluations of the Program design parameters relative to design evaluation criteria and other factors established in coordination with FHWA and USACE. Throughout the process, MassDOT obtained input from and reviewed the results of its analyses with agencies and Program stakeholders and the public. Based on its assessments, MassDOT identified the Program's Build Alternative to be Retained for Detailed Study in the NEPA and MEPA environmental review documents, as documented in the *Cape Cod Bridges Program Alternatives Analysis Report.*

[1] Agency and public review is documented in the Program's Public Involvement Plan and the Scoping Process Memorandum, May 18, 2024.

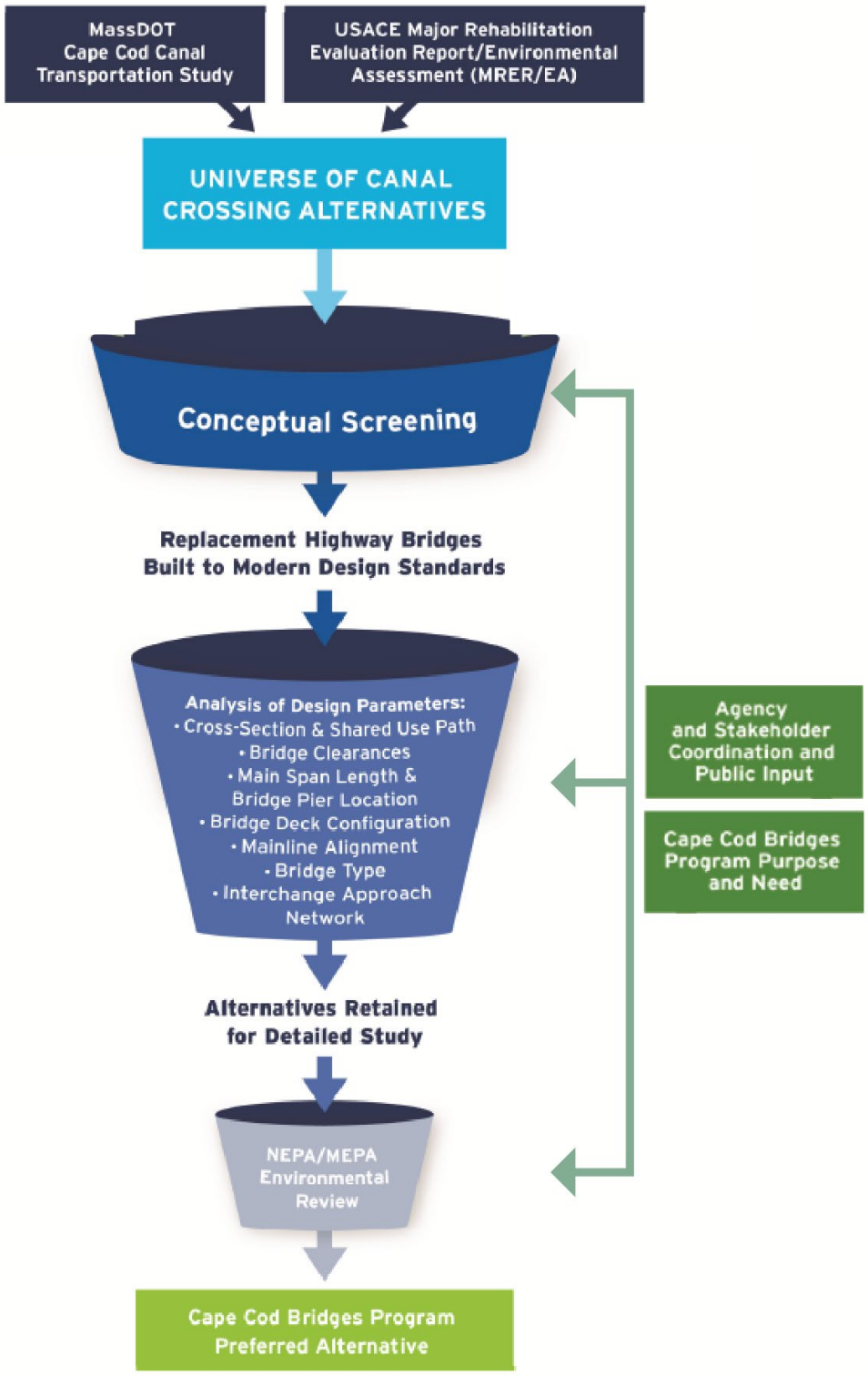


Figure 2-1. Summary Graphic of the Cape Cod Bridges Program Alternatives Analysis Process

2.2 Summary of Build Alternative Retained for Detailed Study

The proposed action will replace the Bourne and Sagamore highway bridges with parallel, twin tied-arch bridge structures supported on Delta frames with an approximate 700-foot mainline span length. The replacement bridge mainline alignment locations will be fully offline (outside of the existing bridge footprints) and inboard of the existing highway bridge (immediately east of the existing Bourne Bridge and immediately west of the existing Sagamore Bridge). Additionally, at both canal crossings, the proposed action will reconfigure the highway interchange approach networks north and south of Cape Cod Canal to align with the replacement highway bridges.

Table 2-1 presents a summary of the program elements/design parameters that comprise the Alternative to be Retained for Detailed Study, as determined from MassDOT's alternatives analysis process reported in the *Cape Cod Bridges Program Alternatives Analysis Report*. As indicated in Table 1-1, MassDOT proposed a secondary and more detailed (Phase 2) assessment of the ten highway interchange approach options to be conducted as design and traffic analysis advanced.

Table 2-1. Summary of MassDOT Analyses and Recommended Alternative Retained for Detailed Study

Program Element/ Program Design Parameter	MassDOT Alternative Analysis Process	Description
Replacement Highway Bridges	Screening of USACE MRER/EA Universe of Alternatives	Replacement of Both Highway Bridges with New Bridges with Four Through-Traffic Lanes and Two Auxiliary Lanes (In-Kind Bridge Replacement, updated to comply with current federal and state highway and design safety standards).
Bridge Highway Cross-Section and Shared Use Path	Assessment of Bridge Highway Cross-Section and Shared Use Path	Each replacement highway bridge would provide a total of four 12-foot-wide through travel lanes (two in each direction), two 12-foot-wide entrance/exit (auxiliary) lanes, a 4-foot-wide left shoulder, and a 10-foot-wide right shoulder. Right and left barriers would be offset an additional 2 feet beyond the limits of the shoulders.
		Each crossing location would include one bi-directional pedestrian and bicycle shared-use path (SUP), separated from vehicular traffic by the shoulder and barrier; the width of SUP would be determined as design advances.
Bridge Clearances	Assessment of Bridge Vertical and Horizontal Clearances	The replacement bridges would maintain the existing vertical clearance of 135 feet above mean high water (MHW) and account for 3 feet of fluctuations in relative sea level.
		The replacement bridges would provide a minimum of 500 feet of horizontal channel width to be consistent with existing conditions.

Program Element/ Program Design Parameter	MassDOT Alternative Analysis Process	Description
Main Span Length and Bridge Pier Location	Initial and Detailed Assessments of Main Span Length and Bridge Pier Location	The replacement bridges would have a main span length of approximately 700 feet, which would locate the bridge piers at the waterline adjacent to the service road (shoreline piers), into the rip rap slope but above the low tide line.
Bridge Deck Configuration	Initial and Detailed Assessments of Bridge Deck Configuration	Each crossing (Bourne and Sagamore) would have two separate decks (twin structures).
Mainline Alignment	Assessment of Mainline Alignment Location	The mainline alignment locations at both crossings would be Offline Inboard. Both main spans of the replacement highway bridge would be located outside the footprint of the existing bridge, approximately 10 feet apart and parallel to each other, and on the side of the canal between the existing Bourne Bridge and Sagamore Bridge. At the Bourne crossing, both main spans of the replacement highway bridge would be located east of the existing Bourne Bridge, toward Cape Cod Bay. At the Sagamore crossing, both main spans of the replacement highway bridge would be located west of the existing Sagamore Bridge, toward Buzzards Bay.
Bridge Type	Conceptual Screening, Initial and Detailed Assessments of Bridge Types	The replacement bridges would be twin Tied-Arch Bridges with Delta Frames supporting an approximate 700-foot mainline span.
Interchange Approach Network	Screening of Universe of Concepts, Initial Assessment of Highway Interchange Approach Options	Ten interchange approach options that passed the initial Phase 1 assessment were proposed to advance to a detailed Phase 2 assessment, consisting of three Bourne North, two Bourne South, two Sagamore North, and three Sagamore South options.

2.3 Results of Initial Assessment of Highway Interchange Approach Options

Table 2-2 lists the ten highway interchange approach options that MassDOT recommended advancing from the initial (Phase 1) assessment to a more detailed, 15 percent design level assessment. The results of the detailed assessment, documented in this report, will then be further assessed in the NEPA and MEPA environmental review documents as part of the Build Alternative Retained for Detailed Study.

Table 2-2. Summary of Initial Assessment of Interchange Approach Options for Bourne and Sagamore Crossings

Program Study Area	Option	Summary Description	Reasons for Advancement
Bourne North	BN-6.1/ Northbound On-Ramp	This option is like the existing interchange configuration, modified to meet the offset mainline while adding a new northbound on-ramp directly from Scenic Highway east of the mainline.	This option would largely mimic the existing interchange configuration. It rated the highest among the options in its performance relative to the highway design evaluation criteria.
	BN-13.1/ Single Exit Partial Interchange	This option builds upon Option BN-6.1 and adds a connection from Route 25 southbound off-ramp directly to Scenic Highway.	This option received favorable and most favorable performance ratings relative to the highway design evaluation criteria. It would result in medium to less environmental and right-of-way impacts.
	BN-14.4b/ Directional Interchange	This option is like Option BN-13.1 and provides a combination of direct connection ramps between Route 25 and Scenic Highway.	This option received favorable and most favorable performance ratings relative to the highway design evaluation criteria. It would result in medium to less environmental and right-of-way impacts.
Bourne South	BS-2/ Diamond Interchange	This option replaces the existing Bourne Rotary with a grade separated diamond interchange.	This option received favorable and most favorable performance ratings relative to the highway design evaluation criteria.
	BS-2.2/ Single-Point Interchange	This option replaces the existing Bourne Rotary with a grade separated single point interchange configuration.	This option received favorable and most favorable performance ratings relative to the highway design evaluation criteria.
Sagamore North	SN-1A/ Similar to Existing Configuration	This option is like the existing interchange ramp configurations with modifications to support the relocated Route 6/Route 3 alignment.	This option would be similar to the existing interchange ramp configuration and would require less modifications than SN-8A to support a relocated Route 6/Route 3 alignment.

Program Study Area	Option	Summary Description	Reasons for Advancement
	SN-8A/ Direct Connection to State Road	This option is like Option SN-1A but provides a single exit point for westbound/northbound traffic from a relocated Route 6/Route 3 alignment.	This option would present a different approach to handling exiting westbound/northbound traffic from existing conditions (and Option SN-1A). It rated the highest in its performance ratings relative to the highway design evaluation criteria, with primarily favorable ratings and no unfavorable ratings.
Sagamore South	SS-1/ Existing Configuration with Cranberry Highway Extension	This option is like the existing interchange ramp configurations with modifications to support the relocated Route 6 alignment. It extends Cranberry Highway under Route 6 to provide a connection to Mid-Cape Connector.	This option would largely maintain the existing ramp configurations with an extension of Cranberry Highway that presents an alternative approach to managing traffic.
	SS-1.1/ Similar to Existing Configuration	This option provides the same interchange configuration as Option SS-1 but eliminates the Cranberry Highway Extension.	This option would mimic the existing interchange configuration without the Cranberry Highway extension.
	SS-3.1A/ Westbound On-Ramp Under Route 6 with Cranberry Highway Extension and Sandwich Road Connector	This option is like Option SS-1 but relocates the westbound on-ramp, so it shares the same entrance point as the eastbound on-ramp off the Mid-Cape Connector. This option includes the Cranberry Highway Extension and also adds a connector road between Cranberry Highway and Sandwich Road.	This option received the highest performance ratings relative to the highway design evaluation criteria.

2.4 Description of Highway Interchange Approach Options Advancing to Detailed Assessment

Section 2.4 presents a description of the highway interchange approach options that advanced to a secondary assessment. The options incorporate the previously determined design parameters identified in Table 2-1. For example, all ten options are based on a mainline alignment location on the inboard side of the existing bridges; the alignment of the Bourne Bridge would be shifted to the east, toward Cape Cod Bay, and the alignment of the Sagamore Bridge would be shifted to the west, toward Buzzards Bay.

2.4.1 Bourne North Interchange Approach Options

The Program limits for the Bourne North interchange options are as follows: the northern limits along Route 25 extend to Mile Marker 8.8, or approximately 7,100 feet from the canal; the western limits along Scenic Highway end at Belmont Circle; and the eastern limits extend 1,200 feet east of Nightingale Road.

2.4.1.1 Northbound On-Ramp Option (BN-6.1)

Figure 2-2 presents the preliminary design layout of Option BN-6.1. This option is most similar to the existing interchange configuration, modified to meet the offset mainline while adding a new northbound on-ramp directly from Scenic Highway (Route 6) east of the mainline. Option BN-6.1 would maintain the same number of ramp connections to Route 25. However, a new ramp would connect Scenic Highway westbound to Route 25 westbound at the intersection of Scenic Highway/Nightingale Road. This ramp would merge with the on-ramp from Belmont Circle prior to meeting up with the Route 25 mainline. Option BN-6.1 would maintain a traffic signal at the intersection of Scenic Highway and Nightingale Road.

Option BN-6.1 would add a direct route of the shared use path (SUP) from the bridge to Scenic Highway, with a SUP along the north side of Scenic Highway to the west of the mainline. Multimodal accommodations to cross Route 6 would be at-grade crossings at the new intersection. To the east of the mainline, the SUP would be located on the south side of Route 6 with a six-foot-wide sidewalk located on the north side. Due to right-of-way (ROW) constraints with existing gas stations, multimodal accommodations west of the mainline to connect to Belmont Circle would consist of two six-foot-wide sidewalks on both sides of Route 6.

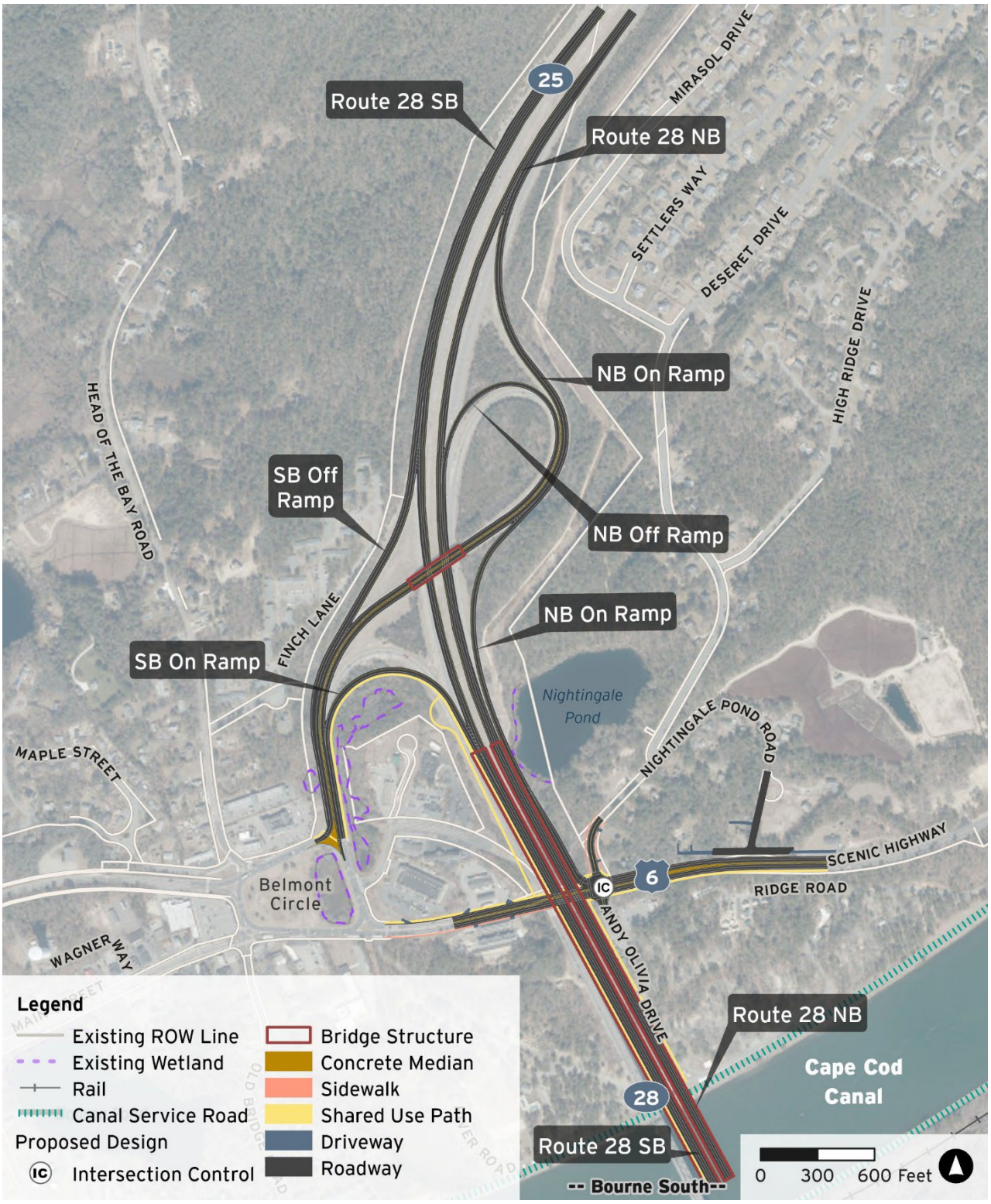


Figure 2-2. Bourne North Crossing: Northbound On-Ramp Option (BN-6.1)

2.4.1.2 Single Exit Partial Interchange (BN-13.1)

Figure 2-3 presents the preliminary design layout of Option BN-13.1. This option is similar to the existing interchange configuration, modified to meet the offset mainline while adding a new northbound on-ramp directly from Scenic Highway east of the mainline. Option BN-13.1 would include the ramp connection from Scenic Highway westbound to Route 25 westbound. Additionally, in Option BN-13.1, a ramp would connect Route 25 eastbound to Scenic Highway, allowing vehicles to bypass Belmont Circle, and would form a T-intersection with Scenic Highway. With this new ramp, a new traffic signal would be required at the new intersection of the southbound off-ramp onto Scenic Highway. The existing Route 28 over Route 25 bridge would be relocated to widen the bridge to allow for this new southbound to eastbound ramp movement. Additionally, the existing southbound off-ramp would be revised to be an option lane,[2] improving the geometry and decision sight distance for drivers. The number of ramp connections (four) on the mainline would remain the same as the existing condition.

Like Option BN-6.1, Option BN-13.1 would provide a direct SUP access coming off the bridge to Scenic Highway. Due to ROW constraints with existing gas stations, multimodal accommodations west of the mainline to connect to Belmont Circle would consist of two six-foot-wide sidewalks on both sides of Route 6.

[2] An option lane is an interior lane serving both movements in which traffic can either leave the route or remain on the route, or choose either destination at a split, from the same lane.

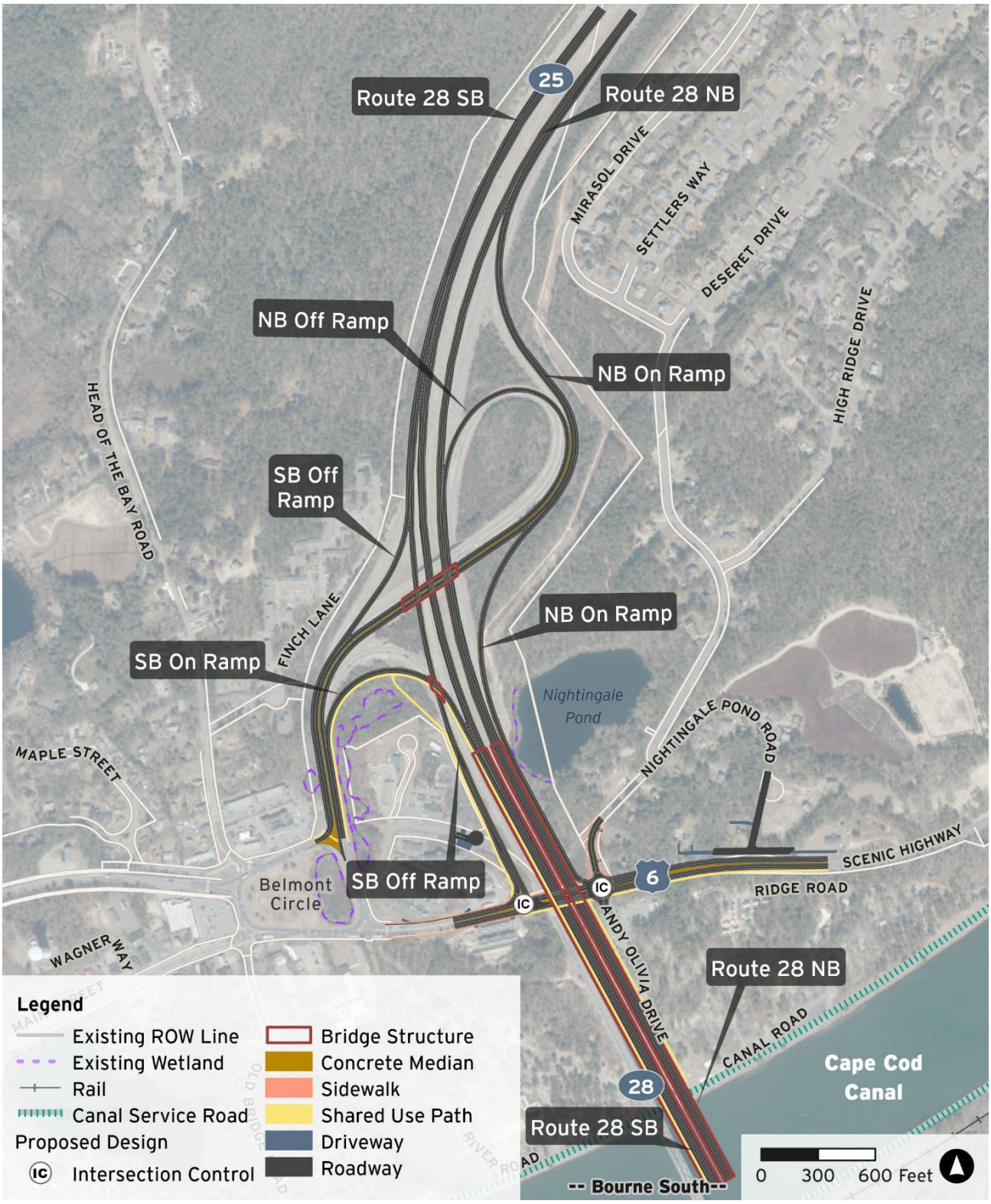


Figure 2-3. Bourne North Crossing: Single Exit Partial Interchange Option (BN-13.1)

2.4.1.3 Directional Interchange Option (BN-14.4b)

Figure 2-4 presents the preliminary design layout of Option BN-14.4b. This option is similar to Option BN-13.1 and would provide a combination of direct connection ramps between Route 25 and Route 6. In Option BN-14.4b, however, the ramp connecting Route 25 eastbound to Scenic Highway would be a direct connect ramp, allowing access to Scenic Highway eastbound only. The new flyover ramp connecting Scenic Highway to Route 25 would allow vehicles to bypass Belmont Circle and would not require an additional traffic signal. This ramp would utilize one of the travel lanes on Scenic Highway and would be a free-flowing movement to reduce congestion. The existing Route 28 over Route 25 bridge would be relocated to widen the bridge to allow for this new southbound to eastbound ramp movement. Additionally, the existing southbound off-ramp would be revised to be an option lane, improving the geometry and decision sight distance for drivers. The intersection control at Route 6/Nightingale Road/Andy Oliva Drive would either be a single lane roundabout or a signalized intersection. MassDOT is continuing to evaluate intersections through the Intersection Control Evaluation (ICE) process to determine the most appropriate intersection control type.[3]

In Option BN-14.4b, the new flyover ramp over Scenic Highway would provide a SUP and grade-separated crossing for pedestrians and bicyclists. Since the flyover ramp would remove traffic from Belmont Circle, the Route 6 lane configuration would be reduced from four lanes to three lanes, which would provide additional space for multimodal accommodations. Option BN-14.4b would provide one continuous 12-foot-wide SUP along the south side of Route 6 connecting to Belmont Circle and a six-foot-wide sidewalk along the north side of Route 6.

[3] Note that at the time of the assessment of highway interchange approaches, conducted in 2024, this determination was not completed.

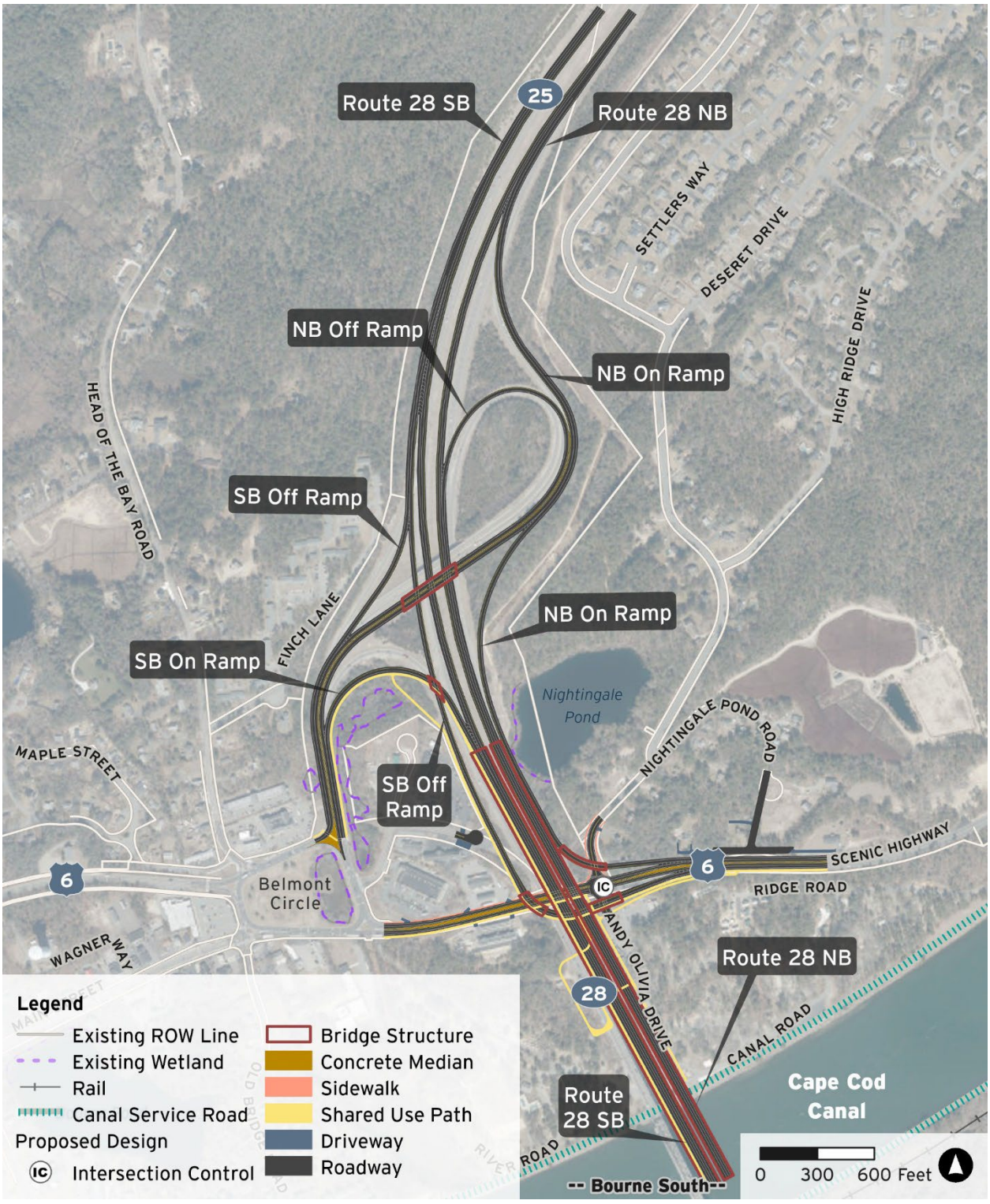


Figure 2-4. Bourne North Crossing: Directional Interchange Option (BN-14.4b)

2.4.2 Bourne South Interchange Approach Options

The Program limits for the Bourne South interchange options are as follows: the southern limits extend to the first U-turn on Route 28 just south of Dump Road, identified as Mile Marker 61.8 on Route 28 or approximately 6,500 feet from the canal; the western limits along Trowbridge Road end at the unsignalized intersection of Trowbridge Road and Sandy Lane; and the eastern limits end at approximately 500 feet east of the existing Upper Cape Cod Regional Technical High School driveway. For both Bourne South crossings, there are several modifications that apply to both interchange options, including:

- The existing rotary would be removed to grade separate regional and local traffic movements;
- Access management for businesses adjacent to Route 28 southbound would be provided via a frontage road; and
- The Upper Cape Cod Regional Technical High School Driveway entrance would be relocated further west along Trowbridge Road to improve safety.

2.4.2.1 Diamond Interchange Option (BS-2)

Figure 2-5 presents the preliminary design layout of Option BS-2. This option would eliminate the Bourne Rotary and replace the existing rotary with a grade separated diamond interchange. Option BS-2 would allow through movements on Route 28 to bypass the intersections with the non-mainline roadways.

Both intersections within the diamond interchange would require either a traffic signal or a roundabout for intersection control; MassDOT is continuing to evaluating the intersections through the Intersection Control Evaluation (ICE) process to determine the appropriate intersection control type.[4]

Based on the traffic analysis, a single lane dogbone roundabout option[5] would be provided to maximize the operations of the diamond interchange. A dogbone roundabout processes more vehicles per hour than a typical roundabout or signalized intersection, resulting in shorter queues and delays. Additionally, a dogbone roundabout eliminates the inside lane of each roundabout, resulting in a reduced number of conflict points at each intersection and improved safety and operations. Replacing the traditional signalized intersection with a dog-bone roundabout option in Option BS-2 would allow better movement and access to the frontage road users from Trowbridge Road and the southbound off-ramp. Additionally, traffic from the frontage road would have direct access to the Route 28 southbound on-ramp. Lastly, the dogbone roundabout would utilize Pedestrian Hybrid Beacons at each intersection leg for visual enhancements to protect pedestrians and bicyclists and increase driver awareness.

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[4] Note that at the time of the assessment of highway interchange approaches, conducted in 2024, this determination was not completed.

[5] A dogbone interchange (a variation of the dumbbell interchange) references its aerial resemblance to a real or toy dog bone; it is a double roundabout interchange where the roundabouts do not form a complete circle, but instead are connected by parallel traffic lanes.[6] Note that at the time of the assessment of highway interchange approaches, conducted in 2024, this determination was not completed.

Additional changes to the Trowbridge Road and Sandwich Road underpass in Option BS-2 would consist of a roundabout at a relocated Upper Cape Cod Regional Technical High School Driveway entrance. Option BS-2's SUP improvements would include providing connections to Trowbridge Road, the Cape Cod Canal Service Road, and the Bourne Recreation Area.

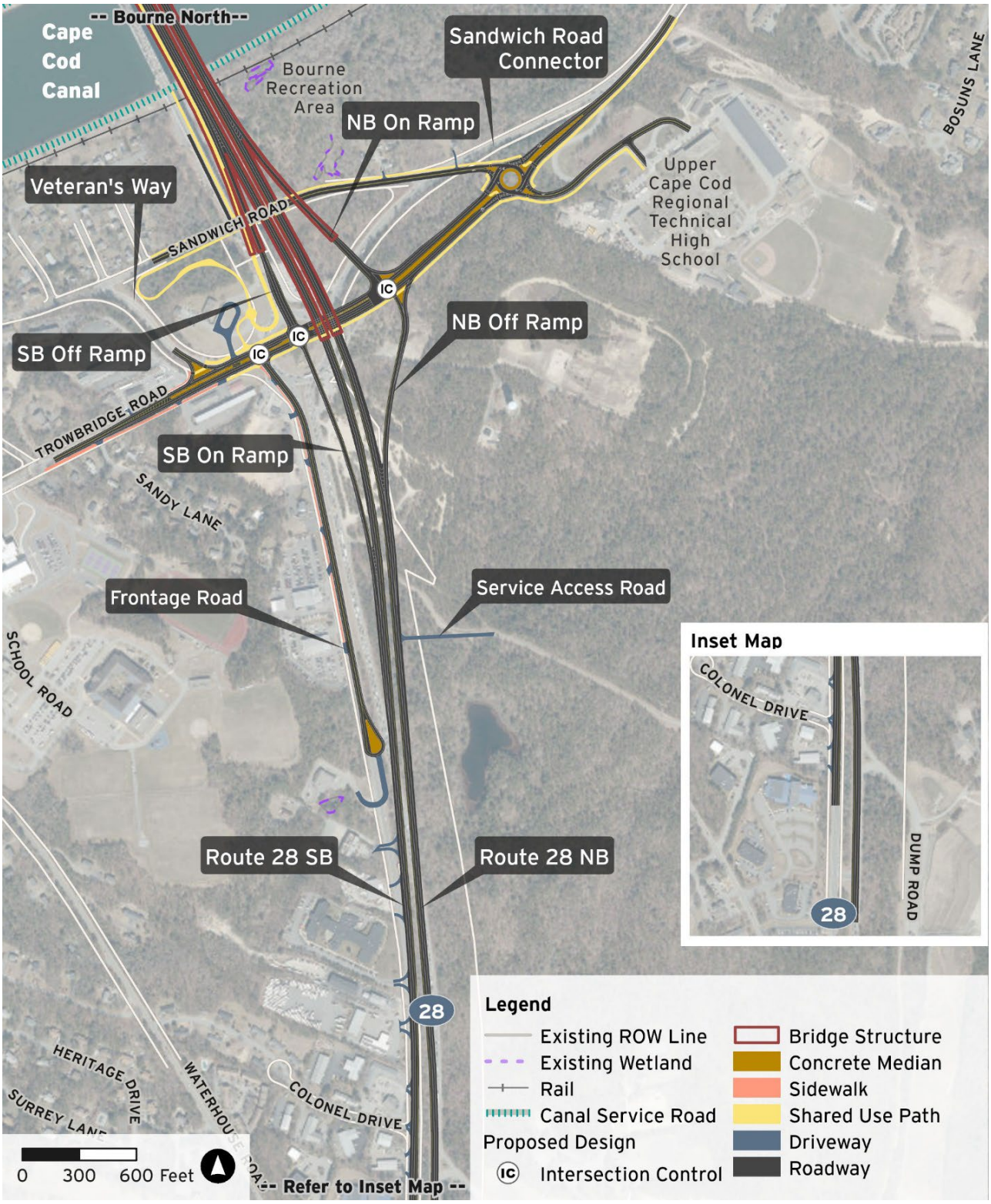


Figure 2-5. Bourne South Crossing: Diamond Interchange Option (BS-2)

2.4.2.2 Single-Point Urban Interchange Option (BS-2.2)

Figure 2-6 presents the preliminary design layout of Option BS-2.2. Option BS-2.2 would replace the existing Bourne Rotary with a grade separated single point urban interchange configuration. With this configuration, a new traffic signal would be required at the single point under the bridge. Similar to Option BS-2, in Option BS-2.2, the intersection at the relocated Upper Cape Cod Regional Technical High School Driveway would be replaced with a roundabout.

Option BS-2.2 would include a SUP along Trowbridge Road and a SUP connecting Trowbridge Road, the bridge to Sandwich Road, and the Canal Service Road.

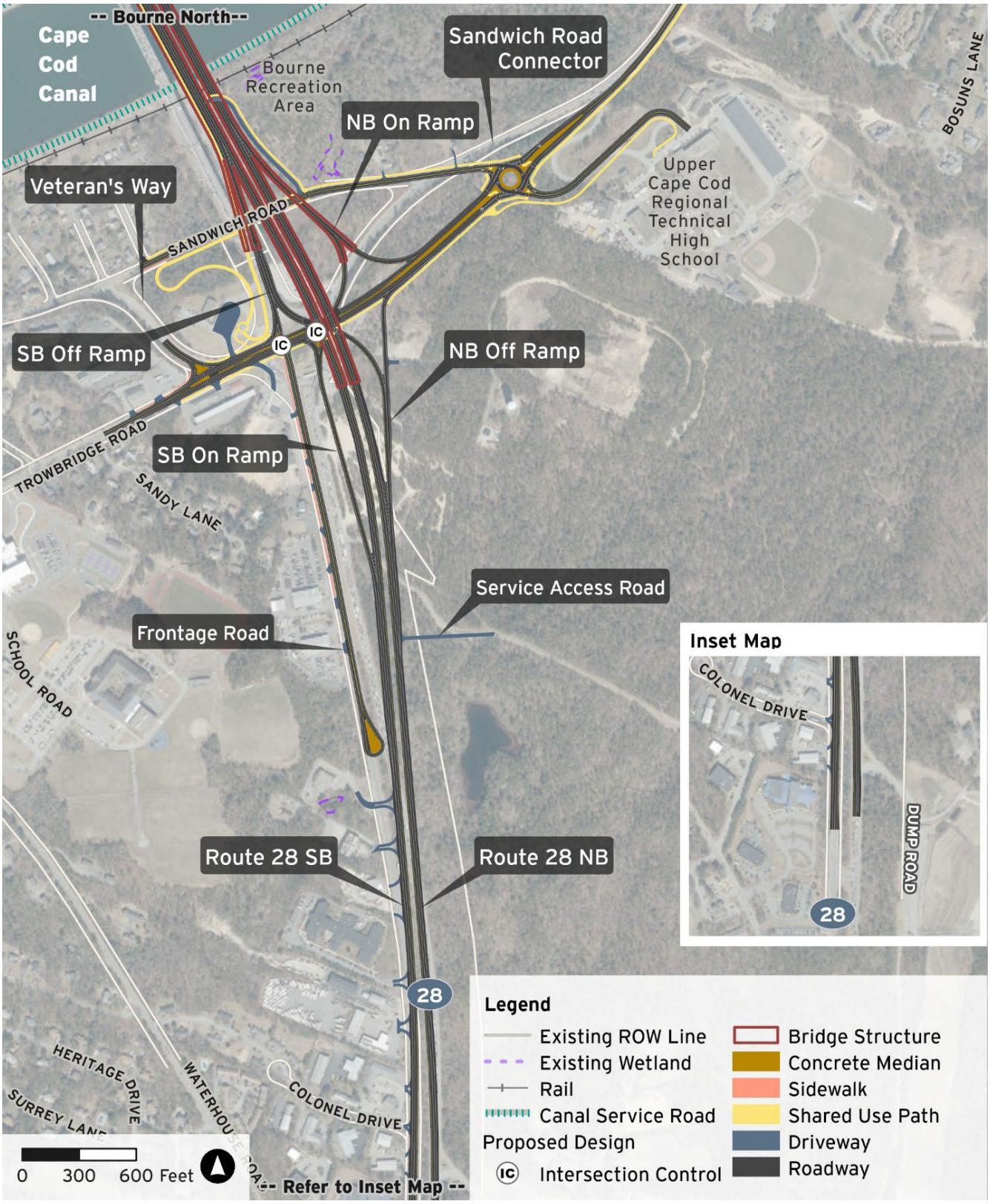


Figure 2-6. Bourne South Crossing: Single-Point Interchange Option (BS-2.2)

2.4.3 Sagamore North Interchange Approach Options

2.4.3.1 Similar to Existing Configuration Option (SN-1A)

Figure 2-7 presents the preliminary design layout of Option SN-1A. This option closely resembles existing conditions with modifications to support the relocated Route 6/Route 3 alignment. The number and locations of ramp connections would be the same as the existing condition; they would be updated to meet current design standards and safety preferences. Signalized intersections along Scenic Highway and Meetinghouse Lane would be modified for new lane configurations. Potential geometric modifications at the intersection of State Road at the Route 3 northbound on-ramp would include installation of a traffic signal. MassDOT is continuing to evaluate intersections through the ICE process to determine the appropriate intersection control type.[6]

Option SN-1A would include a SUP on the Route 6 eastbound main span that would provide connections to the south side of the Scenic Highway, Canal Street, and the Canal Service Road. Option SN-1A would provide SUPs along the southern side of Scenic Highway and Meeting House Lane and along the eastern side of State Road to Homestead Avenue

[6] Note that at the time of the assessment of highway interchange approaches, conducted in 2024, this determination was not completed.

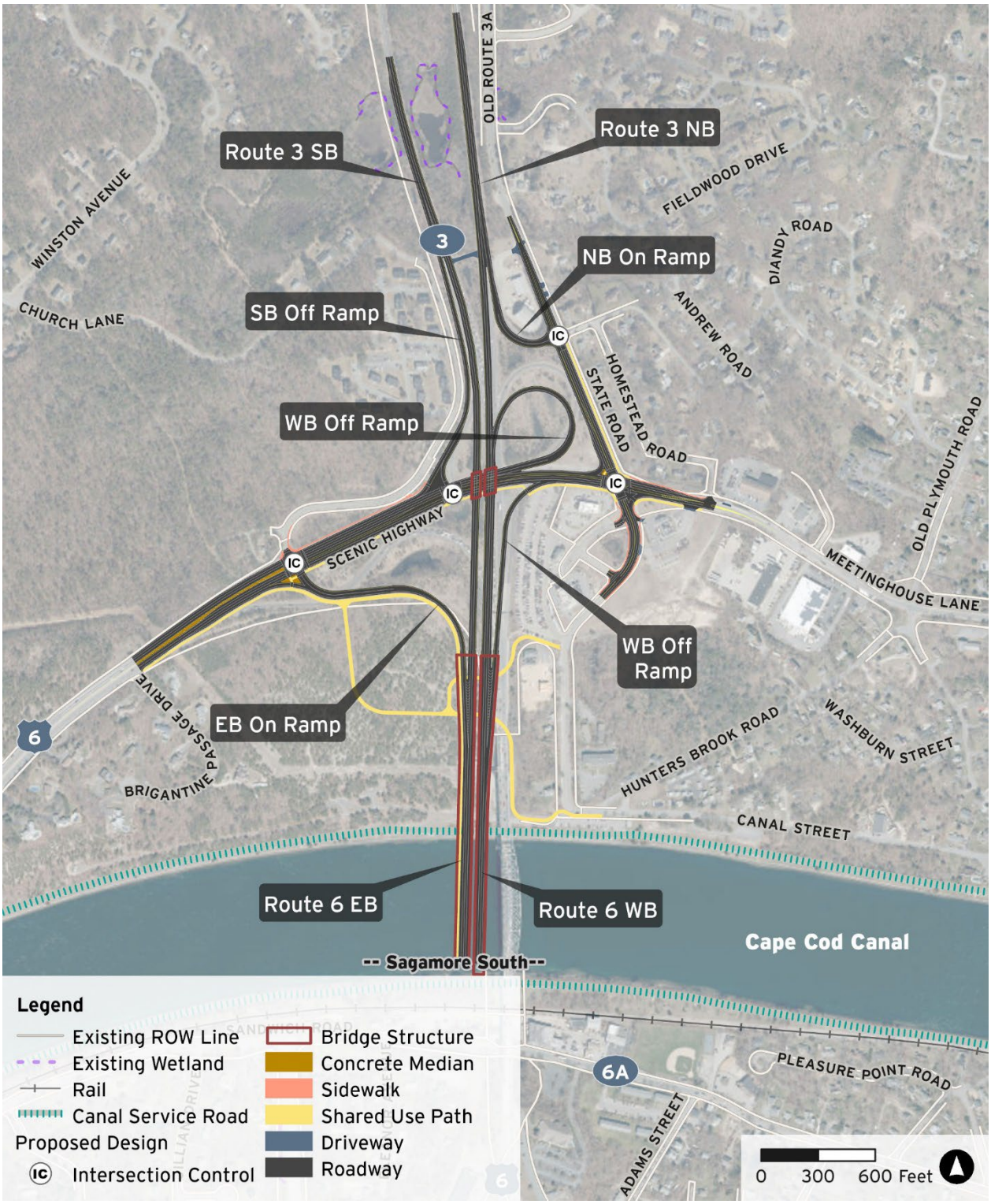


Figure 2-7. Sagamore North Crossing: Similar to Existing Configuration Option (SN-1A)

2.4.3.2 Direct Connection to State Road Option (SN-8A)

Figure 2-8 presents the preliminary design layout of Option SN-8A. This option is like Option SN-1A but would provide a single exit point from a relocated Route 6/Route 3. Option SN-8A would remove the Sagamore Bridge northbound off-ramp connection to Scenic Highway/Meetinghouse Lane eastbound, and instead would connect to State Road, north of Scenic Highway/Meetinghouse Lane. The remaining ramp connections would remain similar to existing conditions. Similar to SN-1A, signalized intersections along Scenic Highway and Meetinghouse Lane would be modified for new lane configurations. The intersection of State Road at the Route 3 northbound would be modified to accommodate the addition of the new Route 3 northbound off-ramp with installation of a traffic signal. MassDOT is continuing to evaluate intersections through the ICE process to determine the appropriate intersection control type.[7]

Like Option SN-1A, Option SN-8A would include a SUP on the Route 6 eastbound main span that would provide connections to the south side of the Scenic Highway, Canal Street, and the Canal Service Road. Like Option SN-1A, Option SN-8A would provide SUPs along the southern side of Scenic Highway and Meetinghouse Lane and along the eastern side of State Road to Homestead Avenue.

[7] Note that at the time of the assessment of highway interchange approaches, conducted in 2024, this determination was not completed.

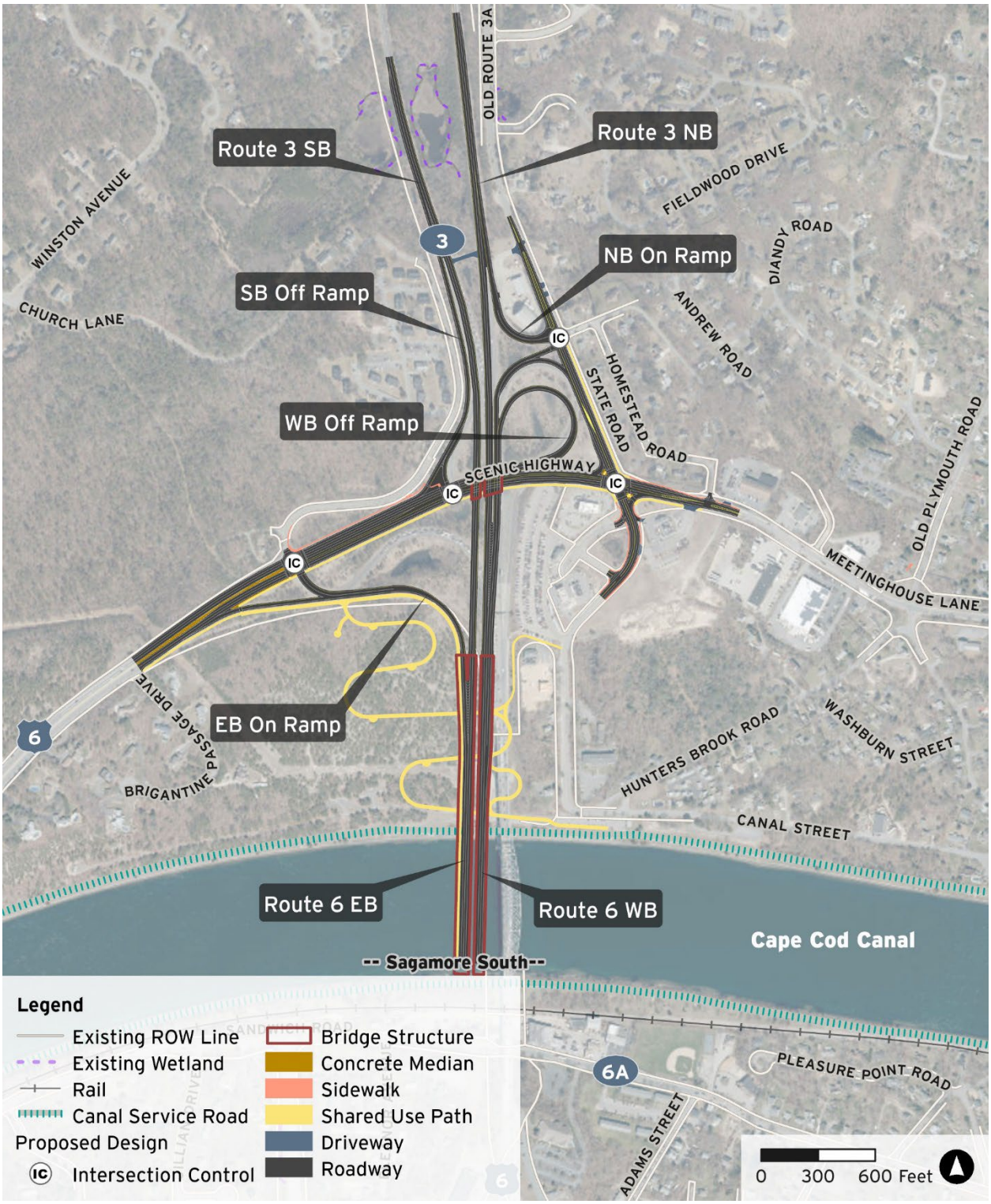


Figure 2-8. Sagamore North Crossing: Direct Connection to State Road Option (SN-8A)

2.4.4 Sagamore South Interchange Approach Options

2.4.4.1 Similar to Existing Configuration with Cranberry Highway Extension (SS-1)

Figure 2-9 presents the preliminary design layout of Option SS-1. This option would modify ramp alignments to accommodate the relocated Route 6 mainline while largely maintaining the existing ramp configurations. In Option SS-1, an extension of Cranberry Highway would be developed under US Route 6 and connect to Factory Outlet Road and the Mid-Cape Connector; the Cranberry Highway extension would provide a more direct access from Cranberry Highway to US Route 6 eastbound as well as to Sandwich Road. The number of ramp connections to US Route 6 would remain the same as the existing condition. Option SS-1 would include improvements to lane arrangements at the intersections of Mid-Cape Connector with Sandwich Road and Cranberry Highway Extension to accommodate the revised traffic patterns resulting from the extension of Cranberry Highway, including modifications to the existing traffic signals. A traffic signal would be provided at the intersection of the Route 6 westbound ramps with Cranberry Highway Extension along with modified access to Market Basket (Factory Outlet Road). MassDOT is continuing to evaluate the traffic signal through the ICE process to confirm the appropriate intersection control type.[8]

Option SS-1 would include a SUP on the Route 6 eastbound main span that would provide connections to Factory Outlet Road, Sandwich Road, and the Canal Service Road. Bicycle and pedestrian improvements also would be included on Cranberry Highway. Option SS-1 would add a new connection through the Cranberry Highway Extension to Mid-Cape Connector. This new connection would improve multimodal connectivity by providing access between local neighborhoods and businesses that currently does not exist.

[8] Note that at the time of the assessment of highway interchange approaches, conducted in 2024, this determination was not completed.

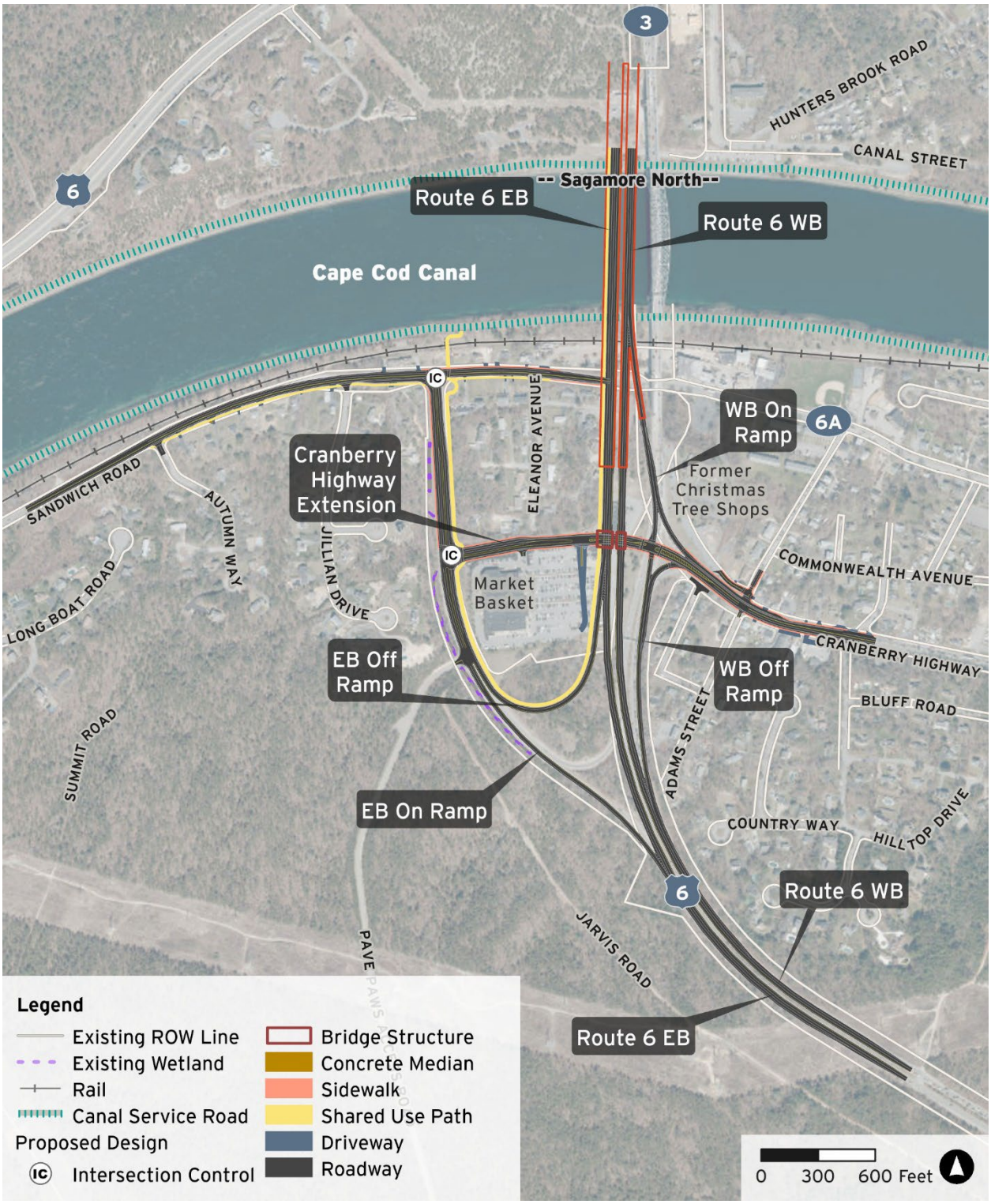


Figure 2-9. Sagamore South Crossing: Similar to Existing Configuration with Cranberry Highway Extension (SS-1)

2.4.4.2 Similar to Existing Configuration Option (SS-1.1)

Figure 2-10 presents the preliminary design layout of Option SS-1.1. This option would closely resemble the existing conditions, with some modifications to ramp geometry and location. The number of ramp connections to Route 6 would remain the same as the existing condition. Improvements to lane arrangements would be provided at the intersection of Mid-Cape Connector with Sandwich Road to accommodate projected increases in traffic volumes. Option SS-1.1 would include improvements to the signalized intersections of Mid-Cape Connector with Sandwich Road and Factory Outlet Road.

Option SS-1.1 would include a SUP on the Route 6 eastbound main span that would provide connections to Factory Outlet Road, Sandwich Road, and the Canal Service Road. Bicycle and pedestrian improvements also would be included on Cranberry Highway.

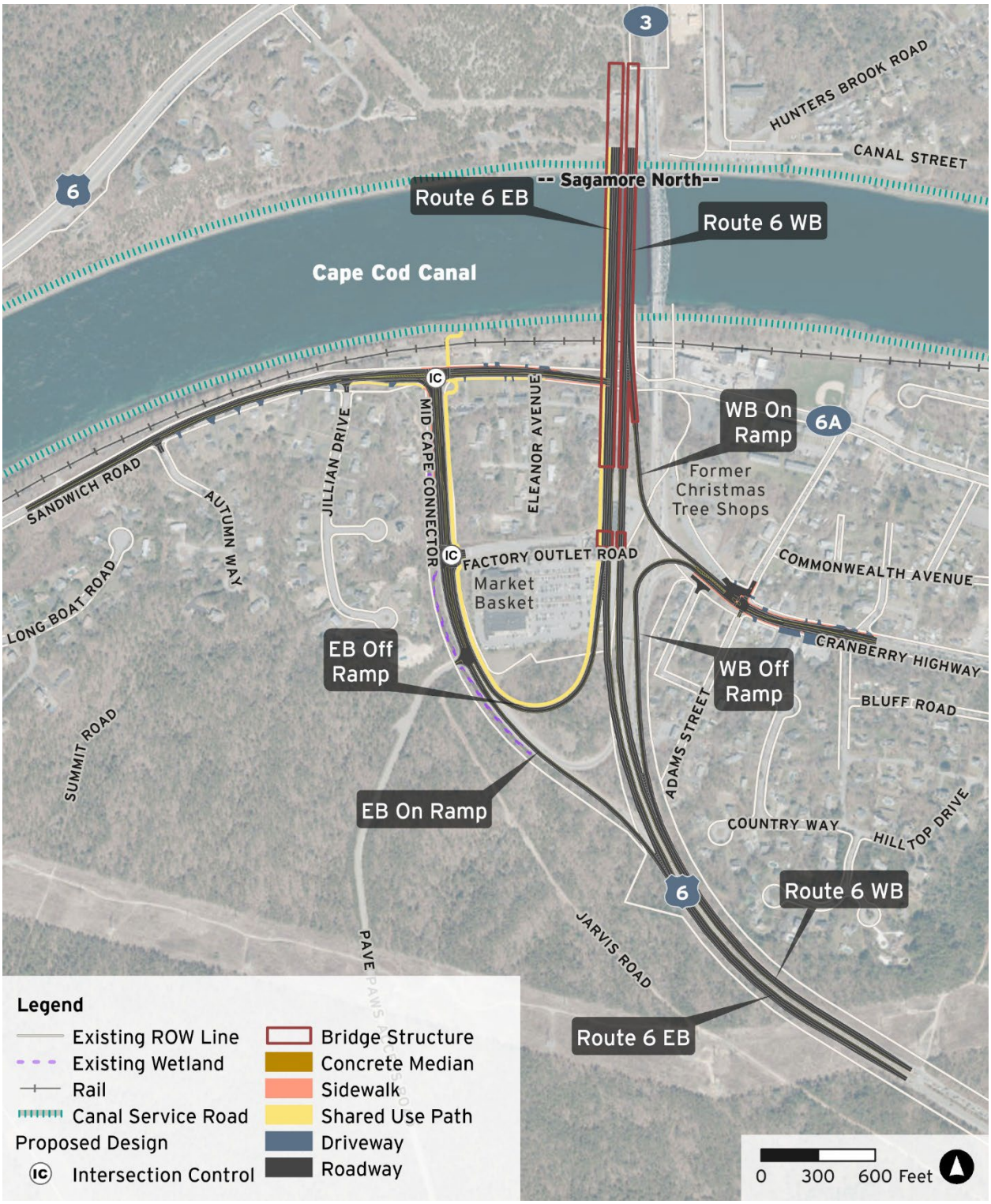


Figure 2-10. Sagamore South Crossing: Similar to Existing Configuration Option (SS-1.1)

2.4.4.3 Westbound On-Ramp under Route 6 with Cranberry Highway Extension and Sandwich Road Connector Option (SS-3.1A)

Figure 2-11 presents the preliminary design layout of Option SS-3.1A. This option is like Option SS-1 with the Cranberry Highway extension. It would relocate the westbound on-ramp, so it would share the same entrance point as the eastbound on-ramp off the Mid-Cape Connector. In Option SS-3.1A, the Cranberry Highway to Sagamore Bridge westbound ramp would be removed and a new westbound on-ramp connection from the Mid-Cape Connector to the Sagamore Bridge westbound would be provided. Modifications to lane arrangements at the intersections of Mid-Cape Connector with Sandwich Road and Cranberry Highway Extension would accommodate the revised traffic patterns resulting from the extension of Cranberry Highway and relocation of access to Route 6 eastbound, including modifications to the existing traffic signals. In addition, there would be a connection from the Cranberry Road Extension to Sandwich Road east of the new mainline bridge structure (Sandwich Road extension). A traffic signal would be provided at the intersection of the Route 6 westbound off-ramp with Cranberry Highway Extension, along with modified access to Market Basket (Factory Outlet Road). Option SS-3.1A also would include an access driveway to the former Christmas Tree Shops area.

Option SS-3.1A would include a SUP on the Route 6 eastbound main span that would provide connections to Factory Outlet Road, Sandwich Road, and the Canal Service Road. Bicycle and pedestrian improvements also would be included on Cranberry Highway. Option SS-3.1A would add a new connection through the Cranberry Highway Extension to Mid-Cape Connector. This new connection would improve multimodal connectivity by providing access between local neighborhoods and businesses that currently does not exist.

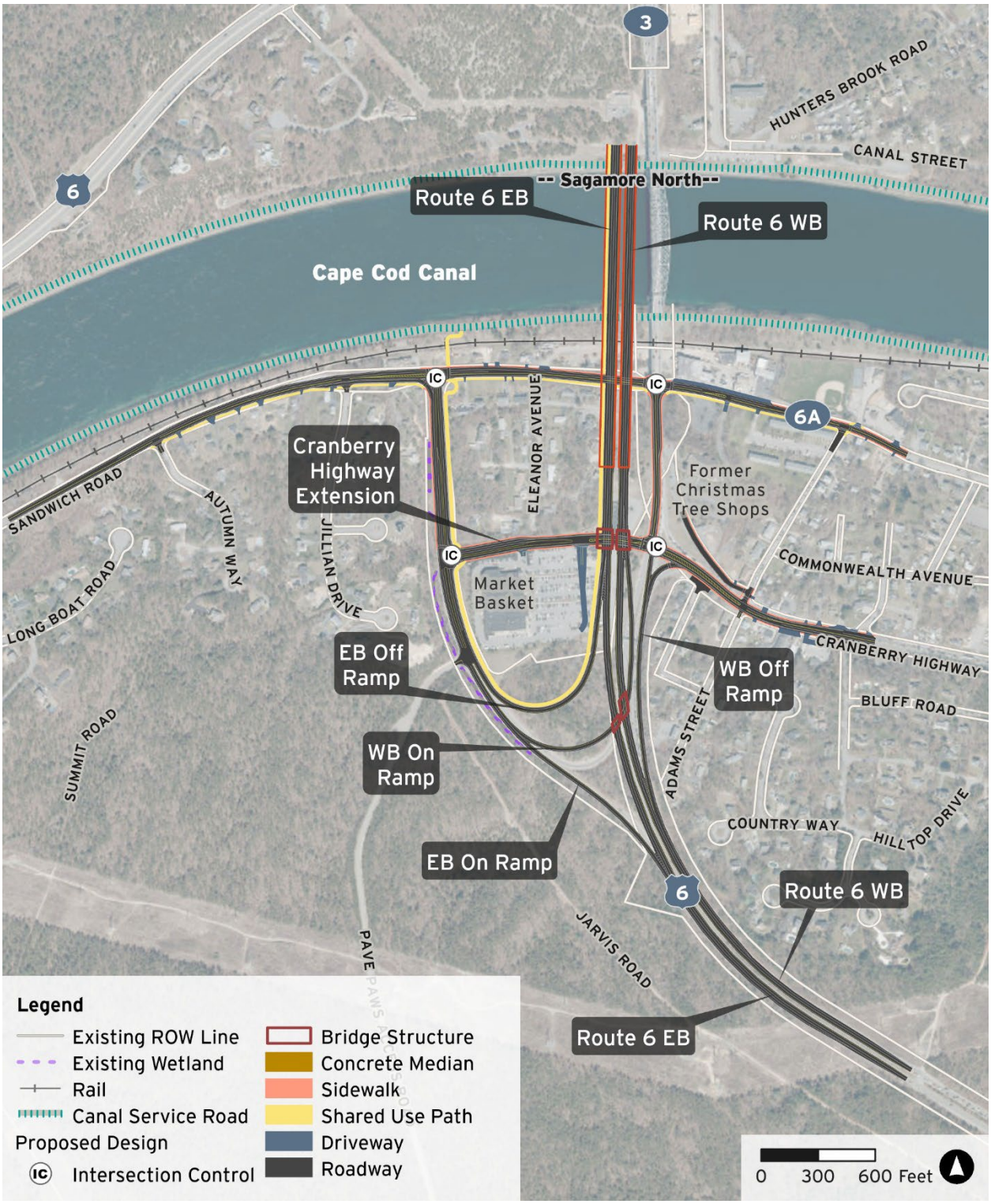


Figure 2-11. Sagamore South Crossing: Westbound On-Ramp under Route 6 Option (SS-3.1A)

2.5 Overview of Detailed Assessment of Highway Interchange Approach Options

MassDOT developed a two-step approach (Phase 2a and Phase 2b) to conduct detailed assessments of the highway interchange approach options. Sections 2.5.1 and 2.5.2 summarize the methodology, which is further described in Sections 3 and 4. Appendix 1 provides a definition of terms used in the detailed assessment.

The highway interchange approach options incorporate the design parameters previously determined in the Alternatives Analysis Report (February 2025), including a mainline alignment location shifted inboard of the existing bridges.

2.5.1 Phase 2a: Assessment of Options Related to Regional Traffic Operations

In Phase 2a, MassDOT assessed traffic operations within the regional network, consisting of the major roadways, interchanges, and intersections within an approximate 2-mile area centered around Sagamore Bridge and Bourne Bridge (Figure 2-12). The purpose of this assessment was: 1) to determine if there were highway interchange approach options in one area of the network that could adversely impact the performance of options in other areas of the network and 2) to identify options with fatal flaws that could adversely impact regional traffic operations.

MassDOT identified a total of 36 possible permutations of options based on the pairing of one option each for Bourne North, Bourne South, Sagamore North, and Sagamore South. MassDOT then narrowed the number of permutations to eliminate pairings that performed similarly (further described in Section 3.2) and conducted multiple analyses of the remaining permutations. MassDOT determined that options that would adversely impact overall network performance would be considered fatally flawed and would be eliminated from further analysis. MassDOT determined that highway interchange options that scored well regarding regional traffic operations would advance to further evaluation (Step 2) based on the Program Purpose and Need evaluation criteria and the Program's goals and objectives.

The results of this detailed regional traffic operations assessment, including a description of the traffic analysis tools, are presented in Section 3. Appendix 2 provides technical reports and memoranda that further explain the regional traffic operations assessment methodology and results.

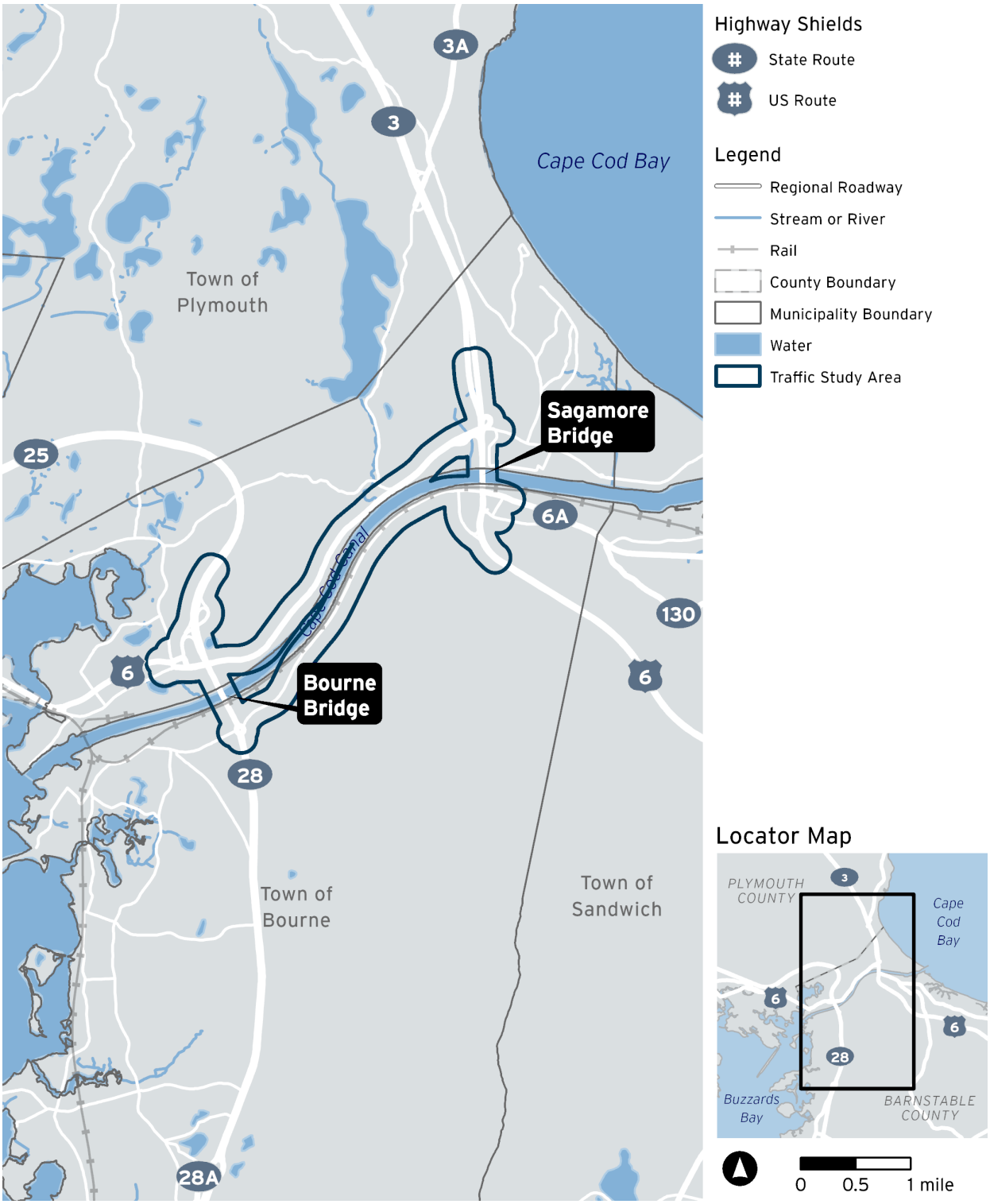


Figure 2-12. Traffic Study Area for Regional Operations Assessment

2.5.2 Phase 2b: Assessment of Options Related to Program Needs and Goals

MassDOT advanced highway interchange options that passed Phase 2a to a Phase 2b evaluation. In the second step, MassDOT identified transportation performance measures and contextual performance measures and then evaluated the options relative to the Program Needs and the Program goals and objectives. Section 4 identifies the Program Needs evaluation criteria, the Program goals and objectives, performance measures, and the scoring system used to evaluate the interchange options that advanced to the Step 2 evaluation. The results of the Step 2 assessment are presented in Sections 5 through 8.

Based on the results of the two-step evaluation process, MassDOT identified the highest-ranking interchange approach options, two per crossing, as the recommended interchange pairings to be incorporated into the Build Alternative to be Retained for Detailed Study. Section 10 identifies the recommended interchange pairings that will be further assessed in the Draft Environmental Impact Report (DEIR).

Appendix 3 provides detailed results of the Program Needs and Goals Assessment, including a description of the data sources used for the analysis.

3 Regional Traffic Operations Assessment

3.1 Introduction

Section 3 presents the results of MassDOT's detailed assessment of the impacts of the highway interchange options relative to regional traffic operations (Phase 2a), including overall operations performance and impact on the regional system. Appendix 2 includes the following technical memoranda developed in support of the regional traffic operations assessment:

- Methodology to Estimate 2019 Base Year Volumes (December 18, 2020);
- Future Demographic Conditions (May 14, 2021);
- Existing 2019 Conditions Traffic Analysis (August 30, 2021);
- Summary of Future No Build Modeling Process and Results (December 17, 2021);
- Future 2045 Build Traffic Volumes (September 1, 2023); and,
- Preliminary Traffic Analysis for Build Analysis Pairings (May 7, 2024).

3.2 Methodology Details

3.2.1 Development of Future Traffic Volumes

MassDOT evaluated Future (2050) Build traffic operations by first developing traffic volumes for the Future (2050) No Build condition, incorporating anticipated 2050 demographic projections for Cape Cod communities developed by the UMass Donahue Institute for the MassDOT Office of Transportation Planning (OTP), as well as projected visitor growth determined in coordination with the

Cape Cod Commission.[9] MassDOT then developed the Future (2050) Build traffic volumes based on the bridge replacements and associated Bourne and Sagamore interchange approach options, as further described in Sections 3.2.2. through 3.2.4.

3.2.2 Development of Traffic Volume Pairings

MassDOT reviewed the 36 possible permutations (pairings) of highway interchange options and narrowed the permutations to focus on those pairings with different impacts relative to travel demand.

It is anticipated that vehicle travel patterns and traffic volumes may differ based on the proposed geometric and operational changes of the specific option. For example, in Bourne North, an option that features a dedicated ramp for the Route 25 eastbound to Scenic Highway eastbound (Options BN-13.1 and BN-14.4b) would likely have different travel patterns and traffic volumes than an option that does not include a dedicated ramp (Option BN-6.1). However, there are some options that are very similar in geometry or vehicular travel paths (such as Options BS-2 and BS-2.2 and Options SN-1A and SN-8A), where vehicle travel patterns and traffic volumes would likely not differ. Therefore, to account for the option pairings where traffic volumes would differ, MassDOT identified six different traffic volume pairings to develop traffic demand volume scenarios, as presented in Table 3-1.

Table 3-1. 2050 Build Travel Demand Model Volume Permutations

Interchange Quadrant	Volume (V) Permutation					
	V1	V2	V3	V4	V5	V6
Sagamore North (SN)	8A	8A	8A	8A	8A	8A
Sagamore South (SS)	1	1.1	3.1A	1	1.1	3.1A
Bourne North (BN)	14.4b	14.4b	14.4b	6.1	6.1	6.1
Bourne South (BS)	2	2	2	2	2	2

The evaluations for the Future (2050) Build traffic operations were completed using the Fall afternoon (PM) time period. The Fall PM time period was chosen as it represents the 85th percentile of traffic volumes; meaning that 85 percent of the time throughout the year, traffic volumes are at the same level or lower than the Fall PM time period. MassDOT also analyzed Summer Saturday peak volumes to understand potential peak season operations, however, the Summer Saturday peak volumes (worst case scenarios) were not used to determine design decisions.

3.2.3 Development of Interchange Analysis Pairings

To identify if any of the options were fatally flawed relative to regional traffic operations, MassDOT developed analysis pairings based on the travel patterns identified in the volume permutations. Of the 36 possible permutations, MassDOT selected 11 different analysis pairings to determine if any of the options in a particular quadrant (SN, SS, BN, and/or BS) resulted in operational impacts to an option in another quadrant. MassDOT narrowed the selection to 11 pairings to include a sampling of possible

[9] MassDOT Office of Transportation Planning. Cape Cod Canal Transportation Study. 2019.

combinations to assess operational trends while maintaining a reasonable number of model permutations to analyze. Details are provided in the technical memoranda listed in Section 3.1.

Table 3-2 identifies the 11 analysis pairings that were evaluated in Phase 2a, as well as the associated volume permutation used for each specific analysis pairing.

Table 3-2. 2050 Build Analysis Pairings of Interchange Options

Quadrant	Analysis Pairings (AP)										
	AP1	AP1.1	AP2	AP3	AP4	AP5	AP6	AP7	AP7.1	AP8.1	AP9
Sagamore North (SN)	1A	8A	8A	1A	1A	8A	1A	8A	8A	1A	8A
Sagamore South (SS)	1	1	1.1	3.1A	1	1.1	3.1A	1	1	1.1	3.1A
Bourne North (BN)	6.1	6.1	6.1	6.1	13.1	13.1	13.1	14.4b	14.4b	14.4b	14.4b
Bourne South (BS)	2	2	2.2	2	2.2	2	2.2	2	2.2	2.2	2

3.2.4 Analysis Tools

The Program Study Area consists of freeway interchanges and local intersections. MassDOT used the following traffic analysis tools to analyze the 2050 Build conditions:

- Synchro – a traffic analysis software based on the Highway Capacity Manual (HCM)[10] methodology used to analyze local unsignalized and signalized intersections;
- Sidra - a traffic analysis software used to analyze roundabouts, rotaries, and traffic circles;
- HCS – a traffic analysis software based on the Highway Capacity Manual (HCM) methodology[11] used to analyze multilane highway segments and freeway weaves/merges/diverges; and
- VISSIM – a microsimulation software used to model the complete network area (encompassing the Bourne and Sagamore bridges and the roadways located within a 2-mile radius of the bridges) to show the interaction among the various classifications of roadway facilities (including road, bicycle and pedestrian infrastructure) and their impacts on each other.

3.3 Results of the Regional Traffic Operations Assessment

3.3.1 Evaluation of Network Performance

To assess the effect of the options on the regional traffic operations, MassDOT conducted a network performance evaluation utilizing the VISSIM software. Each of the Build analysis pairings identified in Table 3-2 was modeled in the VISSIM microsimulation software with the Future (2050) Build traffic volumes and the appropriate geometry and traffic control for that pairing. The simulations were run ten times each and the results were averaged.

[10] National Academies of Sciences, Engineering, and Medicine. Highway Capacity Manual 6th Edition: A Guide for Multimodal Mobility Analysis. Washington, DC: The National Academies Press.

[11] Levels of service were calculated using HCS 7 software, which is based on the HCM, 6th Edition.

The network performance measures evaluated for each analysis pairing included the following:

- Processed Vehicles, consisting of the total number of vehicles that enter the network and reach their destination before the end of the simulation; and
- Average Delay per Vehicle, consisting of the total network delay averaged over the total number of vehicles that are processed (enter and leave the network) and those that are still in the network at the end of the simulation.

Exhibit 3-1 presents the number of processed vehicles for each of the Build analysis pairings analyzed in comparison to the Future No Build condition. Exhibit 3-1 indicates that all of the Build analysis pairings are able to process more vehicles than the No Build condition, indicating a more efficient network, with performances ranging from approximately 3.5 percent to 10 percent better than the No Build condition. Of the 11 analysis pairings, AP1 through AP3 (four analysis pairings) process the least number of vehicles. The commonality among AP1 through AP3 is that they all include Option BN-6.1.

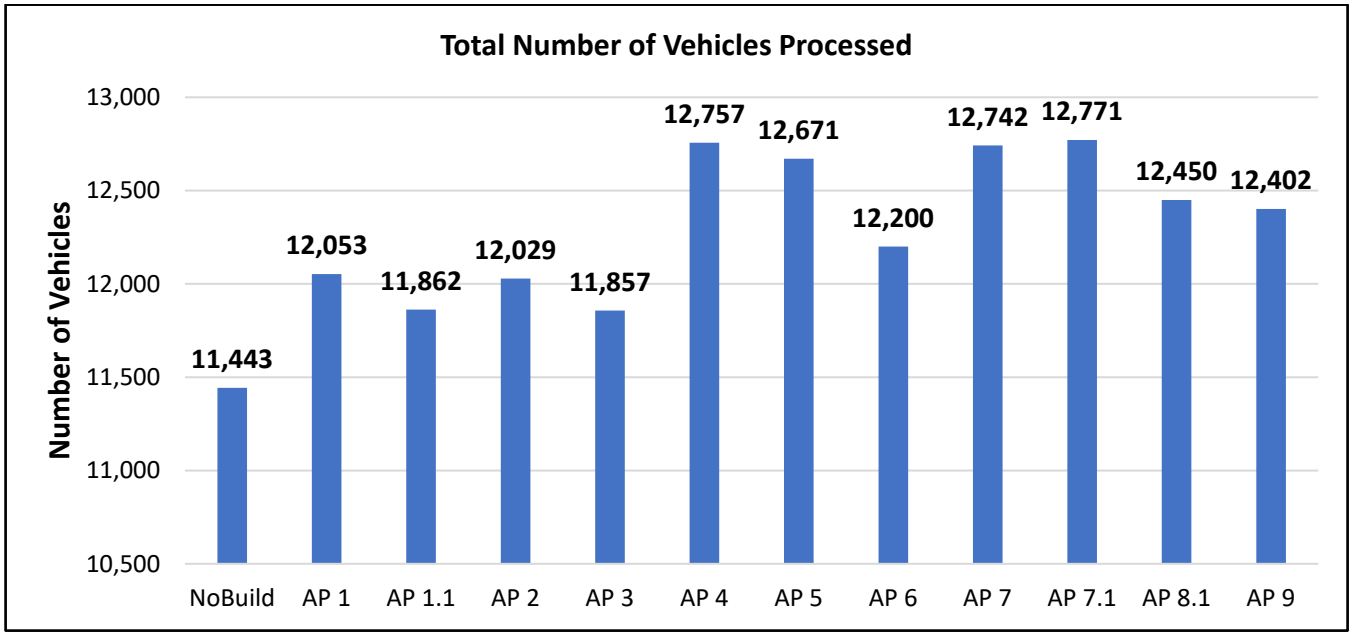


Exhibit 3-1. Network Performance Evaluation: Total Number of Vehicles Processed

Exhibit 3-2 presents the average delay per vehicle in minutes for each of the Build analysis pairings analyzed in comparison to the Future No Build condition. As indicated in Exhibit 3-2, AP4 through AP9 (seven analysis pairings) have a reduction in the average delay per vehicle in comparison to the No Build condition. Conversely, AP1 through AP3 (four analysis pairings) indicate higher average delays per vehicle than the No Build condition. These analysis pairings that include Option BN-6.1 operate relatively poorly in comparison to the other pairings. This poor performance is attributed to congestion at Belmont Circle associated with Option BN-6.1, where the termini of the ramps are in the northeast quadrant of Belmont Circle and circulation around Belmont Circle is required. In contrast, AP4 through

AP9 include either Option BN- 13.1 or Option BN-14.4b, both of which include a direct access ramp which allows vehicles that are traveling from Route 25 eastbound to Scenic Highway eastbound to bypass Belmont Circle, thereby removing a substantial amount of traffic from Belmont Circle and reducing congestion on Route 25 approaching the canal.

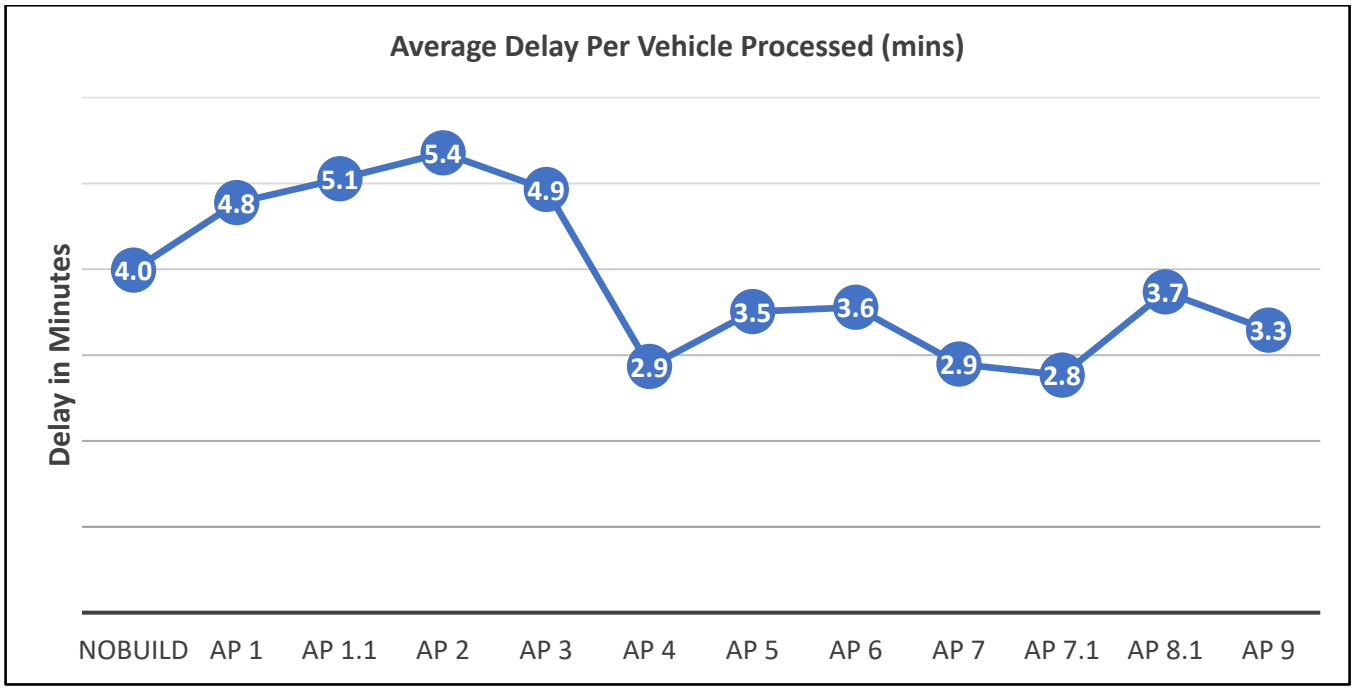


Exhibit 3-2. Network Performance Evaluation: Average Delay Per Vehicle Processed (minutes)

3.3.2 Evaluation of Total Travel Time

Total travel time was evaluated to assess system efficiency and user experience. Decreased travel times signify improved mobility, enhanced accessibility, and potentially reduced road user costs; whereas, prolonged travel times can signal congestion, routing or infrastructure inefficiencies, and potential network bottlenecks. Travel time was evaluated as follows:

- Network-wide assessment, using network-wide travel time data to provide insight into transportation system efficiency, congestion levels, and overall effectiveness;
- Major origin-destination (O-D) evaluation, measuring travel time between origin and destination points.

As traffic volumes and roadway geometries differ among the analysis pairings, operational trends and efficiencies can be difficult to ascertain on a total network vehicle-hours traveled basis. Therefore, two different travel time metrics were used to compare the analysis pairings:

- Percentage change of total travel time per mile per vehicle (compared to the Future No-Build condition), and
- Percentage change of travel time due to delay.

Exhibit 3-3 illustrates the percentage change in total travel time per mile per vehicle compared to the Future No-Build condition, offering a more refined measure of travel efficiency within the network. The results show that AP1 through AP3 have a higher travel time per mile per vehicle than the No-Build condition, while AP4 through AP9 all show improvements when compared to the No-Build condition. Relative to the interchange option analysis pairings, this metric suggests that although Options BN-14.4b, SS-1, and SS-1.1 may require slightly farther distances to travel due to geometric differences between Options BN-13.1 and SS-3.1A, analysis pairings that include these options are still efficient routes when assessing vehicle delay and the number of vehicles traveling through the network.

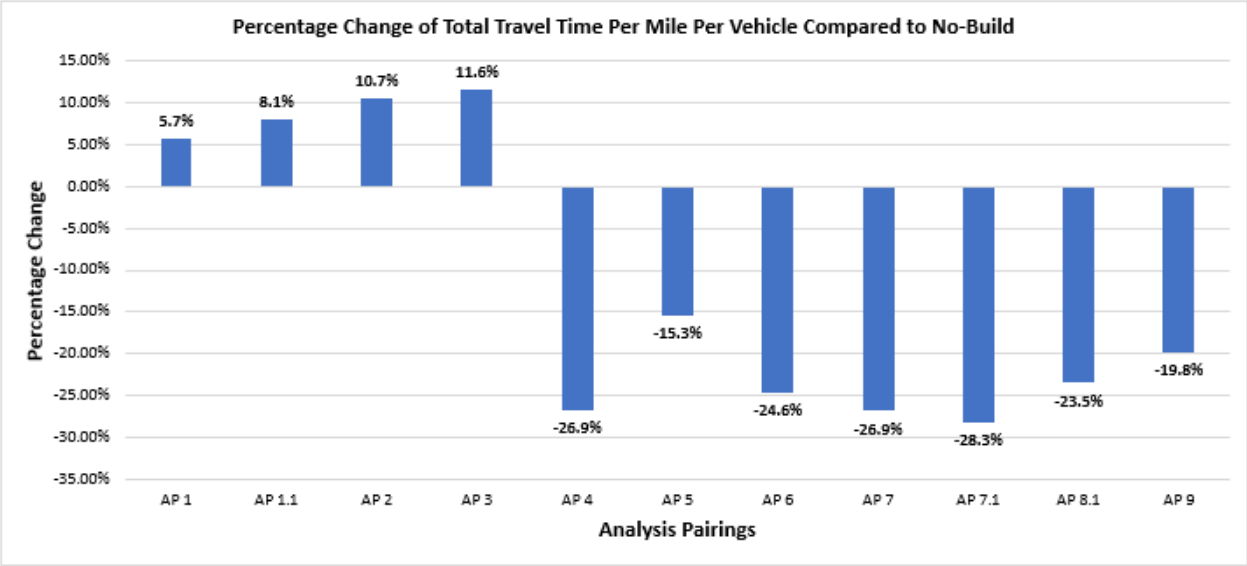


Exhibit 3-3. Percentage Change of Total Travel Time Per Mile Per Vehicle Compared to the Future No-Build Condition

This same efficiency can be seen in Exhibit 3-4, which depicts the percentage of travel time due to delay. Notably, AP7, AP7.1, and AP4 show the lowest percentage of travel time due to delay. All of these analysis pairings include the following: for Bourne North, either Option BN-14.4b or Option BN-13.1; for Sagamore North, either Option SN-8A or Option SN-1A; and for Sagamore South, the Cranberry Highway Extension (either Option SS-1 or Option SS-3.1A). Again, AP1 through AP3 continue to show the highest percent change in travel time due to delay. Similar to the Network Performance metric, AP1 through AP3 perform worse than the other analysis pairings with respect to travel time. AP1 through AP3 all include Option BN-6.1.

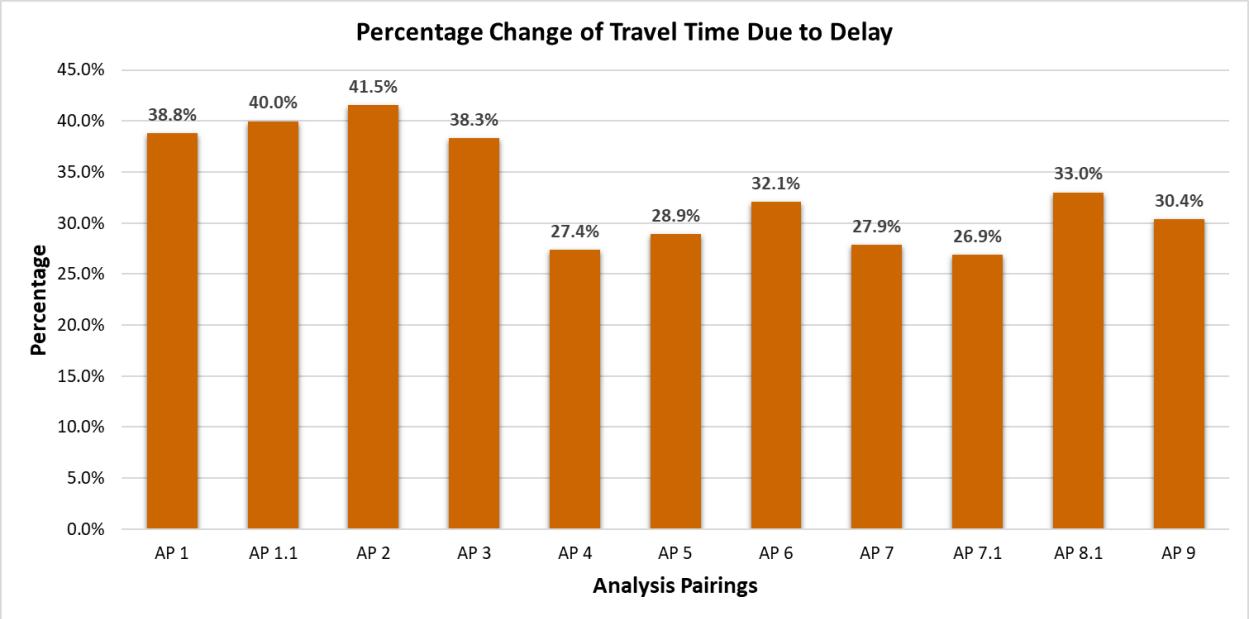


Exhibit 3-4. Percentage of Travel Time Due to Delay

3.3.3 Evaluation of Queue Length

In addition to evaluating the total number of processed vehicles, average delay per vehicle, and travel time, the VISSIM traffic simulations also identified length of average and maximum queues within the network. Similar to the No Build condition, AP1 through AP3 have queues that extend from Belmont Circle to the mainline of Route 25 eastbound. In the Future No Build condition, the average queues on Route 25 eastbound extend approximately a quarter mile from the exit to Belmont Circle and the maximum queues on Route 25 eastbound extend over a mile. AP1 through AP3 have queues on Route 25 eastbound similar to the No Build condition. At all other locations within the network for all other Build analysis pairings, neither the average queues nor maximum queues extend from the ramp terminals to the mainline.

3.4 Recommendation

The findings from the regional traffic operations analysis provided MassDOT with valuable insight into the performance of different alternative pairings relative to optimizing network efficiency and mitigating existing congestion. Addressing key bottlenecks, optimizing signal timings, and judiciously selecting options are essential steps towards enhancing overall network performance and improving the travel experience. Initial observations suggest that permutations involving Option BN-6.1 resulted in the highest levels of congestion and processed the fewest number of vehicles in the Future Build condition, leading to an increased average delay per vehicle compared to other analysis pairings. Additionally, the anticipated queues with permutations involving Option BN-6.1 would have queues that extend to the mainline of Route 25. The relatively poor results of Build analysis pairings that include Option BN-6.1 are primarily attributed to the increased volumes within Belmont Circle and the maintenance of the existing geometry and routing for vehicles traveling from Route 25 eastbound to Scenic Highway. Based

on the results of the regional traffic operations assessment and a clear indication of the operational shortcomings of Option BN-6.1, MassDOT recommended that Option BN-6.1 not be carried further for additional evaluation in a Step 2 evaluation.

By removing Option BN-6.1 from further consideration, MassDOT simplified the analysis and comparison of remaining options: as the route choice across the remaining option pairings is more similar, MassDOT was able to utilize the same set of traffic volumes. When reviewing the volume pairings, it was discovered that the traffic volumes in V1 through V3 and traffic volumes in V3 through V6 were similar to each other. It was determined that the difference in the traffic volumes was dependent on whether or not the volume pairing included Option BN-6.1. Those volume pairings including Option BN-6.1 showed a significant number of trips, heading on Route 25 eastbound crossing the canal, and utilizing the exit in Wareham to continue toward Belmont Circle using Route 6 or local roadways. All other volume pairings (V1 through V3) showed vehicle trips staying on Route 25 eastbound and exiting at Scenic Highway. Additionally, by utilizing the same set of traffic volumes, MassDOT was able to evaluate each option in isolation as well as in pairings.

MassDOT recommended advancing the following options for Step 2 of the detailed assessment:

- Bourne North: Option BN-13.1 and Option BN-14.4b,
- Bourne South: Option BS-2 and Option BS-2.2,
- Sagamore North: Option SN-1A and Option SN-8A, and
- Sagamore South: Option SS-1, Option SS-1.1, and Option SS-3.1A.

4 Development of Program Needs and Goals Performance Measures

4.1 Introduction

Section 4 presents the approach MassDOT used to conduct detailed assessments of the nine highway interchange approach options (Phase 2b) that passed the regional traffic operations assessment (Phase 2a). Refer to Appendix 1 for definitions of terms used in the evaluation criteria and performance measures.

MassDOT's Project Development and Design Guide (PDDG), updated in October 2023, defines the project development process, and guides the planning and design of transportation projects in Massachusetts. The PDDG identifies the means to evaluate transportation options or alternatives using transportation and contextual performance measures (or measures of effectiveness). Transportation performance measures relate to how the transportation facility functions and accommodates its users. Contextual performance measures evaluate how the transportation facility relates to its physical surroundings and community function.

For the Cape Cod Bridges Program, the transportation performance measures are related to the Program Purpose and Need, and contextual performance measures are related to the Program Goals. Performance measures consisted of a mix of qualitative and quantitative assessments. MassDOT also solicited agency, stakeholder, and public input to refine the performance measures.

4.2 Transportation Performance Measures Related to the Program Purpose and Need

MassDOT developed multiple evaluation criteria and quantitative and qualitative performance measures to assess the highway interchange approach options related to the four overall Program needs identified in the Purpose and Need Statement:

- Operations, focusing on poor vehicular traffic operations, including high traffic volumes and congestion resulting in poor levels of service (LOS);
- Geometrics and Safety, focusing on the substandard design elements of the existing Cape Cod Canal highway bridges, the immediate mainline approaches, and their adjacent interchanges and intersections, including abrupt and steep connections to surface roads and nonconforming traffic safety features;
- Multi-Modal Accommodations, focusing on the lack of accessible bicycle and pedestrian accommodations and connections between existing facilities, including gaps and unsafe conditions across the canal and between local area roadways; and
- Structural and Maintenance, focusing on the deteriorating structural condition and escalating maintenance demands of the existing Cape Cod Canal highway bridges, including the needed major rehabilitation programs identified by the USACE in the MRER/EA.[12]

Sections 4.2.1 through 4.2.4 present the performance measures developed to evaluate and compare the interchange options relative to the benefits they would provide in meeting the Program needs.

4.2.1 Operations Program Need

Table 4-1 presents the evaluation criteria and performance measures used to measure the ability of an option to address poor vehicular traffic operations (Operations). MassDOT identified six evaluation

[12] The USACE's MRER/EA, completed in March 2020, indicated that the Sagamore and Bourne bridges would be scheduled to undergo their second major rehabilitation. In 2025-2027, the USACE proposed to rehabilitate the Sagamore Bridge, and in 2029-2031, the USACE proposed to rehabilitate the Bourne Bridge. The USACE determined that the major rehabilitation would have transportation impacts on- and off-Cape, as well as on Martha's Vineyard, Nantucket, and the Elizabeth Islands (the Islands). The USACE determined that lengthy lane closures and full bridge closures would be necessary during the major rehabilitation efforts. Closures of the canal to marine traffic would also be necessary during some bridge work for the superstructure and deck. These closures would result in costs due to traffic delays, congestion, and re-routing, in addition to the costs of bridge rehabilitation itself. Further, the USACE anticipated that another major rehabilitation of both bridges would occur in the 2065-2069 timeframe.

criteria and seven performance measures to assess the Operations Program Need related to reducing congestion on the mainline highways and ramps and regional and local travel times; improving cross-canal mobility; minimizing traffic (queue) spillback from exit or entrance ramps onto the mainline; and separating regional (mid- to lower-Cape) and local (town of Bourne) traffic.

Table 4-1. Operations Evaluation Criteria and Performance Measures

Program Need: Address Poor Vehicular Traffic Operations	
Purpose and Need Evaluation Criteria	Performance Measure
Would the option reduce congestion on the mainline highways and ramps?	Number of passenger cars per mile per lane on mainline highways, compared to 2050 No Build condition.
	Number of passenger cars per mile per lane on ramps, compared to 2050 No Build condition.
Would the option reduce regional travel times?	Travel time (vehicle hours traveled [VHT]) on the mainline from the northern and southern Program limits to the mid-point of the bridge, compared to 2050 No Build condition.
Would the option reduce local travel times?	Travel time (VHT) on local roads between the eastern and western Program limits, compared to 2050 No Build condition.
Would the option improve cross-canal mobility?	Travel time (VHT) on local roads to the mid-point of the bridge, compared to 2050 No Build condition.
Would the option minimize queue spillback onto the highway?	Assessment of queues extending from local ramp terminals onto the mainline highway.
Would the option separate local and regional traffic?	Assessment of ability to separate local and regional traffic.

4.2.2 Geometrics and Safety Program Need

Table 4-2 presents the evaluation criteria and performance measures developed to measure the ability of an option to address the substandard design elements of the bridges and their highway networks (Geometrics and Safety). MassDOT identified seven evaluation criteria and eight performance measures to assess to the Geometrics and Safety Program Need related to the compatibility of the exit and entrance ramps with the mainline highways and local roadway network, including weaving, ramp spacing, and speed variances between ramps and mainline; and the driver's experience within the network, including potential wrong way driving, complexity of decision points, and overall driving expectation compared to existing conditions.

Table 4-2. Geometrics and Safety Evaluation Criteria and Performance Measures

Program Need: Address the Substandard Design Elements of the Bridges and their Highway Networks	
Purpose and Need Evaluation Criteria	Performance Measure
Would the option minimize weaving movements?	Number of weaving movements on mainline highways.
Would the option minimize wrong way driving risk?	Assessment of wrong way driving risks based on the geometrics of the intersections at the ramp terminals.
Would the option reduce the speed differential between the exit ramps and the local roadways?	Assessment of intersection geometry and target speeds between exit ramps and local roadways.
Would the option minimize the complexity of decision points?	Assessment of complexity of ramp decision points relative to ramp spacing.
Would the option provide adequate spacing between entrance and exit ramps?	Evaluation of entrance and exit ramp spacing.
Would the option minimize acceleration/deceleration speed variances between ramps and mainline?	Number of acceleration lane speed variances between ramps and mainline greater than 25 MPH.
	Number of deceleration lane speed variances between ramps and mainline greater than 25 MPH.
Would the option meet driver expectation for navigation?	Assessment of design related to driver navigation and expectation, compared to existing conditions.

4.2.3 Multi-Modal Accommodations Program Need

Table 4-3 presents the evaluation criteria and performance measures developed to measure the ability of an option to address the lack of accessible bicycle and pedestrian accommodations and connections between existing facilities substandard design elements of the bridges and their highway networks (Multi-Modal Accommodations). MassDOT identified eight evaluation criteria and 11 performance measures to assess the Multi-Modal Accommodations Program Need, related to accessibility to local roads, trails, and transit facilities; and the overall user experience, including the grade and safety features of the SUP.

Table 4-3. Multi-Modal Accommodations Evaluation Criteria and Performance Measures

Program Need: Address the Lack of Accessible Bicycle and Pedestrian Accommodations and Connections	
Purpose and Need Evaluation Criteria	Performance Measure
Would the option improve pedestrian/bicycle access from the bridge to local roads?	Distance of Shared Use Path (SUP) from bridge high point to first local road connection, including evaluation of travel time and comfort.
Would the option improve pedestrian/bicycle access adjacent to local roads?	Evaluation of availability and accessibility of SUP adjacent to local roadways.

Program Need: Address the Lack of Accessible Bicycle and Pedestrian Accommodations and Connections	
Purpose and Need Evaluation Criteria	Performance Measure
Would the option improve pedestrian/bicycle access to existing trail facilities?	Distance of SUP from bridge mid- point to first Canal Service Road connection.
Would the option improve pedestrian/bicycle connections at ramp terminals?	Assessment of Shared Use Path across ramp terminals with respect to controlled crossings and route diversions.
Would the option enhance the pedestrian/bicycle experience?	Assessment of Shared Use Path access and comfort through the interchange, including intersection footprint, roadway corridor, and crossings.
Would the option reduce the Shared Use Path grade at the bridge approaches?	Maximum grade of Shared Use Path.
	Maximum length of maximum grade of Shared Use Path.
	Number of Shared Use Path segments that equal or exceed 4.5% for a length of 500 feet or more.
Would the option increase pedestrian/bicycle accommodations in the Program Study Areas?	Percentage of local roadways with pedestrian/bicycle accommodations, compared to 2050 No Build condition.
Would the option improve pedestrian/bicycle access to transit facilities?	Distance of Shared Use Path from bridge mid-point to first public and/or private transit facility location.
	Number of public and/or private transit facility locations within a 0.50-mile radius.

4.2.4 Structural/Maintenance Program Need

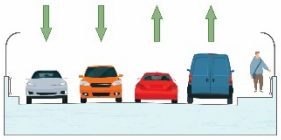
Table 4-4 presents the evaluation criteria and performance measures developed to measure the ability of an option to address the deteriorating structural condition and escalating maintenance demands of the Cape Cod Canal highway bridges (Structural/Maintenance). MassDOT identified two evaluation criteria and two performance measures to assess the Structural/Maintenance Program Need, related to the deteriorating structural condition of the bridges, as follows:

- Ability to minimize the risk of disruptive maintenance and/or rehabilitation on the existing bridges, measured by the time required to remove traffic from the existing bridges and discontinue their use, presented in Figure 4-1 as the optimal construction sequencing approach; and

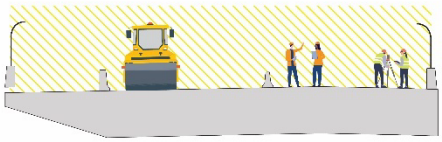
- Compatibility of the interchange approaches with the replacement bridge structures, related to how the ramp structural framing system connects to the structural framing system of the bridge.

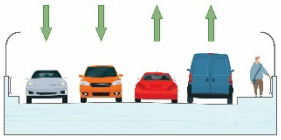
Table 4-4. Structural/Maintenance Evaluation Criteria and Performance Measures

Program Need: Address the Deteriorating Structural Condition and Escalating Maintenance Demands of the Cape Cod Canal Highway Bridges	
Purpose and Need Evaluation Criteria	Performance Measure
Would the option minimize the risk of disruptive maintenance and/or rehabilitation on the existing bridges?	Duration of time to remove traffic from the existing bridge and discontinue its use.
Would the option allow for the most efficient and simplest structural system to accommodate the interchange ramps?	Assessment of compatibility of structural framing system with the main bridge structural system.

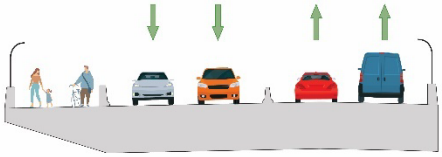


Existing Bridge



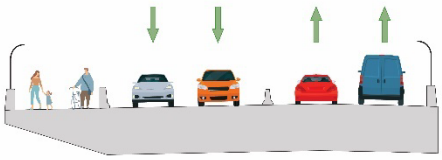


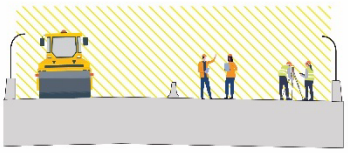
Phase 1 - Construct First Mainline Span



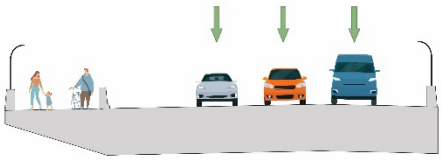


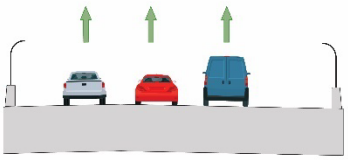
Phase 2 - Shift Traffic to First Mainline Span and Demolish Existing Bridge





Phase 3 - Construct Second Mainline Span





Phase 4 - Reroute Traffic onto Two Mainline Spans in Final Configuration

Figure 4-1. Bridge Construction Conceptual Sequencing Approach

4.3 Contextual Performance Measures Related to the Program Goals and Objectives

MassDOT identified multiple objectives and developed quantitative and qualitative performance measures to assess the highway interchange approach options related to the following Program goals, developed to comply with the Certificate of the Secretary of Energy and Environmental Affairs (EEA) on the ENF (July 7, 2023):

- Maintain and improve the socioeconomic fabric of the surrounding community (Socioeconomics);
- Preserve and protect natural resources (Natural Resources);
- Enhance the resiliency and sustainability of the built environment (Resiliency and Sustainability);
- Maximize constructability (Constructability);
- Facilitate emergency response (Emergency Response); and
- Maximize cost effectiveness (Cost Effectiveness).

The Program's goals, objectives, and performance measures developed to assess the interchange options are presented in Sections 4.3.1 through 4.3.6.

4.3.1 Socioeconomics Program Goal

Table 4-5 presents the objectives and performance measures developed relative to the Program goal to maintain and improve the socioeconomic fabric of the surrounding community. MassDOT identified eight objectives and 15 performance measures related to socioeconomics, to assess effects to residential and commercial properties and neighborhoods, Environmental Justice (EJ) populations, community facilities and services, and the traveling public. Options would be measured according to the impacts they would incur or to the opportunities they would provide in meeting the Socioeconomic Program objectives.

Table 4-5. Socioeconomics Objectives and Performance Measures

Program Goal: Maintain and Improve the Socioeconomic Fabric of the Surrounding Community	
Program Objective	**Performance Measure**
Would the option minimize residential property effects, including acquisitions and displacement?	Number of easements on vacant parcels.
	Number of easements on occupied parcels.
	Number of full parcel acquisitions with displacement.
	Number of full parcel acquisitions without displacement.
Would the option minimize commercial property effects, including acquisitions and displacement?	Number of easements on vacant parcels.
	Number of easements on occupied parcels.
	Number of full parcel acquisitions with displacement.
	Number of full parcel acquisitions without displacement.
Would the option improve access to commercial properties?	Assessment of accessibility to commercial properties.
	Assessment of accessibility to public and/or private community facilities & services, including bus stops.

Program Goal: Maintain and Improve the Socioeconomic Fabric of the Surrounding Community	
Program Objective	**Performance Measure**
Would the option maintain or improve neighborhood accessibility to community facilities & services?	Assessment of neighborhood access to schools, hospitals, and emergency services (police & fire).
Would the option maintain or improve neighborhood cohesion?	Assessment of neighborhood visibility and walkability regarding reduced or eliminated regional traffic.
Would the option avoid disproportionate adverse effects to Environmental Justice (EJ) populations?	Assessment of potential adverse and disproportionate impacts (with respect to all measures) to EJ populations.
Would the option minimize construction period effects upon the traveling public?	Assessment of the number, complexity, and duration of detours/workarounds during construction.
Would the option avoid and/or minimize effects to parks, open space, and recreational facilities?	Acreage of impacts and duration of impacts to parks, open space, and recreational resources.

4.3.2 Natural Resources Program Goal

Table 4-6 presents the objectives and performance measures developed relative to the Program goal to preserve and protect natural resources. MassDOT identified three objectives and three performance measures related to the natural environment; options would be measured by the impacts they would incur to protected habitats and regulated resources.

Table 4-6. Natural Resources Objectives and Performance Measures

Program Goal: Preserve and Protect Natural Resources	
Program Objective	Performance Measure
Would the option minimize effects to Areas of Critical Environmental Concern (ACEC) and wildlife habitats?	Area of direct impact to ACEC.
	Area of direct impact to wildlife (Natural Heritage and Endangered Species Program [NHESP] Priority and Estimated) habitat.
Would the option maintain floodplain functions?	Change in percentage of maintained natural vegetated areas within the floodplain compared to existing conditions.
Would the option maintain wetlands and surface waters, including protected buffers?	Direct impact to protected wetlands and water resources and/or buffer zones.

4.3.3 Resiliency and Sustainability Program Goal

Table 4-7 presents the objectives and performance measures developed relative to the Program goal to enhance the resiliency and sustainability of the built environment. MassDOT identified four objectives and 14 performance measures related to the built environment, to assess effects to air quality, land alteration, and stormwater management. Options would be measured by the impacts they would incur or by the opportunities they would provide in meeting Program objectives.

Table 4-7. Resiliency and Sustainability Objectives and Performance Measures

Program Goal: Enhance the Resiliency and Sustainability of the Built Environment	
Program Objective	**Performance Measure**
Would the option minimize air quality effects?	Total vehicle miles traveled (VMT), compared to 2050 No Build condition.
	Total VHT, compared to 2050 No Build condition.
Would the option minimize land alteration and reduction in tree cover (urban heat island effect)?	Amount of tree clearing.
Would the option minimize vulnerability to flooding?	Area of roadways impacted by storm surge.
	Area of roadways impacted by fluctuations in relative sea level.
Would the option effectively manage stormwater?	Increase in impervious area, compared to 2050 No Build condition.
	Percentage of treated impervious area, compared to minimum goal of 65%.
	Change in 2-year peak discharge rate, compared to minimum goal of 0%.
	Change in 10-year peak discharge rate, compared to minimum goal of 0%.
	Change in 100-year peak discharge rate, compared to minimum goal of 0%.
	Proposed infiltration volume recharge rate, compared to minimum goal of 100%.
	Percentage of total phosphorus removal, compared to minimum goal of 50%.
	Percentage of total suspended solids removal, compared to minimum goal of 80%.

4.3.4 Constructability Program Goal

Table 4-8 presents the objectives and performance measures developed relative to the Program goal to maximize constructability. MassDOT identified two objectives and two performance measures related to constructability; options would be measured by the impacts they would incur related to construction duration and existing travel connections.

Table 4-8. Constructability Objectives and Performance Measures

Program Goal: Maximize Constructability	
Program Objective	**Performance Measure**
Would the option minimize the construction duration?	Assessment of construction schedule relative to opening of second main span of replacement bridge, defined for this analysis as construction completion.
Would the option maintain existing connections during construction?	Assessment of ability to maintain existing travel connections during construction.

4.3.5 Emergency Response Program Goal

Table 4-9 presents the objectives and performance measures developed relative to the Program goal to facilitate emergency response. MassDOT identified two objectives and two performance measures related to emergency response; options would be measured by the opportunities they would provide relative to evacuation capabilities and regional mobility and emergency response.

Table 4-9. Emergency Response Objectives and Performance Measures

Program Goal: Facilitate Emergency Response	
Program Objective	**Performance Measure**
Would the option improve emergency evacuation capabilities off Cape Cod ?	Assessment of feasibility/difficulty of responding to emergency evacuation off Cape Cod.
Would the option improve emergency response?	Assessment of improvements to overall regional mobility regarding emergency response centers/locations.

4.3.6 Cost Effectiveness Program Goal

Table 4-10 presents the objective and the one performance measure developed relative to the Program goal to maximize cost effectiveness. Options would be measured by the opportunities they would provide in maximizing cost effectiveness. Per MassDOT standard operating procedures, estimated cost differences of 10 percent or less are not considered substantive; in these cases, options would receive the same scoring.

Table 4-10. Cost Effectiveness Objectives and Performance Measures

Program Goal: Maximize Cost Effectiveness	
Program Objective	Performance Measure
Would the option maximize construction cost effectiveness?	Comparison of construction cost estimates.

4.4 Assessment Methodology

As described in Section 3.2, MassDOT used multiple traffic analysis tools to analyze the 2050 Build conditions and quantitatively evaluate options based on their performance related to traffic operations as well as to the network within a 2-mile radius of the bridges, including the bridges, roadways and bicycle and pedestrian infrastructure. Appendix 2, Traffic Technical Reports and Memoranda, provides additional details. To arrive at the results for other quantitative and qualitative performance measures, MassDOT used preliminary (approximately 15 percent) design plans.

4.4.1 Further Development of Interchange Analysis Pairings

By removing Option BN-6.1 from further consideration, as discussed in Section 3.3, MassDOT reduced the number of traffic analysis models that required further development and refinement from 11 analysis

pairings (listed in Table 3-2) to six models. This allowed MassDOT to evaluate each option in isolation while also evaluating the option relative to potential network-wide impacts.
Table 4.11 shows the six different models that were developed for the Fall PM time period for the Phase 2b evaluation. MassDOT then conducted traffic simulation runs to compare options within each Program quadrant as follows:

- Bourne North (BN) Options BN-13.1 and BN-14.4b – Model A and Model B
- Bourne South (BS) Options BS-2 and BS-2.2: Model B and Model C
- Sagamore North (SN) Options SN-8A and SN-1A: Model B and Model D
- Sagamore South (SS) Options SS-1, SS-1.1, and SS-3.1A: Model B, Model E, and Model F

To assess and compare the traffic operations for each option, results from the traffic simulation runs were quantified based on travel times, vehicle-hours traveled, and vehicle-miles traveled. For example, to assess the reduction in regional travel times (from the 2050 No Build condition) for the Bourne North options, Model A and Model B results were used, comparing the travel times across the Bourne Bridge from Route 28 to Route 25 and from Route 25 to Route 28. In these traffic simulations, Model A used Option BN-13.1 and Model B used Option BN-14.4B. For the remaining three quadrants, both models were consistent in using Options SN-8A, SS-1, and BS-2, to isolate and understand the difference between the two Bourne North alternatives.

Table 4-11. 2050 Build Model Pairings of Interchange Options

Quadrant	Model Pairings					
	Model A	Model B	Model C	Model D	Model E	Model F
Sagamore North (SN)	8A	8A	8A	1A	8A	8A
Sagamore South (SS)	1	1	1	1	1.1	3.1
Bourne North (BN)	13.1	14.4B	14.4B	14.4B	14.4B	14.4B
Bourne South (BS)	2	2	2.2	2	2	2

4.4.2 Rating System

MassDOT developed a rating system for evaluating the highway interchange approach options based on their quantitative and qualitative performance. Relative to meeting Program Needs, an option was rated according to the benefits it would provide compared to other options or the No Build Alternative condition; benefit ratings were determined to be *substantial*, *marginal/some*, or *insufficient/negligible*. Regarding meeting Program goals and objectives, an option was rated in one of two ways: 1) based on the impacts it would incur compared to the other options, ranging from *more* or *most impacts* to *less,*

least, or no impacts; or 2) based on the opportunities it would provide in meeting Program objectives compared to the other options, ranging from *more* or *most opportunity* to *less* or *least opportunity*. Table 4-11 presents MassDOT's evaluation system for rating the highway interchange approach options, which is used in Sections 5 through 8.

Table 4-11. Highway Interchange Approach Detailed Assessment Rating System

How would the Option meet Program Needs?	How would the Option meet Program Goals and Objectives?		Rating
	Impacts	Opportunities	
The option would provide *Substantial Benefits*.	The option would have *No, Less, or the Least Impacts*.	The option would provide *More or the Most Opportunity* to meet and exceed Program objectives.	Highest
The option would provide ***Marginal/Some Benefits***.	The option would have *Some Impacts*.	The option would provide *Some Opportunity* to meet Program objectives.	Lower
The option would provide *Insufficient/Negligible Benefits*.	The option would have *More or the Most Impacts*.	The option would provide *Less or the Least Opportunity* to meet Program objectives.	Lowest

All evaluation criteria were equally rated; no scaling system, weighted average, or grading system was used. Except for the Program's constructability goal, ratings were isolated between the Bourne and Sagamore bridges as well as between the two quadrants (north and south) for each bridge. To assess the option's constructability, the Program phasing, construction schedules, and construction sequencing were considered holistically for each crossing, incorporating both the north and south quadrants.

MassDOT determined that the options that performed the best and scored the highest ratings would be further assessed in the DEIR as Options to be Retained for Detailed Study and developed to preliminary (25 percent) design.

5 Detailed Assessment of Bourne North Crossing Highway Interchange Approach Options

5.1 Introduction

Section 5 presents the results of the detailed assessment of the two remaining Bourne North options, BN-13.1 and BN-14.4b, relative to meeting the identified Program Needs and the Program goals and objectives. This assessment compares the options to each other, and where applicable, to the 2050 No Build condition. In addition to summary tables presenting the performances of the options, this section

includes descriptions of criteria that are differentiators between the two options. Appendix 3.2 provides technical data supporting this assessment.

5.2 Assessment of Operations Program Need

5.2.1 Summary of Results

Table 5-1 presents the results of the detailed assessment of the two Bourne North crossing interchange approach options relative to the Program need to address poor vehicular traffic operations. It compares the options according to the benefits each would provide in meeting the Operations Program need.

Table 5-1. Detailed Assessment Results of Bourne North Crossing Interchange Approach Options: Operations Program Need

Operations Program Need Evaluation Criteria	BN-13.1	BN-14.4b
Would the option reduce congestion on the mainline highways and ramps?		
• Number of passenger cars per mile per lane for mainline highways, compared to 2050 No Build condition.	Substantial Benefits	Substantial Benefits
• Number of passenger cars per mile per lane for ramps, compared to 2050 No Build condition.	Substantial Benefits	Substantial Benefits
Would the option reduce regional travel times?	Substantial Benefits	Substantial Benefits
Would the option reduce local travel times?	Substantial Benefits	Substantial Benefits
Would the option improve cross-canal mobility?	Substantial Benefits	Substantial Benefits
Would the option minimize queue spillback onto the highway?	Substantial Benefits	Substantial Benefits
Would the option separate local and regional traffic?	Marginal/Some Benefits	Substantial Benefits

Among the six evaluation criteria, both BN-13.1 and BN-14.4b would provide substantial improvements to vehicular traffic operations in comparison to 2050 No Build conditions. Except for one criterion, there would be minimal differences in performance between the two Bourne North options, as presented in Section 5.2.2.

5.2.2 Differences between Interchange Approach Options

5.2.2.1 Would the Option Separate Local and Regional Traffic?

Option BN-14.4b provides more opportunities to separate regional and local traffic than Option BN-13.1. Both options would remove southbound traffic to Scenic Highway eastbound, and westbound traffic to Route 25 northbound from Belmont Circle. Option BN-13.1 would remove traffic using signalized intersections, whereas Option BN-14.4b would use two flyover ramps connecting Route 25 and Scenic Highway (southbound off-ramp and northbound on-ramp) to remove traffic, thereby encouraging regional drivers to travel to and from mid-Cape via Scenic Highway and bypass Belmont

Circle in a free-flow condition. As a result, Option BN-14.4b receives a higher rating than Option BN-13.1 for separating local and regional traffic.

5.3 Assessment of Geometrics and Safety Program Need

5.3.1 Summary of Results

Table 5-2 presents the results of the detailed assessment of the two Bourne North crossing interchange approach options relative to the Program need to address the substandard design elements of the Cape Cod Canal highway bridges, the immediate mainline approaches, and their adjacent interchanges and intersections. It compares the options according to the benefits each would provide in meeting the Geometrics and Safety Program need.

Table 5-2. Detailed Assessment Results of Bourne North Crossing Interchange Approach Options: Geometrics and Safety Program Need

Geometrics and Safety Program Need Evaluation Criteria	BN-13.1	BN-14.4b
Would the option minimize weaving movements?	Marginal/ Some Benefits	Marginal/Some Benefits
Would the option minimize wrong way driving risk?	Marginal/Some Benefits	Substantial Benefits
Would the option reduce the speed differential between the exit ramps and the local roadways?	Substantial Benefits	Substantial Benefits
Would the option minimize the complexity of decision points?	Marginal/Some Benefits	Marginal/Some Benefits
Would the option provide adequate spacing between entrance and exit ramps?	Substantial Benefits	Substantial Benefits
Would the option minimize acceleration/deceleration speed variances between ramps and mainline?		
• Number of acceleration lane speed variances between ramps and mainline greater than 25 MPH.	Marginal/Some Benefits	Marginal/Some Benefits
• Number of deceleration lane speed variances between ramps and mainline greater than 25 MPH.	Marginal/Some Benefits	Marginal/Some Benefits
Would the option meet driver expectation for navigation?	Substantial Benefits	Substantial Benefits

Except for one criterion, there would be minimal differences in performance between the two Bourne North options as presented in Section 5.3.2.

5.3.2 Differences between Interchange Approach Options

5.3.2.1 Would the Option Minimize Wrong-Way Driving Risk?

Option BN-13.1 would introduce a new ramp at the Bourne North interchange that would not geometrically restrict access at the southbound off-ramp to Scenic Highway. In this option, the risk could be reduced with wrong-way driving mitigation techniques, ranging from signage to more advanced Wrong-Way Detection Systems (WWDS), such as light activated signs and driver alerts. MassDOT evaluated a roundabout at this new intersection to reduce the potential for wrong-way

driving; however, due to ROW concerns and impacts to the existing gas pumps, a roundabout would not work in this location. As a result, Option BN-13.1 received a *marginal benefits* rating. In Option BN-14.4b, the potential for wrong-way driving risk would be eliminated; the proposed off-ramp would be a direct connection to Scenic Highway eastbound, thereby geometrically restricting the potential for wrong-way driving. As a result, Option BN-14.4b receives *a substantial benefits* rating.

5.4 Assessment of Multi-Modal Accommodations Program Need

5.4.1 Summary of Results

Table 5-3 presents the results of the detailed assessment of the two Bourne North crossing interchange approach options relative to the program need to address the lack of accessible bicycle and pedestrian accommodations and connections between existing facilities substandard design elements of the bridges and their highway networks. It compares the options according to the benefits each would provide in meeting the Multi-Modal Accommodations Program need.

Table 5-3. Detailed Assessment Results of Bourne North Crossing Interchange Approach Options: Multi-Modal Accommodations Program Need

Multi-Modal Accommodations Evaluation Criteria	BN-13.1	BN-14.4b
Would the option improve pedestrian/bicycle access from the bridge to local roads?	Substantial Benefits	Substantial Benefits
Would the option improve pedestrian/bicycle access adjacent to local roads?	Insufficient/ Negligible Benefit	Substantial Benefits
Would the option improve pedestrian/bicycle access to existing trail facilities?	Marginal/Some Benefits	Substantial Benefits
Would the option improve pedestrian/bicycle connections at ramp terminals?	Marginal/Some Benefits	Substantial Benefits
Would the option enhance the pedestrian/bicycle experience?	Marginal/Some Benefits	Substantial Benefits
Would the option reduce the Shared Use Path grade at the bridge approaches?		
• Maximum grade of Shared Use Path.	Substantial Benefits	Substantial Benefits
• Maximum length of maximum grade of Shared Use Path.	Substantial Benefits	Substantial Benefits
• Number of Shared Use Path segments that equal or exceed 4.5% for a length of 500 feet or more.	Substantial Benefits	Substantial Benefits
Would the option increase pedestrian/bicycle accommodations in the Program Study Areas?	Substantial Benefits	Substantial Benefits
Would the option improve pedestrian/bicycle access to transit facilities?		
• Distance of Shared Use Path at bridge mid-point to first public and/or private transit facility location.	Substantial Benefits	Substantial Benefits
• Number of desired public and/or private transit facility locations within a 0.50-mile radius.	Substantial Benefits	Substantial Benefits

Among the eight evaluation criteria, the Bourne North options generally would provide more opportunities to address the multi-modal accommodations and connections need. Except for four criteria, there would be minimal differences in performance between the two Bourne North options, as presented in Section 5.4.2.

5.4.2 Differences between interchange Approach Options

5.4.2.1 Would the Option Improve Pedestrian/Bicycle Access Adjacent to Local Roads?

Option BN-13.1 would provide 6-foot-wide sidewalks, but not a SUP, along Route 6 westbound and eastbound to connect to pedestrian and bicycle facilities at Belmont Circle. Option BN-13.1 would not meet MassDOT's design standards for pedestrian and bicycle accommodations per its Healthy Transportation Directive. As a result, Option BN-13.1 receives a *negligible benefit* rating in improving pedestrian/bicycle access adjacent to local roads. In contrast, due to the new flyover ramp and the reduced Route 6 lane configuration from four to three lanes, there would be sufficient space in Option BN-14.4b to provide a 6-foot-wide sidewalk along Route 6 westbound and a 12-foot-wide SUP with a landscaped buffer adjacent to Route 6 eastbound to connect to pedestrian and bicycle facilities at Belmont Circle. Additional multi-modal connections include the proposed ten-foot-wide SUP along Scenic Highway eastbound, to be constructed under a separate MassDOT project (Project PFN 606082). Additionally, Option BN-14.4b would provide grade separation over Scenic Highway for pedestrians and bicyclists. As a result, Option BN-14.4b receives a *substantial benefits* rating in improving pedestrian/bicycle access adjacent to local roads.

5.4.2.2 Would the Option Improve Pedestrian/Bicycle Access to Existing Trail Facilities?

In Option BN-13.1, the distance of the SUP from the bridge mid-point to the first Canal Service Road connection would be slightly more than one mile. Option BN-13.1 receives a *marginal benefits* rating due to the several at-grade crossings included in this connection. In Option BN-14.4b, while the distance of the SUP from the bridge mid-point to the first Canal Service Road connection would be longer, approximately 1.25 mile, this option would provide a grade separated crossing, enhancing the comfort and travel time, and resulting in a *substantial benefits* rating.

5.4.2.3 Would the Option Improve Pedestrian/Bicycle Connections at Ramp Terminals?

Option BN-13.1 ranks lower than Option BN-14.4b regarding improved pedestrian/bicycle connections at ramp terminals. Option BN-13.1 would provide a signalized control across from both new on- and off-ramps. In Option BN-14.4b, pedestrian/bicycle access at the new off-ramp would include a mile-long diversion to avoid the high-speed ramp. In both options, the ramps at Belmont Circle would maintain the existing Pedestrian Hybrid Beacon (PHB) control for pedestrians.

5.4.2.4 Would the Option Enhance the Pedestrian/Bicycle Experience?

In Option BN-13.1, the maximum pedestrian intersection crosswalk distance, approximately 70 feet, would be less than that of Option BN-14.4b, approximately 76 feet. However, in Option BN-13.1, the Scenic Highway eastbound to westbound movement would require six intersection/ramp crossings. In Option BN-14-4b, the Scenic Highway eastbound to westbound movement would require two

intersection/ramp crossings. As a result, Option BN-14.4b receives a higher rating regarding the overall pedestrian/bicycle experience.

5.5 Assessment of Maintenance/Structural Program Need

5.5.1 Summary of Results

Table 5-4 presents the results of the detailed assessment of the two Bourne North crossing interchange approach options relative to the program need to address the deteriorating structural condition and escalating maintenance demands of the Cape Cod Canal highway bridges. It compares the options according to the benefits each would provide in meeting the Maintenance/Structural Program need.

Table 5-4. Detailed Assessment Results of Bourne North Crossing Interchange Approach Options: Maintenance/Structural Program Need

Maintenance/Structural Evaluation Criteria	BN-13.1	BN-14.4b
Would the option minimize the risk of disruptive maintenance and/or rehabilitation on the existing bridges?	Marginal/ Some Benefits	Marginal/Some Benefits
Would the option allow for the most efficient and simplest structural system to accommodate the interchange ramps?	Substantial Benefits	Substantial Benefits

The two Bourne North options would perform generally the same in addressing the maintenance/structural needs of the existing Bourne Bridge. The time needed to move traffic from the Bourne Bridge and discontinue use of the existing bridge would be equivalent between the two Bourne North options. Additionally, in both options, the ramp framing system would be compatible with the mainline framing system.

5.6 Assessment of Socioeconomic Program Goal

5.6.1 Summary of Results

Table 5-5 presents the results of the detailed assessment of the two Bourne North crossing interchange approach options relative to the Program goal to maintain and improve the socioeconomic fabric of the surrounding community. It compares the options according to the impacts each would incur or to the opportunities each would provide in meeting the Socioeconomic Program objectives.

Table 5-5. Detailed Assessment Results of Bourne North Crossing Interchange Approach Options: Socioeconomics Program Goal

Socioeconomics Objectives	BN-13.1	BN-14.4b
Would the option minimize residential property effects, including acquisitions and displacement?		
• Number of easements on vacant parcels.	No Impacts	No Impacts
• Number of easements on occupied parcels.	Some Impacts	Some Impacts
• Number of full parcel acquisitions with displacement.	Some Impacts	Some Impacts
• Number of full parcel acquisitions without displacement.	No Impacts	No Impacts
Would the option minimize commercial property effects, including acquisitions and displacement?		

Socioeconomics Objectives	BN-13.1	BN-14.4b
• Number of easements on vacant parcels.	Some Impacts	Some Impacts
• Number of easements on occupied parcels.	Less Impacts	Less Impacts
• Number of full parcel acquisitions with displacement.	Less Impacts	Less Impacts
• Number of full parcel acquisitions without displacement.	Less Impacts	Less Impacts
Would the option improve access to commercial properties?	More Opportunity	More Opportunity
Would the option maintain or improve neighborhood accessibility to community facilities & services?		
• Neighborhood access to public and/or private community facilities & services.	Some Opportunity	More Opportunity
• Neighborhood access to schools, hospitals, and emergency services (police & fire).	Some Opportunity	More Opportunity
Would the option maintain or improve neighborhood cohesion?	Some Opportunity	More Opportunity
Would the option avoid disproportionate adverse effects to Environmental Justice (EJ) populations?	Less Impacts	Less Impacts
Would the option minimize construction period effects upon the traveling public?	Some Impacts	Some Impacts
Would the option avoid and/or minimize effects to parks, open space, and recreational facilities?	Some Impacts	More Impacts

Among the eight evaluation criteria for Socioeconomics, the two Bourne North options would perform similarly, except for accessibility to existing facilities and effects on parks and open space, as presented in Section 5.6.2.

5.6.2 Differences between Interchange Approach Options

5.6.2.1 Would the Option Improve Accessibility to Community Services and Facilities?

Option BN-13.1 scores lower than Option BN-14.4b in maintaining or improving accessibility to community services and facilities, including providing improved connections, Option BN-13.1 would maintain access to existing facilities by adding sidewalks on both sides of Scenic Highway and providing a SUP from the canal crossing to Belmont Circle. In contrast, Option BN-14.4b would improve access to existing facilities by adding a SUP along Scenic Highway and a SUP from the canal crossing to Belmont Circle. Additionally, as cited in Section 6.6.2.2, Option BN-14.4b would improve accessibility for local traffic in the Nightingale Pond residential subdivision. As a result, Option BN-14.4b receives a rating of *more opportunity* in improving accessibility to community services and facilities.

5.6.2.2 Would the Option Maintain or Improve Neighborhood Cohesion?

Option BN-14.4b receives a higher rating than Option BN-13.1 in maintaining or improving neighborhood cohesion, measured by the ability to reduce or eliminate regional (through) traffic. Option BN-13.1 would partially remove Route 28/25 traffic from the local roadway network and would add pedestrian and bicycle facilities, resulting in a *marginal/some benefits* rating. Because it would fully remove Route 28/25 traffic from the local roadway network, in addition to providing pedestrian and bicycle facilities, Option BN-14.4b receives a rating of *more opportunity*.

5.6.2.3 Would the Option Avoid or Minimize Effects to Parks, Open Space and Recreational Facilities?

In both Bourne North options, the North Canal Service Road, which is used as a pedestrian/bicycle path, would be impacted by the construction zone areas for the crane placement for bridge demolition and construction. In both options, temporary closure of the Canal Service Road would affect approximately 0.32 acres.

In Option BN-13.1, approximately 14.2 acres of Bourne Scenic Park campground would be impacted during construction, due to the revised mainline location and new ramp connecting Scenic Highway and Route 25. In comparison, in Option BN-14.4b, approximately 14.8 acres of the campground would be impacted during construction. The new flyover ramp connecting Scenic Highway to Route 25, proposed to reduce congestion in Belmont Circle, would affect the entrance to Bourne Scenic Park, resulting in additional park impacts. Due to the anticipated additional impacts to the park, Option BN-14.4b ranks lower than Option BN-13.1 and receives a rating of more impacts, as opposed to Option BN-13.1's rating of some impacts.

5.7 Assessment of Natural Resources Program Goal

5.7.1 Summary of Results

Table 5-6 presents the results of the detailed assessment of the two Bourne North crossing interchange approach options relative to the Program goal to preserve and protect natural resources. It compares the options according to the impacts each would incur or to the opportunities each would provide in meeting the Natural Resources Program objectives.

Table 5-6. Detailed Assessment Results of Bourne North Crossing Interchange Approach Options: Natural Resources Program Goal

Natural Resources Objectives	BN-13.1	BN-14.4b
Would the option minimize effects to Areas of Critical Environmental Concern (ACEC) and wildlife habitats?		
• Area of impact to ACEC	No Impacts	No Impacts
• Area of impact to wildlife habitat	No Impacts	No Impacts
Would the option maintain floodplain functions?	Some Impacts	Some Impacts
Would the option maintain wetlands and surface waters, including protected buffers?	Some Impacts	Some Impacts

The two Bourne North options receive the same ratings regarding natural resources protection. There are no ACECs or NHESP Priority and Estimated Habitats in Bourne North. Both options would result in an approximate 19 percent loss of vegetated floodplain compared to the existing floodplain area in Bourne North. Both options would result in work within wetland buffer zones.

5.8 Assessment of Resiliency and Sustainability Program Goal

5.8.1 Summary of Results

Table 5-7 presents the results of the detailed assessment of the two Bourne North crossing interchange approach options relative to the Program goal to enhance the resiliency and sustainability of the built environment. It compares the options according to the impacts each would incur or to the opportunities each would provide in meeting Resiliency and Sustainability Program objectives.

Table 5-7. Detailed Assessment Results of Bourne North Crossing Interchange Approach Options: Resiliency and Sustainability Program Goal

Resiliency and Sustainability Objectives	BN-13.1	BN-14.4b
Would the option minimize air quality effects?		
• Total VMT, compared to 2050 No Build	Less Impacts	Less Impacts
• Total VHT, compared to 2050 No Build	Less Impacts	Less Impacts
Would the option minimize land alteration and reduction in tree cover (urban heat island effect)?	Less Impacts	Less Impacts
Would the option minimize vulnerability to flooding?		
• **Area of roadways impacted by storm surge**	Less Impacts	Less Impacts
• **Area of roadways impacted by fluctuations in relative sea level**	Less Impacts	Less Impacts
Would the option effectively manage stormwater?		
• Increase in impervious area, compared to 2050 No Build condition.	More Impacts	More Impacts
• Percentage of treated impervious area, compared to minimum goal of 65%.	More Opportunity	More Opportunity
• Change in 2-year peak discharge rate, compared to minimum goal of 0%.	Some Opportunity	More Opportunity
• Change in 10-year peak discharge rate, compared to minimum goal of 0%.	More Opportunity	More Opportunity
• Change in 100-year peak discharge rate, compared to minimum goal of 0%.	More Opportunity	More Opportunity
• Proposed infiltration volume recharge rate, compared to minimum goal of 100%.	More Opportunity	More Opportunity
• Percentage of total phosphorus removal, compared to minimum goal of 50%.	More Opportunity	More Opportunity
• Percentage of total suspended solids removal, compared to minimum goal of 80%.	Some Opportunity	Some Opportunity

Among the four evaluation criteria and multiple performance measures for resiliency and sustainability, the Bourne North options receive generally the same ratings, except for one stormwater management measure, as presented in Section 5.8.2.

5.8.2 Differences between Interchange Approach Options

5.8.2.1 Would the Option Effectively Manage Stormwater?

Options BN-13.1 and BN-14.4b generally performed the same regarding stormwater management, differing in only one criterion. Relative to meeting the minimum goal of 0 percent for change in the peak 2-year discharge rate, Option BN-13.1 receives a rating of *some opportunity* for the anticipated 4 percent increase in the peak 2-year discharge rate. In contrast, Option BN-14.4b receives a *more opportunity* rating for the anticipated 14 percent decrease in the peak 2-year discharge rate.

5.9 Assessment of Constructability Program Goal

5.9.1 Summary of Results

Table 5-8 presents the results of the detailed assessment of the two Bourne North crossing interchange approach options relative to the Program goal to maximize constructability. It compares the options according to the impacts of each relative to meeting Constructability Program objectives.

Table 5-8. Detailed Assessment Results of Bourne North Crossing Interchange Approach Options: Constructability Program Goal

Constructability Objectives	BN-13.1	BN-14.4b
Would the option minimize the construction duration?	Some Impacts	Some Impacts
Would the option maintain existing connections during construction?	Less Impacts	**Less Impacts**

The two Bourne North options receive the same ratings regarding Program constructability. The anticipated construction duration would be equivalent between the two options. In both options, existing connections would be maintained during construction.

5.10 Assessment of Emergency Response Program Goal

5.10.1 Summary of Results

Table 5-9 presents the results of the detailed assessment of the two Bourne North crossing interchange approach options relative to the Program goal to facilitate emergency response. It compares the options according to the opportunities each would provide in meeting Emergency Response objectives.

Table 5-9. Detailed Assessment Results of Bourne North Crossing Interchange Approach Options: Emergency Response Program Goal

Emergency Response Objectives	BN-13.1	BN-14.4b
Would the option improve emergency evacuation capabilities off Cape Cod?	Some Opportunity	More Opportunity
Would the option improve emergency response?	More Opportunity	More Opportunity

The two Bourne North options receive differing ratings regarding the ability to improve emergency response, as presented in Section 5.10.2.

5.10.2 Differences between Interchange Approach Options

5.10.2.1 Would the Option Improve Emergency Evacuation Capabilities from Cape Cod and the Islands to Mainland Massachusetts?

Both Bourne North options would improve emergency evacuation capabilities over the No Build condition. Due to the grade separated direct connect ramps, Option BN-14.4b would provide a free flow traffic condition without a signalized intersection for westbound Cape Cod departures. In comparison, Option BN-13.1 would route the same westbound Cape Cod departures via a signalized intersection. As a result, Option BN-14.4b receives a *more opportunity* rating and Option BN-13.1 receives a *some opportunity* rating.

5.11 Assessment of Cost Effectiveness Program Goal

5.11.1 Summary of Results

Table 5-10 presents the results of the detailed assessment of the two Bourne North crossing interchange approach options relative to the Program goal to maximize construction cost effectiveness. It compares the options according to the opportunity each would provide in meeting the Cost Effectiveness Program objective.

Table 5-10. Detailed Assessment Results of Bourne North Crossing Interchange Approach Options: Cost Effectiveness Program Goal

Cost Effectiveness Objective	BN-13.1	BN-14.4b
Would the option maximize construction cost effectiveness?	More Opportunity	Some Opportunity

5.11.2 Differences between Interchange Approach Options

Option BN-13.1 is anticipated to cost approximately $178 million and Option BN-144b is estimated to cost $211 million, approximately $33 million (over 15 percent) more than Option BN-13.1.[13] Due to the cost differential of more than 10 percent between the two options, Option BN-14.b receives a lower rating.

5.12 Recommended Bourne North Crossing Highway Interchange Approach Option

Based on the results of the detailed assessment of Bourne North options, MassDOT recommends that Option BN-14.4b advance as the Bourne North Option to be Retained for Detailed Study in the DEIR,

[13] The estimated cost of each Bourne North highway interchange approach option is per year of expenditure (YOE) and does not include mainline (bridge) work. This does not include any of the mainline work. The cost comparison does not account for future cost changes. It is a comparison of anticipated construction costs with risk, escalation and inflation included. Escalation is applied at a compounded rate of 4 percent per year to the midpoint of the cost phase. It is applied to quantified and factored costs as well as contingencies. The cost includes contingency and assumes a base year of 2023. Quarter 3 2026 is the assumed Notice to Proceed (NTP) for the Design-Build contract with an assumed duration of 84 months (seven years).

including advancement to 25 precent design development. Section 5.12 presents a summary overview and details of the detailed assessment.

5.12.1 Summary Comparison of Bourne North Interchange Approach Options

Table 5-11 presents a summary table of the Program Need evaluation criteria and Program goals and objectives that proved to be differentiators between the two options, comparing their relative benefits, impacts, and opportunities.

Table 5-11. Bourne North Performance Evaluation Criteria Summary Table

Program Need/Goal	Evaluation Criteria/Objectives	BN-13.1	BN-14.4b
Program Need	***Evaluation Criteria***		
Operations	Would the option separate local and regional traffic?	Marginal/Some Benefits	Substantial Benefits
Geometrics and Safety	Would the option minimize wrong way driving risk?	Marginal/Some Benefits	Substantial Benefits
Multi-Modal Accommodations	Would the option Improve pedestrian/bicycle access adjacent to local roads?	Insufficient/ Negligible Benefit	Substantial Benefits
	Would the option improve pedestrian/bicycle access to existing trail facilities?	Marginal/Some Benefits	Substantial Benefits
	Would the option improve pedestrian/bicycle connections at ramp terminals?	Marginal/Some Benefits	Substantial Benefits
	Would the option enhance the pedestrian/bicycle experience?	Marginal/Some Benefits	Substantial Benefits
Program Goal	***Objectives***		
Socioeconomics	Would the option improve neighborhood access to community facilities and services, specifically, schools, hospitals, and emergency services (police & fire)?	Some Opportunity	More Opportunity
	Would the option maintain or improve neighborhood cohesion?	Some Opportunity	More Opportunity
	Would the option avoid and/or minimize effects to parks, open space, and recreational facilities?	Some Impacts	More Impacts
Resiliency and Sustainability	Would the option effectively manage stormwater, demonstrated by change in 2-year peak discharge rate?	Some Opportunity	More Opportunity
Emergency Response	Would the option improve emergency evacuation capabilities off Cape Cod?	Some Opportunity	More Opportunity
Cost Effectiveness	Would the option maximize construction cost effectiveness?	More Opportunity	Some Opportunity

5.12.2 Summary of Differences between Interchange Approach Options

As shown in Table 5-11, the detailed assessment of Bourne North options provided different results for twelve measures addressing the Program Needs and/or goals.

5.12.2.1 Operations Program Need

Both Options BN-13.1 and BN-14.4b would separate local and regional traffic. However, Option BN-14.4b would provide more opportunities to separate regional and local traffic, resulting in a *substantial benefits* rating: the two flyover ramps connecting Route 25 and Scenic Highway (southbound off-ramp and northbound on-ramp) encourage travelers to and from mid-Cape to use Scenic Highway and bypass Belmont Circle in a free-flow condition.

5.12.2.2 Geometrics and Safety Program Need

Option BN-14.4b would geometrically restrict the potential for wrong-way driving, thereby eliminating this risk, fully meeting the Program's geometric and safety needs in this performance measure. In contrast, Option BN-13.1 would not geometrically restrict the potential for wrong-way driving.

5.12.2.3 Multimodal Accommodations Program Need

Option BN-14.4b scores higher than Option BN-13.1 in several criteria under the multi-modal accommodations Program Need. Option BN-14.4b would provide grade separation over Scenic Highway for pedestrians and bicyclists, providing *substantial benefits*. Additionally, due to the improved traffic operations of the southbound off-ramp flyover and the reduced lane configuration along Scenic Highway, Option BN-14.4b would meet the pedestrian and bicycle requirements of MassDOT's Healthy Transportation Directive by including a 6-foot sidewalk on the north side and a 12-foot SUP on the south side of Scenic Highway. In contrast, Option BN-13.1 would only moderately improve pedestrian/bicycle access to local roads and would not meet MassDOT's Healthy Transportation Directive standards.

5.12.2.4 Socioeconomics Program Goal

By providing SUPs along Scenic Highway and from the canal crossing to Belmont Circle, Option BN-14.4b would provide *more opportunity* to improve neighborhood accessibility to community facilities and services, specifically to the Nightingale Pond subdivision. In addition to the pedestrian and bicycle facilities, Option BN-14.4b would substantially improve neighborhood cohesion by fully removing mainline Route 28/25 traffic from the local roadway network.

Option BN-14.4b would result in more temporary and permanent impacts to Bourne Scenic Park than would Option BN-13.1, resulting in a lower rating in this criterion. However, in cooperation with FHWA, MassDOT is coordinating with USACE and the Bourne Recreation Authority (BRA), the owners with jurisdiction over the park, to compensate for these impacts, including replacing structures and campsites affected by the operations footprint and providing enhancements, including an improved park entrance. In accordance with Section 4(f) of the U.S. Department of Transportation Act of 1966, MassDOT is proposing to provide a net benefit to Bourne Scenic Park to obtain a Programmatic Section 4(f) Net Benefit Determination.

5.12.2.5 Resiliency and Sustainability Program Goal

Except for the change in the peak 2-year stormwater discharge rate, one criterion in which Option BN-14.4b receives a higher rating than Option BN-13.1, the two Bourne North options would perform similarly in meeting the Program's resiliency and sustainability objectives.

5.12.2.6 Emergency Response Program Goal

Due to the grade separated direct connect ramps provided in Option BN-14.4b, there would be *more opportunity* to improve emergency evacuation capabilities than in Option BN-13.1.

5.12.2.7 Cost Effectiveness Program Goal

Option BN-13.1 would cost over 15 percent less than Option BN-14.4b, thereby receiving higher scores in meeting the Program's cost effectiveness goal. However, the benefits of Option BN-14.4b, including the operational improvement of the direct connect ramps, the separation of local and regional traffic, and the improvement to multimodal accommodations, outweigh its increased cost.

6 Detailed Assessment of Bourne South Crossing Highway Interchange Approach Options

6.1 Introduction

Section 6 presents the results of the detailed assessment of the two Bourne South options, BS-2 and BS-2.2, relative to the identified Program needs and the Program goals and objectives. This assessment compares the options to the 2050 No Build conditions and, where applicable, to each other. The discussion of assessment details focuses only on those criteria that are differentiators between the two options. Appendix 3.1 provides technical data supporting this assessment.

6.2 Assessment of Operations Program Need

6.2.1 Summary of Results

Table 6-1 presents the results of the detailed assessment of the two Bourne South crossing interchange approach options relative to the Program need to address poor vehicular traffic operations. It compares the options according to the benefits each would provide in meeting the Operations Program need.

Table 6-1. Detailed Assessment Results of Bourne South Crossing Interchange Approach Options: Operations Program Need

Operations Evaluation Criteria	BS-2	BS-2.2
Would the option reduce congestion on the mainline highways and ramps?		
• Number of passenger cars per mile per lane for mainline highways, compared to 2050 No Build condition.	Substantial Benefits	Substantial Benefits
• Number of passenger cars per mile per lane for ramps, compared to 2050 No Build condition.	Substantial Benefits	Substantial Benefits
Would the option reduce regional travel times?	Substantial Benefits	Substantial Benefits

Operations Evaluation Criteria	BS-2	BS-2.2
Would the option reduce local travel times?	Substantial Benefits	Substantial Benefits
Would the option improve cross-canal mobility?	Substantial Benefits	Marginal/Some Benefits
Would the option minimize queue spillback onto the highway?	Substantial Benefits	Substantial Benefits
Would the option separate local and regional traffic?	Marginal/Some Benefits	Marginal/Some Benefits

Among five of the six evaluation criteria, both Bourne South options would provide substantial improvements to vehicular traffic operations in comparison to 2050 No Build conditions. There would be minimal differences in performance between the two options. The options differ in only one criterion, as described in Section 6.2.2.

6.2.2 Differences between Interchange Approach Options

6.2.2.1 Would the Option Improve Cross-Canal Mobility?

Option BS-2 would perform more than 20 percent better than Option BS-2.2, with a lower number of vehicle hours traveled and processed volumes, resulting in a *substantial benefits* rating as opposed to Option BS-2.2's *marginal/some benefits* rating.

6.3 Assessment of Geometrics and Safety Program Need

6.3.1 Summary of Results

Table 6-2 presents the results of the detailed assessment of the two Bourne South crossing interchange approach options relative to the Program need to address the substandard design elements of the Cape Cod Canal highway bridges, the immediate mainline approaches, and their adjacent interchanges and intersections. It compares the options according to the benefits each would provide in meeting the Geometrics and Safety Program need.

Table 6-2. Detailed Assessment Results of Bourne South Crossing Interchange Approach Options: Geometrics and Safety Program Need

Geometrics and Safety Evaluation Criteria	BS-2	BS-2.2
Would the option minimize weaving movements?	Marginal/Some Benefits	Marginal/Some Benefits
Would the option minimize wrong way driving risk?	Substantial Benefits	Marginal/Some Benefits
Would the option reduce the speed differential between the exit ramps and the local roadways?	Marginal/Some Benefits	Marginal/Some Benefits
Would the option minimize the complexity of decision points?	Substantial Benefits	Substantial Benefits
Would the option provide adequate spacing between entrance and exit ramps?	Substantial Benefits	Substantial Benefits
Would the option minimize acceleration/deceleration speed variances between ramps and mainline?		

Geometrics and Safety Evaluation Criteria	BS-2	BS-2.2
• Number of acceleration lane speed variances between ramps and mainline greater than 25 MPH.	Marginal/Some Benefits	Marginal/Some Benefits
• Number of deceleration lane speed variances between ramps and mainline greater than 25 MPH.	Marginal/Some Benefits	Marginal/Some Benefits
Would the option meet driver expectation for navigation?	Substantial Benefits	Substantial Benefits

As opposed to the substantial benefit ratings regarding operations, the two Bourne South options showed more pronounced differences in their performances regarding Geometrics and Safety. Except for one criterion, there would be minimal differences in performance between the two Bourne South options as presented in Section 6.3.2.

6.3.2 Differences between Interchange Approach Options

6.3.2.1 Would the Option Minimize Wrong-Way Driving Risk?

The diamond interchange of Option BS-2 would have the design flexibility to geometrically restrict wrong-way ramp access with options to provide roundabouts at the ramp intersections. In contrast, the single point urban interchange of Option BS-2.2 is a less common type of interchange control and the geometry would result in an inherent risk of wrong-way driving with the off-ramps entering at an angle similar to a standard on-ramp. This risk could be reduced with wrong-way driving mitigation signage. However, due to the lack of user comfort with Single Point Urban Interchanges within the region and the potential for wrong-way driving due to the ramp skews, Option BS 2.2 receives a *marginal/some benefits* rating as opposed to Option BS-2's *substantial benefits* rating.

6.4 Assessment of Multi-Modal Accommodations Program Need

6.4.1 Summary of Results

Table 6-3 presents the results of the detailed assessment of the two Bourne South crossing interchange approach options relative to the Program need to address the lack of accessible bicycle and pedestrian accommodations and connections between existing facilities substandard design elements of the bridges and their highway networks. It compares the options according to the benefits each would provide in meeting the Multi-Modal Accommodations Program need.

Table 6-3. Detailed Assessment Results of Bourne South Crossing Interchange Approach Options: Multi-Modal Accommodations Program Need

Multi-Modal Accommodations Evaluation Criteria	BS-2	BS-2.2
Would the option improve pedestrian/bicycle access from the bridge to local roads?	Substantial Benefits	Substantial Benefits
Would the option improve pedestrian/bicycle access adjacent to local roads?	Substantial Benefits	Substantial Benefits
Would the option improve pedestrian/bicycle access to existing trail facilities?	Marginal/Some Benefits	Marginal/Some Benefits
Would the option improve pedestrian/bicycle connections at ramp terminals?	Substantial Benefits	Marginal/Some Benefits

Multi-Modal Accommodations Evaluation Criteria	BS-2	BS-2.2
Would the option enhance the pedestrian/bicycle experience?	Substantial Benefits	Substantial Benefits
Would the option reduce the Shared Use Path grade at the bridge approaches?		
• Maximum grade of Shared Use Path.	Substantial Benefits	Substantial Benefits
• Maximum length of maximum grade of Shared Use Path.	Marginal/Some Benefits	Marginal/Some Benefits
• Number of Shared Use Path segments that equal or exceed 4.5% for a length of 500 feet or more.	Marginal/Some Benefits	Marginal/Some Benefits
Would the option increase pedestrian/bicycle accommodations in the Program Study Areas?	Substantial Benefits	Substantial Benefits
Would the option improve pedestrian/bicycle access to transit facilities?		
• Distance of Shared Use Path from bridge mid-point to first public and/or private transit facility location.	Substantial Benefits	Substantial Benefits
• Number of desired public and/or private transit facility locations within a 0.50-mile radius.	Substantial Benefits	Substantial Benefits

Among the eight evaluation criteria, the Bourne South options generally would provide opportunities to address the multi-modal accommodations and connections need in the Program Study Area, with some exceptions. In all criteria but one, the two options receive the same ratings, as presented in Section 6.4.2.

6.4.2 Differences between Interchange Approach Options

6.4.2.1 Would the Option Improve Pedestrian/Bicycle Connections at Ramp Terminals?

Option BS-2 scores higher in this criterion than Option BS-2.2. Option BS-2 would provide rapid flashing beacons at the pedestrian/bicyclist crossings, including at the frontage road, southbound on-ramp, northbound off-ramp, and Trowbridge Road. These crossings are all single lane crossings. Option BS-2.2 would provide signalized crossings across ramps and Trowbridge Road. This option would require crossings of a variety of lane arrangements across Trowbridge Road, resulting in lack of consistency for drivers and pedestrians/bicyclists. As a result, Option BS-2.2 receives a *marginal/some benefits* rating.

6.5 Assessment of Maintenance/Structural Program Need

6.5.1 Summary of Results

Table 6-4 presents the results of the detailed assessment of the two Bourne South crossing interchange approach options relative to the program need to address the deteriorating structural condition and escalating maintenance demands of the Cape Cod Canal highway bridges. It compares the options according to the benefits each would provide in meeting the Maintenance/Structural Program need.

Table 6-4. Detailed Assessment Results of Bourne South Crossing Interchange Approach Options: Maintenance/Structural Program Need

Maintenance/Structural Evaluation Criteria	BS-2	BS-2.2
Would the option minimize the risk of disruptive maintenance and/or rehabilitation on the existing bridges?	Marginal/Some Benefits	Marginal/Some Benefits
Would the option allow for the most efficient and simplest structural system to accommodate the interchange ramps?	Insufficient/ Negligible Benefits	Insufficient/ Negligible Benefits

The two Bourne South options receive the same ratings in addressing the maintenance and structural needs of the Bourne Bridge. The time needed to move traffic from the Bourne Bridge and discontinue use of the existing bridge would be equivalent between the two Bourne South options. Due to the structural requirements for the network tied arch and the 1,000-foot minimum length required for the highway geometry of the southbound off-ramp and the northbound on-ramp, the structural framing of the steel girders and pier locations would become very complicated for both Bourne South options, resulting in *negligible benefits* ratings.

6.6 Assessment of Socioeconomic Program Goal

6.6.1 Summary of Results

Table 6-5 presents the results of the detailed assessment of the two Bourne South crossing interchange approach options relative to the Program goal to maintain and improve the socioeconomic fabric of the surrounding community. It compares the options according to the impacts each would incur or to the opportunities each would provide in meeting the Socioeconomic Program objectives.

Table 6-5. Detailed Assessment Results of Bourne South Crossing Interchange Approach Options: Socioeconomics Program Goal

Socioeconomics Objectives	BS-2	BS-2-2
Would the option minimize residential property effects, including acquisitions and displacement?		
• Number of easements on vacant parcels.	No Impacts	No Impacts
• Number of easements on occupied parcels.	Less Impacts	Less Impacts
• Number of full parcel acquisitions with displacement.	No Impacts	No Impacts
• Number of full parcel acquisitions without displacement.	No Impacts	No Impacts
Would the option minimize commercial property effects, including acquisitions and displacement?		
• Number of easements on vacant parcels.	Some Impacts	Some Impacts
• Number of easements on occupied parcels.	More Impacts	More Impacts
• Number of full parcel acquisitions with displacement.	Some Impacts	Some Impacts
• Number of full parcel acquisitions without displacement.	Some Impacts	Some Impacts
Would the option improve access to commercial properties?	Some Opportunity	Some Opportunity
Would the option maintain or improve neighborhood accessibility to community facilities & services?		

