US 50/301
WILLIAM PRESTON LANE JR. MEMORIAL (BAY) BRIDGE

LIFE CYCLE COST ANALYSIS

MDTA

December 2015

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MARYLAND TRANSPORTATION AUTHORITY

Prepared by RK&K and Ammann & Whitney

EXECUTIVE SUMMARY

MDTA initiated the Bay Bridge Life Cycle Cost Analysis (Bay Bridge LCCA) to understand the potential approaches and costs to implement Bay Bridge and approach roadway improvements in several future time frames.

The existing Bay Bridge structures are currently in satisfactory condition. The structural analysis shows that with programmed and anticipated rehabilitation and maintenance the existing structures can be maintained in fair or better condition through 2065, at which point the eastbound structure will be 113 years old and the westbound structure will be 92 years old. Beyond 2065, it is difficult to project what rehabilitation and maintenance would be required to keep the bridges in fair or better condition, but it is likely that major rehabilitation projects would be required that would necessitate extensive short-term and/or long-term lane closures. These future projects could have a major, detrimental impact on available bridge capacity and operations. Therefore, 2065 was identified as the horizon year for when Bay Bridge improvements would have to be implemented.

Traffic forecasting and analyses efforts were performed to establish the hourly traffic carrying capacity of the existing bridges, evaluate existing and future traffic operations to assess when the bridge capacity is no longer sufficient, and identify the capacity needed to accommodate future traffic demand. Both the Bay Bridge and the approach roadways within the study limits were analyzed. The traffic analysis shows that without additional capacity by 2040 there will significant queues every day of the week during the summer months. Daily queues in the eastbound direction could extend up to 13 miles. Daily westbound queues could extend three miles and Sunday queues could extend up to 14 miles. Even during non-summer months there would be eastbound queues of up to a mile on Friday evenings and Saturday afternoons.

The traffic analysis showed that to accommodate traffic demand through the study time frame, 8-total Bay Bridge lanes are required, with five lanes in the peak direction and three lanes in the off-peak direction. Similarly, eight mainline lanes (four per direction) are needed along US 50/301 approaching the bridge within the study limits. However, MDTA could consider smaller scale, less costly improvements to the existing bridges that would provide six total bridge lanes. This approach would provide more capacity than the existing condition, but less than is needed to fully accommodate future traffic demand in 2040. Four Build Options were developed to provide the future 8-lane or 6-lane capacity. These Options are described in **Table ES-1**.

Table ES-1. Build Options

Option	Option Components
Build Option 1	• Maintain existing Bay Bridge structures • Provide a new 3-lane Bay Bridge structure • Widen the US 50/301 mainline by one lane
Build Option 2	• Demolish the existing eastbound Bay Bridge • Provide a new 5-lane Bay Bridge structure • Widen the US 50/301 mainline by one lane
Build Option 3	• Demolish both existing Bay Bridge structures • Provide a new 8-lane Bay Bridge structure • Widen the US 50/301 mainline by one lane

Option	Option Components
Build Option 4	• Maintain existing westbound Bay Bridge • Widen and rehabilitate existing eastbound bridge to three lanes • Maintain US 50/301 mainline (no widening)

The Build Options would also include roadway life cycle improvements and programmed and anticipated Bay Bridge rehabilitation and maintenance through 2065. Roadway life cycle improvements include periodic resurfacing of the mainline pavement and reconstruction of the mainline bridges and overpasses within the study limits. For comparison, a No Build Option was developed, which included only the roadway life cycle improvements and programmed and anticipated Bay Bridge rehabilitation and maintenance.

Cost estimates for the Build and No Build Options were developed and then life cycle costs were estimated based on different time frames when the Build Options could be implemented, and when roadway life cycle improvements and Bay Bridge rehabilitation and maintenance would occur. Four time frames were considered:

- 2035, which was considered the earliest feasible completion date for a new Bay Bridge project based on the assumed durations for planning, design, and construction,
- 2040, which was the year of the future traffic analysis,
- 2050, and
- 2060.

The 2050 and 2060 time frames would only apply to Build Options 1, 2, and 3. Build Option 4 would only provide six total bridge lanes, which would be insufficient for projected demand beyond 2040, so it was determined that this approach would not be used if improvements were to be implemented after 2040.

Life cycle costs for each of the four Build Options were developed for the four time frames, yielding 14 Build Option scenarios and a No Build scenario. The life cycle costs were developed using an inflation rate of 2.75% and a discount (interest) rate of 2.9%. The results of the 15 life cycle cost scenarios are presented in **Table ES-2**.

Table ES-2. Life Cycle Costs for Build Option No Build Option Scenarios (in 2014 dollars)

Time Frame	Build Option 1 ($ billion)	Build Option 2 ($ billion)	Build Option 3 ($ billion)	Build Option 4 ($ billion)	No Build ($ billion)
2035	$5.06	$5.45	$5.94	$3.89	$3.25 through 2065
2040	$5.01	$5.58	$6.09	$3.89	
2050	$5.02	$5.67	$6.46	N/A	
2060	$4.98	$5.71	$6.85	N/A	
Life cycle costs include maintenance and rehabilitation costs (in 2014 dollars) for the existing bridges: Eastbound bridge, $1.23 billion; westbound bridge, $1.45 billion.					

In addition to these life cycle costs, MDTA considered the residual value that could be estimated for the Bay Bridge structures at the end of the study time frame in 2065. In 2065, the existing structures, which averaged together will be more than 100 years old, would have less value because they would be near the end of their design life than a new structure built between 2035 and 2060. These values ranged from $30 million for the No Build, where only the unmodified existing structures would remain in 2065, to $1.9 billion for Build Option 3 where a only new 8-lane bridge would remain.

The Bay Bridge LCCA does not include recommendations for a preferred Build Option or the timing to implement those improvements. There are numerous issues that must be addressed before an option or time frame could be chosen, including understanding the position of key political and community stakeholders affected by the Bay Bridge, especially on the Eastern Shore, a determination of when traffic operations necessitate providing additional capacity, and public and political perspectives on Bay Bridge operations and future improvements. Given the scope of the Build Options and the numerous critical environmental features in proximity to the project, especially the Chesapeake Bay, a NEPA Study would have to be completed for any proposed improvements.

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I. INTRODUCTION

A. Project Overview and Background

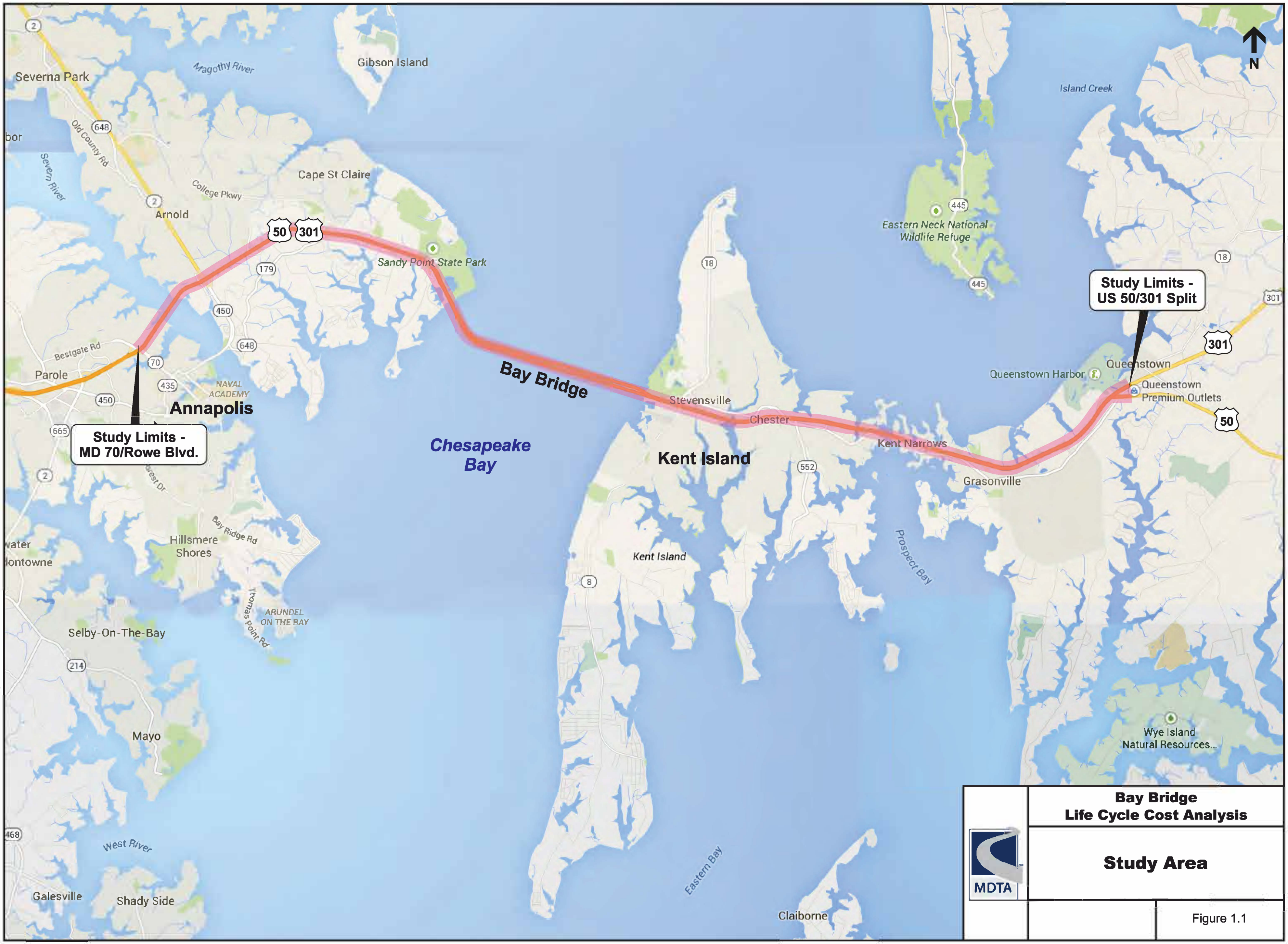
The Maryland Transportation Authority (MDTA) completed the William Preston Lane Jr. Memorial (Bay) Bridge Life Cycle Cost Analysis Study (Bay Bridge LCCA) to evaluate the traffic operations and structural condition of the Bay Bridge, and to understand the costs and time frame associated with implementing future Bay Bridge improvements. The study also evaluated the complementary improvements that would be needed if/when a new structure(s) were built including mainline US 50/301 improvements.

The project limits extend from just west of the Severn River Bridge (near Rowe Boulevard) to the US 50/301 Split on the Eastern Shore, a distance of 21 miles (including the Bay Bridge). The study limits extend well beyond the Bay Bridge because of the major role the Bay Bridge plays in regional transportation as the only crossing of the Chesapeake Bay in Maryland and as the primary connection between the Eastern Shore and the Baltimore and Washington metropolitan areas. As such, if improvements were only made to the Bay Bridge, they would not address the potential capacity limitations of US 50/301 on both sides of the bridge and would; therefore, not provide the regional transportation improvements needed to accommodate future traffic demand. The study area is shown in **Figure 1.1**.

The Bay Bridge LCCA Study time frame extended from the present (2014) through 2065. The latter year was identified because it represents the out year for when maintenance and rehabilitation of the existing bridges has been programmed and/or studied by MDTA. Beyond this date it is hard to predict the maintenance or rehabilitation projects that will be required or the costs associated with those projects.

Prior to the Bay Bridge LCCA, MDTA completed several Bay Bridge studies, including a study prepared by the Bay Crossing Task Force in 2006, to understand future needs for the Bay Bridge and travel across the Bay. In addition, the Maryland State Highway Administration (SHA) is currently evaluating capacity enhancements for the Severn River Bridge to address congestion on US 50/301 in the eastbound direction at that location. These previous and on-going studies were reviewed as part of the Bay Bridge LCCA Study. MDTA coordinated with SHA during the development of the Bay Bridge LCCA, including traffic modeling and growth assumptions, and ongoing and planned US 50/301 corridor improvements.

The Bay Bridge LCCA focused on current and future traffic operations, the costs needed to maintain or remove the existing bridges, construct new structures, and provide roadway improvements. The study did not include an analysis of the user costs or benefits, or any of the operational issues associated with lane or roadway closures while maintaining the existing Bay Bridge structures.



Bay Bridge
Life Cycle Cost Analysis

Study Area

Figure 1.1

B. Existing Conditions

The existing transportation network within the study area was reviewed. In addition, major community and environmental resources were identified.

1. Bay Bridge

The existing Bay Bridge consists of two structures. The southern structure carries two lanes of eastbound US 50/301 across the Chesapeake Bay. The northern structure carries three lanes of westbound US 50/301 across the Bay. Both structures are configured to allow two-way, “contra-flow”, operation. The typical contra-flow operation uses the left lane of the westbound structure for eastbound traffic. Contra-flow operations are typically only used on the eastbound structure when there is maintenance or an incident on the westbound span. Roadway crossovers on both sides of the bridge facilitate contra-flow operations.

Additional information on the existing structures is presented in Section II.

2. Approach Roadways

US 50/301 is a six-lane freeway through the study area. There are numerous auxiliary lanes at and between interchanges. The mainline varies from a closed median to an open grass median through the study limits. Shoulder widths also vary through the study limits with, in general, full 10 to 12 foot wide right shoulders and narrower 2 to 10 foot wide left shoulders.

There are six interchanges within the study limits on the western shore: MD 70, MD 2/MD 450, Bay Dale Drive, MD 179, Whitehall Road, and Oceanic Drive. The Whitehall Road interchange is a right-in/right-out interchange along eastbound US 50/301 only. There are 13 interchanges within the study limits on the Eastern Shore with MD 8, Chester River Beach Road, Nesbit Road, and the US 50/301 split being “traditional” interchanges and the other nine right-in/right-out interchanges. In addition to the many interchanges, there are frontage roads located along both directions of the mainline from just west of MD 179 to Oceanic Drive on the western shore and intermittently from MD 8 to just east of Nesbit Road on the Eastern Shore.

In addition to the Bay Bridges, there are numerous other structures within the study limits which include two major bridges: the Severn River Bridge between MD 70 and MD 450 on the western shore and the Kent Narrows Bridge connecting Kent Island and the remainder of the Eastern Shore. Neither bridge has full shoulders. SHA is currently studying improvements to reconfigure the Severn River Bridge to provide an additional eastbound lane without widening the bridge.