Socioeconomics Objectives	BS-2	BS-2-2
• Maintains and/or improves accessibility to existing facilities	More Opportunity	More Opportunity
• Improves connections to existing facilities	More Opportunity	More Opportunity
Would the option maintain or improve neighborhood cohesion?	More Opportunity	More Opportunity
Would the option avoid disproportionate adverse effects to Environmental Justice (EJ) populations?	Less Impacts	Less Impacts
Would the option minimize construction period effects upon the traveling public?	Some Impacts	Some Impacts
Would the option avoid and/or minimize effects to parks, open space, and recreational facilities?	Less Impacts	Less Impacts

Among the eight evaluation criteria for socioeconomics, the two Bourne South options receive the same ratings. In both Bourne South options, the South Canal Service Road would be impacted by the construction zone designated for the crane placement for bridge demolition and construction. In both options, temporary closure of the Canal Service Road would affect approximately 0.31 acres. Additionally, in both Bourne South options, the entire footprint of Bourne Recreation Area (approximately 4.11 acres) would be impacted during construction.

6.7 Assessment of Natural Resources Program Goal

6.7.1 Summary of Results

Table 6-6 presents the results of the detailed assessment of the two Bourne South crossing interchange approach options relative to the Program goal to preserve and protect natural resources. It compares the options according to the impacts each would incur or to the opportunities each would provide in meeting the Natural Resources Program objectives.

Table 6-6. Detailed Assessment Results of Bourne South Crossing Interchange Approach Options: Natural Resources Program Goal

Natural Resources Objectives	BS-2	BS-2.2
Would the option minimize effects to Areas of Critical Environmental Concern (ACEC) and wildlife habitats?		
• Area of impact to ACEC	No Impacts	No Impacts
• Area of impact to wildlife habitat	Some Impacts	Some Impacts
Would the option maintain floodplain functions?	Less Impacts	Less Impacts
Would the option maintain wetlands and surface waters, including their protected buffers?	Less Impacts	Less Impacts

The two Bourne South options receive the same ratings regarding natural resources protection. There are no ACECs in Bourne South. Both options would impact approximately eight acres of NHESP Priority and Estimated Habitat in Bourne South. Both options would result in less than an 8 percent loss

of vegetated floodplain compared to the existing floodplain area in Bourne South. Both options would result in work within wetland buffer zones.

6.8 Assessment of Resiliency and Sustainability Program Goal

6.8.1 Summary of Results

Table 6-7 presents the results of the detailed assessment of the two Bourne South crossing interchange approach options relative to the Program goal to enhance the resiliency and sustainability of the built environment. It compares the options according to the impacts each would incur or to the opportunities each would provide in meeting Resiliency and Sustainability Program objectives.

Table 6-7. Detailed Assessment Results of Bourne South Crossing Interchange Approach Options: Resiliency and Sustainability Program Goal

Resiliency and Sustainability Objectives	BS-2	BS-2.2
Would the option minimize air quality effects?		
• Total VMT, compared to 2050 No Build	Less Impacts	Less Impacts
• Total VHT, compared to 2050 No Build	Less Impacts	Less Impacts
Would the option minimize land alteration and reduction in tree cover (urban heat island effect)?	Some Impacts	Some Impacts
Would the option minimize vulnerability to flooding?		
• .	Less Impacts	Less Impacts
• **Area of roadways impacted by fluctuations in relative sea level**	Less Impacts	Less Impacts
Would the option effectively manage stormwater?		
• Increase in impervious area, compared to 2050 No Build condition.	More Impacts	More Impacts
• Percentage of treated impervious area, compared to minimum goal of 65%.	More Opportunity	More Opportunity
• Change in 2-year peak discharge rate, compared to minimum goal of 0%.	More Opportunity	More Opportunity
• Change in 10-year peak discharge rate, compared to minimum goal of 0%.	More Opportunity	More Opportunity
• Change in 100-year peak discharge rate, compared to minimum goal of 0%.	More Opportunity	More Opportunity
• Proposed infiltration volume recharge rate, compared to minimum goal of 100%.	More Opportunity	More Opportunity
• Percentage of total phosphorus removal, compared to minimum goal of 50%.	More Opportunity	More Opportunity
• Percentage of total suspended solids removal, compared to minimum goal of 80%.	Some Opportunity	Some Opportunity

Among the four evaluation criteria and multiple performance measures for the resiliency and sustainability Program goal, the Bourne South options receive the same ratings.

6.9 Assessment of Constructability Program Goal

6.9.1 Summary of Results

Table 6-8 presents the results of the detailed assessment of the two Bourne South crossing interchange approach options relative to the Program goal to maximize constructability. It compares the options according to the opportunities each would provide in meeting Constructability Program objectives.

Table 6-8. Detailed Assessment Results of Bourne South Crossing Interchange Approach Options: Constructability Program Goal

Constructability Objectives	BS-2	BS-2.2
Would the option minimize the construction duration?	Some Opportunity	Some Opportunity
Would the option maintain existing connections during construction?	More Opportunity	More Opportunity

The Bourne South options receive the same ratings regarding Program constructability. The anticipated construction duration would be equivalent between the two options. In both options, existing connections would be maintained during construction.

6.10 Assessment of Emergency Response Program Goal

6.10.1 Summary of Results

Table 6-9 presents the results of the detailed assessment of the two Bourne South crossing interchange approach options relative to the Program goal to facilitate emergency response. It compares the options according to the opportunities each would provide in meeting Emergency Response objectives.

Table 6-9. Detailed Assessment Results of Bourne South Crossing Interchange Approach Options: Emergency Response Program Goal

Emergency Response Objectives	BS-2	BS-2.2
Would the option improve emergency evacuation capabilities off Cape Cod?	More Opportunity	More Opportunity
Would the option improve emergency response?	More Opportunity	More Opportunity

The two Bourne South options receive the same ratings regarding the ability to improve emergency response.

6.11 Assessment of Cost Effectiveness Program Goal

6.11.1 Summary of Results

Table 6-10 presents the results of the detailed assessment of the two Bourne South crossing interchange approach options relative to the Program goal to maximize construction cost effectiveness. It compares the options according to the opportunity each would provide in meeting the Cost Effectiveness Program objective.

Table 6-10. Detailed Assessment Results of Bourne South Crossing Interchange Approach Options: Cost Effectiveness Program Goal

Cost Effectiveness Objective	BS-2	BS-2.2
Would the option maximize construction cost effectiveness?	More Opportunity	More Opportunity

6.11.2 Differences between Interchange Approach Options

In comparing construction cost estimates, Options BS-2 and BS-2.2 have comparable scores: with each costing approximately $130 million, construction costs would be equivalent between the options.[14]

6.12 Recommended Bourne South Crossing Highway Interchange Approach Option

Based on the results of the detailed assessment of Bourne South options, MassDOT recommends that Option BS-2 advance as the Bourne South Option to be Retained for Detailed Study in the DEIR, including advancement to 25 precent design development. Section 6.12 presents a summary overview and details of the detailed assessment.

6.12.1 Summary Comparison of Bourne South Interchange Approach Options

Table 6-11 presents a summary table of the Program Need evaluation criteria and Program goals and objectives that proved to be differentiators between the two options.

Table 6-11. Bourne South Performance Evaluation Criteria Summary Table

Program Need	Performance Evaluation Criteria	BS-2	BS-2.2
Operations	Would the option improve cross-canal mobility?	Substantial Benefits	Marginal/Some Benefits
Geometrics and Safety	Would the option minimize wrong way driving risk?	Substantial Benefits	Marginal/Some Benefits
Multi-Modal Accommodations	Would the option improve pedestrian/ bicycle connections at ramp terminals?	Substantial Benefits	Marginal/Some Benefits

6.12.2 Summary of Differences between Interchange Approach Options

6.12.2.1 Operations Program Need

While both Bourne South options would improve cross canal mobility relative to the 2050 No Build condition, Option BS-2 would provide *substantial benefits* in addressing the operations Program. In

[14] The estimated cost of each Bourne South highway interchange option is per YOE and does not include mainline (bridge) work. The cost comparison does not account for future cost changes. It is a comparison of anticipated construction costs with risk, escalation and inflation included. Escalation is applied at a compounded rate of 4 percent per year to the midpoint of the cost phase. It is applied to quantified and factored costs as well as contingencies. The cost includes contingency and assumes a base year of 2023. Quarter 3 2026 is the assumed NTP for the Design-Build contract with an assumed duration of 84 months (seven years).

Option BS-2, there would be an approximate 20 percent reduction in vehicle-hours traveled compared to Option BS-2.2

6.12.2.2 Geometrics and Safety Program Need

Option BS-2 receives a *substantial benefits* rating for minimizing the risk of wrong-way driving. In Option BS-2, the potential for wrong-way driving would be geometrically restricted via the dogbone roundabout. In contrast, Option BS-2.2 receives a *marginal/some benefits* rating, as the design of the single point urban interchange would result in an inherent risk of wrong-way driving.

6.12.2.3 Multi-Modal Accommodations Program Need

Option BS-2 would provide rapid flashing beacons at the four single lane pedestrian/bicycle crossings. Option BS-2.2 would provide signalized crossings across ramps, however, it receives a lower rating than Option BS-2 due to the variety of lane arrangements that pedestrians and bicyclists would have to cross.

7 Detailed Assessment of Sagamore North Crossing Highway Interchange Approach Options

7.1 Introduction

Section 7 presents the results of the detailed assessment of the two Sagamore North options, SN-1A and SN-8A, relative to the identified Program needs and the Program goals and objectives. This assessment compares the options to the 2050 No Build conditions and, where applicable, to each other. The discussion of assessment details focuses only on those criteria that are differentiators between the two options. Appendix 3.2 provides technical data supporting this assessment.

7.2 Detailed Assessment of Operations Program Need

7.2.1 Summary of Results

Table 7-1 presents the results of the detailed assessment of the two Sagamore North crossing interchange approach options relative to the Program need to address poor vehicular traffic operations. It compares the options according to the benefits each would provide in meeting the Operations Program need.

Table 7-1. Detailed Assessment Results of Sagamore North Crossing Interchange Approach Options: Operations Program Need

Operations Evaluation Criteria	SN-1A	SN-8A
Would the option reduce congestion on the mainline highways and ramps?		
• Number of passenger cars per mile per lane for mainline highways, compared to 2050 No Build condition.	Substantial Benefits	Substantial Benefits
• Number of passenger cars per mile per lane for ramps, compared to 2050 No Build condition.	Marginal/Some Benefits	Marginal/Some Benefits
Would the option reduce regional travel times?	Marginal/Some Benefits	Marginal/Some Benefits

Operations Evaluation Criteria	SN-1A	SN-8A
Would the option reduce local travel times?	Marginal/Some Benefits	Marginal/Some Benefits
Would the option improve cross-canal mobility?	Marginal/Some Benefits	Marginal/Some Benefits
Would the option minimize queue spillback onto the highway?	Substantial Benefits	Substantial Benefits
Would the option separate local and regional traffic?	Insufficient/ Negligible Benefits	Marginal/Some Benefits

The two Sagamore North options would provide substantial improvements in reducing congestion compared to the Future No Build condition. Among the remaining five evaluation criteria, Options SN-1A and SN-8A receive similar ratings, with only one rating showing substantial differences, as presented in Section 7.2.2.

7.2.2 Differences between Interchange Approach Options

7.2.2.1 Would the Option Separate Regional and Local Traffic?

Option SN-1A receives an *insufficient/negligible benefits* rating in this criterion; this option would maintain existing traffic patterns. Because it would remove the Sagamore Bridge westbound traffic destined for State Road from the Meetinghouse Lane/Canal Street intersection, Option SN-8A receives a *marginal/some benefits* rating.

7.3 Detailed Assessment of Geometrics and Safety Program Need

7.3.1 Summary of Results

Table 7-2 presents the results of the detailed assessment of the two Sagamore North crossing interchange approach options relative to the Program need to address the substandard design elements of the Cape Cod Canal highway bridges, the immediate mainline approaches, and their adjacent interchanges and intersections. It compares the options according to the benefits each would provide in meeting the Geometrics and Safety Program need.

Table 7-2. Detailed Assessment Results of Sagamore North Crossing Interchange Approach Options: Geometrics and Safety Program Need

Geometrics and Safety Evaluation Criteria	SN-1A	SN-8A
Would the option minimize weaving movements?	Marginal/Some Benefits	Substantial Benefits
Would the option minimize wrong way driving risk?	Substantial Benefits	Marginal/Some Benefits
Would the option reduce the speed differential between the exit ramps and the local roadways?	Marginal/Some Benefits	Marginal/Some Benefits
Would the option minimize the complexity of decision points?	Marginal/Some Benefits	Marginal/Some Benefits

Geometrics and Safety Evaluation Criteria	SN-1A	SN-8A
Would the option provide adequate spacing between entrance and exit ramps?	Substantial Benefits	Substantial Benefits
Would the option minimize acceleration/deceleration speed variances between ramps and mainline?		
• Number of acceleration lane speed variances between ramps and mainline greater than 25 MPH.	Substantial Benefits	Substantial Benefits
• Number of deceleration lane speed variances between ramps and mainline greater than 25 MPH.	Marginal/Some Benefits	Substantial Benefits
Would the option meet driver expectation for navigation?	Marginal/Some Benefits	Marginal/Some Benefits

Among the seven evaluation criteria, Options SN-1A and SN-8A receive generally similar ratings, with only two differing ratings, as presented in Section 7.3.2.

7.3.2 Differences between Interchange Approach Options

7.3.2.1 Would the Option Minimize Weaving Movements?

In both Sagamore North options, the distance from the Route 6 eastbound entrance gore to the mid-span of the bridge would be similar; however, in Option SN-8A, the distance from the mid-span of the bridge to the Route 6 westbound exit gore would be approximately 40 percent longer than in Option SN-1A. Option SN-8A would direct all westbound off-ramp traffic to one exit, whereas Option SN-1A would have two successive westbound off-ramps. By reducing the number of exits, Option SN-8A scores higher than Option SN-1A, providing *substantial benefits* in the safety category for minimizing merge and weave conflicts that result in mainline delay and for improving decision sight distance.

7.3.2.2 Would the Option Minimize Wrong-Way Driving Risk?

Option SN-1A scores higher than Option SN-8A in minimizing the risk of wrong-way driving. The ramp configuration in Option SN-1A mimics a diamond style interchange and would geometrically restrict wrong-way ramp access. In contrast, Option SN-8A would introduce a new Route 6 westbound off-ramp to State Road with a configuration similar to a partial cloverleaf interchange ramp. Studies have shown that the partial cloverleaf interchange style can have a high potential for wrong way driving compared to other interchange types, primarily due to drivers erroneously turning left into the off-ramp rather than into the on-ramp. MassDOT would mitigate this risk in Option SN-8A by adding an island along State Road and providing an entrance ramp with a wider entrance (ramp throat) than the exit ramp. Additionally, the westbound off ramp to State Road northbound approach would be angled to the north to discourage wrong way driving.

7.3.2.3 Would the Option Minimize Deceleration Speed Variances between Ramps and Mainline?

Option SN-8A receives a *substantial benefits* rating for deceleration lane speed variances between ramps and the mainline, with two locations along the mainline with a greater than 25 MPH speed difference. Option SN-1A receives a *marginal/some benefits* rating, with three locations along the mainline with a greater than 25 MPH speed difference. In both options, the geometry of the Route 3 southbound off-

ramp and the Route 6 westbound off-ramp to Meetinghouse Lane could support higher speeds at the exit ramps. In Option SN-1A, the Route 6 westbound loop ramp would turn immediately off the long straight auxiliary lane with little indication of when drivers need to slow down. In contrast, in Option SN-8A, the exit ramp from the auxiliary lane would be well in advance of when drivers would need to slow down.

7.4 Detailed Assessment of Multi-Modal Accommodations Program Need

7.4.1 Summary of Results

Table 7-3 presents the results of the detailed assessment of the two Sagamore North crossing interchange approach options relative to the program need to address the lack of accessible bicycle and pedestrian accommodations and connections between existing facilities substandard design elements of the bridges and their highway networks. It compares the options according to the benefits each would provide in meeting the Multi-Modal Accommodations Program need.

Table 7-3. Detailed Assessment Results of Sagamore North Crossing Interchange Approach Options: Multi-Modal Accommodations Program Need

Multi-Modal Accommodations Evaluation Criteria	SN-1A	SN-8A
Would the option improve pedestrian/bicycle access from the bridge to local roads?	Substantial Benefits	Substantial Benefits
Would the option improve pedestrian/bicycle access adjacent to local roads?	Substantial Benefits	Substantial Benefits
Would the option improve pedestrian/bicycle access to existing trail facilities?	Substantial Benefits	Substantial Benefits
Would the option improve pedestrian/bicycle connections at ramp terminals?	Marginal/Some Benefits	Substantial Benefits
Would the option enhance the pedestrian/bicycle experience?	Marginal/Some Benefits	Substantial Benefits
Would the option reduce the Shared Use Path grade at the bridge approaches?		
• Maximum grade of Shared Use Path.	Substantial Benefits	Substantial Benefits
• Maximum length of maximum grade of Shared Use Path.	Marginal/Some Benefits	Marginal/Some Benefits
• Number of Shared Use Path segments that equal or exceed 4.5% for a length of 500 feet or more.	Marginal/Some Benefits	Marginal/Some Benefits
Would the option increase pedestrian/bicycle accommodations in the Program Study Areas?	Substantial Benefits	Substantial Benefits
Would the option improve pedestrian/bicycle access to transit facilities?		
• Distance of Shared Use Path at bridge mid-point to first public and/or private transit facility location.	Marginal/Some Benefits	Marginal/Some Benefits
• Number of desired public and/or private transit facility locations within a 0.50-mile radius.	Substantial Benefits	Substantial Benefits

Among the eight evaluation criteria, the two Sagamore North options receive the same ratings for six criteria and differing ratings for two criteria, as presented in Section 7.4.2. Both Sagamore North options would include a SUP on the Route 6 eastbound main span that provides connections to the south side of Scenic Highway, Canal Street, and the Canal Service Road. Both Options SN-1A and SN-8A would provide SUPs along the southern side of Scenic Highway and Meetinghouse Lane and along the eastern side of State Road to Homestead Avenue.

7.4.2 Differences between Interchange Approach Options

7.4.2.1 Would the Option Improve Pedestrian/Bicycle Connections at Ramp Terminals?

Option SN-8A receives a higher rating than Option SN-1A in improving pedestrian/bicycle connections at ramp facilities. Option SN-8A would have one SUP crossing at the Scenic Highway eastbound on-ramp, in comparison to Option SN-1A's two SUP crossings at the Scenic Highway eastbound on-ramp and west-bound off ramp.

7.4.2.2 Would the Option Enhance the Pedestrian/Bicycle Experience?

Option SN-8A receives a higher rating than Option SN-1A in enhancing the pedestrian/bicycle experience. While the maximum pedestrian intersection crosswalk distance would be equal in both options, the Scenic Highway west to east movement in Option SN-8A would require four intersection/ramp crossings for pedestrians and bicyclists, as opposed to five intersection/ramp crossings for pedestrians and bicyclists in Option SN-1A.

7.5 Detailed Assessment of Socioeconomic Program Goal

7.5.1 Summary of Results

Table 7-5 presents the results of the detailed assessment of the two Sagamore North crossing interchange approach options relative to the Program goal to maintain and improve the socioeconomic fabric of the surrounding community. It compares the options according to the impacts each would incur or to the opportunities each would provide in meeting the Socioeconomic Program objectives.

Table 7-5. Detailed Assessment Results of Sagamore North Crossing Interchange Approach Options: Socioeconomics Program Goal

Socioeconomics Objectives	SN-1A	SN-8A
Would the option minimize residential property effects, including acquisitions and displacement?		
• Number of easements on vacant parcels.	Less Impacts	Less Impacts
• Number of easements on occupied parcels.	Less Impacts	Less Impacts
• Number of full parcel acquisitions with displacement.	Less Impacts	Less Impacts
• Number of full parcel acquisitions without displacement.	Less Impacts	Less Impacts
Would the option minimize commercial property effects, including acquisitions and displacement?		
• Number of easements on vacant parcels.	No Impacts	No Impacts
• Number of easements on occupied parcels.	Some Impacts	Some Impacts

Socioeconomics Objectives	SN-1A	SN-8A
• Number of full parcel acquisitions with displacement.	Less Impacts	Less Impacts
• Number of full parcel acquisitions without displacement.	Less Impacts	Less Impacts
Would the option improve access to commercial properties?	More Opportunity	More Opportunity
Would the option maintain or improve neighborhood accessibility to community facilities & services?		
• Maintains and/or improves accessibility to existing facilities	More Opportunity	More Opportunity
• Improves connections to existing facilities	More Opportunity	More Opportunity
Would the option maintain or improve neighborhood cohesion?	Some Opportunity	Some Opportunity
Would the option avoid disproportionate adverse effects to Environmental Justice (EJ) populations?	Less Impacts	Less Impacts
Would the option minimize construction period effects upon the traveling public?	Some Impacts	Less Impacts
Would the option avoid and/or minimize effects to parks, open space, and recreational facilities?	Less Impacts	Less Impacts

Among the eight evaluation criteria for socioeconomics, the two Sagamore North options receive the same ratings with one exception, as presented in Section 7.6.2. In both Sagamore North options, the North Canal Service Road would be impacted by the construction zone designated for the crane placement for bridge demolition and construction. In both options, temporary closure of the Canal Service Road would affect approximately 0.32 acres. Additionally, in both options, a portion of the Sagamore Recreation Area (approximately 0.10 to 0.15 acre) would be impacted during construction and operation of the replacement Sagamore Bridge.

7.5.2 Differences between Interchange Approach Options

7.5.2.1 Would the Option Minimize Construction Period Effects upon the Traveling Public?

Option SN-8A receives a higher rating than Option SN-1A in this criterion. In both options, the existing pedestrian and bicycle connections would be maintained, with detours or temporary connections as needed, throughout construction. Additionally, in Option SN-8A, all existing vehicular traffic movements would be maintained throughout construction without the need for detours. As a result, Option SN-8A receives a rating of *less impacts*. Option SN-1A, however, would require a long duration and complicated detour during construction, resulting in a rating of *some impacts*.

7.6 Detailed Assessment of Maintenance/Structural Program Need

7.6.1 Summary of Results

Table 7-4 presents the results of the detailed assessment of the two Sagamore North crossing interchange approach options relative to the program need to address the deteriorating structural condition and

escalating maintenance demands of the Cape Cod Canal highway bridges. It compares the options according to the benefits each would provide in meeting the Maintenance/Structural Program need.

Table 7-4. Detailed Assessment Results of Sagamore North Crossing Interchange Approach Options: Maintenance/Structural Program Need

Maintenance/Structural Evaluation Criteria	SN-1A	SN-8A
Would the option minimize the risk of disruptive maintenance and/or rehabilitation on the existing bridges?	Insufficient/ Negligible Benefits	Substantial Benefits
Would the option allow for the most efficient and simplest structural system to accommodate the interchange ramps?	Marginal/Some Benefits	Marginal/Some Benefits

The Sagamore North options receive substantially different ratings regarding minimizing the risk of disruptive maintenance and/or rehabilitation on the existing Sagamore Bridge, as presented in Section 7.5.2.

7.6.2 Differences between Interchange Approach Options

7.6.2.1 Would the Option Minimize the Risk of Disruptive Maintenance on the Existing Bridge?

The two Sagamore North options differ substantially in how they would address the maintenance/structural needs of the existing Sagamore Bridge. In Option SN-8A, traffic could be shifted off the structurally deficient Sagamore Bridge in an optimal time frame: Option SN-8A would allow for construction of the Route 6 eastbound main span and approaches to accommodate both the Route 6 eastbound and westbound traffic without ramp closings. In contrast, Option SN-1A would prolong the use of the existing Sagamore Bridge. A constructability assessment determined that Option SN-1A would require construction of both the Route 6 eastbound and westbound main spans over the canal, including the approaches, before traffic could be relocated from the Sagamore Bridge to the new main spans. In addition, this option would require long duration ramp closings on the new Route 6 westbound off-ramp to make the connections with the Sagamore South options. Because Option SN-8A would be able to minimize the risk of an extensive and disruptive maintenance program on the existing bridge, it receives substantially higher ratings regarding the maintenance/structural Program Need than Option SN-1A, which receives an *insufficient/negligible benefits* rating.

7.7 Detailed Assessment of Natural Resources Program Goal

7.7.1 Summary of Results

Table 7-6 presents the results of the detailed assessment of the two Sagamore North crossing interchange approach options relative to the Program goal to preserve and protect natural resources. It compares the options according to the impacts each would incur or to the opportunities each would provide in meeting the Natural Resources Program objectives.

Table 7-6. Detailed Assessment Results of Sagamore North Crossing Interchange Approach Options: Natural Resources Program Goal

Natural Resources Objectives	SN-1A	SN-8A
Would the option minimize effects to Areas of Critical Environmental Concern (ACEC) and wildlife habitats?		
• **Area of impact to ACEC**	Some Impacts	Some Impacts
• **Area of impact to wildlife habitat**	No Impacts	No Impacts
Would the option maintain floodplain functions?	Less Impacts	Less Impacts
Would the option maintain wetlands and surface waters, including protected buffers?	Less Impacts	Less Impacts

Among the three evaluation criteria for natural resource protection, the Sagamore North options receive the same ratings. Both options would be within previously disturbed portions of the Herring River Watershed ACEC within the SHLO. There are no identified NHESP habitats in Sagamore North. Both options would result in less than one-half percent loss of vegetated floodplain compared to the existing floodplain area in Sagamore North. Both options would result in work within wetland buffer zones.

7.8 Detailed Assessment of Resiliency and Sustainability Program Goal

7.8.1 Summary of Results

Table 7-7 presents the results of the detailed assessment of the two Sagamore North crossing interchange approach options relative to the Program goal to enhance the resiliency and sustainability of the built environment. It compares the options according to the impacts each would incur or to the opportunities each would provide in meeting Resiliency and Sustainability Program objectives.

Table 7-7. Detailed Assessment Results of Sagamore North Crossing Interchange Approach Options: Resiliency and Sustainability Program Goal

Resiliency and Sustainability Objectives	SN-1A	SN-8A
Would the option minimize air quality effects?		
• Total VMT, compared to 2050 No Build	Some Impacts	Some Impacts
• Total VHT, compared to 2050 No Build	Less Impacts	Less Impacts
Would the option minimize land alteration and reduction in tree cover (urban heat island effect)?	More Impacts	More Impacts
Would the option minimize vulnerability to flooding?		
• Area of roadways impacted by storm surge	Less Impacts	Less Impacts
• Area of roadways impacted by fluctuations in relative sea level	Less Impacts	Less Impacts
Would the option effectively manage stormwater?		
• Increase in impervious area, compared to 2050 No Build condition.	More Impacts	More Impacts
• Percentage of treated impervious area, compared to minimum goal of 65%.	More Opportunity	More Opportunity

Resiliency and Sustainability Objectives	SN-1A	SN-8A
• Change in 2-year peak discharge rate, compared to minimum goal of 0%.	More Opportunity	More Opportunity
• Change in 10-year peak discharge rate, compared to minimum goal of 0%.	Some Opportunity	Some Opportunity
• Change in 100-year peak discharge rate, compared to minimum goal of 0%.	Some Opportunity	Some Opportunity
• Proposed infiltration volume recharge rate, compared to minimum goal of 100%.	Some Opportunity	Some Opportunity
• Percentage of total phosphorus removal, compared to minimum goal of 50%.	More Opportunity	More Opportunity
• Percentage of total suspended solids removal, compared to minimum goal of 80%.	Some Opportunity	Some Opportunity

Among the four evaluation criteria and multiple performance measures for resiliency and sustainability, the Sagamore North options receive the same ratings.

7.9 Detailed Assessment of Constructability Program Goal

7.9.1 Summary of Results

Table 7-8 presents the results of the detailed assessment of the two Sagamore North crossing interchange approach options relative to the Program goal to maximize constructability. It compares the options according to the opportunities each would provide in meeting Constructability Program objectives.

Table 7-8. Detailed Assessment Results of Sagamore North Crossing Interchange Approach Options: Constructability Program Goal

Constructability Objectives	SN-1A	SN-8A
Would the option minimize the construction duration?	More Opportunity	Some Opportunity
Would the option maintain existing connections during construction?	Some Opportunity	More Opportunity

The two Sagamore North options would have differing results regarding Program constructability, as presented in Section 7.9.2.

7.9.2 Differences between Interchange Approach Options

7.9.2.1 Would the Option Minimize Construction Duration?

This constructability objective is measured by the opening of the second main span to traffic, defined as construction completion.

The required construction sequence in Option SN-1A, constructing both replacement main spans before shifting traffic to the replacement bridge, would result in a time savings of approximately 12 to 18 months, in comparison to Option SN-81A. However, Option SN-1A's higher rating for constructability is counteracted by the second constructability objective to maintain connections during Program

construction (Section 7.9.2.2) and the structural/maintenance Program Need related to minimizing the risk of disruptive maintenance and/or rehabilitation on the existing bridge (Section 7.5.2.2).

7.9.2.2 Would the Option Maintain Existing Connections during Construction?

Options SN-8A scores favorably in maintaining connections during construction, as no detours would be required in this option. In Option SN-1A, an extensive detour of long duration would be required. As a result, Option SN-1A scores a lower rating.

7.10 Detailed Assessment of Emergency Response Program Goal

7.10.1 Summary of Results

Table 7-9 presents the results of the detailed assessment of the two Sagamore North crossing interchange approach options relative to the Program goal to facilitate emergency response. It compares the options according to the opportunities each would provide in meeting Emergency Response objectives.

Table 7-9. Detailed Assessment Results of Sagamore North Crossing Interchange Approach Options: Emergency Response Program Goal

Emergency Response Objectives	SN-1A	SN-8A
Would the option improve emergency evacuation capabilities off Cape Cod?	Some Opportunity	Some Opportunity
Would the option improve emergency response?	Some Opportunity	Some Opportunity

The Sagamore North options receive the same ratings for these evaluation criteria for emergency response.

7.11 Detailed Assessment of Cost Effectiveness Program Goal

7.11.1 Summary of Results

Table 7-10 presents the results of the detailed assessment of the two Sagamore North crossing interchange approach options relative to the Program goal to maximize construction cost effectiveness. It compares the options according to the opportunity each would provide in meeting the Cost Effectiveness Program objective.

Table 7-10. Detailed Assessment Results of Sagamore North Crossing Interchange Approach Options: Cost Effectiveness Program Goal

Cost Effectiveness Objective	SN-1A	SN-8A
Would the option maximize construction cost effectiveness?	More Opportunity	More Opportunity

7.11.2 Differences between Interchange Approach Options: Ability to Maximize Construction Cost-Effectiveness

Option SN-1A is anticipated to cost approximately $205 million and Option SN-8A is estimated to cost $219 million, approximately $14 million (six percent) more than Option SN-1A.[15] Due to the cost differential of less than ten percent between the two options, Options SN-1A and SN-8A receive the same rating.

7.12 Recommended Sagamore North Crossing Highway Interchange Approach Option

Based on the results of the detailed assessment of Sagamore North options, MassDOT recommends that Option SN-8A advance as the Sagamore North Option to be Retained for Detailed Study in the DEIR, including advancement to 25 precent design development. Section 8.12 presents a summary overview and details of the detailed assessment.

7.12.1 Summary Comparison of Sagamore North Interchange Approach Options

Table 7-11 presents a summary table of the Program Need evaluation criteria and Program goals and objectives that proved to be differentiators between the two options.

Table 7-11. Sagamore North Performance Evaluation Criteria Summary Table

Program Need/Goal	Evaluation Criteria/Objectives	SN-1A	SN-8A
Program Need	***Evaluation Criteria***		
Operations	Would the option separate local and regional traffic?	Insufficient/ Negligible Benefits	Marginal/ Some Benefits
Geometrics and Safety	Would the option minimize weaving movements?	Marginal/ Some Benefits	Substantial Benefits
	Would the option minimize wrong way driving risk?	Substantial Benefits	Marginal/ Some Benefits
	Would the option minimize deceleration lane speed variances between ramps and mainline greater than 25 MPH?	Marginal/ Some Benefits	Substantial Benefits
Multi-Modal Accommodations	Would the option improve pedestrian/bicycle connections at ramp terminals?	Marginal/ Some Benefits	Substantial Benefits

[15] Estimated costs for the highway interchange approach do not include the mainline (bridge) costs. The estimated cost of each Sagamore North highway interchange approach option is per YOE and does not include mainline (bridge) work. The cost comparison does not account for future cost changes. It is a comparison of anticipated construction costs with risk, escalation and inflation included. Escalation is applied at a compounded rate of 4 percent per year to the midpoint of the cost phase. It is applied to quantified and factored costs as well as contingencies. The cost includes contingency and assumes a base year of 2023. Quarter 3 2026 is the assumed NTP for the Design-Build contract with an assumed duration of 84 months (seven years).

Program Need/Goal	Evaluation Criteria/Objectives	SN-1A	SN-8A
	Would the option enhance the pedestrian/bicycle experience?	Marginal/ Some Benefits	Substantial Benefits
Maintenance/ Structural	Would the option minimize the risk of disruptive maintenance and/or rehabilitation on the existing bridges?	Insufficient/ Negligible Benefits	Substantial Benefits
Program Goal	***Objectives***		
Socioeconomics	Would the option minimize construction period effects upon the traveling public?	Some Impacts	Less Impacts
Constructability	Would the option minimize the construction duration?	More Opportunity	Some Opportunity
	Would the option maintain existing connections during construction?	Some Opportunity	More Opportunity

7.12.2 Summary of Differences between Interchange Approach Options

As shown in Table 7-11, the detailed assessment of Sagamore North options provided different results for seven measures addressing the Program Needs and/or goals.

7.12.2.1 Operations Program Need

Because it would maintain existing traffic patterns, Option SN-1A receives an *insufficient/negligible* benefit rating in operations. Option SN-8A would provide some separation between local and regional traffic by removing the Sagamore Bridge westbound traffic destined for State Road from the Meetinghouse/ Canal intersection, resulting in a higher rating than Option SN-1A.

7.12.2.2 Geometrics and Safety Program Need

The three geometrics and safety differentiators between Options SN-1A and SN-8A, consisting of weaving movements, wrong-way driving risk, and acceleration and deceleration speed variance between the ramps and mainline, weigh in favor of Option SN-8A. Compared to Option SN-1A, Option SN-8A would offer more opportunities to minimize weaving conflicts by providing a longer weaving distance from the mid-span of the bridge to the Route 6 west bound exit gore. To mitigate for Option SN-8A's lower rating on minimizing wrong-way driving risks, MassDOT would incorporate mitigation measures into the design of the new Route 6 westbound off-ramp to State Road, such as adding an island along State Road, providing an entrance ramp with a wider throat than the exit ramp, and angling the off-ramp to the north to discourage wrong way vehicles. Option SN-8A receives a higher rating for minimizing acceleration and deceleration speed variances between ramps and mainline, with two locations along the mainline versus three locations in Option SN-1A.

7.12.2.3 Multi-Modal Accommodations Program Need

Because it would require fewer pedestrian and bicyclist intersection/ramp crossings, Option SN-8A receives a higher rating than Option SN-1A in meeting the Program Need for multi-modal accommodations.

7.12.2.4 Maintenance/Structural Program Need

The two Sagamore North options differed substantially in how they would address the maintenance/structural needs of the existing Sagamore Bridge. Option SN-8A receives a substantially higher ratings regarding the maintenance/structural Program Need, as it would facilitate the discontinuance of the structurally deficient bridge.

7.12.2.5 Socioeconomics Program Goal

Relative to meeting the Program goals, MassDOT determined that Option SN-8A scored higher in minimizing construction period effects upon the traveling public, despite an anticipated longer overall construction period than Option SN-1A (Section 7.12.2.6). In Option SN-8A, all vehicular traffic and pedestrian/bicycle connections would be maintained throughout construction. Further, no detours would be required in Option SN-8A during bridge construction, as opposed to Option SN-1A which would require an extensive detour during bridge construction.

7.12.2.6 Constructability Program Goal

The two performance measures for evaluating the Program goal of constructability offset each other. While Option SN-1A received a higher rating than Option SN-8A for a shorter overall construction duration, due to the completion of both replacement main spans and reduced number of traffic shifts between the existing and replacement bridges, Option SN-8A received a higher rating than Option SN-1A because it would not require extensive detours during construction.

8 Detailed Assessment of Sagamore South Crossing Highway Interchange Approach Options

8.1 Introduction

Section 8 presents the results of the detailed assessment of the three Sagamore South options, Options SS-1, SS-1.1, and SS-3.1A, relative to the identified Program needs and the Program goals and objectives. This assessment compares the options to the 2050 No Build conditions and, where applicable, to each other. The discussion of assessment details focuses only on those criteria that are differentiators among the three options. Appendix 3.2 provides technical data supporting this assessment.

8.2 Detailed Assessment of Operations Program Need

8.2.1 Summary of Results

Table 8-1 presents the results of the detailed assessment of the three Sagamore South crossing interchange approach options relative to the Program need to address poor vehicular traffic operations. It compares the options according to the benefits each would provide in meeting the Operations Program need.

Table 8-1. Detailed Assessment Results of Sagamore South Crossing Interchange Approach Options: Operations Program Need

Operations Evaluation Criteria	SS-1	SS-1.1	SS-3.1A
Would the option reduce congestion on the mainline highways and ramps?			
• Number of passenger cars per mile per lane for mainline highways, compared to 2050 No Build condition.	Substantial Benefits	Substantial Benefits	Substantial Benefits
• Number of passenger cars per mile per lane for ramps, compared to 2050 No Build condition.	Substantial Benefits	Substantial Benefits	Substantial Benefits
Would the option reduce regional travel times?	Marginal/ Some Benefits	Marginal/ Some Benefits	Marginal/ Some Benefits
Would the option reduce local travel times?	Substantial Benefits	Marginal/ Some Benefits	Substantial Benefits
Would the option improve cross-canal mobility?	Substantial Benefits	Marginal/ Some Benefits	Substantial Benefits
Would the option minimize queue spillback onto the highway?	Substantial Benefits	Substantial Benefits	Substantial Benefits
Would the option separate local and regional traffic?	Marginal/ Some Benefits	Insufficient/ Negligible Benefits	Substantial Benefits

The three Sagamore South options would provide substantial improvements in reducing congestion compared to the Future No Build condition. In three of the evaluation criteria, the Sagamore South options would produce mixed results in improving vehicular traffic operations, as presented in Section 8.2.2.

8.2.2 Differences among Interchange Approach Options

8.2.2.1 Would the Option Reduce Local Travel Times?

Options SS-1 and SS-3.1A receive favorable ratings in their ability to reduce local travel times, with Options SS-3.1A performing better than Option SS-1. Due to its noticeably higher number of vehicle hours traveled on local roads compared to the other two SS options, Option SS-1.1 receives a *marginal/some benefits* rating.

8.2.2.2 Would the Option Improve Cross Canal Mobility?

Among the three Sagamore South options, both Options SS-1 and SS-3.1A would provide substantial opportunities to improve cross-canal mobility, as well as compared to the 2050 No Build condition. Option SS-3.1A would perform slightly better than Option SS-3.1A regarding reduced vehicle hours traveled via local roads to the mid-point of the Sagamore Bridge. Due to the anticipated higher number of vehicle hours traveled relative to the other Sagamore South options, Option SS-1.1 receives a lower rating.

8.2.2.3 Would the Option Separate Regional and Local Traffic?

Option SS-3.1A receives a *substantial benefits* rating for separating regional and local traffic. By including a connection from Cranberry Highway to Sandwich Road, Option SS-3.1A would remove all Route 6 westbound to Sandwich Road westbound traffic from the Cranberry Road Extension and would

preserve use of the Extension for local traffic going to the Market Basket Plaza. Option SS-1 would provide some opportunities for separating local and regional traffic by removing Route 6 westbound traffic from Adams Street/Ben Abbey Road, but it would not include the Cranberry Road Extension. Option SS-1.1 would maintain the existing traffic patterns, resulting in an *insufficient/negligible benefits* rating.

8.3 Detailed Assessment of Geometrics and Safety Program Need

8.3.1 Summary of Results

Table 8-2 presents the results of the detailed assessment of the three Sagamore South crossing interchange approach options relative to the Program need to address the substandard design elements of the Cape Cod Canal highway bridges, the immediate mainline approaches, and their adjacent interchanges and intersections. It compares the options according to the benefits each would provide in meeting the Geometrics and Safety Program need.

Table 8-2. Detailed Assessment Results of Sagamore South Crossing Interchange Approach Options: Geometrics and Safety Program Need

Geometrics and Safety Evaluation Criteria	SS-1	SS-1.1	SS-3.1A
Would the option minimize weaving movements?	Marginal/ Some Benefits	Marginal/ Some Benefits	Substantial Benefits
Would the option minimize wrong way driving risk?	Marginal/ Some Benefits	Marginal/ Some Benefits	Marginal/ Some Benefits
Would the option reduce the speed differential between the exit ramps and the local roadways?	Marginal/ Some Benefits	Marginal/ Some Benefits	Marginal/ Some Benefits
Would the option minimize the complexity of decision points?	Marginal/ Some Benefits	Marginal/ Some Benefits	Marginal/ Some Benefits
Would the option provide adequate spacing between entrance and exit ramps?	Substantial Benefits	Substantial Benefits	Substantial Benefits
Would the option minimize acceleration/deceleration speed variances between ramps and mainline?			
• Number of acceleration lane speed variances between ramps and mainline greater than 25 MPH.	Substantial Benefits	Substantial Benefits	Substantial Benefits
• Number of deceleration lane speed variances between ramps and mainline greater than 25 MPH.	Substantial Benefits	Substantial Benefits	Substantial Benefits
Would the option meet driver expectation for navigation?	Marginal/ Some Benefits	Marginal/ Some Benefits	Marginal/ Some Benefits

Among the six evaluation criteria for geometrics and safety, the three Sagamore South options receive the same ratings except for one criterion, as presented in Section 8.3.2.

8.3.2 Differences among Interchange Approach Options

8.3.2.1 Would the Option Minimize Weaving Movements?

While each of the three Sagamore South options would have two weaving movements, Option SS-3.1A receives a higher rating than the other two options due to design improvements associated with the westbound on-ramp. In Option SS-1, the geometry of the westbound on-ramp would improve the merge/weave distance on the main span compared to the other two options; additionally, it would eliminate the two-lane merge from the Cranberry Highway Extension to the approach of the westbound on-ramp required in Options SS-1 and SS-1.1.

8.4 Detailed Assessment of Multi-Modal Accommodations Program Need

8.4.1 Summary of Results

Table 8-3 presents the results of the detailed assessment of the three Sagamore South crossing interchange approach options relative to the program need to address the lack of accessible bicycle and pedestrian accommodations and connections between existing facilities substandard design elements of the bridges and their highway networks. It compares the options according to the benefits each would provide in meeting the Multi-Modal Accommodations Program need.

Table 8-3. Detailed Assessment Results of Sagamore South Crossing Interchange Approach Options: Multi-Modal Accommodations Program Need

Multi-Modal Accommodations Evaluation Criteria	SS-1	SS-1.1	SS-3.1A
Would the option improve pedestrian/bicycle access from the bridge to local roads?	Substantial Benefits	Substantial Benefits	Substantial Benefits
Would the option improve pedestrian/bicycle access adjacent to local roads?	Substantial Benefits	Substantial Benefits	Substantial Benefits
Would the option improve pedestrian/bicycle access to existing trail facilities?	Marginal/Some Benefits	Marginal/Some Benefits	Marginal/Some Benefits
Would the option improve pedestrian/bicycle connections at ramp terminals?	Marginal/Some Benefits	Substantial Benefits	Substantial Benefits
Would the option enhance the pedestrian/bicycle experience?	Marginal/Some Benefits	Marginal/Some Benefits	Substantial Benefits
Would the option reduce the Shared Use Path grade at the bridge approaches?			
• Maximum grade of Shared Use Path.	Substantial Benefits	Substantial Benefits	Substantial Benefits
• Maximum length of maximum grade of Shared Use Path.	Marginal/Some Benefits	Marginal/Some Benefits	Marginal/Some Benefits
• Number of Shared Use Path segments that equal or exceed 4.5% for a length of 500 feet or more.	Marginal/ Some Benefits	Marginal/ Some Benefits	Marginal/ Some Benefits
Would the option increase pedestrian/bicycle accommodations in the Program Study Areas?	Substantial Benefits	Substantial Benefits	Substantial Benefits

Multi-Modal Accommodations Evaluation Criteria	SS-1	SS-1.1	SS-3.1A
Would the option improve pedestrian/bicycle access to transit facilities?			
• Distance of Shared Use Path at bridge mid-point to first public and/or private transit facility location.	Marginal/Some Benefits	Marginal/Some Benefits	Marginal/Some Benefits
• Number of desired public and/or private transit facility locations within a 0.50-mile radius.	Substantial Benefits	Substantial Benefits	Substantial Benefits

Among the eight evaluation criteria addressing multi-modal accommodations, Options SS-1, SS-1.1, and SS-3.1A receive the same ratings except for two criteria, as presented in Section 8.4.2.

8.4.2 Differences among Interchange Approach Options

8.4.2.1 Would the Option Improve Pedestrian/Bicycle Connections at Ramp Terminals?

Options SS-1.1 and SS-3.1A each would require one sidewalk crossing at the Route 6 westbound on/off ramp, as opposed to two sidewalk crossings required in Option SS-1. As a result, Option SS-1 receives a lower rating than Options SS-1.1 and 3.1A.

8.4.2.2 Would the Option Enhance the Pedestrian/Bicycle Experience?

Option SS-3.1A would provide *substantial benefits* regarding an enhanced pedestrian/bicycle experience. Both Options SS-3-1.A and SS-1 would provide SUP connectivity along Cranberry Highway east and west of Route 6; however Option SS-3.1A would require one less intersection/ramp crossings on the Cranberry Highway east to west movement than Option SS-1, resulting in a higher rating. Additionally, with the Sandwich Road extension, Option SS-3.1A would provide more connections/accessibility to the neighborhoods east of the replacement bridge. Further, by revising the geometry of the northbound on-ramp, Option SS-3.1A would open the infield area underneath the mainlines to potentially connect neighborhoods that are bisected by the mainlines. While it would require the least number of intersection/ramp crossings of the three options, Option SS-1.1 would not provide connectivity along Cranberry Highway east and west of Route 6, resulting in a *marginal/some benefits* rating.

8.5 Detailed Assessment of Maintenance/Structural Program Need

8.5.1 Summary of Results

Table 8-4 presents the results of the detailed assessment of the three Sagamore South crossing interchange approach options relative to the program need to address the deteriorating structural condition and escalating maintenance demands of the Cape Cod Canal highway bridges. It compares the options according to the benefits each would provide in meeting the Maintenance/Structural Program need.

Table 8-4. Detailed Assessment Results of Sagamore South Crossing Interchange Approach Options: Maintenance/Structural Program Need

Maintenance/Structural Evaluation Criteria	SS-1	SS-1.1	SS-3.1A
Would the option minimize the risk of disruptive maintenance and/or rehabilitation on the existing bridges?	Insufficient/ Negligible Benefits	Insufficient/ Negligible Benefits	Substantial Benefits
Would the option allow for the most efficient and simplest structural system to accommodate the interchange ramps?	Insufficient/ Negligible Benefits	Insufficient/ Negligible Benefits	Substantial Benefits

The ratings for the three Sagamore South options differ substantially regarding the maintenance and structural evaluation criteria, as presented in Section 8.5.2.

8.5.2 Differences among Interchange Approach Options

8.5.2.1 Would the Option Minimize the Risk of Disruptive Maintenance on the Existing Bridge?

Options SS-1 and SS-1.1 would perform relatively the same in this evaluation criterion. Based on the constructability assessment, Options SS-1 and SS-1.1 would require extensive preparation work, consisting of long term and potentially complicated detours to maintain connections during construction. As a result, these options would prolong use of the Sagamore Bridge, taking 12 to 18 months longer to remove traffic from the existing bridge than would Option SS-3.1A. Consequently, Options SS-1 and SS-1.1 receive an *insufficient/negligible benefits* rating. Option SS-3.1A would not require such preparation work and could accelerate the removal of traffic and discontinued use of the Sagamore Bridge; therefore, it receives a *substantial benefits* rating.

8.5.2.2 Would the Option Allow for the Most Efficient and Simplest Structural System to Accommodate the Interchange Ramps?

Option SS-3.1A scores a *substantial benefits* rating for the compatibility of the ramp framing and tie-ins with the structural system of the bridge mainline. In contrast, Options SS-1 and SS-1.1 receive an *insufficient/negligible benefits* rating: the design configuration of ramps would introduce curvature into the Delta girder framing system and undesirable complexity to the bridge framing system, adversely affecting constructability and performance.

8.6 Detailed Assessment of Socioeconomic Program Goal

8.6.1 Summary of Results

Table 8-5 presents the results of the detailed assessment of the three Sagamore South crossing interchange approach options relative to the Program goal to maintain and improve the socioeconomic fabric of the surrounding community. It compares the options according to the impacts each would incur or to the opportunities each would provide in meeting the Socioeconomic Program objectives.

Table 8-5. Detailed Assessment Results of Sagamore South Crossing Interchange Approach Options: Socioeconomics Program Goal

Socioeconomics Objectives	SS-1	SS-1.1	SS-3.1A
Would the option minimize residential property effects, including acquisitions and displacement?			
• Number of easements on vacant parcels.	Least Impacts	Least Impacts	Least Impacts
• Number of easements on occupied parcels.	Most Impacts	Most Impacts	Most Impacts
• Number of full parcel acquisitions with displacement.	Most Impacts	Most Impacts	Most Impacts
• Number of full parcel acquisitions without displacement.	Some Impacts	Some Impacts	Some Impacts
Would the option minimize commercial property effects, including acquisitions and displacement?			
• Number of easements on vacant parcels.	No Impacts	No Impacts	No Impacts
• Number of easements on occupied parcels.	Some Impacts	Least Impacts	Some Impacts
• Number of full parcel acquisitions with displacement.	Some Impacts	Some Impacts	Some Impacts
• Number of full parcel acquisitions without displacement.	Some Impacts	Some Impacts	Some Impacts
Would the option improve access to commercial properties?	Some Opportunity	Least Opportunity	Some Opportunity
Would the option maintain or improve neighborhood accessibility to community facilities & services?			
• Maintains and/or improves accessibility to existing facilities	Most Opportunity	Least Opportunity	Most Opportunity
• Improves connections to existing facilities	Most Opportunity	Most Opportunity	Most Opportunity
Would the option maintain or improve neighborhood cohesion?	Some Opportunity	Least Opportunity	Most Opportunity
Would the option avoid disproportionate adverse effects to Environmental Justice (EJ) populations?	Least Impacts	Least Impacts	Least Impacts
Would the option minimize construction period effects upon the traveling public?	Some Impacts	Some Impacts	Least Impacts
Would the option avoid and/or minimize effects to parks, open space, and recreational facilities?	Least Impacts	Least Impacts	Least Impacts

Among the eight evaluation criteria, the ratings of three Sagamore South options do not substantially differ, except for some key criteria related to property effects, as presented in Section 8.6.2.

8.6.2 Differences among Interchange Approach Options

8.6.2.1 Would the Option Minimize Commercial Property Effects, Regarding Number of Easements on Occupied Parcels?

Options SS-1 and SS-3.1A would require six and five easements, respectively, on commercial occupied parcels, resulting in a marginal rating for both options. In contrast, Option SS-1.1 would require two

easements on commercial occupied parcels, resulting in a higher rating than the other two Sagamore South options.

8.6.2.2 Would the Option Improve Access to Commercial Properties?

None of the options would improve the existing substandard turn movements into and out of the Adams Street area and accessibility to the former Christmas Tree Shop area. Option SS-1.1, which would offer no change in access to Market Basket or the provision of the Cranberry Highway Extension, receives a *least opportunity* rating. Options SS-1 and SS-3.1A would provide *some opportunity* in commercial property accessibility: both would improve Market Basket accessibility by changing the western driveway to a right in/right out only; and both would include the Cranberry Highway Extension, which would provide more direct east-west access between neighborhoods and Market Basket.

8.6.2.3 Would the Option Maintain or Improve Neighborhood Accessibility to Community Facilities and Services?

In all three Sagamore South options, the additions of the sidewalk and SUP along the roadway network would improve access to public facilities and private community facilities; however, to make the grades more accessible, the distance to facilities would increase for bicyclists and pedestrians coming from the bridge. Options SS-1 and SS-3.1A would substantially improve neighborhood accessibility to facilities due to the Cranberry Highway Extension: Option SS-1 and SS-3.1A would provide east-west connectivity along Cranberry Highway, as well as more direct access between the neighborhoods on the east side of Route 6 and Market Basket on the west side of Route 6. Option SS-1.1 would not include the Cranberry Highway Extension, and therefore receives a *least opportunity* rating.

8.6.2.4 Would the Option Maintain or Improve Neighborhood Cohesion?

All three options would provide bicycle and pedestrian accommodations for all roadways. Because they would reduce the volume of regional traffic on local roads, such as Adams Street and Ben Abbey Road, Options SS-1 and SS-3.1A receive a higher rating than Option SS-1.1, which would not change the regional traffic pattern. Option SS-1.1 would mimic existing conditions by maintaining the use of Adams Street/Ben Abbey Road for the high-volume regional movements. As a result, Option SS-1.1 receives a *least opportunity* rating. In addition to reducing the volume of regional traffic on Adams Street and Ben Abbey Road, Option SS-3.1A also would include the Sandwich Road extension, which would allow drivers to directly access Sandwich Road and avoid the Cranberry Highway Extension and the Market Basket Plaza driveways on Factory Outlet Road. As a result, Option SS-3.1A receives a *most opportunity* rating in improving neighborhood cohesion.

8.6.2.5 Would the Option Minimize Construction Period Effects upon the Traveling Public?

In all three options, all existing pedestrian and bicycle connections would be maintained or improved, as the Program adds pedestrian and bicycle accommodations with flatter grades than the existing limited number of steeply graded sidewalks. It is anticipated that portions of the Canal Service Roads may be closed or would require a detour. All three options would maintain vehicular traffic connections throughout construction. Because Options SS-1 and SS-1.1 would require detours for the bridge

construction, these options receive a rating of *some impacts*. Option SS-3.1A would not require detours during bridge construction, resulting in a *least impacts* rating.

8.7 Detailed Assessment of Natural Resources Program Goal

8.7.1 Summary of Results

Table 8-6 presents the results of the detailed assessment of the three Sagamore South crossing interchange approach options relative to the Program goal to preserve and protect natural resources. It compares the options according to the impacts each would incur or to the opportunities each would provide in meeting the Natural Resources Program objectives.

Table 8-6. Detailed Assessment Results of Sagamore South Crossing Interchange Approach Options: Natural Resources Program Goal

Natural Resources Objectives	SS-1	SS-1.1	SS-3.1A
Would the option minimize effects to Areas of Critical Environmental Concern (ACEC) and wildlife habitats?			
• **Area of impact to ACEC**	No Impacts	No Impacts	No Impacts
• **Area of impact to wildlife habitat**	Some Impacts	Some Impacts	Some Impacts
Would the option maintain floodplain functions?	Less Impacts	Less Impacts	Less Impacts
Would the option maintain wetlands and surface waters, including protected buffers?	Less Impacts	Less Impacts	Less Impacts

Among the three evaluation criteria for natural resource protection, the three Sagamore South options receive the same ratings. There is no ACEC in Sagamore South. The three options would impact approximately 2.6 acres of NHESP habitat in Sagamore South. The three options would result in approximately 2 percent loss of vegetated floodplain compared to the existing floodplain area in Sagamore South. Additionally, North. The three options would result in work within wetland buffer zones.

8.8 Detailed Assessment of Resiliency and Sustainability Program Goal

8.8.1 Summary of Results

Table 8-7 presents the results of the detailed assessment of the three Sagamore South crossing interchange approach options relative to the Program goal to enhance the resiliency and sustainability of the built environment. It compares the options according to the impacts each would incur or to the opportunities each would provide in meeting Resiliency and Sustainability Program objectives.

Table 8-7. Detailed Assessment Results of Sagamore South Crossing Interchange Approach Options: Resiliency and Sustainability Program Goal

Resiliency and Sustainability Objectives	SS-1	SS-1.1	SS-3.1A
Would the option minimize air quality effects?			
• Total VMT, compared to 2050 No Build	Some Impacts	Some Impacts	Some Impacts
• Total VHT, compared to 2050 No Build	Least Impacts	Least Impacts	Least Impacts
Would the option minimize land alteration and reduction in tree cover (urban heat island effect)?	Most Impacts	Most Impacts	Most Impacts
Would the option minimize vulnerability to flooding?			
• Area of roadways impacted by storm surge	Least Impacts	Least Impacts	Least Impacts
• Area of roadways impacted by fluctuations in relative sea level	Least Impacts	Least Impacts	Least Impacts
Would the option effectively manage stormwater?			
• Increase in impervious area, compared to 2050 No Build condition.	Some Impacts	Least Impacts	Some Impacts
• Percentage of treated impervious area, compared to minimum goal of 65%.	Some Opportunity	Some Opportunity	Some Opportunity
• Change in 2-year peak discharge rate, compared to minimum goal of 0%.	Most Opportunity	Most Opportunity	Most Opportunity
• Change in 10-year peak discharge rate, compared to minimum goal of 0%.	Most Opportunity	Most Opportunity	Most Opportunity
• Change in 100-year peak discharge rate, compared to minimum goal of 0%.	Most Opportunity	Most Opportunity	Most Opportunity
• Proposed infiltration volume recharge rate, compared to minimum goal of 100%.	Some Opportunity	Some Opportunity	Some Opportunity
• Percentage of total phosphorus removal, compared to minimum goal of 50%.	Most Opportunity	Most Opportunity	Most Opportunity
• Percentage of total suspended solids removal, compared to minimum goal of 80%.	Some Opportunity	Some Opportunity	Some Opportunity

The three Sagamore South options would perform similarly relative to resiliency and sustainability, with one difference in a stormwater management performance measure, as presented in Section 8.8.2.

8.8.2 Differences among Interchange Approach Options

8.8.2.1 Would the Option Effectively Manage Stormwater, Regarding an Increase in Impervious Area from Existing Conditions?

Options SS-1, SS-1.1, and SS-3.1A were assessed under multiple criteria regarding their ability to effectively manage stormwater, and except for one measure, the options would perform comparably in providing opportunities to meet the Program objective of effectively managing stormwater. Option SS-

1.1 receives a *least impact* rating regarding the increase in impervious area compared to the 2050 No Build condition, projected at 19 percent. Both Options SS-1 and SS-3.1A would increase the impervious area by 30 percent, resulting in *some impacts* ratings.

8.9 Detailed Assessment of Constructability Program Goal

8.9.1 Summary of Results

Table 8-8 presents the results of the detailed assessment of the three Sagamore South crossing interchange approach options relative to the Program goal to maximize constructability. It compares the options according to the opportunities each would provide in meeting Constructability Program objectives.

Table 8-8. Detailed Assessment Results of Sagamore South Crossing Interchange Approach Options: Constructability Program Goal

Constructability Objectives	SS-1	SS-1.1	SS-3.1A
Would the option minimize the construction duration?	Most Opportunity	Most Opportunity	Some Opportunity
Would the option maintain existing connections during construction?	Some Opportunity	Some Opportunity	Most Opportunity

Options SS-1 and SS-1.1 would have differing results from Option SS-3.1A regarding Program constructability, as presented in Section 8.9.2.

8.9.2 Differences among Interchange Approach Options

8.9.2.1 Would the Option Minimize the Construction Duration?

Compared to Option SS-3.1A, Options SS-1 and SS-1.1 receive *most opportunity* ratings regarding the ability to minimize the construction duration, measured by the opening of the second replacement span. The anticipated final Program completion would be equivalent between Options SS-1 and SS-1.1 and up to 12 months sooner than that of Option SS-3.1A. As described in Section 8.5.2.1, the advance construction work required in Options SS-1 and SS-1.1 would result in fewer overall traffic shifts, which in turn would reduce the overall construction duration. However, as described in Section 8.5.2.1 and 8.9.2.2, the tradeoff in achieving an overall shorter construction completion milestone would be the risk of prolonged use of the deteriorating bridge and the need to construct extensive detours to maintain connections during construction.

In contrast to Options SS-1 and SS-1.1, Option SS-3.1A would take approximately 12 months longer for the overall construction duration; however, this option would not require a detour during construction and could accelerate the traffic shift from the existing to the replacement mainline.

8.9.2.2 Would the Option Maintain Existing Connections during Construction?

In this criterion, Option SS-3.1A receives a *most opportunity* rating in ability to meet this objective; the existing travel connections could be maintained with no detours needed during construction of the

bridge. In contrast, Options SS-1 and SS-1.1 receive *some opportunity* ratings. In both Options SS-1 and SS-1.1, construction of the bridge would require detours to maintain existing conditions.

8.10 Detailed Assessment of Emergency Response Program Goal

8.10.1 Summary of Results

Table 8-9 presents the results of the detailed assessment of the three Sagamore South crossing interchange approach options relative to the Program goal to facilitate emergency response. It compares the options according to the opportunities each would provide in meeting Emergency Response objectives.

Table 8-9. Detailed Assessment Results of Sagamore South Crossing Interchange Approach Options: Emergency Response Program Goal

Emergency Response Objectives	SS-1	SS-1.1	SS-3.1A
Would the option improve emergency evacuation capabilities off Cape Cod?	Most Opportunity	Some Opportunity	Most Opportunity
Would the option improve emergency response?	Most Opportunity	Some Opportunity	Most Opportunity

The three Sagamore South options are rated differently regarding the ability to improve emergency response, as presented in Section 8.10.2.

8.10.2 Differences among Interchange Approach Options

8.10.2.1 Ability to Improve Emergency Evacuation Capabilities

In Options SS-1 and SS-3.1A, access to the Sagamore Bridge northbound from Sandwich Road west would be improved with the Cranberry Highway Extension; as a result, both options receive *most opportunity* ratings in meeting this Program objective. In Option SS-1.1, there would be minimal improvement in emergency evacuation capabilities due to upgrading the mainline and ramps to current standards; as a result, Option SS-1.1 receives a *some opportunity* rating.

8.10.2.2 Ability to Improve Emergency Response

Options SS-1 and SS-3.1A receive *most opportunity* ratings for improving emergency response capabilities, due to the improved access to and from Sandwich Road west and the Mid-Cape Connector provided by Cranberry Highway Extension. Because it would maintain the existing configuration, Option SS-1.1 receives a *some opportunity* rating.

8.11 Detailed Assessment of Cost Effectiveness Program Goal

8.11.1 Summary of Results

Table 8-10 presents the results of the detailed assessment of the three Sagamore South crossing interchange approach options relative to the Program goal to maximize construction cost effectiveness. It compares the options according to the opportunity each would provide in meeting the Cost Effectiveness Program objective.

Table 8-10. Detailed Assessment Results of Sagamore South Crossing Interchange Approach Options: Cost Effectiveness Program Goal

Cost Effectiveness Objective	SS-1	SS-1.1	SS-3.1A
Would the option maximize construction cost effectiveness?	Most Opportunity	Most Opportunity	Most Opportunity

8.11.2 Differences among Interchange Approach Options

The construction cost of Options SS-1 and SS-1.1 is approximately $177 million. The construction cost of Option SS-3.1A is approximately $193 million.[16] Although it would cost approximately $16 million (eight percent) more than the other two options, because the cost differential is less than ten percent, the three options receive the same rating.

8.12 Recommended Sagamore South Highway Interchange Approach Option

Based on the results of the detailed assessment of Sagamore South options, MassDOT recommends that Option SS-3.1A advance as the Sagamore South Option to be Retained for Detailed Study in the DEIR, including advancement to 25 precent design development. Section 8.12 presents a summary overview and details of the detailed assessment.

8.12.1 Summary Comparison of Sagamore South Interchange Approach Options

Table 8-11 presents a summary table of the Program Need evaluation criteria and Program goals and objectives that proved to be differentiators among the three options.

Table 8-11. Sagamore South Performance Evaluation Criteria Summary Table

Program Need/Goal	Performance Evaluation Criteria	SS-1	SS-1.1	SS-3.1A
Program Needs				
Operations	Would the option reduce local travel times?	Substantial Benefits	Marginal/ Some Benefits	Substantial Benefits
	Would the option improve cross-canal mobility?	Substantial Benefits	Marginal/ Some Benefits	Substantial Benefits
	Would the option separate local and regional traffic?	Marginal/ Some Benefits	Insufficient/ Negligible Benefits	Substantial Benefits

[16] The estimated cost of each Sagamore South highway interchange approach option is per YOE and does not include mainline (bridge) work. The cost comparison does not account for future cost changes. It is a comparison of anticipated construction costs with risk, escalation and inflation included. Escalation is applied at a compounded rate of 4 percent per year to the midpoint of the cost phase. It is applied to quantified and factored costs as well as contingencies. The cost includes contingency and assumes a base year of 2023. Quarter 3 2026 is the assumed NTP for the Design-Build contract with an assumed duration of 84 months (seven years).

Program Need/Goal	Performance Evaluation Criteria	SS-1	SS-1.1	SS-3.1A
Geometrics and Safety	Would the option minimize weaving movements?	Marginal/ Some Benefits	Marginal/ Some Benefits	Substantial Benefits
Multi-Modal Accommodations	Would the option improve pedestrian/bicycle connections at ramp terminals?	Marginal/ Some Benefits	Substantial Benefits	Substantial Benefits
	Would the option enhance the pedestrian/bicycle experience?	Marginal/ Some Benefits	Marginal/ Some Benefits	Substantial Benefits
Maintenance/ Structural	Would the option minimize the risk of disruptive maintenance and/or rehabilitation on the existing bridges?	Insufficient/ Negligible Benefits	Insufficient/ Negligible Benefits	Substantial Benefits
	Would the option allow for the most efficient and simplest structural system to accommodate the interchange ramps?	Insufficient/ Negligible Benefits	Insufficient/ Negligible Benefits	Substantial Benefits
Program Goals				
Socioeconomics	Would the option minimize commercial property effects, regarding the number of easements on occupied parcels?	Some Impacts	Least Impacts	Some Impacts
	Would the option improve access to commercial properties?	Some Opportunity	Least Opportunity	Some Opportunity
	Would the option maintain or improve neighborhood accessibility to community facilities & services?	Most Opportunity	Some Opportunity	Most Opportunity
	Would the option maintain or improve neighborhood cohesion?	Some Opportunity	Least Opportunity	Most Opportunity
	Would the option minimize construction	Some Impacts	Some Impacts	Least Impacts

Program Need/Goal	Performance Evaluation Criteria	SS-1	SS-1.1	SS-3.1A
	period effects upon the traveling public?			
Resiliency and Sustainability	Would the option effectively manage stormwater, regarding an increase in impervious area from existing conditions?	Some Opportunity	Most Opportunity	Some Opportunity
Constructability	Would the option minimize the construction duration?	Most Opportunity	Most Opportunity	Some Opportunity
	Would the option maintain existing connections during construction?	Some Opportunity	Some Opportunity	Most Opportunity
Emergency Response	Would the option improve emergency evacuation capabilities from Cape Cod and the islands to mainland Massachusetts?	Most Opportunity	Some Opportunity	Most Opportunity
	Would the option improve emergency response?	Most Opportunity	Some Opportunity	Most Opportunity

8.12.2 Summary of Differences among Interchange Approach Options

8.12.2.1 Operations Program Need

The three Sagamore South options would provide substantial improvements in reducing congestion on the mainline and ramps compared to the Future No Build condition. The three options would provide marginal improvements relative to reducing regional travel times. Options SS-1 and SS-3.1A provide substantial improvement in reducing local travel times and improving cross canal mobility with the Cranberry Highway Extension compared to Option SS-1.1. All three options perform differently when assessed for separation of local and regional traffic. In Option SS-1.1, a considerable amount of traffic destined to and from Route 6 westbound would travel on Adams Street and Ben Abbey Road, like the No Build condition. In Option SS-1, this traffic would be removed from these local roads with the Cranberry Highway Extension, mixing with local traffic near Market Basket for a *marginal/some benefits* rating. Option SS-3.1A would further separate local and regional traffic with the Sandwich Road extension, shifting some regional traffic from the Cranberry Highway Extension for a substantial improvement over the No Build condition.

8.12.2.2 Geometrics and Safety Program Need

Except for the evaluation criteria relative to weaving movements, the three Sagamore South options performed comparably in addressing the geometrics and safety Program need. Compared to Options SS-1 and SS-1.1, Option SS-3.1A would provide *substantial benefits* in reducing weaving conflicts and avoiding main span delay. In Option SS-3.1A, relocation of the Route 6 westbound on-ramp would considerably increase the length of the weaving section onto the bridge for traffic leaving Cape Cod.

8.12.2.3 Multi-Modal Accommodations Program Need

Except for two evaluation criteria, the three Sagamore South options performed comparably in addressing the multi-modal accommodations Program need. Regarding improving pedestrian and bicycle connections at ramp terminals, Option SS-1 receives a lower rating than Options SS-1.1 and 3.1A due to its additional sidewalk crossing at the Route 6 westbound on/off ramp. Option SS-3-1A would provide substantial benefits in enhancing the pedestrian/bicycle experience, compared to the marginal ratings of Options SS-1 and SS-1.1, due to the SUP connectivity along Cranberry Highway east and west of Route 6 and the additional connections and accessibility provided by the Sandwich Road connector.

8.12.2.4 Maintenance and Structural Program Need

The three Sagamore South options differed substantially in how they would address the maintenance/structural needs of the existing Sagamore Bridge. Option SS-3.1A receives substantially higher ratings regarding the maintenance/structural Program Need. Option SS-3.1A allows for the construction of the Route 6 EB bridge and approaches to accommodate both the Route 6 EB and WB traffic without ramp closings.

Options SS-1 and SS-1.1 would require long duration ramp closings on the SS-1 and SS-1.1 WB on-ramp. The only other option for SS-1 and SS-1.1 to eliminate ramp closures would be to construct both the Route 6 EB and WB bridges over the Canal (including the approaches) entirely before traffic could relocate from the existing bridge to the new bridges. Placing all traffic from the existing Sagamore Bridge to the proposed WB Bridge will result in a time savings of approximately 12 to 18 months with SS-3.1A than Options SS-1 and SS-1.1. Option SS-3.1A would be able to minimize the risk of an extensive and disruptive maintenance program on the existing bridge. As a result, Option SS-3.1A received a *substantial benefits* rating compared to Options SS-1 and SS-1.1 *insufficient/negligible benefits* ratings.

In comparison, construction of Options SS-1 and SS-1.1 would require long term detours during bridge construction; the advance construction work required for these options would prolong use of the deteriorating Sagamore Bridge, increasing the likelihood of an extensive and disruptive maintenance program on the existing bridge. Additionally, Option SS-3.1A received the highest score for use of the most efficient and simplest structural system to accommodate the interchange ramps. The design configuration of Option SS-3.1A is compatible with the replacement bridge framing system, providing substantial benefits with respect to constructability and performance. In comparison, the design

configuration of ramps in Options SS-1 and SS-1.1 would introduce undesirable complexity to the bridge framing system, adversely effecting constructability and performance.

8.12.2.5 Socioeconomics Program Goal

Relative to minimizing impacts to commercial properties, Option SS-1.1 would require three easements on commercial occupied parcels, resulting in a *least impact* rating compared to the other two Sagamore South options, both of which receive a rating of *some impact*.

Regarding the Program objective to improve access to commercial properties, Options SS-1 and SS-3.1A would include the Cranberry Highway Extension and would improve accessibility to and from Market Basket, receiving *some opportunity* ratings; while Option SS-1.1 would not offer commercial access improvements, receiving a *least opportunity* rating. Options SS-1.1 and SS-3.1A would substantially improve neighborhood accessibility to facilities due to the Cranberry Highway Extension: Option SS-1 and SS-3.1A would provide east-west connectivity along Cranberry Highway, as well as more direct access between the neighborhoods on the east side of Route 6 and Market Basket on the west side of Route 6. Option SS-1.1 would not include the Cranberry Highway Extension, and therefore receives a *least opportunity* rating.

Relative to improving neighborhood cohesion, Option SS-3.1A receives the highest rating of the three Sagamore South options; in addition to reducing the volume of regional traffic on Adams Street and Ben Abbey Road, Option SS-3.1A also would include the Sandwich Road extension, which would allow drivers to directly access Sandwich Road and avoid the Cranberry Highway Extension and the Market Basket Plaza driveways on Factory Outlet Road.

While anticipated Program completion would be up to 12 months longer in Option SS-3.1A than in Options SS-1 or SS-1.1, Option SS-3.1A scored highest in minimizing construction period effects upon the traveling public. Option SS-3.1A would maintain all existing vehicular traffic and pedestrian/bicyclist connections and would not require detours during construction.

8.12.2.6 Resiliency and Sustainability Program Goal

Except for one measure related to stormwater management, Options SS-1, SS-1.1, and SS-3.1A received equivalent ratings in meeting the Program's resiliency and sustainability goal. Option SS-1.1 receives a *most opportunity* rating regarding the increase in impervious area compared to the 2050 No Build condition and to the other Sagamore South options; Option SS-1.1 is anticipated to increase the impervious area by 19 percent, compared to an estimated 30 percent in Options SS-1 and SS-3.1A.

8.12.2.7 Constructability Program Goal

Compared to Option SS-3.1A, Options SS-1 and SS-1.1 receive *most opportunity* ratings regarding the ability to minimize construction duration. The anticipated final Program completion in Options SS-1 and SS-1.1 would be up to 12 months sooner than that of Option SS-3.1A. However, Option SS-3.1A receives a *most opportunity* rating by maintaining existing travel connections without detours during

construction. In contrast, both Options SS-1 and SS-1.1 would require detours to maintain existing conditions during bridge construction, resulting in *some opportunity* ratings.

8.12.2.8 Emergency Response Program Goal

In Options SS-1 and SS-3.1A, access to the Sagamore Bridge northbound from Sandwich Road west would be improved with Cranberry Highway Extension; as a result, both options receive *most opportunity* ratings regarding the ability to meet this objective of emergency response and emergency evacuation improvements. In contrast, Option SS-1.1 would maintain the existing configuration, resulting in a rating of *some opportunity*.

9 Summary of Highway Interchange Approach Options Retained for Detailed Study

9.1 Introduction

Section 9 presents the results of the detailed assessment of highway interchange approach options.

9.2 Bourne Crossing Highway Interchange Approach Options Retained for Detailed Study

Based upon the results of the detailed assessments, MassDOT recommended that the following Bourne crossing highway interchange approach pairing advance for further evaluation in the DEIR as the part of the Build Alternative Retained for Detailed Study:

- Bourne North Crossing - Directional Interchange Option, BN-14.4b; and
- Bourne South Crossing - Diamond Interchange Option, BS-2.

Sections 9.2.1 and 9.2.2 provide a summary of the overall comparisons among the Bourne crossing interchange approach options.

9.2.1 Summary of Bourne North Crossing Interchange Approach Options

Both Bourne North options would address the Program Needs in providing *substantial benefits* in operations, geometrics and safety, multi-modal accommodations, and maintenance and structural issues. MassDOT determined that Option BN-14.b would provide more opportunities to meet the Program Needs than would Option BN-13.1, particularly regarding multi-modal accommodations and meeting MassDOT's Healthy Transportation Policy Directive.

Relative to meeting the Program goals, MassDOT determined that the two Bourne North options scored fairly evenly across many of the Program goals and objectives. Of the six differentiating Program objectives, Option BN-14.4b scored higher than Option BN-13.1 in four objectives and scored lower than Option BN-13.1 in two objectives.

In sum, MassDOT determined that the benefits of Option BN-14.4b, including the operational improvements of the direct connect ramps, the separation of local and regional traffic, and the improvement to multimodal accommodations, would outweigh its increased impacts to park and recreational areas and higher cost. Further, MassDOT would compensate USACE and BRA for impacts, including providing an overall net benefit to Bourne Scenic, per a Programmatic Section 4(f) Net Benefit Determination.

9.2.2 Summary of Bourne South Crossing Interchange Approach Options

In addressing the Program Needs, both Bourne South options would substantially improve operations in comparison to the Future No Build condition. Compared to each other, the Bourne South options received almost identical scores, except for three evaluation criteria addressing operations, geometrics and safety, and multi-modal accommodations Program Needs, where Option BS-2 received higher ratings than Option BS-2.2.

Relative to meeting the Program goals, MassDOT determined that the two Bourne South options scored fairly evenly.

9.3 Sagamore Crossing Highway Interchange Approach Options Retained for Detailed Study

Based upon the results of the detailed assessments, MassDOT recommended that the following Sagamore crossing highway interchange approach pairing advance for further evaluation in the DEIR as the part of the Build Alternative Retained for Detailed Study:

- Sagamore North Crossing - Direct Connection to State Road Option, SN-8A; and
- Sagamore South Crossing - Westbound On-Ramp under Route 6 with Sandwich Road Extension Option, SS-3.1A.

Sections 9.3.1 and 9.3.2 provide a summary of the overall comparisons among the Sagamore crossing interchange approach options.

9.3.1 Summary of Sagamore North Crossing Interchange Approach Options

In general, both Sagamore North options would address the Program Needs in substantially improving operations, geometrics and safety, multi-modal accommodations, and maintenance and structural issues relative to the Future No Build condition. Comparing the two Build options, however, MassDOT determined that Option SN-8A would provide more opportunities to meet the Program Needs than would Option SN-1A, particularly regarding the option's ability to remove traffic from the existing bridge and avoid or minimize the potential for a disruptive maintenance/rehabilitation of the existing Sagamore Bridge.

Relative to meeting the Program goals, MassDOT determined that the two Sagamore North options scored fairly evenly; of the four objectives where the two options received different results, the differences canceled each other out. Important to the Program with a relatively long construction period, Option SN-8A scored higher than Option SN-1A in minimizing impacts to the traveling public during construction.

9.3.2 Summary of Sagamore South Crossing Interchange Approach Options

Except for three evaluation criteria, the three Sagamore South options performed comparably in addressing the Program Needs related to geometrics and safety and multi-modal accommodations. The three options varied considerably in addressing the Program Needs related to operations and the maintenance/structural needs of the existing Sagamore Bridge. Of the eight total evaluation criteria differentiators, Option SS-3.1A consistently received the highest rating of *substantial benefits*. As a result, MassDOT determined that Option SS-3.1A would provide the most opportunities to meet the Program Needs, particularly regarding the option's ability to remove traffic from the existing bridge and avoid and/or minimize the potential for a disruptive maintenance and/or rehabilitation of the existing Sagamore Bridge.

Relative to meeting the Program goals, MassDOT determined that the three Sagamore South options scored fairly evenly. Important to the Program with a relatively long construction period, Option SS-3.1A scored highest among the options in maintaining existing connections during Program construction.

10 Appendices

Appendix 1 Glossary of Terms

Appendix 2 Traffic Technical Reports and Memoranda

2.1 Methodology to Estimate 2019 Base Year Volumes (December 18, 2020)

2.2 Future Demographic Conditions (May 14, 2021)

2.3 Existing 2019 Conditions Traffic Analysis (August 30, 2021)

2.4 Summary of Future No Build Modeling Process and Results (December 17, 2021)

2.5 Future 2045 Build Traffic Volumes (September 1, 2023)

2.6 Preliminary Traffic Analysis for Build Analysis Pairings (May 7, 2024)

Appendix 3 CCBP Evaluation Criteria Performance Measures Scoring Matrix

3.1 Bourne Evaluation Criteria Performance Measures Scoring Matrix

3.2 Sagamore Evaluation Criteria Performance Measures Scoring Matrix

Appendix 1 Glossary of Terms

Glossary of Terms

Acceleration- The act of increasing vehicular speed over time.

Access Management – Tool used to maintain safe and efficient roadway operations; exercised by statute, zoning, right-of-way purchases, driveway controls, turning and parking regulations, and geometric design.

Acquisition - Buying or obtaining an asset or object. In this case, a purchase of land by MassDOT.

Air Quality- The measure of pollutants in the air. The U.S. Environmental Protection Agency (EPA) developed a scale known as an Air Quality Index (AQI) that provides real-time information on the amount of pollution in the air.

AQI Basics for Ozone and Particle Pollution

Daily AQI Color	Levels of Concern	Values of Index	Description of Air Quality
Green	Good	0 to 50	Air quality is satisfactory, and air pollution poses little or no risk.
Yellow	Moderate	51 to 100	Air quality is acceptable. However, there may be a risk for some people, particularly those who are unusually sensitive to air pollution.
Orange	Unhealthy for Sensitive Groups	101 to 150	Members of sensitive groups may experience health effects. The general public is less likely to be affected.
Red	Unhealthy	151 to 200	Some members of the general public may experience health effects; members of sensitive groups may experience more serious health effects.
Purple	Very Unhealthy	201 to 300	Health alert: The risk of health effects is increased for everyone.
Maroon	Hazardous	301 and higher	Health warning of emergency conditions: everyone is more likely to be affected.

Areas of Critical Environmental Concern (ACEC) – Refers to places in Massachusetts that receive special recognition because of the quality, uniqueness, and significance of their natural and cultural resources. Such an area is identified and nominated at the community level and is reviewed and designated by the state's Secretary of Energy and Environmental Affairs.

Average Delay per Vehicle – The difference between a motorist's actual travel time and expected travel time to a location, divided by the total number of vehicles studied within said location.

Bridge Approach- The transition area from roadway to bridge structure.



Bridge Midpoint- The exact middle of the bridge span used as a main point of reference to measure distances and times, to and from other points of interest.

Congestion- In transportation, a crowd of vehicles on a roadway allowing little to no movement, causing lack of traffic flow.

Controlled Crossing- An intersection or roadway crossing that has traffic system device(s) in place to queue pedestrian and vehicular mobility.

Cross-Canal – In reference to mobility improvements of all users across the Cape Cod Canal.



Deceleration- The act of decreasing vehicular speed over time.

Deceleration Speed Variances- Traffic speed variance is the difference in speeds between vehicles traveling on the same road. Deceleration speed variances is used for traffic safety and can decrease the risk of accidents. Reducing the differences in speed for decelerating vehicles aids in all cars traveling at similar speeds, resulting in less speed variance and thus fewer accidents.

Decision Points- On interchanges, these are areas where the motorist has two or more options on where to navigate. Theoretically, these areas should be designed with simplicity for the motorist to make their decision with ease. In designing successive ramp terminals, which require decision points from the motorist, the measure of spacing between successive ramp terminals should be a minimum of 800 feet.



Discharge Rate- A measure of flow from a culvert, sewer, channel, or other watercourse.

Displacement - The removal of someone or something by someone or something else which takes their place.

Diversion- An instance of turning something aside from its course.

Driver Expectation – Assessment of a motorist's navigational needs/wants to provide direct access between mainline and local roadways consistent with said needs/wants.

Dogbone Roundabout – A variation of a typical roundabout, the dogbone roundabout, often called a dogbone interchange due to its aerial resemblance to a real or toy dog bone, and sometimes also called a double roundabout interchange, occurs when the roundabouts do not form a complete circle but instead have a "raindrop" or "teardrop" shape.

Easements- The right of MassDOT to use all or part of a property for a specific transportation or utility purpose. Easements can be permanent or temporary (limited to a stated period of time).



Entrance Ramp – One-way roadway that allows traffic to enter a freeway. Entrance ramps consist of acceleration lane(s) that allow traffic to accelerate in order to reach operating speed of the freeway to then be able to merge safely and comfortably.

Environmental Justice (EJ)- Fair treatment and meaningful involvement of all people, regardless of race, ethnicity, income and education level, in environmental decision making, including protection of human health and the environment, empowerment via public participation, and the dissemination of relevant information to inform and educate affected communities.

Evapotranspiration- The sum of evaporation (transformation of water from liquid to gas or vapor) and transpiration (also known as guttation, the process by which moisture moves through plants and is released into the atmosphere as vapor). Collectively the process of the evapotranspiration represents the movements and exchange of water among plants, land, waterbodies, and the atmosphere.

Exit Ramp – One-way roadway to allow traffic to exit the freeway, and they provide access to other crossing highways. Exit ramps consist of deceleration lane(s) that allow traffic exiting a major street or freeway to slow down to a speed safe enough to make a left or right turn at an intersection without affecting the main flow of traffic.

Fatal flaw – Fatal flaw is a term used for screening of design options and used to identify and dismiss options and/or design elements that are unreasonable, nonviable, substandard and should not be developed for further detailed analysis. A fatal flaw analysis is a level of screening of a broad number of improvements or concepts to eliminate unreasonable or nonviable alternatives from further detailed analysis.

Flooding- When the volume of water on land exceeds the capacity of natural and built drainage systems, also known as Inland Flooding.

Flood Plain – Refers to the lowland adjacent to a river, lake, or ocean. Floodplains are designated by the rarity of the flood that is large enough to inundate them.

Free-flowing – Refers to a traffic condition where traffic is able to move without any controls, such as a signalized intersection, stopping the movement.

Future (2050) Build Condition – The expected traffic volumes and movement patterns that should occur with the Proposed Action (Preferred Alternative), consisting of the replacement bridges and interchange improvements.

Future (2050) No Build Condition- The expected traffic volumes and movement patterns that should occur with no change to the existing bridges and interchanges.

Flyover Ramp – A type of "overpass, used for elevated connecting ramps between two sections of a highways.

Grade separate – Used to separate different types of traffic, such as pedestrians, bicyclists, and motor vehicles, or to keep roads, railways, or canals, separate. Grade-separated crossings are often built at busy intersections or across major roads and can take the form of a bridge.

HCS- A traffic analysis software based on the Highway Capacity Manual (HCM) methodology[1] used to analyze multilane highway segments and freeway weaves/merges/diverges;

Impervious Area- Within the project boundary, surfaces that do not absorb water, i.e., asphalt or concrete pavement.

Infiltration- The process of water entering the upper layers of the soil profile.

Infiltration Volume – The rate at which water is absorbed into the soil over a period of time.

Interchange – Provides access between roadways by incorporating a network of ramps.

[1] Levels of service were calculated using HCS 7 software, which is based on the HCM, 6th Edition.

Intersection Footprint – The area or amount of space it takes to construct an intersection.



Interchange Ramp Proximity - Refers to the physical distance separating the successive access ramps on each side of the Program bridges. This metric assesses whether there is sufficient distance available to fully develop independent ramp facilities per design standards. To fully develop independent ramp facilities, each ramp must have sufficient acceleration/deceleration lane distance plus a taper without overlapping into the taper or acceleration/deceleration lane of the adjacent ramp. If sufficient distance is not available and an overlap is identified, the facility meets the criteria to warrant a continuous auxiliary lane.

Life Cycle Costs- The total cost of owning, operating, maintaining, an asset over its lifetime. Typically used as a method of estimating the total cost of ownership, it is used as a datapoint to assist in making decisions regarding the investment of funds for a project.

Local- Belonging or relating to a particular area or neighborhood, typically exclusively so. Refers to users making trips within a town or county. Local travel for the Program is defined as travel within the town of Bourne.

Mainline- The primary travel lanes of the interstate, freeway, or expressway.

Maintenance – The upkeep of property and equipment, i.e., repair or replacement of failed equipment and its restoration to safe, normal operation.

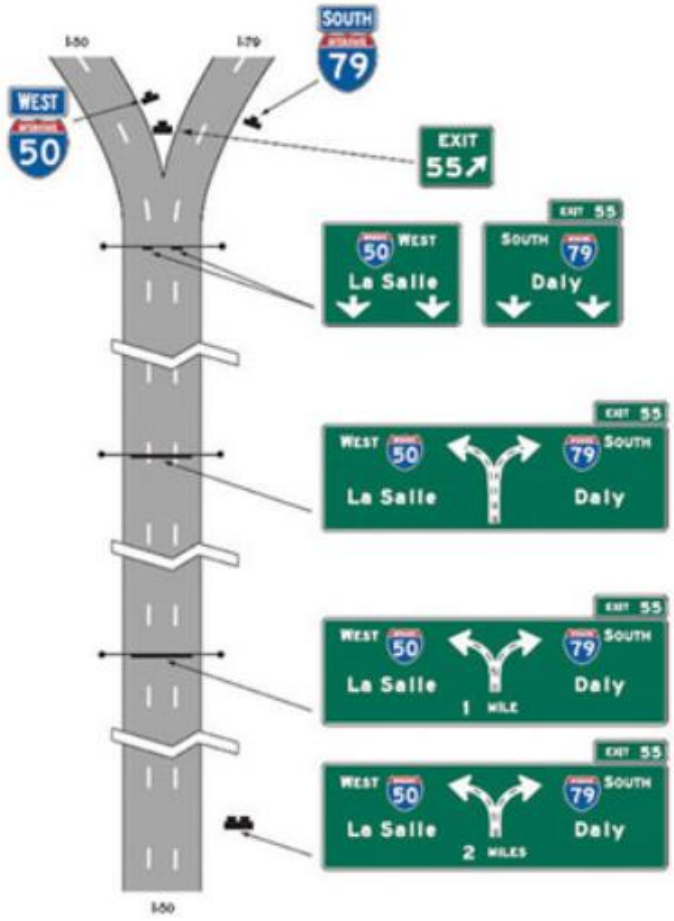
Mobility- Ability to move or be moved from place to place.

Network- A road network is a system of interconnected roads and facilities that are designed to accommodate pedestrians and vehicles. Road networks can serve many purposes, including

social: connecting people to facilitate social interaction; economic: transporting people, goods, and services to create welfare; and mobility: allowing people to move from one area to another.

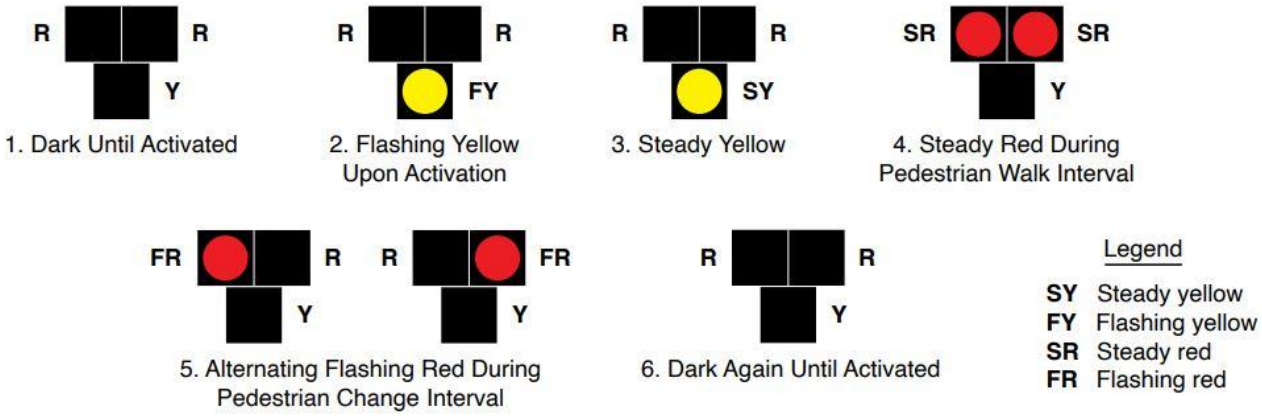
Open Space- Refers to conservation land, forested land, recreation land, agricultural land, corridor parks, and amenities such as small parks, green buffers along roadways, or any open area that is owned by an agency or organization dedicated to conservation.

Option lane – A type of off-ramp containing an interior option lane in which traffic can choose either destination at the split of the ramps.



Parcel- The limits of a property owner's land.

Pedestrian Hybrid Beacon crossing- The pedestrian hybrid beacon (PHB) is a traffic control device designed to help pedestrians safely cross higher-speed roadways at midblock crossings and uncontrolled intersections. The beacon head consists of two red lenses above a single yellow lens. The lenses remain "dark" until a pedestrian desiring to cross the street pushes the call button to activate the beacon, which then initiates a yellow to red lighting sequence consisting of flashing and steady lights that directs motorists to slow and come to a stop, and provides the right-of-way to the pedestrian to safely cross the roadway before going dark again.



Phosphorus Removal- A storm water treatment process to remove phosphorus from roadway runoff and reduce the potential for eutrophication in receiving waters aiming to achieve low effluent concentrations in wastewater.

Queue - A line of vehicles, bicycles, or persons waiting to be served by the system in which the flow rate from the front of the queue determines the average speed within the queue. Slowly moving vehicles or people joining the rear of the queue are usually considered part of the queue. The internal queue dynamics can involve starts and stops. A faster-moving line of vehicles is often referred to as a moving queue or a platoon.

Queue Spillback- Can occur when traffic flow is constrained by storage or capacity limitations. Queue spillback can happen at intersections and on freeways.

Ramp – short sections of road, consisting of entrance or exit roads, which connect roadways and allow vehicles to enter or exit a highway or freeway. Ramps are designed to facilitate the flow of traffic between the main highway and local roadways or between highways.

Ramp decision points –Location along a highway at the ramp advising vehicles of future decisions where taking a wrong turn cannot easily be corrected. Typically used for locating regulatory or warning signs.

Ramp Spacing – The distance between the painted tips of successive ramps. Spacing distances depends on ramp pair functionality (entrance to entrance/entrance to exit/exit to exit/exit to entrance) and interchange classification (system to system or service to service). The minimum interchange spacing requirements for an entrance to exit ramp is 1600-feet. This allows for vehicles to get up to the design speed and have enough spacing for a weaving motion for vehicles that are exiting the mainline. Any distance shorter than the minimum interchange spacing of 1600 feet could cause delays and vehicles to slow down on the mainline which results in a safety concern.

Ramp Terminus- The end of a ramp facility at the connection to a secondary roadway where vehicles can exit or enter the ramp.

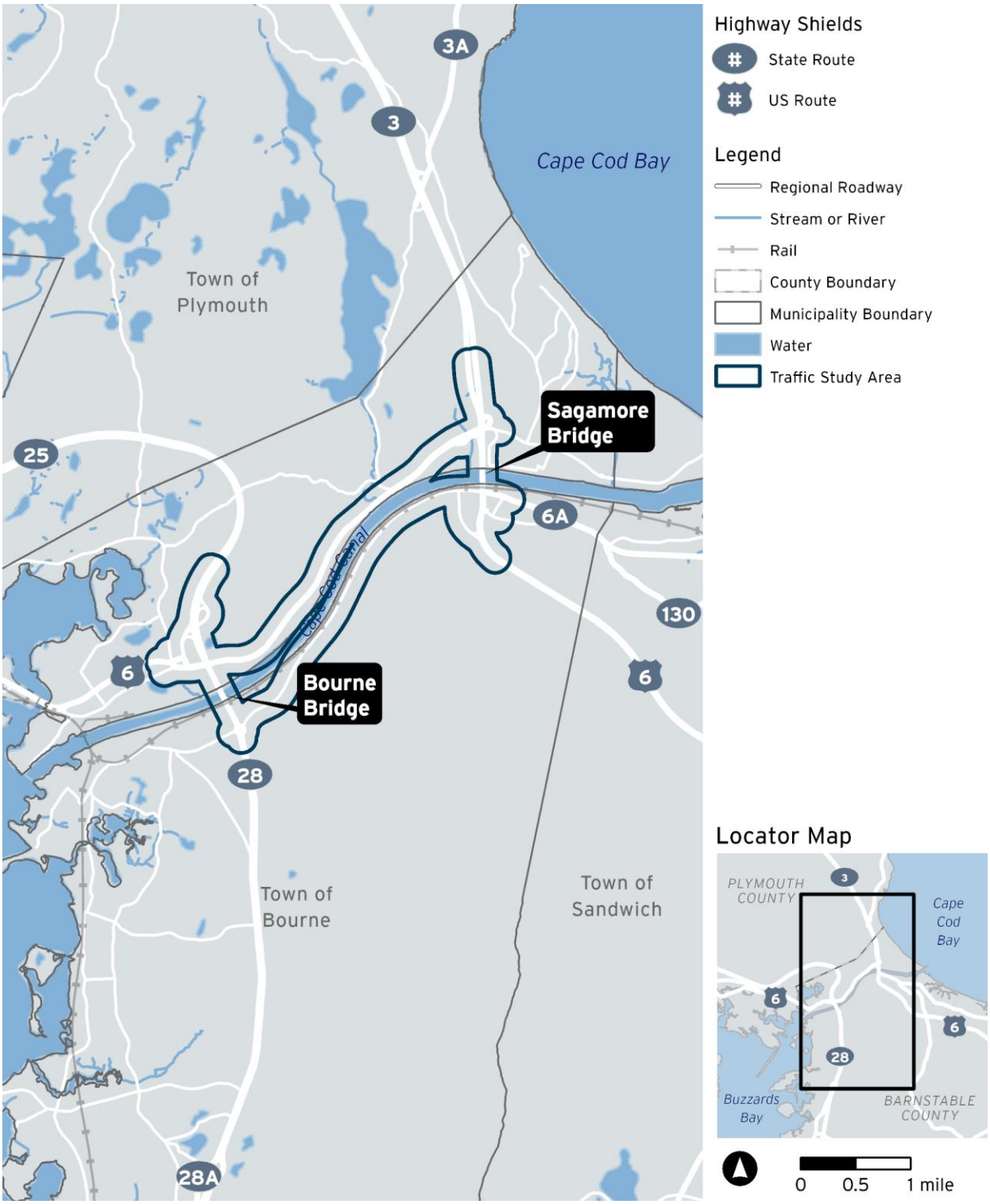


Recreational Facilities- An indoor or outdoor park, building, site, or other facility that is dedicated to recreation purposes and administered by a public or private nonprofit agency to serve the recreation needs of community.

Recreational Resources – Refers to designated areas such as national and state parks, national and state recreation areas, national seashores, national monuments, national historic sites, state beaches, and state fishing areas.

Regional- The travel of persons from distances that are larger than an administrative region, i.e., users of a facility whose trips originate from outside the county, state, or country. Regional travel for the Program is defined as travel with mid- or lower-Cape destinations.

Regional Network - The regional network consists of the major roadways, interchanges and intersections within a 2-mile area centered around the Sagamore and Bourne Bridges, also referred to as the traffic study area.



Cape Cod Bridges Program Traffic Study Area (Regional Network)

Roadway Corridor- Routes or pathways that facilitate movement between different areas by providing transportation infrastructure such as roads, sidewalks, and bicycle facilities.

Runoff – The portion of rain and melting snow that flows off impervious areas such as building rooftops, driveways, lawns, streets, parking lots, construction sites, and industrial storage yards and makes it way towards waterways, lakes, or oceans as surface or subsurface flow.

Sea Level Rise- The average increase in the water level of the Earth's oceans as is experienced at a given location.

Shared Use Path (SUP) - Facilities for non-motorized users that may be independently aligned and not necessarily associated with parallel roadways. Shared use paths are designed to accommodate a variety of users, including walkers, bicyclists, joggers, people with disabilities, skaters, pets, and sometimes equestrians. For the Cape Cod Bridges Program, Shared Use Path refers to the grade-separated paved area adjacent to the roadway dedicated to pedestrians and bicyclists.

Sidra- A traffic analysis software used to analyze roundabouts, rotaries, and traffic circles.

Speed Differential- The difference between the free speed at a given location and the anticipated operating speed of a device at that location. These differentials can exist between different highway sections or between vehicles in the same traffic stream.

Speed Variances- Refers to the difference in operating speeds among vehicles on a roadway especially in adjacent travel lanes.

Spill Back – The blockage of a roadway or intersection due to the traffic control means preventing operational progress of congestion.

Storm Surge- An abnormal water level rise generated by a storm over and above the predicted astronomical tide at a given location.



Storm Water- Excess rainwater that runs off from land surfaces during and following rainfall. See also "Runoff."

Structural System- Refers to the load-resisting sub-system of a building or object. The structural system transfers loads through interconnected elements or members.

Structural Framing System – System of inter-connected structural elements, primarily reinforced concrete or steel, which transfer applied loadings from vehicles, wind, seismic events, and other forms of loading thru the structural elements to the bridge foundations.

Surface Water Buffers- Vegetated lands adjacent to a body of water serve as a buffer to protect the stream system's ability to fulfill its natural functions, including protect water quality by filtering pollutants, provide storage for floodwaters, allow streams to meander naturally, and provide suitable habitats for wildlife.

Synchro- A traffic analysis software based on the Highway Capacity Manual (HCM)[2] methodology used to analyze local unsignalized and signalized intersections.

Target Speed- The highest operating speed at which drivers should ideally operate on a roadway given a specific context.

Throat – Distance or width from the outer edge of traveled way to the inside edge of travel way at the physical nose of the ramp entrance or exit.

[2] National Academies of Sciences, Engineering, and Medicine. Highway Capacity Manual 6th Edition: A Guide for Multimodal Mobility Analysis. Washington, DC: The National Academies Press.

Total Suspended Solids- Refers to waterborne particles that exceed 2 microns in size.

Traffic Operations- The planning and control of vehicle and group movements on streets and highways to ensure safety and efficiency.

Transit Facilities- A physical structure whose primary function is to facilitate access to and from a transportation system which has scheduled stops at the structure, including bus and train stop locations.



Travel Times- The time required to traverse a route between any two defined points of interest within a roadway network.

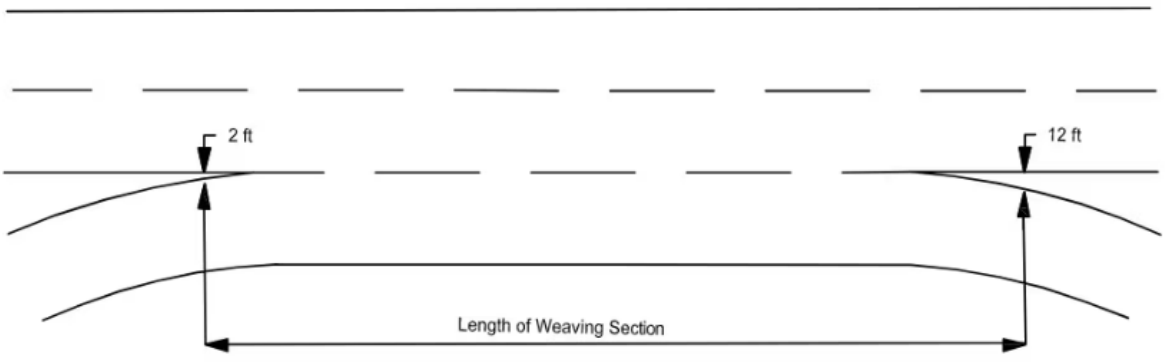
Traveling Public – Refers to any person making a trip including pedestrian and bicyclists using sidewalks, shared-use paths, and trails and vehicles using highways and roadway facilities.

Tree Cover – Defined as the surface area of the land covered by the combined leaves, branches, and trunks of all standing trees in a given area when viewed from above.

Urban Heat Island Effect – An observed increase in urban air and surface temperatures compared with surrounding rural areas typically caused by the built infrastructure and/or environment.

VISSIM - A microsimulation software used to model the complete program area (the network encompassing the Bourne and Sagamore bridges and the roadways located within a 2-mile radius of the bridges) to show the interaction among the various classifications of roadway facilities (including road, bicycle and pedestrian infrastructure) and their impacts on each other.

Weaving Movements – The act performed by a vehicle in moving obliquely (sideways) from one lane to an adjacent lane, thus crossing the path of other vehicles moving in the same direction. Weaving occurs where one-way traffic streams cross by merging and diverging maneuvers. This frequently occurs within an interchange or between two closely space interchanges.



Source: Adapted from Highway Capacity Manual, TRB, 2000. Exhibits 13-7, 13-11



Wetland – Land that is transitional between aquatic and terrestrial ecosystems and is covered with water for at least part of the year.

Wildlife Habitats - Areas distributed horizontally and vertically across the landscape that fulfill the needs of a specific wildlife species for the basic requirements of food, water, reproduction (nesting), and protection against predators and competitors (cover).

Appendix 2 Traffic Technical Reports and Memoranda

2.1 Methodology to Estimate 2019 Base Year Volumes (December 18, 2020)

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Woburn, MA 01801
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Tel: (888) 710-5380
Fax: (888) 710-5380

MEMORANDUM

TO: Dave Anderson, P.E. and Alexandra Siu, P.E., HNTB
FROM: Deanna Peabody, P.E. and Sudhir Murthy, P.E.
DATE: December 18, 2020
SUBJECT: **Cape Cod Canal Area Transportation Program Management & Project Development**
Methodology to Estimate 2019 Base Year Volumes

INTRODUCTION

As a part of the Cape Cod Canal Area Transportation Program Management and Project Development, the HNTB team is updating the traffic analyses to reflect current conditions and an updated design year to evaluate design alternatives. The Cape Cod Canal Crossing Study utilized 2014 traffic counts to generate the 2014 base year volumes for both travel demand modeling and traffic analyses. New traffic counts were planned to be collected in Spring and Summer 2020; however, given the unusual traffic volumes prevalent in 2020 due to COVID-19, collecting new traffic counts to update the 2014 counts to a new base year was not feasible. At a meeting in June 2020 with MassDOT, it was determined that a methodology should be developed for projecting the prior 2014 counts to an updated base year for use in travel demand modeling and traffic analyses throughout the project. Furthermore, given the availability of traffic counts that were conducted in 2019 and the abnormal traffic patterns in 2020, it was determined that 2019 should be used as the base year. This memorandum describes the methodology used to generate 2019 base year traffic volumes.

MASSDOT ENGINEERING DIRECT E-20-005

MassDOT issued Engineering Directive E-20-005 in May 2020 to provide guidance on how to estimate existing (2019) traffic volumes using historic traffic data, dating back as far as 2014. This guidance was developed to aid in project development as any new traffic counts after March 13, 2020 were lower than normal and have still not rebounded. The Engineering Directive provides annual traffic growth rates by functional classification and area type.

Prior to applying the methodology suggested in the Engineering Directive it was decided to review the traffic growth patterns at three MassDOT continuous count stations in the vicinity of the Cape Cod Canal Bridges. There are three MassDOT continuous count stations in the vicinity of the Bourne and Sagamore Bridges as follows:

- Station 707 – Route 25, north of Bourne Bridge (south of exit to Belmont Circle)
- Station 708 – Route 6, south of Sagamore Bridge (north of Exit 1C)

- Station 20 – Route 3, south of Herring Pond Road (north of Sagamore Bridge)

Station 707 comprises of traffic going over the Bourne Bridge while Station 708 comprises of traffic going over the Sagamore Bridge. Figures 1 and 2 show the historic traffic trends from 2014 to 2019 on the Bourne and Sagamore Bridges, respectively.

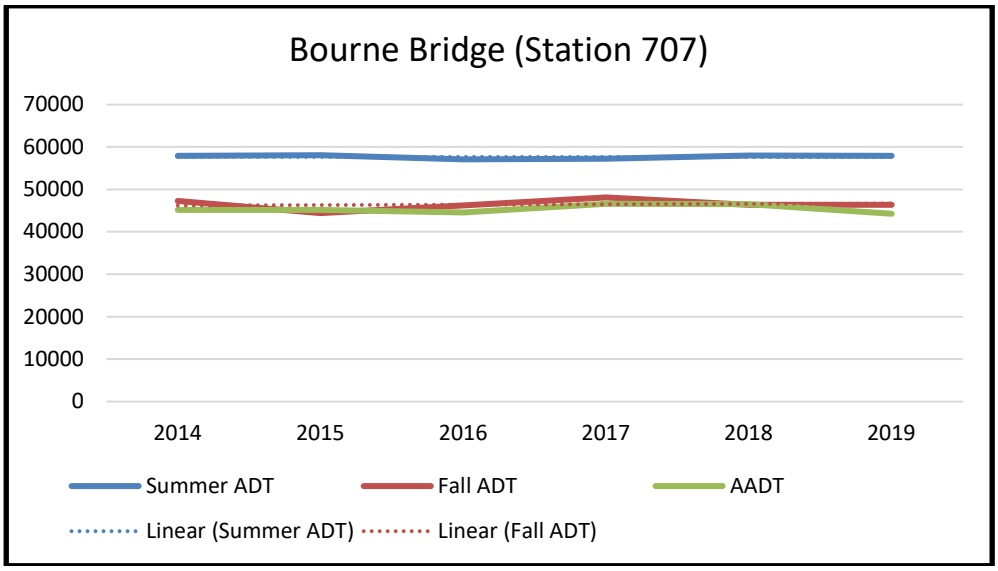


Figure 1 – Bourne Bridge (Sta. 707) Traffic Trends (2014-2019)

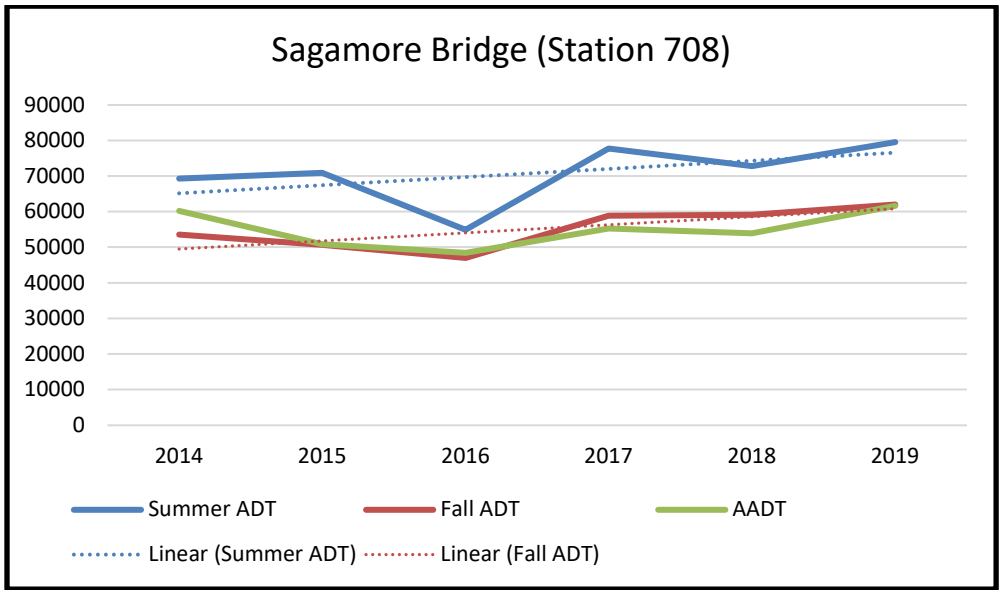


Figure 2 – Sagamore Bridge (Sta. 708) Traffic Trends (2014-2019)

As shown in Figure 1, the historic traffic trends on the Bourne Bridge (Sta. 707) indicate a constant Average Daily Traffic (ADT) both in the summer (July/August) and fall (September/October) months. On the other hand, as shown in Figure 2, the ADT on Sagamore Bridge (Sta. 708) has been increasing from 2014 to 2019, except in 2016 when the ADT fell, likely due to equipment malfunction that occurred both in the summer and fall months. The overall Average Annual Daily

Traffic (AADT), which represents traffic volumes for the entire year, also depicts similar trends at each location.

Figure 3 presents the annual growth rates for each of the three MassDOT continuous count stations as well as the growth rate from the MassDOT Engineering Directive.

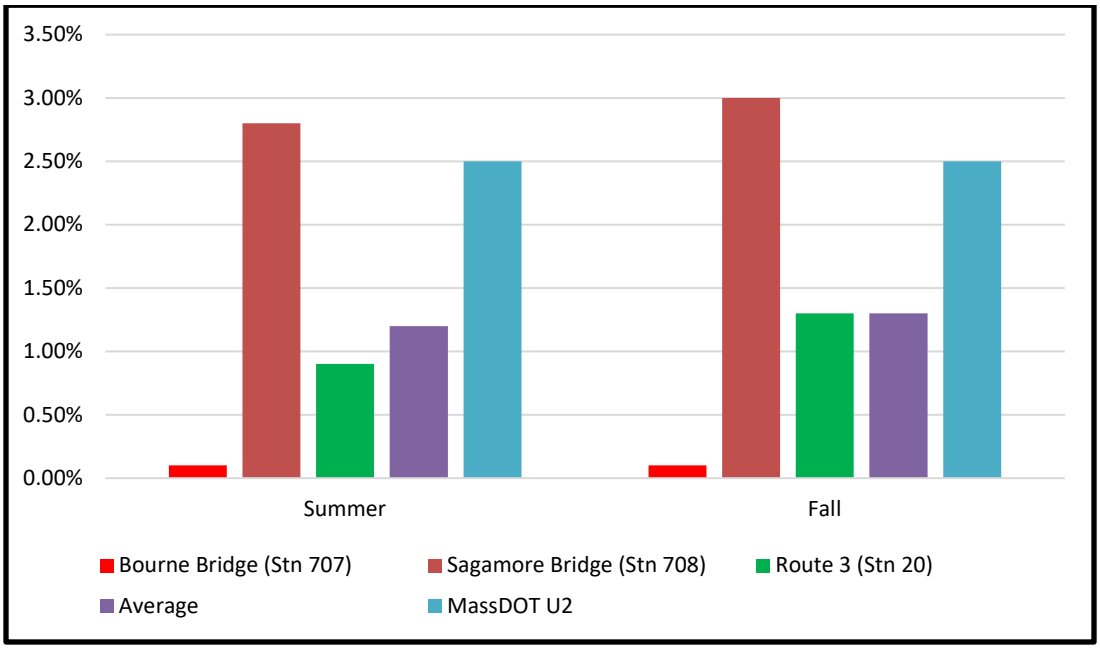


Figure 3 – Comparison of Traffic Growth Rates

As indicated in Figure 3, the Bourne Bridge (Sta. 707) has almost no change in ADT between 2014 and 2019, while Sagamore Bridge (Sta. 708) experienced a growth rate of 2.8% during the summer months and 3% during the fall months. Route 3 north of the Sagamore Bridge (Sta. 20) experienced a growth of 0.9% during the summer months and 1.3% during the fall months. The average growth rate among these three continuous count stations was about 1.2% in the summer months and 1.3% in the fall months. In comparison, the MassDOT Engineering Directive indicates a suggested growth rate of 2.5%.

In reviewing the information presented in Figure 3, the following conclusions can be made:

- Estimating 2019 volumes using the Engineering Directive would result in a significantly higher growth rate than the average growth rate indicated by the continuous count stations in the vicinity of the project area.

- The methodology to update the 2014 volumes to 2019 would have to account for the differing growth rates on the Bourne and Sagamore bridges.

Table 1 shows the ADTs for Summer and Fall on the two bridges as well as the relative split in volumes crossing the Cape Cod Canal between the Bourne and Sagamore Bridges between 2014 and 2019.

Table 1 – ADT on Cape Cod Canal Bridge Crossings

Bridge	Summer		Fall	
	2014	2019	2014	2019
Bourne	57,870	57,860	47,270	46,370
Sagamore	69,270	79,560	53,580	62,020
Relative Split				
Bourne	46%	42%	47%	43%
Sagamore	54%	58%	53%	57%

As shown in Table 1, the relative proportion of traffic volumes crossing the Cape Cod Canal has increased on the Sagamore Bridge with respect to the Bourne Bridge.

Given that in 2019 traffic growth on Sagamore Bridge was higher than the Bourne Bridge, it would not be appropriate to apply a uniform growth rate either based on MassDOT's Engineering Directive or an average growth rate derived from the three MassDOT continuous count stations. If updated 2019 traffic volumes were to be generated by applying a uniform growth rate to the 2014 volumes, it would retain the traffic patterns that were prevalent in 2014 and not reflect the new traffic patterns in 2019. Based on this analysis, it was deemed necessary to update the 2014 volumes to 2019 using a methodology that would account for this change in traffic patterns as discussed in the follow section.

2019 BASE YEAR VOLUMES ESTIMATIONS METHODOLOGY

Figure 4 presents the methodology that was used to estimate the 2019 Base Year volumes.

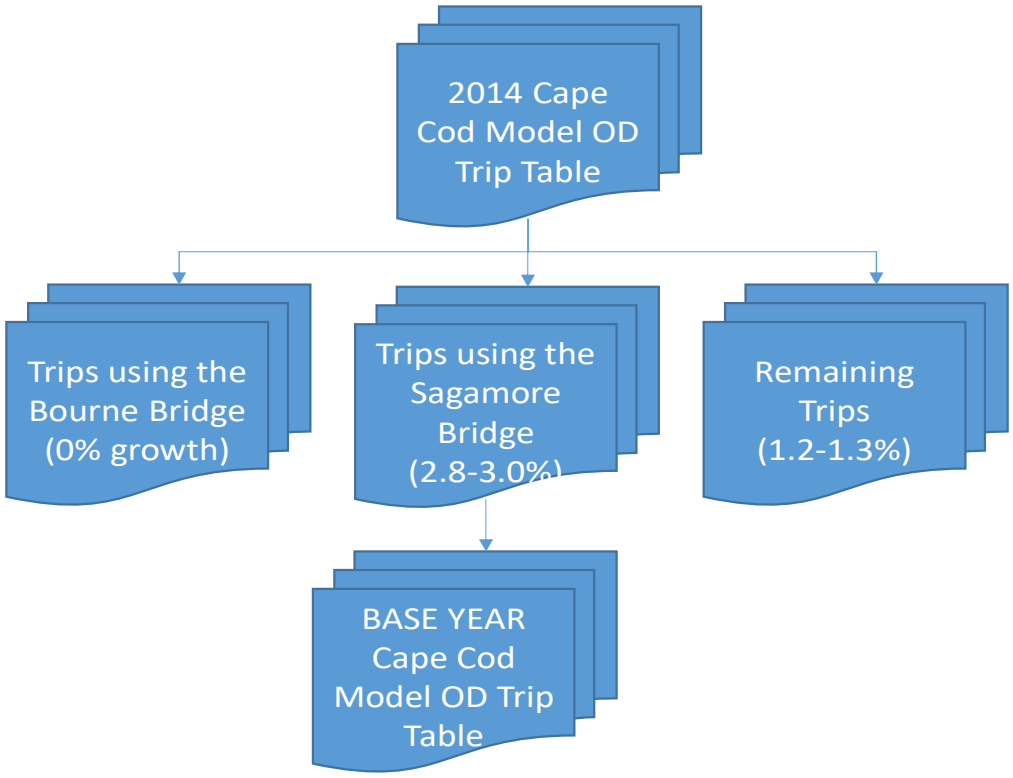


Figure 4 - 2019 Base Year Volumes Estimation Methodology

The starting point was the travel demand model developed for the previous study, which included a 2014 Base Year calibrated model.

It should be noted that when the 2014 total trip table is referred in this discussion, it is meant to cover all trip tables developed in the previous travel demand forecasting model. The prior model included the following seasons, with a total of four (4) separate trip tables for each season covering the AM, Midday, PM and Nighttime time periods:

- 2014 Fall Weekday
- 2014 Fall Weekend
- 2014 Summer Weekday
- 2014 Summer Weekend

Each time period trip table in each season was in turn broken into two trip tables consisting of visitor and non-visitor trips. The previous model had a total of 4 seasons x 4 time periods x 2 trip types = 32 trip tables. However, to generate the 2019 Base Year peak hour volumes, only the following 6 x 2=12 2014 trip tables were projected to the year 2019:

- 2014 Fall Weekday AM (visitor & non-visitor)
- 2014 Fall Weekday PM (visitor & non-visitor)
- 2014 Fall Weekday Midday (visitor & non-visitor)

- 2014 Summer Weekday AM (visitor & non-visitor)
- 2014 Summer Weekday PM (visitor & non-visitor)
- 2014 Summer Weekend Midday (visitor & non-visitor)

The first step was to break each of the 12 trip tables into the following three components:

- Trips crossing the canal over the Bourne Bridge
- Trips crossing the canal over the Sagamore Bridge
- All remaining trips

To identify trips that use each bridge, the model was run using "Select Link Analysis" in which all trips using a specific link in the network are extracted. Once the trips that use Bourne and Sagamore Bridges were extracted, the remaining trips were determined by subtracting the Bourne and Sagamore Bridges trips from the total 2014 trips.

The next step was to apply a growth factor to each of the above three components to estimate the 2019 trips. Based on the analysis of historic traffic trends discussed above, the trip table with trips traveling over the Bourne Bridge were not subject to any growth thereby retaining the 2014 trips over the Bourne Bridge in 2019. The trip table with trips traveling over the Sagamore Bridge was factored up by a rate of 2.8% per year for summer and 3% per year for fall. All remaining trips were factored up by a rate of 1.2% per year for summer and 1.3% per year for fall based on the average growth rate from the three MassDOT continuous count stations in the vicinity of the project area.

After each trip table corresponding to trips over the Bourne and Sagamore Bridges and remaining trips were factored, they were combined to generate the 2019 trip tables. These 2019 trip tables were assigned to the network using a Multi-class Equilibrium Assignment method to account for different Value of Time values for visitor and non-visitor trips. As mentioned above, the trip tables cover the AM and PM peak periods each consisting of a 3-hour period and the midday period covering a 6-hour time frame. These peak period assignments were then converted to peak hour volumes based on the same ratio of peak hour to peak period volumes from 2014.

The resulting 2019 peak hour traffic volumes on the Bourne and Sagamore Bridges did not exactly match the actual volumes obtained for the two bridges from MassDOT continuous count stations 707 and 708. The final step was to manually adjust the volumes along Route 3, Route 6, Route 25, Route 28, Scenic Highway and Sandwich Road to ensure that the 2019 peak hour volumes on the bridges match the actual counts. The final 2019 base year volumes computed using this methodology are attached to this memorandum.

MassDOT

Cape Cod Canal Program Management

Fall Weekday AM Peak
2019 Existing Conditions

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Scale: 1" = 300'

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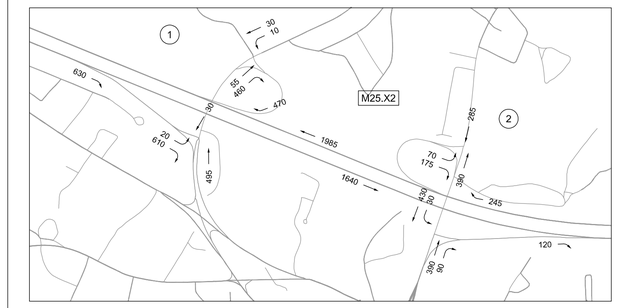
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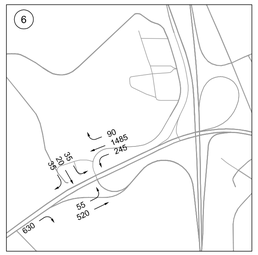
MassDOT

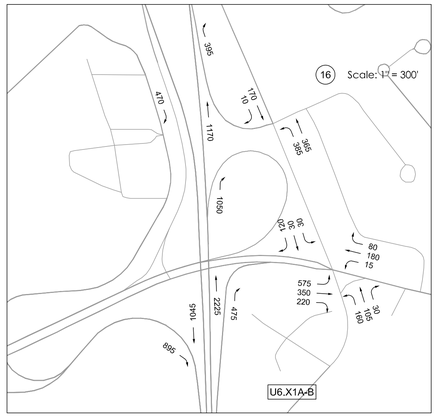
Cape Cod Canal Program Management

Fall Weekday PM Peak
2019 Existing Conditions

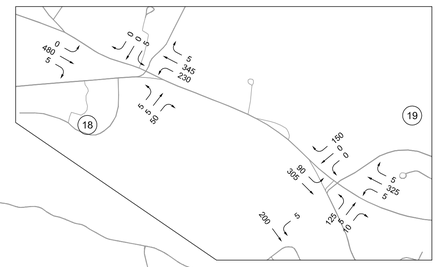
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Kelly Cronin

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MassDOT

Cape Cod Canal Program Management

Fall Saturday Midday Peak
2019 Existing Conditions

Scale: 1" = 2500'

Scale: 1" = 300'

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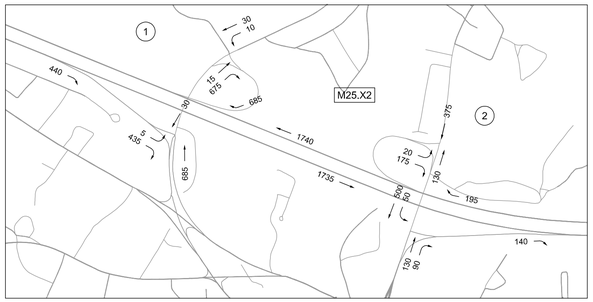
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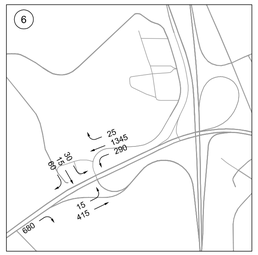
Cape Cod Canal Program Management

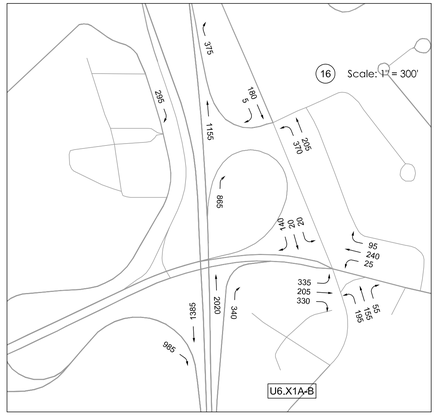
Summer Weekday AM Peak
2019 Existing Conditions

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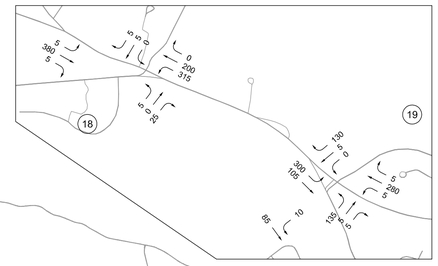
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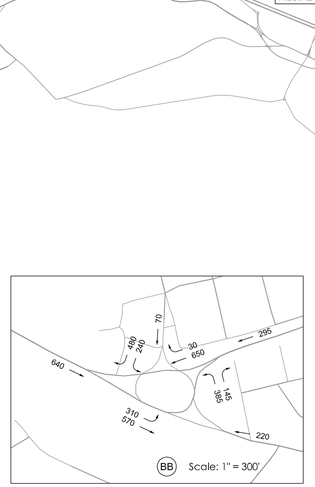


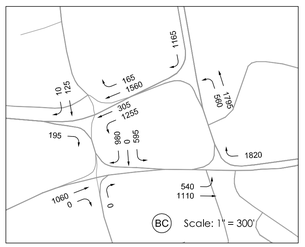


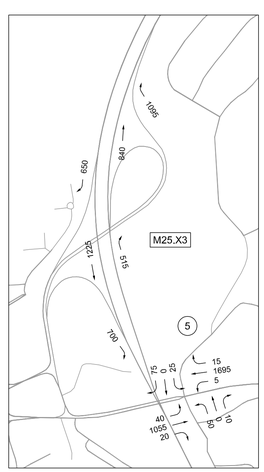


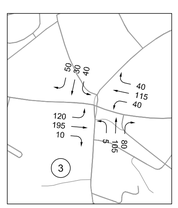


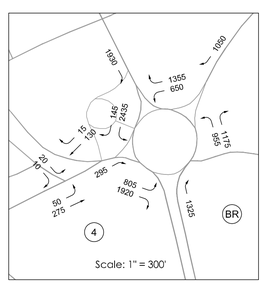


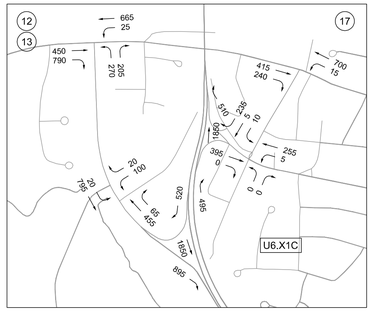


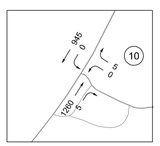


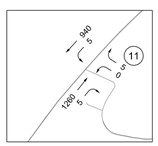


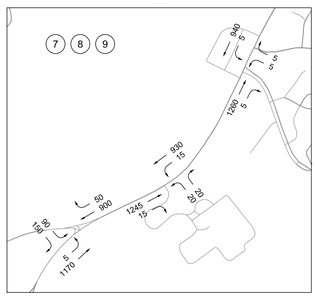


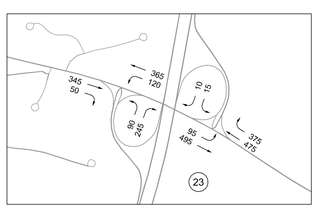


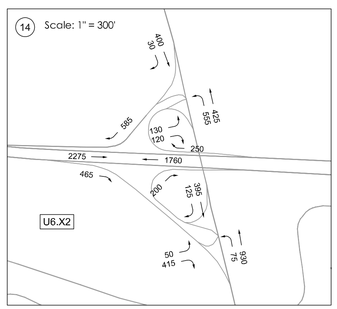


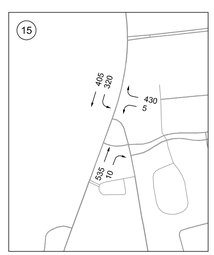




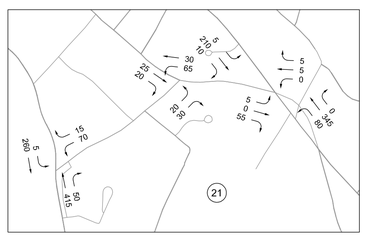


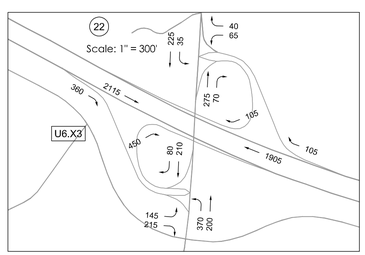








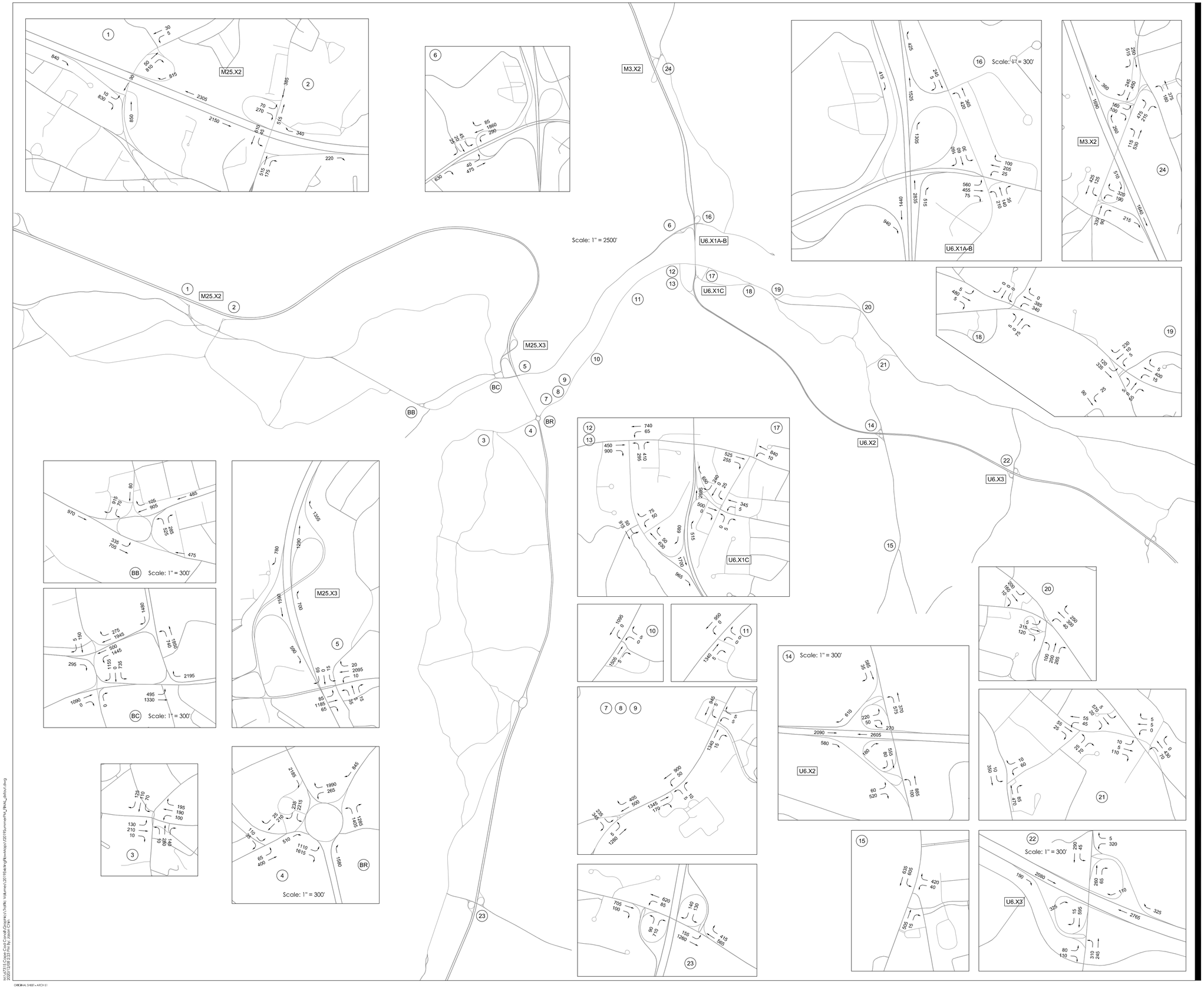




MassDOT

Cape Cod Canal Program Management

Summer Weekday PM Peak
2019 Existing Conditions



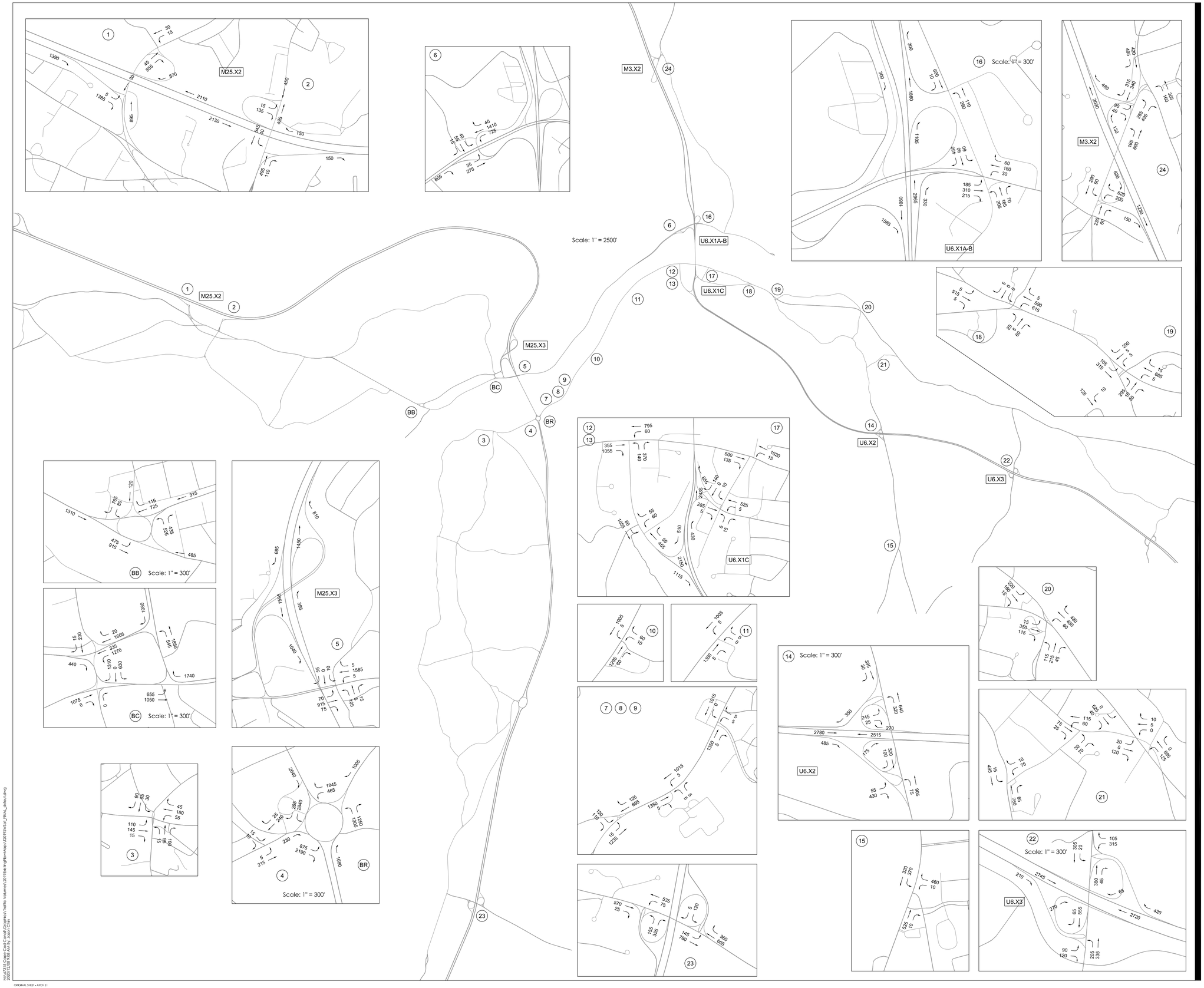
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MassDOT

Cape Cod Canal Program Management

Summer Saturday Midday Peak
2019 Existing Conditions



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Nov 27, 2019 - 4:08pm Kyle Zeller

2.2 Future Demographic Conditions (May 14, 2021)

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Date
5/14/2021

To
Amy Getchell, MassDOT

From
Alexandra Siu, P.E., PTOE
Paul Nelson

PROJECT CORRESPONDENCE

Subject
Cape Cod Canal Bridges Program – Future Demographic Conditions

Overview:

The future design year for the Cape Cod Canal Bridges Program has been set as 2045. Future demographic projections for Cape Cod communities developed by the UMass Donahue Institute in 2018 for the MassDOT Office of Transportation Planning (OTP) estimate a steady decline in population, households and employment through the year 2040. According to the UMass Donahue Institute projections, these demographic declines are a result of the continuation of one longstanding trend: the aging of the Cape population resulting in very low births and fewer labor force participants to drive job growth. Based on discussions with the UMass Donahue Institute, one aspect unique to Cape Cod that was not considered is the net in-migrations to the year-round population from retirees converting seasonal to year-round homes. This issue was brought to MassDOT's attention by the Cape Cod Commission during the Cape Cod Canal Transportation Study back in 2015. The Cape Cod Commission was also concerned that by focusing exclusively on demographic changes, the impact of the visitors would not be reflected in the model. By not accounting for these aspects unique to Cape Cod, the Cape Cod Commission was concerned that the future design year traffic volumes on the bridges would be under-estimated. The consensus approach to modeling future conditions for the Cape Cod Canal area from that study was to adopt separate forecasting methods for the two groups included in the model: visitors and non-visitors. The non-visitor trips were projected using the demographic forecasts approved by MassDOT while the visitor trips were projected using growth rates estimated by a separate model developed by FXM Associates. Given the relatively high level of visitor trips crossing the bridges, particularly during weekends and more so during summer months, the net effect of this methodology was an overall growth in traffic volumes by the year 2040 that was acceptable to both MassDOT and the Cape Cod Commission.

Although it is too soon to fully understand the long-term traffic impacts due to COVID-19, the pandemic has likely changed household mobility, location preferences, and travel patterns in ways that are not reflected in the MassDOT demographic projections developed in 2018. Two trends that have likely played out that would lead to growth in population and creation of permanent households in Cape Cod communities are the increased popularity and feasibility of remote work (teleworking) and an increase in Baby Boomer retirements to homes owned on Cape Cod that were once rented out or only occupied on a seasonal basis. We expect the same pushback from the Cape Cod Commission as was the case in 2015 if there is no recognition that COVID-19 has likely led to longer-term changes in household formation and travel patterns. For example, and notwithstanding the post-pandemic impacts, a 2017 survey of second home owners on Cape Cod[1], indicated that about 19% of second home owners planned to convert their seasonal homes to permanent residences over the next 5-20 years. This data was not considered in the prior forecasts and would have added 11,000 households (13%) to the projected 2040 number of 82,000 households in Barnstable County.

Additionally, release of the 2020 US Census data on a more traditional timeframe would have allowed MassDOT and the project team to confirm the project travel demand model's existing demographics

[1] Cape Cod Second Homeowners, Technical Report of 2017 Survey Findings, UMASS Donahue Institute, Applied Research and Program Evaluation, Cape Cod Commission, June 2017.

information with greater accuracy and whether trends in population, household and employment needed to be recalibrated from the previous MassDOT forecasts. Unfortunately, release of data from the 2020 Census has been delayed to the late summer/early fall of 2021. Upon release of the 2020 US Census data, MassDOT OTP intends to create a demographic projections working group with membership consisting of subject matter experts and representatives from the regional planning agencies across the Commonwealth. MassDOT OTP's working group will take up to a year to evaluate 2020 US Census results and apply them to forecasts for future planning horizon years. Modeling of existing and future traffic conditions is currently a critical path element of the Cape Cod Canal Bridges Program development. The travel demand modeling cannot be delayed until the release of the 2020 US Census data or the conclusions of the MassDOT OTP working group without impacting the overall project schedule.

Recommendation:

We recommend developing the following three scenarios in order to begin alternatives development and to make certain that the measures of effectiveness are capturing the range of anticipated possible projections:

1. 2019 Existing Conditions travel demand model – To be used for an initial screening of the alternatives and to test feasibility while the Future Conditions models are being developed. While the eventual preferred alternative will analyze all peak time periods (weekday AM, weekday PM, and Saturday mid-day) for the fall and summer, this feasibility analysis will focus on the summer weekday PM and summer Saturday mid-day peak hours.

2. 2045 Future Conditions travel demand model – To be used to further refine the measures of effectiveness for the alternatives with the goal of choosing a preferred concept. The background methodology for projecting future volumes include:

    a. A similar method as the initial planning study, with changes in visitor and non-visitor trips estimated separately. Estimated growth in visitor trips between 2019 and 2045 will use a similar econometric model with updated, and possibly expanded, supporting data.
    b. The 2040 population, households, and employment levels identified by MassDOT OTP will be used to estimate the changes in non-visitor trips by 2045. The demographic data will not be extrapolated from 2040 to 2045 because continuation of the trends between the 2030 and 2040 will result in unrealistically low estimates of trips.
    c. To ensure the 2045 demographic information is reasonably allocated to the model's Traffic Analysis Zones (TAZs), planned development projects in the communities of Bourne, Sandwich, Plymouth and Wareham will be identified and reviewed as well as other relevant evidence of confirmed growth not anticipated in prior projections.

3. 2045 Future Conditions Sensitivity analysis – To be used to test the sensitivity of modeled vehicle volumes to changes in trends tied to remote working and retirement of the Baby Boomer generation. This will involve research to confirm trends in seasonal home conversions and remote work affecting the number of year-round residents. The second scenario will also identify how recent trends in the proportion of trips taken outside the peak hour may result in different estimates of peak trip volumes within the study area.

2.3 Existing 2019 Conditions Traffic Analysis (August 30, 2021)

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Date
August 30, 2021

To
Amy Getchell, MassDOT

From
Alexandra Siu, PE, PTOE
Joshua Herman, PE
Elena Aung, EIT

PROJECT CORRESPONDENCE

Subject
Cape Cod Canal Area Transportation Improvement Program
Existing 2019 Conditions Traffic Analysis

Introduction

HNTB developed existing conditions traffic models for the 2019 Base Year utilizing Massachusetts Department of Transportation (MassDOT) approved traffic analysis tools, including Synchro (version 10), SIDRA 7, HCS 7, and VISSIM (version 11). This memorandum describes the methodology used to calibrate the existing traffic analysis models for the 2019 Base Year for Cape Cod Canal Area Transportation Improvement Program (CCC TIP) and summarizes the results of the analysis. The general study area is shown in Figure 1, which includes major regional roadways, interchanges and intersections within Plymouth, Wareham, Bourne, and Sandwich that are impacted by traffic crossing the Cape Cod Canal. The focus area for the study consists of the 2-mile area centered around the Bourne and Sagamore Bridges.

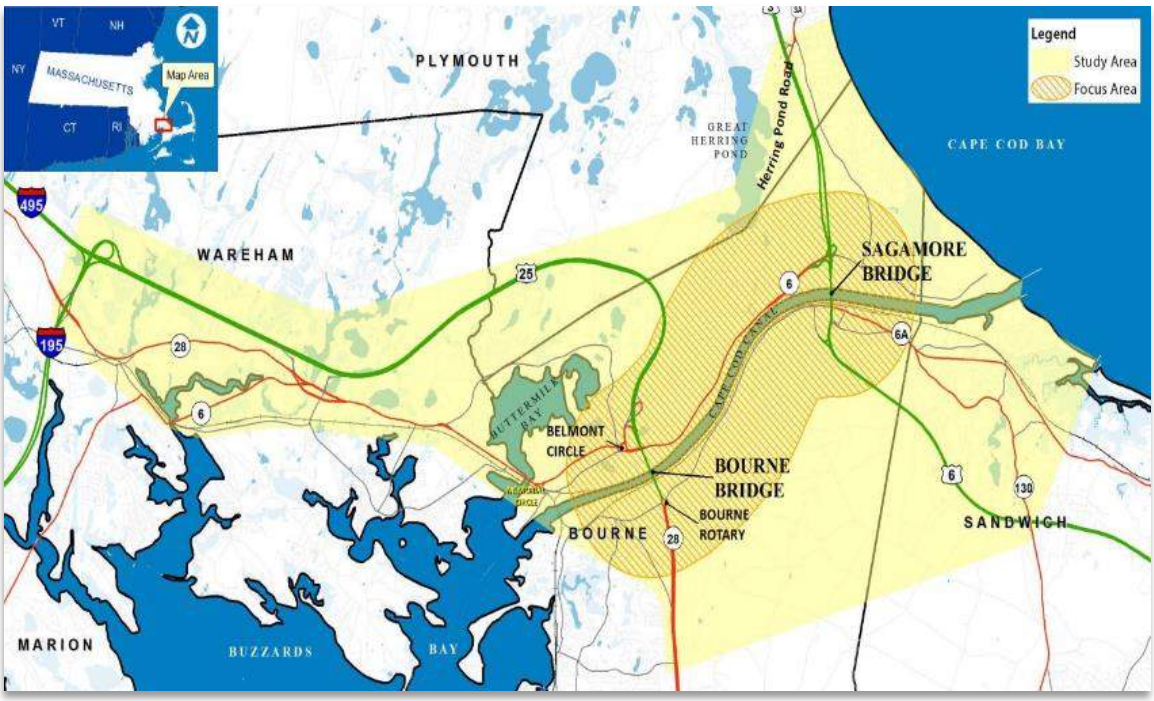


Figure 1: Overall Study Area Map

Existing Traffic Data

Base Year 2019 traffic models were developed for the following six time periods:

- Fall Weekday AM peak hour (off-peak season)
- Fall Weekday PM peak hour (off-peak season)
- Fall Saturday Midday peak hour (off-peak season)
- Summer Weekday AM peak hour (peak season)
- Summer Weekday PM peak hour (peak season)
- Summer Saturday Midday peak hour (peak season)

New traffic counts were not collected in 2020 given the non-typical traffic patterns and volumes due to the ongoing COVID-19 pandemic. Instead, an alternate methodology to adjust the 2014 count data to the 2019 Base Year was used. This methodology is detailed in the memorandum *Methodology to Estimate 2019 Base Year Volumes* dated December 18, 2020 and approved by MassDOT. The approved 2019 Base Year traffic volumes are provided in Appendix A.

Based on the 2014 count data and adjusted 2019 Base Year traffic volumes, the peak hours were identified as follows:

- Weekday AM Peak Hour (Summer and Fall): 7:00AM – 8:00AM
- Weekday PM Peak Hour (Summer and Fall): 4:00PM – 5:000PM
- Saturday Midday Peak Hour (Summer and Fall): 12:00PM – 1:00PM

In order to calibrate the 2019 Base Year traffic models, data was collected from the following sources:

- Record plans for the traffic signals within the study area were obtained by MassDOT District 5
- A site visit was performed to inspect the traffic signal controllers and download current timing information
- Field observations were conducted to observe traffic patterns and behavior
- Google Maps "Typical Traffic Conditions" feature for typical queue lengths
- INRIX typical travel times

Traffic Analysis Methodology

Existing capacity analyses assign a qualitative level-of-service (LOS) letter grade to traffic facilities during various peak hours. The concept of LOS is defined as a qualitative measure based on quantitative model outputs that describe operational conditions within a traffic stream and their perception by the traveling public. LOS is identified based on average delay per vehicle (measured in seconds per vehicle) at local signalized and unsignalized intersections and based on densities on freeway sections and at merge-diverge points (measured in vehicles per mile per lane). LOS is represented using letter grades "A" through "F", with LOS A representing very low delays and free flow conditions and LOS F representing unacceptable conditions for most drivers and conditions in which vehicle demand generally exceeds roadway capacity. LOS A, LOS B, and LOS C are generally considered acceptable conditions; LOS D is generally considered marginally acceptable conditions; and LOS E and LOS F are generally considered unacceptable to most drivers.

The program study area consists of freeway interchanges and intersections. The following analysis tools were used to analyze the 2019 Base Year conditions:

- Synchro 10 – local unsignalized and signalized intersections
- SIDRA 7 – roundabouts, rotaries, and traffic circles
- HCS 7 – multilane highway segments and freeway merges/diverges
- VISSIM 11 – all key highways and intersections within the focus area (2-mile radius of the bridges) to show the interaction between the above roadway facilities and their impacts on each other

The calibrated existing conditions 2019 Base Year traffic models will be used to create Future Year 2045 No Build and Build condition models to assess expected traffic operations with proposed roadway concept alternatives and future year traffic volumes.

Existing Traffic Operations

Traffic volumes and congestion levels in the vicinity of the Cape Cod Canal are typically highest during the Summer when there are more visitor trips to Cape Cod and the islands. Vehicular access to Cape Cod is exclusively possible via the Bourne Bridge and the Sagamore Bridge. Both bridges operate with two 10-foot-wide travel lanes per direction with speed limits of 40 miles per hour. Commercial traffic is permitted across both bridges, and the narrow 10-foot-wide lanes combined with steep grades on both bridges cause traffic slowdowns on the inclines from both directions.

The Bourne Bridge is accessed from points north and west via Route 25, which carries three travel lanes per direction, but narrows to two travel lanes approaching the bridge. Heavy traffic volumes merging from the entrance ramp from Belmont Circle combined with steep inclines on the bridge itself cause congestion on the bridge approach in most peak hours. Route 25 EB terminates immediately south of the Bourne Bridge at the Bourne Rotary, which is another source of congestion during peak hours. Difficulty merging into the rotary causes queueing on Route 25 to extend for several miles during some peak hours. Limited capacity and heavy traffic volumes in the Bourne Rotary also causes queueing to extend back onto its other approaches from northbound Route 28, westbound Sandwich Road, and eastbound Trowbridge Road. Queuing on northbound Route 28 often extends approximately 1 to 2 miles during peak hours.

The Sagamore Bridge is accessed from points north via Route 3/Pilgrims Highway and from points on Cape Cod via US Route 6. In the southbound direction, Route 3 carries two travel lanes toward the Sagamore Bridge and narrows to a single lane as Route 3 approaches the bridge. The single lane from Route 3 is joined by an add lane from the entrance ramp from Scenic Highway (US Route 6), to form the two lanes that are carried over the bridge. Congestion stemming from the steep grade and the narrow lanes on the bridge and the lane reduction on Route 3 cause queues to extend back from the bridge approximately 1 to 2 miles during peak hours. In the northbound direction, US Route 6 carries two travel lanes toward the Sagamore Bridge. A heavy merge from the entrance ramp from Cranberry Highway immediately upstream of the bridge causes traffic on Route 6 to slow, creating congestion approaching the Sagamore Bridge.

Since the bridges are only approximately three and a half miles apart, drivers often use the bridges interchangeably based on congestion levels. Scenic Highway generally carries two lanes of east-west traffic per direction and connects the Bourne Bridge with the Sagamore Bridge on the north side of the canal. Sandwich Road generally carries one lane of east-west traffic per direction connecting the bridges on the south side of the canal. Drivers use Scenic Highway and Sandwich Road to reach the other bridge if

navigational apps and dynamic message signage along the highways indicate lesser congestion on one of the two bridges during peak hours. The traffic models discussed in this memo were calibrated to closely reflect these unique operating conditions.

SYNCHRO 10 Analysis

Existing local intersection traffic models were built using Synchro 10. The following intersections were included in the models and analyzed:

Unsignalized Intersections

- Maple Springs Rd at NB Rte. 25 on-ramp
- Maple Springs Rd at SB Rte. 25 off-ramp
- Glen Charlie Rd at NB Rte. 25 off-ramp
- Glen Charlie Rd at SB Rte. 25 on-ramp
- Sandwich Rd/County Rd at Trowbridge/Shore Rd
- Trowbridge Rd at Veterans Way
- Sandwich Rd at Bourne Rotary Connector
- Sandwich Rd at Upper Cape Cod Tech School
- Sandwich Rd at Harbor Lights Rd
- Sandwich Rd at Jefferson Rd
- Sandwich Rd at Jarvis Rd
- Herring Pond Rd at State Rd
- Herring Pond Rd at NB Rte. 3 ramps
- Herring Pond Rd at SB Rte. 3 ramps
- State Rd at NB Rte. 3 on-ramp
- Cranberry Hwy at Adams St
- Sandwich Rd at Adams St
- Cranberry Hwy at Sandwich Rd/Regency Drive
- Old King's Hwy (Rte. 6A) at Main St (Rte. 130)/Tupper Rd
- Old King's Hwy (Rte. 6A) at Tupper Rd
- Water St. (Rte. 130) at Beale Avenue
- Main St at Beale Avenue
- Old King's Hwy (Rte. 6A) at Main St/Old Main St
- Quaker Meeting House Rd at EB Rte. 6 ramps
- Quaker Meeting House Rd. at WB Rte. 6 ramps
- Rte. 130 at Cotuit Rd
- Nathan Ellis Hwy (Rte. 151) at NB Rte. 28 ramps
- Nathan Ellis Hwy (Rte. 151) at SB Rte. 28 ramps

Signalized Intersections

- Scenic Hwy (Rte. 6) at Nightingale Rd/Andy Olivia Drive
- Sandwich Rd at Mid-Cape Connector
- Mid-Cape Connector at Factor Outlet Way
- Scenic Hwy at Church Lane
- Scenic Hwy at SB Rte. 3 off-ramp
- Meetinghouse Lane at State Rd./Canal St
- Forestdale Rd (Rte. 130) at EB Rte. 6 ramps
- Water St (Rte. 130) at WB Rte. 6 ramps

The levels of service for individual traffic movements at signalized and unsignalized intersections within the study area were determined based on criteria set forth in the Transportation Research Board's (TRB) Highway Capacity Manual (HCM) 6th Edition. Table 1 summarizes the delay criteria for each level of service letter grade at unsignalized and signalized intersections.

Table 1: Intersection LOS Criteria (HCM 6th Edition)

	Delay (seconds per vehicle)	
LOS	Unsignalized	Signalized
A	≤10	≤10
B	>10 and ≤15	>10 and ≤20
C	>15 and ≤25	>20 and ≤35
D	>25 and ≤35	>35 and ≤55
E	>35 and ≤50	>55 and ≤80
F	>50	>80

Exhibits 19-8, 20-2, and 21-8, HCM 6th Edition

The study area intersections within a 2-mile radius of the two bridges typically experience higher levels of traffic volumes and congestion than intersections further from the bridges due to the high concentration of traffic crossing the two bridges.

During the three Fall peak hours, most of the intersections analyzed operate at overall intersection LOS D or better. The following locations within the focus area operate at LOS E or F during one or more of the Fall peak hours:

- Sandwich Rd./County Rd. at Trowbridge Rd./Shore Rd. (Weekday PM – LOS F)
- Sandwich Rd. at Bourne Rotary Connector (Weekday AM/PM- LOS F; Saturday Midday- LOS E)
- Sandwich Rd. at Upper Cape Cod Technical School (Weekday PM– LOS F)
- Meetinghouse Lane at State Rd./Canal St. (Weekday PM – LOS E)
- Cranberry Hwy. at Sandwich Rd./Regency Drive (Weekday AM – LOS E; Weekday PM and Saturday Midday – LOS F)

During the three Summer peak hours, most of the intersections analyzed operate at overall intersection LOS D or better, with the following exceptions:

- Scenic Hwy. (Rte. 6) at Nightingale Rd./Andy Olivia Drive (Weekday PM– LOS F)
- Sandwich Rd./County Rd. at Trowbridge Rd./Shore Rd. (Weekday PM– LOS F)
- Sandwich Rd. at Bourne Rotary Connector (All Peak Hours– LOS F)
- Meetinghouse Lane at State Rd./Canal St. (Weekday PM – LOS E)
- Cranberry Hwy. at Sandwich Rd./Regency Drive (Weekday AM and PM – LOS F)

Level of Service tables that summarize the results of the existing capacity and queue analyses performed in Synchro for all six peak hours at all study area intersections can be found in Tables B-1 and B-2, which are provided in Appendix B. A graphical representation of the intersection levels of service are provided in Figures 2 and 3.

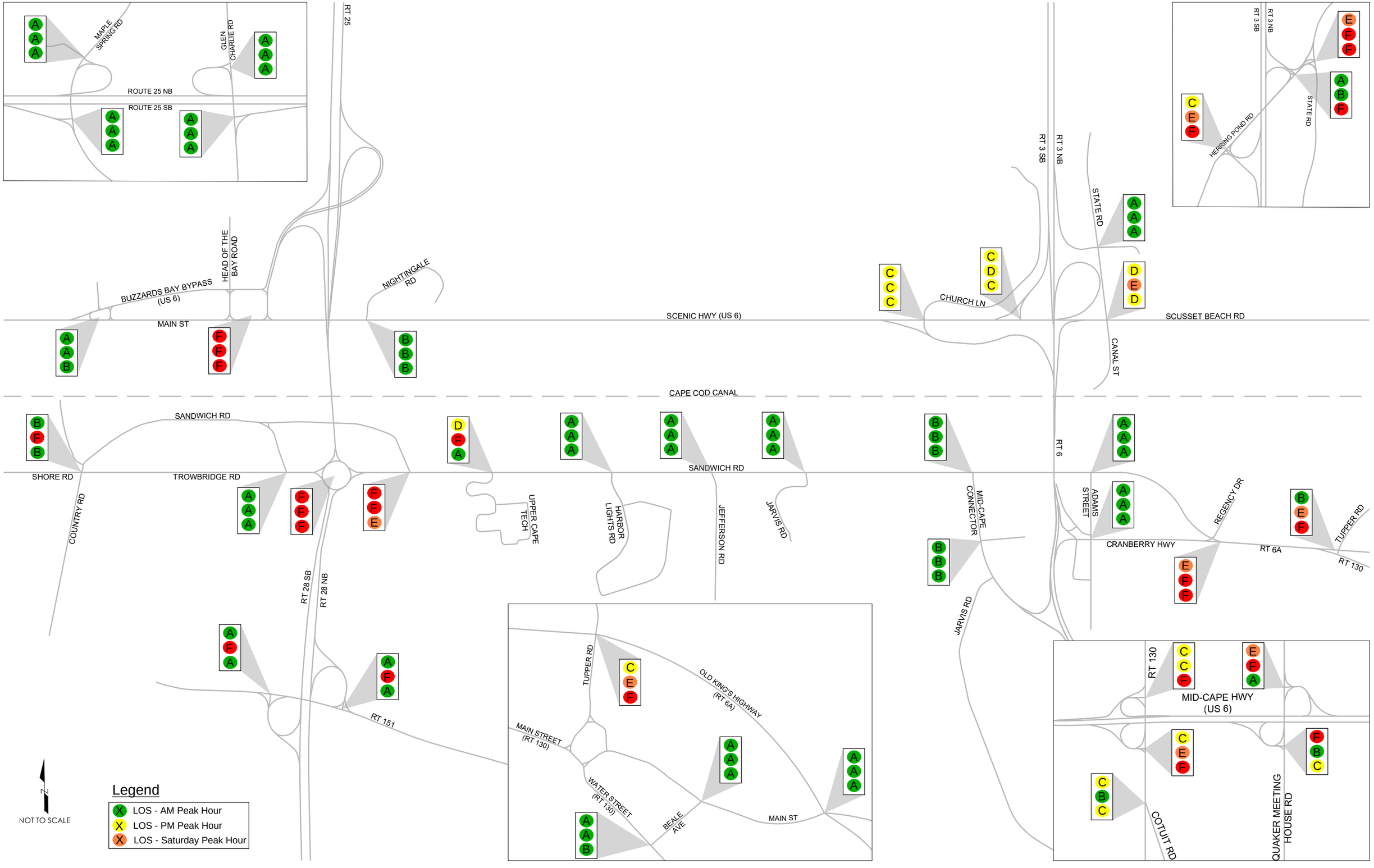


Figure 2: Existing (2019) Intersection Level of Service Summary - Fall

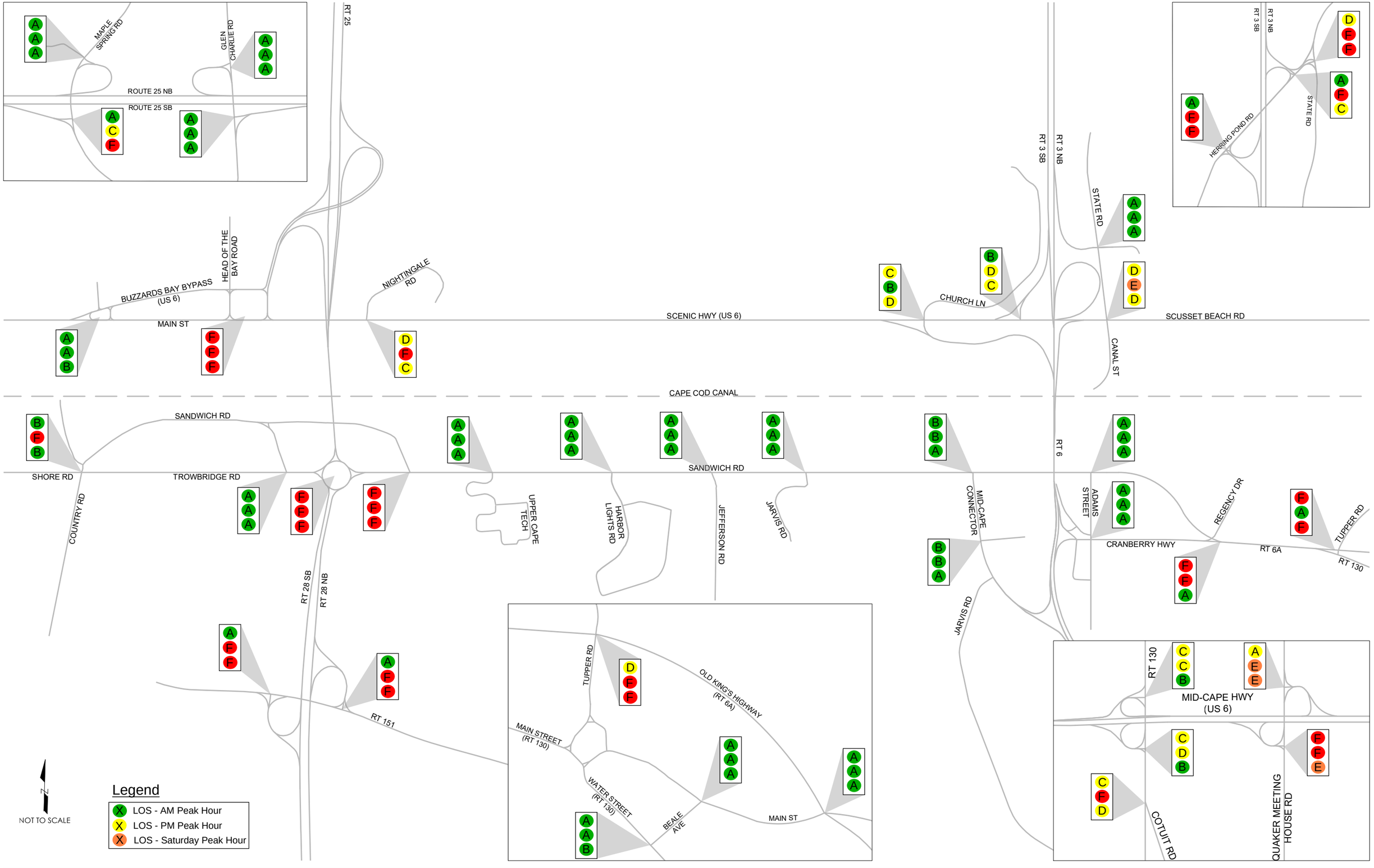


Figure 3: Existing (2019) Intersection Level of Service Summary - Summer

SIDRA 7 Analysis

Several unsignalized traffic circles and rotaries could be found throughout the study area. The Buzzards Bay Rotary and Belmont Circle are located on the north side of the Bourne Bridge, while the Bourne Rotary is located on the south side of the Bourne Bridge. SIDRA 7, which is based on the methodology prescribed in HCM 6th Edition, was used to analyze the existing traffic conditions at each of these intersections.

Table 2 summarizes the level of service criteria for traffic movements at each of the rotaries. Level of Service tables that summarize the results of the SIDRA analysis performed for all six peak hours can be found in Tables B-1 and B-2 in Appendix B. A graphical representation of the traffic circle/rotary levels of service is provided in Figures 2 and 3.

Table 2: LOS Criteria for Roundabouts (HCM 6th Edition)

LOS	Delay (seconds per vehicle)
A	≤10
B	>10 and ≤15
C	>15 and ≤25
D	>25 and ≤35
E	>35 and ≤50
F	>50

Exhibit 22-8, HCM 6th Edition

The Bourne Rotary and Belmont Circle each operate at overall LOS F during all three peak hours analyzed for the Fall and Summer seasons. Heavy traffic volumes from all approaches combined with geometric constraints at the Bourne Rotary and Belmont Circle contribute the poor levels of service at both intersections. The Buzzards Bay Rotary carries lower volumes than the other two traffic circles and operates at overall LOS A or LOS B during all six peak hours analyzed.

HCS 7 Analysis

The levels of service for multi-lane highways and/or freeways is based on vehicle density per mile of roadway segment and is measured in passenger cars per mile per lane (pc/mi/ln). Levels of Service for the study area freeway segments and freeway merges/diverges were calculated using HCS 7 software, which is based on the HCM, 6th Edition. Table 3 summarizes the level of service criteria for freeway segments. Table 4 summarizes the level of service criteria for freeway merging and diverging segments.

Table 3: LOS Criteria for Freeway Segments (HCM 6th Edition)

LOS	Density (pc/mi/ln)
A	≤11
B	>11-18
C	>18-26
D	>26-35
E	>35-45
F	Demand exceeds capacity OR density > 45

Exhibit 12-15, HCM 6th Edition

Table 4: LOS Criteria for Freeway Merges and Diverges (HCM 6th Edition)

LOS	Density (pc/mi/ln)
A	≤10
B	>10-20
C	>20-28
D	>28-35
E	>35
F	Demand exceeds capacity

Exhibit 14-3, HCM 6th Edition

Most freeway and merge/diverge sections throughout the study area operate at LOS C or better during all six peak hours analyzed. In general, sections closer to each of the bridges operate at unacceptable LOS D, LOS E, or LOS F during one or more peak hours. The following locations operate at LOS D, LOS E, or LOS F during one or more peak hours, consistent with field observations:

- Southbound Route 25 approaching Exit 10 (Belmont Circle) – (Fall Weekday PM – LOS D; Fall Weekday AM and Fall/Summer Saturday Midday – LOS E; Summer Weekday PM – LOS F)
- Southbound Bourne Bridge – (Summer Weekday AM, Fall Weekday PM and Fall Saturday Midday – LOS E; Fall Weekday AM, Summer Weekday PM and Summer Saturday Midday – LOS F)
- Northbound Bourne Bridge – (Fall/Summer Saturday Midday – LOS D; Fall Weekday PM – LOS E; Summer Weekday PM – LOS F)
- Southbound Route 25 Exit 10 merge – (Summer Weekday PM and Saturday Midday – LOS F)
- Southbound Route 3 approaching Exit 1A (Scenic Highway) – (Fall/Summer Weekday AM – LOS D; Fall Weekday PM and Summer Saturday Midday – LOS E; Summer Weekday PM and Fall Saturday Midday – LOS F)
- Southbound Sagamore Bridge – (Fall Weekday PM – LOS D; Fall/Summer Weekday AM and Fall Saturday Midday – LOS E; Summer Weekday PM and Summer Saturday Midday – LOS F)
- Northbound Sagamore Bridge – (Fall/Summer Weekday AM and Fall Saturday Midday – LOS E; Fall/Summer Weekday PM and Summer Saturday Midday – LOS F)
- Southbound Route 6 south of Sagamore Bridge – (Fall/Summer Weekday AM, Summer Weekday PM, and Fall Saturday Midday – LOS D; Summer Saturday Midday – LOS E)
- Northbound Route 6 south of Sagamore Bridge – (Summer Weekday AM, Fall Weekday PM, and Summer Saturday Midday – LOS D; Fall Weekday PM – LOS F)
- Southbound Route 3 Diverge to Exit 1A – (Summer Weekday PM – LOS F)
- Northbound Route 3 Diverge to Exit 1A – (Summer Saturday Midday – LOS D)
- Northbound Route 6 Diverge to Cranberry Highway – (Fall/Summer Weekday PM – LOS D)
- Northbound Route 6 Merge from Cranberry Highway – (Fall Weekday PM and Summer Saturday Midday – LOS D; Summer Weekday PM – LOS F)

HCS analysis was performed for all six analysis periods at the immediate key locations north and south of Bourne Bridge and Sagamore Bridge. The capacity adjustment factors (CAF) and safety adjustment factors (SAF) were calibrated to reflect the existing operation conditions and are tabulated in Tables C-1 and C-2 which are provided in Appendix C. A graphical representation of the LOS and density results of the freeway segments and merging-diverging segments are provided in Figures 4 and 5.



Route 25 WB E□it 3 MERGE		
PERIOD	LOS	DENSITY
AM	B	16□2
PM	B	12□6
SAT	B	16□□

Route 25 WB E□it 3 DIVERGE		
PERIOD	LOS	DENSITY
AM	B	11□□
PM	B	12□3
SAT	B	11□6

Route 25 EB SEGMENT		
PERIOD	LOS	DENSITY
AM	E	36□6
PM	D	3□□5
SAT	E	3□□□

Route 25 WB SEGMENT		
PERIOD	LOS	DENSITY
AM	B	11□□
PM	B	13□5
SAT	A	11□0

Route 25 EB E□it 3 DIVERGE		
PERIOD	LOS	DENSITY
AM	B	10□□
PM	B	13□□
SAT	B	13□□

Route 25 EB E□it 3 MERGE		
PERIOD	LOS	DENSITY
AM	B	13□□
PM	B	15□□
SAT	B	13□□

Route 25 EB E□it 10 DIVERGE		
PERIOD	LOS	DENSITY
AM	B	12□1
PM	B	15□□
SAT	B	1□□1

Route 25 WB E□it 10 MERGE		
PERIOD	LOS	DENSITY
AM	B	1□□3
PM	B	18□6
SAT	B	16□0

Route 25 WB E□it 10 DIVERGE		
PERIOD	LOS	DENSITY
AM	A	□1
PM	B	16□2
SAT	B	1□□3

Route 25 EB E□it 10 MERGE		
PERIOD	LOS	DENSITY
AM	C	20□□
PM	B	1□□□
SAT	C	22□□

Route 28 NB Bridge SEGMENT		
PERIOD	LOS	DENSITY
AM	C	22□□
PM	E	□1□1
SAT	D	2□□□

Route 28 SB Bridge SEGMENT		
PERIOD	LOS	DENSITY
AM	F	□5□0
PM	E	36□2
SAT	E	38□□

Route 28 SB SEGMENT		
PERIOD	LOS	DENSITY
AM	C	20□3
PM	B	1□□2
SAT	B	16□5

Route 28 NB SEGMENT		
PERIOD	LOS	DENSITY
AM	B	15□8
PM	B	1□□0
SAT	B	16□6

Route 28 SB - Route 151 DIVERGE		
PERIOD	LOS	DENSITY
AM	B	1□□□
PM	B	1□□3
SAT	B	16□□

Route 28 NB - Route 151 MERGE		
PERIOD	LOS	DENSITY
AM	C	20□3
PM	B	18□□
SAT	C	22□0

Route 28 SB - Route 151 MERGE		
PERIOD	LOS	DENSITY
AM	C	22□□
PM	B	1□□6
SAT	C	20□1

Route 28 NB - Route 151 DIVERGE		
PERIOD	LOS	DENSITY
AM	B	1□□1
PM	B	15□5
SAT	B	1□□8

Route 3 SB SEGMENT		
PERIOD	LOS	DENSITY
AM	D	2□□2
PM	E	3□□□
SAT	F	□5□0

Route 3 NB SEGMENT		
PERIOD	LOS	DENSITY
AM	B	11□5
PM	B	16□0
SAT	B	1□□□

Route 3 NB E□it 1 MERGE		
PERIOD	LOS	DENSITY
AM	B	13□3
PM	B	1□□1
SAT	B	18□□

Route 3 SB E□it 1A DIVERGE		
PERIOD	LOS	DENSITY
AM	B	11□5
PM	B	1□□□
SAT	B	16□□

Route 3 NB E□it 1B DIVERGE		
PERIOD	LOS	DENSITY
AM	A	6□□
PM	C	21□2
SAT	B	18□5

Route 3 NB E□it 1A DIVERGE		
PERIOD	LOS	DENSITY
AM	B	1□□1
PM	C	26□6
SAT	C	22□□

Route 6 SB Bridge SEGMENT		
PERIOD	LOS	DENSITY
AM	E	□1□□
PM	D	32□6
SAT	E	38□6

Route 6 NB Bridge SEGMENT		
PERIOD	LOS	DENSITY
AM	E	35□□
PM	F	□5□0
SAT	E	□0□5

US 6 WB E□it 55 MERGE		
PERIOD	LOS	DENSITY
AM	C	22□□
PM	D	28□□
SAT	C	2□□□

US 6 EB E□it 55 DIVERGE		
PERIOD	LOS	DENSITY
AM	B	20□0
PM	C	21□1
SAT	C	2□□□

US 6 WB E□it 55 DIVERGE		
PERIOD	LOS	DENSITY
AM	B	1□□2
PM	D	28□2
SAT	C	20□3

US 6 WB E□it 5□ MERGE		
PERIOD	LOS	DENSITY
AM	B	1□□0
PM	C	26□3
SAT	B	1□□3

US 6 WB E□it 61 MERGE		
PERIOD	LOS	DENSITY
AM	B	16□2
PM	C	2□□1
SAT	C	23□□

US 6 EB E□it 55 MERGE		
PERIOD	LOS	DENSITY
AM	C	2□□3
PM	C	22□□
SAT	C	2□□1

US 6 WB SEGMENT		
PERIOD	LOS	DENSITY
AM	C	20□5
PM	D	30□□
SAT	C	20□□

US 6 WB E□it 5□DIVERGE		
PERIOD	LOS	DENSITY
AM	B	11□8
PM	B	20□0
SAT	B	1□□6

US 6 WB E□it 61 DIVERGE		
PERIOD	LOS	DENSITY
AM	B	16□1
PM	C	25□2
SAT	C	2□□□

US 6 EB SEGMENT		
PERIOD	LOS	DENSITY
AM	D	2□□□
PM	C	23□□
SAT	D	31□6

US 6 EB E□it 5□ DIVERGE		
PERIOD	LOS	DENSITY
AM	C	22□5
PM	B	18□□
SAT	C	25□8

US 6 EB E□it 5□MERGE		
PERIOD	LOS	DENSITY
AM	B	20□0
PM	B	15□2
SAT	C	21□□

US 6 EB E□it 61 DIVERGE		
PERIOD	LOS	DENSITY
AM	C	23□6
PM	B	1□□8
SAT	C	2□□6

US 6 EB E□it 61 MERGE		
PERIOD	LOS	DENSITY
AM	C	26□2
PM	B	1□□2
SAT	C	25□□

Route 3 NB E□it 3 MERGE		
PERIOD	LOS	DENSITY
AM	B	16□3
PM	B	16□6
SAT	B	1□□□

Route 3 SB E□it 3 DIVERGE		
PERIOD	LOS	DENSITY
AM	B	13□3
PM	B	13□3
SAT	B	1□□□

Route 3 NB E□it 3 DIVERGE		
PERIOD	LOS	DENSITY
AM	B	12□5
PM	B	15□□
SAT	B	18□0

Route 3 SB E□it 3 MERGE		
PERIOD	LOS	DENSITY
AM	B	16□□
PM	B	16□5
SAT	B	1□□□

Figure □: E□isting (201□) Free□ay Level of Service Summary - Fall



Route 25 WB E□it 3 MERGE		
PERIOD	LOS	DENSITY
AM	B	16□□
PM	C	20□□
SAT	B	1□□8

Route 25 WB E□it 3 DIVERGE		
PERIOD	LOS	DENSITY
AM	B	12□□
PM	B	15□8
SAT	B	1□□3

Route 25 EB SEGMENT		
PERIOD	LOS	DENSITY
AM	C	21□6
PM	F	□5□0
SAT	E	□□□□

Route 25 WB SEGMENT		
PERIOD	LOS	DENSITY
AM	B	12□0
PM	B	16□0
SAT	B	13□6

Route 25 EB E□it 3 DIVERGE		
PERIOD	LOS	DENSITY
AM	B	12□6
PM	B	16□0
SAT	B	1□□5

Route 25 EB E□it 10 DIVERGE		
PERIOD	LOS	DENSITY
AM	B	12□8
PM	B	15□1
SAT	B	1□□□

Route 25 WB E□it 10 MERGE		
PERIOD	LOS	DENSITY
AM	B	1□□3
PM	C	21□6
SAT	B	18□0

Route 25 EB E□it 3 MERGE		
PERIOD	LOS	DENSITY
AM	B	13□□
PM	B	16□1
SAT	B	15□□

Route 25 WB E□it 10 DIVERGE		
PERIOD	LOS	DENSITY
AM	B	12□6
PM	B	13□1
SAT	B	13□3

Route 25 EB E□it 10 MERGE		
PERIOD	LOS	DENSITY
AM	C	21□0
PM	F	□□5□0
SAT	F	□□5□0

Route 28 NB Bridge SEGMENT		
PERIOD	LOS	DENSITY
AM	C	2□□8
PM	F	□5□0
SAT	D	33□1

Route 28 SB Bridge SEGMENT		
PERIOD	LOS	DENSITY
AM	E	□□□□
PM	F	□5□0
SAT	F	□5□0

Route 28 SB SEGMENT		
PERIOD	LOS	DENSITY
AM	C	20□□
PM	B	1□□1
SAT	C	23□3

Route 28 NB SEGMENT		
PERIOD	LOS	DENSITY
AM	B	1□□6
PM	B	16□□
SAT	B	18□0

Route 28 SB - Route 151 DIVERGE		
PERIOD	LOS	DENSITY
AM	C	20□1
PM	B	16□□
SAT	C	22□5

Route 28 NB - Route 151 MERGE		
PERIOD	LOS	DENSITY
AM	B	18□8
PM	C	21□5
SAT	C	21□8

Route 28 SB - Route 151 MERGE		
PERIOD	LOS	DENSITY
AM	C	23□2
PM	B	20□0
SAT	C	25□□

Route 28 NB - Route 151 DIVERGE		
PERIOD	LOS	DENSITY
AM	B	16□0
PM	B	18□1
SAT	B	1□□1

Route 3 SB SEGMENT		
PERIOD	LOS	DENSITY
AM	D	32□5
PM	F	□5□0
SAT	E	□3□6

Route 3 NB SEGMENT		
PERIOD	LOS	DENSITY
AM	B	15□6
PM	C	1□□□
SAT	C	21□□

Route 3 NB E□it 1 MERGE		
PERIOD	LOS	DENSITY
AM	B	16□8
PM	C	20□5
SAT	C	22□3

Route 3 SB E□it 1A DIVERGE		
PERIOD	LOS	DENSITY
AM	B	1□□0
PM	F	□□5□0
SAT	B	10□□

Route 3 NB E□it 1B DIVERGE		
PERIOD	LOS	DENSITY
AM	B	10□□
PM	B	1□□5
SAT	B	1□□6

Route 3 NB E□it 1A DIVERGE		
PERIOD	LOS	DENSITY
AM	C	20□1
PM	C	2□□□
SAT	D	2□□1

Route 6 SB Bridge SEGMENT		
PERIOD	LOS	DENSITY
AM	E	□2□5
PM	F	□□5□0
SAT	F	□□5□0

Route 6 NB Bridge SEGMENT		
PERIOD	LOS	DENSITY
AM	E	□2□3
PM	F	□5□0
SAT	F	□5□0

US 6 WB E□it 55 MERGE		
PERIOD	LOS	DENSITY
AM	C	25□5
PM	F	□□5□0
SAT	D	33□□

US 6 EB E□it 55 DIVERGE		
PERIOD	LOS	DENSITY
AM	C	20□6
PM	B	18□□
SAT	C	23□2

US 6 WB E□it 55 DIVERGE		
PERIOD	LOS	DENSITY
AM	C	20□3
PM	D	28□□
SAT	C	25□□

US 6 WB E□it 5□ MERGE		
PERIOD	LOS	DENSITY
AM	C	23□5
PM	D	31□1
SAT	D	28□2

US 6 EB E□it 55 MERGE		
PERIOD	LOS	DENSITY
AM	C	2□□0
PM	C	25□□
SAT	D	31□0

US 6 WB SEGMENT		
PERIOD	LOS	DENSITY
AM	D	31□0
PM	D	2□□5
SAT	E	□1□1

US 6 WB E□it 5□ DIVERGE		
PERIOD	LOS	DENSITY
AM	B	1□□1
PM	C	25□3
SAT	C	2□□□

US 6 WB E□it 61 MERGE		
PERIOD	LOS	DENSITY
AM	C	20□8
PM	D	28□□
SAT	C	2□□6

US 6 WB E□it 61 DIVERGE		
PERIOD	LOS	DENSITY
AM	C	21□□
PM	D	30□0
SAT	D	2□□5

US 6 EB SEGMENT		
PERIOD	LOS	DENSITY
AM	D	26□1
PM	F	□5□0
SAT	D	33□8

US 6 EB E□it 5□ DIVERGE		
PERIOD	LOS	DENSITY
AM	C	26□2
PM	C	23□□
SAT	D	30□6

US 6 EB E□it 5□ MERGE		
PERIOD	LOS	DENSITY
AM	C	22□1
PM	B	1□□□
SAT	C	25□8

US 6 EB E□it 61 DIVERGE		
PERIOD	LOS	DENSITY
AM	C	23□5
PM	C	22□□
SAT	D	2□□0

US 6 EB E□it 61 MERGE		
PERIOD	LOS	DENSITY
AM	C	25□8
PM	C	2□□□
SAT	D	2□□□

Route 3 NB E□it 3 MERGE		
PERIOD	LOS	DENSITY
AM	B	18□0
PM	C	20□8
SAT	C	2□□6

Route 3 SB E□it 3 DIVERGE		
PERIOD	LOS	DENSITY
AM	B	13□□
PM	B	1□□0
SAT	B	13□2

Route 3 NB E□it 3 DIVERGE		
PERIOD	LOS	DENSITY
AM	B	16□□
PM	B	1□□□
SAT	C	22□8

Route 3 SB E□it 3 MERGE		
PERIOD	LOS	DENSITY
AM	B	18□1
PM	B	1□□5
SAT	B	15□□

Figure 5: E□isting (201□) Free□ay Level of Service Summary - Summer

VISSIM 11 Analysis

Existing conditions were modeled for each of the six peak hours identified above using PTV's VISSIM traffic microsimulation software for all key intersections, rotaries and traffic circles, and freeway segments within a 2-mile radius of the Bourne and Sagamore Bridges. Each of the models were run for 60 minutes to represent each peak hour, with a 30-minute seeding time. Each of the models were run 10 times, and the model results presented in Tables B-3 through B-6 in Appendix B reflect the averages of those 10 runs. Measures of Effectiveness (MOEs) that were output from each model and tabulated in Tables B-3 to B-6 include the following:

- Vehicle travel time
- Speed
- Processed volumes
- Density

Models were calibrated by comparing queueing observed in the model with both queue observations from field visits and using Google Maps "Typical Traffic Conditions" feature. In addition, volumes processing through the model were compared to the model inputs (from the 2019 Base Year traffic volumes) to confirm the appropriate number of vehicles were processing through the model. Finally, travel times for vehicles in the model were compared with typical real-world travel time information from INRIX. Factors were tweaked in the model to mimic real-world driving behavior to the extent possible and to calibrate the model such that the above data points (VISSIM travel times vs. INRIX travel times; VISSIM processed volumes vs. balanced 2019 traffic volume flow maps; and VISSIM queue lengths vs. Google Maps Typical Traffic Conditions) were comparable to each other. Comparison of model outputs to real-world data are presented in Tables B-3 through B-6 in Appendix B. Factors that were modified during the calibration process are presented in Table C-3 of Appendix C.

Processed volumes indicate the number of vehicles that were able to move through the study area in an hour, which is based on the demand and capacity. A comparison between VISSIM processed volumes and 2019 existing traffic volume flow maps is provided in Table B-5 of Appendix B. Locations in which the VISSIM model processes less than 80% of the expected volume based on 2019 traffic volume flow maps are highlighted in Table B-5. Such differences could be expected in a microsimulation model of this size and could be attributed to upward balancing of traffic volumes that are unable to process through congested intersections that cannot process that much volume.

Travel times from the VISSIM models along major travel routes in the study area (Routes 3, 6, 25, 28, Scenic Highway, and Sandwich Road) were selected to compare with typical travel times from INRIX; the comparisons are presented in Table B-3 of Appendix B. Locations in which the VISSIM model travel times are more than 4 minutes different from INRIX travel times are highlighted in Table B-3.

While the majority of VISSIM model outputs closely reflect INRIX data, qualitative queue lengths from Google Maps, and other real-world data collected, some model results vary from collected data due to traffic model limitations, different times of year in which data were collected, and wide variations in traffic operations from day-to-day and week-to-week. INRIX travel time data were an average of Fridays in August and October 2019 to represent Summer and Fall weekday travel times, respectively, and an average of Saturdays in August and October 2019 to represent Summer and Fall Saturday travel times, respectively. INRIX travel time data were somewhat inconsistent with field conditions and observed congestion levels.

For example, while traffic congestion is worse during Summer peak hours, travel times from INRIX for the Fall Weekday PM peak hour were longer than their Summer Weekday PM peak hour travel times on the same segments. However, the VISSIM models represent an average of all the datasets and represent a typical weekday and Saturday during the Fall and Summer seasons. These models and their results best represent base year conditions that could be used as a baseline to assess future conditions with various build alternatives.

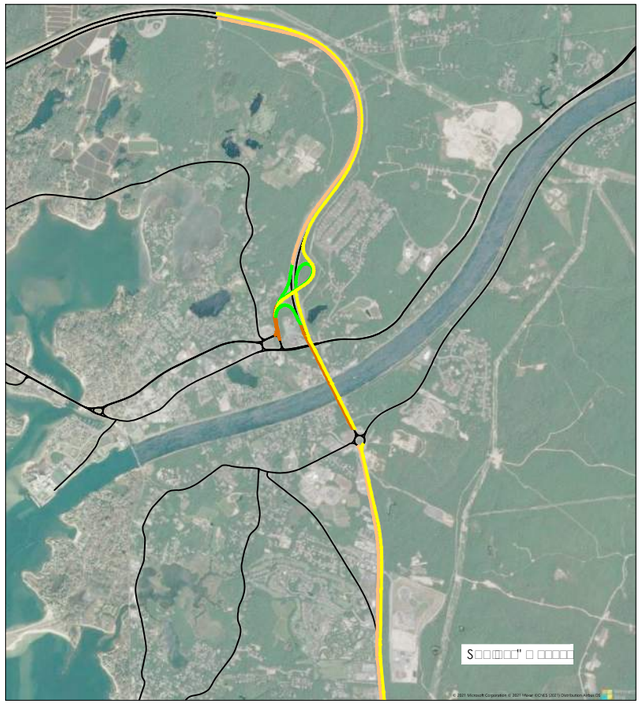
The vehicle density criteria for each level of service letter grade for freeway sections are presented in Tables 3 and 4. The densities of major freeway segments from each of the VISSIM models and their associated LOS grades are presented in Table B-6. A graphical representation of the levels of service for these major freeway sections are presented in Figures 6, 7 and 8. As expected, the approaches to both bridges from both directions operate at poor levels of service during all peak hours analyzed

During the Fall and Summer Weekday AM peak hours, the southbound side of the Bourne Bridge operates at LOS F due to congestion at the Bourne Rotary. Southbound Route 25 approaching the exit for Belmont Circle operates at LOS D during the Fall Weekday AM peak hour, and LOS E during the Summer Weekday PM peak hour. Northbound Route 28 approaching the Bourne Rotary operates at LOS D during both Fall and Summer Weekday AM peak hours. Westbound Route 6 operates at LOS F during the Fall and Summer Weekday AM peak hours approaching the northbound Sagamore Bridge; southbound Route 3 approaching the Sagamore Bridge operates at LOS F and LOS E during the Fall and Summer Weekday AM peak hours, respectively. Both directions of the Sagamore Bridge operate at LOS F during the Fall and Summer Weekday AM peak hours.

During the Fall and Summer Weekday PM peak hours, the southbound side of the Bourne Bridge and southbound Route 25 approaching the exit for Belmont Circle operate at LOS F due to congestion at the Bourne Rotary. Northbound Route 28 approaching the Bourne Rotary also operates at LOS F during both Fall and Summer Weekday PM peak hours. Westbound Route 6 operates at LOS F during the Fall and Summer Weekday PM peak hours approaching the northbound Sagamore Bridge; southbound Route 3 approaching the Sagamore Bridge operates at LOS E and LOS F during the Fall and Summer Weekday PM peak hours, respectively. Both directions of the Sagamore Bridge operate at LOS F during the Fall and Summer Weekday PM peak hours.

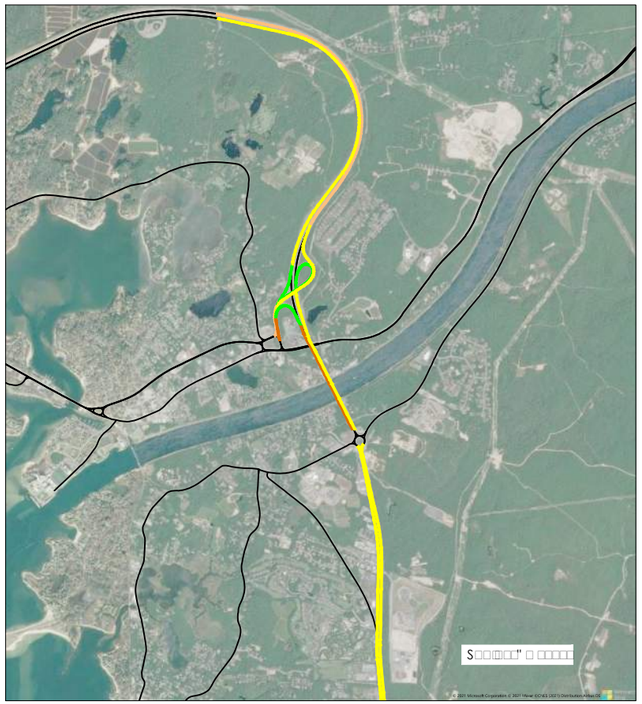
During the Fall and Summer Saturday Midday peak hours, the southbound side of the Bourne Bridge operates at LOS F due to congestion at the Bourne Rotary. Southbound Route 25 approaching the exit for Belmont Circle operates at LOS E during the Fall Saturday Midday peak hour and at LOS F during the Summer Saturday Midday peak hour, Northbound Route 28 approaching the Bourne Rotary operates at LOS F during both Fall and Summer Saturday Midday peak hours. Westbound Route 6 and Southbound Route 3 approaching the Sagamore Bridge operate at LOS F during the Fall and Summer Saturday Midday peak hours. Both directions of the Sagamore Bridge also operate at LOS F during the Fall and Summer Saturday Midday peak hours.

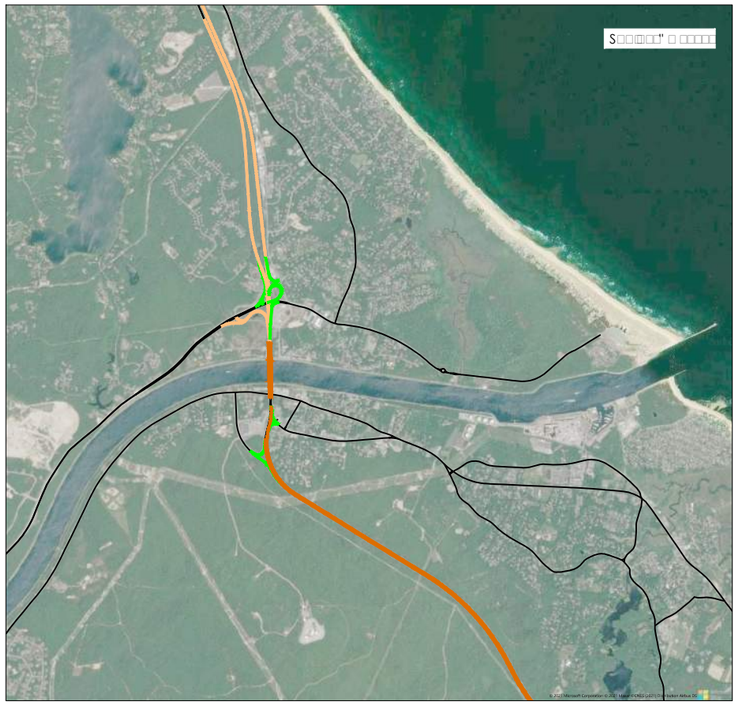
FALL WEEKDAY A□M□PEAK HOUR





SUMMER WEEKDAY A□M□PEAK HOUR





N

NAD 83

LEGEND

LOS	Density (□c□mi□n)
A□B□C	□26 for Free□ay □28 for Merge-Diverge
D	26 - 35 for Free□ay 28 - 35 for Merge-Diverge
E	35-□5
F	□5-80
F	80-100
F	□100

NOTE:

1□ Figures are re□resentative of t□e density of ve□icles □er lane on eac□ □articular road□ay segment identified in Ta□le B-6 and do not re□resent □ueue lengt□s during □eriods of traffic congestion□

2□ Queues during □ea□ □ours may □e s□orter or may e□tend □eyond t□e segments s□o□n

Figure 6

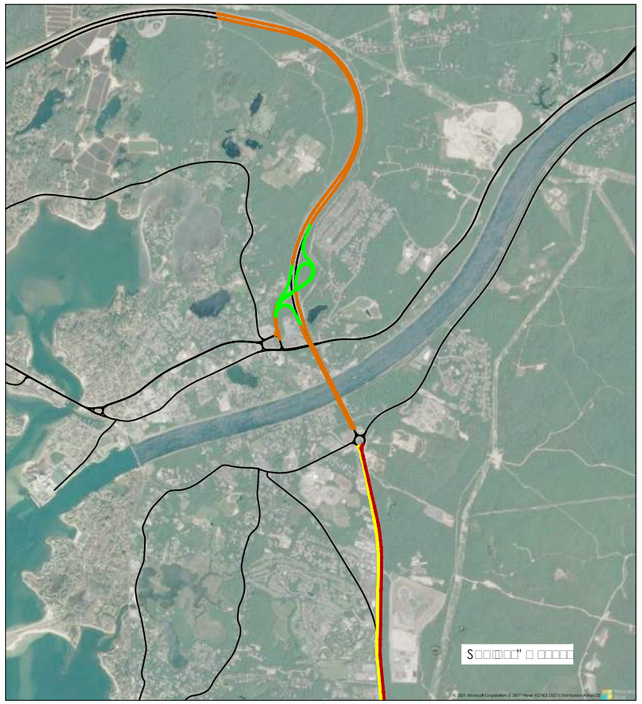
MassDOT

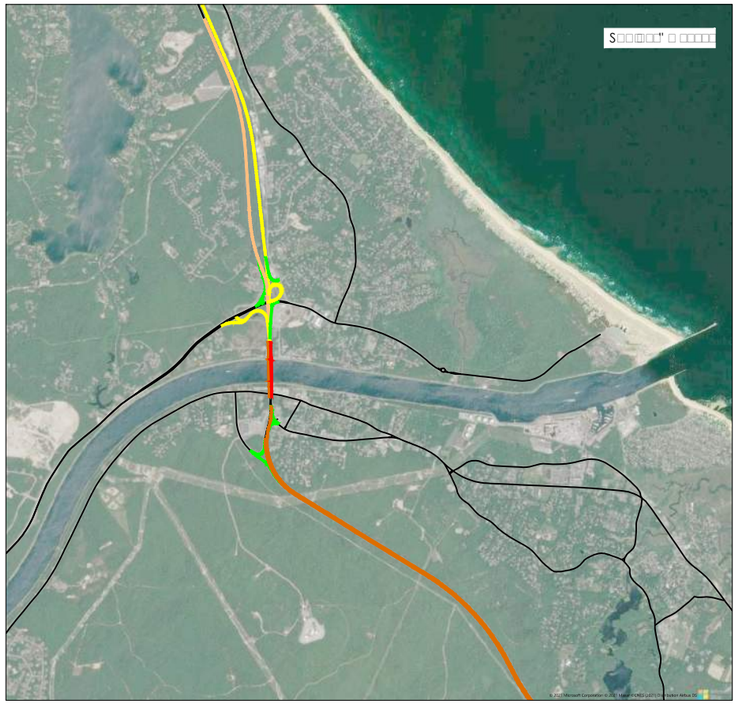
Ca□e Cod Canal Program Management

Bourne Bridge and Sagamore Bridge Density□
Fall and Summer AM
Pea□ Hour

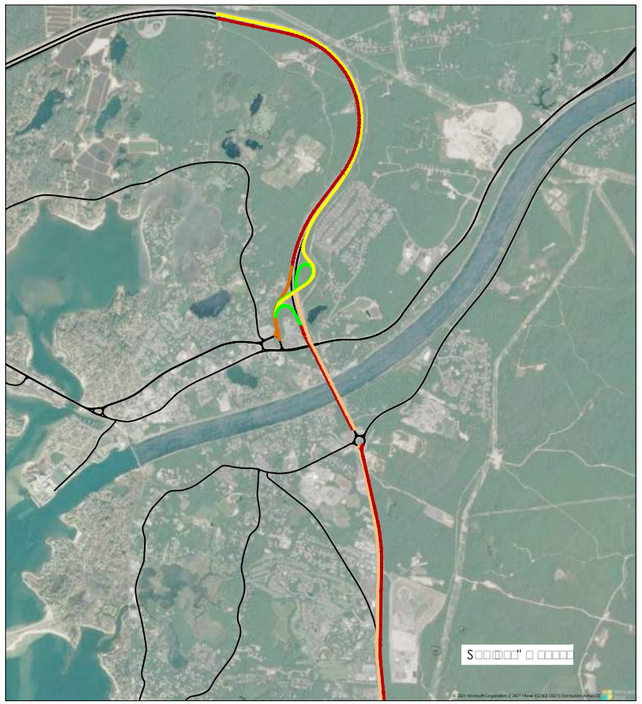
201□ E□isting Conditions

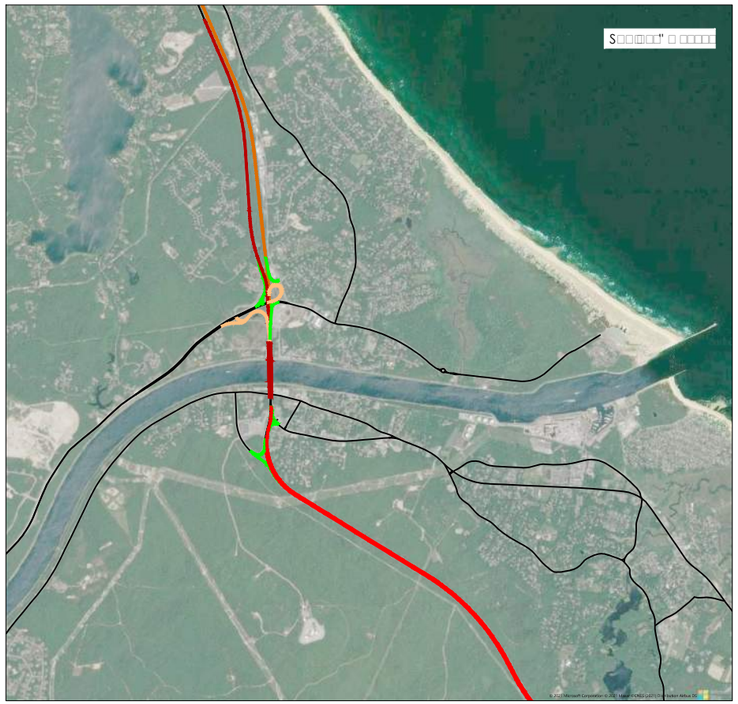
FALL WEEKDAY P□M□PEAK HOUR





SUMMER WEEKDAY P□M□PEAK HOUR





N

NAD 83

LEGEND

LOS	Density (□c□mi□n)
A□B□C	□26 for Free□ay □28 for Merge-Diverge
D	26 - 35 for Free□ay 28 - 35 for Merge-Diverge
E	35-□5
F	□5-80
F	80-100
F	□100

NOTE:

1□ Figures are re□resentative of t□e density of ve□icles □er lane on eac□ □articular road□ay segment identified in Ta□le B-6 and do not re□resent □ueue lengt□s during □eriods of traffic congestion□

2□ Queues during □ea□ □ours may □e s□orter or may e□tend □eyond t□e segments s□o□n

Figure □

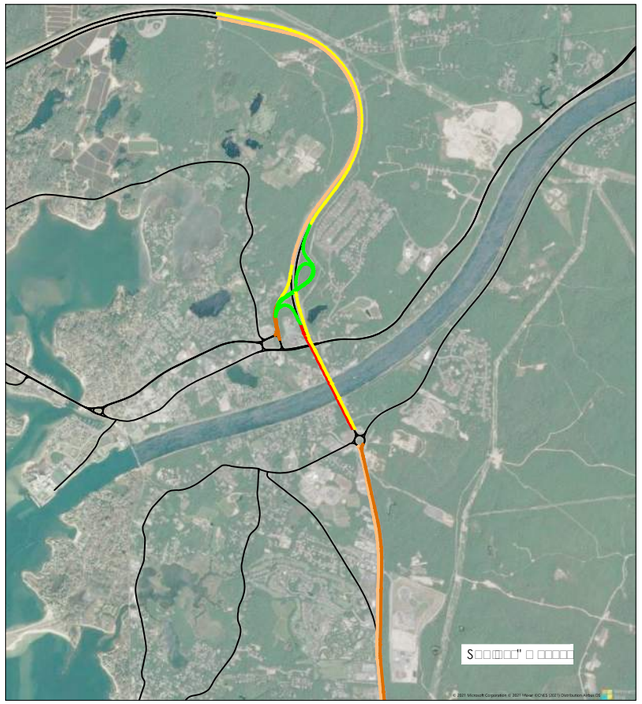
MassDOT

Ca□e Cod Canal Program Management

Bourne Bridge and Sagamore Bridge Density□
Fall and Summer PM
Pea□ Hour

201□ E□isting Conditions

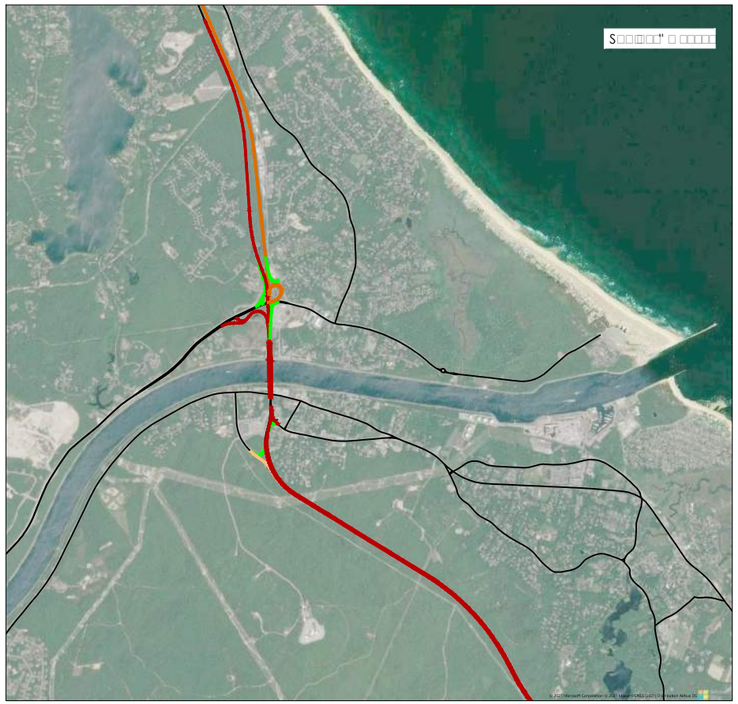
FALL SAT PEAK HOUR





SUMMER SAT PEAK HOUR





N

NAD 83

LEGEND

LOS	Density (□c□mi□n)
A□B□C	□26 for Free□ay □28 for Merge-Diverge
D	26 - 35 for Free□ay 28 - 35 for Merge-Diverge
E	35-□5
F	□5-80
F	80-100
F	□100

NOTE:

1□ Figures are re□resentative of t□e density of ve□icles □er lane on eac□ □articular road□ay segment identified in Ta□le B-6 and do not re□resent □ueue lengt□s during □eriods of traffic congestion□

2□ Queues during □ea□ □ours may □e s□orter or may e□tend □eyond t□e segments s□o□n

Figure 8

MassDOT

Ca□e Cod Canal Program Management

Bourne Bridge and Sagamore Bridge Density□
Fall and Summer SAT
Pea□ Hour

201□ E□isting Conditions

Appendix A

2019 Base Year Traffic Volumes

MassDOT

Cape Cod Canal Program Management

Fall Weekday AM Peak
2019 Existing Conditions

MassDOT

Cape Cod Canal Program Management

Fall Weekday PM Peak
2019 Existing Conditions

MassDOT

Cape Cod Canal Program Management

Fall SAT Peak
2019 Existing Conditions

MassDOT

Cape Cod Canal Program Management

Summer Weekday AM Peak
2019 Existing Conditions

MassDOT

Cape Cod Canal Program Management

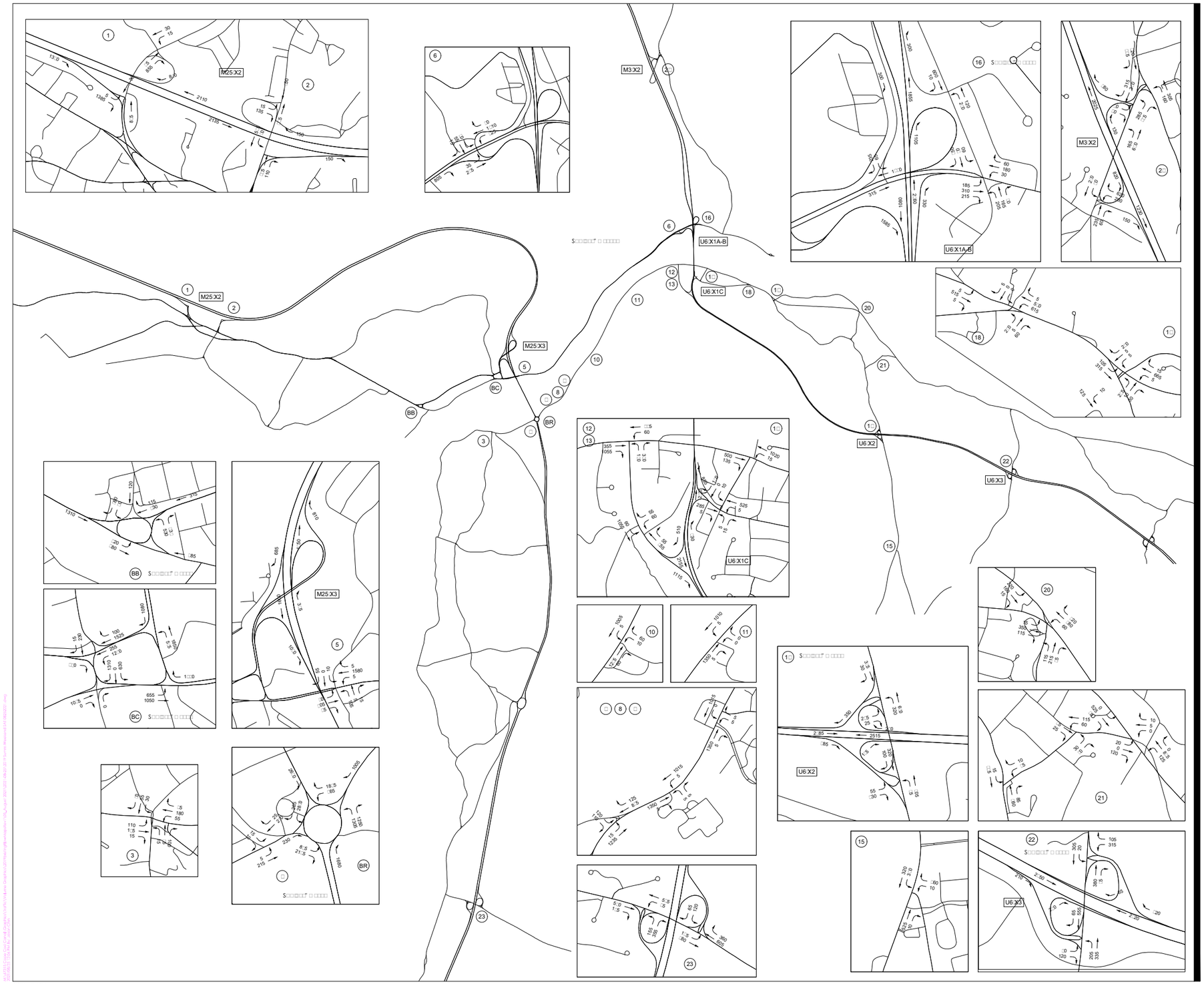
Summer Weekday PM Peak
2019 Existing Conditions



MassDOT

Cape Cod Canal Program Management

Summer SAT Peak
2019 Existing Conditions



Appendix B

Results Summary Tables

SYNCHRO and SIDRA

Table B-1: Synchro and SIDRA Results Summary - 2019 Existing Fall

Intersection	2019 Existing Fall AM					2019 Existing Fall PM					2019 Existing Fall MID				
	LOS	Delay (sec)	v/c Ratio	50% Queue (feet)	95% Queue (feet)	LOS	Delay (sec)	v/c Ratio	50% Queue (feet)	95% Queue (feet)	LOS	Delay (sec)	v/c Ratio	50% Queue (feet)	95% Queue (feet)
1:: Maple Springs Rd / Route 25 NB On-Ramp	A	0.3				A	0.2				A	0.1			
Maple Springs Rd NB (thru)	A	0.0	0.01	-	0	A	0.0	0.03	-	0	A	0.0	0.02	-	0
Maple Springs Rd NB (thru/right)	A	0.0	0.42	-	0	A	0.0	0.35	-	0	A	0.0	0.52	-	0
Maple Springs Rd SB (left/thru)	A	2.5	0.02	-	1	A	1.9	0.01	-	1	A	1.4	0.01	-	1
2:: Maple Springs Rd / Route 25 SB Off-Ramp	A	5.5				A	7.8				A	7.0			
Route 25 SB Off-Ramp EB (left)	B	11.7	0.04	-	87	B	10.7	0.03	-	131	B	12.5	0.05	-	148
Route 25 SB Off-Ramp EB (right)	B	13.0	0.54	-	87	B	14.8	0.66		131	C	16.1	0.68		148
Maple Springs Rd NB (thru)	A	0.0	0.00	-	0	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Maple Springs Rd NB (thru)	A	0.0	0.00	-	0	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Maple Springs Rd SB (thru)	A	0.0	0.00	-	0	A	0.0	0.00	-	0	A	0.0	0.00	-	0
3:: Glen Charlie Road / Route 25 NB Off-Ramp	A	6.5				A	3.6				A	1.9			
Route 25 NB Off-Ramp EB (left)	B	14.1	0.02	-	97	C	16.2	0.20	-	27	C	17.3	0.05	-	21
Route 25 NB Off-Ramp EB (right)	C	20.1	0.60		97	B	11.6	0.27		27	B	12.9	0.22		21
Glen Charlie Rd NB (thru)	A	0.0	0.00	-	0	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Glen Charlie Rd SB (thru)	A	0.0	0.00	-	0	A	0.0	0.00	-	0	A	0.0	0.00	-	0
4:: Glen Charlie Road / Route 25 SB On-Ramp	A	1.4				A	0.4				A	0.5			
Glen Charlie Rd NB (thru)	A	0.0	0.12	-	0	A	0.0	0.26	-	0	A	0.0	0.24	-	0
Glen Charlie Rd NB (right)	A	0.0	0.17	-	0	A	0.0	0.06	-	0	A	0.0	0.06	-	0
Glen Charlie Rd SB (left/thru)	A	2.3	0.09	-	8	A	0.9	0.03	-	2	A	0.9	0.03	-	3
5:: Buzzards Bay Rotary	A	7.3				A	8.2				B	12.6			
Main Street (Route 6) EB (left)	A	8.1	0.42	-	42	A	7.0	0.33	-	30	A	9.1	0.48	-	55
Main Street (Route 6) EB (left/thru)	A	8.1	0.42	-	42	A	7.0	0.33	-	30	A	9.1	0.48	-	52
Main Street WB (thru/right)	A	6.9	0.26	-	20	A	9.0	0.45	-	43	C	20.3	0.77	-	158
Lincoln Avenue SB (left/thru/right)	A	6.1	0.12	-	7	A	8.5	0.18	-	12	A	9.7	0.23	-	16
Buzzards Bay Bypass (Route 6) SWB (left)	A	6.0	0.18	-	14	A	9.1	0.38	-	33	A	9.3	0.3	-	24
Buzzards Bay Bypass (Route 6) SWB (left/right)	A	5.9	0.18	-	13	A	9.0	0.38	-	31	A	9.0	0.3	-	23
6:: Scenic Highway (Route 6) / Main Street (Route 6) / Nightingale Road / Andy Olivia Drive	B	14.7				B	17.9				B	16.7			
Main Street (Route 6) EB (left/thru)	A	6.2	0.70	162	207	A	7.1	0.74	132	157	A	6.7	0.69	139	226
Main Street (Route 6) EB (thru/right)	A	6.2	0.70	162	207	A	7.1	0.74	132	157	A	6.7	0.69	139	226
Scenic Hwy (Route 6) WB (left/thru)	B	19.9	0.84	420	535	C	24.6	0.91	495	#677	C	21.6	0.85	394	#626
Scenic Hwy (Route 6) WB (thru/right)	B	19.9	0.84	420	535	C	24.6	0.91	495	#677	C	21.6	0.85	394	#626
Andy Olivia Dr NB (left/thru/right)	D	39.5	0.02	0	0	D	39.5	0.03	0	0	D	48.6	0.65	50	67
Nightingale Pond Rd SB (left/thru)	D	40.8	0.28	18	46	D	40.1	0.15	10	28	D	38.5	0.18	14	33
Nightingale Pond Rd SB (right)	D	39.5	0.05	0	14	D	39.5	0.03	0	0	D	37.8	0.06	0	13
7:: Sandwich Road / Trowbridge Road / County Road / Shore Road	B	12.0				F	254.9				B	10.7			
Shore Rd EB (left/thru/right)	A	7.8	0.07	-	6	A	8.3	0.05	-	4	A	7.9	0.07	-	6
Trowbridge Rd WB (left/thru/right)	A	7.8	0.04	-	3	A	8.0	0.09	-	7	A	7.7	0.03	-	2
County Rd NB (left/thru/right)	C	18.1	0.46	-	60	F	142.9	1.16	-	345	C	18.1	0.45	-	56
Sandwich Rd SB (left/thru/right)	D	31.0	0.57	-	91	F	1122.2	3.26	-	645	D	28.2	0.57	-	89
8:: Trowbridge Rd./Veterans Way	A	0.7				A	2.9				A	0.7			
Trowbridge Rd EB (left/thru/right)	A	8.0	0.01	-	0	A	7.9	0.02	-	1	A	8.6	0.01	-	1
Trowbridge Rd WB (left/thru/right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Veterans Way NB (left/thru/right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Driveway SB (left/thru/right)	B	13.4	0.09	-	7	C	18.4	0.32	-	34	C	17.1	0.12	-	10
9:: Bourne Rotary	F	521.0				F	419.8				F	762.5			
General MacArthur Boulevard NB (left/thru)	F	360.4	1.75	-	4706	F	597.7	2.28	-	6836	F	489.6	2.04	-	5755
General MacArthur Boulevard NB (right)	C	16.3	0.62	-	101	C	22.9	0.72	-	132	B	13.1	0.48	-	61
Sandwich Road WB (left/thru)	F	236.0	1.44	-	1849	C	23.0	0.66	-	98	F	117.7	1.16	-	904
Sandwich Road WB (right)	B	10.0	0.13	-	10	F	311.9	1.63	-	2831	B	14.2	0.41	-	43
Route 28 (Bourne Bridge) SB (left/thru)	F	941.9	3.05	-	11668	F	594.7	2.28	-	8618	F	1407.9	4.09	-	16858
Route 28 (Bourne Bridge) SB (right)	A	6.5	0.09	-	8	A	6.1	0.15	-	14	C	21.3	0.72	-	139
Trowbridge Road EB (left/thru/right)	F	136.4	1.18	-	810	F	206.2	1.36	-	1371	F	80.2	1	-	325

Table B-1: Synchro and SIDRA Results Summary - 2019 Existing Fall

Intersection	2019 Existing Fall AM					2019 Existing Fall PM					2019 Existing Fall MID				
	LOS	Delay (sec)	v/c Ratio	50% Queue (feet)	95% Queue (feet)	LOS	Delay (sec)	v/c Ratio	50% Queue (feet)	95% Queue (feet)	LOS	Delay (sec)	v/c Ratio	50% Queue (feet)	95% Queue (feet)
10:: Sandwich Road / Bourne Rotary Connector	F	103.7				F	352.0				E	79.6			
Sandwich Rd EB (left/right)	F	648.6	2.29	-	717	F	1996.4	5.25	-	Err	F	712.8	2.38	-	565
Bourne Rotary Connector NB (left/thru)	A	9.4	0.01	-	0	A	0.0	0.00	-	0	A	9.1	0.01	-	1
Sandwich Rd SB (thru/right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0	A	0.0	0.00	-	0
11:: Sandwich Road / Upper Cape Cod Technical School Driveway	D	42.5				F	181.3				A	0.4			
Cape Cod Technical School Driveway WB (left/right)	F	630.1	2.08	-	335	F	2709.6	6.44	-	Err	F	59.0	0.16	-	13
Sandwich Rd NB (thru/right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Sandwich Rd SB (left)	B	12.3	0.22	-	21	B	13.5	0.13	-	11	B	12.3	0.01	-	1
Sandwich Rd SB (thru)	A	0.0	0.00	-	0	A	0.0	0.00	-	0	A	0.0	0.00	-	0
12:: Sandwich Road / Harbor Lights Road	A	0.3				A	1.1				A	1.5			
Harbor Lights Rd WB (left/right)	E	40.4	0.12	-	10	F	175.6	0.48	-	41	F	95.7	0.48	-	49
Sandwich Rd NB (thru/right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Sandwich Rd SB (left/thru)	B	10.3	0.01	-	1	B	12.4	0.01	-	1	B	12.1	0.00	-	1
13:: Sandwich Road / Jefferson Road (Tech Drive)	A	0.0				A	0.0				A	0.1			
Jefferson Rd (Tech Dr) WB (left/right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0	D	26.9	0.05	-	4
Sandwich Rd NB (thru/right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Sandwich Rd SB (left/thru)	A	0.0	0.00	-	0	A	0.0	0.00	-	0	A	0.0	0.00	-	0
14:: Sandwich Road / Jarvis Road	A	0.5				A	0.5				A	0.3			
Jarvis Rd WB (left/right)	F	70.7	0.19	-	15	F	99.5	0.25	-	20	D	28.1	0.11	-	9
Sandwich Rd NB (thru/right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Sandwich Rd SB (left/thru)	B	10.5	0.01		1	B	12.4	0.01	-	1	B	12.3	0.01	-	1
15:: Sandwich Road (Route 6 Bypass) / Mid-Cape Connector	B	11.4				B	12.4				B	10.1			
Sandwich Rd EB (thru)	C	21.3	0.69	133	234	C	21.0	0.71	159	266	C	20.2	0.74	156	309
Sandwich Rd EB (right)	A	0.9	0.44	0	0	A	1.7	0.60	0	0	A	1.6	0.58	0	0
Sandwich Rd WB (left)	A	8.6	0.29	22	46	A	8.8	0.40	30	56	A	8.0	0.36	22	54
Sandwich Rd WB (thru)	A	9.0	0.48	106	180	B	14.0	0.78	234	360	A	6.9	0.45	87	186
Mid-Cape Connector NB (left)	C	24.2	0.72	118	#241	C	26.6	0.71	115	#265	C	23.1	0.59	78	169
Mid-Cape Connector NB (right)	B	10.9	0.16	0	29	B	14.4	0.41	33	118	B	14.2	0.32	22	77
16:: Mid-Cape Connector / Factory Outlet Way	B	11.1				B	15.2				B	14.5			
Factory Outlet Way (Market Basket Driveway) WB (left)	C	26.9	0.10	5	17	C	30.0	0.25	30	52	C	30.8	0.24	26	51
Factory Outlet Way (Market Basket Driveway) WB (left)	C	26.9	0.10	5	17	C	30.0	0.25	30	52	C	30.8	0.24	26	51
Factory Outlet Way (Market Basket Driveway) WB (right)	B	14.0	0.15	20	46	B	16.8	0.37	79	111	B	14.5	0.30	63	96
Mid-Cape Connector NB (thru)	B	17.1	0.68	170	303	C	21.8	0.65	207	#381	B	19.2	0.43	115	205
Mid-Cape Connector NB (right)	A	7.1	0.05	0	12	A	7.1	0.07	0	18	A	8.7	0.06	0	19
Mid-Cape Connector SB (left)	C	25.7	0.46	47	111	C	35.0	0.64	93	149	D	35.1	0.72	129	180
Mid-Cape Connector SB (thru)	A	3.4	0.31	47	79	A	5.4	0.36	84	113	A	5.0	0.36	82	95
Mid-Cape Connector SB (thru)	A	3.4	0.31	47	79	A	5.4	0.36	84	113	A	5.0	0.36	82	95
17:: Herring Pond Road / State Road	E	42.9				F	178.9				F	358.3			
Herring Pond Rd EB (left/right)	F	92.4	1.06	-	758	F	362.2	1.73	-	1316	F	625.0	2.33	-	Err
State Rd NB (left/thru)	A	7.9	0.12	-	10	A	7.8	0.08	-	7	A	8.0	0.10	-	8
State Rd SB (thru/right)	A	0.0	0.00		0	A	0.0	0.00	-	0	A	0.0	0.00	-	0
18:: Herring Pond Road / Route 3 NB Ramps	A	7.4				B	12.0				F	56.8			
Route 3 NB Ramps EB (left/right)	E	45.3	0.75	-	175	F	53.8	0.87	-	257	F	455.1	1.82	-	426
Herring Pond Rd NB (left/thru)	A	9.0	0.18	-	16	A	8.3	0.05	-	4	A	8.7	0.14	-	12
Herring Pond Rd SB (thru)	A	0.0	0.00	-	0	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Herring Pond Rd SB (right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0	A	0.0	0.00	-	0
19:: Herring Pond Road / Route 3 SB Ramps	C	35.0				E	38.5				F	374.7			
Route 3 SB Ramps WB (left/right)	F	89.3	1.06	-	528	F	99.0	1.10	-	579	F	718.7	2.53	-	1945
Herring Pond Rd NB (thru/right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Herring Pond Rd SB (left/thru)	A	8.2	0.18	-	17	A	8.1	0.15	-	13	A	8.5	0.17	-	15

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Intersection	2019 Existing Fall AM					2019 Existing Fall PM					2019 Existing Fall MID				
	LOS	Delay (sec)	v/c Ratio	50% Queue (feet)	95% Queue (feet)	LOS	Delay (sec)	v/c Ratio	50% Queue (feet)	95% Queue (feet)	LOS	Delay (sec)	v/c Ratio	50% Queue (feet)	95% Queue (feet)
20:: Scenic Highway (Route 6) / Church Lane / Route 6 SB On-Ramp	C	22.1				C	20.7				C	23.3			
Scenic Hwy (Route 6) EB (left)	D	54.9	0.44	10	36	D	45.0	0.53	39	80	D	44.1	0.44	29	80
Scenic Hwy (Route 6) EB (thru)	C	26.6	0.97dr	304	#591	C	24.0	0.87dr	320	437	C	29.1	0.98dr	228	413
Scenic Hwy (Route 6) EB (thru/right)	C	26.6	0.97dr	304	#591	C	24.0	0.87dr	320	437	C	29.1	0.98dr	228	413
Scenic Hwy (Route 6) WB (left)	E	56.2	0.85	195	316	D	46.5	0.77	149	247	D	39.0	0.78	209	381
Scenic Hwy (Route 6) WB (thru)	A	8.9	0.85	126	305	B	11.3	0.55	209	313	B	11.9	0.50	189	285
Scenic Hwy (Route 6) WB (thru)	A	8.9	0.85	126	305	B	11.3	0.55	209	313	B	11.9	0.50	189	285
Scenic Hwy (Route 6) WB (thru/right)	A	8.9	0.51	126	305	B	11.3	0.55	209	313	B	11.9	0.50	189	285
Church Lane SB (left/thru/right)	D	52.4	0.66	76	151	D	43.7	0.56	56	99	D	42.4	0.61	80	126
21:: Scenic Highway (Route 6) & Route 3 SB Off-Ramp	C	29.5				D	38.6				C	26.2			
Scenic Hwy (Route 6) EB (thru)	B	10.7	0.44	176	247	B	13.6	0.57	236	319	B	12.5	0.39	129	183
Scenic Hwy (Route 6) WB (thru)	C	23.2	0.90	606	555	B	19.1	0.81	428	515	B	18.8	0.78	345	387
Scenic Hwy (Route 6) WB (thru)	C	23.2	0.90	606	555	B	19.1	0.81	428	515	B	18.8	0.78	345	387
Route 3 Off-Ramp SB (left/right)	F	82.3	0.98	~315	#529	F	124.2	1.14	~433	#693	E	56.9	0.95	285	#640
22:: Meetinghouse Lane / State Road / Canal Street	D	51.1				E	63.9				E	73.2			
Meetinghouse Ln EB (left)	C	27.5	0.69	199	#624	C	34.1	0.88	265	#807	D	54.0	0.90	180	#472
Meetinghouse Ln EB (thru)	B	19.2	0.23	74	202	C	21.7	0.50	121	#479	D	38.9	0.52	164	304
Meetinghouse Ln EB (right)	B	19.1	0.21	0	75	B	16.8	0.17	0	63	C	32.2	0.36	0	65
Meetinghouse Ln WB (left)	D	37.8	0.11	8	34	D	37.5	0.11	5	22	D	41.3	0.17	16	40
Meetinghouse Ln WB (thru/right)	F	141.0	1.13	249	#435	F	261.8	1.43	~222	#328	F	258.7	1.41	~337	#423
Canal St NB (left)	D	40.7	0.72	147	167	C	31.1	0.61	94	145	C	25.8	0.63	84	143
Canal St NB (thru/right)	D	40.9	0.53	156	187	C	34.8	0.37	82	138	C	24.6	0.29	111	190
State Rd SB (left)	D	44.5	0.18	18	38	D	36.4	0.16	18	36	C	22.4	0.10	21	45
State Rd SB (thru/right)	D	49.6	0.36	35	109	D	40.6	0.27	23	69	C	33.1	0.60	168	#323
23:: State Road / Route 3 NB On-Ramp	A	4.4				A	3.4				A	3.1			
State Rd NB (left)	A	9.0	0.33	-	37	A	8.7	0.29	-	31	B	10.2	0.34	-	38
State Rd NB (thru)	A	0.0	0.13	-	0	A	0.0	0.23	-	0	A	0.0	0.14	-	0
State Rd SB (thru)	A	0.0	0.13	-	0	A	0.0	0.13	-	0	A	0.0	0.31	-	0
State Rd SB (right)	A	0.0	0.01	-	0	A	0.0	0.01	-	0	A	0.0	0.01	-	0
24:: Cranberry Highway / Adams Street	A	4.4				A	3.6				A	5.2			
Cranberry Highway EB (thru)	A	0.0	0.00	-	0	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Cranberry Highway EB (thru/right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Cranberry Highway WB (left/thru)	A	7.6	0.00	-	0	A	8.9	0.01	-	0	A	0.0	0.00	-	0
Cranberry Highway WB (thru)	A	0.0	0.00	-	0	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Adams Street NB [left/thru/right]	B	10.6	0.07	-	6	C	15.0	0.06	-	7	A	9.6	0.04	-	3
Adams Street SB [left/thru/right]	B	11.0	0.30	-	32	B	13.2	0.43	-	55	C	17.1	0.58	-	93
25:: Sandwich Road / Adams Street	A	0.3				A	0.6				A	0.5			
Sandwich Rd EB (thru/right)	A	0.0	0.37	-	0	A	0.0	0.50	-	0	A	0.0	0.48	-	0
Sandwich Rd WB (left/thru)	A	0.7	0.03	-	2	A	1.0	0.03	-	2	A	1.0	0.04	-	3
26:: Cranberry Highway / Sandwich Road / Regency Drive	E	75.4				F	855.0				F	2370.9			
Sandwich Rd EB (left/thru/right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0	A	8.5	0.01	-	0
Sandwich Rd WB (left/thru/right)	A	8.5	0.16	-	14	B	10.1	0.28	-	28	B	12.0	0.51	-	74
Cranberry Highway NB (left/thru)	F	403.7	1.68	-	368	F	3111.5	7.65	-	Err	F	$12,573.2	27.78	-	Err
Cranberry Highway NB (right)	B	10.6	0.09	-	7	B	13.3	0.13	-	11	B	12.3	0.10	-	8
Regency Dr SB (left/thru/right)	A	0.0	0.00	-	0	F	78.7	0.11	-	8	B	11.8	0.02	-	1
27:: Old King's Highway (Route 6A) / Main Street (Route 130) / Tupper Road	B	10.7				E	38.0				F	363.3			
Old King's Hwy (Route 6A) EB (left/thru/right)	A	8.1	0.06	-	5	A	8.4	0.09	-	8	A	8.8	0.12	-	10
Old King's Hwy (Route 6A) WB (left/thru/right)	A	7.7	0.00	-	0	A	8.0	0.01	-	0	A	7.9	0.00	-	0
Main St (Route 130) NB (left/thru/right)	E	47.2	0.71	-	138	F	322.5	1.47	-	317	F	1686.4	4.51	-	Err
Tupper Rd SB (left/thru/right)	B	11.2	0.18	-	17	B	12.8	0.29	-	30	C	18.2	0.48	-	65
28:: Old King's Highway (Route 6A) / Tupper Road	C	31.9				E	58.6				F	215.5			
Old King's Hwy (Route 6A) EB (left)	C	23.0	0.03	2	13	C	23.1	0.03	2	12	B	19.7	0.05	4	19
Old King's Hwy (Route 6A) EB (thru/right)	C	26.5	0.46	75	171	D	40.2	0.82	191	299	C	25.3	0.54	168	317
Old King's Hwy (Route 6A) WB (left/thru)	C	33.9	0.73	132	253	F	106.9	1.07	~140	#323	D	41.6	0.85	222	#509
Old King's Hwy (Route 6A) WB (right)	C	23.9	0.16	12	55	C	23.8	0.12	6	47	C	21.5	0.25	39	119
Tupper Rd NB (left/thru/right)	D	37.0	0.77	121	#348	D	51.0	0.86	142	#358	F	476.0	1.94	~551	#696
Tupper Rd SB (left)	D	39.9	0.65	35	#149	F	93.1	0.96	76	#281	F	522.3	2.00	~210	#414
Tupper Rd SB (thru/right)	C	26.7	0.23	32	102	C	28.4	0.25	42	123	D	37.3	0.39	74	154

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29:: Water Street (Route 130) / Beale Avenue	A	5.7				A	1.5				B	13.2			
Beale Ave WB (left/right)	D	32.6	0.62	-	98	C	18.5	0.21	-	19	F	123.8	1.00	-	196
Water St (Route 130) NB (thru/right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Water St (Route 130) SB (left/thru)	A	8.6	0.01	-	1	A	8.3	0.01	-	1	B	10.6	0.05	-	4
30:: Main Street / Beale Avenue	A	5.9				A	4.9				A	7.4			
Main St EB (thru/right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Main St WB (left/thru)	A	7.7	0.09	-	7	A	7.5	0.03	-	3	A	7.7	0.11	-	9
Beale Ave NB (left/right)	B	10.6	0.17	-	15	A	9.5	0.13	-	11	B	12.9	0.38	-	45
31:: Old King's Highway (Route 6A) / Main Street / Old Main Street	A	3.2				A	2.7				A	4.4			
Main St EB (left)	C	24.7	0.07	-	5	C	18.1	0.02	-	2	F	63.2	0.29	-	25
Main St EB (thru/right)	B	11.9	0.18	-	16	B	11.9	0.20	-	18	C	17.2	0.42	-	50
Old Main St WB (left/thru/right)	C	15.8	0.05	-	4	C	16.5	0.04	-	3	B	13.0	0.01	-	1
Old King's Hwy (Route 6A) NB (left/thru/right)	A	8.3	0.10	-	9	A	8.1	0.05	-	4	A	9.0	0.16	-	14
Old King's Hwy (Route 6A) SB (left/thru/right)	A	0.0	0.00	-	0	A	7.9	0.00	-	0	A	8.7	0.00	-	0
32:: Forestdale Road (Route 130) / Route 6 EB Ramps	C	21.0				E	63.7				F	104.0			
Route 6 EB Ramps EB (left)	C	24.1	0.17	15	35	C	24.2	0.14	18	43	C	24.4	0.41	22	#56
Route 6 EB Ramps EB (right)	D	38.7	0.76	34	#129	F	161.5	1.29	~303	#487	F	430.4	1.84	~139	#305
Forestdale Rd (Route 130) NB (left)	A	6.6	0.33	16	33	A	7.9	0.36	14	28	B	11.4	0.32	6	13
Forestdale Rd (Route 130) NB (thru)	B	12.6	0.81	248	#525	B	18.4	0.84	233	92	A	8.6	0.76	165	261
Forestdale Rd (Route 130) SB (thru/right)	B	19.6	0.67	106	m164	C	21.6	0.85	92	m#364	D	38.8	0.99	~330	#438
33:: Water Street (Route 130) / Route 6 WB Ramps	C	26.2				C	28.7				F	332.4			
Route 6 WB Ramps EB (left)	D	35.4	0.71	59	105	D	47.6	0.86	101	#197	F	873.3	2.87	~590	#733
Route 6 WB Ramps EB (right)	A	0.1	0.10	0	0	A	0.1	0.10	0	0	A	0.1	0.08	0	0
Forestdale Rd (Route 130) NB (left)	C	33.6	0.86	157	m#210	D	37.3	0.93	143	m#218	C	23.1	0.60	61	94
Forestdale Rd (Route 130) NB (left)	C	33.6	0.86	157	m#210	D	37.3	0.93	143	m#218	C	23.1	0.60	61	94
Forestdale Rd (Route 130) NB (thru)	A	5.8	0.27	71	m115	A	8.3	0.28	69	m116	A	7.2	0.56	115	181
Forestdale Rd (Route 130) SB (thru)	D	36.9	0.88	~227	#276	C	31.0	0.83	192	#328	F	167.2	1.30	~370	#509
Forestdale Rd (Route 130) SB (right)	A	0.0	0.03	0	0	A	0.0	0.01	0	0	A	0.0	0.03	0	0
34:: Quaker Meeting House Road / Route 6 EB Ramps	F	134.6				B	12.1				C	22.0			
Route 6 EB Ramps EB (left/right)	F	1865.4	4.51	-	331	F	77.7	0.87	-	218	F	132.8	1.07	-	266
Quaker Meetinghouse Rd NB (left/thru)	B	11.7	0.49	-	69	B	10.3	0.27	-	28	A	9.8	0.24	-	24
Quaker Meetinghouse Rd SB (thru/right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0	A	0.0	0.00	-	0
35:: Quaker Meeting House Road / Route 6 WB Ramps	E	42.6				F	60.9				A	7.5			
Route 6 WB Ramps WB (left/right)	F	180.8	1.26	-	421	F	152.8	1.23	-	508	D	28.8	0.63	-	120
Quaker Meetinghouse Rd NB (thru/right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Quaker Meetinghouse Rd SB (left/thru)	A	8.7	0.08	-	7	A	7.9	0.05	-	4	A	8.0	0.05	-	4
36:: Route 130 / Cotuit Rd	C	17.3				B	13.8				C	17.0			
Cotuit Rd WB (left)	A	0.0	0.00	-	0	F	1764.0	1.42	-	41	F	133.3	0.16	-	12
Cotuid Rd WB (right)	E	49.5	0.94	-	309	D	26.6	0.71	-	143	F	57.4	0.96	-	313
Route 130 NB (thru/right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Route 130 SB (left)	A	9.9	0.31	-	33	C	16.1	0.69	-	147	B	11.6	0.47	-	64
Route 130 SB (thru)	A	0.0	0.00	-	0	A	0.0	0.00	-	0	A	0.0	0.00	-	0
37:: Nathan Ellis Highway (Route 151) / Route 28 NB Ramps	A	1.8				F	67.5				A	9.4			
Nathan Ellis Hwy (Route 151) EB (left/thru)	A	9.0	0.12	-	10	A	8.8	0.14	-	12	A	8.2	0.07	-	5
Nathan Ellis Hwy (Route 151) WB (thru)	A	0.0	0.00	-	0	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Nathan Ellis Hwy (Route 151) WB (right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Route 28 NB Ramps SB (left/right)	D	29.8	0.32	-	38	F	663.2	2.27	-	464	F	83.4	0.93	-	231

Table B-1: Synchro and SIDRA Results Summary - 2019 Existing Fall

Intersection	2019 Existing Fall AM					2019 Existing Fall PM					2019 Existing Fall MID				
	LOS	Delay (sec)	v/c Ratio	50% Queue (feet)	95% Queue (feet)	LOS	Delay (sec)	v/c Ratio	50% Queue (feet)	95% Queue (feet)	LOS	Delay (sec)	v/c Ratio	50% Queue (feet)	95% Queue (feet)
38:: Nathan Ellis Highway (Route 151) / Route 28 SB Ramps	A	8.8				F	139.0				A	7.4			
Nathan Ellis Hwy (Route 151) EB (thru)	A	0.0	0.00	-	0	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Nathan Ellis Hwy (Route 151) EB (right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Nathan Ellis Hwy (Route 151) WB (left/thru)	A	9.0	0.17	-	15	A	8.7	0.09	-	7	A	8.2	0.06	-	5
Route 28 SB Ramps NB (left/right)	D	26.4	0.74	-	500	F	337.7	1.69	-	1295	C	20.7	0.72	-	372
39:: Belmont Circle	F	274.1				F	315.9				F	301.2			
Buzzards Bay Bypass (Route 6) EB (left/thru/right)	B	13.1	0.32	-	24	C	16.8	0.60	-	66	D	30.9	0.74	-	88
Main Street (Route 6) WB (left/thru)	A	9.3	0.35	-	29	C	21.9	0.72	-	109	C	17.8	0.61	-	72
Main Street (Route 6) WB (right)	F	472.0	2.01	-	6334	F	420.1	1.89	-	5143	F	464.6	1.98	-	5236
Old Bridge Road NB (left/thru/right)	B	10.1	0.02	-	1	A	9.1	0.01	-	1	B	10.7	0.02	-	1
Route 28/25 Ramps SB (left/thru/right)	F	241.7	1.49	-	151	F	490.3	2.05	-	6322	F	394.8	1.84	-	5797
Main Street NEB (left/thru/right)	F	226.5	1.43	-	2032	F	268.6	1.54	-	2963	F	256.1	1.5	-	2100
Head of the Bay Road SEB (left/thru/right)	F	74.5	1.03	-	425	C	18.0	0.57	-	57	F	101.6	1.11	-	672

Legend

~ : Volume exceeds capacity

$: Delay exceeds 300s

+ : Computation not defined

* : All major volume in platoon

: 95th percentile volume exceeds capacity; queue may be longer

m : Volume for 95th percentile queue is metered by upstream signal

Err : Error

dr : Defacto right lane

Table B-2: Synchro and SIDRA Results Summary - 2019 Existing Summer

Intersection	2019 Existing Summer AM					2019 Existing Summer PM					2019 Existing Summer MID				
	LOS	Delay (sec)	v/c Ratio	50% Queue (feet)	95% Queue (feet)	LOS	Delay (sec)	v/c Ratio	50% Queue (feet)	95% Queue (feet)	LOS	Delay (sec)	v/c Ratio	50% Queue (feet)	95% Queue (feet)
1:: Maple Springs Rd / Route 25 NB On-Ramp	A	0.1				A	0.0				A	0.2			
Maple Springs Rd NB (thru)	A	0.0	0.01	-	0	A	0.0	0.02	-	0	A	0.0	0.02	-	0
Maple Springs Rd NB (thru/right)	A	0.0	0.45	-	0	A	0.0	0.52	-	0	A	0.0	0.55	-	0
Maple Springs Rd SB (left/thru)	A	1.9	0.01	-	1	A	1.0	0.00	-	0	A	2.5	0.01	-	1
2:: Maple Springs Rd / Route 25 SB Off-Ramp	A	5.1				C	15.7				F	119.8			
Route 25 SB Off-Ramp EB (left)	B	11.3	0.01	-	83	B	12.4	0.02	-	363	B	12.6	0.01	-	1600
Route 25 SB Off-Ramp EB (right)	B	12.7	0.53	-	83	D	31.8	0.92		363	F	207.7	1.42		1600
Maple Springs Rd NB (thru)	A	0.0	0.00	-	0	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Maple Springs Rd NB (thru)	A	0.0	0.00	-	0	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Maple Springs Rd SB (thru)	A	0.0	0.00	-	0	A	0.0	0.00	-	0	A	0.0	0.00	-	0
3:: Glen Charlie Road / Route 25 NB Off-Ramp	A	3.8				A	4.8				A	2.0			
Route 25 NB Off-Ramp EB (left)	B	13.5	0.05	-	40	C	24.7	0.30	-	67	C	18.6	0.06	-	26
Route 25 NB Off-Ramp EB (right)	B	14.7	0.36		40	C	16.5	0.49		67	B	13.2	0.26		26
Glen Charlie Rd NB (thru)	A	0.0	0.00	-	0	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Glen Charlie Rd SB (thru)	A	0.0	0.00	-	0	A	0.0	0.00	-	0	A	0.0	0.00	-	0
4:: Glen Charlie Road / Route 25 SB On-Ramp	A	0.8				A	0.6				A	0.5			
Glen Charlie Rd NB (thru)	A	0.0	0.08	-	0	A	0.0	0.32	-	0	A	0.0	0.32	-	0
Glen Charlie Rd NB (right)	A	0.0	0.06	-	0	A	0.0	0.11	-	0	A	0.0	0.07	-	0
Glen Charlie Rd SB (left/thru)	A	1.1	0.04	-	3	A	1.2	0.05	-	4	A	1.1	0.04	-	3
5:: Buzzards Bay Rotary	A	6.6				A	10.1				B				
Main Street (Route 6) EB (left)	A	7.0	0.34	-	31	A	9.2	0.49	-	56	B	13.2	0.66	-	106
Main Street (Route 6) EB (left/thru)	A	6.9	0.34	-	31	A	9.1	0.49	-	56	B	13.2	0.66	-	106
Main Street WB (thru/right)	A	6.7	0.28	-	22	A	12.6	0.59	-	74	C	16.8	0.69	-	105
Lincoln Avenue SB (left/thru/right)	A	6.1	0.11	-	7	A	8.7	0.16	-	11	A	8.2	0.21	-	15
Buzzards Bay Bypass (Route 6) SWB (left)	A	6.1	0.18	-	14	A	10.0	0.37	-	33	A	7.8	0.23	-	17
Buzzards Bay Bypass (Route 6) SWB (left/right)	A	6.0	0.18	-	13	A	9.8	0.37	-	31	A	7.5	0.23	-	17
6:: Scenic Highway (Route 6) / Main Street (Route 6) / Nightingale Road / Andy Olivia Drive	D	37.1				F	84.4				C	32.1			
Main Street (Route 6) EB (left/thru)	A	5.9	0.68	132	160	B	13.0	0.87	152	#321	A	8.9	0.67	134	171
Main Street (Route 6) EB (thru/right)	A	5.9	0.68	132	160	B	13.0	0.87	152	#321	A	8.9	0.67	134	171
Scenic Hwy (Route 6) WB (left/thru)	E	57.9	1.06	~667	#808	F	132.0	1.24	~917	#1106	D	44.7	1.00	~566	#748
Scenic Hwy (Route 6) WB (thru/right)	E	57.9	1.06	~667	#808	F	132.0	1.24	~917	#1106	D	44.7	1.00	~566	#748
Andy Olivia Dr NB (left/thru/right)	D	38.5	0.06	0	4	D	42.4	0.51	36	60	D	52.7	0.75	91	#150
Nightingale Pond Rd SB (left/thru)	D	39.4	0.26	18	39	D	39.8	0.14	9	30	D	35.5	0.06	6	22
Nightingale Pond Rd SB (right)	D	38.4	0.06	0	17	D	39.3	0.05	0	11	D	35.3	0.04	0	2
7:: Sandwich Road / Trowbridge Road / County Road / Shore Road	B	12.7				F	281.4				B	14.0			
Shore Rd EB (left/thru/right)	A	7.9	0.10		8	A	8.7	0.13	-	11	A	8.0	0.09	-	8
Trowbridge Rd WB (left/thru/right)	A	7.9	0.04		3	A	8.0	0.09	-	7	A	7.7	0.05	-	3
County Rd NB (left/thru/right)	D	29.7	0.62		97	F	969.9	3.03	-	1170	D	29.9	0.65	-	109
Sandwich Rd SB (left/thru/right)	D	33.8	0.52		70	F	Err	Err	-	Err	D	29.9	0.58	-	90
8:: Trowbridge Rd./Veterans Way	A	1.7				A	8.2				A	0.8			
Trowbridge Rd EB (left/thru/right)	A	7.7	0.04	-	3	A	7.9	0.05	-	4	A	7.8	0.00	-	0
Trowbridge Rd WB (left/thru/right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Veterans Way NB (left/thru/right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Driveway SB (left/thru/right)	B	13.1	0.09	-	7	D	34.1	0.66	-	107	B	11.8	0.06	-	5
9:: Bourne Rotary	F	491.7				F	579.5				F	787			
General MacArthur Boulevard NB (left/thru)	F	291.8	1.60	-	3671	F	814.3	2.76	-	8786	F	464.9	1.99	-	6148
General MacArthur Boulevard NB (right)	F	36.3	0.88	-	265	D	26.8	0.76	-	151	C	20.3	0.72	-	150
Sandwich Road WB (left/thru)	F	260.9	1.50	-	2140	C	18.2	0.54	-	67	F	83.2	1.03	-	463
Sandwich Road WB (right)	E	49.3	0.88	-	218	F	154.5	1.26	-	1358	F	188.9	1.34	-	1533
Route 28 (Bourne Bridge) SB (left/thru)	F	981.9	3.14	-	11966	F	774.2	2.68	-	11862	F	1442.5	4.17	-	17421
Route 28 (Bourne Bridge) SB (right)	A	6.2	0.03	-	2	A	4.7	0.04	-	3	A	6	0.05	-	4
Trowbridge Road EB (left/thru/right)	F	82.9	1.00	-	327	F	422.8	1.87	-	3287	E	40.9	0.8	-	129

Table B-2: Synchro and SIDRA Results Summary - 2019 Existing Summer

Intersection	2019 Existing Summer AM					2019 Existing Summer PM					2019 Existing Summer MID				
	LOS	Delay (sec)	v/c Ratio	50% Queue (feet)	95% Queue (feet)	LOS	Delay (sec)	v/c Ratio	50% Queue (feet)	95% Queue (feet)	LOS	Delay (sec)	v/c Ratio	50% Queue (feet)	95% Queue (feet)
10:: Sandwich Road / Bourne Rotary Connector	F	86.0				F	568.8				F	147.7			
Sandwich Rd EB (left/right)	F	819.2	2.61	-	604	F	2553.5	6.50	-	Err	F	1540.8	4.12	-	Err
Bourne Rotary Connector NB (left/thru)	B	10.2	0.01	-	1	B	10.3	0.01	-	1	B	10.8	0.03	-	2
Sandwich Rd SB (thru/right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0	A	0.0	0.00	-	0
11:: Sandwich Road / Upper Cape Cod Technical School Driveway	A	3.7				A	1.1				A	0.5			
Cape Cod Technical School Driveway WB (left/right)	F	171.1	0.81	-	91	F	115.1	0.38	-	33	F	90.7	0.23	-	19
Sandwich Rd NB (thru/right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Sandwich Rd SB (left)	B	11.9	0.03	-	2	C	15.2	0.14	-	12	B	12.2	0.01	-	1
Sandwich Rd SB (thru)	A	0.0	0.00	-	0	A	0.0	0.00	-	0	A	0.0	0.00	-	0
12:: Sandwich Road / Harbor Lights Road	A	0.5				A	0.6				A	0.5			
Harbor Lights Rd WB (left/right)	F	80.0	0.23	-	19	F	94.5	0.27	-	22	F	91.2	0.267	-	22
Sandwich Rd NB (thru/right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Sandwich Rd SB (left/thru)	B	11.8	0.01	-	1	B	12.3	0.01	-	1	A	0.0	0.00	-	0
13:: Sandwich Road / Jefferson Road (Tech Drive)	A	0.1				A	0.1				A	1.1			
Jefferson Rd (Tech Dr) WB (left/right)	D	26.2	0.06	-	4	D	26.1	0.06	-	5	E	38.5	0.42	-	48
Sandwich Rd NB (thru/right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Sandwich Rd SB (left/thru)	A	0.0	0.00	-	0	A	0.0	0.00	-	0	A	0.0	0.00	-	0
14:: Sandwich Road / Jarvis Road	A	0.1				A	0.1				A	0.0			
Jarvis Rd WB (left/right)	D	27.1	0.04	-	3	D	26.0	0.04	-	3	A	0.0	0.00	-	0
Sandwich Rd NB (thru/right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Sandwich Rd SB (left/thru)	B	12.5	0.01	-	1	A	0.0	0.00	-	0	B	12.3	0.01	-	1
15:: Sandwich Road (Route 6 Bypass) / Mid-Cape Connector	B	10.8				B	11.2				A	7.9			
Sandwich Rd EB (thru)	B	18.1	0.68	134	251	B	19.2	0.69	138	267	B	12.4	0.49	81	166
Sandwich Rd EB (right)	A	1.2	0.52	0	0	A	1.6	0.59	0	0	A	2.2	0.67	0	0
Sandwich Rd WB (left)	A	6.9	0.07	4	14	A	7.3	0.16	10	27	A	4.2	0.11	7	22
Sandwich Rd WB (thru)	B	11.6	0.72	175	321	B	11.6	0.72	180	354	A	8.2	0.71	156	346
Mid-Cape Connector NB (left)	C	23.2	0.65	88	213	C	23.8	0.67	94	222	C	21.4	0.52	38	116
Mid-Cape Connector NB (right)	B	12.8	0.14	0	40	B	14.5	0.43	32	123	B	14.0	0.30	5	65
16:: Mid-Cape Connector / Factory Outlet Way	B	10.4				B	10.2				A	8.5			
Factory Outlet Way (Market Basket Driveway) WB (left)	C	21.1	0.36	28	38	C	33.6	0.17	13	28	D	35.2	0.26	17	34
Factory Outlet Way (Market Basket Driveway) WB (left)	C	21.1	0.36	28	38	C	33.6	0.17	13	28	D	35.2	0.26	17	34
Factory Outlet Way (Market Basket Driveway) WB (right)	B	12.0	0.07	7	17	C	23.1	0.21	32	58	C	23.5	0.16	24	47
Mid-Cape Connector NB (thru)	B	14.7	0.64	141	247	B	14.4	0.65	232	421	B	10.9	0.49	152	237
Mid-Cape Connector NB (right)	A	4.9	0.05	0	9	A	4.4	0.04	0	9	A	4.5	0.04	0	8
Mid-Cape Connector SB (left)	C	25.1	0.17	7	28	D	35.6	0.34	26	58	D	35.6	0.38	29	63
Mid-Cape Connector SB (thru)	A	5.6	0.41	63	105	A	3.8	0.38	75	119	A	3.4	0.39	77	109
Mid-Cape Connector SB (thru)	A	5.6	0.41	63	105	A	3.8	0.38	75	119	A	3.4	0.39	77	109
17:: Herring Pond Road / State Road	D	33.4				F	432.8				F	302.8			
Herring Pond Rd EB (left/right)	F	69.4	0.99	-	691	F	905.0	2.93	-	Err	F	635.8	2.34	-	Err
State Rd NB (left/thru)	A	7.8	0.10	-	8	A	8.2	0.15	-	13	A	8.7	0.15	-	13
State Rd SB (thru/right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0	A	0.0	0.00	-	0
18:: Herring Pond Road / Route 3 NB Ramps	A	3.9				F	61.3				C	17.3			
Route 3 NB Ramps EB (left/right)	C	23.0	0.48	-	89	F	378.4	1.69	-	498	F	181.6	1.14	-	205
Herring Pond Rd NB (left/thru)	A	8.7	0.13	-	11	A	9.1	0.13	-	11	A	8.5	0.15	-	13
Herring Pond Rd SB (thru)	A	0.0	0.00	-	0	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Herring Pond Rd SB (right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0	A	0.0	0.00	-	0
19:: Herring Pond Road / Route 3 SB Ramps	A	6.6				F	173.3				F	84.1			
Route 3 SB Ramps WB (left/right)	C	15.9	0.48	-	177	F	478.6	1.98	-	1133	F	154.2	1.27	-	1129
Herring Pond Rd NB (thru/right)	A	0.0	0.00	-	0	A	CO	0.00	-	0	A	0.0	0.00	-	0
Herring Pond Rd SB (left/thru)	A	8.7	0.26	-	26	A	8.5	0.12	-	10	A	8.0	0.08	-	6

Table B-2: Synchro and SIDRA Results Summary - 2019 Existing Summer

Intersection	2019 Existing Summer AM					2019 Existing Summer PM					2019 Existing Summer MID				
	LOS	Delay (sec)	v/c Ratio	50% Queue (feet)	95% Queue (feet)	LOS	Delay (sec)	v/c Ratio	50% Queue (feet)	95% Queue (feet)	LOS	Delay (sec)	v/c Ratio	50% Queue (feet)	95% Queue (feet)
20:: Scenic Highway (Route 6) / Church Lane / Route 6 SB On-Ramp	C	20.3				B	19.4				D	51.5			
Scenic Hwy (Route 6) EB (left)	D	51.7	0.42	11	35	D	48.5	0.53	25	73	E	63.2	0.45	33	71
Scenic Hwy (Route 6) EB (thru)	C	24.1	0.89dr	262	441	C	23.9	0.73	250	458	E	61.3	1.31dr	473	#648
Scenic Hwy (Route 6) EB (thru/right)	C	24.1	0.89dr	262	441	C	23.9	0.73	250	458	E	61.3	1.31dr	473	#648
Scenic Hwy (Route 6) WB (left)	D	50.1	0.83	188	307	D	41.5	0.76	172	315	F	113.1	1.12	~725	#1004
Scenic Hwy (Route 6) WB (thru)	A	7.9	0.45	97	244	B	11.8	0.67	290	436	A	9.9	0.43	204	273
Scenic Hwy (Route 6) WB (thru)	A	7.9	0.45	97	244	B	11.8	0.67	290	436	A	9.9	0.43	204	273
Scenic Hwy (Route 6) WB (thru/right)	A	7.9	0.45	97	244	B	11.8	0.67	290	436	A	9.9	0.43	204	273
Church Lane SB (left/thru/right)	D	47.1	0.58	57	106	D	42.4	0.53	55	119	E	72.9	0.79	143	148
21:: Scenic Highway (Route 6) & Route 3 SB Off-Ramp	B	16.4				D	40.8				C	20.3			
Scenic Hwy (Route 6) EB (thru)	B	9.1	0.46	146	238	B	10.7	0.47	206	285	A	7.9	0.31	110	153
Scenic Hwy (Route 6) WB (thru)	B	13.9	0.77	333	482	C	29.2	0.95	777	801	B	17.5	0.85	566	736
Scenic Hwy (Route 6) WB (thru)	B	13.9	0.77	333	482	C	29.2	0.95	777	801	B	17.5	0.85	566	736
Route 3 Off-Ramp SB (left/right)	D	41.0	0.76	154	#331	F	135.0	1.14	~413	#623	D	52.6	0.81	223	#352
22:: Meetinghouse Lane / State Road / Canal Street	D	46.4				E	78.0				D	49.1			
Meetinghouse Ln EB (left)	C	27.2	0.64	165	#501	E	67.8	1.01	283	#754	D	52.7	0.83	130	#209
Meetinghouse Ln EB (thru)	B	19.5	0.26	82	217	C	31.7	0.68	230	#574	E	64.6	0.86	271	#408
Meetinghouse Ln EB (right)	B	19.3	0.23	0	77	C	20.3	0.05	0	0	D	38.2	0.16	0	54
Meetinghouse Ln WB (left)	C	33.7	0.09	8	34	D	35.6	0.15	8	31	D	41.7	0.26	19	41
Meetinghouse Ln WB (thru/right)	F	105.3	1.04	259	#522	F	271.0	1.45	~236	#400	F	124.7	1.06	213	#324
Canal St NB (left)	D	41.4	0.74	160	181	C	34.0	0.77	127	#186	C	21.4	0.62	74	176
Canal St NB (thru/right)	D	43.9	0.64	187	218	C	29.7	0.43	115	165	B	19.8	0.29	101	233
State Rd SB (left)	D	45.1	0.13	13	29	C	32.8	0.14	14	34	B	18.3	0.11	19	58
State Rd SB (thru/right)	D	49.4	0.25	17	80	D	43.1	0.64	93	159	C	30.9	0.67	230	#645
23:: State Road / Route 3 NB On-Ramp	A	4.3				A	3.7				A	3.1			
State Rd NB (left)	A	8.9	0.31	-	33	A	9.5	0.37	-	100	B	10.9	0.34	-	38
State Rd NB (thru)	A	0.0	0.13	-	0	A	0.0	0.24	-	0	A	0.0	0.08	-	0
State Rd SB (thru)	A	0.0	0.12	-	0	A	0.0	0.18	-	0	A	0.0	0.39	-	0
State Rd SB (right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0	A	0.0	0.01	-	0
24:: Cranberry Highway / Adams Street	A	3.2				A	3.5				A	2.5			
Cranberry Highway EB (thru)	A	0.0	0.00	-	0	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Cranberry Highway EB (thru/right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Cranberry Highway WB (left/thru)	A	9.2	0.01	-	0	A	8.5	0.01	-	0	A	7.9	0.00	-	0
Cranberry Highway WB (thru)	A	0.0	0.00	-	0	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Adams Street NB [left/thru/right]	A	0.0	0.00	-	0	B	10.0	0.02	-	1	B	12.5	0.06	-	5
Adams Street SB [left/thru/right]	B	11.3	0.32	-	35	B	13.6	0.43	-	54	B	12.5	0.28	-	28
25:: Sandwich Road / Adams Street	A	0.3				A	0.2				A	0.3			
Sandwich Rd EB (thru/right)	A	0.0	0.42	-	0	A	0.0	0.52	-	0	A	0.0	0.41	-	0
Sandwich Rd WB (left/thru)	A	0.5	0.02	-	2	A	0.4	0.01	-	1	A	0.6	0.02	-	1
26:: Cranberry Highway / Sandwich Road / Regency Drive	F	498.4				F	1019.7				A	4.4			
Sandwich Rd EB (left/thru/right)	A	7.7	0.00	-	0	A	8.2	0.01	-	0	A	8.8	0.01	-	0
Sandwich Rd WB (left/thru/right)	A	9.8	0.33	-	36	B	10.5	0.38	-	44	C	15.2	0.65	-	127
Cranberry Highway NB (left/thru)	F	1863.3	4.91	-	Err	F	4523.4	10.63	-	Err	A	0.0	0.00	-	Err
Cranberry Highway NB (right)	B	11.1	0.05	-	4	B	13.1	0.18	-	16	B	13.2	0.13	-	11
Regency Dr SB (left/thru/right)	D	29.5	0.08	-	7	A	0.0	0.00	-	0	A	0.0	0.00	-	1
27:: Old King's Highway (Route 6A) / Main Street (Route 130) / Tupper Road	F	91.1				A	5.1				F	2211.3			
Old King's Hwy (Route 6A) EB (left/thru/right)	A	9.1	0.30	-	31	A	8.5	0.11	-	9	B	10.0	0.15	-	13
Old King's Hwy (Route 6A) WB (left/thru/right)	A	7.5	0.00	-	0	A	8.1	0.01	-	1	A	8.0	0.01	-	0
Main St (Route 130) NB (left/thru/right)	F	635.8	2.13	-	393	C	15.4	0.16	-	15	F	13382.0	29.39	-	Err
Tupper Rd SB (left/thru/right)	B	12.6	0.23	-	21	C	17.3	0.47	-	63	F	68.8	0.94	-	241
28:: Old King's Highway (Route 6A) / Tupper Road	D	39.4				F	239.7				F	143.9			
Old King's Hwy (Route 6A) EB (left)	C	25.3	0.05	2	12	B	19.7	0.02	2	12	C	20.4	0.11	6	28
Old King's Hwy (Route 6A) EB (thru/right)	C	32.6	0.64	102	191	C	29.4	0.69	225	436	C	30.2	0.72	245	#493
Old King's Hwy (Route 6A) WB (left/thru)	D	41.7	0.79	111	234	C	33.4	0.75	184	#416	F	162.8	1.25	~409	#767
Old King's Hwy (Route 6A) WB (right)	C	25.9	0.15	6	57	C	22.0	0.27	37	123	C	24.7	0.51	106	263
Tupper Rd NB (left/thru/right)	D	54.9	0.91	140	#380	F	480.1	1.95	~568	#949	F	208.6	1.32	~302	#601
Tupper Rd SB (left)	D	37.8	0.67	43	#165	F	858.5	2.74	~217	#424	F	548.0	2.06	~227	#449
Tupper Rd SB (thru/right)	C	24.5	0.20	31	94	D	37.7	0.50	98	200	D	39.0	0.52	102	207

Table B-2: Synchro and SIDRA Results Summary - 2019 Existing Summer

Intersection	2019 Existing Summer AM					2019 Existing Summer PM					2019 Existing Summer MID				
	LOS	Delay (sec)	v/c Ratio	50% Queue (feet)	95% Queue (feet)	LOS	Delay (sec)	v/c Ratio	50% Queue (feet)	95% Queue (feet)	LOS	Delay (sec)	v/c Ratio	50% Queue (feet)	95% Queue (feet)
29:: Water Street (Route 130) / Beale Avenue	A	3.1				A	1.8				A	4.8			
Beale Ave WB (left/right)	C	23.1	0.41	-	48	C	21.6	0.29	-	29	F	71.5	0.70	-	100
Water St (Route 130) NB (thru/right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Water St (Route 130) SB (left/thru)	A	8.7	0.01	-	0	A	8.7	0.01	-	1	A	9.9	0.02	-	2
30:: Main Street / Beale Avenue	A	5.1				A	4.6				A	3.7			
Main St EB (thru/right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Main St WB (left/thru)	A	7.5	0.06	-	5	A	7.5	0.03	-	3	A	7.6	0.06	-	4
Beale Ave NB (left/right)	A	9.7	0.08	-	7	A	9.5	0.12	-	10	B	10.4	0.14	-	12
31:: Old King's Highway (Route 6A) / Main Street / Old Main Street	A	2.4				A	2.8				A	4.8			
Main St EB (left)	C	20.3	0.03	-	2	E	37.9	0.10	-	7	F	198.6	0.64	-	51
Main St EB (thru/right)	B	10.0	0.10	-	8	C	17.7	0.32	-	34	C	15.4	0.30	-	32
Old Main St WB (left/thru/right)	B	14.5	0.04	-	4	C	21.6	0.05	-	4	E	40.5	0.16	-	11
Old King's Hwy (Route 6A) NB (left/thru/right)	A	7.9	0.07	-	6	A	9.3	0.08	-	7	A	9.4	0.14	-	12
Old King's Hwy (Route 6A) SB (left/thru/right)	A	8.1	0.01	-	0	A	8.3	0.00	-	0	A	0.0	0.00	-	0
32:: Forestdale Road (Route 130) / Route 6 EB Ramps	C	21.4				D	54.6				B	13.9			
Route 6 EB Ramps EB (left)	C	24.8	0.25	22	45	C	21.7	0.21	26	53	C	22.3	0.38	19	51
Route 6 EB Ramps EB (right)	D	35.4	0.72	33	#119	F	155.2	1.23	~199	#295	C	22.1	0.33	0	#76
Forestdale Rd (Route 130) NB (left)	A	6.5	0.22	11	23	B	11.0	0.42	13	28	A	4.0	0.16	7	15
Forestdale Rd (Route 130) NB (thru)	B	18.0	0.89	318	#601	B	15.4	0.83	229	390	B	11.8	0.83	183	336
Forestdale Rd (Route 130) SB (thru/right)	B	16.8	0.69	99	195	C	22.1	0.89	105	m126	A	9.2	0.48	82	144
33:: Water Street (Route 130) / Route 6 WB Ramps	C	19.3				C	34.6				B	19.5			
Route 6 WB Ramps EB (left)	D	36.9	0.71	53	103	E	60.1	0.92	99	#216	D	35.8	0.82	97	#220
Route 6 WB Ramps EB (right)	A	0.1	0.09	0	0	A	0.0	0.04	0	0	A	0.0	0.02	0	0
Forestdale Rd (Route 130) NB (left)	C	26.8	0.81	137	m156	C	34.2	0.89	130	m#193	C	22.0	0.58	63	93
Forestdale Rd (Route 130) NB (left)	C	26.8	0.81	137	m156	C	34.2	0.89	130	m#193	C	22.0	0.58	63	93
Forestdale Rd (Route 130) NB (thru)	A	6.5	0.38	121	m145	A	7.1	0.31	74	m130	A	9.3	0.68	150	221
Forestdale Rd (Route 130) SB (thru)	C	24.0	0.70	168	#305	D	46.5	0.96	251	#440	C	26.8	0.82	142	#275
Forestdale Rd (Route 130) SB (right)	A	0.0	0.02	0	0	A	0.0	0.02	0	0	A	0.0	0.02	0	0
34:: Quaker Meeting House Road / Route 6 EB Ramps	F	191.7				F	67.3				E	46.9			
Route 6 EB Ramps EB (left/right)	F	611.1	2.24	-	873	F	426.8	1.76	-	435	F	275.1	1.44	-	411
Quaker Meetinghouse Rd NB (left/thru)	A	9.1	0.33	-	36	B	11.0	0.36	-	41	B	10.1	0.25	-	24
Quaker Meetinghouse Rd SB (thru/right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0	A	0.0	0.00	-	0
35:: Quaker Meeting House Road / Route 6 WB Ramps	A	2.4				E	45.8				E	47.6			
Route 6 WB Ramps WB (left/right)	B	12.3	0.21	-	29	F	131.8	1.16	-	413	F	125.0	1.16	-	498
Quaker Meetinghouse Rd NB (thru/right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Quaker Meetinghouse Rd SB (left/thru)	A	8.2	0.03	-	3	A	7.9	0.04	-	3	A	8.1	0.02	-	1
36:: Route 130 / Cotuit Rd	C	22.5				F	54.1				D	30.5			
Cotuit Rd WB (left)	F	63.0	0.09	-	7	F	2225.1	4.30	-	Err	F	98.8	0.23	-	19
Cotuid Rd WB (right)	F	74.8	1.02	-	364	F	52.3	0.92	-	271	F	104.3	1.11	-	432
Route 130 NB (thru/right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Route 130 SB (left)	B	10.8	0.35	-	39	C	15.2	0.64	-	121	B	11.8	0.43	-	56
Route 130 SB (thru)	A	0.0	0.00	-	0	A	0.0	0.00	-	0	A	0.0	0.00	-	0
37:: Nathan Ellis Highway (Route 151) / Route 28 NB Ramps	A	2.0				F	458.3				F	65.8			
Nathan Ellis Hwy (Route 151) EB (left/thru)	A	8.9	0.11	-	9	A	9.3	0.17	-	15	A	9.5	0.16	-	14
Nathan Ellis Hwy (Route 151) WB (thru)	A	0.0	0.00	-	0	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Nathan Ellis Hwy (Route 151) WB (right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Route 28 NB Ramps SB (left/right)	C	20.5	0.35	-	60	F	4153.4	9.70	-	Err	F	$685.2	2.29	-	433

Table B-2: Synchro and SIDRA Results Summary - 2019 Existing Summer

Intersection	2019 Existing Summer AM					2019 Existing Summer PM					2019 Existing Summer MID				
	LOS	Delay (sec)	v/c Ratio	50% Queue (feet)	95% Queue (feet)	LOS	Delay (sec)	v/c Ratio	50% Queue (feet)	95% Queue (feet)	LOS	Delay (sec)	v/c Ratio	50% Queue (feet)	95% Queue (feet)
38:: Nathan Ellis Highway (Route 151) / Route 28 SB Ramps	A	5.6				F	324.9				F	93.1			
Nathan Ellis Hwy (Route 151) EB (thru)	A	0.0	0.00	-	0	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Nathan Ellis Hwy (Route 151) EB (right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Nathan Ellis Hwy (Route 151) WB (left/thru)	A	8.6	0.13	-	11	A	9.6	0.10	-	9	A	9.0	0.09	-	7
Route 28 SB Ramps NB (left/right)	C	19.7	0.61	-	293	F	888.7	2.90	-	1999	F	343.3	1.67	-	1023
39:: Belmont Circle	F	274.9				F	401.3				F	223.7			
Buzzards Bay Bypass (Route 6) EB (left/thru/right)	B	13.7	0.41	-	34	C	17.2	0.57	-	58	F	180.9	1.31	-	1262
Main Street (Route 6) WB (left/thru)	C	18.4	0.70	-	112	D	25.5	0.83	-	196	D	28.4	0.83	-	179
Main Street (Route 6) WB (right)	F	389.0	1.82	-	5539	F	481.5	2.03	-	7396	F	279.8	1.57	-	3757
Old Bridge Road NB (left/thru/right)	A	0.0	0.01	-	1	A	8.0	0.01	-	1	A	8.2	0.01	-	1
Route 28/25 Ramps SB (left/thru/right)	F	359.0	1.75	-	4645	F	711.4	2.54	-	8095	F	113.5	1.17	-	1242
Main Street NEB (left/thru/right)	F	243.7	1.49	-	3359	F	228.8	1.46	-	3360	F	379.7	1.8	-	5277
Head of the Bay Road SEB (left/thru/right)	B	12.5	0.31	-	23	B	11.7	0.27	-	19	C	18.6	0.51	-	45

Legend

~ : Volume exceeds capacity

$: Delay exceeds 300s

+ : Computation not defined

* : All major volume in platoon

: 95th percentile volume exceeds capacity; queue may be longer

m : Volume for 95th percentile queue is metered by upstream signal

Err : Error

dr : Defacto right lane

VISSIM

Table B-3: INRIX vs. VISSIM Travel Time Comparison

	From	To	Start Point	End point	Travel Time (min)											
					Fall						Summer					
					Weekday AM		Weekday PM		Saturday MID		Weekday AM		Weekday PM		Saturday MID	
					INRIX	*VISSIM*	*INRIX*	*VISSIM*	*INRIX*	*VISSIM*	*INRIX*	*VISSIM*	*INRIX*	*VISSIM*	*INRIX*	*VISSIM*
Bourne Bridge	Route 25 SB	Route 28	Route 25 SB at Plymouth Lane Overpass	Route 28 SB at Clay Pond Road	10.9	7.3	14.6	10.1	10.4	7.5	10.9	6.0	18.8	13.9	24.1	19.5
		Scenic Highway (Route 6)		Scenic Highway at Off-Ramp to Sagamore Bridge	11.8	8.7	15.2	11.6	12.0	8.9	11.6	7.5	24.5	16.2	28.0	18.4
		Bourne Bridge		End of Bourne Bridge SB	8.7	4.6	12.6	7.5	8.3	4.8	8.8	3.9	16.8	10.9	21.9	16.1
		Sagamore Bridge		End of Sagamore Bridge SB (via Scenic Highway)	13.0	10.5	16.5	13.3	13.3	10.7	12.9	9.2	27.7	19.0	31.4	23.3
	Route 28 NB	Belmont Circle Off-Ramp	Route 28 NB at Clay Pond Road	End of the Route 25/28 Off Ramp	5.2	5.7	14.7	12.9	6.8	8.7	4.6	5.6	11.4	11.3	7.1	7.6
		Sandwich Road		Sandwich Road at Mid-Cape Connector	7.7	6.5	17.6	14.4	9.0	9.4	6.5	6.2	14.7	13.7	10.3	11.0
		Sagamore Bridge		End of Sagamore Bridge NB (via Sandwich Road)	9.6	9.0	19.5	17.1	10.9	12.1	8.4	8.8	16.6	16.5	12.5	16.1
		Route 25		Route 25 NB at Plymouth Lane Overpass	10.1	6.4	19.5	15.7	11.3	9.4	9.3	6.9	16.0	12.0	11.6	7.9
		Bourne Bridge		End of Bourne Bridge NB	4.0	3.7	13.5	10.6	5.6	6.6	3.4	3.5	10.2	9.2	5.9	5.1
Sagamore Bridge	Route 3 SB	Off-Ramp to Scenic Highway	Route 3 SB south of Herring Pond Road	End of Off-Ramp to Scenic Highway	2.7	3.4	2.7	2.5	3.9	3.4	2.7	2.6	11.2	5.9	12.1	5.8
		Off-Ramp to Mid-Cape Connector		End of Off-Ramp to Mid-Cape Connector	4.0	6.5	4.1	4.9	5.2	6.6	4.0	4.8	12.9	12.1	14.2	10.9
		Route 6		Route 6 E SB north of Route 130	6.8	8.4	6.8	6.7	8.0	8.6	6.8	6.4	16.0	15.5	17.8	14.5
		Bourne Bridge		End of Bourne Bridge SB (via Scenic Highway)	10.9	11.4	11.5	10.2	10.9	11.7	10.6	10.8	27.4	19.3	29.2	19.4
		Sagamore Bridge		End of Sagamore Bridge SB	3.0	5.5	3.0	3.7	4.2	5.6	3.0	3.9	11.7	10.7	12.8	9.6
	Route 6 E NB	Off-Ramp to Cranberry Highway	Route 6 E NB north of Route 130	End of Off-Ramp to Cranberry Highway	3.8	3.1	5.0	3.5	3.6	3.1	3.8	3.4	3.7	3.6	8.0	5.6
		Off-Ramp to Scenic Highway WB		End of Off-Ramp to Scenic Highway	4.5	4.8	5.8	5.5	4.3	4.8	4.5	5.3	4.5	5.6	9.4	9.6
		Route 3		Route 3 NB south of Herring Pond Road	6.4	6.2	7.6	6.8	6.1	6.2	6.4	7.0	6.3	7.3	11.3	10.6

Note: Route 6 E = Route 6 east/south of Sagamore Bridge

Table B-4: VISSIM Speed Summary

Name	Start Point	End Point	Speed (mph)					
			Fall			Summer		
			Weekday AM	Weekday PM	Saturday MID	Weekday AM	Weekday PM	Saturday MID
Route 25 SB	Route 25 SB at Plymouth Lane Overpass	Off-Ramp diverge to Belmont Circle	50	23	50	60	16	12
Route 25 NB	On-Ramp merge from Belmont Circle	Route 25 NB at Plymouth Lane Overpass	60	27	60	46	60	60
Bourne Bridge SB	On-Ramp merge from Belmont Circle	Bourne Rotary	25	26	23	28	17	13
Bourne Bridge NB	Bourne Rotary	Off-Ramp diverge to Belmont Circle	42	37	42	43	42	42
Route 28 SB	Bourne Rotary	Route 28 SB at Clay Pond Road	41	42	42	54	37	33
Route 28 NB	Route 28 NB at Clay Pond Road	Bourne Rotary	41	12	21	42	13	28
Scenic Highway EB	Belmont Circle	Off-Ramp to Sagamore Bridge	37	38	37	43	29	28
Scenic Highway WB	Off-Ramp to Sagamore Bridge	Belmont Circle	36	38	35	33	23	28
Sandwich Road EB	Bourne Rotary	Mid-Cape Connector	43	33	44	46	35	30
Sandwich Road WB	Mid-Cape Connector	Bourne Rotary	30	20	30	31	32	16
Route 3 SB	Route 3 SB south of Herring Pond Road	Off-Ramp diverge to Scenic Highway	28	38	28	38	15	15
Route 3 NB	On-Ramp merge from State Road	Route 3 NB south of Herring Pond Road	50	51	51	42	42	42
Sagamore Bridge SB	On-Ramp merge from Scenic Highway	Off-Ramp diverge to Mid-Cape Connector	32	36	32	35	18	18
Sagamore Bridge NB	On-Ramp merge from Cranberry Highway	Off-Ramp diverge to Meetinghouse Lane	36	32	36	33	31	20
Route 6 E SB	On-Ramp merge from Mid Cape Connector	Route 6 E SB north of Route 130	44	43	42	49	26	25
Route 6 E NB	Route 6 E NB north of Route 130	Off-Ramp diverge to Cranberry Highway	41	35	41	37	35	21

Table B-5: VISSIM Processed Volumes Summary and Comparison with Volumes from Flow Maps

From	Location/Movement	Processed Volume																	
		Fall									Summer								
		Weekday AM			Weekday PM			Saturday MID			Weekday AM			Weekday PM			Saturday MID		
		Flow Maps	VISSIM	% Processed	Flow Maps	VISSIM	% Processed	Flow Maps	VISSIM	% Processed	Flow Maps	VISSIM	% Processed	Flow Maps	VISSIM	% Processed	Flow Maps	VISSIM	% Processed
Buzzards Bay Rotary																			
Main Street (Route 6) EB	Approach west of BB Rotary	675	673	99.8%	580	577	99.6%	880	1025	116.5%	640	689	107.6%	970	964	99.4%	1310	1309	99.9%
Main Street (Route 6) WB	West of BB Rotary	430	412	95.7%	755	748	99.1%	905	744	82.3%	495	461	93.1%	920	843	91.6%	760	647	85.1%
Main Street WB	Approach east of BB Rotary	180	159	88.2%	340	308	90.6%	625	432	69.1%	220	189	86.0%	475	426	89.7%	485	423	87.1%
Buzzards Bay Bypass (Route 6) SWB		285	292	102.5%	520	566	108.8%	365	388	106.3%	295	299	101.3%	485	468	96.6%	315	251	79.5%
Lincoln Avenue SB		65	67	102.7%	65	67	102.7%	105	107	102.0%	70	73	103.6%	80	82	103.0%	120	123	102.6%
Belmont Circle																			
Buzzards Bay Bypass (Route 6) EB		135	183	135.7%	340	372	109.5%	310	351	113.2%	195	194	99.4%	295	302	102.3%	440	358	81.3%
Belmont Circle WB	Thru	240	292	121.7%	550	566	102.8%	405	388	95.8%	305	299	98.0%	500	468	93.7%	255	251	98.3%
Route 25/28 Ramps SB		1185	1136	95.8%	1350	1279	94.7%	1365	1310	96.0%	1165	1127	96.7%	1480	1399	94.6%	1080	973	90.1%
Belmont Circle NB	Thru to the ramps	1915	1813	94.7%	1770	1657	93.6%	1925	1789	93.0%	1795	1734	96.6%	1950	1687	86.5%	1850	1471	79.5%
Main Street (Route 6) WB		1605	1501	93.5%	1630	1496	91.7%	1495	1383	92.5%	1815	1705	93.9%	2195	1903	86.7%	1740	1486	85.4%
Main Street NEB	Thru	700	726	103.7%	895	904	101.0%	665	732	110.0%	1060	1180	111.3%	1095	1062	97.0%	1075	1059	98.5%
Belmont Circle EB	Thru	1290	1294	100.3%	1135	1120	98.7%	1275	1208	94.8%	1115	1183	106.1%	1335	1264	94.7%	1050	904	86.1%
North of Bourne Bridge - Route 25 Ramps																			
Route 25 SB	Approach before Exit 10	1845	1831	99.2%	1755	1721	98.1%	1915	2059	107.5%	1880	1871	99.5%	2370	2592	109.4%	2285	2786	121.9%
Route 25 SB Off-Ramp to Belmont Circle		715	695	97.2%	700	659	94.1%	760	791	104.0%	650	632	97.2%	780	811	104.0%	685	592	86.4%
Route 25 SB On-Ramp from Belmont Circle		760	714	93.9%	700	651	93.0%	1025	832	81.1%	700	673	96.2%	595	512	86.1%	1040	822	79.0%
Route 25 NB Off-Ramp to Belmont Circle		470	445	94.6%	650	630	96.9%	605	526	87.0%	515	501	97.3%	700	597	85.2%	395	392	99.3%
Route 25 NB On-Ramp from Belmont Circle		1155	1090	94.4%	1070	999	93.4%	900	950	105.6%	1095	1055	96.3%	1355	1163	85.8%	810	638	78.7%
Route 25 NB	After On-Ramp from Belmont Circle	1910	1787	93.6%	2230	2054	92.1%	1820	1729	95.0%	1935	1837	94.9%	2645	2224	84.1%	2260	2049	90.7%
Bourne Bridge																			
Bourne Bridge SB		1890	1804	95.4%	1755	1639	93.4%	2180	2048	94.0%	1930	1871	96.9%	2185	2123	97.2%	2640	2353	89.1%
Bourne Bridge NB		1225	1178	96.1%	1810	1755	97.0%	1525	1328	87.1%	1355	1325	97.8%	1990	1689	84.9%	1845	1839	99.6%
South of Bourne Bridge - Bourne Rotary																			
Bourne Bridge SB		1890	1804	95.4%	1755	1639	93.4%	2180	2048	94.0%	1930	1871	96.9%	2185	2123	97.2%	2640	2353	89.1%
Trowbridge Road EB		350	338	96.5%	415	422	101.7%	305	296	97.0%	295	281	95.4%	510	412	80.7%	230	237	103.1%
Trowbridge Road WB	West of Bourne Rotary	285	261	91.6%	215	181	84.2%	455	403	88.5%	145	138	95.3%	235	204	86.6%	265	211	79.5%
Route 28 NB		1435	1410	98.2%	1305	1503	115.2%	1545	1475	95.5%	1325	1310	98.9%	1580	1537	97.3%	1680	1838	109.4%
Route 28 SB	South of Bourne Rotary	1890	1753	92.7%	1335	1198	89.7%	1560	1479	94.8%	1925	1837	95.4%	1610	1464	90.9%	2195	1892	86.2%
Sandwich Road WB		670	633	94.4%	970	776	79.9%	725	783	107.9%	1050	1056	100.6%	845	785	92.9%	1005	825	82.1%
Sandwich Road EB	East of Bourne Rotary	945	897	95.0%	1085	980	90.3%	1215	1084	89.2%	1175	1127	95.9%	1285	1091	84.9%	1250	1116	89.3%
Between Bourne and Sagamore Bridges																			
Scenic Highway EB		1270	1248	98.2%	1060	1027	96.9%	1190	1115	93.7%	1090	1141	104.7%	1215	1123	92.4%	930	788	84.7%
Scenic Highway WB		1550	1450	93.6%	1520	1493	98.2%	1330	1324	99.6%	1405	1637	116.5%	1885	1950	103.4%	1425	1381	96.9%
Sandwich Road EB		940	1031	109.6%	1085	1054	97.1%	1205	1162	96.4%	1170	1198	102.4%	1280	1227	95.9%	1235	1192	96.5%
Sandwich Road WB		775	774	99.9%	1030	1126	109.3%	680	810	119.1%	935	1038	111.0%	1035	1039	100.4%	935	983	105.1%
Scenic Highway (Route 6) / Church Lane																			
Scenic Highway (Route 6) EB	Thru	435	421	96.7%	520	496	95.3%	330	320	96.9%	415	425	102.5%	475	451	94.9%	275	226	82.1%
Scenic Highway (Route 6) EB	Right	865	828	95.7%	630	597	94.7%	745	727	97.6%	680	699	102.8%	630	597	94.8%	805	649	80.7%
Scenic Highway (Route 6) WB	Left	296	302	102.0%	245	250	101.9%	340	350	103.0%	290	293	100.9%	290	290	100.2%	725	601	82.9%
Scenic Highway (Route 6) WB	Thru	1500	1433	95.6%	1485	1414	95.2%	1285	1237	96.3%	1345	1310	97.4%	1860	1780	95.7%	1410	1227	87.0%
Scenic Highway (Route 6) / Route 3 SB Off-Ramp																			
Route 3 SB Off-Ramp SB	Left	115	114	99.1%	160	156	97.5%	120	115	96.0%	75	74	99.0%	60	61	101.5%	65	82	126.1%
Route 3 SB Off-Ramp SB	Right	265	253	95.6%	310	294	94.9%	380	356	93.7%	220	213	96.7%	355	364	102.4%	235	294	125.3%

Table B-5: VISSIM Processed Volumes Summary and Comparison with Volumes from Flow Maps

From	Location/Movement	Processed Volume																	
		Fall									Summer								
		Weekday AM			Weekday PM			Saturday MID			Weekday AM			Weekday PM			Saturday MID		
		Flow Maps	VISSIM	% Processed	Flow Maps	VISSIM	% Processed	Flow Maps	VISSIM	% Processed	Flow Maps	VISSIM	% Processed	Flow Maps	VISSIM	% Processed	Flow Maps	VISSIM	% Processed
Meetinghouse Lane / State Road / Canal Street																			
Meetinghouse Lane WB	Approach east of intersection	325	316	97.4%	275	267	97.1%	325	316	97.4%	360	354	98.3%	330	322	97.6%	270	264	97.6%
Meetinghouse Lane EB	East of intersection	255	239	93.8%	440	418	95.0%	340	320	94.1%	275	267	97.0%	525	484	92.2%	440	384	87.4%
North of Sagamore Bridge - Route 3 Ramps																			
Route 3 SB	Approach before Exit 1A	1510	1460	96.7%	1510	1464	97.0%	1670	1713	102.6%	1680	1630	97.0%	1855	1953	105.3%	1380	1707	123.7%
Route 3 SB Off-Ramp to Scenic Highway	Exit 1A-B	380	372	97.8%	470	455	96.8%	500	476	95.3%	295	289	98.0%	415	429	103.3%	300	381	127.2%
Route 3 SB On-Ramp from Scenic Highway		1180	1125	95.3%	895	840	93.8%	1120	1072	95.8%	985	986	100.1%	940	885	94.1%	1585	1200	75.7%
Route 3 NB Off-Ramp to Meetinghouse Lane	Exit 1A	290	277	95.4%	475	453	95.3%	310	293	94.7%	340	329	96.7%	515	483	93.8%	330	286	86.5%
Route 3 NB Off-Ramp to Scenic Highway WB	Exit 1B	1015	976	96.2%	1050	1004	95.7%	565	538	95.1%	865	853	98.7%	1305	1237	94.8%	1105	925	83.7%
Route 3 NB On-Ramp from State Road		435	424	97.4%	395	368	93.2%	325	313	96.2%	375	342	91.2%	425	403	94.8%	300	271	90.4%
Route 3 NB	After On-Ramp from State Road	1130	1077	95.3%	1570	1480	94.3%	1710	1642	96.0%	1530	1473	96.3%	1955	1813	92.8%	2155	1841	85.4%
Sagamore Bridge																			
Sagamore Bridge SB		2310	2167	93.8%	1935	1820	94.1%	2290	2256	98.5%	2370	2292	96.7%	2380	2176	91.4%	2665	2396	89.9%
Sagamore Bridge NB		2000	1938	96.9%	2700	2605	96.5%	2260	2199	97.3%	2360	2347	99.5%	3350	3182	95.0%	3290	2938	89.3%
South of Sagamore Bridge - Route 6 E Ramps																			
Route 6 E SB Off-Ramp to Mid-Cape Connector	Exit 1C	530	498	93.9%	605	573	94.7%	380	378	99.5%	520	506	97.3%	680	623	91.6%	510	462	90.6%
Route 6 E SB On-Ramp from Mid-Cape Connector		680	594	87.4%	925	796	86.1%	885	795	89.8%	895	838	93.7%	965	767	79.5%	1115	920	82.5%
Route 6 E SB	After On-Ramp from Mid-Cape Connector	2460	2207	89.7%	2255	2001	88.7%	2795	2615	93.6%	2745	2573	93.7%	2665	2238	84.0%	3270	2766	84.6%
Route 6 E NB	Approach before Exit 1C	1840	1818	98.8%	2670	2638	98.8%	1855	1833	98.8%	2345	2313	98.7%	3215	3177	98.8%	2865	2926	102.1%
Route 6 E NB Off-Ramp to Cranberry Highway	Exit 1C	305	290	95.0%	635	605	95.2%	530	507	95.7%	495	474	95.8%	515	497	96.5%	430	377	87.6%
Route 6 E NB On-Ramp from Cranberry Highway		465	443	95.4%	665	633	95.2%	935	913	97.6%	510	551	108.1%	650	573	88.1%	855	613	71.7%
Sandwich Road (Route 6A) / Cranberry Highway																			
Sandwich Road (Route 6A) WB	Approach east of intersection	480	474	98.7%	580	591	101.9%	920	933	101.4%	515	536	104.0%	725	631	87.0%	1210	1141	94.3%
Sandwich Road (Route 6A) EB	East of intersection	330	405	122.7%	535	539	100.8%	495	451	91.1%	405	413	101.9%	555	556	100.2%	575	529	92.0%

Table B-5: VISSIM Processed Volumes Summary and Comparison with Volumes from Flow Maps

From	Location/Movement	Processed Volume																	
		Fall									Summer								
		Weekday AM			Weekday PM			Saturday MID			Weekday AM			Weekday PM			Saturday MID		
		Flow Maps	VISSIM	% Processed	Flow Maps	VISSIM	% Processed	Flow Maps	VISSIM	% Processed	Flow Maps	VISSIM	% Processed	Flow Maps	VISSIM	% Processed	Flow Maps	VISSIM	% Processed
Buzzards Bay Rotary																			
Main Street (Route 6) EB	Approach west of BB Rotary	675	673	99.8%	580	577	99.6%	880	1025	116.5%	640	689	107.6%	970	964	99.4%	1310	1309	99.9%
Main Street (Route 6) WB	West of BB Rotary	430	412	95.7%	755	748	99.1%	905	744	82.3%	495	461	93.1%	920	843	91.6%	760	647	85.1%
Main Street WB	Approach east of BB Rotary	180	159	88.2%	340	308	90.6%	625	432	69.1%	220	189	86.0%	475	426	89.7%	485	423	87.1%
Buzzards Bay Bypass (Route 6) SWB		285	292	102.5%	520	566	108.8%	365	388	106.3%	295	299	101.3%	485	468	96.6%	315	251	79.5%
Lincoln Avenue SB		65	67	102.7%	65	67	102.7%	105	107	102.0%	70	73	103.6%	80	82	103.0%	120	123	102.6%
Belmont Circle																			
Buzzards Bay Bypass (Route 6) EB		135	183	135.7%	340	372	109.5%	310	351	113.2%	195	194	99.4%	295	302	102.3%	440	358	81.3%
Belmont Circle WB	Thru	240	292	121.7%	550	566	102.8%	405	388	95.8%	305	299	98.0%	500	468	93.7%	255	251	98.3%
Route 25/28 Ramps SB		1185	1136	95.8%	1350	1279	94.7%	1365	1310	96.0%	1165	1127	96.7%	1480	1399	94.6%	1080	973	90.1%
Belmont Circle NB	Thru to the ramps	1915	1813	94.7%	1770	1657	93.6%	1925	1789	93.0%	1795	1734	96.6%	1950	1687	86.5%	1850	1471	79.5%
Main Street (Route 6) WB		1605	1501	93.5%	1630	1496	91.7%	1495	1383	92.5%	1815	1705	93.9%	2195	1903	86.7%	1740	1486	85.4%
Main Street NEB	Thru	700	726	103.7%	895	904	101.0%	665	732	110.0%	1060	1180	111.3%	1095	1062	97.0%	1075	1059	98.5%
Belmont Circle EB	Thru	1290	1294	100.3%	1135	1120	98.7%	1275	1208	94.8%	1115	1183	106.1%	1335	1264	94.7%	1050	904	86.1%
North of Bourne Bridge - Route 25 Ramps																			
Route 25 SB	Approach before Exit 10	1845	1831	99.2%	1755	1721	98.1%	1915	2059	107.5%	1880	1871	99.5%	2370	2592	109.4%	2285	2786	121.9%
Route 25 SB Off-Ramp to Belmont Circle		715	695	97.2%	700	659	94.1%	760	791	104.0%	650	632	97.2%	780	811	104.0%	685	592	86.4%
Route 25 SB On-Ramp from Belmont Circle		760	714	93.9%	700	651	93.0%	1025	832	81.1%	700	673	96.2%	595	512	86.1%	1040	822	79.0%
Route 25 NB Off-Ramp to Belmont Circle		470	445	94.6%	650	630	96.9%	605	526	87.0%	515	501	97.3%	700	597	85.2%	395	392	99.3%
Route 25 NB On-Ramp from Belmont Circle		1155	1090	94.4%	1070	999	93.4%	900	950	105.6%	1095	1055	96.3%	1355	1163	85.8%	810	638	78.7%
Route 25 NB	After On-Ramp from Belmont Circle	1910	1787	93.6%	2230	2054	92.1%	1820	1729	95.0%	1935	1837	94.9%	2645	2224	84.1%	2260	2049	90.7%
Bourne Bridge																			
Bourne Bridge SB		1890	1804	95.4%	1755	1639	93.4%	2180	2048	94.0%	1930	1871	96.9%	2185	2123	97.2%	2640	2353	89.1%
Bourne Bridge NB		1225	1178	96.1%	1810	1755	97.0%	1525	1328	87.1%	1355	1325	97.8%	1990	1689	84.9%	1845	1839	99.6%
South of Bourne Bridge - Bourne Rotary																			
Bourne Bridge SB		1890	1804	95.4%	1755	1639	93.4%	2180	2048	94.0%	1930	1871	96.9%	2185	2123	97.2%	2640	2353	89.1%
Trowbridge Road EB		350	338	96.5%	415	422	101.7%	305	296	97.0%	295	281	95.4%	510	412	80.7%	230	237	103.1%
Trowbridge Road WB	West of Bourne Rotary	285	261	91.6%	215	181	84.2%	455	403	88.5%	145	138	95.3%	235	204	86.6%	265	211	79.5%
Route 28 NB		1435	1410	98.2%	1305	1503	115.2%	1545	1475	95.5%	1325	1310	98.9%	1580	1537	97.3%	1680	1838	109.4%
Route 28 SB	South of Bourne Rotary	1890	1753	92.7%	1335	1198	89.7%	1560	1479	94.8%	1925	1837	95.4%	1610	1464	90.9%	2195	1892	86.2%
Sandwich Road WB		670	633	94.4%	970	776	79.9%	725	783	107.9%	1050	1056	100.6%	845	785	92.9%	1005	825	82.1%
Sandwich Road EB	East of Bourne Rotary	945	897	95.0%	1085	980	90.3%	1215	1084	89.2%	1175	1127	95.9%	1285	1091	84.9%	1250	1116	89.3%
Between Bourne and Sagamore Bridges																			
Scenic Highway EB		1270	1248	98.2%	1060	1027	96.9%	1190	1115	93.7%	1090	1141	104.7%	1215	1123	92.4%	930	788	84.7%
Scenic Highway WB		1550	1450	93.6%	1520	1493	98.2%	1330	1324	99.6%	1405	1637	116.5%	1885	1950	103.4%	1425	1381	96.9%
Sandwich Road EB		940	1031	109.6%	1085	1054	97.1%	1205	1162	96.4%	1170	1198	102.4%	1280	1227	95.9%	1235	1192	96.5%
Sandwich Road WB		775	774	99.9%	1030	1126	109.3%	680	810	119.1%	935	1038	111.0%	1035	1039	100.4%	935	983	105.1%
Scenic Highway (Route 6) / Church Lane																			
Scenic Highway (Route 6) EB	Thru	435	421	96.7%	520	496	95.3%	330	320	96.9%	415	425	102.5%	475	451	94.9%	275	226	82.1%
Scenic Highway (Route 6) EB	Right	865	828	95.7%	630	597	94.7%	745	727	97.6%	680	699	102.8%	630	597	94.8%	805	649	80.7%
Scenic Highway (Route 6) WB	Left	296	302	102.0%	245	250	101.9%	340	350	103.0%	290	293	100.9%	290	290	100.2%	725	601	82.9%
Scenic Highway (Route 6) WB	Thru	1500	1433	95.6%	1485	1414	95.2%	1285	1237	96.3%	1345	1310	97.4%	1860	1780	95.7%	1410	1227	87.0%
Scenic Highway (Route 6) / Route 3 SB Off-Ramp																			
Route 3 SB Off-Ramp SB	Left	115	114	99.1%	160	156	97.5%	120	115	96.0%	75	74	99.0%	60	61	101.5%	65	82	126.1%
Route 3 SB Off-Ramp SB	Right	265	253	95.6%	310	294	94.9%	380	356	93.7%	220	213	96.7%	355	364	102.4%	235	294	125.3%

Table B-5: VISSIM Processed Volumes Summary and Comparison with Volumes from Flow Maps

From	Location/Movement	Processed Volume																	
		Fall									Summer								
		Weekday AM			Weekday PM			Saturday MID			Weekday AM			Weekday PM			Saturday MID		
		Flow Maps	VISSIM	% Processed	Flow Maps	VISSIM	% Processed	Flow Maps	VISSIM	% Processed	Flow Maps	VISSIM	% Processed	Flow Maps	VISSIM	% Processed	Flow Maps	VISSIM	% Processed
Meetinghouse Lane / State Road / Canal Street																			
Meetinghouse Lane WB	Approach east of intersection	325	316	97.4%	275	267	97.1%	325	316	97.4%	360	354	98.3%	330	322	97.6%	270	264	97.6%
Meetinghouse Lane EB	East of intersection	255	239	93.8%	440	418	95.0%	340	320	94.1%	275	267	97.0%	525	484	92.2%	440	384	87.4%
North of Sagamore Bridge - Route 3 Ramps																			
Route 3 SB	Approach before Exit 1A	1510	1460	96.7%	1510	1464	97.0%	1670	1713	102.6%	1680	1630	97.0%	1855	1953	105.3%	1380	1707	123.7%
Route 3 SB Off-Ramp to Scenic Highway	Exit 1A-B	380	372	97.8%	470	455	96.8%	500	476	95.3%	295	289	98.0%	415	429	103.3%	300	381	127.2%
Route 3 SB On-Ramp from Scenic Highway		1180	1125	95.3%	895	840	93.8%	1120	1072	95.8%	985	986	100.1%	940	885	94.1%	1585	1200	75.7%
Route 3 NB Off-Ramp to Meetinghouse Lane	Exit 1A	290	277	95.4%	475	453	95.3%	310	293	94.7%	340	329	96.7%	515	483	93.8%	330	286	86.5%
Route 3 NB Off-Ramp to Scenic Highway WB	Exit 1B	1015	976	96.2%	1050	1004	95.7%	565	538	95.1%	865	853	98.7%	1305	1237	94.8%	1105	925	83.7%
Route 3 NB On-Ramp from State Road		435	424	97.4%	395	368	93.2%	325	313	96.2%	375	342	91.2%	425	403	94.8%	300	271	90.4%
Route 3 NB	After On-Ramp from State Road	1130	1077	95.3%	1570	1480	94.3%	1710	1642	96.0%	1530	1473	96.3%	1955	1813	92.8%	2155	1841	85.4%
Sagamore Bridge																			
Sagamore Bridge SB		2310	2167	93.8%	1935	1820	94.1%	2290	2256	98.5%	2370	2292	96.7%	2380	2176	91.4%	2665	2396	89.9%
Sagamore Bridge NB		2000	1938	96.9%	2700	2605	96.5%	2260	2199	97.3%	2360	2347	99.5%	3350	3182	95.0%	3290	2938	89.3%
South of Sagamore Bridge - Route 6 E Ramps																			
Route 6 E SB Off-Ramp to Mid-Cape Connector	Exit 1C	530	498	93.9%	605	573	94.7%	380	378	99.5%	520	506	97.3%	680	623	91.6%	510	462	90.6%
Route 6 E SB On-Ramp from Mid-Cape Connector		680	594	87.4%	925	796	86.1%	885	795	89.8%	895	838	93.7%	965	767	79.5%	1115	920	82.5%
Route 6 E SB	After On-Ramp from Mid-Cape Connector	2460	2207	89.7%	2255	2001	88.7%	2795	2615	93.6%	2745	2573	93.7%	2665	2238	84.0%	3270	2766	84.6%
Route 6 E NB	Approach before Exit 1C	1840	1818	98.8%	2670	2638	98.8%	1855	1833	98.8%	2345	2313	98.7%	3215	3177	98.8%	2865	2926	102.1%
Route 6 E NB Off-Ramp to Cranberry Highway	Exit 1C	305	290	95.0%	635	605	95.2%	530	507	95.7%	495	474	95.8%	515	497	96.5%	430	377	87.6%
Route 6 E NB On-Ramp from Cranberry Highway		465	443	95.4%	665	633	95.2%	935	913	97.6%	510	551	108.1%	650	573	88.1%	855	613	71.7%
Sandwich Road (Route 6A) / Cranberry Highway																			
Sandwich Road (Route 6A) WB	Approach east of intersection	480	474	98.7%	580	591	101.9%	920	933	101.4%	515	536	104.0%	725	631	87.0%	1210	1141	94.3%
Sandwich Road (Route 6A) EB	East of intersection	330	405	122.7%	535	539	100.8%	495	451	91.1%	405	413	101.9%	555	556	100.2%	575	529	92.0%

Table B-6: VISSIM Density and LOS Summary

Name	Start Point	End Point	Fall						Summer					
			Weekday AM		Weekday PM		Saturday MID		Weekday AM		Weekday PM		Saturday MID	
			Density	LOS	Density	LOS	Density	LOS	Density	LOS	Density	LOS	Density	LOS
Route 25 SB	Route 25 SB at Plymouth Lane Overpass	On-Ramp merge from Belmont Circle	36	E	68	F	41	E	31	D	149	F	252	F
Route 25 NB	Off-Ramp diverge to Belmont Circle	Route 25 NB at Plymouth Lane Overpass	27	D	66	F	27	D	36	E	35	D	34	D
Belmont Circle Off-Ramp	Off-Ramps merge	Belmont Circle	46	F	52	F	54	F	45	E	60	F	69	F
SB Off-Ramp to Belmont Circle	Route 25 SB	Off-Ramps merge	21	C	26	C	28	C	16	B	52	F	44	E
NB Off-Ramp to Belmont Circle	Route 25 NB	Off-Ramps merge	13	B	24	C	15	B	15	B	18	B	12	B
Belmont Circle On-Ramp	Belmont Circle	On-Ramps diverge	71	F	54	F	64	F	59	F	58	F	89	F
On-Ramp to Route 25 SB	On-Ramps diverge	Route 25 SB	19	B	17	B	22	C	18	B	14	B	60	F
On-Ramp to Route 25 NB	On-Ramps diverge	Route 25 NB	30	D	27	C	26	C	29	D	32	D	17	B
Bourne Bridge SB	On-Ramp merge from Belmont Circle	Bourne Rotary	72	F	62	F	93	F	67	F	125	F	175	F
Bourne Bridge NB	Bourne Rotary	Off-Ramp diverge to Belmont Circle	30	D	61	F	34	D	33	D	43	E	47	F
Route 28 SB	Bourne Rotary	Route 28 SB at Clay Pond Road	42	E	28	D	36	E	34	D	39	E	57	F
Route 28 NB	Route 28 NB at Clay Pond Road	Bourne Rotary	35	D	131	F	74	F	31	D	131	F	67	F
Route 3 SB	Route 3 SB south of Herring Pond Road	On-Ramp merge from Scenic Highway	58	F	38	E	68	F	44	E	152	F	118	F
Route 3 NB	Off-Ramp diverge to Meetinghouse Lane	Route 3 NB south of Herring Pond Road	25	C	34	D	35	D	37	E	48	F	64	F
Route 3 SB Off-Ramp to Scenic Highway	Route 3 SB	Scenic Highway	13	B	13	B	17	B	9	A	16	B	15	B
Scenic Highway On-Ramp to Sagamore Bridge SB	Scenic Highway EB	Sagamore Bridge SB	45	E	31	D	42	E	38	E	44	E	159	F
Route 3 NB Off-Ramp to Scenic Highway EB	Route 3 NB	Scenic Highway EB	8	A	13	B	8	A	9	A	18	C	8	A
Route 3 NB Off-Ramp to Scenic Highway WB	Route 3 NB	Scenic Highway WB	28	C	29	D	15	B	24	C	36	E	77	F
State Road On-Ramp to Route 3 NB	State Road	Route 3 NB	14	B	12	B	10	A	11	B	13	B	9	A
Sagamore Bridge SB	On-Ramp merge from Scenic Highway	Off-Ramp diverge to Mid-Cape Connector	66	F	51	F	69	F	65	F	121	F	134	F
Sagamore Bridge NB	On-Ramp merge from Cranberry Highway	Off-Ramp diverge to Meetinghouse Lane	54	F	83	F	62	F	73	F	104	F	151	F
Route 6 E SB	Off-Ramp diverge to Mid-Cape Connector	Route 6 E SB north of Route 130	50	F	45	F	61	F	51	F	84	F	105	F
Route 6 E NB	Route 6 E NB north of Route 130	On-Ramp merge from Cranberry Highway	48	F	79	F	48	F	67	F	98	F	149	F
Route 6 E SB Off-Ramp to Mid-Cape Connector	Route 6 E SB	Mid-Cape Connector	17	B	20	B	13	B	17	B	22	C	16	B
Mid-Cape Connector On-Ramp to Route 6 E SB	Mid-Cape Connector	Route 6 E SB	16	B	25	C	23	C	22	C	22	C	36	E
Route 6 E NB Off-Ramp to Cranberry Highway	Route 6 E NB	Cranberry Highway	12	B	26	C	21	C	20	B	20	B	15	B
Cranberry Highway On-Ramp to Route 6 E NB	Cranberry Highway	Route 6 E NB	11	B	18	B	26	C	14	B	22	C	109	F

Appendix C
Model Calibrations

HCS

Table C-1: HCS CAF and SAF Calibration Summary - Fall

			Fall AM						Fall PM						Fall SAT					
			Freeway Capacity Adjustment Factor			Speed Adjustment Factor			Freeway Capacity Adjustment Factor			Speed Adjustment Factor			Freeway Capacity Adjustment Factor			Speed Adjustment Factor		
			Default	New	Notes	Default	New	Notes	Default	New	Notes	Default	New	Notes	Default	New	Notes	Default	New	Notes
Bourne Bridge	North of Bourne Bridge	Route 25 SB	0.939	No change		0.95	0.29		0.939	No change	At 0.39, LOS goes from B to F.	0.95	0.29		0.939	No change		0.95	0.29	
		Route 25 NB	0.939	No change		0.95	No change		0.939	No change		0.95	No change		0.939	No change		0.95	No change	
	Bourne Bridge	Bridge SB	0.939	No change		0.95	0.71		0.939	No change		0.95	0.81		0.939	-		0.95	-	
		Bridge NB	0.939	No change		0.95	No change		0.939	No change		0.95	0.75		0.939	-		0.95	-	
	North of Bourne Bridge	Route 25 SB Diverge	0.939	No change		0.95	No change		0.939	No change	At 0.25, LOS goes from B to F.	0.95	No change		0.939	-		0.95	-	
		Route 25 SB Merge	0.939	0.47	At 0.46, LOS goes from C to F.	0.95	0.29		0.939	0.53	At 0.54, it was still LOS C.	0.95	No change		0.939	0.64	At 0.65, it was still LOS C.	0.95	No change	
		Route 25 NB Diverge	0.939	-		0.95	-		0.939	-		0.95	-		0.939	-		0.95	-	
		Route 25 NB Merge	0.939	-		0.95	-		0.939	-		0.95	-		0.939	-		0.95	-	
Sagamore Bridge	North of Sagamore Bridge	Route 3 SB	0.939	0.7	At 0.41, LOS goes from B to F.	0.95	0.5	Congestion due to speed reduction downstream on bridge.	0.939	0.7	At 0.48, LOS jumps from C to F.	0.95	0.38	Congestion due to speed reduction downstream on bridge.	0.939	0.6		0.95	0.3	Congestion due to speed reduction downstream on bridge.
		Route 3 NB	0.939	No change		0.95	No change		0.939	No change		0.95	-		0.939	No change		0.95	No change	
	Sagamore Bridge	Bridge SB	0.939	-		0.95	-		0.939	0.71		0.95	-		0.939	0.79		0.95	No change	
		Bridge NB	0.939	-		0.95	-		0.939	No change		0.95	-		0.939	No change		0.95	No change	
	South of Sagamore	Route 6 SB	0.939	-		0.95	-		0.939	-		0.95	-		0.939	-		0.95	-	
		Route 6 NB	0.939	-		0.95	-		0.939	0.89		0.95	-		0.939	-		0.95	-	
	North of Sagamore Bridge	Route 3 SB Diverge	0.939	No change		0.95	No change	Changing SAF doesn't affect.	0.939	0.35	At 0.36, it was still LOS B	0.95	-	Changing SAF doesn't affect.	0.939	-		0.95	-	
		Route 3 NB Diverge to Scenic Highway EB	0.939	-		0.95	-		0.939	-		0.95	-		0.939	-		0.95	-	
		Route 3 NB Diverge to Scenic Highway WB	0.939	-		0.95	-		0.939	-		0.95	-		0.939	-		0.95	-	
		Route 3 NB Merge	0.939	-		0.95	-		0.939	-		0.95	-		0.939	-		0.95	-	
	South of Sagamore Bridge	Route 6 SB Diverge	0.939	-		0.95	-		0.939	-		0.95	-		0.939	-		0.95	-	
		Route 6 SB Merge	0.939	-		0.95	-		0.939	-		0.95	-		0.939	-		0.95	-	
		Route 6 NB Diverge	0.939	-		0.95	-		0.939	-		0.95	-		0.939	-		0.95	-	
		Route 6 NB Merge	0.939	-		0.95	-		0.939	0.82	At 0.83, it was still LOS D	0.95	-		0.939	0.82	At 0.81, LOS goes from D to F.	0.95	No change	

Table C-2: HCS CAF and SAF Calibration Summary - Summer

			Summer AM						Summer PM						Summer SAT					
			Freeway Capacity Adjustment Factor			Speed Adjustment Factor			Freeway Capacity Adjustment Factor			Speed Adjustment Factor			Freeway Capacity Adjustment Factor			Speed Adjustment Factor		
			Default	New	Notes	Default	New	Notes	Default	New	Notes	Default	New	Notes	Default	New	Notes	Default	New	Notes
Bourne Bridge	North of Bourne Bridge	Route 25 SB	0.939	No change	At 0.31, LOS jumps from B to F.	0.95	0.5	Congestion due to speed reduction downstream on bridge	0.939	No change	At 0.39, LOS goes from B to F.	0.95	0.29		0.939	No change		0.95	0.29	
		Route 25 NB	0.939	No change		0.95	No change		0.939	No change		0.95	No change		0.939	No change		0.95	No change	
	Bourne Bridge	Bridge SB	0.939	0.62	At 0.61, LOS jumps from D to F.	0.95	0.74	At 0.73, LOS jumps from E to F.	0.939	No change		0.95	0.81		0.939	-		0.95	-	
		Bridge NB	0.939	No change		0.95	No change		0.939	No change		0.95	0.75		0.939	-		0.95	-	
	North of Bourne Bridge	Route 25 SB Diverge	0.939	No change	At 0.19, LOS jumps from B to F.	0.95	No change	Has no effect	0.939	No change	At 0.25, LOS goes from B to F.	0.95	No change		0.939	-		0.95	-	
		Route 25 SB Merge	0.939	No change	At 0.47, LOS jumps from C to F	0.95	No change	Has no effect	0.939	0.53	At 0.54, it was still LOS C.	0.95	No change		0.939	0.64	At 0.65, it was still LOS C.	0.95	No change	
		Route 25 NB Diverge	0.939	-		0.95	-		0.939	-		0.95	-		0.939	-		0.95	-	
		Route 25 NB Merge	0.939	-		0.95	-		0.939	-		0.95	-		0.939	-		0.95	-	
Sagamore Bridge	North of Sagamore Bridge	Route 3 SB	0.939	0.70	At 0.44, LOS jumps from B to F.	0.95	0.5	Congestion due to speed reduction downstream on bridge	0.939	0.7	At 0.48, LOS jumps from C to F.	0.95	0.38	Congestion due to speed reduction downstream on bridge.	0.939	0.6		0.95	0.3	Congestion due to speed reduction downstream on bridge.
		Route 3 NB	0.939	No change		0.95	No change		0.939	No change		0.95	-		0.939	No change		0.95	No change	
	Sagamore Bridge	Bridge SB	0.939	-		0.95	-		0.939	0.71		0.95	-		0.939	0.79		0.95	No change	
		Bridge NB	0.939	-		0.95	-		0.939	No change		0.95	-		0.939	No change		0.95	No change	
	South of Sagamore	Route 6 SB	0.939	-		0.95	-		0.939	-		0.95	-		0.939	-		0.95	-	
		Route 6 NB	0.939	-		0.95	-		0.939	0.89		0.95	-		0.939	-		0.95	-	
	North of Sagamore Bridge	Route 3 SB Diverge	0.939	0.35	At 0.34, LOS jumps from B to F	0.95	No change	Changing SAF doesn't change much	0.939	0.35	At 0.36, it was still LOS B	0.95	-	Changing SAF doesn't affect.	0.939	-		0.95	-	
		Route 3 NB Diverge to Scenic Highway EB	0.939	-		0.95	-		0.939	-		0.95	-		0.939	-		0.95	-	
		Route 3 NB Diverge to Scenic Highway WB	0.939	-		0.95	-		0.939	-		0.95	-		0.939	-		0.95	-	
		Route 3 NB Merge	0.939	-		0.95	-		0.939	-		0.95	-		0.939	-		0.95	-	
	South of Sagamore Bridge	Route 6 SB Diverge	0.939	-		0.95	-		0.939	-		0.95	-		0.939	-		0.95	-	
		Route 6 SB Merge	0.939	-		0.95	-		0.939	-		0.95	-		0.939	-		0.95	-	
		Route 6 NB Diverge	0.939	-		0.95	-		0.939	-		0.95	-		0.939	-		0.95	-	
		Route 6 NB Merge	0.939	-		0.95	-		0.939	0.82	At 0.83, it was still LOS D	0.95	-		0.939	0.82	At 0.81, LOS goes from D to F.	0.95	No change	

VISSIM

Table C-3: VISSIM Calibration Summary

Setting	No.	Name	Link 1	Link 2	Type	Original	Modified
Conflict Area	-	-	10002: Route 6A EB	10189: Sandwich Road WB/SB	Critical Gap	3.5	2
Conflict Area	-	-	10002: Route 6A EB	10189: Sandwich Road WB/SB	Rear Gap	0.5	0.1
Conflict Area	-	-	10002: Route 6A EB	10189: Sandwich Road WB/SB	Front Gap	0.5	0.1
Conflict Area	-	-	10002: Route 6A EB	10189: Sandwich Road WB/SB	Safe Distance Factor	1.5	1
Conflict Area	-	-	10008: Route 6A WB	10189: Sandwich Road WB/SB	Critical Gap	3.5	2
Conflict Area	-	-	10008: Route 6A WB	10189: Sandwich Road WB/SB	Rear Gap	0.5	0.1
Conflict Area	-	-	10008: Route 6A WB	10189: Sandwich Road WB/SB	Front Gap	0.5	0.1
Conflict Area	-	-	10008: Route 6A WB	10189: Sandwich Road WB/SB	Safe Distance Factor	1.5	1
Conflict Area	-	-	10073: Buzzards Bay Bypass (Route 6) WB/SWB	10075: Head of the Bay Road SB	Critical Gap	3.5	2
Conflict Area	-	-	10073: Buzzards Bay Bypass (Route 6) WB/SWB	10075: Head of the Bay Road SB	Rear Gap	0.5	0.2
Conflict Area	-	-	10073: Buzzards Bay Bypass (Route 6) WB/SWB	10075: Head of the Bay Road SB	Front Gap	0.5	0.2
Conflict Area	-	-	10073: Buzzards Bay Bypass (Route 6) WB/SWB	10258: Bourne Rotary N SB	Critical Gap	3.5	2
Conflict Area	-	-	10073: Buzzards Bay Bypass (Route 6) WB/SWB	10258: Bourne Rotary N SB	Rear Gap	0.5	0.2
Conflict Area	-	-	10073: Buzzards Bay Bypass (Route 6) WB/SWB	10258: Bourne Rotary N SB	Front Gap	0.5	0.2
Conflict Area	-	-	10075: Head of the Bay Road SB	10258: Bourne Rotary N SB	Critical Gap	3.5	2
Conflict Area	-	-	10075: Head of the Bay Road SB	10258: Bourne Rotary N SB	Rear Gap	0.5	0.1
Conflict Area	-	-	10075: Head of the Bay Road SB	10258: Bourne Rotary N SB	Front Gap	0.5	0.1
Conflict Area	-	-	10075: Head of the Bay Road SB	10258: Bourne Rotary N SB	Safe Distance Factor	1.5	1
Conflict Area	-	-	10083: Bourne Rotary N NB	10119: Bourne Rotary N NB	Critical Gap	3.5	2
Conflict Area	-	-	10083: Bourne Rotary N NB	10119: Bourne Rotary N NB	Rear Gap	0.5	0.1
Conflict Area	-	-	10083: Bourne Rotary N NB	10119: Bourne Rotary N NB	Front Gap	0.5	0.1
Conflict Area	-	-	10083: Bourne Rotary N NB	10119: Bourne Rotary N NB	Safe Distance Factor	1.5	1
Conflict Area	-	-	10086: Route 25/28 Off-Ramps SB	10261: Route 25/28 Off-Ramps SB	Critical Gap	3.5	2
Conflict Area	-	-	10086: Route 25/28 Off-Ramps SB	10261: Route 25/28 Off-Ramps SB	Rear Gap	0.5	0.1
Conflict Area	-	-	10086: Route 25/28 Off-Ramps SB	10261: Route 25/28 Off-Ramps SB	Front Gap	0.5	0.1
Conflict Area	-	-	10086: Route 25/28 Off-Ramps SB	10261: Route 25/28 Off-Ramps SB	Safe Distance Factor	1.5	1
Conflict Area	-	-	10122: Bourne Rotary N SB	10258: Bourne Rotary N SB	Critical Gap	3.5	2
Conflict Area	-	-	10122: Bourne Rotary N SB	10258: Bourne Rotary N SB	Rear Gap	0.5	0.1
Conflict Area	-	-	10122: Bourne Rotary N SB	10258: Bourne Rotary N SB	Front Gap	0.5	0.1
Conflict Area	-	-	10128: Bourne Rotary S	10254: Bourne Rotary S SB	Critical Gap	3.5	2
Conflict Area	-	-	10128: Bourne Rotary S	10254: Bourne Rotary S SB	Rear Gap	0.5	0.1
Conflict Area	-	-	10128: Bourne Rotary S	10254: Bourne Rotary S SB	Front Gap	0.5	0.1
Conflict Area	-	-	10128: Bourne Rotary S	10254: Bourne Rotary S SB	Front Gap	1.5	1

Table C-3: VISSIM Calibration Summary

Setting	No.	Name	Link 1	Link 2	Type	Original	Modified
Conflict Area	-	-	10129: Route 28 NB	10249: Bourne Rotary S EB	Critical Gap	3.5	2
Conflict Area	-	-	10129: Route 28 NB	10249: Bourne Rotary S EB	Rear Gap	0.5	0.1
Conflict Area	-	-	10129: Route 28 NB	10249: Bourne Rotary S EB	Front Gap	0.5	0.1
Conflict Area	-	-	10129: Route 28 NB	10249: Bourne Rotary S EB	Safe Distance Factor	1.5	1
Conflict Area	-	-	10131: Bourne Rotary S WB	10132: Bourne Rotary S WB	Critical Gap	3.5	2
Conflict Area	-	-	10131: Bourne Rotary S WB	10132: Bourne Rotary S WB	Rear Gap	0.5	0.2
Conflict Area	-	-	10131: Bourne Rotary S WB	10132: Bourne Rotary S WB	Front Gap	0.5	0.2
Conflict Area	-	-	10133: Sandwich Road WB/SB	10271: Sandwich Road WB/SB	Critical Gap	3.5	2
Conflict Area	-	-	10133: Sandwich Road WB/SB	10271: Sandwich Road WB/SB	Rear Gap	0.5	0.2
Conflict Area	-	-	10133: Sandwich Road WB/SB	10271: Sandwich Road WB/SB	Front Gap	0.5	0.2
Conflict Area	-	-	10133: Sandwich Road WB/SB	10271: Sandwich Road WB/SB	Safe Distance Factor	1.5	1
Conflict Area	-	-	10134: Sandwich Road EB/NB	10271: Sandwich Road WB/SB	Critical Gap	3.5	2
Conflict Area	-	-	10134: Sandwich Road EB/NB	10271: Sandwich Road WB/SB	Rear Gap	0.5	0.2
Conflict Area	-	-	10134: Sandwich Road EB/NB	10271: Sandwich Road WB/SB	Front Gap	0.5	0.2
Conflict Area	-	-	10134: Sandwich Road EB/NB	10271: Sandwich Road WB/SB	Safe Distance Factor	1.5	1
Conflict Area	-	-	10134: Sandwich Road EB/NB	10270: Sandwich Road EB/NB	Critical Gap	3.5	2
Conflict Area	-	-	10134: Sandwich Road EB/NB	10270: Sandwich Road EB/NB	Rear Gap	0.5	0.2
Conflict Area	-	-	10134: Sandwich Road EB/NB	10270: Sandwich Road EB/NB	Front Gap	0.5	0.2
Conflict Area	-	-	10183: Cranberry Highway WB/SB	10189: Sandwich Road WB/SB	Critical Gap	3.5	2.5
Conflict Area	-	-	10186: Regency Drive NB	10189: Sandwich Road WB/SB	Critical Gap	3.5	2
Conflict Area	-	-	10253: Bourne Rotary S SB	10255: Bourne Rotary S WB	Critical Gap	3.5	2
Conflict Area	-	-	10253: Bourne Rotary S SB	10255: Bourne Rotary S WB	Rear Gap	0.5	0.1
Conflict Area	-	-	10253: Bourne Rotary S SB	10255: Bourne Rotary S WB	Front Gap	0.5	0.1
Conflict Area	-	-	10253: Bourne Rotary S SB	10255: Bourne Rotary S WB	Safe Distance Factor	1.5	1
Conflict Area	-	-	10310: Scenic Highway (Route 6) WB	10311: Side Street - 7	Critical Gap	3.5	2
Conflict Area	-	-	10310: Scenic Highway (Route 6) WB	10311: Side Street - 7	Rear Gap	0.5	0.2
Conflict Area	-	-	10310: Scenic Highway (Route 6) WB	10311: Side Street - 7	Front Gap	0.5	0.2
Conflict Area	-	-	10321: Sandwich Road WB/SB	10322: Side Street - 10	Critical Gap	3.5	2
Conflict Area	-	-	10321: Sandwich Road WB/SB	10322: Side Street - 10	Rear Gap	0.5	0.1
Conflict Area	-	-	10321: Sandwich Road WB/SB	10322: Side Street - 10	Front Gap	0.5	0.1
Conflict Area	-	-	10321: Sandwich Road WB/SB	10322: Side Street - 10	Safe Distance Factor	1.5	1
Connector	10037	Route 6 NB	-	-	Desired Direction	All	Left
Connector	10016	Scenic Highway (Route 6) WB	-	-	Lane Change	656.2	1000
Connector	10023	Route 3 SB	-	-	Lane Change	656.2	2000
Connector	10024	Route 3 SB	-	-	Lane Change	656.2	2000
Connector	10025	Route 3 SB	-	-	Lane Change	656.2	2000
Connector	10026	Route 3 NB	-	-	Lane Change	656.2	2000
Connector	10027	Route 3 NB	-	-	Lane Change	656.2	2000
Connector	10028	Route 6 SB	-	-	Lane Change	656.2	2000

Table C-3: VISSIM Calibration Summary

Setting	No.	Name	Link 1	Link 2	Type	Original	Modified
Connector	10029	Route 6 SB	-	-	Lane Change	656.2	2000
Connector	10030	Route 6 SB	-	-	Lane Change	656.2	2000
Connector	10031	Route 6 SB	-	-	Lane Change	656.2	2000
Connector	10032	Route 6 SB	-	-	Lane Change	656.2	2000
Connector	10033	Route 3 NB	-	-	Lane Change	656.2	2000
Connector	10034	Route 6 NB	-	-	Lane Change	656.2	2000
Connector	10035	Route 6 NB	-	-	Lane Change	656.2	2000
Connector	10036	Route 6 NB	-	-	Lane Change	656.2	2000
Connector	10037	Route 6 NB	-	-	Lane Change	656.2	2000
Connector	10038	Route 6 NB	-	-	Lane Change	656.2	2000
Connector	10039	Route 25 SB	-	-	Lane Change	656.2	2000
Connector	10040	Route 25 SB	-	-	Lane Change	656.2	2000
Connector	10041	Route 25 SB	-	-	Lane Change	656.2	2000
Connector	10042	Route 25 NB	-	-	Lane Change	656.2	2000
Connector	10043	Route 25 NB	-	-	Lane Change	656.2	2000
Connector	10044	Route 28 SB	-	-	Lane Change	656.2	2000
Connector	10045	Route 28 SB	-	-	Lane Change	656.2	2000
Connector	10046	Route 28 NB	-	-	Lane Change	656.2	2000
Connector	10047	Route 28 NB	-	-	Lane Change	656.2	2000
Connector	10048	Route 28 NB	-	-	Lane Change	656.2	2000
Connector	10069	Bourne Rotary N EB	-	-	Lane Change	656.2	2000
Connector	10071	Bourne Rotary N WB	-	-	Lane Change	656.2	2000
Connector	10073	Buzzards Bay Bypass (Route 6) WB/SWB	-	-	Lane Change	656.2	1000
Connector	10077	Main Street WB	-	-	Lane Change	656.2	1000
Connector	10081	Route 25/28 On-Ramps NB	-	-	Lane Change	656.2	2000
Connector	10084	Route 25 Off-Ramp SB	-	-	Lane Change	656.2	2000
Connector	10085	Route 25 On-Ramp NB	-	-	Lane Change	656.2	2000
Connector	10087	Route 28 SB Off-Ramp	-	-	Lane Change	656.2	2000
Connector	10089	Route 28 SB On-Ramp	-	-	Lane Change	656.2	2000
Connector	10122	Bourne Rotary N SB	-	-	Lane Change	656.2	1000
Connector	10130	Bourne Rotary Connector NB	-	-	Lane Change	656.2	200
Connector	10160	Route 6 SB Off-Ramp Exit 1C	-	-	Lane Change	656.2	2000
Connector	10161	Route 6 SB On-Ramp from Mid-Cape Connector	-	-	Lane Change	656.2	2000
Connector	10173	Route 6 NB Off-Ramp Exit 1C	-	-	Lane Change	656.2	2000
Connector	10176	Cranberry Highway WB/SB	-	-	Lane Change	656.2	1000
Connector	10179	Cranberry Highway EB/NB	-	-	Lane Change	656.2	2000
Connector	10180	Cranberry Highway EB/NB	-	-	Lane Change	656.2	2000
Connector	10205	Route 6 SB On-Ramp from Scenic Highway	-	-	Lane Change	656.2	2000
Connector	10206	Route 6 SB On-Ramp from Scenic Highway	-	-	Lane Change	656.2	2000
Connector	10207	Route 6 SB On-Ramp from Scenic Highway	-	-	Lane Change	656.2	1000

Table C-3: VISSIM Calibration Summary

Setting	No.	Name	Link 1	Link 2	Type	Original	Modified
Connector	10213	Route 3 SB Off-Ramp Exit 1A	-	-	Lane Change	656.2	2000
Connector	10217	Route 6 NB Off-Ramp Exit 1B	-	-	Lane Change	656.2	2500
Connector	10243	Route 6 NB	-	-	Lane Change	656.2	2000
Connector	10244	Route 6 NB On-Ramp from Cranberry Highway	-	-	Lane Change	656.2	2000
Connector	10245	Route 6 NB Off-Ramp Exit 1A	-	-	Lane Change	656.2	2000
Connector	10248	Route 28 SB	-	-	Lane Change	656.2	1000
Connector	10249	Bourne Rotary S EB	-	-	Lane Change	656.2	800
Connector	10250	Bourne Rotary S EB	-	-	Lane Change	656.2	1000
Connector	10257	Bourne Rotary S NB	-	-	Lane Change	656.2	200
Link	43	Route 6 NB	-	-	Look Ahead Distance	1640	2500
Link	45	Route 6 NB	-	-	Look Ahead Distance	1640	2500
Link	170	Route 28 NB	-	-	No Lane Change Right		Check
Link	53	Route 28 SB	-	-	No Lane Change Right		Check
Driving Behavior	1	Urban (motorized)	-	-	Consider next turn		Check
Driving Behavior	1	Urban (motorized)	-	-	Cooperative lane change		Check
Driving Behavior	3	Freeway (free lane selection)	-	-	Consider next turn		Check
Driving Behavior	3	Freeway (free lane selection)	-	-	Cooperative lane change		Check

2.4 Summary of Future No Build Modeling Process and Results (December 17, 2021)

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Date
12/17/2021

To
Amy Getchell, MassDOT

From
Alexandra Siu, P.E., PTOE
Paul Nelson

PROJECT CORRESPONDENCE

Subject
Cape Cod Canal Bridges Program – Summary of Future No Build Modeling Process and Results

Overview:

Use of the "Sensitivity Case" Future No Build scenario is recommended based on our evaluation of relevant travel trends and how they impact traffic volumes within the Cape Cod Canal study area. While travel patterns are similar for both 2045 Future No Build scenarios tested, the Sensitivity Case reflects higher overall traffic volumes and provides a more conservative baseline for the comparison of alternatives. The Sensitivity Case Future No Build scenario has the added benefit of capturing travel pattern changes due to several emerging trends, including:

- Migrations of non-retired families to their vacation homes on Cape Cod during the COVID-19 pandemic may have been a one-time phenomenon as many have reportedly returned to their primary residence once in-person schooling resumed.
- New housing construction on Cape Cod is expected to continue to cater to higher income retirees and people seeking vacation homes (based on trends identified from IRS data), and this will continue the trend of lower-wage workers seeking housing outside of Cape Cod.
- Some conversion of homes from seasonal use to year-round households is expected, but no information indicated it would be higher than the 11,000 homes (~10% of total existing supply) indicated in the stated preference survey conducted by the Cape Cod Commission.
- Total employment levels are expected to stay at 2020 levels through 2045 due to counteracting trends affecting future employment levels.
    - The first trend is the decrease in employment driven by the overall decrease in population (in jobs like education, government services, and grocery stores).
    - The second trend is the growth in jobs related to Cape Cod's aging population (healthcare, administrative and support services) and popularity as a vacation destination (food services and drinking places, construction of buildings, etc.).