The Bay Bridge toll plaza is located along eastbound US 50/301 on the western shore between the Oceanic Drive interchange and the western landing of the bridge (only eastbound vehicles are tolled). The toll plaza includes 11 toll lanes and is operated to allow vehicles to access both the eastbound and westbound bridge if contra-flow operations are in effect.

3. Environmental Resources

The most significant environmental feature within the study limits is the Chesapeake Bay, but on the western shore, the US 50/301 mainline also crosses the Severn River and several smaller tributaries that feed the Bay. On the Eastern Shore, the mainline crosses Kent Narrows (which separates Kent Island from the remainder of the Eastern Shore), Thompson Creek, and several smaller tributaries that feed the Bay.

There are numerous wetlands adjacent to the mainline and interchanges. US 50/301 is within the 100-year floodplain adjacent to the east and west Bay shores and near Kent Narrows.

The mainline runs adjacent to Sandy Point State Park on the western shore and Terrapin Beach Park on the Eastern Shore. US 50/301 passes through several forested areas on the western shore and on the eastern limits of the study area on the Eastern Shore. US 50/301 is adjacent to the Stevensville Historic District located on the Eastern Shore just east of MD 8.

II. BAY BRIDGE STRUCTURAL EVALUATION

The Bay Bridge LCCA included an evaluation of the existing Bay Bridge structures to identify programmed and future rehabilitation and ongoing maintenance needed to keep the structures serviceable through the study time frame. The costs for bridge rehabilitation and maintenance were computed and included in the overall life cycle cost analysis.

A. Current Bridge Condition

MDTA has an ongoing condition assessment program for the Bay Bridge, as it does for all its major structures, which includes visual inspections and structural evaluations. Condition statements are used to describe structural condition and are defined as follows:

a. Very good condition – no problems noted.
b. Good condition – some minor problems.
c. Satisfactory condition – structural elements show some minor deterioration.
d. Fair condition – all primary structural elements are sound but may have minor section loss, cracking, spalling, or scour.
e. Poor condition – advanced section loss, deterioration, spalling, or scour.
f. Serious condition – loss of section, deterioration, spalling or scour have seriously affected primary structural components.

Sections A.1 and A.2 below provide a condition summary of the eastbound and westbound spans, based on the *2014 Executive Summary Report* (Bay Bridge inspection report).

1. Eastbound Bridge Condition

Overall, the eastbound bridge is in satisfactory condition. The general condition of the major bridge elements is as follows:

a. The bridge deck and approach slabs are in fair condition.
b. The superstructure members in the beam spans, girder spans, deck truss spans, through-truss spans, and suspension spans are in satisfactory condition.
c. The concrete abutments, concrete piers and pier caps, concrete anchorages and steel towers are in satisfactory condition.
d. The substructure and channel are in satisfactory condition.

There are Priority 1 Repair contracts (for defects identified as needing repair within one year of being identified) presently under construction addressing various bridge deck and approach deficiencies, various superstructure deficiencies, and various substructure deficiencies. In addition, other contracts, including painting of the superstructure, structural steel, and bearings are under development.

2. Westbound Bridge Condition

Overall, the westbound bridge is in fair condition. The general condition of the major bridge elements is as follows:

a. The bridge deck slabs and approach slabs are in fair condition.
b. The superstructure members in the beam spans, girder spans, deck truss spans, through-truss spans and suspension spans are in fair condition.
c. The concrete abutments, concrete piers and pier caps, concrete anchorages and steel towers are in fair condition.
d. The substructure and channel are in satisfactory condition.

There are Priority 1 Repair contracts presently under construction addressing various bridge deck and approach deficiencies. There are Priority 1 Repair and Painting contracts presently under construction addressing various superstructure deficiencies and various substructure deficiencies.

B. Programmed/Future Maintenance and Rehabilitation Projects

A study of the past and future anticipated rehabilitation costs for the eastbound and westbound Bay Bridge structures was performed as part of the Bay Bridge LCCA to present probable expenditures to maintain the bridges in satisfactory condition through the year 2065. At that time, the eastbound bridge will have been in service for 113 years and the westbound bridge for 92 years. The projected rehabilitation expenditures are based on current conditions, load rating analyses, and MDTA's long-range needs. It is difficult to project with any measure of certainty the required rehabilitation and maintenance needs beyond 2065. However, it is anticipated that maintaining the serviceability of these structures beyond 2065 will require major superstructure and substructure rehabilitation/replacement. These major replacement projects beyond 2065 will likely necessitate partial closures of the structures during construction, which could include regular short-term closures during peak periods and long-term lane closures. It may also be necessary to close an entire structure for short durations. These more extensive lane closure requirements would make this level of rehabilitation problematic without prior provision for additional capacity.

MDTA has more than 20 rehabilitation projects programed for both existing structures, which include on-call structural repairs, painting, deck rehabilitation, suspension span rehabilitation, and numerous smaller projects to address bridge structural, traffic, and electrical elements.

Based on the current condition of the Bay Bridge structures, numerous future projects are anticipated. These include suspension span rehabilitation, deck replacement, superstructure, and substructure replacement/repairs, painting, future maintenance, and capital improvements.

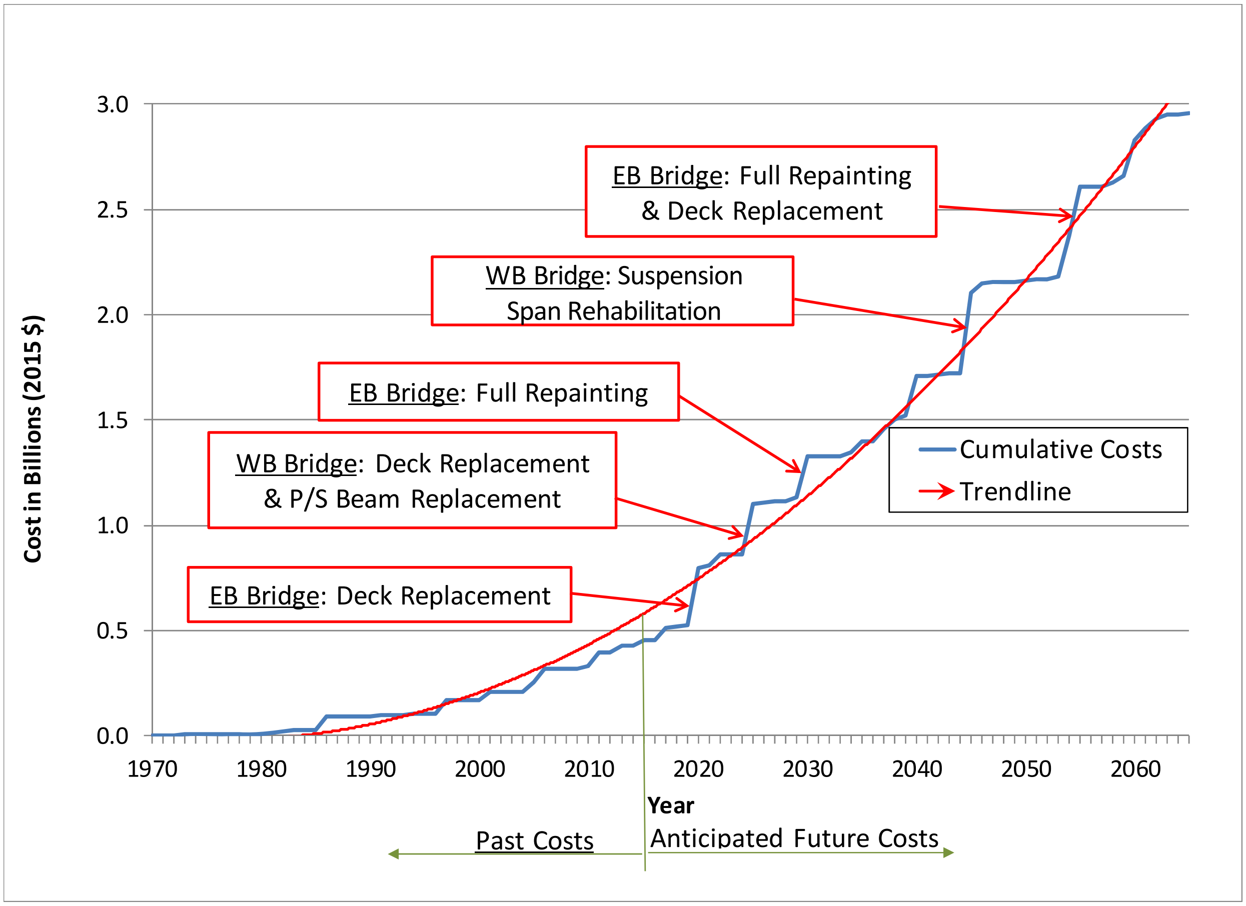
C. Maintenance and Rehabilitation Costs

The total past and future expenditures (through 2065) for each Bay Bridge structure are summarized in **Table 2.1**. The cumulative costs are depicted in **Figure 2.1**. The future costs were included as part of the life cycle costs presented in Section V.

Table 2.1. Bay Bridge Rehabilitation, Maintenance, and Improvement Costs (2014 dollars)

Eastbound Bridge Costs (in millions of dollars)	
Rehabilitation Costs from 1952 to 2014	$217
Anticipated Rehabilitation and Maintenance Costs from 2015 to 2065	$1,227
Westbound Bridge (in millions of dollars)	
Rehabilitation Costs from 1973 to 2014	$212
Anticipated Rehabilitation and Maintenance Costs from 2015 to 2065	$1,453
Total Anticipated Future Costs for Both Structures	**$2,680**

Figure 2.1. Eastbound and Westbound Bay Bridge Cumulative Rehabilitation Costs – Both Structures Combined



III. EXISTING BRIDGE CAPACITY AND POTENTIAL FUTURE TRAFFIC DEMAND

This chapter discusses the traffic analyses and forecasting efforts performed as part of the Bay Bridge LCCA. After establishing the hourly traffic carrying capacity of the current bridges, existing and future traffic operations were evaluated to assess when the existing bridge capacity would be insufficient to accommodate future traffic demand. Both the Bay Bridge and the approach roadways within the study area were analyzed.

A. Existing Bridge Capacity

1. Data Collection

Traffic volume data from two sources were obtained to analyze existing traffic patterns across the bridge. First, data from the Bay Bridge toll plaza were obtained for the months of October 2012, March 2013, May 2013, and August 2013. In addition, data from a new permanent traffic recording station just east of the toll plaza were obtained from June 19, 2013 through September 12, 2013.

The toll plaza data provide highly accurate volume counts for every day of the year, but only for the eastbound direction. The permanent traffic recording station collects data for both directions of traffic, but with a somewhat lower degree of accuracy.

2. Hourly Capacity

The capacity of the Bay Bridge is a fundamental metric for evaluating its operational performance. Roadway capacity is typically estimated using the techniques outlined in the Highway Capacity Manual (HCM). These traditional analysis methods assume an ideal per-lane capacity, and apply adjustment factors to account for lane and shoulder width, grade, truck percentage, traffic composition, etc., to develop an appropriate capacity estimate.

Although traditional analysis methods based on the HCM generally provide reasonable estimates of capacity for basic freeway segments, estimating the capacity of the Bay Bridge is more challenging due to its numerous unique characteristics, including long segments at a high elevations over open water (causing some drivers to adjust speed to take in picturesque views, and others to change lanes and reduce speed out of a fear of heights), contra-flow operation on the westbound span, and highly seasonal traffic in the summer months with drivers that may be unfamiliar with the area. For these reasons, establishing an accurate capacity for the bridge has been challenging.

Over the years, a number of capacity estimates have been developed based on a variety of traditional theoretical analysis methods, as illustrated in **Table 3.1**.

In addition to these prior capacity estimates, traffic volumes have also been recorded or observed during peak travel periods at various times over the past decade. A summary of historic observed maximum volumes is provided in **Table 3.2**.

Table 3.1: Previous Capacity Estimates (vehicles/hour) of the Bay Bridge

Source	Eastbound				Westbound			
	2 Lanes	per Lane	3 Lanes (w/ contra-flow)	per Lane	2 Lanes (w/ contra-flow)	per Lane	3 Lanes	per Lane
1/13/2009	3,985	1,993	5,585	1,862	3,650	1,825	5,870	1,957
3/18/2005	3,280	1,640	4,890	1,630	3,340	1,670	5,070	1,690
	4,250	2,125	5,880	1,960	3,710	1,855	6,180	2,060
6/2005	3,400	1,700	4,900	1,633	3,200	1,600	5,100	1,700
	3,985	1,993	5,585	1,862	3,650	1,825	5,870	1,957

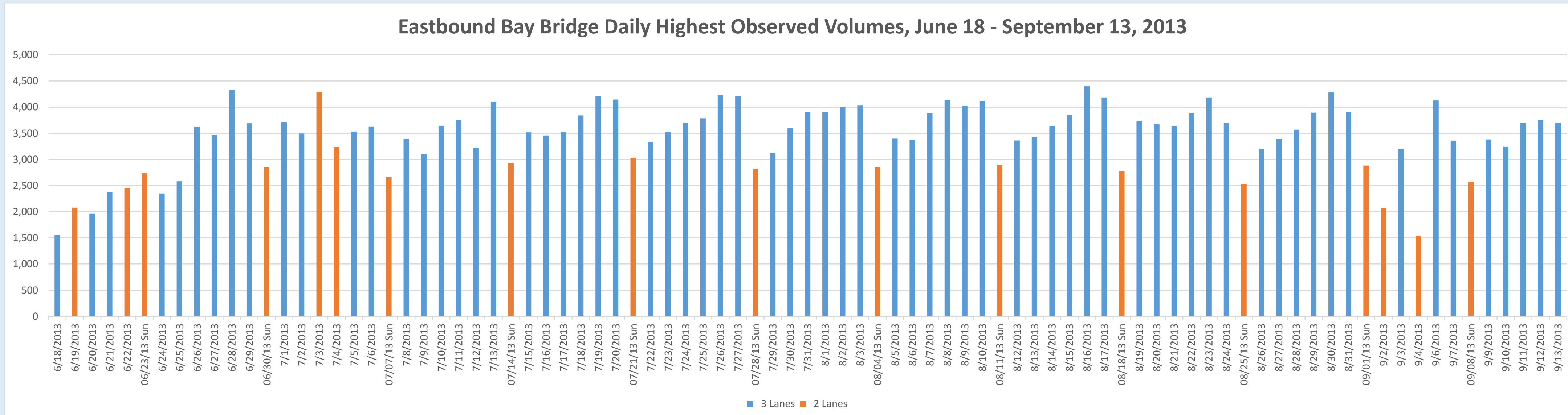
Table 3.2: Historic Observed Maximum Volumes (vehicles/hour) on the Bay Bridge