The Barnstable County socio-economic forecast under the "Sensitivity Case" Future No Build scenario is summarized in Table 1. The resulting change in traffic volumes during peak hour conditions for Summer Weekday PM and Summer Weekend Saturday for the Cape Cod Canal bridges is shown in Table 2 and the change in volumes on the Canalside Roadways (Scenic Highway and Sandwich Road) is shown in Table 3.

Table 1: Barnstable County Socio-Economic Forecasts - Comparison of 2019 Existing Conditions to the Future No Build "Sensitivity Case" Scenario

Model Condition	Population	Households	Employment
2019 Existing Conditions	212,990	94,323	97,672
2045 Sensitivity Case (FXM)	192,559	90,323	96,878
Diff. from Existing	*-9.6%*	*-4.2%*	*-0.8%*

Table 2: Bridge Traffic Volumes - Comparison of 2019 Existing Conditions to the Future No Build "Sensitivity Case" Scenario

Model Condition	Bourne Bridge		Sagamore Bridge		Total Crossings
	North	South	North	South	
Summer Weekday PM					
2019 Existing Conditions	1,990	2,185	3,350	2,380	**9,905**
2045 Sensitivity Case (FXM)	2,915	2,285	3,955	2,605	**11,760**
Diff. from Existing	*46.5%*	*4.6%*	*18.1%*	*9.5%*	***18.7%***
Summer Weekend Saturday					
2019 Existing Conditions	1,845	2,640	3,290	2,665	**10,440**
2045 Sensitivity Case (FXM)	2,295	2,710	3,880	3,470	**12,355**
Diff. from Existing	*24.4%*	*2.7%*	*17.9%*	*30.2%*	***18.3%***

Table 3: Canal Roadway Traffic Volumes - Comparison of 2019 Existing Conditions to the Future No Build "Sensitivity Case" Scenario

Model Condition	Scenic Highway		Sandwich Rd		Total Canalside
	East	West	East	West	
Summer Weekday PM					
2019 Existing Conditions	1,215	2,125	1,350	1,035	**5,725**
2045 Sensitivity Case (FXM)	1,840	2,375	1,300	1,685	**7,200**
Diff. from Existing	*51.4%*	*11.8%*	*-3.7%*	*62.8%*	***25.8%***
Summer Weekend Saturday					
2019 Existing Conditions	930	1,590	1,410	935	**4,865**
2045 Sensitivity Case (FXM)	1,495	1,910	1,305	1,145	**5,855**
Diff. from Existing	*60.8%*	*20.1%*	*-7.4%*	*22.5%*	***20.3%***

Summary of Future No Build Scenario Development:

As outlined in the "Future Demographic Conditions" memo dated May 14, 2021, two scenarios were developed for the Future No Build conditions within the study area for the Cape Cod Bridges Program, a "Base Case" scenario and a "Sensitivity Case" scenario. The two Future No Build conditions scenarios were investigated to ensure that the measures of effectiveness for the project's alternatives development capture the range of anticipated possible future projections.

Establishing the Base Case scenario followed a similar method as the initial planning study, with changes in visitor and non-visitor trips estimated separately. In a memorandum prepared by FXM Associates, dated August 4, 2021 an annual growth rate of 0.70% was established for visitor tips based on evaluation of historic growth in Cape Cod Canal bridge volumes and employment trends in jobs classified as Accommodations and Food Services (NAICS 72). Applying this growth rate to the 2019 visitor trips leads to the following changes in visitor volumes during the time periods evaluated:

- Summer Weekday PM peak hour visitor trips increase from 3,905 to 4,695 (20% increase)
- Summer Weekend Saturday peak hour visitor trips increase from 6,115 to 7,425 (21% increase)

The 2040 population, households, and employment levels identified by the UMass Donahue Institute (UMDI) and approved MassDOT OTP were used as the basis for estimating the changes in non-visitor trips by 2045. The total population, households, and employment levels for Barnstable County are shown in Table 4. This future data indicates a decrease in all three categories. The demographic data was not extrapolated from 2040 to 2045 because continuation of the trends between the 2030 and 2040 will result in unrealistically low estimates of trips.

Table 4: Barnstable County Socio-Economic Forecasts - Comparison of 2019 Existing Conditions to the Future No Build "Base Case" Scenario

Model Condition	Population	Households	Employment
2019 Existing Conditions	212,990	94,323	97,672
2045 Base Case (UMDI)	176,007	82,313	75,299
Diff. from Existing	*-17.4%*	*-12.7%*	*-22.9%*

Adjustments were required to the allocation of population, households, and employment in the Town of Bourne to ensure accurate estimation of vehicle trips in the Future No Build scenarios. As the first adjustment, the 2019 existing population, household, and employment totals for each traffic analysis zone (TAZ) in the Town of Bourne were re-allocated based on data obtained from US Bureau of Census' American Community Survey (ACS). This adjustment was required because the overall distribution of population, households, and employment between TAZs did not match actual levels of development and having an inaccurate breakdown in the 2019 existing conditions travel demand model was leading to skewed growth rates in the Future No Build scenarios.

As another adjustment, twelve new TAZs were created in the Town of Bourne and one new TAZ was created in the Town of Sandwich in both the 2019 Existing Conditions and Future No Build Conditions, all in the vicinity of the canal bridges and approach roadways to improve the overall accuracy of the travel demand model. Each new TAZ was created by splitting an existing TAZ into smaller zones and allocating a specified percentage of the original zone's population, households, and employment. Table 5 provides information on how demographic information was allocated to each new TAZ and Figure 1 shows the final configuration of TAZs used in the travel demand model.

Table 5: Overview of additional TAZs created in the Towns of Bourne and Sandwich

Original TAZ	New TAZ	Percent	Original TAZ	New TAZ	Percent
2999 - Bournedale Road	2998 (new) 2999	*25%* *75%*	3079 – Sagamore Bridge South	2989 (new) 2990 (new) 2995 (new) 2996 (new) 3079	*10%* *10%* *30%* *20%* *30%*
3000 – Sagamore Flyover	2997 (new) 3000	*15%* *85%*	3087 – East of Bourne Rotary	2991 (new) 2992 (new) 2993 (new) 3087	*10%* *10%* *20%* *60%*
3001 – Buzzards Bay	3001 3187 (new)	*50%* *50%*	3185 – North of Belmont Circle	3185 3186 (new)	*60%* *40%*
3078 – Joint Base CC	2994 (new) 3078	*30%* *70%*	3099 – East of Joint Base CC (Town of Sandwich)	2988 (new) 3099	*60%* *40%*

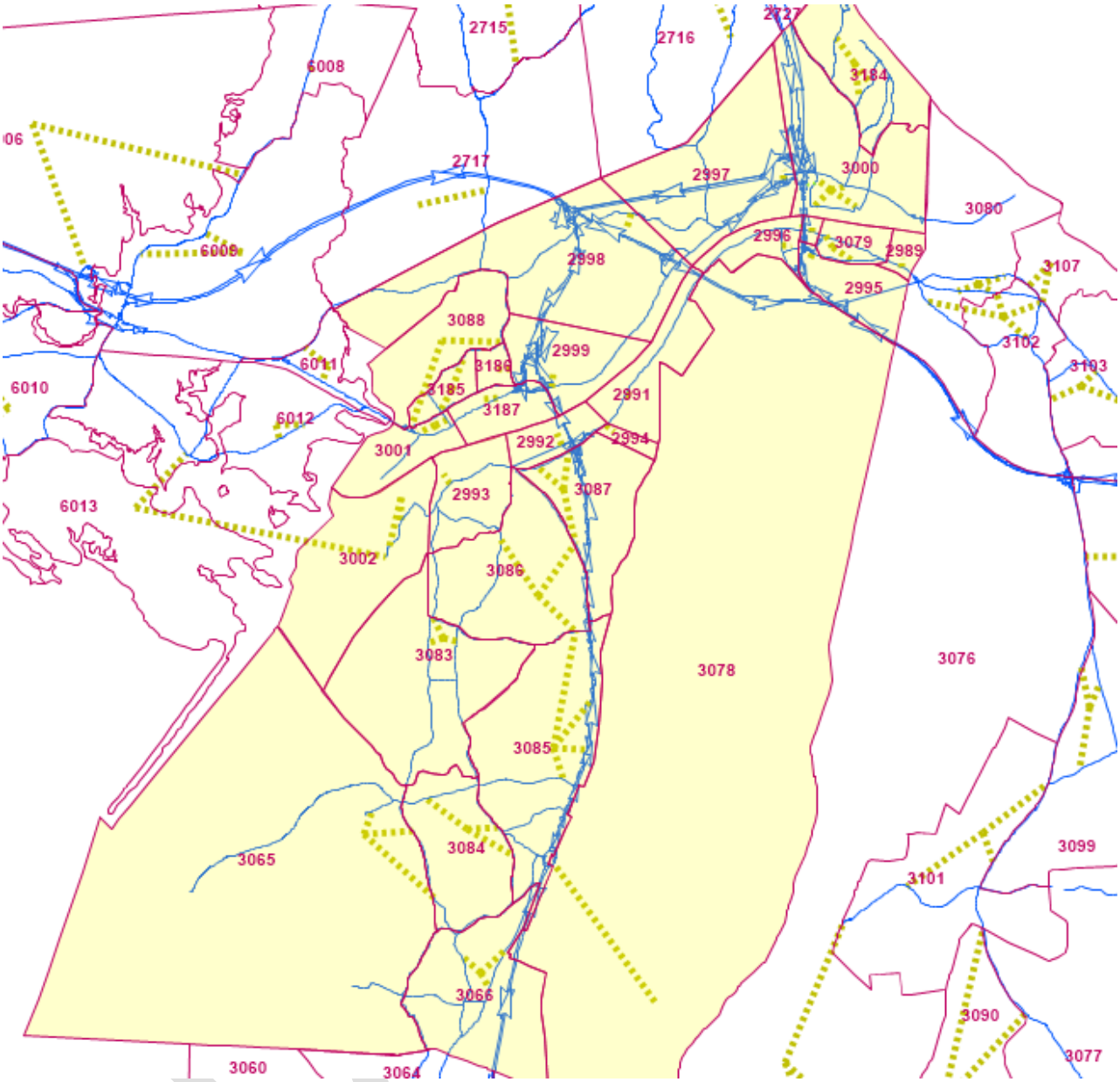


Figure 1: Map of new TAZ structure in the Town of Bourne

Final adjustments to population, households, and employment for TAZs in the Town of Bourne and some in the Town of Plymouth for the Future No Build conditions were made to reflect the following planned and/or permitted projects:

<u>Town of Bourne</u>

- Canalside Commons
- Cape View Way
- Canal Street Crossing
- Buzzards Bay Growth Incentive Zone (GIZ)

<u>Town of Plymouth</u>

- Residences at Elbow Pond Road
- Redbrook
- Sandy Pines

DRAFT FOR REVIEW

Projects in the town of Bourne are expected to add a total of 1,057 new households, 2,600 new population, and 328 new jobs by 2045 while projects in the Town of Plymouth are expected to add a total of 872 new households, 240 new population, and 90 new jobs by 2045. The growth expected in the Town of Bourne due to these planned and/or permitted projects is at odds with the estimated decreases in population, households, and employment in the UMDI projections. This meant that the growth could not be reallocated to the affected TAZs while keeping the same overall community total without resulting in TAZs that lose an unrealistic amount of people, households, and/or employment. As a result, population and households were transferred from TAZs in the Town of Mashpee as outlined in Table 6 and employment was transferred as outlined in Table 7. The Town of Mashpee, as a community in Barnstable County with identified growth, was selected for the transfer due to its proximity to the Town of Bourne and less favorable access conditions. The combined overall total for both communities in all three demographic categories was maintained.

Table 6: Reallocation of Population and Households from select TAZs in Mashpee to Bourne

Model Condition	Mashpee Population			Mashpee Households		
	3070	3075	3077	3070	3075	3077
2019 Existing Conditions	1965	2120	3357	892	964	1411
2045 Unadjusted Conditions	2196	2833	3758	1083	1445	1786
2045 Adjusted Conditions	1749	1455	2983	890	960	1407
Allocation to Bourne TAZs	*-447*	*-1378*	*-775*	*-193*	*-485*	*-379*
		Subtotal	***-2600***		***Subtotal***	***-1057***
Bourne TAZ						
3000 (East of Sagamore Flyover)	41	127	72	12	30	24
3187 (Buzzards Bay GIZ)	222	684	384	99	248	194
3087 (SE Bourne Rotary)	184	567	319	82	207	161
Allocation from Mashpee TAZs	*447*	*1378*	*775*	*193*	*485*	*379*

Table 7: Reallocation of Employment from select Mashpee to Bourne TAZs

Model Condition	Mashpee Employment		
	3070	3075	3077
2019 Existing Conditions	433	613	508
2045 Unadjusted Conditions	1142	444	1091
2045 Adjusted Conditions	962	444	943
Allocation to Bourne TAZs	*-180*	*N.C.*	*-148*
		Subtotal	***-328***
Bourne TAZ			
3000 (East of Sagamore Flyover)	56		46
3187 (Buzzards Bay GIZ)	54		46
3087 (SE Bourne Rotary)	70		56
Allocation from Mashpee TAZs	*180*	*0*	*148*

Future No Build Conditions Sensitivity Case

The purpose of the Sensitivity Case scenario is to test how trends tied to remote working, retirement of the Baby Boomer generation, and other more recent changes in travel behavior may impact traffic volumes within the study area differently from the methods employed in the Base Case scenario. Research into the prevailing trends was completed by FXM Associates and document in their memo "Sensitivity Tests for Travel Demand Modeling," dated October 8, 2021. These revised demographics were determined to best capture the impact of following major trends:

- Post "great recession" migration trends between 2010-2019 indicate net in-migrations to Barnstable County, but these are not sufficient to outpace natural population decline over this period, continuing the long term trends.
- Migrations of non-retired families to their vacation homes on Cape Cod during the COVID-19 pandemic may have been a one-time phenomenon as many have reportedly returned to their primary residence once in-person schooling resumed.
- In-migration to Cape Cod may trend more towards retired persons moving into the Cape as they are more likely to be able to afford the higher real estate prices.
- These population trends are not anticipated to impact the growth in visitor trips forecasted from the Base Case scenario (0.7% per year). Factors limiting visitor growth could include the parking and occupancy limits of Cape Cod's major attractions.
- New housing construction on Cape Cod is expected to continue to cater to higher income retirees and people seeking vacation homes (based on trends identified from IRS data), and this will continue the trend of lower-wage workers seeking housing outside of Cape Cod,
- Some conversion of homes from seasonal use to year-round households is expected, but no information indicated it would be higher than the 11,000 homes (~10% of total existing supply) indicated in the stated preference survey conducted by the Cape Cod Commission,
- Ultimately, the overall decrease in population will result in a similar decrease in households, although not to the same level predicted in the original UMDI estimates.
- Total employment levels are expected to stay at 2020 levels through 2045 due to counteracting trends affecting future employment levels.
    - The first trend is the decrease in employment driven by the overall decrease in population (in jobs like education, government services, and grocery stores).
    - The second trend is the growth in jobs related to Cape Cod's aging population (healthcare, administrative and support services) and popularity as a vacation destination (food services and drinking places, construction of buildings, etc.).
- The relatively strong employment picture compared to the decrease in population is another factor that will increase the number of people commuting to Cape Cod from the mainland for work.

The population, households, and employment levels estimated by FXM Associates based on this research are shown in Table 8 in comparison to 2019 Existing Conditions and the 2045 Future No Build Base Case scenario.

Table 8: Barnstable County Socio-Economic Forecasts - Comparison of 2019 Existing Conditions to both Future No Build Scenarios

Model Condition	Population	Households	Employment
2019 Existing Conditions	212,990	94,323	97,672
2045 Base Case (UMDI)	176,007	82,313	75,299
Diff. from Existing	*-17.4%*	*-12.7%*	*-22.9%*
2045 Sensitivity Case (FXM)	192,559	90,323	96,878
Diff. from Existing	*-9.6%*	*-4.2%*	*-0.8%*

Future No Build Travel Demand Modeling Results:

The traffic volumes modeled for both Future No Build scenarios during the Summer Weekday PM and Summer Weekend Saturday peak hours are shown in Table 9 and Table 10.

Table 9: Bridge Traffic Volumes - Comparison of 2019 Existing Conditions to both Future No Build Scenarios

Model Condition	Bourne Bridge		Sagamore Bridge		Total Crossings
	North	South	North	South	
Summer Weekday PM					
2019 Existing Conditions	1,990	2,185	3,350	2,380	**9,905**
2045 Base Case (UMDI)	2,695	2,260	3,650	2,550	**11,155**
Diff. from Existing	*35.4%*	*3.4%*	*9.0%*	*7.1%*	***12.6%***
2045 Sensitivity Case (FXM)	2,915	2,285	3,955	2,605	**11,760**
Diff. from Existing	*46.5%*	*4.6%*	*18.1%*	*9.5%*	***18.7%***
Summer Weekend Saturday					
2019 Existing Conditions	1,845	2,640	3,290	2,665	**10,440**
2045 Base Case (UMDI)	2,185	2,680	3,680	3,375	**11,920**
Diff. from Existing	*18.4%*	*1.5%*	*11.9%*	*26.6%*	***14.2%***
2045 Sensitivity Case (FXM)	2,295	2,710	3,880	3,470	**12,355**
Diff. from Existing	*24.4%*	*2.7%*	*17.9%*	*30.2%*	***18.3%***

Table 10: Canal Roadway Traffic Volumes - Comparison of 2019 Existing Conditions to both Future No Build Scenarios

Model Condition	Scenic Highway		Sandwich Rd		Total Canalside
	East	West	East	West	
Summer Weekday PM					
2019 Existing Conditions	1,215	2,125	1,350	1,035	**5,725**
2045 Base Case (UMDI)	1,825	2,325	1,280	1,575	**7,005**
Diff. from Existing	*50.2%*	*9.4%*	*-5.2%*	*52.2%*	***22.4%***
2045 Sensitivity Case (FXM)	1,840	2,375	1,300	1,685	**7,200**
Diff. from Existing	*51.4%*	*11.8%*	*-3.7%*	*62.8%*	***25.8%***
Summer Weekend Saturday					
2019 Existing Conditions	930	1,590	1,410	935	**4,865**
2045 Base Case (UMDI)	1,475	1,860	1,275	1,085	**5,695**
Diff. from Existing	*58.6%*	*17.0%*	*-9.6%*	*16.0%*	***17.1%***
2045 Sensitivity Case (FXM)	1,495	1,910	1,305	1,145	**5,855**
Diff. from Existing	*60.8%*	*20.1%*	*-7.4%*	*22.5%*	***20.3%***

The general trends shown in both future scenarios are:

- Highest growth in canal crossings for Bourne Bridge NB traffic volumes
- Highest growth in canal roadways is Scenic Highway eastbound and Sandwich Road westbound.

General Findings

Evaluation of existing traffic volumes and the INRIX Origin-Destination (OD) information has shown that vehicles prefer not to travel through the Bourne Rotary if they can avoid it. This driver preference has been coded into the travel demand models and is what most directly leads to the decrease in canal roadway volumes on Sandwich Road eastbound in both scenarios.

It is also important to note that both scenarios show growth over existing conditions but are lower increases in traffic volume when compared to the 2040 Future No Build volumes from the previous planning study. This is due to the following factors:

- Calibration of this travel demand model based on INRIX origin-destination traffic flows. This information was not available during the planning study. The calibration of the prior model resulted in roughly 40% of the traffic on the bridges coming from the areas immediately adjacent to the two canal bridges, primarily from within the Town of Bourne. The new INRIX OD data indicated that only about 26% of the traffic on the bridges are local traffic.
- The prior study was based on an earlier set of existing 2014 socio-economic data and available 2040 socio-economic forecasts from UMDI. While the forecasts indicated an overall decline for Barnstable County, it indicated an increase in population and employment for the Town of Bourne between 2014 and 2040. Those forecasts were revised by UMDI and now indicate a decline for the Town of Bourne. The current model is based on the existing 2019 socio-economic data and that recently updated 2040 socio-economic forecasts.

The higher level of local traffic combined with growth in Bourne-related trips resulted in the prior study having higher bridge volumes than what is currently predicted. We have confidence in the accuracy of this model based on the following tests:

- The current model has been calibrated to 2019 traffic volumes on the bridges but also for the 2019 origin-destination patterns based on probe data collected by INRIX which results in a more reasonable split in bridge traffic between regional and local trips.
- Total network volume of the 2045 Future No Build models is higher than the 2040 Future No Build network from the previous study, further strengthening the argument that the added calibration steps and revised socio-economic projects from UMDI shows fewer bridge crossings in the network than in the prior planning study.

Conclusion

The Sensitivity Case scenario should be used for the Future No Build analysis and testing of potential roadway alternatives. Travel patterns are similar for each 2045 Future No Build scenario, but the Sensitivity Case reflects higher overall traffic volumes and provides a more conservative baseline for the comparison of alternatives.

DRAFT

2.5 Future 2045 Build Traffic Volumes (September 1, 2023)

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Date
September 1, 2023

To
Bryan Cordeiro, MassDOT

From
Alexandra Siu, P.E., PTOE (HNTB)
David Giel, P.E., PTOE (HNTB)
Sudhir Murthy, P.E., PTOE (TrafInfo)

Subject
Cape Cod Canal Bridges Program –
Future 2045 Build Traffic Volumes

PROJECT CORRESPONDENCE

Introduction

As a part of the Cape Cod Canal Bridge Program, several roadway and interchange alternatives are being developed for each of the touchdown points on either side of the Sagamore and Bourne bridges. These four quadrants have been designated as:

- Sagamore North (SN)
- Sagamore South (SS)
- Bourne North (BN)
- Bourne South (BS)

Future (2045) No Build traffic volumes were developed with the methodology and results summarized in the memorandum titled *"Cape Cod Canal Bridges Program – Summary of Future No Build Modeling Process and Results"* and dated December 17, 2021. Future (2045) No Build traffic volumes are for Fall PM and Summer Saturday are provided in **Attachment A.** Based on safety and operational issues that have previously been identified in Road Safety Audits (RSAs) and observed in the field, a series of build alternatives have been developed to address these issues. The interchange alternatives have gone through an initial screening process, with alternatives narrowed down based on traffic operations, connectivity, geometrics, safety, shared use paths, utilities, constructability, environmental impacts, and right-of-way impacts. The following alternatives for each quadrant have been vetted with MassDOT, FHWA, and USACE and have been included in the Environmental Notification Form (ENF). Each of these concepts are provided in **Attachment B.**

Sagamore North (SN)	Sagamore South (SS)	Bourne North (BN)	Bourne South (BS)
SN-1A	SS-1	BN-6.1	BS-2
SN-8A	SS-1.1	BN-13.1	BS-2.2
	SS-3.1A	BN-14.4B	

Based on the above number of alternatives per quadrant, there are 36 possible permutations of alternatives. We understand that geometric and operational changes at the interchanges to the north and south of the bridges will have impacts to vehicle routing through the program area and region. However, some of the alternatives are similar and will result in comparable impacts to the travel demand model. For example, SN-1A and SN-8A are nearly identical other than the northbound off-ramp to Meetinghouse Lane. The SN-1A northbound off-ramp to Meetinghouse Lane exits the mainline south of the ramp to Scenic Highway, while the SN-8A ramp exits north of Scenic Highway. It is not anticipated that these

differences will have a significant impact to the travel demand model. Similarly, BN-13.1 and BN-14.4B as well as BS-2 and BS-2.2 result in equivalent impacts to the travel demand model. Based on these acknowledgements, six (6) permutations of alternatives were paired together to develop travel demand volume scenarios. **Table 1** shows the alternatives that were paired together for each of the travel demand model runs.

Table 1 – 2045 Build Travel Demand Model Volume Permutations

	Volume Permutation					
Quadrant	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**
SN	8A	8A	8A	8A	8A	8A
SS	1	1.1	3.1A	1	1.1	3.1A
BN	14.4B	14.4B	14.4B	6.1	6.1	6.1
BS	2	2	2	2	2	2

Fall (2045) PM peak hour traffic volumes for each of the volume permutations are provided in **Attachment C.** As previously documented, the fall time period represents the 85th percentile traffic volumes and will be used as the design time period. Summer Saturday is also being analyzed to understand potential peak season operations, however, will not drive design decisions. In our review of the Summer (2045) Saturday peak hour volumes and Origin-Destination (OD) flows, it was determined that the traffic patterns are not the same nor follow the same trends as the Fall PM due to the heavier congestion. However, it is essential to have an overall understanding of the Summer Saturday peak volume levels. Therefore, P1 and P4 were chosen as representative volume permutations for the Summer Saturday peak hours, which are provided in **Attachment D.** This technical memorandum provides a discussion of the OD flow comparisons during the Future 2045 design year between the No-Build and six (6) Build Alternative volume permutations and the impacts that the Build Alternatives have on vehicle routing.

Volume Comparisons

The OD flows were extracted from the TransModeler®-based Cape Cod Bridge Model between each pair of cordon points established as shown in Figure 1. These signify the major roadway entry points into the study area. The OD flows were obtained for the 3-hour Fall PM peak period (3PM-6PM) and the 6-hour Summer Saturday Midday peak period (9AM-3PM) and converted to peak 1-hour flows.

The cordon points established for the OD flows analysis as shown in Figure 1 include:

- Route 25 west of the Belmont Circle Interchange
- Route 6 west of the Buzzards Bay Rotary (Route 6W)
- Route 28 south of Waterhouse Road
- Route 3 north of Herring Pond Road Interchange
- Route 6 east of the Mid Cape Connector/Cranberry Highway Interchange (Route 6E)
- Meeting House Lane west of State Road
- Trowbridge Road west of Bourne Rotary
- Route 6A (Sandwich Road) east of Cranberry Highway

The OD flows between each cordon point pair was extracted from TransModeler using the ***Critical Link Tool***. Residual peak period volumes at each cordon point that is not destined to any one of the above cordon points was allocated to a separate volume bucket noted in this memo as “Other Points”.

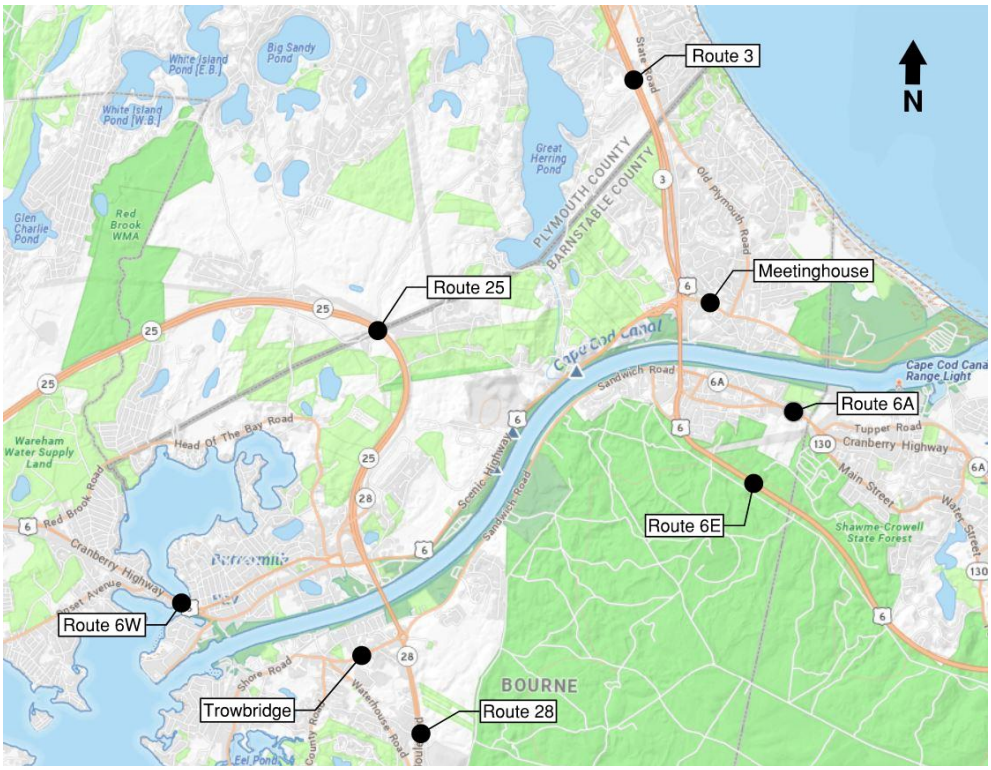


Figure 1 – Cordon Points for OD Flow Analysis

Route 25 EB

One of the major movements within the program study area is the movement between Route 25 and Route 6E. Vehicles have two paths to choose between when traveling from Route 25 to Route 6E on the Cape: via Sagamore Bridge using Scenic Highway or via Bourne Bridge using Sandwich Road. The peak hour OD flow comparisons are shown in Figure 2.

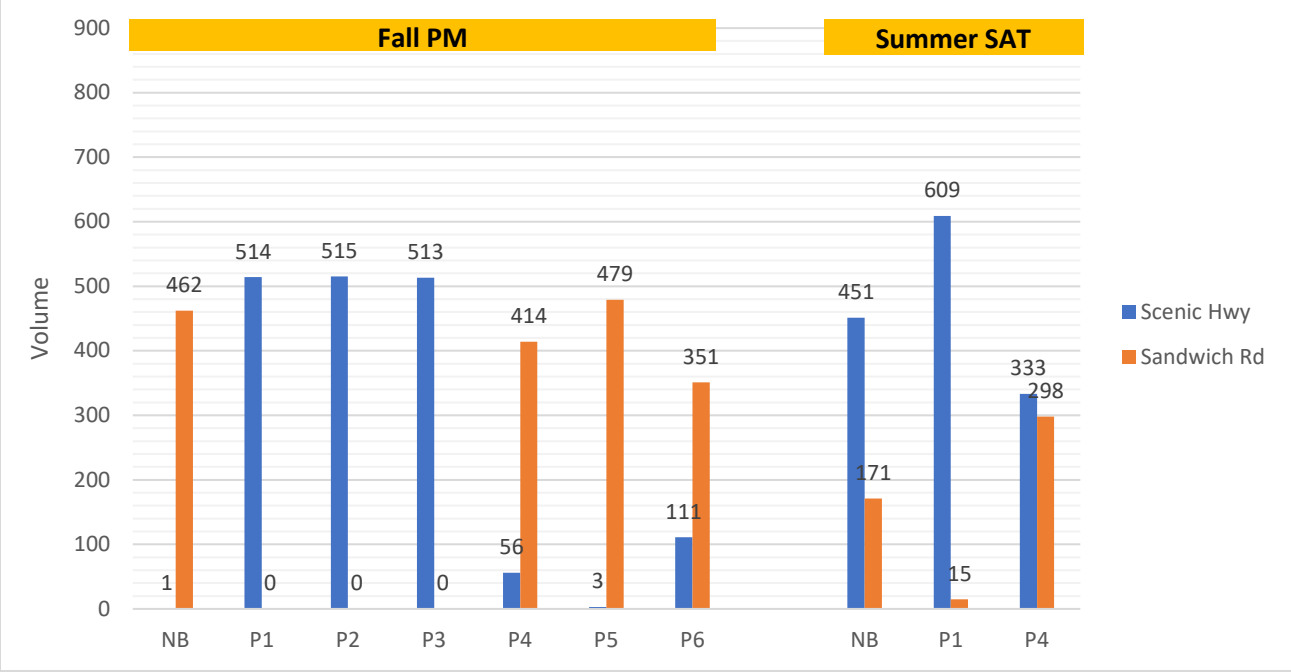


Figure 2 – Route 25 EB Peak Hour Volumes to Route 6E

During Fall PM peak hour, under the No-Build condition, the traffic from this Route 25 cordon point to Route 6E almost exclusively uses Sandwich Road to avoid navigating through Belmont Circle. With P1 through P3, this change to the exclusive use of Scenic Highway is due to the presence of a direct ramp from Route 25 EB to Scenic Highway EB under BN-14.4B. Under Pairings 4 thru 6, since BN-6.1 does not have this direct ramp from Route 25 EB to Scenic Highway EB, this movement will continue to primarily use Sandwich Road.

During the Summer Saturday peak hour, the Route 25 to Route 6E movement under the No-Build conditions primarily uses Scenic Highway with some using Sandwich Road. Under P1 (through P3), the usage of Scenic Highway further increases due to the presence of the direct ramp in BN-14.4B with the associated decrease in use of Sandwich Road. However, under P4 (through P6), without the direct ramp in BN-6.1, while there is still use of Scenic Highway. The usage of Sandwich Road goes up significantly due to the improvements resulting from BS-2 at Bourne South.

It should be noted that under existing conditions, there are vehicles that exit Route 25 in Wareham (at the Maple Springs Road exit) that approach the study area via Main Street or Buzzards Bay Bypass. These vehicles are not included the OD comparison above. However, it is evident in the total Fall PM peak hour volumes that all of the pairings have a higher volume on Route 25 EB than under the No Build, as shown in Figure 3. This is primarily due to the shift in traffic from Route 6W to Route 25, which can also be seen in Figure 15.

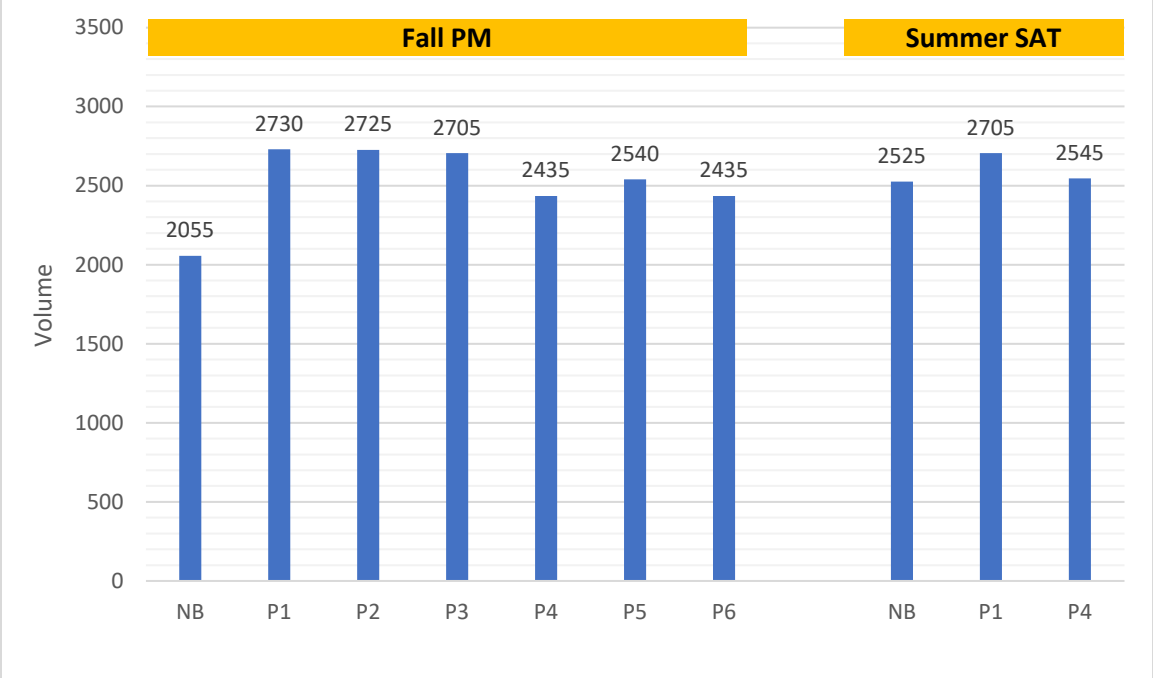


Figure 3 – Route 25 EB Total Peak Hour Volumes

With improvements under BN-14.4B, traffic shifts from Route 6 to Route 25 thereby showing an increase in volume. This shift occurs for all pairings; however, P1 through P3 show a greater shift than P4 through P6, as BN 14.4B reduces traffic using Belmont Circle. With BN-6.1 under Pairings 4 thru 6, two of the components, namely traffic destined to Buzzards Bay/Main St/Scenic Highway exit Route 25 to cut through Wareham on Route 6. However, the component of traffic from Route 25 to Route 3 remains on Route 25 until Belmont Circle and do not cut through Wareham via Route 6. Thus, the volumes on Route 25 are higher under Pairings 4 thru 6 than the No Build scenario, although not as high as under P1 through P3.

During the Summer Saturday peak hour, given the higher level of congestion throughout the system, the increase in volume on Route 25 as a result of the shift in traffic from Route 6 in Wareham is only seen in P1. There is no observable shift in traffic for P4 likely due to BN-6.1 not having the direct ramp from Route 25 SB to Scenic Highway.

Traffic on Route 25 EB destined to Other Points include destinations such as the White Island Shores in Wareham, West Wind Shores in Plymouth or developments along the Head of the Bay Road in the Bournedale village of Bourne. A portion of this traffic exits at the Maple Spring Road exit under No Build conditions during the Fall PM peak hour, as shown in Figure 4.

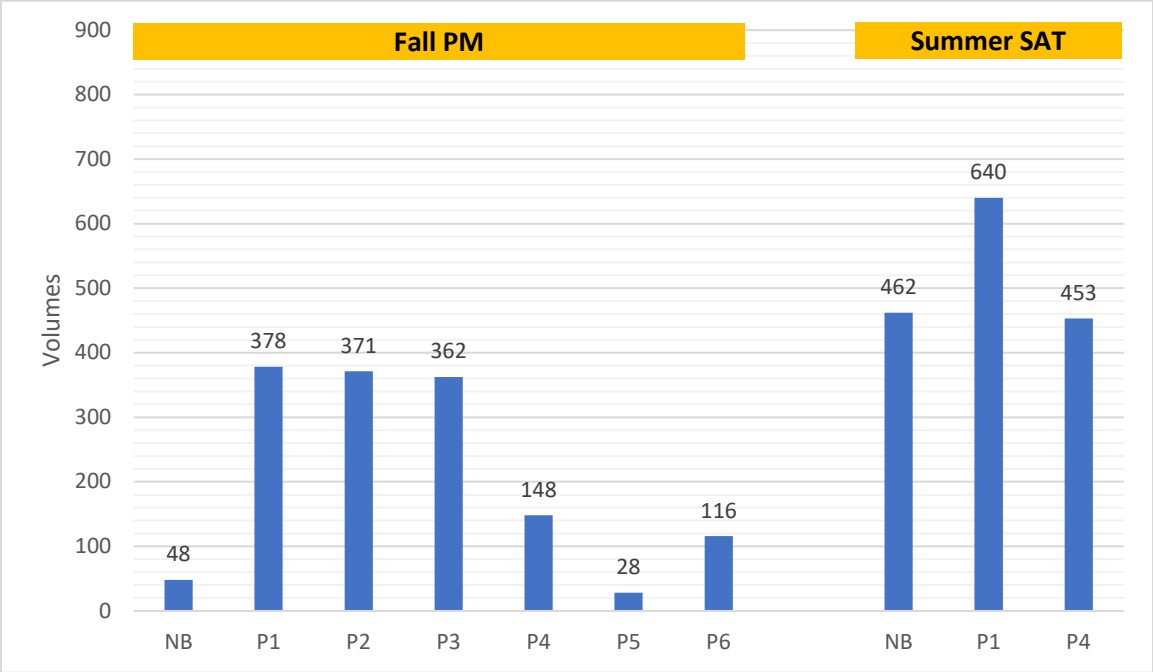


Figure 4 – Route 25 EB Peak Hour Volumes to Other Points

With improvements under BN-14.4B, most of this traffic stays on Route 25 and reaches these Other Points via Belmont Circle. As this traffic stays on Route 25 and goes through the Route 25 cordon point, the volume of traffic to Other Points is higher under P1 through P3. However, without the direct ramp under BN-6.1, this traffic exits as at the Maple Spring Road exit as under the No Build scenario, albeit to a lesser extent under P4 through P6.

During the Summer Saturday peak hour, due to the improvements under BN-14.4B, the traffic on Route 25 EB to the Other Points mentioned above stays and travels through the Route 25 cordon point to exit at Belmont Circle under P1. However, under P4 varying portions of this traffic stays on Route 25 with remaining traffic exiting at the Maple Spring Road exit.

ROUTE 3 SB

The other major origin point for traffic onto the Cape, is Route 3. During the Fall PM peak hour, traffic from Route 3 SB to Route 28 SB is split between Scenic Highway and Sandwich Road under the No Build condition, as shown in Figure 5.

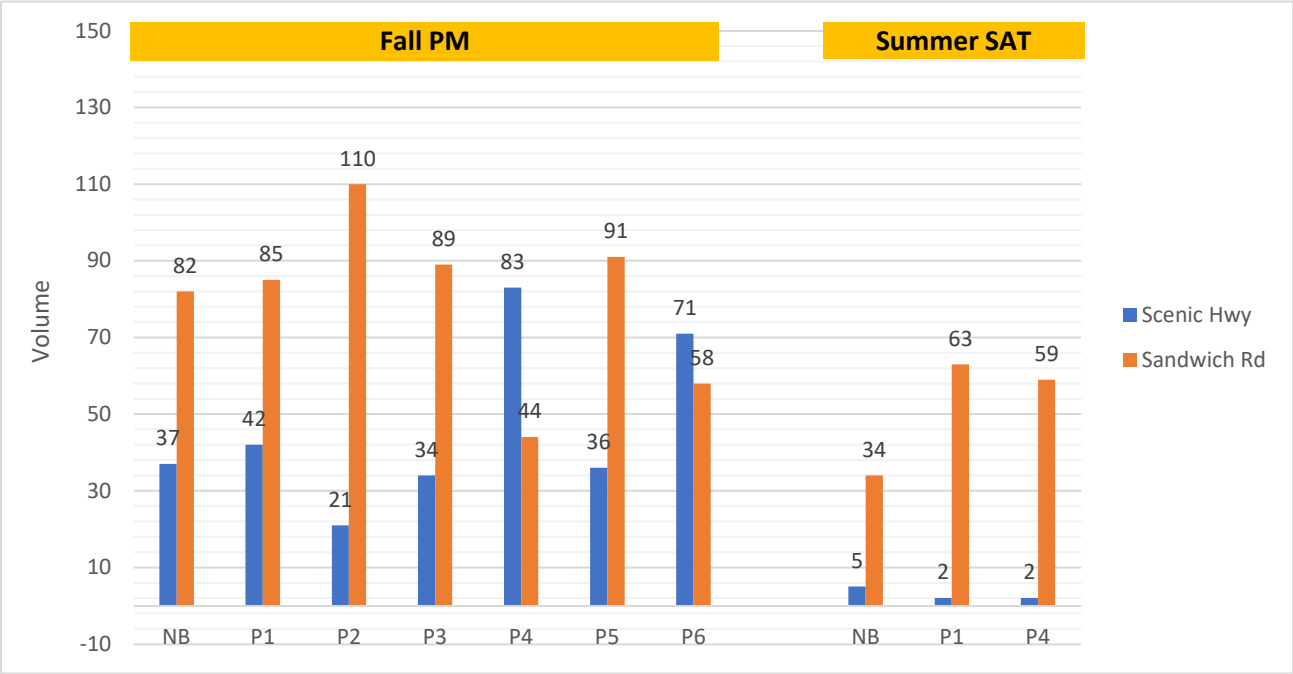


Figure 5 – Route 3 SB Peak Hour Volumes to Route 28 SB

This pattern remains similar to No Build under P1, P2, P3, and P5 which uses Sandwich Road compared to Scenic Highway. Whereas, the amount of traffic using Scenic Highway is higher under P4 and P6. These alternatives have a combination of more traffic through Belmont Circle under BN-6.1 as well as the Cranberry Highway extension in Sagamore South.

Under the Summer Saturday peak hour, a small amount of traffic from Route 3 SB to Route 28 SB uses Scenic Highway with a majority using Sandwich Road. This continues to occur in P1 and P4. However, the total number of trips from Route 3 SB to Route 28 SB appear to be higher under all the pairings. This is related to the path utilized by the Route 3 SB traffic destined to areas situated west of Route 28 such as Monument Beach. Under No Build and P4, this traffic exits at the Bourne Rotary to get onto Trowbridge Road and then onto County Road. In P1, this same traffic continues further south on Route 28, past the cordon point to access the areas via the Otis Rotary.

As shown in Figure 6 and Figure 7 total volumes on Route 3 SB and volumes to Other Points remain consistent between No Build and all of the pairings. This is due to there being fewer roadways that will allow traffic to cut through or bypass Sagamore North from north of the Route 3 cordon point.

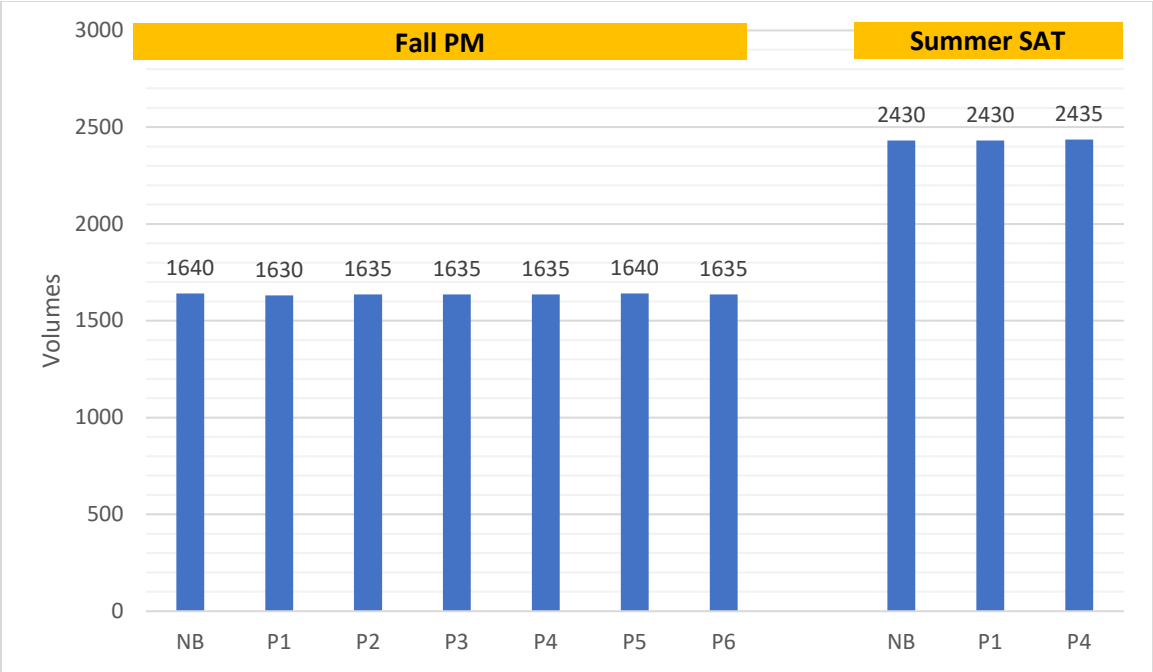


Figure 6 – Route 3 SB Total Peak Hour Volumes

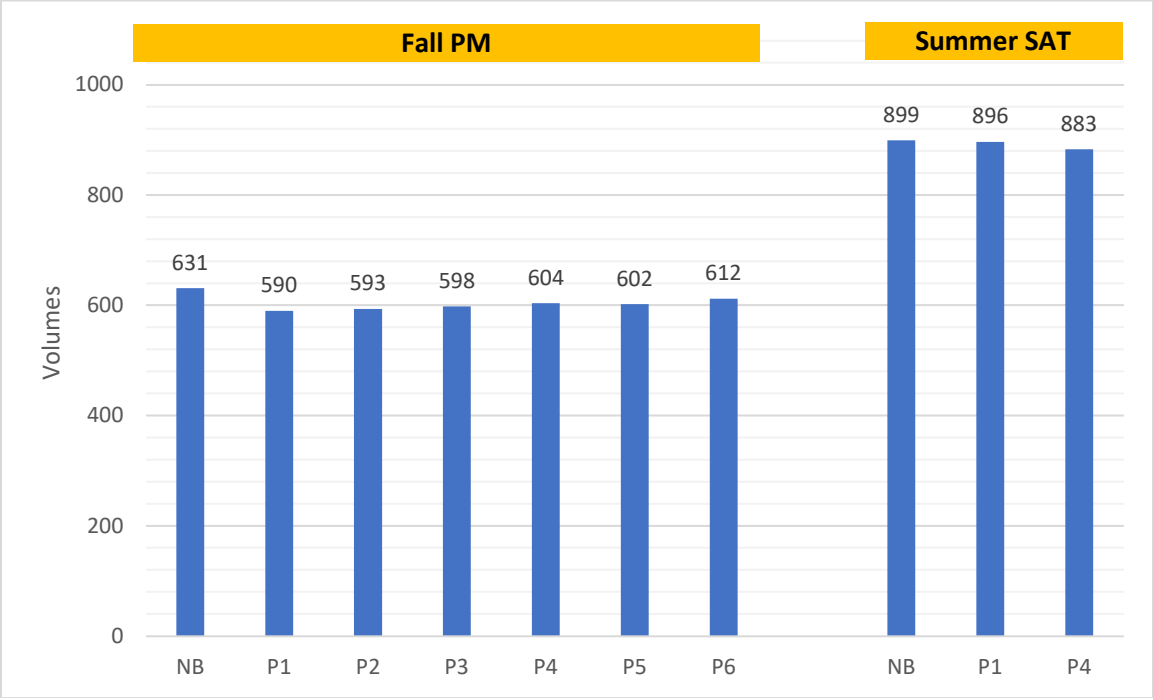


Figure 7 – Route 3 SB Peak Hour Volumes to Other Points

ROUTE 28 NB

Route 28 is the major roadway that carries traffic to and from Falmouth. In the Fall PM, under No Build conditions as well as all of the pairings, vehicles traveling from Route 28 to Route 3 NB exclusively use Sandwich Road to cross over the Sagamore Bridge, as shown in **Figure 8**. This is to avoid having to go through Belmont Circle. During the Summer Saturday peak hour, traffic splits between Scenic Highway and Sandwich Road under the No Build conditions due to the traffic both on and off Cape. In P1 and P4, vehicles exclusively use Sandwich Road due to the improvements in Bourne South and Sagamore South, while Bourne North does not provide improvements to this specific movement to Scenic Highway.

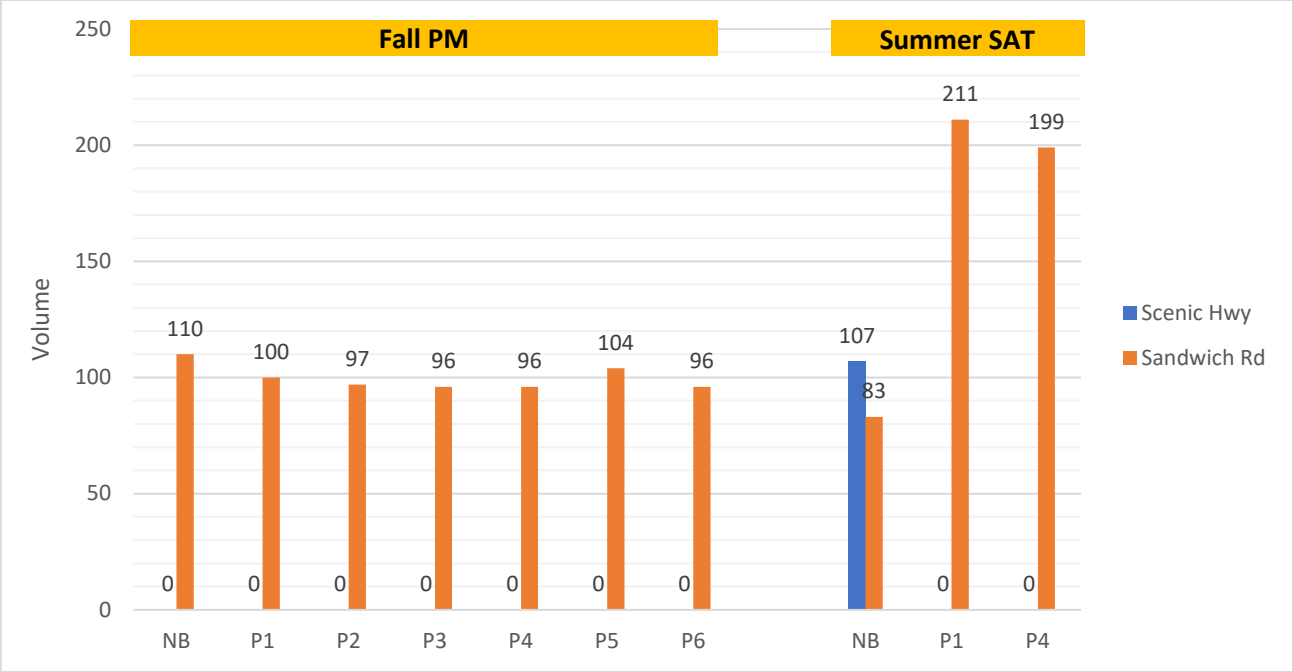


Figure 8 – Route 28 NB Peak Hour Volumes to Route 3 NB

Figure 9 compares the total volumes at the Route 28 NB cordon. In the Fall PM, the volumes under P1 through P6 are marginally higher than the No Build condition. As the congestion on Route 28 NB approaching the Bourne Rotary is not that significant during the Fall PM peak period, there is no significant change.

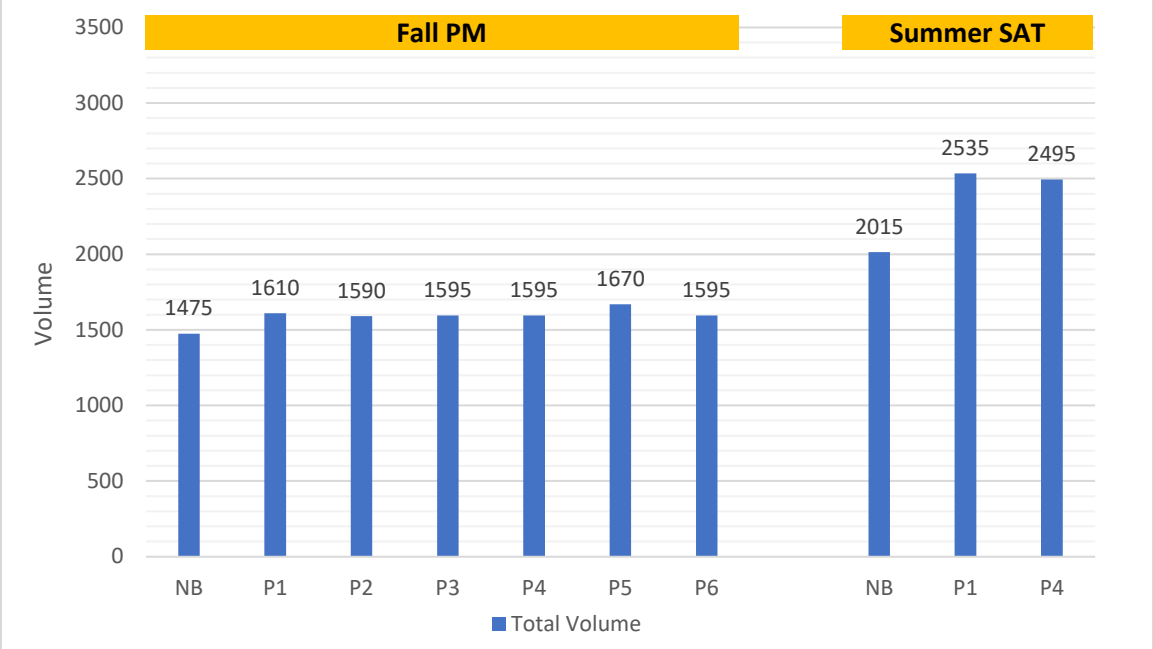


Figure 9 – Route 28 NB Total Peak Hour Volumes

However, during Summer Saturday, when traffic congestion on Route 28 NB approaching Bourne Rotary is much higher, the volumes on Route 28 NB are higher under P1 and P4 than the No Build condition. This is primarily a result of traffic on Route 28, destined to areas within the Gray Gables village in Bourne such as Agawam Point and other areas west and adjacent to the canal, exit Route 28 further south at either the Otis Rotary or at the Route 151 interchange under the No Build condition to avoid the queue on the Route 28 NB approach to the Bourne Rotary. Under P1 and P4, with improvements to traffic operations under BS-2, traffic stays on Route 28 until the intersection with Waterhouse Road or until the new Bourne South interchange.

Figure 10 compares the volumes on the Route 28 NB cordon point destined to Other Points.

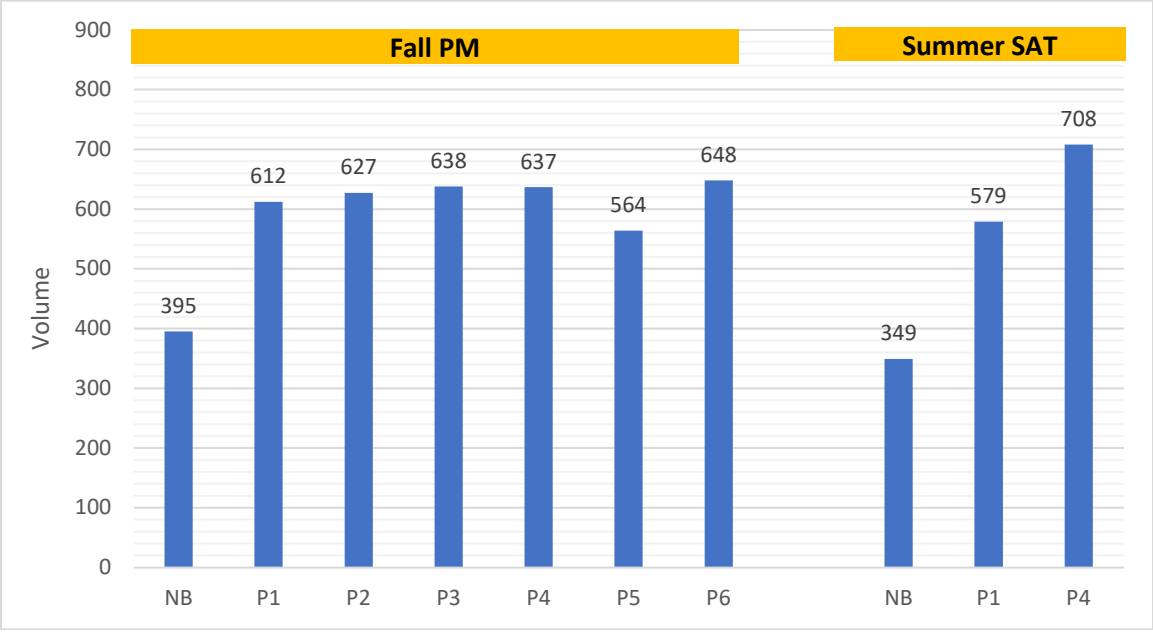


Figure 10 – Route 28 NB Peak Hour Volumes to Other Points

As discussed previously, due to improvements in traffic operations on Route 28 NB approaching the Bourne Rotary interchange, the total traffic crossing the Route 28 cordon point under P1 through P6 are higher than No Build during both Fall PM and Summer Saturday. As discussed earlier, the increase is primarily due to traffic destined to Other Points staying on Route 28 until the Waterhouse Road intersection instead of exiting earlier at either the Otis Rotary or the Route 151 interchange as under the No Build condition.

ROUTE 6E WB

The final major roadway that approaches the canal carrying vehicles off the Cape is Route 6 WB (labeled as Route 6E in the Sagamore South quadrant). Figure 11 shows the traffic between the Route 6E WB to Route 25. In both the Fall PM and Summer Saturday, almost all the traffic for this movement uses Scenic Highway under the No Build condition and all the pairings.

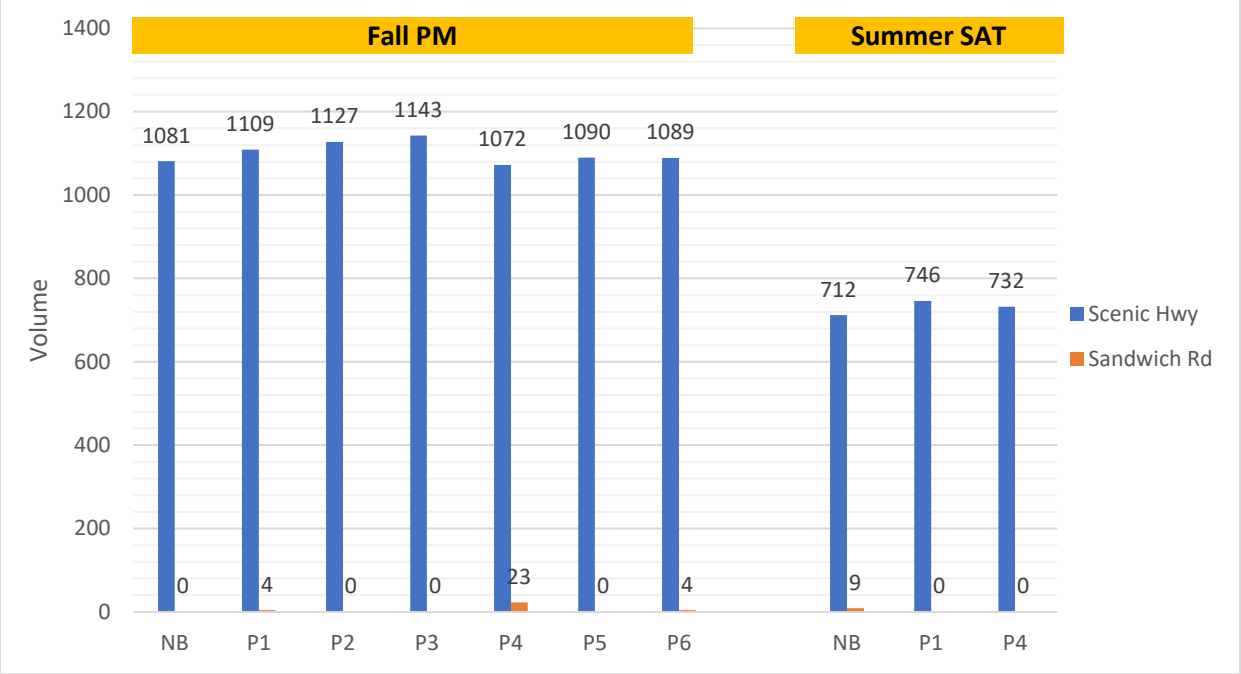


Figure 11 – Route 6E WB Peak Hour Volumes to Route 25

Figure 12 shows the traffic between the Route 6E WB to Route 6W WB. In the No Build Fall PM, all of this traffic uses Scenic Highway.

The chart shows a significant drop under P1 through P6 compared to the No Build condition. This is related to a different traffic movement between Route 6E WB to Route 25. Under No Build, traffic from Route 6E WB to Route 25, when it reaches Belmont Circle via Scenic Highway may either get onto Route 25 or continue through Belmont Circle on Route 6. Under P1 through P6, due to the presence of a direct on-ramp from Scenic Highway WB to Route 25 NB, all of this traffic between Route 6E WB and Route 6W WB gets onto Route 25.

In the Summer Saturday scenario, all of the traffic under No Build uses Scenic Highway. However, under P1, a portion of traffic uses Sandwich Road with associated decrease in use of Scenic Highway. Given the greater shifts in traffic on to Scenic Highway, some traffic also uses Sandwich Road. Under P4, given

higher volumes on Sandwich Road, all of the traffic from Route 6E WB to Route 6W WB uses Scenic Highway.

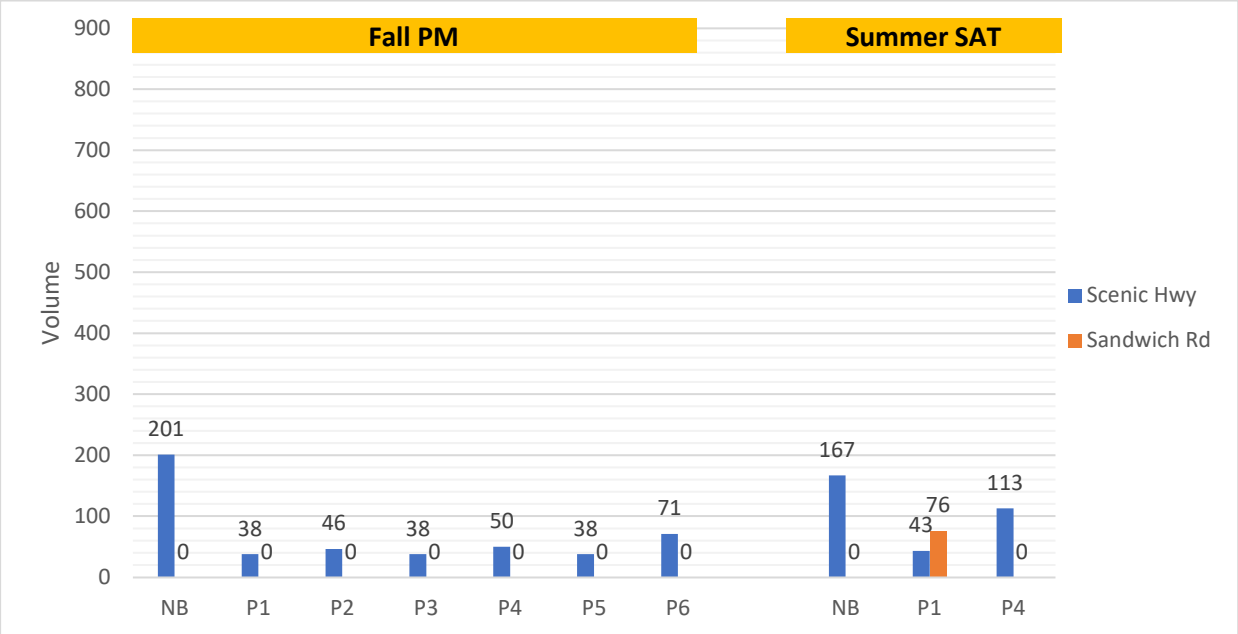


Figure 12 – Route 6E WB Peak Hour Volumes to Route 6W WB

Figure 13 shows the total Route 6E WB peak hour traffic volumes at the cordon point. As shown, volumes are relatively consistent between No Build and all of the pairings. This is due to the fact that once on Route 6E WB, there are few roadways that will allow you to cut through or bypass Sagamore South.

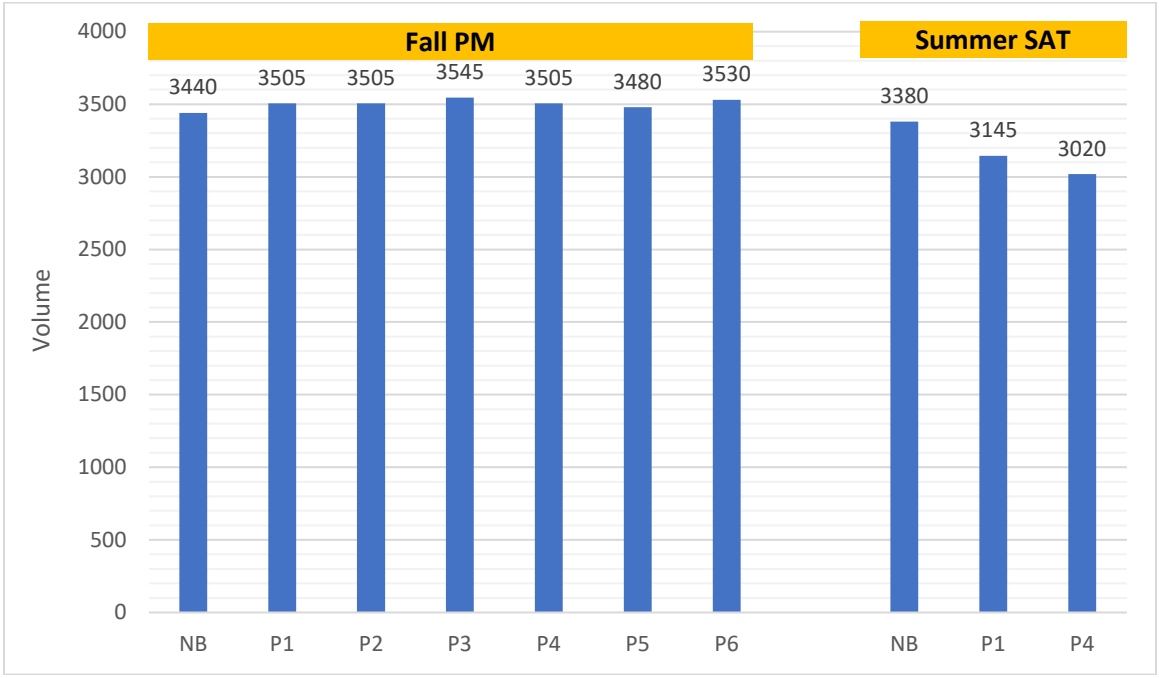


Figure 13 – Route 6E WB Total Peak Hour Volumes

ROUTE 6W EB

As discussed in the Route 25 EB section, Route 6 through Wareham is often used as a parallel roadway to Route 25 carrying traffic toward Belmont Circle when Route 25 is congested. **Figure 14** shows traffic volumes from Route 6W EB to Route 6E WB. As shown, all vehicles making this movement exclusively uses Scenic Highway to the Sagamore Bridge under No Build conditions and all of the pairings. During the Summer Saturday, the volume for this movement is more significant than during the Fall PM.

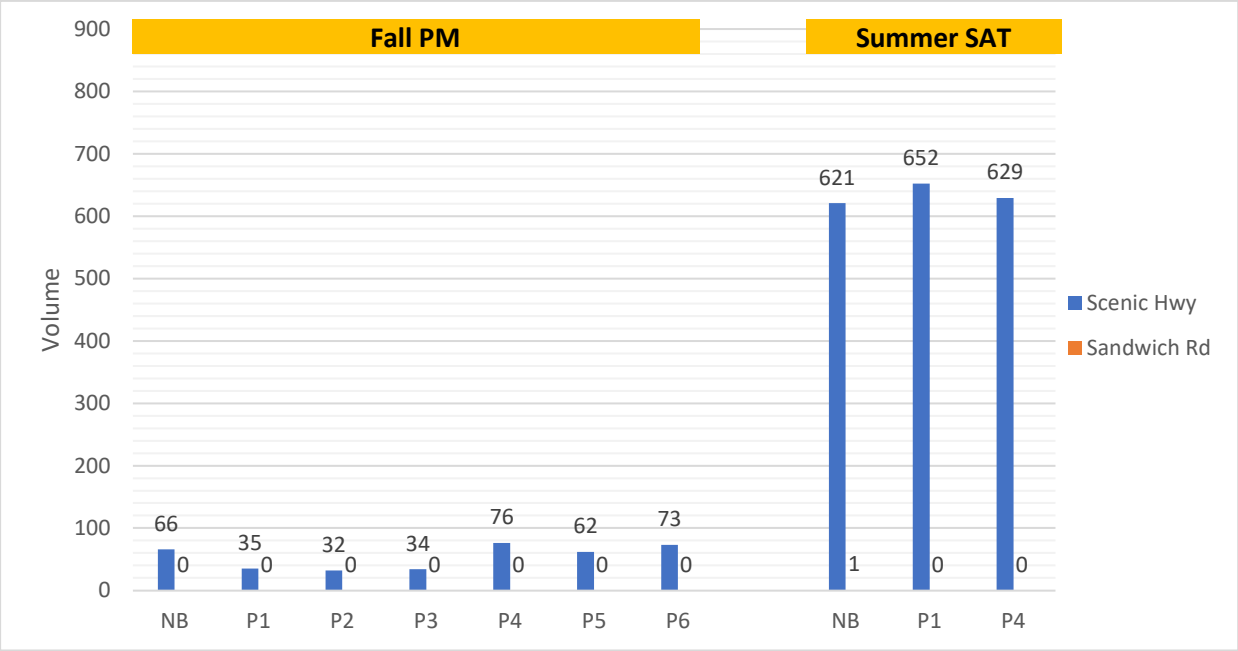


Figure 14 – Route 6W EB Peak Hour Volumes to Route 6E EB

Under Route 25, the discussion highlighted the shift in traffic from Route 6 to Route 25. **Figure 15** shows the same information from the perspective of Route 6.

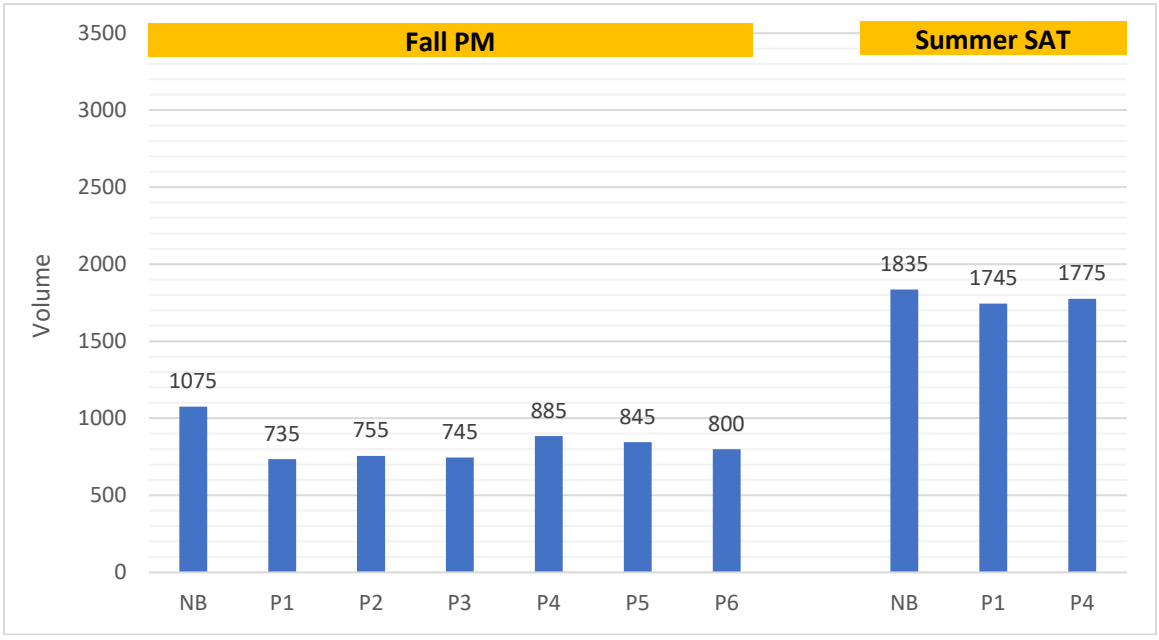


Figure 15 – Route 6W EB Total Peak Hour Volumes

In the Fall PM, traffic volumes at the Route 6W cordon point are lower under P1 through P6 than under the No Build conditions, with the reduction higher under P1 through P3 than under P4 through P6. In the Summer Saturday, the reduction is not as significant as under the Fall PM condition. However, all pairings show a slight reduction in volumes when compared with the No Build condition.

An important reason for the significant drop in total volume at the Route 6W cordon point in Fall PM as discussed above results from a change in the path of traffic from Route 25 and origin points within Wareham to destinations accessed by Route 3. Figure 16 show the traffic volumes from Route 6W EB to Route 3 NB.

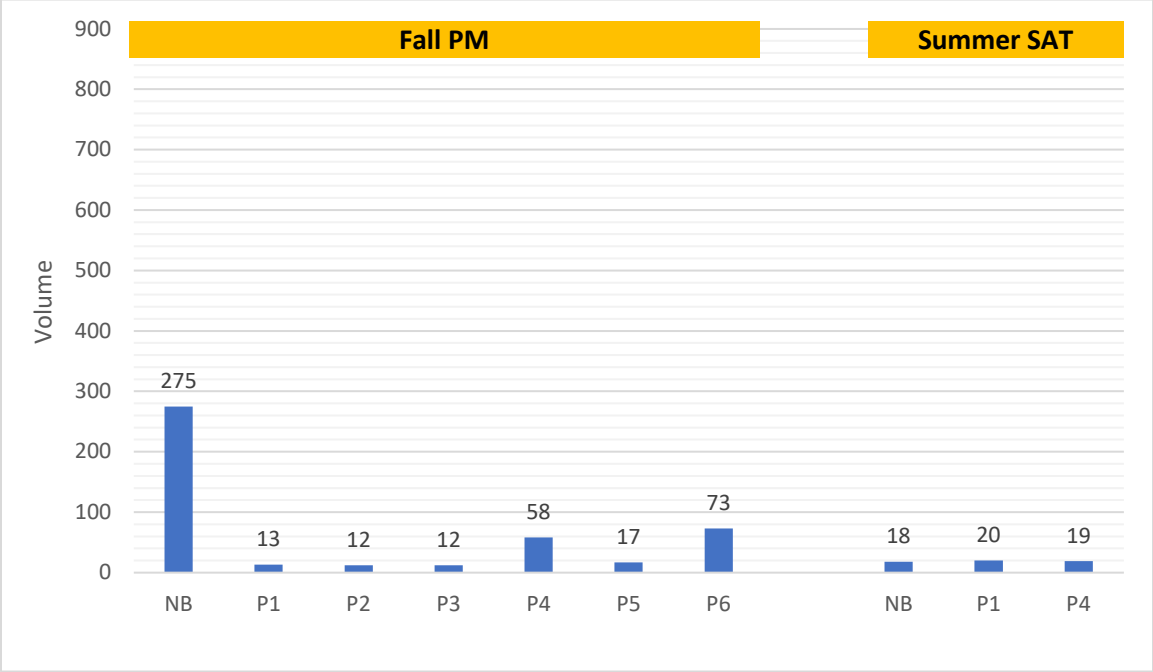


Figure 16 – Route 6W EB Peak Hour Volumes to Route 3 NB

A portion of this traffic uses the Mineral Springs Road exit onto Route 6 under the No Build condition. With P1 through P6, only a very small portion of this traffic diverts to Route 6 instead of taking Route 25 to Belmont Circle.

In the Summer Saturday, the total volumes of traffic between Route 25 and origin points within Wareham to destinations accessed by Route 3 is not as high as under the Fall PM. This small amount of traffic continues to use Route 6 in all pairings as under the No Build conditions.

ROUTE 6A WB

Route 6A WB runs parallel to Route 6 and carries traffic from points east such as the East Sandwich residential areas and Spring Hill and East Sandwich Beach. Figure 17 and Figure 18 show volumes from Route 6A WB to Route 25 and to Route 6W WB, respectively.

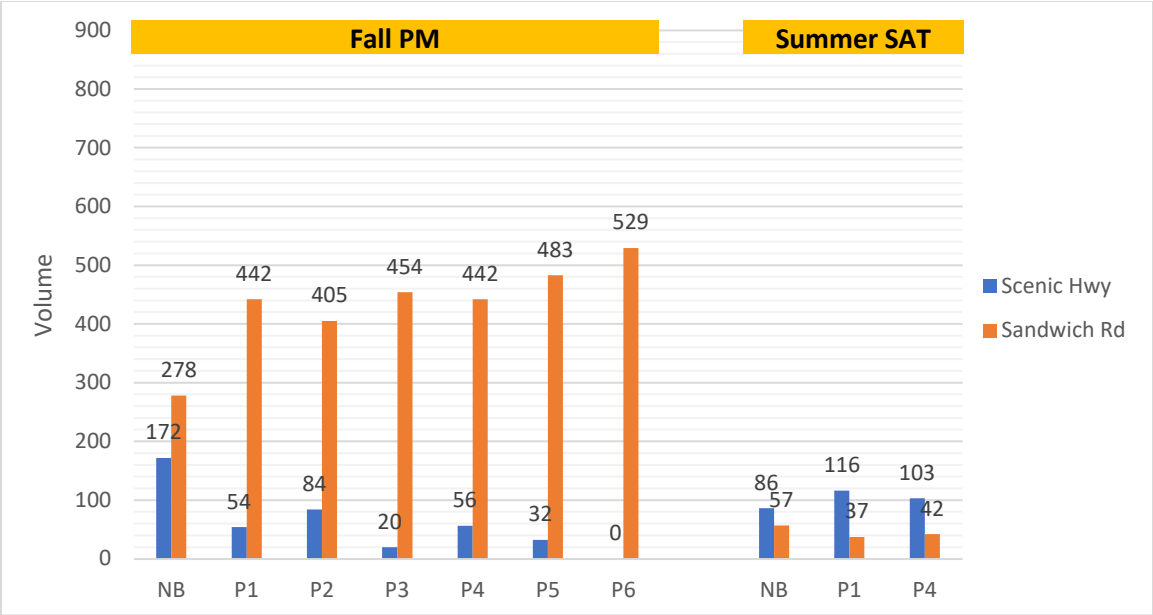


Figure 17 – Route 6A WB Peak Hour Volumes to Route 25

In Fall PM, under No Build conditions the traffic between Route 6A WB to Route 25 WB use both Scenic Highway and Sandwich Road. Under P1 through P6, a majority of this traffic uses Sandwich Road. This is due to the new ramp from Scenic Highway WB to Route 25 NB that bypasses Belmont Circle. In the Summer Saturday, the volumes are low, and the split tends to be slightly more towards Scenic Highway over Sandwich Road.

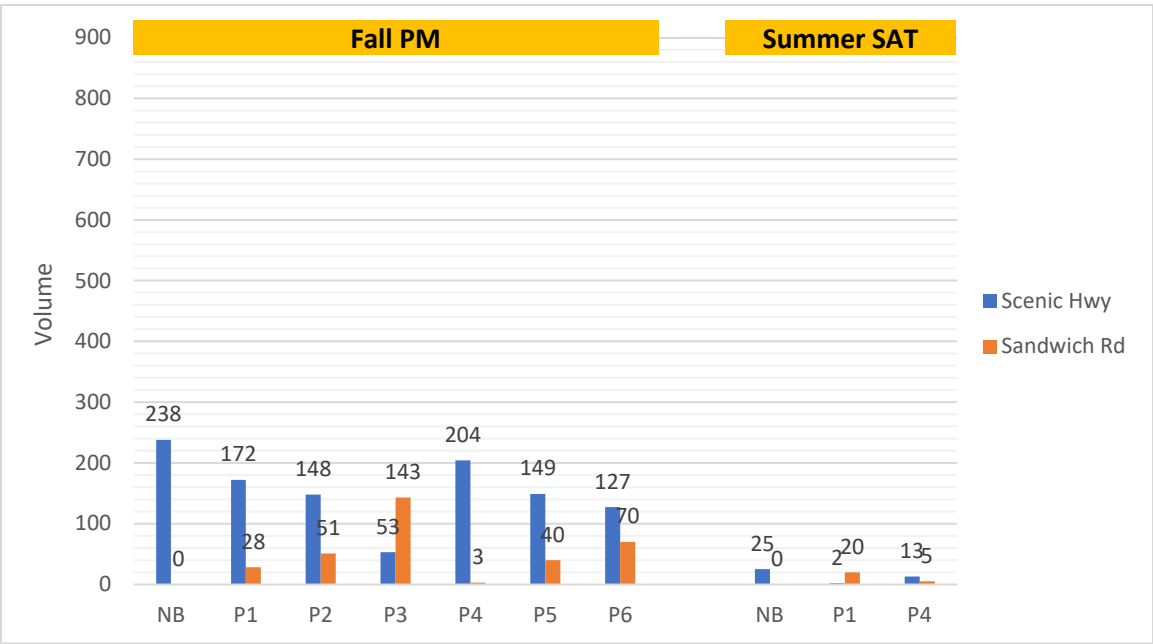


Figure 18 – Route 6A WB Peak Hour Volumes to Route 6W WB

In the Fall PM, all the traffic from Route 6A WB to Route 6W WB use Scenic Highway under No-Build but use Sandwich Road as well under P1 through P6. P4 has most of the traffic using Scenic Highway, while P3 has the majority of traffic using Sandwich Road. In the Summer Saturday, the traffic volumes for this movement are low.

Figure 19 shows the total volumes on Route 6A WB at the cordon point. Volumes for each of the pairings are similar to the No Build conditions; however, they are slightly lower.

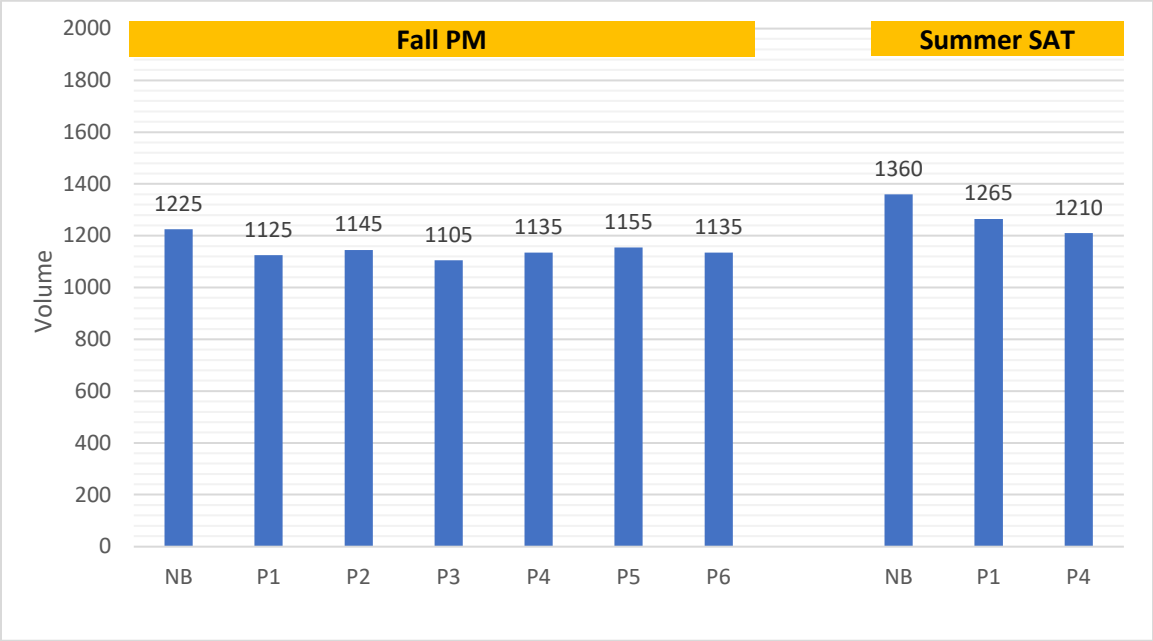


Figure 19 – Route 6A WB Total Peak Hour Volumes

Conclusions

As shown through the volume trends, the alternatives in the Bourne North quadrant appear to have the greatest impact to routing decisions within the study area. The direct ramp from Route 25 SB to Scenic Highway removes a significant amount of traffic from Belmont Circle, which greatly improves congestion on Route 25 approaching the canal. With the improved operations more vehicles stay on Route 25 instead of using Route 6 as a cut-through. The direct ramp in BN-14.4B also results in a greater shift in the Route 25 to Route 6A traffic from using Sandwich Road to using Scenic Highway.

The Cranberry Highway Extension in Sagamore South was anticipated to have more of an impact to volumes using Sandwich Road WB. However, after reviewing the models, it appeared to only have localized impacts shifting volumes between Route 6A and Cranberry Highway.

The alternatives for Sagamore North and Bourne South all have similar impacts to each other and do not vary significantly between SN-1A and SN-8A or BS-2 and BS-2.2.

The Bourne South improvements result in more of the Route 28 northbound traffic to use the highway rather than cut-through the Monument Beach neighborhood to reach destinations in the Gray Gables neighborhood.

Attachments

Attachment A – 2045 No-Build Traffic Volumes
Attachment B – Interchange Alternatives
Attachment C – 2045 Fall PM Build Traffic Volumes
Attachment D – 2045 Summer Saturday Build Traffic Volumes
Attachment E – Origin-Destination

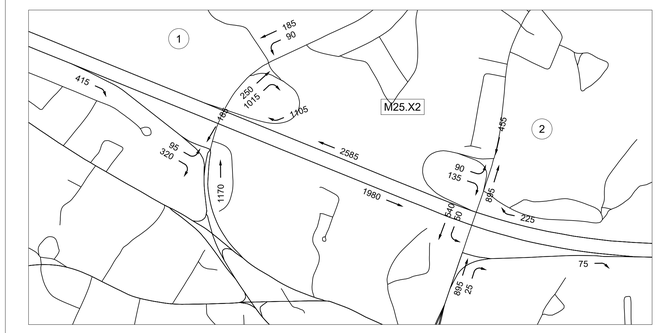
Attachment A – 2045 No-Build Traffic Volumes

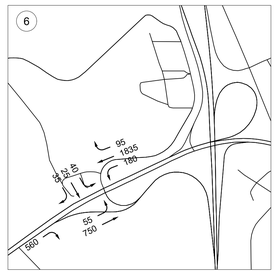
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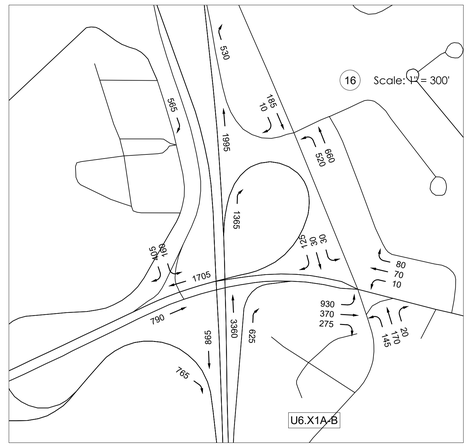
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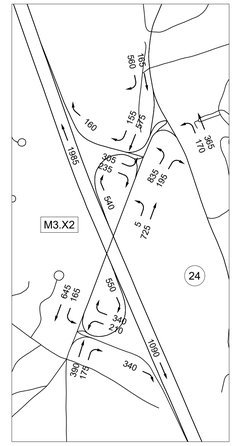
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No-Build Conditions
2023-04-03

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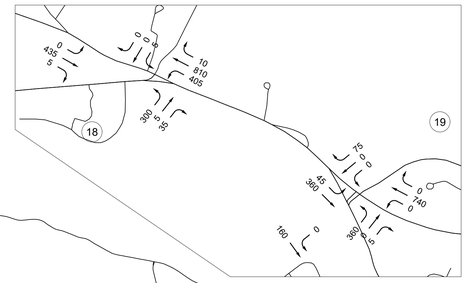


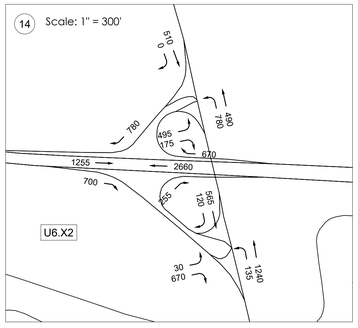






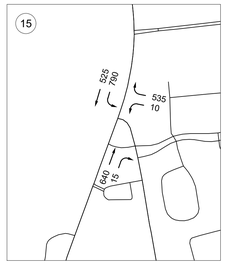


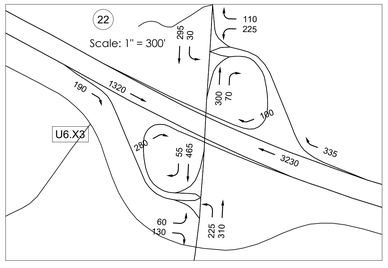












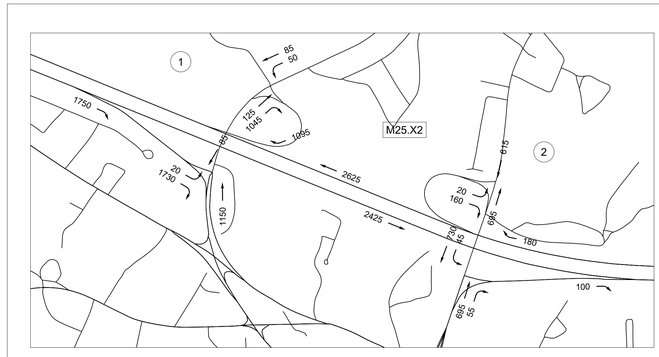
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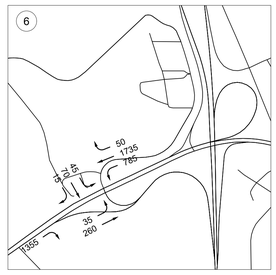
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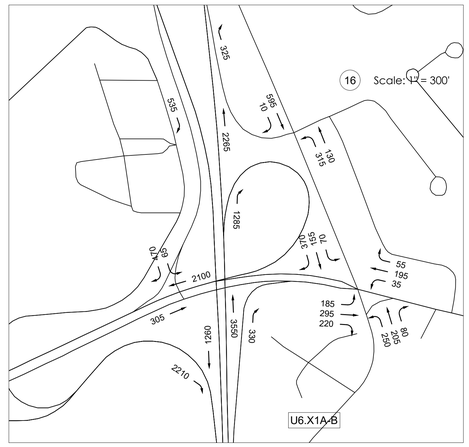
Cape Cod Canal Program Management

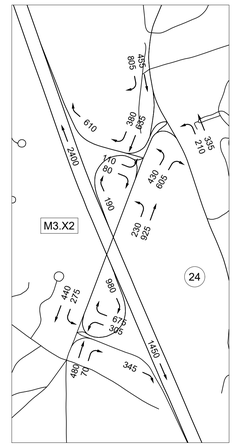
2045 Summ SAT
No-Build Conditions
2022-02-07

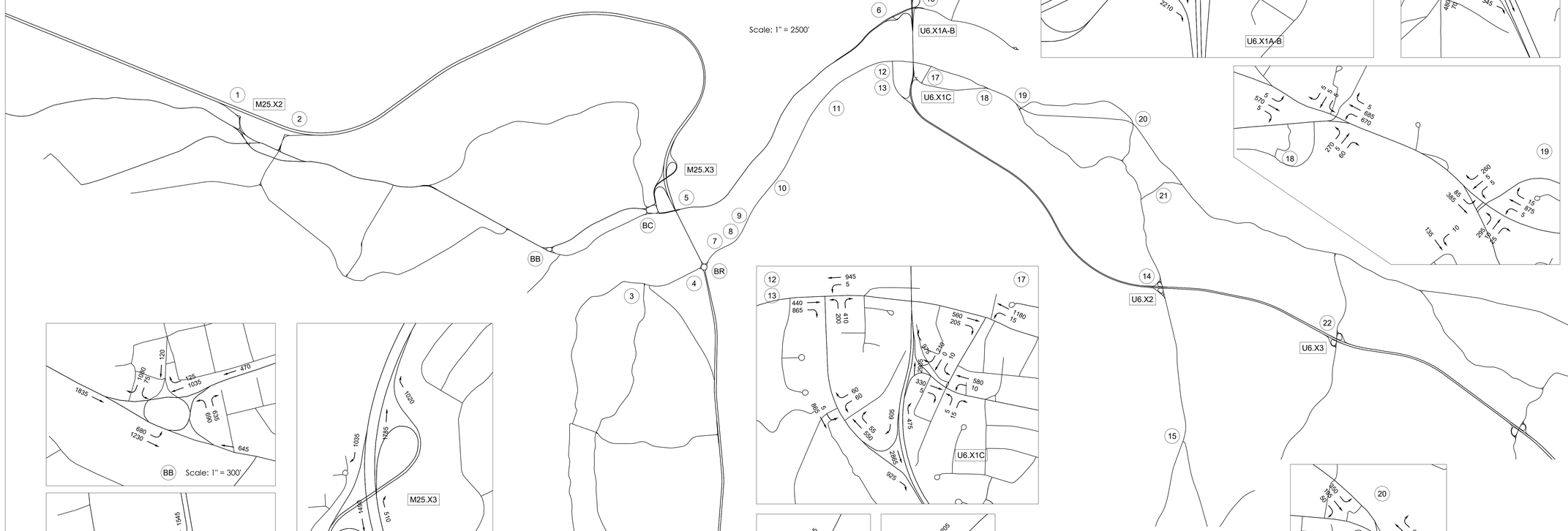
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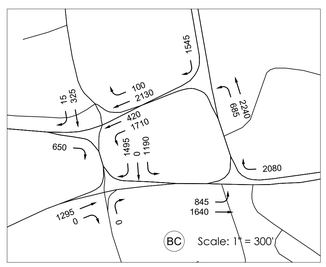


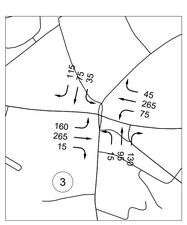


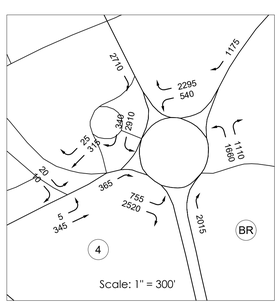


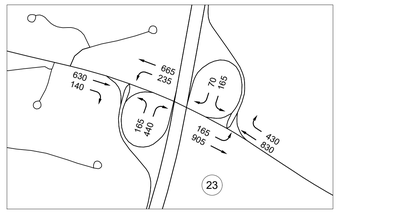


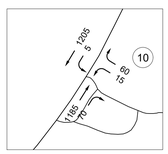


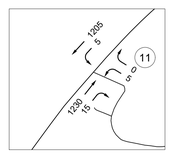


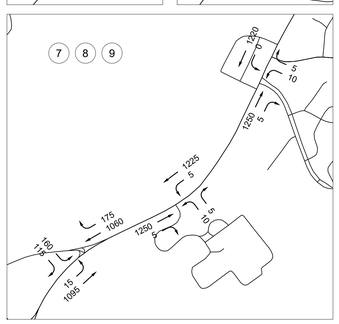


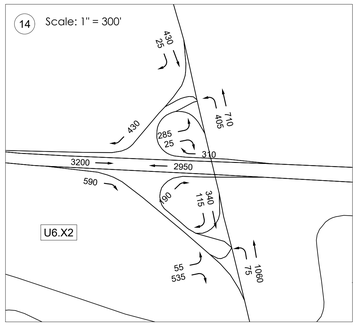




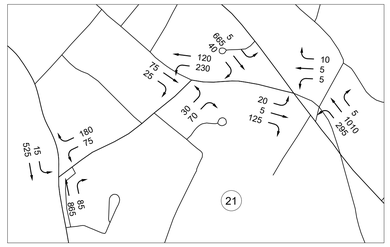


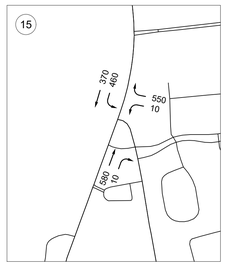


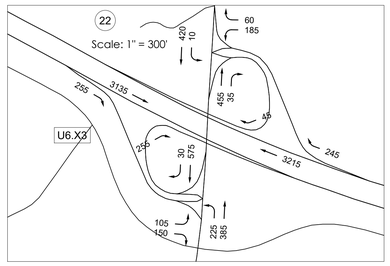








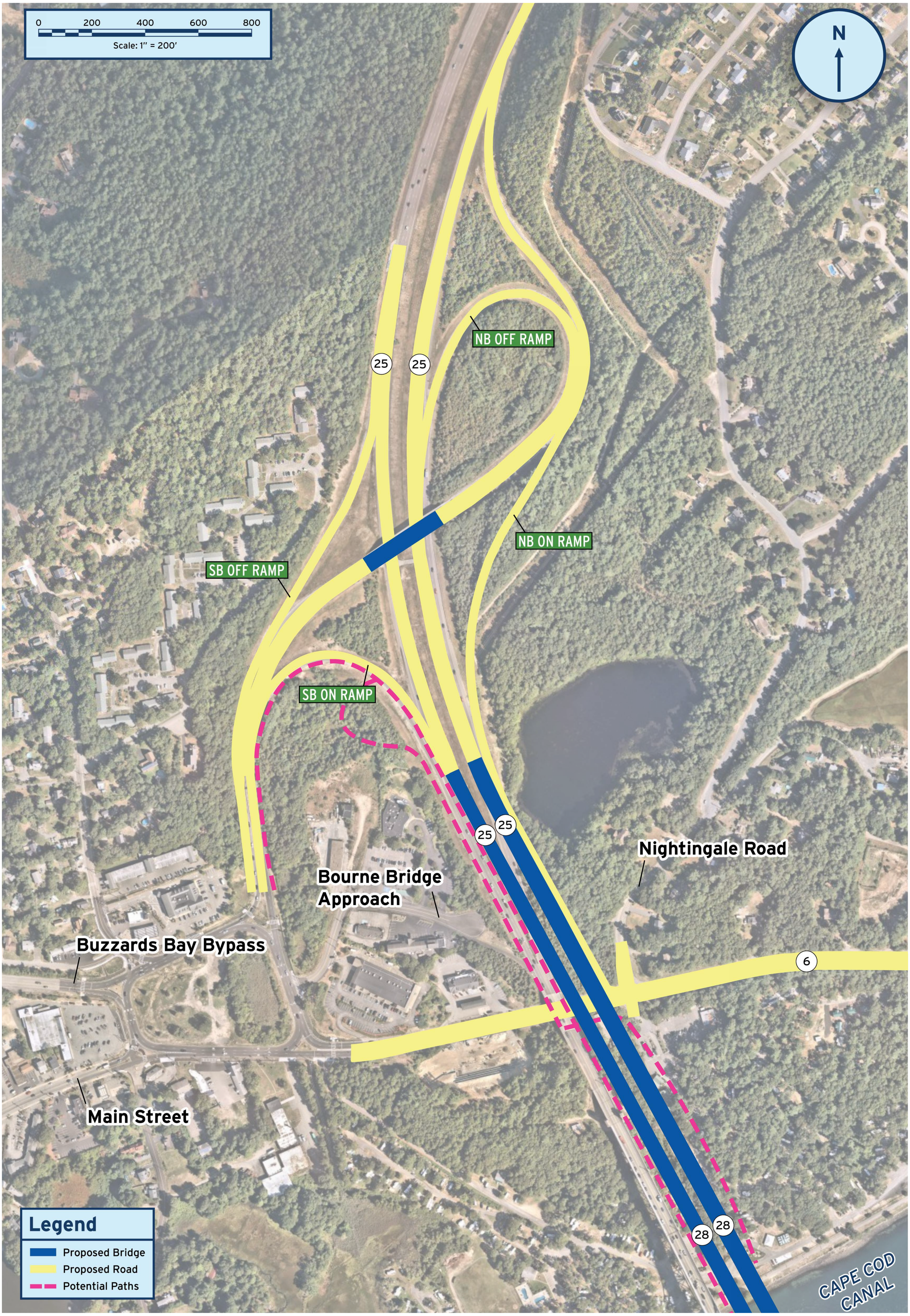




Attachment B – Interchange Alternatives

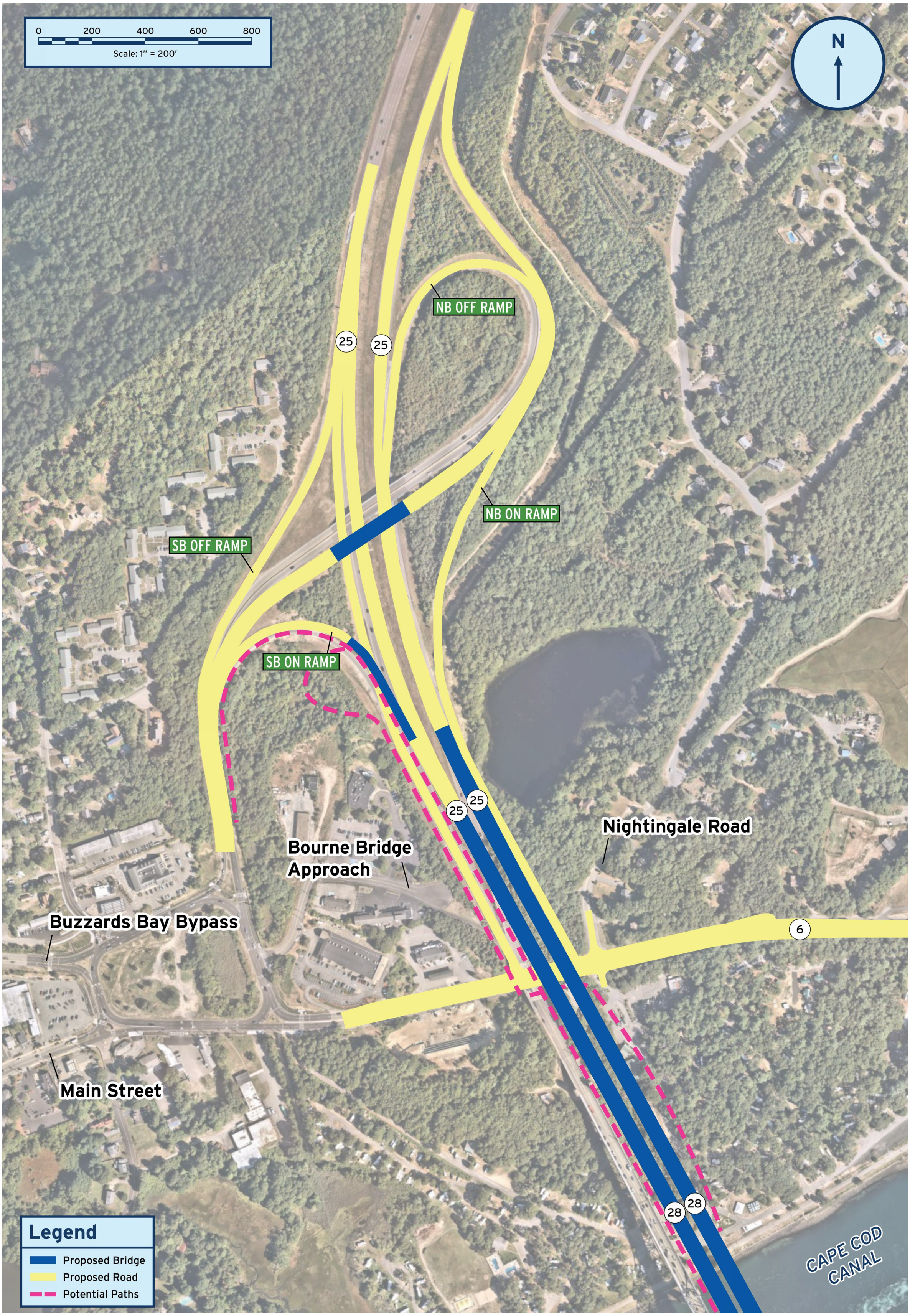
Bourne North Crossing: Interchange Approach
Northbound On-Ramp Alternative

BN-6.1



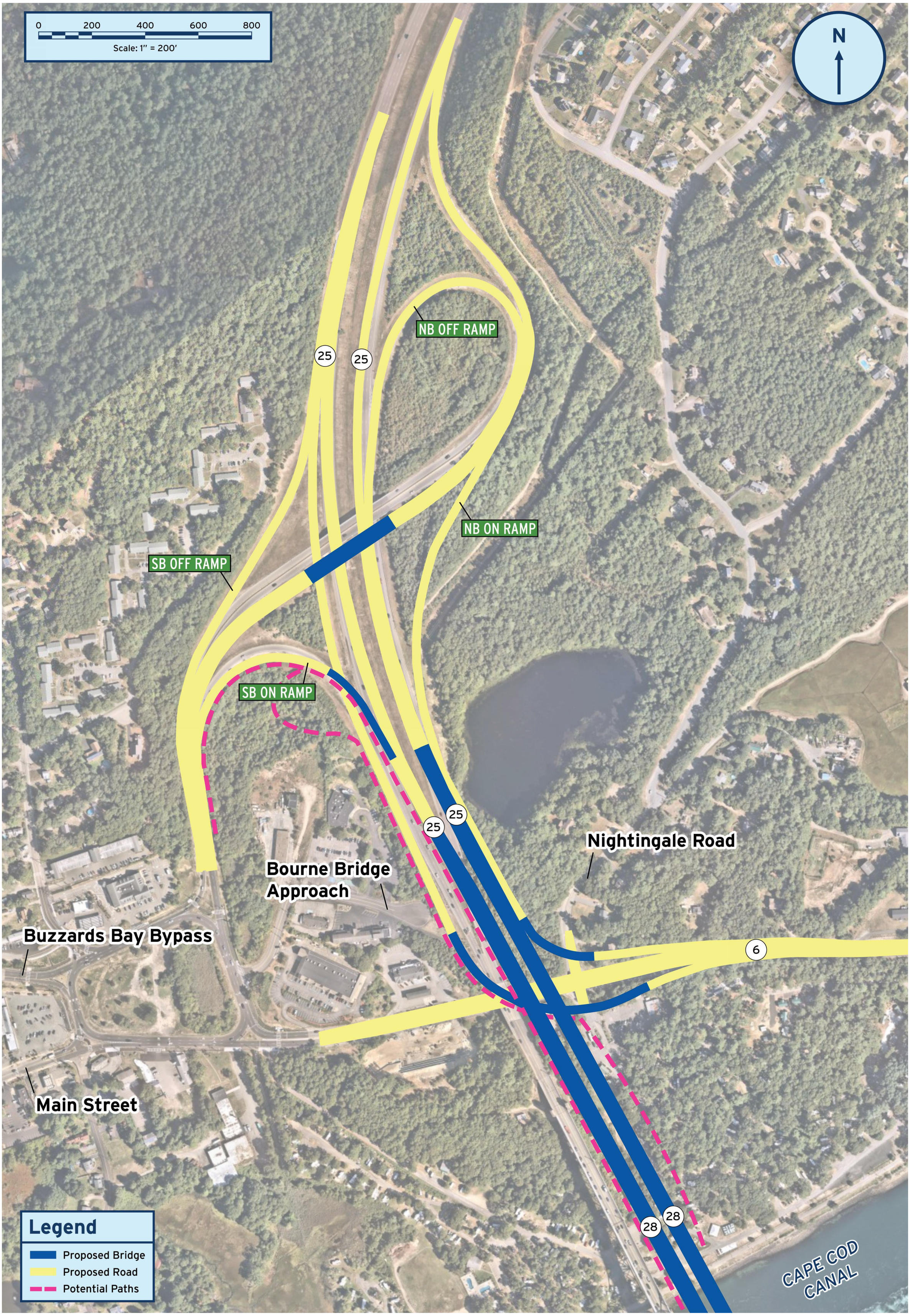
Bourne North Crossing: Interchange Approach
Single Exit Partial Interchange Alternative

BN-13.1



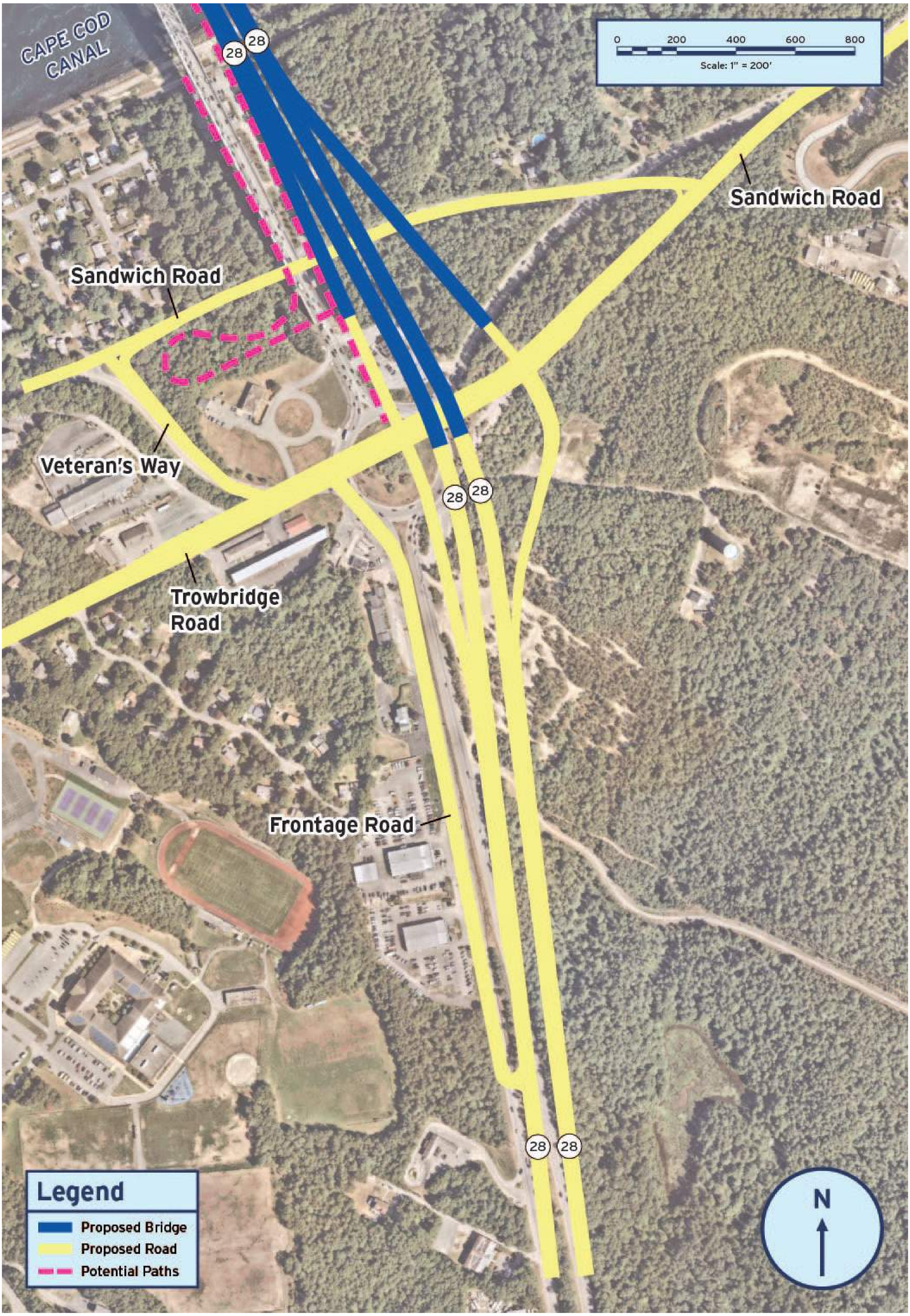
Bourne North Crossing: Interchange Approach
Directional Interchange Alternative

BN-14.4B



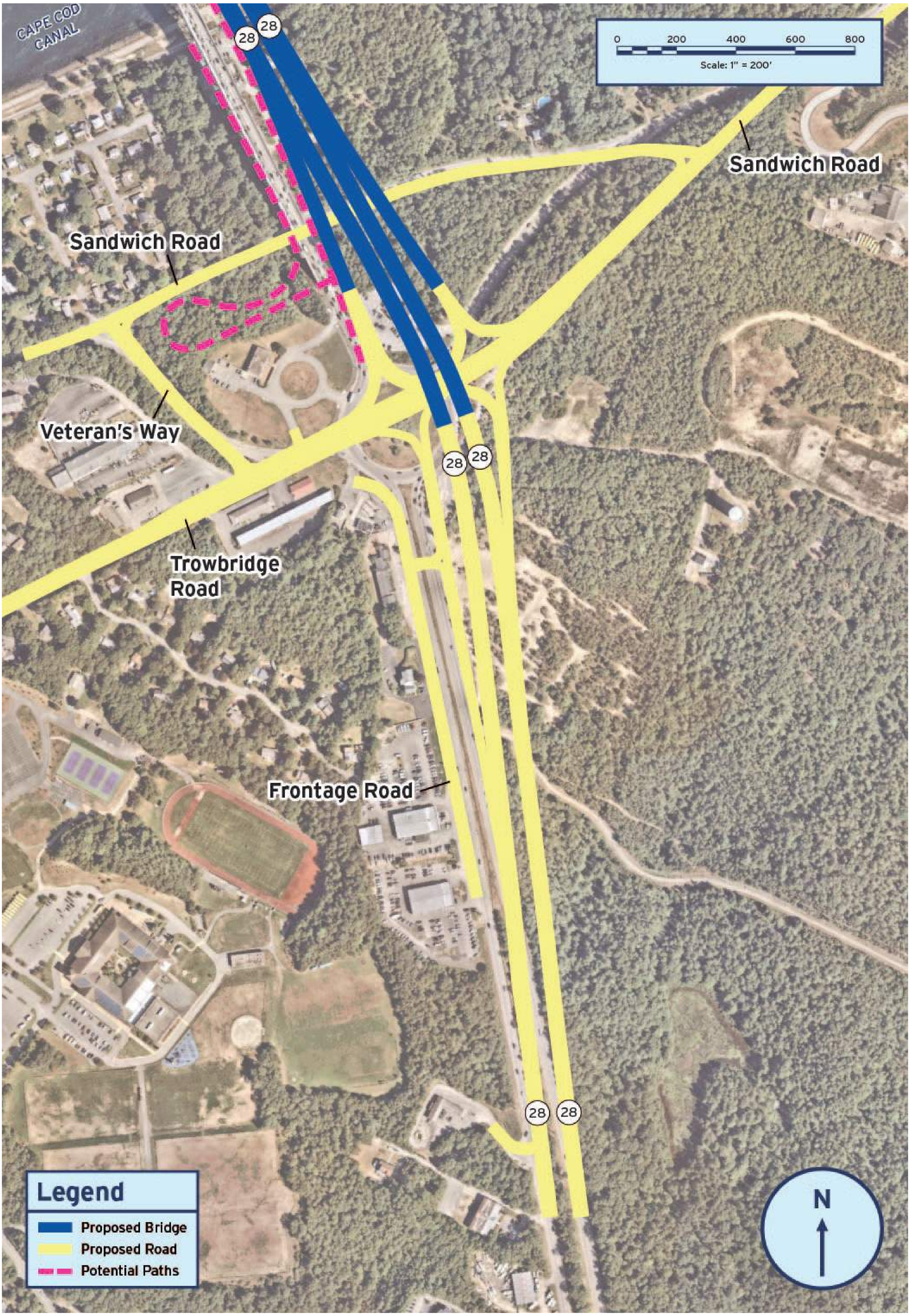
Bourne South Crossing: Interchange Approach
Diamond Interchange Alternative

BS-2



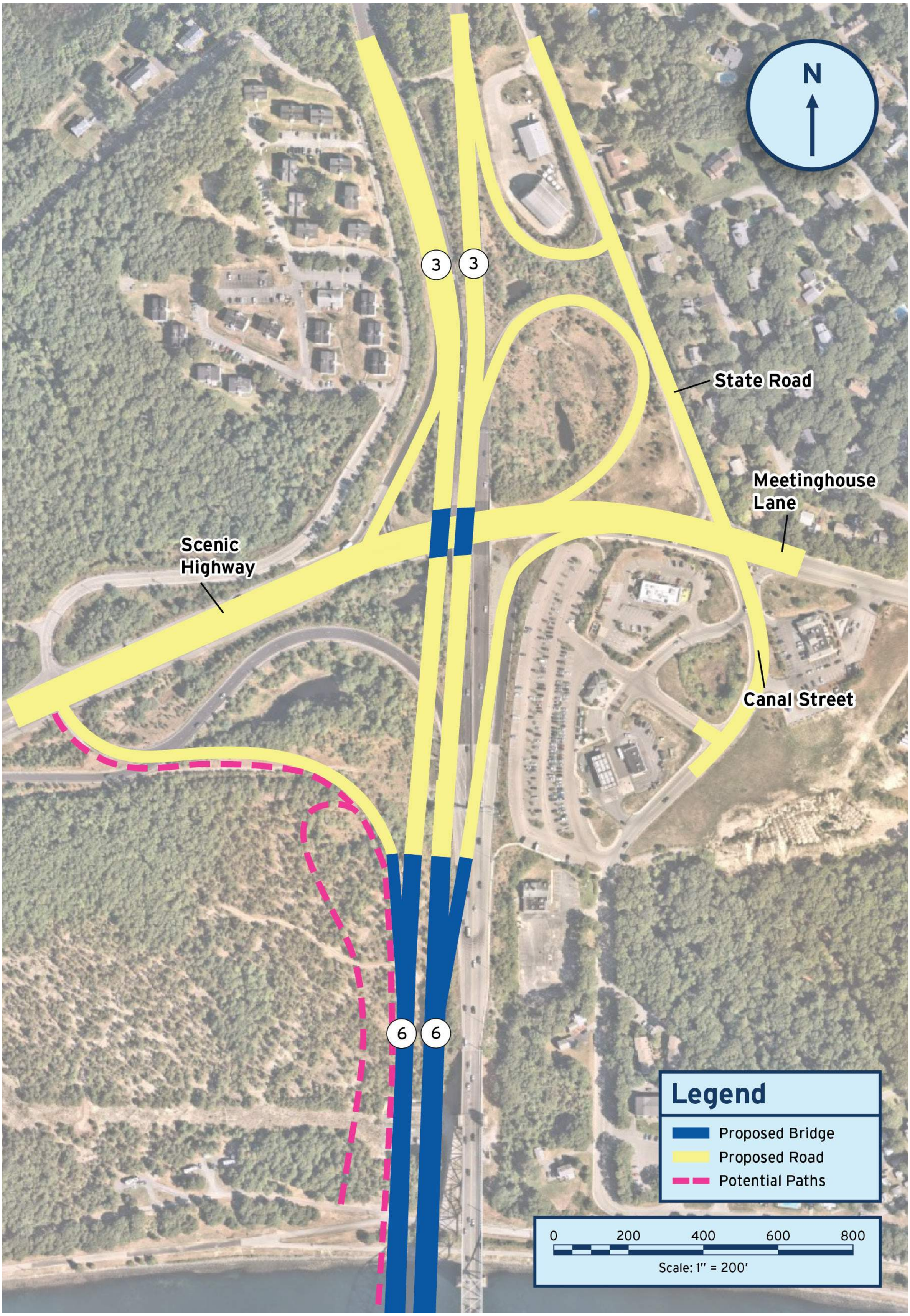
Bourne South Crossing: Interchange Approach
Single-Point Interchange Alternative

BS-2.2



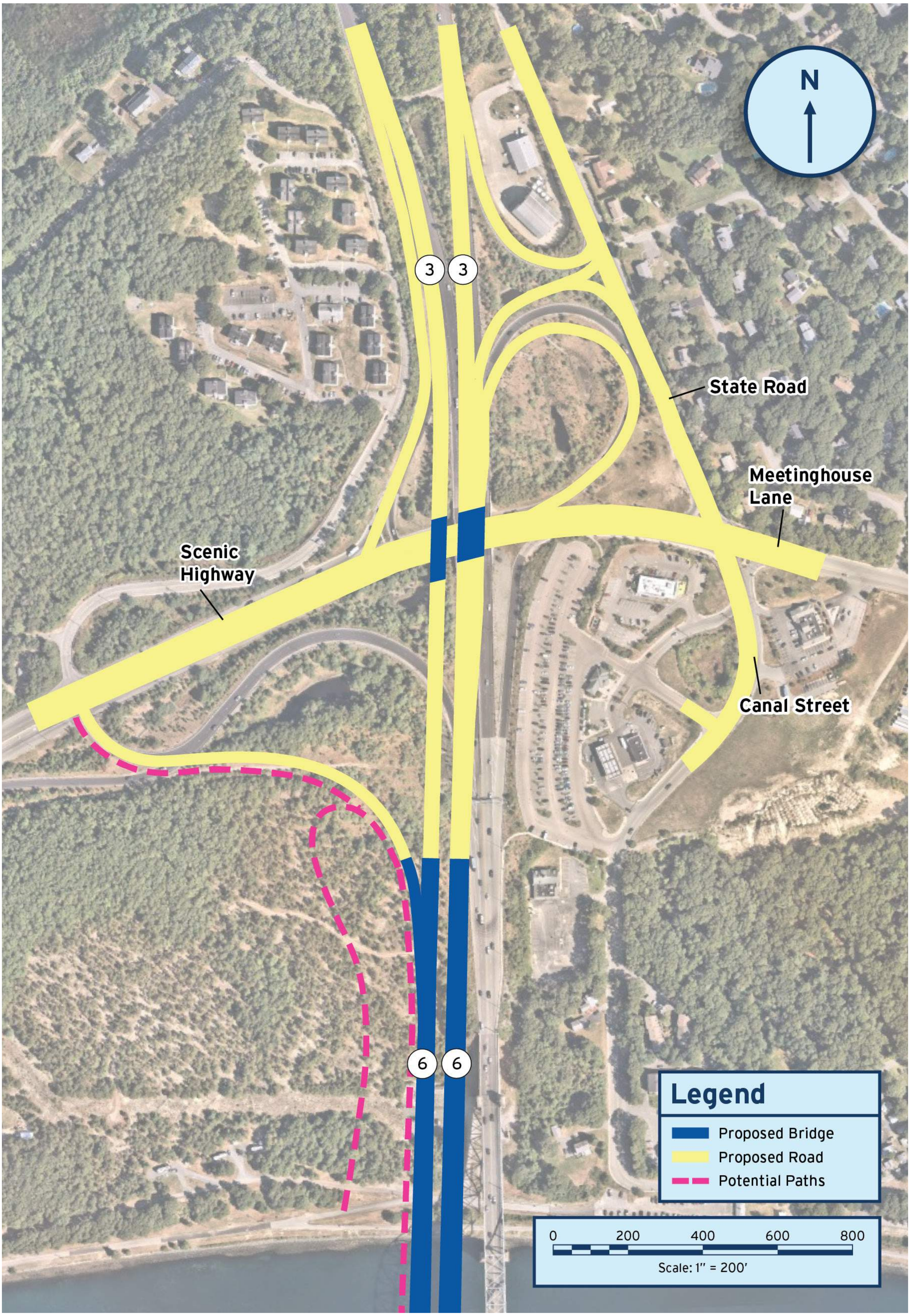
Sagamore North Crossing: Interchange Approach Similar to Existing Configuration Alternative

SN-1A



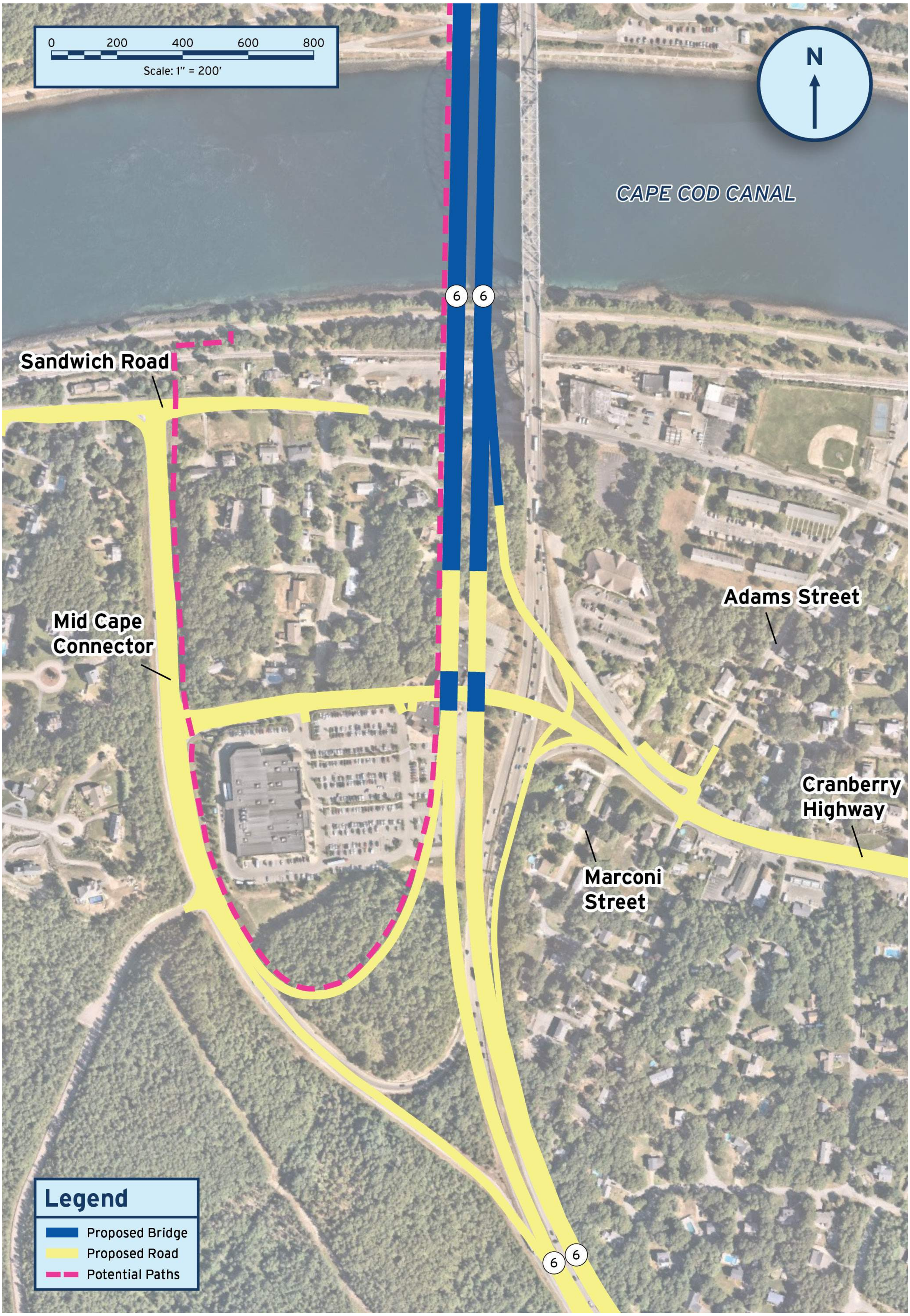
Sagamore North Crossing: Interchange Approach
Direct Connection to State Road Alternative

SN-8A



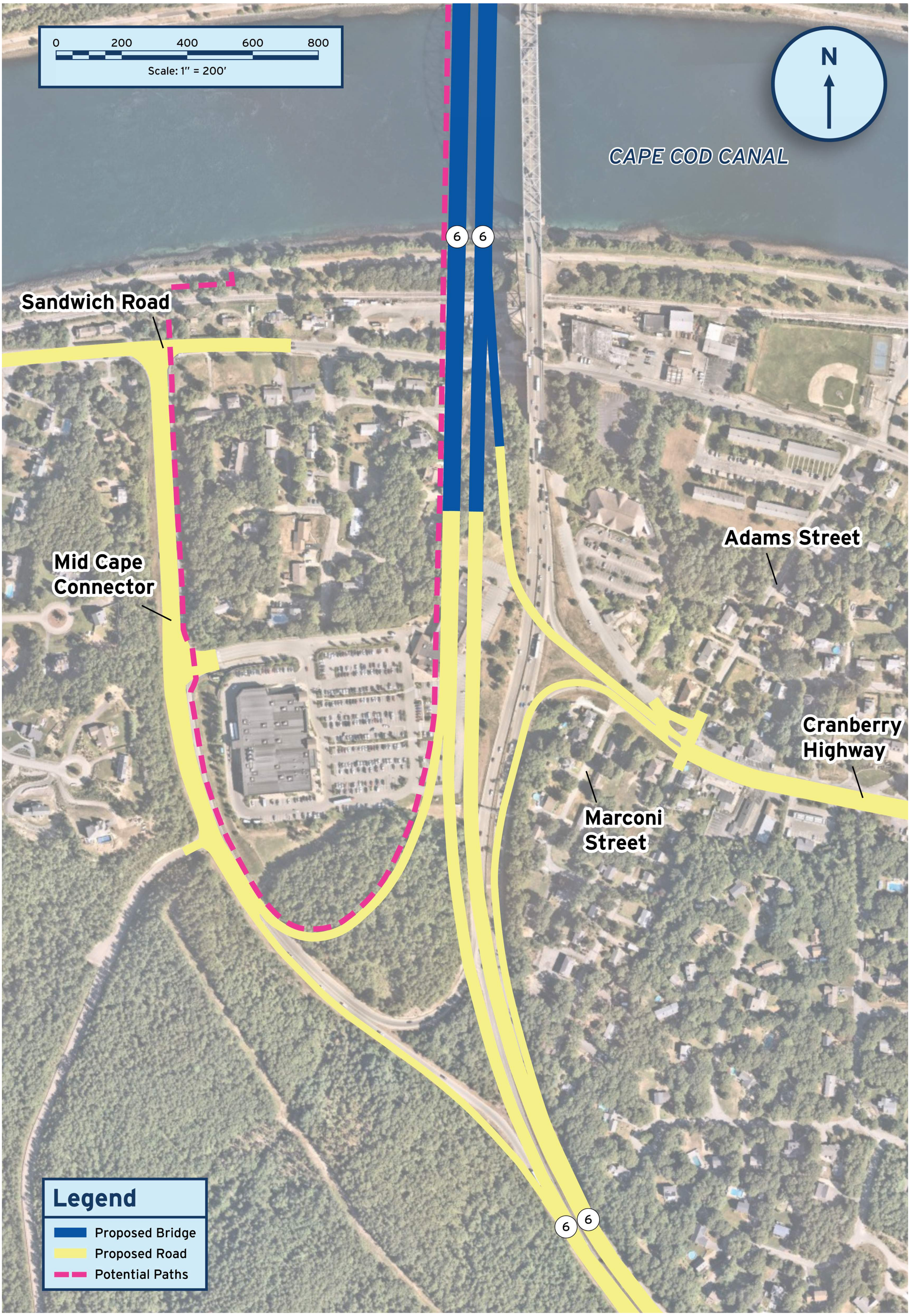
Sagamore South Crossing: Interchange Approach
Similar to Existing Configuration with Cranberry Highway Extension Alternative

SS-1



Sagamore South Crossing: Interchange Approach Similar to Existing Configuration Alternative

SS-1.1



Attachment C – 2045 Fall PM Build Traffic Volumes

Cape Cod Canal Bridge Crossings Fall PM Peak Hour

Bourne Bridge and Sagamore Bridge

Sandwich Rd and Scenic Highway

Sagamore SB	
	Fall PM
No Build	1,630
P1	2,070
P2	2,095
P3	2,130
P4	1,590
P5	1,565
P6	1,695

Sagamore NB	
	Fall PM
No Build	3,985
P1	3,495
P2	3,530
P3	3,435
P4	3,500
P5	3,510
P6	3,505

Scenic Hwy EB	
	Fall PM
No Build	1,320
P1	2,110
P2	2,100
P3	2,100
P4	1,600
P5	1,545
P6	1,615

Scenic Hwy WB	
	Fall PM
No Build	1,870
P1	1,585
P2	1,580
P3	1,525
P4	1,630
P5	1,530
P6	1,610

Sandwich Rd EB	
	Fall PM
No Build	1,075
P1	810
P2	835
P3	765
P4	1,090
P5	995
P6	1,030

Sandwich Rd WB	
	Fall PM
No Build	1,510
P1	1,910
P2	1,935
P3	2,005
P4	1,850
P5	1,925
P6	1,925

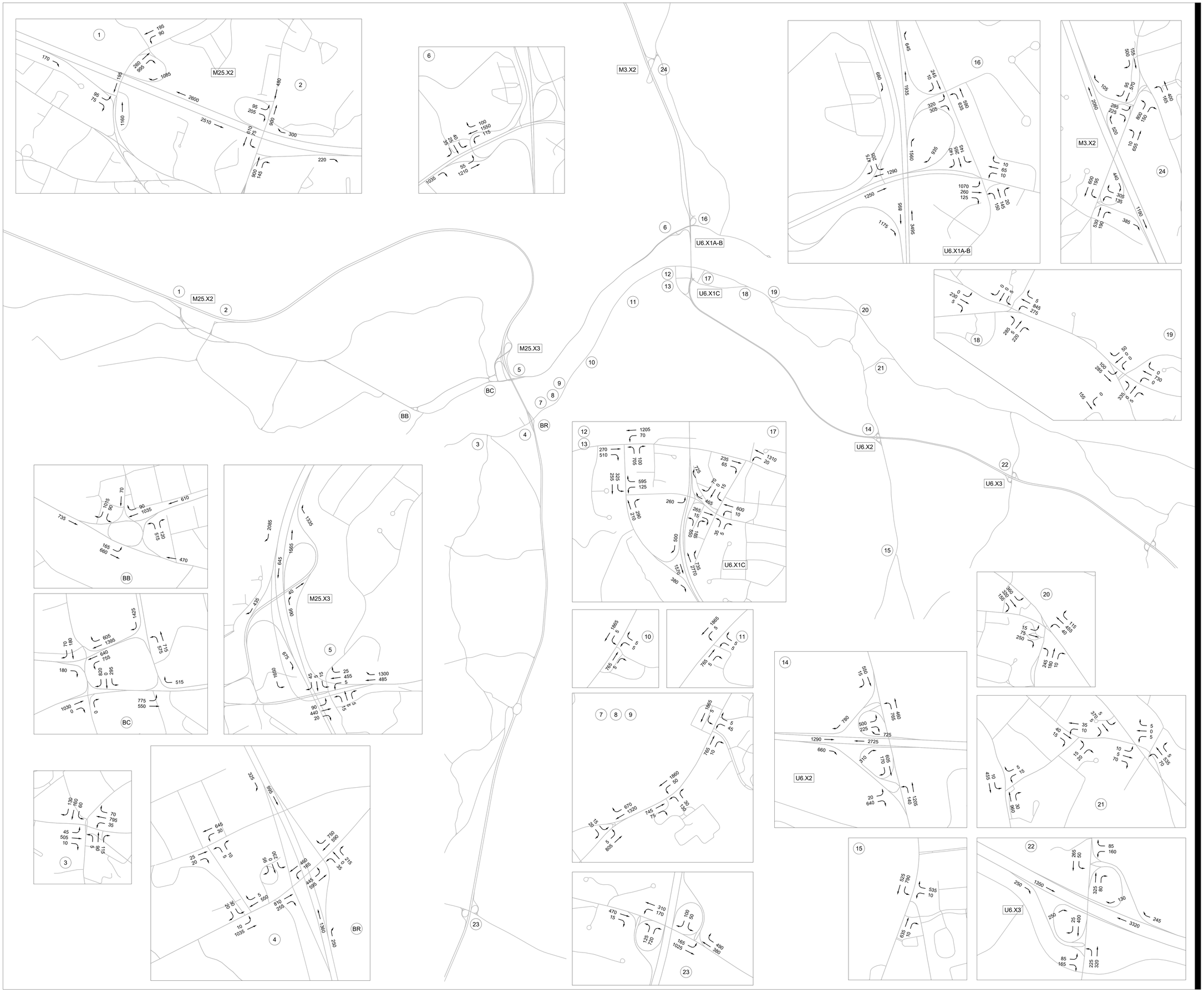
Bourne Bridge SB	
	Fall PM
No Build	1,970
P1	1,320
P2	1,300
P3	1,260
P4	1,800
P5	1,865
P6	1,760

Bourne Bridge NB	
	Fall PM
No Build	2,405
P1	2,555
P2	2,570
P3	2,630
P4	2,560
P5	2,595
P6	2,630

MassDOT

Cape Cod Canal Program Management

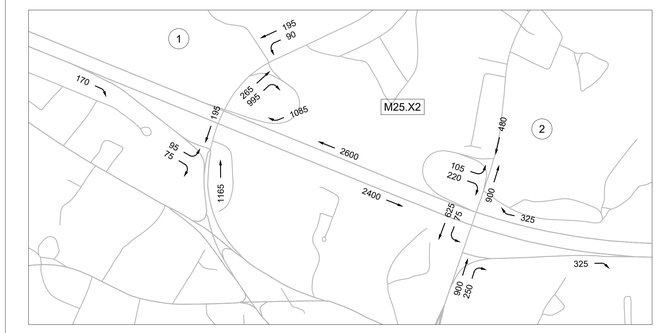
2045 Fall PM
Pairing 1 Build Conditions



MassDOT

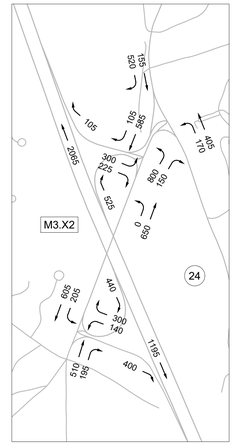
Cape Cod Canal Program Management

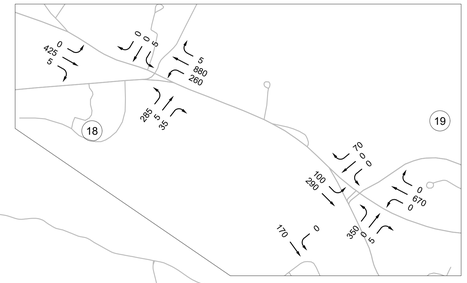
2045 Fall PM
Pairing 2 Build Conditions







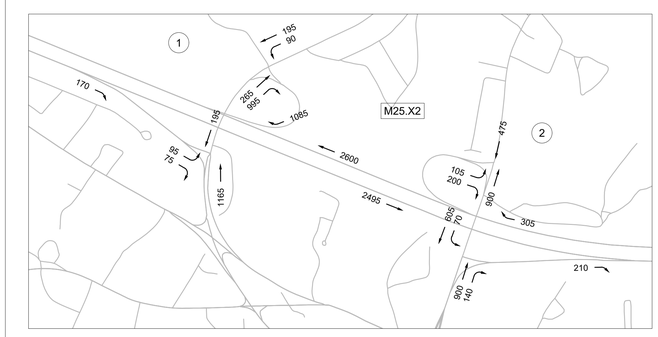


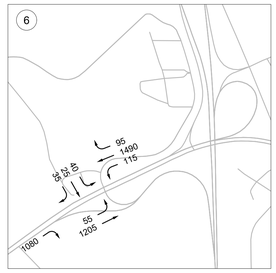


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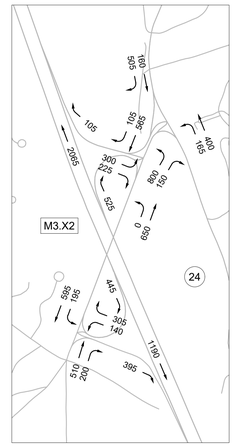
Cape Cod Canal Program Management

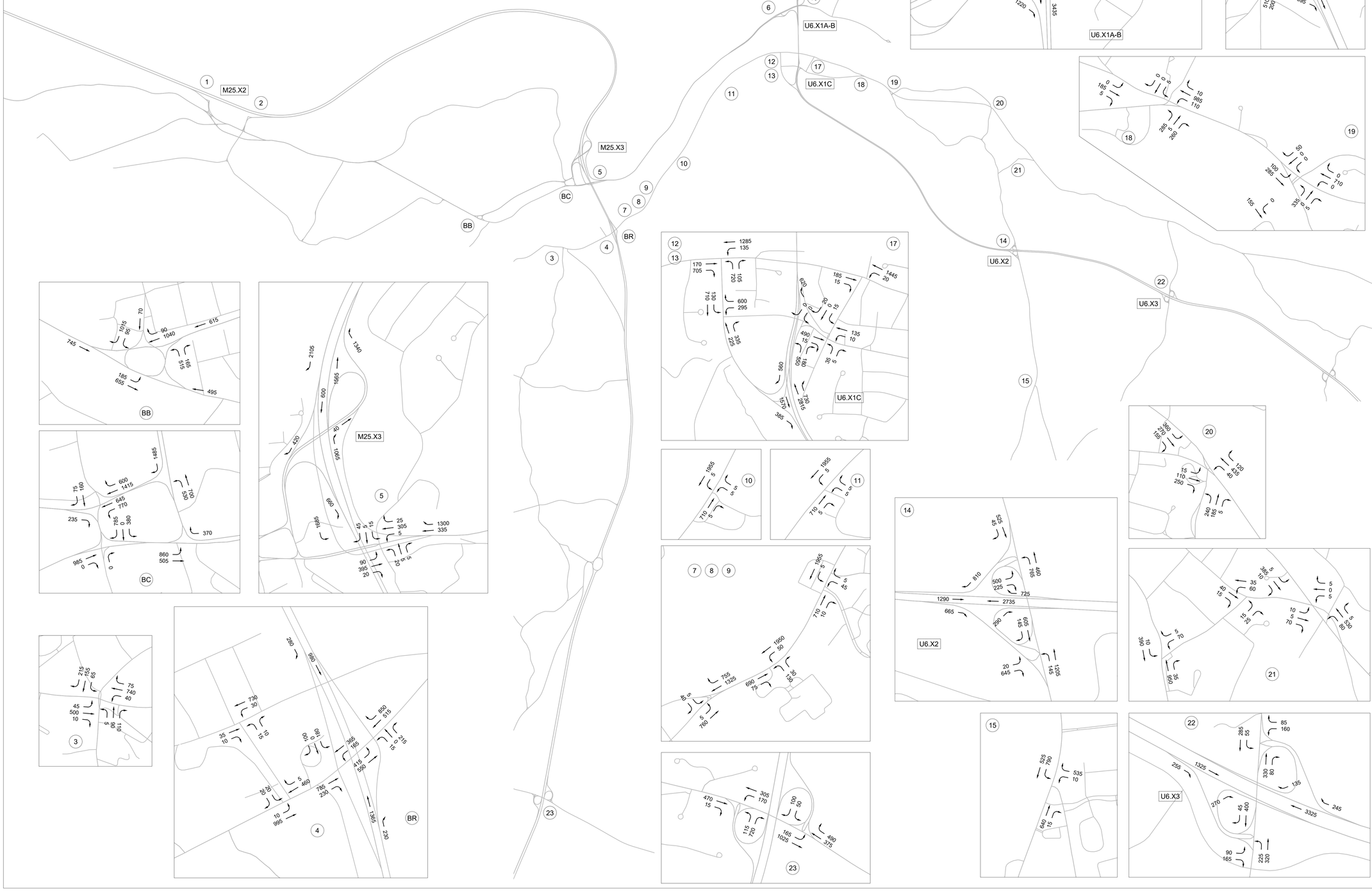
2045 Fall PM
Pairing 3 Build Conditions







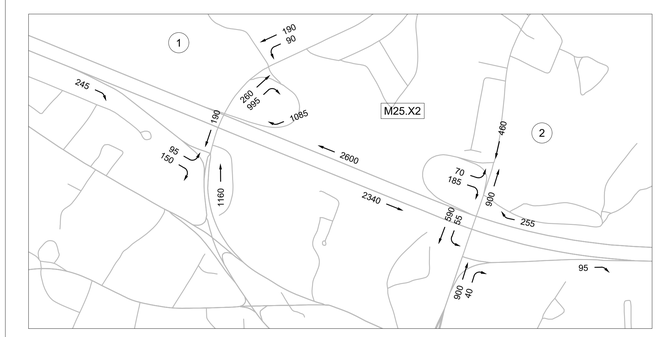


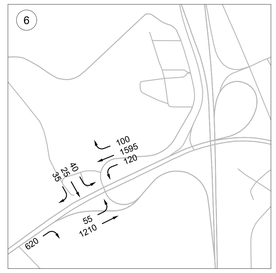


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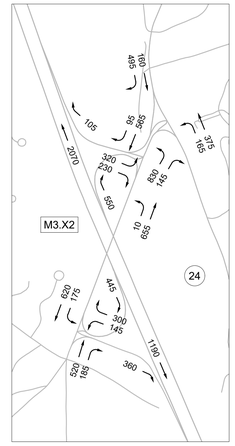
Cape Cod Canal Program Management

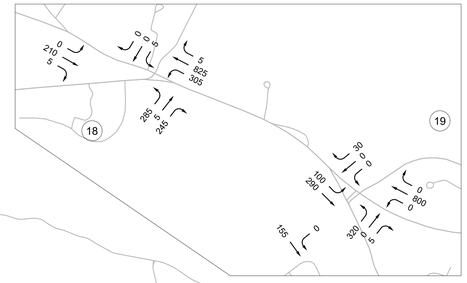
2045 Fall PM
Pairing 4 Build Conditions







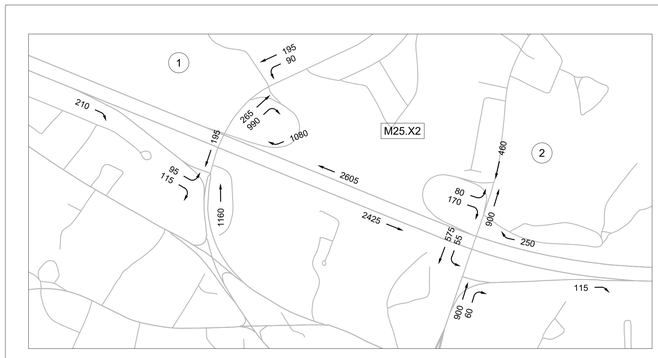


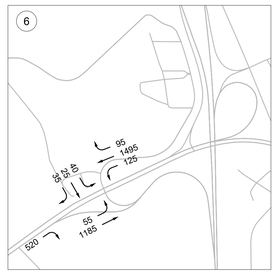


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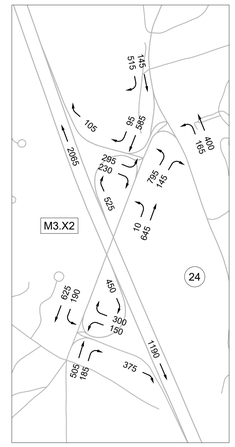
Cape Cod Canal Program Management

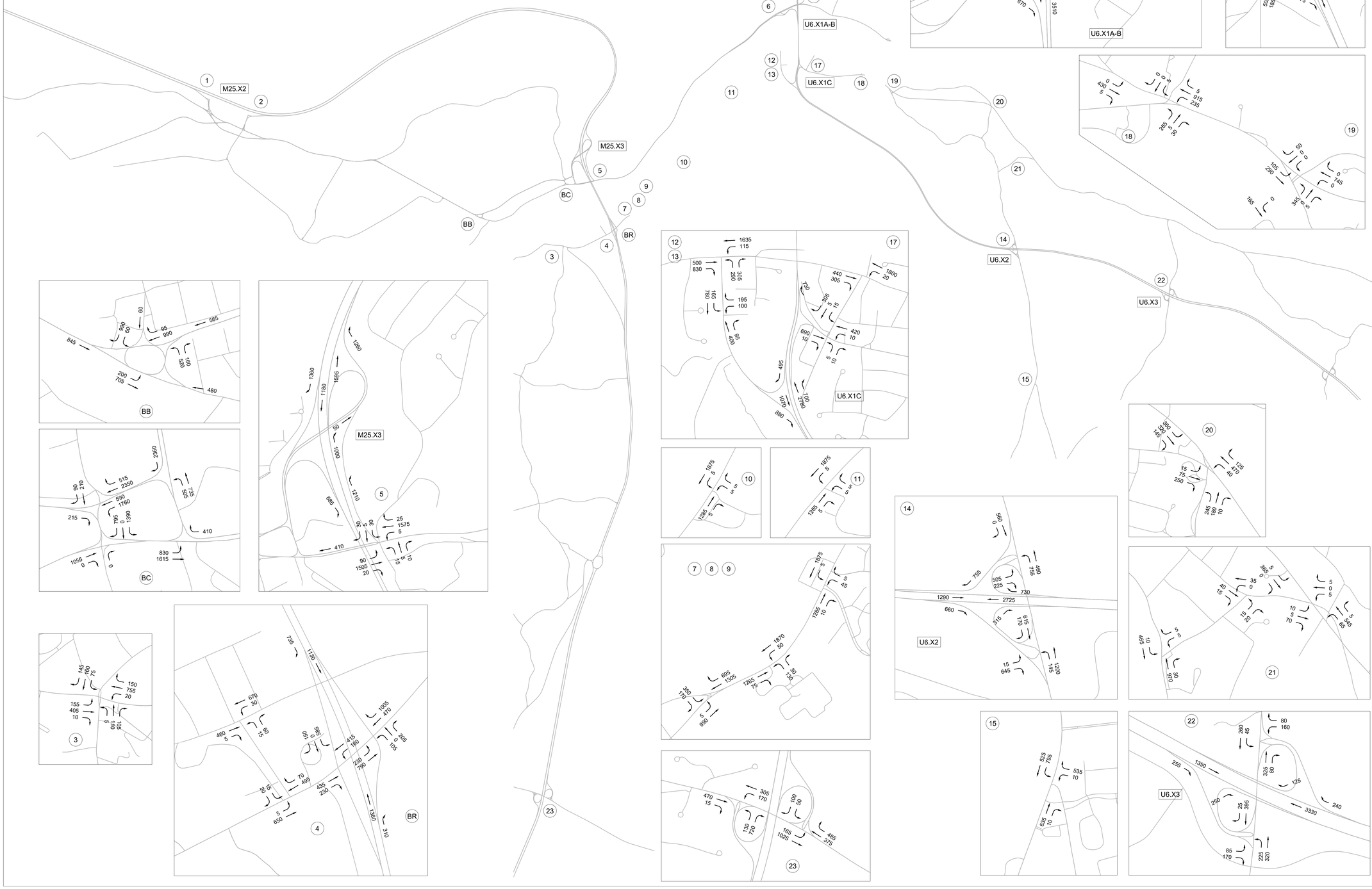
2045 Fall PM
Pairing 5 Build Conditions







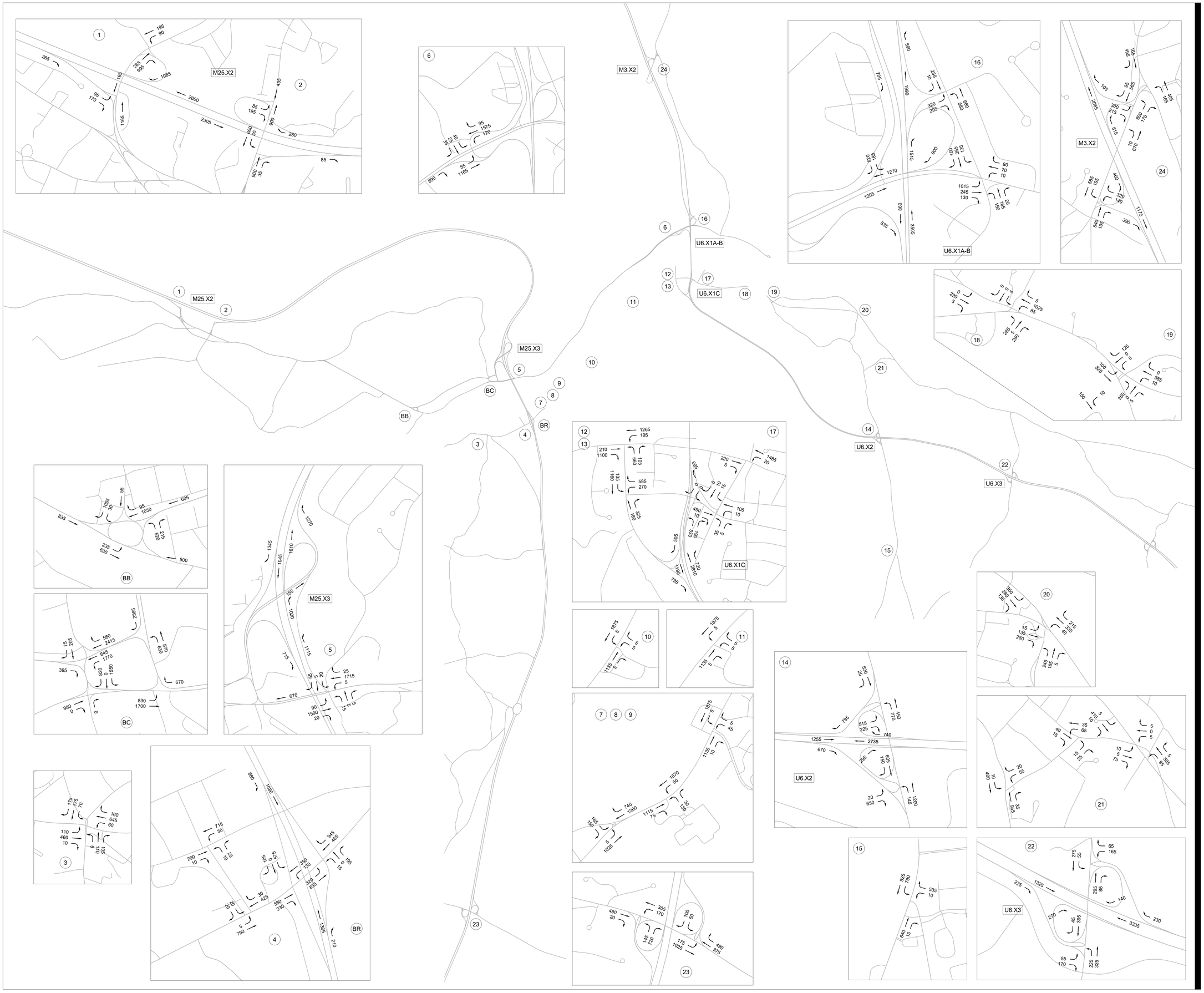




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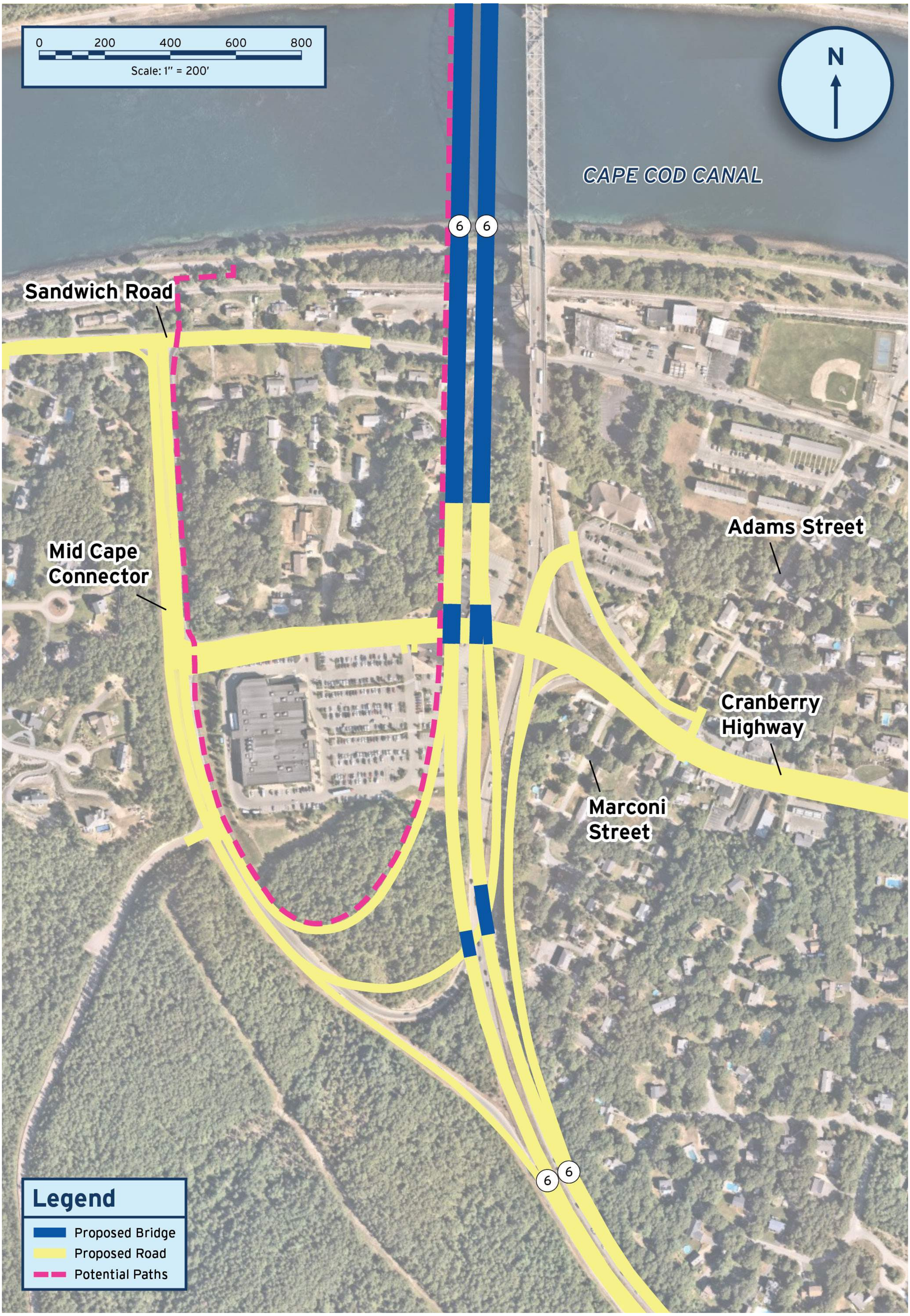
Cape Cod Canal Program Management

2045 Fall PM
Pairing 6 Build Conditions



Sagamore South Crossing: Interchange Approach
Westbound On-Ramp Under Route 6 Alternative

SS-3.1A

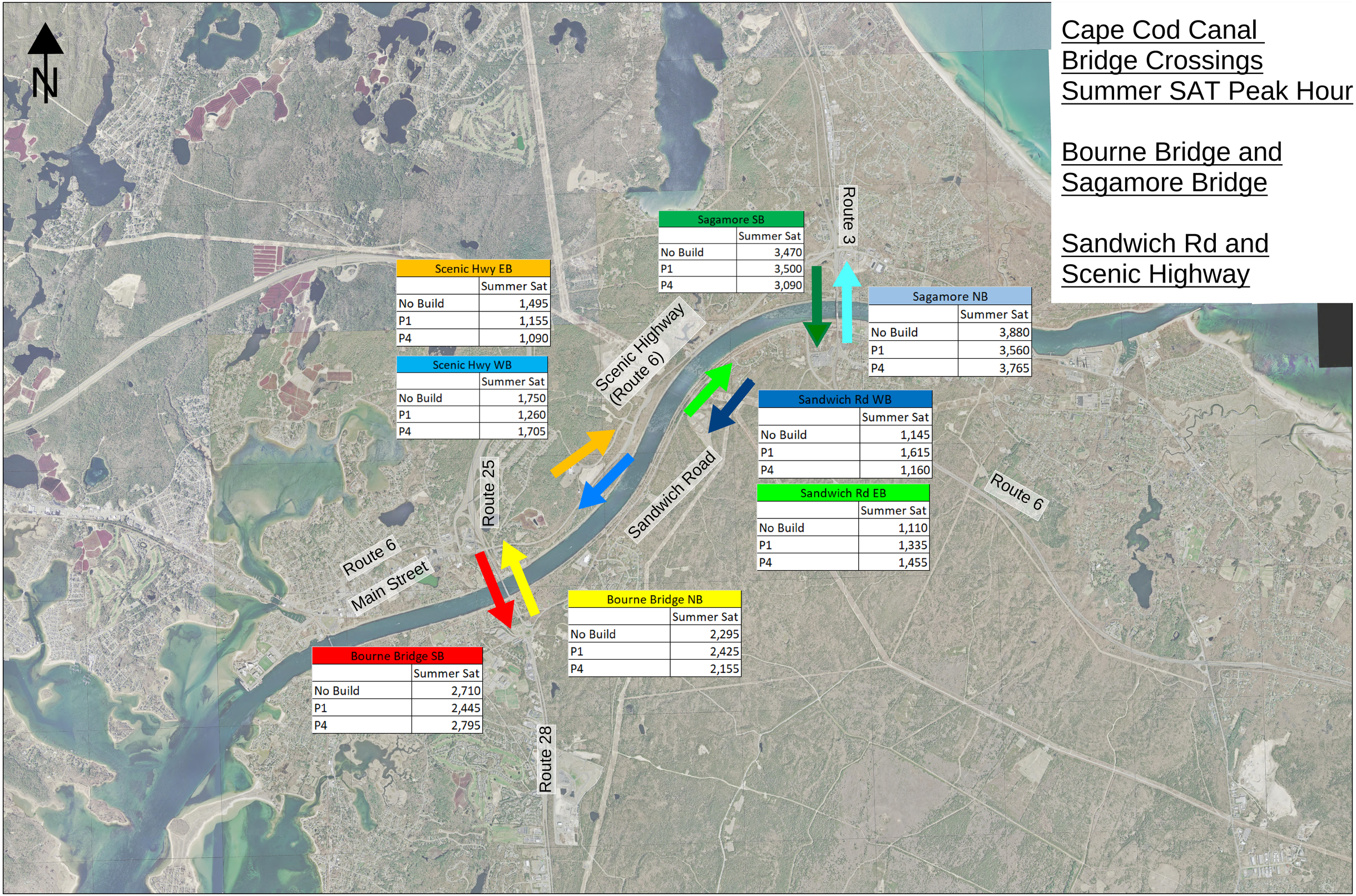


Attachment D – 2045 Summer Saturday Build Traffic Volumes

Cape Cod Canal Bridge Crossings Summer SAT Peak Hour

Bourne Bridge and Sagamore Bridge

Sandwich Rd and Scenic Highway



Sagamore SB	
	Summer Sat
No Build	3,470
P1	3,500
P4	3,090

Sagamore NB	
	Summer Sat
No Build	3,880
P1	3,560
P4	3,765

Scenic Hwy EB	
	Summer Sat
No Build	1,495
P1	1,155
P4	1,090

Scenic Hwy WB	
	Summer Sat
No Build	1,750
P1	1,260
P4	1,705

Sandwich Rd WB	
	Summer Sat
No Build	1,145
P1	1,615
P4	1,160

Sandwich Rd EB	
	Summer Sat
No Build	1,110
P1	1,335
P4	1,455

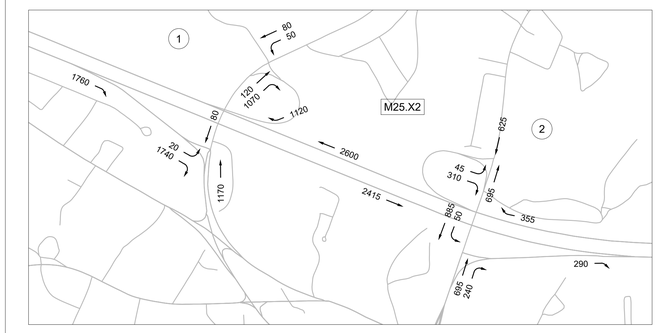
Bourne Bridge NB	
	Summer Sat
No Build	2,295
P1	2,425
P4	2,155

Bourne Bridge SB	
	Summer Sat
No Build	2,710
P1	2,445
P4	2,795

MassDOT

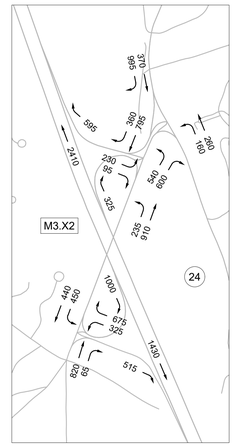
Cape Cod Canal Program Management

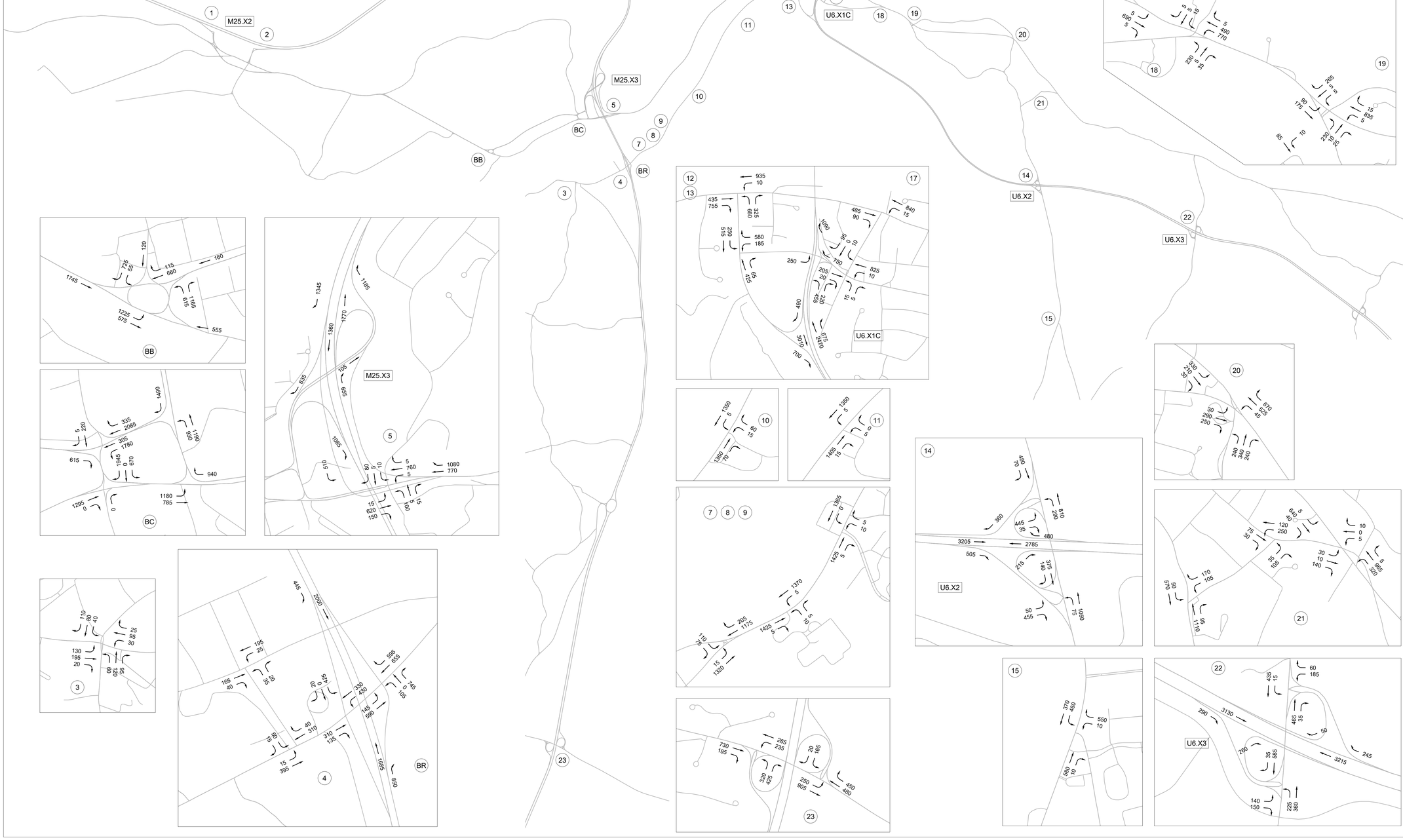
2045 Summer SAT
Pairing 1 Build Conditions







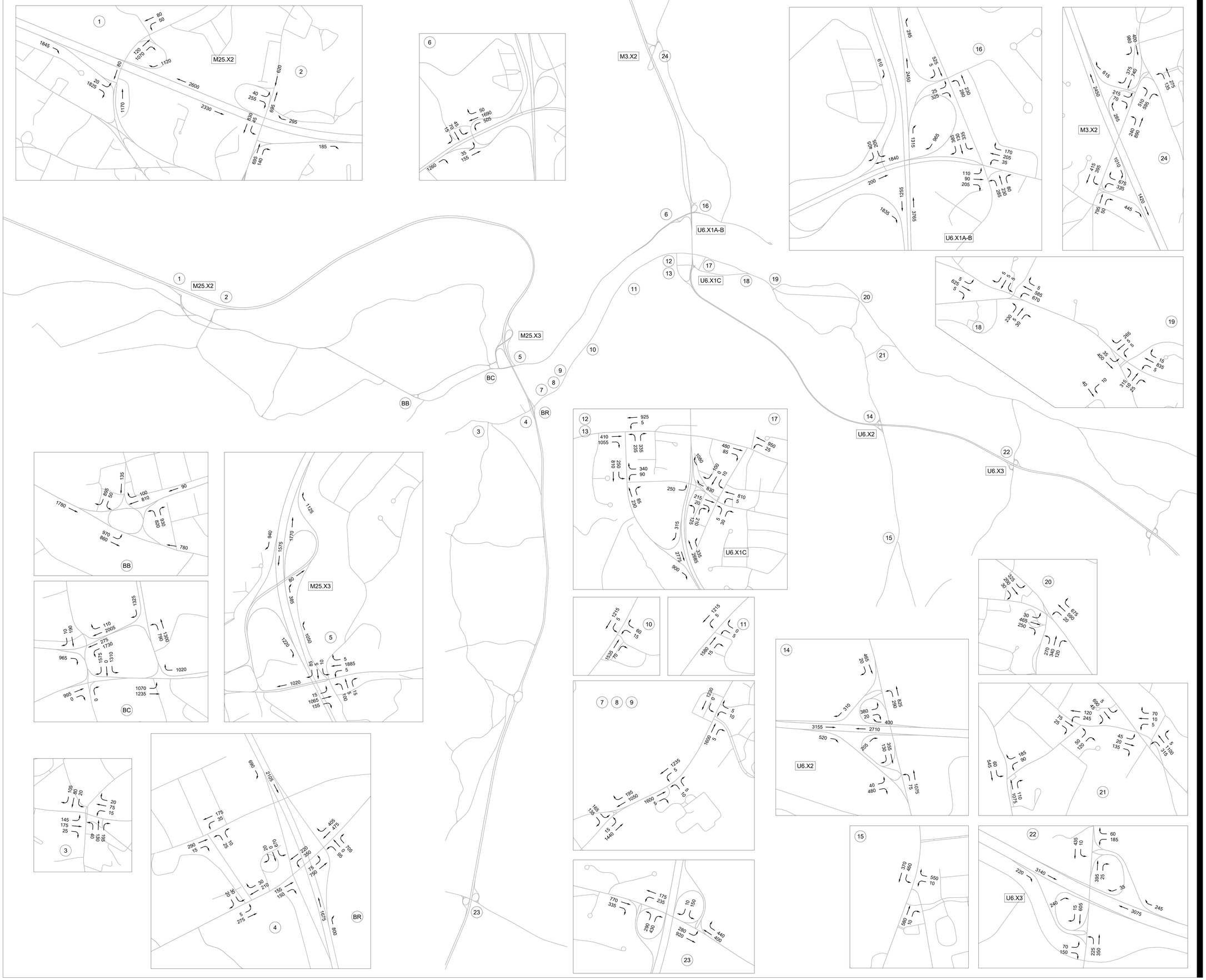




MassDOT

Cape Cod Canal Program Management

2045 Summer SAT
Pairing 4 Build Conditions



Attachment E – Origin-Destination

Origin - Destination Routes - Fall PM 2045

To Cape Cod

TOTAL Route 25 Volumes:
NB - 2,055
P1 - 2,730
P2 - 2,725
P3 - 2,705
P4 - 2,435
P5 - 2,540
P6 - 2,435

From Route 3 Volumes:
NB - 1,640
P1 - 1,630
P2 - 1,635
P3 - 1,635
P4 - 1,635
P5 - 1,640
P6 - 1,635

Route 25

Route 3

Scenic Highway (Route 6)

Sandwich Road

Route 6

Route 6

Main Street

To: Route 6 EB

Via Sandwich Rd	Via Scenic Hwy
NB - 462 (100%)	NB - 0 (0%)
P1 - 0 (0%)	P1 - 514 (100%)
P2 - 0 (0%)	P2 - 515 (100%)
P3 - 0 (0%)	P3 - 513 (100%)
P4 - 414 (88%)	P4 - 56 (12%)
P5 - 479 (99%)	P5 - 3 (1%)
P6 - 351 (76%)	P6 - 111 (24%)

To: Route 28 SB

Via Sandwich Rd	Via Scenic Hwy
NB - 82 (69%)	NB - 37 (31%)
P1 - 85 (67%)	P1 - 42 (33%)
P2 - 110 (84%)	P2 - 21 (16%)
P3 - 89 (72%)	P3 - 34 (28%)
P4 - 44 (35%)	P4 - 83 (65%)
P5 - 91 (72%)	P5 - 36 (28%)
P6 - 58 (45%)	P6 - 71 (55%)

N

Origin - Destination Routes - Fall PM 2045

From Cape Cod

To: Route 25 WB

Via Sandwich Rd	Via Scenic Hwy
NB - 0	NB - 1081
P1 - 4	P1 - 1109
P2 - 0	P2 - 1127
P3 - 0	P3 - 1143
P4 - 23	P4 - 1072
P5 - 0	P5 - 1090
P6 - 4	P6 - 1089

To: Route 3 NB

Via Sandwich Rd	Via Scenic Hwy
NB - 110	NB - 0
P1 - 100	P1 - 0
P2 - 97	P2 - 0
P3 - 96	P3 - 0
P4 - 96	P4 - 0
P5 - 104	P5 - 0
P6 - 96	P6 - 0

From Route 6
Volumes:
NB - 3440
P1 - 3505
P2 - 3505
P3 - 3545
P4 - 3505
P5 - 3480
P6 - 3530

From Route 28
Volumes:
NB - 1475
P1 - 1610
P2 - 1590
P3 - 1595
P4 - 1595
P5 - 1670
P6 - 1595

Route 25

Route 6

Route 6

Main Street

Scenic Highway (Route 6)

Sandwich Road

N

Origin - Destination Routes - Summer SAT 2045

To Cape Cod

TOTAL Route 25
Volumes:
NB - 2,525
P1 - 2,705
P4 - 2,545

From Route 3
Volumes:
NB - 2,430
P1 - 2,430
P4 - 2,435

Route 25

Route 3

Scenic Highway (Route 6)

Sandwich Road

Route 6

Route 6

Main Street

To: Route 6 EB

Via Sandwich Rd
NB - 171 (27%)
P1 - 15 (2%)
P4 - 298 (47%)

Via Scenic Hwy
NB - 452 (73%)
P1 - 609 (98%)
P4 - 333 (53%)

To: Route 28 SB

Via Sandwich Rd
NB - 34 (87%)
P1 - 63 (97%)
P4 - 59 (97%)

Via Scenic Hwy
NB - 5 (13%)
P1 - 2 (3%)
P4 - 2 (3%)

N

Origin - Destination Routes - Summer SAT 2045

From Cape Cod

To: Route 25 WB

Via Sandwich Rd
NB - 9
P1 - 0
P4 - 0

Via Scenic Hwy
NB - 712
P1 - 746
P4 - 732

To: Route 3 NB

Via Sandwich Rd
NB - 83
P1 - 211
P4 - 199

Via Scenic Hwy
NB - 107
P1 - 0
P4 - 0

From Route 6
Volumes:
NB - 3380
P1 - 3145
P4 - 3020

From Route 28
Volumes:
NB - 2015
P1 - 2535
P4 - 2495

Route 25
Route 3
Scenic Highway (Route 6)
Sandwich Road
Route 6
Route 6
Main Street
N

2.6 Preliminary Traffic Analysis for Build Analysis Pairings (May 7, 2024)

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Date
May 7, 2024

To
Bryan Cordeiro, MassDOT

From
Alexandra Siu, P.E., PTOE
David Giel, P.E., PTOE

Subject
Cape Cod Canal Bridges Program – Preliminary Traffic Analysis for Build Analysis Pairings – Revised

PROJECT CORRESPONDENCE

Introduction

HNTB previously submitted preliminary traffic analysis of proposed interchange alternatives for the Cape Cod Canal Bridge Program on December 4, 2023. This document serves to update the analysis findings based on continued interchange alternative development and model refinements. As a part of the Cape Cod Canal Bridge Program, several roadway and interchange alternatives are being developed for each of the touchdown points on either side of the Sagamore and Bourne bridges. These four quadrants have been designated as:

- Sagamore North (SN)
- Sagamore South (SS)
- Bourne North (BN)
- Bourne South (BS)

Future (2045) No-Build traffic volumes were developed with the methodology and results summarized in the memorandum titled *"Cape Cod Canal Bridges Program – Summary of Future No-Build Modeling Process and Results"* and dated December 17, 2021. Future (2045) Build traffic volume results and summary were included in the memorandum titled *"Cape Cod Canal Bridges Program – Future 2045 Build Traffic Volumes"* and dated September 1, 2023. As discussed in that memo, the Future 2045 traffic volumes were developed to take into account expected changes that were anticipated to be included in the upcoming 2050 data. With the release of the 2050 socioeconomic data, the team reviewed the updated information and determined that traffic volumes that were projected for 2045 are similar to or slightly higher than the 2050 projections. Therefore, in order to maintain consistency in analysis, the 2050 traffic volumes utilize the same socioeconomic data and volume projections as the 2045 traffic volumes.

The interchange alternatives currently being considered for each quadrant are as follows:

Sagamore North (SN)	Sagamore South (SS)	Bourne North (BN)	Bourne South (BS)
SN-1A	SS-1	BN-6.1	BS-2
SN-8A	SS-1.1	BN-13.1	BS-2.2
	SS-3.1A	BN-14.4B	

Alternatives

In all of the alternatives, the alignment of the Sagamore Bridge is proposed to be shifted to the west, on the inboard side of the existing structure. The alignment of the Bourne Bridge is proposed to be shifted to the east, also on the inboard side of the existing structure.

Sagamore North

SN-1A

This alternative closely resembles the existing conditions. The number of ramp connections relative locations remain the same as existing. They have just been updated to meet current design standards and safety preferences.

SN-8A

SN-8A removes the Sagamore Bridge NB off-ramp connection to Meetinghouse Lane EB and instead connects to State Road, north of Meetinghouse Lane. The remaining ramp connections remain similar to existing conditions.

Sagamore South

SS-1

In this alternative, an extension of Cranberry Highway is developed under US 6 and connects to Factory Outlet Way and the Mid-Cape Connector. This is to provide a more direct access from Cranberry Highway to US 6 southbound as well as Sandwich Road. The number of ramp connections to US 6 remain the same as existing.

SS-1.1

This alternative closely resembles the existing conditions, with some modifications to ramp geometry and location. The number of ramp connections to US 6 remain the same as existing.

SS-3.1A

This alternative is similar to SN-1 with the Cranberry Highway extension. However, in SS-3.1A, the Cranberry Highway to Sagamore Bridge NB ramp is removed. Instead, a new NB on-ramp connection from Mid-Cape Connector to Sagamore Bridge NB is developed.

Bourne North

BN-6.1

This alternative maintains the number of ramp connections to Route 25 as the existing condition. However, a new ramp is proposed to connect Scenic Highway WB to Route 25 WB at the intersection of Scenic Highway (Route 6) / Nightingale Road intersection. This ramp merges with the on-ramp from Belmont circle prior to meeting up with the Route 25 mainline.

BN-13.1

This alternative includes the ramp connection from Scenic Highway WB to Route 25 WB, similar to BN-6.1. Additionally, a ramp is proposed to connect Route 25 EB to Scenic Highway, allowing vehicles to bypassing the Belmont Circle and forming T-intersection with Scenic Highway. The number of ramp connections on the mainline remain the same as existing.

BN-14.4B

BN-14.4B is similar to BN-13.1. However, the proposed ramp connecting Route 25 EB to Scenic Highway is a direct connect ramp, allowing access to Scenic Highway EB only.

Bourne South

BS-2

This alternative eliminates the Bourne Rotary and replaces it with a diamond interchange. This allows through movements on Route 28 to bypass the intersections with the local roadways.

BS-2.2

This alternative is similar to BS-2; however, it replaces Bourne Rotary with a single point interchange.

Based on the above number of alternatives per quadrant, there are 36 possible permutations of alternatives. As discussed in the *Future 2045 Build Traffic Volumes* memo, six (6) permutations of alternatives were paired together to develop travel demand volumes. **Table 1** shows the alternatives that were paired together for each of the travel demand model runs. See **Attachment A** for the Build traffic volumes for each of the volume permutations.

Table 1 – 2050 Build Travel Demand Model Volume Permutations

Quadrant	Volume Permutation					
	P1	**P2**	**P3**	**P4**	**P5**	**P6**
SN	8A	8A	8A	8A	8A	8A
SS	1	1.1	3.1A	1	1.1	3.1A
BN	14.4B	14.4B	14.4B	6.1	6.1	6.1
BS	2	2	2	2	2	2

The alternatives for each of the quadrants were paired up to develop analysis pairings (AP) based on the travel patterns identified in the volume permutations. **Table 2** below shows the eleven (11) alternative analysis pairings that were developed to pair with the six (6) volume permutations. A graphical representation of each of these alternatives can be found in **Attachment B**

Table 2 – 2050 Build Analysis Pairings

Quadrant	Analysis Pairings (AP)										
	AP1	**AP1.1**	**AP2**	**AP3**	**AP4**	**AP5**	**AP6**	**AP7**	**AP7.1**	**AP8.1**	**AP9**
SN	1A	8A	8A	1A	1A	8A	1A	8A	8A	1A	8A
SS	1	1	1.1	3.1A	1	1.1	3.1A	1	1	1.1	3.1A
BN	6.1	6.1	6.1	6.1	13.1	13.1	13.1	14.4B	14.4B	14.4B	14.4B
BS	2	2	2.2	2	2.2	2	2.2	2	2.2	2.2	2
Corresponding Volumes (Fall PM)	P4	P4	P5	P6	P1	P2	P3	P1	P1	P2	P3
Corresponding Volume (Summer SAT)	P4	P4	P4	P4	P1	P1	P1	P1	P1	-	P1

The analysis periods that were analyzed for the purpose of this memo are the Fall Weekday PM Peak Hour and Summer Saturday Midday Peak Hour.

Preliminary Build Alternatives Analysis

The program study area consists of freeway interchanges and intersections. The following analysis tools were used to analyze the 2050 Build alternative conditions:

- Synchro – local unsignalized and signalized intersections
- SIDRA – roundabouts, rotaries, and traffic circles
- HCS – multilane highway segments and freeway weaves/merges/diverges.
- VISSIM – all key highways and intersections within the focus area (2-mile radius of the bridges) to show the interaction between the above roadway facilities and their impacts on each other.

SYNCHRO / SIDRA Analysis

Traffic Models for both the No-Build and Build local intersection traffic models were built using Synchro 11 for unsignalized and signalized intersections. The models were prepared on a per quadrant basis. The following intersections were included in the models and analyzed:

Unsignalized Intersections

- Maple Springs Rd at NB Rte. 25 on-ramp
- Maple Springs Rd at SB Rte. 25 off-ramp
- Glen Charlie Rd at NB Rte. 25 off-ramp
- Glen Charlie Rd at SB Rte. 25 on-ramp
- Sandwich Rd/County Rd at Trowbridge/Shore Rd
- Trowbridge Rd at Veterans Way
- Sandwich Rd at Bourne Rotary Connector
- Sandwich Rd at Upper Cape Cod Tech School
- Sandwich Rd at Harbor Lights Rd
- Sandwich Rd at Jefferson Rd
- Sandwich Rd at Jarvis Rd
- Herring Pond Rd at State Rd
- Herring Pond Rd at NB Rte. 3 ramps
- Herring Pond Rd at SB Rte. 3 ramps
- State Rd at NB Rte. 3 on-ramp
- Cranberry Hwy at Adams St
- Sandwich Rd at Adams St
- Cranberry Hwy at Sandwich Rd/Regency Drive
- Old King's Hwy (Rte. 6A) at Main St (Rte. 130)/Tupper Rd
- Old King's Hwy (Rte. 6A) at Tupper Rd
- Water St. (Rte. 130) at Beale Avenue
- Main St at Beale Avenue
- Old King's Hwy (Rte. 6A) at Main St/Old Main St
- Quaker Meeting House Rd at EB Rte. 6 ramps
- Quaker Meeting House Rd. at WB Rte. 6 ramps
- Rte. 130 at Cotuit Rd
- Nathan Ellis Hwy (Rte. 151) at NB Rte. 28 ramps
- Nathan Ellis Hwy (Rte. 151) at SB Rte. 28 ramps

Signalized Intersections

- Scenic Hwy (Rte. 6) at Nightingale Rd/Andy Olivia Drive
- Sandwich Rd at Mid-Cape Connector
- Mid-Cape Connector at Factor Outlet Way
- Scenic Hwy at Church Lane
- Scenic Hwy at SB Rte. 3 off-ramp
- Meetinghouse Lane at State Rd./Canal St
- Forestdale Rd (Rte. 130) at EB Rte. 6 ramps
- Water St (Rte. 130) at WB Rte. 6 ramps

SIDRA was used to analyze the traffic circles (roundabouts and rotaries). The levels of service for individual traffic movements at signalized and unsignalized intersections and traffic circles within the study area were determined based on criteria set forth in the Transportation Research Board's (TRB) Highway Capacity Manual (HCM) 6th Edition. **Table 3** summarizes the delay criteria for each level of service letter grade at unsignalized and signalized intersections.

Table 3 – Intersection LOS Criteria (HCM 6th Edition)

	Delay (seconds per vehicle)	
LOS	**Unsignalized / Traffic Circle**	**Signalized**
A	≤10	≤10
B	>10 and ≤15	>10 and ≤20
C	>15 and ≤25	>20 and ≤35
D	>25 and ≤35	>35 and ≤55
E	>35 and ≤50	>55 and ≤80
F	>50	>80

Exhibits 19-8, 20-2, 21-8, and 22-8, HCM 6th Edition.

During the Fall PM peak hour, most of the intersections analyzed operate at overall intersection LOS D or better. The following locations within the focus area operate at LOS E or F:

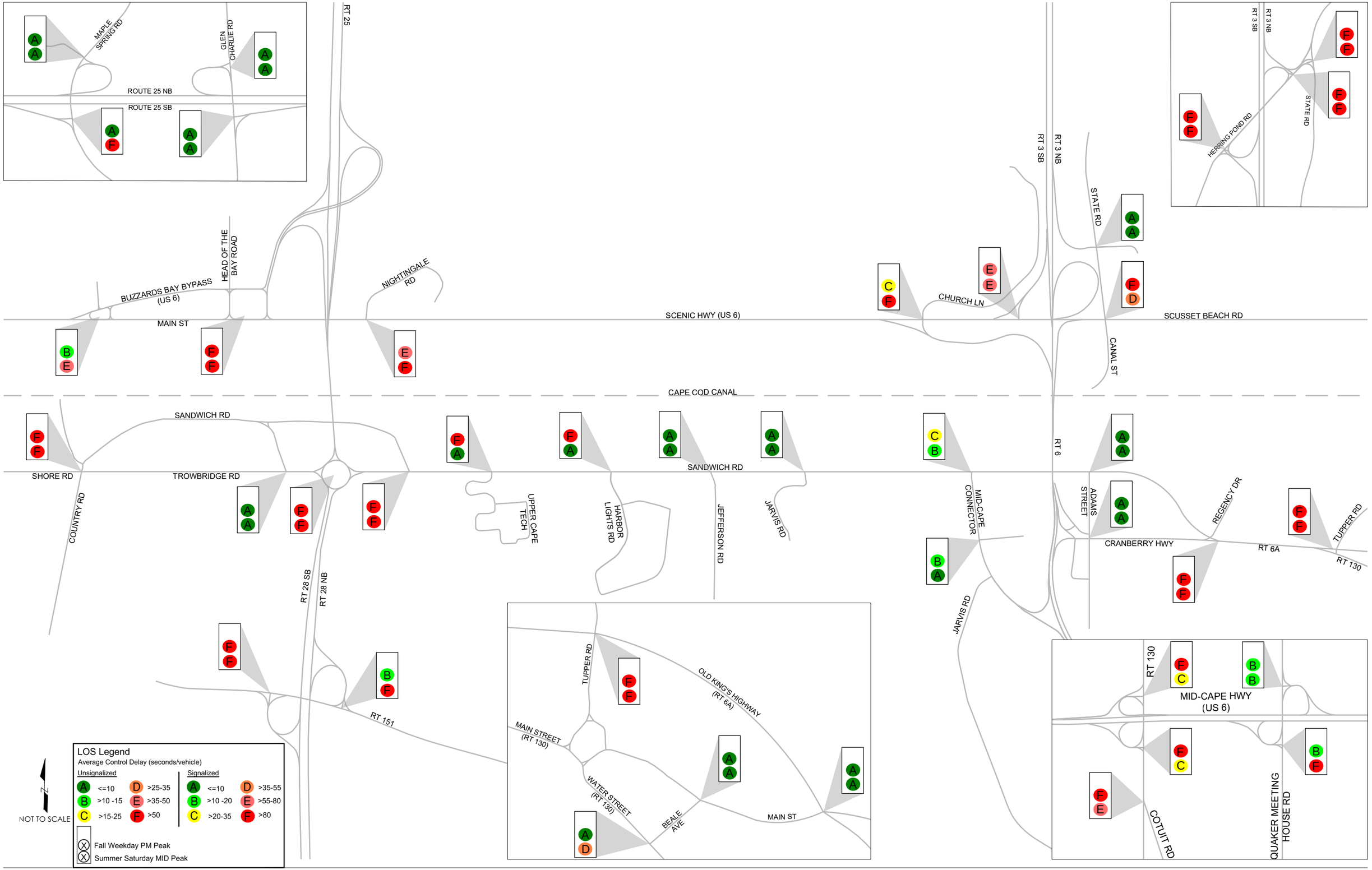
- Scenic Hwy. (Rte. 6) at Nightingale Rd./Andy Olivia Drive (LOS E – No-Build)
- Sandwich Rd./County Rd. at Trowbridge Rd./Shore Rd. (LOS F – No-Build)
- Sandwich Rd. at Bourne Rotary Connector (LOS F – No-Build, AP1-9)
- Sandwich Rd. at Upper Cape Cod Technical School (LOS F – No-Build, AP1-9)
- Scenic Hwy. (Rte. 6) at Rte. 3 SB Off-Ramp (LOS E – No-Build)
- Meetinghouse Lane at State Rd./Canal St. (LOS F – No-Build)
- Cranberry Hwy. at Sandwich Rd./Regency Drive (LOS F – No-Build, AP1-9)

During the Summer SAT peak hour, most of the intersections analyzed operate at overall intersection LOS D or better, with the following exceptions:

- Scenic Hwy. (Rte. 6) at Nightingale Rd./Andy Olivia Drive (LOS F – No-Build)
- Sandwich Rd./County Rd. at Trowbridge Rd./Shore Rd. (LOS F – No-Build)
- Sandwich Rd. at Bourne Rotary Connector (LOS E – AP4-9; LOS F – No-Build, AP1-3)
- Scenic Hwy. (Rte. 6) at Church Lane (LOS F – No-Build)
- Scenic Hwy. (Rte. 6) at Rte. 3 SB Off-Ramp (LOS E – No-Build)
- Cranberry Hwy. at Sandwich Rd./Regency Drive (LOS F – No-Build)

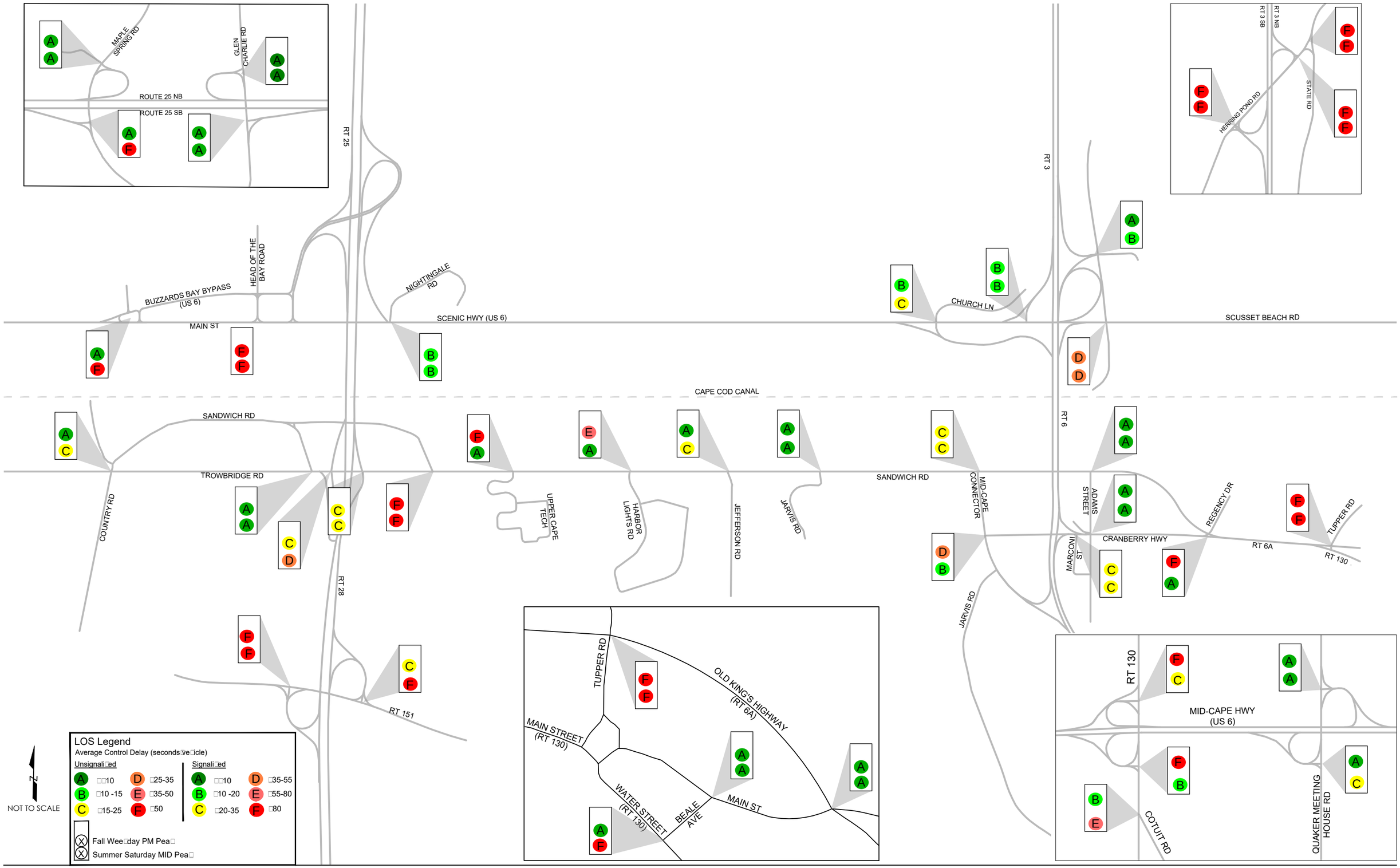
The Bourne Rotary, which was analyzed only under No-Build, and Belmont Circle each operate at overall LOS F during the peak hours analyzed for the Fall and Summer seasons. Heavy traffic volumes from all approaches combined with geometric constraints contribute the poor levels of service at both intersections. The Buzzards Bay Rotary carries lower volumes than the other two traffic circles and operates at overall LOS A or LOS B during fall weekday PM peak hour and LOS E or LOS F during summer Saturday midday peak hour.

Level of Service tables that summarize the results of the no-build and build alternatives capacity and queue analyses performed in Synchro for fall weekday PM and summer Saturday MID peak hours at the study area intersections can be found in **Tables C-1** to **C-13**, which are provided in **Attachment C**. A graphical representation of the intersection levels of service are provided in **Figure 1** through **Figure 12.**



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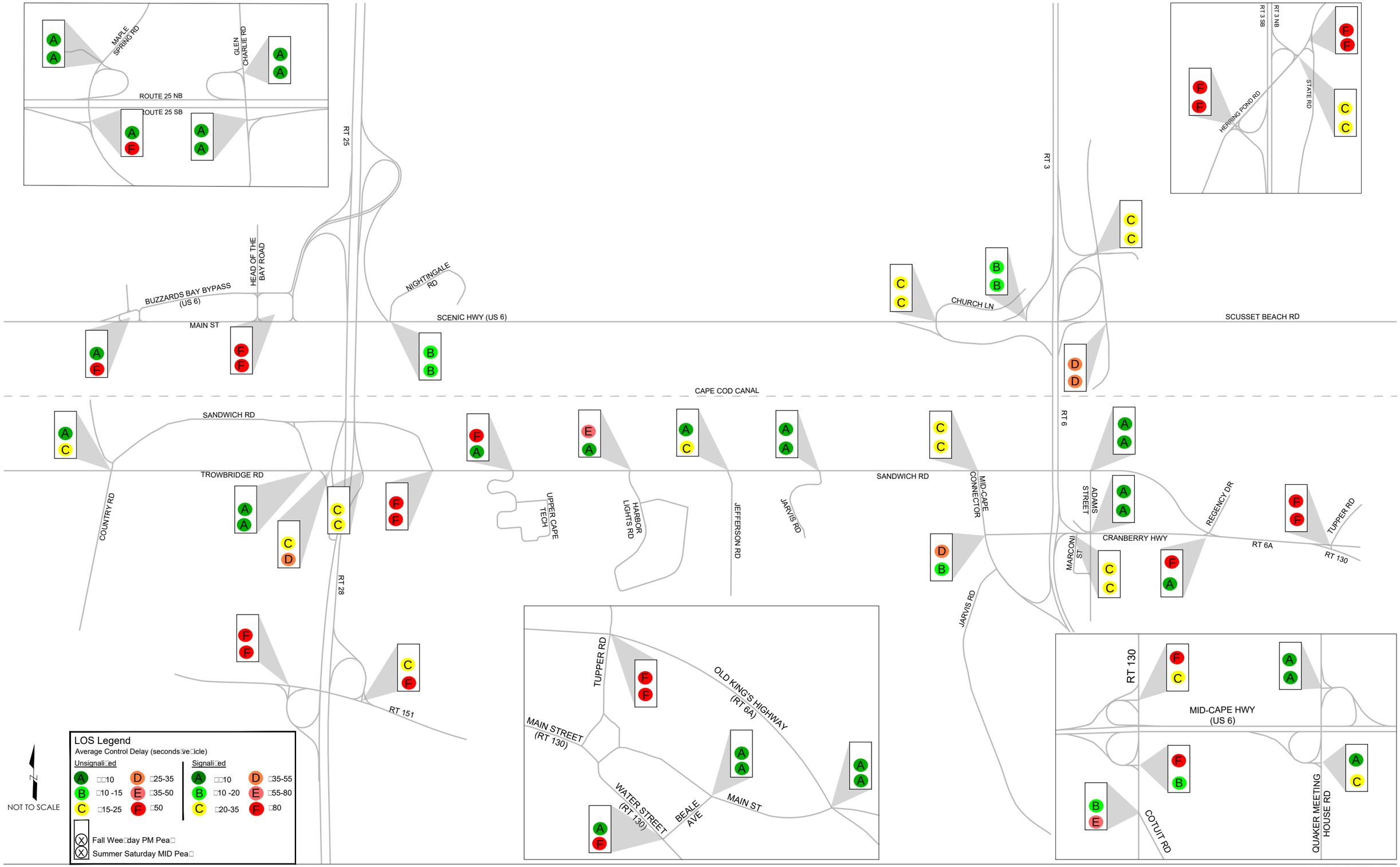
Figure 1: Intersection Level of Service Summary - No-Build Fall PM & Summer SAT (2050)



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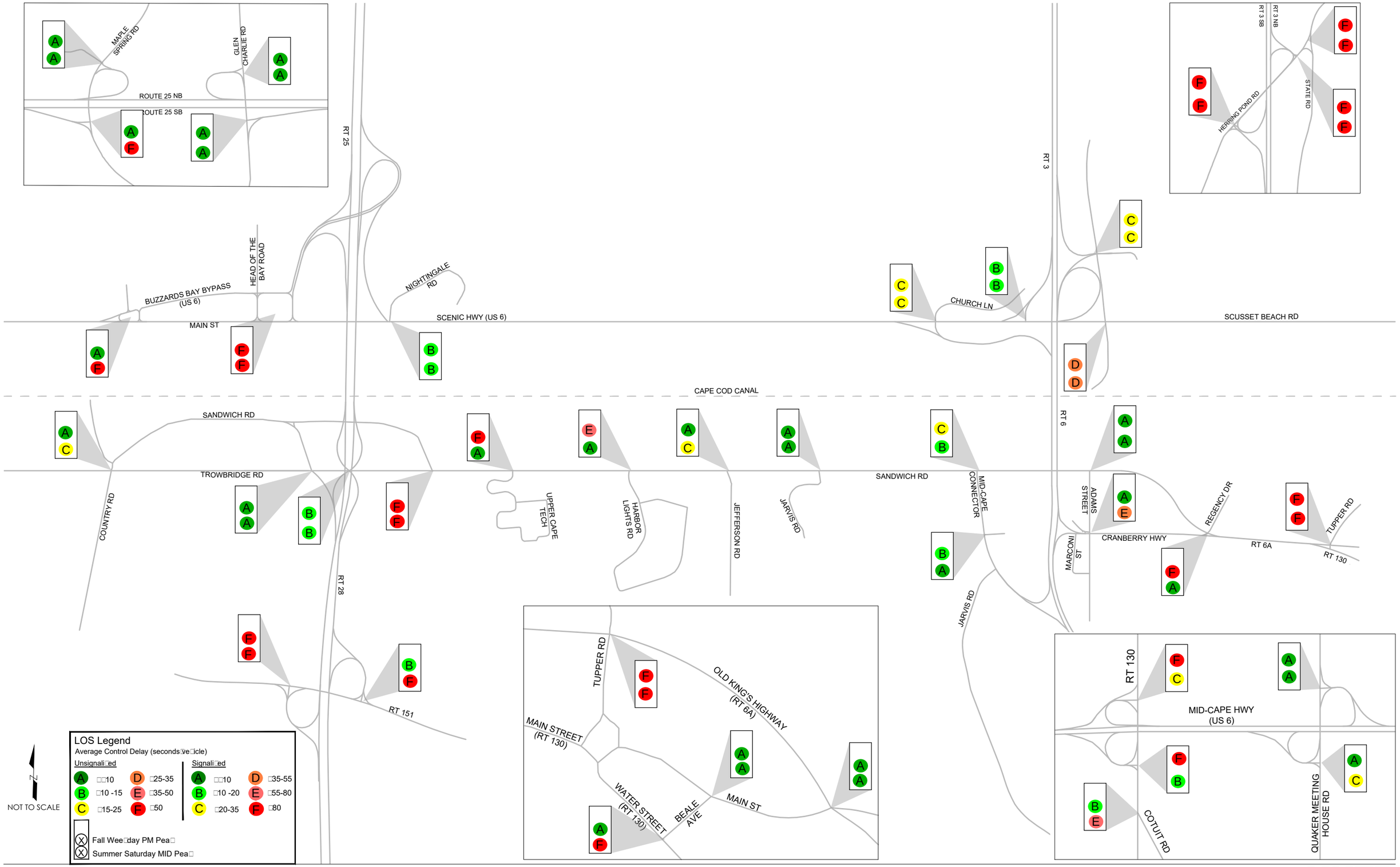
Figure 2: Intersection Level of Service Summary - AP1 Fall PM & Summer SAT (2050)

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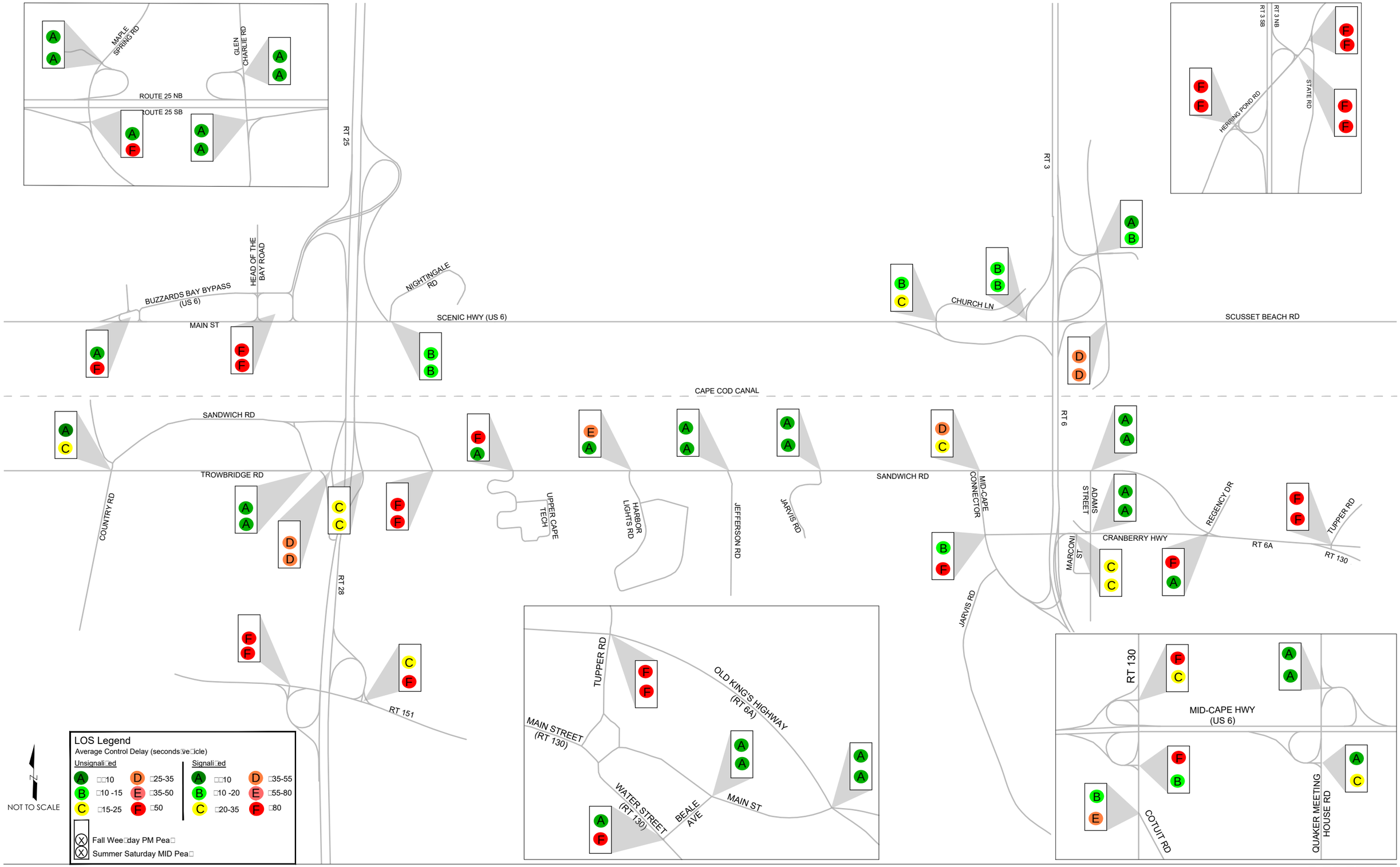
PRE-DECISIONAL & DELIBERATIVE

Figure 3 : Intersection Level of Service Summary - AP1.1 Fall PM & Summer SAT (2050)



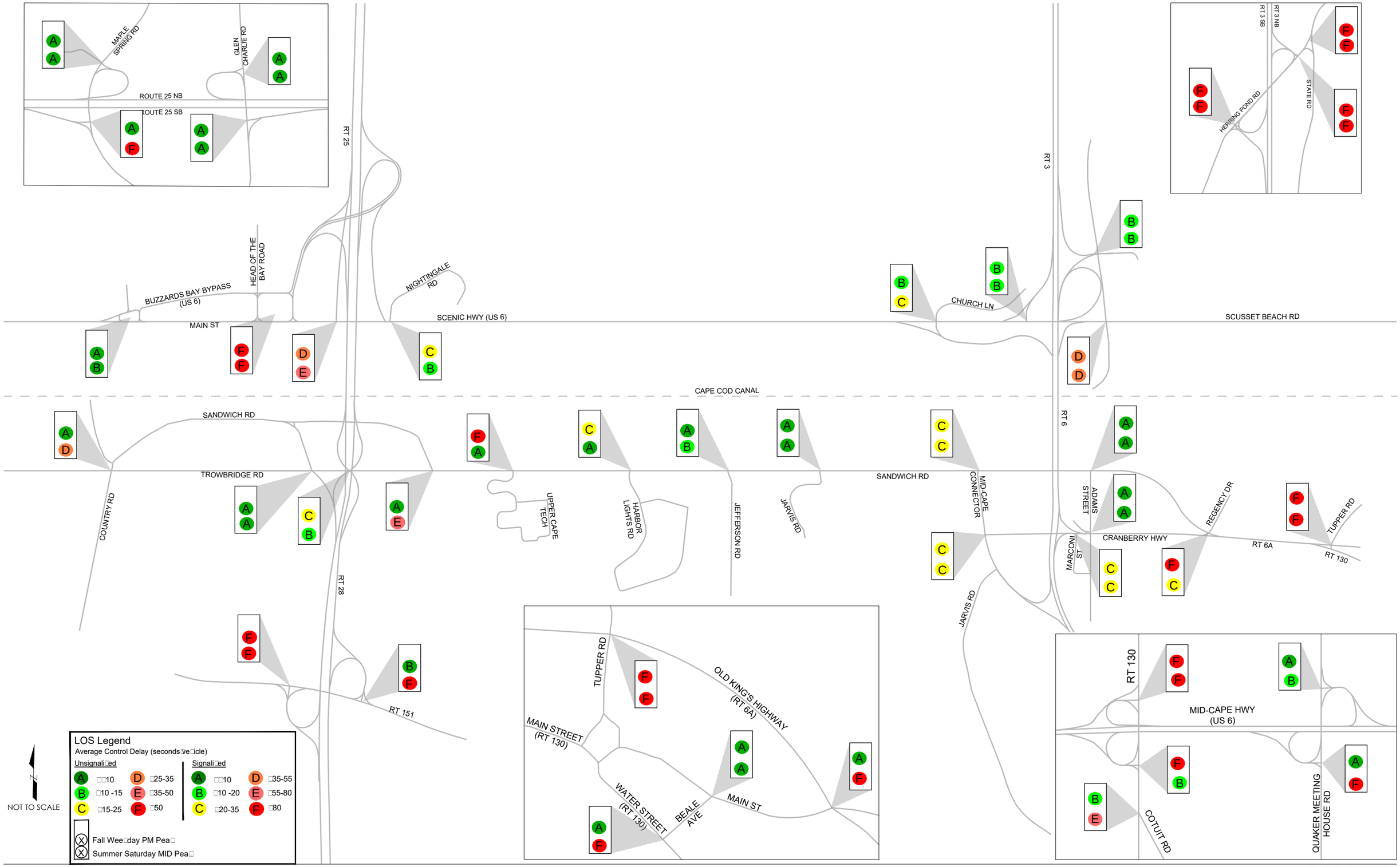
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Figure 4 : Intersection Level of Service Summary - AP2 Fall PM & Summer SAT (2050)



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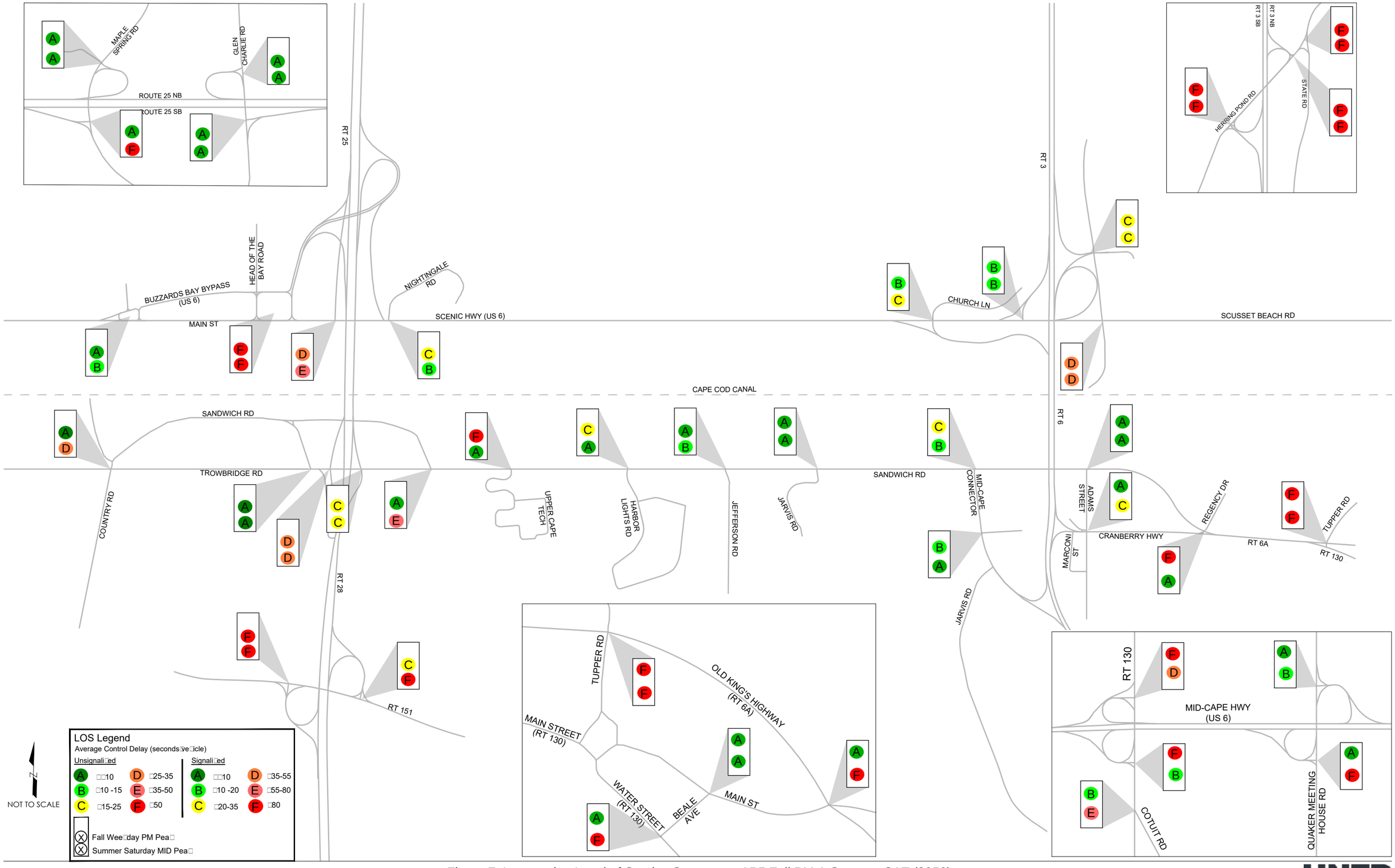
Figure 5 : Intersection Level of Service Summary - AP3 Fall PM & Summer SAT (2050)



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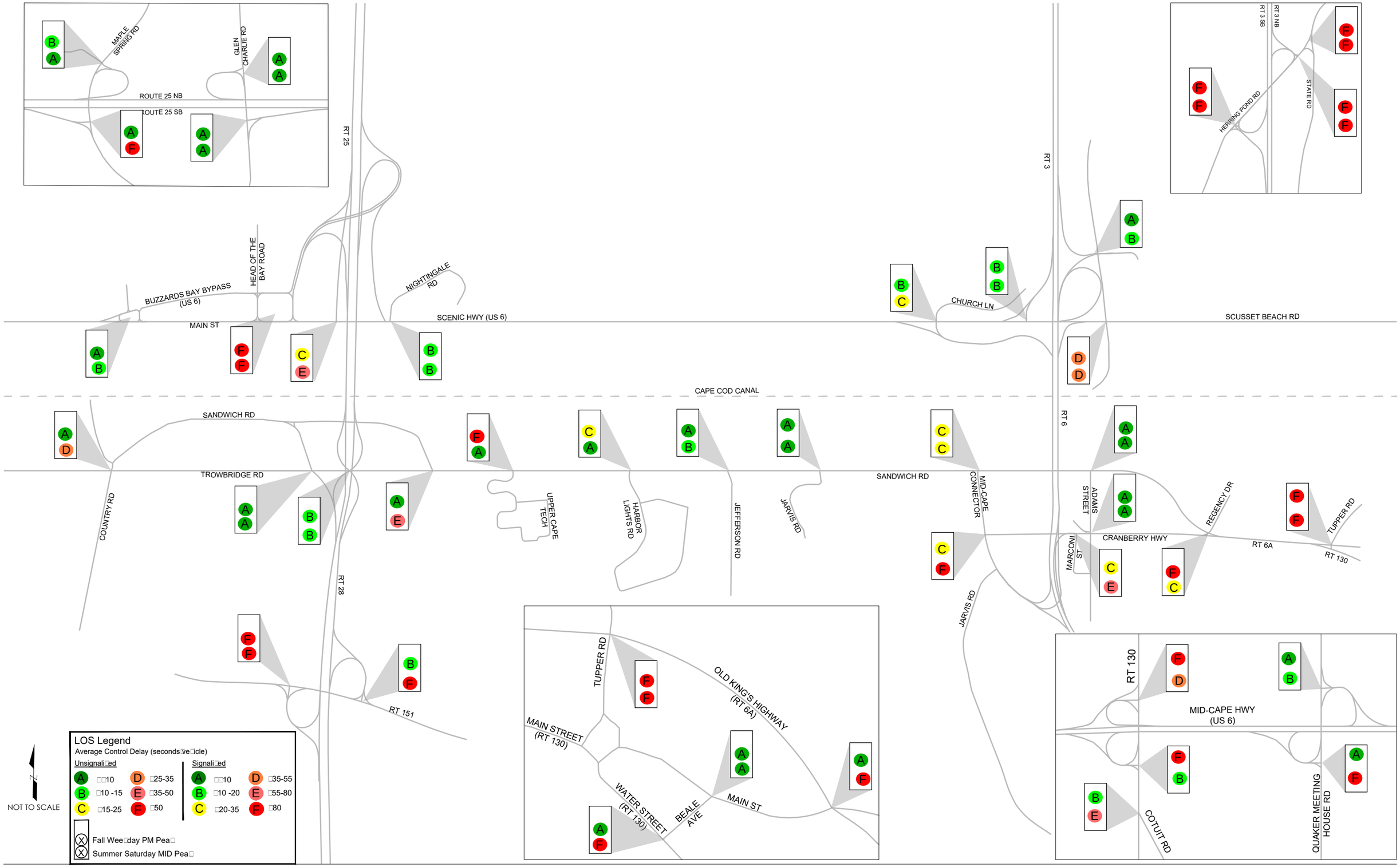
Figure 6: Intersection Level of Service Summary - AP4 Fall PM & Summer SAT (2050)

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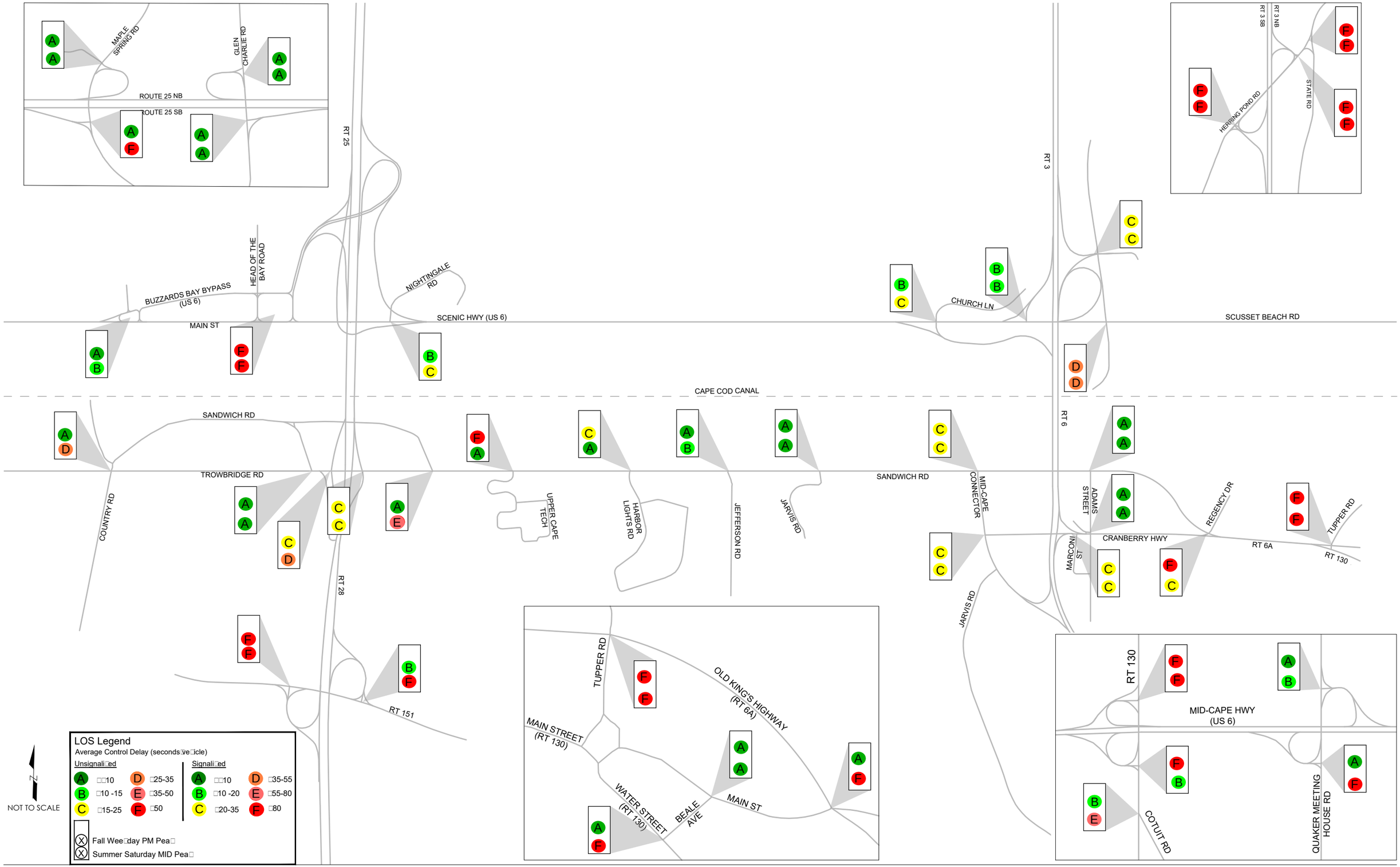
PRE-DECISIONAL & DELIBERATIVE

Figure 7: Intersection Level of Service Summary - AP5 Fall PM & Summer SAT (2050)



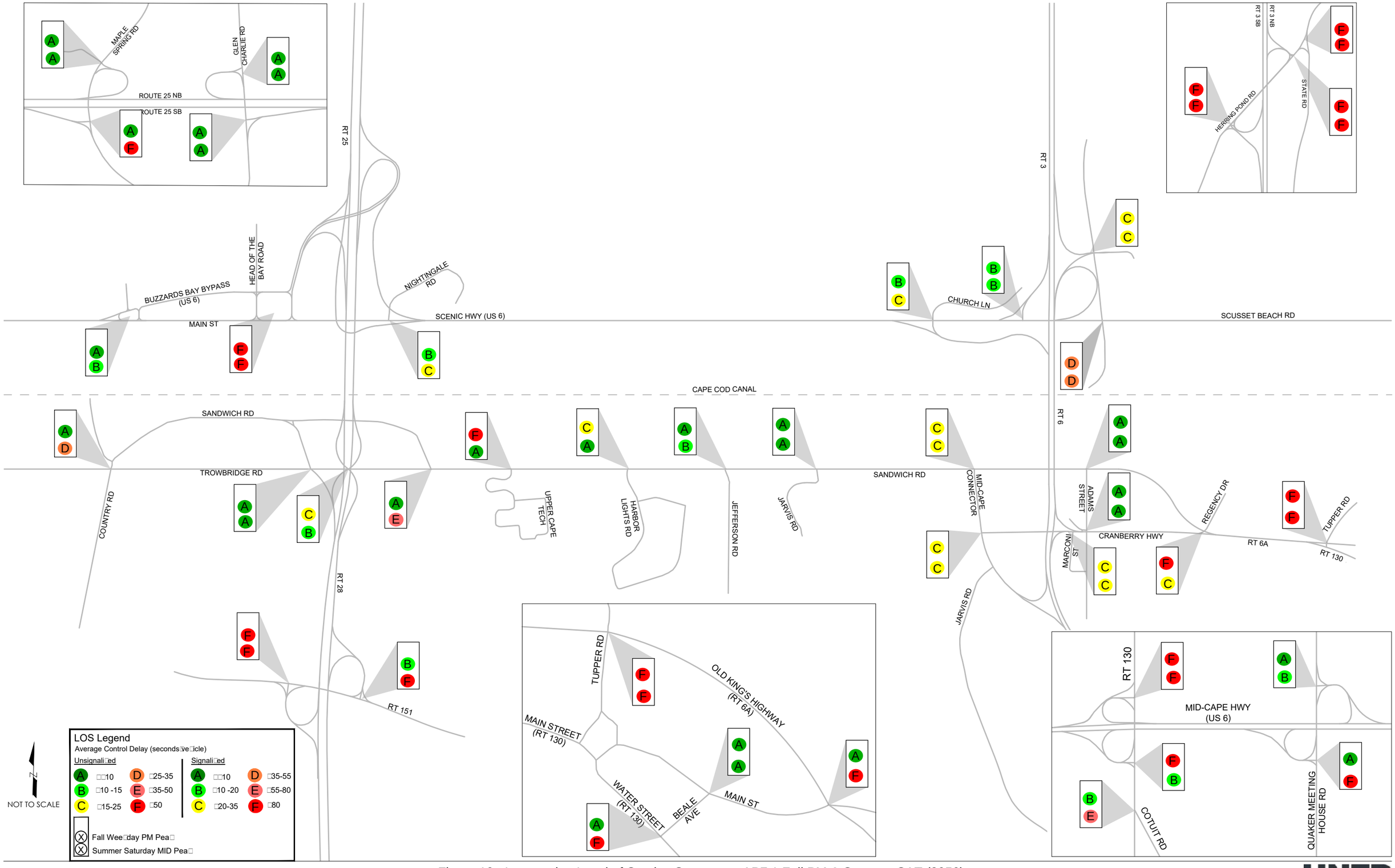
PRE-DECISIONAL & DELIBERATIVE

Figure 8: Intersection Level of Service Summary - AP6 Fall PM & Summer SAT (2050)



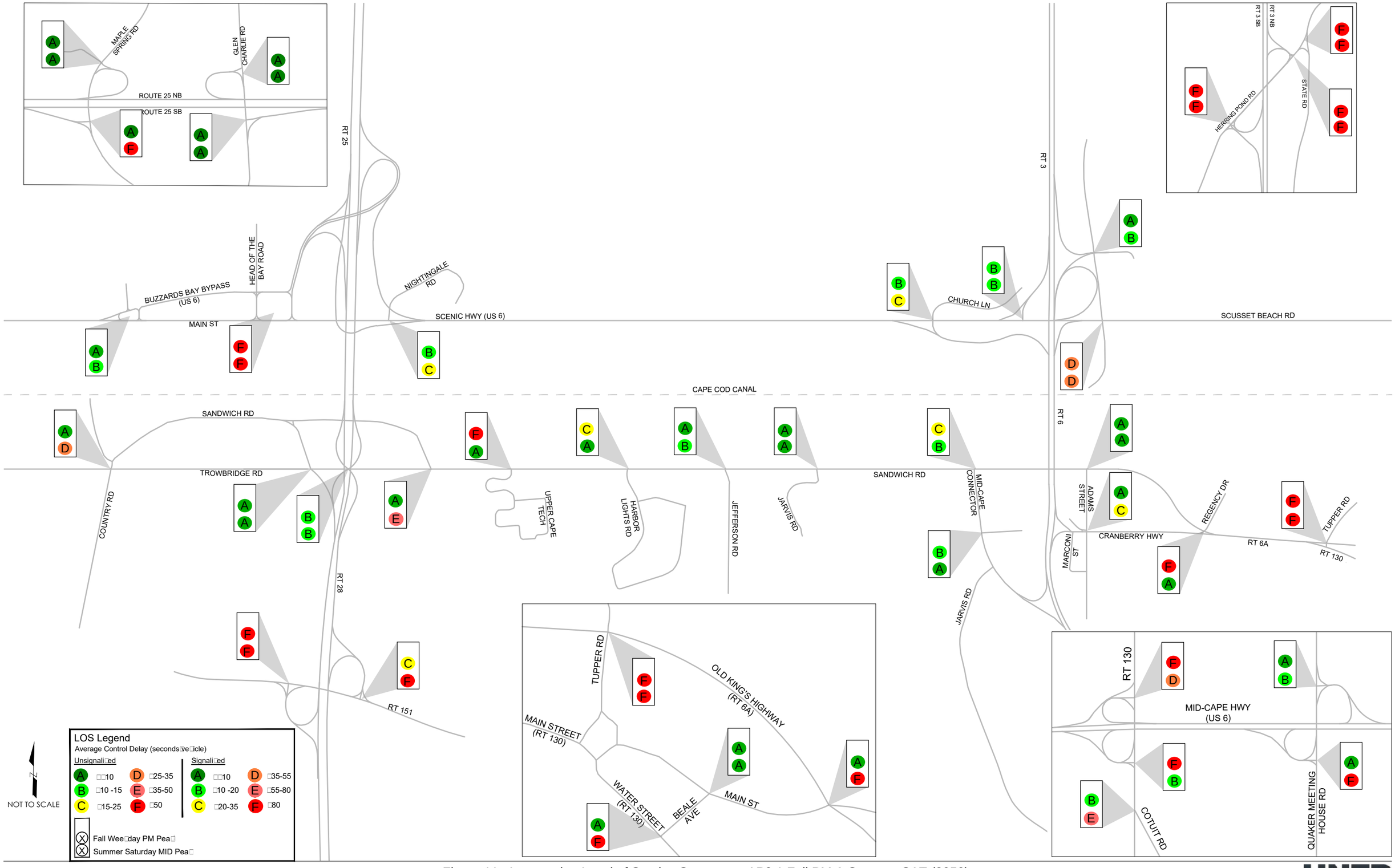
PRE-DECISIONAL & DELIBERATIVE

Figure 9: Intersection Level of Service Summary - AP7 Fall PM & Summer SAT (2050)



PRE-DECISIONAL & DELIBERATIVE

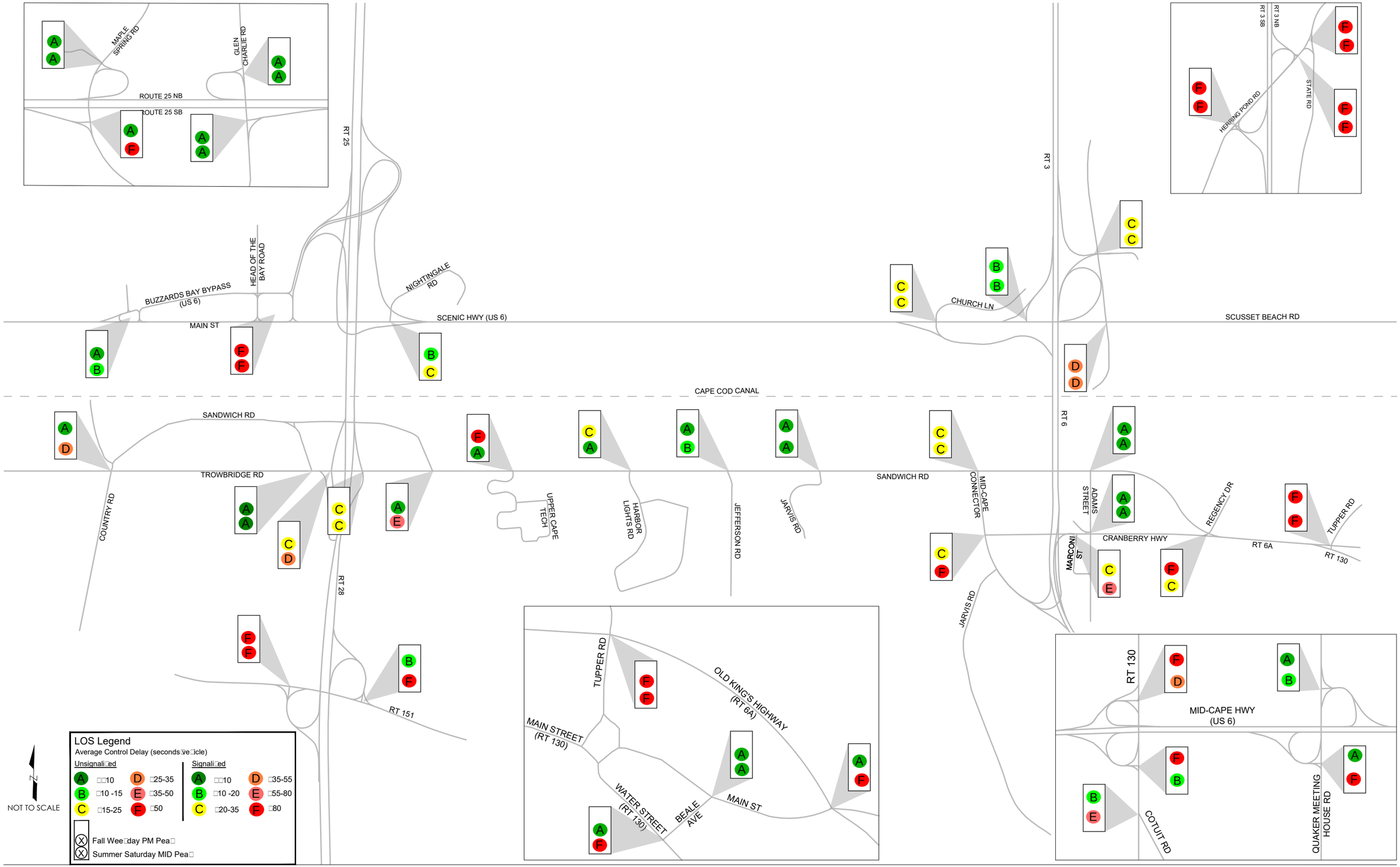
Figure 10 : Intersection Level of Service Summary - AP7.1 Fall PM & Summer SAT (2050)



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Figure 11 : Intersection Level of Service Summary - AP8.1 Fall PM & Summer SAT (2050)

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Figure 12 : Intersection Level of Service Summary - AP9 Fall PM & Summer SAT (2050)

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HCS Analysis

The levels of service for multi-lane highways and/or freeways is based on vehicle density per mile of roadway segment and is measured in passenger cars per mile per lane (pc/mi/ln). Levels of Service for the study area freeway segments and freeway merges/diverges were calculated using HCS 7 software, which is based on the HCM, 6th Edition. **Table 4** summarizes the level of service criteria for freeway segments. **Table 5** summarizes the level of service criteria for freeway weaving, merging, and diverging segments.

Table 4 – LOS Criteria for Freeway Segments (HCM 6th Edition)

LOS	Density (pc/mi/ln)
A	≤11
B	>11-18
C	>18-26
D	>26-35
E	>35-45
F	Demand exceeds capacity OR density > 45

Exhibit 12-15, HCM 6th Edition.

Table 5 – LOS Criteria for Freeway Weaves, Merges and Diverges (HCM 6th Edition)

LOS	Density (pc/mi/ln)
A	≤10
B	>10-20
C	>20-28
D	>28-35
E	>35
F	Demand exceeds capacity

Exhibit 13-6 and 14-3, HCM 6th Edition.

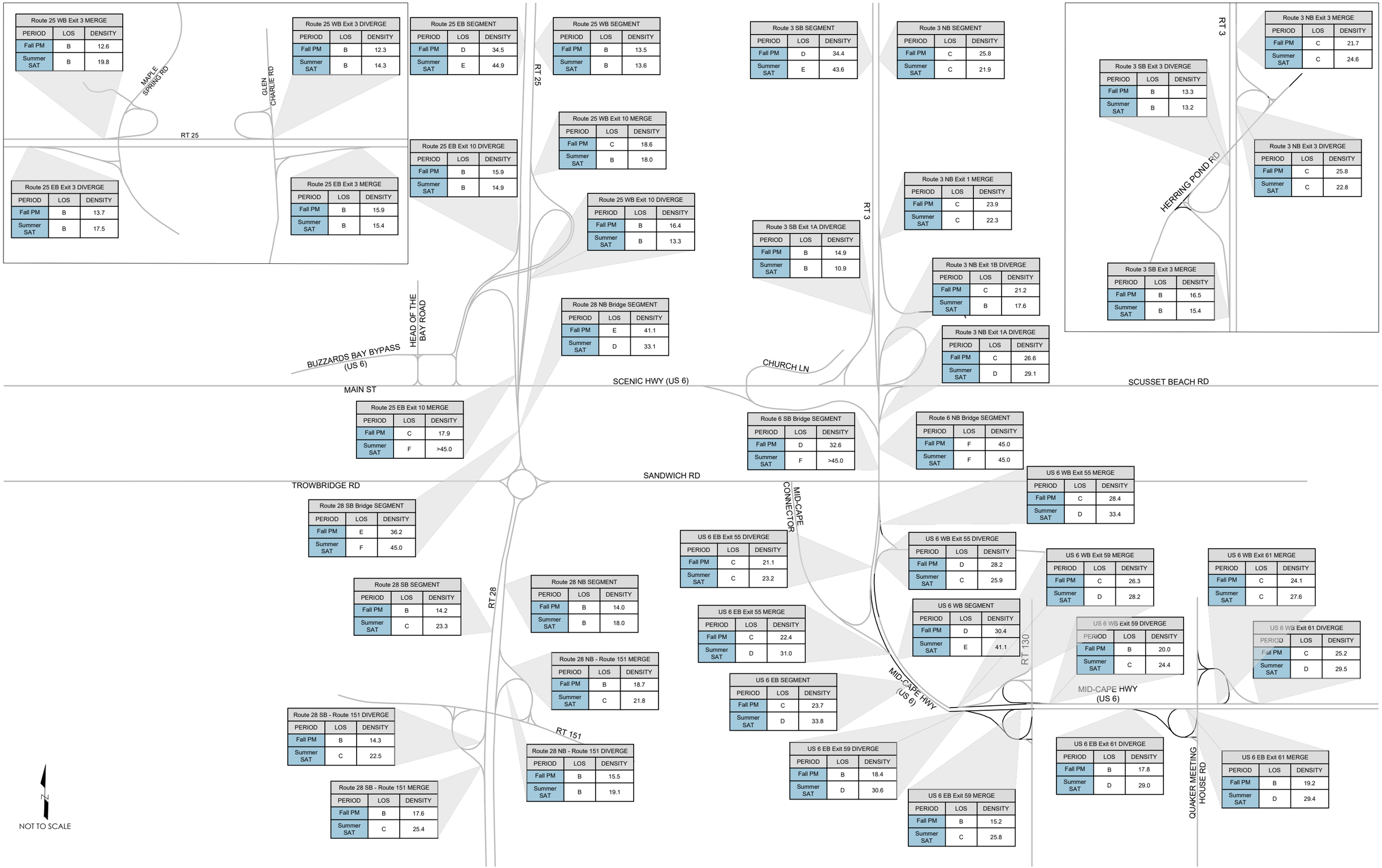
Most freeway and weave/merge/diverge sections throughout the study area operate at LOS C or better during both analysis periods. The following locations within the focus area operate at LOS E or LOS F during fall PM peak hour:

- Southbound Route 25 north of Bourne Bridge (LOS F – AP1-9)
- Southbound Bourne Bridge – (LOS E – No-Build)
- Northbound Bourne Bridge – (LOS E – No-Build)
- Southbound Route 3 north of Sagamore Bridge – (LOS E – No-Build, AP1-9)
- Northbound Sagamore Bridge – (LOS F – No-Build)
- Northbound Route 6 south of Sagamore Bridge (LOS F – AP1-9)

The following locations within the focus area operate at LOS E or LOS F during summer SAT peak hour:

- Southbound Route 25 north of Bourne Bridge – (LOS E – No-Build, LOS F – AP1-9)
- Southbound Bourne Bridge – (LOS F – No-Build)
- Southbound Route 25 Exit 10 merge – (LOS F – No-Build)
- Southbound Route 28 merge – (LOS F – AP1-9)
- Southbound Route 3 north of Sagamore Bridge – (LOS E – No-Build, LOS F – AP1-9)
- Southbound Sagamore Bridge – (LOS F – No-Build)
- Northbound Sagamore Bridge – (LOS F – No-Build)
- Southbound Route 6 south of Sagamore Bridge (LOS F – AP1-9)
- Northbound Route 6 south of Sagamore Bridge (LOS E – No-Build, AP1-9)

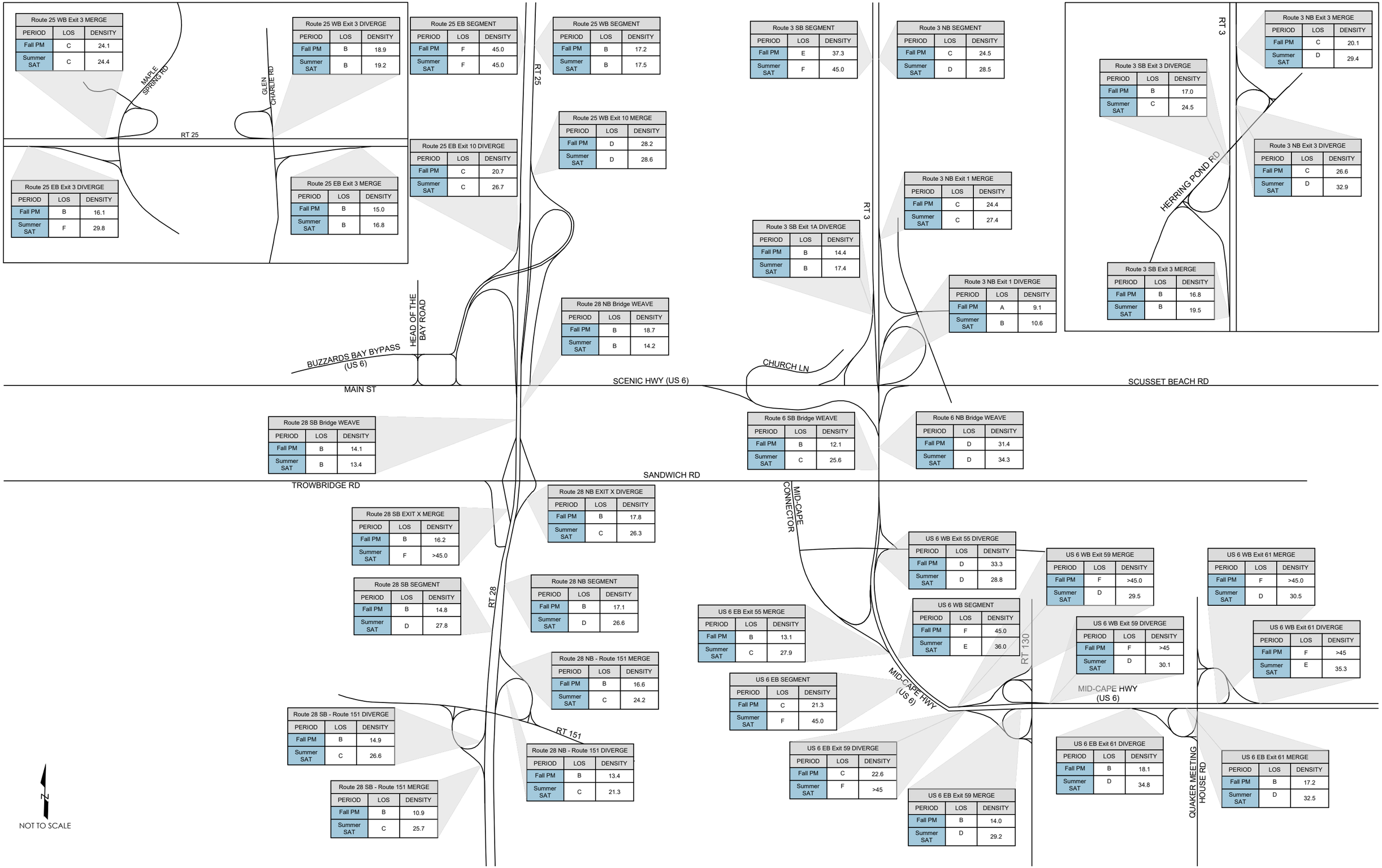
HCS analysis was performed for both analysis periods at the immediate key locations north and south of Bourne Bridge and Sagamore Bridge. A graphical representation of the LOS and density results of the freeway segments and merging-diverging segments are provided in **Figure 13** through **Figure 24**.



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Figure 13 : Freeway Level of Service Summary - No-Build Fall PM & Summer SAT (2050)

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Route 25 WB Exit 3 MERGE		
PERIOD	LOS	DENSITY
Fall PM	C	24.1
Summer SAT	C	24.4

Route 25 WB Exit 3 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	B	18.9
Summer SAT	B	19.2

Route 25 EB SEGMENT		
PERIOD	LOS	DENSITY
Fall PM	F	45.0
Summer SAT	F	45.0

Route 25 WB SEGMENT		
PERIOD	LOS	DENSITY
Fall PM	B	17.2
Summer SAT	B	17.5

Route 25 WB Exit 10 MERGE		
PERIOD	LOS	DENSITY
Fall PM	D	28.2
Summer SAT	D	28.6

Route 25 EB Exit 10 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	C	20.7
Summer SAT	C	26.7

Route 25 EB Exit 3 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	B	16.1
Summer SAT	F	29.8

Route 25 EB Exit 3 MERGE		
PERIOD	LOS	DENSITY
Fall PM	B	15.0
Summer SAT	B	16.8

Route 3 SB SEGMENT		
PERIOD	LOS	DENSITY
Fall PM	E	37.3
Summer SAT	F	45.0

Route 3 NB SEGMENT		
PERIOD	LOS	DENSITY
Fall PM	C	24.5
Summer SAT	D	28.5

Route 3 NB Exit 3 MERGE		
PERIOD	LOS	DENSITY
Fall PM	C	20.1
Summer SAT	D	29.4

Route 3 SB Exit 3 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	B	17.0
Summer SAT	C	24.5

Route 3 NB Exit 3 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	C	26.6
Summer SAT	D	32.9

Route 3 NB Exit 1 MERGE		
PERIOD	LOS	DENSITY
Fall PM	C	24.4
Summer SAT	C	27.4

Route 3 SB Exit 1A DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	B	14.4
Summer SAT	B	17.4

Route 3 NB Exit 1 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	A	9.1
Summer SAT	B	10.6

Route 3 SB Exit 3 MERGE		
PERIOD	LOS	DENSITY
Fall PM	B	16.8
Summer SAT	B	19.5

Route 28 NB Bridge WEAVE		
PERIOD	LOS	DENSITY
Fall PM	B	18.7
Summer SAT	B	14.2

Route 28 SB Bridge WEAVE		
PERIOD	LOS	DENSITY
Fall PM	B	14.1
Summer SAT	B	13.4

Route 6 SB Bridge WEAVE		
PERIOD	LOS	DENSITY
Fall PM	B	12.1
Summer SAT	C	25.6

Route 6 NB Bridge WEAVE		
PERIOD	LOS	DENSITY
Fall PM	D	31.4
Summer SAT	D	34.3

Route 28 NB EXIT X DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	B	17.8
Summer SAT	C	26.3

Route 28 SB EXIT X MERGE		
PERIOD	LOS	DENSITY
Fall PM	B	16.2
Summer SAT	F	>45.0

Route 28 SB SEGMENT		
PERIOD	LOS	DENSITY
Fall PM	B	14.8
Summer SAT	D	27.8

Route 28 NB SEGMENT		
PERIOD	LOS	DENSITY
Fall PM	B	17.1
Summer SAT	D	26.6

Route 28 NB - Route 151 MERGE		
PERIOD	LOS	DENSITY
Fall PM	B	16.6
Summer SAT	C	24.2

Route 28 SB - Route 151 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	B	14.9
Summer SAT	C	26.6

Route 28 NB - Route 151 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	B	13.4
Summer SAT	C	21.3

Route 28 SB - Route 151 MERGE		
PERIOD	LOS	DENSITY
Fall PM	B	10.9
Summer SAT	C	25.7

US 6 WB Exit 55 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	D	33.3
Summer SAT	D	28.8

US 6 WB Exit 59 MERGE		
PERIOD	LOS	DENSITY
Fall PM	F	>45.0
Summer SAT	D	29.5

US 6 WB Exit 61 MERGE		
PERIOD	LOS	DENSITY
Fall PM	F	>45.0
Summer SAT	D	30.5

US 6 EB Exit 55 MERGE		
PERIOD	LOS	DENSITY
Fall PM	B	13.1
Summer SAT	C	27.9

US 6 WB SEGMENT		
PERIOD	LOS	DENSITY
Fall PM	F	45.0
Summer SAT	E	36.0

US 6 WB Exit 59 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	F	>45
Summer SAT	D	30.1

US 6 WB Exit 61 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	F	>45
Summer SAT	E	35.3

US 6 EB SEGMENT		
PERIOD	LOS	DENSITY
Fall PM	C	21.3
Summer SAT	F	45.0

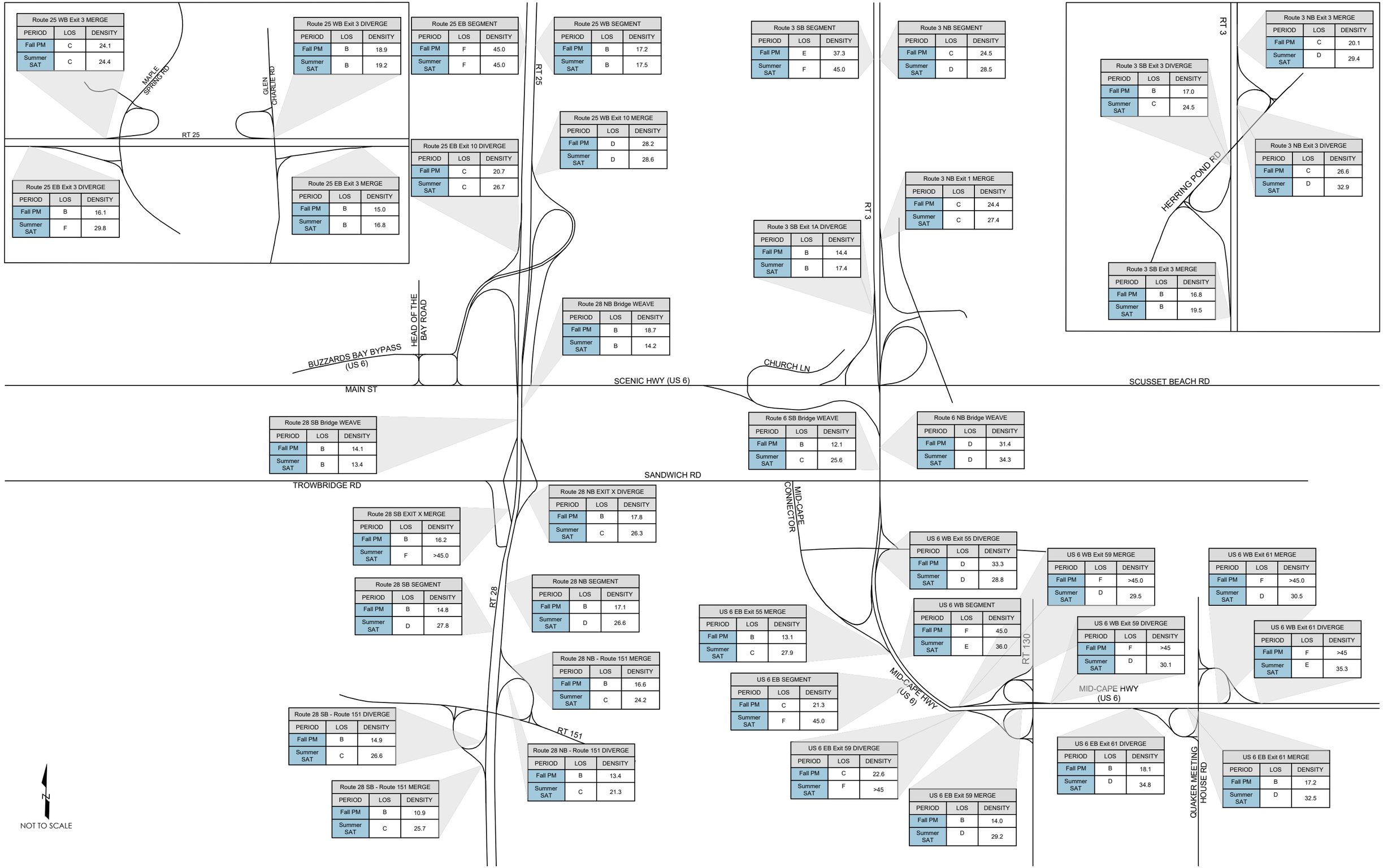
US 6 EB Exit 59 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	C	22.6
Summer SAT	F	>45

US 6 EB Exit 61 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	B	18.1
Summer SAT	D	34.8

US 6 EB Exit 59 MERGE		
PERIOD	LOS	DENSITY
Fall PM	B	14.0
Summer SAT	D	29.2

US 6 EB Exit 61 MERGE		
PERIOD	LOS	DENSITY
Fall PM	B	17.2
Summer SAT	D	32.5

Figure 14 : Freeway Level of Service Summary - AP1 Fall PM & Summer SAT (2050)



Route 25 WB Exit 3 MERGE		
PERIOD	LOS	DENSITY
Fall PM	C	24.1
Summer SAT	C	24.4

Route 25 WB Exit 3 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	B	18.9
Summer SAT	B	19.2

Route 25 EB SEGMENT		
PERIOD	LOS	DENSITY
Fall PM	F	45.0
Summer SAT	F	45.0

Route 25 WB SEGMENT		
PERIOD	LOS	DENSITY
Fall PM	B	17.2
Summer SAT	B	17.5

Route 25 WB Exit 10 MERGE		
PERIOD	LOS	DENSITY
Fall PM	D	28.2
Summer SAT	D	28.6

Route 25 EB Exit 10 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	C	20.7
Summer SAT	C	26.7

Route 25 EB Exit 3 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	B	16.1
Summer SAT	F	29.8

Route 25 EB Exit 3 MERGE		
PERIOD	LOS	DENSITY
Fall PM	B	15.0
Summer SAT	B	16.8

Route 28 NB Bridge WEAVE		
PERIOD	LOS	DENSITY
Fall PM	B	18.7
Summer SAT	B	14.2

Route 28 SB Bridge WEAVE		
PERIOD	LOS	DENSITY
Fall PM	B	14.1
Summer SAT	B	13.4

Route 28 NB EXIT X DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	B	17.8
Summer SAT	C	26.3

Route 28 SB EXIT X MERGE		
PERIOD	LOS	DENSITY
Fall PM	B	16.2
Summer SAT	F	>45.0

Route 28 SB SEGMENT		
PERIOD	LOS	DENSITY
Fall PM	B	14.8
Summer SAT	D	27.8

Route 28 NB SEGMENT		
PERIOD	LOS	DENSITY
Fall PM	B	17.1
Summer SAT	D	26.6

Route 28 NB - Route 151 MERGE		
PERIOD	LOS	DENSITY
Fall PM	B	16.6
Summer SAT	C	24.2

Route 28 SB - Route 151 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	B	14.9
Summer SAT	C	26.6

Route 28 NB - Route 151 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	B	13.4
Summer SAT	C	21.3

Route 28 SB - Route 151 MERGE		
PERIOD	LOS	DENSITY
Fall PM	B	10.9
Summer SAT	C	25.7

Route 3 SB SEGMENT		
PERIOD	LOS	DENSITY
Fall PM	E	37.3
Summer SAT	F	45.0

Route 3 NB SEGMENT		
PERIOD	LOS	DENSITY
Fall PM	C	24.5
Summer SAT	D	28.5

Route 3 NB Exit 3 MERGE		
PERIOD	LOS	DENSITY
Fall PM	C	20.1
Summer SAT	D	29.4

Route 3 SB Exit 3 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	B	17.0
Summer SAT	C	24.5

Route 3 NB Exit 3 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	C	26.6
Summer SAT	D	32.9

Route 3 NB Exit 1 MERGE		
PERIOD	LOS	DENSITY
Fall PM	C	24.4
Summer SAT	C	27.4

Route 3 SB Exit 1A DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	B	14.4
Summer SAT	B	17.4

Route 3 SB Exit 3 MERGE		
PERIOD	LOS	DENSITY
Fall PM	B	16.8
Summer SAT	B	19.5

Route 6 SB Bridge WEAVE		
PERIOD	LOS	DENSITY
Fall PM	B	12.1
Summer SAT	C	25.6

Route 6 NB Bridge WEAVE		
PERIOD	LOS	DENSITY
Fall PM	D	31.4
Summer SAT	D	34.3

US 6 WB Exit 55 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	D	33.3
Summer SAT	D	28.8

US 6 WB Exit 59 MERGE		
PERIOD	LOS	DENSITY
Fall PM	F	>45.0
Summer SAT	D	29.5

US 6 WB Exit 61 MERGE		
PERIOD	LOS	DENSITY
Fall PM	F	>45.0
Summer SAT	D	30.5

US 6 EB Exit 55 MERGE		
PERIOD	LOS	DENSITY
Fall PM	B	13.1
Summer SAT	C	27.9

US 6 WB SEGMENT		
PERIOD	LOS	DENSITY
Fall PM	F	45.0
Summer SAT	E	36.0

US 6 WB Exit 59 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	F	>45
Summer SAT	D	30.1

US 6 WB Exit 61 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	F	>45
Summer SAT	E	35.3

US 6 EB SEGMENT		
PERIOD	LOS	DENSITY
Fall PM	C	21.3
Summer SAT	F	45.0

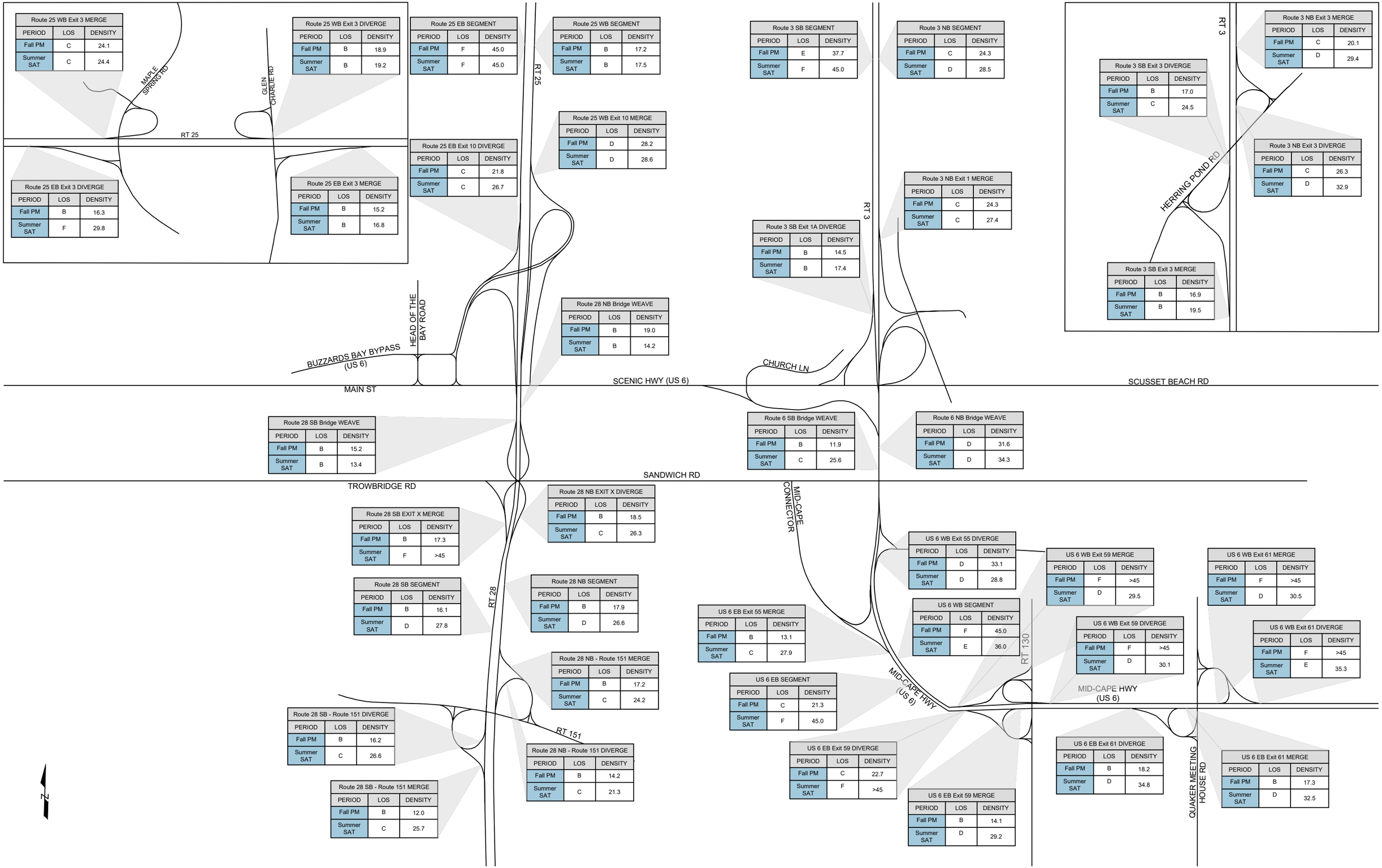
US 6 EB Exit 59 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	C	22.6
Summer SAT	F	>45

US 6 EB Exit 61 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	B	18.1
Summer SAT	D	34.8

US 6 EB Exit 59 MERGE		
PERIOD	LOS	DENSITY
Fall PM	B	14.0
Summer SAT	D	29.2

US 6 EB Exit 61 MERGE		
PERIOD	LOS	DENSITY
Fall PM	B	17.2
Summer SAT	D	32.5

Figure 15 : Freeway Level of Service Summary - AP1.1 Fall PM & Summer SAT (2050)



Route 25 WB Exit 3 MERGE		
PERIOD	LOS	DENSITY
Fall PM	C	24.1
Summer SAT	C	24.4

Route 25 WB Exit 3 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	B	18.9
Summer SAT	B	19.2

Route 25 EB SEGMENT		
PERIOD	LOS	DENSITY
Fall PM	F	45.0
Summer SAT	F	45.0

Route 25 WB SEGMENT		
PERIOD	LOS	DENSITY
Fall PM	B	17.2
Summer SAT	B	17.5

Route 25 WB Exit 10 MERGE		
PERIOD	LOS	DENSITY
Fall PM	D	28.2
Summer SAT	D	28.6

Route 25 EB Exit 10 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	C	21.8
Summer SAT	C	26.7

Route 25 EB Exit 3 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	B	16.3
Summer SAT	F	29.8

Route 25 EB Exit 3 MERGE		
PERIOD	LOS	DENSITY
Fall PM	B	15.2
Summer SAT	B	16.8

Route 3 SB SEGMENT		
PERIOD	LOS	DENSITY
Fall PM	E	37.7
Summer SAT	F	45.0

Route 3 NB SEGMENT		
PERIOD	LOS	DENSITY
Fall PM	C	24.3
Summer SAT	D	28.5

Route 3 NB Exit 3 MERGE		
PERIOD	LOS	DENSITY
Fall PM	C	20.1
Summer SAT	D	29.4

Route 3 SB Exit 3 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	B	17.0
Summer SAT	C	24.5

Route 3 NB Exit 3 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	C	26.3
Summer SAT	D	32.9

Route 3 NB Exit 1 MERGE		
PERIOD	LOS	DENSITY
Fall PM	C	24.3
Summer SAT	C	27.4

Route 3 SB Exit 1A DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	B	14.5
Summer SAT	B	17.4

Route 3 SB Exit 3 MERGE		
PERIOD	LOS	DENSITY
Fall PM	B	16.9
Summer SAT	B	19.5

Route 28 NB Bridge WEAVE		
PERIOD	LOS	DENSITY
Fall PM	B	19.0
Summer SAT	B	14.2

Route 28 SB Bridge WEAVE		
PERIOD	LOS	DENSITY
Fall PM	B	15.2
Summer SAT	B	13.4

Route 6 SB Bridge WEAVE		
PERIOD	LOS	DENSITY
Fall PM	B	11.9
Summer SAT	C	25.6

Route 6 NB Bridge WEAVE		
PERIOD	LOS	DENSITY
Fall PM	D	31.6
Summer SAT	D	34.3

Route 28 NB EXIT X DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	B	18.5
Summer SAT	C	26.3

Route 28 SB EXIT X MERGE		
PERIOD	LOS	DENSITY
Fall PM	B	17.3
Summer SAT	F	>45

Route 28 NB SEGMENT		
PERIOD	LOS	DENSITY
Fall PM	B	17.9
Summer SAT	D	26.6

Route 28 SB SEGMENT		
PERIOD	LOS	DENSITY
Fall PM	B	16.1
Summer SAT	D	27.8

Route 28 NB - Route 151 MERGE		
PERIOD	LOS	DENSITY
Fall PM	B	17.2
Summer SAT	C	24.2

Route 28 SB - Route 151 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	B	16.2
Summer SAT	C	26.6

Route 28 NB - Route 151 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	B	14.2
Summer SAT	C	21.3

Route 28 SB - Route 151 MERGE		
PERIOD	LOS	DENSITY
Fall PM	B	12.0
Summer SAT	C	25.7

US 6 WB Exit 55 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	D	33.1
Summer SAT	D	28.8

US 6 WB Exit 59 MERGE		
PERIOD	LOS	DENSITY
Fall PM	F	>45
Summer SAT	D	29.5

US 6 WB Exit 61 MERGE		
PERIOD	LOS	DENSITY
Fall PM	F	>45
Summer SAT	D	30.5

US 6 EB Exit 55 MERGE		
PERIOD	LOS	DENSITY
Fall PM	B	13.1
Summer SAT	C	27.9

US 6 WB SEGMENT		
PERIOD	LOS	DENSITY
Fall PM	F	45.0
Summer SAT	E	36.0

US 6 WB Exit 59 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	F	>45
Summer SAT	D	30.1

US 6 WB Exit 61 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	F	>45
Summer SAT	E	35.3

US 6 EB SEGMENT		
PERIOD	LOS	DENSITY
Fall PM	C	21.3
Summer SAT	F	45.0

US 6 EB Exit 59 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	C	22.7
Summer SAT	F	>45

US 6 EB Exit 61 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	B	18.2
Summer SAT	D	34.8

US 6 EB Exit 59 MERGE		
PERIOD	LOS	DENSITY
Fall PM	B	14.1
Summer SAT	D	29.2

US 6 EB Exit 61 MERGE		
PERIOD	LOS	DENSITY
Fall PM	B	17.3
Summer SAT	D	32.5

Figure 16 : Freeway Level of Service Summary - AP2 Fall PM & Summer SAT (2050)

Route 25 WB Exit 3 MERGE		
PERIOD	LOS	DENSITY
Fall PM	C	24.1
Summer SAT	C	24.4

Route 25 WB Exit 3 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	B	19.1
Summer SAT	B	19.2

Route 25 EB SEGMENT		
PERIOD	LOS	DENSITY
Fall PM	F	45.0
Summer SAT	F	45.0

Route 25 WB SEGMENT		
PERIOD	LOS	DENSITY
Fall PM	B	17.2
Summer SAT	B	17.5

Route 25 WB Exit 10 MERGE		
PERIOD	LOS	DENSITY
Fall PM	D	28.4
Summer SAT	D	28.6

Route 25 EB Exit 10 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	C	20.3
Summer SAT	C	26.7

Route 25 EB Exit 3 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	B	16.1
Summer SAT	F	29.8

Route 25 EB Exit 3 MERGE		
PERIOD	LOS	DENSITY
Fall PM	B	14.6
Summer SAT	B	16.8

*Volume to Capacity Ratio (1.09) exceeds 1.0

MAPLE SPRING RD

GLEN CHARLIE RD

RT 25

Route 3 SB SEGMENT		
PERIOD	LOS	DENSITY
Fall PM	E	37.7
Summer SAT	F	45.0

Route 3 NB SEGMENT		
PERIOD	LOS	DENSITY
Fall PM	C	24.2
Summer SAT	D	28.5

Route 3 NB Exit 3 MERGE		
PERIOD	LOS	DENSITY
Fall PM	C	20.1
Summer SAT	D	29.4

Route 3 SB Exit 3 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	B	17.0
Summer SAT	C	24.5

Route 3 NB Exit 3 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	C	26.2
Summer SAT	D	32.9

Route 3 NB Exit 1 MERGE		
PERIOD	LOS	DENSITY
Fall PM	C	24.0
Summer SAT	C	27.4

Route 3 SB Exit 1A DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	B	14.5
Summer SAT	B	17.4

Route 3 NB Exit 1 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	A	8.8
Summer SAT	B	10.6

Route 3 SB Exit 3 MERGE		
PERIOD	LOS	DENSITY
Fall PM	B	16.9
Summer SAT	B	19.5

RT 3

HERRING POND RD

Route 28 NB Bridge WEAVE		
PERIOD	LOS	DENSITY
Fall PM	B	19.3
Summer SAT	B	14.2

HEAD OF THE BAY ROAD

BUZZARDS BAY BYPASS (US 6)

MAIN ST

SCENIC HWY (US 6)

CHURCH LN

SCUSSET BEACH RD

Route 6 SB Bridge WEAVE		
PERIOD	LOS	DENSITY
Fall PM	B	13.0
Summer SAT	C	25.6

Route 6 NB Bridge WEAVE		
PERIOD	LOS	DENSITY
Fall PM	D	31.4
Summer SAT	D	33.8

Route 28 SB Bridge WEAVE		
PERIOD	LOS	DENSITY
Fall PM	B	14.4
Summer SAT	B	13.4

TROWBRIDGE RD

SANDWICH RD

MID-CAPE CONNECTOR

Route 28 NB EXIT X DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	B	17.6
Summer SAT	C	26.3

Route 28 SB EXIT X MERGE		
PERIOD	LOS	DENSITY
Fall PM	B	16.7
Summer SAT	F	>45.0

Route 28 SB SEGMENT		
PERIOD	LOS	DENSITY
Fall PM	B	15.3
Summer SAT	D	27.8

Route 28 NB SEGMENT		
PERIOD	LOS	DENSITY
Fall PM	B	16.9
Summer SAT	D	26.6

RT 28

Route 28 NB - Route 151 MERGE		
PERIOD	LOS	DENSITY
Fall PM	B	16.4
Summer SAT	C	24.2

Route 28 SB - Route 151 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	B	15.4
Summer SAT	C	26.6

RT 151

Route 28 NB - Route 151 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	B	13.1
Summer SAT	C	21.3

Route 28 SB - Route 151 MERGE		
PERIOD	LOS	DENSITY
Fall PM	B	11.2
Summer SAT	C	25.7

US 6 WB Exit 55 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	D	33.6
Summer SAT	D	28.8

US 6 WB Exit 59 MERGE		
PERIOD	LOS	DENSITY
Fall PM	F	>45
Summer SAT	D	29.5

US 6 WB Exit 61 MERGE		
PERIOD	LOS	DENSITY
Fall PM	F	>45
Summer SAT	D	30.5

US 6 EB Exit 55 MERGE		
PERIOD	LOS	DENSITY
Fall PM	B	12.9
Summer SAT	C	27.9

US 6 WB SEGMENT		
PERIOD	LOS	DENSITY
Fall PM	F	45.0
Summer SAT	E	36.0

US 6 WB Exit 59 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	F	>45
Summer SAT	D	30.1

US 6 WB Exit 61 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	F	>45
Summer SAT	E	35.3

US 6 EB SEGMENT		
PERIOD	LOS	DENSITY
Fall PM	C	21.1
Summer SAT	F	45.0

RT 130

MID-CAPE HWY (US 6)

MID-CAPE HWY (US 6)

US 6 EB Exit 59 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	C	22.4
Summer SAT	F	>45

US 6 EB Exit 61 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	B	17.7
Summer SAT	D	34.8

US 6 EB Exit 59 MERGE		
PERIOD	LOS	DENSITY
Fall PM	B	13.7
Summer SAT	D	29.2

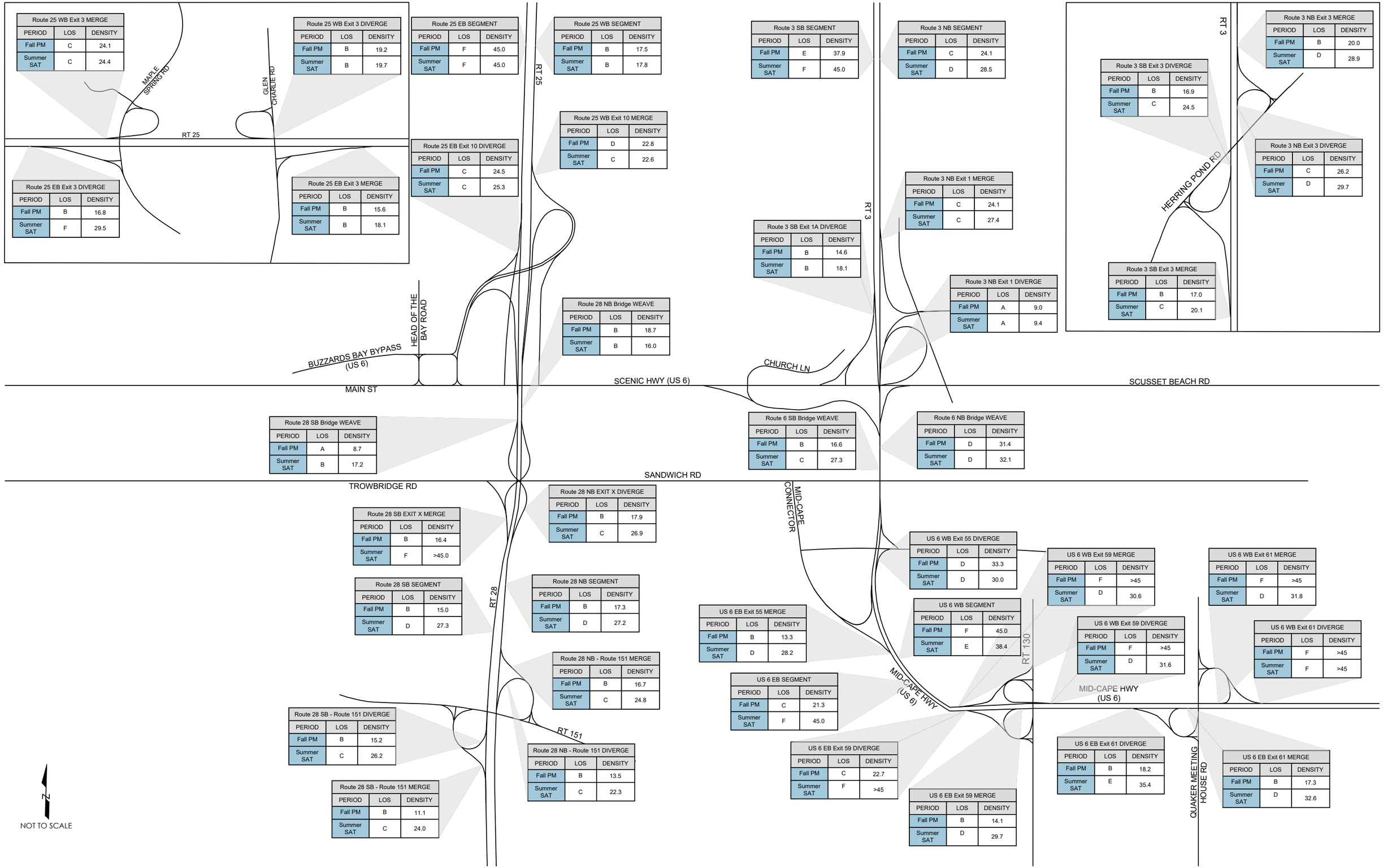
US 6 EB Exit 61 MERGE		
PERIOD	LOS	DENSITY
Fall PM	B	17.2
Summer SAT	D	32.5

QUAKER MEETING HOUSE RD

NOT TO SCALE

PRE-DECISIONAL & DELIBERATIVE

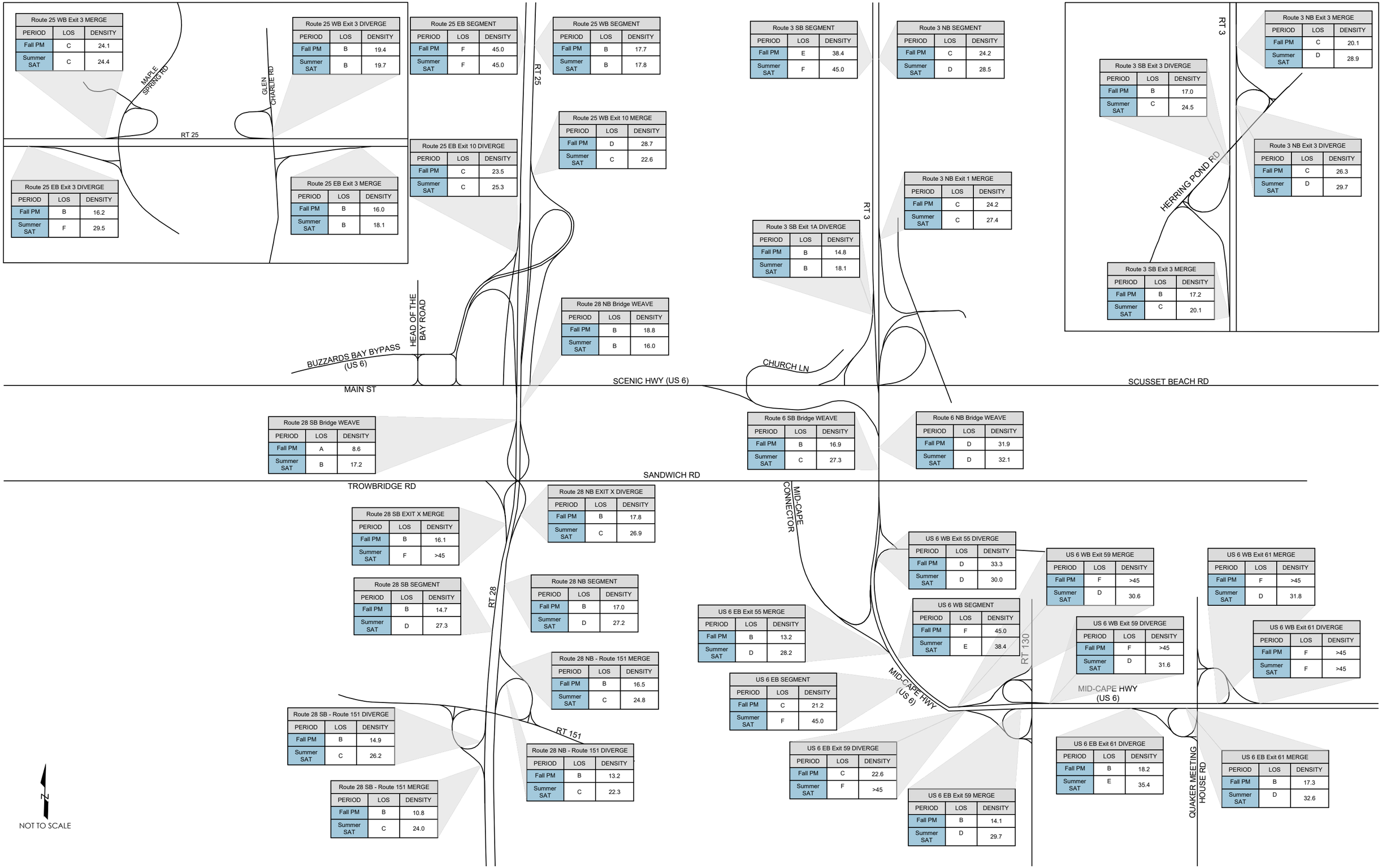
Figure 17 : Freeway Level of Service Summary - AP3 Fall PM & Summer SAT (2050)



PRE-DECISIONAL & DELIBERATIVE

Figure 18 : Freeway Level of Service Summary - AP4 Fall PM & Summer SAT (2050)

HNTB



Route 25 WB Exit 3 MERGE		
PERIOD	LOS	DENSITY
Fall PM	C	24.1
Summer SAT	C	24.4

Route 25 WB Exit 3 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	B	19.4
Summer SAT	B	19.7

Route 25 EB SEGMENT		
PERIOD	LOS	DENSITY
Fall PM	F	45.0
Summer SAT	F	45.0

Route 25 WB SEGMENT		
PERIOD	LOS	DENSITY
Fall PM	B	17.7
Summer SAT	B	17.8

Route 25 WB Exit 10 MERGE		
PERIOD	LOS	DENSITY
Fall PM	D	28.7
Summer SAT	C	22.6

Route 25 EB Exit 10 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	C	23.5
Summer SAT	C	25.3

Route 25 EB Exit 3 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	B	16.2
Summer SAT	F	29.5

Route 25 EB Exit 3 MERGE		
PERIOD	LOS	DENSITY
Fall PM	B	16.0
Summer SAT	B	18.1

Route 3 SB SEGMENT		
PERIOD	LOS	DENSITY
Fall PM	E	38.4
Summer SAT	F	45.0

Route 3 NB SEGMENT		
PERIOD	LOS	DENSITY
Fall PM	C	24.2
Summer SAT	D	28.5

Route 3 NB Exit 3 MERGE		
PERIOD	LOS	DENSITY
Fall PM	C	20.1
Summer SAT	D	28.9

Route 3 SB Exit 3 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	B	17.0
Summer SAT	C	24.5

Route 3 NB Exit 3 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	C	26.3
Summer SAT	D	29.7

Route 3 NB Exit 1 MERGE		
PERIOD	LOS	DENSITY
Fall PM	C	24.2
Summer SAT	C	27.4

Route 3 SB Exit 1A DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	B	14.8
Summer SAT	B	18.1

Route 3 SB Exit 3 MERGE		
PERIOD	LOS	DENSITY
Fall PM	B	17.2
Summer SAT	C	20.1

Route 28 NB Bridge WEAVE		
PERIOD	LOS	DENSITY
Fall PM	B	18.8
Summer SAT	B	16.0

Route 28 SB Bridge WEAVE		
PERIOD	LOS	DENSITY
Fall PM	A	8.6
Summer SAT	B	17.2

Route 6 SB Bridge WEAVE		
PERIOD	LOS	DENSITY
Fall PM	B	16.9
Summer SAT	C	27.3

Route 6 NB Bridge WEAVE		
PERIOD	LOS	DENSITY
Fall PM	D	31.9
Summer SAT	D	32.1

Route 28 NB EXIT X DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	B	17.8
Summer SAT	C	26.9

Route 28 SB EXIT X MERGE		
PERIOD	LOS	DENSITY
Fall PM	B	16.1
Summer SAT	F	>45

Route 28 SB SEGMENT		
PERIOD	LOS	DENSITY
Fall PM	B	14.7
Summer SAT	D	27.3

Route 28 NB SEGMENT		
PERIOD	LOS	DENSITY
Fall PM	B	17.0
Summer SAT	D	27.2

Route 28 NB - Route 151 MERGE		
PERIOD	LOS	DENSITY
Fall PM	B	16.5
Summer SAT	C	24.8

Route 28 SB - Route 151 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	B	14.9
Summer SAT	C	26.2

Route 28 NB - Route 151 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	B	13.2
Summer SAT	C	22.3

Route 28 SB - Route 151 MERGE		
PERIOD	LOS	DENSITY
Fall PM	B	10.8
Summer SAT	C	24.0

US 6 WB Exit 55 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	D	33.3
Summer SAT	D	30.0

US 6 WB Exit 59 MERGE		
PERIOD	LOS	DENSITY
Fall PM	F	>45
Summer SAT	D	30.6

US 6 WB Exit 61 MERGE		
PERIOD	LOS	DENSITY
Fall PM	F	>45
Summer SAT	D	31.8

US 6 EB Exit 55 MERGE		
PERIOD	LOS	DENSITY
Fall PM	B	13.2
Summer SAT	D	28.2

US 6 WB SEGMENT		
PERIOD	LOS	DENSITY
Fall PM	F	45.0
Summer SAT	E	38.4

US 6 WB Exit 59 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	F	>45
Summer SAT	D	31.6

US 6 WB Exit 61 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	F	>45
Summer SAT	F	>45

US 6 EB SEGMENT		
PERIOD	LOS	DENSITY
Fall PM	C	21.2
Summer SAT	F	45.0

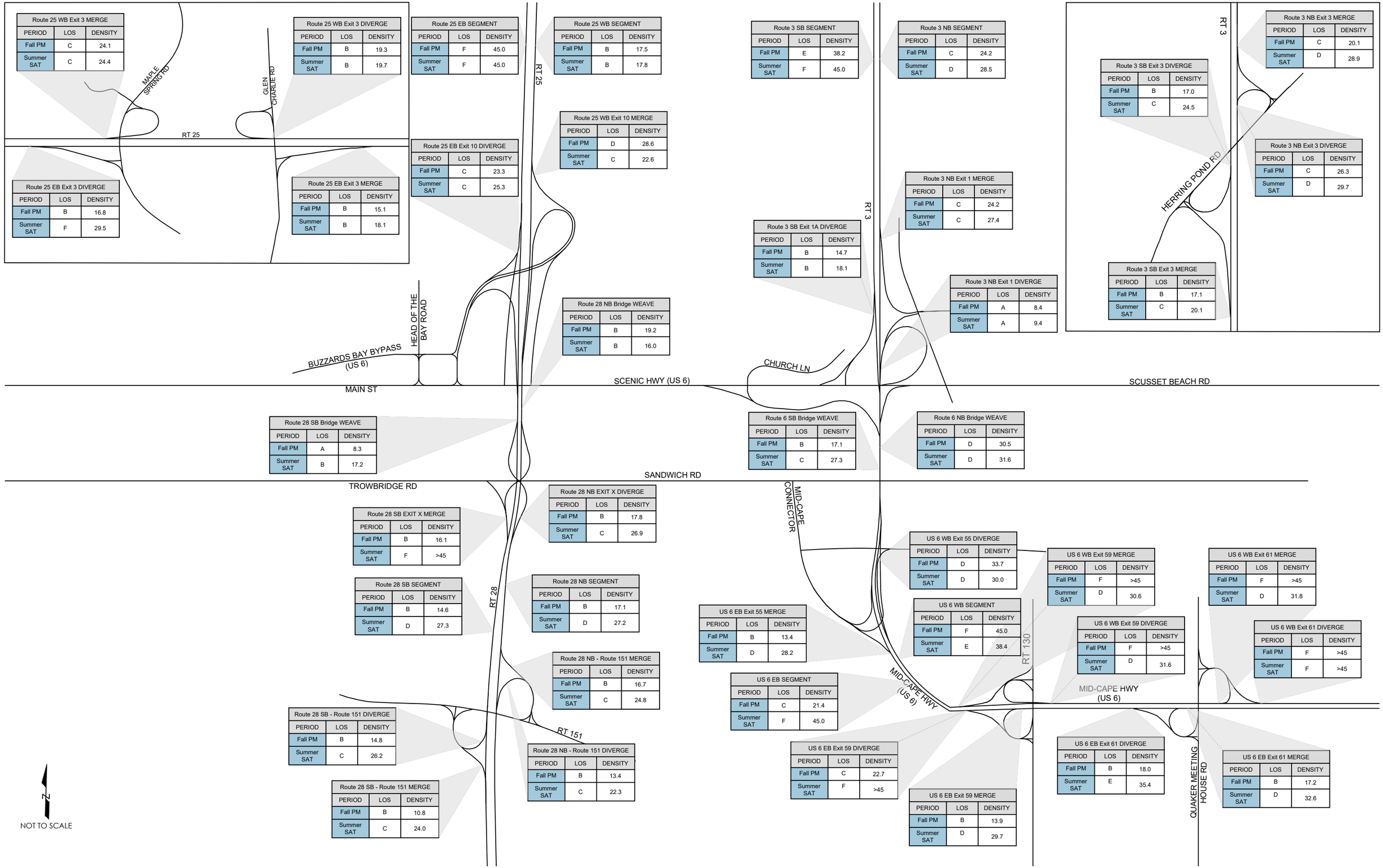
US 6 EB Exit 59 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	C	22.6
Summer SAT	F	>45

US 6 EB Exit 61 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	B	18.2
Summer SAT	E	35.4

US 6 EB Exit 59 MERGE		
PERIOD	LOS	DENSITY
Fall PM	B	14.1
Summer SAT	D	29.7

US 6 EB Exit 61 MERGE		
PERIOD	LOS	DENSITY
Fall PM	B	17.3
Summer SAT	D	32.6

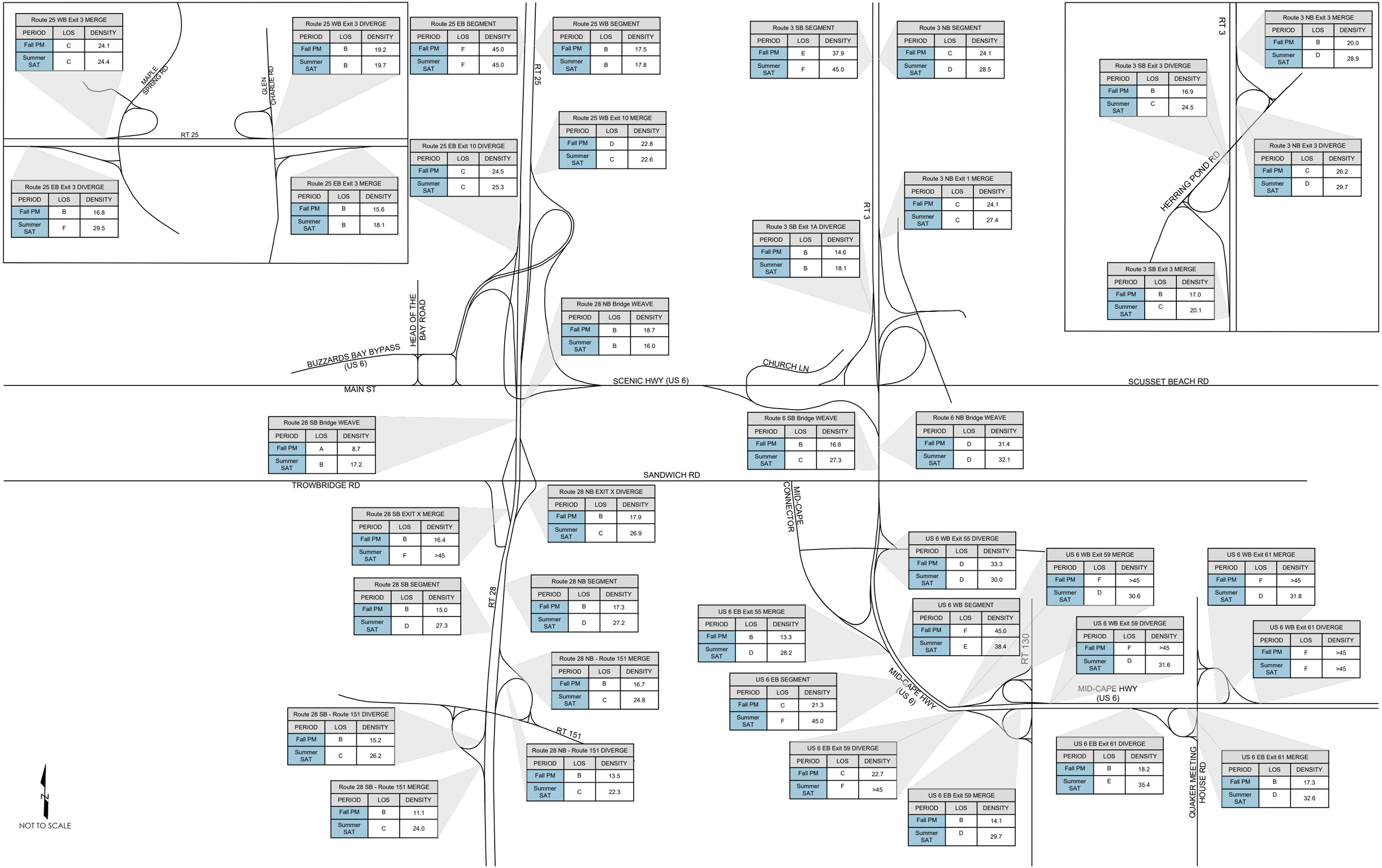
Figure 19 : Freeway Level of Service Summary - AP5 Fall PM & Summer SAT (2050)



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Figure 20 : Freeway Level of Service Summary - AP6 Fall PM & Summer SAT (2050)

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Route 25 WB Exit 3 MERGE		
PERIOD	LOS	DENSITY
Fall PM	C	24.1
Summer SAT	C	24.4

Route 25 WB Exit 3 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	B	19.2
Summer SAT	B	19.7

Route 25 EB SEGMENT		
PERIOD	LOS	DENSITY
Fall PM	F	45.0
Summer SAT	F	45.0

Route 25 WB SEGMENT		
PERIOD	LOS	DENSITY
Fall PM	B	17.5
Summer SAT	B	17.8

Route 3 SB SEGMENT		
PERIOD	LOS	DENSITY
Fall PM	E	37.9
Summer SAT	F	45.0

Route 3 NB SEGMENT		
PERIOD	LOS	DENSITY
Fall PM	C	24.1
Summer SAT	D	28.5

Route 3 NB Exit 3 MERGE		
PERIOD	LOS	DENSITY
Fall PM	B	20.0
Summer SAT	D	28.9

Route 3 SB Exit 3 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	B	16.9
Summer SAT	C	24.5

Route 3 NB Exit 3 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	C	26.2
Summer SAT	D	29.7

Route 25 WB Exit 10 MERGE		
PERIOD	LOS	DENSITY
Fall PM	D	22.8
Summer SAT	C	22.6

Route 25 EB Exit 10 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	C	24.5
Summer SAT	C	25.3

Route 25 EB Exit 3 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	B	16.8
Summer SAT	F	29.5

Route 25 EB Exit 3 MERGE		
PERIOD	LOS	DENSITY
Fall PM	B	15.6
Summer SAT	B	18.1

Route 3 NB Exit 1 MERGE		
PERIOD	LOS	DENSITY
Fall PM	C	24.1
Summer SAT	C	27.4

Route 3 SB Exit 1A DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	B	14.6
Summer SAT	B	18.1

Route 3 SB Exit 3 MERGE		
PERIOD	LOS	DENSITY
Fall PM	B	17.0
Summer SAT	C	20.1

Route 28 NB Bridge WEAVE		
PERIOD	LOS	DENSITY
Fall PM	B	18.7
Summer SAT	B	16.0

Route 6 SB Bridge WEAVE		
PERIOD	LOS	DENSITY
Fall PM	B	16.6
Summer SAT	C	27.3

Route 6 NB Bridge WEAVE		
PERIOD	LOS	DENSITY
Fall PM	D	31.4
Summer SAT	D	32.1

Route 28 SB Bridge WEAVE		
PERIOD	LOS	DENSITY
Fall PM	A	8.7
Summer SAT	B	17.2

Route 28 NB EXIT X DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	B	17.9
Summer SAT	C	26.9

Route 28 SB EXIT X MERGE		
PERIOD	LOS	DENSITY
Fall PM	B	16.4
Summer SAT	F	>45

Route 28 SB SEGMENT		
PERIOD	LOS	DENSITY
Fall PM	B	15.0
Summer SAT	D	27.3

Route 28 NB SEGMENT		
PERIOD	LOS	DENSITY
Fall PM	B	17.3
Summer SAT	D	27.2

Route 28 NB - Route 151 MERGE		
PERIOD	LOS	DENSITY
Fall PM	B	16.7
Summer SAT	C	24.8

Route 28 SB - Route 151 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	B	15.2
Summer SAT	C	26.2

Route 28 NB - Route 151 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	B	13.5
Summer SAT	C	22.3

Route 28 SB - Route 151 MERGE		
PERIOD	LOS	DENSITY
Fall PM	B	11.1
Summer SAT	C	24.0

US 6 WB Exit 55 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	D	33.3
Summer SAT	D	30.0

US 6 WB Exit 59 MERGE		
PERIOD	LOS	DENSITY
Fall PM	F	>45
Summer SAT	D	30.6

US 6 WB Exit 61 MERGE		
PERIOD	LOS	DENSITY
Fall PM	F	>45
Summer SAT	D	31.8

US 6 WB SEGMENT		
PERIOD	LOS	DENSITY
Fall PM	F	45.0
Summer SAT	E	38.4

US 6 WB Exit 59 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	F	>45
Summer SAT	D	31.6

US 6 WB Exit 61 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	F	>45
Summer SAT	F	>45

US 6 EB Exit 55 MERGE		
PERIOD	LOS	DENSITY
Fall PM	B	13.3
Summer SAT	D	28.2

US 6 EB SEGMENT		
PERIOD	LOS	DENSITY
Fall PM	C	21.3
Summer SAT	F	45.0

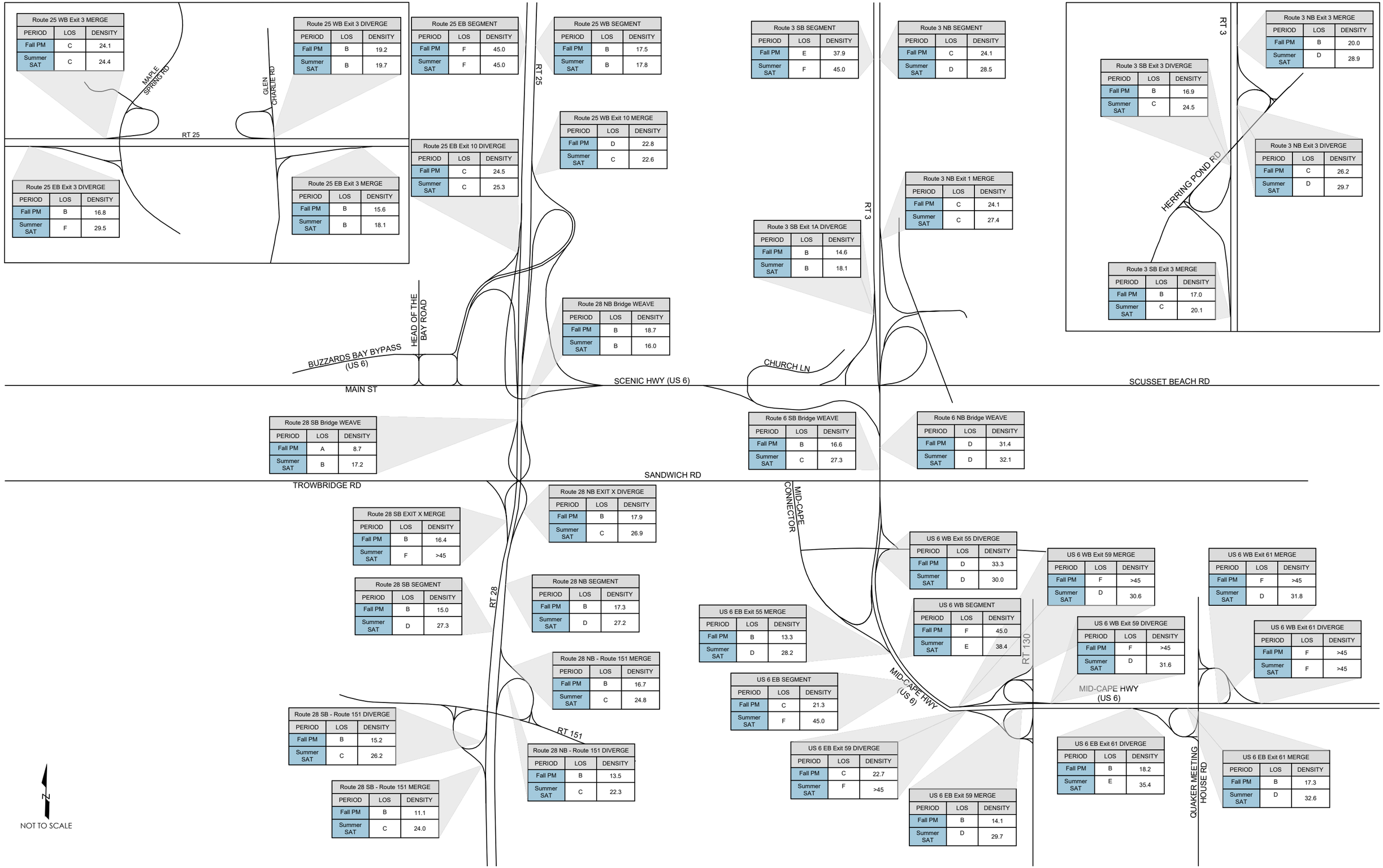
US 6 EB Exit 59 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	C	22.7
Summer SAT	F	>45

US 6 EB Exit 61 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	B	18.2
Summer SAT	E	35.4

US 6 EB Exit 59 MERGE		
PERIOD	LOS	DENSITY
Fall PM	B	14.1
Summer SAT	D	29.7

US 6 EB Exit 61 MERGE		
PERIOD	LOS	DENSITY
Fall PM	B	17.3
Summer SAT	D	32.6

Figure 21 : Freeway Level of Service Summary - AP7 Fall PM & Summer SAT (2050)



Route 25 WB Exit 3 MERGE		
PERIOD	LOS	DENSITY
Fall PM	C	24.1
Summer SAT	C	24.4

Route 25 WB Exit 3 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	B	19.2
Summer SAT	B	19.7

Route 25 EB SEGMENT		
PERIOD	LOS	DENSITY
Fall PM	F	45.0
Summer SAT	F	45.0

Route 25 WB SEGMENT		
PERIOD	LOS	DENSITY
Fall PM	B	17.5
Summer SAT	B	17.8

Route 25 WB Exit 10 MERGE		
PERIOD	LOS	DENSITY
Fall PM	D	22.8
Summer SAT	C	22.6

Route 25 EB Exit 10 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	C	24.5
Summer SAT	C	25.3

Route 25 EB Exit 3 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	B	16.8
Summer SAT	F	29.5

Route 25 EB Exit 3 MERGE		
PERIOD	LOS	DENSITY
Fall PM	B	15.6
Summer SAT	B	18.1

Route 3 SB SEGMENT		
PERIOD	LOS	DENSITY
Fall PM	E	37.9
Summer SAT	F	45.0

Route 3 NB SEGMENT		
PERIOD	LOS	DENSITY
Fall PM	C	24.1
Summer SAT	D	28.5

Route 3 NB Exit 3 MERGE		
PERIOD	LOS	DENSITY
Fall PM	B	20.0
Summer SAT	D	28.9

Route 3 SB Exit 3 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	B	16.9
Summer SAT	C	24.5

Route 3 NB Exit 3 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	C	26.2
Summer SAT	D	29.7

Route 3 NB Exit 1 MERGE		
PERIOD	LOS	DENSITY
Fall PM	C	24.1
Summer SAT	C	27.4

Route 3 SB Exit 1A DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	B	14.6
Summer SAT	B	18.1

Route 3 SB Exit 3 MERGE		
PERIOD	LOS	DENSITY
Fall PM	B	17.0
Summer SAT	C	20.1

Route 28 NB Bridge WEAVE		
PERIOD	LOS	DENSITY
Fall PM	B	18.7
Summer SAT	B	16.0

Route 28 SB Bridge WEAVE		
PERIOD	LOS	DENSITY
Fall PM	A	8.7
Summer SAT	B	17.2

Route 6 SB Bridge WEAVE		
PERIOD	LOS	DENSITY
Fall PM	B	16.6
Summer SAT	C	27.3

Route 6 NB Bridge WEAVE		
PERIOD	LOS	DENSITY
Fall PM	D	31.4
Summer SAT	D	32.1

Route 28 NB EXIT X DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	B	17.9
Summer SAT	C	26.9

Route 28 SB EXIT X MERGE		
PERIOD	LOS	DENSITY
Fall PM	B	16.4
Summer SAT	F	>45

Route 28 SB SEGMENT		
PERIOD	LOS	DENSITY
Fall PM	B	15.0
Summer SAT	D	27.3

Route 28 NB SEGMENT		
PERIOD	LOS	DENSITY
Fall PM	B	17.3
Summer SAT	D	27.2

Route 28 NB - Route 151 MERGE		
PERIOD	LOS	DENSITY
Fall PM	B	16.7
Summer SAT	C	24.8

Route 28 SB - Route 151 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	B	15.2
Summer SAT	C	26.2

Route 28 NB - Route 151 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	B	13.5
Summer SAT	C	22.3

Route 28 SB - Route 151 MERGE		
PERIOD	LOS	DENSITY
Fall PM	B	11.1
Summer SAT	C	24.0

US 6 WB Exit 55 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	D	33.3
Summer SAT	D	30.0

US 6 WB Exit 59 MERGE		
PERIOD	LOS	DENSITY
Fall PM	F	>45
Summer SAT	D	30.6

US 6 WB Exit 61 MERGE		
PERIOD	LOS	DENSITY
Fall PM	F	>45
Summer SAT	D	31.8

US 6 WB SEGMENT		
PERIOD	LOS	DENSITY
Fall PM	F	45.0
Summer SAT	E	38.4

US 6 WB Exit 59 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	F	>45
Summer SAT	D	31.6

US 6 WB Exit 61 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	F	>45
Summer SAT	F	>45

US 6 EB Exit 55 MERGE		
PERIOD	LOS	DENSITY
Fall PM	B	13.3
Summer SAT	D	28.2

US 6 EB SEGMENT		
PERIOD	LOS	DENSITY
Fall PM	C	21.3
Summer SAT	F	45.0

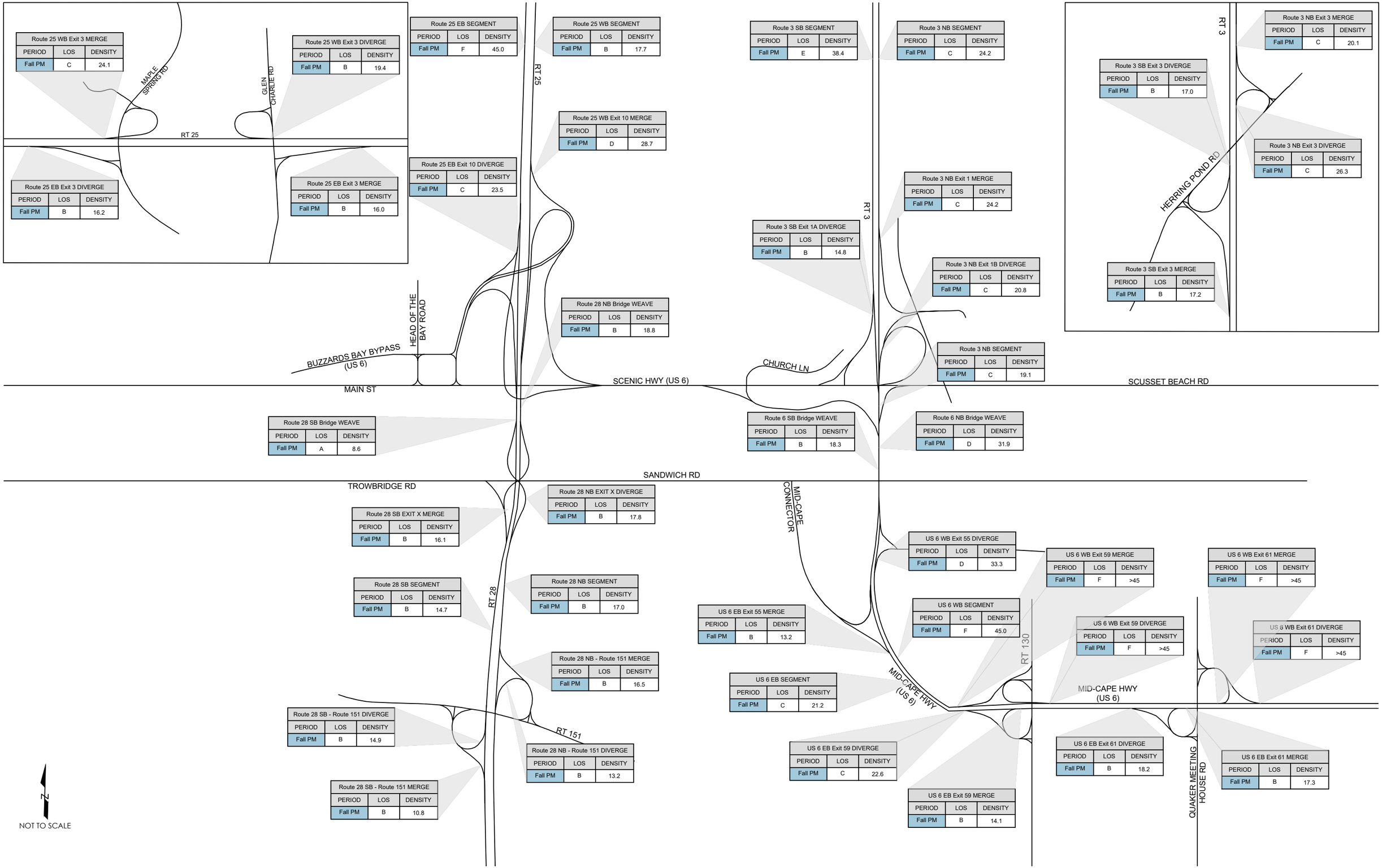
US 6 EB Exit 59 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	C	22.7
Summer SAT	F	>45

US 6 EB Exit 59 MERGE		
PERIOD	LOS	DENSITY
Fall PM	B	14.1
Summer SAT	D	29.7

US 6 EB Exit 61 DIVERGE		
PERIOD	LOS	DENSITY
Fall PM	B	18.2
Summer SAT	E	35.4

US 6 EB Exit 61 MERGE		
PERIOD	LOS	DENSITY
Fall PM	B	17.3
Summer SAT	D	32.6

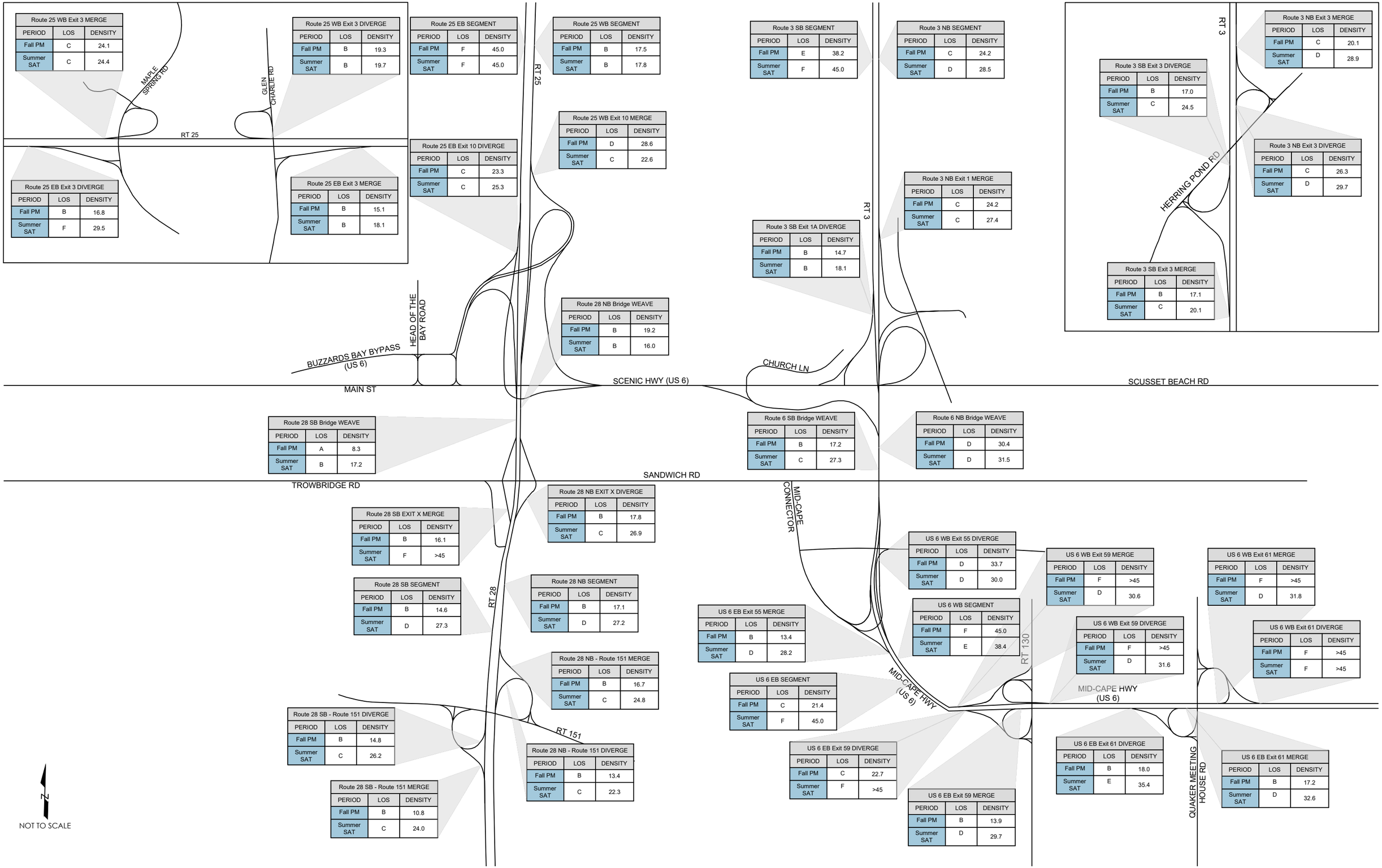
Figure 22 : Freeway Level of Service Summary - AP7.1 Fall PM & Summer SAT (2050)



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Figure 23 : Freeway Level of Service Summary - AP8.1 Fall PM & Summer SAT (2050)

HNTB



PRE-DECISIONAL & DELIBERATIVE

Figure 24 : Freeway Level of Service Summary - AP9 Fall PM & Summer SAT (2050)

HNTB

VISSIM Analysis

The VISSIM networks have been constructed in alignment with the Analysis Pairings outlined in the introduction of this memorandum. All subsequent summaries and observations of model outputs will be framed within the context of these Analysis Pairings and/or the individual quadrant alternatives. It is important to note that the VISSIM models are in a conceptual state and will continue to be refined as the evaluation criteria is further developed.
The VISSIM analysis in this memo will focus on:

- **Network Performance Evaluations** – The metric offers a comprehensive overview of the network, facilitating quick comparisons between alternatives. It encompasses all vehicles in the network, regardless of network entry point and travel route. Apart from standard measures of effectiveness like vehicle delay and stops, network performance evaluation includes additional insights, such as, the number of vehicles processed and cumulative statistics representing the networkwide operations. The Network Performance measures and the definitions for each measure, are included in Attachment C. The primary Network Performance Evaluation measures to be discussed include the following:
    - ***Processed Vehicles*** – The total number of vehicles that have entered the network and reached their destination before the end of the simulation. This measure is analogous to the number of vehicles arrived in the VISSIM results output.
    - ***Average Delay per Vehicle*** – The Total Network Delay averaged over the total number of vehicles that have been processed and those that are still in the network at the end of the simulation.
- **Total Travel Time** – Travel time serves as a crucial performance metric, offering a direct indication of system efficiency and user experience. Decreased travel times signify improved mobility, enhanced accessibility, and potentially reduced road user costs. Conversely, prolonged travel times can signal congestion, routing or infrastructure inefficiencies, and potential network bottlenecks. To assess the effectiveness of the analysis, travel time evaluation was conducted in two facets:
    - ***Network-wide Assessment*** - This analysis focused on evaluating performance using network-wide travel time data, providing a comprehensive insight into transportation system efficiency, congestion levels, and overall effectiveness.
    - ***Major O-D Evaluation*** - By measuring travel time between origin and destination points, the efficacy of pairings was assessed, offering valuable insights into their effectiveness. This includes total travel time of vehicles within or exiting the network. Additionally, Travel Time Performance along critical Origin-Destination Routes, as detailed in the memorandum titled "Cape Cod Canal Bridges Program – Future 2045 Build Traffic Volumes" dated September 1, 2023, was considered.
- **Queue Length of Analysis Pairings** – Queue length was assessed in terms of distance rather than the number of vehicles, using nodes for measurement. Nodes offer a convenient means to gather data within specific areas of interest, such as intersections or ramp junctions. This visualization of queue lengths can prove valuable for model evaluation.