Date	Eastbound				Westbound			
	2 Lane	per Lane	3 Lane	per Lane	2 Lane	per Lane	3 Lane	per Lane
Max. Obs. 2002-2004	3,950	1,975	4,890	1,630	3,170	1,585		
Max. Obs. Summer 2003 and 2004			4,892	1,631				
Max. Obs. 10/2006 thru 9/2007							4,722	1,574
Max. Obs. 10/2006 thru 10/2008			4,955	1,652				

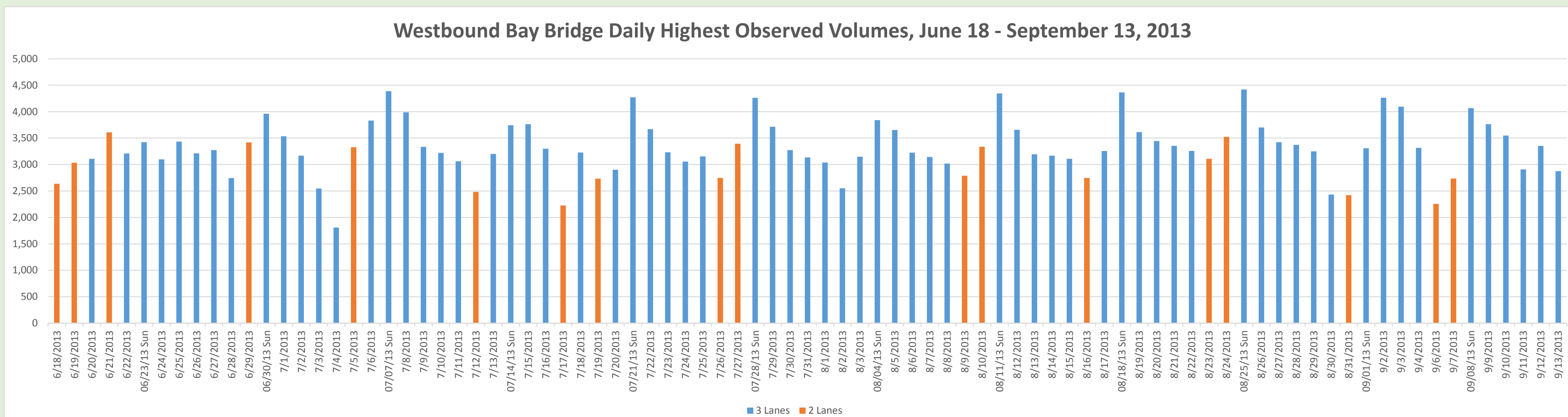
In 2013, a permanent count station was installed at the Bay Bridge that continuously monitors traffic volumes on the bridge. Unlike the toll plaza data, which only provides data in the eastbound direction, the count station provides data in both directions. Data collected from this station during summer 2013 showed the highest observed volumes in each direction, under one-way and contra-flow conditions (see **Figure 3.1**). These analyses revealed that the maximum observed traffic flow never exceeded 3,495 vehicles/hour in the eastbound direction, and 4,420 vehicles/hour in the westbound direction. Under contra-flow operations, the maximum observed traffic flows were 4,400 vehicles/hour and 3,355 vehicles/hour in the eastbound and westbound direction, respectively. These values are below the theoretical capacity estimates shown in **Table 3.1**.

Therefore, rather than using theoretical methods to estimate the capacity of the Bay Bridge, it was established based on actual traffic volumes measured on the bridge during some of the heaviest periods of traffic demand of the year (considered to be at or above "capacity" conditions). Based on the continuous data collected at the permanent count station, and in consultation with MDTA, the directional capacities in **Table 3.3** were established for this study. Essentially, these are assumed to be the highest volumes of traffic that the bridge can carry under ideal conditions. If the demand (volume) exceeds these capacity thresholds, traffic operations would break down (Level of Service (LOS) F). Accordingly, the threshold for LOS E was selected to be 150 vehicles/hour/lane below the LOS F thresholds shown in **Table 3.3**.

EASTBOUND



WESTBOUND



Legend

- 3 Lanes (standard operation)
- 2 Lanes (contra-flow operation)

Chesapeake Bay Bridge
Life Cycle Cost Analysis

Highest Observed Daily Volumes; Summer 2013

Figure 3.1

Table 3.3: Recommended Bridge Capacity Values (vehicles/hour)

Eastbound				Westbound			
2 Lanes		3 Lanes		2 Lanes		3 Lanes	
Per Lane	2 Lanes	Per Lane	3 Lanes	Per Lane	2 Lanes	Per Lane	3 Lanes
1,600	3,200	1,600 (EB Span) 1,500 (contra-flow lane)	4,700	1,600	3,200	1,600	4,800

B. Projected Traffic Growth

1. Bay Bridge

Forecasts for Bay Bridge traffic were prepared for the year 2040. The forecasts were developed by combing four different components:

1. Historic volumes,
2. Growth trends,
3. Output from the Integrated Bay-Nice Model (IBNM), and
4. Trend line analysis.

Historic volumes for 1995 through 2013 were obtained from the Bay Bridge toll plaza. The average annual daily traffic volumes are provided in **Table 3.4**. Between 1995 and 2007, traffic volumes increased annually, reaching a maximum of 79,900 vehicles per day (vpd) in 2007. The growth from 1995 to 2007 represents an annual linear growth rate of 2.5 percent. Following the 2008 recession, traffic volumes in 2009 decreased and by 2013 had still not returned to the levels seen in 2007. In fact, from 2007 to 2012 traffic *decreased* at a rate of 0.7 percent per year. These volume fluctuations mirror nationwide trends. Combining the prior growth with the more recent declines in traffic volumes, for the entire period from 1995 – 2013, traffic volumes grew at an annual rate of 1.6 percent.

Table 3.4: Bay Bridge Historic Daily Volumes

Year	Average Annual Daily Traffic
1995	55,200
2000	64,900
2005	71,100
2006	72,700
2007	73,900
2008	73,300
2009	69,800
2010	71,200
2011	72,300
2012	71,700
2013	70,700

The Integrated Bay-Nice Model (IBNM) is a travel demand model that was developed for MDTA as part of the 2006 Bay Bridge Task Force effort. This travel demand model combined the travel demand models from four metropolitan areas (Fredericksburg Area Metropolitan Planning Organization, National Capital Transportation Planning Board, Baltimore Regional Transportation Board, and Delaware Department of Transportation) into a single model. Development of this single model was needed to study regional traffic patterns, specifically, potential shifts in traffic patterns between the Eastern and western shores of Delaware, Maryland and Virginia, because the four source models used the Chesapeake Bay as their respective model boundaries. Only by combining the four models was it possible to study traffic flows across the Bay Bridge as well as on potential parallel routes such as I-95 through Cecil County, Maryland and New Castle County, Delaware.

The original IBNM had a 2005 base year and 2030 horizon year. However, the goal for this study was to develop year 2040 traffic forecasts, ten years beyond the horizon year of the original IBNM. Therefore, the IBNM was updated for this study to year 2035 using updated information from the respective Metropolitan Planning Organizations. Specifically, the base and future year model networks were updated with new roadways that were constructed since 2005 (such as the Intercounty Connector, MD 200) or are planned to be in place by 2035 (such as US 301 in Delaware and US 50 improvements between US 301 and MD 404), and verified that the land use assumptions for 2030 in the original IBNM model now more closely reflected 2035 conditions.

It should be noted that the updated IBNM was not sensitive to the number of lanes provided across the Bay. That is, a capacity increase on the Bay Bridge did not result in a higher assignment of traffic under 2035 conditions. This result would indicate that all the traffic that theoretically wants to use the bridge can use it, and that traffic volumes are either not constrained by capacity or alternative routes are not attractive enough for any excess demand, even in 2035, to shift their travel route. It should be noted, however, that the IBNM represents average weekday conditions, and does not account for the large seasonal fluctuations seen on the Bay Bridge.

Final projected traffic growth for the Bay Bridge was estimated by combining the historic volumes, growth trends, and IBNM output into one regression analysis. Essentially, the IBNM output was considered as an additional future data point to the historic volumes, so that the growth factor was based both on historic data as well as future projected volume. Through an iterative process, and comparing projections with other studies for reasonableness, including the forecasts being prepared simultaneously by SHA for the nearby Severn River Bridge Study using the Maryland Statewide Model, the following growth assumptions were established for this study:

- No growth through 2016 (accounts for the anticipated lag in return to typical traffic volume growth following the 2008-2009 recession), and
- 1.3 percent per year linear growth from 2017 through 2040.

Under these assumptions, the resulting 2040 average daily volume is projected to be 92,800 vehicles per day. **Table 3.5** provides a comparison of the final projected volume to other recently completed forecasts for the Bridge.

Table 3.5: Summary of Forecasts

Traffic Forecast Description	Annual Growth Rate	Existing 2013	2025	2030	2035	2040
IBNM Raw Model Output	3.3%	82,072		130,587	N/A	N/A
Trend Line Volume Forecasts	1.24%	70,700		91,600	96,300	101,000
Final Volume Forecasts (Zero Growth Through 2016)	***1.3%***	***70,700***		***83,600***	***88,200***	***92,800***
Maryland Statewide Model				89,300		
Bay Bridge T&R Forecast			71,200 (2023)			
Bay Bridge Needs Forecast (Summer Weekend)			135,000			

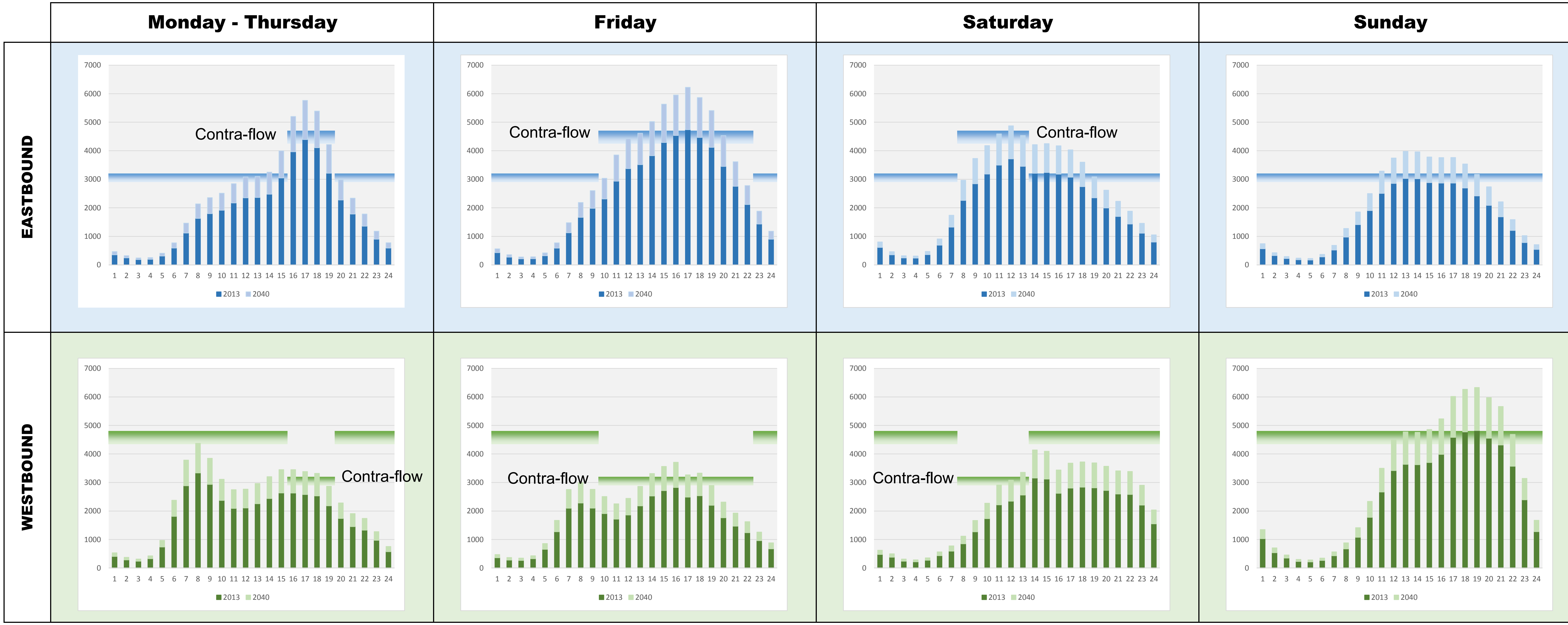
As discussed earlier, the Bay Bridge experiences significant seasonal traffic volume fluctuations. During summer months, weekend traffic destined for the Maryland and Delaware beaches results in severe congestion on the eastbound approach on Friday afternoons, and on the westbound approach on Sunday evenings. To estimate both the monthly variation as well as the diurnal patterns for each weekday, hourly traffic counts at the Bay Bridge toll plaza and the permanent count station were analyzed. Daily and hourly correction factors for summer and non-summer traffic conditions were developed from the entire data set to obtain typical hourly eastbound and westbound traffic volumes, and for both summer and non-summer periods for the following days:

- Monday through Thursday average,
- Friday,
- Saturday, and
- Sunday.

Volumes were developed for summer and non-summer conditions for both 2013 and 2040. Typical summer conditions were assumed to occur in August; non-summer conditions were assumed to occur in October. **Table 3.6** provides a summary of 2013 and 2040 projected daily volumes. **Figures 3.2** and **3.3** show the corresponding hourly volumes for all scenarios.

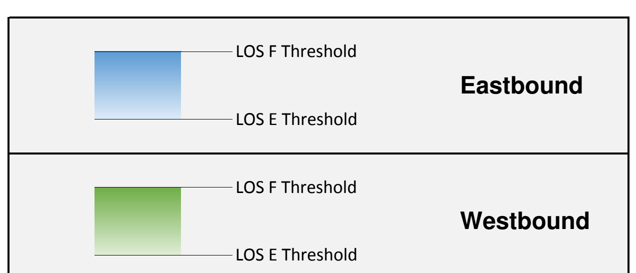
Table 3.6: Projected Daily Volumes

Time Period	Summer		Non-Summer	
	2013	2040	2013	2040
Annual Average	70,700	92,800	70,700	92,800
Monday – Thursday	86,200	113,100	59,200	77,600
Friday	94,300	128,800	73,200	95,900
Saturday	90,200	118,400	63,200	82,800
Sunday	95,900	125,900	57,900	75,900



Note: Exact times of change to contraflow operations vary by day, depending on conditions.

Daily Traffic Volumes (Summer)		
	2013	2040
AADT	70,700	92,800
Mon-Thu	86,200	113,100
Friday	94,300	123,800
Saturday	90,200	118,400
Sunday	95,900	125,900



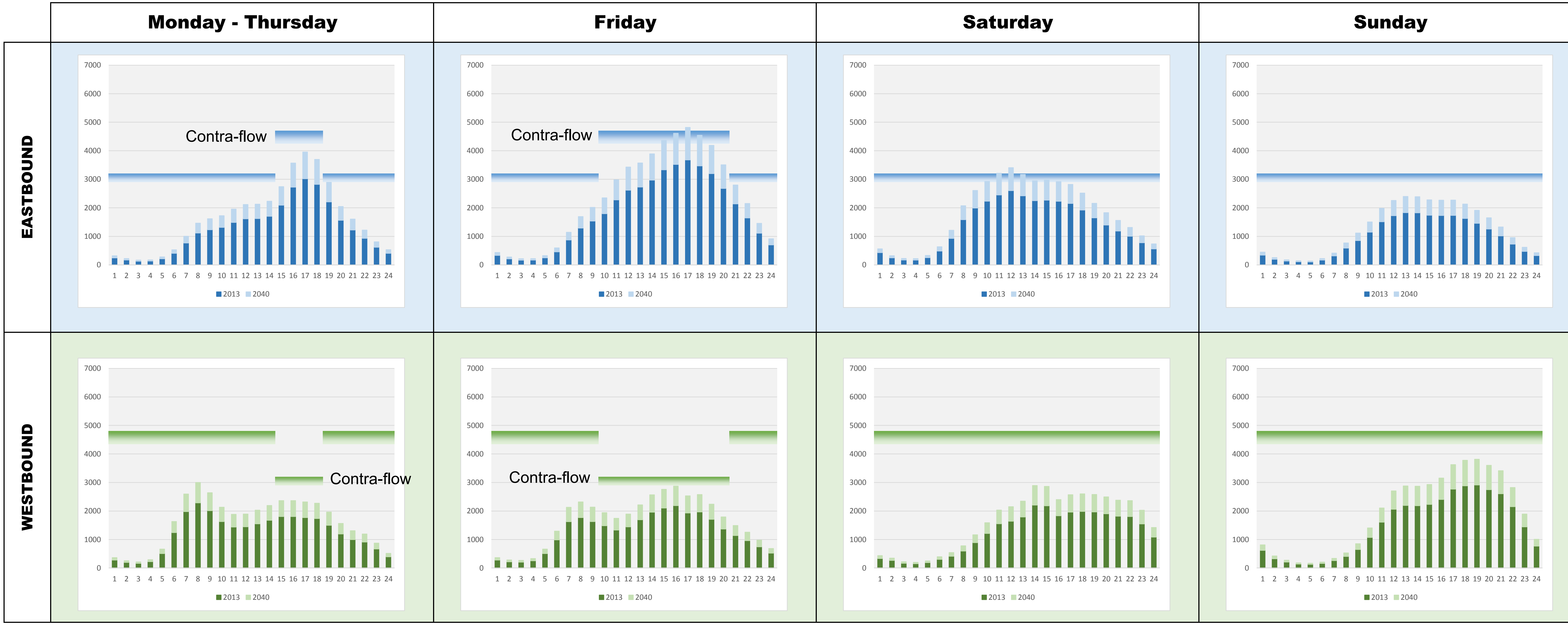
Daily Hours Operating at Level of Service E or F					
	LOS	M-T	Fri	Sat	Sun
Eastbound	E	3	3	3	1
	F	5	6	6	8
	Total	8	9	9	9
Westbound	E	1	0	2	4
	F	3	5	1	7
	Total	4	5	3	11

MDTA

Chesapeake Bay Bridge
Life Cycle Cost Analysis

Daily Volumes and Capacities
2013 Existing and 2040 No Build
Summer Months

Figure 3.2



Note: Exact times of change to contraflow operations vary by day, depending on conditions.

Daily Traffic Volumes (Non-Summer)		
	2013	2040
AADT	70,700	92,800
Mon-Thu	59,200	77,600
Friday	73,200	95,900
Saturday	63,200	82,800
Sunday	57,900	75,900

LOS F Threshold / LOS E Threshold		Eastbound
LOS F Threshold / LOS E Threshold		Westbound

Daily Hours Operating at Level of Service E or F					
	LOS	M-T	Fri	Sat	Sun
Eastbound	E	0	3	5	0
	F	0	1	2	0
	Total	0	4	7	0
Westbound	E	0	0	0	0
	F	0	0	0	0
	Total	0	0	0	0

MDTA

Chesapeake Bay Bridge
Life Cycle Cost Analysis

Daily Volumes and Capacities
2013 Existing and 2040 No Build
Non-Summer Months

Figure 3.3

2. Approach Roadways

In addition to Bay Bridge traffic forecasts, 2040 weekday peak hour volume projections were also developed for the mainline segments of US 50/301 on both the east and west sides of the bridge. The main purpose of the approach roadway projections was to determine, at a planning-level, the number of mainline lanes needed to reasonably accommodate future traffic demand within the study area from Rowe Boulevard to the US 50/US 301 split on Maryland's Eastern Shore. Detailed cross-street projections were not developed.

Weekday peak hour 2040 forecasts for the approach roadways were developed by holding the 2040 typical daily peak hour volumes at the bridge, and adding/subtracting ramp volumes to the east and west. Ramp volumes were generally grown by 0.5 percent per year as most areas along US 50 are well developed; however, based on a review of the 2010 *Queen Anne's County Comprehensive Plan Update*, volumes on the Jackson Creek Road, Chester River Road, and Station Lane/VFW Road interchange ramps were grown at 1, 1.5 and 1 percent per year, respectively, to account for anticipated development on Kent Island. Ramp volumes at the MD 70, MD 2/450, Bay Dale Drive and MD 179 interchanges were matched to those developed for the US 50 Severn River Bridge Study, which is currently underway by SHA. The resulting peak hour volumes on the mainline represent an annual growth of approximately 1.3 percent per year.

Summer Friday peak hour volumes were developed by holding the 2040 Friday peak hour bridge volumes, and adding/subtracting the 2040 weekday peak hour ramp volumes along the mainline.

Summer Sunday peak hour volumes were developed by holding the 2040 Sunday peak hour bridge volumes, reducing the ramp volumes by a factor based on the ratio between typical peak hour and peak Sunday volumes, and then adding/subtracting the adjusted ramp volumes along the mainline. The ramp volume adjustment factors were estimated by calculating the ratio between typical Friday peak and typical Sunday peak volumes for a limited number of ramps for which data was available. Using this process, the ramp volumes on the western shore were reduced by 30 percent, and ramp volumes on the Eastern Shore were reduced by 20 percent.

As a final check on the Friday and Sunday volumes, the ratio of Friday peak/weekday peak and Sunday peak/weekday peak mainline volumes at the eastern and western end of the study area were compared to existing ratios available from nearby automatic traffic recorder (ATR) stations (ATR #24 at the Anne Arundel County/Prince George's County line and ATR #22 south of Longwoods Road in Talbot County). This check confirmed that the computed mainline volumes at the ends of the study area were consistent with weekday/Friday/Sunday patterns found at the ATRs.

C. 2013 and 2040 Operational Analyses

1. Bay Bridge

The hourly volumes for all scenarios were compared with the LOS E/F thresholds discussed in Section III.A. Based on queue observations at the Bay Bridge in the summer of 2013, it was determined that queues begin to form when traffic volumes reach approximately 50 percent of the range between LOS E and LOS F conditions. Thus, queue lengths were estimated by calculating the number of vehicles that exceed this threshold in each hour, and reassigning those vehicles to the next hour. The queue length was then computed by multiplying the total "unmet demand" by an average vehicle length of 25 feet, and dividing that length by the number of lanes that is available for vehicles to queue (3 lanes). An average travel speed of 5 mph in the queue was assumed to estimate queue delay.

The results of the capacity analysis for the Bay Bridge are shown in **Figures 3.2** and **3.3**. Projected queue lengths, with landmarks indicating the potential extent that queues may reach under the various scenarios, are shown in **Figures 3.4** and **3.5**. This information is also summarized in **Figure 3.6**, which shows in which year and under which conditions (summer or non-summer, weekday, Friday, Saturday or Sunday) queues are expected to reach certain lengths. For example, on Fridays during the summer, maximum queues are projected to reach 3 miles by 2025 and 10.8 miles by 2040. During non-summer months, queues would be expected to reach these landmarks beyond 2065.

Examination of **Figures 3.4** through **3.5** yields the following observations:

Non-Summer Months:

- Currently (2013), volumes do not yet reach capacity.

- By 2040, volumes will reach capacity on:
  - Friday evenings in the eastbound direction for 1 hour with up to 1-mile queue.
  - Saturday afternoons in the eastbound direction for 2 hours with up to 1-mile queue.

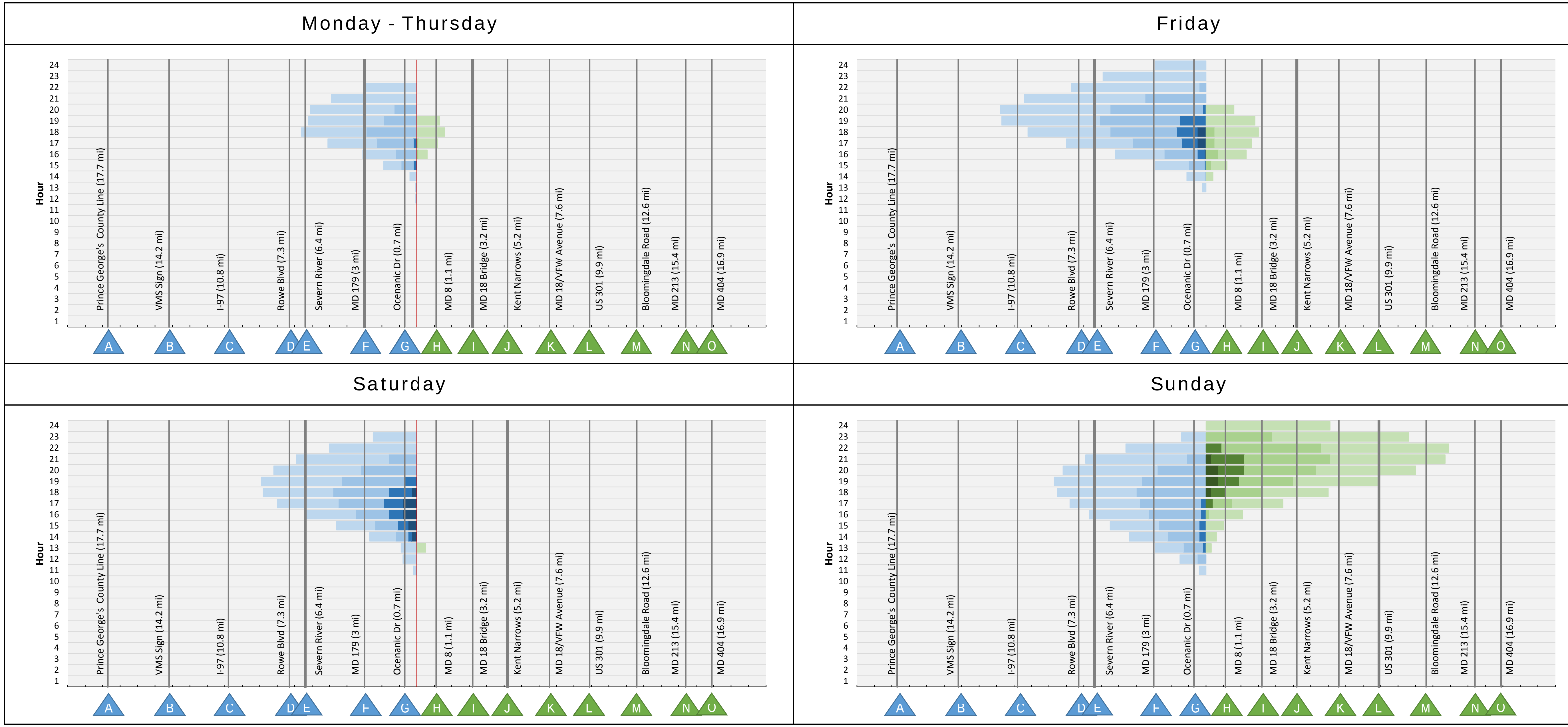
Summer Months:

- Currently (2013), volumes reach capacity on:
  - Friday evenings in the eastbound direction for 1 hour with up to a 1-mile queue.
  - Saturday afternoons in the eastbound direction for 2 hours with up to a 1-mile queue.
  - Sunday evenings in the westbound direction for 1 hour with up to a 1-mile queue.

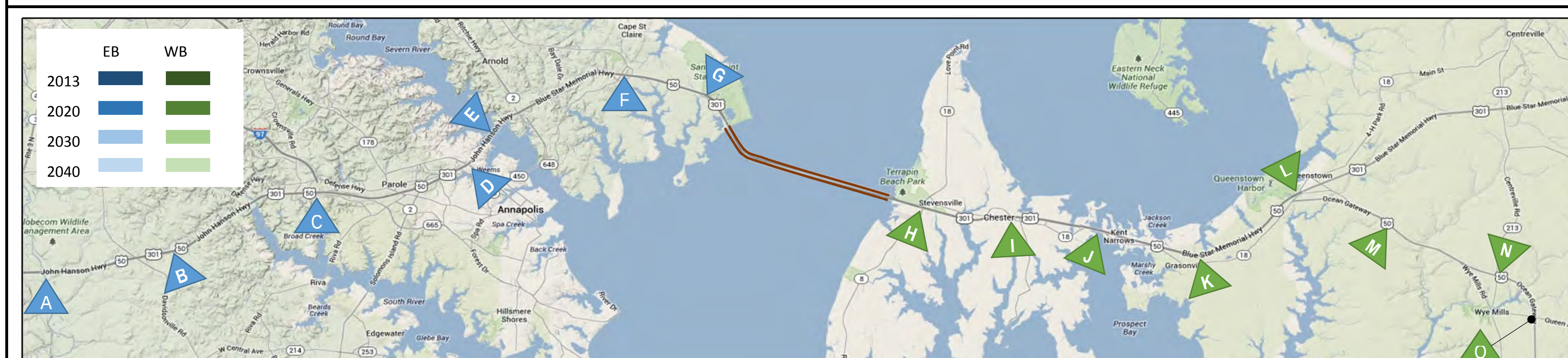
- By 2040, volumes will reach capacity:
  - Every day of the week in both directions.
  - For up to 6 hours, every day in the eastbound direction with up to a 12-mile queue.
  - For up to 5 hours, Monday through Saturday in the westbound direction with up to a 3-mile queue.
  - For 11 hours Sunday in the westbound direction with up to a 14-mile queue.
  - In the eastbound direction, every day of the week will be similar to the congestion and delays currently experienced on the Friday of Memorial Day weekend.
  - In the westbound direction, all Sundays will be similar to the congestion and delays currently experienced on the last day of a July 4th weekend.