Network Performance Evaluations

The examination of both Fall PM and Summer Saturday time periods were conducted. The Fall PM time period has been chosen as the design time period as it represents the 85th percentile traffic volumes over the course of the year. The Summer Saturday time period represents the yearly peak, which will provide insight into the worst-case operations. This memo will primarily delve into the findings from Fall models, while results from the summer models will be utilized to further refine the roadway geometry and lane use.

Processed Vehicles - Figure 25 below depicts the total vehicle count processed under the No-Build condition and 11 Analysis Pairing models. The analysis outcomes indicate that all analysis pairings process a higher number of vehicles compared to the No-Build condition, ranging from approximately 3.5% more to 10% more when compared to AP 1.1 and AP 7, respectively. The lower end of this range is attributed to congestion in Belmont Circle for alternatives that incorporate BN-6.1. The network performance for pairings including alternative BN-6.1 indicate that Belmont Circle cannot accommodate the projected increase in traffic volumes estimated by the travel demand model. The resulting congestion is primarily due to heavy traffic movement connecting Route 25 EB to Scenic Highway eastbound. Under alternatives BN-13.1 and BN-14.4b, a direct access ramp is provided to allow this movement to bypass Belmont Circle, where in BN-6.1 the circulation around Belmont Circle is still required. Similarly, under Fall PM conditions, AP 6 is anticipated to handle a reduced number of vehicles compared to other analysis pairings that include 13.1 and 14.4b alternative. This is mainly attributed to the performance of SN-1A under heightened traffic volumes. Conversely, AP 4, 5, 6, 7, 7.1, 8.1, and 9 all demonstrate the largest increases in processed vehicles, signaling a more efficient network. Figure 25 also highlights the volume permutation from P1 to P6 along with their corresponding analysis pairings.

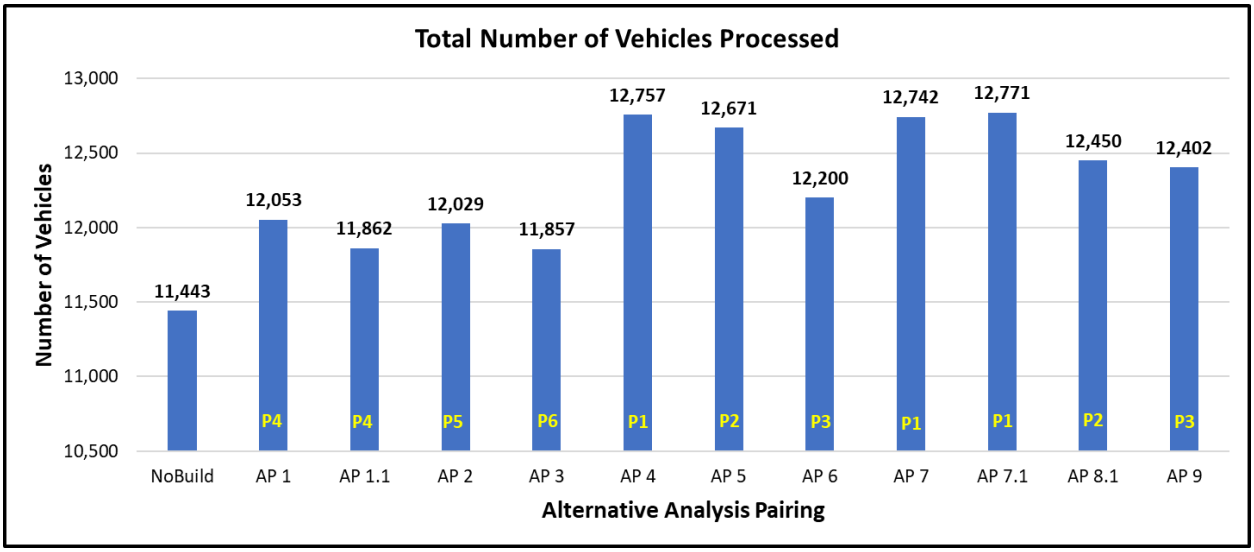


Figure 25 – Total Number of Vehicles Processed

Considering that the analysis pairings were formulated based on volume permutations, resulting in models carrying distinct vehicle inputs, it was essential to account for these variations. To accommodate these differences, a comparison was conducted on a networkwide scale, evaluating the processed vehicles in relation to the corresponding vehicle inputs.

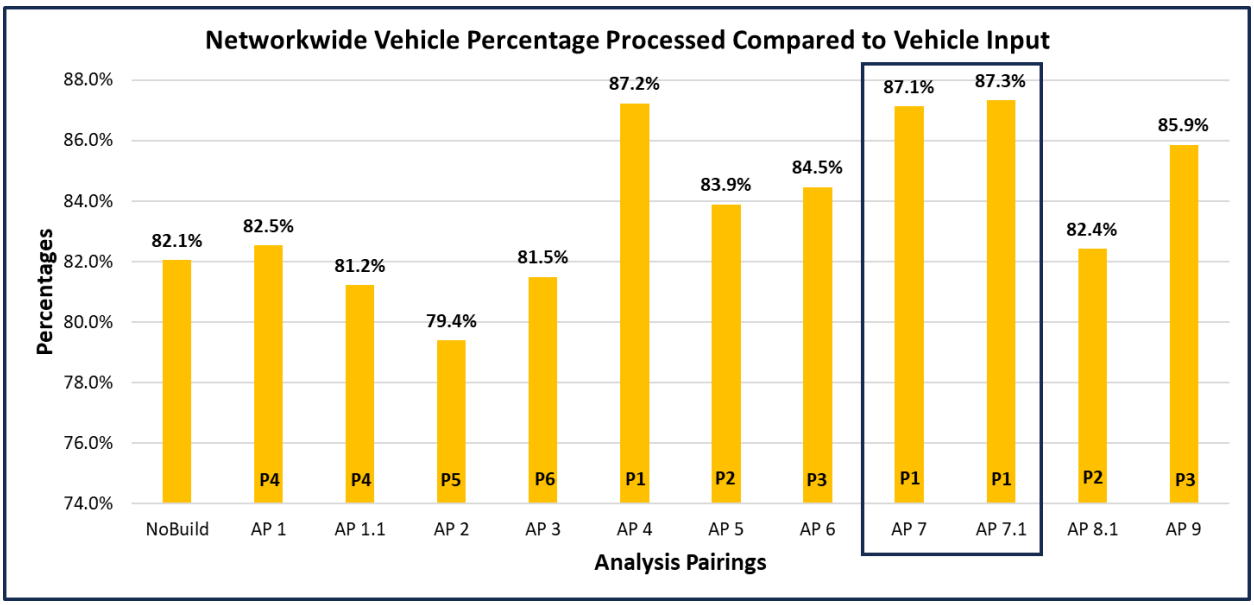


Figure 26 – Percentage of Vehicle Processed Compared to Vehicle Input

Figure 26 illustrates the percentage of processed vehicles relative to their respective volume inputs in the alternative models. Examining the results in Figure 26 reveals that AP 1.1, AP 2, and AP 3 process a lower number of vehicles networkwide compared to their inputs than the No-Build condition. AP 1 and AP 8.1 exhibit improvements of less than 1%. A noteworthy observation pertains to the comparison between AP 7 and AP 7.1. Both analysis pairings share the same vehicle inputs (Volume Pairing P1) but differ in the Bourne South alternative, with BS-2 in AP 7 analysis pairing and BS-2.2 in AP 7.1 analysis pairing. Upon closer examination of networkwide performance, it appears that AP 7.1 paired with BS-2.2 and AP 7 paired with BS-2 function comparably, displaying only slight operational disparities. Again AP 4, AP 7, AP 7.1, and AP 9 have better performance compared to the No-Build condition.

Average Delay Per Vehicle - Another performance metric assessed at a network-wide level is the average delay per vehicle which includes processed as well as active vehicles, as illustrated in Figure 27. Consistent with previous findings, AP 1, AP 1.1, AP 2, and AP 3 exhibit higher average delays per vehicle processed compared to No-Build and all other alternative analysis pairings, with BN-6.1 being the common alternative among these pairings. The analysis indicates that including BN-6.1 in the analysis pairing results in lower processed volume and higher delays, leading to an increased average delay per vehicle compared to other analysis pairings. Once again, these issues are linked to projected volume increases at Belmont Circle under BN-6.1 (AP 1, 1.1, 2, and 3). Conversely, AP 4, 7, and 7.1 demonstrate approximately 28% reductions in average delay per vehicle compared to the No-Build Conditions. These pairings all include either BN-13.1 or BN-14.4B, and a Sagamore South alternative that incorporates the Cranberry Highway Extension under SS-1. AP 5 and 8.1 do not include the Cranberry Highway Extension (SS-1.1) and exhibit reductions of approximately 12.5% and 7.5% in average vehicle delay compared to the No-Build Condition, respectively. AP 6 and AP 9, which include SS-3.1A, show approximately a 14% reduction in average delay per vehicle. Additional comprehensive analysis is warranted to thoroughly assess AP 4 and AP 6, given their identical pairings of alternatives except for Sagamore South. From the current examination, it appears that SS-1 demonstrates better performance relative to average vehicle delay compared to SS-3.1A.

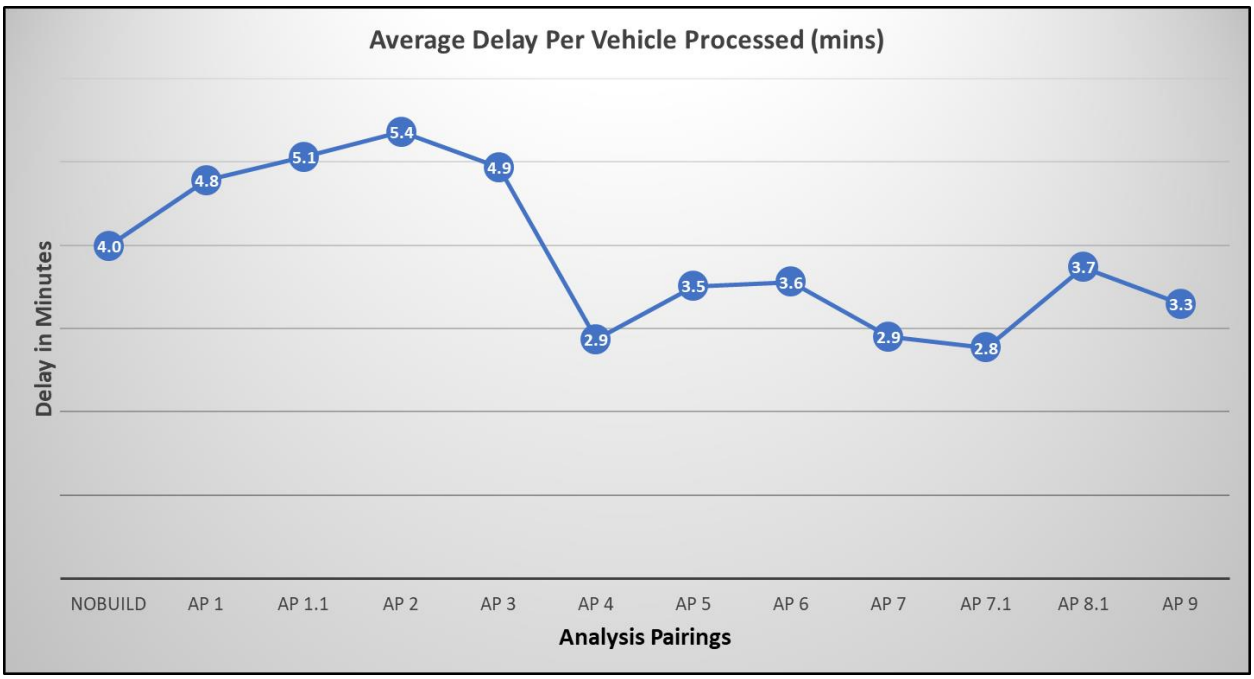


Figure 27 – Average Delay Per Vehicle Processed (mins)

Key Highlights

1. Figure 25 illustrates that all analysis pairings handle a higher number of vehicles compared to the No-Build condition, with variations ranging from approximately 3.5% to 10%.
2. Pairings incorporating alternative BN-6.1 project congestion at Belmont Circle, impacting network performance negatively.
3. Comparison between AP 7 and AP 7.1 reveals similar performance. BS-2.2 under AP 7.1 results in slightly more efficient network.
4. Networkwide evaluation in Figure 26 shows that AP 1.1, AP 2 and AP 3 process the fewest vehicles compared to their inputs, while AP 1 and AP 8.1 exhibit less than 1% improvements.
5. Figure 27 highlights that AP 4, 7, and 7.1 demonstrate approximately 28% reductions in average delay per vehicle compared to the No-Build conditions, while AP 1, AP 1.1, AP 2, and AP 3 exhibit higher average delays, primarily due to the inclusion of alternative BN-6.1.

Total Travel Time – The total travel time is a metric which is influenced by the total distance traveled within the network, the delay experienced within the network, the number of vehicles processed, as well as the number of vehicles still active within the network at the end of the simulation. The travel time was evaluated networkwide as well as for major O-D movements within the network.

Network-wide Assessment - By analyzing aggregated travel time data at the network level, valuable insights can be gained into overall efficiencies and the effectiveness of operational strategies. Additionally, evaluating travel time network-wide can pinpoint areas requiring capacity enhancements, signal optimization, or realignment improvements. Key metrics assessed include the percent change in travel time compared to the No-Build scenario, the percentage of travel time per mile per vehicle compared to the No-Build scenario, and the percentage change in travel time due to delay. Each metric, along with its corresponding analysis results, is detailed in this section.

Percentage Change of Total Travel Time Compared to No-Build

Similar to Figure 25, Figure 28 demonstrates decreased travel times across the network compared to the No-Build condition. It is evident from the analysis that travel time improves between 10-15% for analysis pairings AP 1 to AP 3, and AP 5. The highest reduction in travel time can be attributed to AP

7.1 followed by AP 7 both exceeding 23%. AP 4, AP 6, AP 7, AP7.1 and AP 9 all have shown travel time improvements in excess of 20%.

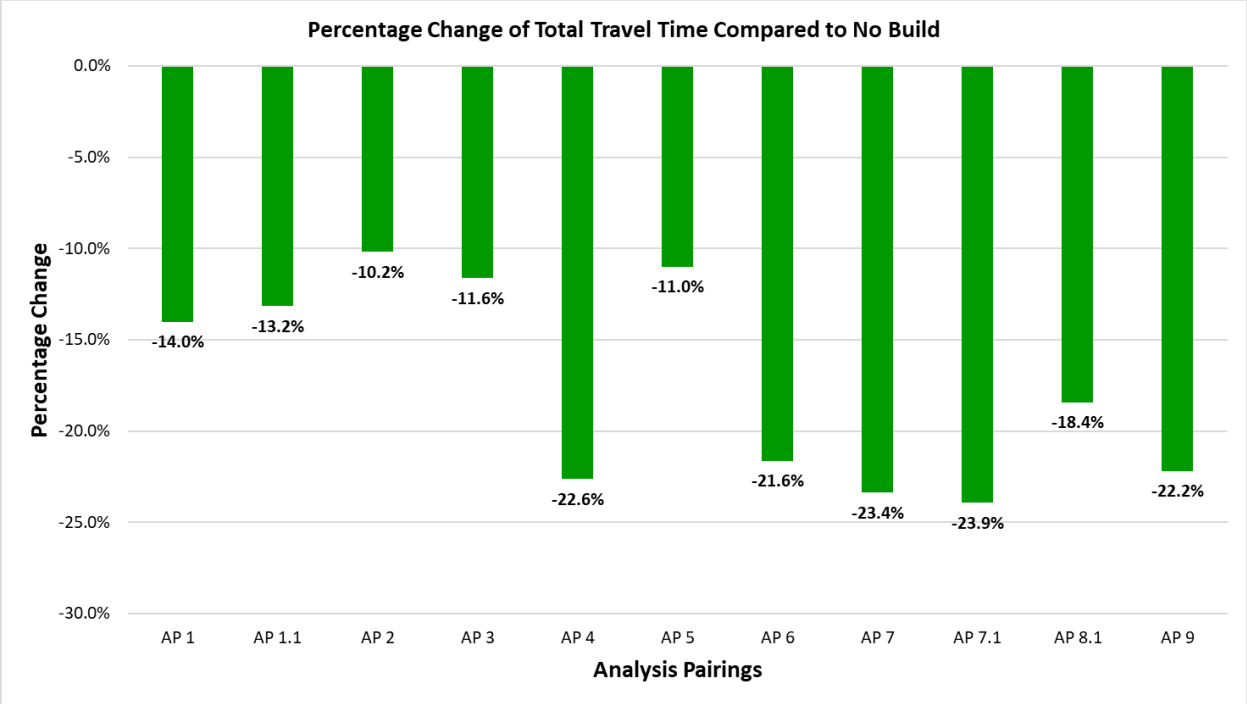


Figure 28 – Percentage Change of Total Travel Time Compared to No-Build

Percentage Change of Total Travel Time Per Mile Per Vehicle Compared to No-Build

Considering that the travel time metric is affected by the number of vehicles still operational within the network, an assessment was conducted on travel time per vehicle. This was achieved by converting Total Travel Time to Total Travel Time per mile per vehicle, which helps mitigate the impact of factors such as geometric disparities, variations in active vehicles, or differences in model vehicle inputs. Figures 29 illustrate the percentage change in Total Travel Time per mile per vehicle compared to the No-Build Condition, offering a more refined measure of travel efficiency within the network. The results show that relative to Total Travel Time per mile per vehicle for AP 4, AP 7 and AP 7.1 all have the greatest improvement of approximately more than 25% compared to the No-Build Condition, which is in line with the overall Total Travel Time metric. In this refined case, the analysis pairings from AP 1 to AP 3 shows a higher travel time per mile per vehicle. For AP 5 and AP 9 shows a range of 15% to 20% whereas AP 6 & AP 9.1 ranges in 23.4 to 24.6%. The significance of this metric is that relative to the interchange alternatives, this suggests that although BN-14.4B, SS-1 and SS-1.1 may require slightly farther distances to travel due to geometric differences between BN-13.1 and SS-3.1A, these pairings are still efficient routes relative to vehicle delay and the number of vehicles simulated by VISSIM. Note that Route 6 WB/Route 3 NB On-Ramp is approximately 44% longer under SS-3.1A compared to SS-1. At the same time, with BN-6.1 the analysis pairings of AP1, AP 1.1, AP 2 and AP 3 has higher travel time per vehicle per mile.

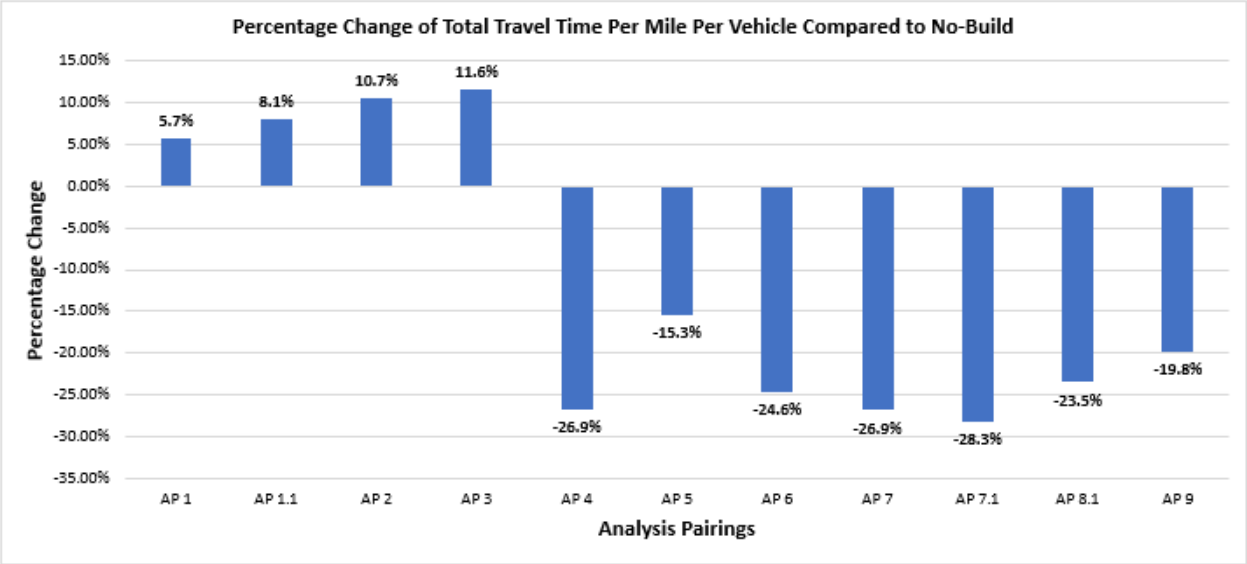


Figure 29 – Percentage Change of Total Travel Time Per Mile Per Vehicle Compared to No-Build

This same efficiency can be seen in Figure 30 which depicts the percentage of travel time due to delay. Notably, AP 7, 7.1, and 4 show the lowest percentage of travel time due to delay. All of these pairings include BN-14.4B or BN-13.1, SN-8A or SN-1A and the Cranberry Highway Extension (either SS-1 or SS-3.1A).

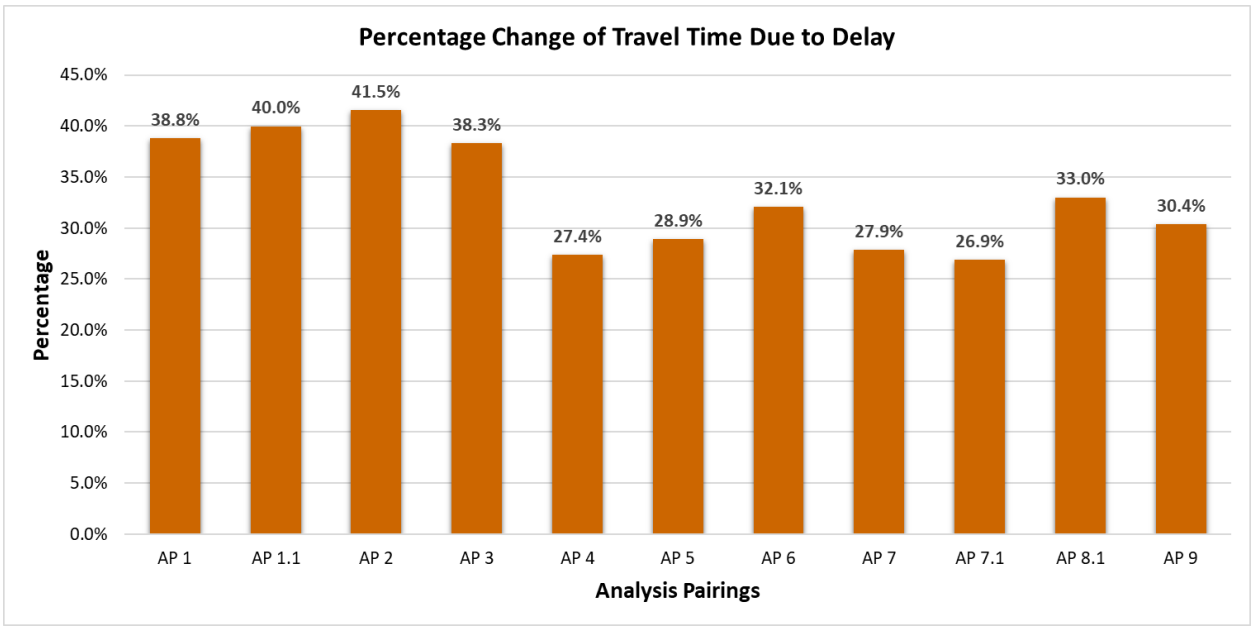


Figure 30 –Percentage Change of Travel Time Due to Delay

Key Highlights

1. It is evident from various analysis performed above that analysis pairings involving BN-6.1 show worse performance compared to all other analysis pairings. According to Figure 29, all analysis pairing including BN-6.1 show worse travel time per mile per vehicle than the No-Build conditions.
2. Similarly, the inclusion of a direct connection from Route 25 in analysis pairings featuring alternatives BN-13.1 and BN-14.4B significantly improves networkwide performance.

2. Similarly, the inclusion of a direct connection from Route 25 in analysis pairings featuring alternatives BN-13.1 and BN-14.4B significantly improves networkwide performance.
3. The integration of Cranberry Highway Extension in conjunction with analysis pairings SS-1 and SS-3.1A contributes to an overall enhancement of traffic flow across the network.
4. SS-1 shows a better performance networkwide when compared to SS-3.1A.
5. Signal optimization within the analysis pairings is further expected to enhance the results networkwide.

Major O-D Evaluation - As previously mentioned, travel time measurements were gathered along critical Origin-Destination Routes as defined in the memorandum titled *"Cape Cod Canal Bridges Program – Future 2045 Build Traffic Volumes"* and dated September 1, 2023, for each VISSIM network model. The travel time measurements presented in this document encompass both diagonal bridge crossings and through bridge crossings. Diagonal bridge crossings involve entry into the network from either the Bourne or Sagamore side, utilizing Scenic Highway or Sandwich Road, and exiting via the Sagamore or Bourne side, using either of the bridges. Meanwhile, through bridge crossings entail direct passage through the network along Route 25/28 via the Bourne Bridge or along Route 3/6 via the Sagamore Bridge.

The specific start and end locations for each travel time measurement are listed below and depicted in **Figure 31**.

- Diagonal Bridge Crossings
  - Route 25 EB to Route 6 EB
  - Route 28 NB to Route 3 NB
  - Route 3 SB to Route 28 SB
  - Route 6 WB to Route 25 WB

- Through Bridge Crossings
  - Route 25 EB to Route 28 SB
  - Route 28 NB to Route 25 WB
  - Route 3 SB to Route 6 EB
  - Route 6 WB to Route 3 NB

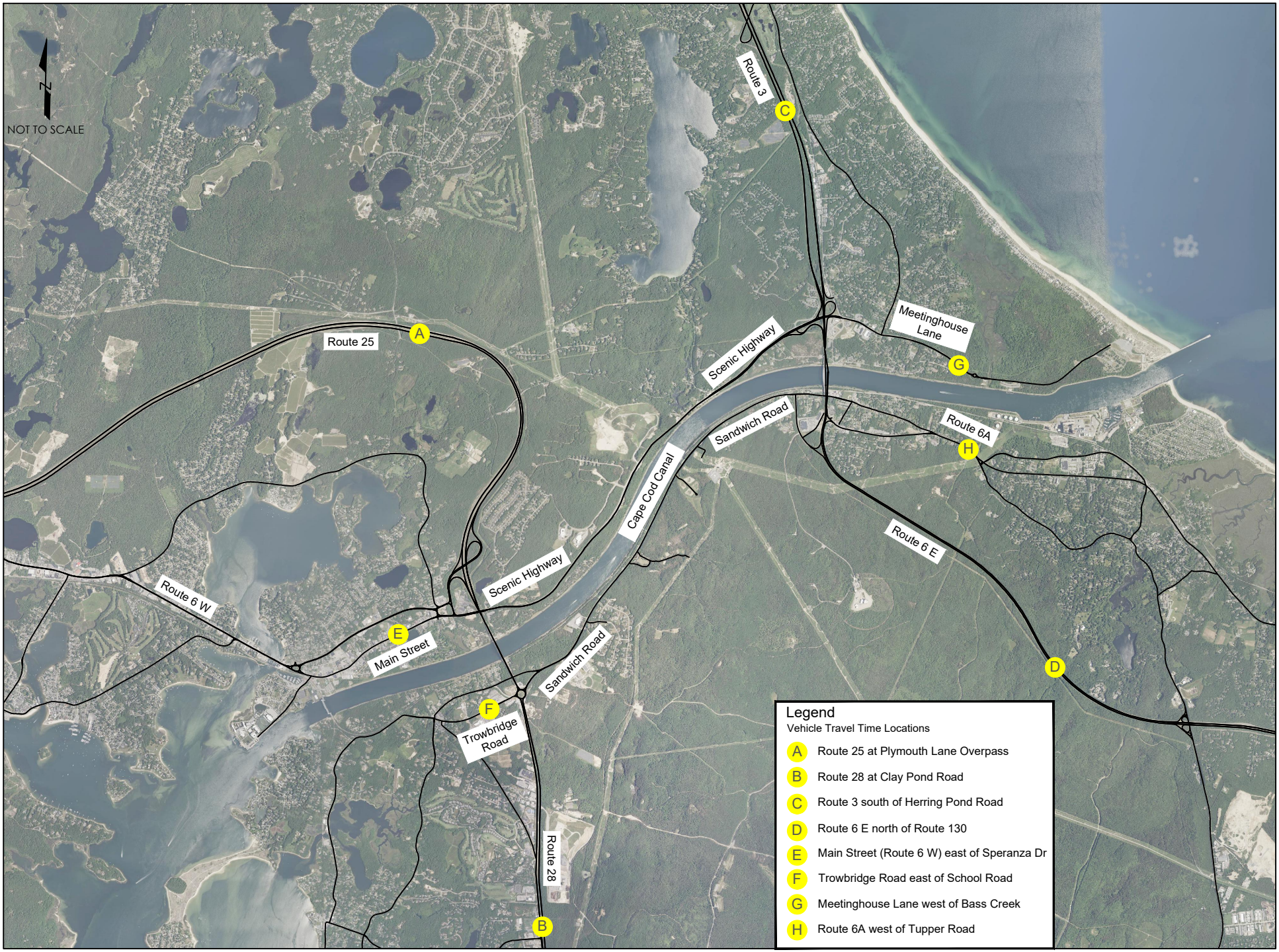


Figure 31 : Travel Time Start and End Locations Map

Diagonal Bridge Crossings

An overview summary of Travel Time Measurements along each diagonal crossing route follows:

- **Route 25 EB to Route 6 EB**
  Figure 32 presents a comparison of travel times for the diagonal movement from Route 25 EB to Route 6 EB, illustrating two alternatives: one via Scenic Highway and the other via Sandwich Road. The graph below illustrates that travel time via Scenic Highway is consistently improved across all analysis pairings compared to the No-Build condition. Furthermore, the average travel time for analysis pairings AP 1, AP 1.1, and AP 2 is approximately 14 to 15 minutes, while for analysis pairings AP 4 to AP 8.1, it is approximately 11 to 13 minutes, resulting in a saving of 3 minutes per vehicle. AP 3 and AP 9 is approximately 15 to 20 minutes. Similarly, when comparing the alternatives, analysis pairings AP 1, AP 1.1, AP 2, and AP 3 show higher travel times via Scenic Highway whereas for analysis pairings AP 4 onwards, apart from AP 9, Scenic Highway has lower travel time. The analysis reveals that congestion at Belmont Circle result in significant delays and increased travel times for routes via Scenic Highway for AP 1, AP 2, and AP 3, which utilize BN-6.1. This corresponds with previous findings from origin-destination reports, indicating that vehicles associated with congestion at Belmont Circle tend to favor Sandwich Road similar to the No-Build scenario. Conversely, routes from AP 4 to AP 8.1 prefer Scenic Highway. While AP 9 analysis also indicates Scenic Highway usage, it requires further assessment due to potential refinements and signal timing. It may also be a result of P3 volumes placing greater pressure on SS-3.1A that tends to underperform compared to P1 with SS-1. Overall, all alternative analyses demonstrate improvements compared to the No-Build option.

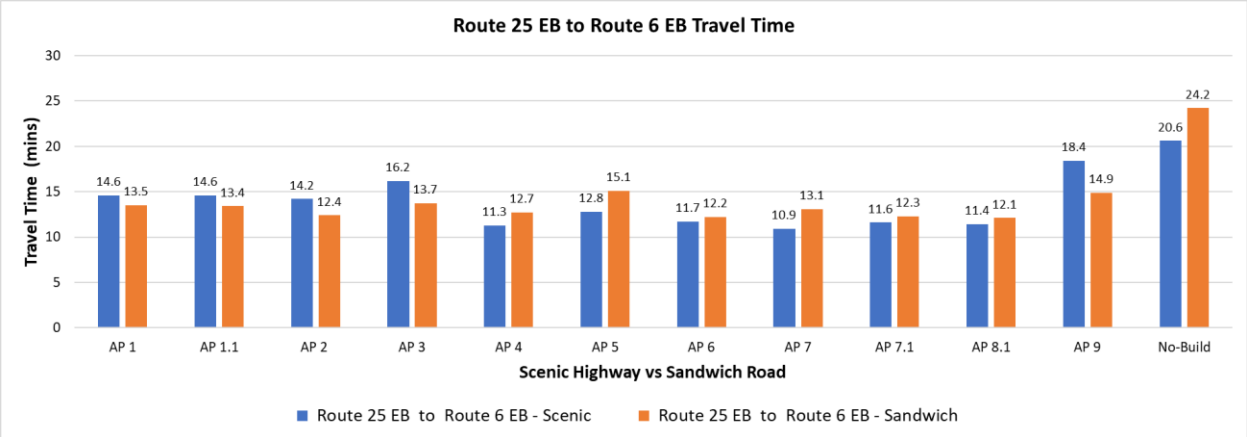


Figure 32 – Travel Time from Route 25 EB to Route 6 EB via Scenic Highway vs Sandwich Road

- **Route 28 NB to Route 3 NB**
  Similar to the previous diagonal movement, the route from Route 28 NB to Route 3 NB is summarized relative to the Scenic Highway and Sandwich Road canal-side routes. As illustrated in Figure 33, traffic flow predominantly favors Sandwich Road over Scenic Highway. This routing alignment echoes findings from previous origin-destination studies, indicating consistent preference for Sandwich Road across all analysis pairings, including the No-Build scenario. The longer travel times associated with analysis pairings using Scenic Highway are primarily attributed to the lack of a direct connection to Scenic eastbound. In contrast, a quicker route is available via Sandwich Road utilizing either BS-2 or BS-2.2 in Bourne South and SS-1 or SS-3.1A in Sagamore South for analysis pairings. The discrepancy in travel times between Scenic Highway and Sandwich

Road is notably wider in analysis pairings compared to the No-Build condition, indicating a strong preference for Sandwich Road. Furthermore, travel times via Sandwich Road also demonstrate slightly improved performance compared to the No-Build scenario. The models are showing a longer travel time on Scenic than No-Build may be due to small sample size compared to larger sample size in No-Build that dampens the outlier travel times.

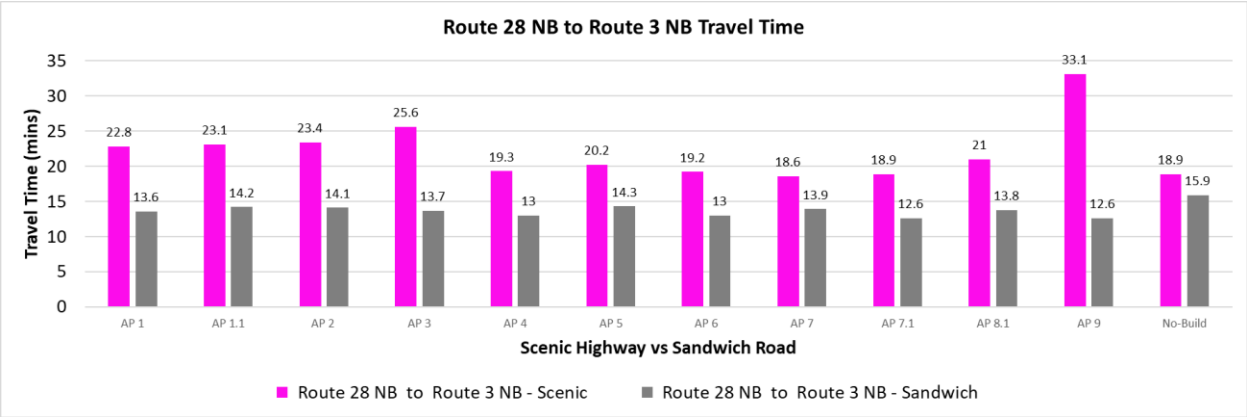


Figure 33 – Travel Time from Route 28 NB to Route 3 NB via Scenic Highway vs Sandwich Road

- **Route 3 SB to Route 28 SB**

  Figure 34 illustrates the comparison of travel times for diagonal movement from Route 3 SB to Route 28 SB, whether using Scenic Highway or Sandwich Highway. It shows that the preferred route in this scenario is via Scenic Highway rather than Sandwich Highway. The graph also indicates that Bourne North alternatives such as BN-6.1, BN-13.1, and BN-14.4 have minimal impact on travel times across all analysis pairings, as traffic flow still predominantly utilizes Belmont Circle. This is because the access to the Bourne Bridge/Route 28 SB does not change between the alternatives. Furthermore, all analysis pairings demonstrate a decrease in travel time compared to the No-Build condition. Similar to previous analyses, Figure 34 underscores a notable difference in travel times between Scenic Highway and Sandwich Road in analysis pairings compared to the No-Build condition, indicating that this may be preferential route in the future for the Scenic route.

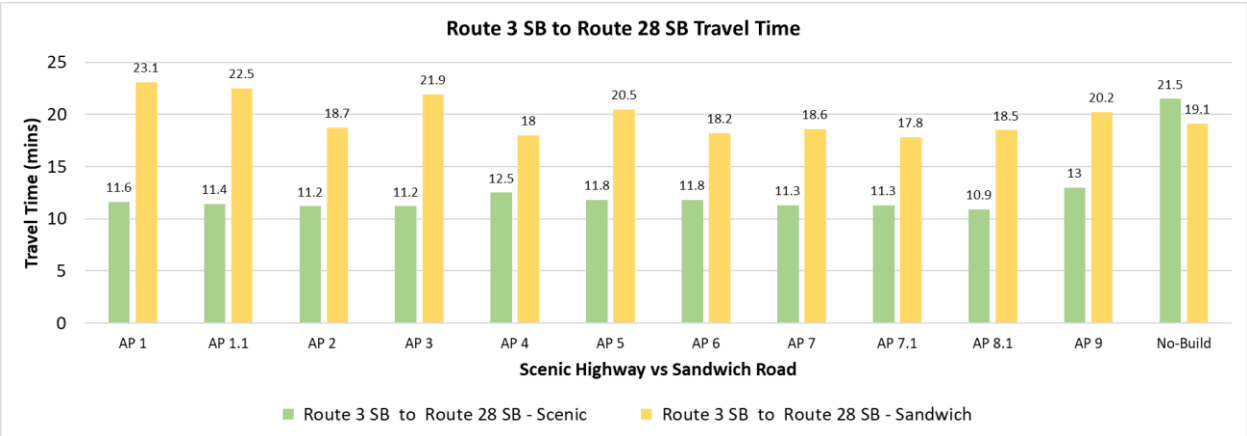


Figure 34 – Travel Time from Route 3 SB to Route 28 SB via Scenic Highway vs Sandwich Road

- **Route 6 WB to Route 25 WB**
  The analysis presented in Figure 35 indicates that for the journey from Route 6 WB to Route 25 WB, traffic tends to use Scenic Highway over Sandwich Highway, which aligns with findings from previous origin-destination reports. This preference contrasts with the No-Build condition depicted in Figure 35, where Sandwich Highway is favored primarily due to congestion at Belmont Circle. However, in all Build analysis scenarios, Scenic Highway serves as an alternative route to bypass Belmont Circle, resulting in approximately similar travel times across all analysis pairings. Nevertheless, it's evident that travel times are generally shorter compared to the No-Build scenario when using Scenic Highway. The comparison of travel times via Sandwich Highway is influenced by other traffic movements within the network because while the Scenic Highway is preferred choice this O-D, Sandwich is preferred by locals. For AP 2, AP 5 and AP 8.1 all have common SS-1.1 option which uses Sandwich compared to No-Build condition.

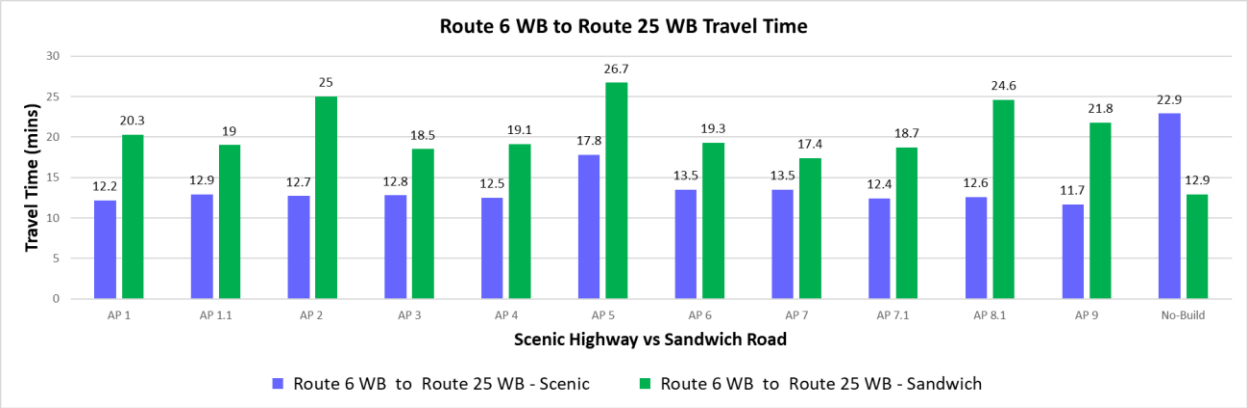


Figure 35 – Travel Time from Route 6 WB to Route 25 WB via Scenic Highway vs Sandwich Road

Through Bridge Crossings

- **Route 25 to Route 28 (SB and NB)**
  The travel duration from Route 25 EB to Route 28 SB remains similar across all analysis pairings compared to the No-Build option, with an average reduction in travel time of about 47%. Compared to No-Build, the elimination of the Bourne Rotary directly results in reduced bridge crossing times. Interestingly, despite the preference for using Sandwich Road, as noted in the origin destination report for diagonal movement of Route 25 EB to Route 6 EB, the analysis pairings AP 1, AP 1.1, AP 2, and AP 3 don't notably affect travel time for Route 25 EB to Route 28 SB, even due to congestion at Belmont Circle with BN-6.1 potentially due to queues on the mainline within BN-6.1 alternative being contained in the off-ramp lanes, not disrupting mainline through traffic. For Route 28 NB to Route 25 WB, there's an average travel time reduction of approximately 55% compared to the No-Build scenario. With the exception of AP 3, which exhibits slightly higher travel times, all other analysis pairings show an average reduction of 6.4 minutes. It's worth noting that this may be because AP 3 utilizes P6 volumes, representing the highest traffic volumes across all volume pairings.

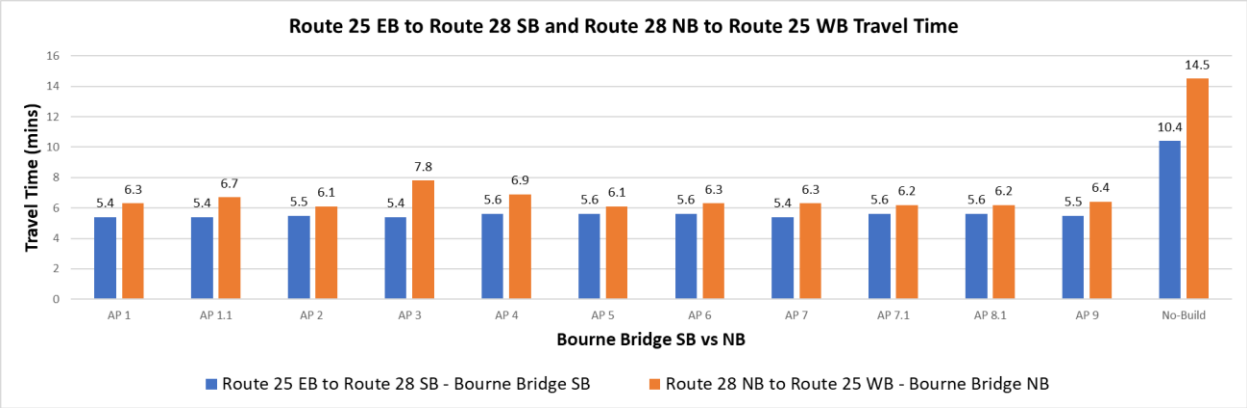


Figure 36 – Route 25 EB to Route 28 SB and Route 28 NB to Route 25 WB – Bourne Bridge

- **Route 3 SB to Route 6 (SB and NB)**
  The travel time from Route 3 SB to Route 6 EB is estimated to experience a significant reduction of approximately 58% compared to the No-Build scenario, while the travel time for northbound movement from Route 6 WB to Route 3 NB saw a more modest reduction of about 36%. It's worth noting that AP 5 exhibits higher values compared to other analysis pairings and the No-Build condition for the northbound movement, indicating a need for further investigation. Both AP 5 and AP 8.1 utilize volume pairing P2 as both include SS-1.1. Additionally, the travel time across the Sagamore Bridge is similar under each alternative pairing, suggesting no major impact on through movements as a result of different analysis pairings.

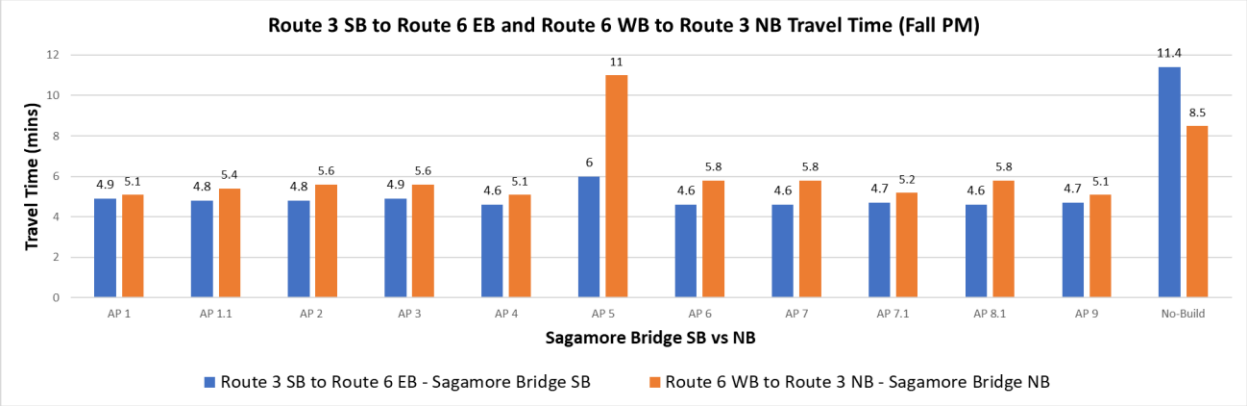


Figure 37 – Route 3 SB to Route 6 EB and Route 6 WB to Route 3 NB – Sagamore Bridge

Key highlights:

1. Route 25 EB to Route 6 EB (Figure 32):
    - Travel time via Scenic Highway consistently improves across all analysis pairings compared to the No-Build condition.
    - Routes utilizing Scenic Highway show higher travel times for analysis pairings AP 1 to AP 3 due to congestion at Belmont Circle but improves for analysis pairings from AP 4 to AP 9 overall.
2. Route 28 NB to Route 3 NB (Figure 33):
    - Traffic flow predominantly favors Sandwich Road over Scenic Highway, aligning with previous studies of Origin and Destination submitted.
    - Longer travel times via Scenic Highway are attributed to the lack of a direct connection eastbound forcing vehicles to utilize Belmont Circle.
    - Travel times via Sandwich Road demonstrate slightly improved performance compared to the No-Build scenario.
3. Route 3 SB to Route 28 SB (Figure 34):
    - The preferred route is via Scenic Highway over Sandwich Highway.
    - Bourne North alternatives have minimal impact on travel times.
    - All analysis pairings show a decrease in travel time compared to the No-Build condition.
4. Route 6 WB to Route 25 WB (Figure 35):
    - Traffic tends to favor Scenic Highway over Sandwich Highway, contrasting with the No-Build condition due to direct connection from Scenic Highway to Route 25 WB provided by all BN.
    - Travel times are generally shorter compared to the No-Build scenario when using Scenic Highway.
5. Travel Time over Bourne Bridge (Figure 36):
    - Travel time is consistent across all analysis pairings and shows a reduction of approximately 47% for the southbound movement from Route 25 EB to Route 28 SB.
    - The northbound travel time from Route 28 NB to Route 25 WB experiences an average travel time reduction of approximately 55% compared to the No-Build.
    - AP 3 shows slightly higher travel times possibly due to higher traffic volumes represented by P6 volume pairing.
6. Travel Time over Sagamore Bridge (Figure 37):
    - Route 3 SB to Route 6 EB travel time is reduced by approximately 57% compared to No-Build.
    - An average reduction of travel time along the northbound movement from Route 6 WB to Route 3 NB of approximately 35% is estimated across all alternatives.

- Similar to the Bourne Bridge, Sagamore Bridge travel times remained consistent across different analysis pairings. This is a great benefit seen with the alternatives compared to No-Build but no appreciable difference between the alternatives.

Queue Length of Analysis Pairings

VISSIM Network average and maximum vehicle queue length graphics are included in **Attachment D**. The following observations have been made based on the queues for the Fall PM peak:

- All pairings including BN-6.1 exhibit long vehicle queues during the Fall PM peak on Route 25 EB at Exit 10 and Route 25 WB off ramp at the entrance of Belmont Circle.
- Extensive vehicle queues are noted along Sandwich Road in Sagamore South under AP 5 related to SS-1.1 which does not provide the Cranberry Highway Extension.
- Other notable observations include sandwich road queues in Sagamore South. SN-8A queues extending from State Road to Route 3 NB. Queues under SN-1A extending to Route 3 NB. Similarly, queues at the tech school drive when offset from Sandwich Rd. This is alleviated when the roundabout is installed making Tech School and Sandwich a 4-legged roundabout. AP 6 and AP 8.1 both show significant queues on scenic EB upstream of Church Lane. It should be noted, and we can likely disclaim this as additional signal refinement necessary.

Conclusions

The analysis of various analysis pairings sheds light on the performance and effectiveness of alternative transportation scenarios in optimizing network traffic flow. Overall, the findings reveal several key insights into the impacts of different alternatives on travel times and congestion levels across critical routes within the network. Firstly, it is evident that all analysis pairings result in higher volumes of processed vehicles compared to the No-Build condition, indicating potential improvements in network efficiency. However, pairings incorporating alternative BN-6.1 exhibit congestion at Belmont Circle, adversely affecting network performance. Additionally, network-wide evaluations reveal variations in vehicle processing efficiency among different analysis pairings. While some pairings exhibit marginal improvements, others experience delays and inefficiencies, primarily due to the inclusion of specific alternatives such as BN-6.1. This underscores the importance of carefully selecting alternatives to minimize disruptions and enhance overall network performance. Moreover, the analysis of critical routes highlights the impact of alternative configurations on travel times and traffic flow dynamics. Routes utilizing Scenic Highway show improvements in travel times, while longer travel times via other routes underscore the importance of direct connections and efficient route planning.

In conclusion, the findings from this analysis provide valuable insights into the performance of alternative transportation scenarios in optimizing network efficiency and mitigating congestion. Addressing key bottlenecks, optimizing signal timings, and selecting alternatives judiciously are essential steps towards enhancing overall network performance and improving the travel experience. Initial observations suggest that permutations involving BN-6.1 tend to experience the highest levels of congestion and process the fewest number of vehicles. This is primarily attributed to the increased volumes within Belmont Circle and the maintenance of the existing geometry and routing for vehicles traveling from Route 25 EB to Scenic Highway. With these results and clear indication of operational shortcomings with BN-6.1, it is recommended that this alternative be removed from consideration. With the removal of BN-6.1, analysis and comparison of alternatives can be simplified as traffic volumes and route choice across the remaining alternative pairings are more similar. Furthermore, it is evident that although the Fall PM has been designated as the design time period, additional calibrations and refinements are necessary for the Summer Saturday models to provide a more accurate depiction of the worst-case scenario.

Attachments

Attachment A – 2050 No-Build and Build Fall PM and Summer SAT Traffic Volumes
Attachment B – Alternative Graphics
Attachment C – Results Summary Table
Attachment D – VISSIM Queue Lengths Summary Graphics

Attachment A
2050 No-Build and Build Fall PM and Summer SAT Traffic Volumes

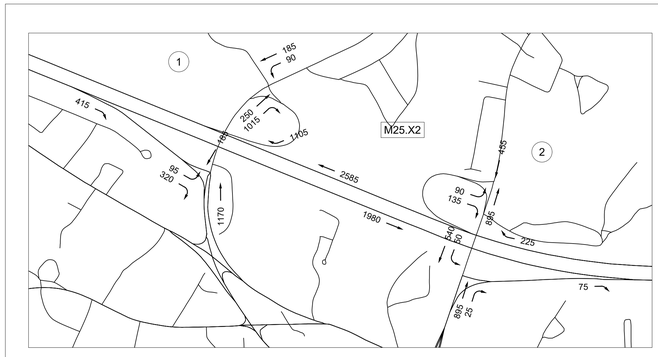
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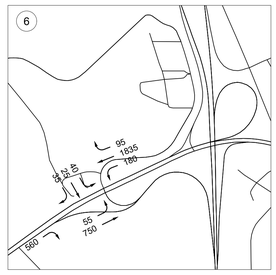
Cape Cod Canal Program Management

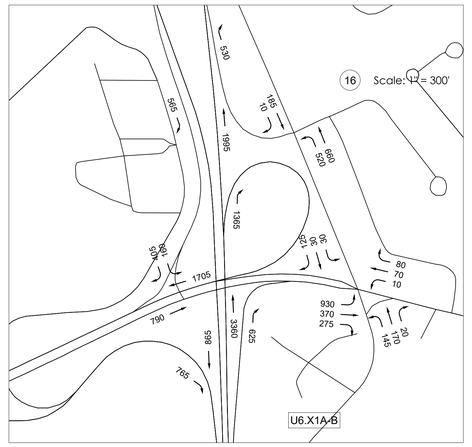
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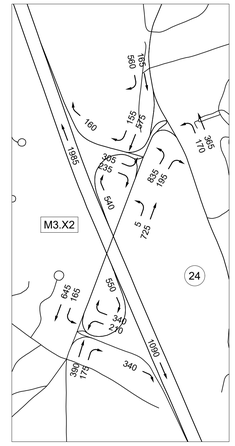
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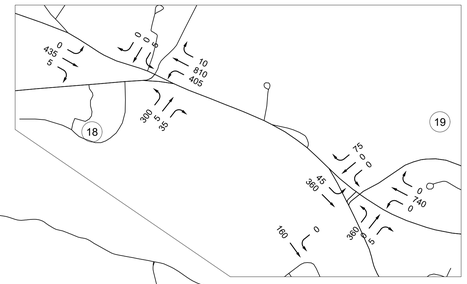
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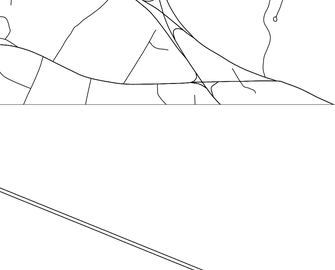


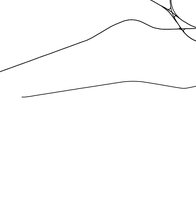


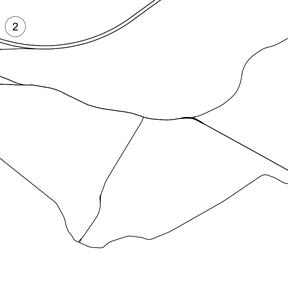


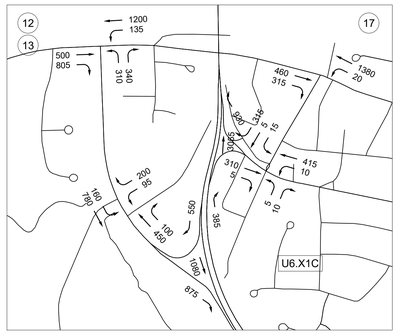


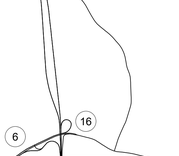


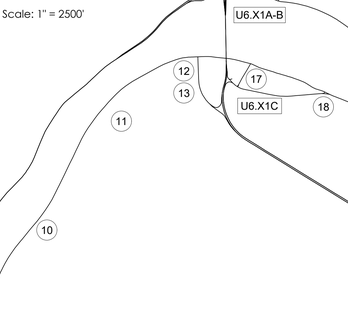


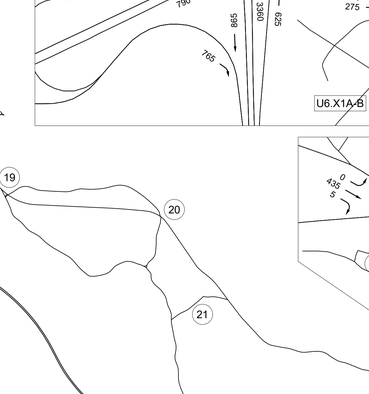


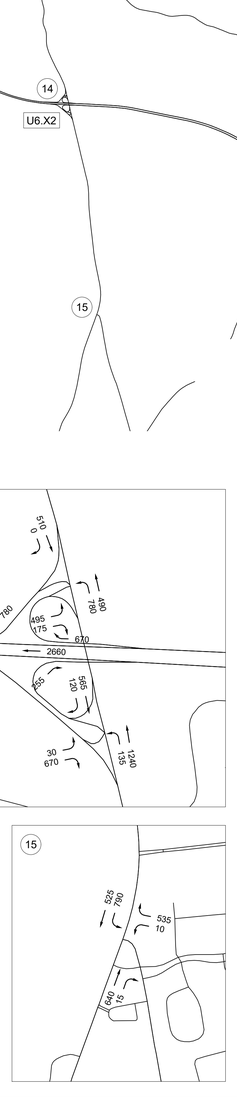














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2050 Summ SAT 2022-02-07
No-Build Conditions

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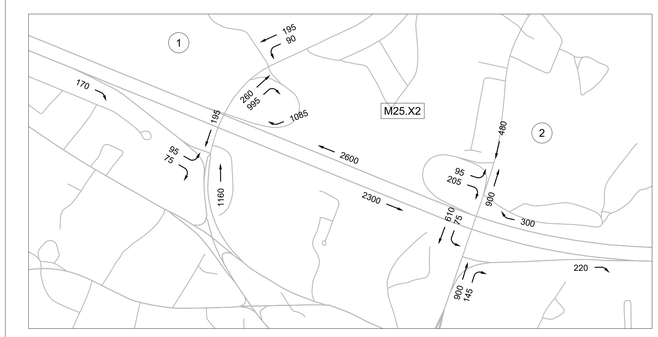
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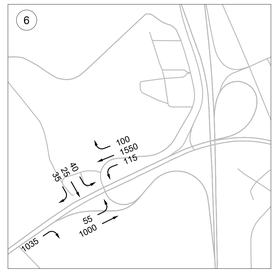
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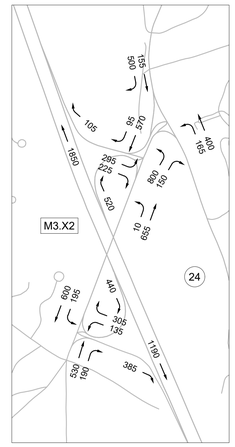
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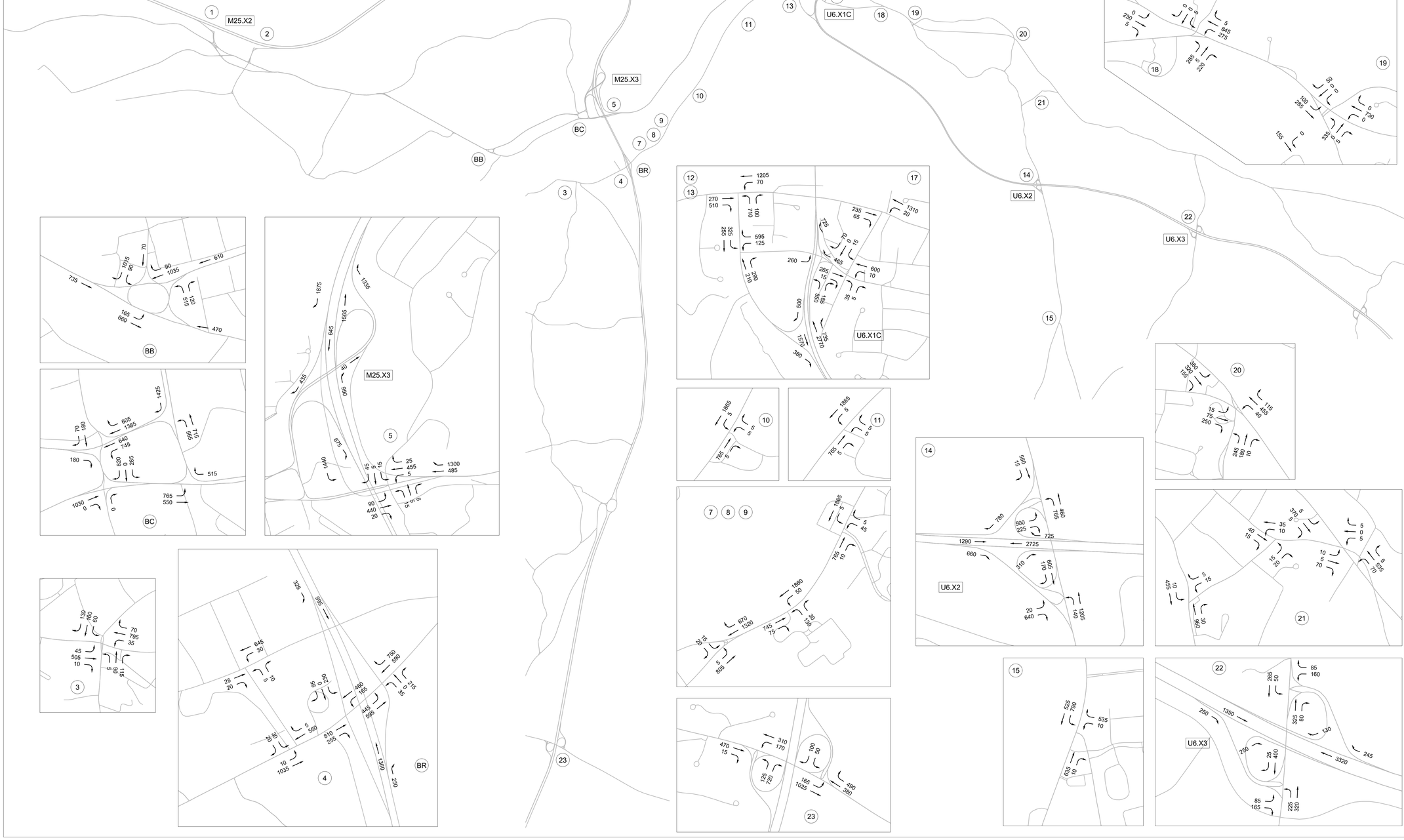
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2050 Summer SAT
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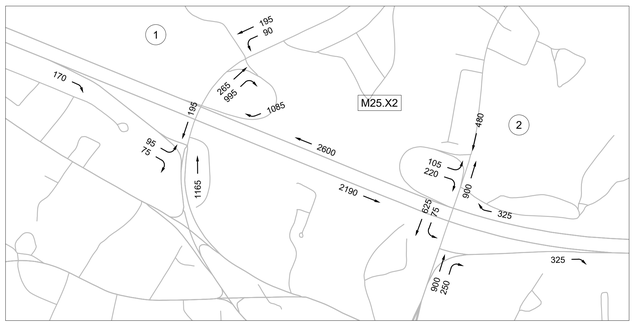
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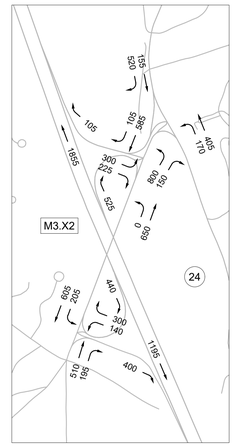
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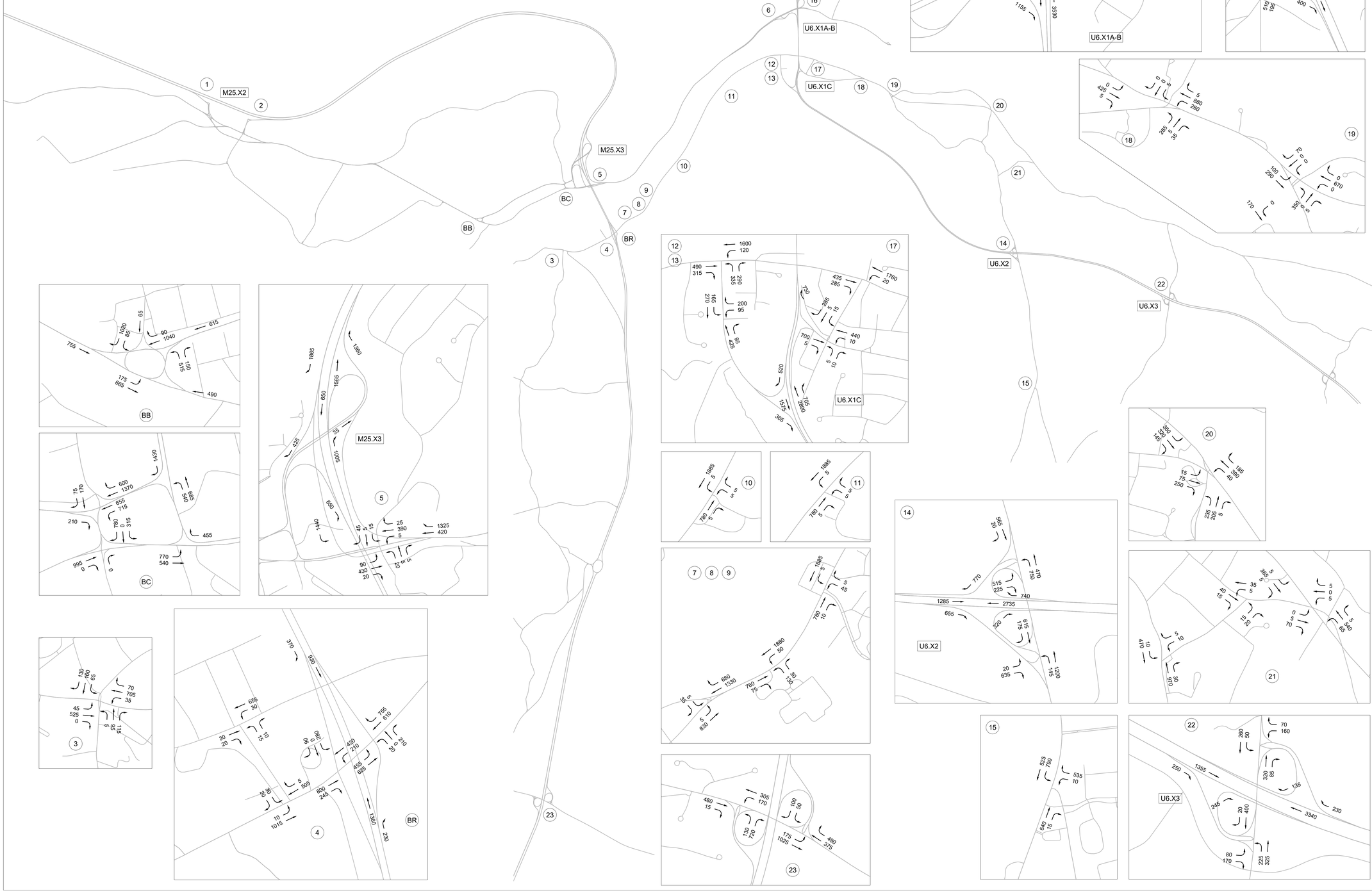
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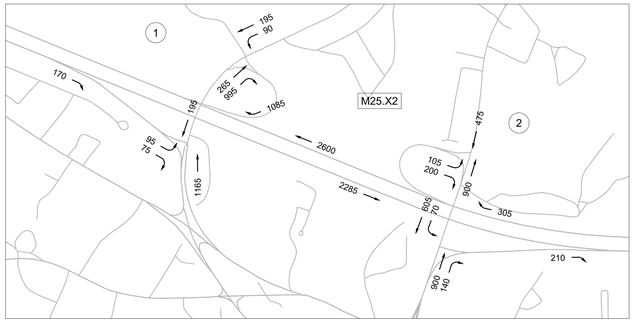


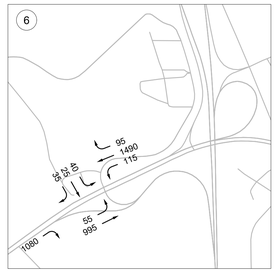
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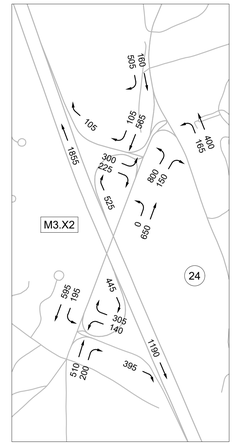
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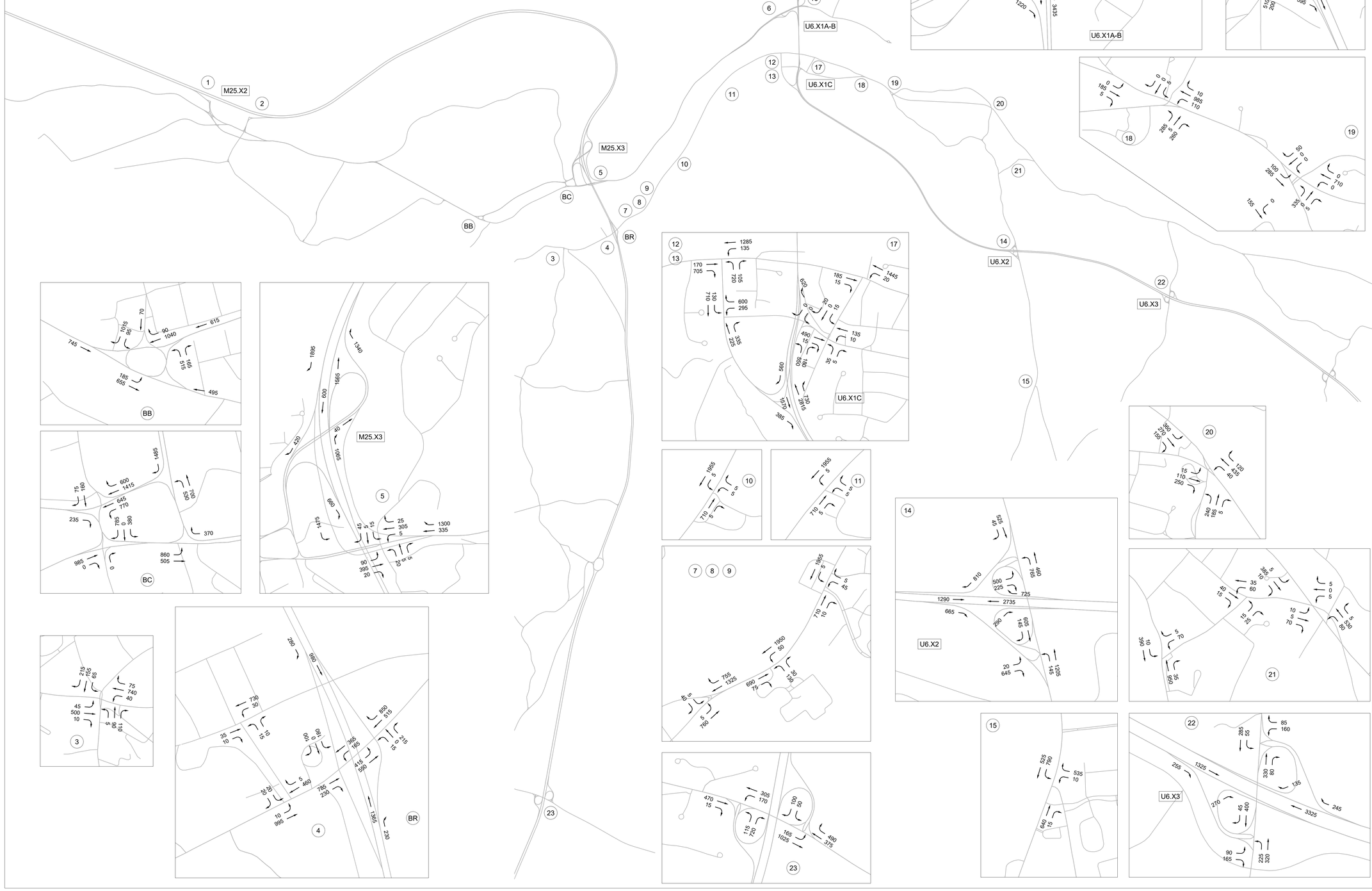
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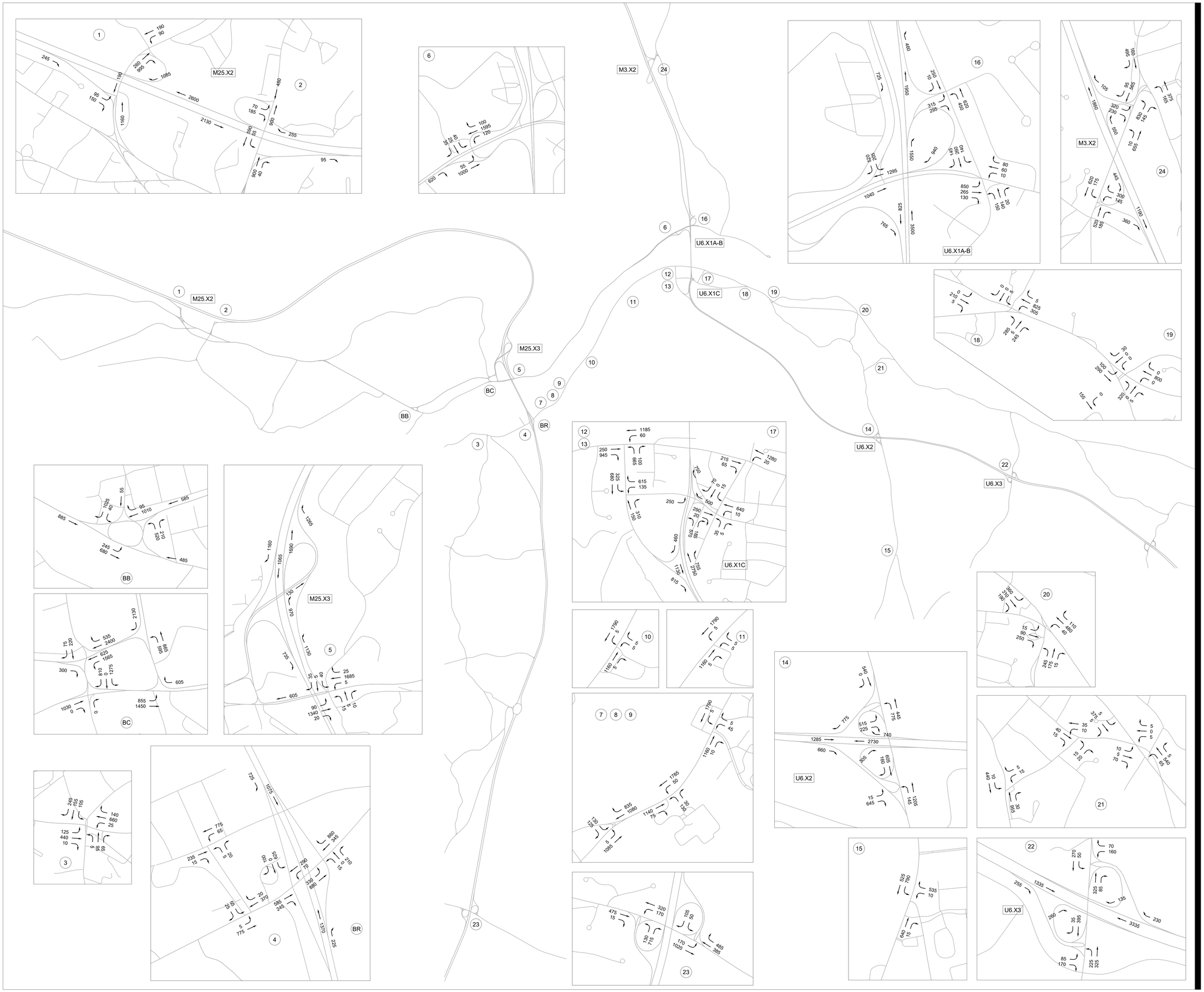


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2050 Fall PM
Pairing 4 Build Conditions
2024-01-05

PRE-DECISIONAL & DELIBERATIVE

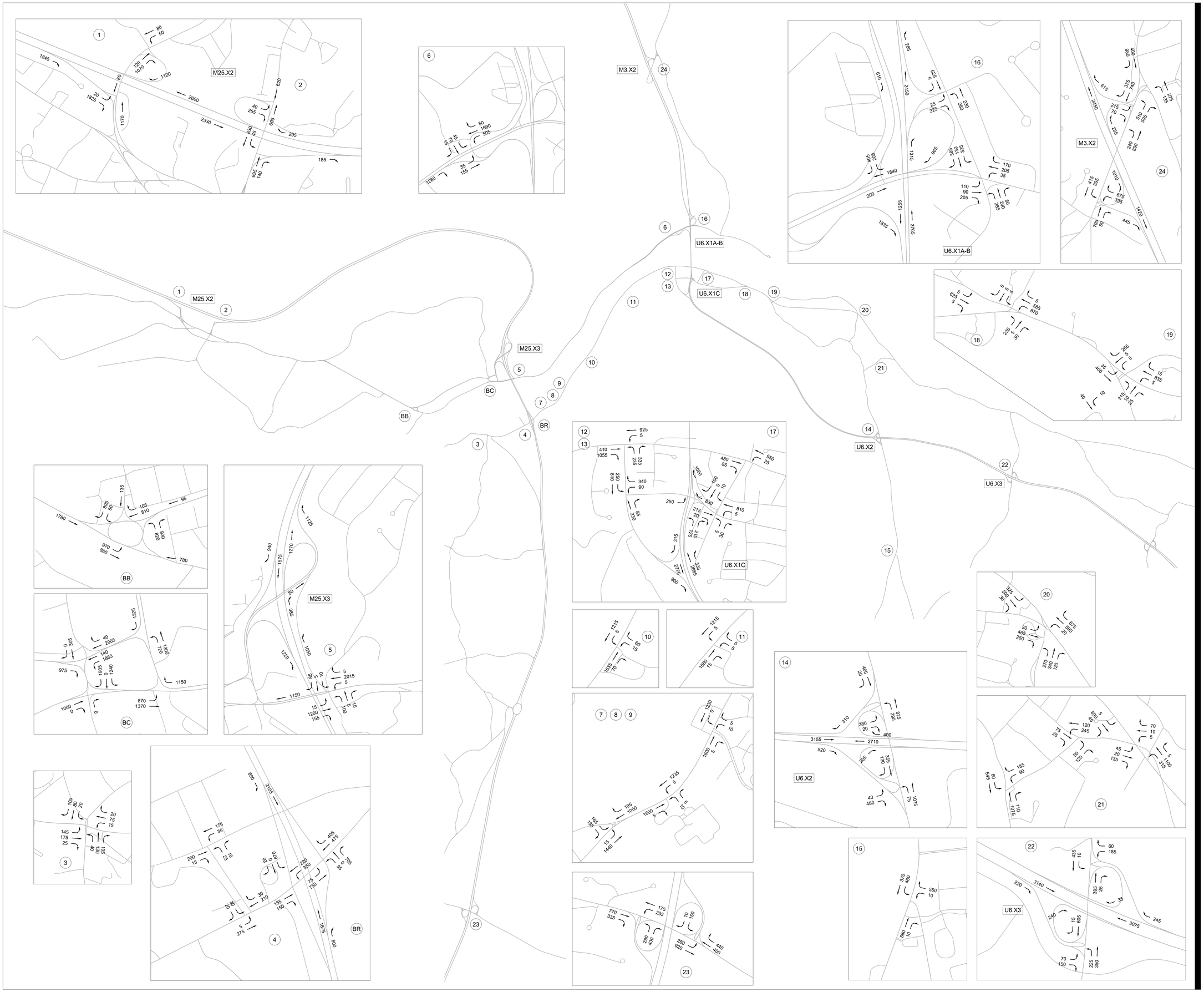


MassDOT

Cape Cod Canal Program Management

2050 Summer SAT
Pairing 4 Build Conditions
2023-10-20

PRE-DECISIONAL & DELIBERATIVE

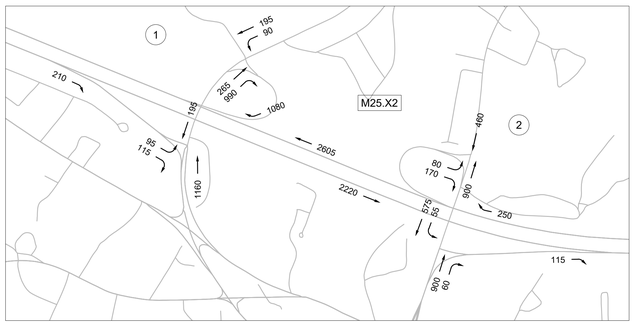


MassDOT

Cape Cod Canal Program Management

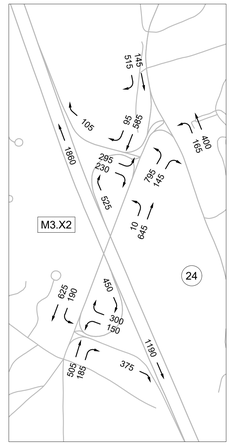
2050 Fall PM
Pairing 5 Build Conditions
2024-01-05

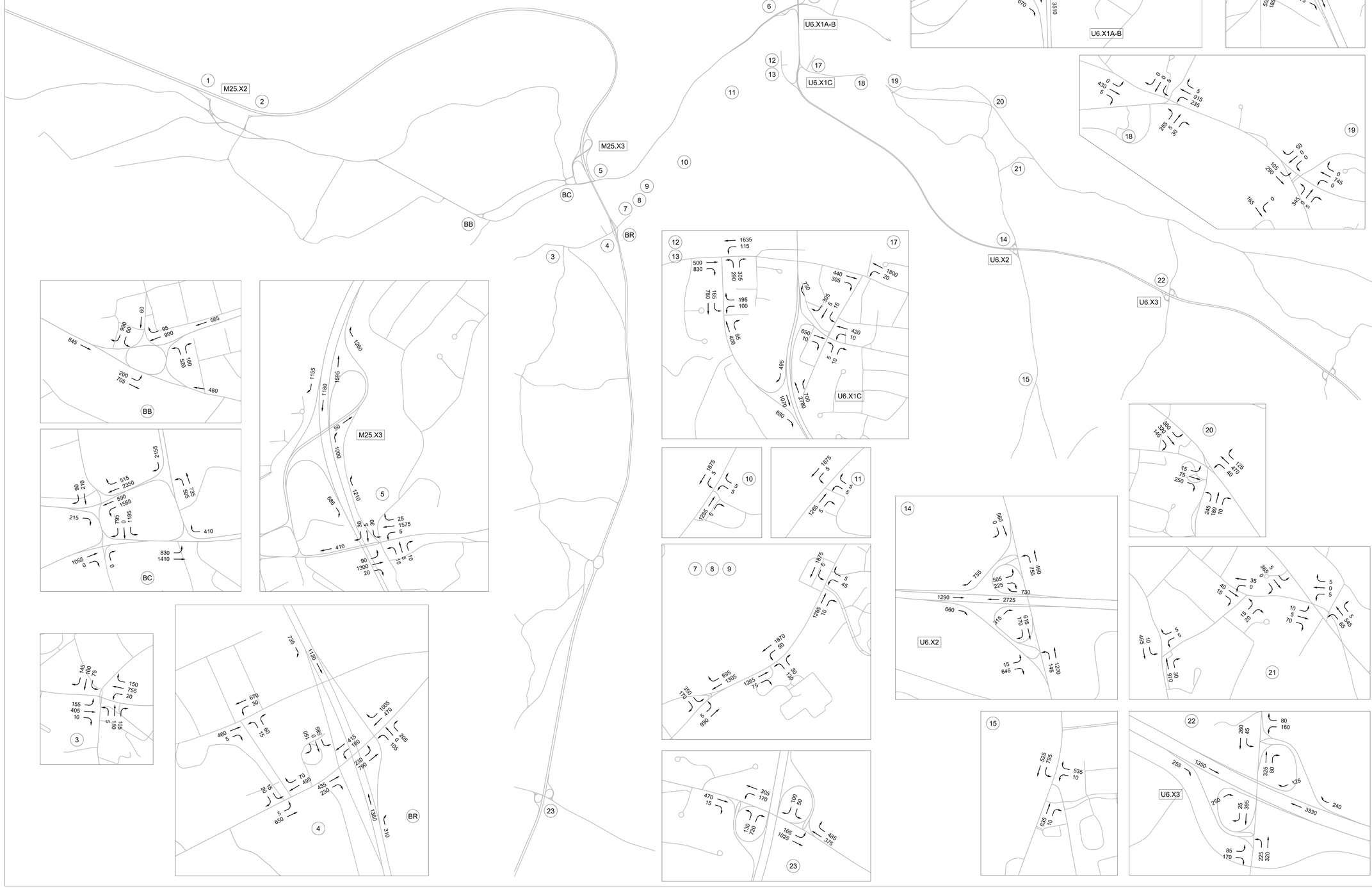
PRE-DECISIONAL & DELIBERATIVE









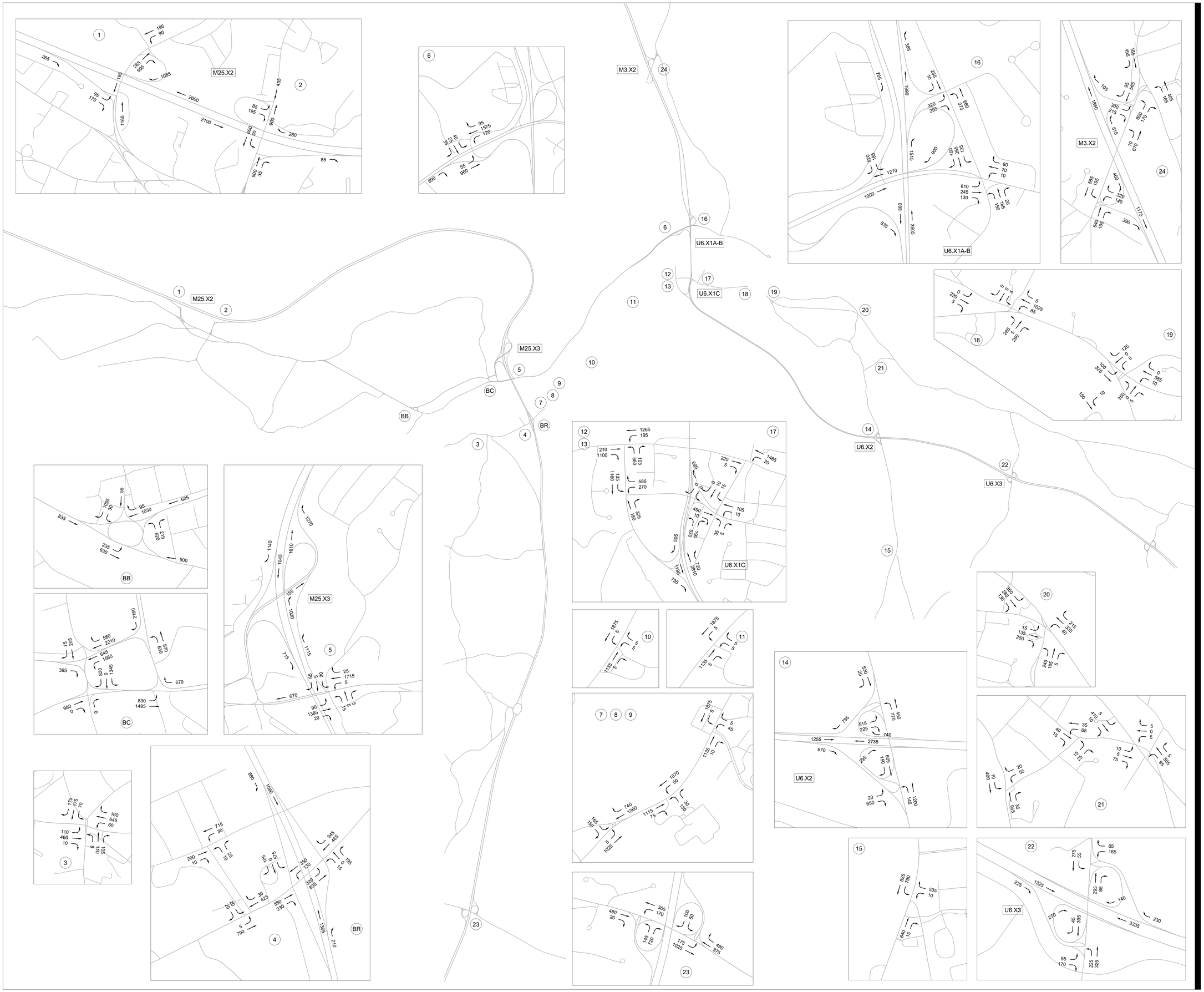


MassDOT

Cape Cod Canal Program Management

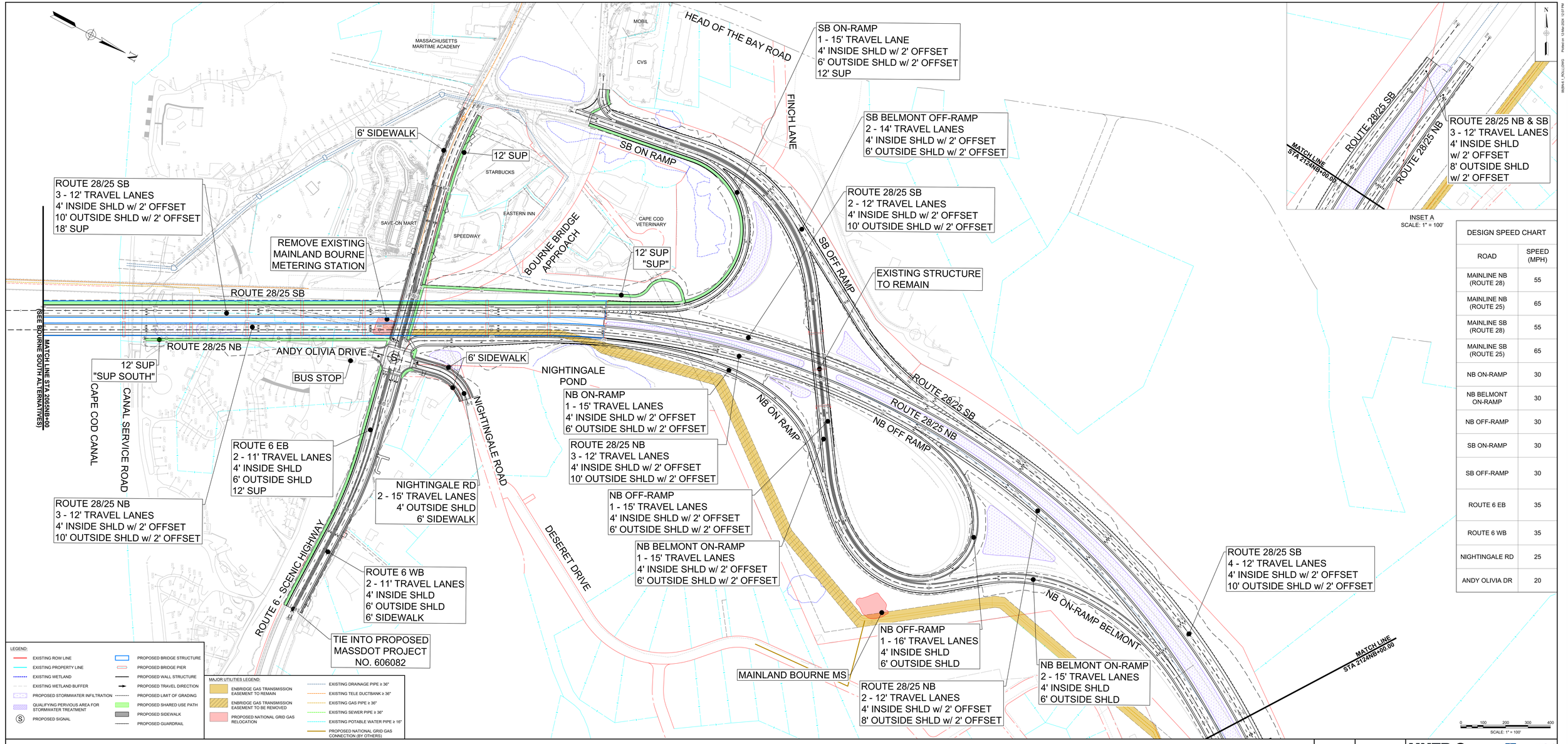
2050 Fall PM
Pairing 6 Build Conditions
2024-01-05

PRE-DECISIONAL & DELIBERATIVE



Attachment B
Alternative Graphics

PRE-DECISIONAL AND DELIBERATIVE



INSET A
SCALE: 1" = 100'

DESIGN SPEED CHART	
ROAD	SPEED (MPH)
MAINLINE NB (ROUTE 28)	55
MAINLINE NB (ROUTE 25)	65
MAINLINE SB (ROUTE 28)	55
MAINLINE SB (ROUTE 25)	65
NB ON-RAMP	30
NB BELMONT ON-RAMP	30
NB OFF-RAMP	30
SB ON-RAMP	30
SB OFF-RAMP	30
ROUTE 6 EB	35
ROUTE 6 WB	35
NIGHTINGALE RD	25
ANDY OLIVIA DR	20

LEGEND:
- EXISTING ROW LINE
- EXISTING PROPERTY LINE
- EXISTING WETLAND
- EXISTING WETLAND BUFFER
- PROPOSED STORMWATER INFILTRATION
- QUALIFYING PERVIOUS AREA FOR STORMWATER TREATMENT
- PROPOSED SIGNAL
- PROPOSED BRIDGE STRUCTURE
- PROPOSED BRIDGE PIER
- PROPOSED WALL STRUCTURE
- PROPOSED TRAVEL DIRECTION
- PROPOSED LIMIT OF GRADING
- PROPOSED SHARED USE PATH
- PROPOSED SIDEWALK
- PROPOSED GUARDRAIL

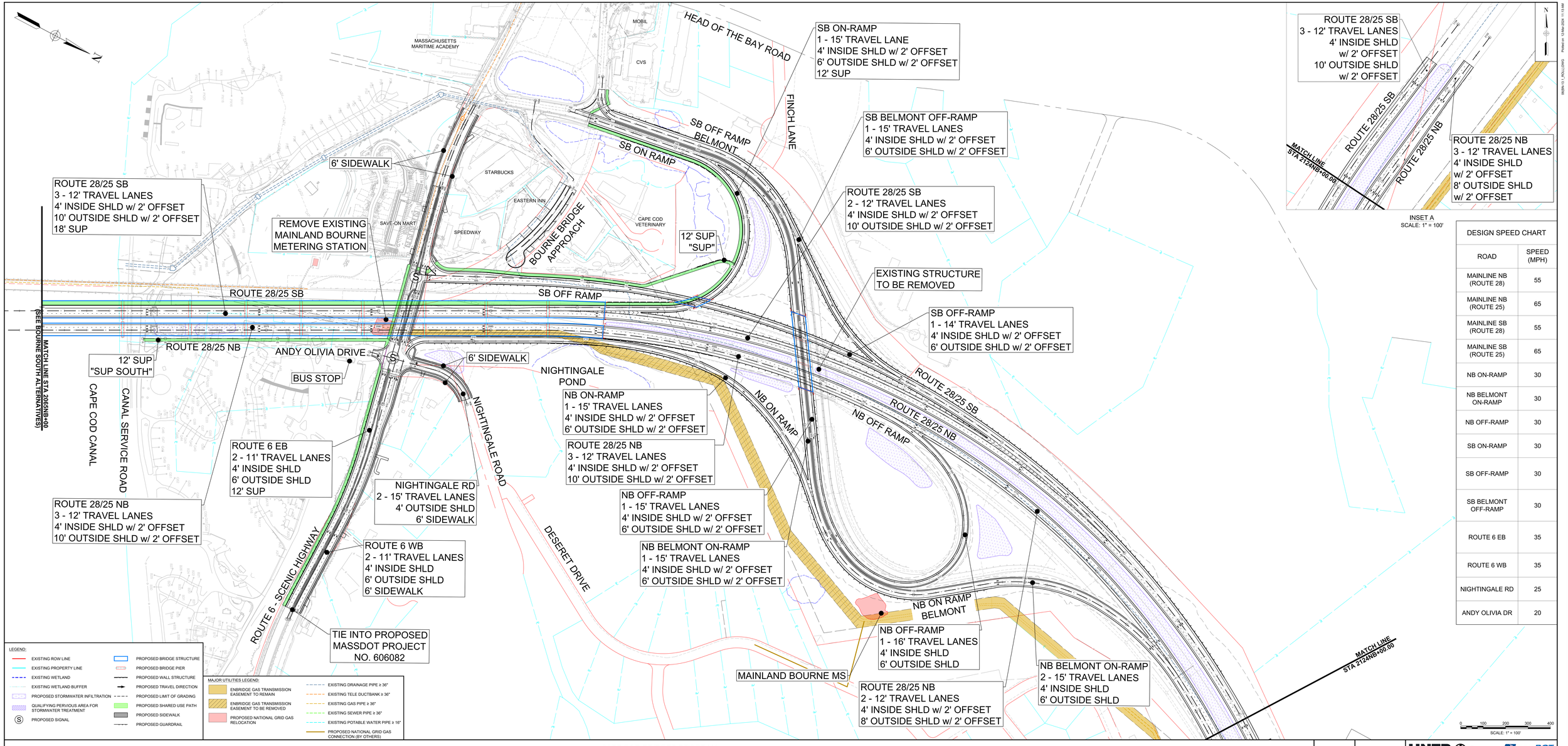
MAJOR UTILITIES LEGEND:
- ENBRIDGE GAS TRANSMISSION EASEMENT TO REMAIN
- ENBRIDGE GAS TRANSMISSION EASEMENT TO BE REMOVED
- PROPOSED NATIONAL GRID GAS RELOCATION
- EXISTING DRAINAGE PIPE ≥ 36"
- EXISTING TELE DUCTBANK ≥ 36"
- EXISTING GAS PIPE ≥ 36"
- EXISTING SEWER PIPE ≥ 36"
- EXISTING POTABLE WATER PIPE ≥ 16"
- PROPOSED NATIONAL GRID GAS CONNECTION (BY OTHERS)

CAPE COD BRIDGES PROGRAM
BOURNE NORTH ROLL PLAN
ALTERNATIVE BN-6.1

PRE-DECISIONAL & DELIBERATIVE

SCALE: 1" = 100'	HNTB Stantec MassDOT		
DATE: 5-Mar-24	DRAWN BY: NLA	CHECKED BY: DF	SHEET NO:

PRE-DECISIONAL AND DELIBERATIVE



INSET A
SCALE: 1" = 100'

DESIGN SPEED CHART	
ROAD	SPEED (MPH)
MAINLINE NB (ROUTE 28)	55
MAINLINE NB (ROUTE 25)	65
MAINLINE SB (ROUTE 28)	55
MAINLINE SB (ROUTE 25)	65
NB ON-RAMP	30
NB BELMONT ON-RAMP	30
NB OFF-RAMP	30
SB ON-RAMP	30
SB OFF-RAMP	30
SB BELMONT OFF-RAMP	30
ROUTE 6 EB	35
ROUTE 6 WB	35
NIGHTINGALE RD	25
ANDY OLIVIA DR	20

LEGEND:

- EXISTING ROW LINE
- EXISTING PROPERTY LINE
- EXISTING WETLAND
- EXISTING WETLAND BUFFER
- PROPOSED STORMWATER INFILTRATION
- QUALIFYING PERVIOUS AREA FOR STORMWATER TREATMENT
- PROPOSED SIGNAL
- PROPOSED BRIDGE STRUCTURE
- PROPOSED BRIDGE PIER
- PROPOSED WALL STRUCTURE
- PROPOSED TRAVEL DIRECTION
- PROPOSED LIMIT OF GRADING
- PROPOSED SHARED USE PATH
- PROPOSED SIDEWALK
- PROPOSED GUARDRAIL

MAJOR UTILITIES LEGEND:

- ENBRIDGE GAS TRANSMISSION EASEMENT TO REMAIN
- ENBRIDGE GAS TRANSMISSION EASEMENT TO BE REMOVED
- PROPOSED NATIONAL GRID GAS RELOCATION
- EXISTING DRAINAGE PIPE ≥ 36"
- EXISTING TELE DUCTBANK ≥ 36"
- EXISTING GAS PIPE ≥ 36"
- EXISTING SEWER PIPE ≥ 36"
- EXISTING POTABLE WATER PIPE ≥ 16"
- PROPOSED NATIONAL GRID GAS CONNECTION (BY OTHERS)

CAPE COD BRIDGES PROGRAM
BOURNE NORTH ROLL PLAN
ALTERNATIVE BN-13.1

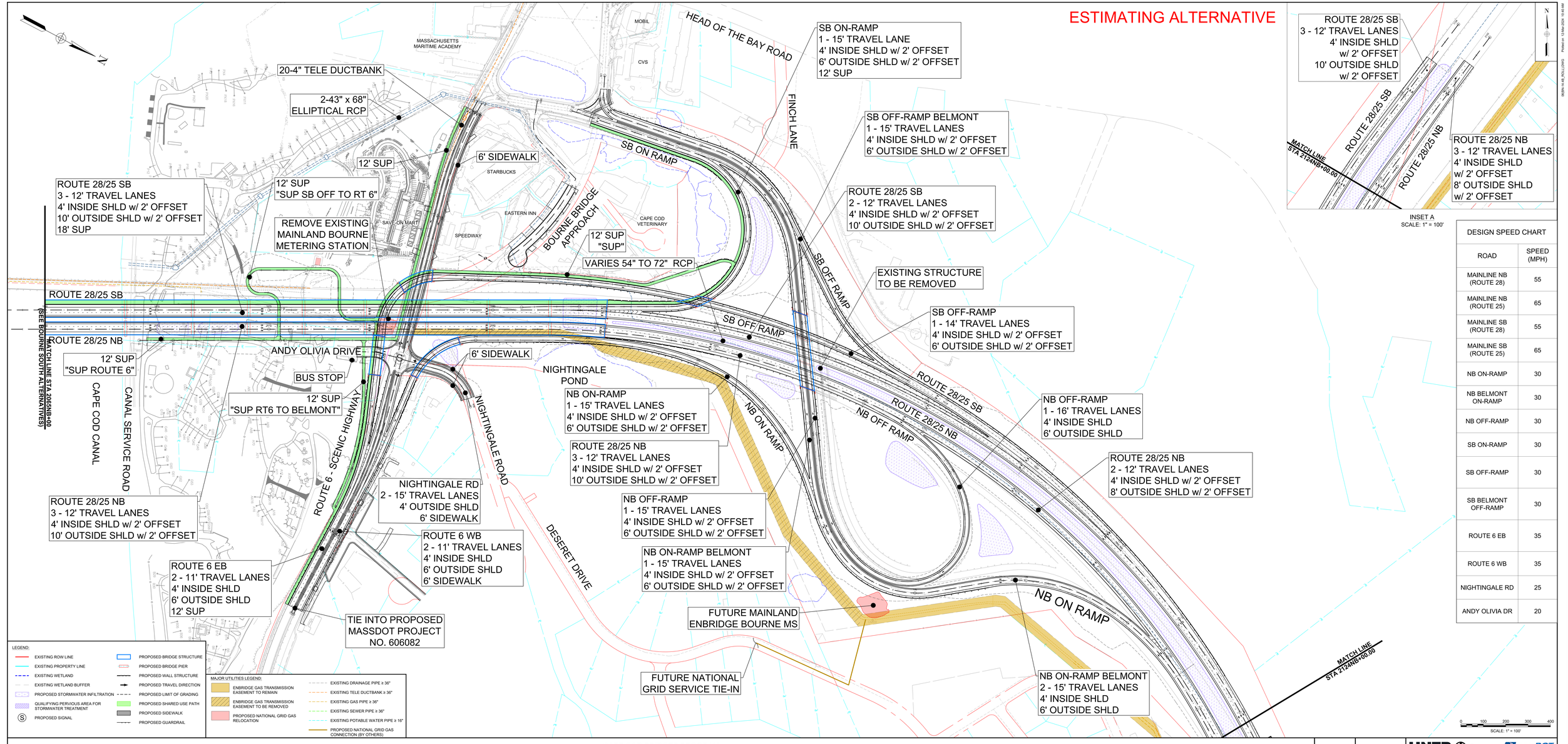
PRE-DECISIONAL & DELIBERATIVE

SCALE: 1" = 100'
DATE: 5-Mar-24
DRAWN BY: AKR
CHECKED BY: DAF
SHEET NO:

HNTB Stantec MassDOT

PRE-DECISIONAL AND DELIBERATIVE

ESTIMATING ALTERNATIVE



DESIGN SPEED CHART	
ROAD	SPEED (MPH)
MAINLINE NB (ROUTE 28)	55
MAINLINE NB (ROUTE 25)	65
MAINLINE SB (ROUTE 28)	55
MAINLINE SB (ROUTE 25)	65
NB ON-RAMP	30
NB BELMONT ON-RAMP	30
NB OFF-RAMP	30
SB ON-RAMP	30
SB OFF-RAMP	30
SB BELMONT OFF-RAMP	30
ROUTE 6 EB	35
ROUTE 6 WB	35
NIGHTINGALE RD	25
ANDY OLIVIA DR	20

LEGEND:

- EXISTING ROW LINE
- EXISTING PROPERTY LINE
- EXISTING WETLAND
- EXISTING WETLAND BUFFER
- PROPOSED STORMWATER INFILTRATION
- QUALIFYING PERVIOUS AREA FOR STORMWATER TREATMENT
- PROPOSED SIGNAL
- PROPOSED BRIDGE STRUCTURE
- PROPOSED BRIDGE PIER
- PROPOSED WALL STRUCTURE
- PROPOSED TRAVEL DIRECTION
- PROPOSED LIMIT OF GRADING
- PROPOSED SHARED USE PATH
- PROPOSED SIDEWALK
- PROPOSED GUARDRAIL

MAJOR UTILITIES LEGEND:

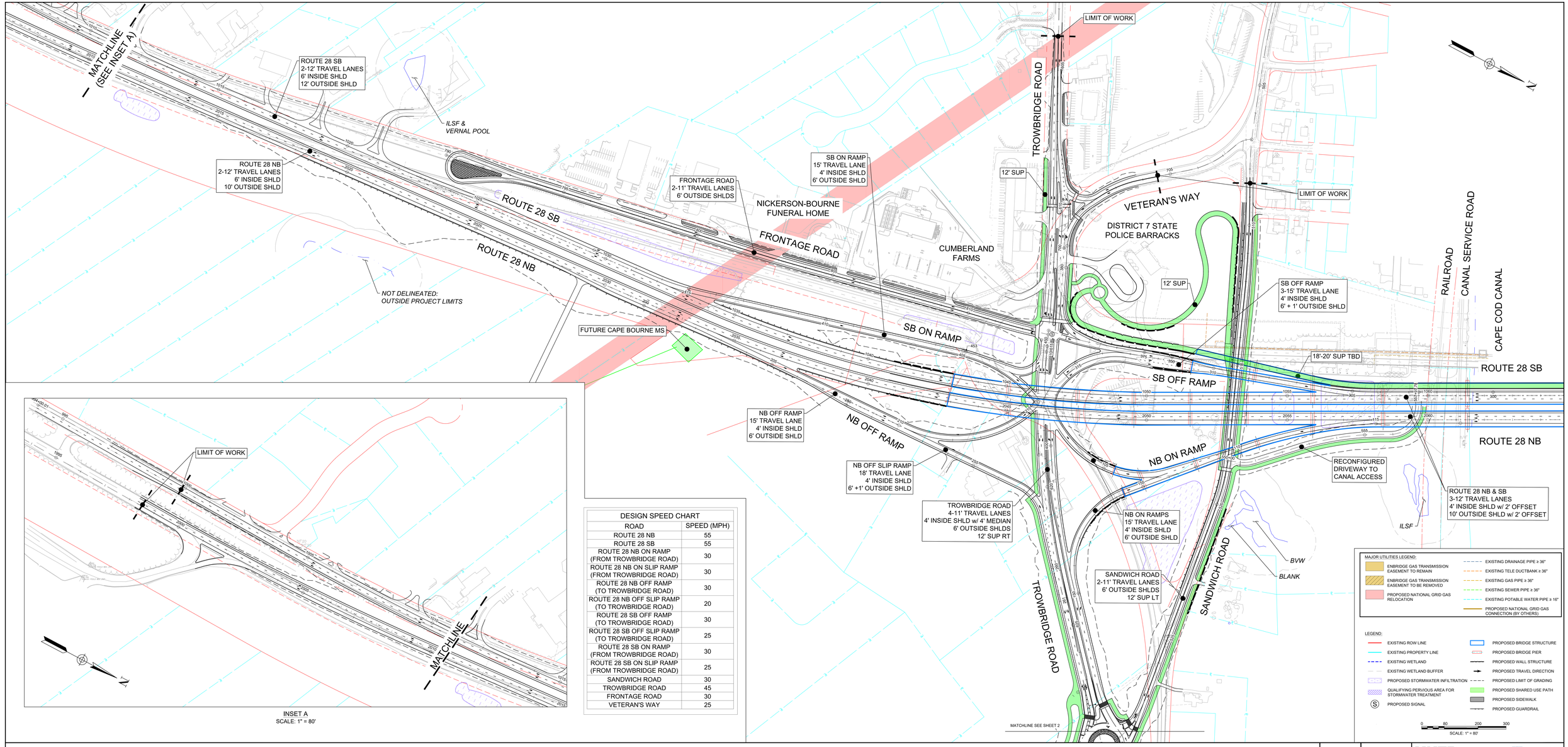
- ENBRIDGE GAS TRANSMISSION EASEMENT TO REMAIN
- ENBRIDGE GAS TRANSMISSION EASEMENT TO BE REMOVED
- PROPOSED NATIONAL GRID GAS RELOCATION
- EXISTING DRAINAGE PIPE ≥ 36"
- EXISTING TELE DUCTBANK ≥ 36"
- EXISTING GAS PIPE ≥ 36"
- EXISTING SEWER PIPE ≥ 36"
- EXISTING POTABLE WATER PIPE ≥ 16"
- PROPOSED NATIONAL GRID GAS CONNECTION (BY OTHERS)

CAPE COD BRIDGES PROGRAM
BOURNE NORTH ROLL PLAN
ALTERNATIVE BN-14.4b

PRE-DECISIONAL & DELIBERATIVE

SCALE: 1" = 100'	HNTB Stantec MassDOT		
DATE: 5-Mar-24	DRAWN BY: AKR	CHECKED BY: DAF	SHEET NO:

PRE-DECISIONAL AND DELIBERATIVE



INSET A
SCALE: 1" = 80'

DESIGN SPEED CHART	
ROAD	SPEED (MPH)
ROUTE 28 NB	55
ROUTE 28 SB	55
ROUTE 28 NB ON RAMP (FROM TROWBRIDGE ROAD)	30
ROUTE 28 NB ON SLIP RAMP (FROM TROWBRIDGE ROAD)	30
ROUTE 28 NB OFF RAMP (TO TROWBRIDGE ROAD)	30
ROUTE 28 NB OFF SLIP RAMP (TO TROWBRIDGE ROAD)	20
ROUTE 28 SB OFF RAMP (TO TROWBRIDGE ROAD)	30
ROUTE 28 SB OFF SLIP RAMP (TO TROWBRIDGE ROAD)	25
ROUTE 28 SB ON RAMP (FROM TROWBRIDGE ROAD)	30
ROUTE 28 SB ON SLIP RAMP (FROM TROWBRIDGE ROAD)	25
SANDWICH ROAD	30
TROWBRIDGE ROAD	45
FRONTAGE ROAD	30
VETERAN'S WAY	25

MAJOR UTILITIES LEGEND:
- ENBRIDGE GAS TRANSMISSION EASEMENT TO REMAIN
- ENBRIDGE GAS TRANSMISSION EASEMENT TO BE REMOVED
- PROPOSED NATIONAL GRID GAS RELOCATION
- EXISTING DRAINAGE PIPE ≥ 36"
- EXISTING TELE DUCTBANK ≥ 36"
- EXISTING GAS PIPE ≥ 36"
- EXISTING SEWER PIPE ≥ 36"
- EXISTING POTABLE WATER PIPE ≥ 16"
- PROPOSED NATIONAL GRID GAS CONNECTION (BY OTHERS)

LEGEND:
- EXISTING ROW LINE
- EXISTING PROPERTY LINE
- EXISTING WETLAND
- EXISTING WETLAND BUFFER
- PROPOSED STORMWATER INFILTRATION
- QUALIFYING PERVIOUS AREA FOR STORMWATER TREATMENT
- PROPOSED SIGNAL
- PROPOSED BRIDGE STRUCTURE
- PROPOSED BRIDGE PIER
- PROPOSED WALL STRUCTURE
- PROPOSED TRAVEL DIRECTION
- PROPOSED LIMIT OF GRADING
- PROPOSED SHARED USE PATH
- PROPOSED SIDEWALK
- PROPOSED GUARDRAIL

0 80 200 300
SCALE: 1" = 80'

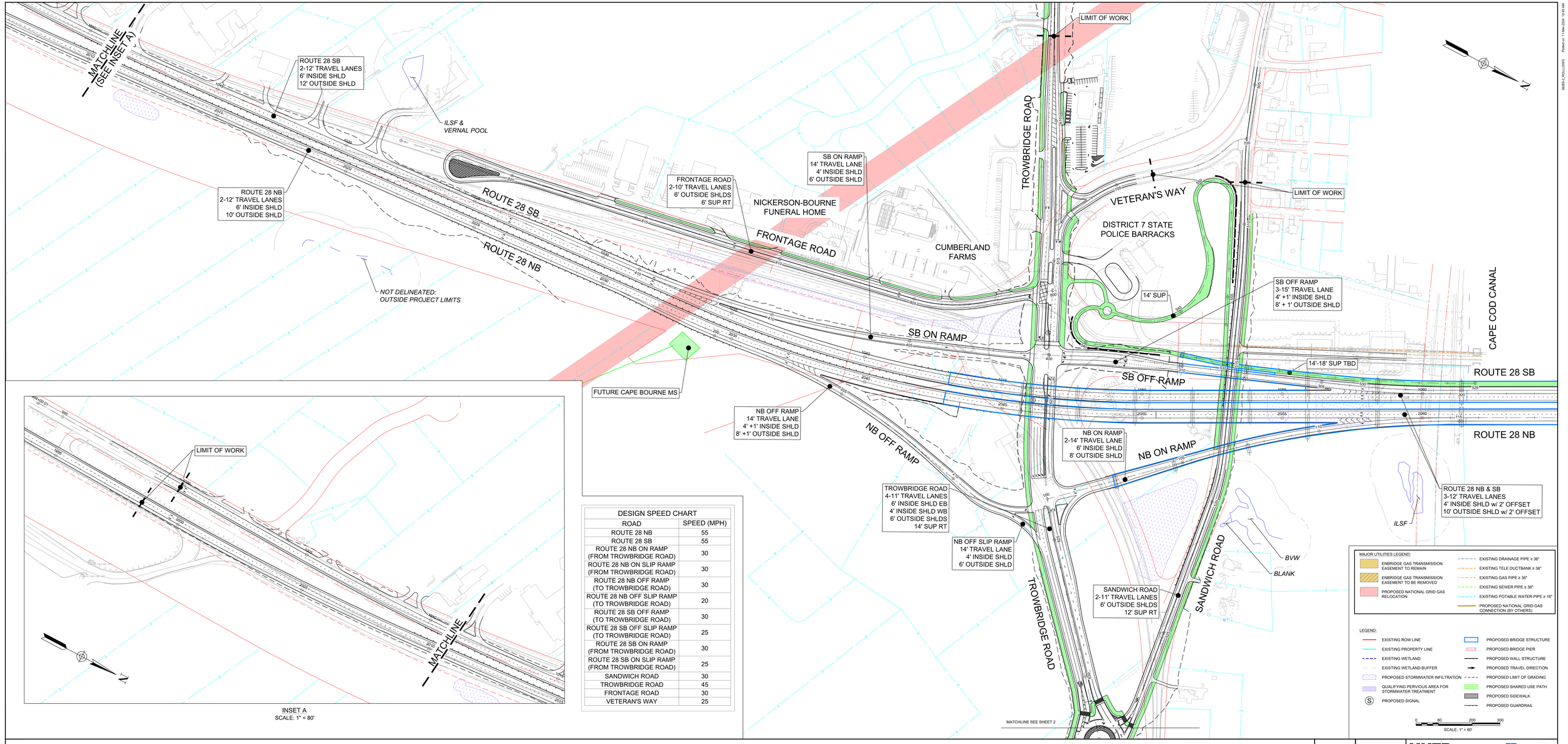
CAPE COD BRIDGES PROGRAM
BOURNE SOUTH ROLL PLAN
ALTERNATIVE BS-2.2

PRE-DECISIONAL & DELIBERATIVE

SCALE: 1" = 80'	HNTB	massDOT Highway Division		
DATE: 12-Mar-24	DRAWN BY: ELL	CHECKED BY: JTB	SHEET NO:	

Plotted on 13-Mar-2024 at 2:19 PM
D:\WO\17XX\17XX-2\17XX-2_PCTL1.DWG

PRE-DECISIONAL AND DELIBERATIVE



INSET A
SCALE: 1" = 80'

DESIGN SPEED CHART	
ROAD	SPEED (MPH)
ROUTE 28 NB	55
ROUTE 28 SB	55
ROUTE 28 NB ON RAMP (FROM TROWBRIDGE ROAD)	30
ROUTE 28 NB ON SLIP RAMP (FROM TROWBRIDGE ROAD)	30
ROUTE 28 NB OFF RAMP (TO TROWBRIDGE ROAD)	30
ROUTE 28 NB OFF SLIP RAMP (TO TROWBRIDGE ROAD)	20
ROUTE 28 SB OFF RAMP (TO TROWBRIDGE ROAD)	30
ROUTE 28 SB OFF SLIP RAMP (TO TROWBRIDGE ROAD)	25
ROUTE 28 SB ON RAMP (FROM TROWBRIDGE ROAD)	30
ROUTE 28 SB ON SLIP RAMP (FROM TROWBRIDGE ROAD)	25
SANDWICH ROAD	30
TROWBRIDGE ROAD	45
FRONTAGE ROAD	30
VETERAN'S WAY	25

MAJOR UTILITIES LEGEND:

- ENBRIDGE GAS TRANSMISSION EASEMENT TO REMAIN
- ENBRIDGE GAS TRANSMISSION EASEMENT TO BE REMOVED
- PROPOSED NATIONAL GRID GAS RELOCATION
- EXISTING DRAINAGE PIPE ≥ 36"
- EXISTING TELE DUCTBANK ≥ 36"
- EXISTING GAS PIPE ≥ 36"
- EXISTING SEWER PIPE ≥ 36"
- EXISTING POTABLE WATER PIPE ≥ 16"
- PROPOSED NATIONAL GRID GAS CONNECTION (BY OTHERS)

LEGEND:

- EXISTING ROW LINE
- EXISTING PROPERTY LINE
- EXISTING WETLAND
- EXISTING WETLAND BUFFER
- PROPOSED STORMWATER INFILTRATION
- QUALIFYING PERVIOUS AREA FOR STORMWATER TREATMENT
- PROPOSED SIGNAL
- PROPOSED BRIDGE STRUCTURE
- PROPOSED BRIDGE PIER
- PROPOSED WALL STRUCTURE
- PROPOSED TRAVEL DIRECTION
- PROPOSED LIMIT OF GRADING
- PROPOSED SHARED USE PATH
- PROPOSED SIDEWALK
- PROPOSED GUARDRAIL

0 80 200 300
SCALE: 1" = 80'

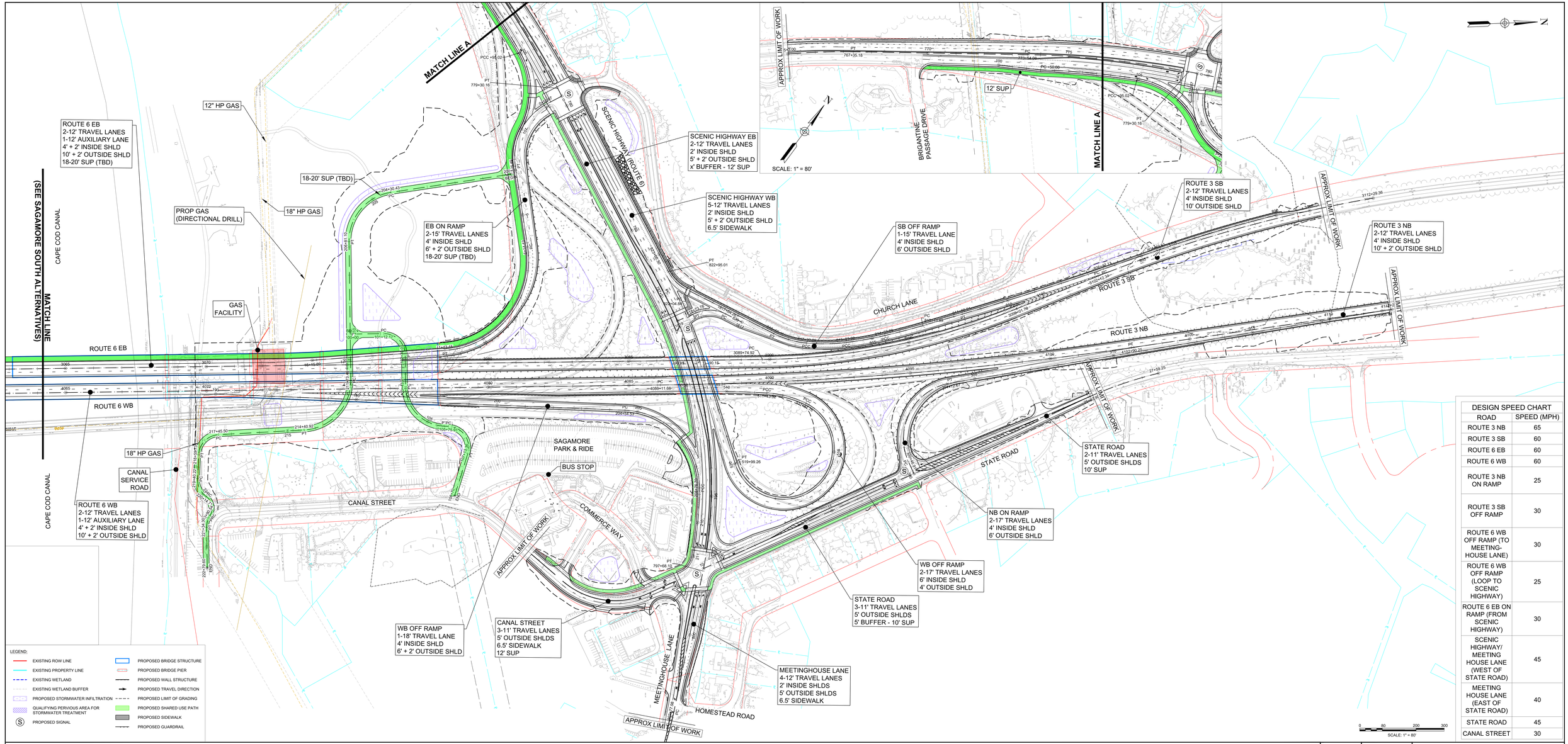
CAPE COD BRIDGES PROGRAM
BOURNE SOUTH ROLL PLAN
ALTERATIVE BS-2.2

PRE-DECISIONAL & DELIBERATIVE

SCALE: 1" = 80'	HNTB	MassDOT Highway Division		
DATE: 11-Mar-24	DRAWN BY: ELL	CHECKED BY: JTB	SHEET NO:	

Plotted on 11-Mar-2024 10:16 AM
06869-2_ROLL1.DWG

PRE-DECISIONAL AND DELIBERATIVE



LEGEND:

- EXISTING ROW LINE
- EXISTING PROPERTY LINE
- EXISTING WETLAND
- EXISTING WETLAND BUFFER
- PROPOSED STORMWATER INFILTRATION
- QUALIFYING PERVIOUS AREA FOR STORMWATER TREATMENT
- PROPOSED SIGNAL
- PROPOSED BRIDGE STRUCTURE
- PROPOSED BRIDGE PIER
- PROPOSED WALL STRUCTURE
- PROPOSED TRAVEL DIRECTION
- PROPOSED LIMIT OF GRADING
- PROPOSED SHARED USE PATH
- PROPOSED SIDEWALK
- PROPOSED GUARDRAIL

DESIGN SPEED CHART	
ROAD	SPEED (MPH)
ROUTE 3 NB	65
ROUTE 3 SB	60
ROUTE 6 EB	60
ROUTE 6 WB	60
ROUTE 3 NB ON RAMP	25
ROUTE 3 SB OFF RAMP	30
ROUTE 6 WB OFF RAMP (TO MEETING-HOUSE LANE)	30
ROUTE 6 WB OFF RAMP (LOOP TO SCENIC HIGHWAY)	25
ROUTE 6 EB ON RAMP (FROM SCENIC HIGHWAY)	30
SCENIC HIGHWAY/ MEETING HOUSE LANE (WEST OF STATE ROAD)	45
MEETING HOUSE LANE (EAST OF STATE ROAD)	40
STATE ROAD	45
CANAL STREET	30

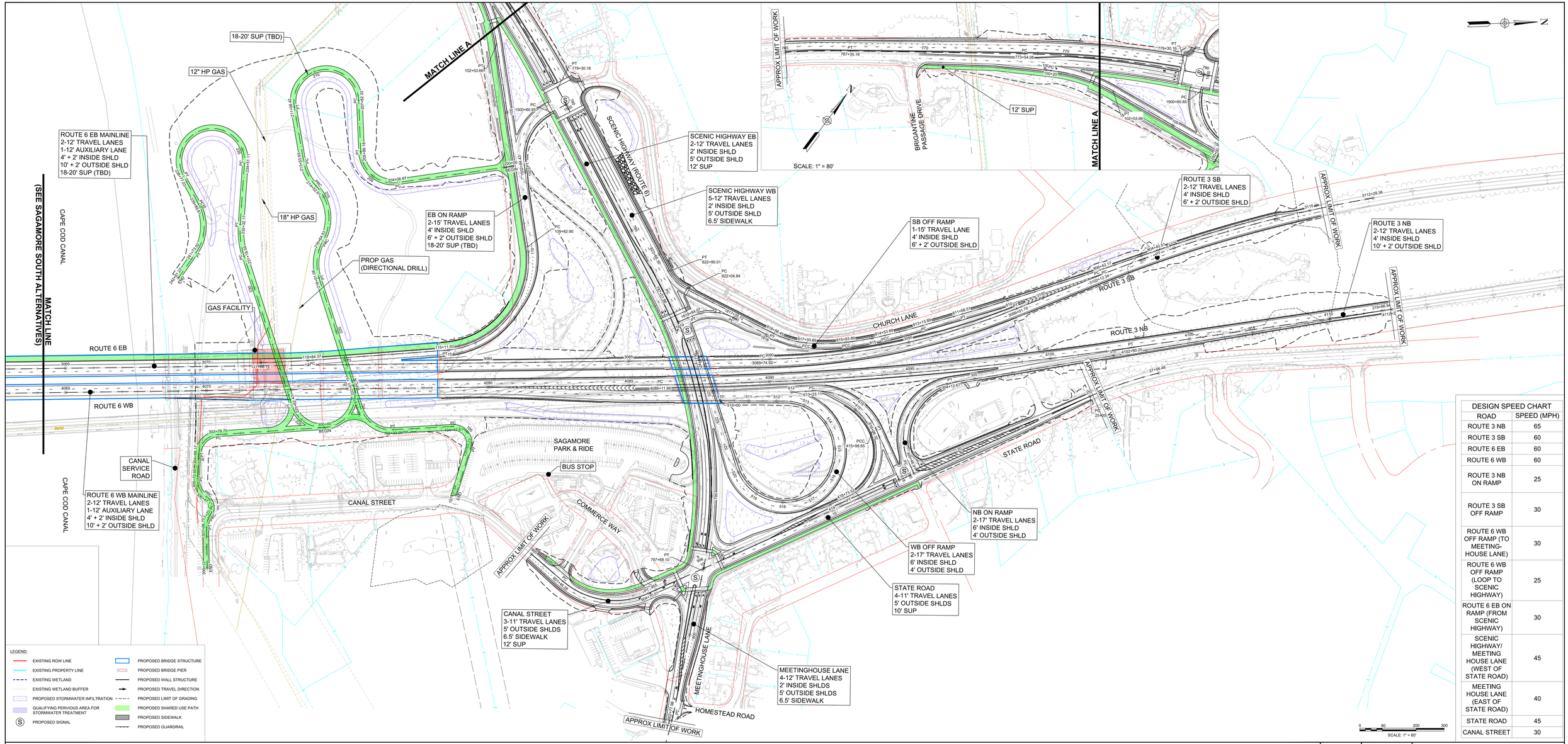
THE CAPE COD BRIDGES PROGRAM
SAGAMORE NORTH ALTERNATIVE SN-1A
ROLL PLAN

PRE-DECISIONAL & DELIBERATIVE

SCALE: 1" = 80'	HNTB Stantec MassDOT Highway Division		
DATE: 02/19/2024	DRAWN BY: NMS	CHECKED BY: ALC	SHEET NO: 1

Plotted on: 19-Feb-2024 12:41 PM
668500_SN1ARA1A_ROLL.DWG

PRE-DECISIONAL AND DELIBERATIVE



LEGEND:

- EXISTING ROW LINE
- EXISTING PROPERTY LINE
- EXISTING WETLAND
- EXISTING WETLAND BUFFER
- PROPOSED STORMWATER INFILTRATION
- QUALIFYING PERVIOUS AREA FOR STORMWATER TREATMENT
- PROPOSED SIGNAL
- PROPOSED BRIDGE STRUCTURE
- PROPOSED BRIDGE PIER
- PROPOSED WALL STRUCTURE
- PROPOSED TRAVEL DIRECTION
- PROPOSED LIMIT OF GRADING
- PROPOSED SHARED USE PATH
- PROPOSED SIDEWALK
- PROPOSED GUARDRAIL

DESIGN SPEED CHART

ROAD	SPEED (MPH)
ROUTE 3 NB	65
ROUTE 3 SB	60
ROUTE 6 EB	60
ROUTE 6 WB	60
ROUTE 3 NB ON RAMP	25
ROUTE 3 SB OFF RAMP	30
ROUTE 6 WB OFF RAMP (TO MEETING-HOUSE LANE)	30
ROUTE 6 WB OFF RAMP (LOOP TO SCENIC HIGHWAY)	25
ROUTE 6 EB ON RAMP (FROM SCENIC HIGHWAY)	30
SCENIC HIGHWAY/ MEETING HOUSE LANE (WEST OF STATE ROAD)	45
MEETING HOUSE LANE (EAST OF STATE ROAD)	40
STATE ROAD	45
CANAL STREET	30

THE CAPE COD BRIDGES PROGRAM
SAGAMORE NORTH ALTERNATIVE SN-8A
ROLL PLAN

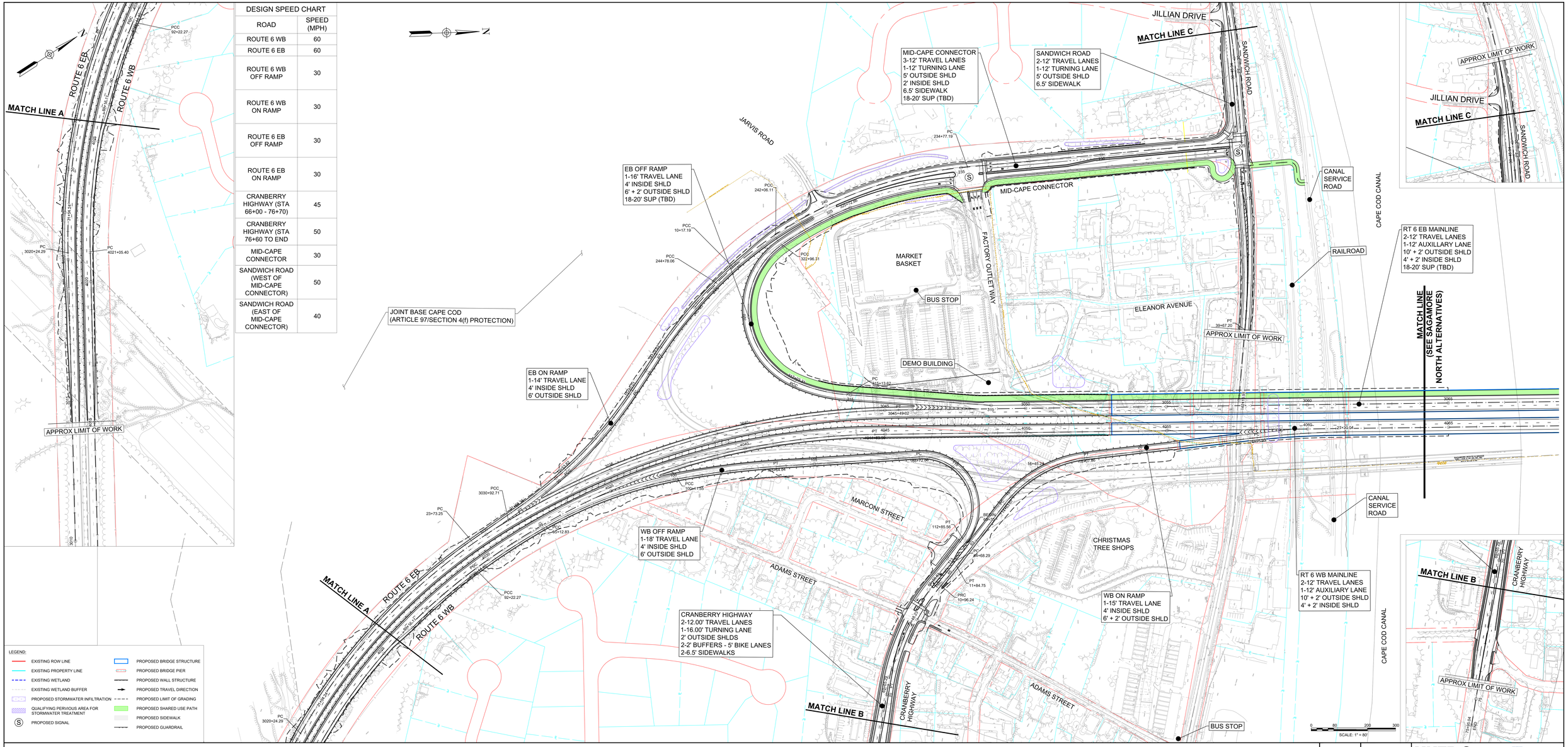
PRE-DECISIONAL & DELIBERATIVE

SCALE: 1" = 80'	HNTB Stantec MassDOT Highway Division		
DATE: 02/19/2024	DRAWN BY: NMS	CHECKED BY: ALC	SHEET NO: 1

Plotted on: 19-Feb-2024 12:34 PM
668600_SDK\ROLL\ROLL.DWG

PRE-DECISIONAL AND DELIBERATIVE

DESIGN SPEED CHART	
ROAD	SPEED (MPH)
ROUTE 6 WB	60
ROUTE 6 EB	60
ROUTE 6 WB OFF RAMP	30
ROUTE 6 WB ON RAMP	30
ROUTE 6 EB OFF RAMP	30
ROUTE 6 EB ON RAMP	30
CRANBERRY HIGHWAY (STA 66+00 - 76+70)	45
CRANBERRY HIGHWAY (STA 76+60 TO END	50
MID-CAPE CONNECTOR	30
SANDWICH ROAD (WEST OF MID-CAPE CONNECTOR)	50
SANDWICH ROAD (EAST OF MID-CAPE CONNECTOR)	40



LEGEND:

- EXISTING ROW LINE
- EXISTING PROPERTY LINE
- EXISTING WETLAND
- EXISTING WETLAND BUFFER
- PROPOSED STORMWATER INFILTRATION
- QUALIFYING PERVIOUS AREA FOR STORMWATER TREATMENT
- PROPOSED SIGNAL
- PROPOSED BRIDGE STRUCTURE
- PROPOSED BRIDGE PIER
- PROPOSED WALL STRUCTURE
- PROPOSED TRAVEL DIRECTION
- PROPOSED LIMIT OF GRADING
- PROPOSED SHARED USE PATH
- PROPOSED SIDEWALK
- PROPOSED GUARDRAIL

THE CAPE COD BRIDGES PROGRAM
SAGAMORE SOUTH ALTERNATIVE SS-1.1
ROLL PLAN

PRE-DECISIONAL & DELIBERATIVE

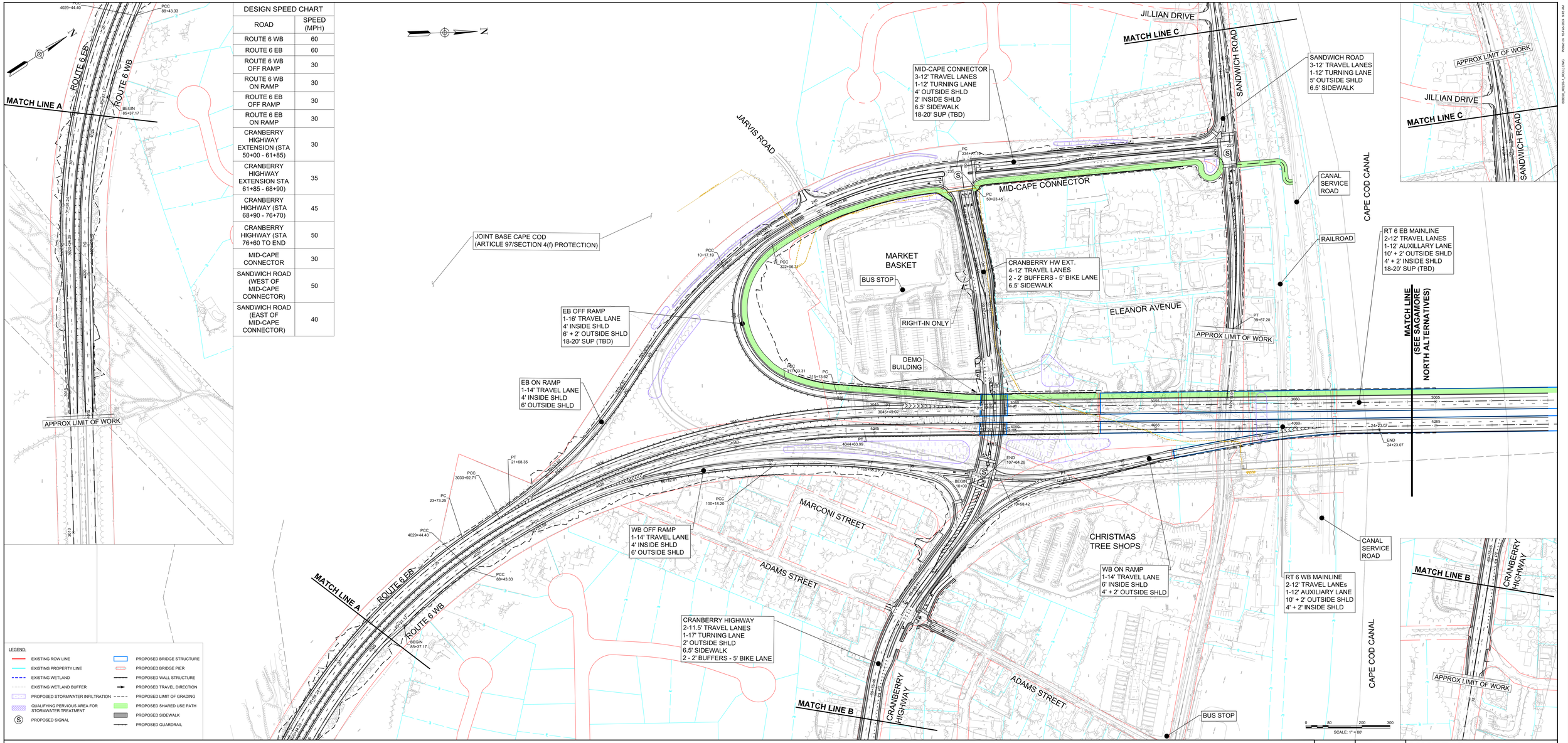
SCALE: 1" = 80'			
DATE: 02/19/2024	DRAWN BY: NMS	CHECKED BY: ALC	SHEET NO: 1

HNTB Stantec MassDOT Highway Division

Plotted on: 19-Feb-2024 9:39 AM
668600_SS1SS-1.1_ROLL.DWG

PRE-DECISIONAL AND DELIBERATIVE

DESIGN SPEED CHART	
ROAD	SPEED (MPH)
ROUTE 6 WB	60
ROUTE 6 EB	60
ROUTE 6 WB OFF RAMP	30
ROUTE 6 WB ON RAMP	30
ROUTE 6 EB OFF RAMP	30
ROUTE 6 EB ON RAMP	30
CRANBERRY HIGHWAY EXTENSION (STA 50+00 - 61+85)	30
CRANBERRY HIGHWAY EXTENSION STA 61+85 - 68+90)	35
CRANBERRY HIGHWAY (STA 68+90 - 76+70)	45
CRANBERRY HIGHWAY (STA 76+60 TO END	50
MID-CAPE CONNECTOR	30
SANDWICH ROAD (WEST OF MID-CAPE CONNECTOR)	50
SANDWICH ROAD (EAST OF MID-CAPE CONNECTOR)	40