2. Approach Roadways

Mainline capacity analyses were performed using the 2010 Highway Capacity Software (HCS) for the mainline segments between MD 70 and the US 50/301 split. The results of the 2040 analyses are provided in **Figures 3.7** and **3.8**. These figures show that without widening, roadways are expected to experience unacceptable operating conditions (LOS E or F), in particular along eastbound US 50/301 during the PM peak hour and Summer Fridays, and along westbound US 50/301 during summer Sundays.



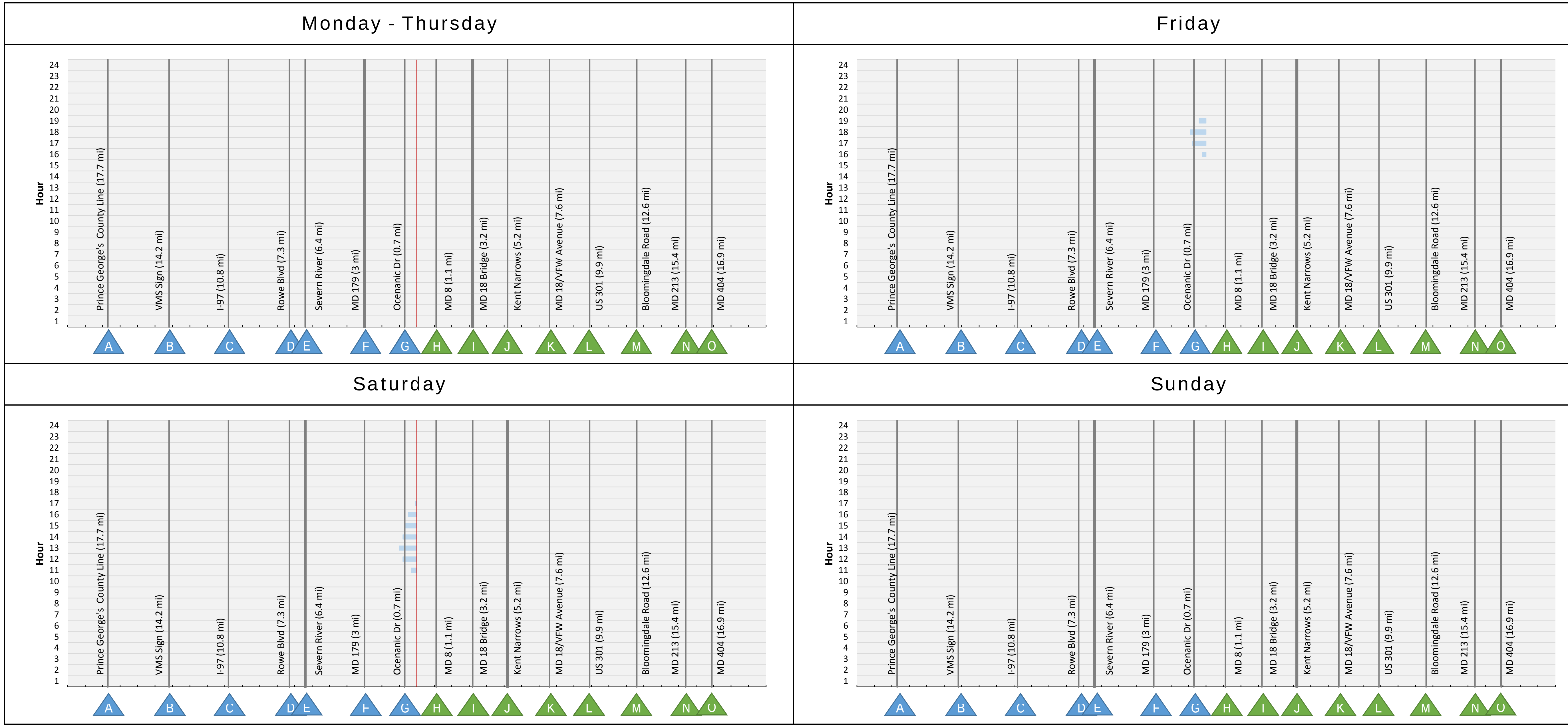
Note: Queue lengths do not account for effect of other upstream bottlenecks (e.g., Rowe Boulevard interchange, Severn River Bridge)



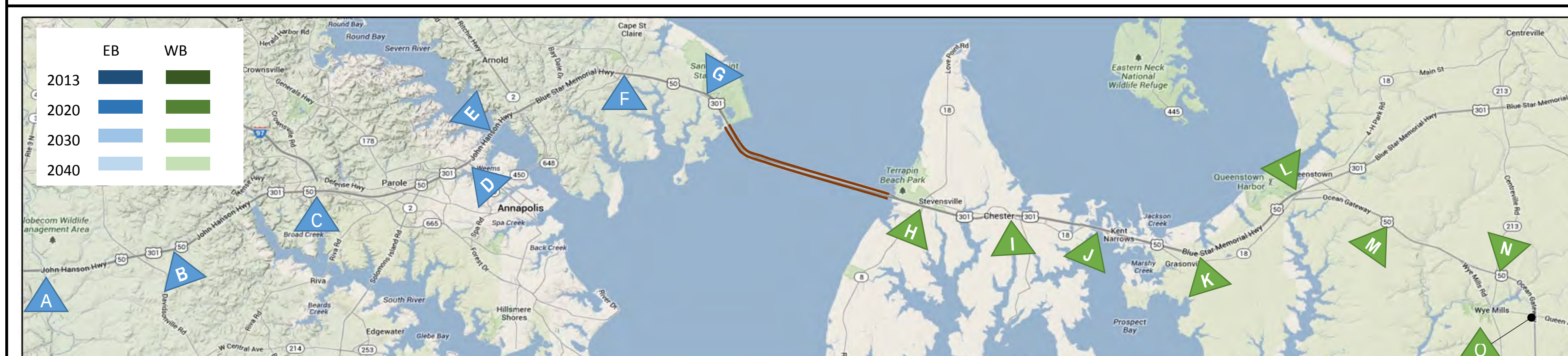
Chesapeake Bay Bridge
Life Cycle Cost Analysis

Estimated Queues by Hour
(2013 **Existing**, 2020, 2030 and
2040 **No Build)**
Summer Months

Figure 3.4



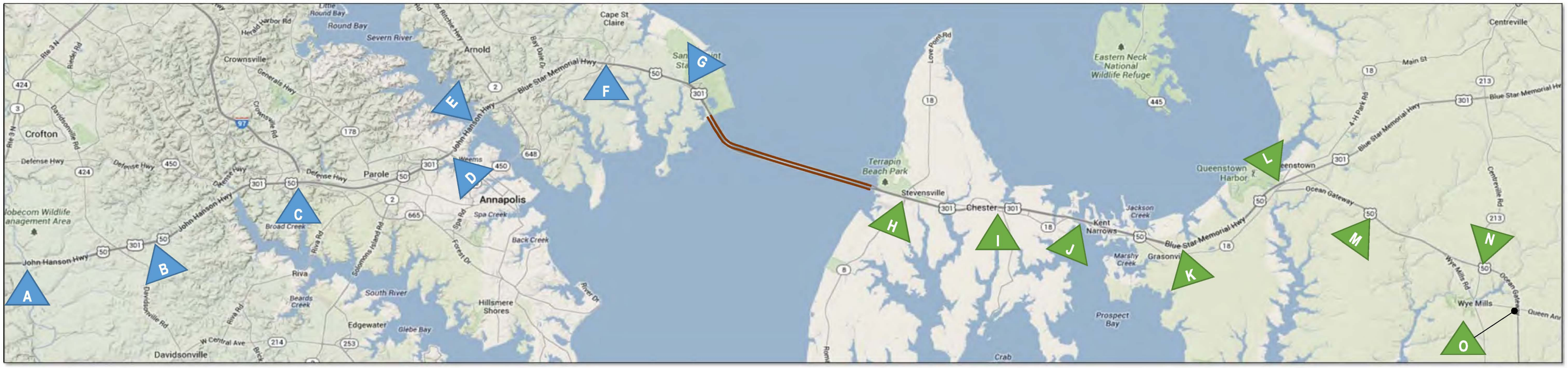
Note: Queue lengths do not account for effect of other upstream bottlenecks (e.g., Rowe Boulevard interchange, Severn River Bridge)



Chesapeake Bay Bridge
Life Cycle Cost Analysis

Estimated Queues by Hour
(2013 **Existing**, 2020, 2030 and 2040 **No Build)**
Non-Summer Months

Figure 3.5



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
Miles from Bridge (delay)	**17.7 (3½ hrs)**	**14.2 (3 hrs)**	**10.8 (2 hrs)**	**7.3 (1½ hrs)**	**6.4 (1¼ hrs)**	**3.0 (½ hr)**	**0.7 (15 min)**	**1.1 (15 min)**	**3.2 (½ hr)**	**5.2 (1 hr)**	**7.6 (1½ hrs)**	**9.9 (2 hrs)**	**12.6 (2½ hrs)**	**15.4 (3 hrs)**	**16.9 (3½ hrs)**
Landmark/ Interchange	Prince George's County line	VMS Sign	I-97	Rowe Boulevard	Severn River Bridge	MD 179 (Cape St. Clair Road)	Oceanic Drive	MD 8	MD 18 Bridge	Kent Narrows Bridge	MD 8/VFW Road	US 301 Split	Blooming-dale Road	MD 213	MD 404
Summer Months															
Mon - Thu			**2055**		**2040**	**2035**			**2055**	**2065+**		**2065+**			
Friday			**2040**		**2035**	**2025**			**2040**	**2055**		**2065+**			
Saturday			**2045**		**2040**	**2025**			**2065+**	**2065+**		**2065+**			
Sunday			**2050**		**2035**	**2030**			**2025**	**2030**		**2035**			
Non-Summer Months															
Mon - Thu			**2065+**		**2065+**	**2065+**			**2065+**	**2065+**		**2065+**			
Friday			**2065+**		**2065+**	**2055**			**2065+**	**2065+**		**2065+**			
Saturday			**2065+**		**2065+**	**2055**			**2065+**	**2065+**		**2065+**			
Sunday			**2065+**		**2065+**	**2065+**			**2065+**	**2065+**		**2065+**			

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Bay Bridge Life Cycle Cost Analysis

Potential Queues Under No-Build Conditions by Location by Year

Figure 3.6

Scenario	Period	Direction	Measure	MD 70 to MD 2/450 (Severn River Bridge)	MD 2/450 to MD 648	MD 648 to Bay Dale Drive	Bay Dale Drive to MD 179	MD 179 to Whitehall Road	Whitehall Road to W.H. Road Slip Ramp	W.H. Road Slip Ramp to Oceanic Drive	Oceanic Drive to Bay Bridge	BAY BRIDGE	Bay Bridge to MD 8	MD 8 to MD 835A	MD 835A to Shopping Center	Shopping Center to Shopping Center	Shopping Center to Cox Neck Road	Cox Neck Road to MD 552	MD 552 to South Piney Road	Piney Creek Road to Dundee Avenue	Dundee Avenue to Piney Narrows Road	Piney Narrows Road to Kent Narrows Road (Kent Narrows Bridge)	Kent Narrows Road to Jackson Creek Road	Jackson Creek Road to Chester River Beach Road	Chester River Beach Road to VFW Avenue	VFW Avenue to Evans Avenue	Evans Avenue to Hess Road	Hess Road to Nesbit Road	Nesbit Road to Ocean Gateway
2040 Weekday (Annual Average) No Build	AM	Westbound	Level of Service	F	E	E	D	C	C	C	C	C	C		B	B			B	B	B	B	C		B				C
			Volume	7,220	6,190	6,205	4,815	3,585	3,585	3,585	3,590	3,590	3,590	3,075	3,125	3,160	3,225	2,955	2,965	2,945	2,945	2,990	3,045	3,225	2,860	3,030	3,200	3,365	3,340
		Eastbound	Volume	3,405	3,070	3,070	2,560	2,030	1,990	1,830	1,750	1,750	1,750	2,350	2,295	2,295	2,295	2,450	2,350	2,355	2,350	2,290	2,315	2,315	2,290	2,290	2,290	2,290	2,315
			Level of Service	C	B	B	B	B	A	A	A	A	A		B	B	B		B			B	B						B
	PM	Westbound	Level of Service	C	C	C	C	B	B	B	B	E	B		C	C			C	C	C	C	C		C				C
			Volume	4,765	4,115	4,110	3,495	2,970	2,970	2,970	2,830	2,830	2,830	3,835	3,790	3,790	3,855	3,570	3,590	3,595	3,595	3,655	3,680	3,690	3,420	3,420	3,420	3,420	3,460
		Eastbound	Volume	8,035	7,285	7,285	6,430	5,130	4,990	4,820	4,730	4,730	4,730	4,815	4,815	4,815	4,815	4,830	4,460	4,515	4,515	4,440	4,495	4,595	4,395	4,395	4,395	4,395	4,335
			Level of Service	F	F	F	E	D	D	D	C	F	D		D	D	D		C			C	C						C
2040 Weekday (Annual Average) Build Options 1, 2, and 3 (8-Lane Bridge and Mainline Widening)	AM	Westbound	Level of Service	D	D	D	C	B	B	B	B	C	B		B	B			B	B	B	B	B		B				B
			Volume	7,220	6,190	6,205	4,815	3,585	3,585	3,585	3,590	3,590	3,590	3,075	3,125	3,160	3,225	2,955	2,965	2,945	2,945	2,990	3,045	3,225	2,860	3,030	3,200	3,365	3,340
		Eastbound	Volume	3,405	3,070	3,070	2,560	2,030	1,990	1,830	1,750	1,750	1,750	2,350	2,295	2,295	2,295	2,450	2,350	2,355	2,350	2,290	2,315	2,315	2,290	2,290	2,290	2,290	2,315
			Level of Service	B	B	B	A	A	A	A	A	A	A		A	A	A		A			A	A						A
	PM	Westbound	Level of Service	C	B	B	B	B	B	B	B	B	B		B	B			B	B	B	B	B		B				B
			Volume	4,765	4,115	4,110	3,495	2,970	2,970	2,970	2,830	2,830	2,830	3,835	3,790	3,790	3,855	3,570	3,590	3,595	3,595	3,655	3,680	3,690	3,420	3,420	3,420	3,420	3,460
		Eastbound	Volume	8,035	7,285	7,285	6,430	5,130	4,990	4,820	4,730	4,730	4,730	4,815	4,815	4,815	4,815	4,830	4,460	4,515	4,515	4,440	4,495	4,595	4,395	4,395	4,395	4,395	4,335
			Level of Service	E	D	D	D	C	C	C	C	B	C		C	C	C		C			C	C						C
2040 Weekday (Annual Average) Build Option 4 (6-Lane Bridge, no Mainline Widening)	AM	Westbound	Level of Service	F	E	E	D	C	C	C	C	C	C		B	B			B	B	B	B	C		B				C
			Volume	7,220	6,190	6,205	4,815	3,585	3,585	3,585	3,590	3,590	3,590	3,075	3,125	3,160	3,225	2,955	2,965	2,945	2,945	2,990	3,045	3,225	2,860	3,030	3,200	3,365	3,340
		Eastbound	Volume	3,405	3,070	3,070	2,560	2,030	1,990	1,830	1,750	1,750	1,750	2,350	2,295	2,295	2,295	2,450	2,350	2,355	2,350	2,290	2,315	2,315	2,290	2,290	2,290	2,290	2,315
			Level of Service	7220	B	B	B	B	A	A	A	A	A		B	B	B		B			B	B						B
	PM	Westbound	Level of Service	C	C	C	C	B	B	B	B	E	B		C	C			C	C	C	C	C		C				C
			Volume	4,765	4,115	4,110	3,495	2,970	2,970	2,970	2,830	2,830	2,830	3,835	3,790	3,790	3,855	3,570	3,590	3,595	3,595	3,655	3,680	3,690	3,420	3,420	3,420	3,420	3,460
		Eastbound	Volume	8,035	7,285	7,285	6,430	5,130	4,990	4,820	4,730	4,730	4,730	4,815	4,815	4,815	4,815	4,830	4,460	4,515	4,515	4,440	4,495	4,595	4,395	4,395	4,395	4,395	4,335
			Level of Service	F	F	F	E	D	D	D	C	C	D		D	D	D		C			C	C						C

Notes:
- Level of Service based on 2010 HCM methodology, except Bay Bridge LOS
- Bay Bridge LOS methodology based on capacities established during project in coordination with MDTA
- Under No Build conditions, Bay Bridge LOS assumes reversible lane operation with 3 lanes in the peak direction, and 2 lanes in the non-peak direction
- Under 8-Lane Bridge Options, Bay Bridge LOS assumes reversible lane operations with 5 lanes in the peak direction and 3 lanes in the non-peak direction
- Under 6-Lane Bridge Option, Bay Bridge LOS assumes reversible lane operations with 4 lanes in the peak direction and 2 lanes in the non-peak direction
- All Build scenarios assume mainline widening to 8 lanes (one additional lane in each direction)

MDTA

Chesapeake Bay Bridge
Life Cycle Cost Analysis

2040 Mainline Peak Hour Volumes and Level of Service **for No Build and Build Options**
Average Weekday

Figure 3.7

Scenario	Period	Direction	Measure	MD 70 to MD 2/450 (Severn River Bridge)	MD 2/450 to MD 648	MD 648 to Bay Dale Drive	Bay Dale Drive to MD 179	MD 179 to Whitehall Road	Whitehall Road to W.H. Road Slip Ramp	W.H. Road Slip Ramp to Oceanic Drive	Oceanic Drive to Bay Bridge	BAY BRIDGE	Bay Bridge to MD 8	MD 8 to MD 835A	MD 835A to Shopping Center	Shopping Center to Shopping Center	Shopping Center to Cox Neck Road	Cox Neck Road to MD 552	MD 552 to South Piney Road	Piney Creek Road to Dundee Avenue	Dundee Avenue to Piney Narrows Road	Piney Narrows Road to Kent Narrows Road (Kent Narrows Bridge)	Kent Narrows Road to Jackson Creek Road	Jackson Creek Road to Chester River Beach Road	Chester River Beach Road to VFW Avenue	VFW Avenue to Evans Avenue	Evans Avenue to Hess Road	Hess Road to Nesbit Road	Nesbit Road to Ocean Gateway
2040 Summer Friday No Build	PM	Westbound	Level of Service	D	D	D	C	C	C	C	C	F	C		D	D			D	C	C	D	D		C				C
		Westbound	Volume	5,640	4,990	4,985	4,370	3,845	3,845	3,845	3,705	3,705	3,705	4,710	4,665	4,665	4,730	4,445	4,465	4,470	4,470	4,530	4,555	4,565	4,295	4,295	4,295	4,295	4,335
		Eastbound	Volume	9,230	8,480	8,480	7,625	6,325	6,185	6,015	5,925	5,925	5,925	6,010	6,010	6,010	6,010	6,025	5,655	5,710	5,710	5,635	5,690	5,790	5,590	5,590	5,590	5,590	5,530
		Eastbound	Level of Service	F	F	F	F	E	E	E	E	F	E		E	E	E		E			E	E						D
2040 Summer Friday Build Options 1, 2, and 3	PM	Westbound	Level of Service	C	C	C	B	B	B	B	B	D	B		C	C			C	C	C	C	C		B				C
		Westbound	Volume	5,640	4,990	4,985	4,370	3,845	3,845	3,845	3,705	3,705	3,705	4,710	4,665	4,665	4,730	4,445	4,465	4,470	4,470	4,530	4,555	4,565	4,295	4,295	4,295	4,295	4,335
		Eastbound	Volume	9,230	8,480	8,480	7,625	6,325	6,185	6,015	5,925	5,925	5,925	6,010	6,010	6,010	6,010	6,025	5,655	5,710	5,710	5,635	5,690	5,790	5,590	5,590	5,590	5,590	5,530
		Eastbound	Level of Service	F	E	E	D	C	C	C	C	C	C		C	C	C		C			C	C						C
2040 Summer Friday Build Option 4	PM	Westbound	Level of Service	D	D	D	C	C	C	C	C	F	C		D	D			D	C	C	D	D		C				C
		Westbound	Volume	5,640	4,990	4,985	4,370	3,845	3,845	3,845	3,705	3,705	3,705	4,710	4,665	4,665	4,730	4,445	4,465	4,470	4,470	4,530	4,555	4,565	4,295	4,295	4,295	4,295	4,335
		Eastbound	Volume	9,230	8,480	8,480	7,625	6,325	6,185	6,015	5,925	5,925	5,925	6,010	6,010	6,010	6,010	6,025	5,655	5,710	5,710	5,635	5,690	5,790	5,590	5,590	5,590	5,590	5,530
		Eastbound	Level of Service	F	F	F	F	E	E	E	E	E	E		E	E	E		E			E	E						D
2040 Summer Sunday No Build	PM	Westbound	Level of Service	F	F	F	F	E	E	E	E	F	F		F	F			F	F	F	F	F		F				F
		Westbound	Volume	7,670	7,220	7,220	6,790	6,425	6,425	6,425	6,330	6,330	6,330	7,135	7,100	7,100	7,150	6,920	6,935	6,940	6,940	6,990	7,010	7,020	6,805	6,790	6,790	6,790	6,820
		Eastbound	Volume	6,395	5,870	5,870	5,270	4,050	3,950	3,830	3,765	3,765	3,765	3,830	3,830	3,830	3,830	3,840	3,545	3,585	3,585	3,525	3,570	3,650	3,490	3,490	3,490	3,490	3,440
		Eastbound	Level of Service	E	E	E	D	C	C	C	C	F	C		C	C	C		C			C	C						C
2040 Summer Sunday Build Options 1, 2, and 3	PM	Westbound	Level of Service	D	D	D	D	D	D	D	D	D	D		D	D			D	D	D	D	D		D				D
		Westbound	Volume	7,670	7,220	7,220	6,790	6,425	6,425	6,425	6,330	6,330	6,330	7,135	7,100	7,100	7,150	6,920	6,935	6,940	6,940	6,990	7,010	7,020	6,805	6,790	6,790	6,790	6,820
		Eastbound	Volume	6,395	5,870	5,870	5,270	4,050	3,950	3,830	3,765	3,765	3,765	3,830	3,830	3,830	3,830	3,840	3,545	3,585	3,585	3,525	3,570	3,650	3,490	3,490	3,490	3,490	3,440
		Eastbound	Level of Service	D	C	C	C	B	B	B	B	D	B		B	B	B		B			B	B						B
2040 Summer Sunday Build Option 4	PM	Westbound	Level of Service	F	F	F	F	E	E	E	E	F	F		F	F			F	F	F	F	F		F				F
		Westbound	Volume	7,670	7,220	7,220	6,790	6,425	6,425	6,425	6,330	6,330	6,330	7,135	7,100	7,100	7,150	6,920	6,935	6,940	6,940	6,990	7,010	7,020	6,805	6,790	6,790	6,790	6,820
		Eastbound	Volume	6,395	5,870	5,870	5,270	4,050	3,950	3,830	3,765	3,765	3,765	3,830	3,830	3,830	3,830	3,840	3,545	3,585	3,585	3,525	3,570	3,650	3,490	3,490	3,490	3,490	3,440
		Eastbound	Level of Service	E	E	E	D	C	C	C	C	F	C		C	C	C		C			C	C						C

Notes:
- Level of Service based on 2010 HCM methodology, except Bay Bridge LOS
- Bay Bridge LOS methodology based on capacities established during project in coordination with MDTA
- Under No Build conditions, Bay Bridge LOS assumes reversible lane operation with 3 lanes in the peak direction, and 2 lanes in the non-peak direction
- Under 8-Lane Bridge Options, Bay Bridge LOS assumes reversible lane operations with 5 lanes in the peak direction and 3 lanes in the non-peak direction
- Under 6-Lane Bridge Option, Bay Bridge LOS assumes reversible lane operations with 4 lanes in the peak direction and 2 lanes in the non-peak direction
- All Build scenarios assume mainline widening to 8 lanes (one additional lane in each direction)

MDTA

Chesapeake Bay Bridge
Life Cycle Cost Analysis

2040 Mainline Peak Hour Volumes and Level of Service **for No Build and Build Options**
Summer Friday and Sunday

Figure 3.8

D. Future Number of Bridge and Roadway Lanes

1. Potential MDTA Approaches to Provide Additional Bridge and Roadway Capacity

MDTA could use one of three approaches to providing capacity on the Bay Bridge:

Approach 1: No Build. With this approach no additional capacity would be provided on the existing Bay Bridges and no widening would be implemented along US 50/301 within the study limits. The potential 2040 operations under a No Build condition were presented in Section III.C.

Approach 2: Fully accommodate 2040 traffic demand. Ideally, MDTA would be able to provide sufficient future capacity to fully accommodate future traffic demand. This would result in no routine congestion/queuing along the mainline or Bay Bridge in 2040. The number of bridge and roadway lanes needed to fully accommodate future traffic demand are presented in Section III.D.2.

Approach 3: Partially accommodate 2040 traffic demand. MDTA may implement less expensive improvements that provide some additional capacity, but not enough capacity to fully accommodate future traffic demand. The potential 2040 operations if some additional capacity is provided are presented in Section III.D.3.

2. Future Number of Bridge and Roadway Lanes to Fully Accommodate 2040 Traffic Demand

For the Bay Bridge, **Table 3.7** indicates the per-lane maximum vehicular flow for the eastbound and westbound bridges for certain levels of service. These values are based on the eastbound and westbound capacity described in Section III.B, and assume that each Level of Service threshold is 150 vehicles per hour per lane lower.

Table 3.7. Maximum Flow (vehicles per hour)

Level of Service	Eastbound		Westbound	
	Total (3 lanes)	Per Lane	Total (3 lanes)	Per Lane
D	3,800	1,267	3,900	1,300
E	4,250	1,417	4,350	1,450
F	4,700	1,567	4,800	1,600

In order to accommodate the highest projected 2040 eastbound and westbound volumes (6,225 vph on Friday afternoon, and 6,330 vph on Sunday evening in the eastbound and westbound direction, respectively) at Level of Service D or E, a minimum of 5 lanes in the peak direction would be required. However, due to the highly directional nature of seasonal volumes, no more than three lanes will be needed in the off-peak direction. To minimize the footprint of the bridge, these operating conditions lend themselves well to the use of reversible lanes.

Given the long design life of a new or expanded Bay Bridge, long-range, planning-level traffic volume projections were extended beyond 2040 to estimate the approximate number of years until traffic conditions on a future bridge (with five lanes in the peak direction) would reach levels that are similar to current conditions. For the purposes of this study, it was assumed that traffic volumes will continue to grow beyond 2040 at 0.6 percent per year, which is slightly less than half the assumed rate of growth until 2040 (1.3 percent per year).

It should be noted that forecasts beyond 2040 are subject to a high degree of uncertainty. Land use projections that form the basis for all travel demand models are not available beyond 2040. Furthermore, current demographic and economic trends may result in volumes and roadway capacity estimates 50, 60 or 70 years out that vary significantly from current projections. These include an aging population and lower rates of auto ownership among the young, fluctuating gasoline prices, advances in technology that facilitate telecommuting, and the impact of improved vehicle technology, such as automated/connected vehicles.

Nonetheless, applying these very long-term growth assumptions uniformly for all scenarios, it is expected that no more than five lanes will be needed in any direction through the 2060s. Similarly, in the opposing direction (off-peak direction), no more than three lanes will be needed through the 2060s. This analysis indicates that an 8-lane bridge with reversible operations that provide a 5/3 configuration, will likely be sufficient to accommodate traffic at or better than current congestion levels through the 2060s.

For the mainline, provision of one additional through lane in each direction would yield generally acceptable levels of service (D or better) through 2040, except during summer Fridays along eastbound US 50/301 between Rowe Boulevard and Bay Dale Drive. Additional improvements, such as auxiliary lanes, could be considered in this location to improve mainline operations.

3. Future Number of Bridge and Roadway Lanes to Provide Additional Capacity but Not Fully Accommodate 2040 Traffic Demand

MDTA could determine that smaller scale, less costly improvements should be provided. As presented above, the eastbound bridge currently carries two lanes of traffic. MDTA could consider widening the eastbound bridge to carry three lanes of traffic, matching the number of lanes provided on the westbound bridge. The Bay Bridges would then have a total of six lanes, which could be operated with three lanes per direction or in a contra-flow (4 lanes/2 lanes) configuration. With three lanes on each bridge, contra-flow could be utilized in either direction, allowing four lanes to be directed eastbound or westbound as needed for the peak travel direction.