LEGEND:

- EXISTING ROW LINE
- EXISTING PROPERTY LINE
- EXISTING WETLAND
- EXISTING WETLAND BUFFER
- PROPOSED STORMWATER INFILTRATION
- QUALIFYING PERVIOUS AREA FOR STORMWATER TREATMENT
- PROPOSED SIGNAL
- PROPOSED BRIDGE STRUCTURE
- PROPOSED BRIDGE PIER
- PROPOSED WALL STRUCTURE
- PROPOSED TRAVEL DIRECTION
- PROPOSED LIMIT OF GRADING
- PROPOSED SHARED USE PATH
- PROPOSED SIDEWALK
- PROPOSED GUARDRAIL

THE CAPE COD BRIDGES PROGRAM
SAGAMORE SOUTH ALTERNATIVE SS-1
ROLL PLAN

PRE-DECISIONAL & DELIBERATIVE

	SCALE: 1" = 80'			
	DATE: 02/19/2024	DRAWN BY: NMS	CHECKED BY: ALC	SHEET NO: 1

HNTB Stantec MassDOT Highway Division

Plotted on: 19-Feb-2024 9:49 AM
600005_SS1SB1_1_ROLL1.DWG

PRE-DECISIONAL AND DELIBERATIVE

DESIGN SPEED CHART	
ROAD	SPEED (MPH)
ROUTE 6 WB	60
ROUTE 6 EB	60
ROUTE 6 WB OFF RAMP	30
ROUTE 6 WB ON RAMP	30
ROUTE 6 EB OFF RAMP	30
ROUTE 6 EB ON RAMP	30
CRANBERRY HIGHWAY EXTENSION (STA 50+00 - 61+85)	30
CRANBERRY HIGHWAY EXTENSION (STA 61+85 - 68+90)	35
CRANBERRY HIGHWAY (STA 68+90 - 76+60)	45
CRANBERRY HIGHWAY (STA 76+60 TO END)	50
MIDCAPE CONNECTOR	30
SANDWICH ROAD (WEST OF MIDCAPE CONNECTOR)	50
SANDWICH ROAD (EAST OF MIDCAPE CONNECTOR)	40

MATCH LINE A

APPROX LIMIT OF WORK

ROUTE 6 EB

ROUTE 6 WB

PCC 4029+44.40
PCC 275+86.95

MID-CAPE CONNECTOR
3-12' TRAVEL LANES
1-12' TURNING LANE
4' OUTSIDE SHLDS
2' INSIDE SHLDS
6.5' SIDEWALK
18-20' SUP (TBD)

JILLIAN DRIVE

MATCH LINE C

SANDWICH ROAD

SANDWICH ROAD
6.5' SIDEWALK
3-12' TRAVEL LANES
1-12' TURNING LANE
5' OUTSIDE SHLDS

APPROX LIMIT OF WORK

JILLIAN DRIVE

MATCH LINE C

SANDWICH ROAD

JARVIS ROAD

EB OFF RAMP
1-16' TRAVEL LANE
4' INSIDE SHLD
6' + 2' OUTSIDE SHLD
18-20' SUP (TBD)

JOINT BASE CAPE COD
(ARTICLE 97/SECTION 4(f) PROTECTION)

WB ON RAMP
1-15' TRAVEL LANE
6' INSIDE SHLD
4' + 2' OUTSIDE SHLD

EB ON RAMP
1-14' TRAVEL LANE
4' INSIDE SHLD
6' + 2' OUTSIDE SHLD

WB OFF RAMP
1-14' TRAVEL LANE
4' INSIDE SHLD
6' OUTSIDE SHLD

MID-CAPE CONNECTOR

CRANBERRY HWY EXT.
4-12' TRAVEL LANES
2-2' BUFFERS - 5' BIKE LANES
2' INSIDE SHLDS
2-6.5' SIDEWALK

MARKET BASKET

BUS STOP

RIGHT-IN ONLY

ELEANOR AVENUE

CANAL SERVICE ROAD

SANDWICH ROAD
2-6.5' SIDEWALKS
3-12' TRAVEL LANES
5' OUTSIDE SHLDS

RAILROAD

CAPE COD CANAL

RT 6 EB MAINLINE
2-12' TRAVEL LANES
1-12' AUXILIARY LANE
10' + 2' OUTSIDE SHLD
4' + 2' INSIDE SHLD
18-20' SUP (TBD)

MATCH LINE
(SEE SAGAMORE
NORTH ALTERNATIVES)

APPROX LIMIT OF WORK

MARCONI STREET

ADAMS STREET

5.5' SIDEWALK

CHRISTMAS TREE SHOPS

RT 6 WB MAINLINE
2-12' TRAVEL LANES
1-12' AUXILIARY LANE
10' + 2' OUTSIDE SHLDS
4'+ 2' INSIDE SHLDS

CANAL SERVICE ROAD

CRANBERRY HIGHWAY
2-12' TRAVEL LANES
2-12' TURNING LANE
6.5' SIDEWALK
2-2' BUFFERS, 5' BIKE LANES
12' SUP

CRANBERRY HIGHWAY
2-12' TRAVEL LANES
1-16' TURNING LANE
2-2' BUFFERS - 5' BIKE LANES
5' OUTSIDE SHLD
2-6.5' SIDEWALKS

CRANBERRY HIGHWAY

MATCH LINE B

MATCH LINE B

CRANBERRY HIGHWAY

APPROX LIMIT OF WORK

BUS STOP

CAPE COD CANAL

LEGEND:

- EXISTING ROW LINE
- EXISTING PROPERTY LINE
- EXISTING WETLAND
- EXISTING WETLAND BUFFER
- PROPOSED STORMWATER INFILTRATION
- QUALIFYING PERVIOUS AREA FOR STORMWATER TREATMENT
- PROPOSED SIGNAL
- PROPOSED BRIDGE STRUCTURE
- PROPOSED BRIDGE PIER
- PROPOSED WALL STRUCTURE
- PROPOSED TRAVEL DIRECTION
- PROPOSED LIMIT OF GRADING
- PROPOSED SHARED USE PATH
- PROPOSED SIDEWALK
- PROPOSED GUARDRAIL

SCALE: 1" = 80'

0 80 200 300

THE CAPE COD BRIDGES PROGRAM
SAGAMORE SOUTH ALTERNATIVE SS-3.1A
ROLL PLAN

PRE-DECISIONAL & DELIBERATIVE

HNTB Stantec MassDOT Highway Division

SCALE: 1" = 80'			
DATE: 02/19/2024	DRAWN BY: NMS	CHECKED BY: ALC	SHEET NO: 1

Plotted on: 19-Feb-2024 9:59 AM
668800_HDSS-3.1A_ROLL.DWG

Attachment C
Results Summary Table

PRE-DECISIONAL & DELIBERATIVE

Table C-1: Synchro and SIDRA Results Summary - 2050 No-Build

Intersection	2050 No-Build Weekday Fall PM					2050 No-Build Summer Saturday MID				
	LOS	Delay (sec)	v/c Ratio	50% Queue (feet)	95% Queue (feet)	LOS	Delay (sec)	v/c Ratio	50% Queue (feet)	95% Queue (feet)
1:: Maple Springs Rd / Route 25 NB On-Ramp	A	0.5				A	0.3			
Maple Springs Rd NB (thru)	A	0.0	0.11	-	0	A	0.0	0.05	-	0
Maple Springs Rd NB (thru/right)	A	0.0	0.70	-	0	A	0.0	0.69	-	0
Maple Springs Rd SB (left/thru)	A	3.1	0.08	-	6	A	3.0	0.07	-	3
2:: Maple Springs Rd / Route 25 SB Off-Ramp	A	3.4				F	255.3			
Route 25 SB Off-Ramp EB (left)	C	21.2	0.32	-	55	B	14.9	0.057	-	3084
Route 25 SB Off-Ramp EB (right)	B	12.3	0.42	-	55	F	$440.4	1.943	-	3084
Maple Springs Rd NB (thru)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Maple Springs Rd NB (thru)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Maple Springs Rd SB (thru)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
3:: Glen Charlie Road / Route 25 NB Off-Ramp	A	5.3				A	2.3			
Route 25 NB Off-Ramp EB (left)	F	73.3	0.69	-	123	D	32.8	0.14	-	44
Route 25 NB Off-Ramp EB (right)	B	13.3	0.25	-	123	C	17.6	0.38	-	44
Glen Charlie Rd NB (thru)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Glen Charlie Rd SB (thru)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
4:: Glen Charlie Road / Route 25 SB On-Ramp	A	0.8				A	0.8			
Glen Charlie Rd NB (thru)	A	0.0	0.57	-	0	A	0.0	0.44	-	0
Glen Charlie Rd NB (right)	A	0.0	0.02	-	0	A	0.0	0.04	-	0
Glen Charlie Rd SB (left/thru)	A	2.0	0.08	-	6	A	1.5	0.06	-	4
5:: Buzzards Bay Rotary	B	11.2				E	40.1			
Main Street (Route 6) EB (left)	A	8.1	0.45	-	51	E	37.2	0.95	-	1068
Main Street (Route 6) EB (left/thru)	A	8.2	0.45	-	51	E	37.4	0.95	-	1068
Main Street WB (thru/right)	B	11.2	0.57	-	97	F	75.1	1.06	-	796
Lincoln Avenue SB (left/thru/right)	A	10.0	0.13	-	9	B	10.4	0.25	-	18
Buzzards Bay Bypass (Route 6) SWB (left)	B	14.6	0.58	-	95	B	10.9	0.39	-	38
Buzzards Bay Bypass (Route 6) SWB (left/right)	B	13.9	0.58	-	15'	B	10.6	0.39	-	37
6:: Scenic Highway (Route 6) / Main Street (Route 6) / Nightingale Road / Andy Olivia Drive	D	53.9				F	101.2			
Main Street (Route 6) EB (left/thru)	A	9.4	0.81	135'	#180'	F	101.9	1.18	~563	#900
Main Street (Route 6) EB (thru/right)	A	9.4	0.81	135'	#180'	F	101.9	1.18	~563	#900
Scenic Hwy (Route 6) WB (left/thru)	F	82.6	1.12	~791'	#932'	F	107.0	1.17	~821	#975
Scenic Hwy (Route 6) WB (thru/right)	F	82.6	1.12	~791'	#932'	F	107.0	1.17	~821	#975
Andy Olivia Dr NB (left/thru/right)	D	40.4	0.22	15'	43'	D	48.4	0.7	77	#151
Nightingale Pond Rd SB (left/thru)	D	40.2	0.17	11	34	D	35.9	0.06	66	22
Nightingale Pond Rd SB (right)	D	39.5	0.03	0	0	D	35.9	0.05	0	23
7:: Sandwich Road / Trowbridge Road / County Road / Shore Road	A	1.5				F	81.2			
Shore Rd EB (left/thru/right)	A	9.6	0.19	-	18	A	8.4	0.14	-	12
Trowbridge Rd WB (left/thru/right)	A	8.6	0.15	-	13	A	8.0	0.06	-	5
County Rd NB (left/thru/right)	F	Err	Err	-	Err	F	141.4	1.12	-	283
Sandwich Rd SB (left/thru/right)	F	Err	Err	-	Err	F	$305.8	1.50	-	398
8:: Trowbridge Rd./Veterans Way	A	0.9				A	0.7			
Trowbridge Rd EB (left/thru/right)	A	8.1	0.01	-	0	A	8.0	0.01	-	0
Trowbridge Rd WB (left/thru/right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Driveway NB (left/thru/right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Veterans Way SB (left/thru/right)	C	17.3	0.13	-	10	B	14.7	0.08	-	7
9:: Bourne Rotary	F	496.5				F	829.6			
General MacArthur Boulevard NB (left/thru)	F	621.1	2.33	-	7033	F	627.4	2.35	-	8327
General MacArthur Boulevard NB (right)	A	9.9	0.30	-	28	C	20.3	0.72	-	214
Sandwich Road WB (left/thru)	C	20.9	0.62	-	104	F	200.0	1.35	-	1584
Sandwich Road WB (right)	F	442.9	1.93	-	4166	F	265.6	1.52	-	2229
Route 28 (Bourne Bridge) SB (left/thru)	F	671.5	2.45	-	10114	F	1466.3	4.22	-	18408
Route 28 (Bourne Bridge) SB (right)	A	6.9	0.23	-	22	A	6.0	0.06	-	5
Trowbridge Road EB (left/thru/right)	F	283.1	1.55	-	2064	F	81.1	1.00	-	454
10:: Sandwich Road / Bourne Rotary Connector	F	784.4				F	264.4			
Sandwich Rd SB (left/right)	F	$4536.7	10.77	-	1790	F	$2518.5	6.227	-	Err
Bourne Rotary Connector EB (left/thru)	B	14.8	0.02	-	0	B	12.1	0.031	-	2
Sandwich Rd WB (thru/right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
11:: Sandwich Road / Upper Cape Cod Technical School Driveway	F	282.7				A	1.1			
Cape Cod Technical School Driveway NB (left/right)	F	$5262	11.59	-	568	F	185.0	0.48	-	41
Sandwich Rd EB (thru/right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Sandwich Rd WB (left)	B	13.5	0.11	-	10	B	12.1	0.01	-	1
Sandwich Rd WB (thru)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
12:: Sandwich Road / Harbor Lights Road	A	26.1				A	1.1			
Harbor Lights Rd NB (left/right)	F	$1452	3.20	-	Err	F	185	0.48	-	40
Sandwich Rd EB (thru/right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Sandwich Rd WB (left/thru)	B	12.3	0.01	-	1	A	0.0	0.00	-	0
13:: Sandwich Road / Jefferson Road (Tech Drive)	A	0.7				A	5.6			
Jefferson Rd (Tech Dr) NB (left/right)	F	199.4	0.39	-	30	F	187.7	0.99	-	133
Sandwich Rd EB (thru/right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Sandwich Rd WB (left/thru)	B	12.2	0.01	-	1	B	12.1	0.01	-	1
14:: Sandwich Road / Jarvis Road	A	0.7				A	0.4			
Jarvis Rd NB (left/right)	F	199.4	0.39	-	30	F	194.4	0.23	-	15
Sandwich Rd EB (thru/right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Sandwich Rd WB (left/thru)	B	12.2	0.01	-	0	B	12.1	0.01	-	1

PRE-DECISIONAL & DELIBERATIVE

Table C-1: Synchro and SIDRA Results Summary - 2050 No-Build

Intersection	2050 No-Build Weekday Fall PM					2050 No-Build Summer Saturday MID				
	LOS	Delay (sec)	v/c Ratio	50% Queue (feet)	95% Queue (feet)	LOS	Delay (sec)	v/c Ratio	50% Queue (feet)	95% Queue (feet)
15:: Sandwich Road (Route 6 Bypass) / Mid-Cape Connector	C	32.9				B	12.7			
Sandwich Rd EB (thru)	B	17.2	0.62	204	326	B	14.7	0.58	135	255
Sandwich Rd EB (right)	A	1.4	0.55	0	0	A	1.5	0.58	0	0
Sandwich Rd WB (left)	A	8.5	0.32	28	51	A	5.8	0.01	1	5
Sandwich Rd WB (thru)	E	64.9	1.08	~766	#1010	B	16.6	0.86	290	#695
Mid-Cape Connector NB (left)	D	40.0	0.81	157	#274	C	24.8	0.57	85	159
Mid-Cape Connector NB (right)	C	21.0	0.43	52	115	B	19.3	0.54	58	149
16:: Mid-Cape Connector / Factory Outlet Way	B	14.1				A	8.0			
Factory Outlet Way (Market Basket Driveway) WB (left)	C	29.8	0.20	23	44	C	34.9	0.23	15	34
Factory Outlet Way (Market Basket Driveway) WB (left)	C	29.8	0.20	23	44	C	34.9	0.23	15	34
Factory Outlet Way (Market Basket Driveway) WB (right)	B	17.2	0.35	73	110	C	24.2	0.17	24	54
Mid-Cape Connector NB (thru)	B	19.4	0.58	178	313	B	11.0	0.53	175	274
Mid-Cape Connector NB (right)	A	6.7	0.07	0	17	A	4.2	0.04	0	8
Mid-Cape Connector SB (left)	C	34.4	0.60	82	134	C	34.1	0.04	2	13
Mid-Cape Connector SB (thru)	A	5.2	0.34	76	106	A	3.2	0.34	64	90
Mid-Cape Connector SB (thru)	A	5.2	0.34	76	106	A	3.2	0.34	64	90
17:: Herring Pond Road / State Road	F	828.7				F	878.5			
Herring Pond Rd EB (left/right)	F	$1390.6	4.01	-	Err	F	$1725.3	4.75	-	Err
State Rd NB (left/thru)	A	8.0	0.13	-	11	A	9.2	0.21	-	20
State Rd SB (thru/right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
18:: Herring Pond Road / Route 3 NB Ramps	F	223.0				F	235.0			
Route 3 NB Ramps EB (left/right)	F	$825.8	2.73	-	1270	F	$2906.5	6.88	-	Err
Herring Pond Rd NB (left/thru)	A	8.8	0.01	-	0	B	10.5	0.28	-	28
Herring Pond Rd SB (thru)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Herring Pond Rd SB (right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
19:: Herring Pond Road / Route 3 SB Ramps	F	291.3				F	1065.3			
Route 3 SB Ramps WB (left/right)	F	$1016.9	3.15	-	1378	F	$2437.7	6.30	-	Err
Herring Pond Rd NB (thru/right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Herring Pond Rd SB (left/thru)	A	8.8	0.16	-	15	A	10.0	0.29	-	31
20:: Scenic Highway (Route 6) / Church Lane / Route 6 SB On-Ramp	D	46.7				F	131.9			
Scenic Hwy (Route 6) EB (left)	D	45.8	0.49	33'	93'	E	62.3	0.45	32	71
Scenic Hwy (Route 6) EB (thru)	F	82.7	1.11	233'	415'	F	253.0	2.11dr	~995	#1203
Scenic Hwy (Route 6) EB (thru/right)	F	82.7	1.11	233'	415'	F	253.0	2.11dr	~995	#1203
Scenic Hwy (Route 6) WB (left)	D	43.8	0.68	105'	226'	F	172.7	1.27	~898	#1219
Scenic Hwy (Route 6) WB (thru)	B	13.0	0.68	300'	456'	B	10.5	0.55	286	403
Scenic Hwy (Route 6) WB (thru)	B	13.0	0.68	300'	456'	B	10.5	0.55	286	403
Scenic Hwy (Route 6) WB (thru/right)	B	13.0	0.68	300'	456'	B	10.5	0.55	286	403
Church Lane SB (left/thru/right)	D	44.0	0.53	51	131	E	65.8	0.70	113	184
21:: Scenic Highway (Route 6) & Route 3 SB Off-Ramp	E	59.2				E	69.9			
Scenic Hwy (Route 6) EB (thru)	B	12.7	0.56	252'	347'	A	8.9	0.27	101	147
Scenic Hwy (Route 6) WB (thru)	C	20.0	0.85	523	632	C	33.1	0.97	832	#1093
Scenic Hwy (Route 6) WB (thru)	C	20.0	0.85	523	632	C	33.1	0.97	832	#1093
Route 3 Off-Ramp SB (left/right)	F	227.1	1.38	~640'	#883'	F	249.1	1.42	~616	#842
22:: Meetinghouse Lane / State Road / Canal Street	D	45.4				D	47.7			
Meetinghouse Ln EB (left)	E	75.4	1.07	366'	#1074'	D	53.7	0.82	118	#203
Meetinghouse Ln EB (thru)	B	19.7	0.47	112'	#449'	E	62.7	0.82	232	#375
Meetinghouse Ln EB (right)	B	15.9	0.19	0'	68'	D	39.8	0.15	0	66
Meetinghouse Ln WB (left)	D	37.5	0.07	3'	17'	D	42.2	0.26	20	46
Meetinghouse Ln WB (thru/right)	D	51.8	0.57	65'	131'	F	122.0	1.05	199	#346
Canal St NB (left)	C	28.8	0.53	81'	126'	C	26.5	0.74	96	230
Canal St NB (thru/right)	D	36.2	0.54	123'	188'	B	19.5	0.35	134	298
State Rd SB (left)	D	35.3	0.15	16'	36'	B	18.3	0.14	24	70
State Rd SB (thru/right)	D	39.4	0.24	20'	80'	C	34.8	0.76	311	#832
23:: State Road / Route 3 NB On-Ramp	B	10.3				A	3.3			
State Rd NB (left)	C	18.7	0.83	-	266	B	11.0	0.36	-	42
State Rd NB (thru)	A	0.0	0.42	-	0	A	0.0	0.08	-	0
State Rd SB (thru)	A	0.0	0.12	-	0	A	0.0	0.38	-	0
State Rd SB (right)	A	0.0	0.01	-	0	A	0.0	0.01	-	0
24:: Cranberry Highway / Adams Street	A	4.8				A	3.0			
Cranberry Highway EB (thru)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Cranberry Highway EB (thru/right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Cranberry Highway WB (left/thru)	A	8.0	0.01	-	1	A	8.0	0.01	-	1
Cranberry Highway WB (thru)	A	0.0	0.00	-	1	A	0.1	0.00	-	0
Adams Street NB [left/thru/right]	B	13.7	0.04	-	3	B	14.2	0.05	-	5
Adams Street SB [left/thru/right]	B	14.9	0.50	-	70	B	14.0	0.38	-	44
25:: Sandwich Road / Adams Street	A	1.5				A	0.5			
Sandwich Rd EB (thru/right)	A	0.0	0.50	-	0	A	0.0	0.49	-	0
Sandwich Rd WB (left/thru)	A	2.3	0.03	-	2	A	0.9	0.02	-	2
26:: Cranberry Highway / Sandwich Road / Regency Drive	F	2311.5				A	5.7			
Sandwich Rd EB (left/thru/right)	A	0.0	0.00	-	0	A	9.2	0.01	-	0
Sandwich Rd WB (left/thru/right)	B	10.5	0.40	-	49	C	19.4	0.76	-	186
Cranberry Highway NB (left/thru)	F	$15195.6	33.15	-	1,078	A	0.0	0.00	-	Err
Cranberry Highway NB (right)	B	11.6	0.07	-	5	B	13.6	0.13	-	11
Regency Dr SB (left/thru/right)	F	$1338.3	1.09	-	38	A	0.0	0.00	-	Err

PRE-DECISIONAL & DELIBERATIVE

Table C-1: Synchro and SIDRA Results Summary - 2050 No-Build

Intersection	2050 No-Build Weekday Fall PM					2050 No-Build Summer Saturday MID				
	LOS	Delay (sec)	v/c Ratio	50% Queue (feet)	95% Queue (feet)	LOS	Delay (sec)	v/c Ratio	50% Queue (feet)	95% Queue (feet)
27:: Old King's Highway (Route 6A) / Main Street (Route 130) / Tupper Road	F	361.7				F	4359.8			
Old King's Hwy (Route 6A) EB (left/thru/right)	A	9.6	0.06	-	5	B	10.7	0.13	-	11
Old King's Hwy (Route 6A) WB (left/thru/right)	A	0.0	0.00	-	0	A	8.1	0.01	-	0
Main St (Route 130) NB (left/thru/right)	F	$1724.6	4.61	-	Err	F	$27653.9	59.78	-	Err
Tupper Rd SB (left/thru/right)	C	16.8	0.21	-	20	F	107.3	1.05	-	281
28:: Old King's Highway (Route 6A) / Tupper Road	F	234.8				F	302.4			
Old King's Hwy (Route 6A) EB (left)	B	19.9	0.07	6	25	C	24.3	0.34	13	54
Old King's Hwy (Route 6A) EB (thru/right)	C	28.6	0.67	203	415	D	49.7	0.93	352	#750
Old King's Hwy (Route 6A) WB (left/thru)	D	38.3	0.82	230	#518	F	240.3	1.44	~516	#906
Old King's Hwy (Route 6A) WB (right)	C	22.1	0.30	49	144	D	43.6	0.89	265	#640
Tupper Rd NB (left/thru/right)	F	610.0	2.23	~487	#828	F	729.3	2.5	~700	#1112
Tupper Rd SB (left)	F	485.0	1.95	~366	#661	F	774.7	2.59	~389	#680
Tupper Rd SB (thru/right)	F	160.1	1.21	~297	#606	D	47.3	0.74	148	#327
29:: Water Street (Route 130) / Beale Avenue	A	1.5				D	33.6			
Beale Ave WB (left/right)	E	45.2	0.36	-	38	F	229.2	1.35	-	391
Water St (Route 130) NB (thru/right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Water St (Route 130) SB (left/thru)	B	10.8	0.02	-	3	B	10.4	0.02	-	2
30:: Main Street / Beale Avenue	A	4.6				A	5.5			
Main St EB (thru/right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Main St WB (left/thru)	A	7.4	0.03	-	3	A	7.9	0.17	-	15
Beale Ave NB (left/right)	A	9.1	0.08	-	8	B	12.3	0.18	-	16
31:: Old King's Highway (Route 6A) / Main Street / Old Main Street	A	1.9				A	1.6			
Main St EB (left)	D	31.4	0.04	-	3	F	1291.8	2.20	-	93
Main St EB (thru/right)	B	13.3	0.19	-	16	E	41.4	0.60	-	88
Old Main St WB (left/thru/right)	D	26.4	0.06	-	5	F	568.2	1.17	-	75
Old King's Hwy (Route 6A) NB (left/thru/right)	A	8.8	0.01	-	5	B	11.6	0.38	-	44
Old King's Hwy (Route 6A) SB (left/thru/right)	A	8.4	0.06	-	0	B	10.7	0.01	-	1
32:: Forestdale Road (Route 130) / Route 6 EB Ramps	F	123.6				C	21.0			
Route 6 EB Ramps EB (left)	C	22.9	0.11	11	33	C	25.3	0.38	21	52
Route 6 EB Ramps EB (right)	F	327.6	1.63	~252	#448	D	42.6	0.75	21	#188
Forestdale Rd (Route 130) NB (left)	B	11.1	0.53	19	44	A	3.8	0.16	7	15
Forestdale Rd (Route 130) NB (thru)	F	84.2	1.14	~640	#868	B	16.3	0.9	253	#598
Forestdale Rd (Route 130) SB (thru/right)	C	22.1	0.89	116	m#428	A	8.6	0.49	97	170
33:: Water Street (Route 130) / Route 6 WB Ramps	F	115.4				C	23.2			
Route 6 WB Ramps EB (left)	F	317.1	1.62	~338	#510	D	53.7	0.93	112	#269
Route 6 WB Ramps EB (right)	A	0.2	0.13	0	0	A	0.0	0.02	0	0
Forestdale Rd (Route 130) NB (left)	F	130.5	1.24	~230	m#188	C	22.6	0.63	75	115
Forestdale Rd (Route 130) NB (left)	F	130.5	1.24	~230	m#188	C	22.6	0.63	75	115
Forestdale Rd (Route 130) NB (thru)	B	10.9	0.45	150'	m134'	A	9.3	0.69	156	257
Forestdale Rd (Route 130) SB (thru)	D	36.3	0.88	192	#351	C	29.2	0.84	150	#318
Forestdale Rd (Route 130) SB (right)	A	0.0	0.00	0	0	A	0.0	0.02	0	0
34:: Quaker Meeting House Road / Route 6 EB Ramps	A	5.6				F	60.5			
Route 6 EB Ramps EB (left/right)	D	25.9	0.55	-	80	F	$339.7	1.59	-	452
Quaker Meetinghouse Rd NB (left/thru)	A	9.4	0.23	-	23	B	10.1	0.26	-	26
Quaker Meetinghouse Rd SB (thru/right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
35:: Quaker Meeting House Road / Route 6 WB Ramps	A	7.9				A	9.5			
Route 6 WB Ramps WB (left/right)	C	23.5	0.66	-	123	E	45.0	0.78	-	194
Quaker Meetinghouse Rd NB (thru/right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Quaker Meetinghouse Rd SB (left/thru)	A	8.0	0.03	-	2.5	A	8.4	0.01	-	1
36:: Route 130 / Cotuit Rd	B	13.9				E	47.0			
Cotuit Rd WB (left)	A	0.0	0.00	-	0	F	181.9	0.36	-	29
Cotuid Rd WB (right)	F	192.6	1.34	-	663	F	155.1	1.25	-	606
Route 130 NB (thru/right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Route 130 SB (left)	E	44.3	0.97	-	405	B	13.0	0.53	-	79
Route 130 SB (thru)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
37:: Nathan Ellis Highway (Route 151) / Route 28 NB Ramps	A	9.2				F	334.0			
Nathan Ellis Hwy (Route 151) EB (left/thru)	A	8.8	0.12	-	10	B	11.2	0.24	-	23
Nathan Ellis Hwy (Route 151) WB (thru)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Nathan Ellis Hwy (Route 151) WB (right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Route 28 NB Ramps SB (left/right)	F	91.9	0.97	-	228	F	$3637.4	8.51	-	Err
38:: Nathan Ellis Highway (Route 151) / Route 28 SB Ramps	F	111.8				F	550.5			
Nathan Ellis Hwy (Route 151) EB (thru)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Nathan Ellis Hwy (Route 151) EB (right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Nathan Ellis Hwy (Route 151) WB (left/thru)	A	8.9	0.12	-	10	B	10.4	0.28	-	28
Route 28 SB Ramps NB (left/right)	F	286.5	1.57	-	1060	F	$2066.2	5.44	-	Err
39:: Belmont Circle	F	525.0				F	473.0			
Buzzards Bay Bypass (Route 6) EB (left/thru/right)	C	17.1	0.62	-	93	F	345.3	1.69	-	2518
Main Street (Route 6) WB (left/thru)	D	34.7	0.88	-	296	E	42.4	0.94	-	549
Main Street (Route 6) WB (right)	F	576.3	2.24	-	7001	F	481.0	2.03	-	6822
Old Bridge Road NB (left/thru/right)	A	9.5	0.01	-	0	A	9.1	0.01	-	1
Route 28/25 Ramps SB (left/thru/right)	F	921.0	3.01	-	10367	F	714.4	2.55	-	8548
Main Street NEB (left/thru/right)	F	348.3	1.73	-	3873	F	568.6	2.22	-	6532
Head of the Bay Road SEB (left/thru/right)	C	19.2	0.59	-	66	E	47.3	0.87	-	175

PRE-DECISIONAL & DELIBERATIVE

Table C-2: Synchro and SIDRA Results Summary - 2050 AP1

Intersection	2050 AP1 Weekday Fall PM					2050 AP1 Summer Saturday MID				
	LOS	Delay (sec)	v/c Ratio	50% Queue (feet)	95% Queue (feet)	LOS	Delay (sec)	v/c Ratio	50% Queue (feet)	95% Queue (feet)
6:: Scenic Highway (Route 6) / Main Street (Route 6) / Nightingale Road / Andy Olivia Drive	**B**	**17.1**				**B**	**13.0**			
Main Street (Route 6) EB (left)	D	46.4	0.62	43	#159	F	172.2	0.84	7	27
Main Street (Route 6) EB (thru)	B	11.7	0.67	129	#760	A	8.8	0.63	136	308
Main Street (Route 6) EB (thru/right)	B	11.7	0.67	129	#760	A	8.8	0.63	136	308
Scenic Hwy (Route 6) WB (left)	E	59.4	0.36	2	16	D	47.5	0.26	2	13
Scenic Hwy (Route 6) WB (thru)	B	17.5	0.73	217	#690	B	10.4	0.72	166	384
Scenic Hwy (Route 6) WB (thru/right)	B	17.5	0.73	217	#690	B	10.4	0.72	166	384
Scenic Hwy (Route 6) WB (right)	B	19.4	0.73	179	#716	B	10.5	0.67	110	356
Andy Olivia Dr NB (left/thru/right)	D	40.3	0.21	9	46	E	62.0	0.81	54	#165
Nightingale Pond Rd SB (left/thru)	D	43.8	0.48	20	#75	C	33.0	0.09	6	26
Nightingale Pond Rd SB (right)	D	41.6	0.35	16	61	D	38.0	0.54	39	#103
8:: Trowbridge Road / Veterans Way	**A**	**1.2**				**A**	**1.0**			
Trowbridge Rd EB (left/thru)	A	8.3	0.01	-	0	A	7.9	0.00	-	0
Trowbridge Rd EB (thru)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Trowbridge Rd WB (thru)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Trowbridge Rd WB (thru/right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Veterans Way SB (left/right)	C	17.6	0.23	-	23	B	10.9	0.08	-	8
9:: Trowbridge Road / Route 25 SB Off-Ramp	**C**	**34.4**				**D**	**42.2**			
Trowbridge Rd EB (thru)	D	35.6	0.74	252	#500	D	44.1	0.33	53	118
Trowbridge Rd EB (thru/right)	D	35.6	0.74	252	#500	D	44.1	0.33	53	118
Trowbridge Rd WB (left)	E	78.4	0.62	58	#116	D	44.6	0.69	167	#589
Trowbridge Rd WB (thru)	B	19.0	0.19	24	118	B	17.9	0.12	27	118
Trowbridge Rd WB (thru)	B	19.0	0.19	24	118	B	17.9	0.12	27	118
Route 25 SB Off-Ramp (left)	D	37.9	0.73	254	#537	D	54.2	0.84	287	405
Route 25 SB Off-Ramp (thru/right)	C	32.0	0.56	156	#364	D	41.5	0.63	184	293
9:: Sandwich Road / Trowbridge Road / Route 28 NB Off-Ramp	**C**	**20.6**				**C**	**31.3**			
Trowbridge Rd EB (left)	D	40.2	0.66	119	#244	D	35.7	0.43	31	m53
Trowbridge Rd EB (left)	D	40.2	0.66	119	#244	D	35.7	0.43	31	m53
Trowbridge Rd EB (thru)	A	4.9	0.38	108	234	B	17.1	0.38	283	391
Trowbridge Rd EB (thru)	A	4.9	0.38	108	234	B	17.1	0.38	283	391
Sandwich Road WB (thru)	B	15.8	0.21	60	155	B	18.0	0.29	103	#300
Sandwich Road WB (thru)	B	15.8	0.21	60	155	B	18.0	0.29	103	#300
Sandwich Road WB (right)	C	23.9	0.62	15	#343	B	18.4	0.28	0	100
Route 28 NB Off-Ramp (left/thru)	D	47.9	0.12	11	34	D	41.4	0.29	67	111
Route 28 NB Off-Ramp (right)	D	48.1	0.14	0	#89	E	61.0	0.82	101	#368
10:: Sandwich Road / Bourne Rotary Connector	**F**	**56.1**				**F**	**99.7**			
Sandwich Road EB (left/right)	F	$1348.8	3.53	-	400	F	$1717.6	4.37	-	515
Sandwich Road (Bourne Rotary Connector) NB (left/thru)	C	18.6	0.02	-	3	B	12.2	0.03	-	3
Sandwich Road (Bourne Rotary Connector) NB (thru)	A	0.5	0.00	-	0	A	1.4	0.00	-	0
Sandwich Rd SB (thru/right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
15:: Sandwich Road (Route 6 Bypass) / Mid-Cape Connector	**C**	**21.8**				**C**	**20.3**			
Sandwich Rd EB (thru)	B	12.6	0.27	78	210	C	29.0	0.66	228	335
Sandwich Rd EB (right)	A	4.2	0.61	0	42	A	5.4	0.68	0	53
Sandwich Rd WB (left/thru)	C	20.5	0.77	296	#708	C	33.6	0.83	295	376
Sandwich Rd WB (thru)	C	20.5	0.77	296	#708	C	33.6	0.83	295	376
Mid-Cape Connector NB (left)	D	48.4	0.88	257	#287	B	19.8	0.30	70	130
Mid-Cape Connector NB (left/right)	D	48.4	0.88	257	#287	B	19.8	0.30	70	130
16:: Mid-Cape Connector / Cranberry Highway Extension	**D**	**37.2**				**B**	**16.2**			
Cranberry Highway Extension WB (left)	D	53.2	0.68	84	m126	D	40.2	0.52	61	110
Cranberry Highway Extension WB (right)	E	77.4	0.24	38	72	A	7.0	0.13	0	5
Cranberry Highway Extension WB (right)	E	77.4	0.24	38	72	A	7.0	0.13	0	5
Mid-Cape Connector NB (thru)	C	21.5	0.23	63	168	B	18.6	0.30	88	#288
Mid-Cape Connector NB (right)	B	13.8	0.21	0	31	B	10.4	0.06	0	18
Mid-Cape Connector SB (left)	D	48.1	0.86	208	m#370	D	50.0	0.82	163	m#255
Mid-Cape Connector SB (thru)	A	6.7	0.31	62	205	A	6.8	0.36	72	278
Mid-Cape Connector SB (thru)	A	6.7	0.31	62	205	A	6.8	0.36	72	278
16:: Cranberry Highway / Route 6 E NB Off-Ramp	**C**	**28.8**				**C**	**21.1**			
Cranberry Highway EB (left)	C	28.4	0.63	141	m#259	C	26.1	0.57	146	m#251
Cranberry Highway EB (thru)	C	28.6	0.53	229	m#380	C	21.3	0.13	46	m87
Cranberry Highway WB (thru)	D	51.7	0.75	160	#376	D	38.6	0.29	51	105
Cranberry Highway WB (right)	B	12.1	0.52	147	268	B	19.5	0.83	335	#773
Route 6 E NB Off-Ramp (left)	D	36.8	0.86	340	464	B	15.9	0.17	48	88
Route 6 E NB Off-Ramp (right)	C	20.3	0.31	82	127	B	17.3	0.31	87	147
20:: Scenic Highway (Route 6) / Church Lane / Route 6 SB On-Ramp	**B**	**18.1**				**C**	**24.9**			
Scenic Hwy (Route 6) EB (left)	E	68.9	0.62	50	97	E	63.1	0.57	29	66
Scenic Hwy (Route 6) EB (thru)	C	21.4	0.57	237	492	C	33.7	0.17	43	102
Scenic Hwy (Route 6) EB (thru/right)	C	21.4	0.57	237	492	C	33.7	0.17	43	102
Scenic Hwy (Route 6) WB (left)	D	40.8	0.32	53	74	C	31.7	0.46	159	167
Scenic Hwy (Route 6) WB (left)	D	40.8	0.32	53	74	C	31.7	0.46	159	167
Scenic Hwy (Route 6) WB (thru)	A	9.9	0.61	94	211	B	18.4	0.64	169	#641
Scenic Hwy (Route 6) WB (thru)	A	9.9	0.61	94	211	B	18.4	0.64	169	#641
Scenic Hwy (Route 6) WB (thru/right)	A	9.9	0.61	94	211	B	18.4	0.64	169	#641
Church Lane SB (left/thru/right)	E	68.0	0.70	89	#171	E	64.8	0.74	107	175
21:: Scenic Highway (Route 6) & Route 3 SB Off-Ramp	**B**	**11.2**				**B**	**14.0**			
Scenic Hwy (Route 6) EB (thru)	A	4.6	0.51	36	38	A	4.0	0.10	7	31
Scenic Hwy (Route 6) EB (thru)	A	4.6	0.51	36	38	A	4.0	0.10	7	31
Scenic Hwy (Route 6) WB (thru)	B	12.6	0.44	119	388	B	13.2	0.64	180	#662
Scenic Hwy (Route 6) WB (thru)	B	12.6	0.44	119	388	B	13.2	0.64	180	#662
Scenic Hwy (Route 6) WB (thru)	B	12.6	0.44	119	388	B	13.2	0.64	180	#662
Route 3 Off-Ramp SB (left)	E	63.3	0.77	181	258	E	58.2	0.76	166	241
Route 3 Off-Ramp SB (right)	A	0.6	0.36	0	0	A	0.4	0.28	0	0

PRE-DECISIONAL & DELIBERATIVE

Table C-2: Synchro and SIDRA Results Summary - 2050 AP1

Intersection	2050 AP1 Weekday Fall PM					2050 AP1 Summer Saturday MID				
	LOS	Delay (sec)	v/c Ratio	50% Queue (feet)	95% Queue (feet)	LOS	Delay (sec)	v/c Ratio	50% Queue (feet)	95% Queue (feet)
22:: Meetinghouse Lane / State Road / Canal Street	**D**	**42.1**				**D**	**54.5**			
Meetinghouse Ln EB (left)	D	42.9	0.92	564	#693	D	39.5	0.30	53	#113
Meetinghouse Ln EB (left)	D	42.9	0.92	564	#693	D	39.5	0.30	53	#113
Meetinghouse Ln EB (thru/right)	C	23.1	0.77	196	#907	F	86.8	1.07	302	#1022
Meetinghouse Ln WB (left)	E	67.0	0.41	9	30	E	63.1	0.57	29	#78
Meetinghouse Ln WB (thru)	D	46.2	0.20	40	102	D	38.3	0.47	125	240
Meetinghouse Ln WB (right)	D	42.9	0.26	35	69	C	31.6	0.37	49	143
Canal St NB (left)	E	76.4	0.83	123	#244	D	38.6	0.73	188	#279
Canal St NB (thru/right)	F	96.3	0.91	147	#281	D	53.8	0.81	249	#398
State Rd SB (left)	D	48.4	0.12	11	32	C	34.2	0.14	17	40
State Rd SB (thru)	E	55.6	0.50	79	139	D	42.1	0.34	81	139
State Rd SB (right)	B	17.5	0.20	54	88	D	43.1	0.79	193	#513
23:: State Road / Route 3 NB On-Ramp	**A**	**8.4**				**B**	**11.4**			
State Rd NB (left)	B	14.2	0.51	42	151	B	17.8	0.46	29	#125
State Rd NB (left)	B	14.2	0.51	42	151	B	17.8	0.46	29	#125
State Rd NB (thru)	A	4.7	0.72	0	#710	A	1.6	0.19	0	102
State Rd SB (thru/right)	B	11.8	0.44	40	197	B	12.7	0.68	87	#424
24:: Cranberry Highway / Adams Street	**A**	**1.9**				**A**	**1.7**			
Cranberry Highway EB (thru/left)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Cranberry Highway EB (thru/right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Cranberry Highway WB (left/thru)	A	8.0	0.01	-	0	A	7.8	0.00	-	0
Cranberry Highway WB (thru/right)	A	0.1	0.00	-	0	A	0.0	0.00	-	0
Adams Street NB (left/thru/right)	C	18.4	0.14	-	13	B	10.7	0.06	-	5
Adams Street SB (left/thru/right)	B	13.9	0.19	-	18	C	15.1	0.25	-	25

PRE-DECISIONAL & DELIBERATIVE

Table C-3: Synchro and SIDRA Results Summary - 2050 AP1.1

Intersection	2050 AP1.1 Weekday Fall PM					2050 AP1.1 Summer Saturday MID				
	LOS	Delay (sec)	v/c Ratio	50% Queue (feet)	95% Queue (feet)	LOS	Delay (sec)	v/c Ratio	50% Queue (feet)	95% Queue (feet)
6:: Scenic Highway (Route 6) / Main Street (Route 6) / Nightingale Road / Andy Olivia Drive	**B**	**17.1**				**B**	**13.0**			
Main Street (Route 6) EB (left)	D	46.4	0.62	43	#159	F	172.2	0.84	7	27
Main Street (Route 6) EB (thru)	B	11.7	0.67	129	#760	A	8.8	0.63	136	308
Main Street (Route 6) EB (thru/right)	B	11.7	0.67	129	#760	A	8.8	0.63	136	308
Scenic Hwy (Route 6) WB (left)	E	59.4	0.36	2	16	D	47.5	0.26	2	13
Scenic Hwy (Route 6) WB (thru)	B	17.5	0.73	217	#690	B	10.4	0.72	166	384
Scenic Hwy (Route 6) WB (thru/right)	B	17.5	0.73	217	#690	B	10.4	0.72	166	384
Scenic Hwy (Route 6) WB (right)	B	19.4	0.73	179	#716	B	10.5	0.67	110	356
Andy Olivia Dr NB (left/thru/right)	D	40.3	0.21	9	46	E	62.0	0.81	54	#165
Nightingale Pond Rd SB (left/thru)	D	43.8	0.48	20	#75	C	33.0	0.09	6	26
Nightingale Pond Rd SB (right)	D	41.6	0.35	16	61	D	38.0	0.54	39	#103
8:: Trowbridge Road / Veterans Way	**A**	**1.2**				**A**	**1.0**			
Trowbridge Rd EB (left/thru)	A	8.3	0.01	-	0	A	7.9	0.00	-	0
Trowbridge Rd EB (thru)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Trowbridge Rd WB (thru)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Trowbridge Rd WB (thru/right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Veterans Way SB (left/right)	C	17.6	0.23	-	23	B	10.9	0.08	-	8
9:: Trowbridge Road / Route 25 SB Off-Ramp	**C**	**34.4**				**D**	**42.2**			
Trowbridge Rd EB (thru)	D	35.6	0.74	252	#500	D	44.1	0.33	53	118
Trowbridge Rd EB (thru/right)	D	35.6	0.74	252	#500	D	44.1	0.33	53	118
Trowbridge Rd WB (left)	E	78.4	0.62	58	#116	D	44.6	0.69	167	#589
Trowbridge Rd WB (thru)	B	19.0	0.19	24	118	B	17.9	0.12	27	118
Trowbridge Rd WB (thru)	B	19.0	0.19	24	118	B	17.9	0.12	27	118
Route 25 SB Off-Ramp (left)	D	37.9	0.73	254	#537	D	54.2	0.84	287	405
Route 25 SB Off-Ramp (thru/right)	C	32.0	0.56	156	#364	D	41.5	0.63	184	293
9:: Sandwich Road / Trowbridge Road / Route 28 NB Off-Ramp	**C**	**20.6**				**C**	**31.3**			
Trowbridge Rd EB (left)	D	40.2	0.66	119	#244	D	35.7	0.43	31	m53
Trowbridge Rd EB (left)	D	40.2	0.66	119	#244	D	35.7	0.43	31	m53
Trowbridge Rd EB (thru)	A	4.9	0.38	108	234	B	17.1	0.38	283	391
Trowbridge Rd EB (thru)	A	4.9	0.38	108	234	B	17.1	0.38	283	391
Sandwich Road WB (thru)	B	15.8	0.21	60	155	B	18.0	0.29	103	#300
Sandwich Road WB (thru)	B	15.8	0.21	60	155	B	18.0	0.29	103	#300
Sandwich Road WB (right)	C	23.9	0.62	15	#343	B	18.4	0.28	0	100
Route 28 NB Off-Ramp (left/thru)	D	47.9	0.12	11	34	D	41.4	0.29	67	111
Route 28 NB Off-Ramp (right)	D	48.1	0.14	0	#89	E	61.0	0.82	101	#368
10:: Sandwich Road / Bourne Rotary Connector	**F**	**56.1**				**F**	**99.7**			
Sandwich Road EB (left/right)	F	$1348.8	3.53	-	400	F	$1717.6	4.37	-	515
Sandwich Road (Bourne Rotary Connector) NB (left/thru)	C	18.6	0.02	-	3	B	12.2	0.03	-	3
Sandwich Road (Bourne Rotary Connector) NB (thru)	A	0.5	0.00	-	0	A	1.4	0.00	-	0
Sandwich Rd WB (thru/right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
15:: Sandwich Road (Route 6 Bypass) / Mid-Cape Connector	**C**	**21.8**				**C**	**20.3**			
Sandwich Rd EB (thru)	B	12.6	0.27	78	210	C	29.0	0.66	228	335
Sandwich Rd EB (right)	A	4.2	0.61	0	42	A	5.4	0.68	0	53
Sandwich Rd WB (left/thru)	C	20.5	0.77	296	#708	C	33.6	0.83	295	376
Sandwich Rd WB (thru)	C	20.5	0.77	296	#708	C	33.6	0.83	295	376
Mid-Cape Connector NB (left)	D	48.4	0.88	257	#287	B	19.8	0.30	70	130
Mid-Cape Connector NB (left/right)	D	48.4	0.88	257	#287	B	19.8	0.30	70	130
16:: Mid-Cape Connector / Cranberry Highway Extension	**D**	**37.2**				**B**	**16.2**			
Cranberry Highway Extension WB (left)	D	53.2	0.68	84	m126	D	40.2	0.52	61	110
Cranberry Highway Extension WB (right)	E	77.4	0.24	38	72	A	7.0	0.13	0	5
Cranberry Highway Extension WB (right)	E	77.4	0.24	38	72	A	7.0	0.13	0	5
Mid-Cape Connector NB (thru)	C	21.5	0.23	63	168	B	18.6	0.3	88	#288
Mid-Cape Connector NB (right)	B	13.8	0.21	0	31	B	10.4	0.06	0	18
Mid-Cape Connector SB (left)	D	48.1	0.86	208	m#370	D	50.0	0.82	163	m#255
Mid-Cape Connector SB (thru)	A	6.7	0.31	62	205	A	6.8	0.36	72	278
Mid-Cape Connector SB (thru)	A	6.7	0.31	62	205	A	6.8	0.36	72	278
16:: Cranberry Highway / Route 6 E NB Off-Ramp	**C**	**28.8**				**C**	**21.1**			
Cranberry Highway EB (left)	C	28.4	0.63	141	m#259	C	26.1	0.57	146	m#251
Cranberry Highway EB (thru)	C	28.6	0.53	229	m#380	C	21.3	0.13	46	m87
Cranberry Highway WB (thru)	D	51.7	0.75	160	#376	D	38.6	0.29	51	105
Cranberry Highway WB (right)	B	12.1	0.52	147	268	B	19.5	0.83	335	#773
Route 6 E NB Off-Ramp (left)	D	36.8	0.86	340	464	B	15.9	0.17	48	88
Route 6 E NB Off-Ramp (right)	C	20.3	0.31	82	127	B	17.3	0.31	87	147
20:: Scenic Highway (Route 6) / Church Lane / Route 6 SB On-Ramp	**C**	**22.4**				**C**	**23.2**			
Scenic Hwy (Route 6) EB (left)	E	57.5	0.55	46	89	E	63.1	0.57	29	66
Scenic Hwy (Route 6) EB (thru)	C	21.9	0.60	205	#580	C	33.7	0.17	43	102
Scenic Hwy (Route 6) EB (thru/right)	C	21.9	0.60	205	#580	C	33.7	0.17	43	102
Scenic Hwy (Route 6) WB (left)	D	49.0	0.34	50	67	C	28.1	0.46	152	167
Scenic Hwy (Route 6) WB (left)	D	49.0	0.34	50	67	C	28.1	0.46	152	167
Scenic Hwy (Route 6) WB (thru)	B	17.7	0.65	138	#689	B	16.9	0.64	99	#642
Scenic Hwy (Route 6) WB (thru)	B	17.7	0.65	138	#689	B	16.9	0.64	99	#642
Scenic Hwy (Route 6) WB (thru/right)	B	17.7	0.65	138	#689	B	16.9	0.64	99	#642
Church Lane SB (left/thru/right)	E	57.0	0.63	82	137	E	64.8	0.74	107	175
21:: Scenic Highway (Route 6) & Route 3 SB Off-Ramp	**B**	**10.4**				**B**	**16.6**			
Scenic Hwy (Route 6) EB (thru)	A	2.7	0.53	9	21	A	4.0	0.10	7	31
Scenic Hwy (Route 6) EB (thru)	A	2.7	0.53	9	21	A	4.0	0.10	7	31
Scenic Hwy (Route 6) WB (thru)	B	13.3	0.46	119	m371	B	16.9	0.64	215	#672
Scenic Hwy (Route 6) WB (thru)	B	13.3	0.46	119	m371	B	16.9	0.64	215	#672
Scenic Hwy (Route 6) WB (thru)	B	13.3	0.46	119	m371	B	16.9	0.64	215	#672
Route 3 Off-Ramp SB (left)	E	56.3	0.74	166	236	E	58.2	0.76	166	241
Route 3 Off-Ramp SB (right)	A	0.6	0.36	0	0	A	0.4	0.28	0	0

PRE-DECISIONAL & DELIBERATIVE

Table C-3: Synchro and SIDRA Results Summary - 2050 AP1.1

Intersection	2050 AP1.1 Weekday Fall PM					2050 AP1.1 Summer Saturday MID				
	LOS	Delay (sec)	v/c Ratio	50% Queue (feet)	95% Queue (feet)	LOS	Delay (sec)	v/c Ratio	50% Queue (feet)	95% Queue (feet)
22:: Meetinghouse Lane / State Road / Canal Street	**D**	**51.5**				**D**	**52.3**			
Meetinghouse Ln EB (left)	D	45.6	0.88	~382	#500	D	53.3	0.47	51	#107
Meetinghouse Ln EB (left)	D	45.6	0.88	~382	#500	D	53.3	0.47	51	#107
Meetinghouse Ln EB (thru/right)	C	23.0	0.51	94	#345	D	35.6	0.65	241	#453
Meetinghouse Ln WB (left)	F	183.2	0.79	8	29	E	73.9	0.64	29	#78
Meetinghouse Ln WB (thru)	D	43.4	0.20	36	96	D	41.4	0.47	124	#294
Meetinghouse Ln WB (right)	D	38.9	0.25	24	65	C	22.9	0.28	45	137
Canal St NB (left)	F	143.3	1.09	~112	#227	C	32.7	0.61	164	243
Canal St NB (thru/right)	D	46.8	0.56	124	199	E	77.5	0.93	257	#428
State Rd SB (left)	D	48.4	0.65	95	156	E	79.1	1.00	~229	#431
State Rd SB (thru)	F	84.4	0.94	218	#382	D	39.3	0.34	93	155
State Rd SB (right)	B	18.8	0.21	54	88	E	57.2	0.88	212	#472
23:: State Road / Route 3 NB Ramps	**C**	**24.9**				**C**	**26.8**			
Route 3 NB Off-Ramp (left)	C	28.5	0.73	115	#363	C	28.8	0.15	10	41
Route 3 NB Off-Ramp (right)	B	12.3	0.43	50	120	D	47.3	0.90	107	#320
State Rd NB (left)	C	27.9	0.69	85	#222	C	29.8	0.60	56	#151
State Rd NB (left)	C	27.9	0.69	85	#222	C	29.8	0.60	56	#151
State Rd NB (thru)	B	18.6	0.76	176	#608	A	5.2	0.21	26	130
State Rd SB (thru/right)	D	44.5	0.84	104	#345	C	22.0	0.76	168	#542
24:: Cranberry Highway / Adams Street	**A**	**1.9**				**A**	**1.7**			
Cranberry Highway EB (thru/left)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Cranberry Highway EB (thru/right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Cranberry Highway WB (left/thru)	A	8.0	0.01	-	0	A	7.8	0.00	-	0
Cranberry Highway WB (thru)	A	0.1	0.00	-	0	A	0.0	0.00	-	0
Adams Street NB (left/thru/right)	C	18.4	0.14	-	13	B	10.7	0.06	-	5
Adams Street SB (left/thru/right)	B	13.9	0.19	-	18	C	15.1	0.25	-	25

PRE-DECISIONAL & DELIBERATIVE

Table C-4: Synchro and SIDRA Results Summary - 2050 AP2

Intersection	2050 AP2 Weekday Fall PM					2050 AP2 Summer Saturday MID				
	LOS	Delay (sec)	v/c Ratio	50% Queue (feet)	95% Queue (feet)	LOS	Delay (sec)	v/c Ratio	50% Queue (feet)	95% Queue (feet)
6:: Scenic Highway (Route 6) / Main Street (Route 6) / Nightingale Road / Andy Olivia Drive	**B**	**15.5**				**B**	**13.0**			
Main Street (Route 6) EB (left)	D	44.8	0.6	43	#159	F	172.2	0.84	7	27
Main Street (Route 6) EB (thru)	B	10.1	0.63	122	#724	A	8.8	0.63	136	308
Main Street (Route 6) EB (thru/right)	B	10.1	0.63	122	#724	A	8.8	0.63	136	308
Scenic Hwy (Route 6) WB (left)	E	58.7	0.36	2	16	D	47.5	0.26	2	13
Scenic Hwy (Route 6) WB (thru)	B	14.2	0.63	175	#564	B	10.4	0.72	166	384
Scenic Hwy (Route 6) WB (thru/right)	B	14.2	0.63	175	#564	B	10.4	0.72	166	384
Scenic Hwy (Route 6) WB (right)	B	19.7	0.77	205	#790	B	10.5	0.67	110	356
Andy Olivia Dr NB (left/thru/right)	D	42.7	0.29	9	46	E	62.0	0.81	54	#165
Nightingale Pond Rd SB (left/thru)	D	45.3	0.47	16	61	C	33.0	0.09	6	26
Nightingale Pond Rd SB (right)	D	44.7	0.43	14	55	D	38.0	0.54	39	#103
8:: Trowbridge Road / Veterans Way	**A**	**0.3**				**A**	**1.0**			
Trowbridge Rd EB (left/thru)	A	8.9	0.01	-	0	A	7.9	0.00	-	0
Trowbridge Rd EB (thru/right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Trowbridge Rd WB (thru)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Trowbridge Rd WB (thru/right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Veterans Way SB (left/thru/right)	B	10.3	0.03		3	B	10.4	0.08	-	5
9:: Trowbridge Road / Sandwich Road / Route 25 SB Off-Ramp / Route 28 NB Off-Ramp	**B**	**17.6**				**B**	**17.9**			
Trowbridge Rd EB (left)	D	39.6	0.78	98	#293	D	36.0	0.52	32	90
Trowbridge Rd EB (thru)	C	21.3	0.24	36	94	C	28.3	0.16	16	47
Trowbridge Rd EB (thru)	C	21.3	0.24	36	94	C	28.3	0.16	16	47
Trowbridge Rd WB (left)	C	32.9	0.62	67	157	D	37	0.82	141	#392
Trowbridge Rd WB (thru)	C	33.7	0.77	127	#352	B	18.9	0.23	41	115
Trowbridge Rd WB (right)	A	2.5	0.69	0	0	A	0.4	0.28	0	0
Route 25 SB Off-Ramp (left)	C	30.6	0.77	120	#274	C	32.5	0.82	139	#324
Route 25 SB Off-Ramp (left)	C	30.6	0.77	120	#274	C	32.5	0.82	139	#324
Route 25 SB Off-Ramp (right)	A	0.1	0.10	0	0	A	0.0	0.01	0	0
Route 28 NB Off-Ramp (left)	C	22.9	0.27	36	103	C	22.4	0.22	32	94
Route 28 NB Off-Ramp (right)	A	0.2	0.14	0	0	A	1.1	0.48	0	0
10:: Sandwich Road / Bourne Rotary Connector	**F**	**503.4**				**F**	**99.7**			
Sandwich Road EB (left/right)	F	$4809.5	11.19	-	1160	F	$1717.6	4.37	-	515
Sandwich Road (Bourne Rotary Connector) NB (left/thru)	C	19.8	0.02	-	3	B	12.2	0.03	-	3
Sandwich Road (Bourne Rotary Connector) NB (thru)	A	0.5	0.00	-	0	A	1.4	0.00	-	0
Sandwich Rd SB (thru/right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
15:: Sandwich Road (Route 6 Bypass) / Mid-Cape Connector	**C**	**22.2**				**B**	**18.4**			
Sandwich Rd EB (thru)	C	23.5	0.71	192	#536	C	32.3	0.89	317	#899
Sandwich Rd EB (right)	B	18.7	0.84	208	#873	B	12.0	0.71	147	#724
Sandwich Rd WB (left)	B	11.4	0.34	21	80	B	17.3	0.50	18	#102
Sandwich Rd WB (thru)	B	18.1	0.86	284	#808	A	9.3	0.50	120	371
Sandwich Rd WB (thru)	B	18.1	0.86	284	#808	A	9.3	0.50	120	371
Mid-Cape Connector NB (left)	D	51.0	0.87	138	#396	C	33.5	0.52	75	178
Mid-Cape Connector NB (right)	C	28.2	0.67	109	#242	C	27.2	0.43	63	104
16:: Mid-Cape Connector / Cranberry Highway Extension	**B**	**15.1**				**A**	**9.0**			
Cranberry Highway Extension WB (left)	C	25.9	0.27	17	62	C	22.3	0.18	7	35
Cranberry Highway Extension WB (left)	C	25.9	0.27	17	62	C	22.3	0.18	7	35
Cranberry Highway Extension WB (right)	B	18.4	0.45	42	#141	B	19.1	0.23	8	31
Mid-Cape Connector NB (thru)	C	23.9	0.73	125	#397	B	12.1	0.39	61	206
Mid-Cape Connector NB (right)	B	10.7	0.13	14	74	A	7.1	0.07	6	39
Mid-Cape Connector SB (left)	C	25.0	0.54	52	#220	C	22.9	0.03	1	13
Mid-Cape Connector SB (thru)	A	6.8	0.40	53	237	A	6.4	0.45	56	242
Mid-Cape Connector SB (thru)	A	6.8	0.40	53	237	A	6.4	0.45	56	242
20:: Scenic Highway (Route 6) / Church Lane / Route 6 SB On-Ramp	**C**	**21.8**				**C**	**23.2**			
Scenic Hwy (Route 6) EB (left)	E	57.5	0.55	46	89	E	63.1	0.57	29	66
Scenic Hwy (Route 6) EB (thru)	C	21.6	0.58	198	#556	C	33.7	0.17	43	102
Scenic Hwy (Route 6) EB (thru/right)	C	21.6	0.58	198	#556	C	33.7	0.17	43	102
Scenic Hwy (Route 6) WB (left)	D	47.5	0.36	51	68	C	28.1	0.46	152	167
Scenic Hwy (Route 6) WB (left)	D	47.5	0.36	51	68	C	28.1	0.46	152	167
Scenic Hwy (Route 6) WB (thru)	B	16.4	0.61	105	#620	B	16.9	0.64	99	#642
Scenic Hwy (Route 6) WB (thru)	B	16.4	0.61	105	#620	B	16.9	0.64	99	#642
Scenic Hwy (Route 6) WB (thru/right)	B	16.4	0.61	105	#620	B	16.9	0.64	99	#642
Church Lane SB (left/thru/right)	E	57.0	0.63	82	137	E	64.8	0.74	107	175
21:: Scenic Highway (Route 6) & Route 3 SB Off-Ramp	**B**	**11.0**				**B**	**16.6**			
Scenic Hwy (Route 6) EB (thru)	A	2.8	0.52	12	21	A	4.0	0.10	7	31
Scenic Hwy (Route 6) EB (thru)	A	2.8	0.52	12	21	A	4.0	0.10	7	31
Scenic Hwy (Route 6) WB (thru)	B	13.8	0.44	119	m361	B	16.9	0.64	215	#672
Scenic Hwy (Route 6) WB (thru)	B	13.8	0.44	119	m361	B	16.9	0.64	215	#672
Scenic Hwy (Route 6) WB (thru)	B	13.8	0.44	119	m361	B	16.9	0.64	215	#672
Route 3 Off-Ramp SB (left)	E	56.6	0.75	169	241	E	58.2	0.76	166	241
Route 3 Off-Ramp SB (right)	A	0.5	0.32	0	0	A	0.4	0.28	0	0
22:: Meetinghouse Lane / State Road / Canal Street	**D**	**49.2**				**D**	**52.3**			
Meetinghouse Ln EB (left)	D	39.5	0.86	366	#481	D	53.3	0.47	51	#107
Meetinghouse Ln EB (left)	D	39.5	0.86	366	#481	D	53.3	0.47	51	#107
Meetinghouse Ln EB (thru/right)	B	16.3	0.51	80	#338	D	35.6	0.65	241	#453
Meetinghouse Ln WB (left)	F	183.2	0.79	8	29	E	73.9	0.64	29	#78
Meetinghouse Ln WB (thru)	D	43.6	0.20	36	96	D	41.4	0.47	124	#294
Meetinghouse Ln WB (right)	D	37.6	0.10	9	31	C	22.9	0.28	45	137
Canal St NB (left)	F	143.2	1.09	~112	#228	C	32.7	0.61	164	243
Canal St NB (thru/right)	D	48.8	0.62	142	223	E	77.5	0.93	257	#428
State Rd SB (left)	D	52.0	0.70	95	#172	E	79.1	1.00	~229	#431
State Rd SB (thru)	F	86.0	0.94	222	#390	D	39.3	0.34	93	155
State Rd SB (right)	B	18.4	0.18	46	77	E	57.2	0.88	212	#472

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Table C-4: Synchro and SIDRA Results Summary - 2050 AP2

Intersection	2050 AP2 Weekday Fall PM					2050 AP2 Summer Saturday MID				
	LOS	Delay (sec)	v/c Ratio	50% Queue (feet)	95% Queue (feet)	LOS	Delay (sec)	v/c Ratio	50% Queue (feet)	95% Queue (feet)
23:: State Road / Route 3 NB Ramps	**C**	**23.2**				**C**	**26.8**			
Route 3 NB Off-Ramp (left)	C	28.5	0.73	115	#363	C	28.8	0.15	10	41
Route 3 NB Off-Ramp (right)	B	13.1	0.45	55	123	D	47.3	0.90	107	#320
State Rd NB (left)	C	27.7	0.65	75	#175	C	29.8	0.60	56	#151
State Rd NB (left)	C	27.7	0.65	75	#175	C	29.8	0.60	56	#151
State Rd NB (thru)	B	18.8	0.77	179	#614	A	5.2	0.21	26	130
State Rd SB (thru/right)	C	32.7	0.72	92	#314	C	22	0.76	168	#542
24:: Cranberry Highway / Adams Street	**A**	**6.3**				**E**	**42.0**			
Cranberry Highway EB (thru/right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Cranberry Highway WB (left)	A	9.2	0.01	-	0	A	8.1	0.01	-	0
Cranberry Highway WB (thru/right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Adams Street NB (left/thru/right)	E	38.7	0.13	-	10	F	$829.9	1.90	-	128
Adams Street SB (left/thru/right)	D	26.3	0.69	-	133	F	92.2	1.04	-	330

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Table C-5: Synchro and SIDRA Results Summary - 2050 AP3

Intersection	2050 AP3 Weekday Fall PM					2050 AP3 Summer Saturday MID				
	LOS	Delay (sec)	v/c Ratio	50% Queue (feet)	95% Queue (feet)	LOS	Delay (sec)	v/c Ratio	50% Queue (feet)	95% Queue (feet)
6:: Scenic Highway (Route 6) / Main Street (Route 6) / Nightingale Road / Andy Olivia Drive	**B**	**17.3**				**B**	**13.0**			
Main Street (Route 6) EB (left)	D	46.4	0.62	43	#159	F	172.2	0.84	7	27
Main Street (Route 6) EB (thru)	B	12.1	0.69	136	#798	A	8.8	0.63	136	308
Main Street (Route 6) EB (thru/right)	B	12.1	0.69	136	#798	A	8.8	0.63	136	308
Scenic Hwy (Route 6) WB (left)	E	59.4	0.36	2	16	D	47.5	0.26	2	13
Scenic Hwy (Route 6) WB (thru)	B	18.1	0.76	229	#723	B	10.4	0.72	166	384
Scenic Hwy (Route 6) WB (thru/right)	B	18.1	0.76	229	#723	B	10.4	0.72	166	384
Scenic Hwy (Route 6) WB (right)	B	19.0	0.72	174	#701	B	10.5	0.67	110	356
Andy Olivia Dr NB (left/thru/right)	D	40.2	0.20	9	43	E	62.0	0.81	54	#165
Nightingale Pond Rd SB (left/thru)	D	40.9	0.26	11	48	C	33.0	0.09	6	26
Nightingale Pond Rd SB (right)	D	45.8	0.55	26	#95	D	38.0	0.54	39	#103
8:: Trowbridge Road / Veterans Way	**A**	**0.5**				**A**	**1.0**			
Trowbridge Rd EB (left/thru)	A	8.5	0.01	-	0	A	7.9	0.00	-	0
Trowbridge Rd EB (thru)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Trowbridge Rd WB (thru)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Trowbridge Rd WB (thru/right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Veterans Way SB (left/right)	C	15.2	0.11	-	10	B	10.9	0.08	-	8
9:: Trowbridge Road / Route 25 SB Off-Ramp	**D**	**46.3**				**D**	**42.2**			
Trowbridge Rd EB (thru)	E	67.7	1.00	250	#466	D	44.1	0.33	53	118
Trowbridge Rd EB (thru/right)	E	67.7	1.00	250	#466	D	44.1	0.33	53	118
Trowbridge Rd WB (left)	E	68.0	0.59	98	#223	D	44.6	0.69	167	#589
Trowbridge Rd WB (thru)	C	21.2	0.24	30	152	B	17.9	0.12	27	118
Trowbridge Rd WB (thru)	C	21.2	0.24	30	152	B	17.9	0.12	27	118
Route 25 SB Off-Ramp (left)	C	31.8	0.67	210	#502	D	54.2	0.84	287	405
Route 25 SB Off-Ramp (thru/right)	C	27.4	0.50	116	#327	D	41.5	0.63	184	293
9:: Sandwich Road / Trowbridge Road / Route 28 NB Off-Ramp	**C**	**21.4**				**C**	**31.3**			
Trowbridge Rd EB (left)	C	33.7	0.61	110	m#200	D	35.7	0.43	31	m53
Trowbridge Rd EB (left)	C	33.7	0.61	110	m#200	D	35.7	0.43	31	m53
Trowbridge Rd EB (thru)	A	4.8	0.38	111	m205	B	17.1	0.38	283	391
Trowbridge Rd EB (thru)	A	4.8	0.38	111	m205	B	17.1	0.38	283	391
Sandwich Road WB (thru)	B	17.8	0.31	81	207	B	18.0	0.29	103	#300
Sandwich Road WB (thru)	B	17.8	0.31	81	207	B	18.0	0.29	103	#300
Sandwich Road WB (right)	C	28.8	0.74	32	#417	B	18.4	0.28	0	100
Route 28 NB Off-Ramp (left/thru)	D	42.9	0.11	10	31	D	41.4	0.29	67	111
Route 28 NB Off-Ramp (right)	D	43.1	0.13	0	70	E	61.0	0.82	101	#368
10:: Sandwich Road / Bourne Rotary Connector	**F**	**111.6**				**F**	**99.7**			
Sandwich Road EB (left/right)	F	$2157.4	5.28	-	533	F	$1717.6	4.37	-	515
Sandwich Road (Bourne Rotary Connector) NB (left/thru)	C	19.8	0.02	-	3	B	12.2	0.03	-	3
Sandwich Road (Bourne Rotary Connector) NB (thru)	A	0.50	0.00	-	0	A	1.4	0.00	-	0
Sandwich Rd SB (thru/right)	A	0.00	0.00	-	0	A	0.0	0.00	-	0
15:: Sandwich Road (Route 6 Bypass) / Mid-Cape Connector	**D**	**39.1**				**C**	**27.9**			
Sandwich Rd EB (thru)	C	26.3	0.34	115	228	D	41.9	0.75	306	#609
Sandwich Rd EB (right)	D	52.7	1.03	607	#1349	B	19.3	0.9	360	#1309
Sandwich Rd WB (left)	B	16.2	0.40	77	175	C	25.1	0.14	12	37
Sandwich Rd WB (thru)	C	23.8	0.77	378	#729	C	31.4	0.70	322	#510
Sandwich Rd WB (thru)	C	23.8	0.77	378	#729	C	31.4	0.70	322	#510
Mid-Cape Connector NB (left)	D	53.9	0.76	312	344	C	27.9	0.44	177	305
Mid-Cape Connector NB (right)	D	53.9	0.76	312	344	C	27.9	0.44	177	305
16:: Mid-Cape Connector / Cranberry Highway Extension	**B**	**16.8**				**F**	**84.2**			
Cranberry Highway Extension WB (left)	D	49.0	0.84	196	m#315	F	178	1.30	~999	#1224
Cranberry Highway Extension WB (right)	B	15.8	0.53	90	209	B	12.7	0.25	80	80
Cranberry Highway Extension WB (right)	B	15.8	0.53	90	209	B	12.7	0.25	80	80
Mid-Cape Connector NB (thru)	C	24.5	0.28	90	202	D	46.2	0.58	144	#444
Mid-Cape Connector NB (right)	B	13.1	0.40	95	155	A	7.5	0.09	10	40
Mid-Cape Connector SB (left)	C	32.7	0.45	87	m97	D	43.0	0.04	4	m5
Mid-Cape Connector SB (thru)	A	7.8	0.58	111	m364	D	42.9	0.94	403	#853
Mid-Cape Connector SB (thru)	A	7.8	0.58	111	m364	D	42.9	0.94	403	#853
16:: Cranberry Highway / Route 6 E NB Off-Ramp	**C**	**31.2**				**C**	**27.2**			
Cranberry Highway EB (left)	C	0.0	0.00	0	0	A	0.0	0.00	0	0
Cranberry Highway EB (thru)	C	30.2	0.70	244	#634	A	6.2	0.02	6	20
Cranberry Highway WB (thru/right)	C	23.1	0.21	68	148	B	17.1	0.77	418	817
Route 6 E NB Off-Ramp (left/thru)	D	38.9	0.88	340	473	D	46.7	0.54	95	166
Route 6 E NB Off-Ramp (right)	B	18.2	0.28	83	122	E	61.3	0.80	167	#305
20:: Scenic Highway (Route 6) / Church Lane / Route 6 SB On-Ramp	**B**	**17.7**				**C**	**24.9**			
Scenic Hwy (Route 6) EB (left)	E	68.9	0.62	29	66	E	63.1	0.57	29	66
Scenic Hwy (Route 6) EB (thru)	C	21.0	0.55	43	102	C	33.7	0.17	43	102
Scenic Hwy (Route 6) EB (thru/right)	C	21.0	0.55	43	102	C	33.7	0.17	43	102
Scenic Hwy (Route 6) WB (left)	D	39.9	0.32	159	167	C	31.7	0.46	159	167
Scenic Hwy (Route 6) WB (left)	D	39.9	0.32	159	167	C	31.7	0.46	159	167
Scenic Hwy (Route 6) WB (thru)	A	9.5	0.60	169	#641	B	18.4	0.64	169	#641
Scenic Hwy (Route 6) WB (thru)	A	9.5	0.60	169	#641	B	18.4	0.64	169	#641
Scenic Hwy (Route 6) WB (thru/right)	A	9.5	0.60	169	#641	B	18.4	0.64	169	#641
Church Lane SB (left/thru/right)	E	68.0	0.70	107	175	E	64.8	0.74	107	175
21:: Scenic Highway (Route 6) & Route 3 SB Off-Ramp	**B**	**10.4**				**B**	**14.0**			
Scenic Hwy (Route 6) EB (thru)	A	4.0	0.48	7	31	A	4.0	0.10	7	31
Scenic Hwy (Route 6) EB (thru)	A	4.0	0.48	7	31	A	4.0	0.10	7	31
Scenic Hwy (Route 6) WB (thru)	B	11.8	0.42	180	#662	B	13.2	0.64	180	#662
Scenic Hwy (Route 6) WB (thru)	B	11.8	0.42	180	#662	B	13.2	0.64	180	#662
Scenic Hwy (Route 6) WB (thru)	B	11.8	0.42	180	#662	B	13.2	0.64	180	#662
Route 3 Off-Ramp SB (left)	E	62.6	0.74	166	241	E	58.2	0.76	166	241
Route 3 Off-Ramp SB (right)	A	0.6	0.36	0	0	A	0.4	0.28	0	0

PRE-DECISIONAL & DELIBERATIVE

Table C-5: Synchro and SIDRA Results Summary - 2050 AP3

Intersection	2050 AP3 Weekday Fall PM					2050 AP3 Summer Saturday MID				
	LOS	Delay (sec)	v/c Ratio	50% Queue (feet)	95% Queue (feet)	LOS	Delay (sec)	v/c Ratio	50% Queue (feet)	95% Queue (feet)
22:: Meetinghouse Lane / State Road / Canal Street	**D**	**43.5**				**D**	**54.5**			
Meetinghouse Ln EB (left)	D	44.9	0.92	543	#676	D	39.5	0.30	53	#113
Meetinghouse Ln EB (left)	D	44.9	0.92	543	#676	D	39.5	0.30	53	#113
Meetinghouse Ln EB (thru/right)	C	24.3	0.77	193	#892	F	86.8	1.07	302	#1022
Meetinghouse Ln WB (left)	E	67.0	0.41	9	30	E	63.1	0.57	29	#78
Meetinghouse Ln WB (thru)	D	46.4	0.24	47	115	D	38.3	0.47	125	240
Meetinghouse Ln WB (right)	D	42.8	0.26	34	69	C	31.6	0.37	49	143
Canal St NB (left)	E	71.3	0.80	121	#232	D	38.6	0.73	188	#279
Canal St NB (thru/right)	F	94.5	0.92	169	#314	D	53.8	0.81	249	#398
State Rd SB (left)	D	46.5	0.04	3	15	C	34.2	0.14	17	40
State Rd SB (thru)	D	54.4	0.51	91	154	D	42.1	0.34	81	139
State Rd SB (right)	B	17.6	0.20	56	92	D	43.1	0.79	193	#513
23:: State Road / Route 3 NB On-Ramp	**A**	**9.1**				**B**	**11.4**			
State Rd NB (left)	C	20.1	0.56	29	#125	B	17.8	0.46	29	#125
State Rd NB (left)	C	20.1	0.56	29	#125	B	17.8	0.46	29	#125
State Rd NB (thru)	A	5.0	0.74	0	102	A	1.6	0.19	0	102
State Rd SB (thru/right)	A	9.3	0.33	87	#424	B	12.7	0.68	87	#424
24:: Cranberry Highway / Adams Street	**A**	**1.6**				**A**	**2.1**			
Cranberry Highway EB (thru/right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Cranberry Highway WB (left)	A	8.6	0.01	-	0	A	7.8	0.00	-	0
Cranberry Highway WB (thru/right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Adams Street NB (left/thru/right)	C	16.1	0.12	-	10	B	13.7	0.09	-	8
Adams Street SB (left/thru/right)	C	15.7	0.08	-	5	C	22.0	0.32	-	33

PRE-DECISIONAL & DELIBERATIVE

Table C-6: Synchro and SIDRA Results Summary - 2050 AP4

Intersection	2050 AP4 Weekday Fall PM					2050 AP4 Summer Saturday MID				
	LOS	Delay (sec)	v/c Ratio	50% Queue (feet)	95% Queue (feet)	LOS	Delay (sec)	v/c Ratio	50% Queue (feet)	95% Queue (feet)
6:: Main Street (Route 6) / Route 25 SB Off-Ramp	**D**	**47.3**				**E**	**71.6**			
Main Street (Route 6) EB (thru)	C	27.9	0.44	178	278	B	12.4	0.40	147	317
Main Street (Route 6) EB (thru)	C	27.9	0.44	178	278	B	12.4	0.40	147	317
Scenic Hwy (Route 6) WB (thru)	C	32.9	0.79	394	#728	C	28.4	0.90	666	m#1211
Route 25 SB Off-Ramp SB (left)	E	59.9	1.02	534	#842	F	242.4	1.40	~536	#754
Route 25 SB Off-Ramp SB (left)	E	59.9	1.02	534	#842	F	242.4	1.40	~536	#754
Route 25 SB Off-Ramp SB (right)	A	0.0	0.00	0	0	A	0.0	0.00	0	0
6:: Scenic Highway (Route 6) / Main Street (Route 6) / Nightingale Road / Andy Olivia Drive	**C**	**20.1**				**B**	**19.1**			
Main Street (Route 6) EB (left)	E	58.1	0.48	67	m#133	E	71.0	0.44	13	m24
Main Street (Route 6) EB (thru)	B	13.7	0.83	24	m#1191	A	8.3	0.60	54	m296
Main Street (Route 6) EB (thru/right)	B	13.7	0.83	24	m#1191	A	8.3	0.60	54	m296
Scenic Hwy (Route 6) WB (left)	E	71.8	0.33	4	18	E	71.8	0.33	4	18
Scenic Hwy (Route 6) WB (thru)	B	15.1	0.46	166	410	B	16.9	0.70	178	#974
Scenic Hwy (Route 6) WB (right)	C	25.5	0.85	375	#859	B	14.2	0.63	118	#642
Scenic Hwy (Route 6) WB (right)	C	25.5	0.85	375	#859	B	14.2	0.63	118	#642
Andy Olivia Dr NB (left/thru/right)	E	56.5	0.27	16	46	F	152.3	1.05	98	#230
Nightingale Pond Rd SB (left/thru)	E	56.5	0.27	16	43	D	50.3	0.11	12	35
Nightingale Pond Rd SB (right)	E	67.7	0.60	37	80	E	61.0	0.63	66	#136
8:: Trowbridge Road / Veterans Way	**A**	**0.7**				**A**	**1.2**			
Trowbridge Rd EB (left/thru)	A	8.9	0.01	-	0	A	8.2	0.01	-	0
Trowbridge Rd EB (thru/right)	A	0.1	0.00	-	0	A	0.1	0.00	-	0
Trowbridge Rd WB (thru)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Trowbridge Rd WB (thru/right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Veterans Way SB (left/thru/right)	B	10.3	0.03	-	3	B	13.0	0.14	-	13
9:: Trowbridge Road / Sandwich Road / Route 25 SB Off-Ramp / Route 28 NB Off-Ramp	**C**	**23.8**				**B**	**15.5**			
Trowbridge Rd EB (left)	D	48.5	0.93	185	#509	C	31.2	0.58	60	146
Trowbridge Rd EB (thru)	B	15.1	0.28	52	136	C	28.4	0.36	35	84
Trowbridge Rd EB (thru/right)	B	15.1	0.28	52	136	C	28.4	0.36	35	84
Trowbridge Rd WB (left)	D	35.1	0.65	69	161	C	30.8	0.81	159	#439
Trowbridge Rd WB (thru)	D	49.8	0.92	179	#490	C	20.1	0.42	73	200
Trowbridge Rd WB (right)	A	1.2	0.51	0	0	A	0.8	0.41	0	0
Route 25 SB Off-Ramp (left)	D	37.6	0.68	52	#135	C	31.2	0.72	90	#215
Route 25 SB Off-Ramp (left)	D	37.6	0.68	52	#135	C	31.2	0.72	90	#215
Route 25 SB Off-Ramp (right)	A	0.1	0.07	0	0	A	0.0	0.01	0	0
Route 28 NB Off-Ramp (left)	C	31.3	0.20	15	51	C	26.0	0.34	40	111
Route 28 NB Off-Ramp (right)	A	0.2	0.15	0	0	A	1.2	0.51	0	0
10:: Sandwich Road / Bourne Rotary Connector	**A**	**1.0**				**E**	**43.8**			
Sandwich Road EB (left/right)	F	152.1	0.42	-	35	F	$1109.4	2.99	-	333
Sandwich Road (Bourne Rotary Connector) NB (left/thru)	C	19.7	0.02	-	3	B	13.2	0.04	-	3
Sandwich Road (Bourne Rotary Connector) NB (thru)	A	0.4	0.00	-	0	A	1.1	0.00	-	0
Sandwich Rd WB (thru/right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
15:: Sandwich Road (Route 6 Bypass) / Mid-Cape Connector	**C**	**22.4**				**C**	**21.7**			
Sandwich Rd EB (thru)	B	12.8	0.29	85	227	C	21.5	0.54	228	#429
Sandwich Rd EB (right)	A	2.8	0.40	0	231	A	3.8	0.59	0	468
Sandwich Rd WB (left/thru)	C	21.6	0.80	311	#735	C	23.4	0.65	280	#501
Sandwich Rd WB (thru)	C	21.6	0.80	311	#735	C	23.4	0.65	280	#501
Mid-Cape Connector NB (left)	D	39.3	0.95	134	#369	C	33.7	0.91	197	#531
Mid-Cape Connector NB (right)	D	39.3	0.95	134	#369	C	33.7	0.91	197	#531
16:: Mid-Cape Connector / Cranberry Highway Extension	**C**	**22.9**				**C**	**26.4**			
Cranberry Highway Extension WB (left)	D	36.5	0.62	88	m122	E	62.0	0.86	144	#271
Cranberry Highway Extension WB (right)	B	14.0	0.58	148	187	C	22.0	0.65	230	246
Cranberry Highway Extension WB (right)	B	14.0	0.58	148	187	C	22.0	0.65	230	246
Mid-Cape Connector NB (thru)	C	22.1	0.31	87	#278	B	17.1	0.46	188	269
Mid-Cape Connector NB (right)	B	15.0	0.40	80	#179	A	6.3	0.06	12	24
Mid-Cape Connector SB (left)	E	55.5	0.90	217	m#354	E	76.1	0.93	194	#362
Mid-Cape Connector SB (thru)	A	4.9	0.12	18	m53	A	4.8	0.21	50	120
Mid-Cape Connector SB (thru)	A	4.9	0.12	18	m53	A	4.8	0.21	50	120
16:: Cranberry Highway / Route 6 E NB Off-Ramp	**C**	**24.8**				**C**	**21.0**			
Cranberry Highway EB (left)	B	13.9	0.61	65	m#231	B	17.1	0.58	73	m218
Cranberry Highway EB (thru)	B	13.6	0.47	91	m280	B	12.9	0.09	18	m45
Cranberry Highway WB (thru)	D	49.0	0.72	155	#343	D	40.1	0.47	120	212
Cranberry Highway WB (right)	B	12.3	0.49	136	240	B	14.5	0.72	263	620
Route 6 E NB Off-Ramp (left)	D	38.4	0.86	331	457	C	27.0	0.65	268	412
Route 6 E NB Off-Ramp (right)	C	21.4	0.32	84	132	C	21.5	0.35	110	184
20:: Scenic Highway (Route 6) / Church Lane / Route 6 SB On-Ramp	**B**	**17.1**				**C**	**31.2**			
Scenic Hwy (Route 6) EB (left)	E	68.9	0.62	50	97	E	63.1	0.57	29	66
Scenic Hwy (Route 6) EB (thru)	C	20.4	0.56	221	492	C	24.3	0.07	16	61
Scenic Hwy (Route 6) EB (thru/right)	C	20.4	0.56	221	492	C	24.3	0.07	16	61
Scenic Hwy (Route 6) WB (left)	D	39.3	0.31	51	71	D	49.3	0.76	255	187
Scenic Hwy (Route 6) WB (left)	D	39.3	0.31	51	71	D	49.3	0.76	255	187
Scenic Hwy (Route 6) WB (thru)	A	8.8	0.58	83	191	B	19.3	0.48	156	270
Scenic Hwy (Route 6) WB (thru)	A	8.8	0.58	83	191	B	19.3	0.48	156	270
Scenic Hwy (Route 6) WB (thru/right)	A	8.8	0.58	83	191	B	19.3	0.48	156	270
Church Lane SB (left/thru/right)	E	67.0	0.66	75	#141	E	63.2	0.73	105	173
21:: Scenic Highway (Route 6) & Route 3 SB Off-Ramp	**B**	**10.8**				**B**	**17.4**			
Scenic Hwy (Route 6) EB (thru)	A	3.8	0.51	37	42	A	9.7	0.07	40	34
Scenic Hwy (Route 6) EB (thru)	A	3.8	0.51	37	42	A	9.7	0.07	40	34
Scenic Hwy (Route 6) WB (thru)	B	11.9	0.44	106	m381	B	14.2	0.58	147	473
Scenic Hwy (Route 6) WB (thru)	B	11.9	0.44	106	m381	B	14.2	0.58	147	473
Scenic Hwy (Route 6) WB (thru)	B	11.9	0.44	106	m381	B	14.2	0.58	147	473
Route 3 Off-Ramp SB (left)	E	62.4	0.76	181	256	E	62.2	0.82	202	295
Route 3 Off-Ramp SB (right)	A	0.5	0.33	0	0	A	0.3	0.20	0	0

PRE-DECISIONAL & DELIBERATIVE

Table C-6: Synchro and SIDRA Results Summary - 2050 AP4

Intersection	2050 AP4 Weekday Fall PM					2050 AP4 Summer Saturday MID				
	LOS	Delay (sec)	v/c Ratio	50% Queue (feet)	95% Queue (feet)	LOS	Delay (sec)	v/c Ratio	50% Queue (feet)	95% Queue (feet)
22:: Meetinghouse Lane / State Road / Canal Street	**D**	**49.3**				**D**	**40.6**			
Meetinghouse Ln EB (left)	D	55.0	0.99	~608	#735	E	60.0	0.46	57	m88
Meetinghouse Ln EB (left)	D	55.0	0.99	~608	#735	E	60.0	0.46	57	m88
Meetinghouse Ln EB (thru/right)	C	28.8	0.84	354	#913	D	35.2	0.89	260	#645
Meetinghouse Ln WB (left)	E	68.4	0.46	9	30	F	89.1	0.72	30	#84
Meetinghouse Ln WB (thru)	D	51.7	0.28	44	#113	C	30.3	0.48	174	262
Meetinghouse Ln WB (right)	D	44.4	0.01	0	0	B	17.9	0.15	0	36
Canal St NB (left)	F	88.2	0.89	~139	#300	D	45.5	0.80	188	#261
Canal St NB (thru/right)	F	81.9	0.85	~176	#329	E	68.3	0.90	252	#477
State Rd SB (left)	D	49.5	0.14	11	33	C	33.6	0.47	59	103
State Rd SB (thru)	E	55.9	0.53	81	#155	D	42.1	0.43	102	169
State Rd SB (right)	B	15.2	0.11	0	26	C	30.9	0.18	0	61
23:: State Road / Route 3 NB On-Ramp	**B**	**10.4**				**B**	**11.5**			
State Rd NB (left)	C	20.5	0.66	54	147	C	20.3	0.53	33	#125
State Rd NB (left)	C	20.5	0.66	54	147	C	20.3	0.53	33	#125
State Rd NB (thru)	A	5.7	0.76	0	#724	A	1.7	0.26	0	130
State Rd SB (thru/right)	B	10.2	0.38	39	#191	B	12.8	0.69	89	#448
24:: Cranberry Highway / Adams Street	**A**	**1.9**				**A**	**1.8**			
Cranberry Highway EB (thru)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Cranberry Highway EB (thru/right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Cranberry Highway WB (left/thru)	A	7.9	0.01	-	0	A	7.8	0.01	-	0
Cranberry Highway WB (thru/right)	A	0.1	0.00	-	0	A	0.1	0.00	-	0
Adams Street NB (left/thru/right)	C	17.1	0.13	-	10	C	17.2	0.07	-	5
Adams Street SB (left/thru/right)	B	13.3	0.18	-	15	C	15.2	0.25	-	25

PRE-DECISIONAL & DELIBERATIVE

Table C-7: Synchro and SIDRA Results Summary - 2050 AP5

Intersection	2050 AP5 Weekday Fall PM					2050 AP5 Summer Saturday MID				
	LOS	Delay (sec)	v/c Ratio	50% Queue (feet)	95% Queue (feet)	LOS	Delay (sec)	v/c Ratio	50% Queue (feet)	95% Queue (feet)
6:: Main Street (Route 6) / Route 25 SB Off-Ramp	**D**	**36.7**				**E**	**71.6**			
Main Street (Route 6) EB (thru)	D	39.0	0.61	208	270	B	12.4	0.40	147	317
Main Street (Route 6) EB (thru)	D	39.0	0.61	208	270	B	12.4	0.40	147	317
Scenic Hwy (Route 6) WB (thru)	E	68.5	0.97	387	#604	C	28.4	0.90	666	m#1211
Route 25 SB Off-Ramp SB (left)	C	25.9	0.82	402	#854	F	242.4	1.40	~536	#754
Route 25 SB Off-Ramp SB (left)	C	25.9	0.82	402	#854	F	242.4	1.40	~536	#754
Route 25 SB Off-Ramp SB (right)	A	0.0	0.00	0	0	A	0.0	0.00	0	0
6:: Scenic Highway (Route 6) / Main Street (Route 6) / Nightingale Road / Andy Olivia Drive	**C**	**20.3**				**B**	**19.1**			
Main Street (Route 6) EB (left)	D	51	0.48	64	m#157	E	71	0.44	13	m24
Main Street (Route 6) EB (thru)	B	13.4	0.82	26	m#1226	A	8.3	0.60	54	m296
Main Street (Route 6) EB (thru/right)	B	13.4	0.82	26	m#1226	A	8.3	0.60	54	m296
Scenic Hwy (Route 6) WB (left)	E	71.8	0.33	4	18	E	71.8	0.33	4	18
Scenic Hwy (Route 6) WB (thru)	B	14.1	0.39	135	338	B	16.9	0.70	178	#974
Scenic Hwy (Route 6) WB (right)	C	26.6	0.86	390	#884	B	14.2	0.63	118	#642
Scenic Hwy (Route 6) WB (right)	C	26.6	0.86	390	#884	B	14.2	0.63	118	#642
Andy Olivia Dr NB (left/thru/right)	E	57.6	0.35	20	54	F	152.3	1.05	98	#230
Nightingale Pond Rd SB (left/thru)	E	56.6	0.28	16	43	D	50.3	0.11	12	35
Nightingale Pond Rd SB (right)	E	67.7	0.60	37	80	E	61.0	0.63	66	#136
8:: Trowbridge Road / Veterans Way	**A**	**0.8**				**A**	**1.3**			
Trowbridge Rd EB (left/thru)	A	8.7	0.01	-	0	A	8.2	0.01	-	0
Trowbridge Rd EB (thru)	A	0.1	0.00	-	0	A	0.1	0.00	-	0
Trowbridge Rd WB (thru)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Trowbridge Rd WB (thru/right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Veterans Way SB (left/right)	C	21.4	0.20	-	18	B	13.9	0.15	-	13
9:: Trowbridge Road / Route 25 SB Off-Ramp	**D**	**42.4**				**D**	**44.3**			
Trowbridge Rd EB (thru)	D	50.2	0.94	350	#600	D	44.8	0.59	144	#308
Trowbridge Rd EB (thru/right)	D	50.2	0.94	350	#600	D	44.8	0.59	144	#308
Trowbridge Rd WB (left)	E	62.1	0.63	175	#355	E	58.5	0.74	388	#675
Trowbridge Rd WB (thru)	B	13.8	0.21	35	162	B	14.0	0.16	38	172
Trowbridge Rd WB (thru)	B	13.8	0.21	35	162	B	14.0	0.16	38	172
Route 25 SB Off-Ramp (left)	D	44.9	0.64	140	#335	E	60.1	0.80	189	281
Route 25 SB Off-Ramp (thru/right)	D	38.5	0.29	41	#131	D	44.9	0.47	87	172
9:: Sandwich Road / Trowbridge Road / Route 28 NB Off-Ramp	**C**	**24.7**				**C**	**34.8**			
Trowbridge Rd EB (left)	D	50.4	0.75	192	m#263	E	58.7	0.56	66	m#108
Trowbridge Rd EB (left)	D	50.4	0.75	192	m#263	E	58.7	0.56	66	m#108
Trowbridge Rd EB (thru)	A	2.9	0.27	47	m97	B	18.6	0.34	148	203
Trowbridge Rd EB (thru)	A	2.9	0.27	47	m97	B	18.6	0.34	148	203
Sandwich Road WB (thru)	C	20.2	0.40	127	302	C	28.7	0.51	206	#414
Sandwich Road WB (thru)	C	20.2	0.40	127	302	C	28.7	0.51	206	#414
Sandwich Road WB (right)	C	23.6	0.53	3	154	C	29.3	0.47	27	197
Route 28 NB Off-Ramp (left/thru)	D	48.2	0.17	15	41	C	34.0	0.23	62	128
Route 28 NB Off-Ramp (right)	D	48.1	0.14	0	#89	D	53.0	0.83	145	#473
10:: Sandwich Road / Bourne Rotary Connector	**A**	**0.4**				**E**	**43.8**			
Sandwich Road EB (left/right)	F	118.4	0.15	-	13	F	$1109.4	2.99	-	333
Sandwich Road (Bourne Rotary Connector) NB (left/thru)	C	20.0	0.02	-	3	B	13.2	0.04	-	3
Sandwich Road (Bourne Rotary Connector) NB (thru)	A	0.4	0.00	-	0	A	1.1	0.00	-	0
Sandwich Rd WB (thru/right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
15:: Sandwich Road (Route 6 Bypass) / Mid-Cape Connector	**C**	**23.8**				**B**	**18.0**			
Sandwich Rd EB (thru)	C	25.9	0.74	196	#534	C	22.9	0.77	231	#742
Sandwich Rd EB (right)	A	7.5	0.31	39	182	A	9.6	0.56	94	412
Sandwich Rd WB (left)	B	13.3	0.4	24	89	B	11.1	0.21	9	52
Sandwich Rd WB (thru)	C	22.9	0.90	310	#820	B	11.9	0.71	202	#739
Sandwich Rd WB (thru)	C	22.9	0.90	310	#820	B	11.9	0.71	202	#739
Mid-Cape Connector NB (left)	D	43.3	0.84	155	#434	C	34.6	0.60	79	188
Mid-Cape Connector NB (right)	C	24.5	0.60	98	#227	D	43.2	0.84	132	#296
16:: Mid-Cape Connector / Cranberry Highway Extension	**B**	**18.6**				**A**	**9.9**			
Cranberry Highway Extension WB (left)	C	26.6	0.27	17	55	C	25.9	0.20	9	44
Cranberry Highway Extension WB (left)	C	26.6	0.27	17	55	C	25.9	0.20	9	44
Cranberry Highway Extension WB (right)	C	20.8	0.51	50	#144	C	22.7	0.25	12	47
Mid-Cape Connector NB (thru)	C	21.6	0.71	124	#453	B	12.9	0.56	118	377
Mid-Cape Connector NB (right)	A	9.9	0.12	12	72	A	6.4	0.06	6	42
Mid-Cape Connector SB (left)	C	29.8	0.63	57	#224	C	26.5	0.04	1	15
Mid-Cape Connector SB (thru)	A	5.5	0.14	15	79	A	5.4	0.32	40	184
Mid-Cape Connector SB (thru)	A	5.5	0.14	15	79	A	5.4	0.32	40	184
20:: Scenic Highway (Route 6) / Church Lane / Route 6 SB On-Ramp	**B**	**13.5**				**C**	**31.2**			
Scenic Hwy (Route 6) EB (left)	E	57.5	0.55	46	89	E	63.1	0.57	29	66
Scenic Hwy (Route 6) EB (thru)	B	14.2	0.51	241	331	C	24.3	0.07	16	61
Scenic Hwy (Route 6) EB (thru/right)	B	14.2	0.51	241	331	C	24.3	0.07	16	61
Scenic Hwy (Route 6) WB (left)	D	37.1	0.26	47	53	D	49.3	0.76	256	186
Scenic Hwy (Route 6) WB (left)	D	37.1	0.26	47	53	D	49.3	0.76	256	186
Scenic Hwy (Route 6) WB (thru)	A	7.2	0.51	91	215	B	19.3	0.48	102	271
Scenic Hwy (Route 6) WB (thru)	A	7.2	0.51	91	215	B	19.3	0.48	102	271
Scenic Hwy (Route 6) WB (thru/right)	A	7.2	0.51	91	215	B	19.3	0.48	102	271
Church Lane SB (left/thru/right)	E	57.5	0.63	82	137	E	63.2	0.73	107	176
21:: Scenic Highway (Route 6) & Route 3 SB Off-Ramp	**B**	**12.5**				**B**	**17.4**			
Scenic Hwy (Route 6) EB (thru)	A	8.1	0.53	34	512	A	9.7	0.07	40	34
Scenic Hwy (Route 6) EB (thru)	A	8.1	0.53	34	512	A	9.7	0.07	40	34
Scenic Hwy (Route 6) WB (thru)	B	13.2	0.46	112	m374	B	14.2	0.58	265	521
Scenic Hwy (Route 6) WB (thru)	B	13.2	0.46	112	m374	B	14.2	0.58	265	521
Scenic Hwy (Route 6) WB (thru)	B	13.2	0.46	112	m374	B	14.2	0.58	265	521
Route 3 Off-Ramp SB (left)	E	56.3	0.74	166	236	E	62.2	0.82	202	295
Route 3 Off-Ramp SB (right)	A	0.5	0.31	0	0	A	0.3	0.20	0	0

PRE-DECISIONAL & DELIBERATIVE

Table C-7: Synchro and SIDRA Results Summary - 2050 AP5

Intersection	2050 AP5 Weekday Fall PM					2050 AP5 Summer Saturday MID				
	LOS	Delay (sec)	v/c Ratio	50% Queue (feet)	95% Queue (feet)	LOS	Delay (sec)	v/c Ratio	50% Queue (feet)	95% Queue (feet)
22:: Meetinghouse Lane / State Road / Canal Street	**D**	**53.1**				**D**	**53.0**			
Meetinghouse Ln EB (left)	D	39.7	0.86	376	#493	E	67.0	0.64	48	m#84
Meetinghouse Ln EB (left)	D	39.7	0.86	376	#493	E	67.0	0.64	48	m#84
Meetinghouse Ln EB (thru/right)	C	20.3	0.50	92	298	D	43.9	0.59	232	#458
Meetinghouse Ln WB (left)	F	183.2	0.79	8	29	E	63.1	0.57	29	#78
Meetinghouse Ln WB (thru)	D	43.6	0.20	36	96	D	42.8	0.60	176	#455
Meetinghouse Ln WB (right)	A	0.0	0.00	0	0	C	21.9	0.33	59	174
Canal St NB (left)	F	190.1	1.21	~126	#240	D	36.0	0.71	161	237
Canal St NB (thru/right)	D	48.6	0.60	130	208	E	77.5	0.93	257	#428
State Rd SB (left)	D	51.4	0.69	96	#172	F	89.4	1.03	~250	#444
State Rd SB (thru)	F	86.0	0.94	222	#390	D	43.4	0.60	173	263
State Rd SB (right)	B	18.0	0.19	50	82	D	43.9	0.72	146	#288
23:: State Road / Route 3 NB Ramps	**C**	**23.7**				**C**	**25.2**			
Route 3 NB Off-Ramp (left)	C	28.4	0.73	117	#372	C	28.3	0.15	10	41
Route 3 NB Off-Ramp (right)	B	12.5	0.44	52	123	D	44.5	0.88	107	#320
State Rd NB (left)	C	27.8	0.67	80	#204	C	28.6	0.57	53	#140
State Rd NB (left)	C	27.8	0.67	80	#204	C	28.6	0.57	53	#140
State Rd NB (thru)	B	17.1	0.71	157	#544	A	5.5	0.26	34	162
State Rd SB (thru/right)	D	39.5	0.80	99	330	C	22.0	0.76	163	#528
24:: Cranberry Highway / Adams Street	**A**	**5.9**				**C**	**21.6**			
Cranberry Highway EB (thru/right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Cranberry Highway WB (left/thru)	A	9.3	0.01	-	0	A	9.2	0.01	-	0
Cranberry Highway WB (thru/right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Adams Street NB (left/thru/right)	E	38.4	0.13	-	10	F	$690.3	1.36	-	80
Adams Street SB (left/thru/right)	D	26.2	0.68	-	125	F	64.7	0.95	-	270

PRE-DECISIONAL & DELIBERATIVE

Table C-8: Synchro and SIDRA Results Summary - 2050 AP6

Intersection	2050 AP6 Weekday Fall PM					2050 AP6 Summer Saturday MID				
	LOS	Delay (sec)	v/c Ratio	50% Queue (feet)	95% Queue (feet)	LOS	Delay (sec)	v/c Ratio	50% Queue (feet)	95% Queue (feet)
6:: Main Street (Route 6) / Route 25 SB Off-Ramp	**C**	**33.1**				**E**	**71.6**			
Main Street (Route 6) EB (thru)	D	38.3	0.57	187	275	B	12.4	0.40	147	317
Main Street (Route 6) EB (thru)	D	38.3	0.57	187	275	B	12.4	0.40	147	317
Scenic Hwy (Route 6) WB (thru)	D	51.1	0.79	279	#553	C	28.4	0.90	666	m#1211
Route 25 SB Off-Ramp SB (left)	C	26.7	0.84	439	#791	F	242.4	1.40	~536	#754
Route 25 SB Off-Ramp SB (left)	C	26.7	0.84	439	#791	F	242.4	1.40	~536	#754
Route 25 SB Off-Ramp SB (right)	A	0.0	0.00	0	0	A	0.0	0.00	0	0
6:: Scenic Highway (Route 6) / Main Street (Route 6) / Nightingale Road / Andy Olivia Drive	**B**	**17.9**				**B**	**19.1**			
Main Street (Route 6) EB (left)	E	56.6	0.48	78	m#162	E	71.0	0.44	13	m24
Main Street (Route 6) EB (thru)	A	9.1	0.82	210	#1218	A	8.3	0.60	54	m296
Main Street (Route 6) EB (thru/right)	A	9.1	0.82	210	#1218	A	8.3	0.60	54	m296
Scenic Hwy (Route 6) WB (left)	E	71.8	0.33	4	18	E	71.8	0.33	4	18
Scenic Hwy (Route 6) WB (thru)	B	13.0	0.31	99	254	B	16.9	0.70	178	#974
Scenic Hwy (Route 6) WB (right)	C	25.5	0.85	375	#859	B	14.2	0.63	118	#642
Scenic Hwy (Route 6) WB (right)	C	25.5	0.85	375	#859	B	14.2	0.63	118	#642
Andy Olivia Dr NB (left/thru/right)	E	57.6	0.35	20	54	F	152.3	1.05	98	#230
Nightingale Pond Rd SB (left/thru)	E	56.6	0.28	16	43	D	50.1	0.08	12	35
Nightingale Pond Rd SB (right)	E	67.7	0.60	37	80	E	63.0	0.65	66	#136
8:: Trowbridge Road / Veterans Way	**A**	**0.4**				**A**	**1.2**			
Trowbridge Rd EB (left/thru)	A	8.6	0.01	-	0	A	8.2	0.01	-	0
Trowbridge Rd EB (thru)	A	0.1	0.00	-	0	A	0.1	0.00	-	0
Trowbridge Rd WB (thru)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Trowbridge Rd WB (thru/right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Veterans Way SB (left/thru/right)	A	9.9	0.03	-	3	B	13.0	0.14	-	13
9:: Trowbridge Road / Sandwich Road / Route 25 SB Off-Ramp / Route 28 NB Off-Ramp	**B**	**14.5**				**B**	**15.5**			
Trowbridge Rd EB (left)	C	29.6	0.77	67	#201	C	31.2	0.58	60	146
Trowbridge Rd EB (left)	C	29.6	0.77	67	#201	C	31.2	0.58	60	146
Trowbridge Rd EB (thru)	B	18.2	0.42	51	133	C	28.4	0.36	35	84
Trowbridge Rd EB (thru/right)	B	18.2	0.42	51	133	C	28.4	0.36	35	84
Trowbridge Rd WB (left)	C	25.9	0.59	49	#166	C	30.8	0.81	159	#439
Trowbridge Rd WB (thru)	C	26.3	0.76	101	#339	C	20.1	0.42	73	200
Trowbridge Rd WB (right)	A	1.6	0.58	0	0	A	0.8	0.41	0	0
Route 25 SB Off-Ramp (left)	C	23.7	0.40	28	75	C	31.2	0.72	90	#215
Route 25 SB Off-Ramp (left)	C	23.7	0.40	28	75	C	31.2	0.72	90	#215
Route 25 SB Off-Ramp (right)	A	0.1	0.07	0	0	A	0.0	0.01	0	0
Route 28 NB Off-Ramp (left)	C	22.1	0.06	4	24	C	26.0	0.34	40	111
Route 28 NB Off-Ramp (right)	A	0.2	0.15	0	0	A	1.2	0.51	0	0
10:: Sandwich Road / Bourne Rotary Connector	**A**	**0.0**				**E**	**43.8**			
Sandwich Road EB (left/right)	A	0.0	0.00	-	0	F	$1109.4	2.99	-	333
Sandwich Road (Bourne Rotary Connector) NB (left/thru)	A	0.0	0.00	-	0	B	13.2	0.04	-	3
Sandwich Road (Bourne Rotary Connector) NB (thru)	A	0.0	0.00	-	0	A	1.1	0.00	-	0
Sandwich Rd WB (thru/right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
15:: Sandwich Road (Route 6 Bypass) / Mid-Cape Connector	**C**	**25.4**				**C**	**28.9**			
Sandwich Rd EB (thru)	C	24.3	0.27	90	178	D	45.3	0.75	283	#499
Sandwich Rd EB (right)	B	10.3	0.64	159	600	A	9.3	0.70	188	#895
Sandwich Rd WB (left)	B	15.4	0.26	53	121	C	27.6	0.20	18	46
Sandwich Rd WB (thru)	C	24.8	0.79	403	#721	D	36.6	0.78	353	474
Sandwich Rd WB (thru)	C	24.8	0.79	403	#721	D	36.6	0.78	353	474
Mid-Cape Connector NB (left)	D	41.0	0.81	280	#447	C	31.9	0.69	370	m#558
Mid-Cape Connector NB (right)	D	41.0	0.81	280	#447	C	31.9	0.69	370	m#558
16:: Mid-Cape Connector / Cranberry Highway Extension	**C**	**20.4**				**F**	**103.5**			
Cranberry Highway Extension WB (left)	D	44.9	0.81	213	m311	F	246.0	1.47	~1084	m#1073
Cranberry Highway Extension WB (right)	B	16.9	0.55	155	m260	B	17.4	0.45	154	m173
Cranberry Highway Extension WB (right)	B	16.9	0.55	155	m260	B	17.4	0.45	154	m173
Mid-Cape Connector NB (thru)	C	25.4	0.34	112	#270	E	69.4	0.93	290	#776
Mid-Cape Connector NB (right)	B	11.5	0.40	80	162	A	7.4	0.07	8	32
Mid-Cape Connector SB (left)	D	45.6	0.51	99	m#183	D	52.0	0.04	4	m5
Mid-Cape Connector SB (thru)	B	11.1	0.37	166	305	C	30.6	0.68	217	#556
Mid-Cape Connector SB (thru)	B	11.1	0.37	166	305	C	30.6	0.68	217	#556
16:: Cranberry Highway / Route 6 E NB Off-Ramp	**C**	**32.0**				**E**	**71.2**			
Cranberry Highway EB (left)	C	0.0	0.00	0	0	B	0.0	0.00	0	0
Cranberry Highway EB (thru)	C	29.6	0.72	276	#619	B	14.3	0.01	2	10
Cranberry Highway WB (thru/right)	C	24.9	0.29	99	198	E	76.5	1.06	745	#1240
Route 6 E NB Off-Ramp (left/thru)	D	41.1	0.90	354	#559	F	80.5	1.00	~384	#611
Route 6 E NB Off-Ramp (right)	B	17.6	0.26	76	118	C	30.4	0.43	141	217
20:: Scenic Highway (Route 6) / Church Lane / Route 6 SB On-Ramp	**B**	**17.3**				**C**	**31.2**			
Scenic Hwy (Route 6) EB (left)	E	68.9	0.62	50	97	E	63.1	0.57	29	66
Scenic Hwy (Route 6) EB (thru)	C	20.4	0.56	221	489	C	24.3	0.07	16	61
Scenic Hwy (Route 6) EB (thru/right)	C	20.4	0.56	221	489	C	24.3	0.07	16	61
Scenic Hwy (Route 6) WB (left)	D	40.4	0.34	52	70	D	49.3	0.76	255	187
Scenic Hwy (Route 6) WB (left)	D	40.4	0.34	52	70	D	49.3	0.76	255	187
Scenic Hwy (Route 6) WB (thru)	A	8.7	0.57	86	173	B	19.3	0.48	156	270
Scenic Hwy (Route 6) WB (thru)	A	8.7	0.57	86	173	B	19.3	0.48	156	270
Scenic Hwy (Route 6) WB (thru/right)	A	8.7	0.57	86	173	B	19.3	0.48	156	270
Church Lane SB (left/thru/right)	E	68.0	0.70	89	#171	E	63.2	0.73	105	173
21:: Scenic Highway (Route 6) & Route 3 SB Off-Ramp	**B**	**10.9**				**B**	**17.4**			
Scenic Hwy (Route 6) EB (thru)	A	3.5	0.51	39	38	A	9.7	0.07	40	34
Scenic Hwy (Route 6) EB (thru)	A	3.5	0.51	39	38	A	9.7	0.07	40	34
Scenic Hwy (Route 6) WB (thru)	B	12.3	0.42	114	m366	B	14.2	0.58	147	473
Scenic Hwy (Route 6) WB (thru)	B	12.3	0.42	114	m366	B	14.2	0.58	147	473
Scenic Hwy (Route 6) WB (thru)	B	12.3	0.42	114	m366	B	14.2	0.58	147	473
Route 3 Off-Ramp SB (left)	E	63.3	0.77	181	258	E	62.2	0.82	202	295
Route 3 Off-Ramp SB (right)	A	0.5	0.32	0	0	A	0.3	0.20	0	0

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Table C-8: Synchro and SIDRA Results Summary - 2050 AP6

Intersection	2050 AP6 Weekday Fall PM					2050 AP6 Summer Saturday MID				
	LOS	Delay (sec)	v/c Ratio	50% Queue (feet)	95% Queue (feet)	LOS	Delay (sec)	v/c Ratio	50% Queue (feet)	95% Queue (feet)
22:: Meetinghouse Lane / State Road / Canal Street	**D**	**39.9**				**D**	**40.6**			
Meetinghouse Ln EB (left)	D	41.3	0.90	559	#673	E	60.0	0.46	57	m88
Meetinghouse Ln EB (left)	D	41.3	0.90	559	#673	E	60.0	0.46	57	m88
Meetinghouse Ln EB (thru/right)	C	24.1	0.78	187	#883	D	35.2	0.89	260	#645
Meetinghouse Ln WB (left)	E	67.0	0.41	9	30	F	89.1	0.72	30	#84
Meetinghouse Ln WB (thru)	D	49.8	0.24	44	110	C	30.3	0.48	174	262
Meetinghouse Ln WB (right)	D	43.9	0.04	4	14	B	17.9	0.15	0	36
Canal St NB (left)	E	71.1	0.81	~140	#304	D	45.5	0.80	188	#261
Canal St NB (thru/right)	E	69.7	0.79	~176	#330	E	68.3	0.90	252	#477
State Rd SB (left)	D	49.9	0.08	8	26	C	33.6	0.47	59	103
State Rd SB (thru)	E	56.6	0.53	85	#148	D	42.1	0.43	102	169
State Rd SB (right)	B	17.1	0.19	54	88	C	30.9	0.18	0	61
23:: State Road / Route 3 NB On-Ramp	**A**	**8.0**				**B**	**11.5**			
State Rd NB (left)	B	12.5	0.46	32	141	C	20.3	0.53	33	#125
State Rd NB (left)	B	12.5	0.46	32	141	C	20.3	0.53	33	#125
State Rd NB (thru)	A	4.7	0.71	0	#681	A	1.7	0.26	0	130
State Rd SB (thru/right)	B	12.5	0.49	39	197	B	12.8	0.69	89	#448
24:: Cranberry Highway / Adams Street	**A**	**1.6**				**A**	**2.1**			
Cranberry Highway EB (thru/right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Cranberry Highway WB (left)	A	8.6	0.01	-	0	A	7.7	0.01	-	0
Cranberry Highway WB (thru)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Adams Street NB (left/thru/right)	C	16.8	0.13	-	10	D	31.0	0.14	-	13
Adams Street SB (left/thru/right)	B	12.3	0.07	-	5	C	21.7	0.29	-	30

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Table C-9: Synchro and SIDRA Results Summary - 2050 AP7

Intersection	2050 AP7 Weekday Fall PM					2050 AP7 Summer Saturday MID				
	LOS	Delay (sec)	v/c Ratio	50% Queue (feet)	95% Queue (feet)	LOS	Delay (sec)	v/c Ratio	50% Queue (feet)	95% Queue (feet)
6:: Scenic Highway (Route 6) / Main Street (Route 6) / Nightingale Road / Andy Olivia Drive	**B**	**12.5**				**C**	**22.5**			
Main Street (Route 6) EB (left)	A	6.8	0.22	10	63	B	12.9	0.08	2	17
Main Street (Route 6) EB (thru/right)	A	9.7	0.49	66	#441	B	19.9	0.79	200	#934
Scenic Hwy (Route 6) WB (left)	A	8.3	0.01	1	8	B	12.8	0.03	1	8
Scenic Hwy (Route 6) WB (thru/right)	B	12.9	0.58	126	#482	B	20.0	0.80	202	#933
Andy Olivia Dr NB (left/thru/right)	C	30.7	0.24	6	37	D	46.4	0.67	49	#218
Nightingale Pond Rd SB (left/thru/right)	C	30.8	0.26	6	52	D	35.1	0.13	6	65
8:: Trowbridge Road / Veterans Way	**A**	**0.8**				**A**	**1.3**			
Trowbridge Rd EB (left/thru)	A	8.9	0.01	-	0	A	8.2	0.01	-	0
Trowbridge Rd EB (thru)	A	0.1	0.00	-	0	A	0.1	0.00	-	0
Trowbridge Rd WB (thru)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Trowbridge Rd WB (thru/right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Veterans Way SB (left/thru/right)	C	23.4	0.22	-	20	B	13.9	0.15	-	13
9:: Trowbridge Road / Route 25 SB Off-Ramp	**C**	**31.9**				**D**	**44.3**			
Trowbridge Rd EB (thru)	C	31.2	0.78	314	#603	D	44.8	0.59	144	#308
Trowbridge Rd EB (thru/right)	C	31.2	0.78	314	#603	D	44.8	0.59	144	#308
Trowbridge Rd WB (left)	E	65.5	0.65	137	#276	E	58.5	0.74	388	#675
Trowbridge Rd WB (thru)	B	11.7	0.22	41	161	B	14.0	0.16	38	172
Trowbridge Rd WB (thru)	B	11.7	0.22	41	161	B	14.0	0.16	38	172
Route 25 SB Off-Ramp (left)	D	49.9	0.67	125	#288	E	60.1	0.80	189	281
Route 25 SB Off-Ramp (thru/right)	D	40.8	0.25	26	103	D	44.9	0.47	87	172
9:: Sandwich Road / Trowbridge Road / Route 28 NB Off-Ramp	**C**	**25.7**				**C**	**34.8**			
Trowbridge Rd EB (left)	E	56.1	0.76	188	#293	E	58.7	0.56	66	m#108
Trowbridge Rd EB (left)	E	56.1	0.76	188	#293	E	58.7	0.56	66	m#108
Trowbridge Rd EB (thru)	A	2.9	0.26	39	95	B	18.6	0.34	148	203
Trowbridge Rd EB (thru)	A	2.9	0.26	39	95	B	18.6	0.34	148	203
Sandwich Road WB (thru)	B	19.5	0.39	121	290	C	28.7	0.51	206	#414
Sandwich Road WB (thru)	B	19.5	0.39	121	290	C	28.7	0.51	206	#414
Sandwich Road WB (right)	C	23.0	0.52	1	144	C	29.3	0.47	27	197
Route 28 NB Off-Ramp (left/thru)	D	49.2	0.29	26	60	C	34.0	0.23	62	128
Route 28 NB Off-Ramp (right)	D	48.1	0.15	0	#91	D	53.0	0.83	145	#473
10:: Sandwich Road / Bourne Rotary Connector	**A**	**1.0**				**E**	**43.8**			
Sandwich Road EB (left/right)	F	152.1	0.42	-	35	F	$1109.4	2.99	-	333
Sandwich Road (Bourne Rotary Connector) NB (left/thru)	C	19.7	0.02	-	3	B	13.2	0.04	-	3
Sandwich Road (Bourne Rotary Connector) NB (thru)	A	0.4	0.00	-	0	A	1.1	0.00	-	0
Sandwich Rd WB (thru/right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
15:: Sandwich Road (Route 6 Bypass) / Mid-Cape Connector	**C**	**22.4**				**C**	**21.7**			
Sandwich Rd EB (thru)	B	12.8	0.29	85	227	C	21.5	0.54	228	#429
Sandwich Rd EB (right)	A	2.8	0.40	0	231	A	3.8	0.59	0	468
Sandwich Rd WB (left/thru)	C	21.6	0.80	311	#735	C	23.4	0.65	280	#501
Sandwich Rd WB (thru)	C	21.6	0.80	311	#735	C	23.4	0.65	280	#501
Mid-Cape Connector NB (left)	D	39.3	0.95	134	#369	C	33.7	0.91	197	#531
Mid-Cape Connector NB (right)	D	39.3	0.95	134	#369	C	33.7	0.91	197	#531
16:: Mid-Cape Connector / Cranberry Highway Extension	**C**	**22.9**				**C**	**26.4**			
Cranberry Highway Extension WB (left)	D	36.5	0.62	88	m122	E	62.0	0.86	144	#271
Cranberry Highway Extension WB (right)	B	14.0	0.58	148	187	C	22.0	0.65	230	246
Cranberry Highway Extension WB (right)	B	14.0	0.58	148	187	C	22.0	0.65	230	246
Mid-Cape Connector NB (thru)	C	22.1	0.31	87	#278	B	17.1	0.46	188	269
Mid-Cape Connector NB (right)	B	15.0	0.40	80	#179	A	6.3	0.06	12	24
Mid-Cape Connector SB (left)	E	55.5	0.90	217	m#354	E	76.1	0.93	194	#362
Mid-Cape Connector SB (thru)	A	4.9	0.12	18	m53	A	4.8	0.21	50	120
Mid-Cape Connector SB (thru)	A	4.9	0.12	18	m53	A	4.8	0.21	50	120
16:: Cranberry Highway / Route 6 E NB Off-Ramp	**C**	**24.8**				**C**	**21.0**			
Cranberry Highway EB (left)	B	13.9	0.61	65	m#231	B	17.1	0.58	73	m218
Cranberry Highway EB (thru)	B	13.6	0.47	91	m280	B	12.9	0.09	18	m45
Cranberry Highway WB (thru)	D	49.0	0.72	155	#343	D	40.1	0.47	120	212
Cranberry Highway WB (right)	B	12.3	0.49	136	240	B	14.5	0.72	263	620
Route 6 E NB Off-Ramp (left)	D	38.4	0.86	331	457	C	27	0.65	268	412
Route 6 E NB Off-Ramp (right)	C	21.4	0.32	84	132	C	21.5	0.35	110	184
20:: Scenic Highway (Route 6) / Church Lane / Route 6 SB On-Ramp	**B**	**17.1**				**C**	**29.4**			
Scenic Hwy (Route 6) EB (left)	E	57.5	0.55	46	89	E	63.1	0.57	29	66
Scenic Hwy (Route 6) EB (thru)	C	21.2	0.59	200	#567	C	24.4	0.07	16	61
Scenic Hwy (Route 6) EB (thru/right)	C	21.2	0.59	200	#567	C	24.4	0.07	16	61
Scenic Hwy (Route 6) WB (left)	D	37.5	0.36	48	67	D	44.8	0.76	256	186
Scenic Hwy (Route 6) WB (left)	D	37.5	0.36	48	67	D	44.8	0.76	256	186
Scenic Hwy (Route 6) WB (thru)	A	9.5	0.63	208	#663	B	18.4	0.48	102	271
Scenic Hwy (Route 6) WB (thru)	A	9.5	0.63	208	#663	B	18.4	0.48	102	271
Scenic Hwy (Route 6) WB (thru/right)	A	9.5	0.63	208	#663	B	18.4	0.48	102	271
Church Lane SB (left/thru/right)	E	57.0	0.63	82	137	E	63.4	0.73	107	176
21:: Scenic Highway (Route 6) & Route 3 SB Off-Ramp	**B**	**14.7**				**B**	**19.9**			
Scenic Hwy (Route 6) EB (thru)	B	14.3	0.53	94	247	A	9.7	0.07	40	34
Scenic Hwy (Route 6) EB (thru)	B	14.3	0.53	94	247	A	9.7	0.07	40	34
Scenic Hwy (Route 6) WB (thru)	B	13.7	0.46	121	m375	B	17.7	0.58	265	521
Scenic Hwy (Route 6) WB (thru)	B	13.7	0.46	121	m375	B	17.7	0.58	265	521
Scenic Hwy (Route 6) WB (thru)	B	13.7	0.46	121	m375	B	17.7	0.58	265	521
Route 3 Off-Ramp SB (left)	E	56.3	0.74	166	236	E	62.2	0.82	202	295
Route 3 Off-Ramp SB (right)	A	0.5	0.33	0	0	A	0.3	0.20	0	0

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Table C-9: Synchro and SIDRA Results Summary - 2050 AP7

Intersection	2050 AP7 Weekday Fall PM					2050 AP7 Summer Saturday MID				
	LOS	Delay (sec)	v/c Ratio	50% Queue (feet)	95% Queue (feet)	LOS	Delay (sec)	v/c Ratio	50% Queue (feet)	95% Queue (feet)
22:: Meetinghouse Lane / State Road / Canal Street	**D**	**51.4**				**D**	**53.0**			
Meetinghouse Ln EB (left)	D	37.3	0.86	394	#498	E	67.0	0.64	48	m#84
Meetinghouse Ln EB (left)	D	37.3	0.86	394	#498	E	67.0	0.64	48	m#84
Meetinghouse Ln EB (thru/right)	B	13.7	0.49	118	278	D	43.9	0.59	232	#458
Meetinghouse Ln WB (left)	F	183.2	0.79	8	29	E	63.1	0.57	29	#78
Meetinghouse Ln WB (thru)	D	44.2	0.22	39	103	D	42.8	0.60	176	#455
Meetinghouse Ln WB (right)	D	37.2	0.03	3	14	C	21.9	0.33	59	174
Canal St NB (left)	F	186.4	1.20	~126	#240	D	36.0	0.71	161	237
Canal St NB (thru/right)	D	48.3	0.59	130	208	E	77.5	0.93	257	#428
State Rd SB (left)	D	55.0	0.73	100	#190	F	89.4	1.03	~250	#444
State Rd SB (thru)	F	90.0	0.96	224	#398	D	43.4	0.60	173	263
State Rd SB (right)	B	17.9	0.21	52	86	D	43.9	0.72	146	#288
23:: State Road / Route 3 NB Ramps	**C**	**24.1**				**C**	**25.2**			
Route 3 NB Off-Ramp (left)	C	28.4	0.73	117	#372	C	28.3	0.15	10	41
Route 3 NB Off-Ramp (right)	B	12.6	0.45	52	126	D	44.5	0.88	107	#320
State Rd NB (left)	C	27.8	0.67	80	#204	C	28.6	0.57	53	#140
State Rd NB (left)	C	27.8	0.67	80	#204	C	28.6	0.57	53	#140
State Rd NB (thru)	B	17.7	0.73	163	#565	A	5.5	0.26	34	162
State Rd SB (thru/right)	D	40.9	0.82	102	#336	C	22.0	0.76	163	#528
24:: Cranberry Highway / Adams Street	**A**	**1.9**				**A**	**1.8**			
Cranberry Highway EB (thru)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Cranberry Highway EB (thru/right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Cranberry Highway WB (left/thru)	A	7.9	0.01	-	0	A	7.8	0.01	-	0
Cranberry Highway WB (thru/right)	A	0.1	0.00	-	0	A	0.1	0.00	-	0
Adams Street NB [left/thru/right]	C	17.1	0.13	-	10	C	17.2	0.07	-	5
Adams Street SB [left/thru/right]	B	13.3	0.18	-	15	C	15.2	0.25	-	25

PRE-DECISIONAL & DELIBERATIVE

Table C-10: Synchro and SIDRA Results Summary - 2050 AP7.1

Intersection	2050 AP7.1 Weekday Fall PM					2050 AP7.1 Summer Saturday MID				
	LOS	Delay (sec)	v/c Ratio	50% Queue (feet)	95% Queue (feet)	LOS	Delay (sec)	v/c Ratio	50% Queue (feet)	95% Queue (feet)
6:: Scenic Highway (Route 6) / Main Street (Route 6) / Nightingale Road / Andy Olivia Drive	**B**	**12.5**				**C**	**22.5**			
Main Street (Route 6) EB (left)	A	6.8	0.22	10	63	B	12.9	0.08	2	17
Main Street (Route 6) EB (thru/right)	A	9.7	0.49	66	#441	B	19.9	0.79	200	#934
Scenic Hwy (Route 6) WB (left)	A	8.3	0.01	1	8	B	12.8	0.03	1	8
Scenic Hwy (Route 6) WB (thru/right)	B	12.9	0.58	126	#482	B	20.0	0.80	202	#933
Andy Olivia Dr NB (left/thru/right)	C	30.7	0.24	6	37	D	46.4	0.67	49	#218
Nightingale Pond Rd SB (left/thru)	C	30.8	0.26	6	52	D	35.1	0.13	6	65
8:: Trowbridge Road / Veterans Way	**A**	**0.7**				**A**	**1.2**			
Trowbridge Rd EB (left/thru)	A	8.9	0.01	-	0	A	8.2	0.01	-	0
Trowbridge Rd EB (thru/right)	A	0.1	0.00	-	0	A	0.1	0.00	-	0
Trowbridge Rd WB (thru)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Trowbridge Rd WB (thru/right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Veterans Way SB (left/thru/right)	B	10.3	0.03	-	3	B	13.0	0.14	-	13
9:: Trowbridge Road / Sandwich Road / Route 25 SB Off-Ramp / Route 28 NB Off-Ramp	**C**	**23.8**				**B**	**15.5**			
Trowbridge Rd EB (left)	D	48.5	0.93	185	#509	C	31.2	0.58	60	146
Trowbridge Rd EB (thru)	B	15.1	0.28	52	136	C	28.4	0.36	35	84
Trowbridge Rd EB (thru/right)	B	15.1	0.28	52	136	C	28.4	0.36	35	84
Trowbridge Rd WB (left)	D	35.1	0.65	69	161	C	30.8	0.81	159	#439
Trowbridge Rd WB (thru)	D	49.8	0.92	179	#490	C	20.1	0.42	73	200
Trowbridge Rd WB (right)	A	1.2	0.51	0	0	A	0.8	0.41	0	0
Route 25 SB Off-Ramp (left)	D	37.6	0.68	52	#135	C	31.2	0.72	90	#215
Route 25 SB Off-Ramp (left)	D	37.6	0.68	52	#135	C	31.2	0.72	90	#215
Route 25 SB Off-Ramp (right)	A	0.1	0.07	0	0	A	0.0	0.01	0	0
Route 28 NB Off-Ramp (left)	C	31.3	0.20	15	51	C	26.0	0.34	40	111
Route 28 NB Off-Ramp (right)	A	0.2	0.15	0	0	A	1.2	0.51	0	0
10:: Sandwich Road / Bourne Rotary Connector	**A**	**1.0**				**E**	**43.8**			
Sandwich Road EB (left/right)	F	152.1	0.42	-	35	F	$1109.4	2.99	-	333
Sandwich Road (Bourne Rotary Connector) NB (left/thru)	C	19.7	0.02	-	3	B	13.2	0.04	-	3
Sandwich Road (Bourne Rotary Connector) NB (thru)	A	0.4	0.00	-	0	A	1.1	0.00	-	0
Sandwich Rd WB (thru/right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
15:: Sandwich Road (Route 6 Bypass) / Mid-Cape Connector	**C**	**22.4**				**C**	**21.7**			
Sandwich Rd EB (thru)	B	12.8	0.29	85	227	C	21.5	0.54	228	#429
Sandwich Rd EB (right)	A	2.8	0.40	0	231	A	3.8	0.59	0	468
Sandwich Rd WB (left/thru)	C	21.6	0.80	311	#735	C	23.4	0.65	280	#501
Sandwich Rd WB (thru)	C	21.6	0.80	311	#735	C	23.4	0.65	280	#501
Mid-Cape Connector NB (left)	D	39.3	0.95	134	#369	C	33.7	0.91	197	#531
Mid-Cape Connector NB (right)	D	39.3	0.95	134	#369	C	33.7	0.91	197	#531
16:: Mid-Cape Connector / Cranberry Highway Extension	**C**	**22.9**				**C**	**26.4**			
Cranberry Highway Extension WB (left)	D	36.5	0.62	88	m122	E	62.0	0.86	144	#271
Cranberry Highway Extension WB (right)	B	14.0	0.58	148	187	C	22.0	0.65	230	246
Cranberry Highway Extension WB (right)	B	14.0	0.58	148	187	C	22.0	0.65	230	246
Mid-Cape Connector NB (thru)	C	22.1	0.31	87	#278	B	17.1	0.46	188	269
Mid-Cape Connector NB (right)	B	15.0	0.40	80	#179	A	6.3	0.06	12	24
Mid-Cape Connector SB (left)	E	55.5	0.90	217	m#354	E	76.1	0.93	194	#362
Mid-Cape Connector SB (thru)	A	4.9	0.12	18	m53	A	4.8	0.21	50	120
Mid-Cape Connector SB (thru)	A	4.9	0.12	18	m53	A	4.8	0.21	50	120
16:: Cranberry Highway / Route 6 E NB Off-Ramp	**C**	**24.8**				**C**	**21.0**			
Cranberry Highway EB (left)	B	13.9	0.61	65	m#231	B	17.1	0.58	73	m218
Cranberry Highway EB (thru)	B	13.6	0.47	91	m280	B	12.9	0.09	18	m45
Cranberry Highway WB (thru)	D	49.00	0.72	155	#343	D	40.1	0.47	120	212
Cranberry Highway WB (right)	B	12.3	0.49	136	240	B	14.5	0.72	263	620
Route 6 E NB Off-Ramp (left)	D	38.4	0.86	331	457	C	27.0	0.65	268	412
Route 6 E NB Off-Ramp (right)	C	21.4	0.32	84	132	C	21.5	0.35	110	184
20:: Scenic Highway (Route 6) / Church Lane / Route 6 SB On-Ramp	**B**	**17.1**				**C**	**29.4**			
Scenic Hwy (Route 6) EB (left)	E	57.5	0.55	46	89	E	63.1	0.57	29	66
Scenic Hwy (Route 6) EB (thru)	C	21.2	0.59	200	#567	C	24.4	0.07	16	61
Scenic Hwy (Route 6) EB (thru/right)	C	21.2	0.59	200	#567	C	24.4	0.07	16	61
Scenic Hwy (Route 6) WB (left)	D	37.5	0.36	48	67	D	44.8	0.76	256	186
Scenic Hwy (Route 6) WB (left)	D	37.5	0.36	48	67	D	44.8	0.76	256	186
Scenic Hwy (Route 6) WB (thru)	A	9.5	0.63	208	#663	B	18.4	0.48	102	271
Scenic Hwy (Route 6) WB (thru)	A	9.5	0.63	208	#663	B	18.4	0.48	102	271
Scenic Hwy (Route 6) WB (thru/right)	A	9.5	0.63	208	#663	B	18.4	0.48	102	271
Church Lane SB (left/thru/right)	E	57.0	0.63	82	137	E	63.4	0.73	107	176
21:: Scenic Highway (Route 6) & Route 3 SB Off-Ramp	**B**	**14.7**				**B**	**19.9**			
Scenic Hwy (Route 6) EB (thru)	B	14.3	0.53	94	247	A	9.7	0.07	40	34
Scenic Hwy (Route 6) EB (thru)	B	14.3	0.53	94	247	A	9.7	0.07	40	34
Scenic Hwy (Route 6) WB (thru)	B	13.7	0.46	121	m375	B	17.7	0.58	265	521
Scenic Hwy (Route 6) WB (thru)	B	13.7	0.46	121	m375	B	17.7	0.58	265	521
Scenic Hwy (Route 6) WB (thru)	B	13.7	0.46	121	m375	B	17.7	0.58	265	521
Route 3 Off-Ramp SB (left)	E	56.3	0.74	166	236	E	62.2	0.82	202	295
Route 3 Off-Ramp SB (right)	A	0.5	0.33	0	0	A	0.3	0.20	0	0

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Table C-10: Synchro and SIDRA Results Summary - 2050 AP7.1

Intersection	2050 AP7.1 Weekday Fall PM					2050 AP7.1 Summer Saturday MID				
	LOS	Delay (sec)	v/c Ratio	50% Queue (feet)	95% Queue (feet)	LOS	Delay (sec)	v/c Ratio	50% Queue (feet)	95% Queue (feet)
22:: Meetinghouse Lane / State Road / Canal Street	**D**	**51.4**				**D**	**53.0**			
Meetinghouse Ln EB (left)	D	37.3	0.86	394	#498	E	67.0	0.64	48	m#84
Meetinghouse Ln EB (left)	D	37.3	0.86	394	#498	E	67.0	0.64	48	m#84
Meetinghouse Ln EB (thru/right)	B	13.7	0.49	118	278	D	43.9	0.59	232	#458
Meetinghouse Ln WB (left)	F	183.2	0.79	8	29	E	63.1	0.57	29	#78
Meetinghouse Ln WB (thru)	D	44.2	0.22	39	103	D	42.8	0.60	176	#455
Meetinghouse Ln WB (right)	D	37.2	0.03	3	14	C	21.9	0.33	59	174
Canal St NB (left)	F	186.4	1.20	~126	#240	D	36.0	0.71	161	237
Canal St NB (thru/right)	D	48.3	0.59	130	208	E	77.5	0.93	257	#428
State Rd SB (left)	D	55.0	0.73	100	#190	F	89.4	1.03	~250	#444
State Rd SB (thru)	F	90.0	0.96	224	#398	D	43.4	0.60	173	263
State Rd SB (right)	B	17.9	0.21	52	86	D	43.9	0.72	146	#288
23:: State Road / Route 3 NB Ramps	**C**	**24.1**				**C**	**25.2**			
Route 3 NB Off-Ramp (left)	C	28.4	0.73	117	#372	C	28.3	0.15	10	41
Route 3 NB Off-Ramp (right)	B	12.6	0.45	52	126	D	44.5	0.88	107	#320
State Rd NB (left)	C	27.8	0.67	80	#204	C	28.6	0.57	53	#140
State Rd NB (left)	C	27.8	0.67	80	#204	C	28.6	0.57	53	#140
State Rd NB (thru)	B	17.7	0.73	163	#565	A	5.5	0.26	34	162
State Rd SB (thru/right)	D	40.9	0.82	102	#336	C	22.0	0.76	163	#528
24:: Cranberry Highway / Adams Street	**A**	**1.9**				**A**	**1.8**			
Cranberry Highway EB (thru)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Cranberry Highway EB (thru/right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Cranberry Highway WB (left/thru)	A	7.9	0.01	-	0	A	7.8	0.01	-	0
Cranberry Highway WB (thru/right)	A	0.1	0.00	-	0	A	0.1	0.00	-	0
Adams Street NB (left/thru/right)	C	17.1	0.13	-	10	C	17.2	0.07	-	5
Adams Street SB (left/thru/right)	B	13.3	0.18	-	15	C	15.2	0.25	-	25

PRE-DECISIONAL & DELIBERATIVE

Table C-12: Synchro and SIDRA Results Summary - 2050 AP8.1

Intersection	2050 AP8.1 Weekday Fall PM					2050 AP8.1 Summer Saturday MID				
	LOS	Delay (sec)	v/c Ratio	50% Queue (feet)	95% Queue (feet)	LOS	Delay (sec)	v/c Ratio	50% Queue (feet)	95% Queue (feet)
6:: Scenic Highway (Route 6) / Main Street (Route 6) / Nightingale Road / Andy Olivia Drive	**B**	**12.8**				**C**	**22.5**			
Main Street (Route 6) EB (left)	A	6.8	0.21	10	65	B	12.9	0.08	2	17
Main Street (Route 6) EB (thru/right)	B	10.5	0.51	64	#479	B	19.9	0.79	200	#934
Scenic Hwy (Route 6) WB (left)	A	9.00	0.01	1	9	B	12.8	0.03	1	8
Scenic Hwy (Route 6) WB (thru/right)	B	13.1	0.55	103	#439	B	20.0	0.80	202	#933
Andy Olivia Dr NB (left/thru/right)	C	28.7	0.27	7	39	D	46.4	0.67	49	#218
Nightingale Pond Rd SB (left/thru/right)	C	28.3	0.23	5	48	D	35.1	0.13	6	65
8:: Trowbridge Road / Veterans Way	**A**	**0.7**				**A**	**1.2**			
Trowbridge Rd EB (left/thru)	A	8.7	0.01	-	0	A	8.2	0.01	-	0
Trowbridge Rd EB (thru/right)	A	0.1	0.00	-	0	A	0.1	0.00	-	0
Trowbridge Rd WB (thru)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Trowbridge Rd WB (thru/right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Veterans Way SB (left/thru/right)	B	10.1	0.03	-	3	B	13.0	0.14	-	13
9:: Trowbridge Road / Sandwich Road / Route 25 SB Off-Ramp / Route 28 NB Off-Ramp	**B**	**17.4**				**B**	**15.5**			
Trowbridge Rd EB (left)	C	31.1	0.77	82	#223	C	31.2	0.58	60	146
Trowbridge Rd EB (left)	C	31.1	0.77	82	#223	C	31.2	0.58	60	146
Trowbridge Rd EB (thru)	B	18.5	0.36	51	136	C	28.4	0.36	35	84
Trowbridge Rd EB (thru/right)	B	18.5	0.36	51	136	C	28.4	0.36	35	84
Trowbridge Rd WB (left)	C	30.3	0.68	72	176	C	30.8	0.81	159	#439
Trowbridge Rd WB (thru)	C	28.5	0.79	130	#399	C	20.1	0.42	73	200
Trowbridge Rd WB (right)	A	1.2	0.52	0	0	A	0.8	0.41	0	0
Route 25 SB Off-Ramp (left)	C	29.7	0.64	51	#137	C	31.2	0.72	90	#215
Route 25 SB Off-Ramp (left)	C	29.7	0.64	51	#137	C	31.2	0.72	90	#215
Route 25 SB Off-Ramp (right)	A	0.1	0.06	0	0	A	0.0	0.01	0	0
Route 28 NB Off-Ramp (left)	C	24.8	0.09	7	31	C	26.0	0.34	40	111
Route 28 NB Off-Ramp (right)	A	0.2	0.14	0	0	A	1.2	0.51	0	0
10:: Sandwich Road / Bourne Rotary Connector	**A**	**0.0**				**E**	**43.8**			
Sandwich Road EB (left/right)	A	0.0	0.00	-	0	F	$1109.4	2.99	-	333
Sandwich Road (Bourne Rotary Connector) NB (left/thru)	A	0.0	0.00	-	0	B	13.2	0.04	-	3
Sandwich Road (Bourne Rotary Connector) NB (thru)	A	0.0	0.00	-	0	A	1.1	0.00	-	0
Sandwich Rd WB (thru/right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
15:: Sandwich Road (Route 6 Bypass) / Mid-Cape Connector	**C**	**23.8**				**B**	**18.0**			
Sandwich Rd EB (thru)	C	25.9	0.74	196	#534	C	22.9	0.77	231	#742
Sandwich Rd EB (right)	A	7.5	0.31	39	182	A	9.6	0.56	94	412
Sandwich Rd WB (left)	B	13.3	0.40	24	89	B	11.1	0.21	9	52
Sandwich Rd WB (thru)	C	22.9	0.90	310	#820	B	11.9	0.71	202	#739
Sandwich Rd WB (thru)	C	22.9	0.90	310	#820	B	11.9	0.71	202	#739
Mid-Cape Connector NB (left)	D	43.3	0.84	155	#434	C	34.6	0.60	79	188
Mid-Cape Connector NB (right)	C	24.5	0.60	98	#227	D	43.2	0.84	132	#296
16:: Mid-Cape Connector / Cranberry Highway Extension	**B**	**18.6**				**A**	**9.9**			
Cranberry Highway Extension WB (left)	C	26.6	0.27	17	55	C	25.9	0.20	9	44
Cranberry Highway Extension WB (left)	C	26.6	0.27	17	55	C	25.9	0.20	9	44
Cranberry Highway Extension WB (right)	C	20.8	0.51	50	#144	C	22.7	0.25	12	47
Mid-Cape Connector NB (thru)	C	21.6	0.71	124	#453	B	12.9	0.56	118	377
Mid-Cape Connector NB (right)	A	9.9	0.12	12	72	A	6.4	0.06	6	42
Mid-Cape Connector SB (left)	C	29.8	0.63	57	#224	C	26.5	0.04	1	15
Mid-Cape Connector SB (thru)	A	5.5	0.14	15	79	A	5.4	0.32	40	184
Mid-Cape Connector SB (thru)	A	5.5	0.14	15	79	A	5.4	0.32	40	184
20:: Scenic Highway (Route 6) / Church Lane / Route 6 SB On-Ramp	**B**	**17.7**				**C**	**31.2**			
Scenic Hwy (Route 6) EB (left)	E	68.9	0.62	50	97	E	63.1	0.57	29	66
Scenic Hwy (Route 6) EB (thru)	C	21.0	0.57	225	495	C	24.3	0.07	16	61
Scenic Hwy (Route 6) EB (thru/right)	C	21.0	0.57	225	495	C	24.3	0.07	16	61
Scenic Hwy (Route 6) WB (left)	D	40.7	0.33	54	73	D	49.3	0.76	255	187
Scenic Hwy (Route 6) WB (left)	D	40.7	0.33	54	73	D	49.3	0.76	255	187
Scenic Hwy (Route 6) WB (thru)	A	9.2	0.59	100	194	B	19.3	0.48	156	270
Scenic Hwy (Route 6) WB (thru)	A	9.2	0.59	100	194	B	19.3	0.48	156	270
Scenic Hwy (Route 6) WB (thru/right)	A	9.2	0.59	100	194	B	19.3	0.48	156	270
Church Lane SB (left/thru/right)	E	68.0	0.70	89	#171	E	63.2	0.73	105	173
21:: Scenic Highway (Route 6) & Route 3 SB Off-Ramp	**B**	**11.1**				**B**	**17.4**			
Scenic Hwy (Route 6) EB (thru)	A	3.6	0.51	33	43	A	9.7	0.07	40	34
Scenic Hwy (Route 6) EB (thru)	A	3.6	0.51	33	43	A	9.7	0.07	40	34
Scenic Hwy (Route 6) WB (thru)	B	12.7	0.45	113	398	B	14.2	0.58	147	473
Scenic Hwy (Route 6) WB (thru)	B	12.7	0.45	113	398	B	14.2	0.58	147	473
Scenic Hwy (Route 6) WB (thru)	B	12.7	0.45	113	398	B	14.2	0.58	147	473
Route 3 Off-Ramp SB (left)	E	62.4	0.76	181	256	E	62.2	0.82	202	295
Route 3 Off-Ramp SB (right)	A	0.5	0.31	0	0	A	0.3	0.20	0	0
22:: Meetinghouse Lane / State Road / Canal Street	**D**	**40.7**				**D**	**40.6**			
Meetinghouse Ln EB (left)	D	41.0	0.9	563	#677	E	60.0	0.46	57	m88
Meetinghouse Ln EB (left)	D	41.0	0.9	563	#677	E	60.0	0.46	57	m88
Meetinghouse Ln EB (thru/right)	C	23.1	0.78	191	#897	D	35.2	0.89	260	#645
Meetinghouse Ln WB (left)	E	67.0	0.41	9	30	F	89.1	0.72	30	#84
Meetinghouse Ln WB (thru)	D	48.6	0.21	40	102	C	30.3	0.48	174	262
Meetinghouse Ln WB (right)	A	0.0	0.00	0	0	B	17.9	0.15	0	36
Canal St NB (left)	E	73.2	0.81	126	#287	D	45.5	0.80	188	#261
Canal St NB (thru/right)	F	87.0	0.87	~167	#318	E	68.3	0.90	252	#477
State Rd SB (left)	D	50.9	0.30	27	60	C	33.6	0.47	59	103
State Rd SB (thru)	E	57.3	0.54	80	142	D	42.1	0.43	102	169
State Rd SB (right)	B	17.2	0.18	50	83	C	30.9	0.18	0	61
23:: State Road / Route 3 NB On-Ramp	**A**	**7.9**				**B**	**11.5**			
State Rd NB (left)	B	12.2	0.45	31	142	C	20.3	0.53	33	#125
State Rd NB (left)	B	12.2	0.45	31	142	C	20.3	0.53	33	#125
State Rd NB (thru)	A	4.5	0.70	0	#666	A	1.7	0.26	0	130
State Rd SB (thru/right)	B	12.6	0.49	38	189	B	12.8	0.69	89	#448

PRE-DECISIONAL & DELIBERATIVE

Table C-12: Synchro and SIDRA Results Summary - 2050 AP8.1

Intersection	2050 AP8.1 Weekday Fall PM					2050 AP8.1 Summer Saturday MID				
	LOS	Delay (sec)	v/c Ratio	50% Queue (feet)	95% Queue (feet)	LOS	Delay (sec)	v/c Ratio	50% Queue (feet)	95% Queue (feet)
24:: Cranberry Highway / Adams Street	**A**	**5.9**				**C**	**21.6**			
Cranberry Highway EB (thru/right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Cranberry Highway WB (left/thru)	A	9.3	0.01	-	0	A	9.2	0.01	-	0
Cranberry Highway WB (thru/right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Adams Street NB (left/thru/right)	E	38.4	0.13	-	10	F	$690.3	1.36	-	80
Adams Street SB (left/thru/right)	D	26.2	0.68	-	125	F	64.7	0.95	-	270

PRE-DECISIONAL & DELIBERATIVE

Table C-13: Synchro and SIDRA Results Summary - 2050 AP9

Intersection	2050 AP9 Weekday Fall PM					2050 AP9 Summer Saturday MID				
	LOS	Delay (sec)	v/c Ratio	50% Queue (feet)	95% Queue (feet)	LOS	Delay (sec)	v/c Ratio	50% Queue (feet)	95% Queue (feet)
6:: Scenic Highway (Route 6) / Main Street (Route 6) / Nightingale Road / Andy Olivia Drive	**B**	**12.4**				**C**	**22.5**			
Main Street (Route 6) EB (left)	A	6.4	0.18	10	65	B	12.9	0.08	2	17
Main Street (Route 6) EB (thru/right)	B	10.3	0.48	57	#432	B	19.9	0.79	200	#934
Scenic Hwy (Route 6) WB (left)	A	9.2	0.01	1	9	B	12.8	0.03	1	8
Scenic Hwy (Route 6) WB (thru/right)	B	12.2	0.45	76	#324	B	20.0	0.80	202	#933
Andy Olivia Dr NB (left/thru/right)	C	27.9	0.27	6	39	D	46.4	0.67	49	#218
Nightingale Pond Rd SB (left/thru)	C	27.6	0.23	5	48	D	35.1	0.13	6	65
8:: Trowbridge Road / Veterans Way	**A**	**0.6**				**A**	**1.3**			
Trowbridge Rd EB (left/thru)	A	8.6	0.01	-	0	A	8.2	0.01	-	0
Trowbridge Rd EB (thru)	A	0.1	0.00	-	0	A	0.1	0.00	-	0
Trowbridge Rd WB (thru)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Trowbridge Rd WB (thru/right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Veterans Way SB (left/thru/right)	C	17.6	0.13	-	13	B	13.9	0.15	-	13
9:: Trowbridge Road / Route 25 SB Off-Ramp	**C**	**31.5**				**D**	**44.3**			
Trowbridge Rd EB (thru)	C	30.9	0.79	272	#553	D	44.8	0.59	144	#308
Trowbridge Rd EB (thru/right)	C	30.9	0.79	272	#553	D	44.8	0.59	144	#308
Trowbridge Rd WB (left)	E	58.9	0.63	124	#263	E	58.5	0.74	388	#675
Trowbridge Rd WB (thru)	B	14.4	0.18	26	163	B	14.0	0.16	38	172
Trowbridge Rd WB (thru)	B	14.4	0.18	26	163	B	14.0	0.16	38	172
Route 25 SB Off-Ramp (left)	D	43.1	0.6	97	#251	E	60.1	0.8	189	281
Route 25 SB Off-Ramp (thru/right)	D	36.3	0.11	2	64	D	44.9	0.47	87	172
9:: Sandwich Road / Trowbridge Road / Route 28 NB Off-Ramp	**C**	**25.8**				**C**	**34.8**			
Trowbridge Rd EB (left)	D	52.0	0.71	160	#267	E	58.7	0.56	66	m#108
Trowbridge Rd EB (left)	D	52.0	0.71	160	#267	E	58.7	0.56	66	m#108
Trowbridge Rd EB (thru)	A	3.4	0.25	31	88	B	18.6	0.34	148	203
Trowbridge Rd EB (thru)	A	3.4	0.25	31	88	B	18.6	0.34	148	203
Sandwich Road WB (thru)	B	19.6	0.36	98	#265	C	28.7	0.51	206	#414
Sandwich Road WB (thru)	B	19.6	0.36	98	#265	C	28.7	0.51	206	#414
Sandwich Road WB (right)	C	26.6	0.64	21	#332	C	29.3	0.47	27	197
Route 28 NB Off-Ramp (left/thru)	D	42.9	0.11	10	31	C	34.0	0.23	62	128
Route 28 NB Off-Ramp (right)	D	43.2	0.15	0	#79	D	53.0	0.83	145	#473
10:: Sandwich Road / Bourne Rotary Connector	**A**	**0.3**				**E**	**43.8**			
Sandwich Road EB (left/right)	F	114.9	0.14	-	13	F	$1109.4	2.99	-	333
Sandwich Road (Bourne Rotary Connector) NB (left/thru)	C	21.0	0.02	-	3	B	13.2	0.04	-	3
Sandwich Road (Bourne Rotary Connector) NB (thru)	A	0.4	0.00	-	0	A	1.1	0.00	-	0
Sandwich Rd WB (thru/right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
15:: Sandwich Road (Route 6 Bypass) / Mid-Cape Connector	**C**	**25.4**				**C**	**28.9**			
Sandwich Rd EB (thru)	C	24.3	0.27	90	178	D	45.3	0.75	283	#499
Sandwich Rd EB (right)	B	10.3	0.64	159	600	A	9.3	0.70	188	#895
Sandwich Rd WB (left)	B	15.4	0.26	53	121	C	27.6	0.20	18	46
Sandwich Rd WB (thru)	C	24.8	0.79	403	#721	D	36.6	0.78	353	474
Sandwich Rd WB (thru)	C	24.8	0.79	403	#721	D	36.6	0.78	353	474
Mid-Cape Connector NB (left)	D	41.0	0.81	280	#447	C	31.9	0.69	370	m#558
Mid-Cape Connector NB (right)	D	41.0	0.81	280	#447	C	31.9	0.69	370	m#558
16:: Mid-Cape Connector / Cranberry Highway Extension	**C**	**20.4**				**F**	**103.5**			
Cranberry Highway Extension WB (left)	D	44.9	0.81	213	m311	F	246	1.47	~1084	m#1073
Cranberry Highway Extension WB (right)	B	16.9	0.55	155	m260	B	17.4	0.45	154	m173
Cranberry Highway Extension WB (right)	B	16.9	0.55	155	m260	B	17.4	0.45	154	m173
Mid-Cape Connector NB (thru)	C	25.4	0.34	112	#270	E	69.4	0.93	290	#776
Mid-Cape Connector NB (right)	B	11.5	0.40	80	162	A	7.4	0.07	8	32
Mid-Cape Connector SB (left)	D	45.6	0.51	99	m#183	D	52	0.04	4	m5
Mid-Cape Connector SB (thru)	B	11.1	0.37	166	305	C	30.6	0.68	217	#556
Mid-Cape Connector SB (thru)	B	11.1	0.37	166	305	C	30.6	0.68	217	#556
16:: Cranberry Highway / Route 6 E NB Off-Ramp	**C**	**32.0**				**E**	**71.2**			
Cranberry Highway EB (left)	C	0.0	0.00	0	0	B	0.0	0.00	0	0
Cranberry Highway EB (thru)	C	29.6	0.72	276	#619	B	14.3	0.01	2	10
Cranberry Highway WB (thru/right)	C	24.9	0.29	99	198	E	76.5	1.06	745	#1240
Route 6 E NB Off-Ramp (left/thru)	D	41.1	0.90	354	#559	F	80.5	1.00	~384	#611
Route 6 E NB Off-Ramp (right)	B	17.6	0.26	76	118	C	30.4	0.43	141	217
20:: Scenic Highway (Route 6) / Church Lane / Route 6 SB On-Ramp	**C**	**21.5**				**C**	**29.4**			
Scenic Hwy (Route 6) EB (left)	E	57.5	0.55	46	89	E	63.1	0.57	29	66
Scenic Hwy (Route 6) EB (thru)	C	21.1	0.59	198	#562	C	24.4	0.07	16	61
Scenic Hwy (Route 6) EB (thru/right)	C	21.1	0.59	198	#562	C	24.4	0.07	16	61
Scenic Hwy (Route 6) WB (left)	D	47.8	0.36	47	64	D	44.8	0.76	256	186
Scenic Hwy (Route 6) WB (left)	D	47.8	0.36	47	64	D	44.8	0.76	256	186
Scenic Hwy (Route 6) WB (thru)	B	16.4	0.61	106	#615	B	18.4	0.48	102	271
Scenic Hwy (Route 6) WB (thru)	B	16.4	0.61	106	#615	B	18.4	0.48	102	271
Scenic Hwy (Route 6) WB (thru/right)	B	16.4	0.61	106	#615	B	18.4	0.48	102	271
Church Lane SB (left/thru/right)	E	57.0	0.63	82	137	E	63.4	0.73	107	176
21:: Scenic Highway (Route 6) & Route 3 SB Off-Ramp	**B**	**10.7**				**B**	**19.9**			
Scenic Hwy (Route 6) EB (thru)	A	2.7	0.52	14	21	A	9.7	0.07	40	34
Scenic Hwy (Route 6) EB (thru)	A	2.7	0.52	14	21	A	9.7	0.07	40	34
Scenic Hwy (Route 6) WB (thru)	B	13.8	0.43	116	m353	B	17.7	0.58	265	521
Scenic Hwy (Route 6) WB (thru)	B	13.8	0.43	116	m353	B	17.7	0.58	265	521
Scenic Hwy (Route 6) WB (thru)	B	13.8	0.43	116	m353	B	17.7	0.58	265	521
Route 3 Off-Ramp SB (left)	E	56.3	0.74	166	236	E	62.2	0.82	202	295
Route 3 Off-Ramp SB (right)	A	0.5	0.32	0	0	A	0.3	0.20	0	0

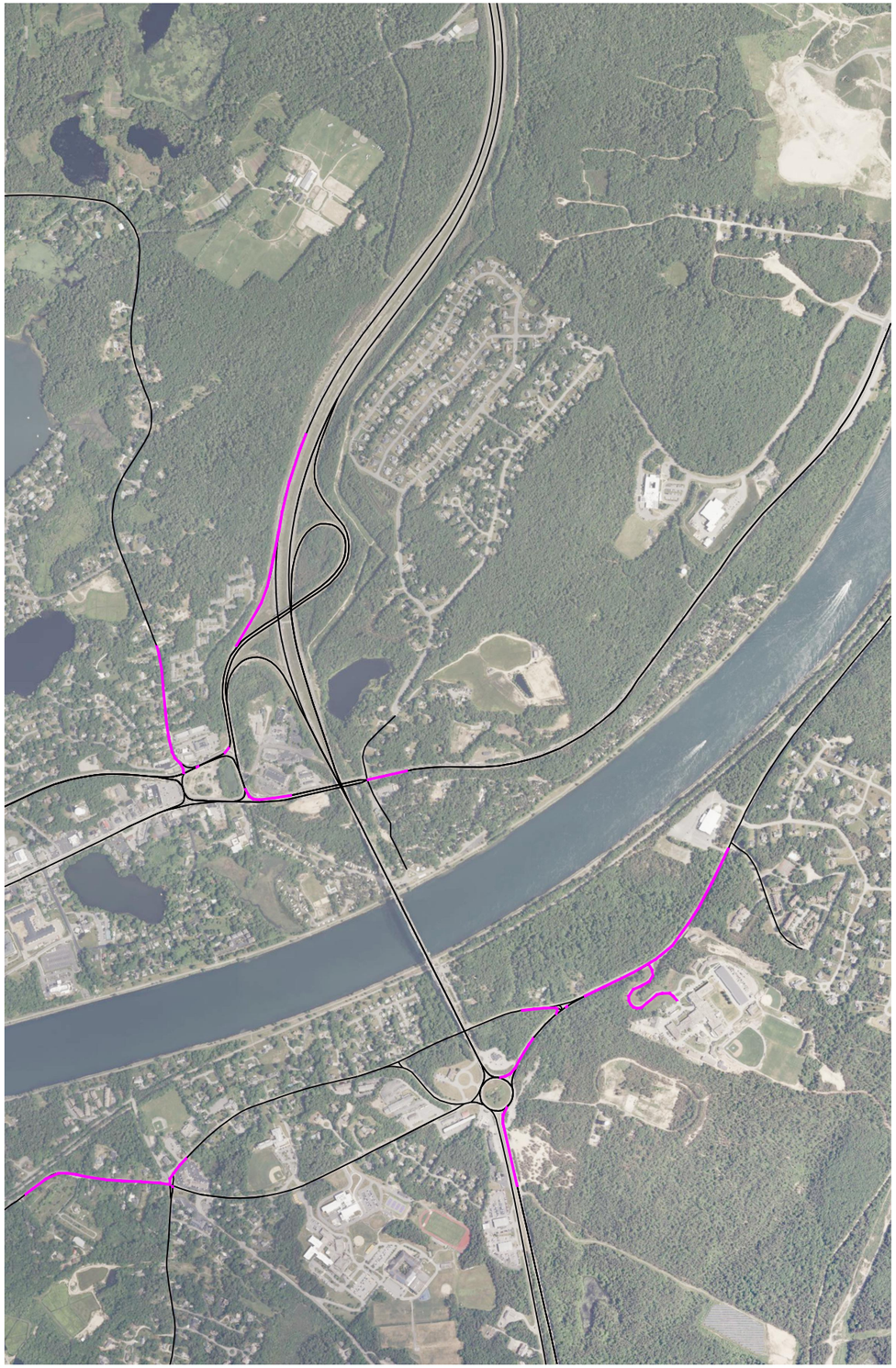
PRE-DECISIONAL & DELIBERATIVE

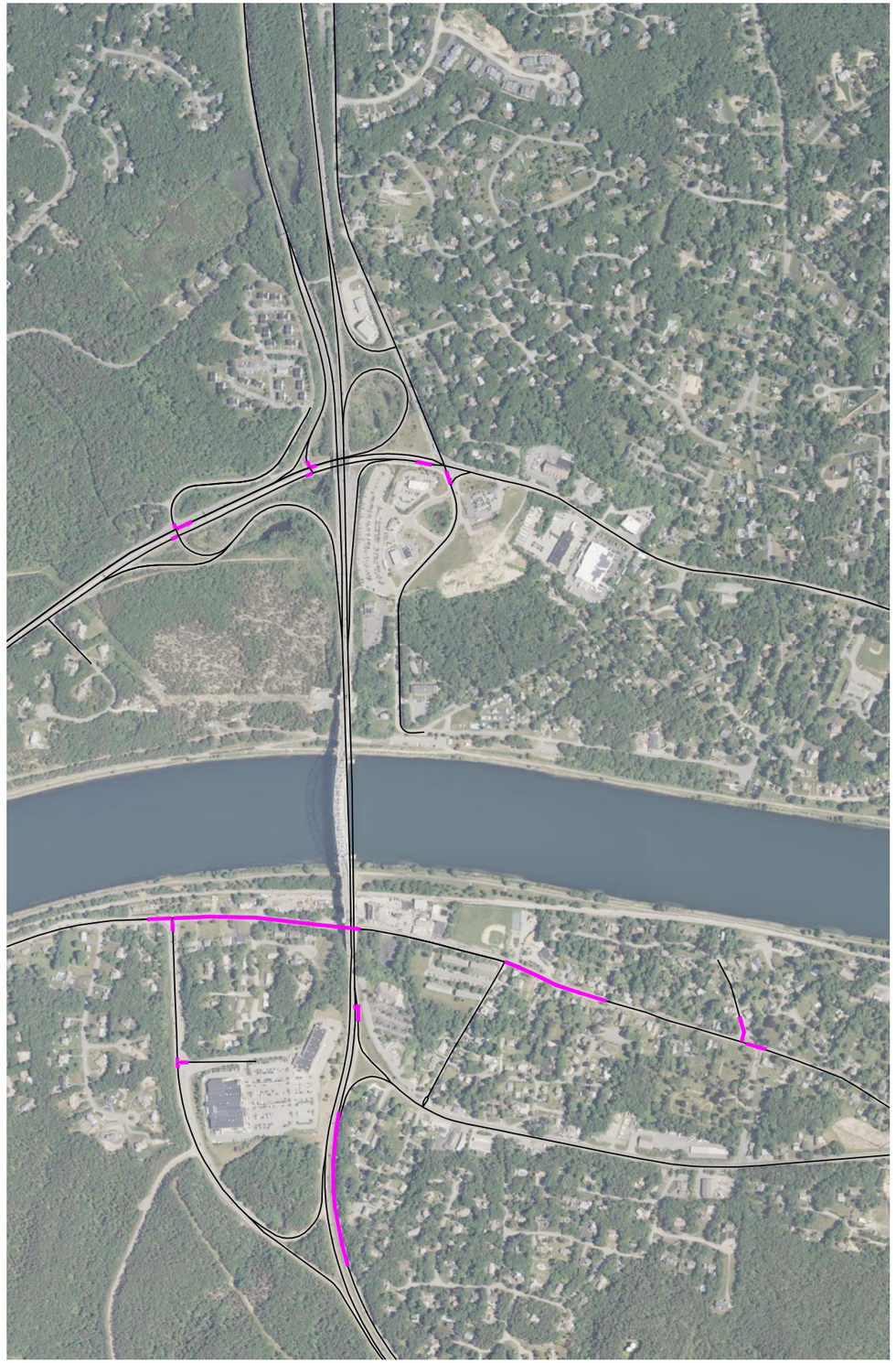
Table C-13: Synchro and SIDRA Results Summary - 2050 AP9

Intersection	2050 AP9 Weekday Fall PM					2050 AP9 Summer Saturday MID				
	LOS	Delay (sec)	v/c Ratio	50% Queue (feet)	95% Queue (feet)	LOS	Delay (sec)	v/c Ratio	50% Queue (feet)	95% Queue (feet)
22:: Meetinghouse Lane / State Road / Canal Street	**D**	**50.2**				**D**	**53.0**			
Meetinghouse Ln EB (left)	D	41.0	0.88	~382	#500	E	67.0	0.64	48	m#84
Meetinghouse Ln EB (left)	D	41.0	0.88	~382	#500	E	67.0	0.64	48	m#84
Meetinghouse Ln EB (thru/right)	B	15.9	0.51	80	#322	D	43.9	0.59	232	#458
Meetinghouse Ln WB (left)	F	183.2	0.79	8	29	E	63.1	0.57	29	#78
Meetinghouse Ln WB (thru)	D	43.9	0.22	39	103	D	42.8	0.6	176	#455
Meetinghouse Ln WB (right)	D	37.0	0.03	3	14	C	21.9	0.33	59	174
Canal St NB (left)	F	154	1.12	~120	#239	D	36.0	0.71	161	237
Canal St NB (thru/right)	D	47.5	0.59	133	211	E	77.5	0.93	257	#428
State Rd SB (left)	D	49.7	0.67	95	#163	F	89.4	1.03	~250	#444
State Rd SB (thru)	F	86.0	0.94	222	#390	D	43.4	0.60	173	263
State Rd SB (right)	B	18.7	0.21	54	88	D	43.9	0.72	146	#288
23:: State Road / Route 3 NB Ramps	**C**	**24.4**				**C**	**25.2**			
Route 3 NB Off-Ramp (left)	C	28	0.73	116	#372	C	28.3	0.15	10	41
Route 3 NB Off-Ramp (right)	B	12.5	0.44	52	123	D	44.5	0.88	107	#320
State Rd NB (left)	C	27.8	0.67	79	#200	C	28.6	0.57	53	#140
State Rd NB (left)	C	27.8	0.67	79	#200	C	28.6	0.57	53	#140
State Rd NB (thru)	B	17.8	0.73	163	#565	A	5.5	0.26	34	162
State Rd SB (thru/right)	D	43.0	0.83	104	#345	C	22.0	0.76	163	#528
24:: Cranberry Highway / Adams Street	**A**	**1.6**				**A**	**2.1**			
Cranberry Highway EB (thru/right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Cranberry Highway WB (left)	A	8.6	0.01	-	0	A	7.7	0.01	-	0
Cranberry Highway WB (thru/right)	A	0.0	0.00	-	0	A	0.0	0.00	-	0
Adams Street NB (left/thru/right)	C	16.8	0.13	-	10	D	31	0.14	-	13
Adams Street SB (left/thru/right)	B	12.3	0.07	-	5	C	21.7	0.29	-	30

PRE-DECISIONAL & DELIBERATIVE

Attachment D
VISSIM Queue Lengths Summary Graphics





N

NAD 83

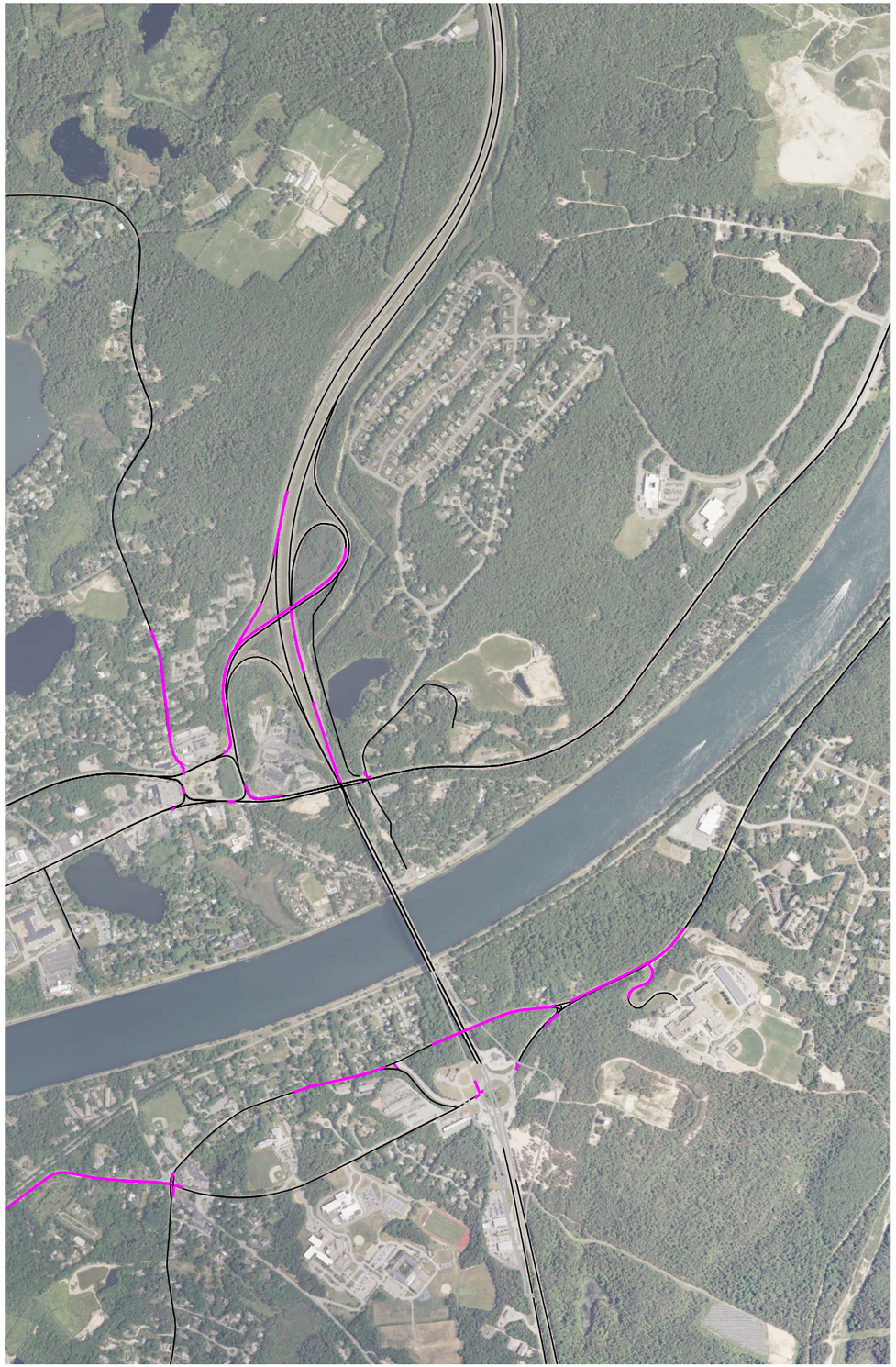
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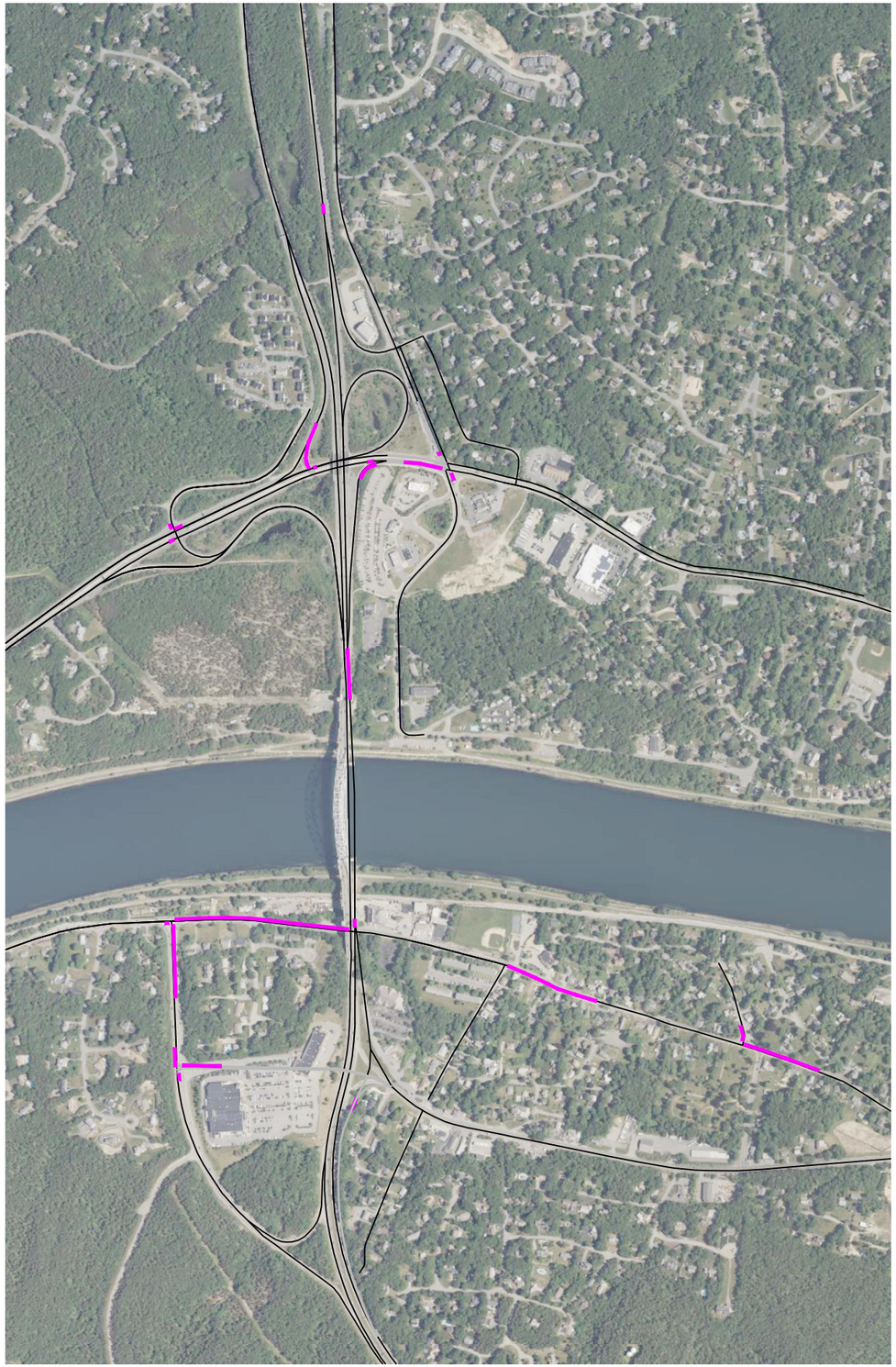
2050 No Build Condition

Note:

1. Figure only shows queues that are greater than or equal to 20 ft

Color	Description
	Avg Q's Fall PM





N

NAD 83

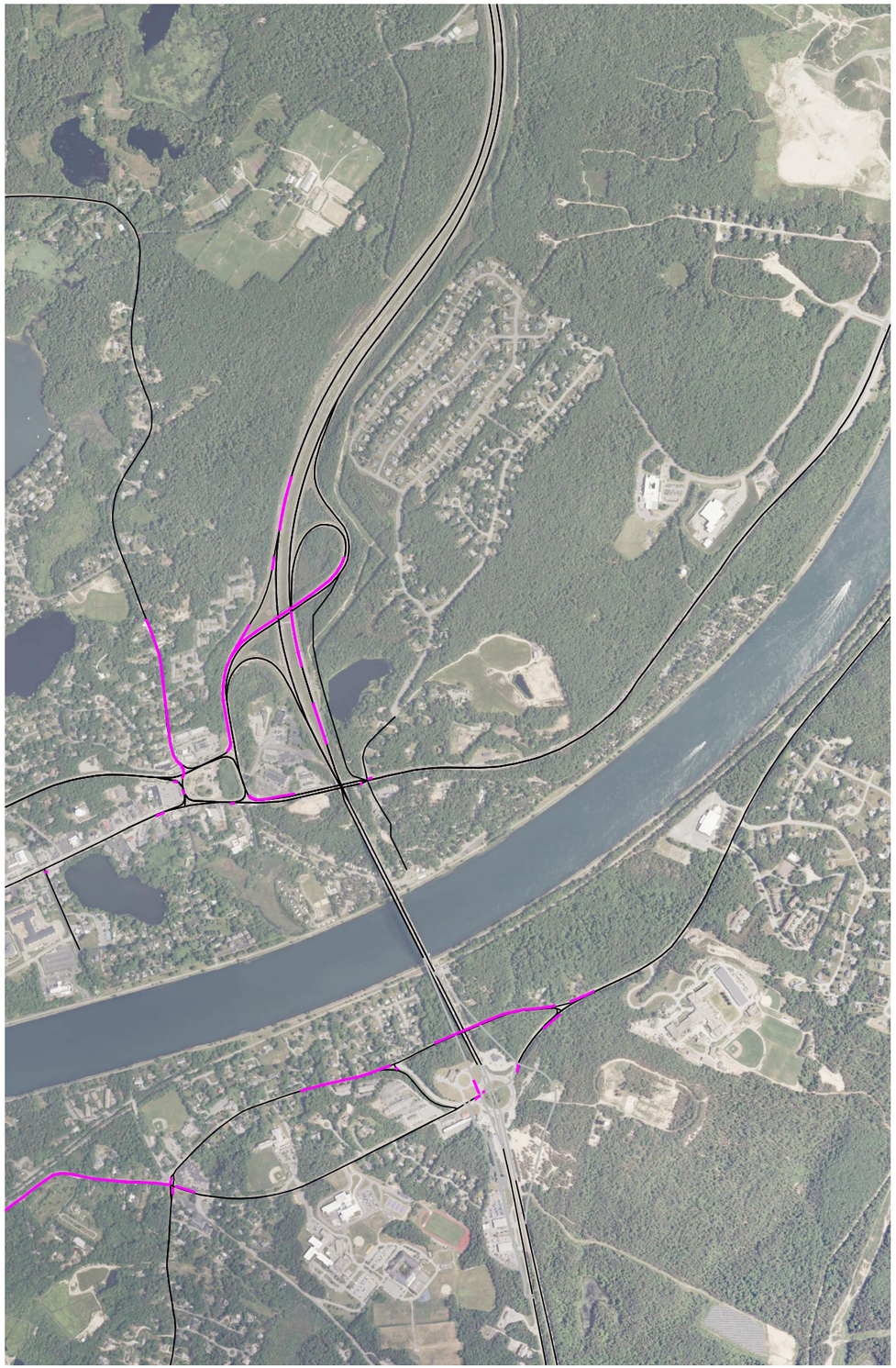
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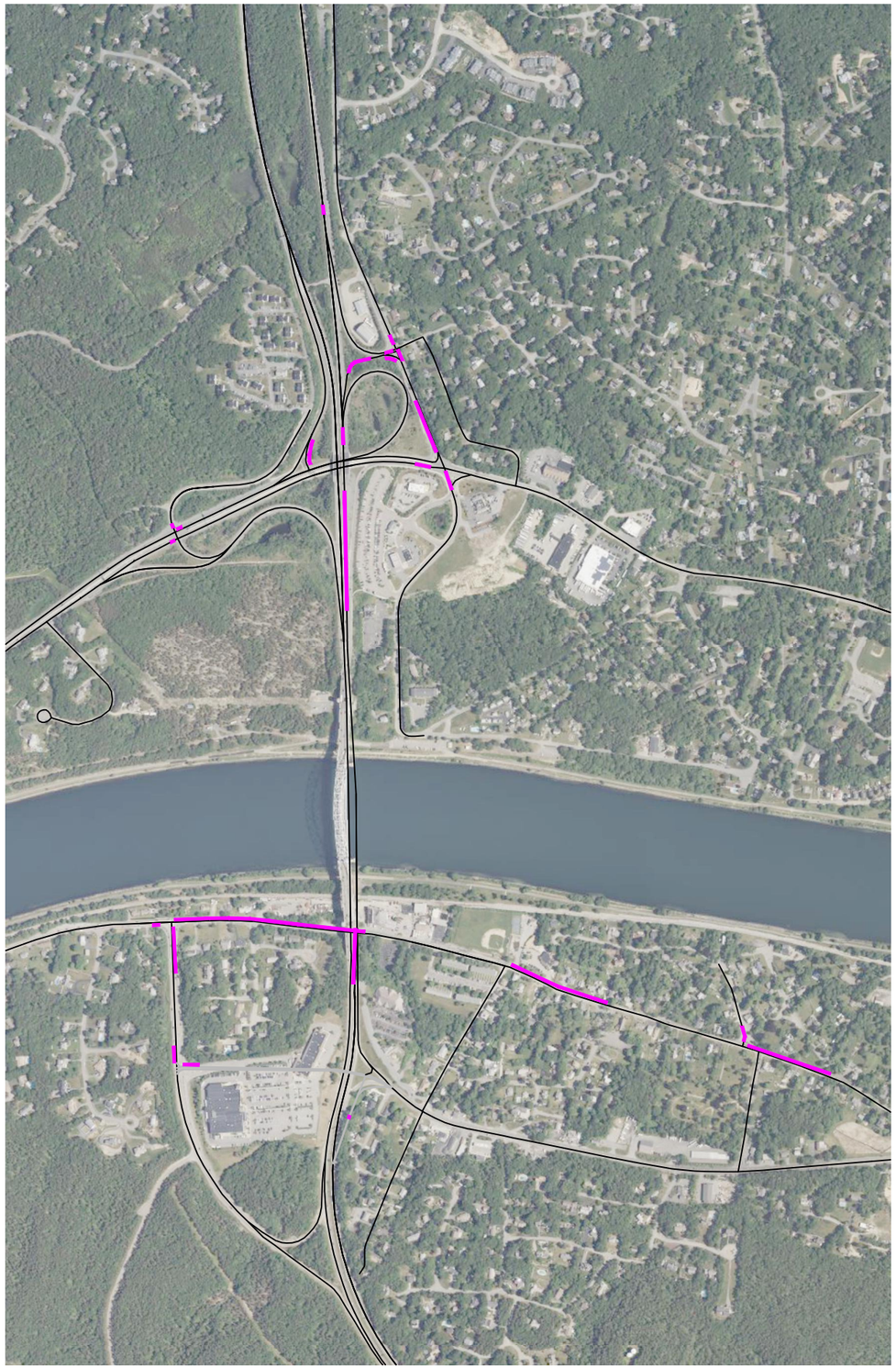
2050 Build Condition - AP 1

Note:

1. Figure only shows queues that are greater than or equal to 20 ft

Color	Description
	Avg Q's Fall PM





N

NAD 83

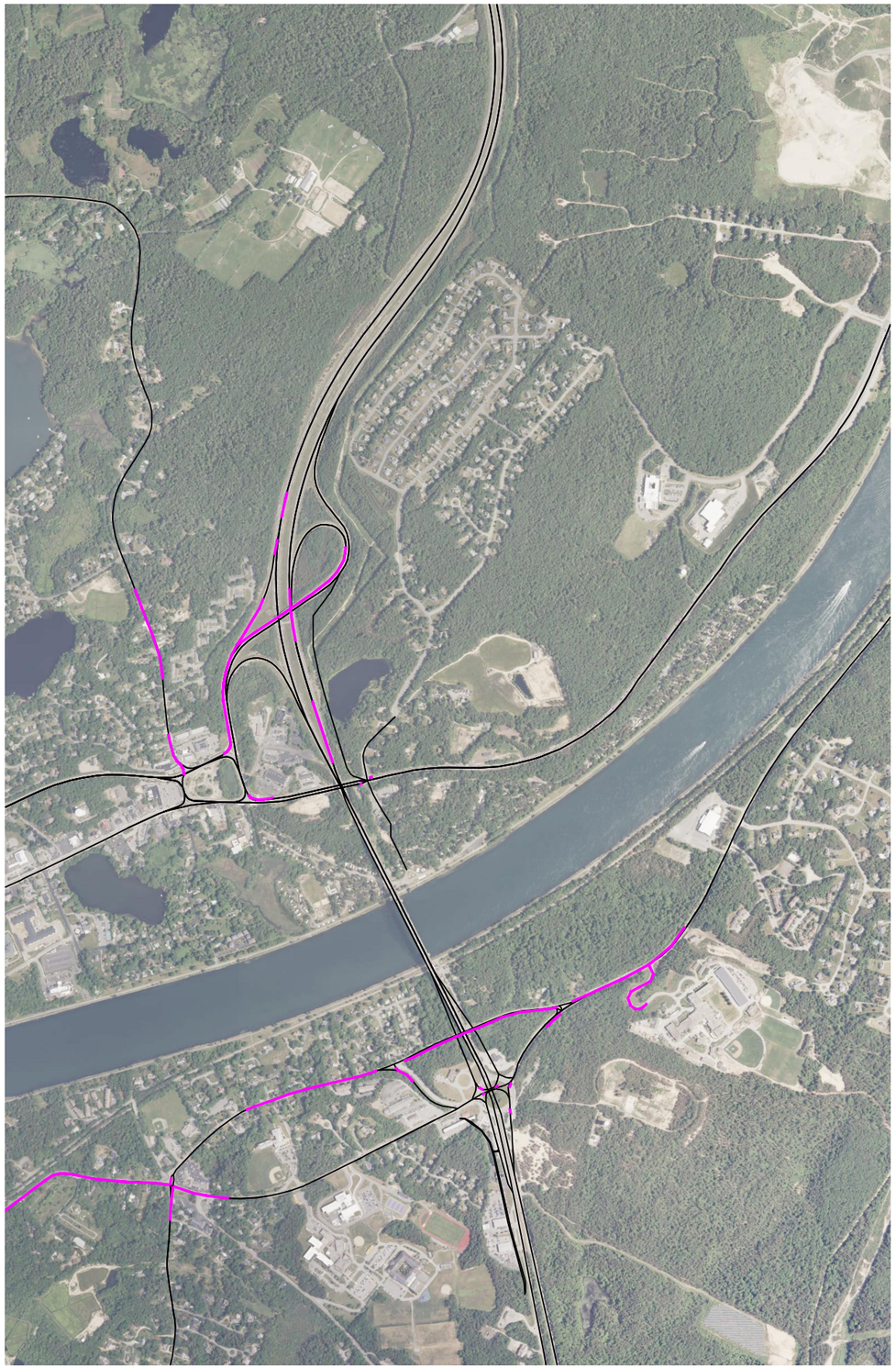
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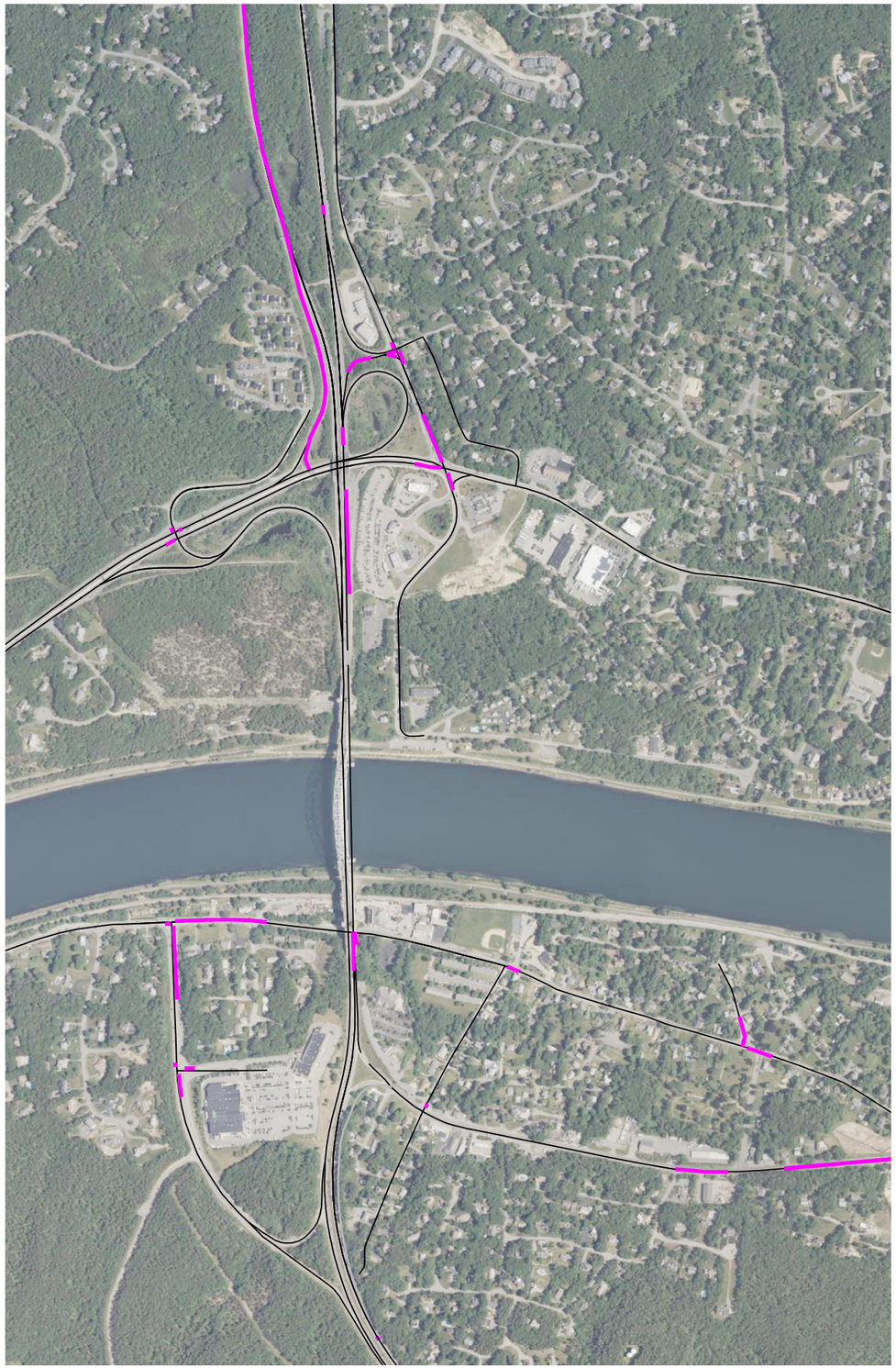
2050 Build Condition - AP 1.1

Note:

1. Figure only shows queues that are greater than or equal to 20 ft

Color	Description
	Avg Q's Fall PM





N

NAD 83

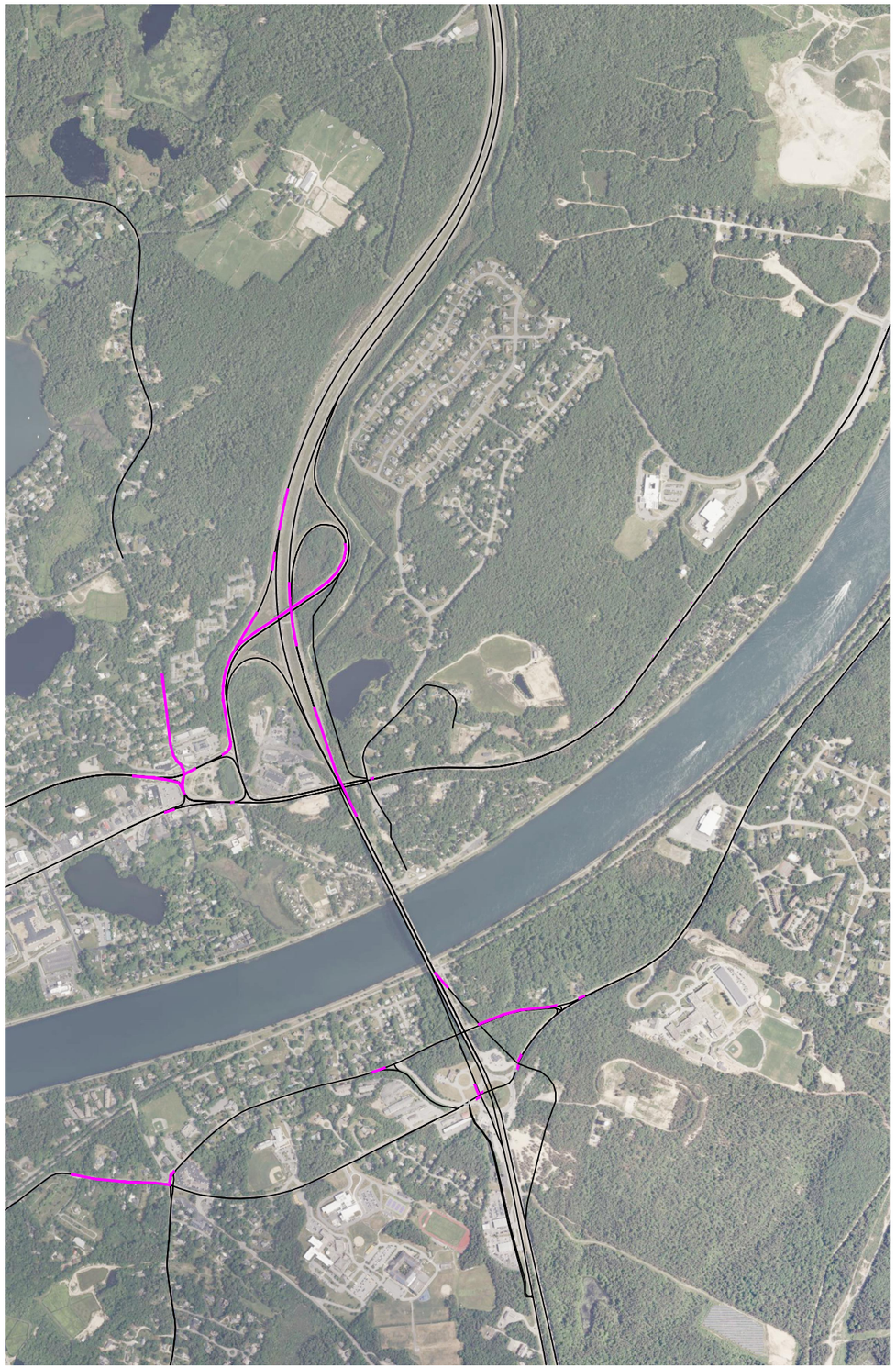
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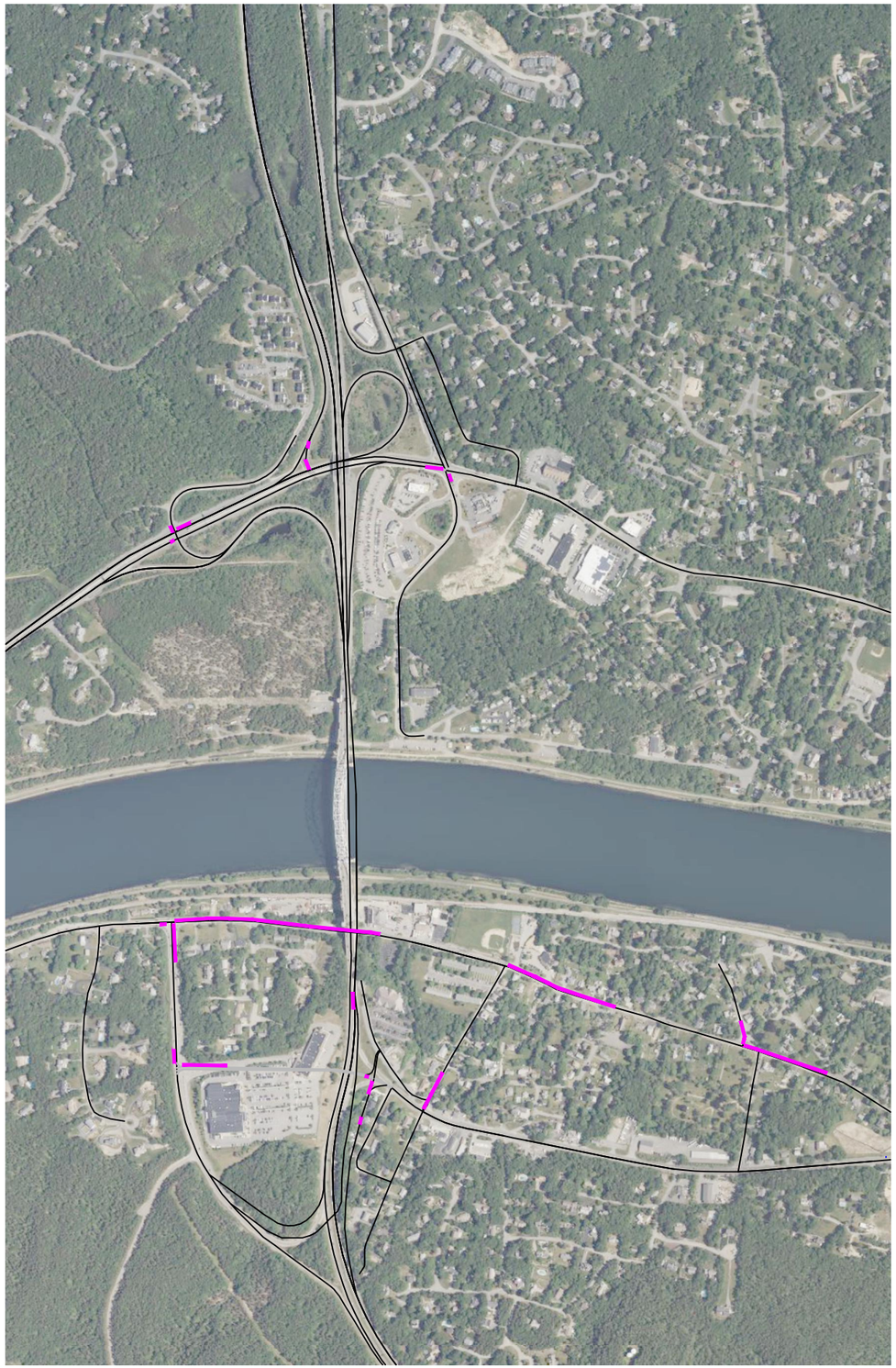
2050 Build Condition - AP 2

Note:

1. Figure only shows queues that are greater than or equal to 20 ft

Color	Description
	Avg Q's Fall PM





N

NAD 83

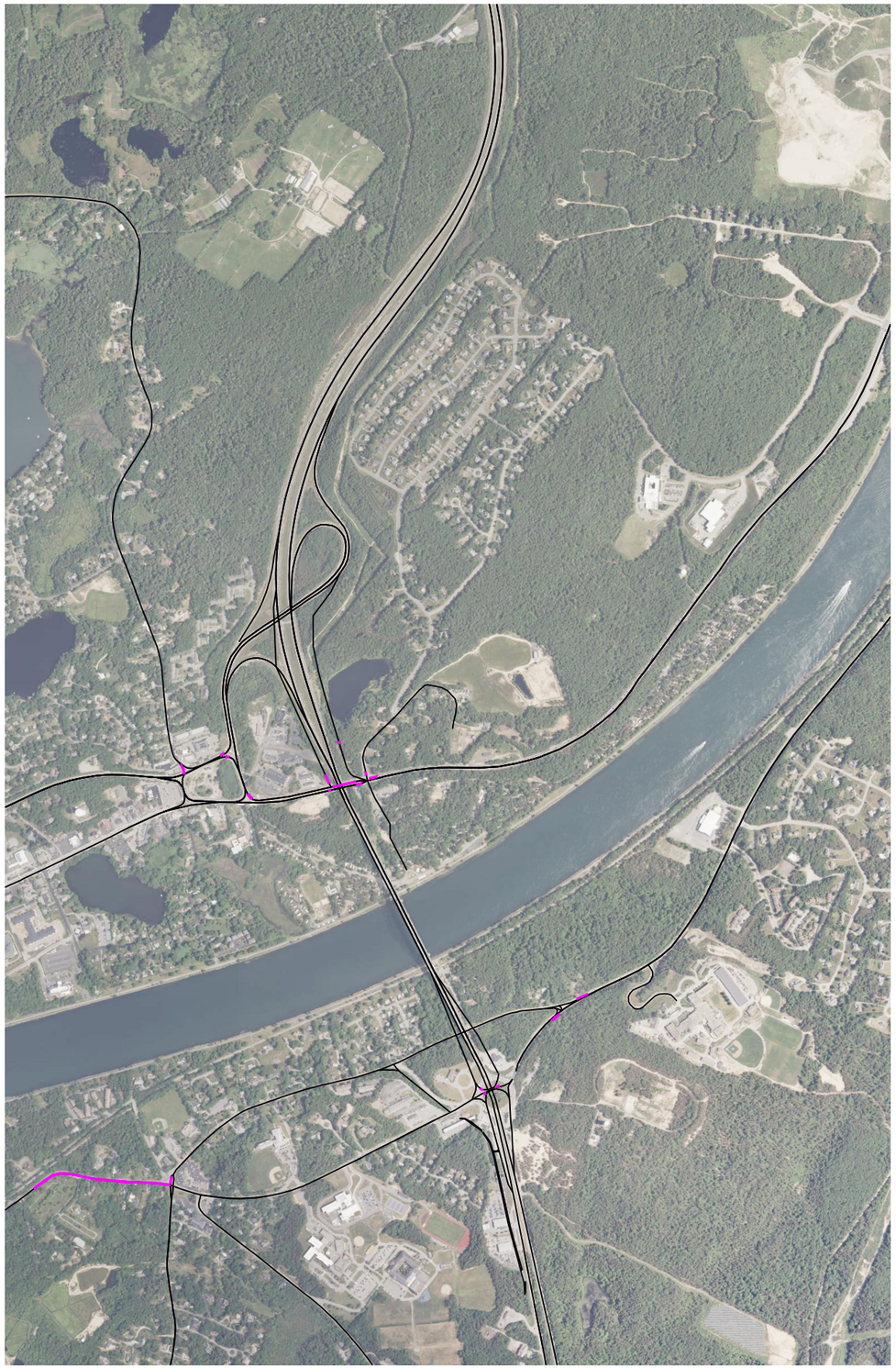
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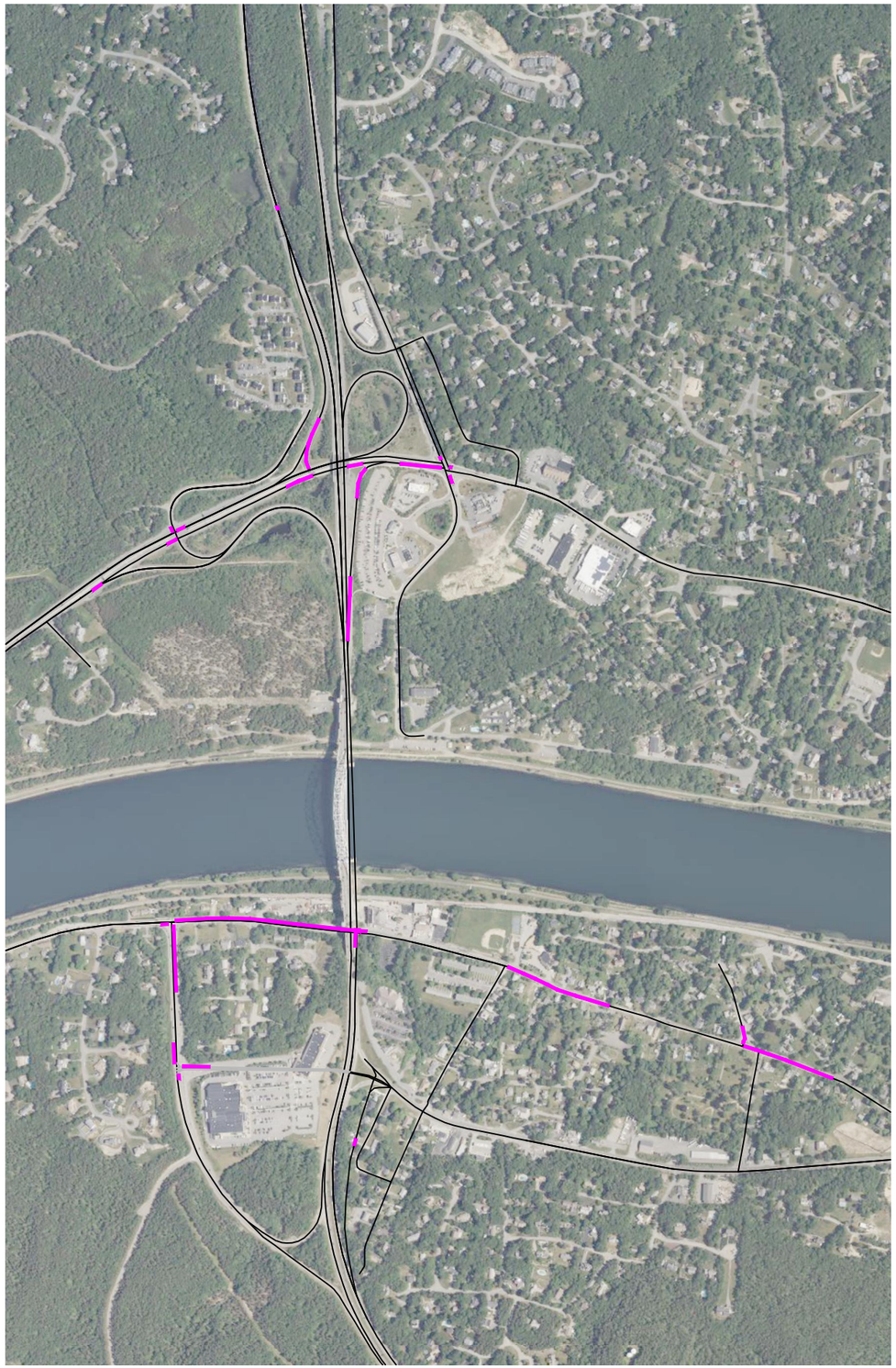
2050 Build Condition - AP 3

Note:

1. Figure only shows queues that are greater than or equal to 20 ft

Color	Description
	Avg Q's Fall PM





N

NAD 83

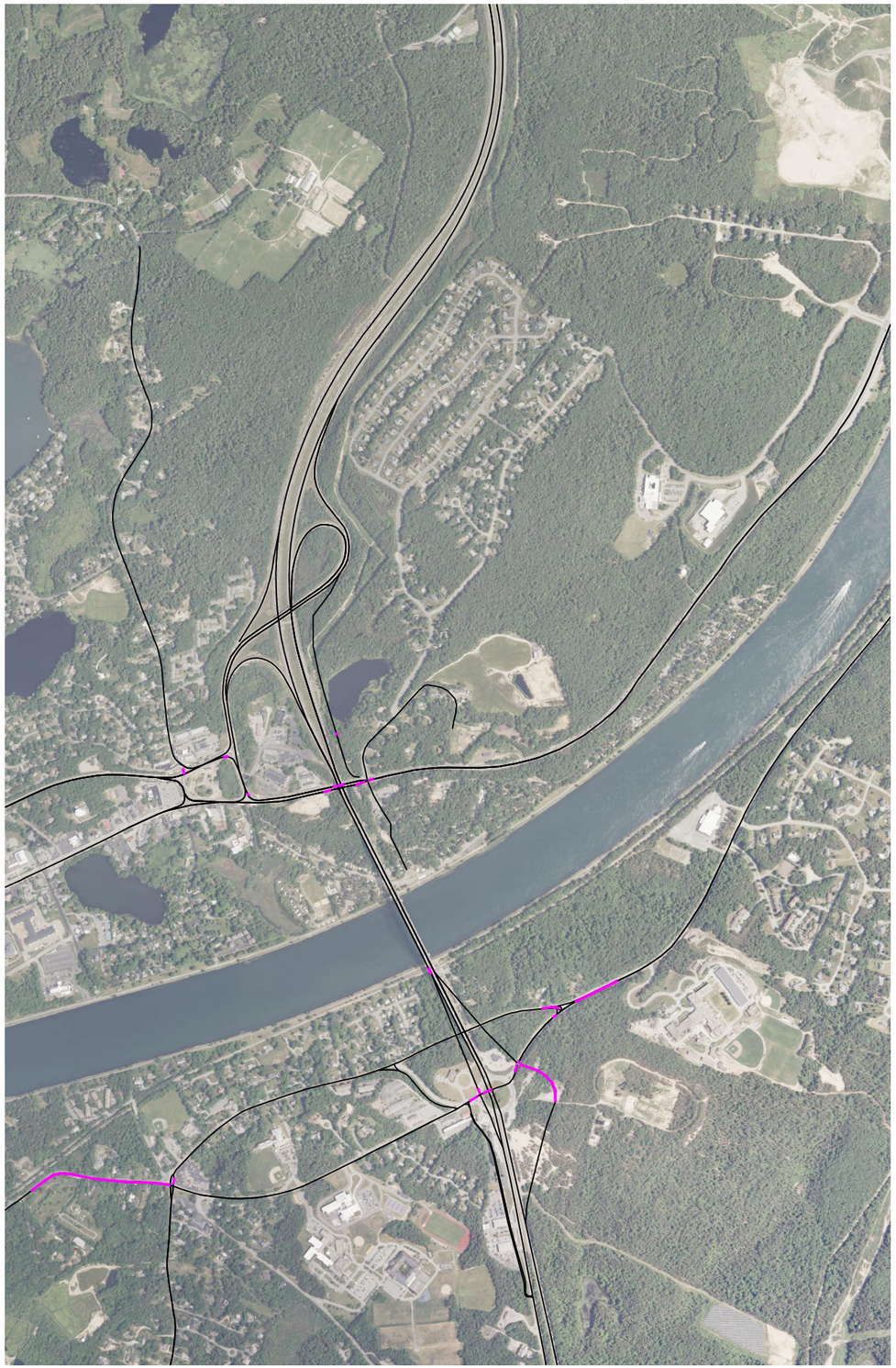
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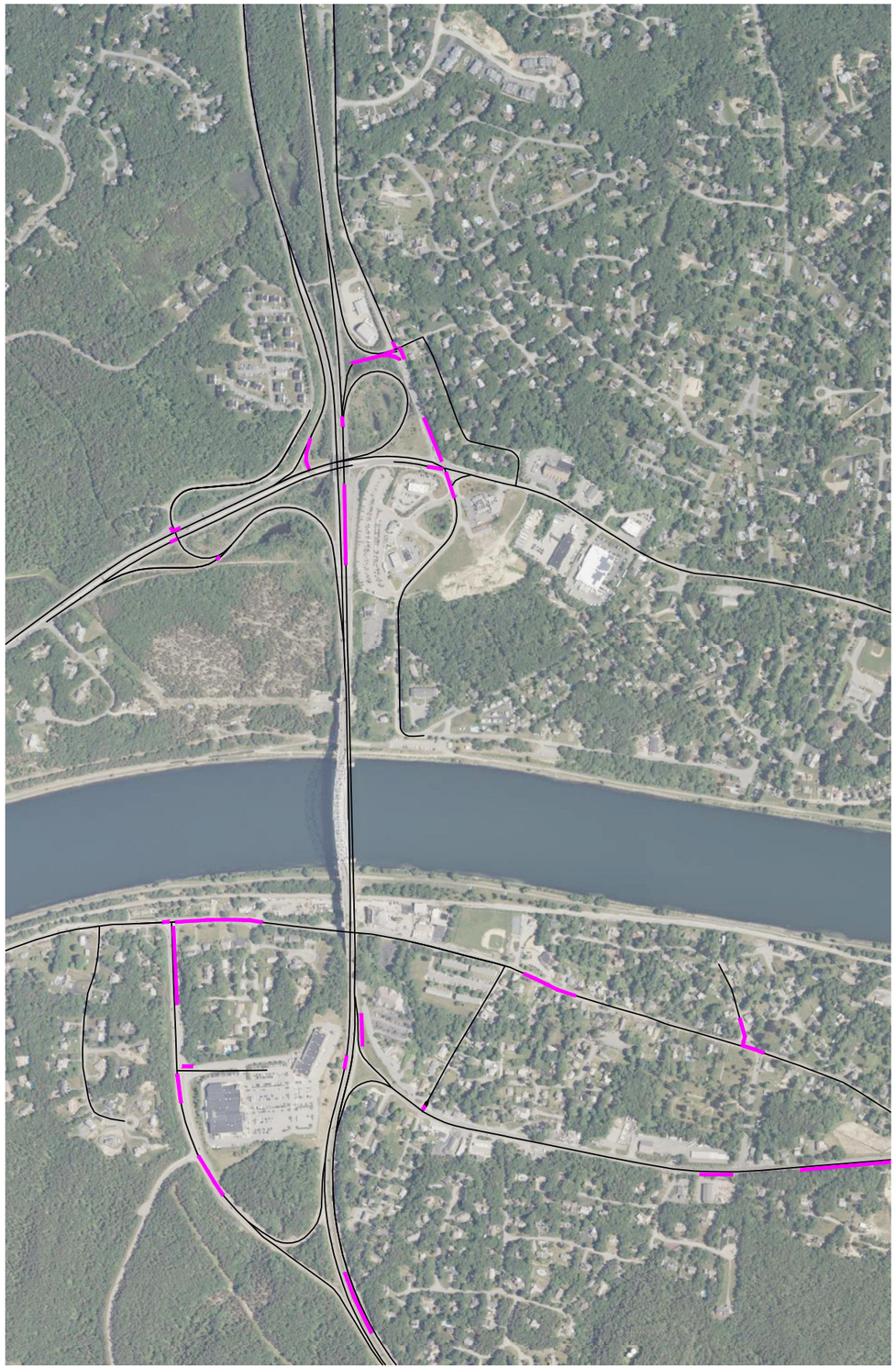
2050 Build Condition - AP 4

Note:

1. Figure only shows queues that are greater than or equal to 20 ft

Color	Description
	Avg Q's Fall PM





N

NAD 83

NOT TO SCALE

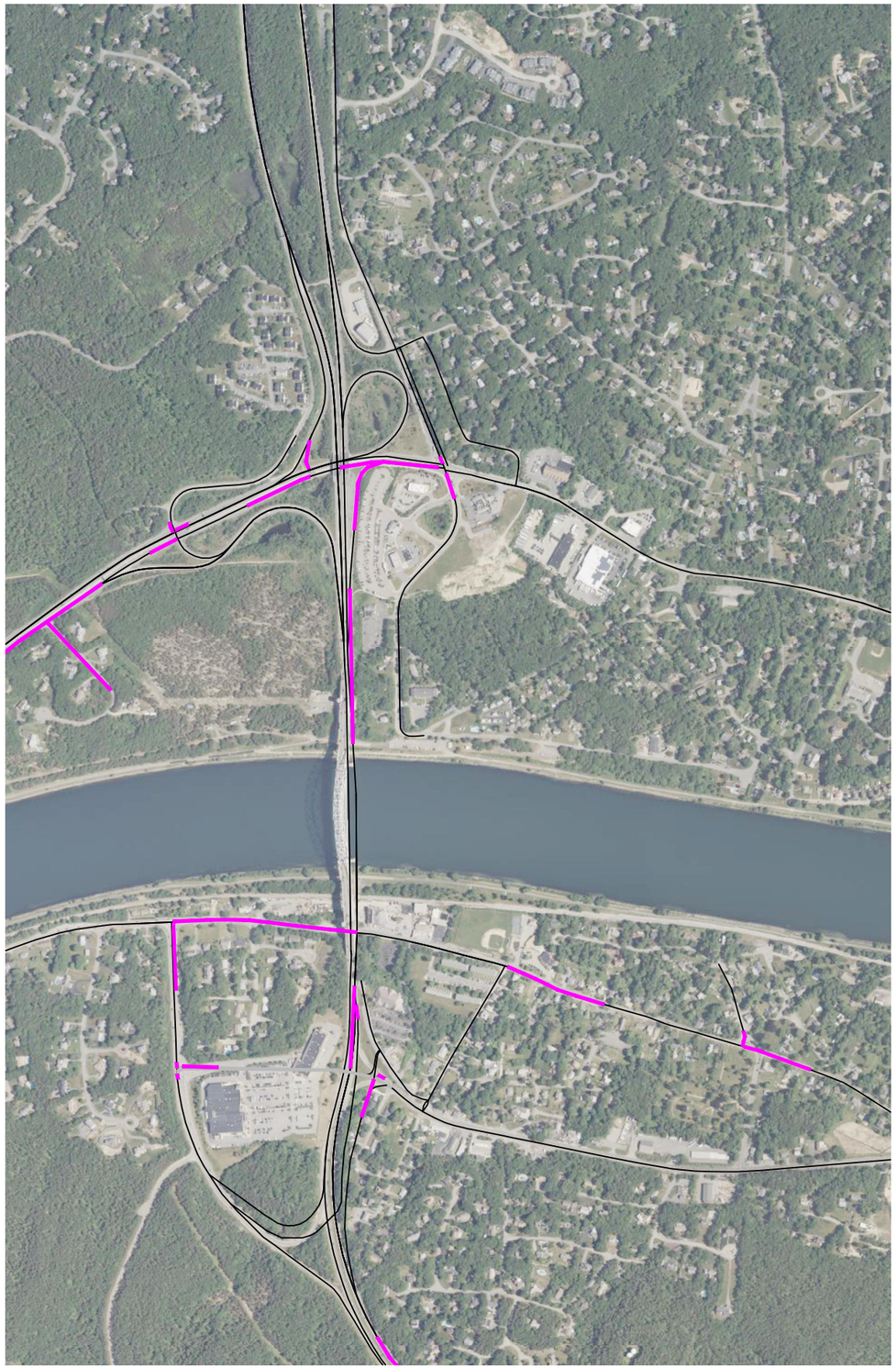
2050 Build Condition - AP 5

Note:

1. Figure only shows queues that are greater than or equal to 20 ft

Color	Description
	Avg Q's Fall PM





N

NAD 83

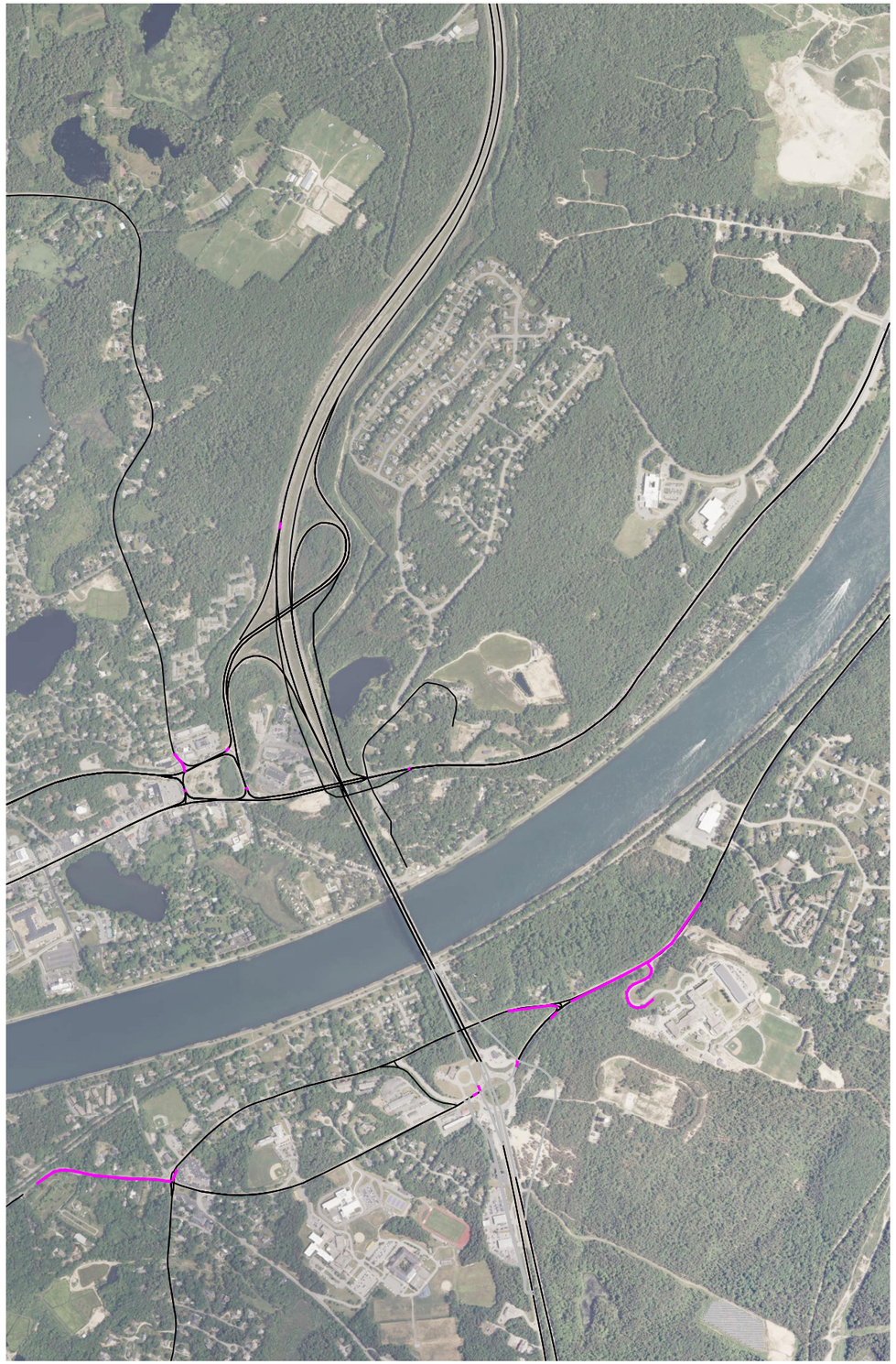
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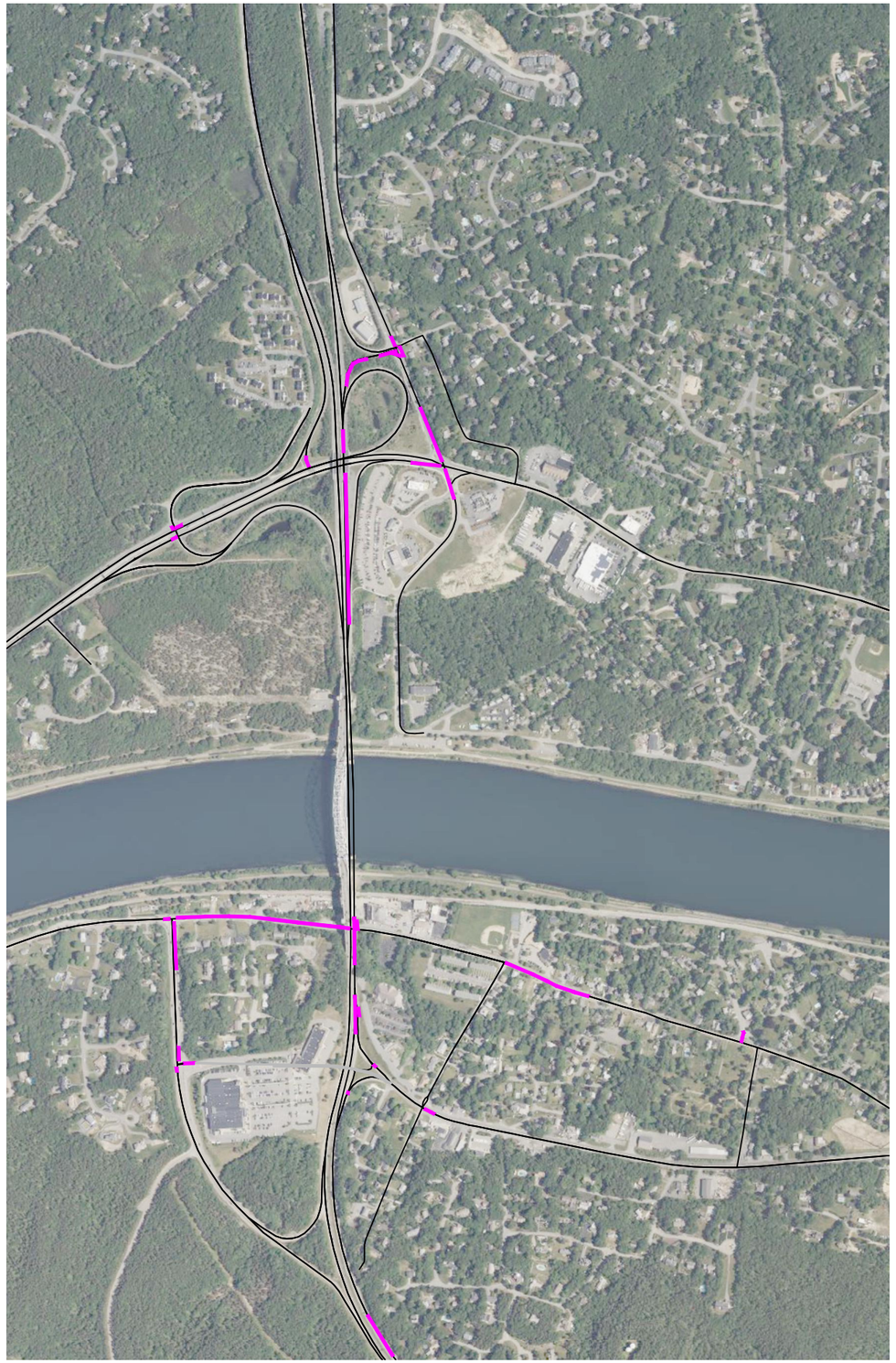
2050 Build Condition - AP 6

Note:

1. Figure only shows queues that are greater than or equal to 20 ft

Color	Description
	Avg Q's Fall PM





N

NAD 83

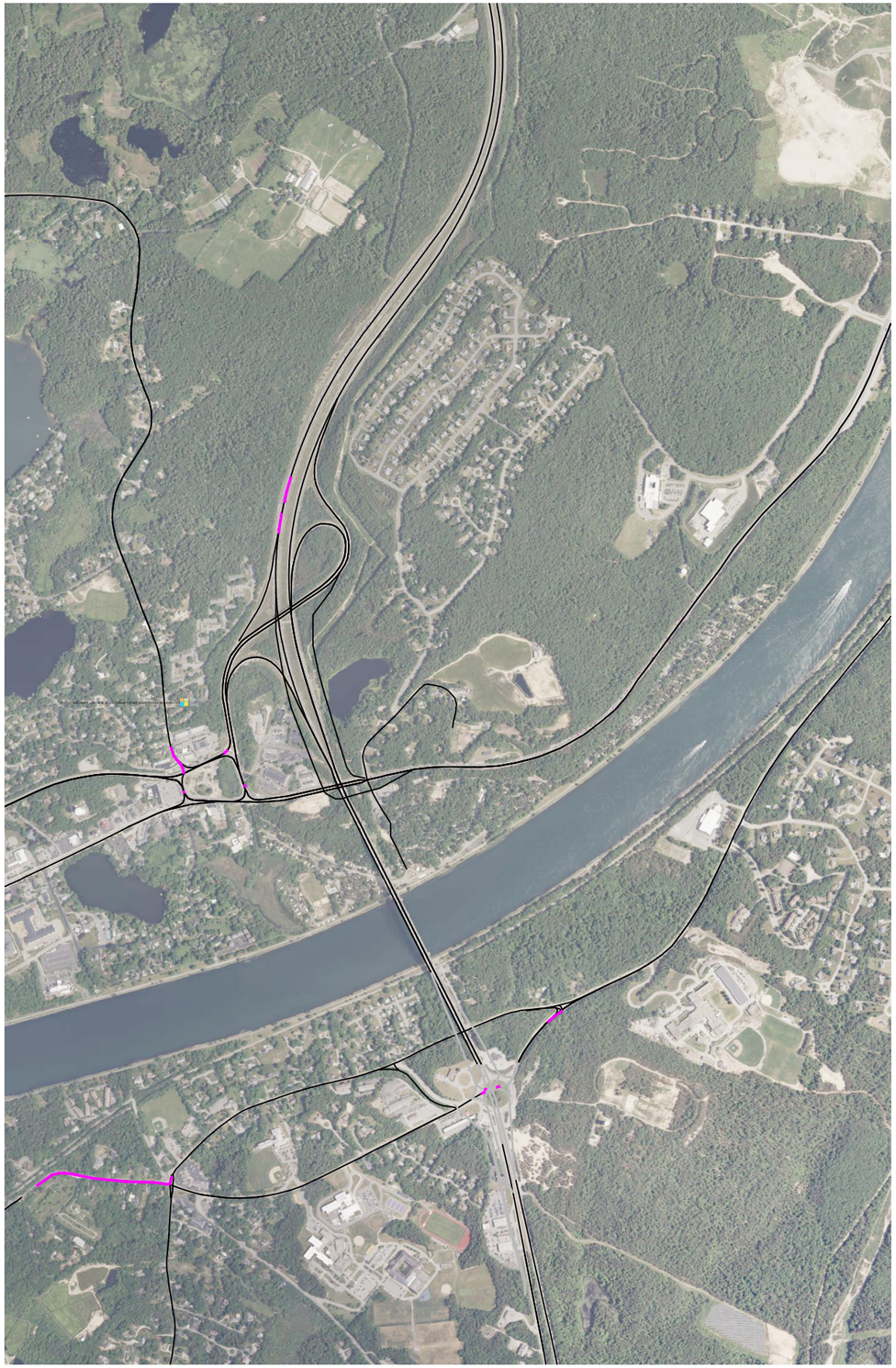
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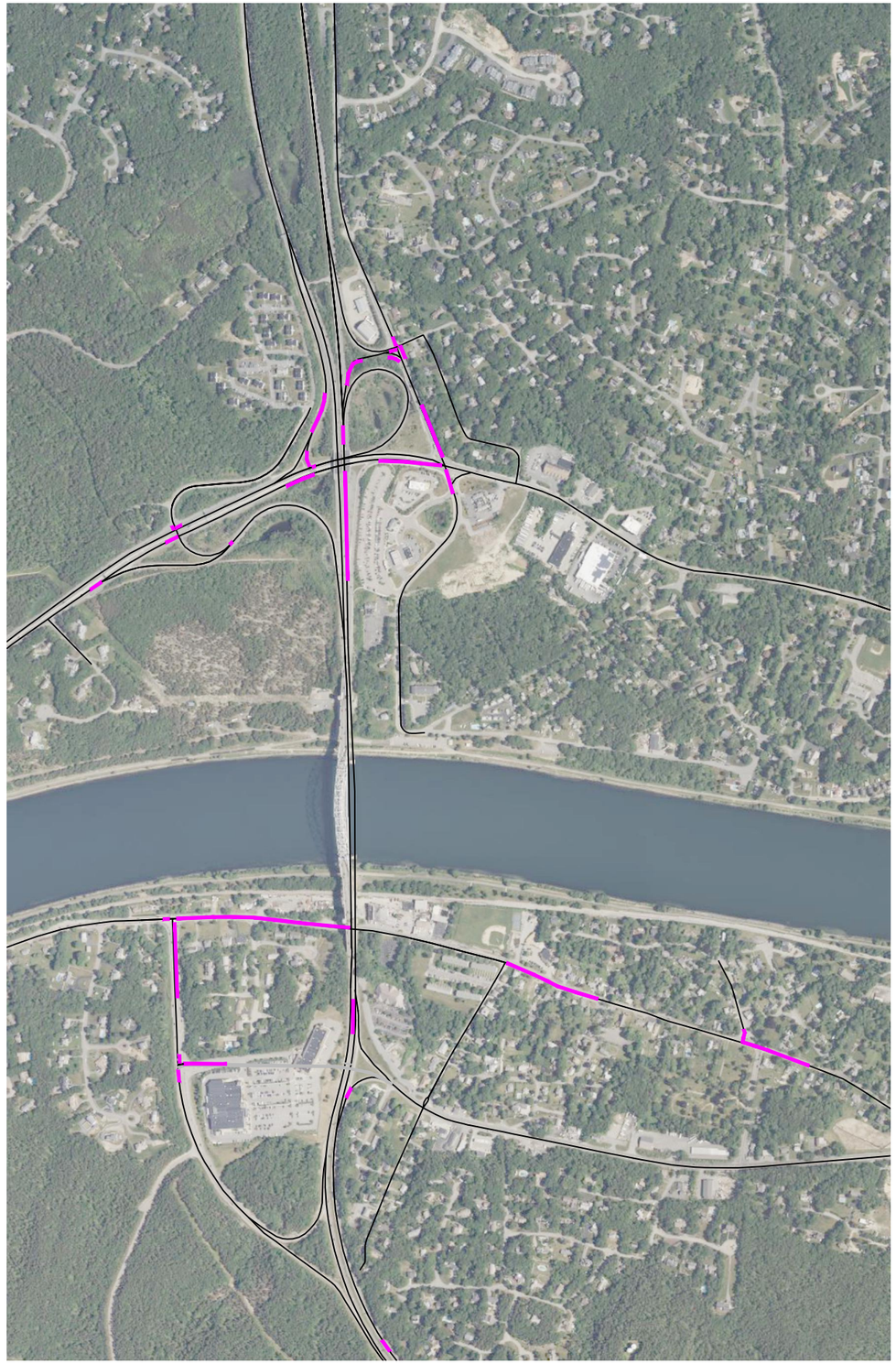
2050 Build Condition - AP 7

Note:

1. Figure only shows queues that are greater than or equal to 20 ft

Color	Description
	Avg Q's Fall PM





N

NAD 83

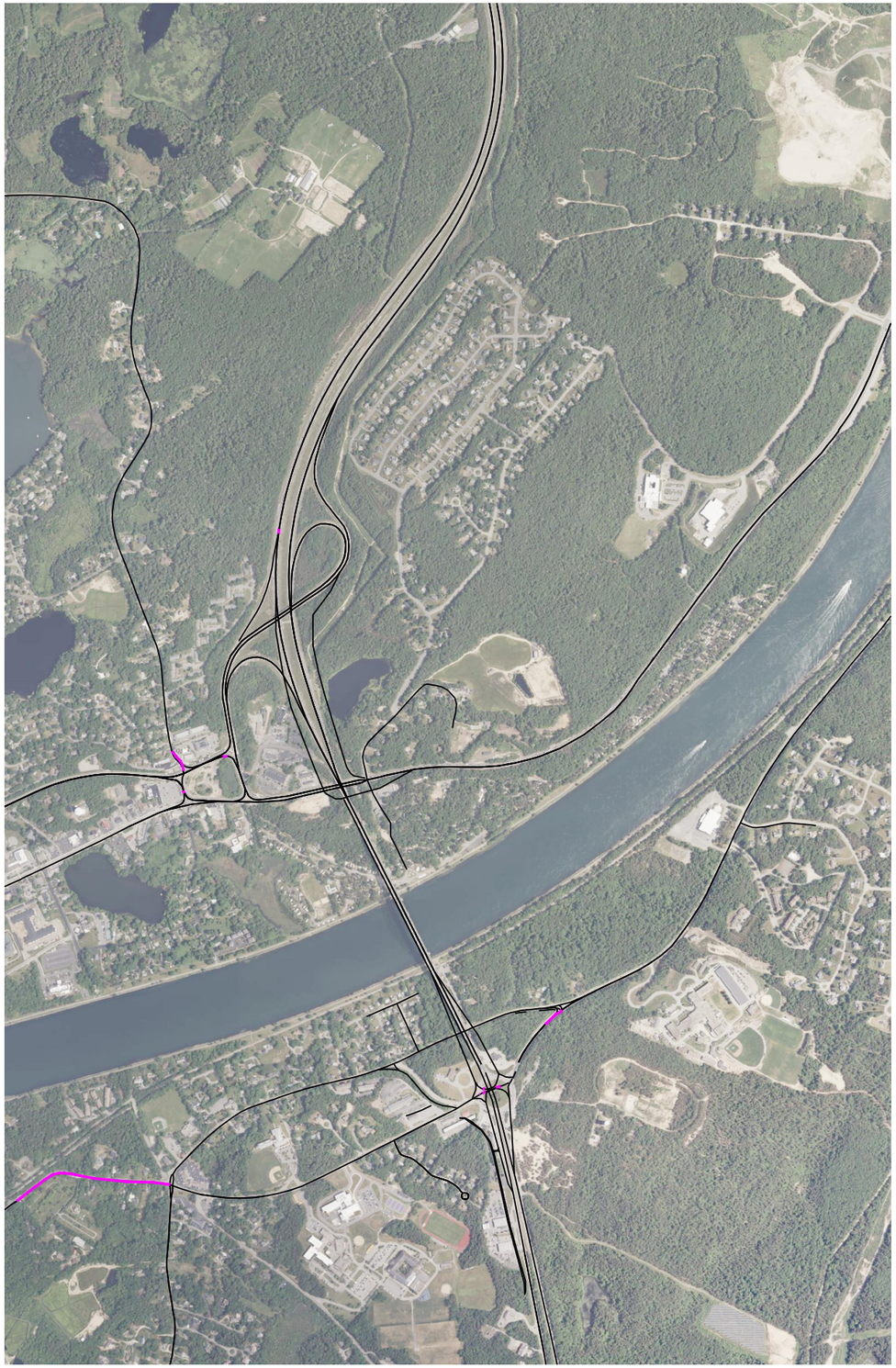
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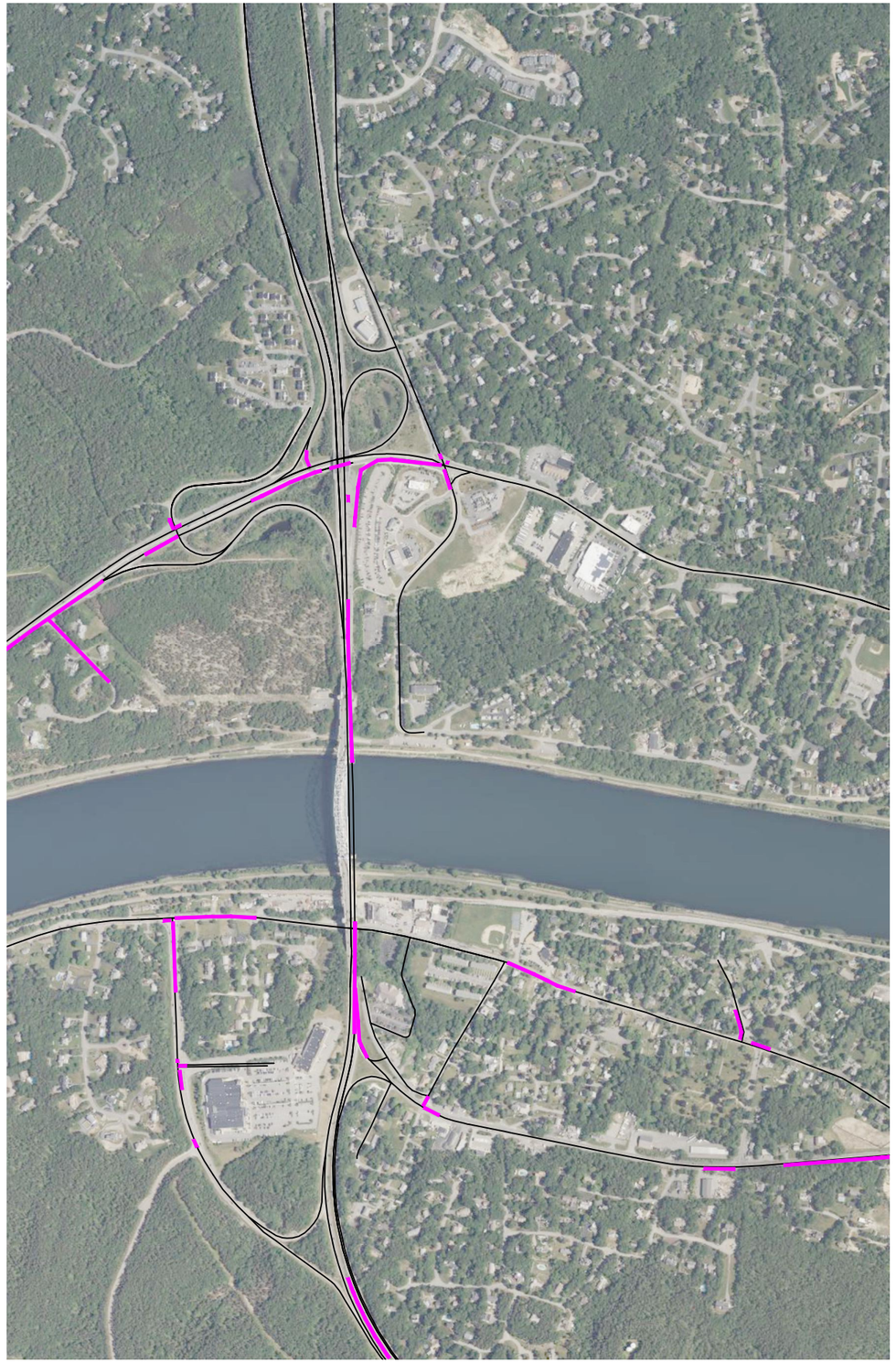
2050 Build Condition - AP 7.1

Note:

1. Figure only shows queues that are greater than or equal to 20 ft

Color	Description
	Avg Q's Fall PM





N

NAD 83

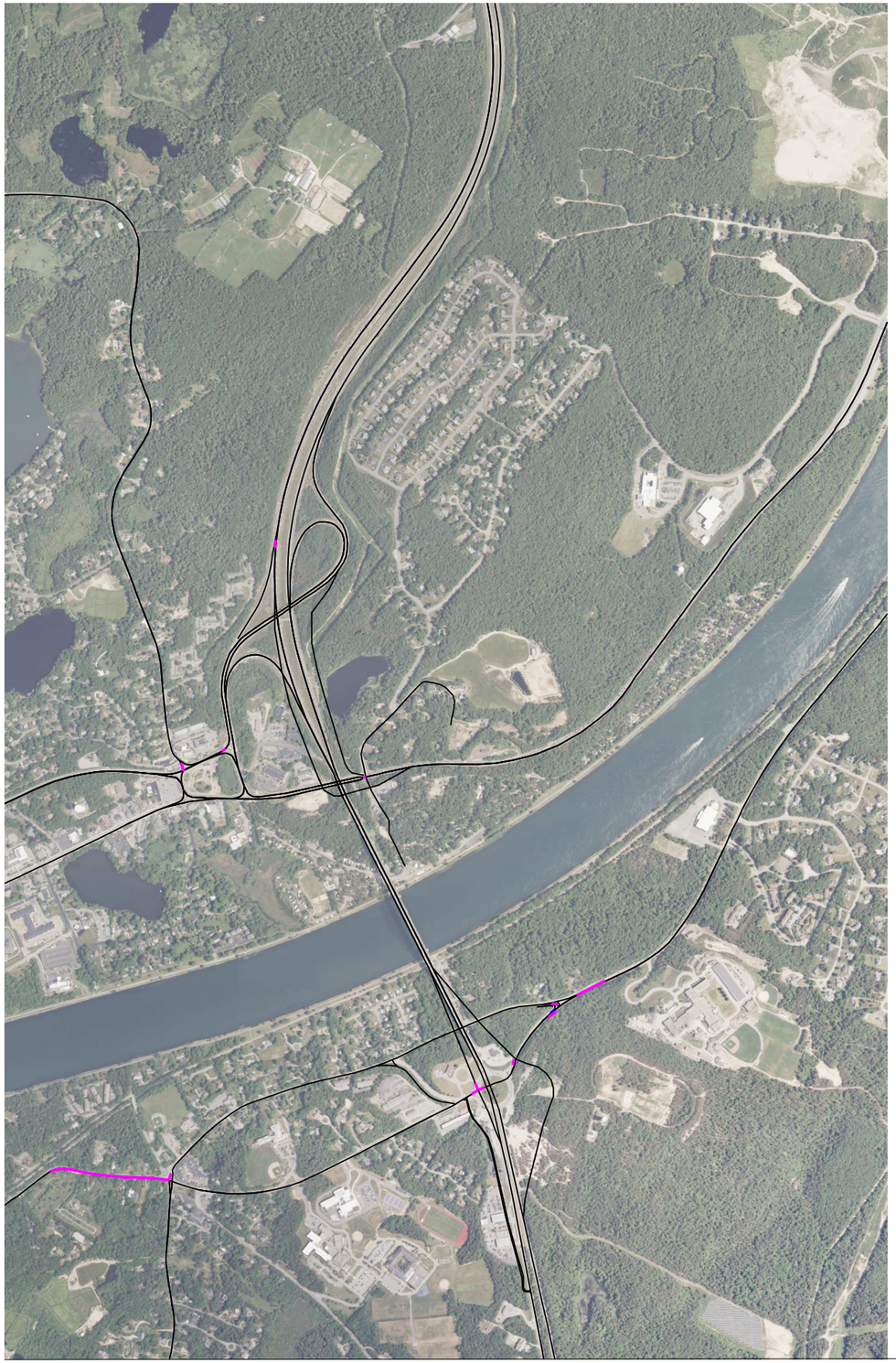
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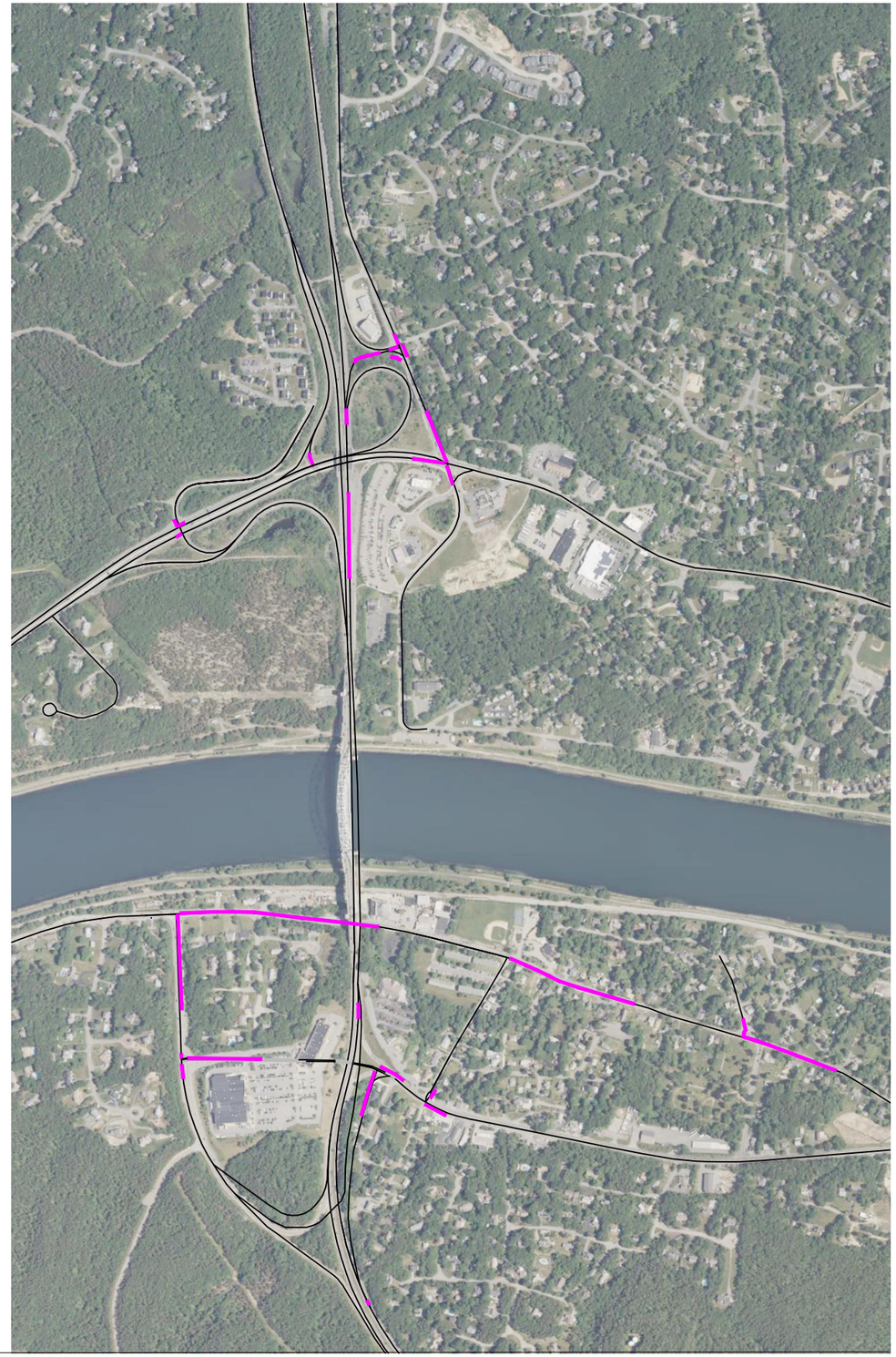
2050 Build Condition - AP 8.1

Note:

1. Figure only shows queues that are greater than or equal to 20 ft

Color	Description
	Avg Q's Fall PM





N

NAD 83

NOT TO SCALE

2050 Build Condition - AP 9

Note:

1. Figure only shows queues that are greater than or equal to 20 ft

Color	Description
	Avg Q's Fall PM

Figure 49 : Avg Queues in AP 9 for Fall

2.6 Preliminary Traffic Analysis for Build Analysis Pairings (May 7, 2024)

Appendix 3 CCBP Evaluation Criteria Performance Measures Scoring Matrix

3.1 Bourne Evaluation Criteria Performance Measures Scoring Matrix

Goals	Objectives	Performance Measures	Quantitative/ Qualitative	Alternatives Analysis Report Findings					Bourne - South Approach Options			
				Mainline Alignment	BN-13.1	*BN-13.1*	BN-14.4b	*BN 14.4b*	BS-2	*BS-2*	BS-2.2	*BS 2.2*
Phase 2b Assessment												
Maintain and Improve the Socioeconomic Fabric of the Surrounding Community	Minimize residential property impacts, including acquisitions and displacement	Number of easements, vacant parcel	Quantitative	0	0	◈◈◈	0	◈◈◈	0	◈◈◈	0	◈◈◈
		Number of easements, occupied parcels	Quantitative	1	1	◈◈	1	◈◈	0	◈◈◈	0	◈◈◈
		Number of full parcel acquisitions with displacements	Quantitative	0	1	◈◈	1	◈◈	0	◈◈◈	0	◈◈◈
		Number of full parcel acquisitions without displacements	Quantitative	0	0	◈◈◈	0	◈◈◈	0	◈◈◈	0	◈◈◈
	Minimize commercial property impacts, including acquisitions and displacement	Number of easements, vacant parcel	Quantitative	0	1	◈◈	1	◈◈	1	◈◈	1	◈◈
		Number of easements, occupied parcels	Quantitative	2	0	◈◈◈	0	◈◈◈	6	◈	6	◈
		Number of full parcel acquisitions with displacements	Quantitative	1	0	◈◈◈	0	◈◈◈	1	◈◈	1	◈◈
		Number of full parcel acquisitions without displacements	Quantitative	4	0	◈◈◈	0	◈◈◈	5	◈◈	5	◈◈
	Improve access to commercial properties	Assess modifications to commercial property access	Qualitative		All commercial business access is unchanged.	◈◈◈	All commercial business access is unchanged.	◈◈◈	Five properties change roadway access from Route 28 Mainline to Frontage Road. Access becomes bidirectional.	◈◈	Five properties change roadway access from Route 28 Mainline to Frontage Road. Access becomes bidirectional.	◈◈
	Improve neighborhood accessibility to community facilities & services	Improve and/or maintain accessibility to public and/or private community facilities & services	Qualitative	Not evaluated during mainline alignment analysis	Maintains access to existing facilities by adding sidewalks on both sides of Scenic Highway and shared use path from canal crossing to Belmont Circle.	◈◈	Improves access to existing facilities by adding a shared use path along Scenic Highway and shared use path from canal crossing to Belmont Circle.	◈◈◈	Improves access to existing facilities by adding a shared use path along Trowbridge and shared use path from canal crossing to Canal Service Road and transit facilities.	◈◈◈	Improves access to existing facilities by adding a shared use path along Trowbridge and shared use path from canal crossing to Canal Service Road and transit facilities.	◈◈◈
		Assess neighborhood access to schools, hospitals, and emergency services (police & fire)	Qualitative	Not evaluated during mainline alignment analysis	Provides some improved connections to existing community facilities & services within Bourne Bridge project area.	◈◈	Provides some improved connections to existing community facilities & services within Bourne Bridge project area.	◈◈◈	Provide new Shared-Use Path connections to vocational and public high schools. Driveway modifications made to Police Barracks Driveway.	◈◈◈	Provide new Shared-Use Path connections to vocational and public high schools. Driveway modifications made to Police Barracks Driveway.	◈◈◈
	Improve neighborhood cohesion	Assess neighborhood visibility, walkability; assess reduction and/or elimination of regional (through) traffic	Qualitative	Not evaluated during mainline alignment analysis	Mainline Route 28/25 traffic is partially removed from local roadway network. Added pedestrian and bicycle facilities.	◈◈	Mainline Route 28/25 traffic is fully removed from local roadway network. Added pedestrian and bicycle facilities.	◈◈◈	Mainline Route 28 traffic is removed from local roadway network. Added pedestrian and bicycle facilities.	◈◈◈	Mainline Route 28 traffic is removed from local roadway network. Added pedestrian and bicycle facilities.	◈◈◈
	Avoid disproportionate adverse impact to Environmental Justice (EJ) populations	Assess of adverse impacts (with respect to all measures) and potential to disproportionately affect EJ populations	Qualitative	No direct impacts to EJ populations	Less EJ communities within Bourne Bridge project area.	◈◈◈	Less EJ communities within Bourne Bridge project area.	◈◈◈	Less EJ communities within Bourne Bridge project area.	◈◈◈	Less EJ communities within Bourne Bridge project area.	◈◈◈

Goals	Objectives	Performance Measures	Quantitative/ Qualitative	Alternatives Analysis Report Findings					Bourne - South Approach Options			
				Mainline Alignment	BN-13.1	*BN-13.1*	BN-14.4b	*BN 14.4b*	BS-2	*BS-2*	BS-2.2	*BS 2.2*
	Minimize construction period effects upon the traveling public	Assess number, complexity, and duration of detours/work-arounds during construction	Qualitative	Selected mainline alignment will have least impact to public during construction with shortest construction period.	All existing pedestrian and bicycle connections maintained or improved thorughout construction.	◈◈	All existing pedestrian and bicycle connections maintained or improved thorughout construction.	◈◈	All existing pedestrian and bicycle connections maintained or improved thorughout construction.	◈◈	All existing pedestrian and bicycle connections maintained or improved thorughout construction.	◈◈
	Avoid and/or minimize effects to parks, open space, and recreational facilities	Number (in acreage) of impacts and duration of impacts to parks, open space, and recreational resources.	Quantitative	333,000 sf permanent impact USACE leased; 744,000 sf temporary USACE leased; 118,000 sf temporary BRA owned	Construction to occur over Bourne Scenic Park campground. 14.2246 AC of land impacted during construction.	◈◈	Construction to occur over Bourne Scenic Park campground. 14.8400 AC of land impacted during construction.	◈	Construction to occur over Bourne Recreation Area - 4.11 acre of land.	◈◈◈	Construction to occur over Bourne Recreation Area - 4.11 acre of land.	◈◈◈
Preserve and Protect Natural Resources	Minimize effects to Areas of Critical Environmental Concern (ACEC) and wildlife habitats	Quantify direct impact to ACEC	Quantitative	No ACEC in Bourne North or South.	No impacts	◈◈◈	No Impacts	◈◈◈	No impacts	◈◈◈	No impacts	◈◈◈
		Quantify direct impact to wildlife, defined as NHESP priority and estimated (subset of priority) habitat.		No endangered species impacts	0 (no defined NHESP habitat)	◈◈◈	0 (no defined NHESP habitat)	◈◈◈	349,213 sf (8.02 ac)	◈◈	384,443 sf (8.82 ac)	◈◈
	Maintain floodplain functions	Quantify change between existing percent vegetative cover in floodplain and proposed percent vegetative cover in floodplain; for entire quadrant). Change of less than 10% =less impact; change of less than 20% = some impact	Quantitative	Not evaluated during mainline alignment analysis; Some impact to floodplain anticipated for the construction of the main span and piers.	Existing veg cover =47.2%. 15.2 veg acres removed. Remaining veg cover = 28.0%. Change = - 19.2%	◈◈	Existing veg cover =47.2%. 15.3 veg acres removed. Remaining veg cover = 27.8%. Change = - 19.4%	◈◈	Existing veg cover =47.3%. 2.5 veg acres removed. Remaining veg cover = 39.8%. Change = - 7.6%	◈◈◈	Existing veg cover =47.3%. 2.5 veg acres removed. Remaining veg cover = 39.8%. Change = - 7.6%	◈◈◈
	Maintain wetland and surface water buffers	Quantify direct impact to protected wetlands and water resources and/or buffer zones.	Quantitative	No direct impacts to MA WPA wetlands or ecological resources; Ramp connection is within the 100-foot buffer zone of Nightingale Pond.	Less direct impact to wetlands. Work within wetland buffers = 176,981 SF (4.06 ac)	◈◈	Less direct impact to wetlands. Work within wetland buffers = 186,427 SF (4.28 ac)	◈◈	Less direct impact to wetlands. Work within wetland buffers = 26,500 SF (0.61 ac)	◈◈◈	Less direct impact to wetlands. Work within wetland buffers = 26,500 SF (0.61 ac)	◈◈◈
	Minimize air quality effects	Total vehicle miles traveled, compared to 2050 No Build condition.	Quantitative	Not evaluated during mainline alignment analysis	221,747	◈◈◈	221,612	◈◈◈	221,612	◈◈◈	219,657	◈◈◈
		Total vehicle hours traveled, compared to 2050 No Build condition.	Quantitative	Not evaluated during mainline alignment analysis	6,174	◈◈◈	6,091	◈◈◈	6,091	◈◈◈	6,165	◈◈◈
	Minimize land alteration and reduction in tree cover (urban heat island effect)	Amount of reduction in tree cover	Quantitative	Not evaluated during mainline alignment analysis	14.92 ac	◈◈◈	16.86 ac	◈◈◈	39.67 ac	◈◈	38.99 ac	◈◈
		Assess area of roadways impacted by storm surge	Qualtitative	Not evaluated during mainline alignment analysis	Storm surge impact is minimal to local roadways. Impacts are isolated to portions of the Route 6 (Scenic Highway) adjacent to Belmont Circle. No impacts to the proposed mainline and/or ramp locations.	◈◈◈	Storm surge impact is minimal to local roadways. Impacts are isolated to portions of the Route 6 (Scenic Highway) adjacent to Belmont Circle. No impacts to the proposed mainline and/or ramp locations.	◈◈◈	Storm surge impact is minimal to local roadways	◈◈◈	Storm surge impact is minimal to local roadways	◈◈◈

Goals	Objectives	Performance Measures	Quantitative/ Qualitative	Alternatives Analysis Report Findings					Bourne - South Approach Options			
				Mainline Alignment	BN-13.1	*BN-13.1*	BN-14.4b	*BN 14.4b*	BS-2	*BS-2*	BS-2.2	*BS 2.2*
Enhance the Resiliency and Sustainability of the Built Environment	Minimize vulnerability to flooding	Assess area of roadways impacted by flucations in relative sea level	Qualitative	Not evaluated during mainline alignment analysis	Impact due to fluctuations in relative sea level impact is minimal to local roadways. Impacts are isolated to portions of the Route 6 (Scenic Highway) adjacent to Belmont Circle. No impacts to the proposed mainline and/or ramp locations.	◈◈◈	Impact due to fluctuations in relative sea level impact is minimal to local roadways. Impacts are isolated to portions of the Route 6 (Scenic Highway) adjacent to Belmont Circle. No impacts to the proposed mainline and/or ramp locations.	◈◈◈	Impact to local roadways due to fluctuations in relatve sea level is minimal.	◈◈◈	Impact to local roadways due to fluctuations in relatve sea level is minimal.	◈◈◈
	Effectively Manage Stormwater - Assess stormwater runoff that infiltrates, evapotranspirates, is reused, and/or is treated while not exceeding rate or quantity runoff targets	Impervious Area Increase (%)	Quantitative	Not evaluated during mainline alignment analysis	55%	◈	59%	◈	69%	◈	77%	◈
		Treated Impervious Area (%)			76%	◈◈◈	78%	◈◈◈	81%	◈◈◈	81%	◈◈◈
		Peak 2-Year Discharge Rate Delta (%)			4%	◈◈	-14%	◈◈◈	-69%	◈◈◈	-72%	◈◈◈
		Peak 10-Year Discharge Rate Delta (%)			-14%	◈◈◈	-24%	◈◈◈	-70%	◈◈◈	-73%	◈◈◈
		Peak 100-Year Discharge Rate Delta (%)			-14%	◈◈◈	-22%	◈◈◈	-71%	◈◈◈	-75%	◈◈◈
		Proposed Infiltration Volume (% of Required Volu			159%	◈◈◈	177%	◈◈◈	216%	◈◈◈	223%	◈◈◈
		Total Phosphorus Removal (%)			76%	◈◈◈	78%	◈◈◈	81%	◈◈◈	81%	◈◈◈
		Total Suspended Solids Removal (%)			82%	◈◈	84%	◈◈	86%	◈◈	86%	◈◈
Maximize Constructability	Minimize the construction duration	Construction duration compared to other alternatives	Quantitative	Selected mainline alignment will have least impact to public during construction with shortest construction period.	Duration equivalent between alternates.	◈◈	Duration equivalent between alternates.	◈◈	Duration equivalent between alternates.	◈◈	Duration equivalent between alternates.	◈◈
	Maintain existing connections during construction	Assess ability to maintain existing travel connections	Qualitative	Existing ramp connections can be maintained during construction with added benefits from offline construction that improve overall schedule. Minimial impacts to existing traffic pattersn to maintain existing flow of traffic.	Able to maintain all connections during construction.	◈◈◈	Able to maintain all connections during construction.	◈◈◈	Able to maintain all connections during construction.	◈◈◈	Able to maintain all connections during construction.	◈◈◈

Goals	Objectives	Performance Measures	Quantitative/ Qualitative	Alternatives Analysis Report Findings					Bourne - South Approach Options			
				Mainline Alignment	BN-13.1	*BN-13.1*	BN-14.4b	*BN 14.4b*	BS-2	*BS-2*	BS-2.2	*BS 2.2*
Facilitate Emergency Response	Improve emergency evacuation capabilities off Cape Cod	Assess feasibility/difficulty of responding to emergency evacuation off Cape Cod	Qualitative	Not evaluated during mainline alignment analysis	Opportunity for more improvment of emergency evacuation capabilities.	◈◈	Opportunity for more improvment of emergency evacuation capabilities.Due to the grade separated direct connect ramps, emergency evacuation is significantly improved.	◈◈◈	Opportunity for more improvment of emergency evacuation capabilities.	◈◈◈	Opportunity for more improvment of emergency evacuation capabilities.	◈◈◈
	Improve emergency response	Consider improvements to overall regional mobility with special focus on emergency response centers/locations	Qualitative	Not evaluated during mainline alignment analysis	Regional traffic movements separated from local traffic for through movements along Route 28.	◈◈◈	Regional traffic movements separated from local traffic for through movements along Route 28.	◈◈◈	Regional traffic movements separated from local traffic for through movements along Route 28.	◈◈◈	Regional traffic movements separated from local traffic for through movements along Route 28.	◈◈◈
Costs	Maximize construction cost effectiveness	Compare cost estimates of options	Quantitative	Not evaluated during mainline alignment analysis	$30M less than 14.4b	◈◈◈	$30M higher than 13.1	◈◈	Costs equivalent between alternatives	◈◈◈	Costs equivalent between alternatives	◈◈◈

Program Need	Evaluation Criteria	Performance Measure	Quantitative/ Qualitative	Bourne - South Approach Options			
				BN 13.1	BN 14.4b	BS-2	BS-2.2
Phase 2a Assessment							
Operations	Assess impact on regional traffic operations	Average Delay per Vehicle in minutes (network wide using the alternative pairings)	Quantitative	3.3	3.2	3.2	3.3
Phase 2b Assessment							
Operations	Reduce congestion on mainline and ramps	Number of passenger cars per mile per lane for mainline highways, compared to 2050 No Build condition	Quantitative	11.55	11.33	11.33	11.58
		Number of passenger cars per mile per lane for ramps, compared to 2050 No Build condition	Quantitative	26.55	27.94	12.34	9.61
	Reduce regional travel times	Travel times from predetermined start (Northern/southern limit of the mainline) to the mid-point of the bridge, compared to 2050 No Build condition. (vehicle-hours traveled)	Quantitative	62.75	62.41	62.41	63.28
	Reduce local travel times	Travel times from predetermined start and end points (east-west) on local roads, compared to 2050 No Build condition. (vehicle-hours traveled)	Quantitative	103.89	100.36	90.01	103.11
	Improve cross-canal mobility	Travel times from predetermined location to mid-point of bridge on local roads, compared to 2050 No Build condition. (vehicle-hours traveled)	Quantitative	112.14	105.29	37.38	48.41
	Minimize queue spillback onto the highway	Assessment if queues spillback from the local ramp terminals onto the highway	Qualitative	Less	Less	Less	Less
	Separate local and regional traffic	Assessment of approach to separating local and regional traffic.	Qualitative	Removes SB traffic to Scenic Highway EB and WB traffic to Route 25 NB from Belmont Circle.	Removes SB traffic to Scenic Highway EB and WB traffic to Route 25 NB from Belmont Circle.	Grade separates Route 28 NB and SB through traffic.	Grade separates Route 28 NB and SB through traffic.
Geometrics/Safety	Minimize weaving movements	Number of weaving movements on mainline highways.	Quantitative	2	2	2	2
	Minimize wrong-way driving risk	Assess wrong-way driving risks based on geometrics of the intersections at the ramp terminals	Qualitative	Introduces new ramp without flexibility to geometrically restrict access at SB Off-Ramp to Scenic Hwy. Risk can be reduced with typical "Wrong-Way" driving mitigation techniques. Ranging from Signage" to WWDS.	The proposed off-ramp is a direct connect to Scenic Hwy EB which geometrically restricts wrong-way access.	Allows for design flexibility to geometrically restricts wrong-way ramp access with options to provide roundabouts at the ramp intersections.	The SPUI is a less common type of interchange control and the geometry results in an inherent risk of wrong way driving with off-ramps entering at an angle similar to a standard on-ramp.
	Assess flexibility to achieve speed differential for exit ramps onto local roadways	Assessment of geometry to allow for flexibility to achieve speed differential for exit ramps onto local roadways.	Qualitative	Geometry allows flexibility to maintain target speed. The new intersection at and the SB Off-Ramp is close to the intersection of Scenic Hwy and Nightingale Road, as well as Belmont Circle. The closely spaced intersections on Scenic Hwy allow for opportunities to control speeds.	Geometry allows flexibility to maintain target speed. Speed differential calculations between Scenic Highway EB and SB Flyover Ramp Add-Lane condtion creates less than a 4mph speed differential.	Geometry allows for flexibility to achieve target speed with roundabouts or traffic signal control.	Geometry allows flexibility to maintain target speed with traffic signal control.
	Minimize complexity of decision points	Assessment of complexity of ramp decision points, including number and difficulty	Qualitative	Route 25 SB off-ramp splits between Belmont Circle and Scenic Hwy. Gore at split is approx. 1300ft from exit gore.	Route 25 SB off-ramp splits between Belmont Circle and Scenic Hwy. Gore at split is approx. 1300ft from exit gore.	Grade separation of Route 28 simplifies the decisions points for the local traffic. Less complex decisions for typical diamond interchange.	Grade separation of Route 28 simplifies the decisions points for the local traffic. Less complex decisions for SPUI.
	Evaluate spacing between entrance and exit ramps	Evaluate entrance and exit ramp spacing relative to traffic volume	Qualitative	SB Off Ramp gore to SB On Ramp gore = 1650-ft NB Off Ramp gore to NB On Ramp gore = 1360-ft	SB Off Ramp gore to SB On Ramp gore = 1650-ft NB Off Ramp gore to NB On Ramp gore = 1360-ft	SB Off Ramp gore to SB On Ramp gore = 2230-ft NB Off Ramp gore to NB On Ramp gore = 1855-ft	SB Off Ramp gore to SB On Ramp gore = 2195-ft NB Off Ramp gore to NB On Ramp gore = 1855-ft
	Minimize acceleration/deceleration speed variances	Number of acceleration lane speed variances with the mainline greater than 25 MPH.	Quantitative	0 (all ramps design speed = 30 MPH and ML = 55 MPH, ramp speed is within the recommended design speed for mainline speed of 55 MPH)	0 (all ramps design speed = 30 MPH and ML = 55 MPH, ramp speed is within the recommended design speed for mainline speed of 55 MPH)	0 (all ramps design speed = 30 MPH and ML = 55 MPH, ramp speed is within the recommended design speed for mainline speed of 55 MPH)	0 (all ramps design speed = 30 MPH and ML = 55 MPH, ramp speed is within the recommended design speed for mainline speed of 55 MPH)
		Number of deceleration lane speed variances with the mainline greater than 25 MPH.	Quantitative	0 (all ramps design speed = 30 MPH and ML = 55 MPH, ramp speed is within the recommended design speed for mainline speed of 55 MPH)	0 (all ramps design speed = 30 MPH and ML = 55 MPH, ramp speed is within the recommended design speed for mainline speed of 55 MPH)	0 (all ramps design speed = 30 MPH and ML = 55 MPH, ramp speed is within the recommended design speed for mainline speed of 55 MPH)	0 (all ramps design speed = 30 MPH and ML = 55 MPH, ramp speed is within the recommended design speed for mainline speed of 55 MPH)
	Assess design relative to driver navigation and expectation	Assessment of design related to driver navigation and expectation	Qualitative	Provides direct a connection from Route 25/28 SB to Scenic Hwy and from Scenic Hwy WB to Route 25/28 NB. SB off ramp and NB on ramp are both at the same location off of Scenic Hwy.	Provides direct a connection from Route 25/28 SB to Scenic Hwy EB and from Scenic Hwy WB to Route 25/28 NB. SB off ramp and NB on ramp are both at the same location off of Scenic Hwy.	Provides direct access between mainline and local roadways consistent with driver expectation.	Provides direct access between mainline and local roadways consistent with driver expectation.
	Improve pedestrian/bicycle access to local roads	Evaluate distance of Shared Use Path from bridge mid-point to first local road connection, travel time from bridge mid-point to first local road connection and comfort from bridge mid-point to first local road connection.	Quantitative	Distance is approximatley 4200-ft, time and comfort provide some improvements. Several at-grade crossings negatively impact comfort and travel time.	Distance is approximatley 4200-ft, travel time and comfort provide more improvements.	Distance is approximatley 2225-ft, travel time and comfort provide more improvements.	Distance is approximatley 2175-ft, travel time and comfort provide more improvements.
	Improve pedestrian/bicycle access on local roads	Evaluate access and comfort of Shared Use Path's adjacent to local roadways.	Quantitative	Design provides 6' sidewalks along Route 6 WB and EB to connect to pedestrian and bicycle facilities at Belmont Circle.	Design provides no accomodations along Route 6 WB and a 12' SUP with landscaped buffer adjacent to Route 6 EB to connect to pedestrian and bicycle facilities at Belmont Circle.	Design provides no accomodations along Trowbridge WB and a 12' SUP with landscaped buffer adjacent to Trowbridge EB.	Design provides no accomodations along Trowbridge WB and a 12' SUP with landscaped buffer adjacent to Trowbridge EB.

Program Need	Evaluation Criteria	Performance Measure	Quantitative/ Qualitative	BN 13.1		BN 14.4b		Bourne - South Approach Options BS-2		BS-2.2	
Multi-Modal Accommodations	Improve pedestrian/bicycle access to existing trail facilities	Evaluate distance of Shared Use Path from bridge mid-point to first Canal Service Road connection, travel time from bridge mid-point to first Canal Service Road connection and comfort from bridge mid-point to first Canal Service Road connection.	Quantitative	Distance is approximatley 6070-ft, time and comfort provide some improvements. Several at-grade crossings negatively impact comfort and travel time.	◊◊	Distance is approximatley 6580-ft, time and comfort provide more improvements. A grade separated crossing provides more improvements for comfort and travel time.	◊◊◊	Distance is approximatley 4715-ft, time and comfort provide more improvements. One at-grade crossing at a low volume road with RRFB's do not impact comfort and travel time.	◊◊	Distance is approximatley 4700-ft, time and comfort provide more improvements. One at-grade crossing at a low volume road with RRFB's do not impact comfort and travel time.	◊◊
	Improve pedestrian/bicycle connections at ramp terminals	Assessment of pedestrian/bicycle facilities across ramp terminals with respect to controlled crossing, diversions, etc.	Qualitative	Provides signalized control across of both of the new On/Off-Ramps. The ramps at Belmont Circle maintain the existing Pedestrian Hybrid Beacon (PHB) control for pedestrians.	◊◊	At the proposed off-ramp pedestrian access has miles' diversion to avoid high speed ramp. The ramps at Belmont Circle maintain the existing Pedestrian Hybrid Beacon (PHB) control for pedestrians.	◊◊◊	Provides for flexibility for either signalized crossings or for Pedestrian Hybrid Beacon crossings if roundabout intersection control.	◊◊◊	Provides flexibility for signalized crossings across ramps. However, does not allow for consistent crossings across Trowbridge Road.	◊◊
	Enhance pedestrian/bicycle experience	Assessment of interchange configuration relative to intersection footprint, roadway corridor and complication of route (large intersection footprints, wide roadway corridors and complicated routing are intimidating to pedestrians/bicyclists).	Qualitative	Maximum pedestrian intersection crosswalk distance = 70-ft Scenic Hwy EB to WB movement requires 6 intersection/ramp crossings	◊◊	Maximum pedestrian intersection crosswalk distance = 76-ft Scenic Hwy EB to WB movement requires 2 intersection/ramp crossings	◊◊◊	Maximum pedestrian intersection crosswalk distance = 80-ft Trowbridge EB to WB movement requires 6 intersection/ramp crossings Roadways with SUP/SW mimic BS-2.2 alternative, Less additional facilities	◊◊◊	Maximum pedestrian intersection crosswalk distance = 90-ft Trowbridge EB to WB movement requires 7 intersection/ramp crossings Roadways with SUP/SW mimic BS-2 alternative, Less additional facilities	◊◊◊
	Reduce Shared Use Path grade at bridge approaches	Maximum grade of Shared Use Path.	Quantitative	4.50%	◊◊◊	4.50%	◊◊◊	4.50%	◊◊◊	4.50%	◊◊◊
		Maximum length of maximum grade of Shared Use Path.	Quantitative	135-ft	◊◊◊	479-ft	◊◊◊	1600-ft	◊◊	1235-ft	◊◊
		Number of Shared Use path segments that equal or exceed 4.50% for a length of 500 feet or more.	Quantitative	0	◊◊◊	0	◊◊◊	3	◊◊	3	◊◊
	Increase pedestrian/bicycle accommodations in Program Study Area	Percentage of local roadways in Program Study Area that have pedestrian/bicycle accommodations, compared to 2050 No Build condition.	Quantitative	Increase in Pedestrian Accommodations = 147% (EX = 2610-ft, PR = 3840-ft)	◊◊◊	Increase in Pedestrian Accommodations = 152% (EX = 2610-ft, PR = 3960-ft)	◊◊◊	Increase in Pedestrian Accommodations = 2,836% (EX = 260-ft, PR = 7635-ft)	◊◊◊	Increase in Pedestrian Accommodations = 2,871% (EX = 260-ft, PR = 7725-ft)	◊◊◊
	Improve pedestrian/bicycle access to transit facilities	Distance of Shared Use Path at bridge mid-point to first public and/or private transit facility location (transit stop, e.g., County Road, Main Street, Route 28A/Sandwich Road; transit facility, e.g., Park and Ride).	Quantitative	Scenic Hwy to Belmont Circle: 2375-ft SB Mainline to Belmont Circle: 1905-ft SB Mainline to Scenic Hwy: 1570-ft Scenic Hwy to Canal Service Road: 1570-ft	◊◊◊	Scenic Hwy to Belmont Circle: 3620-ft SB Mainline to Belmont Circle: 1905-ft SB Mainline to Scenic Hwy: 3985-ft Scenic Hwy to Canal Service Road: 1570-ft	◊◊◊	Bridge Mid-point Distance to Greyhound Bus Stop: 2770-ft Bridge Mid-point Distance to Bourne Stations (train): 4920-ft Bridge Mid-point to Trowbridge Road: 2225-ft Trowbridge Road to Sandwich Road Underpass: 2025-ft	◊◊◊	Bridge Mid-point Distance to Greyhound Bus Stop: 2728-ft Bridge Mid-point Distance to Bourne Stations (train): 4860-ft Bridge Mid-point to Trowbridge Road: 2175-ft Trowbridge Road to Sandwich Road Underpass: 1925-ft	◊◊◊
		Number of desired public and/or private transit facility locations within a 0.50 mile radius.	Quantitative	5	◊◊◊	5	◊◊◊	4	◊◊◊	4	◊◊◊
Maintenance/Structural	Minimize risk of disruptive maintenance on existing bridges	Relative duration of time to remove most traffic from existing brdiges as compared to other alternatives	Quantitative	Duration equivalent between alternates.	◊◊	Duration equivalent between alternates.	◊◊	Duration equivalent between alternates.	◊◊	Duration equivalent between alternates.	◊◊
		Relative duration of time to remove all traffic from existing brdiges as compared to other alternatives	Quantitative	Duration equivalent between alternates.	◊◊	Duration equivalent between alternates.	◊◊	Duration equivalent between alternates.	◊◊	Duration equivalent between alternates.	◊◊
	Implement most efficient and simplest structural system to accommodate the interchange ramps	Assess compatibility of structural framing systems required for ramp tie-ins with Main bridge structural system.	Qualitative	Ramp Framing compatible with Mainline Framing.	◊◊◊	Ramp Framing compatible with Mainline Framing.	◊◊◊	Current design configuration of ramps (1000 foot minimum ramp length) introduces undesirable complexity to brdige framing system, affecting constructability and performance.	◊	Current design configuration of ramps (1000 foot minimum ramp length) introduces undesirable complexity to brdige framing system, affecting constructability and performance.	◊

3.2 Sagamore Evaluation Criteria Performance Measures Scoring Matrix

Goals	Objectives	Performance Measures	Quantitative/ Qualitative	Alternatives Analysis Report Findings	Sagamore - North Approach Options				Sagamore - South Approach Options					
				Mainline Alignment	SN-1A*		SN-8A*		SS-1		SS-1.1		SS-3.1A	
Phase 2b Assessment														
Maintain and Improve the Socioeconomic Fabric of the Surrounding Community	Minimize residential property impacts, including acquisitions and displacement	Number of easements, vacant parcels	Quantitative	0	1	◊◊◊	1	◊◊◊	1	◊◊◊	1	◊◊◊	1	◊◊◊
		Number of easements, occupied parcels	Quantitative	0	1	◊◊◊	1	◊◊◊	16	◊	13	◊	14	◊
		Number of full parcel acquisitions with displacements	Quantitative	10	1	◊◊◊	1	◊◊◊	12	◊	12	◊	12	◊
		Number of full parcel acquisitions without displacements	Quantitative	1	0	◊◊◊	0	◊◊◊	5	◊◊	5	◊◊	5	◊◊
	Minimize commercial property impacts, including acquisitions and displacement	Number of easements, vacant parcels	Quantitative	0	0	◊◊◊	0	◊◊◊	0	◊◊◊	0	◊◊◊	0	◊◊◊
		Number of easements, occupied parcels	Quantitative	1	5	◊◊	5	◊◊	6	◊◊	2	◊◊◊	5	◊◊
		Number of full parcel acquisitions with displacements	Quantitative	1	0	◊◊◊	0	◊◊◊	2	◊◊	2	◊◊	2	◊◊
		Number of full parcel acquisitions without displacements	Quantitative	1	0	◊◊◊	0	◊◊◊	2	◊◊	2	◊◊	2	◊◊
	Improve access to commercial properties	Assess modifications to commercial property access	Qualitative		All commercial business access is unchanged.	◊◊◊	All commercial business access is unchanged.	◊◊◊	Market Basket western driveway changed to right in/right out only. Does not improve substandard turn movements into and out of the Adams St area. Includes Cranberry Highway Extension that provides more direct east west access between the neighborhoods and Market Basket.	◊◊	No change in access to Market Basket. Does not improve substandard turn movements into and out of the Adams St area. Does not include Cranberry Highway Extension.	◊	Market Basket western driveway changed to right in/right out only. Does not improve substandard turn movements into and out of the Adams St area. Includes Cranberry Highway Extension that provides more direct east west access between the neighborhoods and Market Basket.	◊◊
	Improve neighborhood accessibility to community facilities & services	Improve and/or maintain accessibility to public and/or private community facilities & services	Qualitative	Not evaluated during mainline alignment analysis	The addition of sidewalk and shared use path along the roadway network improves access to public facilities and private community facilities however, the distance to facilities is increased for bicyclists and pedestrians coming from the bridge due to making grades more accessible.	◊◊◊	The addition of sidewalk and shared use path along the roadway network improves access to public facilities and private community facilities however, the distance to facilities is increased for bicyclists and pedestrians coming from the bridge due to making grades more accessible.	◊◊◊	The addition of sidewalk and shared use path along the roadway network improves access to public facilities and private community facilities however, the distance to facilities is increased for bicyclists and pedestrians coming from the bridge due to making grades more accessible. Cranberry Highway Extension provides more direct access between the neighborhoods on the east side of Route 6 and Market Basket on the west side of Route 6.	◊◊◊	The addition of sidewalk and shared use path along the roadway network improves access to public facilities and private community facilities however, the distance to facilities is increased for bicyclists and pedestrians coming from the bridge due to making grades more accessible.	◊	The addition of sidewalk and shared use path along the roadway network improves access to public facilities and private community facilities however, the distance to facilities is increased for bicyclists and pedestrians coming from the bridge due to making grades more accessible. Cranberry Highway Extension provides more direct access between the neighborhoods on the east side of Route 6 and Market Basket on the west side of Route 6.	◊◊◊
		Assess neighborhood access to schools, hospitals, and emergency services (police & fire)	Qualitative	Not evaluated during mainline alignment analysis	There are no schools, hospitals, and emergency services within the Sagamore project limits.	◊◊◊	There are no schools, hospitals, and emergency services within the Sagamore project limits.	◊◊◊	There are no schools, hospitals, and emergency services within the Sagamore project limits.	◊◊◊	There are no schools, hospitals, and emergency services within the Sagamore project limits.	◊◊◊	There are no schools, hospitals, and emergency services within the Sagamore project limits.	◊◊◊
	Improve neighborhood cohesion	Assess neighborhood visibility, walkability; assess reduction and/or elimination of regional (through) traffic	Qualitative	Not evaluated during mainline alignment analysis	Added bicycle and pedestrian accommodations for all roadways. No change to regional traffic pattern	◊◊	Added bicycle and pedestrian accommodations for all roadways. Slight reduction in regional traffic through State/Meetinghouse intersection.	◊◊	Added bicycle and pedestrian accommodations for all roadways. Reduces volume of regional traffic on local roads (Adams St/Ben Abbey Rd.)	◊◊	Added bicycle and pedestrian accommodations for all roadways. No change to regional traffic pattern.	◊	Added bicycle and pedestrian accommodations for all roadways. Reduces regional traffic on local roads (Adams St/Ben Abbey Rd.)	◊◊◊
	Avoid disproportionate adverse impact to Environmental Justice (EJ) populations	Assess of adverse impacts (with respect to all measures) and potential to disproportionately affect EJ populations	Qualitative	No direct impacts to EJ populations	There are no EJ populations within the Sagamore North project limits.	◊◊◊	There are no EJ populations within the Sagamore North project limits.	◊◊◊	There are no impacts to EJ populations within the Sagamore South project limits.	◊◊◊	There are no impacts to EJ populations within the Sagamore South project limits.	◊◊◊	There are no impacts to EJ populations within the Sagamore South project limits.	◊◊◊
	Minimize construction period effects upon the traveling public	Assess number, complexity, and duration of detours/work-arounds during construction	Qualitative		All existing pedestrian and bicycle connections maintained or improved throughout construction. Canal Service Road access may require closure or longer detour. Vehicular traffic will be maintained throughout construction. SN-1A construction staging is requires detours for one bridge construction.	◊◊	All existing pedestrian and bicycle connections maintained or improved throughout construction. Canal Service Road access may require closure or longer detour. Vehicular traffic will be maintained throughout construction.	◊◊◊	All existing pedestrian and bicycle connections maintained or improved throughout construction. Canal Service Road access may require closure or longer detour. Vehicular traffic will be maintained throughout construction. SS-1 construction staging requires detours for one bridge construction.	◊◊	All existing pedestrian and bicycle connections maintained or improved throughout construction. Canal Service Road access may require closure or longer detour. Vehicular traffic will be maintained throughout construction. SS-1.1 construction staging requires detours for one bridge construction.	◊◊	All existing pedestrian and bicycle connections maintained or improved throughout construction. Canal Service Road access may require closure or longer detour. Vehicular traffic will be maintained throughout construction.	◊◊◊

Goals	Objectives	Performance Measures	Quantitative/ Qualitative	Alternatives Analysis Report Findings	Sagamore - North Approach Options				Sagamore - South Approach Options					
				Mainline Alignment	SN-1A*		SN-8A*		SS-1		SS-1.1		SS-3.1A	
	Avoid and/or minimize effects to parks, open space, and recreational facilities	Number (in acreage) of impacts and duration of impacts to parks, open space, and recreational resources.	Quantitative	43,100 sf (0.99 acre) impact to Town of Bourne owned property; 369,500 sf temporary impact & 304,000 sf permanent impact to USACE property	Temporary Closure of Canal Service Road (0.32 AC) Impacts to Sagamore Recreation Area; Permanent Removal of Canal Parking (29 spaces, 0.15 AC); Temporary Removal of Canal Parking (25 spaces, 0.10 AC)	◊◊◊	Temporary Closure of Canal Service Road (0.32 AC) Impacts to Sagamore Recreation Area; Permanent Removal of Canal Parking (29 spaces, 0.15 AC)	◊◊◊	Temporary Closure of Canal Service Road (0.27 AC)	◊◊◊	Temporary Closure of Canal Service Road (0.27 AC)	◊◊◊	Temporary Closure of Canal Service Road (0.27 AC)	◊◊◊
Preserve and Protect Natural Resources	Minimize effects to Areas of Critical Environmental Concern (ACEC) and wildlife habitats	Quantify direct impact to ACEC	Quantitative	Within previously disturbed portions of the Herring River Watershed ACEC within State highway layout.	ACEC Impact: 584,150 SF (13.41 ac)	◊◊	ACEC Impact: 584,150 SF (13.41 ac)	◊◊	0	◊◊◊	0	◊◊◊	0	◊◊◊
		Quantify direct impact to wildlife, defined as NHESP priority and estimated (subset of priority) habitat.	Quantitative	0	0 (No identified NHESP habitat)	◊◊◊	0 (No identified NHESP habitat)	◊◊◊	113,356 sf (2.60ac)	◊◊	113,356 sf (2.60 ac)	◊◊	113,356 sf (2.60 ac)	◊◊
	Maintain floodplain functions	Quantify change between existing percent vegetative cover in floodplain and proposed percent vegetative cover in floodplain; for entire quadrant). Change of less than 10% =less impact; change of less than 20% = some impact	Quantitative	Not evaluated during mainline alignment analysis; Some impact to floodplain anticipated for the construction of the main span and piers.	Existing veg cover =2.7%. 0.3 veg acre removed. Remaining veg cover = 0.4%. Change = - 2.2%.	◊◊◊	Existing veg cover =2.7%. 0.3 veg acre removed. Remaining veg cover = 0.4%. Change = - 2.3%.	◊◊◊	Existing veg cover =4.6%. 0.3 veg acre removed. Remaining veg cover = 2.6% Change = - 2.0%.	◊◊◊	Existing veg cover =4.6%. 0.3 veg acre removed. Remaining veg cover = 2.6% Change = - 2.0%.	◊◊◊	Existing veg cover =4.6%. 0.3 veg acre removed. Remaining veg cover = 2.6% Change = - 2.0%.	◊◊◊
	Maintain wetland and surface water buffers	Quantify direct impact to protected wetlands and water resources and/or buffer zones.	Quantitative	No direct wetland impacts	No direct wetland impacts. Work within wetland buffer = 260,800 SF (5.99 ac)	◊◊◊	No direct wetland impacts. Work within wetland buffer = 260,800 SF (5.99 ac)	◊◊◊	No direct wetland impacts. Work within wetland buffer = 125,000 SF(2.87ac)	◊◊◊	No direct wetland impacts. Work within wetland buffer = 125,000 SF (2.87 ac)	◊◊◊	No direct wetland impacts. Work within wetland buffer = 125,000 SF (2.87ac)	◊◊◊
Enhance the Resiliency and Sustainability of the Built Environment	Minimize air quality effects	Total vehicle miles traveled, compared to 2050 No Build condition.	Quantitative	Not evaluated during mainline alignment analysis	220,976	◊◊	221,612	◊◊	221,612	◊◊	226,407	◊◊	219,237	◊◊
		Total vehicle hours traveled, compared to 2050 No Build condition.	Quantitative		6,180	◊◊◊	6,091	◊◊◊	6,091	◊◊◊	6,115	◊◊◊	6,175	◊◊◊
	Minimize land alteration and reduction in tree cover (urban heat island effect)	Amount of reduction in tree cover	Quantitative		40.7 Acres	◊	45.1 Acres	◊	28.2 Acres	◊	28.6 Acres	◊	30.3 Acres	◊
	Minimize vulnerability to flooding	Assess area of roadways impacted by storm surge	Qualitative		0; no impact anticipated	◊◊◊	0; no impact anticipated	◊◊◊	0; no impact anticipated	◊◊◊	0; no impact anticipated	◊◊◊	0; no impact anticipated	◊◊◊
		Assess area of roadways impacted by fluctuations in relative sea level	Qualtitative		0; no impact anticipated	◊◊◊	0; no impact anticipated	◊◊◊	0; no impact anticipated	◊◊◊	0; no impact anticipated	◊◊◊	0; no impact anticipated	◊◊◊
	Effecitvely Manage Stormwater - Assess stormwater runoff that infiltrates, evapotranspirates, is reused, and/or is treated while not exceeding rate or quantity runoff targets	Impervious Area Increase (%)	Quantitative		36%	◊	42%	◊	30%	◊◊	19%	◊◊◊	30%	◊◊
		Treated Impervious Area (%)			80%	◊◊◊	79%	◊◊◊	65%	◊◊	65%	◊◊	65%	◊◊
		Peak 2-Year Discharge Rate Delta (%)			-16%	◊◊◊	-2%	◊◊◊	-35%	◊◊◊	-35%	◊◊◊	-31%	◊◊◊
		Peak 10-Year Discharge Rate Delta (%)			+10%	◊◊	+13%	◊◊	-20%	◊◊◊	-16%	◊◊◊	-18%	◊◊◊
		Peak 100-Year Discharge Rate Delta (%)			+8%	◊◊	+23%	◊◊	-25%	◊◊◊	-20%	◊◊◊	-22%	◊◊◊
		Proposed Infiltration Volume (% of Required Volume)			111%	◊◊	109%	◊◊	112%	◊◊	113%	◊◊	124%	◊◊
		Total Phosphorus Removal (%)			80	◊◊◊	79	◊◊◊	68	◊◊◊	68	◊◊◊	68	◊◊◊
		Total Suspended Solids Removal (%)			84	◊◊	84	◊◊	81	◊◊	82	◊◊	81	◊◊
Maximize Constructability	Minimize the construction duration	Construction Duration compared to other alternates	Quantitative		Duration approximately equivalent between alternates, final completion may be up to 12 months sooner than SN-8A assuming building Two Bridge before shifting traffic from existing.	◊◊◊	Duration approximately equivalent between alternates, final completion may be up to 12 months later than SN-1A.	◊◊	Duration approximately equivalent between alternates, final completion may be up to 12 months sooner than SS-3.1A assuming building Two Bridge before shifting traffic from existing.	◊◊◊	Duration approximately equivalent between alternates, final completion may be up to 12 months sooner than SS-3.1A assuming building Two Bridge before shifting traffic from existing.	◊◊◊	Duration approximately equivalent between alternates, final completion may be up to 12 months later than SS-1 and SS-1.1	◊◊
	Maintain existing connections during construction	Assess ability to maintain existing travel connections	Qualitative		One Bridge needs detours for local ramps. Two Bridge, no detours needed.	◊◊	No detours needed.	◊◊◊	One Bridge needs detours for local ramps. Two Bridge, no detours needed.	◊◊	One Bridge needs detours for local ramps. Two Bridge, no detours needed.	◊◊	No detours needed.	◊◊◊

Goals	Objectives	Performance Measures	Quantitative/ Qualitative	Alternatives Analysis Report Findings	Sagamore - North Approach Options				Sagamore - South Approach Options					
				Mainline Alignment	SN-1A*		SN-8A*		SS-1		SS-1.1		SS-3.1A	
Facilitate Emergency Response	Improve emergency evacuation capabilities off Cape Cod	Assess feasibility/difficulty of responding to emergency evacuation off Cape Cod	Qualitative	Not evaluated during mainline alignment analysis	Minimal improvement from bringing mainline/ramps up to current standards.	◊◊	Minimal improvement from bringing mainline/ramps up to current standards and reducing volumes at State Rd/Meetinghouse intersection.	◊◊	Access to Sagamore Bridge NB from Sandwich Rd west improved with Cranberry Hwy Ext.	◊◊◊	Minimal improvement from bringing mainline/ramps up to current standards	◊◊	Access to Sagamore Bridge NB from Sandwich Rd west improved with Cranberry Hwy Ext.	◊◊◊
	Improve emergency response	Consideration of improvements to overall regional mobility with special focus on emergency response centers/locations	Qualitative	Not evaluated during mainline alignment analysis	Minimal improvement from bringing mainline/ramps up to current standards.	◊◊	Minimal improvement from bringing mainline/ramps up to current standards and reducing volumes at State Rd/Meetinghouse intersection.	◊◊	Improved access to/from Sandwich Rd west with Cranberry Hwy Ext.	◊◊◊	Minimal improvement from bringing mainline/ramps up to current standards	◊◊	Improved access to/from Sandwich Rd west with Cranberry Hwy Ext.	◊◊◊
Costs	Maximize construction cost effectiveness	Compare cost estimates of options	Quantitative		Costs equivalent between options; $205 million	◊◊◊	Costs equivalent between options; $219 million	◊◊◊	Costs equivalent among options; $177 million	◊◊◊	Costs equivalent among options; $177 million.	◊◊◊	Costs equivalent among options; $193 million	◊◊◊

Program Need	Evaluation Criteria	Performance Measure	Quantitative/ Qualitative	Sagamore - North Approach Options				Sagamore - South Approach Options					
				SN-1A*		SN-8A*		SS-1		SS-1.1		SS-3.1A	
Phase 2a Assessment													
Operations	Assess impact on regional traffic operations	Average Delay per Vehicle in minutes (network wide using the alternative pairings)	Quantitative	3.4	◊◊◊	3.1	◊◊◊	2.9	◊◊◊	3.6	◊◊◊	3.5	◊◊◊
Phase 2b Assessment													
Operations	Reduce congestion on mainline and ramps	Number of passenger cars per mile per lane for mainline highways, compared to 2050 No Build condition	Quantitative	17.42	◊◊◊	17.16	◊◊◊	17.16	◊◊◊	18.12	◊◊◊	17.41	◊◊◊
		Number of passenger cars per mile per lane for ramps, compared to 2050 No Build condition	Quantitative	21.92	◊◊	22.96	◊◊	13.79	◊◊◊	14.64	◊◊◊	14.67	◊◊◊
	Reduce regional travel times	Travel times from predetermined start (northern/southern limit of the mainline) to the mid-point of the bridge, compared to 2050 No Build condition. (vehicle-hours traveled)	Quantitative	86.96 VHT	◊◊	82.02 VHT	◊◊	82.02 VHT	◊◊	82.36 VHT	◊◊	88.41 VHT	◊◊
	Reduce local travel times	Travel times from predetermined start (northern/southern limit of the mainline) to the mid-point of the bridge, compared to 2050 No Build condition. (vehicle-hours traveled)	Quantitative	152.54 VHT	◊◊	149.83 VHT	◊◊	82.9 VHT	◊◊◊	97.2 VHT	◊◊	69.67 VHT	◊◊◊
	Improve cross-canal mobility	Travel times from predetermined location to mid-point of bridge on local roads, compared to 2050 No Build condition. (vehicle-hours traveled)	Quantitative	87.51 VHT	◊◊	87.47 VHT	◊◊	42.86 VHT	◊◊◊	56.67 VHT	◊◊	38.13 VHT	◊◊◊
	Minimize queue spillback onto the highway	Assessment if queues spillback from the local ramp terminals onto the highway	Qualitative	Less	◊◊◊	Less	◊◊◊	Less	◊◊◊	Less	◊◊◊	Less	◊◊◊
	Separate local and regional traffic	Assessment of approach to separating local and regional traffic.	Qualitative	Maintains existing traffic patterns	◊	Removes Sagamore NB to State Rd. traffic from Meetinghouse/Canal intersection	◊◊	Removes Route 6 WB traffic from Adams St./Ben Abbey Rd.	◊◊	Maintains existing traffic patterns	◊	Removes Route 6 WB traffic from Adams St./Ben Abbey Rd.	◊◊◊
Geometrics/Safety	Minimize weaving movements	Number of weaving movements on mainline highways.	Quantitative	2	◊◊	2	◊◊◊	2	◊◊	2	◊◊	2	◊◊◊
	Minimize wrong-way driving risk	Assess wrong-way driving risks based on geometrics of the intersections at the ramp terminals	Qualitative	Geometrically restricts wrong-way ramp access.	◊◊◊	Introduces new Route 3 NB off-ramp to State Rd without geometrically restricted access if the intersection is signalized. Can be mitigated with Installation of roundabout	◊◊	Geometrically restricts wrong-way ramp access, If raised median provided for Cranberry Hwy Ext at Route 6 WB Ramps.	◊◊	Geometrically restricts wrong-way ramp access, If raised median provided for Cranberry Hwy Ext at Rte 6 WB Ramps.	◊◊	Geometrically restricts wrong-way ramp access, If raised median provided for Cranberry Hwy Ext at Rte 6 WB Ramps.	◊◊
	Assess flexibility to achieve speed differential for exit ramps onto local roadways	Assessment of geometry to allow for flexibility to achieve speed differential for exit ramps onto local roadways.	Qualitative	Maintains existing flexibility for target speeds.	◊◊	Allows for design flexibility for target speeds.	◊◊	Allows for design flexibility for target speeds.	◊◊	Allows for design flexibility for target speeds with traffic calming measures or roundabout at Cranberry Highway/Adams Street.	◊◊	Allows for design flexibility for target speeds.	◊◊
	Minimize complexity of decision points	Assessment of complexity of ramp decision points, including number and difficulty	Qualitative	Maintains 1 basic decision point (Scenic Hwy EB/WB) on Route 3 SB Off-Ramp	◊◊	Introduces 2 consecutive decision points on Route 3 NB Off-ramp. 1 - requiring advance signage (Scenic Hwy WB/State Rd) and 1- basic (State Rd NB/SB). Maintains 1 basic decision point on Route 3 SB Off-ramp.	◊◊	Introduces 1 basic decision point (Cranberry Hwy EB/WB) on the Route 6 WB Off-ramp.	◊◊	There are no ramp decision points.	◊◊	Introduces 1 basic decision point (Cranberry Hwy EB/WB) on the Route 6 WB Off-ramp.	◊◊
	Evaluate spacing between entrance and exit ramps	evaluate entrance and exit ramp spacing relative to traffic volume	Qualitative	SB Off-ramp gore to EB On-ramp gore = 2,930 ft WB Off-ramp gore to WB Off-ramp gore (loop ramp) = 1,550 ft WB Off-ramp gore to NB On-ramp gore = 1,400 ft	◊◊◊	SB Off-ramp gore to EB On-ramp gore = 2,930 ft WB Off-ramp gore to NB On-ramp gore = 2,000 ft WB Off-ramp gore to State Rd Off-ramp gore = 960 ft	◊◊◊	SB Off-ramp gore to SB On-ramp gore = 1,760 ft NB Off-ramp gore to NB On-ramp gore = 2,630 ft	◊◊◊	SB Off-ramp gore to SB On-ramp gore = 1,760 ft NB Off-ramp gore to NB On-ramp gore = 2,630 ft	◊◊◊	SB Off-ramp gore to SB On-ramp gore = 1,760 ft NB Off-ramp gore to NB On-ramp gore = 2,630 ft	◊◊◊
	Minimize acceleration/deceleration speed variances	Number of acceleration lane speed variances with the mainline greater than 25 MPH.	Quantitative	2 (1-30 MPH design speed difference 1-40 MPH design speed difference) (SB On-Ramp 30 MPH/Mainline 60 MPH, ramp geometry supports acceleration prior to merge such that speed differential is less than 25 MPH. NB On-ramp 25 MPH/Mainline 65 MPH, acceleration lane has been extended to mitigate speed differential)	◊◊◊	2 (1-30 MPH design speed difference 1-40 MPH design speed difference) (SB On-Ramp 30 MPH/Mainline 60 MPH, ramp geometry supports acceleration prior to merge such that speed differential is less than 25 MPH. NB On-ramp 25 MPH/Mainline 65 MPH)	◊◊◊	2 - 30 MPH design speed difference (all ramp design speeds = 30 MPH and ML = 60 MPH, ramp speed is within recommended design speed for mainline speed of 60 MPH) Ramp geometry supports acceleration prior to the merge such that speed differential is less than 25 MPH.	◊◊◊	2 - 30 MPH design speed difference (all ramp design speeds = 30 MPH and ML = 60 MPH, ramp speed is within recommended design speed for mainline speed of 60 MPH) Ramp geometry supports acceleration prior to the merge such that speed differential is less than 25 MPH.	◊◊◊	2 - 30 MPH design speed difference (all ramp design speeds = 30 MPH and ML = 60 MPH, ramp speed is within recommended design speed for mainline speed of 60 MPH) Ramp geometry supports acceleration prior to the merge such that speed differential is less than 25 MPH.	◊◊◊
		Number of deceleration lane speed variances with the mainline greater than 25 MPH.	Quantitative	3 (2-30 MPH design speed difference, 1-35 MPH design speed difference) (Route 3 SB Off and Route 6 WB Off ramps 30 MPH/60 MPH mainline, ramp geometry has flexibility to support higher speeds at exit gore, Route 6 WB loop ramp 25 MPH/Mainline 60 MPH, limited flexibility for ramp geometry to support higher speeds at exit gore)	◊◊	2 (2-30 MPH design speed difference) (Ramps design 30 MPH/Mainline 60 MPH, ramp geometry has flexibility to support higher speeds at exit gore)	◊◊◊	2 - 30 MPH design speed difference (all ramp design speeds = 30 MPH and ML = 60 MPH, ramp speed is within recommended design speed for mainline speed of 60 MPH) Ramp geometry has flexibility to support higher ramp speeds at exit gore.	◊◊◊	2 - 30 MPH design speed difference (all ramp design speeds = 30 MPH and ML = 60 MPH, ramp speed is within recommended design speed for mainline speed of 60 MPH) Ramp geometry has flexibility to support higher ramp speeds at exit gore.	◊◊◊	2 - 30 MPH design speed difference (all ramp design speeds = 30 MPH and ML = 60 MPH, ramp speed is within recommended design speed for mainline speed of 60 MPH) Ramp geometry has flexibility to support higher ramps speeds at exit gore.	◊◊◊
	Assess design relative to driver navigation and expectation	Assessment of design related to driver navigation and expectation	Qualitative	Maintains existing network patterns	◊◊	There are two additional decision points introduced on the loop ramp, which can be mitigated with signage/pavement markings.	◊◊	Traffic destined to/from Sandwich Road west has more direct route	◊◊	Maintains existing network patterns	◊◊	Traffic destined to/from Sandwich Road west has more direct route	◊◊

Program Need	Evaluation Criteria	Performance Measure	Quantitative/ Qualitative	Sagamore - North Approach Options				Sagamore - South Approach Options					
				SN-1A*		SN-8A*		SS-1		SS-1.1		SS-3.1A	
Multi-Modal Accommodations	Improve pedestrian/bicycle access to local roads	Evaluate distance of Shared Use Path from bridge mid-point to first local road connection, travel time from bridge mid-point to first local road connection and comfort from bridge mid-point to first local road connection.	Quantitative	EB On-ramp Designs are Interchangeable. Distances are as follows: Scenic Highway Connection Free Flow Right - 2,670 Ft Yield Control Right - 2,410 Ft Canal St Connection 4,860 Ft Travel time is increased when compared to the existing condition, however access is now more accessible for all users and comfort is improved.	◊◊◊	EB On-ramp Designs are Interchangeable. Distances are as follows: Scenic Highway Connection Free Flow Right - 2,670 Ft Yield Control Right - 2,410 Ft Canal St Connection 4,860 Ft Travel time is increased when compared to the existing condition, however access is now more accessible for all users and comfort is improved.	◊◊◊	Distance is approximately 3,515 Ft to Cranberry Highway Extension connection. Travel time is increased when compared to the existing condition, however access is now more accessible for all users and comfort is improved.	◊◊◊	Distance is approximately 3,515 Ft to Factory Outlet Way connection. Travel time is increased when compared to the existing condition, however access is now more accessible for all users and comfort is improved.	◊◊◊	Distance is approximately 3,515 Ft to Cranberry Highway Extension connection. Travel time is increased when compared to the existing condition, however access is now more accessible for all users and comfort is improved.	◊◊◊
	Improve pedestrian/bicycle access on local roads	Evaluate access and comfort of Shared Use Path's adjacent to local roadways.	Quantitative	Design provides SUP along Scenic Highway/Meetinghouse Lane and State Road. Design provides in road bike lanes along Canal Street.	◊◊◊	Design provides SUP along Scenic Highway/Meetinghouse Lane and State Road. Design provides in road bike lanes along Canal Street.	◊◊◊	Design provides SUP along Mid Cape Connector and Sandwich Road. Design provides a separated bike lane along Cranberry Highway/Cranberry Highway Extension.	◊◊◊	Design provides SUP along Mid Cape Connector and Sandwich Road. Design provides a separated bike lane along Cranberry Highway/Cranberry Highway Extension.	◊◊◊	Design provides SUP along Mid Cape Connector and Sandwich Road. Design provides a separated bike lane along Cranberry Highway/Cranberry Highway Extension.	◊◊◊
	Improve pedestrian/bicycle access to existing trail facilities	Evaluate distance of Shared Use Path from bridge mid-point to first Canal Service Road connection, travel time from bridge mid-point to first Canal Service Road connection and comfort from bridge mid-point to first Canal Service Road connection.	Quantitative	SUP Alternatives are interchangeable. Distances are as follows: Flatter SUP Option: 5,790 Ft Steeper SUP Option: 4,510 Ft Travel time is increased when compared to the existing condition, however access is now more accessible for all users. Comfort is improved by accessibility improvements and access is separate from the roadway facilities off bridge.	◊◊◊	SUP Alternatives are interchangeable. Distances are as follows: Flatter SUP Option: 5,790 Ft Steeper SUP Option: 4,510 Ft Travel time is increased when compared to the existing condition, however access is now more accessible for all users. Comfort is improved by accessibility improvements and access is separate from the roadway facilities off bridge.	◊◊◊	Distance is approximately 4,870 Ft (Assumes access via at grade crossing at Sandwich Road). Requires 1 at grade crossing at Sandwich Road. Requires 1 at grade crossing of a railroad. Travel time is increased when compared to the existing condition, however access is now more accessible for all users.	◊◊	Distance is approximately 4,870 Ft (Assumes access via at grade crossing at Sandwich Road). Requires 1 at grade crossing at Sandwich Road. Requires 1 at grade crossing of a railroad. Travel time is increased when compared to the existing condition, however access is now more accessible for all users.	◊◊	Distance is approximately 4,870 Ft (Assumes access via at grade crossing at Sandwich Road). Requires 1 at grade crossing at Sandwich Road. Requires 1 at grade crossing of a railroad. Travel time is increased when compared to the existing condition, however access is now more accessible for all users.	◊◊
	Improve pedestrian/bicycle connections at ramp terminals	Assessment of pedestrian/bicycle facilities across ramp terminals with respect to controlled crossing, diversions, etc.	Qualitative	SUP Crossings at: EB On-ramp (2) WB Off-ramp (Scenic) Sidewalk Crossings at: SB Off-ramp	◊◊	SUP Crossings at: EB On-ramp (2) Sidewalk Crossings at: SB Off-ramp	◊◊◊	Sidewalk Crossings at: Route 6 WB Off-ramp (2) Route 6 WB On-ramp (2)	◊◊	Sidewalk Crossings at: Route 6 WB On and Off Ramps	◊◊◊	Sidewalk Crossings at: Route 6 WB Off-ramp (2)	◊◊◊
	Enhance pedestrian/bicycle experience	Assessment of interchange configuration relative to intersection footprint, roadway corridor and complication of route (large intersection footprints, wide roadway corridors and complicated routing are intimidating to pedestrians/bicyclists).	Qualitative	Maximum pedestrian intersection crosswalk distance = 105 Ft Scenic Highway west to east movement requires 5 intersection/ramp crossings Roadways with SUP/SW mimic SN-8A alternative, no additional facilities	◊◊	Maximum pedestrian intersection crosswalk distance = 105 Ft Scenic Highway west to east movement requires 4 intersection/ramp crossings Roadways with SUP/SW mimic SN-1A alternative, no additional facilities	◊◊◊	Maximum pedestrian intersection crosswalk distance = 95 Ft Cranberry Highway west to east movement requires 5 intersection/ramp crossings Provides connectivity along Cranberry Highway east and west of Route 6	◊◊	Maximum pedestrian intersection crosswalk distance = 55 Ft Cranberry Highway west to east movement requires 3 intersection/ramp crossings Does not provide connectivity along Cranberry Highway/Factory Outlet Way east and west of Route 6	◊◊	Maximum pedestrian intersection crosswalk distance = 95 Ft Cranberry Highway west to east movement requires 4 intersection/ramp crossings Provides connectivity along Cranberry Highway east and west of Route 6	◊◊◊
	Reduce Shared Use Path grade at bridge approaches	Maximum grade of Shared Use Path.	Quantitative	4-6.6%	◊◊◊	4-4.6%	◊◊◊	4-4.9%	◊◊◊	4-4.9%	◊◊◊	4-4.9%	◊◊◊
		Maximum length of maximum grade of Shared Use Path.	Quantitative	Flatter Canal Service Road SUP Option: From Mid-Point of Bridge to EB On Ramp: 1,125 FT (4-4.11%) Steeper Canal Service Road SUP Option: From Mid-Point of Bridge to EB On Ramp: 1,125 FT (4-4.11%) From EB On Ramp to Canal Service Road: 1,300 Ft (4%) From SUP to Canal Street: 125 Ft (6.6%) Scenic Highway: 1,710 Ft (4-6%) State Road: 400 Ft (4.7%)	◊◊	Flatter Canal Service Road SUP Option: From Mid-Point of Bridge to EB On Ramp: 1,125 FT (4-4.11%) Steeper Canal Service Road SUP Option: From Mid-Point of Bridge to EB On Ramp: 1,125 FT (4-4.11%) From EB On Ramp to Canal Service Road: 1,300 Ft (4%) From SUP to Canal Street: 125 Ft (6.6%) Scenic Highway: 1,710 Ft (4-6%) State Road: 400 Ft (4.7%)	◊◊	From Mid-Point of Bridge to EB Off Ramp: 950 Ft (4%) Along Mid Cape Connector 1,500 Ft(4.9%) From Sandwich Road to the Canal Service Road: 95 Ft (4.5%)	◊◊	From Mid-Point of Bridge to EB Off Ramp: 950 Ft (4%) Along Mid Cape Connector 1,500 Ft(4.9%) From Sandwich Road to the Canal Service Road: 95 Ft (4.5%)	◊◊	From Mid-Point of Bridge to EB Off Ramp: 950 Ft (4%) Along Mid Cape Connector 1,500 Ft(4.9%) From Sandwich Road to the Canal Service Road: 95 Ft (4.5%)	◊◊
		Number of Shared Use path segments that equal or exceed 4.50% for a length of 500 feet or more.	Quantitative	1 (Scenic Highway)	◊◊	1 (Scenic Highway)	◊◊	1 (Mid Cape Connector)	◊◊	1 (Mid Cape Connector)	◊◊	1 (Mid Cape Connector)	◊◊
	Increase pedestrian/bicycle accommodations in Program Study Area	Percentage of local roadways in Program Study Area that have pedestrian/bicycle accommodations, compared to 2050 No Build condition.	Quantitative	100%	◊◊◊	100%	◊◊◊	100%	◊◊◊	100%	◊◊◊	100%	◊◊◊
	Improve pedestrian/bicycle access to transit facilities	Distance of Shared Use Path at bridge mid-point to first public and/or private transit facility location (transit stop, e.g., County Road, Main Street, Route 28A/Sandwich Road; transit facility, e.g., Park and Ride).	Quantitative	Flatter SUP Option: 5,250 FT (via Canal St) Steeper SUP Option: 4,415 FT (via Canal St) (Bus Location: Park and Ride)	◊◊	Flatter SUP Option: 5,250 FT (via Canal St) Steeper SUP Option: 4,415 FT (via Canal St) (Bus Location: Park and Ride)	◊◊	4,015 Ft (Bus Location: Market Basket)	◊◊	4,015 Ft (Bus Location: Market Basket)	◊◊	4,015 Ft (Bus Location: Market Basket)	◊◊
		Number of desired public and/or private transit facility locations within a 0.50 mile radius.	Quantitative	1 (Park and Ride)	◊◊◊	1 (Park and Ride)	◊◊◊	2 (Market Basket Bus Stop, Adams St Bus Stop)	◊◊◊	2 (Market Basket Bus Stop, Adams St Bus Stop)	◊◊◊	2 (Market Basket Bus Stop, Adams St Bus Stop)	◊◊◊

Program Need	Evaluation Criteria	Performance Measure	Quantitative/ Qualitative	Sagamore - North Approach Options				Sagamore - South Approach Options					
				SN-1A*		SN-8A*		SS-1		SS-1.1		SS-3.1A	
	Minimize risk of disruptive maintenance on existing bridges	Relative duration of time to remove all traffic from existing bridge as compared to other alternatives	Quantitative	Construction requires either long term detours or building both canal crossings (2 bridge) prior to removing all traffic from existing. Would take 12-18 months longer to remove all traffic than for SN-8A.	◊	Would take 12-18 months less to remove all traffic than SN-1A.	◊◊◊	Construction requires either long term detours or building both canal crossings (2 bridge) prior to removing all traffic from existing. Would take 12-18 months longer to remove all traffic than for SS-3.1A.	◊	Construction requires either long term detours or building both canal crossings (2 bridge) prior to removing all traffic from existing. Would take 12-18 months longer to remove all traffic than for SS-3.1A.	◊	Would take 12-18 months less to remove all traffic than SS-1 or SS-1.1.	◊◊◊
	Implement most efficient and simplest structural system to accommodate the interchange ramps	Assess compatibility of structural framing systems required for ramp tie-ins with Main bridge structural system.	Qualitative	Ramp Framing compatible with Mainline Framing.	◊◊	Ramp Framing compatible with Mainline Framing.	◊◊	Current design configuration of ramps (1000 foot minimum ramp length) introduces undesirable complexity to bridge framing system, affecting constructability and performance.	◊	Current design configuration of ramps (1000 foot minimum ramp length) introduces undesirable complexity to bridge framing system, affecting constructability and performance.	◊	Ramp Framing compatible with Mainline Drawing.	◊◊◊

* Assumes roundabout at the Scenic Highway/Meetinghouse Lane/State Road/Canal St intersection.