Contrary to an 8-lane scenario as described in Section D.2, a 6-lane configuration, whether operated in contra-flow or non-contra-flow configuration, would leave insufficient capacity to accommodate all vehicular bridge demand at certain times. As shown in Figure 3.9, the following observations can be made for summer 2040 traffic conditions:

With standard operations (3 lanes per direction) during summer months:

- During weekdays (Monday to Thursday), queues of approximately 4 miles would be expected in the eastbound direction for up to 6 hours, but no queues in the westbound direction would be expected.
- On Fridays, queues in the eastbound direction would be slightly less compared to the No Build conditions but still reach approximately 11 miles for up to 11 hours. No queuing in the westbound direction would be expected.
- On Saturdays, queues in the eastbound direction would reach 0.5 miles for up to 3 hours; in the westbound direction, no queuing would be expected.
- On Sundays, no queuing would be expected in the eastbound direction, but queues in the westbound direction would be equal to those under the No Build conditions and reach approximately 14 miles for up to 11 hours.

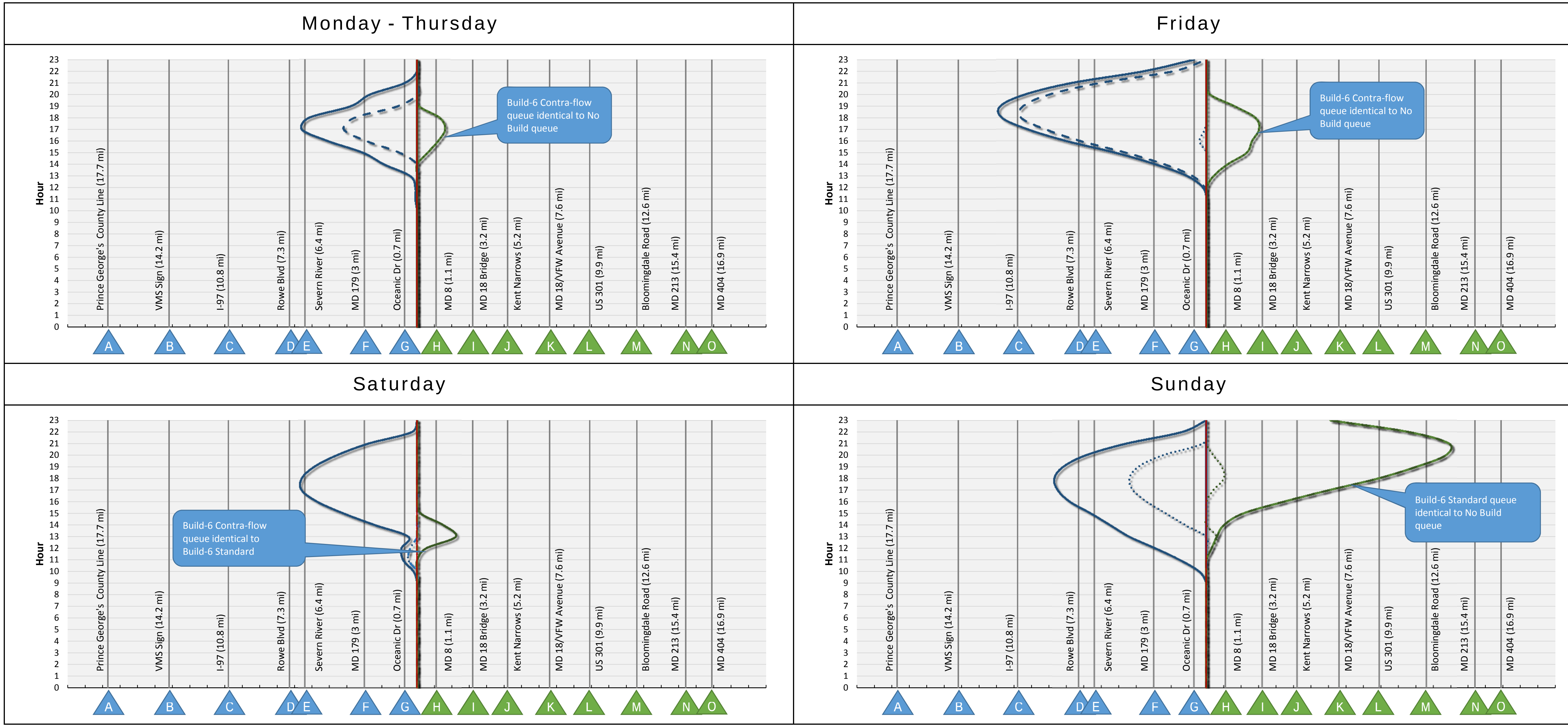
With contra-flow operations (4 lanes peak direction / 2 lanes off-peak direction) during summer months:

- During weekdays (Monday to Thursday), no queuing would be expected in the eastbound direction. However, in the westbound direction queues would be identical to the No Build condition and exceed one mile for up to 5 hours.
- On Fridays, minor queues less than 0.5 miles would be expected in the eastbound direction for up to 3 hours; in the westbound direction, queues up to 3 miles would be expected (identical to the No Build condition) for approximately 8 hours.
- On Saturdays, queues in the eastbound direction would reach 0.5 miles for up to 3 hours; in the westbound direction, no queuing would be expected.
- On Sundays, queues of approximately 4 miles would be expected in the eastbound direction for up to 8 hours, which is approximately half the projected queue length under No Build conditions. In the westbound direction, queues of approximately 1 mile would be expected for up to 5 hours, which is considerably less than the 14-mile queue expected under No Build conditions.

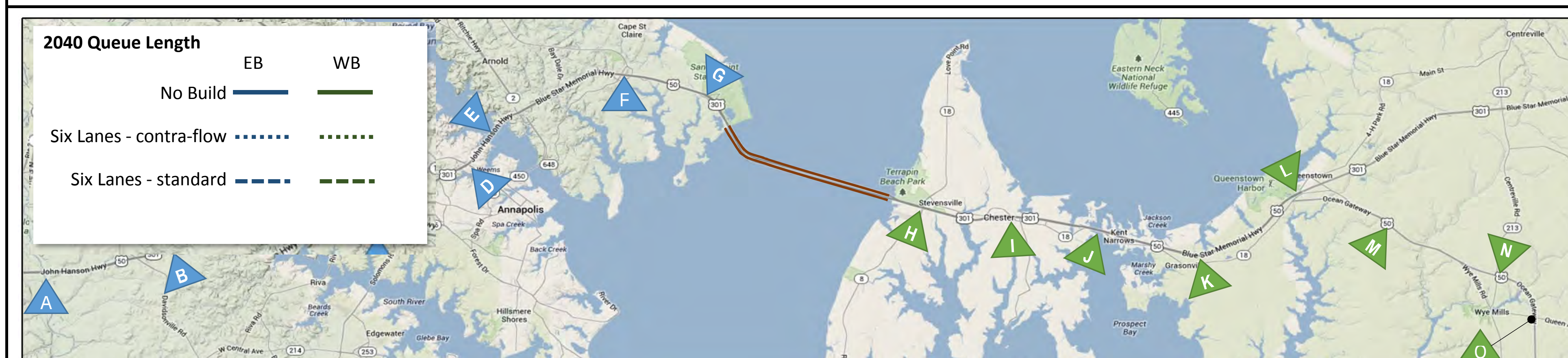
Although constructing one additional lane on the eastbound span would provide some congestion relief compared to No Build conditions there would still be numerous operations issues:

- The eastbound queues Monday through Friday would only be marginally reduced under standard operation, and would require contra-flow operation (4 eastbound lanes) to significantly reduce/eliminate congestion. However, implementing contra-flow operation would result in westbound queues that are the same as the No Build operation.
- The significant westbound queues experienced on Sundays would only be reduced if contra-flow was used. However, utilizing contra-flow (4 lanes westbound) would result in eastbound congestion.

Under all time frames the 6-lane approach would operate worse than the 8-lane approach where no congestion or queuing is projected.



Note: Queue lengths do not account for effect of other upstream bottlenecks (e.g., Rowe Boulevard interchange, Severn River Bridge)



Maryland Transportation Authority

RK&K

Chesapeake Bay Bridge
Life Cycle Cost Analysis

Comparison of 2040
Summer Queues;
No Build vs. Six Lane Bridge

Figure 3.9

IV. BRIDGE AND ROADWAY OPTIONS

The Bay Bridge LCCA included an analysis of several options to increase capacity across the Chesapeake Bay and the evaluation of potential improvements to the US 50/301 mainline within the study limits.

A. Bridge Options

Based on the structural analysis presented in Chapter II, the existing Bay Bridge structures could be maintained throughout the study time frame. As a result, potential Bay Bridge improvements to increase capacity could include demolition of the existing structures and construction of a new structure(s) or a combination of maintaining the existing and building new structures.

The traffic analysis presented in Chapter III indicates that a total of eight bridge lanes would be required across the Bay to accommodate future traffic demand. In addition, the traffic analysis showed that five lanes would be required in the peak direction and three lanes in the off-peak direction.

Using these parameters, three bridge options were developed:

- Bridge Option 1 – Maintain the existing bridges and build a new 3-lane bridge.
- Bridge Option 2 – Demolish the existing eastbound bridge, maintain the existing westbound bridge, and build a new 5-lane bridge.
- Bridge Option 3 – Demolish both existing bridges and build a new 8-lane bridge.

As discussed in Chapter III, MDTA could also consider smaller scale, less costly improvements that would add capacity to the existing bridges, but not enough capacity to accommodate all of the future traffic demand in 2040. Using this approach, a fourth bridge option was developed:

- Bridge Option 4 – Maintain the existing 3-lane westbound bridge, and rehabilitate and widen the existing eastbound bridge to three lanes. Another approach to this option would be to add a lane to the newer westbound bridge. This study did not evaluate adding a lane to the existing 3-lane westbound bridge.

For each bridge option, the design details for the new bridge, including bridge types (e.g., steel girder, cable-stayed, suspension, etc.) were not determined during the Bay Bridge LCCA, but assumptions were used to develop structure costs as presented in Chapter IV.D.

1. Bridge Option 1

Option 1 would maintain both existing structures and construct a new bridge south of the existing eastbound structure. The combination of existing and new structures would provide eight total lanes, three each on the outside bridges (existing westbound bridge and new bridge) and two on the middle bridge (existing eastbound bridge). This configuration would allow for the two, three-lane outside bridges to operate exclusively in the eastbound and westbound directions and the middle two-lane structure to operate with reversible lanes to provide additional capacity in the peak direction.

2. Bridge Option 2

Option 2 would maintain the existing three-lane westbound structure, demolish the existing two-lane eastbound structure, and construct a new bridge south of the existing eastbound structure. The new bridge would carry five total lanes, with a concrete barrier separating the two-lane and three-lane roadways. The combination of the existing and new structure would provide eight total lanes. The three-lane existing bridge would operate exclusively in the westbound direction. The three right lanes on the new bridge would operate exclusively in the eastbound direction, and the two left lanes on the new bridge would operate as reversible lanes to provide additional capacity in the peak direction.

3. Bridge Option 3

Option 3 would demolish both existing bridges and construct a new eight-lane bridge in place of the existing structures. The eight lanes would be separated into three-lane, two-lane, and three-lane roadways. The outside three-lanes roadways would be operated exclusively in the westbound and eastbound directions and the middle two-lane roadway would operate as reversible lanes to provide additional capacity in the peak direction.

4. Bridge Option 4

Option 4 would maintain both existing bridges and widen the eastbound bridge to carry three lanes. The two structures would provide six total lanes, three on each bridge. This configuration would allow for the bridges to operate exclusively in the eastbound and westbound directions during standard operation or in a 4-lane/2-lane configuration (either direction) during contra-flow operations. Unlike Bridge Options 1 through 3, which allow for physically separated reversible lane operations, Bridge Option 4 would allow for contra-flow operation very similar to today's operation where opposing traffic would not physically separated.

B. Roadway Improvements

1. Roadway Widening

Based on the traffic analysis presented in Section III, a total of eight mainline lanes, four per direction, are required through the study limits to accommodate future traffic demand. This typical section would necessitate widening the mainline by one lane in each direction. In addition to widening by one lane per direction, the median and outside shoulders would be widened to 12 feet to meet AASHTO design guidelines for freeways. To reduce potential impacts to properties and environmental features, it was assumed that the median would have a closed section with concrete barrier throughout the study limits. The mainline widening would only be implemented in conjunction with the 8-lane bridge options (Build Options 1, 2, and 3).

At the western end of the study limits, the additional lane would be added/dropped just west of the MD 70 interchange. At the eastern limits, the additional lane would be added/dropped at the US 50/301 interchange with the additional (third) lane heading to/from US 50. It was assumed that the additional lane to/from US 50 would tie into long-term improvements planned by SHA to widen US 50 from east of the US 301 split to MD 404.

The traffic analysis in Chapter III indicated that current interchange ramp configurations at all interchanges could accommodate 2040 traffic volumes. Therefore, the interchange ramps would only be modified to tie into the widened mainline section, including widening mainline bridges and replacing overpasses that are directly impacted by the roadway widening.

2. Roadway Life Cycle Cost Improvements

The cost of roadway maintenance and improvements within the project limits were included in the life cycle cost analysis. Roadway maintenance includes periodic resurfacing of the mainline pavement, which was assumed to occur at regular intervals throughout the study time frame (2014 to 2065).

Several overpasses would be impacted by the mainline widening; therefore, these overpasses would have to be reconstructed. Additionally, several US 50/301 structures would have to be widened. However, all bridges within the study limits would reach or approach the limit of their design life by the end of the study time frame. As such, it was assumed that all bridges within the limits would have to be completely replaced by 2065. The mainline bridge replacements were assumed to be part of the life cycle cost analysis. Existing bridge replacement would likely occur over a period of many years due to the large number of bridges that would need to be replaced. However, for the purposes of this analysis, it was assumed that the costs for the complete bridge replacements would be incurred at the time of the roadway widening (and new Bay Bridge construction) for the Build Options. For the No Build Option, the costs were incurred in 2045, which was chosen as a median year for complete mainline bridge replacement.

C. Build and No Build Options

The bridge options and roadway improvements were combined into system-wide Build Options. The improvements included in each Build Option are presented in **Table 4.1**.

Table 4.1. Build Option Improvements

	Improvements
Build Option 1	• New 3-lane Bay Bridge structure (see Section IV.A) • Roadway widening (see Section IV.B) • Programmed and anticipated Bay Bridge maintenance • Periodic roadway resurfacing (see Section IV.B) • Complete mainline bridge and overpasses replacement (see Section IV.B)
Build Option 2	• Demolition of existing eastbound Bay Bridge • New 5-lane Bay Bridge structure • Roadway widening • Programmed and anticipated westbound Bay Bridge maintenance • Periodic roadway resurfacing • Complete mainline bridge and overpasses replacement
Build Option 3	• Demolition of both existing Bay Bridge structures • New 8-lane Bay Bridge structure • Roadway widening • Periodic roadway resurfacing • Complete mainline bridge and overpasses replacement
Build Option 4	• Widen eastbound Bay Bridge structure to three lanes • Programmed and anticipated Bay Bridge maintenance • Periodic roadway resurfacing (no widening) • Complete mainline bridge and overpasses replacement
No Build	• Programmed and anticipated Bay Bridge maintenance • Periodic roadway resurfacing • Complete mainline bridge replacement

D. Bridge and Roadway Costs

The bridge and roadway costs were developed based on the improvements and Build and No Build Options described in Sections IV.A, IV.B, and IV.C. The assumptions used to develop the cost estimates and the estimated costs are presented in this section.

1. Cost Assumptions

The relatively preliminary nature of the Bay Bridge LCCA means that several structural and roadway assumptions were made to estimate the cost for the improvements presented in Sections IV.A and IV.B. The Bay Bridge structural assumptions are presented in **Table 4.2** and the roadway assumptions are presented in **Table 4.3**.

Table 4.2. Bay Bridge Structural Cost Assumptions

Element	Description	Option
New bridge width	Build Option 1 – New 3-lane bridge: 68 feet wide Build Option 2 – New 5-lane bridge: 110 feet wide Build Option 3 – New 8-lane bridge: 168 feet wide Build Option 4 – Widen EB bridge to 41 feet	All Build Options
New bridge square foot costs	Based on assumed most suitable structural sub-unit mix for the new structure. Consideration is given to matching the existing substructure spacing and span lengths. Cost data taken from recent similar projects for each sub-unit type from across the country.	Build Options 1, 2, and 3
Existing bridge demolition costs	Based on several recent similar deconstruction projects and the existing as-built quantities	Build Options 2 and 3
Existing EB bridge widening costs	Derived from estimated quantities obtained from available design records for the existing EB and WB Bay Bridge structure. Cost data taken from recent projects from across the country with consideration given to actual site conditions and limitations, including maintaining traffic on the existing bridges during construction	Build Option 4
Contingencies and additives	40% planning contingency 12% construction inspection 5% construction contingency 5% preliminary engineering	No Build and all Build Options

Table 4.3. Roadway Cost Assumptions

Element	Description	Option
Approach roadway reconstruction	Reconfigured to direct traffic to the new/existing Bay Bridge structures	Build Options 1, 2, and 3
Toll plaza removal/AET conversion	Assumed to be removed and the highway converted to AET prior to new bridge construction, costs not included	N/A
Resurfacing	All existing lanes resurfaced and periodic resurfacing throughout the study time frame	No Build and all Build Options

Element	Description	Option
Full depth pavement	All widening and all existing shoulders reconstructed	Build Options 1, 2, and 3
Structures widening	All mainline structures widened to accommodate the proposed roadway typical section	Build Options 1, 2, and 3
Structure replacement	All structures within the study limits would be reconstructed within the study time frame. Structures along US 50/301 would be widening to accommodate roadway widening (Build Option only)	No Build and all Build Options
Contingencies and additives	40% planning contingency 12% construction inspection 5% construction contingency 5% preliminary engineering	No Build and all Build Options
Right-of-way	Right-of-way costs not included	N/A

2. Bridge Improvements Cost Estimates

The cost estimate for the Bay Bridge cost elements are presented in **Table 4.4**. These costs include the programmed and anticipated rehabilitation and maintenance, new Bay Bridge structures, and demolition of the existing bridges.

Table 4.4. Bay Bridge Costs (in 2014 dollars)

Element	Cost ($ millions)	Options	Comments
New 3-lane structure	$1,451	Build Option 1	
New 5-lane structure	$2,708	Build Option 2	
New 8-lane structure	$4,253	Build Option 3	
Widen EB Bay Bridge to 3 lanes	$930	Build Option 4	
EB existing Bay Bridge demolition	$190	Build Option 2	
EB and WB existing Bay Bridge demolition	$478	Build Option 3	
Programmed and anticipated existing Bay Bridge structure rehabilitation and maintenance	$2,680	No Build and Build Options 1, 2, and 3	• $1,227 for existing EB bridge (see II.C) • $1,453 for existing WB bridge (see II.C) • Rehab/maintenance costs applied based on when the Build Options would be implemented (see V)
Programmed and anticipated existing Bay Bridge structure rehabilitation and maintenance	$2,334	Build Option 4	• $881 for existing EB bridge • $1,453 for existing WB bridge • Rehab/maintenance costs applied based on when the Build Options would be implemented

3. Roadway Improvements Cost Estimates

The cost estimates for the roadway elements included as part of the Build Options are presented in **Table 4.5**. These costs include widening to provide an additional mainline lane in each directions, a one-time roadway resurfacing, and complete replacement of the existing bridges and overpasses within the study limits.

Table 4.5. Roadway Costs (in 2014 dollars)

Element	Cost ($ millions)	Options	Comments
Roadway widening	$900	Build Options 1, 2, and 3	• Includes roadway widening • Includes a one-time roadway resurfacing • Includes complete mainline bridges and overpasses replacements

The cost estimates for the roadway life cycle cost elements are presented in **Table 4.6**. These costs include periodic roadway resurfacing and complete replacement of the existing bridges and overpasses within the study limits.

Table 4.6. Roadway Life Cycle Costs (in 2014 dollars)

Element	Cost ($ millions)	Options	Comments
Periodic roadway resurfacing	$41	No Build and all Build Options	• Resurfacing to occur every 8 years starting in 2020 • Cost includes contingencies and other additives
Mainline bridge replacement	$450	No Build and Build Option 4	• Only bridge replacement, no widening • Cost includes contingencies and other additives

4. Build Options Cost Estimates

The cost estimates for the four Build Options are presented in **Table 4.7**. For Build Options 1, 2, and 3 these costs include new Bay Bridge structures, existing Bay Bridge structure demolition, roadway widening, and complete replacement of roadway bridges and overpasses within the study limits. For Build Option 4, these cost include eastbound Bay Bridge widening and complete replacement of roadway bridges and overpasses within the study limits. The Build Option costs do not include programmed and anticipated existing Bay Bridge rehabilitation and maintenance because those costs would vary depending upon if/when the existing bridges are demolished and a new Bay Bridge structure constructed. Similarly the Build Options costs do not include periodic resurfacing because those costs would vary depending upon when roadway widening would occur. The full costs for the Build Options including the programmed and anticipated existing Bay Bridge rehabilitation and maintenance and periodic roadway resurfacing were calculated as part of the life cycle costs presented in Chapter V.

Table 4.7. Build Options Costs (in 2014 dollars)

Option	New Bridge Cost ($million)	Existing Bridge Demolition ($ million)	Roadway Cost ($ million)	Total ($ million)
Option 1	$1,451	$0	$900	**$2,351**
Option 2	$2,708	$190	$900	**$3,798**
Option 3	$4,253	$478	$900	**$5,631**
Option 4	$930	$0	$0	**$930**

As presented above, the No Build costs include programmed and anticipated existing Bay Bridge rehabilitation and maintenance, periodic roadway resurfacing, and complete replacement of the existing mainline bridge within the study limits. These improvements would be implemented over time and the resulting life cycle costs are presented in Chapter V.

V. LIFE CYCLE COST SCENARIOS

A. Inflation and Discount Rates

A Life Cycle Cost Analysis is an economic analysis tool used to quantify and compare projected investments in system preservation and improvement scenarios. With this tool, the costs of the No Build and four Build Options could be compared over several time frames. The value of dollars tends to decrease over time due to inflation (inflation rate). To counter the effects of inflation, money can be invested such that it will tend to grow over time (discount or interest rate). Money spent in constructing or maintaining a facility over different time frames cannot simply be added together to determine the overall life cycle costs. The inflation rate and discount rate must be used to convert anticipated future costs to present dollar values so that the lifetime costs of different options can be compared directly.

The life cycle cost process used for this project was as follows:

1. Identify initial construction and future rehabilitation/maintenance needs and their associated costs.
2. Determine the timing for each Build Option and the No Build Option.
3. Estimate Present Cost (PC) for each improvement identified under each Option. (These values are presented in **Tables 4.4** and **4.5**.)
4. Determine the Future Cost (FC) for each improvement based on the inflation rate.
5. Determine the Present Worth (PW) (i.e. present dollar value) for each improvement based on the discount rate.
6. Develop life cycle cost scenarios based on when each Build Option would be implemented (and include the No Build as one scenario).
7. Determine the Life Cycle Cost for each scenario by summing the PW of improvements identified for each Build Option and the No Build Option.

The inflation rate used in the life cycle cost analysis was 2.75 percent, which is consistent with current long-term inflation rates used by the Maryland Department of Transportation at the time this report was prepared.

The discount rate used in the net present value (NPV) analysis was based on the assumption that the project would be financed through debt funding. As a AA-rated agency, MDTA achieves a relatively low cost of borrowing. This low cost, coupled with MDTA's ability to utilize cash funding for projects in addition to debt financing, lowers MDTA's cost of capital. Additionally, on recent mega projects, funding plans were created that allowed MDTA to utilize funding from other sources, such as TIFIA loans and GARVEE bonds. Although this is not the typical approach MDTA uses to fund projects, the potential for alternative funding sources on mega-projects does exist.

To determine the appropriate discount rate to use, an analysis of the weighted average cost of capital on recent projects was completed. The majority of MDTA's recent system preservation projects have been cash-funded, which would suggest using the current investment rate as the discount rate. However, for larger projects, some mix of cash and debt funding may be more appropriate. When considering all funding sources for the ICC and the I-95 ETLs, a weighted average cost of capital (WACC) of 2.9 percent and 2.3 percent, respectively, was obtained. Considering a conservative approach, the higher of these two rates, 2.9 percent, was used as the discount rate in the NPV analysis.

To provide one example calculation, in Build Option 2, the demolition of the existing eastbound bridge is estimated to cost $190.2 million in 2014 dollars. If the bridge is demolished in 2035, an inflation rate of 2.75 percent would be applied over 21 years. The future (2035) demolition cost would be $327.2 million. The present (2014) worth would then be calculated by applying a 2.9 percent discount rate to the future cost over the same 21-year period. The present worth of the eastbound bridge demolition would be $184.7 million. These calculations were applied for each study improvement to develop a total net present worth for each scenario.

B. Life Cycle Cost Time Frames and Scenarios

1. Life Cycle Costs

The four Build Options could be implemented over a wide range of time within the overall study time frame (2014 to 2065). The ultimate decision of when a Bay Bridge Project would occur would be based on a variety of factors that include traffic operations along US 50/301, the level and duration of traffic congestion on Kent Island and in Annapolis, public perception, and political direction. It was beyond the scope of the Bay Bridge LCCA Study to consider all of these potential factors to determine a single year in which a new Bay Bridge should be constructed. Therefore, a range of time frames were considered to provide information to policy makers about the potential cost for a Bay Bridge project at various times within the study time frame.

The selection of the time frame for which to conduct the life cycle cost analyses was driven by multiple factors, including the earliest year in which a new bridge could be feasibly constructed. This year was determined based on the estimated time frame to complete the required National Environmental Policy Act (NEPA) studies, design, permitting and construction. MDTA assumed that completion of these steps requires a 20-year time period, yielding an earliest completion year of 2035.

MDTA then identified three additional years for potential implementation: 2040, which is the year used for the future traffic analysis, 2050, and 2060. The four dates provide MDTA with life cycle cost information over a 25-year window when a Bay Bridge Project could be completed.

The combination of four Build Options considered over four time frames (Build Options 1, 2, and 3) or two time frames (Build Option 4) and a No Build results in 15 life cycle cost scenarios. The costs for these 15 scenarios are presented in **Table 5.1**.

Table 5.1: Life Cycle Costs (in billions of dollars)

Completion Year	Build Option 1	Build Option 2	Build Option 3	Build Option 4	No Build
2035	$5.06	$5.45	$5.94	$3.89	$3.25 through 2065
2040	$5.01	$5.58	$6.09	$3.89	
2050	$5.02	$5.67	$6.46	N/A	
2060	$4.98	$5.71	$6.85	N/A	

2. Depreciated Values of Existing Bay Bridge Structures in 2065

The life cycle cost scenarios considered in this analysis mix old and new Bay Bridge structures. To account for the concept that a 100 year old structure does not have the same residual value as a new structure, a Depreciated Value was calculated for each life cycle cost scenario based on the structures remaining in service at the LCCA Horizon Year of 2065. The Depreciated Value attempts to quantify a value of the remaining structure(s) at the end of the study time frame.

The Depreciated Value is not intended to indicate any particular return that can be "withdrawn" from the overall system investment. Instead, the Depreciated Value is intended as a return on investment comparison between life cycle cost scenarios considered in this study. In general, a higher relative Depreciated Value likely correlates with lower maintenance costs in the years beyond the LCCA horizon year.

The Depreciated Value calculation is summarized as follows:

1. Determine the 2014 construction cost for each structure that will remain beyond the Bay Bridge LCCA study horizon year (2065). For the existing eastbound and westbound bridges, this value is determined by taking the original bridge construction costs and converting them to 2014 dollars using the 2.75% LCCA inflation rate.
2. Assume linear depreciation of the present day construction cost over 100 years (i.e. 1% per year) to determine the present day Depreciated Value. Assume structures aged over 100 years prior to the LCCA horizon year have no remaining value.
3. Determine the Future Depreciated Value in the LCCA horizon year based on the inflation rate.
4. Determine the Present Worth Depreciated Value (i.e. present dollar value) in the LCCA horizon year based on the discount rate.

The total depreciated value of the remaining structures in 2065 based for the Build Options and No Build option are presented in **Table 5.2**.

Table 5.2: Total Depreciated Value of Remaining Structures in 2065 (in billions of dollars)

Completion Year	Build Option 1	Build Option 2	Build Option 3	Build Option 4	No Build
2035	$0.58	$0.98	$1.42	$0.16	$0.03 through 2065
2040	$0.62	$1.05	$1.52	$0.17	
2050	$0.70	$1.19	$1.73	N/A	
2060	$0.78	$1.32	$1.93	N/A	